VALEOL

Eighteen Month Review Meeting

24th - 25th November 2016, DLR - Göttingen

Presented by Claire Taymans

Summary

WP 2

Task : Investigation of predicted non-linear behaviour of wind turbine blades submitted to gust using incompressible flow model and overset Cartesian/Bodyfitted grids

Overall aim :

- 3D incompressible Navier-Stokes parallel solver with overset Octree/Bodyfitted grids

What we have now :

- 2D sequential Navier-Stokes solver with overset Cartesian/Bodyfitted grids
- 2D Quadtree grid with parallel Navier-Stokes solver
- 3D Octree grid in progress

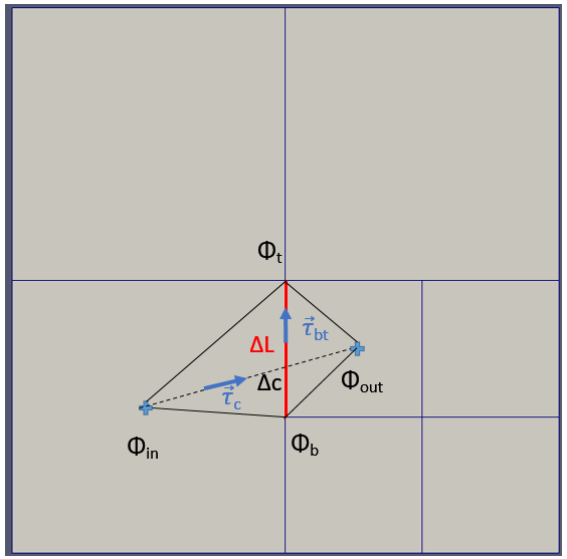
WP 4

Task : Collection of in-service wind turbine data

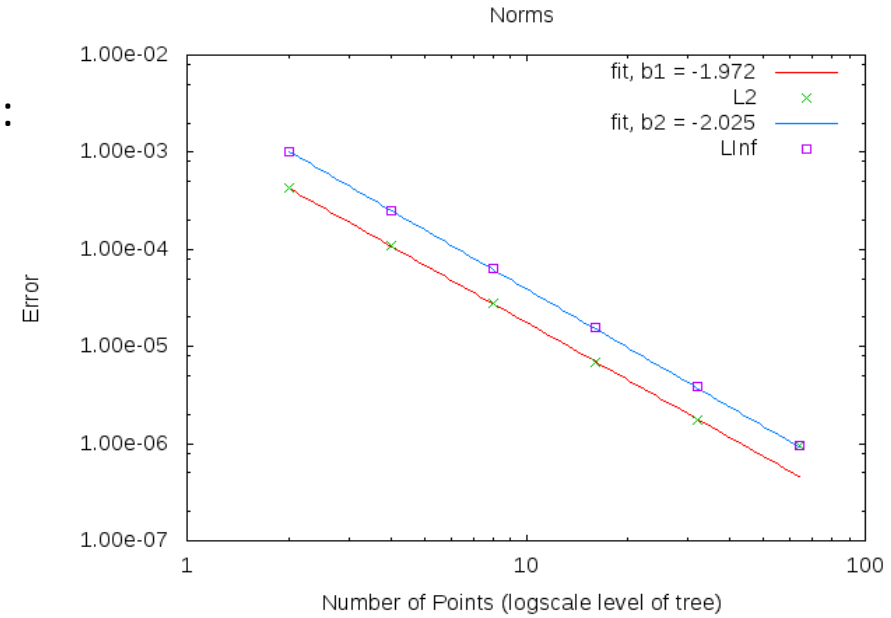
- Specifications of data has been defined
- Technical solutions for wind blade instrumentation have been chosen
- Plot for meteorological mast (= met mast) and wind turbine in the plant have been chosen

2D Parallel Laplacian Solver with Quadtree grid

- A 2D parallel Laplacian solver that deals with quadtree grids has been implemented with finite volume method
- If we have a gap in refinement level : diamond's method is used : $\begin{cases} \vec{\nabla}\Phi.\overrightarrow{\tau_C} = \frac{\Phi_{out}-\Phi_{in}}{\Delta_C} \\ \vec{\nabla}\Phi.\overrightarrow{\tau_{bt}} = \frac{\Phi_t-\Phi_b}{\Delta_L} \end{cases}$



