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

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C2 – Regional Atmospheric and Oceanic Circulation Systems

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Climate service perspective

- Energy sector is **critical infrastructure** in transition for which implications can result in severe and long-lasting consequences

- **Planning and operational horizons** for projects concerning energy infrastructure usually **span several years to decades**

  → Potential direct and indirect impacts related to climate change are of interest to **assure secure and sustainable energy supply**

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Climate service perspective

- Europe's future installed capacity for **wind energy expected to contribute most** compared to other renewables (Banja et al., 2013)

- **Wind energy** is **capital intensive technology** requiring as up to 80% of total project cost upfront project realisation (Blanco, 2009)
  - Most large-scale wind power plant projects based on financing
  - Project financing key for successful wind energy implementation

- **Project financing** and repayment conditions **based on assumptions of expected yield** over lifetime of wind power plant
  - Currently solely based on retrospective experience

- Consideration of **impacts related to climate change** as **additional influencing factor on project financing** in wind energy sector

Methodological approach

I. Identification and determination of **most significant physical quantities** affecting measures within **different phases of project financing** in wind energy industry

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- Current **design standards of turbines and foundations are conservative** and not likely to be exceeded by extreme and fatigue loads (Pryor and Barthelmie, 2013)
- **Operation and maintenance** strongly linked to conservative design standards or **adjustable on shorter time scales**
- Yield through **wind climate is essential component** within project financing exposed to climate change

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Methodological approach

II. Generation of suitable **sector-specific climate information** to quantify projected changes in wind climate

- Wind energy climate **information deducted from near surface wind parameters** extrapolated to turbine hub heights

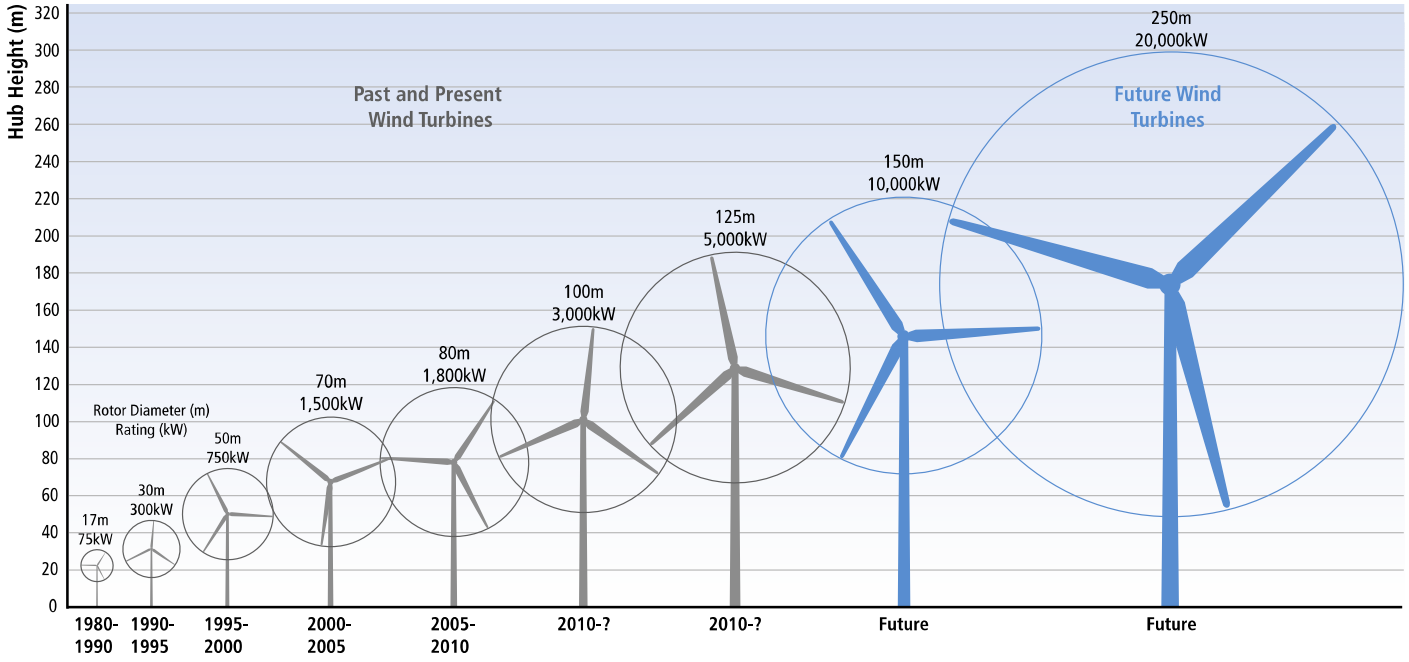

Figure TS.7.2 | Growth in size of typical commercial wind turbines. [Figure 7.6]

