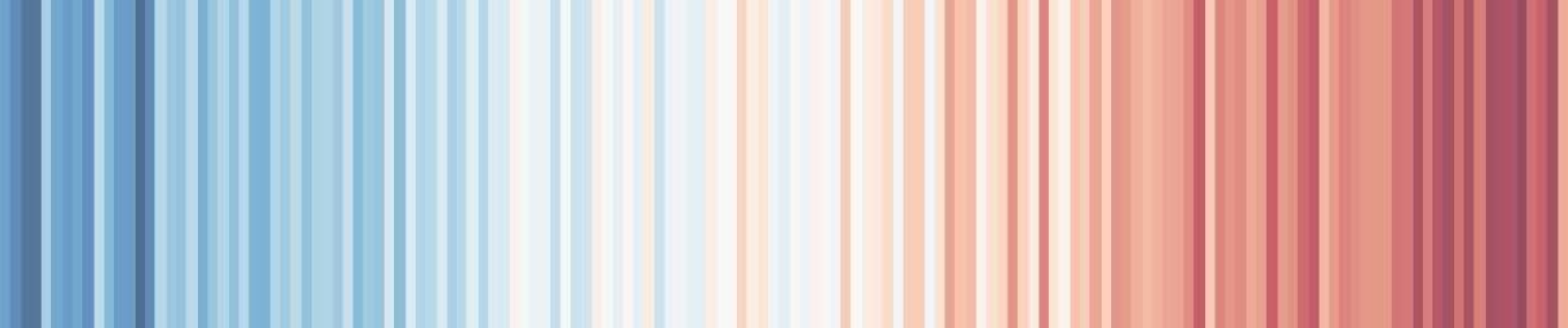

KliWiSt – Predicting future wind speeds based on climate projections and MCP methods

Fraunhofer IWES

Johanna Borowski, Martin Dörenkämper

Supported by:

Federal Ministry
for Economic Affairs
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KliWiSt

GERICS Climate Service Center Germany
Eine Einrichtung des Helmholtz-Zentrums Hereon

Helmholtz-Zentrum hereon

Fraunhofer IWES

Motivation

High resolution time series-based analysis

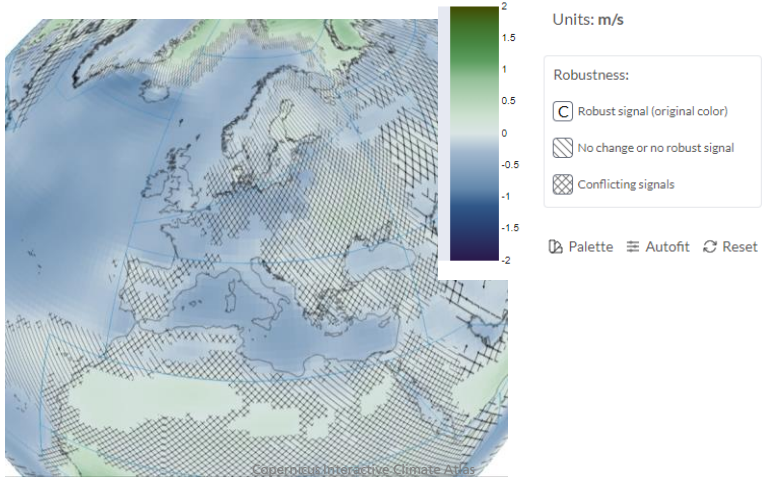
- State-of-the-Art (TR6 – Rev.10):
  Assumption of persistence of past wind climate
  (+ maybe additional uncertainty)

- Still valid?
  - Timing of energy production (e.g. by time of day and season) becomes more crucial

- How to improve?
  - Include future climate information in wind resource assessment
  - Perform time series analysis in addition to mean values

