From day ahead to decadal wind power forecasting

Francisco Doblas-Reyes, Albert Soret, Melanie Davis, Verónica Torralba Fernandez, Nube Gonzalez-Reviriego

Consorcio Español

CENER | CENTRO NACIONAL DE ENERGÍAS RENOVABLES
FUNDACIÓN CENER-CIEMAT
ADItech

UNIVERSITAS COMPLUTENSIS MATRITENSIS

NEW EUROPEAN WIND ATLAS
newa

IC3
Barcelona Supercomputing Center
Centro Nacional de Supercomputación

GOBIERNO DE ESPAÑA
MINISTERIO DE ECONOMÍA Y COMPETITIVIDAD

Ciemat
Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas

UIB Universitat de les Illes Balears

Support by

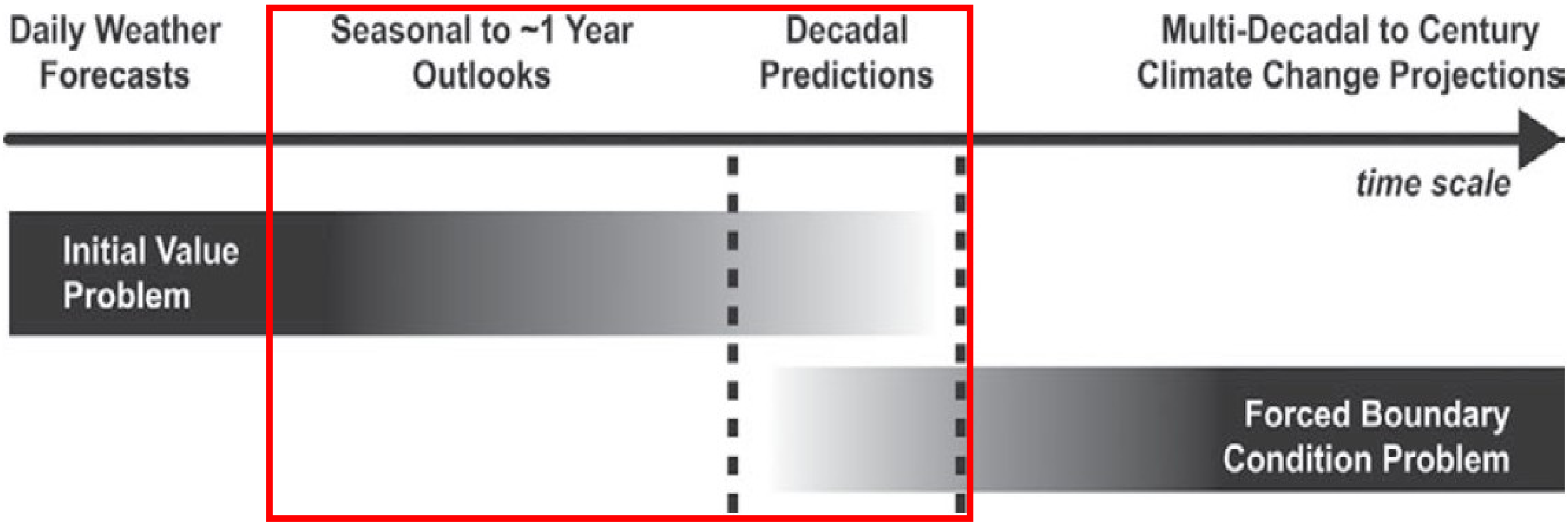
SEVENTH FRAMEWORK PROGRAMME

EUPORIAS: EUropean Provision Of Regional Impact Assessment on a Seasonal-to-decadal timescale

SPECS: Seasonal-to-decadal climate Prediction for the improvement of European Climate Services

NEWA: New European Wind Atlas

- Initial-value problems (weather forecasting) to forced boundary condition problem (climate projections)
- Climate forecasts (sub-seasonal, seasonal and decadal) in the middle

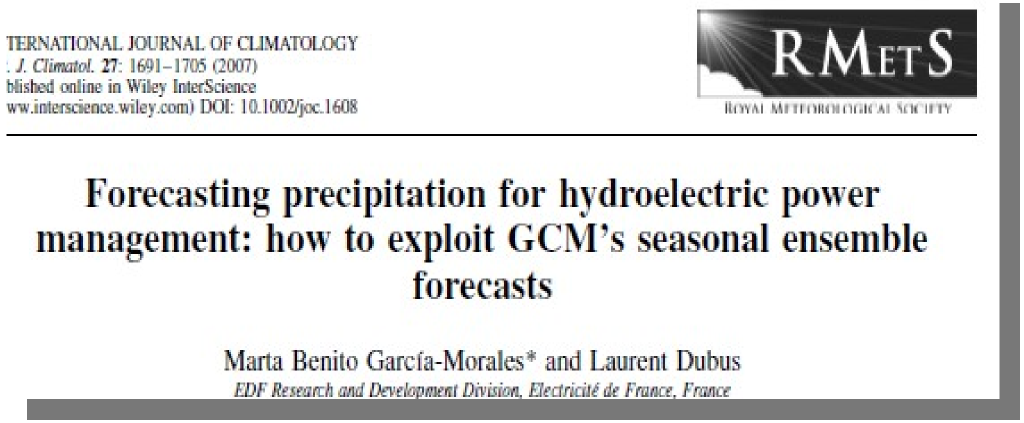


Meehl et al. (2009)

Wind power variability at monthly to decadal time scales has not been traditionally taken into account in wind power facilities planning and management

In other sectors as hydropower or electricity generation and demand balance, climate information on seasonal-to-interannuel time scales have already been illustrated for management decisions.

