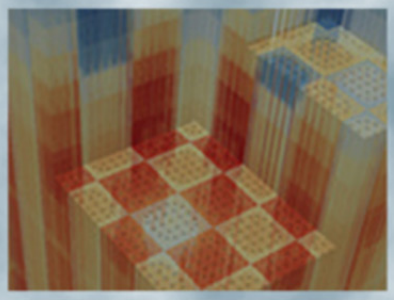
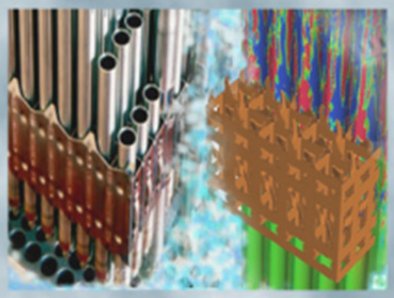
CASL-U-2015-0206-000

VERA Benchmarking Results for Watts Bar Nuclear Plant Unit 1 Cycles 1-12





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June 30, 2015

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REVISION LOG

Revision	Date	Affected Pages	Revision Description
0	6/30/2015	All	Initial Release

Document pages that are:

Export Controlled ___None_____

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EXECUTIVE SUMMARY

Among the most important accomplishments during Phase 1 of the Consortium for Advanced Simulation of Light Water Reactors (CASL) is the development and deployment of what is known as VERA-CS, the steady-state nuclear reactor core simulation capability of the Virtual Environment for Reactor Applications, VERA. With this product CASL now has the ability to perform and support analyses relating to common evolutions of operating commercial pressurized water reactors (PWRs), including startup testing, power escalation, fuel cycle depletion, and fuel assembly discharge, reinsert, and shuffling. VERA-CS is a high-fidelity, multi-physics engineering tool that utilizes modest high-performance computing (HPC) systems and engineering-scale clusters to simultaneously simulate the local fuel rod neutronics and coolant channel thermal-hydraulics over the life of the reactor. Though it is still under development, the results demonstrated in this report provide encouraging evidence that VERA-CS will become highly acclaimed for industrial, scientific, and educational applications alike.

The success of VERA development is born from the foundation of the CASL consortium, combining and building on the expertise of reactor operators, engineers, physicists, mathematicians, and computer scientists. Though the focus in Phase 1 has largely been on development, the goal of CASL is the application and deployment of VERA for challenges facing the commercial nuclear power industry. This mission will be fulfilled first by the use of VERA-CS for pseudo-steady-state depletion and shuffling of the reactor fuel, which will establish very accurate local power histories and isotopics for all fuel rods, and will provide a starting point for performing many complex analyses not possible with current industrial methods.

This document provides the first demonstration of reactor simulation of multiple fuel cycles by VERA-CS. Through the user-friendly input and the use of INL's Falcon HPC computer, CASL has successfully modeled the entire operating history of Watts Bar Nuclear Plant, an operating commercial PWR currently in its 20th year and 13th fuel cycle. A rigorous benchmark was also performed using a significant amount of operating data provided by TVA, using the same rigorous analyses that are used for the validation and licensing of industrial methods. These data include criticality measurements, physics testing results, critical soluble boron concentrations, and measured in-core neutron flux distributions. A high level summary of the benchmark results is shown below.

Table 1 Summary of VERA-CS Benchmarking Results

Measurement	Mean ± 1 sigma†	Runtime per Cycle‡
BOC HZP Critical Boron	-9 ± 24 ppm	1.75 hours
BOC HZP Bank Worth	1.2 ± 4.3%	3.33 hours
BOC HZP ITC	-0.8 ± 0.7 pcm/°F	0.75 hours
HFP Boron Letdown	-24 ± 19 ppm	21.9 hours
HFP Flux Maps – Radial	1.9 ± 0.3% RMS	--
Total	3.7 ± 0.4% RMS	

†Suspect measurements or known anomalies are excluded from this summary
‡Typical number of compute cores is 4307 cores

These results demonstrate successful application of VERA-CS for the depletion and benchmarking of twelve fuel cycles of a commercial PWR. Its ability to represent realistic and detailed reactor core models and perform simulations in a reasonable turn-around time is confirmed. While there is still some room for improvement in the results, these comparisons to measured data are relatively good for the first time performing these types of calculations, and they provide CASL with an important resource of information and realistic test cases for targeting future enhancements and development.

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CONTENTS

REVISION LOG ii

EXECUTIVE SUMMARY iii

CONTENTS v

FIGURES vii

TABLES ix

ACRONYMS x

ACKNOWLEDGEMENTS xi

1. INTRODUCTION 1

2. WATTS BAR NUCLEAR PLANT 4

3. VERA-CS DESCRIPTION 7
   - 3.1 VERAIn 12
   - 3.2 MPACT 13
   - 3.3 CTF 15
   - 3.4 Bison-CASL 17
   - 3.5 ORIGEN 18
   - 3.6 VERAView 20

4. BENCHMARKING RESULTS 22
   - 4.1 Model Charactistics 22
   - 4.2 BOC HZP Critical Boron Concentration 22
   - 4.3 BOC HZP Control Bank Worths 24
   - 4.4 BOC HZP Isothermal Temperature Coefficient 26
   - 4.5 HFP Critical Boron Letdown 28
   - 4.6 HFP Flux Maps 35

5. FUTURE WORK 41

6. CONCLUSIONS 43

REFERENCES 43

APPENDIX A - SAMPLE VERAIN INPUT FOR DEPLETION AND SHUFFLE 47

APPENDIX B - FUEL TEMPERATURES FROM BISON-CASL 58
   - B.1 Methodology 58
   - B.2 Results 61
   - B.3 Discussion 64

B.4 Summary 64
B.5 References 65

APPENDIX C - ISOTOPES IN REDUCED ORIGEN LIBRARY 66

APPENDIX D - VERA-CS DEPLETION SUMMARIES 67

APPENDIX E - FLUX MAPS FOR ALL CYCLES 79

FIGURES

Figure 1 The CASL Founding Partners 1

Figure 2 VERA-CS Validation Plan Components[2] 3

Figure 3 Watts Bar Nuclear Plant [3] 4

Figure 4 WBN1 Reactor Core with 193 Fuel Assemblies (Cycle 1) [4] 4

Figure 5 Sample 17x17 Fuel Rod Lattice with 104 IFBA rods and 20 WABA rods [1] 5

Figure 6 17x17 Fuel Assembly Components and Rod Cluster Control Assembly [1] 5

Figure 7 WBN1 Control Bank Locations [4] (quarter symmetry) 6

Figure 8 WBN1 In-Core Detector Locations [4] 6

Figure 9 VERA-CS HFP Fuel Rod Power Distribution for WBN1 Cycle 11 @ BOC 9

Figure 10 VERA-CS 3D Channel Coolant Densities (kg/m3) and Fuel Rod Steaming Rates (kg/s) for WBN1 Cycle 11 @ Middle-Of-Cycle 10

Figure 11 VERA-CS Fuel Rod Exposure Distribution for WBN1 Cycle 11 @ EOC (GWd/MTU)11

Figure 12 Current Components of VERA 12

Figure 13 Watts Bar Nuclear EOC1 and BOC2 Fuel Rod Exposures 14

Figure 14 Example of CTF rod-bundle meshing approach in VERA-CS 16

Figure 15 VERA-CS Exit Temperature Distribution from CTF in WBN1 Cycle 12 (°C) 16

Figure 16 Full-length view (left) and close-up view of the top of the fuel rod (right) of a Bison-CASL model, with radial dimensions scaled up by a factor of 100 due to the aspect ratio of the fuel rod 17

Figure 17 Organization of the ORIGEN code in SCALE 19

Figure 18 VERA-CS ^{239}Pu Distribution from ORIGEN for WBN1 EOC2 19

Figure 19 VERAView Main Window 21

Figure 20 BOC HZP Critical Boron Concentration Differences 23

Figure 21 BOC HZP Individual Control Bank Worth Errors 25

Figure 22 BOC HZP Total Control Bank Worth Errors 26

Figure 23 BOC HZP Isothermal Temperature Coefficient Differences 27

Figure 24 Calculated HFP Critical Boron Letdowns 29

Figure 25 HFP Critical Boron Differences 30

Figure 26 Estimated HFP ^{10}B Depletion Worth by Fuel Cycle 32

Figure 27 ^{10}B Depletion-Corrected HFP Critical Boron Differences 33

Figure 28 HFP Core Average Fuel Temperatures 34

Figure 30 Sample HFP Flux Map – Middle of Cycle 10 37

Figure 31 Flux Map Results – Radial Power Distribution 38

Figure 32 Flux Map Results – Total Power Distribution 38

Figure 33 Flux Map Results – Axial Offset Differences 39

Figure 34 Probability Distribution of the 3D Flux Map Response Differences by Cycle (%) 40

Figure B.1 An illustration showing the approach used for initial simple test problems to use Bison-CASL to calculate average fuel temperatures for VERA-CS 60

Figure B.2 VERA-CS relative power (left) and nodal LHR (right) as a function of axial position for each Bison-CASL simulation performed 60

Figure B.3 Full-length view (left) and close-up view of the top of the fuel rod (right) of the mesh used for the model, with radial dimensions scaled up by a factor of 100 due to the aspect ratio of the fuel rod 61

Figure B.4 Average fuel temperature as a function of rod-average LHR at several different burnup levels, assuming a uniform axial power profile for the fuel rod 62

Figure B.5 Nodal average burnup as a function of nodal average LHR extracted at five different points in time from Bison-CASL results, with a red line showing MPACT-calculated bounds of operating fuel for WBN1 Cycle 1 63

Figure B.6 Nodal volume-average ΔT as a function of nodal average LHR as calculated by Bison-CASL, with results binned into data series according to the nodal burnup of the fuel at that point in time 63

TABLES

Table 1 Summary of VERA-CS Benchmarking Results iii

Table 2 VERA Capabilities for Reactor Core Simulation 8

Table 3 Boron Difference Statistics By Cycle (VERA-meas.) 33

Table 4 HFP Flux Map Results Summary by Cycle (%) 39

Table C.1 Nuclides in the Simplified Burnup Chain "CASL2.0" 66

ACRONYMS

AO	Axial Offset
API	Application Programming Interface
ARO	All-rods-out
BOC	Beginning-of-Cycle
CASL	Consortium for Advanced Simulation of Light Water Reactors
CBW	Control Bank Reactivity Worth
CE	continuous energy
CIPS	CRUD-Induced Power Shift
CTF	COBRA-TF subchannel thermal-hydraulics code
COBRA-TF	Coolant Boling in Rod Arrays-Two Fluids
DOE	U.S. Department of Energy
DNB	Departure from Nucleate Boiling
EFPD	Effective Full Power Days
EOC	End-of-Cycle
FMC	Fuel Materials and Chemistry Focus Area
GUI	Graphical User Interface
HFP	Hot-Full-Power
HPC	High-Performance Computing
HZP	Hot-Zero-Power
IFBA	Integral Fuel Burnable Absorber
INL	Idaho National Laboratory
ITC	Isothermal Temperature Coefficient of Reactivity
JNFK	Jacobian-free, Newton-Krylov Method
LPFA	Lower Plenum Flow Anomaly
LWR	Light Water Reactor
M&S	Methods and Software
MOC	Method of Characteristics
OLCF	Oak Ridge Leadership Computing Facility
ORIGEN	Oak Ridge Isotope Generation
ORNL	Oak Ridge National Laboratory
PCI	Pellet-Clad Interaction
PCM	percent mille (10-5)
PPM	parts per million
PHI	Physics Integration Focus Area
PNNL	Pacific Northwest National Laboratory
PSU	Pennsylvania State University
PWR	Pressurized Water Reactor
RBHT	Rod Bundle Heat Transfer Testing Facility
RCCA	Rod Cluster Control Assembly
RIA	Reactivity Insertion Accident
RMS	Root Mean Square
RTM	Radiation Transport Methods Focus Area
T/H	Thermal-Hydraulics
TCP0	Transport-corrected P0 scattering treatment
TPBAR	Tritium-Producing Burnable Absorber Rod
TVA	Tennessee Valley Authority
UM	University of Michigan
UTK	University of Tennessee - Knoxville
VERA	Virtual Environment for Reactor Applications
VERA-CS	The VERA core simulator capability
WABA	Wet Annular Burnable Absorber
WEC	Westinghouse Electric Company

ACKNOWLEDGEMENTS

The authors of this report acknowledge the many contributions that have been made by others to reach this important milestone. The results presented in this document are the culmination of years of research and development, software testing and debugging, data collection, project planning, and many other tasks performed by many CASL participants, especially including those individuals named below. Without the collaboration of many, this success would not have been possible.

- Jeff Banta, ORNL
- Peter Cebull, INL
- Kevin Clarno, ORNL
- Bill Clontz, TVA
- Kathleen Cunningham, TVA
- Tom Downar, UM
- Brian Elder, TVA
- Fausto Franceschini, WEC
- Jess Gehin, ORNL
- Aaron Graham, UM
- Tami Grimmett, INL
- Travis Lange, UTK
- Bill Martin, UM
- Scott Palmtag, Core Physics Inc.
- Srdjan Simunovic, ORNL
- Kim Sissom, TVA
- Yixing Sung, WEC
- Erik Walker, UTK

This research made use of the resources of the High Performance Computing Center at Idaho National Laboratory (INL), which is supported by the Office of Nuclear Energy of the U.S. Department of Energy under Contract No. DE-AC07-05ID14517. INL has provided approximately 5.8 million cpu-hours on the new Falcon supercomputer to support completion of these analyses, would not have been possible otherwise.

1. INTRODUCTION

The Consortium for Advanced Simulation of Light Water Reactors (CASL) has developed a suite of high-fidelity software and methods that is capable of simulating the full operating history of a commercial pressurized water reactor (PWR), including the loading, depletion, shuffling, and discharge of all nuclear fuel assemblies. These tools, collectively known as the Virtual Environment for Reactor Applications, or VERA, include advanced solvers and multi-physics coupling algorithms that provide the most rigorous solutions available today for steady-state nuclear reactor analysis. To demonstrate this capability, VERA has recently been used to simulate over 18 years of operation of Watts Bar Nuclear Unit 1 (WBN1), and the results of these calculations are used to quantify its performance in an industry-grade benchmarking activity.

The mission of CASL is to improve the efficiency and lifetime of the U.S. nuclear fleet by the development and deployment of advanced physics methods and software capabilities. These goals will be achieved through the application of VERA to the CASL "challenge problems", which target operational (CIPS,CILC, PCI,GTRF) and safety (DNB, RIA,LOCA) issues that have not been fully resolved by currently available tools. At the heart of these simulations is the VERA core simulator, known as VERA-CS, which provides the capabilities to simulate an operating reactor over long time scales and provides the starting and bounding conditions to the challenge problem analyses. VERA-CS can perform the same functions as currently licensed reactor core analysis tools, but at higher resolutions and with fewer approximations. Section 0 describes the capabilities and components of VERA-CS.

Paramount to the success of CASL is application of VERA to engineering analyses relating to operating commercial nuclear power reactors. Often R&D projects focus on idealized problems that require less computational resources or minimal specifications. However, the CASL consortium includes founding partners Tennessee Valley Authority (TVA) and Westinghouse Electric Company (WEC), who provide the actual nuclear fuel and reactor specifications, the core operating history, the fuel discharge and shuffling plans, and the knowledge and expertise that is required to design and operate a commercial plant. The partnership between these organizations and the national laboratories and universities (Figure 1) ensures that VERA development is both advanced and practical; this is the primary contributor to the successful capabilities in VERA. Section 2 describes Watts Bar Nuclear Plant, its operating history, and the Westinghouse fuel assemblies utilized for electric power generation.

Figure 1 The CASL Founding Partners

The analyses presented in this report are similar to those performed by license industrial methods for reactor core design and safety analysis applications. These types of activities typically include the demonstration of software performance for a significant number of nuclear plants, reactors, and fuel cycles, including measured core reactivity, physic parameters, and in-core fuel assembly power distribution. In practice, the differences in calculated and measured parameters are statistically quantified for future use as a margin of safety factor for predicted parameters.

Likewise, this report documents the performance of VERA-CS for all of the fuel cycles operated at Watts Bar Nuclear Unit 1. The results demonstrate that VERA-CS can now be used relatively easily for basic reactor core depletion and shuffling calculations, given several thousand computing cores. This capability is the foundation of all future reactor analyses such as the CASL challenge problems, and in itself is valuable for comparisons to other methods and investigation of operational issues. The benchmarking results exhibit overall good agreement with the majority of the measured data, and comparisons to nearly two hundred flux maps also are very respectable for this first application. The 3D RMS difference in the power distributions is approximately 4.1%, and the radial RMS difference is 1.9%, even including at least one cycle which experienced the CIPS phenomenon.

Some of the results do indicate a negative bias in reactivity. More research and development is underway to improve this performance, as discussed in Section 0. The differences are large by industrial standards but are not completely unreasonable given the current state of ongoing VERA development.

This achievement also marks the successful completion of the VERA Core Physics Benchmark Progression Problems [1], which were developed four years ago by industry-experienced CASL staff to guide the development of VERA on a path focused on solving real problems based on actual power plant geometries. The ten progression problems initiated with single 2D fuel rod calculations and progressed to reactor depletion and fuel shuffling, along the way providing the opportunity for comparison to reference solutions and measured data. The problems also provided simple ways to communicate amongst the CASL participants from various backgrounds, assisted in the milestone and project planning, and provided an education source for those new to reactor physics. With the successful simulation of all of the fuel cycles at WBN1, the goals of the progression problems have been realized for PWR applications. The VERA-CS solutions to the progression problems will be documented and released publicly in a separate document, so as to provide an alternate source of code comparisons to new methods development in the U.S. and abroad.

The activity also formally completes one of the first tasks in the VERA-CS Validation Plan [2], which includes commercial power plant benchmarking as one of the four highlighted sources of validation. Now that VERA-CS has been applied successfully to WBN1 the next step in the plan is to broaden the application scope to include other types of plants, fuel, and burnable absorbers. Assistance will be needed from others within and external to the CASL organization to accomplish these goals. Figure 2 demonstrates how this activity fits within the context of the overall VERA-CS validation.

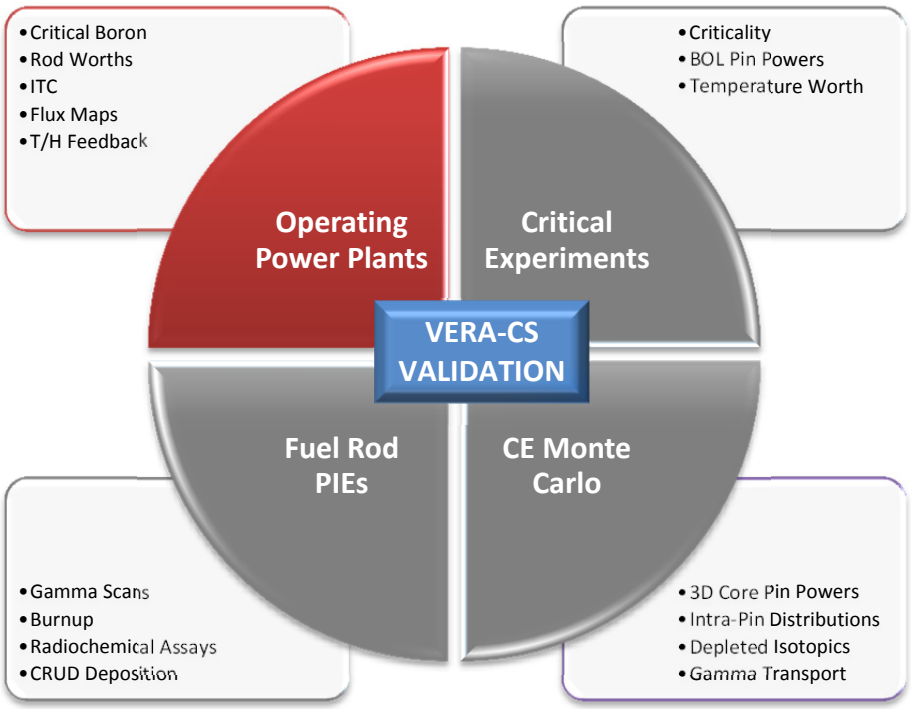


Figure 2 VERA-CS Validation Plan Components[2]

2. WATTS BAR NUCLEAR PLANT

Tennessee Valley Authority's (TVA) Watts Bar Nuclear Plant is a traditional Westinghouse four-loop PWR with ice condenser containment design [3]. Located in Spring City, TN, Unit 1 began operation in 1996 at a thermal power rating of 3411 MW_{th}, and underwent a 1.4% power uprate in 2001. Since it began operation, Watts Bar has been a leader in reliable electrical generation, with capacity factors up to 99%. Now in its 13th fuel cycle, WBN1 has been on the grid for over 6000 effective full power days (EFPD). Unit 2 is scheduled to come online in 2016 and will be the first new U.S. nuclear power plant to do so in the 21st century.

Figure 3 Watts Bar Nuclear Plant [3]

The WBN1 reactor core is comprised of 193 nuclear fuel assemblies arranged in a cylindrical arrangement (Figure 4). The fuel assemblies are the Westinghouse 17x17 design comprised of 264 cylindrical fuel rods containing a twelve foot stack of UO_2 pellets and 25 cylindrical guide and instrument tubes. Approximately 1/3rd of these assemblies are replaced with fresh (or new) fuel during each refueling cycle, while the remaining fuel is shuffled to new core locations to optimize the subsequent fuel cycle length and fuel rod power distributions. The fuel cycles have been approximately 18 months in length, with approximately 40 day refueling outages between cycles. All of these operational characteristics must be considered when performing any realistic reactor analyses.

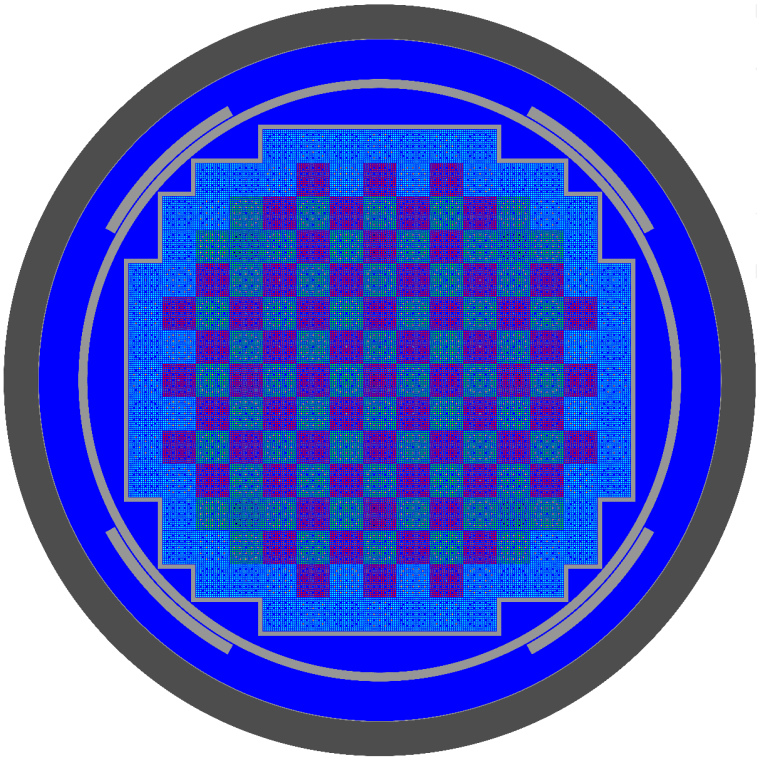


Figure 4 WBN1 Reactor Core with 193 Fuel Assemblies (Cycle 1) [4]

The fuel assemblies utilized in WBN1 have been the traditional 17x17 design (Figure 5), with only minor changes to the mechanical structure over time, such as improved spacer grids or minor changes in materials. Burnable absorbers are used to control the power distribution in the fresh fuel, including Pyrex discrete absorbers in Cycle 1, and then combinations of the Integral Fuel Burnable Absorber (IFBA) and the Wet Annular Burnable Absorber (WABA) since Cycle 2 (Figure 5). Additionally, WBN1 has participated in the U.S. Department of Energy's Tritium Production Program resulting in the loading of a number of Tritium-Producing Burnable Absorber Rods (TPBAR) for many of the cycles [5]. Each fuel cycle utilized a unique fuel placement pattern (or loading pattern) that can generally be characterized as a traditional three batch, ultra-low leakage, ring-of-fire design, with the fuel with the highest burnup on the core periphery. The cores are designed to have quarter or approximate octant symmetry.

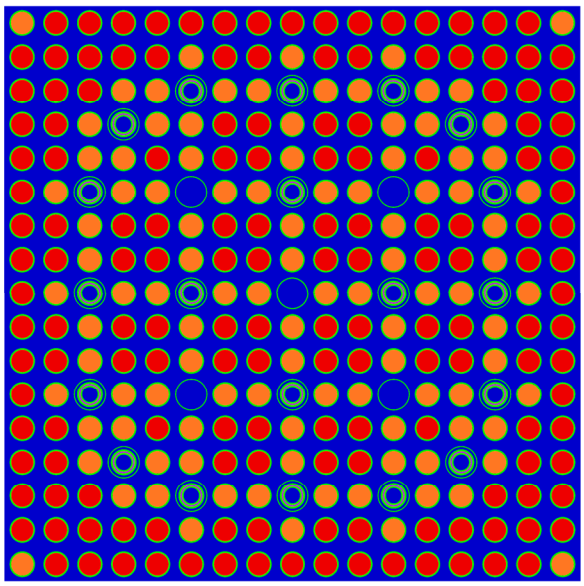


Figure 5 Sample 17x17 Fuel Rod Lattice with 104 IFBA rods and 20 WABA rods [1]

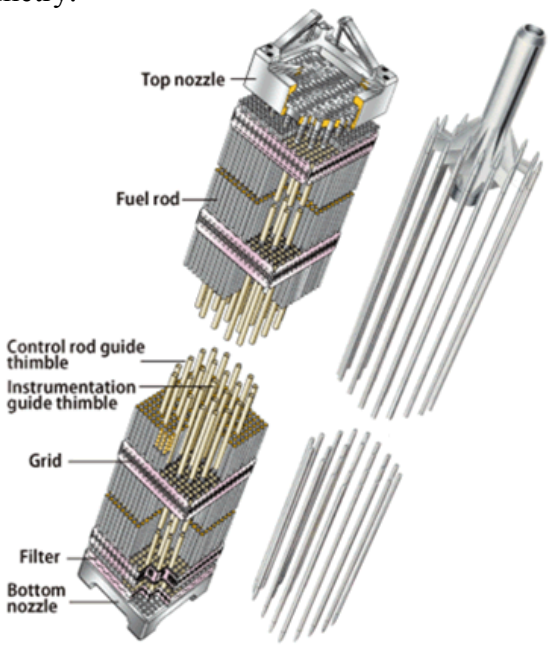


Figure 6 17x17 Fuel Assembly Components and Rod Cluster Control Assembly [1]

The current WBN1 reactor core generates 3459 MW_{th} of power (1100 MWe) in 50,952 fuel rods containing approximately 89 metric tons of enriched uranium. The fuel rods are cooled by borated water driven through the pressurized reactor vessel at 144.7 Mlbm/hr by four constant-volume reactor coolant pumps. The average conditions of the coolant are approximately 590 °F @ 2250 psig. The boric acid injected into the coolant provides a chemical shim for reactivity control that can be nearly continuously removed/diluted as the reactor fuel depletes over a fuel cycle [4]. This boron "letdown" is commonly used for validation of the reactivity prediction of reactor core simulators.

In addition to the chemical shim, neutron-absorbing control rods are utilized for instantaneous reactivity control and for safe shutdown of the plant in case of unplanned events. The rods are clustered into assemblies with 24 rodlets connected to a central spider hub at the top of the assembly (Figure 6). There are 57 total Rod Cluster Control Assemblies (RCCA) grouped into eight separate "banks". The banks can be positioned at any elevation in the reactor core using the control rod drives, which allow the RCCAs to traverse the height of the reactor core in approximately 230 discrete 0.625" steps. Four of the banks (~42%) are reserved to ensure safe shutdown margin, while the other four are used for reactivity control. Only one bank, Bank D, is positioned slightly in the core during nominal full-power operation. The WBN1 control bank locations are shown in Figure 7, using quarter-core symmetry.

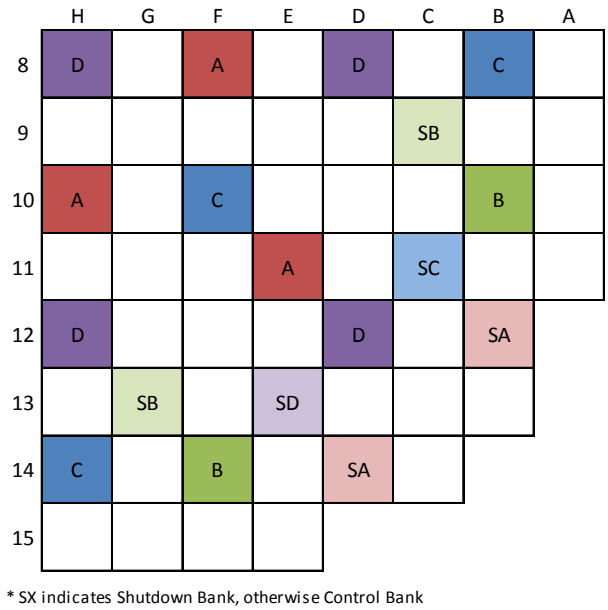


Figure 7 WBN1 Control Bank Locations [4] (quarter symmetry)

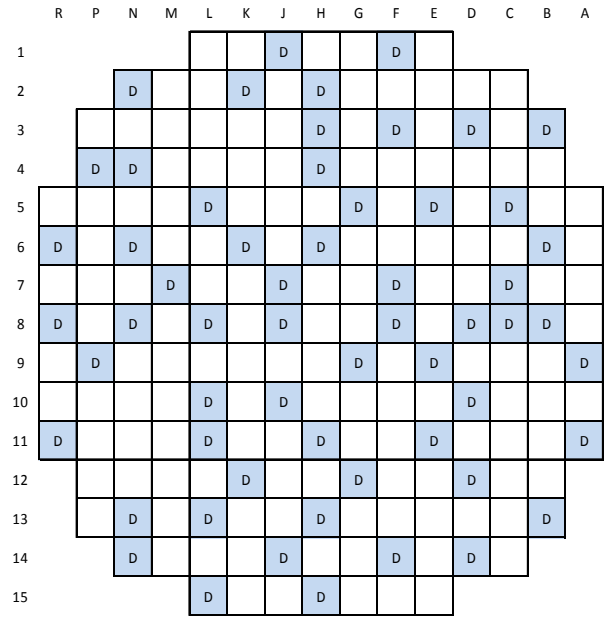


Figure 8 WBN1 In-Core Detector Locations [4]

WBN1 utilizes both in-core and ex-core instruments to monitor the neutron flux in the reactor. The in-core detectors are moveable fission chambers that are used to perform core surveillance activities and ex-core calibration at prescribed intervals ranging from one to three months. The detectors are driven into the reactor core through installed thimble tubes in the center of selected fuel assemblies, shown in Figure 8. The signals returned from these detectors are aligned and processed into "flux maps" that are compared to predicted power distributions. The flux maps are also an excellent source of validation data for reactor physics applications.

Over 13 fuel cycles, each lasting approximately 18 months, WBN1 has irradiated over 1000 fuel assemblies containing over 300,000 fuel rods. The purpose of the VERA core simulator is to model the entire irradiation history for each of these rods and to accurately calculate the isotopics, coolant conditions, CRUD deposition, cladding strain, rod internal pressure, or any other rod-wise quantities. The results in this document represent the first time VERA has been used to simulate an operating reactor over multiple fuel cycles, and is the next step in achieving the long term CASL goals for the challenge problems. VERA-CS has been utilized to calculate the following measured quantities for each fuel cycle at WBN1:

a. Beginning-of-cycle (BOC) criticality of the reactor, including fuel assembly shuffling and isotopic decay during the refueling outage
b. BOC hot-zero-power (HZP) control bank reactivity worths (CBW)
c. BOC HZP isothermal temperature coefficient (ITC)
d. Hot-full-power (HFP) critical boron letdown over the entire fuel cycle
e. HFP in-core instrument response distributions (flux maps) over the entire fuel cycle

Using these measurements, VERA-CS has been utilized to simulate Cycles 1 through 12 of WBN1 (Cycle 13 is currently operating), and benchmarking has been performed for 12 BOC HZP criticalities, 96 CBWs, 12 BOC HZP ITCs, 418 exposure-dependent HFP critical boron concentrations, and 183 HFP flux maps. These results are provided in Section 4.

3. VERA-CS DESCRIPTION

Modern methods for reactor core analysis are limited in fidelity and usually rely on couplings to coarse T/H methods followed by separate (and sometimes inconsistent) bounding analyses. The methods are not necessarily difficult to use, but may be time consuming to build models and require different inputs and technical knowledge for each physics package. Most notably the core simulation is a multi-stage approach using several levels of condensation, resulting in an increase in computation speed but a loss of accuracy at the local rod level. The T/H and fuel performance analyses supporting reactor core reload and design are not typically a part of the neutronics core simulator, and therefore are not directly used for reactor simulation. Despite these shortcomings, modern industrial methods have been used for decades to successfully support the design and operation of power reactors all over the world.

The VERA-CS components have been selected to eliminate the barriers facing modern methods for improved accuracy on smaller spatial scales. It has several advantages, including the list below and those in Table 2, where they are contrasted with common industrial methods.

- The VERA-CS user needs to interact with only a single simplified input format for all physics methods being employed. The input is mostly geometry-based and has been optimized with appropriate defaults so that a user need not be an expert in any particular area of physics. (Currently there exists some exceptions to this goal, but these will be resolved with further development). VERA-CS also internally manages the calculation flow of each physics component and iterates between them until convergence is reached.

- VERA-CS is based on advanced physics and mathematical methods and limits the number of stages and approximations made between user input and solution. Because it is a more direct approach to simulation, the amount of input and expertise required is minimized, which also reduces the likelihood of human error.

- The individual methods employed by VERA-CS are each an advancement in technology beyond current analysis methods, either in methodology and/or spatial scale and refinement. For instance both the neutronics and T/H methods in VERA-CS solve directly on the fuel rod level as opposed to a lumped 2x2 per assembly scale.

- The individual physics codes in VERA are directly coupled, and multi-physics problems are fully solved iteratively to convergence. Any complicated data mapping between methods is handled automatically, and any user can easily employ the methods of the core simulator without requiring substantial training in that methodology. The results of this process are always best-estimate, and therefore the coupling is, in itself, and advancement beyond current practice. (Note that the fuel mechanics coupling in VERA is still under development)

- Currently the VERA-CS user needs to interact with only a single binary output file, which uses a standardized HDF5 format, rather than navigating the output of each physics code individually. The common VERA-CS output file will contain or have the ability to enable any commonly used edit from any of the three dominate physics areas (The VERA-CS output is still under development). The HDF5 output can be accessed via available third-party tools (such as HDFView [6]), or can be visualized by the new CASL utility VERAView (Section 3.6), or converted to SILO format for use with VisIt [7] or ParaView [8].

Table 2 VERA Capabilities for Reactor Core Simulation
(*italics* represents items under development)

Capability	VERA-CS	Typical Industry Methods
Neutron Transport	3D (2D/1D) whole-core pin-resolved transport based on actual fuel, core, and support structure geometry	Transport-based 2D infinite lattice physics + 3D nodal diffusion theory with approximate reflectors
Cross Section Energies	Finer energy group structures (47 groups) but minimized for performance	Lattice physics in hundreds of groups with 3D diffusion in few groups (2-3)
Pin-by-pin Powers	Explicit 3D pin and intra-pin powers on fine axial mesh	3D pin average powers reconstructed from 2D infinite lattice calculations and nodal solution
Thermal-Hydraulics	Directly coupled multi-phase sub-channel for each flow channel (between fuel rods) with cross flow	Simplified single-phase lumped channel models for nodal neutronics with detailed sub-channel bounding analyses uncoupled
Fuel Mechanics	*Directly coupled for intra-pin fuel temperature feedback and cladding stress calculations.*	Simplified average fuel temperature models for nodal neutronics with detailed risk analyses uncoupled
Instrumentation	Direct in-core *and ex-core* instrument response models	In-core response from 2D infinite lattice calculations; no ex-core models
Short Lived Fission Product Poisons	Explicit pin-by-pin buildup, decay, and depletion of Xenon and all fission products via detailed decay chains	Average Xenon and Samarium concentrations tracked nodally without feedback to pin powers
Depletion	Explicit intra-pin depletion at actual local spectral conditions, *including component depletion such as control rods and instrumentation*, and including explicit pin-by-pin shutdown decay calculations	Depletion performed explicitly at 2D lattice levels for various anticipated spectral and geometric conditions and pin exposures inferred at 3D level from node-average exposure for approximate spectral conditions
Spacer Grids	Direct effects on neutron flux, depletion, instrument response, and T/H	Typically not explicitly resolved or included in neutronics calculations
CRUD	Direct accumulation of CRUD containing boron based on sub-channel steaming, with feedback to neutrons and depletion	CRUD not modelled directly but assessed for risk as a post-processing step to the analyses.
Safety Analysis	Direct calculations for parameters such as DNB, PCI, CFM, etc	Bounding analyses performed separate from neutronics, sometimes with manual iteration between physics
Gamma Transport	*3D gamma transport for local energy deposition and instrumentation response*	Gamma transport in 2D at the lattice physics level and included only in the relative pin power distributions
Neutron Fluence	*Direct accumulation in structural components for lifetime evaluations*	Approximated from few group nodal flux in nearest fuel locations
Computer Resources	Single statepoint calculations in ~30 minutes on ~4000 cores, in quarter symmetry	Neutronics single statepoint calculations in < 1 minute on 1 core following a few hours to pre-tabulate cross sections. Detailed T/H and fuel mechanics calculated separately.

In summary, VERA-CS is a user-friendly, high-fidelity reactor core simulator built by direct coupling of multiple advanced physics methods and solvers, making it one of the most advanced capabilities of its kind in the world. Figure 9 through Figure 10 provides examples of some of the high-fidelity results which are easily obtainable with VERA-CS.

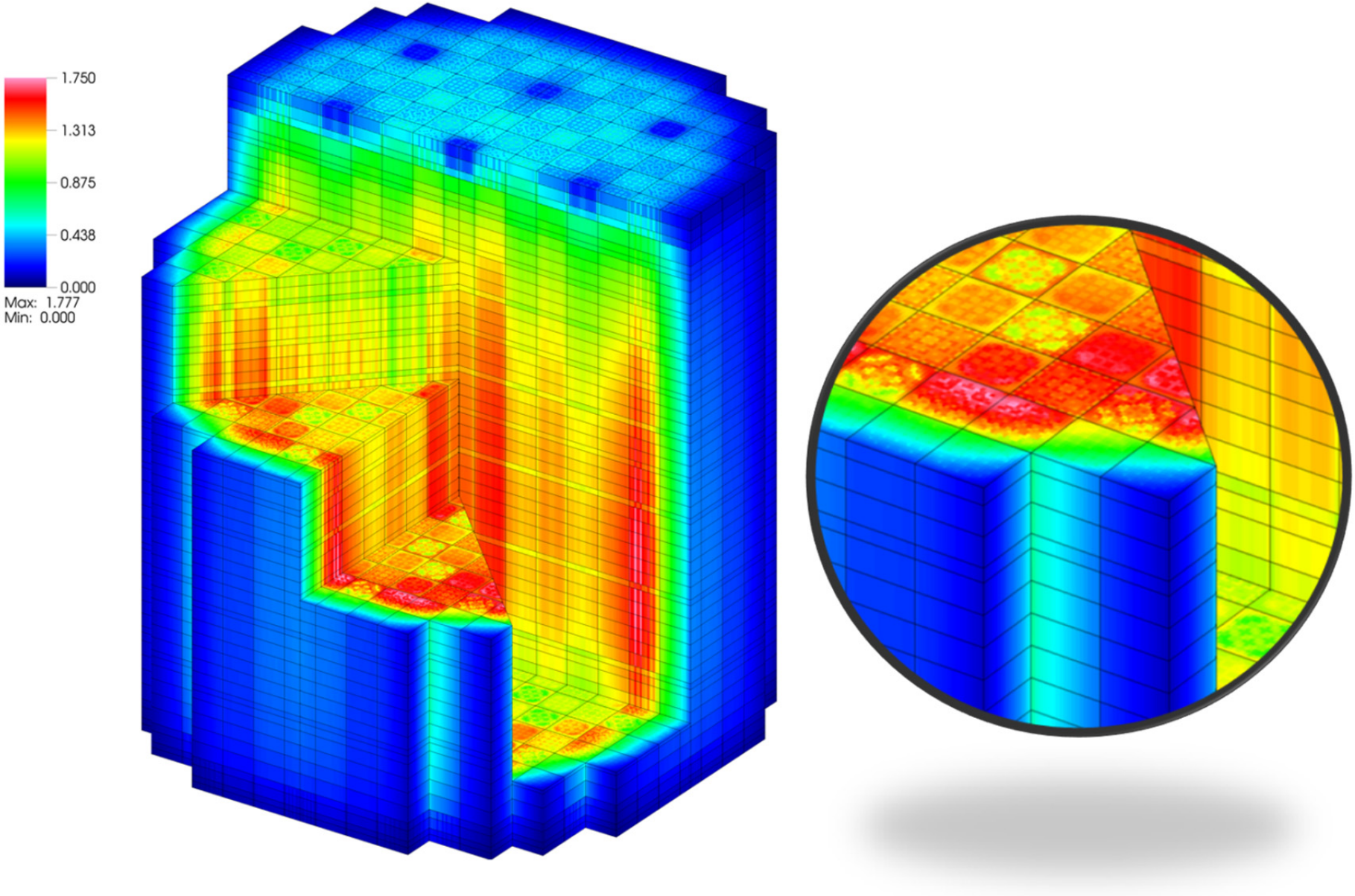


Figure 9 VERA-CS HFP Fuel Rod Power Distribution for WBN1 Cycle 11 @ BOC

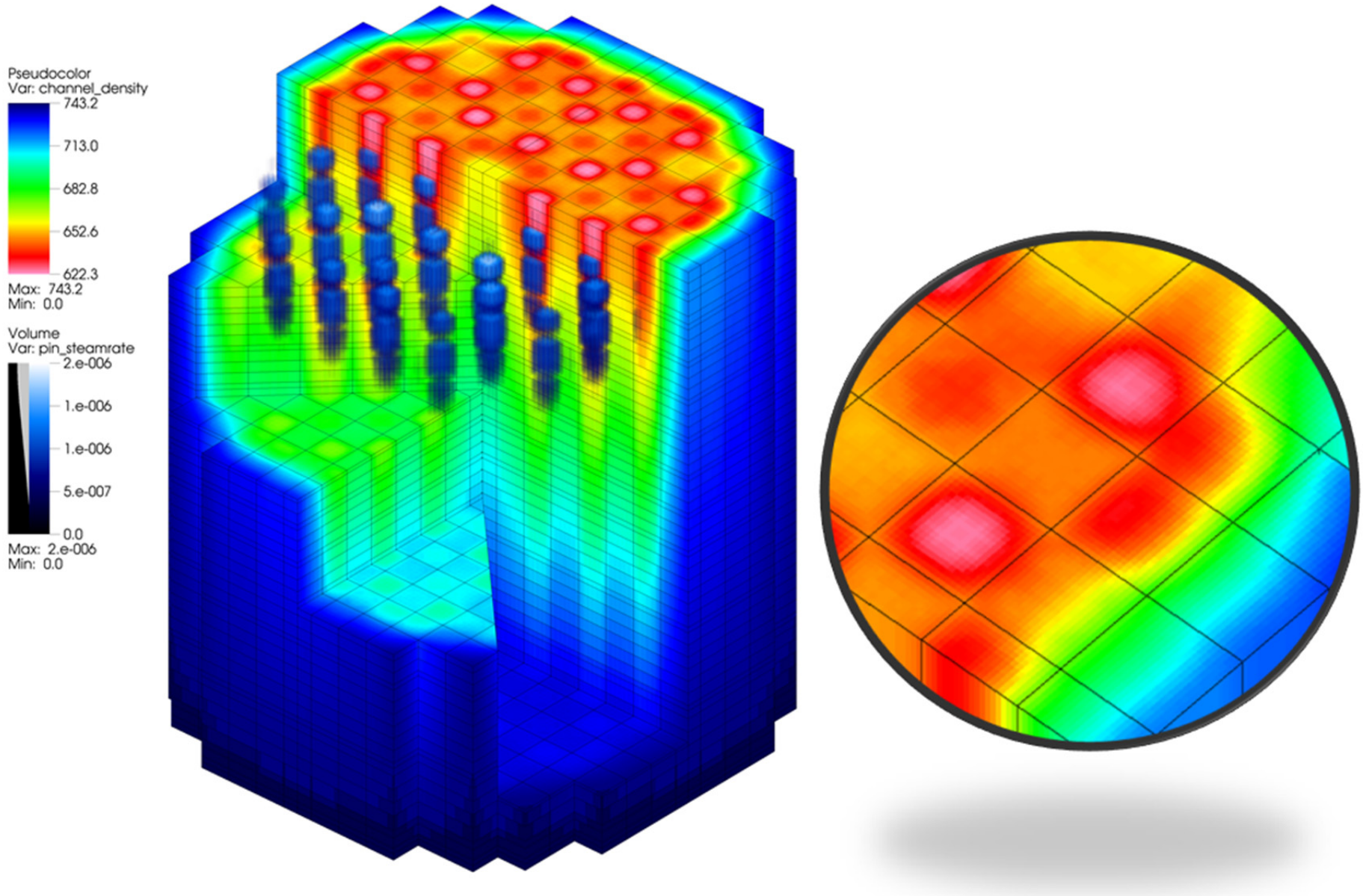


Figure 10 VERA-CS 3D Channel Coolant Densities (kg/m3) and Fuel Rod Steaming Rates (kg/s) for WBN1 Cycle 11 @ Middle-Of-Cycle

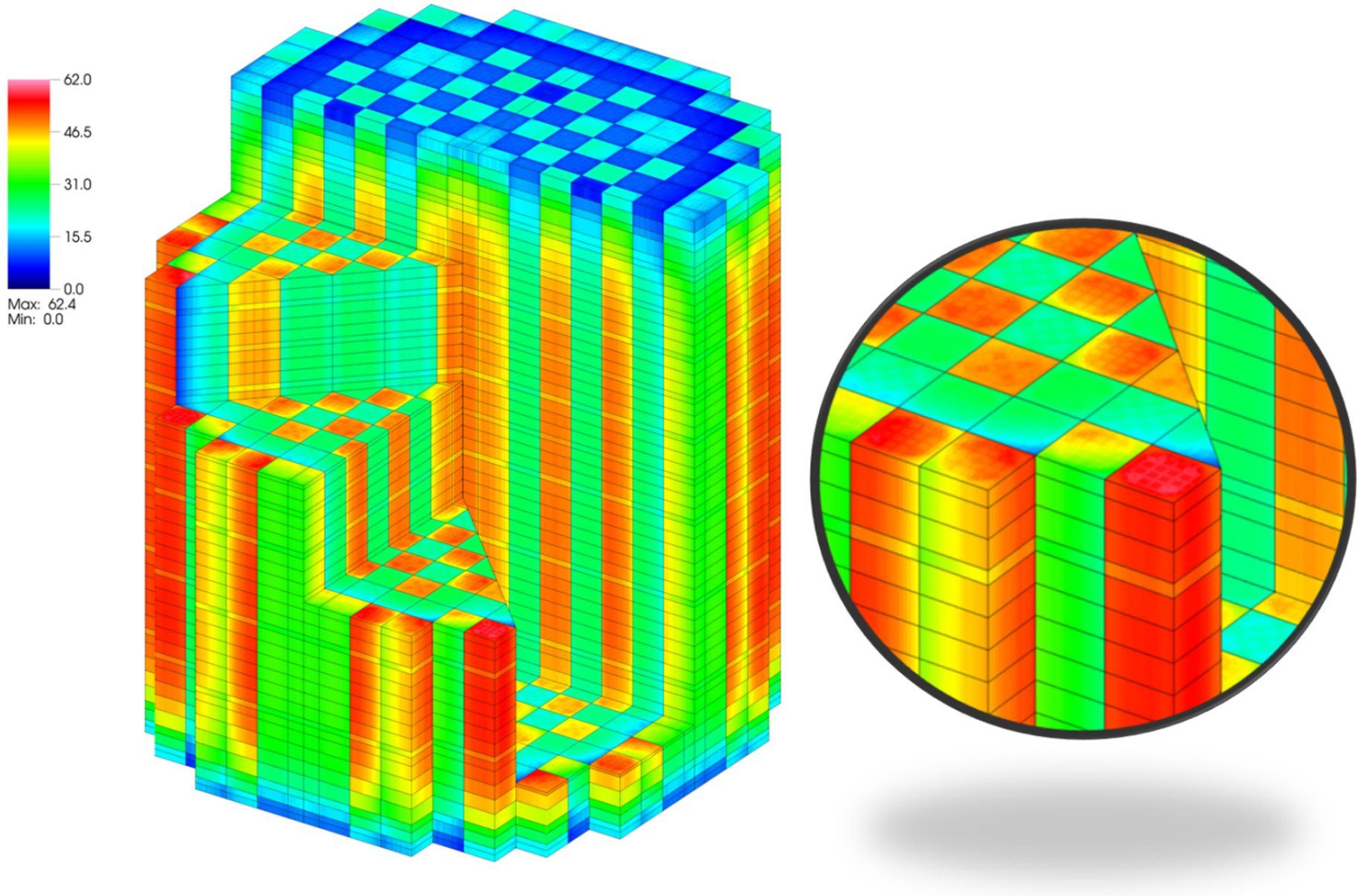


Figure 11 VERA-CS Fuel Rod Exposure Distribution for WBN1 Cycle 11 @ EOC (GWd/MTU)

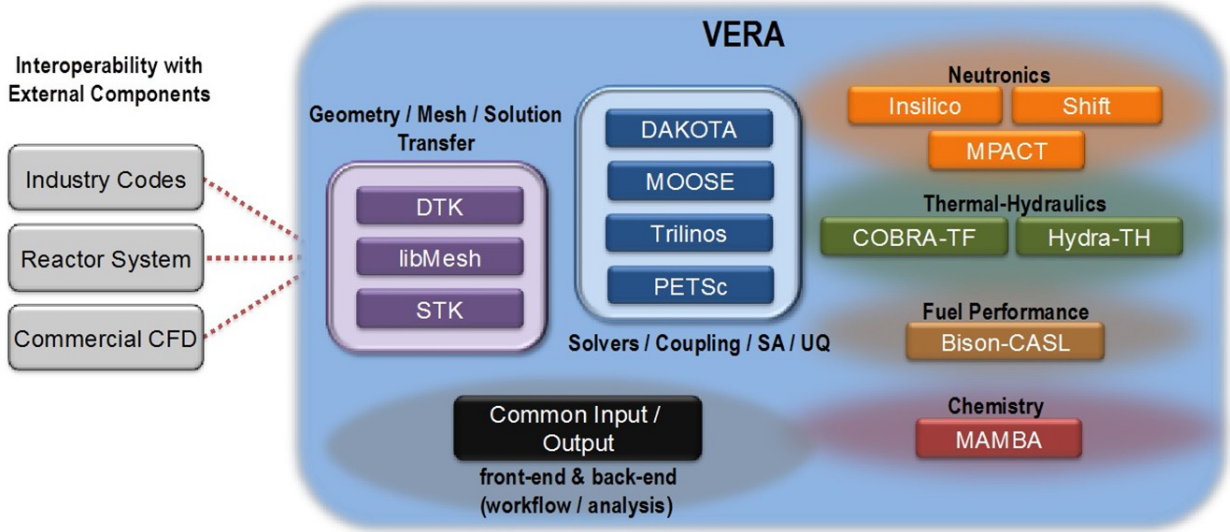


Figure 12 Current Components of VERA

Figure 12 displays all of the major individual components of VERA. It contains many tools, including reactor physics methods such as neutronics, thermal-hydraulics, and fuel rod mechanics, as well as mathematical solvers, data coupling algorithms, and tools for uncertainty quantification. This section summarizes the computer codes and methodologies utilized in VERA to perform this simulation of WBN1. For more details, refer to previous completed CASL reports listed as references or posted on the CASL website at http://www.casl.gov/TechnicalReports.shtml. The VERA components used for this benchmarking activity are described in the subsequent sections.

3.1 VERAIn

VERAIn is the name given to the ASCII-based input interface created for VERA-CS. It provides a common input source for all of the coupled physics codes employed in VERA-CS, ensuring ease-of use and geometric consistency for the entire problem. Through VERAIn it is possible to easily create full core models of typical PWR power plants with a simple and minimal input structure in a short period of time. From a user perspective, this input provides a high level of usability that allows complex three-dimensional multi-physics models to be easily generated.

The VERAIn structure is a free-format text file with minimal delimiters and a clearly defined and minimal set of keywords. It is designed to be simple for engineers to create and modify, even on remote systems. The input quantities are intuitive to engineers familiar with modern core analysis tools, and are based on engineering drawing or specification quantities with little knowledge of the individual physics codes. The main section of input is specific to the model geometry and is not dependent on the component of VERA being executed. The input is separated into modular 'blocks' and can include comments following an exclamation mark (!). An example of the input format is provided in APPENDIX A , and the user manual can be downloaded directly from the CASL website [9].

The input is parsed as a pre-processing step before execution of the individual physics codes. The user data are converted to a common geometry model for use by all VERA codes, and stored in an XML database which is easy to interpret by computer codes. During the parsing process, VERAIn also performs error checking on a large portion of the input data allowing users to catch input errors earlier in the workflow. The abstraction of the XML data layer can support other types of input in

the future, such as a GUI, but VERAIn is the simplest and most familiar to potential users today. The XML input can also be manipulated directly, but it is not recommended.

Recently the materials input to VERAIn has been overhauled, largely due to feedback from the Westinghouse Test Stand [10]. Now it is possible to define custom materials in either weight fraction, volume fraction, or atom density using any isotope found on the cross section library. Default materials for standard reactor analyses are now provided through ASCII initialization files, if desired, via the –init option of the VERAIn application. The user can choose to use default materials, include custom materials that are specific to the VERA installation, or include materials local to a specifc input file. The formats of these options are all identical and easy for the user to modify. Processing of the materials occurs at the higher level of VERAIn so that the downstream physics codes all have access to the same material definitions.

3.2 MPACT

The reactor core simulator MPACT has been developed collaboratively by researchers at the Oak Ridge National Laboratory (ORNL) and University of Michigan (UM) to provide an advanced pin-resolved transport capability within VERA. The key characteristics of the MPACT code include the subgroup method and the embedded self-shielding method (ESSM) for resonance treatment, depletion capability based on the ORIGEN exponential matrix method, and a whole core solver with a 2-D/1-D synthesis method on the frame of a 3-D coarse mesh finite difference (CMFD) method for which axial and radial correction factors are obtained from 2-D method of characteristics (MOC) and 1-D Simplified P_N. Reference [11] contains a detailed description of the methods used in MPACT as a part of VERA-CS.

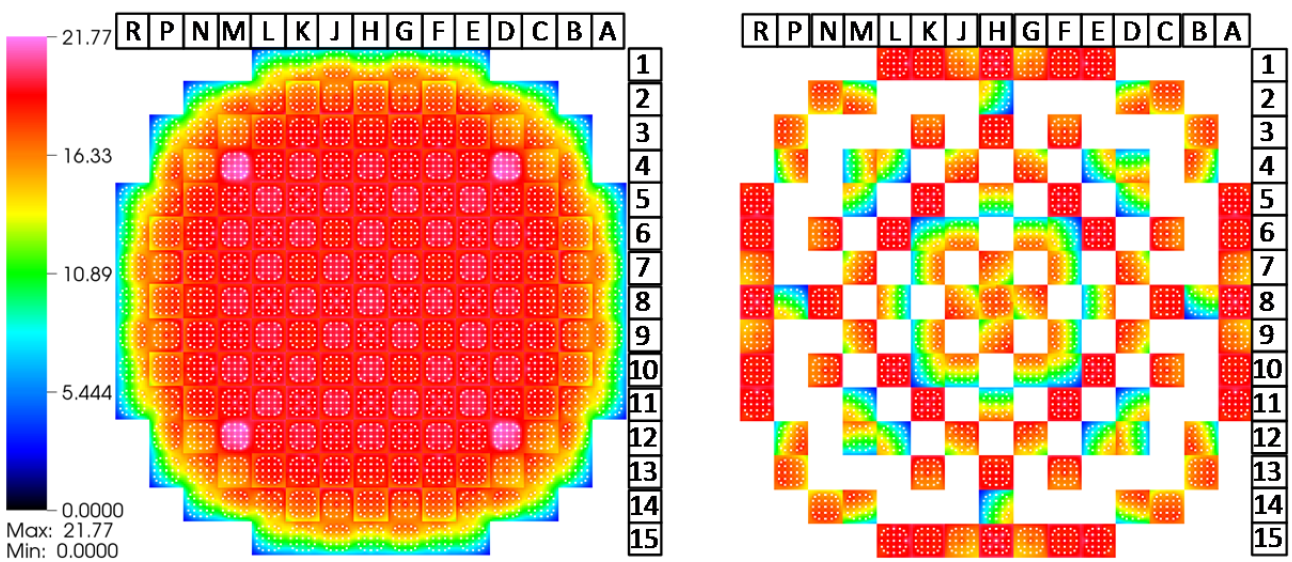
The 2-D/1-D synthesis approach is a numerical method for whole-core transport solutions pioneered largely by the DeCART code [12], but another variation was developed around the same time in the CRX code [13]. Since then, the method has been gaining wider use in the reactor physics community [14,15] and has been demonstrated to provide practical high fidelity solutions [16]. For many practical reactor calculations, the 2-D/1-D method has become popular because its computational costs are considerably lower than those of full 3-D transport. The 2-D/1-D equations approximate the 3-D Boltzmann equation more accurately than the conventional 3-D diffusion equation; they preserve exact transport physics in the radial directions (x and y), but they use diffusion physics in the axial direction (z). The 2-D/1-D equations can be systematically discretized to yield accurate simulation methods for many 3-D reactor core problems.

Like any deterministic transport solver, the accuracy of the methods in MPACT are highly dependent on the quality of the cross-section library. The AMPX code package [17] has been developed at ORNL to generate the multi-group (MG) and continuous energy (CE) AMPX libraries for the SCALE code package [40] by processing the evaluated nuclear data such as ENDF/B and JEFF. The AMPX library, based on ENDF/B-VII.0, has been used to generate a 47-group library [18] based on the HELIOS group structure [19]. The subgroup method for resonance self-shielding calculation in MPACT requires subgroup data that are composed of subgroup levels and weights. A standalone subgroup program, SUBGR, has been developed to generate the subgroup data by a least squares fitting which utilizes resonance self-shielded cross sections as a function of background cross section converted from the MG AMPX library. In order to accommodate high order scattering accuracy with a transport corrected P0 (TCP0) calculation, transport cross sections have been generated for light nuclides by using various transport correction methods [20,21].

In addition to the transport solver, MPACT provides several support capabilities for VERA-CS including:

- Critical boron search and equilibrium Xenon models
- Direct integration of CTF to improve coupling efficiency (Section 3.3)
- Burnup-dependent fuel temperature lookup tables as an alternative to the internal heat conduction model
- Predictor-corrector depletion interface which directly calls the ORIGEN API (Section 3.5
- In-core detector response calculations
- Treatment of control rod cusping effect
- Ability to save all isotopes to a file at a current statepoint and restart the solution using this file
- Ability to shuffle fuel between fuel cycles including shut down decay calculation between cycles

All of these capabilities are essential to perform practical core analysis using VERA-CS. An example of the shuffling capability is demonstrated the Figure 13.



(a) EOC 1 pin-wise exposures (b) BOC 2 pin-wise exposures

Figure 13 Watts Bar Nuclear EOC1 and BOC2 Fuel Rod Exposures

The pin-wise exposures are given at the end of Cycle 1 and then the shuffled map at the beginning of Cycle 2 is shown on the right. This demonstrates the transfer of the pin exposures, along with all of the isotopes tracked by ORIGEN, to the new location in the core.

3.3 CTF

CTF is a modernized, improved, quality-controlled version of the COBRA-TF [22] subchannel thermal-hydraulic code. The code is being developed and maintained by Oak Ridge National Laboratory and Pennsylvania State University as part of the CASL program. In VERA-CS, CTF is directly coupled to MPACT and is executed in full for each neutronics-T/H iteration until convergence is reached between the two codes.

CTF uses a transient two-fluid, three-field (i.e. liquid film, liquid drops, and vapor) modeling approach. A wide range of flow-regime dependent closure models are available for capturing complex two-phase flow behavior, which includes rod-to-fluid heat transfer, inter-phase heat and mass transfer, wall and inter-phase drag, turbulent mixing and void drift, grid-droplet breakup, and grid heat transfer enhancement effects [23]. The rod-to-fluid heat transfer models were designed to handle the entire boiling curve, including single-phase flow, subcooled and bulk boiling, critical heat flux, and post-critical heat flux heat transfer. It has found many applications before and during the CASL program, including: modeling single-phase normal operating conditions, modeling two-phase flow in accident conditions [24,25,26], modeling of BWRs [27], uncertainty quantification [28], and benchmarking activities [29]. A higher-fidelity model of the core is achieved with CTF by modeling each rod-bundle coolant channel and pin in the core individually. An example of the meshing approached utilized in VERA-CS is given in Figure 14.

The incorporation of CTF into CASL has led to many major improvements to code quality and the user interface as well as the addition of new features. Specific improvements include:

- Implementation of a source version control system
- Integration into an automated build and testing system using TriBITS [30]
- Application of unit and integral regression testing and validation testing [31]
- Development of a PWR preprocessor for building CTF models directly from the VERAIn common input deck
- Addition of HDF5 capabilities for improved data accessibility and better integration with VERA-CS post-processing tools
- Source code optimization and code parallelization for reduction in runtime and memory usage [32]
- Improvements to closure models
- Development of a code coupling interface for linking with other VERA-CS components
- Creation of a cycle modeling capability and coupling with the MAMBA chemistry code [33,34]
- Application of the code to high-fidelity, large-scale DNB analysis [35]
- Implementation of a capability for specifying non-uniform inlet temperature and flow maps through VERAIn
- Implementation of a rotational symmetry capability

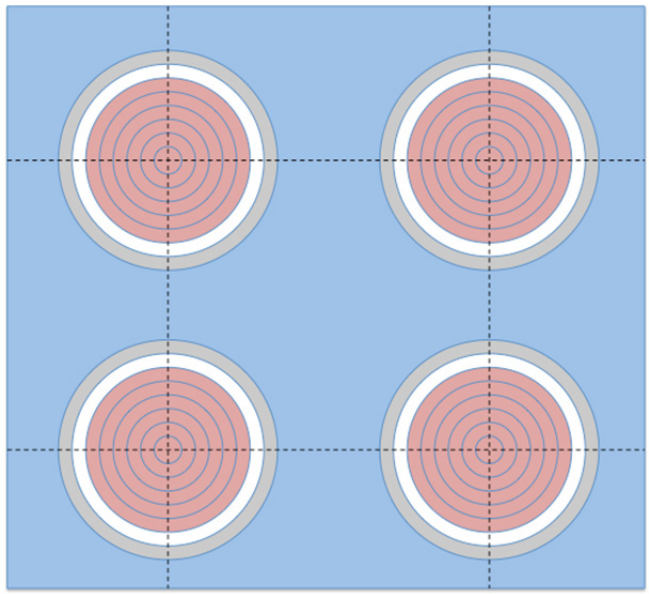


Figure 14 Example of CTF rod-bundle meshing approach in VERA-CS

Due to the pin-cell resolved modeling approach utilized in CTF, it is possible to capture core thermal-hydraulics with a relatively high level of detail. Figure 15 gives an example of the CTF predicted coolant outlet temperature distribution for Cycle 12 of WBN1. The distribution is more smeared than the power distribution supplied to CTF due to the modeling of lateral cross resulting from turbulent mixing and pressure differences. This is the type of high-fidelity physics that can be difficult to setup and execute normally, but VERA-CS performs the calculation for every time step and outer iteration.

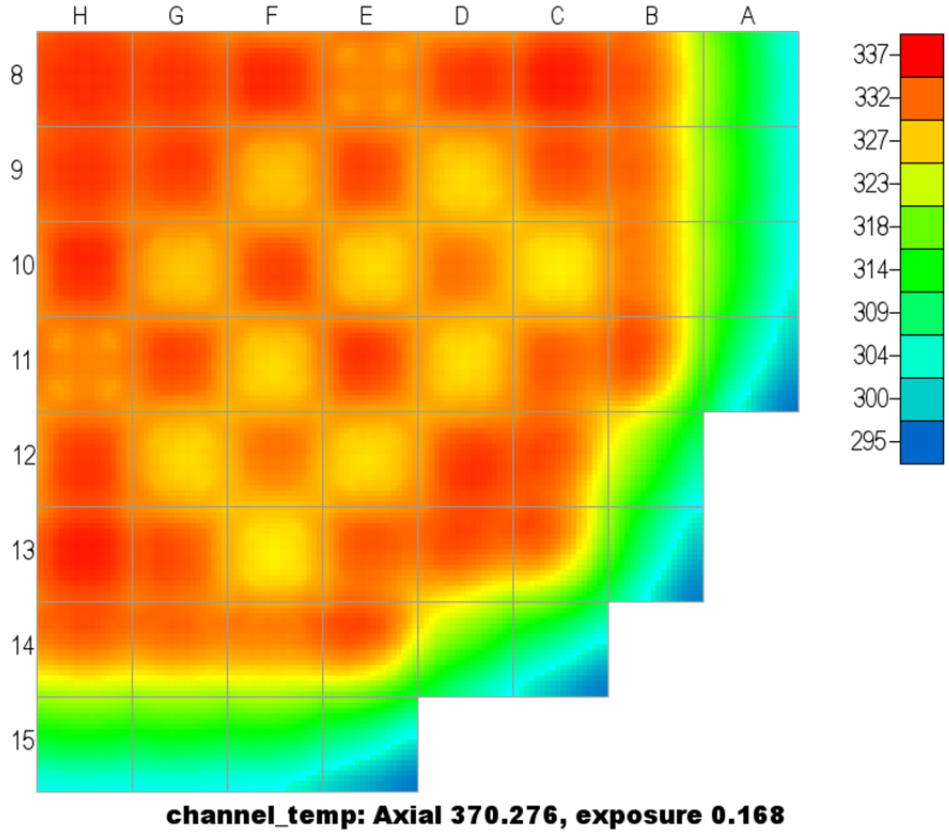


Figure 15 VERA-CS Exit Temperature Distribution from CTF in WBN1 Cycle 12 (°C)

3.4 Bison-CASL

The complexities of fuel rod operation, material performance, and fuel rod design characteristics drive the need for an integral fuel performance and analysis code to simulate the multiple interacting processes that impact UO_2-Zircaloy fuel rods [36]. The Bison-CASL fuel performance code is being developed as a tool for calculating the fuel thermomechanical behavior during normal operation and operational transients. The multi-physics, multi-dimensional characteristics of the PCI failure mechanism has been the main focus for advanced modeling and simulation of nuclear fuel. Such a capability can then be used to evaluate the PCI failure potential under a variety of operating conditions and fuel rod designs.

Bison-CASL builds on the Multiphysics Object-Oriented Simulation Environment (MOOSE) [37] framework developed at Idaho National Laboratory (INL). MOOSE is a massively parallel finite element computational system that uses a Jacobian-free, Newton-Krylov (JFNK) method to solve coupled systems of non-linear partial differential equations. The MOOSE framework enables the effective use of massively parallel computational capabilities needed to create high fidelity 3-D models of a fuel rod, as well as full-length R-Z rods and R-Theta geometric representations.

Bison-CASL expands upon the underlying architecture of BISON, the development of which has been led by INL [38]. This architecture includes the ability to incorporate, or develop, material properties libraries and fuel behavior models for UO_2 fuel and zirconium alloy cladding commonly used in PWRs. A major focus of the CASL effort on modeling nuclear fuel performance, beyond the Bison-CASL development, has been to develop physics-based material models for ceramic UO_2 fuels and zirconium alloys [39]. These models consist of irradiation induced clad creep and growth, clad corrosion, the hydrogen pickup and hydride precipitation in the clad, and the release and transport of fission gas. However, since Bison-CASL is being developed simultaneously with the effort to develop improved mechanistic behavior models that are not yet ready for implementation, empirical models from the open literature and selected EPRI/Falcon models have been incorporated to date. This strategy allows for testing of the numerical framework of Bison-CASL, as well as identifying material models that require further development. Figure 16 shows a representative finite element mesh used to model a fuel rod in Bison-CASL.

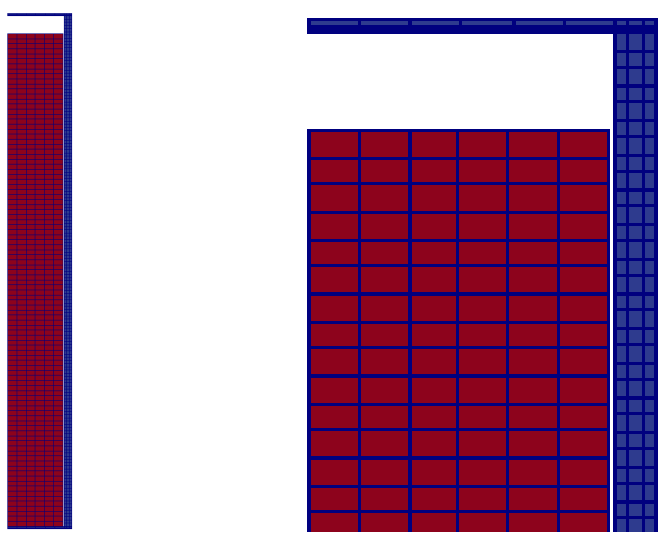


Figure 16 Full-length view (left) and close-up view of the top of the fuel rod (right) of a Bison-CASL model, with radial dimensions scaled up by a factor of 100 due to the aspect ratio of the fuel rod

The primary objective of Bison-CASL for this analysis was to provide estimates of the volume-averaged fuel temperatures as a function of power and exposure for use in the VERA-CS simulations of the Watts Bar Nuclear Plant (WBN1). Using Bison-CASL to calculate average fuel temperatures will provide improvements over the use of volume-averaged fuel temperatures from CTF calculations due to the detailed thermomechanical fuel behavior treatment in Bison-CASL including pellet-clad gap closure, fission gas release, and the evolution and degradation of material properties (e.g., UO_2 thermal conductivity).

The increased physical representation of fuel behavior provided by Bison-CASL-calculated fuel temperatures will improve the accuracy of calculated plant parameters during cycle operations such as soluble boron concentration, power distributions, and flux map data for specific assembly locations. The coupled neutronics-thermal hydraulics simulations used to calculate these plant parameters depend strongly upon the neutron cross sections for a given material, which vary according to the temperature of that material at a given point in time. Through the material neutron cross-sections, fuel temperatures greatly impact the results of reactor physics depletion calculations, with fuel temperature decreases generally producing corresponding increases in reactivity for LWRs.

Appendix B provides details of the methodology employed to generate average fuel temperature for VERA-CS using Bison-CASL, selected results from the analyses, and a discussion of the findings and recommendations for the WBN1 VERA-CS calculations in this work.

3.5 ORIGEN

The Oak Ridge Isotope Generation (ORIGEN) depletion/decay code was developed at ORNL in 1973. In 1980, the development was forked into two versions, ORIGEN2 and ORIGEN-S, with ORIGEN2 intended for "stand-alone" depletion/decay calculations and ORIGEN-S intended for coupled neutron transport/depletion/decay analysis within SCALE [40]. Since then, many new versions have been created, mostly modified versions of ORIGEN2, readily available from RSICC. In 1989, support for ORIGEN2 was cancelled. Since 1989, ORIGEN-S, recently rebranded as just "ORIGEN", is the only variant under active development, and has been since the inception of the original ORIGEN in 1973, the only version supported by ORNL, with continuous updates to both data and methodology, as part of the SCALE code system. See Reference [39] for history details.

For more information on the ORIGEN depletion capability in CASL please see the previous CASL technical reports in references [42] and [43].

ORIGEN has been used to model nuclide transmutation for over 40 years, with capability to generate source terms for accident analyses, characterize used fuel (including activity, decay heat, radiation emission rates, and radiotoxicity), activate structural materials, and perform fuel cycle analysis studies [40,44,45,46]. This wide range of applications is possible because the guiding principle has been to explicitly simulate all decay and neutron reaction pathways using the best available data and rigorously validate the result versus experiment. As an integral part of SCALE 6.1 [40], ORIGEN has been subject to hundreds of validation cases using measured data from destructive isotopic assay of spent fuel, decay heat of spent fuel, gamma spectra resulting from burst fission, and neutron spectra resulting from spontaneous fission and (α,n) reactions.

An active modernization has taken place over the last few years [39,47] and the ORIGEN depletion/decay module has received extensive improvement including an application programming

interface (API) for both C++ and Fortran with modern object-oriented design, and various solver enhancements which are available in SCALE 6.2 [48,49]. Figure 17 shows the ORIGEN API and ORIGEN data in green—both are necessary to perform any realistic calculation. The ORIGEN API is contained within SCALE and used by SCALE to fulfill depletion needs for numerous sequences, e.g. TRITON, ORIGEN, ORIGAMI, Polaris. Currently the Monte Carlo code SHIFT and deterministic transport code MPACT use ORIGEN through the API.

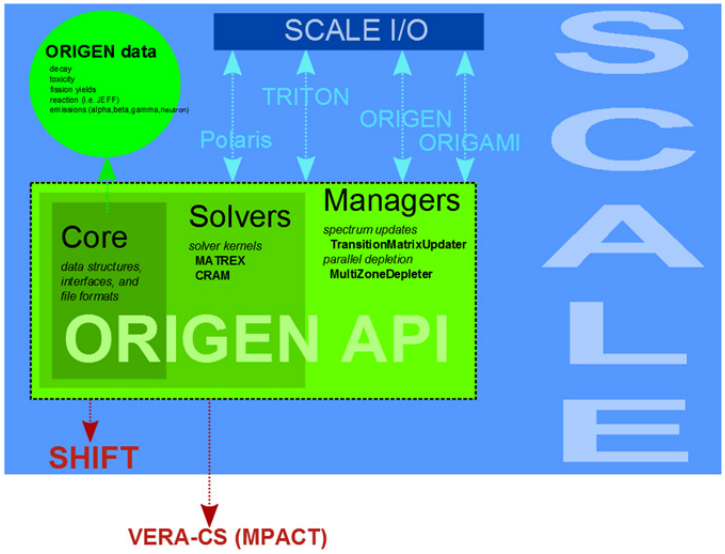


Figure 17 Organization of the ORIGEN code in SCALE

In 2013, the ORIGEN API required a runtime per solution of 1 second. In order for depletion time to be small compared to transport runtime, a desired runtime of 0.1 second was proposed. In order to achieve this goal, the general-purpose burnup chain with ~2200 nuclides and ~54000 transitions (valid for any time-scale, any material), was simplified to include only isotopes important for LWR core physics. The current simplified burnup chain "CASL2.0" contains the 263 nuclides shown in APPENDIX C and reduced total runtime by a factor of 10 while preserving such quantities as total energy production, activity, mass, and macroscopic cross sections.

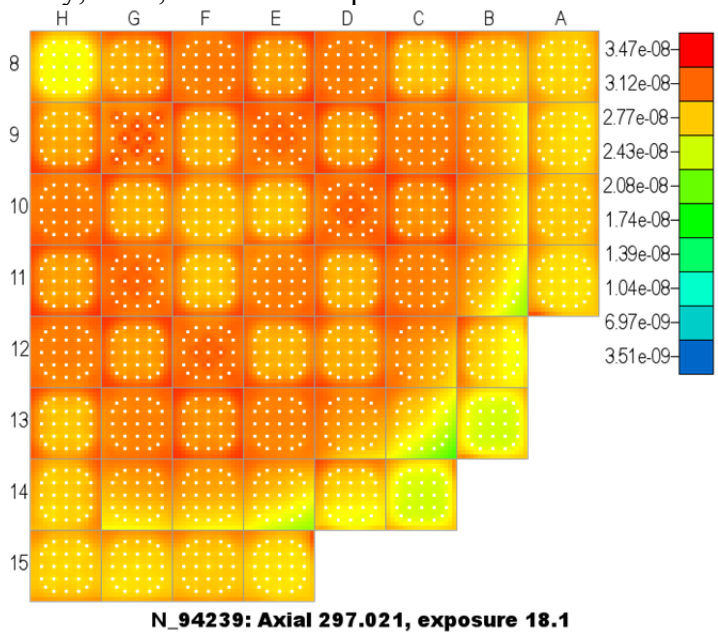


Figure 18 VERA-CS ^{239}Pu Distribution from ORIGEN for WBN1 EOC2

3.6 VERAView

VERAView was created to provide an extensible, easy-to-use viewer, browser, and analysis capability for the VERA output. It has recently been developed using rapid prototyping and lightweight python utilities, reading HDF5 files that adhere to the CASL VERAOut specification [50] and also supporting some extensions to the specification. Datasets are categorized as channel, detector, pin, or scalar data. With the exception of the detector category, the dataset shape determines its type.

VERAView is architected around a data model, an event system representing user selections, and a widget framework. The data model represents the content of a VERA output file and provides the necessary processing to categorize and access the datasets it contains. Events represent the "state" of the user's current selections, such as the state point, axial level, assembly, pin, and channel cell. Ultimately, VERAView is a graphical user interface (GUI) application implemented as a container of user-selectable widgets, where each widget is responsible for providing a view or representation of some portion of the data. Individual widgets may process whatever datasets are of interest but are typically focused on a particular type or category. Although widgets in the initial distributed prototype consist of 2D views and plots, 3D views can and will be added in the future. All widgets receive events representing the user selection state, and each widget can be the source of such events. Several widgets have been implemented in the initially distributed VERAView prototype. These are demonstrated in Figure 19.

As the capabilities in VERA increase, new widgets can be added to VERAView as needed. Each widget implementation extends a Widget class (or one of its subclasses) and thus must implement some methods required by the framework. In many cases default behavior can be inherited, but a few methods and properties must be implemented for the widget to function correctly. This makes the VERAView platform an ideal way to interact with the data produced from an evolving multi-physics reactor analysis code like VERA-CS.

Users interact with VERAView by simply opening an HDF5 file that conforms to the VERAOut specification [50] and either clicking in the widgets or sliding the statepoint or axial sliders. For the main screen, clicking in a widget with a radial map selects an assembly, pin, or channel, which causes the other widgets to update, if desired. Clicking an axial plot selects a particular axial elevation which updates the radial widgets. In the future more functionality will be added so that a user can find the limiting locations in a dataset, plot an element of a dataset over time, or compare two datasets.

VERAView can also produce image files of any of the widget color maps or plots, which have been conveniently used in many of the figures in this document.

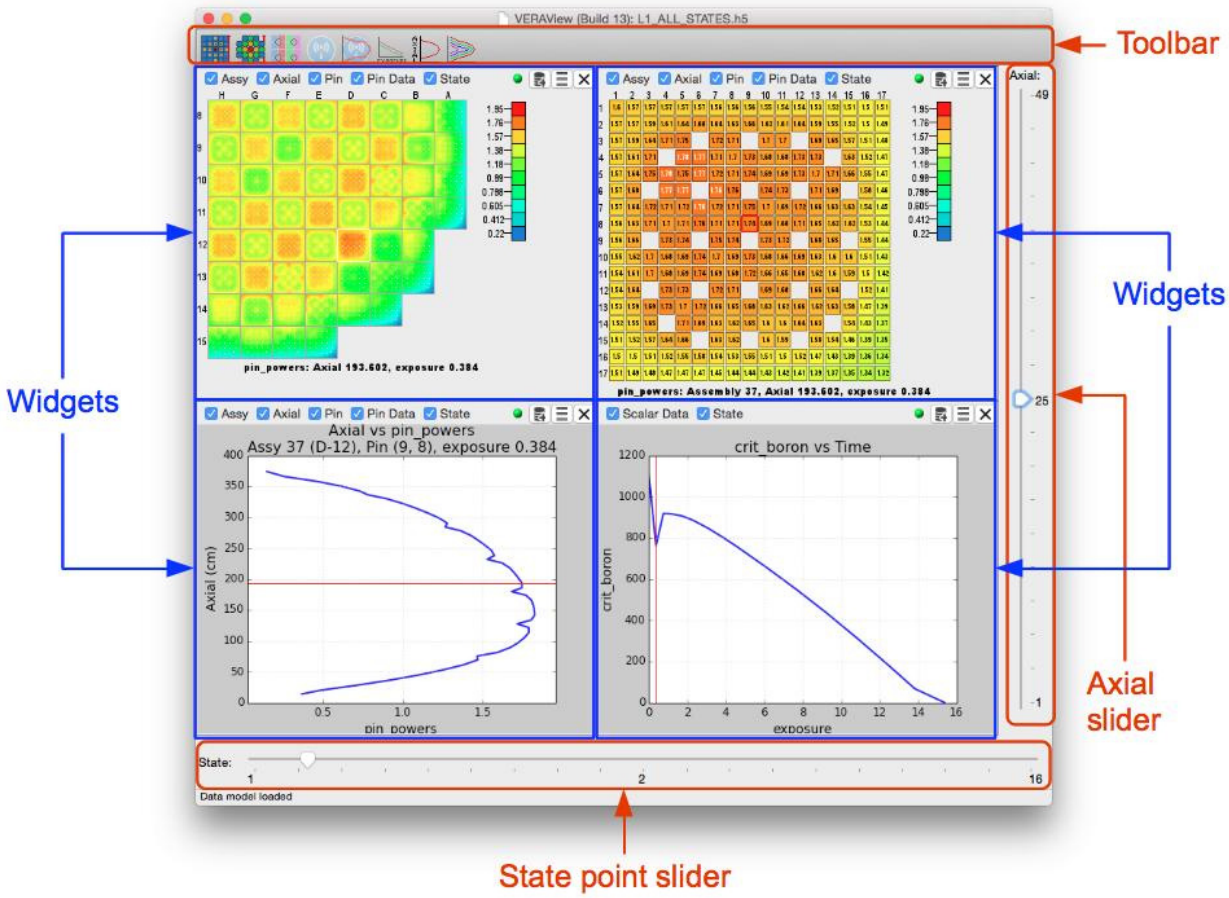


Figure 19 VERAView Main Window

4. BENCHMARKING RESULTS

4.1 Model Charactistics

The WBN1 models for VERA-CS were constructed with the common ASCII input based on the fuel reactor and fuel assembly specifications provided by TVA and Westinghouse. The models are very detailed and include features such as end plugs, plenum springs, IFM spacer grids, and thimble plugs. Because of the nature of the transport method, the models were massaged slightly to ensure everything lined up on an axial mesh boundary, other than partially inserted control rods. The radial reflector included only the baffle and not the barrel or neutron pads. Homogenized axial reflector regions were automatically created for the assembly nozzles and core plate regions.

Many of the WBN1 fuel cycles had some distinguishing characteristics, including:

- Cycle 1 is the only cycle to use discrete Pyrex burnable absorber rods and lower enriched axial blankets in the fuel. The power history of Cycle 1 was also more complicated than the other cycles due to more significant periods low power operation or shutdowns.
- Cycle 2 began the use of the traditional IFBA/WABA poison types. Cycle 2 also included a few TPBAR LTAs.
- Cycle 3 began the use of annular blanket pellets for the fuel rods containing IFBA.
- Cycle 4 performed a mid-cycle power uprate of approximately 1.4%.
- Cycle 6 transitioned to a slightly different fuel assembly type with IFM grids and began the irradiation of production TPBARs.
- Cycle 7 experienced CIPS.
- Cycle 11 significantly increased the number of TPBARs and had no WABAs.
- Cycle 12 changed the control rod design and also no WABAs.

A 53 axial level model was chosen in the fuel for the edits and T/H coupling. This resolves each spacer grids and utilizes an approximately three inch mesh in between grids. For parallelization, complete spatial decomposition was performed by axial plane and by fuel assembly, resulting in 59 axial planes (3 for the top reflector and 3 for the bottom) and 73 radial nodes, for a total of 4307 processors. The number of processors could be reduced to as few as 472 cores, requiring less than 4 GB/core of memory. However, this would increase the runtime by approximately a factor of ten.

4.2 BOC HZP Critical Boron Concentration

Initial criticality is achieved at the beginning of each fuel cycle at hot-zero-power (HZP) conditions by dilution of the reactor coolant system and positioning of the regulating control bank, Bank D. The soluble boron concentration at criticality is recorded and compared to predicted values at the time as part of standard BOC physics testing procedures. The acceptance criterion for this test is typically within 50 ppm of the predicted value, but much better agreement is expected. In specific situations, the criteria can be relaxed to a maximum limit of 1% reactivity (in equivalent terms of boron deviation from the predicted value).

The measured values from WBN1 have been provided by TVA as part of the zero power physics test results transmittals, References [51] and [52]. For Cycles 2-12, the 'Boron Endpoint' test was performed, which measured the critical boron concentration with Bank D partially inserted and the reactivity worth of Bank D. The all-rods-out (ARO) critical boron concentration is then estimated using the predicted differential boron worth from the cycle core design. Typically the amount of

inserted reactivity is small (~50-70 pcm), so the estimated ARO critical boron concentration is insensitive to differences in the predicted boron worth. For this reason, the VERA-CS simulations are simply critical boron searches at ARO conditions.

Each of the VERA-CS calculations was performed after reloading the core and shuffling the fuel from the previous cycle (except Cycle 1). The previous fuel compositions were decayed by ORIGEN over the time span of the refueling outage, also resulting in the complete decay of ^{135}Xe and buildup of ^{149}Sm. The calculations were performed without T/H feedback, in quarter-core symmetry, and the MOC ray spacing was significantly decreased by 10x to improve the accuracy of neutron transport near the very thin IFBA coating. The differences between the measured endpoint critical boron concentrations and the calculated values with VERA-CS are shown in Figure 20.

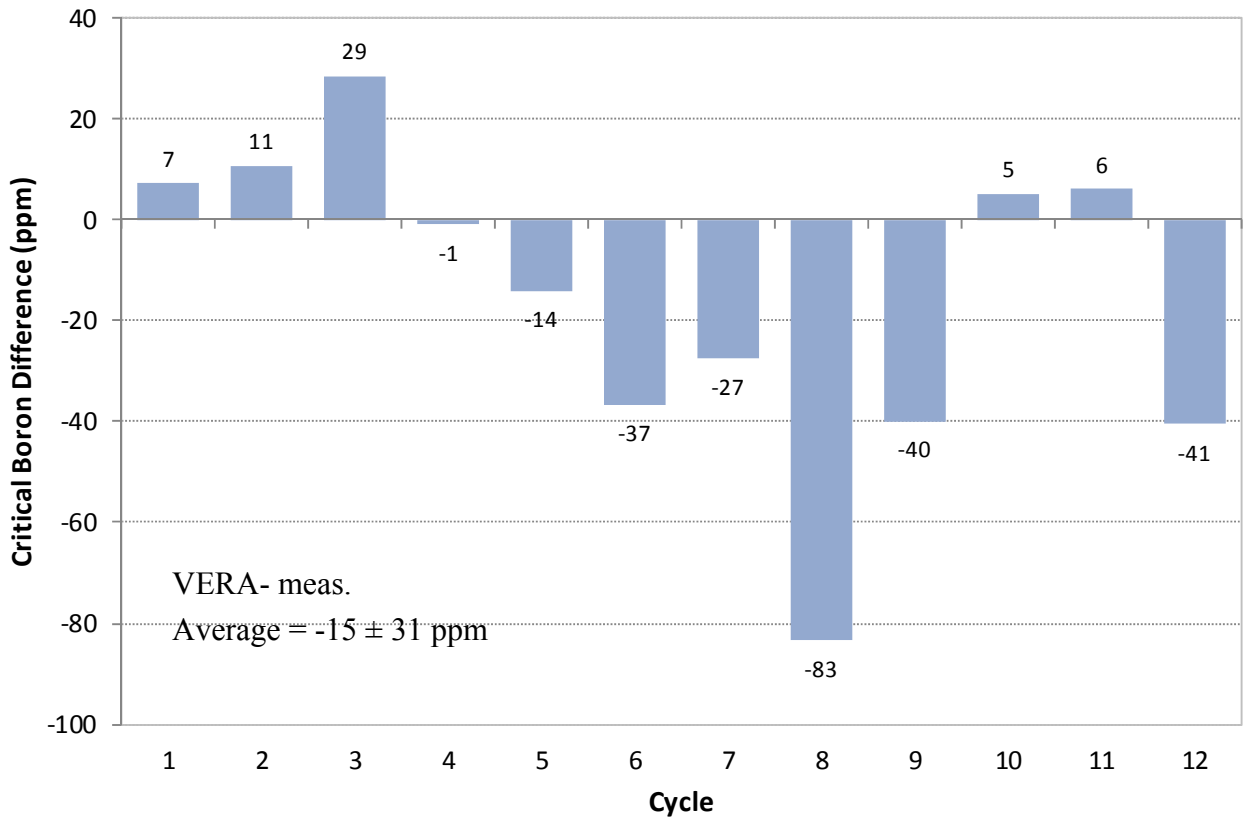


Figure 20 BOC HZP Critical Boron Concentration Differences

The average BOC HZP critical boron difference is -15 ppm, with about half of the cycles having good agreement and the others with significant under-predictions in reactivity. Cycle 8 is particularly bad, but this is likely due to the occurrence of CRUD Induced Power Shift (CIPS) in the previous cycle. Additionally, Cycles 6-12 included TPBARs and due to the classified nature of these components their absorber loading is approximate. The reactivity effect of thermal expansion is also not present in these results.

Another uncertainty in the models is the ^{10}B abundance in the soluble boron. Complete measured data is not available, but it is known from experience that the ^{10}B content can vary at BOC by several tenths of a percent. With the concentrations used at WBN1, this could be a significant effect on the perceived reactivity agreement. The results in Figure 20 assume 19.8 at% ^{10}B rather than the 19.9 at% used by default in VERA-CS, which reduces the difference by up to 1/3rd for some cycles.

Furthermore, if Cycle 8 is removed from the statistics, which is believed to deviate due to the occurrence of CIPS in Cycle 7, the average BOC HZP critical boron error becomes -9 ± 24 ppm.

The VERA-CS runtimes of these cases were 105 ± 21 minutes on 4307 cores (180 nodes) on the Falcon supercomputer at INL for each cycle. These includes reading the previous cycle isotopic data from disk, performing the fuel shuffle and decay, solving the critical boron search, and writing a new restart file. The variation in runtime is due to the number of files being read for restart (due to fuel being reinserted into the core from the spent fuel pool), and due to variations in file I/O performance on the computer. These cases also took longer than is typical because the MOC ray spacing was decreased by a factor of ten due to the use of IFBA. This effect has been shown previous to be worth approximately -10-15 ppm at BOC and it decays quickly as the IFBA is depleted.

4.3 BOC HZP Control Bank Worths

The control bank reactivity worths (CBW) are measured at the beginning of each fuel cycle as part of the startup test procedures. The measured worths are compared to predicted data from the core design and analysis teams to ensure that the fuel shuffle has been performed correctly and that the uncertainty in the worths assumed in the safety analyses is still bounding. Typically a plant will not continue their startup procedures until any CBW differences are adequately addressed. The criteria for these tests are typically 15% or 100 pcm agreement for any bank and 10% on the total worth (sum of all banks).

Different types of CBW tests were performed at WBN1, including rod swap in Cycle 1, subcritical rod worth measurement in Cycles 8-11, and dynamic rod worth measurement in the remaining cycles. None of these tests procedures can be directly simulated by VERA at this time because they would require transient neutronics (kinetics) and ex-core response models, as well as inclusion of the secondary source rods. Instead the VERA calculations have been performed at steady-state critical conditions, in the same manner in which the predictions would be made by core design methods prior to startup. Thus, these results are not directly consistent, but mimic those that would be obtained if VERA was used to predict a future startup.

The measured values from WBN1 have been provided by TVA as part of the zero power physics test results transmittals, References [51] and [52]. The individual bank worths were not measured in Cycles 8-11, and only the total worth is reported. For Cycle 1, the measured values have been slightly adjusted to account for different rod “shadow” factors for the rod swap. The shadow factors are calculated adjustment factors for the test banks that relate the worth of the reference bank to its worth when other banks are simultaneously inserted [55]. For all cycles, Bank D is the highest worth bank and Bank SA is the lowest worth bank. In all cases, the VERA calculated CBW is simply the reactivity worth of inserting the bank fully at representative HZP conditions. The calculations are performed using quarter-core rotational symmetry, and the results are compared to measured values for the individual banks in Figure 21 below.

The individual bank worth performance of VERA is mixed, with some cycles demonstrating excellent agreement while others do not. The Cycle 5 calculations consistently over-predict the bank worths, and Bank D even fails the 15% criterion. However, there were also large deviations between measument and predictions during the actual startup testing, so this gives some indication that a portion of this differences is due to the uncertainty in the measurements. This is also true for Bank D in Cycle 2, which also had a large deviation from predictions during the startup. The average absolute error is 4.1%, and 3.2% in all the cycles other than Cycle 5.

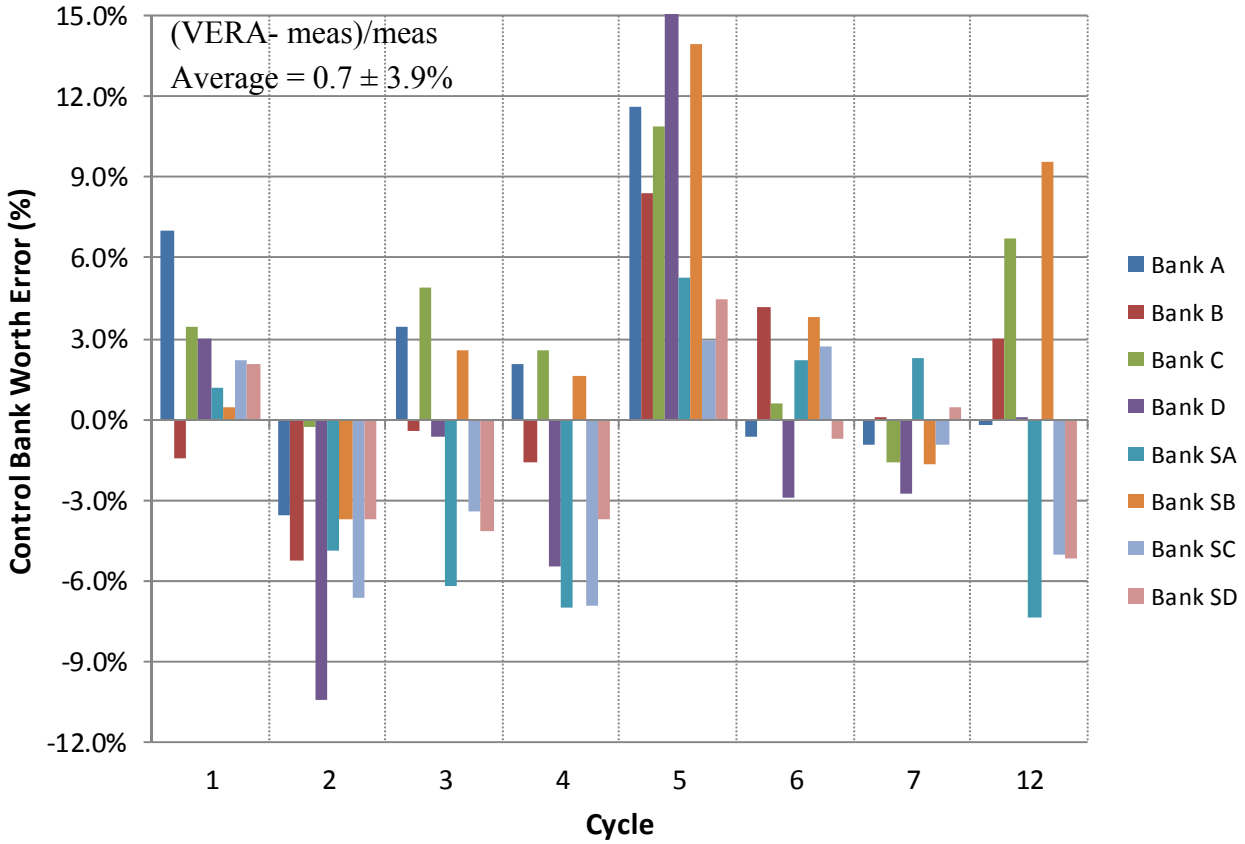


Figure 21 BOC HZP Individual Control Bank Worth Errors

The possible uncertainties in this comparison are many. First, the CBW test technique is in itself quite different from the calculation method. The results are dependent on delayed neutron data (unknown) and other constants installed on the plant computer, some of these dependent on the nuclear analysis methods in place at the time of the core design. Dynamic rod worth also relies on ex-core detector response factors and the specifications of the secondary source rodlets, which are not included in the model. The individual control rodlet as-built absorber loading is also unknown.

On the calculation side, these results were produced using transport-corrected P_0 scattering treatment, which is known to result in larger reactivity differences for single assembly cases with heavy control rods. To reduce the runtime, the nominal MOC ray spacing was used even though the fresh fuel contains a large number of IFBA rods. Finally, the control rod cusping model was employed which homogenizes the control rod tips axially (in the guide tube) in the affected axial plane using an approach that is an improvement over volume-weighting for black absorbers. This should also be a small effect because for Cycles 2-12 the calculations only include cases where the rods are either fully inserted or fully withdrawn.

The total rod worth errors for all of the WBN1 cycles are shown in Figure 22. In most cases the values represent the sum of the individual bank worths, but for subcritical rod worth measurement in Cycles 8-11 it is the deviation in the reactivity of all of the control banks simultaneously (in a sub-critical condition). These comparisons are not ideal for code validation, but they demonstrate what agreement could be obtained if VERA-CS were used for startup testing predictions with the same methodologies as used for currently NRC-licensed industrial methods.

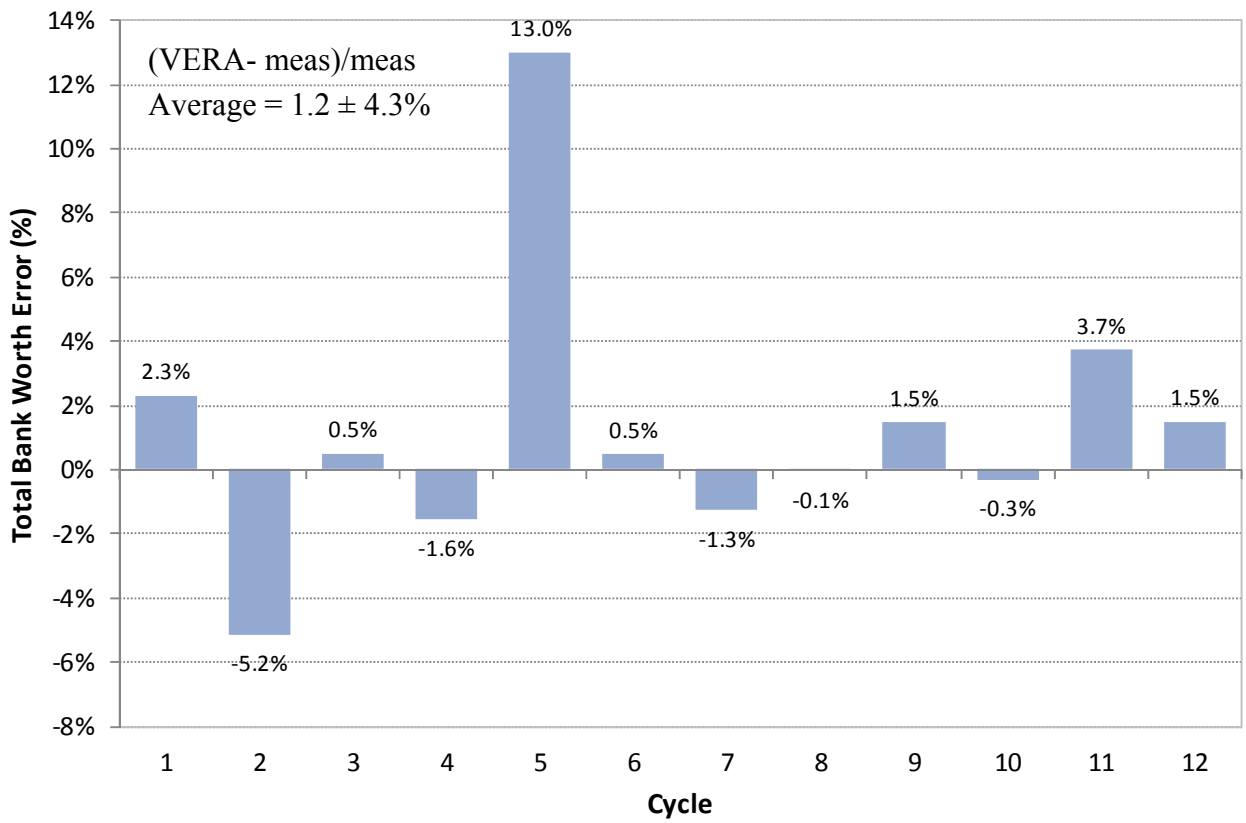


Figure 22 BOC HZP Total Control Bank Worth Errors

As in the cases of the individual bank worths, the Cycle 5 results are inconsistent compared to previous and subsequent cycles. It is unclear what is causing this large deviation, but it is believed that this is partly due to the measurement uncertainty because the original test results were also problematic. Without Cycle 5, the total rod worth error for the remaining cycles is excellent at 0.1% ± 2.3%, and 1.7% is the average absolute deviation (average of absolute values).

The VERA-CS runtimes for the cases with individual bank worth calculations are approximately 3 hours ± 20 minutes on 4307 cores. This includes reading the BOC restart file and running nine statepoints with different bank configurations but no T/H feedback.

4.4 BOC HZP Isothermal Temperature Coefficient

Like the control bank worths, the startup physics testing procedures also include the measurement of the isothermal temperature coefficient (ITC) of reactivity to ensure the installed reactor core conforms to designed safety parameters and Technical Specification limits for temperature feedback. The reactor coolant system is forced through a series of small cool-downs and heat-ups (usually less than 5 °F) without producing any sensible nuclear heat. The reactivity effects of the temperature changes are measured with the plant computer. The typical acceptance criterion for this test is differences between predicted and measured ITCs of less than 2 pcm/F.

VERA-CS cases were executed for each cycle starting from the BOC shuffle restart file and encompassing the actual temperature range of the tests. The cases were run at BOC HZP conditions with control banks either at the initial critical position or fully withdrawn. The soluble boron

concentration, an important parameter for accurately predicting the temperature coefficient, was set to the measured critical value for each cycle. Finally, the MPACT internal T/H model was used to get the perturbations in moderator density accurate and consistent for the input inlet temperature. (i.e. without feedback, moderator density must be entered by hand, which can easily lead to larger errors in the calculated ITC). Typically the calculations included three stacked cases.

Figure 23 provides the ITC differences between VERA-CS and the average measured value for each cycle. The ITC is calculated as the average reactivity worth per degree temperature change between the eigenvalue search cases.

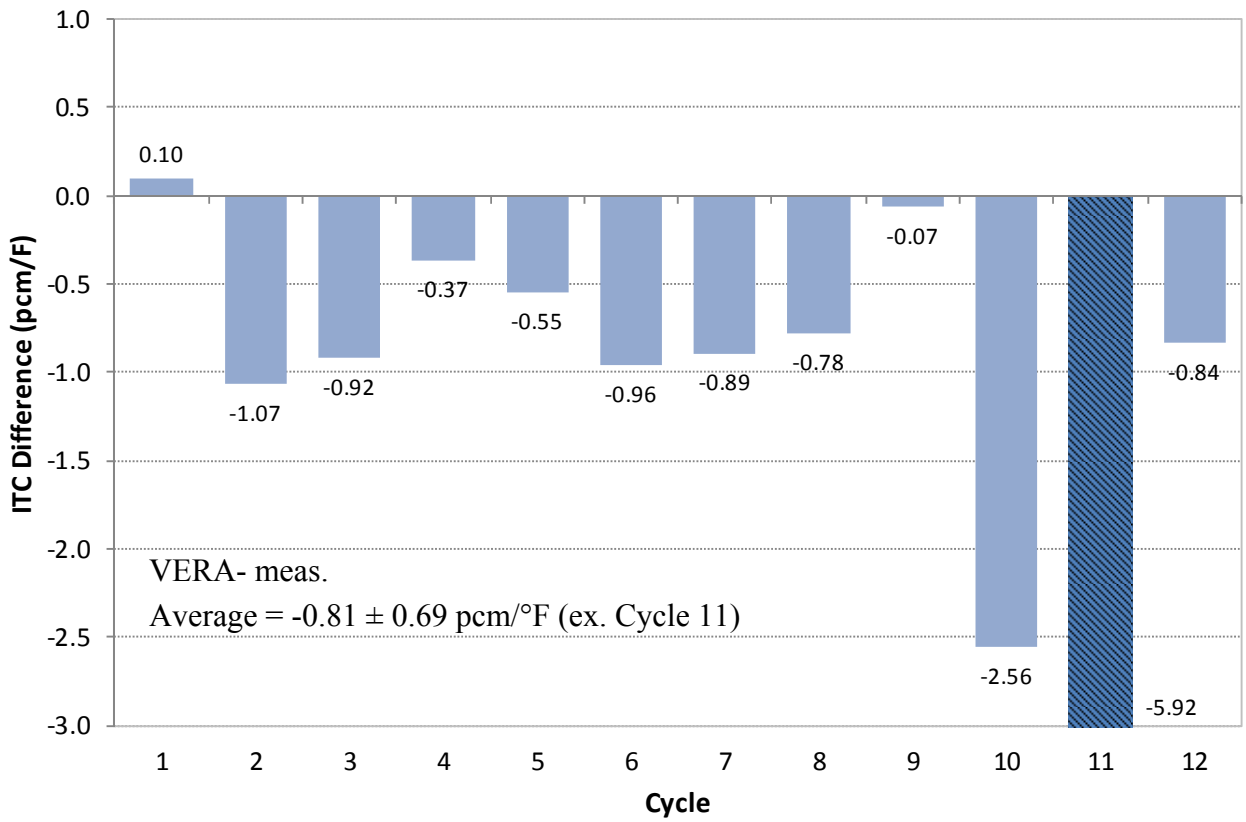


Figure 23 BOC HZP Isothermal Temperature Coefficient Differences

The ITC results are reasonable except for Cycles 9 and 10. There is a consistent negative bias indicating VERA-CS tends to predict a more negative coefficient than measured. Excluding Cycle 11, the average difference is -0.81 pcm/°F. Additionally excluding Cycle 10 results in a bias of -0.63 ± 0.4 pcm/°F. It is unclear what is creating the large differences for Cycles 10 and 11, but the test results from the original measurement demonstrate the same trends, and comparisons between VERA-CS and the predicted values at the time are much more consistent. This brings into suspect the measured data as valid point of comparison, and further investigation with TVA personnel may be required.

The VERA-CS runtimes for the ITC calculations are approximately 45 ± 2 minutes on 4307 cores. This includes reading the BOC restart file and running two statepoints with different inlet temperatures, employing the MPACT internal T/H module at zero power to get the correct moderator densities.

4.5 HFP Critical Boron Letdown

As previously discussed, the excess reactivity in a PWR is controlled by burnable poisons and soluble boron. As the fuel depletes over a fuel cycle, the boron concentration in the reactor coolant is reduced via dilution to allow the reactor to remain critical. The measured boron concentrations for the entire fuel cycle are then used for code validation to establish the accuracy of the core reactivity vs. fuel burnup. TVA has provided all of the measured boron concentrations from each fuel cycle, usually in daily increments, through References [53] and [54].

The fuel cycle depletions were performed by simulating the WBN1 reactor core at an approximate power history over the entire length of each fuel cycle, which was approximately 18 months each. The depletions are performed as a function of cycle exposure in order to preserve the total burnup on the fuel. The average conditions of power, inlet temperature, and control bank positions are also input, as needed, to attempt to match the power shape and energy spectrum for the depletion. In most cycles, the extremely efficient operation can be simulated as a constant depletion at equilibrium full power conditions. This actually results in somewhat faster runtimes and a simpler process for comparison to measured data. However, the Cycle 1 history includes several shutdowns and extended periods of low power operation, so that cycle was depleted at average conditions, and restart points were written in order for subsequent cases to simulate the instantaneous conditions for each measured point. Fortunately this was only required for Cycle 1.

Cycles 2 through 12 depletions were simulated at HFP conditions with the average inlet temperature and Bank D position over most (or the entire) length of the cycle. Typically the cycle BOC restart file is read (following the shuffle), and the first statepoint is at zero power and zero xenon conditions. Then a single power escalation case was used to deplete the core for the slow power ascension for startup (typically a few EFPD), and then the nominal depletion is performed at approximately two week intervals assuming full power and equilibrium xenon conditions. The depletion time steps sizes are conservatively small to ensure accurate depletion in the highest powered regions of the core. As much as possible, each time step corresponds to either a measured soluble boron point or a measured flux map. Near the end-of-cycle (EOC) a power coastdown is also simulated to match the actual plant operating history and an EOC restart file is written at the official EOC burnup point.

Each cycle depletion was run using quarter-core rotational symmetry to reduce the computational requirements, even though a few of the cycles were not symmetric. For these cases it is assumed that the effect on the core power distribution is small and the asymmetric assemblies, being low power and on the core periphery, are not critical to model for either core reactivity or flux mapping. Also, because the in-core instrument thimbles are not quarter-core symmetric, they were excluded from the depletion calculations, and the instrument response was calculated for every assembly location in the core.

Note that it is not necessary to model every power maneuver and shutdown performed in each cycle, nor to use small time steps on hourly time scales, as long as depletion is performed by burnup at representative conditions. In this case, comparison points (boron and flux maps) must be made at HFP conditions at sufficient intervals following maneuvers that that the plant is considered to be close to equilibrium isotopics. For these analyses, that interval is assumed to be approximately 1 week at full power conditions. The depletion is always performed using the equilibrium xenon option for comparison to plant data.

The critical boron letdown for each WBN1 fuel cycle is calculated by the use of the boron search option in VERA-CS. The boron concentration in the coolant is found to keep the simulation critical (k_{eff}=1.0) as the fuel and burnable poisons depletes. At EOC, if the critical boron drops to zero, VERA-CS will switch back to an eigenvalue calculation at 0 ppm boron. To perform the criticality comparison in terms of boron, an EOC differential boron worth was calculated in a separate, subsequent job in order to convert the calculated sub-critical eigenvalue to an equivalent negative boron concentration. This was only required for a few of the cycles.

The calculated critical boron letdown curve for each cycle is displayed in Figure 24. Note that critical boron concentration increases initially in many of the cycles because of the rate of depletion of the thin IFBA coating on the fresh fuel. Once the burnable absorbers are sufficiently depleted, the boron letdown takes on a nearly linear trajectory until the end-of-cycle. In some cycles, a power coastdown was employed to increase the cycle length following nearly complete dilution of the reactor coolant system. In these cases, the soluble boron becomes minimized at 5-10 ppm, and then reactor power is reduced to maintain criticality.

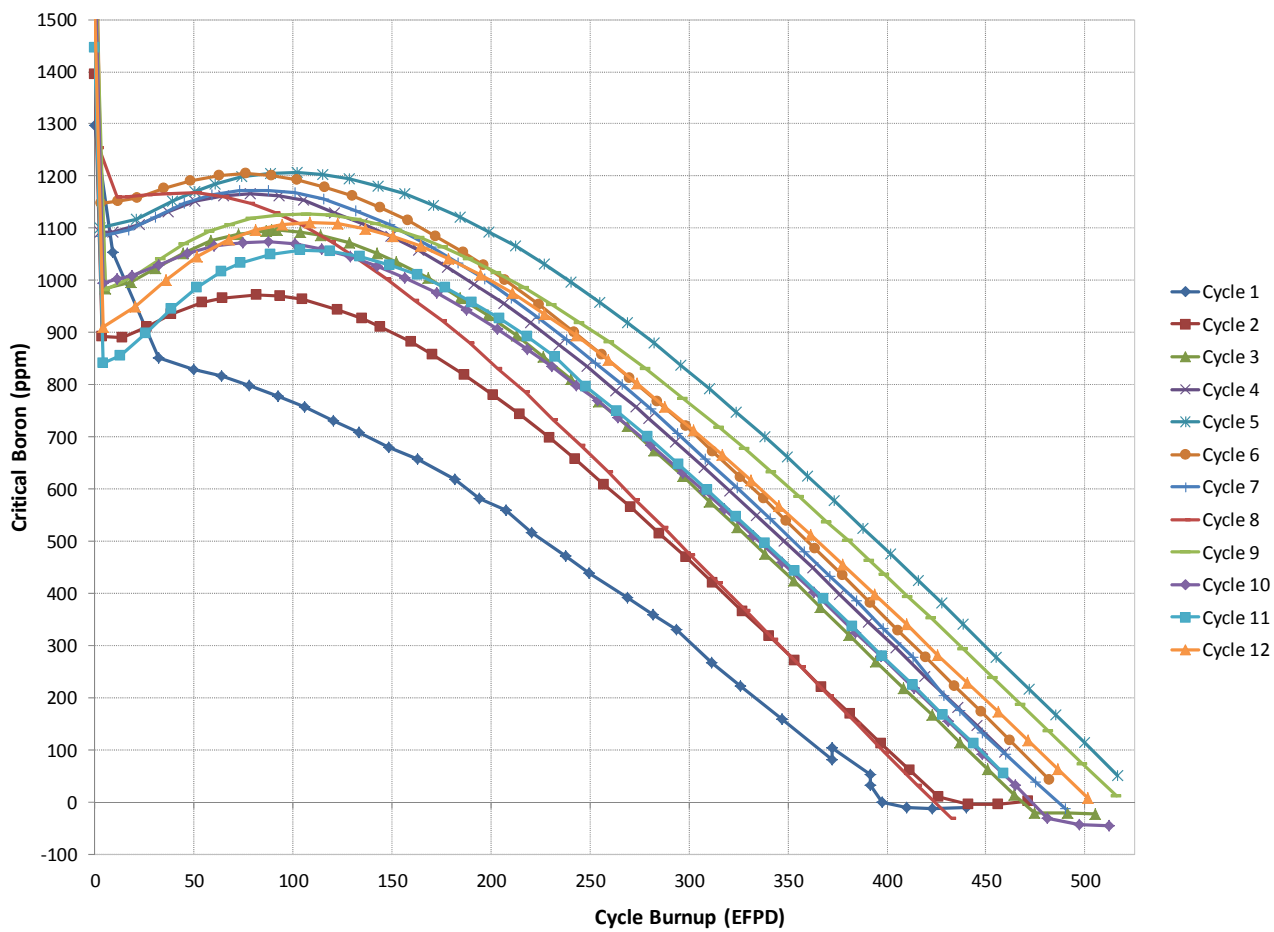


Figure 24 Calculated HFP Critical Boron Letdowns

The fuel cycle depletions were executed on the INL supercomputer Falcon using 180 nodes and 4307 cores. The average time to deplete each cycle was 21.9 hours, or 88,000 cpu-hours. The total cpu resource utilization over all cycles was 1.06 million cpu-hours. For the 440 statepoints calculated (~37 per cycle), the average runtime of a single statepoint was 35.9 minutes, and the

average number of iterations between MPACT and CTF was 11.1. In total, 4899 fully coupled iterations were successfully performed and fully converged.