  → Data based uncertainty estimation

  → Analysis of seasons and time of day possible



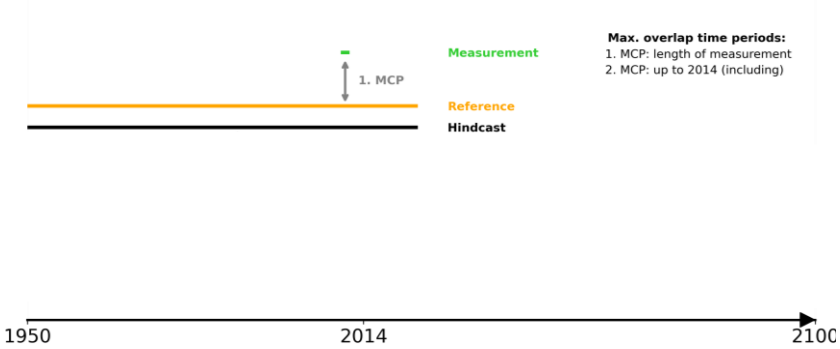
Method

Handling climate model data in wind resource assessment

Borowski et al. - Part 1 (in internal review) on the impact of inter-annual variability on long-term wind speed predictions based on the MCP method

Base: State-of-the-Art method to predict hindcast wind speed
(using Measure-Correlate-Predict (MCP) Methodology)

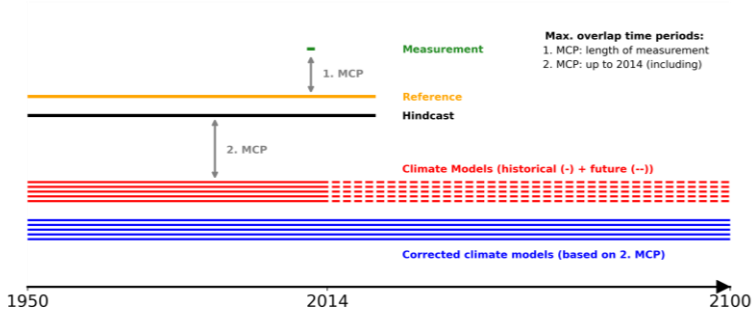
- Input:
  - **Short-term on-site data (One-year measurement)**
  - **Long-term reference data (e.g. reanalysis)**
- Output:
  - **Hindcast:** Prediction of wind speeds of the past
    - Including: Site specific wind characteristics and long-term wind variability
- Method:
  - Statistical relationship (correlation): e.g. linear regression



Method

Handling climate model data in wind resource assessment

- Input:
  - **Hindcast**
  - **Ensemble of climate models (historical)**
- Output:
  - **Corrected climate models (ensemble)**: Prediction of the wind climate from past to future
- Method to link input data:
  - Statistical relationship (correlation): e.g., linear regression
    - **Issue**: Time inconsistency between Hindcast and climate models data sets



Issue: Excurse – Weather forecast VS Climate model

Initial value – Boundary value problem

Weather Model/Reanalysis ⟷ ! Connection not time consistent ! ⟷ **Climate Model**

- Short-term predictions (**hours to days**)
- High precision thanks to accurate **initial conditions**

- Long-term trends and averages (**decades to centuries**)
- Focus on **boundary conditions** and **external drivers** (e.g., CO_2 emissions, solar cycle, Ocean currents, Weather Systems (e.g. NAO))

