Super ensembles for wind climate assessment

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and the New European Wind Atlas (NEWA) – WP3 Mesoscale
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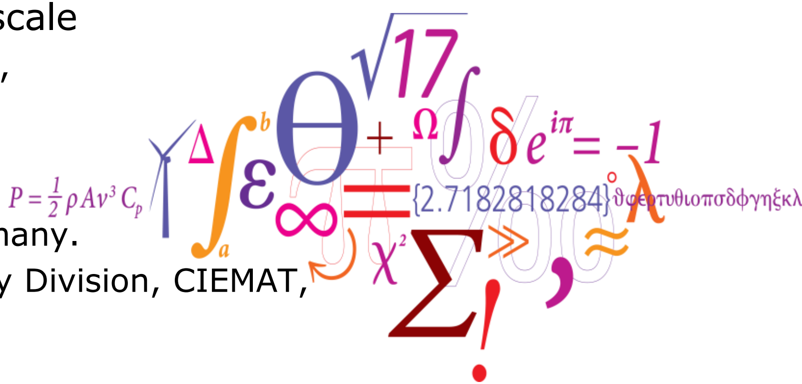
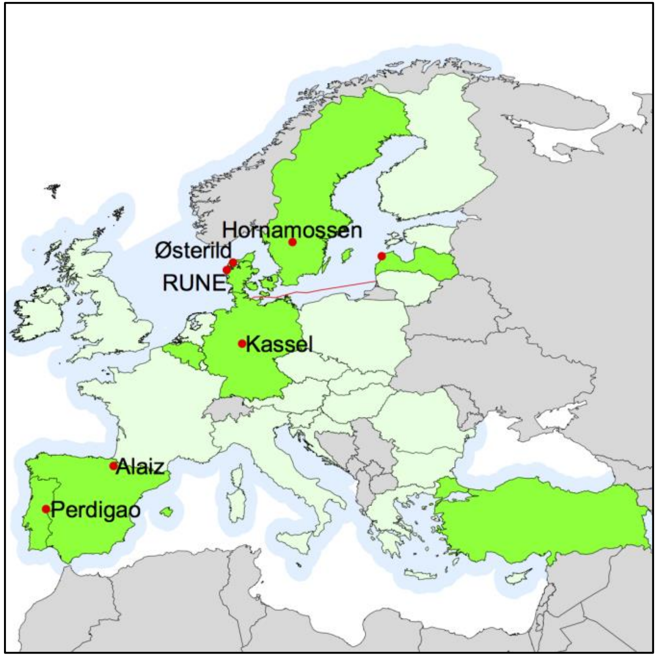


DTU Wind Energy
Department of Wind Energy

The New European Wind Atlas (NEWA) project

Objectives:

- **Accurate mapping of wind conditions for the estimation of wind resources** and loads
- **Development and testing of the "model-chain"** (global → mesoscale → microscale)
- A series of field atmospheric experiments to validate the models and the final atlas



Green – NEWA member countries

Red – field experiments sites

http://www.neweuropeanwindatlas.eu

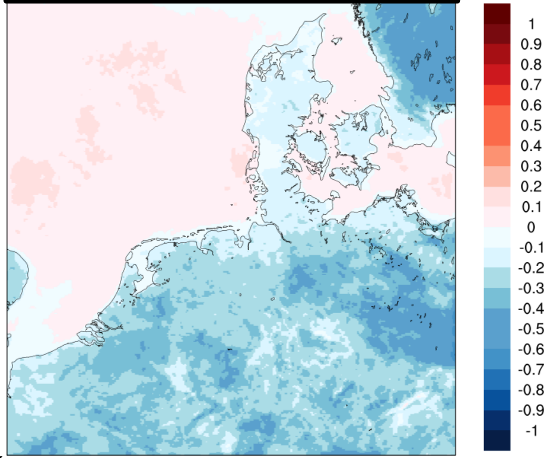
Mesoscale modelling in NEWA

As part of NEWA, mesoscale model simulations are planned to:

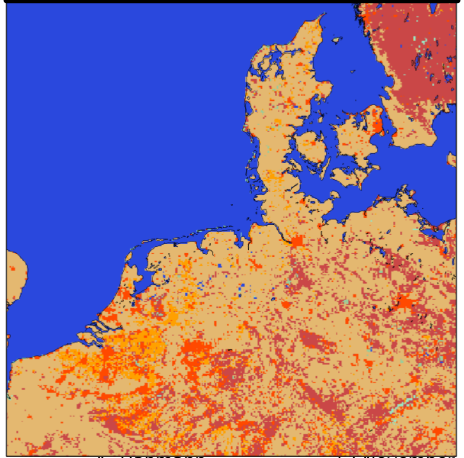
- Mesoscale simulations for the wind atlas covering all Europe for 30 years (1998-2017)
- Ensemble of mesoscale simulations to:
  - Find the best WRF setup for the production run
  - Try to quantify uncertainty in the wind atlas resulting from the choices made in the model setup.

