Wind power and extreme wind predictability in the wind resource assessment phase

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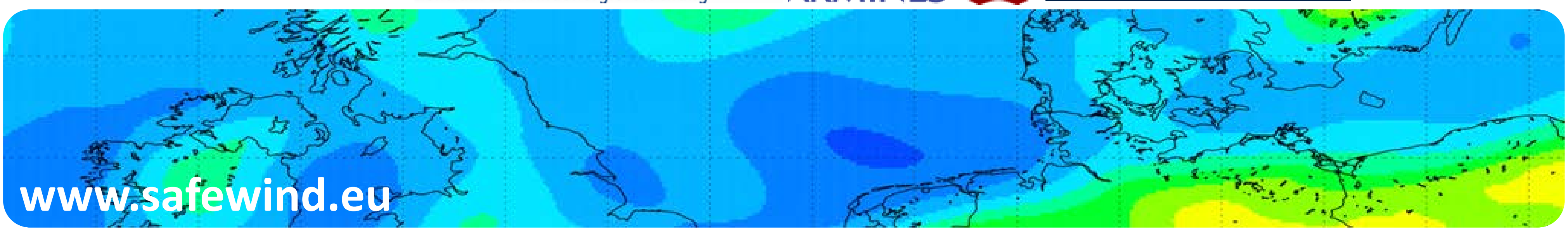

Background

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Two aspects traditionally separated…

- **Wind resource assessment** is related to the estimation of the annual energy production of a wind farm based on the local wind speed distribution
  - ❑ When: Planning phase
  - ❑ Why: Technical and economical feasibility of wind energy deployment
  - ❑ Who: Developers, manufacturers, financiers, policy makers
- **Predictability** is related to forecasting wind power
  - ❑ When: Operational phase
  - ❑ Why: integration with conventional energy production in the electricity grid (transmission balancing costs, energy trading, etc)
  - ❑ Who: Operators, traders, TSOs, DSOs, policy makers

→ **Scope**: Explore synergies between both domains and anticipate the value of predictability during the planning phase of wind energy → life-cycle approach → more efficient integration of wind energy at large penetration levels

Objectives

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Value of Wind Power Predictability in Spatial Planning

Consider predictability as a decision factor in the planning phase of wind energy by…

- ❑ Anticipating the economical impact of (lack of) predictability at different scales and therefore
- ❑ Defining strategies for optimum penetration of wind energy at European, regional and wind farm levels

Value of Extreme Wind Predictability in Site Assessment

New techniques for 50-year extreme wind (Vref) assessment based on numerical weather prediction outputs to:

- ❑ Avoid using historical observations which are scarce and of low quality (lack of homogeneity and representativeness)
- ❑ Produce a unified methodology that allows for trans-national mapping of Vref

Test Cases: From EU to Site Level

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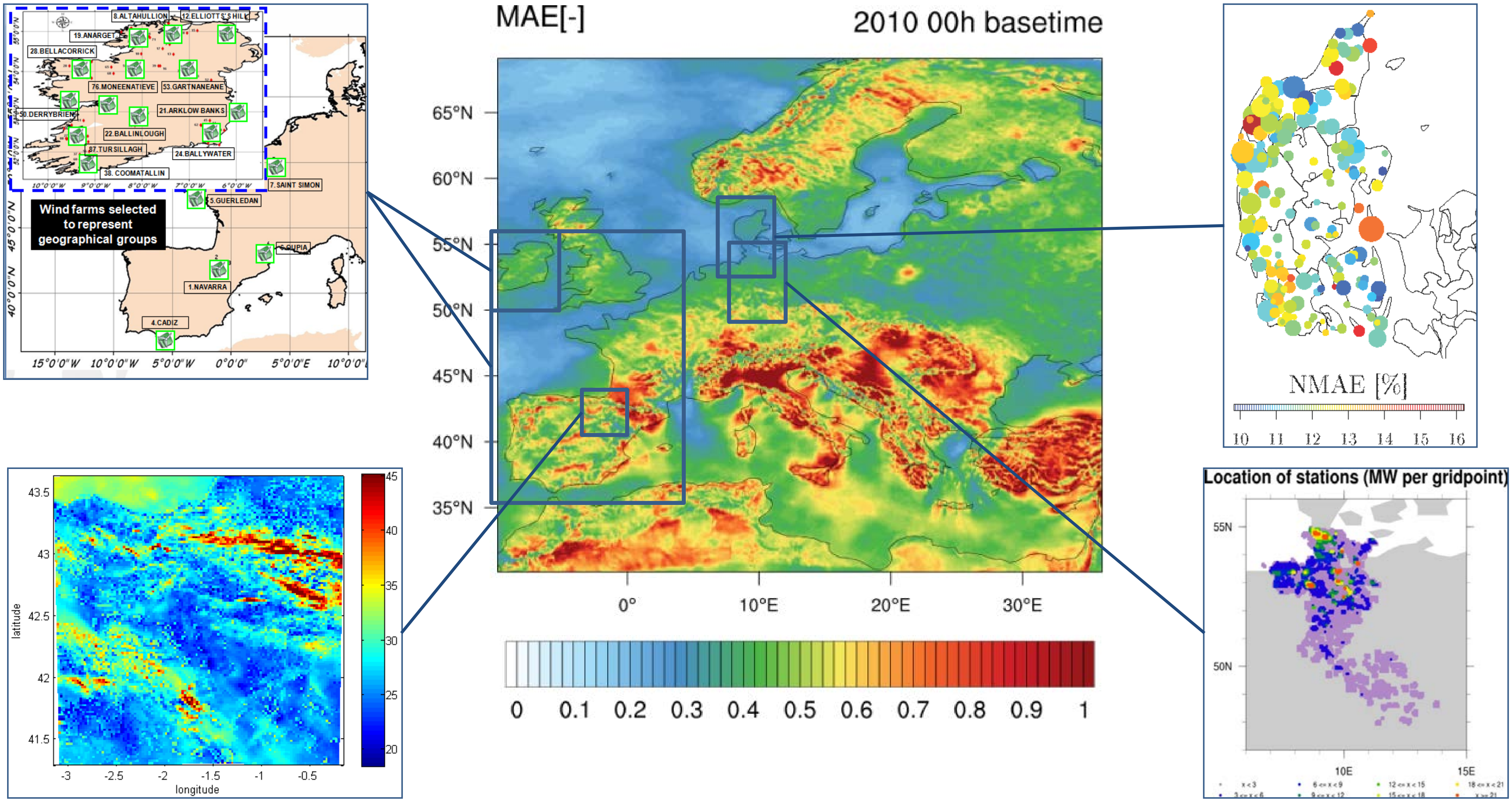

