Model evaluation of downscaled ERA5 time series for British and Dutch offshore sites

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Rémi Gandoin (C2Wind)

Gil Lizcano, Pau Casso and Elies Campmany (Vortex)

rga@c2wind.com; gil.lizcano@vortex.es

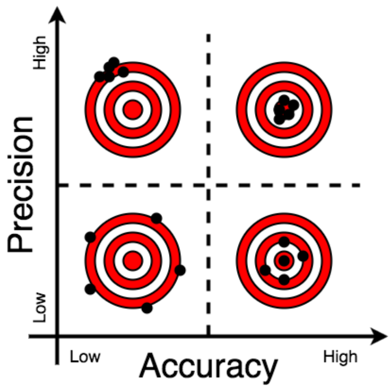
@remi_wnd; @gil_lizcano

1. Outline and problem statement

Accuracy and precision of ERA5-driven WRF time series ?

Added value in WRA/design, compared with using only ERA5 ?

Inspiration: (Sanz, 2018).



1. Introduction and problem statement.
2. Measurement- and model data.

3. Analysis results:
   a) Correlations,
   b) Spatial variations (horizontal and vertical),
   c) Wind farm power time series analysis.

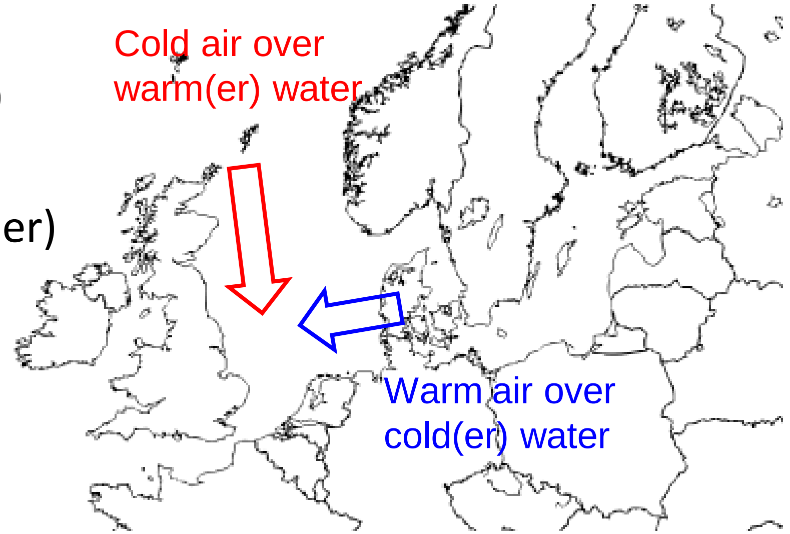
4. Key take-aways

5. References and ongoing work.

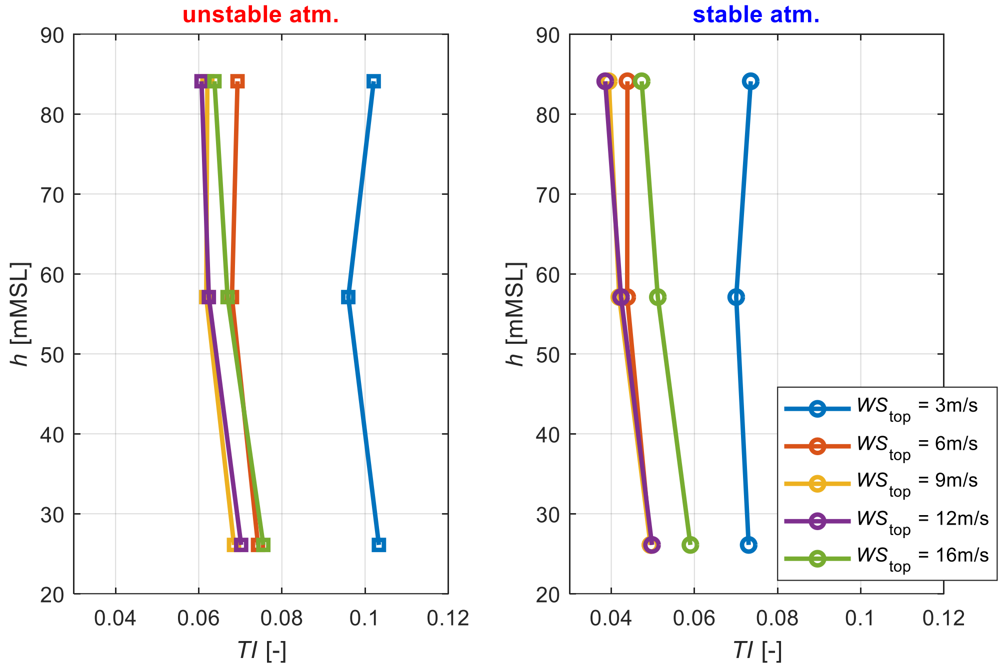
1. Stability, in this presentation:

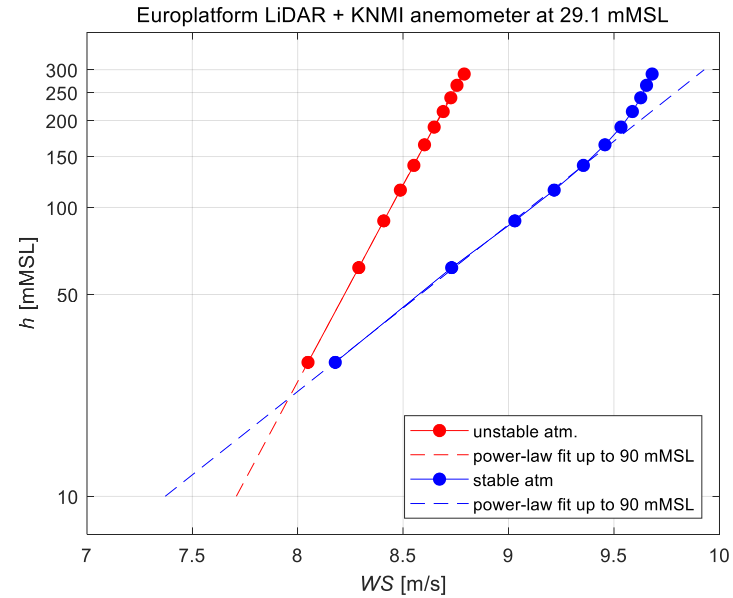
Stable: $T_{air} > T_{water}$ (small *TI*, large shear and veer)

Unstable: $T_{air} \leq T_{water}$ (large *TI*, small shear and veer)