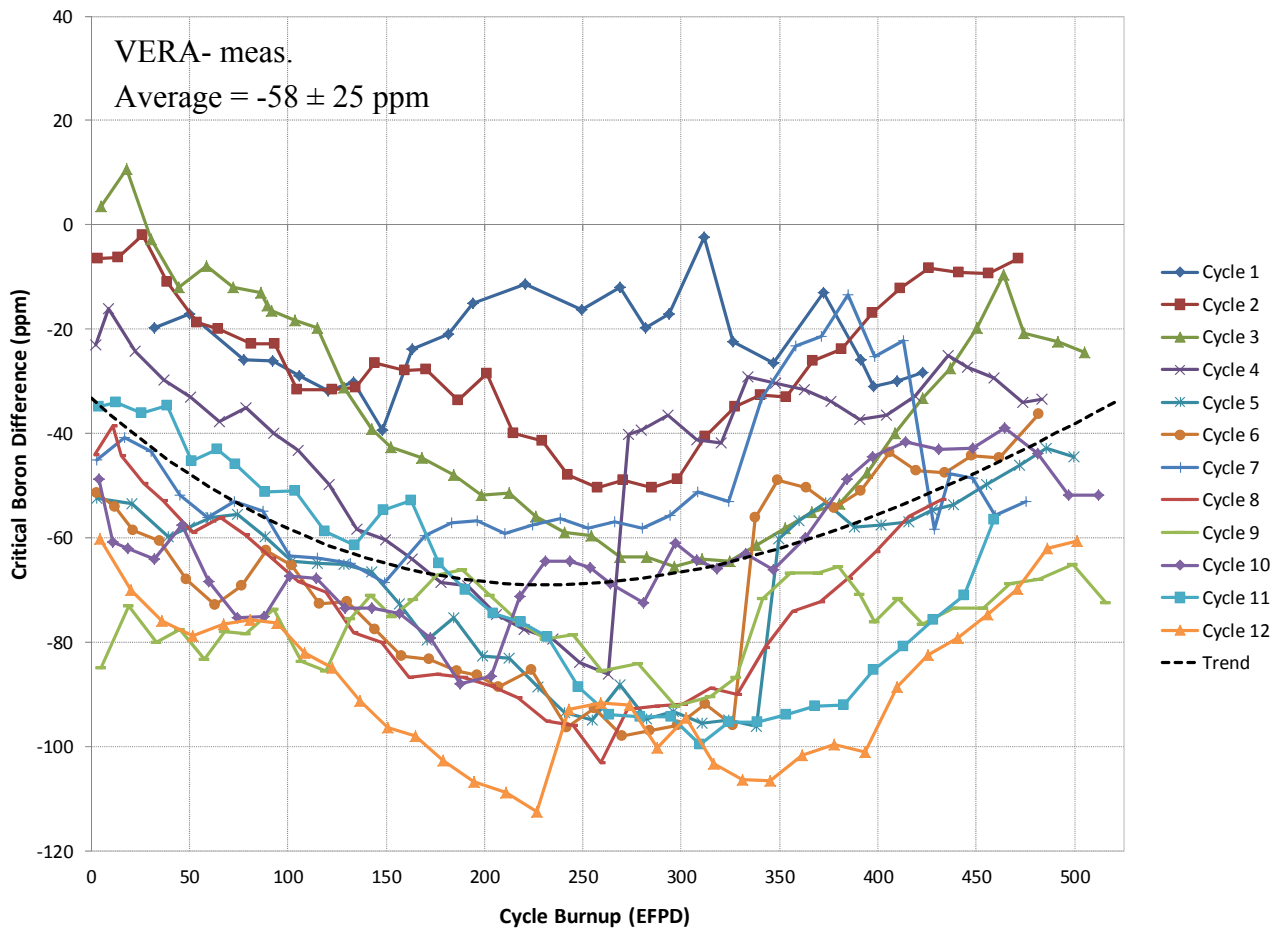


Figure 25 HFP Critical Boron Differences

Figure 25 displays the differences between the critical boron concentrations calculated by VERA-CS and the actual measured values from WBN1, as a function of cycle burnup. The agreement is fairly poor, with the average difference being -58 ppm, greater than the typical acceptance criteria for plant surveillance. There is a clear trend of under-predicting the reactivity, and the effect is maximized near the middle of the cycle – a classic symptom of the depletion of ^{10}B in the coolant.

Certainty in the coolant ^{10}B isotopics is critical to understanding any trends in the reactivity comparisons made for HFP depletion. As the cycle depletes, the soluble boron in the coolant becomes depleted, and the ^{10}B abundance may be reduced to as low as 17.0 at% (from a natural abundance of ~19.8 at%). Additions of fresh acid may occur at any point during the cycle, due to power maneuvers or shutdowns, which will replenish some of the depleted ^{10}B. For very high performing cycles with few additions, the ^{10}B depletion effect is maximized, typically in the middle of the cycle when significant depletion has occurred but there is also still a substantial concentration of boron in the system. VERA-CS assumes 19.9% at% ^{10}B for all cases, and though there is a model in MPACT for depleting the soluble ^{10}B, it has not been significantly tested nor can it easily accommodate the uncertainty in the amount of replenishments.

In order to better quantify the performance of VERA-CS, an effort has been made to correct the measurements for ^{10}B depletion. In the data provided by TVA, only the last few cycles contained regular ^{10}B isotopic measurements. Determining proper corrections for the majority of the cycles, and estimating the boron content after additions, is essentially good engineering guesswork based on experience and expertise. In this case some correction is better than none to help isolate the components of the boron errors. The following procedure was performed to adjust the measured values to 19.9 at% equivalent boron for consistency with VERA-CS.

- The Cycle 11 and 12 data provided by TVA contains ^{10}B measurements obtained approximately monthly. Additionally these cycles had few boron additions to the reactor coolant system. Therefore there is high confidence in the results for these cycles.

- The Cycle 4-10 ^{10}B data was not available but was inferred from data provided from the core monitoring system. More ^{10}B measurements were performed in the more recent cycles than in earlier ones. In some cycles only 4-6 points are available. The fewer the points, the more presumptions and approximations are required to fill in the gaps, based on the depletion rates from known cycles and additions that result in consistency with the measured points. Therefore, there is only medium confidence in the results from these cycles, with decreasing confidence going backwards in time. (Note that the Cycle 7 data appears to be fairly complete and reliable).

- There is no data available for Cycles 1-3 and no way to accurately infer any values. However, using the measured depletion rates from other cycles and a reasonable estimation of the replenishment amounts provides some results, though they are with low confidence.

Based on the items above, the boron depletion worth was estimated for each cycle based on the available data and is provided in Figure 26. It is clear that ^{10}B depletion in the reactor coolant is a large contributor to the HFP boron letdown errors shown in Figure 25, resulting in differences of up to 80 ppm at middle-of cycle.

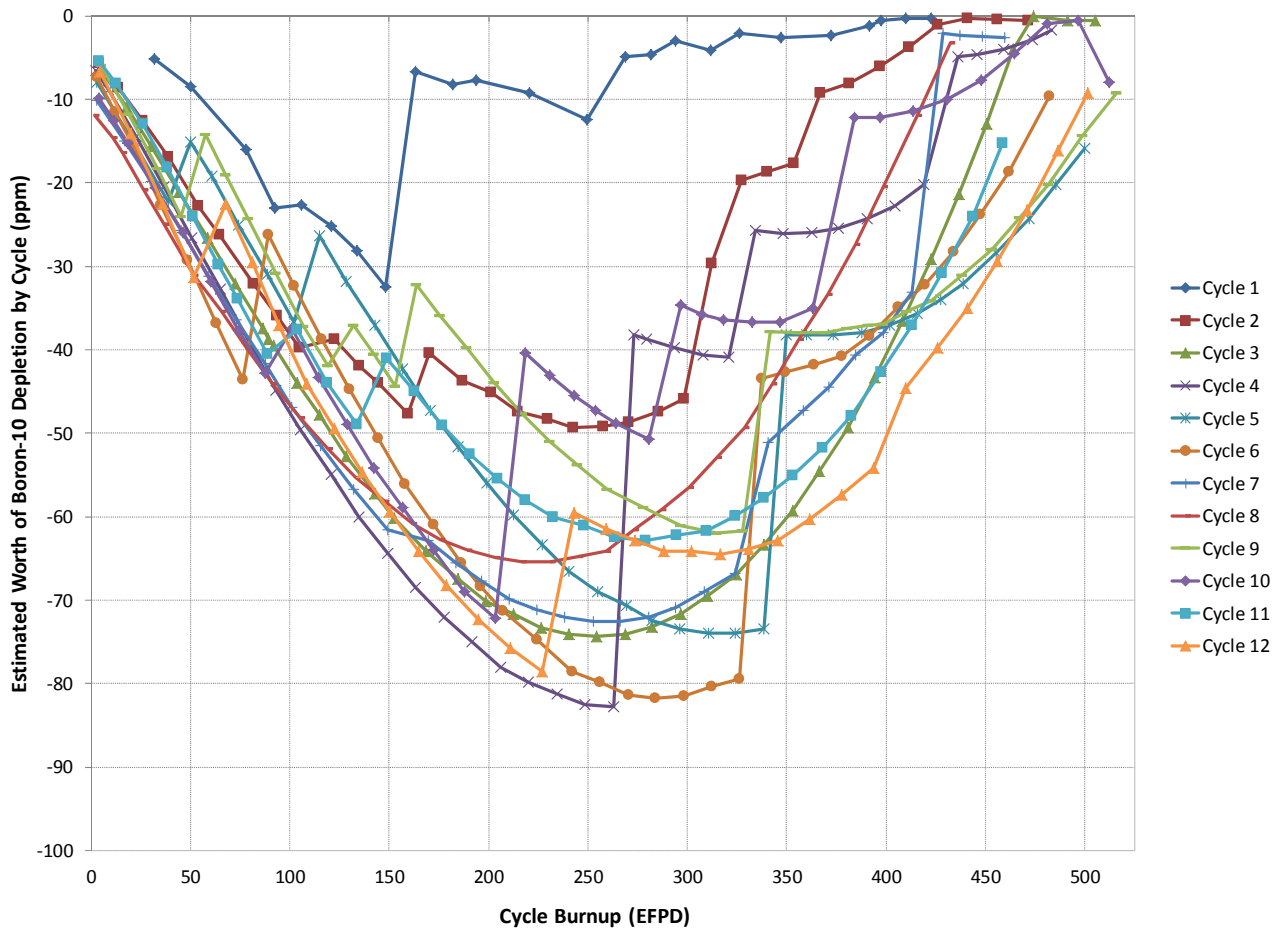


Figure 26 Estimated HFP ^{10}B Depletion Worth by Fuel Cycle

Using these corrections, the HFP soluble boron letdown comparison is repeated in Figure 27, now assuming a consistent ^{10}B abundance. Table 3 also shows the performance statistics by cycle with and without the corrections.

There are several things to note about the corrected results. The estimated ^{10}B corrections reduced the mean error from -58 to 23 ppm, and the standard deviation from 25 to 20 ppm, including all cycles. Since the corrections are less certain for Cycle 1-3, if they are excluded from the population then the average difference between VERA-CS and measurements is -30 ± 17 ppm.

Finally, the boron letdown trend for Cycle 7 becomes more obviously suspicious after making the ^{10}B depletion corrections. The standard deviation is more than double, and Figure 27 shows a steep drop in the differences at about 418 EFPD. This point corresponds to an extended mid-cycle shutdown. The critical boron seems to change by approximately -60 ppm just do to the outage, which may correspond to the worth of CRUD on the fuel rods following operation with CIPS. During the long outage, the CRUD and boron deposits can come off the fuel rods increasing the total core reactivity. A similar effect can be seen in the BOC8 critical boron comparison. A significant change in the axial power distributions also occurs at this burnup.

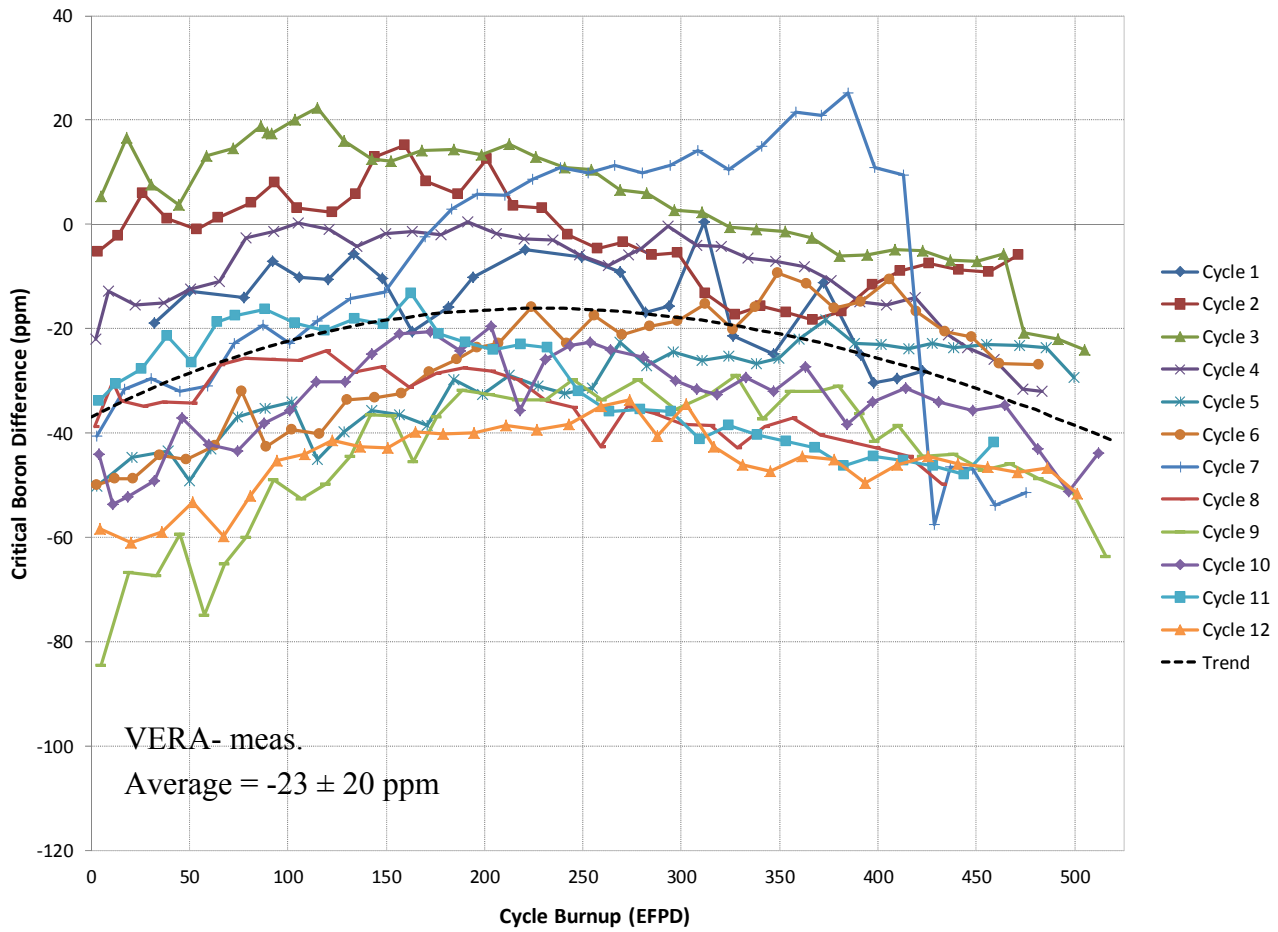


Figure 27 ^{10}B Depletion-Corrected HFP Critical Boron Differences

Table 3 Boron Difference Statistics By Cycle (VERA-meas.)

		Without ^{10}B Corrections		With ^{10}B Corrections	
Cycle	**Points**	**Mean (ppm)**	**St. Dev. (ppm)**	**Mean (ppm)**	**St. Dev. (ppm)**
1	24	-22	8	-15	8
2	35	-27	14	-2	9
3	39	-35	22	5	12
4	37	-44	19	-10	9
5	37	-68	17	-31	8
6	36	-69	19	-27	12
7	34	-50	14	-10	25
8	33	-73	18	-34	7
9	39	-76	7	-45	14
10	37	-63	13	-34	9
11	33	-69	22	-30	12
12	34	-88	15	-45	7
Total	**418**	**-58**	**25**	**-23**	**20**

Another potential source of discrepancy is the fuel temperature inputs provided by Bison-CASL (Section 3.4 and APPENDIX B). The average fuel temperatures shown in Figure 28 may be too high and could result in a significant reactivity bias at operating conditions. Furthermore, the lack of fuel temperature data above 25 GWd/MTU is likely an issue as well, as often the core average exposure and the exposure of many of the 2nd and 3rd fuel regions is greater than that value. Future efforts to improve the fuel temperature models in VERA-CS and investigate the performance of Bison-CASL are needed (See APPENDIX B).

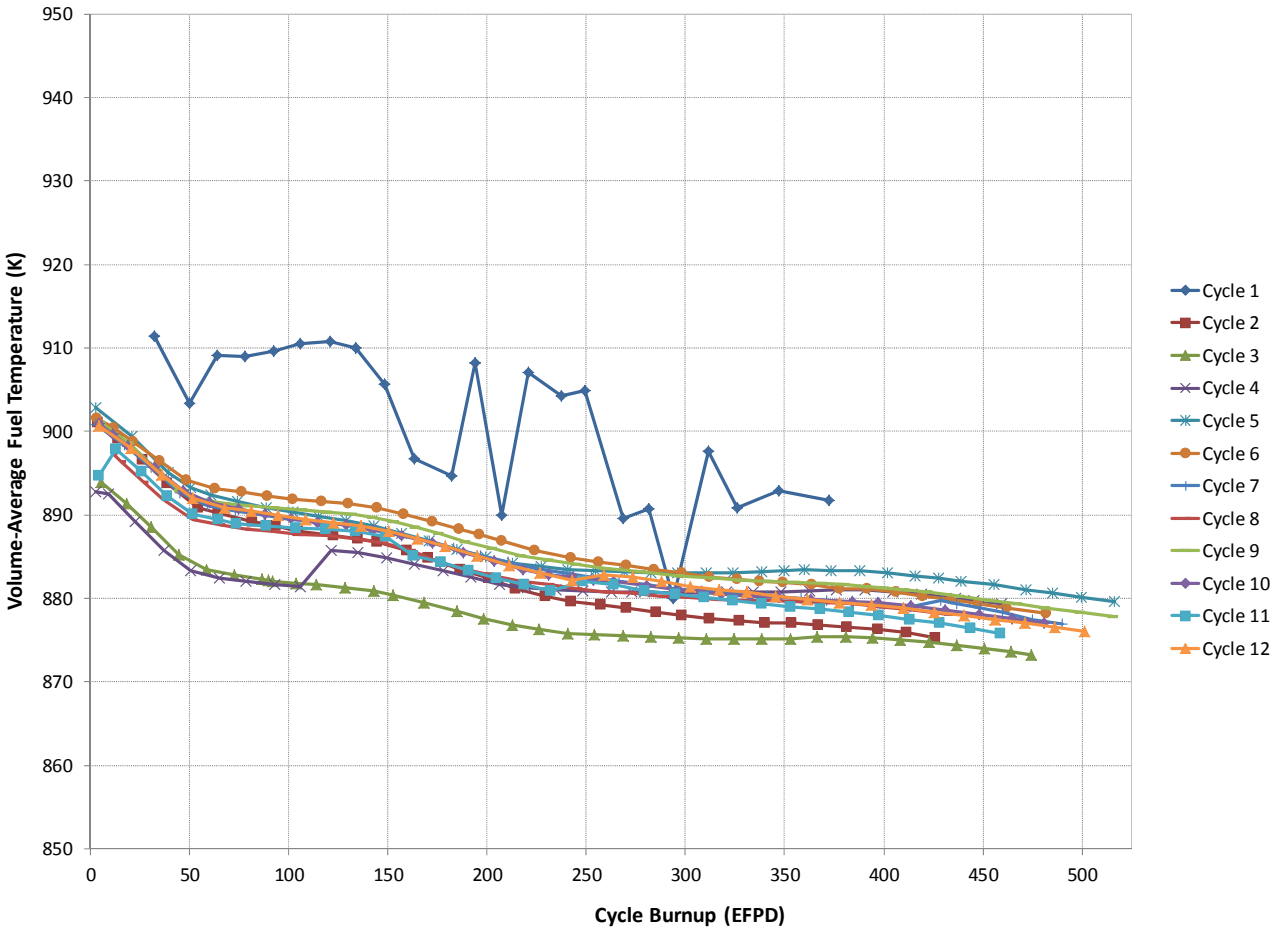


Figure 28 HFP Core Average Fuel Temperatures

Another contributing factor to these deviations has already been discussed in Section 4.2 . Several of the BOC HZP boron concentrations showed large negative deviations from the measured values. Since these measurements are taken at BOC HZP conditions, they should not be impacted by significant ^{10}B depletion or fuel temperature biases, so there is likely a third issue that happens to contribute in the same direction and results in an increasingly low reactivity prediction. It is possible that the uncertainty in TPBAR absorber loading is contributing to these deviations as well.

Finally, a -10 to -15 ppm bias is expected at BOC due to the thin IFBA coating in fresh fuel assemblies. Testing has shown that the MOC ray spacing needs to be reduced to eliminate this, but it comes at significant computational cost. Since the effect decays quickly as the IFBA layer depletes, the nominal ray spacing for non-IFBA fuel rods has been used. Research is ongoing to improve MPACT in this area.

4.6 HFP Flux Maps

The final set of comparisons to measured data is the in-core instrument response distributions commonly known as "flux maps". As part of standard core monitoring activities, the in-core neutron flux distribution is measured by insertion of the movable in-core detectors, which are small fission chambers. As these are inserted into various locations in the core and then removed their signals are recorded and processed into a normalized response distribution with 61 axial points (610 levels are recorded initially and then reduced for analysis). The processing typically includes adjustments for background noise, changes in power level, axial alignment, and other checks for indications of bad data. The flux maps are usually retrieved at HFP equilibrium conditions at prescribed intervals, typically one per month in earlier WBN1 fuel cycles and more recently once per quarter. The flux map data are an invaluable source of validation to establish the uncertainty in predicting the power distributions of operating LWRs.

For VERA-CS, MPACT calculates the normalized response at the center of the locations which are indicated as detectors in VERAIn. For this activity, quarter-core symmetry was used in all cases to reduce the runtime requirements. Since the instruments are not quarter-core symmetric, the physical instrument thimble was removed from the model, and "virtual" detectors were inserted in every location. This means that the VERA-CS response calculations do not include the spatial effects of the instruments themselves, which may result in small radial power differences, and there is a calculated response for every location in the quarter-core, even if it is not instrumented physically.

Currently MPACT calculates the instrument response on the same axial mesh that is used for the power distribution edits and coupling to CTF. A post-processing step performs a spline fit to expand the 53 axial level data to the 61 level mesh comparable to that provided in the measurements. This methodology will be improved in the future so that MPACT provides the response on a mesh specific to the detectors themselves.

The measured signals are provided from instrumented locations all around the core with only a fraction of the locations being in quarter-symmetric or octant-symmetric locations. In each map, a small number of locations may be indicated as inoperable (unscanned or otherwise suspect). For this analysis, the measured signals have been collapsed to quarter-core geometry by selection of the corresponding cross-core symmetric locations which are flagged as operable. In the case of multiple operable symmetric locations, their instrument responses have been averaged for the single location in the southeast quadrant. This method is very good for cases with a low quadrant power tilt (the measured core power level is similar in all four quadrants), but for cases with a significant tilt, selection of cross-core partners for non-instrumented locations can lead to a broader distribution of power differences. On the other hand, averaging of symmetric locations can sometimes tend to cancel out the effects of quadrant power tilts.

WBN1 is also known to have experienced Lower Plenum Flow Anomaly (LPFA), which is often indicated by larger-than-normal quadrant power tilts and larger radial flux map deviations between measurements and predictions. No corrections have been made to the measured data to account for this possibility, so its effects are included in the deviations of the results.

Additionally WBN1 experienced the CIPS phenomenon in Cycle 7 (and perhaps mildly in Cycle 6). This also results in a large deviation in axial offset (AO) and the 3D detector response comparisons. It could also potential result in an increase in radial power deviations since the peripheral assemblies are lower powered and do not uptake as much CRUD as the more central assemblies.

TVA has provided all the available flux map data from WBN1 for this analysis [53,54]. For Cycles 1 through 3, the complete set of processed 3D signals was available and is used for comparison. However, for each cycle thereafter, only the processed 2D (radial or axially-integrated) signals were available. In order to try to make some useful comparisons, the axial shapes of each signal has been reconstructed from the raw traces taken by the plant, unprocessed. Some modifications were performed to ensure alignment and in the cases of missing data, substitutions have sometimes been made from signals in similar fuel assembly types. Locations without enough information for the reconstruction were simply flagged as inoperable to be left out of the comparison statistics. Because there was not enough data to completely regenerate the 3D signals, the 3D statistics and measured instrument axial offset should not be regarded too seriously. It is included here for the belief that any data is better than no data, and because the results are really not too bad to be considered useless.

Over all twelve cycles, 183 flux maps were selected for comparison to calculations from VERA-CS. Only maps believed to be at equilibrium conditions were selected, since the calculations did not include any effects of short time scale maneuvering. Both the calculated and measured response distributions were normalized for the operable detector strings, and then compared by absolute difference. Likewise, the radial response distribution was isolated by axial integration of each 3D distribution and compared in the same way. The core average axial distributions are also compared by radial integration over the operable instrument strings. Finally, the axial offset (AO) of each measured distribution was calculated and then the scalar difference was reported (AO is the difference in power between the top half and bottom half of the core, expressed in % of the total power). The results of these comparisons are expressed in terms of root mean square (RMS) difference (times 100 percent) and maximum absolute difference (times 100 percent). Relative errors are not used so as to not over-emphasize regions in the core at low powers (top, bottom, and peripheral locations).

APPENDIX E contains the detailed results of all 183 flux maps. A sample is shown in Figure 30 below. The image is a depiction of the SE quadrant of the reactor core, with locations containing at least one operable symmetric instrument containing data. The data is a simplified axial plot of the measured (red) and calculated (blue) signals at 61 axial locations. In the upper right of each instrumented location is the value of the 3D RMS difference of the 61 locations in that string. The lower right corner contains the difference in radial powers for that instrument (times 100). Values above 5% are highlighted in red. At the bottom right is another simplified axial plot of the 1D average axial shape of the operable instruments, with corresponding RMS. The box to the right provides the cycle, exposure, power level, and radial (2D) and total (3D) RMS values for the entire distributions. The difference in measured and calculated axial offset is also provided.

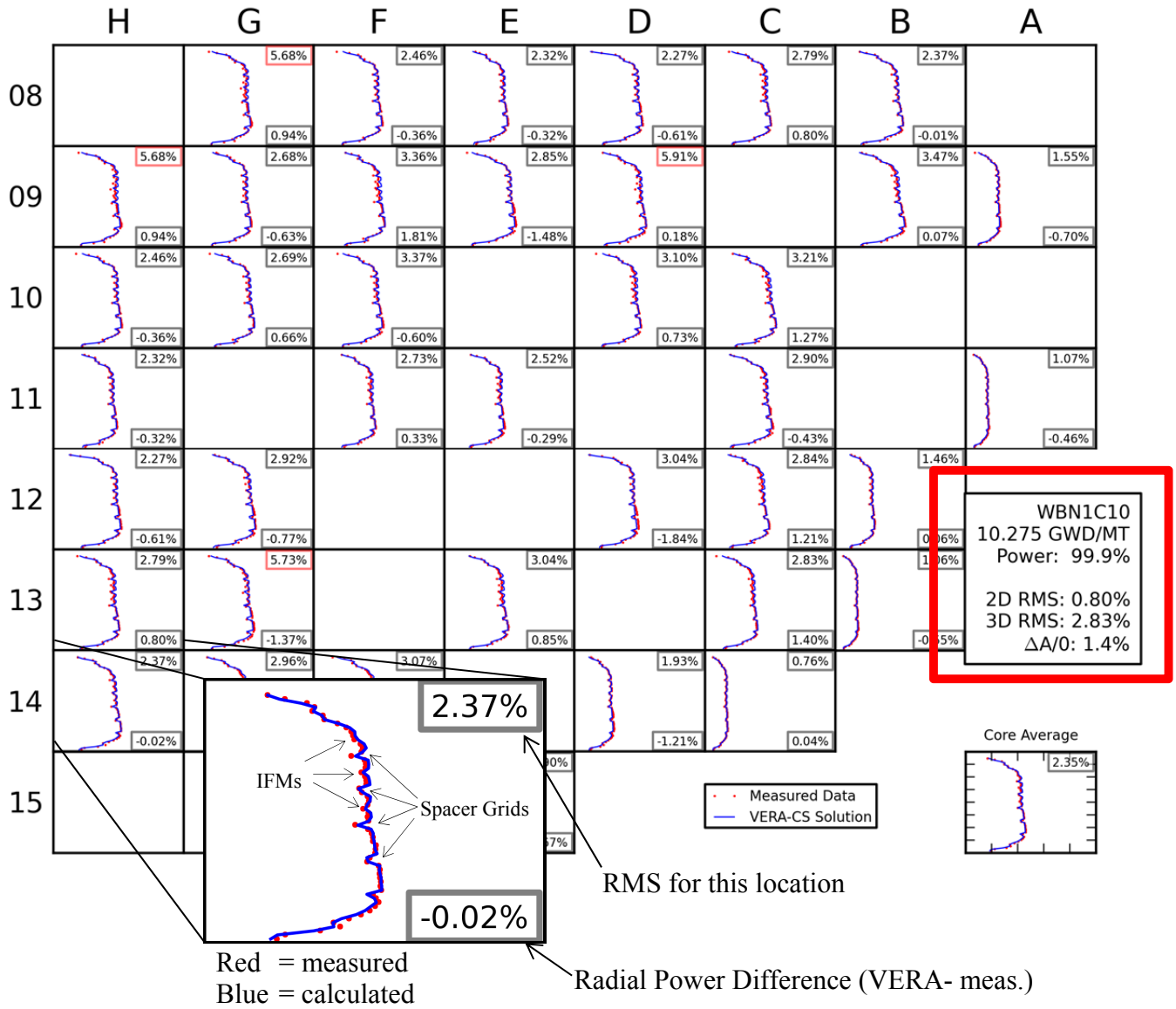


Figure 30 Sample HFP Flux Map – Middle of Cycle 10

Figure 31 though Figure 33 display the 2D, 3D, and AO flux map summary results for each fuel cycle vs. burnup. Then Table 4 summarizes the statistics for each cycle and results are discussed subsequently.

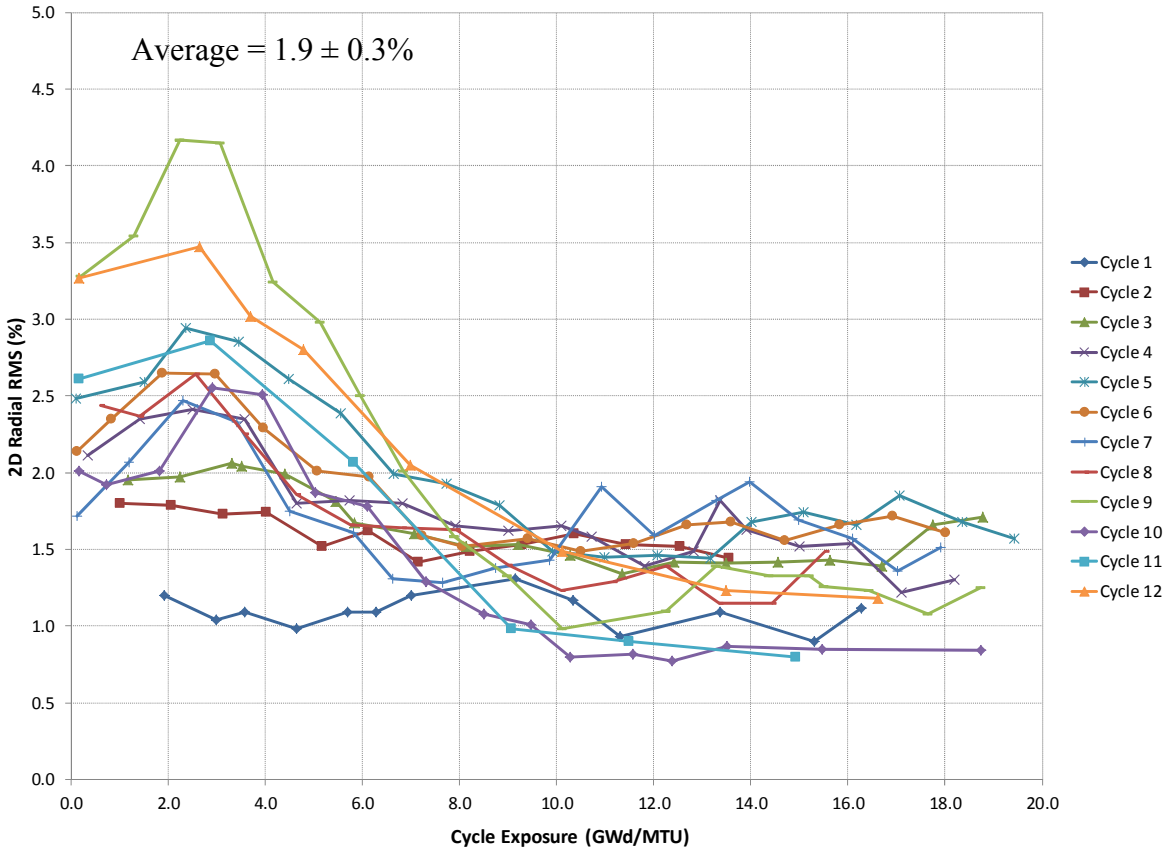


Figure 31 Flux Map Results – Radial Power Distribution

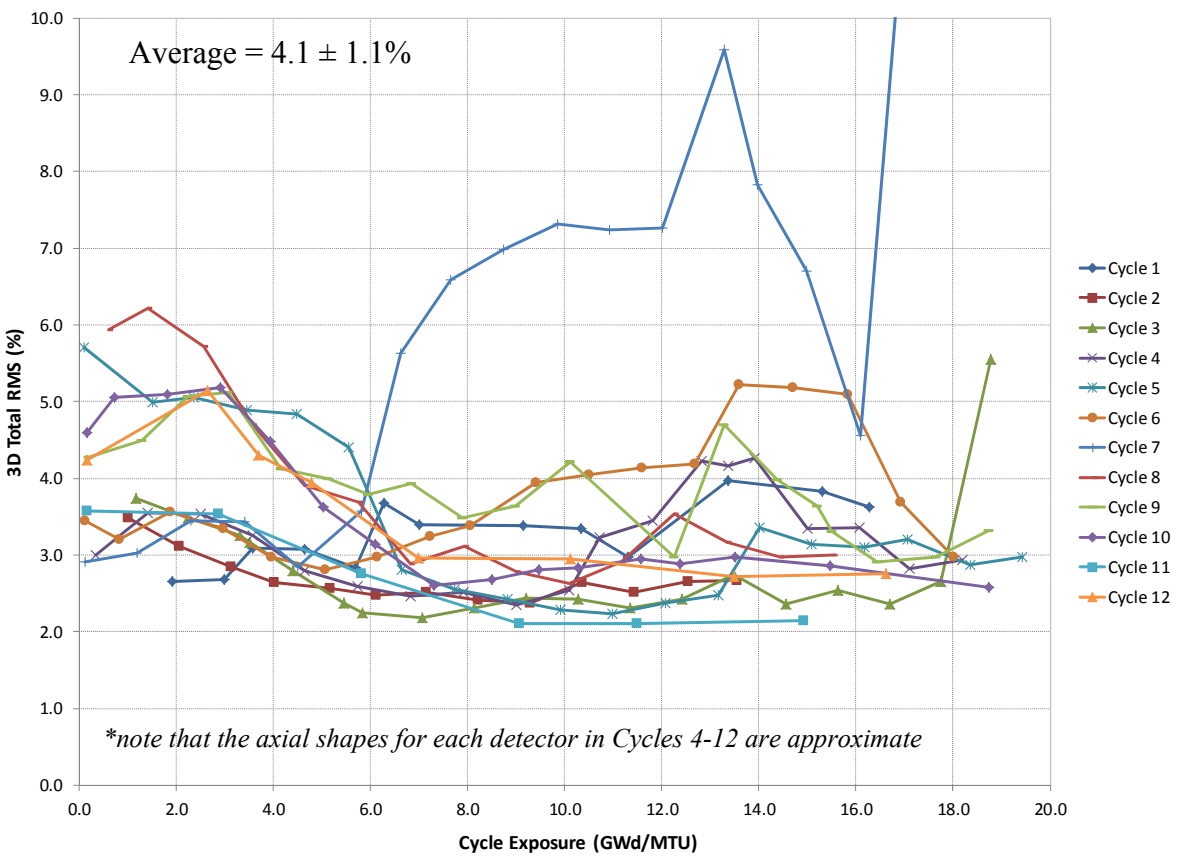


Figure 32 Flux Map Results – Total Power Distribution

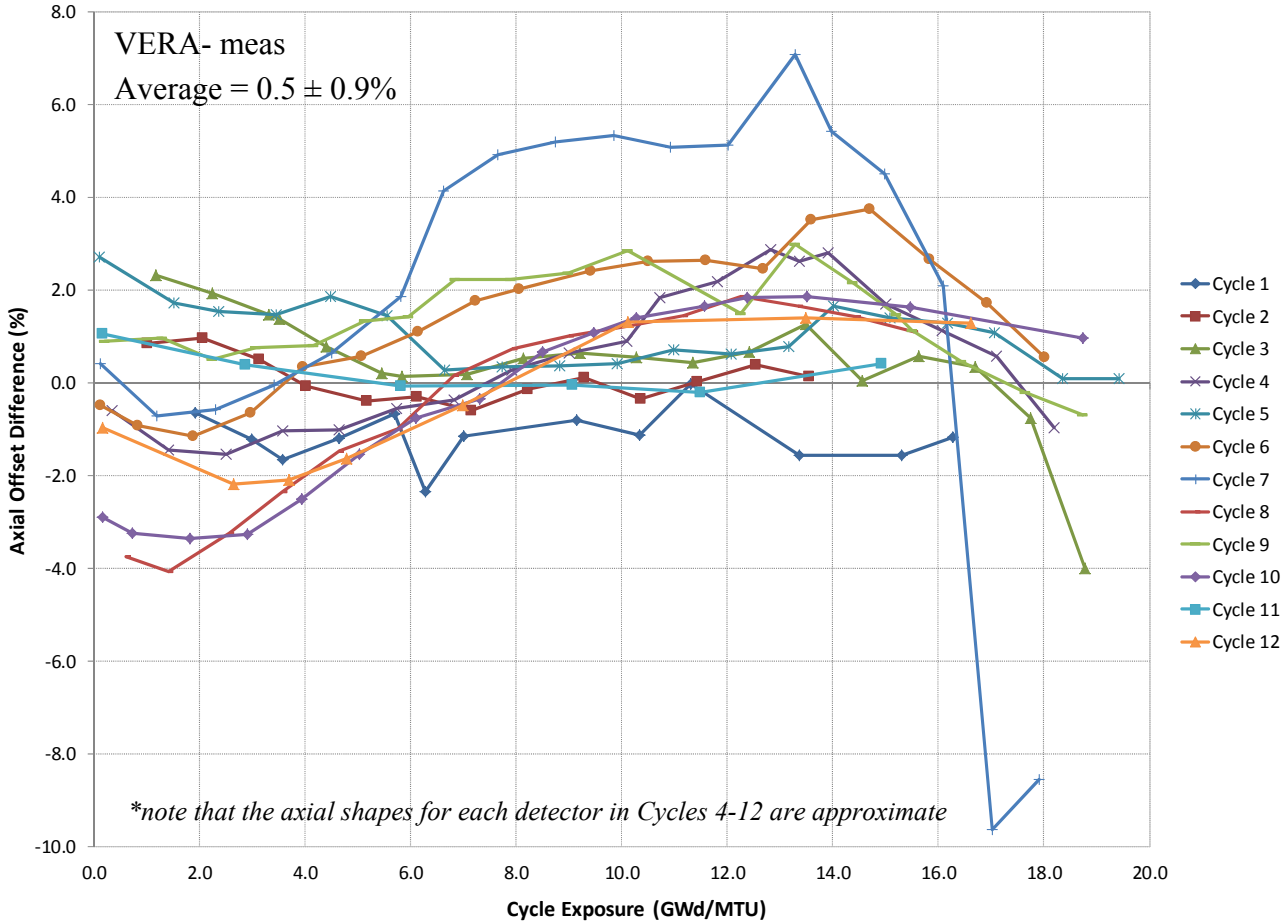


Figure 33 Flux Map Results – Axial Offset Differences

Table 4 HFP Flux Map Results Summary by Cycle (%)

Cycle	Count	ΔAO	1D RMS	2D RMS	3D RMS	2D Max	Det Max	3D Max
1	13	-1.17	2.55	1.10	3.29	3.37	7.25	27.28
2	13	0.08	1.11	1.60	2.70	3.99	7.29	31.79
3	19	0.45	1.87	1.67	2.92	5.95	8.34	42.03
4	19	0.52	2.14	1.77	3.23	4.82	8.37	40.74
5	19	1.04	2.33	2.05	3.64	8.02	9.61	38.74
6	18	1.38	2.60	1.92	3.77	6.15	9.60	41.77
7	18	1.79	5.17	1.74	6.73	5.94	15.70	33.31
8	15	-0.35	3.03	1.77	4.00	7.67	10.27	43.63
9	19	1.32	2.41	2.35	3.94	10.03	11.88	41.72
10	16	-0.43	2.79	1.56	3.64	7.55	9.62	38.15
11	6	0.25	1.52	1.88	2.77	7.36	7.85	21.51
12	8	-0.43	2.23	2.47	3.72	11.54	12.32	37.15
Total	**183**	**0.50**	**2.75**	**1.95**	**4.08**	**11.54**	**15.70**	**43.63**
St. Dev.		**0.85**	**0.98**	**0.32**	**1.05**			

**note that the axial shapes for each detector in Cycles 4-12 are approximate*

The flux map comparisons show that VERA-CS can calculate the measured power distributions reasonably well, especially given the fuel temperature limitations, larger reactivity differeces, and known quadrant power tilts. The radial power distribution RMS is only 1.9%, with errors tending to be ~50% higher in the first 6-8 GWd/MTU of the cycles. For the latter half of the cycles, the 2D RMS approaches 1.25% for all cycles. The source of this radial bias is unclear and requires some additional investigation.

The 3D RMS is rightfully larger than the 2D but it is also good at 4.1% over all cases, which is remarkable agreement considering the actual 3D data is not available for Cycles 4-12. The distribution of differences in all cycles is shown in Figure 34. If Cycle 7 is removed from the statistics (due to having CIPS), the 3D RMS drops to 3.7%. Future activities should include obtaining more 3D data from the plant, perhaps even the raw 610 level data, for more thorough validation. Note that this is the 3D RMS of ALL measured locations and axial planes, not the RMS of a subset of the data, or merely the difference in the locations of peak power.

Likewise the axial offset calculation is reasonable with an average difference of 0.5% ± 0.9%. Clearly this result is unrealistically biased because of Cycle 7, so if it is removed the average becomes 0.33 ± 0.8%. Though this is quite good, there is still room for improvement, particularly through the use of thermal expansion and perhaps a cusping model for discrete poison tips that do not lie on an axial mesh boundary.

See APPENDIX E for the 183 detailed flux map results for all cycles and burnups.

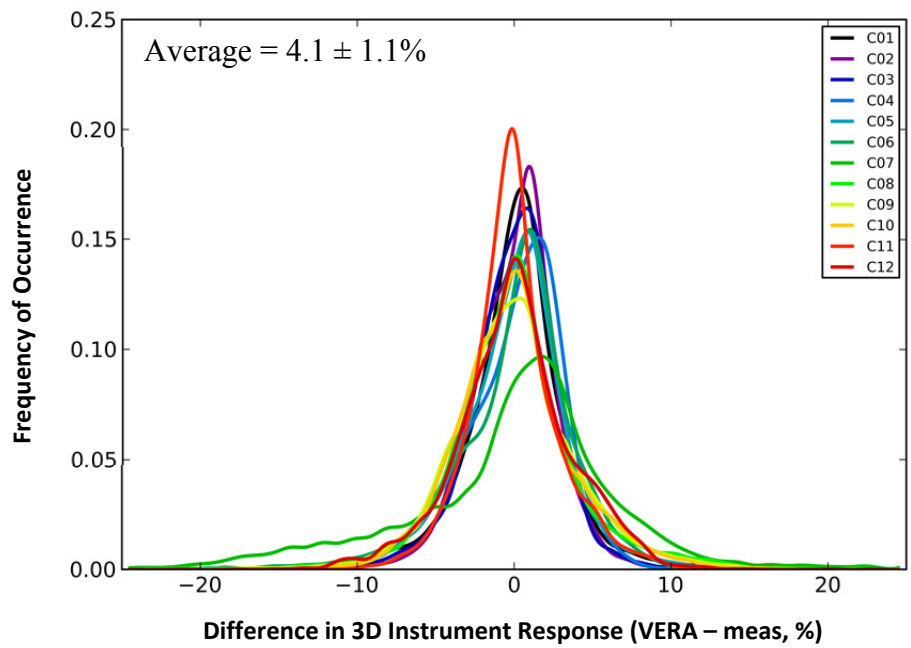


Figure 34 Probability Distribution of the 3D Flux Map Response Differences by Cycle (%)

5. FUTURE WORK

This activity has been a thorough and rigorous application of VERA-CS to actual plant models and data, and is the first of its kind since CASL's formation. It is not surprising that many minor bugs, limitations, and needed enhancements were discovered in the process. These will be provided to the PHI and RTM focus areas for incorporation into their work tracking system. The following list contains the more important and substantial items that may require more research or significant investment in development to ensure the VERA-CS can continue to grow in application and validation space.

1) **Generation of complete fuel temperatures and verification against values from other codes**: The fuel temperatures from Bison-CASL for the VERA-CS models only covered the first 25 GWd/MTU of burnup, and were only provided for one fuel type. Furthermore, the values appear to be high compared to results from other codes. Before too much analysis is done for the HFP reactivity biases, fuel temperatures need to be provided to encompass the full burnup range and comparisons should be made to other codes to provide confidence in the VERA-CS input. Obviously, the long term goal is to forego the input temperature tables and move towards a directly coupled approach.

2) **Investigate reactivity bias**: The BOC HZP critical boron concentrations demonstrate a large negative bias for about half of the cycles. Since these cases do not have T/H feedback, and were run with 10x the number of MOC rays, there must be another unknown contributor to these errors. Comparison of data from a different plant (without TPBARs) may also be useful.

3) **Investigate radial in/out bias in first half of cycles**: The radial power distribution comparisons shown in Figure 31 show a clear trend of a larger radial power deviation for the first half of almost every cycle. Further comparison of the individual flux maps shows that VERA-CS tends to under-predict the power in the core center (by about 5%) and over-predict the power in the fresh fuel adjacent to peripheral fuel assemblies. This phenomenon is referred to as an in/out tilt in the radial power, and it could be due to the cross section methods, the lack of a detailed radial reflector model, the TPBAR specifications, the Bison-CASL fuel temperatures (APPENDIX B) , the measured data (such as LPFA effects), or any or all of the above.

4) **Axial re-meshing**: Fortunately, the fuel assembly designs used in the WBN1 cycles have been extremely similar, which allowed for an assumption that all the fuel could be simulated on one common axial mesh. However, this assumption will not be true for most U.S. reactors and soon the capability will be required to change the axial mesh between fuel cycles, as the plant transitions from one fuel type to another.

5) **Multiple fuel/guide tube types in CTF**: The simulations used for this report were forced to ignore the dashpot region of the guide tubes, as well as the (minor) change in guide tube design between V5H and RFA-2 fuel assemblies. This is because the CTF pre-processor can only support one fuel rod type and one guide tube type. Like the axial remeshing, this limitation will become more important as CASL and others attempt to apply VERA-CS for other plants.

6) **Thermal expansion**: Industrial methods provide simple corrections for the changes in the fuel dimensions (at least radially) as the reactor system heats up to operating conditions. For most cases this is not significant but it has a small effect on reactivity and could potentially impact the

radial power distribution comparisons. Also thermal expansion axially can impact the elevation of the control rods and discrete burnable absorbers relative to the fuel stack, so this feature should also be considered for future development.

7) **Reduced computer requirements**: The cycle depletions in this report completed in a fairly reasonable wall time of approximately 21 hours. This time scale is reasonable for the level of fidelity of results produced by VERA-CS. However, the 4307 core count utilized to reach that time limits the number of simultaneous cases that can be run, and the number of users who can use the code simultaneously. The goal of CASL is to reach a level of approximately 1000 cores, which will allow VERA-CS to be used by many more individuals at the national labs and industry sites with larger computers. A brief look at the runtime history of the neutronics in VERA makes it clear that CASL is making great progress at reaching this goal.

8) **Comparisons to CE Monte Carlo**: Monte Carlo benchmarking is another aspect of the VERA-CS Validation Plan [2]. Significant effort has been done in this area for the BOC Cycle 1 configuration, including hundreds of continuous-energy Monte Carlo reference solutions created for the benchmark progression problems [1] and the Westinghouse Test Stand [10]. In the near future CASL would like to expand this capability to multi-cycle scenarios, where the burned fuel isotopics can be used in Shift, the CASL massively-parallel Monte Carlo particle transport capability, to generate high-fidelity reference solutions for criticality, control bank worths, temperature coefficients, instrument responses, and pin power distributions. If good agreement was demonstrated between Shift and VERA-CS predictions, this would also help to eliminate the deterministic methods and multi-group transport-corrected cross section treatments as causes in some of the other issues listed here.

9) **Perform power maneuvering or startup benchmarking**: This benchmarking activity did not include any cases requiring slow changes in reactor power, such as initial power escalation or load follow or testing maneuvers. Such comparisons (also listed in the validation plan) provide validation for the transient xenon calculations in VERA-CS and ensure that the T/H feedback physics do not introduce a power-dependent bias. This is a somewhat coarse check of the fuel temperature models as well. Power escalation testing also includes flux maps as various power plateaus during startup.

10) **Comparisons for mid-cycle outage criticals**: This benchmarking include BOC HZP critical comparisons and burnup-dependent HFP comparisons. However, data also exists for mid-cycle outages with the reactor returning to criticality. These comparisons are valuable because they provide a burnup dependency to HZP data without the increased complexity of thermal-hydraulics. Also, these results help to determine if the T/H models are producing a power-dependent bias for a given cycle exposure. Unfortunately, the better the plant performs the less of this type of data are produced.

11) **Work with WBN1 for benchmarking and applications with current and future cycles**: Now that CASL has simulated the entire operating history of WBN1, it can move forward modeling the current plant operations, which provides better opportunities for data comparison and interaction with the expertise of the TVA personnel. This also may provide VERA-CS the opportunity to help TVA diagnose future issues should they arise unexpectedly. Finally the startup of WBN2 will provide another excellent opportunity for CASL to have a positive impact on the nuclear industry.

6. CONCLUSIONS

VERA-CS has been successfully utilized by CASL to perform traditional core follow type calculations for Cycles 1 through 12 of TVA's Watts Bar Nuclear Plant. The results of these calculations have been compared to measured plant data, including startup test results, over 400 critical boron measurements and 183 HFP measured flux maps. The majority of the results look very good, especially for being the first application of VERA this type of problem. A few outliers exist and may require further investigation to rule out possible issues with the methods.

Doing the course of this activity, many minor issues such as code bugs or input/output problems were discovered and will be provided to the development teams in a separate communication. The more prominent deficiencies and development needs identified for this task have been provided in Section 5.

The VERA-CS calculations were performed on the INL Falcon HPC resource, and the average fuel cycle depletion required approximately 21 hours on 4307 cores. This is encouraging because as further improvements are made it is likely that VERA-CS will continue to get faster and/or require less processors for the same turn-around time. The goal of CASL to deploy VERA-CS on a 1000 core machine for an over-night cycle depletion now seems feasible.

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APPENDIX A SAMPLE VERAIN INPUT FOR DEPLETION AND SHUFFLE

```
[CASEID]
  title 'CASL VERA Problem 9 - Watts Bar Unit 1 Cycle 1 Depletion - Public'

[STATE]
  title   'WBN1C1 Depletion'
  power    1e-8         ! %
  flow     100.0        ! %
  tinlet   557.0 F
  pressure 2250         ! psia
  boron    1300         ! ppm
  rodbank  A 230  B 230  C 230  D 186  SA 230  SB 230  SC 230  SD 230

  sym      qtr
  feedback on
  search   boron

[STATE] power 65.7 ; tinlet 557.6 F ; rodbank D 192 ; deplete EFPD 9.0
[STATE] power 99.7 ; tinlet 558.1 F ; rodbank D 219 ; deplete EFPD 32.0
[STATE] power 98.0 ; tinlet 558.2 F ; rodbank D 218 ; deplete EFPD 50.0
[STATE] power 100.0; tinlet 558.6 F ; rodbank D 219 ; deplete EFPD 64.0
[STATE] power 99.7 ; tinlet 558.7 F ; rodbank D 215 ; deplete EFPD 78.0
[STATE] power 99.7 ; tinlet 558.6 F ; rodbank D 217 ; deplete EFPD 92.7
[STATE] power 99.8 ; tinlet 558.8 F ; rodbank D 220 ; deplete EFPD 105.8
[STATE] power 99.8 ; tinlet 558.4 F ; rodbank D 220 ; deplete EFPD 120.9
[STATE] power 99.5 ; tinlet 557.9 F ; rodbank D 219 ; deplete EFPD 133.8
[STATE] power 98.0 ; tinlet 558.0 F ; rodbank D 214 ; deplete EFPD 148.4
[STATE] power 95.1 ; tinlet 557.9 F ; rodbank D 216 ; deplete EFPD 163.3
[STATE] power 94.8 ; tinlet 557.9 F ; rodbank D 214 ; deplete EFPD 182.2
[STATE] power 99.8 ; tinlet 557.8 F ; rodbank D 220 ; deplete EFPD 194.3
[STATE] power 93.9 ; tinlet 557.5 F ; rodbank D 218 ; deplete EFPD 207.7
[STATE] power 100.1; tinlet 558.0 F ; rodbank D 222 ; deplete EFPD 221.1
[STATE] power 99.7 ; tinlet 557.7 F ; rodbank D 220 ; deplete EFPD 238.0
[STATE] power 100.2; tinlet 557.6 F ; rodbank D 222 ; deplete EFPD 250.0
[STATE] power 95.6 ; tinlet 557.9 F ; rodbank D 211 ; deplete EFPD 269.3
[STATE] power 96.4 ; tinlet 558.1 F ; rodbank D 215 ; deplete EFPD 282.3
[STATE] power 93.4 ; tinlet 557.4 F ; rodbank D 211 ; deplete EFPD 294.6
[STATE] power 99.7 ; tinlet 557.5 F ; rodbank D 217 ; deplete EFPD 312.1
[STATE] power 98.0 ; tinlet 557.6 F ; rodbank D 215 ; deplete EFPD 326.8
[STATE] power 99.4 ; tinlet 557.7 F ; rodbank D 220 ; deplete EFPD 347.8
[STATE] power 99.9 ; tinlet 557.8 F ; rodbank D 219 ; deplete EFPD 373.2
[STATE] power 86.9 ; tinlet 556.7 F ; rodbank D 202                        ! step change in power
[STATE]                                                 deplete EFPD 392.3
[STATE] power 99.6 ; tinlet 558.0 F ; rodbank D 220
[STATE]                                                 deplete EFPD 398.6
[STATE] power 89.9 ; tinlet 557.1 F ; rodbank D 224 ; deplete EFPD 410.7
[STATE] power 78.8 ; tinlet 556.3 F ; rodbank D 228 ; deplete EFPD 423.6
[STATE] power 64.5 ; tinlet 554.9 F ; rodbank D 230 ; deplete EFPD 441.0
        restart_write wb1c1.res EOC
        op_date '9/6/1997'

[CORE]
  name   WBN             ! Watts Bar Nuclear
  unit   1
  cycle  1
  size   15
  apitch 21.5            ! cm
  rated  3411 131.68     ! MW, Mlbs/hr
  height 406.337
  bc_sym rot

  xlabel  R P N M L K J H G  F  E  D  C  B  A
  ylabel  1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
```

```
  core_shape
    0 0 0 0 1 1 1 1 1 1 1 0 0 0 0
    0 0 1 1 1 1 1 1 1 1 1 1 1 0 0
    0 1 1 1 1 1 1 1 1 1 1 1 1 1 0
    0 1 1 1 1 1 1 1 1 1 1 1 1 1 0
    1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
    1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
    1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
    1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
    1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
    1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
    1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
    0 1 1 1 1 1 1 1 1 1 1 1 1 1 0
    0 1 1 1 1 1 1 1 1 1 1 1 1 1 0
    0 0 1 1 1 1 1 1 1 1 1 1 1 0 0
    0 0 0 0 1 1 1 1 1 1 1 0 0 0 0

  assm_map
    1                       ! 1=2.1%
    2 1                     ! 2=2.6%
    1 2 1                   ! 3=3.1%
    2 1 2 1
    1 2 1 2 2
    2 1 2 1 2 3
    1 3 1 3 3 3
    3 3 3 3

  insert_map
     -
    20 TP                   ! ##=number of Pyrex rods
     - 24  -                ! TP=thimble plugs
    20 TP 20  -
     - 20 TP 20  -
    20  - 16  - 24 12
     - 24  - 16  - TP
    12 TP  8 TP

  crd_map
    1
    - -
    1 - 1
    - - - 1
    1 - - - 1
    - 1 - 1 - -
    1 - 1 - 1 -
    - - - -

  crd_bank
    D  -  A  -  D  -  C  -
    -  -  -  -  - SB  -  -
    A  -  C  -  -  -  B  -
    -  -  -  A  - SC  -  -
    D  -  -  -  D  - SA
    - SB  - SD  -  -  -
    C  -  B  - SA  -
    -  -  -  -

   det_map 193*2
!  det_map
!            - - 1 - - 1 -
!        1 - - 1 - 1 - - - - -
!      - - - - - - 1 - 1 - 1 - 1
!      1 1 - - - - 1 - - - - - -
!    - - - - 1 - - - 1 - 1 - 1 - -
!    1 - 1 - - 1 - 1 - - - - - 1 -
!    - - - 1 - - 1 - - 1 - - 1 - -
!    1 - 1 - 1 - 1 - - 1 - 1 1 1 -
!    - 1 - - - - - - 1 - 1 - - - 1
!    - - - - 1 - 1 - - - - 1 - - -
!    1 - - - 1 - - 1 - - 1 - - - 1
!      - - - - 1 - - 1 - - 1 - -
!      - 1 - 1 - - 1 - - - - - 1
!        1 - - - 1 - - 1 - 1 -
!            1 - - 1 - - -
```

```
  baffle ss 0.19 2.85
  lower_plate ss  5.0 0.5   ! mat, thickness, vol frac
  upper_plate ss  7.6 0.5   ! mat, thickness, vol frac

[ASSEMBLY]
  title "Westinghouse 17x17"
  npin 17
  ppitch 1.260

  fuel U21 10.257 94.5 / 2.110
  fuel U26 10.257 94.5 / 2.619
  fuel U31 10.257 94.5 / 3.100

  cell 1     0.4096 0.418 0.475 / U21 he zirc4
  cell 2     0.4096 0.418 0.475 / U26 he zirc4
  cell 3     0.4096 0.418 0.475 / U31 he zirc4
  cell 4            0.561 0.602 / mod    zirc4      ! guide/instrument tube
  cell 5            0.418 0.475 /     he zirc4      ! plenum
  cell 6                  0.475 /        zirc4      ! plug
  cell 7                  0.475 /        mod        ! empty


  rodmap LAT21
       4
       1 1
       1 1 1
       4 1 1 4
       1 1 1 1 1
       1 1 1 1 1 4
       4 1 1 4 1 1 1
       1 1 1 1 1 1 1 1
       1 1 1 1 1 1 1 1 1

  rodmap LAT26
       4
       2 2
       2 2 2
       4 2 2 4
       2 2 2 2 2
       2 2 2 2 2 4
       4 2 2 4 2 2 2
       2 2 2 2 2 2 2 2
       2 2 2 2 2 2 2 2 2

  rodmap LAT31
       4
       3 3
       3 3 3
       4 3 3 4
       3 3 3 3 3
       3 3 3 3 3 4
       4 3 3 4 3 3 3
       3 3 3 3 3 3 3 3
       3 3 3 3 3 3 3 3 3

  rodmap PLEN
       4
       5 5
       5 5 5
       4 5 5 4
       5 5 5 5 5
       5 5 5 5 5 4
       4 5 5 4 5 5 5
       5 5 5 5 5 5 5 5
       5 5 5 5 5 5 5 5 5

  rodmap PLUG
       4
       6 6
       6 6 6
       4 6 6 4
       6 6 6 6 6
       6 6 6 6 6 4
       4 6 6 4 6 6 6
       6 6 6 6 6 6 6 6
       6 6 6 6 6 6 6 6 6

  rodmap GAP
       4
       7 7
       7 7 7
       4 7 7 4
       7 7 7 7 7
       7 7 7 7 7 4
       4 7 7 4 7 7 7
       7 7 7 7 7 7 7 7
       7 7 7 7 7 7 7 7 7


  axial  1  6.053 GAP 10.281 PLUG 11.951 LAT21 377.711 PLEN 393.711 PLUG 395.381 GAP 397.51
  axial  2  6.053 GAP 10.281 PLUG 11.951 LAT26 377.711 PLEN 393.711 PLUG 395.381 GAP 397.51
  axial  3  6.053 GAP 10.281 PLUG 11.951 LAT31 377.711 PLEN 393.711 PLUG 395.381 GAP 397.51

  grid END inc   1017 3.866
  grid MID zirc4 875  3.810

  grid_axial
      END  13.884
      MID  75.2
      MID 127.4
      MID 179.6
      MID 231.8
      MID 284.0
      MID 336.2
      END 388.2

  lower_nozzle  ss 6.053 6250.0  ! mat, height, mass (g)
  upper_nozzle  ss 8.827 6250.0  ! mat, height, mass (g)
```

```
[INSERT]
  title "Pyrex"
  npin 17

  cell X  0.214 0.231 0.241 0.427 0.437 0.484 / he ss he pyrex-vera he ss ! pyrex
  cell P                          0.437 0.484 /                     he ss ! plenum
  cell G                                0.484 /                        ss ! plug/cap
  cell T                                0.538 /                        ss ! thimble plug

  rodmap  PY8
     -
     - -
     - - -
     X - - -
     - - - - -
     - - - - - X
     - - - - - - -
     - - - - - - - -
     - - - - - - - - -

  rodmap  PY12
     -
     - -
     - - -
     X - - -
     - - - - -
     - - - - - -
     - - - X - - -
     - - - - - - - -
     - - - - - - - - -

  rodmap  PY16
     -
     - -
     - - -
     X - - -
     - - - - -
     - - - - - X
     - - - X - - -
     - - - - - - - -
     - - - - - - - - -

  rodmap  PY20
     -
     - -
     - - -
     X - - -
     - - - - -
     - - - - - X
     X - - X - - -
     - - - - - - - -
     - - - - - - - - -

  rodmap  PY24
     -
     - -
     - - -
     X - - X
     - - - - -
     - - - - - X
     X - - X - - -
     - - - - - - - -
     - - - - - - - - -

  rodmap  PL8
     -
     - -
     - - -
     P - - -
     - - - - -
     - - - - - P
     - - - - - - -
     - - - - - - - -
     - - - - - - - - -

  rodmap  PL12
     -
     - -
     - - -
     P - - -
     - - - - -
     - - - - - -
     - - - P - - -
     - - - - - - - -
     - - - - - - - - -

  rodmap  PL16
     -
     - -
     - - -
     P - - -
     - - - - -
     - - - - - P
     - - - P - - -
     - - - - - - - -
     - - - - - - - - -

  rodmap  PL20
     -
     - -
     - - -
     P - - -
     - - - - -
     - - - - - P
     P - - P - - -
     - - - - - - - -
     - - - - - - - - -

  rodmap  PL24
     -
     - -
     - - -
     P - - P
     - - - - -
     - - - - - P
     P - - P - - -
     - - - - - - - -
     - - - - - - - - -

  rodmap  PG8
     -
     - -
     - - -
     G - - -
     - - - - -
     - - - - - G
     - - - - - - -
     - - - - - - - -
     - - - - - - - - -

  rodmap  PG12
     -
     - -
     - - -
     G - - -
     - - - - -
     - - - - - -
     - - - G - - -
     - - - - - - - -
     - - - - - - - - -
```

```
  rodmap  PG16
     -
     - -
     - - -
     G - - -
     - - - - -
     - - - - - G
     - - - G - - -
     - - - - - - - -
     - - - - - - - - -

  rodmap  PG20
     -
     - -
     - - -
     G - - -
     - - - - -
     - - - - - G
     G - - G - - -
     - - - - - - - -
     - - - - - - - - -

  rodmap  PG24
     -
     - -
     - - -
     G - - G
     - - - - -
     - - - - - G
     G - - G - - -
     - - - - - - - -
     - - - - - - - - -

  rodmap  TP8
     -
     - -
     - - -
     P - - T
     - - - - -
     - - - - - P
     T - - T - - -
     - - - - - - - -
     - - - - - - - - -
```

```
  rodmap  TP12
     -
     - -
     - - -
     P - - T
     - - - - -
     - - - - - T
     T - - P - - -
     - - - - - - - -
     - - - - - - - - -

  rodmap  TP16
     -
     - -
     - - -
     P - - T
     - - - - -
     - - - - - P
     T - - P - - -
     - - - - - - - -
     - - - - - - - - -

  rodmap  TP20
     -
     - -
     - - -
     P - - T
     - - - - -
     - - - - - P
     P - - P - - -
     - - - - - - - -
     - - - - - - - - -

  rodmap  TP24
     -
     - -
     - - -
     T - - T
     - - - - -
     - - - - - T
     T - - T - - -
     - - - - - - - -
     - - - - - - - - -
```

```
  axial   8  13.277 PG8  15.817 PY8  376.497 PL8  383.31 TP8  398.641 ! shifted slightly to
  axial  12  13.277 PG12 15.817 PY12 376.497 PL12 383.31 TP12 398.641 ! align tip with grid
  axial  16  13.277 PG16 15.817 PY16 376.497 PL16 383.31 TP16 398.641
  axial  20  13.277 PG20 15.817 PY20 376.497 PL20 383.31 TP20 398.641
  axial  24  13.277 PG24 15.817 PY24 376.497 PL24             398.641
  axial  TP                                       383.31 TP24 394.31  ! thimble plug

[CONTROL]
  title "B4C with AIC tips"
  npin 17
  stroke  365.125 230     ! approx for 1.5875 step sizes and 230 max stroke

  cell A  0.382 0.386 0.484 / aic he ss
  cell B  0.373 0.386 0.484 / b4c he ss
  cell P        0.386 0.484 /     he ss ! plenum
  cell G              0.484 /        ss ! plug

  rodmap AIC
     -
     - -
     - - -
     A - - A
     - - - - -
     - - - - - A
     A - - A - - -
     - - - - - - - -
     - - - - - - - - -

  rodmap B4C
     -
```

```
     - -
     - - -
     B - - B
     - - - - -
     - - - - - B
     B - - B - - -
     - - - - - - - -
     - - - - - - - - -

  rodmap PLEN
     -
     - -
     - - -
     P - - P
     - - - - -
     - - - - - P
     P - - P - - -
     - - - - - - - -
     - - - - - - - - -

  rodmap PLUG
     -
     - -
     - - -
     G - - G
     - - - - -
     - - - - - G
     G - - G - - -
     - - - - - - - -
     - - - - - - - - -

  axial  1    15.131
        PLUG  17.031
         AIC 118.631
         B4C 377.711
        PLEN 388.411
        PLUG 390.311

[DETECTOR]
  title "Incore instrument thimble"
  npin 17

  cell 1  0.258 0.382 / he ss
  cell 2        0.382 / mod    ! don't model thimble - just get response

  rodmap  LAT1
     1
     - -
     - - -
     - - - -
     - - - - -
     - - - - - -
     - - - - - - -
     - - - - - - - -
     - - - - - - - - -
  rodmap  LAT2
     2
     - -
     - - -
     - - - -
     - - - - -
     - - - - - -
     - - - - - - -
     - - - - - - - -
     - - - - - - - - -


  axial 1  0.0 LAT1 397.51
  axial 2  0.0 LAT2 397.51
```

```
[EDITS]
  axial_edit_bounds
     11.951  15.817  27.191  34.811  42.431  50.147  57.863  65.579  73.295  77.105
     85.17   93.235 101.3   109.365 117.43  125.495 129.305 137.37  145.435 153.5
    161.565 169.63  177.695 181.505 189.57  197.635 205.7   213.765 221.83  229.895
    233.705 241.77  249.835 257.9   265.965 274.03  282.095 285.905 293.97  302.035
    310.1   318.165 326.23  334.295 338.105 347.231 354.851 362.471 370.091 377.711

[MPACT]
  coupling_method ctf
  grid_treatment  homogenize
  flux_tolerance  5e-6

  num_space       4234
  num_angle       1
  num_threads     1
  par_method      EXPLICITFILE
  par_file        part_p5_73r_58z.txt

[COBRATF]
  gridloss  END  0.9070
  gridloss  MID  0.9065
  parallel       1

[SHIFT]
  transport             ce_mc
  num_cycles            2000
  num_inactive_cycles   500
  Np                    500000000

! All other input comes from --init default option in VERAIn parser
```

Example of core shuffle input:

```
[CASEID]
  title 'CASL VERA Problem 10 - Watts Bar Unit 1 Cycle 2 - Public'

[STATE]
  title    'WBN1C2 BOC Fuel Shuffle and Decay'
  power    0.0          ! %
  flow     100.0        ! %
  tinlet   565 K
  tfuel    565 K
  modden   0.743        ! g/cc
  rodbank  D 215  C 230  B 230  A 230  SD 230  SC 230  SB 230  SA 230

  sym      qtr
  feedback off
  search   boron
  boron    1400         ! ppmB

  restart_shuffle wb1c1.res EOC
  shuffle_label        N-6  K-7  D-3  E-6  M-3  F-7  C-6
             F-14 D-2  +    +    +    A-11 +    +    +    M-2  K-14
       B-10 +    +    +    G-2  +    H-13 +    J-2  +    +    +    P-10
       P-12 +    R-10 B-13 +    L-2  +    E-2  +    P-13 K-1  +    B-12
   K-3  +    +    C-14 +    G-4  +    H-15 +    J-4  +    N-14 +    +    F-3
   J-6  +    P-9 +     M-9  L-1  J-1  +    G-1  A-5  D-9  +    B-9 +     G-6
   N-12 +    +    P-5  +    R-7  +    C-13 +    A-7  +    B-5  +    +    C-12
   K-5  E-1  C-8  +    A-8  +    C-3  H-14 N-13 +    R-8  +    N-8  L-15 F-11
   N-4  +    +    P-11 +    R-9  +    N-3  +    A-9  +    B-11 +    +    C-4
   J-10 +    P-7  +    M-7  R-11 J-15 +    G-15 E-15 D-7  +    B-7  +    G-10
   K-13 +    +    C-2  +    G-12 +    H-1  +    J-12 +    N-2  +    +    F-13
        P-4  +    F-15 B-3  +    L-14 +    E-14 +    P-3  A-6  +    B-4
        B-6  +    +    +    G-14 +    H-3  +    J-14 +    +    +    P-6
             F-2  D-14 +    +    +    R-5  +    +    +    M-14 K-2
                       N-10 K-9  D-13 L-10 M-13 F-9  C-10
[CORE]
  include ../wb1/CORE.ini  ! load typical CORE block input

  op_date  10/18/1997      ! cycle 2 startup date for decay

  assm_map
    B1
    B3   104I
    128L B3   B3
    B3   104I B2   128L
    128I B3   104I B3   B3
    B2   128L B3   128I 104I 0I
    B3   48I  48I  48I  B3   B1
    B2   B2   B2   B2

  insert_map
     -
    TP 8T
     - TP  -
    TP 8W TP  -
     - TP 8W TP  -
    TP  - TP  - 4W TP
     - TP  - TP  - TP
    TP TP TP TP

[ASSEMBLY]
  include ../wb1/batch1-3.ini      ! include input for old batches 1-3

[ASSEMBLY]
  title  "Westinghouse 17x17 Batch 4"
  npin   17
  ppitch 1.260

  fuel U37 10.257 94.5 / 3.709
  fuel BKT 10.257 94.5 / 2.613

  mat ifba 3.85   zr 0.81306
                b-10 0.09347
                b-11 0.09347
```

```
cell F   0.4096        0.418 0.475 / U37      he zirc4
cell X   0.4096 0.4106 0.418 0.475 / U37 ifba he zirc4
cell B   0.4096        0.418 0.475 / BKT      he zirc4

rodmap NOIFBA
     G
     F F
     F F F
     G F F G
     F F F F F
     F F F F F G
     G F F G F F F
     F F F F F F F F
     F F F F F F F F F

rodmap 128IFBA
     G
     X F
     X F F
     G X X G
     X F F X F
     X F F X X G
     G X X G X X F
     X F F X F F X F
     F X F F X F F F X

rodmap 48IFBA
     G
     X F
     F F F
     G X F G
     F F F X F
     F F F F X G
     G X F G X F F
     F F F F F F F F
     F F F F F F F F X

rodmap BLKT
     G
     B B
     B B B
     G B B G
     B B B B B
     B B B B B G
     G B B G B B B
     B B B B B B B B
     B B B B B B B B B

rodmap 104IFBA
     G
     X F
     X F F
     G X X G
     X F F X F
     X F F X X G
     G X X G X X F
     X F F X F F F F
     F F F F F F F F X

axial   0I 6.053 GAP 10.281 PLUG 11.951 BLKT 24.028                NOIFBA                361.8686 BLKT 377.711 PLEN 393.711 PLUG 395.381 GAP 397.51
axial  48I 6.053 GAP 10.281 PLUG 11.951 BLKT 24.028 NOIFBA 40.45   48IFBA 346.0262 NOIFBA 361.8686 BLKT 377.711 PLEN 393.711 PLUG 395.381 GAP 397.51
axial 104I 6.053 GAP 10.281 PLUG 11.951 BLKT 24.028 NOIFBA 40.45  104IFBA 346.0262 NOIFBA 361.8686 BLKT 377.711 PLEN 393.711 PLUG 395.381 GAP 397.51
axial 128I 6.053 GAP 10.281 PLUG 11.951 BLKT 24.028 NOIFBA 40.45  128IFBA 346.0262 NOIFBA 361.8686 BLKT 377.711 PLEN 393.711 PLUG 395.381 GAP 397.51
axial 128L 6.053 GAP 10.281 PLUG 11.951 BLKT 24.028              128IFBA                361.8686 BLKT 377.711 PLEN 393.711 PLUG 395.381 GAP 397.51

[INSERT]
 title "Westinghouse Wet Annular Burnable Absorber (WABA)"
 npin  17

 mat waba   3.65   b4c 0.0949
                 al2o3 0.9051

 cell X  0.286 0.339 0.353 0.404 0.418 0.484 / mod zirc4 he waba he zirc4
 cell P  0.286 0.339             0.418 0.484 / mod zirc4         he zirc4  ! plenum
 cell G  0.286                       0.484 / mod                   zirc4  ! plug/cap
 cell T                              0.538 /                          ss  ! thimble plug

 rodmap  LAT4
    -
    - -
    - - -
    - - - -
    - - - - -
    - - - - - X
    - - - - - - -
    - - - - - - - -
    - - - - - - - - -

 rodmap  PLEN4
    -
    - -
    - - -
    - - - -
    - - - - -
    - - - - - P
    - - - - - - -
    - - - - - - - -
    - - - - - - - - -

 rodmap  LAT8
    -
    - -
    - - -
    X - - -
    - - - - -
    - - - - - X
    - - - - - - -
    - - - - - - - -
    - - - - - - - - -

 rodmap  PLEN8
    -
    - -
    - - -
    P - - -
    - - - - -
    - - - - - P
    - - - - - - -
    - - - - - - - -
    - - - - - - - - -
```

```
  rodmap  PLUG4
     -
     - -
     - - -
     - - - -
     - - - - -
     - - - - - G
     - - - - - - -
     - - - - - - - -
     - - - - - - - - -

  rodmap  PLUG8
     -
     - -
     - - -
     G - - -
     - - - - -
     - - - - - G
     - - - - - - -
     - - - - - - - -
     - - - - - - - - -

  rodmap  PLPG4
     -
     - -
     - - -
     T - - T
     - - - - -
     - - - - - P
     T - - T - - -
     - - - - - - - -
     - - - - - - - - -

  rodmap  PLPG8
     -
     - -
     - - -
     P - - T
     - - - - -
     - - - - - P
     T - - T - - -
     - - - - - - - -
     - - - - - - - - -

  rodmap  TP24
     -
     - -
     - - -
     T - - T
     - - - - -
     - - - - - T
     T - - T - - -
     - - - - - - - -
     - - - - - - - - -

   axial  4W    24.028 LAT4 361.8686 PLEN4 383.31 PLPG4 394.31
   axial  8W    24.028 LAT8 361.8686 PLEN8 383.31 PLPG8 394.31
   axial  TP                           383.31  TP24 394.31

[INSERT]
  title "Tritium-Producing Burnable Absorber Rods"
  npin  17

  mat tpbar      2.153  li-6  2.9377E-02
                        li-7  7.3028E-02
                       al-27  4.1062E-01
                        o-16  4.8697E-01

  mat tpbar_clad  0.0  cr-50  3.56307E-04
                       cr-52  6.87103E-03
                       cr-53  7.79120E-04
                       cr-54  1.93939E-04
                       mn-55  6.65250E-04
                       fe-54  1.65589E-03
                       fe-56  2.59939E-02
                       fe-57  6.00313E-04
                       fe-58  7.98906E-05
                       ni-58  1.84454E-02
                       ni-60  7.10515E-03
                       ni-61  3.08856E-04
                       ni-62  9.84768E-04
                       ni-64  2.50791E-04
                       zr-90  5.01283E-03
                       zr-91  1.09318E-03
                       zr-92  1.67094E-03
                       zr-94  1.69335E-03
                       zr-96  2.72807E-04
                       mo-00  6.3490E-04

  cell 1  0.283 0.384 0.484 / he tpbar tpbar_clad ! absorber
  cell 2        0.384 0.484 / he       tpbar_clad ! plenum
  cell 3              0.484 /          tpbar_clad ! end plug
```

```
  rodmap  TBAR8
     -
     - -
     - - -
     1 - - -
     - - - - -
     - - - - - 1
     - - - - - - -
     - - - - - - - -
     - - - - - - - - -

  rodmap  TPLEN8
     -
     - -
     - - -
     2 - - -
     - - - - -
     - - - - - 2
     - - - - - - -
     - - - - - - - -
     - - - - - - - - -

  rodmap  TPLUG8
     -
     - -
     - - -
     3 - - -
     - - - - -
     - - - - - 3
     - - - - - - -
     - - - - - - - -
     - - - - - - - - -

  rodmap  TPLPG8
     -
     - -
     - - -
     2 - - T
     - - - - -
     - - - - - 2
     T - - T - - -
     - - - - - - - -
     - - - - - - - - -

   axial 8T       11.951
           TPLEN8 24.028
            TBAR8 361.8686
           TPLEN8 383.31
           TPLPG8 394.31

[CONTROL]
  include ../wb1/control.ini    ! load typical control rod inputs

[DETECTOR]
  include ../wb1/detector.ini   ! load tpical detector input

[EDITS]
  include ../wb1/edits.inp      ! load typical edits

[MPACT]
  include ../wb1/mpact.ini      ! load typical MPACT input

[COBRATF]
  include ../wb1/cobratf.ini    ! load typical CTF input

[SHIFT]
  include ../shift.ini          ! load typical SHIFT input


! All other input comes from --init default option in VERAIn parser
```

APPENDIX B FUEL TEMPERATURES FROM BISON-CASL

The primary objective of Bison-CASL for this analysis was to provide estimates of the volume-averaged fuel temperatures as a function of power and exposure for use in the VERA-CS simulations of the Watts Bar Nuclear Plant (WBN1). Using Bison-CASL to calculate average fuel temperatures will provide improvements over the use of volume-averaged fuel temperatures from CTF calculations due to the detailed thermomechanical fuel behavior treatment in Bison-CASL including pellet-clad gap closure, fission gas release, and the evolution and degradation of material properties (e.g., UO_2 thermal conductivity).

The increased physical representation of fuel behavior provided by Bison-CASL-calculated fuel temperatures will improve the accuracy of calculated plant parameters during cycle operations such as soluble boron concentration, power distributions, and flux map data for specific assembly locations. The coupled neutronics-thermal hydraulics simulations used to calculate these plant parameters depend strongly upon the neutron cross sections for a given material, which vary according to the temperature of that material at a given point in time. Through the material neutron cross-sections, fuel temperatures greatly impact the results of reactor physics depletion calculations, with fuel temperature decreases generally producing corresponding increases in reactivity for LWRs.

B.1 Methodology

Transferring heat from the fuel pellet to the coolant requires conducting that heat from the UO_2 fuel pellet, across the pellet-clad gap, through the cladding (and oxide or CRUD layers that may be present), and finally to the bulk coolant after a small loss term at the coolant-cladding interface boundary layer.

The primary input parameters needed to perform the Bison-CASL calculations are the fuel rod geometry, material models to be used for the UO_2 fuel and Zircaloy cladding, and a time-dependent fuel rod power. The geometry and material models, while very important, are fairly well known; vendor data and/or VERA-CS input files provide the vast majority of the fuel rod geometry parameters needed, and prior experience using the Bison-CASL code has established best practices for which material models to use as well as values for parameters within those models [1-3]. Establishing time-dependent power histories for Bison-CASL calculations proves more difficult, however, because they depend upon both the rod-average linear heat rate (LHR) for a specific fuel rod and the axial power shape that the fuel rod experiences during operation. The nodal burnup in a fuel element is calculated within Bison-CASL based upon the local power history, which includes both time and power level factors, along with user-specified values in the Bison-CASL input file that define the amount of energy released per fission event and a conversion factor to translate the specific burnup from units of fraction of initial heavy metal atoms fissioned (FIMA) to units of gigawatt-days per ton of heavy metal (GWd/tHM) or megawatt-days per kilogram of uranium (MWd/kgU). The bulk coolant temperature, LHR, and burnup values at a specific axial node are the primary parameters that determine the average fuel temperature at that node; other factors impact the fuel temperature as well (e.g., gap thickness and gap gas conductivity) but these factors often depend upon LHR and burnup and are explicitly accounted for within Bison-CASL calculations. Volume-averaged fuel temperatures are calculated according to Equation 1,

$$\mathrm{T}_{avg,fuel}(j) = \frac{\sum_{i \in j} \mathrm{T}_i \mathrm{V}_i}{\sum_{i \in j} \mathrm{V}_i} \quad , \qquad \text{(Eq. 1)}$$

where $T_{avg,fuel}$ is the average temperature of all fuel pellet elements i belonging to axial node j, T_i is the temperature of element i, and is the volume of element i.

It should be noted that throughout this appendix, values will be referred to as being nodal values when they are the volume-averaged values for a given axial region of a fuel rod. This term comes from nodal depletion methods in radiation transport and should not be confused with the technical usage of the term "node" within finite element-based analysis codes such as Bison-CASL. Referring to a value as a nodal value means it has been localized to a given axial bin of a particular fuel rod, but is also distinguished as not being a truly "local" value which would take into account radial variations within that axial node and would also be on a finer axial mesh.

Based upon the information above, the average fuel temperature at a given axial node may be calculated as the bulk coolant temperature at that axial position (T_{bulk}) plus a term accounting for the temperature difference between the average fuel temperature and bulk coolant temperature at that axial node (ΔT). This notation allows the average fuel temperature calculated for a given LHR and burnup combination of a node to be specified independent of the axial position of that node to first-order; for example, two symmetric axial nodes at different heights but with the same burnup and LHR conditions would have two different calculated average fuel temperatures but the primary difference between the nodes would be the T_{bulk} term with only a very small variation in the ΔT term. This simplifies the lookup tables for VERA-CS calculations by allowing them to interpolate between ΔT terms calculated over a range of LHR and burnup combinations and then add that term to the CTF-calculated T_{bulk} to obtain the average fuel temperature to be used for calculations neutron cross sections at that axial node. It should be noted that the Bison-CASL calculations must adequately cover the expected space of combined LHR and burnup combinations in order to provide sufficient information to the VERA-CS core simulations.

This work used a two-phase approach: an initial first phase with simplified calculations to scope out the methodology and the needed assumptions, followed by a second phase with more detailed calculations to obtain results with the desired accuracy and range of applicability.

During the first phase, initial calculations were performed assuming a uniform axial power profile for a full-length fuel rod over a range of LHR values typical for LWR fuel rods. These simple test problems helped develop the methodology for more detailed follow-on Bison-CASL calculations. Figure B.1illustrates the approach used in this first phase; the blue line shows a 24-hour power ramp to 8 kW/ft, while the orange line shows a constant 300-day operation at a core average power level (5 kW/ft) followed by a ramp to zero power and subsequent power ramp to 8 kW/ft. The blue curve approximates beginning of cycle (BOC) operation, while the orange curve approximates middle of cycle (MOC) and end of cycle (EOC) operation with burnup accumulation achieved at a constant power of 5 kW/ft. A full cycle power history is therefore constructed for fuel rods at various LHR values by running the blue curve once followed by the orange curve twice in succession.

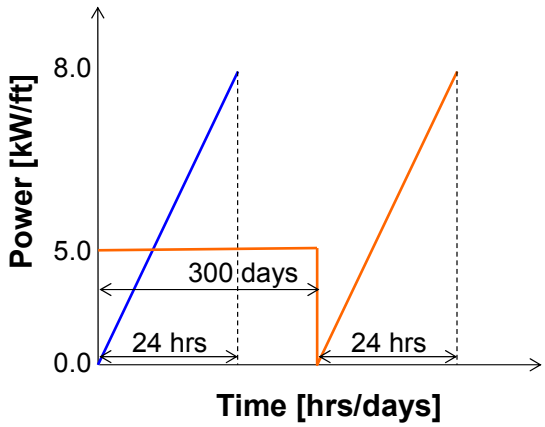

Figure B.1 An illustration showing the approach used for initial simple test problems to use Bison-CASL to calculate average fuel temperatures for VERA-CS

The second phase of this work involved performing Bison-CASL calculations for multiple rod LHRs and multiple axial power shapes. It was expected that this approach could envelope expected conditions during WBN1 Cycle 1 while avoiding running explicit Bison-CASL calculations for every rod power history present in WBN1; this approach should therefore produce reasonable results on a short time frame while avoiding large computational costs and challenges.

Nine different power histories were defined for Bison-CASL full-length fuel rod calculations by combining three rod-average LHRs (70%, 100%, and 130% of core-average) with three axial offsets (-10%, 0%, and +10%). VERA-CS calculations using the internal CTF heat conduction model generated core-average axial power distributions for each power history assuming WBN1 BOC HFP equilibrium xenon conditions. Figure B.2 shows the relative power (on the left) and resultant nodal LHR (on the right) as a function of axial position for each Bison-CASL simulation (labeled #1–#9), with precise values plotted at the axial height corresponding to the middle of each axial node and linear interpolations in-between. These power histories bound the combinations of LHR and burnup for WBN1 Cycle 1 and thus provide average fuel temperature information for all low burnup calculations; concerns of the applicability of this approach to higher-burnup fuel temperature calculations were expressed early in the process and eventually shown to be justified, as will be discussed further below.

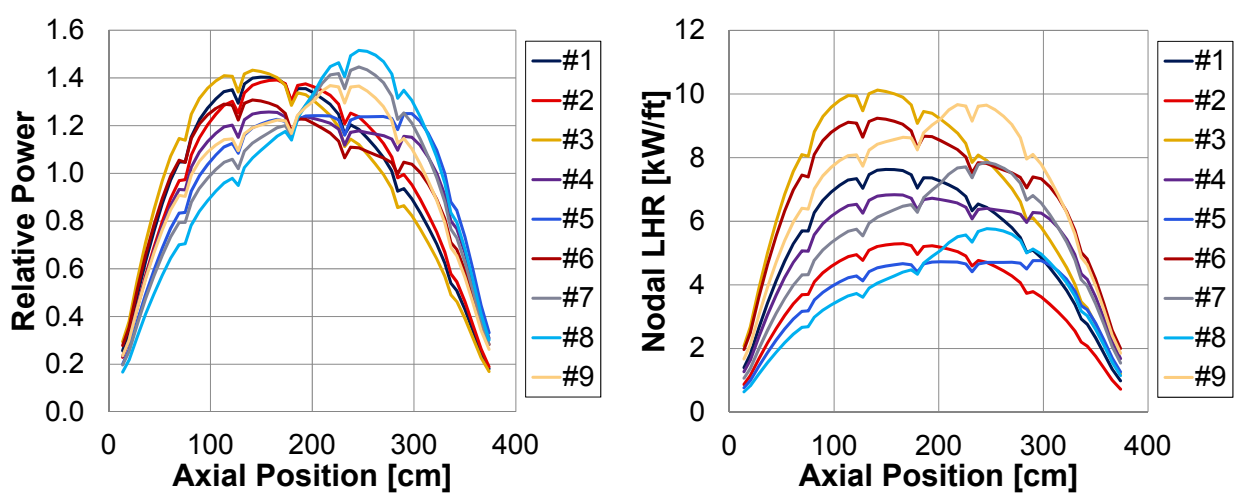

Figure B.2 VERA-CS relative power (left) and nodal LHR (right) as a function of axial position for each Bison-CASL simulation performed

The 2-D RZ Bison-CASL model used for all of these calculations used fuel rod geometry dimensions based on the WBN1 fuel specifications, including fuel pellet diameter, gap thickness, cladding thickness, fuel stack height, and total cladding height. The fuel pellet stack mesh used 6 radial intervals, 100 axial intervals, and QUAD4 elements. The cladding mesh used 3 radial intervals, a finer axial mesh than the fuel, and QUAD4 elements. Bulk coolant temperature profiles for use in Bison-CASL were generated using the initial VERA-CS calculations. The *GapHeatTransferLWR* model within Bison-CASL was used to model gap conductance, combining radiative and conductive heat transfer properties. Thermal conductivity of UO_2 was modeled using the *UO2Therm* model within Bison-CASL, which is based on the NFIR model for thermal conductivity of UO_2 during irradiation [1,2]. Figure B.3 shows a 2D render from ParaView of the actual mesh used for the model, with both a full-length view (on the left) and a close-up view of the top of the fuel rod (on the right) after scaling the radial dimensions of the model up by a factor of 100 due to the aspect ratio of the fuel rod.

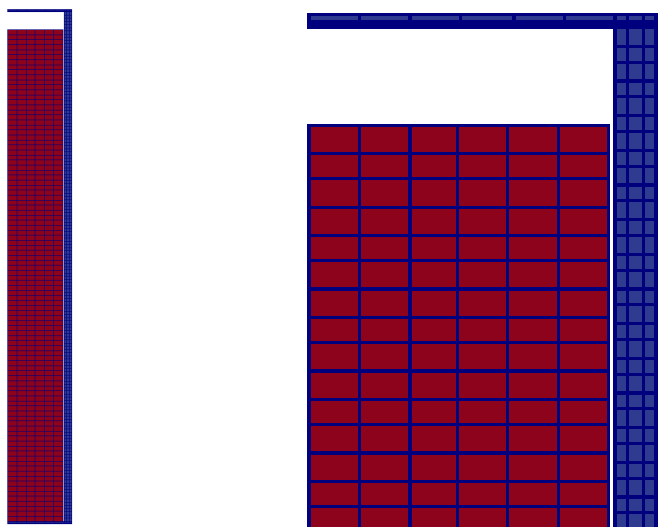

Figure B.3 Full-length view (left) and close-up view of the top of the fuel rod (right) of the mesh used for the model, with radial dimensions scaled up by a factor of 100 due to the aspect ratio of the fuel rod

B.2 Results

Phase 1 involved a series of sensitivity studies to characterize the relationship between LHR and accumulated burnup on the average fuel temperatures. These calculations were performed using full-length 2-D R-Z axisymmetric models. The results provide average fuel temperatures as a function of LHR and burnup, which are used for temperature-informed cross section analyses. The analysis assumed a uniform axial power profile, uniform coolant temperature, and started at hot-zero-power before being ramped to 8 kW/ft for a number of different burnups. Burnup accumulation was achieved by assuming a constant power operation at 5 kW/ft. Figure B.4 shows the volume average fuel temperatures calculated by Bison-CASL during this analysis. The discontinuity near an LHR of 4 kW/ft in fresh fuel occurs because of fuel cracking and relocation; the steep radial temperature gradients experienced by fuel pellets cause radial cracks to form. The discontinuity occurs when the fuel reaches a specified threshold LHR (4kW/ft) to cause relocation, with expansion of the fuel leading to a reduction in the pellet-cladding gap thickness and increases in the gap conductance and ultimately, decreasing the volume-averaged fuel temperature.

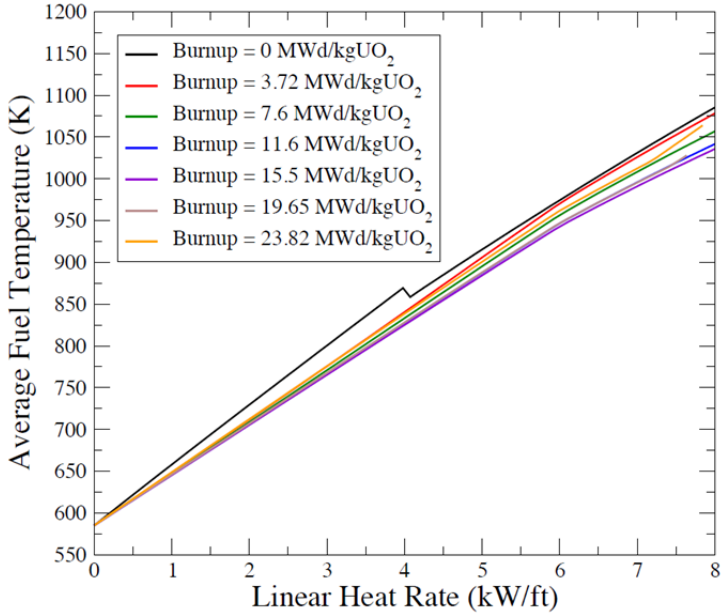

Figure B.4 Average fuel temperature as a function of rod-average LHR at several different burnup levels, assuming a uniform axial power profile for the fuel rod

The results show the volume-averaged fuel temperature is dependent on both burnup and LHR, with stronger burnup dependence at high LHR values. The fuel temperatures are highest for fresh fuel and then decrease until the burnup reaches 15.5 MWd/kgUO_2, at which point the volume-averaged fuel temperature begins to increase again. This behavior occurs primarily because of irradiation-induced changes in the pellet-cladding gap thickness. The as-fabricated (i.e., zero burnup or fresh fuel) gap thickness begins to close with burnup because of fuel pellet swelling and cladding creep. This decrease in gap thickness increases the gap conductance, which reduces the fuel temperature. However, once full gap closure occurs around 15.5 MWd/kgUO_2, the gap conductance remains relatively constant; fuel temperatures then start to increase due to degradation of UO_2 thermal conductivity. As fission events build up, UO_2 thermal conductivity is significantly reduced due to multiple factors including the damage created by the fission events, accumulation of solid fission products, and increased porosity in the pellet. It should be noted that the mass basis for burnup in these Phase 1 calculations was per unit mass of UO_2, while Phase 2 calculations switched to being per unit mass of uranium (U); these units are accurately specified in the appropriate portions of this document.

Phase 2 calculations used the 9 nodal LHR distributions shown in Figure B.2 (3 rod-average LHRs with 3 axial power shapes each). This second approach allows for integral fuel rod effects to be considered in the calculation of the nodal volume-average fuel temperatures, primarily through fission gas release. The results, shown in Figure B.5 and Figure B.6, establish a dataset that can be sampled to estimate the nodal volume-averaged fuel temperature for a given combination of LHR and specific burnup.

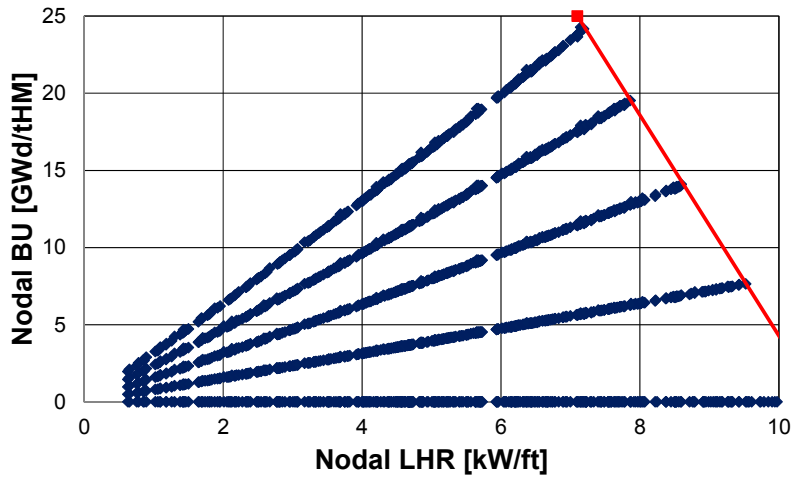

Figure B.5 Nodal average burnup as a function of nodal average LHR extracted at five different points in time from Bison-CASL results, with a red line showing MPACT-calculated bounds of operating fuel for WBN1 Cycle 1

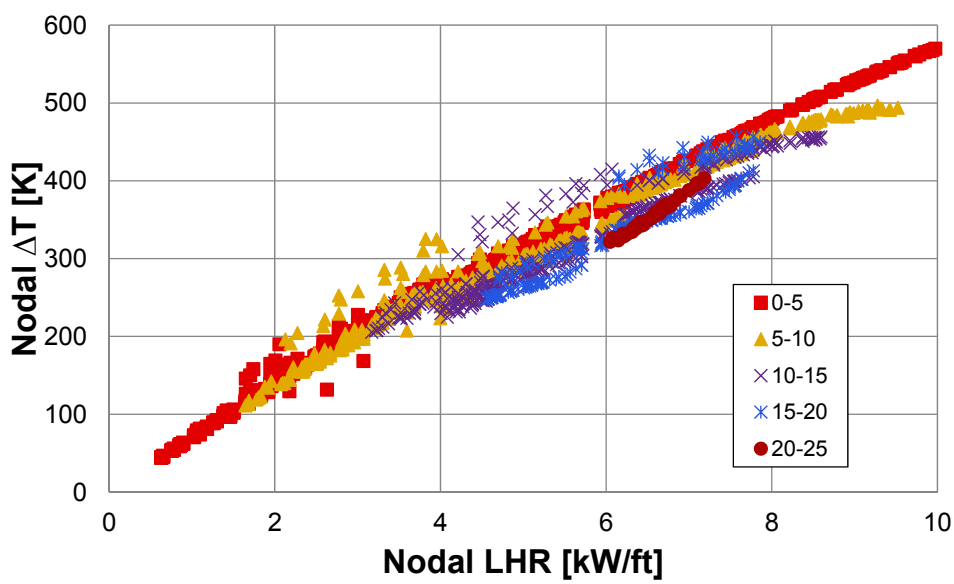

Figure B.6 Nodal volume-average ΔT as a function of nodal average LHR as calculated by Bison-CASL, with results binned into data series according to the nodal burnup of the fuel at that point in time

Figure B.5 shows the burnup ranges that are covered for the given LHRs for the WBN1 Cycle 1 total effective fuel power days, with the underlying data allowing an analyst to look up what the nodal-averaged fuel temperature would be for a given combination of nodal-average burnup and LHR values. This nodal-average fuel temperatures are then be used to calculate the neutron cross sections for the local fuel region (corresponding to a nodal value). Figure B.6 shows the temperature difference between the bulk coolant temperature and the volume-averaged fuel temperature as a function of nodal average LHR; furthermore, it breaks the data into groups by binning the associated burnup value of each data point. This figure allows an analyst to directly determine the temperature rise (or drop) across the fuel rod different for combinations of nodal average LHR and burnup. The temperature data is fairly linear with respect to LHR, with small deviations in the higher burnup simulations largely attributed to degraded heat transfer through the gap due to fission gas release and reduced UO_2 thermal conductivity. It should be noted that the pellet-cladding gap can also contribute

to the deviations in the temperatures; when the gap begins to close, it can cause significant deviations in the volume-averaged fuel temperature. Gap closure depends on many factors including temperature, power history, burnup, fast neutron fluence, LHR, and fission gas release. Current calculations in this work account for burnup and LHR; however, understanding the volume-averaged fuel temperature when the gap closes is much more complicated and would require detailed studies analyzing all the factors listed above.

B.3 Discussion

The results shown above provide the ΔT for volume-averaged fuel temperatures over a range of nodal LHR and burnup combinations. These results, after being processed into a lookup table and converted into polynomial fits, provide VERA-CS with the ability to used Bison-CASL generated volume-averaged fuel rod temperatures for WBN1 Cycle 1 with a peak burnup of about 25 GWd/tHM achieved at an LHR of about 7 kW/ft.

For higher burnup values needed for subsequent cycles, Bison-CASL simulations were performed using the same LHR axial profiles shown in Figure B.2; however, some of these calculations ran into computation issues (e.g., convergence problems) and the results obtained from simulations that completed appeared nonphysical. Both of these problems demonstrate that unrealistic irradiation conditions are being used for the simulations, such as high LHRs being demanded of relatively high burnup fuel that would most likely actual operate at lower LHRs either by design (i.e., core designs would design loading patterns that put higher burnup fuel in lower power locations) or by necessity because fission rates would naturally decrease at the fissile content in the fuel rod depletes. These problems indicate that the irradiation conditions requested in the calculations exceeded the limitations of the methodology being used.

In light of these issues, established knowledge of expected behaviors of fuel temperatures in operating PWR fuel rods was used as a basis for providing general guidance for VERA-CS calculations with fuel burnup levels above the results shown in Figure B.6. This guidance recommended using the ΔT at the highest burnup currently provided for each LHR as a constant ΔT value for higher fuel burnups at that LHR. Polynomial fits developed for the data in Figure B.6 could also be extrapolated forward in burnup, but this would be somewhat complicated because it would have to be done in a way that precluded average fuel temperatures decreasing to an unrealistically low value if the polynomial showed fuel temperatures still decreasing for all increasing burnup at a given LHR. Average fuel temperatures should reasonably be expected to hit a minimum value when full gap closure occurs and then increase afterward, as seen in Figure B.4.

B.4 Summary

Volume-averaged fuel temperatures were generated for WBN1 benchmarking calculations with VERA-CS using Bison-CASL simulations assuming rod-average LHRs and axial power shapes provided by VERA-CS for Cycle 1. These Bison-CASL simulations successfully generated data used in lookup tables and fit with polynomials to allow VERA-CS to calculate the temperature difference between the bulk coolant temperature and volume-averaged fuel temperature for any axial node given a combination of nodal LHR and burnup. Higher burnup fuel temperatures were not explicitly provided for VERA-CS due to limitations in the methodology being used. Instead, general guidance was provided to MPACT developers that the temperature difference at the highest burnup provided for each LHR should be used as a constant value for higher fuel burnups, with the understanding that this should yield reasonably accurate results but any problems should be reported back to the thermomechanical fuel performance team.

Future work should focus on assessing the accuracy of fuel temperatures calculated in Bison-CASL, modeling new fuel types that include new features such as integral fuel burnable absorber (IFBA) poison material or annular fuel pellets, demonstrating effective approaches to modeling the fuel operational lifetime of fuel rods within Bison-CASL, and simplifying the process of extracting fuel temperatures from Bison-CASL for use in VERA-CS.

B.5 References

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APPENDIX C ISOTOPES IN REDUCED ORIGEN LIBRARY

The following isotopes are in the simplified burnup chain created for this analysis.

