Numerical prediction of wind turbine wakes using adaptative mesh refinement

Why?

- Harvesting of wind energy produced by large wind farms = source of **clean** and **renewable** energy

—> Maximizing the electrical power of windfarms is a key issue.

- Power production and fatigue loads related to **wind** or **wake** coming from an upstream generator

Challenges?

Wakes —> complex 3D unsteady flow phenomena —> high computational cost

Objectives?

- Demonstrate the feasibility of AMR for wind turbine wake prediction
- Determinate mesh adaptivity parameters ensuring a good compromise between **accuracy** and **computing time**

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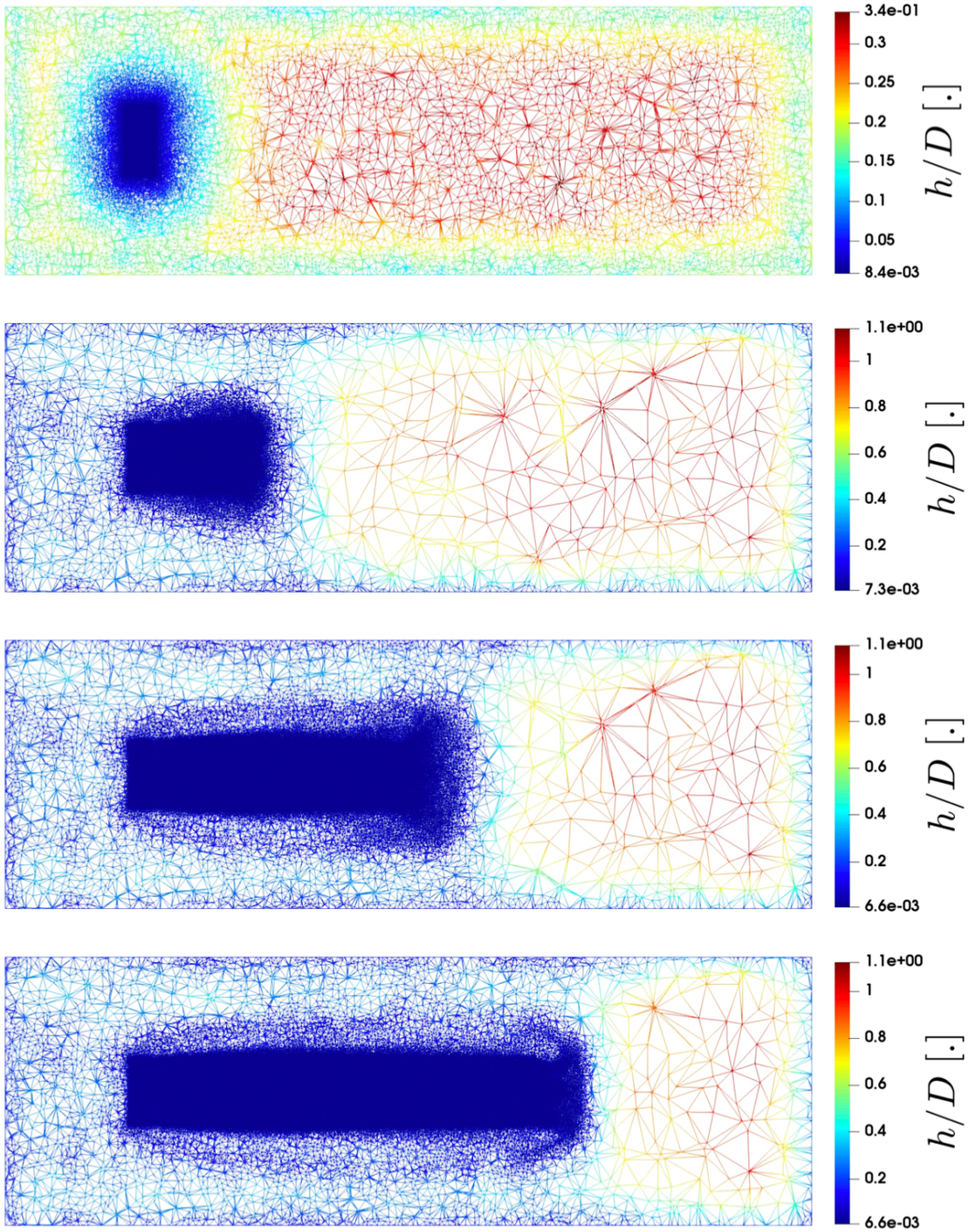
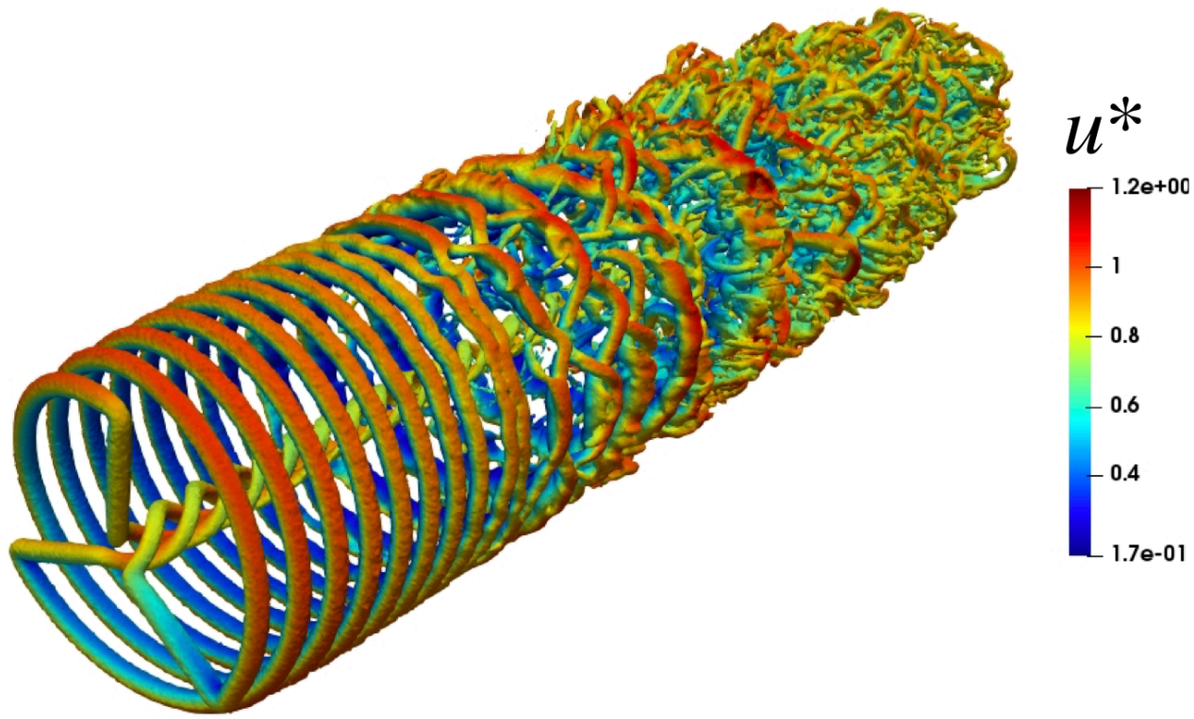
Visualization of the dynamic mesh adaptation





