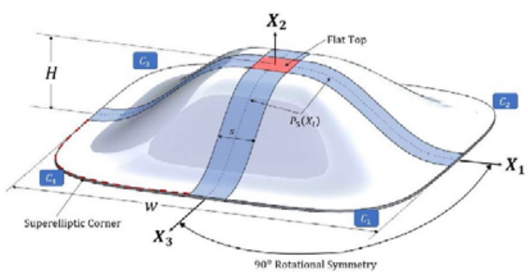
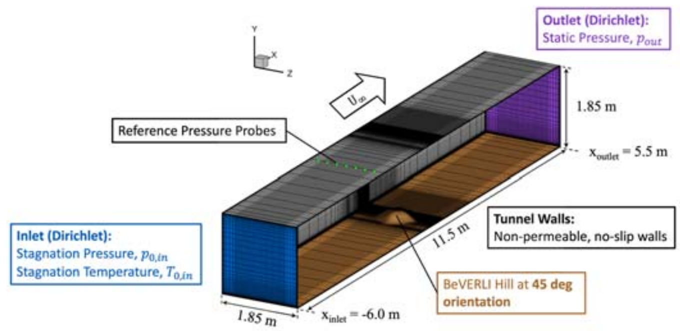
VT-NASA CFD Turbulence Model Validation Challenge

A Blind Validation CFD Challenge Case for 3D Smooth-Body Turbulent Flow Separation

Virginia Tech, with support from NASA-Langley, has recently acquired high-quality turbulence model validation data for three-dimensional smooth-body flow separation. The geometry, called the BeVERLI Hill (Benchmark Validation Experiments for RANS and LES Investigations), has been studied at height-based Reynolds numbers of 250k to 650k for subsonic flow. Experimental data have been obtained for the hill at zero and 45 degree orientations and includes extensive oil flow visualizations, surface pressures, skin friction via oil film interferometry, and mean and fluctuating velocities using particle image velocimetry, laser doppler velocimetry, and pitot-static rakes. Extensive boundary conditions and oncoming boundary layer data have also been measured. We propose a blind CFD turbulence modeling challenge case with the BeVERLI Hill oriented at 30 degrees to the oncoming freestream. Two turbulence models are strongly recommended: the standard Spalart-Allmaras model and the Menter k-ω SST model. Additional turbulence model submissions are welcome. While extensive boundary condition information will be made available to participants, the surface pressure, surface skin friction, and velocity data will be withheld until the computations have been submitted, thus making this a blind CFD challenge. A two-dimensional verification case will also be required.



BeVERLI Hill Model



Grid with Boundary Conditions and Reference Pressures

Currently Available Information

- As-designed geometry files systematically-refined family of structured grids:
  https://roy.aoe.vt.edu/vt-nasa-validation-challenge/meshes/index.html
- Inflow/outflow boundary conditions, reference pressures, and boundary layer parameters:
  https://roy.aoe.vt.edu/vt-nasa-validation-challenge/boundary-conditions/BeVERLI_BCs.pdf

Information to be Made Available by June 2023 (AIAA Aviation Meeting)

- As-built geometry files (tunnel and hill)
- A family of systematically-refined structured grids for the as-built geometry
- Additional inflow boundary conditions

Proposed Timeline

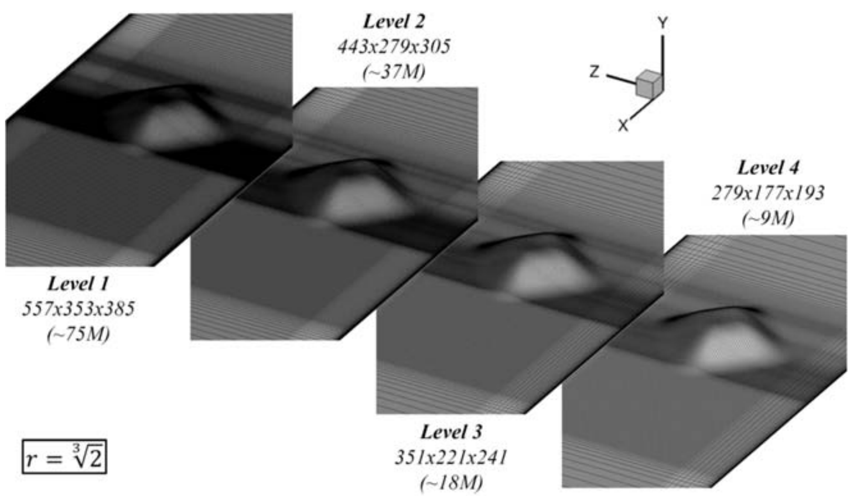
- *October 2022:* wind tunnel entry for surface pressures, oil flow, BCs (completed)
- *June 2023:* AIAA paper and ASME V&V symposium presentation discussing validation challenge
- *July and October 2023:* wind tunnel entries for PIV, LDV, OFI
- *April 2024:* contributors submit data to VT for compilation and analysis
- *Aviation 2024:* special session w/ summary paper, contributor presentations, and exp. data release

VT-NASA CFD Turb. Model Challenge Web Site: https://roy.aoe.vt.edu/vt-nasa-validation-challenge

For more information, contact: Prof. Chris Roy at cjroy@vt.edu

Nominal Boundary Conditions for BeVERLI Hill Simulations

Reynolds Number, Re_H	250,000	650,000
Stagnation Pressure, $p_{0,in}$	94,220 Pa	94,450 Pa
Stagnation Temperature, $T_{0,in}$	297 K	297 K
Outflow Pressure, $p_{outflow}$	93,961 Pa	92,692 Pa
Reference Pressure, p_{ref}	93,974 Pa	92,771 Pa
Reference Velocity, U_{ref}	21.11 m/s	55.22 m/s
Reference Mach Number, M_{ref}	0.06	0.16
Reference Density, ρ_{ref}	1.103 kg/m^3	1.093 kg/m^3
Turbulence Intensity, T.I.	0.021%	0.030%
Inflow Viscosity Ratio, $(\mu_t/\mu)_{in}$	1.5	3.0
Inflow TKE, k_{in}	2.9E-5 m^2/s^2	4.0E-4 m^2/s^2
Inflow Spec. Dissipation Rate, ω_{in}	1.17 1/s	8.12 1/s
Inflow SA Working Variable, ν_{in}	4.5E-5	9.2E-5



Example Grids for the 45 Degree Case (Challenge Case is 30 Degrees); Flow in the Positive *x* Direction

Verification Case: 2D Bump-in-Channel

- Turbulence Modeling Resources Page: https://turbmodels.larc.nasa.gov/bump.html
- Run with Spalart-Allmaras one-equation and Menter k-ω SST two-equation models
- Results on at least three systematically-refined grids are required
- Relative iterative convergence levels must be reported for each governing equation
- Grids found here (1409×641 to 89×41 nodes): https://turbmodels.larc.nasa.gov/bump_grids.html
- Data available here for various turbulence models: https://turbmodels.larc.nasa.gov/bump.html

Additional Information

- Specific data submission formats will be provided by May 2023
- Two hill height-based Reynolds numbers are required: Re_H = 250,000 and 650,000
- Results with two turbulence models are strongly recommended: the standard Spalart-Allmaras one-equation model and the Menter k-ω SST two-equation model
- Results for other turbulence models are also encouraged, especially nonlinear models (e.g., QCR)
- Results on at least three systematically-refined grids are required
- Relative iterative convergence levels must be reported for each governing equation