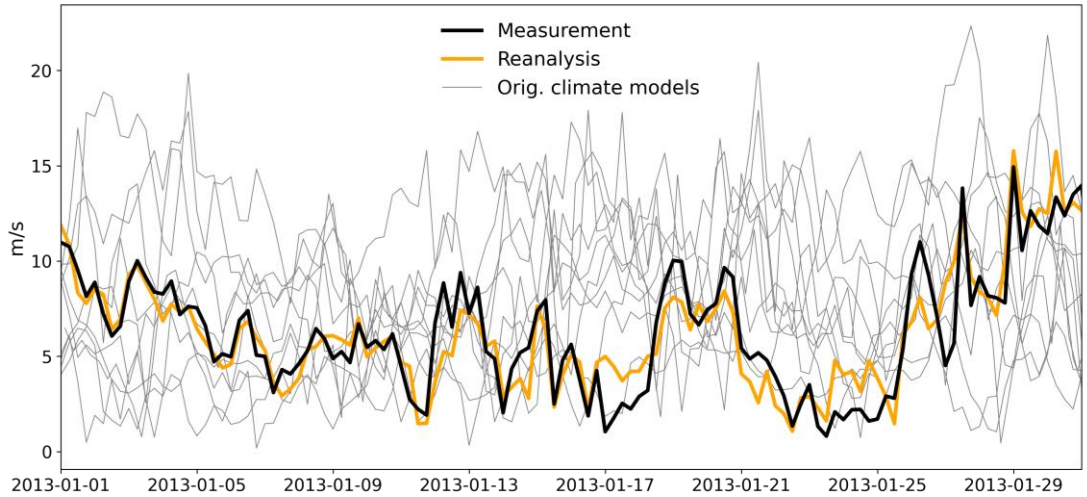
The uncertainties in the initial conditions grow strongly over longer periods of time, which makes it impossible to make precise long-term predictions based on initial values alone.

!!! Climate model data represent averages/trends/statistical values **BUT NOT** a precise prediction for a certain time step !!!

Problem: Excurse – Weather forecast VS Climate model

Visualization

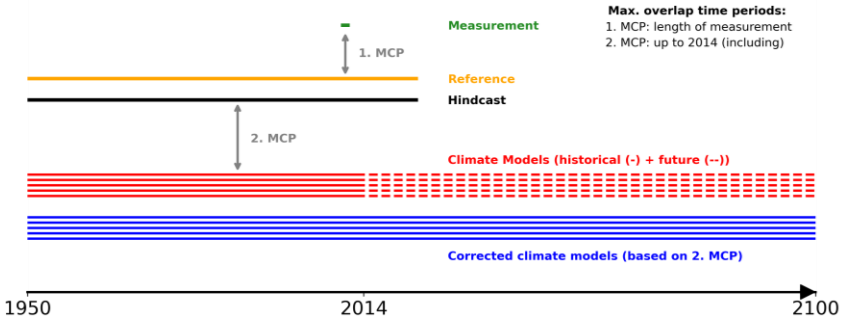
- Weather model/reanalysis:
  - Exact values at the specified time steps!
- Climate models:
  - Represent the probabilistic value of the time step based on the surrounding decades!



Solution

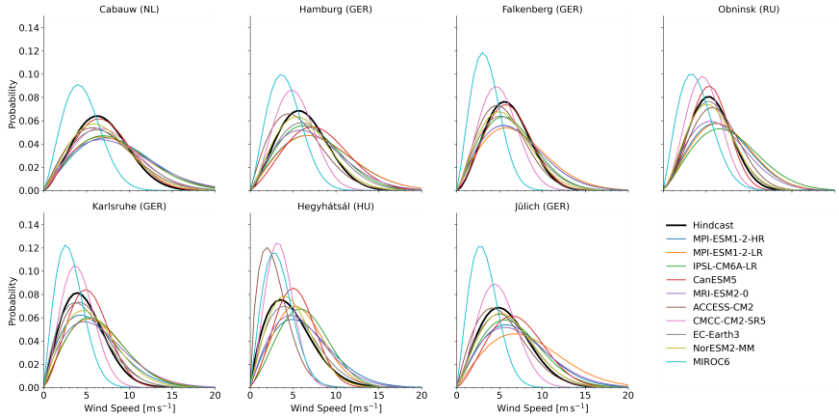
Handling climate model data in wind resource assessment

- Input:
  - **Hindcast**
  - **Ensemble of climate models (historical)**
- Output:
  - **Corrected climate models (ensemble)**: Prediction of the wind climate from past to future
- Method to link input data:
  - Statistical relationship (correlation): e.g., linear regression
    - **Solution**: Methods that do not require time consistency