Task 7.1: Predictability in Spatial Planning

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Advantages of wind power predictability assessment:

- Reduce the costs for balancing energy production (distribution, storage)
- Better integration with conventional energy generation by reducing the spatio-temporal variability of wind energy
- Better design of EU electricity market model by better estimation of the costs of wind predictability
- Better assessment of revenues for wind farm developers and operators

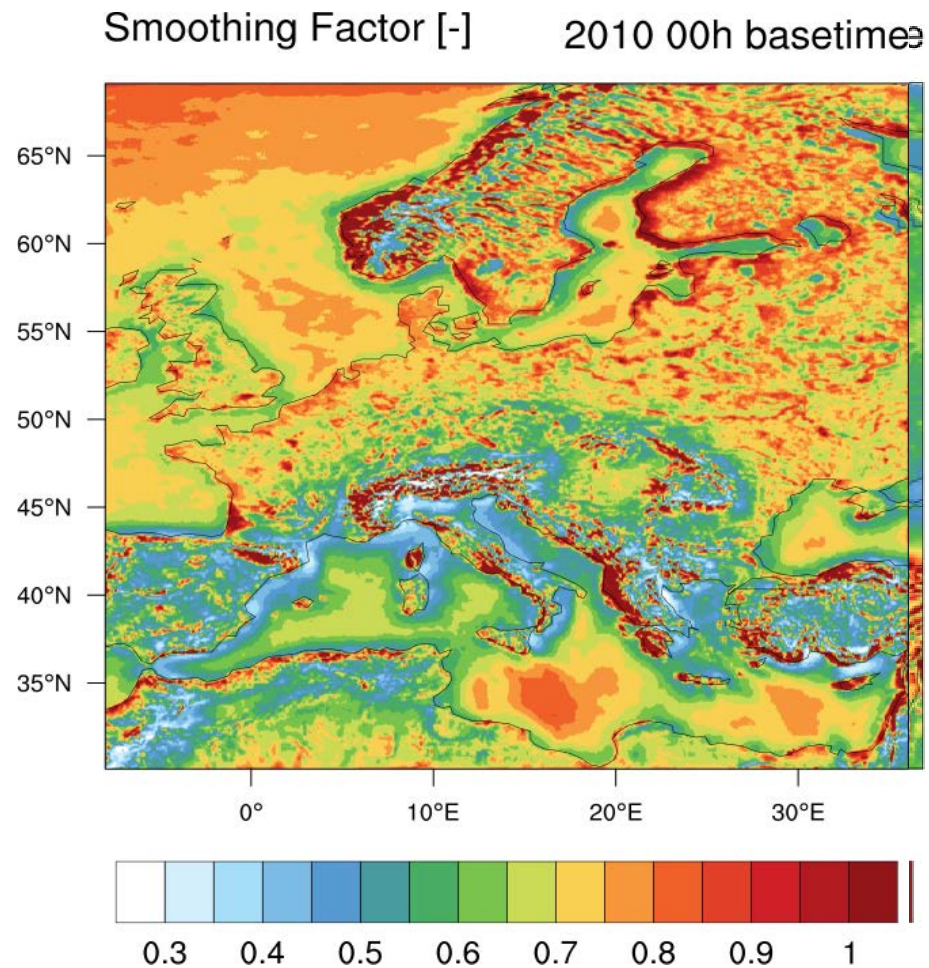
The challenge: generate virtual wind power production data based on historical weather data to run forecasting models and determine the long-term predictability level