IPCC SR, 2012

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Methodological approach

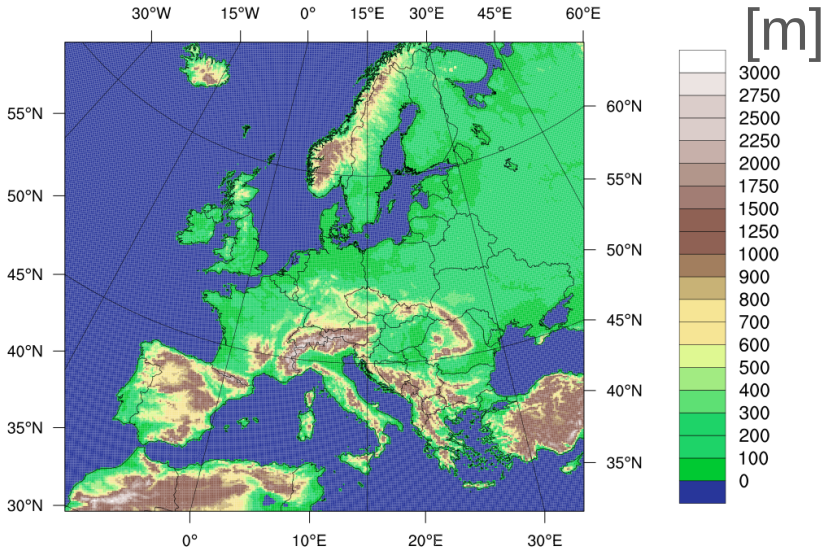
II. Generation of suitable **sector-specific climate information** to quantify projected changes in wind climate

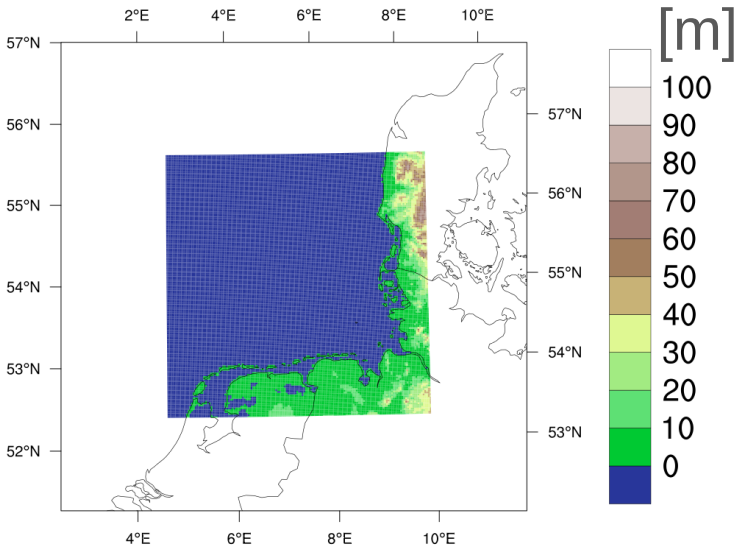
- Vertical resolution allowing for **instantaneous wind conditions** at hub height or across rotor blade swept area
- **Increased spatial and temporal resolution** to better resolve variability, atmospheric BL as well as topography and roughness
- Framework for **high-resolution climate simulations** suiting wind conditions in atmospheric BL

Experiment design (offshore case)

- **REMO** (hydrostatic)
- EURO-CORDEX setup with 0.11º horizontal resolution
- 27 & 49 vertical levels
- 10min wind speed at 20m intervals up to 300m
- Forced with ERA-Interim

- **REMO-NH** (non-hydrostatic)
- German Bight domain with 0.022º horizontal resolution
- 49 vertical levels
- 10min wind speed at 20m intervals up to 300m
- Forced with REMO 0.11º (49 levels)





Domain orography as resolved by REMO (left) and REMO-NH (right)