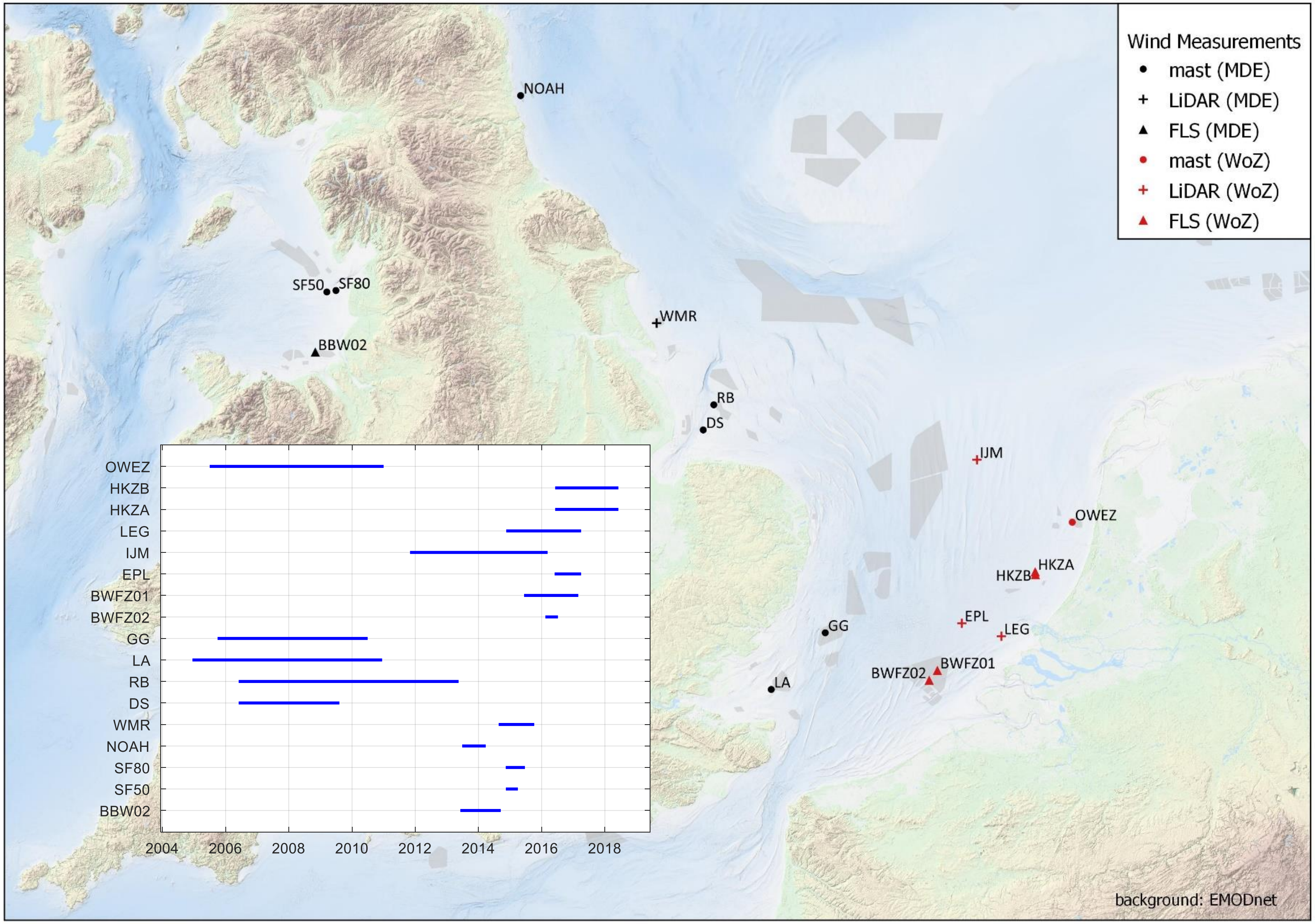
IJmuiden mast (Southern North Sea)





WES papers: (Peña, 2008) (Sanz et al., 2015)

2. Measurements



WoZ = Wind op Zee www.windopzee.net

MDE = Marine Data Exchange www.marinedataexchange.co.uk

2. Model

WRF 3.6

Driver: Copernicus ERA5

Period: 2000-2018

Resolution:

3km/ Hourly averages

12 levels below 200m above ground

Microphysics: Thompson Scheme

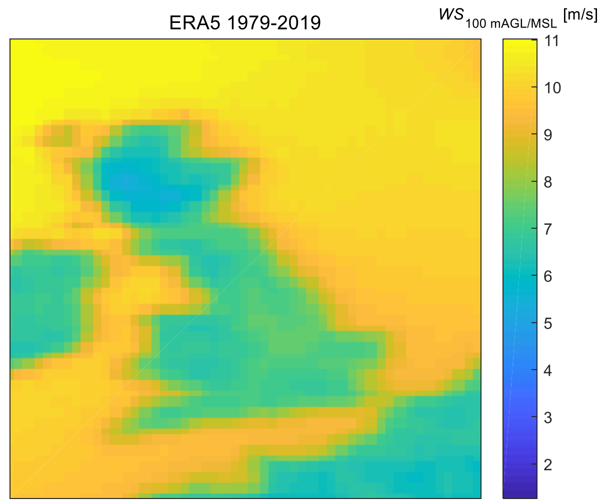
Planetary Boundary Layer (PBL) Physics: MYNN 2.5 level TKE

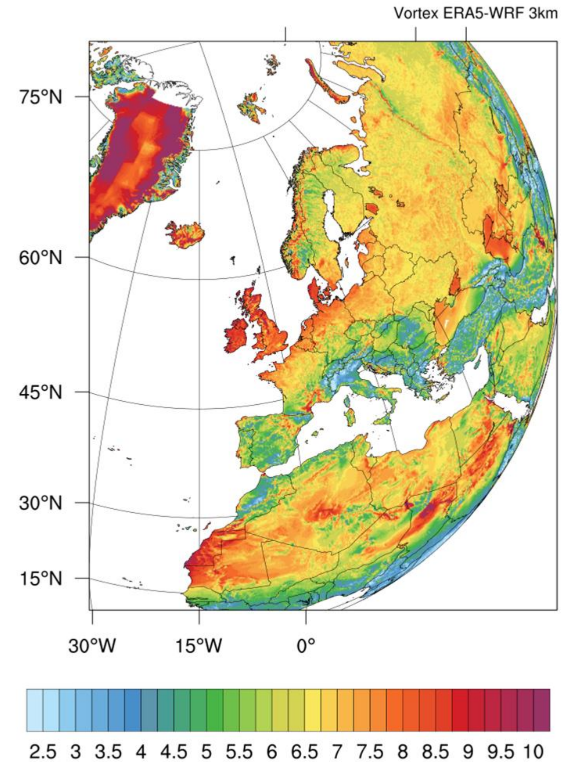
Cumulus Parameterization Options: Kain Fritsch

Shortwave and Longwave Physics: LW RRTM

Land Surface Option: 5-layer thermal diffusion

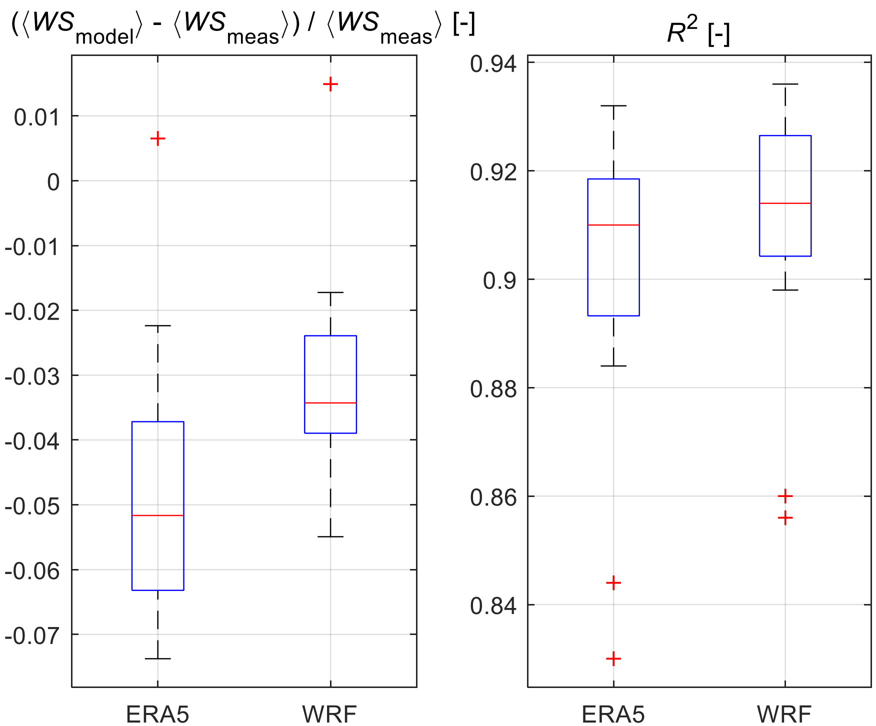
Surface Layer Options: Mellor –Yamada-Nakanishi-Niino

