Machine Learning in NWP: **Opportunities and Challenges**

What the headlines are saying...

The AI Forecaster: Machine Learning Takes On Weather Prediction

A novel approach to weather forecasting uses convolutional neural networks to generate exceptionally fast global forecasts based on past weather data.

Boosting Weather Prediction with Machine Learning

WeatherBench is a data set compiled to serve as a standard for evaluating new approaches to artificial intelligence–driven weather forecasting.

IBM and NASA Collaborate to Research Impact of Climate Change with AI

New IBM Foundation Model Technology Leverages NASA Earth Science Data for Geospatial Intelligence

Feb 1, 2023

Machine Learning Improves Weather and Climate Models

New research evaluates the performance of generative adversarial networks for stochastic parameterizations.

During the recent year the progress has been very fast in machine learning for weather prediction, for example:

Examples to be used here:

- FourCastNet (NVIDIA) is fully open
- PanguWeather (Huawei) is open for non-commercial use

Both forecasts are trained on ERA5

$$X(T) = X(0) + \int_0^T M(t)dt$$

In all experiments below, we have initialised both PanguWeather and FourCastNet from ECMWF initial conditions.

It poses a lot of questions!

Can they do genesis of extra-tropical cyclones from baroclinic waves?

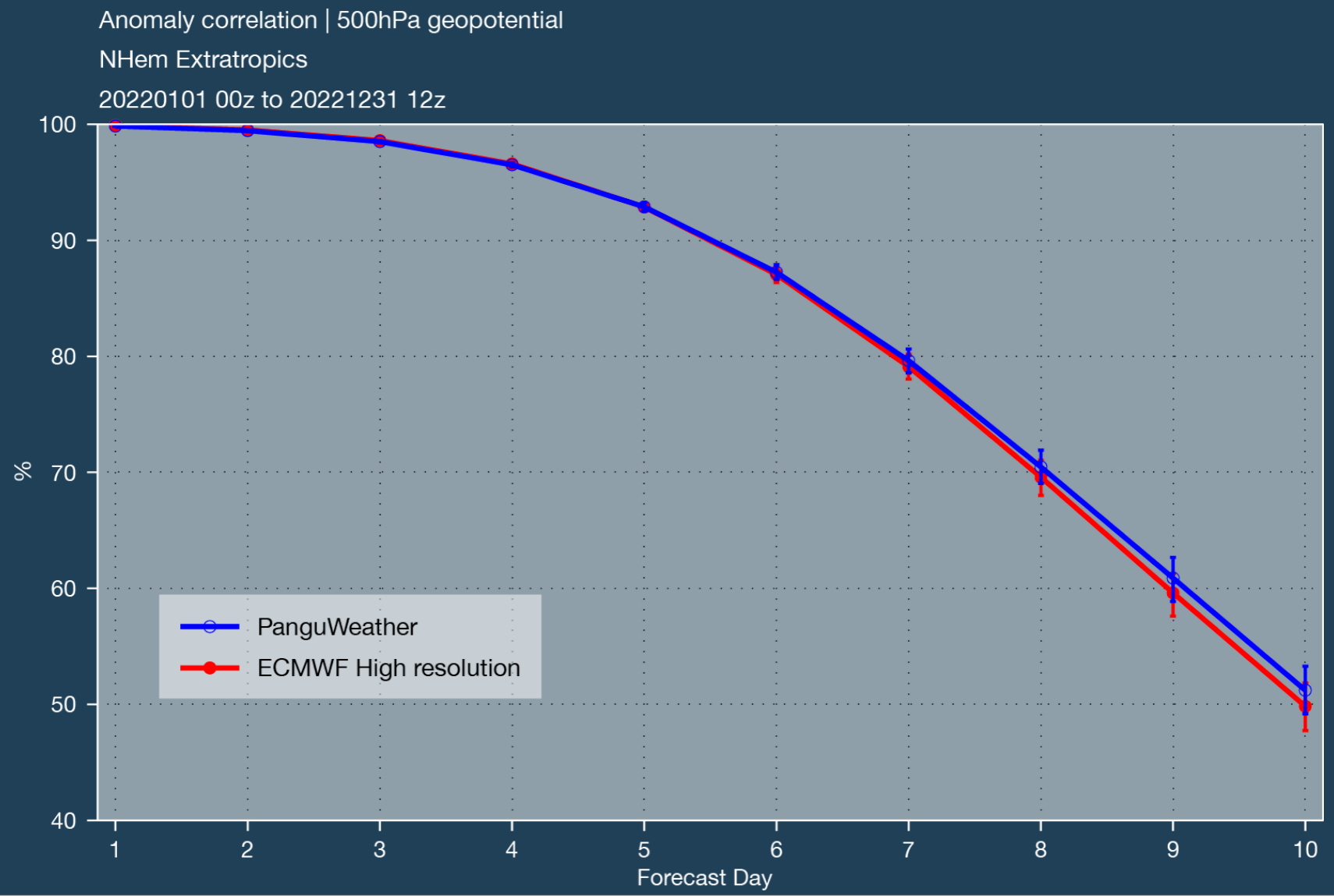
What about (unseen) extremes?

Tropical cyclones?

Do they produce similar error growth?

