Towards the assessment of climate change impacts on critical energy infrastructure applied for wind energy

Thomas Remke[1,2] and Daniela Jacob[1,2]
[1] Climate Service Center Germany (GERICS), Helmholtz Center Geesthacht, Hamburg, Germany
[2] Leuphana University of Lüneburg, Lüneburg, Germany

1. Introduction & climate service perspective

Planning and operational horizons of critical energy infrastructure span several years to decades. Hence, climate information of potential direct and indirect impacts for such facilities is of interest for planning purposes serving risk management and assuring secure energy supply.
Europe's energy sector is in transition towards a substantial increased share in energy production by renewables with wind energy expected to contribute most compared to other renewables (Banja et al., 2013). As a capital intensive technology requiring up to 80% of the total project cost upfront project realisation (Blanco, 2009), most large-scale wind power plant projects are based on financing – being key for successful wind energy implementation. Currently, project financing is based on assumptions of expected yield derived from retrospective data. However, climate change potentially affects the wind resource and could foster disruptions or outages (Pryor & Barthelmie, 2010). Therefore, the consideration of impacts related to climate change as additional influencing factor on project financing for wind energy is being investigated.

2. Methodological approach & conceptual results

I. Firstly, the most significant physical quantities affecting measures within different phases of project financing for wind energy have been identified:
- Current design standards conservative and not likely to be exceeded by extreme and fatigue loads (Pryor & Barthelmie, 2013)
- Operation and maintenance strongly linked to conservative design standards or adjustable on shorter time scales
- Yield through wind climate essential component within project financing exposed to climate change

II. Secondly, a framework for sector-specific climate information is set up aiming to identify responsible processes and to quantify projected changes in wind climate. To account for the following circumstances, dynamical high-resolution simulations have been carried out:
- Extrapolation of near surface wind parameters to turbine heights physically limited (Stull, 1988) and not accounting for non-linearity
- Atmospheric boundary layer (ABL) characteristics of higher importance with respect to increasing turbine hub heights and rotor diameters (Emeis, 2014)
- State-of-the-art regional downscaled climate model projections from EURO-CORDEX initiative indicate changes in turbulent energy transport potentially affecting ABL stability (Figure 1)
- Addressing ABL conditions specifically by high-resolution modelling

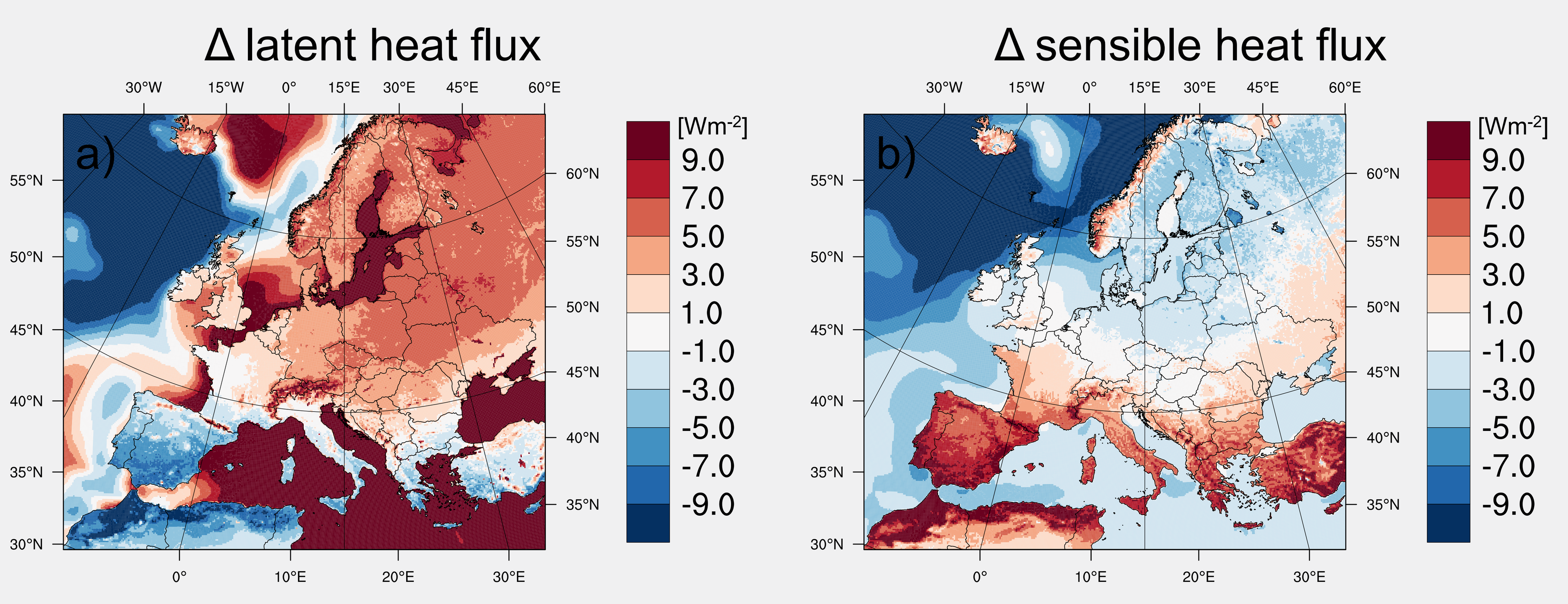
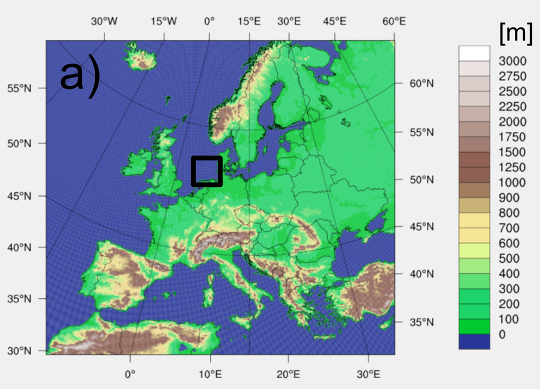


