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European  
Commission

Horizon 2020  
European Union funding  
for Research & Innovation

# Code of the Month Alya & SOD2D

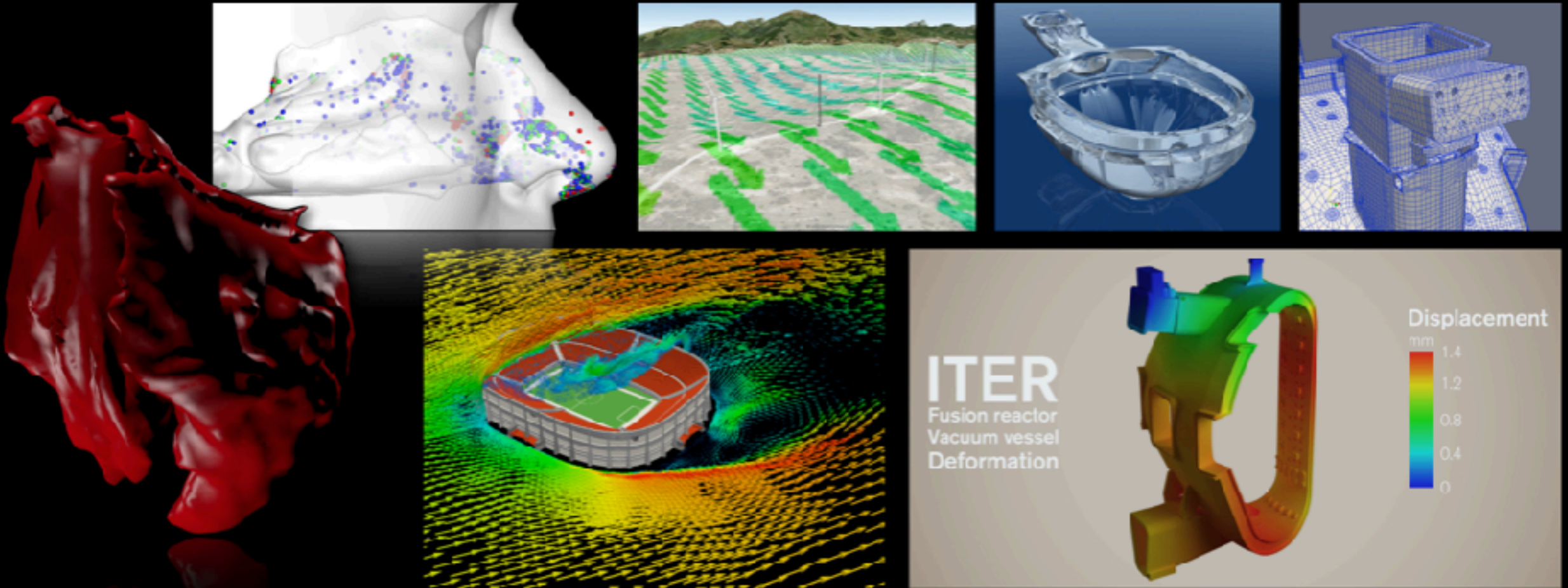
Herbert Owen  
Barcelona Supercomputing Center

18 Sep 2024

# Alya

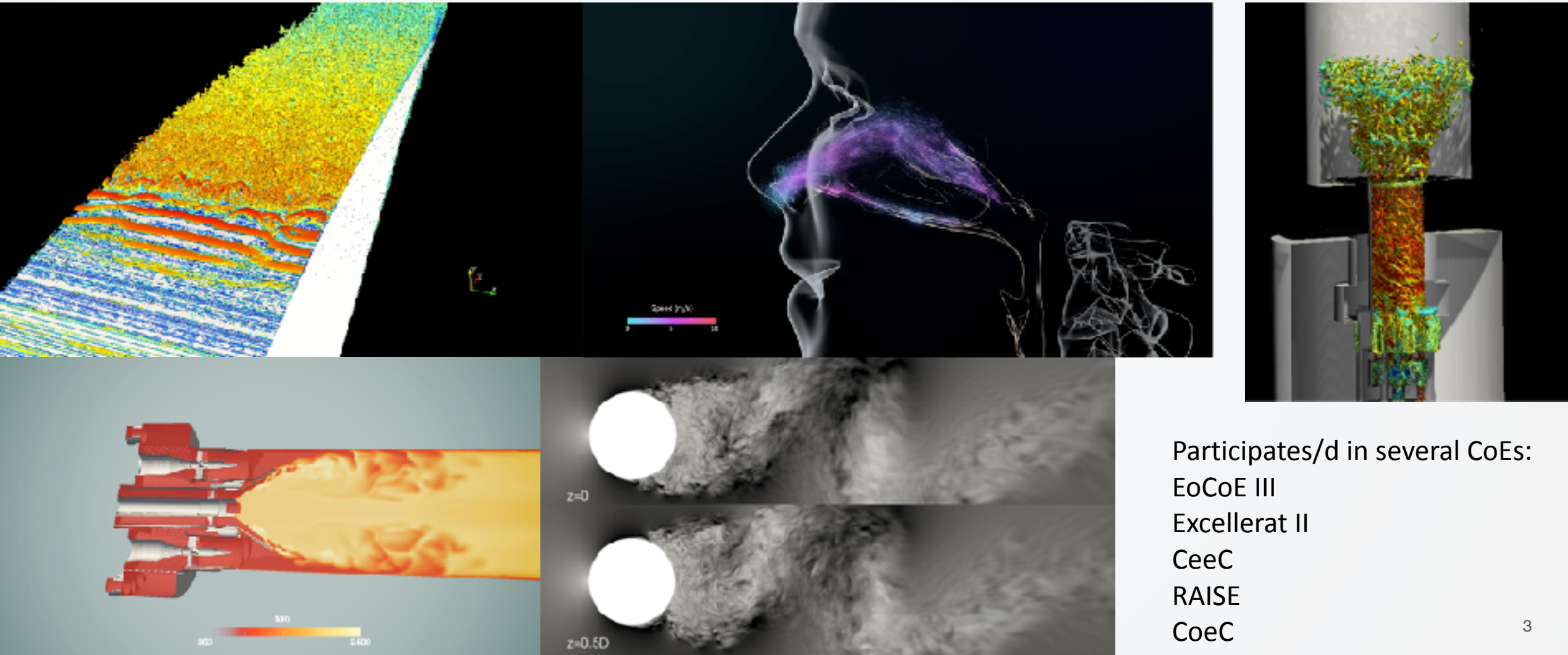
Alya: HPC finite element multiphysics code developed at BSC

<https://www.bsc.es/research-development/research-areas/engineering-simulations/alya-high-performance-computational>



# Alya

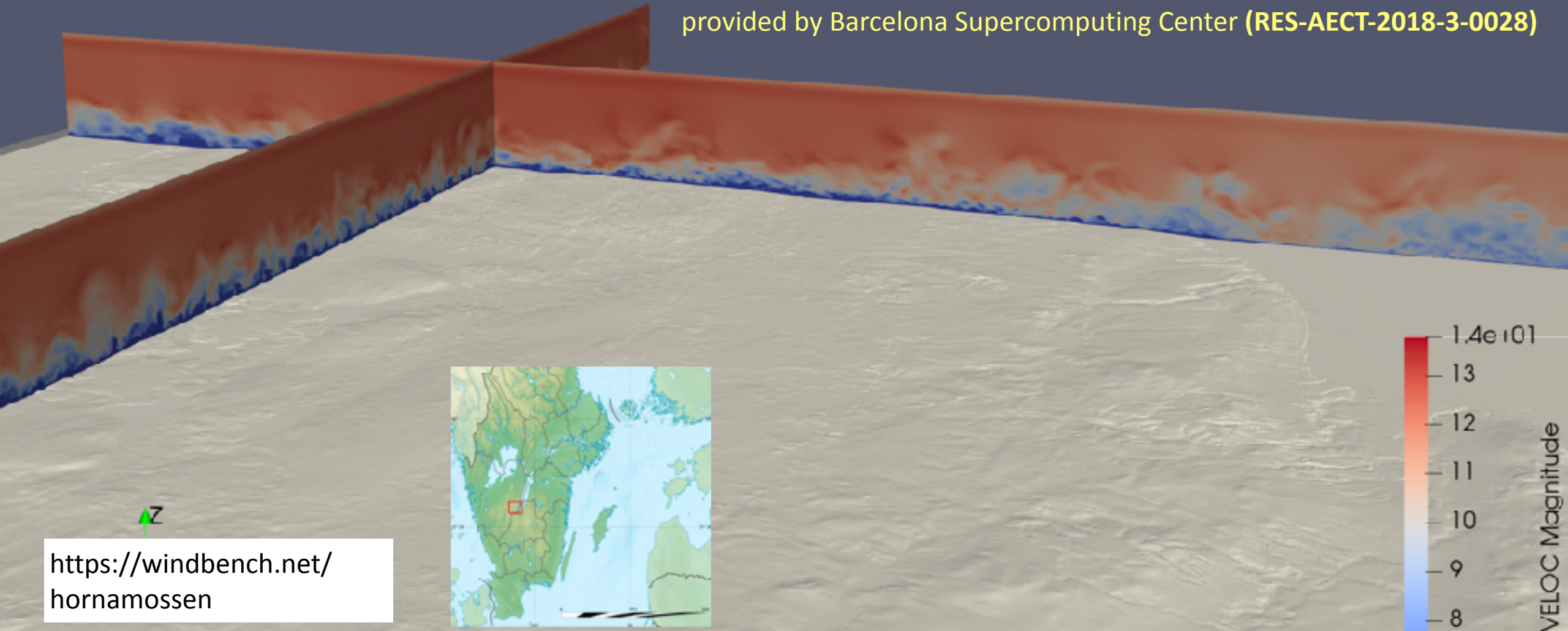
Alya is one of the two CFD codes in the Prace Benchmark Suite. Scalability has been tested on most European Supercomputers





