CFS Engineering & RUAG Aerospace DPW4 Results

Jan B. Vos*, Stephan Sanchi*, Alain Gehri ¥, Philippe Stephani¥

*CFS Engineering
PSE-A
1015 Lausanne
Switzerland

¥ RUAG Aerospace

6032 Emmen
Switzerland

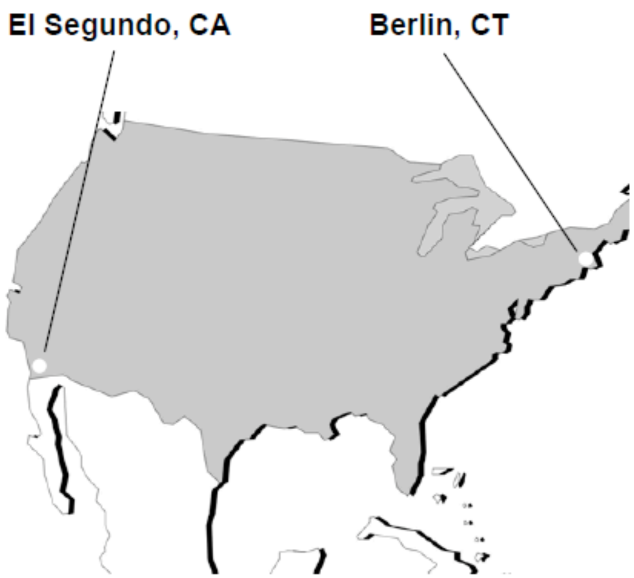
Contents

- Who we are
- The CFD Code we use
- DPW4 results using our own grid
- Comparison of results obtained with other grids
- Concluding Remarks

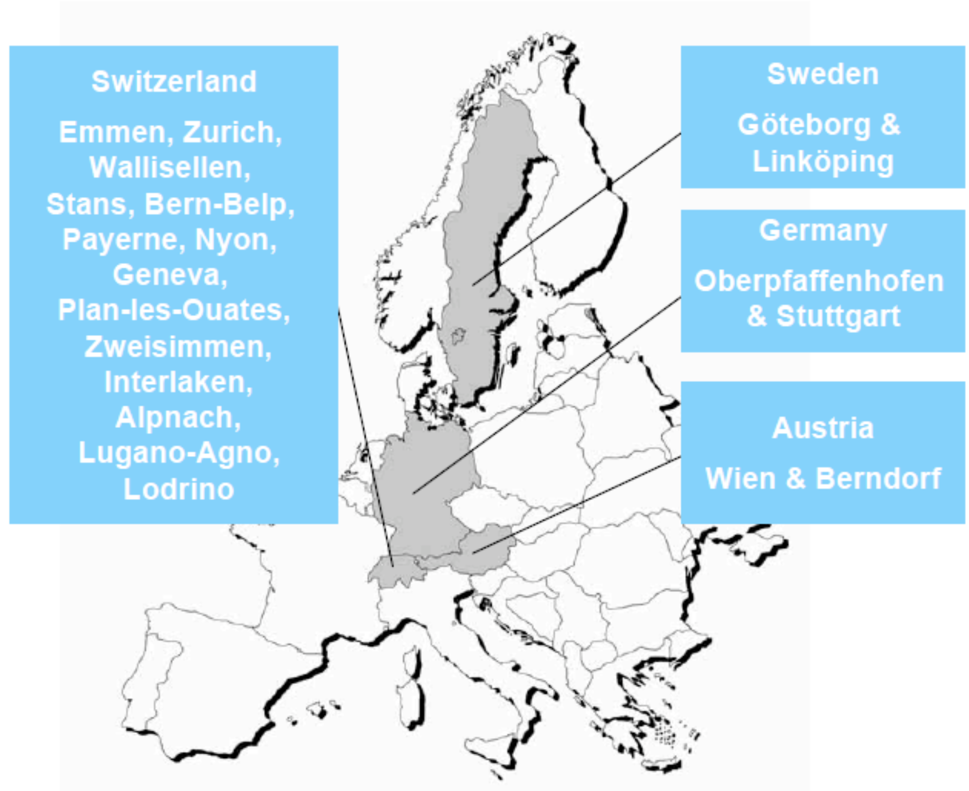
Who we are – RUAG Aerospace

Focused on aviation and space technology

USA



Europe



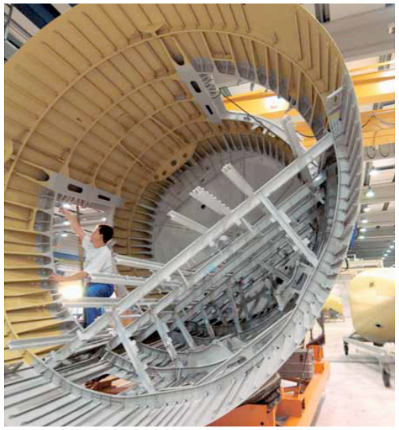
Who we are – RUAG Aerospace

- **Aircraft Services:**
  Business and executive jets, regional aircraft, helicopters,programs and special aircraft, technical logistic support

- **Aircraft & Defence Systems:**
  Fighter and training jets, helicopters, simulators, self-defence systems

Who we are – RUAG Aerospace

- **Space:**
  Equipment for satellites and launchers

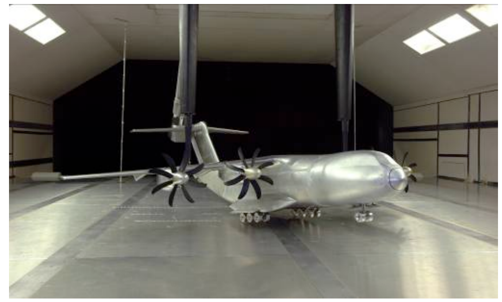


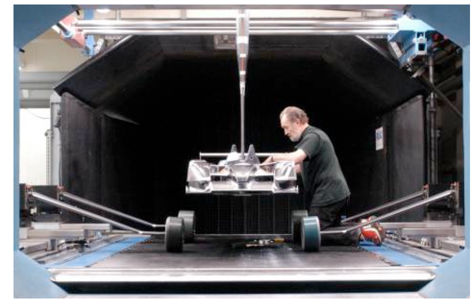
- **Aerostructures:**
  Wing and fuselages sub-assemblies, engine cases

- **Engineering & Technology**

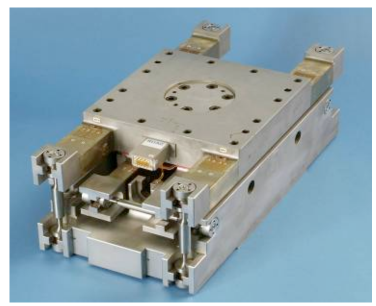
Who we are – RUAG Aerospace – Aerodynamics Center

- **Wind Tunnel Tests Aviation- and Automotive Industry**

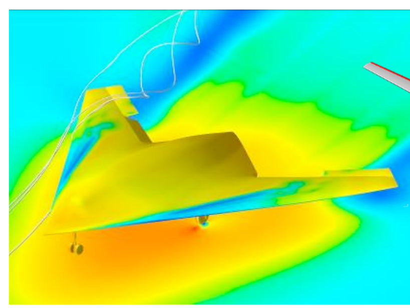


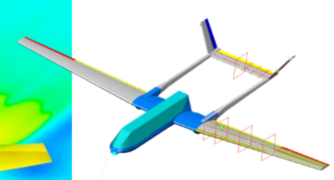


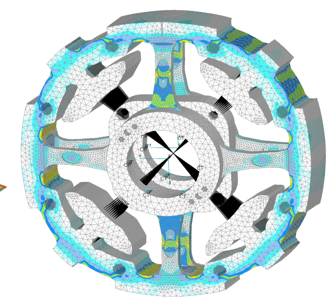
- **Instrumentation / Model D&M**



- **CFD & Flight Physics Engineering**







Who we are – CFS Engineering

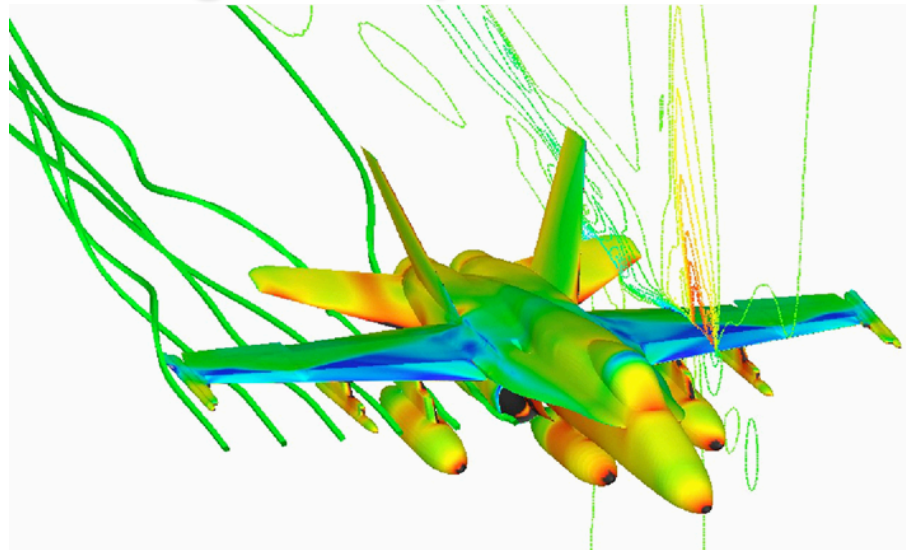
CFS Engineering was created in 1999 and is located at the Business park of the Swiss Federal Institute of Technology in Lausanne (EPFL)

The major shareholder of CFS Engineering is RUAG Aerospace

We offer services in the numerical simulation of fluid and structural mechanics engineering problems

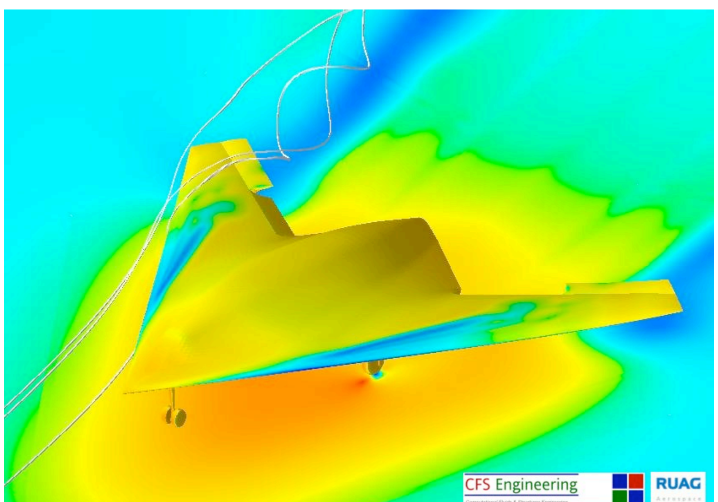
CFS Engineering

Who we are – CFS Engineering – compressible flows



Aerodynamic analysis of the F/A-18 including dynamic Fluid Structure Interaction

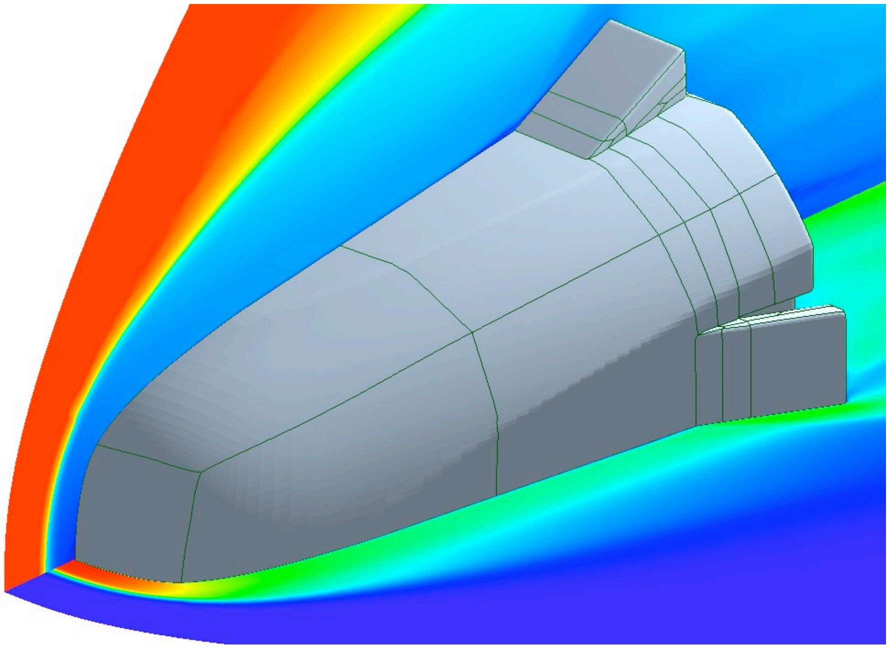
RUAG Aerospace



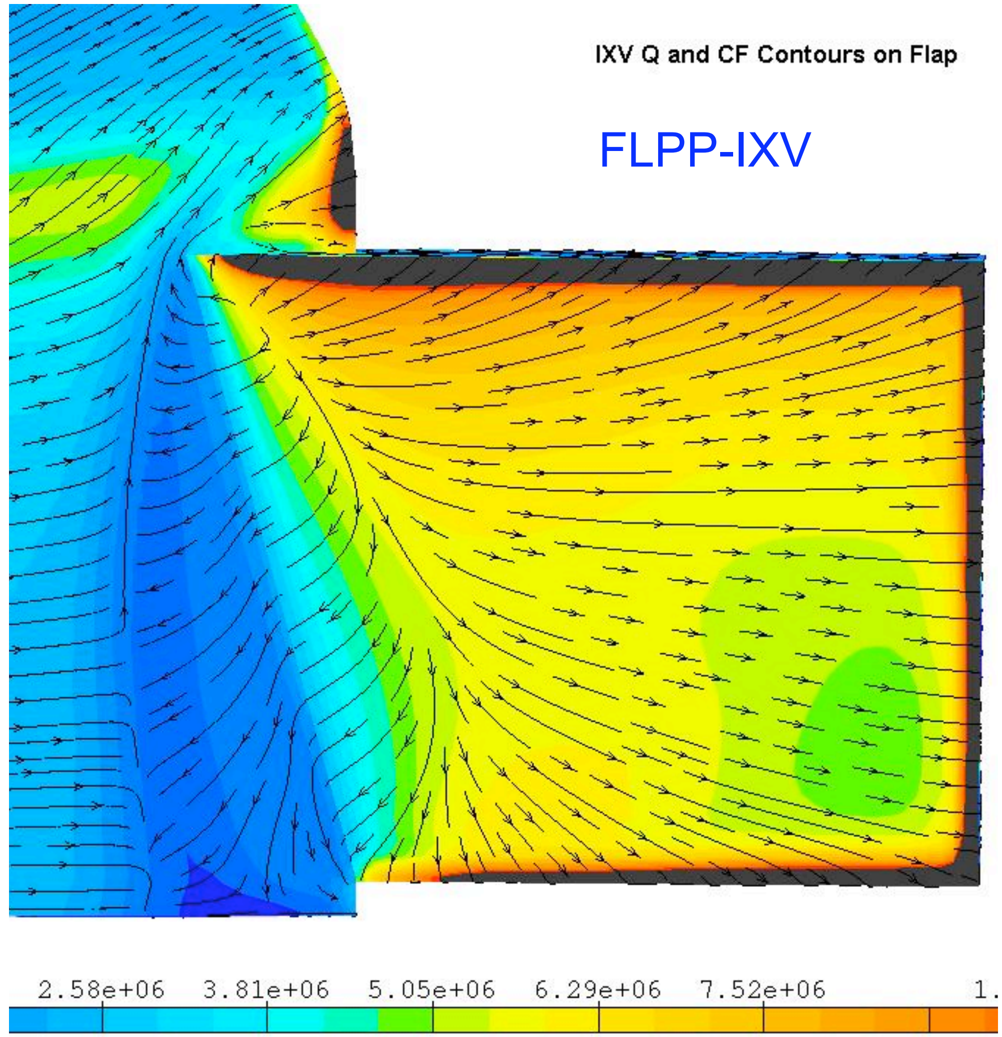
Ground effect studies NEURON

Dassault Aviation

Who we are – CFS Engineering – hypersonic flows



EXPERimental Re-Entry Test bed



FLPP-IXV

The CFD code we use - NSMB

NSMB was based on an Euler code (EULMB) developed at EPFL in 1989 with support from CERFACS and KTH. The first version of NSMB became available in November 1991.

