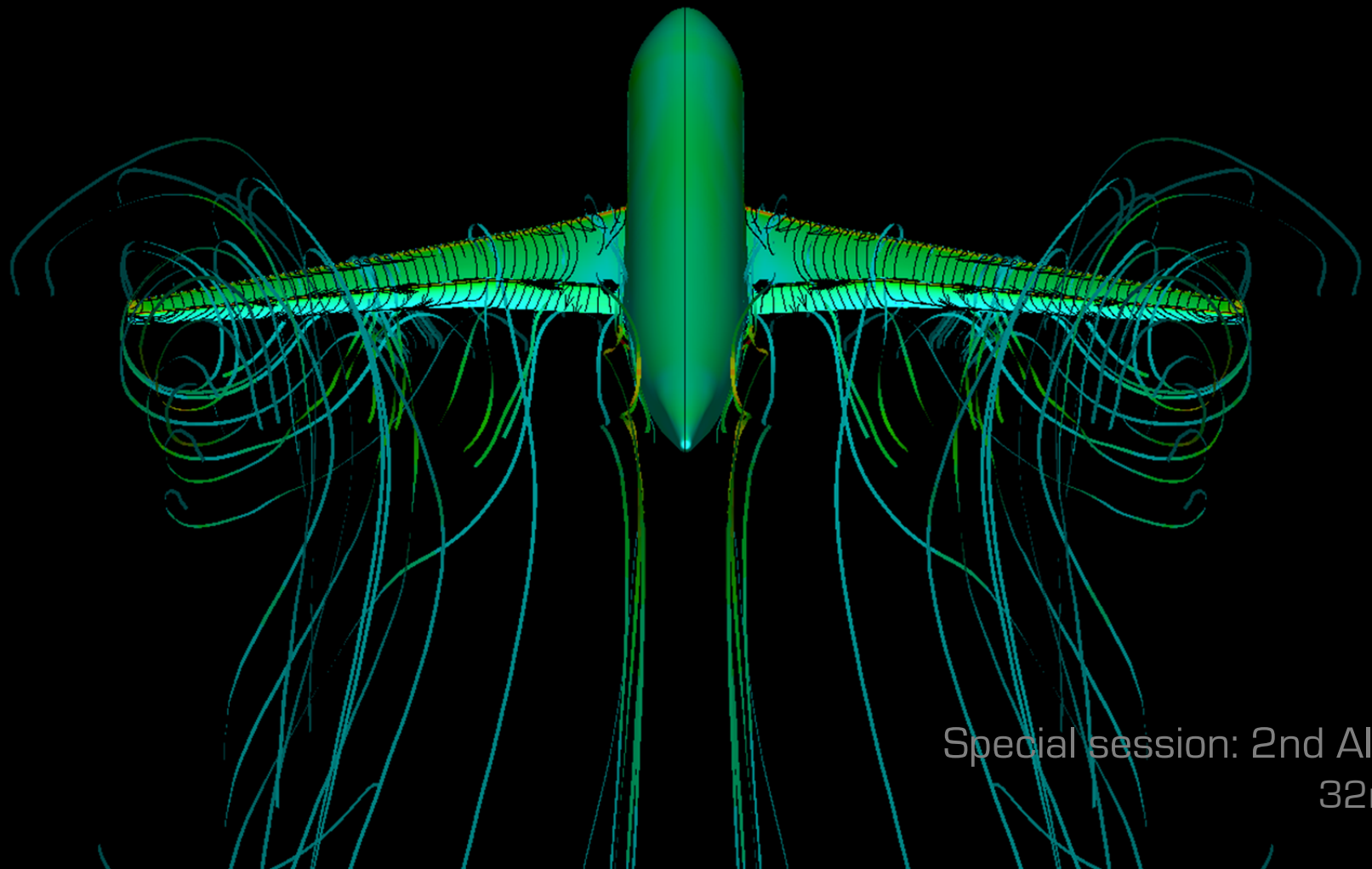
Detached Eddy Simulation of the DLR-F11 wing/body Configuration as a Contribution to the 2nd AIAA CFD High Lift Prediction Workshop



Jaime A. Escobar
Carlos G. Silva
Camilo A. Suarez

Universidad de San Buenaventura

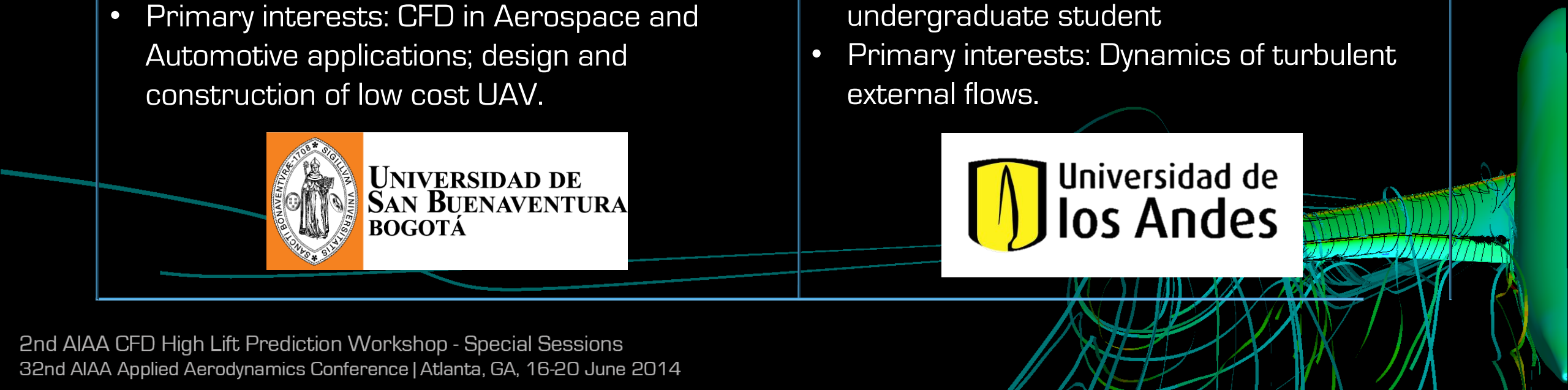
Omar D. López
Juan S. Velandia
Carlos Lara

Universidad de Los Andes

Special session: 2nd AIAA CFD High Lift Prediction Workshop
32nd AIAA Applied Aerodynamics Conference
Atlanta, GA, 16-20 June 2014

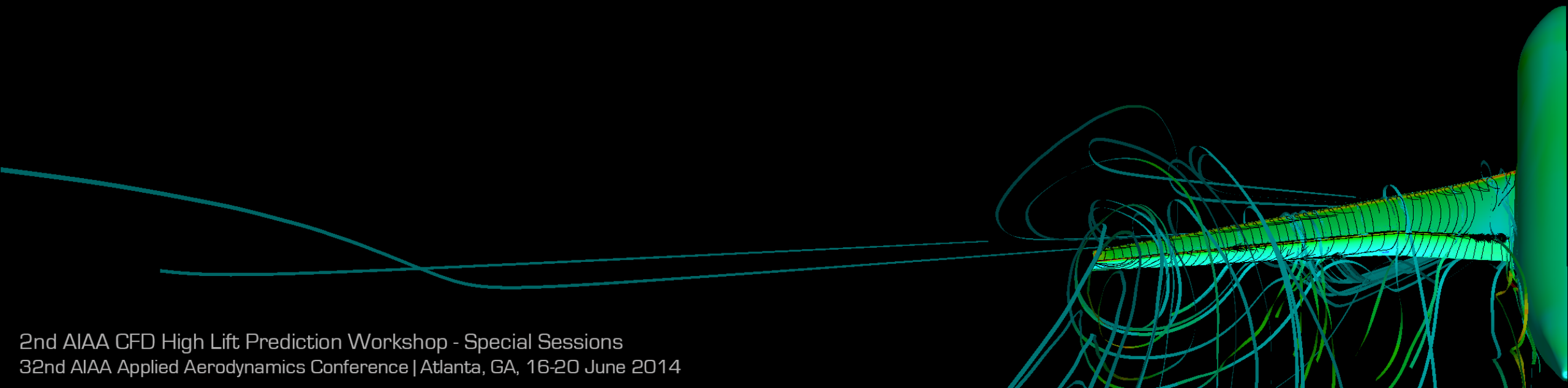
Research Team

Universidad de San Buenaventura	Universidad de Los Andes
• Research group in Aerospace Technologies (AeroTech) • Department of Aerospace Engineering • 1 professor, 2 undergraduate students. • Primary interests: CFD in Aerospace and Automotive applications; design and construction of low cost UAV.	• Research group in Computational Mechanics. • Department of Mechanical Engineering • 1 professor, 1 graduate student, and 1 undergraduate student • Primary interests: Dynamics of turbulent external flows.



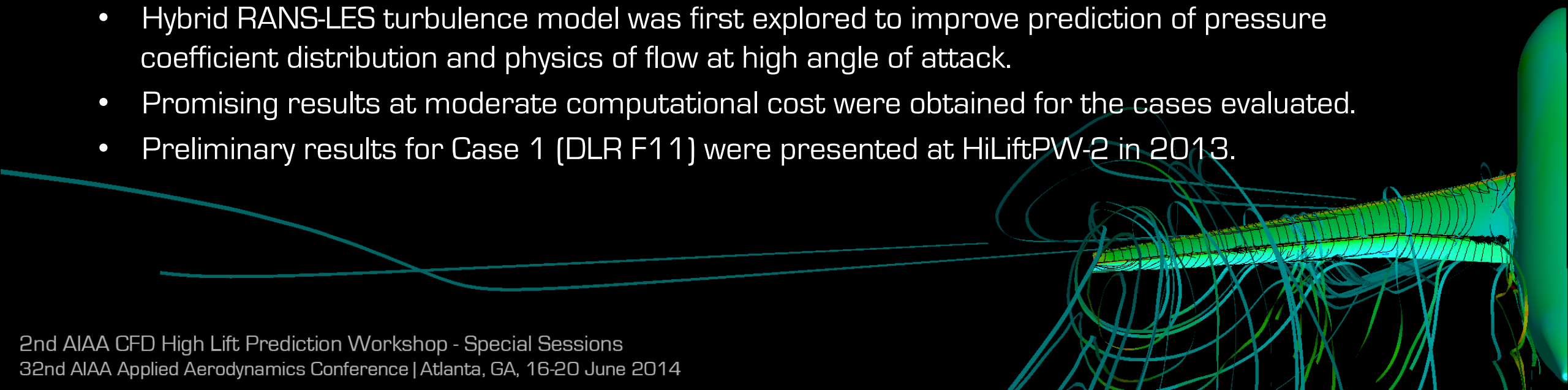
Motivation

- Develop experience in numerical simulation of external aerodynamic problems.
- Assess our capabilities to solve complex flows involved in real-life engineering problems.
- Test hybrid turbulence models and mesh adaption techniques in well studied problems for which reliable experimental and numerical data are available.
- Contribute to the goals of the High Lift Prediction Workshop.