- First set of simulations concentrated on:
  - Size and position of the domain(s) → smaller domains are most accurate
  - Are model sensitivities specific to various regions of Europe → sensitivity to PBL appear unsensitive to region

Annual mean wind speed (100 m, m/s) difference, MYNN-YSU



Surface roughness length



Various setups of the ensemble members

PBL schemes	Surface layer scheme	Land surface model	Forcing reanalysis	Sea surface temperature	Surface roughness length
MYNN	MYNN	**NOAH**	**ERA5**	**OSTIA**	**NEWA**
YSU	**MO**	RUC			
MYJ	MM5	PX LSM			
ACM2	Plein-Xue	SLAB			
		NOAH-MP			

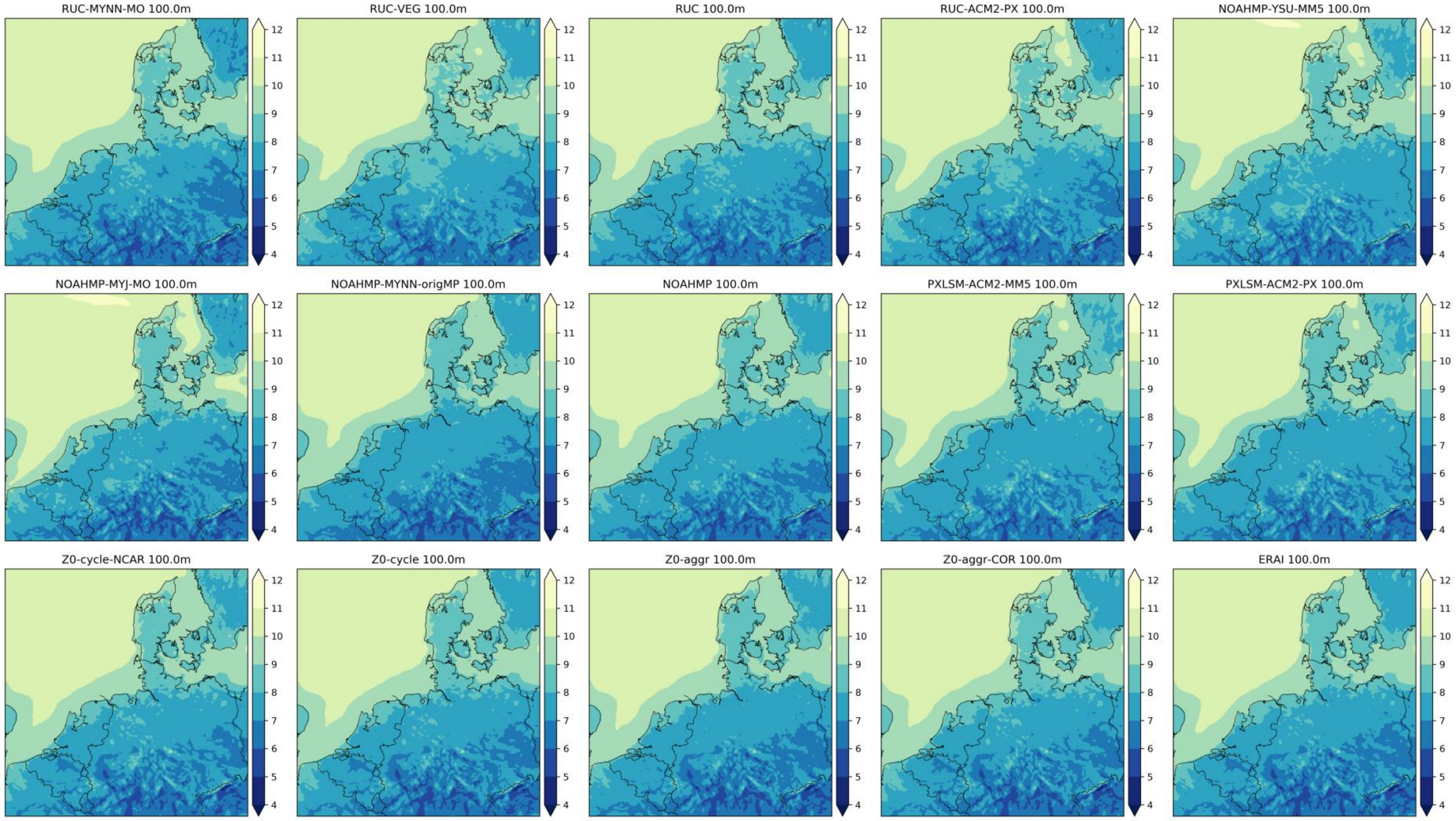
BASE run setup

Multi-parameter combinations

Not all planne

Experiment type		Nickname	Ensemble Member/Name	WRF version (6: V3.6.1, 8:V3.8.1)	setup	test DTU	submitted to MN4	Submitted by	MN4 run completed	All files complete (raw + post-processed)	Data transferred	Run cleaned	Forcing (E: ERA5, I:ERA-Interim, M:MERRA2, C:CFSR2, F:FNL)	SST/sea-ice (S: OSTIA, H: HRSST, O: OISST)	Surface roughness (1: constant, 2: annual cycle, 3: aggregated, 4: agg+mod table)	Land IC (E: ERA5, I:ERA-Interim, G: GLDAS, M:MERRA2, C:CFSR2, F:FNL)	Land surface model (WRF notation)	PBL/surface layer (WRF notation)	surface layer (WRF notation)
Sensitivity experiments	0	base	EES81_2551040004	3.8.1	☑	☑	☐	MD	☑	☑	☑	☑	ERA5	OSTIA	constant Z0	ERA5	NOAH	MYNN*	MYNN*
	1	xw_36_yw_36	EES81_2551040004_A	3.8.1	☑	☑	☑	EG	☑	☑	☑	☑	ERA5	OSTIA	constant Z0	ERA5	NOAH	MYNN*	MYNN*
	2	large_relax	EES81_2551040004_B	3.8.1	☑	☑	☑	EG	☑	☑	☑	☑	ERA5	OSTIA	constant Z0	ERA5	NOAH	MYNN*	MYNN*
	3	2-way-nest	EES81_2551040004_C	3.8.1	☑	☑	☑	EG	☑	☑	☑	☑	ERA5	OSTIA	constant Z0	ERA5	NOAH	MYNN*	MYNN*
	4	grid-nudging-D3	EES81_2551040004_H	3.8.1	☑	☐	☑	BW	☑	☑	☑	☑	ERA5	OSTIA	constant Z0	ERA5	NOAH	MYNN*	MYNN*