Hydroelectric power management

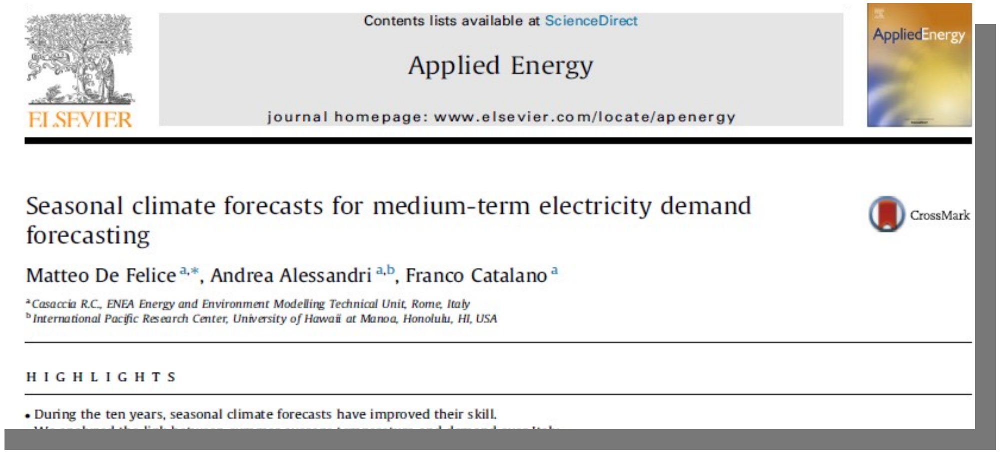

TERNATIONAL JOURNAL OF CLIMATOLOGY
. J. Climatol. 27: 1691–1705 (2007)
blished online in Wiley InterScience
ww.interscience.wiley.com) DOI: 10.1002/joc.1608

RMetS
ROYAL METEOROLOGICAL SOCIETY

Forecasting precipitation for hydroelectric power management: how to exploit GCM's seasonal ensemble forecasts

Marta Benito García-Morales* and Laurent Dubus
EDF Research and Development Division, Electricité de France, France

Electricity demand


ELSEVIER

Contents lists available at ScienceDirect

Applied Energy

journal homepage: www.elsevier.com/locate/apenergy

AppliedEnergy

Seasonal climate forecasts for medium-term electricity demand forecasting

CrossMark

Matteo De Felice [a,*], Andrea Alessandri [a,b], Franco Catalano [a]

[a] Casaccia R.C., ENEA Energy and Environment Modelling Technical Unit, Rome, Italy
[b] International Pacific Research Center, University of Hawaii at Manoa, Honolulu, HI, USA

HIGHLIGHTS

- During the ten years, seasonal climate forecasts have improved their skill.

Pre-Constuction Decisions: Annual to Decadal Timescales

- **Wind farm planners:** Site selection
- **Wind farm investors:** Evaluate return on investments
- **Policy makers:** Understand changes to energy mix

Post-Construction Decisions: Monthly to Seasonal Timescales

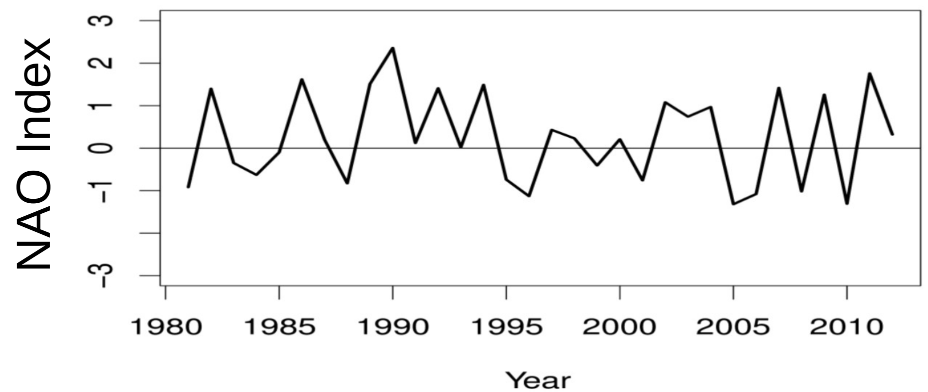
- Energy producers: Resource management strategies
- Energy traders: Resource effects on markets
- Wind farm operators: Planning for maintenance works
- Wind farm investors: Optimize return on investments

Objective within the NEWA project

To complement the probabilistic mesoscale model chain with climate predications to produce predictability information at different scales/horizons:

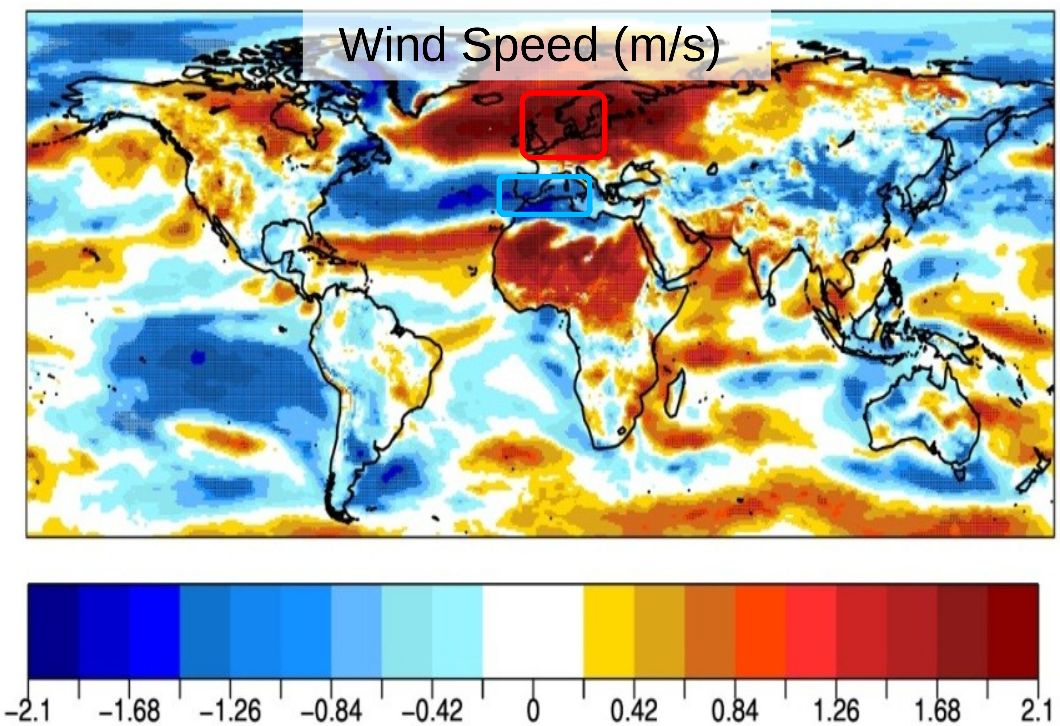
- hours
- days
- weeks
- seasons
- and decades

