Can data-driven models beat numerical weather prediction models in forecasting weather extremes?

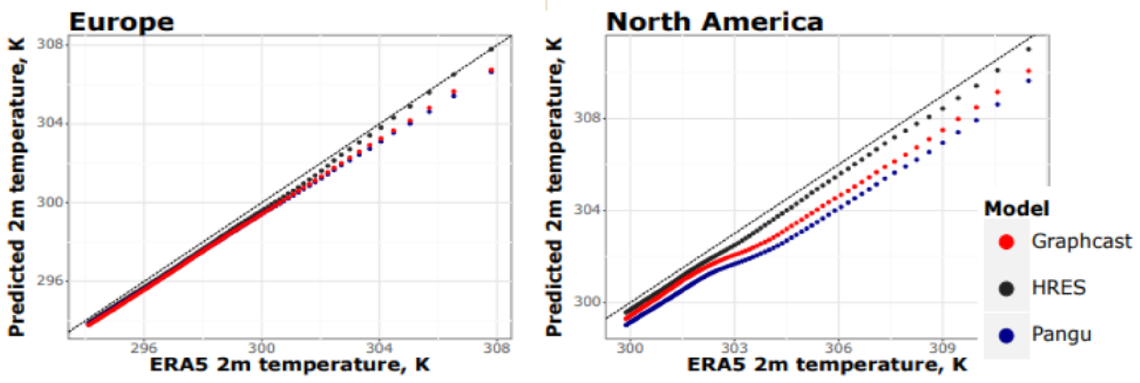
Do deep learning weather models struggle with extreme events?

- Deep learning (DL) models can now outperform NWP in several standard metrics of global skill.
- However, DL models may struggle to accurately forecast extreme weather events, due to:

  -Small training set and challenges related to extrapolation (Watson, 2023; Molina et al., 2023)

  -Use of symmetric loss functions (MAE/MSE) aimed at maximising average skill (Xu et al., 2024; Olivetti and Messori, 2024)

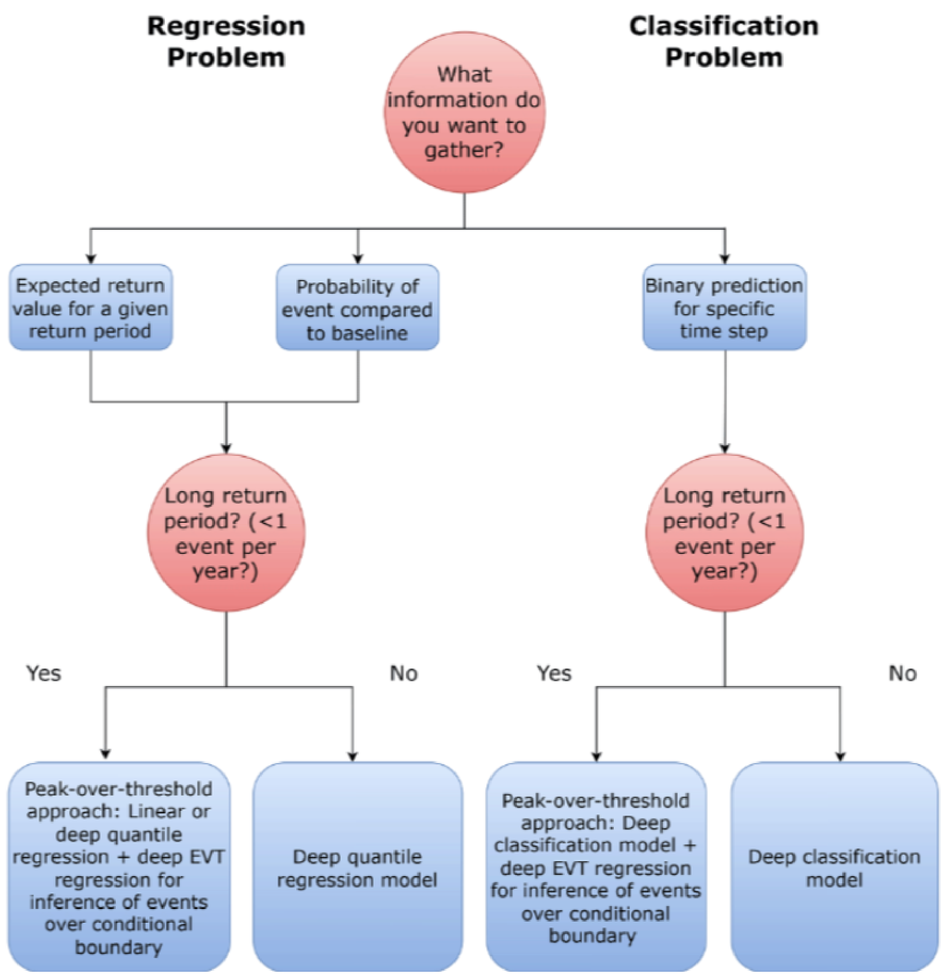
  -Multi-task learning over global domain.