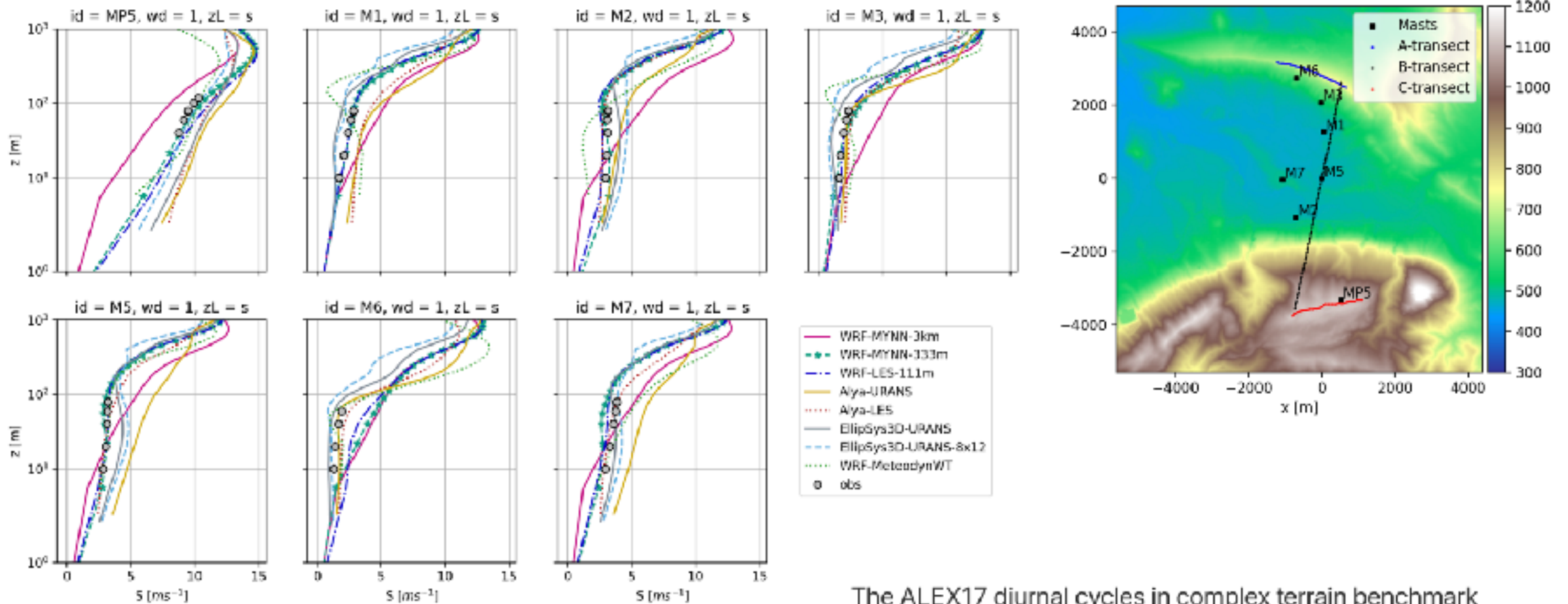
# Hornamossen Benchmark

Computer resources at MareNostrum and the technical support provided by Barcelona Supercomputing Center (**RES-AECT-2018-3-0028**)



<https://windbench.net/hornamossen>

# Wind Large Eddy Simulation - Alaiz Benchmark



Vertical profiles of wind speed at each mast for stable conditions

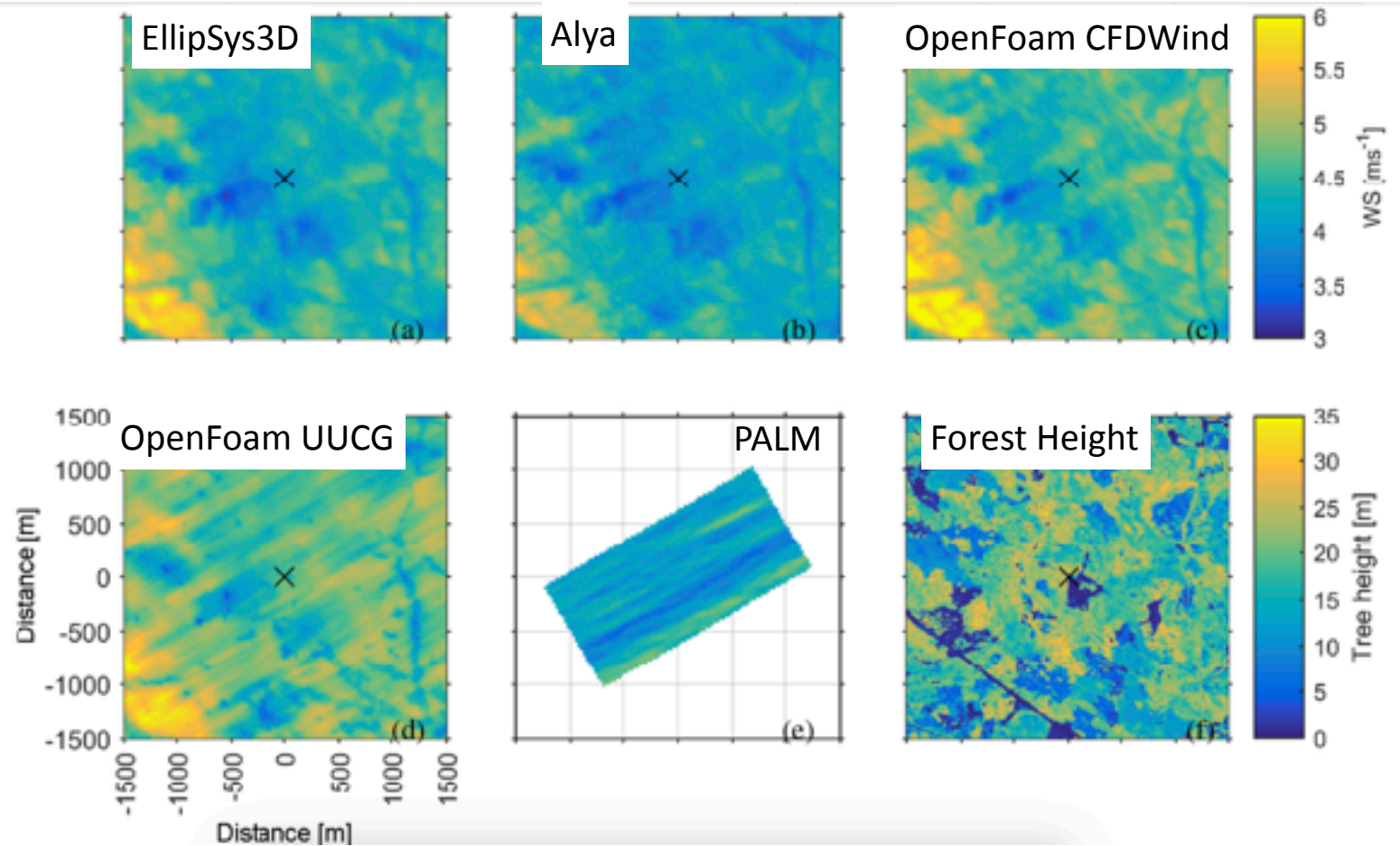
## The ALEX17 diurnal cycles in complex terrain benchmark

J Sanz Rodrigo<sup>1,2</sup>, P Santos<sup>3,4</sup>, R Chávez Arroyo<sup>5</sup>, M Avila<sup>6</sup>, D Cavar<sup>4</sup>, O Lehmkühl<sup>6</sup>, H Owen<sup>6</sup>, R Li<sup>7</sup> and E Tromeur<sup>7</sup>

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[Journal of Physics: Conference Series, Volume 1934, Wake Conference 2021 16–17 June 2021, Västby, Sweden](#)

# Ryningsnäs Benchmark



Forested site with moderately complex topography in Sweden

Simulated wind speed at 40 m above the local ground height

# Awaken Benchmark



Currently the most important Wind energy benchmark is AWAKEN  
Organised by NREL (US) - <https://www.nrel.gov/wind/awaken.html>  
Unfortunately it is not free and it seems Spain will not to pay

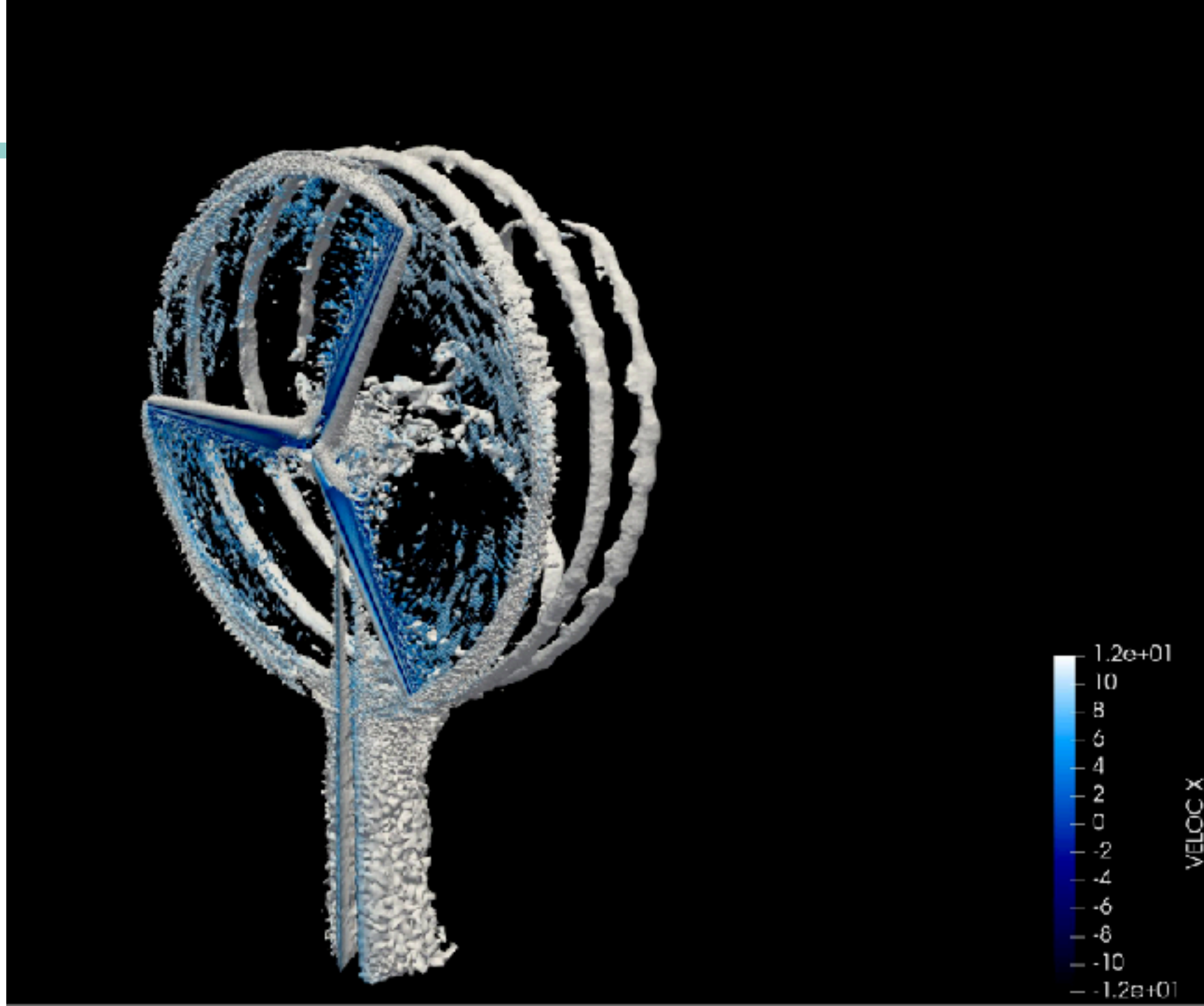


# Full rotor simulations

Full rotor model where the actual geometry of the wind turbine blades and tower is modelled exactly

Sliding mesh approach to incorporate the rotation of the blades.