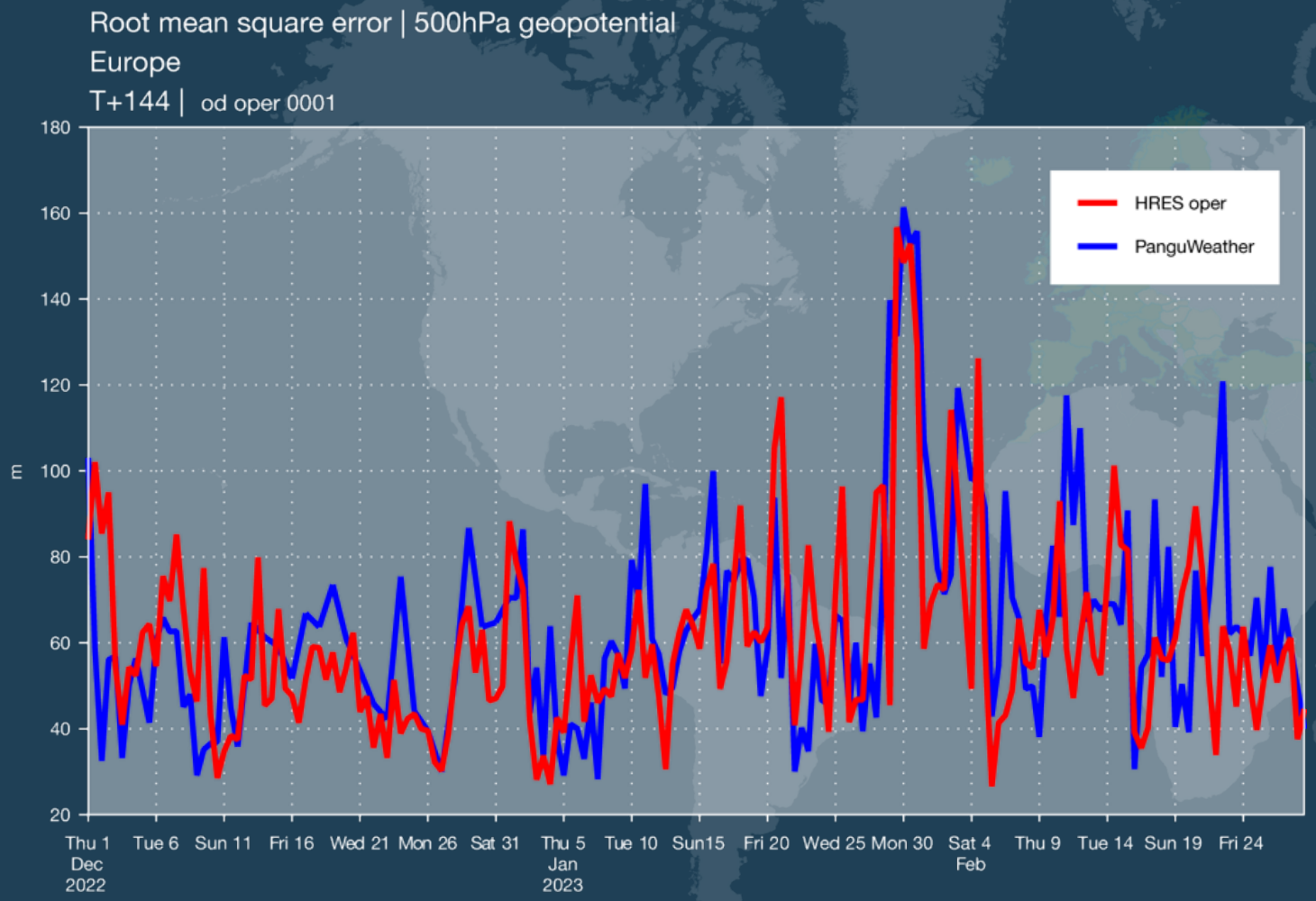
Can it generate a reliable ensemble?

Latest experiments: **scores over a whole year**

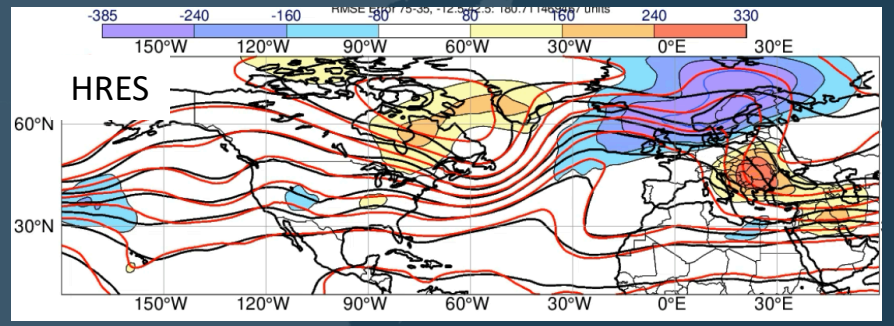


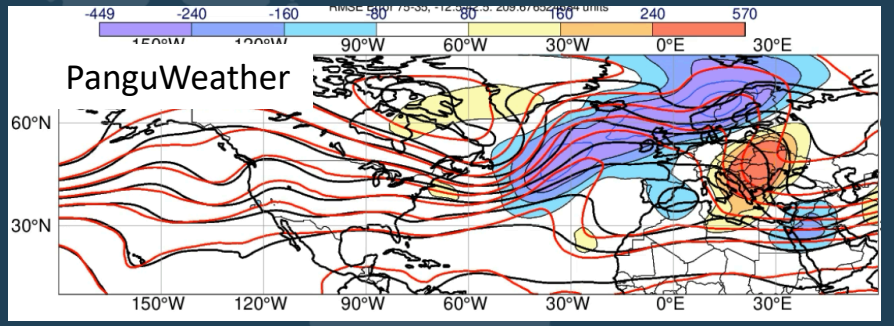
What results are showing: **Time-series of day 6, RMSE over Europe**

