Probabilistic products for NWP

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ECMWF

The ECMWF operational forecasting system

High resolution forecast (HRES) :

- twice per day **9 km** 137 levels, to 10 days ahead

Ensemble forecast (ENS):

- twice per day 51 members, **18 km** 137 levels, to 15 days ahead
- Monday/Thursday 00 UTC extended to 46 days ahead (**Monthly Forecast, 18/36 km**)

Ocean waves: twice per day

- **HRES-WAM**: 10 days ahead at **14 km** (coupled)
- **ENS-WAM:** 15 days ahead at **28 km** (coupled)

Seasonal forecast: once a month

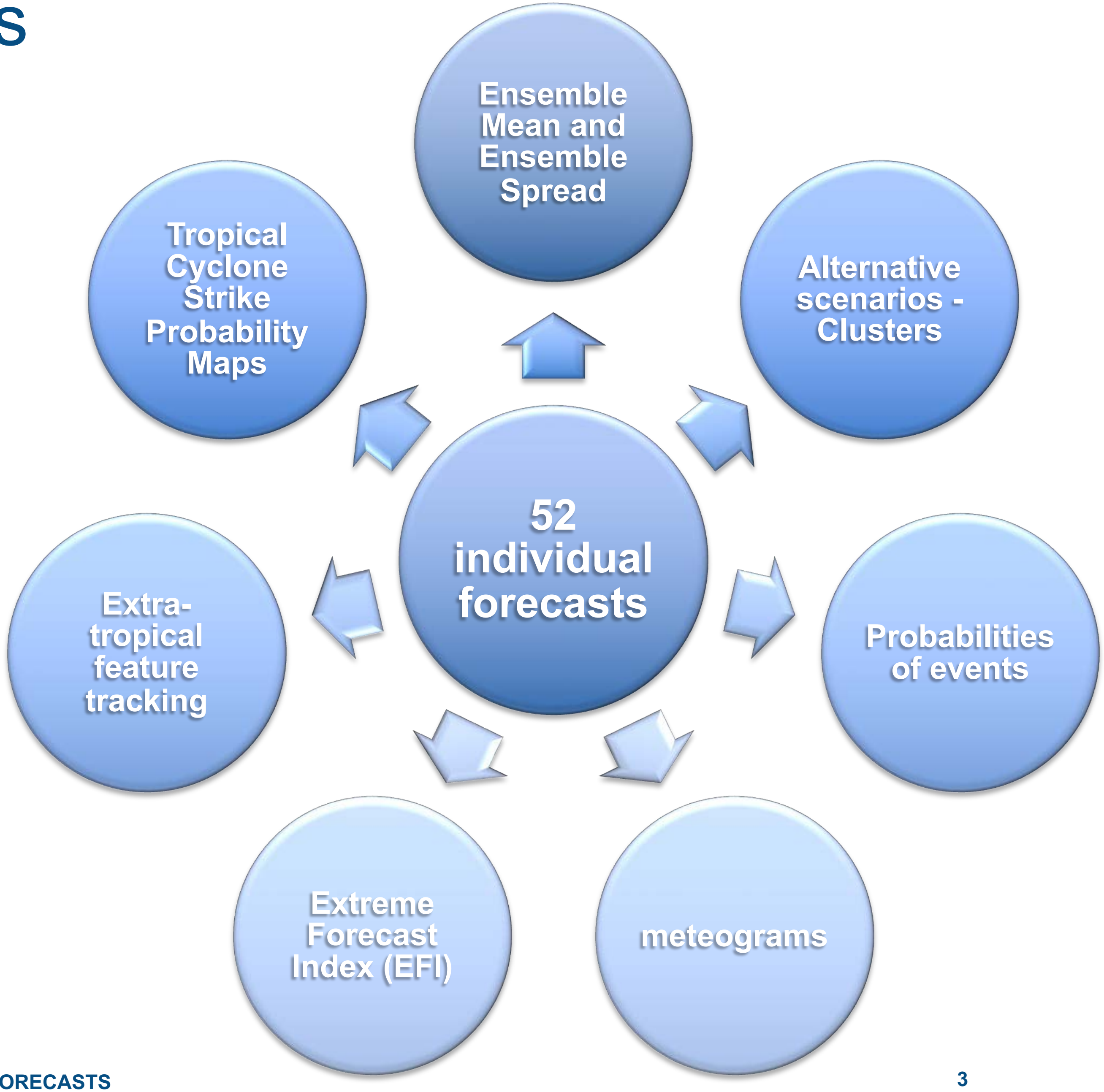
- 51-members, **~35 km** 91 levels, to 7 months ahead
- sub-set of 15 members is run for 13 months every quarter (**30 years of hindcasts**)

