

ExtremA 2023

Stürme, Windereignisse

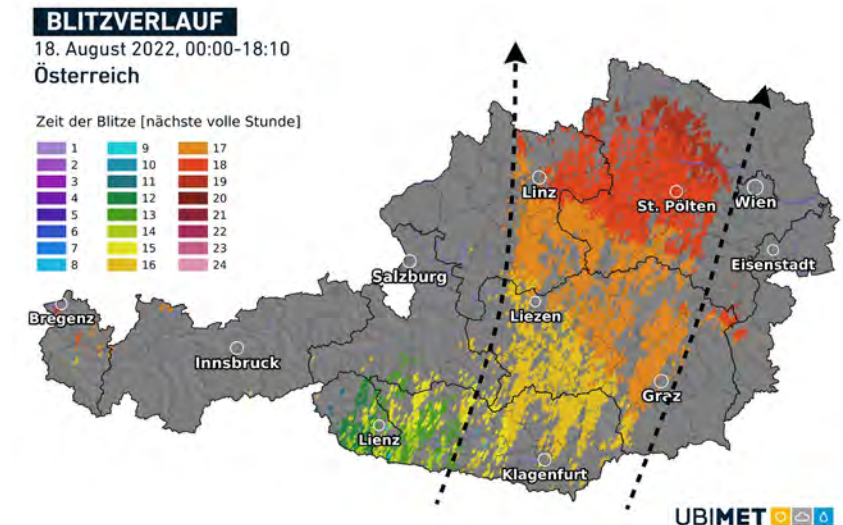
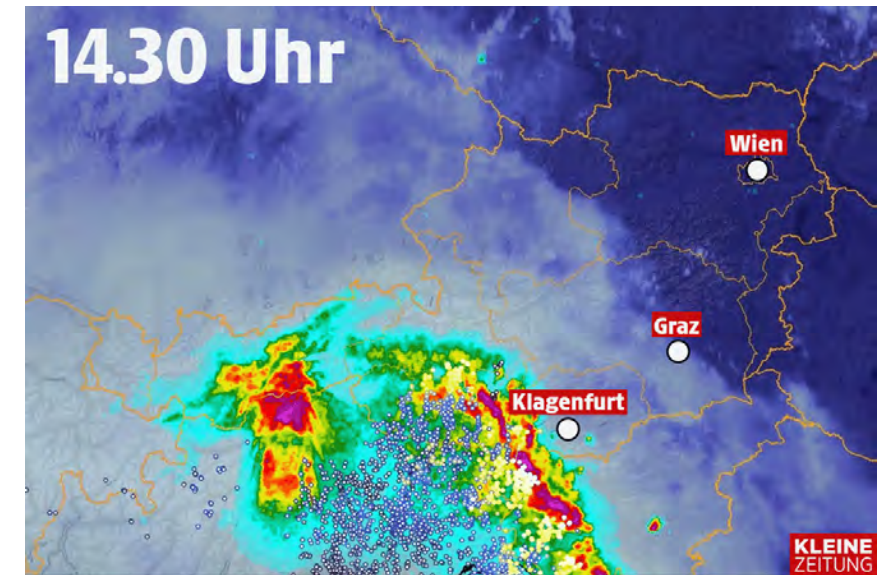
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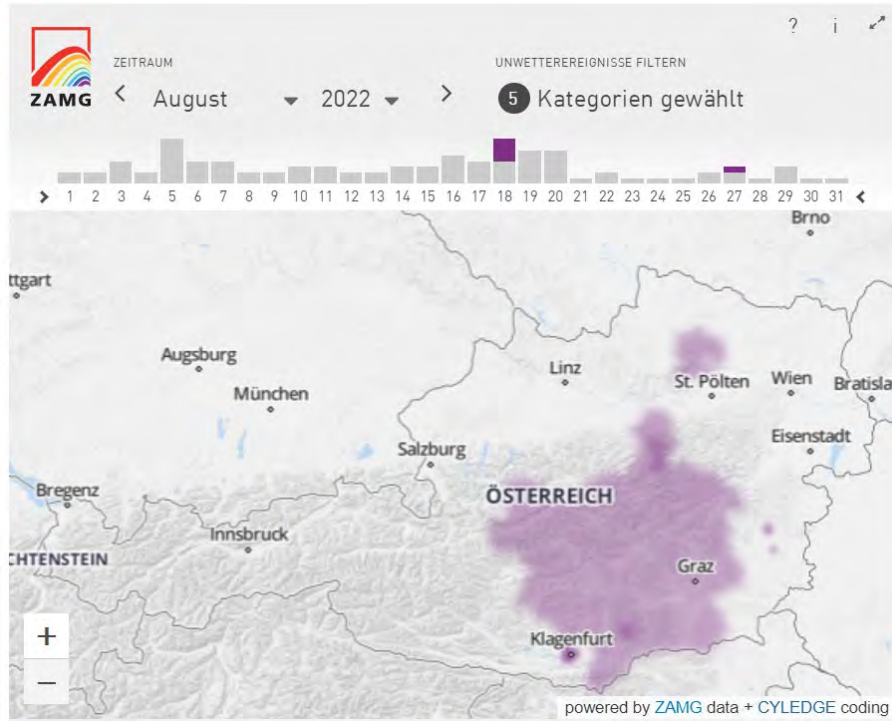
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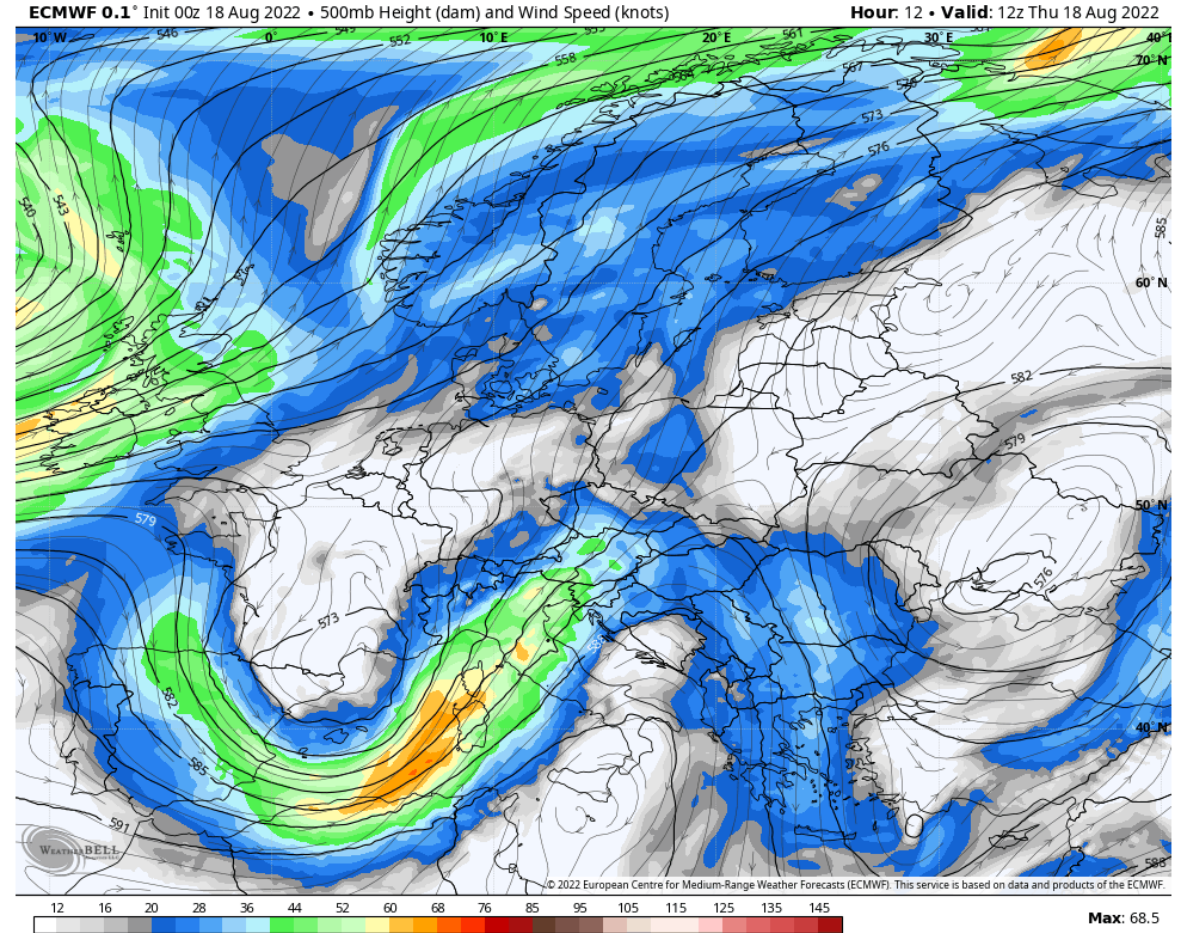
- Extreme Windgeschwindigkeiten, Böen und langanhaltend “normal stärkere” Windgeschwindigkeitsereignisse aber auch hybride Ereignisse (Wind + Niederschlag) können die Infrastruktur, Landwirtschaft, Energieproduktion stark beeinflussen und stören.
- Sturm Lothar (Dezember 1999) verursachte Schäden im Ausmaß von 12 Milliarden US\$.
- Obere und untere Percentile der jeweiligen Verteilungen sind oft entweder nicht ausreichend reproduziert bei Modellen, oft sind hier höhere räumliche und zeitliche Auflösungen nötig bzw. sogenannte rapid update cycle (RUC) Modelle welche stündlich gerechnet werden und die aktuellen Daten (Satelliten, Radar, Beobachtungen) assimilieren.
- Wichtiger Parameter: 98er Perzentil der täglichen maximalen Windgeschwindigkeit (W98), oft verwendet in Abschätzungen für die Konvertierung der verursachten Schäden in Geldwert.
- Zusätzliche Faktoren in den Alpen: hohe räumliche Variabilität, starker Einfluss der Topographie. Rücken, Kämme, tiefe/enge Täler, Talwindssysteme