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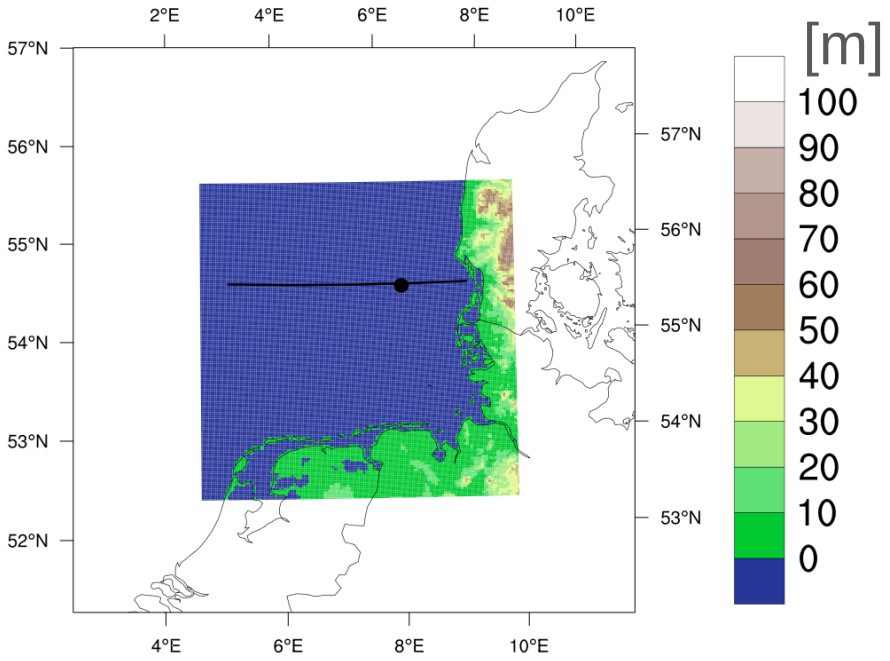
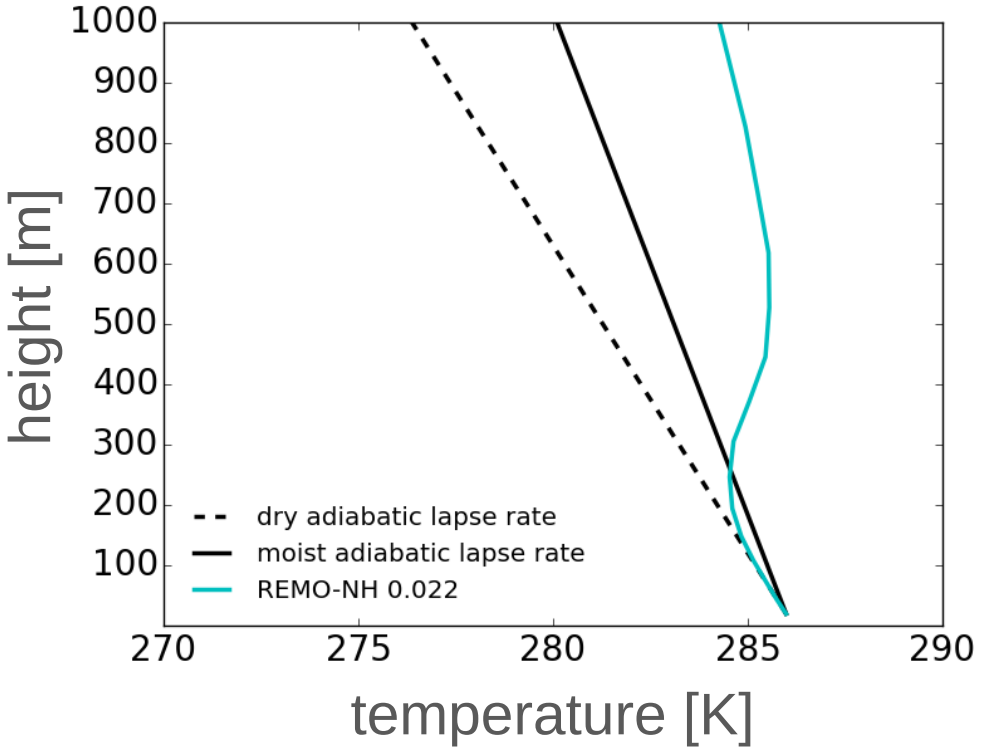
First results

- Sensitivity study for an offshore case
  - 1-month simulation
  - Identification of period of unstable atmospheric BL conditions
  - Longitudinal transect





