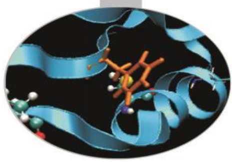
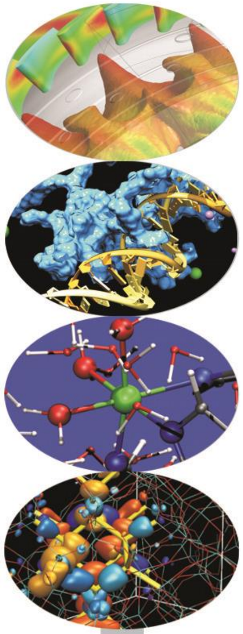


HPC Computer Aided Engineering @ CINECA

Raffaele Ponzini Ph.D.

CINECA

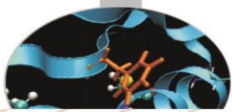
SuperComputing Applications and Innovation Department – SCAI

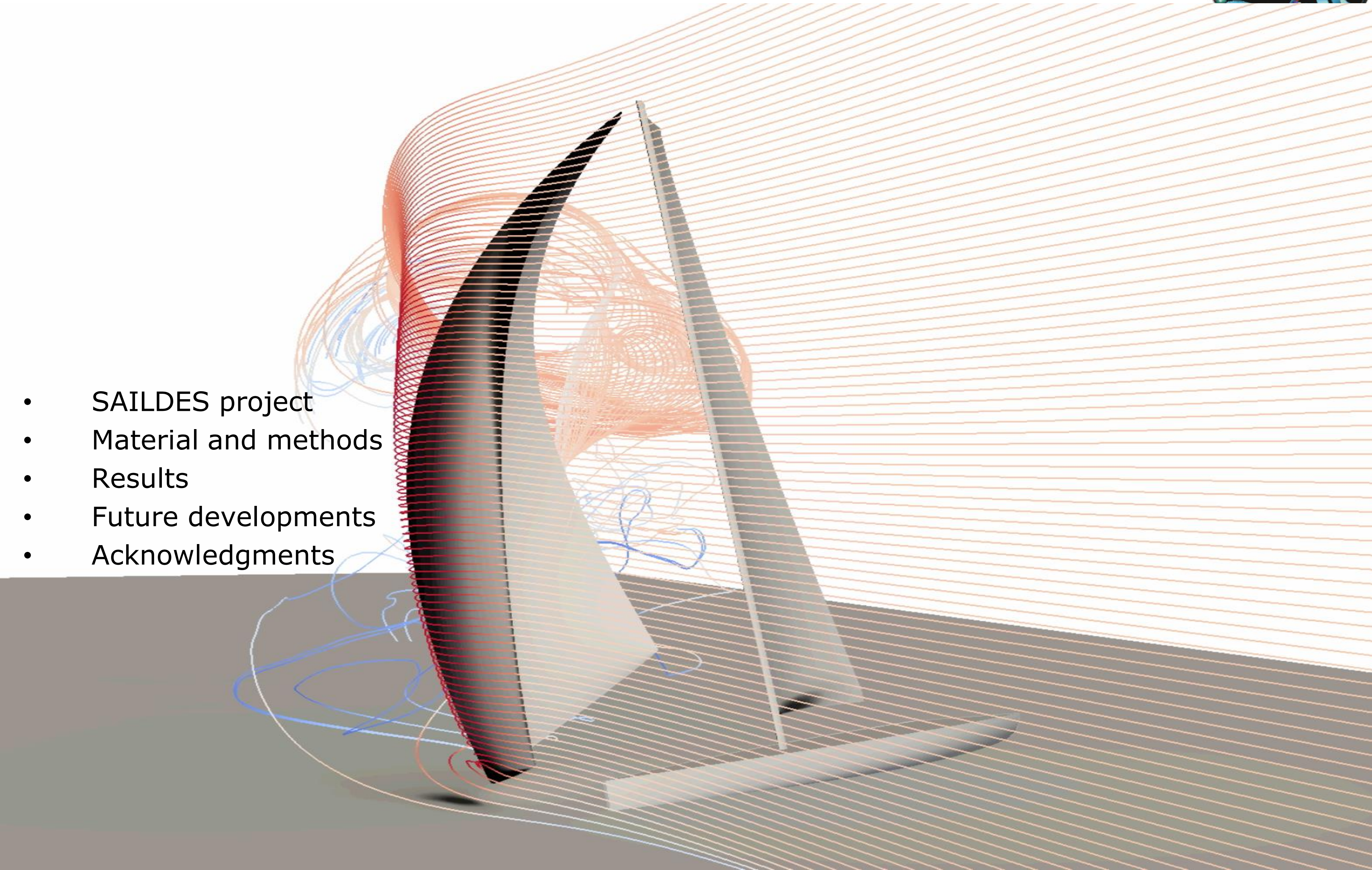


16-18 June 2014

Segrate (MI), Italy

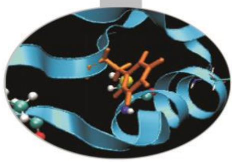
Outline of the presentation





- SAILDES project
- Material and methods
- Results
- Future developments
- Acknowledgments