Snapshot of a wind turbine turbulent wake: Q criterion colored by dimensionless velocity $u^* = u/U_\infty$, TSR = 6

Adaptation strategies

Static adaptation based on flow statistics

$$Qc_1 = \Delta^2 \max_{i,j=1,2,3} \left\{ \left| \frac{\partial^2 \mathbf{u}_j^*}{\partial x_i^2} \right| \right\}.$$

$$Qc_2 = \frac{E_{sgs}}{E_{sgs} + E_R}$$

[Bénard et al. in Int. J. Numer. Meth. Fluids (2015)

$$\downarrow$$

$$Qc_1 = f(ncells\,ratio) \quad Qc_2 = 0.2$$

$$\rightarrow h_{local}$$

Dynamic adaptation based on vorticity

$$\omega_{max} = \frac{\Gamma}{\pi \epsilon^2}$$

$$\Gamma = 0.5\, C_L\, c\, R\, U_{\text{inf}}$$

$$h_{blade} = \frac{R}{32}$$

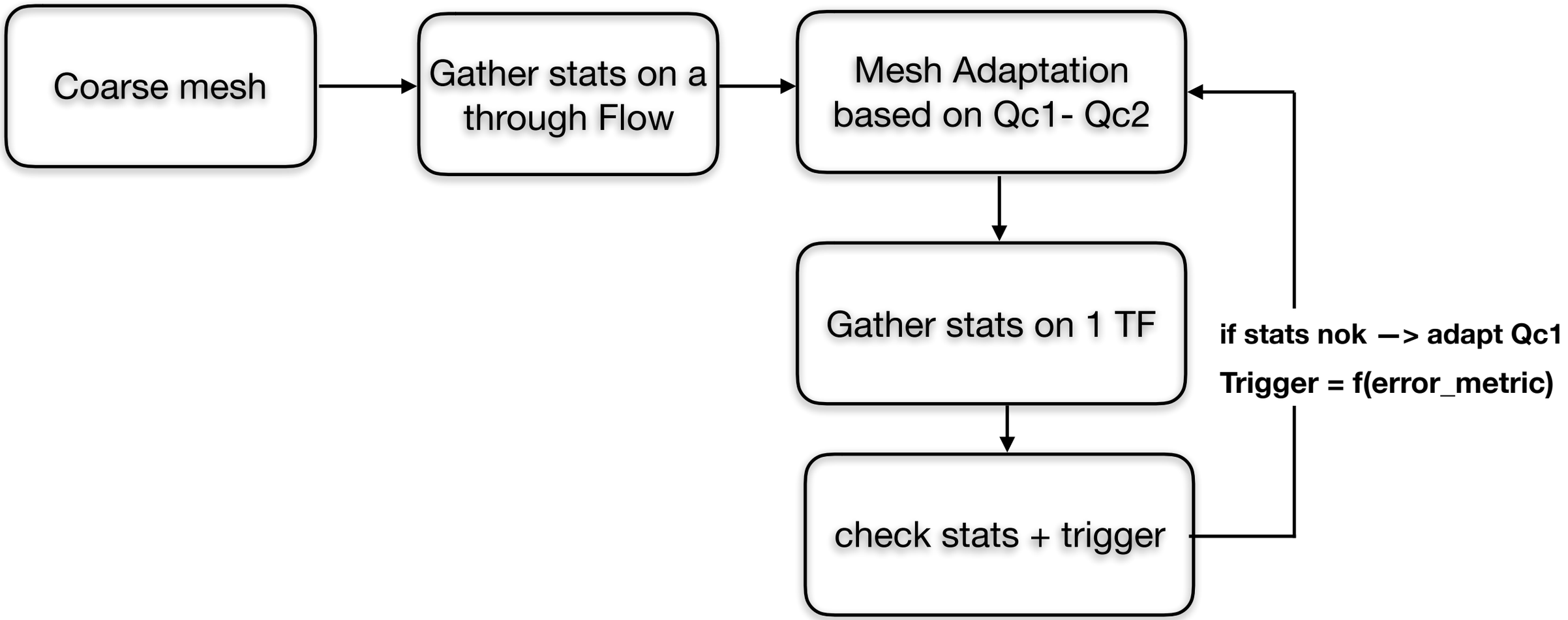
$$\downarrow$$

$$\omega_{local} > k\, \omega_{max}$$

$$\rightarrow h_{local} \leq h_{blade}$$

Trigger = f(error_metric)

