Wind farms in the North Sea

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Intoduction

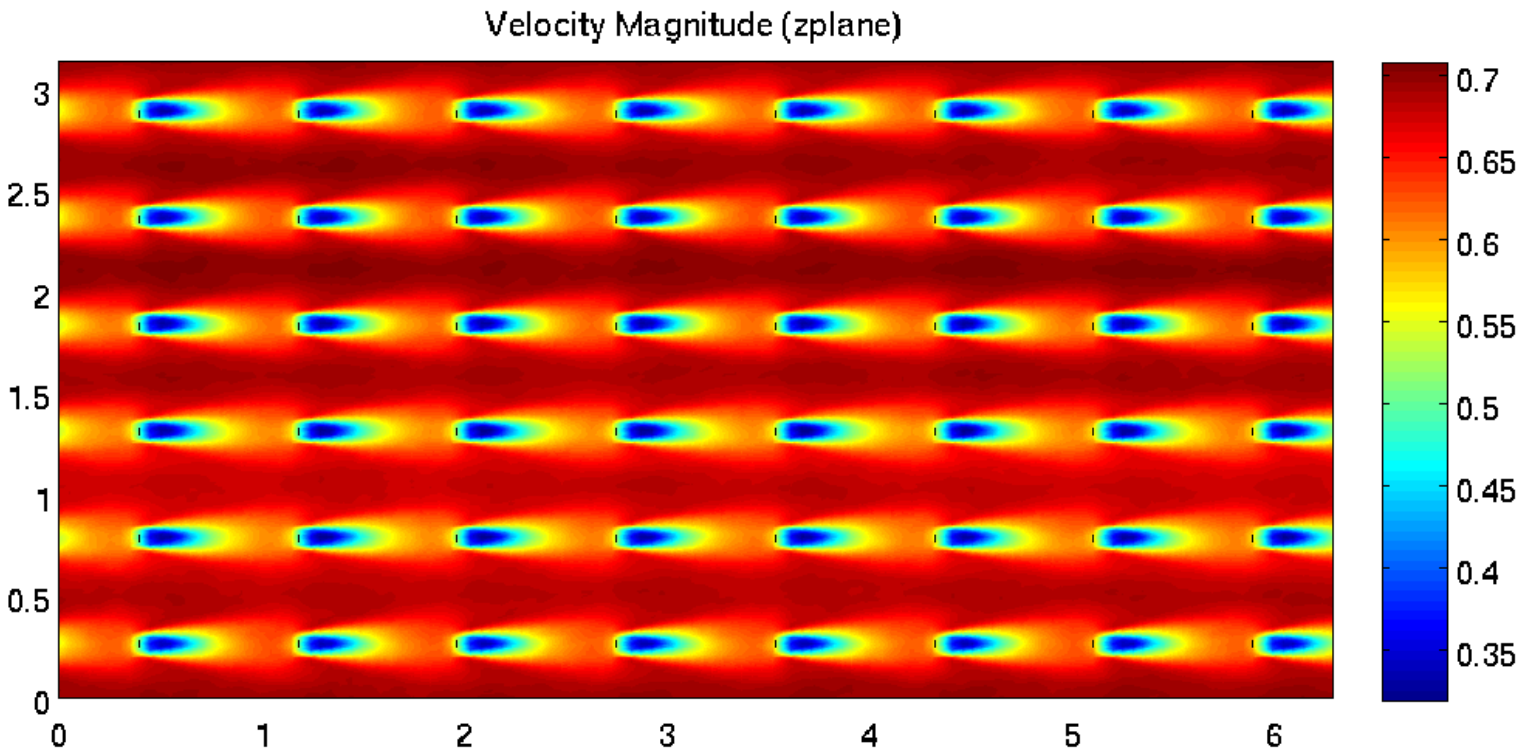
http://www.4coffshore.com/

- Strong Expansion in windfarm deployment: 40 GW by 2020
- Changes in local climatology at North Sea coasts
- Wind Farm representation in climate models not fully understood
- difficulty of wind farm measurements