A NSMB Memorandum of Understanding was signed in May 1992 between Aerospatiale, CERFACS, KTH and EPFL, and the NSMB project was born which had as objective to further develop the NSMB flow solver. Other parties joined the NSMB project, like SAAB Military Aircraft, SERAM, IMFT, CFS Engineering.

In 2003 Airbus-France and CERFACS moved away from NSMB to the ONERA code elsA and the NSMB project was officially terminated.

Since 2004 NSMB is further developed in a consortium led by CFS Engineering and composed of several Swiss, French and German Universities and industries.

Development activities are focused on turbulence, multi-physics including fluid - structure interaction, hypersonic flow modeling, re-meshing, combustion, ..

The CFD code we use - NSMB

NSMB uses the cell centered Finite Volume method on multi block structured grids.

Various space discretisation schemes are available, among them 2nd and 4th order central schemes, and 2nd, 3rd and 5th order upwind schemes.

Time integration methods include the explicit Runge Kutta time stepping or the implicit LU-SGS scheme. Convergence acceleration methods as residual smoothing, multi grid or full multi grid are available.

NSMB includes a fully patched block connectivity boundary condition to simplify the mesh generation for complex geometries.

Different turbulence models have been implemented in NSMB, among them the Spalart-Allmaras 1 eq.model and the Wilcox and Menter Shear Stress k-ω models.

The code is fully parallel.

DPW4 calculations - grid

We generated our own grids using ICEM CFD Hexa since no base grid was available when we started our activities

H-type grid using the O-strategy around fuselage, wing and horizontal tail

1-to-1 correspondence between blocks

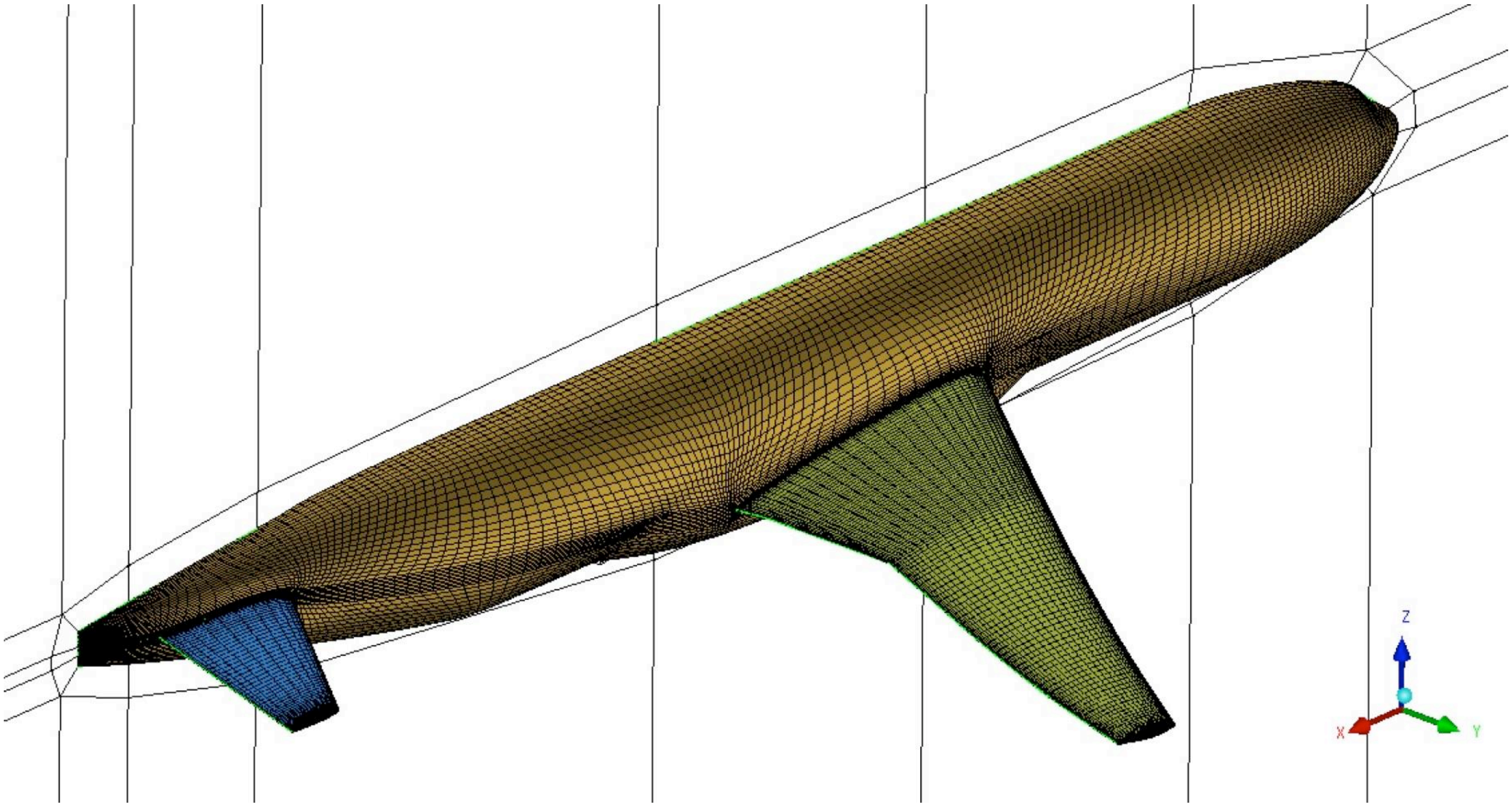
Possibility to use multi grid and/or grid sequencing

Mesh generation guide lines were followed

Coarse grid: 3.8 Million points
Medium grid: 11.3 Million points (11.0 without tail)
Fine grid: 36.3 Million points

DPW4 calculations - grid

Picture of coarse grid and block topology in symmetry plane



DPW4 calculations – CFD parameter settings

All calculations were made using the following parameters

Space discretization: 4th order central scheme with artificial dissipation
Time integration: LU-SGS, CFL increased from 0.1 to 1.e12
Turbulence model: k-ω Menter Shear Stress

For the calculations on the CFSE grids we used 2 or 3 levels of grid sequencing. (Not used for the calculations comparing different grids).

Number of iterations: 2500 on the coarse grid, 3500 on the medium grid and 3000 on the fine grid (6000 for the calculations comparing different grids).

Calculation times on 10 cores: around 20 hours for the medium CFSE grid

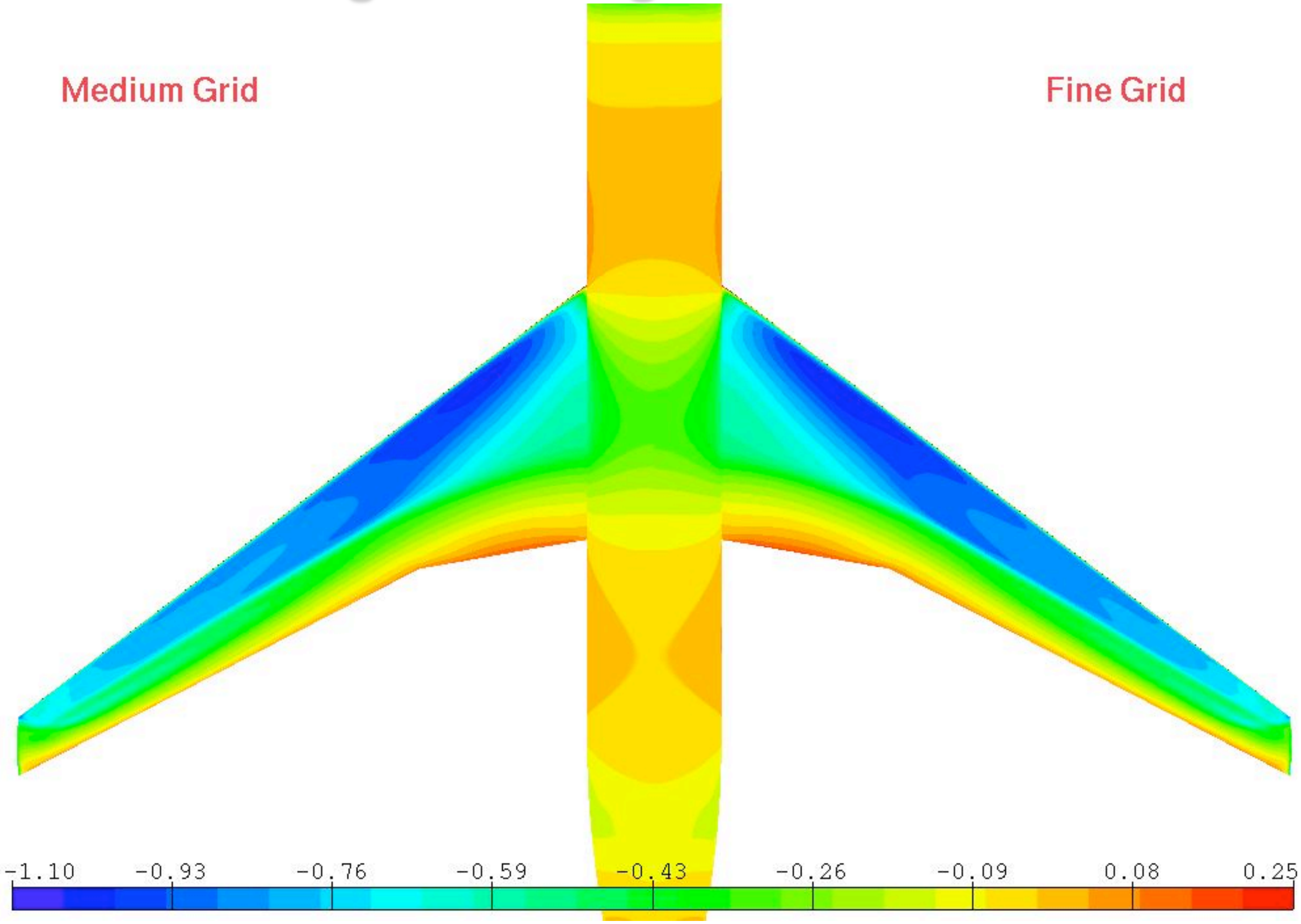
No problems with the calculations.

Results using our own grids

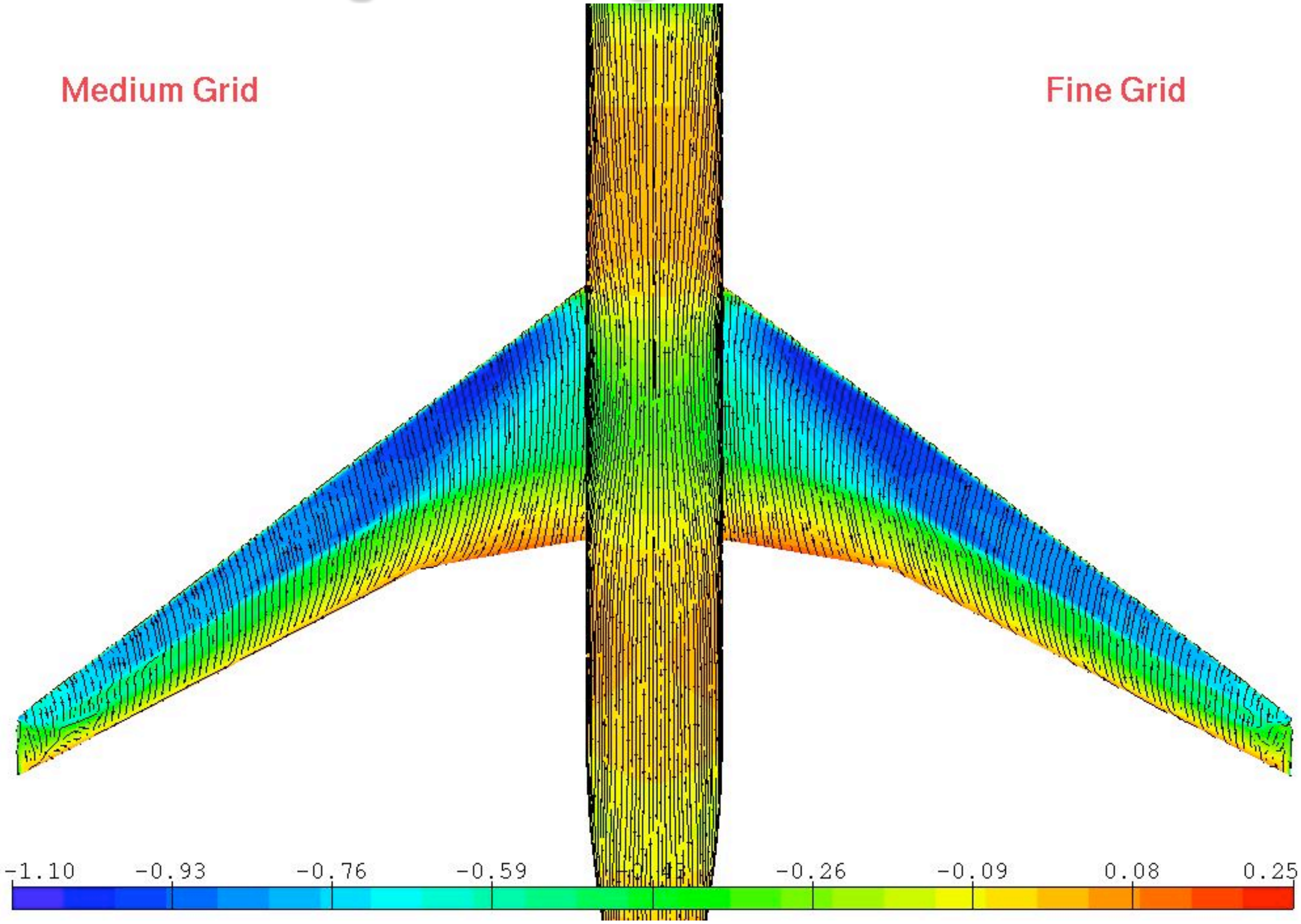
Grid convergence study results

	α	CD	CL	CMy
coarse	**2.4064**	**0.03548**	**0.5010**	**-0.06323**
medium	**2.3805**	**0.03087**	**0.5003**	**-0.05554**
fine	**2.4129**	**0.02978**	**0.4999**	**-0.03734**