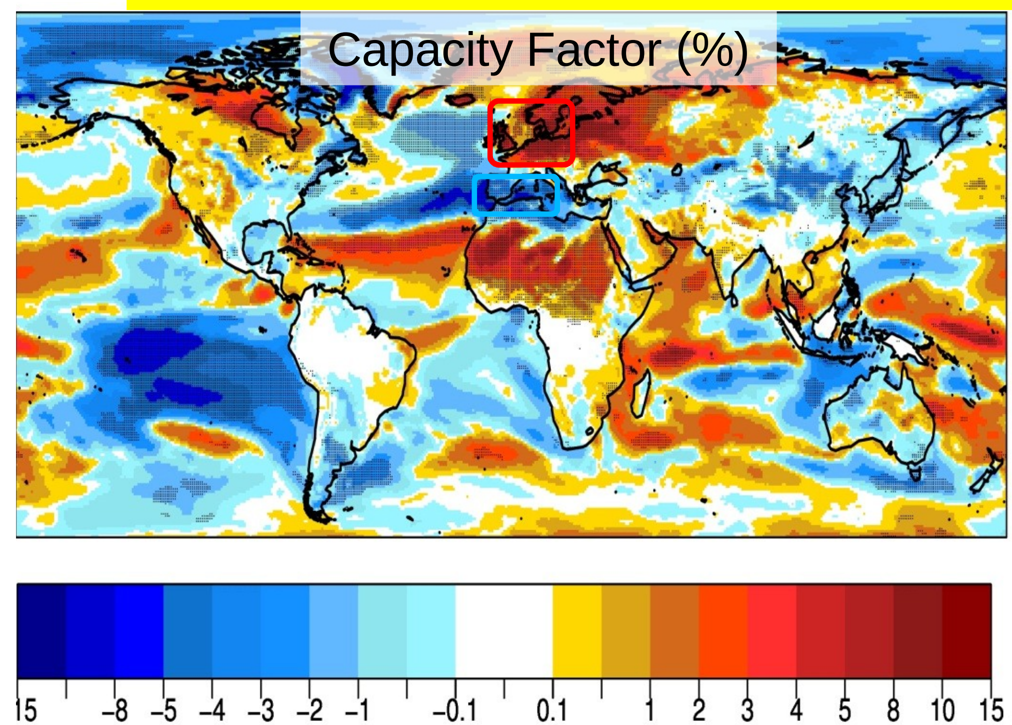
Some examples:
Impact of NAO on Wind Speed and Capacity Factor



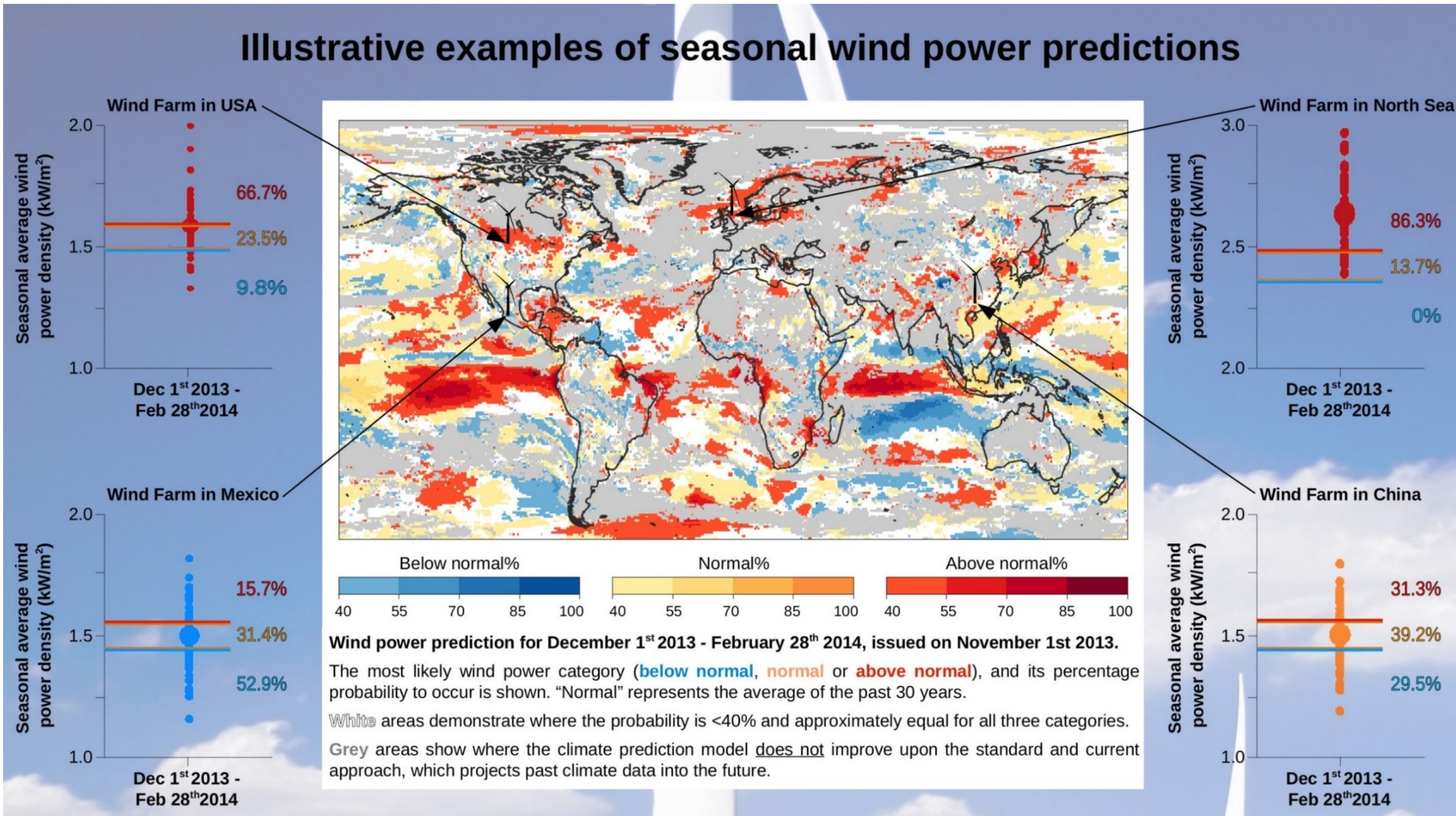
10m wind speed “observations”: ERA-Interim
Boreal winter season period 1981-2012