	5	grid-nudging-D1	EES81_2551040004_I	3.8.1	☑	☐	☑	BW	☑	☑	☑	☑	ERA5	OSTIA	constant Z0	ERA5	NOAH	MYNN*	MYNN*
	6	spec-nudging-D3	EES81_2551040004_J	3.8.1	☑	☐	☑	BW	☑	☑	☑	☑	ERA5	OSTIA	constant Z0	ERA5	NOAH	MYNN*	MYNN*
	7	ERAI	IIS81_2551040004	3.8.1	☑	☐	☑	MD	☑	☑	☑	☑	ERAI	OSTIA	constant Z0	ERAI	NOAH	MYNN*	MYNN*
	8	MERRA2	MMS81_2551040004	3.8.1	☑	☐	☑	MD	☑	☑	☑	☑	MERRA2	OSTIA	constant Z0	MERRA2	NOAH	MYNN*	MYNN*
	9	CFSR	CCS81_2551040004	3.8.1	☑	☑	☑	AH/FG	☐	☐	☐	☐	CFSR	OSTIA	constant Z0	CFSR	NOAH	MYNN*	MYNN*
	10	FNL	FFS81_2551040004	3.8.1	☑	☐	☑	AH	☑	☑	☐	☐	FNL	OSTIA	constant Z0	FNL	NOAH	MYNN*	MYNN*
	11	Vers-361	EES61_2550040004	3.6.1	☑	☐	☑	BW	☑	☑	☑	☑	ERA5	OSTIA	constant Z0	ERA5	NOAH	MYNN	MYNN
	12	MYNN-unmod	EES81_2550040004	3.8.1	☑	☐	☑	BW	☑	☑	☑	☑	ERA5	OSTIA	constant Z0	ERA5	NOAH	MYNN	MYNN
	13	GLDAS	EGS81_2551040004	3.8.1	☐	☐	☐		☐	☐	☐	☐	ERA5	OSTIA	constant Z0	GLDAS	NOAH	MYNN*	MYNN*
	14	Z0-cycle	EES82_2551040004	3.8.1	☑	☑	☐	AH	☑	☑	☑	☑	ERA5	OSTIA	annual cycle Z0	ERA5	NOAH	MYNN*	MYNN*
	15	Z0-cycle-NCAR	EES82_2551040004_A	3.8.1	☑	☑	☑	AH	☑	☑	☑	☑	ERA5	OSTIA	annual cycle Z0	ERA5	NOAH	MYNN*	MYNN*
	16	Z0-aggr	EES83_2551040004	3.8.1	☑	☑	☑	AH	☑	☑	☑	☑	ERA5	OSTIA	aggregated Z0	ERA5	NOAH	MYNN*	MYNN*
	17	Z0-aggr-COR	EES84_2551040004	3.8.1	☑	☑	☑	AH	☑	☑	☑	☑	ERA5	OSTIA	gregated Z0 (corin	ERA5	NOAH	MYNN*	MYNN*
	18	HRSST	EEH81_2551040004	3.8.1	☑	☐	☑	YE	☑	☑	☑	☑	ERA5	HRSST	constant Z0	ERA5	NOAH	MYNN*	MYNN*
	19	OISST	EEO81_2551040004	3.8.1	☑	☐	☑	YE	☐	☐	☐	☐	ERA5	OISST	constant Z0	ERA5	NOAH	MYNN*	MYNN*
	20	SST_ERA5	EEE81_2551040004	3.8.1	☑	☑	☑	AH	☑	☑	☑	☑	ERA5	ERA5	constant Z0	ERA5	NOAH	MYNN*	MYNN*
	21	radt_3	EES81_2551040004_D	3.8.1	☑	☑	☑	BW	☑	☑	☑	☑	ERA5	OSTIA	constant Z0	ERA5	NOAH	MYNN*	MYNN*
	22	radt_12	EES81_2551040004_E	3.8.1	☑	☑	☑	BW	☑	☑	☑	☑	ERA5	OSTIA	constant Z0	ERA5	NOAH	MYNN*	MYNN*