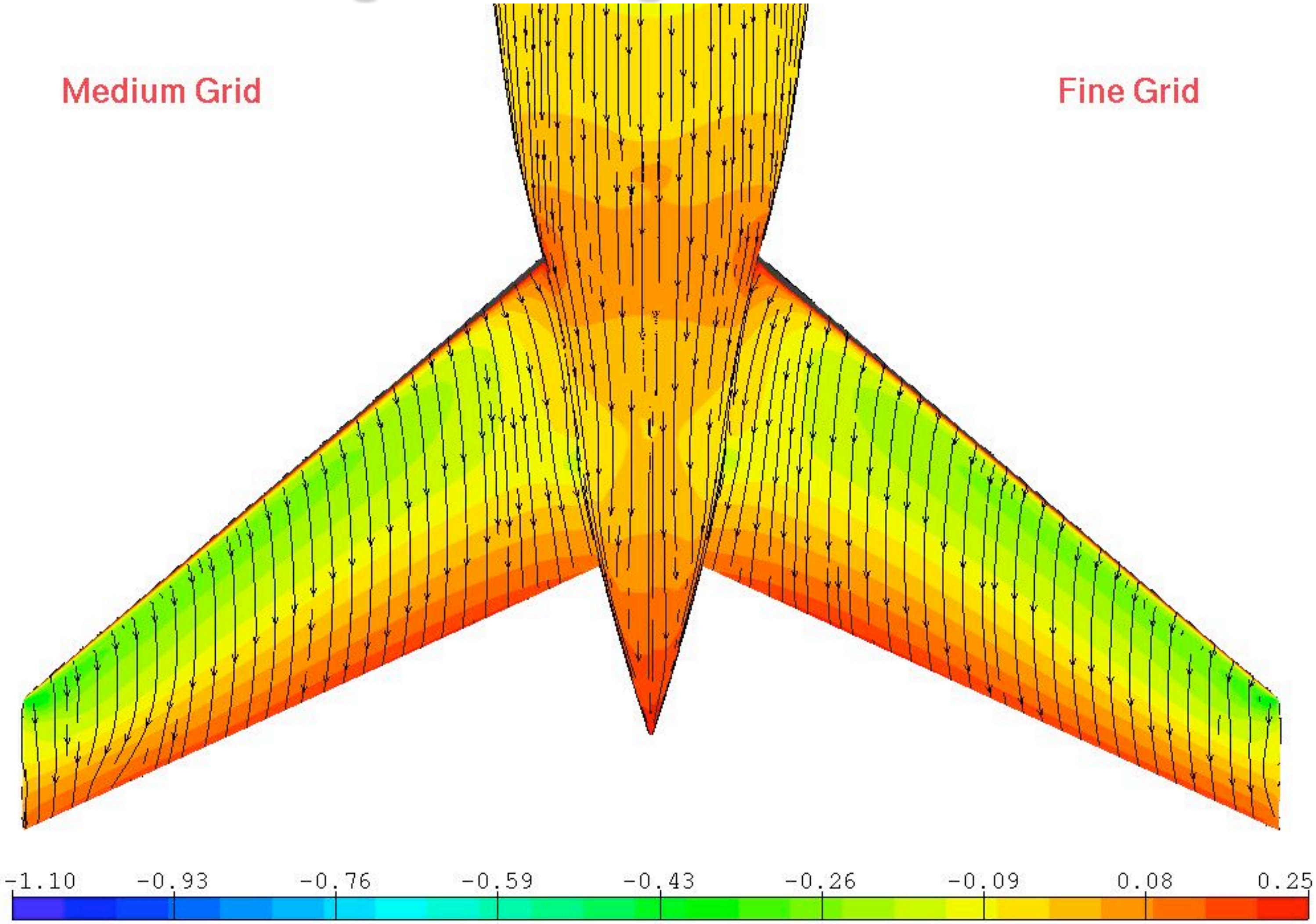
Results using our own grids



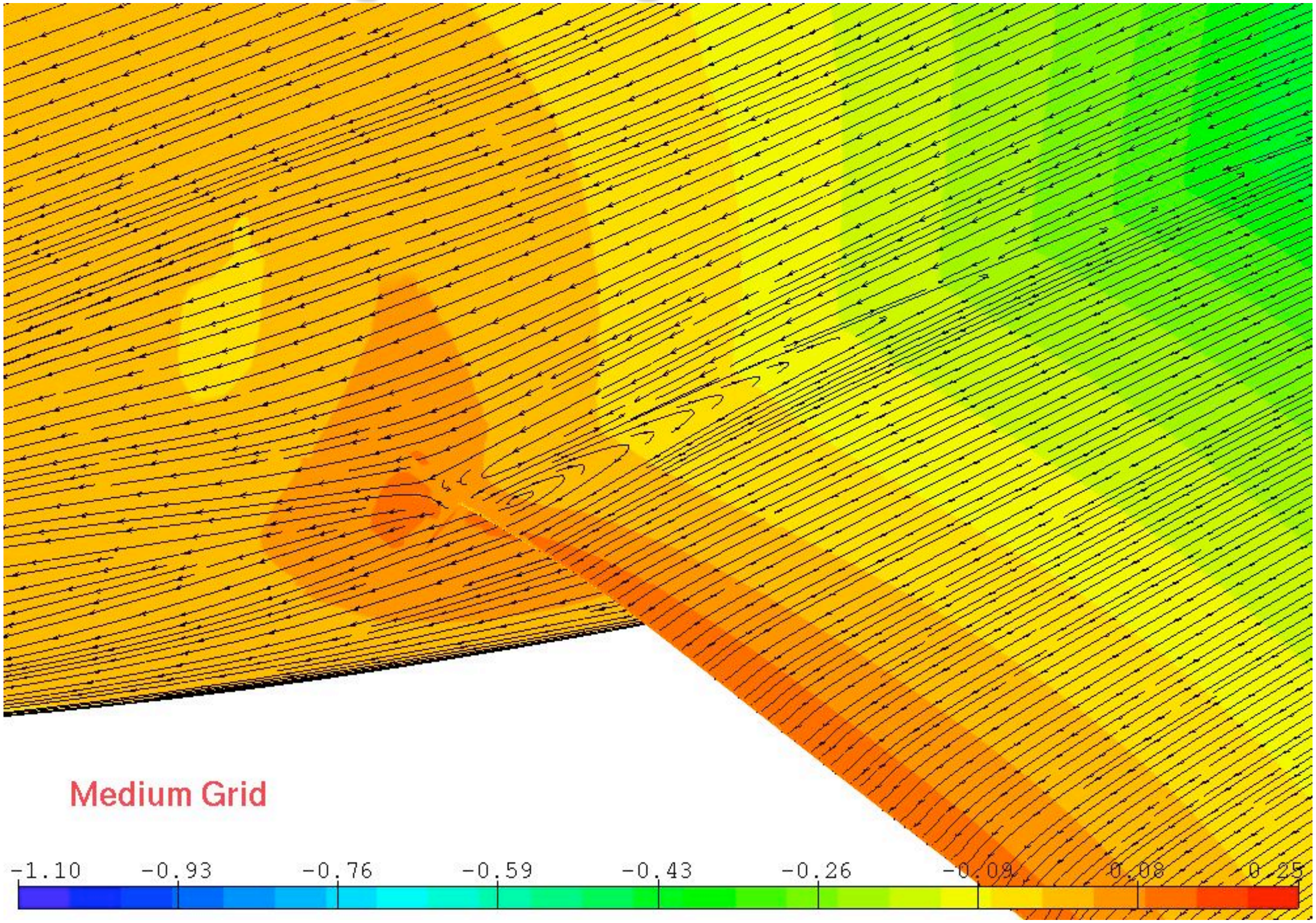
Results using our own grids



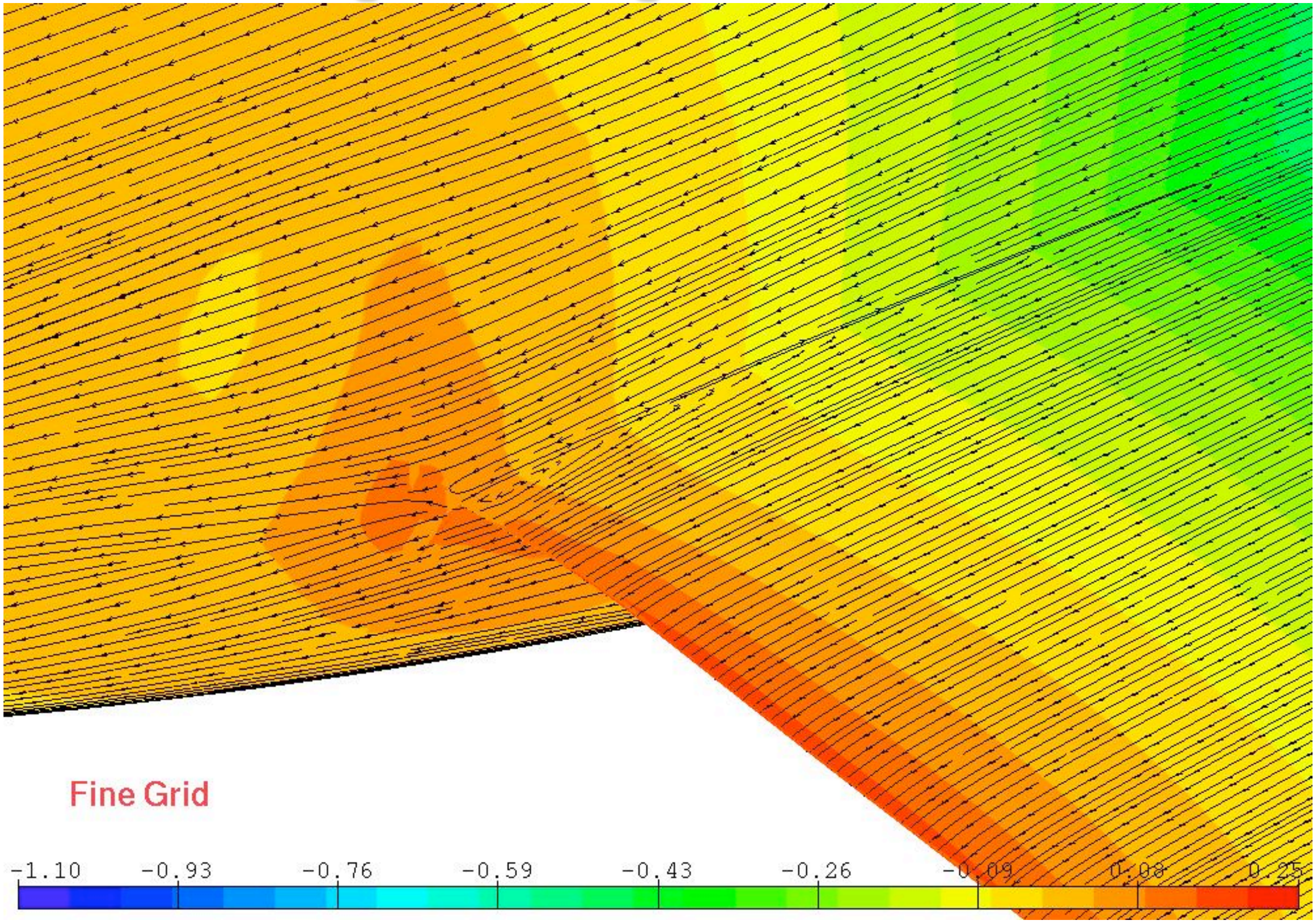
Results using our own grids



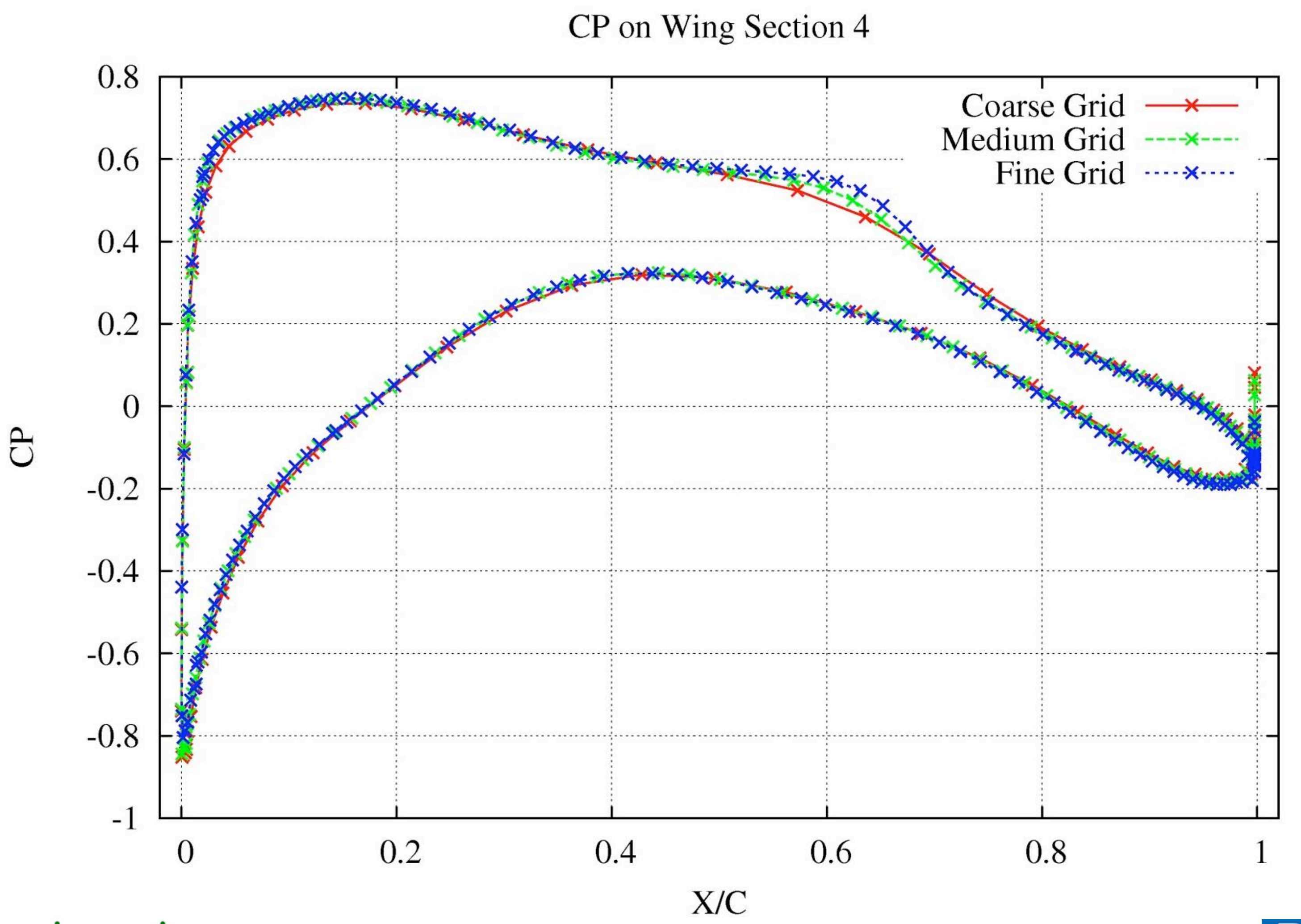
Results using our own grids



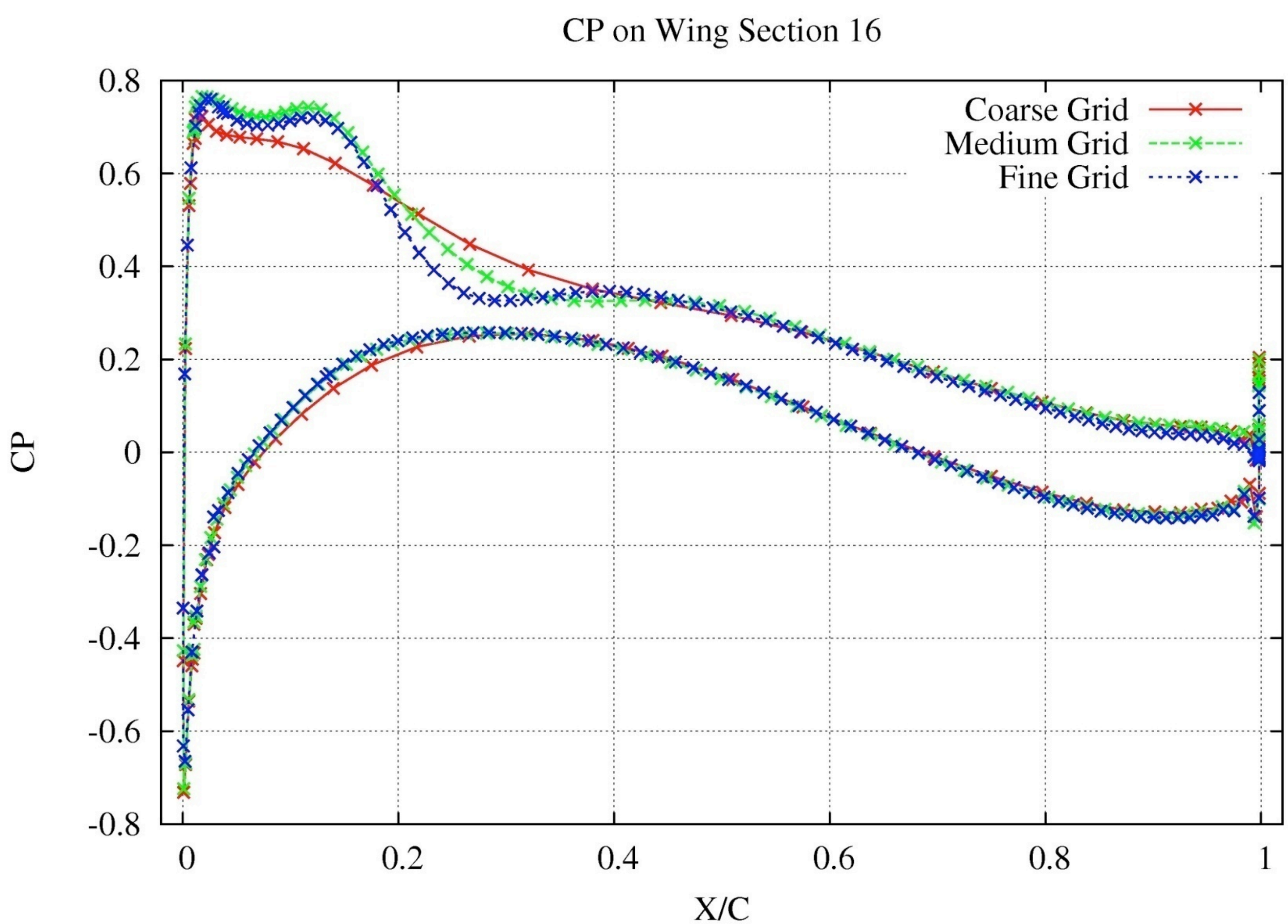
Results using our own grids



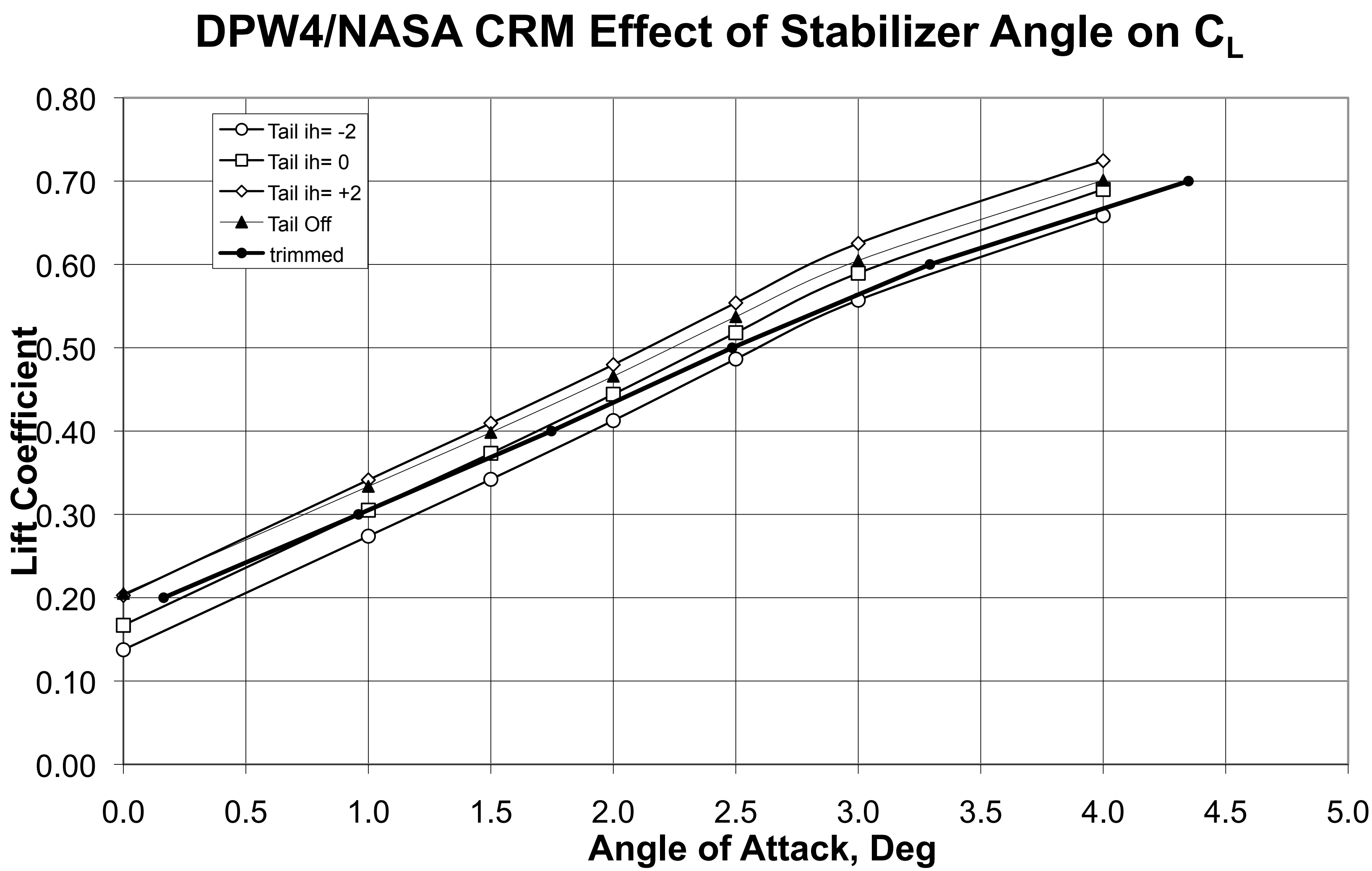
Results using our own grids



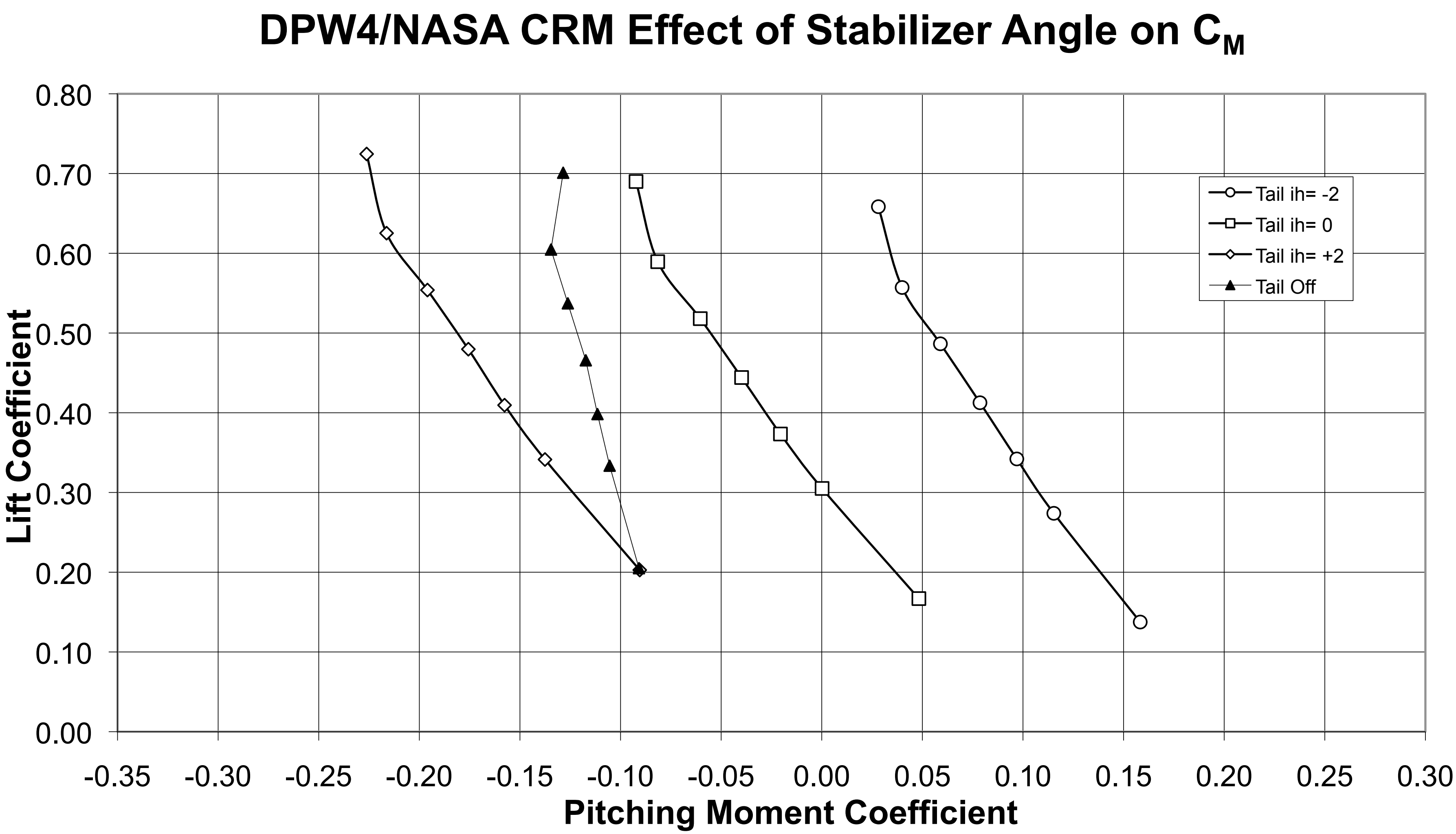
Results using our own grids



Results using our own grids – down wash study



Results using our own grids – downwash study



Comparison of results obtained using other grids

Since about 2 weeks, several other structured multi block grids became available on the DPW4 web site.

