Wind speed maps for Austria: An artificial-intelligence approach

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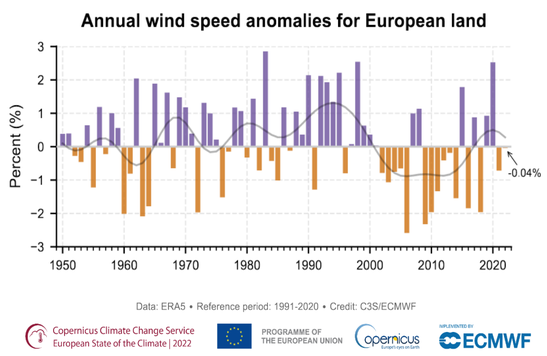
1. Motivation

Past

http://s0.geograph.org.uk/geophotos/02/57/05/2570527_eea1b3ec.jpg

Present



Future

?

Wind in future climate

- Wind energy plays a crucial role in energy transition and hence in future energy generation. Therefore the question: How do wind resources change in future climate?
- Goal of the project ‚Wind4Future': Improve knowledge about impacts of climate change on wind energy potential in Austria
- To assess future wind speed from global and regional climate models, climatological wind speed maps with high spatial and temporal resolution are needed for Austria
- Requirements for maps that cover the territory of Austria
  - Cover period: 1991 to 2020
  - Temporal resolution: hourly (or subhourly)
  - Spatial resolution: horizontal 1 km x 1 km (or sub-km) and different vertical levels
  - Should consider wind speed observations

2. Modelling setup

Station data

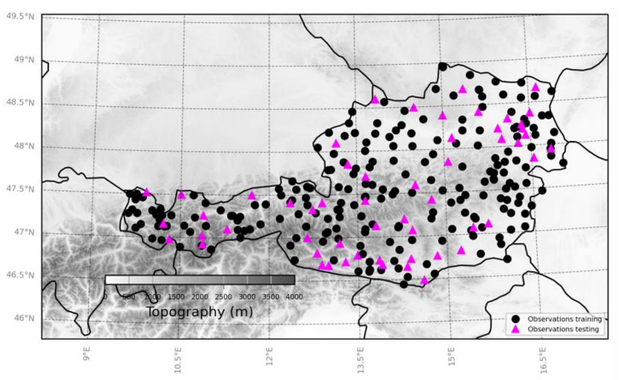


Fig.1: Location of measurement sites. Black: Stations for training, Pink: Stations for verification

- ~ 250 measurement sites with 10 m wind speed operated by the national weather service in Austria
- Experimental setup covers time period 2006 to 2022 (16 years)
- Data is quality controlled but gaps in time series are (not yet) filled
- Sub-setting to a random forest 85 % / 15 %-selection of sites below / above 1 000 m altitude
- Remaining non-used sites are used in verification process

Interpolation methods

<u>Generalized additive regression model (GAM) using BAMLSS</u>

- principle similar to GAM/GLM regression kriging
- two simple baseline approaches, fitted and predicted for every hour of the day separately (no globally pre-trained model used):
- *approach 1:* station and topography based, uses current station observations of wind speed and site metadata, predicted on the grid
- *approach 2:* uses station observations of wind speed, site metadata, and the ERA5 10 m wind speed at the location site for fitting, ERA5 field and topography for prediction/interpolation.

<u>Deep Neural Network (DNN) model (ongoing)</u>

- Based on the work of Amato et al. (2020)
- Using topographic information and fitting on SVD-decomposed observations
- Baseline: only topography and observations used

3. Challenge

Roughness length calculations for extrapolation of wind speed

<u>Motivation:</u>
Not for all sites a roughness length is available or seasonal changes / different behaviour per wind direction are present, respectively.