SAILDES project



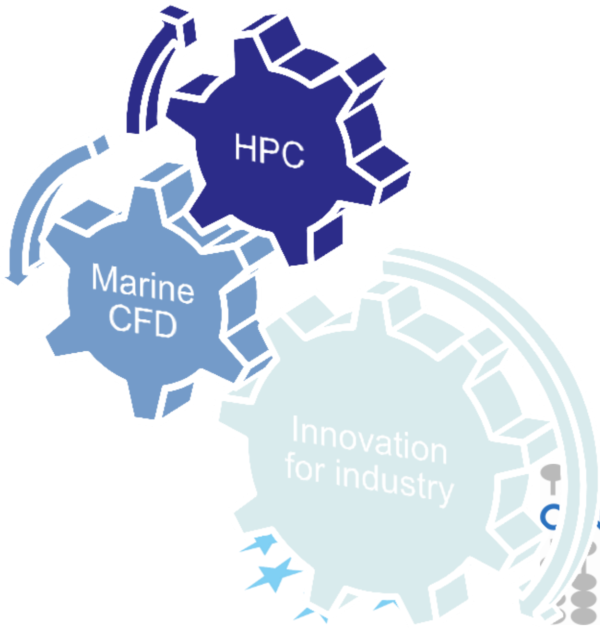
Collaboration between CINECA and The University of Newcastle upon Tyne (UK) through its School of Marine Science and Technology (Prof. I.M. Viola), investigating the use of scientific engineering computations in the marine field.

Student Internship involved actively:

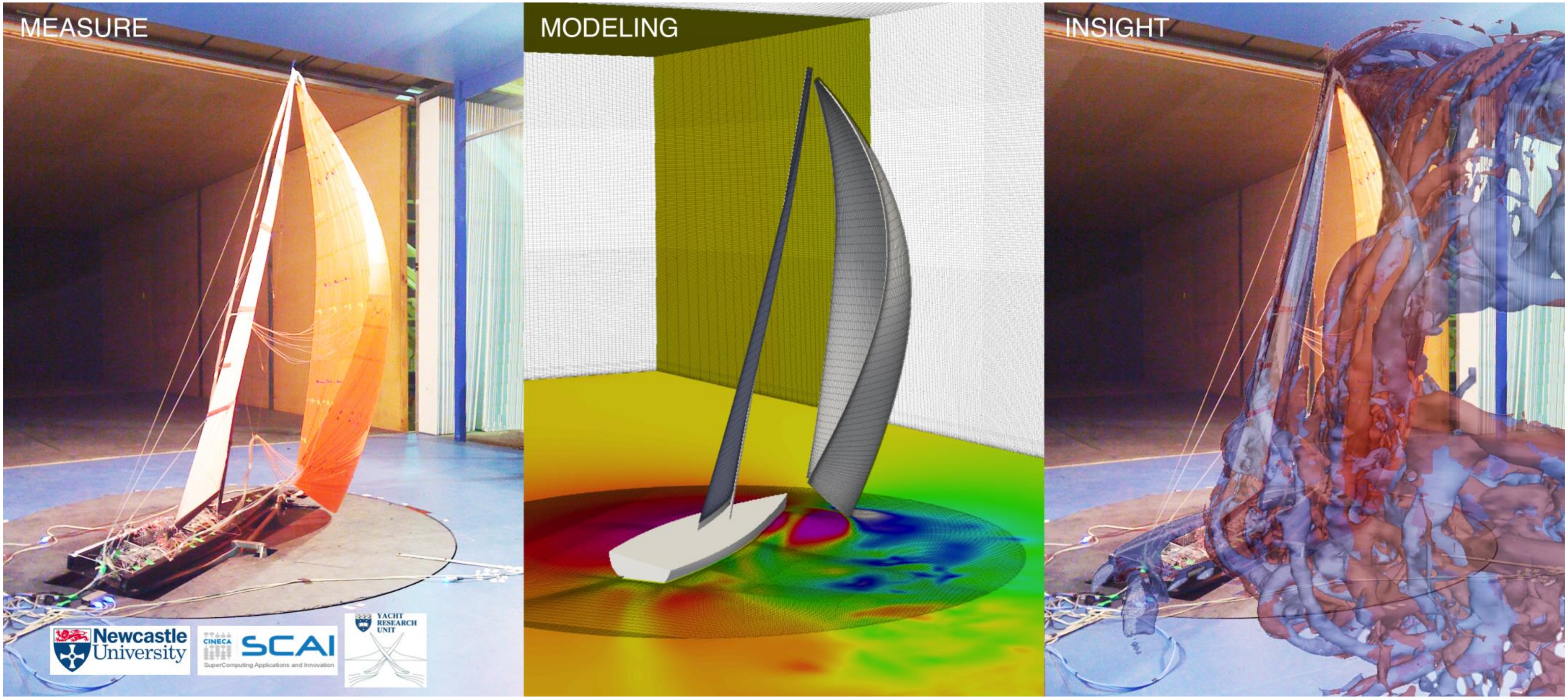
S. Bartesaghi (PhD. Politecnico di Milano, Italy);

T. Van Renterghem (Arts et Métiers ParisTech, France)

First outcome of the SAILDES project in collaboration with Ansys Italy:
Delayed Detached Eddy Simulation of Yacht Sails with Experimental Validation