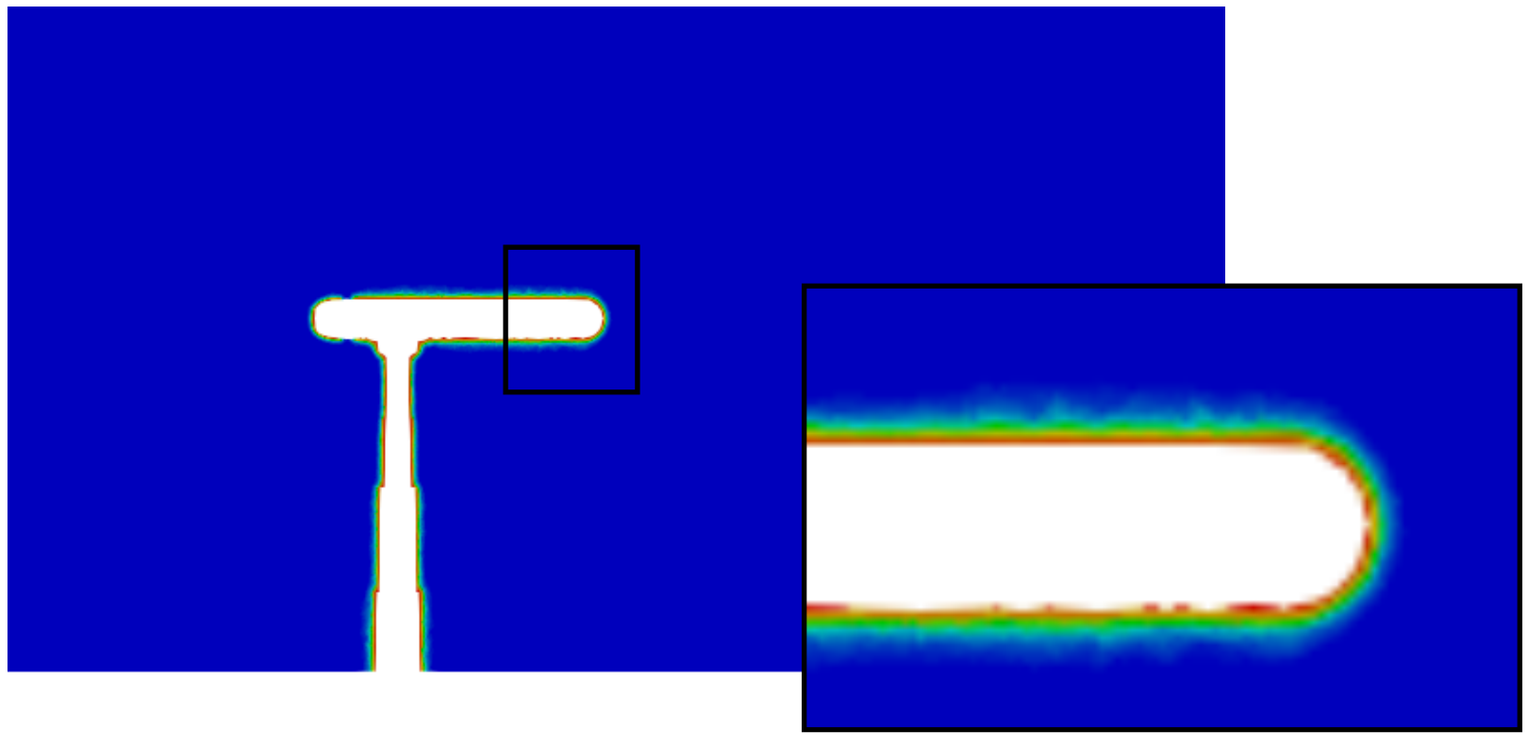
Static adaptation based on flow statistics