Maps of Forecast Skill in Europe

ForWind
Zentrum für Windenergieforschung

New tool for spatial planning purposes

- Method: Based on mesoscale wind speed forecasts (COSMO-EU, 7x4.1 km grid) and a reference power curve.
  - ❑ Not valid for local (wind farm) assessment, only regional predictability (TSO focus)
- Case Study: Europe
  - ❑ Better predictability in offshore and simple terrain
  - ❑ Large improvements of predictability by spatial smoothing in areas of large wind variability
- Highlight: Better assessment of distributed generation for strategic planning

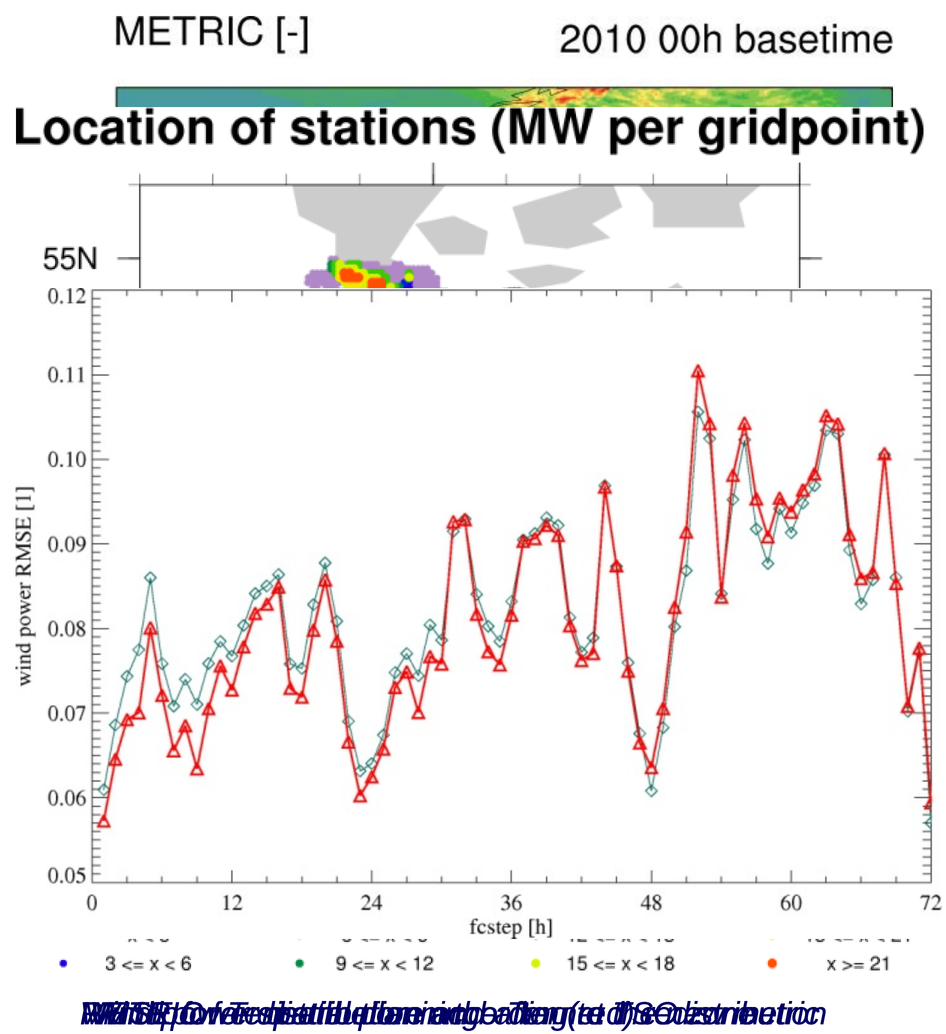


MAE for 2010 for forecast day 2 normalised with the load factor
Smoothing factor of RSME for an area of 100km

Predictability-Based Planning (TSO)

New metric for the spatial planning of wind energy that maximizes predictability and minimizes variability (TSO focus)

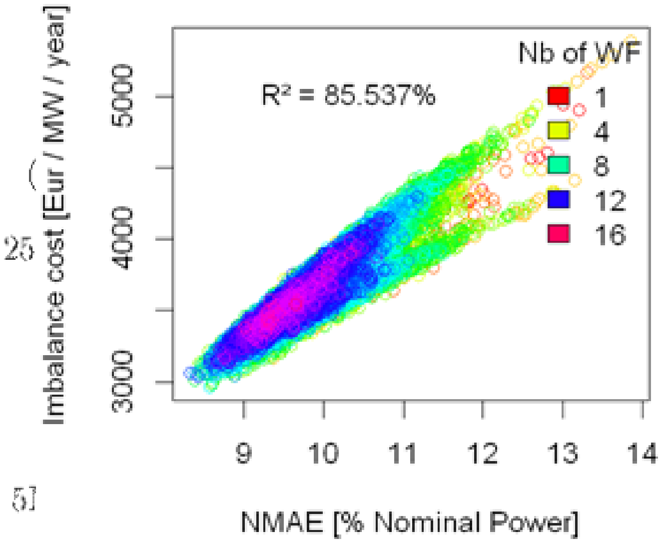
- Case Study: Tennet TSO zone, Germany
  - ❑ Size of area of interest: 100 km
  - ❑ Redistribution of wind power to improve predictability
- Results:
  - ❑ METRIC = RMSE (10%) + spatial correlation of wind (10%) + smoothing factor of RMSE (80%)
  - ❑ Decrease of ~1% on RMSE
  - ❑ Higher predictability also results in lower capacity factor due to both factors being highly correlated