ECMWF forecast products

- Summarise information in HRES and ENS
- Represent uncertainty
- Broad-scale evolution out to 15 days
- Changes in weather regime
- Highlight potential for severe weather few days ahead
- Monthly and seasonal outlooks

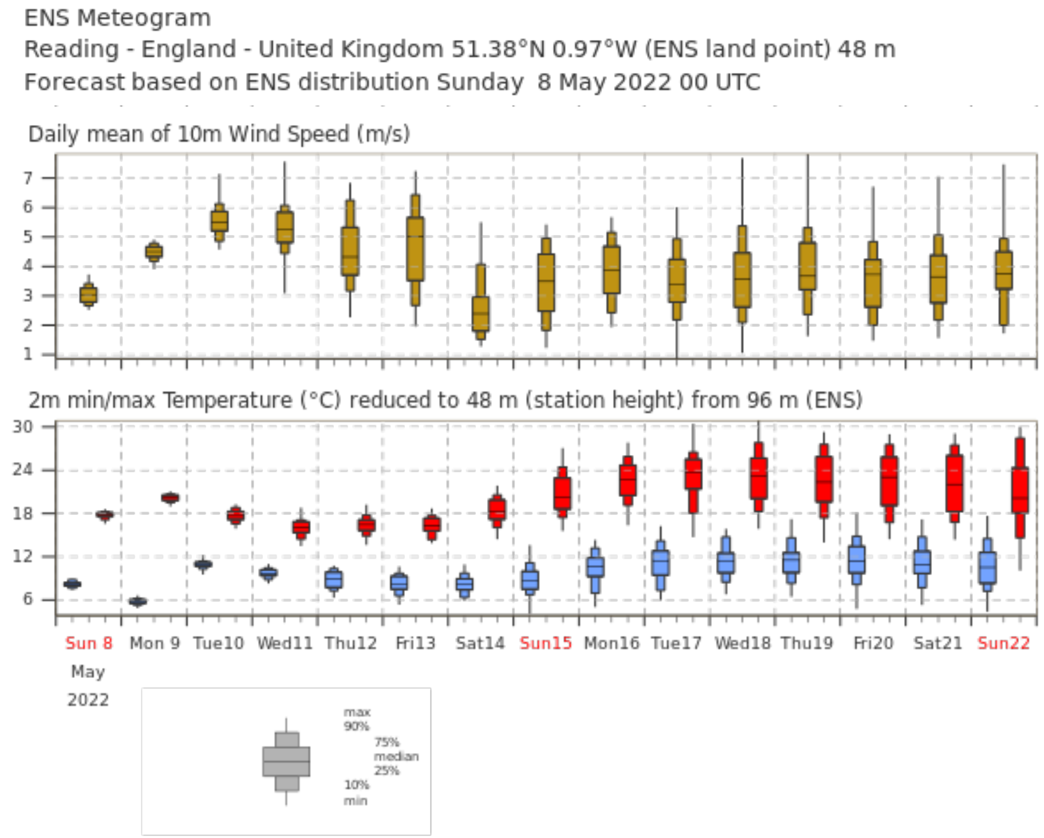
- To assist operational forecasters (in Member States)

