Steady Turbulence Modeling versus Turbulence-Resolving Simulations

Philippe Spalart
Head of Flow Physics

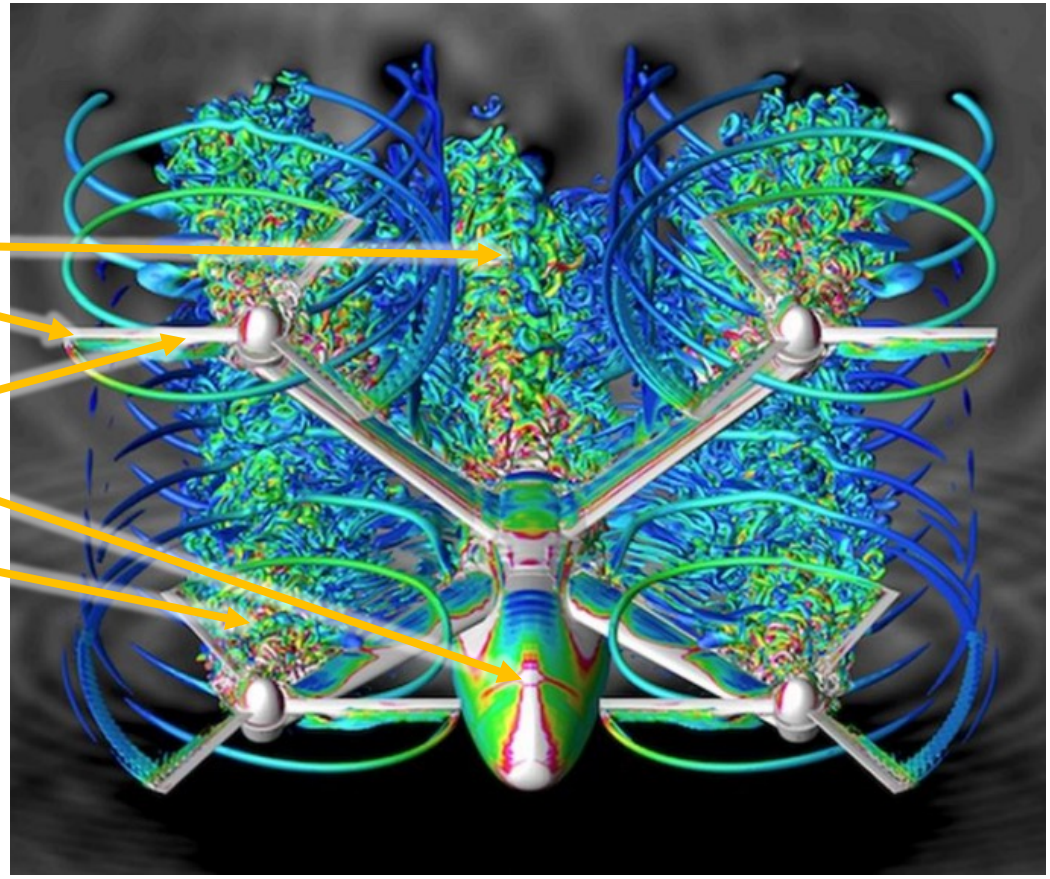
Turbulence Videos

- 1: A Visual Introduction to Turbulence and its Prediction in CFD
- 2: The Basics of Turbulence Modeling
- 3: Steady Turbulence Modeling versus Turbulence-Resolving Simulations