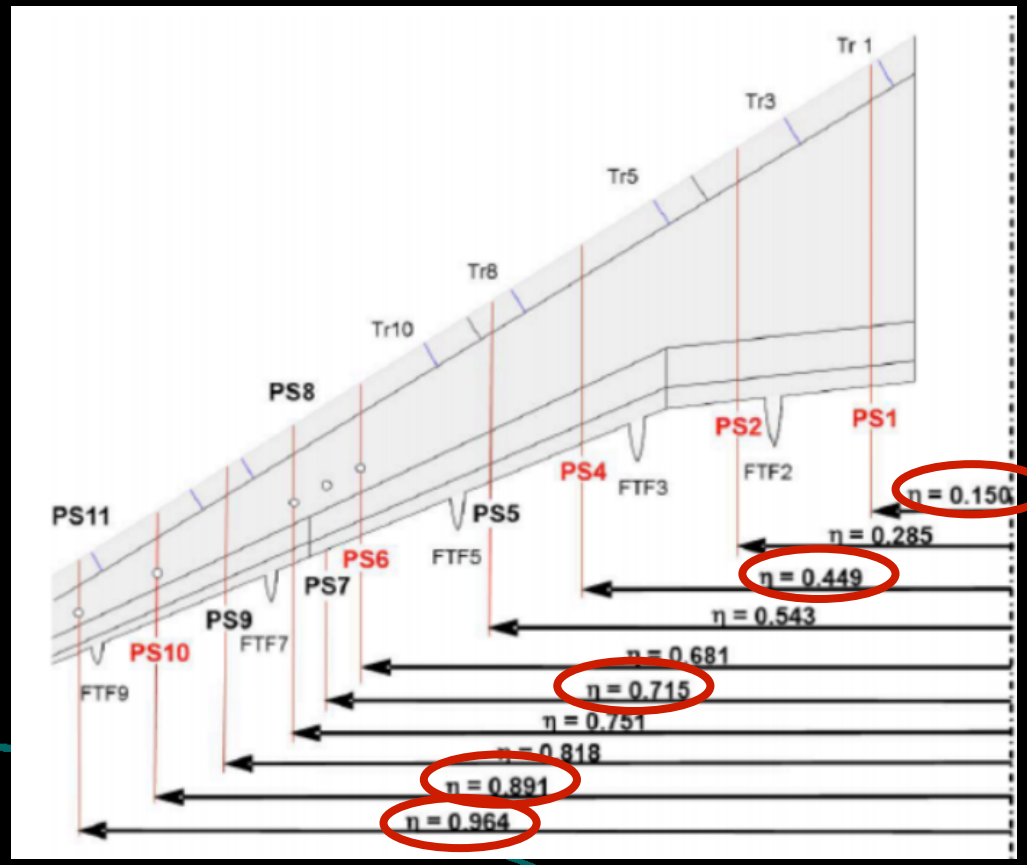


Background

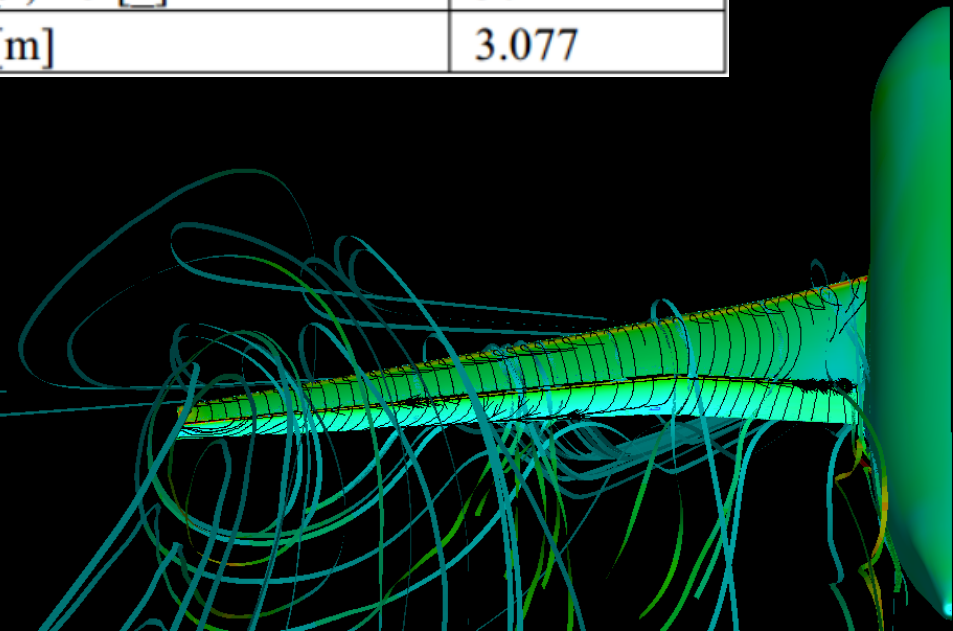
- The DLR-F11 wing/body high lift configuration was selected for the HiLiftPW-2.
- There is reliable wind tunnel test data obtained in the framework of the EC-Project EUROLIFT. The experimental data was obtained in the low speed wind tunnel of AIRBUS-Deutschland named B-LSWT and in the European Transonic Wind Tunnel ETW3.
- First contribution to the High Lift Prediction Workshop was presented at the Special Sessions in 2012.
- Hybrid RANS-LES turbulence model was first explored to improve prediction of pressure coefficient distribution and physics of flow at high angle of attack.
- Promising results at moderate computational cost were obtained for the cases evaluated.
- Preliminary results for Case 1 (DLR F11) were presented at HiLiftPW-2 in 2013.



Background (Cont'd)



Half span , s [m]	1.4
Wing reference area [m2]	0.41913
Mean aerodynamic chord (MAC) [m]	0.34709
Aspect Ratio , _ [-]	9.353
Taper Ratio , _ [-]	0.3
0.25 Chord Sweep , '25 [_]	30
Fuselage Length [m]	3.077



Wing Geometry & Dimensions

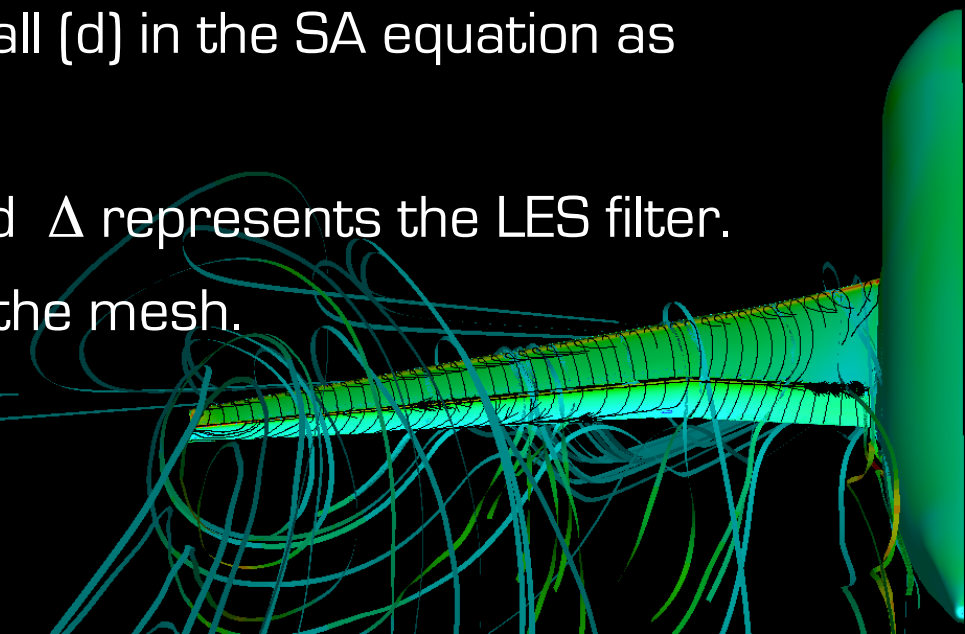
Turbulence Model

- Due to simplicity and reliability the RANS Spalart-Allmaras model was used.
- Reduced computational cost and satisfactory numerical results, are the characteristics that make SA model very attractive for aerodynamic applications.
- Hybrid RANS- LES model such as Detached-Eddy simulation (DES), perfom RANS close to the wall and LES elsewhere.
- DES is obtained by redefining the distance to the wall (d) in the SA equation as

$$\tilde{d} = \min(d, C_{DES}\Delta)$$

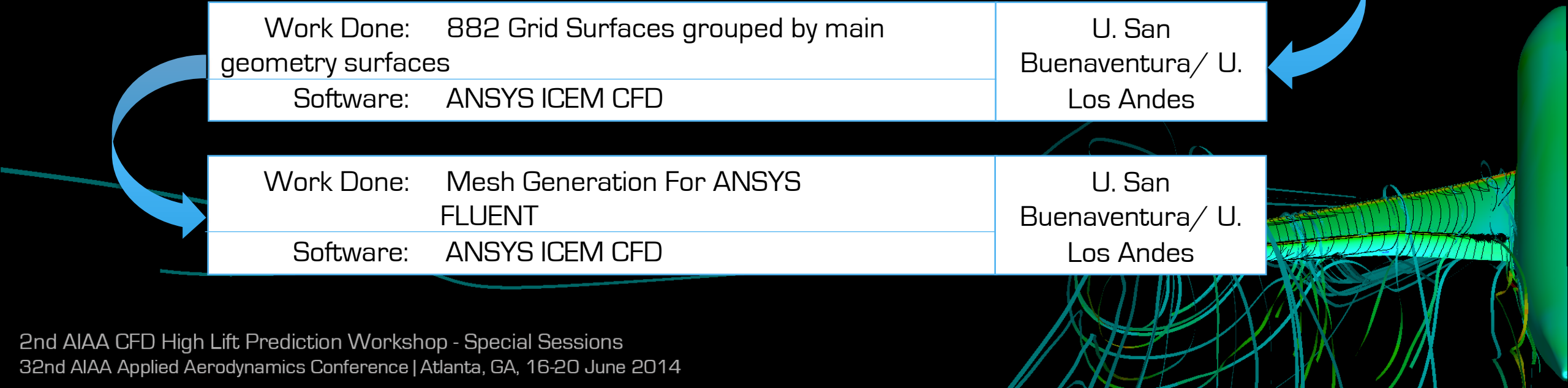
where CDES is a model constant equal to 0,65 and Δ represents the LES filter.

- Transition between RANS and LES is controlled by the mesh.



Grids

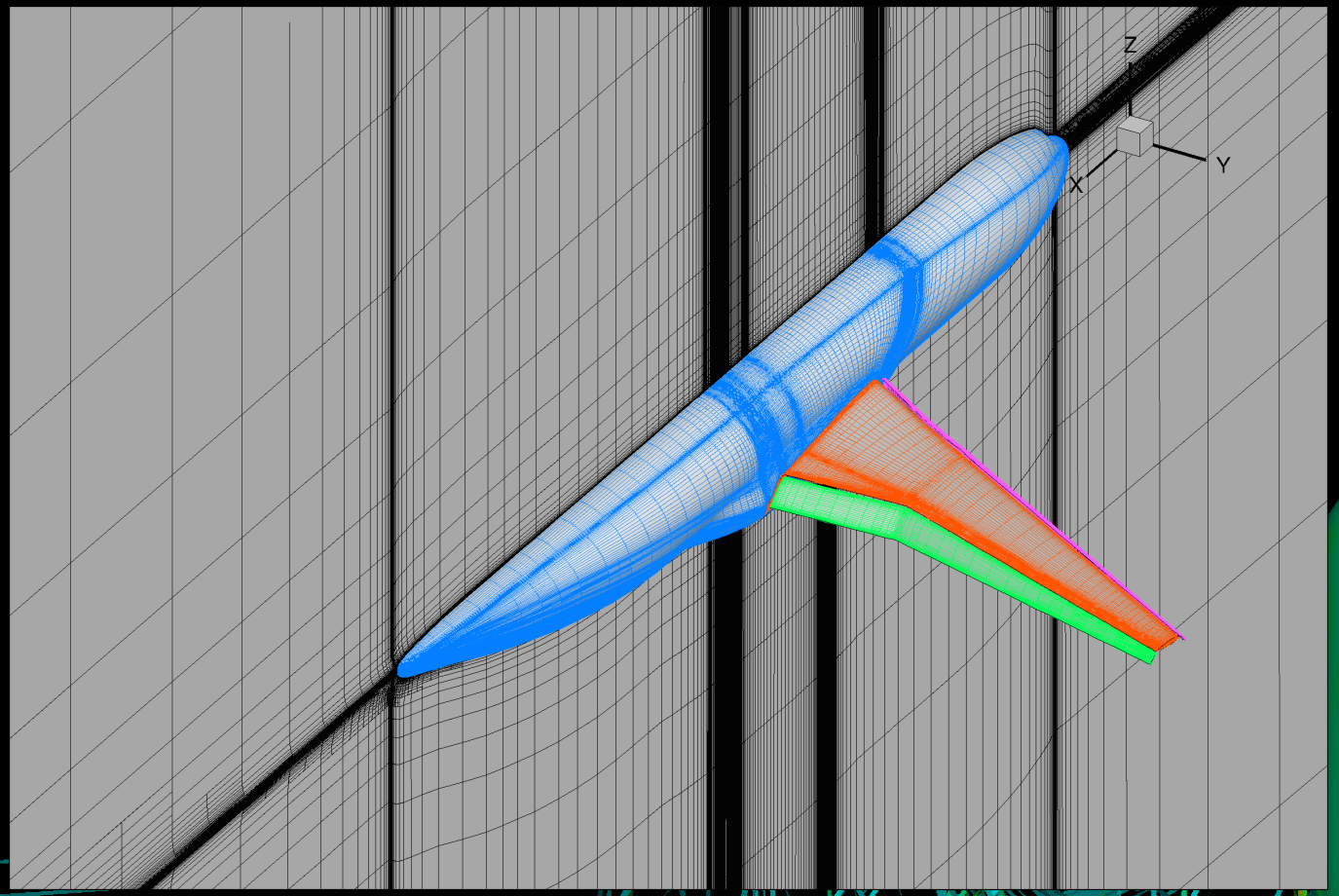
Grid : A_str_1to1_Case 1 config2_v2 Type : Multi-zone one-to-one Software : ANSYS ICEM CFD	Boeing - Huntington Beach
Grid : A_str_1to1_Case 1 config2_v2 Type : Unstructured version of Boeing´s Grids Software : Unknown	C. Rumsey - NASA
Work Done: 882 Grid Surfaces grouped by main geometry surfaces Software: ANSYS ICEM CFD	U. San Buenaventura/ U. Los Andes
Work Done: Mesh Generation For ANSYS FLUENT Software: ANSYS ICEM CFD	U. San Buenaventura/ U. Los Andes



Grids (Cont'd)