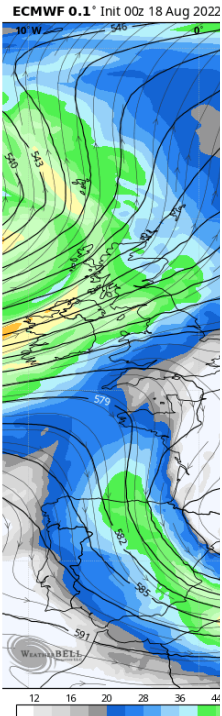


- Fallbeispiel Wind und Vorhersagbarkeit
- Vorhersage von Wind-Extremereignissen quer durch die Vorhersagezeiträume
- Ausblick



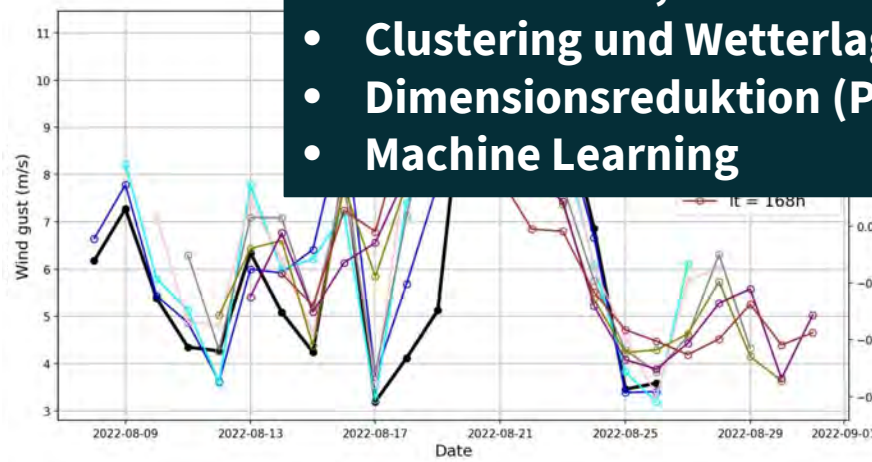
- WIND SCHWERE WINDBÖE**
 18. AUGUST
 Gaming, Krems (Land), Scheibbs
- WIND SCHWERE WINDBÖE**
 18. AUGUST
 Kemeten, Pinkalied
- WIND SCHWERE WINDBÖE**
 18. AUGUST
 Bruck-Mürzzuschlag, Murtal, Leoben, Graz-Umgebung, Deutschlandsberg, Murau, Leibnitz, Voitsberg, Weiz + 2 weitere
- WIND SCHWERE WINDBÖE**
 18. AUGUST
 St.Andra, Vöckernmarkt, Sankt Veit an der Glan, Wolfsberg, Lavanttal
- WIND SCHWERE WINDBÖE**
 27. AUGUST
 Klagenfurt (Stadt)





Detektion(?)....

- EFI Index des ECMWF: recht einfach, schnell, robust
- Schwellwerte, ähnlich zu EFI
- Clustering und Wetterlagenklassifikation
- Dimensionsreduktion (PCA, EOF)
- Machine Learning