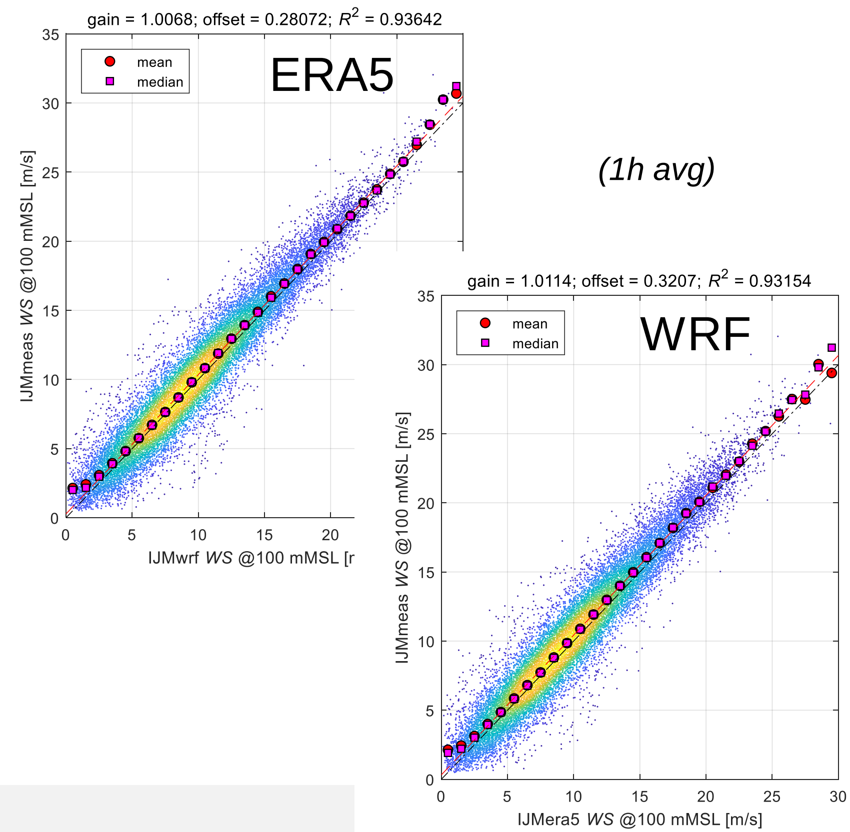




Average Wind Speed / 100m
Vortex WRF 3Km driven by ERA5

3. Correlations





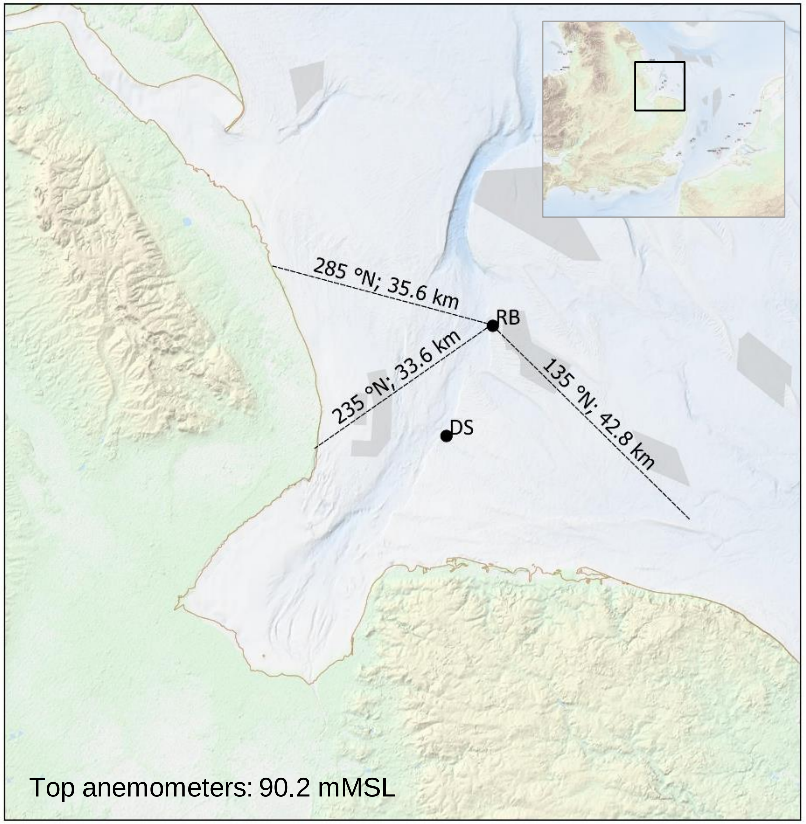
(1h avg)

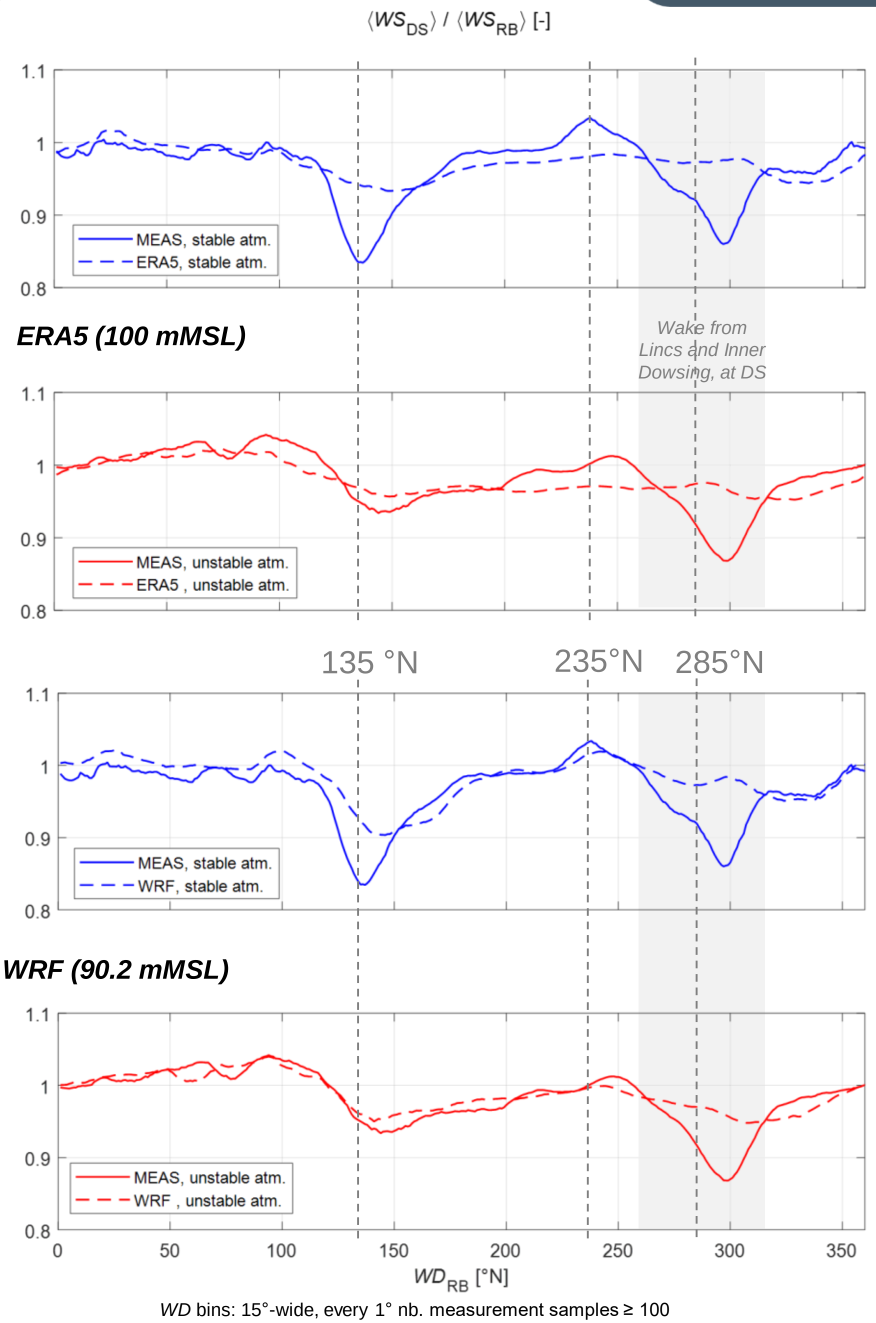
(Ramli, 2010):

- MCP uncertainty driven by:
  - Number of valid long-term time series,
  - Length of concurrency period between short-term/long-term.
- R^2 not a decisive variable for MCP uncertainty.