AIRBUS:	cgns file, use of patch grid block connectivity bc
ANSYS:	cgns file + meshing files (.tin + .blk)
BOEING:	plot3d file + info on bcs
JAXA:	plot3d file + info on bcs
ZEUS:	cgns file

The cgns grid files could be easily imported, for the other formats conversion programs were written to get the boundary conditions correct.

AIRBUS moved the origin of the model
BOEING changed the axis directions, this grid was after import divided in 30 blocks to permit parallel computations.

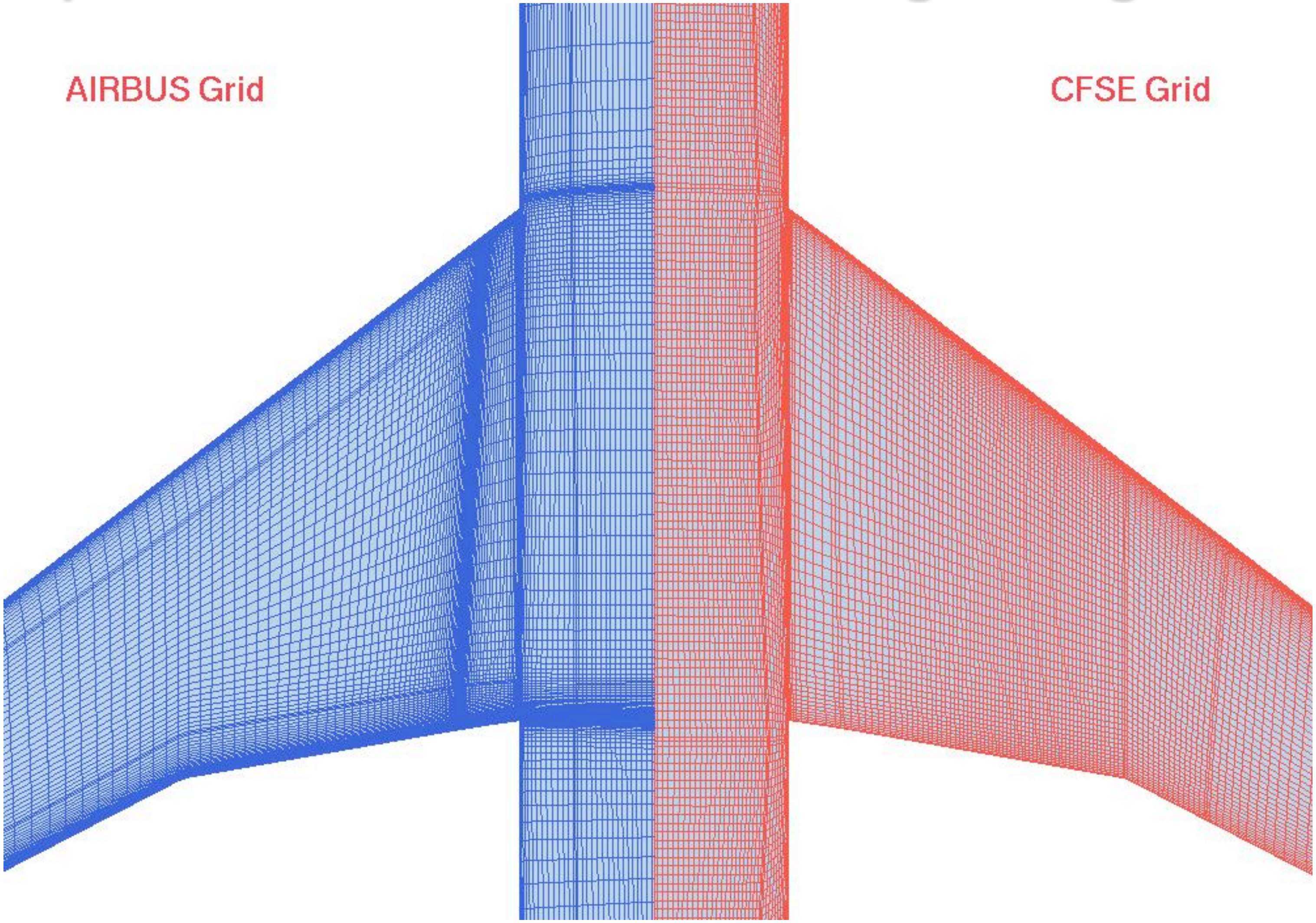
Comparison of results obtained using other grids

Computed case: HT0, α=2.5

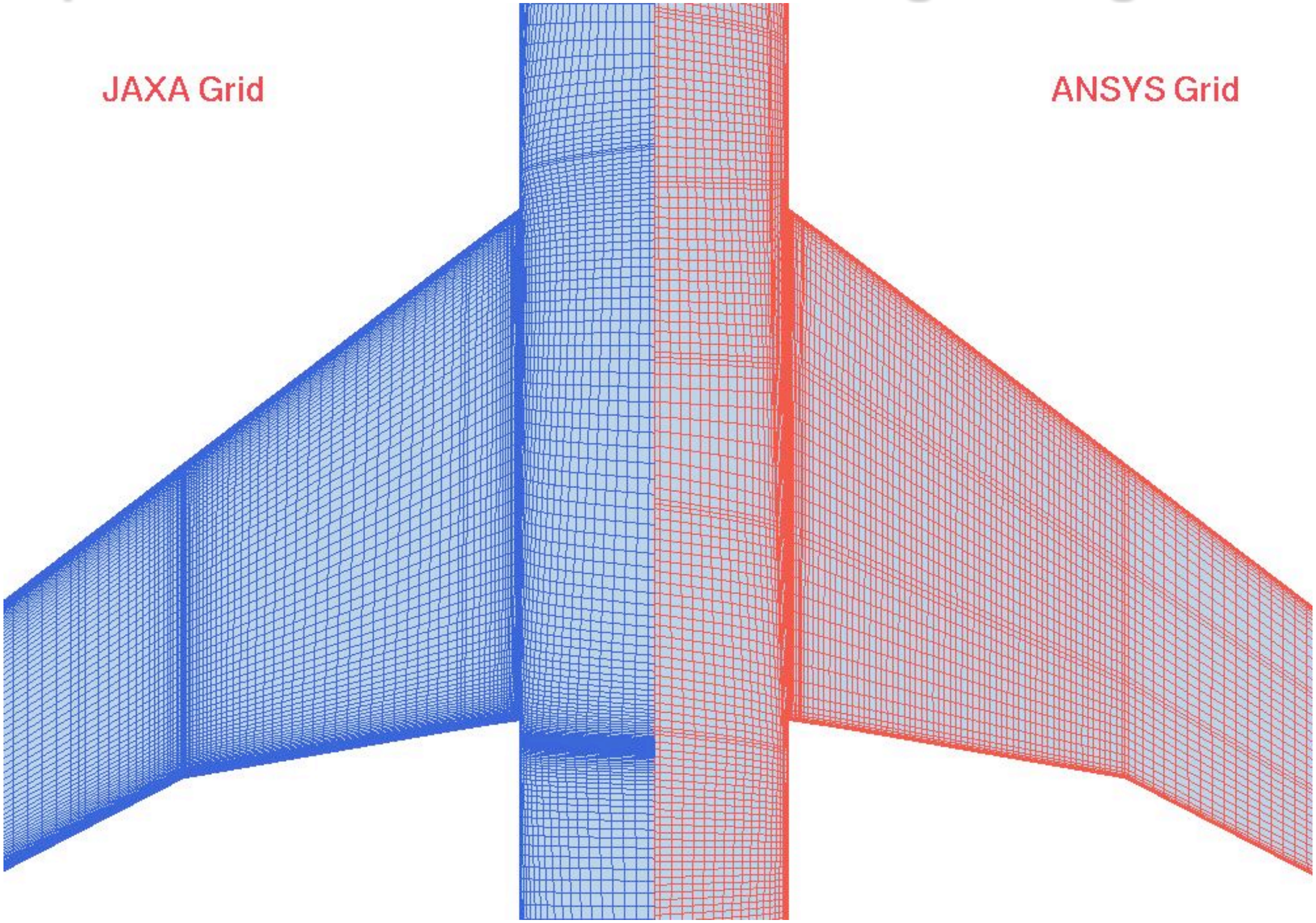
Numerical parameters + boundary conditions all the same