Basis

NASA

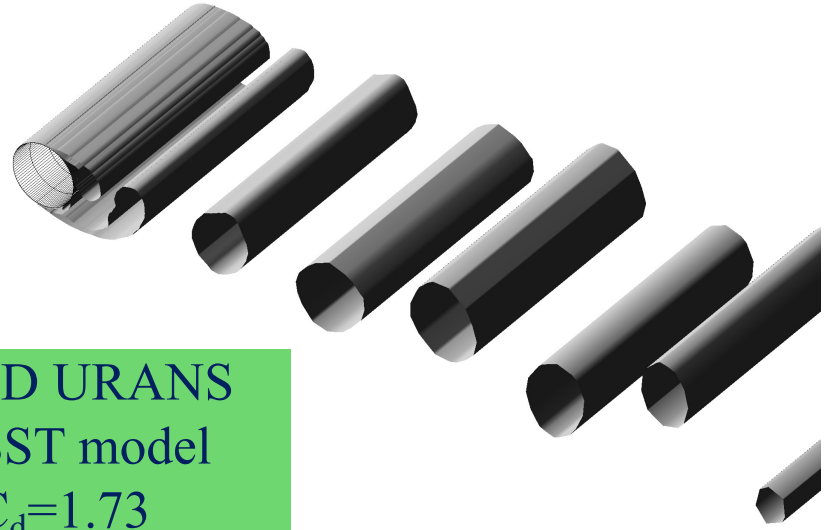
- Direct Numerical Simulation is out of the question
- Two common reasons for unsteady simulations:
  - The geometry is time-dependent
  - Steady turbulence modeling is not accurate enough
- Industrial CFD begs for different treatments in same run:
  - High Reynolds numbers!
  - Thin attached boundary layers are best with RANS
  - Regions of massive separation need Large-Eddy Simulation (LES). This only needs a benign SubGrid-Scale model
- This is the century of Hybrid RANS-LES Methods
  - The principle was established in 1997 with Detached-Eddy Simulation (DES)
    - First 3D results in 1999
  - Many HRLMs followed
    - VLES, XLES, ZDES, SAS, PANS, PITM, SBES…
  - The principal distinction is into “seamless” and “zonal”
  - We have many “success stories,” but also “loose ends”
    - There is no clear LES filter
    - Seamless methods can “hesitate” where to switch modes



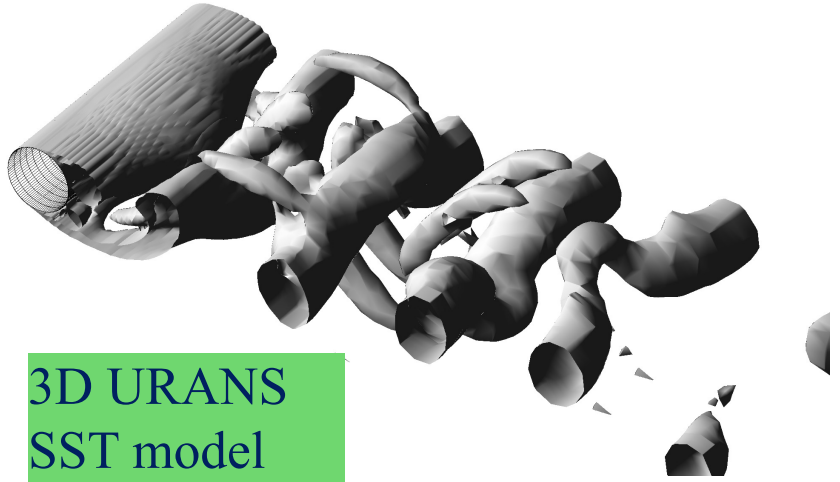
The Archetype of a Flow Forcing 3D Unsteady Simulations on Us

Experiment: C_d ~ 1.25 to 1.35, at subcritical Reynolds number (laminar separation)