Same starting point....Similar results

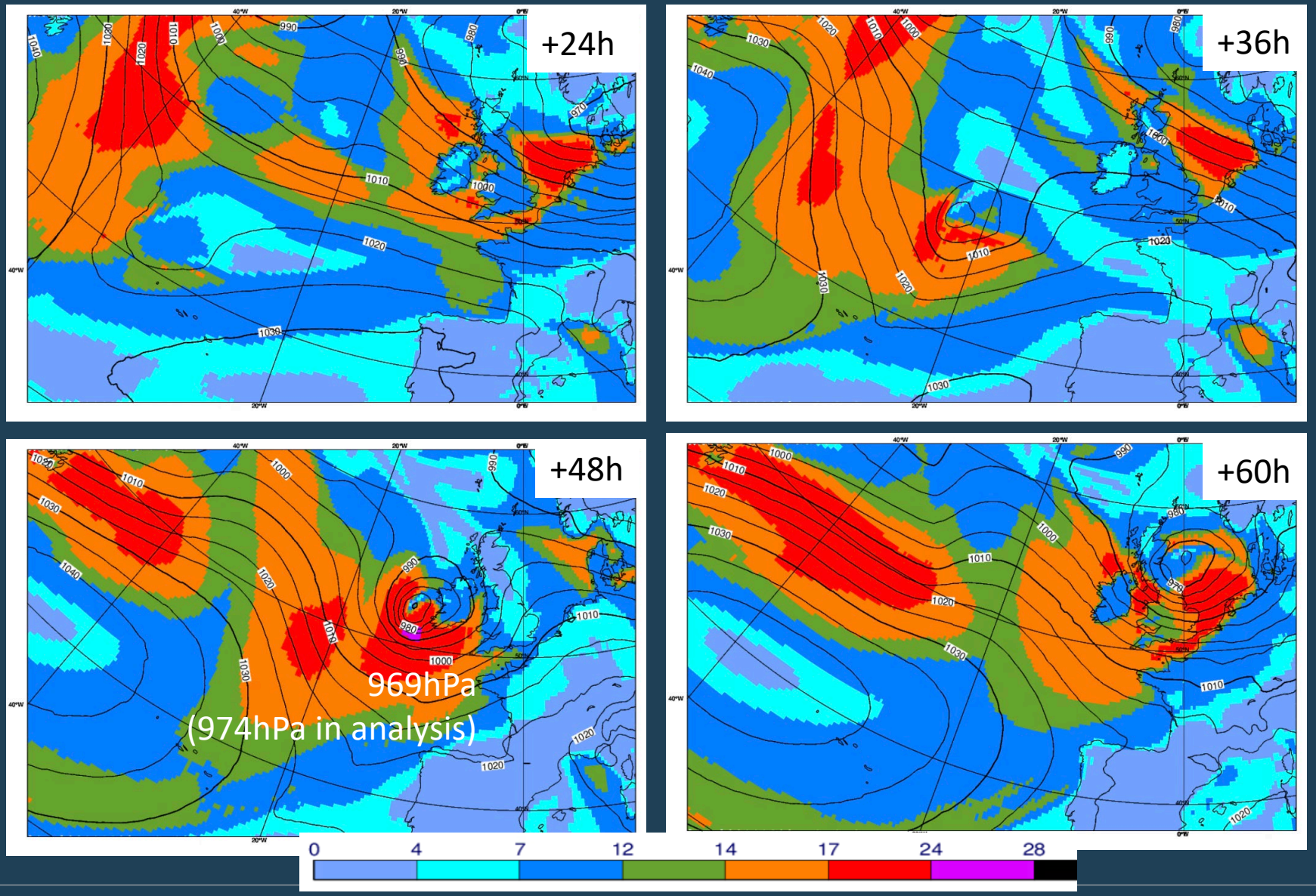


+144h forecast errors 30 January 00UTC



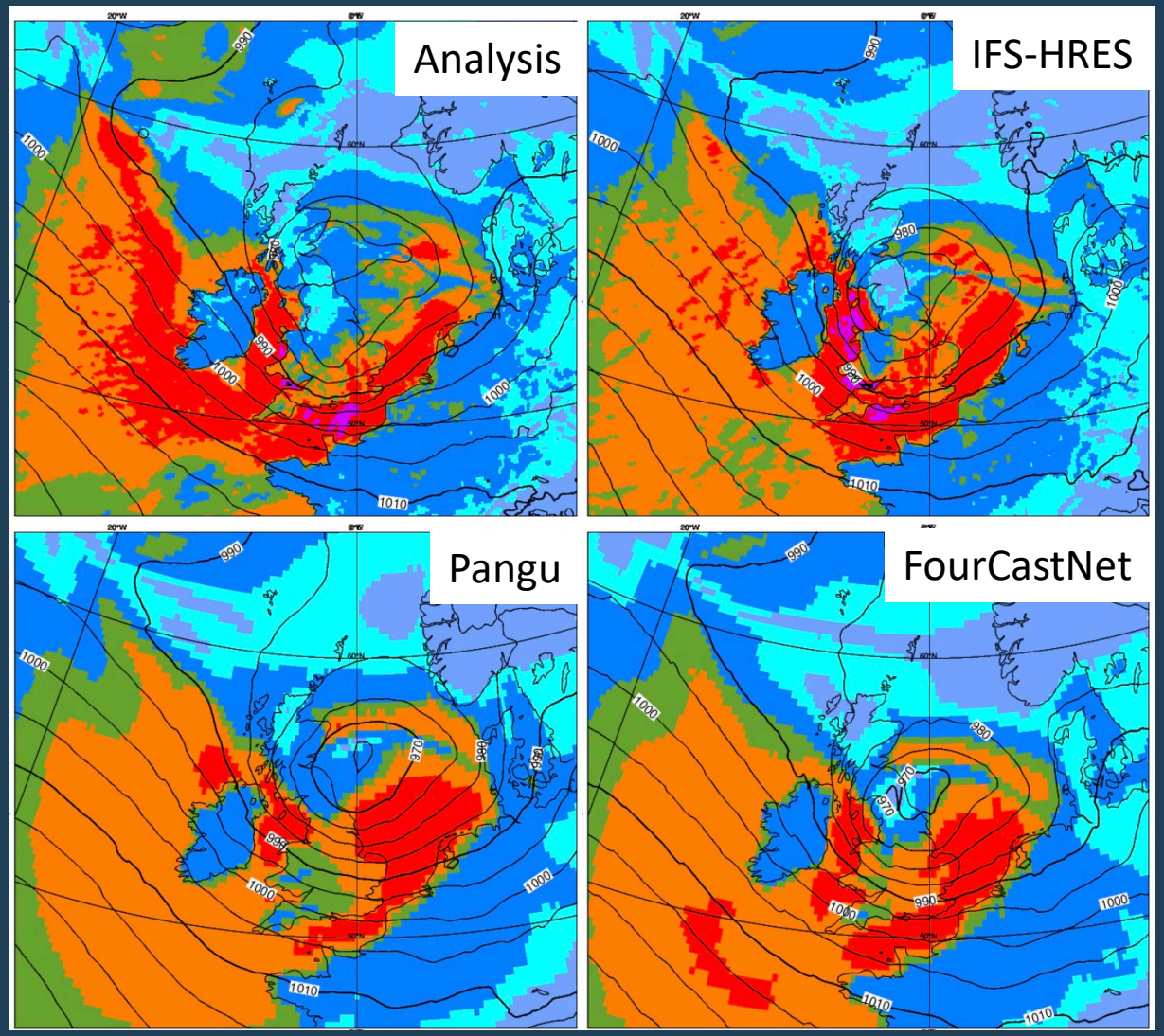