Table C.1 Nuclides in the Simplified Burnup Chain "CASL2.0"

Light/Activation Nuclides (71)		Actinides (42)	Fission Products (150)		
1-H-1	72-Hf-176	90-Th-230	35-BR-81	52-TE-129m	63-EU-151
1-H-2	72-Hf-177	90-Th-231	35-BR-82	52-TE-132	63-EU-153
1-H-3	72-Hf-178	90-Th-232	36-KR-82	53-I-127	63-EU-154
2-He-3	72-Hf-179	90-Th-233	36-KR-83	53-I-128	63-EU-155
2-He-4	72-Hf-180	90-Th-234	36-KR-84	53-I-129	63-EU-156
3-Li-6	72-Hf-181	91-Pa-231	36-KR-85	53-I-130	63-EU-157
3-Li-7	73-Ta-181	91-Pa-232	36-KR-86	53-I-131	64-GD-154
4-Be-9	73-Ta-182	91-Pa-233	38-SR-89	53-I-132	64-GD-155
5-B-10		91-Pa-234	38-SR-90	53-I-135	64-GD-156
5-B-11		92-U-232	39-Y-89	54-XE-128	64-GD-157
8-O-16		92-U-233	39-Y-90	54-XE-130	64-GD-158
47-Ag-107		92-U-234	39-Y-91	54-XE-131	64-GD-159
47-Ag-109		92-U-235	40-ZR-91	54-XE-132	64-GD-160
47-Ag-110		92-U-236	40-ZR-93	54-XE-133	64-GD-161
48-Cd-110		92-U-237	40-ZR-95	54-XE-134	65-TB-159
48-Cd-111		92-U-238	40-ZR-96	54-XE-135	65-TB-160
48-Cd-112		92-U-239	41-NB-95	54-XE-135m	65-TB-161
48-Cd-113		93-Np-236	42-MO-95	54-XE-136	66-DY-160
48-Cd-114		93-Np-237	42-MO-96	54-XE-137	66-DY-161
48-Cd-115		93-Np-238	42-MO-97	55-CS-133	66-DY-162
49-In-113		93-Np-239	42-MO-98	55-CS-134	66-DY-163
49-In-115		93-Np-240	42-MO-99	55-CS-135	66-DY-164
62-Sm-152		93-Np-240m	42-MO-100	55-CS-136	66-DY-165
62-Sm-153		94-Pu-236	43-TC-99	55-CS-137	67-HO-165
63-Eu-151		94-Pu-237	43-TC-99m	56-BA-134	
63-Eu-152		94-Pu-238	43-TC-100	56-BA-137	
63-Eu-152m		94-Pu-239	44-RU-100	56-BA-140	
63-Eu-153		94-Pu-240	44-RU-101	57-LA-139	
63-Eu-154		94-Pu-241	44-RU-102	57-LA-140	
63-Eu-155		94-Pu-242	44-RU-103	58-CE-140	
63-Eu-156		94-Pu-243	44-RU-104	58-CE-141	
63-Eu-157		95-Am-241	44-RU-105	58-CE-142	
64-Gd-152		95-Am-242	44-RU-106	58-CE-143	
64-Gd-154		95-Am-242m	45-RH-102	58-CE-144	
64-Gd-155		95-Am-243	45-RH-102m	59-PR-141	
64-Gd-156		95-Am-244	45-RH-103	59-PR-142	
64-Gd-157		95-Am-244m	45-RH-103m	59-PR-143	
64-Gd-158		96-Cm-242	45-RH-104	59-PR-144	
64-Gd-159		96-Cm-243	45-RH-105	60-ND-142	
64-Gd-160		96-Cm-244	45-RH-105m	60-ND-143	
64-Gd-161		96-Cm-245	45-RH-106	60-ND-144	
65-Tb-159		96-Cm-246	45-RH-106m	60-ND-145	
65-Tb-160			46-PD-104	60-ND-146	
65-Tb-161			46-PD-105	60-ND-147	
66-Dy-160			46-PD-106	60-ND-148	
66-Dy-161			46-PD-107	60-ND-149	
66-Dy-162			46-PD-108	60-ND-150	
66-Dy-163			46-PD-109	60-ND-151	
66-Dy-164			47-AG-109	61-PM-147	
66-Dy-165			47-AG-109m	61-PM-148	
67-Ho-165			47-AG-110	61-PM-148m	
68-Er-162			47-AG-110m	61-PM-149	
68-Er-164			47-AG-111	61-PM-150	
68-Er-166			48-CD-110	61-PM-151	
68-Er-167			48-CD-111	62-SM-147	
68-Er-168			48-CD-113	62-SM-148	
68-Er-169			49-IN-115	62-SM-149	
68-Er-170			51-SB-121	62-SM-150	
68-Er-171			51-SB-123	62-SM-151	
69-Tm-169			51-SB-125	62-SM-152	
69-Tm-170			51-SB-127	62-SM-153	
69-Tm-171			52-TE-127	62-SM-154	
72-Hf-174			52-TE-127m	62-SM-155	

APPENDIX D VERA-CS DEPLETION SUMMARIES

WBN1 Cycle 1

#	EFPD	Ecyc	Ecore	Emax	k-eff	Boron	AO	Pavg	Fassy	FdH	Fq	Power	Tin(F)	Tavg(F)	Tout(F)	pin	pavg	pout	Tf(K)	Tfmx(K)	Outrs
1	0.0	0.000	0.000	0.000	1.00000	1296.2	-7.4%	1.0000	1.2698	1.3931	2.2587	0.0%	557.0	557.0	557.0	0.742	0.742	0.742	564.8	564.8	8
2	9.0	0.346	0.341	0.468	1.00000	1053.8	-9.1%	1.0000	1.2277	1.3501	1.9999	65.7%	557.6	580.0	598.7	0.741	0.714	0.689	809.7	1008.7	14
3	32.0	1.230	1.224	1.664	1.00000	851.2	-8.8%	1.0000	1.2239	1.3566	1.8589	99.7%	558.1	591.5	618.4	0.741	0.698	0.658	911.4	1100.0	13
4	49.9	1.919	1.913	2.594	1.00000	830.0	-8.4%	1.0000	1.2129	1.3446	1.8292	98.0%	558.2	591.0	617.6	0.741	0.698	0.659	903.4	1090.9	12
5	63.8	2.457	2.451	3.315	1.00000	816.5	-7.9%	1.0000	1.2069	1.3357	1.7856	100.0%	558.6	592.0	619.0	0.740	0.697	0.656	909.1	1092.4	11
6	77.8	2.994	2.988	4.029	1.00000	798.9	-7.4%	1.0000	1.2093	1.3225	1.7465	99.7%	558.7	592.0	618.9	0.740	0.697	0.657	909.0	1086.8	10
7	92.5	3.562	3.555	4.778	1.00000	778.4	-6.4%	1.0000	1.2122	1.3175	1.7009	99.7%	558.6	591.6	618.8	0.740	0.697	0.657	909.6	1080.2	11
8	105.6	4.065	4.058	5.440	1.00000	757.2	-5.8%	1.0000	1.2151	1.3133	1.6643	99.8%	558.8	591.8	619.0	0.740	0.697	0.656	910.5	1075.0	11
9	120.6	4.642	4.635	6.196	1.00000	730.9	-5.2%	1.0000	1.2139	1.3059	1.6279	99.8%	558.4	591.3	618.7	0.740	0.698	0.657	910.8	1066.6	14
10	133.5	5.139	5.132	6.843	1.00000	708.2	-4.6%	1.0000	1.2105	1.2985	1.5976	99.5%	557.9	590.8	618.1	0.741	0.699	0.658	910.0	1058.3	13
11	148.1	5.700	5.692	7.567	1.00000	681.0	-4.5%	1.0000	1.2024	1.2851	1.5724	98.0%	558.0	590.4	617.4	0.741	0.699	0.659	905.6	1046.0	10
12	163.0	6.273	6.265	8.303	1.00000	657.6	-3.5%	1.0000	1.2039	1.2832	1.5358	95.1%	557.9	589.2	615.6	0.741	0.701	0.662	896.7	1028.7	15
13	181.9	7.000	6.992	9.232	1.00000	617.9	-2.8%	1.0000	1.2047	1.2714	1.4977	94.8%	557.9	589.1	615.5	0.741	0.701	0.662	894.7	1021.5	11
14	193.9	7.463	7.454	9.821	1.00000	581.5	-3.3%	1.0000	1.2041	1.2753	1.4900	99.8%	557.8	590.7	618.2	0.741	0.699	0.658	908.2	1031.5	12
15	207.3	7.978	7.969	10.476	1.00000	559.9	-2.2%	1.0000	1.2015	1.2690	1.4639	93.9%	557.5	588.3	614.7	0.741	0.702	0.664	889.9	1008.5	14
16	220.6	8.493	8.484	11.130	1.00000	515.9	-2.8%	1.0000	1.1981	1.2683	1.4621	100.1%	558.0	590.9	618.6	0.741	0.698	0.657	907.1	1023.8	12
17	237.5	9.140	9.130	11.948	1.00000	471.1	-2.1%	1.0000	1.1919	1.2604	1.4392	99.7%	557.7	590.3	618.1	0.741	0.699	0.658	904.3	1022.2	13
18	249.5	9.602	9.592	12.530	1.00000	439.4	-2.1%	1.0000	1.1872	1.2593	1.4354	100.2%	557.6	590.5	618.3	0.741	0.699	0.658	904.9	1021.1	12
19	268.7	10.344	10.334	13.455	1.00000	393.1	-1.9%	1.0000	1.1759	1.2348	1.4205	95.6%	557.9	589.3	616.0	0.741	0.701	0.662	889.6	1002.9	14
20	281.7	10.842	10.831	14.071	1.00000	359.2	-1.4%	1.0000	1.1709	1.2383	1.4071	96.4%	558.1	589.4	616.7	0.741	0.701	0.661	890.7	1007.0	12
21	293.9	11.314	11.303	14.653	1.00000	331.1	-1.1%	1.0000	1.1603	1.2270	1.4118	93.4%	557.4	588.0	614.4	0.741	0.703	0.664	880.0	995.3	11
22	311.5	11.988	11.977	15.482	1.00000	267.3	-1.5%	1.0000	1.1603	1.2329	1.4064	99.7%	557.5	590.1	618.0	0.741	0.700	0.658	897.6	1017.4	12
23	326.1	12.552	12.540	16.175	1.00000	223.6	-1.3%	1.0000	1.1556	1.2236	1.4029	98.0%	557.6	589.6	617.2	0.741	0.701	0.660	890.8	1009.2	12
24	347.1	13.360	13.348	17.165	1.00000	158.7	-1.2%	1.0000	1.1609	1.2274	1.4041	99.4%	557.7	590.0	618.0	0.741	0.700	0.659	892.9	1014.4	11
25	372.4	14.335	14.322	18.356	1.00000	81.6	-0.5%	1.0000	1.1557	1.2159	1.3858	99.9%	557.8	590.3	618.4	0.741	0.700	0.658	891.8	1018.8	13
26	372.4	14.335	14.322	18.356	1.00000	103.8	0.1%	1.0000	1.1299	1.1766	1.3980	86.9%	556.7	585.2	610.1	0.742	0.707	0.671	848.7	954.6	7
27	391.5	15.068	15.054	19.216	1.00000	53.0	-0.1%	1.0000	1.1251	1.1692	1.3848	86.9%	556.7	585.3	610.3	0.742	0.707	0.671	845.9	950.6	13
28	391.5	15.068	15.054	19.216	1.00000	32.2	0.2%	1.0000	1.1557	1.2144	1.4096	99.6%	558.0	590.2	618.5	0.741	0.700	0.658	888.5	1026.8	12
29	397.7	15.308	15.294	19.507	1.00000	0.6	-0.7%	1.0000	1.1539	1.2116	1.3827	99.6%	558.0	590.4	618.5	0.741	0.699	0.658	888.0	1017.4	14
30	409.8	15.774	15.760	20.073	0.99903	0.0	1.8%	1.0000	1.1605	1.2177	1.4373	89.9%	557.1	586.0	612.2	0.742	0.706	0.668	852.8	984.5	15
31	422.7	16.270	16.255	20.678	0.99888	0.0	4.7%	1.0000	1.1662	1.2222	1.5027	78.8%	556.3	581.3	605.2	0.743	0.712	0.679	812.7	942.2	18
32	440.1	16.939	16.924	21.496	0.99900	0.0	5.9%	1.0000	1.1690	1.2207	1.5340	64.5%	554.9	575.4	595.6	0.744	0.720	0.693	761.4	874.7	20

WBN1 Cycle 2

#	EFPD	Ecyc	Ecore	Emax	k-eff	Boron	AO	Pavg	Fassy	FdH	Fq	Power	Tin(F)	Tavg(F)	Tout(F)	pin	pavg	pout	Tf(K)	Tfmx(K)	Outrs
1	0.0	0.000	8.754	20.281	1.00000	1395.3	12.4%	1.0000	1.3061	1.4942	1.8916	0.0%	557.0	557.0	557.0	0.742	0.742	0.742	564.8	564.8	22
2	3.7	0.142	8.891	20.423	1.00000	893.1	-5.0%	1.0000	1.2760	1.4104	1.8585	100.0%	557.0	590.3	617.0	0.742	0.699	0.658	901.0	1135.1	15
3	13.6	0.521	9.270	20.817	1.00000	890.3	-4.6%	1.0000	1.2780	1.4098	1.7674	100.0%	557.0	590.1	617.0	0.742	0.699	0.658	899.1	1100.3	10
4	26.1	1.000	9.749	21.314	1.00000	910.4	-5.0%	1.0000	1.2896	1.4145	1.6955	100.0%	557.0	590.2	617.0	0.742	0.699	0.658	896.6	1076.0	11
5	38.6	1.479	10.228	21.812	1.00000	935.2	-4.9%	1.0000	1.3008	1.4160	1.6830	100.0%	557.0	590.1	617.0	0.742	0.699	0.658	893.8	1063.4	12
6	53.9	2.065	10.814	22.421	1.00000	957.3	-4.7%	1.0000	1.3124	1.4140	1.6816	100.0%	557.0	590.0	617.0	0.742	0.699	0.658	890.9	1064.8	11
7	64.6	2.475	11.224	22.848	1.00000	967.0	-4.3%	1.0000	1.3197	1.4118	1.6791	100.0%	557.0	590.0	617.0	0.742	0.699	0.658	890.2	1066.7	9
8	81.7	3.130	11.879	23.531	1.00000	972.2	-4.0%	1.0000	1.3297	1.4088	1.6773	100.0%	557.0	589.9	617.0	0.742	0.700	0.658	889.2	1070.4	11
9	93.4	3.579	12.327	23.999	1.00000	970.1	-3.6%	1.0000	1.3359	1.4043	1.6688	100.0%	557.0	589.9	616.9	0.742	0.700	0.658	888.7	1071.7	9
10	104.9	4.019	12.767	24.459	1.00000	963.4	-3.3%	1.0000	1.3405	1.4126	1.6630	100.0%	557.0	589.7	616.9	0.742	0.700	0.658	888.1	1072.5	9
11	122.6	4.698	13.445	25.167	1.00000	944.5	-2.9%	1.0000	1.3493	1.4270	1.6703	100.0%	557.0	589.7	616.9	0.742	0.700	0.658	887.5	1075.4	12
12	134.7	5.161	13.908	25.650	1.00000	927.9	-2.4%	1.0000	1.3561	1.4347	1.6786	100.0%	557.0	589.6	616.9	0.742	0.700	0.658	887.1	1078.4	9
13	144.2	5.525	14.272	26.030	1.00000	911.9	-2.2%	1.0000	1.3612	1.4404	1.6823	100.0%	557.0	589.6	616.9	0.742	0.700	0.658	886.7	1078.4	7
14	159.5	6.111	14.858	26.641	1.00000	881.6	-1.8%	1.0000	1.3675	1.4478	1.6835	100.0%	557.0	589.6	616.9	0.742	0.700	0.658	885.7	1077.8	10
15	170.3	6.525	15.271	27.073	1.00000	858.8	-1.5%	1.0000	1.3700	1.4510	1.6813	100.0%	557.0	589.4	616.9	0.742	0.700	0.658	884.8	1076.9	9
16	186.5	7.146	15.891	27.719	1.00000	819.1	-1.2%	1.0000	1.3731	1.4554	1.6742	100.0%	557.0	589.4	616.9	0.742	0.700	0.658	883.5	1074.8	11
17	201.1	7.705	16.450	28.301	1.00000	780.4	-1.0%	1.0000	1.3745	1.4578	1.6653	100.0%	557.0	589.4	616.9	0.742	0.700	0.658	882.4	1072.9	11
18	214.5	8.219	16.963	28.834	1.00000	743.2	-0.7%	1.0000	1.3743	1.4581	1.6530	100.0%	557.0	589.3	616.9	0.742	0.700	0.658	881.2	1071.2	12
19	229.5	8.794	17.538	29.431	1.00000	697.9	-0.6%	1.0000	1.3733	1.4579	1.6404	100.0%	557.0	589.3	616.9	0.742	0.700	0.658	880.2	1071.8	11
20	242.4	9.288	18.031	29.943	1.00000	658.6	-0.1%	1.0000	1.3719	1.4571	1.6254	100.0%	557.0	589.2	616.9	0.742	0.700	0.658	879.6	1075.2	11
21	257.3	9.859	18.602	30.535	1.00000	609.3	-0.3%	1.0000	1.3692	1.4547	1.6196	100.0%	557.0	589.3	616.9	0.742	0.700	0.658	879.2	1075.4	11
22	270.3	10.357	19.100	31.050	1.00000	565.9	-0.4%	1.0000	1.3664	1.4524	1.6145	100.0%	557.0	589.3	617.0	0.742	0.700	0.658	878.8	1076.4	12
23	285.3	10.932	19.674	31.643	1.00000	514.7	-0.2%	1.0000	1.3630	1.4491	1.6045	100.0%	557.0	589.2	616.9	0.742	0.701	0.658	878.3	1078.2	11
24	298.3	11.430	20.172	32.157	1.00000	469.7	-0.3%	1.0000	1.3595	1.4456	1.6005	100.0%	557.0	589.2	616.9	0.742	0.701	0.658	878.0	1078.2	10
25	312.2	11.962	20.704	32.705	1.00000	420.1	-0.4%	1.0000	1.3552	1.4412	1.5949	100.0%	557.0	589.2	616.9	0.742	0.701	0.658	877.6	1078.0	10
26	327.3	12.541	21.282	33.300	1.00000	366.1	-0.3%	1.0000	1.3511	1.4369	1.5849	100.0%	557.0	589.3	617.0	0.742	0.700	0.658	877.3	1080.6	12
27	340.3	13.039	21.779	33.811	1.00000	319.6	-0.3%	1.0000	1.3468	1.4323	1.5777	100.0%	557.0	589.2	617.0	0.742	0.700	0.658	877.1	1082.7	11
28	353.3	13.537	22.277	34.322	1.00000	272.4	-0.3%	1.0000	1.3424	1.4276	1.5711	100.0%	557.0	589.2	617.0	0.742	0.701	0.658	877.0	1083.9	12
29	367.1	14.066	22.805	34.863	1.00000	221.6	-0.4%	1.0000	1.3380	1.4227	1.5654	100.0%	557.0	589.3	617.0	0.742	0.700	0.658	876.8	1085.0	15
30	381.5	14.618	23.357	35.427	1.00000	169.2	-0.4%	1.0000	1.3330	1.4170	1.5608	100.0%	557.0	589.3	617.1	0.742	0.700	0.658	876.6	1085.5	14
31	397.1	15.215	23.954	36.036	1.00000	112.4	-0.5%	1.0000	1.3283	1.4108	1.5566	100.0%	557.0	589.3	617.0	0.742	0.701	0.658	876.3	1084.9	14
32	411.4	15.763	24.501	36.594	1.00000	60.4	-0.7%	1.0000	1.3240	1.4047	1.5533	100.0%	557.0	589.3	617.1	0.742	0.701	0.658	875.9	1081.3	11
33	425.9	16.319	25.056	37.207	1.00000	9.6	-0.2%	1.0000	1.3229	1.3989	1.5388	100.0%	557.0	589.2	617.1	0.742	0.701	0.658	875.3	1082.1	13
34	441.1	16.901	25.638	37.863	0.99972	0.0	3.3%	1.0000	1.3227	1.3956	1.5768	89.9%	557.0	585.5	611.6	0.742	0.706	0.667	835.9	1041.3	13
35	456.1	17.476	26.213	38.511	0.99969	0.0	7.5%	1.0000	1.3240	1.3940	1.6709	77.3%	557.0	581.1	604.6	0.742	0.712	0.679	789.3	983.6	12
36	471.4	18.062	26.798	39.172	1.00000	1.6	11.3%	1.0000	1.3226	1.3955	1.7648	63.2%	557.0	576.2	596.5	0.742	0.719	0.691	740.2	909.0	11

WBN1 Cycle 3

#	EFPD	Ecyc	Ecore	Emax	k-eff	Boron	AO	Pavg	Fassy	FdH	Fq	Power	Tin(F)	Tavg(F)	Tout(F)	pin	pavg	pout	Tf(K)	Tfmx(K)	Outrs
1	0.0	0.000	12.814	33.003	1.00000	1569.7	42.8%	1.0000	1.4225	1.5351	2.9304	0.0%	557.0	557.0	557.0	0.742	0.742	0.742	564.8	564.8	14
2	5.1	0.195	13.004	33.052	1.00000	984.7	-4.6%	1.0000	1.3648	1.4880	1.8618	100.0%	557.0	590.2	617.0	0.742	0.699	0.658	893.9	1133.1	17
3	18.1	0.692	13.501	33.180	1.00000	996.8	-3.8%	1.0000	1.3728	1.4818	1.7424	100.0%	557.0	590.0	617.0	0.742	0.700	0.658	891.3	1096.3	11
4	30.5	1.166	13.975	33.302	1.00000	1023.0	-4.1%	1.0000	1.3833	1.4881	1.7579	100.0%	557.0	589.9	617.0	0.742	0.700	0.658	888.5	1087.3	11
5	44.4	1.698	14.506	33.439	1.00000	1052.7	-4.2%	1.0000	1.3933	1.4921	1.7845	100.0%	557.0	589.9	617.0	0.742	0.700	0.658	885.2	1084.3	12
6	58.7	2.245	15.053	33.580	1.00000	1075.7	-4.2%	1.0000	1.4008	1.4922	1.8039	100.0%	557.0	589.9	617.0	0.742	0.700	0.658	883.5	1091.7	14
7	72.4	2.769	15.576	33.716	1.00000	1089.5	-3.9%	1.0000	1.4059	1.4898	1.8138	100.0%	557.0	589.9	617.0	0.742	0.700	0.658	882.8	1096.7	10
8	86.4	3.304	16.111	33.855	1.00000	1095.4	-3.8%	1.0000	1.4092	1.4844	1.8227	100.0%	557.0	589.8	617.0	0.742	0.700	0.658	882.3	1100.5	9
9	89.4	3.419	16.226	33.885	1.00000	1096.0	-3.8%	1.0000	1.4097	1.4830	1.8226	100.0%	557.0	589.8	617.0	0.742	0.700	0.658	882.2	1101.1	7
10	91.8	3.511	16.318	33.908	1.00000	1096.0	-3.7%	1.0000	1.4100	1.4818	1.8219	100.0%	557.0	589.8	617.0	0.742	0.700	0.658	882.1	1101.5	7
11	103.5	3.958	16.765	34.025	1.00000	1093.1	-3.4%	1.0000	1.4109	1.4810	1.8150	100.0%	557.0	589.8	616.9	0.742	0.700	0.658	881.8	1102.6	9
12	113.8	4.352	17.158	34.128	1.00000	1086.6	-3.3%	1.0000	1.4112	1.4815	1.8086	100.0%	557.0	589.7	617.0	0.742	0.700	0.658	881.6	1102.9	10
13	128.4	4.910	17.716	34.311	1.00001	1071.3	-3.0%	1.0000	1.4101	1.4805	1.7917	100.0%	557.0	589.7	617.0	0.742	0.700	0.658	881.3	1101.7	8
14	142.7	5.457	18.263	34.578	1.00000	1051.3	-2.6%	1.0000	1.4081	1.4801	1.7871	100.0%	557.0	589.7	617.0	0.742	0.700	0.658	880.9	1100.3	8
15	152.3	5.824	18.629	34.758	1.00000	1036.0	-2.4%	1.0000	1.4075	1.4814	1.7833	100.0%	557.0	589.5	617.0	0.742	0.700	0.658	880.4	1099.0	9
16	168.3	6.436	19.241	35.060	1.00000	1004.0	-2.1%	1.0000	1.4039	1.4809	1.7770	100.0%	557.0	589.5	617.0	0.742	0.700	0.658	879.5	1095.4	10
17	184.6	7.059	19.863	35.368	1.00000	967.0	-1.8%	1.0000	1.3998	1.4789	1.7735	100.0%	557.0	589.5	617.0	0.742	0.700	0.658	878.5	1092.1	10
18	198.3	7.583	20.387	35.629	1.00000	933.2	-1.3%	1.0000	1.3971	1.4774	1.7612	100.0%	557.0	589.4	616.9	0.742	0.700	0.658	877.6	1088.5	11
19	212.7	8.134	20.937	35.905	1.00000	893.8	-1.2%	1.0000	1.3929	1.4739	1.7514	100.0%	557.0	589.4	617.0	0.742	0.700	0.658	876.8	1089.4	9
20	226.3	8.654	21.457	36.167	1.00000	854.6	-1.1%	1.0000	1.3886	1.4744	1.7425	100.0%	557.0	589.4	617.0	0.742	0.700	0.658	876.3	1092.5	10
21	240.6	9.201	22.003	36.443	1.00000	811.7	-0.7%	1.0000	1.3852	1.4750	1.7278	100.0%	557.0	589.2	617.0	0.742	0.700	0.658	875.8	1094.0	11
22	254.3	9.725	22.526	36.710	1.00000	768.2	-0.6%	1.0000	1.3806	1.4735	1.7174	100.0%	557.0	589.2	617.0	0.742	0.700	0.658	875.6	1095.3	11
23	268.7	10.276	23.077	36.992	1.00000	720.5	-0.6%	1.0000	1.3759	1.4709	1.7085	100.0%	557.0	589.2	617.0	0.742	0.700	0.658	875.5	1096.9	9
24	282.3	10.796	23.596	37.260	1.00000	674.7	-0.4%	1.0000	1.3726	1.4691	1.6956	100.0%	557.0	589.3	617.0	0.742	0.700	0.658	875.4	1097.8	11
25	296.7	11.346	24.146	37.716	1.00000	625.0	-0.2%	1.0000	1.3682	1.4655	1.6841	100.0%	557.0	589.3	617.0	0.742	0.700	0.658	875.3	1101.1	11
26	310.4	11.870	24.670	38.275	1.00000	576.8	-0.4%	1.0000	1.3637	1.4611	1.6778	100.0%	557.0	589.3	617.0	0.742	0.700	0.658	875.2	1105.7	11
27	324.5	12.409	25.209	38.850	1.00000	526.6	-0.2%	1.0000	1.3599	1.4575	1.6663	100.0%	557.0	589.2	617.0	0.742	0.700	0.658	875.2	1108.1	13
28	338.5	12.945	25.743	39.420	1.00000	475.8	-0.4%	1.0000	1.3554	1.4523	1.6613	100.0%	557.0	589.2	617.0	0.742	0.700	0.658	875.2	1112.9	11
29	352.7	13.488	26.286	39.999	1.00000	425.4	0.4%	1.0000	1.3518	1.4487	1.6354	100.0%	557.0	589.1	617.0	0.742	0.701	0.658	875.2	1111.0	12
30	366.4	14.012	26.809	40.556	1.00000	373.8	-0.5%	1.0000	1.3478	1.4436	1.6447	100.0%	557.0	589.4	617.1	0.742	0.700	0.658	875.4	1119.7	15
31	380.7	14.559	27.356	41.138	1.00000	320.6	-0.6%	1.0000	1.3435	1.4379	1.6379	100.0%	557.0	589.4	617.1	0.742	0.700	0.658	875.4	1116.5	10
32	394.5	15.086	27.883	41.699	1.00000	269.8	-0.6%	1.0000	1.3400	1.4337	1.6283	100.0%	557.0	589.4	617.2	0.742	0.700	0.658	875.3	1112.1	11
33	408.5	15.622	28.418	42.268	1.00000	218.7	-0.6%	1.0000	1.3363	1.4287	1.6179	100.0%	557.0	589.3	617.1	0.742	0.700	0.658	875.0	1108.4	11
34	422.6	16.161	28.957	42.841	1.00000	166.7	-0.7%	1.0000	1.3323	1.4231	1.6126	100.0%	557.0	589.3	617.1	0.742	0.700	0.658	874.8	1104.0	11
35	436.7	16.700	29.495	43.413	1.00000	114.8	-0.8%	1.0000	1.3288	1.4184	1.6087	100.0%	557.0	589.4	617.1	0.742	0.700	0.658	874.4	1100.8	13
36	450.6	17.232	30.027	43.977	1.00000	63.9	-0.9%	1.0000	1.3249	1.4129	1.6063	100.0%	557.0	589.4	617.2	0.742	0.700	0.658	874.0	1098.1	12
37	464.1	17.748	30.542	44.524	1.00000	15.4	-0.8%	1.0000	1.3215	1.4082	1.5994	100.0%	557.0	589.4	617.2	0.742	0.700	0.658	873.6	1095.0	11
38	474.4	18.142	30.936	44.941	0.99837	0.0	0.5%	1.0000	1.3194	1.4056	1.5652	100.0%	557.0	589.1	617.2	0.742	0.701	0.658	873.2	1104.7	12
39	491.3	18.788	31.582	45.625	0.99847	0.0	4.2%	1.0000	1.3194	1.4095	1.6409	85.9%	557.0	584.2	609.4	0.742	0.708	0.671	818.5	1036.8	12
40	505.3	19.324	32.117	46.190	0.99830	0.0	7.4%	1.0000	1.3190	1.4116	1.7178	75.8%	557.0	580.5	603.8	0.742	0.713	0.680	781.4	987.2	10

WBN1 Cycle 4

#	EFPD	Ecyc	Ecore	Emax	k-eff	Boron	AO	Pavg	Fassy	FdH	Fq	Power	Tin(F)	Tavg(F)	Tout(F)	pin	pavg	pout	Tf(K)	Tfmx(K)	Outrs
1	0.0	0.000	14.917	36.580	1.00000	1735.7	32.4%	1.0000	1.3130	1.4587	2.3585	0.0%	557.7	557.7	557.7	0.741	0.741	0.741	565.2	565.2	11
2	2.6	0.099	15.011	36.605	1.00000	1092.4	-1.6%	1.0000	1.2741	1.3882	1.7208	99.7%	557.7	590.0	617.3	0.741	0.699	0.657	892.7	1121.2	14
3	9.0	0.345	15.257	36.671	1.00000	1093.3	-1.3%	1.0000	1.2784	1.3831	1.7098	100.0%	557.7	590.1	617.5	0.741	0.699	0.657	892.5	1112.1	7
4	22.6	0.867	15.779	36.823	1.00000	1106.1	-1.3%	1.0000	1.2859	1.3810	1.7396	100.0%	557.7	590.1	617.5	0.741	0.699	0.657	889.2	1101.4	9
5	36.9	1.417	16.328	37.009	1.00000	1131.5	-1.4%	1.0000	1.2942	1.3883	1.7704	100.0%	557.7	590.0	617.5	0.741	0.699	0.657	885.7	1095.1	12
6	50.6	1.941	16.852	37.186	1.00000	1151.0	-1.5%	1.0000	1.3076	1.3962	1.7882	100.0%	557.7	590.0	617.5	0.741	0.699	0.657	883.3	1095.0	10
7	65.0	2.494	17.405	37.404	1.00000	1162.2	-1.6%	1.0000	1.3230	1.4010	1.7941	100.0%	557.7	590.0	617.5	0.741	0.699	0.657	882.4	1093.1	8
8	78.6	3.015	17.926	37.627	1.00000	1165.9	-1.7%	1.0000	1.3341	1.4101	1.7901	100.0%	557.7	590.0	617.5	0.741	0.699	0.657	882.0	1094.8	9
9	93.0	3.570	18.480	37.865	1.00000	1161.9	-1.8%	1.0000	1.3426	1.4196	1.7903	100.0%	557.7	590.0	617.5	0.741	0.699	0.657	881.6	1097.1	10
10	105.5	4.047	18.957	38.090	1.00000	1153.7	-1.8%	1.0000	1.3469	1.4242	1.7870	100.0%	557.7	590.0	617.5	0.741	0.699	0.657	881.4	1098.5	9
11	121.1	4.647	19.557	38.373	1.00000	1129.2	-2.3%	1.0000	1.3462	1.4230	1.7773	101.4%	557.7	590.6	618.2	0.741	0.698	0.655	885.8	1102.5	10
12	134.9	5.175	20.084	38.623	1.00000	1109.8	-2.4%	1.0000	1.3479	1.4247	1.7687	101.4%	557.7	590.6	618.2	0.741	0.698	0.655	885.5	1099.1	9
13	149.5	5.736	20.645	38.890	1.00000	1084.9	-2.1%	1.0000	1.3487	1.4268	1.7497	101.4%	557.7	590.6	618.2	0.741	0.698	0.655	884.8	1093.9	11
14	163.2	6.264	21.172	39.142	1.00000	1058.3	-2.3%	1.0000	1.3509	1.4322	1.7398	101.4%	557.7	590.6	618.2	0.741	0.698	0.656	884.1	1089.5	9
15	177.8	6.824	21.732	39.410	1.00000	1026.0	-2.3%	1.0000	1.3597	1.4415	1.7312	101.4%	557.7	590.6	618.2	0.741	0.698	0.656	883.3	1087.1	10
16	191.6	7.352	22.260	39.664	1.00000	993.5	-2.4%	1.0000	1.3673	1.4512	1.7218	101.4%	557.7	590.6	618.2	0.741	0.698	0.655	882.5	1084.7	9
17	206.3	7.917	22.824	39.937	1.00000	955.2	-2.1%	1.0000	1.3696	1.4545	1.7130	101.4%	557.7	590.6	618.2	0.741	0.698	0.655	881.7	1083.4	9
18	220.0	8.442	23.349	40.192	1.00000	918.4	-1.9%	1.0000	1.3752	1.4612	1.7122	101.4%	557.7	590.6	618.2	0.741	0.698	0.655	881.3	1086.9	14
19	234.6	9.001	23.907	40.466	1.00000	875.8	-2.0%	1.0000	1.3802	1.4672	1.7188	101.4%	557.7	590.6	618.2	0.741	0.698	0.655	881.0	1091.4	9
20	248.3	9.528	24.434	40.725	1.00000	834.6	-1.8%	1.0000	1.3818	1.4691	1.7196	101.4%	557.7	590.6	618.2	0.741	0.698	0.656	880.9	1096.2	15
21	262.9	10.089	24.994	41.003	1.00000	788.4	-1.8%	1.0000	1.3848	1.4723	1.7248	101.4%	557.7	590.6	618.3	0.741	0.698	0.655	880.8	1102.5	10
22	273.1	10.479	25.384	41.198	1.00000	756.9	-1.5%	1.0000	1.3857	1.4732	1.7197	101.4%	557.7	590.6	618.2	0.741	0.699	0.656	880.7	1105.2	11
23	279.6	10.729	25.634	41.323	1.00000	735.7	-1.5%	1.0000	1.3865	1.4738	1.7205	101.4%	557.7	590.6	618.2	0.741	0.699	0.656	880.7	1108.0	9
24	293.3	11.255	26.159	41.588	1.00000	689.9	-1.6%	1.0000	1.3870	1.4740	1.7201	101.4%	557.7	590.6	618.2	0.741	0.699	0.656	880.6	1115.3	11
25	307.9	11.815	26.719	41.873	1.00000	640.4	-1.2%	1.0000	1.3862	1.4727	1.7094	101.4%	557.7	590.5	618.2	0.741	0.699	0.656	880.6	1122.3	12
26	320.6	12.303	27.206	42.280	1.00000	597.0	-1.2%	1.0000	1.3855	1.4713	1.7049	101.4%	557.7	590.5	618.3	0.741	0.699	0.656	880.7	1129.2	12
27	334.1	12.818	27.721	42.881	1.00000	549.9	-1.3%	1.0000	1.3839	1.4689	1.7112	101.4%	557.7	590.5	618.3	0.741	0.699	0.656	880.7	1136.6	12
28	348.1	13.357	28.259	43.508	1.00000	499.9	-1.1%	1.0000	1.3819	1.4658	1.7092	101.4%	557.7	590.5	618.3	0.741	0.699	0.656	880.8	1140.8	11
29	362.4	13.905	28.807	44.145	1.00000	449.0	-0.5%	1.0000	1.3786	1.4614	1.6949	101.4%	557.7	590.5	618.4	0.741	0.699	0.656	880.9	1140.0	11
30	376.1	14.432	29.333	44.755	1.00000	398.9	-0.9%	1.0000	1.3764	1.4581	1.7019	101.4%	557.7	590.5	618.4	0.741	0.699	0.656	881.0	1146.0	14
31	390.7	14.993	29.894	45.404	1.00000	344.8	-1.0%	1.0000	1.3733	1.4538	1.7018	101.4%	557.7	590.6	618.4	0.741	0.699	0.656	881.0	1156.7	9
32	404.4	15.519	30.419	46.010	1.00000	295.8	-1.0%	1.0000	1.3701	1.4506	1.6968	101.4%	557.7	590.5	618.4	0.741	0.699	0.656	880.8	1153.3	12
33	419.1	16.082	30.982	46.657	1.00000	241.9	-1.0%	1.0000	1.3657	1.4458	1.6919	101.4%	557.7	590.5	618.4	0.741	0.699	0.656	880.5	1151.0	10
34	436.0	16.730	31.629	47.399	1.00000	180.9	-1.0%	1.0000	1.3617	1.4414	1.6831	101.4%	557.7	590.5	618.5	0.741	0.699	0.656	880.0	1146.6	11
35	445.6	17.097	31.996	47.818	1.00000	146.8	-1.0%	1.0000	1.3587	1.4379	1.6787	101.4%	557.7	590.5	618.5	0.741	0.699	0.656	879.8	1144.9	9
36	459.3	17.622	32.520	48.416	1.00000	97.1	-1.0%	1.0000	1.3551	1.4336	1.6708	101.4%	557.7	590.5	618.4	0.741	0.699	0.656	879.4	1140.6	11
37	473.9	18.183	33.081	49.054	1.00000	43.6	-1.0%	1.0000	1.3498	1.4272	1.6623	101.4%	557.7	590.5	618.4	0.741	0.699	0.656	879.0	1136.6	9
38	483.5	18.554	33.452	49.474	1.00000	9.3	-1.1%	1.0000	1.3465	1.4232	1.6579	101.4%	557.7	590.5	618.4	0.741	0.699	0.656	878.7	1134.2	9
39	493.2	18.923	33.820	49.891	0.99801	0.0	-0.9%	1.0000	1.3436	1.4196	1.6467	101.4%	557.7	590.5	618.5	0.741	0.699	0.656	878.4	1128.3	8

WBN1 Cycle 5

#	EFPD	Ecyc	Ecore	Emax	k-eff	Boron	AO	Pavg	Fassy	FdH	Fq	Power	Tin(F)	Tavg(F)	Tout(F)	pin	pavg	pout	Tf(K)	Tfmx(K)	Outrs
1	0.0	0.000	17.212	45.545	1.00000	1813.7	39.8%	1.0000	1.4529	1.5207	2.6528	0.0%	557.4	557.4	557.4	0.742	0.741	0.741	565.0	565.0	11
2	2.7	0.105	17.312	45.561	1.00000	1100.8	-2.3%	1.0000	1.3986	1.4663	1.7467	100.0%	557.4	590.3	617.5	0.742	0.699	0.655	902.9	1159.0	16
3	20.6	0.801	18.008	45.669	1.00000	1116.6	-2.3%	1.0000	1.4036	1.4664	1.7143	100.0%	557.4	590.4	617.5	0.742	0.698	0.655	899.4	1153.1	10
4	39.0	1.516	18.724	45.782	1.00000	1151.2	-2.1%	1.0000	1.3968	1.4585	1.7283	100.0%	557.4	590.4	617.5	0.742	0.698	0.655	895.1	1149.9	11
5	50.2	1.952	19.159	45.852	1.00000	1170.8	-2.2%	1.0000	1.3935	1.4534	1.7365	100.0%	557.4	590.5	617.6	0.742	0.698	0.655	893.3	1146.5	11
6	60.6	2.356	19.563	45.918	1.00000	1184.7	-2.1%	1.0000	1.3869	1.4457	1.7379	100.0%	557.4	590.5	617.6	0.742	0.698	0.655	892.4	1141.7	9
7	74.2	2.885	20.092	46.028	1.00000	1198.2	-1.9%	1.0000	1.3821	1.4387	1.7338	100.0%	557.4	590.3	617.7	0.742	0.699	0.655	891.6	1133.9	12
8	88.7	3.449	20.656	46.215	1.00000	1204.8	-1.9%	1.0000	1.3721	1.4271	1.7454	100.0%	557.4	590.3	617.7	0.742	0.699	0.655	890.9	1128.1	8
9	102.2	3.974	21.180	46.391	1.00000	1206.2	-1.9%	1.0000	1.3745	1.4270	1.7585	100.0%	557.4	590.3	617.7	0.742	0.699	0.655	890.3	1123.6	10
10	115.0	4.471	21.678	46.560	1.00000	1202.7	-1.9%	1.0000	1.3772	1.4351	1.7655	100.0%	557.4	590.3	617.7	0.742	0.699	0.655	889.8	1119.4	10
11	128.6	5.000	22.207	46.742	1.00000	1194.5	-1.9%	1.0000	1.3796	1.4426	1.7677	100.0%	557.4	590.3	617.6	0.742	0.699	0.655	889.3	1114.4	10
12	142.9	5.556	22.762	46.935	1.00000	1181.3	-1.9%	1.0000	1.3820	1.4486	1.7617	100.0%	557.4	590.3	617.7	0.742	0.699	0.655	888.7	1108.9	10
13	156.6	6.089	23.295	47.122	1.00000	1165.2	-1.9%	1.0000	1.3836	1.4545	1.7597	100.0%	557.4	590.3	617.7	0.742	0.699	0.655	887.8	1103.0	10
14	170.9	6.645	23.851	47.320	1.00000	1144.2	-1.9%	1.0000	1.3848	1.4596	1.7550	100.0%	557.4	590.3	617.7	0.742	0.699	0.655	886.9	1098.0	9
15	184.5	7.174	24.379	47.510	1.00000	1121.6	-2.0%	1.0000	1.3857	1.4636	1.7489	100.0%	557.4	590.3	617.7	0.742	0.699	0.655	885.9	1095.2	9
16	199.0	7.738	24.943	47.714	1.00000	1093.5	-1.8%	1.0000	1.3867	1.4662	1.7367	100.0%	557.4	590.3	617.7	0.742	0.699	0.655	885.0	1095.9	12
17	212.5	8.263	25.467	47.906	1.00000	1065.2	-1.8%	1.0000	1.3867	1.4685	1.7285	100.0%	557.4	590.3	617.7	0.742	0.699	0.655	884.2	1099.4	9
18	227.0	8.826	26.031	48.125	1.00000	1030.7	-1.7%	1.0000	1.3864	1.4696	1.7154	100.0%	557.4	590.3	617.7	0.742	0.699	0.655	883.8	1101.7	13
19	240.5	9.351	26.555	48.331	1.00000	997.1	-1.7%	1.0000	1.3855	1.4702	1.7121	100.0%	557.4	590.3	617.8	0.742	0.699	0.655	883.5	1103.3	10
20	254.8	9.907	27.111	48.552	1.00000	958.7	-1.6%	1.0000	1.3846	1.4699	1.7035	100.0%	557.4	590.3	617.8	0.742	0.699	0.655	883.3	1104.2	13
21	269.1	10.463	27.667	48.775	1.00000	918.7	-1.4%	1.0000	1.3864	1.4690	1.6981	100.0%	557.4	590.3	617.8	0.742	0.699	0.655	883.2	1106.3	11
22	282.5	10.984	28.187	48.986	1.00000	879.5	-1.5%	1.0000	1.3894	1.4673	1.7021	100.0%	557.4	590.3	617.8	0.742	0.699	0.655	883.0	1110.8	10
23	296.1	11.513	28.716	49.203	1.00000	838.1	-1.2%	1.0000	1.3911	1.4675	1.6990	100.0%	557.4	590.2	617.8	0.742	0.699	0.656	883.0	1114.6	13
24	310.4	12.069	29.272	49.433	1.00000	792.1	-1.3%	1.0000	1.3920	1.4672	1.7026	100.0%	557.4	590.2	617.8	0.742	0.699	0.656	883.0	1121.6	10
25	324.0	12.598	29.800	49.654	1.00000	747.8	-1.3%	1.0000	1.3921	1.4659	1.7023	100.0%	557.4	590.2	617.8	0.742	0.699	0.655	883.1	1129.2	10
26	338.3	13.154	30.356	49.890	1.00000	699.9	-1.1%	1.0000	1.3916	1.4641	1.6942	100.0%	557.4	590.2	617.9	0.742	0.699	0.656	883.2	1135.4	13
27	349.7	13.597	30.799	50.079	1.00000	661.1	-1.0%	1.0000	1.3907	1.4620	1.6890	100.0%	557.4	590.2	617.8	0.742	0.699	0.656	883.3	1140.9	11
28	360.1	14.002	31.203	50.253	1.00000	624.8	-1.0%	1.0000	1.3891	1.4591	1.6855	100.0%	557.4	590.2	617.8	0.742	0.699	0.656	883.4	1146.1	11
29	373.6	14.526	31.727	50.482	1.00000	578.5	-0.2%	1.0000	1.3874	1.4562	1.6624	100.0%	557.4	590.1	617.9	0.742	0.699	0.656	883.3	1139.9	13
30	388.0	15.086	32.287	50.728	1.00000	525.2	-1.0%	1.0000	1.3845	1.4517	1.6831	100.0%	557.4	590.3	617.9	0.742	0.699	0.656	883.3	1144.1	16
31	401.6	15.615	32.815	50.963	1.00000	475.9	-1.1%	1.0000	1.3808	1.4463	1.6837	100.0%	557.4	590.3	618.0	0.742	0.699	0.656	883.1	1146.5	10
32	415.9	16.171	33.371	51.214	1.00000	424.6	-0.8%	1.0000	1.3780	1.4422	1.6758	100.0%	557.4	590.1	617.9	0.742	0.699	0.656	882.7	1142.9	11
33	427.5	16.622	33.822	51.418	1.00000	382.2	-0.8%	1.0000	1.3744	1.4371	1.6732	100.0%	557.4	590.1	617.9	0.742	0.699	0.656	882.4	1141.8	12
34	438.7	17.058	34.257	51.618	1.00000	340.3	-0.9%	1.0000	1.3716	1.4333	1.6714	100.0%	557.4	590.2	618.0	0.742	0.699	0.656	882.1	1140.6	10
35	455.4	17.707	34.906	51.919	1.00000	277.7	-1.0%	1.0000	1.3652	1.4247	1.6689	100.0%	557.4	590.2	618.0	0.742	0.699	0.656	881.6	1138.9	10
36	471.8	18.345	35.543	52.219	1.00000	217.5	-0.8%	1.0000	1.3607	1.4187	1.6625	100.0%	557.4	590.2	618.0	0.742	0.699	0.656	881.0	1136.2	13
37	485.4	18.874	36.071	52.470	1.00000	167.2	-0.9%	1.0000	1.3554	1.4136	1.6601	100.0%	557.4	590.2	618.0	0.742	0.699	0.656	880.6	1134.8	10
38	499.7	19.430	36.627	52.743	1.00000	113.7	-0.9%	1.0000	1.3504	1.4111	1.6573	100.0%	557.4	590.2	618.0	0.742	0.699	0.656	880.1	1133.6	14
39	516.3	20.075	37.272	53.073	1.00000	51.8	-0.9%	1.0000	1.3456	1.4074	1.6521	100.0%	557.4	590.2	618.1	0.742	0.699	0.656	879.6	1131.3	12

WBN1 Cycle 6

#	EFPD	Ecyc	Ecore	Emax	k-eff	Boron	AO	Pavg	Fassy	FdH	Fq	Power	Tin(F)	Tavg(F)	Tout(F)	pin	pavg	pout	Tf(K)	Tfmx(K)	Outrs
1	0.0	0.000	18.518	49.659	1.00000	1847.0	36.7%	1.0000	1.3882	1.4867	2.4805	0.0%	557.3	557.3	557.3	0.742	0.742	0.741	565.0	565.0	11
2	3.1	0.121	18.633	49.678	1.00000	1148.6	-2.7%	1.0000	1.3086	1.4366	1.6852	100.0%	557.3	590.3	617.8	0.742	0.699	0.656	901.6	1123.2	15
3	11.9	0.463	18.976	49.733	1.00000	1151.8	-2.6%	1.0000	1.3024	1.4248	1.6747	100.0%	557.3	590.3	617.8	0.742	0.699	0.656	900.4	1124.9	7
4	21.4	0.833	19.346	49.792	1.00000	1158.4	-2.5%	1.0000	1.3016	1.4217	1.6789	100.0%	557.3	590.3	617.7	0.742	0.699	0.656	898.8	1133.0	9
5	34.9	1.358	19.871	49.876	1.00000	1176.1	-2.6%	1.0000	1.3011	1.4196	1.6912	100.0%	557.3	590.4	617.8	0.742	0.699	0.656	896.5	1147.0	8
6	48.4	1.884	20.397	49.960	1.00000	1191.7	-2.5%	1.0000	1.2993	1.4143	1.6918	100.0%	557.3	590.4	617.8	0.742	0.699	0.656	894.2	1156.7	9
7	62.9	2.448	20.961	50.050	1.00000	1200.8	-2.3%	1.0000	1.2962	1.4071	1.6850	100.0%	557.3	590.4	617.9	0.742	0.699	0.656	893.2	1160.2	9
8	76.4	2.974	21.487	50.132	1.00000	1204.5	-2.1%	1.0000	1.2926	1.4005	1.6746	100.0%	557.3	590.3	617.8	0.742	0.699	0.656	892.7	1154.9	9
9	89.3	3.476	21.989	50.211	1.00000	1201.2	-2.0%	1.0000	1.2889	1.3929	1.6618	100.0%	557.3	590.3	617.8	0.742	0.699	0.656	892.3	1148.6	10
10	101.9	3.966	22.479	50.288	1.00000	1193.4	-1.9%	1.0000	1.2875	1.3852	1.6470	100.0%	557.3	590.3	617.8	0.742	0.699	0.656	891.9	1141.5	8
11	116.3	4.527	23.040	50.376	1.00000	1179.0	-1.8%	1.0000	1.3028	1.3772	1.6429	100.0%	557.3	590.3	617.8	0.742	0.699	0.656	891.6	1132.5	10
12	130.0	5.060	23.573	50.477	1.00000	1161.6	-1.7%	1.0000	1.3159	1.3884	1.6432	100.0%	557.3	590.3	617.8	0.742	0.699	0.656	891.3	1124.0	10
13	144.3	5.617	24.129	50.600	1.00000	1139.3	-1.5%	1.0000	1.3237	1.3987	1.6485	100.0%	557.3	590.2	617.8	0.742	0.699	0.656	890.8	1117.7	11
14	158.0	6.150	24.662	50.719	1.00000	1114.4	-1.5%	1.0000	1.3347	1.4130	1.6591	100.0%	557.3	590.2	617.8	0.742	0.699	0.656	890.1	1112.9	9
15	172.2	6.702	25.215	50.843	1.00000	1084.8	-1.5%	1.0000	1.3446	1.4264	1.6675	100.0%	557.3	590.2	617.8	0.742	0.699	0.656	889.2	1107.2	9
16	186.0	7.240	25.751	50.965	1.00000	1053.7	-1.5%	1.0000	1.3527	1.4372	1.6726	100.0%	557.3	590.2	617.8	0.742	0.699	0.656	888.3	1101.1	10
17	196.2	7.637	26.148	51.055	1.00000	1029.0	-1.4%	1.0000	1.3548	1.4397	1.6688	100.0%	557.3	590.2	617.8	0.742	0.699	0.656	887.7	1096.9	10
18	207.1	8.061	26.572	51.152	1.00000	1000.9	-1.4%	1.0000	1.3597	1.4461	1.6718	100.0%	557.3	590.2	617.8	0.742	0.699	0.656	886.9	1092.3	10
19	224.1	8.723	27.234	51.304	1.00000	954.5	-1.2%	1.0000	1.3649	1.4527	1.6705	100.0%	557.3	590.1	617.8	0.742	0.699	0.656	885.8	1087.0	12
20	242.1	9.423	27.934	51.467	1.00000	901.7	-1.2%	1.0000	1.3691	1.4578	1.6731	100.0%	557.3	590.1	617.8	0.742	0.699	0.656	884.9	1083.3	11
21	256.1	9.968	28.478	51.595	1.00000	858.6	-1.3%	1.0000	1.3708	1.4598	1.6747	100.0%	557.3	590.1	617.8	0.742	0.699	0.656	884.4	1085.3	11
22	270.2	10.517	29.027	51.725	1.00000	813.5	-1.1%	1.0000	1.3715	1.4601	1.6712	100.0%	557.3	590.2	617.8	0.742	0.699	0.656	883.9	1088.5	13
23	284.1	11.058	29.568	51.862	1.00000	767.7	-1.2%	1.0000	1.3711	1.4593	1.6710	100.0%	557.3	590.2	617.9	0.742	0.699	0.656	883.5	1092.2	11
24	298.3	11.611	30.120	52.177	1.00000	720.0	-1.0%	1.0000	1.3703	1.4577	1.6645	100.0%	557.3	590.1	617.9	0.742	0.699	0.656	883.0	1096.2	13
25	312.1	12.148	30.657	52.486	1.00000	672.4	-1.0%	1.0000	1.3687	1.4552	1.6579	100.0%	557.3	590.1	617.9	0.742	0.699	0.656	882.6	1101.9	10
26	326.2	12.697	31.205	52.803	1.00000	622.4	-0.9%	1.0000	1.3664	1.4518	1.6507	100.0%	557.3	590.1	617.9	0.742	0.699	0.656	882.3	1107.3	12
27	337.6	13.140	31.649	53.062	1.00000	581.8	-1.0%	1.0000	1.3634	1.4479	1.6457	100.0%	557.3	590.1	617.9	0.742	0.699	0.656	882.0	1111.8	11
28	349.3	13.596	32.104	53.329	1.00000	539.1	-0.9%	1.0000	1.3621	1.4455	1.6419	100.0%	557.3	590.1	617.9	0.742	0.699	0.656	881.9	1114.6	11
29	363.6	14.152	32.660	53.658	1.00000	485.9	-1.0%	1.0000	1.3571	1.4390	1.6413	100.0%	557.3	590.1	617.9	0.742	0.699	0.656	881.6	1118.3	10
30	377.9	14.709	33.216	53.990	1.00000	435.3	0.1%	1.0000	1.3538	1.4342	1.6129	100.0%	557.3	589.9	617.9	0.742	0.700	0.656	881.2	1117.8	12
31	391.6	15.242	33.749	54.310	1.00000	382.8	-0.9%	1.0000	1.3495	1.4291	1.6302	100.0%	557.3	590.1	618.0	0.742	0.699	0.656	881.1	1120.1	14
32	405.9	15.799	34.305	54.647	1.00000	328.6	-1.0%	1.0000	1.3445	1.4234	1.6261	100.0%	557.3	590.1	618.0	0.742	0.699	0.656	880.7	1118.8	14
33	419.6	16.332	34.838	54.972	1.00000	277.2	-0.9%	1.0000	1.3396	1.4177	1.6200	100.0%	557.3	590.1	618.0	0.742	0.699	0.656	880.3	1115.9	10
34	433.9	16.888	35.394	55.314	1.00000	223.2	-1.0%	1.0000	1.3350	1.4123	1.6152	100.0%	557.3	590.1	618.0	0.742	0.699	0.656	879.9	1113.5	13
35	447.4	17.414	35.919	55.640	1.00000	172.7	-1.1%	1.0000	1.3310	1.4076	1.6135	100.0%	557.3	590.1	618.0	0.742	0.699	0.656	879.4	1112.8	16
36	461.9	17.978	36.483	55.992	1.00000	117.6	-1.1%	1.0000	1.3247	1.4026	1.6079	100.0%	557.3	590.1	618.1	0.742	0.699	0.656	878.9	1110.0	11
37	482.0	18.761	37.265	56.486	1.00000	42.5	-1.0%	1.0000	1.3206	1.3969	1.5965	100.0%	557.3	590.1	618.1	0.742	0.699	0.656	878.2	1104.7	13

WBN1 Cycle 7

#	EFPD	Ecyc	Ecore	Emax	k-eff	Boron	AO	Pavg	Fassy	FdH	Fq	Power	Tin(F)	Tavg(F)	Tout(F)	pin	pavg	pout	Tf(K)	Tfmx(K)	Outs
1	0.0	0.000	17.237	51.416	1.00000	1749.7	32.4%	1.0000	1.4061	1.4863	2.3409	0.0%	556.4	556.4	556.4	0.743	0.743	0.742	564.5	564.5	10
2	2.8	0.109	17.341	51.442	1.00000	1084.2	-4.3%	1.0000	1.3346	1.4168	1.7392	100.0%	556.4	589.8	617.1	0.743	0.700	0.657	900.8	1151.7	15
3	17.0	0.662	17.894	51.584	1.00000	1096.6	-4.2%	1.0000	1.3231	1.4054	1.7337	100.0%	556.4	589.8	617.1	0.743	0.700	0.657	898.4	1148.5	8
4	30.4	1.184	18.416	51.718	1.00000	1121.7	-4.4%	1.0000	1.3052	1.4046	1.7587	100.0%	556.4	589.9	617.2	0.743	0.699	0.657	895.7	1154.0	9
5	45.0	1.752	18.984	51.865	1.00000	1147.2	-4.3%	1.0000	1.3128	1.4038	1.7707	100.0%	556.4	589.9	617.2	0.743	0.699	0.657	892.6	1156.8	10
6	59.2	2.306	19.537	52.008	1.00000	1163.8	-4.1%	1.0000	1.3217	1.4100	1.7749	100.0%	556.4	589.9	617.2	0.743	0.699	0.657	891.1	1155.5	9
7	73.0	2.843	20.074	52.147	1.00000	1172.8	-3.8%	1.0000	1.3296	1.4160	1.7675	100.0%	556.4	589.7	617.2	0.743	0.700	0.657	890.5	1148.7	10
8	87.4	3.404	20.634	52.293	1.00000	1173.0	-3.6%	1.0000	1.3361	1.4204	1.7760	100.0%	556.4	589.7	617.2	0.743	0.700	0.657	890.0	1140.2	10
9	100.9	3.929	21.160	52.435	1.00000	1167.3	-3.4%	1.0000	1.3409	1.4241	1.7825	100.0%	556.4	589.7	617.2	0.743	0.700	0.657	889.5	1130.0	10
10	115.3	4.490	21.720	52.597	1.00000	1155.1	-3.0%	1.0000	1.3447	1.4277	1.7774	100.0%	556.4	589.6	617.2	0.743	0.700	0.657	889.2	1117.6	13
11	131.9	5.137	22.366	52.783	1.00000	1134.0	-2.7%	1.0000	1.3481	1.4313	1.7668	100.0%	556.4	589.6	617.2	0.743	0.700	0.657	888.7	1106.8	10
12	149.0	5.803	23.032	52.978	1.00000	1106.5	-2.2%	1.0000	1.3502	1.4332	1.7466	100.0%	556.4	589.5	617.2	0.743	0.700	0.657	888.0	1095.1	12
13	169.8	6.613	23.841	53.216	1.00000	1064.8	-1.9%	1.0000	1.3512	1.4338	1.7195	100.0%	556.4	589.5	617.2	0.743	0.700	0.657	886.9	1085.7	10
14	183.4	7.142	24.371	53.374	1.00000	1034.3	-1.8%	1.0000	1.3511	1.4334	1.7031	100.0%	556.4	589.5	617.3	0.743	0.700	0.657	886.0	1080.2	10
15	196.6	7.656	24.884	53.528	1.00000	1003.0	-1.3%	1.0000	1.3503	1.4321	1.6828	100.0%	556.4	589.3	617.2	0.743	0.700	0.657	885.1	1077.5	11
16	210.3	8.190	25.418	53.689	1.00000	966.7	-1.2%	1.0000	1.3491	1.4307	1.6675	100.0%	556.4	589.3	617.2	0.743	0.700	0.657	884.3	1076.6	11
17	224.5	8.743	25.970	53.857	1.00000	926.6	-1.1%	1.0000	1.3474	1.4298	1.6562	100.0%	556.4	589.3	617.2	0.743	0.700	0.657	883.6	1078.2	10
18	238.4	9.284	26.511	54.023	1.00000	886.0	-0.8%	1.0000	1.3458	1.4287	1.6510	100.0%	556.4	589.3	617.2	0.743	0.700	0.657	883.0	1079.9	13
19	252.6	9.837	27.064	54.245	1.00000	842.3	-0.7%	1.0000	1.3435	1.4266	1.6542	100.0%	556.4	589.3	617.3	0.743	0.700	0.657	882.5	1081.6	11
20	266.3	10.371	27.597	54.538	1.00000	799.7	-0.4%	1.0000	1.3412	1.4243	1.6494	100.0%	556.4	589.2	617.2	0.743	0.701	0.657	882.0	1084.2	11
21	280.5	10.924	28.149	54.842	1.00000	752.8	-0.5%	1.0000	1.3383	1.4212	1.6531	100.0%	556.4	589.2	617.2	0.743	0.700	0.657	881.6	1084.7	10
22	294.3	11.461	28.687	55.139	1.00000	706.5	-0.5%	1.0000	1.3355	1.4179	1.6540	100.0%	556.4	589.2	617.2	0.743	0.700	0.657	881.2	1088.9	10
23	308.3	12.007	29.231	55.441	1.00000	658.2	-0.4%	1.0000	1.3330	1.4169	1.6486	100.0%	556.4	589.2	617.3	0.743	0.700	0.657	880.9	1094.6	15
24	324.2	12.626	29.850	55.785	1.00000	602.7	-0.3%	1.0000	1.3295	1.4172	1.6430	100.0%	556.4	589.2	617.3	0.743	0.701	0.657	880.6	1101.6	13
25	340.9	13.276	30.500	56.148	1.00000	542.9	-0.4%	1.0000	1.3274	1.4164	1.6408	100.0%	556.4	589.2	617.3	0.743	0.701	0.657	880.3	1109.4	11
26	358.5	13.962	31.185	56.533	1.00000	479.2	-0.4%	1.0000	1.3282	1.4140	1.6428	100.0%	556.4	589.2	617.3	0.743	0.701	0.657	880.0	1115.0	14
27	371.4	14.464	31.687	56.816	1.00000	432.4	-0.5%	1.0000	1.3286	1.4120	1.6453	100.0%	556.4	589.2	617.3	0.743	0.701	0.657	879.8	1119.5	11
28	384.7	14.982	32.205	57.109	1.00000	385.5	0.6%	1.0000	1.3284	1.4096	1.6185	100.0%	556.4	589.0	617.3	0.743	0.701	0.657	879.5	1110.6	13
29	398.3	15.512	32.734	57.411	1.00000	333.0	-0.5%	1.0000	1.3275	1.4064	1.6428	100.0%	556.4	589.3	617.4	0.743	0.700	0.657	879.4	1125.9	15
30	412.9	16.080	33.302	57.736	1.00000	278.4	-0.5%	1.0000	1.3264	1.4031	1.6378	100.0%	556.4	589.3	617.4	0.743	0.701	0.657	879.0	1123.7	12
31	428.8	16.699	33.921	58.093	1.00000	203.4	-4.2%	1.0000	1.3224	1.4055	1.7022	100.0%	556.4	590.1	617.4	0.743	0.699	0.657	879.8	1155.6	13
32	436.9	17.015	34.236	58.277	1.00000	176.2	-3.4%	1.0000	1.3217	1.4025	1.6824	100.0%	556.4	589.9	617.4	0.743	0.700	0.657	879.3	1145.8	11
33	448.4	17.463	34.684	58.539	1.00000	133.6	-3.1%	1.0000	1.3199	1.3992	1.6721	100.0%	556.4	589.8	617.4	0.743	0.700	0.657	878.9	1140.9	12
34	459.8	17.907	35.127	58.799	1.00000	92.6	-2.5%	1.0000	1.3180	1.3950	1.6572	100.0%	556.4	589.7	617.4	0.743	0.700	0.657	878.4	1133.5	12
35	475.2	18.506	35.727	59.152	1.00000	39.5	-1.3%	1.0000	1.3155	1.3893	1.6279	100.0%	556.4	589.4	617.4	0.743	0.700	0.658	877.5	1119.2	11
36	490.1	19.087	36.306	59.496	0.99904	0.0	-0.5%	1.0000	1.3133	1.3851	1.6047	100.0%	556.4	589.3	617.5	0.743	0.701	0.657	876.9	1108.1	10

WBN1 Cycle 8

#	EFPD	Ecyc	Ecore	Emax	k-eff	Boron	AO	Pavg	Fassy	FdH	Fq	Power	Tin(F)	Tavg(F)	Tout(F)	pin	pavg	pout	Tf(K)	Tfmx(K)	Outrs
1	0.0	0.000	18.534	48.402	1.00000	1790.4	16.2%	1.0000	1.3807	1.4903	2.3109	0.0%	554.4	554.4	554.4	0.745	0.745	0.745	563.4	563.4	10
2	1.9	0.074	18.603	48.419	1.00000	1253.4	-2.9%	1.0000	1.3324	1.4223	1.8470	74.1%	554.1	579.2	600.6	0.745	0.714	0.684	806.8	1036.7	13
3	11.0	0.428	18.957	48.505	1.00001	1159.4	-1.8%	1.0000	1.3357	1.4031	1.7426	100.0%	556.4	589.3	617.0	0.743	0.700	0.657	897.4	1178.5	10
4	15.6	0.607	19.136	48.549	1.00000	1159.7	-1.0%	1.0000	1.3394	1.3980	1.7316	100.0%	556.4	589.3	617.0	0.743	0.700	0.657	896.3	1170.0	8
5	26.5	1.031	19.560	48.654	1.00000	1163.4	-0.5%	1.0000	1.3483	1.4039	1.7326	100.0%	556.4	589.1	617.1	0.743	0.700	0.657	893.9	1161.3	11
6	36.5	1.420	19.949	48.751	1.00000	1167.0	-0.3%	1.0000	1.3555	1.4125	1.7326	100.0%	557.0	589.7	617.5	0.742	0.700	0.656	891.9	1153.4	9
7	51.5	2.004	20.533	48.900	1.00000	1167.8	-0.4%	1.0000	1.3647	1.4230	1.7278	100.0%	557.0	589.7	617.5	0.742	0.700	0.656	889.5	1142.2	10
8	65.7	2.557	21.085	49.073	1.00000	1160.7	-0.5%	1.0000	1.3717	1.4334	1.7370	100.0%	557.0	589.7	617.5	0.742	0.700	0.656	888.8	1130.3	9
9	78.4	3.051	21.579	49.310	1.00000	1148.5	-0.6%	1.0000	1.3766	1.4427	1.7404	100.0%	557.0	589.7	617.5	0.742	0.700	0.656	888.3	1120.1	10
10	91.5	3.561	22.088	49.555	1.00000	1130.1	-0.6%	1.0000	1.3812	1.4496	1.7351	100.0%	557.0	589.6	617.5	0.742	0.700	0.656	888.0	1110.8	9
11	105.4	4.102	22.629	49.817	1.00000	1104.8	-0.8%	1.0000	1.3836	1.4555	1.7270	100.0%	557.0	589.6	617.5	0.742	0.700	0.656	887.7	1099.2	9
12	119.5	4.650	23.177	50.085	1.00000	1073.9	-1.0%	1.0000	1.3856	1.4597	1.7204	100.0%	557.0	589.8	617.6	0.742	0.699	0.656	887.5	1098.9	11
13	133.4	5.191	23.718	50.351	1.00000	1040.3	-1.2%	1.0000	1.3859	1.4624	1.7135	100.0%	557.0	589.8	617.6	0.742	0.699	0.656	887.1	1096.2	10
14	147.5	5.740	24.266	50.622	1.00000	1002.5	-1.2%	1.0000	1.3860	1.4641	1.7044	100.0%	557.0	589.9	617.6	0.742	0.699	0.656	886.6	1093.3	12
15	161.4	6.281	24.806	50.892	1.00000	963.0	-1.2%	1.0000	1.3850	1.4645	1.6984	100.0%	557.0	589.8	617.6	0.742	0.699	0.656	885.8	1090.3	12
16	175.5	6.829	25.355	51.168	1.00000	923.8	-1.1%	1.0000	1.3831	1.4636	1.6966	100.0%	555.9	588.8	616.7	0.743	0.701	0.658	884.4	1087.4	10
17	189.4	7.370	25.895	51.441	1.00000	879.5	-1.3%	1.0000	1.3806	1.4627	1.6989	100.0%	555.9	588.8	616.7	0.743	0.701	0.658	883.5	1083.7	10
18	203.5	7.919	26.443	51.721	1.00000	832.1	-1.3%	1.0000	1.3786	1.4627	1.6979	100.0%	555.9	588.9	616.7	0.743	0.701	0.658	882.7	1081.9	11
19	217.0	8.444	26.968	51.991	1.00000	785.9	-1.5%	1.0000	1.3763	1.4609	1.7002	100.0%	555.9	588.9	616.7	0.743	0.701	0.658	882.1	1083.5	11
20	231.5	9.009	27.532	52.282	1.00000	733.8	-1.4%	1.0000	1.3749	1.4589	1.6970	100.0%	555.9	589.0	616.8	0.743	0.701	0.658	881.6	1085.7	11
21	245.3	9.546	28.069	52.562	1.00000	684.2	-1.4%	1.0000	1.3728	1.4563	1.6920	100.0%	555.9	588.9	616.8	0.743	0.701	0.658	881.2	1087.1	13
22	259.2	10.086	28.609	52.846	1.00000	633.2	-1.1%	1.0000	1.3704	1.4539	1.6812	100.0%	555.9	588.8	616.8	0.743	0.701	0.658	880.8	1090.7	11
23	272.9	10.620	29.142	53.127	1.00000	580.7	-1.3%	1.0000	1.3676	1.4508	1.6794	100.0%	555.9	588.9	616.8	0.743	0.701	0.658	880.6	1093.2	9
24	287.0	11.168	29.690	53.420	1.00000	526.7	-1.4%	1.0000	1.3643	1.4470	1.6745	100.0%	555.9	588.9	616.8	0.743	0.701	0.658	880.3	1098.1	10
25	300.8	11.705	30.227	53.831	1.00000	474.3	-1.4%	1.0000	1.3616	1.4436	1.6727	100.0%	555.9	588.9	616.8	0.743	0.701	0.658	880.1	1103.6	13
26	314.8	12.250	30.771	54.259	1.00000	420.6	-1.1%	1.0000	1.3582	1.4394	1.6656	100.0%	555.9	588.9	616.8	0.743	0.701	0.658	879.9	1106.5	11
27	328.7	12.791	31.312	54.686	1.00000	366.8	-1.3%	1.0000	1.3543	1.4346	1.6675	100.0%	555.9	588.9	616.8	0.743	0.701	0.658	879.8	1112.3	9
28	342.8	13.340	31.860	55.121	1.00000	312.1	-1.3%	1.0000	1.3515	1.4308	1.6651	100.0%	555.9	589.0	616.9	0.743	0.701	0.658	879.7	1116.1	12
29	356.5	13.873	32.393	55.544	1.00000	259.2	-1.4%	1.0000	1.3476	1.4256	1.6620	100.0%	555.9	589.0	616.9	0.743	0.701	0.658	879.6	1119.6	9
30	370.7	14.425	32.945	55.985	1.00000	204.3	-1.4%	1.0000	1.3443	1.4213	1.6569	100.0%	555.9	589.0	616.9	0.743	0.701	0.658	879.5	1125.0	11
31	384.6	14.966	33.485	56.418	1.00000	151.2	-1.1%	1.0000	1.3406	1.4163	1.6458	100.0%	555.9	588.9	616.9	0.743	0.701	0.658	879.3	1126.7	10
32	398.8	15.519	34.037	56.862	1.00000	96.6	-1.3%	1.0000	1.3366	1.4108	1.6433	100.0%	555.9	588.9	616.9	0.743	0.701	0.658	879.0	1126.3	9
33	415.5	16.169	34.687	57.386	1.00000	32.7	-1.3%	1.0000	1.3339	1.4056	1.6369	100.0%	555.9	589.0	617.0	0.743	0.701	0.658	878.6	1123.0	12
34	432.3	16.822	35.340	57.915	0.99766	0.0	-1.1%	1.0000	1.3313	1.4004	1.6216	100.0%	555.9	588.8	616.9	0.743	0.701	0.658	878.1	1115.7	10

WBN1 Cycle 9

#	EFPD	Ecyc	Ecore	Emax	k-eff	Boron	AO	Pavg	Fassy	FdH	Fq	Power	Tin(F)	Tavg(F)	Tout(F)	pin	pavg	pout	Tf(K)	Tfmx(K)	Outrs
1	0.0	0.000	13.985	46.306	1.00000	1652.5	24.7%	1.0000	1.3032	1.4948	2.3002	0.0%	555.9	555.9	555.9	0.743	0.743	0.743	564.2	564.2	10
2	5.2	0.204	14.184	46.364	1.00000	982.7	-7.2%	1.0000	1.2757	1.4618	1.8756	100.0%	555.9	589.9	616.9	0.743	0.700	0.658	901.1	1157.1	17
3	19.1	0.745	14.725	46.523	1.00000	1006.6	-6.4%	1.0000	1.2751	1.4442	1.8563	100.0%	556.5	590.3	617.5	0.743	0.699	0.657	898.6	1151.6	10
4	33.2	1.292	15.272	46.683	1.00000	1041.3	-6.6%	1.0000	1.2785	1.4369	1.8690	100.0%	556.5	590.3	617.5	0.743	0.699	0.657	895.4	1162.6	10
5	45.2	1.758	15.738	46.819	1.00000	1070.6	-6.8%	1.0000	1.2793	1.4303	1.8736	100.0%	556.5	590.3	617.5	0.743	0.699	0.657	892.9	1165.0	9
6	57.7	2.245	16.225	46.961	1.00000	1093.9	-6.6%	1.0000	1.2756	1.4199	1.8624	100.0%	556.5	590.3	617.5	0.743	0.699	0.657	891.8	1162.6	7
7	67.9	2.640	16.619	47.076	1.00000	1108.0	-6.4%	1.0000	1.2713	1.4109	1.8486	100.0%	556.5	590.3	617.5	0.743	0.699	0.657	891.4	1159.2	9
8	78.9	3.070	17.049	47.201	1.00000	1118.7	-6.2%	1.0000	1.2734	1.4091	1.8439	100.0%	556.5	590.3	617.4	0.743	0.699	0.657	891.1	1154.3	9
9	92.9	3.614	17.593	47.360	1.00000	1126.3	-5.8%	1.0000	1.2772	1.4129	1.8507	100.0%	556.5	590.1	617.4	0.743	0.699	0.657	890.8	1147.6	9
10	106.9	4.158	18.137	47.518	1.00000	1127.3	-5.5%	1.0000	1.2824	1.4183	1.8514	100.0%	556.5	590.1	617.4	0.743	0.699	0.657	890.6	1139.3	9
11	119.4	4.645	18.624	47.671	1.00000	1124.4	-5.0%	1.0000	1.2845	1.4202	1.8439	100.0%	556.5	590.0	617.4	0.743	0.699	0.657	890.3	1131.6	8
12	132.0	5.136	19.114	47.830	1.00000	1116.5	-4.7%	1.0000	1.2857	1.4234	1.8321	100.0%	556.5	590.0	617.4	0.743	0.699	0.657	890.1	1123.1	9
13	142.1	5.527	19.505	47.956	1.00000	1108.1	-4.2%	1.0000	1.2854	1.4249	1.8176	100.0%	556.5	589.9	617.4	0.743	0.699	0.657	889.7	1115.9	10
14	152.9	5.947	19.925	48.092	1.00000	1096.1	-4.0%	1.0000	1.2854	1.4253	1.8022	100.0%	556.5	589.9	617.4	0.743	0.699	0.657	889.2	1108.4	9
15	163.8	6.374	20.352	48.230	1.00000	1082.3	-3.5%	1.0000	1.2896	1.4252	1.7820	100.0%	556.5	589.8	617.4	0.743	0.700	0.657	888.5	1100.3	9
16	175.8	6.839	20.816	48.381	1.00000	1064.2	-3.2%	1.0000	1.2944	1.4233	1.7607	100.0%	556.5	589.8	617.4	0.743	0.700	0.657	887.8	1093.6	9
17	188.9	7.348	21.325	48.547	1.00000	1042.4	-2.7%	1.0000	1.2986	1.4213	1.7384	100.0%	556.5	589.6	617.4	0.743	0.700	0.657	886.8	1089.8	12
18	202.7	7.886	21.863	48.722	1.00000	1015.5	-2.3%	1.0000	1.3030	1.4170	1.7193	100.0%	556.5	589.6	617.4	0.743	0.700	0.657	886.0	1089.3	8
19	216.9	8.440	22.416	48.903	1.00000	985.8	-1.8%	1.0000	1.3065	1.4134	1.6997	100.0%	556.5	589.5	617.3	0.743	0.700	0.657	885.1	1089.1	14
20	230.9	8.983	22.959	49.080	1.00000	953.5	-1.5%	1.0000	1.3097	1.4111	1.6856	100.0%	556.5	589.5	617.4	0.743	0.700	0.657	884.6	1088.9	11
21	244.9	9.529	23.505	49.260	1.00000	919.5	-1.0%	1.0000	1.3121	1.4100	1.6680	100.0%	556.5	589.4	617.3	0.743	0.700	0.657	884.1	1086.7	12
22	259.8	10.106	24.081	49.450	1.00000	881.7	-0.3%	1.0000	1.3142	1.4089	1.6460	100.0%	556.5	589.2	617.4	0.743	0.700	0.657	883.6	1089.7	10
23	277.9	10.813	24.788	49.685	1.00000	830.3	-0.4%	1.0000	1.3161	1.4073	1.6416	100.0%	556.5	589.3	617.4	0.743	0.700	0.657	883.2	1088.8	13
24	296.9	11.552	25.526	49.932	1.00000	774.5	-0.0%	1.0000	1.3189	1.4052	1.6304	100.0%	556.5	589.2	617.3	0.743	0.700	0.657	882.7	1092.6	12
25	315.0	12.255	26.229	50.169	1.00000	718.6	0.0%	1.0000	1.3220	1.4024	1.6235	100.0%	556.5	589.2	617.4	0.743	0.700	0.657	882.4	1095.9	11
26	327.9	12.757	26.730	50.339	1.00000	678.4	0.4%	1.0000	1.3233	1.4008	1.6104	100.0%	556.5	589.2	617.4	0.743	0.701	0.657	882.2	1101.7	12
27	341.7	13.293	27.266	50.522	1.00000	632.9	0.3%	1.0000	1.3246	1.3983	1.6080	100.0%	556.5	589.2	617.3	0.743	0.701	0.657	882.0	1103.3	10
28	355.6	13.834	27.806	50.785	1.00000	586.1	0.2%	1.0000	1.3254	1.3956	1.6052	100.0%	556.5	589.2	617.4	0.743	0.701	0.657	881.9	1106.4	10
29	369.6	14.380	28.352	51.167	1.00000	538.2	0.4%	1.0000	1.3255	1.3935	1.6061	100.0%	556.5	589.2	617.4	0.743	0.701	0.657	881.8	1110.7	12
30	380.2	14.794	28.766	51.457	1.00000	501.6	0.4%	1.0000	1.3256	1.3913	1.6098	100.0%	556.5	589.2	617.4	0.743	0.701	0.657	881.6	1113.7	11
31	391.0	15.211	29.182	51.750	1.00000	464.6	0.5%	1.0000	1.3255	1.3895	1.6095	100.0%	556.5	589.1	617.4	0.743	0.701	0.657	881.4	1118.0	12
32	398.6	15.510	29.481	51.960	1.00000	437.4	0.4%	1.0000	1.3253	1.3879	1.6136	100.0%	556.5	589.1	617.4	0.743	0.701	0.657	881.3	1119.5	10
33	410.5	15.973	29.944	52.286	1.00000	395.1	0.4%	1.0000	1.3246	1.3860	1.6151	100.0%	556.5	589.1	617.4	0.743	0.701	0.657	881.0	1122.4	12
34	422.5	16.437	30.407	52.613	1.00000	352.4	0.3%	1.0000	1.3238	1.3852	1.6195	100.0%	556.5	589.1	617.4	0.743	0.701	0.657	880.7	1118.9	13
35	438.5	17.060	31.030	53.054	1.00000	293.8	0.3%	1.0000	1.3222	1.3833	1.6209	100.0%	556.5	589.2	617.4	0.743	0.701	0.657	880.3	1116.2	15
36	453.5	17.645	31.614	53.468	1.00000	239.0	0.1%	1.0000	1.3205	1.3815	1.6230	100.0%	556.5	589.2	617.5	0.743	0.701	0.657	879.8	1116.5	11
37	467.4	18.186	32.155	53.853	1.00000	189.0	0.1%	1.0000	1.3196	1.3795	1.6203	100.0%	556.5	589.2	617.5	0.743	0.701	0.657	879.3	1115.4	16
38	481.6	18.739	32.707	54.248	1.00000	137.0	0.1%	1.0000	1.3183	1.3770	1.6172	100.0%	556.5	589.2	617.5	0.743	0.701	0.657	878.9	1114.0	13
39	499.0	19.415	33.383	54.732	1.00000	73.2	-0.1%	1.0000	1.3162	1.3735	1.6151	100.0%	556.5	589.2	617.5	0.743	0.701	0.657	878.4	1113.0	14
40	515.8	20.068	34.035	55.201	1.00000	12.1	-0.1%	1.0000	1.3140	1.3699	1.6088	100.0%	556.5	589.2	617.5	0.743	0.701	0.657	877.8	1110.0	15

WBN1 Cycle 10

#	EFPD	Ecyc	Ecore	Emax	k-eff	Boron	AO	Pavg	Fassy	FdH	Fq	Power	Tin(F)	Tavg(F)	Tout(F)	pin	pavg	pout	Tf(K)	Tfmx(K)	Outrs
1	0.0	0.000	16.821	47.403	1.00000	1634.4	7.8%	1.0000	1.3793	1.5444	2.3146	0.0%	555.1	555.1	555.1	0.744	0.744	0.744	563.8	563.8	12
2	4.0	0.156	16.972	47.437	1.00000	995.0	-3.2%	1.0000	1.2766	1.4267	1.6641	100.0%	555.6	588.8	616.5	0.744	0.701	0.658	900.9	1152.0	16
3	11.2	0.436	17.252	47.500	1.00000	1002.8	-2.4%	1.0000	1.2801	1.4291	1.6565	100.0%	555.6	588.8	616.5	0.744	0.701	0.658	899.7	1149.4	9
4	18.6	0.724	17.540	47.565	1.00000	1008.5	-2.3%	1.0000	1.2876	1.4173	1.6457	100.0%	555.6	588.8	616.5	0.744	0.701	0.658	898.3	1144.8	8
5	32.2	1.253	18.069	47.685	1.00000	1029.4	-2.2%	1.0000	1.2972	1.3925	1.6537	100.0%	555.6	588.8	616.5	0.744	0.701	0.658	895.7	1136.7	10
6	46.5	1.809	18.626	47.813	1.00000	1051.9	-2.0%	1.0000	1.3048	1.3729	1.6700	100.0%	555.6	588.7	616.6	0.744	0.701	0.658	892.9	1130.1	10
7	60.0	2.335	19.151	47.934	1.00000	1065.9	-2.0%	1.0000	1.3115	1.3768	1.6754	100.0%	555.6	588.7	616.6	0.744	0.701	0.658	891.5	1123.1	10
8	74.4	2.895	19.711	48.064	1.00000	1072.9	-1.9%	1.0000	1.3171	1.3819	1.6812	100.0%	555.6	588.7	616.6	0.744	0.701	0.658	890.7	1118.3	8
9	87.8	3.416	20.232	48.187	1.00000	1074.1	-1.8%	1.0000	1.3216	1.3857	1.6924	100.0%	555.6	588.7	616.6	0.744	0.701	0.658	890.1	1113.0	10
10	100.9	3.926	20.742	48.308	1.00000	1069.9	-1.8%	1.0000	1.3253	1.3883	1.6957	100.0%	555.6	588.7	616.6	0.744	0.701	0.658	889.6	1107.3	10
11	114.5	4.455	21.271	48.518	1.00000	1060.5	-1.8%	1.0000	1.3281	1.3900	1.6948	100.0%	555.6	588.7	616.6	0.744	0.701	0.658	889.1	1100.8	10
12	128.9	5.015	21.831	48.746	1.00001	1045.9	-1.6%	1.0000	1.3321	1.3923	1.6837	100.0%	555.6	588.6	616.6	0.744	0.701	0.658	888.8	1094.4	8
13	142.5	5.545	22.360	48.963	1.00000	1028.1	-1.7%	1.0000	1.3331	1.3966	1.6844	100.0%	555.6	588.6	616.6	0.744	0.701	0.658	888.2	1089.8	10
14	156.6	6.093	22.908	49.188	1.00000	1005.1	-1.7%	1.0000	1.3333	1.3995	1.6842	100.0%	555.6	588.6	616.6	0.744	0.701	0.658	887.5	1084.6	9
15	172.4	6.708	23.523	49.441	1.00000	975.5	-1.5%	1.0000	1.3331	1.4017	1.6758	100.0%	555.6	588.6	616.6	0.744	0.701	0.658	886.6	1078.6	13
16	187.9	7.311	24.126	49.691	1.00000	942.8	-1.6%	1.0000	1.3317	1.4022	1.6810	100.0%	555.6	588.6	616.6	0.744	0.701	0.658	885.5	1074.1	9
17	203.4	7.914	24.729	49.941	1.00000	906.4	-1.5%	1.0000	1.3300	1.4018	1.6783	100.0%	555.6	588.7	616.6	0.744	0.701	0.658	884.5	1070.9	10
18	218.2	8.490	25.304	50.181	1.00000	869.0	-1.6%	1.0000	1.3273	1.4001	1.6795	100.0%	555.6	588.7	616.7	0.744	0.701	0.658	883.5	1071.6	10
19	230.7	8.976	25.790	50.385	1.00000	836.1	-1.5%	1.0000	1.3250	1.4005	1.6755	100.0%	555.6	588.6	616.6	0.744	0.701	0.658	882.8	1074.8	12
20	243.3	9.467	26.280	50.591	1.00000	798.2	-1.5%	1.0000	1.3223	1.4029	1.6753	100.0%	556.2	589.2	617.1	0.743	0.700	0.658	882.6	1078.6	9
21	253.6	9.868	26.681	50.760	1.00000	769.2	-0.9%	1.0000	1.3195	1.4046	1.6597	100.0%	556.2	589.0	617.1	0.743	0.701	0.658	882.2	1078.1	11
22	263.9	10.268	27.081	50.930	1.00000	737.2	-1.4%	1.0000	1.3188	1.4054	1.6686	100.0%	556.2	589.2	617.1	0.743	0.700	0.658	882.0	1083.2	11
23	280.6	10.918	27.730	51.207	1.00000	683.8	-1.4%	1.0000	1.3172	1.4062	1.6667	100.0%	556.2	589.2	617.2	0.743	0.700	0.658	881.5	1087.9	11
24	296.8	11.548	28.360	51.478	1.00000	631.5	-1.3%	1.0000	1.3196	1.4062	1.6587	100.0%	556.2	589.1	617.2	0.743	0.701	0.658	881.0	1091.5	12
25	307.7	11.973	28.784	51.661	1.00000	595.5	-1.3%	1.0000	1.3209	1.4055	1.6545	100.0%	556.2	589.1	617.2	0.743	0.701	0.658	880.8	1096.3	10
26	318.0	12.373	29.185	51.835	1.00000	561.0	-1.0%	1.0000	1.3218	1.4047	1.6442	100.0%	556.2	589.1	617.2	0.743	0.701	0.658	880.5	1098.5	11
27	332.6	12.941	29.752	52.083	1.00000	510.0	-1.1%	1.0000	1.3218	1.4030	1.6401	100.0%	556.2	589.1	617.2	0.743	0.701	0.658	880.3	1104.6	10
28	346.8	13.494	30.304	52.326	1.00000	460.3	-0.9%	1.0000	1.3216	1.4024	1.6358	100.0%	556.2	589.1	617.2	0.743	0.701	0.658	880.1	1107.7	12
29	363.2	14.132	30.942	52.613	1.00000	401.8	-1.0%	1.0000	1.3201	1.4022	1.6414	100.0%	556.2	589.1	617.2	0.743	0.701	0.658	879.9	1112.6	12
30	384.3	14.953	31.762	53.004	1.00000	325.4	-0.9%	1.0000	1.3182	1.4005	1.6419	100.0%	556.2	589.1	617.2	0.743	0.701	0.658	879.6	1115.1	13
31	397.2	15.455	32.264	53.331	1.00000	278.9	-1.0%	1.0000	1.3157	1.3990	1.6441	100.0%	556.2	589.1	617.3	0.743	0.701	0.658	879.5	1120.2	11
32	413.8	16.101	32.909	53.764	1.00000	218.2	-0.9%	1.0000	1.3128	1.3973	1.6403	100.0%	556.2	589.1	617.3	0.743	0.701	0.658	879.1	1123.6	13
33	430.8	16.762	33.570	54.211	1.00000	155.9	-0.9%	1.0000	1.3112	1.3953	1.6379	100.0%	556.2	589.1	617.3	0.743	0.701	0.658	878.6	1123.7	15
34	448.1	17.435	34.243	54.669	1.00000	92.5	-0.9%	1.0000	1.3093	1.3926	1.6334	100.0%	556.2	589.1	617.3	0.743	0.701	0.658	878.1	1121.3	13
35	464.7	18.081	34.888	55.111	1.00000	31.8	-0.9%	1.0000	1.3072	1.3896	1.6295	100.0%	556.2	589.1	617.3	0.743	0.701	0.658	877.6	1119.4	11
36	481.1	18.719	35.526	55.549	0.99783	0.0	-0.7%	1.0000	1.3046	1.3856	1.6174	100.0%	556.2	589.1	617.3	0.743	0.701	0.658	877.1	1113.9	10
37	497.0	19.338	36.144	55.977	0.99693	0.0	3.2%	1.0000	1.3051	1.3855	1.5902	91.5%	556.2	585.7	612.6	0.743	0.706	0.666	842.9	1068.9	12
38	512.3	19.933	36.739	56.389	0.99692	0.0	6.9%	1.0000	1.3072	1.3872	1.6823	80.9%	556.2	581.7	606.6	0.743	0.711	0.676	802.4	1023.1	12

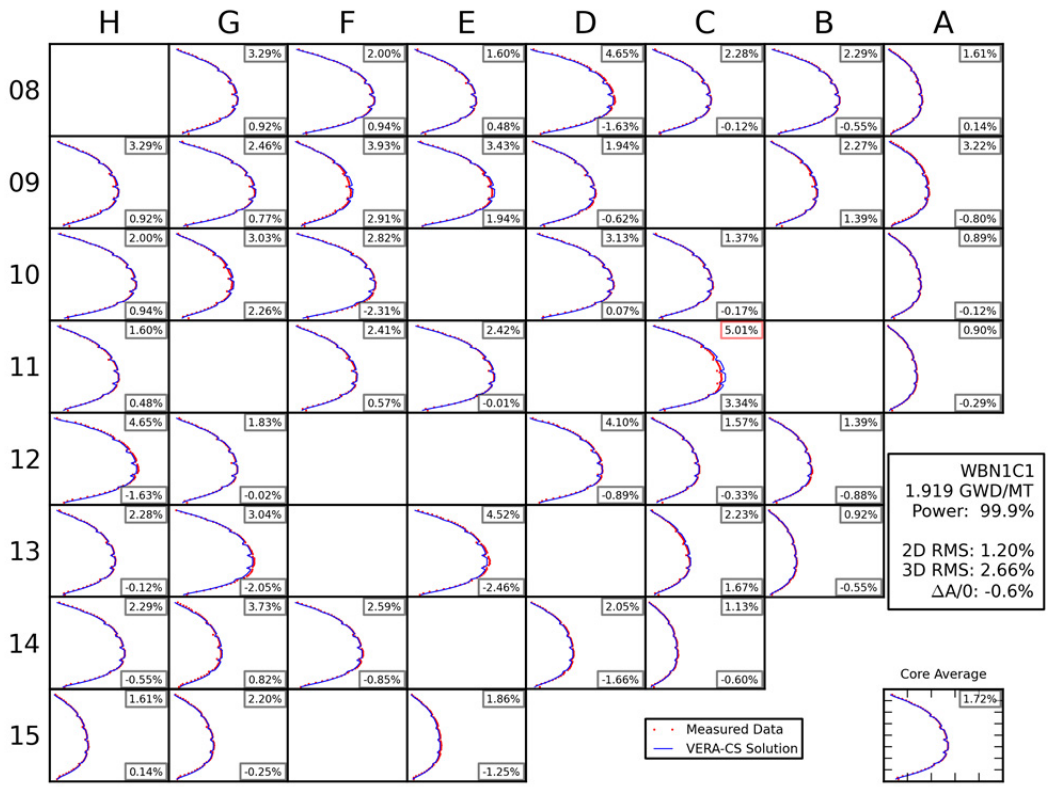
WBN1 Cycle 11

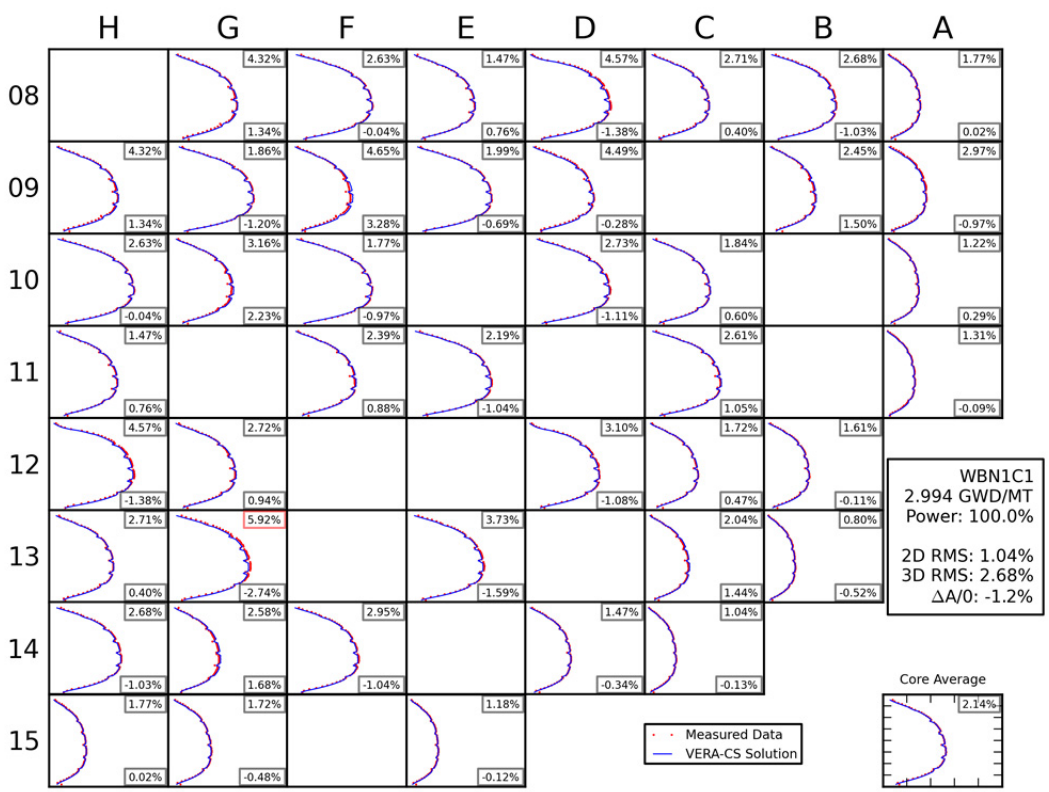
#	EFPD	Ecyc	Ecore	Emax	k-eff	Boron	AO	Pavg	Fassy	FdH	Fq	Power	Tin(F)	Tavg(F)	Tout(F)	pin	pavg	pout	Tf(K)	Tfmx(K)	Outrs
1	0.0	0.000	14.472	50.151	1.00000	1445.3	3.3%	1.0000	1.3207	1.5032	2.2108	0.0%	551.2	551.2	551.2	0.748	0.748	0.748	561.6	561.6	13
2	4.1	0.161	14.628	50.179	1.00000	841.8	-7.1%	1.0000	1.2863	1.4168	1.7770	98.8%	551.2	585.3	612.4	0.748	0.706	0.666	894.7	1161.3	14
3	12.8	0.500	14.967	50.241	1.00000	856.4	-6.6%	1.0000	1.2809	1.4099	1.7786	100.0%	552.6	586.7	614.3	0.747	0.704	0.663	897.9	1163.0	9
4	25.7	1.000	15.467	50.331	1.00000	899.3	-7.2%	1.0000	1.2574	1.4150	1.8244	100.0%	552.6	586.8	614.3	0.747	0.704	0.663	895.2	1163.6	12
5	38.5	1.500	15.967	50.418	1.00000	946.5	-7.3%	1.0000	1.2452	1.4193	1.8572	100.0%	552.6	586.8	614.3	0.747	0.704	0.663	892.2	1169.4	10
6	51.3	2.000	16.467	50.504	1.00000	986.5	-7.4%	1.0000	1.2553	1.4184	1.8734	100.0%	552.6	586.8	614.2	0.747	0.704	0.663	890.1	1171.5	11
7	64.1	2.500	16.966	50.587	1.00000	1016.6	-7.1%	1.0000	1.2660	1.4176	1.8732	100.0%	552.6	586.8	614.2	0.747	0.704	0.663	889.5	1168.6	8
8	73.4	2.860	17.326	50.646	1.00000	1033.6	-6.8%	1.0000	1.2726	1.4168	1.8686	100.0%	552.6	586.7	614.1	0.747	0.704	0.663	888.9	1164.6	10
9	88.5	3.449	17.915	50.741	1.00000	1050.3	-6.4%	1.0000	1.2804	1.4115	1.8490	99.9%	552.7	586.7	614.2	0.747	0.704	0.662	888.7	1155.0	10
10	103.6	4.038	18.503	50.835	1.00000	1057.5	-5.7%	1.0000	1.2868	1.4061	1.8201	99.9%	552.7	586.6	614.2	0.747	0.704	0.662	888.4	1142.6	9
11	118.7	4.626	19.091	50.928	1.00000	1055.7	-4.9%	1.0000	1.2916	1.3997	1.7861	99.9%	552.7	586.5	614.2	0.747	0.704	0.662	888.3	1128.9	11
12	133.8	5.215	19.680	51.019	1.00000	1046.1	-4.2%	1.0000	1.3002	1.3930	1.7713	99.9%	552.7	586.3	614.1	0.747	0.704	0.662	888.0	1117.3	12
13	148.9	5.804	20.268	51.111	1.00000	1029.8	-3.4%	1.0000	1.3072	1.3916	1.7510	99.9%	552.7	586.2	614.1	0.747	0.704	0.662	887.4	1107.7	13
14	162.8	6.345	20.809	51.195	1.00000	1011.9	-2.5%	1.0000	1.3125	1.3968	1.7280	99.4%	552.7	585.9	613.8	0.747	0.705	0.663	885.1	1094.5	10
15	176.7	6.887	21.350	51.279	1.00000	986.9	-2.0%	1.0000	1.3191	1.4003	1.7049	99.4%	552.7	585.9	613.8	0.747	0.705	0.663	884.3	1086.8	10
16	190.6	7.429	21.892	51.363	1.00000	958.9	-1.2%	1.0000	1.3242	1.4034	1.6786	99.4%	552.7	585.7	613.8	0.747	0.705	0.663	883.3	1079.4	12
17	204.5	7.971	22.433	51.447	1.00000	926.5	-0.9%	1.0000	1.3294	1.4085	1.6564	99.4%	552.7	585.7	613.9	0.747	0.705	0.663	882.4	1075.4	10
18	218.4	8.512	22.974	51.532	1.00000	892.1	-0.3%	1.0000	1.3323	1.4125	1.6395	99.4%	552.7	585.5	613.8	0.747	0.705	0.663	881.6	1075.4	12
19	232.3	9.054	23.516	51.618	1.00000	854.4	0.2%	1.0000	1.3348	1.4157	1.6335	99.4%	552.7	585.5	613.8	0.747	0.705	0.663	880.9	1078.4	12
20	247.9	9.662	24.123	51.715	1.00000	797.0	-0.1%	1.0000	1.3378	1.4187	1.6195	99.4%	555.9	588.6	616.5	0.743	0.701	0.659	882.1	1081.6	14
21	263.5	10.270	24.731	51.813	1.00000	748.8	0.0%	1.0000	1.3384	1.4194	1.6144	99.4%	555.9	588.6	616.6	0.743	0.701	0.658	881.6	1084.8	11
22	279.2	10.882	25.342	52.088	1.00000	699.7	0.4%	1.0000	1.3381	1.4190	1.6130	99.4%	555.9	588.3	616.5	0.743	0.702	0.659	880.9	1088.6	12
23	294.8	11.490	25.950	52.453	1.00000	647.9	0.5%	1.0000	1.3370	1.4175	1.6054	99.4%	555.9	588.3	616.6	0.743	0.702	0.659	880.5	1089.8	11
24	309.4	12.059	26.518	52.796	1.00000	598.0	0.6%	1.0000	1.3353	1.4152	1.6069	99.4%	555.9	588.4	616.6	0.743	0.702	0.659	880.1	1093.6	12
25	324.0	12.628	27.087	53.141	1.00000	547.5	0.7%	1.0000	1.3332	1.4124	1.6054	99.4%	555.9	588.4	616.6	0.743	0.702	0.659	879.7	1098.0	15
26	338.6	13.197	27.656	53.488	1.00001	495.8	0.6%	1.0000	1.3306	1.4090	1.5988	99.4%	555.9	588.4	616.6	0.743	0.702	0.659	879.3	1102.0	10
27	353.2	13.766	28.224	53.836	1.00000	443.4	0.5%	1.0000	1.3279	1.4054	1.5912	99.4%	555.9	588.4	616.6	0.743	0.702	0.659	879.0	1105.8	14
28	367.8	14.335	28.793	54.187	1.00000	390.4	0.4%	1.0000	1.3244	1.4008	1.5933	99.4%	555.9	588.4	616.6	0.743	0.702	0.659	878.7	1107.6	11
29	382.4	14.904	29.361	54.540	1.00000	336.8	0.3%	1.0000	1.3216	1.3969	1.5928	99.4%	555.9	588.5	616.7	0.743	0.702	0.659	878.4	1110.3	11
30	397.7	15.501	29.957	54.912	1.00000	280.9	0.3%	1.0000	1.3177	1.3918	1.5902	99.4%	555.9	588.5	616.7	0.743	0.702	0.659	877.9	1111.3	14
31	413.0	16.097	30.553	55.287	1.00000	224.7	0.1%	1.0000	1.3137	1.3865	1.5877	99.4%	555.9	588.5	616.7	0.743	0.702	0.659	877.5	1107.7	12
32	428.3	16.693	31.149	55.664	1.00000	168.0	-0.0%	1.0000	1.3103	1.3817	1.5855	99.4%	555.9	588.6	616.7	0.743	0.702	0.659	877.0	1105.0	11
33	443.6	17.290	31.744	56.044	1.00000	112.0	-0.1%	1.0000	1.3061	1.3762	1.5811	99.4%	555.9	588.5	616.7	0.743	0.702	0.659	876.4	1100.7	15
34	458.9	17.886	32.340	56.426	1.00000	55.9	-0.2%	1.0000	1.3019	1.3705	1.5775	99.4%	555.9	588.5	616.7	0.743	0.702	0.659	875.8	1096.6	14

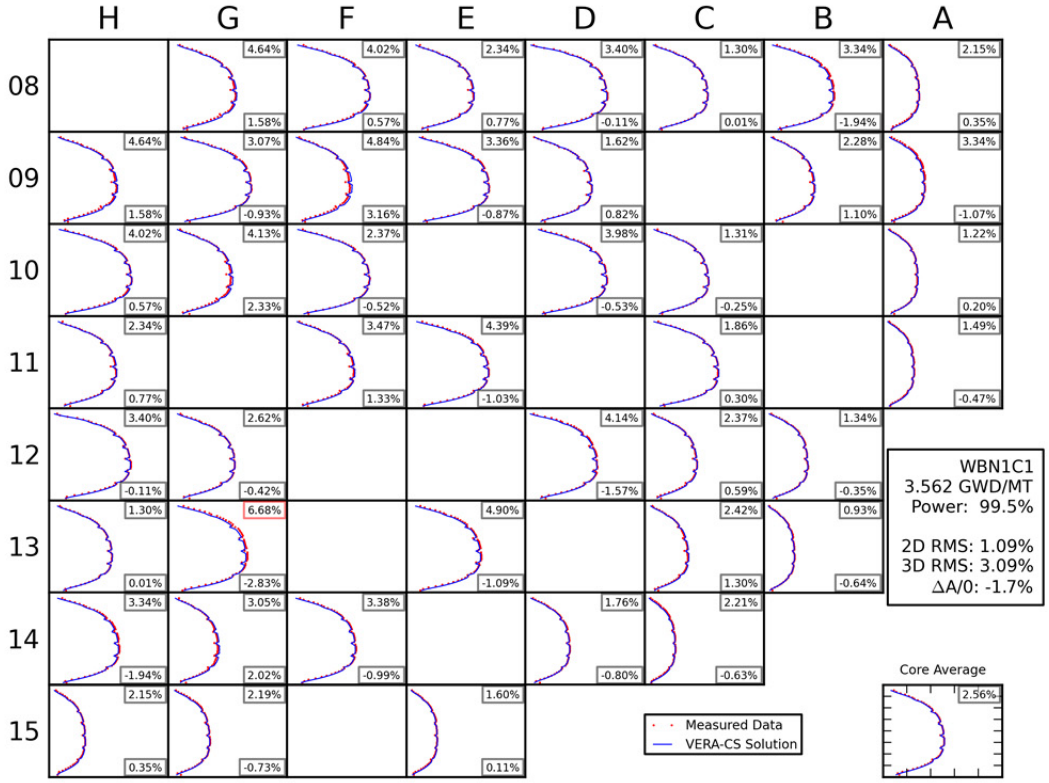
WBN1 Cycle 12

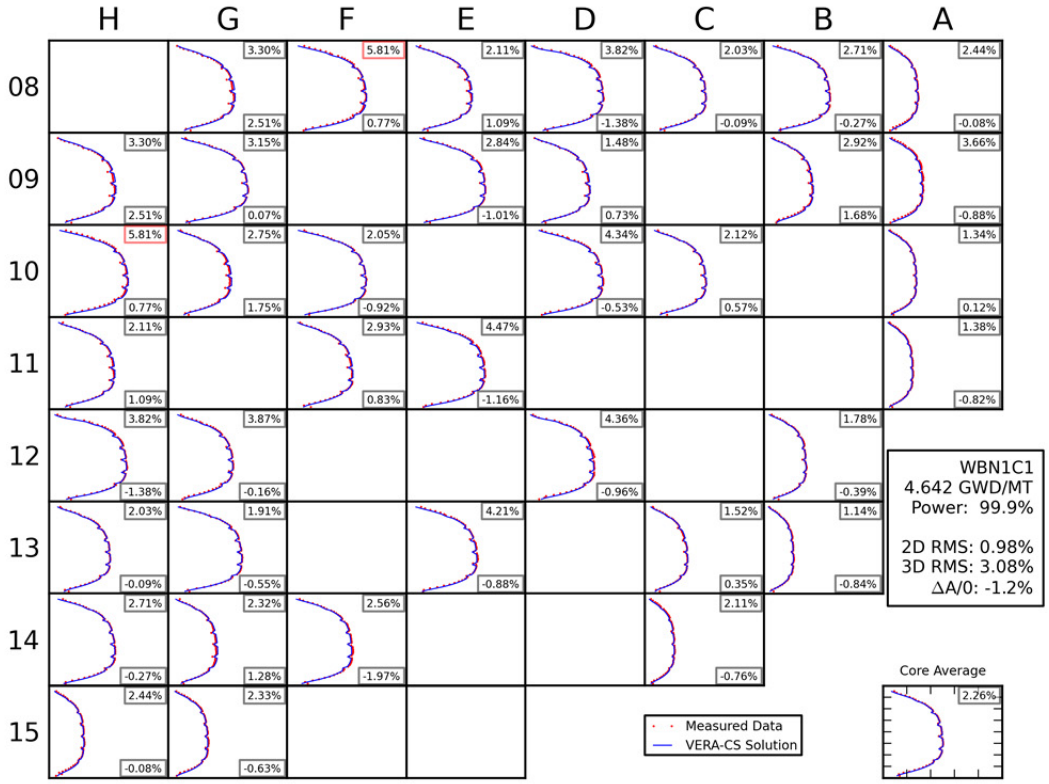
#	EFPD	Ecyc	Ecore	Emax	k-eff	Boron	AO	Pavg	Fassy	FdH	Fq	Power	Tin(F)	Tavg(F)	Tout(F)	pin	pavg	pout	Tf(K)	Tfmx(K)	Outs
1	0.0	0.000	13.001	43.117	1.00000	1523.9	-1.9%	1.0000	1.3262	1.4731	2.1647	0.0%	554.9	554.9	554.9	0.744	0.744	0.744	563.6	563.7	12
2	4.3	0.168	13.164	43.167	1.00000	911.0	-5.5%	1.0000	1.2838	1.3938	1.6949	99.6%	556.1	589.7	617.0	0.743	0.700	0.658	900.7	1152.1	16
3	20.1	0.785	13.781	43.351	1.00000	949.9	-5.7%	1.0000	1.2686	1.3735	1.6839	99.6%	556.1	589.7	617.0	0.743	0.700	0.658	898.0	1153.1	12
4	35.9	1.402	14.397	43.535	1.00000	1000.6	-5.8%	1.0000	1.2364	1.3489	1.7120	99.6%	556.1	589.7	617.0	0.743	0.700	0.658	894.8	1151.8	10
5	51.7	2.019	15.014	43.715	1.00000	1045.5	-5.9%	1.0000	1.2201	1.3547	1.7342	99.6%	556.1	589.7	617.0	0.743	0.700	0.658	892.0	1150.1	12
6	67.5	2.636	15.631	43.904	1.00000	1077.7	-5.7%	1.0000	1.2231	1.3677	1.7511	99.6%	556.1	589.7	617.0	0.743	0.700	0.658	890.9	1146.9	11
7	81.0	3.163	16.158	44.075	1.00000	1096.5	-5.4%	1.0000	1.2296	1.3756	1.7609	99.6%	556.1	589.7	617.0	0.743	0.700	0.658	890.4	1142.2	9
8	94.5	3.690	16.685	44.245	1.00000	1107.7	-5.1%	1.0000	1.2322	1.3784	1.7678	99.6%	556.1	589.5	617.0	0.743	0.700	0.658	889.9	1134.6	8
9	108.5	4.237	17.232	44.420	1.00000	1110.9	-4.7%	1.0000	1.2356	1.3823	1.7741	99.6%	556.1	589.5	617.0	0.743	0.700	0.658	889.5	1124.9	8
10	122.6	4.788	17.782	44.596	1.00000	1108.1	-4.1%	1.0000	1.2393	1.3848	1.7721	99.6%	556.1	589.4	617.0	0.743	0.700	0.658	889.1	1114.0	11
11	136.6	5.334	18.328	44.770	1.00000	1098.7	-3.7%	1.0000	1.2451	1.3892	1.7692	99.6%	556.1	589.4	617.0	0.743	0.700	0.658	888.7	1105.6	10
12	150.6	5.881	18.875	44.943	1.00000	1084.7	-3.1%	1.0000	1.2488	1.3939	1.7590	99.6%	556.1	589.2	617.0	0.743	0.700	0.658	888.0	1096.3	11
13	164.7	6.432	19.425	45.118	1.00000	1065.2	-2.7%	1.0000	1.2522	1.4004	1.7476	99.6%	556.1	589.2	617.0	0.743	0.700	0.658	887.2	1089.7	10
14	178.7	6.978	19.971	45.291	1.00000	1042.5	-2.1%	1.0000	1.2543	1.4050	1.7296	99.6%	556.1	589.0	617.0	0.743	0.701	0.658	886.2	1084.8	12
15	194.8	7.607	20.599	45.491	1.00000	1010.7	-1.7%	1.0000	1.2565	1.4088	1.7126	99.6%	556.1	589.0	617.0	0.743	0.701	0.658	885.1	1079.5	10
16	210.9	8.236	21.228	45.691	1.00000	975.8	-1.1%	1.0000	1.2580	1.4111	1.6923	99.6%	556.1	588.9	617.0	0.743	0.701	0.658	884.0	1080.3	12
17	226.9	8.861	21.852	45.891	1.00000	936.2	-0.8%	1.0000	1.2586	1.4120	1.6784	99.6%	556.1	588.9	617.0	0.743	0.701	0.658	883.0	1080.5	10
18	243.0	9.489	22.480	46.092	1.00000	894.1	-0.1%	1.0000	1.2589	1.4126	1.6571	99.6%	556.1	588.7	617.0	0.743	0.701	0.658	882.2	1081.6	14
19	259.1	10.118	23.108	46.295	1.00000	847.7	0.3%	1.0000	1.2586	1.4123	1.6407	100.0%	556.1	588.7	617.2	0.743	0.701	0.658	882.8	1086.4	10
20	273.5	10.681	23.670	46.477	1.00000	803.5	0.0%	1.0000	1.2578	1.4109	1.6426	100.0%	556.1	588.9	617.2	0.743	0.701	0.658	882.5	1086.5	12
21	287.9	11.243	24.232	46.661	1.00000	758.4	0.0%	1.0000	1.2568	1.4091	1.6378	100.0%	556.1	588.9	617.3	0.743	0.701	0.658	882.0	1088.2	11
22	302.3	11.805	24.794	46.845	1.00000	713.4	0.3%	1.0000	1.2563	1.4078	1.6264	100.0%	556.1	588.7	617.2	0.743	0.701	0.658	881.4	1091.3	12
23	316.7	12.368	25.356	47.031	1.00000	665.9	0.3%	1.0000	1.2548	1.4051	1.6202	100.0%	556.1	588.7	617.2	0.743	0.701	0.658	881.0	1095.3	11
24	331.1	12.930	25.918	47.218	1.00000	617.0	0.4%	1.0000	1.2534	1.4024	1.6114	100.0%	556.1	588.8	617.2	0.743	0.701	0.658	880.7	1099.1	11
25	345.5	13.492	26.480	47.407	1.00000	568.0	0.4%	1.0000	1.2520	1.3995	1.6016	100.0%	556.1	588.8	617.3	0.743	0.701	0.658	880.3	1101.9	13
26	361.5	14.117	27.104	47.619	1.00001	512.2	0.4%	1.0000	1.2503	1.3958	1.6026	100.0%	556.1	588.8	617.3	0.743	0.701	0.658	879.9	1105.7	10
27	377.6	14.746	27.732	47.834	1.00000	455.6	0.3%	1.0000	1.2485	1.3920	1.6033	100.0%	556.1	588.8	617.2	0.743	0.701	0.658	879.5	1108.9	14
28	393.6	15.371	28.356	48.050	1.00000	398.4	0.1%	1.0000	1.2466	1.3879	1.6046	100.0%	556.1	588.8	617.2	0.743	0.701	0.658	879.2	1111.0	11
29	409.7	15.999	28.984	48.269	1.00000	340.3	0.1%	1.0000	1.2451	1.3843	1.6029	100.0%	556.1	588.9	617.3	0.743	0.701	0.658	878.8	1112.9	11
30	425.7	16.624	29.609	48.489	1.00000	282.7	0.0%	1.0000	1.2432	1.3800	1.5996	100.0%	556.1	588.8	617.3	0.743	0.701	0.658	878.4	1108.3	15
31	440.8	17.214	30.198	48.701	1.00000	228.2	-0.1%	1.0000	1.2414	1.3760	1.5971	100.0%	556.1	588.8	617.3	0.743	0.701	0.658	877.9	1103.9	14
32	456.0	17.807	30.791	48.920	1.00000	173.1	-0.3%	1.0000	1.2395	1.3716	1.5950	100.0%	556.1	588.8	617.3	0.743	0.701	0.658	877.4	1102.9	11
33	471.1	18.397	31.380	49.140	1.00000	118.2	-0.4%	1.0000	1.2380	1.3679	1.5907	100.0%	556.1	588.9	617.3	0.743	0.701	0.658	877.0	1100.7	13
34	486.3	18.991	31.973	49.364	1.00000	63.3	-0.5%	1.0000	1.2362	1.3635	1.5872	100.0%	556.1	588.9	617.4	0.743	0.701	0.658	876.5	1099.0	11
35	501.4	19.580	32.562	49.589	1.00000	9.1	-0.6%	1.0000	1.2345	1.3595	1.5815	100.0%	556.1	588.9	617.3	0.743	0.701	0.658	876.1	1096.7	12

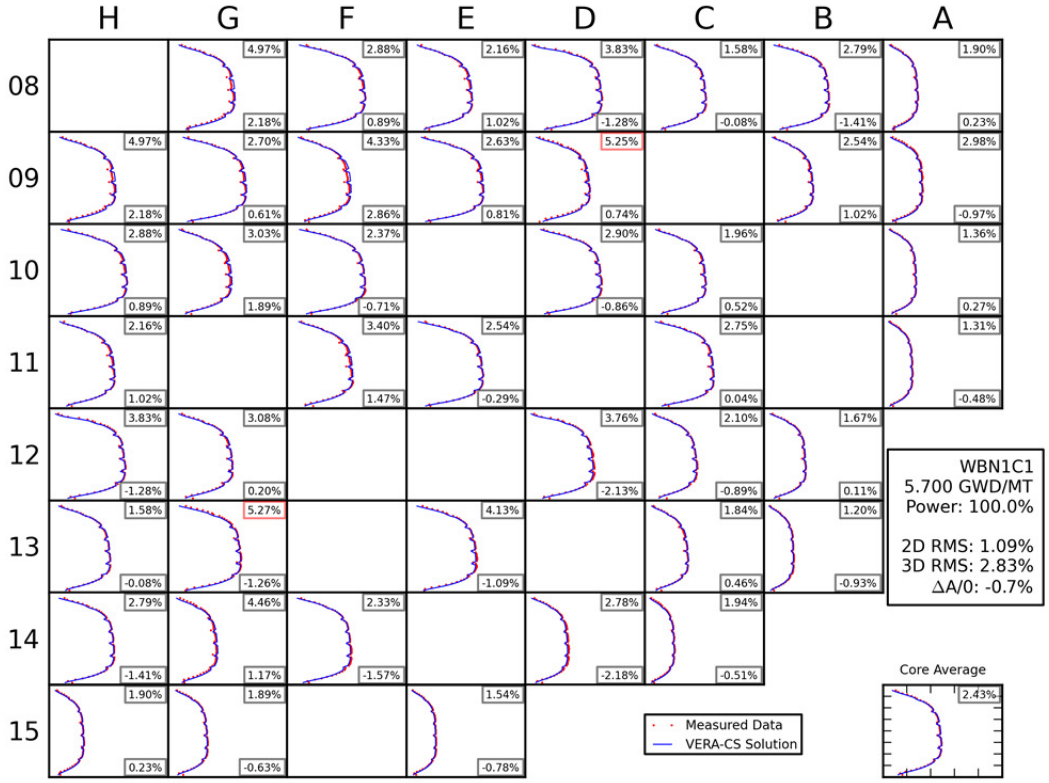
APPENDIX E FLUX MAPS FOR ALL CYCLES

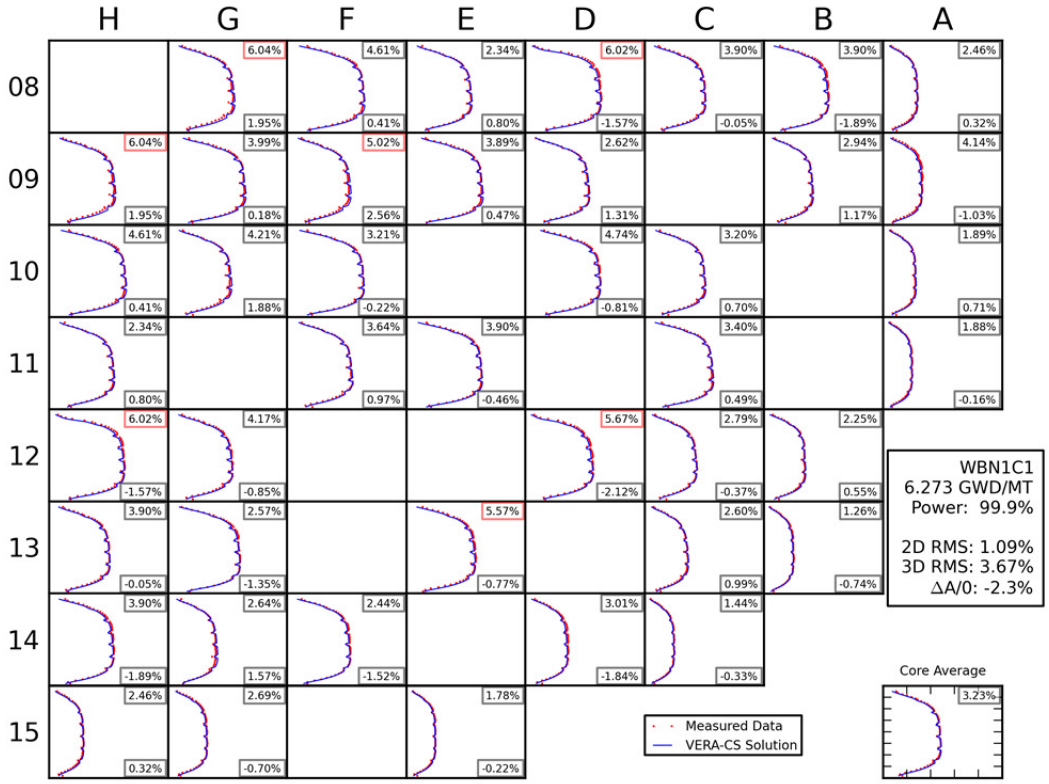


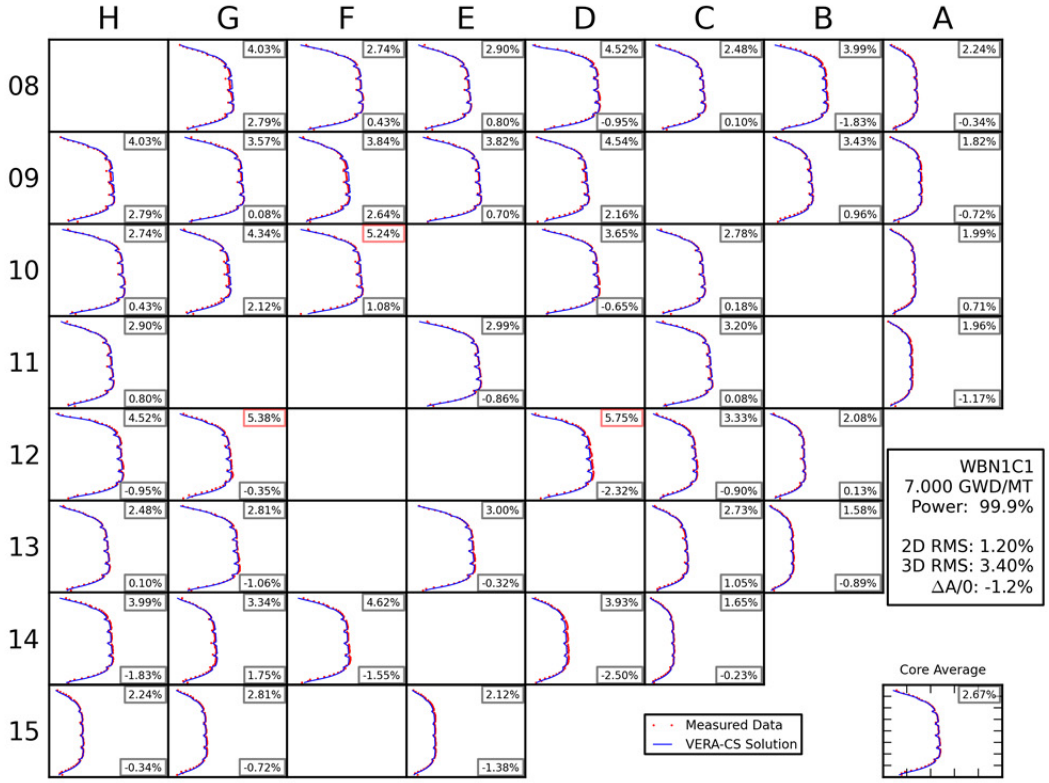


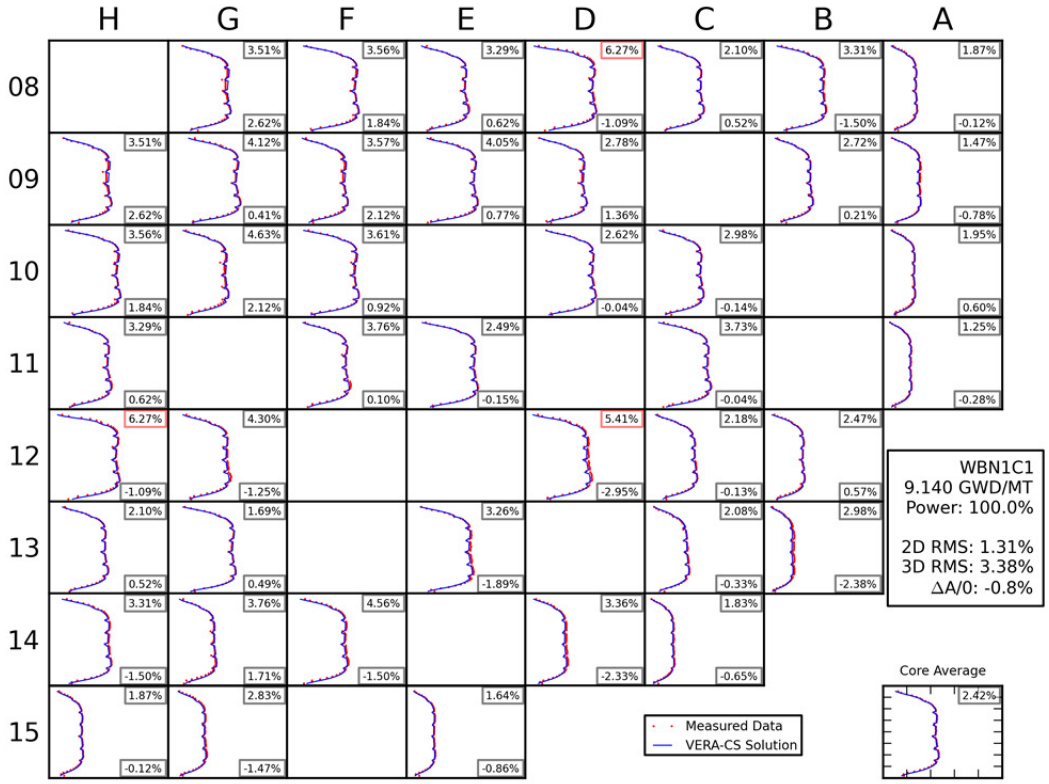

H G F E D C B A
08 09 10 11 12 13 14 15
4.64% 1.58%
4.02% 0.57%
2.34% 0.77%
3.40% -0.11%
1.30% 0.01%
3.34% -1.94%
2.15% 0.35%
4.64% 1.58%
3.07% -0.93%
4.84% 3.16%
3.36% -0.87%
1.62% 0.82%
2.28% 1.10%
3.34% -1.07%
4.02% 0.57%
4.13% 2.33%
2.37% -0.52%
3.98% -0.53%
1.31% -0.25%
1.22% 0.20%
2.34% 0.77%
3.47% 1.33%
4.39% -1.03%
1.86% 0.30%
1.49% -0.47%
3.40% -0.11%
2.62% -0.42%
4.14% -1.57%
2.37% 0.59%
1.34% -0.35%
1.30% 0.01%
6.68% -2.83%
4.90% -1.09%
2.42% 1.30%
0.93% -0.64%
3.34% -1.94%
3.05% 2.02%
3.38% -0.99%
1.76% -0.80%
2.21% -0.63%
2.15% 0.35%
2.19% -0.73%
1.60% 0.11%
WBN1C1
3.562 GWD/MT
Power: 99.5%
2D RMS: 1.09%
3D RMS: 3.09%
ΔA/0: -1.7%
Measured Data
VERA-CS Solution
Core Average
2.56%

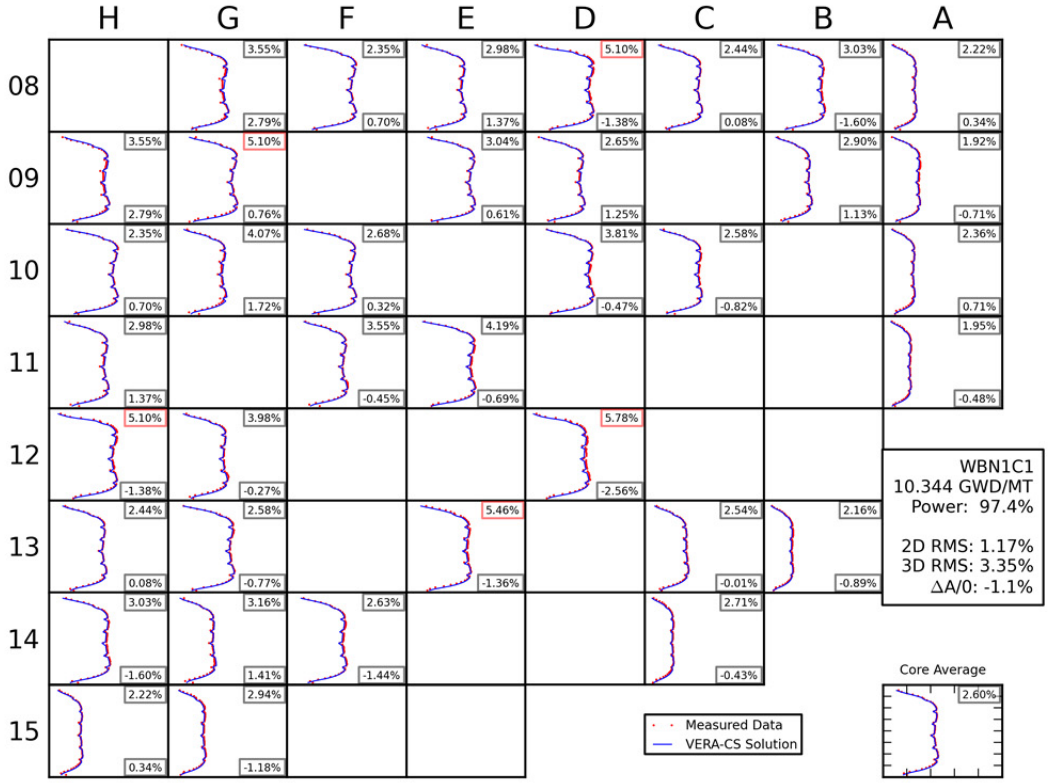

H G F E D C B A
08 09 10 11 12 13 14 15
3.30% 2.51%
5.81% 0.77%
2.11% 1.09%
3.82% -1.38%
2.03% -0.09%
2.71% -0.27%
2.44% -0.08%
3.30% 2.51%
3.15% 0.07%
2.84% -1.01%
1.48% 0.73%
2.92% 1.68%
3.66% -0.88%
5.81% 0.77%
2.75% 1.75%
2.05% -0.92%
4.34% -0.53%
2.12% 0.57%
1.34% 0.12%
2.11% 1.09%
2.93% 0.83%
4.47% -1.16%
1.38% -0.82%
3.82% -1.38%
3.87% -0.16%
4.36% -0.96%
1.78% -0.39%
2.03% -0.09%
1.91% -0.55%
4.21% -0.88%
1.52% 0.35%
1.14% -0.84%
2.71% -0.27%
2.32% 1.28%
2.56% -1.97%
2.11% -0.76%
2.44% -0.08%
2.33% -0.63%
WBN1C1
4.642 GWD/MT
Power: 99.9%
2D RMS: 0.98%
3D RMS: 3.08%
ΔA/0: -1.2%
Measured Data
VERA-CS Solution
Core Average
2.26%