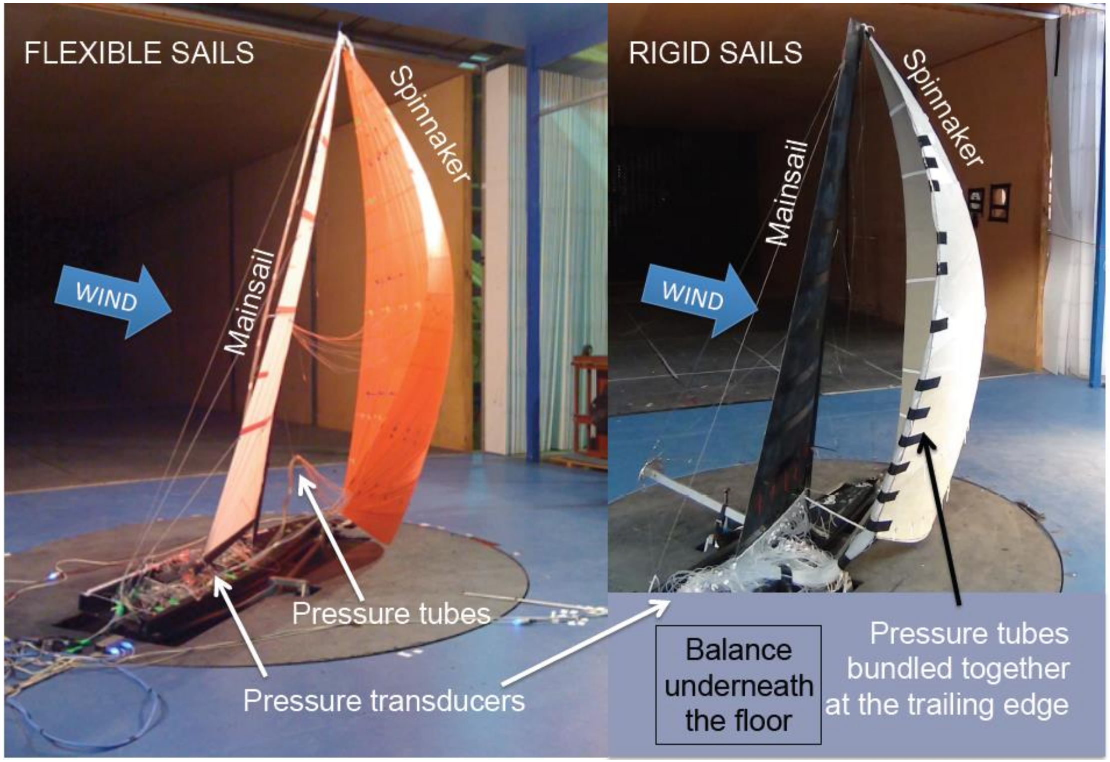
SAILDES project



Experimental setup

- Sails of a candidate America's Cup (AC) class, AC90, were designed and tested in the wind tunnel of the Yacht Research Unit, University of Auckland.

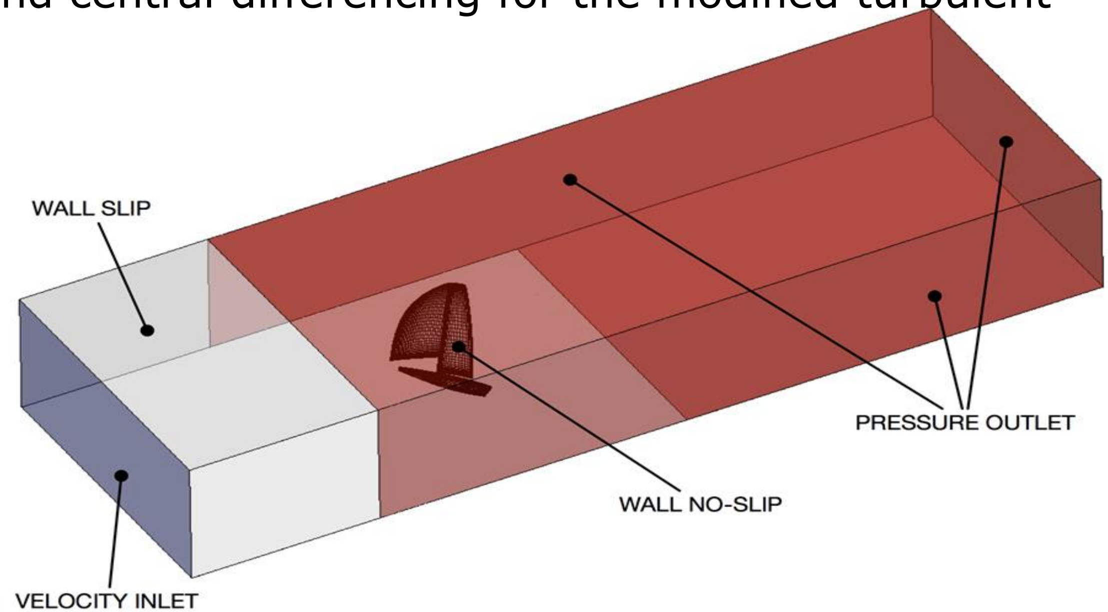
- This experimental model was designed, build and instrumented with a specific focus on providing a benchmark for numerical methods and thus the experimental setup was simplified as explained in a previous work from Viola and Flay [1] and in Viola *et al.* (2011) (see [2]).



[1] Viola I.M. and Flay R.G.J., Pressure Distribution on Modern Asymmetric Spinnakers, International Journal of Small Craft Technology, Trans. RINA, vol. 152, part B1, pp. 41-50, 2010.
[2] Viola I.M., Pilate J., Flay R.G.J., Upwind Sail Aerodynamics: a Pressure Distribution Database for the Validation of Numerical Codes, International Journal of Small Craft Technology, Trans. RINA, vol. 153, part B1, pp. 47-58, 2011.