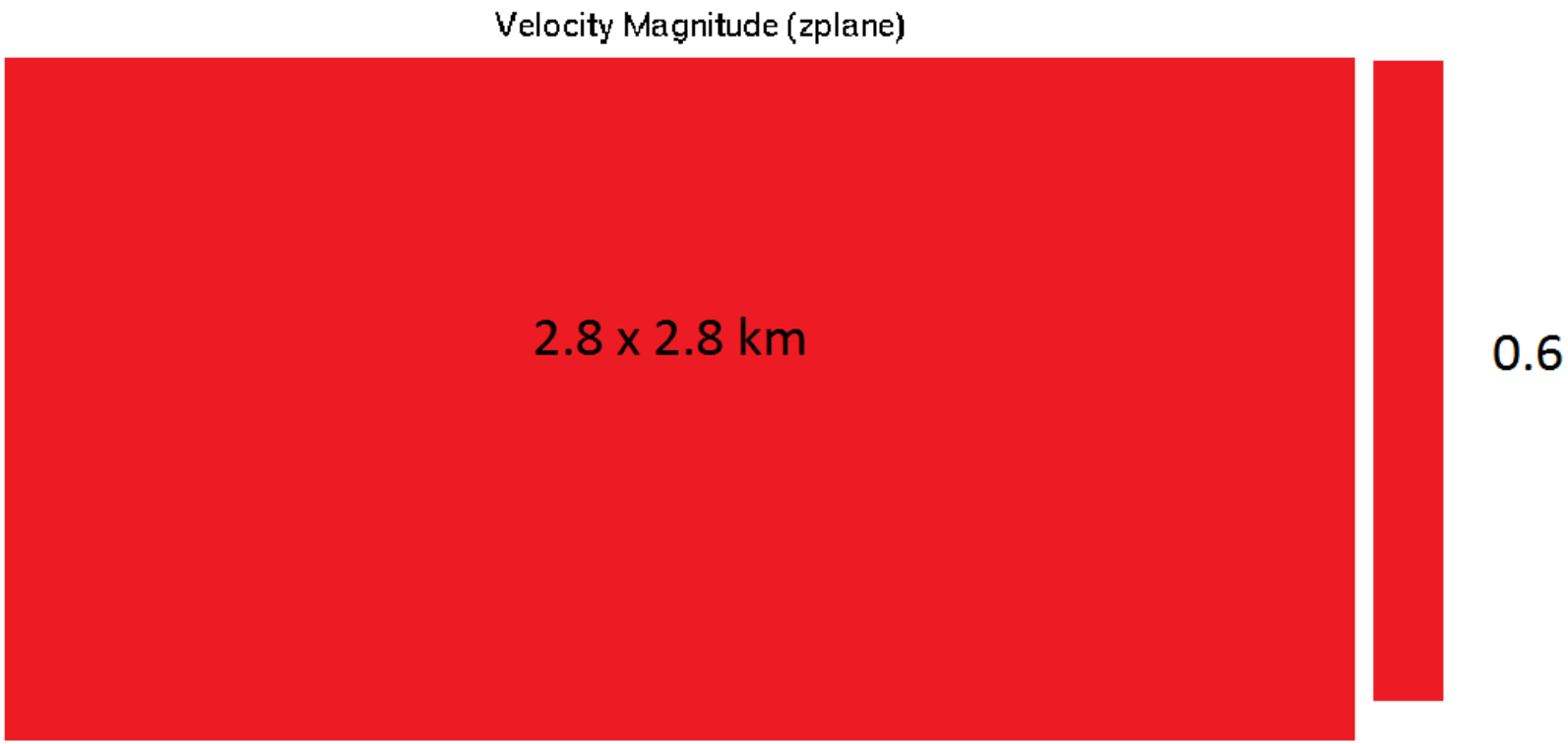
Outline

- LES to validate wind farm parameterisation
- Wind farm parameterisation
- COSMO-CLM model specifics
- Description of experiments and results
- Outlook
- Conclusions

LES to evaluate COSMO-CLM



LES to evaluate COSMO-CLM



Wind Farms in COSMO-CLM

Velocity Magnitude (zplane)

$$F_D = \frac{1}{2}\frac{C_T NAU^2}{\Delta z}$$

$$TKE_{WF} = \frac{1}{2}\frac{(C_T - C_P)NAU^3}{\Delta z}$$

U averaged

C_T uncertain

z_h=100 m

C_T=0.75

N=20/pixel

0.6

Experiment: Set Up

- Reynolds Averaged Navier Stokes equation
- 1.5 Order Closure for Turbulent Kinetic Energy
- Dry, neutral stratification, periodic lateral boundary condition
- Surface boundary: Bulk transfer scheme based on Monin-Obukhov
- Top boundary: Zero stress