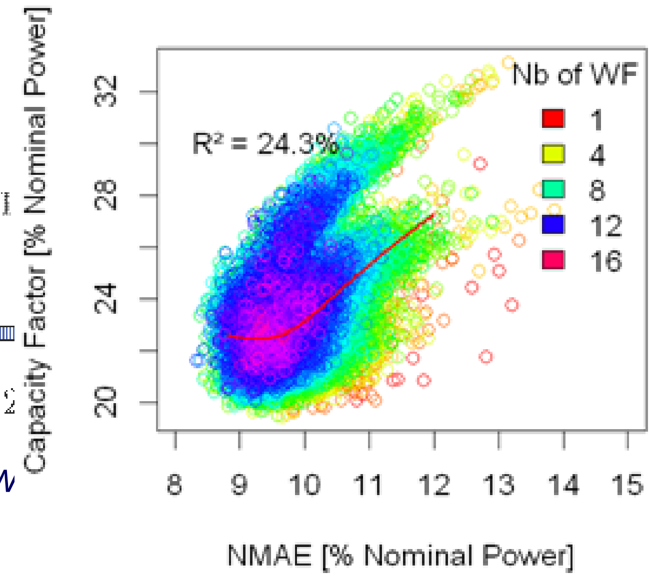


Predictability-Based Planning (Developer)

Financial benefit of increasing predictability (Developer's focus)

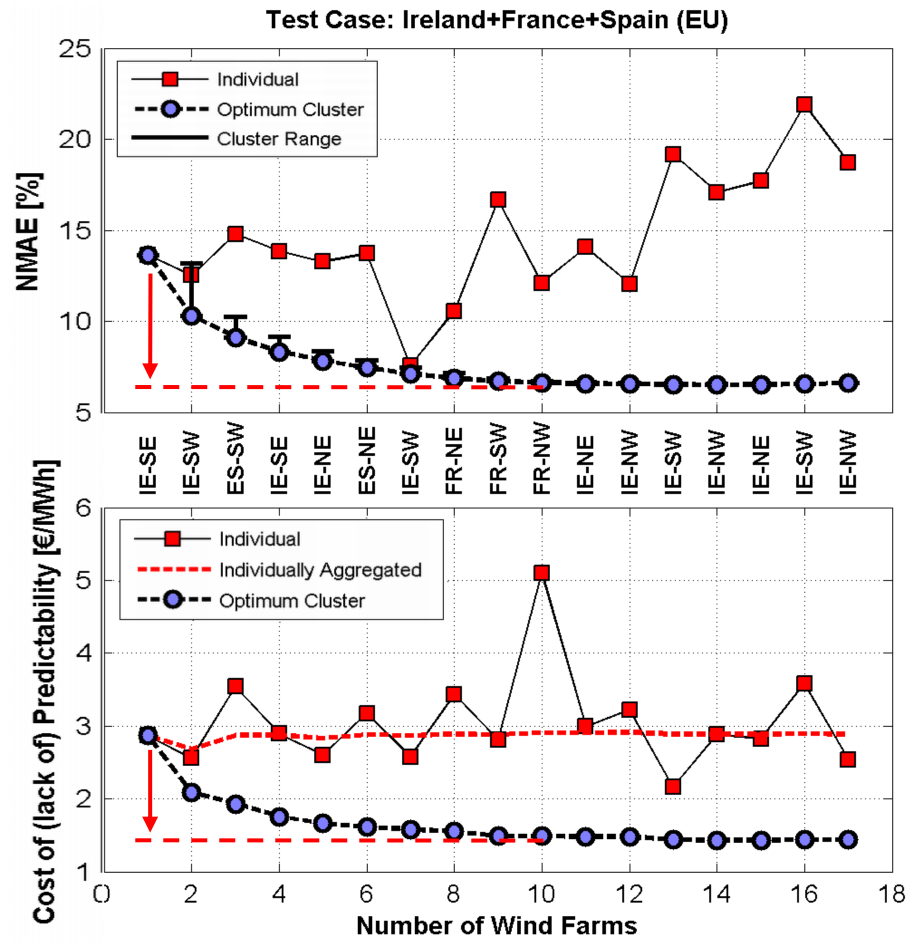
- Method:
  - ❑ Quantify the % of trading revenue's variance explained by predictability
- Case Study: DK1 TSO zone (~200 stations), DK
  - ❑ Only 0.02%/0.15% of revenue's variance can be explained when single wind farms/ clusters are considered
  - ❑ Little incentive to use predictability from the developer's point of view
  - ❑ Higher shares would be obtained if larger areas are considered and if O&M costs are included (offshore)
- Highlight: Predictability is not a decision maker for a developer, it is rather a quality-of-energy indicator