- Users generate their own tailored products for specific applications



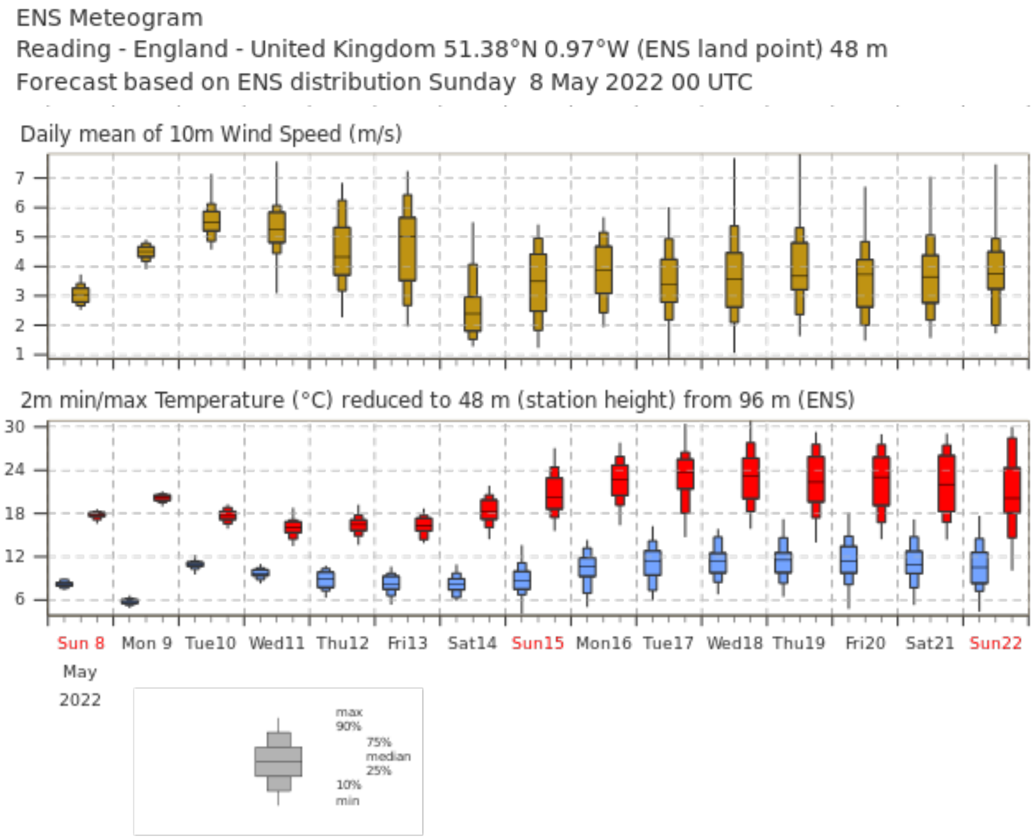
Forecast products – medium-range

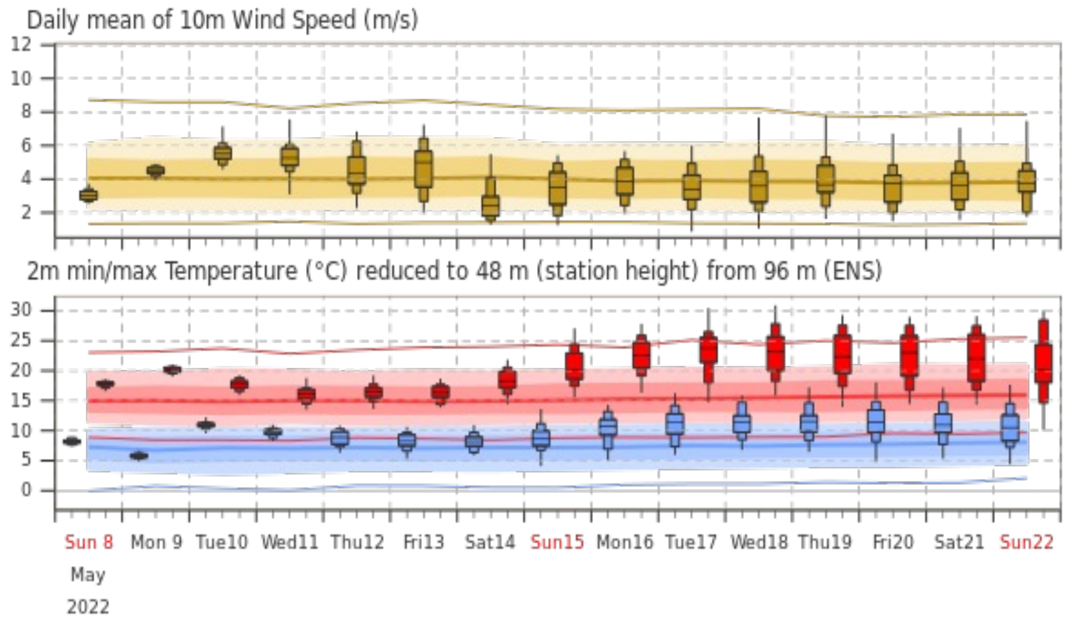
- Medium-range
  - Mostly direct model output

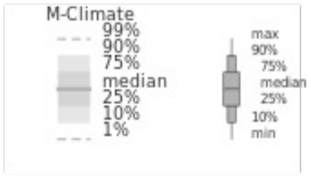


Forecast products – medium-range

- Medium-range
  - Mostly direct model output
  - Some put the direct output in context of model climate (from reforecasts)