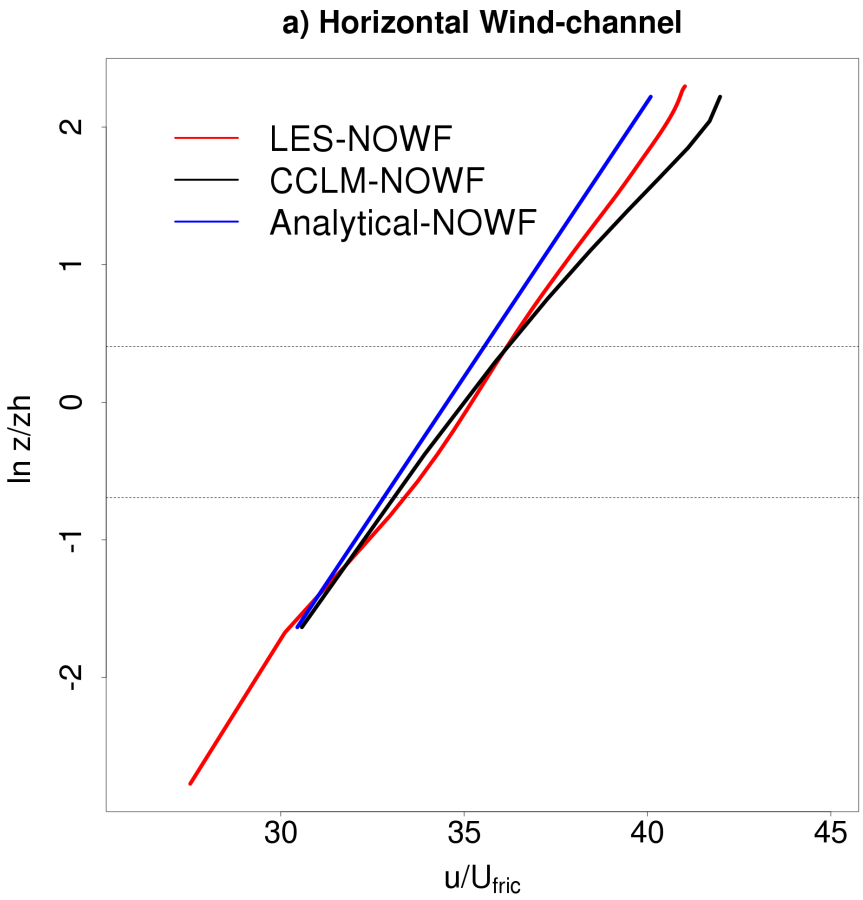
Experiment: The no Coriolis case

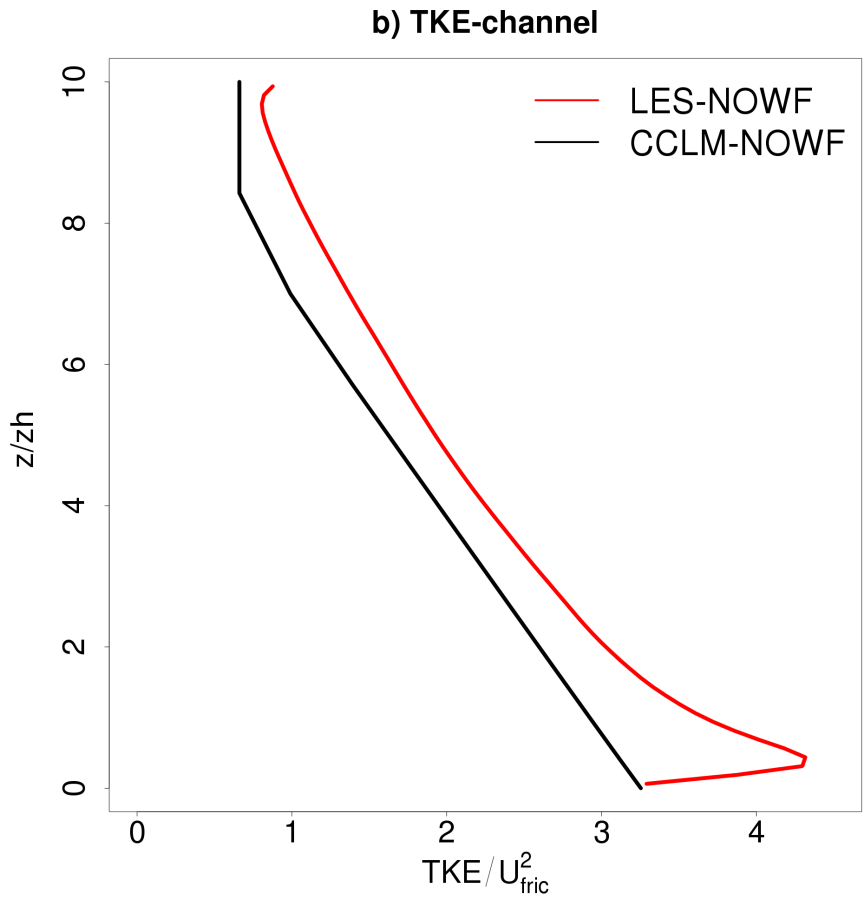
- Pressure gradient force balanced by surface friction
- Height 1000m, 10 layers
- No wind Farm - Wind Farm - increase C_T
- Compare with LES, Wind Farm LES, staggered wind farm LES

Experiment: The Coriolis case

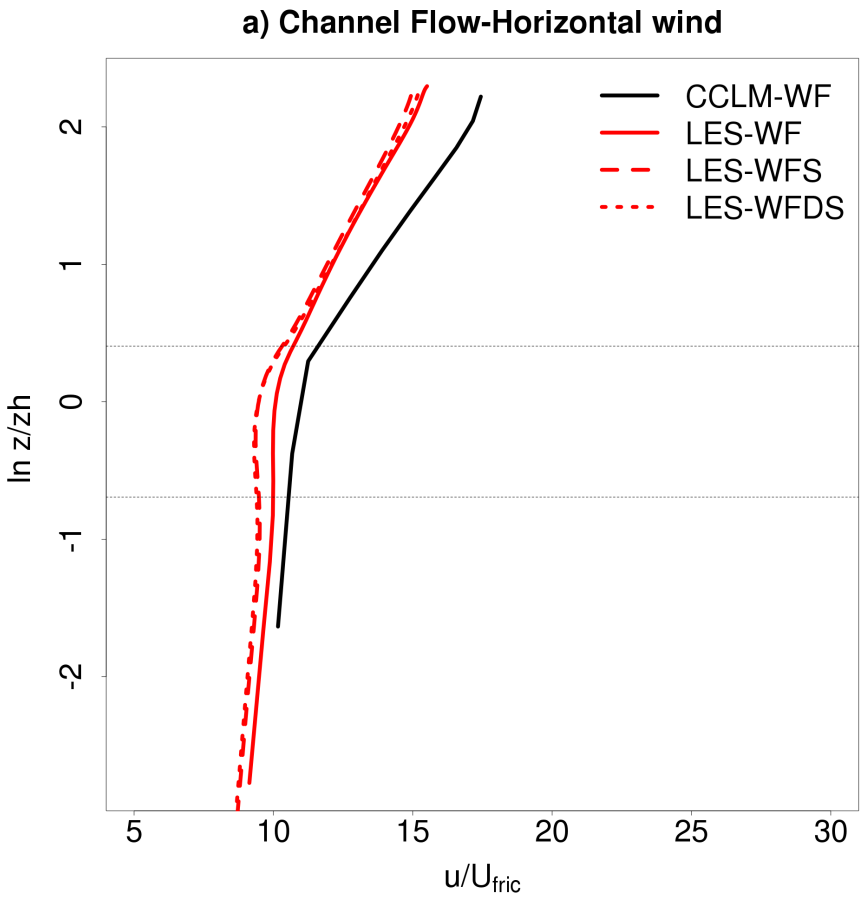
- Pressure gradient force balanced by surface friction and Coriolis
- Height 5000m, 16 layers
- No wind Farm - Wind Farm - increase, decrease C_T
- Compare with LES, Wind Farm LES, staggered wind farm LES