PanguWeather: **Storm Eunice (forecast from 16th Feb 2022 00UTC)**

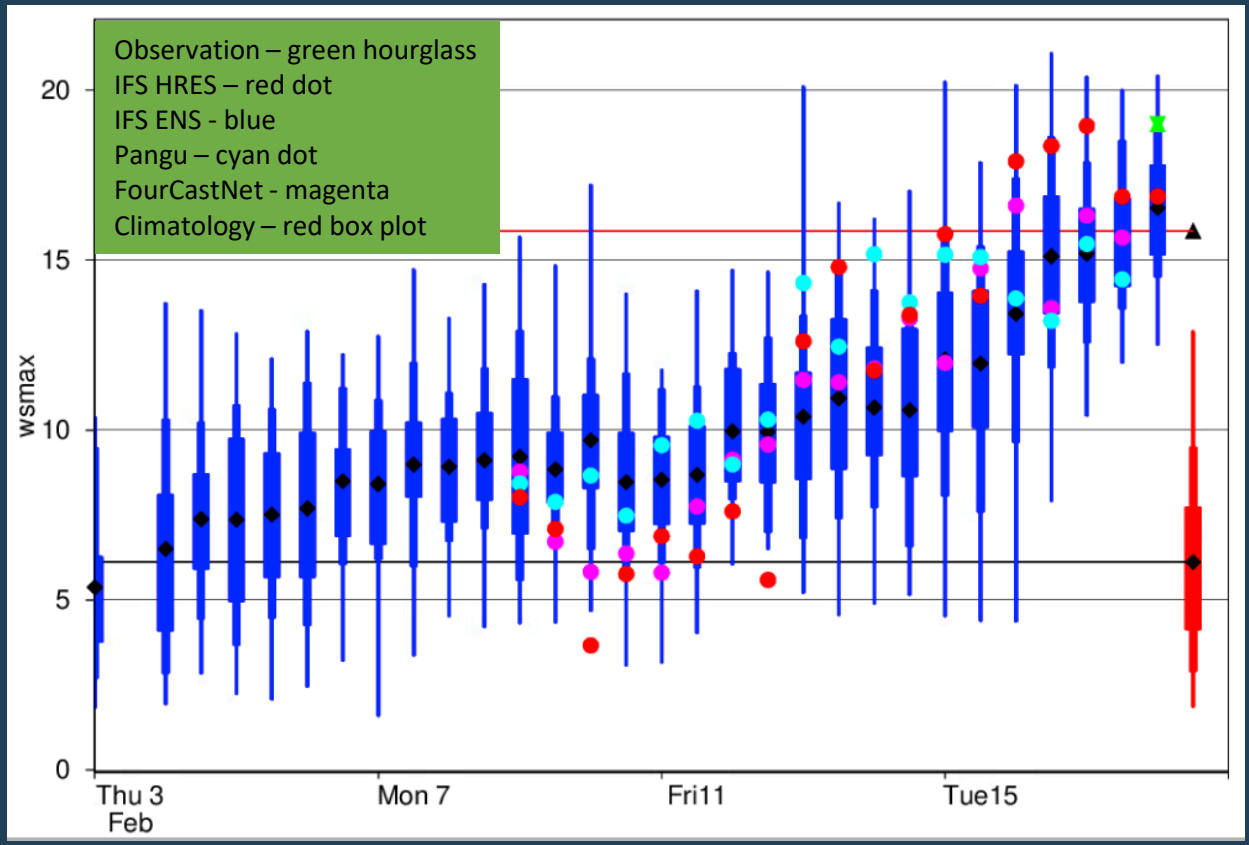


MSLP and wind speed from PanguWeather model

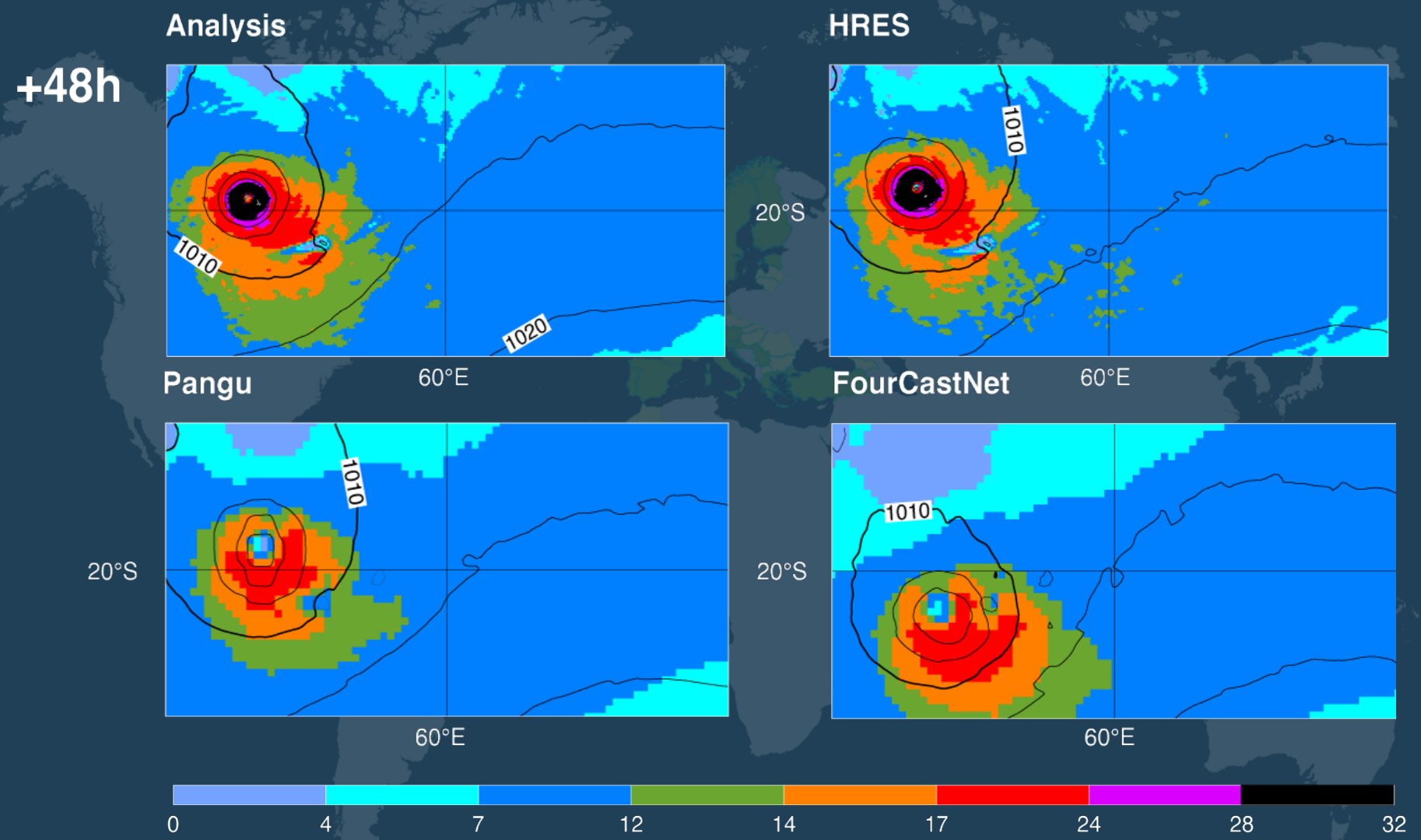