Developed with Alya within EoCoE2



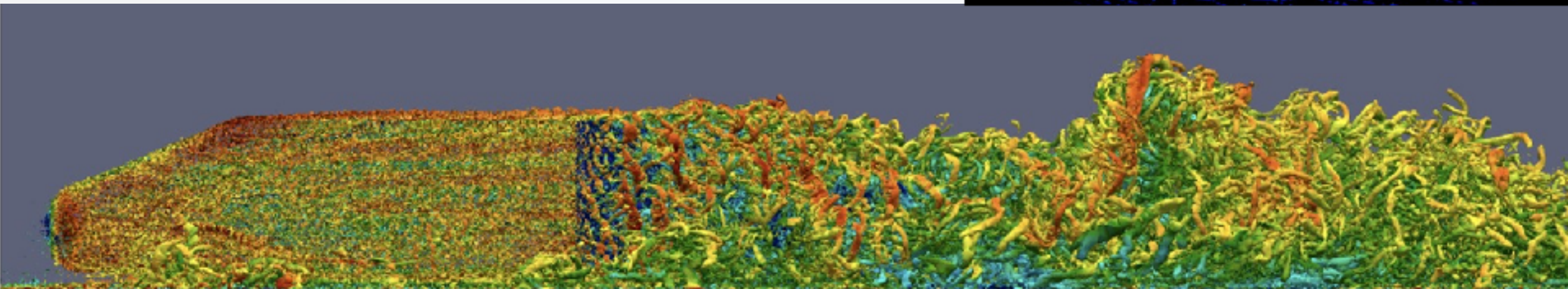
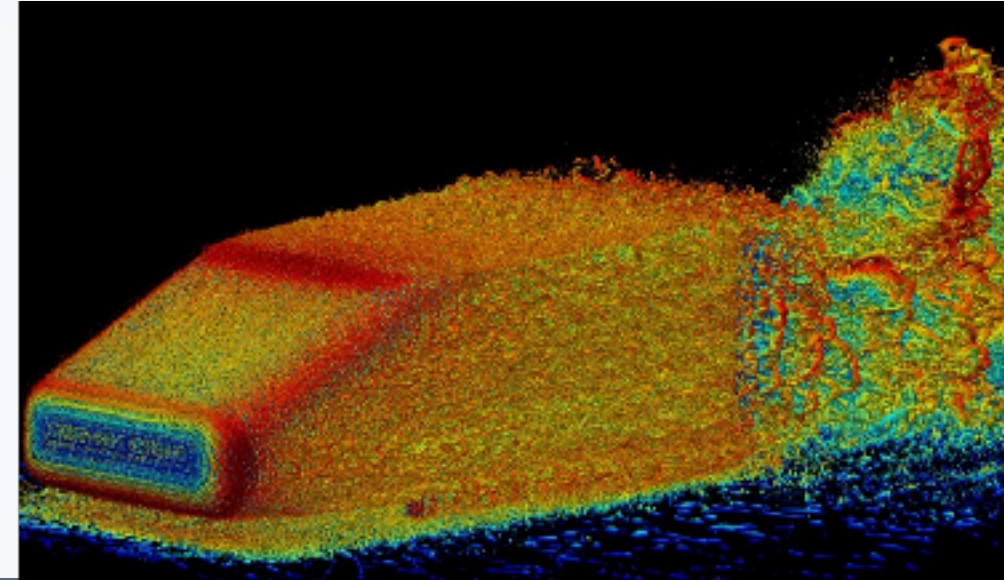


# SOD2D

SOD2D: Spectral element, **high order**, flow code developed at BSC

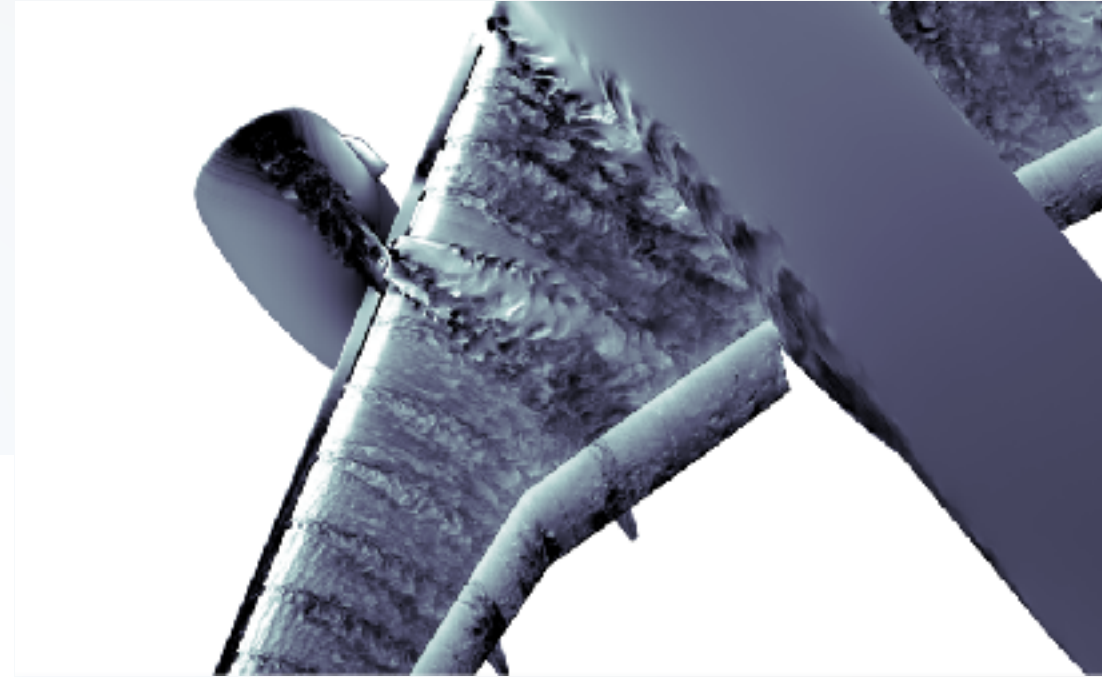
[https://gitlab.com/groups/bsc\\_sod2d](https://gitlab.com/groups/bsc_sod2d) Open source

Also Participates in EoCoE III, Excellerat II & CeeC.  
Started a couple of years ago with the PhD thesis of Lucas Gasparino  
Now it is the main code of the LSCFD group @ BSC.  
Can be used as a library within Alya for Multiphysics problems.



# SOD2D

It is now the main code of the LSCFD group @ BSC.  
Focus only on CFD (Compressible and incompressible), will shortly include thermal coupling.  
Works fully on the GPU. (Fortran + OpenACC)  
Excellent scalability in several European Supercomputers.  
Will shortly be tested on the full MN5 ACC. (Currently up to 2048 H100)



Compares satisfactorily against the highly mature code Nek5000

[Assessment of turbulence closure strategies for large-eddy simulations within a spectral element framework](#)  
V Kumar, A Tomboulides, M Min, P Fischer, O Lehmkuhl  
[Bulletin of the American Physical Society](#)



# Collaboration with industry

# Iberdrola

## The Iberdrola group is a global energy leader

BSC has been collaborating with Iberdrola on wind resource assessment for more than **10 years**.

**New physics** ( and numerics) has been added to **Alya** to address the needs of **wind farm modelling**.

- Coriolis forces
- Canopy terms
- Actuator disc models
- Thermal coupling for stable and convective regimes
- Modifications to RANS models
- Boundary Conditions, etc..

Moreover, BSC has developed specific pre and post- processing tools.

Iberdrola can run Alya as a more powerful alternative to commercial codes.