QQ-plot t2m hot extremes 2020, 5-days forecast vs reanalysis

Some possible solutions

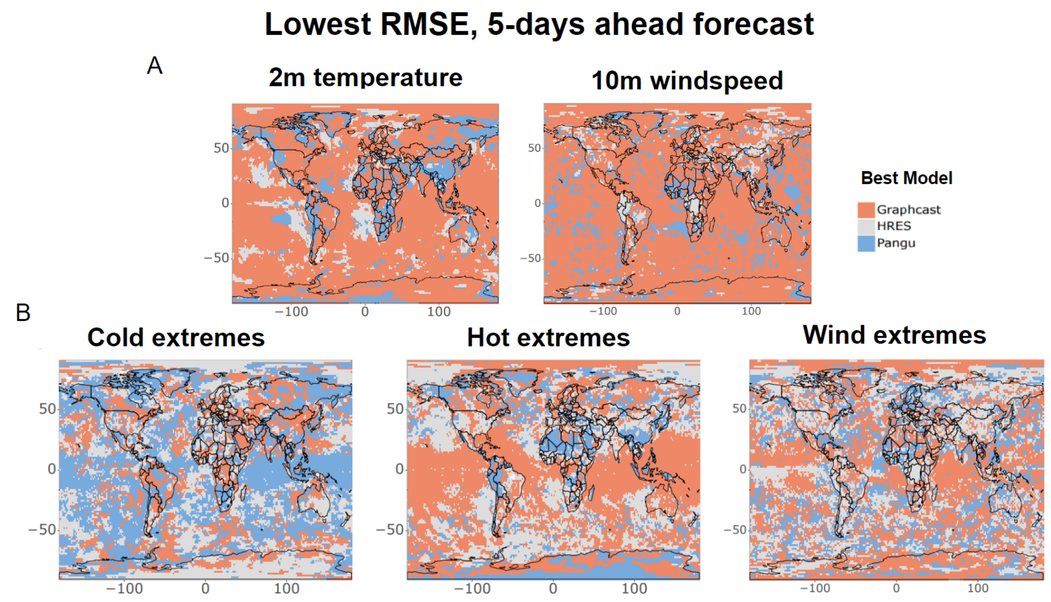
- Ensemble approach for DL weather models (e.g. Hu et al., 2023), similar to NWP models.
- Regional/limited area modelling (e.g. Oskarsson, 2023).
- Specific model for weather extremes.



Olivetti and Messori, 2024

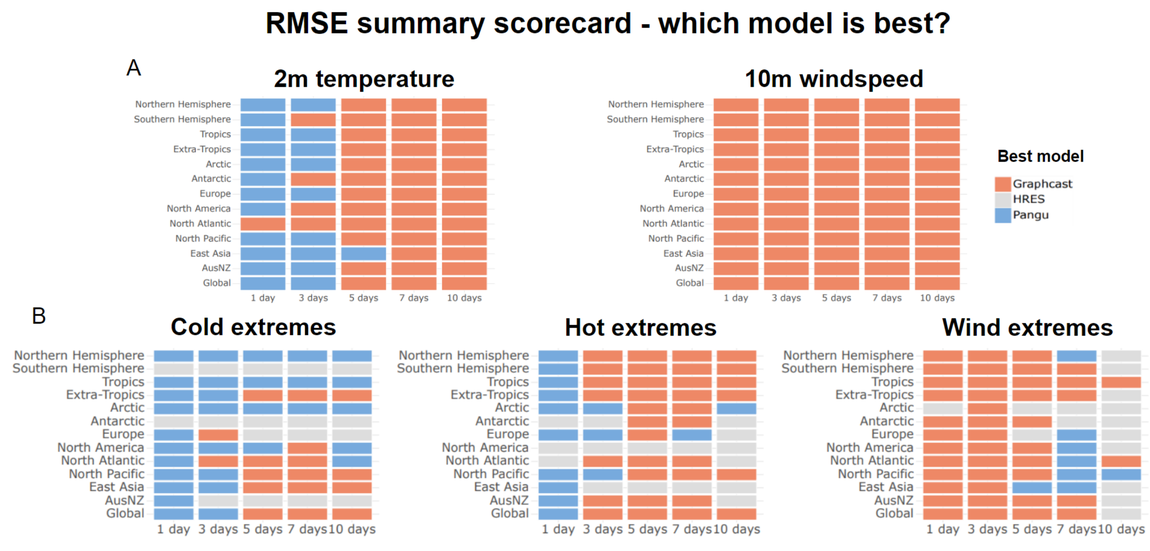
Are DL models already better than NWP models at forecasting extremes?

- We evaluate the performance of DL models on near-surface hot, cold and windy extremes globally using operational forecasts for 2020 provided by the WeatherBench 2 (Rasp et al., 2023).
- We compute the grid-point level RMSE based on all the observations (A) and on the extremes only (B), using ERA5 as ground-truth.



Best model in terms of RMSE. The extremes are defined as the 5% most extreme events for 2020 at each grid-point, based on the IFS HRES forecast.

- We perform the same analysis at regional level, and find that DL models outperform IFS HRES in terms of average skill (A), but that the best model for extremes is highly region and variable dependent (B).



Best model in terms of RMSE. The extremes are defined as the 5% grid-point level most extreme events within the given region.

To know more

Olivetti, L., Messori, G. Advances and Prospects of Deep Learning for Medium-Range Extreme Weather Forecasting. *Geosci. Mod. Dev., highlight article.*

Olivetti, L., Messori, G. Do data-driven models beat numerical models in forecasting weather extremes? A comparison of IFS HRES, Pangu-Weather and GraphCast. Under review at *Geosci. Mod. Dev.*

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