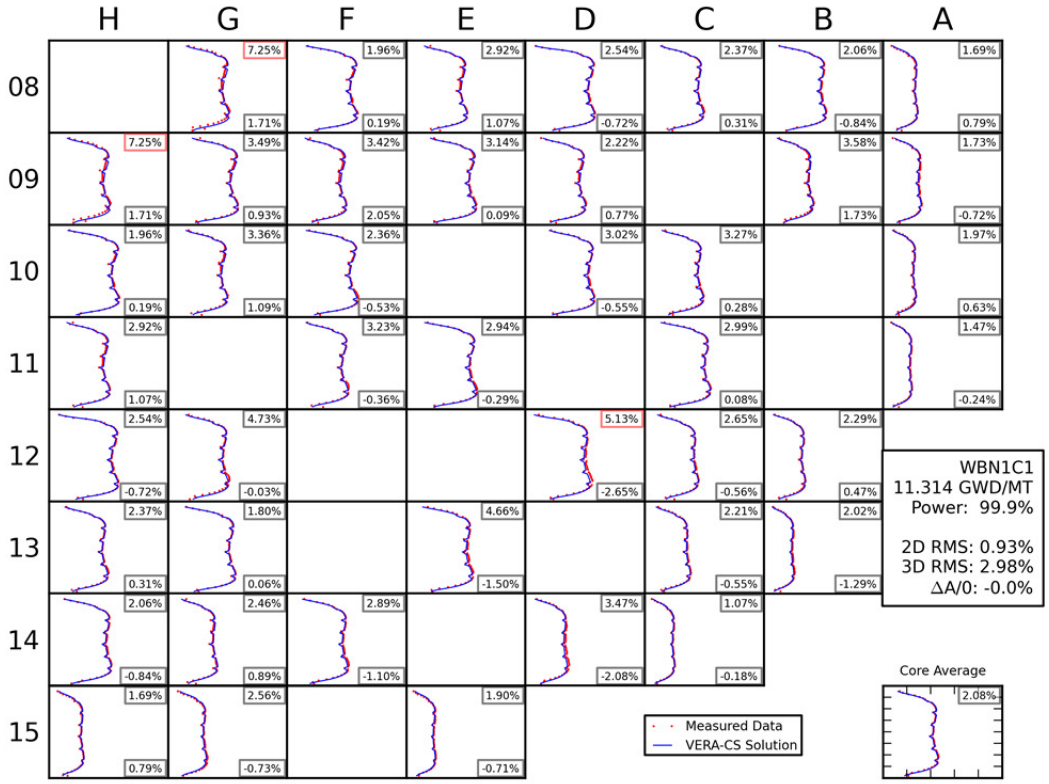

H G F E D C B A
08
4.97% 2.18%
2.88% 0.89%
2.16% 1.02%
3.83% -1.28%
1.58% -0.08%
2.79% -1.41%
1.90% 0.23%
09
4.97% 2.18%
2.70% 0.61%
4.33% 2.86%
2.63% 0.81%
5.25% 0.74%
2.54% 1.02%
2.98% -0.97%
10
2.88% 0.89%
3.03% 1.89%
2.37% -0.71%
2.90% -0.86%
1.96% 0.52%
1.36% 0.27%
11
2.16% 1.02%
3.40% 1.47%
2.54% -0.29%
2.75% 0.04%
1.31% -0.48%
12
3.83% -1.28%
3.08% 0.20%
3.76% -2.13%
2.10% -0.89%
1.67% 0.11%
13
1.58% -0.08%
5.27% -1.26%
4.13% -1.09%
1.84% 0.46%
1.20% -0.93%
14
2.79% -1.41%
4.46% 1.17%
2.33% -1.57%
2.78% -2.18%
1.94% -0.51%
15
1.90% 0.23%
1.89% -0.63%
1.54% -0.78%
WBN1C1
5.700 GWD/MT
Power: 100.0%
2D RMS: 1.09%
3D RMS: 2.83%
ΔA/0: -0.7%
Measured Data
VERA-CS Solution
Core Average
2.43%

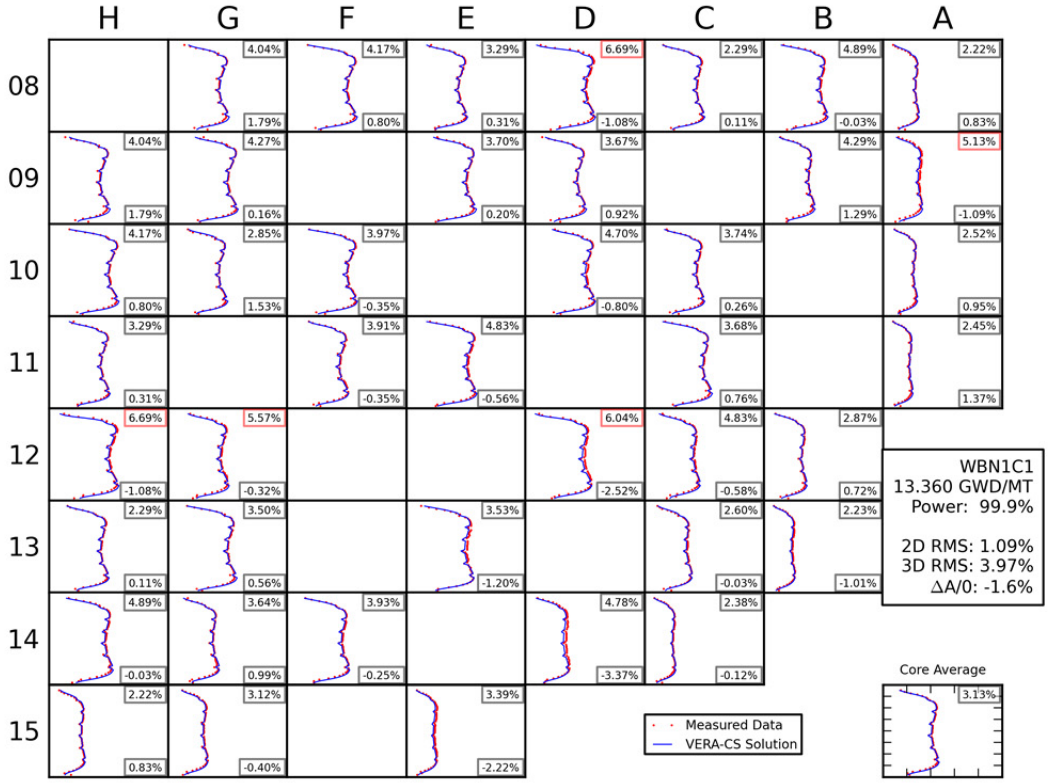

H G F E D C B A
08
6.04% 1.95%
4.61% 0.41%
2.34% 0.80%
6.02% -1.57%
3.90% -0.05%
3.90% -1.89%
2.46% 0.32%
09
6.04% 1.95%
3.99% 0.18%
5.02% 2.56%
3.89% 0.47%
2.62% 1.31%
2.94% 1.17%
4.14% -1.03%
10
4.61% 0.41%
4.21% 1.88%
3.21% -0.22%
4.74% -0.81%
3.20% 0.70%
1.89% 0.71%
11
2.34% 0.80%
3.64% 0.97%
3.90% -0.46%
3.40% 0.49%
1.88% -0.16%
12
6.02% -1.57%
4.17% -0.85%
5.67% -2.12%
2.79% -0.37%
2.25% 0.55%
13
3.90% -0.05%
2.57% -1.35%
5.57% -0.77%
2.60% 0.99%
1.26% -0.74%
14
3.90% -1.89%
2.64% 1.57%
2.44% -1.52%
3.01% -1.84%
1.44% -0.33%
15
2.46% 0.32%
2.69% -0.70%
1.78% -0.22%
WBN1C1
6.273 GWD/MT
Power: 99.9%
2D RMS: 1.09%
3D RMS: 3.67%
ΔA/0: -2.3%
Measured Data
VERA-CS Solution
Core Average
3.23%

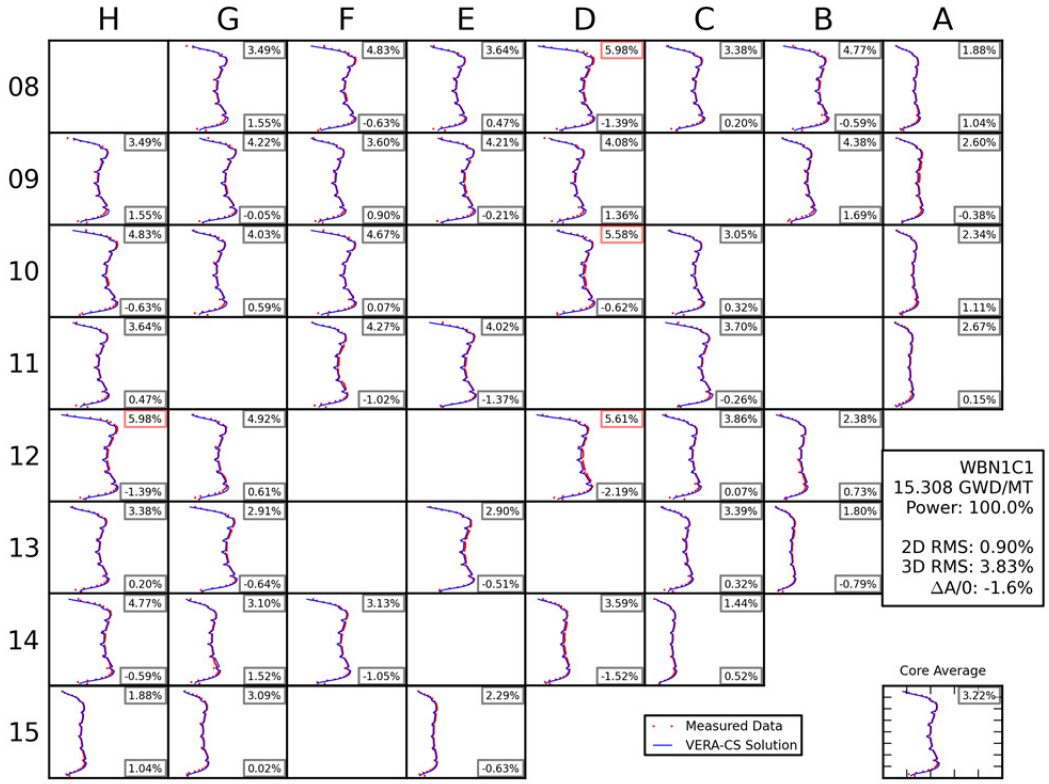

H G F E D C B A
08
09
10
11
12
13
14
15
WBN1C1
7.000 GWD/MT
Power: 99.9%
2D RMS: 1.20%
3D RMS: 3.40%
ΔA/0: -1.2%
Core Average
Measured Data
VERA-CS Solution

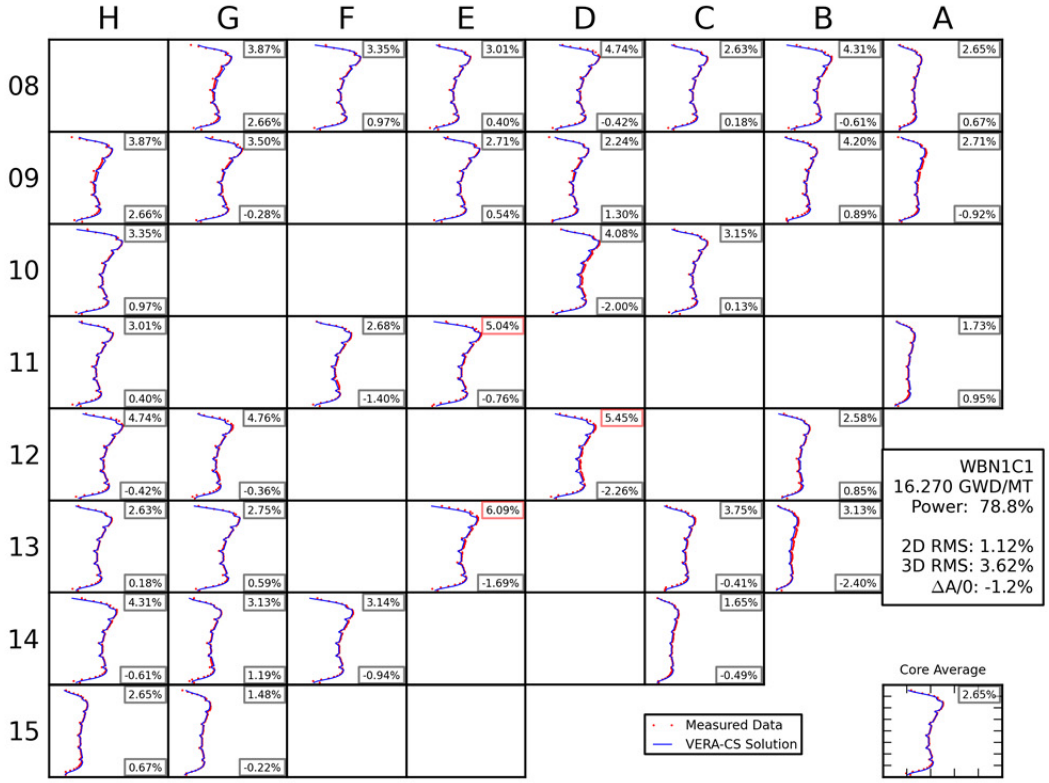

H G F E D C B A
08
09
10
11
12
13
14
15
WBN1C1
9.140 GWD/MT
Power: 100.0%
2D RMS: 1.31%
3D RMS: 3.38%
ΔA/0: -0.8%
Core Average
Measured Data
VERA-CS Solution

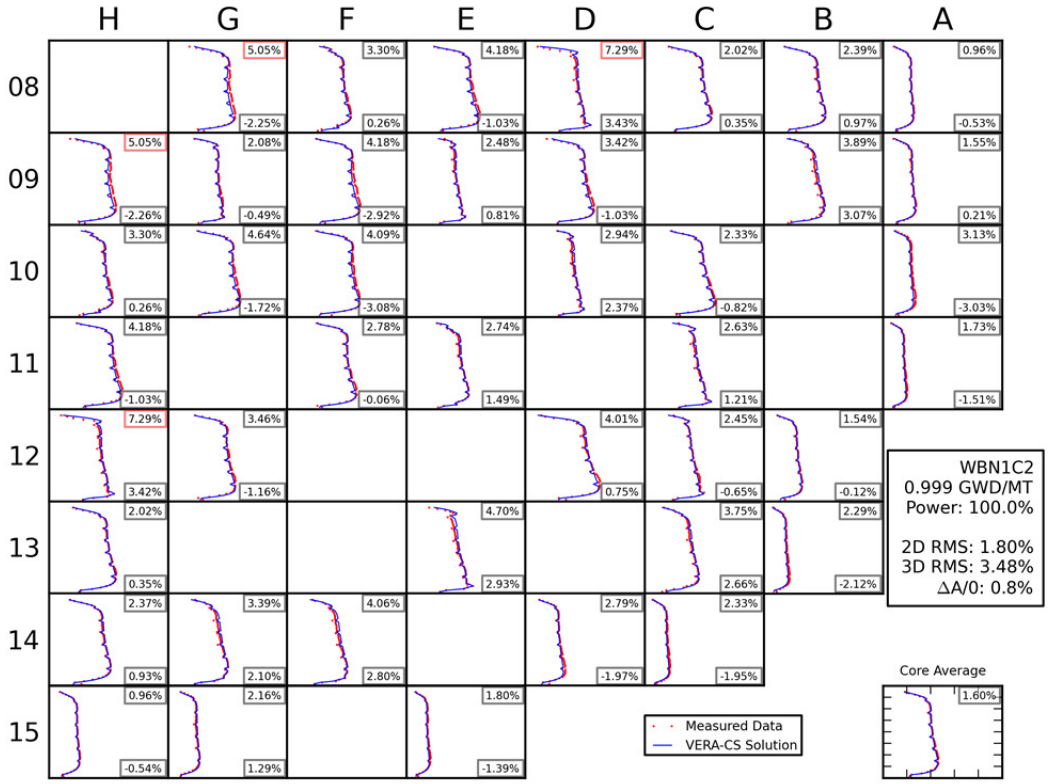

H G F E D C B A
08
3.55% 2.79%
2.35% 0.70%
2.98% 1.37%
5.10% -1.38%
2.44% 0.08%
3.03% -1.60%
2.22% 0.34%
09
3.55% 2.79%
5.10% 0.76%
3.04% 0.61%
2.65% 1.25%
2.90% 1.13%
1.92% -0.71%
10
2.35% 0.70%
4.07% 1.72%
2.68% 0.32%
3.81% -0.47%
2.58% -0.82%
2.36% 0.71%
11
2.98% 1.37%
3.55% -0.45%
4.19% -0.69%
1.95% -0.48%
12
5.10% -1.38%
3.98% -0.27%
5.78% -2.56%
13
2.44% 0.08%
2.58% -0.77%
5.46% -1.36%
2.54% -0.01%
2.16% -0.89%
14
3.03% -1.60%
3.16% 1.41%
2.63% -1.44%
2.71% -0.43%
15
2.22% 0.34%
2.94% -1.18%
WBN1C1
10.344 GWD/MT
Power: 97.4%
2D RMS: 1.17%
3D RMS: 3.35%
ΔA/0: -1.1%
Measured Data
VERA-CS Solution
Core Average
2.60%

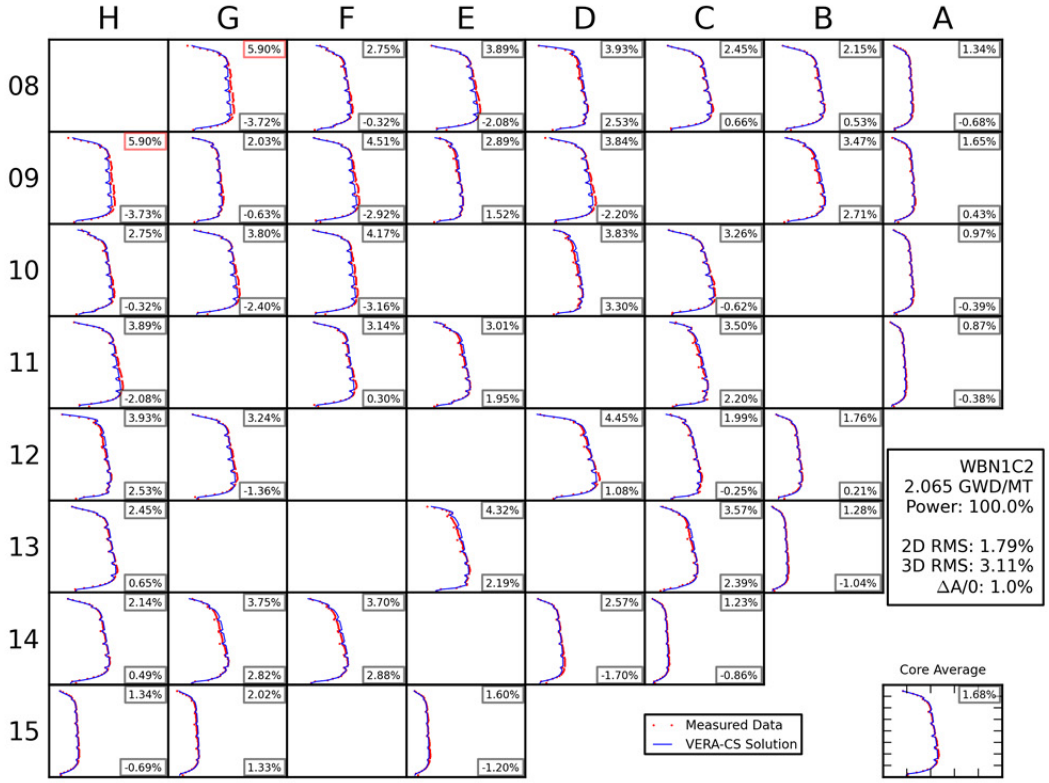

H G F E D C B A
08
7.25% 1.71%
1.96% 0.19%
2.92% 1.07%
2.54% -0.72%
2.37% 0.31%
2.06% -0.84%
1.69% 0.79%
09
7.25% 1.71%
3.49% 0.93%
3.42% 2.05%
3.14% 0.09%
2.22% 0.77%
3.58% 1.73%
1.73% -0.72%
10
1.96% 0.19%
3.36% 1.09%
2.36% -0.53%
3.02% -0.55%
3.27% 0.28%
1.97% 0.63%
11
2.92% 1.07%
3.23% -0.36%
2.94% -0.29%
2.99% 0.08%
1.47% -0.24%
12
2.54% -0.72%
4.73% -0.03%
5.13% -2.65%
2.65% -0.56%
2.29% 0.47%
13
2.37% 0.31%
1.80% 0.06%
4.66% -1.50%
2.21% -0.55%
2.02% -1.29%
14
2.06% -0.84%
2.46% 0.89%
2.89% -1.10%
3.47% -2.08%
1.07% -0.18%
15
1.69% 0.79%
2.56% -0.73%
1.90% -0.71%
WBN1C1
11.314 GWD/MT
Power: 99.9%
2D RMS: 0.93%
3D RMS: 2.98%
ΔA/0: -0.0%
Measured Data
VERA-CS Solution
Core Average
2.08%

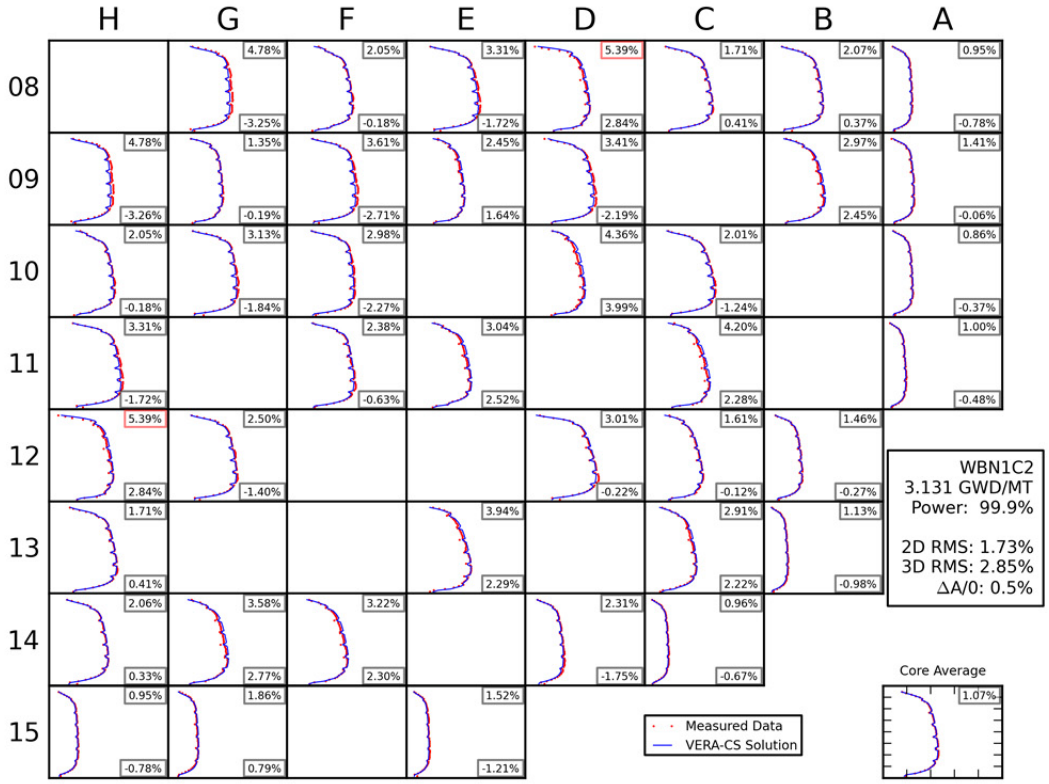

H G F E D C B A
08
4.04% 1.79%
4.17% 0.80%
3.29% 0.31%
6.69% -1.08%
2.29% 0.11%
4.89% -0.03%
2.22% 0.83%
09
4.04% 1.79%
4.27% 0.16%
3.70% 0.20%
3.67% 0.92%
4.29% 1.29%
5.13% -1.09%
10
4.17% 0.80%
2.85% 1.53%
3.97% -0.35%
4.70% -0.80%
3.74% 0.26%
2.52% 0.95%
11
3.29% 0.31%
3.91% -0.35%
4.83% -0.56%
3.68% 0.76%
2.45% 1.37%
12
6.69% -1.08%
5.57% -0.32%
6.04% -2.52%
4.83% -0.58%
2.87% 0.72%
13
2.29% 0.11%
3.50% 0.56%
3.53% -1.20%
2.60% -0.03%
2.23% -1.01%
14
4.89% -0.03%
3.64% 0.99%
3.93% -0.25%
4.78% -3.37%
2.38% -0.12%
15
2.22% 0.83%
3.12% -0.40%
3.39% -2.22%
WBN1C1
13.360 GWD/MT
Power: 99.9%
2D RMS: 1.09%
3D RMS: 3.97%
ΔA/0: -1.6%
Measured Data
VERA-CS Solution
Core Average
3.13%

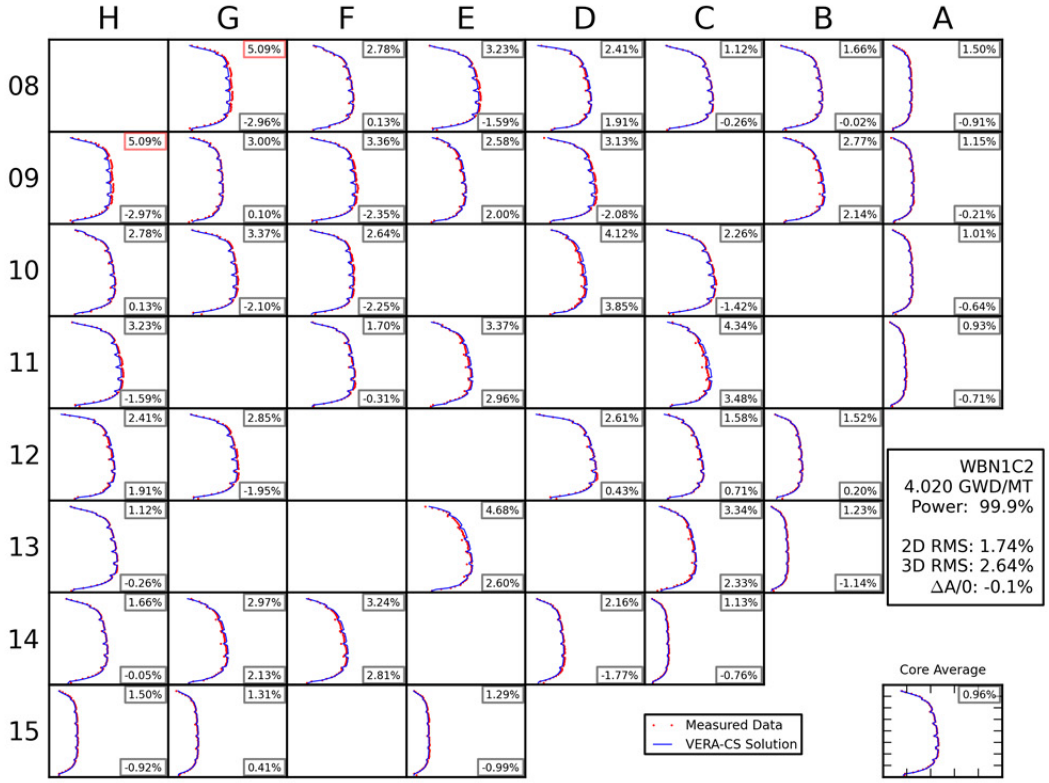

H G F E D C B A
08
3.49% 1.55%
4.83% -0.63%
3.64% 0.47%
5.98% -1.39%
3.38% 0.20%
4.77% -0.59%
1.88% 1.04%
09
3.49% 1.55%
4.22% -0.05%
3.60% 0.90%
4.21% -0.21%
4.08% 1.36%
4.38% 1.69%
2.60% -0.38%
10
4.83% -0.63%
4.03% 0.59%
4.67% 0.07%
5.58% -0.62%
3.05% 0.32%
2.34% 1.11%
11
3.64% 0.47%
4.27% -1.02%
4.02% -1.37%
3.70% -0.26%
2.67% 0.15%
12
5.98% -1.39%
4.92% 0.61%
5.61% -2.19%
3.86% 0.07%
2.38% 0.73%
13
3.38% 0.20%
2.91% -0.64%
2.90% -0.51%
3.39% 0.32%
1.80% -0.79%
14
4.77% -0.59%
3.10% 1.52%
3.13% -1.05%
3.59% -1.52%
1.44% 0.52%
15
1.88% 1.04%
3.09% 0.02%
2.29% -0.63%
WBN1C1
15.308 GWD/MT
Power: 100.0%
2D RMS: 0.90%
3D RMS: 3.83%
ΔA/0: -1.6%
Measured Data
VERA-CS Solution
Core Average
3.22%

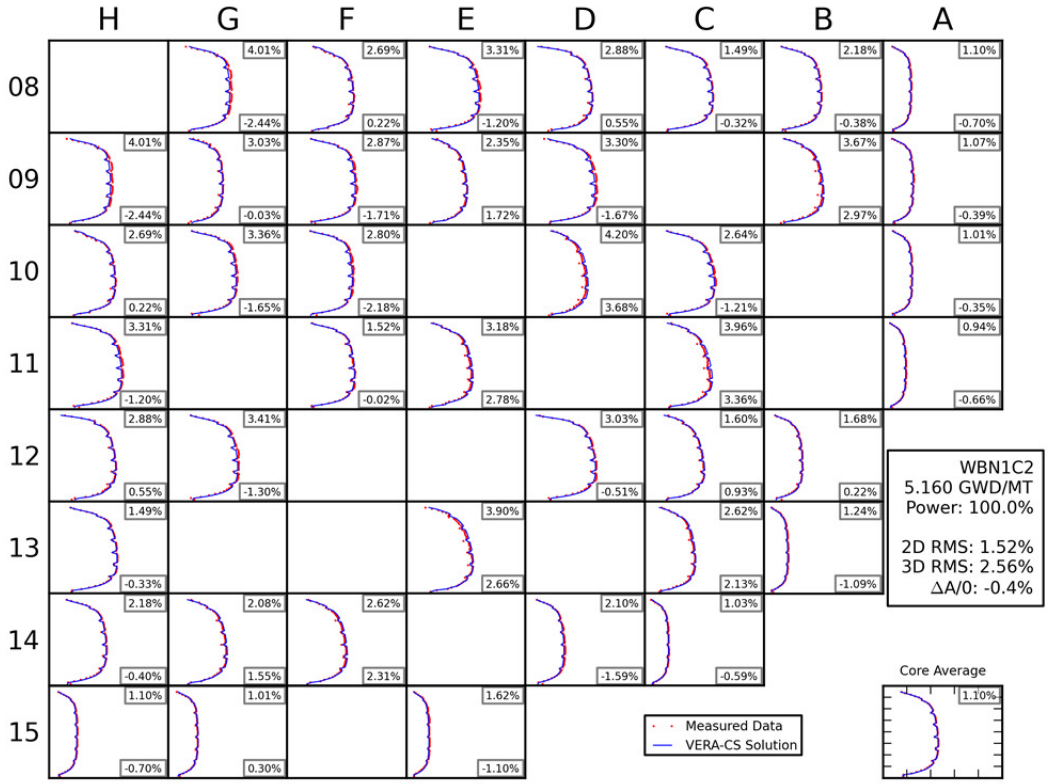

H G F E D C B A
08
3.87% 2.66%
3.35% 0.97%
3.01% 0.40%
4.74% -0.42%
2.63% 0.18%
4.31% -0.61%
2.65% 0.67%
09
3.87% 2.66%
3.50% -0.28%
2.71% 0.54%
2.24% 1.30%
4.20% 0.89%
2.71% -0.92%
10
3.35% 0.97%
4.08% -2.00%
3.15% 0.13%
11
3.01% 0.40%
2.68% -1.40%
5.04% -0.76%
1.73% 0.95%
12
4.74% -0.42%
4.76% -0.36%
5.45% -2.26%
2.58% 0.85%
13
2.63% 0.18%
2.75% 0.59%
6.09% -1.69%
3.75% -0.41%
3.13% -2.40%
14
4.31% -0.61%
3.13% 1.19%
3.14% -0.94%
1.65% -0.49%
15
2.65% 0.67%
1.48% -0.22%
WBN1C1
16.270 GWD/MT
Power: 78.8%
2D RMS: 1.12%
3D RMS: 3.62%
ΔA/0: -1.2%
Core Average
2.65%
Measured Data
VERA-CS Solution

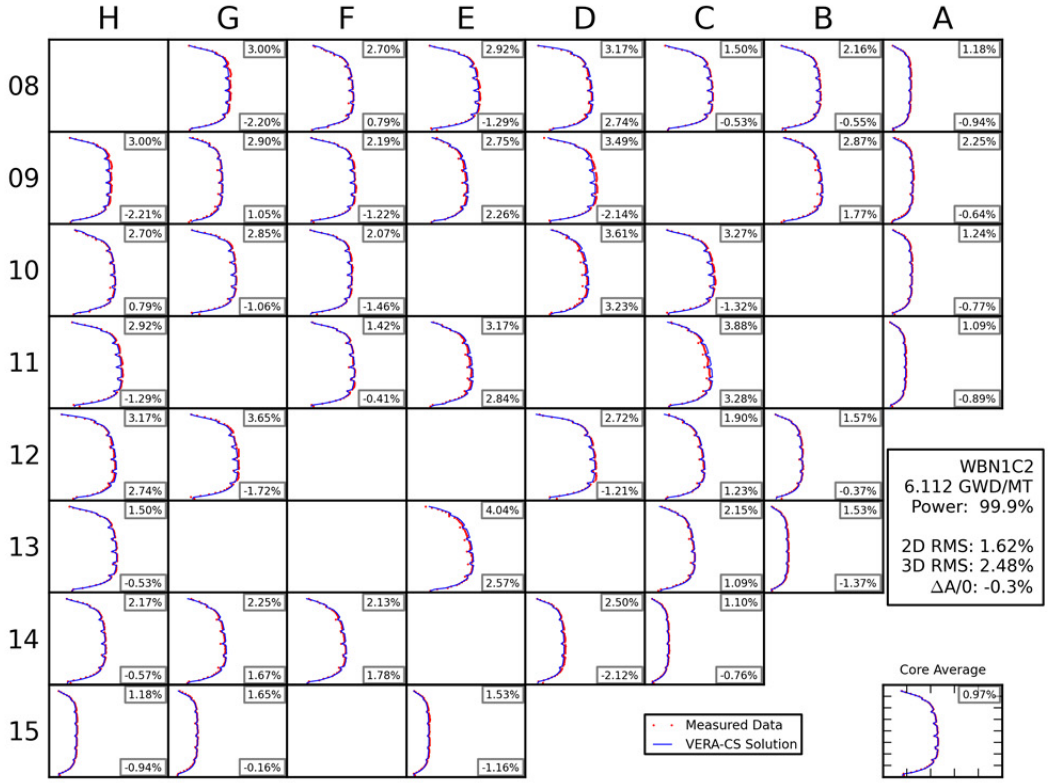

H G F E D C B A
08
5.05% -2.25%
3.30% 0.26%
4.18% -1.03%
7.29% 3.43%
2.02% 0.35%
2.39% 0.97%
0.96% -0.53%
09
5.05% -2.26%
2.08% -0.49%
4.18% -2.92%
2.48% 0.81%
3.42% -1.03%
3.89% 3.07%
1.55% 0.21%
10
3.30% 0.26%
4.64% -1.72%
4.09% -3.08%
2.94% 2.37%
2.33% -0.82%
3.13% -3.03%
11
4.18% -1.03%
2.78% -0.06%
2.74% 1.49%
2.63% 1.21%
1.73% -1.51%
12
7.29% 3.42%
3.46% -1.16%
4.01% 0.75%
2.45% -0.65%
1.54% -0.12%
13
2.02% 0.35%
4.70% 2.93%
3.75% 2.66%
2.29% -2.12%
14
2.37% 0.93%
3.39% 2.10%
4.06% 2.80%
2.79% -1.97%
2.33% -1.95%
15
0.96% -0.54%
2.16% 1.29%
1.80% -1.39%
WBN1C2
0.999 GWD/MT
Power: 100.0%
2D RMS: 1.80%
3D RMS: 3.48%
ΔA/0: 0.8%
Core Average
1.60%
Measured Data
VERA-CS Solution

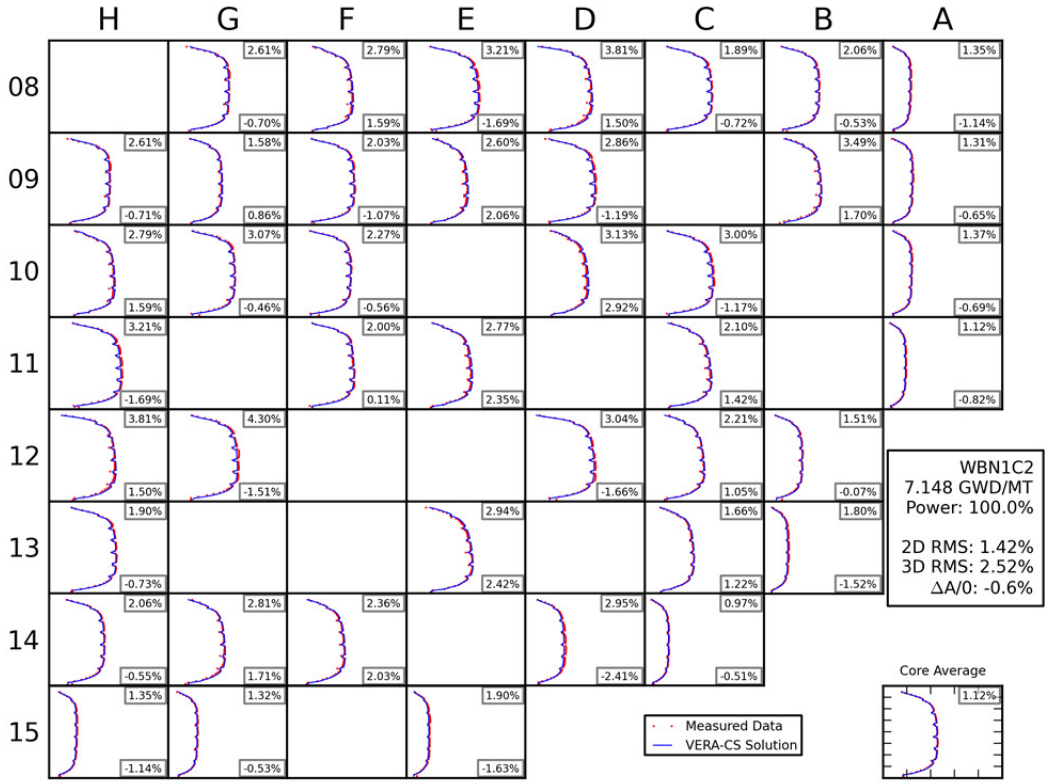

H G F E D C B A
08 09 10 11 12 13 14 15
5.90% -3.72%
2.75% -0.32%
3.89% -2.08%
3.93% 2.53%
2.45% 0.66%
2.15% 0.53%
1.34% -0.68%
5.90% -3.73%
2.03% -0.63%
4.51% -2.92%
2.89% 1.52%
3.84% -2.20%
3.47% 2.71%
1.65% 0.43%
2.75% -0.32%
3.80% -2.40%
4.17% -3.16%
3.83% 3.30%
3.26% -0.62%
0.97% -0.39%
3.89% -2.08%
3.14% 0.30%
3.01% 1.95%
3.50% 2.20%
0.87% -0.38%
3.93% 2.53%
3.24% -1.36%
4.45% 1.08%
1.99% -0.25%
1.76% 0.21%
2.45% 0.65%
4.32% 2.19%
3.57% 2.39%
1.28% -1.04%
2.14% 0.49%
3.75% 2.82%
3.70% 2.88%
2.57% -1.70%
1.23% -0.86%
1.34% -0.69%
2.02% 1.33%
1.60% -1.20%
WBN1C2
2.065 GWD/MT
Power: 100.0%
2D RMS: 1.79%
3D RMS: 3.11%
ΔA/0: 1.0%
Measured Data
VERA-CS Solution
Core Average
1.68%

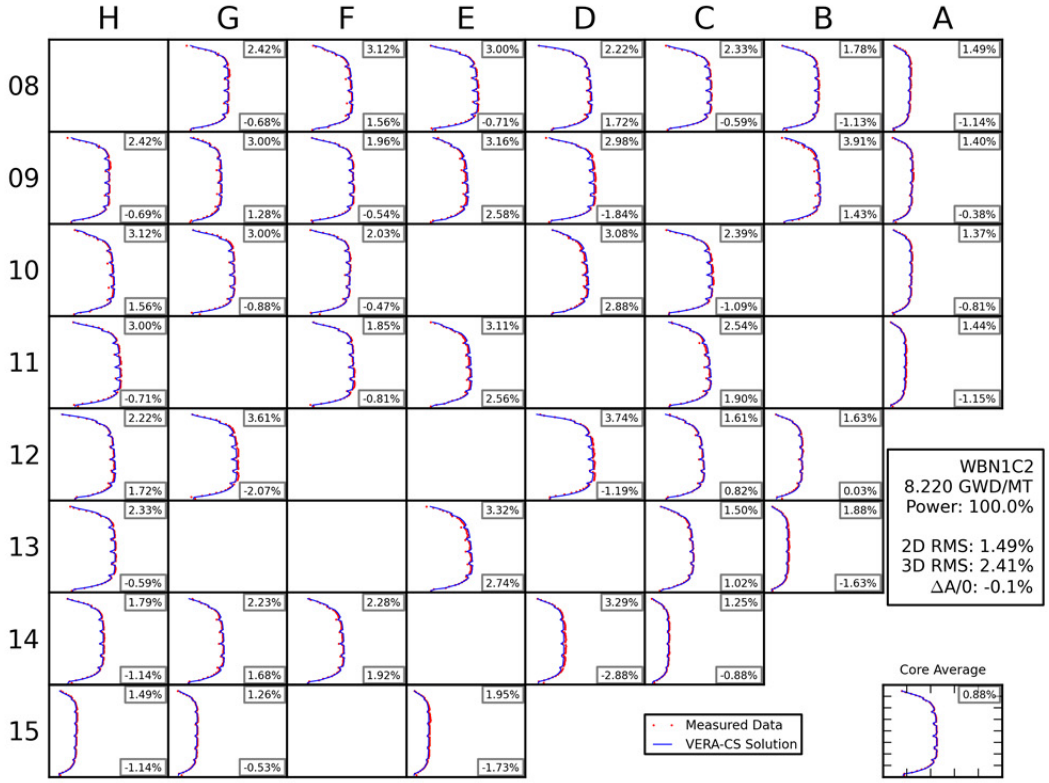

H G F E D C B A
08 09 10 11 12 13 14 15
4.78% -3.25%
2.05% -0.18%
3.31% -1.72%
5.39% 2.84%
1.71% 0.41%
2.07% 0.37%
0.95% -0.78%
4.78% -3.26%
1.35% -0.19%
3.61% -2.71%
2.45% 1.64%
3.41% -2.19%
2.97% 2.45%
1.41% -0.06%
2.05% -0.18%
3.13% -1.84%
2.98% -2.27%
4.36% 3.99%
2.01% -1.24%
0.86% -0.37%
3.31% -1.72%
2.38% -0.63%
3.04% 2.52%
4.20% 2.28%
1.00% -0.48%
5.39% 2.84%
2.50% -1.40%
3.01% -0.22%
1.61% -0.12%
1.46% -0.27%
1.71% 0.41%
3.94% 2.29%
2.91% 2.22%
1.13% -0.98%
2.06% 0.33%
3.58% 2.77%
3.22% 2.30%
2.31% -1.75%
0.96% -0.67%
0.95% -0.78%
1.86% 0.79%
1.52% -1.21%
WBN1C2
3.131 GWD/MT
Power: 99.9%
2D RMS: 1.73%
3D RMS: 2.85%
ΔA/0: 0.5%
Measured Data
VERA-CS Solution
Core Average
1.07%

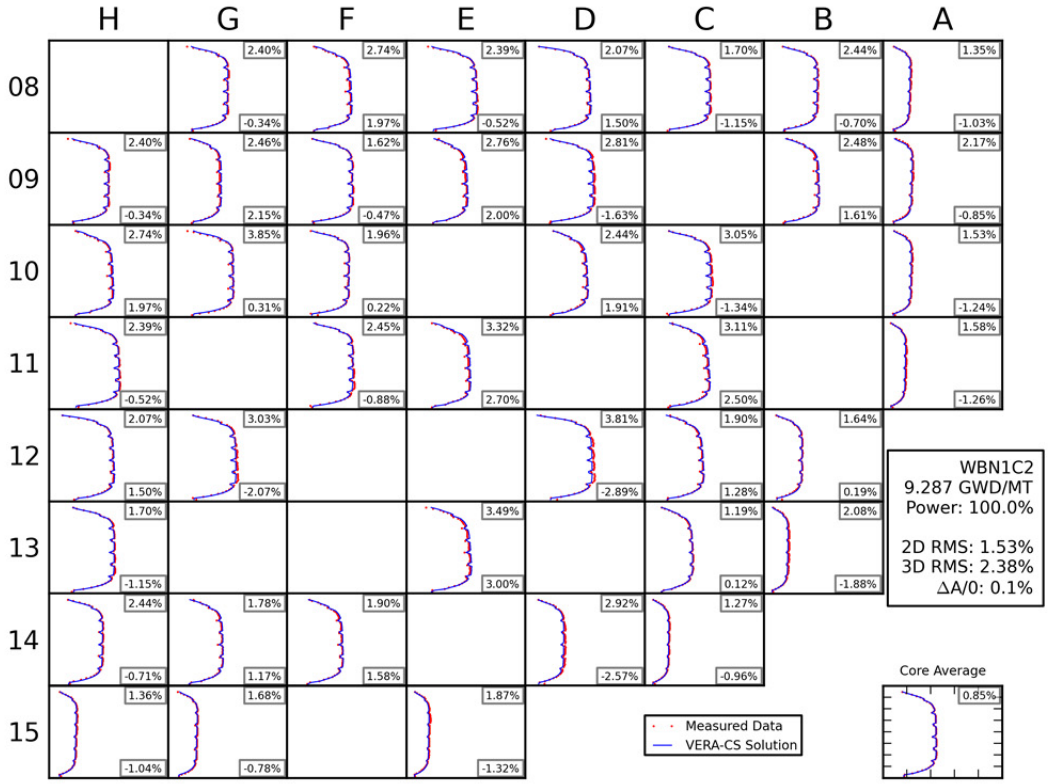

H G F E D C B A
08
09
10
11
12
13
14
15
WBN1C2
4.020 GWD/MT
Power: 99.9%
2D RMS: 1.74%
3D RMS: 2.64%
ΔA/0: -0.1%
Core Average
Measured Data
VERA-CS Solution

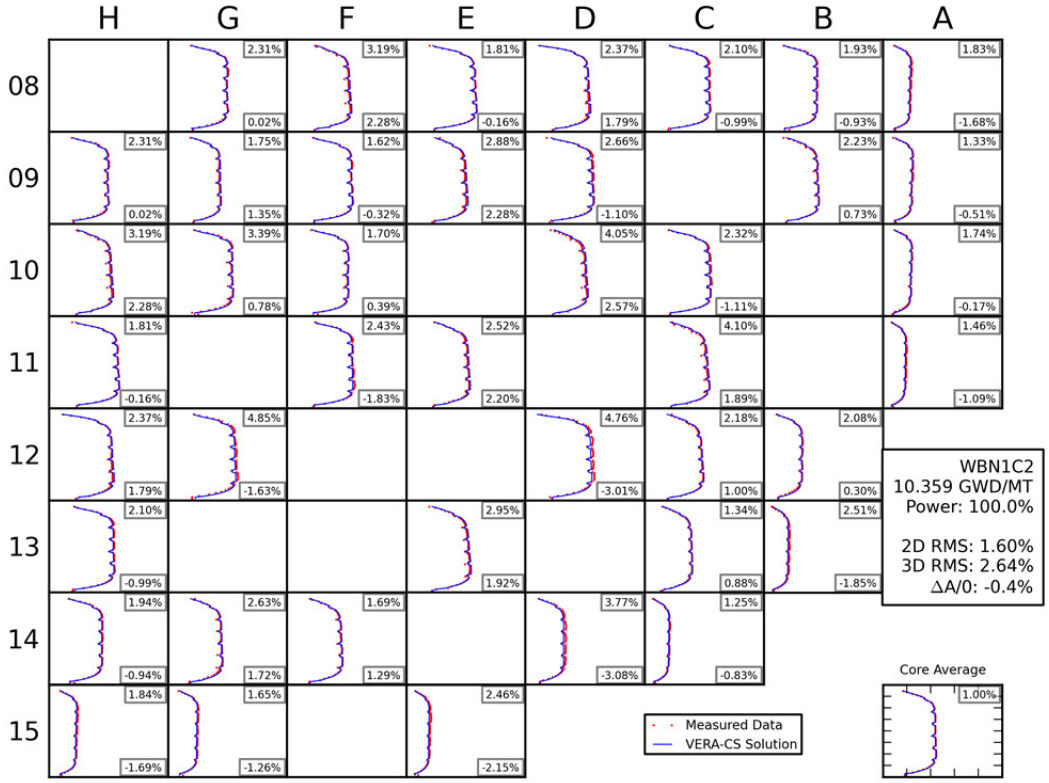

H G F E D C B A
08
09
10
11
12
13
14
15
WBN1C2
5.160 GWD/MT
Power: 100.0%
2D RMS: 1.52%
3D RMS: 2.56%
ΔA/0: -0.4%
Core Average
Measured Data
VERA-CS Solution

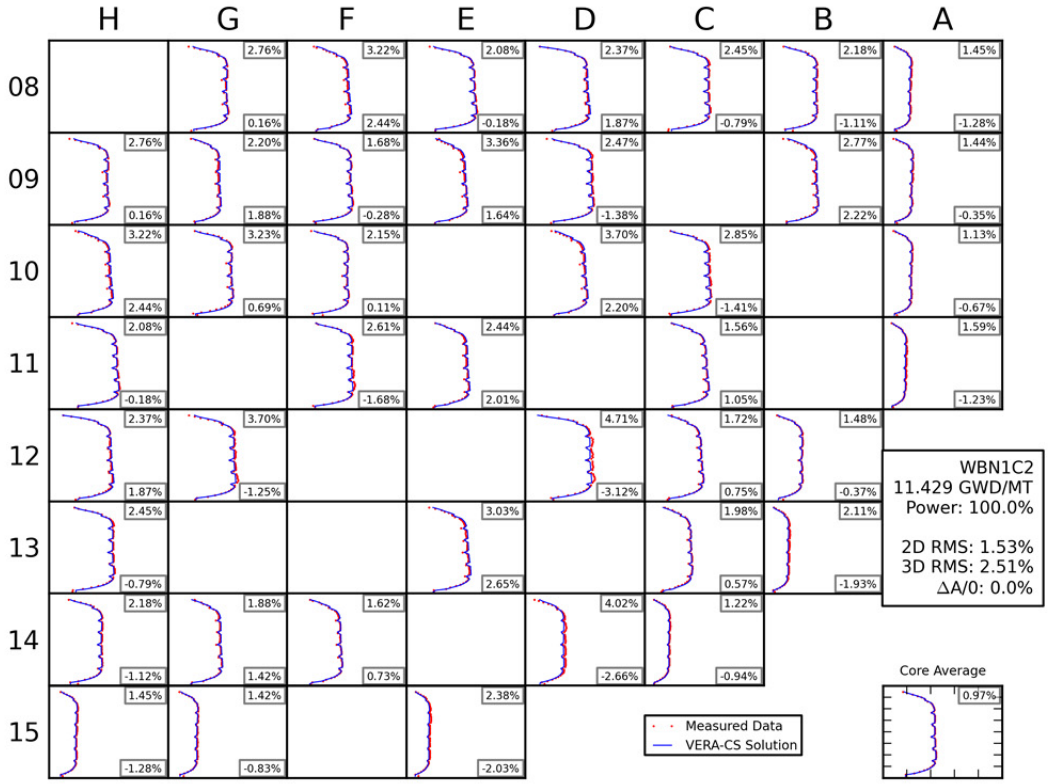

H G F E D C B A
08
09
10
11
12
13
14
15
WBN1C2
6.112 GWD/MT
Power: 99.9%
2D RMS: 1.62%
3D RMS: 2.48%
ΔA/0: -0.3%
Core Average
Measured Data
VERA-CS Solution

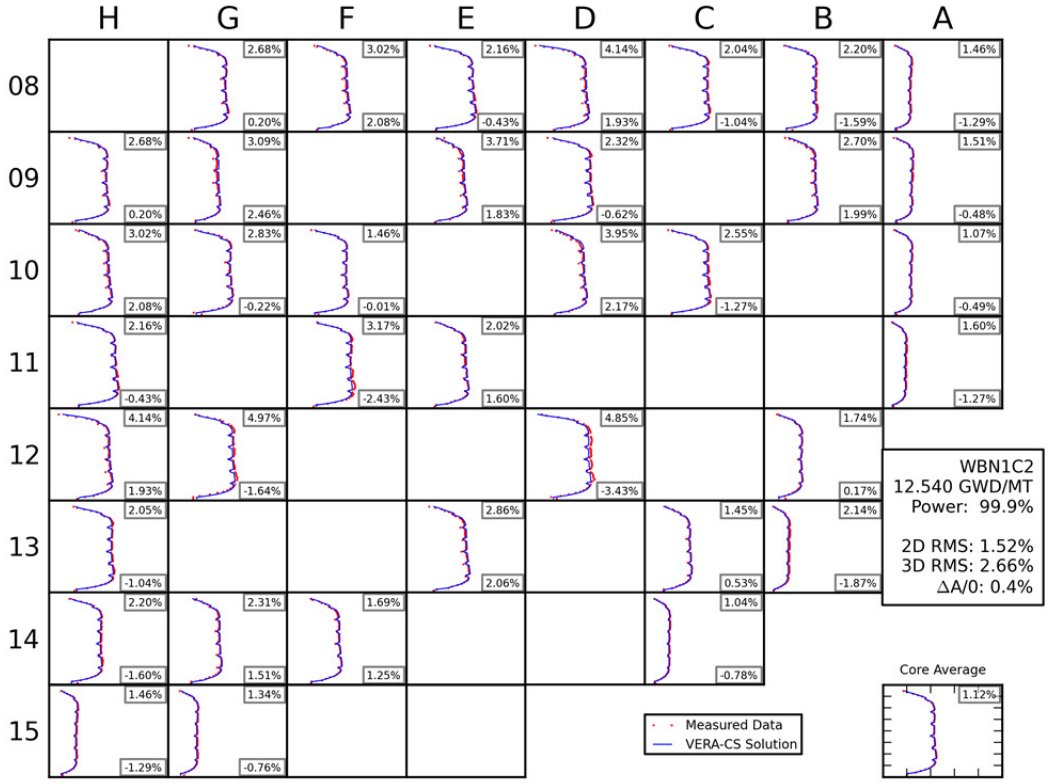

H G F E D C B A
08
09
10
11
12
13
14
15
WBN1C2
7.148 GWD/MT
Power: 100.0%
2D RMS: 1.42%
3D RMS: 2.52%
ΔA/0: -0.6%
Core Average
Measured Data
VERA-CS Solution

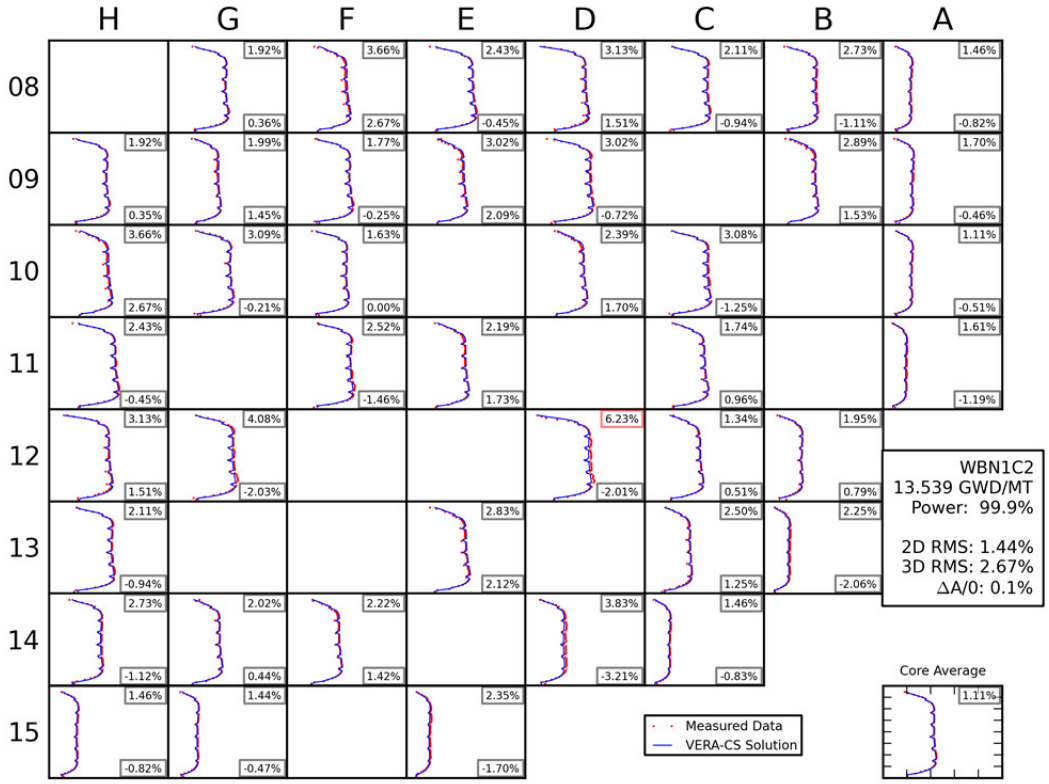

H G F E D C B A
08
09
10
11
12
13
14
15
WBN1C2
8.220 GWD/MT
Power: 100.0%
2D RMS: 1.49%
3D RMS: 2.41%
ΔA/0: -0.1%
Core Average
Measured Data
VERA-CS Solution

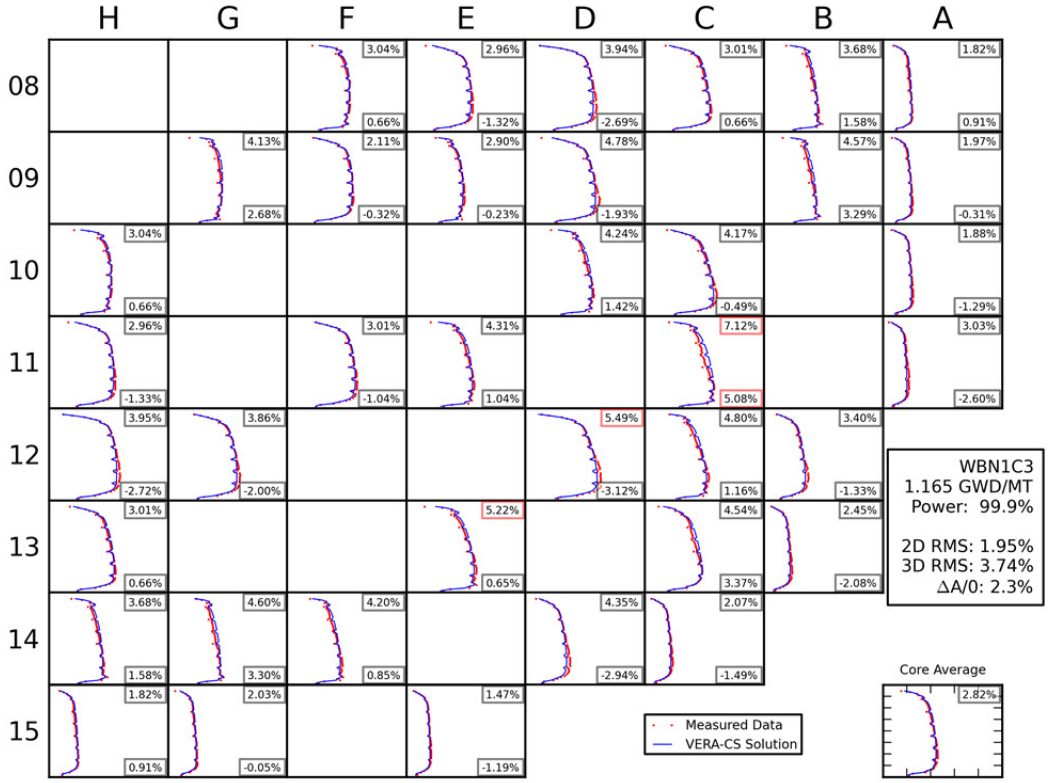

H G F E D C B A
08
09
10
11
12
13
14
15
WBN1C2
9.287 GWD/MT
Power: 100.0%
2D RMS: 1.53%
3D RMS: 2.38%
ΔA/0: 0.1%
Core Average
Measured Data
VERA-CS Solution

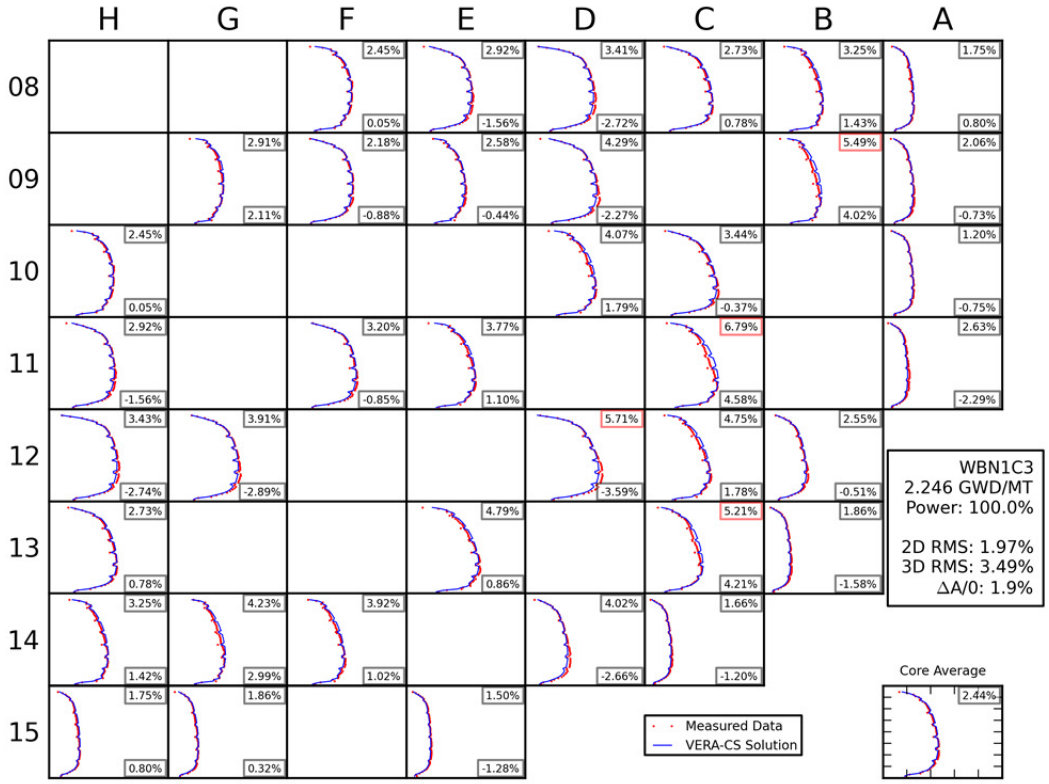

H G F E D C B A
08
2.31% 0.02%
3.19% 2.28%
1.81% -0.16%
2.37% 1.79%
2.10% -0.99%
1.93% -0.93%
1.83% -1.68%
09
2.31% 0.02%
1.75% 1.35%
1.62% -0.32%
2.88% 2.28%
2.66% -1.10%
2.23% 0.73%
1.33% -0.51%
10
3.19% 2.28%
3.39% 0.78%
1.70% 0.39%
4.05% 2.57%
2.32% -1.11%
1.74% -0.17%
11
1.81% -0.16%
2.43% -1.83%
2.52% 2.20%
4.10% 1.89%
1.46% -1.09%
12
2.37% 1.79%
4.85% -1.63%
4.76% -3.01%
2.18% 1.00%
2.08% 0.30%
13
2.10% -0.99%
2.95% 1.92%
1.34% 0.88%
2.51% -1.85%
14
1.94% -0.94%
2.63% 1.72%
1.69% 1.29%
3.77% -3.08%
1.25% -0.83%
15
1.84% -1.69%
1.65% -1.26%
2.46% -2.15%
WBN1C2
10.359 GWD/MT
Power: 100.0%
2D RMS: 1.60%
3D RMS: 2.64%
ΔA/0: -0.4%
Measured Data
VERA-CS Solution
Core Average
1.00%

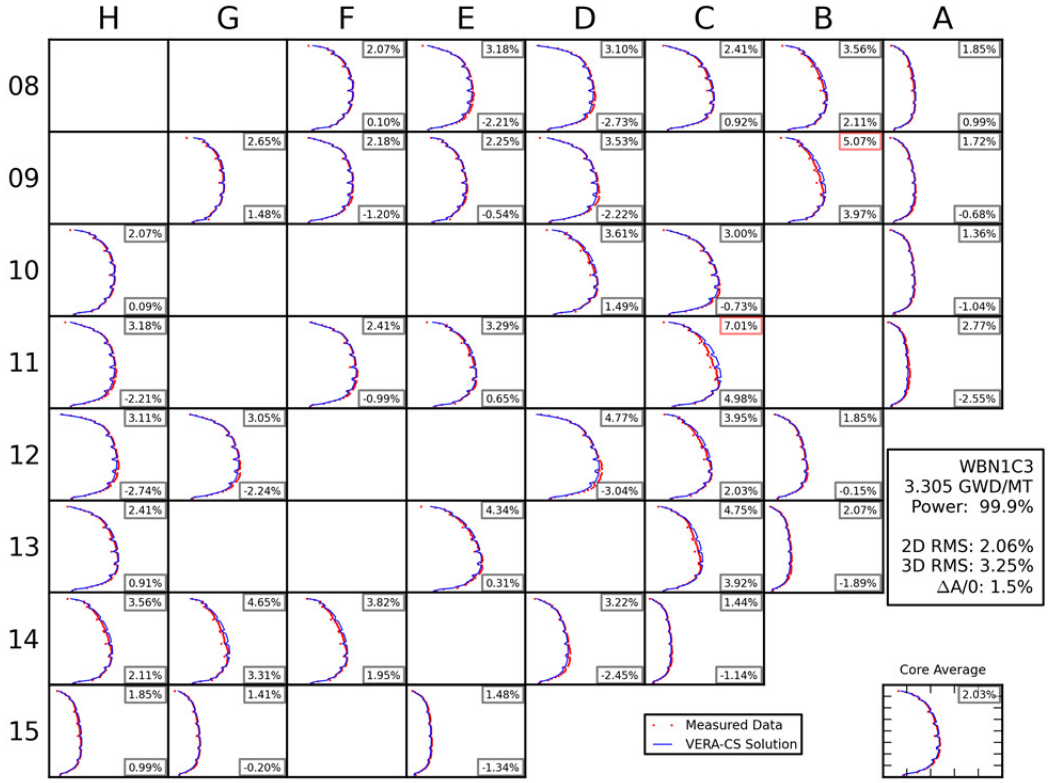

H G F E D C B A
08
2.76% 0.16%
3.22% 2.44%
2.08% -0.18%
2.37% 1.87%
2.45% -0.79%
2.18% -1.11%
1.45% -1.28%
09
2.76% 0.16%
2.20% 1.88%
1.68% -0.28%
3.36% 1.64%
2.47% -1.38%
2.77% 2.22%
1.44% -0.35%
10
3.22% 2.44%
3.23% 0.69%
2.15% 0.11%
3.70% 2.20%
2.85% -1.41%
1.13% -0.67%
11
2.08% -0.18%
2.61% -1.68%
2.44% 2.01%
1.56% 1.05%
1.59% -1.23%
12
2.37% 1.87%
3.70% -1.25%
4.71% -3.12%
1.72% 0.75%
1.48% -0.37%
13
2.45% -0.79%
3.03% 2.65%
1.98% 0.57%
2.11% -1.93%
14
2.18% -1.12%
1.88% 1.42%
1.62% 0.73%
4.02% -2.66%
1.22% -0.94%
15
1.45% -1.28%
1.42% -0.83%
2.38% -2.03%
WBN1C2
11.429 GWD/MT
Power: 100.0%
2D RMS: 1.53%
3D RMS: 2.51%
ΔA/0: 0.0%
Measured Data
VERA-CS Solution
Core Average
0.97%

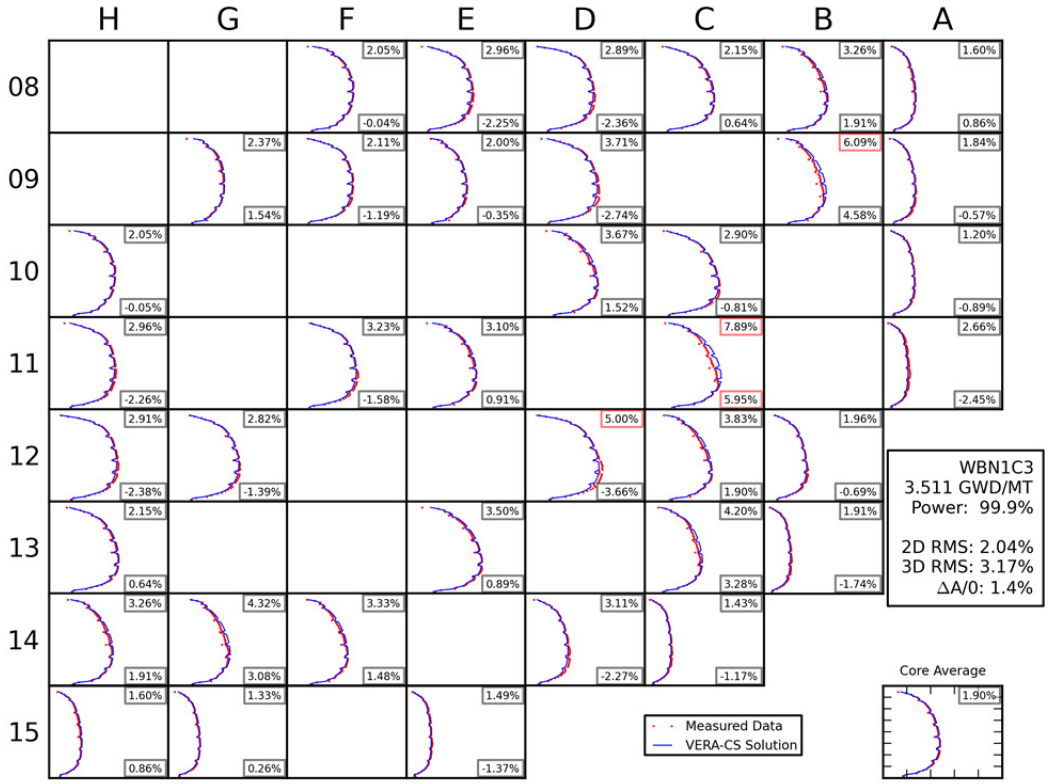

H G F E D C B A
08
09
10
11
12
13
14
15
WBN1C2
12.540 GWD/MT
Power: 99.9%
2D RMS: 1.52%
3D RMS: 2.66%
ΔA/0: 0.4%
Core Average
Measured Data
VERA-CS Solution

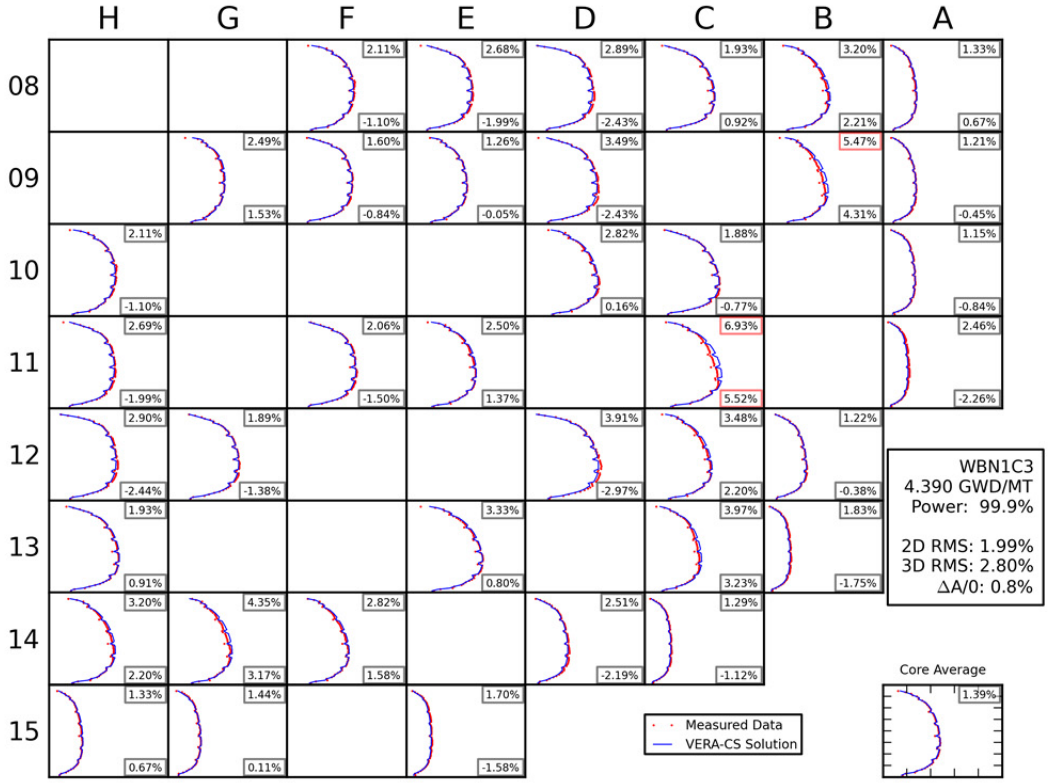

H G F E D C B A
08
09
10
11
12
13
14
15
WBN1C2
13.539 GWD/MT
Power: 99.9%
2D RMS: 1.44%
3D RMS: 2.67%
ΔA/0: 0.1%
Core Average
Measured Data
VERA-CS Solution

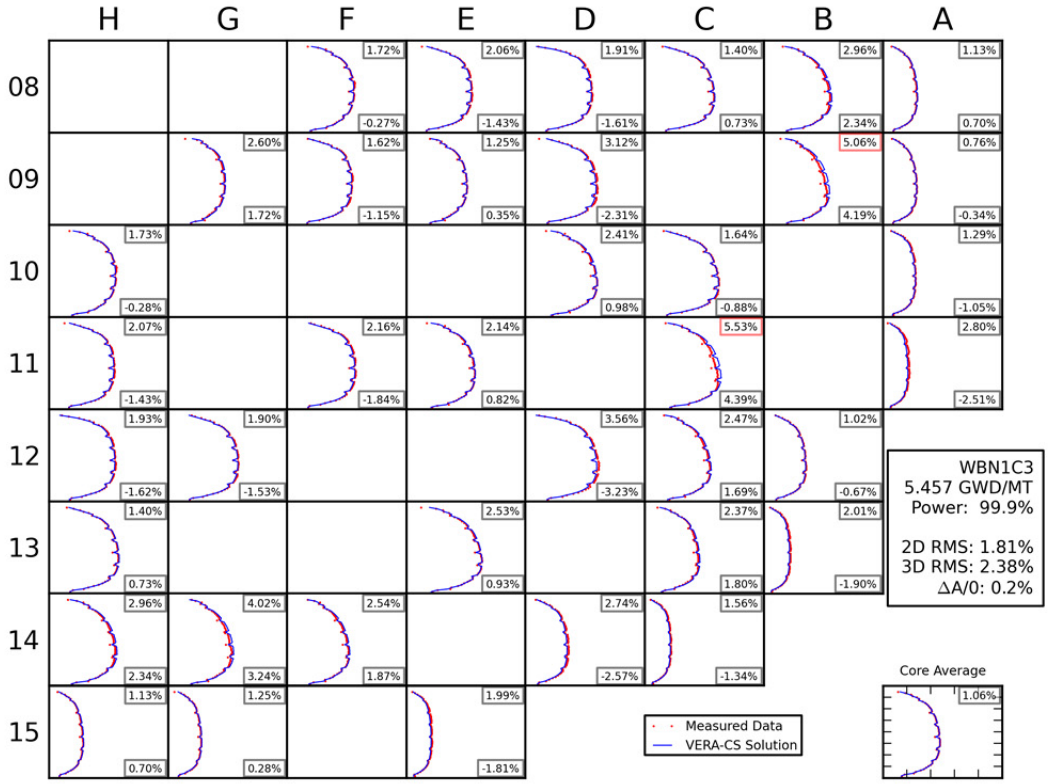

H G F E D C B A
08 09 10 11 12 13 14 15
3.04% 0.66%
2.96% -1.32%
3.94% -2.69%
3.01% 0.66%
3.68% 1.58%
1.82% 0.91%
4.13% 2.68%
2.11% -0.32%
2.90% -0.23%
4.78% -1.93%
4.57% 3.29%
1.97% -0.31%
3.04% 0.66%
4.24% 1.42%
4.17% -0.49%
1.88% -1.29%
2.96% -1.33%
3.01% -1.04%
4.31% 1.04%
7.12% 5.08%
3.03% -2.60%
3.95% -2.72%
3.86% -2.00%
5.49% -3.12%
4.80% 1.16%
3.40% -1.33%
3.01% 0.66%
5.22% 0.65%
4.54% 3.37%
2.45% -2.08%
3.68% 1.58%
4.60% 3.30%
4.20% 0.85%
4.35% -2.94%
2.07% -1.49%
1.82% 0.91%
2.03% -0.05%
1.47% -1.19%
WBN1C3
1.165 GWD/MT
Power: 99.9%
2D RMS: 1.95%
3D RMS: 3.74%
ΔA/0: 2.3%
Measured Data
VERA-CS Solution
Core Average
2.82%

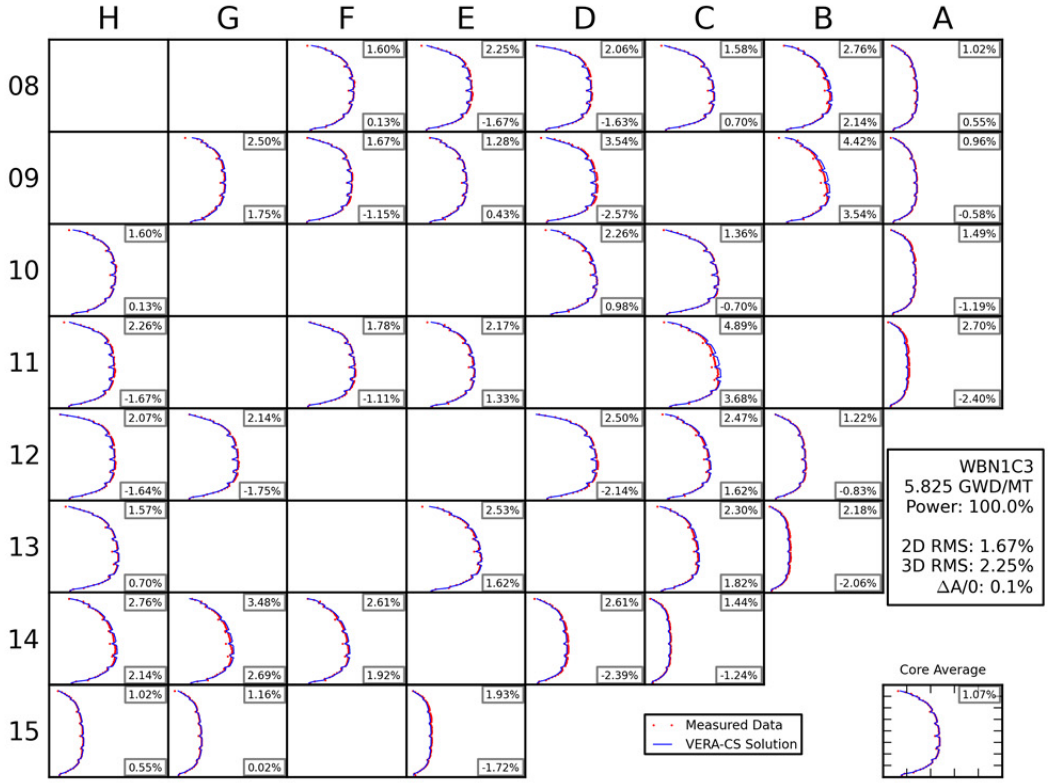

H G F E D C B A
08 09 10 11 12 13 14 15
2.45% 0.05%
2.92% -1.56%
3.41% -2.72%
2.73% 0.78%
3.25% 1.43%
1.75% 0.80%
2.91% 2.11%
2.18% -0.88%
2.58% -0.44%
4.29% -2.27%
5.49% 4.02%
2.06% -0.73%
2.45% 0.05%
4.07% 1.79%
3.44% -0.37%
1.20% -0.75%
2.92% -1.56%
3.20% -0.85%
3.77% 1.10%
6.79% 4.58%
2.63% -2.29%
3.43% -2.74%
3.91% -2.89%
5.71% -3.59%
4.75% 1.78%
2.55% -0.51%
2.73% 0.78%
4.79% 0.86%
5.21% 4.21%
1.86% -1.58%
3.25% 1.42%
4.23% 2.99%
3.92% 1.02%
4.02% -2.66%
1.66% -1.20%
1.75% 0.80%
1.86% 0.32%
1.50% -1.28%
WBN1C3
2.246 GWD/MT
Power: 100.0%
2D RMS: 1.97%
3D RMS: 3.49%
ΔA/0: 1.9%
Measured Data
VERA-CS Solution
Core Average
2.44%

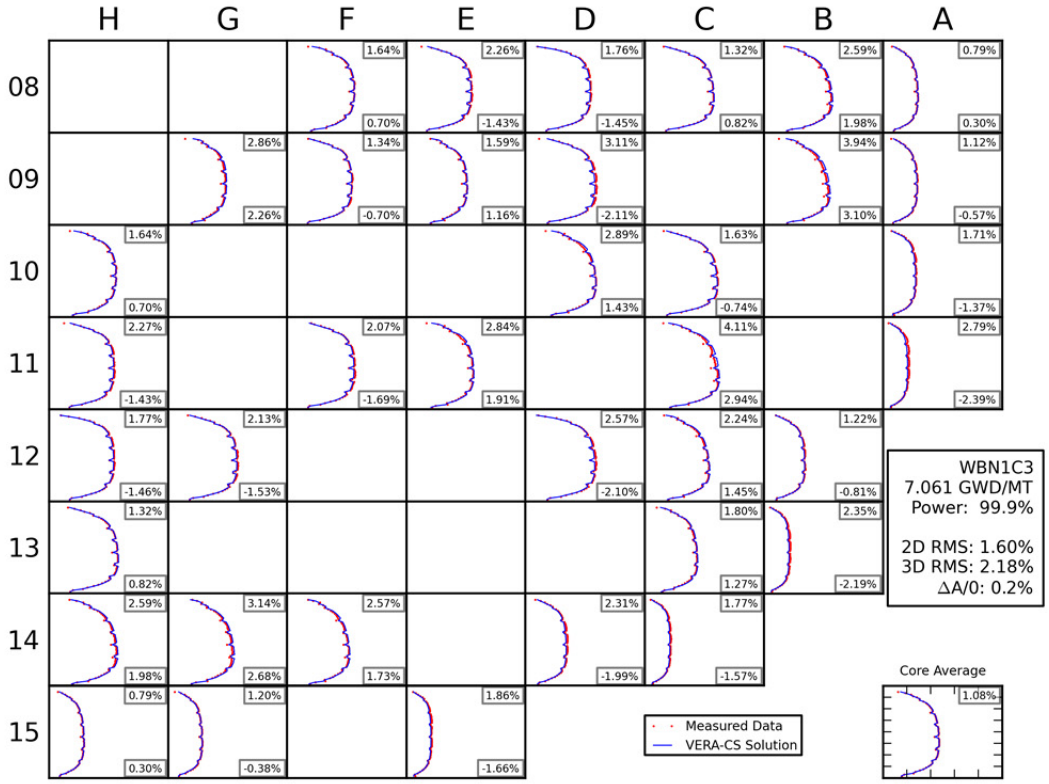

H G F E D C B A
08
09
10
11
12
13
14
15
WBN1C3
3.305 GWD/MT
Power: 99.9%
2D RMS: 2.06%
3D RMS: 3.25%
ΔA/0: 1.5%
Core Average
Measured Data
VERA-CS Solution

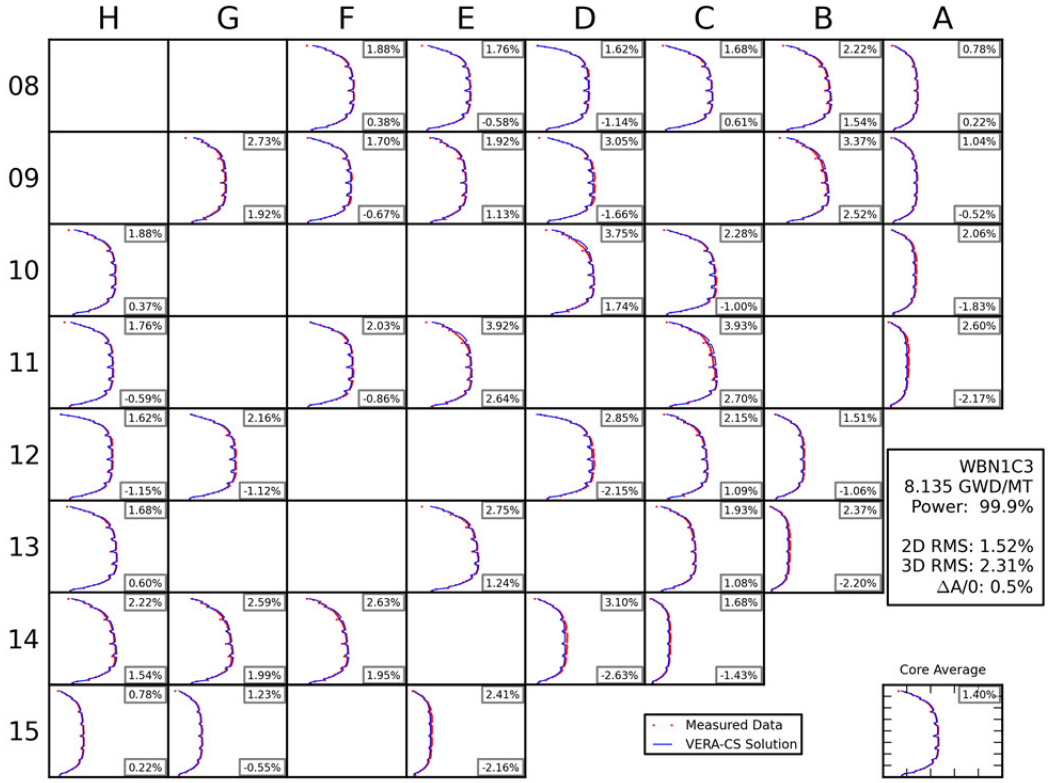

H G F E D C B A
08
09
10
11
12
13
14
15
WBN1C3
3.511 GWD/MT
Power: 99.9%
2D RMS: 2.04%
3D RMS: 3.17%
ΔA/0: 1.4%
Core Average
Measured Data
VERA-CS Solution

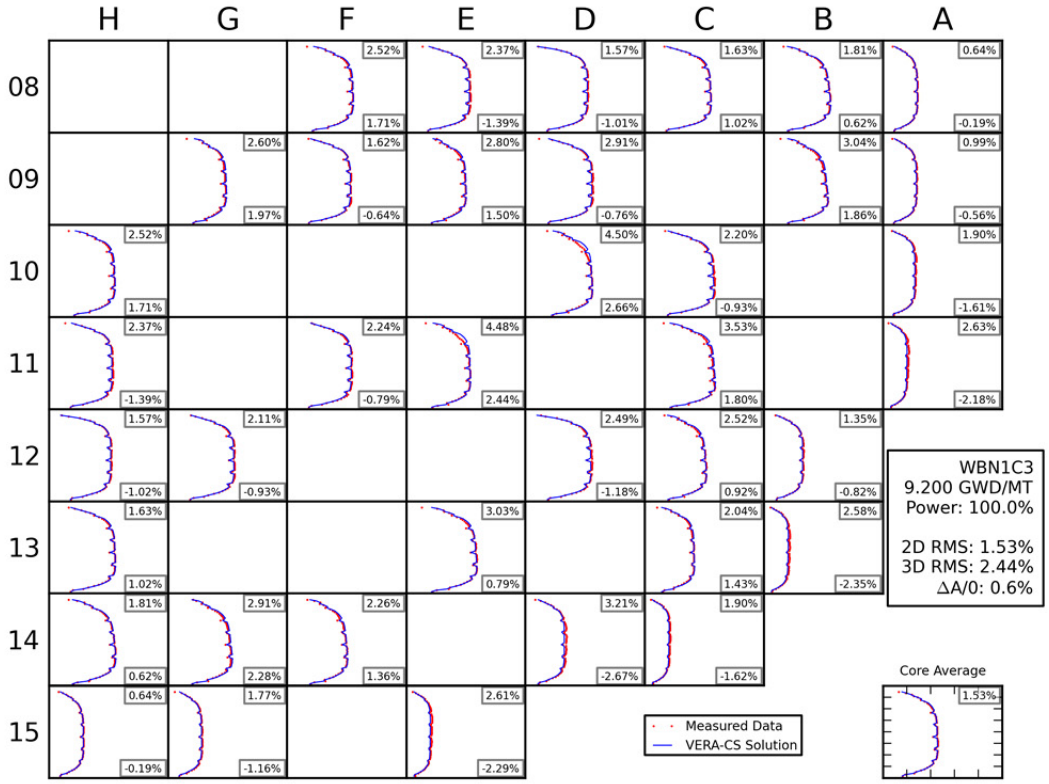

H G F E D C B A
08 09 10 11 12 13 14 15
2.11% -1.10%
2.68% -1.99%
2.89% -2.43%
1.93% 0.92%
3.20% 2.21%
1.33% 0.67%
2.49% 1.53%
1.60% -0.84%
1.26% -0.05%
3.49% -2.43%
5.47% 4.31%
1.21% -0.45%
2.11% -1.10%
2.82% 0.16%
1.88% -0.77%
1.15% -0.84%
2.69% -1.99%
2.06% -1.50%
2.50% 1.37%
6.93% 5.52%
2.46% -2.26%
2.90% -2.44%
1.89% -1.38%
3.91% -2.97%
3.48% 2.20%
1.22% -0.38%
1.93% 0.91%
3.33% 0.80%
3.97% 3.23%
1.83% -1.75%
3.20% 2.20%
4.35% 3.17%
2.82% 1.58%
2.51% -2.19%
1.29% -1.12%
1.33% 0.67%
1.44% 0.11%
1.70% -1.58%
WBN1C3
4.390 GWD/MT
Power: 99.9%
2D RMS: 1.99%
3D RMS: 2.80%
ΔA/0: 0.8%
Measured Data
VERA-CS Solution
Core Average
1.39%

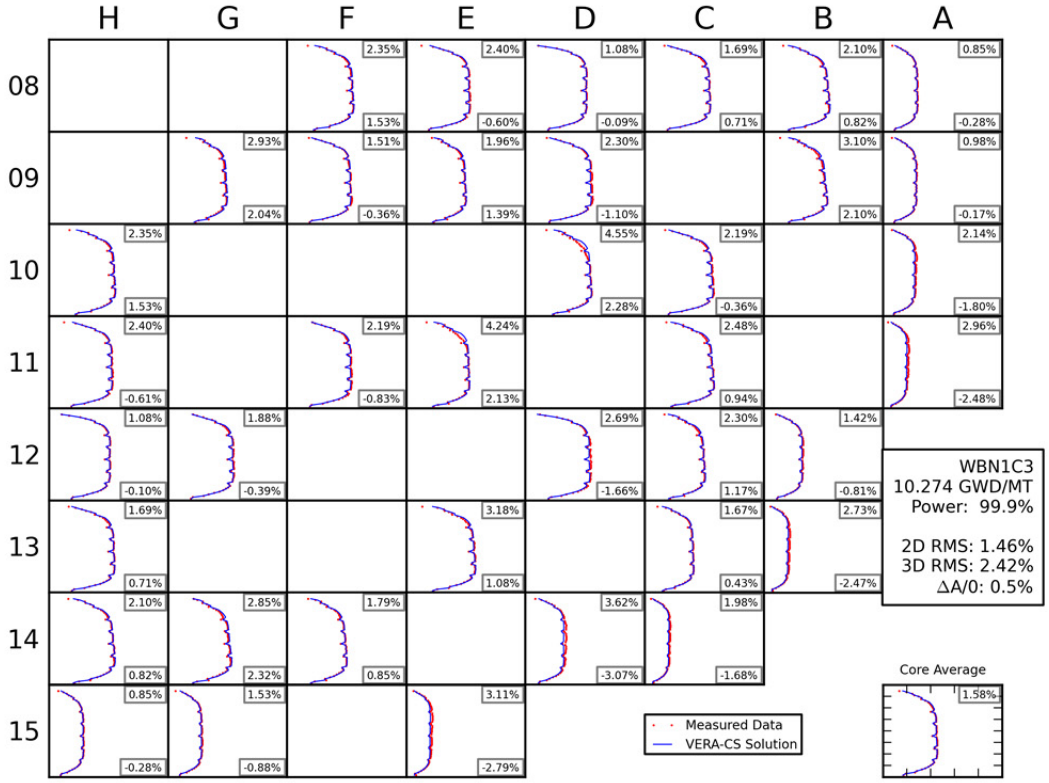

H G F E D C B A
08 09 10 11 12 13 14 15
1.72% -0.27%
2.06% -1.43%
1.91% -1.61%
1.40% 0.73%
2.96% 2.34%
1.13% 0.70%
2.60% 1.72%
1.62% -1.15%
1.25% 0.35%
3.12% -2.31%
5.06% 4.19%
0.76% -0.34%
1.73% -0.28%
2.41% 0.98%
1.64% -0.88%
1.29% -1.05%
2.07% -1.43%
2.16% -1.84%
2.14% 0.82%
5.53% 4.39%
2.80% -2.51%
1.93% -1.62%
1.90% -1.53%
3.56% -3.23%
2.47% 1.69%
1.02% -0.67%
1.40% 0.73%
2.53% 0.93%
2.37% 1.80%
2.01% -1.90%
2.96% 2.34%
4.02% 3.24%
2.54% 1.87%
2.74% -2.57%
1.56% -1.34%
1.13% 0.70%
1.25% 0.28%
1.99% -1.81%
WBN1C3
5.457 GWD/MT
Power: 99.9%
2D RMS: 1.81%
3D RMS: 2.38%
ΔA/0: 0.2%
Measured Data
VERA-CS Solution
Core Average
1.06%

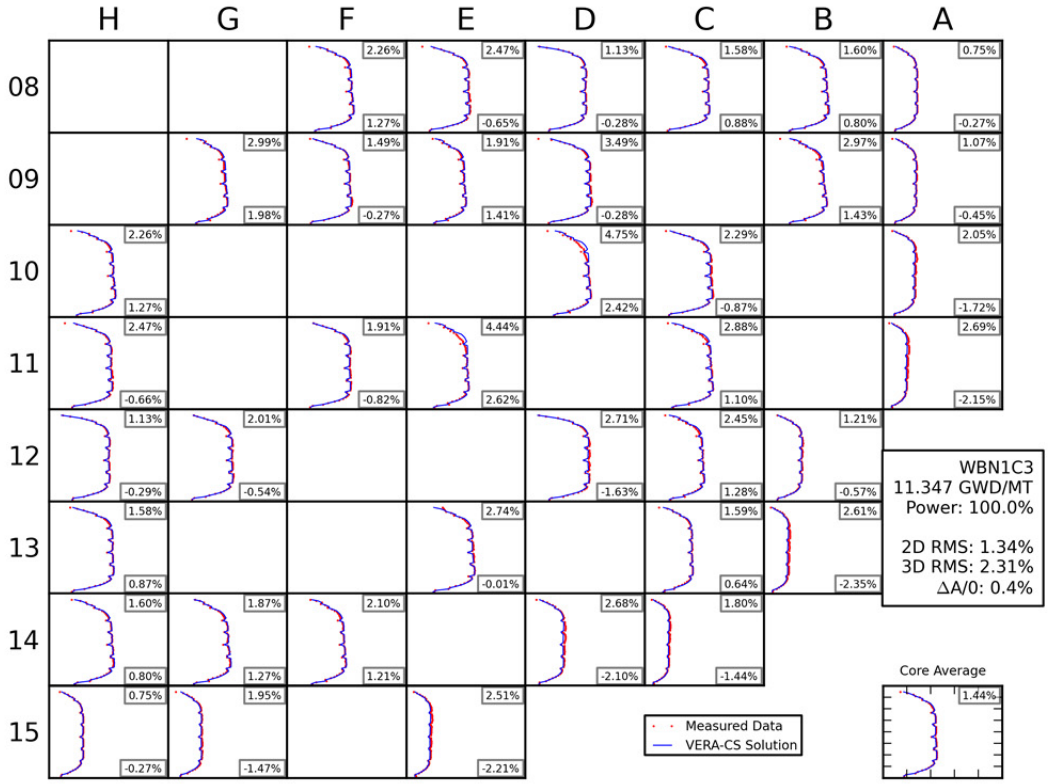

H G F E D C B A
08
1.60% 0.13%
2.25% -1.67%
2.06% -1.63%
1.58% 0.70%
2.76% 2.14%
1.02% 0.55%
09
2.50% 1.75%
1.67% -1.15%
1.28% 0.43%
3.54% -2.57%
4.42% 3.54%
0.96% -0.58%
10
1.60% 0.13%
2.26% 0.98%
1.36% -0.70%
1.49% -1.19%
11
2.26% -1.67%
1.78% -1.11%
2.17% 1.33%
4.89% 3.68%
2.70% -2.40%
12
2.07% -1.64%
2.14% -1.75%
2.50% -2.14%
2.47% 1.62%
1.22% -0.83%
13
1.57% 0.70%
2.53% 1.62%
2.30% 1.82%
2.18% -2.06%
14
2.76% 2.14%
3.48% 2.69%
2.61% 1.92%
2.61% -2.39%
1.44% -1.24%
15
1.02% 0.55%
1.16% 0.02%
1.93% -1.72%
WBN1C3
5.825 GWD/MT
Power: 100.0%
2D RMS: 1.67%
3D RMS: 2.25%
ΔA/0: 0.1%
Measured Data
VERA-CS Solution
Core Average
1.07%

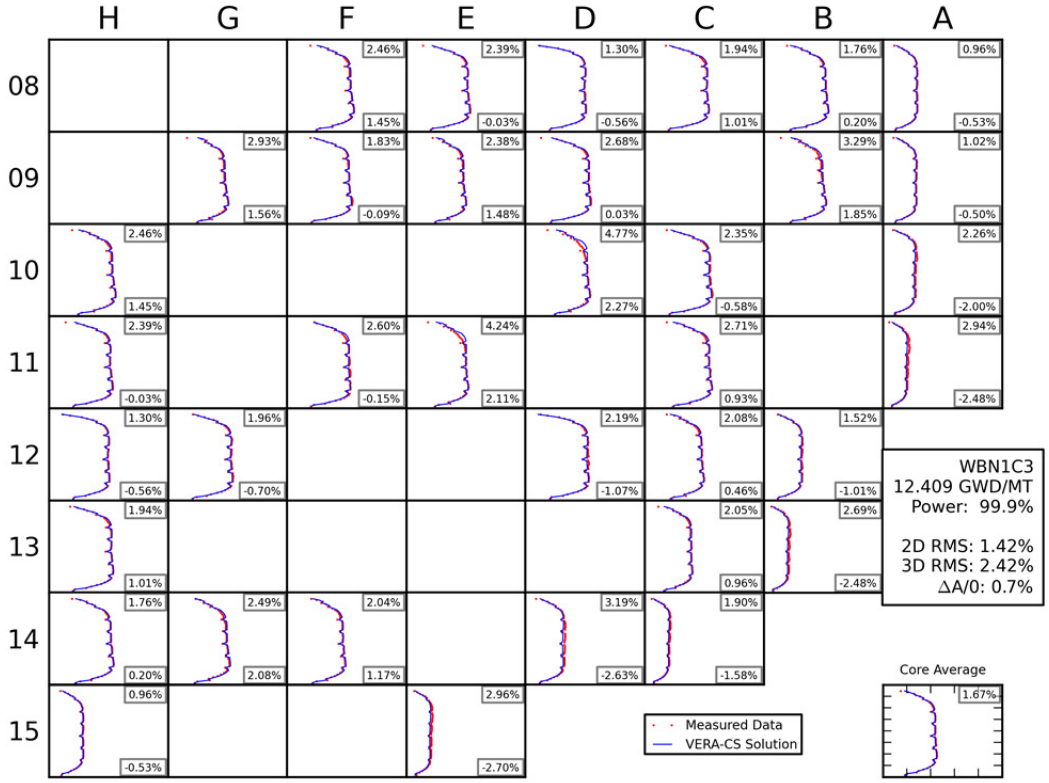

H G F E D C B A
08
1.64% 0.70%
2.26% -1.43%
1.76% -1.45%
1.32% 0.82%
2.59% 1.98%
0.79% 0.30%
09
2.86% 2.26%
1.34% -0.70%
1.59% 1.16%
3.11% -2.11%
3.94% 3.10%
1.12% -0.57%
10
1.64% 0.70%
2.89% 1.43%
1.63% -0.74%
1.71% -1.37%
11
2.27% -1.43%
2.07% -1.69%
2.84% 1.91%
4.11% 2.94%
2.79% -2.39%
12
1.77% -1.46%
2.13% -1.53%
2.57% -2.10%
2.24% 1.45%
1.22% -0.81%
13
1.32% 0.82%
1.80% 1.27%
2.35% -2.19%
14
2.59% 1.98%
3.14% 2.68%
2.57% 1.73%
2.31% -1.99%
1.77% -1.57%
15
0.79% 0.30%
1.20% -0.38%
1.86% -1.66%
WBN1C3
7.061 GWD/MT
Power: 99.9%
2D RMS: 1.60%
3D RMS: 2.18%
ΔA/0: 0.2%
Measured Data
VERA-CS Solution
Core Average
1.08%

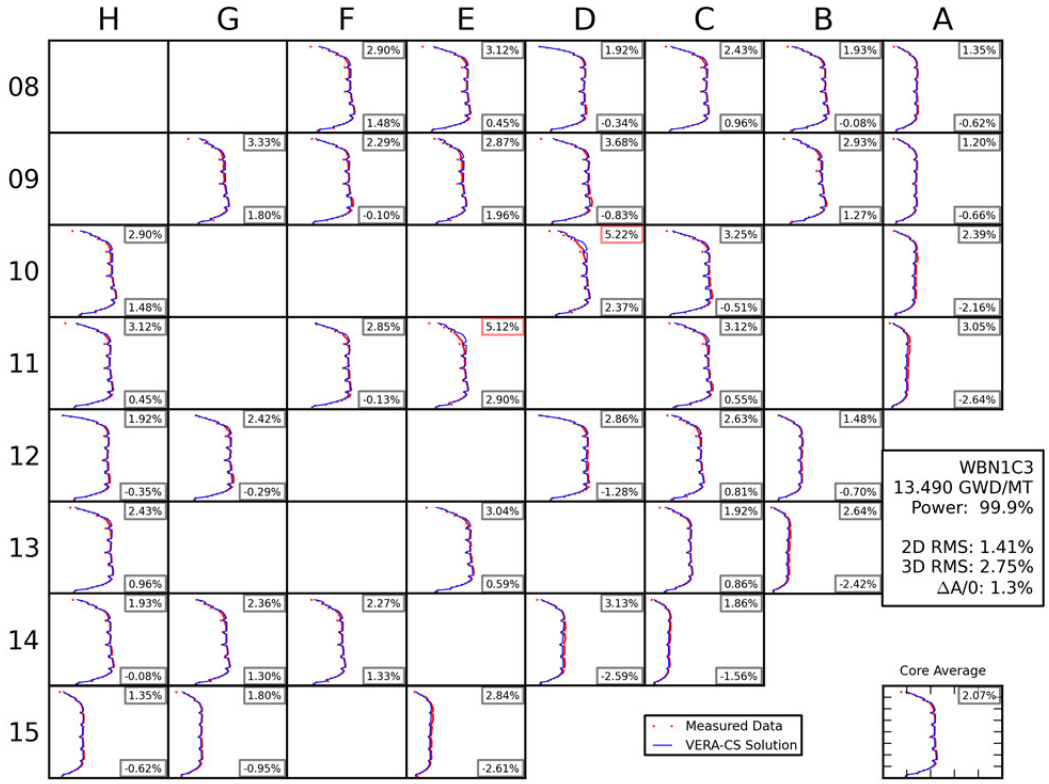

H G F E D C B A
08
09
10
11
12
13
14
15
WBN1C3
8.135 GWD/MT
Power: 99.9%
2D RMS: 1.52%
3D RMS: 2.31%
ΔA/0: 0.5%
Core Average
Measured Data
VERA-CS Solution

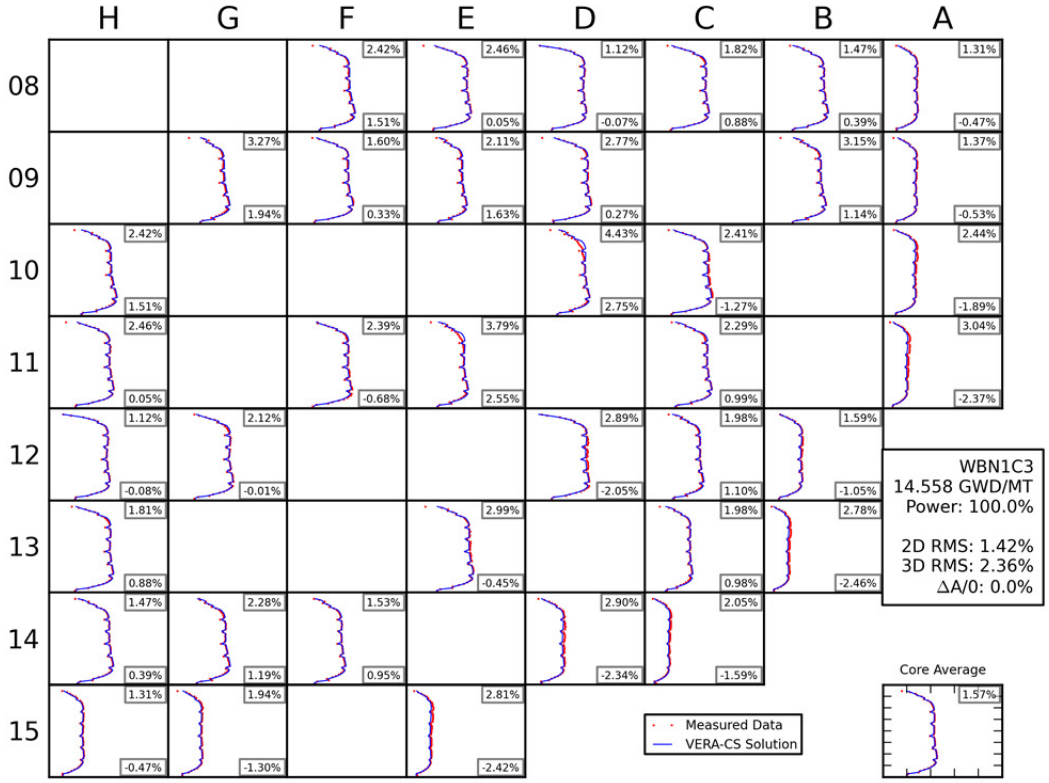

H G F E D C B A
08
09
10
11
12
13
14
15
WBN1C3
9.200 GWD/MT
Power: 100.0%
2D RMS: 1.53%
3D RMS: 2.44%
ΔA/0: 0.6%
Core Average
Measured Data
VERA-CS Solution

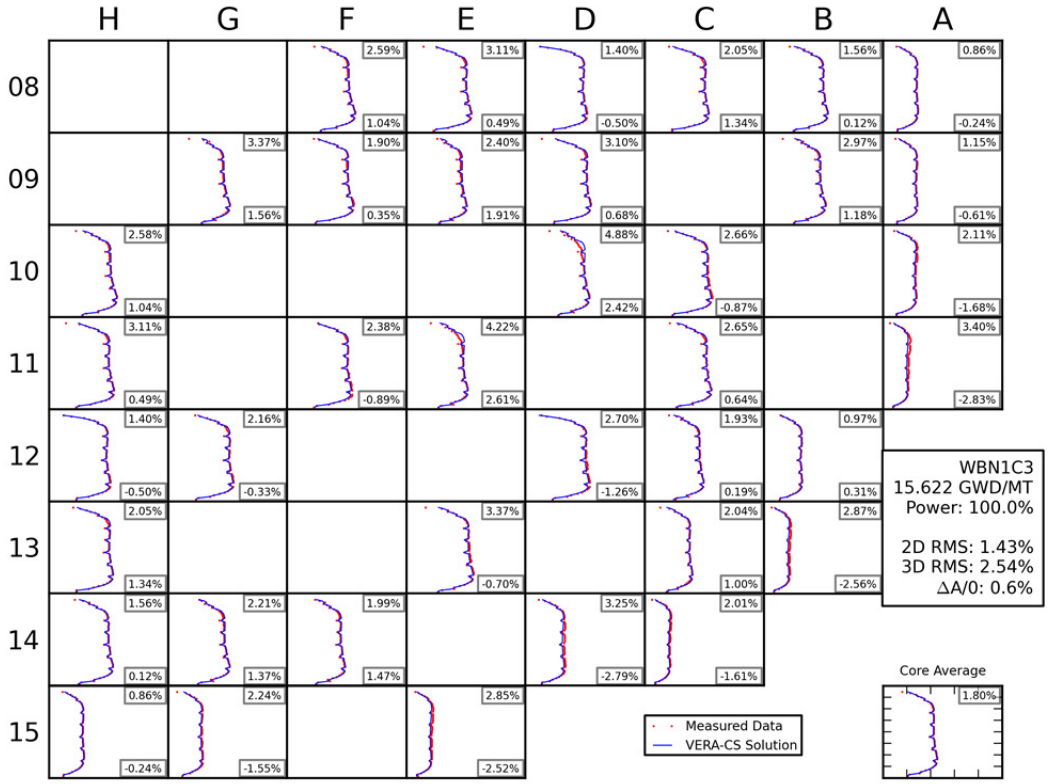

H G F E D C B A
08 09 10 11 12 13 14 15
2.35% 1.53%
2.40% -0.60%
1.08% -0.09%
1.69% 0.71%
2.10% 0.82%
0.85% -0.28%
2.93% 2.04%
1.51% -0.36%
1.96% 1.39%
2.30% -1.10%
3.10% 2.10%
0.98% -0.17%
2.35% 1.53%
4.55% 2.28%
2.19% -0.36%
2.14% -1.80%
2.40% -0.61%
2.19% -0.83%
4.24% 2.13%
2.48% 0.94%
2.96% -2.48%
1.08% -0.10%
1.88% -0.39%
2.69% -1.66%
2.30% 1.17%
1.42% -0.81%
1.69% 0.71%
3.18% 1.08%
1.67% 0.43%
2.73% -2.47%
2.10% 0.82%
2.85% 2.32%
1.79% 0.85%
3.62% -3.07%
1.98% -1.68%
0.85% -0.28%
1.53% -0.88%
3.11% -2.79%
WBN1C3
10.274 GWD/MT
Power: 99.9%
2D RMS: 1.46%
3D RMS: 2.42%
ΔA/0: 0.5%
Measured Data
VERA-CS Solution
Core Average
1.58%

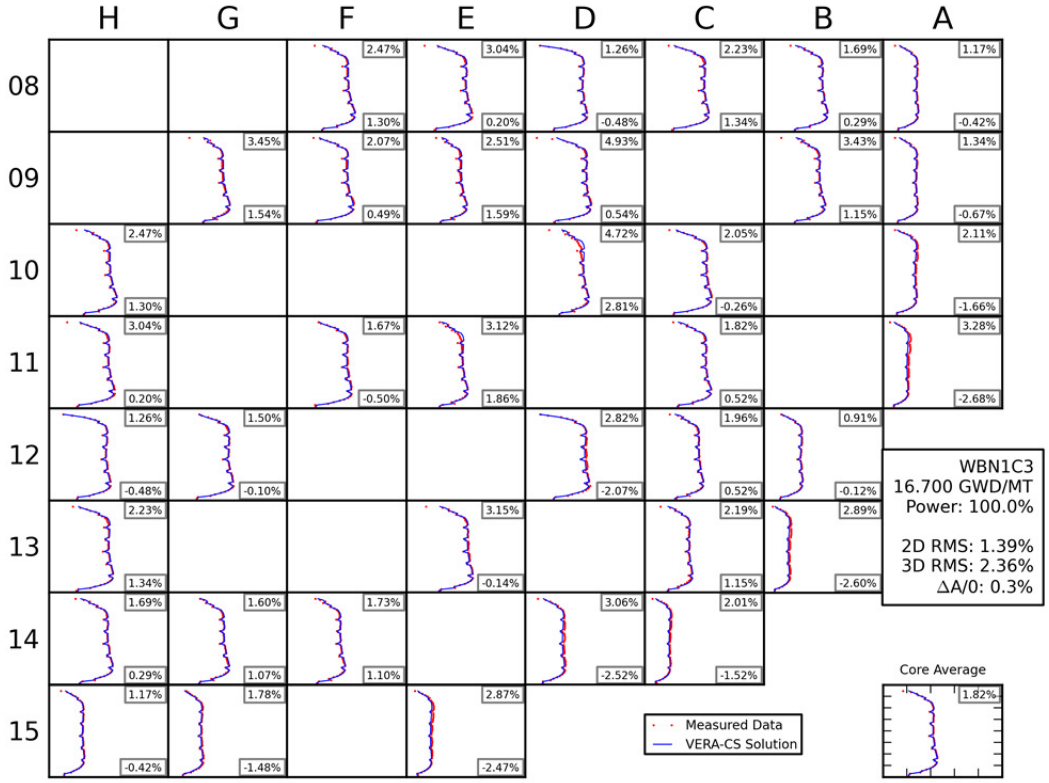

H G F E D C B A
08 09 10 11 12 13 14 15
2.26% 1.27%
2.47% -0.65%
1.13% -0.28%
1.58% 0.88%
1.60% 0.80%
0.75% -0.27%
2.99% 1.98%
1.49% -0.27%
1.91% 1.41%
3.49% -0.28%
2.97% 1.43%
1.07% -0.45%
2.26% 1.27%
4.75% 2.42%
2.29% -0.87%
2.05% -1.72%
2.47% -0.66%
1.91% -0.82%
4.44% 2.62%
2.88% 1.10%
2.69% -2.15%
1.13% -0.29%
2.01% -0.54%
2.71% -1.63%
2.45% 1.28%
1.21% -0.57%
1.58% 0.87%
2.74% -0.01%
1.59% 0.64%
2.61% -2.35%
1.60% 0.80%
1.87% 1.27%
2.10% 1.21%
2.68% -2.10%
1.80% -1.44%
0.75% -0.27%
1.95% -1.47%
2.51% -2.21%
WBN1C3
11.347 GWD/MT
Power: 100.0%
2D RMS: 1.34%
3D RMS: 2.31%
ΔA/0: 0.4%
Measured Data
VERA-CS Solution
Core Average
1.44%

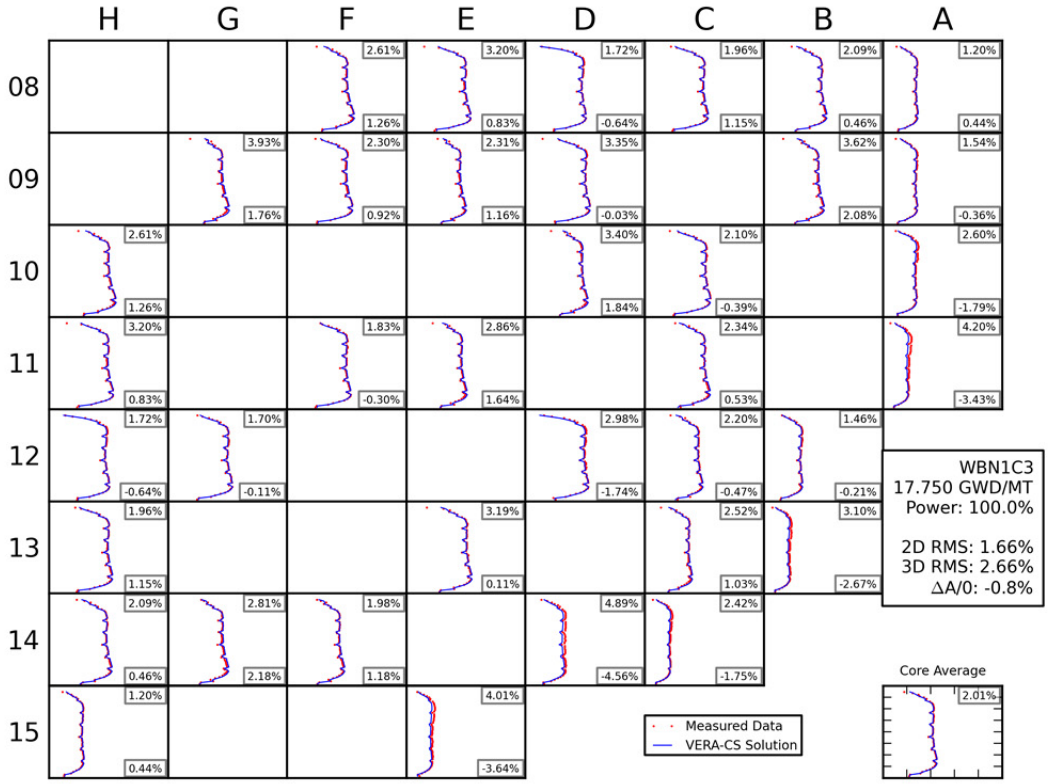

H G F E D C B A
08
09
10
11
12
13
14
15
WBN1C3
12.409 GWD/MT
Power: 99.9%
2D RMS: 1.42%
3D RMS: 2.42%
ΔA/0: 0.7%
Core Average
Measured Data
VERA-CS Solution