Using ERA5 or ERA5-driven WRF makes no discernible difference.

3. Horizontal variations (UK East)

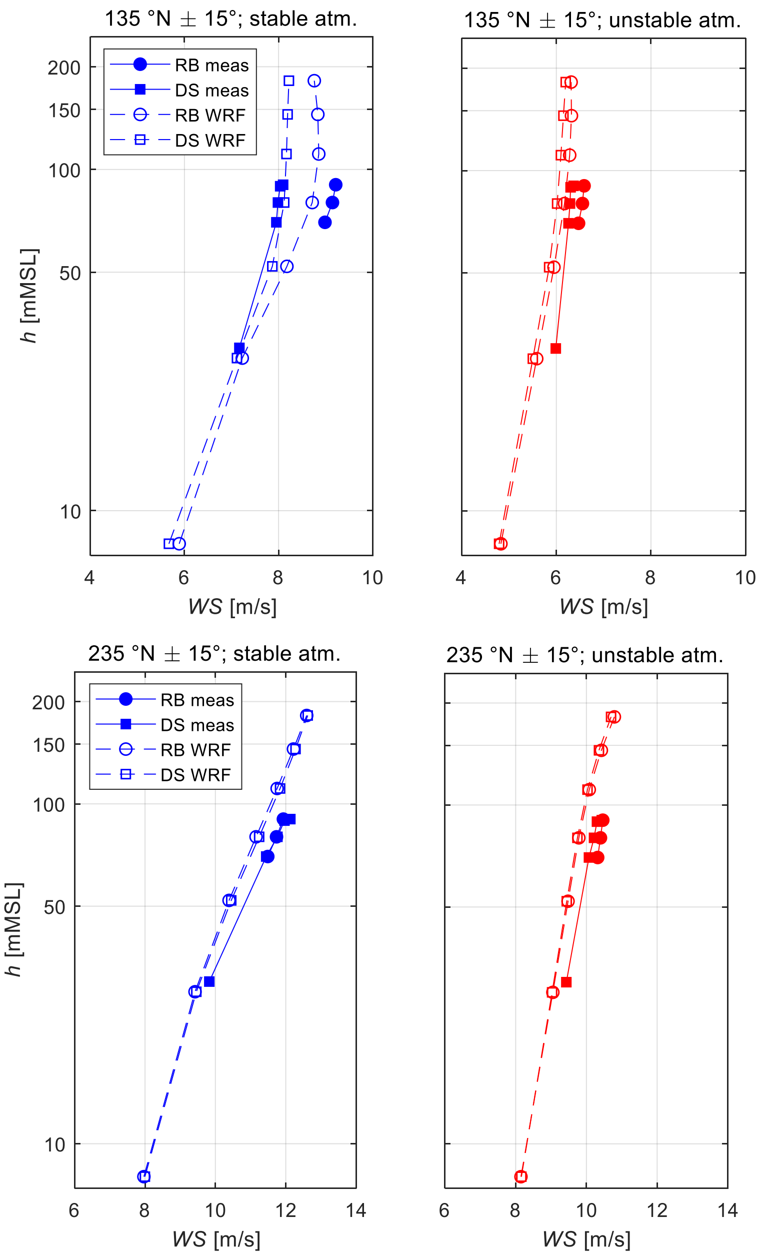


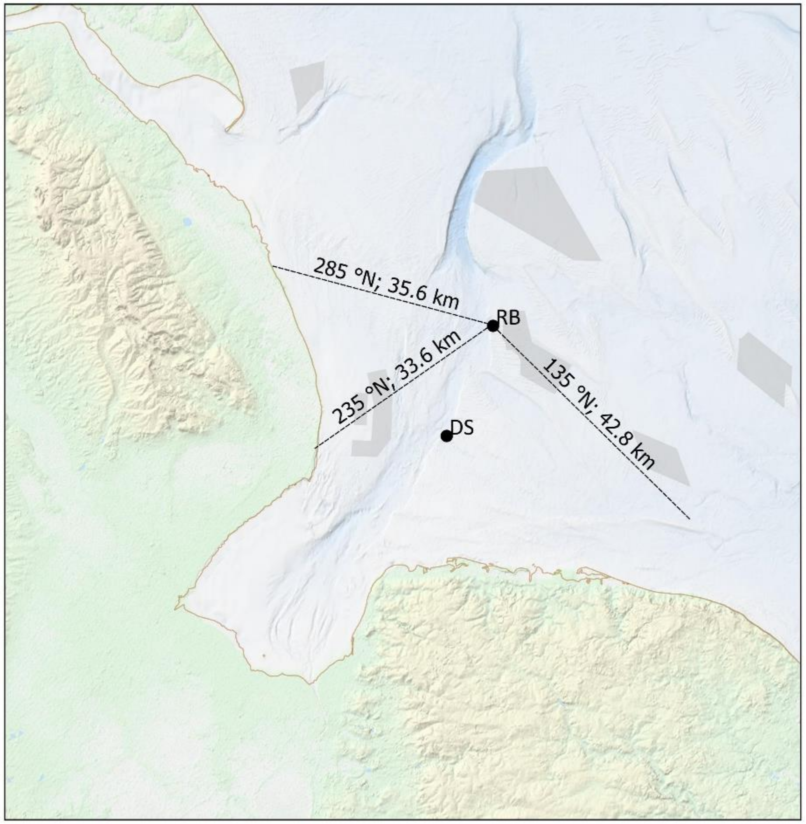


WRF performs better than ERA5, in particular in stable conditions (135°N, 235 °N), likely because:

1) it knows better than ERA5 where the coastline is,
2) it handles atmospheric stability better.