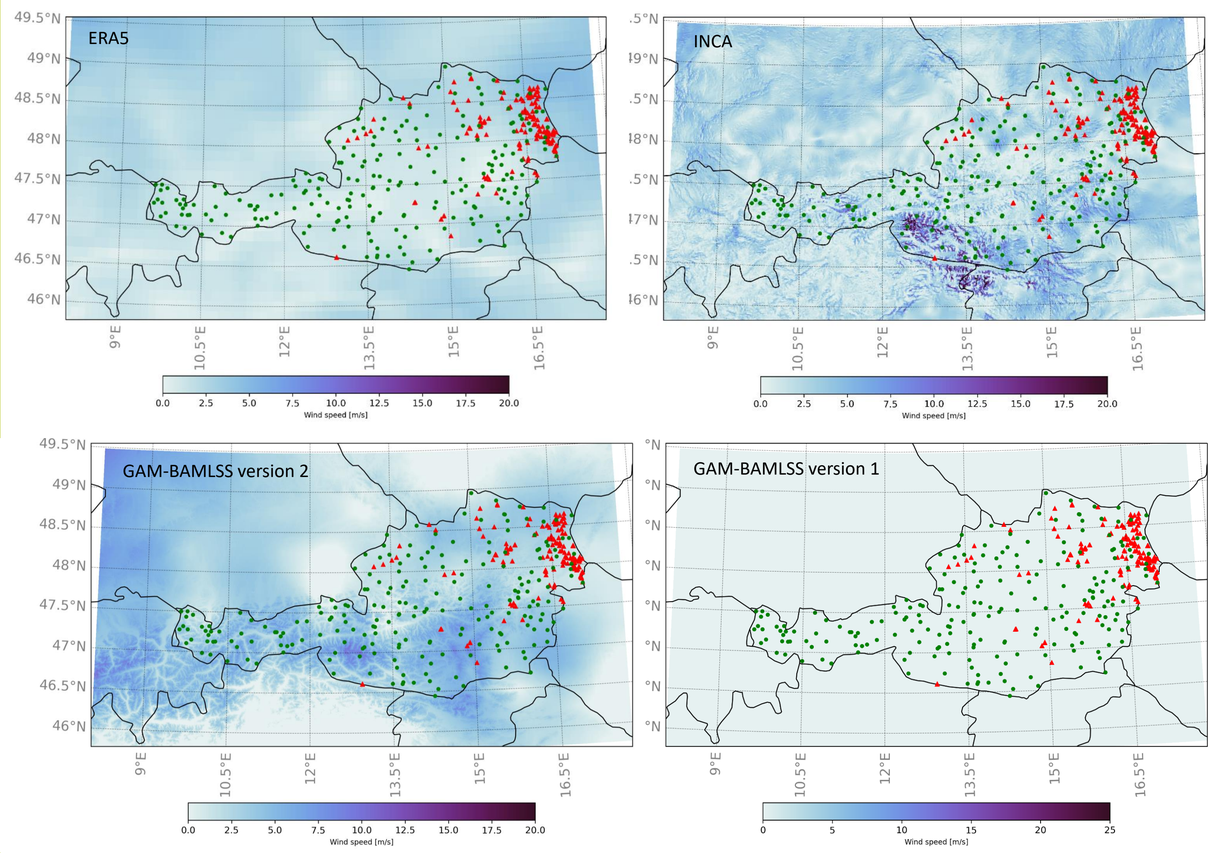
<u>Open questions:</u>

- What to use for ‚first shot' extrapolation of wind analysis maps to include as much details as possible?
- Can we safely use z0-approximation (see Alserkans 2022)? Other possibilities?

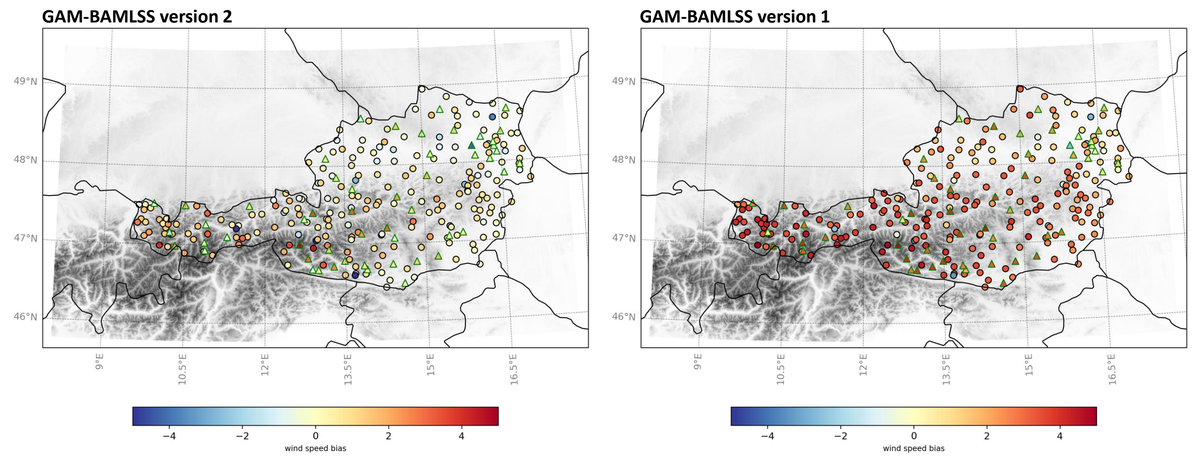
$$z0 = z\,exp\left(-C * k * \left(\frac{v}{Sigma_v}\right)\right)$$

4. Preliminary interpolation results

Test case June 12, 2018 (15 UTC)



5. Preliminary validation results test year



BIAS
In-sample BIAS = 0.48 m/s
Out-sample BIAS = 0.75

BIAS
In-sample BIAS = 2.59 m/s
Out-sample BIAS = 2.65

6. In a nutshell …

- **Motivation:** Investigation of wind resources in Austria in future climate
- **Problem:** Lack of gridded wind speed analyses for the past years with a spatial resolution of 1 km x 1 km
- **Approach:** Interpolation of wind speed observations with statistical (GAM), statistical-dynamical (INCA) and artificial-intelligence (DNN) approaches
- **(Preliminary) results:** Technical requirements are met, scientific evaluation still ongoing
- **Outlook:** Downscaling of climate models using newly generated historic wind speed dataset; Investigating future wind power potential

Literature
Haiden T, Kann A, Wittmann C, Pistotnik G, Bica B, Gruber C. 2011. The Integrated Nowcasting through Comprehensive Analysis (INCA) System and Its Validation over the Eastern Alpine Region. Weather and Forecasting, 26/2, 166-183, doi: 10.1175/2010WAF2222451.1
Alerskans, E. M. K. (2022). *Hyper-local forecasting system for agricultural applications*. Niels Bohr Institute, Faculty of Science, University of Copenhagen.
Amato, F., Guignard, F., Robert, S. et al. A novel framework for spatio-temporal prediction of environmental data using deep learning. Sci Rep 10, 22243 (2020). https://doi.org/10.1038/s41598-020-79148-7

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