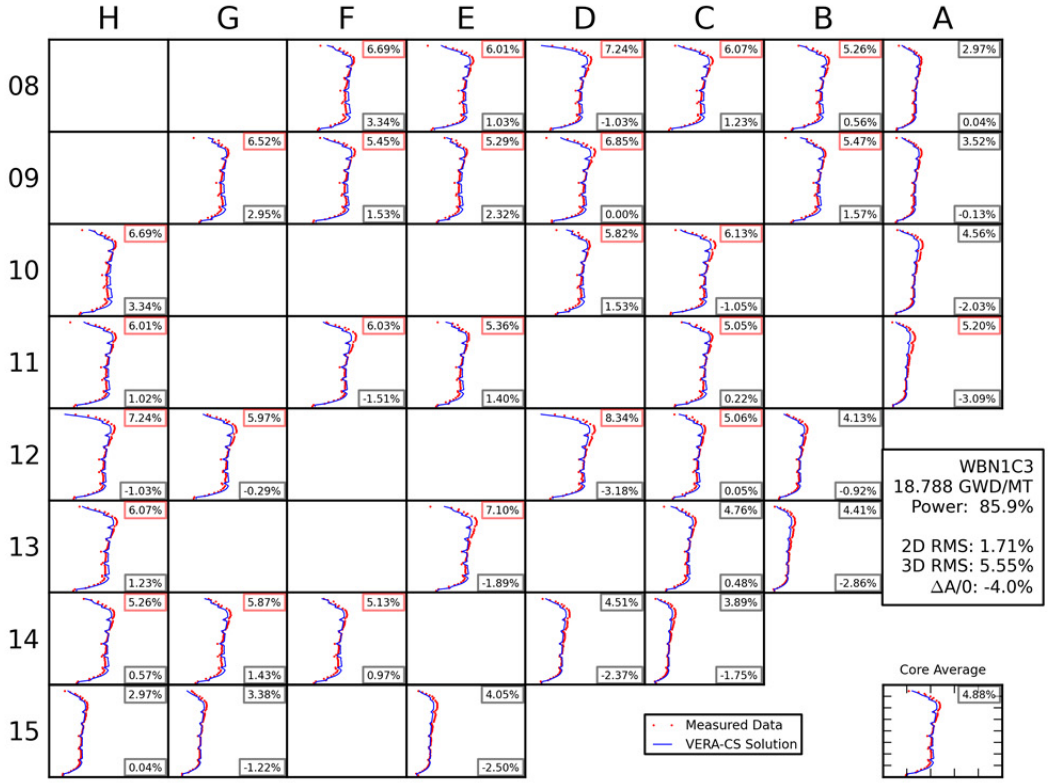

H G F E D C B A
08
09
10
11
12
13
14
15
WBN1C3
13.490 GWD/MT
Power: 99.9%
2D RMS: 1.41%
3D RMS: 2.75%
ΔA/0: 1.3%
Core Average
Measured Data
VERA-CS Solution

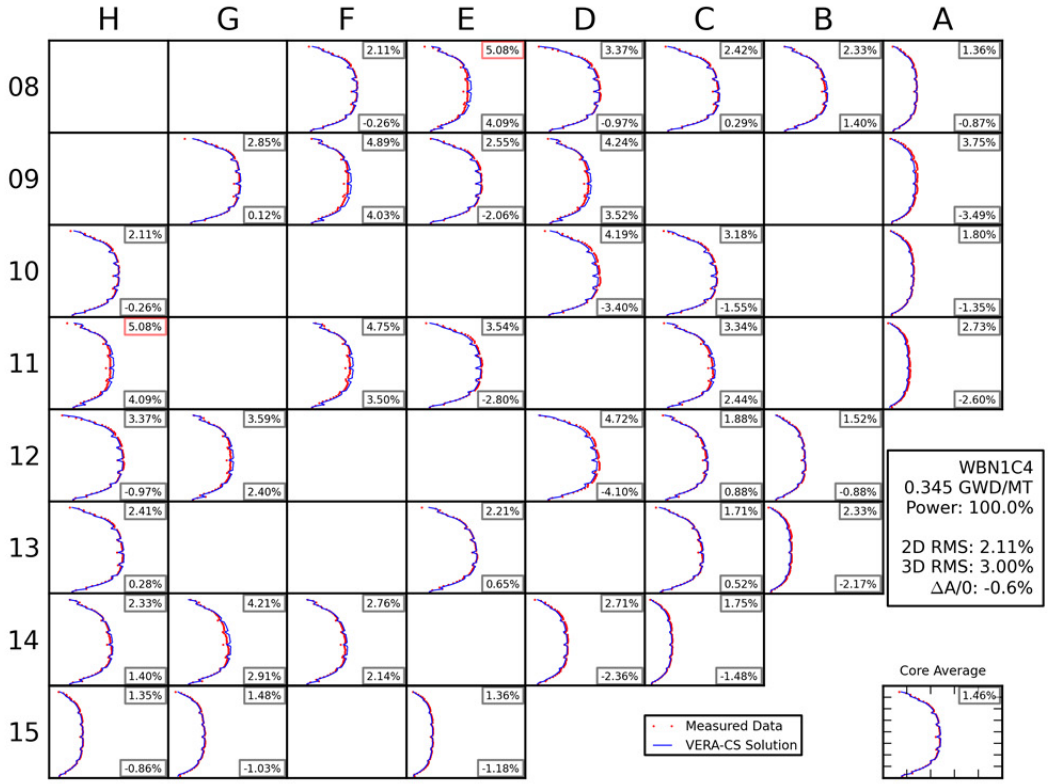

H G F E D C B A
08
09
10
11
12
13
14
15
WBN1C3
14.558 GWD/MT
Power: 100.0%
2D RMS: 1.42%
3D RMS: 2.36%
ΔA/0: 0.0%
Core Average
Measured Data
VERA-CS Solution

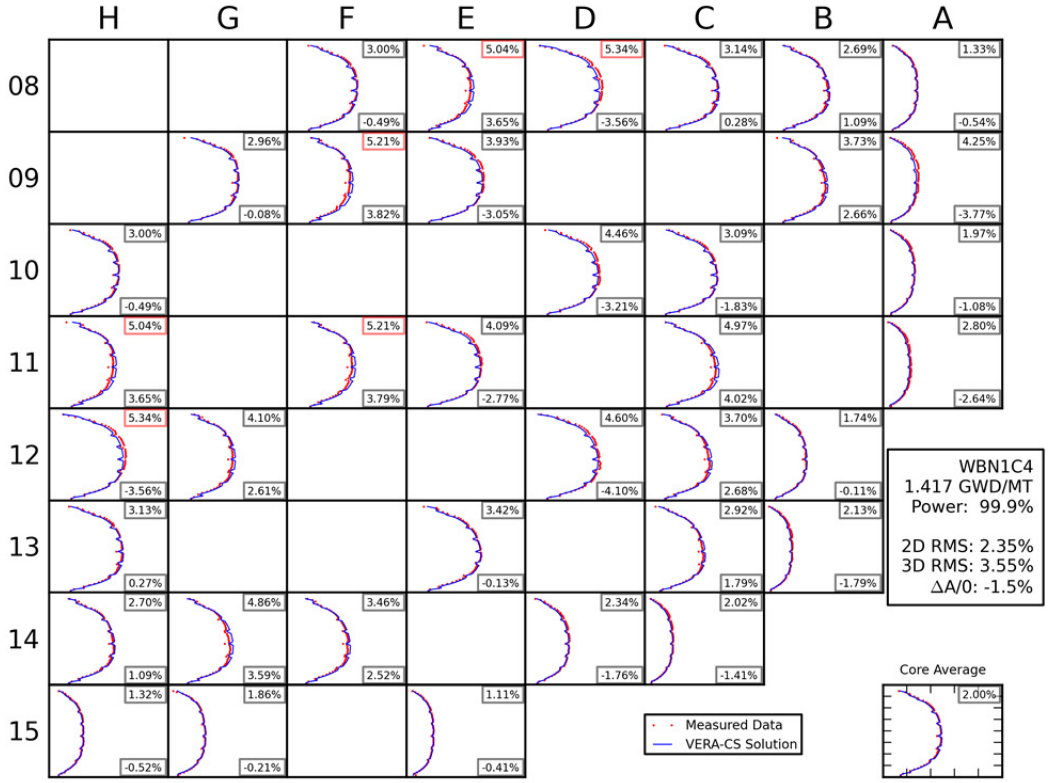

H G F E D C B A
08
09
10
11
12
13
14
15
WBN1C3
15.622 GWD/MT
Power: 100.0%
2D RMS: 1.43%
3D RMS: 2.54%
ΔA/0: 0.6%
Core Average
Measured Data
VERA-CS Solution

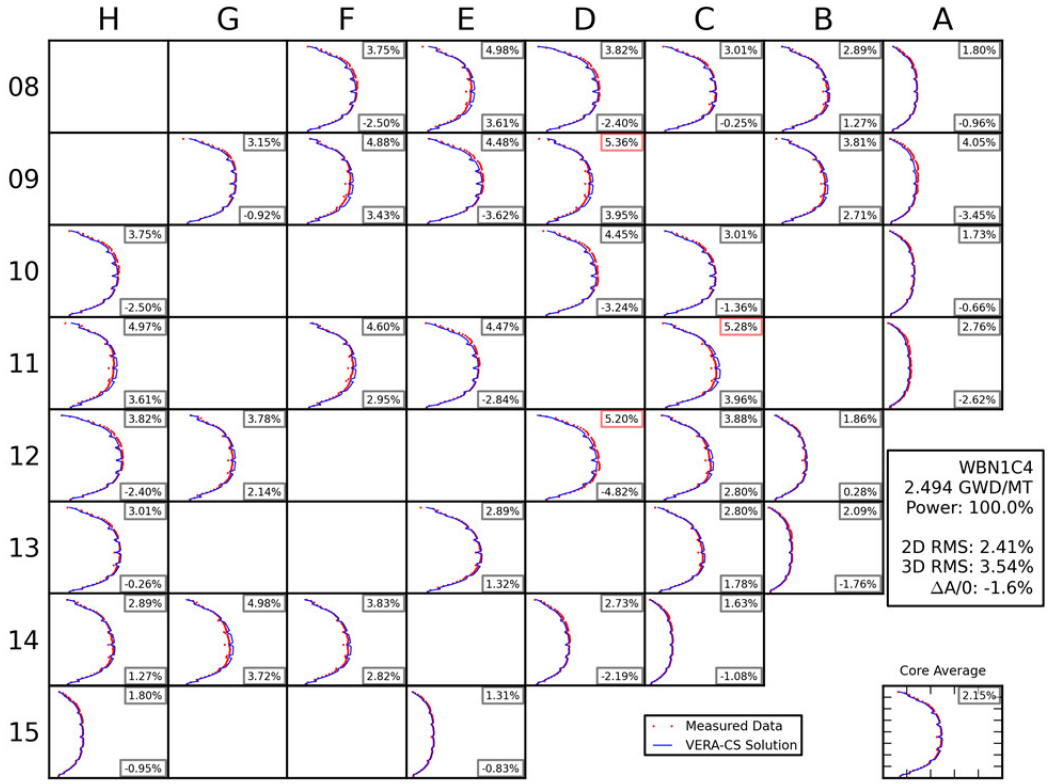

H G F E D C B A
08
09
10
11
12
13
14
15
WBN1C3
16.700 GWD/MT
Power: 100.0%
2D RMS: 1.39%
3D RMS: 2.36%
ΔA/0: 0.3%
Core Average
Measured Data
VERA-CS Solution

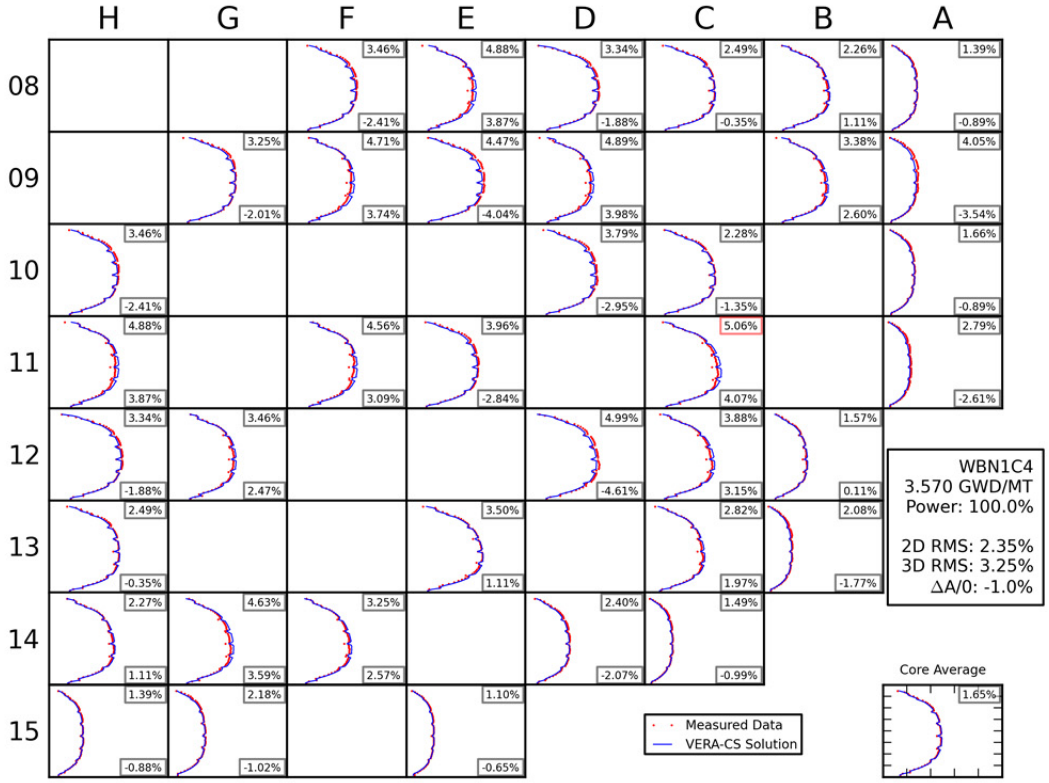

H G F E D C B A
08
09
10
11
12
13
14
15
WBN1C3
17.750 GWD/MT
Power: 100.0%
2D RMS: 1.66%
3D RMS: 2.66%
ΔA/0: -0.8%
Core Average
Measured Data
VERA-CS Solution

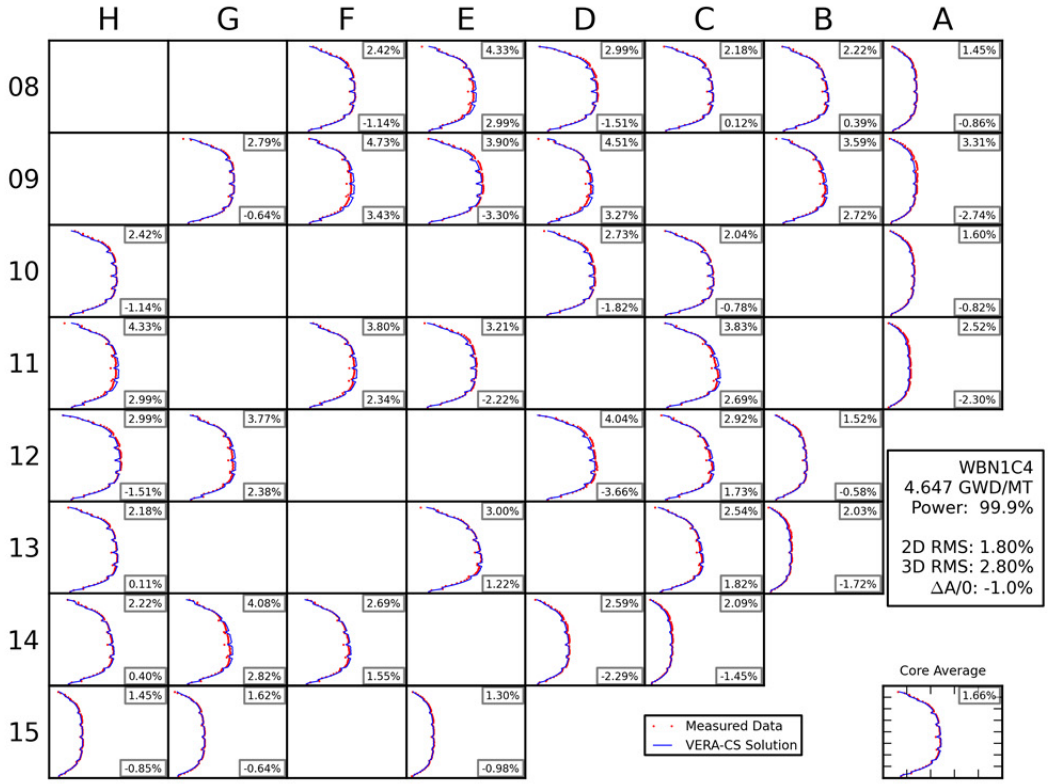

H G F E D C B A
08
09
10
11
12
13
14
15
WBN1C3
18.788 GWD/MT
Power: 85.9%
2D RMS: 1.71%
3D RMS: 5.55%
ΔA/0: -4.0%
Core Average
Measured Data
VERA-CS Solution

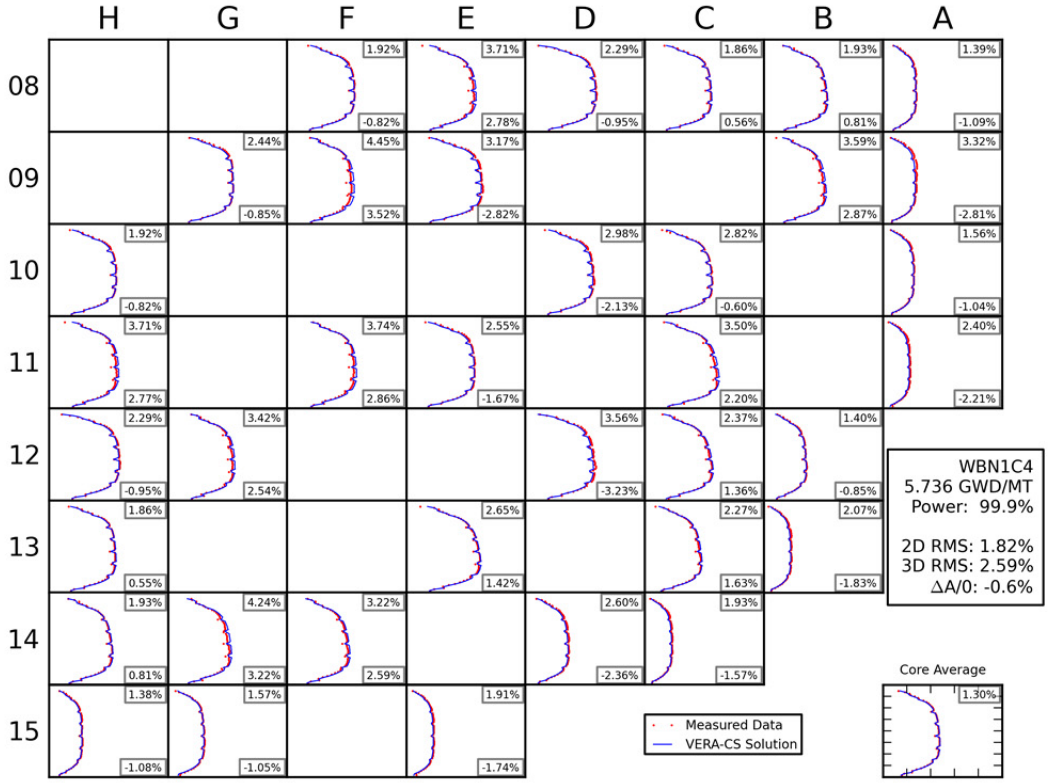

H G F E D C B A
08
09
10
11
12
13
14
15
WBN1C4
0.345 GWD/MT
Power: 100.0%
2D RMS: 2.11%
3D RMS: 3.00%
ΔA/0: -0.6%
Core Average
Measured Data
VERA-CS Solution

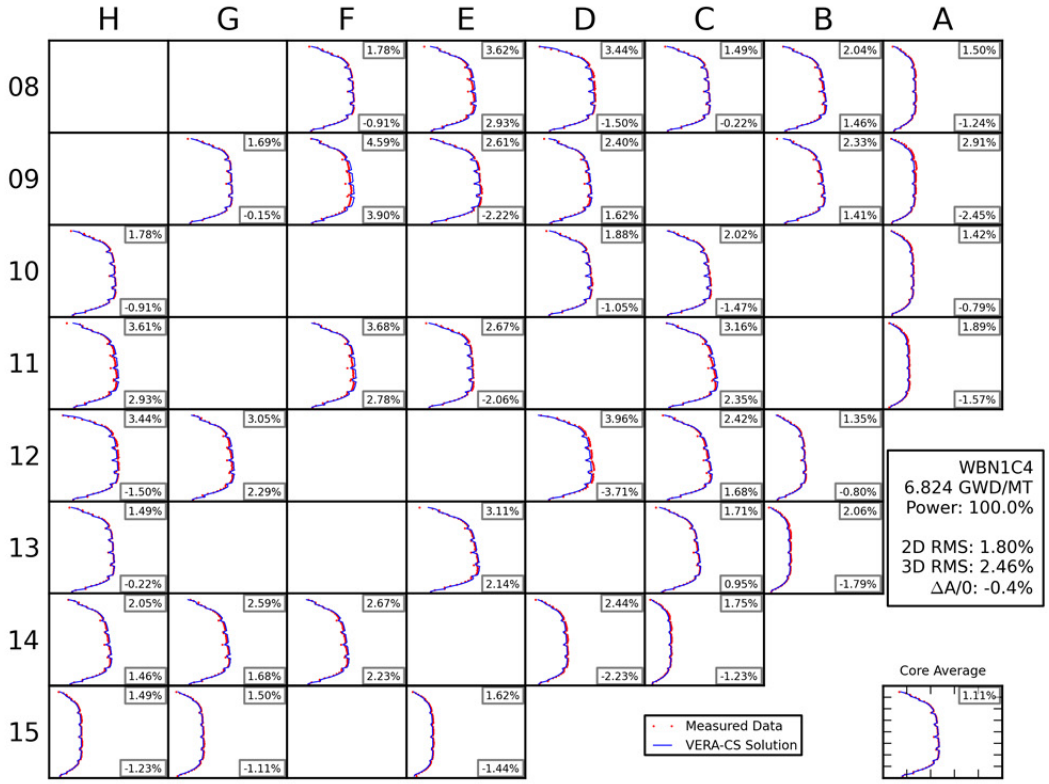

H G F E D C B A
08 09 10 11 12 13 14 15
3.00% -0.49%
5.04% 3.65%
5.34% -3.56%
3.14% 0.28%
2.69% 1.09%
1.33% -0.54%
2.96% -0.08%
5.21% 3.82%
3.93% -3.05%
3.73% 2.66%
4.25% -3.77%
3.00% -0.49%
4.46% -3.21%
3.09% -1.83%
1.97% -1.08%
5.04% 3.65%
5.21% 3.79%
4.09% -2.77%
4.97% 4.02%
2.80% -2.64%
5.34% -3.56%
4.10% 2.61%
4.60% -4.10%
3.70% 2.68%
1.74% -0.11%
3.13% 0.27%
3.42% -0.13%
2.92% 1.79%
2.13% -1.79%
2.70% 1.09%
4.86% 3.59%
3.46% 2.52%
2.34% -1.76%
2.02% -1.41%
1.32% -0.52%
1.86% -0.21%
1.11% -0.41%
WBN1C4
1.417 GWD/MT
Power: 99.9%
2D RMS: 2.35%
3D RMS: 3.55%
ΔA/0: -1.5%
Measured Data
VERA-CS Solution
Core Average
2.00%

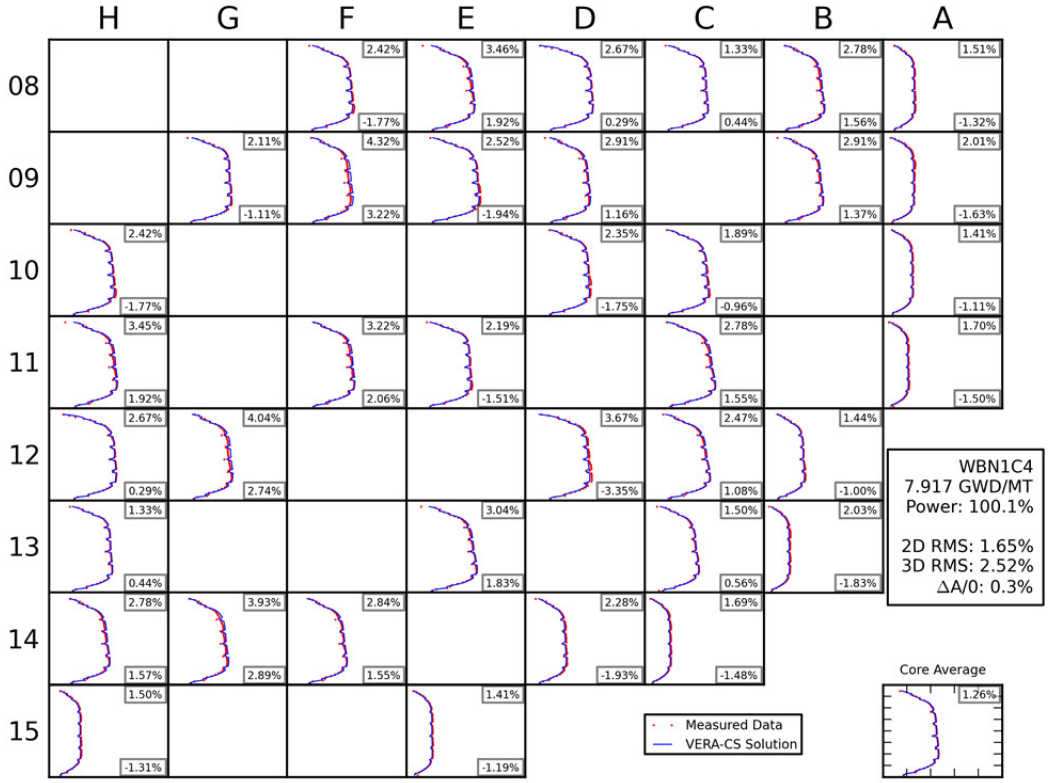

H G F E D C B A
08 09 10 11 12 13 14 15
3.75% -2.50%
4.98% 3.61%
3.82% -2.40%
3.01% -0.25%
2.89% 1.27%
1.80% -0.96%
3.15% -0.92%
4.88% 3.43%
4.48% -3.62%
5.36% 3.95%
3.81% 2.71%
4.05% -3.45%
3.75% -2.50%
4.45% -3.24%
3.01% -1.36%
1.73% -0.66%
4.97% 3.61%
4.60% 2.95%
4.47% -2.84%
5.28% 3.96%
2.76% -2.62%
3.82% -2.40%
3.78% 2.14%
5.20% -4.82%
3.88% 2.80%
1.86% 0.28%
3.01% -0.26%
2.89% 1.32%
2.80% 1.78%
2.09% -1.76%
2.89% 1.27%
4.98% 3.72%
3.83% 2.82%
2.73% -2.19%
1.63% -1.08%
1.80% -0.95%
1.31% -0.83%
WBN1C4
2.494 GWD/MT
Power: 100.0%
2D RMS: 2.41%
3D RMS: 3.54%
ΔA/0: -1.6%
Measured Data
VERA-CS Solution
Core Average
2.15%

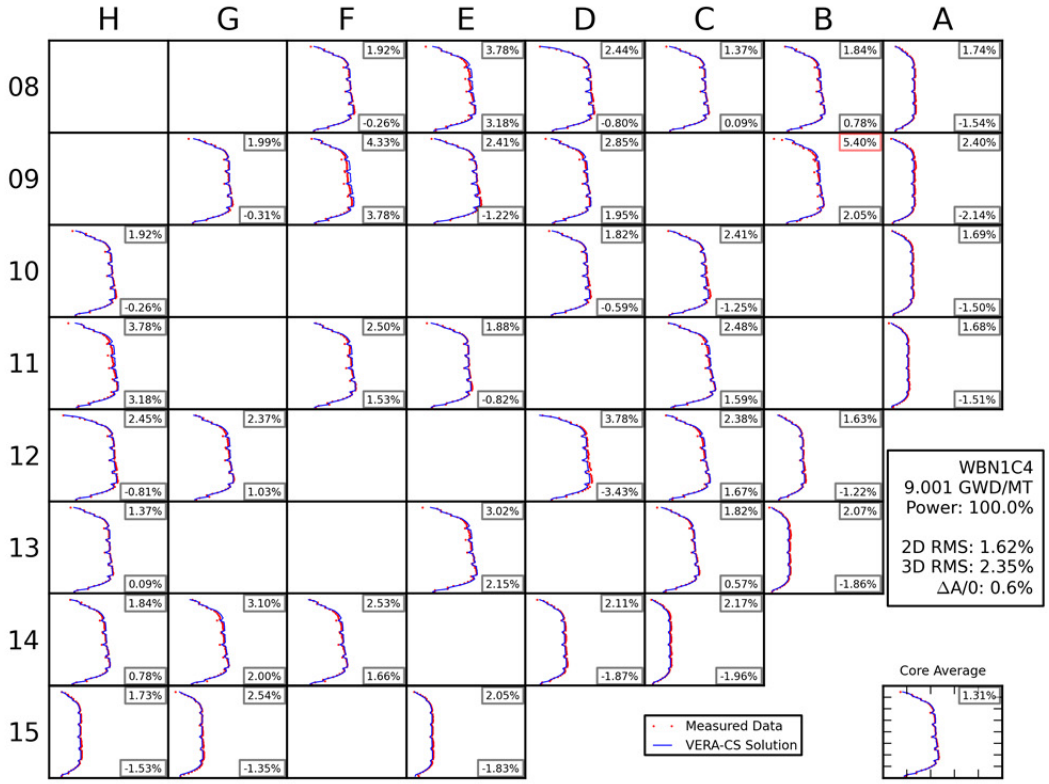

H G F E D C B A
08
09
10
11
12
13
14
15
WBN1C4
3.570 GWD/MT
Power: 100.0%
2D RMS: 2.35%
3D RMS: 3.25%
ΔA/0: -1.0%
Core Average
Measured Data
VERA-CS Solution

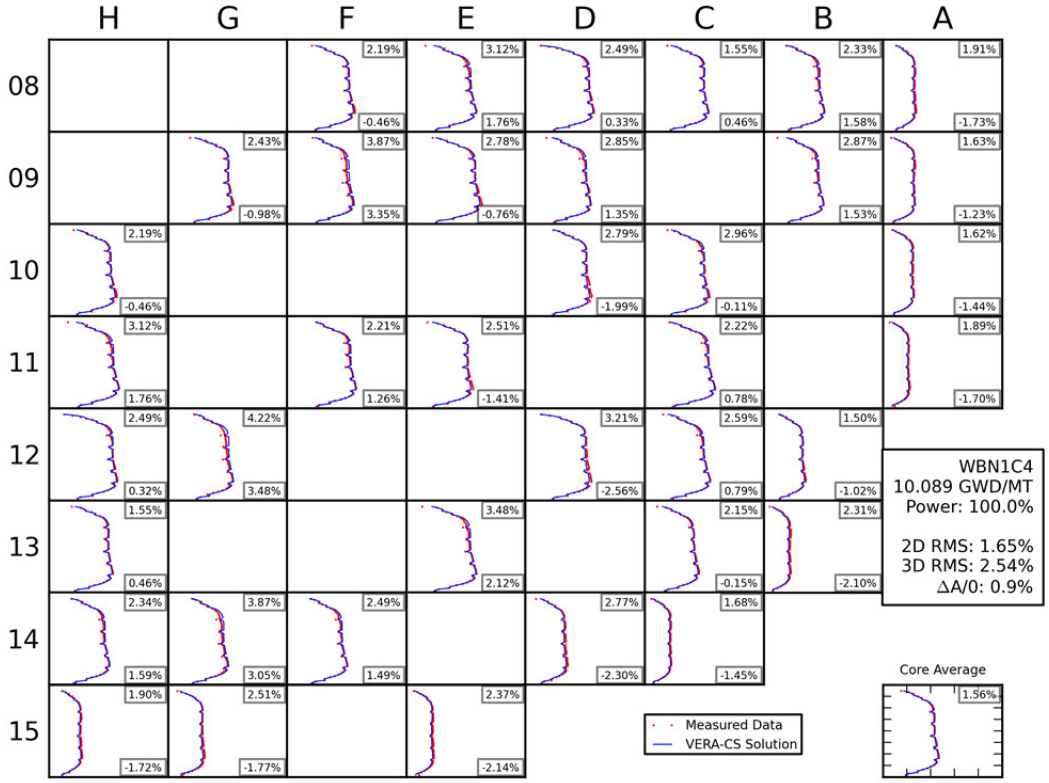

H G F E D C B A
08
09
10
11
12
13
14
15
WBN1C4
4.647 GWD/MT
Power: 99.9%
2D RMS: 1.80%
3D RMS: 2.80%
ΔA/0: -1.0%
Core Average
Measured Data
VERA-CS Solution

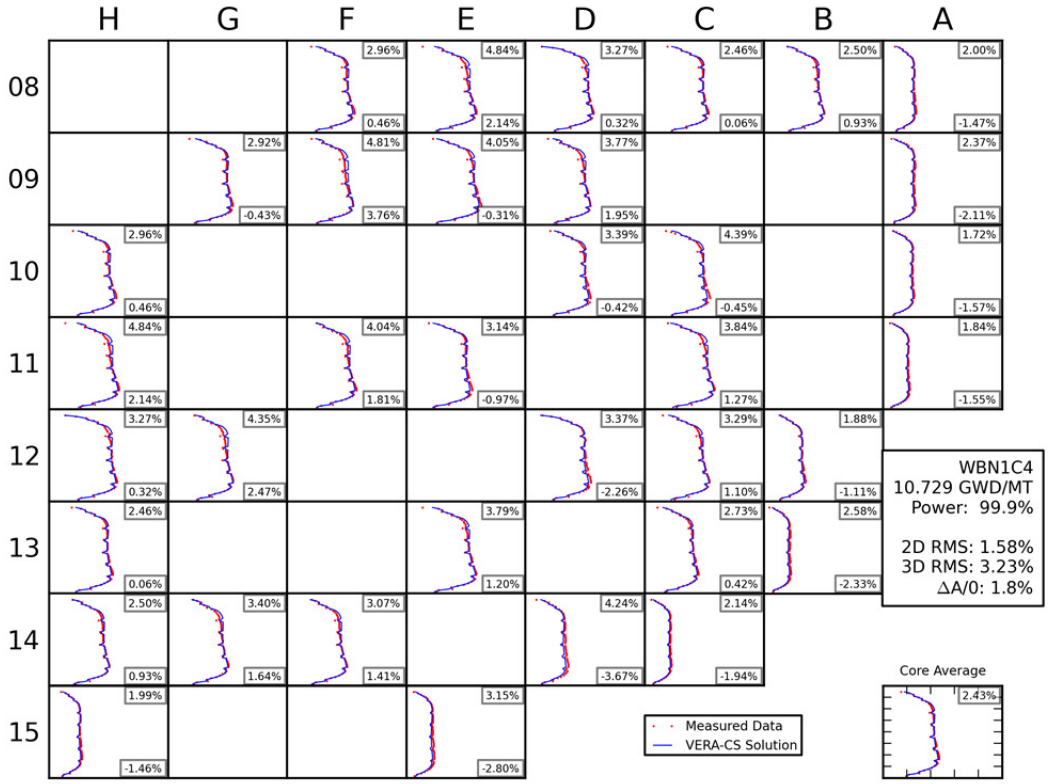

H G F E D C B A
08 09 10 11 12 13 14 15
WBN1C4
5.736 GWD/MT
Power: 99.9%
2D RMS: 1.82%
3D RMS: 2.59%
ΔA/0: -0.6%
Core Average
Measured Data
VERA-CS Solution

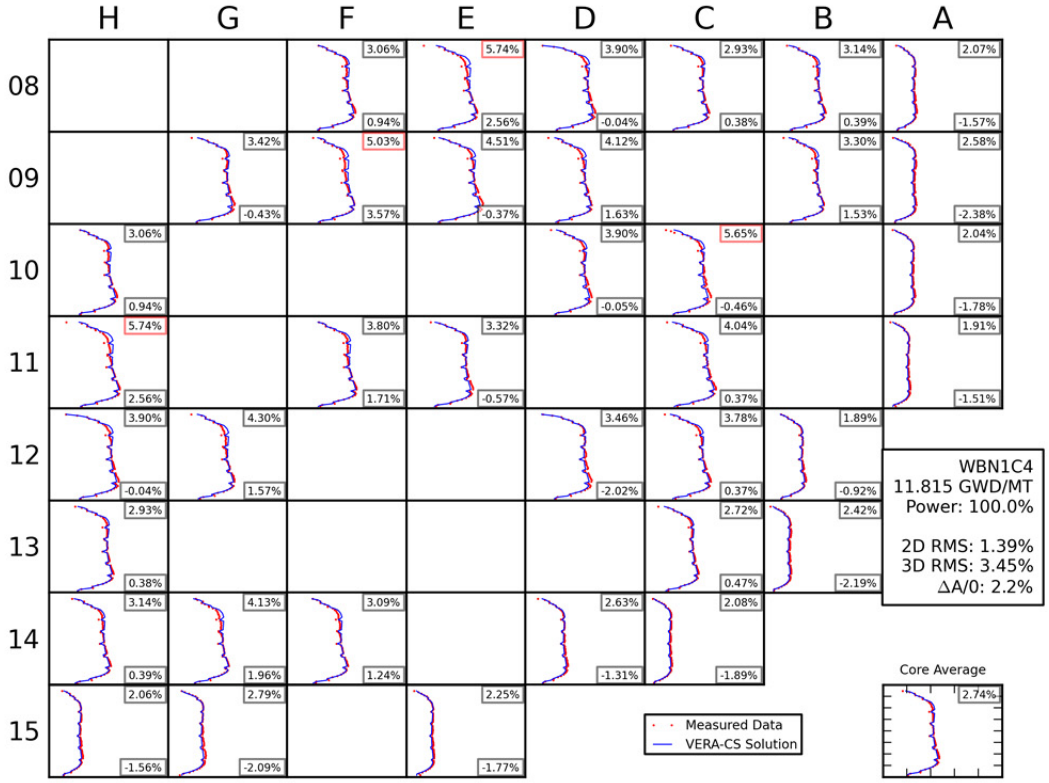

H G F E D C B A
08 09 10 11 12 13 14 15
WBN1C4
6.824 GWD/MT
Power: 100.0%
2D RMS: 1.80%
3D RMS: 2.46%
ΔA/0: -0.4%
Core Average
Measured Data
VERA-CS Solution

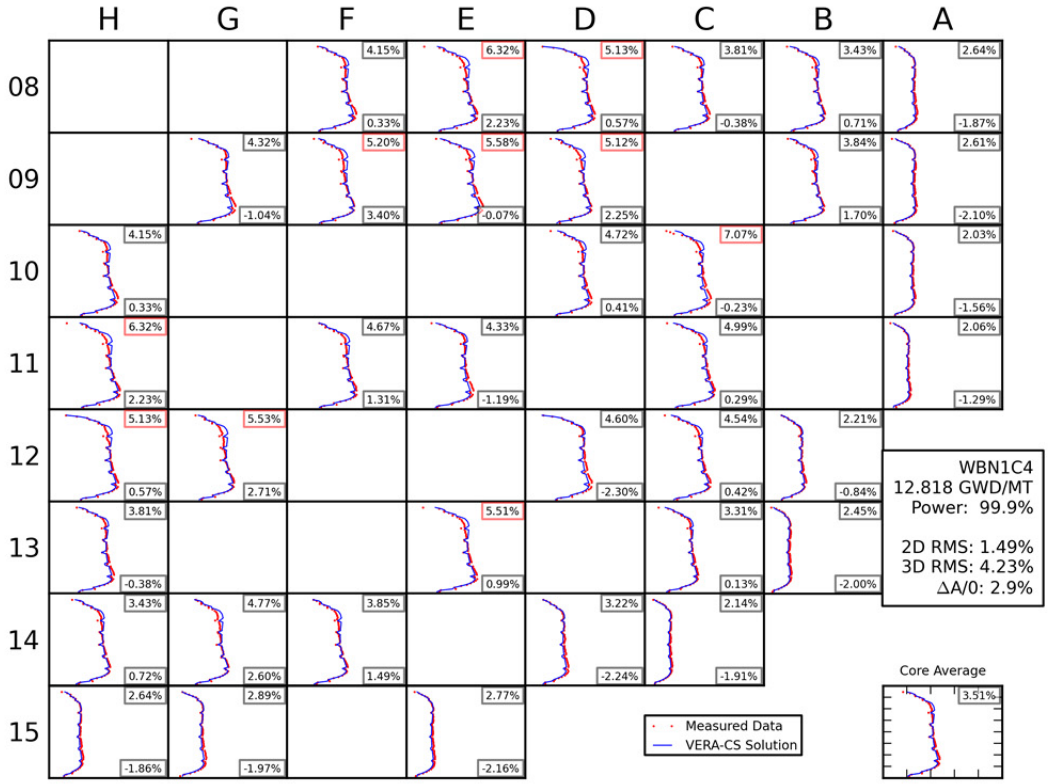

H G F E D C B A
08 09 10 11 12 13 14 15
2.42% -1.77%
3.46% 1.92%
2.67% 0.29%
1.33% 0.44%
2.78% 1.56%
1.51% -1.32%
2.11% -1.11%
4.32% 3.22%
2.52% -1.94%
2.91% 1.16%
2.91% 1.37%
2.01% -1.63%
2.42% -1.77%
2.35% -1.75%
1.89% -0.96%
1.41% -1.11%
3.45% 1.92%
3.22% 2.06%
2.19% -1.51%
2.78% 1.55%
1.70% -1.50%
2.67% 0.29%
4.04% 2.74%
3.67% -3.35%
2.47% 1.08%
1.44% -1.00%
1.33% 0.44%
3.04% 1.83%
1.50% 0.56%
2.03% -1.83%
2.78% 1.57%
3.93% 2.89%
2.84% 1.55%
2.28% -1.93%
1.69% -1.48%
1.50% -1.31%
1.41% -1.19%
WBN1C4
7.917 GWD/MT
Power: 100.1%
2D RMS: 1.65%
3D RMS: 2.52%
ΔA/0: 0.3%
Core Average
1.26%
Measured Data
VERA-CS Solution

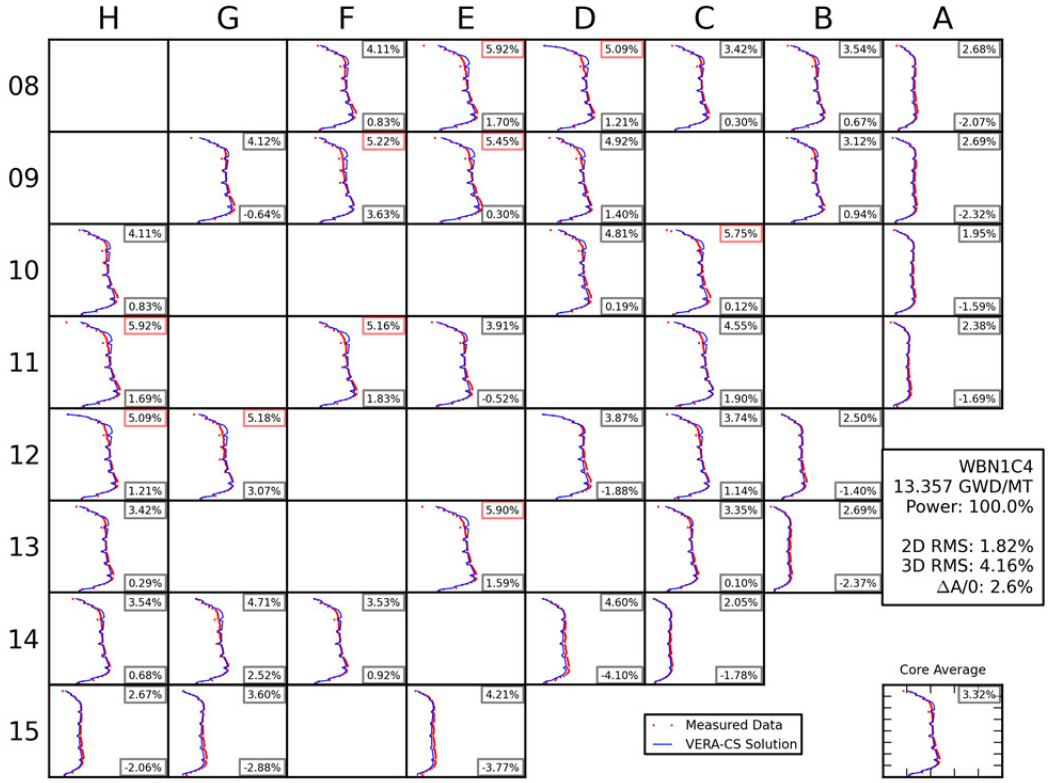

H G F E D C B A
08 09 10 11 12 13 14 15
1.92% -0.26%
3.78% 3.18%
2.44% -0.80%
1.37% 0.09%
1.84% 0.78%
1.74% -1.54%
1.99% -0.31%
4.33% 3.78%
2.41% -1.22%
2.85% 1.95%
5.40% 2.05%
2.40% -2.14%
1.92% -0.26%
1.82% -0.59%
2.41% -1.25%
1.69% -1.50%
3.78% 3.18%
2.50% 1.53%
1.88% -0.82%
2.48% 1.59%
1.68% -1.51%
2.45% -0.81%
2.37% 1.03%
3.78% -3.43%
2.38% 1.67%
1.63% -1.22%
1.37% 0.09%
3.02% 2.15%
1.82% 0.57%
2.07% -1.86%
1.84% 0.78%
3.10% 2.00%
2.53% 1.66%
2.11% -1.87%
2.17% -1.96%
1.73% -1.53%
2.54% -1.35%
2.05% -1.83%
WBN1C4
9.001 GWD/MT
Power: 100.0%
2D RMS: 1.62%
3D RMS: 2.35%
ΔA/0: 0.6%
Core Average
1.31%
Measured Data
VERA-CS Solution

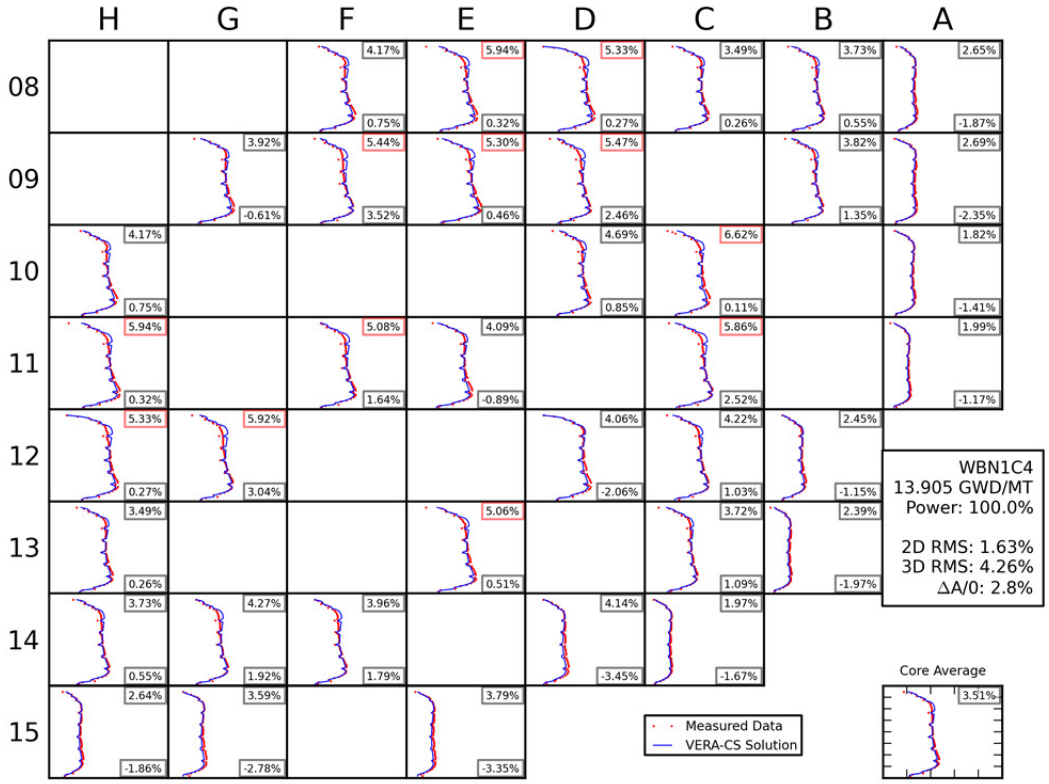

H G F E D C B A
08
09
10
11
12
13
14
15
WBN1C4
10.089 GWD/MT
Power: 100.0%
2D RMS: 1.65%
3D RMS: 2.54%
ΔA/0: 0.9%
Core Average
Measured Data
VERA-CS Solution

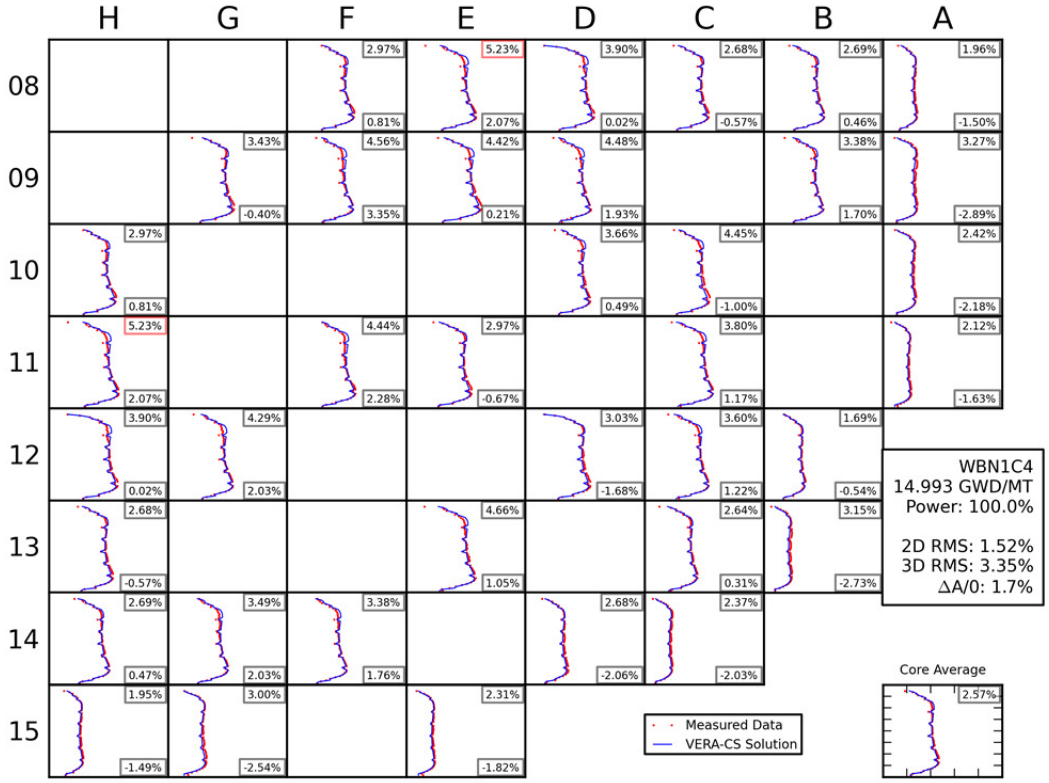

H G F E D C B A
08
09
10
11
12
13
14
15
WBN1C4
10.729 GWD/MT
Power: 99.9%
2D RMS: 1.58%
3D RMS: 3.23%
ΔA/0: 1.8%
Core Average
Measured Data
VERA-CS Solution

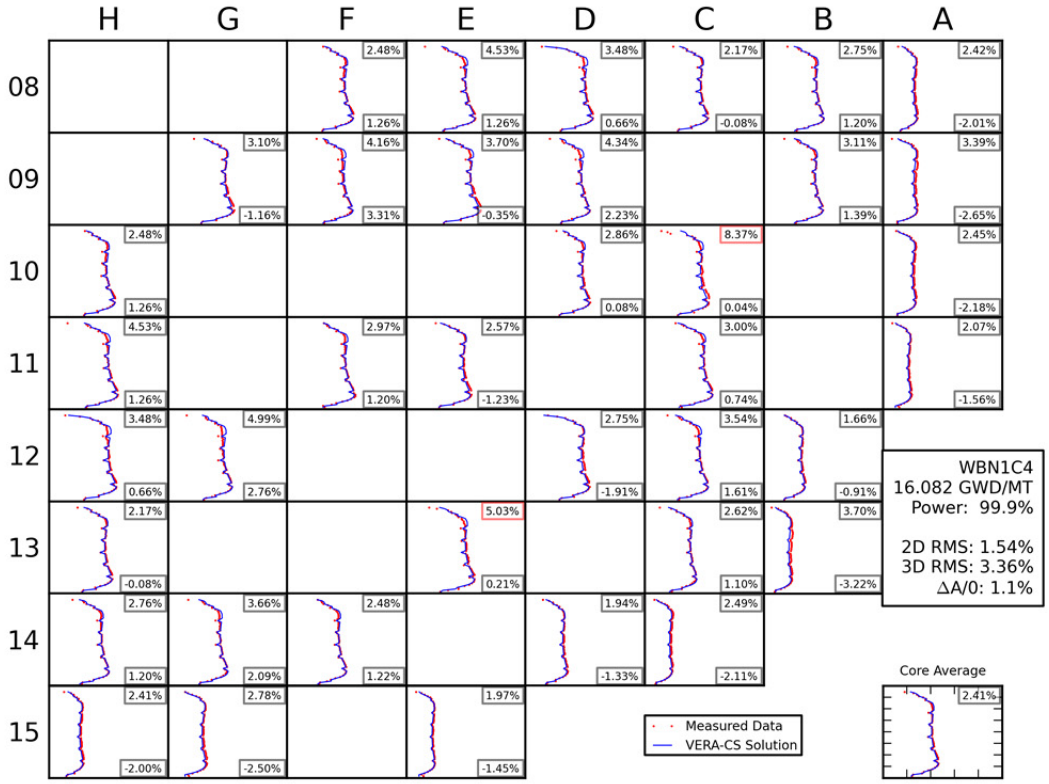

H G F E D C B A
08
3.06% 0.94%
5.74% 2.56%
3.90% -0.04%
2.93% 0.38%
3.14% 0.39%
2.07% -1.57%
09
3.42% -0.43%
5.03% 3.57%
4.51% -0.37%
4.12% 1.63%
3.30% 1.53%
2.58% -2.38%
10
3.06% 0.94%
3.90% -0.05%
5.65% -0.46%
2.04% -1.78%
11
5.74% 2.56%
3.80% 1.71%
3.32% -0.57%
4.04% 0.37%
1.91% -1.51%
12
3.90% -0.04%
4.30% 1.57%
3.46% -2.02%
3.78% 0.37%
1.89% -0.92%
13
2.93% 0.38%
2.72% 0.47%
2.42% -2.19%
14
3.14% 0.39%
4.13% 1.96%
3.09% 1.24%
2.63% -1.31%
2.08% -1.89%
15
2.06% -1.56%
2.79% -2.09%
2.25% -1.77%
WBN1C4
11.815 GWD/MT
Power: 100.0%
2D RMS: 1.39%
3D RMS: 3.45%
ΔA/0: 2.2%
Measured Data
VERA-CS Solution
Core Average
2.74%

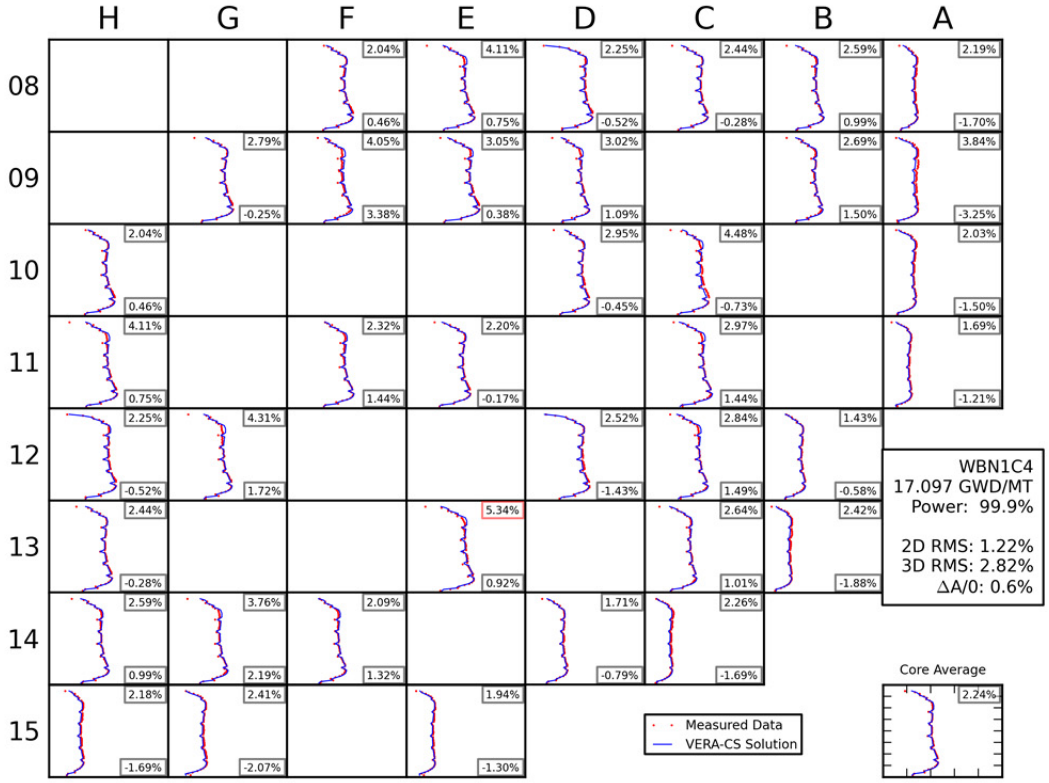

H G F E D C B A
08
4.15% 0.33%
6.32% 2.23%
5.13% 0.57%
3.81% -0.38%
3.43% 0.71%
2.64% -1.87%
09
4.32% -1.04%
5.20% 3.40%
5.58% -0.07%
5.12% 2.25%
3.84% 1.70%
2.61% -2.10%
10
4.15% 0.33%
4.72% 0.41%
7.07% -0.23%
2.03% -1.56%
11
6.32% 2.23%
4.67% 1.31%
4.33% -1.19%
4.99% 0.29%
2.06% -1.29%
12
5.13% 0.57%
5.53% 2.71%
4.60% -2.30%
4.54% 0.42%
2.21% -0.84%
13
3.81% -0.38%
5.51% 0.99%
3.31% 0.13%
2.45% -2.00%
14
3.43% 0.72%
4.77% 2.60%
3.85% 1.49%
3.22% -2.24%
2.14% -1.91%
15
2.64% -1.86%
2.89% -1.97%
2.77% -2.16%
WBN1C4
12.818 GWD/MT
Power: 99.9%
2D RMS: 1.49%
3D RMS: 4.23%
ΔA/0: 2.9%
Measured Data
VERA-CS Solution
Core Average
3.51%

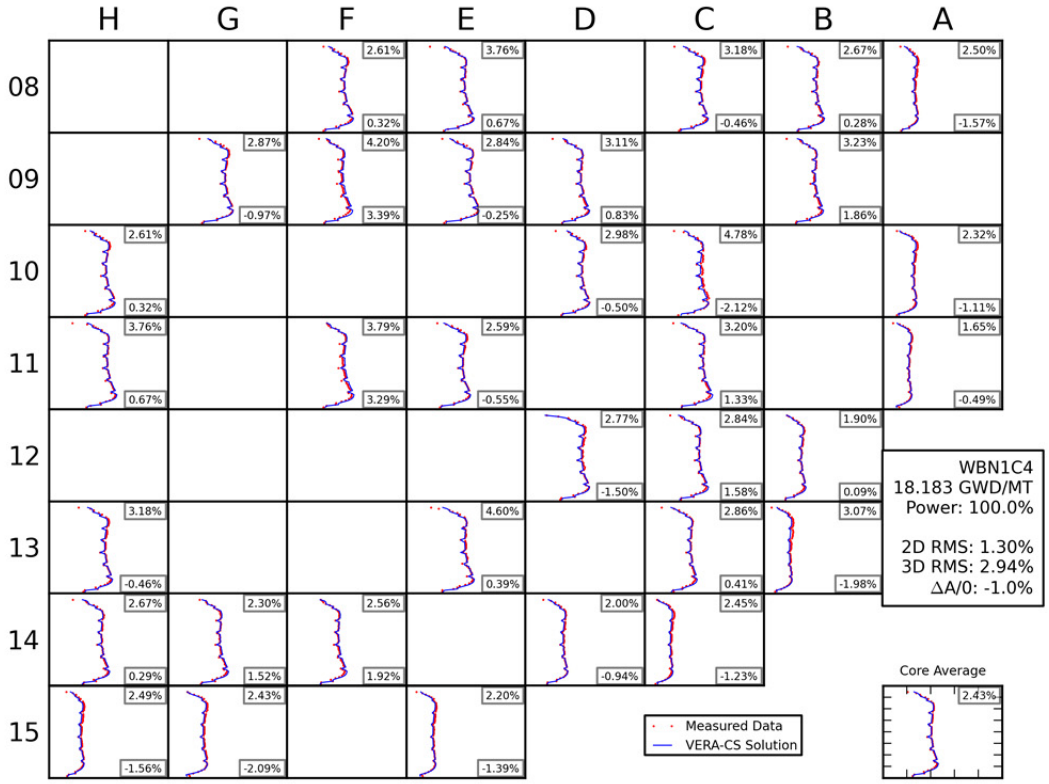

H G F E D C B A
08
09
10
11
12
13
14
15
WBN1C4
13.357 GWD/MT
Power: 100.0%
2D RMS: 1.82%
3D RMS: 4.16%
ΔA/0: 2.6%
Core Average
Measured Data
VERA-CS Solution

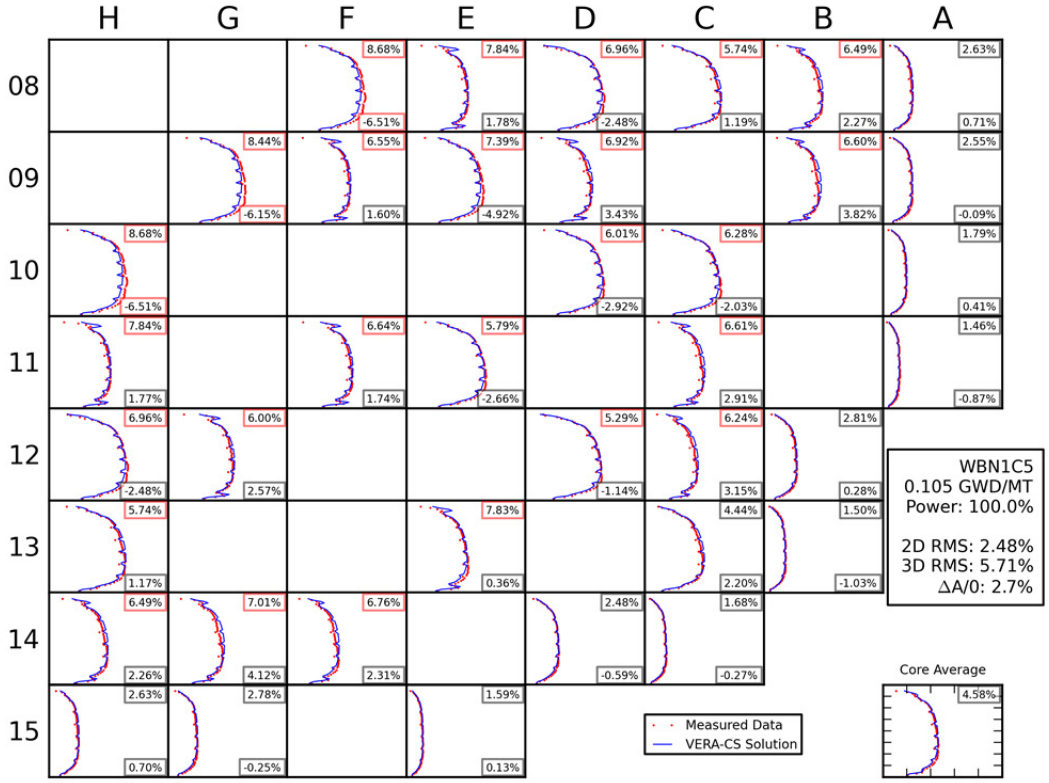

H G F E D C B A
08
09
10
11
12
13
14
15
WBN1C4
13.905 GWD/MT
Power: 100.0%
2D RMS: 1.63%
3D RMS: 4.26%
ΔA/0: 2.8%
Core Average
Measured Data
VERA-CS Solution

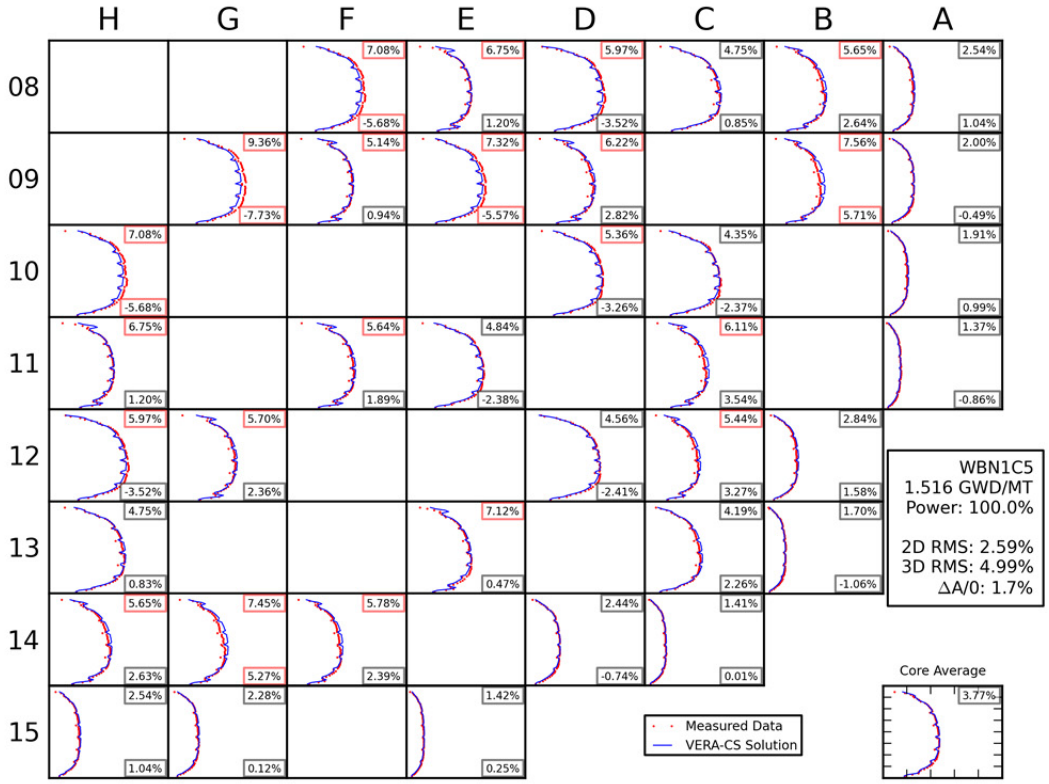

H G F E D C B A
08
2.97% 0.81%
5.23% 2.07%
3.90% 0.02%
2.68% -0.57%
2.69% 0.46%
1.96% -1.50%
09
3.43% -0.40%
4.56% 3.35%
4.42% 0.21%
4.48% 1.93%
3.38% 1.70%
3.27% -2.89%
10
2.97% 0.81%
3.66% 0.49%
4.45% -1.00%
2.42% -2.18%
11
5.23% 2.07%
4.44% 2.28%
2.97% -0.67%
3.80% 1.17%
2.12% -1.63%
12
3.90% 0.02%
4.29% 2.03%
3.03% -1.68%
3.60% 1.22%
1.69% -0.54%
13
2.68% -0.57%
4.66% 1.05%
2.64% 0.31%
3.15% -2.73%
14
2.69% 0.47%
3.49% 2.03%
3.38% 1.76%
2.68% -2.06%
2.37% -2.03%
15
1.95% -1.49%
3.00% -2.54%
2.31% -1.82%
WBN1C4
14.993 GWD/MT
Power: 100.0%
2D RMS: 1.52%
3D RMS: 3.35%
ΔA/0: 1.7%
Core Average
2.57%
Measured Data
VERA-CS Solution

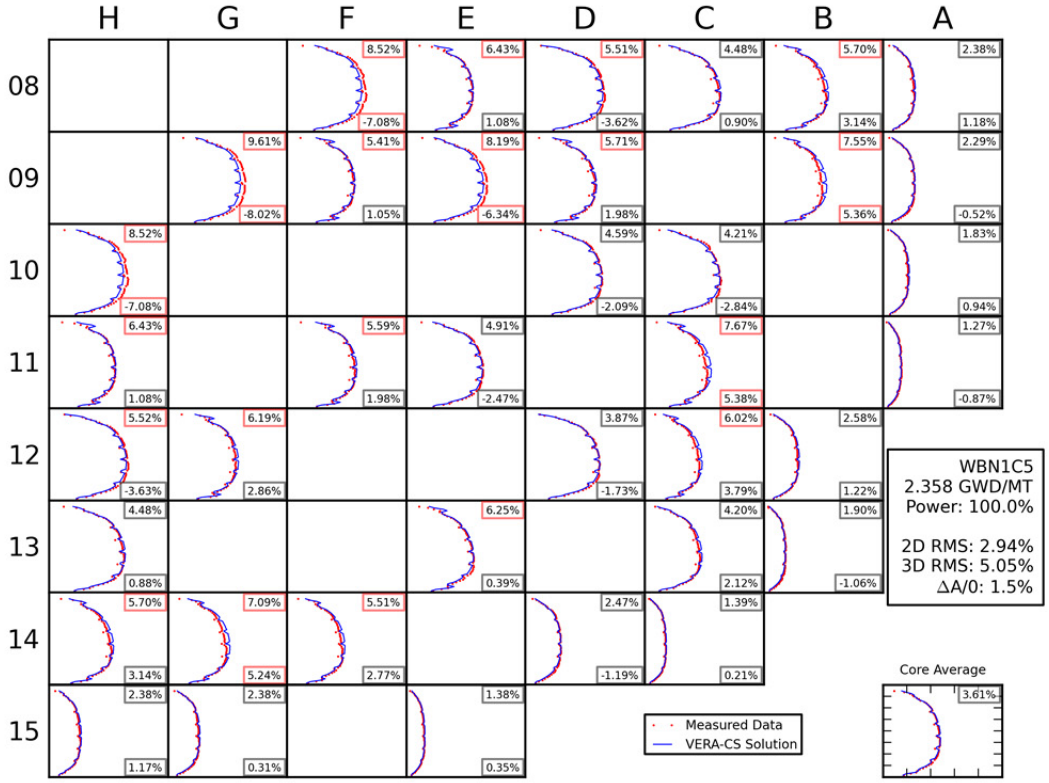

H G F E D C B A
08
2.48% 1.26%
4.53% 1.26%
3.48% 0.66%
2.17% -0.08%
2.75% 1.20%
2.42% -2.01%
09
3.10% -1.16%
4.16% 3.31%
3.70% -0.35%
4.34% 2.23%
3.11% 1.39%
3.39% -2.65%
10
2.48% 1.26%
2.86% 0.08%
8.37% 0.04%
2.45% -2.18%
11
4.53% 1.26%
2.97% 1.20%
2.57% -1.23%
3.00% 0.74%
2.07% -1.56%
12
3.48% 0.66%
4.99% 2.76%
2.75% -1.91%
3.54% 1.61%
1.66% -0.91%
13
2.17% -0.08%
5.03% 0.21%
2.62% 1.10%
3.70% -3.22%
14
2.76% 1.20%
3.66% 2.09%
2.48% 1.22%
1.94% -1.33%
2.49% -2.11%
15
2.41% -2.00%
2.78% -2.50%
1.97% -1.45%
WBN1C4
16.082 GWD/MT
Power: 99.9%
2D RMS: 1.54%
3D RMS: 3.36%
ΔA/0: 1.1%
Core Average
2.41%
Measured Data
VERA-CS Solution

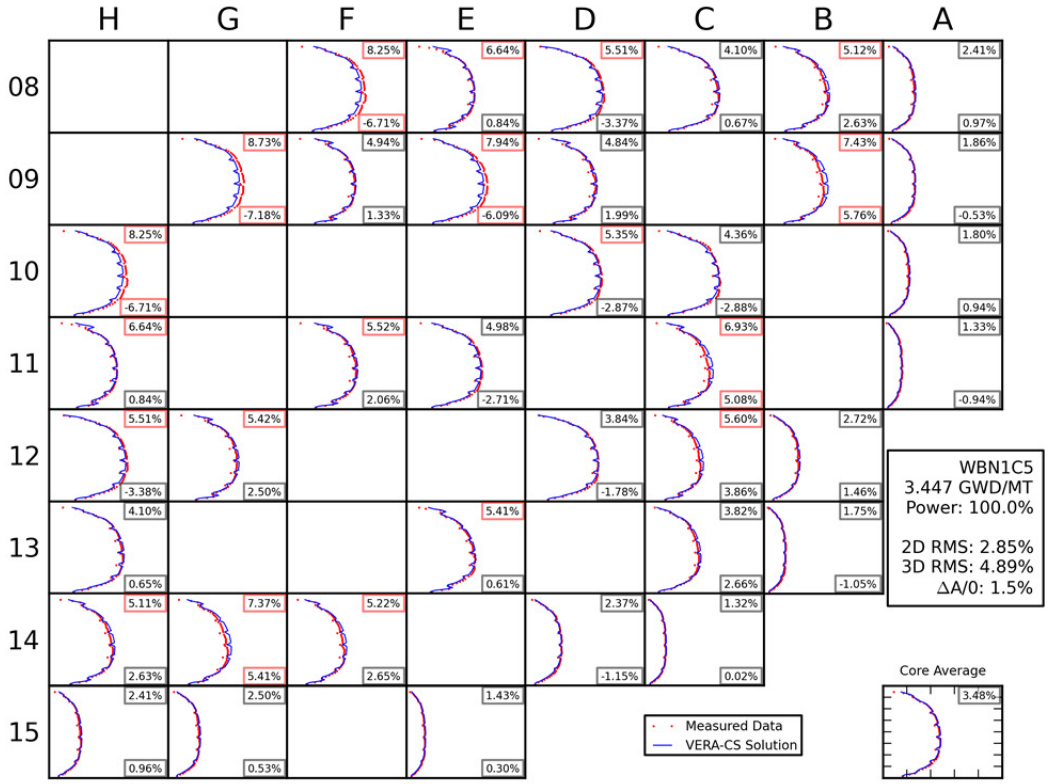

H G F E D C B A
08
09
10
11
12
13
14
15
2.04% 0.46%
4.11% 0.75%
2.25% -0.52%
2.44% -0.28%
2.59% 0.99%
2.19% -1.70%
2.79% -0.25%
4.05% 3.38%
3.05% 0.38%
3.02% 1.09%
2.69% 1.50%
3.84% -3.25%
2.04% 0.46%
2.95% -0.45%
4.48% -0.73%
2.03% -1.50%
4.11% 0.75%
2.32% 1.44%
2.20% -0.17%
2.97% 1.44%
1.69% -1.21%
2.25% -0.52%
4.31% 1.72%
2.52% -1.43%
2.84% 1.49%
1.43% -0.58%
2.44% -0.28%
5.34% 0.92%
2.64% 1.01%
2.42% -1.88%
2.59% 0.99%
3.76% 2.19%
2.09% 1.32%
1.71% -0.79%
2.26% -1.69%
2.18% -1.69%
2.41% -2.07%
1.94% -1.30%
WBN1C4
17.097 GWD/MT
Power: 99.9%
2D RMS: 1.22%
3D RMS: 2.82%
ΔA/0: 0.6%
Core Average
2.24%
Measured Data
VERA-CS Solution

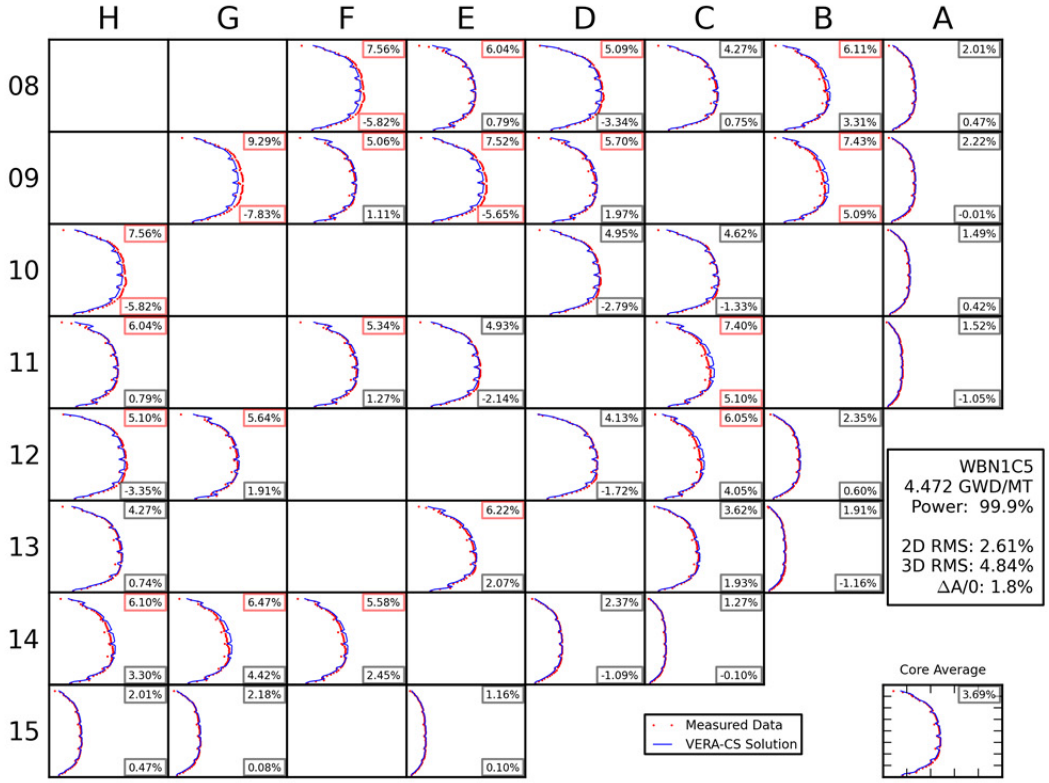

H G F E D C B A
08
09
10
11
12
13
14
15
2.61% 0.32%
3.76% 0.67%
3.18% -0.46%
2.67% 0.28%
2.50% -1.57%
2.87% -0.97%
4.20% 3.39%
2.84% -0.25%
3.11% 0.83%
3.23% 1.86%
2.61% 0.32%
2.98% -0.50%
4.78% -2.12%
2.32% -1.11%
3.76% 0.67%
3.79% 3.29%
2.59% -0.55%
3.20% 1.33%
1.65% -0.49%
2.77% -1.50%
2.84% 1.58%
1.90% 0.09%
3.18% -0.46%
4.60% 0.39%
2.86% 0.41%
3.07% -1.98%
2.67% 0.29%
2.30% 1.52%
2.56% 1.92%
2.00% -0.94%
2.45% -1.23%
2.49% -1.56%
2.43% -2.09%
2.20% -1.39%
WBN1C4
18.183 GWD/MT
Power: 100.0%
2D RMS: 1.30%
3D RMS: 2.94%
ΔA/0: -1.0%
Core Average
2.43%
Measured Data
VERA-CS Solution

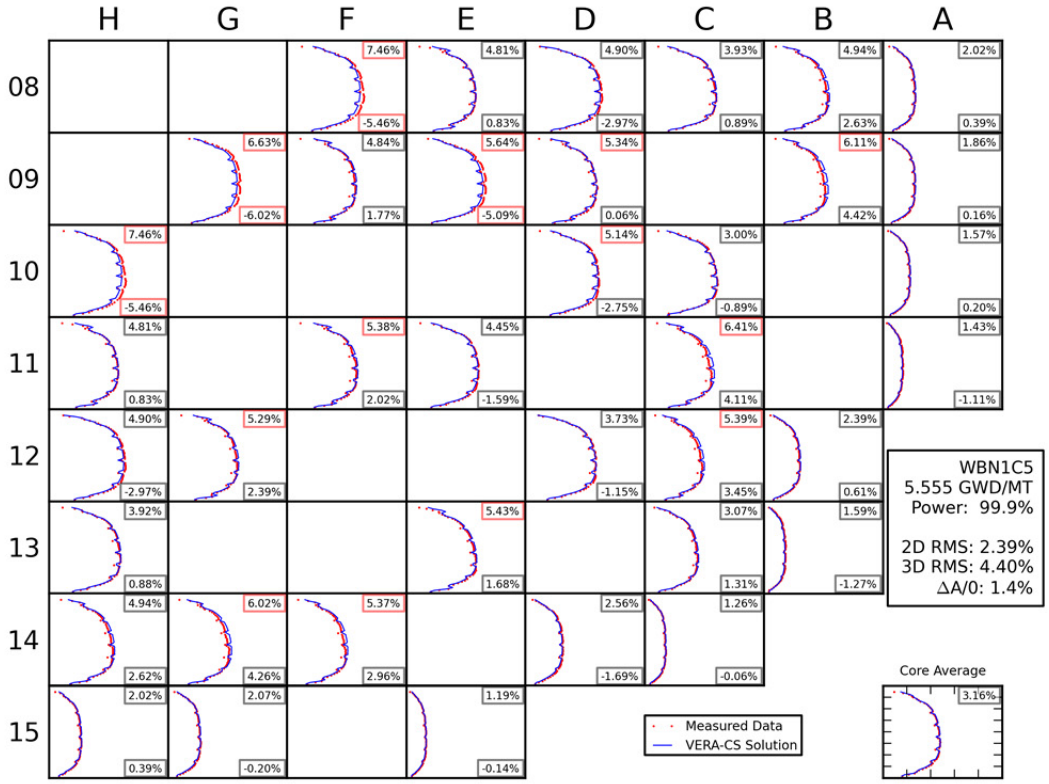

H G F E D C B A
08
09
10
11
12
13
14
15
WBN1C5
0.105 GWD/MT
Power: 100.0%
2D RMS: 2.48%
3D RMS: 5.71%
ΔA/0: 2.7%
Core Average
Measured Data
VERA-CS Solution

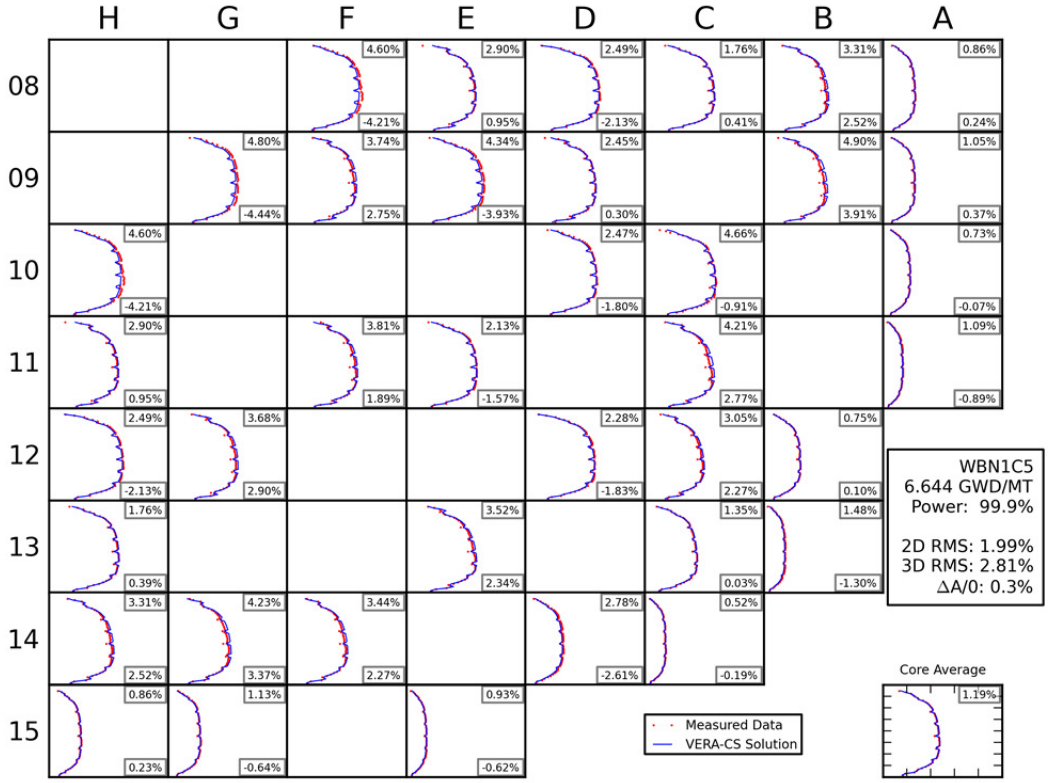

H G F E D C B A
08
09
10
11
12
13
14
15
WBN1C5
1.516 GWD/MT
Power: 100.0%
2D RMS: 2.59%
3D RMS: 4.99%
ΔA/0: 1.7%
Core Average
Measured Data
VERA-CS Solution

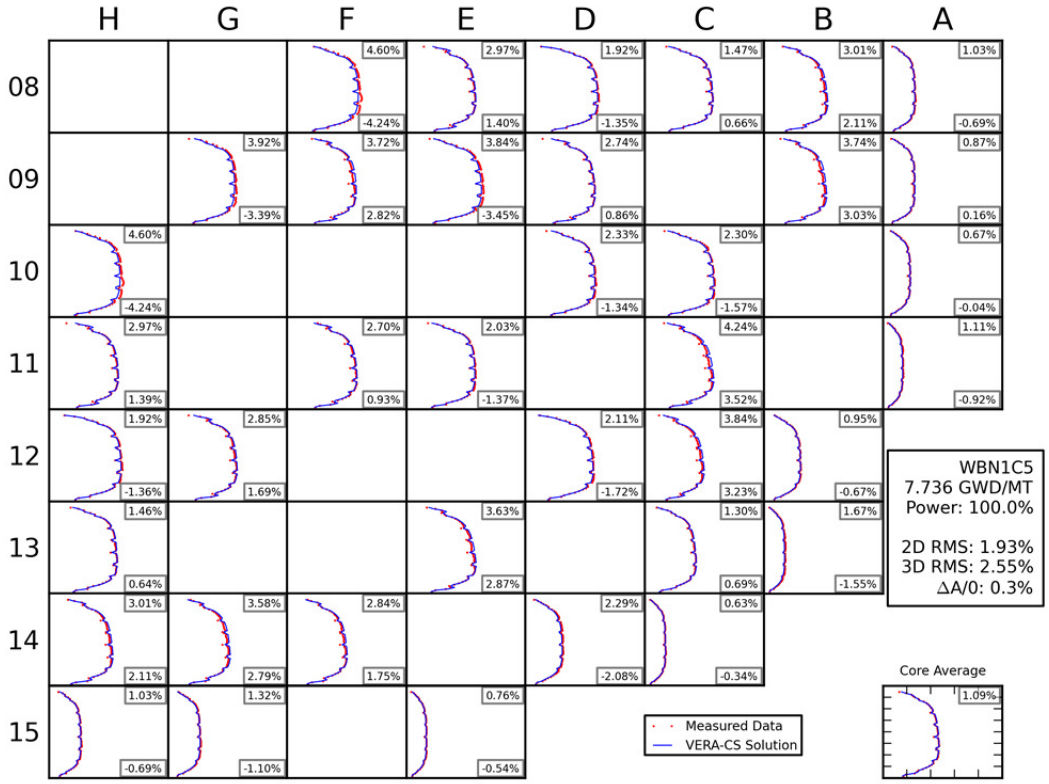

H G F E D C B A
08 09 10 11 12 13 14 15
8.52% -7.08%
6.43% 1.08%
5.51% -3.62%
4.48% 0.90%
5.70% 3.14%
2.38% 1.18%
9.61% -8.02%
5.41% 1.05%
8.19% -6.34%
5.71% 1.98%
7.55% 5.36%
2.29% -0.52%
8.52% -7.08%
4.59% -2.09%
4.21% -2.84%
1.83% 0.94%
6.43% 1.08%
5.59% 1.98%
4.91% -2.47%
7.67% 5.38%
1.27% -0.87%
5.52% -3.63%
6.19% 2.86%
3.87% -1.73%
6.02% 3.79%
2.58% 1.22%
4.48% 0.88%
6.25% 0.39%
4.20% 2.12%
1.90% -1.06%
5.70% 3.14%
7.09% 5.24%
5.51% 2.77%
2.47% -1.19%
1.39% 0.21%
2.38% 1.17%
2.38% 0.31%
1.38% 0.35%
WBN1C5
2.358 GWD/MT
Power: 100.0%
2D RMS: 2.94%
3D RMS: 5.05%
ΔA/0: 1.5%
Measured Data
VERA-CS Solution
Core Average
3.61%

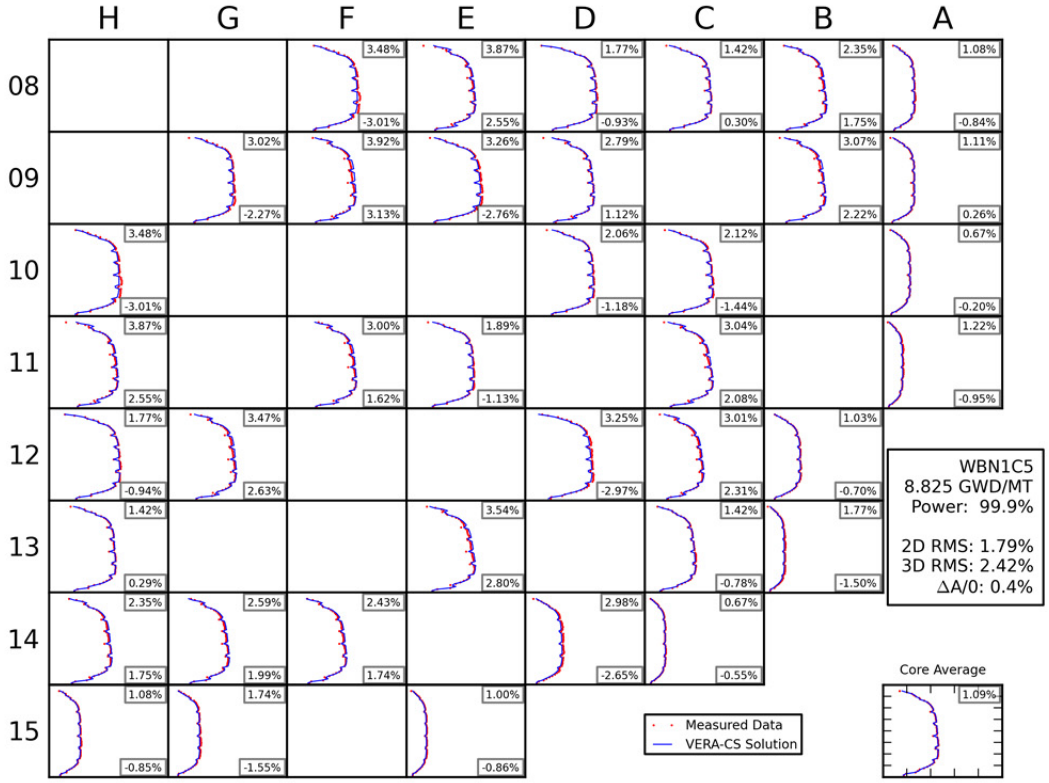

H G F E D C B A
08 09 10 11 12 13 14 15
8.25% -6.71%
6.64% 0.84%
5.51% -3.37%
4.10% 0.67%
5.12% 2.63%
2.41% 0.97%
8.73% -7.18%
4.94% 1.33%
7.94% -6.09%
4.84% 1.99%
7.43% 5.76%
1.86% -0.53%
8.25% -6.71%
5.35% -2.87%
4.36% -2.88%
1.80% 0.94%
6.64% 0.84%
5.52% 2.06%
4.98% -2.71%
6.93% 5.08%
1.33% -0.94%
5.51% -3.38%
5.42% 2.50%
3.84% -1.78%
5.60% 3.86%
2.72% 1.46%
4.10% 0.65%
5.41% 0.61%
3.82% 2.66%
1.75% -1.05%
5.11% 2.63%
7.37% 5.41%
5.22% 2.65%
2.37% -1.15%
1.32% 0.02%
2.41% 0.96%
2.50% 0.53%
1.43% 0.30%
WBN1C5
3.447 GWD/MT
Power: 100.0%
2D RMS: 2.85%
3D RMS: 4.89%
ΔA/0: 1.5%
Measured Data
VERA-CS Solution
Core Average
3.48%

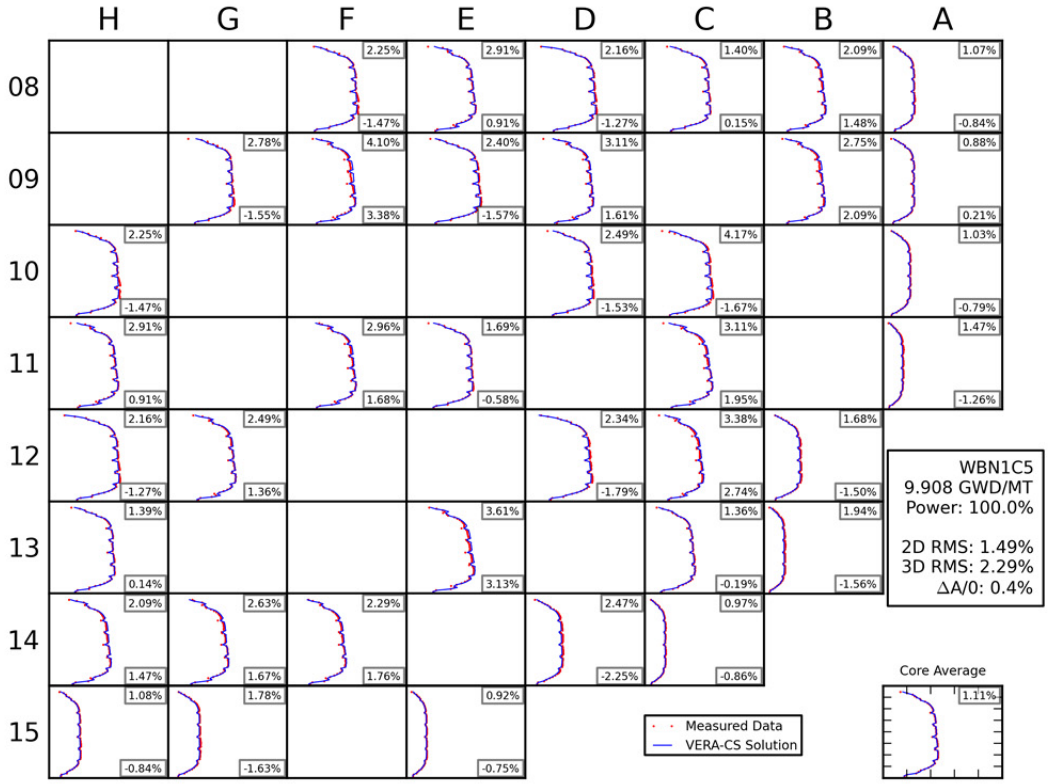

H G F E D C B A
08 09 10 11 12 13 14 15
7.56% -5.82%
6.04% 0.79%
5.09% -3.34%
4.27% 0.75%
6.11% 3.31%
2.01% 0.47%
9.29% -7.83%
5.06% 1.11%
7.52% -5.65%
5.70% 1.97%
7.43% 5.09%
2.22% -0.01%
7.56% -5.82%
4.95% -2.79%
4.62% -1.33%
1.49% 0.42%
6.04% 0.79%
5.34% 1.27%
4.93% -2.14%
7.40% 5.10%
1.52% -1.05%
5.10% -3.35%
5.64% 1.91%
4.13% -1.72%
6.05% 4.05%
2.35% 0.60%
4.27% 0.74%
6.22% 2.07%
3.62% 1.93%
1.91% -1.16%
6.10% 3.30%
6.47% 4.42%
5.58% 2.45%
2.37% -1.09%
1.27% -0.10%
2.01% 0.47%
2.18% 0.08%
1.16% 0.10%
WBN1C5
4.472 GWD/MT
Power: 99.9%
2D RMS: 2.61%
3D RMS: 4.84%
ΔA/0: 1.8%
Core Average
3.69%
Measured Data
VERA-CS Solution

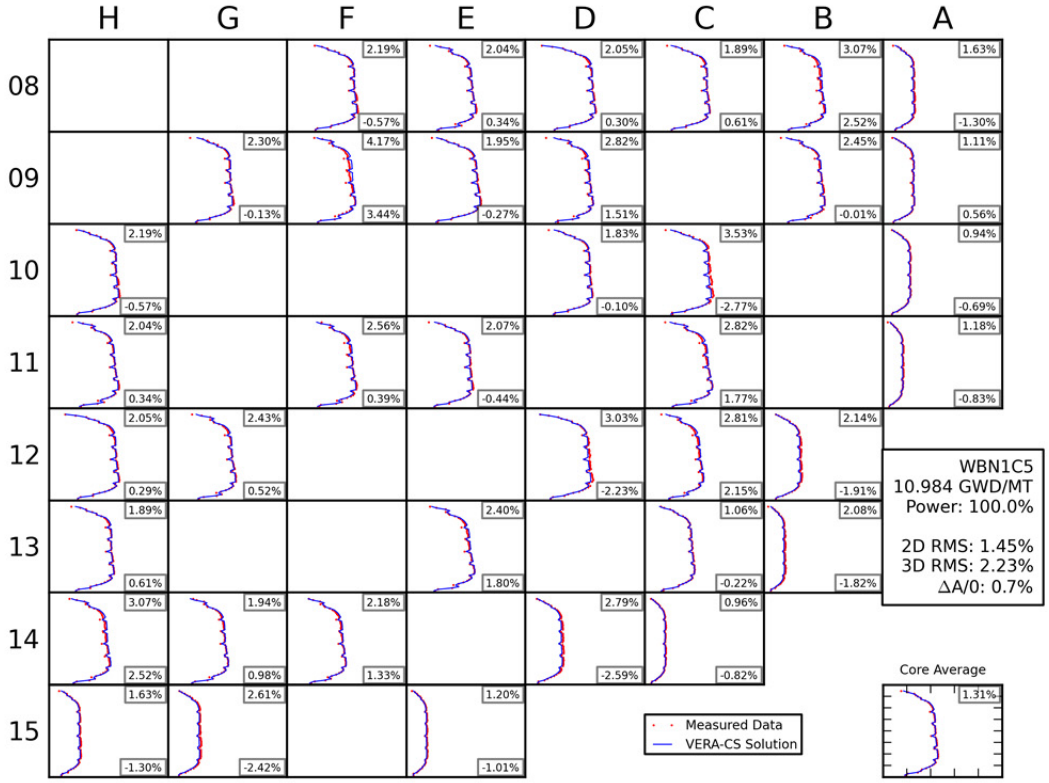

H G F E D C B A
08 09 10 11 12 13 14 15
7.46% -5.46%
4.81% 0.83%
4.90% -2.97%
3.93% 0.89%
4.94% 2.63%
2.02% 0.39%
6.63% -6.02%
4.84% 1.77%
5.64% -5.09%
5.34% 0.06%
6.11% 4.42%
1.86% 0.16%
7.46% -5.46%
5.14% -2.75%
3.00% -0.89%
1.57% 0.20%
4.81% 0.83%
5.38% 2.02%
4.45% -1.59%
6.41% 4.11%
1.43% -1.11%
4.90% -2.97%
5.29% 2.39%
3.73% -1.15%
5.39% 3.45%
2.39% 0.61%
3.92% 0.88%
5.43% 1.68%
3.07% 1.31%
1.59% -1.27%
4.94% 2.62%
6.02% 4.26%
5.37% 2.96%
2.56% -1.69%
1.26% -0.06%
2.02% 0.39%
2.07% -0.20%
1.19% -0.14%
WBN1C5
5.555 GWD/MT
Power: 99.9%
2D RMS: 2.39%
3D RMS: 4.40%
ΔA/0: 1.4%
Core Average
3.16%
Measured Data
VERA-CS Solution

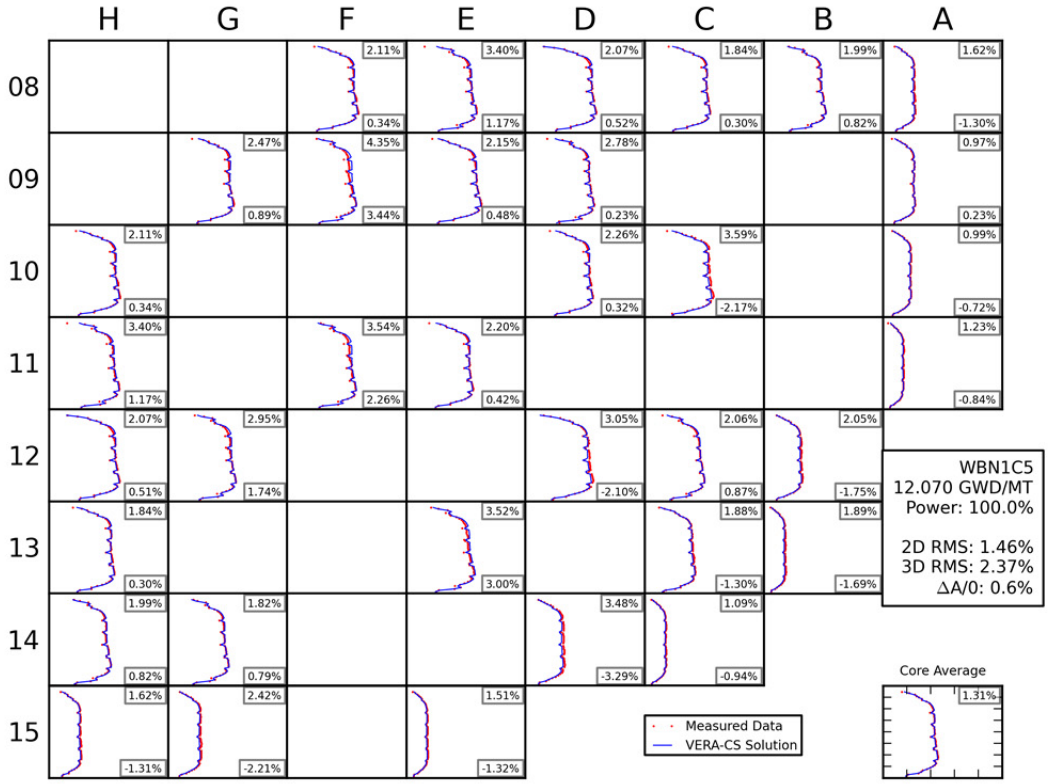

H G F E D C B A
08 09 10 11 12 13 14 15
4.60% -4.21%
2.90% 0.95%
2.49% -2.13%
1.76% 0.41%
3.31% 2.52%
0.86% 0.24%
4.80% -4.44%
3.74% 2.75%
4.34% -3.93%
2.45% 0.30%
4.90% 3.91%
1.05% 0.37%
4.60% -4.21%
2.47% -1.80%
4.66% -0.91%
0.73% -0.07%
2.90% 0.95%
3.81% 1.89%
2.13% -1.57%
4.21% 2.77%
1.09% -0.89%
2.49% -2.13%
3.68% 2.90%
2.28% -1.83%
3.05% 2.27%
0.75% 0.10%
1.76% 0.39%
3.52% 2.34%
1.35% 0.03%
1.48% -1.30%
3.31% 2.52%
4.23% 3.37%
3.44% 2.27%
2.78% -2.61%
0.52% -0.19%
0.86% 0.23%
1.13% -0.64%
0.93% -0.62%
WBN1C5
6.644 GWD/MT
Power: 99.9%
2D RMS: 1.99%
3D RMS: 2.81%
ΔA/0: 0.3%
Measured Data
VERA-CS Solution
Core Average
1.19%

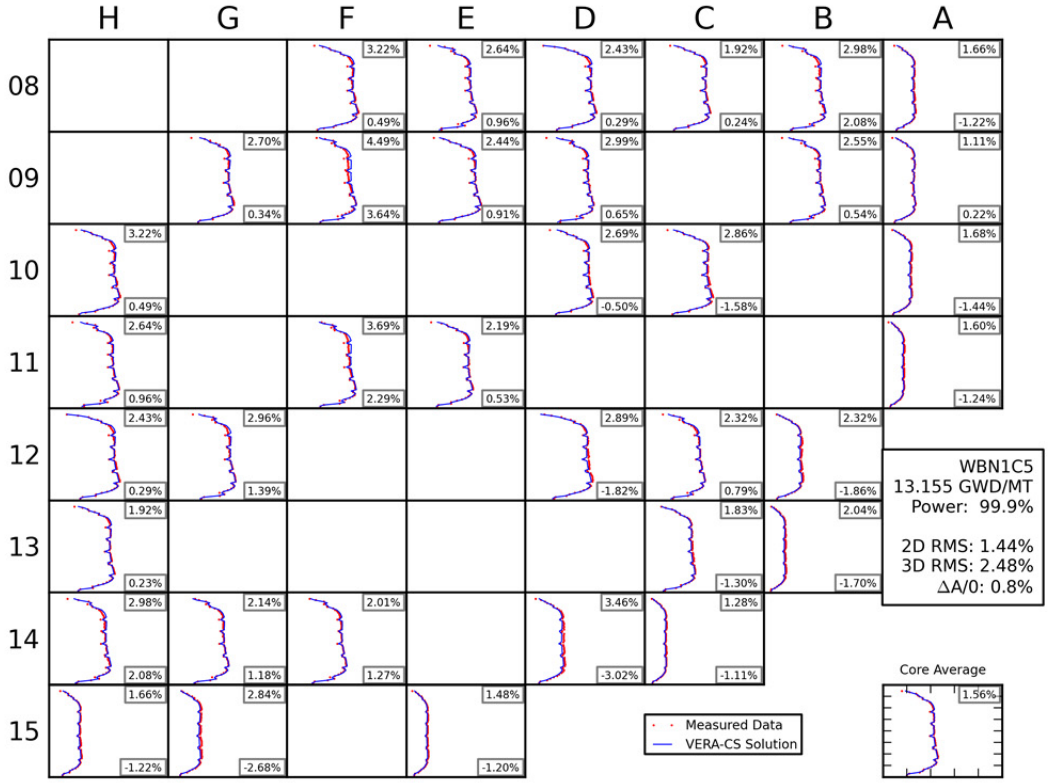

H G F E D C B A
08 09 10 11 12 13 14 15
4.60% -4.24%
2.97% 1.40%
1.92% -1.35%
1.47% 0.66%
3.01% 2.11%
1.03% -0.69%
3.92% -3.39%
3.72% 2.82%
3.84% -3.45%
2.74% 0.86%
3.74% 3.03%
0.87% 0.16%
4.60% -4.24%
2.33% -1.34%
2.30% -1.57%
0.67% -0.04%
2.97% 1.39%
2.70% 0.93%
2.03% -1.37%
4.24% 3.52%
1.11% -0.92%
1.92% -1.36%
2.85% 1.69%
2.11% -1.72%
3.84% 3.23%
0.95% -0.67%
1.46% 0.64%
3.63% 2.87%
1.30% 0.69%
1.67% -1.55%
3.01% 2.11%
3.58% 2.79%
2.84% 1.75%
2.29% -2.08%
0.63% -0.34%
1.03% -0.69%
1.32% -1.10%
0.76% -0.54%
WBN1C5
7.736 GWD/MT
Power: 100.0%
2D RMS: 1.93%
3D RMS: 2.55%
ΔA/0: 0.3%
Measured Data
VERA-CS Solution
Core Average
1.09%

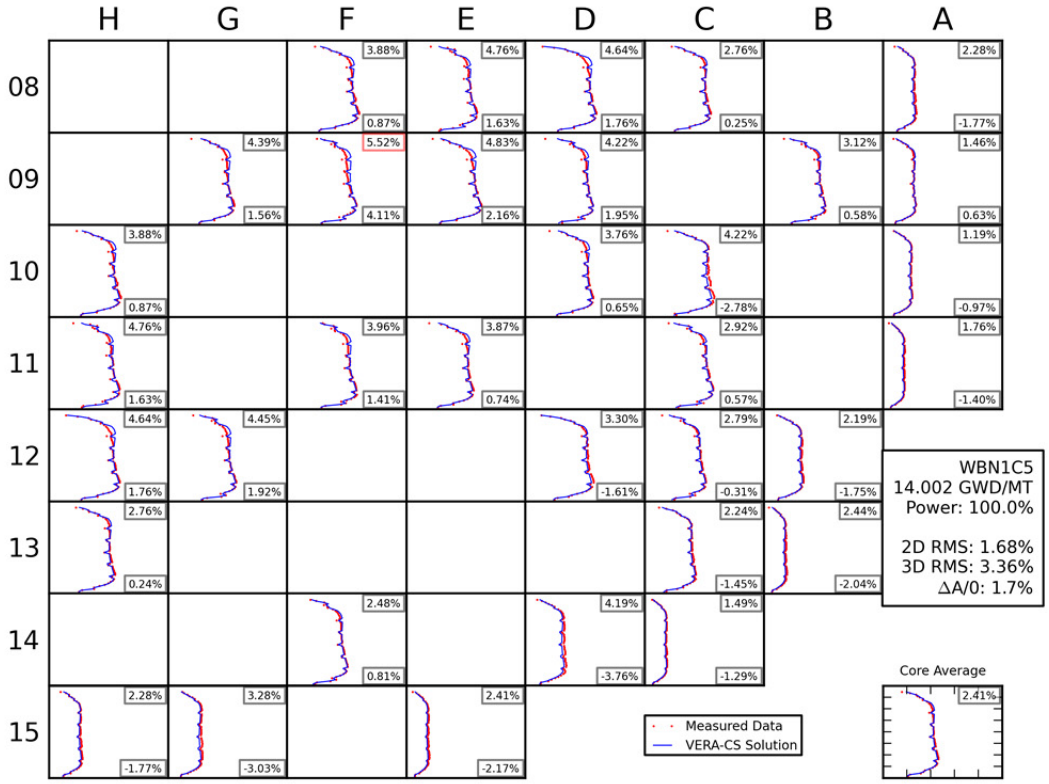

H G F E D C B A
08
3.48% -3.01%
3.87% 2.55%
1.77% -0.93%
1.42% 0.30%
2.35% 1.75%
1.08% -0.84%
09
3.02% -2.27%
3.92% 3.13%
3.26% -2.76%
2.79% 1.12%
3.07% 2.22%
1.11% 0.26%
10
3.48% -3.01%
2.06% -1.18%
2.12% -1.44%
0.67% -0.20%
11
3.87% 2.55%
3.00% 1.62%
1.89% -1.13%
3.04% 2.08%
1.22% -0.95%
12
1.77% -0.94%
3.47% 2.63%
3.25% -2.97%
3.01% 2.31%
1.03% -0.70%
13
1.42% 0.29%
3.54% 2.80%
1.42% -0.78%
1.77% -1.50%
14
2.35% 1.75%
2.59% 1.99%
2.43% 1.74%
2.98% -2.65%
0.67% -0.55%
15
1.08% -0.85%
1.74% -1.55%
1.00% -0.86%
WBN1C5
8.825 GWD/MT
Power: 99.9%
2D RMS: 1.79%
3D RMS: 2.42%
ΔA/0: 0.4%
Measured Data
VERA-CS Solution
Core Average
1.09%

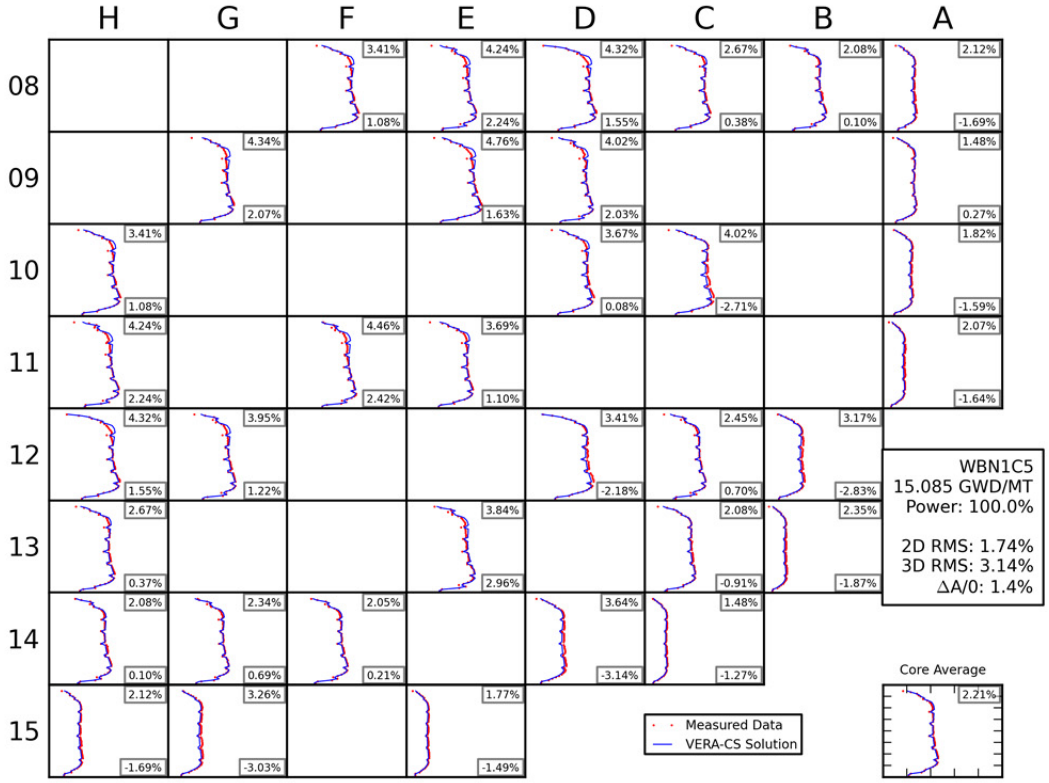

H G F E D C B A
08
2.25% -1.47%
2.91% 0.91%
2.16% -1.27%
1.40% 0.15%
2.09% 1.48%
1.07% -0.84%
09
2.78% -1.55%
4.10% 3.38%
2.40% -1.57%
3.11% 1.61%
2.75% 2.09%
0.88% 0.21%
10
2.25% -1.47%
2.49% -1.53%
4.17% -1.67%
1.03% -0.79%
11
2.91% 0.91%
2.96% 1.68%
1.69% -0.58%
3.11% 1.95%
1.47% -1.26%
12
2.16% -1.27%
2.49% 1.36%
2.34% -1.79%
3.38% 2.74%
1.68% -1.50%
13
1.39% 0.14%
3.61% 3.13%
1.36% -0.19%
1.94% -1.56%
14
2.09% 1.47%
2.63% 1.67%
2.29% 1.76%
2.47% -2.25%
0.97% -0.86%
15
1.08% -0.84%
1.78% -1.63%
0.92% -0.75%
WBN1C5
9.908 GWD/MT
Power: 100.0%
2D RMS: 1.49%
3D RMS: 2.29%
ΔA/0: 0.4%
Measured Data
VERA-CS Solution
Core Average
1.11%

