An overview of Atmospheric Environment Applications with *Code_Saturne*

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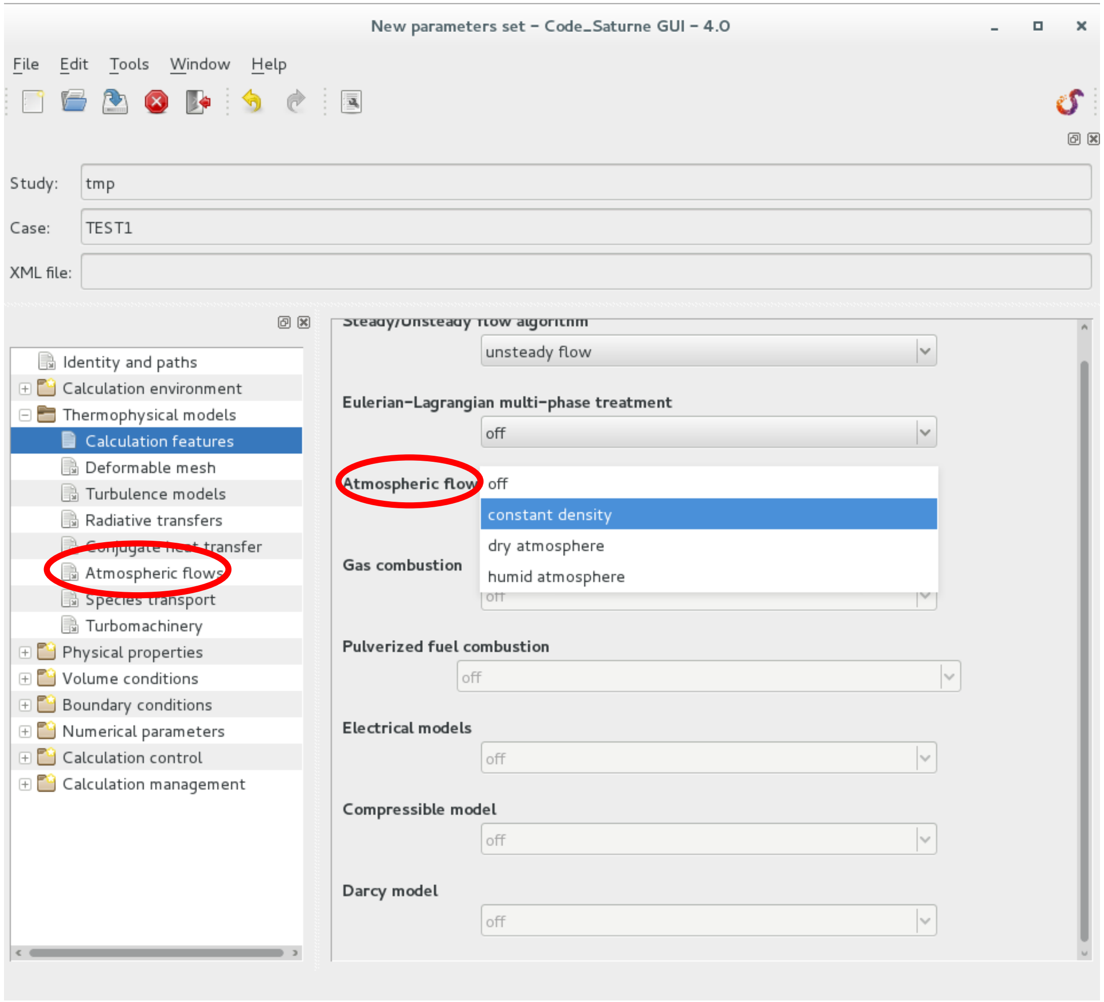
Code_Saturne **user meeting - April 1st, 2016 – EDF Lab Chatou**

Outline

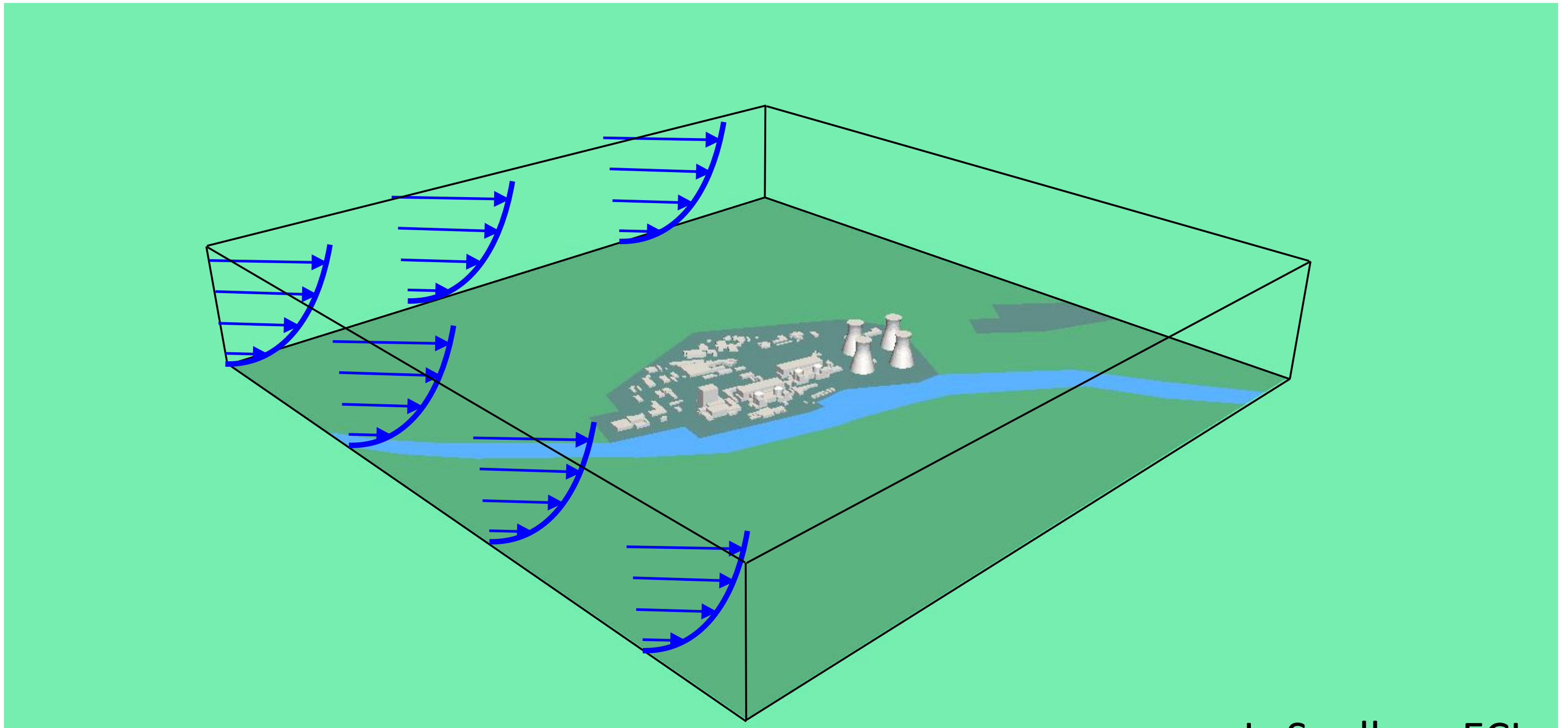
- Introduction
- Meteorological boundary conditions
- Topography – buildings
- Example from wind farms
- Example from SIRTA
- Cooling towers (see poster)
- Perspectives

Atmospheric option :