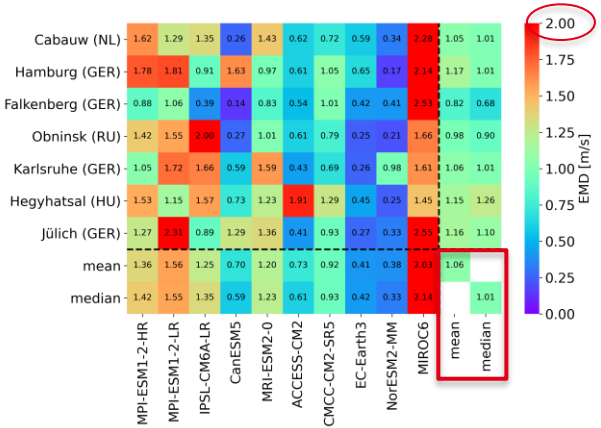


Historical: Validation

Original climate models (CMs)



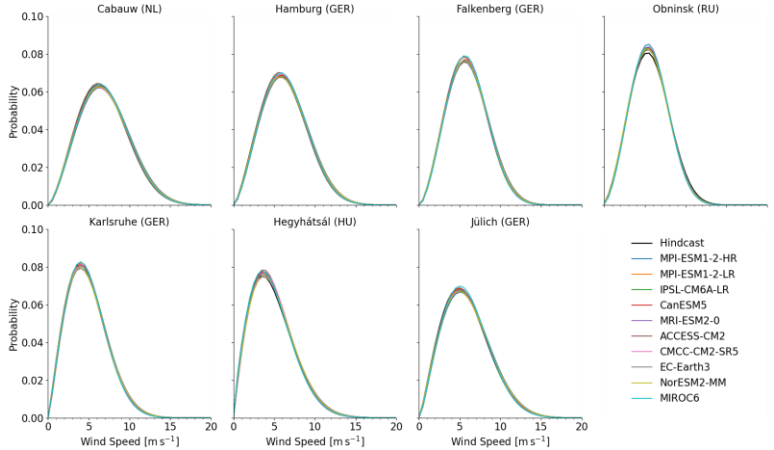
- Earth Mover's Distance (EMD) used here to compare two histograms
- Performance of climate models in the past:
  - Site dependent
  - Mean of EMD: 1.06 m/s
  - High-resolution models fit better to hindcasts than low-resolution models at most sites (e.g., MPI-ESM1-2-HR/LR)

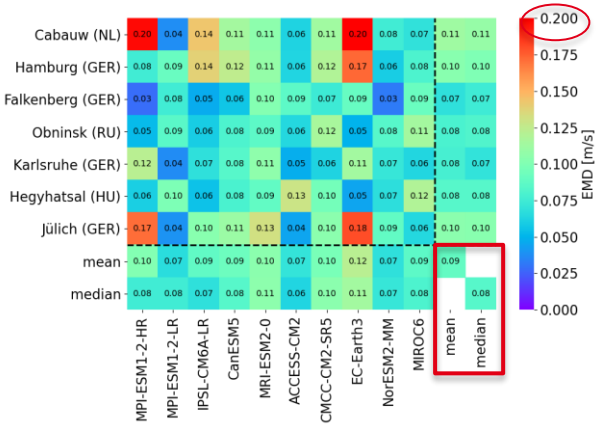


Historical: Validation

Corrected climate models (CMs)

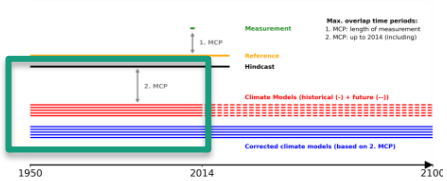
- Method is beneficial
  - Reduction of EMD: 0.09 m/s (vs 1.06 m/s)
  - Correction depending on site
  - Regardless of resolution (low/high): models can be fitted quite well
- Seasonal cycle?