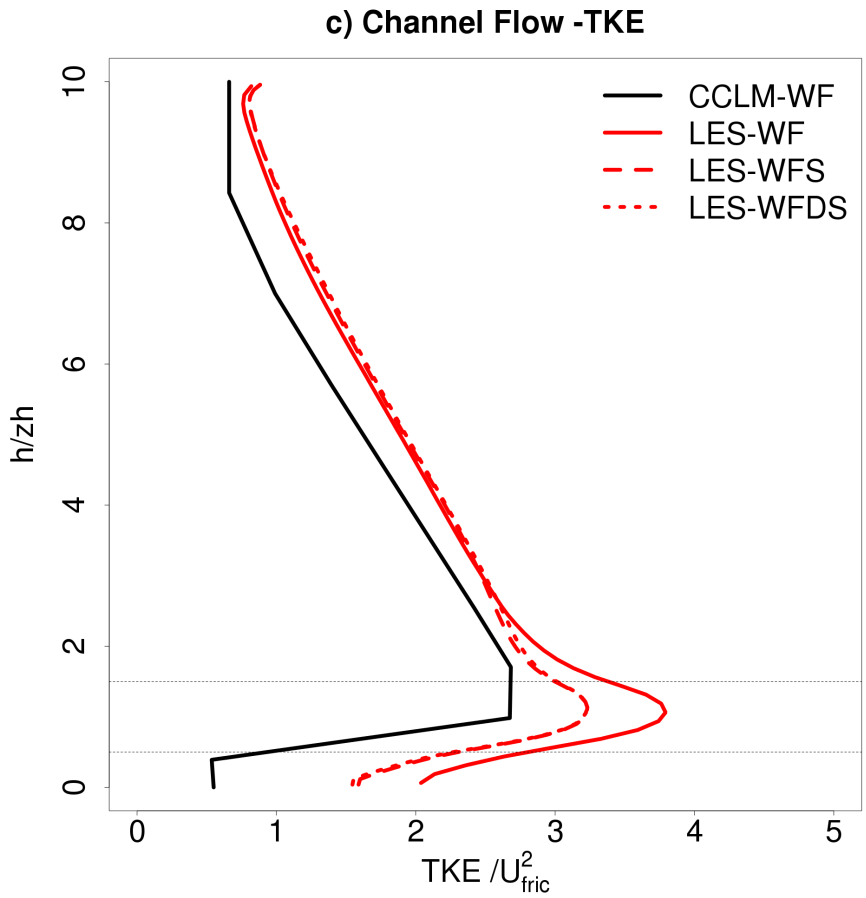
No Coriolis: No Farm





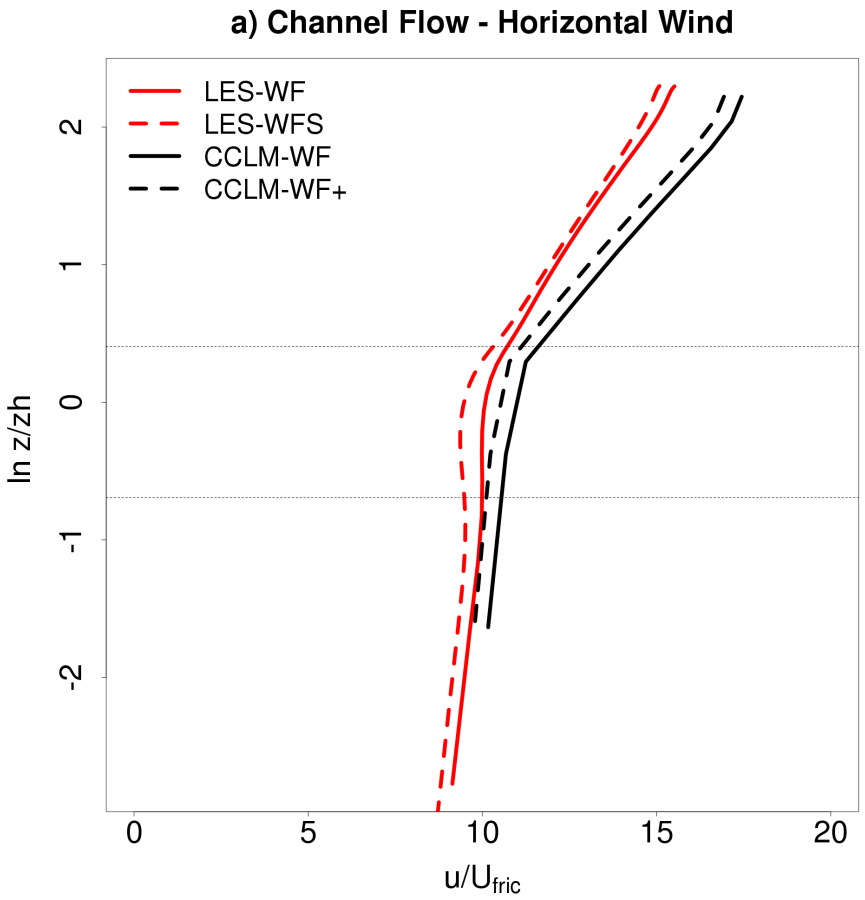
No Coriolis:Wind Farm

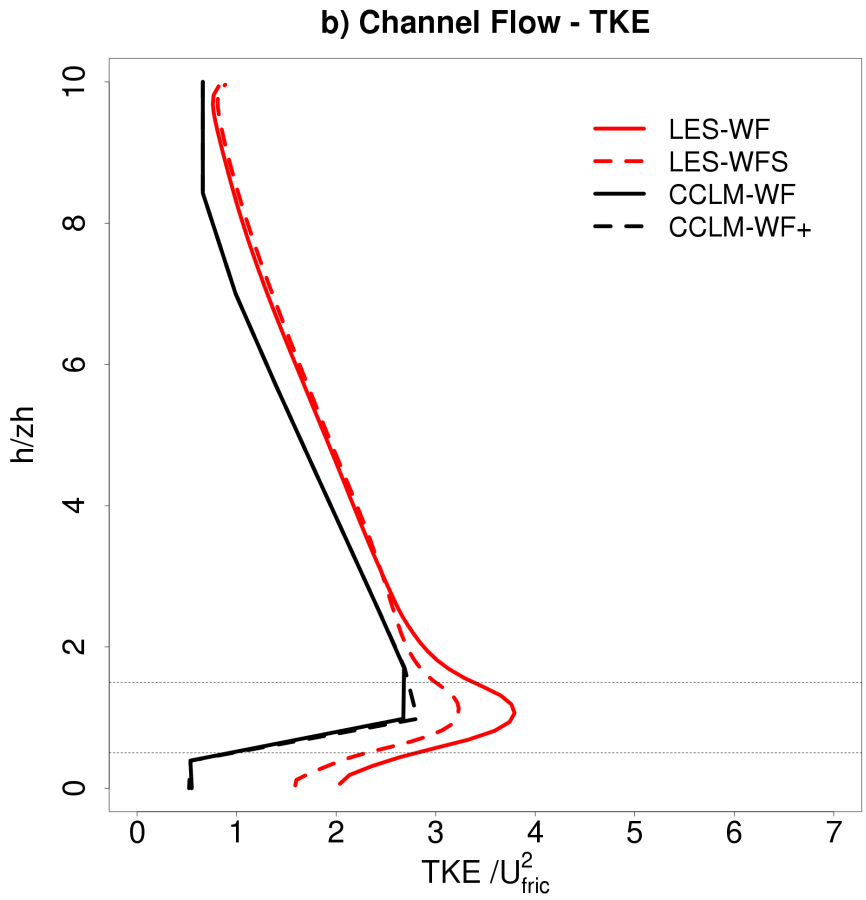