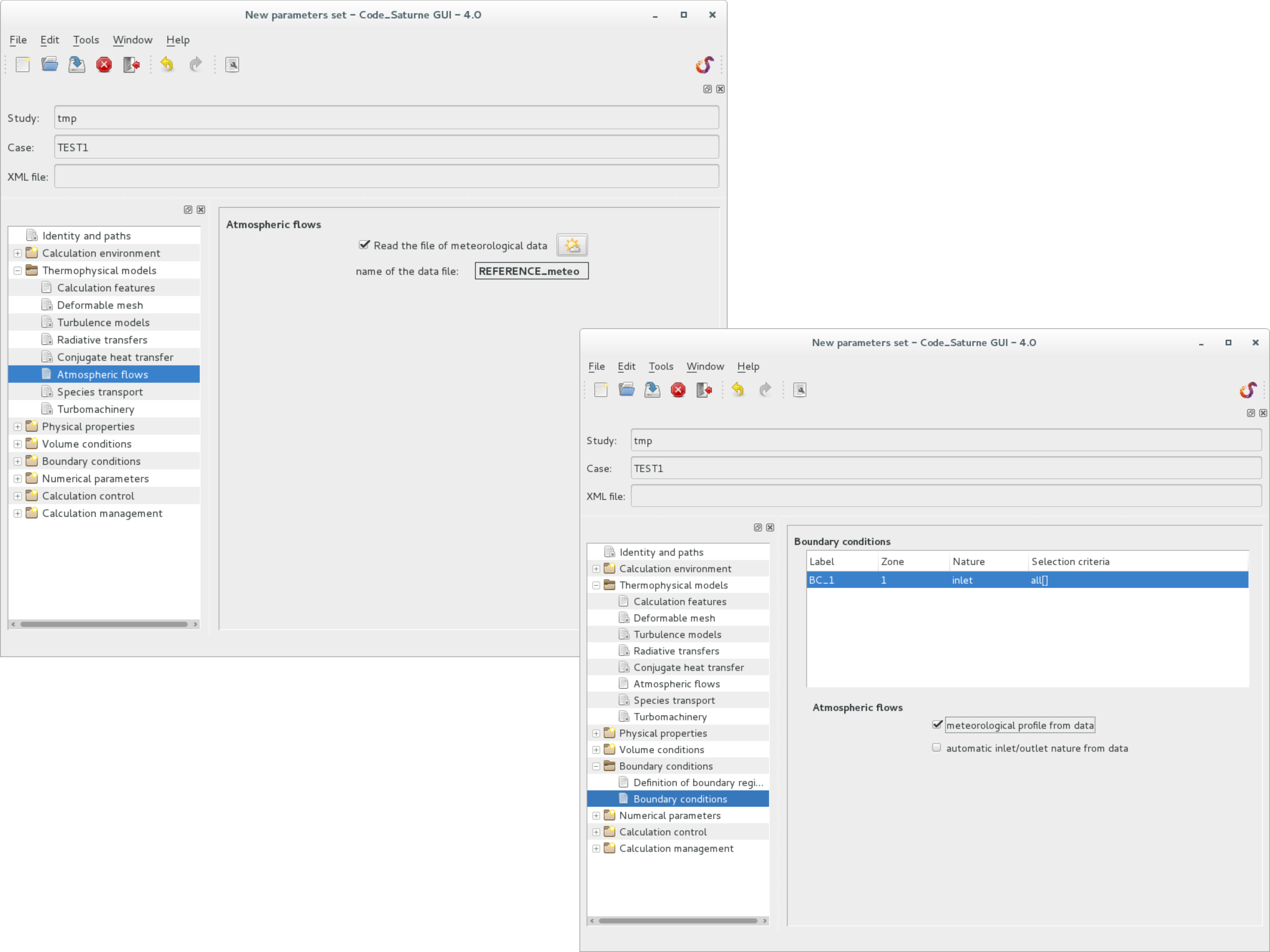


Meteorological boundary conditions

- Specify a boundary layer formula (U,V,k,eps) in the interface or use a « meteo » file



L. Soulhac, ECL


New parameters set – Code_Saturne GUI – 4.0
File
Edit
Tools
Window
Help
Study:
tmp
Case:
TEST1
XML file:
Identity and paths
Calculation environment
Thermophysical models
Calculation features
Deformable mesh
Turbulence models
Radiative transfers
Conjugate heat transfer
Atmospheric flows
Species transport
Turbomachinery
Physical properties
Volume conditions
Boundary conditions
Numerical parameters
Calculation control
Calculation management
Atmospheric flows
Read the file of meteorological data
name of the data file:
REFERENCE_meteo
New parameters set – Code_Saturne GUI – 4.0
File
Edit
Tools
Window
Help
Study:
tmp
Case:
TEST1
XML file:
Identity and paths
Calculation environment
Thermophysical models
Calculation features
Deformable mesh
Turbulence models
Radiative transfers
Conjugate heat transfer
Atmospheric flows
Species transport
Turbomachinery
Physical properties
Volume conditions
Boundary conditions
Definition of boundary regi...
Boundary conditions
Numerical parameters
Calculation control
Calculation management
Boundary conditions
Label
Zone
Nature
Selection criteria
BC_1
1
inlet
all[]
Atmospheric flows
meteorological profile from data
automatic inlet/outlet nature from data

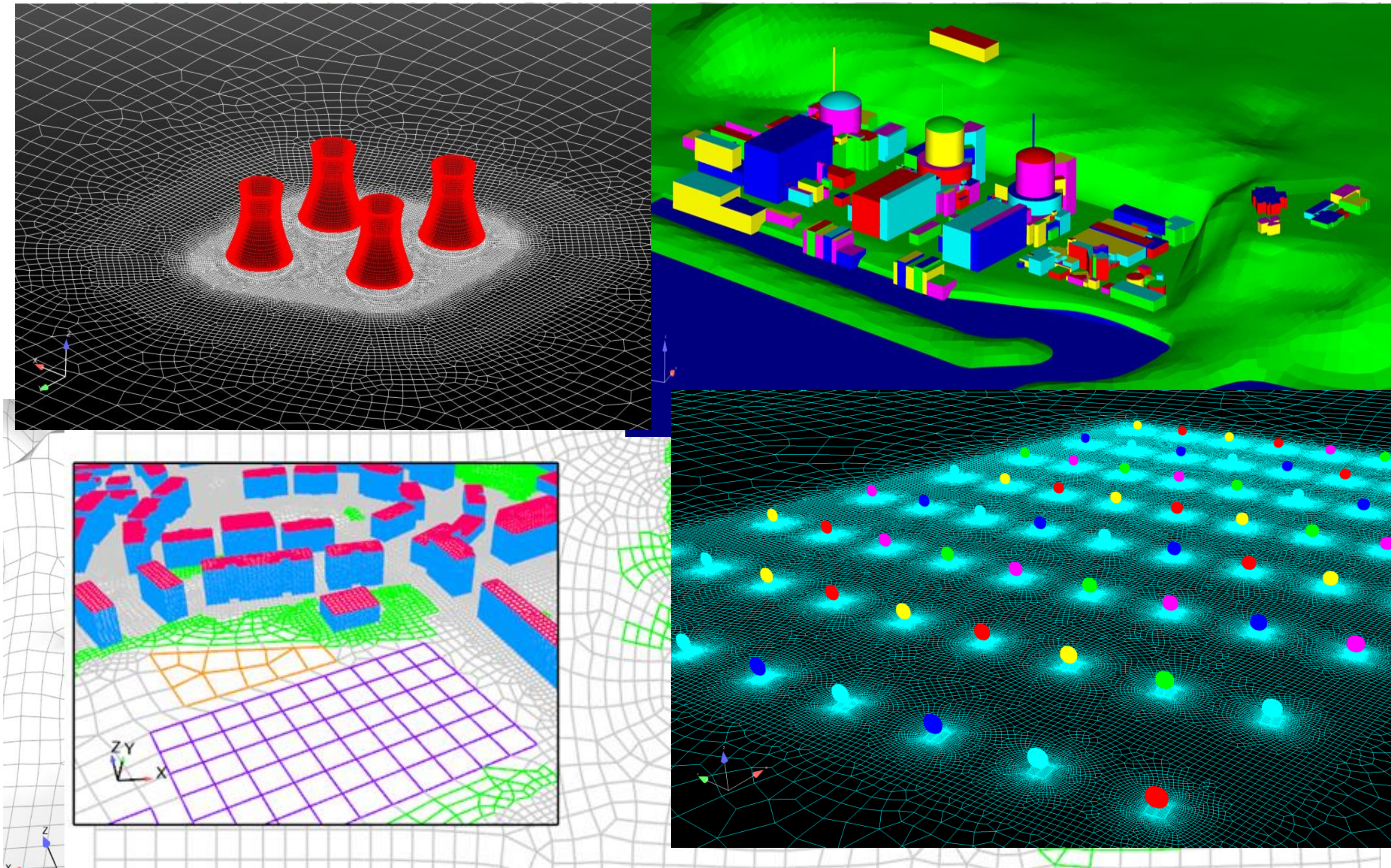
Atmo user subroutines:

rgrep atmo SRC/*

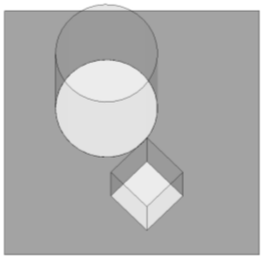
- EXAMPLES/**cs_user_initialization-atmospheric.f90**:!> \file cs_user_initialization.f90 atmospheric example
- EXAMPLES/**cs_user_boundary_conditions-atmospheric.f90**:!> \file cs_user_boundary_conditions-atmospheric.f90
- REFERENCE/**cs_user_physical_properties.f90**:!>   atmospheric module
- REFERENCE/**usatch.f90**:!> \brief Routines for user defined atmospheric chemical scheme
- REFERENCE/**cs_user_atmospheric_model.f90**:!   Data Entry for the atmospheric ground model.
- REFERENCE/**cs_user_parameters.f90**:!   - atmospheric modelling