What the forecasts are showing: **Storm Eunice (2.5-day forecasts valid18th Feb 2022 12UTC)**



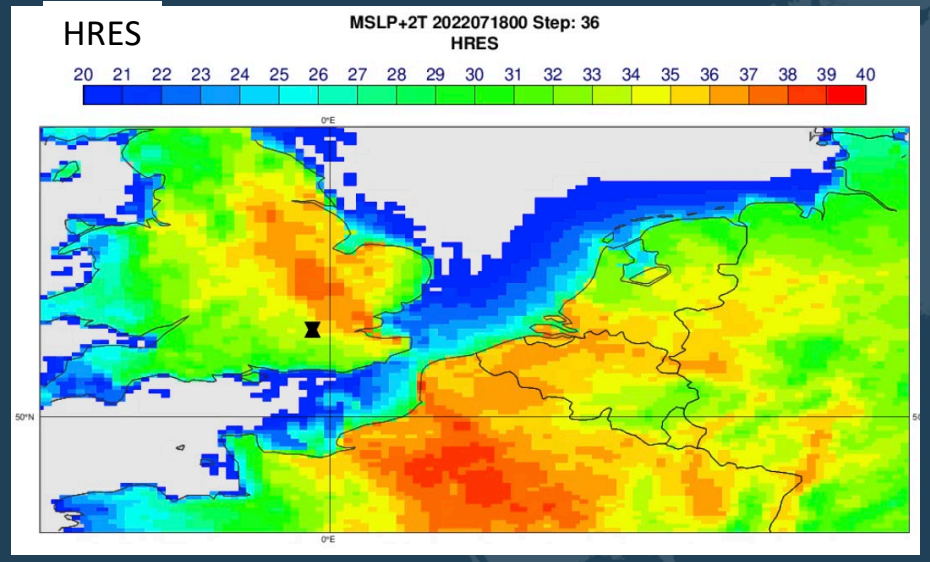
Maximum mean wind Heathrow 18 Feb (00, 06, 12 and 18UTC)