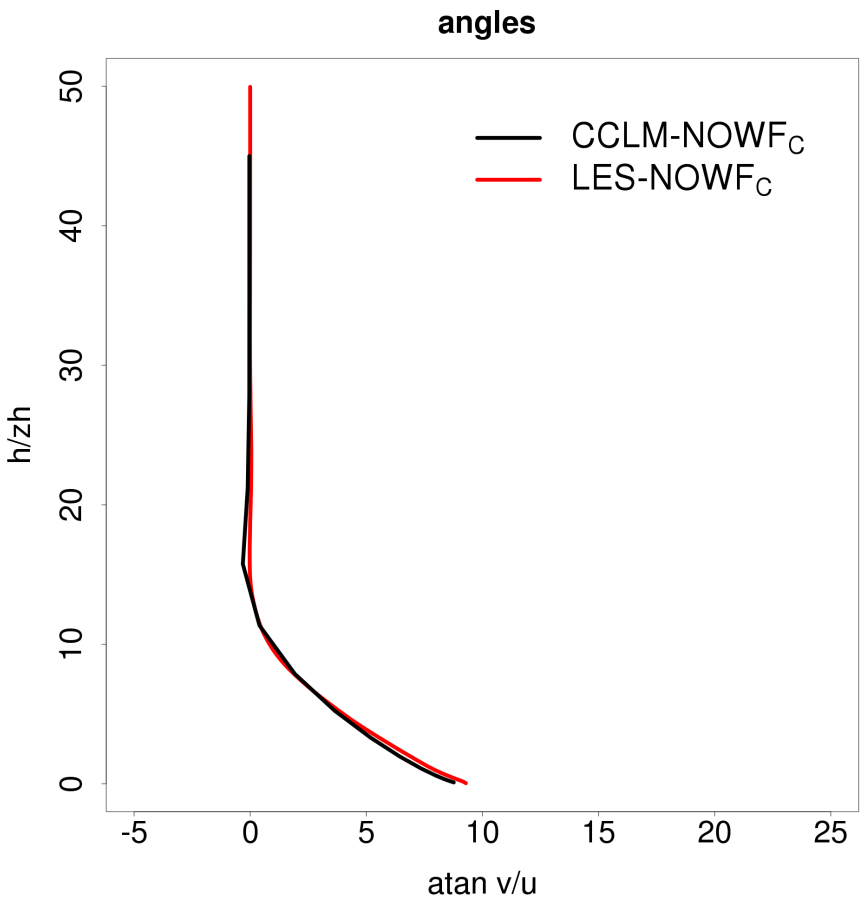
mean absolute bias u: 13 %

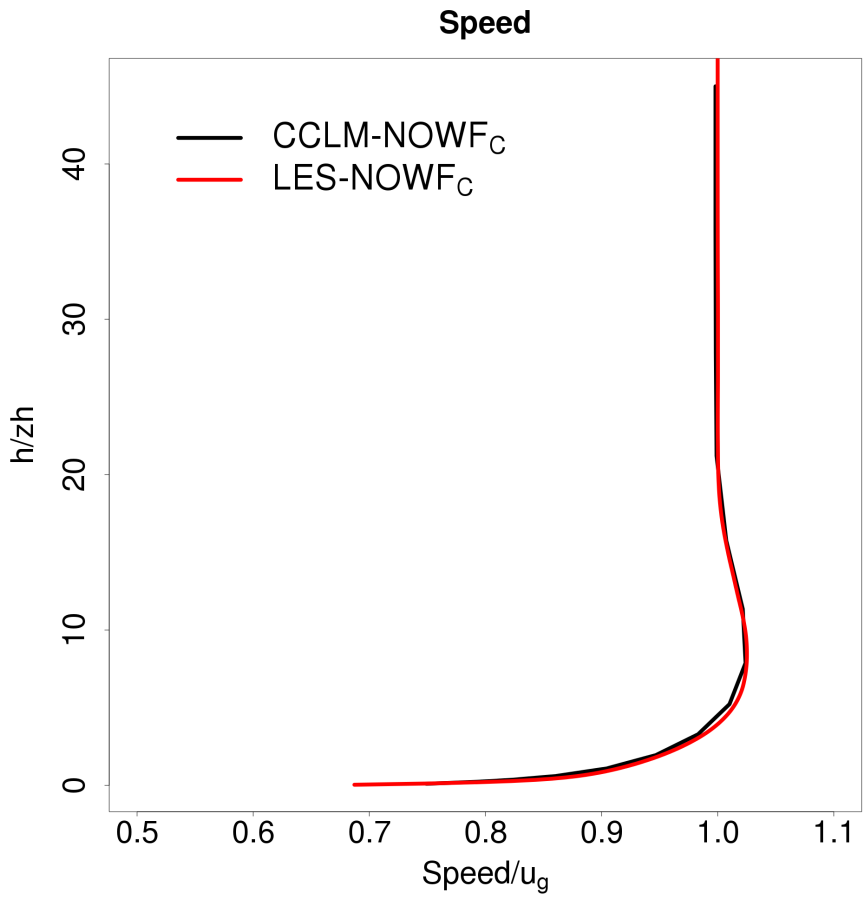
No Coriolis: increase thrust coefficient