3. Vertical variations (UK East)

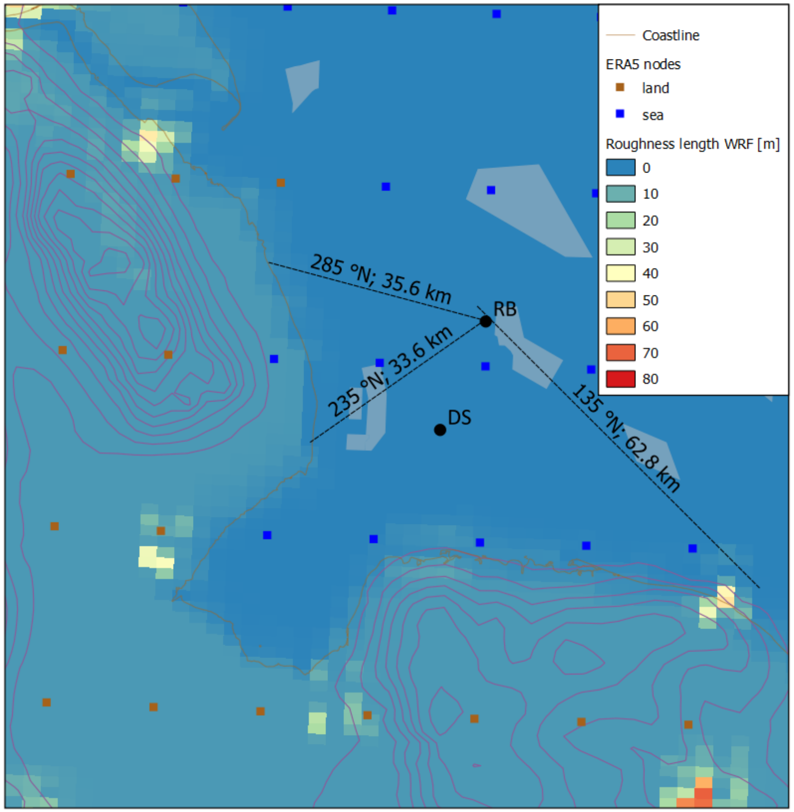




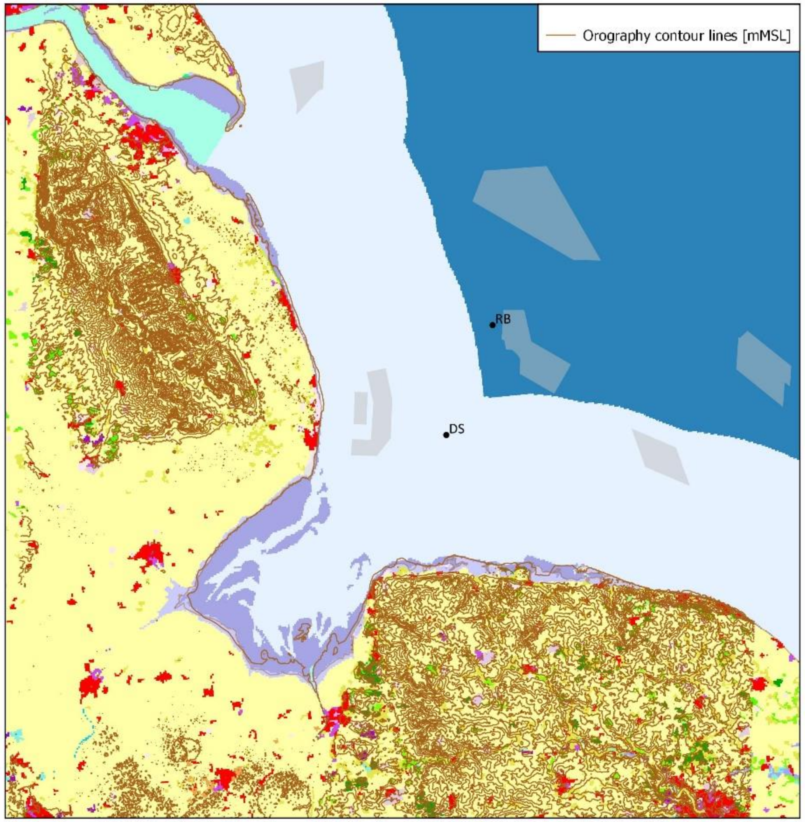
The model behaviour is better understood by considering the mean wind speed profiles.

However, met mast measurements are not high enough, and generally of poor quality due to mast disturbance, to fully characterise the profile.

3. Model inputs (UK East)



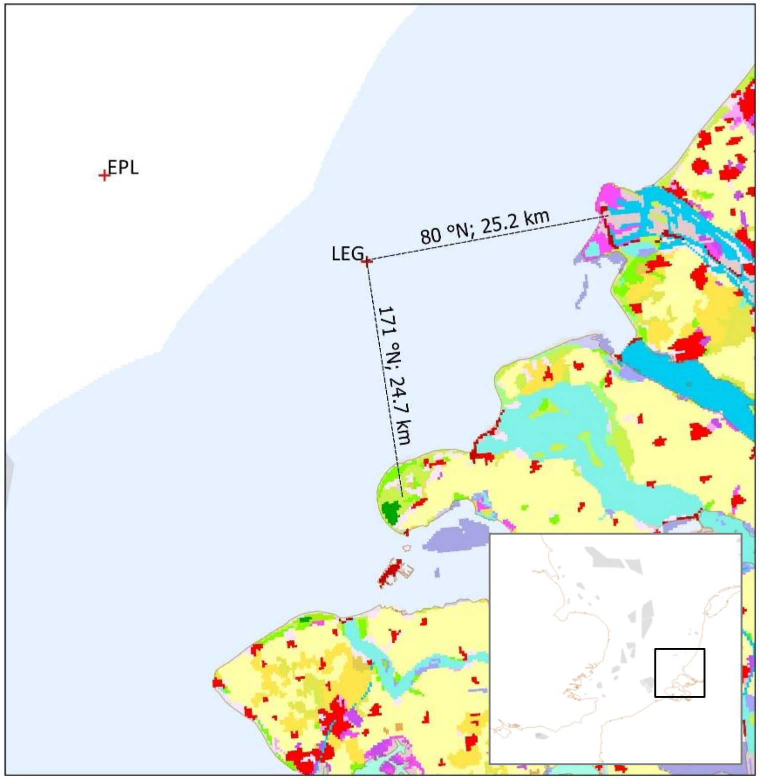
Source: WRF roughness and orography inputs.



Source: EMODnet (DTM 2018) and Corine Land Cover 2006.

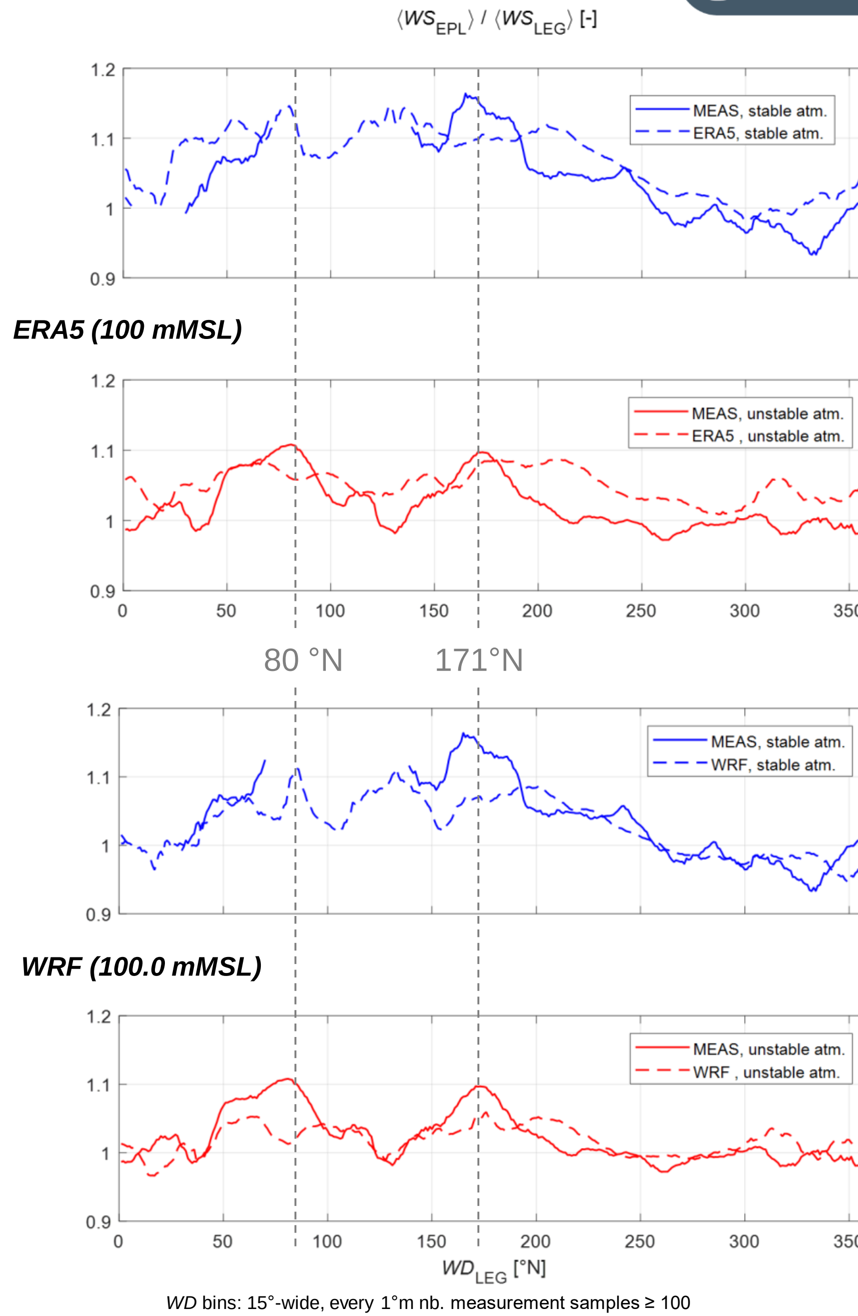
When analysing results, it is important to keep in mind how the roughness and orography inputs of WRF (and ERA5 too), compare with the reality.