Differences with NAO + and NAO - conditions

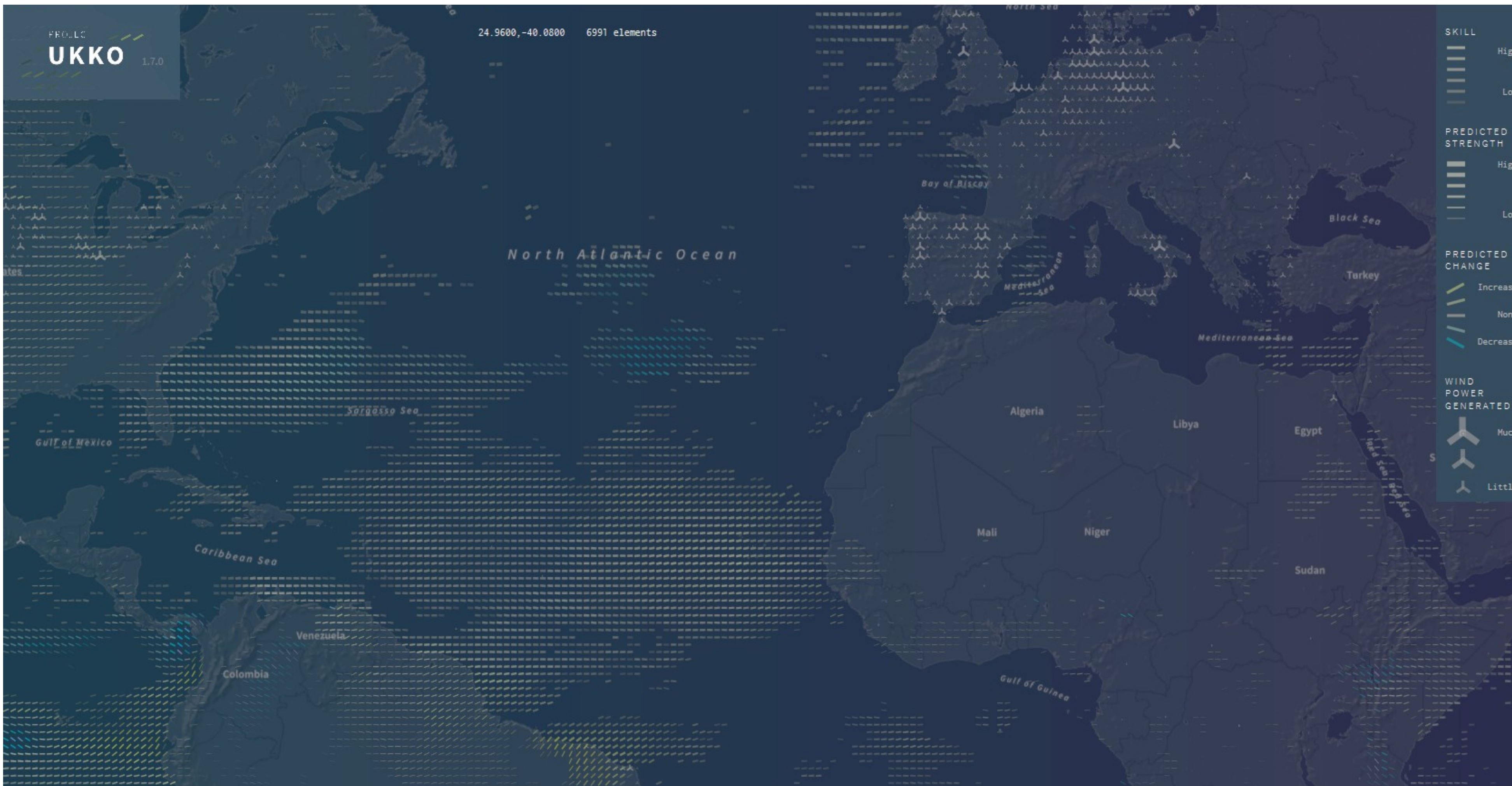




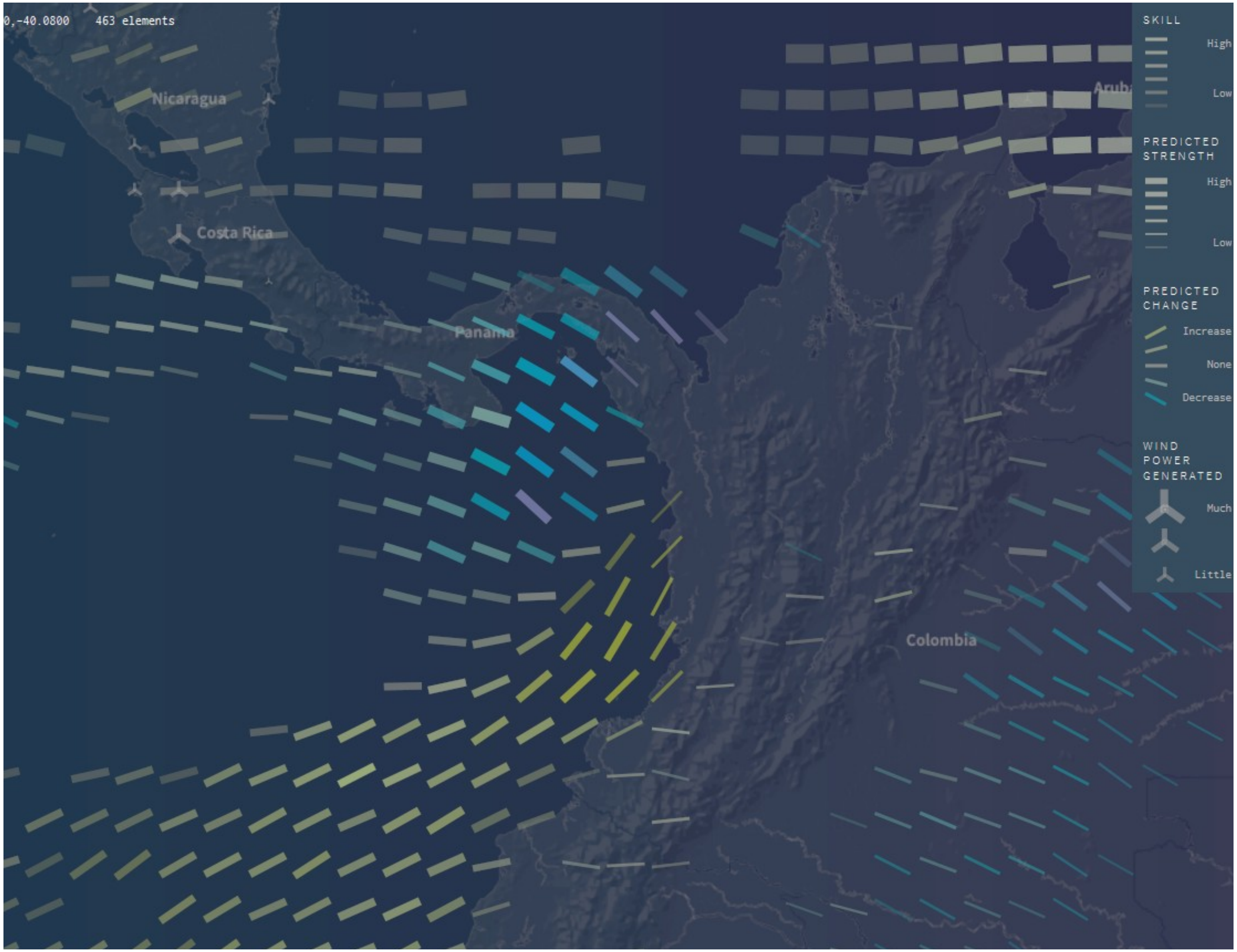
Some examples:
Seasonal wind power predictions