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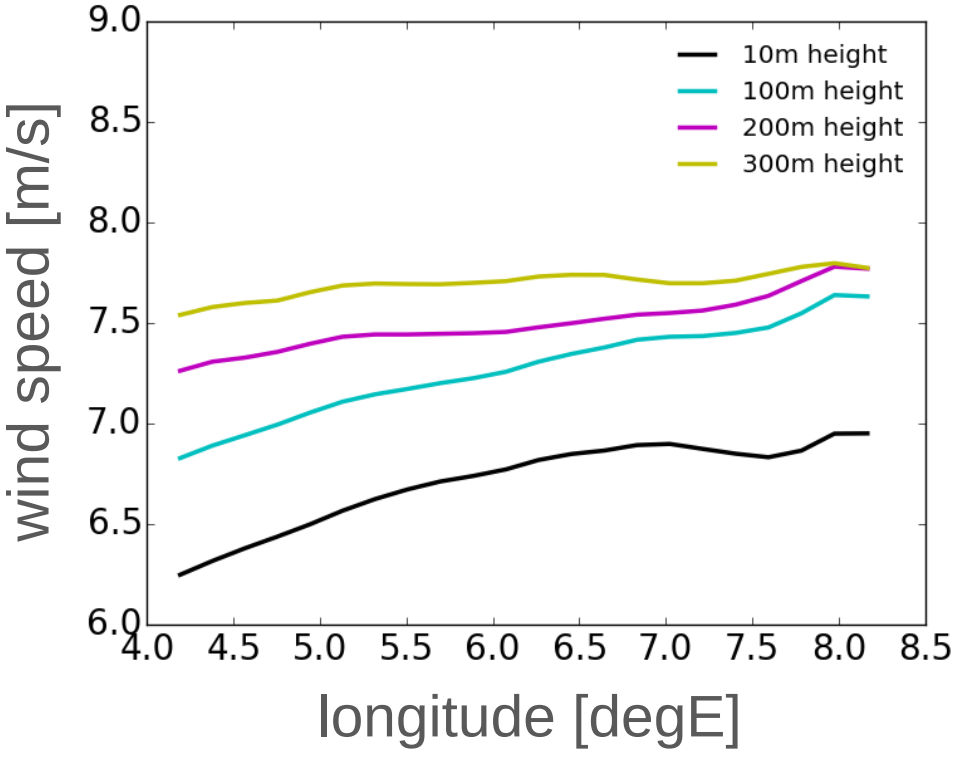
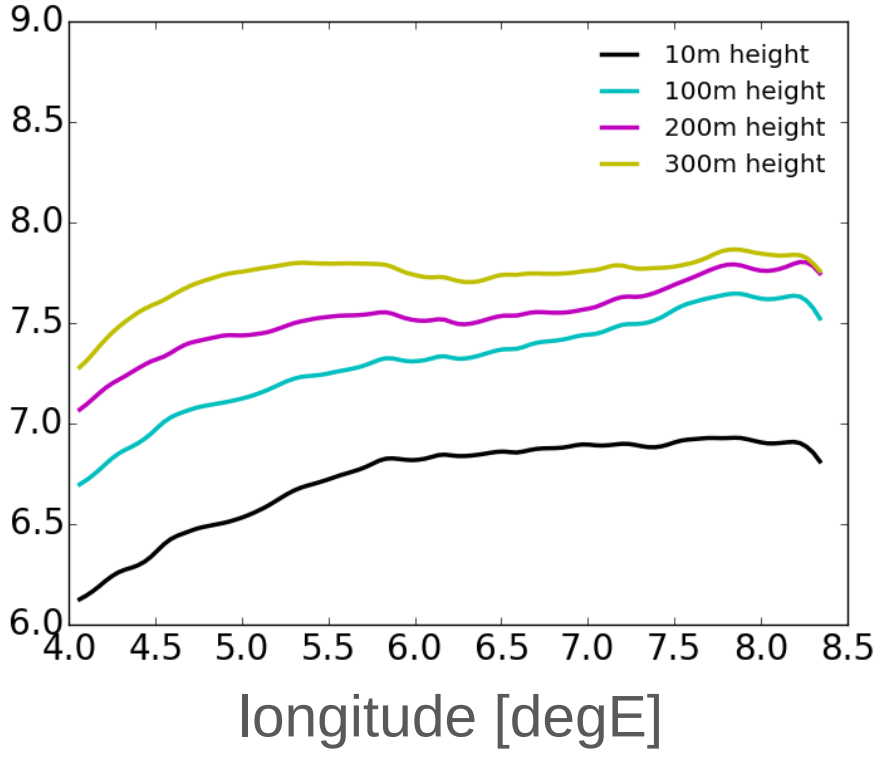
First results

- Longitudinal transect of 10min wind speed averaged over 5-day unstable atmospheric BL conditions at different height levels (online calculation)
  - Tendency for slightly enhanced variability

REMO 0.11º, 49 level



REMO-NH 0.022º



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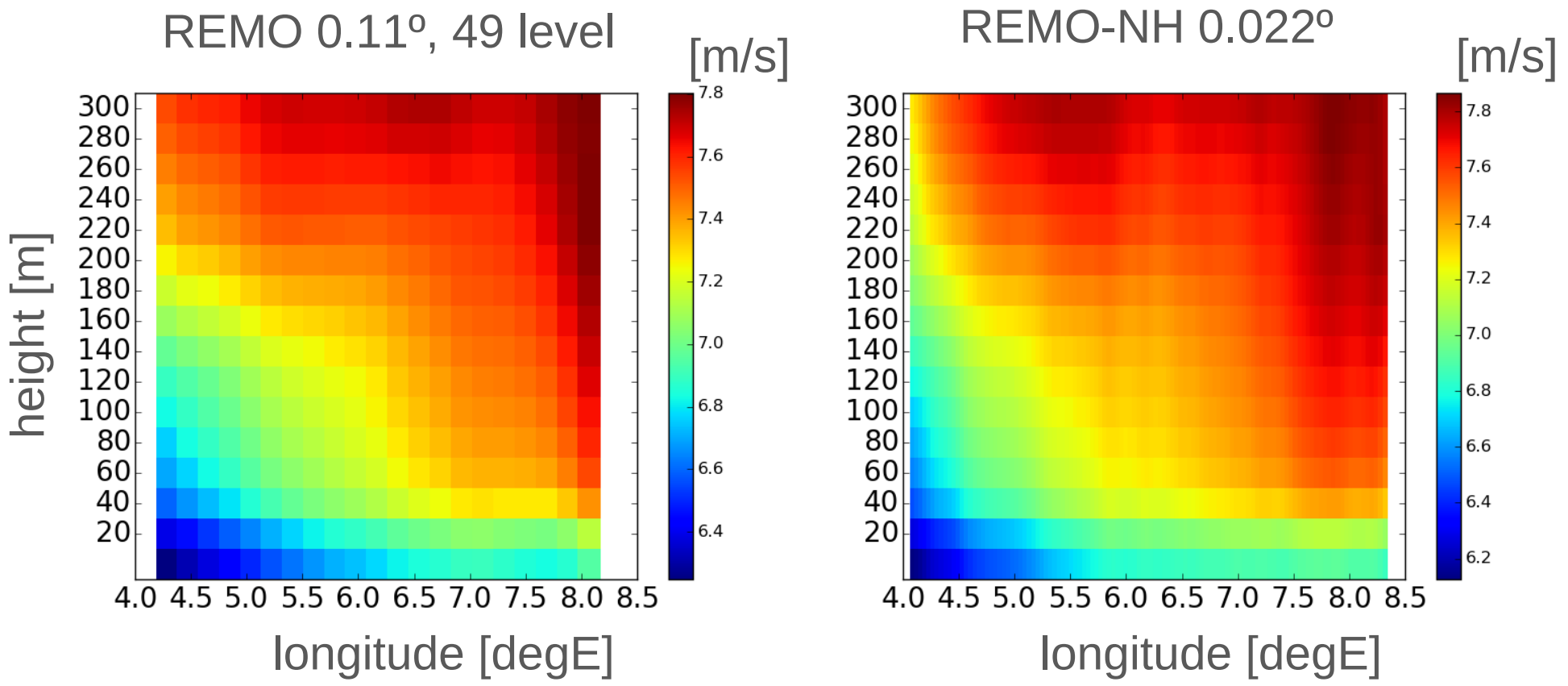