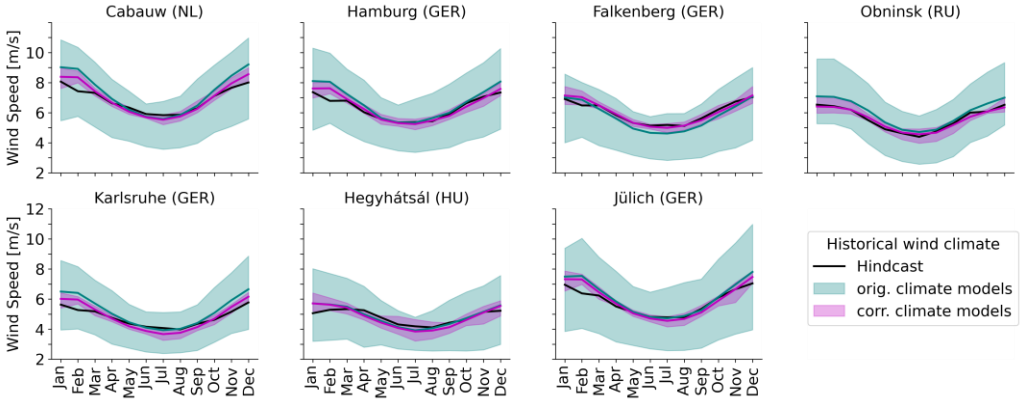


Historical: Validation

Seasonal cycle



- Improvement:
  - Monthly mean of corrected CMs fit better to Hindcast
  - Reduction of spread of CMs
  - Greatest adjustment: Winter
- Further improvements:
  - Usage of downscalings/regional models