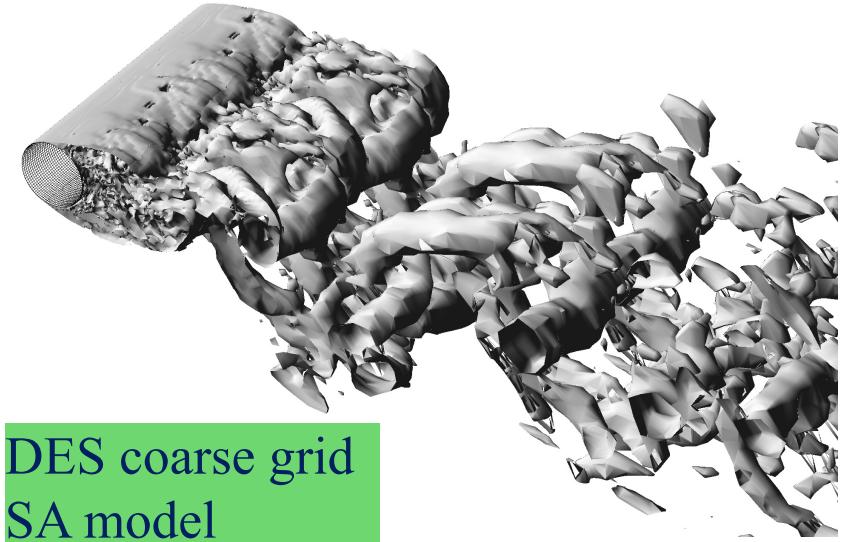
Steady RANS
SST model
C_d=0.78



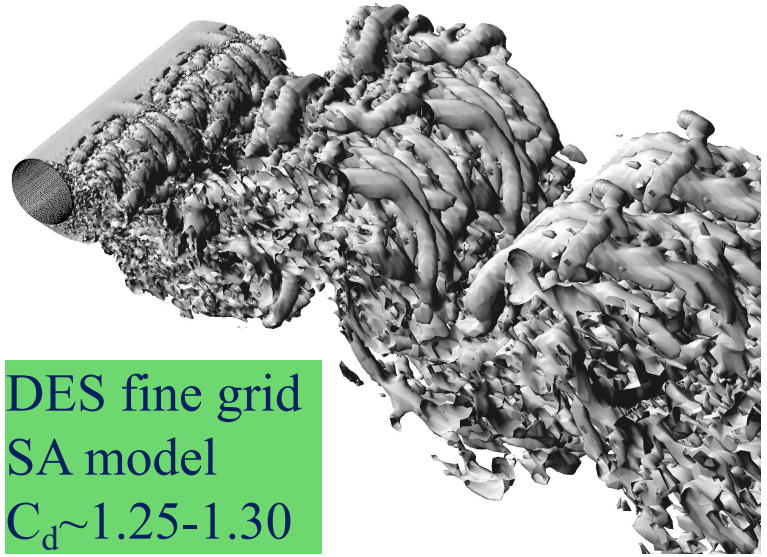
2D URANS
SST model
C_d=1.73



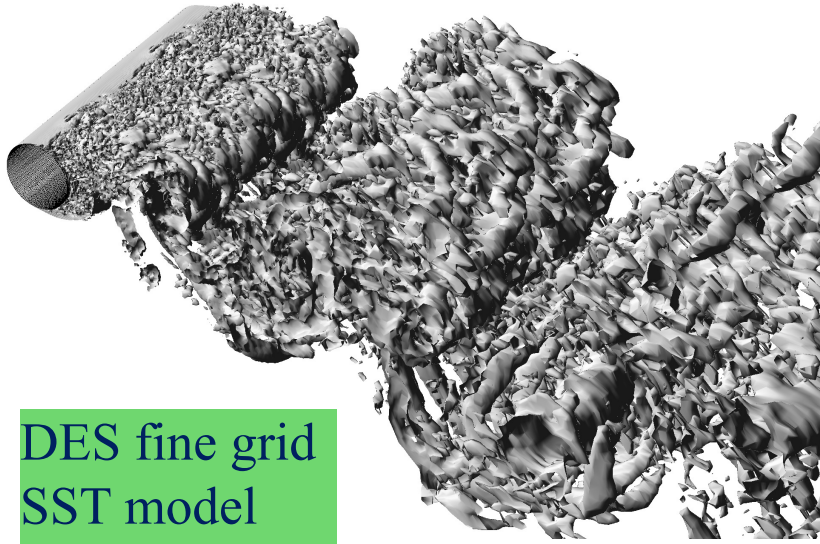
3D URANS
SST model
C_d=1.24



DES coarse grid
SA model
C_d~1.25-1.30



DES fine grid
SA model