3. Horizontal variations (NL)



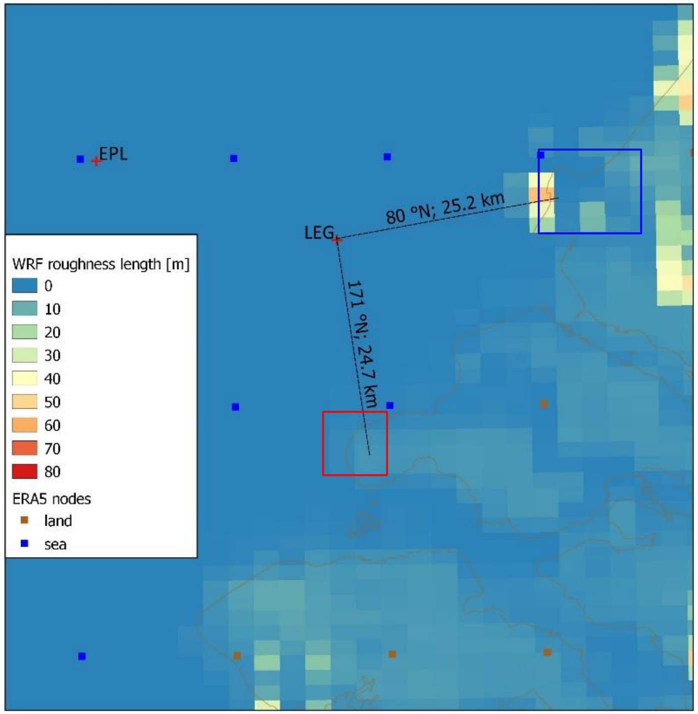
WRF compensates for the mean bias in ERA5

Largest speed ups in *WD* which do <u>*not*</u> correspond to the shortest distance to the coast -> two upstream large roughness areas seem to affect the measurements more than what the model predicts (80 and 171°N).



3. Model inputs (NL)

Source: WRF roughness and orography inputs.



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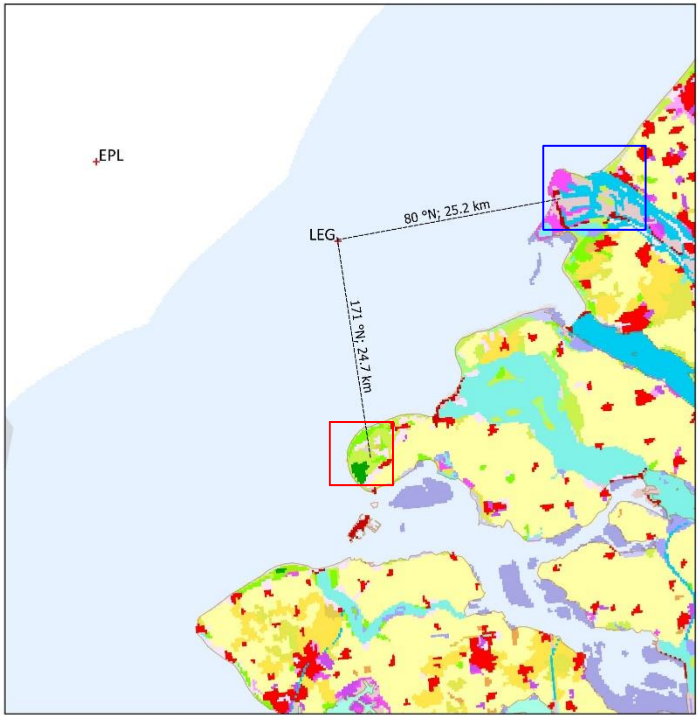
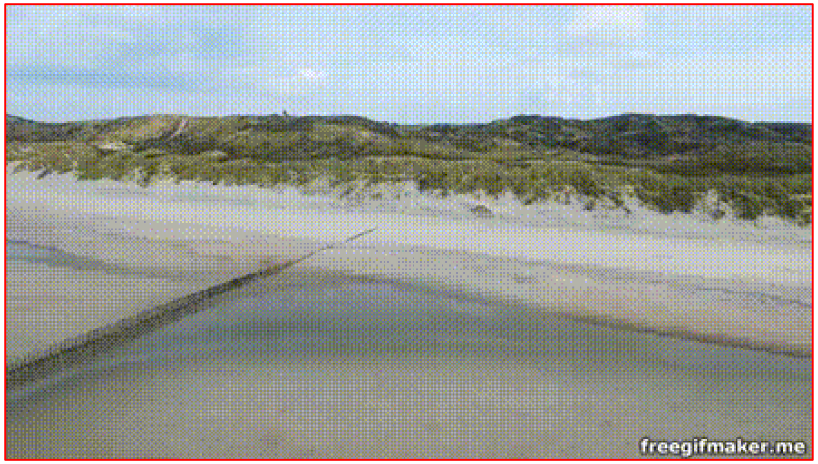
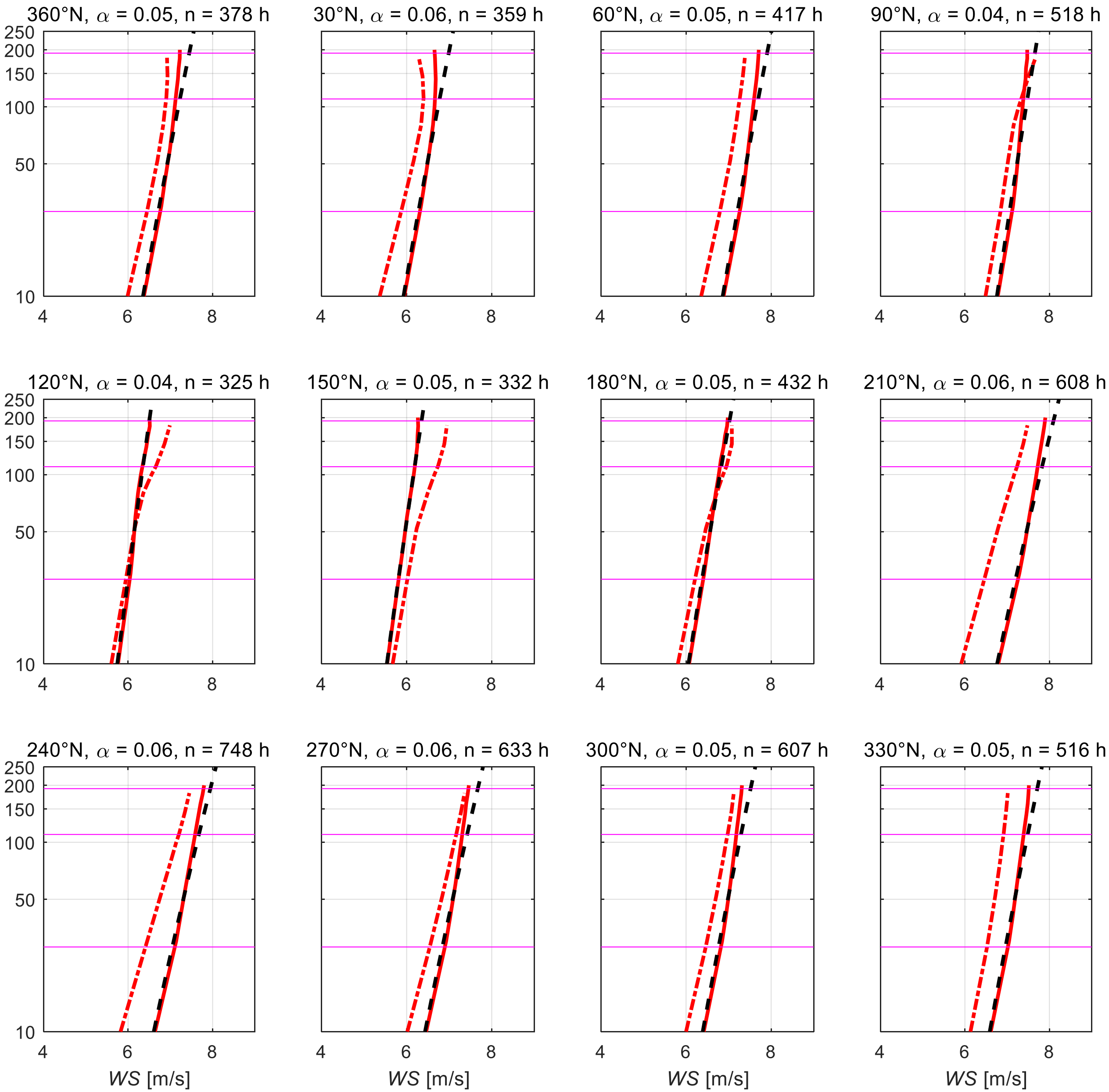