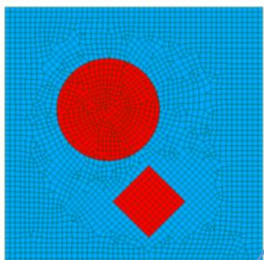
- + Doxygen documentation > 4.2
- + tutorial available upon request

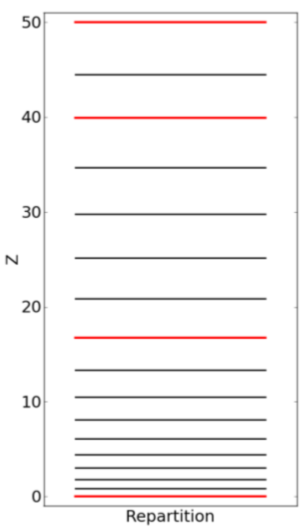
Examples of atmospheric mesh generated with Salome (www.salome-platform.org)
…and « some » python scripting (R. Bresson):



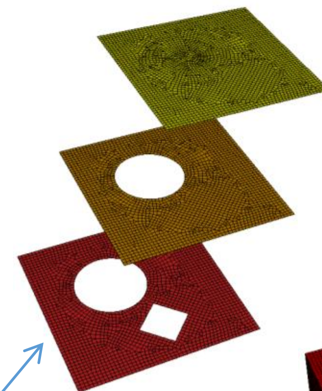
Geometry and mesh construction with Salome

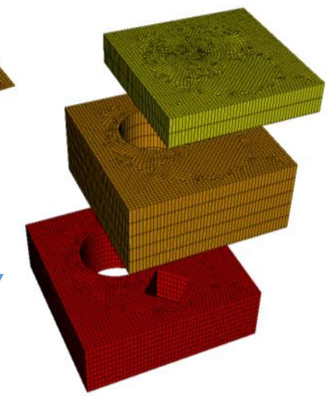


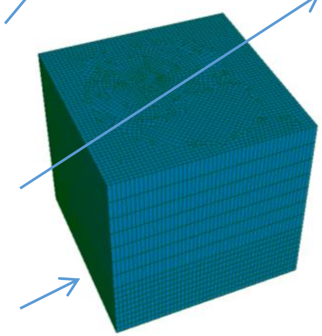


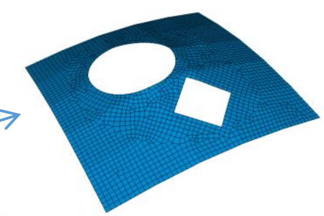


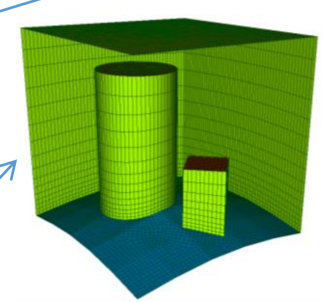
1. Géométrie
2. Maillages 2D
3. Maillage vertical 1D
4. Concaténations 2D et translations
5. Extrusions verticales
6. Concaténation 3D
7. Interpolation du relief au sol
8. Déplacement des nœuds du maillage