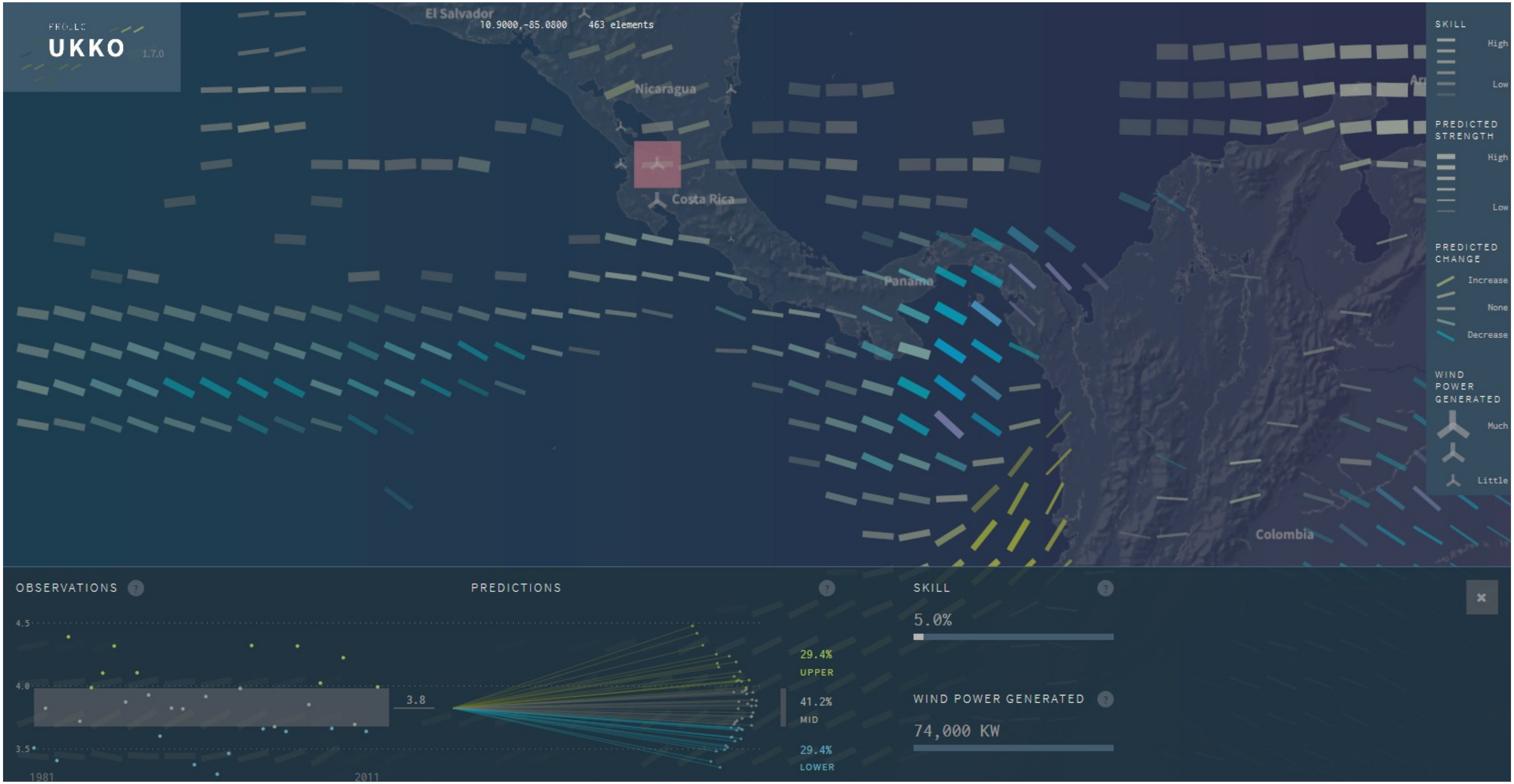
Some examples:
RESILIENCE Prototype (EUPORIAS project)



Some examples:
RESILIENCE Prototype (EUPORIAS project)



Some examples:
RESILIENCE Prototype (EUPORIAS project)



Some examples:
RESILIENCE Prototype (EUPORIAS project)

Thank you!

For further information:
albert.soret@bsc.es

CHALLENGE : models don’t provide capacity factor forecasts.

The wind power can be estimated from predictions of wind speeds and temperatures at the surface.

Limitations:

- The wind turbines are at 100m so 10m wind speed must be scaled up.
- Seasonal/monthly means of wind speed and temperature masks sub-seasonal/daily variability.