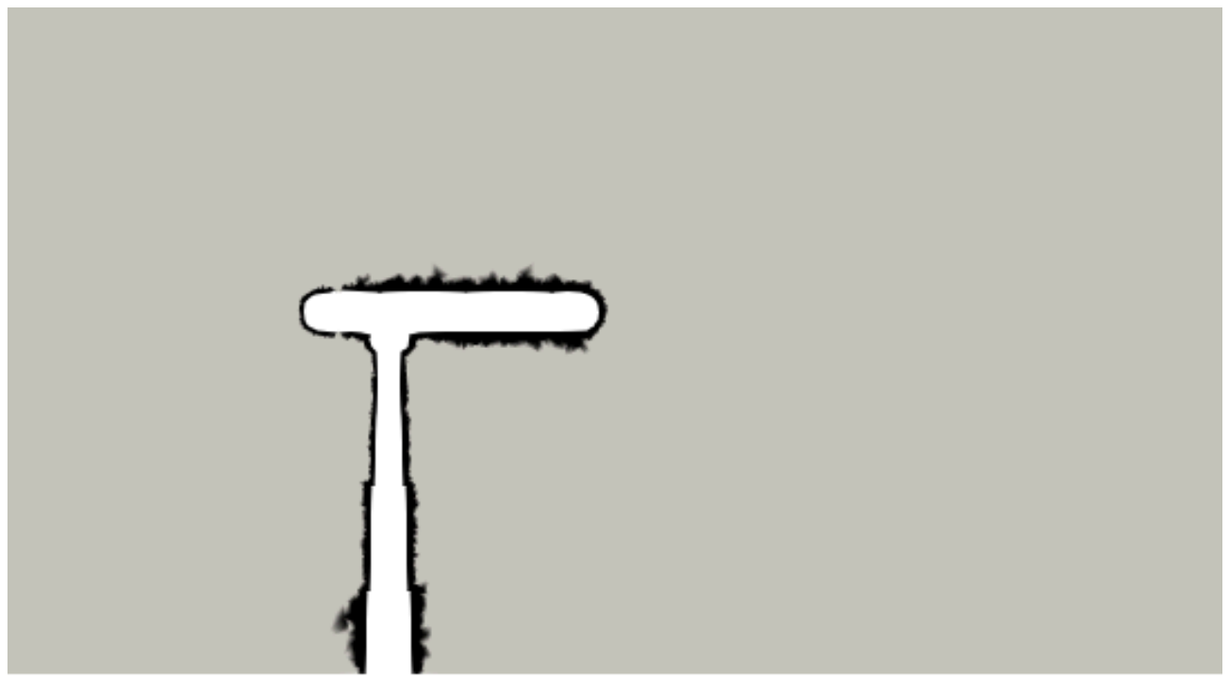
- **Mesh adaptivity parameters :** QC1 value or ncells ratio and QC2 value
- **Number of adaptation steps :** depends on metric error

Use level set for masking

LS PHI



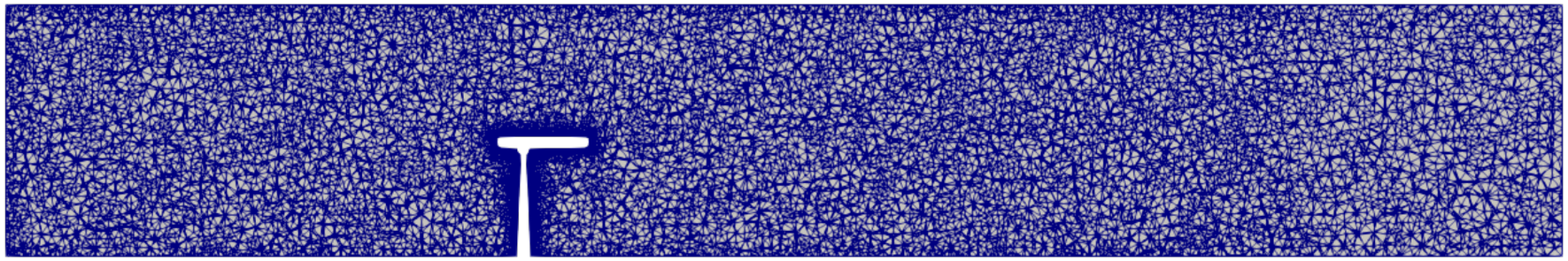
Mask



- **Tower and nacelle wall modeled**
- **use the level set to limit the number of cells in these regions**
- **No mesh adaptation in black regions**