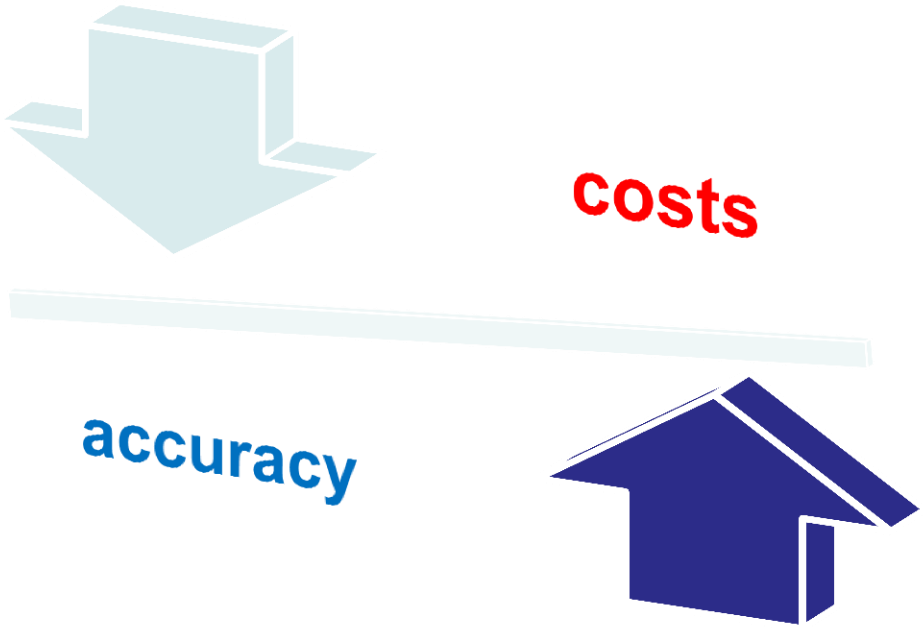
Numerical models

- Incompressible Navier-Stokes equations for Newtonian fluids.
- Delayed Detached Eddy Simulation model implemented in Ansys Fluent, version 13.1.
- Turbulence model: Spalart–Allmaras
- Standard Wall-function
- 3D double precision unsteady pressure based solver
- SIMPLEC pressure-velocity coupling scheme was used with a skewness correction equal to zero.
- The discretization scheme adopted was second order for the pressure, central differencing for the momentum and central differencing for the modified turbulent viscosity.
- Intensity 2% uniform at the inlet
- Flat velocity profile: 3.5 m/s
- Reynolds-spi: 4 x 10^5

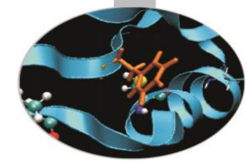


DDES model

- Development of hybrid models that attempt to combine the best aspects of RANS and LES methodologies in a hybrid technique: the detached-eddy simulation (DES) approach by Spalart et al (1997)
- This model attempts to treat near-wall regions in a RANS-like manner, and treat the rest of the flow in an LES-like manner.



Numerical setup



- Different mesh sizes - from 4 to 32 million cells – were built and the scalability on up to 256 computational cores was tested.
- About twenty loops (5.2 seconds/loop) of the whole domain using time steps from $\mathbf{5 \cdot 10^{-4}}$ to $\mathbf{2 \cdot 10^{-3}}$ seconds were performed in order to obtain statistically reliable data and to perform a comparison with the experimental results of pressures over the sails surfaces.

Mesh Size	Wind-Tunnel Loops	Time-step	RANS
4 mln	**38**	$\mathbf{2 \cdot 10^{-3}}$	**y**
32 mln	**10**	$\mathbf{5 \cdot 10^{-4}}$	**y**
256 mln	**--**	**--**	**n**

HPC environment

HP x86_64 cluster:

- Using up to 256 cores - X5660 (exa-core)
- Equipped with 2GB of RAM per core
- Infiniband QDR

+

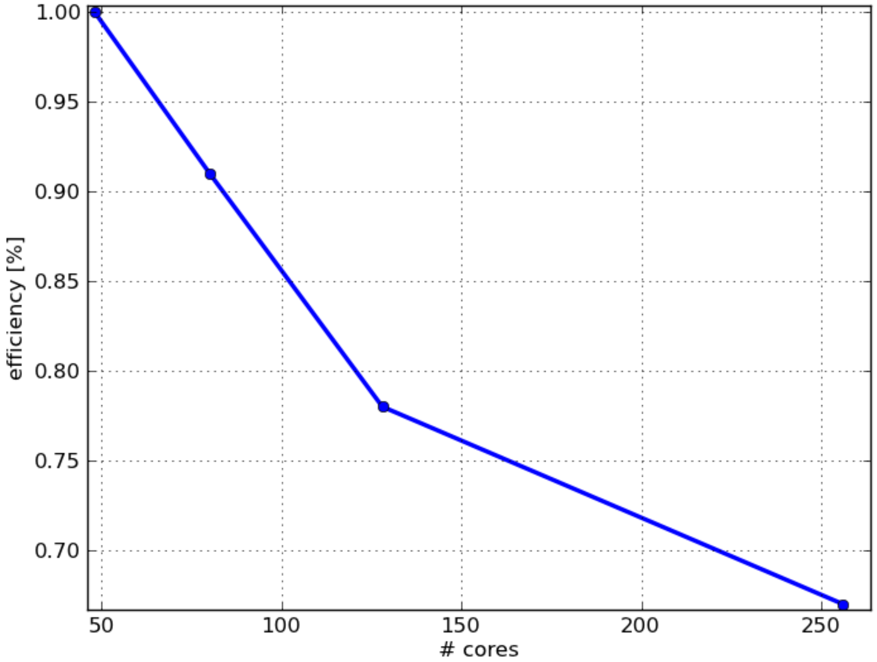
Remote Visualization node:

DL980 (8cpu Intel E5420 - 512GB RAM - with NICE DCV technology (image compression)

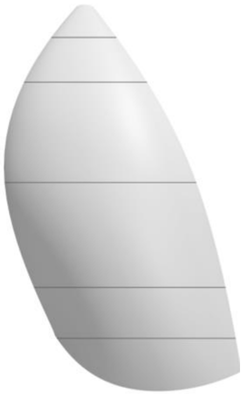
Scalability results

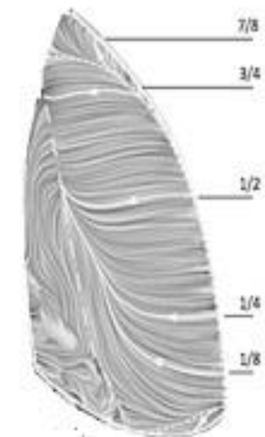
- Speed-up on HPC clusters: efficiency of about 70% on up to 256 cores