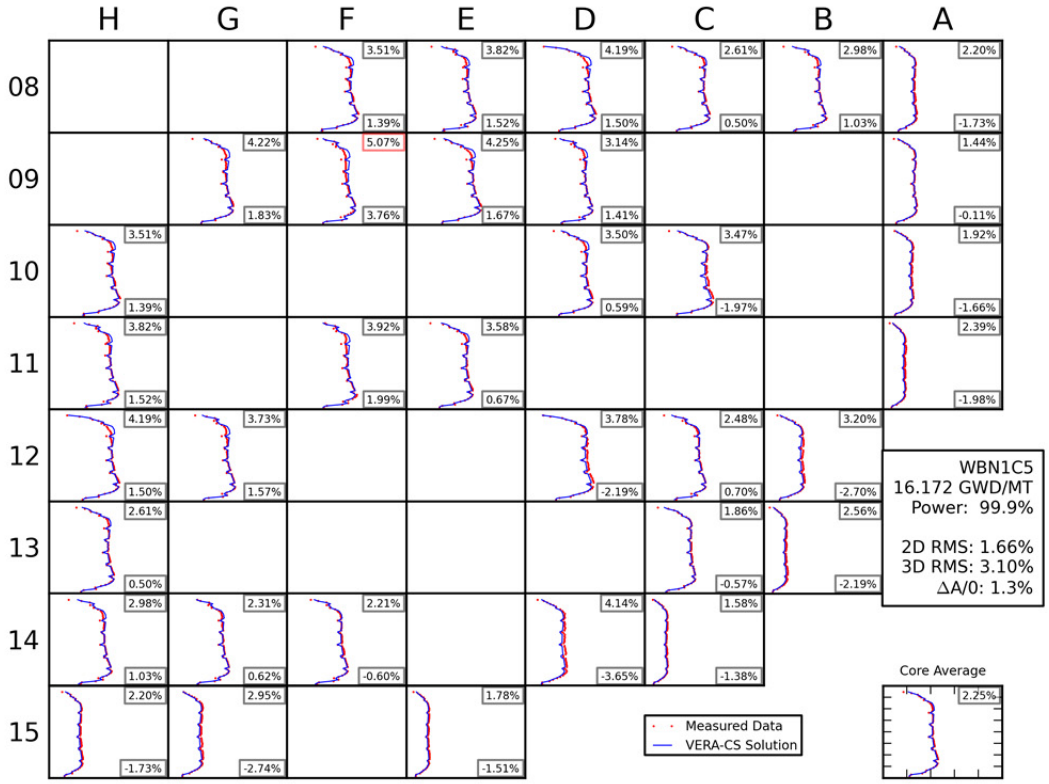

H G F E D C B A
08 09 10 11 12 13 14 15
2.19% -0.57%
2.04% 0.34%
2.05% 0.30%
1.89% 0.61%
3.07% 2.52%
1.63% -1.30%
2.30% -0.13%
4.17% 3.44%
1.95% -0.27%
2.82% 1.51%
2.45% -0.01%
1.11% 0.56%
2.19% -0.57%
1.83% -0.10%
3.53% -2.77%
0.94% -0.69%
2.04% 0.34%
2.56% 0.39%
2.07% -0.44%
2.82% 1.77%
1.18% -0.83%
2.05% 0.29%
2.43% 0.52%
3.03% -2.23%
2.81% 2.15%
2.14% -1.91%
1.89% 0.61%
2.40% 1.80%
1.06% -0.22%
2.08% -1.82%
3.07% 2.52%
1.94% 0.98%
2.18% 1.33%
2.79% -2.59%
0.96% -0.82%
1.63% -1.30%
2.61% -2.42%
1.20% -1.01%
WBN1C5
10.984 GWD/MT
Power: 100.0%
2D RMS: 1.45%
3D RMS: 2.23%
ΔA/0: 0.7%
Core Average
1.31%
Measured Data
VERA-CS Solution

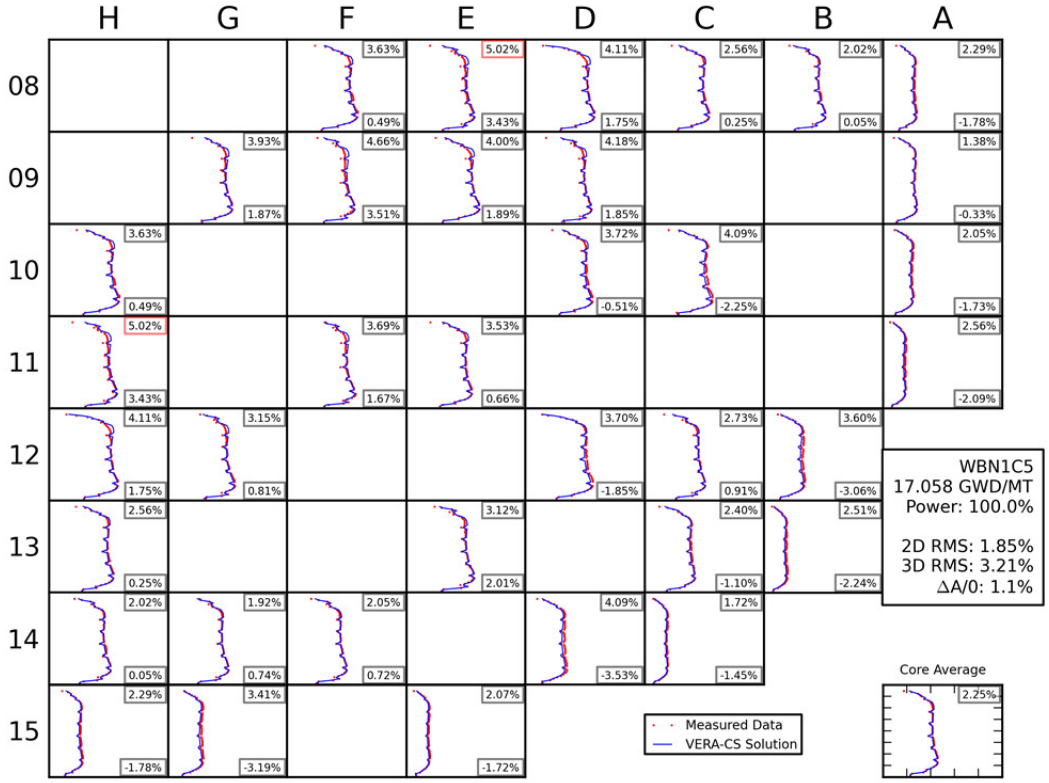

H G F E D C B A
08 09 10 11 12 13 14 15
2.11% 0.34%
3.40% 1.17%
2.07% 0.52%
1.84% 0.30%
1.99% 0.82%
1.62% -1.30%
2.47% 0.89%
4.35% 3.44%
2.15% 0.48%
2.78% 0.23%
0.97% 0.23%
2.11% 0.34%
2.26% 0.32%
3.59% -2.17%
0.99% -0.72%
3.40% 1.17%
3.54% 2.26%
2.20% 0.42%
1.23% -0.84%
2.07% 0.51%
2.95% 1.74%
3.05% -2.10%
2.06% 0.87%
2.05% -1.75%
1.84% 0.30%
3.52% 3.00%
1.88% -1.30%
1.89% -1.69%
1.99% 0.82%
1.82% 0.79%
3.48% -3.29%
1.09% -0.94%
1.62% -1.31%
2.42% -2.21%
1.51% -1.32%
WBN1C5
12.070 GWD/MT
Power: 100.0%
2D RMS: 1.46%
3D RMS: 2.37%
ΔA/0: 0.6%
Core Average
1.31%
Measured Data
VERA-CS Solution

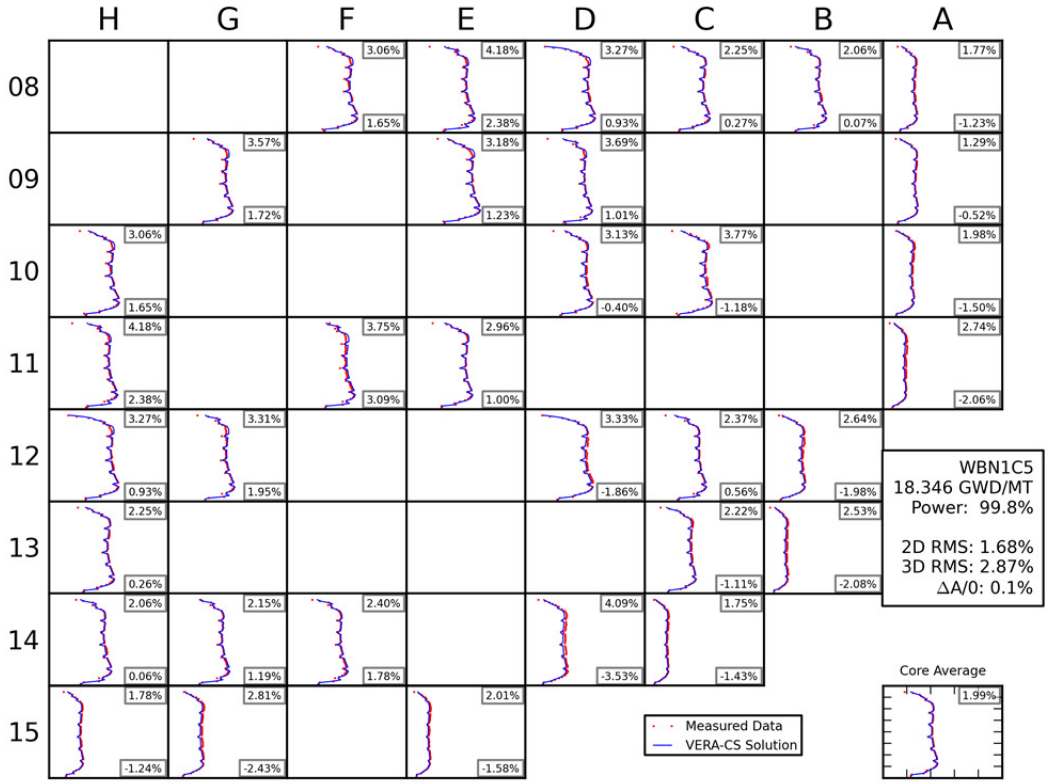

H G F E D C B A
08
09
10
11
12
13
14
15
WBN1C5
13.155 GWD/MT
Power: 99.9%
2D RMS: 1.44%
3D RMS: 2.48%
ΔA/0: 0.8%
Core Average
Measured Data
VERA-CS Solution

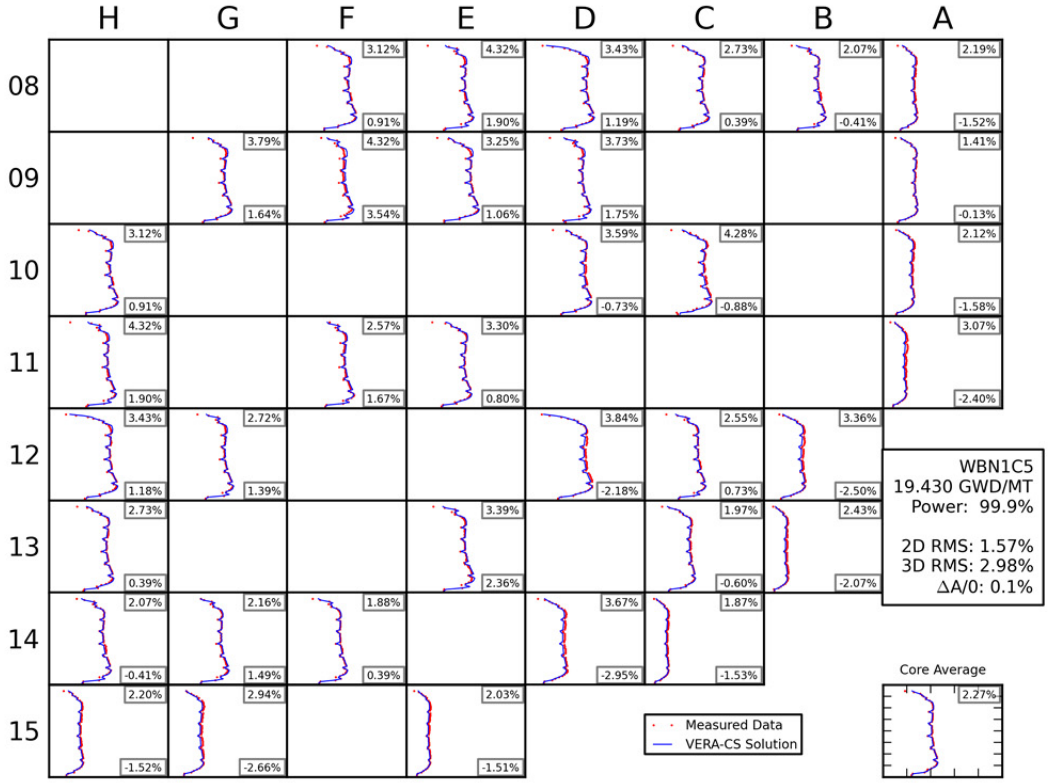

H G F E D C B A
08
09
10
11
12
13
14
15
WBN1C5
14.002 GWD/MT
Power: 100.0%
2D RMS: 1.68%
3D RMS: 3.36%
ΔA/0: 1.7%
Core Average
Measured Data
VERA-CS Solution

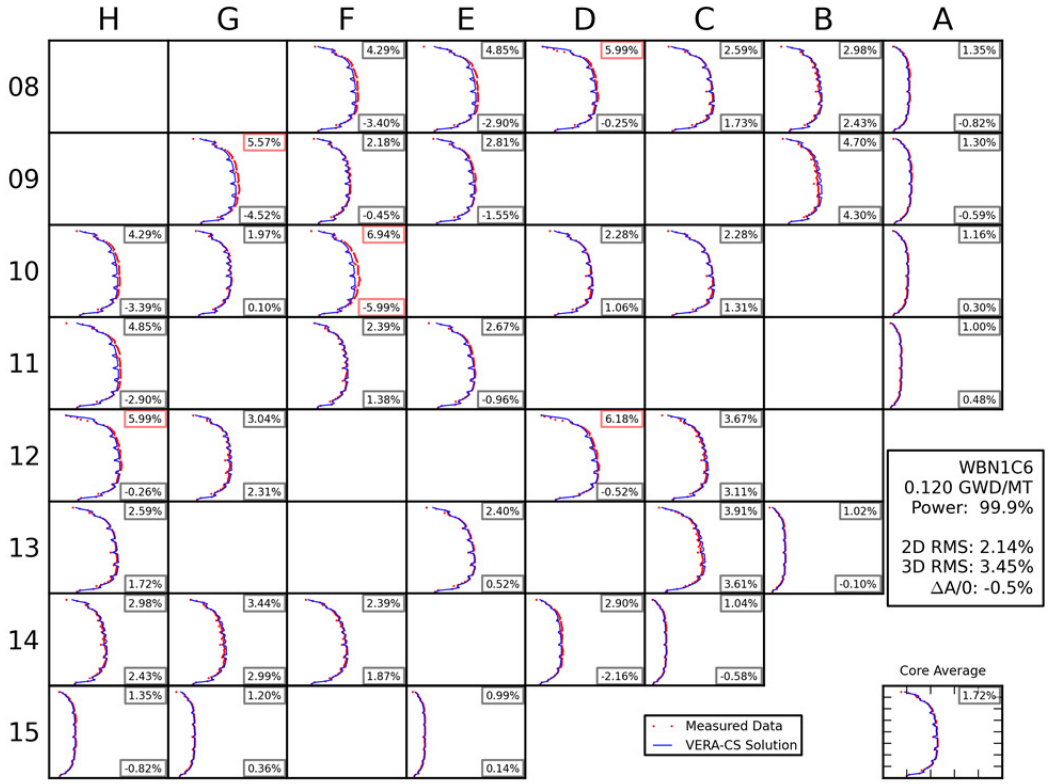

H G F E D C B A
08 09 10 11 12 13 14 15
3.41% 1.08%
4.24% 2.24%
4.32% 1.55%
2.67% 0.38%
2.08% 0.10%
2.12% -1.69%
4.34% 2.07%
4.76% 1.63%
4.02% 2.03%
1.48% 0.27%
3.41% 1.08%
3.67% 0.08%
4.02% -2.71%
1.82% -1.59%
4.24% 2.24%
4.46% 2.42%
3.69% 1.10%
2.07% -1.64%
4.32% 1.55%
3.95% 1.22%
3.41% -2.18%
2.45% 0.70%
3.17% -2.83%
2.67% 0.37%
3.84% 2.96%
2.08% -0.91%
2.35% -1.87%
2.08% 0.10%
2.34% 0.69%
2.05% 0.21%
3.64% -3.14%
1.48% -1.27%
2.12% -1.69%
3.26% -3.03%
1.77% -1.49%
WBN1C5
15.085 GWD/MT
Power: 100.0%
2D RMS: 1.74%
3D RMS: 3.14%
ΔA/0: 1.4%
Measured Data
VERA-CS Solution
Core Average
2.21%

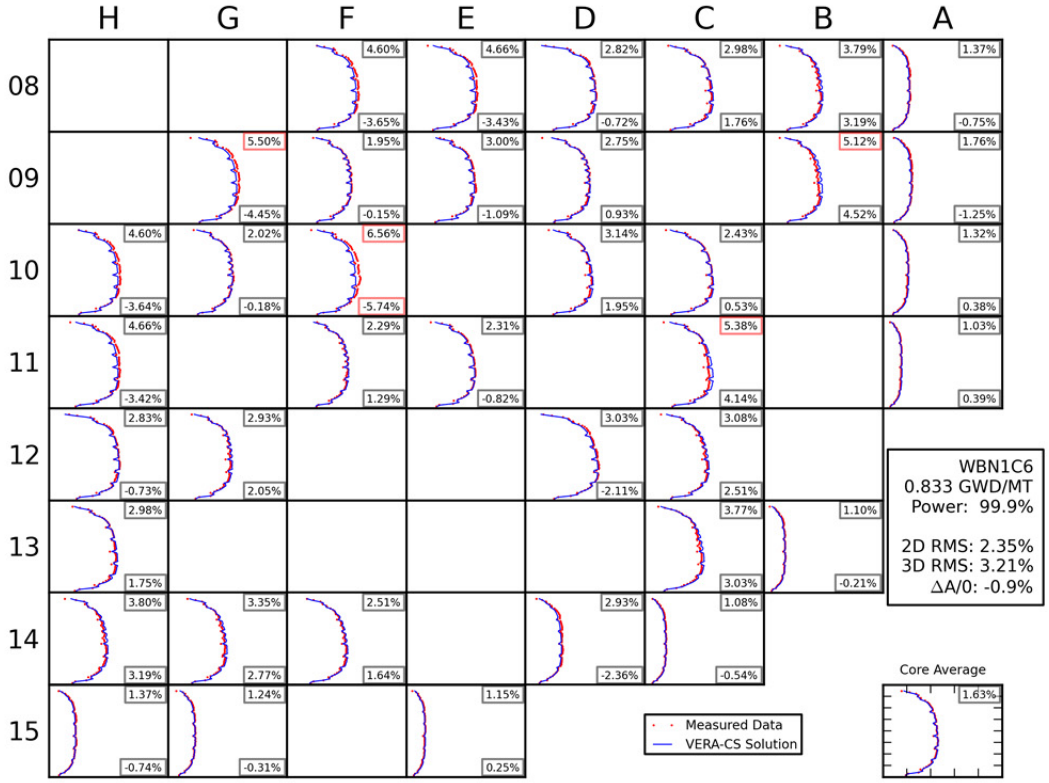

H G F E D C B A
08 09 10 11 12 13 14 15
3.51% 1.39%
3.82% 1.52%
4.19% 1.50%
2.61% 0.50%
2.98% 1.03%
2.20% -1.73%
4.22% 1.83%
5.07% 3.76%
4.25% 1.67%
3.14% 1.41%
1.44% -0.11%
3.51% 1.39%
3.50% 0.59%
3.47% -1.97%
1.92% -1.66%
3.82% 1.52%
3.92% 1.99%
3.58% 0.67%
2.39% -1.98%
4.19% 1.50%
3.73% 1.57%
3.78% -2.19%
2.48% 0.70%
3.20% -2.70%
2.61% 0.50%
1.86% -0.57%
2.56% -2.19%
2.98% 1.03%
2.31% 0.62%
2.21% -0.60%
4.14% -3.65%
1.58% -1.38%
2.20% -1.73%
2.95% -2.74%
1.78% -1.51%
WBN1C5
16.172 GWD/MT
Power: 99.9%
2D RMS: 1.66%
3D RMS: 3.10%
ΔA/0: 1.3%
Measured Data
VERA-CS Solution
Core Average
2.25%

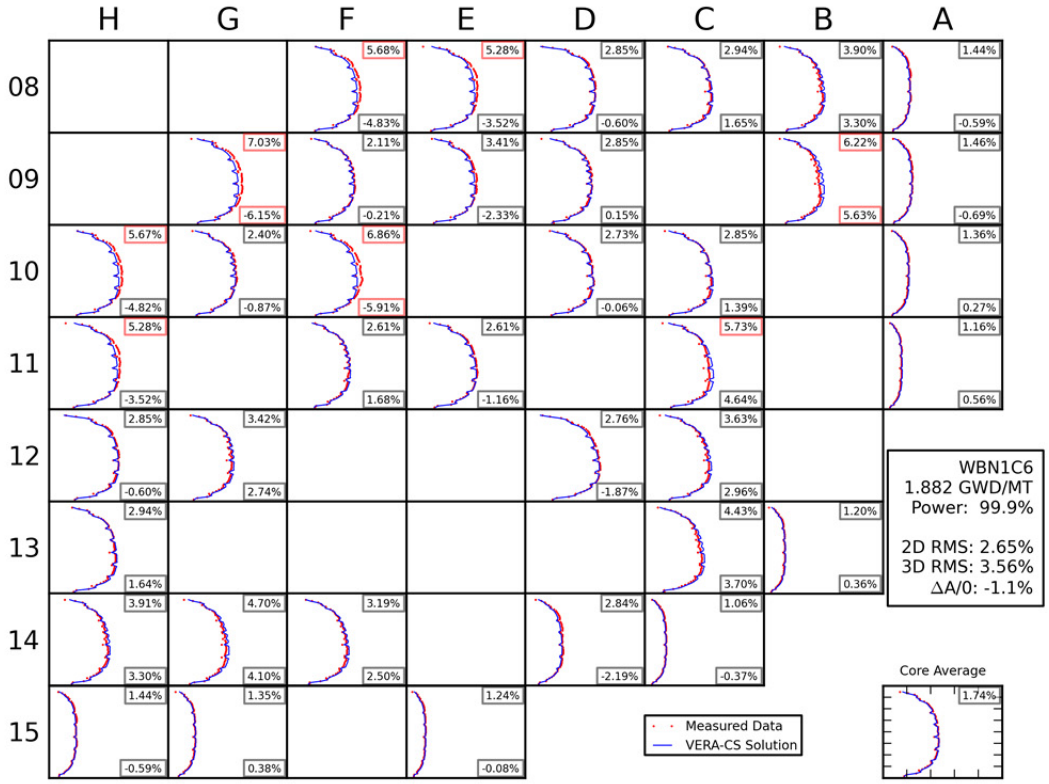

H G F E D C B A
08 09 10 11 12 13 14 15
3.63% 0.49%
5.02% 3.43%
4.11% 1.75%
2.56% 0.25%
2.02% 0.05%
2.29% -1.78%
3.93% 1.87%
4.66% 3.51%
4.00% 1.89%
4.18% 1.85%
1.38% -0.33%
3.63% 0.49%
3.72% -0.51%
4.09% -2.25%
2.05% -1.73%
5.02% 3.43%
3.69% 1.67%
3.53% 0.66%
2.56% -2.09%
4.11% 1.75%
3.15% 0.81%
3.70% -1.85%
2.73% 0.91%
3.60% -3.06%
2.56% 0.25%
3.12% 2.01%
2.40% -1.10%
2.51% -2.24%
2.02% 0.05%
1.92% 0.74%
2.05% 0.72%
4.09% -3.53%
1.72% -1.45%
2.29% -1.78%
3.41% -3.19%
2.07% -1.72%
WBN1C5
17.058 GWD/MT
Power: 100.0%
2D RMS: 1.85%
3D RMS: 3.21%
ΔA/0: 1.1%
Core Average
2.25%
Measured Data
VERA-CS Solution

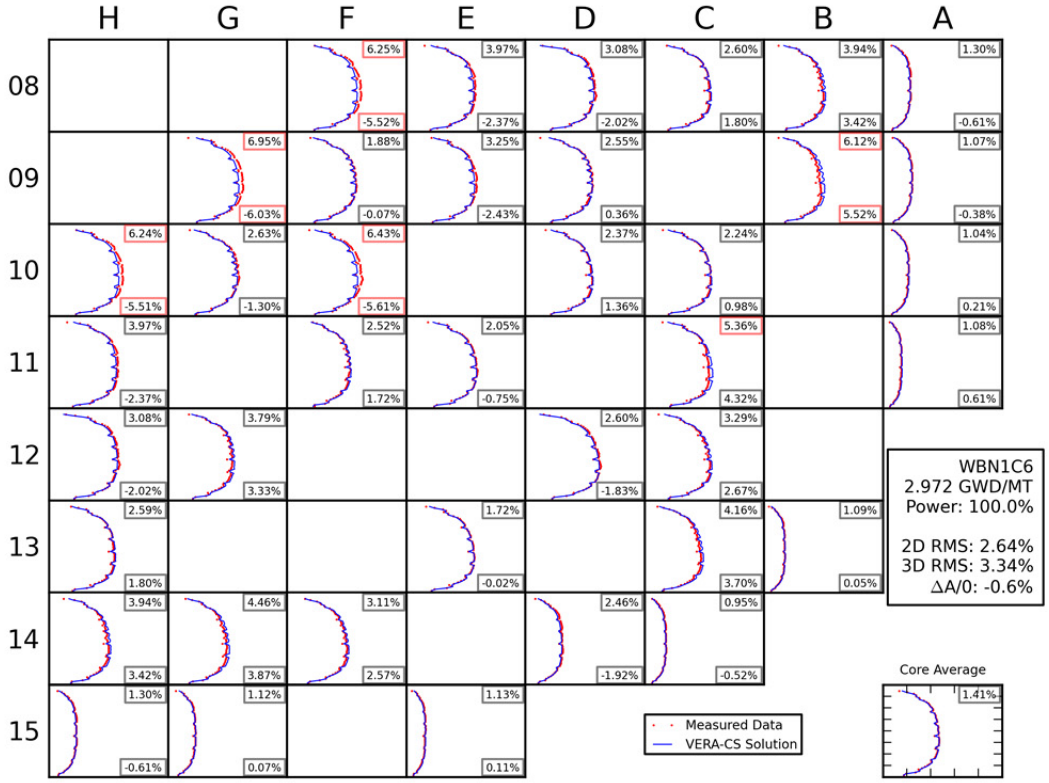

H G F E D C B A
08 09 10 11 12 13 14 15
3.06% 1.65%
4.18% 2.38%
3.27% 0.93%
2.25% 0.27%
2.06% 0.07%
1.77% -1.23%
3.57% 1.72%
3.18% 1.23%
3.69% 1.01%
1.29% -0.52%
3.06% 1.65%
3.13% -0.40%
3.77% -1.18%
1.98% -1.50%
4.18% 2.38%
3.75% 3.09%
2.96% 1.00%
2.74% -2.06%
3.27% 0.93%
3.31% 1.95%
3.33% -1.86%
2.37% 0.56%
2.64% -1.98%
2.25% 0.26%
2.22% -1.11%
2.53% -2.08%
2.06% 0.06%
2.15% 1.19%
2.40% 1.78%
4.09% -3.53%
1.75% -1.43%
1.78% -1.24%
2.81% -2.43%
2.01% -1.58%
WBN1C5
18.346 GWD/MT
Power: 99.8%
2D RMS: 1.68%
3D RMS: 2.87%
ΔA/0: 0.1%
Core Average
1.99%
Measured Data
VERA-CS Solution

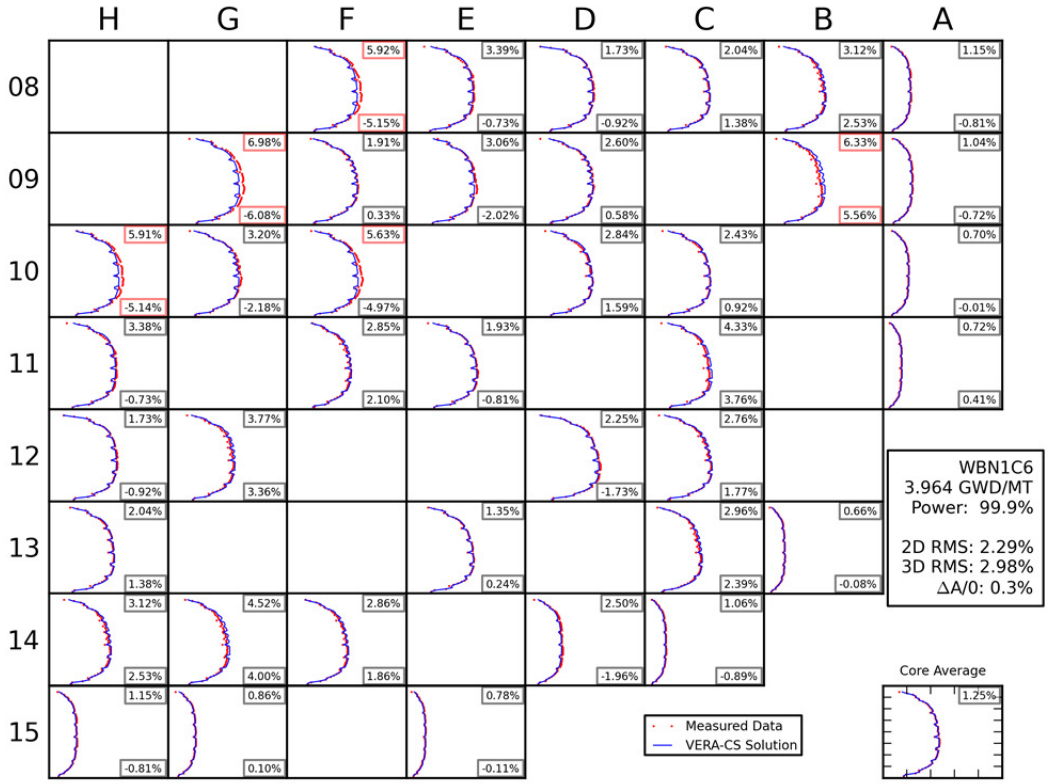

H G F E D C B A
08
09
10
11
12
13
14
15
WBN1C5
19.430 GWD/MT
Power: 99.9%
2D RMS: 1.57%
3D RMS: 2.98%
ΔA/0: 0.1%
Core Average
Measured Data
VERA-CS Solution

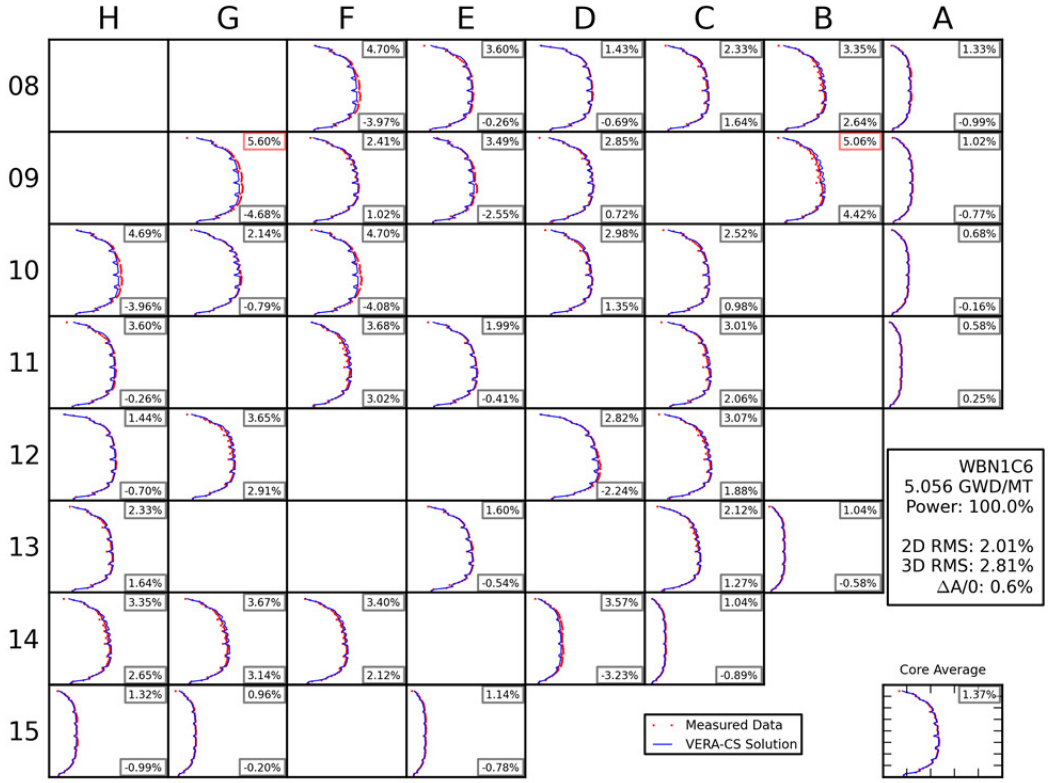

H G F E D C B A
08
09
10
11
12
13
14
15
WBN1C6
0.120 GWD/MT
Power: 99.9%
2D RMS: 2.14%
3D RMS: 3.45%
ΔA/0: -0.5%
Core Average
Measured Data
VERA-CS Solution

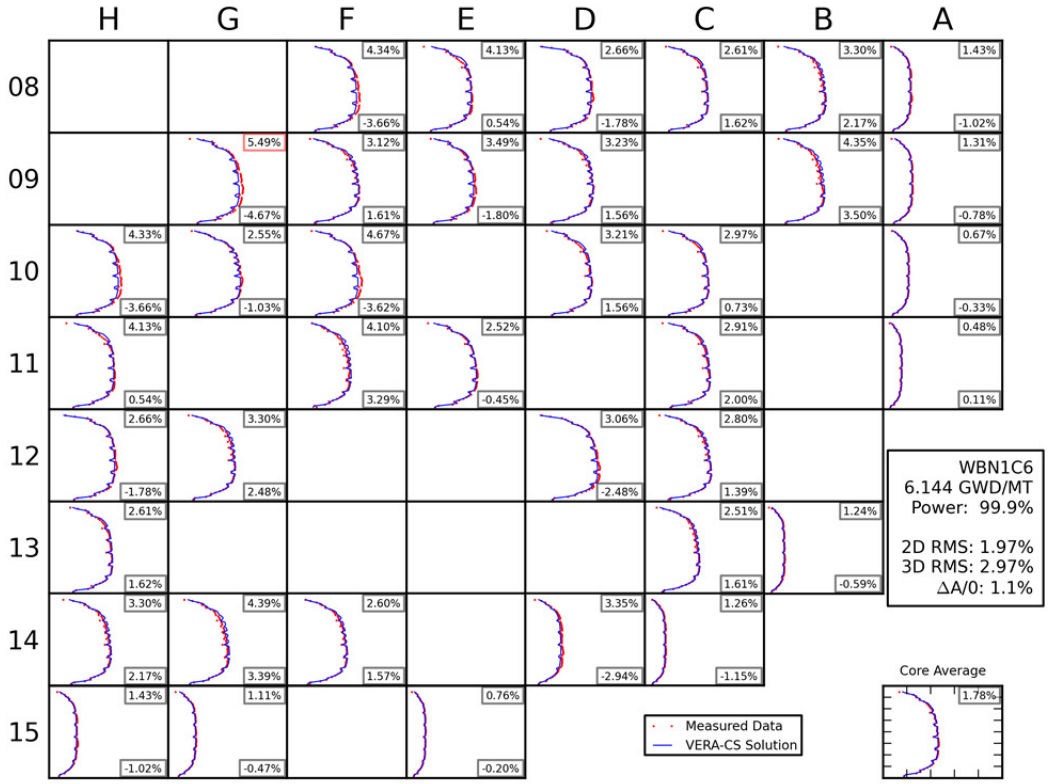

H G F E D C B A
08 09 10 11 12 13 14 15
4.60% -3.65%
4.66% -3.43%
2.82% -0.72%
2.98% 1.76%
3.79% 3.19%
1.37% -0.75%
5.50% -4.45%
1.95% -0.15%
3.00% -1.09%
2.75% 0.93%
5.12% 4.52%
1.76% -1.25%
4.60% -3.64%
2.02% -0.18%
6.56% -5.74%
3.14% 1.95%
2.43% 0.53%
1.32% 0.38%
4.66% -3.42%
2.29% 1.29%
2.31% -0.82%
5.38% 4.14%
1.03% 0.39%
2.83% -0.73%
2.93% 2.05%
3.03% -2.11%
3.08% 2.51%
2.98% 1.75%
3.77% 3.03%
1.10% -0.21%
3.80% 3.19%
3.35% 2.77%
2.51% 1.64%
2.93% -2.36%
1.08% -0.54%
1.37% -0.74%
1.24% -0.31%
1.15% 0.25%
WBN1C6
0.833 GWD/MT
Power: 99.9%
2D RMS: 2.35%
3D RMS: 3.21%
ΔA/0: -0.9%
Core Average
1.63%
Measured Data
VERA-CS Solution

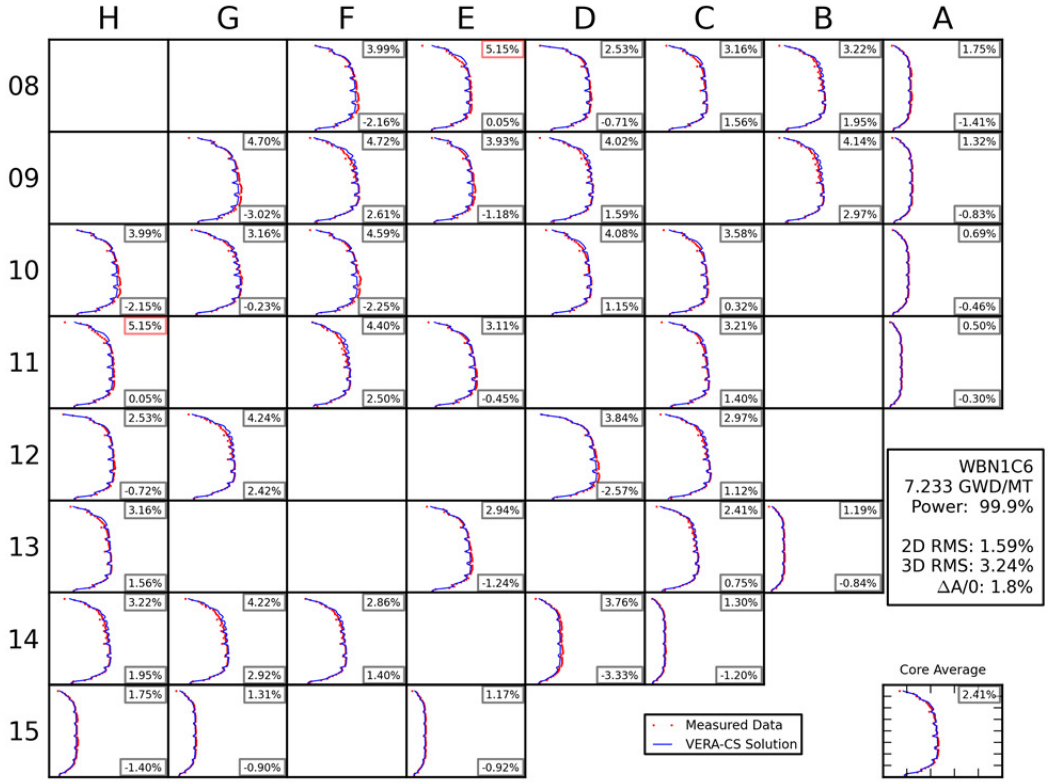

H G F E D C B A
08 09 10 11 12 13 14 15
5.68% -4.83%
5.28% -3.52%
2.85% -0.60%
2.94% 1.65%
3.90% 3.30%
1.44% -0.59%
7.03% -6.15%
2.11% -0.21%
3.41% -2.33%
2.85% 0.15%
6.22% 5.63%
1.46% -0.69%
5.67% -4.82%
2.40% -0.87%
6.86% -5.91%
2.73% -0.06%
2.85% 1.39%
1.36% 0.27%
5.28% -3.52%
2.61% 1.68%
2.61% -1.16%
5.73% 4.64%
1.16% 0.56%
2.85% -0.60%
3.42% 2.74%
2.76% -1.87%
3.63% 2.96%
2.94% 1.64%
4.43% 3.70%
1.20% 0.36%
3.91% 3.30%
4.70% 4.10%
3.19% 2.50%
2.84% -2.19%
1.06% -0.37%
1.44% -0.59%
1.35% 0.38%
1.24% -0.08%
WBN1C6
1.882 GWD/MT
Power: 99.9%
2D RMS: 2.65%
3D RMS: 3.56%
ΔA/0: -1.1%
Core Average
1.74%
Measured Data
VERA-CS Solution

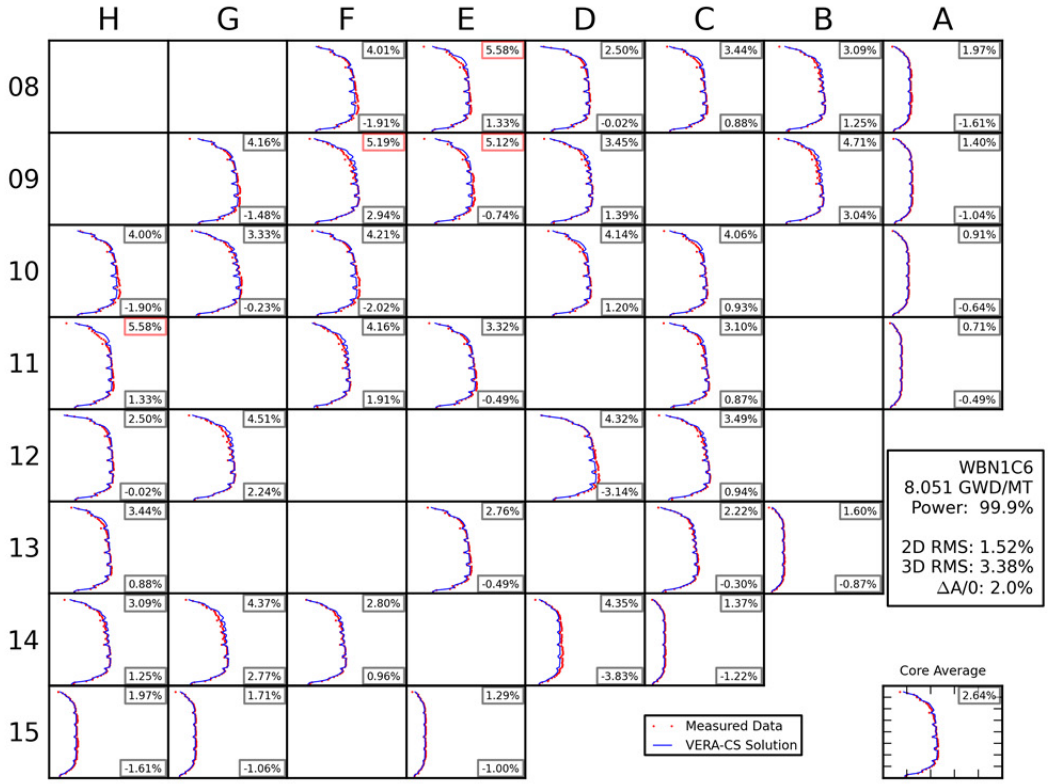

H G F E D C B A
08
6.25% -5.52%
3.97% -2.37%
3.08% -2.02%
2.60% 1.80%
3.94% 3.42%
1.30% -0.61%
09
6.95% -6.03%
1.88% -0.07%
3.25% -2.43%
2.55% 0.36%
6.12% 5.52%
1.07% -0.38%
10
6.24% -5.51%
2.63% -1.30%
6.43% -5.61%
2.37% 1.36%
2.24% 0.98%
1.04% 0.21%
11
3.97% -2.37%
2.52% 1.72%
2.05% -0.75%
5.36% 4.32%
1.08% 0.61%
12
3.08% -2.02%
3.79% 3.33%
2.60% -1.83%
3.29% 2.67%
13
2.59% 1.80%
1.72% -0.02%
4.16% 3.70%
1.09% 0.05%
14
3.94% 3.42%
4.46% 3.87%
3.11% 2.57%
2.46% -1.92%
0.95% -0.52%
15
1.30% -0.61%
1.12% 0.07%
1.13% 0.11%
WBN1C6
2.972 GWD/MT
Power: 100.0%
2D RMS: 2.64%
3D RMS: 3.34%
ΔA/0: -0.6%
Measured Data
VERA-CS Solution
Core Average
1.41%

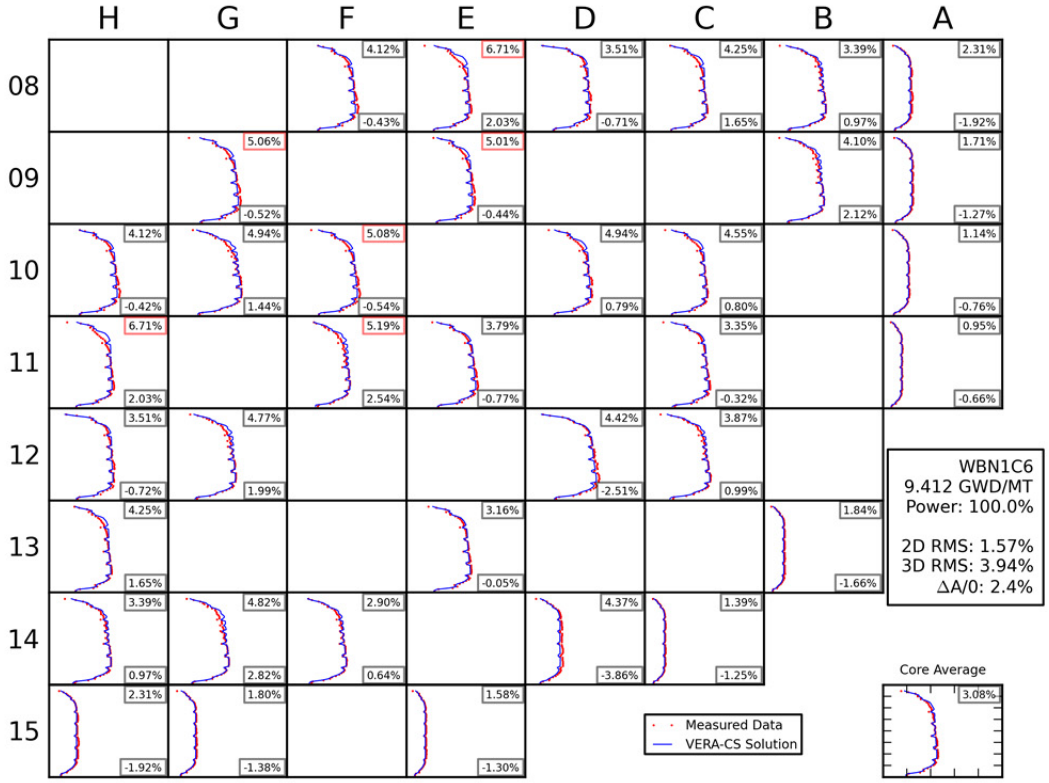

H G F E D C B A
08
5.92% -5.15%
3.39% -0.73%
1.73% -0.92%
2.04% 1.38%
3.12% 2.53%
1.15% -0.81%
09
6.98% -6.08%
1.91% 0.33%
3.06% -2.02%
2.60% 0.58%
6.33% 5.56%
1.04% -0.72%
10
5.91% -5.14%
3.20% -2.18%
5.63% -4.97%
2.84% 1.59%
2.43% 0.92%
0.70% -0.01%
11
3.38% -0.73%
2.85% 2.10%
1.93% -0.81%
4.33% 3.76%
0.72% 0.41%
12
1.73% -0.92%
3.77% 3.36%
2.25% -1.73%
2.76% 1.77%
13
2.04% 1.38%
1.35% 0.24%
2.96% 2.39%
0.66% -0.08%
14
3.12% 2.53%
4.52% 4.00%
2.86% 1.86%
2.50% -1.96%
1.06% -0.89%
15
1.15% -0.81%
0.86% 0.10%
0.78% -0.11%
WBN1C6
3.964 GWD/MT
Power: 99.9%
2D RMS: 2.29%
3D RMS: 2.98%
ΔA/0: 0.3%
Measured Data
VERA-CS Solution
Core Average
1.25%

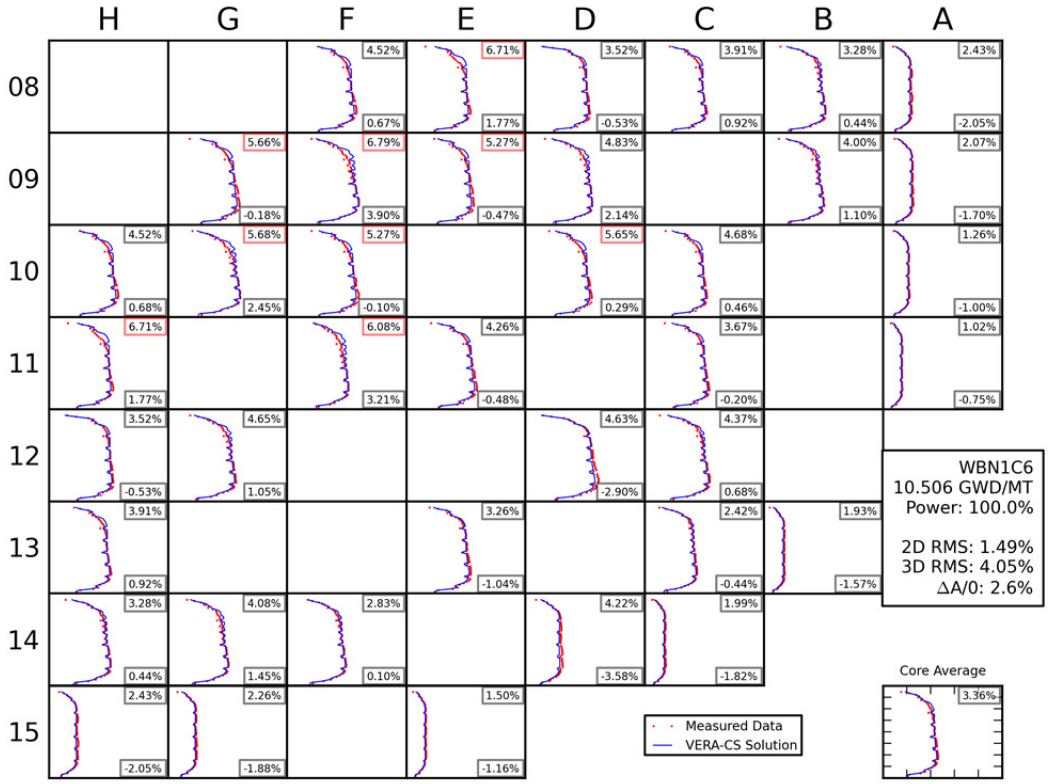

H G F E D C B A
08
09
10
11
12
13
14
15
WBN1C6
5.056 GWD/MT
Power: 100.0%
2D RMS: 2.01%
3D RMS: 2.81%
ΔA/0: 0.6%
Core Average
Measured Data
VERA-CS Solution

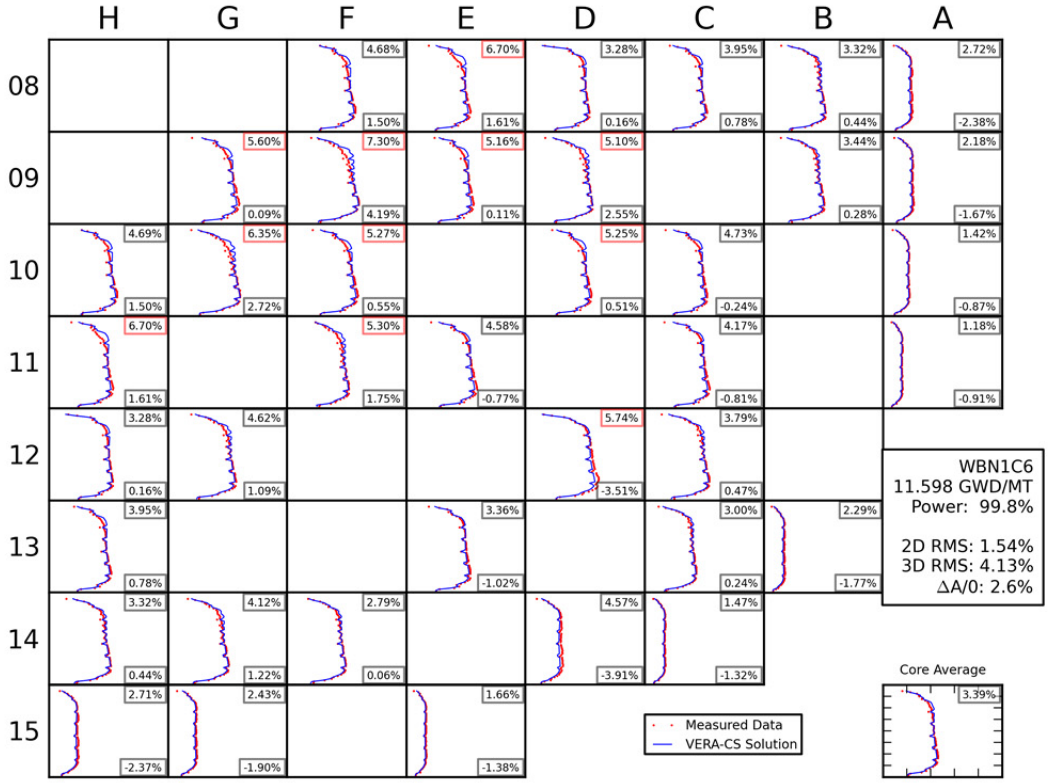

H G F E D C B A
08
09
10
11
12
13
14
15
WBN1C6
6.144 GWD/MT
Power: 99.9%
2D RMS: 1.97%
3D RMS: 2.97%
ΔA/0: 1.1%
Core Average
Measured Data
VERA-CS Solution

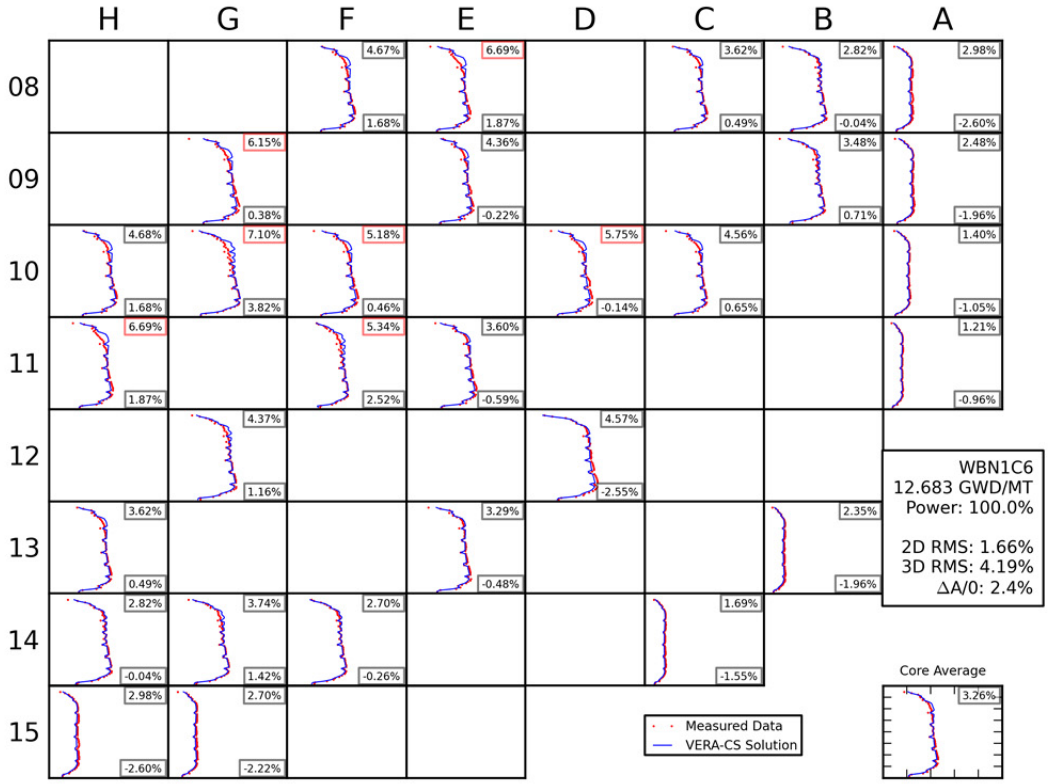

H G F E D C B A
08 09 10 11 12 13 14 15
3.99% -2.16%
5.15% 0.05%
2.53% -0.71%
3.16% 1.56%
3.22% 1.95%
1.75% -1.41%
4.70% -3.02%
4.72% 2.61%
3.93% -1.18%
4.02% 1.59%
4.14% 2.97%
1.32% -0.83%
3.99% -2.15%
3.16% -0.23%
4.59% -2.25%
4.08% 1.15%
3.58% 0.32%
0.69% -0.46%
5.15% 0.05%
4.40% 2.50%
3.11% -0.45%
3.21% 1.40%
0.50% -0.30%
2.53% -0.72%
4.24% 2.42%
3.84% -2.57%
2.97% 1.12%
3.16% 1.56%
2.94% -1.24%
2.41% 0.75%
1.19% -0.84%
3.22% 1.95%
4.22% 2.92%
2.86% 1.40%
3.76% -3.33%
1.30% -1.20%
1.75% -1.40%
1.31% -0.90%
1.17% -0.92%
WBN1C6
7.233 GWD/MT
Power: 99.9%
2D RMS: 1.59%
3D RMS: 3.24%
ΔA/0: 1.8%
Core Average
2.41%
Measured Data
VERA-CS Solution

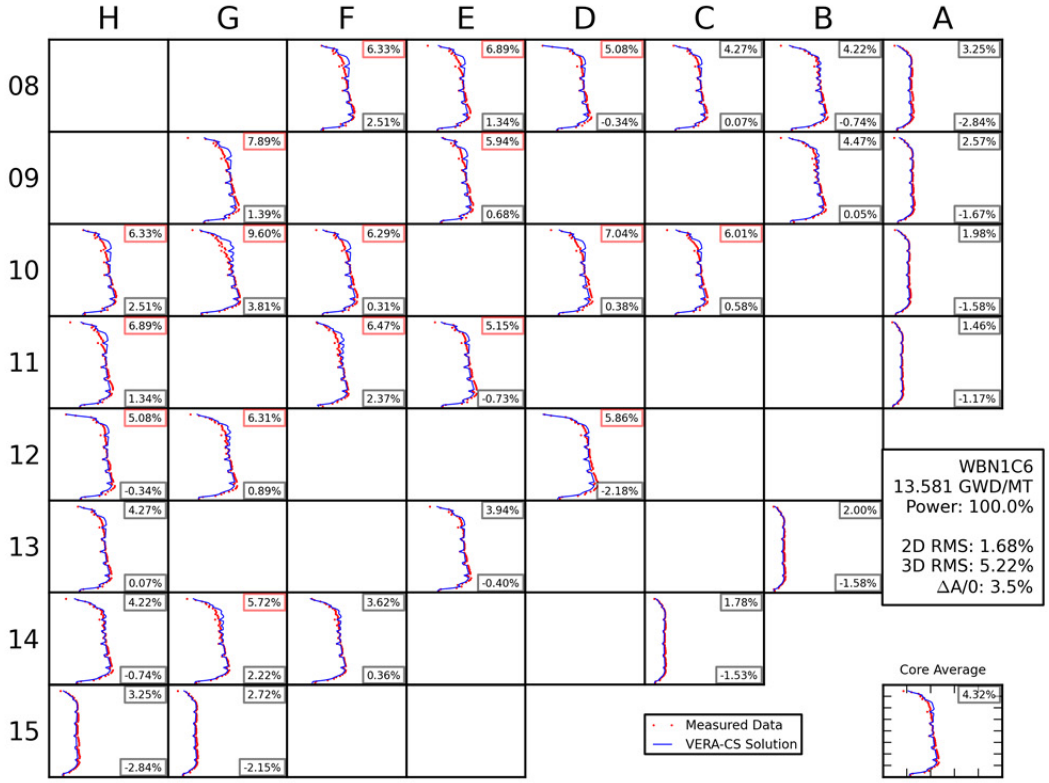

H G F E D C B A
08 09 10 11 12 13 14 15
4.01% -1.91%
5.58% 1.33%
2.50% -0.02%
3.44% 0.88%
3.09% 1.25%
1.97% -1.61%
4.16% -1.48%
5.19% 2.94%
5.12% -0.74%
3.45% 1.39%
4.71% 3.04%
1.40% -1.04%
4.00% -1.90%
3.33% -0.23%
4.21% -2.02%
4.14% 1.20%
4.06% 0.93%
0.91% -0.64%
5.58% 1.33%
4.16% 1.91%
3.32% -0.49%
3.10% 0.87%
0.71% -0.49%
2.50% -0.02%
4.51% 2.24%
4.32% -3.14%
3.49% 0.94%
3.44% 0.88%
2.76% -0.49%
2.22% -0.30%
1.60% -0.87%
3.09% 1.25%
4.37% 2.77%
2.80% 0.96%
4.35% -3.83%
1.37% -1.22%
1.97% -1.61%
1.71% -1.06%
1.29% -1.00%
WBN1C6
8.051 GWD/MT
Power: 99.9%
2D RMS: 1.52%
3D RMS: 3.38%
ΔA/0: 2.0%
Core Average
2.64%
Measured Data
VERA-CS Solution

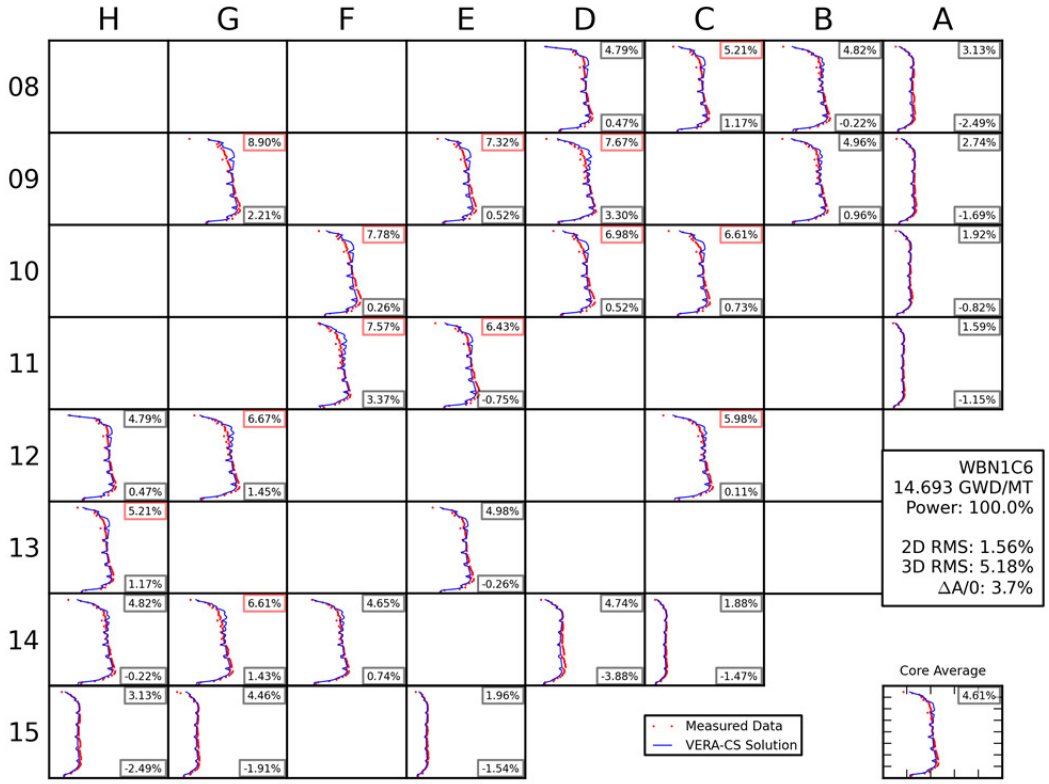

H G F E D C B A
08
09
10
11
12
13
14
15
WBN1C6
9.412 GWD/MT
Power: 100.0%
2D RMS: 1.57%
3D RMS: 3.94%
ΔA/0: 2.4%
Core Average
Measured Data
VERA-CS Solution

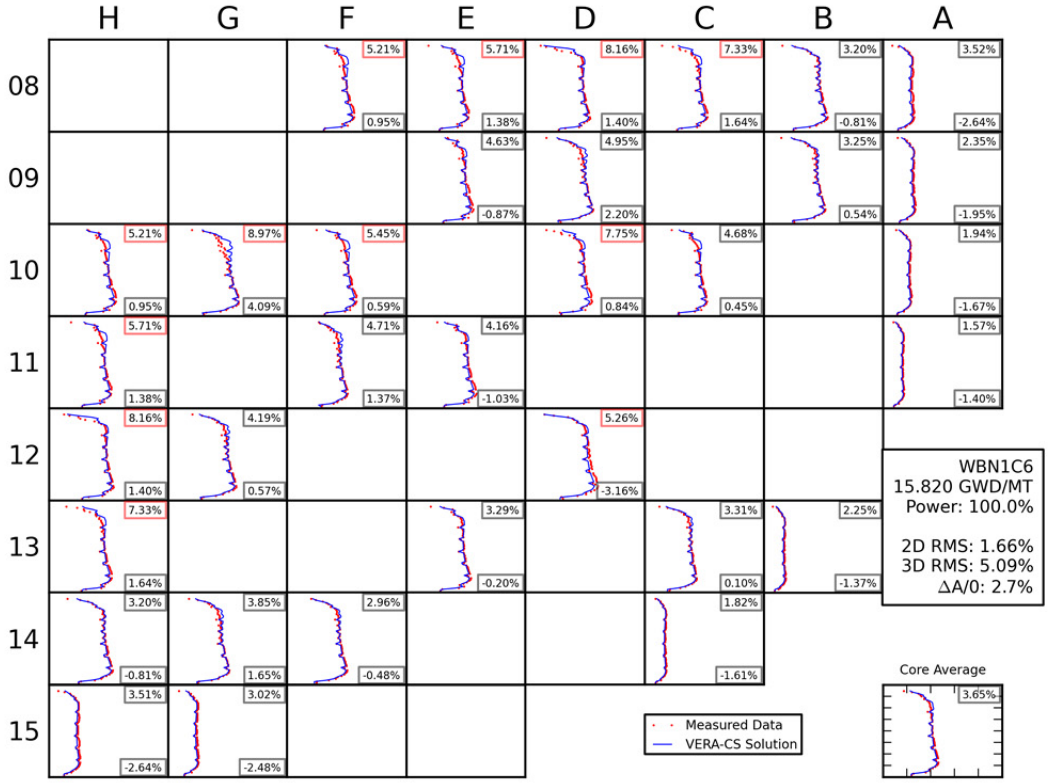

H G F E D C B A
08
09
10
11
12
13
14
15
WBN1C6
10.506 GWD/MT
Power: 100.0%
2D RMS: 1.49%
3D RMS: 4.05%
ΔA/0: 2.6%
Core Average
Measured Data
VERA-CS Solution

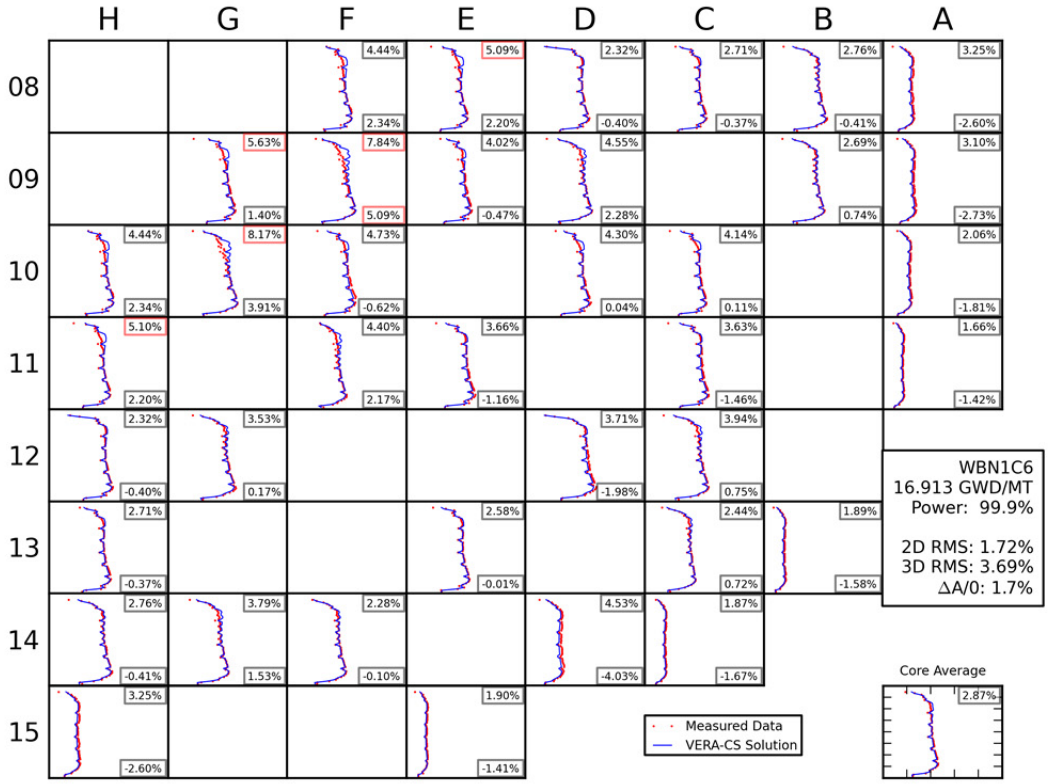

H G F E D C B A
08
09
10
11
12
13
14
15
WBN1C6
11.598 GWD/MT
Power: 99.8%
2D RMS: 1.54%
3D RMS: 4.13%
ΔA/0: 2.6%
Core Average
Measured Data
VERA-CS Solution

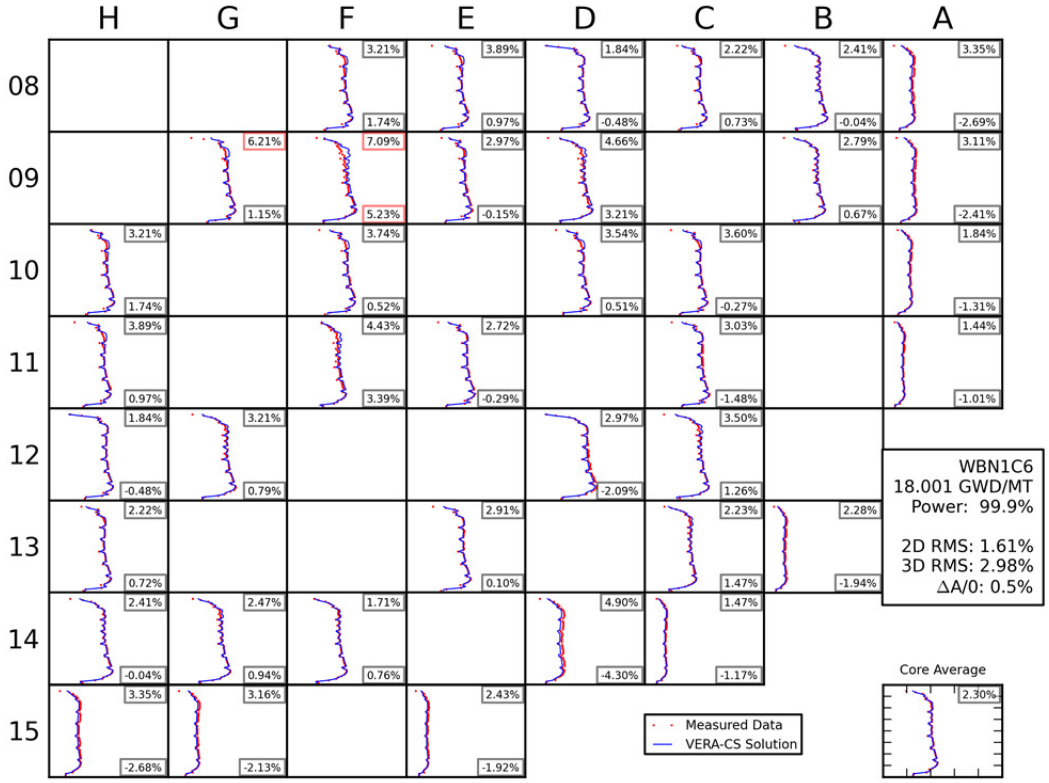

H G F E D C B A
08
09
10
11
12
13
14
15
WBN1C6
12.683 GWD/MT
Power: 100.0%
2D RMS: 1.66%
3D RMS: 4.19%
ΔA/0: 2.4%
Core Average
Measured Data
VERA-CS Solution

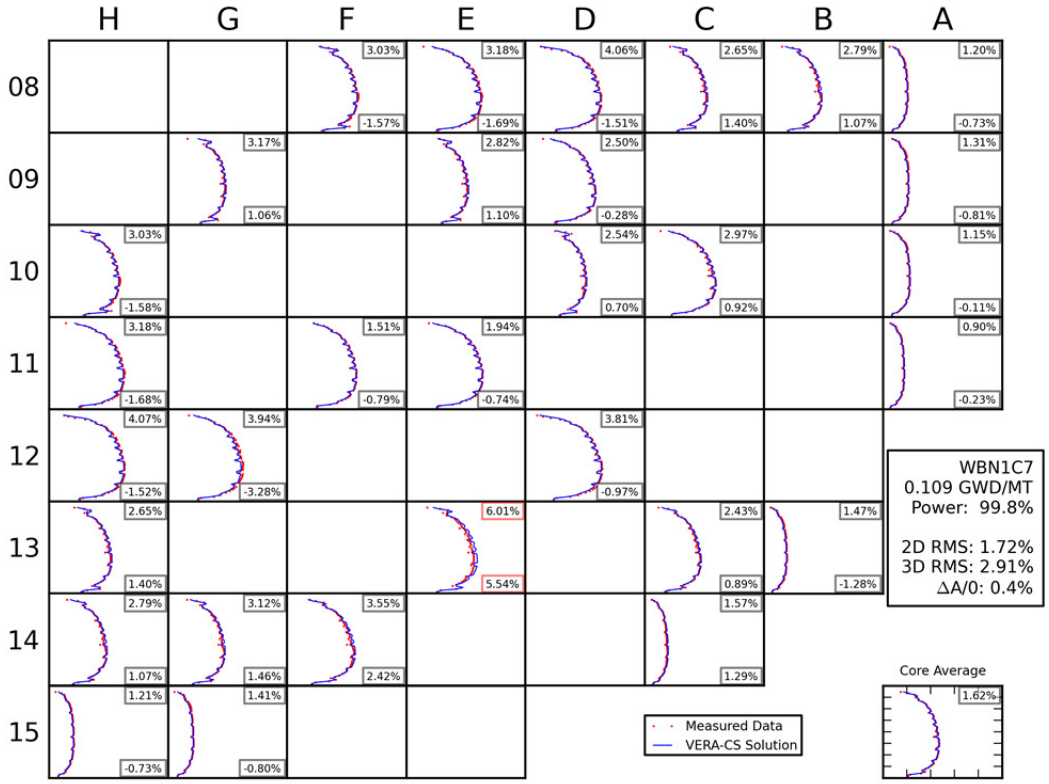

H G F E D C B A
08
09
10
11
12
13
14
15
6.33% 2.51%
6.89% 1.34%
5.08% -0.34%
4.27% 0.07%
4.22% -0.74%
3.25% -2.84%
7.89% 1.39%
5.94% 0.68%
4.47% 0.05%
2.57% -1.67%
6.33% 2.51%
9.60% 3.81%
6.29% 0.31%
7.04% 0.38%
6.01% 0.58%
1.98% -1.58%
6.89% 1.34%
6.47% 2.37%
5.15% -0.73%
1.46% -1.17%
5.08% -0.34%
6.31% 0.89%
5.86% -2.18%
4.27% 0.07%
3.94% -0.40%
2.00% -1.58%
4.22% -0.74%
5.72% 2.22%
3.62% 0.36%
1.78% -1.53%
3.25% -2.84%
2.72% -2.15%
WBN1C6
13.581 GWD/MT
Power: 100.0%
2D RMS: 1.68%
3D RMS: 5.22%
ΔA/0: 3.5%
Core Average
4.32%
Measured Data
VERA-CS Solution

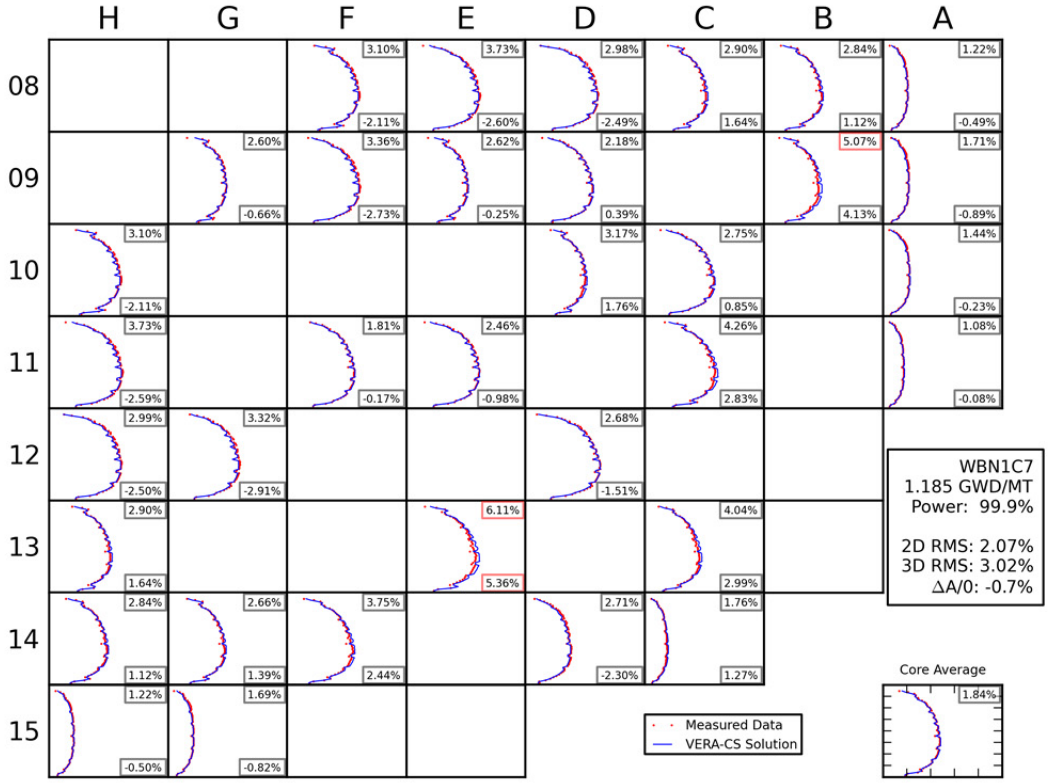

H G F E D C B A
08
09
10
11
12
13
14
15
4.79% 0.47%
5.21% 1.17%
4.82% -0.22%
3.13% -2.49%
8.90% 2.21%
7.32% 0.52%
7.67% 3.30%
4.96% 0.96%
2.74% -1.69%
7.78% 0.26%
6.98% 0.52%
6.61% 0.73%
1.92% -0.82%
7.57% 3.37%
6.43% -0.75%
1.59% -1.15%
4.79% 0.47%
6.67% 1.45%
5.98% 0.11%
5.21% 1.17%
4.98% -0.26%
4.82% -0.22%
6.61% 1.43%
4.65% 0.74%
4.74% -3.88%
1.88% -1.47%
3.13% -2.49%
4.46% -1.91%
1.96% -1.54%
WBN1C6
14.693 GWD/MT
Power: 100.0%
2D RMS: 1.56%
3D RMS: 5.18%
ΔA/0: 3.7%
Core Average
4.61%
Measured Data
VERA-CS Solution

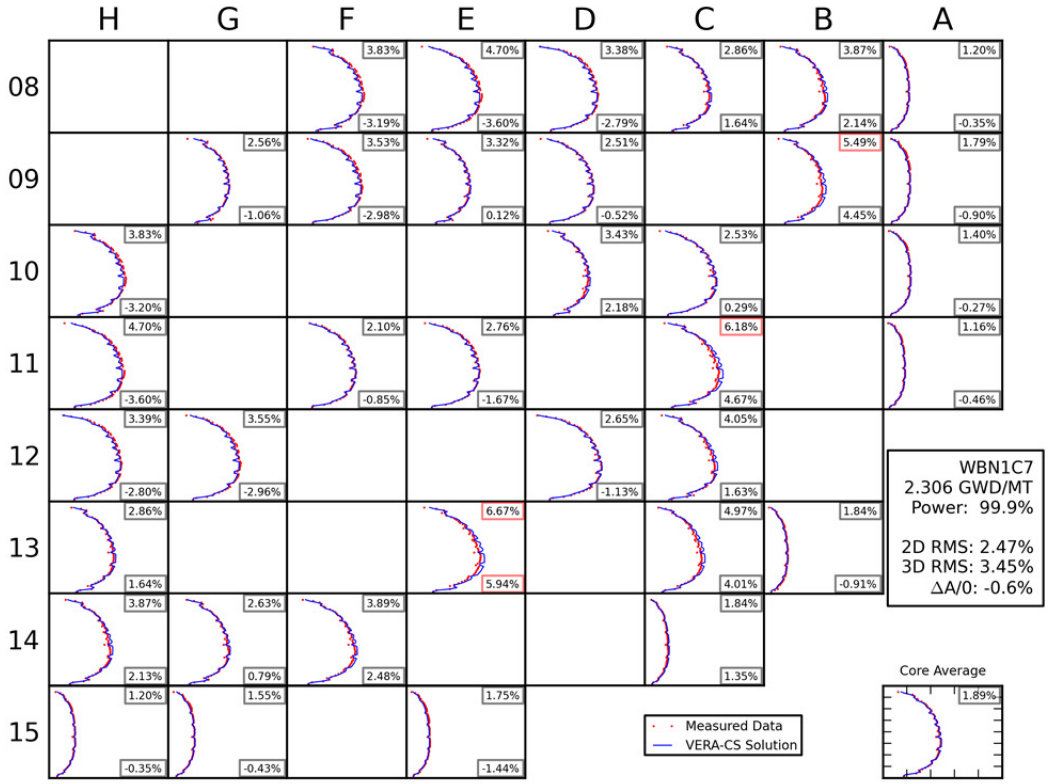

H G F E D C B A
08
09
10
11
12
13
14
15
WBN1C6
15.820 GWD/MT
Power: 100.0%
2D RMS: 1.66%
3D RMS: 5.09%
ΔA/0: 2.7%
Core Average
Measured Data
VERA-CS Solution

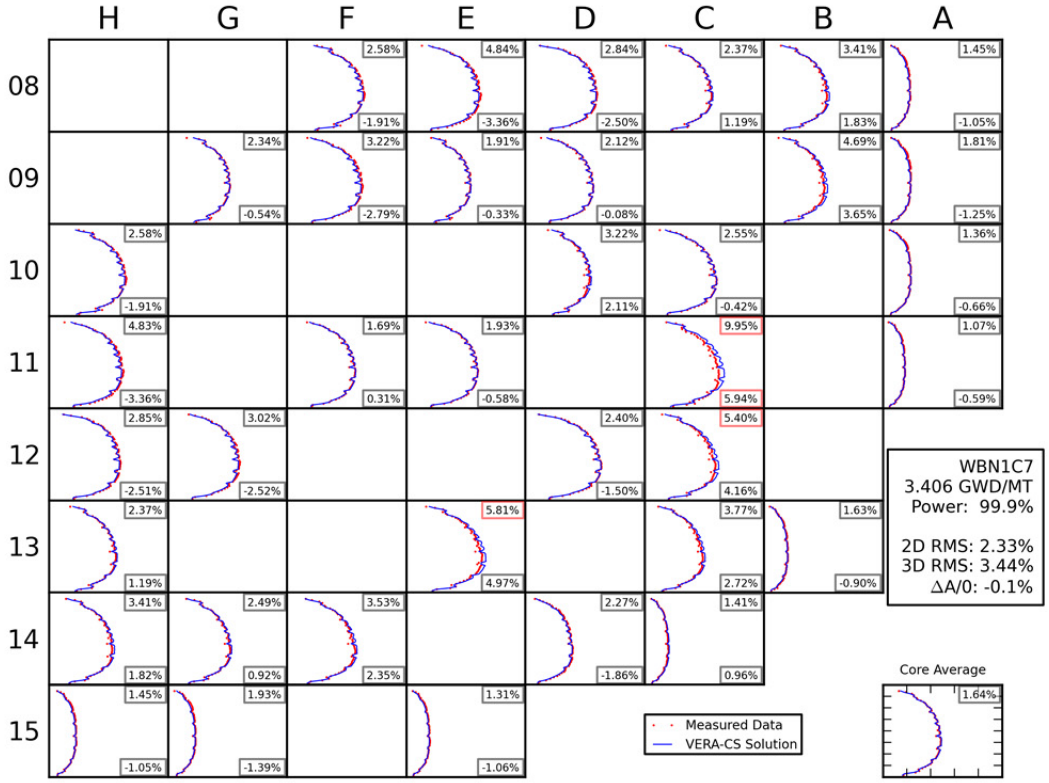

H G F E D C B A
08
09
10
11
12
13
14
15
WBN1C6
16.913 GWD/MT
Power: 99.9%
2D RMS: 1.72%
3D RMS: 3.69%
ΔA/0: 1.7%
Core Average
Measured Data
VERA-CS Solution

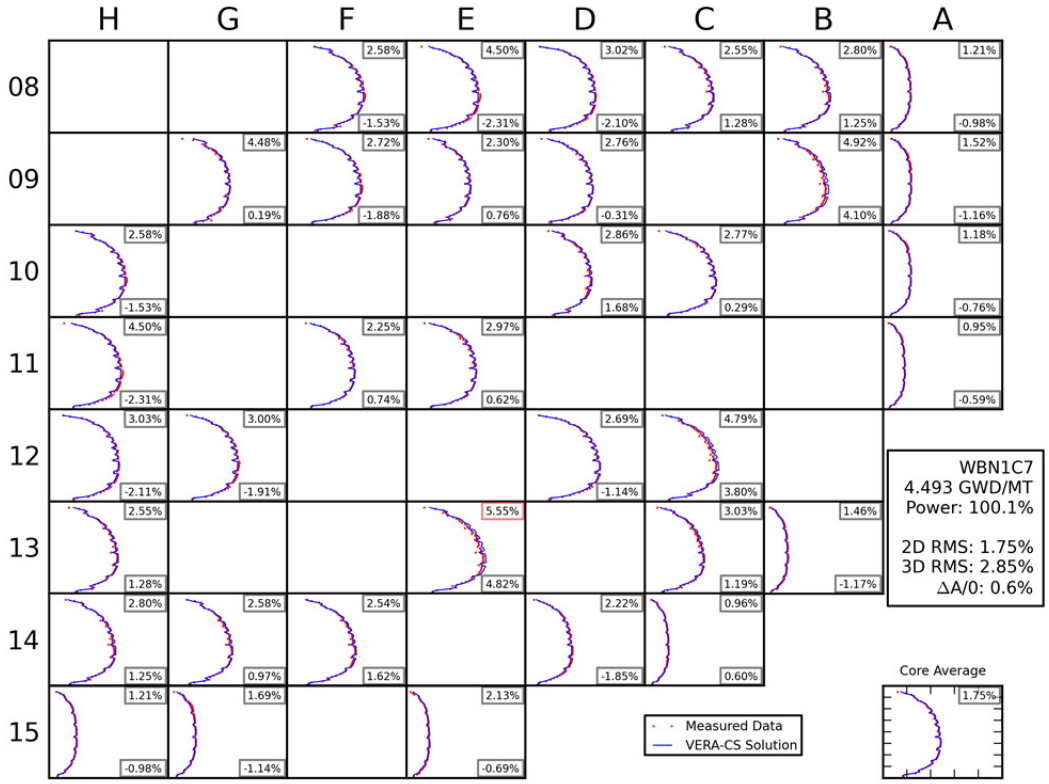

H G F E D C B A
08
09
10
11
12
13
14
15
WBN1C6
18.001 GWD/MT
Power: 99.9%
2D RMS: 1.61%
3D RMS: 2.98%
ΔA/0: 0.5%
Core Average
Measured Data
VERA-CS Solution

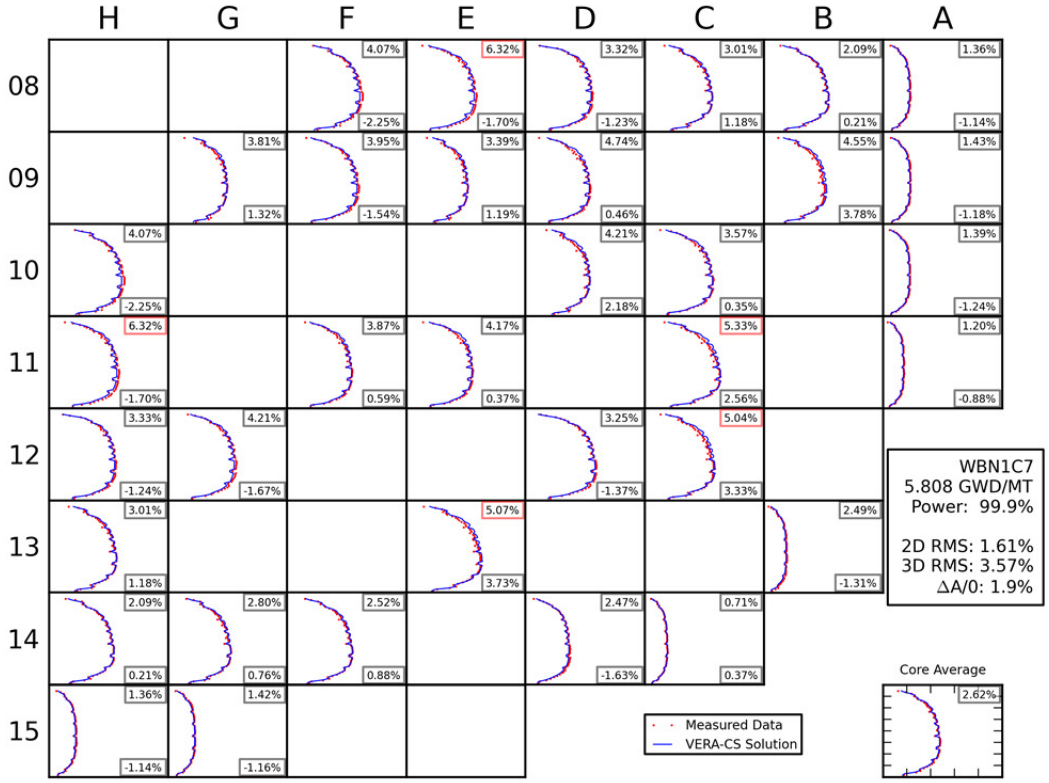

H G F E D C B A
08
09
10
11
12
13
14
15
WBN1C7
0.109 GWD/MT
Power: 99.8%
2D RMS: 1.72%
3D RMS: 2.91%
ΔA/0: 0.4%
Core Average
Measured Data
VERA-CS Solution

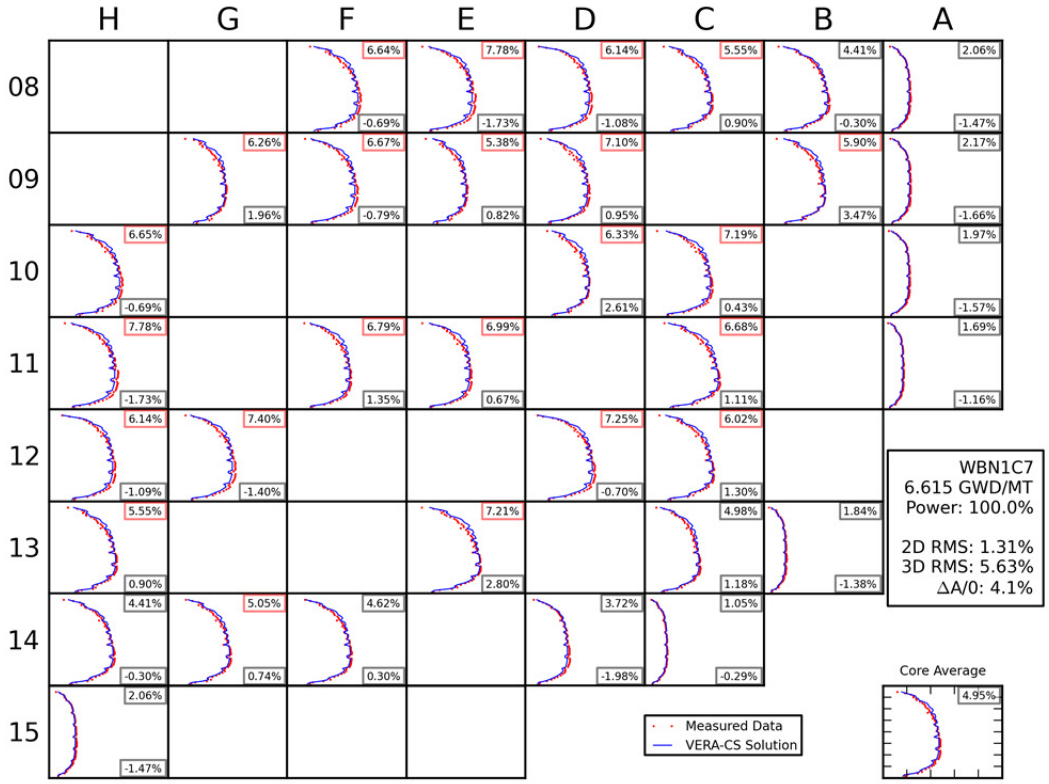

H G F E D C B A
08 09 10 11 12 13 14 15
3.10% -2.11%
3.73% -2.60%
2.98% -2.49%
2.90% 1.64%
2.84% 1.12%
1.22% -0.49%
2.60% -0.66%
3.36% -2.73%
2.62% -0.25%
2.18% 0.39%
5.07% 4.13%
1.71% -0.89%
3.10% -2.11%
3.17% 1.76%
2.75% 0.85%
1.44% -0.23%
3.73% -2.59%
1.81% -0.17%
2.46% -0.98%
4.26% 2.83%
1.08% -0.08%
2.99% -2.50%
3.32% -2.91%
2.68% -1.51%
2.90% 1.64%
6.11% 5.36%
4.04% 2.99%
2.84% 1.12%
2.66% 1.39%
3.75% 2.44%
2.71% -2.30%
1.76% 1.27%
1.22% -0.50%
1.69% -0.82%
WBN1C7
1.185 GWD/MT
Power: 99.9%
2D RMS: 2.07%
3D RMS: 3.02%
ΔA/0: -0.7%
Core Average
1.84%
Measured Data
VERA-CS Solution

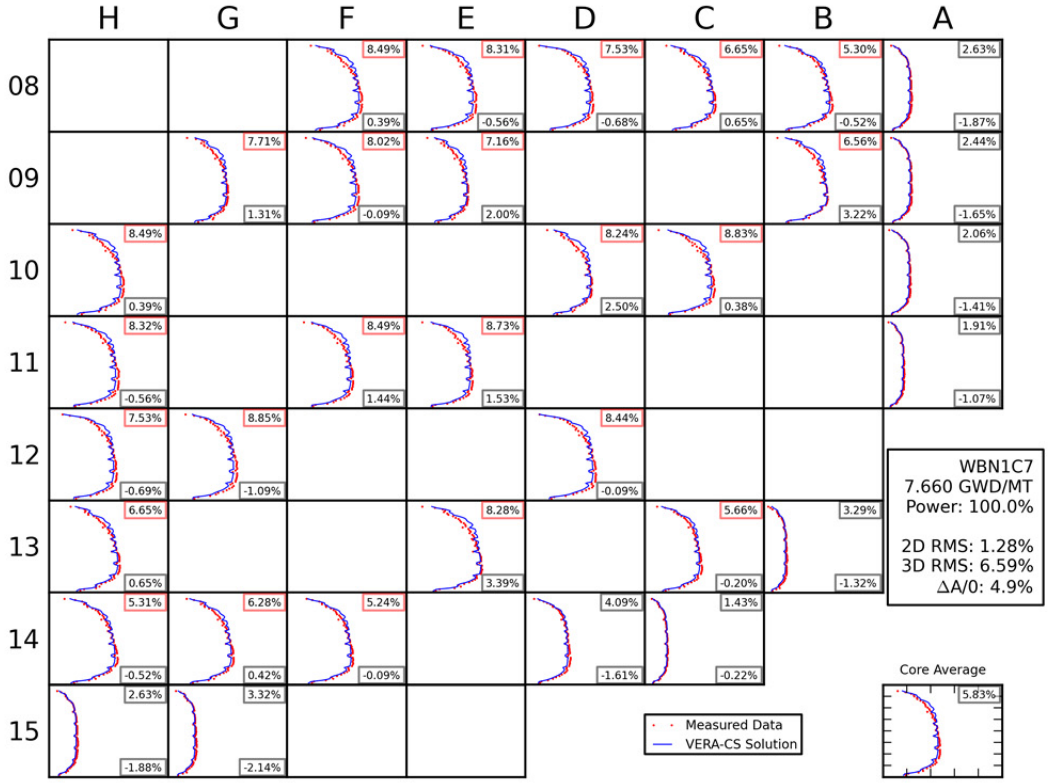

H G F E D C B A
08 09 10 11 12 13 14 15
3.83% -3.19%
4.70% -3.60%
3.38% -2.79%
2.86% 1.64%
3.87% 2.14%
1.20% -0.35%
2.56% -1.06%
3.53% -2.98%
3.32% 0.12%
2.51% -0.52%
5.49% 4.45%
1.79% -0.90%
3.83% -3.20%
3.43% 2.18%
2.53% 0.29%
1.40% -0.27%
4.70% -3.60%
2.10% -0.85%
2.76% -1.67%
6.18% 4.67%
1.16% -0.46%
3.39% -2.80%
3.55% -2.96%
2.65% -1.13%
4.05% 1.63%
2.86% 1.64%
6.67% 5.94%
4.97% 4.01%
1.84% -0.91%
3.87% 2.13%
2.63% 0.79%
3.89% 2.48%
1.84% 1.35%
1.20% -0.35%
1.55% -0.43%
1.75% -1.44%
WBN1C7
2.306 GWD/MT
Power: 99.9%
2D RMS: 2.47%
3D RMS: 3.45%
ΔA/0: -0.6%
Core Average
1.89%
Measured Data
VERA-CS Solution

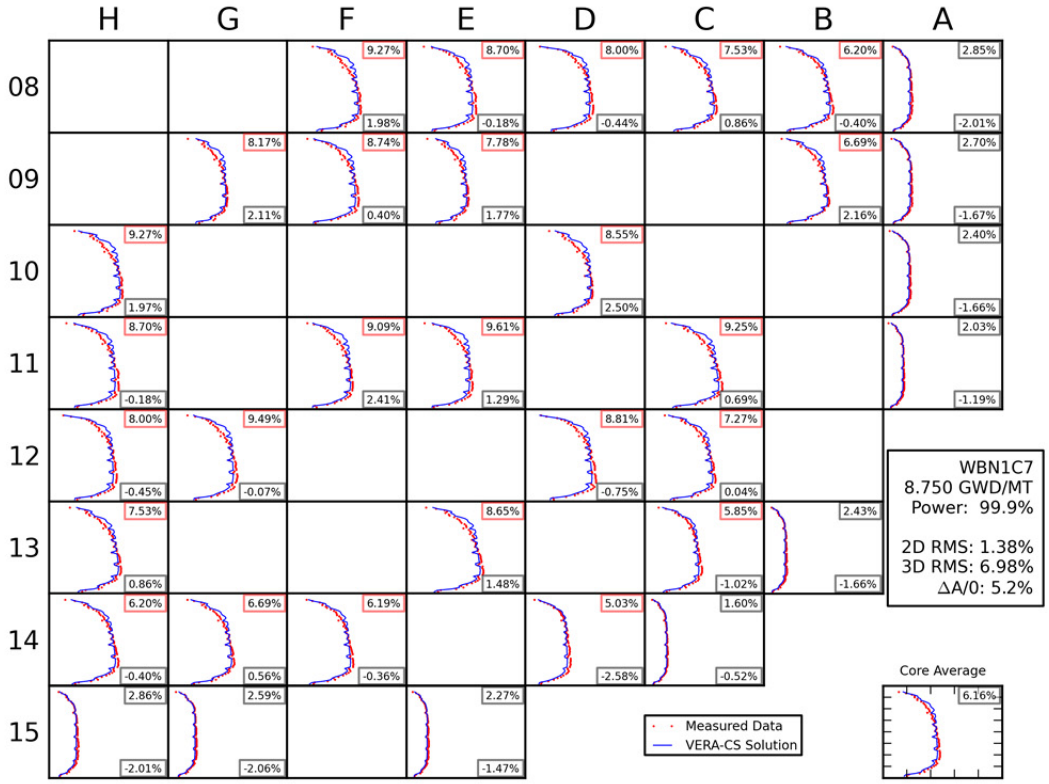

H G F E D C B A
08
09
10
11
12
13
14
15
WBN1C7
3.406 GWD/MT
Power: 99.9%
2D RMS: 2.33%
3D RMS: 3.44%
ΔA/0: -0.1%
Core Average
Measured Data
VERA-CS Solution

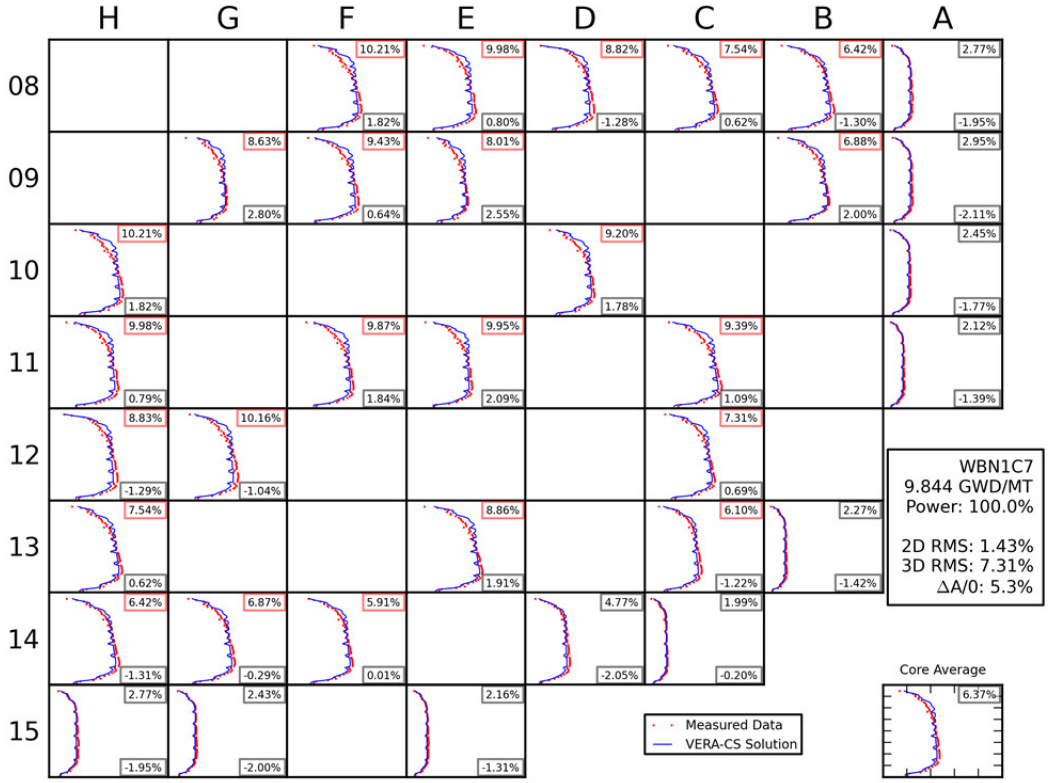

H G F E D C B A
08
09
10
11
12
13
14
15
WBN1C7
4.493 GWD/MT
Power: 100.1%
2D RMS: 1.75%
3D RMS: 2.85%
ΔA/0: 0.6%
Core Average
Measured Data
VERA-CS Solution

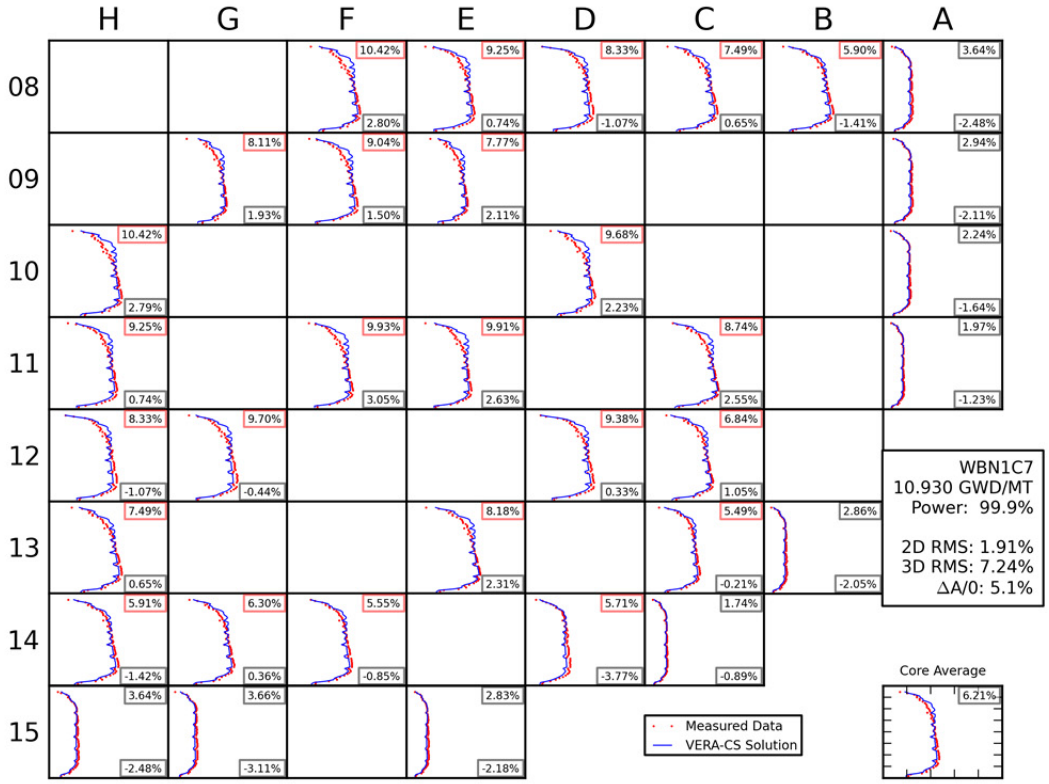

H G F E D C B A
08 09 10 11 12 13 14 15
4.07% -2.25%
6.32% -1.70%
3.32% -1.23%
3.01% 1.18%
2.09% 0.21%
1.36% -1.14%
3.81% 1.32%
3.95% -1.54%
3.39% 1.19%
4.74% 0.46%
4.55% 3.78%
1.43% -1.18%
4.07% -2.25%
4.21% 2.18%
3.57% 0.35%
1.39% -1.24%
6.32% -1.70%
3.87% 0.59%
4.17% 0.37%
5.33% 2.56%
1.20% -0.88%
3.33% -1.24%
4.21% -1.67%
3.25% -1.37%
5.04% 3.33%
3.01% 1.18%
5.07% 3.73%
2.49% -1.31%
2.09% 0.21%
2.80% 0.76%
2.52% 0.88%
2.47% -1.63%
0.71% 0.37%
1.36% -1.14%
1.42% -1.16%
WBN1C7
5.808 GWD/MT
Power: 99.9%
2D RMS: 1.61%
3D RMS: 3.57%
ΔA/0: 1.9%
Core Average
2.62%
Measured Data
VERA-CS Solution

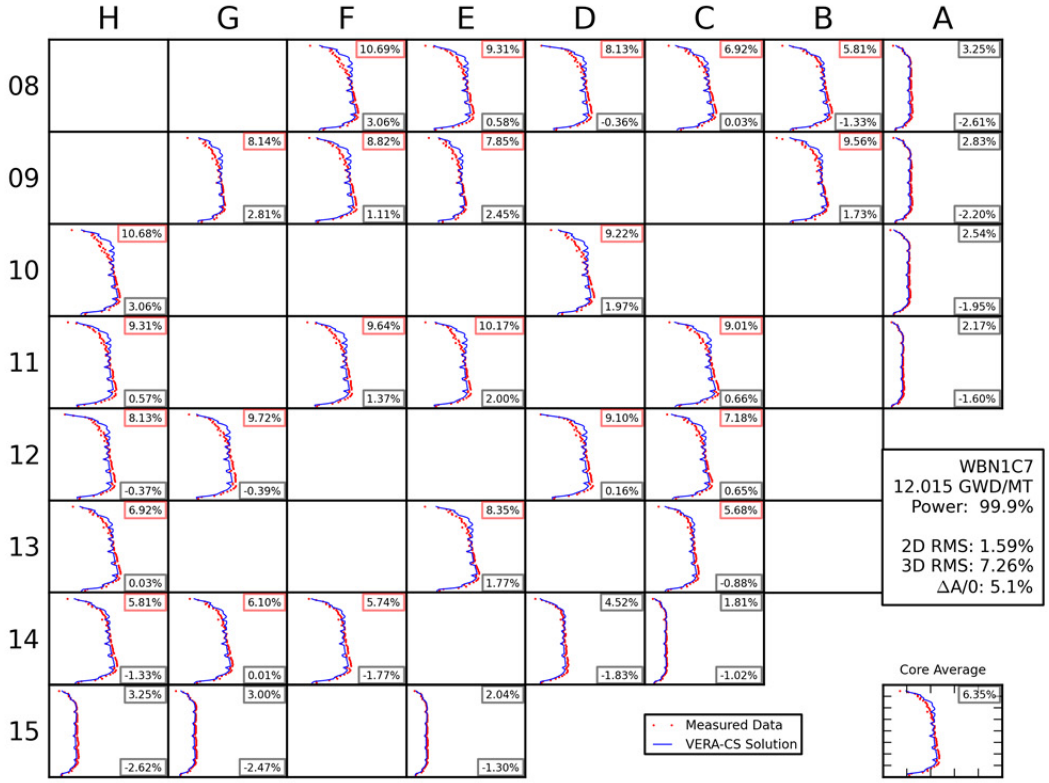

H G F E D C B A
08 09 10 11 12 13 14 15
6.64% -0.69%
7.78% -1.73%
6.14% -1.08%
5.55% 0.90%
4.41% -0.30%
2.06% -1.47%
6.26% 1.96%
6.67% -0.79%
5.38% 0.82%
7.10% 0.95%
5.90% 3.47%
2.17% -1.66%
6.65% -0.69%
6.33% 2.61%
7.19% 0.43%
1.97% -1.57%
7.78% -1.73%
6.79% 1.35%
6.99% 0.67%
6.68% 1.11%
1.69% -1.16%
6.14% -1.09%
7.40% -1.40%
7.25% -0.70%
6.02% 1.30%
5.55% 0.90%
7.21% 2.80%
4.98% 1.18%
1.84% -1.38%
4.41% -0.30%
5.05% 0.74%
4.62% 0.30%
3.72% -1.98%
1.05% -0.29%
2.06% -1.47%
WBN1C7
6.615 GWD/MT
Power: 100.0%
2D RMS: 1.31%
3D RMS: 5.63%
ΔA/0: 4.1%
Core Average
4.95%
Measured Data
VERA-CS Solution

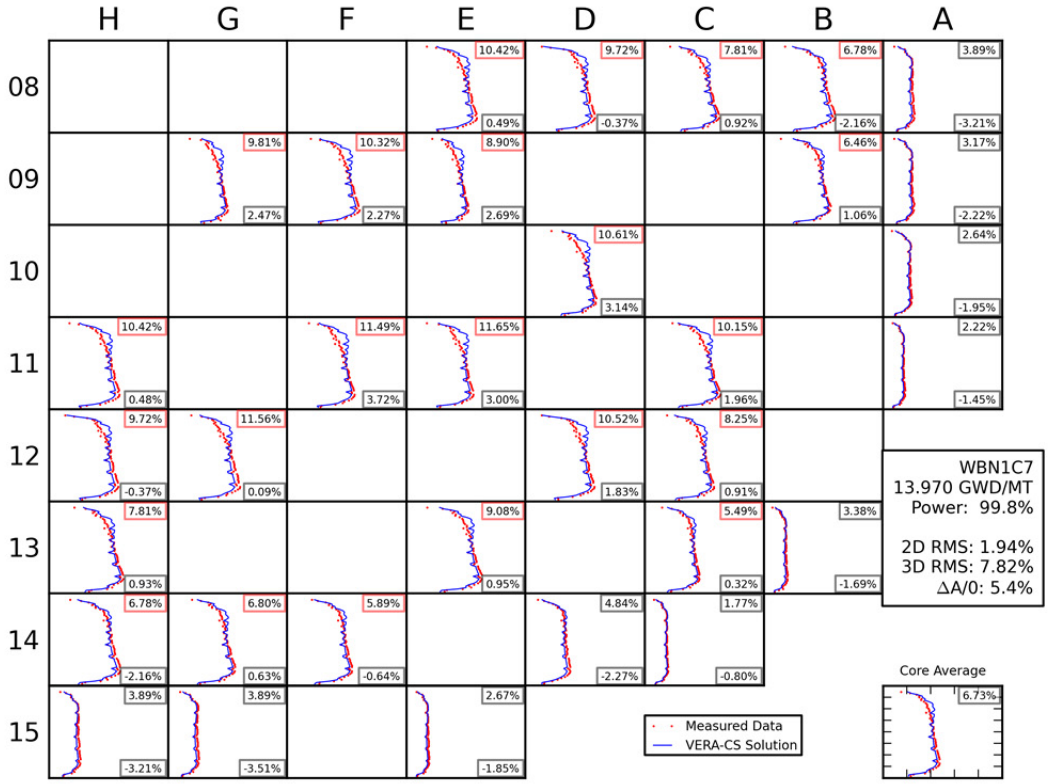

H G F E D C B A
08 09 10 11 12 13 14 15
8.49% 0.39%
8.31% -0.56%
7.53% -0.68%
6.65% 0.65%
5.30% -0.52%
2.63% -1.87%
7.71% 1.31%
8.02% -0.09%
7.16% 2.00%
6.56% 3.22%
2.44% -1.65%
8.49% 0.39%
8.24% 2.50%
8.83% 0.38%
2.06% -1.41%
8.32% -0.56%
8.49% 1.44%
8.73% 1.53%
1.91% -1.07%
7.53% -0.69%
8.85% -1.09%
8.44% -0.09%
6.65% 0.65%
8.28% 3.39%
5.66% -0.20%
3.29% -1.32%
5.31% -0.52%
6.28% 0.42%
5.24% -0.09%
4.09% -1.61%
1.43% -0.22%
2.63% -1.88%
3.32% -2.14%
WBN1C7
7.660 GWD/MT
Power: 100.0%
2D RMS: 1.28%
3D RMS: 6.59%
ΔA/0: 4.9%
Core Average
5.83%
Measured Data
VERA-CS Solution

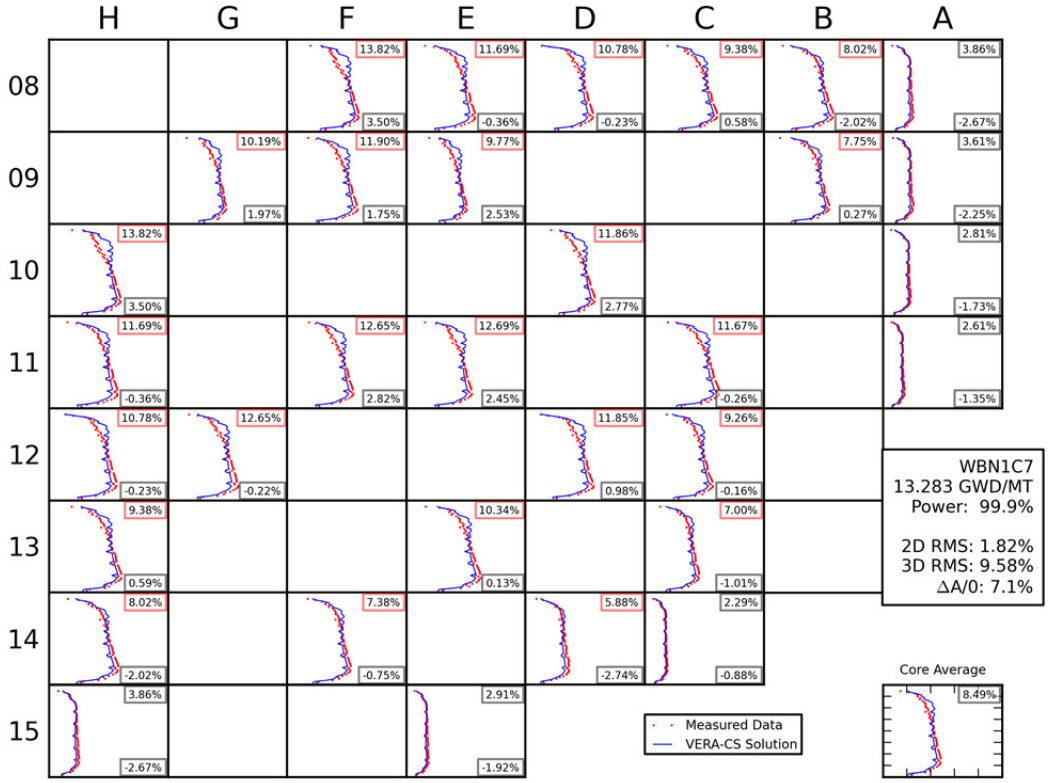

H G F E D C B A
08 09 10 11 12 13 14 15
9.27% 1.98%
8.70% -0.18%
8.00% -0.44%
7.53% 0.86%
6.20% -0.40%
2.85% -2.01%
8.17% 2.11%
8.74% 0.40%
7.78% 1.77%
6.69% 2.16%
2.70% -1.67%
9.27% 1.97%
8.55% 2.50%
2.40% -1.66%
8.70% -0.18%
9.09% 2.41%
9.61% 1.29%
9.25% 0.69%
2.03% -1.19%
8.00% -0.45%
9.49% -0.07%
8.81% -0.75%
7.27% 0.04%
7.53% 0.86%
8.65% 1.48%
5.85% -1.02%
2.43% -1.66%
6.20% -0.40%
6.69% 0.56%
6.19% -0.36%
5.03% -2.58%
1.60% -0.52%
2.86% -2.01%
2.59% -2.06%
2.27% -1.47%
WBN1C7
8.750 GWD/MT
Power: 99.9%
2D RMS: 1.38%
3D RMS: 6.98%
ΔA/0: 5.2%
Core Average
6.16%
Measured Data
VERA-CS Solution

