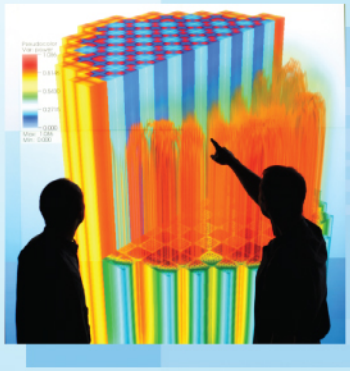
Power uprates
and plant life extension

CASL-U-2011-0184-000-a

Consortium for Advanced Simulation of LWRs



Engineering design
and analysis

Milestone Presentation: Solution Verification Applied to TransAT Calculations of a Smooth-Wall Turbulent Channel Flow using LES

Science-enabling
high performance
computing

Despoina Chatzikyriakou, Jacopo. Buongiorno,
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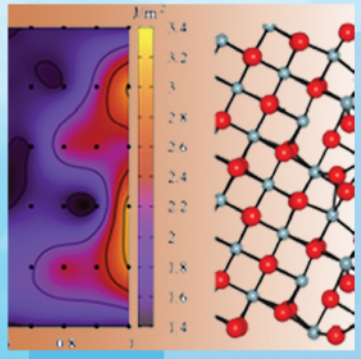
Djamel Lakehal,
ASCOMP & MIT



Fundamental science

November 18, 2011

Plant operational data

U.S. DEPARTMENT OF ENERGY | Nuclear Energy

Solution Verification Applied to TransAT Calculations of a Smooth-Wall Turbulent Channel Flow using LES

Despoina Chatzikyriakou (MIT), Jacopo Buongiorno (MIT),
Djamel Lakehal (Ascomp & MIT)

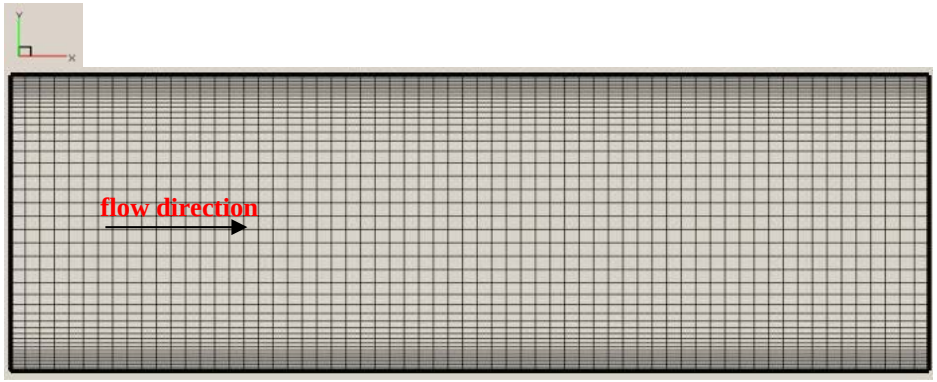
Milestone L3.THM.ITM.P3.01

CASL-U-2011-0184-000-a

Used the solution verification workflow from W. J. Rider, J. R. Kamm, V. G. Weirs in *Procedures for Calculation Verification*, VUQ.VVDA.Y1-1.04_part2, CASL, 2011

1) **Starting with a code that has passed adequate level of QA, choose the executable**
2) **State expected accuracy and stability properties of numerical method implemented**
3) **Define problem of interest and produce code input for this problem**
4) **Select sequence of discretizations and run the code for that sequence**
5) **Choose metrics (figures of merit) and estimate rate of convergence for those metrics**
6) **Compare estimated and expected rates of convergence**
7) **Render overall assessment of method implementation correctness**

Code and Description of Problem of Interest



TransAT

- Incompressible turbulent fully-developed flow between smooth parallel plates (no slip at walls)
- Periodic boundary conditions in spanwise and streamwise directions
- Initial turbulent flow conditions are isotropic
- LES: non-oscillatory 2nd order Central Difference scheme for the discretization of the convective fluxes, and the 2nd order accurate HLPA scheme for density. Explicit 3rd R-K in time. CFL between 0.1 and 0.3
- Friction Reynolds number Re_τ=400
- Statistics acquired over 40,000 solution samples at ergodic conditions
- Space averaging throughout entire domain