- Feasibility in industry:
  - RANS: ½ day / loop
  - DDES: 2 days / loop

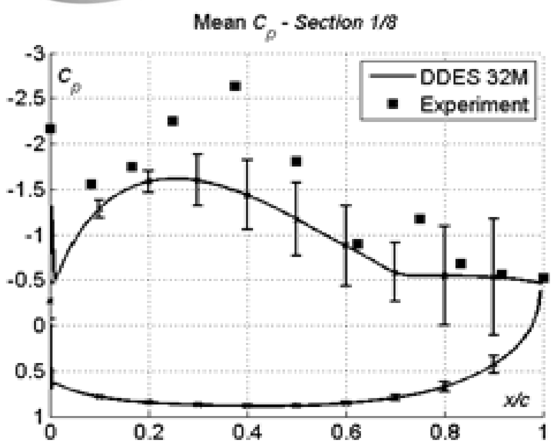


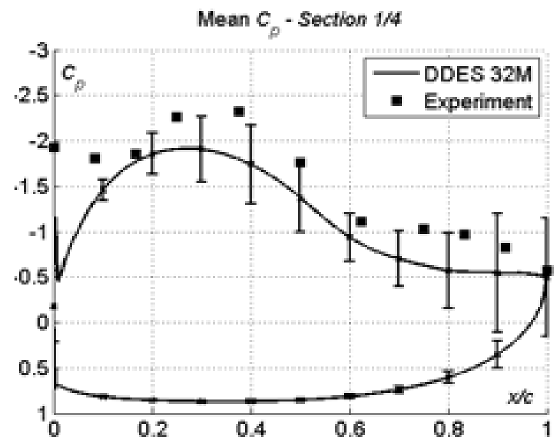
Cp comparisons with uncertainty evaluation

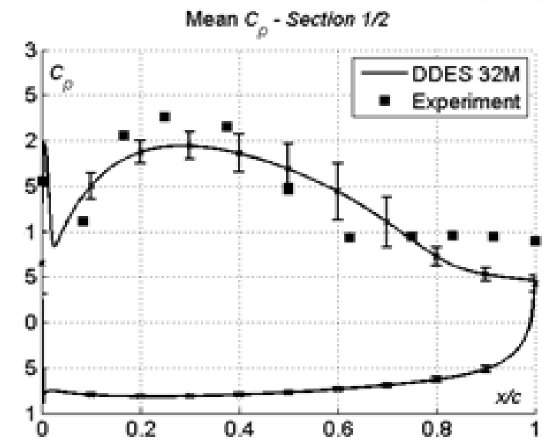


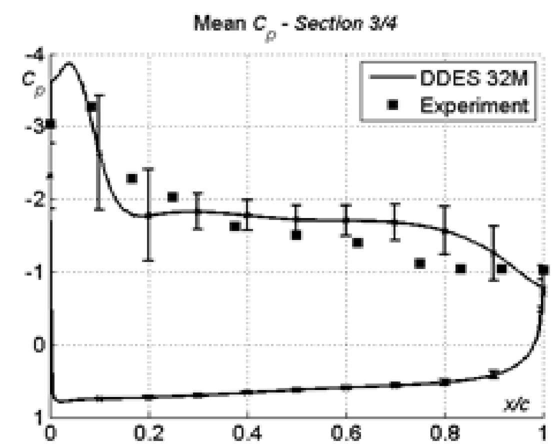


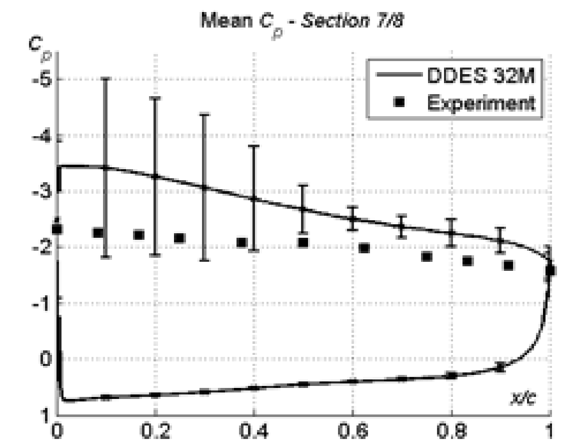
Higher uncertainty located were complex phenomenon occurs (windage estimation due to tip vortex identification)