Financial benefit of portfolio effect in spatial planning (Utility's focus)

- Case Study: Irish utility to buy wind farms in France and Spain
  - ❑ Optimize the aggregation process by minimizing the portfolio NMAE
  - ❑ Cost of predictability vs perfect prediction
- Results:
  - ❑ Clustering limited to Ireland or including France and Spain
  - ❑ NMAE reduction of 42%/52% (IE/EU)
  - ❑ By trading the portfolio instead of the individual wind farm energy, the utility saves 2.69%/2.42% of imbalance losses (~0.5 M€/year 284MW)

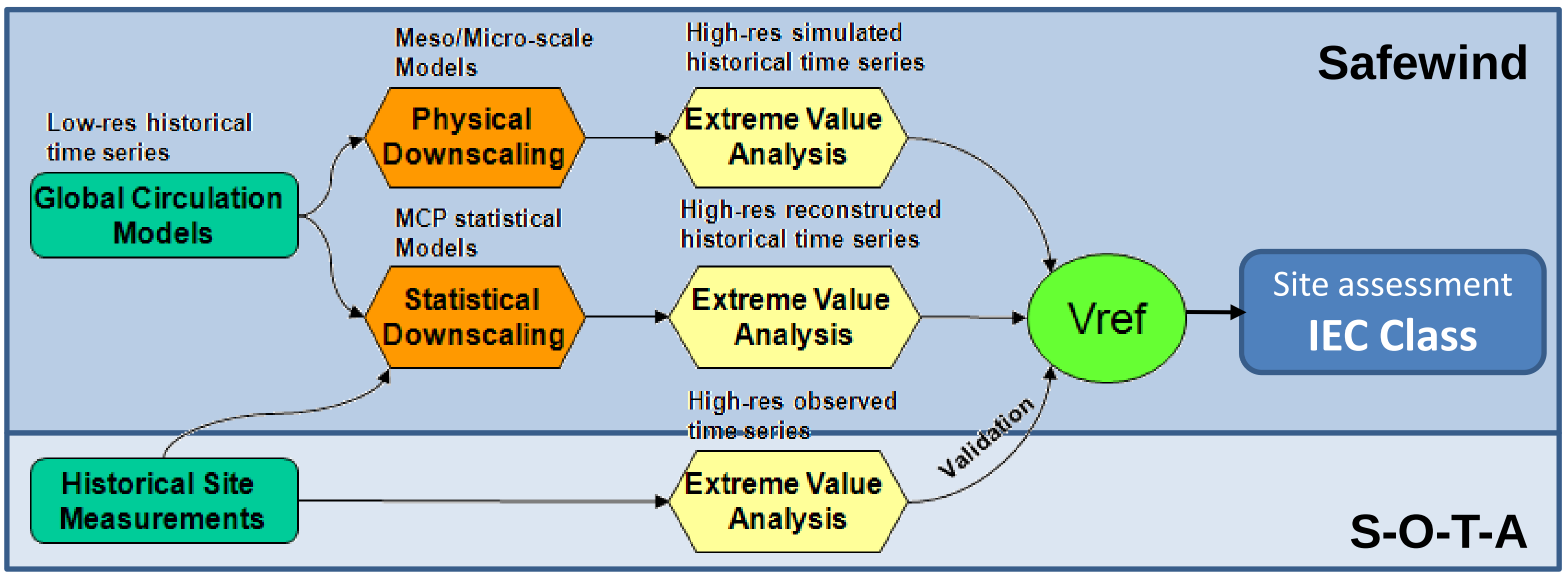


Task 7.2: Extreme Wind Predictability

Scope: IEC site assessment by high-resolution downscaling of extreme winds from Numerical Weather Prediction (NWP) outputs

State-of-the-art:

- Classical methodology based on extreme-value-analysis of historical measurements
- Safewind vision: Replace/combine measurements with NWP outputs to improve robustness, spatio-temporal homogeneity and representativeness



Task 7.2: Extreme Wind Predictability

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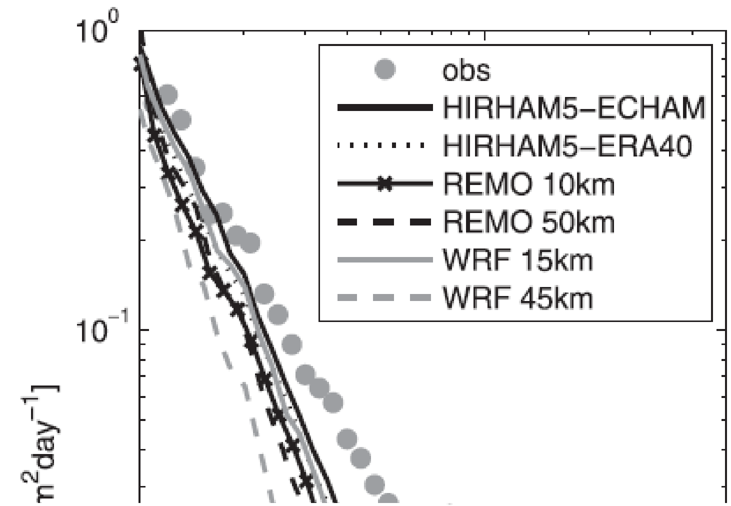
Objectives:
- Develop a robust extreme wind assessment methodology
- Homogeneous assessment of IEC siting conditions across EU countries
- Vref mapping valid for spatial planning
- 50-year representativeness based on reanalyses (ECMWF)