ANNUAL MEAN WIND SPEED (15 ensemble members)



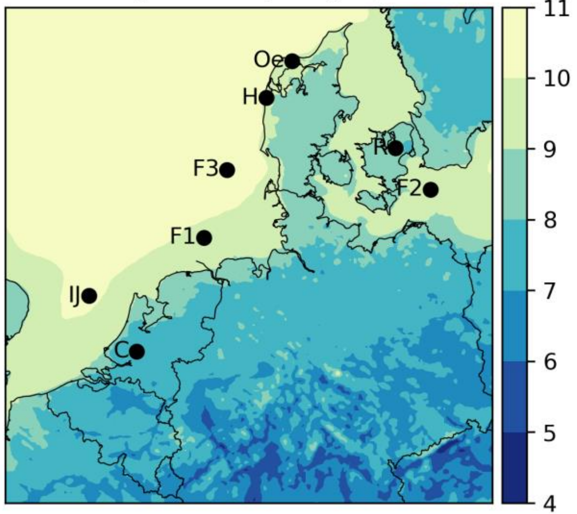
Validation against observations

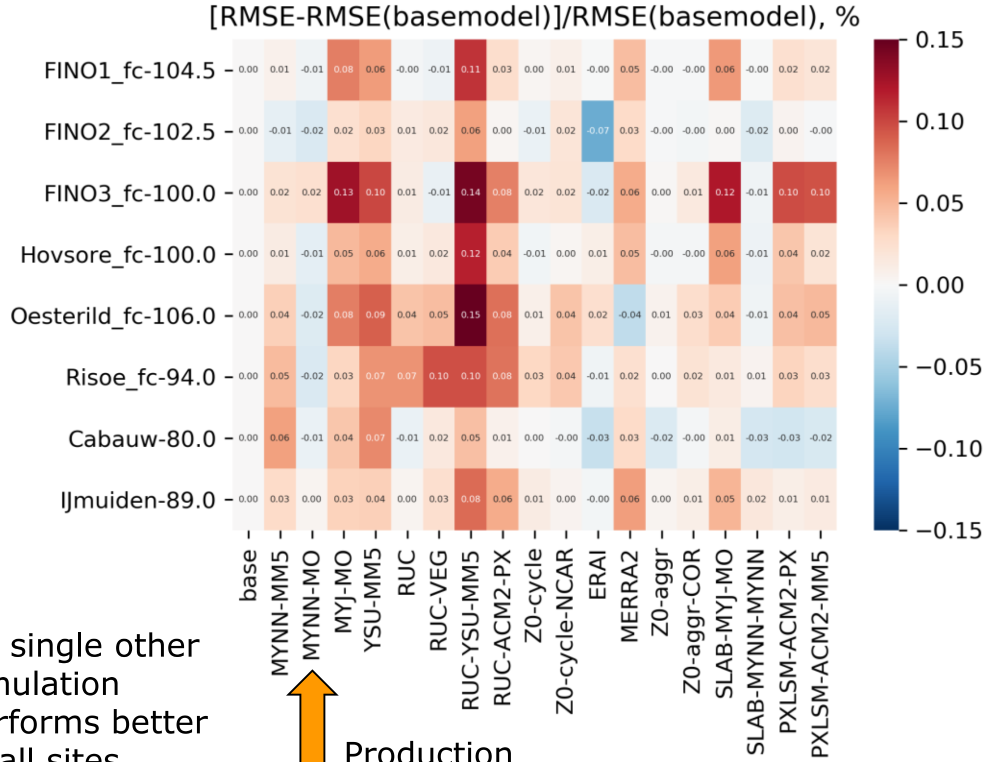
Ratio of RMSE compared to that of BASE

One full year (2015) of simulation

Comparison against observations for 8 sites offshore or over simple terrain

Annual average wind speed, m/s at 100.0m



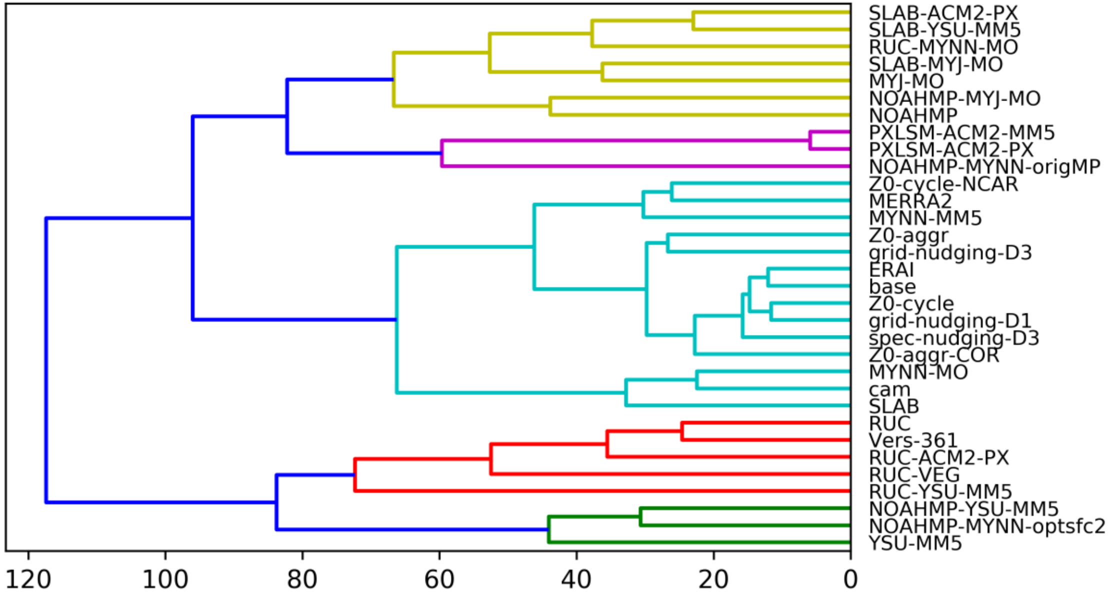


No single other simulation performs better at all sites

Production run