## Iberdrola Group in the world

Iberdrola  
España

ScottishPower

Avangrid

Necenergia

Iberdrola  
México

Iberdrola  
Internacional

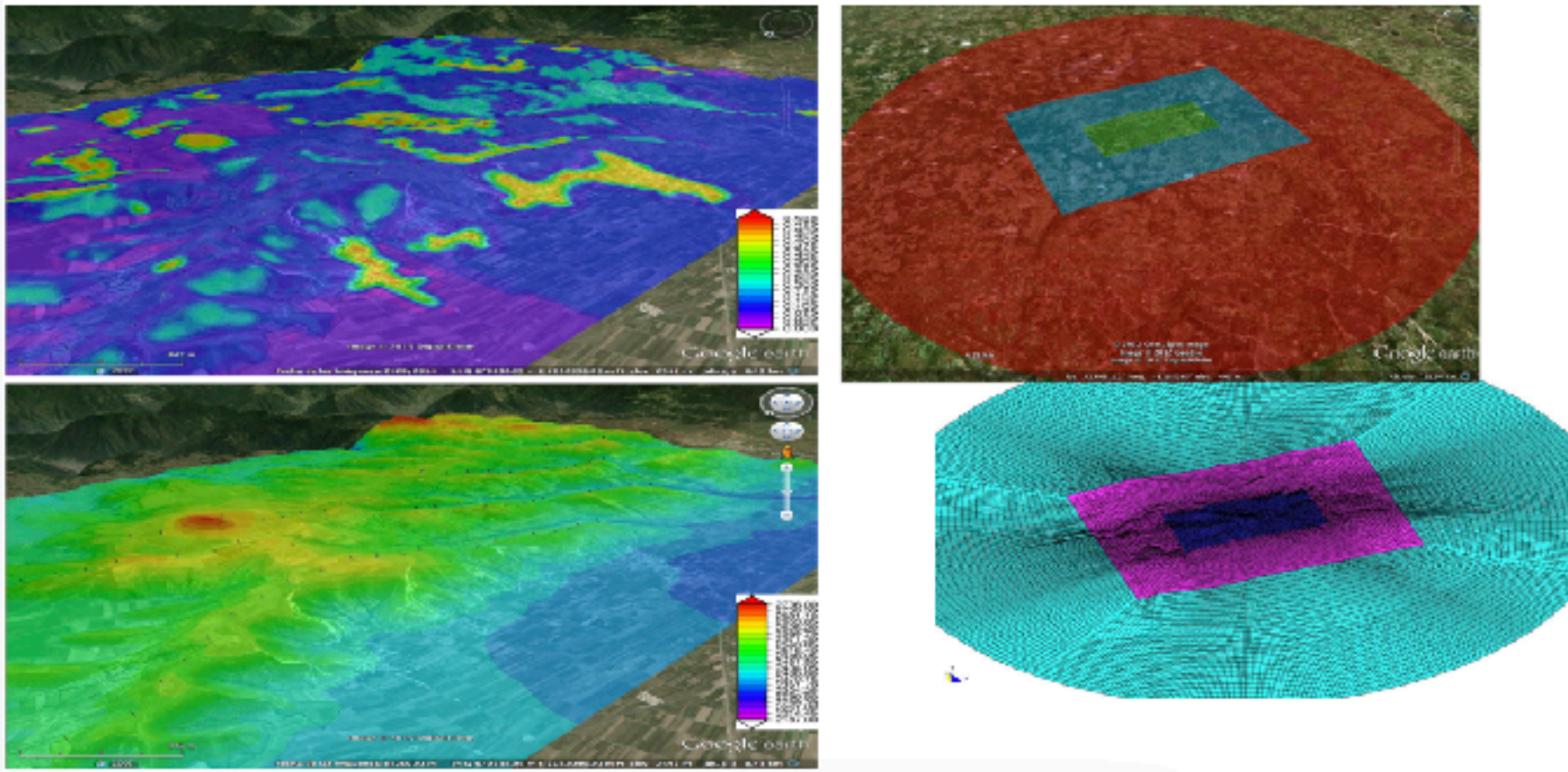




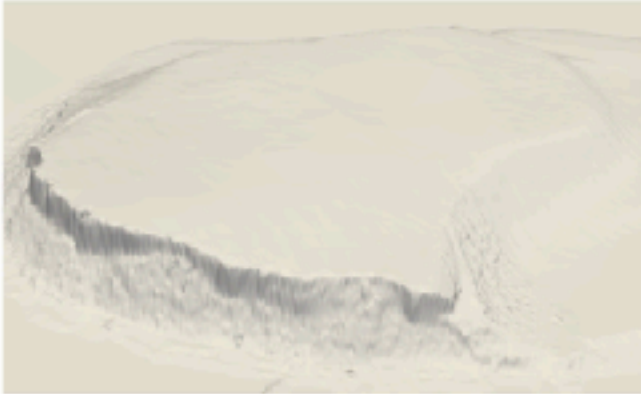
# Iberdrola - Preprocessing - mesh generation

**WindMesh** generates a structured background mesh of hexahedral elements from terrain information (topography, roughness, canopy)

- Flat buffer zone to accommodate the flow and boundary layer near the surface
- Visualisation of terrain data using Google Earth overlays

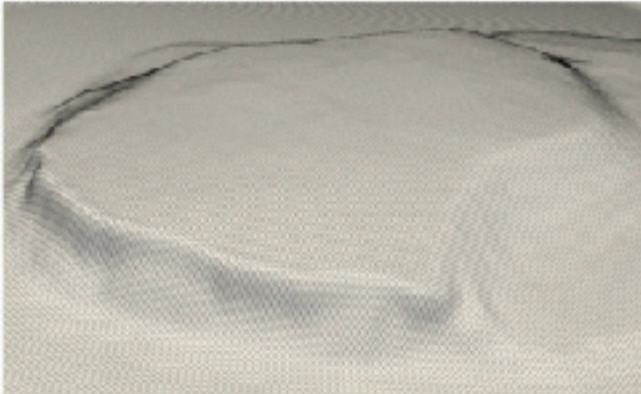


# Iberdrola - Preprocessing - mesh generation



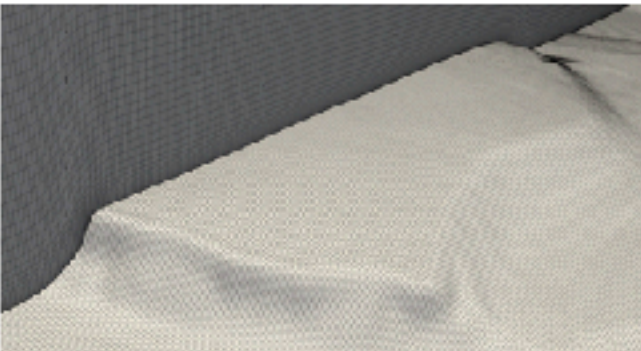
## 1. Topography

- Surface defined from an STL, a point set, a contour map, etc.
- Noise filtering: signal processing smoothing



## 2. Quadrilateral surface mesh

- Structured mesh (can be aligned with the inflow wind direction)
- Mesh optimization

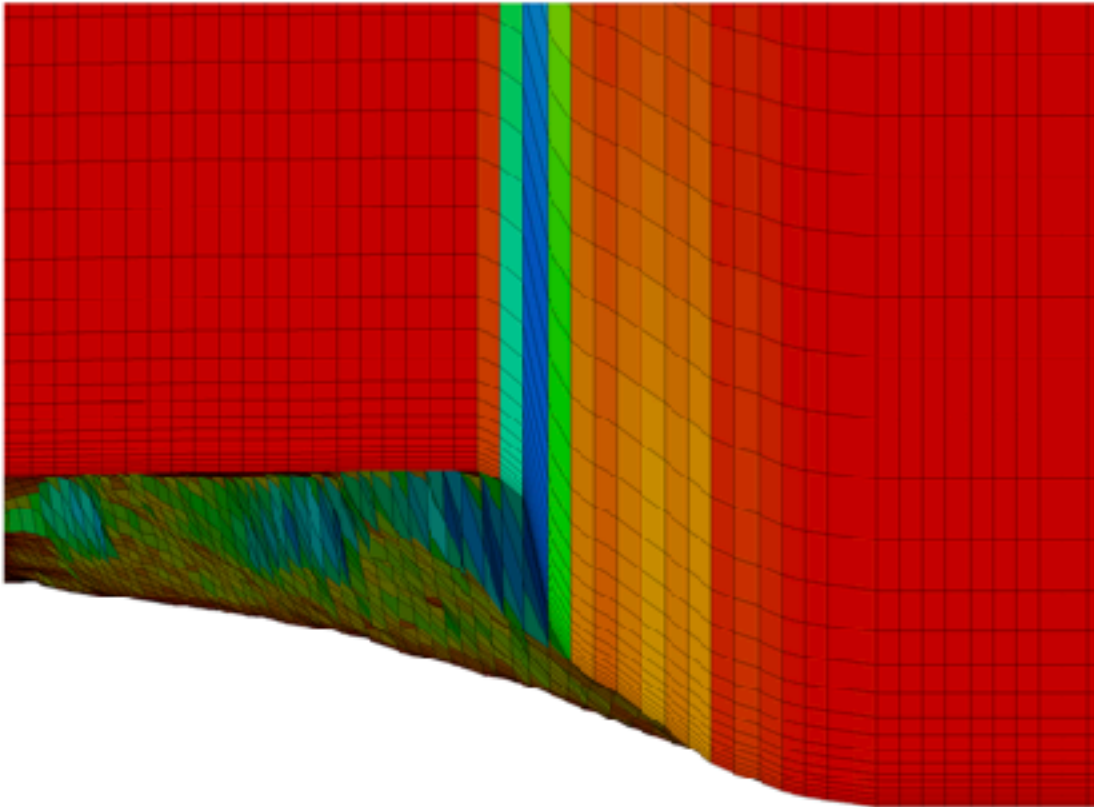


## 3. Hexahedral volume mesh

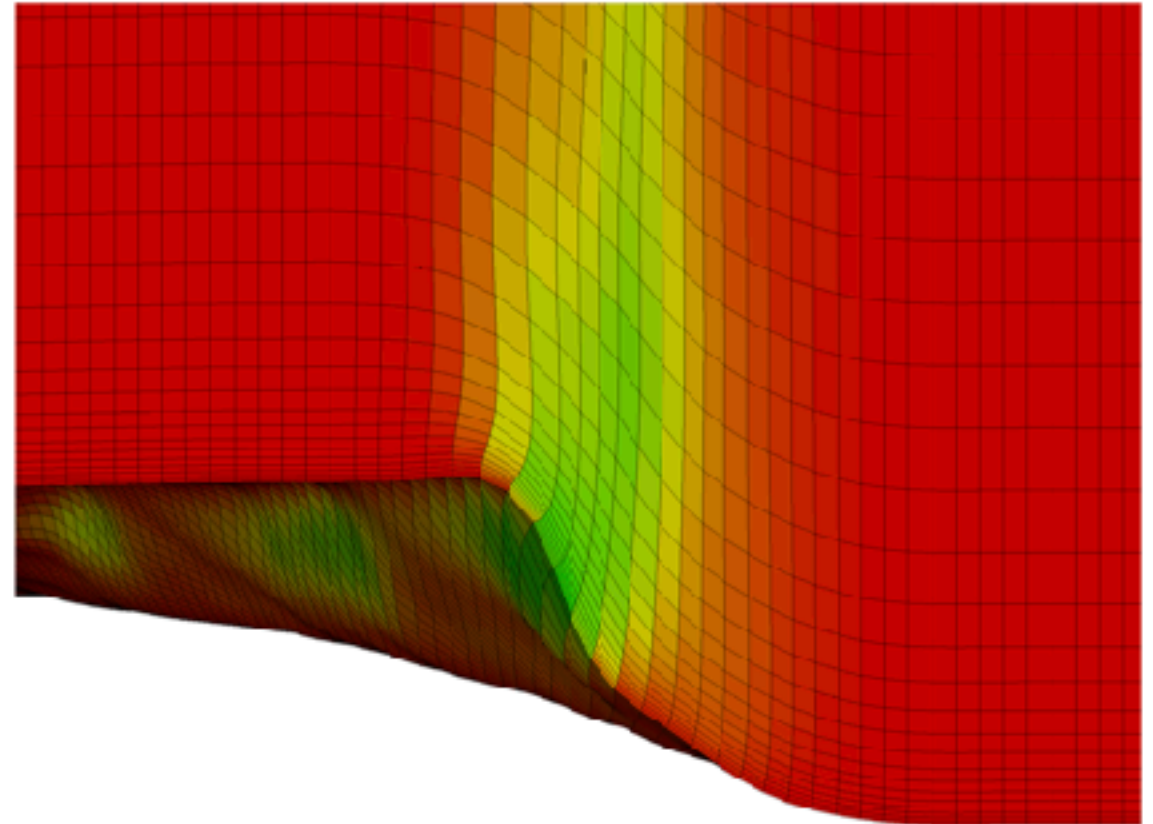
- Structured sweeping mesh (can be aligned with the inflow wind direction)
- Mesh optimization