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Concluding remarks

- **Mitigation strategies** addressing energy sector **go along with adaptation strategies** to climate change due to planning and operational horizons
- Consideration of **impacts related to climate change** as **additional influencing factor on project financing** in wind energy sector
- Yield through **wind climate is the essential component** within project financing exposed to climate change
- Consideration of sector-specific framework to achieve **sector-specific climate information**
- **Convection-permitting simulations** to analyse climate change on process level

Outlook

- **Extended validation** of sensitivity study to test overall performance and limits in simulating atmospheric BL conditions and wind characteristics

- **Long-term climate climate change simulations**

  I. to **quantify climate-related impacts related to yield**

  II. to **identify responsible physical processes** accounting for climate related impacts

  in project financing for onshore and offshore wind energy

- Relation to (EURO-)CORDEX simulation ensemble

Thank you for your attention!

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References

- Banja, M. et al. (2013): Renewable energy progress in EU 27 (2005-2020). JRC European Commission. doi:10.2790/13181

- Blanco, M.I. (2009): The economics of wind energy. Renewable and sustainable Energy Reviews 13(6-7):1372-1382. doi:10.1016/j.rser.2008.09.004

- IEA Technology Roadmap Wind Energy (2013). International Energy Agency. (available via https://www.iea.org/publications/freepublications/publication/Wind_2013_Roadmap.pdf; last accessed 11.05.2016)

- IPCC SR (2012): Renewable Energy Sources and Climate Change Mitigation. Cambridge University Press. ISBN:978-1-107-60710-1

- Pryor, S.C. and R.J. Barthelmie (2013): Assessing the vulnerability of wind energy to climate change and extreme events. Climate Change 121:79-91. doi:10.1007/s10584-013-0889-y

References

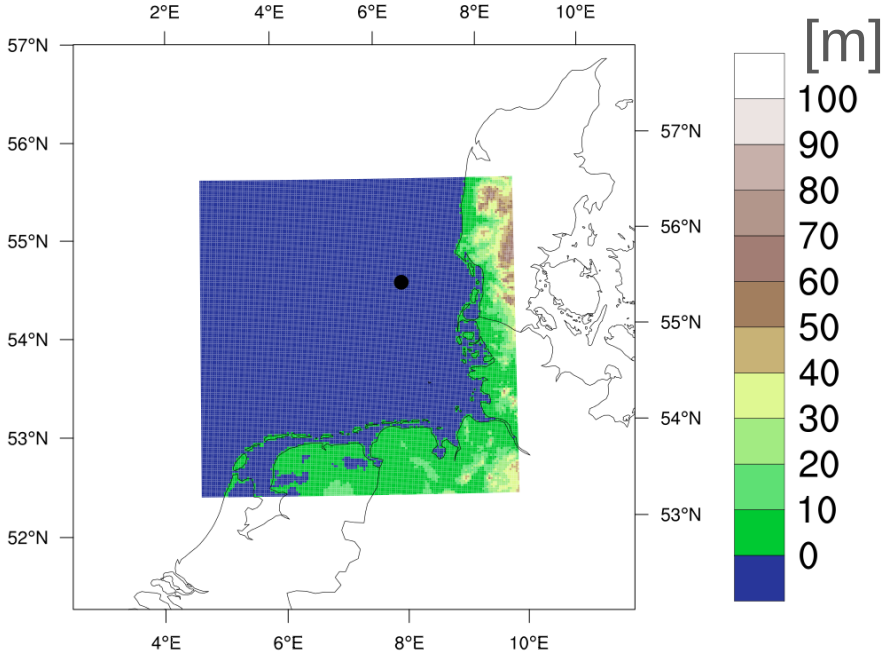
- EWEA (2009): The economics of wind energy. European Wind Energy Association Report. (available via http://www.ewea.org/fileadmin/files/library/publications/reports/Economics_of_Wind_Energy.pdf ; last accessed 16.05.2016)