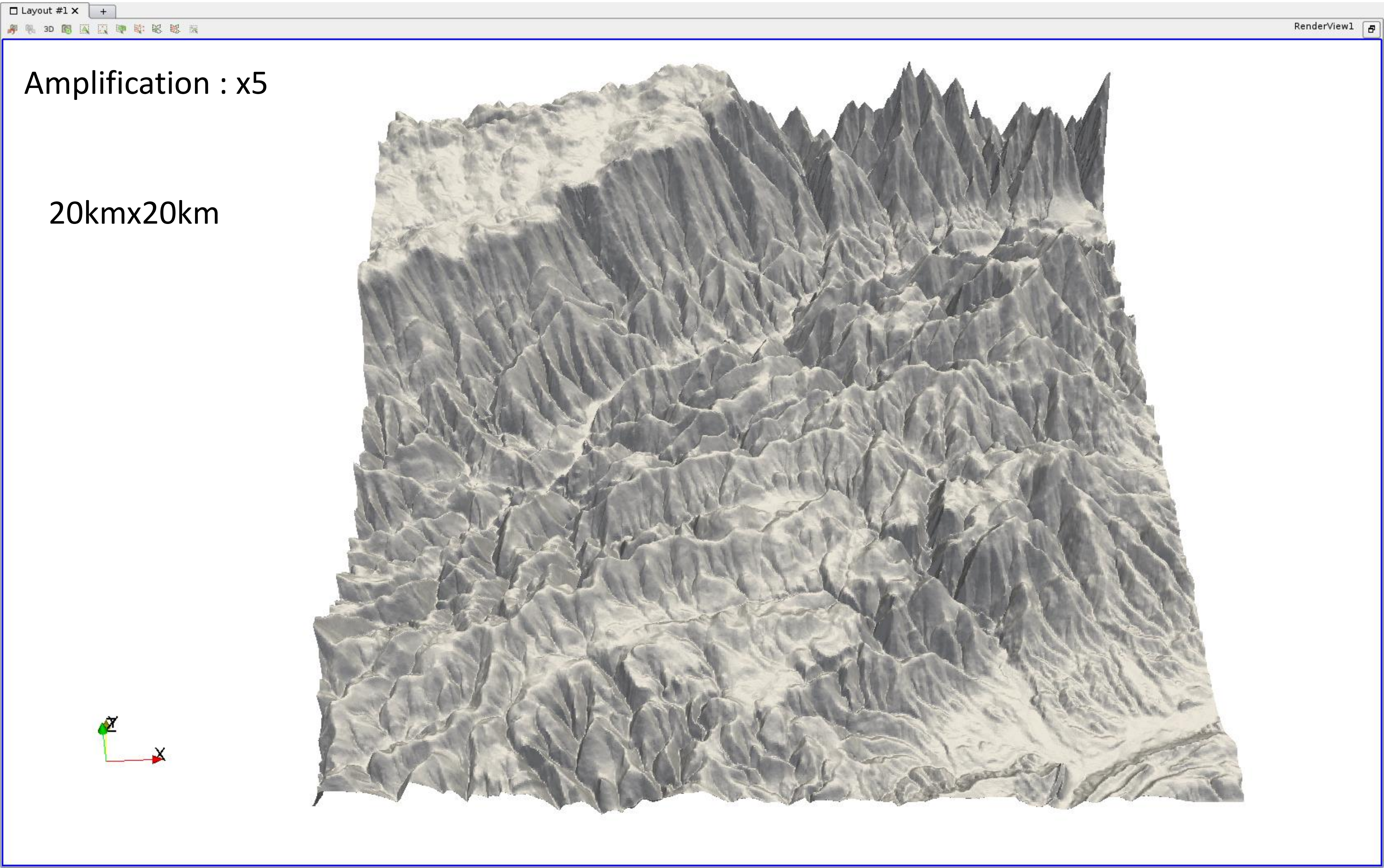




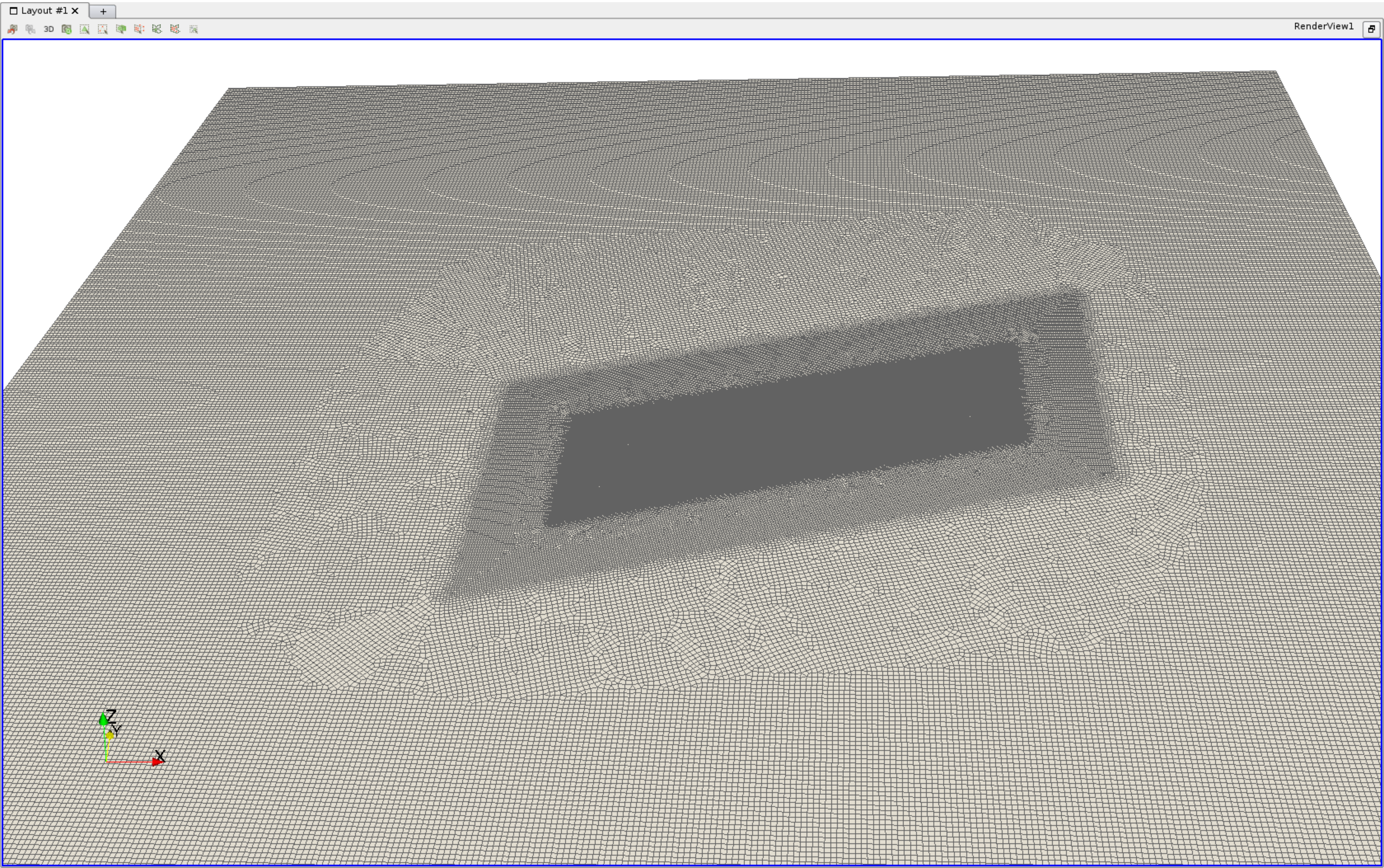




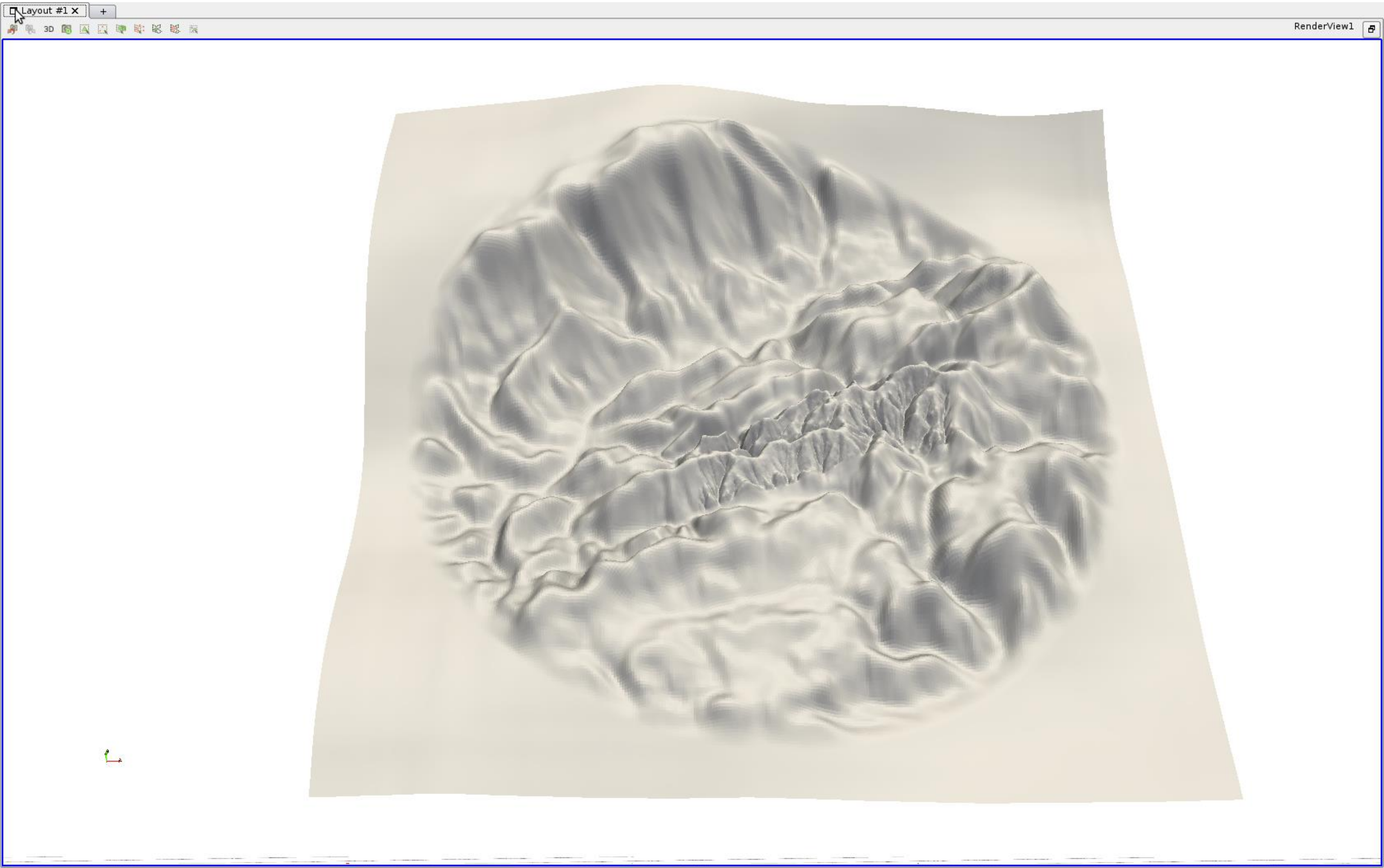
Very complex local topography at high resolution….



… not compatible with lower grid resolution, especially near the boundaries …



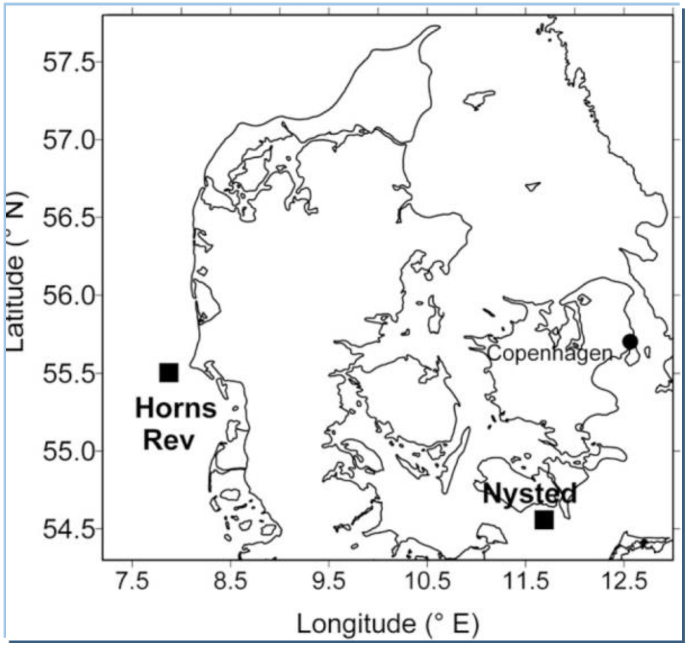
... combine rough topography at the center (original 25m resolution from IGN) with increasing smoothing toward the boundaries



Wake effect modelling with *Code_Saturne*: comparison with Nysted and Horns Rev data sets

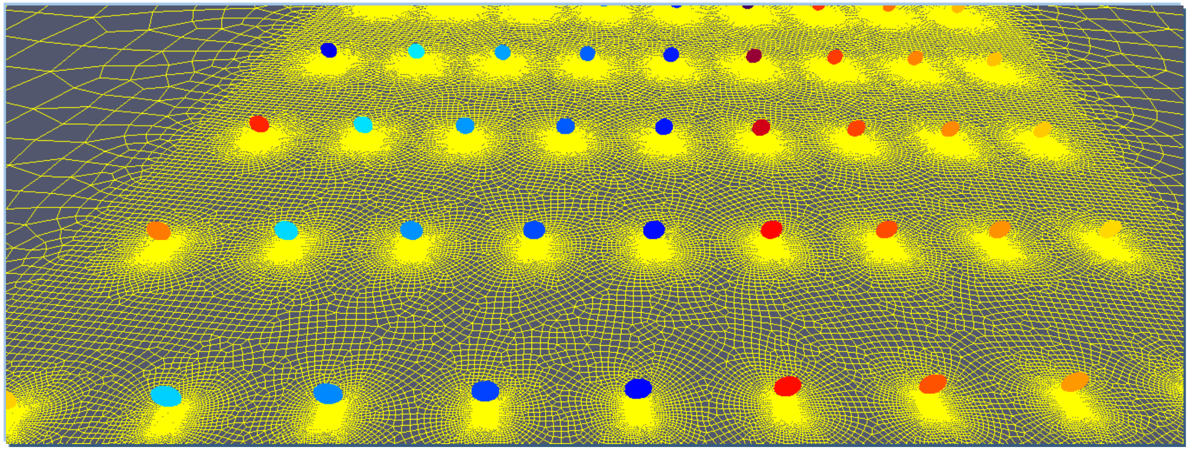
C. Dall'Ozzo, V. Hergault, R. Bresson, E. Dupont (EDF-R&D, CEREA)