Static adaptation based on flow statistics

Step 1 : 1.3M cells

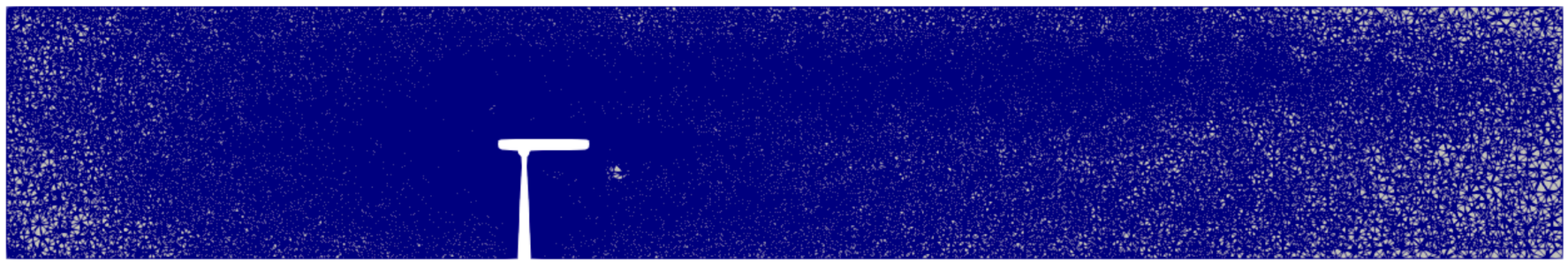


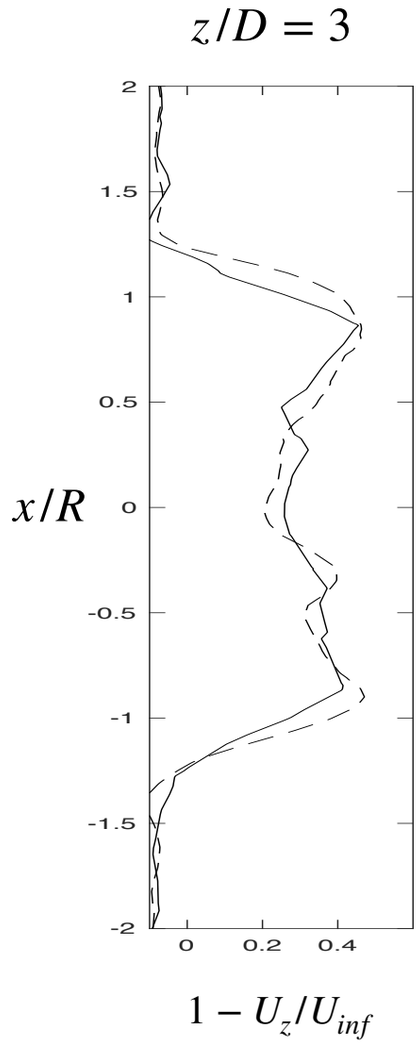
y

z

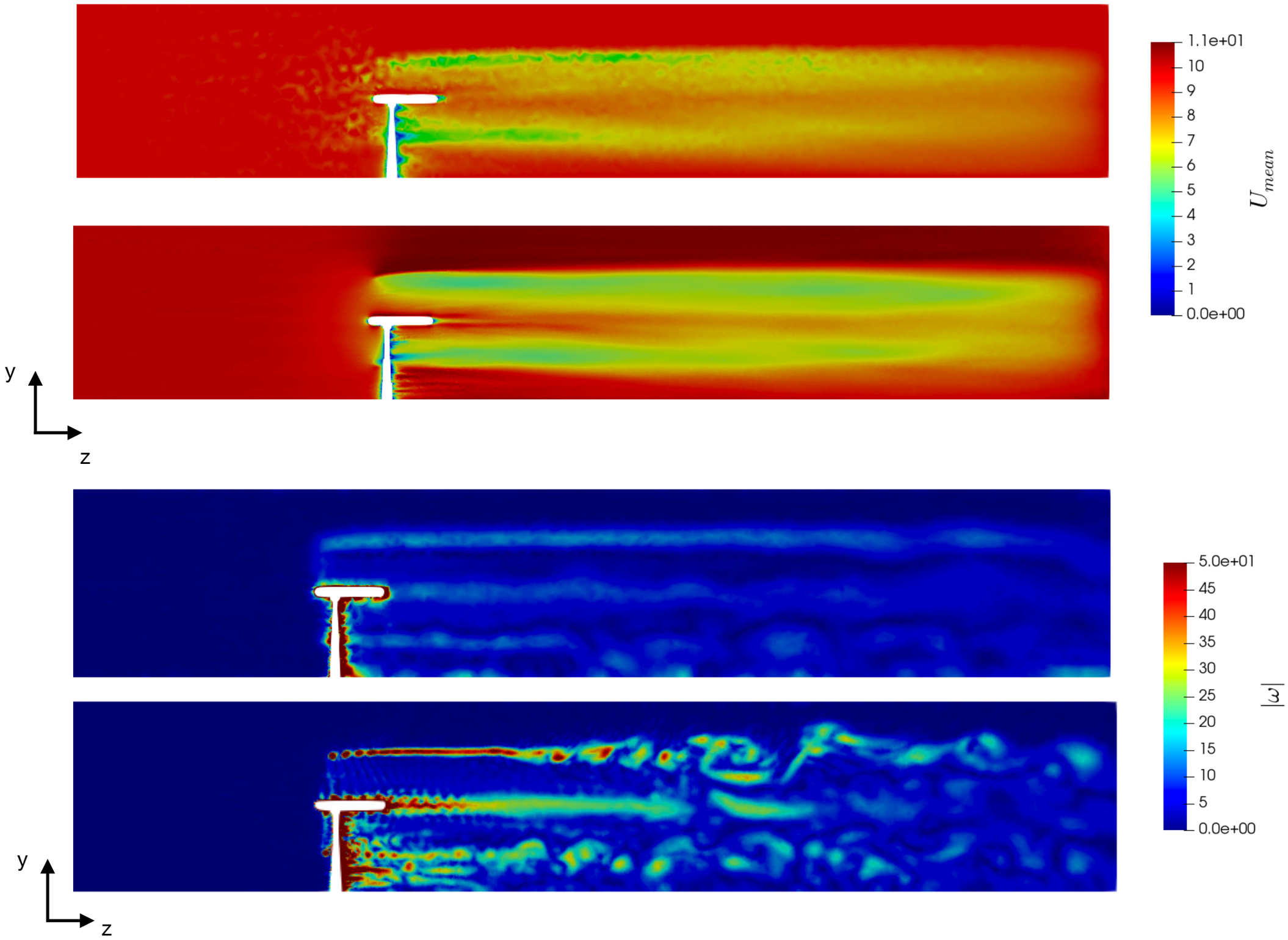
