Application of reanalysis datasets for calculating extreme wind climate

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Summary:

Estimation of extreme wind statistics, in this case the 50-year wind, usually requires high quality wind measurement data, preferably for over a long period (over 10 years). It is often very difficult to find suitable measurements and therefore there is a strong motivation to develop methods based on reanalysis data plus mesoscale modeling to determine extreme wind climates.

Two methods, which both use reanalysis datasets as their starting point, are described.

The first method is a selective dynamical downscaling methodology, whereby storm episodes are simulated in the mesoscale model WRF. The second method is based on a statistical-dynamical downscaling methodology, whereby large scale wind maximum characteristics determined for an area of interest and the mesoscale model KAMM is used.

The selective dynamical downscaling consists of three steps: identifying of storms for a particular area of interest, downscaling of the storms using the mesoscale modeling (WRF) and post-processing. The post-processing generalizes the winds from the mesoscale modeling to standard conditions, i.e. 10 m height over a flat homogeneous surface with roughness length of 5 cm. The generalized winds are then used to calculate the 50-year wind using the Annual Maximum Method for each mesoscale grid point.

The statistical-dynamical downscaling methodology is intended to be even more efficient than the selective dynamical downscaling method. For a particular area of interest, the annual maximum geostrophic wind at low levels are determined for 12 direction sectors for 30 years from reanalysis data. This results in 360 extreme geostrophic winds. Each of these geostrophic winds is used as a stationary forcing in the KAMM mesoscale model. Then for each mesoscale model grid point the Annual Maximum Method is used to calculate the 50-year wind. To cover a larger area a method is developed to account for slight variation in the extreme geostrophic winds with location.

The generalization of the mesoscale winds through the post-processing provides a basis for data validation. Measurement derived extreme wind climates are generalized in the same way to give the extreme wind for the same conditions (i.e. over a flat homogeneous surface with roughness length of 5 cm). Thus the local effects of a measurement site's surface roughness length changes and orography can be removed (consider how extreme wind may be modified by orographic speed up at a hill top measurement site).

The generalization method also allows mesoscale model derived extreme wind statistics to be further downscaled through microscale modeling to determine local extreme wind climate at specific places. In this process microscale models are used to calculate the local effects at a site, which may significantly enhance or reduce the strength of the extreme winds.

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Selective dynamical downscaling

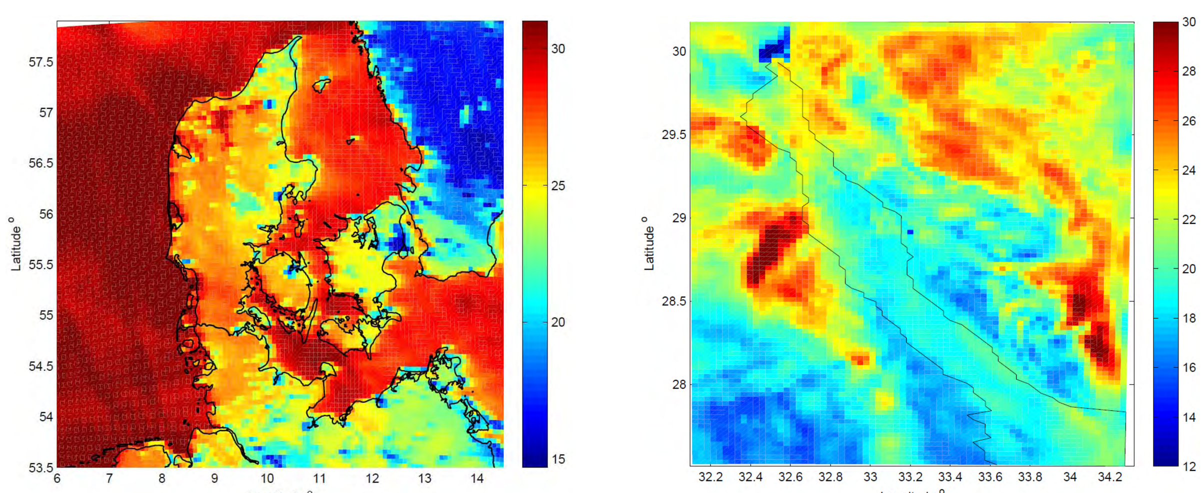
Reanalysis data:
Storms identified by NCEP/NCAR reanalysis in period 1999 - 2010
NCEP Final Analysis (FNL) used for WRF boundary conditions.

Simulations :
Simulation length 2-3 days. Yonsei University PBL scheme used. Resolution 45 – 15 – 5 km for Denmark, 27 – 9 – 3 km for Gulf of Suez. 59 storms for Denmark, 57 for Gulf of Suez.

Analysis:
The Annual Maximum Method (AMM) is used. More details of AMM can be found in Abild (1994). It is based on a Gumbel extreme wind distribution.