Visualization from Horns Rev



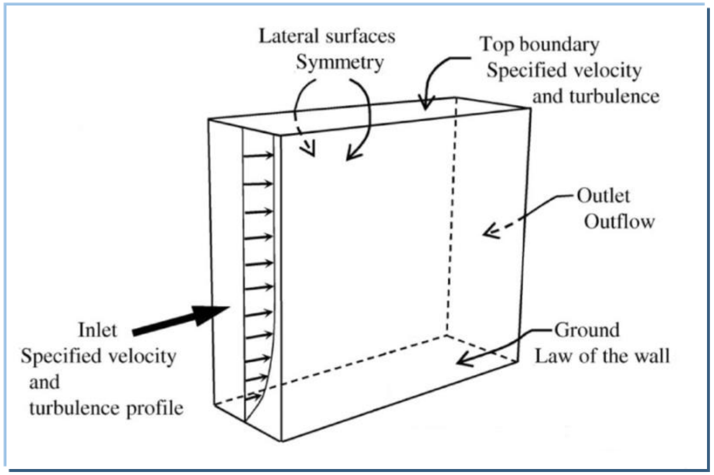
Wakes produced by wind turbines in Horns Rev (Credit: Christian Steiness/Vattenfall)

Numerical simulations with *Code_Saturne*



- ➢ **Mesh**
  - Height : 2km
  - Distance of 50D between first turbines and domain boundaries
  - 1 mesh for each direction
  - 11 825 385 cells
- ➢ **Inlet conditions**
  - Meteo profiles for 8 m/s at hub height, for neutral conditions, with roughness deduced from measured upstream turbulence intensity (with turbulence isotropy or anisotropy hypothesis)

$$z_0 = z_{hub} e^{-(\kappa / \sqrt{f \sqrt{C_\mu}}) / IT}$$

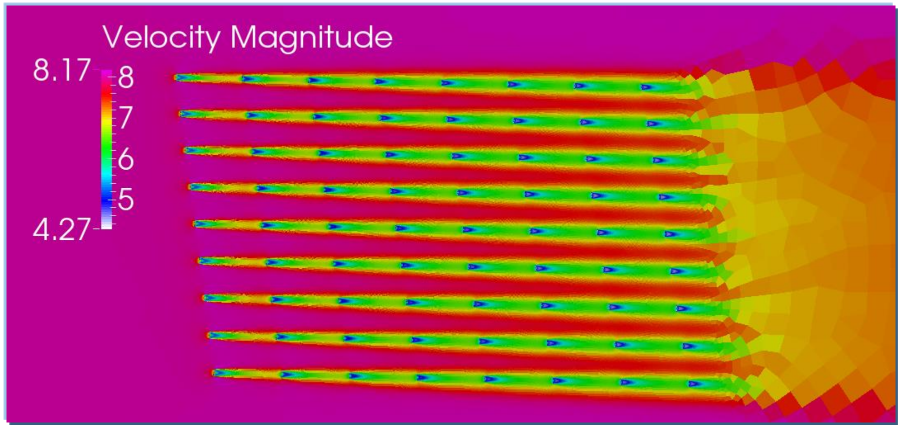


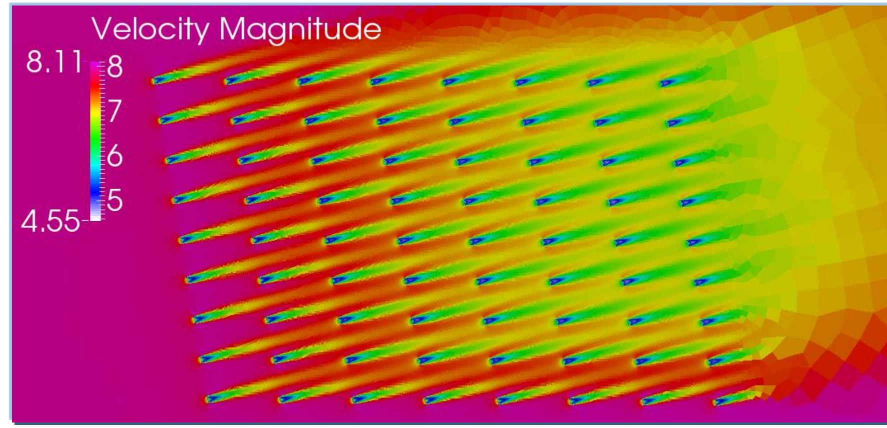
- ➢ **Turbulence models**
  - k-epsilon « standard »
  - k-epsilon « linear production »

Code_Saturne results

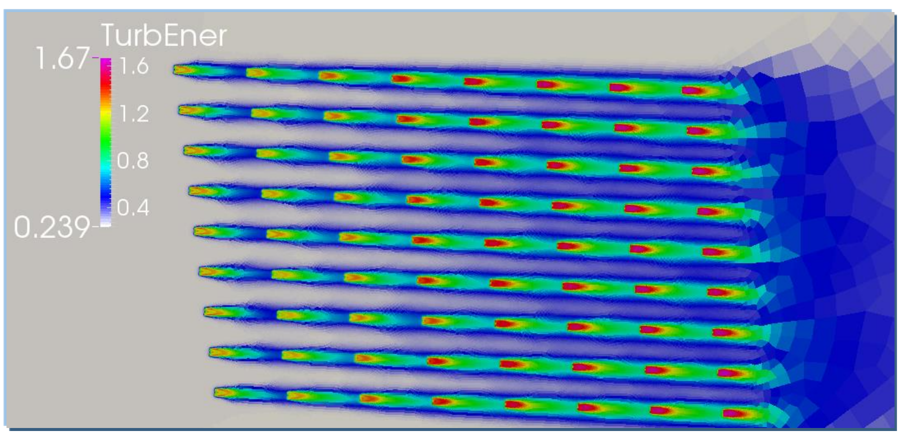
Horizontal cross section at hub height

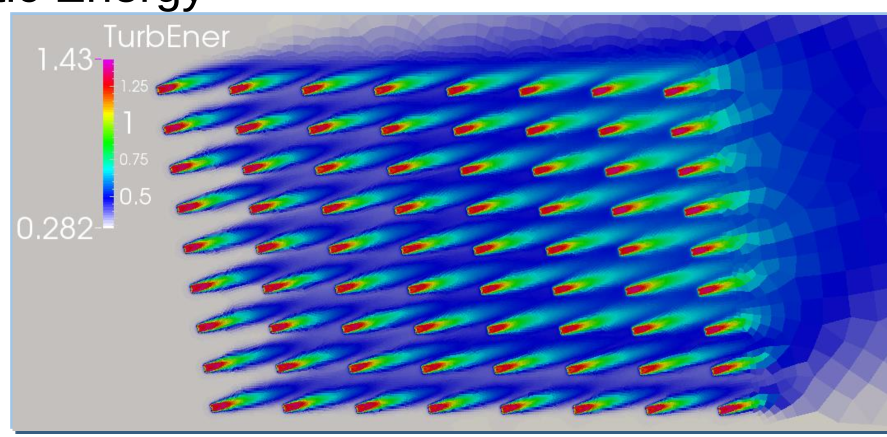
Wind speed





Turbulent Kinetic Energy





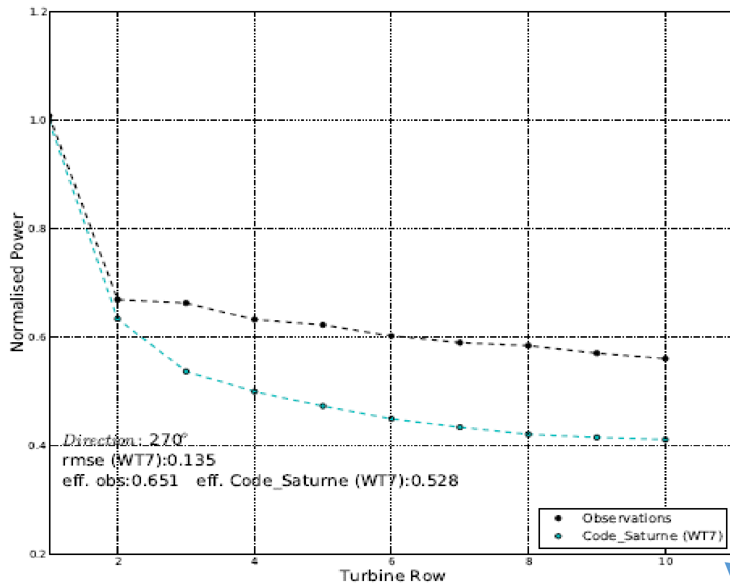
Wind direction: ER (=278°)