Grid	#Mcells	#k surface cells	CL	CD	CMy
AIRBUS	12.6	126	0.51600	0.03002	-0.04948
ANSYS	10.8	73	0.52556	0.03112	-0.05009
BOEING	11.0	64	0.51392	0.02958	-0.04361
CFSE	11.3	80	0.51910	0.03189	-0.06145
JAXA	9.0	100	0.51743	0.02935	-0.03929
ZEUS	15.4	185	0.46118	0.02862	-0.00849

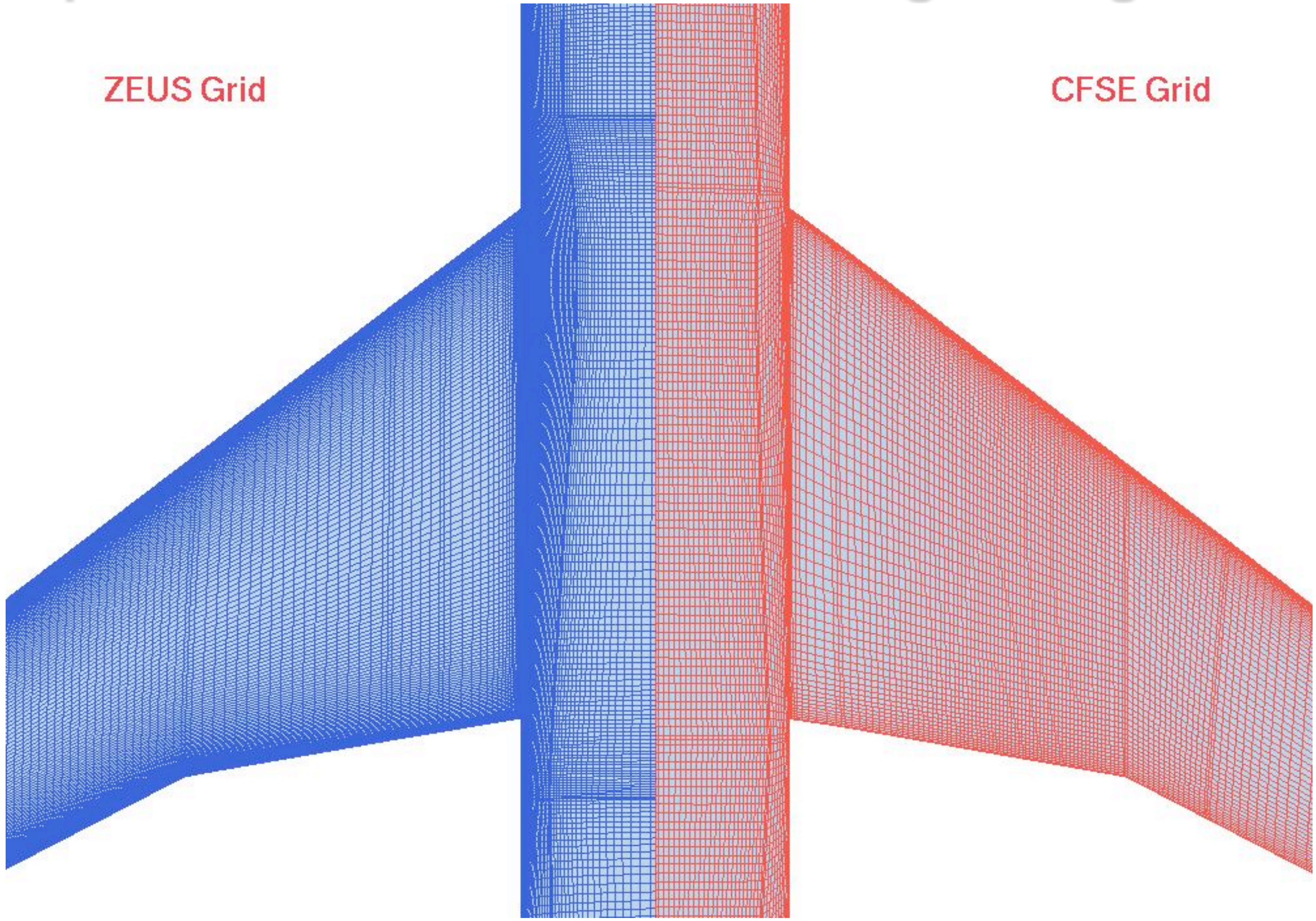
Comparison of results obtained using other grids



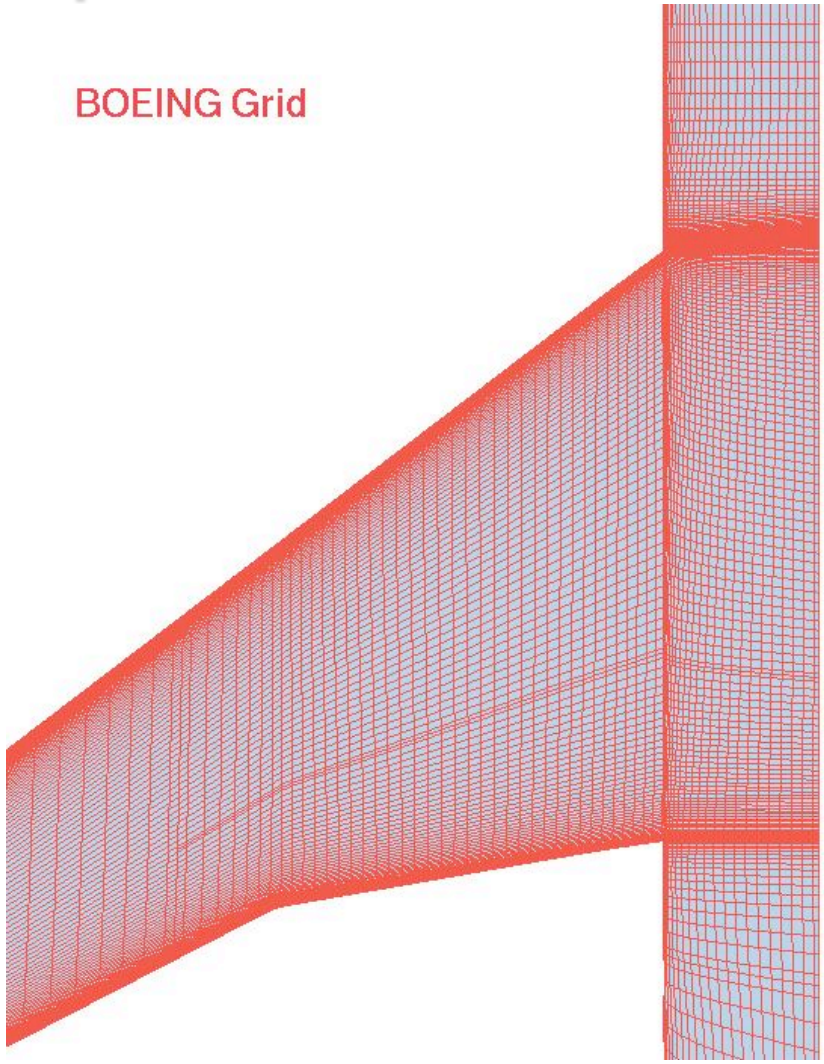
Comparison of results obtained using other grids



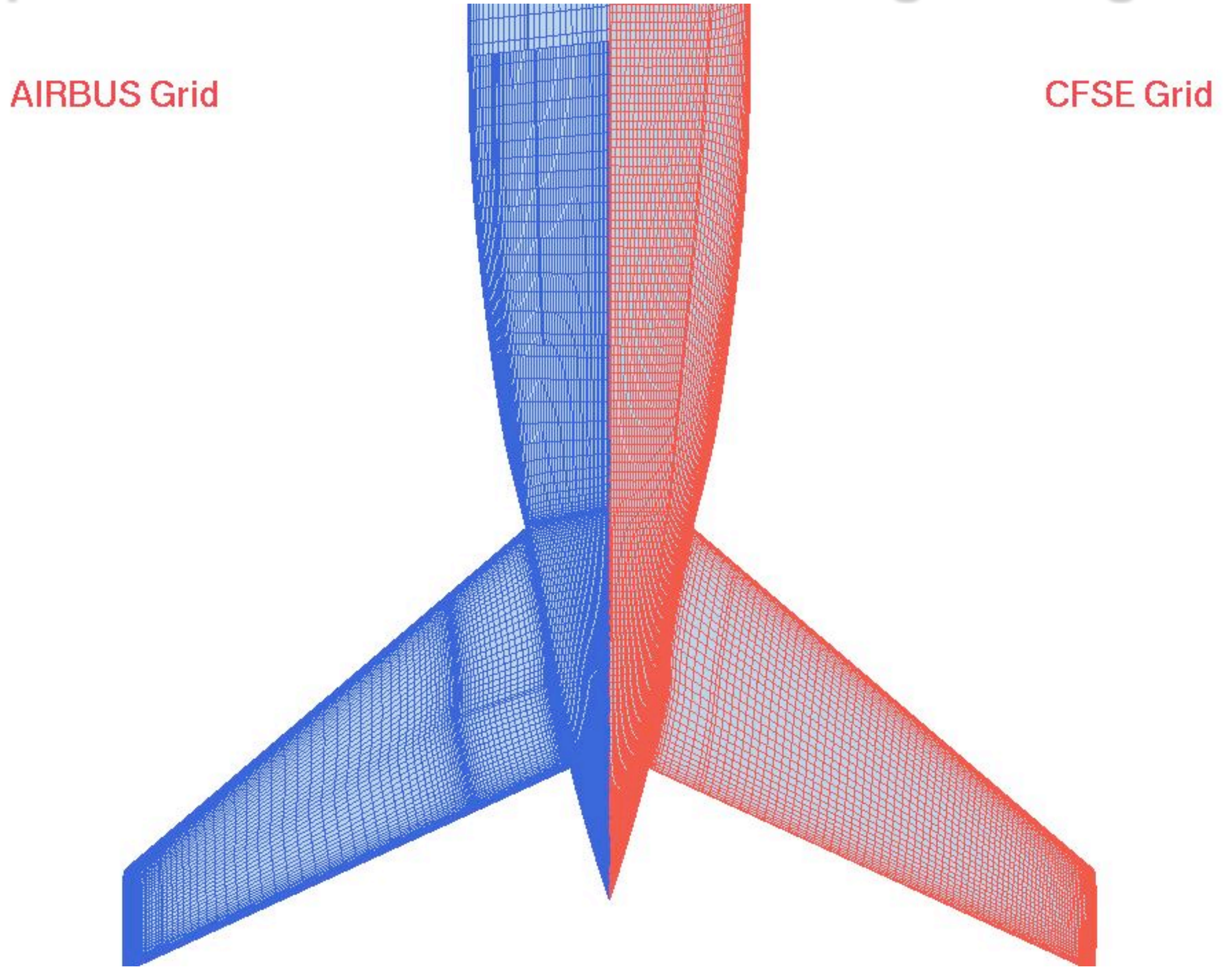
Comparison of results obtained using other grids



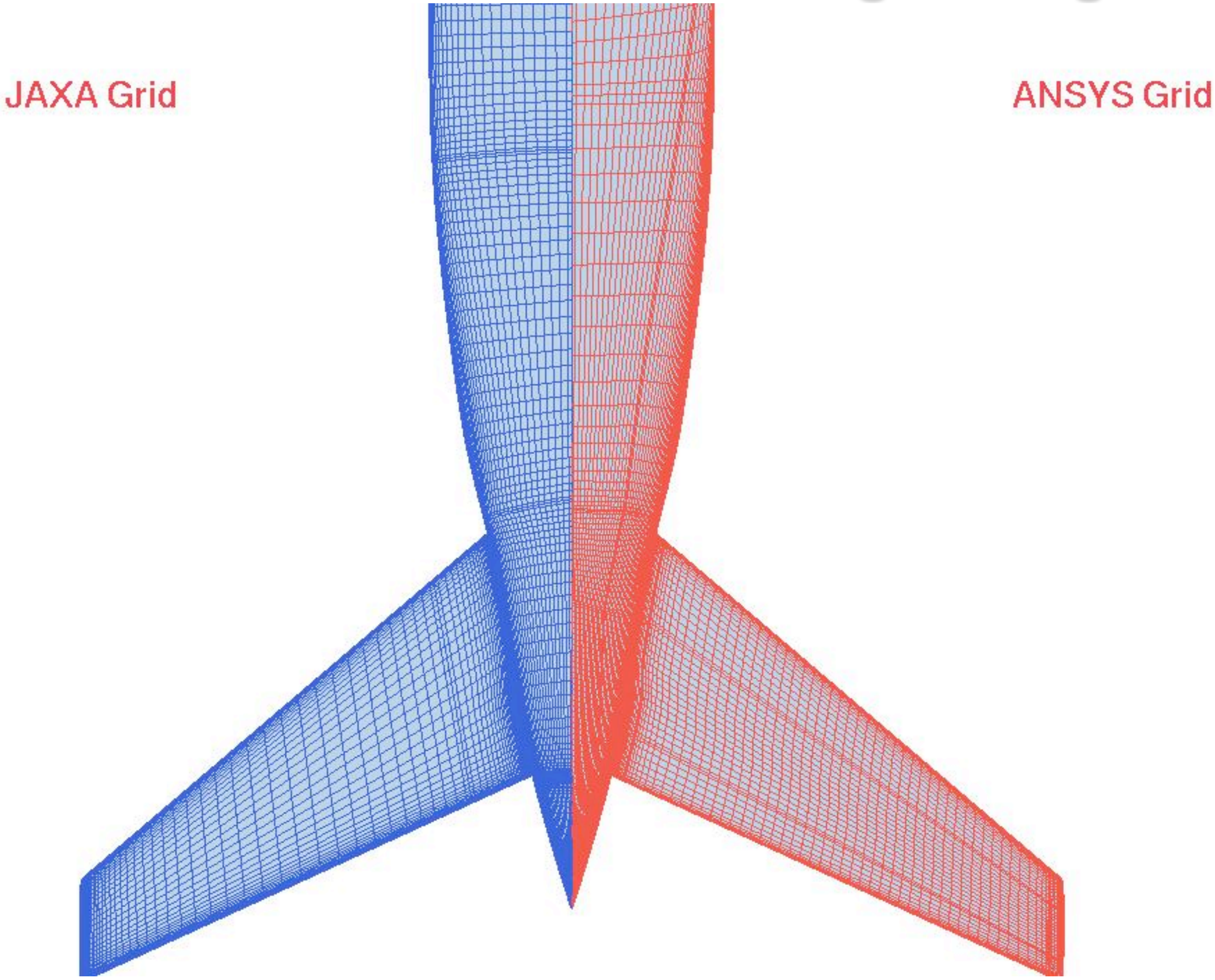
Comparison of results obtained using other grids