# Iberdrola - Preprocessing - mesh generation

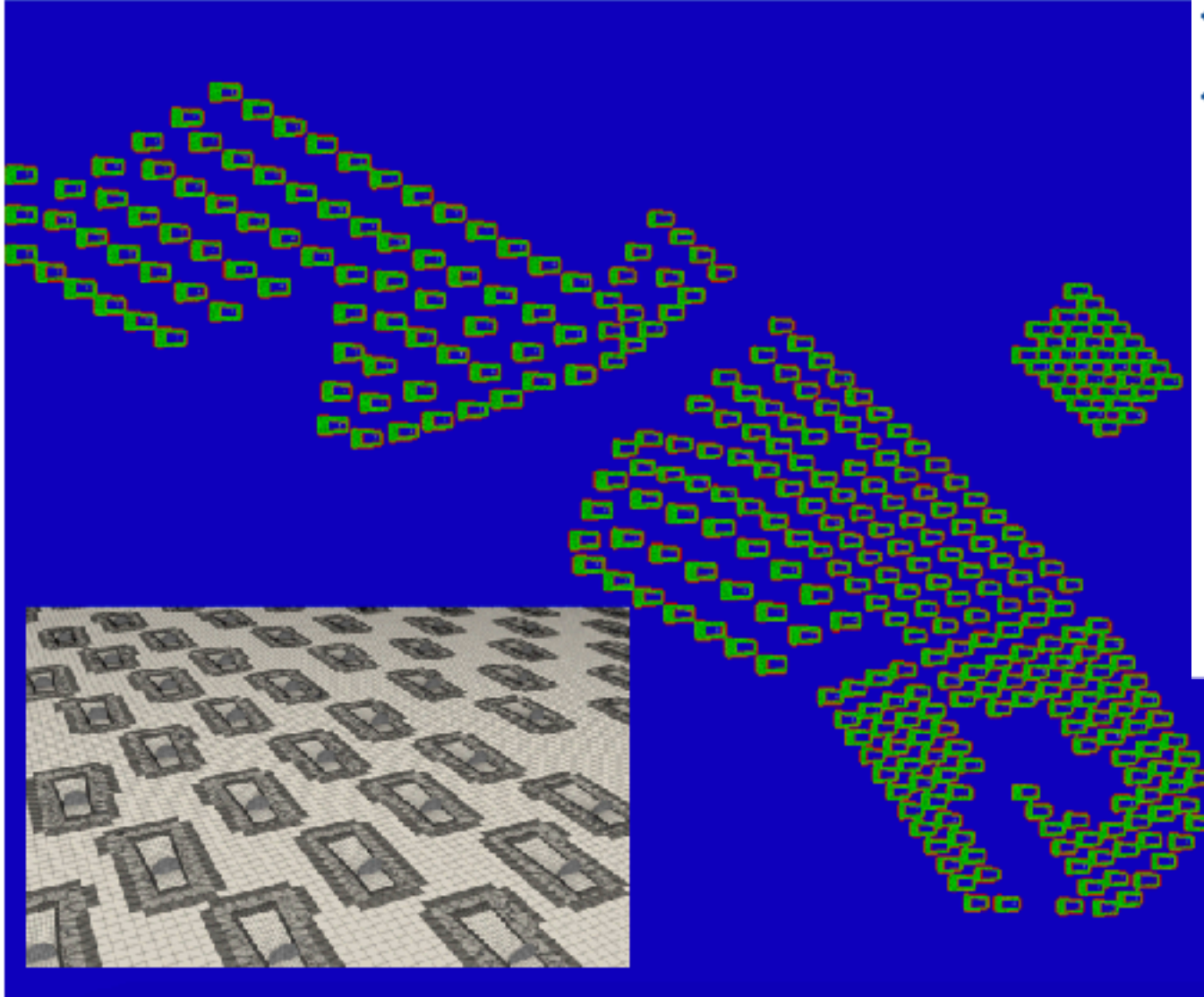


*Mesh generation extruding in the vertical direction without mesh optimization*

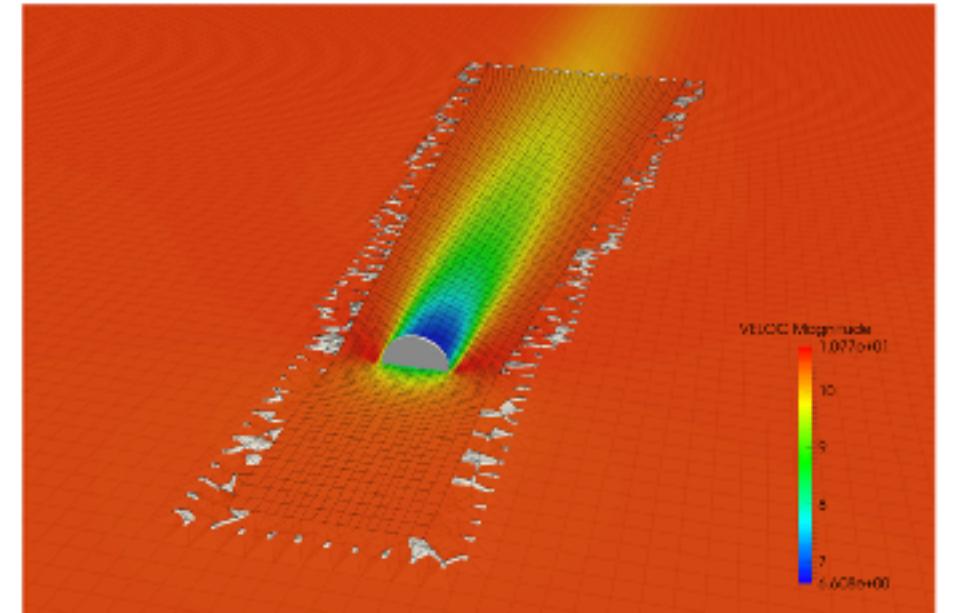


*Mesh generation using the pseudo-normal mesh optimization (colours indicate the quality of the resulting hexahedral elements). Note how the boundary layer is preserved*