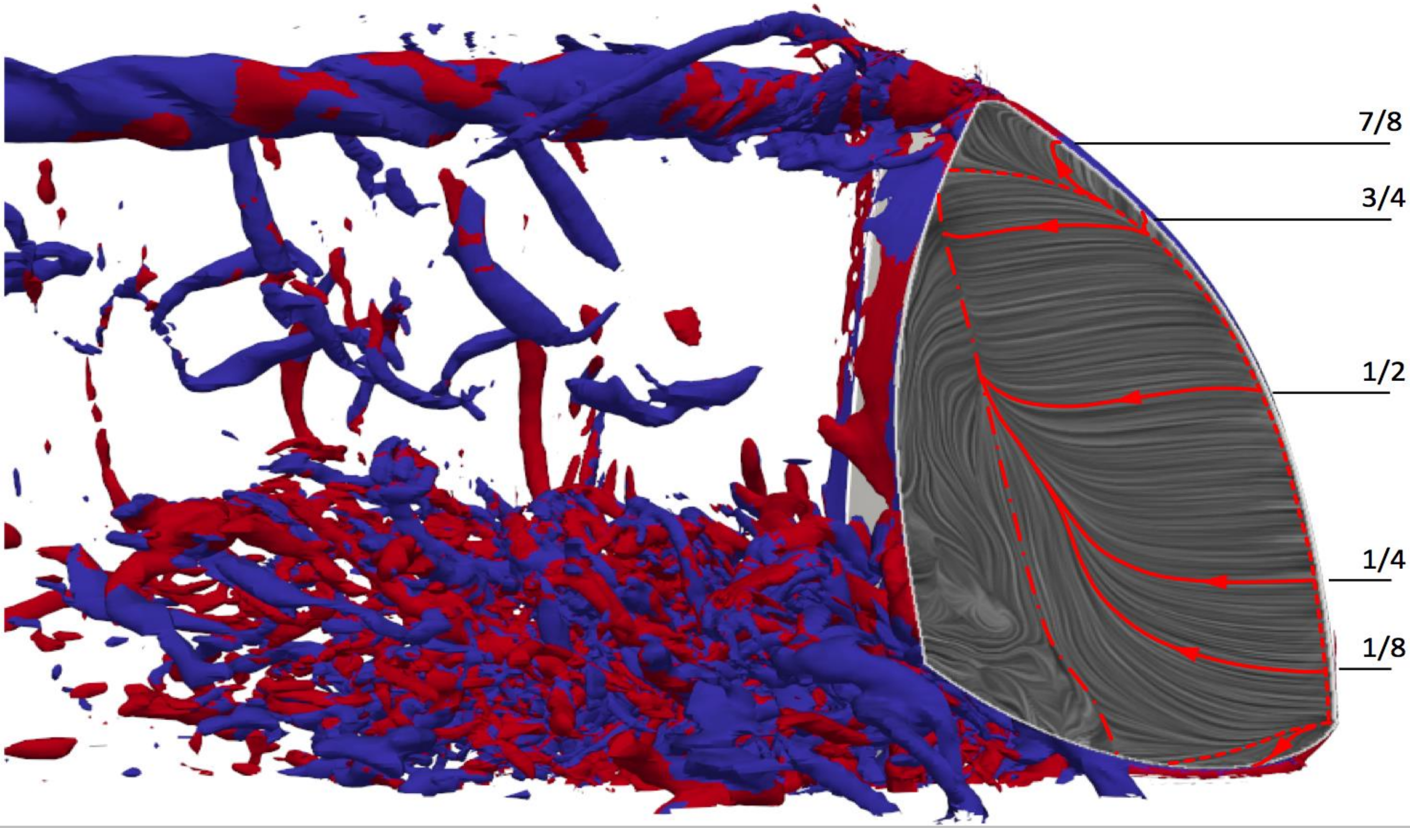




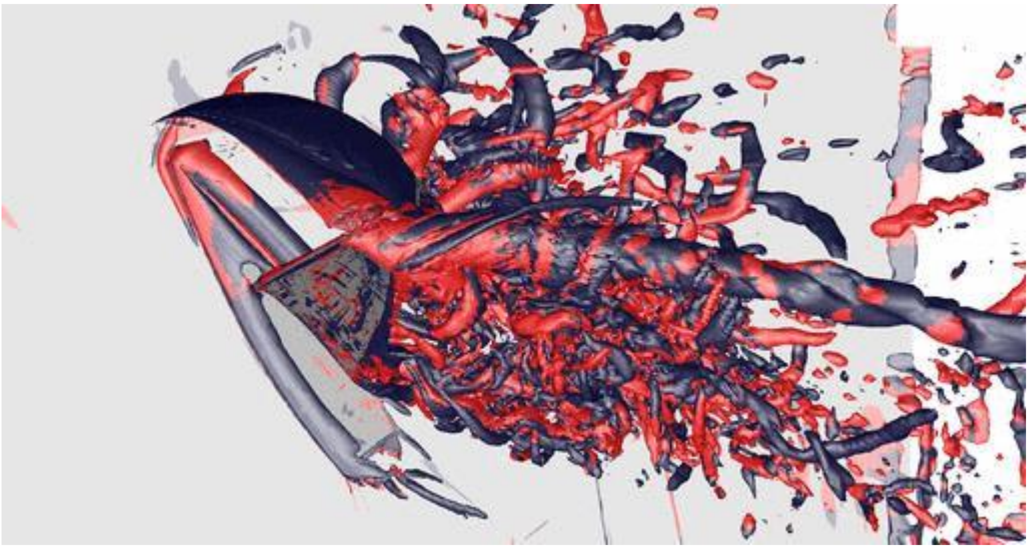


Experimental and numerical Cp on selected chords along the spinnaker surface (1/8h,1/4h, 1/2h,3/4h,7/8h).