- Comparison with analytic solution:

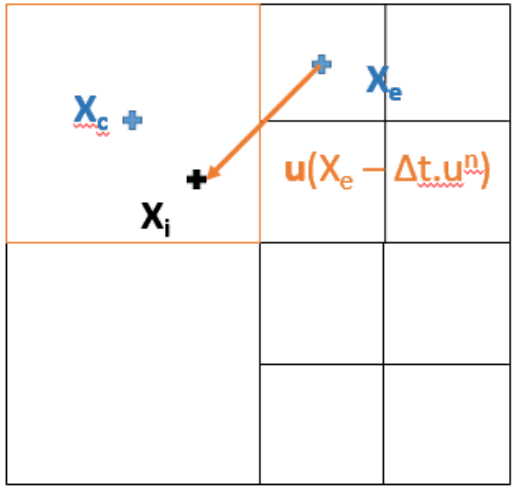


2D Parallel Navier-Stokes Solver with Quadtree grid

- A 2D parallel Navier-Stokes solver has been implemented with finite volume semi-Lagrangian scheme
- Semi-Lagrangian scheme uses an Eulerian framework but the discrete equation come from the Lagrangian perspective

$$\frac{d\boldsymbol{x}}{dt} = \boldsymbol{u}$$

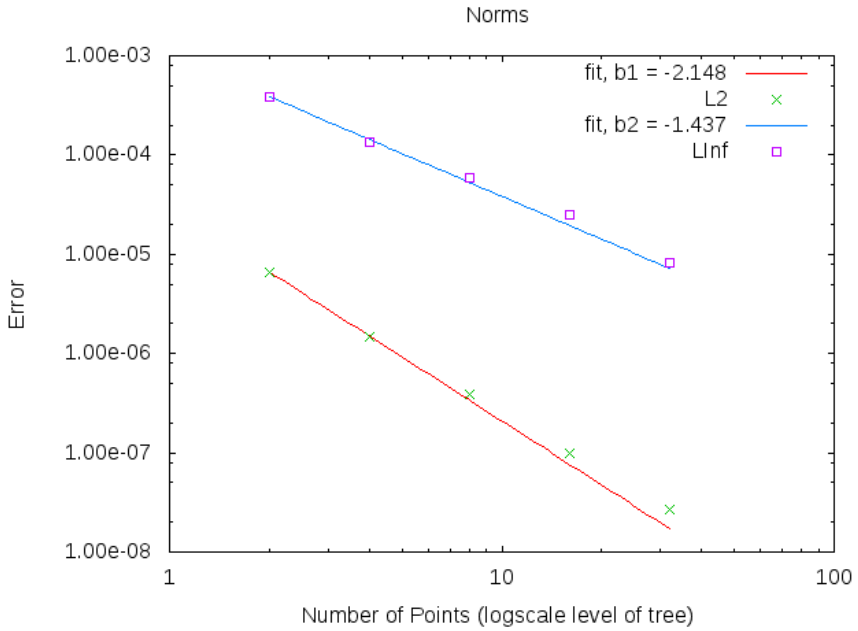
  - Avoids the direct computation of the convective terms
  - Interpolation is used to get velocity at the root of the characteristic
- Implementation of Taylor-Green vortex which has an exact solution of incompressible Navier-Stokes equations
- Computation of gradients at cell-centre with bilinear interpolation when a gap in refinement level occurs
  - Significant errors at gap occurred
  - Use of 3 or 4 neighbours wasn't enough to get an order of convergence of 2 in space