How to select x ensemble members that give the (best) maximum spread?

- Goal: Reduce the number of ensemble members, by throwing out those that are not very different from the base run, but still give reasonable statistics when compared to observations
- Method: hierarchical/agglomerative clustering, on mean annual wind speed at 100 m height
- Other metrics, e.g. Chi-square, EMD (Earth Mover Distance) are also being considered.

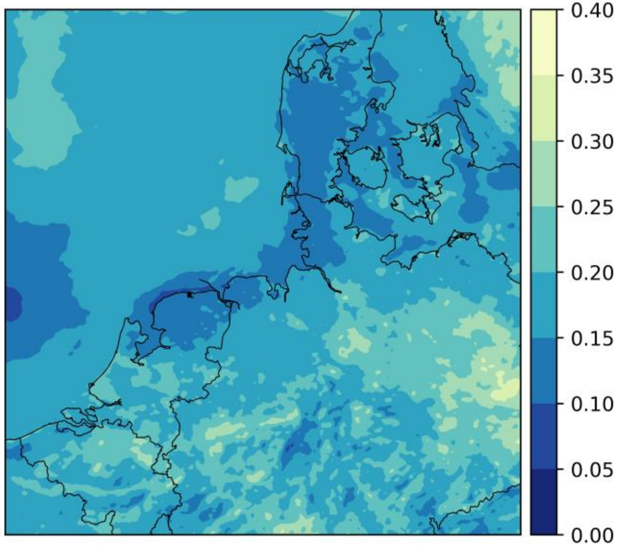


Python package:

scipy.cluster.hierarchy .linkage

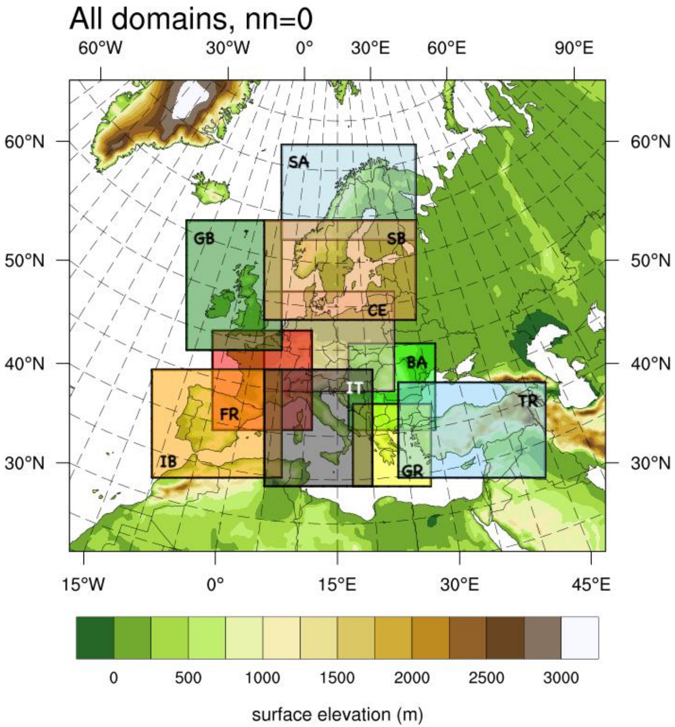
Ensemble spread

Standard deviation (m/s) of the annual mean wind speed at 100m using 5 ensemble members



- Interesting patterns
  - Low spread <u>not</u> collocated with water
  - High spread <u>not</u> collocated with high roughness (forest)
- Can this tell us anything about the uncertainty of the wind atlas?
- At least, areas of more or less confidence in the resulting wind atlas
- More high-quality observations could help clarify any additional value

The production run



NEWA WRF configuration			
27 km x 27 km common outer grid, 9 km x 9 km and final 3 km x 3 km	ERA5 reanalysis OSTIA SST	CORINE land surface Adapted roughness table	Weekly simulations overlapping by 24 hours
MYNN PBL scheme MO surface layer NOAH LSM	Ten domains run separately	Spectral grid nudging in outer domain only above PBL	One way nesting

Granted 56,70 million core hours on MareNostrum4 (Barcelona Supercomputer Center)

Production run is underway

YEAR

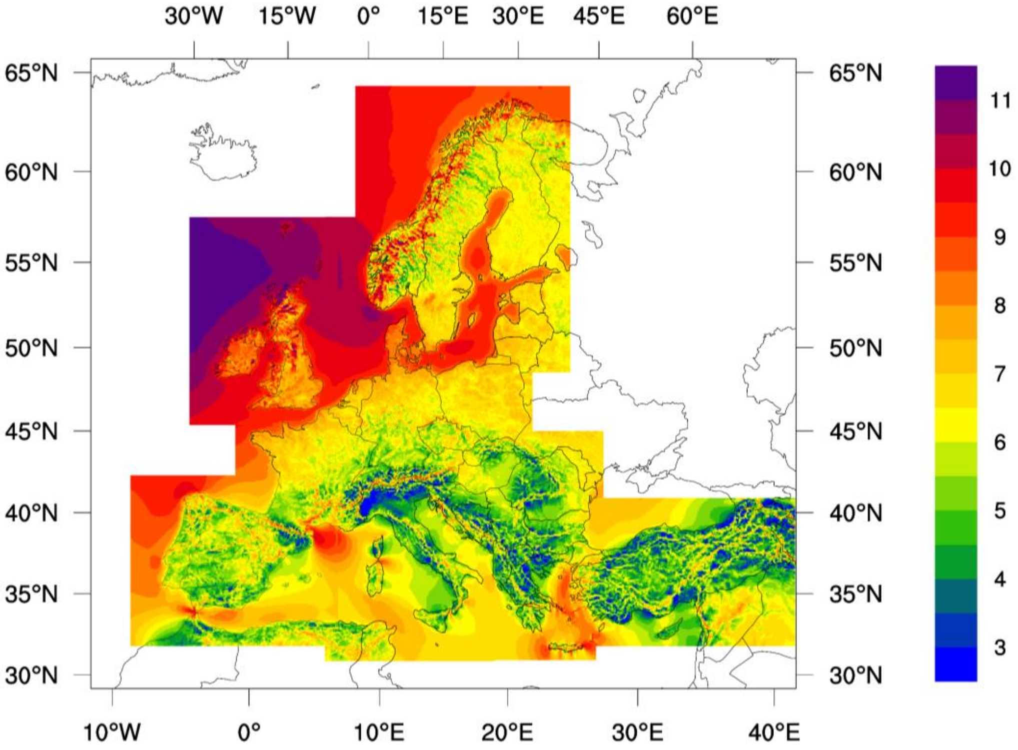
DOMAIN

region/ year	2018	2017	2016	2015	2014	2013	2012	2011	2010	2009	2008	2007	2006	2005	2004	2003	2002	2001	2000	1999	1998	1997	1996	1995	1994	1993	1992	1991	1990	1989	1988
BA		BW	BW	JB	JB	TS	WT	WT	AH	BO	AH	MD	YE	MD	MS																
CE		BW	AH	JB	JB	TS	WT	WT	AH	BO	AH	BW	YE	MS	MS																
FR		BW	AH	JB	JB	TS	BW	WT	AH	EG	AH	MD	YE	MS	MS																
GB		BW	BW	JB	JB	TS	TS	WT	AH	EG	AH	MD	YE	MS	MS																
GR		BW	BW	BW	JB	BW	TS	WT	AH	EG	YE	MD	YE	MS	MS																
IB		BW	JB	BW	JB	TS	TS	WT	AH	EG	YE	MD	YE	MS	MS																
IT		BW	TS	BW	TS	BW	WT	WT	AH	EG	YE	MD	YE	MS	MS																
SA		BW	JB	JB	TS	TS	BW	WT	AH	EG	YE	MD	YE	MS	JN																
SB		BW	JB	JB	TS	TS	WT	WT	AH	EG	YE	MD	YE	MS	JN																
TR		BW	JB	JB	TS	TS	WT	AH	BO	EG	YE	MD	YE	MS																	