PREDICTIONS OF CAPACITY FACTOR

POTENTIAL SOLUTION: The wind power can be estimated from predictions of wind speeds and temperatures at the surface.

Forecasts

10m Wind Speed
2m Temperature

+

Past Observations

10m Wind Speed
2m Temperature

PREDICTIONS OF CAPACITY FACTOR

Corrected forecasts

10m Wind Speed
2m Temperature

Post-processing

Forecasts

10m Wind Speed
2m Temperature

Past Observations

10m Wind Speed
2m Temperature

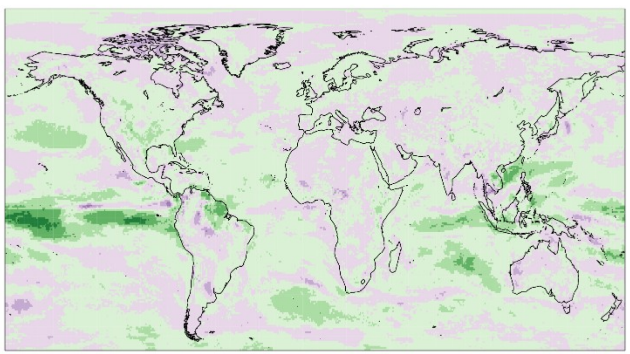
Introduction | Methods | **Results** | Summary | Future work

Forecast quality assessment

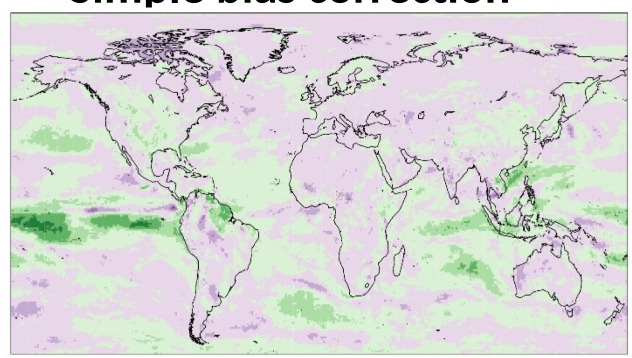
10m Wind Speed
ECMWF S4 1 month lead and ERA Interim in DJF (1981-2013)

RPSS

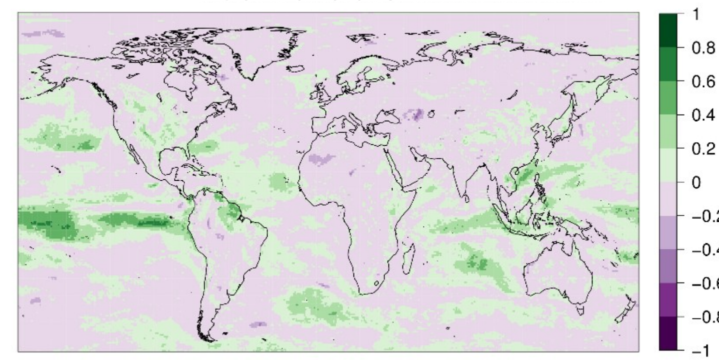
Raw data



Simple bias correction

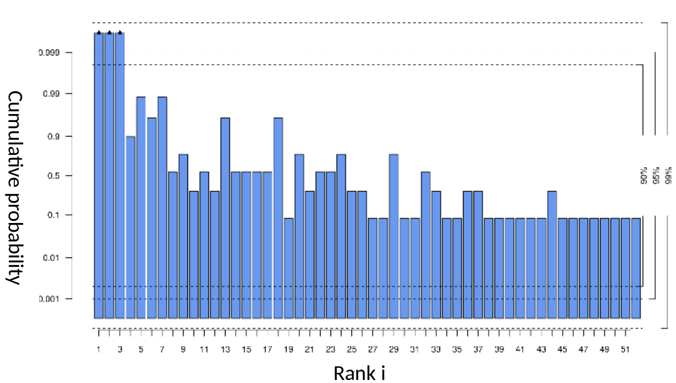


Calibration

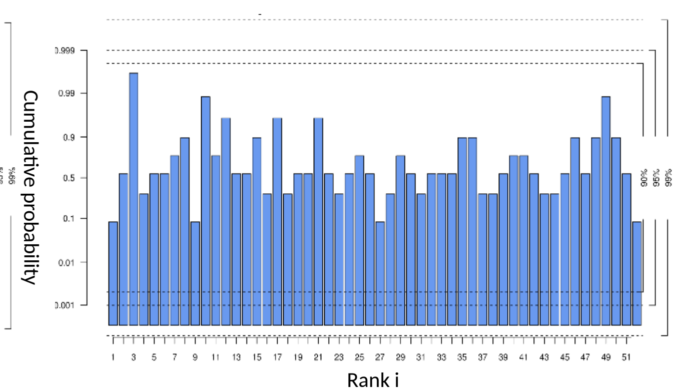


Region of Canada

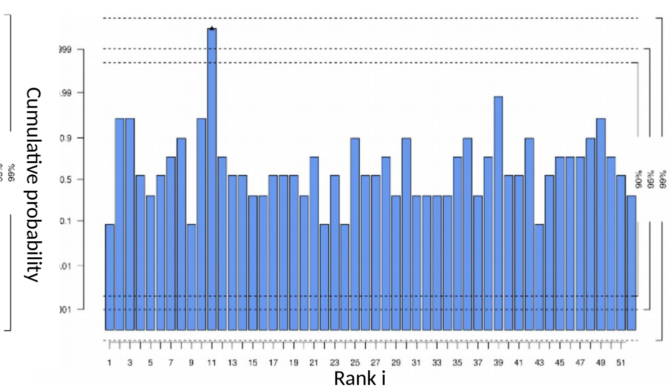
Rank Histograms



	Pearson.Chi2	JP.slope	JP.convex
test statistic	462.69	167.26	83.64
p−value	0	0	0



	Pearson.Chi2	JP.slope	JP.convex
test statistic	54	0.15	0.62
p−value	0.36	0.7	0.43



	Pearson.Chi2	JP.slope	JP.convex
test statistic	62.94	0	2.15
p−value	0.12	0.97	0.14

PREDICTIONS OF CAPACITY FACTOR

Corrected forecasts

10m Wind Speed
2m Temperature

Post-processing

Forecasts

10m Wind Speed
2m Temperature

Past Observations

10m Wind Speed
2m Temperature
Capacity factor

MacLeod's methodology

Past Observations

10m Wind Speed
2m Temperature

PREDICTIONS OF CAPACITY FACTOR

Multivariate regression

Corrected forecasts

10m Wind Speed
2m Temperature

Past Observations

10m Wind Speed
2m Temperature
Capacity factor

Post-processing

MacLeod's methodology

Forecasts

10m Wind Speed
2m Temperature

Past Observations

10m Wind Speed
2m Temperature

Multivariate regression

- How can we get a prediction of the capacity factor with a multivariate regression?