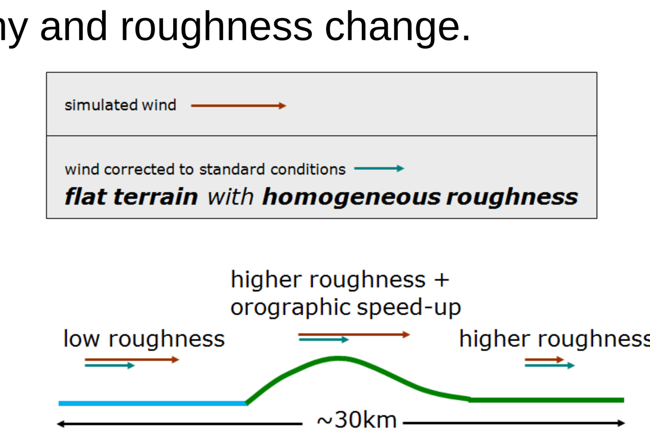
$$U_T = \alpha^{-1} \ln T + \beta, \quad \alpha = \frac{\ln 2}{2b_1 - \overline{U^{max}}}, \; \beta = \overline{U^{max}} - \frac{\gamma_E}{\alpha}$$

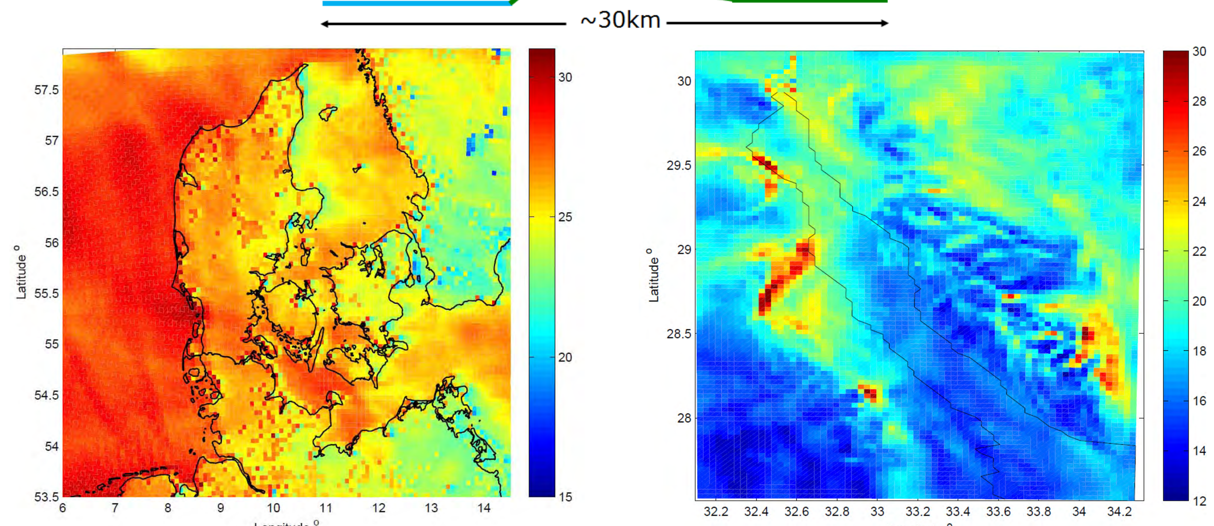
$$\gamma_E \approx 0.577216 \qquad b_1 = \frac{1}{n} \sum_{i=1}^{n} \frac{i-1}{n-1} U_i^{max}.$$



50-year wind at 10 m over Denmark (left) and Gulf of Suez (right) based on WRF simulated winds.

Post-processing:
The surface winds from the mesoscale model are generalized for flat terrain and 5 cm roughness length. This removes the 'local' effects of the mesoscale representation of orography and roughness change.





Generalized 50-year wind at 10 m over Denmark (left) and Gulf of Suez (right) based on WRF simulated winds generalized to flat terrain and 5 cm roughness length.

Verification:
The generalization of the extreme winds makes possible comparison with estimates of generalized extreme winds based on measurements.

	Stations	WRF	OBS
A	Sprogø	24.2±4.4	23.9±2.0 *
	Tystofte	25.0±5.4	25.7±2.9 *
	Kegnæs	25.8±5.5	26.3±3.8 *
	Jylex	27.4±5.4	29.1±2.9 *
	Risø	25.6±5.3	23.7 ± 4.7
	Høvsøre	29.7±5.8	29.8 ± 9.4
	Horns Rev	29.0±5.3	31.6±8.5
	FINO	27.8±4.3	30.3±7.6
B	Abu Darag	20.5±4.8	20.2±3.4
	Zafarana	19.9±4.1	19.8 ± 2.8
	El Zayt	15.5±1.9(x)	17.4±2.6