# Iberdrola - DiscMesh: mesh generation for wind farms

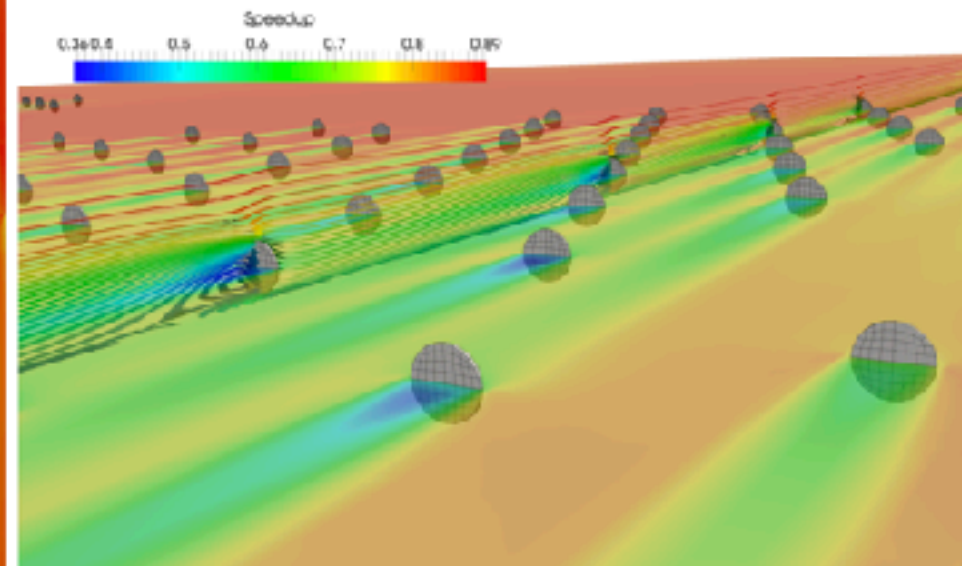
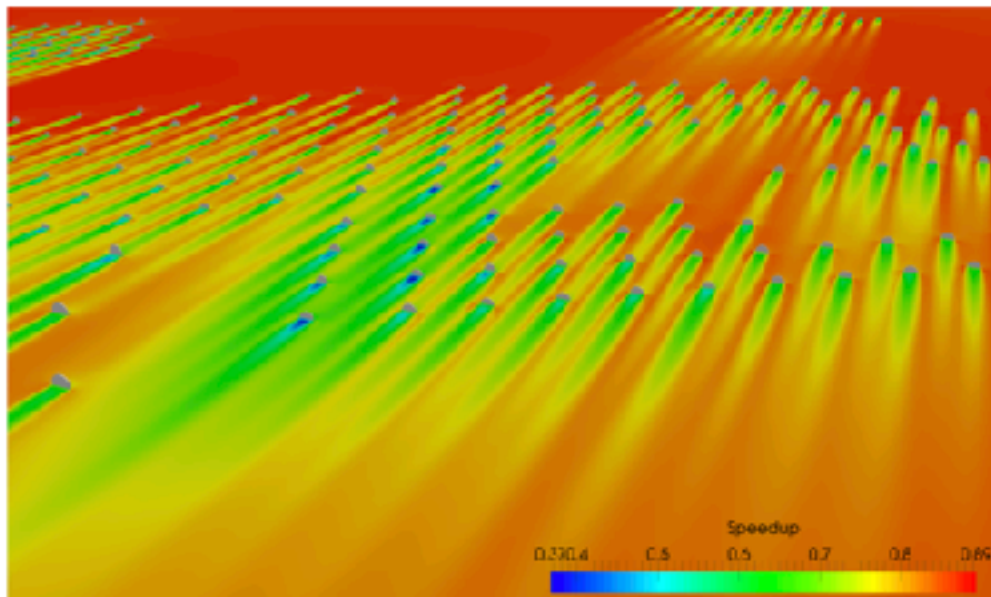
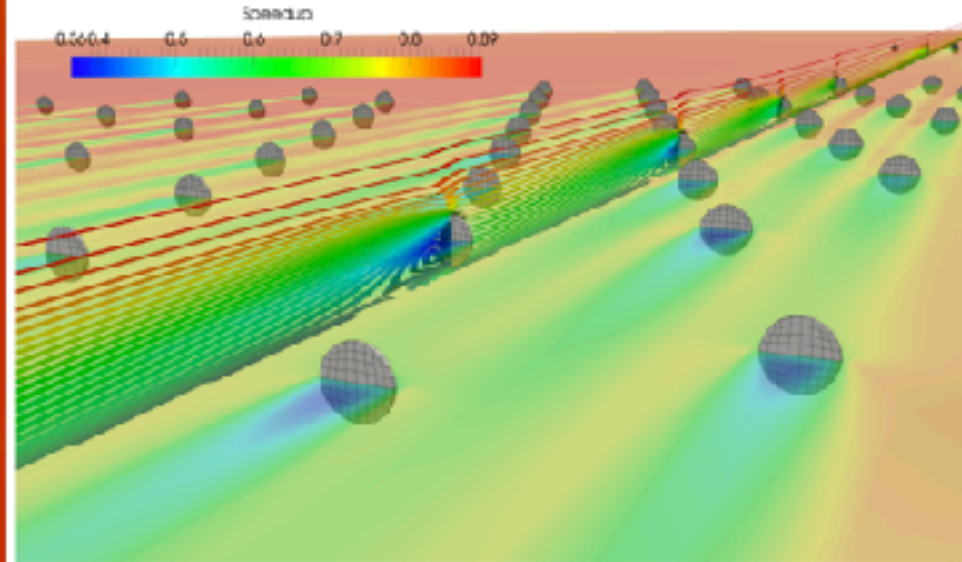
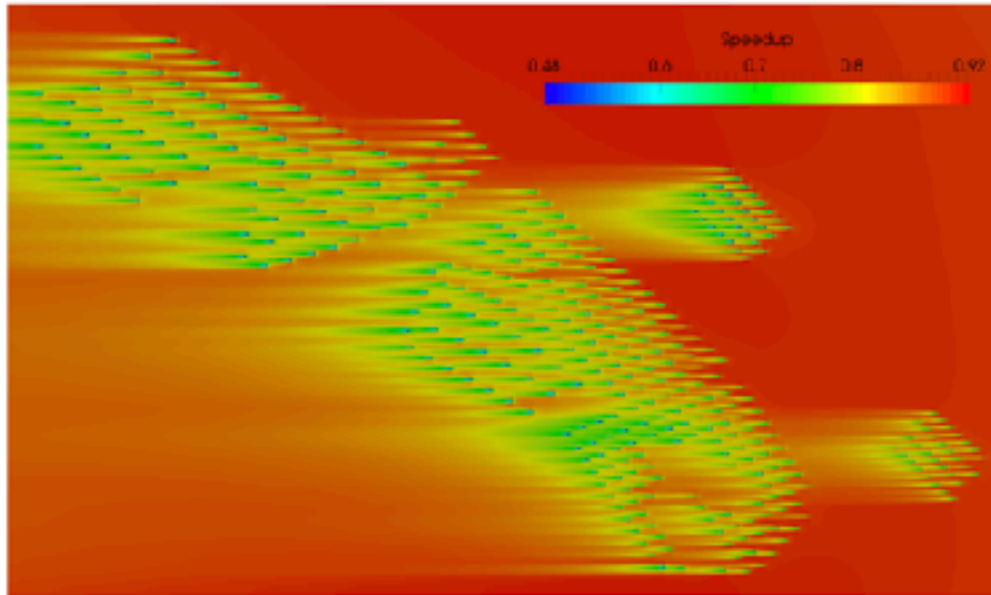


- DiscMesh generates unstructured hybrid meshes for wind turbines and does embedding in a background mesh (generated by WindMesh)
- Downstream element refinement for wake capturing





# Iberdrola - Wind farm modelling



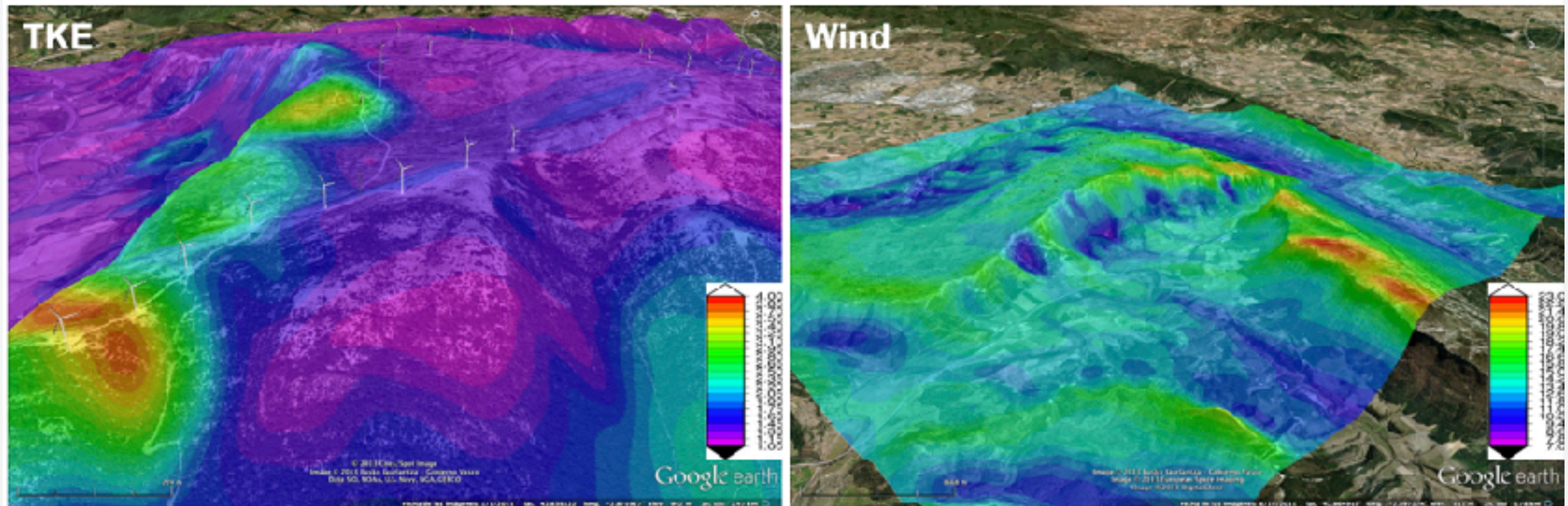
West of Duddon Sands (WoDS, U.K.) off-shore wind farm modelling using Alya

# Iberdrola - Wind farm modelling

Post-process tools for wind resource assessment and visualization:

- Wind fields
- Site Weibull distributions
- Turbulence intensity
- Annual Energy Production (AEP)

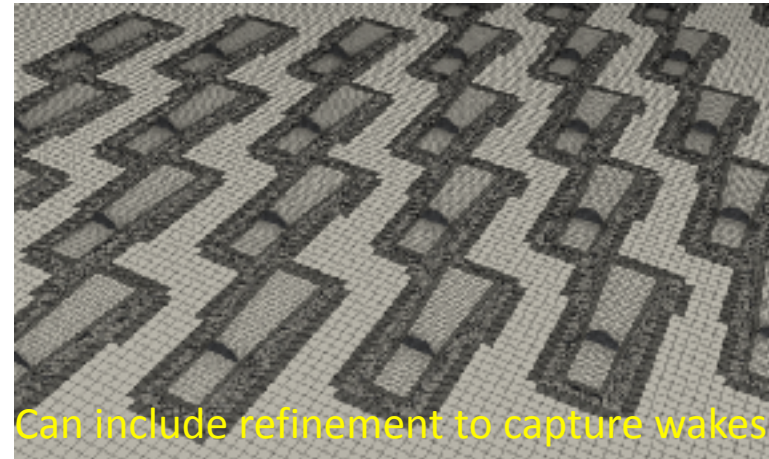
Automated methodology and visualization using Google Earth layers





# Wind Farm Modelling - Alya Workflow

WindMesh inputs:  
Topography and roughness  
files (grd, map, etc) +  
wind farm location + ..

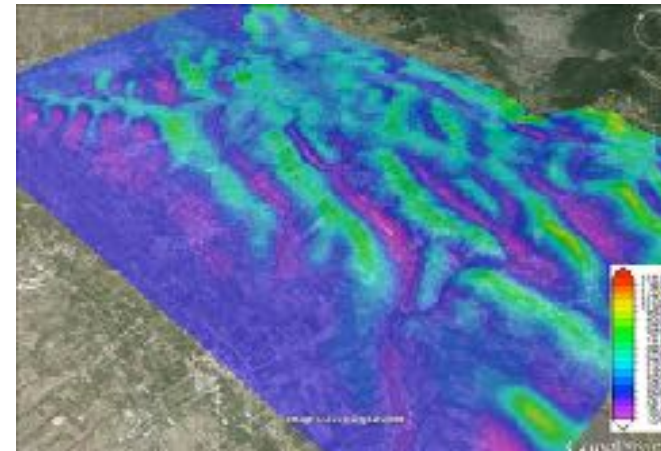


Run ALYA in supercomputer



AlyaFix. Boundary conditions with  
minimal user input:  
Latitude + Geostrophic wind + ..