C_d~1.25-1.30



DES fine grid
SST model
C_d=1.28

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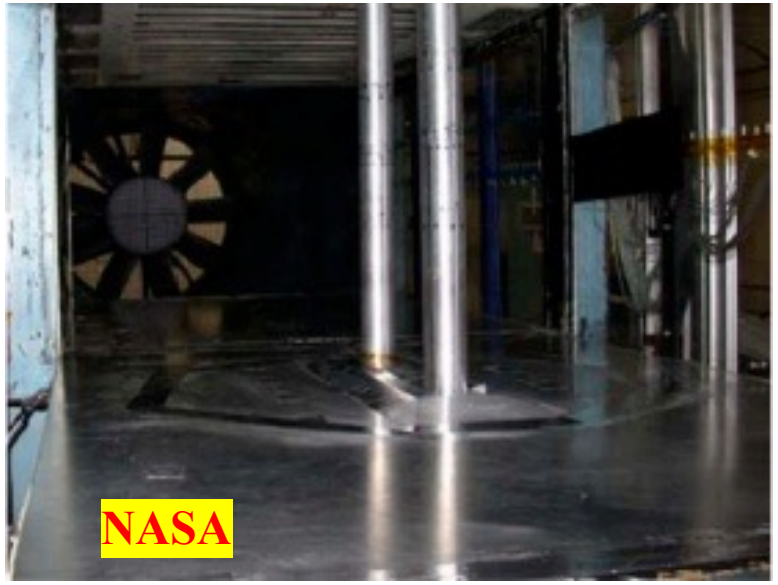
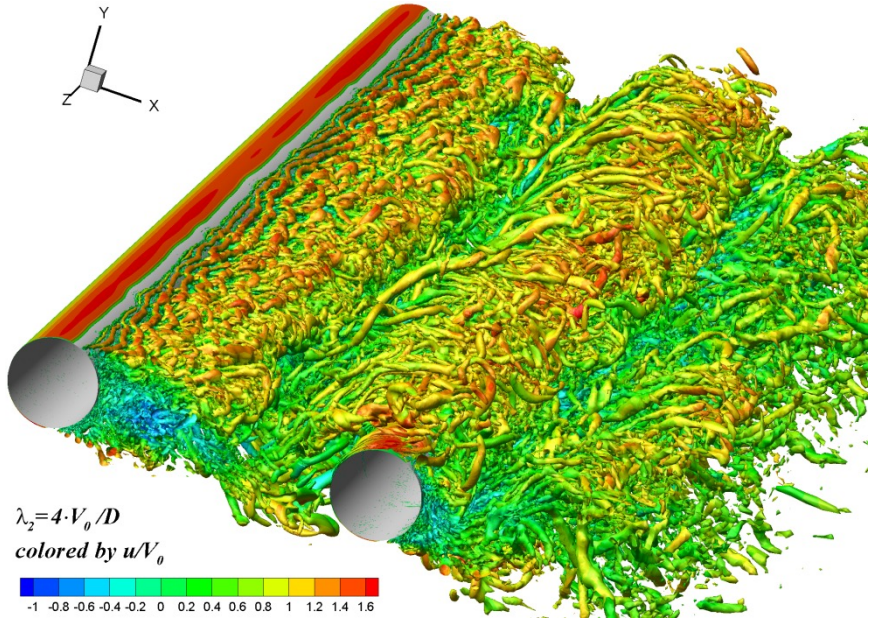
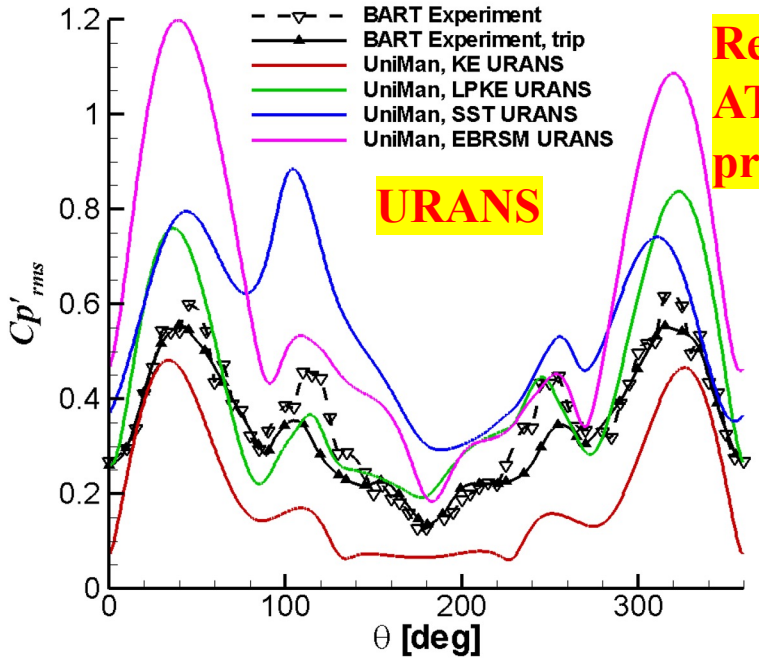
Tandem Cylinders. Pressure Fluctuations on Downstream Body