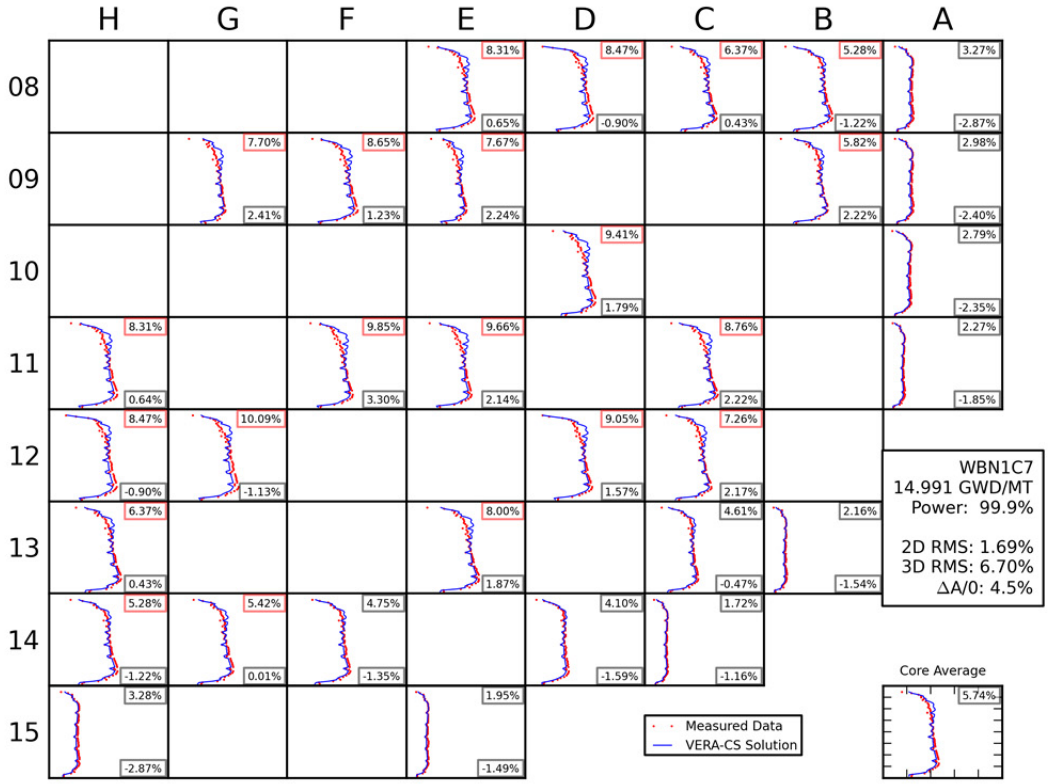

H G F E D C B A
08 09 10 11 12 13 14 15
10.21% 1.82%
9.98% 0.80%
8.82% -1.28%
7.54% 0.62%
6.42% -1.30%
2.77% -1.95%
8.63% 2.80%
9.43% 0.64%
8.01% 2.55%
6.88% 2.00%
2.95% -2.11%
10.21% 1.82%
9.20% 1.78%
2.45% -1.77%
9.98% 0.79%
9.87% 1.84%
9.95% 2.09%
9.39% 1.09%
2.12% -1.39%
8.83% -1.29%
10.16% -1.04%
7.31% 0.69%
7.54% 0.62%
8.86% 1.91%
6.10% -1.22%
2.27% -1.42%
6.42% -1.31%
6.87% -0.29%
5.91% 0.01%
4.77% -2.05%
1.99% -0.20%
2.77% -1.95%
2.43% -2.00%
2.16% -1.31%
WBN1C7
9.844 GWD/MT
Power: 100.0%
2D RMS: 1.43%
3D RMS: 7.31%
ΔA/0: 5.3%
Core Average
6.37%
Measured Data
VERA-CS Solution

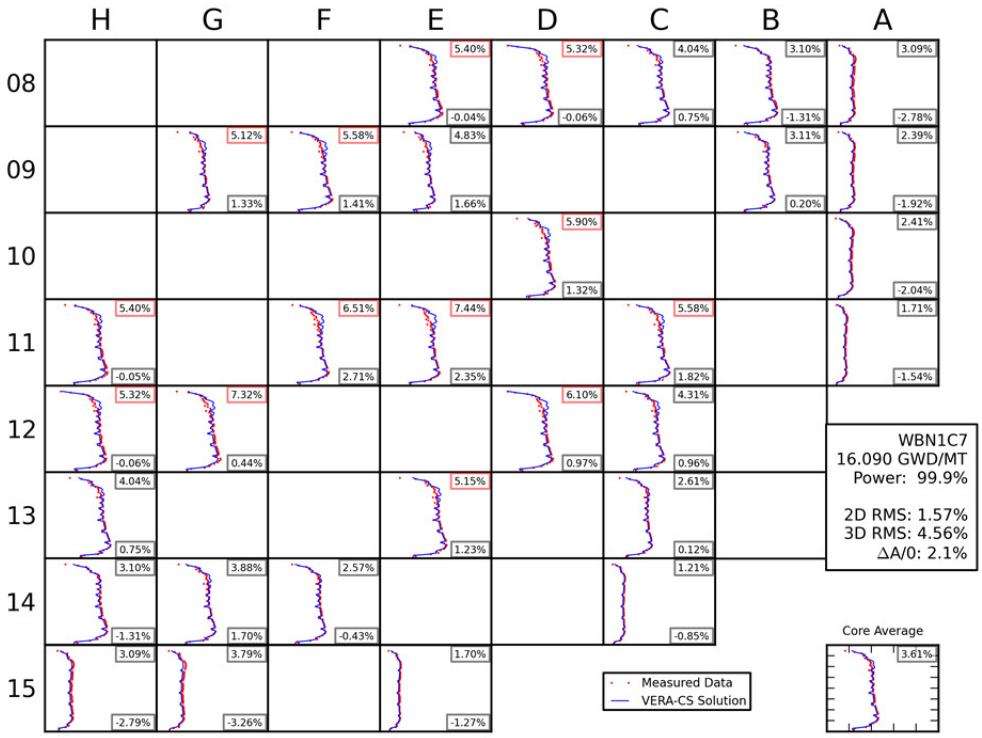

H G F E D C B A
08 09 10 11 12 13 14 15
10.42% 2.80%
9.25% 0.74%
8.33% -1.07%
7.49% 0.65%
5.90% -1.41%
3.64% -2.48%
8.11% 1.93%
9.04% 1.50%
7.77% 2.11%
2.94% -2.11%
10.42% 2.79%
9.68% 2.23%
2.24% -1.64%
9.25% 0.74%
9.93% 3.05%
9.91% 2.63%
8.74% 2.55%
1.97% -1.23%
8.33% -1.07%
9.70% -0.44%
9.38% 0.33%
6.84% 1.05%
7.49% 0.65%
8.18% 2.31%
5.49% -0.21%
2.86% -2.05%
5.91% -1.42%
6.30% 0.36%
5.55% -0.85%
5.71% -3.77%
1.74% -0.89%
3.64% -2.48%
3.66% -3.11%
2.83% -2.18%
WBN1C7
10.930 GWD/MT
Power: 99.9%
2D RMS: 1.91%
3D RMS: 7.24%
ΔA/0: 5.1%
Core Average
6.21%
Measured Data
VERA-CS Solution

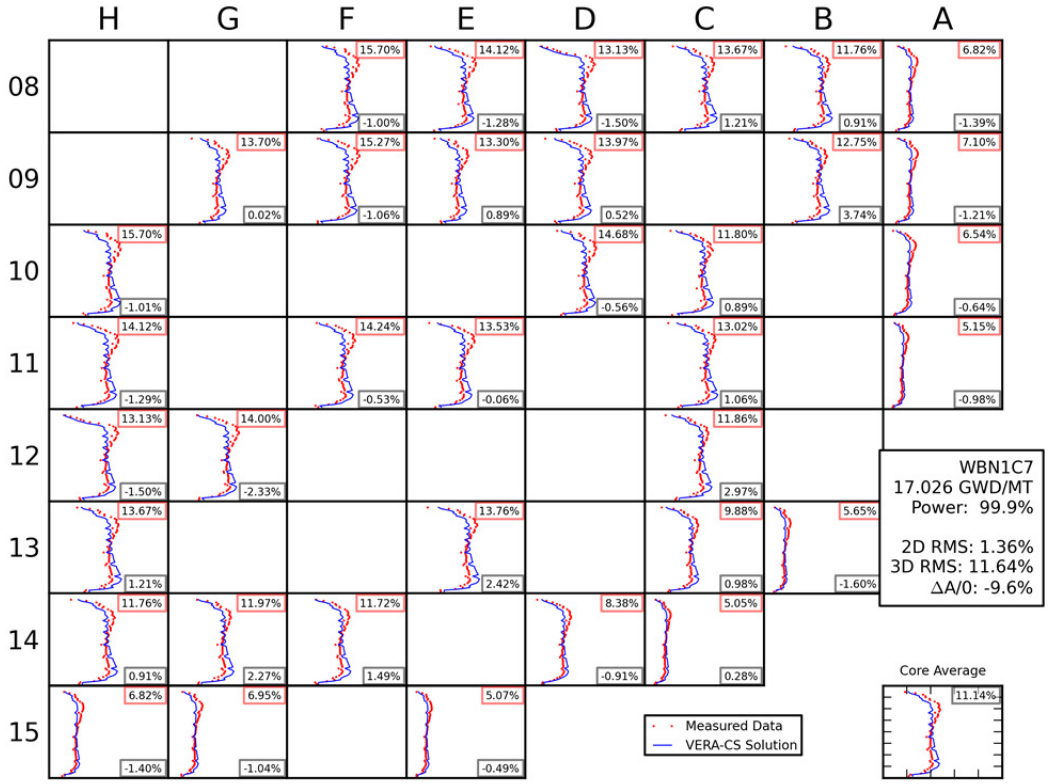

H G F E D C B A
08
10.69% 3.06%
9.31% 0.58%
8.13% -0.36%
6.92% 0.03%
5.81% -1.33%
3.25% -2.61%
09
8.14% 2.81%
8.82% 1.11%
7.85% 2.45%
9.56% 1.73%
2.83% -2.20%
10
10.68% 3.06%
9.22% 1.97%
2.54% -1.95%
11
9.31% 0.57%
9.64% 1.37%
10.17% 2.00%
9.01% 0.66%
2.17% -1.60%
12
8.13% -0.37%
9.72% -0.39%
9.10% 0.16%
7.18% 0.65%
13
6.92% 0.03%
8.35% 1.77%
5.68% -0.88%
14
5.81% -1.33%
6.10% 0.01%
5.74% -1.77%
4.52% -1.83%
1.81% -1.02%
15
3.25% -2.62%
3.00% -2.47%
2.04% -1.30%
WBN1C7
12.015 GWD/MT
Power: 99.9%
2D RMS: 1.59%
3D RMS: 7.26%
ΔA/0: 5.1%
Core Average
6.35%
Measured Data
VERA-CS Solution

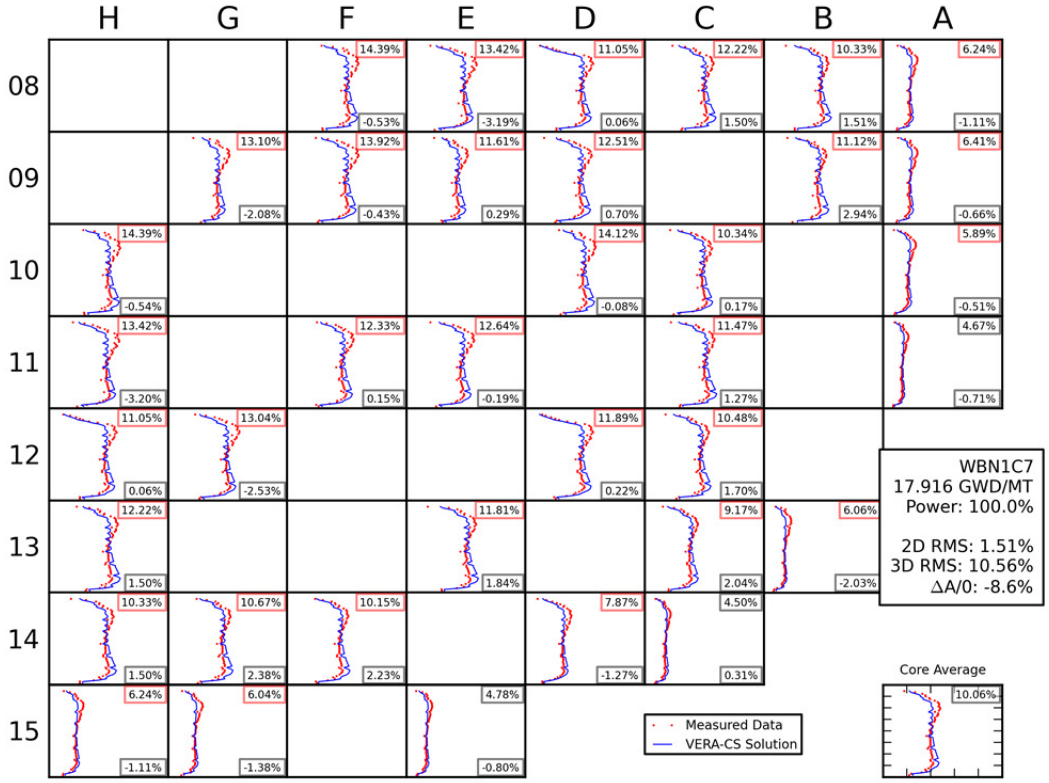

H G F E D C B A
08
10.42% 0.49%
9.72% -0.37%
7.81% 0.92%
6.78% -2.16%
3.89% -3.21%
09
9.81% 2.47%
10.32% 2.27%
8.90% 2.69%
6.46% 1.06%
3.17% -2.22%
10
10.61% 3.14%
2.64% -1.95%
11
10.42% 0.48%
11.49% 3.72%
11.65% 3.00%
10.15% 1.96%
2.22% -1.45%
12
9.72% -0.37%
11.56% 0.09%
10.52% 1.83%
8.25% 0.91%
13
7.81% 0.93%
9.08% 0.95%
5.49% 0.32%
3.38% -1.69%
14
6.78% -2.16%
6.80% 0.63%
5.89% -0.64%
4.84% -2.27%
1.77% -0.80%
15
3.89% -3.21%
3.89% -3.51%
2.67% -1.85%
WBN1C7
13.970 GWD/MT
Power: 99.8%
2D RMS: 1.94%
3D RMS: 7.82%
ΔA/0: 5.4%
Core Average
6.73%
Measured Data
VERA-CS Solution

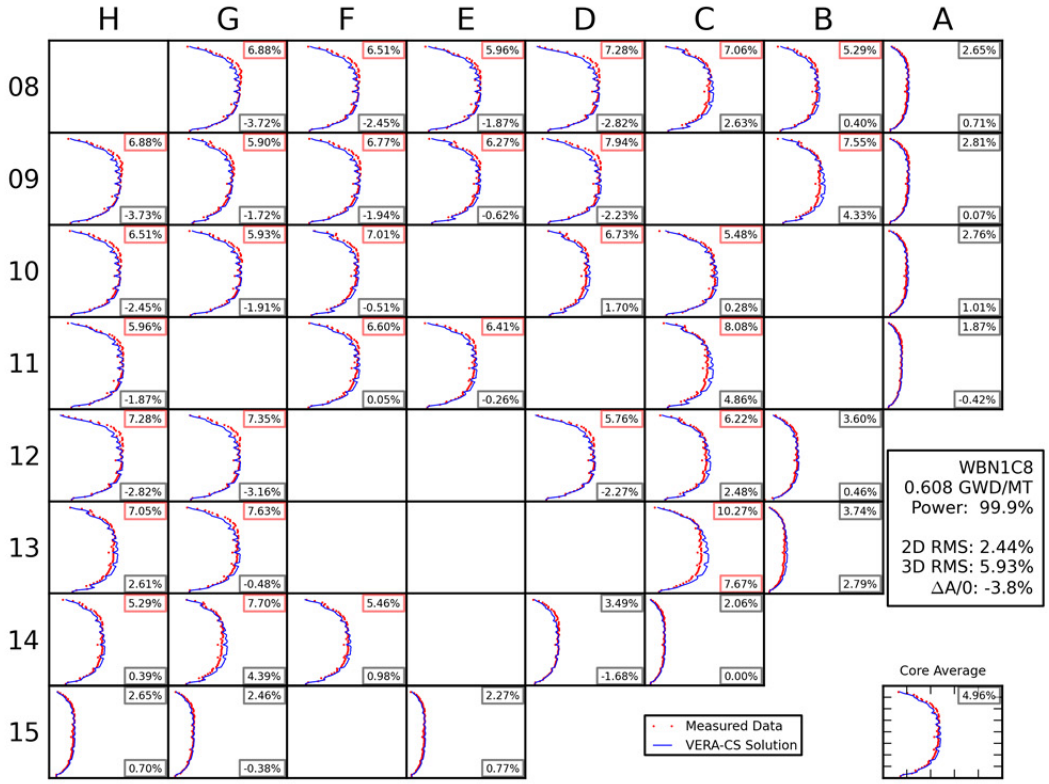

H G F E D C B A
08
09
10
11
12
13
14
15
WBN1C7
13.283 GWD/MT
Power: 99.9%
2D RMS: 1.82%
3D RMS: 9.58%
ΔA/0: 7.1%
Core Average
Measured Data
VERA-CS Solution

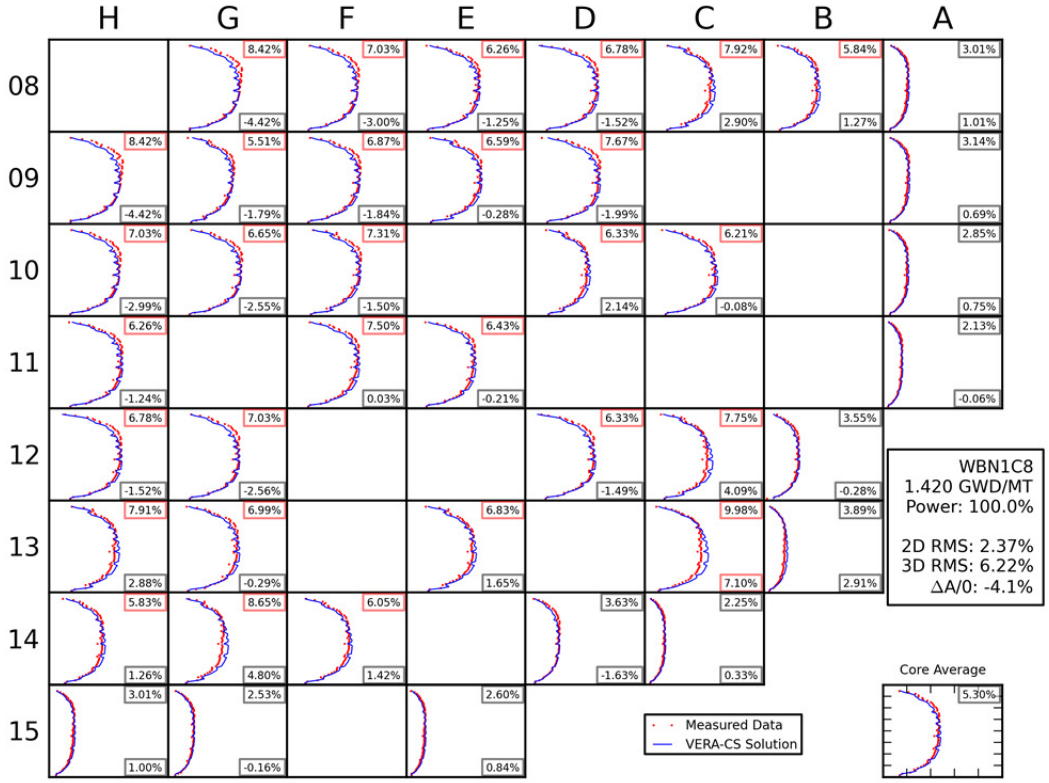

H G F E D C B A
08
09
10
11
12
13
14
15
WBN1C7
14.991 GWD/MT
Power: 99.9%
2D RMS: 1.69%
3D RMS: 6.70%
ΔA/0: 4.5%
Core Average
Measured Data
VERA-CS Solution

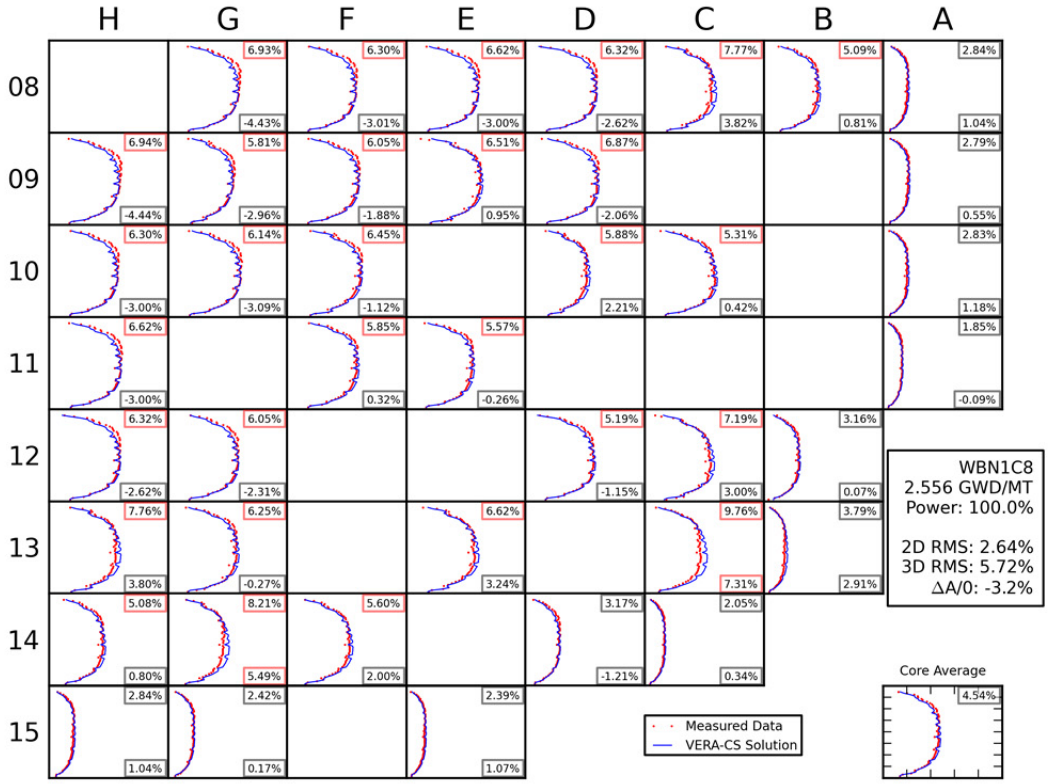

H G F E D C B A
08
09
10
11
12
13
14
15
WBN1C7
16.090 GWD/MT
Power: 99.9%
2D RMS: 1.57%
3D RMS: 4.56%
ΔA/0: 2.1%
Core Average
Measured Data
VERA-CS Solution

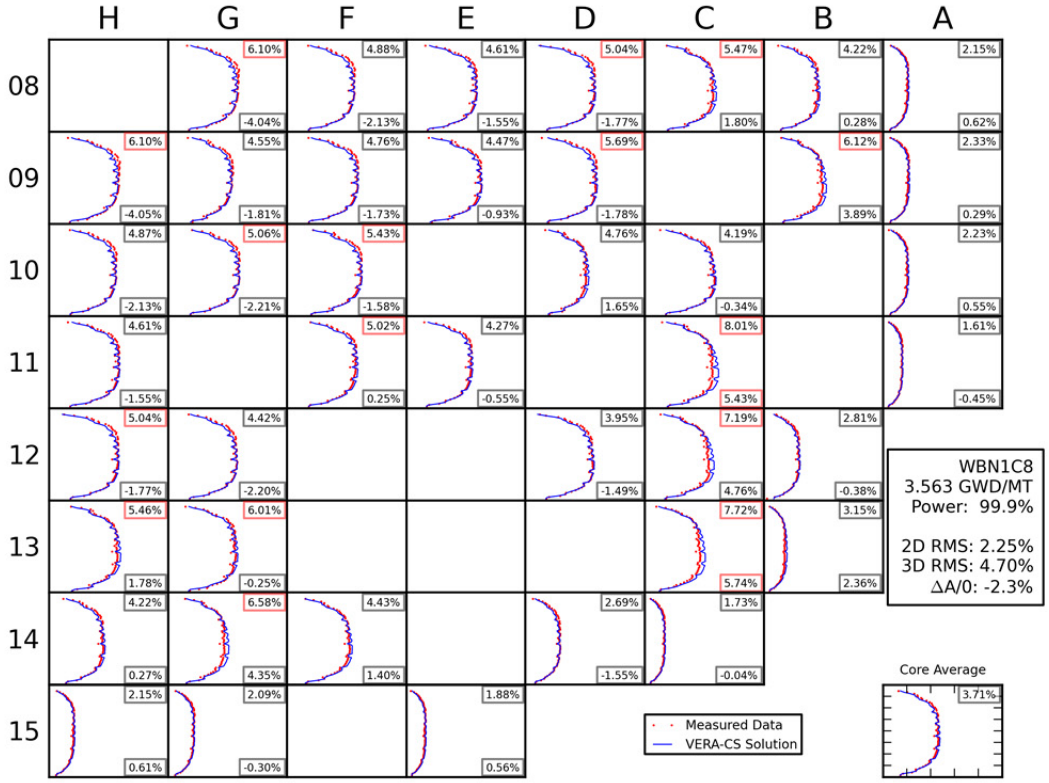

H G F E D C B A
08
09
10
11
12
13
14
15
WBN1C7
17.026 GWD/MT
Power: 99.9%
2D RMS: 1.36%
3D RMS: 11.64%
ΔA/0: -9.6%
Core Average
Measured Data
VERA-CS Solution

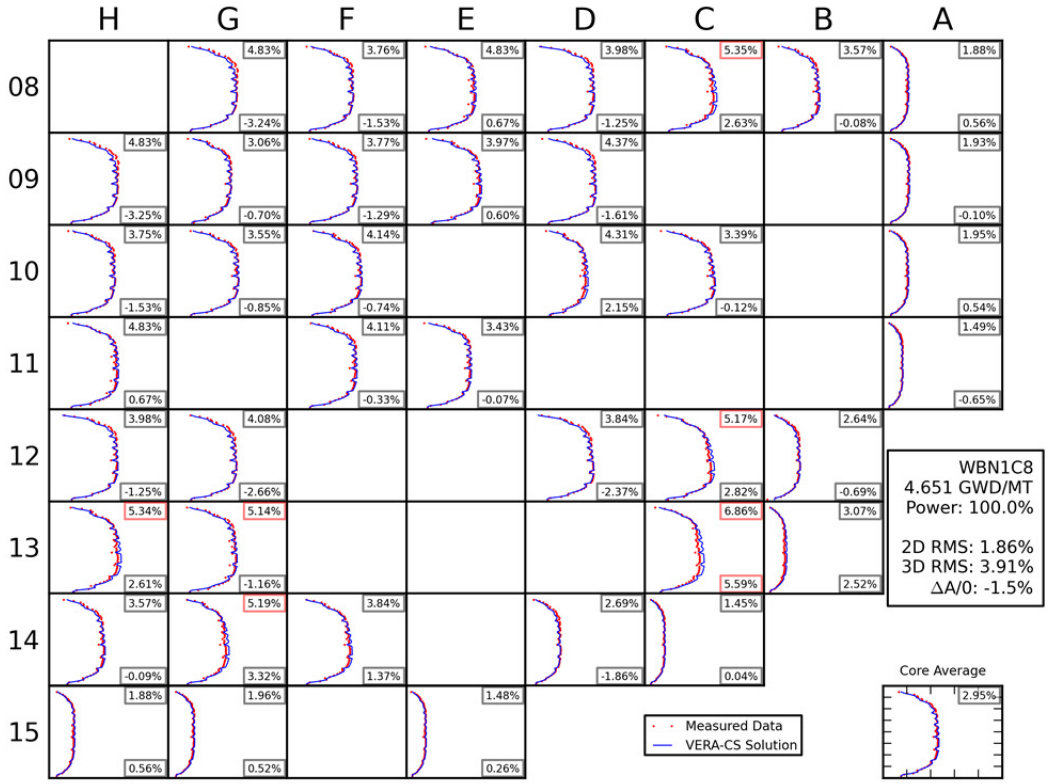

H G F E D C B A
08 09 10 11 12 13 14 15
14.39% -0.53%
13.42% -3.19%
11.05% 0.06%
12.22% 1.50%
10.33% 1.51%
6.24% -1.11%
13.10% -2.08%
13.92% -0.43%
11.61% 0.29%
12.51% 0.70%
11.12% 2.94%
6.41% -0.66%
14.39% -0.54%
14.12% -0.08%
10.34% 0.17%
5.89% -0.51%
13.42% -3.20%
12.33% 0.15%
12.64% -0.19%
11.47% 1.27%
4.67% -0.71%
11.05% 0.06%
13.04% -2.53%
11.89% 0.22%
10.48% 1.70%
12.22% 1.50%
11.81% 1.84%
9.17% 2.04%
6.06% -2.03%
10.33% 1.50%
10.67% 2.38%
10.15% 2.23%
7.87% -1.27%
4.50% 0.31%
6.24% -1.11%
6.04% -1.38%
4.78% -0.80%
WBN1C7
17.916 GWD/MT
Power: 100.0%
2D RMS: 1.51%
3D RMS: 10.56%
ΔA/0: -8.6%
Core Average
10.06%
Measured Data
VERA-CS Solution

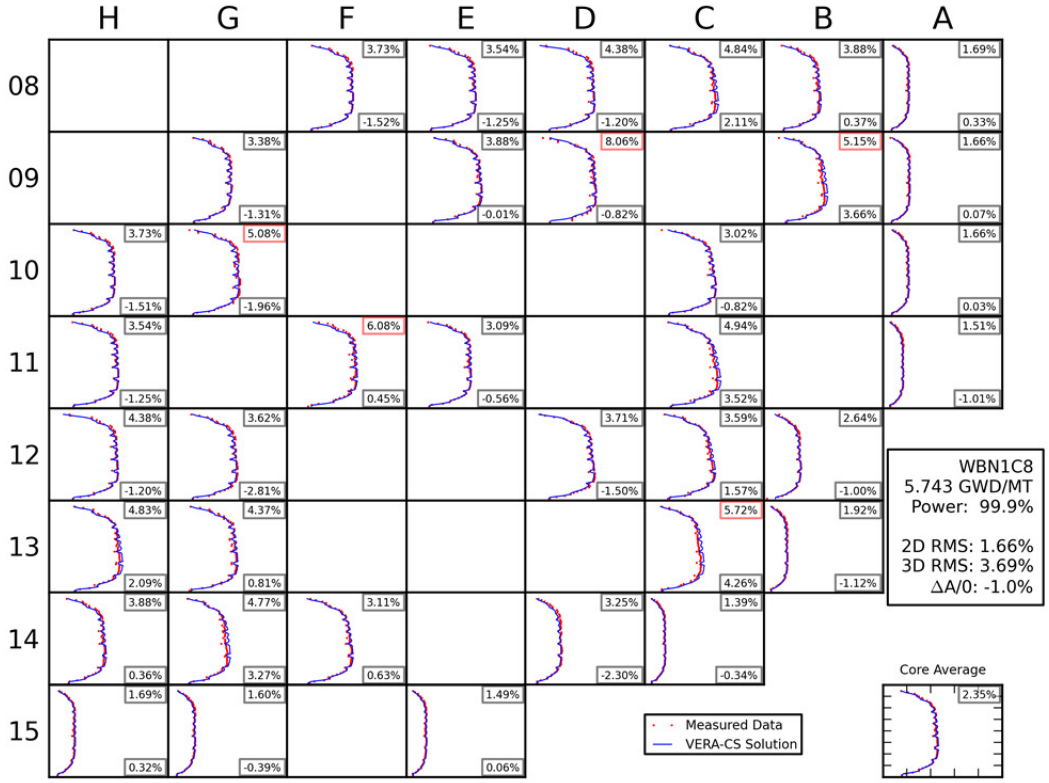

H G F E D C B A
08 09 10 11 12 13 14 15
6.88% -3.72%
6.51% -2.45%
5.96% -1.87%
7.28% -2.82%
7.06% 2.63%
5.29% 0.40%
2.65% 0.71%
6.88% -3.73%
5.90% -1.72%
6.77% -1.94%
6.27% -0.62%
7.94% -2.23%
7.55% 4.33%
2.81% 0.07%
6.51% -2.45%
5.93% -1.91%
7.01% -0.51%
6.73% 1.70%
5.48% 0.28%
2.76% 1.01%
5.96% -1.87%
6.60% 0.05%
6.41% -0.26%
8.08% 4.86%
1.87% -0.42%
7.28% -2.82%
7.35% -3.16%
5.76% -2.27%
6.22% 2.48%
3.60% 0.46%
7.05% 2.61%
7.63% -0.48%
10.27% 7.67%
3.74% 2.79%
5.29% 0.39%
7.70% 4.39%
5.46% 0.98%
3.49% -1.68%
2.06% 0.00%
2.65% 0.70%
2.46% -0.38%
2.27% 0.77%
WBN1C8
0.608 GWD/MT
Power: 99.9%
2D RMS: 2.44%
3D RMS: 5.93%
ΔA/0: -3.8%
Core Average
4.96%
Measured Data
VERA-CS Solution

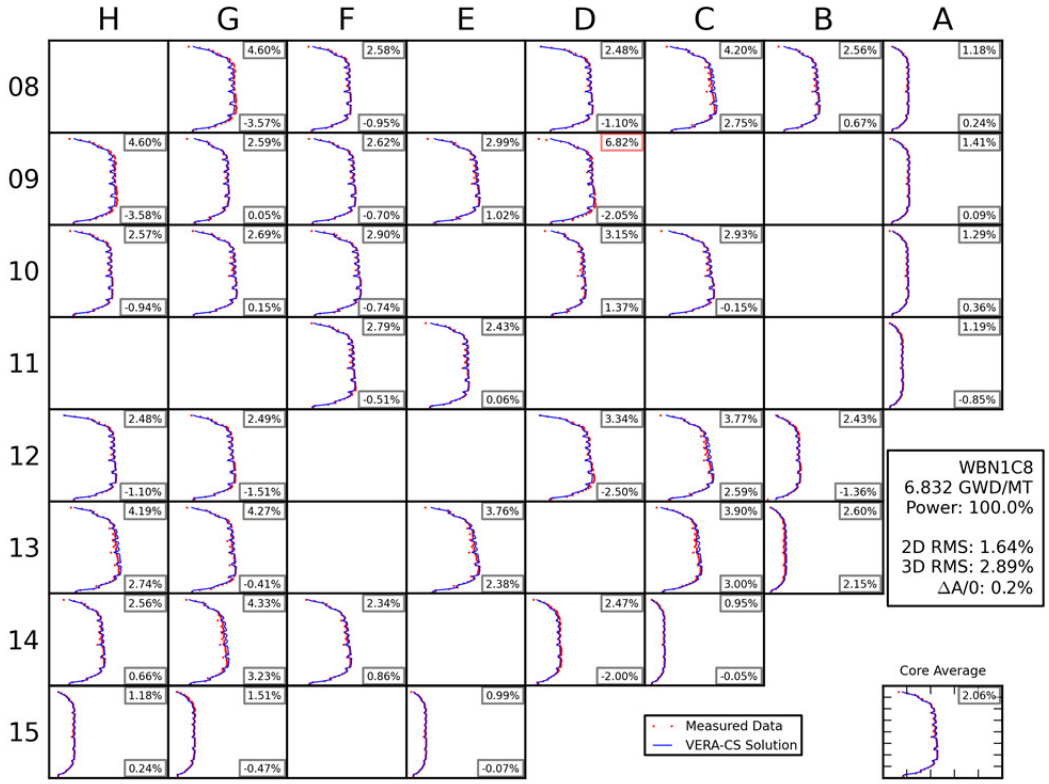

H G F E D C B A
08
09
10
11
12
13
14
15
WBN1C8
1.420 GWD/MT
Power: 100.0%
2D RMS: 2.37%
3D RMS: 6.22%
ΔA/0: -4.1%
Core Average
Measured Data
VERA-CS Solution

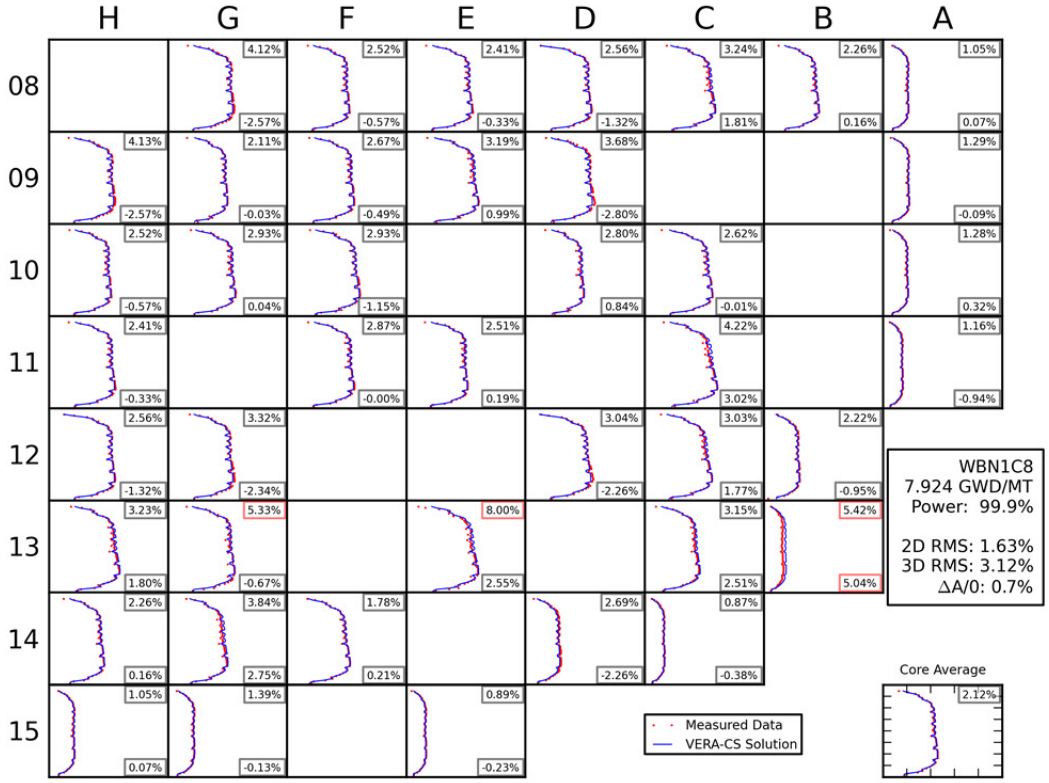

H G F E D C B A
08
09
10
11
12
13
14
15
WBN1C8
2.556 GWD/MT
Power: 100.0%
2D RMS: 2.64%
3D RMS: 5.72%
ΔA/0: -3.2%
Core Average
Measured Data
VERA-CS Solution

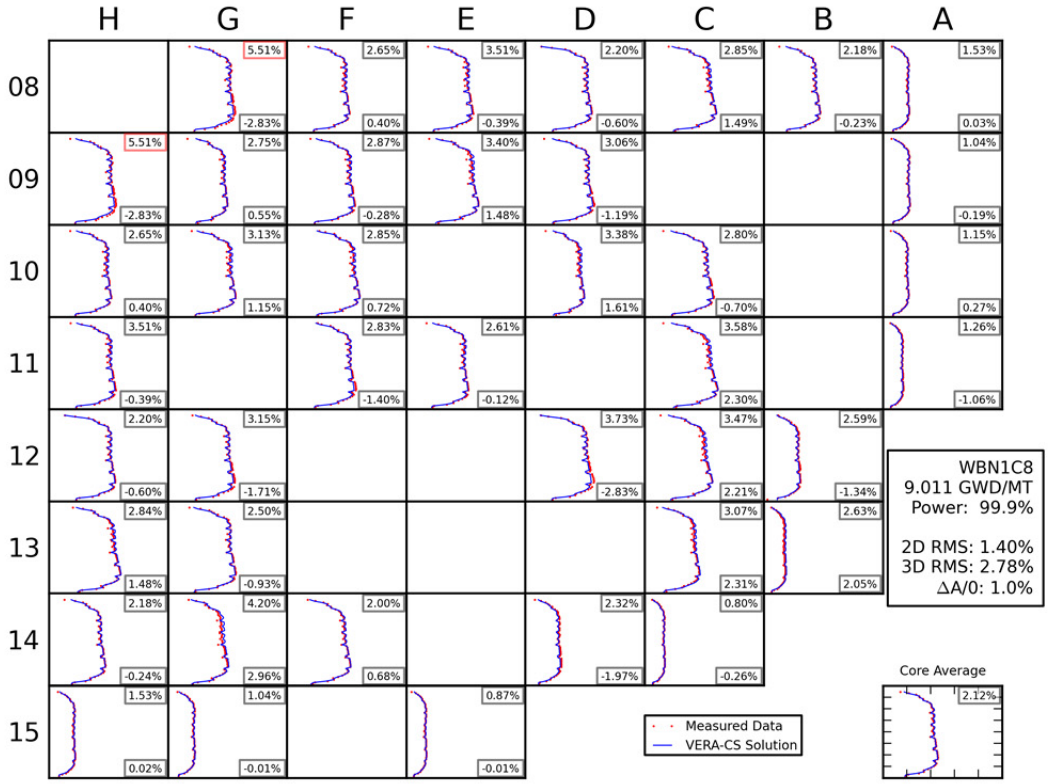

H G F E D C B A
08
09
10
11
12
13
14
15
WBN1C8
3.563 GWD/MT
Power: 99.9%
2D RMS: 2.25%
3D RMS: 4.70%
ΔA/0: -2.3%
Core Average
Measured Data
VERA-CS Solution

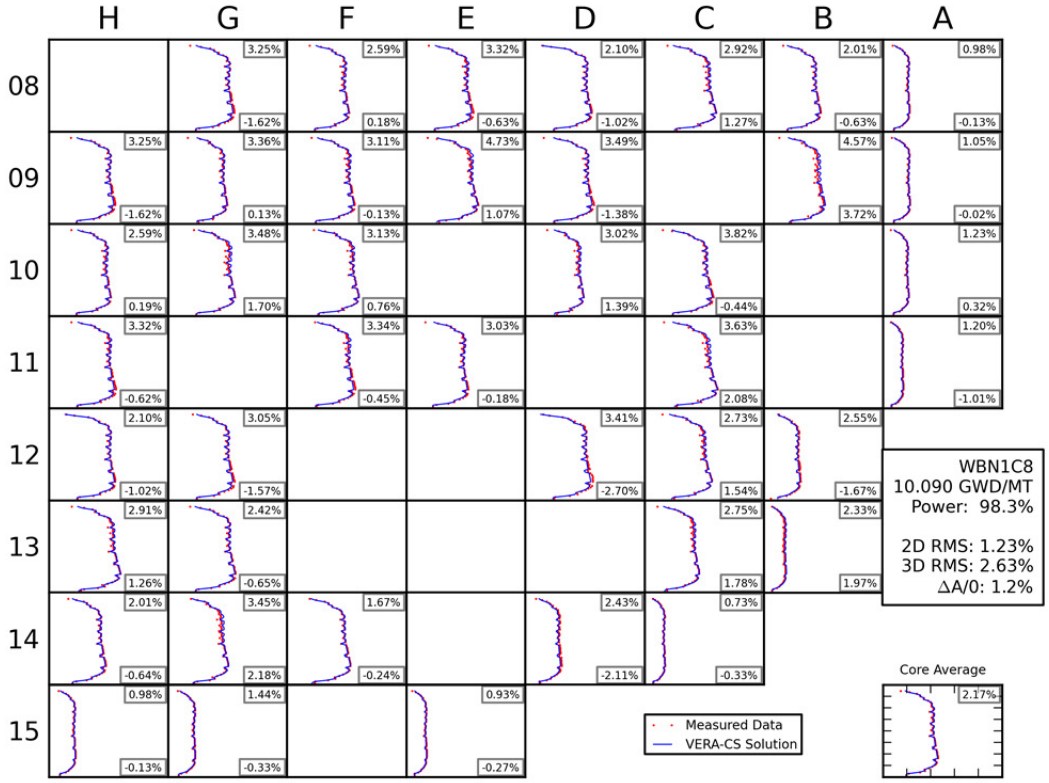

H G F E D C B A
08
09
10
11
12
13
14
15
WBN1C8
4.651 GWD/MT
Power: 100.0%
2D RMS: 1.86%
3D RMS: 3.91%
ΔA/0: -1.5%
Core Average
Measured Data
VERA-CS Solution

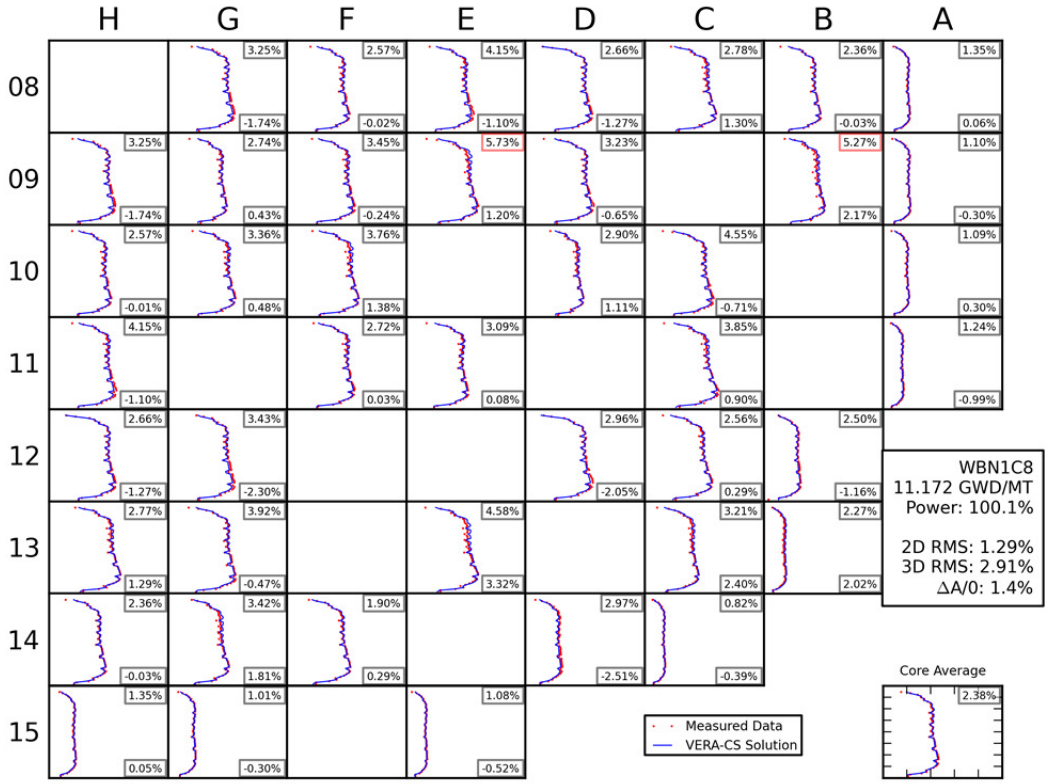

H G F E D C B A
08 09 10 11 12 13 14 15
3.73% -1.52%
3.54% -1.25%
4.38% -1.20%
4.84% 2.11%
3.88% 0.37%
1.69% 0.33%
3.38% -1.31%
3.88% -0.01%
8.06% -0.82%
5.15% 3.66%
1.66% 0.07%
3.73% -1.51%
5.08% -1.96%
3.02% -0.82%
1.66% 0.03%
3.54% -1.25%
6.08% 0.45%
3.09% -0.56%
4.94% 3.52%
1.51% -1.01%
4.38% -1.20%
3.62% -2.81%
3.71% -1.50%
3.59% 1.57%
2.64% -1.00%
4.83% 2.09%
4.37% 0.81%
5.72% 4.26%
1.92% -1.12%
3.88% 0.36%
4.77% 3.27%
3.11% 0.63%
3.25% -2.30%
1.39% -0.34%
1.69% 0.32%
1.60% -0.39%
1.49% 0.06%
WBN1C8
5.743 GWD/MT
Power: 99.9%
2D RMS: 1.66%
3D RMS: 3.69%
ΔA/0: -1.0%
Core Average
2.35%
Measured Data
VERA-CS Solution

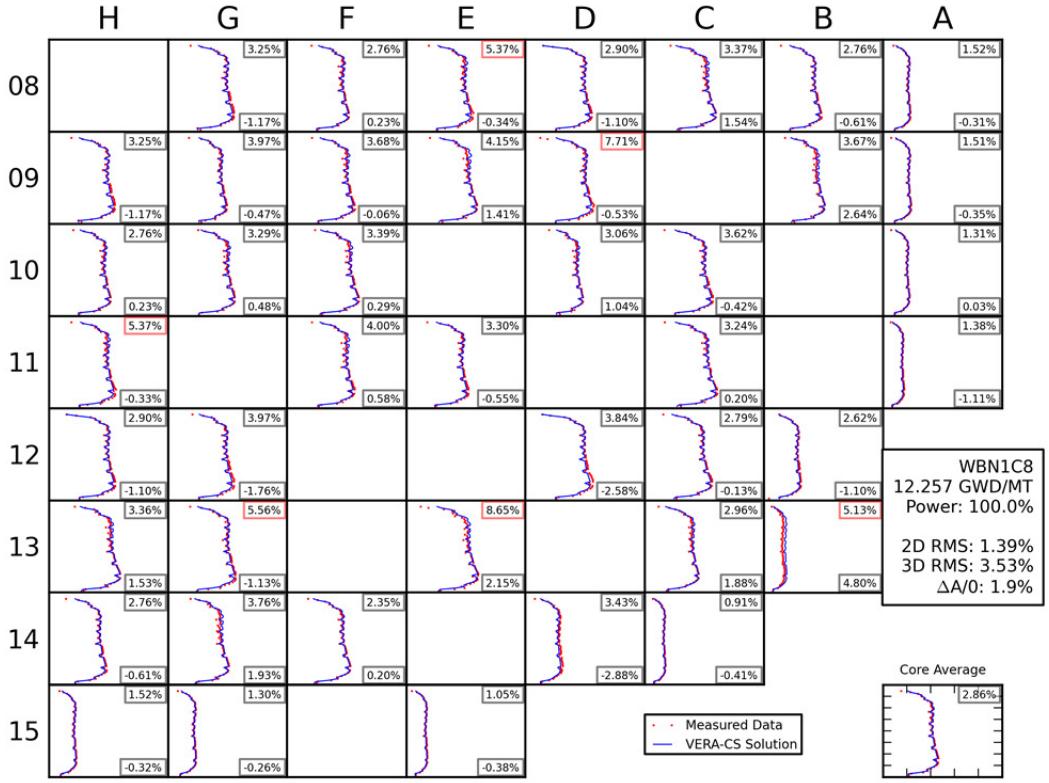

H G F E D C B A
08 09 10 11 12 13 14 15
4.60% -3.57%
2.58% -0.95%
2.48% -1.10%
4.20% 2.75%
2.56% 0.67%
1.18% 0.24%
4.60% -3.58%
2.59% 0.05%
2.62% -0.70%
2.99% 1.02%
6.82% -2.05%
1.41% 0.09%
2.57% -0.94%
2.69% 0.15%
2.90% -0.74%
3.15% 1.37%
2.93% -0.15%
1.29% 0.36%
2.79% -0.51%
2.43% 0.06%
1.19% -0.85%
2.48% -1.10%
2.49% -1.51%
3.34% -2.50%
3.77% 2.59%
2.43% -1.36%
4.19% 2.74%
4.27% -0.41%
3.76% 2.38%
3.90% 3.00%
2.60% 2.15%
2.56% 0.66%
4.33% 3.23%
2.34% 0.86%
2.47% -2.00%
0.95% -0.05%
1.18% 0.24%
1.51% -0.47%
0.99% -0.07%
WBN1C8
6.832 GWD/MT
Power: 100.0%
2D RMS: 1.64%
3D RMS: 2.89%
ΔA/0: 0.2%
Core Average
2.06%
Measured Data
VERA-CS Solution

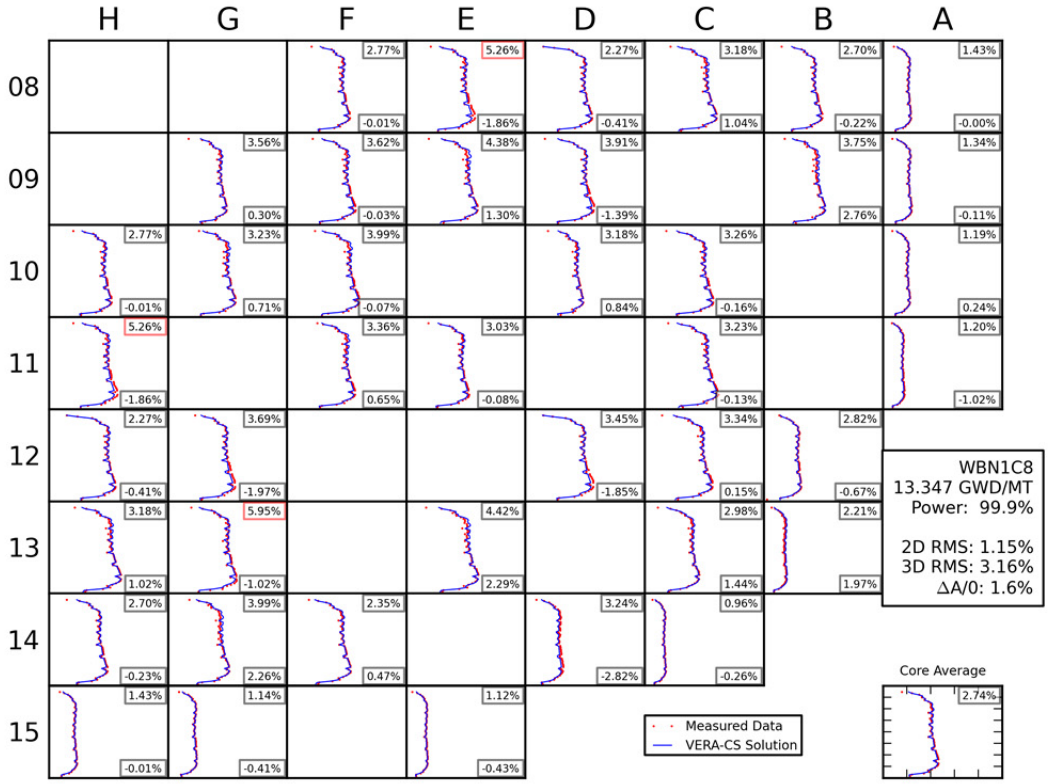

H G F E D C B A
08
09
10
11
12
13
14
15
WBN1C8
7.924 GWD/MT
Power: 99.9%
2D RMS: 1.63%
3D RMS: 3.12%
ΔA/0: 0.7%
Core Average
Measured Data
VERA-CS Solution

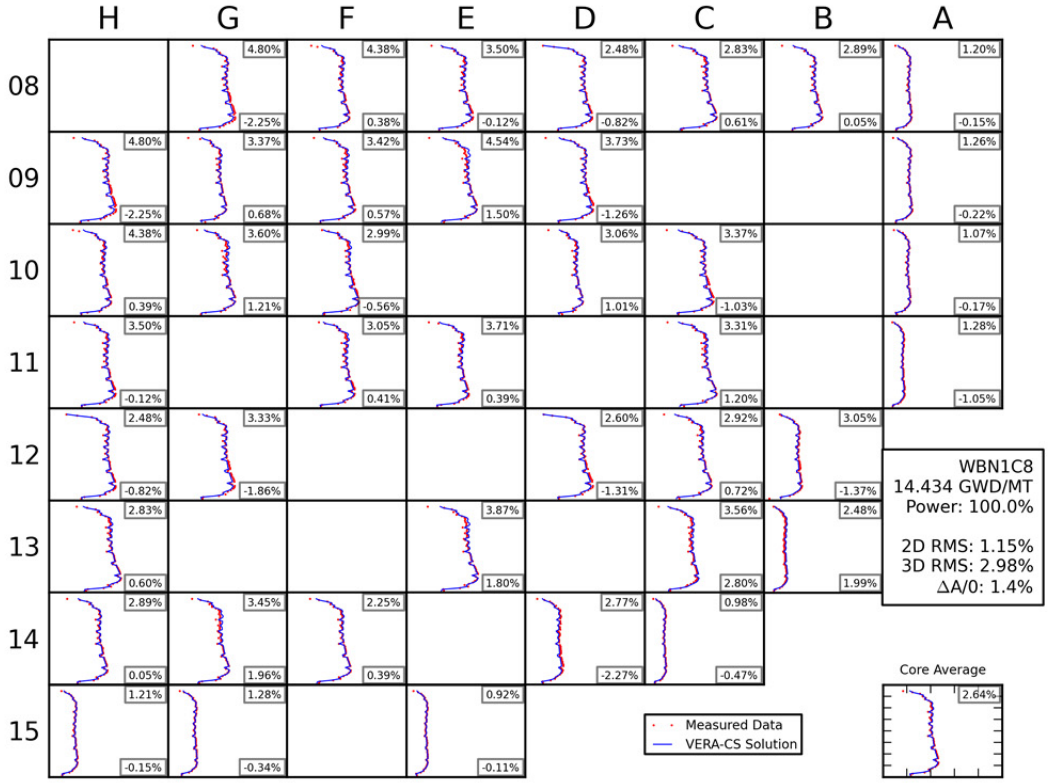

H G F E D C B A
08
09
10
11
12
13
14
15
WBN1C8
9.011 GWD/MT
Power: 99.9%
2D RMS: 1.40%
3D RMS: 2.78%
ΔA/0: 1.0%
Core Average
Measured Data
VERA-CS Solution

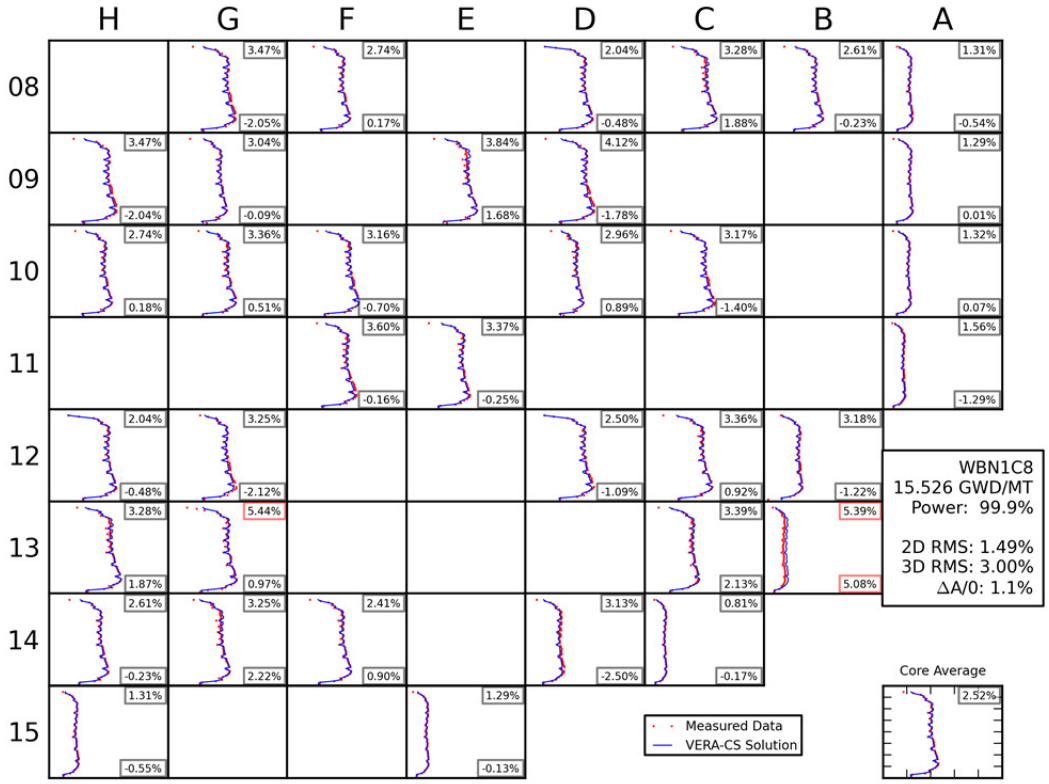

H G F E D C B A
08
09
10
11
12
13
14
15
WBN1C8
10.090 GWD/MT
Power: 98.3%
2D RMS: 1.23%
3D RMS: 2.63%
ΔA/0: 1.2%
Core Average
Measured Data
VERA-CS Solution

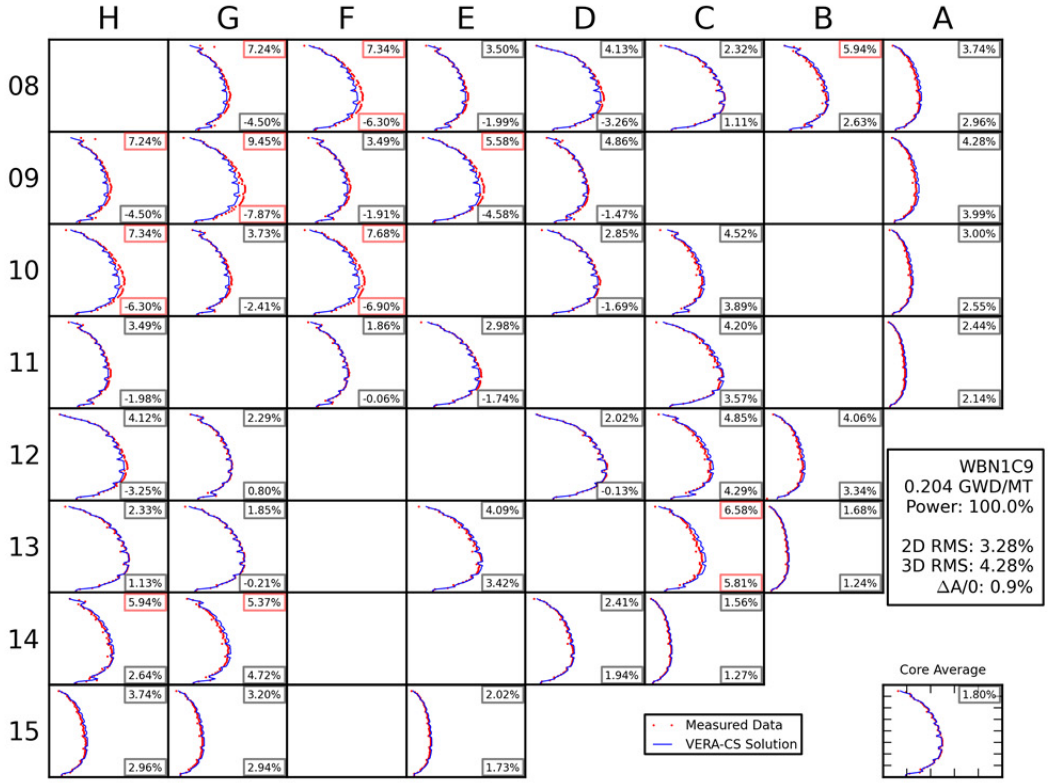

H G F E D C B A
08
09
10
11
12
13
14
15
WBN1C8
11.172 GWD/MT
Power: 100.1%
2D RMS: 1.29%
3D RMS: 2.91%
ΔA/0: 1.4%
Core Average
Measured Data
VERA-CS Solution

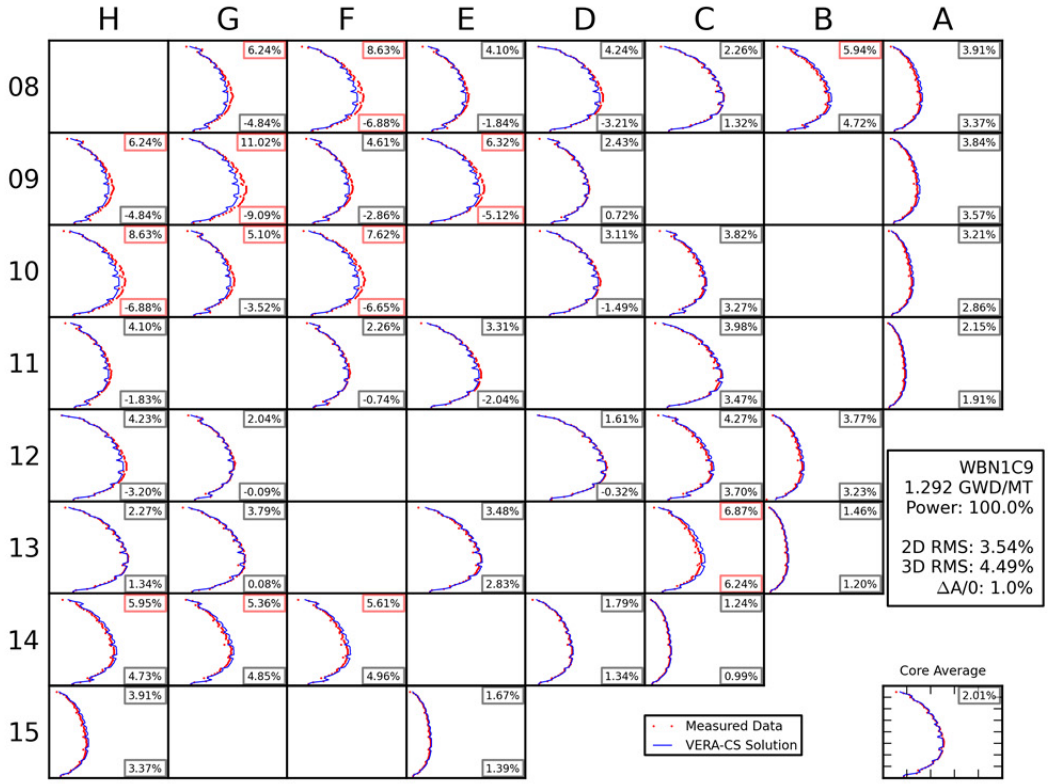

H G F E D C B A
08
09
10
11
12
13
14
15
WBN1C8
12.257 GWD/MT
Power: 100.0%
2D RMS: 1.39%
3D RMS: 3.53%
ΔA/0: 1.9%
Core Average
Measured Data
VERA-CS Solution

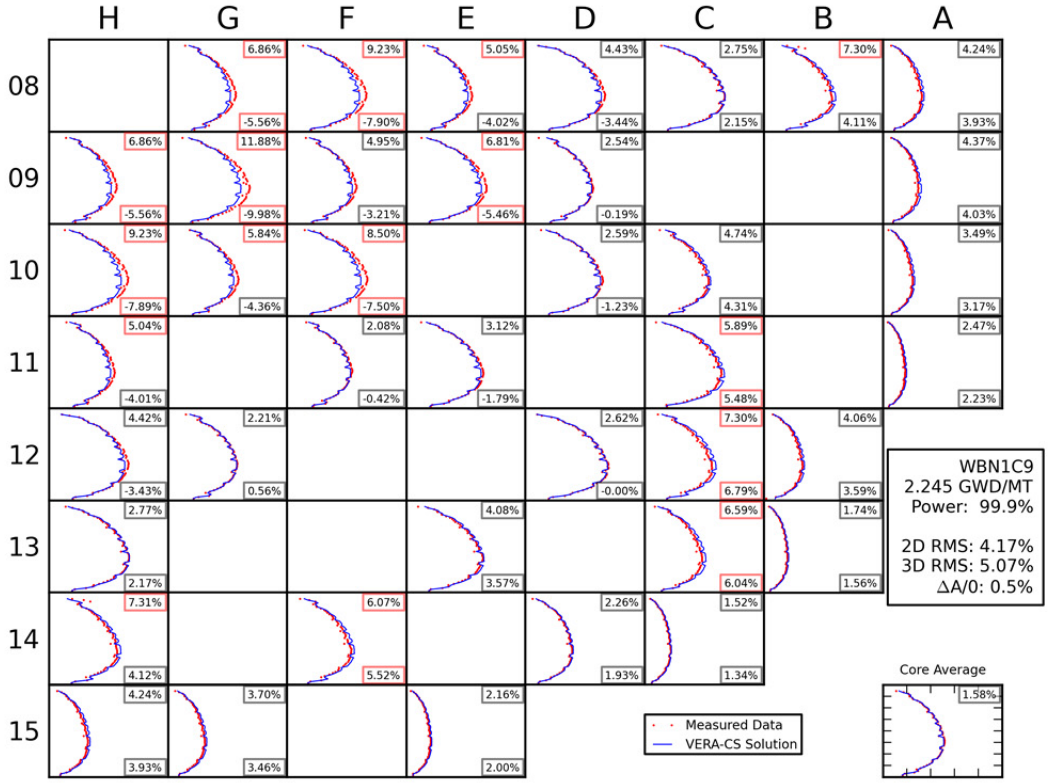

H G F E D C B A
08
09
10
11
12
13
14
15
WBN1C8
13.347 GWD/MT
Power: 99.9%
2D RMS: 1.15%
3D RMS: 3.16%
ΔA/0: 1.6%
Core Average
Measured Data
VERA-CS Solution

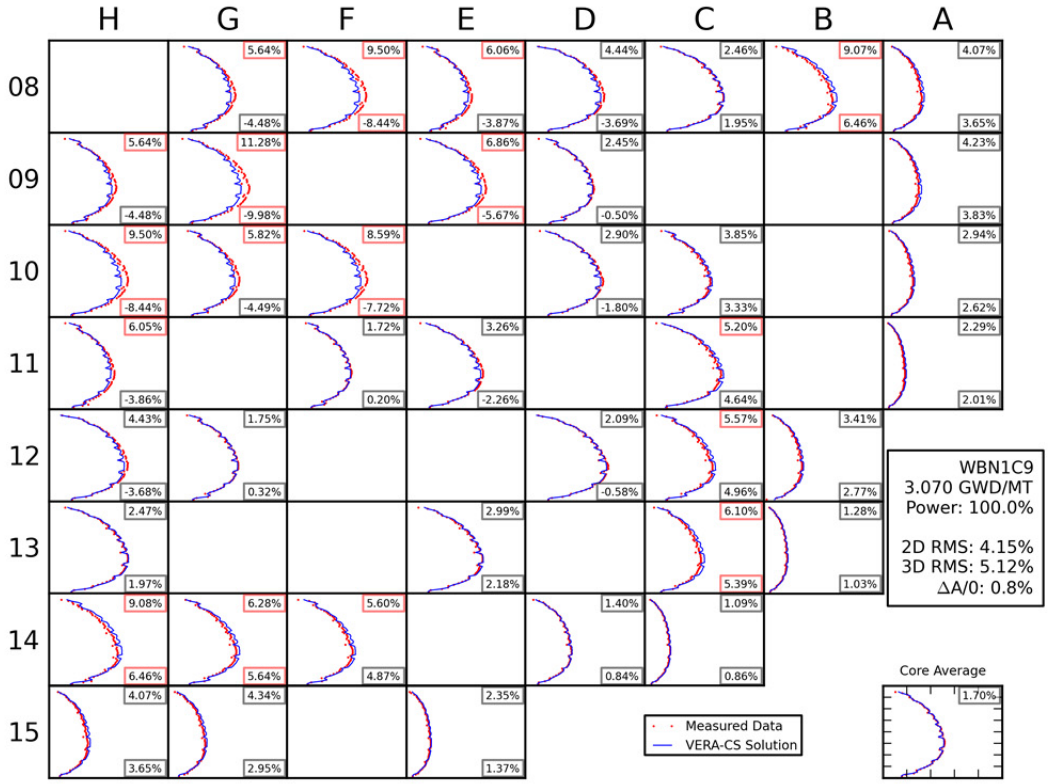

H G F E D C B A
08
09
10
11
12
13
14
15
WBN1C8
14.434 GWD/MT
Power: 100.0%
2D RMS: 1.15%
3D RMS: 2.98%
ΔA/0: 1.4%
Core Average
Measured Data
VERA-CS Solution

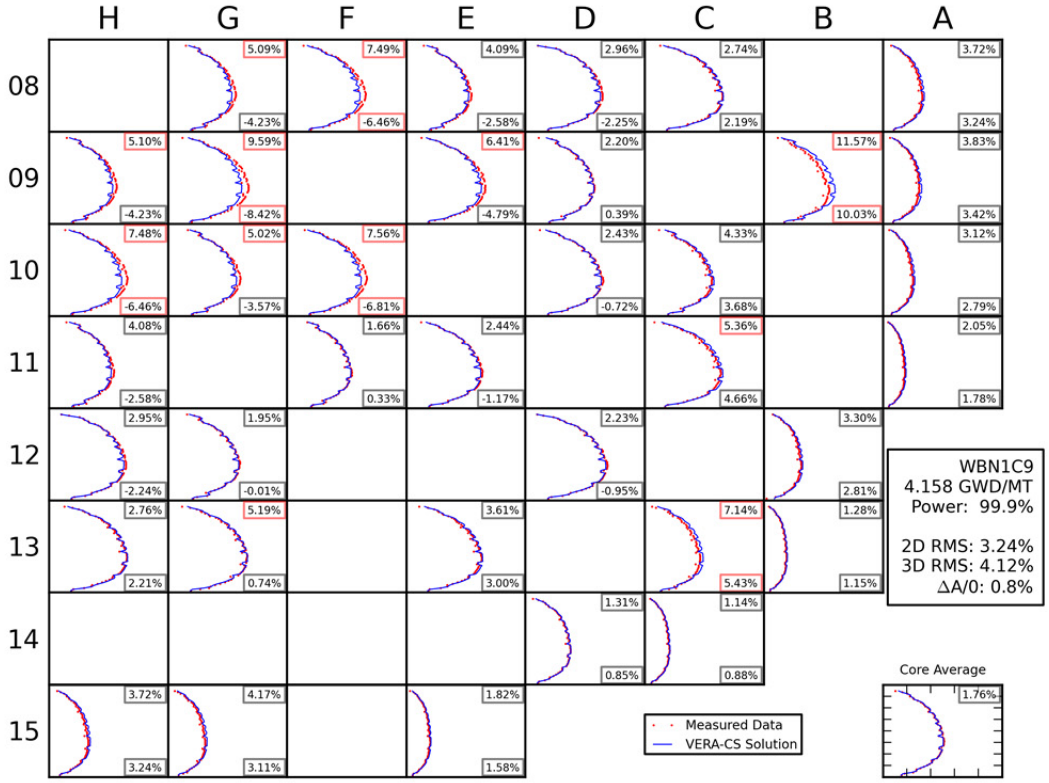

H G F E D C B A
08
09
10
11
12
13
14
15
WBN1C8
15.526 GWD/MT
Power: 99.9%
2D RMS: 1.49%
3D RMS: 3.00%
ΔA/0: 1.1%
Core Average
Measured Data
VERA-CS Solution

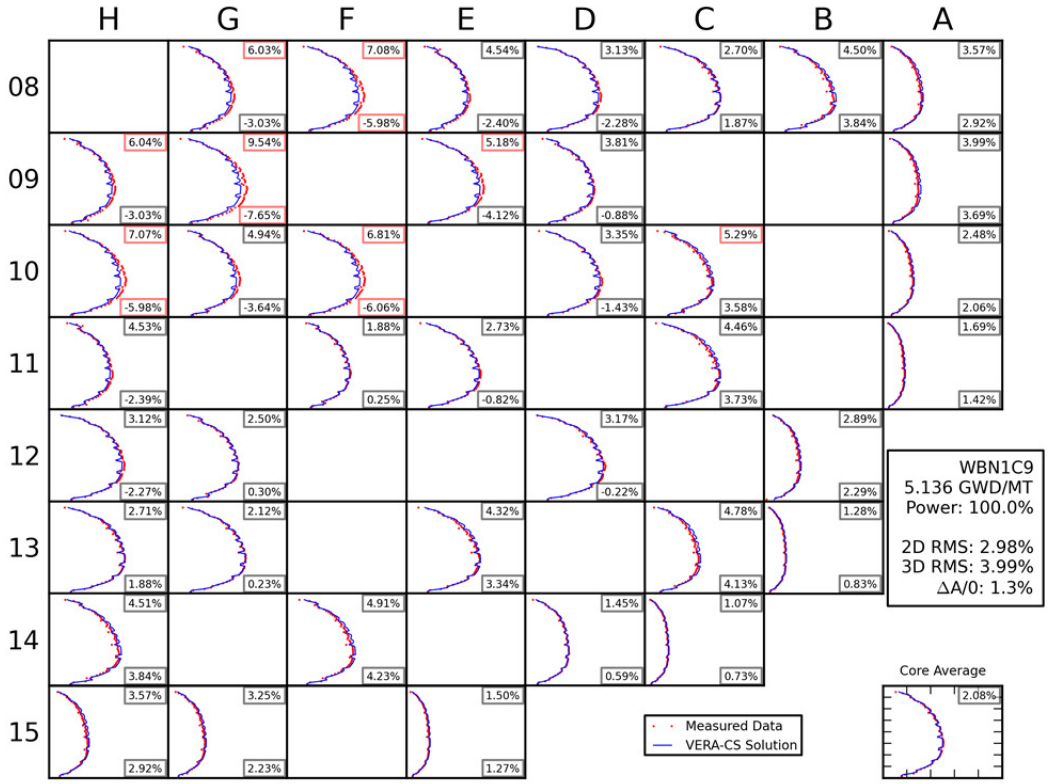

H G F E D C B A
08 09 10 11 12 13 14 15
WBN1C9
0.204 GWD/MT
Power: 100.0%
2D RMS: 3.28%
3D RMS: 4.28%
ΔA/0: 0.9%
Core Average
Measured Data
VERA-CS Solution

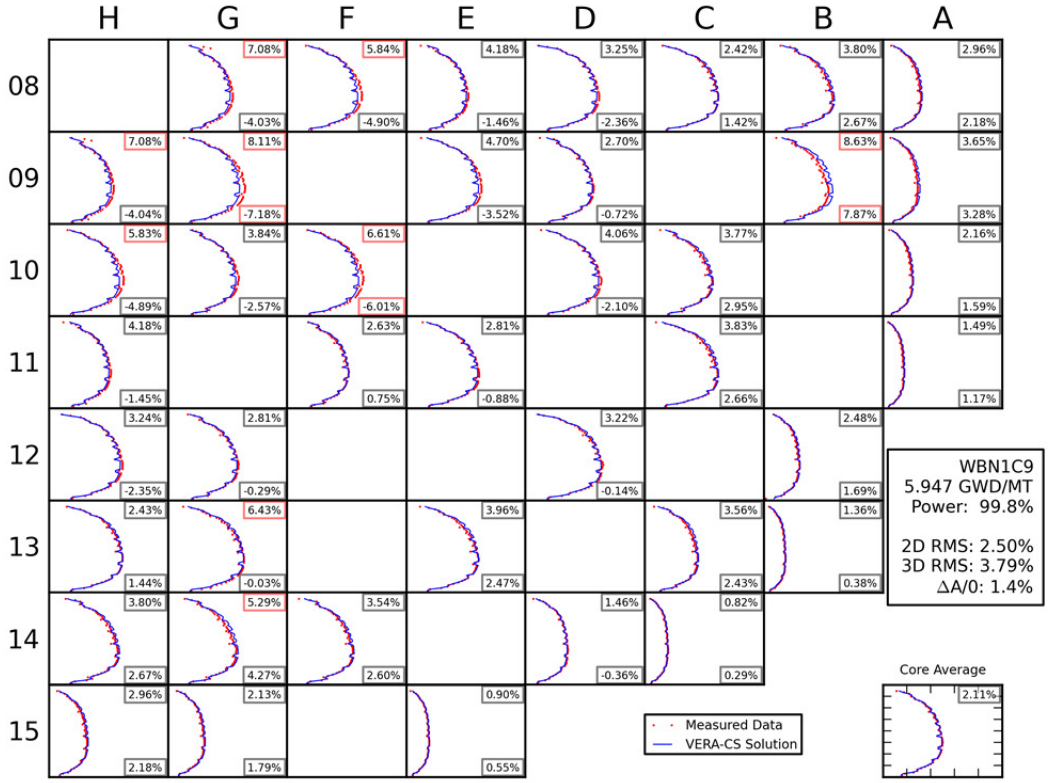

H G F E D C B A
08 09 10 11 12 13 14 15
WBN1C9
1.292 GWD/MT
Power: 100.0%
2D RMS: 3.54%
3D RMS: 4.49%
ΔA/0: 1.0%
Core Average
Measured Data
VERA-CS Solution

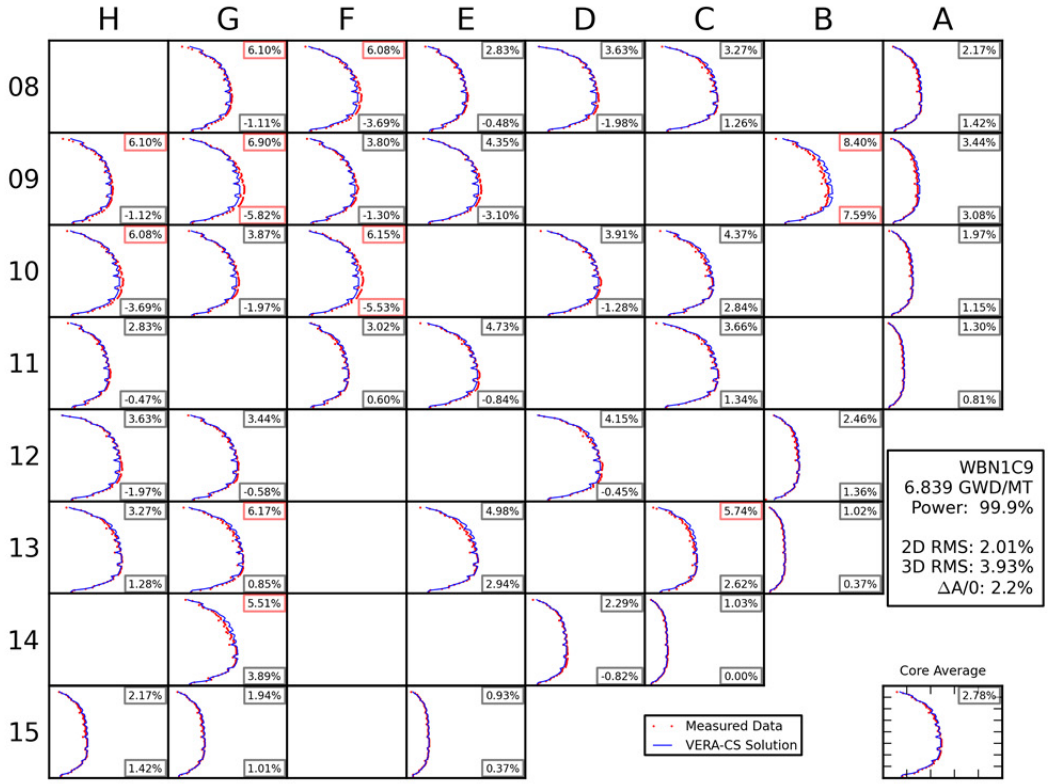

H G F E D C B A
08
09
10
11
12
13
14
15
WBN1C9
2.245 GWD/MT
Power: 99.9%
2D RMS: 4.17%
3D RMS: 5.07%
ΔA/0: 0.5%
Core Average
Measured Data
VERA-CS Solution

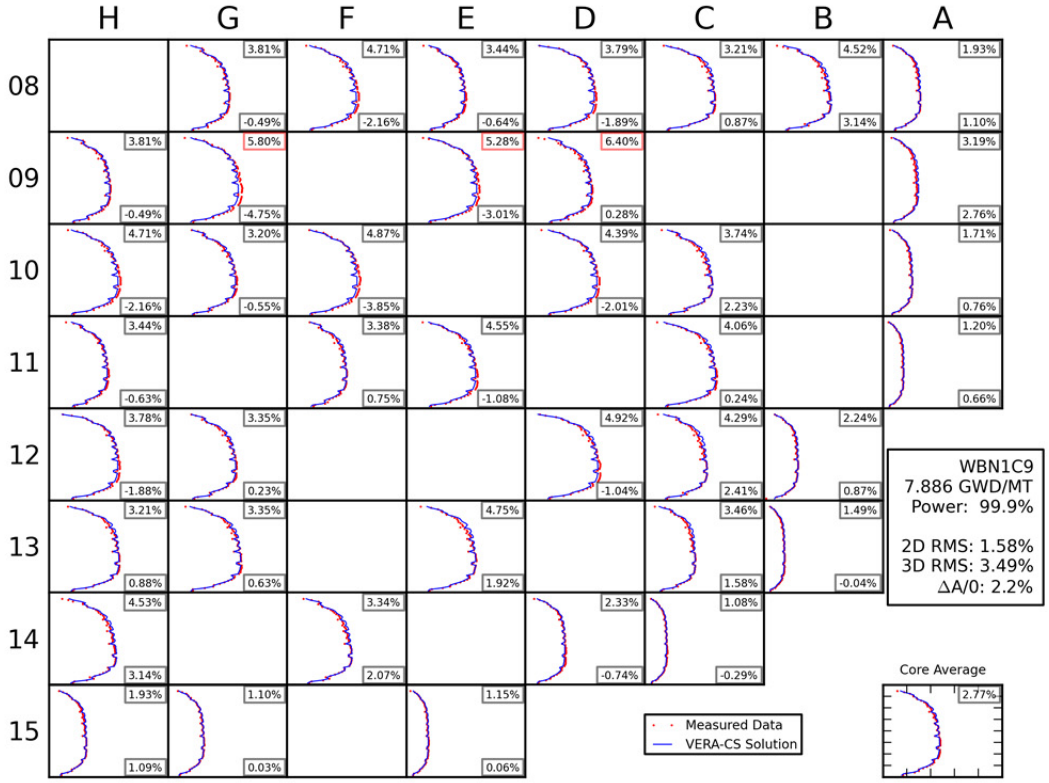

H G F E D C B A
08
09
10
11
12
13
14
15
WBN1C9
3.070 GWD/MT
Power: 100.0%
2D RMS: 4.15%
3D RMS: 5.12%
ΔA/0: 0.8%
Core Average
Measured Data
VERA-CS Solution

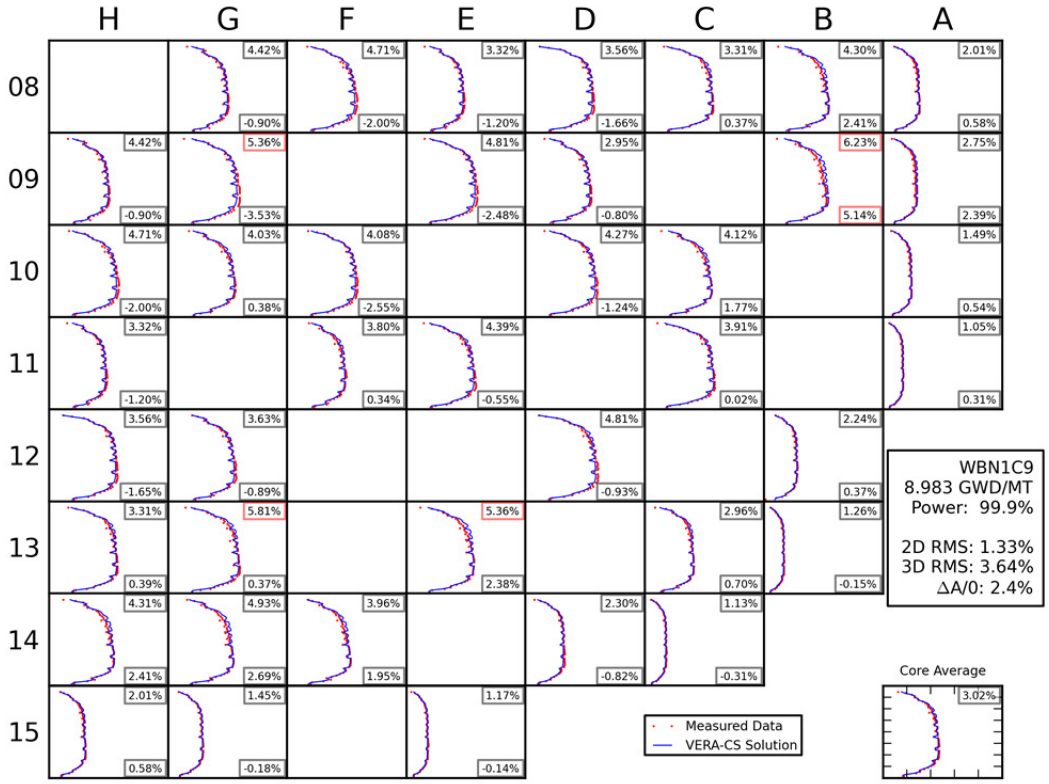

H G F E D C B A
08
09
10
11
12
13
14
15
WBN1C9
4.158 GWD/MT
Power: 99.9%
2D RMS: 3.24%
3D RMS: 4.12%
ΔA/0: 0.8%
Core Average
Measured Data
VERA-CS Solution

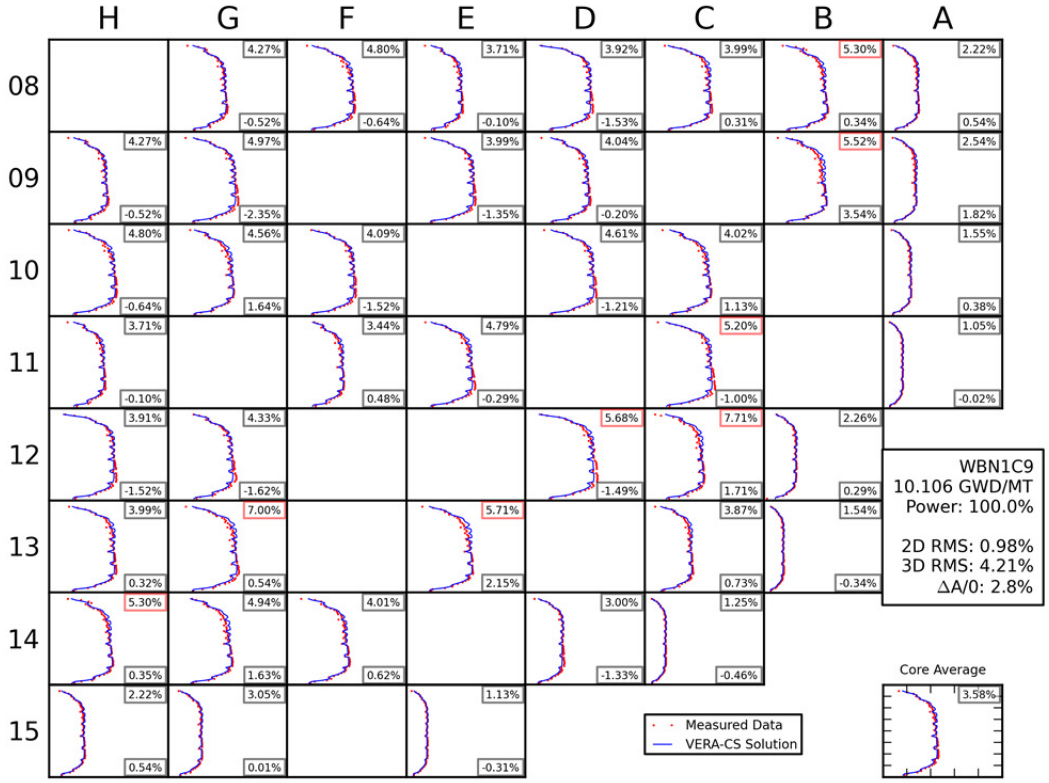

H G F E D C B A
08
09
10
11
12
13
14
15
WBN1C9
5.136 GWD/MT
Power: 100.0%
2D RMS: 2.98%
3D RMS: 3.99%
ΔA/0: 1.3%
Core Average
Measured Data
VERA-CS Solution

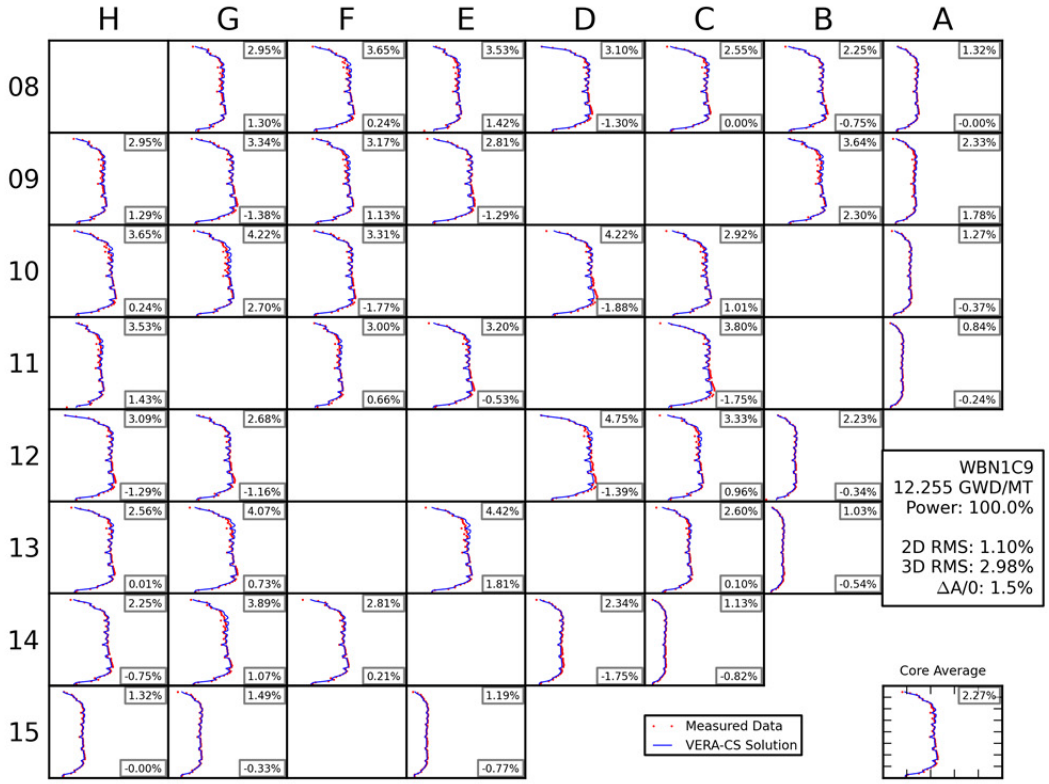

H G F E D C B A
08 09 10 11 12 13 14 15
7.08% -4.03%
5.84% -4.90%
4.18% -1.46%
3.25% -2.36%
2.42% 1.42%
3.80% 2.67%
2.96% 2.18%
7.08% -4.04%
8.11% -7.18%
4.70% -3.52%
2.70% -0.72%
8.63% 7.87%
3.65% 3.28%
5.83% -4.89%
3.84% -2.57%
6.61% -6.01%
4.06% -2.10%
3.77% 2.95%
2.16% 1.59%
4.18% -1.45%
2.63% 0.75%
2.81% -0.88%
3.83% 2.66%
1.49% 1.17%
3.24% -2.35%
2.81% -0.29%
3.22% -0.14%
2.48% 1.69%
2.43% 1.44%
6.43% -0.03%
3.96% 2.47%
3.56% 2.43%
1.36% 0.38%
3.80% 2.67%
5.29% 4.27%
3.54% 2.60%
1.46% -0.36%
0.82% 0.29%
2.96% 2.18%
2.13% 1.79%
0.90% 0.55%
WBN1C9
5.947 GWD/MT
Power: 99.8%
2D RMS: 2.50%
3D RMS: 3.79%
ΔA/0: 1.4%
Core Average
2.11%
Measured Data
VERA-CS Solution

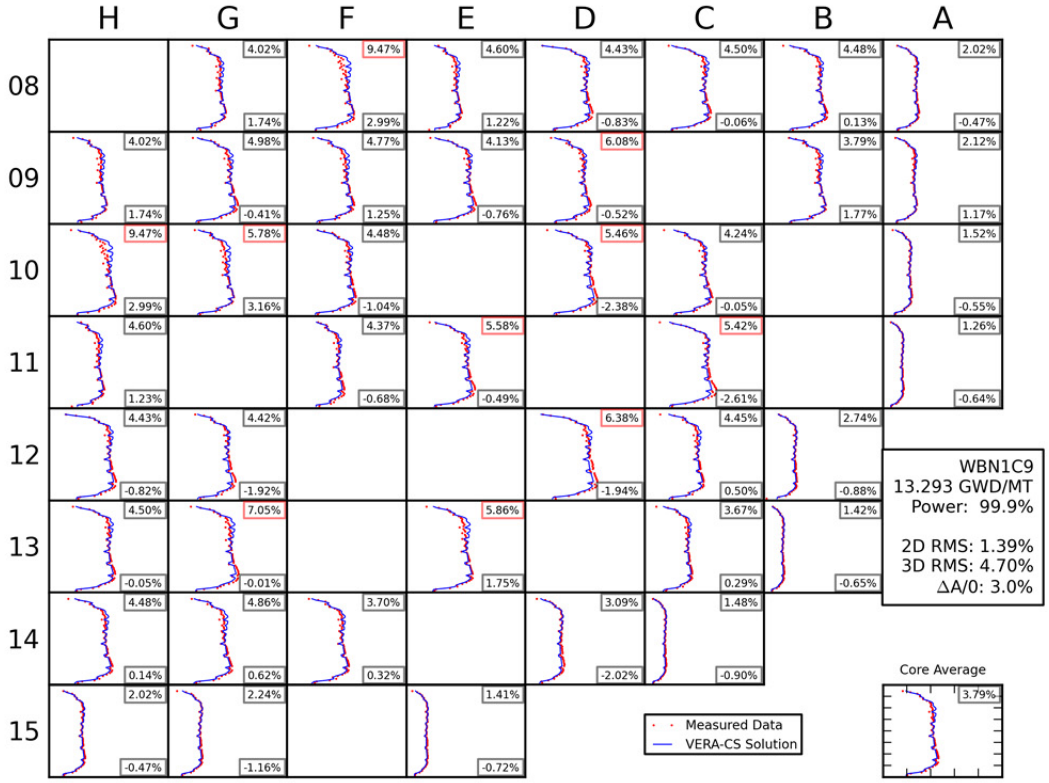

H G F E D C B A
08 09 10 11 12 13 14 15
6.10% -1.11%
6.08% -3.69%
2.83% -0.48%
3.63% -1.98%
3.27% 1.26%
2.17% 1.42%
6.10% -1.12%
6.90% -5.82%
3.80% -1.30%
4.35% -3.10%
8.40% 7.59%
3.44% 3.08%
6.08% -3.69%
3.87% -1.97%
6.15% -5.53%
3.91% -1.28%
4.37% 2.84%
1.97% 1.15%
2.83% -0.47%
3.02% 0.60%
4.73% -0.84%
3.66% 1.34%
1.30% 0.81%
3.63% -1.97%
3.44% -0.58%
4.15% -0.45%
2.46% 1.36%
3.27% 1.28%
6.17% 0.85%
4.98% 2.94%
5.74% 2.62%
1.02% 0.37%
5.51% 3.89%
2.29% -0.82%
1.03% 0.00%
2.17% 1.42%
1.94% 1.01%
0.93% 0.37%
WBN1C9
6.839 GWD/MT
Power: 99.9%
2D RMS: 2.01%
3D RMS: 3.93%
ΔA/0: 2.2%
Core Average
2.78%
Measured Data
VERA-CS Solution

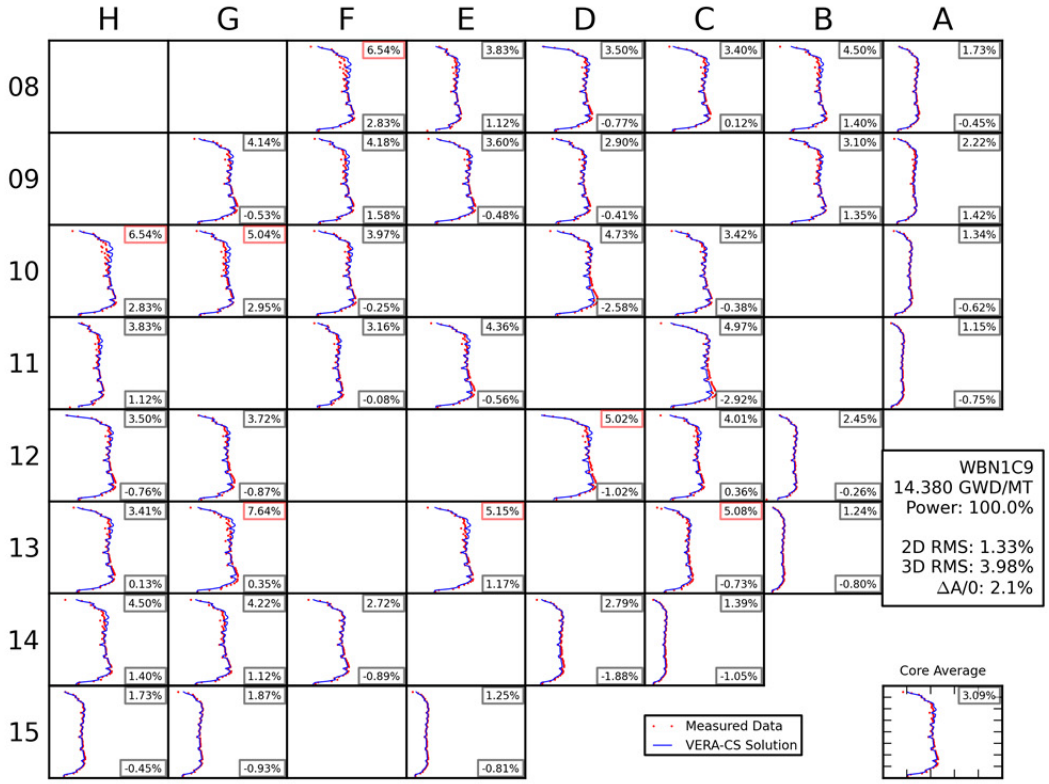

H G F E D C B A
08 09 10 11 12 13 14 15
3.81% -0.49%
4.71% -2.16%
3.44% -0.64%
3.79% -1.89%
3.21% 0.87%
4.52% 3.14%
1.93% 1.10%
3.81% -0.49%
5.80% -4.75%
5.28% -3.01%
6.40% 0.28%
3.19% 2.76%
4.71% -2.16%
3.20% -0.55%
4.87% -3.85%
4.39% -2.01%
3.74% 2.23%
1.71% 0.76%
3.44% -0.63%
3.38% 0.75%
4.55% -1.08%
4.06% 0.24%
1.20% 0.66%
3.78% -1.88%
3.35% 0.23%
4.92% -1.04%
4.29% 2.41%
2.24% 0.87%
3.21% 0.88%
3.35% 0.63%
4.75% 1.92%
3.46% 1.58%
1.49% -0.04%
4.53% 3.14%
3.34% 2.07%
2.33% -0.74%
1.08% -0.29%
1.93% 1.09%
1.10% 0.03%
1.15% 0.06%
WBN1C9
7.886 GWD/MT
Power: 99.9%
2D RMS: 1.58%
3D RMS: 3.49%
ΔA/0: 2.2%
Core Average
2.77%
Measured Data
VERA-CS Solution

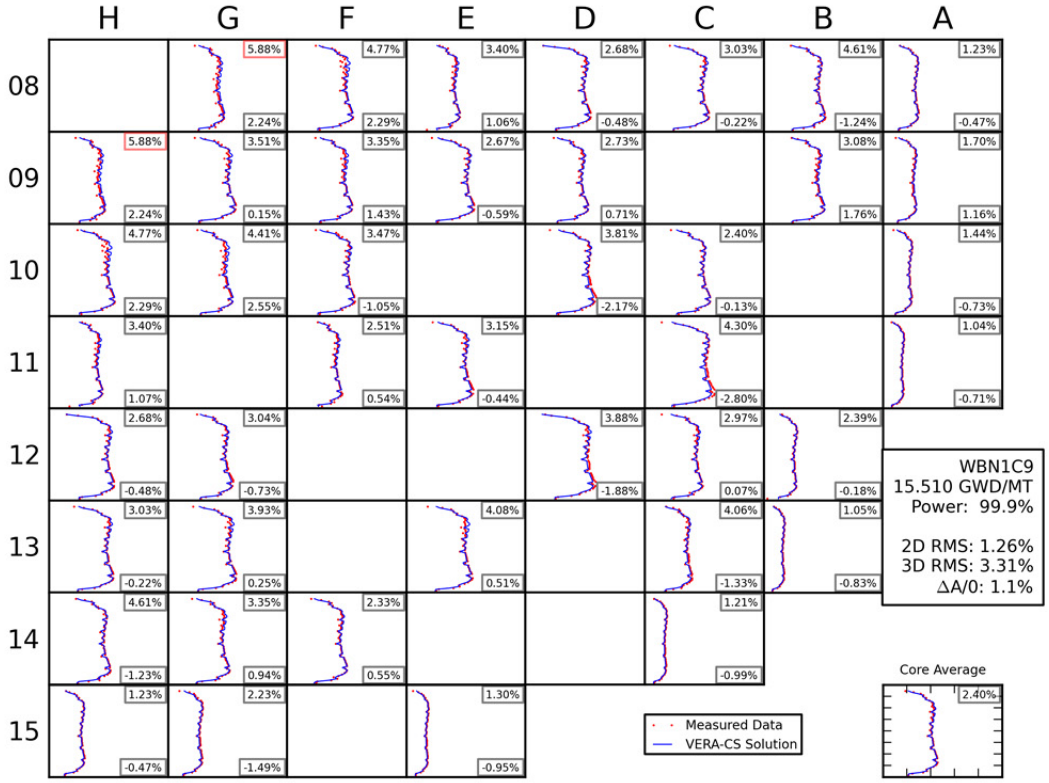

H G F E D C B A
08 09 10 11 12 13 14 15
4.42% -0.90%
4.71% -2.00%
3.32% -1.20%
3.56% -1.66%
3.31% 0.37%
4.30% 2.41%
2.01% 0.58%
4.42% -0.90%
5.36% -3.53%
4.81% -2.48%
2.95% -0.80%
6.23% 5.14%
2.75% 2.39%
4.71% -2.00%
4.03% 0.38%
4.08% -2.55%
4.27% -1.24%
4.12% 1.77%
1.49% 0.54%
3.32% -1.20%
3.80% 0.34%
4.39% -0.55%
3.91% 0.02%
1.05% 0.31%
3.56% -1.65%
3.63% -0.89%
4.81% -0.93%
2.24% 0.37%
3.31% 0.39%
5.81% 0.37%
5.36% 2.38%
2.96% 0.70%
1.26% -0.15%
4.31% 2.41%
4.93% 2.69%
3.96% 1.95%
2.30% -0.82%
1.13% -0.31%
2.01% 0.58%
1.45% -0.18%
1.17% -0.14%
WBN1C9
8.983 GWD/MT
Power: 99.9%
2D RMS: 1.33%
3D RMS: 3.64%
ΔA/0: 2.4%
Core Average
3.02%
Measured Data
VERA-CS Solution

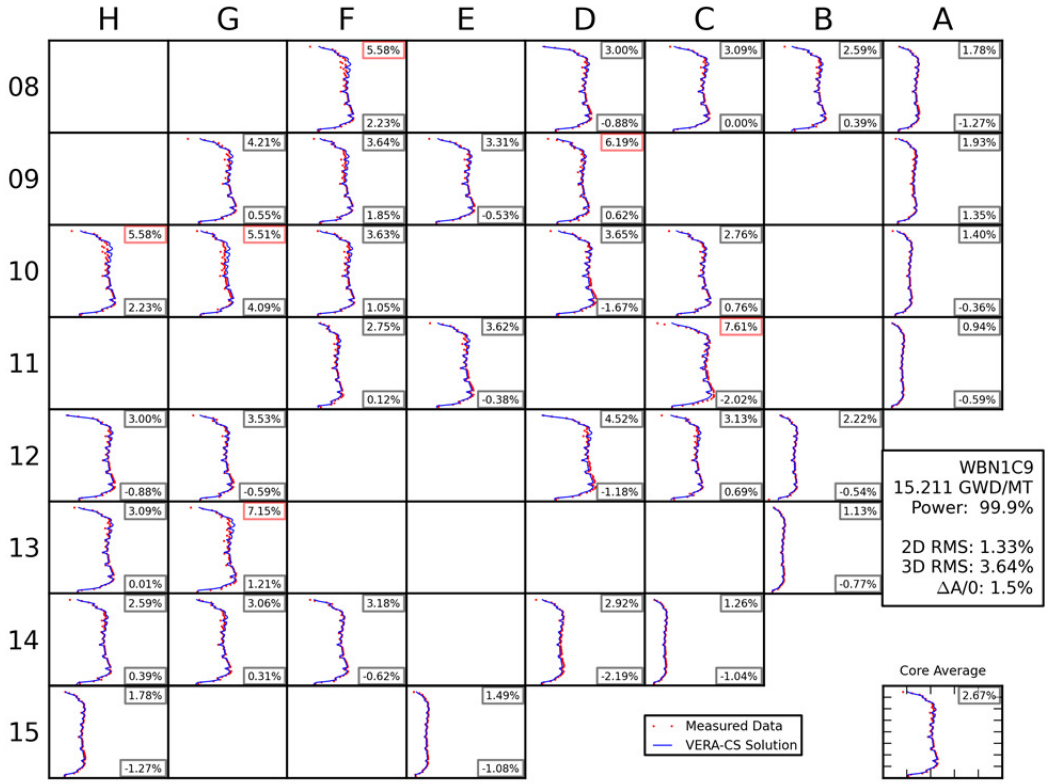

H G F E D C B A
08
09
10
11
12
13
14
15
WBN1C9
10.106 GWD/MT
Power: 100.0%
2D RMS: 0.98%
3D RMS: 4.21%
ΔA/0: 2.8%
Core Average
Measured Data
VERA-CS Solution

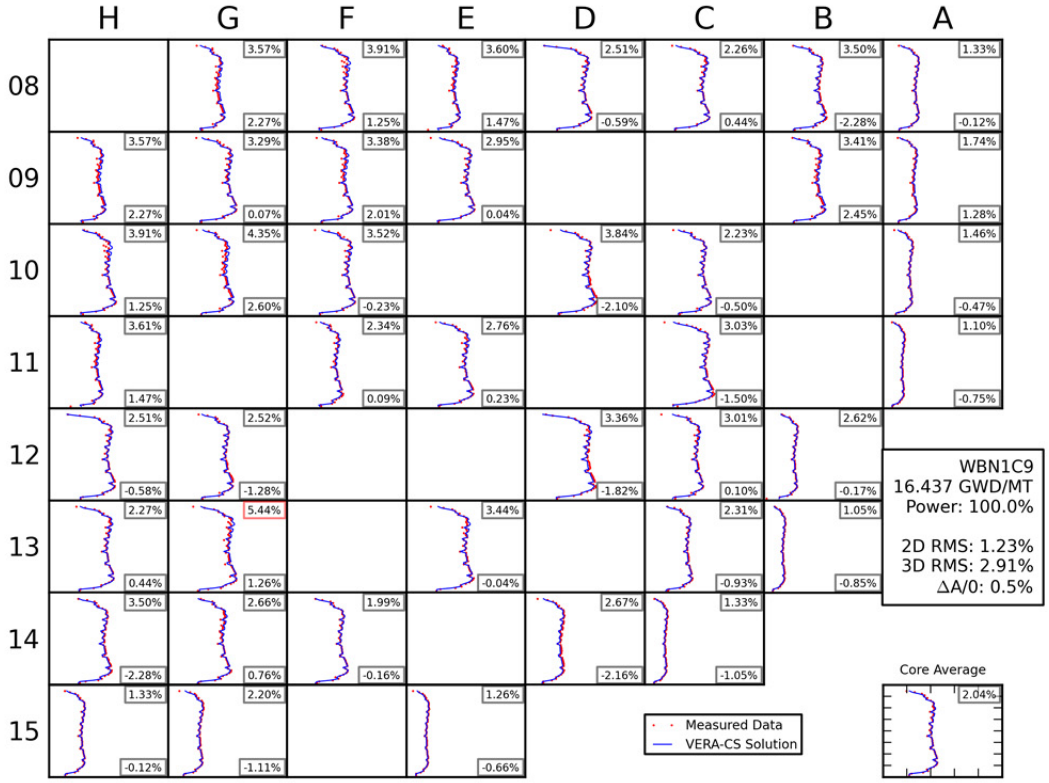

H G F E D C B A
08
09
10
11
12
13
14
15
WBN1C9
12.255 GWD/MT
Power: 100.0%
2D RMS: 1.10%
3D RMS: 2.98%
ΔA/0: 1.5%
Core Average
Measured Data
VERA-CS Solution

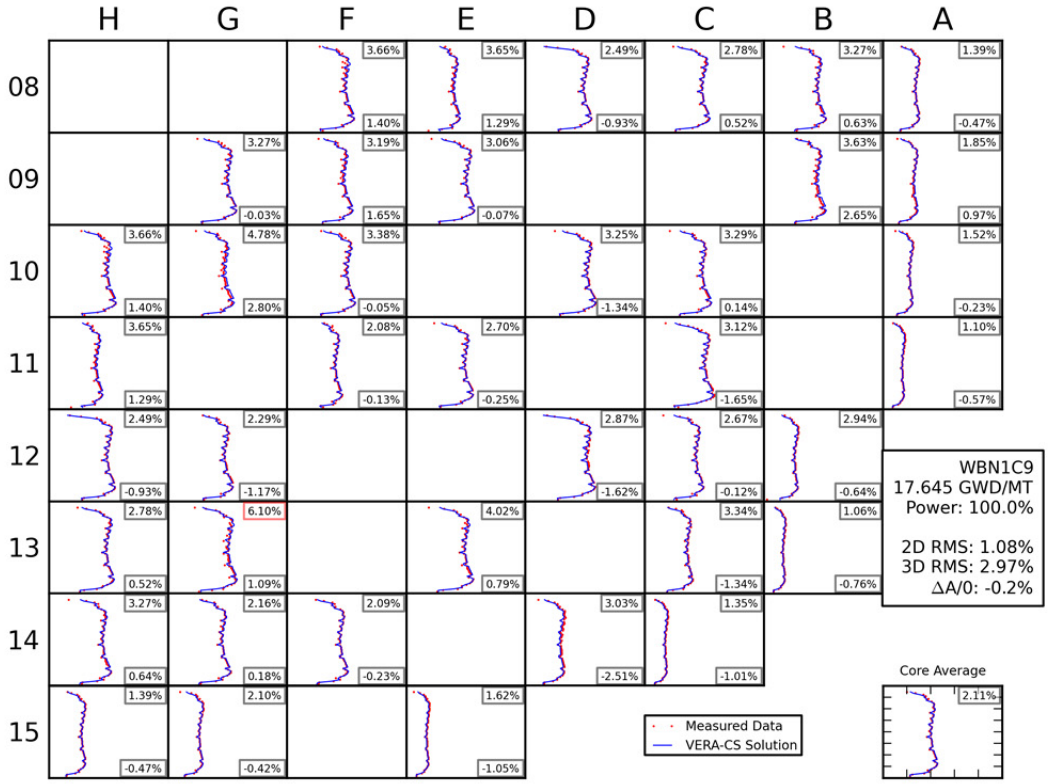

H G F E D C B A
08 09 10 11 12 13 14 15
4.02% 1.74%
4.02% 1.74%
9.47% 2.99%
4.98% -0.41%
4.60% 1.22%
4.77% 1.25%
4.43% -0.83%
4.13% -0.76%
4.50% -0.06%
6.08% -0.52%
4.48% 0.13%
3.79% 1.77%
2.02% -0.47%
2.12% 1.17%
9.47% 2.99%
5.78% 3.16%
4.48% -1.04%
5.46% -2.38%
4.24% -0.05%
1.52% -0.55%
4.60% 1.23%
4.37% -0.68%
5.58% -0.49%
5.42% -2.61%
1.26% -0.64%
4.43% -0.82%
4.42% -1.92%
6.38% -1.94%
4.45% 0.50%
2.74% -0.88%
4.50% -0.05%
7.05% -0.01%
5.86% 1.75%
3.67% 0.29%
1.42% -0.65%
4.48% 0.14%
4.86% 0.62%
3.70% 0.32%
3.09% -2.02%
1.48% -0.90%
2.02% -0.47%
2.24% -1.16%
1.41% -0.72%
WBN1C9
13.293 GWD/MT
Power: 99.9%
2D RMS: 1.39%
3D RMS: 4.70%
ΔA/0: 3.0%
Measured Data
VERA-CS Solution
Core Average
3.79%