Boundary conditions for all grids	
Free-stream boundaries:	Pressure Farfield
Symmetry plane:	Symmetry
Airplane surfaces:	Wall

Grid:	Coarse
Number of cells:	9,556,725
Grid:	Medium
Number of cells:	31,998,440
Grid:	Fine
Number of cells:	100,561,536



Grids (cont'd)

Adaption Methods

Local adaption

↓

Solution from Coarse Grid

↓

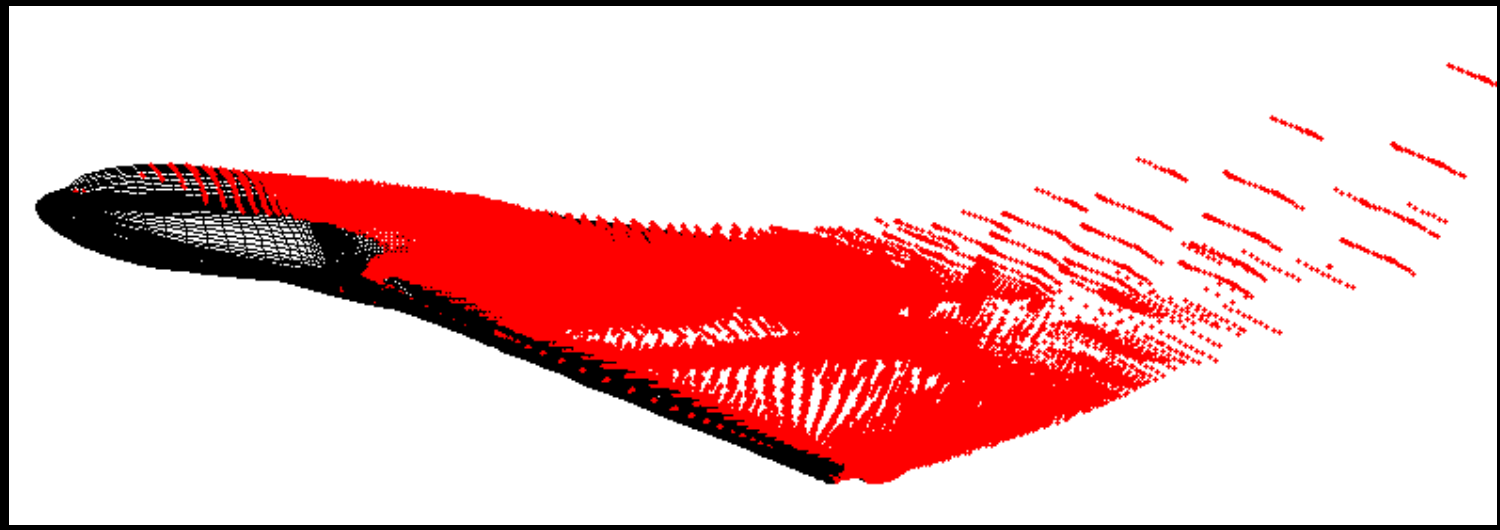
Grid Isovalue Adaption Tool

↓

Range of TVR values predicted by SA turbulence model.

↓

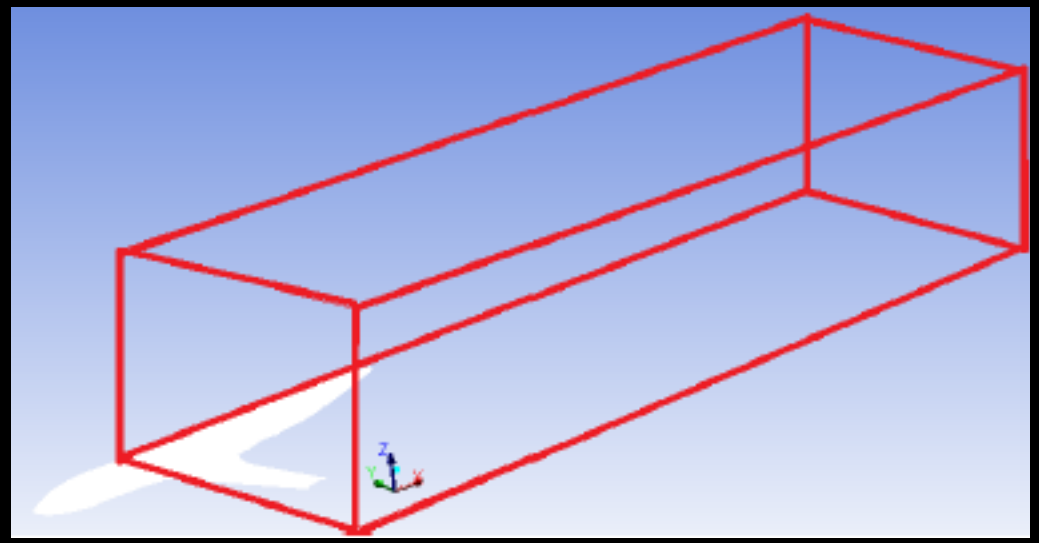
Cells in the boundary layer smaller than $(1\% \text{ MAC})^3$ ~0.05 cm^3 were not refined.



Angles of Attack Evaluated:	21° and 22.4°
Original grid size:	9,556,725
Refined grid size:	11,440,026

Grids (cont'd)

Adaption Methods



Region adaption

↓

Solution from Coarse Grid

↓

Region Adaption Tool

↓

Region of the flowfield over the wing and downstream

↓

Cells in the boundary layer smaller than $(1\% \text{ MAC})^3$ were not refined

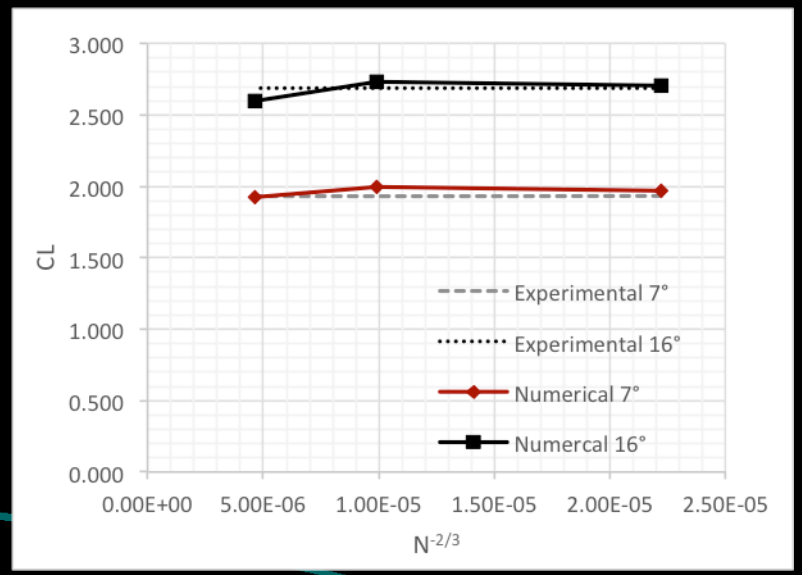
Angles of Attack Evaluated:	21°
Original grid size:	9,556,725
Refined grid size:	16,253,471

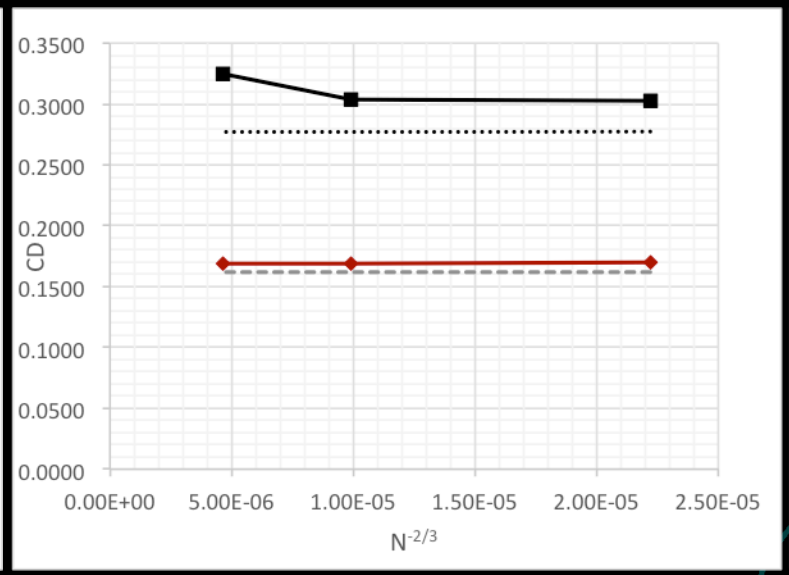
Solver (Fluent)

			RANS Simulations	RANS-LES Simulations
Solver:			Pressure-Based Segregated Algorithm	Pressure-Based Segregated Algorithm
P-V Coupling Algorithm:			SIMPLEC	SIMPLEC
Spatial Discretization:	Pressure:		Standard (First iterations)	Second-Order Upwind Scheme
			Second-Order Upwind Scheme	
	Modified Turbulent Viscosity:		First-Order Upwind Scheme (First iterations)	Second-Order Upwind Scheme
			Second-Order Upwind Scheme	
	Density:		Second-Order Upwind Scheme	Second-Order Upwind Scheme
	Momentum:		Second-Order Upwind Scheme	Bounded Central Differencing
	Energy:		Second-Order Upwind Scheme	Second-Order Upwind Scheme
Gradients of the Scalar Quantities:			Green-Gauss Node Based Theorem	Green-Gauss Node Based Theorem
Time Step Size:			Steady	9.2×10^{-5} sec.