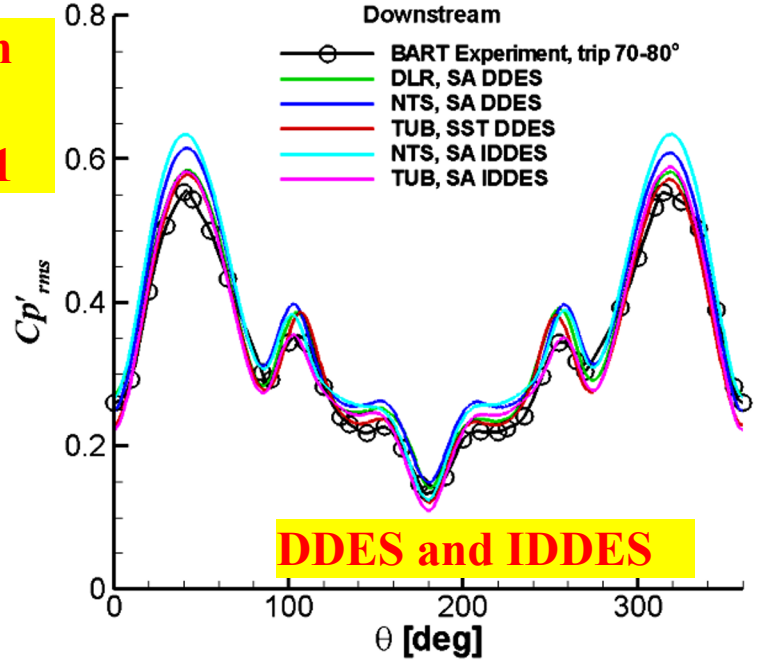




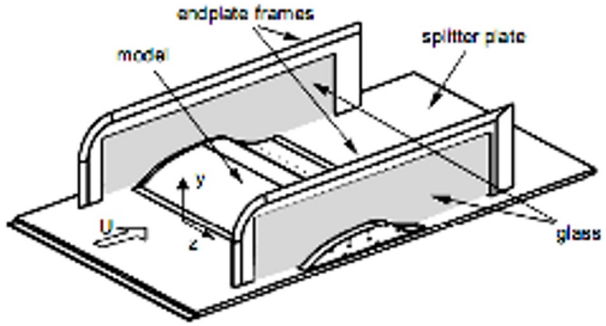
Downstream



Results from ATAAC project, 2011



NASA 2D Wall-Mounted Hump



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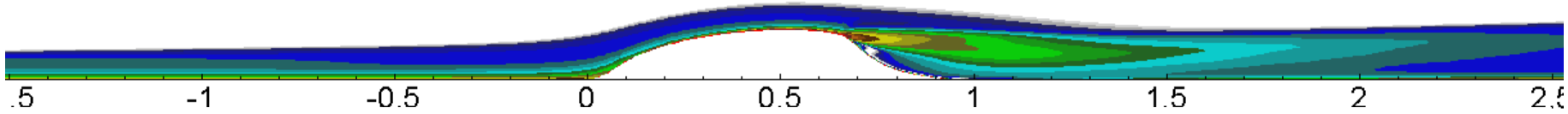
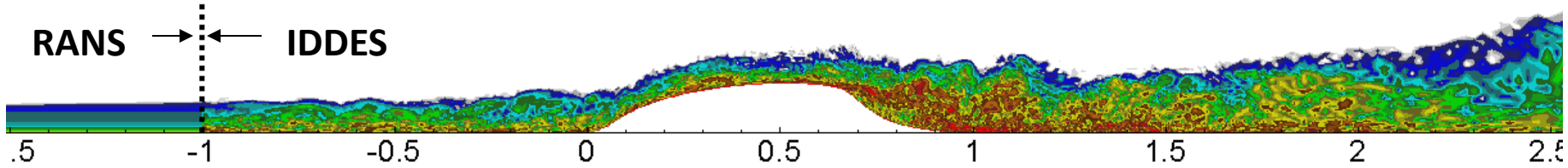
SST RANS, full domain