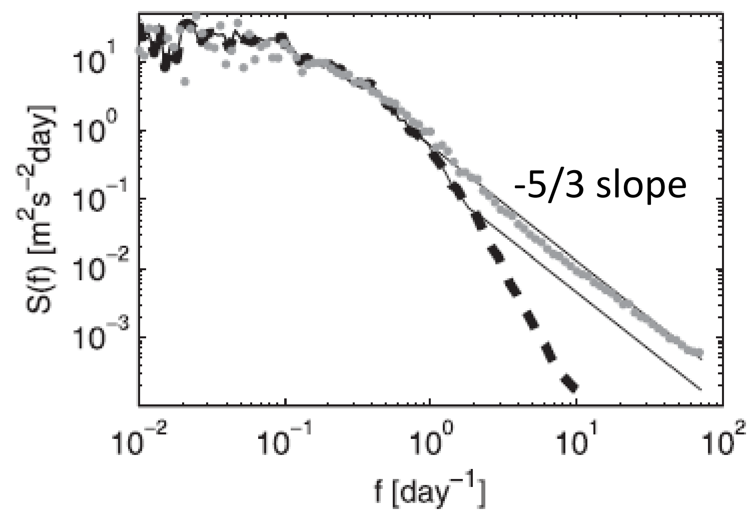
The challenges:
- Lack of historical observations for validation
- Downscaling to microscale level necessary
- Uncertainties difficult to quantify

Spectral method for correcting mesoscale extreme winds

- Method:
  - ❑ Replace the subgrid range of the spectrum with a theoretical spectrum (-5/3 slope)
  - ❑ Calculate peak factor based on spectral moments



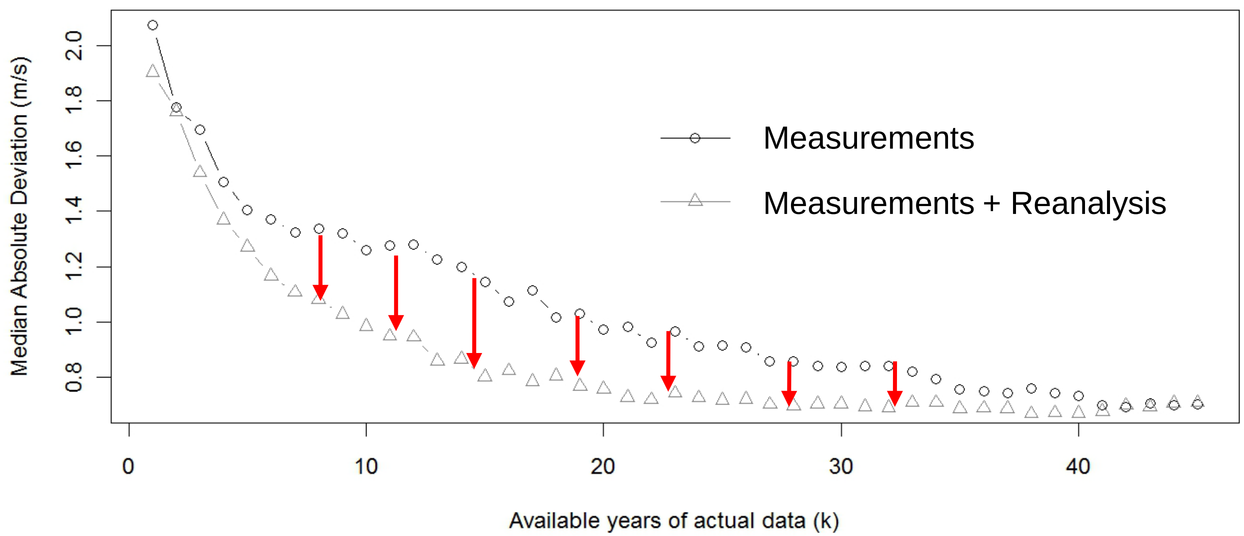
- Case Study: Horns Rev (offshore)
  - ❑ Fairly good result in offshore conditions
  - ❑ Validity of “universal” spectral correction in complex terrain remains a question



Replacing the subgrid range of the spectrum with a -5/3 slope
Impact of the smoothing of NWPs on the wind speed spectrum

Producing a robust extreme wind analysis method based on a limited measurement campaign and a long term reanalysis time series