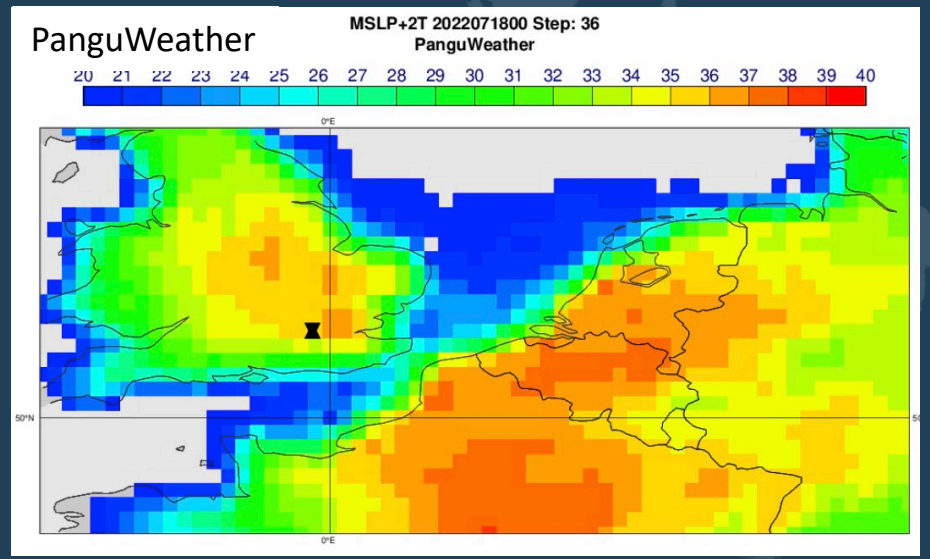


What the forecasts are showing: **Tropical cyclone Freddy (19 Feb 2023 00UTC)**

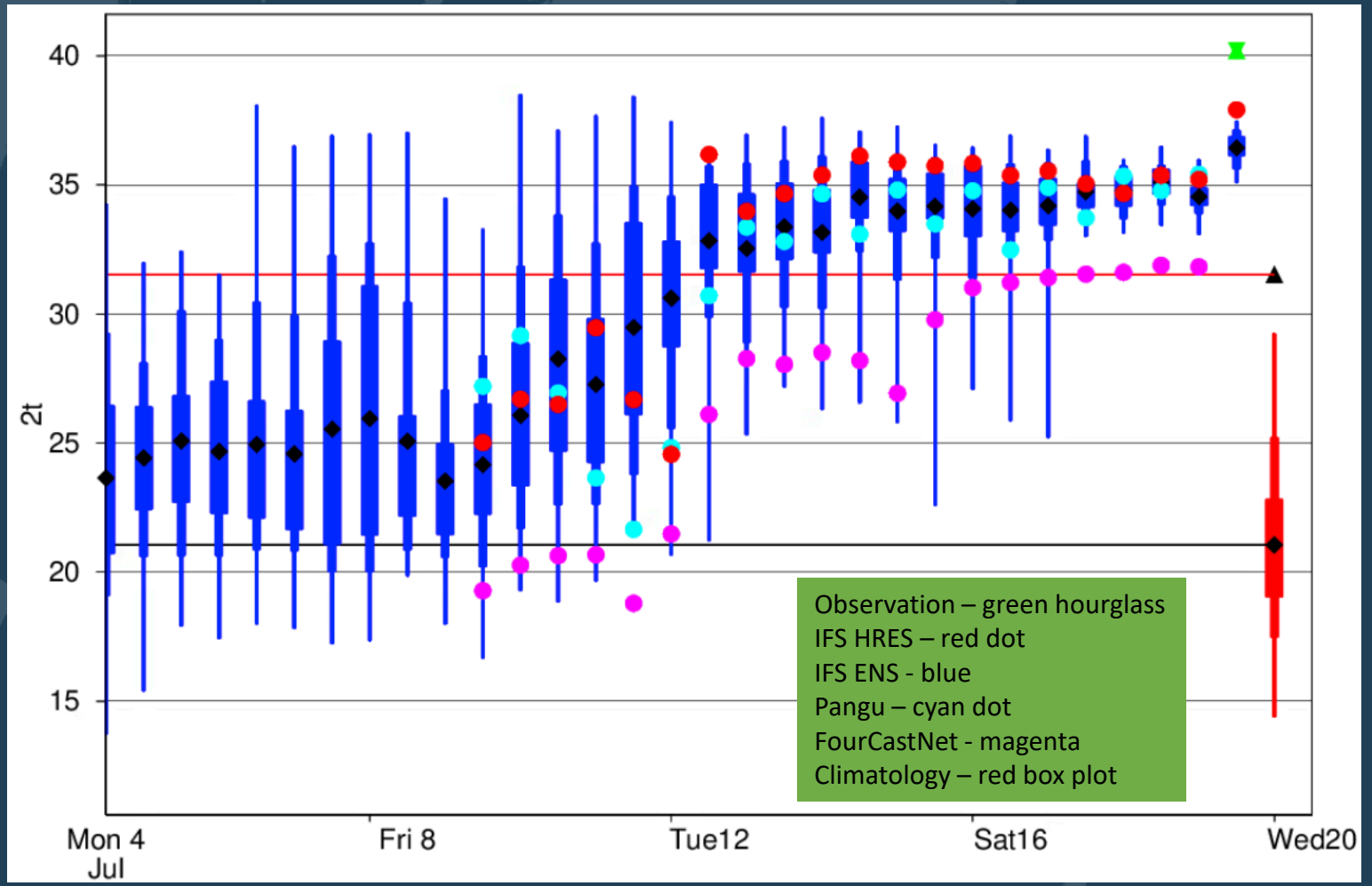


What the forecasts are showing: UK heatwave 2022

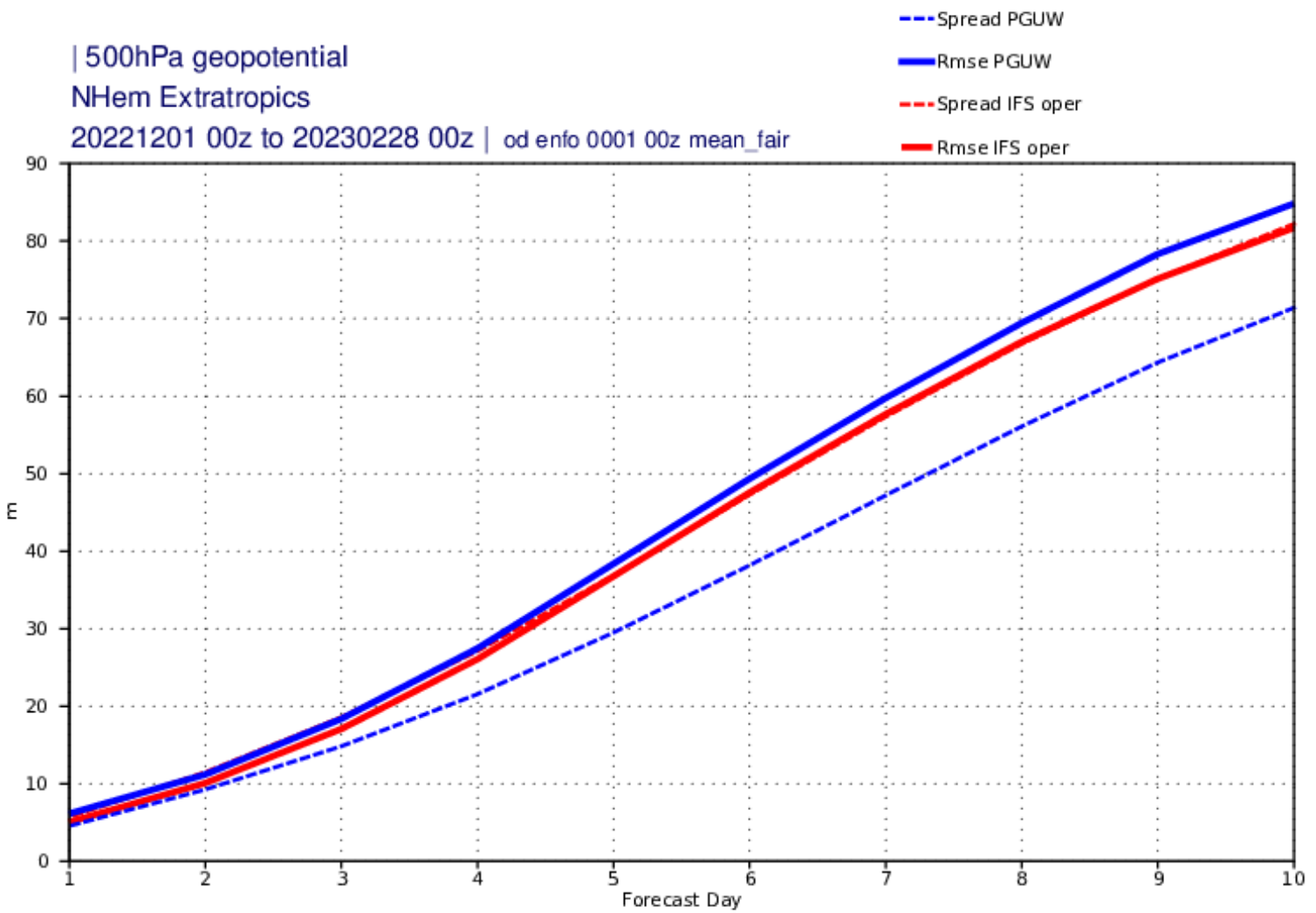




2-metre temperature Heathrow 19 July 12UTC



Ensemble prediction