takes no direct account of
y ENS members beyond
the M-climate extreme

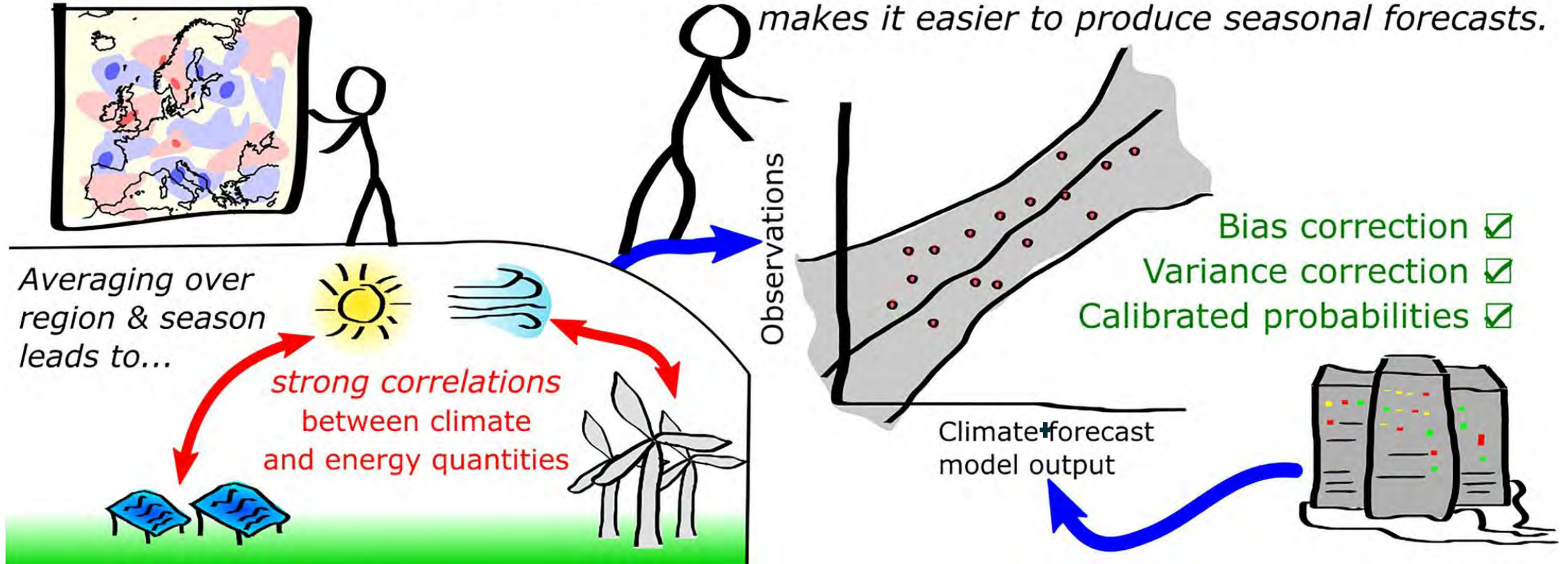
sums the area between
M-climate and the ENS
giving more weight to the
extremes

$$EFI = \frac{2}{\pi} \int_0^1 \frac{Q - Qf(Q)}{\sqrt{Q(1-Q)}} dQ$$

$-1 \leq EFI \leq 1$
 $-100\% \leq EFI \leq 100\%$

Skill in wind & irradiance is patchy...

*... but where there **is** skill, **linear regression** makes it easier to produce seasonal forecasts.*



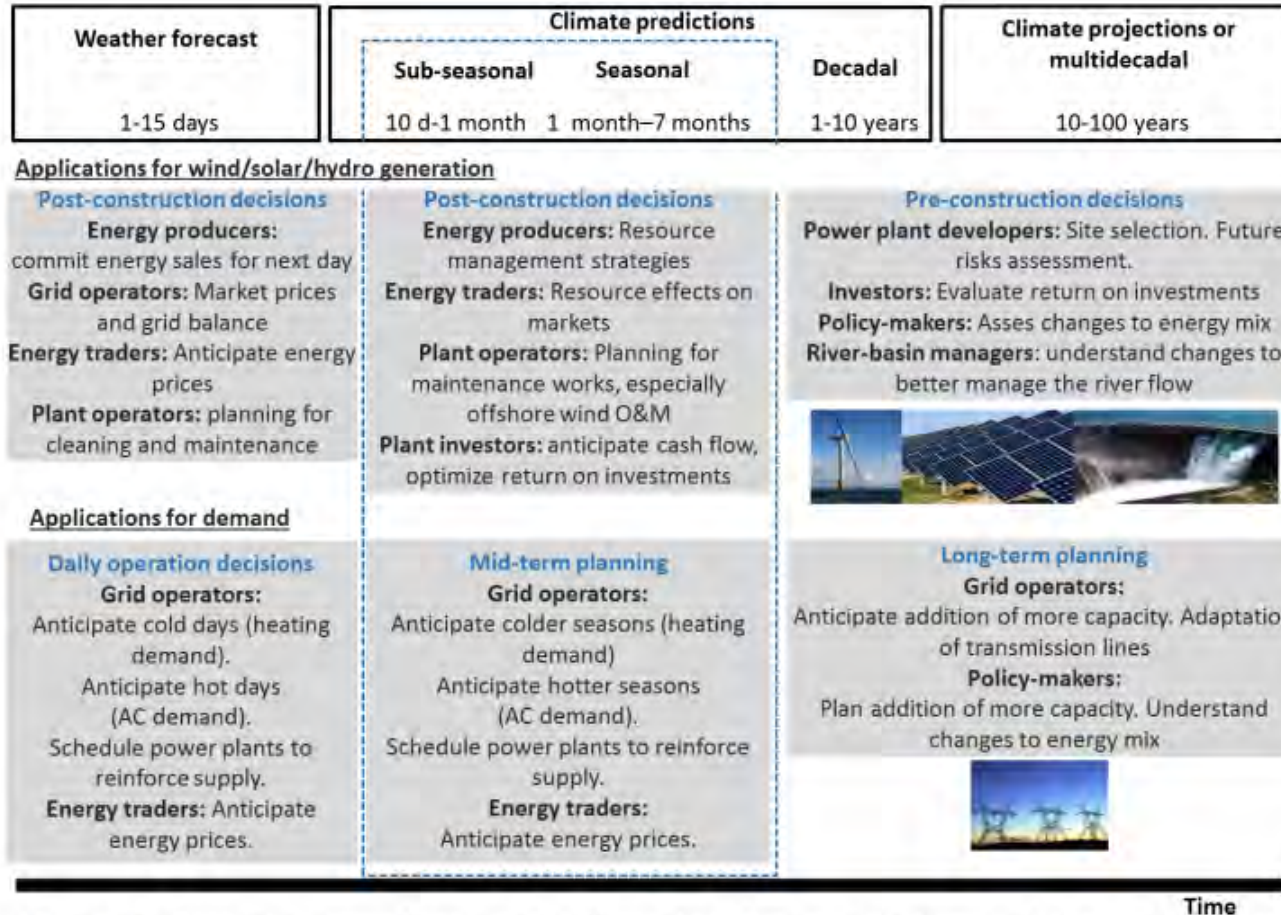


Figure 1. Forecast systems from weather forecast to climate projections including also climate predictions and their potential applications to the energy sector depending on the forecast window. Dotted line highlights the potential applications by using sub-seasonal to seasonal climate predictions.