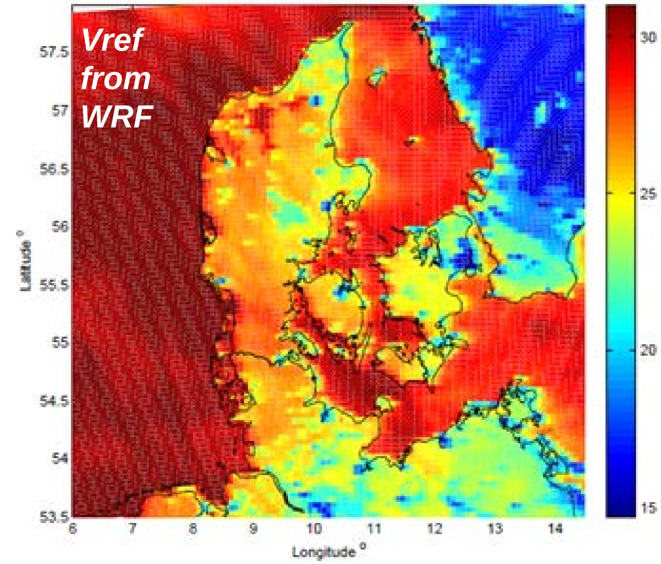
- Method: Statistical downscaling
  - ❑ Quantile calibration of reanalysis data preserving the distribution and autocorrelation characteristics of the measurements
- Case Study: Schiphol airport (45 years)
  - ❑ The calibration method outperforms the classical method when we have less than 20 years of site measurements
  - ❑ The calibration method shows less variability in the extreme wind estimates
- Highlight: New methodology is robust and has less dependency on measurements

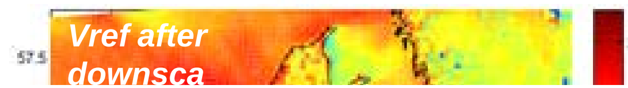


DTU

Selective dynamical downscaling method

- <u>Method</u>:
  - ❑ Identify the most important annual storms from reanalysis data, simulate them with mesoscale model and introduce local speed-up effects with microscale model
- <u>Case Study</u>: Denmark (synoptic), Gulf of Suez (mesoscale) and Navarre (local)
  - ❑ Fairly good results
  - ❑ Challenge in coastal ar due to difficult modelin and complex terrain mi
- <u>Highlight</u>: Seamless trans-r extreme winds suitable for



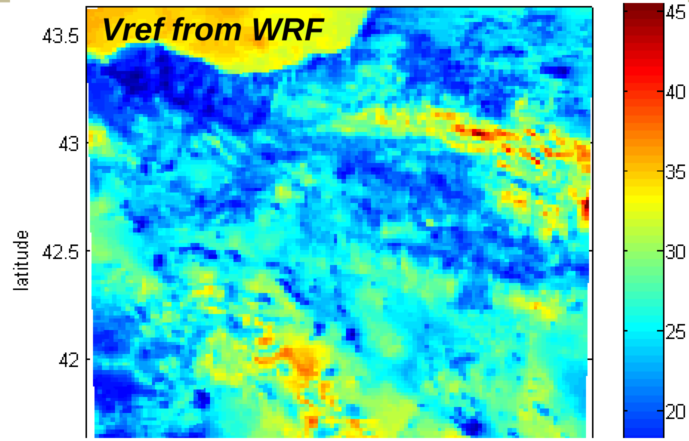


		U_{50}, no generalization				$U_{50,st}$, with generalization		
	Stations	Height (m)	WRF	OBS	ΔU_{50}	WRF	OBS	$\Delta U_{50,st}$
A	Sprogø	70	34.2 ± 6.7	33.0 ± 3.7	1.2	24.2±4.4	23.9±2.0 *	0.3
	Tystofte	39	31.2 ± 6.6	31.5 ± 4.5	-0.3	25.0±5.4	25.7±2.9 *	-0.7
	Kegnæs	23.4	31.2 ± 7.0	35.8 ± 7.0	-4.6	25.8±5.5	26.3±3.8 *	-0.5
	Jylex	24	31.8 ± 6.4	35.4 ± 5.5	-3.6	27.4±5.4	29.1±2.9 *	-1.7
	Risø	76.6	32.0 ± 6.3	33.2 ± 5.4	-1.2	25.6±5.3	23.7 ± 4.7	1.9
	Høvsøre	100	39.5 ± 8.0	44.6 ± 12.5	-5.1	29.7±5.8	29.8 ± 9.4	-0.1
	Horns Rev	62	39.3 ± 7.7	44.2 ± 14.0	-4.9	29.0±5.3	31.6±8.5	-2.6
	FINO1	50	36.5 ± 6.0	38.1 ± 8.8	-1.6	27.8±4.3	27.4±7.6	0.4
B	Abu Darag	24.5	25.7 ± 5.8	26.6 ± 4.0	-0.9	20.5±4.8	20.2±3.4	0.3
	Zafarana	24.5	25.4 ± 5.3	28.1 ± 4.4	-2.7	19.9±4.1	19.8 ± 2.8	0.1
	El Zayt	24.5	20.0 ± 2.2 (x)	24.5 ± 3.4	-4.5	15.5±1.9(+)	17.4±2.6	-1.9