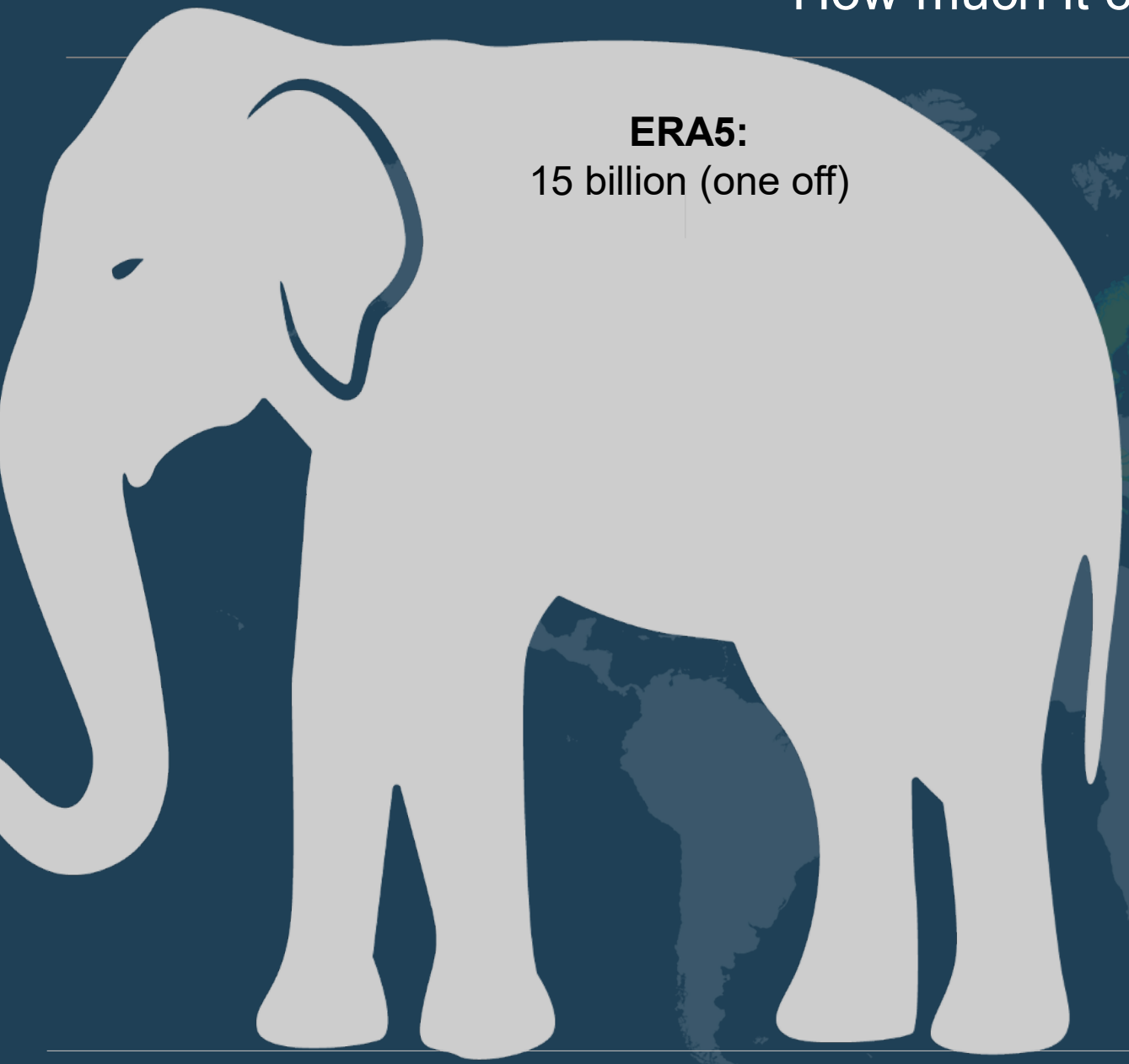
PanguWeather does not currently represent model uncertainty, a key component of the spread development

How much it costs ... **in SBUs**

ERA5:
15 billion (one off)

ECMWF HRES:
180 000
per forecast

Pangu:
0.3
per forecast



Some early answers

Can they do genesis of extra-tropical cyclones from baroclinic waves?