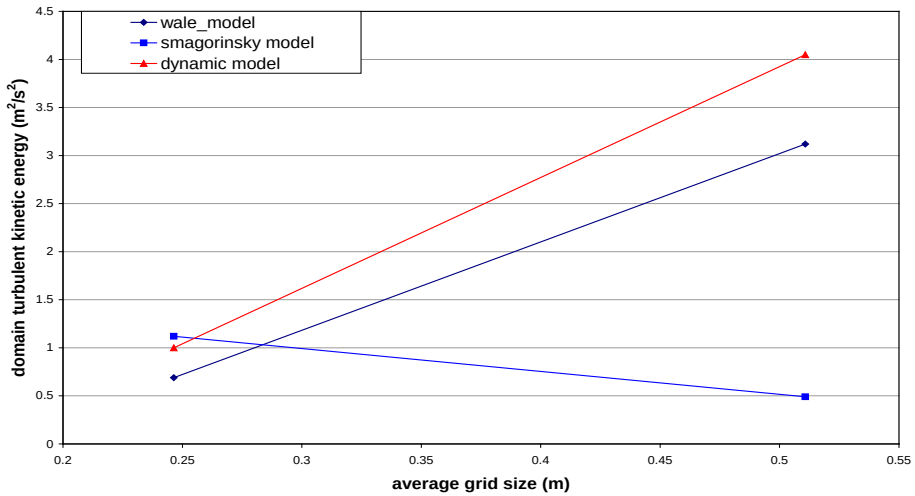
Sequence of discretizations and subgrid scale (SGS) models used

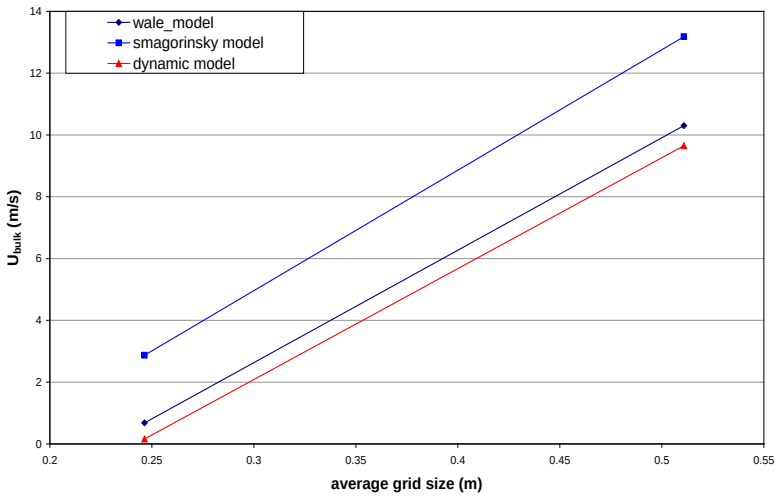
	Grid (N_x,N_y,N_z)	Characteristic length Δh_{avg}	SGS Model		
Very coarse (vc)	16x12x12	Δh_{avg} =0.51m	Modified Smagorinsky	WALE	Dynamic
Coarse (c)	32x24x24	Δh_{avg} /2	Modified Smagorinsky	WALE	Dynamic
Fine (f)	64x48x48	Δh_{avg} /4	Modified Smagorinsky	WALE	Dynamic

Choice of metrics:

- Bulk velocity
- Turbulent kinetic energy
- U_rms

Estimated rate of convergence





$$\alpha = \left[\log\left\| g^f - g^c \right\| - \log\left\| g^c - g^{vc} \right\| \right] / \log\sigma \qquad where \quad \sigma \equiv \Delta h^c_{avg} \,/\, \Delta h^f_{avg}$$

Subgrid scale model	α based on turbulent kinetic energy	α based on bulk velocity	α on u_{rms}
WALE	2.176	3.915	2.905
Smagorinsky	-1.192	2.199	-1.117
Dynamic	2.0179	5.930	-2.857

Overall Assessment and Future Work

- Solution convergence of the TransAT LES simulations was achieved for all figures of merit except for the peak u_{rms} velocity with the Smagorinsly and the Dynamic models.
- However, the estimated order of convergence is not in agreement with the expected convergence order of the method used.
- We suspect the coarsest grid ('vc') chosen for the analysis is responsible for this problem.
- A simulation with a finer grid is in progress to resolve the order of convergence issue.