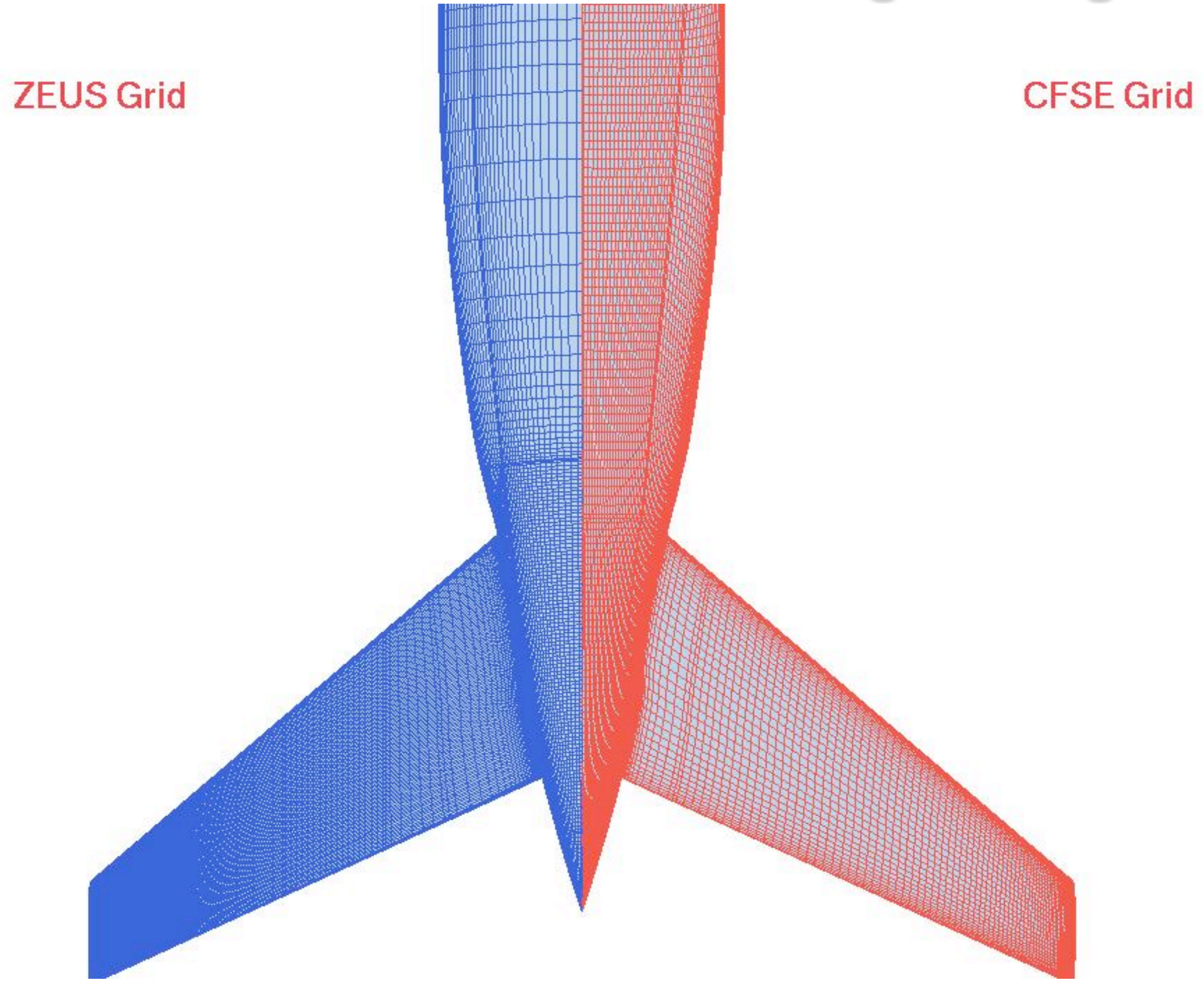
Comparison of results obtained using other grids



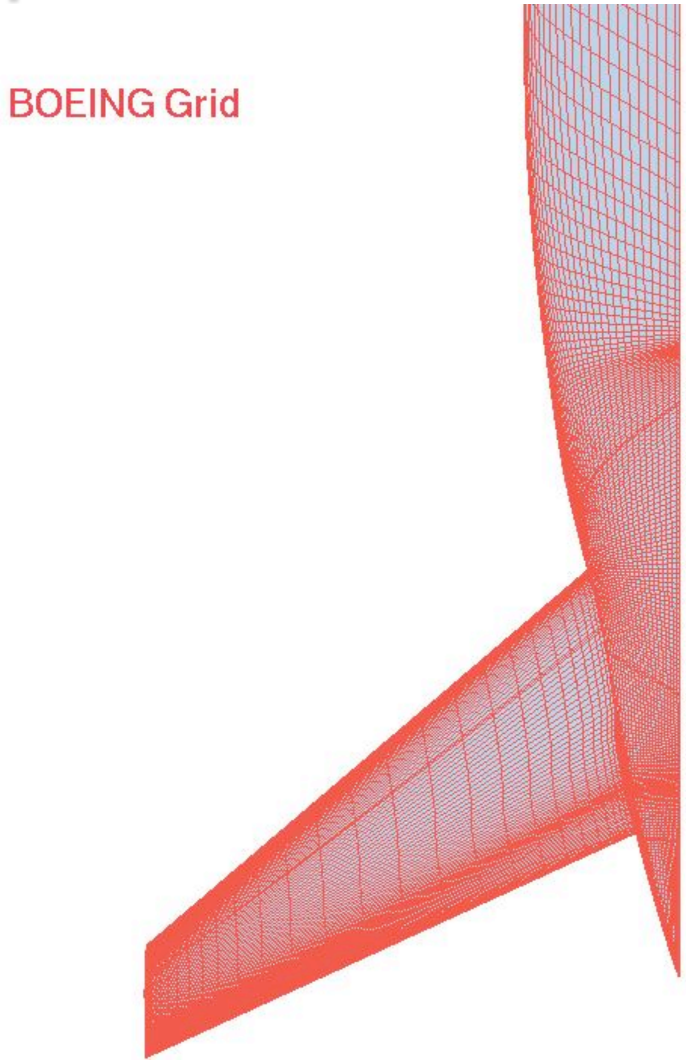
Comparison of results obtained using other grids



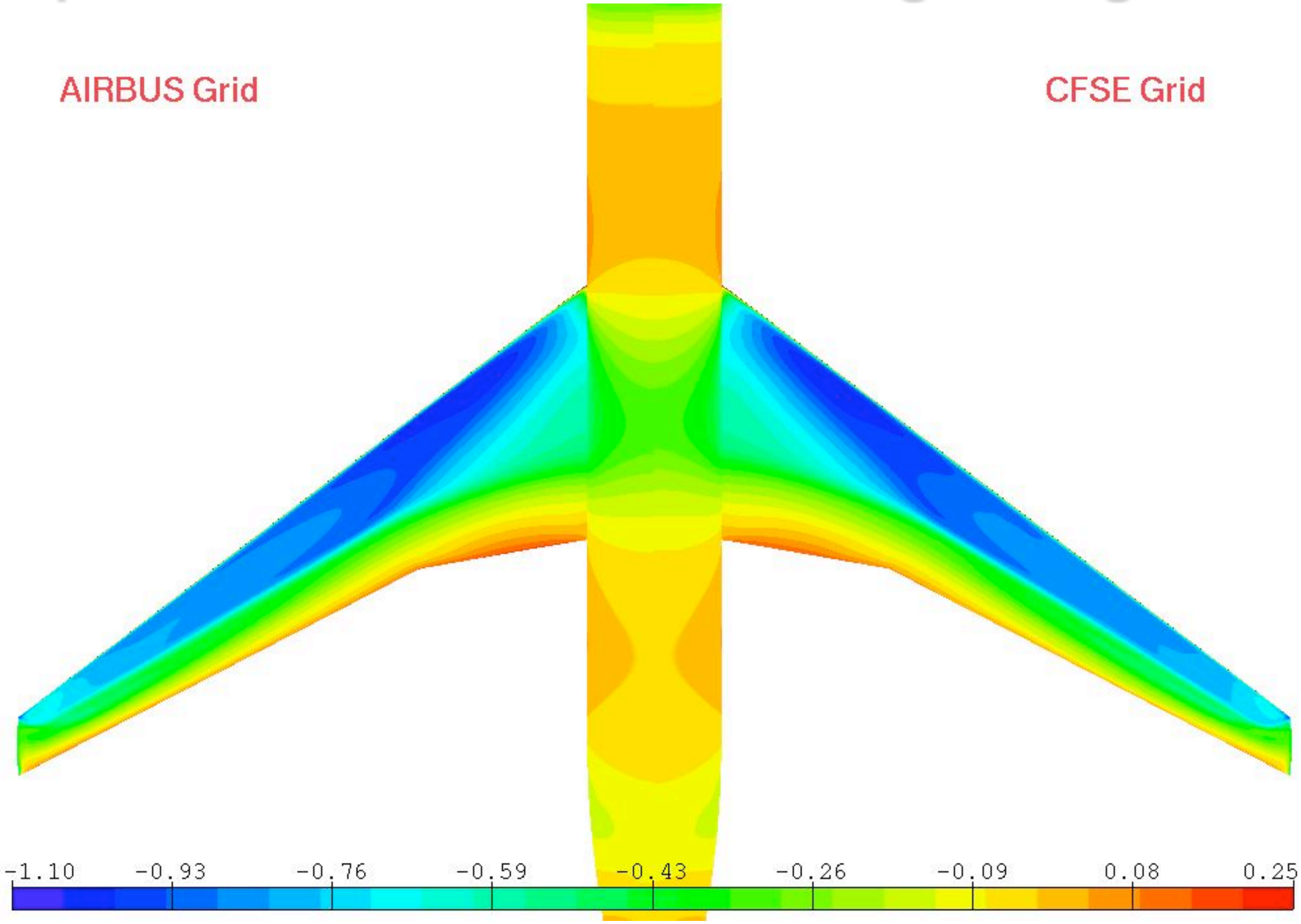
Comparison of results obtained using other grids



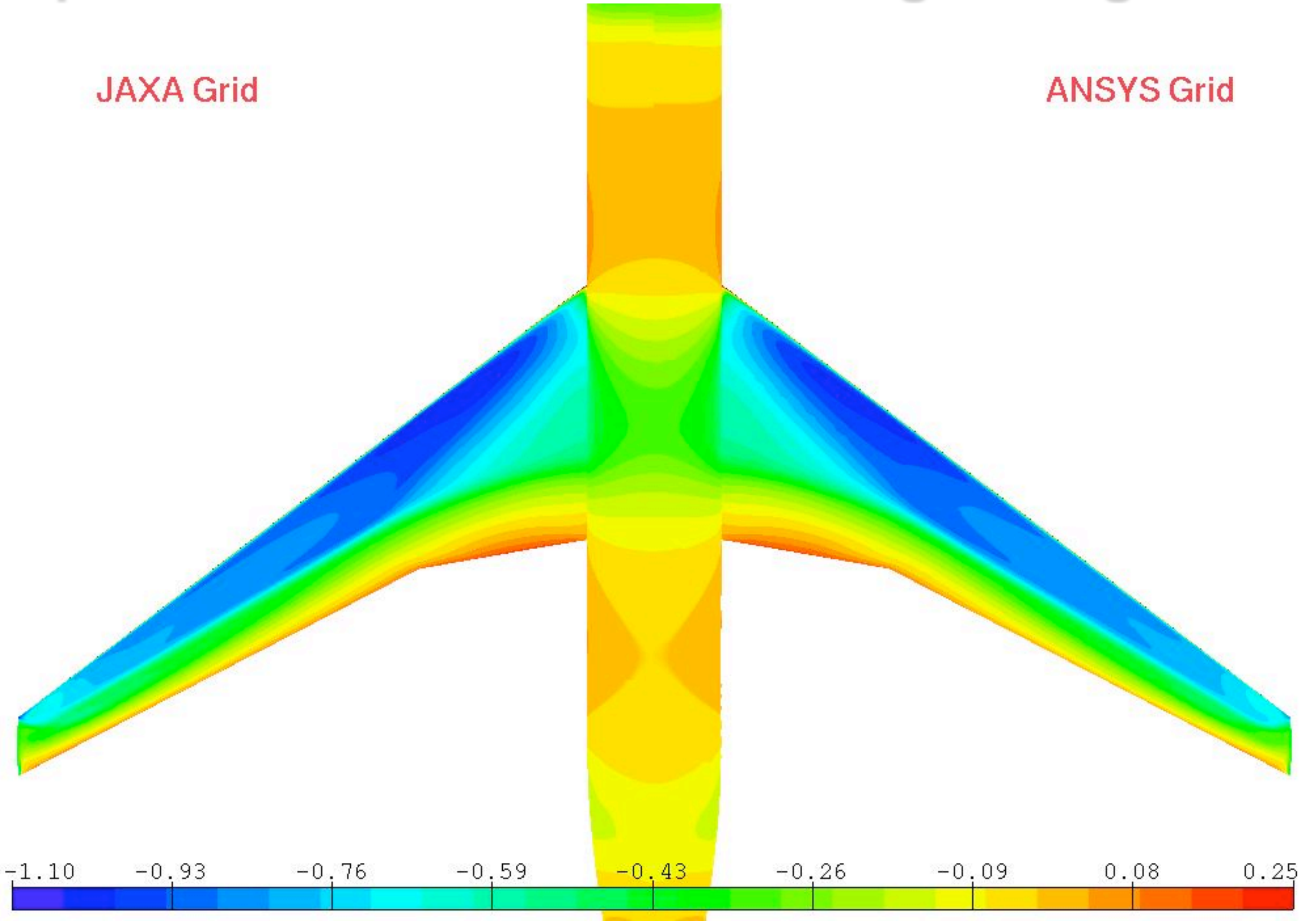
Comparison of results obtained using other grids



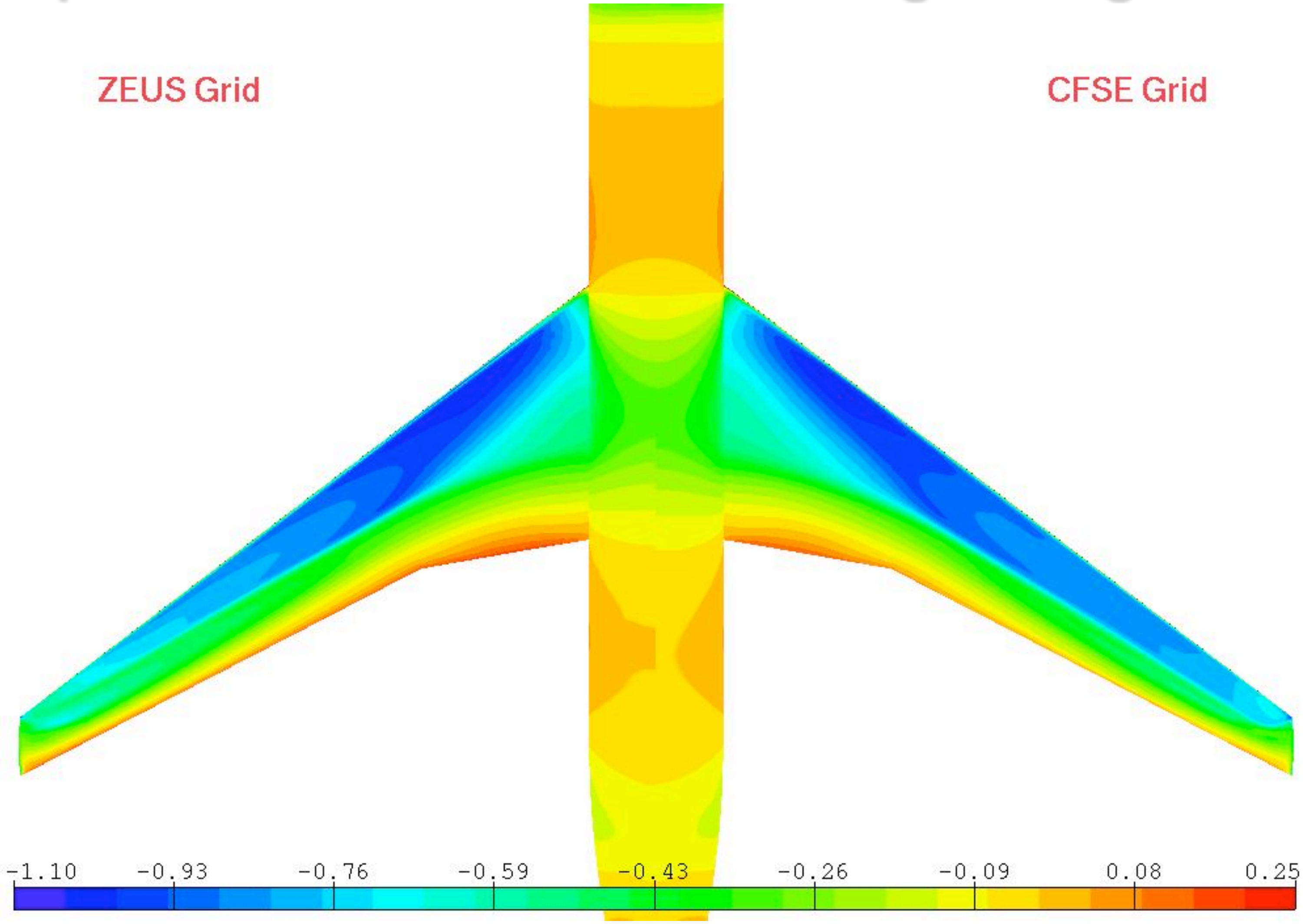
Comparison of results obtained using other grids