PostFarm. Obtain WRG file  
with Weibull parameters A &  
k + Visualisation of results in  
Google Earth or Paraview

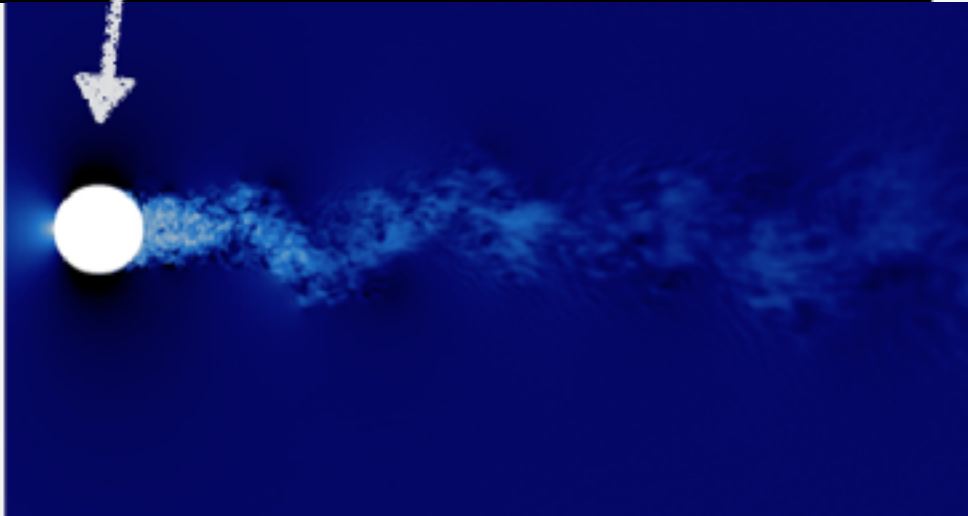
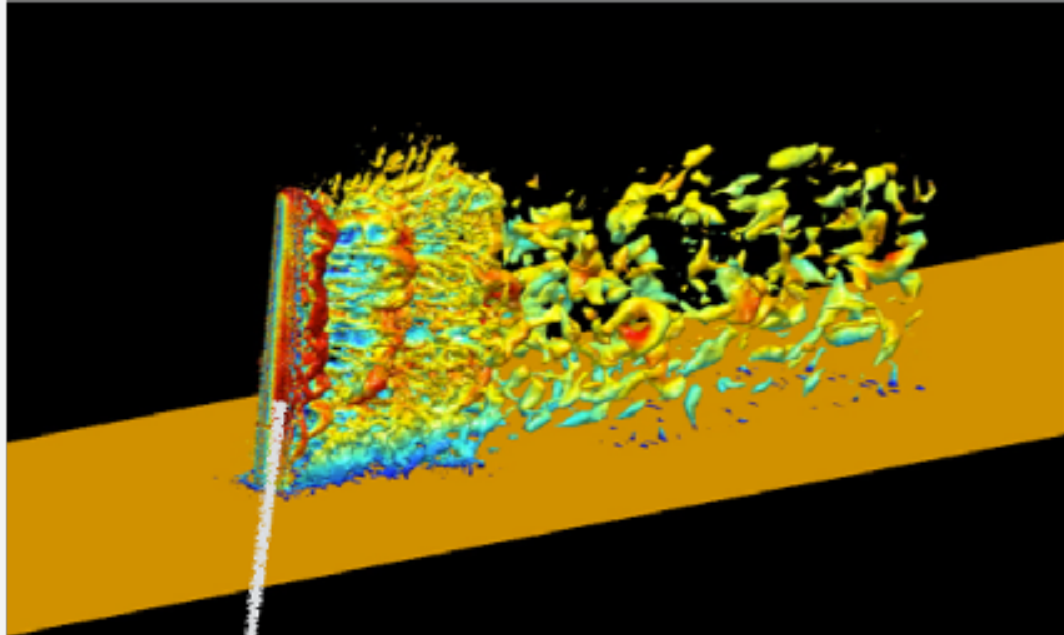


Developed for



Used by them as an  
alternative to commercial tools

# Vortex Bladeless - an SME



Scale-up assessment of the Vortex-Bladeless device  
Optimisation of the device at the aero-elastic level  
Fluid Structure Interaction problem

Within the framework of a H2020 SME Instrument for  
Vortex Bladeless S.L. and a PRACE SHAPE project



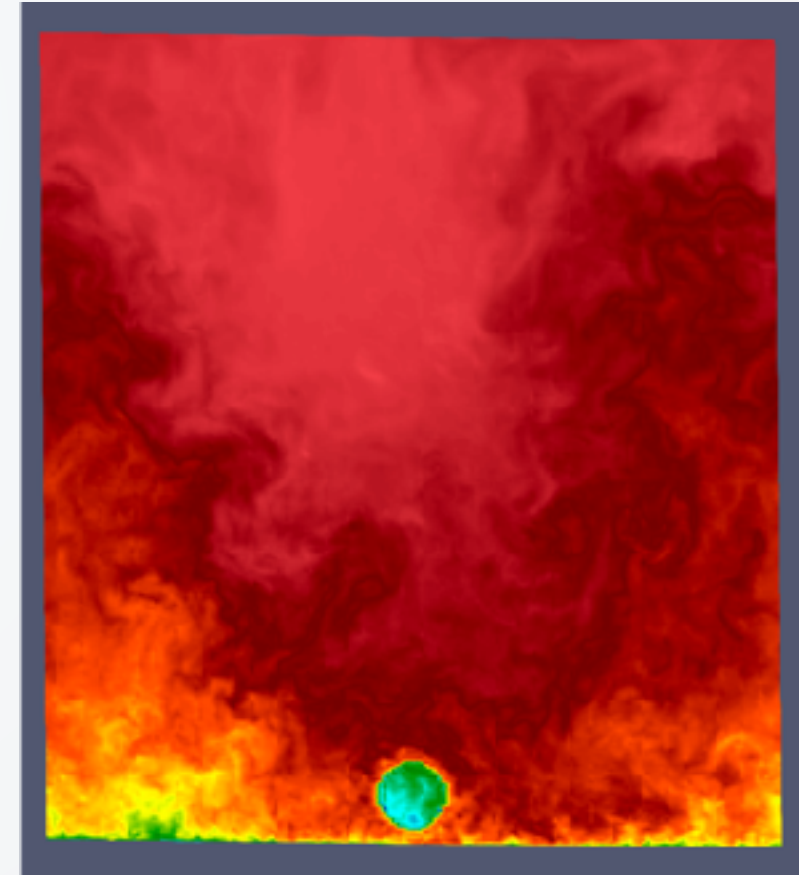
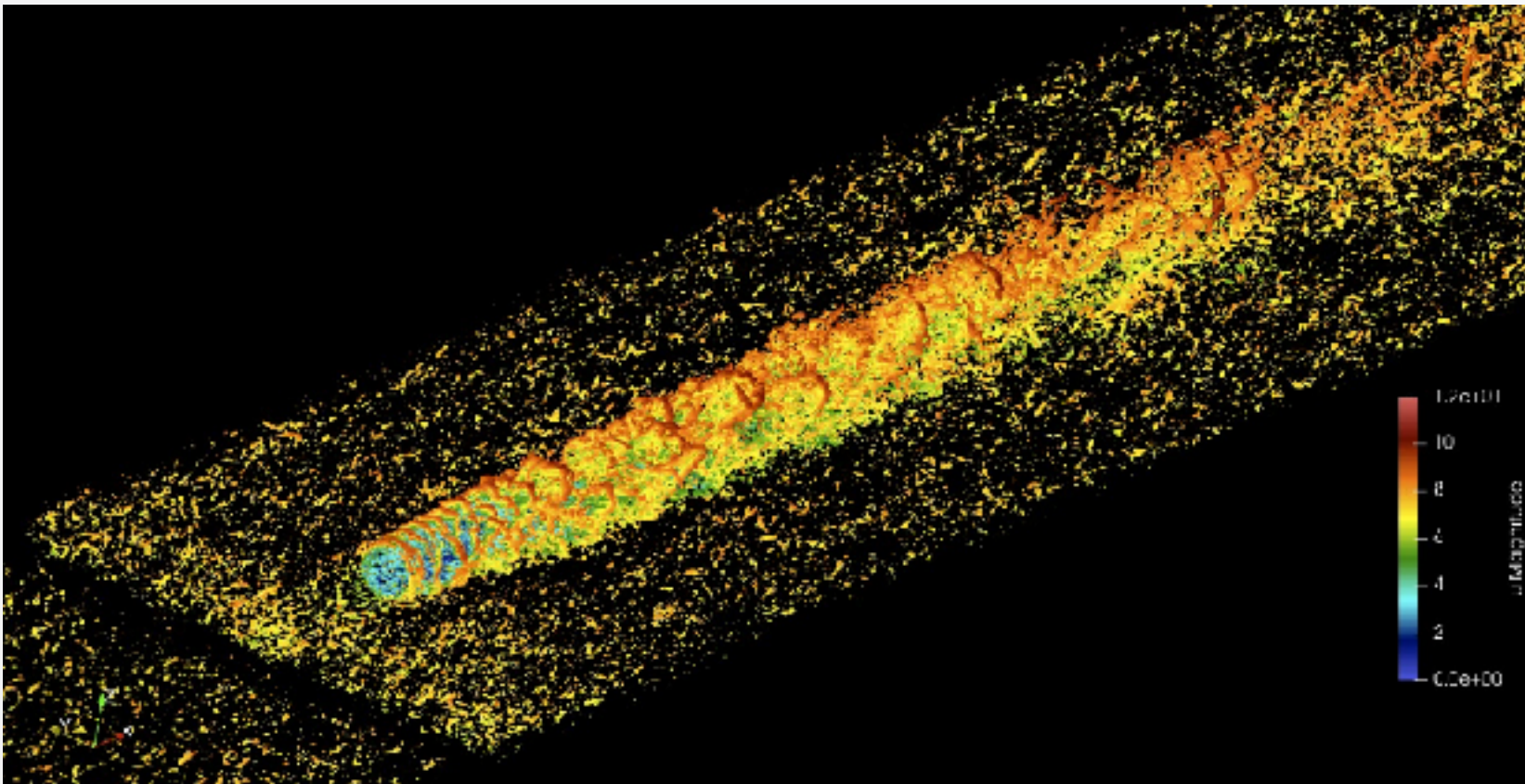


# OceanWinds

OW OCEAN WINDS

Joint venture between **Engie** and **EDP**.