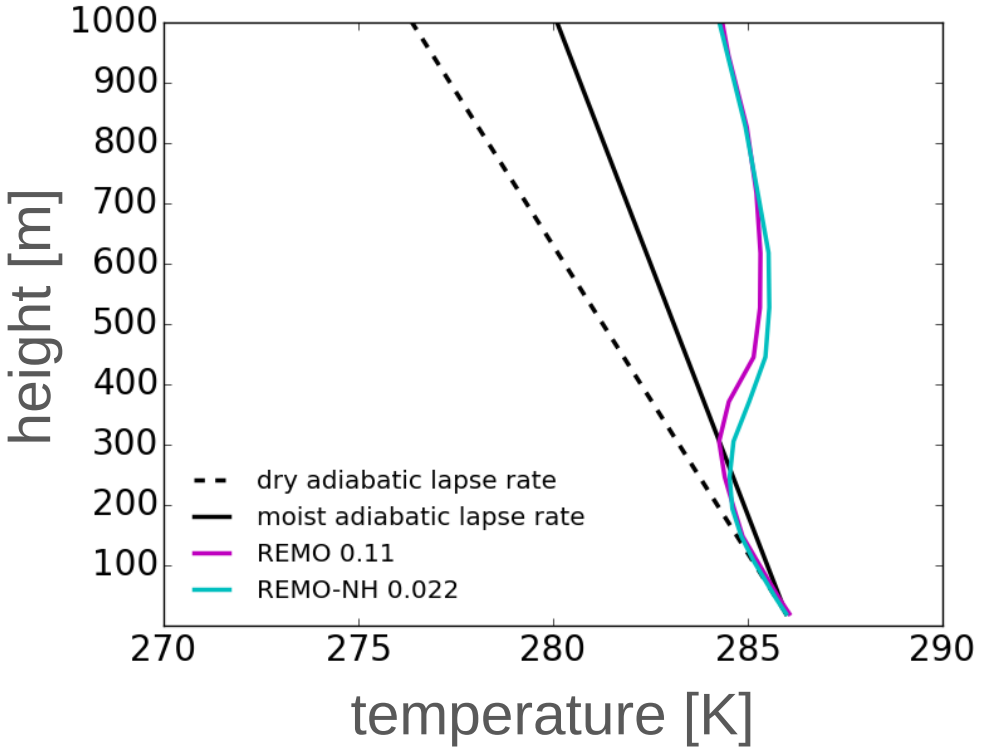
- *https://commons.wikimedia.org/wiki/File:Power_Lines.jpg* (last access 16.05.2016)

- https://en.wikipedia.org/wiki/File:Windmills_D1-D4_(Thornton_Bank).jpg (last accessed 16.05.2016)

Lapse-rate diagram

- Sensitivity study for an offshore case
  - 1-month simulation for three different simulation setups
  - Latitudinal transect through a five-day period of unstable atmospheric BL conditions





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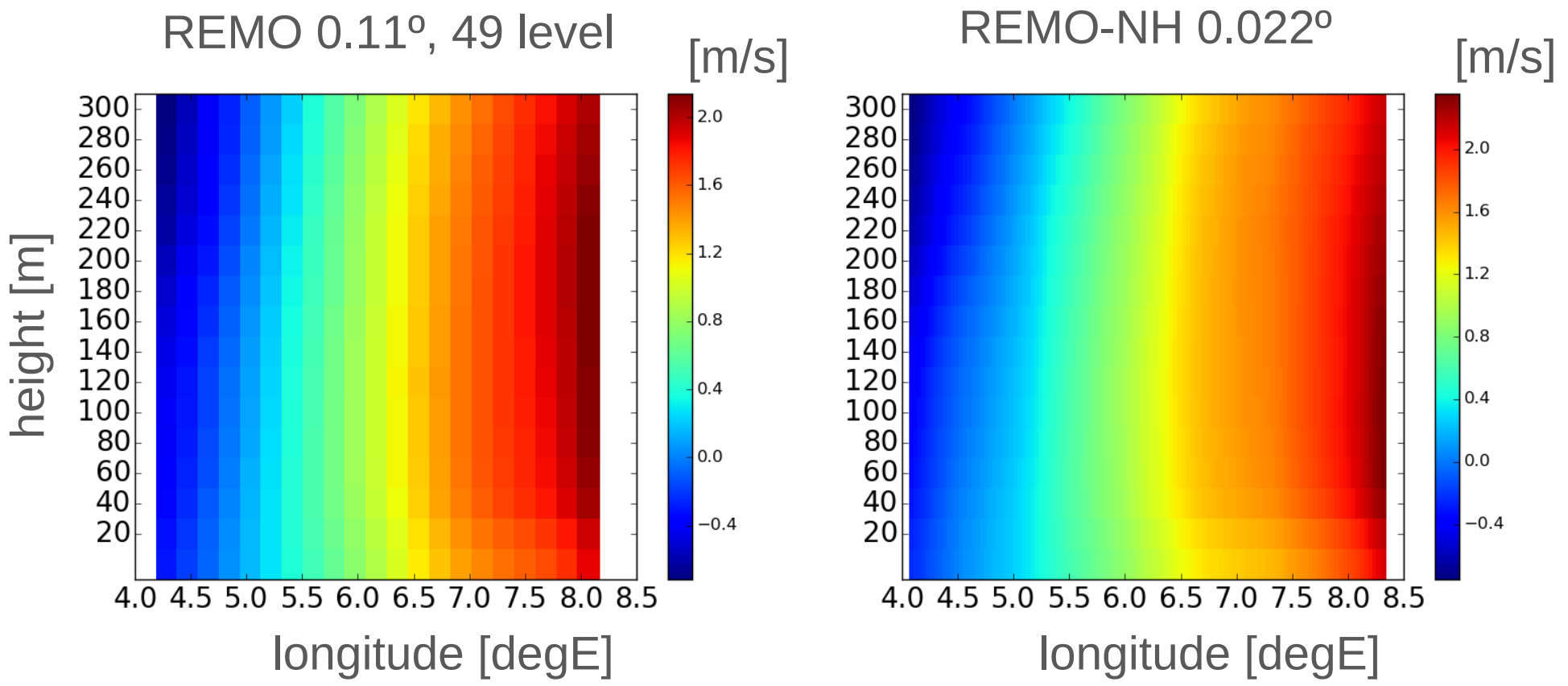
First results