Results

Grid convergence study

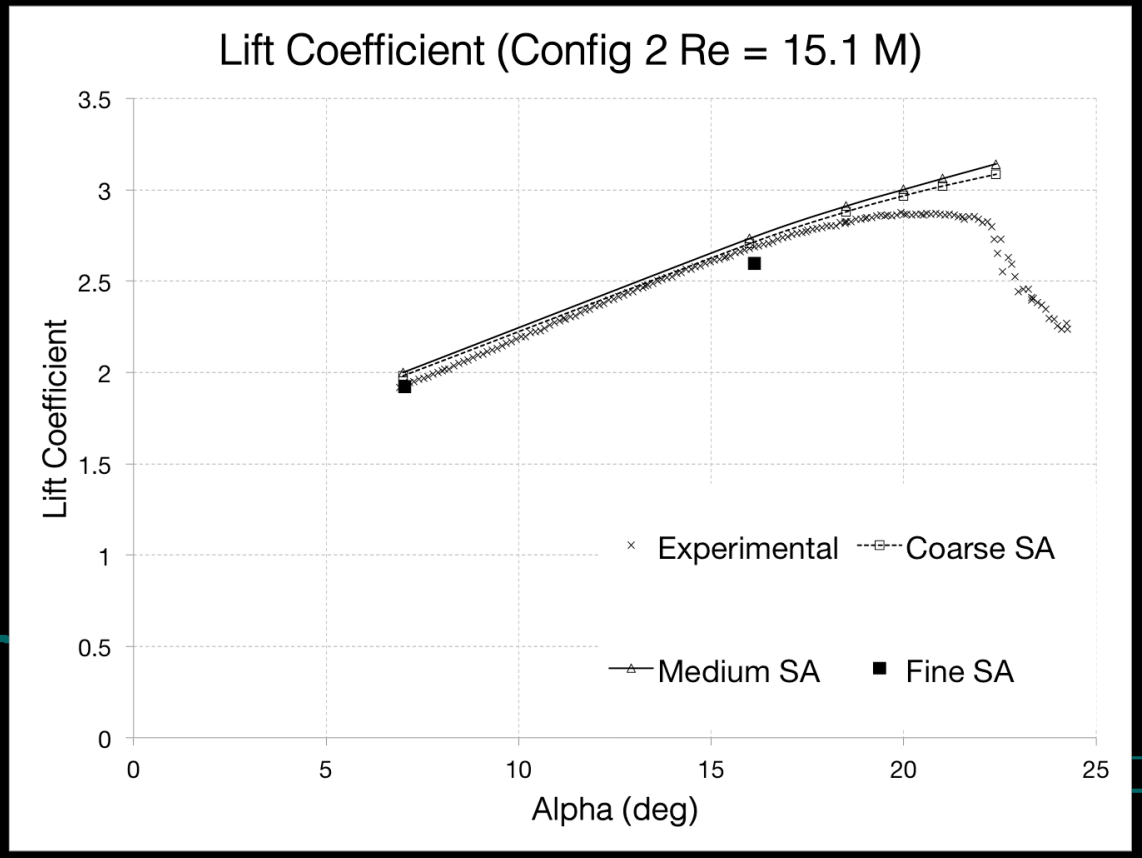


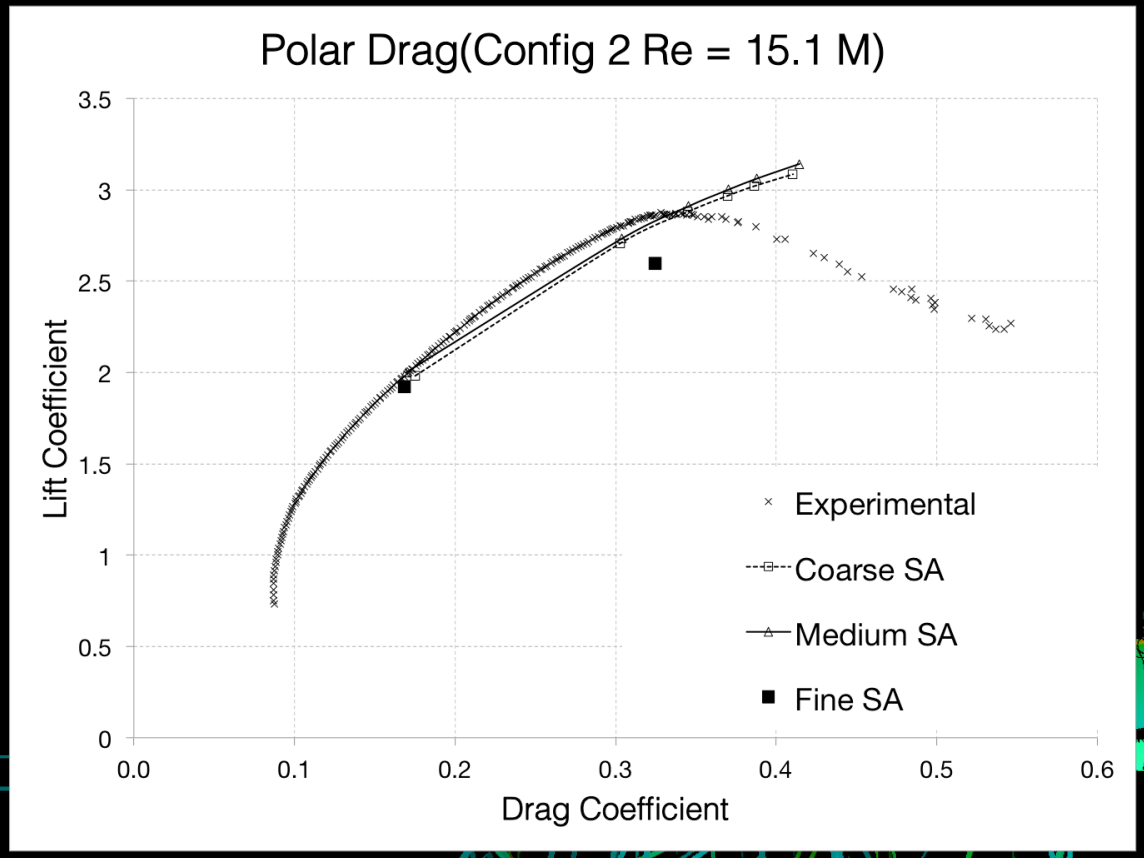


Grid convergence study for angles at 7° and 16°

Results (Cont'd)

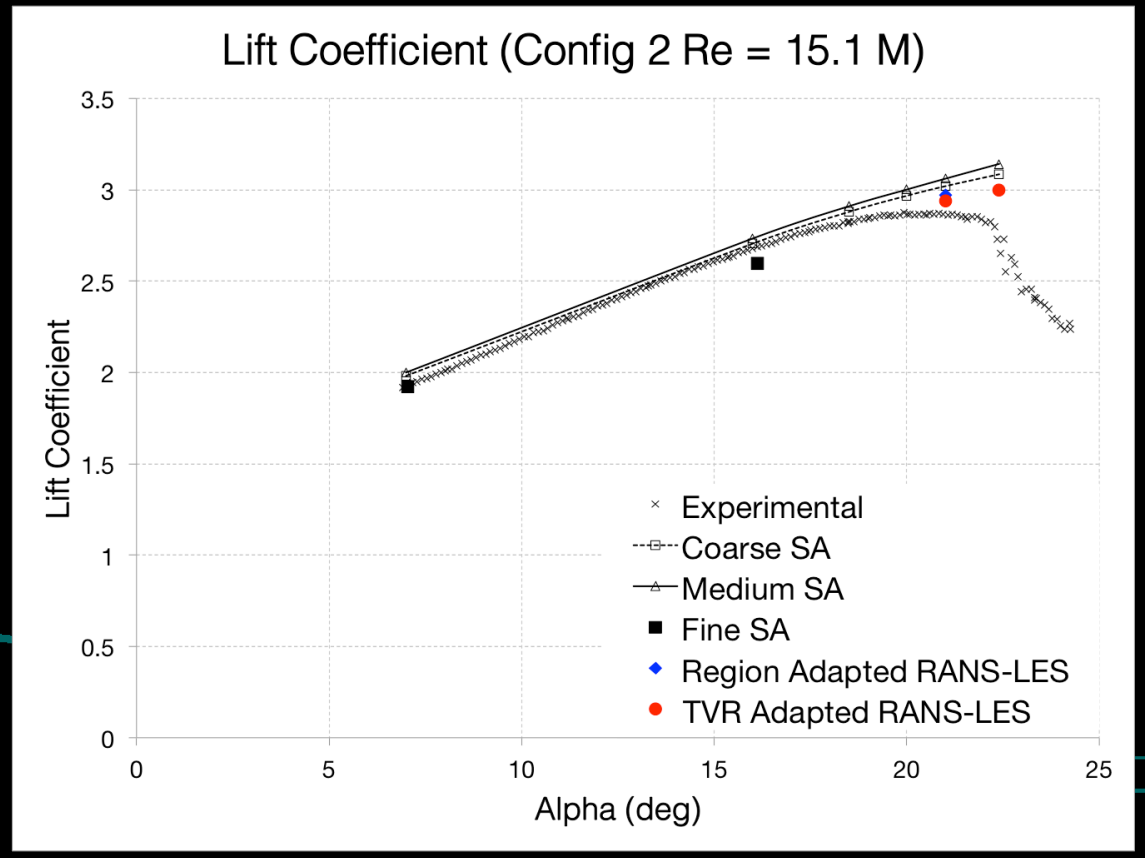
Prediction without grid refinement

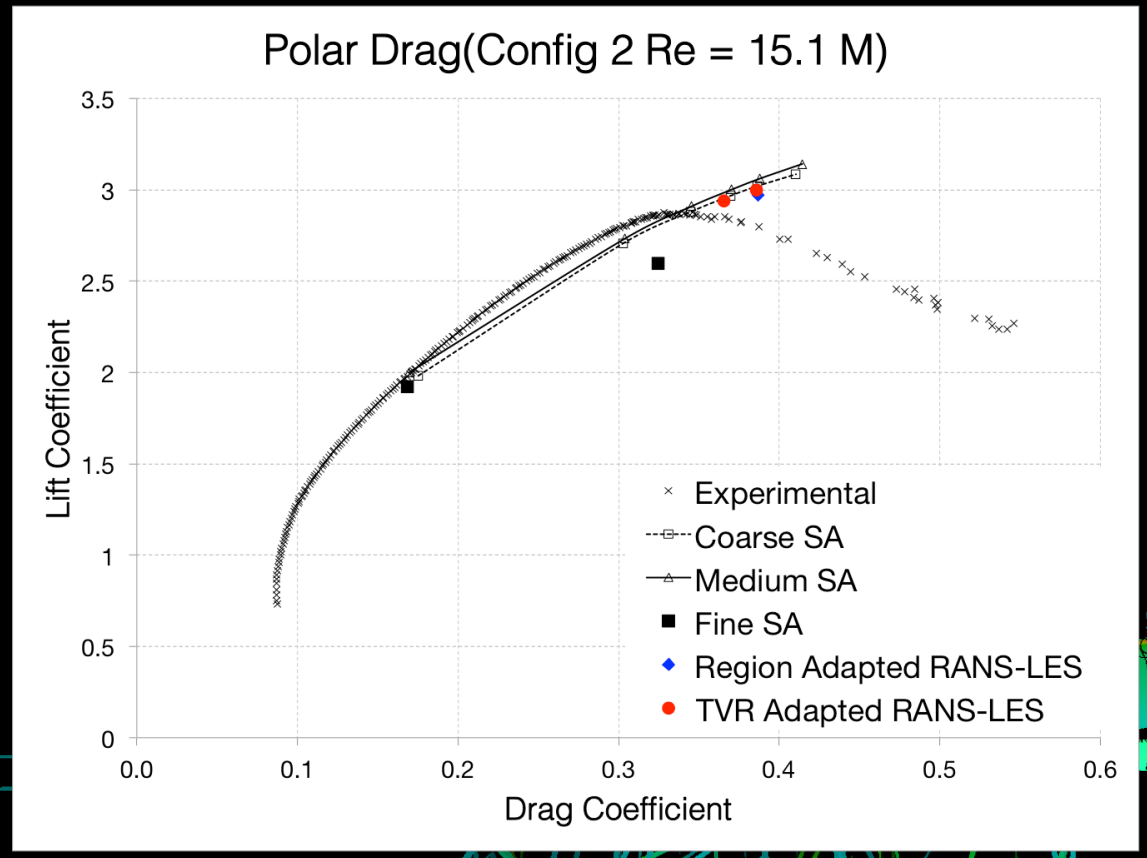




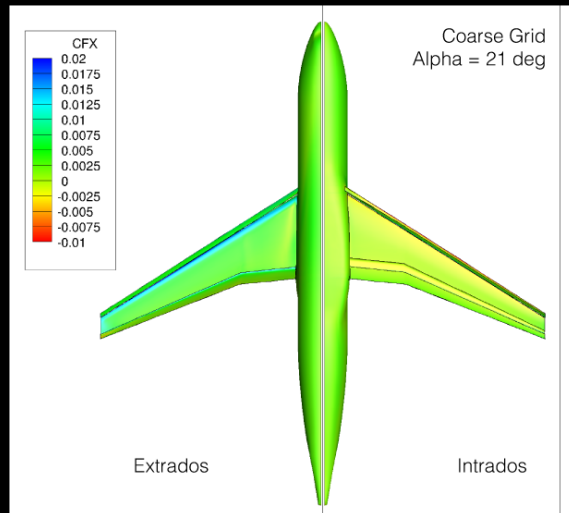
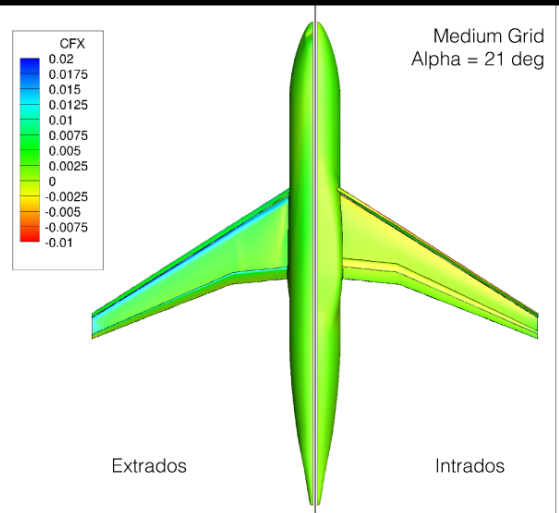
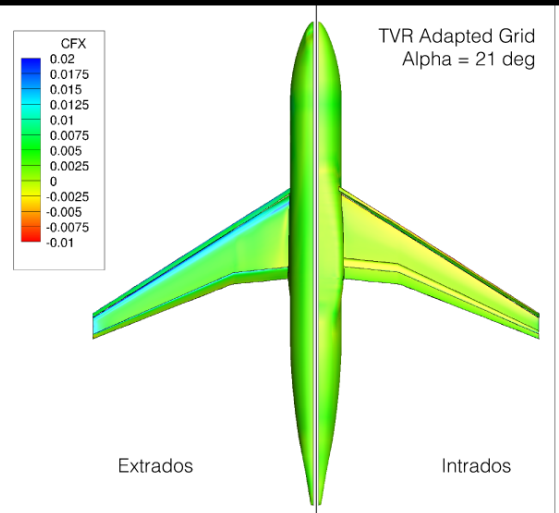
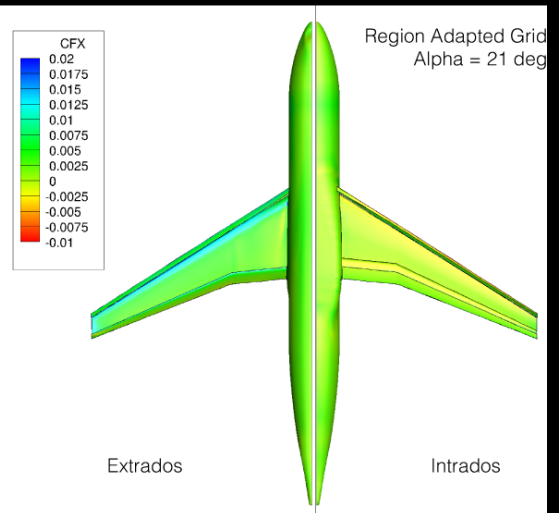
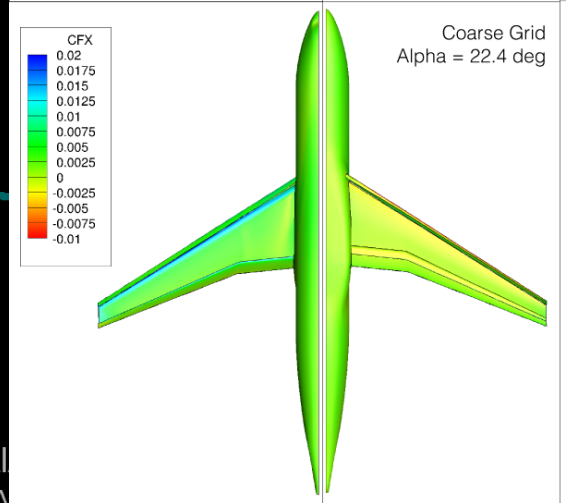
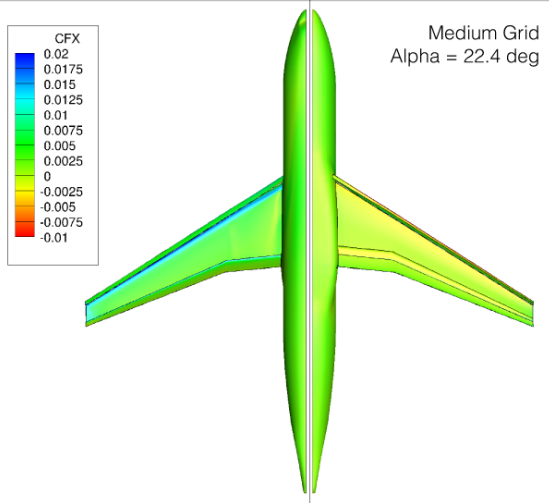
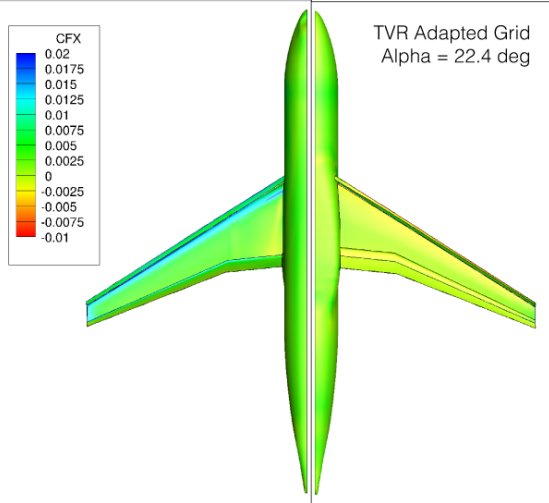
Results (Cont'd)