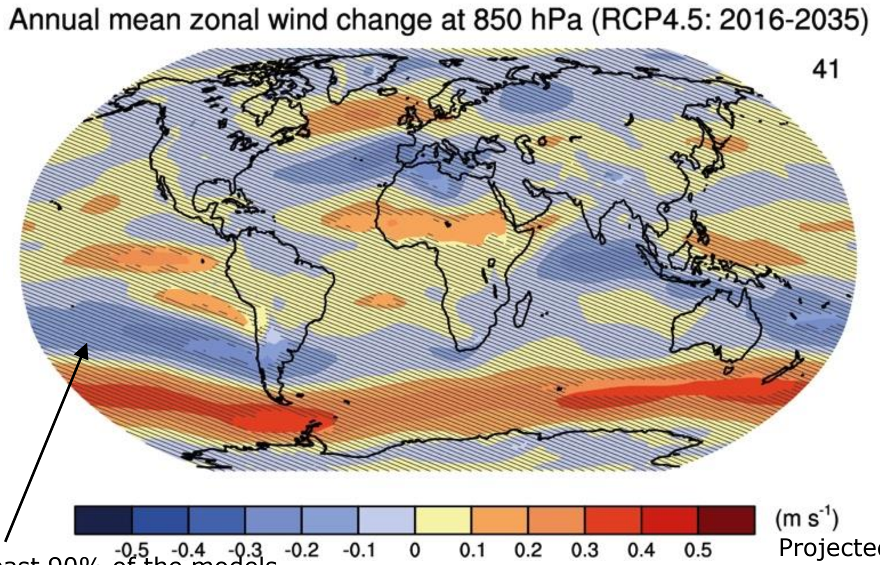
- Tranfer by hand; no remove
- Run completed and data transferred
- Job submitted; running or waiting to run
- Run completed; waiting postprocess
- Main run done; some weeks failed; waiting to run
- Run completed; transfer initiated
- WPS done, WRF failed/was canceled

ERA5 data not yet available

Annual mean wind speed (m/s) at 100 m 2013-2017

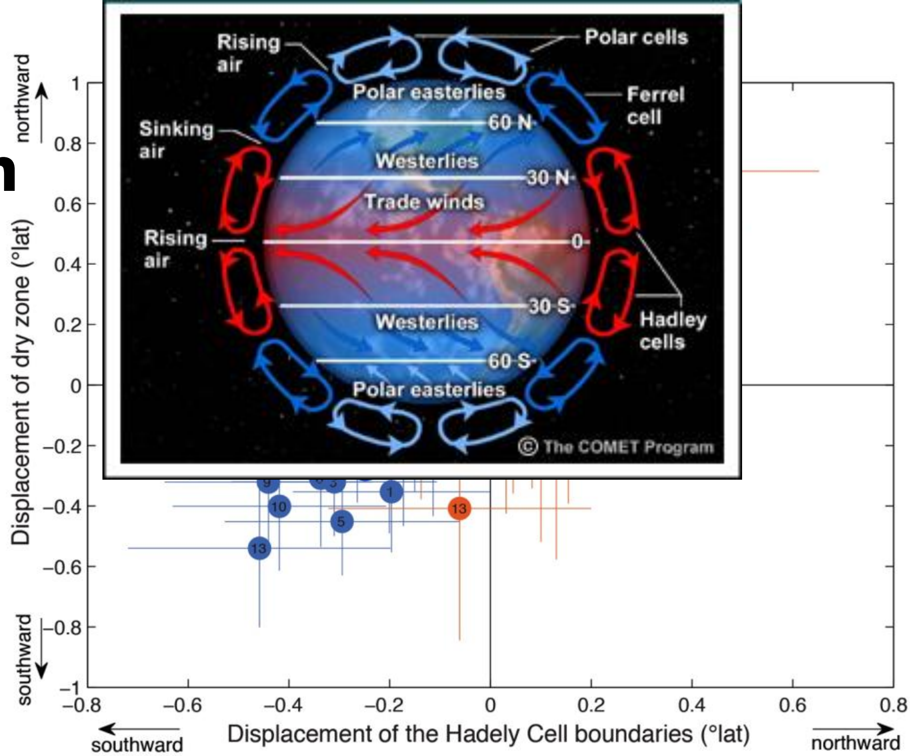


Changes in wind circulation



at least 90% of the models
agree on the sign of change

IPCC 5th Assessment report



Projected changes in the annual averaged poleward edge of the Hadley Circulation (horizontal axis) and sub-tropical dry zones.