Q criterion comparisons: visualization



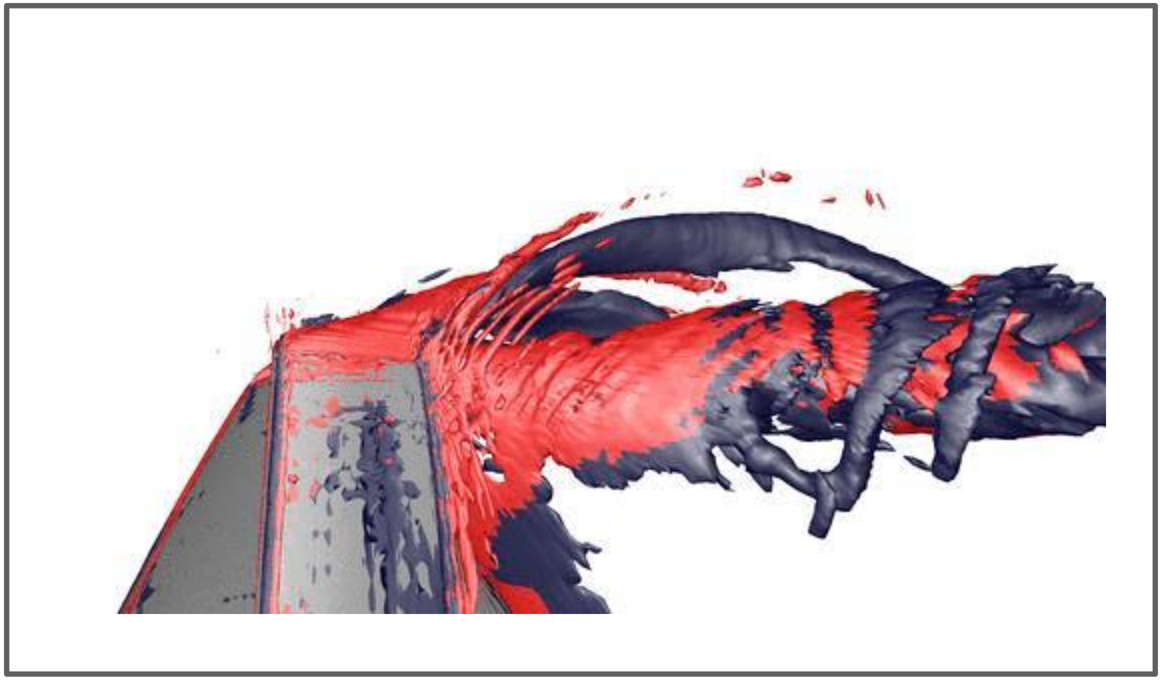
Iso-surfaces of Q-criterion downstream the sails surfaces colored by normalized helicity. Surface shear lines, separation and reattachment lines are also showed on the leeward side of the spinnaker.