impose ncells ratio = 10

Step 2 : 12M cells



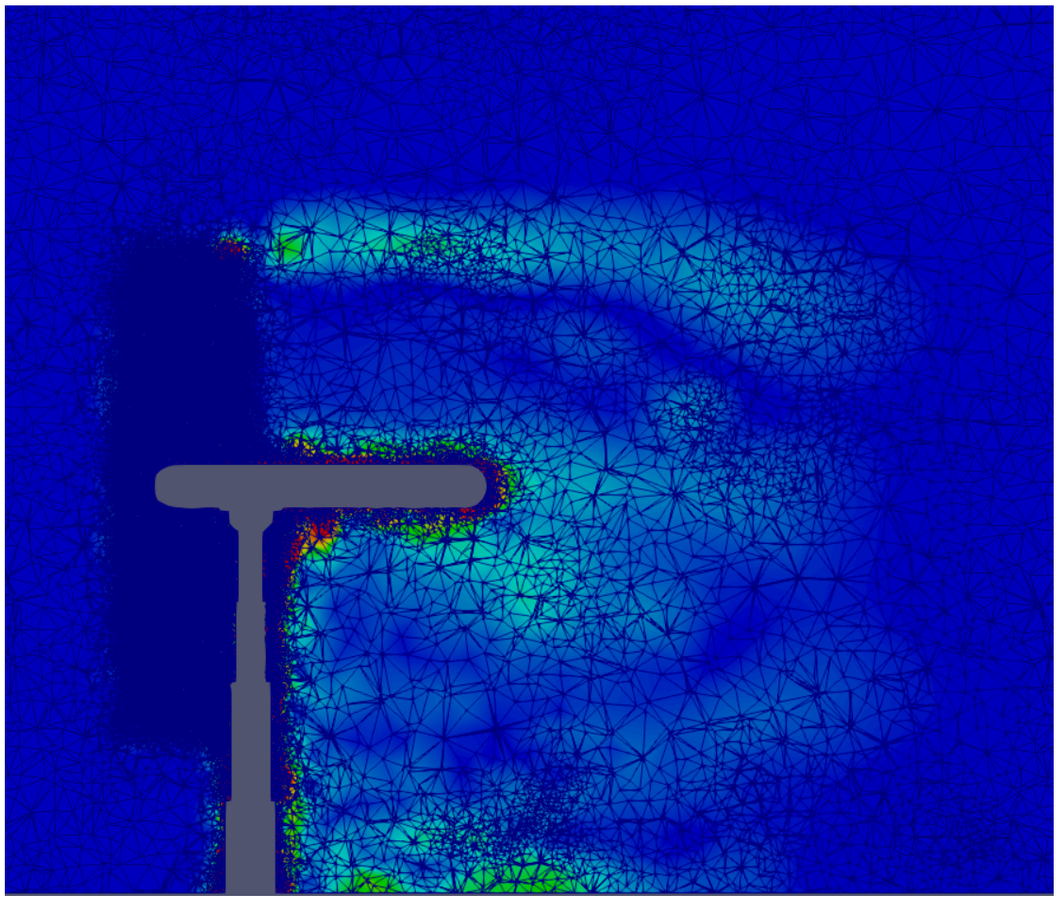


Static adaptation based on flow statistics

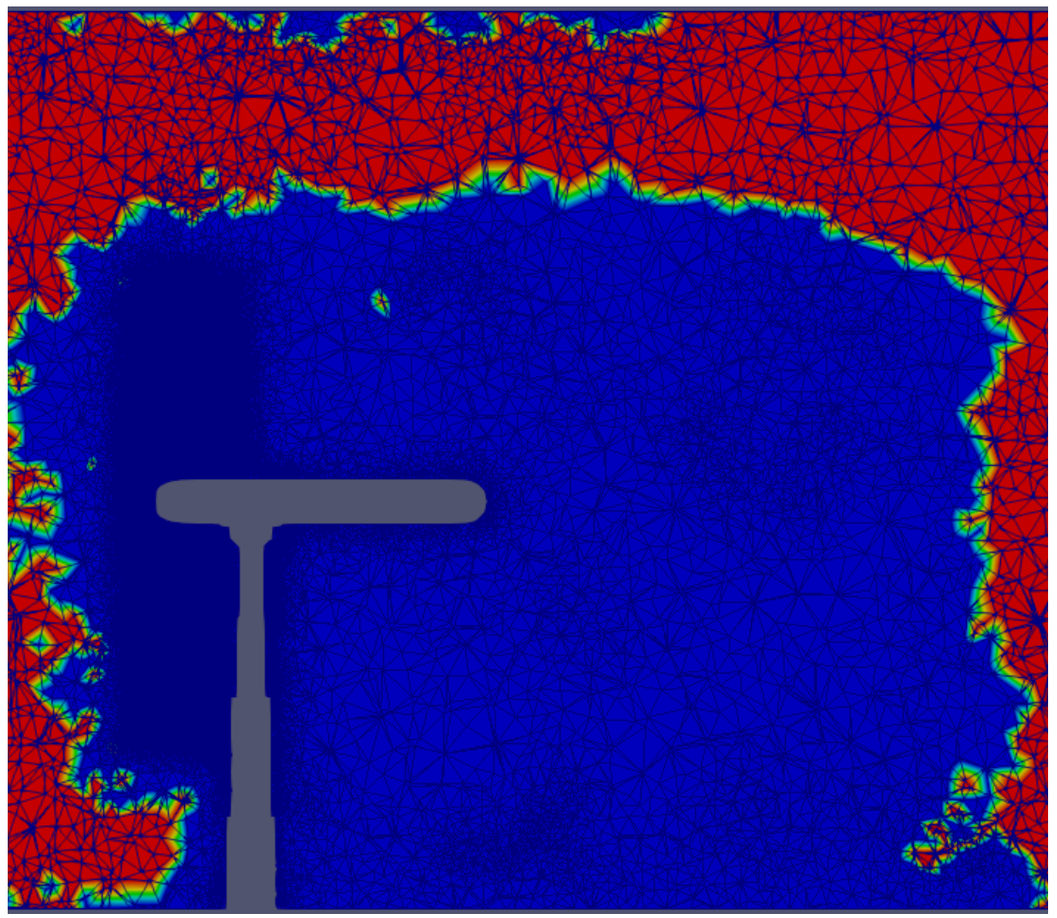


Dynamic adaptation based on vorticity

Vorticity



Mask $\omega_{local} > 1\,\%\,\omega_{max}$



- **Mask based on the voriticiy**
- **Reduce the mask and use mask propagation instead**

Perspective : wind turbine with yaw