- Longitudinal transect of 10min u-velocity averaged over 5-day unstable atmospheric BL conditions at different height levels (online calculation)



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First results

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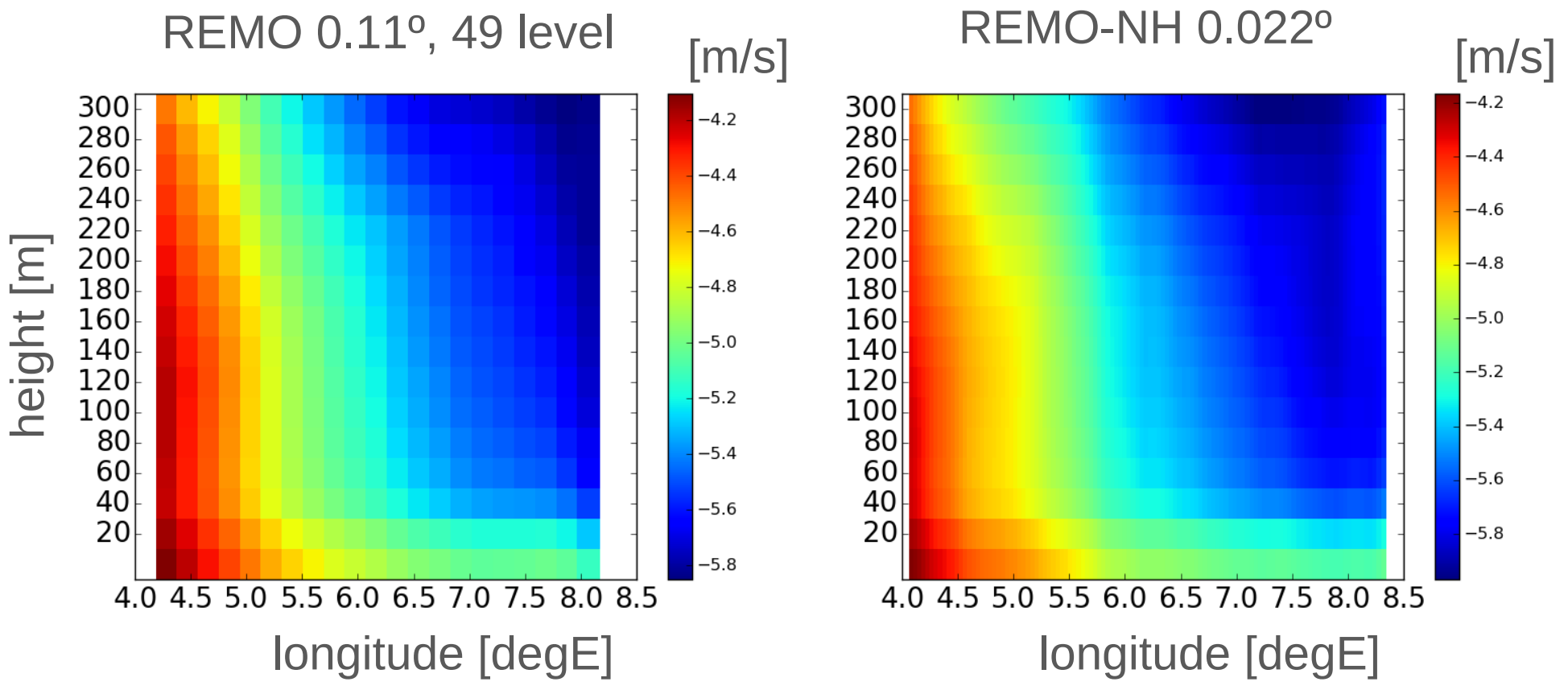