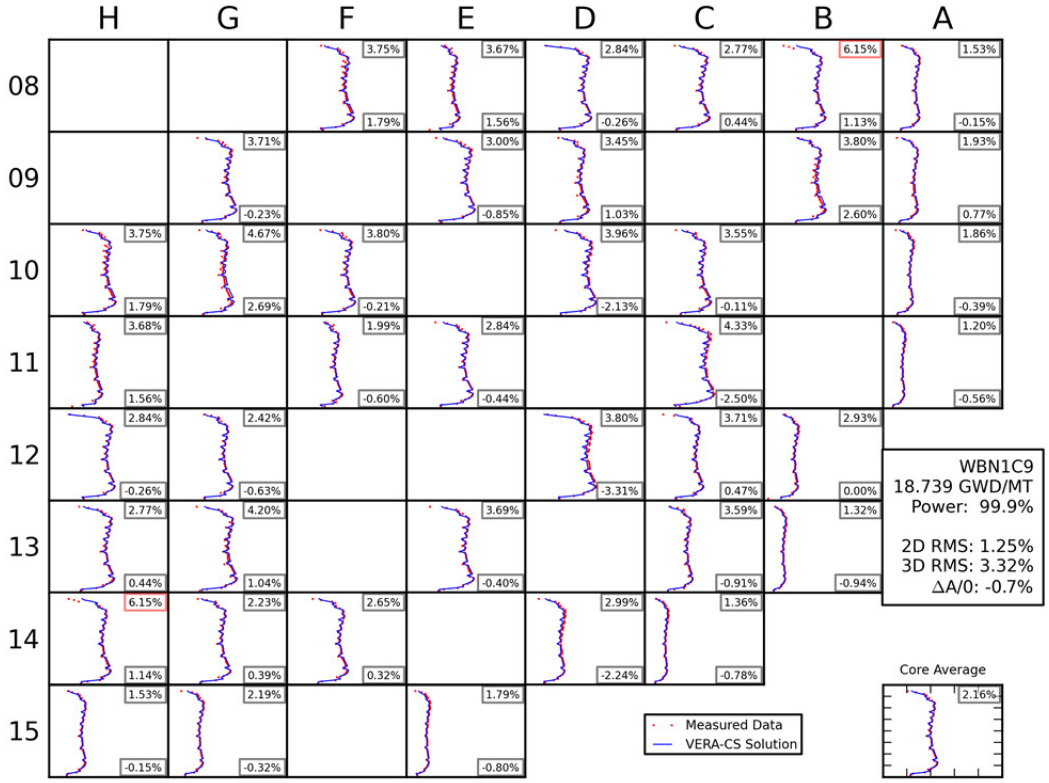

H G F E D C B A
08 09 10 11 12 13 14 15
6.54% 2.83%
3.83% 1.12%
4.14% -0.53%
4.18% 1.58%
3.60% -0.48%
2.90% -0.41%
3.50% -0.77%
3.40% 0.12%
4.50% 1.40%
1.73% -0.45%
2.22% 1.42%
6.54% 2.83%
5.04% 2.95%
3.97% -0.25%
4.73% -2.58%
3.42% -0.38%
1.34% -0.62%
3.83% 1.12%
3.16% -0.08%
4.36% -0.56%
4.97% -2.92%
1.15% -0.75%
3.50% -0.76%
3.72% -0.87%
5.02% -1.02%
4.01% 0.36%
2.45% -0.26%
3.41% 0.13%
7.64% 0.35%
5.15% 1.17%
5.08% -0.73%
1.24% -0.80%
4.50% 1.40%
4.22% 1.12%
2.72% -0.89%
2.79% -1.88%
1.39% -1.05%
1.73% -0.45%
1.87% -0.93%
1.25% -0.81%
WBN1C9
14.380 GWD/MT
Power: 100.0%
2D RMS: 1.33%
3D RMS: 3.98%
ΔA/0: 2.1%
Measured Data
VERA-CS Solution
Core Average
3.09%

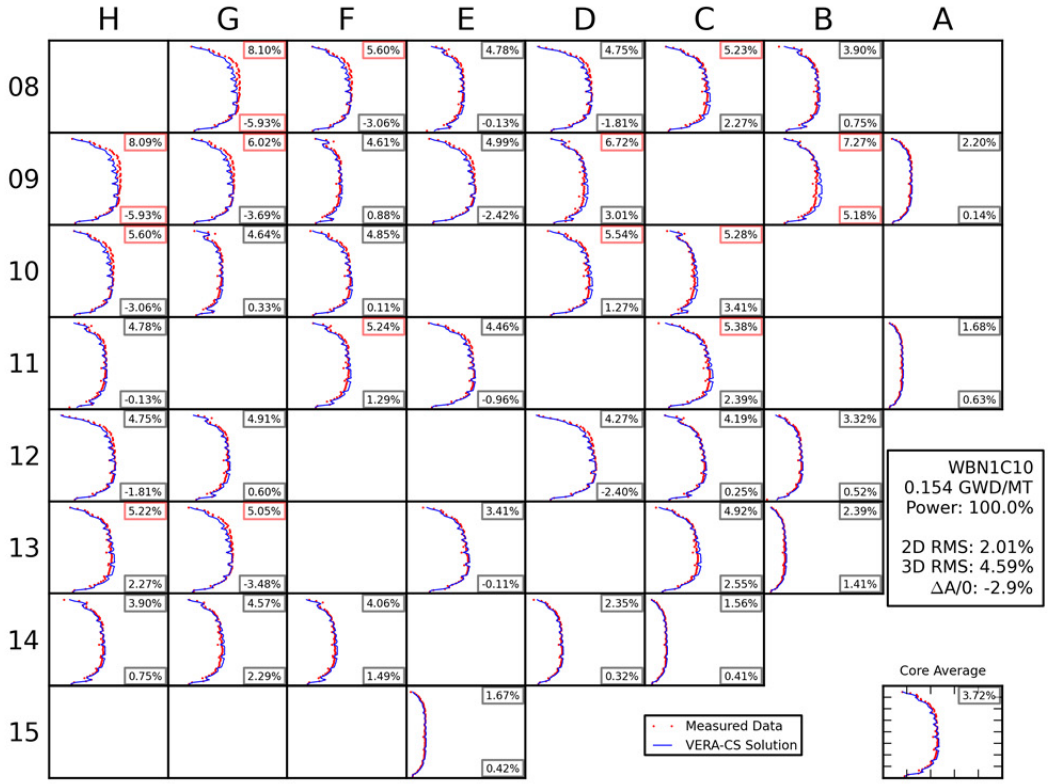

H G F E D C B A
08
5.88% 2.24%
4.77% 2.29%
3.40% 1.06%
2.68% -0.48%
3.03% -0.22%
4.61% -1.24%
1.23% -0.47%
09
5.88% 2.24%
3.51% 0.15%
3.35% 1.43%
2.67% -0.59%
2.73% 0.71%
3.08% 1.76%
1.70% 1.16%
10
4.77% 2.29%
4.41% 2.55%
3.47% -1.05%
3.81% -2.17%
2.40% -0.13%
1.44% -0.73%
11
3.40% 1.07%
2.51% 0.54%
3.15% -0.44%
4.30% -2.80%
1.04% -0.71%
12
2.68% -0.48%
3.04% -0.73%
3.88% -1.88%
2.97% 0.07%
2.39% -0.18%
13
3.03% -0.22%
3.93% 0.25%
4.08% 0.51%
4.06% -1.33%
1.05% -0.83%
14
4.61% -1.23%
3.35% 0.94%
2.33% 0.55%
1.21% -0.99%
15
1.23% -0.47%
2.23% -1.49%
1.30% -0.95%
WBN1C9
15.510 GWD/MT
Power: 99.9%
2D RMS: 1.26%
3D RMS: 3.31%
ΔA/0: 1.1%
Core Average
2.40%
Measured Data
VERA-CS Solution

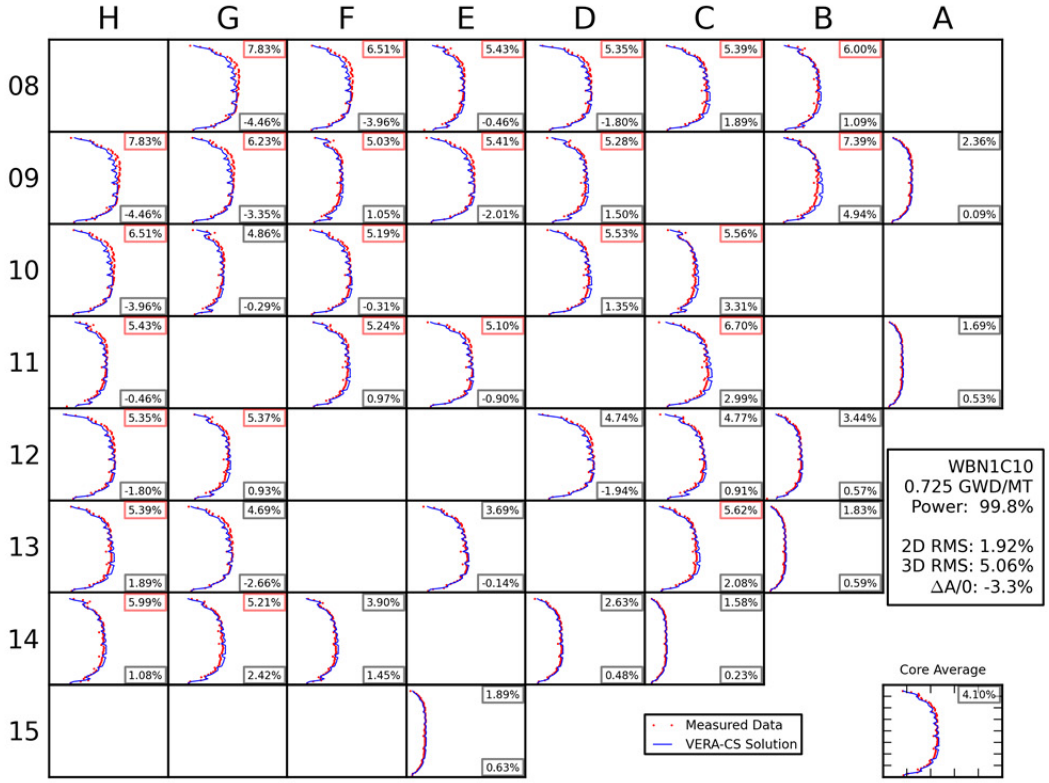

H G F E D C B A
08
5.58% 2.23%
3.00% -0.88%
3.09% 0.00%
2.59% 0.39%
1.78% -1.27%
09
4.21% 0.55%
3.64% 1.85%
3.31% -0.53%
6.19% 0.62%
1.93% 1.35%
10
5.58% 2.23%
5.51% 4.09%
3.63% 1.05%
3.65% -1.67%
2.76% 0.76%
1.40% -0.36%
11
2.75% 0.12%
3.62% -0.38%
7.61% -2.02%
0.94% -0.59%
12
3.00% -0.88%
3.53% -0.59%
4.52% -1.18%
3.13% 0.69%
2.22% -0.54%
13
3.09% 0.01%
7.15% 1.21%
1.13% -0.77%
14
2.59% 0.39%
3.06% 0.31%
3.18% -0.62%
2.92% -2.19%
1.26% -1.04%
15
1.78% -1.27%
1.49% -1.08%
WBN1C9
15.211 GWD/MT
Power: 99.9%
2D RMS: 1.33%
3D RMS: 3.64%
ΔA/0: 1.5%
Core Average
2.67%
Measured Data
VERA-CS Solution

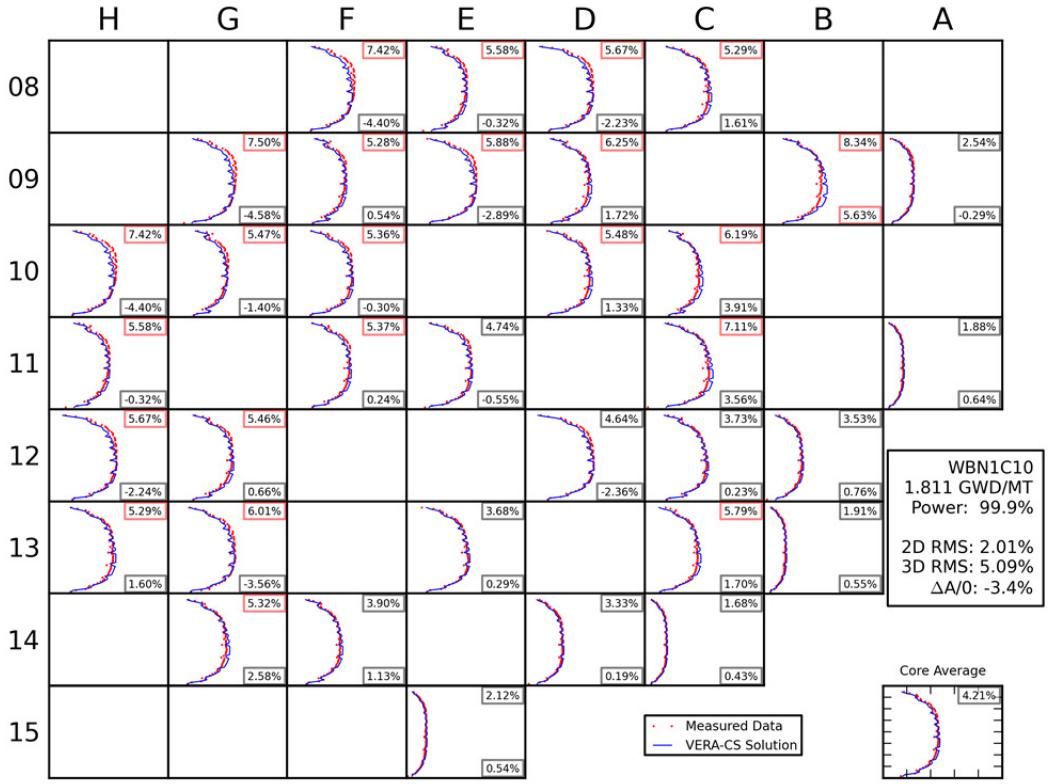

H G F E D C B A
08
09
10
11
12
13
14
15
WBN1C9
16.437 GWD/MT
Power: 100.0%
2D RMS: 1.23%
3D RMS: 2.91%
ΔA/0: 0.5%
Core Average
Measured Data
VERA-CS Solution

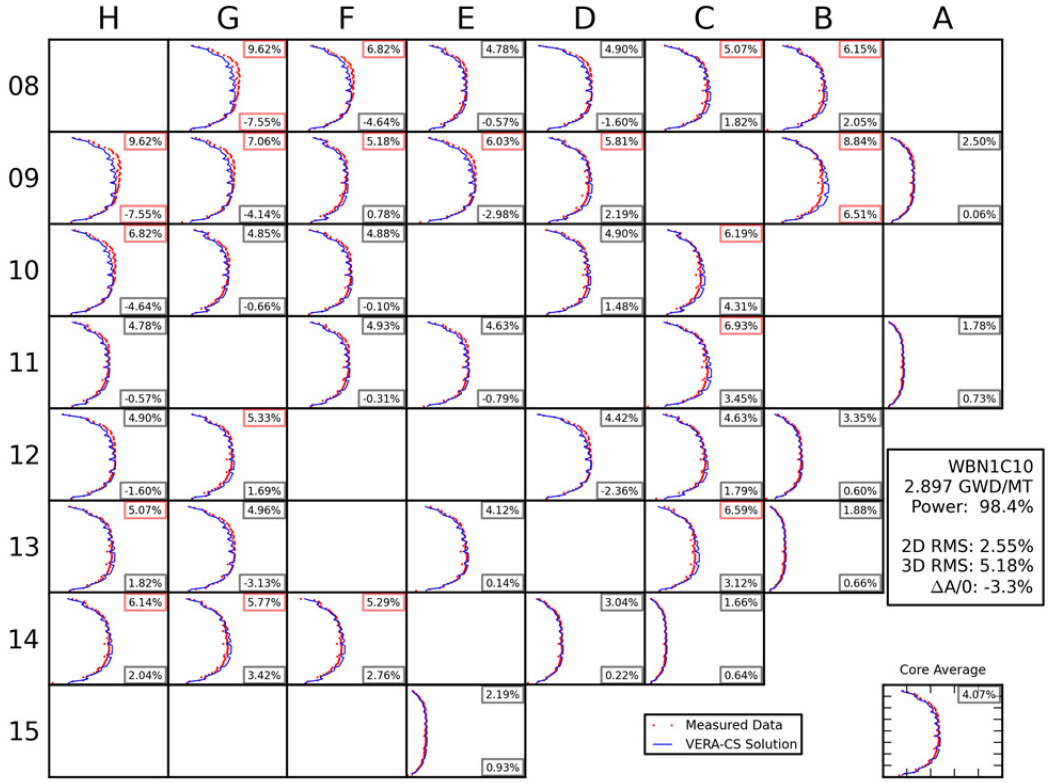

H G F E D C B A
08
09
10
11
12
13
14
15
WBN1C9
17.645 GWD/MT
Power: 100.0%
2D RMS: 1.08%
3D RMS: 2.97%
ΔA/0: -0.2%
Core Average
Measured Data
VERA-CS Solution

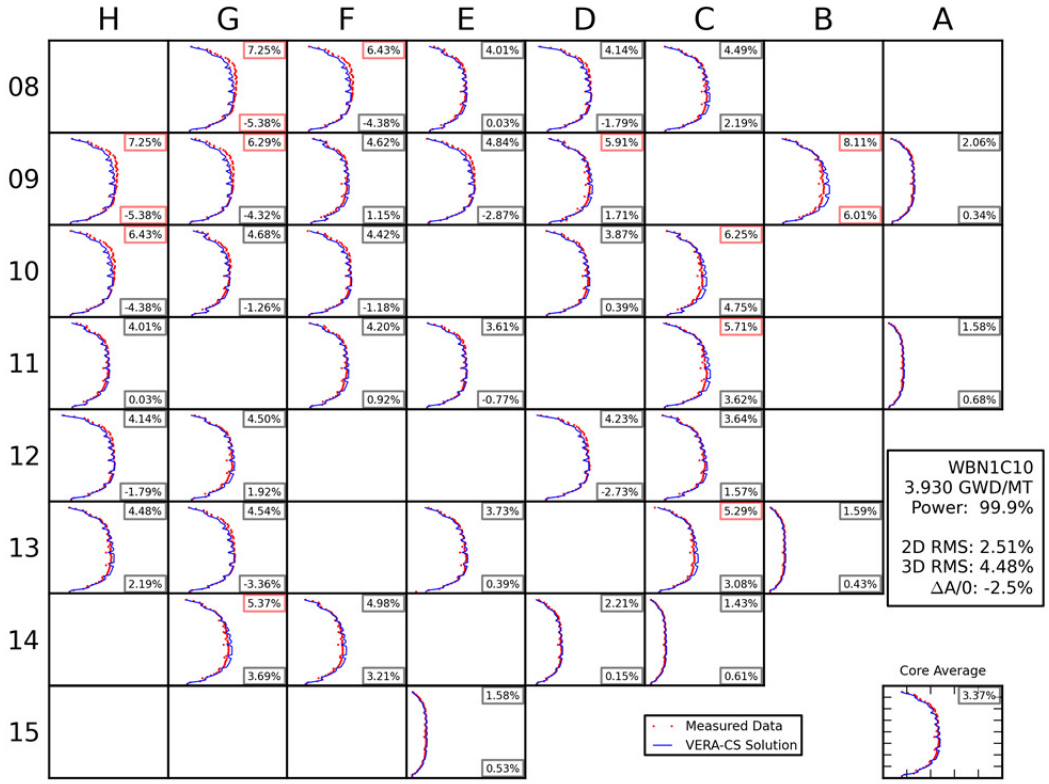

H G F E D C B A
08
3.75% 1.79%
3.67% 1.56%
2.84% -0.26%
2.77% 0.44%
6.15% 1.13%
1.53% -0.15%
09
3.71% -0.23%
3.00% -0.85%
3.45% 1.03%
3.80% 2.60%
1.93% 0.77%
10
3.75% 1.79%
4.67% 2.69%
3.80% -0.21%
3.96% -2.13%
3.55% -0.11%
1.86% -0.39%
11
3.68% 1.56%
1.99% -0.60%
2.84% -0.44%
4.33% -2.50%
1.20% -0.56%
12
2.84% -0.26%
2.42% -0.63%
3.80% -3.31%
3.71% 0.47%
2.93% 0.00%
13
2.77% 0.44%
4.20% 1.04%
3.69% -0.40%
3.59% -0.91%
1.32% -0.94%
14
6.15% 1.14%
2.23% 0.39%
2.65% 0.32%
2.99% -2.24%
1.36% -0.78%
15
1.53% -0.15%
2.19% -0.32%
1.79% -0.80%
WBN1C9
18.739 GWD/MT
Power: 99.9%
2D RMS: 1.25%
3D RMS: 3.32%
ΔA/0: -0.7%
Measured Data
VERA-CS Solution
Core Average
2.16%

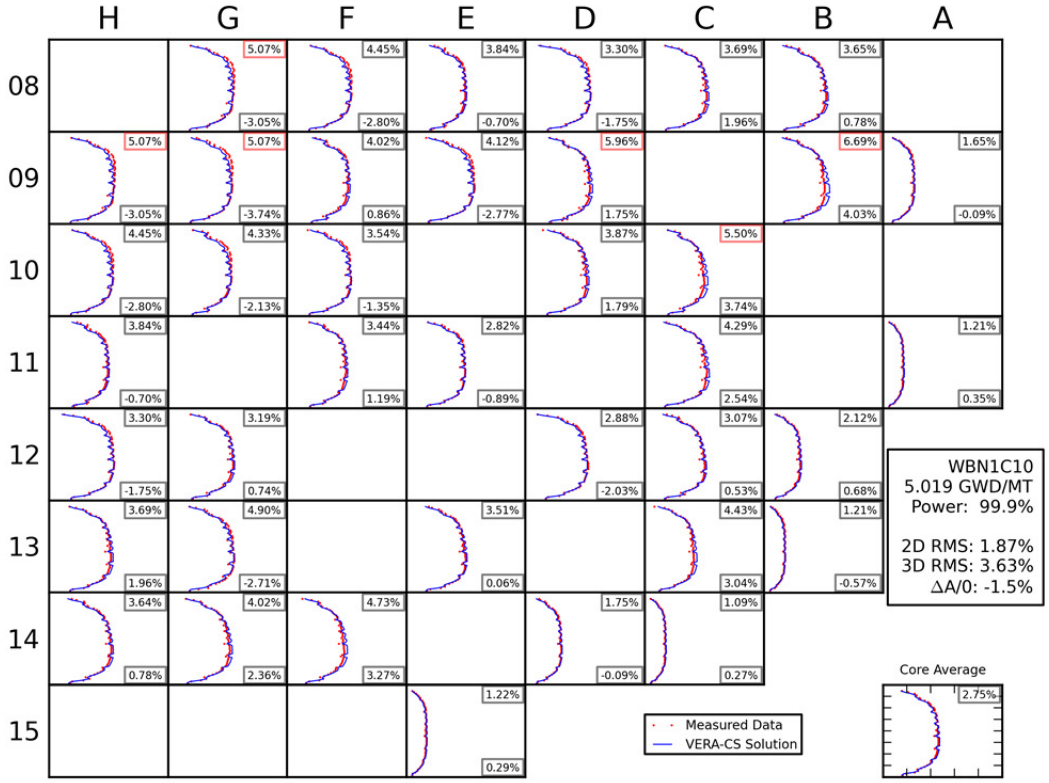

H G F E D C B A
08
8.10% -5.93%
5.60% -3.06%
4.78% -0.13%
4.75% -1.81%
5.23% 2.27%
3.90% 0.75%
09
8.09% -5.93%
6.02% -3.69%
4.61% 0.88%
4.99% -2.42%
6.72% 3.01%
7.27% 5.18%
2.20% 0.14%
10
5.60% -3.06%
4.64% 0.33%
4.85% 0.11%
5.54% 1.27%
5.28% 3.41%
11
4.78% -0.13%
5.24% 1.29%
4.46% -0.96%
5.38% 2.39%
1.68% 0.63%
12
4.75% -1.81%
4.91% 0.60%
4.27% -2.40%
4.19% 0.25%
3.32% 0.52%
13
5.22% 2.27%
5.05% -3.48%
3.41% -0.11%
4.92% 2.55%
2.39% 1.41%
14
3.90% 0.75%
4.57% 2.29%
4.06% 1.49%
2.35% 0.32%
1.56% 0.41%
15
1.67% 0.42%
WBN1C10
0.154 GWD/MT
Power: 100.0%
2D RMS: 2.01%
3D RMS: 4.59%
ΔA/0: -2.9%
Measured Data
VERA-CS Solution
Core Average
3.72%

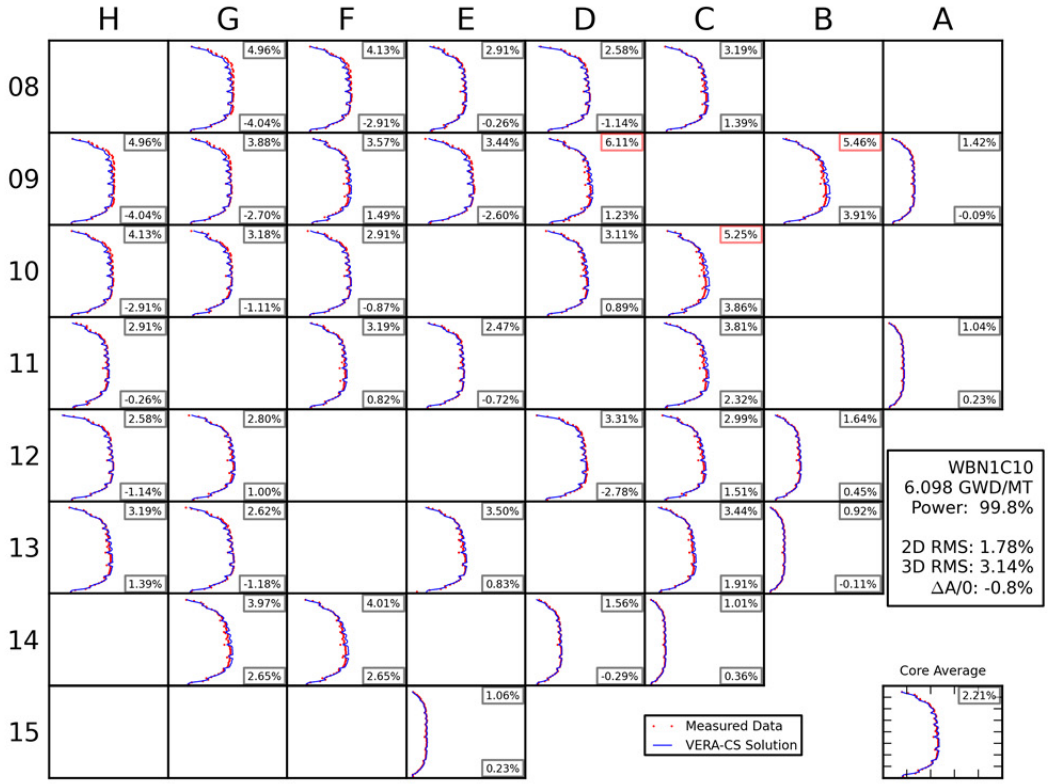

H G F E D C B A
08 09 10 11 12 13 14 15
7.83% -4.46%
6.51% -3.96%
5.43% -0.46%
5.35% -1.80%
5.39% 1.89%
6.00% 1.09%
7.83% -4.46%
6.23% -3.35%
5.03% 1.05%
5.41% -2.01%
5.28% 1.50%
7.39% 4.94%
2.36% 0.09%
6.51% -3.96%
4.86% -0.29%
5.19% -0.31%
5.53% 1.35%
5.56% 3.31%
5.43% -0.46%
5.24% 0.97%
5.10% -0.90%
6.70% 2.99%
1.69% 0.53%
5.35% -1.80%
5.37% 0.93%
4.74% -1.94%
4.77% 0.91%
3.44% 0.57%
5.39% 1.89%
4.69% -2.66%
3.69% -0.14%
5.62% 2.08%
1.83% 0.59%
5.99% 1.08%
5.21% 2.42%
3.90% 1.45%
2.63% 0.48%
1.58% 0.23%
1.89% 0.63%
WBN1C10
0.725 GWD/MT
Power: 99.8%
2D RMS: 1.92%
3D RMS: 5.06%
ΔA/0: -3.3%
Measured Data
VERA-CS Solution
Core Average
4.10%

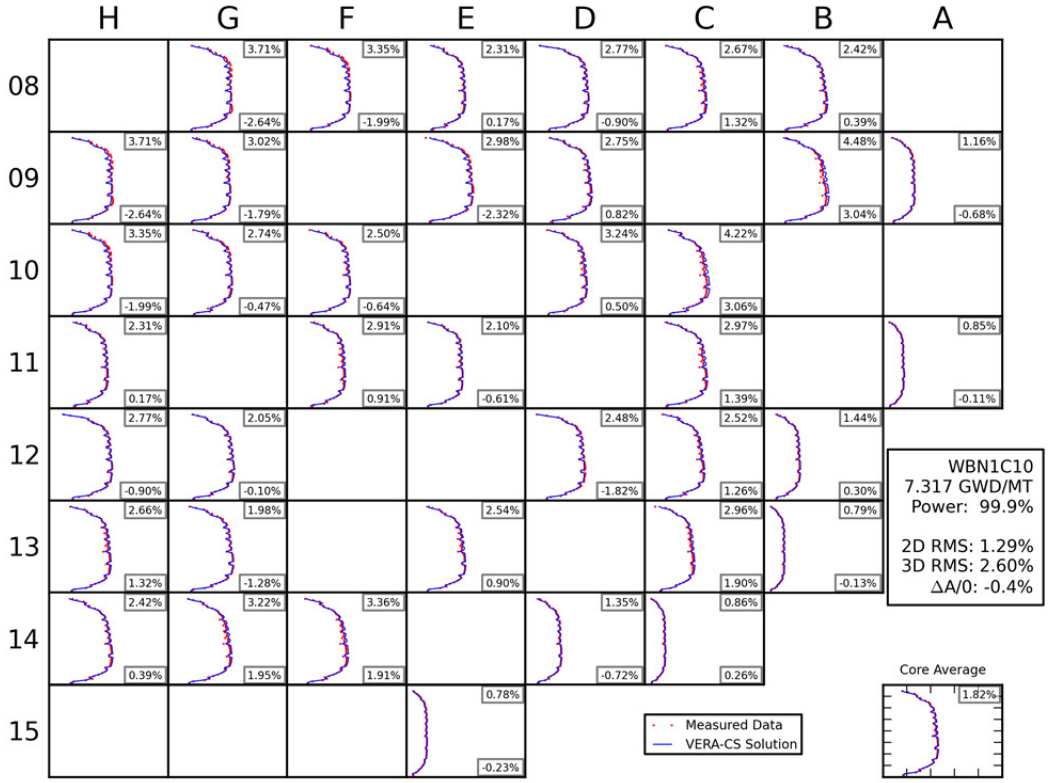

H G F E D C B A
08 09 10 11 12 13 14 15
7.42% -4.40%
5.58% -0.32%
5.67% -2.23%
5.29% 1.61%
7.50% -4.58%
5.28% 0.54%
5.88% -2.89%
6.25% 1.72%
8.34% 5.63%
2.54% -0.29%
7.42% -4.40%
5.47% -1.40%
5.36% -0.30%
5.48% 1.33%
6.19% 3.91%
5.58% -0.32%
5.37% 0.24%
4.74% -0.55%
7.11% 3.56%
1.88% 0.64%
5.67% -2.24%
5.46% 0.66%
4.64% -2.36%
3.73% 0.23%
3.53% 0.76%
5.29% 1.60%
6.01% -3.56%
3.68% 0.29%
5.79% 1.70%
1.91% 0.55%
5.32% 2.58%
3.90% 1.13%
3.33% 0.19%
1.68% 0.43%
2.12% 0.54%
WBN1C10
1.811 GWD/MT
Power: 99.9%
2D RMS: 2.01%
3D RMS: 5.09%
ΔA/0: -3.4%
Measured Data
VERA-CS Solution
Core Average
4.21%

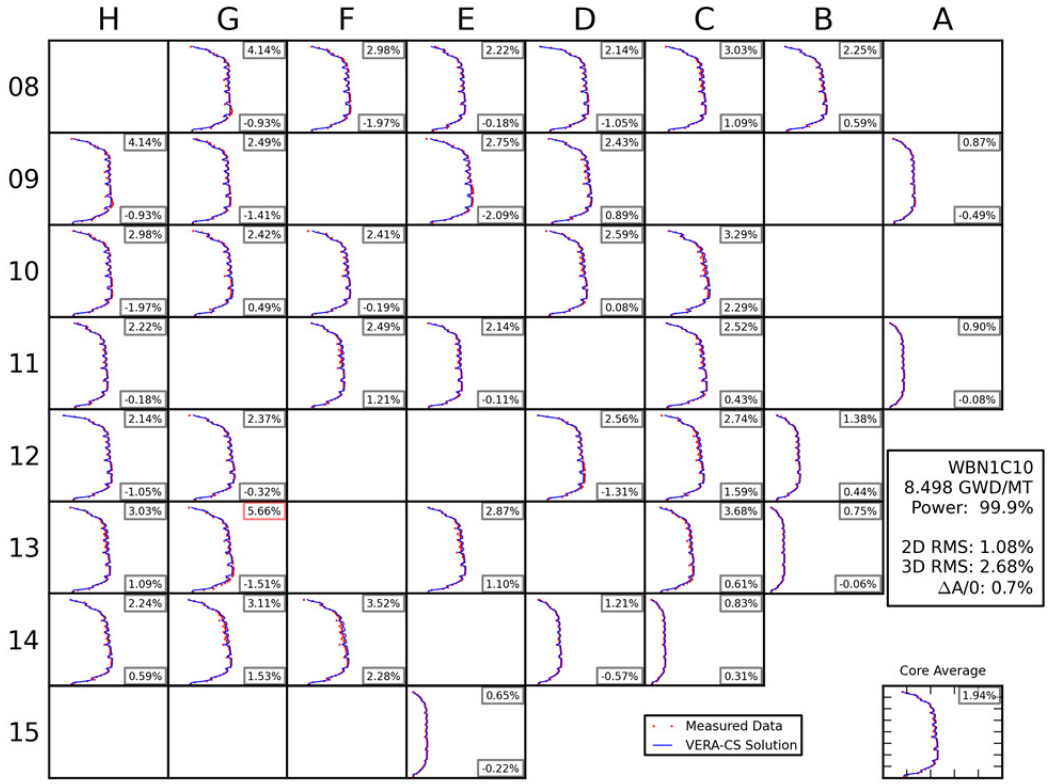

H G F E D C B A
08 09 10 11 12 13 14 15
9.62% -7.55%
6.82% -4.64%
4.78% -0.57%
4.90% -1.60%
5.07% 1.82%
6.14% 2.04%
7.06% -4.14%
5.18% 0.78%
6.03% -2.98%
5.81% 2.19%
8.84% 6.51%
2.50% 0.06%
4.85% -0.66%
4.88% -0.10%
4.90% 1.48%
6.19% 4.31%
4.93% -0.31%
4.63% -0.79%
6.93% 3.45%
1.78% 0.73%
5.33% 1.69%
4.42% -2.36%
4.63% 1.79%
3.35% 0.60%
4.96% -3.13%
4.12% 0.14%
6.59% 3.12%
1.88% 0.66%
5.77% 3.42%
5.29% 2.76%
3.04% 0.22%
1.66% 0.64%
2.19% 0.93%
WBN1C10
2.897 GWD/MT
Power: 98.4%
2D RMS: 2.55%
3D RMS: 5.18%
ΔA/0: -3.3%
Core Average
4.07%
Measured Data
VERA-CS Solution

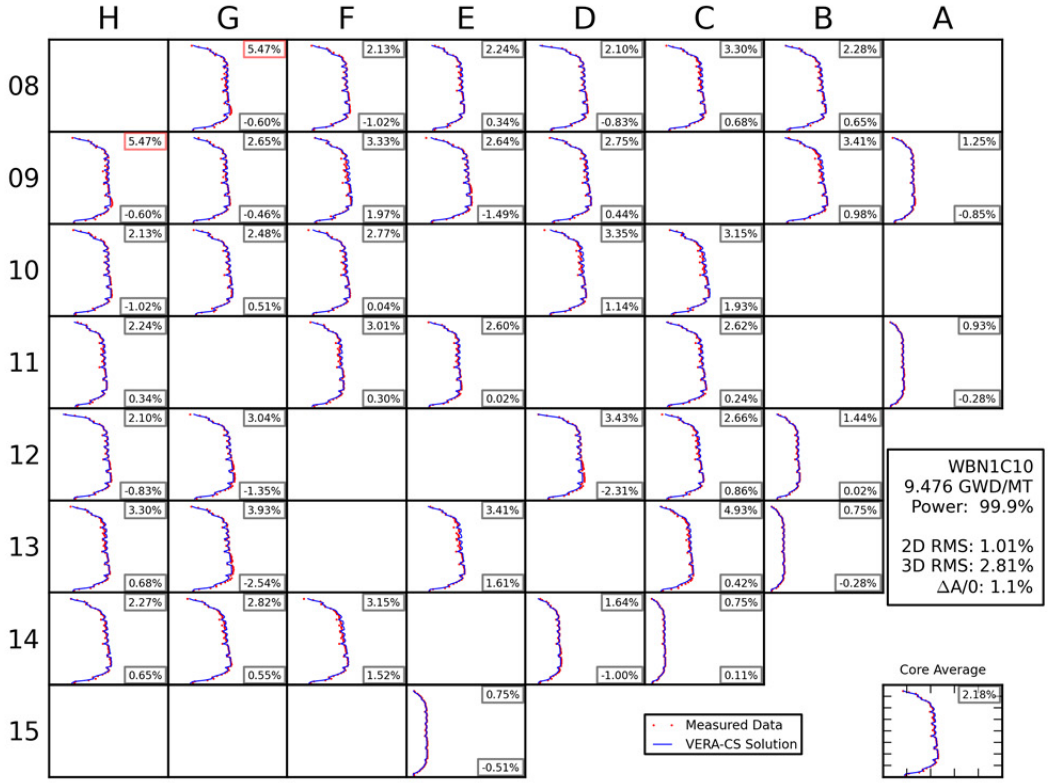

H G F E D C B A
08 09 10 11 12 13 14 15
7.25% -5.38%
6.43% -4.38%
4.01% 0.03%
4.14% -1.79%
4.48% 2.19%
6.29% -4.32%
4.62% 1.15%
4.84% -2.87%
5.91% 1.71%
8.11% 6.01%
2.06% 0.34%
4.68% -1.26%
4.42% -1.18%
3.87% 0.39%
6.25% 4.75%
4.20% 0.92%
3.61% -0.77%
5.71% 3.62%
1.58% 0.68%
4.50% 1.92%
4.23% -2.73%
3.64% 1.57%
4.54% -3.36%
3.73% 0.39%
5.29% 3.08%
1.59% 0.43%
5.37% 3.69%
4.98% 3.21%
2.21% 0.15%
1.43% 0.61%
1.58% 0.53%
WBN1C10
3.930 GWD/MT
Power: 99.9%
2D RMS: 2.51%
3D RMS: 4.48%
ΔA/0: -2.5%
Core Average
3.37%
Measured Data
VERA-CS Solution

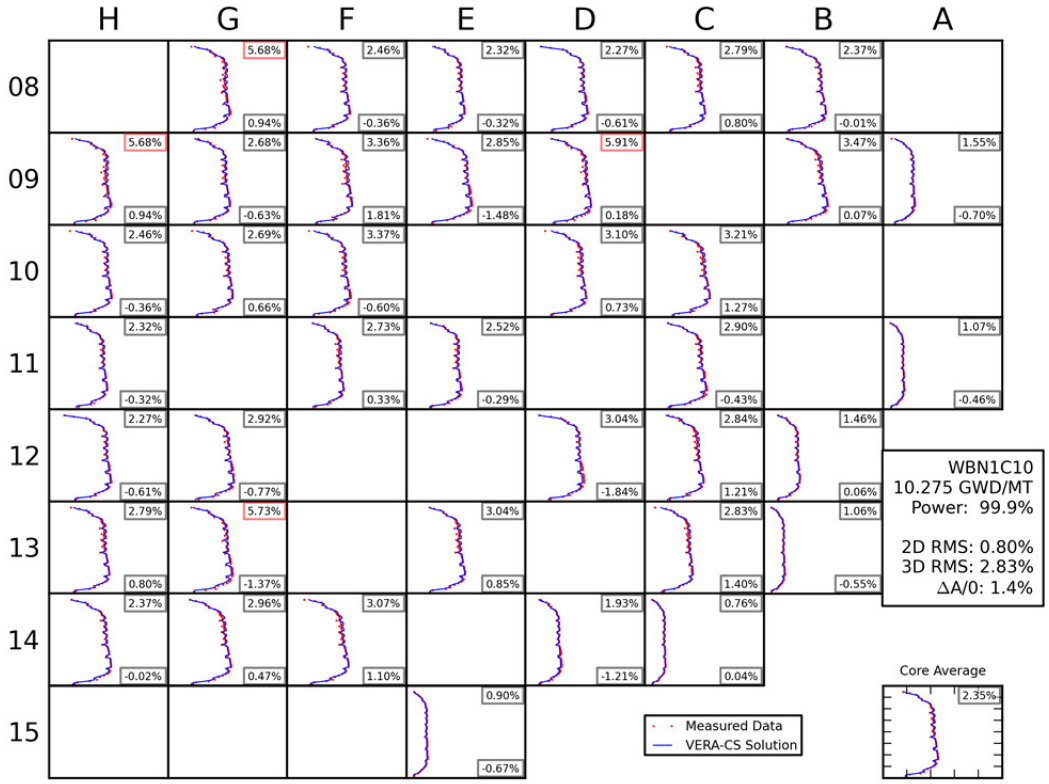

H G F E D C B A
08 09 10 11 12 13 14 15
5.07% -3.05%
5.07% -3.74%
4.45% -2.80%
4.02% 0.86%
3.84% -0.70%
4.12% -2.77%
3.30% -1.75%
5.96% 1.75%
3.69% 1.96%
6.69% 4.03%
3.65% 0.78%
1.65% -0.09%
4.45% -2.80%
4.33% -2.13%
3.54% -1.35%
3.87% 1.79%
5.50% 3.74%
3.84% -0.70%
3.44% 1.19%
2.82% -0.89%
4.29% 2.54%
1.21% 0.35%
3.30% -1.75%
3.19% 0.74%
2.88% -2.03%
3.07% 0.53%
2.12% 0.68%
3.69% 1.96%
4.90% -2.71%
3.51% 0.06%
4.43% 3.04%
1.21% -0.57%
3.64% 0.78%
4.02% 2.36%
4.73% 3.27%
1.75% -0.09%
1.09% 0.27%
1.22% 0.29%
WBN1C10
5.019 GWD/MT
Power: 99.9%
2D RMS: 1.87%
3D RMS: 3.63%
ΔA/0: -1.5%
Core Average
2.75%
Measured Data
VERA-CS Solution

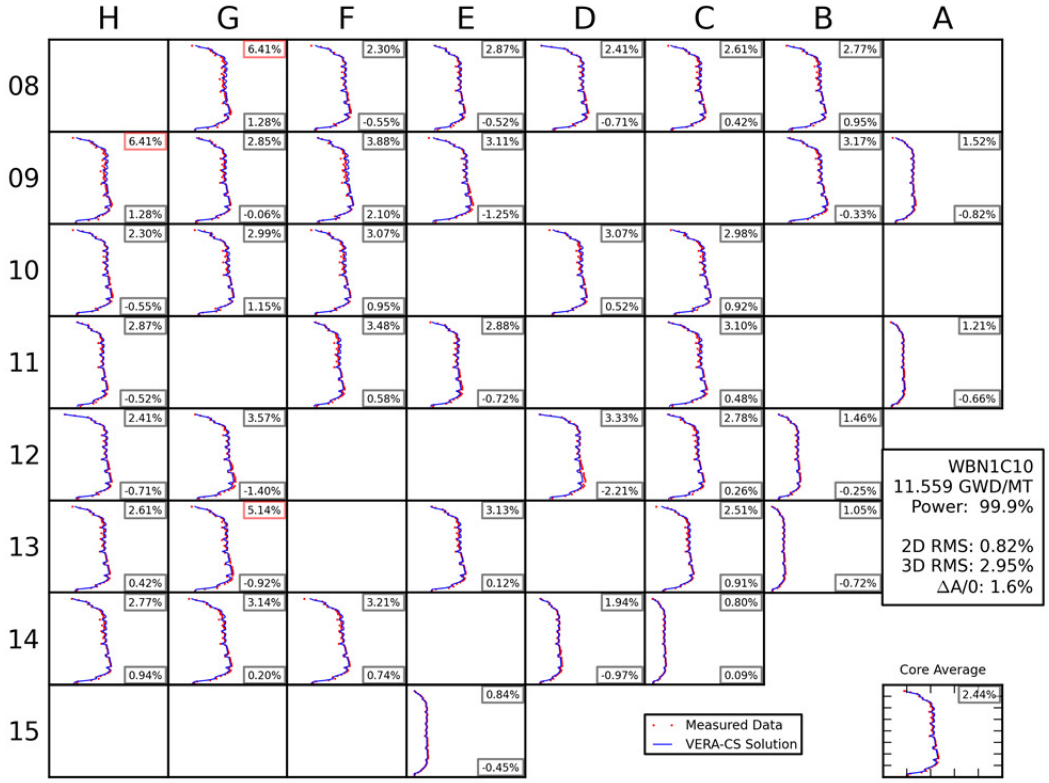

H G F E D C B A
08 09 10 11 12 13 14 15
4.96% -4.04%
4.13% -2.91%
2.91% -0.26%
2.58% -1.14%
3.19% 1.39%
4.96% -4.04%
3.88% -2.70%
3.57% 1.49%
3.44% -2.60%
6.11% 1.23%
5.46% 3.91%
1.42% -0.09%
4.13% -2.91%
3.18% -1.11%
2.91% -0.87%
3.11% 0.89%
5.25% 3.86%
2.91% -0.26%
3.19% 0.82%
2.47% -0.72%
3.81% 2.32%
1.04% 0.23%
2.58% -1.14%
2.80% 1.00%
3.31% -2.78%
2.99% 1.51%
1.64% 0.45%
3.19% 1.39%
2.62% -1.18%
3.50% 0.83%
3.44% 1.91%
0.92% -0.11%
3.97% 2.65%
4.01% 2.65%
1.56% -0.29%
1.01% 0.36%
1.06% 0.23%
WBN1C10
6.098 GWD/MT
Power: 99.8%
2D RMS: 1.78%
3D RMS: 3.14%
ΔA/0: -0.8%
Core Average
2.21%
Measured Data
VERA-CS Solution

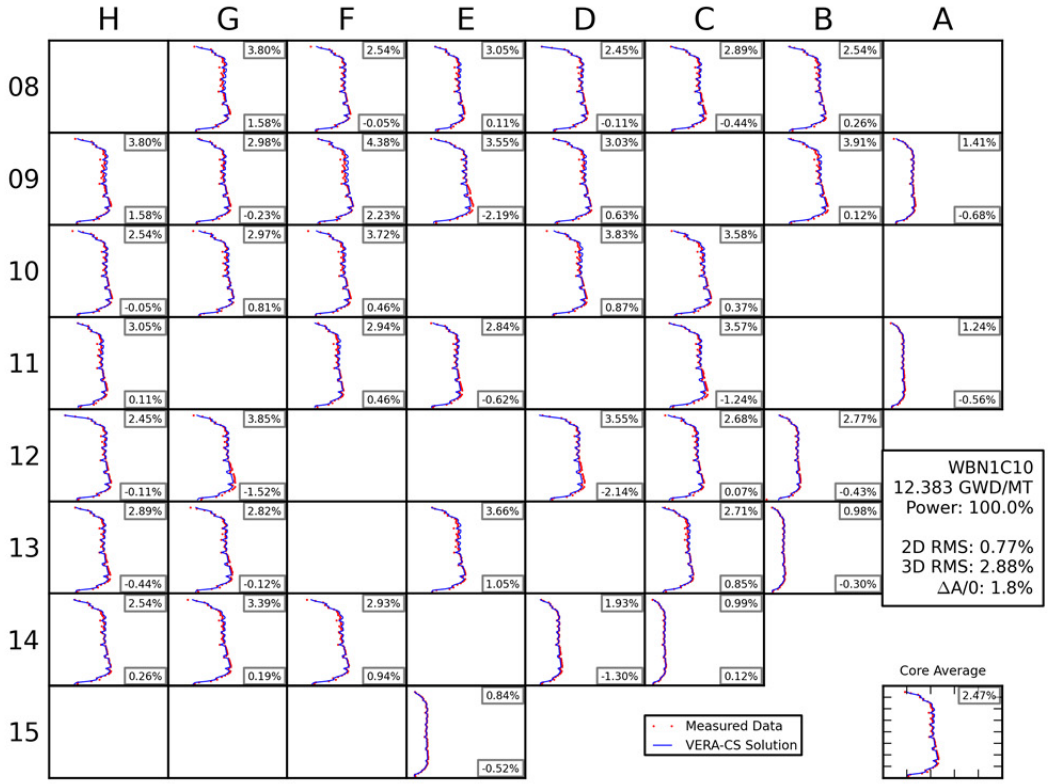

H G F E D C B A
08
3.71% -2.64%
3.35% -1.99%
2.31% 0.17%
2.77% -0.90%
2.67% 1.32%
2.42% 0.39%
09
3.71% -2.64%
3.02% -1.79%
2.98% -2.32%
2.75% 0.82%
4.48% 3.04%
1.16% -0.68%
10
3.35% -1.99%
2.74% -0.47%
2.50% -0.64%
3.24% 0.50%
4.22% 3.06%
11
2.31% 0.17%
2.91% 0.91%
2.10% -0.61%
2.97% 1.39%
0.85% -0.11%
12
2.77% -0.90%
2.05% -0.10%
2.48% -1.82%
2.52% 1.26%
1.44% 0.30%
13
2.66% 1.32%
1.98% -1.28%
2.54% 0.90%
2.96% 1.90%
0.79% -0.13%
14
2.42% 0.39%
3.22% 1.95%
3.36% 1.91%
1.35% -0.72%
0.86% 0.26%
15
0.78% -0.23%
WBN1C10
7.317 GWD/MT
Power: 99.9%
2D RMS: 1.29%
3D RMS: 2.60%
ΔA/0: -0.4%
Measured Data
VERA-CS Solution
Core Average
1.82%

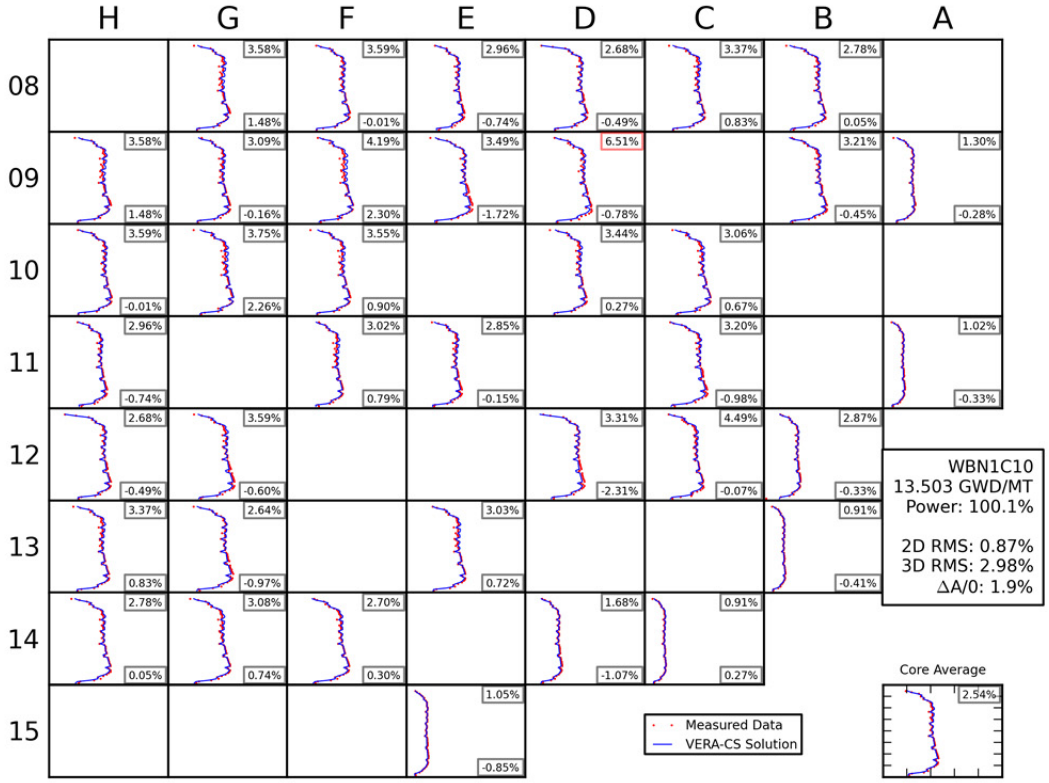

H G F E D C B A
08
4.14% -0.93%
2.98% -1.97%
2.22% -0.18%
2.14% -1.05%
3.03% 1.09%
2.25% 0.59%
09
4.14% -0.93%
2.49% -1.41%
2.75% -2.09%
2.43% 0.89%
0.87% -0.49%
10
2.98% -1.97%
2.42% 0.49%
2.41% -0.19%
2.59% 0.08%
3.29% 2.29%
11
2.22% -0.18%
2.49% 1.21%
2.14% -0.11%
2.52% 0.43%
0.90% -0.08%
12
2.14% -1.05%
2.37% -0.32%
2.56% -1.31%
2.74% 1.59%
1.38% 0.44%
13
3.03% 1.09%
5.66% -1.51%
2.87% 1.10%
3.68% 0.61%
0.75% -0.06%
14
2.24% 0.59%
3.11% 1.53%
3.52% 2.28%
1.21% -0.57%
0.83% 0.31%
15
0.65% -0.22%
WBN1C10
8.498 GWD/MT
Power: 99.9%
2D RMS: 1.08%
3D RMS: 2.68%
ΔA/0: 0.7%
Measured Data
VERA-CS Solution
Core Average
1.94%

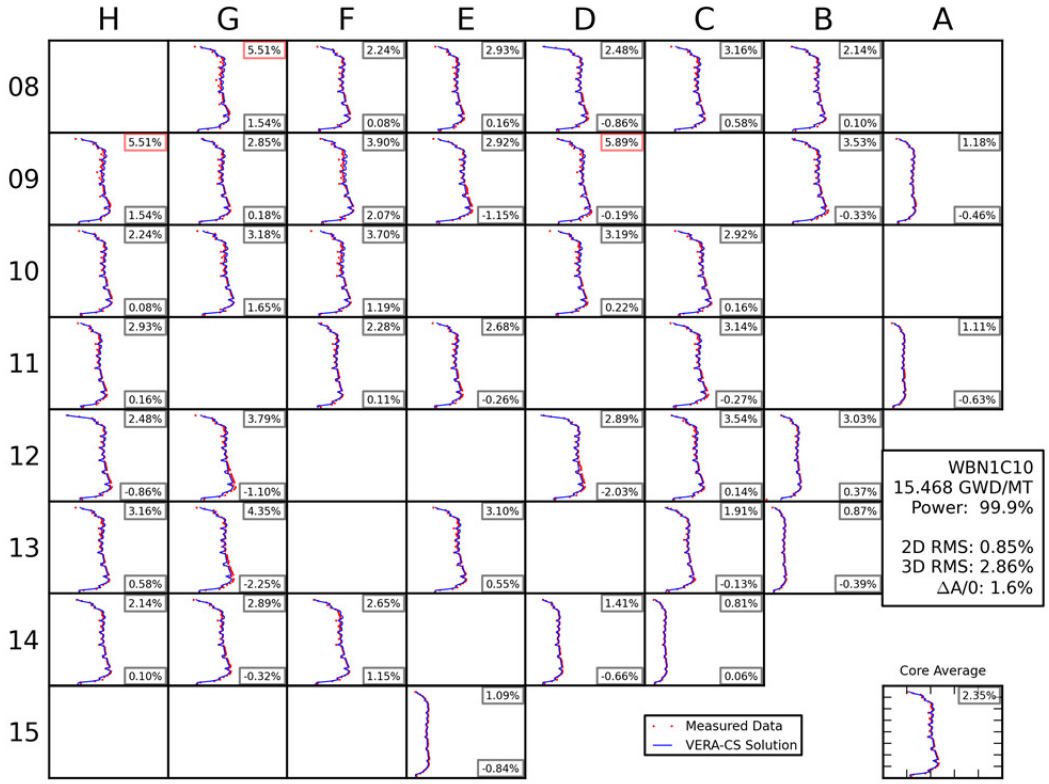

H G F E D C B A
08
09
10
11
12
13
14
15
WBN1C10
9.476 GWD/MT
Power: 99.9%
2D RMS: 1.01%
3D RMS: 2.81%
ΔA/0: 1.1%
Core Average
Measured Data
VERA-CS Solution

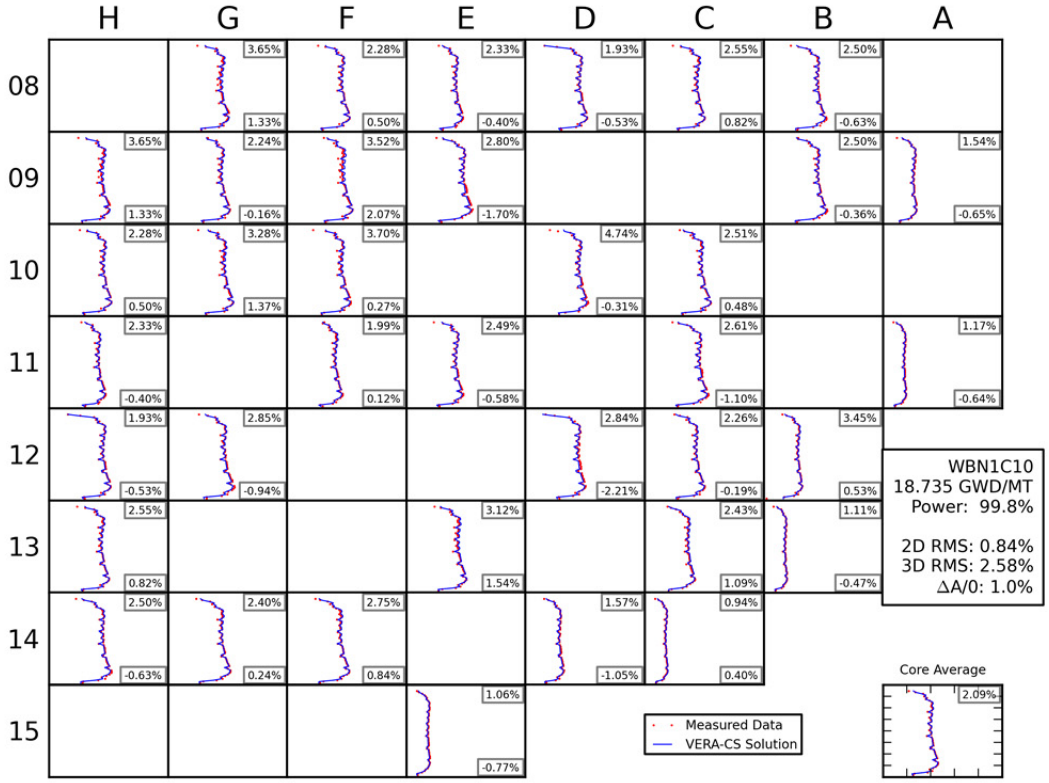

H G F E D C B A
08
09
10
11
12
13
14
15
WBN1C10
10.275 GWD/MT
Power: 99.9%
2D RMS: 0.80%
3D RMS: 2.83%
ΔA/0: 1.4%
Core Average
Measured Data
VERA-CS Solution

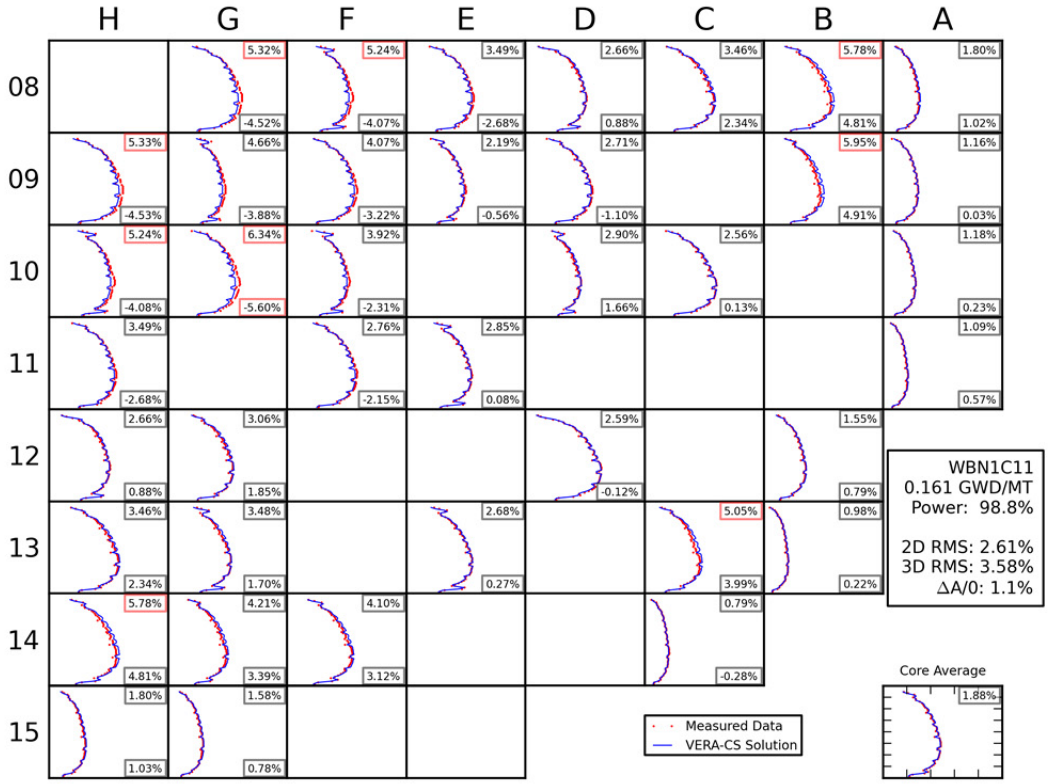

H G F E D C B A
08
6.41% 1.28%
2.30% -0.55%
2.87% -0.52%
2.41% -0.71%
2.61% 0.42%
2.77% 0.95%
09
6.41% 1.28%
2.85% -0.06%
3.88% 2.10%
3.11% -1.25%
3.17% -0.33%
1.52% -0.82%
10
2.30% -0.55%
2.99% 1.15%
3.07% 0.95%
3.07% 0.52%
2.98% 0.92%
11
2.87% -0.52%
3.48% 0.58%
2.88% -0.72%
3.10% 0.48%
1.21% -0.66%
12
2.41% -0.71%
3.57% -1.40%
3.33% -2.21%
2.78% 0.26%
1.46% -0.25%
13
2.61% 0.42%
5.14% -0.92%
3.13% 0.12%
2.51% 0.91%
1.05% -0.72%
14
2.77% 0.94%
3.14% 0.20%
3.21% 0.74%
1.94% -0.97%
0.80% 0.09%
15
0.84% -0.45%
WBN1C10
11.559 GWD/MT
Power: 99.9%
2D RMS: 0.82%
3D RMS: 2.95%
ΔA/0: 1.6%
Core Average
2.44%
Measured Data
VERA-CS Solution

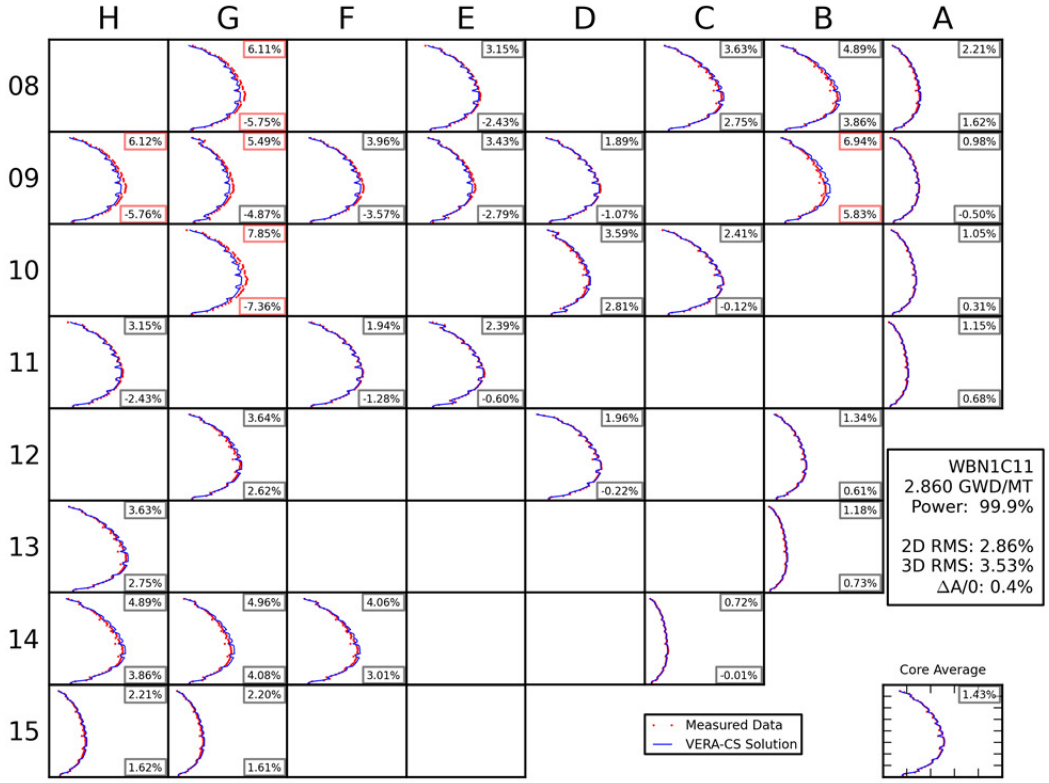

H G F E D C B A
08
3.80% 1.58%
2.54% -0.05%
3.05% 0.11%
2.45% -0.11%
2.89% -0.44%
2.54% 0.26%
09
3.80% 1.58%
2.98% -0.23%
4.38% 2.23%
3.55% -2.19%
3.03% 0.63%
3.91% 0.12%
1.41% -0.68%
10
2.54% -0.05%
2.97% 0.81%
3.72% 0.46%
3.83% 0.87%
3.58% 0.37%
11
3.05% 0.11%
2.94% 0.46%
2.84% -0.62%
3.57% -1.24%
1.24% -0.56%
12
2.45% -0.11%
3.85% -1.52%
3.55% -2.14%
2.68% 0.07%
2.77% -0.43%
13
2.89% -0.44%
2.82% -0.12%
3.66% 1.05%
2.71% 0.85%
0.98% -0.30%
14
2.54% 0.26%
3.39% 0.19%
2.93% 0.94%
1.93% -1.30%
0.99% 0.12%
15
0.84% -0.52%
WBN1C10
12.383 GWD/MT
Power: 100.0%
2D RMS: 0.77%
3D RMS: 2.88%
ΔA/0: 1.8%
Core Average
2.47%
Measured Data
VERA-CS Solution

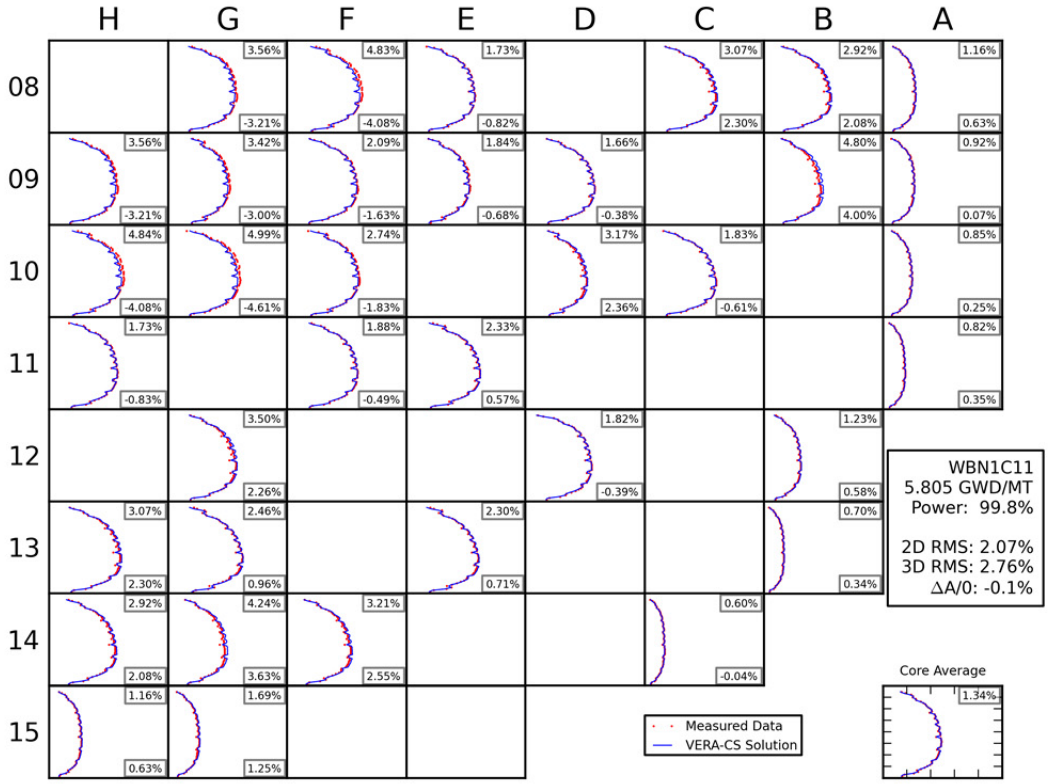

H G F E D C B A
08
3.58% 1.48%
3.59% -0.01%
2.96% -0.74%
2.68% -0.49%
3.37% 0.83%
2.78% 0.05%
09
3.58% 1.48%
3.09% -0.16%
4.19% 2.30%
3.49% -1.72%
6.51% -0.78%
3.21% -0.45%
1.30% -0.28%
10
3.59% -0.01%
3.75% 2.26%
3.55% 0.90%
3.44% 0.27%
3.06% 0.67%
11
2.96% -0.74%
3.02% 0.79%
2.85% -0.15%
3.20% -0.98%
1.02% -0.33%
12
2.68% -0.49%
3.59% -0.60%
3.31% -2.31%
4.49% -0.07%
2.87% -0.33%
13
3.37% 0.83%
2.64% -0.97%
3.03% 0.72%
0.91% -0.41%
14
2.78% 0.05%
3.08% 0.74%
2.70% 0.30%
1.68% -1.07%
0.91% 0.27%
15
1.05% -0.85%
WBN1C10
13.503 GWD/MT
Power: 100.1%
2D RMS: 0.87%
3D RMS: 2.98%
ΔA/0: 1.9%
Measured Data
VERA-CS Solution
Core Average
2.54%

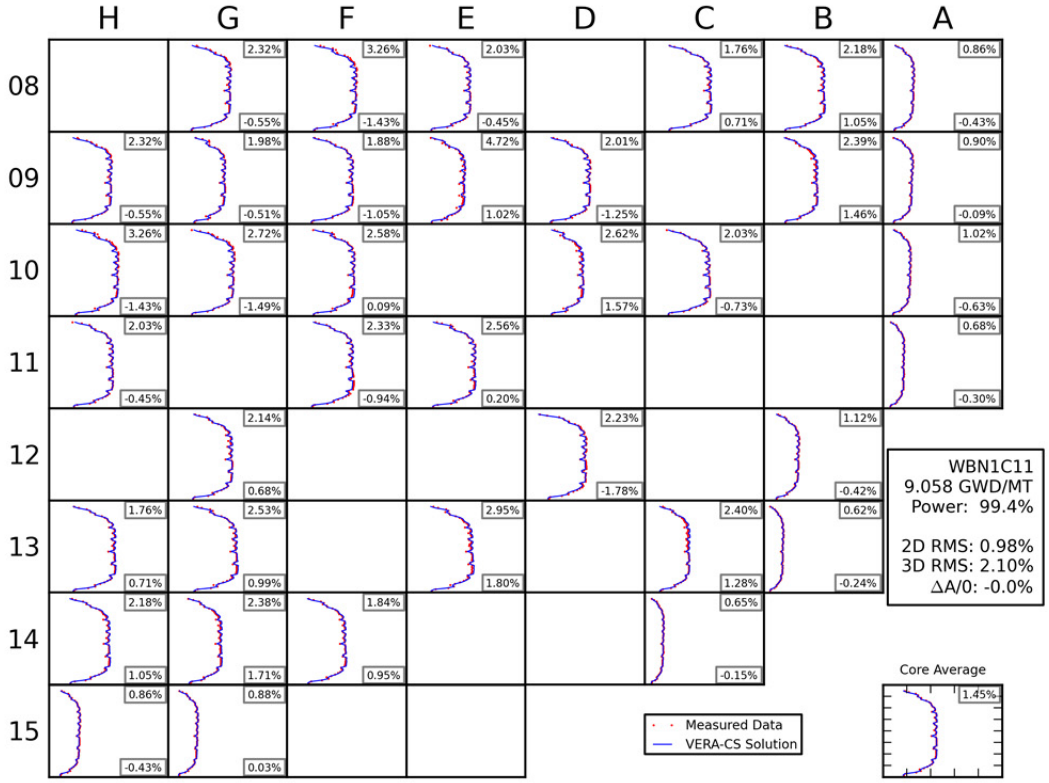

H G F E D C B A
08
5.51% 1.54%
2.24% 0.08%
2.93% 0.16%
2.48% -0.86%
3.16% 0.58%
2.14% 0.10%
09
5.51% 1.54%
2.85% 0.18%
3.90% 2.07%
2.92% -1.15%
5.89% -0.19%
3.53% -0.33%
1.18% -0.46%
10
2.24% 0.08%
3.18% 1.65%
3.70% 1.19%
3.19% 0.22%
2.92% 0.16%
11
2.93% 0.16%
2.28% 0.11%
2.68% -0.26%
3.14% -0.27%
1.11% -0.63%
12
2.48% -0.86%
3.79% -1.10%
2.89% -2.03%
3.54% 0.14%
3.03% 0.37%
13
3.16% 0.58%
4.35% -2.25%
3.10% 0.55%
1.91% -0.13%
0.87% -0.39%
14
2.14% 0.10%
2.89% -0.32%
2.65% 1.15%
1.41% -0.66%
0.81% 0.06%
15
1.09% -0.84%
WBN1C10
15.468 GWD/MT
Power: 99.9%
2D RMS: 0.85%
3D RMS: 2.86%
ΔA/0: 1.6%
Measured Data
VERA-CS Solution
Core Average
2.35%

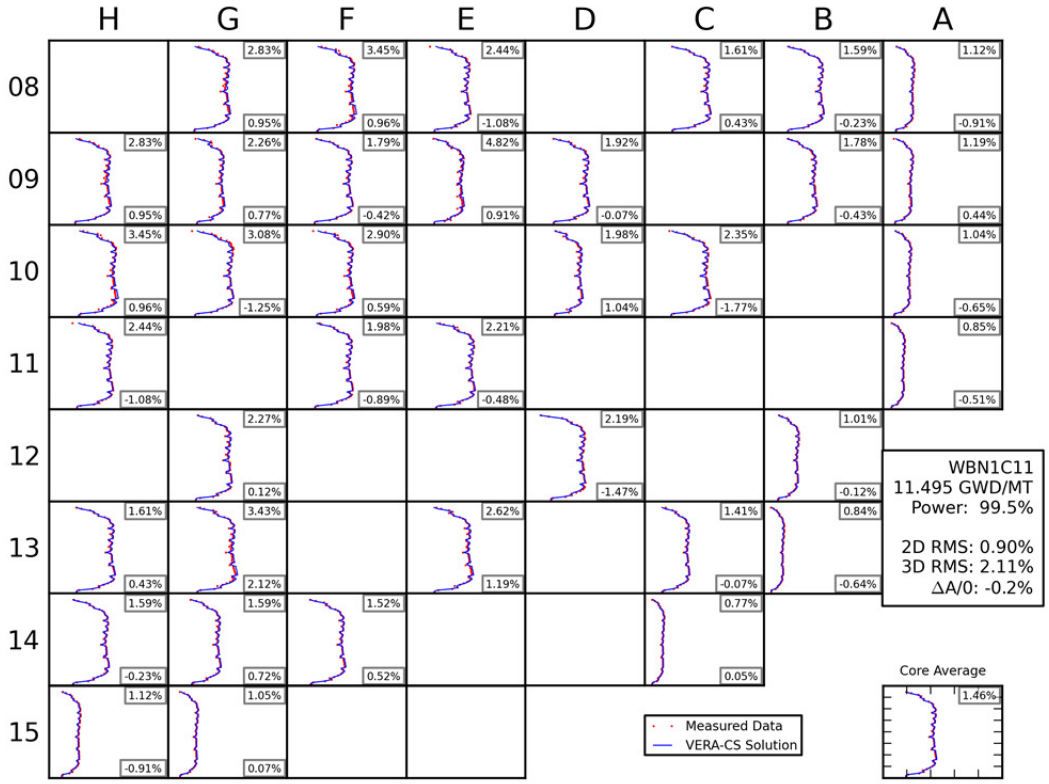

H G F E D C B A
08
09
10
11
12
13
14
15
WBN1C10
18.735 GWD/MT
Power: 99.8%
2D RMS: 0.84%
3D RMS: 2.58%
ΔA/0: 1.0%
Core Average
Measured Data
VERA-CS Solution

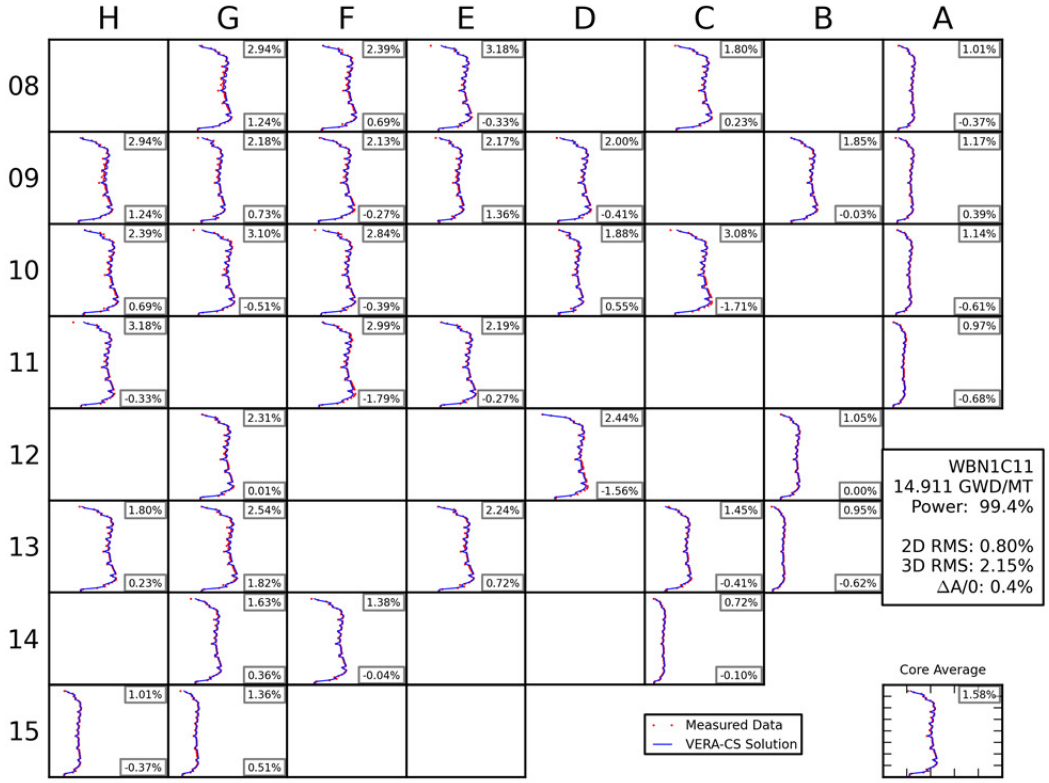

H G F E D C B A
08
09
10
11
12
13
14
15
WBN1C11
0.161 GWD/MT
Power: 98.8%
2D RMS: 2.61%
3D RMS: 3.58%
ΔA/0: 1.1%
Core Average
Measured Data
VERA-CS Solution

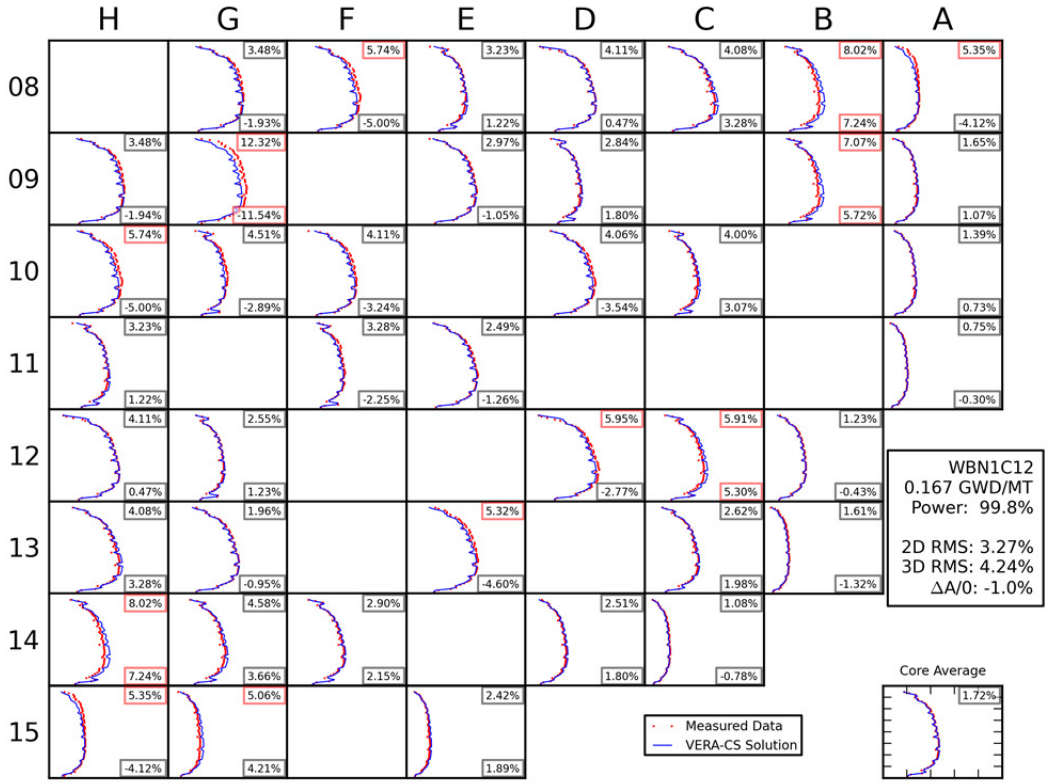

H G F E D C B A
08
09
10
11
12
13
14
15
WBN1C11
2.860 GWD/MT
Power: 99.9%
2D RMS: 2.86%
3D RMS: 3.53%
ΔA/0: 0.4%
Core Average
Measured Data
VERA-CS Solution

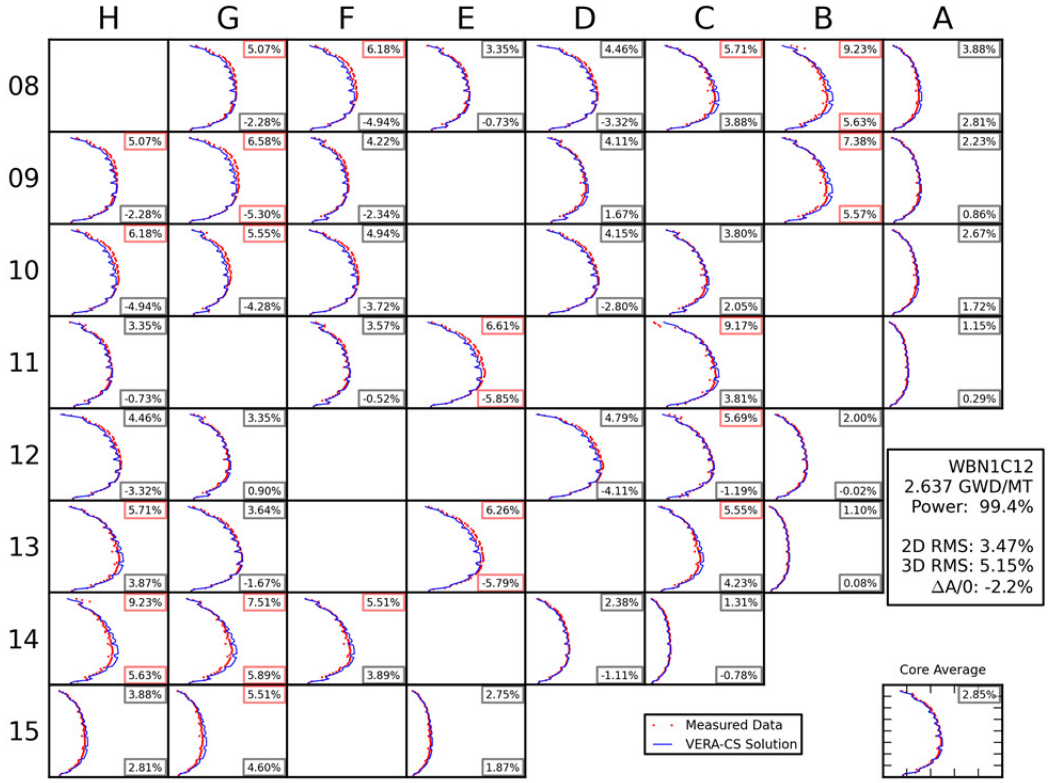

H G F E D C B A
08
09
10
11
12
13
14
15
WBN1C11
5.805 GWD/MT
Power: 99.8%
2D RMS: 2.07%
3D RMS: 2.76%
ΔA/0: -0.1%
Core Average
Measured Data
VERA-CS Solution

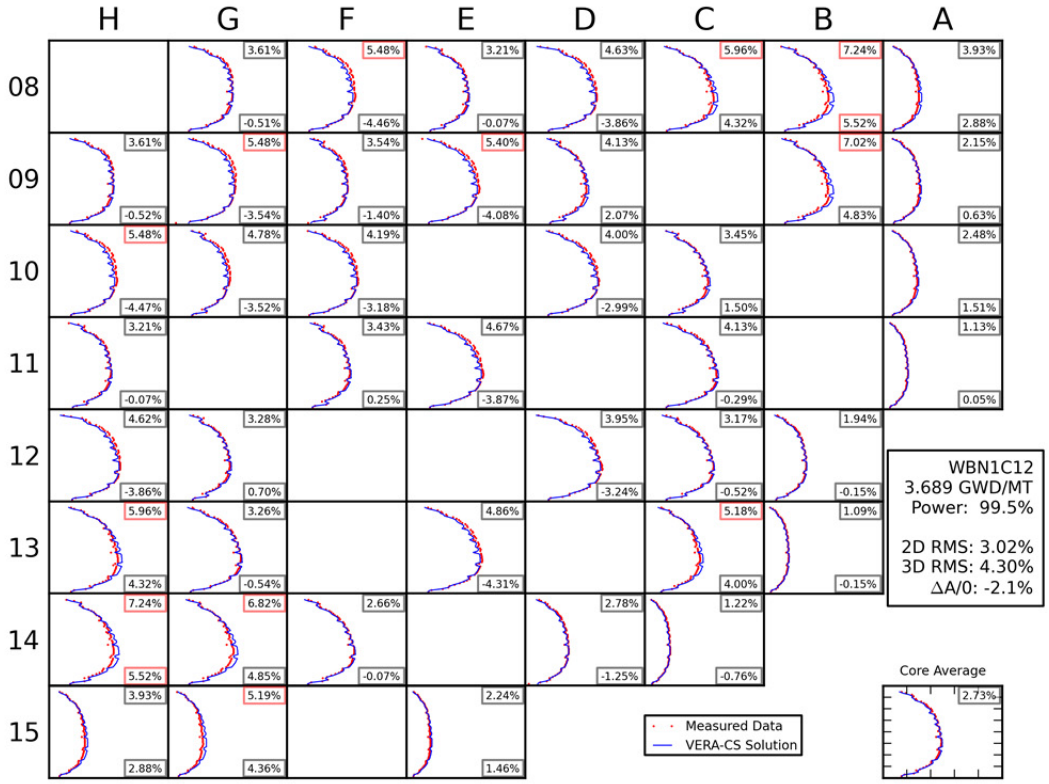

H G F E D C B A
08
2.32% -0.55%
3.26% -1.43%
2.03% -0.45%
1.76% 0.71%
2.18% 1.05%
0.86% -0.43%
09
2.32% -0.55%
1.98% -0.51%
1.88% -1.05%
4.72% 1.02%
2.01% -1.25%
2.39% 1.46%
0.90% -0.09%
10
3.26% -1.43%
2.72% -1.49%
2.58% 0.09%
2.62% 1.57%
2.03% -0.73%
1.02% -0.63%
11
2.03% -0.45%
2.33% -0.94%
2.56% 0.20%
0.68% -0.30%
12
2.14% 0.68%
2.23% -1.78%
1.12% -0.42%
13
1.76% 0.71%
2.53% 0.99%
2.95% 1.80%
2.40% 1.28%
0.62% -0.24%
14
2.18% 1.05%
2.38% 1.71%
1.84% 0.95%
0.65% -0.15%
15
0.86% -0.43%
0.88% 0.03%
WBN1C11
9.058 GWD/MT
Power: 99.4%
2D RMS: 0.98%
3D RMS: 2.10%
ΔA/0: -0.0%
Core Average
1.45%
Measured Data
VERA-CS Solution

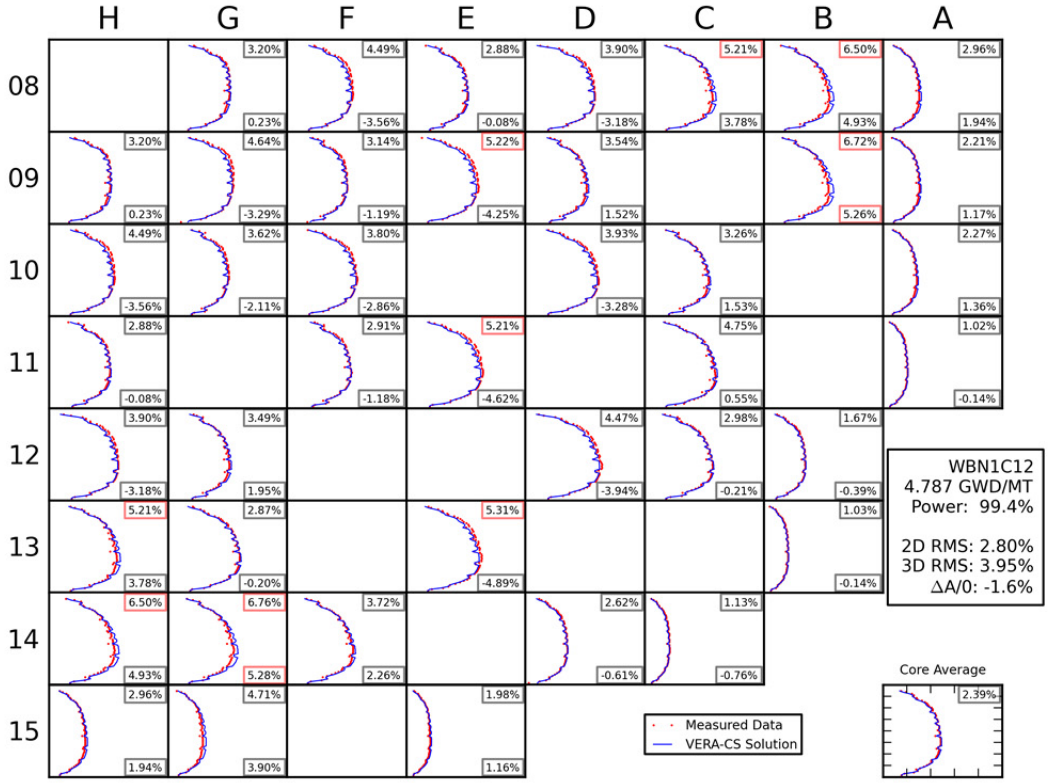

H G F E D C B A
08
2.83% 0.95%
3.45% 0.96%
2.44% -1.08%
1.61% 0.43%
1.59% -0.23%
1.12% -0.91%
09
2.83% 0.95%
2.26% 0.77%
1.79% -0.42%
4.82% 0.91%
1.92% -0.07%
1.78% -0.43%
1.19% 0.44%
10
3.45% 0.96%
3.08% -1.25%
2.90% 0.59%
1.98% 1.04%
2.35% -1.77%
1.04% -0.65%
11
2.44% -1.08%
1.98% -0.89%
2.21% -0.48%
0.85% -0.51%
12
2.27% 0.12%
2.19% -1.47%
1.01% -0.12%
13
1.61% 0.43%
3.43% 2.12%
2.62% 1.19%
1.41% -0.07%
0.84% -0.64%
14
1.59% -0.23%
1.59% 0.72%
1.52% 0.52%
0.77% 0.05%
15
1.12% -0.91%
1.05% 0.07%
WBN1C11
11.495 GWD/MT
Power: 99.5%
2D RMS: 0.90%
3D RMS: 2.11%
ΔA/0: -0.2%
Core Average
1.46%
Measured Data
VERA-CS Solution

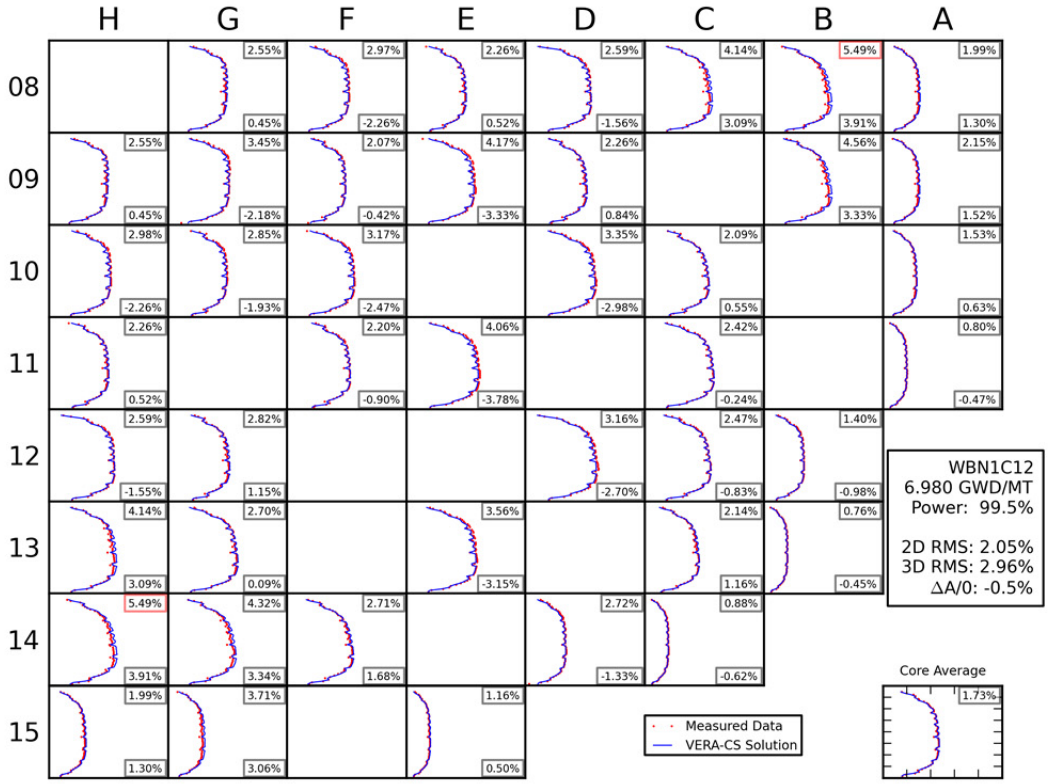

H G F E D C B A
08
09
10
11
12
13
14
15
WBN1C11
14.911 GWD/MT
Power: 99.4%
2D RMS: 0.80%
3D RMS: 2.15%
ΔA/0: 0.4%
Core Average
Measured Data
VERA-CS Solution

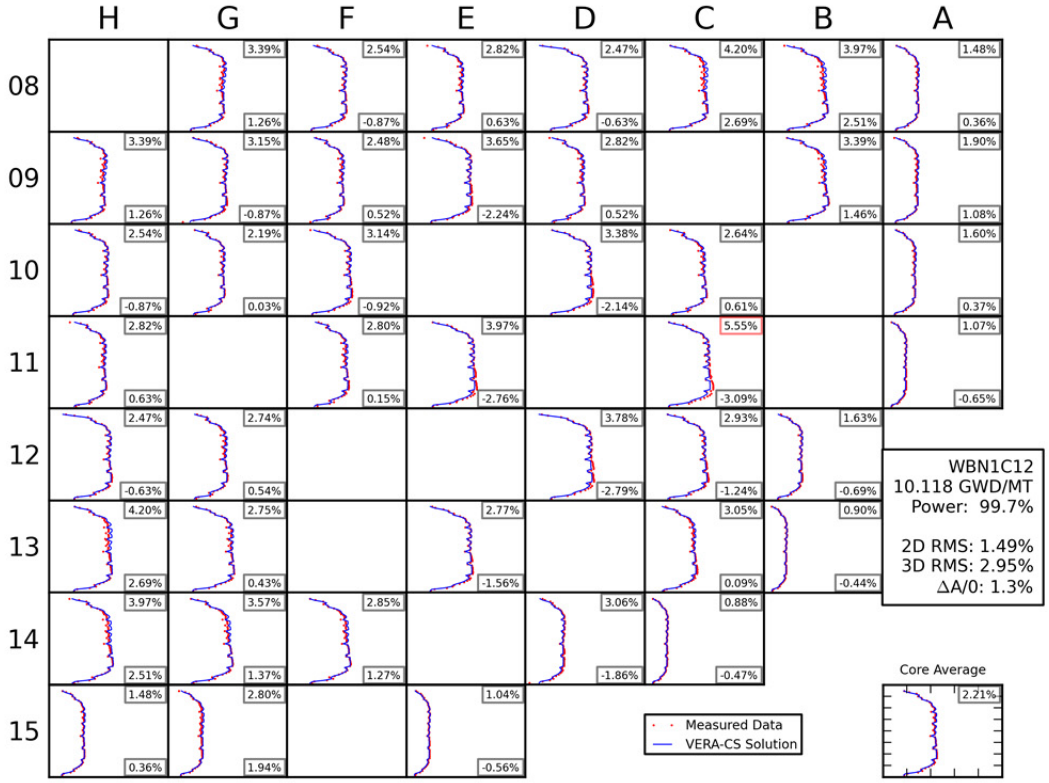

H G F E D C B A
08
09
10
11
12
13
14
15
WBN1C12
0.167 GWD/MT
Power: 99.8%
2D RMS: 3.27%
3D RMS: 4.24%
ΔA/0: -1.0%
Core Average
Measured Data
VERA-CS Solution

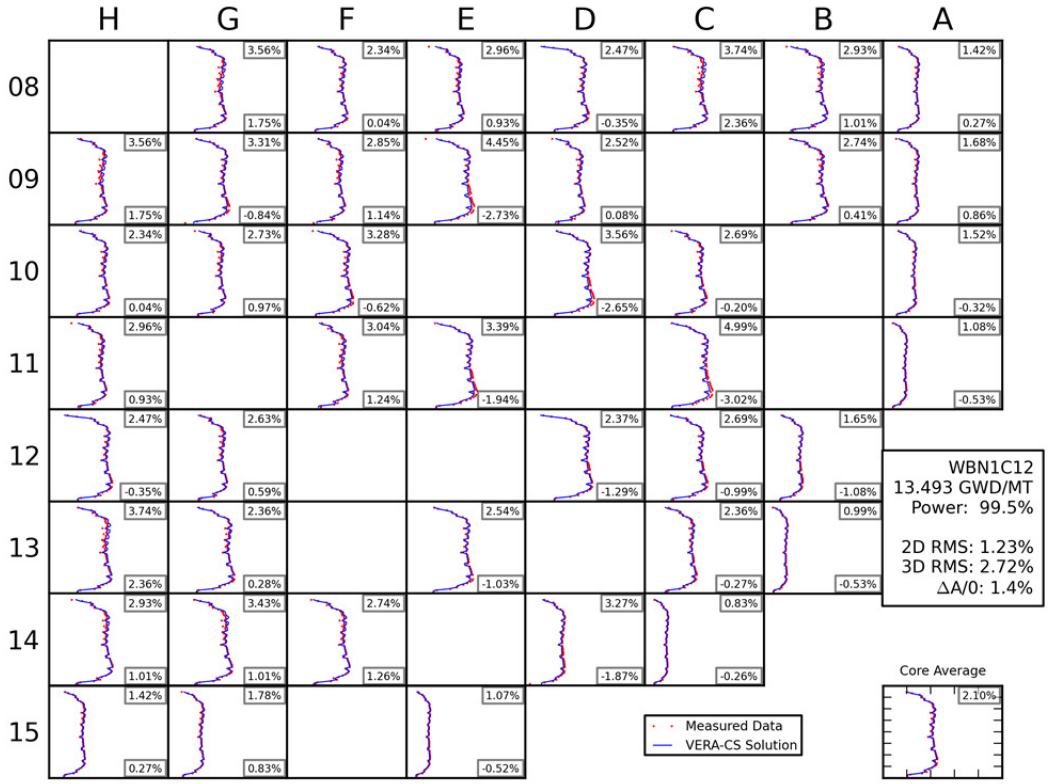

H G F E D C B A
08
09
10
11
12
13
14
15
WBN1C12
2.637 GWD/MT
Power: 99.4%
2D RMS: 3.47%
3D RMS: 5.15%
ΔA/0: -2.2%
Core Average
Measured Data
VERA-CS Solution

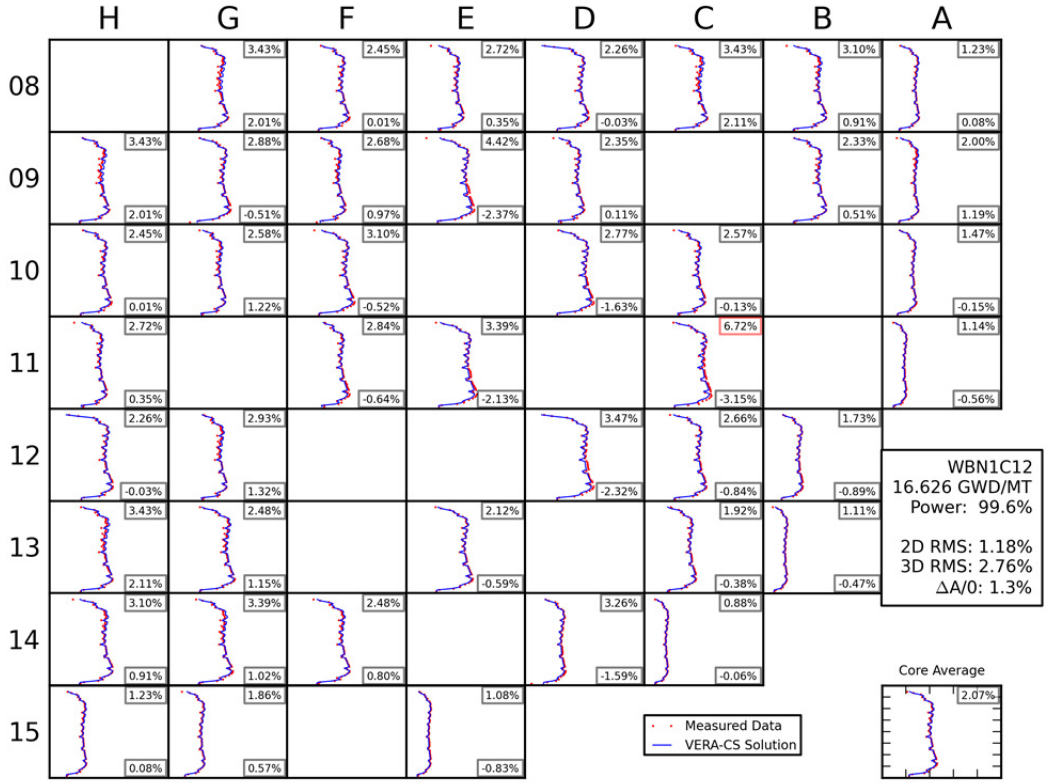

H G F E D C B A
08
09
10
11
12
13
14
15
WBN1C12
3.689 GWD/MT
Power: 99.5%
2D RMS: 3.02%
3D RMS: 4.30%
ΔA/0: -2.1%
Core Average
Measured Data
VERA-CS Solution

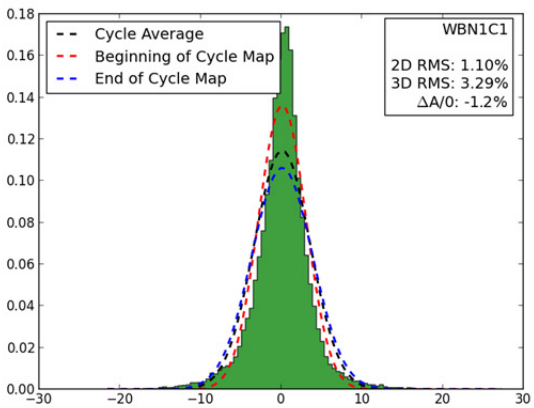

H G F E D C B A
08
09
10
11
12
13
14
15
WBN1C12
4.787 GWD/MT
Power: 99.4%
2D RMS: 2.80%
3D RMS: 3.95%
ΔA/0: -1.6%
Core Average
Measured Data
VERA-CS Solution

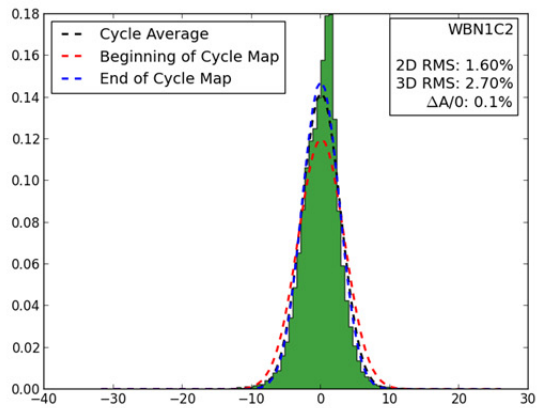

H G F E D C B A
08
09
10
11
12
13
14
15
WBN1C12
6.980 GWD/MT
Power: 99.5%
2D RMS: 2.05%
3D RMS: 2.96%
ΔA/0: -0.5%
Core Average
Measured Data
VERA-CS Solution

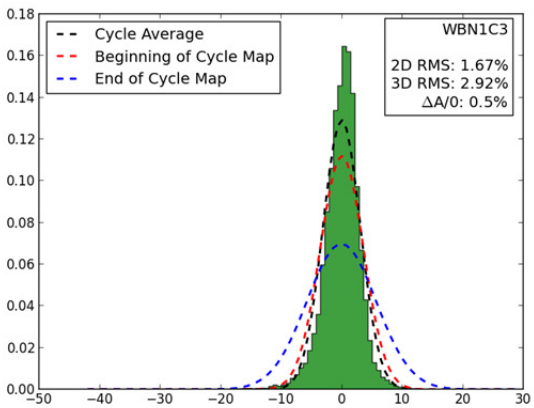

H G F E D C B A
08
09
10
11
12
13
14
15
WBN1C12
10.118 GWD/MT
Power: 99.7%
2D RMS: 1.49%
3D RMS: 2.95%
ΔA/0: 1.3%
Core Average
Measured Data
VERA-CS Solution

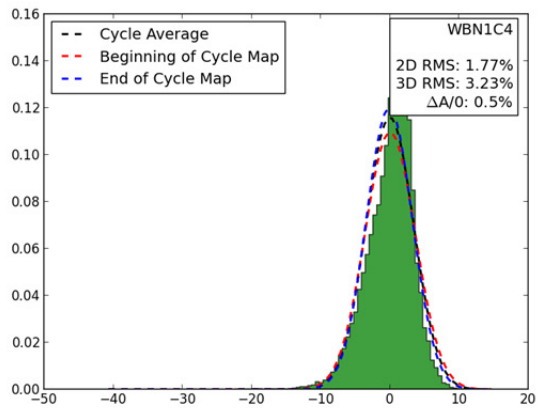

H G F E D C B A
08
09
10
11
12
13
14
15
WBN1C12
13.493 GWD/MT
Power: 99.5%
2D RMS: 1.23%
3D RMS: 2.72%
ΔA/0: 1.4%
Core Average
Measured Data
VERA-CS Solution

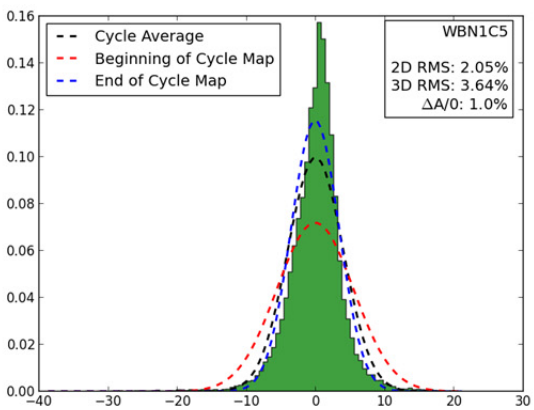

H G F E D C B A
08
09
10
11
12
13
14
15
WBN1C12
16.626 GWD/MT
Power: 99.6%
2D RMS: 1.18%
3D RMS: 2.76%
ΔA/0: 1.3%
Core Average
Measured Data
VERA-CS Solution

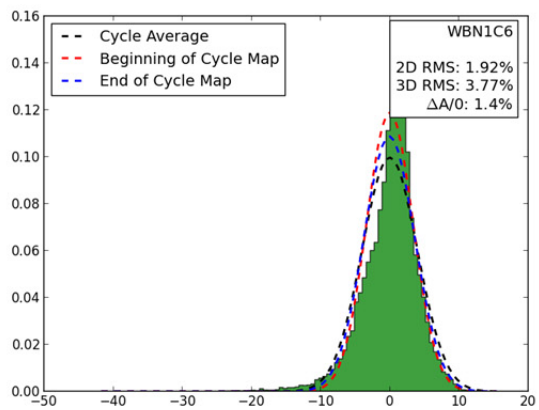

Cycle Average
Beginning of Cycle Map
End of Cycle Map
WBN1C1
2D RMS: 1.10%
3D RMS: 3.29%
ΔA/0: -1.2%

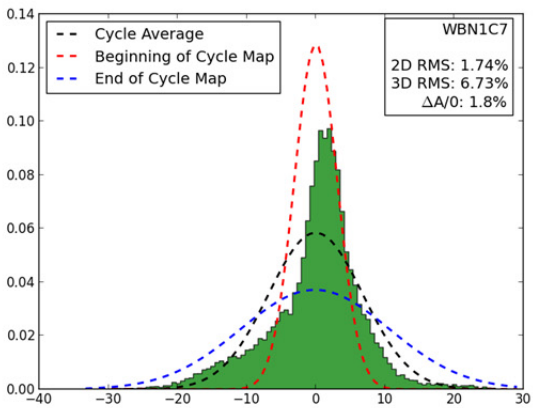

Cycle Average
Beginning of Cycle Map
End of Cycle Map
WBN1C2
2D RMS: 1.60%
3D RMS: 2.70%
ΔA/0: 0.1%

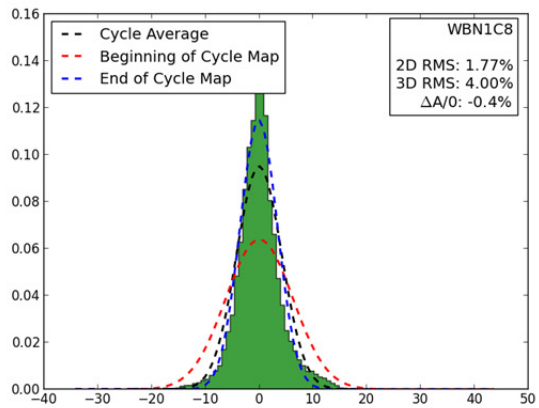

Cycle Average
Beginning of Cycle Map
End of Cycle Map
WBN1C3
2D RMS: 1.67%
3D RMS: 2.92%
ΔA/0: 0.5%

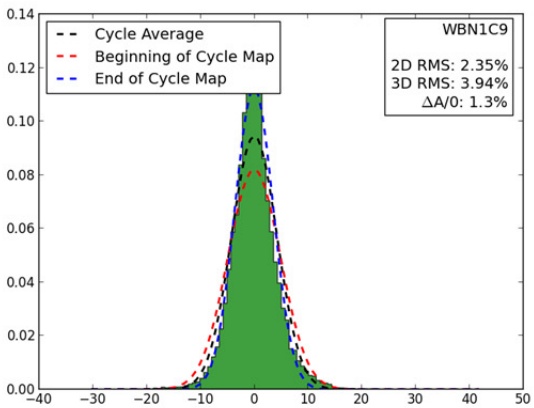

Cycle Average
Beginning of Cycle Map
End of Cycle Map
WBN1C4
2D RMS: 1.77%
3D RMS: 3.23%
ΔA/0: 0.5%

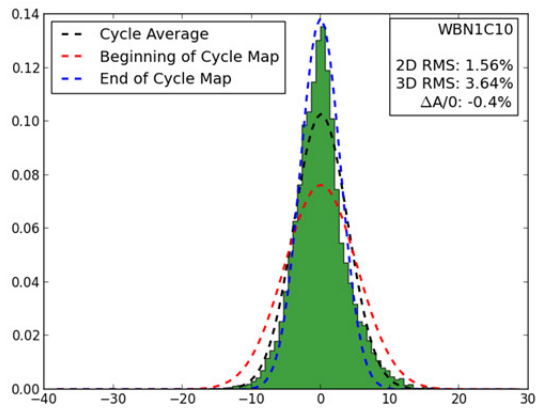

Cycle Average
Beginning of Cycle Map
End of Cycle Map
WBN1C5
2D RMS: 2.05%
3D RMS: 3.64%
ΔA/0: 1.0%

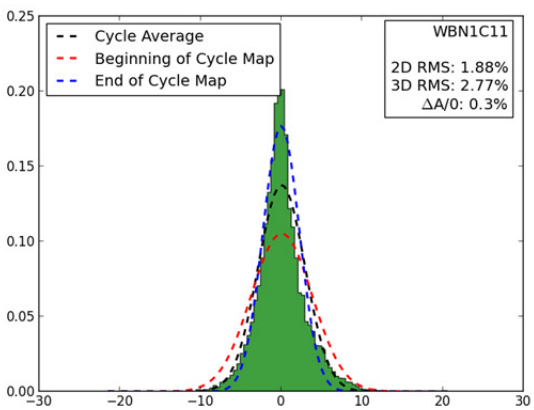

Cycle Average
Beginning of Cycle Map
End of Cycle Map
WBN1C6
2D RMS: 1.92%
3D RMS: 3.77%
ΔA/0: 1.4%

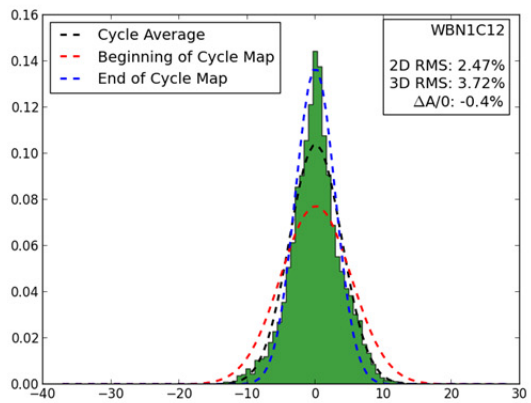

Cycle Average
Beginning of Cycle Map
End of Cycle Map
WBN1C7
2D RMS: 1.74%
3D RMS: 6.73%
ΔA/0: 1.8%


Cycle Average
Beginning of Cycle Map
End of Cycle Map
WBN1C8
2D RMS: 1.77%
3D RMS: 4.00%
ΔA/0: -0.4%


Cycle Average
Beginning of Cycle Map
End of Cycle Map
WBN1C9
2D RMS: 2.35%
3D RMS: 3.94%
ΔA/0: 1.3%


Cycle Average
Beginning of Cycle Map
End of Cycle Map
WBN1C10
2D RMS: 1.56%
3D RMS: 3.64%
ΔA/0: -0.4%


Cycle Average
Beginning of Cycle Map
End of Cycle Map
WBN1C11
2D RMS: 1.88%
3D RMS: 2.77%
ΔA/0: 0.3%


Cycle Average
Beginning of Cycle Map
End of Cycle Map
WBN1C12
2D RMS: 2.47%
3D RMS: 3.72%
ΔA/0: -0.4%