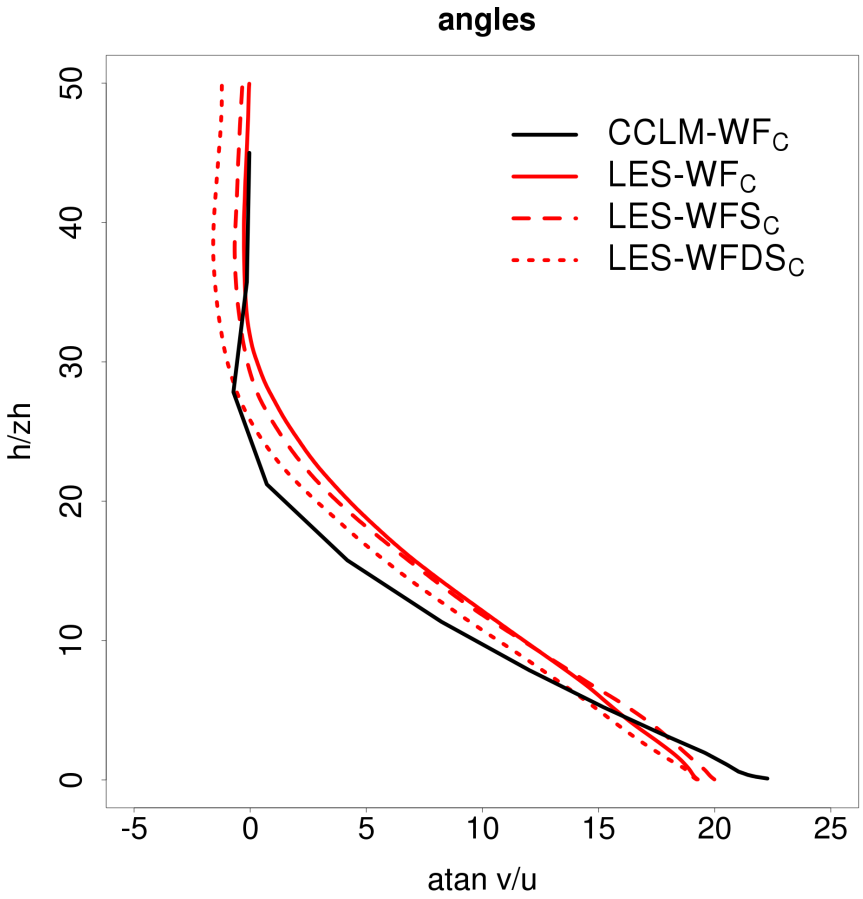


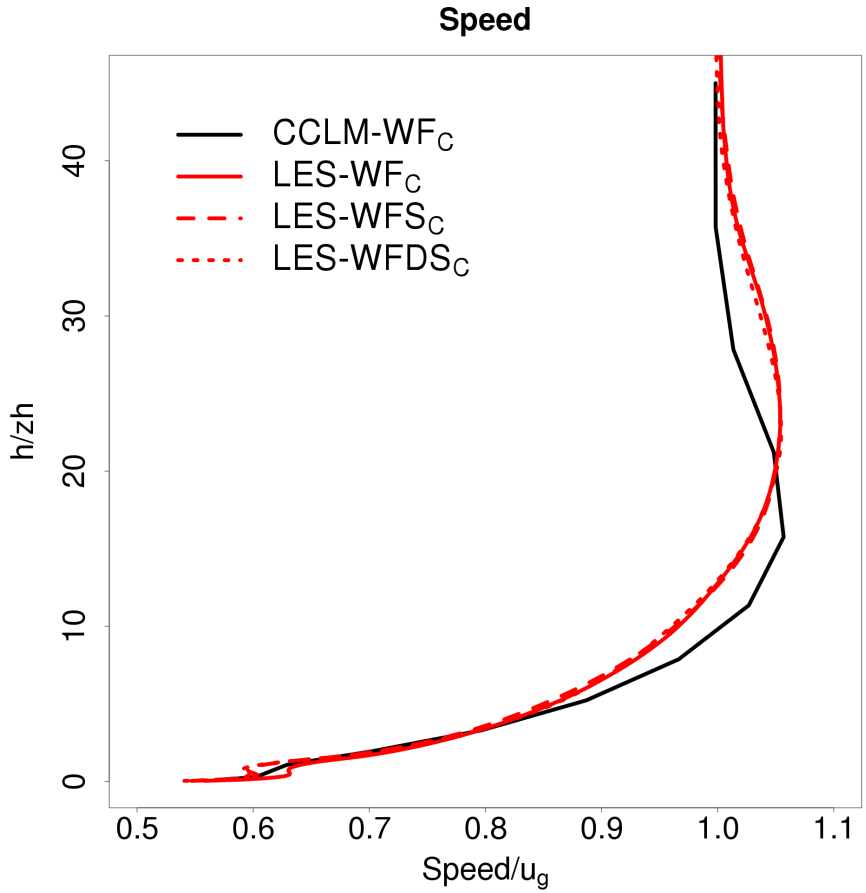
Coriolis case: No Farm





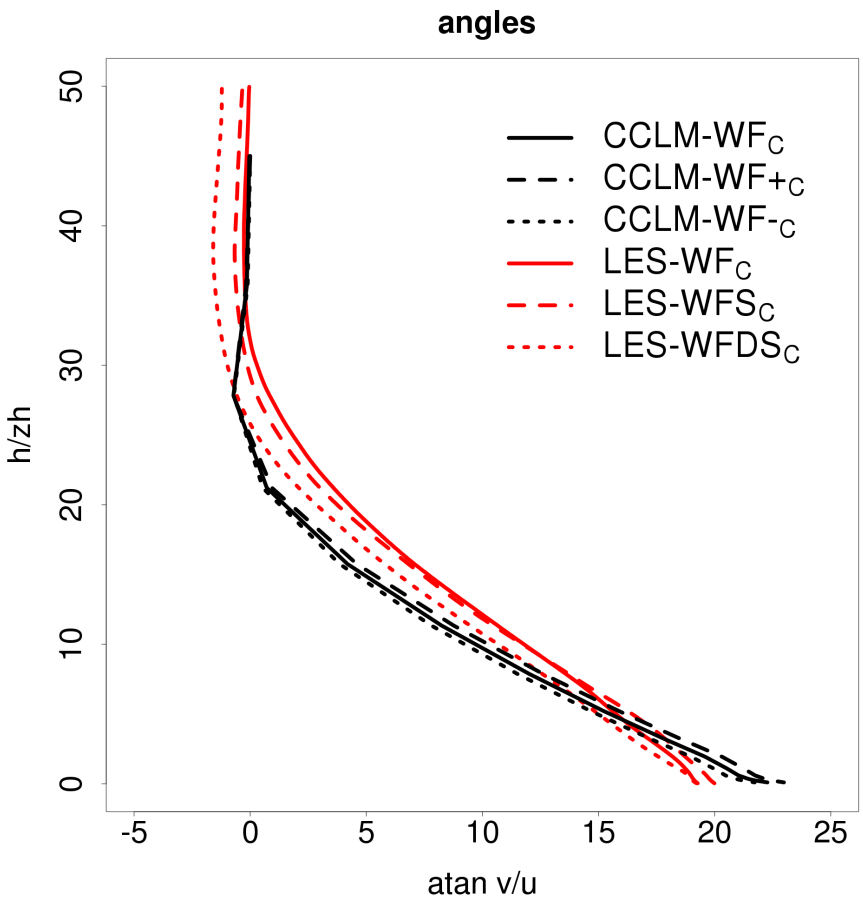
Coriolis case: Wind Farm

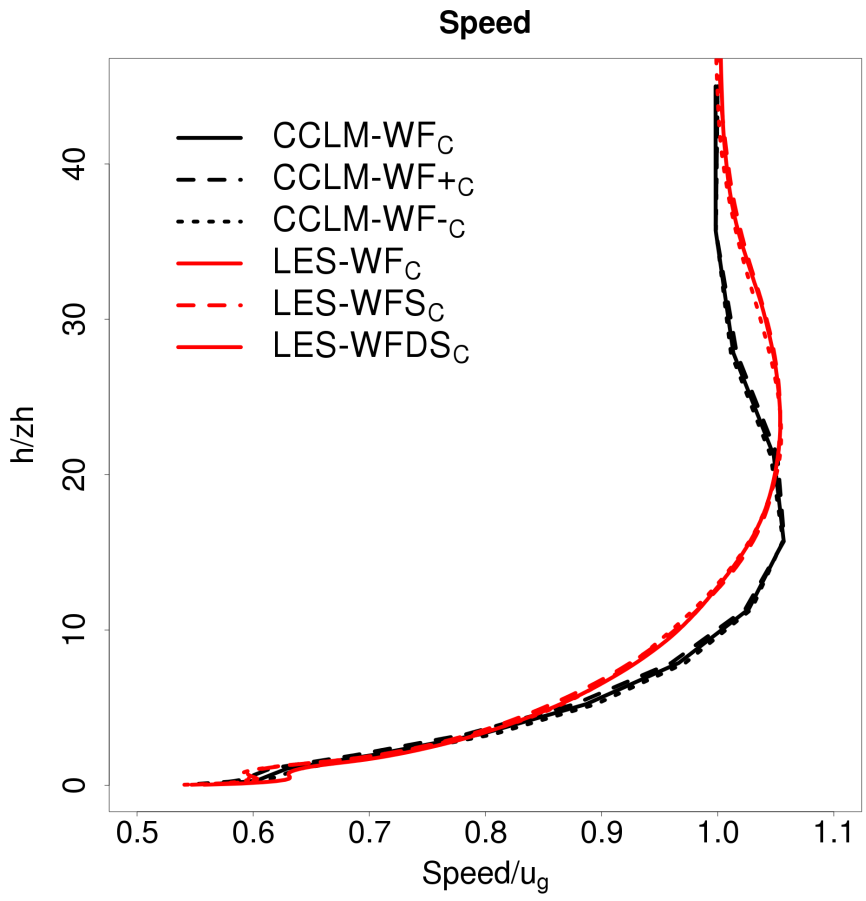




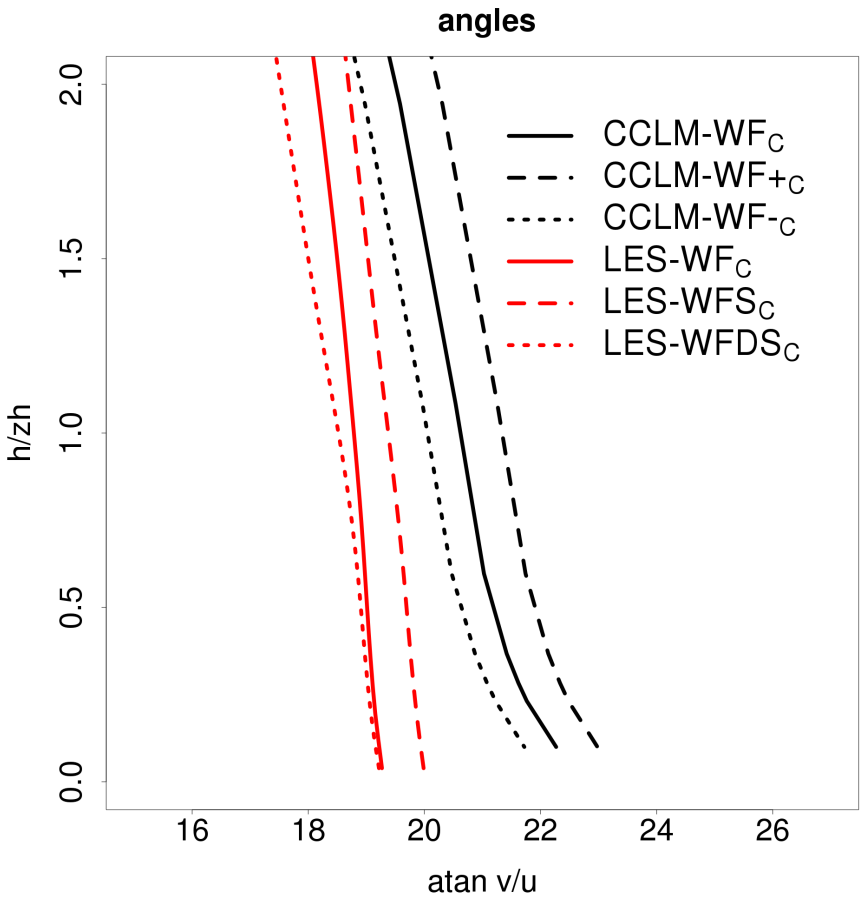
mean absolute bias 12%