Starting new collaboration on Scale Resolving  
Simulations for Offshore Wind energy using **SOD2D**



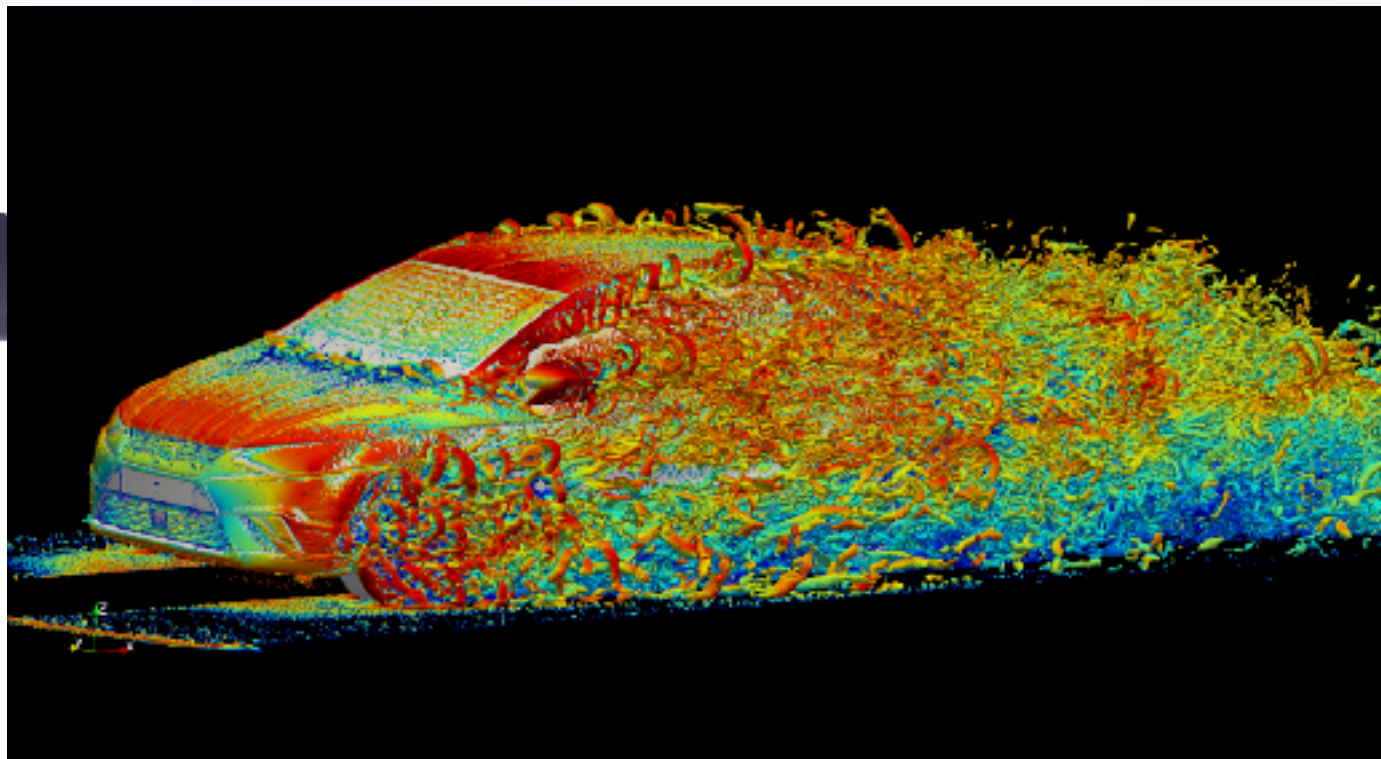
# Other big companies



WMLES as an alternative to RANS for aircraft aerodynamics



WMLES for automotive aerodynamics - rotating wheels

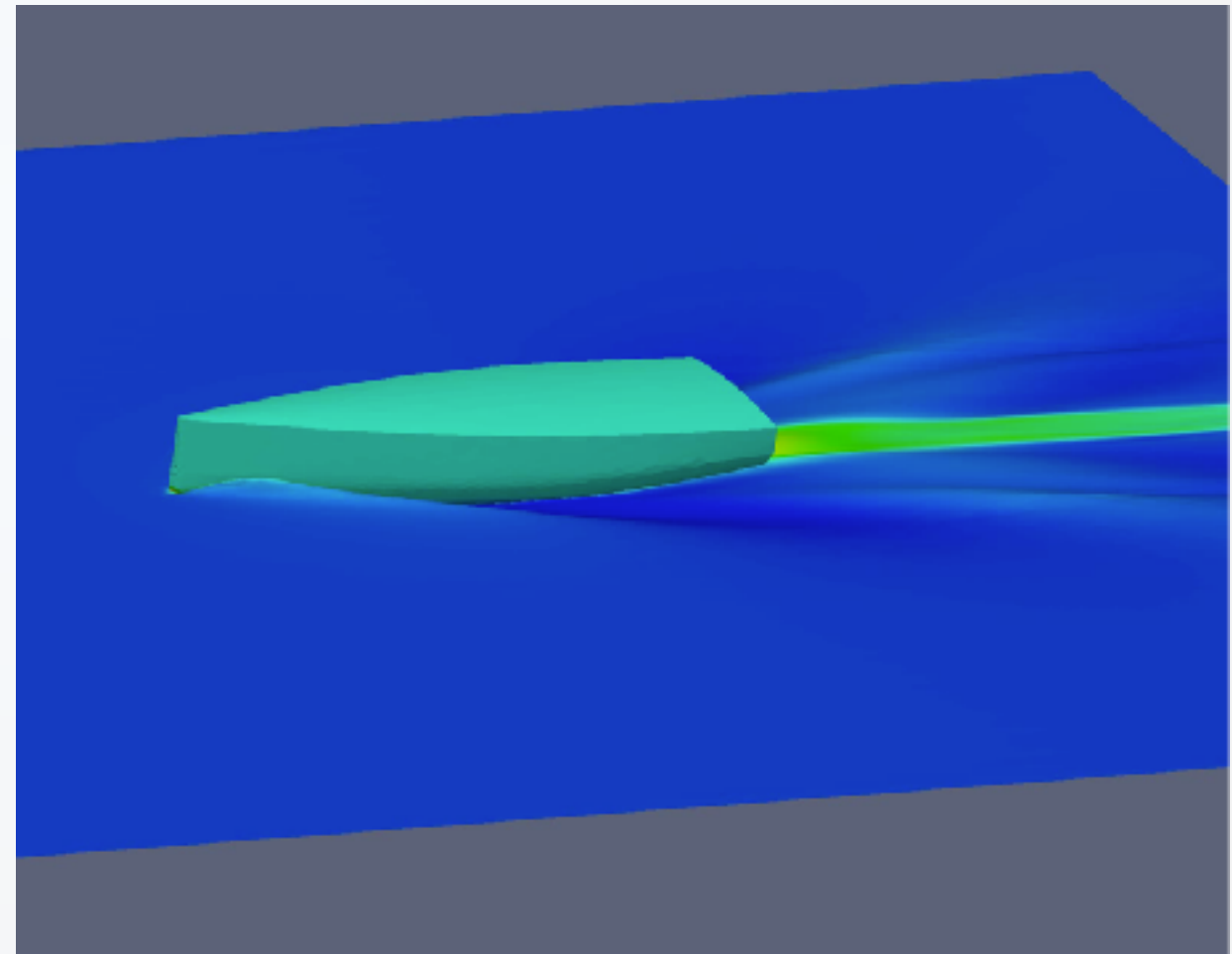
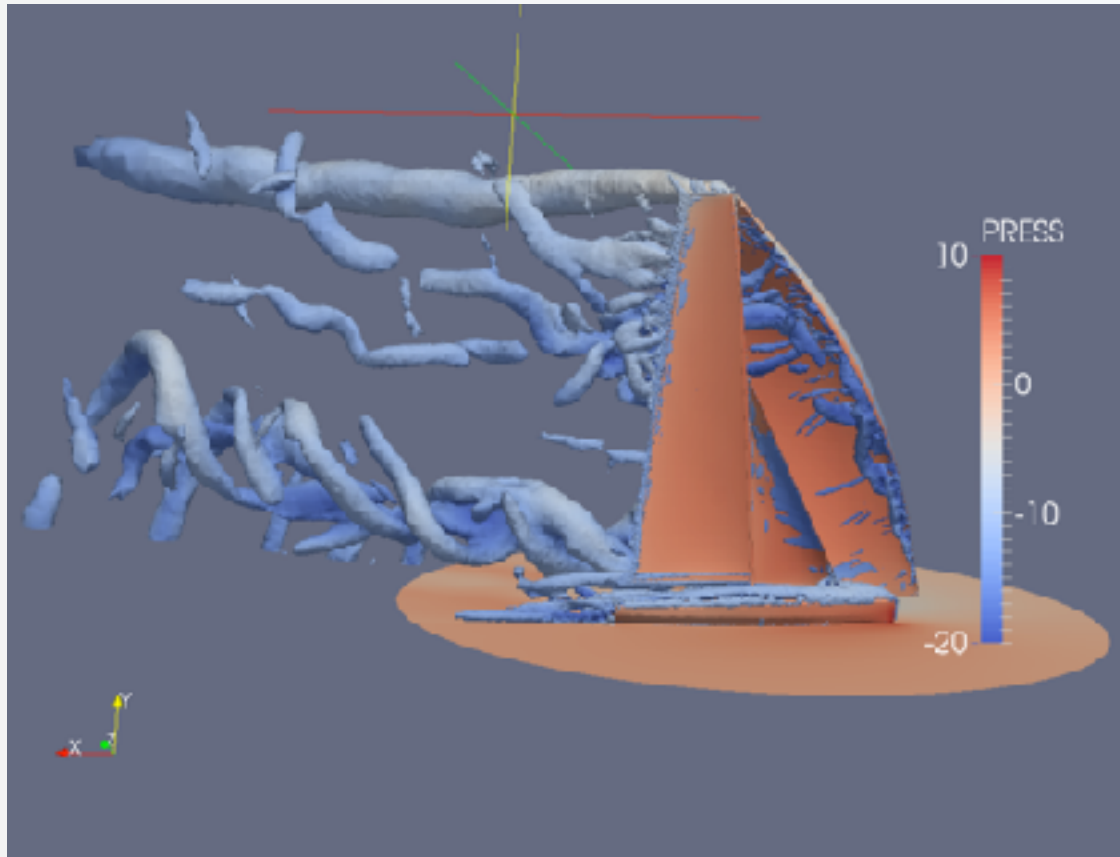


# Other small companies - Juan Yatch Design



Free Surface flow & mesh deformation

RANS vs LES for boat aerodynamics





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