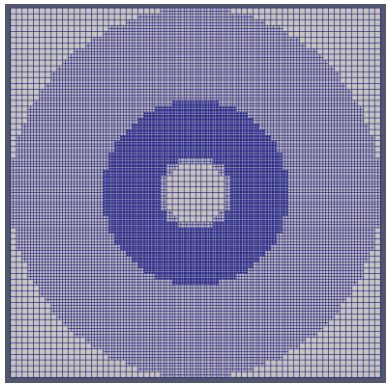


2D Parallel Navier-Stokes Solver with Quadtree grid

- Computation of gradients with Moving Least Squares method
  - Use of all nearest neighbours
  - Computation of gradients and Hessian directly at cell centre
  - Errors at gap still occurs but we obtain the best possible with nearest neighbours
- Order of convergence in space of the Navier-Sokes solver

$$\begin{pmatrix} \frac{\partial u}{\partial x} \\ \frac{\partial u}{\partial y} \\ \frac{\partial^2 u}{\partial x^2} \\ \frac{\partial^2 u}{\partial y^2} \\ \frac{\partial^2 u}{\partial x \partial y} \end{pmatrix} = A^{-1}B$$





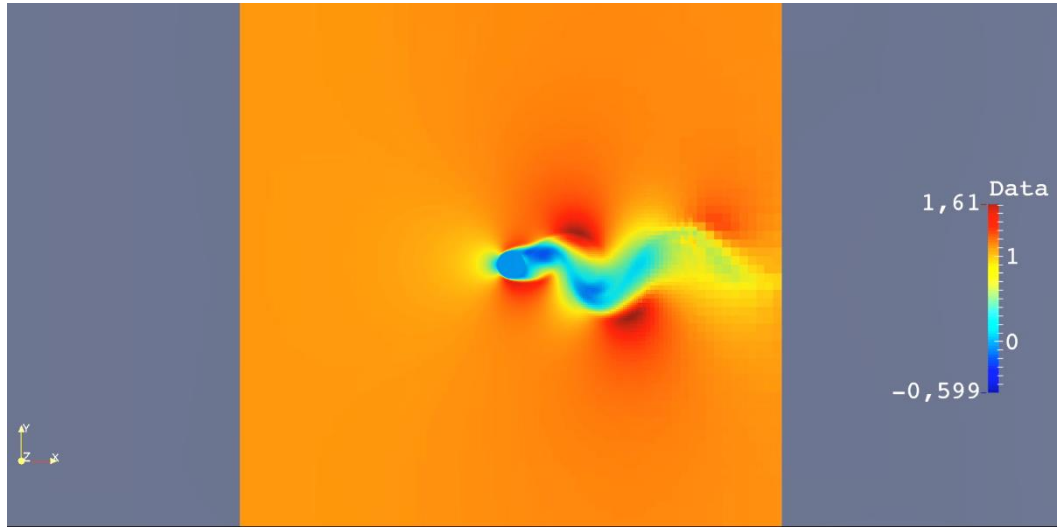
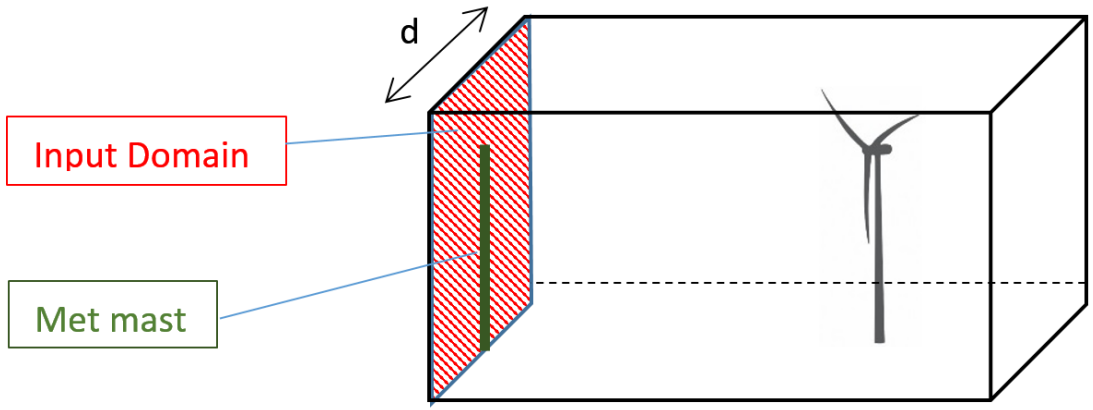