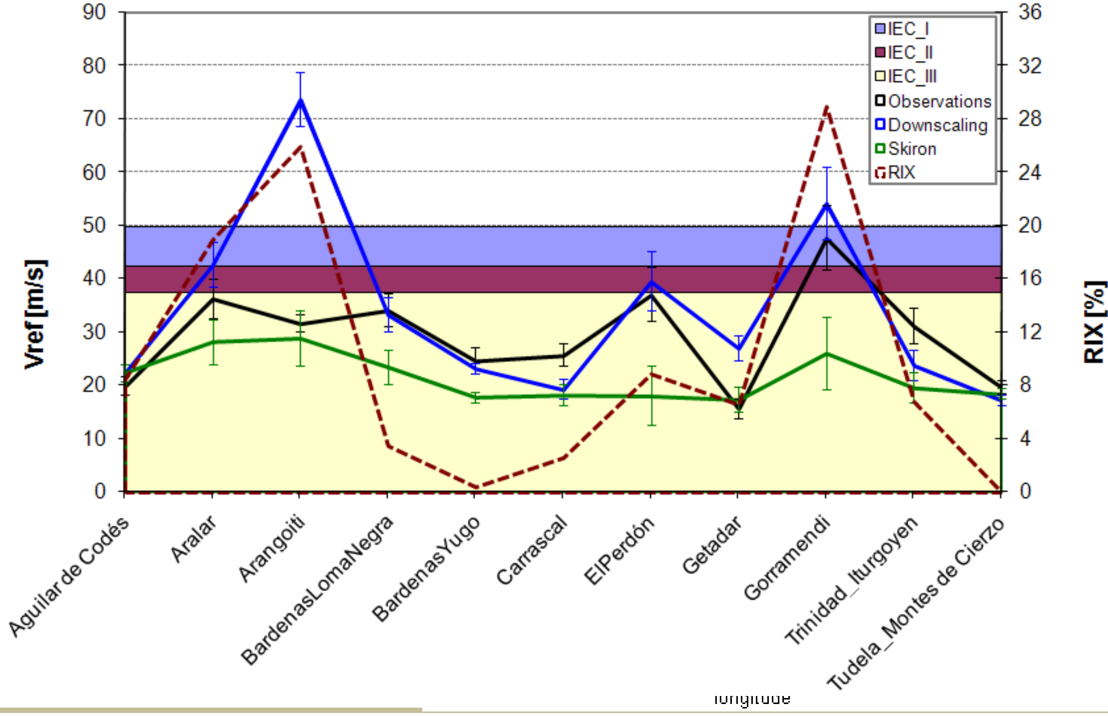
Longitude °

Statistical-dynamical downscaling

- Method: CENER's virtual met-mast
  - ❑ Perform mesoscale simulations of historical period and introduce local speed-up effects with microscale model



- Case Study: Navarre (local)
  - ❑ The method effectively removes the bias in mean wind speed as well as annual maxima
  - ❑ Good results in well-exposed Sites



- Highlight: Virtual met-mast methc for mean and extreme wind asses:

Conclusions and Outlook

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- New methodologies and test cases have been presented to demonstrate the feasibility and the advantages of using predictability during the planning phase of wind energy
- Guidelines on how to generate and use predictability during the planning phase have been produced
- These new tools allow life-cycle approaches that enable a more efficient and integrated promotion of wind energy development

- **Outlook**: Towards an enriched European wind atlas: predictability and extreme wind mapping are new layers that can be integrated in spatial planning activities
    - ❑ ENERGY.2013.10.1.2: ERA-NET Plus – *European wind resources assessment*: Development of the EU-27 Wind Atlas (just published call)

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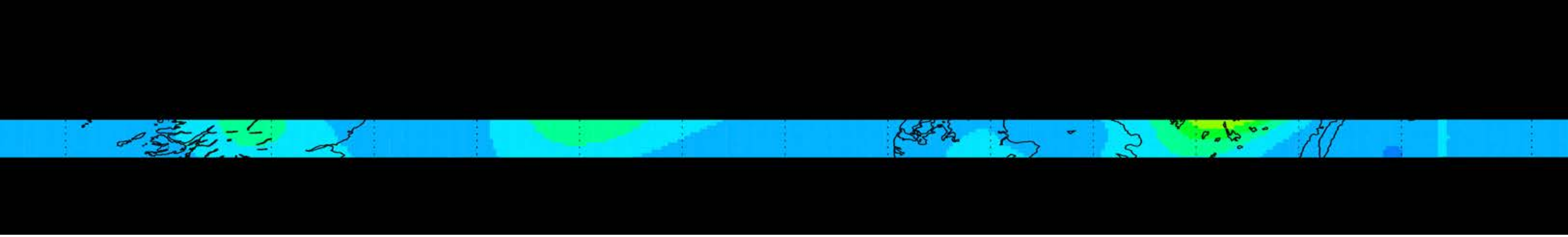

SafeWind

Wind Power Forecasting with Focus on Extremes

Workshop - 31.08.2012

L'Auditorium, Palais Brongniart, Paris