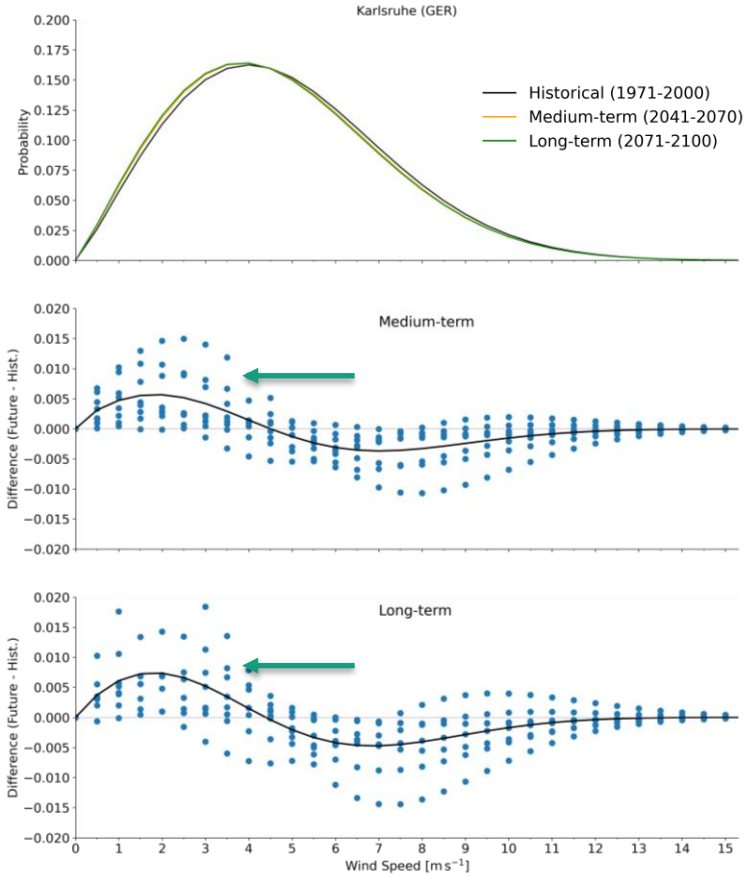


Future Wind Ressource

Karlsruhe: Historical – medium – long-term

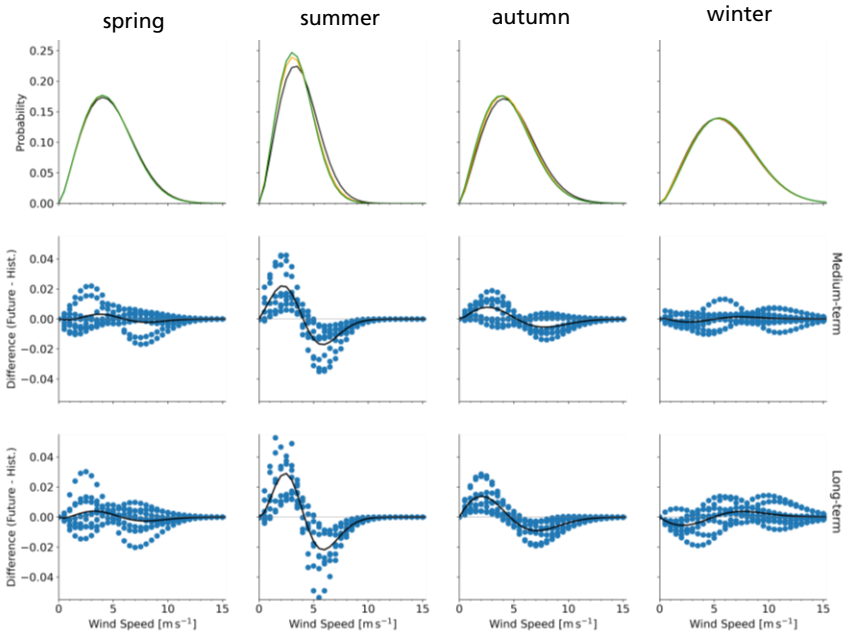
Scenario: Worst case scenario (SSP5 – 8.5)

- Minor differences between historical and future
- More frequent: Low wind speeds (< 4 m/s)
  - More frequent shutdowns
- Less frequent: 5 – 10 m/s
- Spread of CMs: Slightly higher for long-term



Seasonal Future Wind Ressource

Karlsruhe: Historical – medium – long-term



Scenario: Worst case scenario (SSP5 – 8.5)

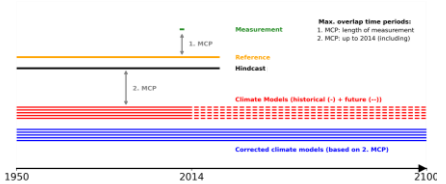
- Difference: Future – Historical
- Degree of deviation varies by season
- Partly conflicting signals:

Wind speed change	Higher to lower	Lower to higher
Clear signal	Summer Autumn + long-term	
Conflicting signal	Spring Autumn + medium-term	Winter + (medium)/long-term

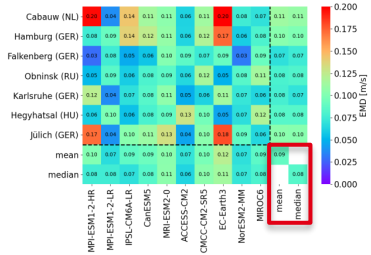
Borowski et al. – *Part 2* (in preparation): Predicting future wind speeds based on climate projections and MCP methods

Conclusion

- **Workflow** to **incorporate climate models** at a **specific site**
  - High resolution: **6 hourly** instead of daily/monthly/annual means
  - **Method** can be used with **every climate model** data set **on any site**



- Future wind speed changes:
  - **Tendency to lower wind speeds** at some sites
    - Seasonal differences
    - Differences in medium- and long-term



- Further improvement: Usage of downscaling/regional climate models
  - **CMIP6 downscaled models** (in preparation) will provide hourly resolution

Thank you for your attention

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