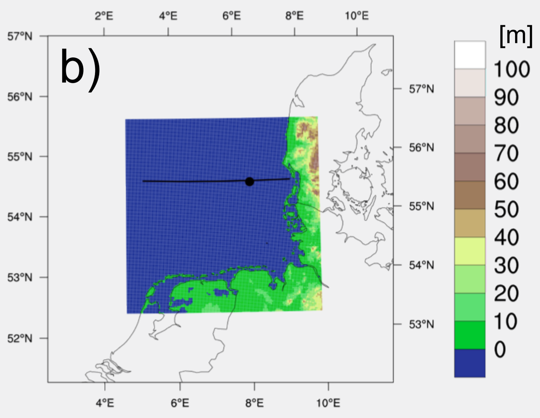
Figure 1. EURO-CORDEX RCP8.5 30-year ensemble mean change of surface upward latent heat flux (a) and surface upward sensible heat flux (b) between 2070 to 2099 and the reference period 1971 to 2000. The ensemble consists of 15 members of different GCM-RCM combinations. Focussing on central Europe, the latent heat flux slightly increases throughout the year while the sensible heat flux remains indistinct on average, however, slight decreases occur during MAM (not shown).

3. High-resolution experimental framework

Framework for high-resolution climate simulations suiting wind conditions in the ABL using the non-hydrostatic regional climate model REMO-NH covers:
- Vertical resolution addressing wind conditions across blade swept area
- Spatial resolution better resolving topography and roughness
- Temporal resolution suiting variability and turbulence measures
- Specific variables characterising turbulence and stability
- Relation to EURO-CORDEX framework



I. Hydrostatic simulation (REMO)
- ○ EURO-CORDEX domain (a) and setup
- ○ 0.11º (~12 km) horizontal resolution
- ○ Simulations on 27 and 49 vertical levels
- ○ ERA-Interim forcing



II. Non-hydrostatic simulation (REMO-NH)
- ○ German Bight domain (b)
- ○ 0.022º (~2.5 km) horizontal resolution
- ○ REMO forcing (49 vertical levels)
- ○ 10min velocity variables every 20 m until 300 m

REMO-NH sensitivity test reveals better resolved ABL with enhanced spatial variability and finer resolved structures (Figure 2).