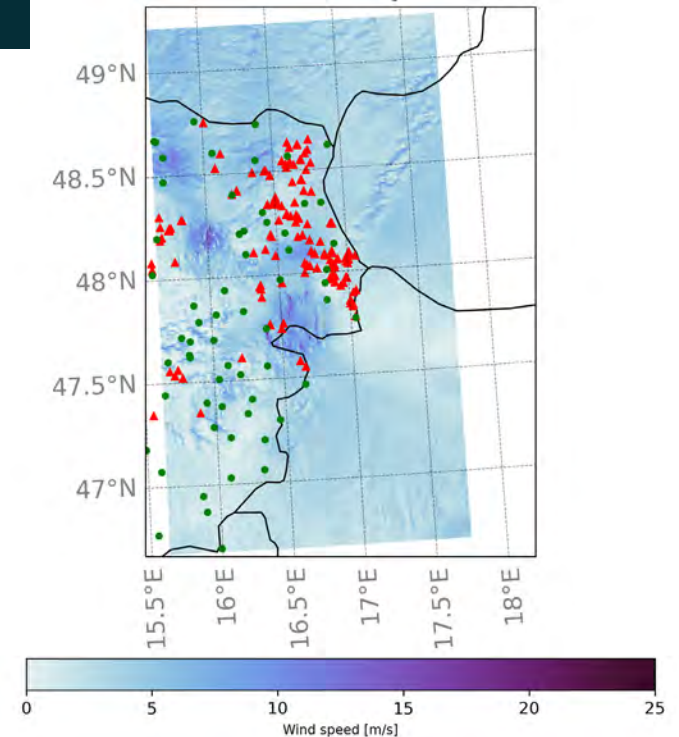
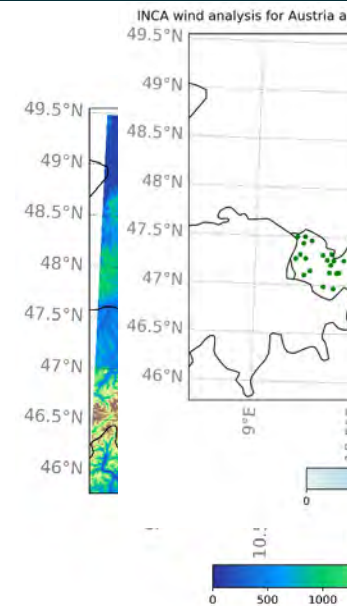
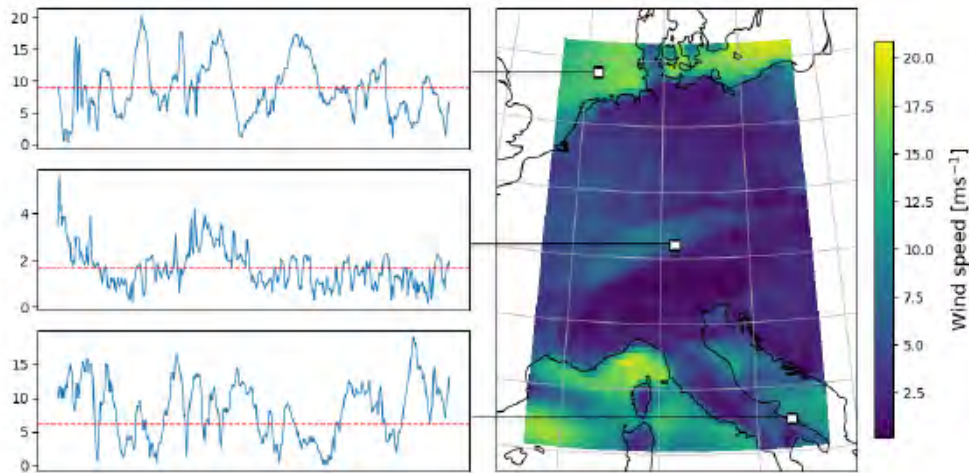
Coarse resolution data-driven part:

- ERA5 hourly data on pressure levels from 1979 to present
- Pressure levels: 1000, 925, 850, 775 hPa
- U, v converted to wind speed
- 1979 – 2010 used for training, 2011 – 2018 used for validation, 2019 – 2021 testing
- 4-fold cross validation 8(6+2)+2
- 64 x 64 grid points between 40-50° N and 5-15° E, 0.25° resolution

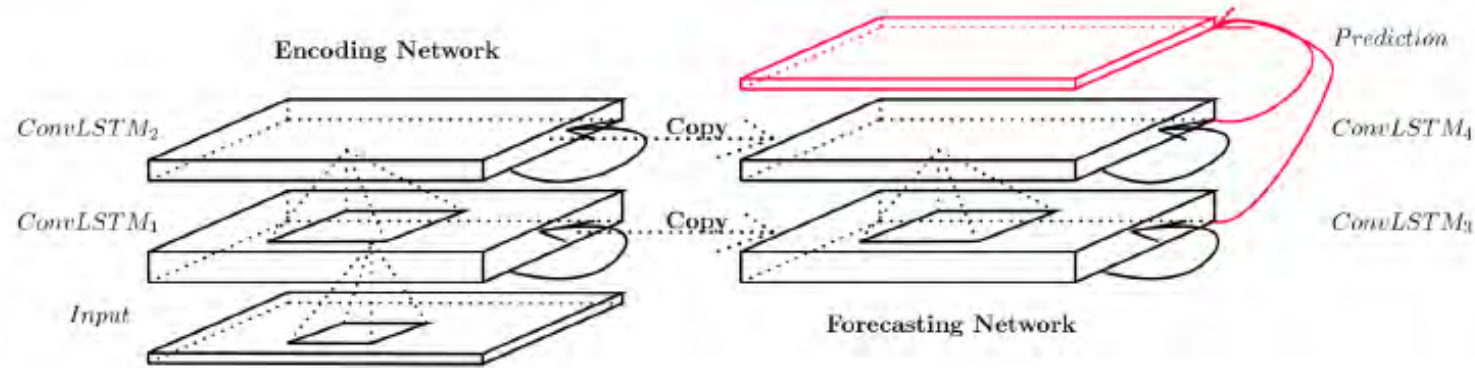
Machine learning to the rescue

High resolution experimental study:

- INCA (Integrated Nowcasting and Analysis) model hourly analysis of 10m wind components converted to wind speed
- Training data: 2014 – 2019, validation 2020, testing 2021-2022



- Multi-layered convolutional long short-term memory (ConvLSTM) network



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- We use 12 frames as input and 12 frames to forecast, i.e:

$(12 \times 64 \times 64)$ input \rightarrow ... bottleneck ... $\rightarrow (12 \times 64 \times 64)$ forecast

- Investigation of architectures with 2-5 layers
- Minibatch gradient descent, Adam optimiser and early-stopping on the validation set
- Trained with **imbalanced regression loss**

- Inversely Weighted Loss

$$L_W(\hat{y}, y) = \frac{1}{N} \sum_{n=1}^N \sum_{i,j=1}^M w(y_{n,i,j}) \cdot L(\hat{y}_{n,i,j}, y_{n,i,j})$$

standardised wind speed [σ]	Proportion [%]
$y < 0$	55.74
$0 \leq y < 1$	28.39
$1 \leq y < 2$	11.89
$2 \leq y < 3$	3.23
$3 \leq y < 4$	0.63
$4 \leq y$	0.11