Wind direction: ER-15° (=263°)

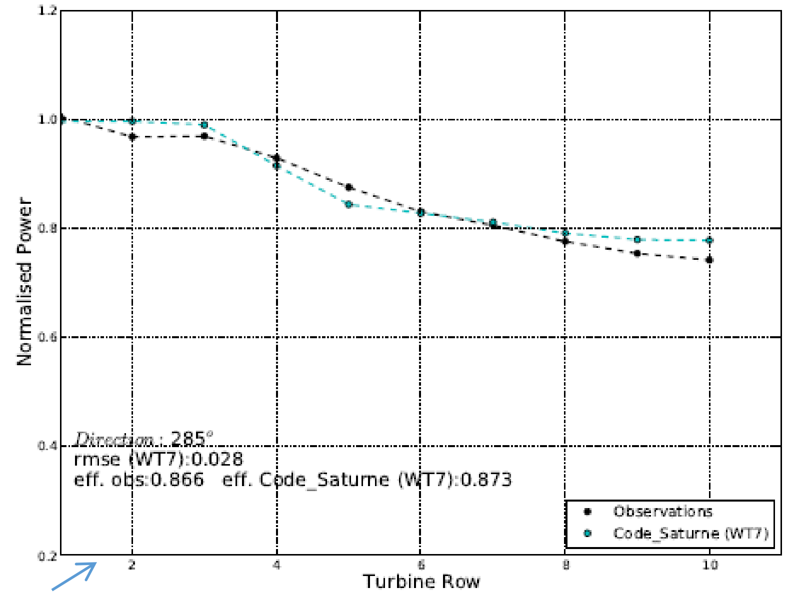
Code_Saturne results

Direction (°)	Measured efficiency	Calculated efficiency (homogeneous)	Calculated efficiency (BEM)	RMSE (homogeneous)	RMSE (BEM)
255	0.816	0.861	0.853	0.055	0.048
260	0.802	0.876	0.866	0.087	0.076
265	0.740	0.709	0.695	0.080	0.084
270	**0.651**	**0.489**	**0.462**	**0.174**	**0.204**
275	0.680	0.703	0.689	0.051	0.046
280	0.823	0.860	0.849	0.054	0.049
285	**0.866**	**0.860**	**0.851**	**0.031**	**0.036**

Horns Rev – Normalised power

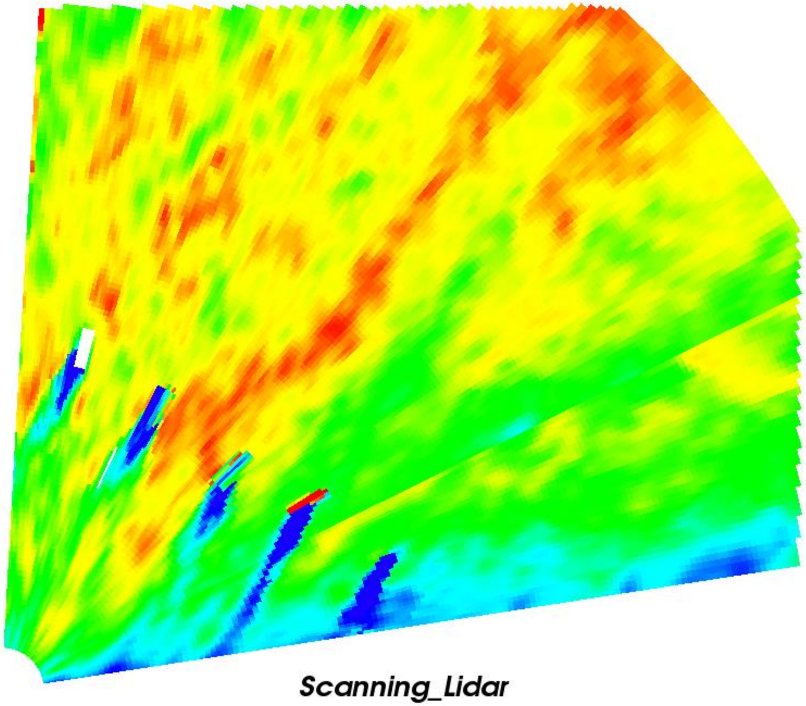


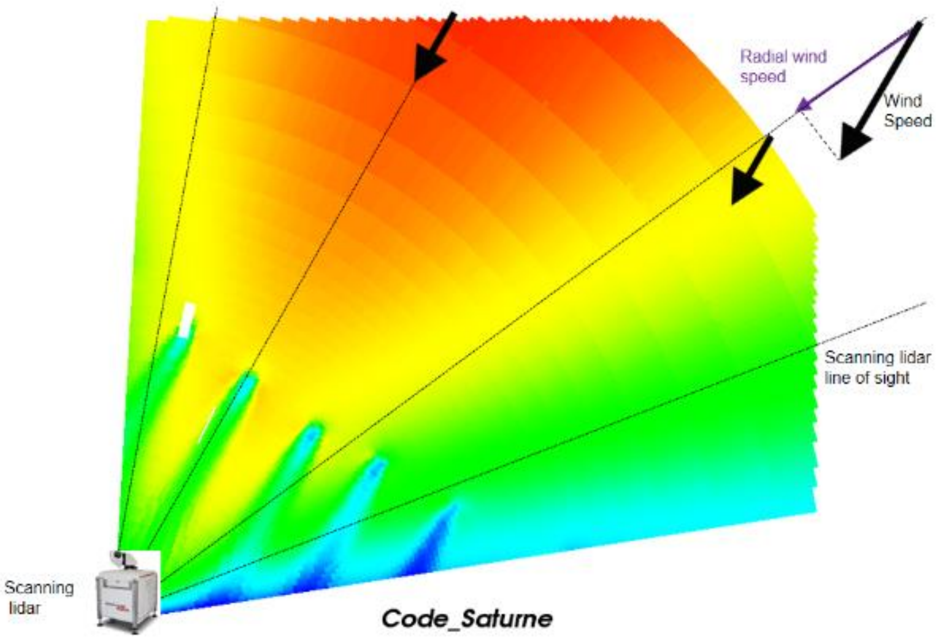
Horns Rev – Normalised power



Results with BEM and Z_0 based on turbulence isotropy hypothesis

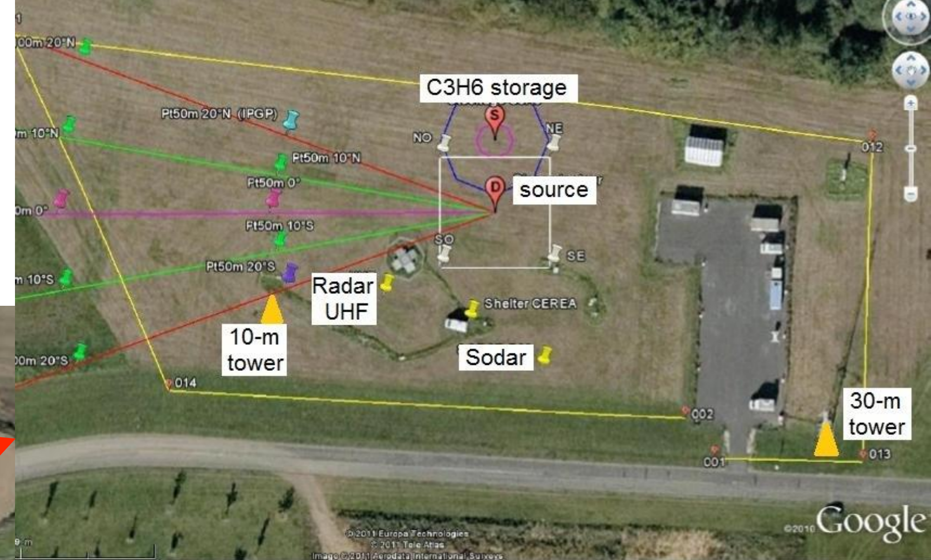
Comparaison *Code_Saturne* results with scanning lidar on radial velocity