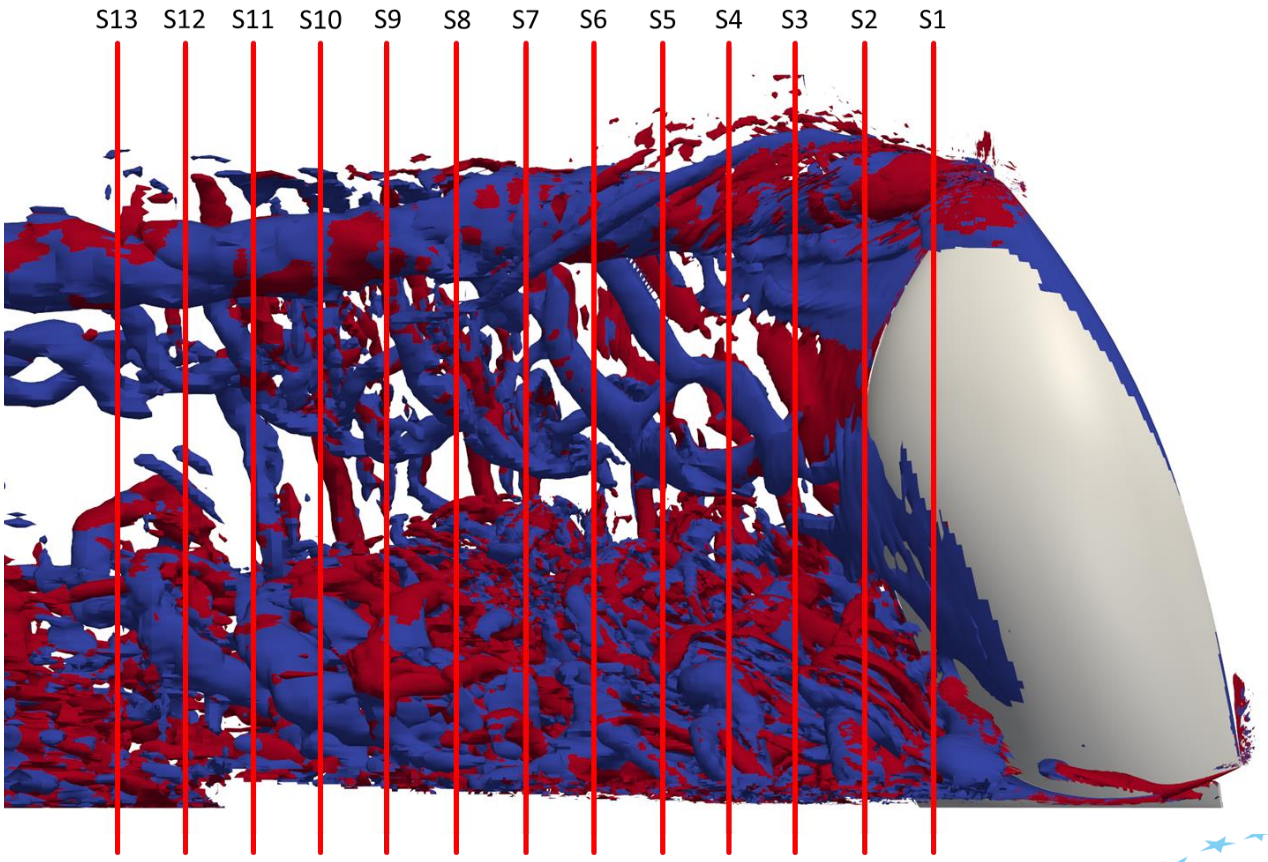
Top view

Side view

Top spinnaker vortex details

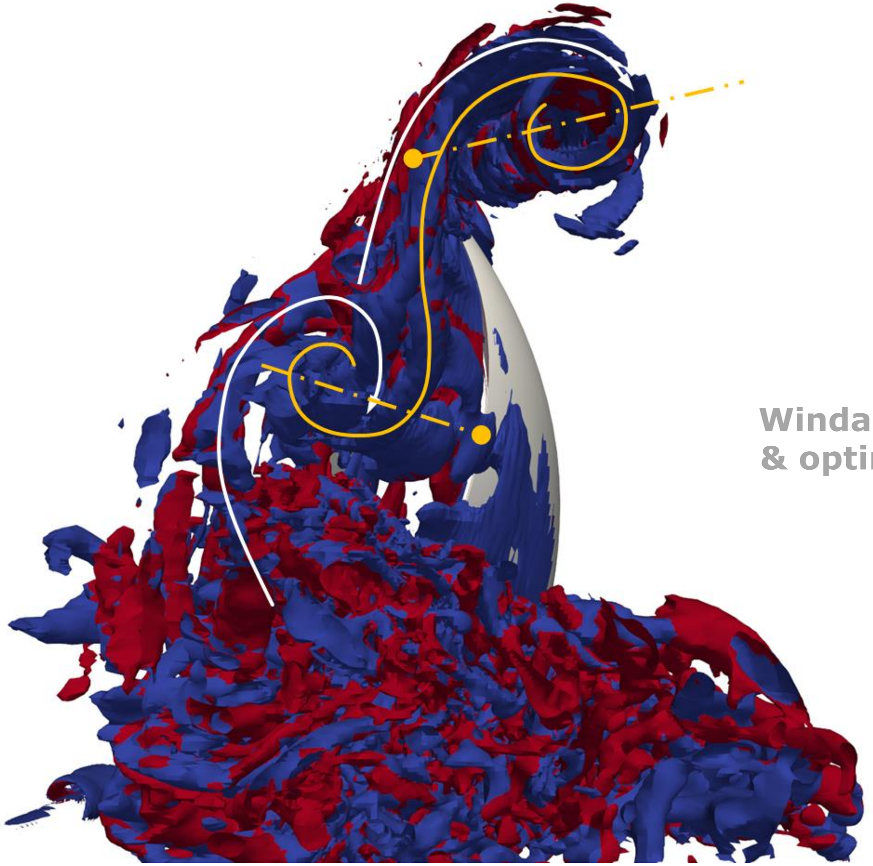


Q criterion comparisons: visualization



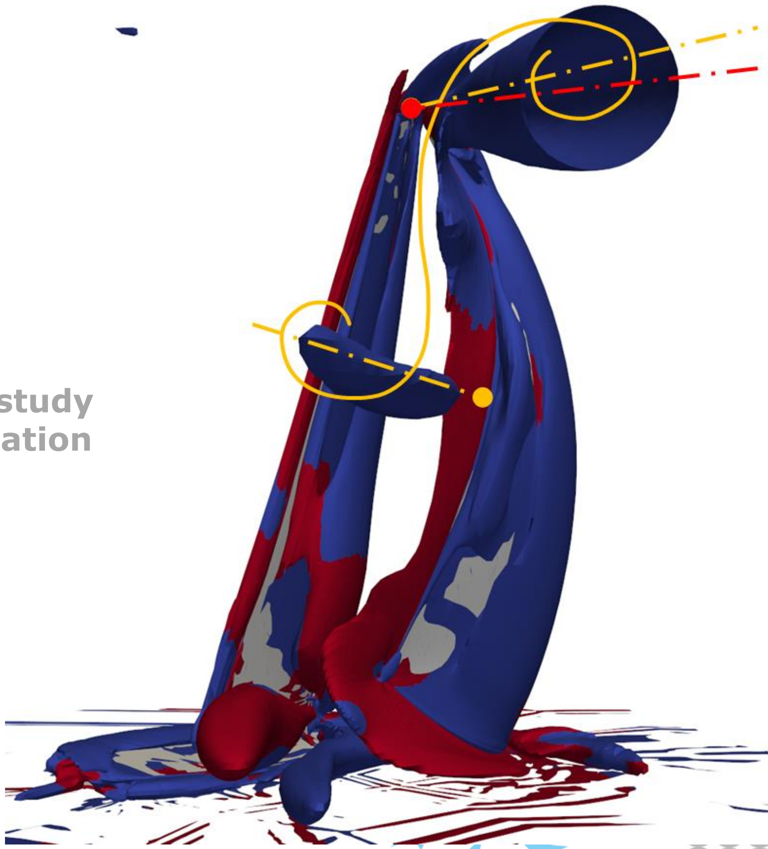
DDES vs RANS

32M_001s_30s – isoQ100_Helicity – S9



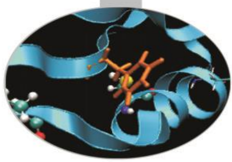
Windage study
& optimization

4M_RANS – isoQ100_Helicity – S9



Implications

- The study of turbulent structures around complex three dimensional geometries and curved surfaces under high lift conditions and their interaction with local flow fields where laminar to turbulent transition, separation and reattachment play a major role, is very challenging both numerically and experimentally.
- A synergy between experiments and numerical simulation can be the way to overcome these challenges:
  - experimental setups can be designed tailored to validate numerical models
  - advances on numerical hybrid modelling methods and high performance computing resources can lead to an affordable cost-effective strategy able to shrink cost and time consumption



Future developments

- Technology dependent: x86_64 next generation improvements
- Application dependent: Enlarging the mesh size and enrich the turbulent scale computed vs modeled

Mesh Size	Model Setup	Scalability	Wind-Tunnel Loops
4 mln	X	X	X
32 mln	X	X	X
256 mln	X	X	X

Acknowledgments

Yachts and Super-Yachts research unit, the Newcastle University (UK)

Yacht Research Unit, the University of Auckland (NZ)

Ansys Italy (IT)