Prediction with grid refinement

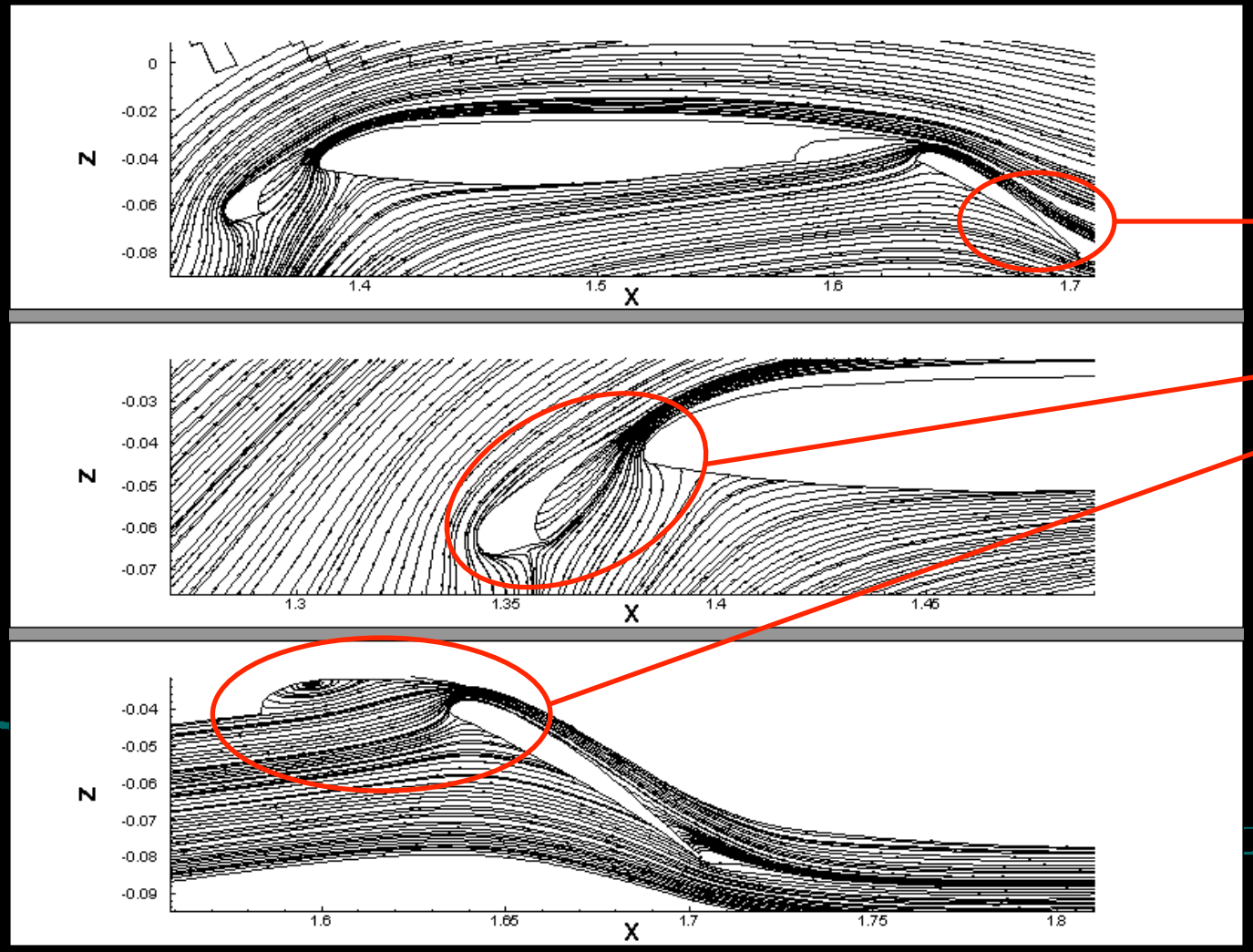




Results (Cont'd)

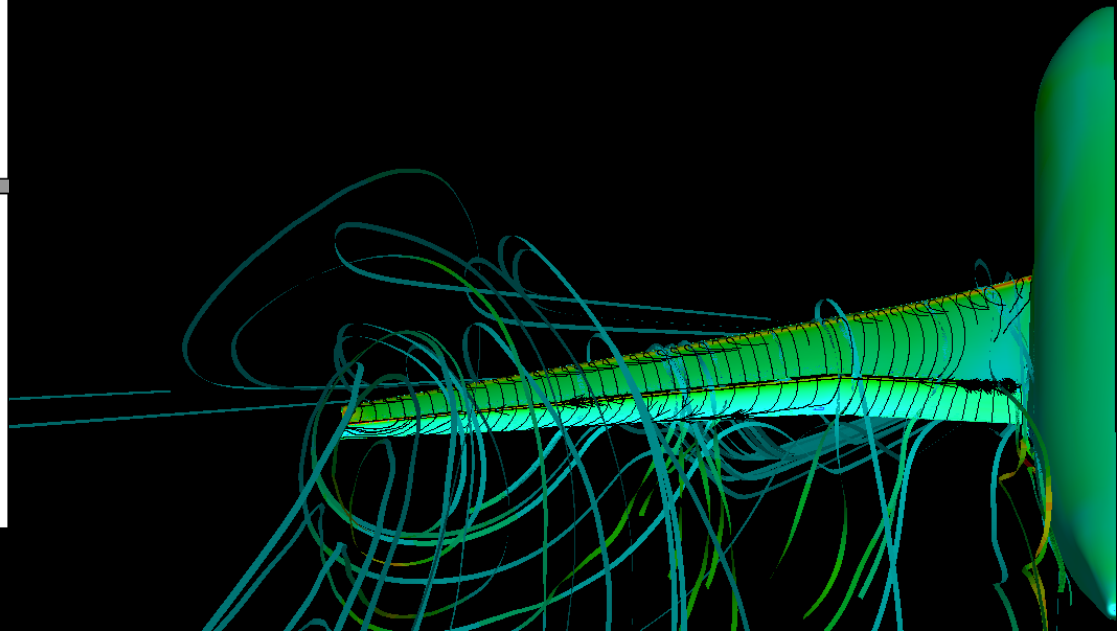
	Coarse Grid	Medium Grid	TVR Adapted Grid	Region Adapted Grid
α = 21 deg.				
α = 22.4 deg.				Contours of Friction Coefficient (x-direction)

Results (Cont'd)

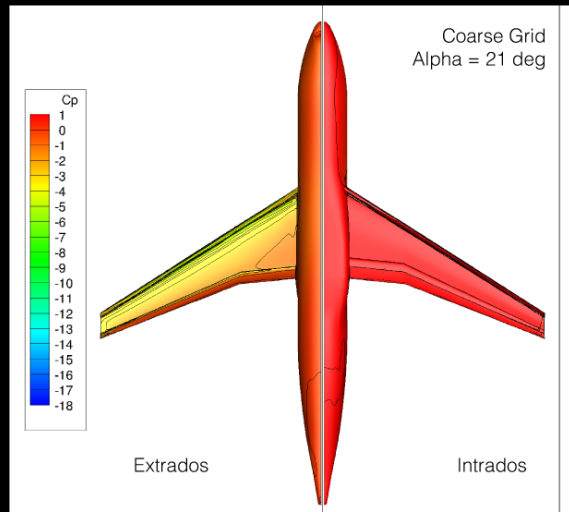
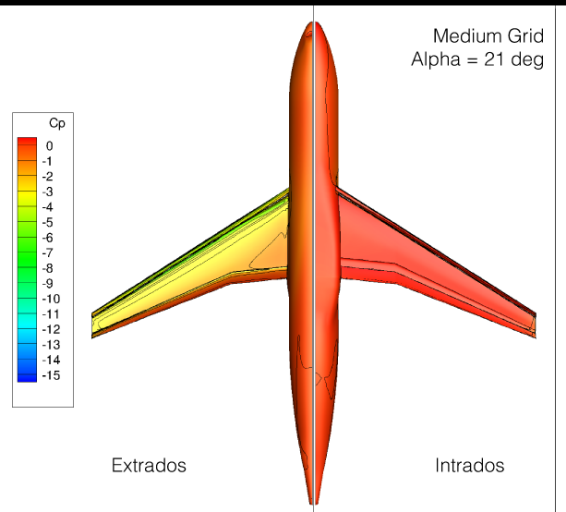
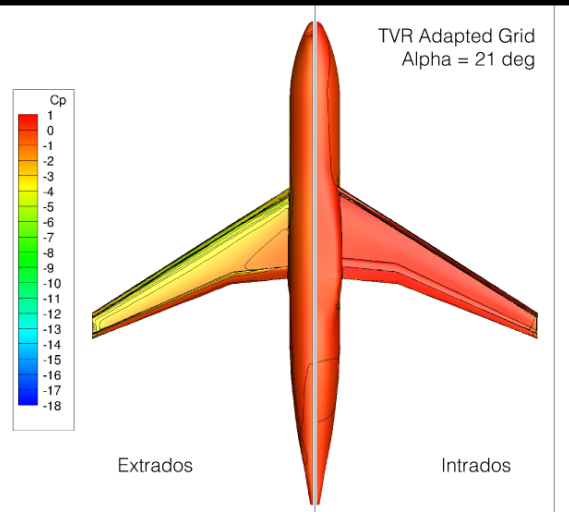
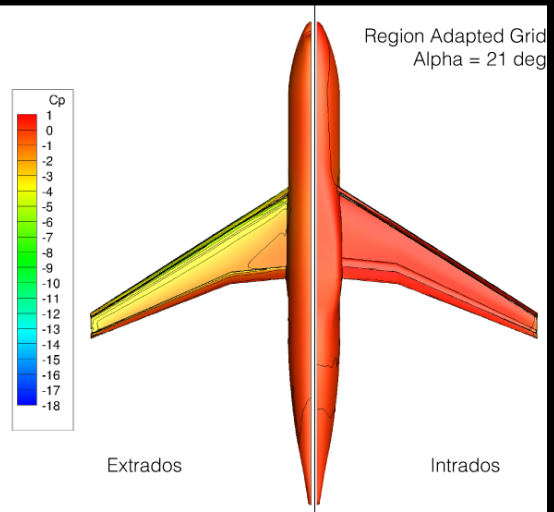
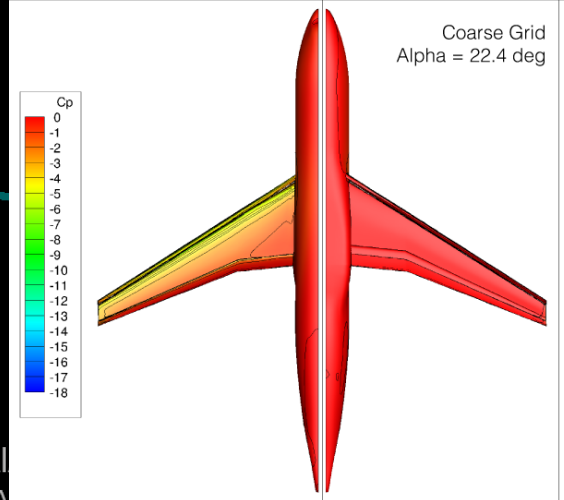
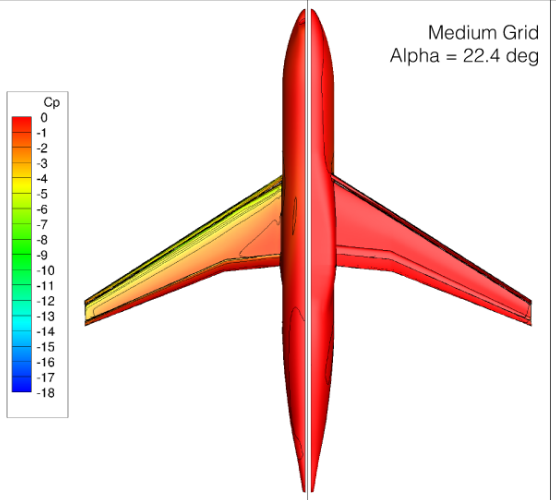
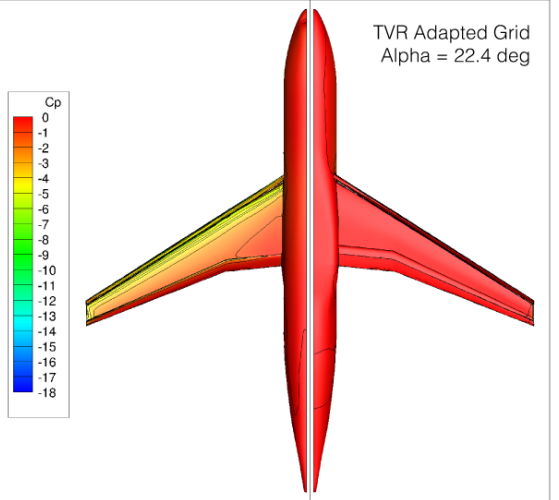