Figure : U Velocity in the computation domain with quadtree mesh

Specifications for wind data

- Wind data is used as an incoming boundary condition
- 50 m height met mast with wind sensors every 5 m from 25 m height (bottom of blade) to 50 m
- Extrapolation of wind measurement in accordance with IEC Standard after 50 m
- Measurement every 10 min of wind velocity, wind direction and wind turbulence
- Position of met mast should be between 2D and 4D (D = diameter of wind turbine) in front of the wind turbine (in direction of main wind)



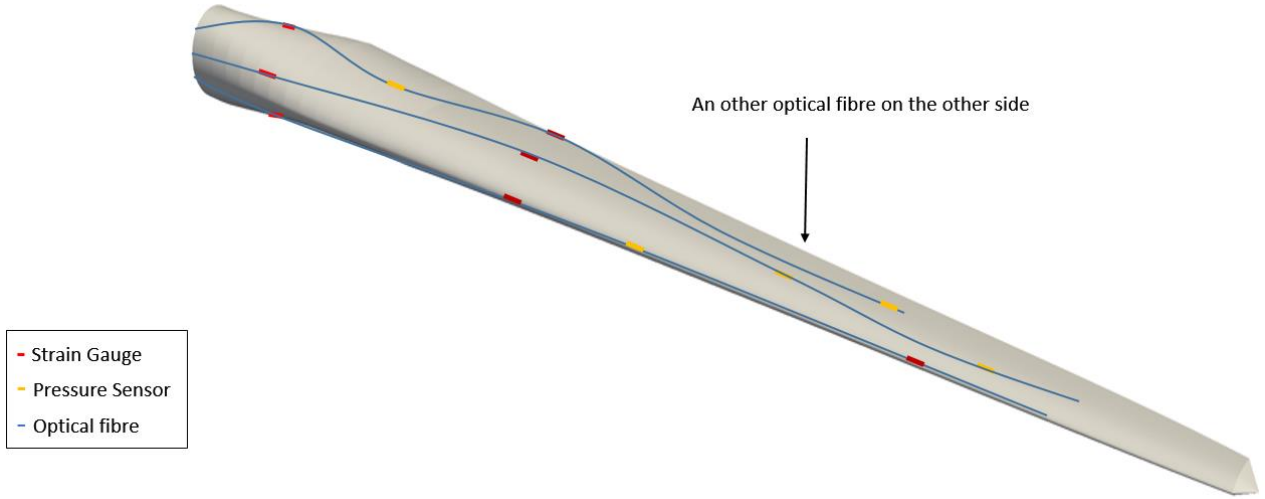
Specifications for blade data

- Pressure measures
  - In order to compare with simulations
  - Several points equitably distributed along blade length
- Strain measures
  - Longitudinal measures at blade root to check the beam model
  - Longitudinal measures equitably distributed along blade length
- Position of blade
  - In order to correlate a blade measure with a wind data
- Sampling of 1s to get enough point for each wind condition
- Synchronization between all measures
- Minimum impact on the blade is required !

→ **Valeol looked for a technological solution with sensors supplying, communication system to get data back and installation**

Explanation of technological solution

- Optical fibre along wind blade that will connect sensors to an inquiry system located on the rotor
- 10 strain gauges and 6 pressure sensors with Fiber Bragg Grating technology
- Position definitions in progress
  - 4 strain gauges on blade root every 90°
  - 4 strain gauges at 1/3 of blade length
  - 2 strain gauges at 2/3 of blade length
  - 6 pressure sensors equitably distributed (4 on pressure side)



Progress on WP 4

- In accordance with owner of wind plant, constraints on plots for met mast : Wind turbine n°5 has been chosen and plot identified
- The owner and farmer of the plot agreed with the project of putting a met mast
- A permit is needed to put a met mast so a file has been built and submitted to the city council
  - Explanation of the building
  - Plans and positions
  - Consultation of civil and military aviation
  - Authorizations of owner and farmer …

→ 2.5 months for examination period

- Technological solution has been chosen
- With constraints for examination of administrative file and design by sensor supplier : installation in February 2017

Future Work

WP 2

- Navier-Stokes parallel solver in 3D on Octree mesh
- Implementation of Navier-Stokes solver on Overset Octree/Bodyfitted grids

WP 4

- Validation of quote for technological solution
- Define the exact position of pressure sensors and preparation of installation procedure
- Inspection of the blade prior to the instrumentation