MEDEA - Meteorologically induced extreme events detection for renewable energy using data driven methods: from weather prediction to climate time scales

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Objectives

Renewable energy production increased in the past years and will continue rising to serve the ambitious goal of (near) zero fossil fuel energy. Given the weather dependency of renewables any sort of extreme event for the respective power system this poses a threat to grid stability, security, and the whole environment. Planning ahead of taking prevention measures to secure energy supply and serve the energy demand needs knowledge on the possibility of occurrence of meteorologically driven extreme events.

In MEDEA, we tackle this by:

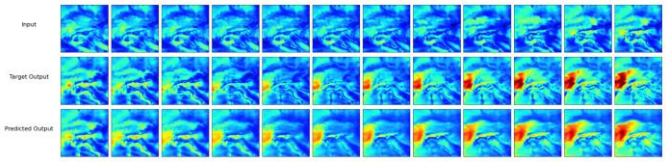
- **Defining** and **identifying meteorologically driven extreme events** for the renewable (solar, wind) power system. This includes "typical" meteorological events which can pose a threat to the system such as prolonged calm episodes with low stratus clouds resulting in reduced wind and solar energy production.
- Develop **automatic** and **data-driven methods** for the **detection of anomalies and causalities** within the weather, climate, and power production data
- **Improving** and **developing machine learning forecasting methods** based on the detection methods for prediction of extreme events for the next days ahead
- **Determine** the **return period** and **frequency** of such events using climate simulations.

Results

Result 1 – WP3 Clustering and anomalies prediction for wind extremes

Based on a ConvLSTM with adapted weighting of loss function and adapted metric using 10 years of ERA5 data for training.

Application to ECMWF IFS forecasts as well as AROME currently in preparation.

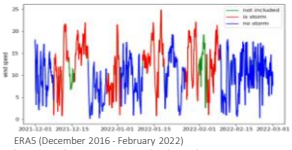


Result 2 – WP4 Granger Causal relationship for storm events

The method HMML determines Granger causal relationships among p > 3 variables using the minimum message length principle (MML) and genetic algorithm for optimization.

$$x_i \approx \nu_i(\beta_i \mathbf{X_i})$$

x_i = wind speed
ν_i = link function
$\mathbf{X_i}$ = subset of all features
beta_i = vector of causal coefficients of target variable x_i



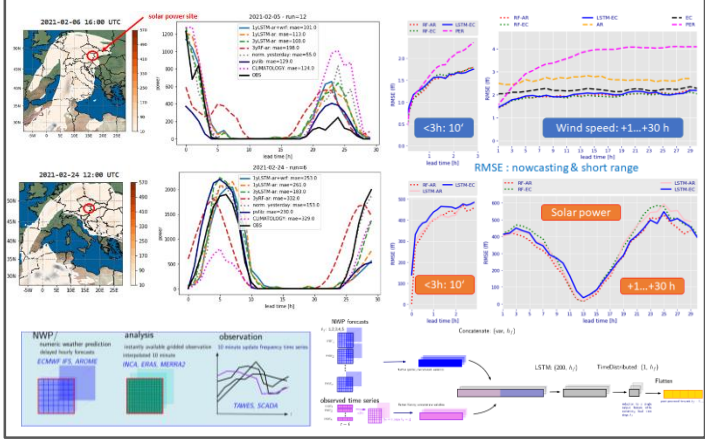
ERAS (December 2016 - February 2022)
lat = 47.74, lon = 17.0, pressure level = 950hPa

Table: Average causal strength of variables

Variables	(long name)	No Storm	Storm
blh	boundary layer height	0.60	0.53
cape	convective energy	0.45	0.32
d	divergence	0.50	0.58
cc	cloud cover	0.65	0.47
z	geopotential	0.55	0.63
o3	ozon mass mixing	0.55	0.68
pv	potential vorticity	0.70	0.74
r	relative humidity	0.60	0.56
q	specific humidity	0.65	0.68
t	temperature	0.70	0.68
vo	relative vorticity	0.60	0.74
w	vertical velocity	0.65	0.74
wd	wind direction	0.35	0.74
ws	wind speed	0.45	0.68

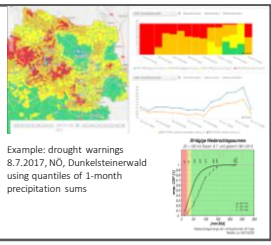
Result 3 – WP 5 Prediction of meteorologically induced extreme events

Sequence-to-Sequence LSTM and random forest used to combine WRF, AROME-forecast, and observation for solar power prediction in East Austria during Sahara dust events.



Result 4 – WP 5 climate indices

- Sustained drought: creation of a continuous precipitation deficit / warning values based on thresholds were calculated for every Julian day.
- HDD/CDD: calculation of heat days, etc. and relation to HDD/CDD
- Precipitation totals based on OEKS15 for RCP2.6, RCP4.5, and RCP8.5



Example: drought warnings 8.7.2017, NÖ, Dunkelsteinerwald using quantiles of 1-month precipitation sums

Dissemination and publications

- **EGU 2021:** Petrina Papazek and Irene Schicker: A deep learning LSTM forecasting approach for renewable energy systems,
- **EGU 2021**: Schicker, I., Papazek, P., Perrone, E., and Arnold, D.: Spatio-temporal ensemble predictions for wind and solar energy combining dispersion modelling methods and machine learning,
- **EMS 2021:** Forecasting of Meteorologically Driven "Extremes" in Wind and Solar Power: Can We Tackle and Improve Selected Cases of Nonforecasted Extreme Events using Deep Learning?, Petrina Papazek, Irene Schicker, and Rosmarie de Wit
- **EMS 2021:** Scheepens, D., Hlavackova-Schindler, K., Plant, C., and Schicker, I.: A deep CNN model for medium-range spatio-temporal wind speed prediction for wind energy applications, EMS Annual Meeting 2021,
- **EMS 2021:** Schicker, I. and DeWit, R.: MEDEA - Meteorologically induced extreme events detection for renewable energy using data driven methods: from weather prediction to climate time scales, EMS Annual Meeting 2021,
- **EGU 2020**: A Deep Learning Method for Short-Range Point Forecasts of Wind Speed, Petrina Papazek and Irene Schicker

In preparation:
Scheepens, D., Schicker, I., Hlavackova-Schindler, K., Plant, C.: A deep convolutional RNN model for spatio-temporal prediction of wind speed extremes in the short-to-medium range for wind energy applications.

Progress

Synergies ACRP projects

- HirMod, ACRP 2009
- PRESENCE, ACRP 2011
- NetZero204
- EXAFOR
- CHIANTI

Dieses Projekt wird aus Mitteln des Klima- und Energiefonds gefördert und im Rahmen des Programms ACRP, MEDEA, KR19AC0K17615, durchgeführt.

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