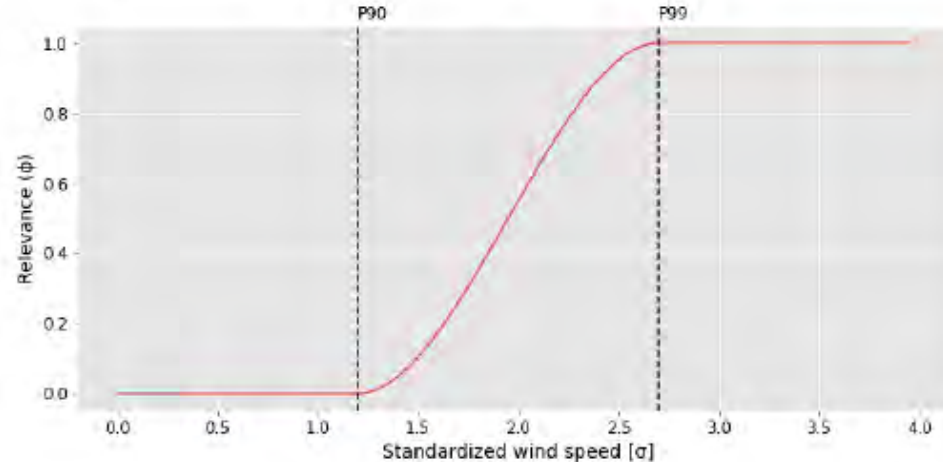
$$w(y) = \begin{cases} 1.0 & \text{if } y < 0 \\ 2.0 & \text{if } 0 \leq y < 1 \\ 4.7 & \text{if } 1 \leq y < 2 \\ 17 & \text{if } 2 \leq y < 3 \\ 88 & \text{if } 3 \leq y < 4 \\ 490 & \text{if } 4 \leq y \end{cases}$$

- W-MAE
- W-MSE

- SERA Loss

Relevance function: $\phi : \mathcal{Y} \rightarrow [0,1]$

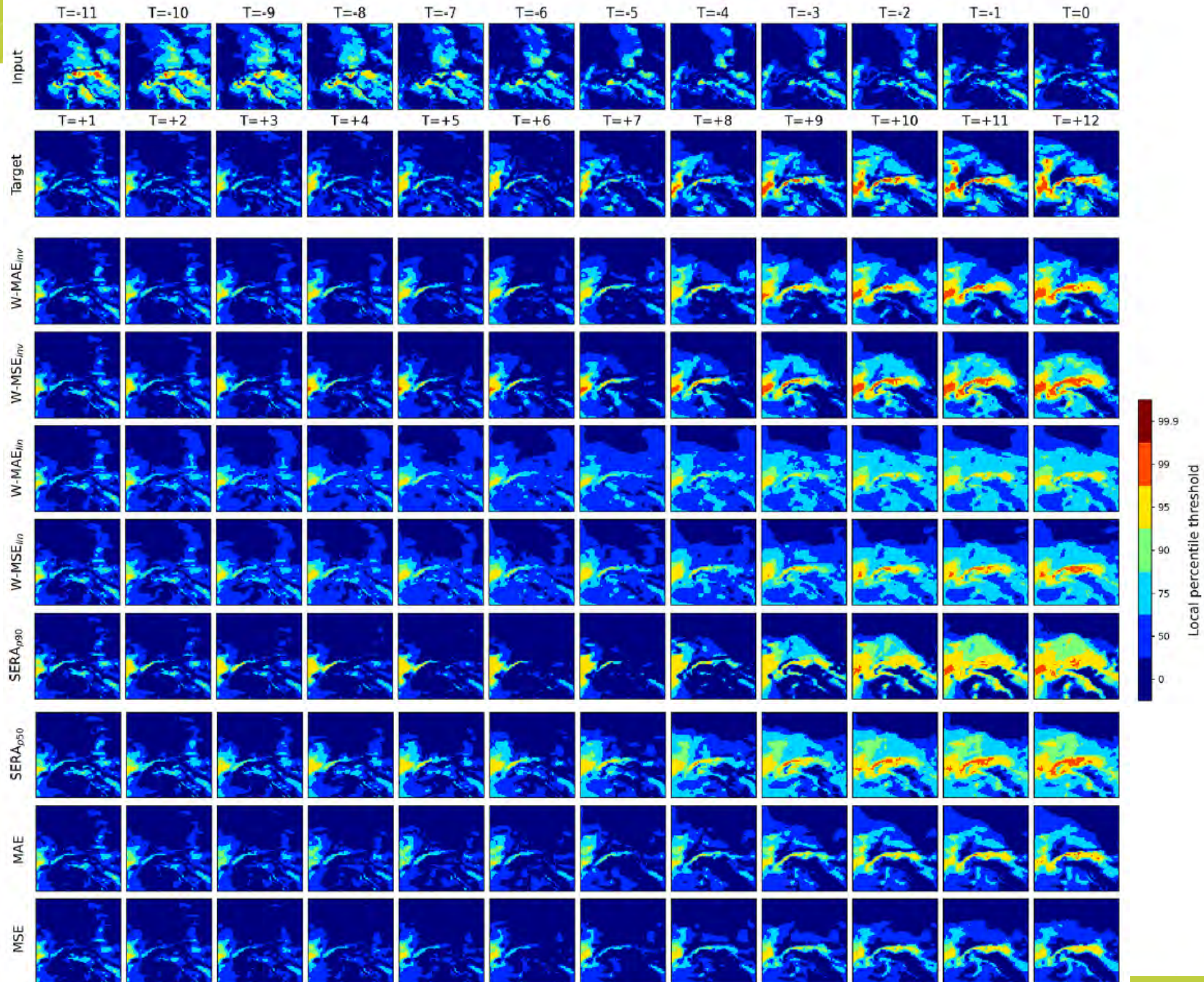
↪ interpolation of 'control-points' using *pchip* algorithm:



+ classical MAE and MSE weights for comparison

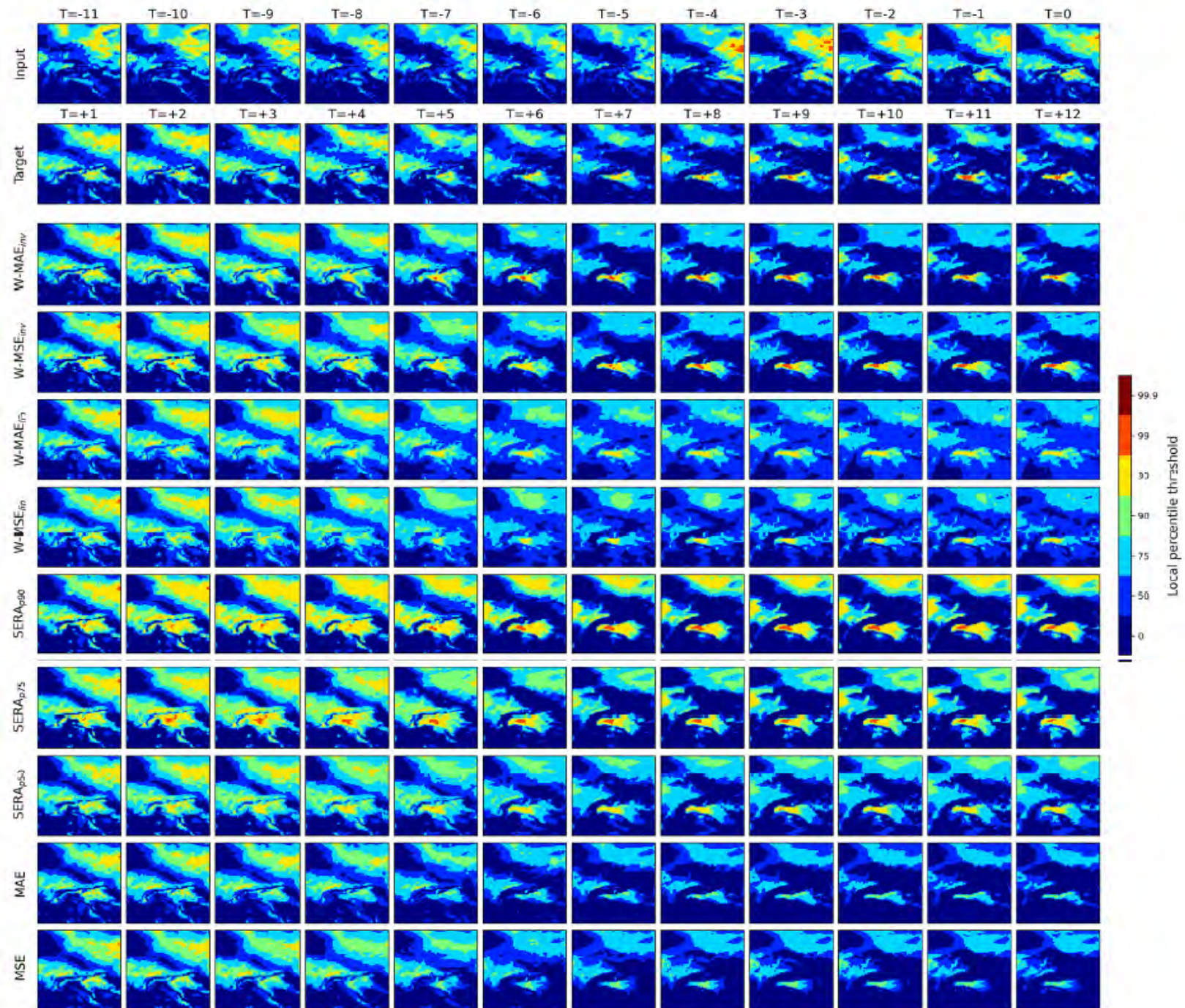
$$D^t = \{ \langle x_i, y_i \rangle \in D \mid \phi(y_i) \geq t \}$$

$$SER_t = \sum_{i \in D^t} (\hat{y}_i - y_i)^2 \quad SERA = \int_0^1 SER_t dt$$

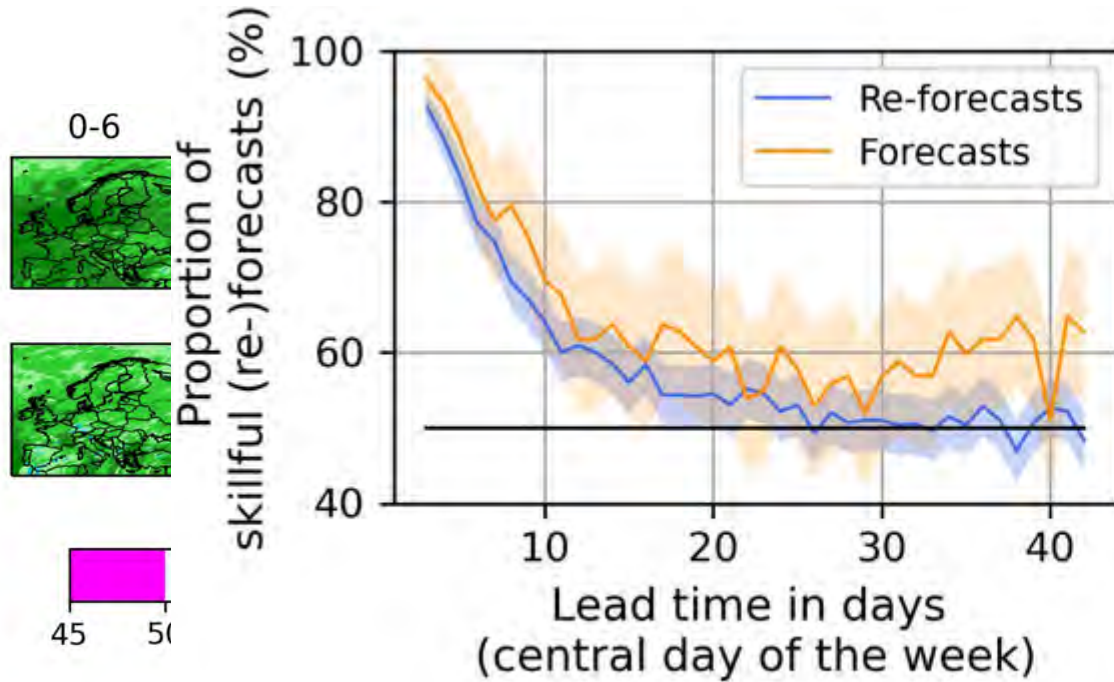


Results

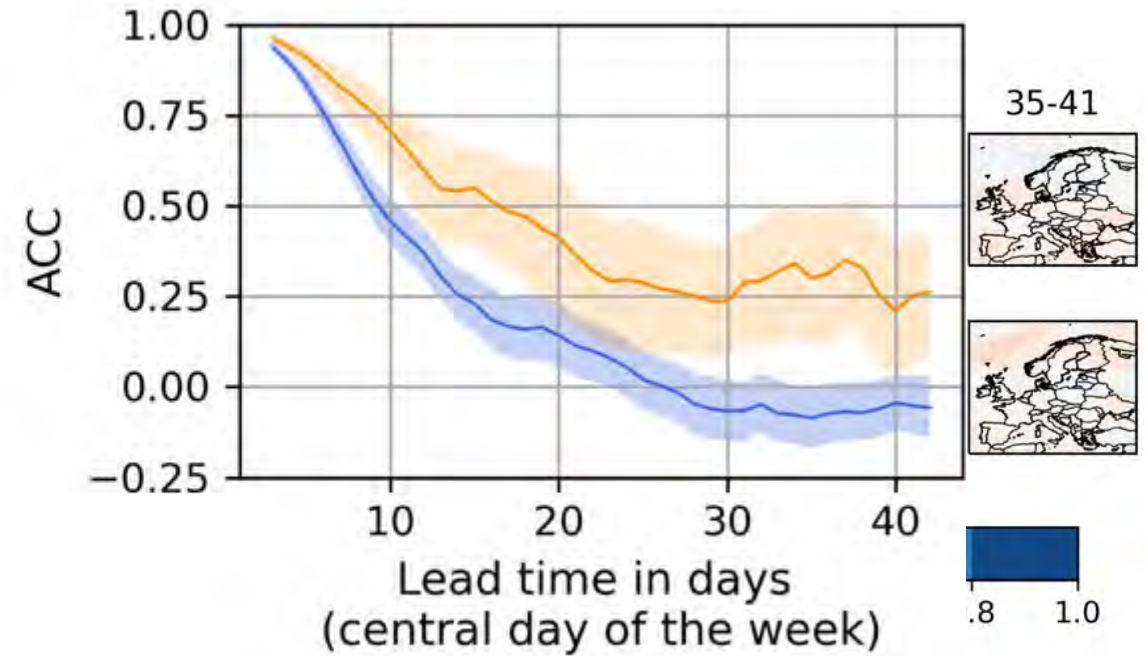
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Wichtig für erneuerbare Energieanwendungen, Produktion aber auch Verteilnetze, Luftqualität,...