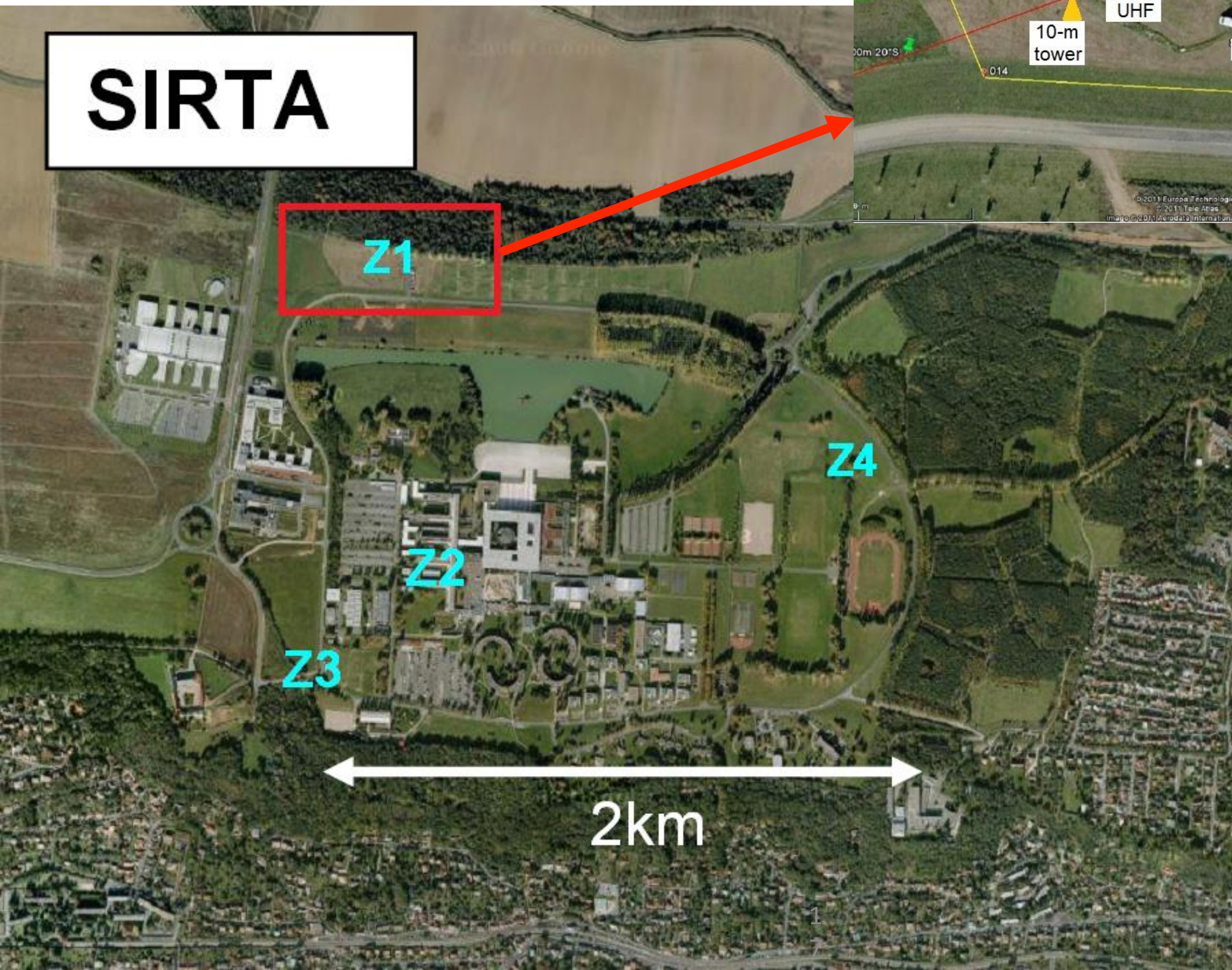




Arièle Défossez[1], Eric Dupont[1], Raphael Bresson[1], Cédric Dall'Ozzo[2], Sami Barbouchi[3], Hugo Herrmann[3], Raghu Krishnamurthy[4], Matthieu Boquet[4]

SIRTA: Site Instrumental de Recherche en Télédétection Atmosphérique
Campus Polytechnique
= site de validation