Separated Flow

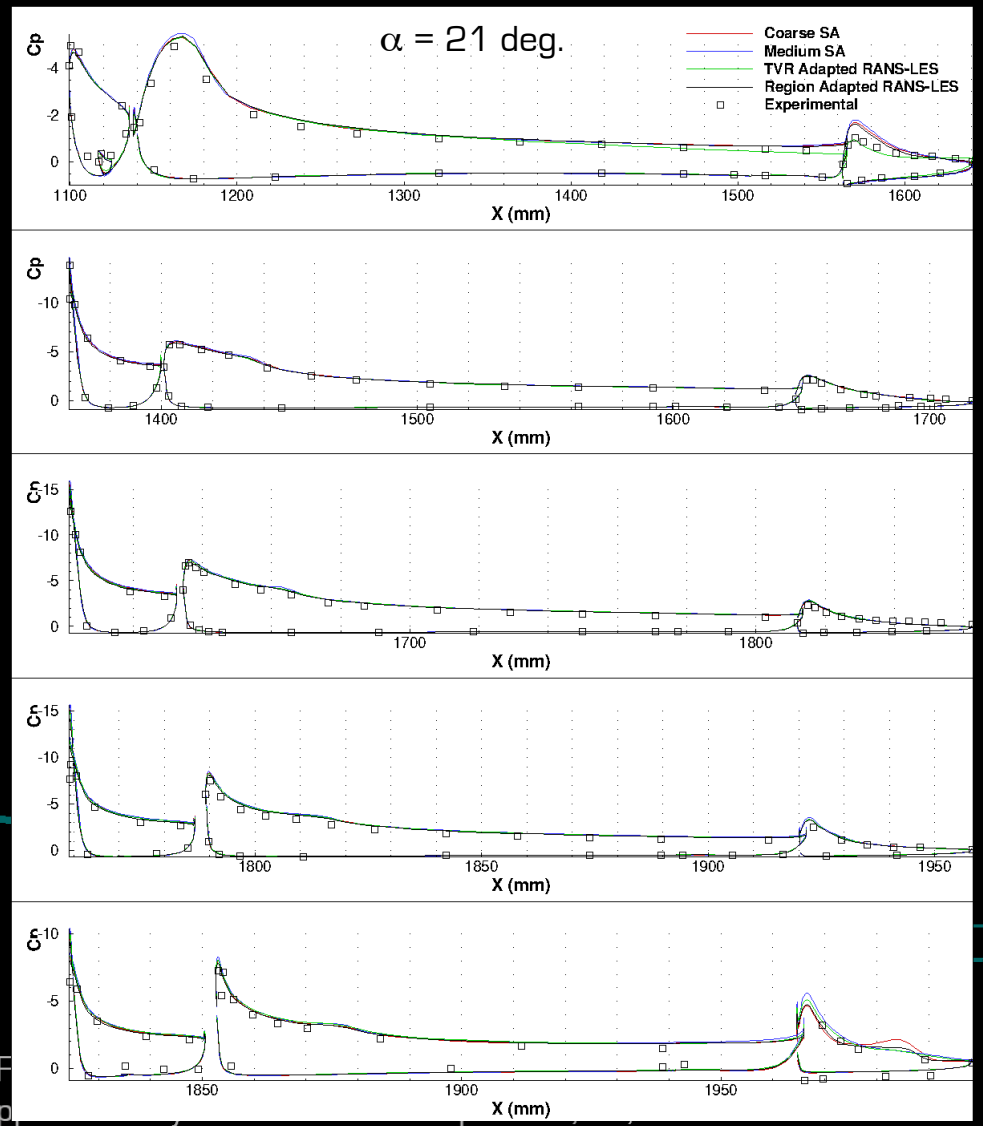
Recirculating Flow

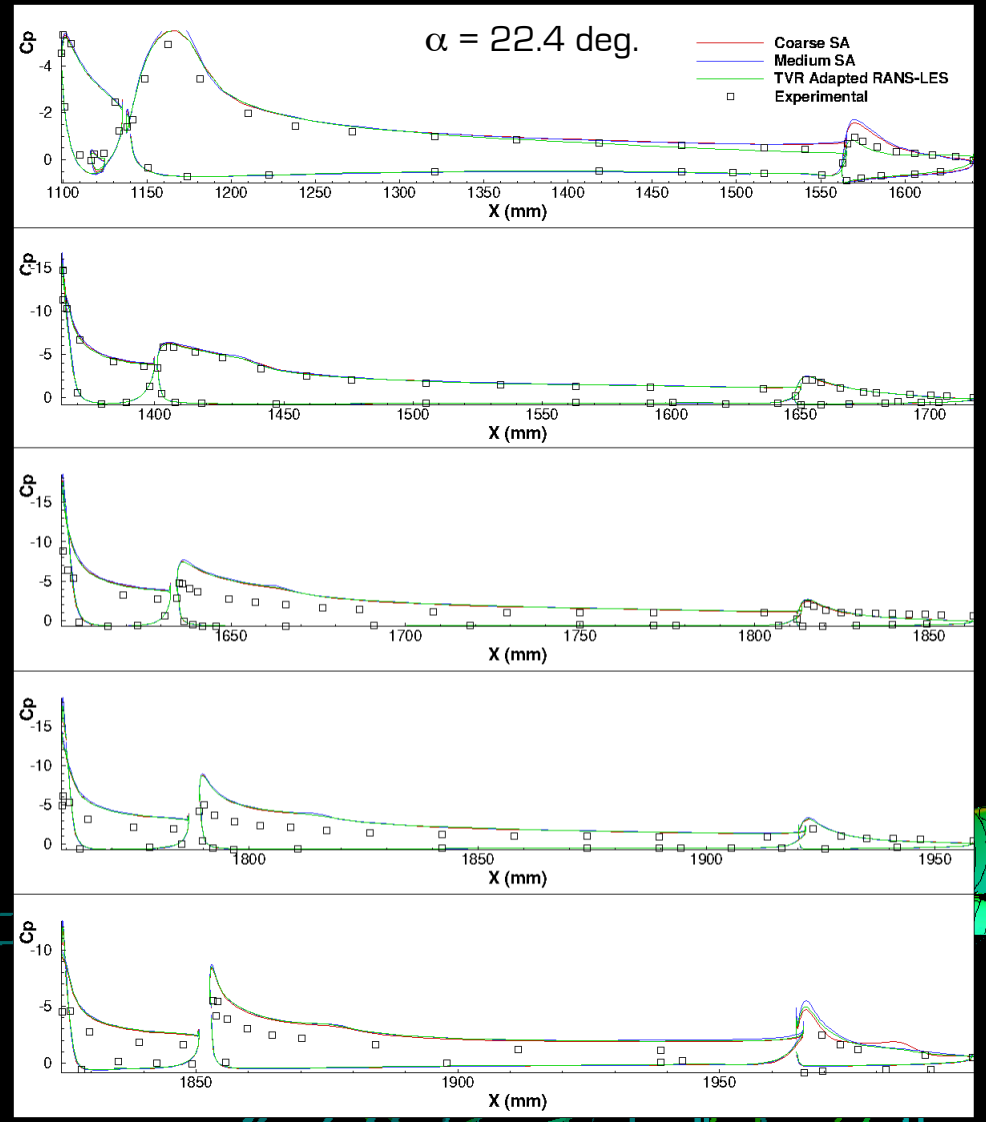


Results (Cont'd)

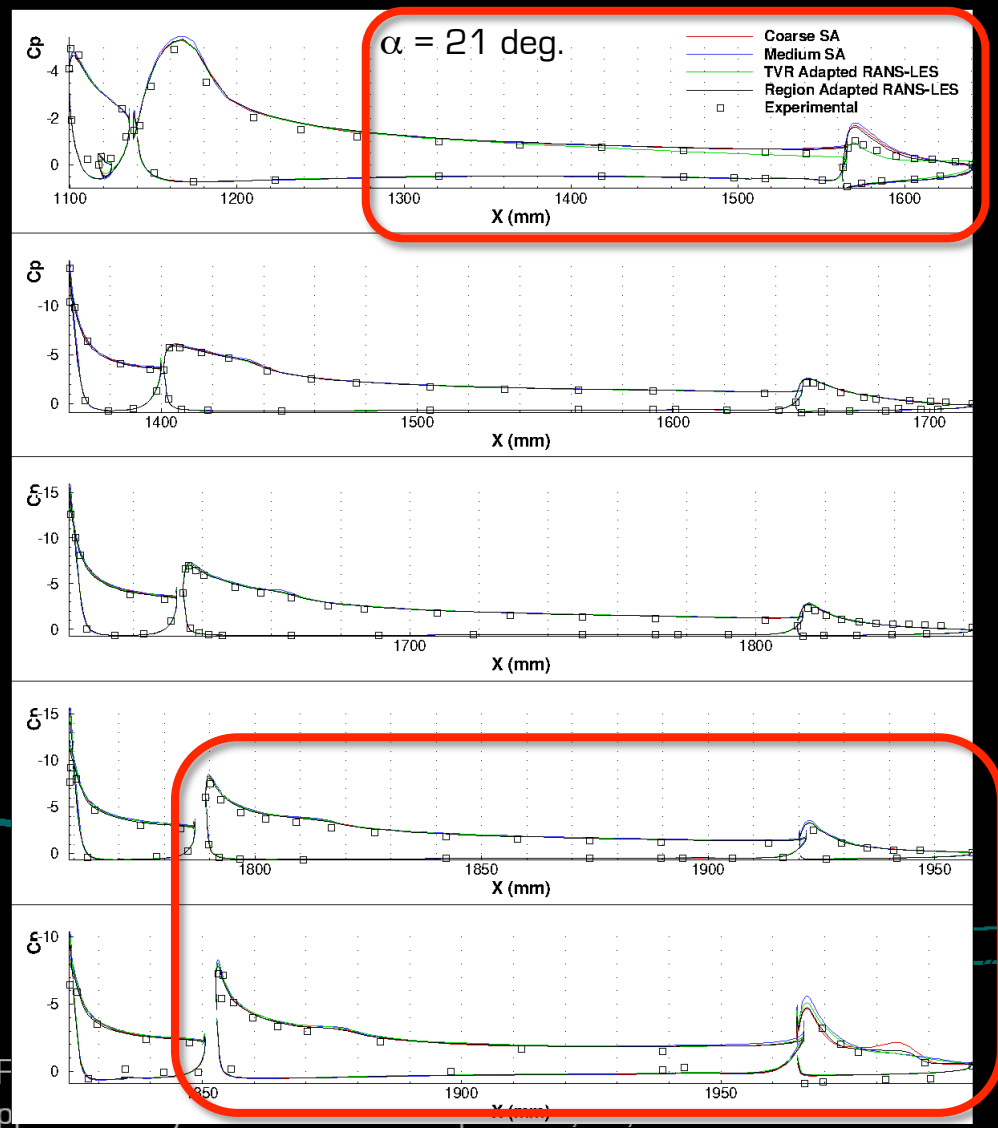
	Coarse Grid	Medium Grid	TVR Adapted Grid	Region Adapted Grid
α = 21 deg.				
α = 22.4 deg.				Contours of Pressure Coefficient