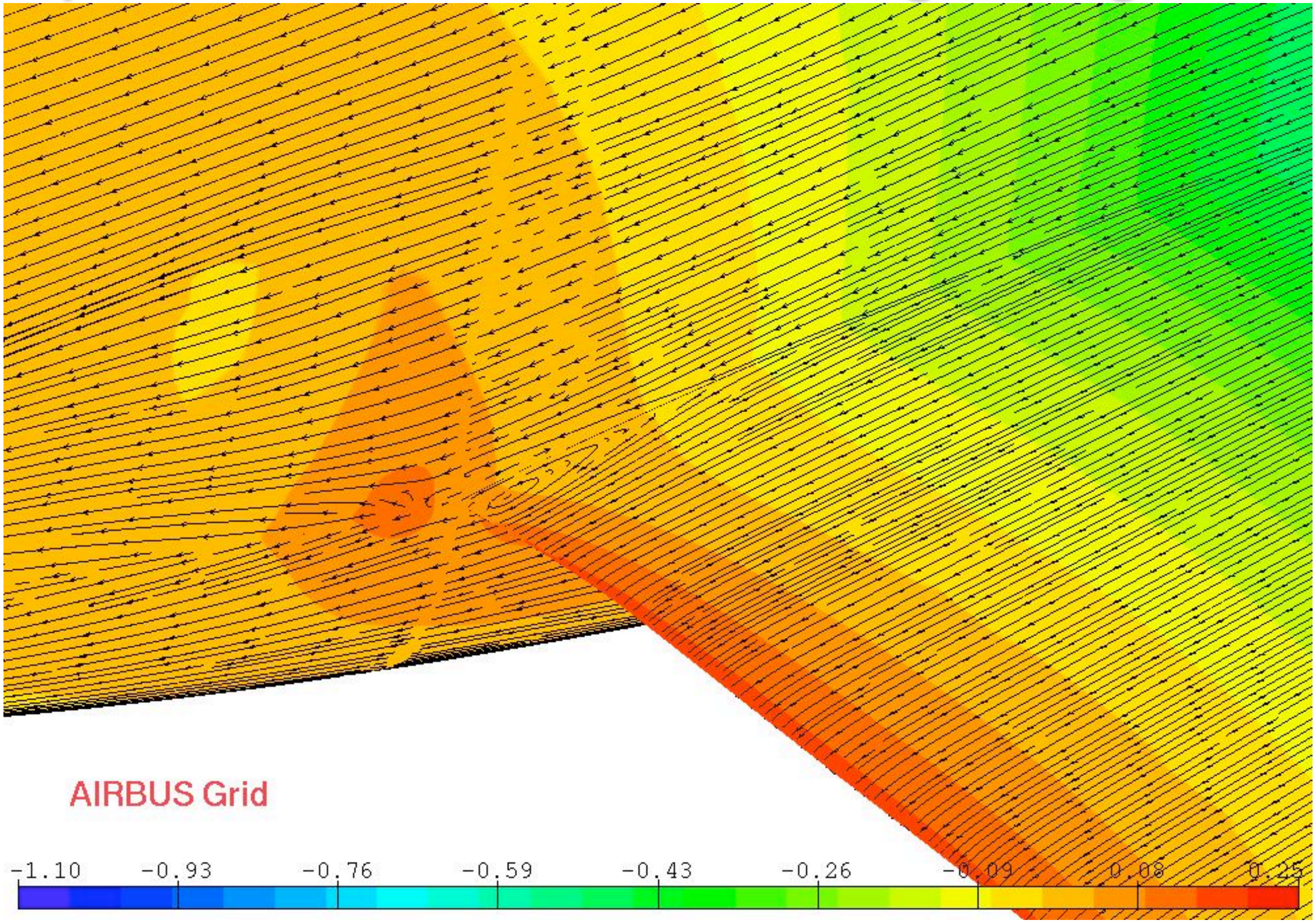
Comparison of results obtained using other grids



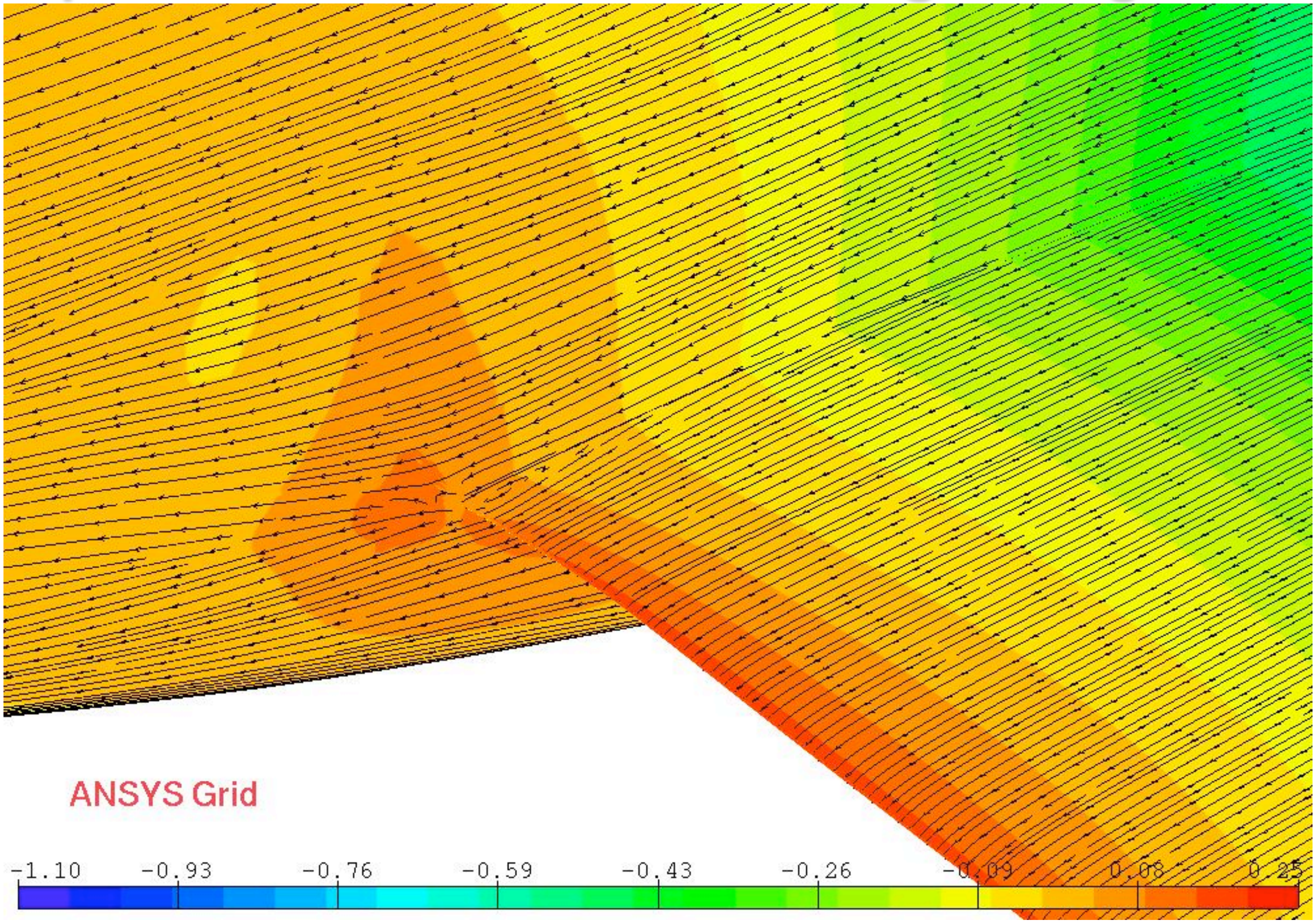
Comparison of results obtained using other grids



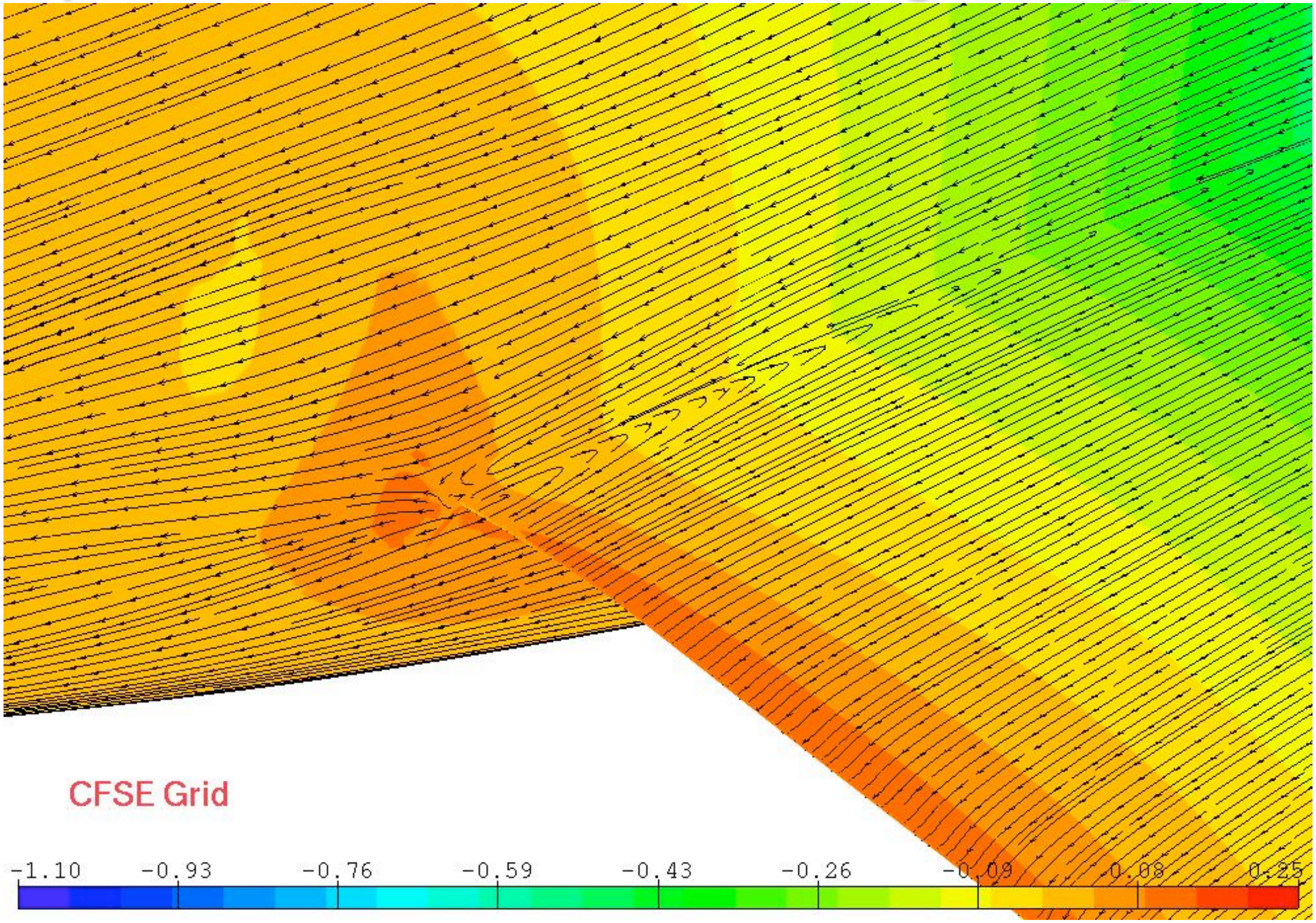
Comparison of results obtained using other grids



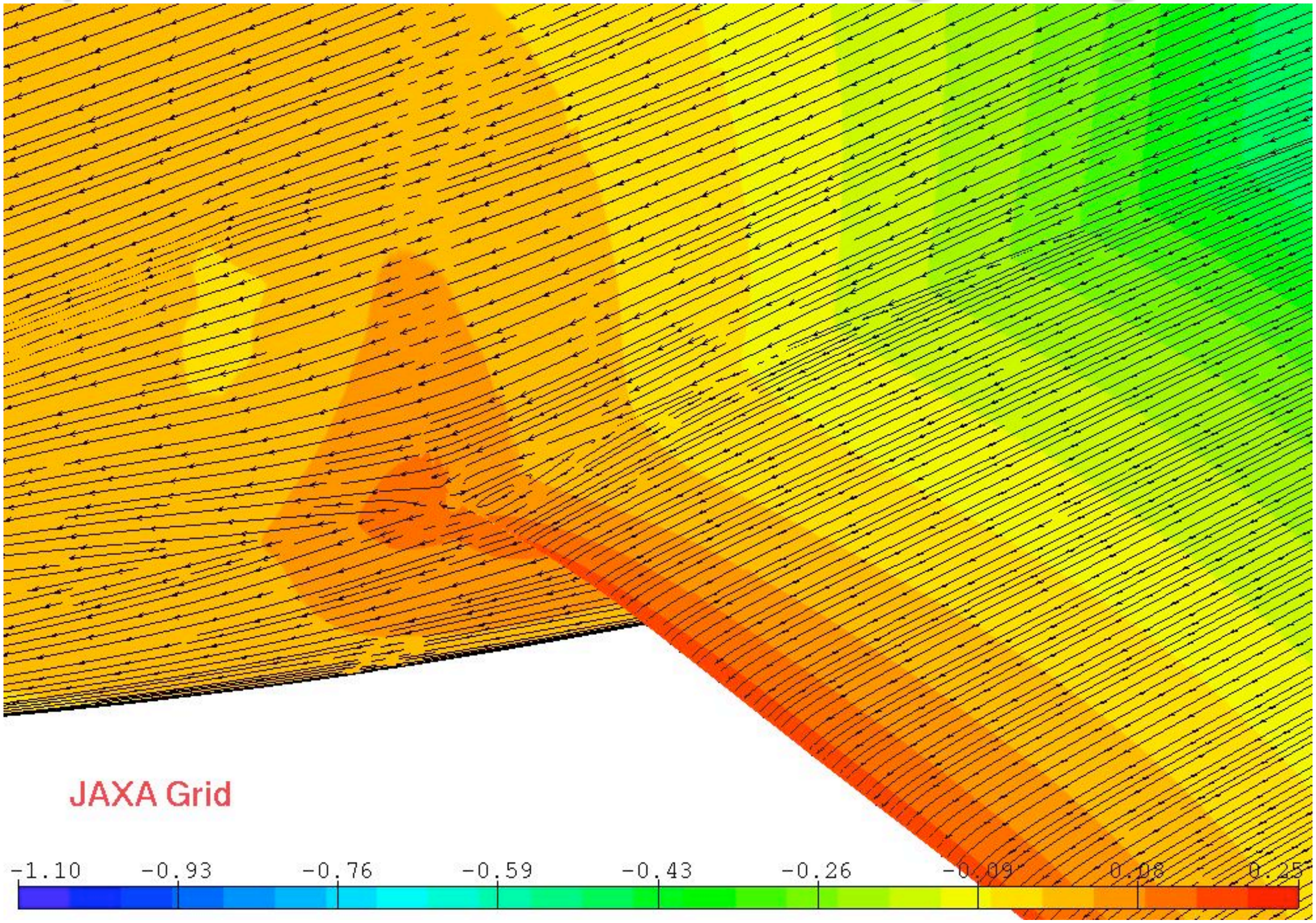
Comparison of results obtained using other grids