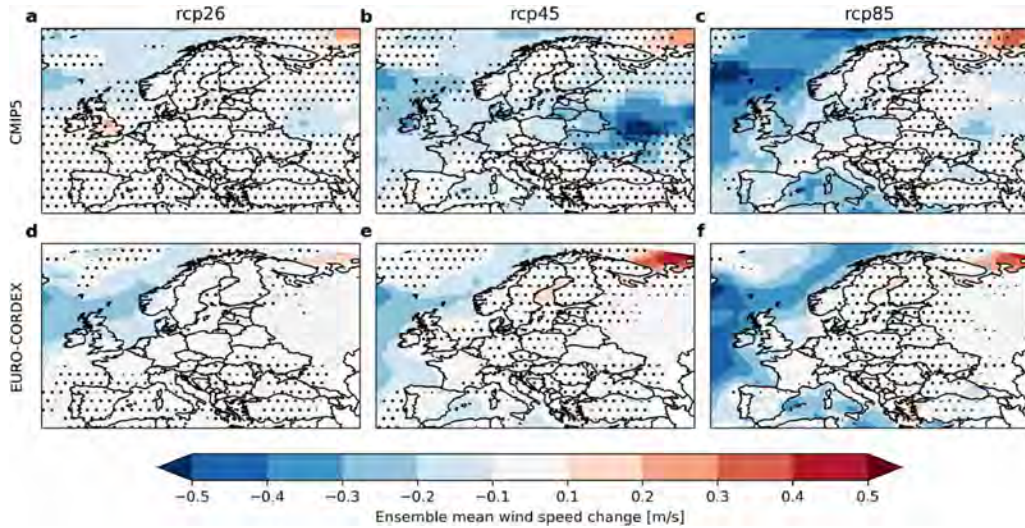


(a)

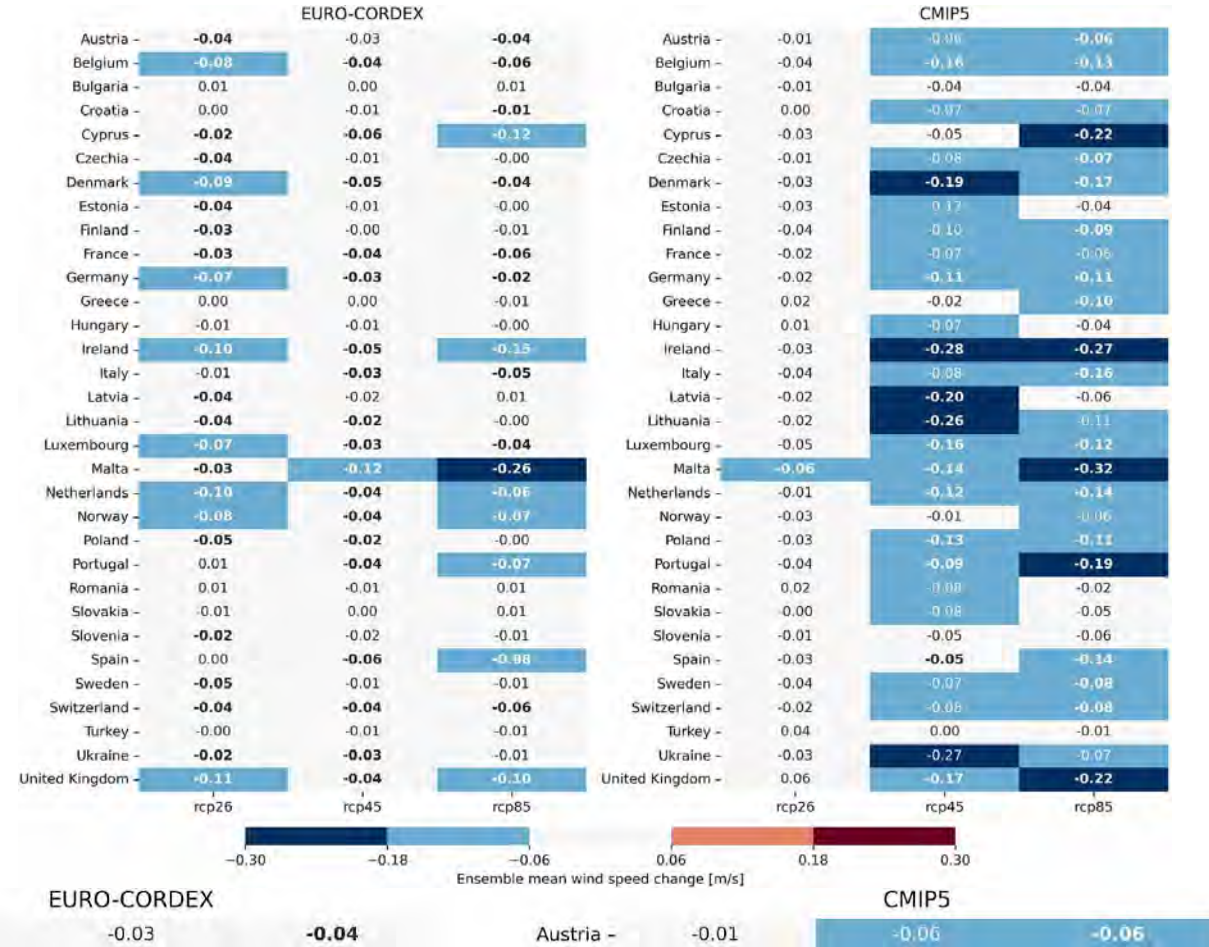


(b)