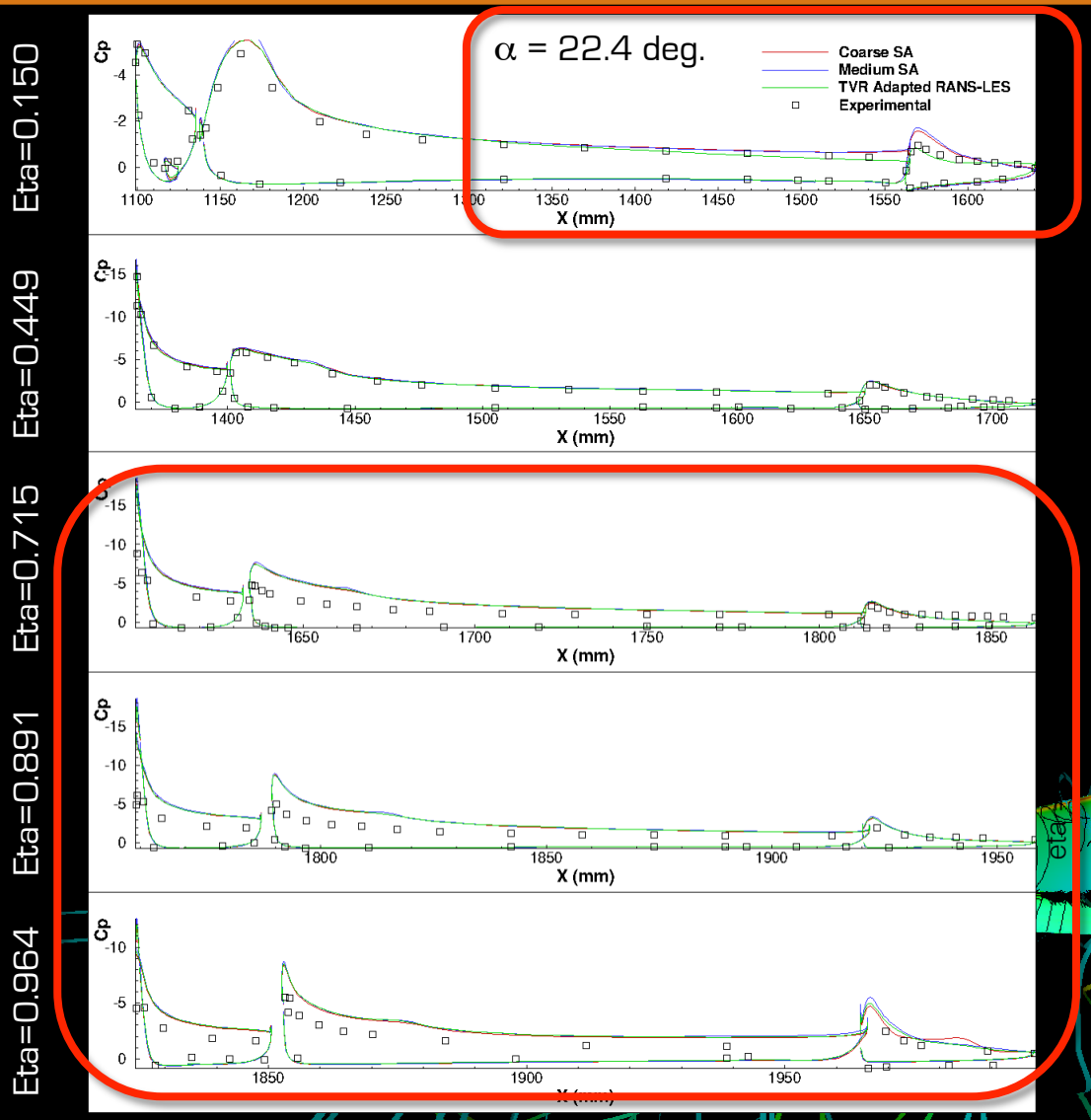
Results (Cont'd)



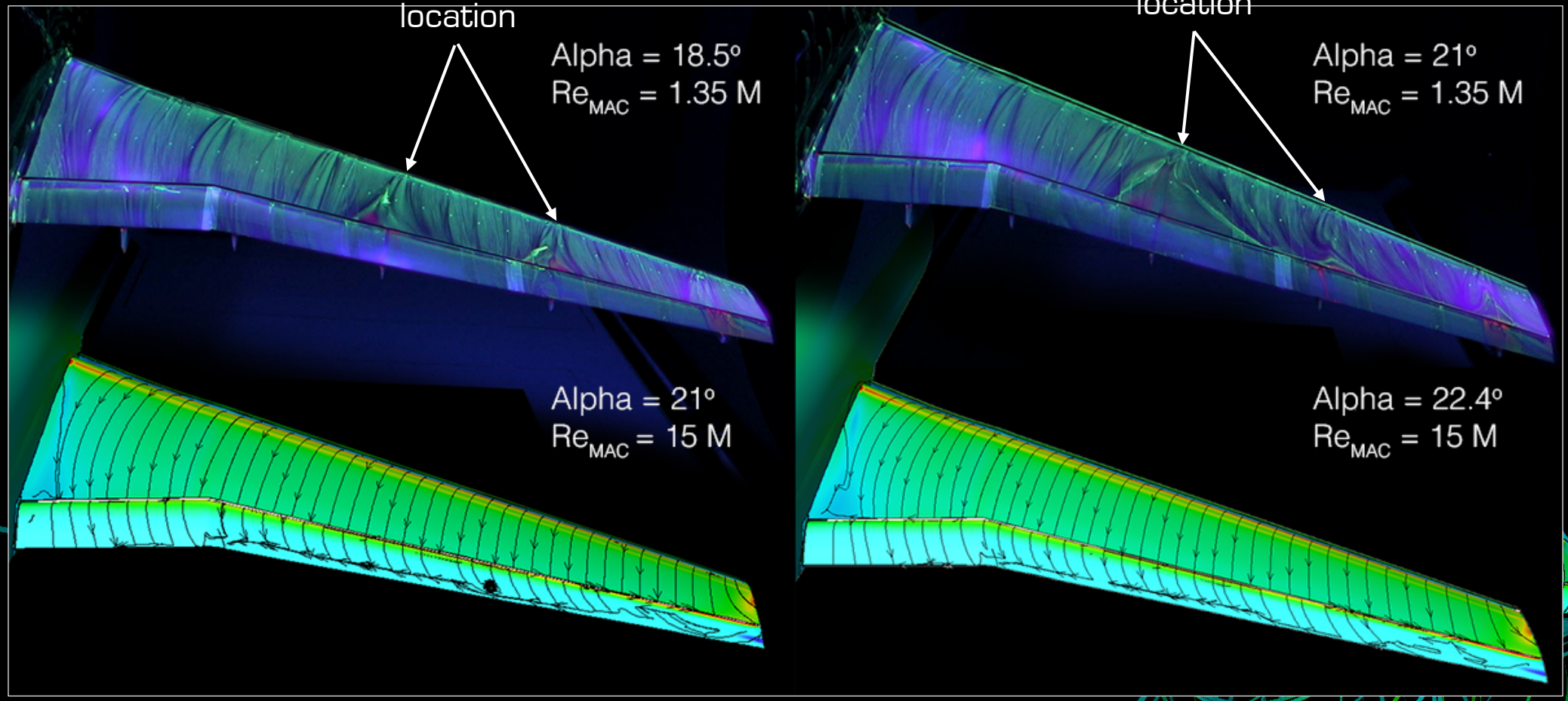


Results (Cont'd)

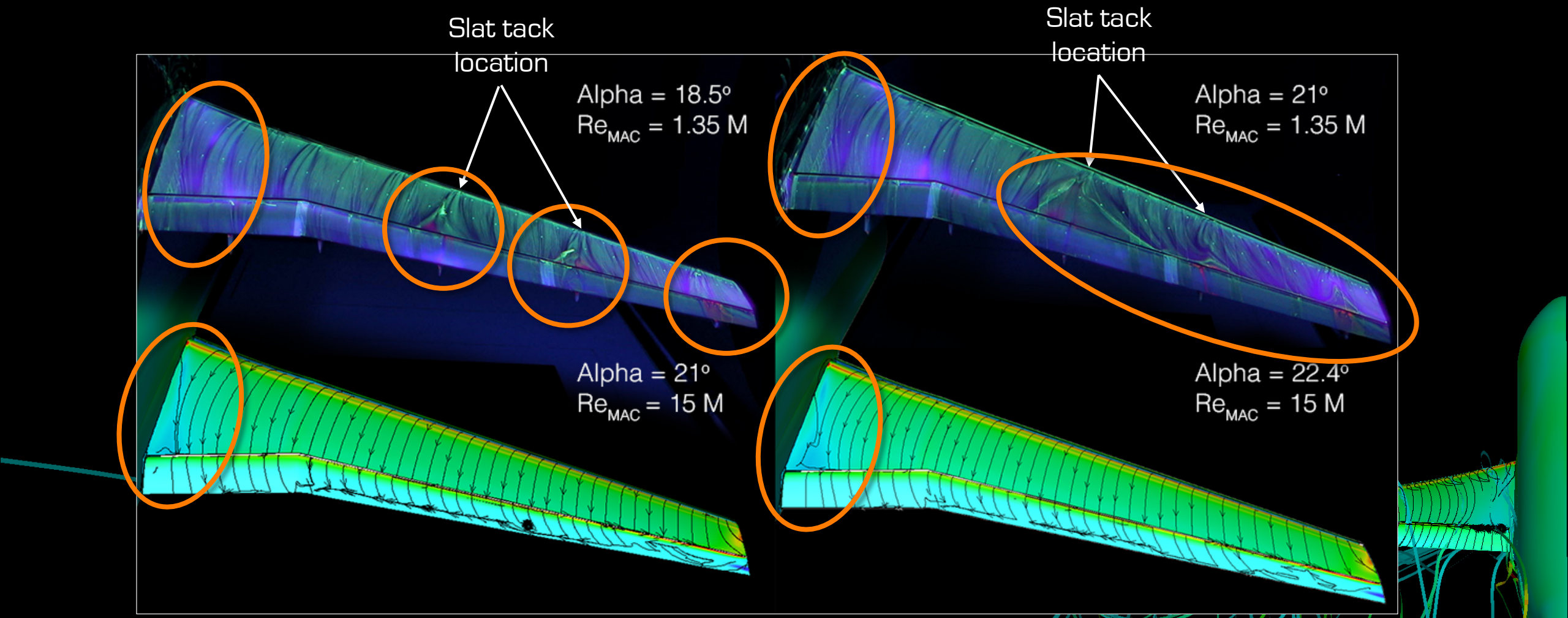




Results (Cont'd)



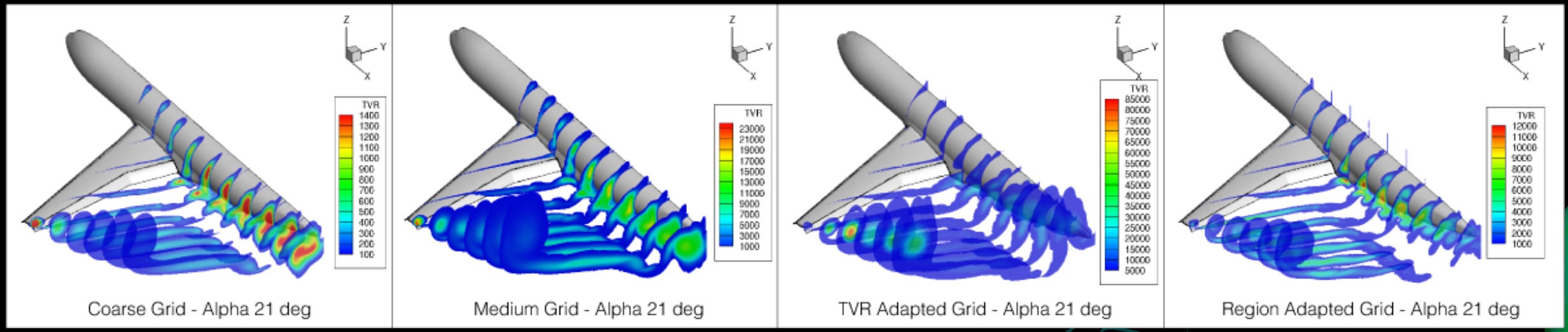
Results (Cont'd)