Original: https://www.youtube.com/watch?v=PqJ4BcfnP-o

Source: https://apps.sentinel-hub.com/eo-browser/?lat=51.9793&lng=4.0835&zoom=12&time=2019-04-21&preset=1_TRUE_COLOR&datasource=Sentinel-2%20L1C

3. Wind profiles (-> REWS)



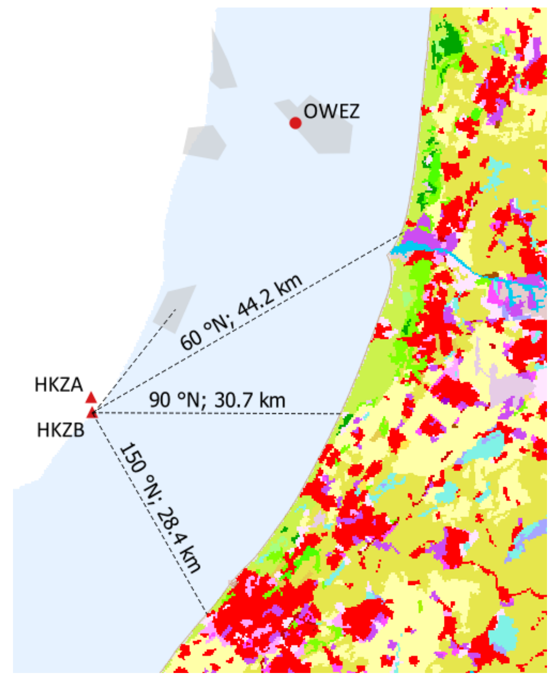
Floating LiDAR HKZB

Unstable conditions.

meas.

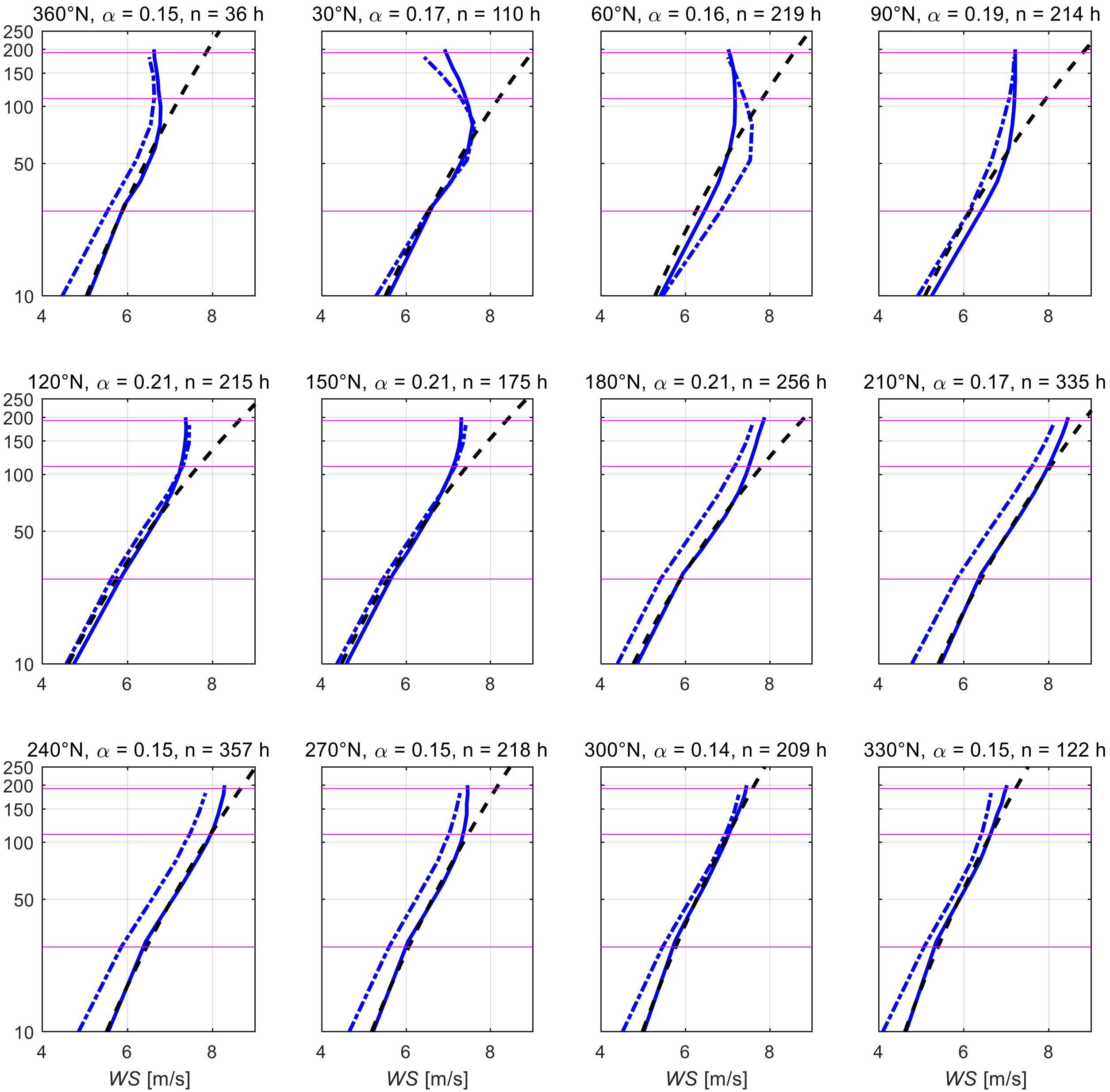
WRF

meas. fitted power-law up to 80 mMSL*



**assumed upper level of the surface layer in stable conditions.*

3. Wind profiles (-> REWS)



Floating LiDAR HKZB

Stable conditions.

- meas.
- WRF
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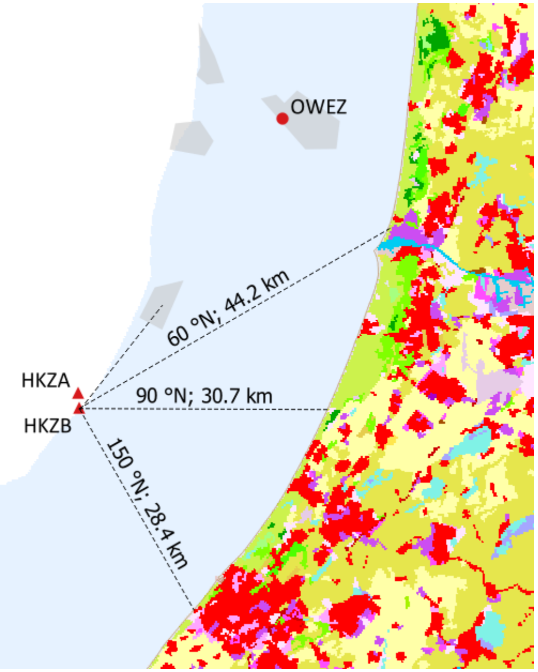


*assumed upper level of the surface layer in stable conditions.

3. Wind profiles and REWS

- Mean variations: WRF outperforms ERA5.
  - Wind speed vertical profiles well rendered and opens up for REWS studies.
  - Simple variations due to orography and distance to the coastline are well captured.
- WRF (in this setup) seems to struggle with peculiar coastal features (ex. along the Dutch coast).
- Generally, WRF and ERA5 show a negative mean bias of the wind speed profile compared with measurements.