1. Past observations of CF , WS and T are fitted to a multivariate regression and the coefficients A, B and C are obtained.

$$CF\ (WS,T) = A\ WS + B\ T + C$$

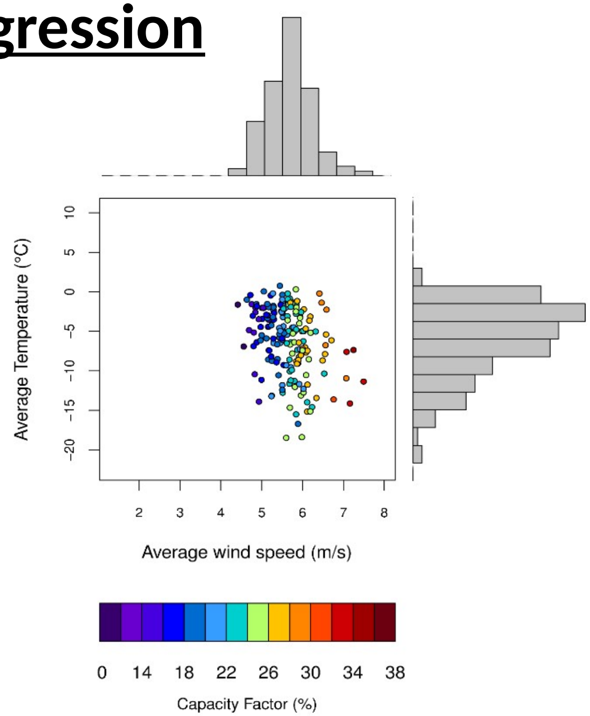
2. Predictions of WS and T in the target period are introduced in the expression with the coefficients A, B, C and the output is the forecast of the capacity factor.

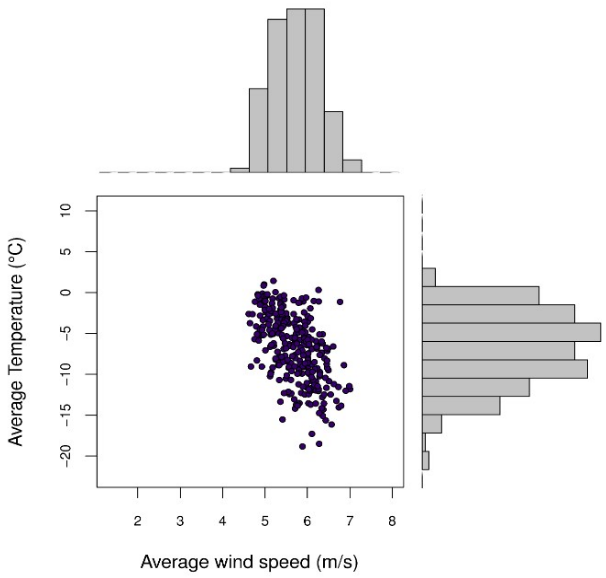
Multivariate regression

Central US region

1

Past observations of CF. December (1981-2011)

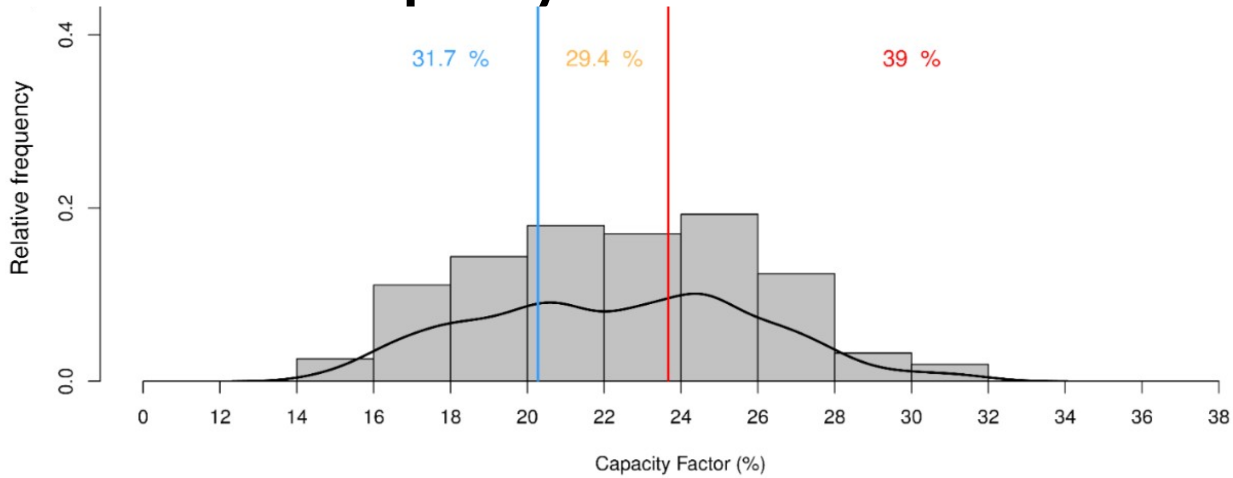




Forecasts of WS and T. Simple bias correction. December (2012)

2

Forecast of capacity factor for December 2012



Bias correction
Simple method

: forecast
: climatology of the ensemble mean
: standard deviation of the reference
: standard deviation of the ensemble mean
: climatology of the reference

Calibration
Inflation method

: ensemble mean of the forecast
:difference of the ensemble member with the ensemble mean
: correlation between the ensemble mean and the reference
: standard deviation of the reference
: standard deviation of the ensemble mean : standard deviation of the anomalies of all ensemble members calculated with respect to corresponding (i.e., same start date and lead time) the ensemble mean.