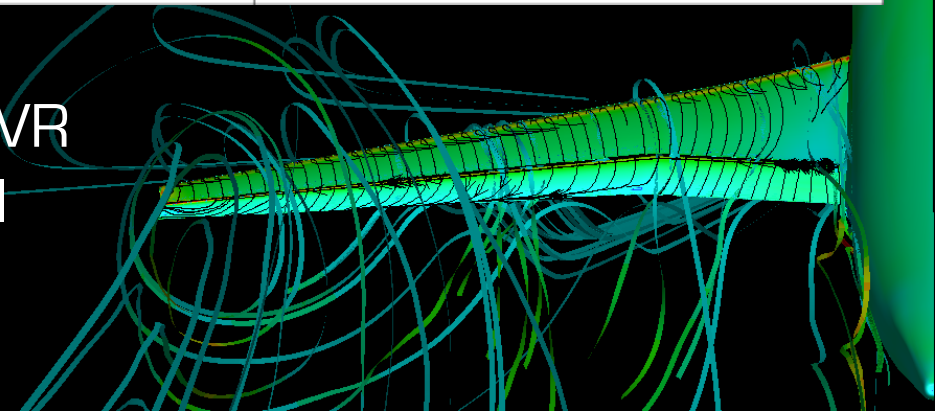
Results (Cont'd)

Turbulence Viscosity Ratio Downstream

Coarse Grid | Medium Grid | TVR Adapted Grid | Region Adapted Grid



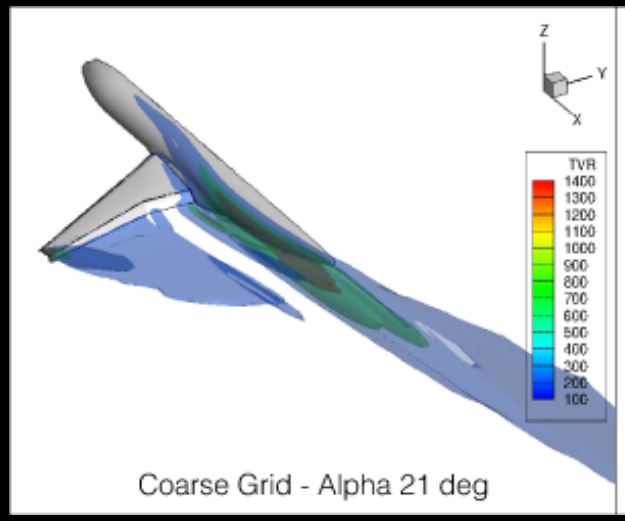
- Coarse and Medium grids show different scales of TVR
- The highest values of TVR are obtained with the local adapted mesh.



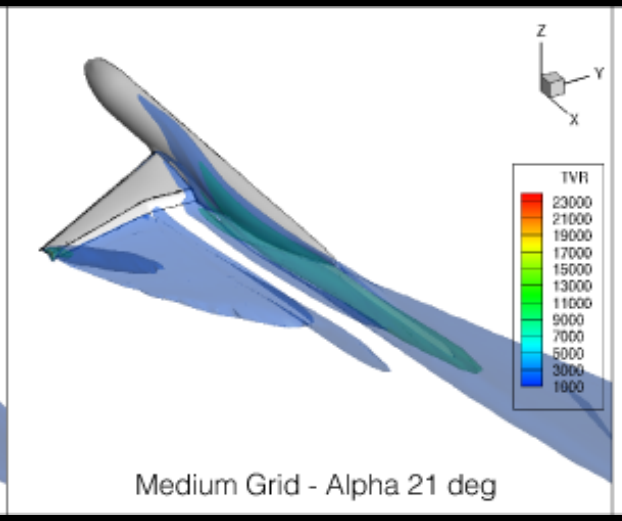
Results (Cont'd)

Iso-surfaces of Turbulence Viscosity Ratio

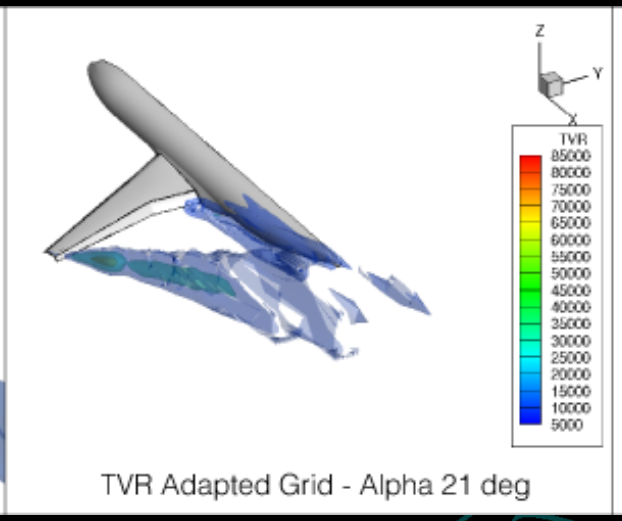
Coarse Grid | Medium Grid | TVR Adapted Grid | Region Adapted Grid



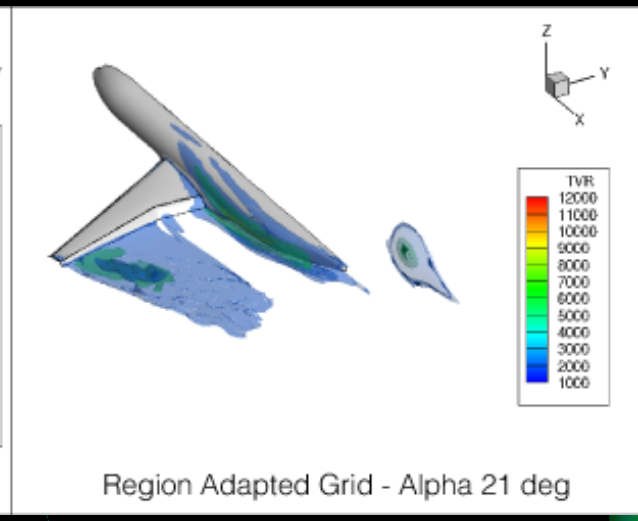
Coarse Grid - Alpha 21 deg



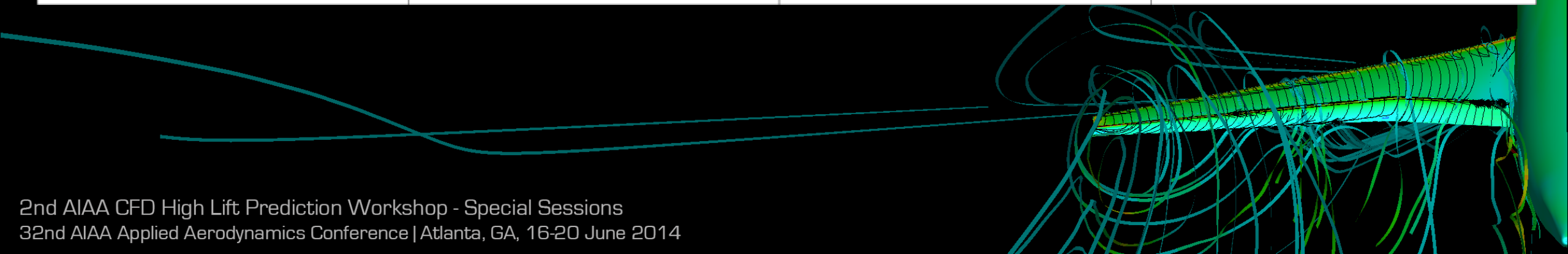
Medium Grid - Alpha 21 deg



TVR Adapted Grid - Alpha 21 deg

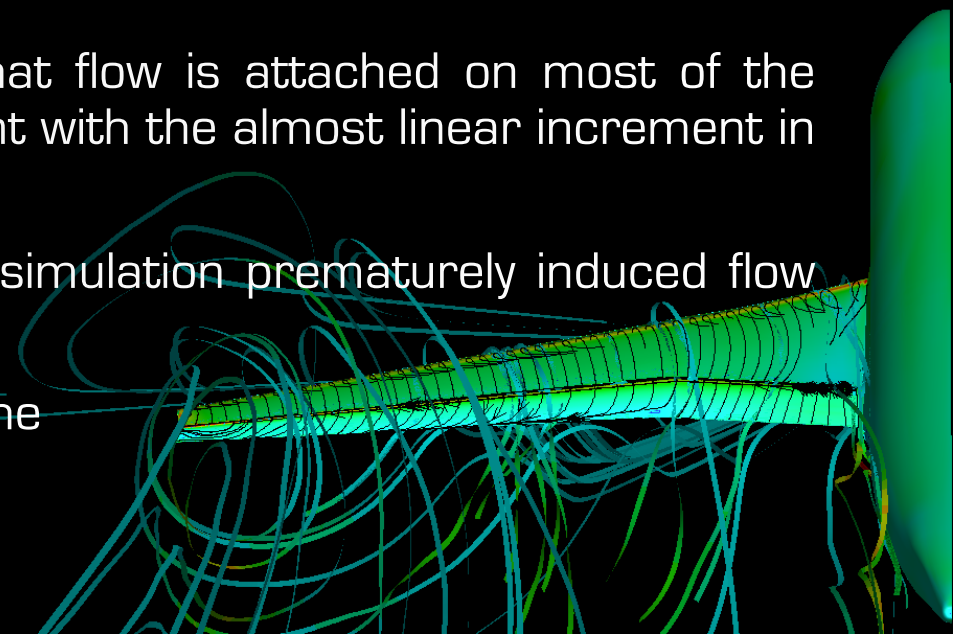


Region Adapted Grid - Alpha 21 deg



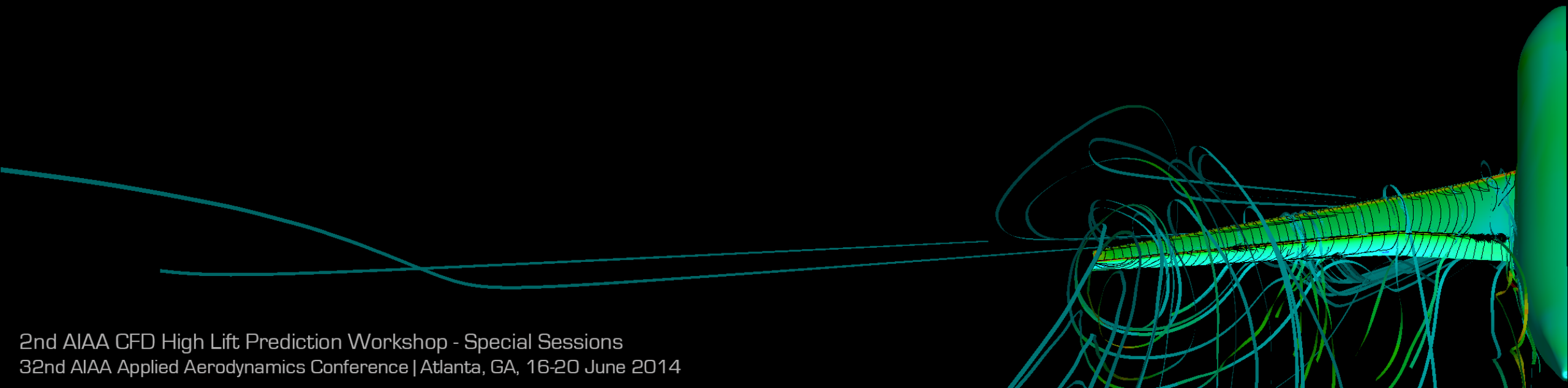
Conclusions

- A computational study of the DLR-F11 model using RANS and RANS-LES turbulence models was presented and discussed.
- Original coarse mesh "A_uns_1to1_Case1Config2_v2" was adapted using two approaches: local adaption based on turbulent viscosity iso-values and region adaption.
- RANS-LES turbulence model demonstrated an overall improvement in prediction of aerodynamic and pressure coefficients over Spalart-Allmaras with adapted grids that were slightly larger than the original coarse mesh.
- Contours of pressure and skin friction coefficient showed that flow is attached on most of the surface of the wing at both angles of attack, which is consistent with the almost linear increment in lift coefficient.
- The slat tracks not included in the CAD model used for the simulation prematurely induced flow separation and an early onset of stall.
- Since all simulations were carried out without the inclusion of the slat tracks, RANS-LES turbulence model fails to predict stall.



Future Work

- Future work will be focused on: custom grid generation and test cases for which more information of flow characteristics is available (e.g. oil flow images, velocity profiles).
- Grids must meet cell size and growth requirements near the walls, as well as cell size and isotropy in the wake of the wing.



Questions?