3. Power time series analysis.

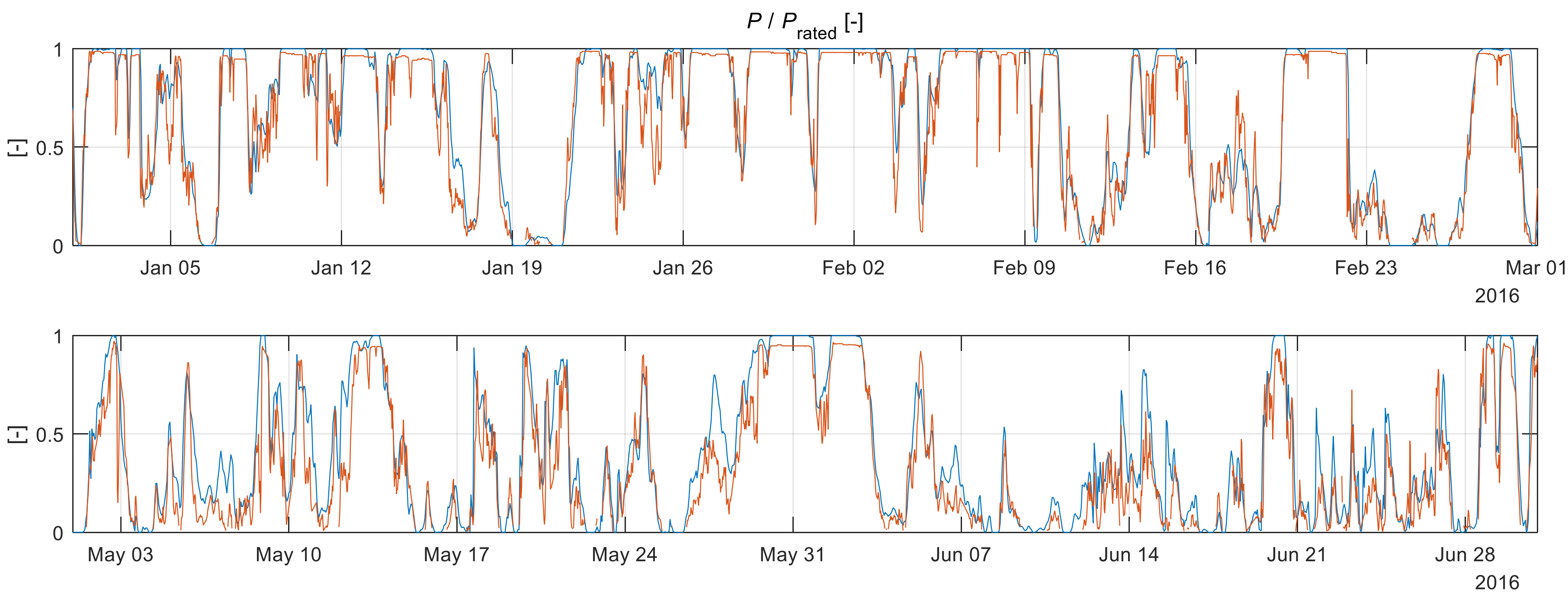
Publicly-available power time series for the UK (half-hourly): Elexon BMRS, see also (Gandoin, 2018).

For a wind farm in the Thames Estuary:

WRF time series using Park Power Curve (only incl. wakes N.O. Jensen *k*=0.04)

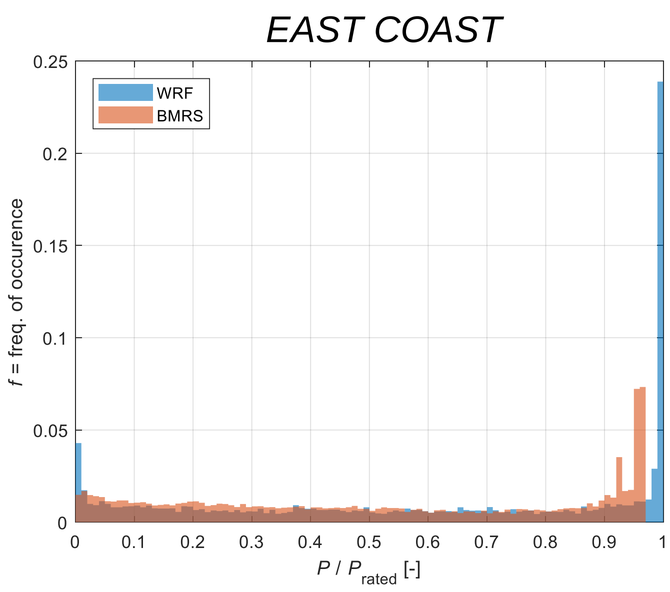
BMRS data

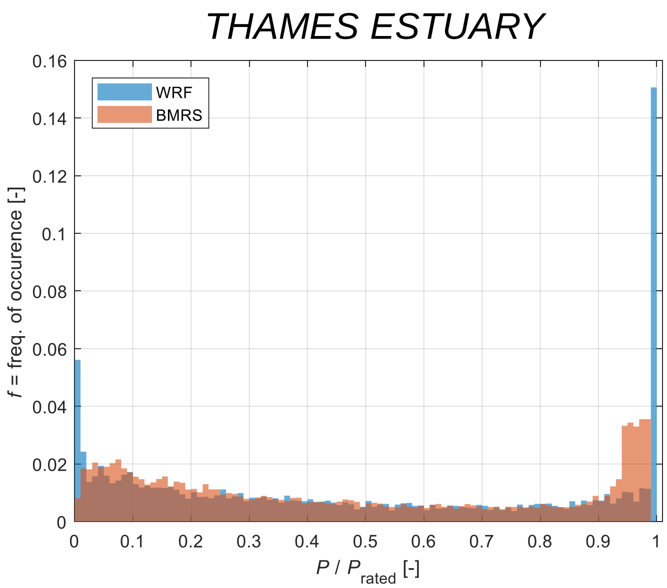
Winter- and summer 2-month periods examples below:



3. Power time series analysis.

Ex: for two parks, one year of BRMS against WRF + Park Power Curve.





AEP can be compared, and various assumptions tested:

- curtailment
- el. Losses
- WTG availability
- wakes.

Note: the location of the metering point(s) (before/after OSS) is not necessarily the same for all parks.

4. Key take aways

1) Analytical models (micro scale fluxes):
- Roughness (Charnock) + atm. stability in surface layer (Stull)
- Above the surface layer: (Peña, 2008).

2) ERA5 and other reanalysis datasets: macro-meso only.

3) WRF combines 1) + 2):
- models rather accurately the physics in the boundary layer,
- captures main coastal features.

Yet, in specific situations (combination of large roughness/complex orography and stability), WRF fail to replicate measurements.

WRF time series can also be used for analysing publicly-available 30-minute Elexon BMRS power time series and carry out re-analysis of yield studies.

4. Ongoing work + acknowledgements

- Adjusting TSA power curve for different stability classes (z/L) using IEC-12 shear and *TI* normalizations:
  1) Compute $\frac{\mathrm{REWS}}{WS_{\mathrm{hub}}}$ from WRF (or if existing: floating LiDARs),
  2) Assume *TI* from (already existing, and multiple) mast measurements.

- Developing robust methodology (i.e.: documented and replicable) on how to use WRF- and ERA5 time series for reanalysis of yield with Elexon BMRS data.

Many (many) thanks, for their excellent work, to:

- The Crown Estate and the Marine Data Exchange team,
- The Dutch Ministry of Economic Affairs, RVO and the Wind op Zee team,
- All involved in gathering these measurement data !

5. References

(Gandoin, 2018) *Using publicly available power time series for re-analysis of offshore wind park energy yield.* VindkraftNet meeting (2018-04-09). LINK.

(Peña, 2008) *Measurements and Modelling of the Wind Speed Profile in the Marine Atmospheric Boundary Layer*. Boundary-Layer Meteorology (2008-01). LINK.

(Ramli, 2010) *Uncertainty in the application of the Measure-Correlate-Predict (MCP) method in wind resource assessment*. EWEA Offshore 2011 (2011-11). LINK.

(Sanz et al, 2015) *Atmospheric stability assessment for the characterization of offshore wind conditions*. Wake Conference 2015 (2015-06) LINK.

(Sanz, 2018) *Comparing Meso-Micro Methodologies for Annual Wind Resource Assessment and Turbine Siting at Cabauw*. LINK.