Both methods are applied in ‘One-year out cross-validated’ mode

Estimation of observational Capacity Factor

Wind Energy:

$$E = \frac{mv^2}{2} = \frac{(Avt\rho)v^2}{2} = \rho\frac{Atv^3}{2}$$

Wind Power:

$$P = \frac{E}{t} = \rho\frac{Av^3}{2} \longrightarrow \boxed{P = \frac{p}{RT}\frac{Av^3}{2}}$$

Ideal gas law $\rho = \frac{p}{RT}$

p : surface pressure
R : ideal gas constant
T: temperature
v : wind speed
A : area of turbine perpendicular to wind direction

Capacity Factor

$$\boxed{\text{CF (\%)}}$$

Power output curve from technical turbine specifications: Vestas 2.0 MW

Assumptions

- **To convert 10 wind speed to the turbine height (100 m) the wind profile power law is used:**

$$\frac{u}{u_r} = \left(\frac{z}{z_r}\right)^{\alpha}$$

: wind speed at vertical height
: wind speed at a reference height
: empirically derived constant (for dry air over land at neutral stability conditions)

- **Daily variability in wind speed and operating limitations (kick-in/kick-out speeds) can be modelled by weighting the wind power over all monthly wind speeds using a Rayleigh distribution:**

$$f(x) = \frac{x}{\sigma^2} e^{-x^2/2\sigma^2}$$

Impact Surfaces

- **What is an impact surface?**

They are a tool to visualise an impact variable in a discretized 'climate space' (Dave MacLeod, Oxford University).

- **How can we get a prediction of the capacity factor from them?**

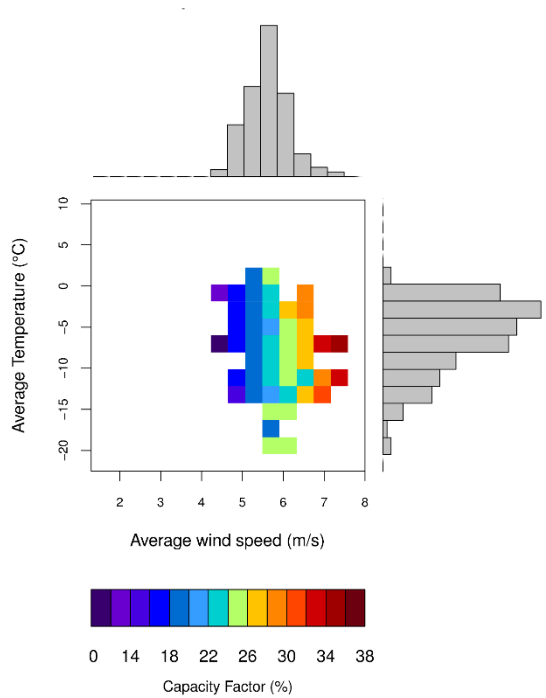
1. **Past observations of CF , WS and T are discretized and represented in an impact surface.**
2. **Predictions in the target period of WS and T are discretized and represented in an impact surface.**
3. **Each box of the two impact surfaces are combined to provide the capacity factor prediction.**

Impact Surfaces

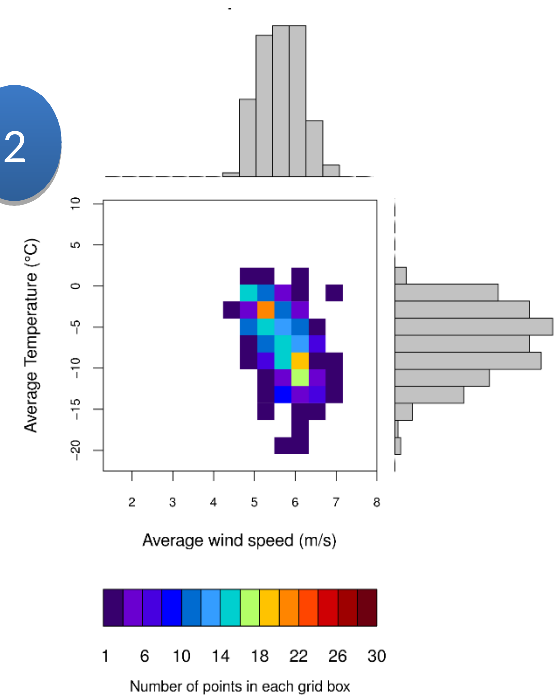
Central US region

1

Past observations of CF. December (1981-2011)



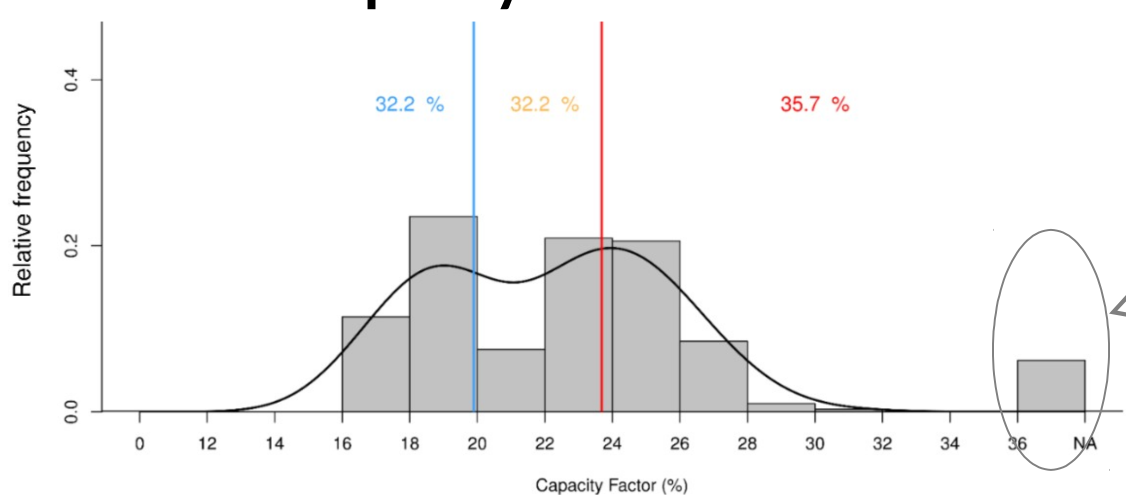
2



Simple bias correction. WS and T bias corrected forecasts. December (2012)

3

Forecast of capacity factor for December 2012



N/A values !!!