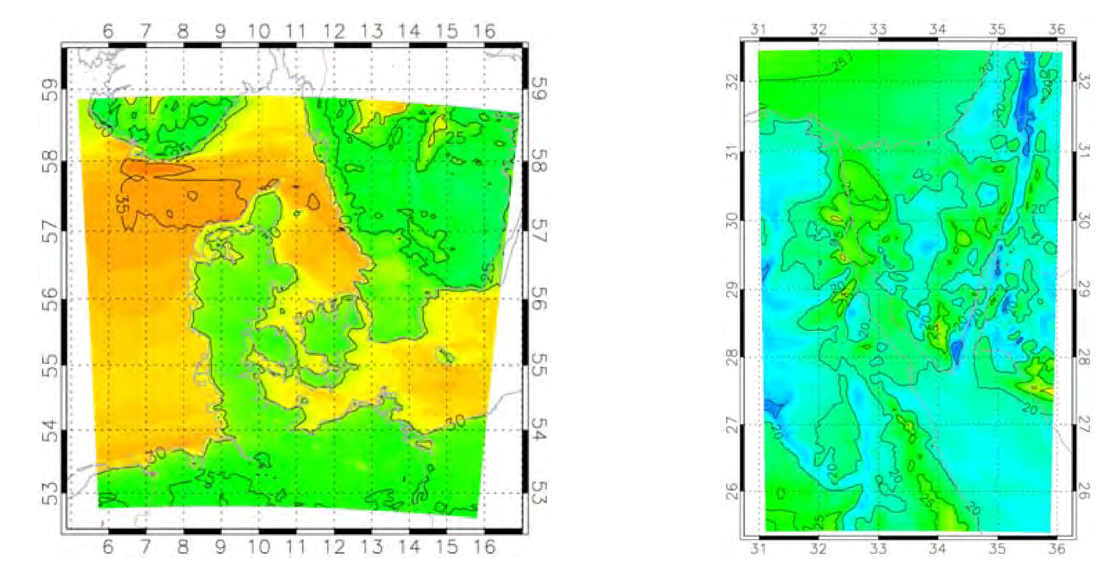
From Larsen, Badger, Hahmann, Mortensen, The selective dynamical downscaling method for extreme wind atlases, sumnitted to Wind Energy, 2012.

Statistical-dynamical downscaling

Reanalysis Data:
NCEP/NCAR reanalysis used for period 1981-2010. Geostrophic wind and virtual potential temperature profiles calculated. For each NCEP/NCAR grid point, for each year and for each 30 degree direction sector, maximum geostrophic wind identified; giving 360 annual sectorwise maximum geostrophic winds per grid point.

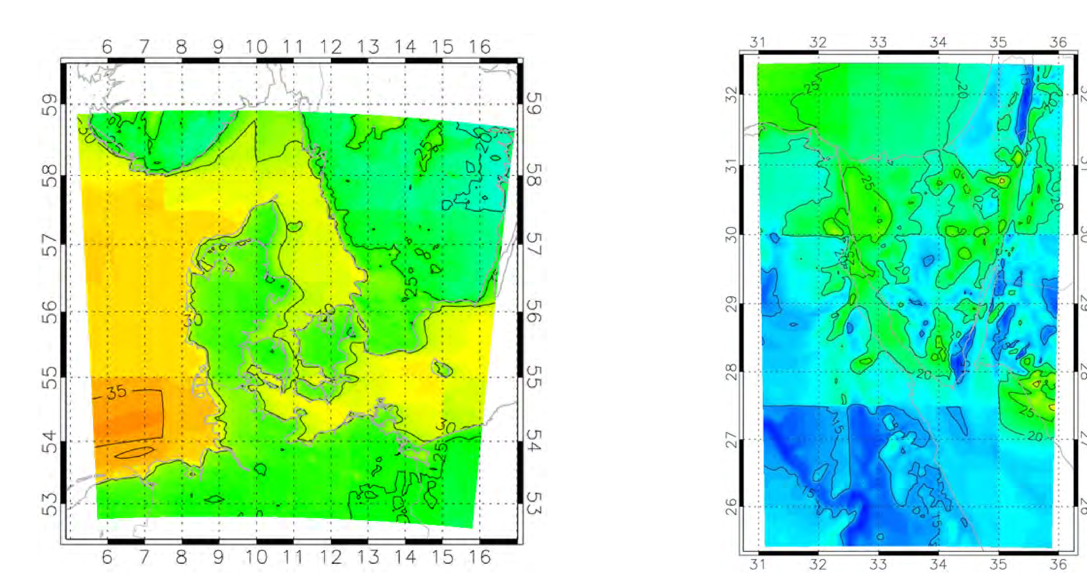
Simulations :
The most suitable NCEP/NCAR grid point's 360 annual sectorwise maximum geostrophic wind (and profiles) are used to drive the KAMM model at 5 km resolution. The result is 360 annual sectorwise maximum mesoscale wind fields.

Analysis:
The Annual Maxima Method (AMM) is used to determine 50-year extreme winds, based on the simulations.



Intermediate estimate of 50-year wind at 50 m over Denmark (left) and Gulf of Suez (right) based on KAMM simulated winds.

However, the annual sectorwise maximum geostrophic winds ought to vary over the domain. For this reason a sectorwise function is determined for the mesoscale winds given the geostrophic wind, for each mesoscale model grid point. Based on the 360 simulations. Then the nearest NCEP/NCAR grid point's annual sectorwise maximum geostrophic winds are used together with the functions to give an estimate of the annual sectorwise maximum for each mesoscale grid point.



Adjusted estimate of 50-year wind at 50 m over Denmark (left) and Gulf of Suez (right) based on WRF simulated winds generalized to flat terrain and 5 cm roughness length.

Useful references:

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