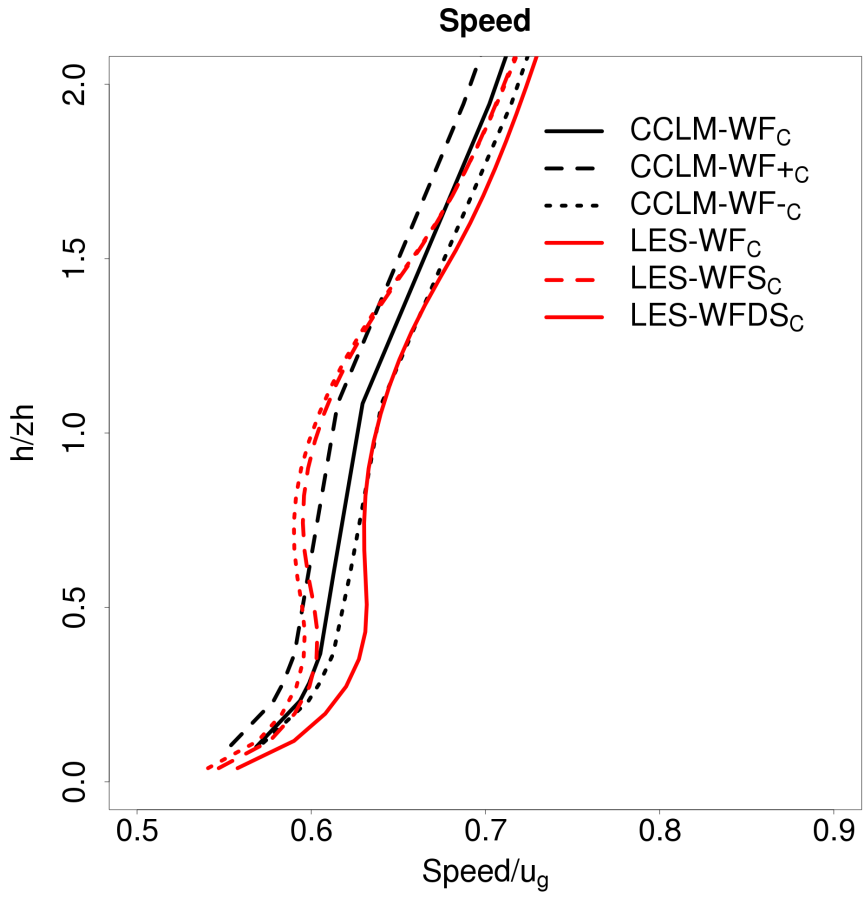
Coriolis case: Changes in Thrust Coefficient





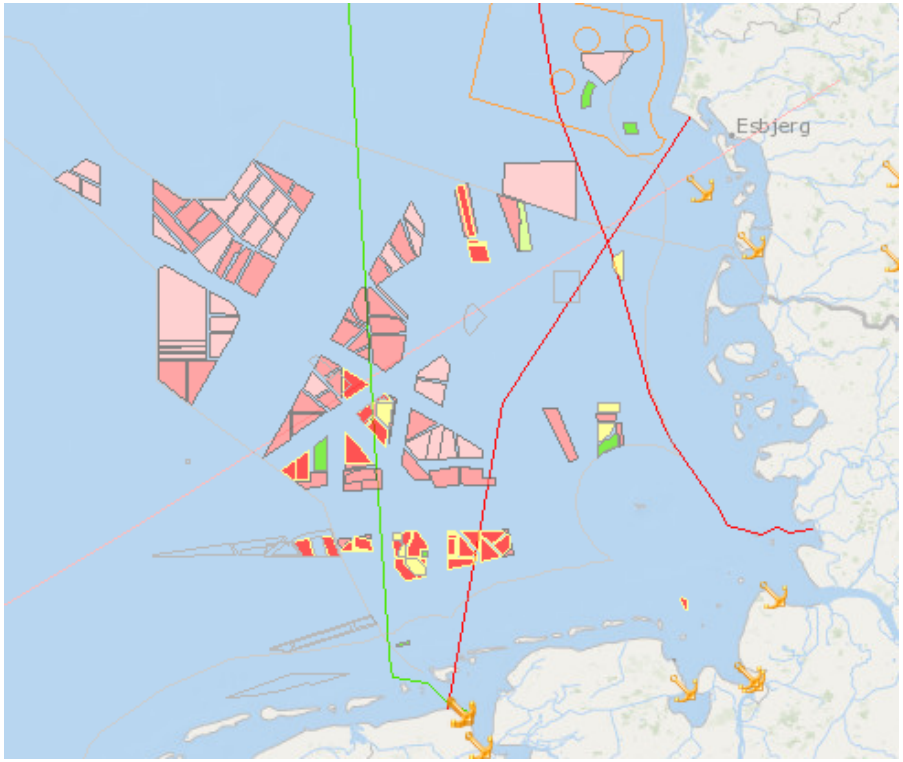
Coriolis case Rotor height: Changes in Thrust Coefficient





Future Work: Climate simulations

- CCLM nested with Euro-CORDEX 11km - 1.5 km
- Shadowing effects
- Geostrophic flow above ekman layer
- Hydrological cycle



Conclusions

- COSMO-CLM is able to reproduce an LES flow with and without Coriolis
- Wind farm Parameterisation reproduces flow with 12 % and 13 % error.
- Increasing C_T improves no Coriolis case
- decreasing C_T improves the Coriolis case