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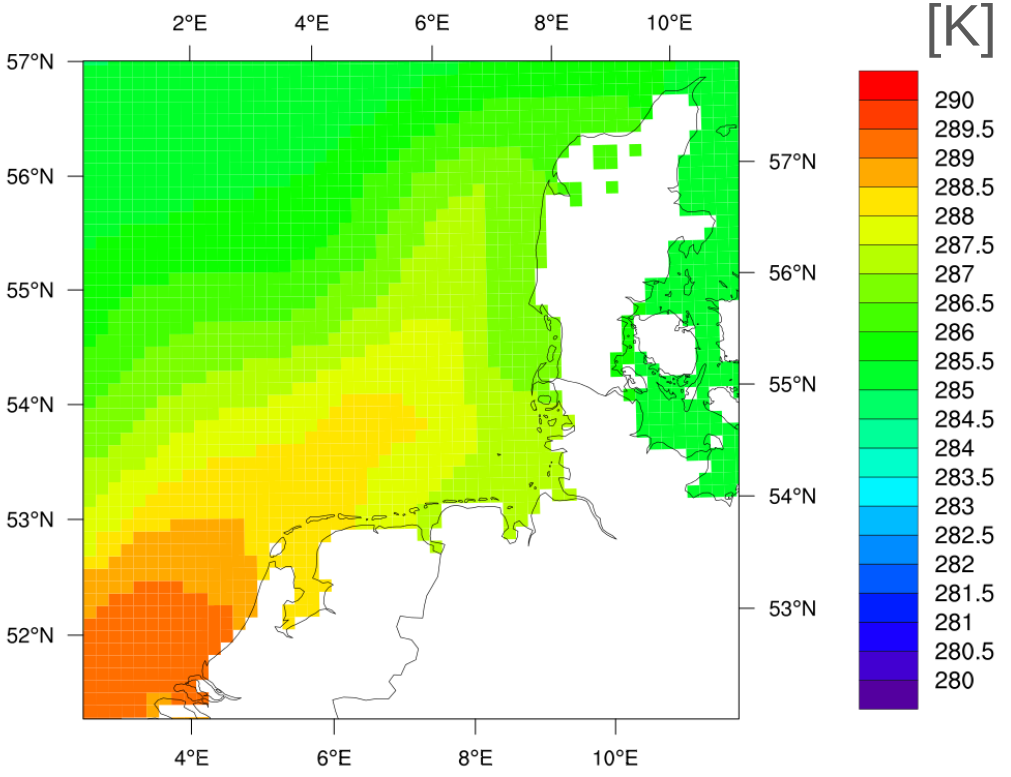
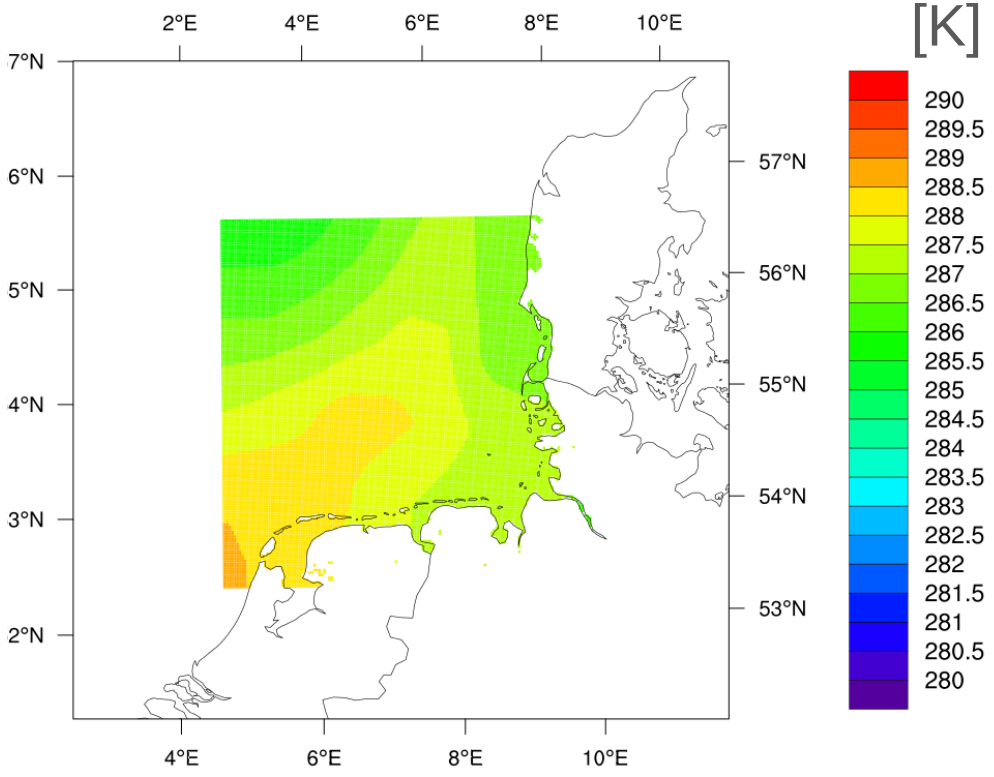
First results

- Sea surface temperature as represented by REMO and REMO-NH

REMO 0.11º, 49 level



REMO-NH 0.022º



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