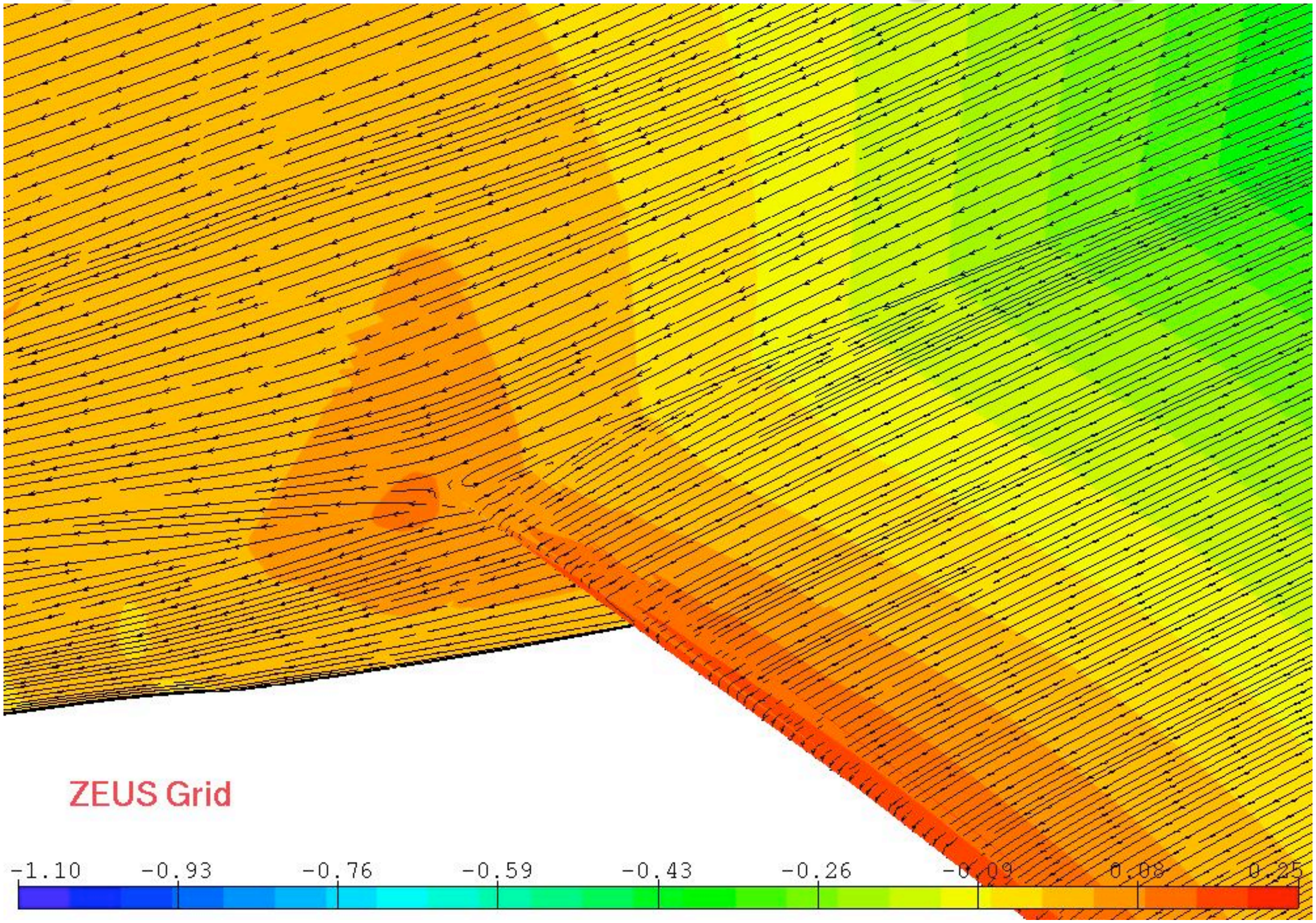
Comparison of results obtained using other grids



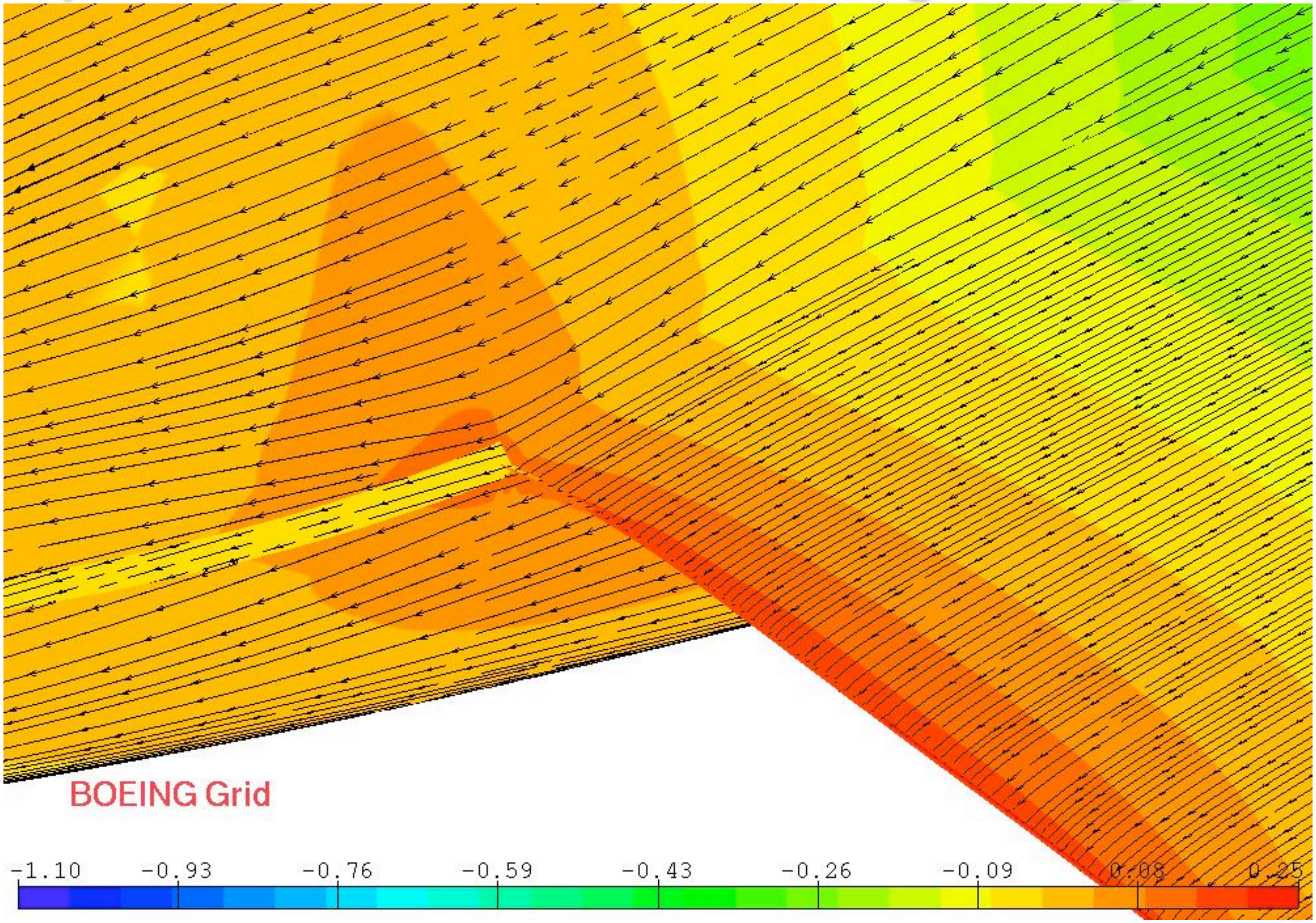
Comparison of results obtained using other grids



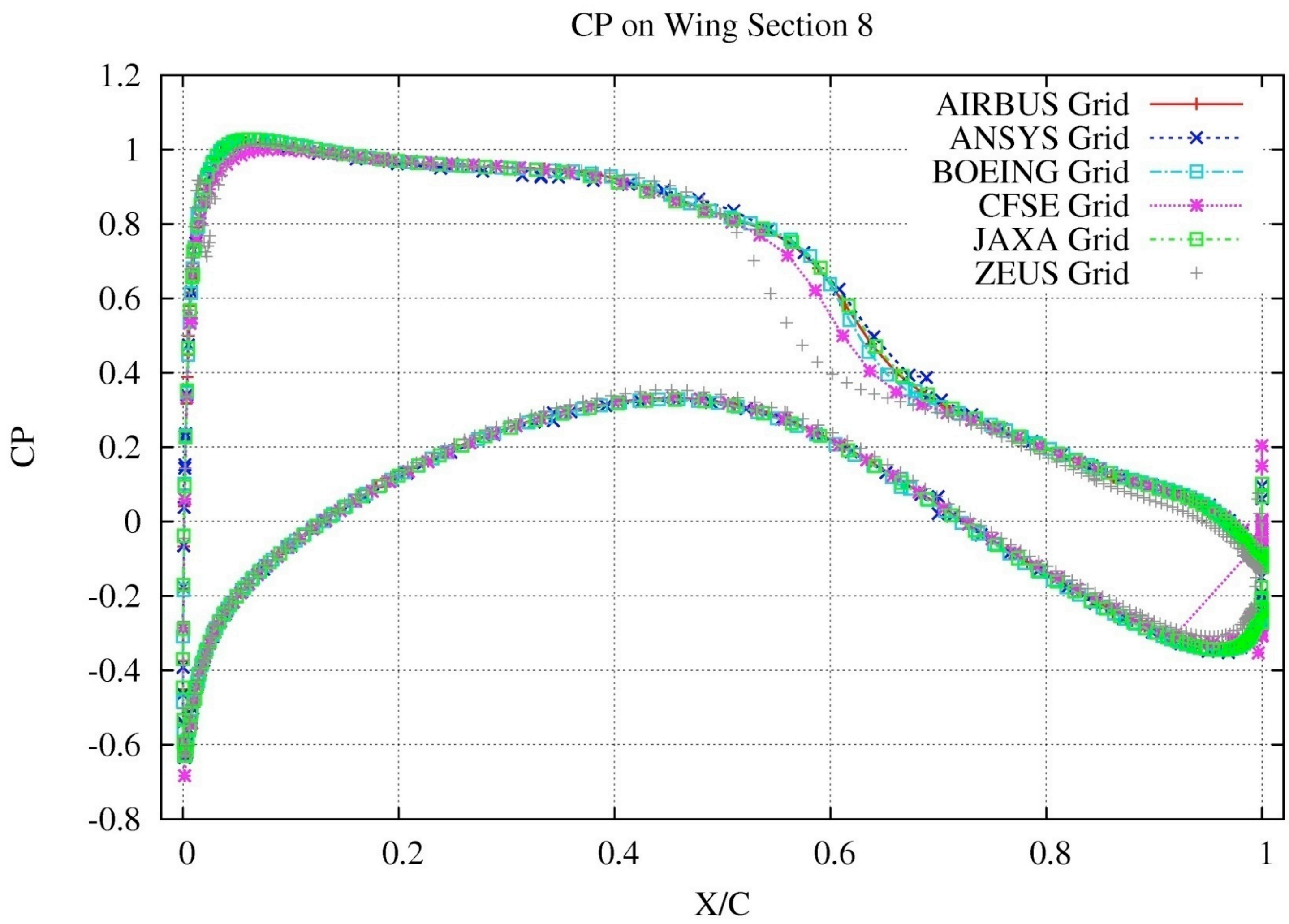
Comparison of results obtained using other grids



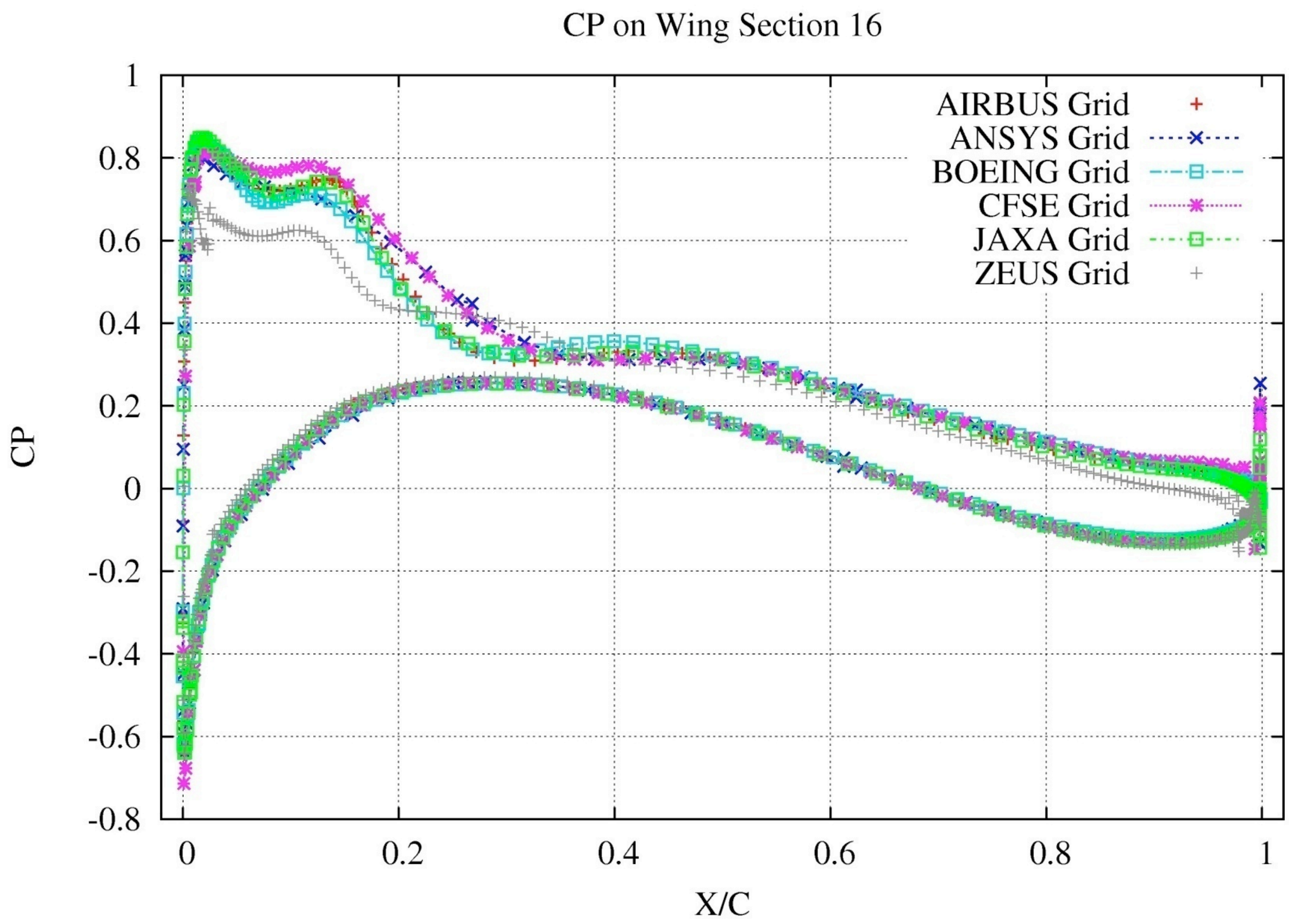
Comparison of results obtained using other grids



Comparison of results obtained using other grids



Comparison of results obtained using other grids



Concluding Remarks

Calculations for the DPW4 test cases were successfully performed.

Grid convergence for the CL=0.5 case was not completely demonstrated.

Results of simulations using different grids showed a large sensitivity of the computed results on the grid used.

We learned many things!

Recommendations

Please use SI units!

Please ask contributors to keep axis orientations + origin locations

Please use the CGNS standard to exchange grids

If the objective of the Workshop is to compare different codes and/or turbulence models, please provide a mandatory grid (on time).

Thank you for your attention.