Yes, in the cases we have investigated

What about (unseen) extremes?

Yes, but limited of small-scale smoothing

Tropical cyclones?

Good track forecasts, problem with intensity

Do they produce similar error growth?

Yes

Can generate a reliable ensemble?

Initial uncertainty yes, but currently missing model uncertainty

Summary

- Very cheap to run once the ML model is trained
- Very good scores for PanguWeather initialised from ECMWF analysis
- Can do temperature extremes, cyclogenesis of both extra-tropical and tropical cyclones
- Similar perturbation growth rate from initial perturbations

- Problem with intense cyclones
- Smooth small scales

- Currently not predicting precipitation
- Missing model uncertainty in ensemble mode

Think back a couple of decades:

Forecasts based on forecasters' experiences from past events

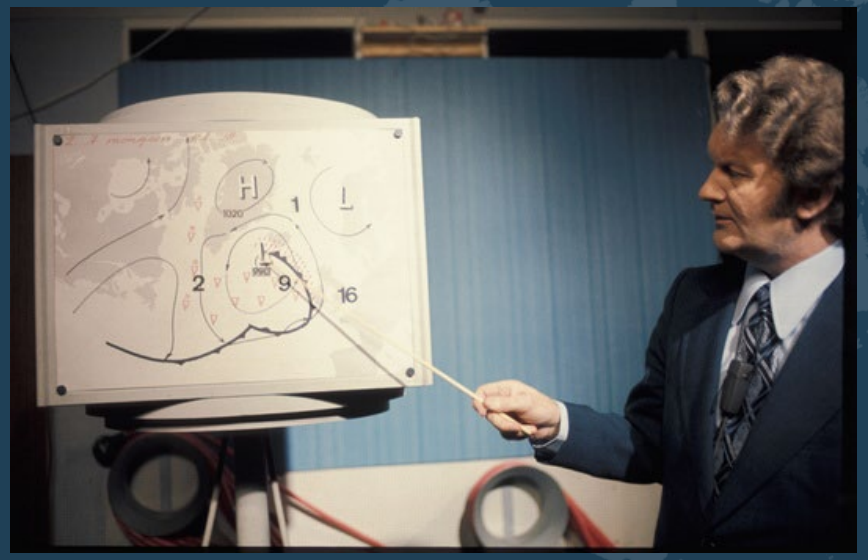
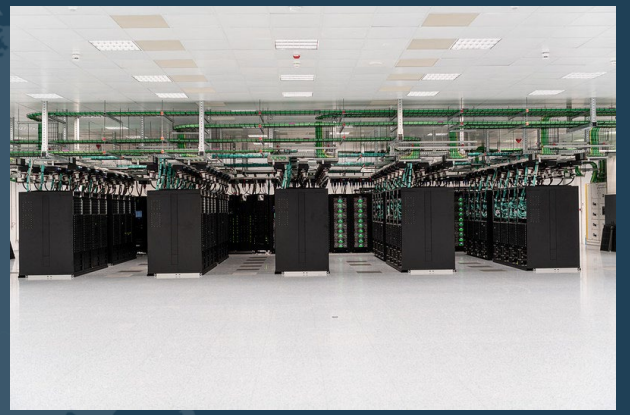
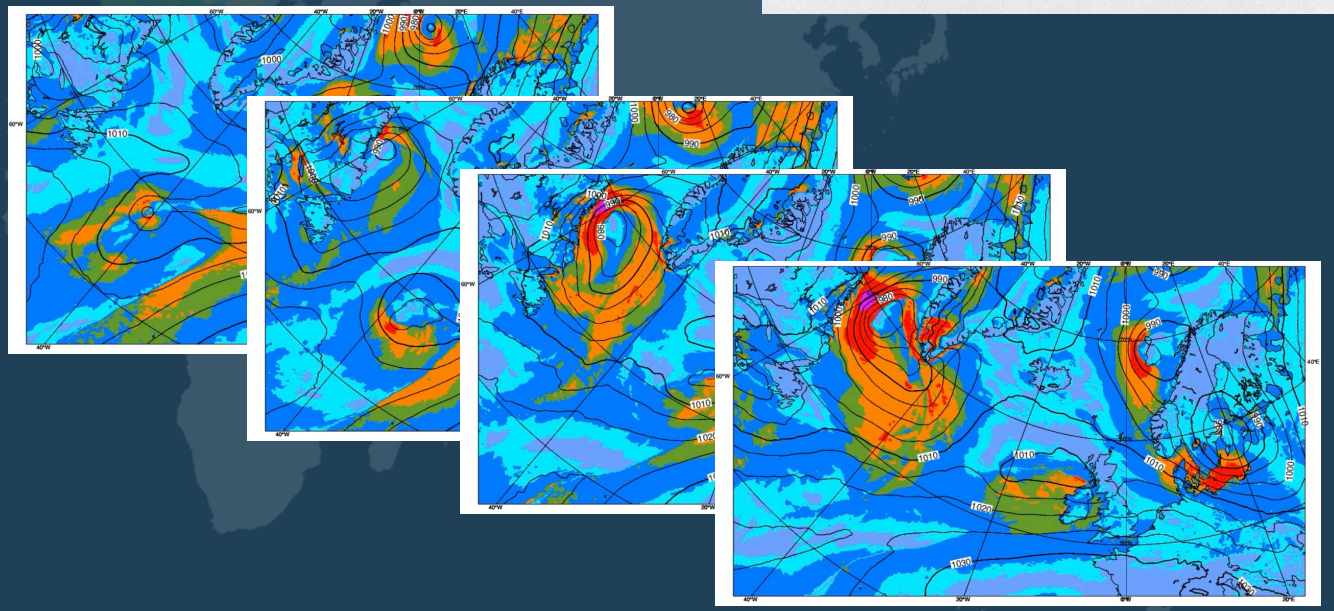


Photo credits: Icelandic Met service

With 40+ years of reanalysis, what if a computer could make forecasts based on the past experiences?