Increases in GHGs are expected to lead to:

- poleward shift of the jet streams and associated zonal mean storm tracks
- a poleward shift of the Hadley Circulation

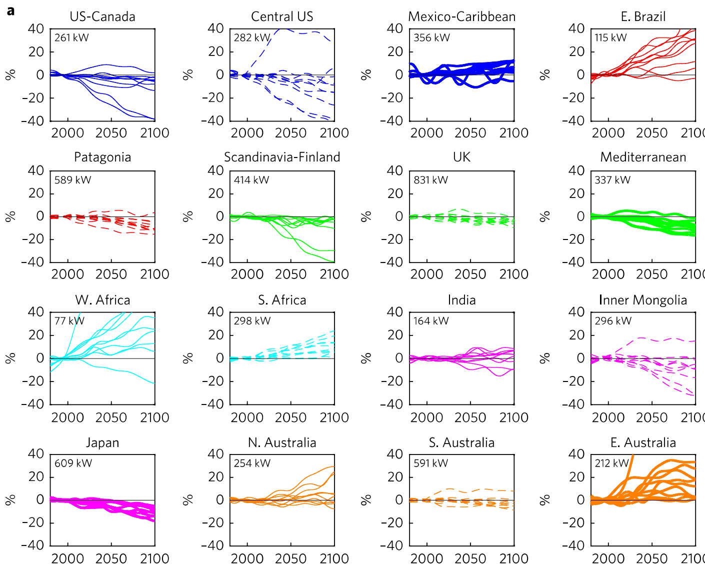
nature geoscience

ARTICLES

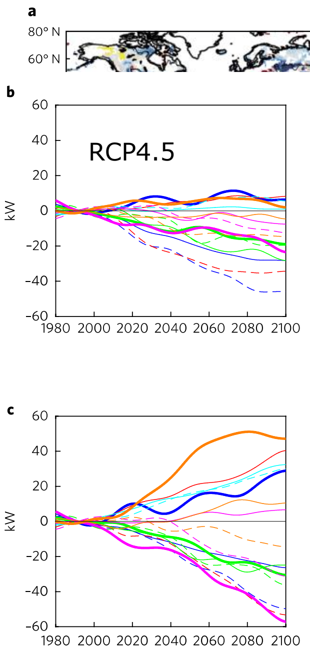
https://doi.org/10.1038/s41561-017-0029-9

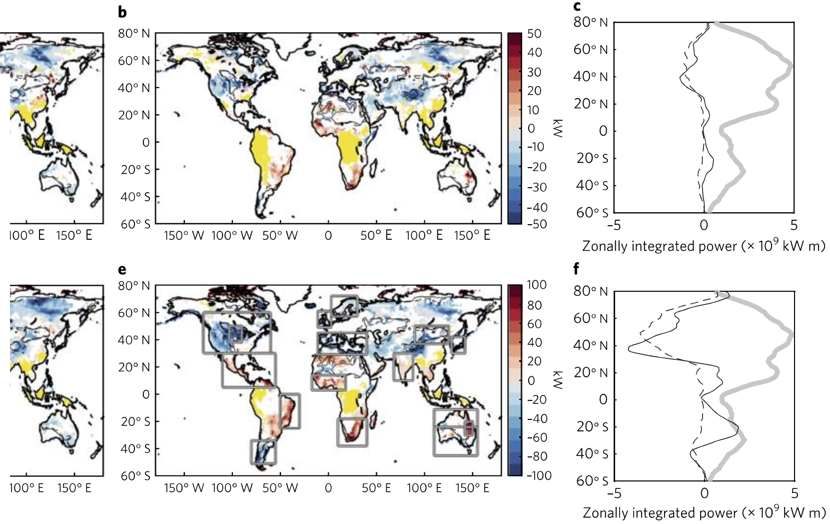
Southward shift of the global wind energy resource under high carbon dioxide emissions

Kristopher B. Karnauskas[1,2*], Julie K. Lundquist[1,3] and Lei Zhang[1]



Evolution of regional wind power over the twenty-first century.





Predicted changes in wind power. a, Multi-model median change in annual mean wind power (kW) in 2020–2040 relative to baseline from the ten CMIP5 coupled GCMs used in this study under the RCP4.5 forcing scenario.

What can be wrong with the previous type of assessment?

- Are wind farms at 10m?
- Do wind farms spin with the wind speed of a 50 km x 50 km wind speed?
- Why did they select some models are not others?

- What is missing?
- Future climate wind atlas?
- How do we consider the multi-models and ensemble information?