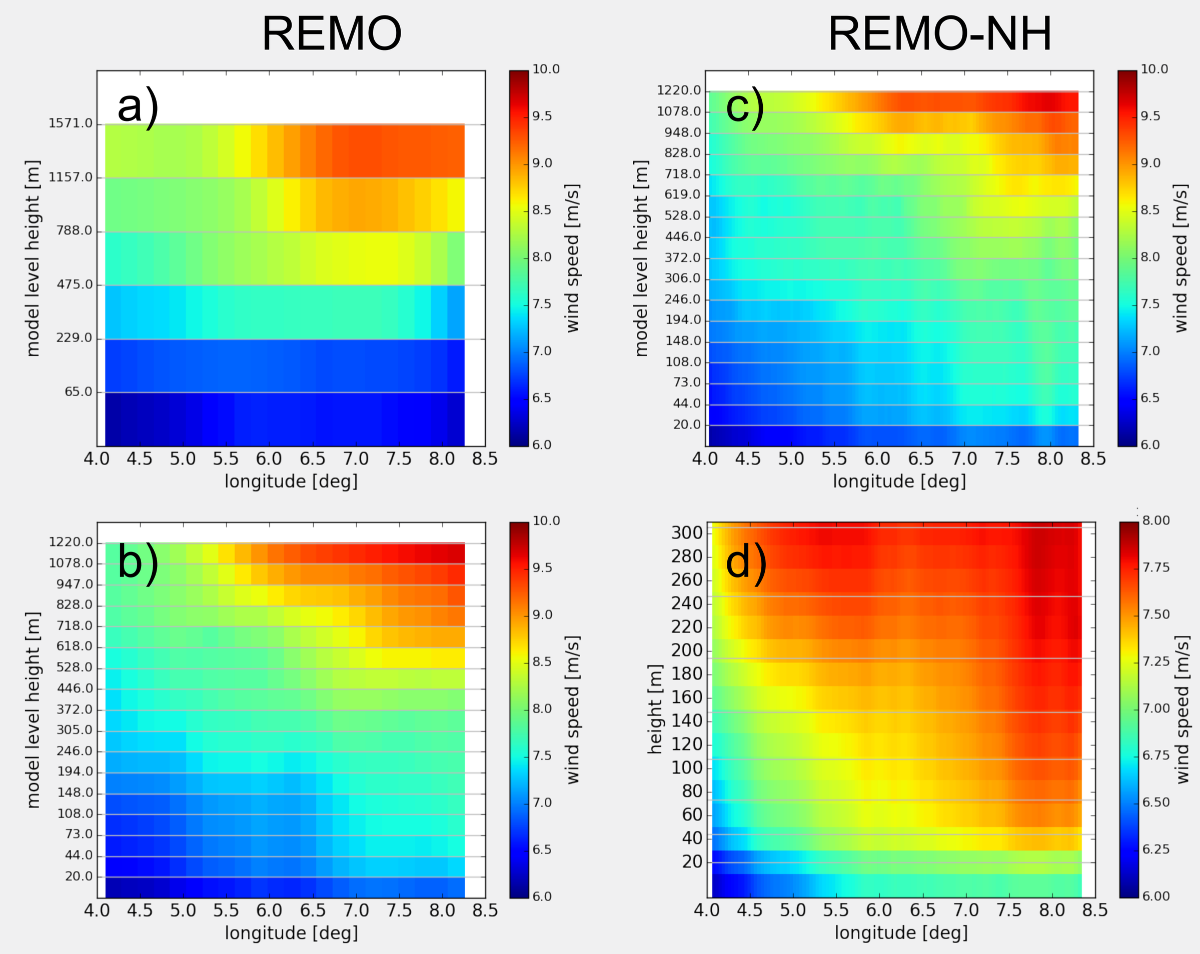


Figure 2. Longitudinal transect through the German Bight (at 55.195º N). Shown are 10min wind speed values averaged over five day unstable ABL conditions during October 2010 for simulations of REMO on 27 vertical levels (a) and REMO on 49 vertical levels (b) as well as for REMO-NH (c) up to about 1000 m height. In addition, the wind speed values at 20 m intervals up to 300 m from REMO-NH (d) are shown. Grey lines indicate the average height of the σ-model levels.

4. Summary & conclusion

Consideration of climate change impacts on expected yield as additional influencing factor on project financing for wind energy is proposed. To achieve suitable sector-specific climate information, high-resolution climate simulations reveal potential to analyse climate change impacts on wind energy on process level by better resolving ABL characteristics.
Subsequently, simulations under different climate conditions will be performed and related to EURO-CORDEX through weather pattern clustering, thus, quantifying climate change impacts on wind energy. In addition, financing will be addressed specifically.

References

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