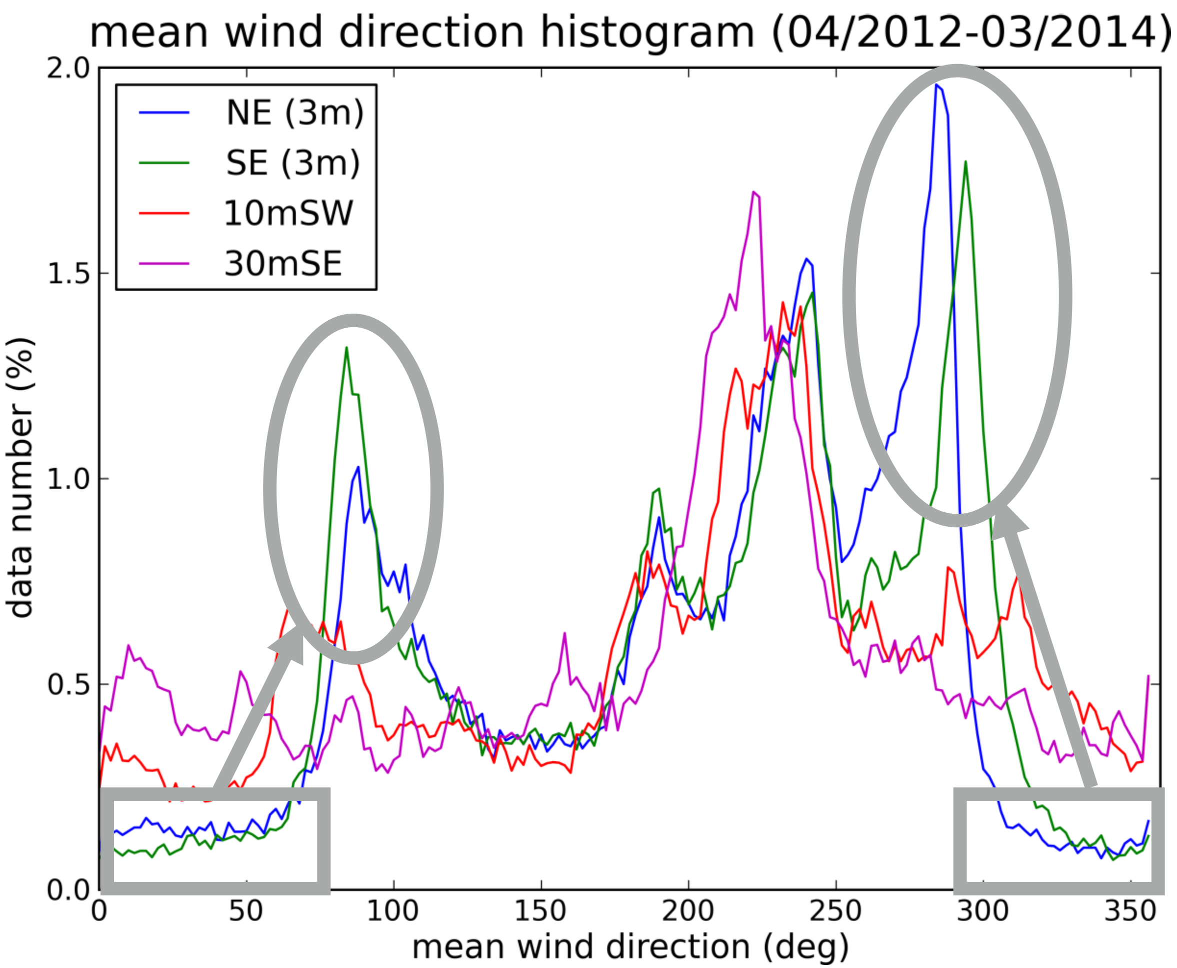


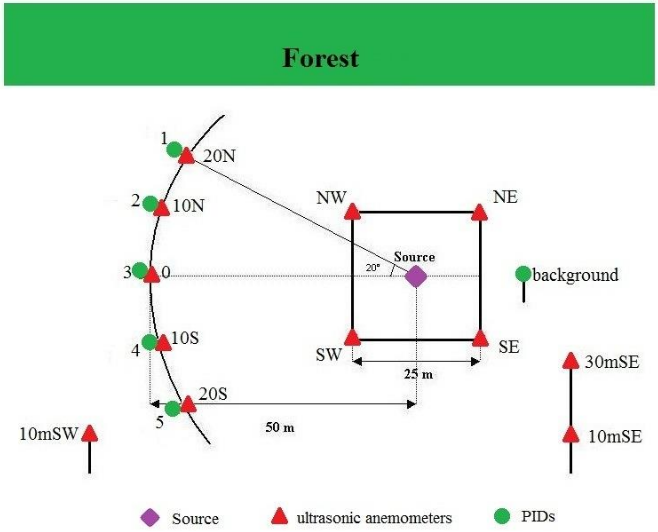


Thèse X. Wei

Direction du vent

Hétérogénéité du terrain en zone 1
Une forêt au nord : hauteur h = 15m





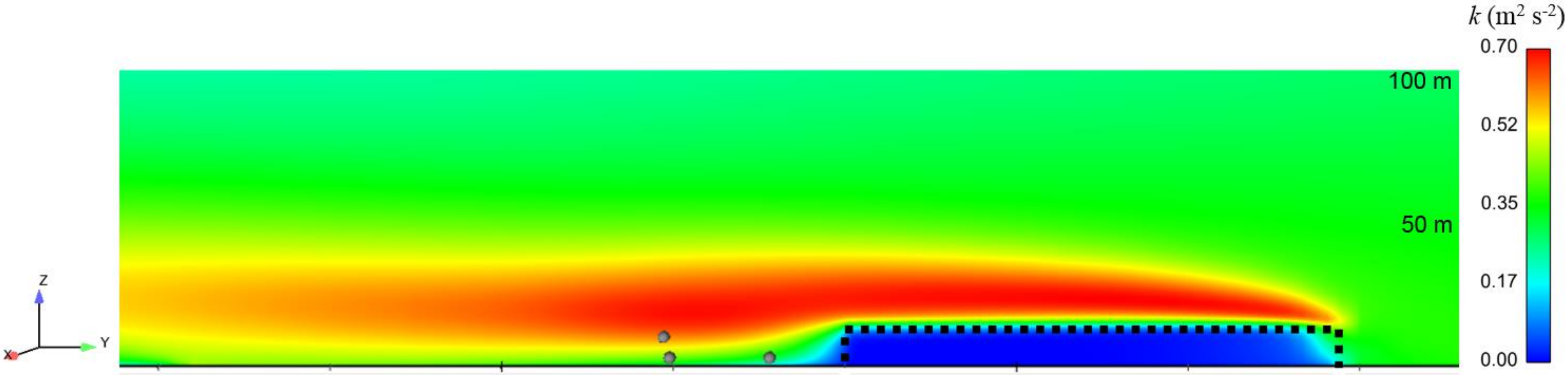
Z=30m : direction du vent dominante de Sud-Ouest

Z=10m : plus de vent d'Est et d'Ouest

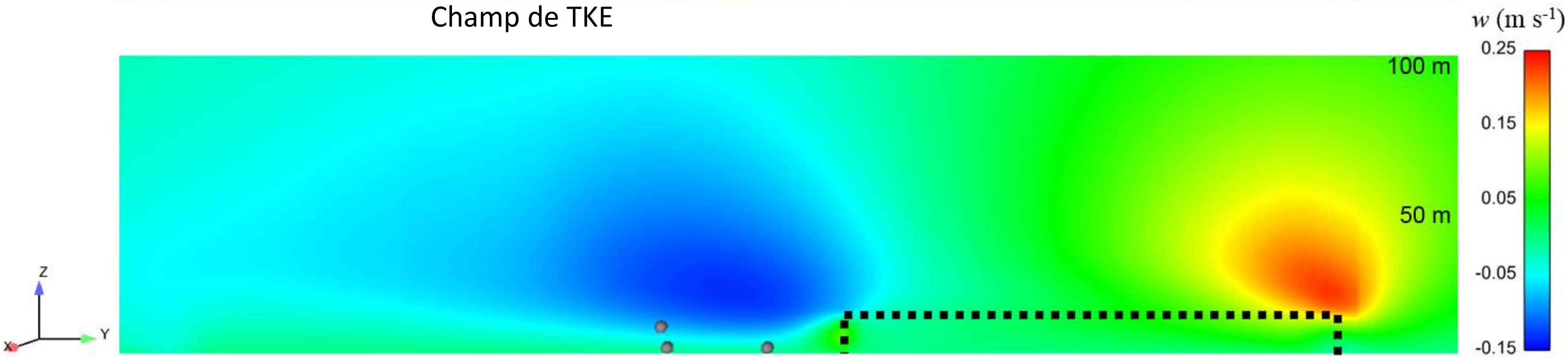
Z=3m :

- Pics autour de 90° et 270°
- Très peu de vent du Nord

Simulation pour la POI-7 (05/06/2013)



Champ de TKE

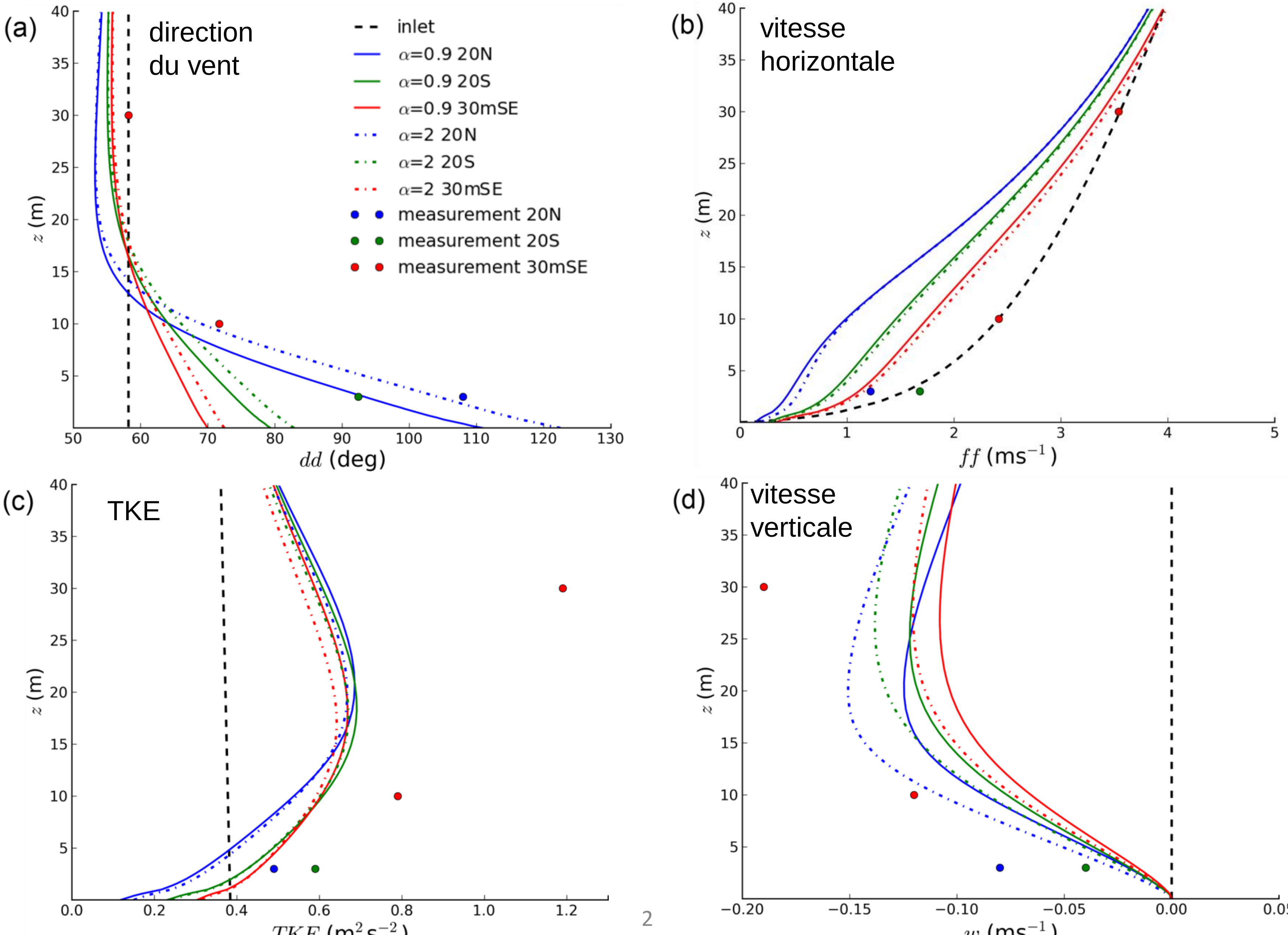


Champ de vitesse verticale *w*

Coupe verticale le long d'axe Sud-Nord

- Forte TKE générée par le cisaillement au-dessus de la forêt
- Vitesse verticale : > 0 devant la forêt, < 0 derrière la forêt

Simulation pour la POI-7 (05/06/2013)



Perspectives

- Use existing Lagrangien module for atmospheric dispersion:
  - atmospheric adaptation and comparison to eulerian dispersion (Thesis started : Meissam Bahlali)
- Data assimilation:
  - Use measurements inside the simulation domain (for example wind) to improve simulations (for example on dispersion of pollutants) (Thesis under discussion)