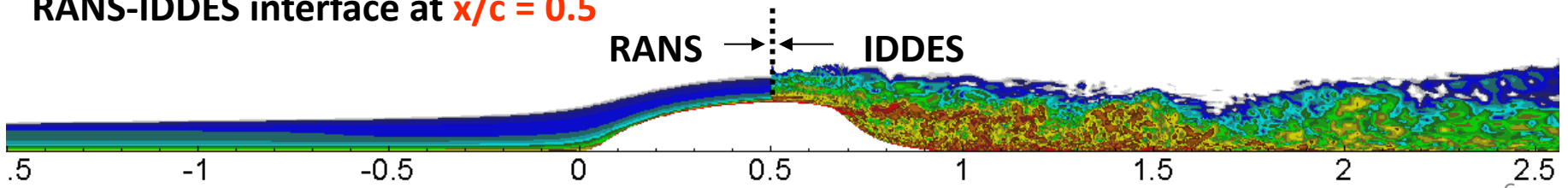


Zonal SST RANS-IDDES

RANS-IDDES interface at x/c = -1

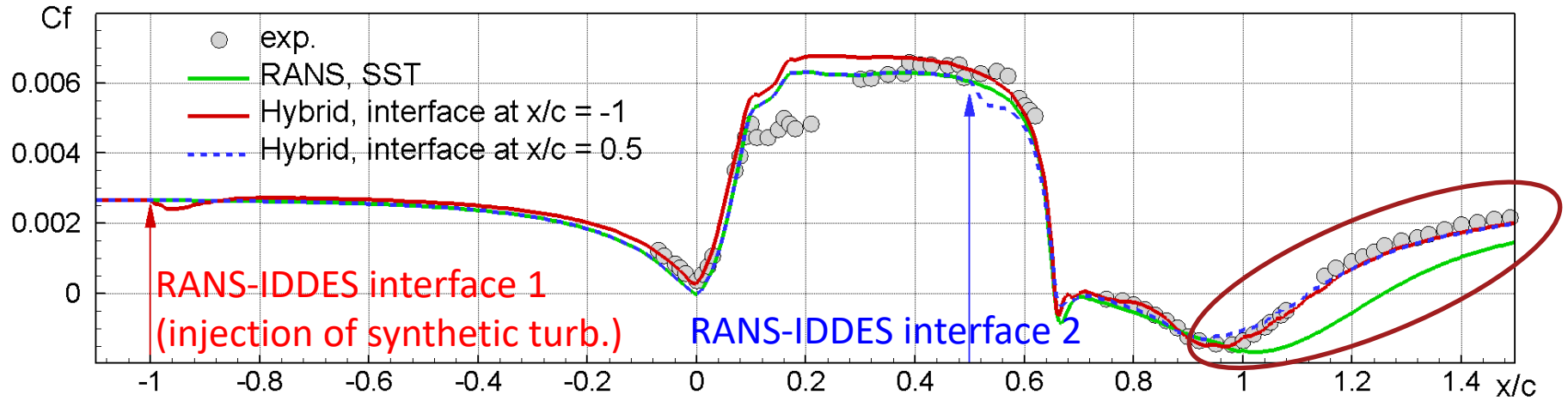


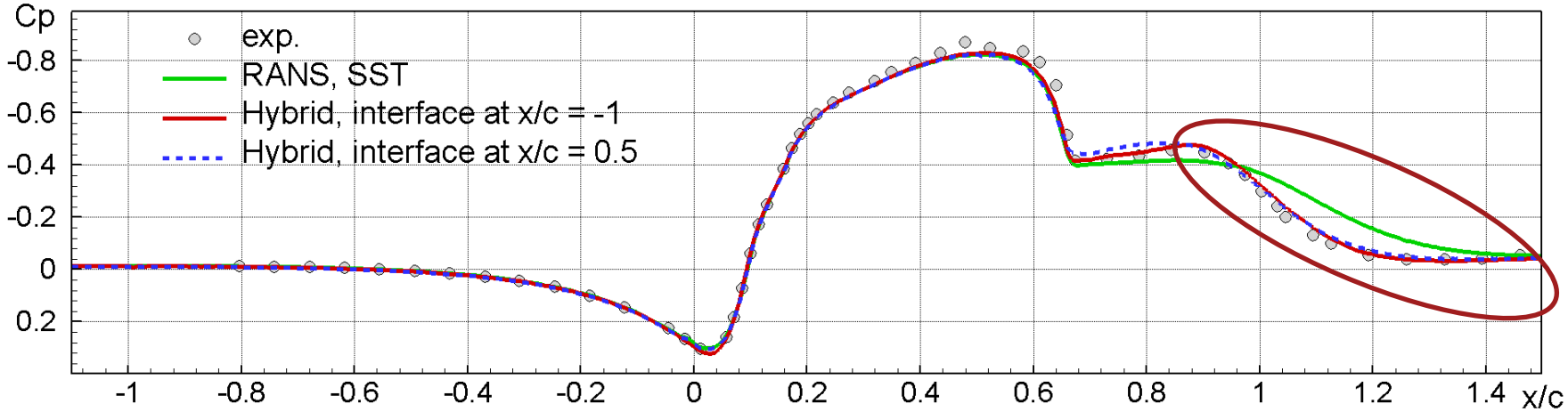
RANS-IDDES interface at x/c = 0.5



Contours of vorticity magnitude

C_f and C_p Distributions on NASA 2D Hump





- RANS has too long a separation bubble (other models fail in other ways)
- IDDES is robust

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