



Energy research Centre of the Netherlands

Energy conservation in the numerical calculation of wind turbine wakes

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Introduction and research goal

- Currently: significant losses in wind farm power output due to wake effects
- Goal: accurate numerical simulation of wind turbine wakes and their interaction in farms. Investigation of the effect of turbulent mixing on wake recovery and power production
- Approach: development and application of high-order discretization schemes with no numerical diffusion for long-distance wake tracking and accurate simulation of turbulence [1]



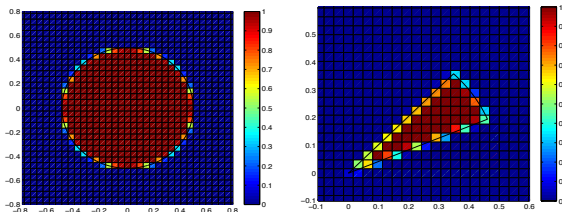
Governing equations

Incompressible Navier-Stokes equations:

$$\nabla \cdot \vec{u} = 0,$$

$$\frac{\partial \vec{u}}{\partial t} + (\vec{u} \cdot \nabla) \vec{u} = -\nabla p + \frac{1}{\text{Re}} \nabla^2 \vec{u} + \vec{f},$$

where $\vec{f}$ is a momentum sink representing the wind turbine blades, using an actuator disk or actuator line.



Energy conserving discretization for accurate turbulence simulation

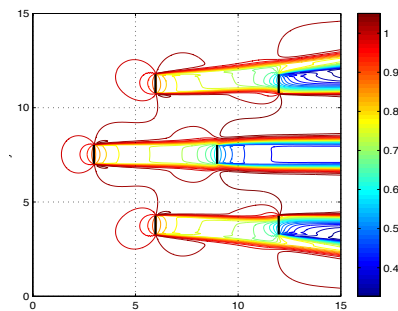
- Finite volume method on staggered Cartesian grid
- Fourth-order, symmetry-preserving discretization [2], mimicking crucial properties of differential operators
- Discrete conservation of kinetic energy

Ongoing work:

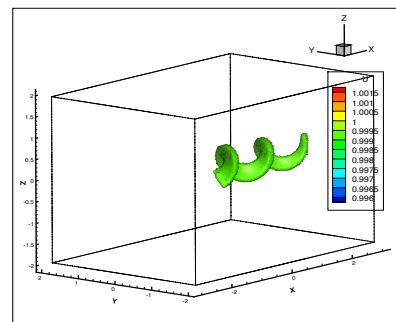
- Construction of symmetry-preserving Large Eddy Simulation models

Results

- Simulation of actuator disk in uniform flow (2D/3D), excellent comparison with analytical solution [3]
- Simulation of multiple actuator disks in uniform flow (2D)



- Preliminary actuator line results show wake vortex (3D)



References

- [1] B. Sanderse. Aerodynamics of wind-turbine wakes. Technical Report ECN-E-09-016, Energy Research Centre of the Netherlands, 2009.
- [2] R.W.C.P. Verstappen and A.E.P. Veldman. Symmetry-preserving discretization of turbulent flow. *Journal of Computational Physics*, 187:343–368, 2003.
- [3] P.-E. Réthoré and N.N. Sørensen. Actuator disc model using a modified Rhie-Chow/SIMPLE pressure correction algorithm. Comparison with analytical solutions. In *European Wind Energy Conference*, Brussels, 2008.