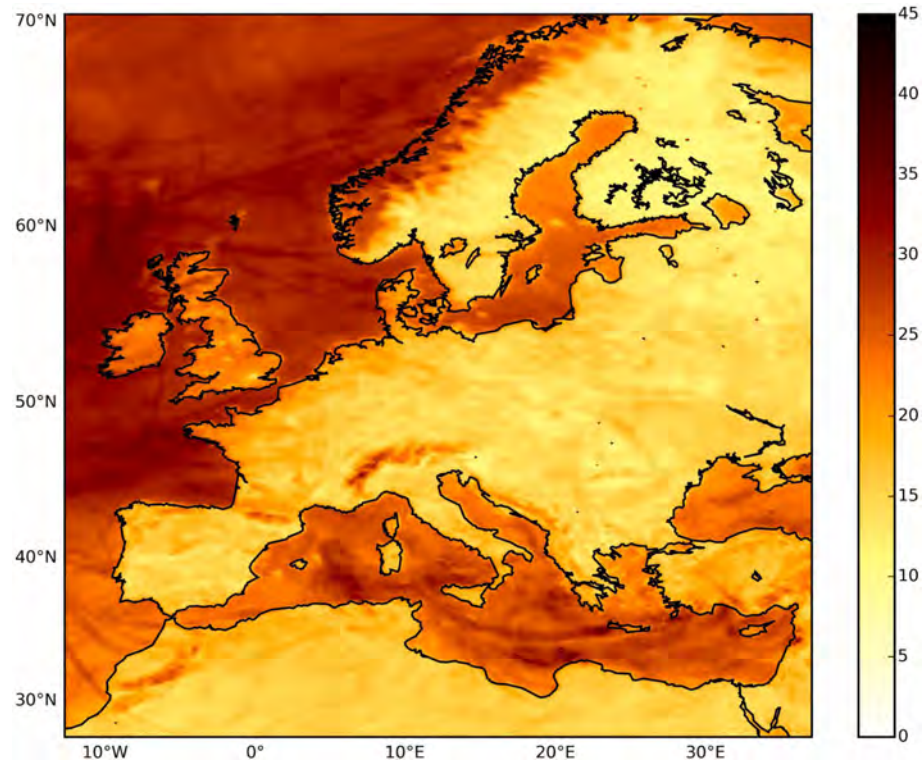
Änderungen - Klimaprojektionen



Changes in 10 m wind speeds (2080–2100 minus 1985–2005) in the ensemble mean. The upper row displays the mean over the CMIP5 GCMs that were downscaled in EURO-CORDEX and the lower row displays the mean over the EURO-CORDEX ensemble. Columns denote different scenarios. Stippling marks statistically insignificant changes at the 95% confidence level. (Wohland, 2022)



Wind speed change breakdown per country—onshore. Values are ensemble mean wind speed changes averaged over all grid boxes within a country. Statistically significant changes are in bold font (95% significance threshold). (Wohland, 2022).



30-year return wind speed for our historical period (1976–2005) over the Euro-CORDEX domain in the SMHI_ICHEC downscaling based on GPD fitted to exceedances of daily maximum wind speed. Units are ms^{-1} . (Outten & Sobolowski, 2021)

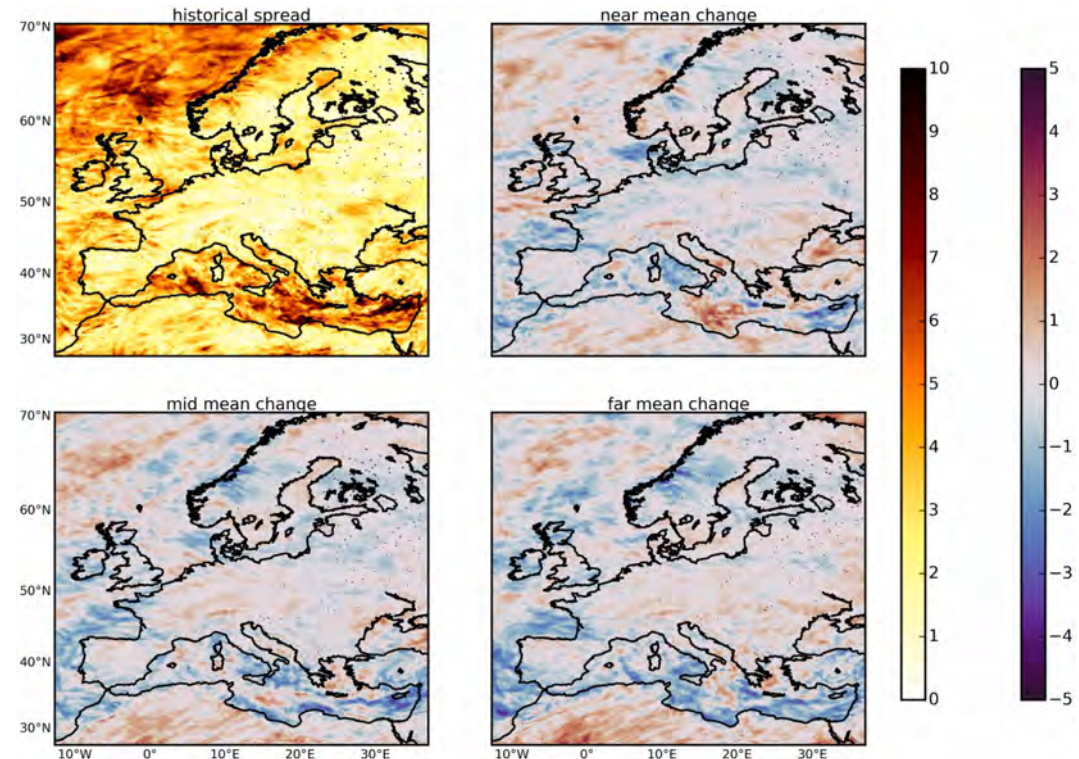


Fig. 5. Range of the 30-year return wind speed between the five SMHI simulations for our historical period (top left) and their mean change from our historical to our near future (top right), mid-future (bottom left), and far future (bottom right) periods. Units are ms^{-1} .

- Vorhersagbarkeit im Kurz- und Mittelfristbereich werden immer besser
- Vorhersagegüte Jahreszeit und Wetterlagenabhängig → trifft auf Wettervorhersagen aber auch Subseasonal und Saisonalprognose sowie Klimaprojektionen zu
- Machine Learning sowie gut optimierte statistische Algorithmen sind in der Lage Extremereignisse bis zu einem gewissen Grad in der Vorhersage / im Post-processing darzustellen ..
- Es braucht aber spezielles Tuning um zu verhindern dass es zu “schwammig” wird und um die Intensitäten korrekt darzustellen. Allerdings, wenn es nicht in den Beobachtungen / Inputdaten ist kann auch die beste künstliche Intelligenz nichts erreichen



Bett, P.E., Hazel E. Thornton, Alberto Troccoli, Matteo De Felice, Emma Suckling, Laurent Dubus, Yves-Marie Saint-Drenan, David J. Brayshaw, A simplified seasonal forecasting strategy, applied to wind and solar power in Europe, *Climate Services*, 27, 2022, <https://doi.org/10.1016/j.cliser.2022.100318>.

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Outten, S. and S. Sobolowski, Extreme wind projections over Europe from the Euro-CORDEX regional climate models, *Weather and Climate Extremes*, Volume 33, 2021, <https://doi.org/10.1016/j.wace.2021.100363>.

Scheepens, D. R., Schicker, I., Hlaváčková-Schindler, K., and Plant, C.: Adapting a deep convolutional RNN model with imbalanced regression loss for improved spatio-temporal forecasting of extreme wind speed events in the short to medium range, *Geosci. Model Dev.*, 16, 251–270, <https://doi.org/10.5194/gmd-16-251-2023>, 2023.

Wohland, J., Process-based climate change assessment for European winds using EURO-CORDEX and global models, *Environmental Research Letters* (provisionally accepted on 28/11/2022), 2022