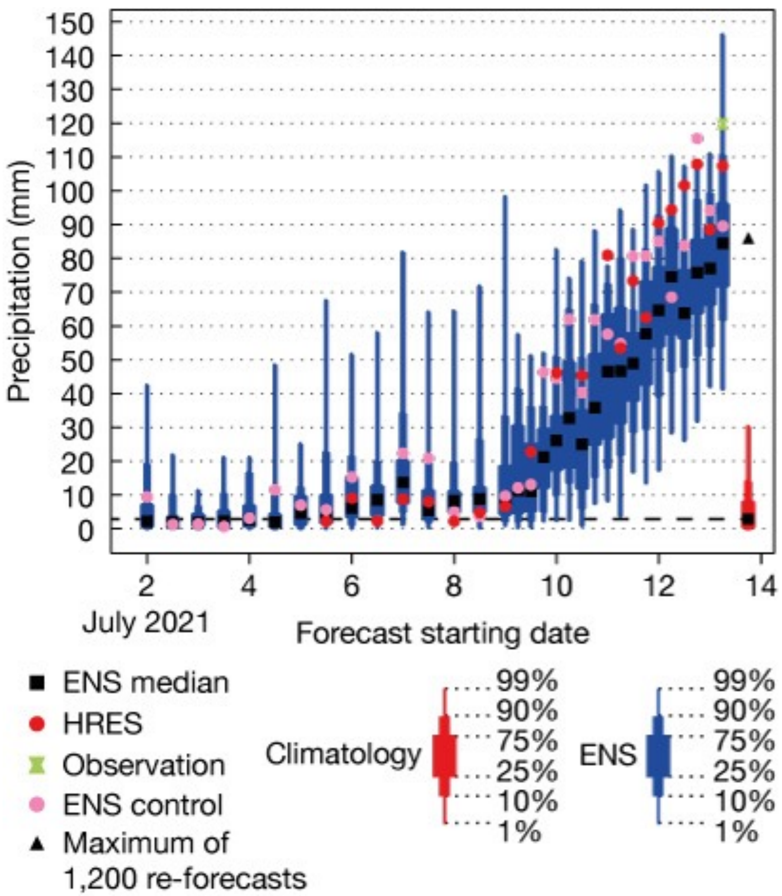


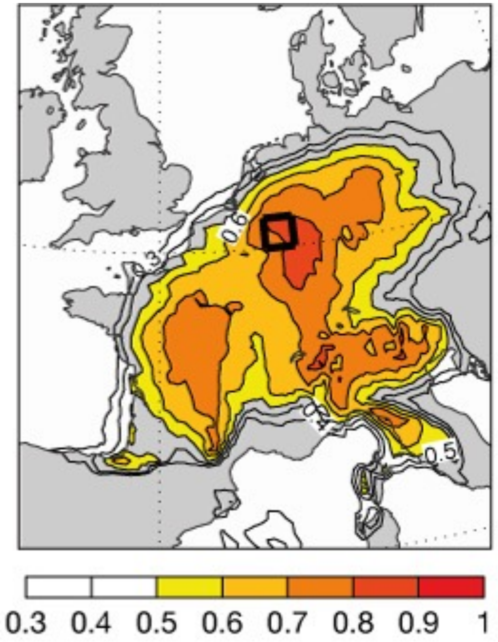


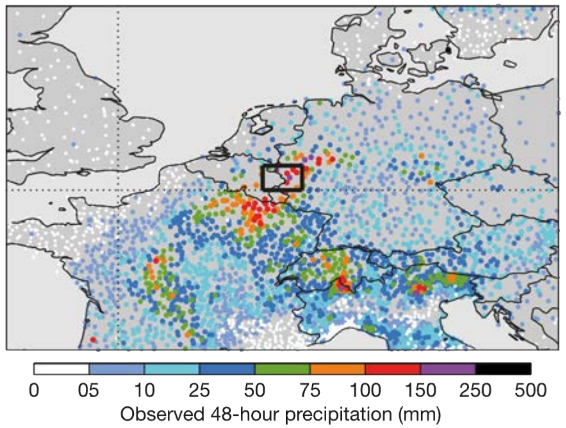
M-Climate: this stands for Model Climate. It is a function of lead time, date (+/-15days), and model version. It is derived by rerunning a 11 member ensemble over the last 20 years twice a week (1980 realisations). M-Climate is always from the same model version as the displayed ENS data.

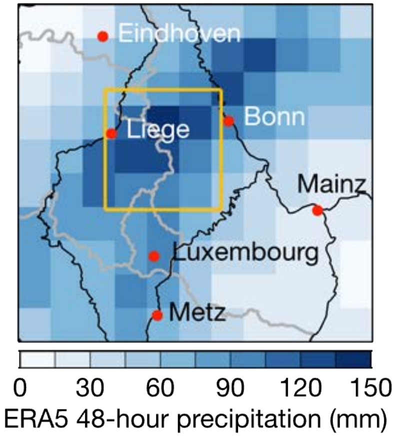
Forecasting extreme events

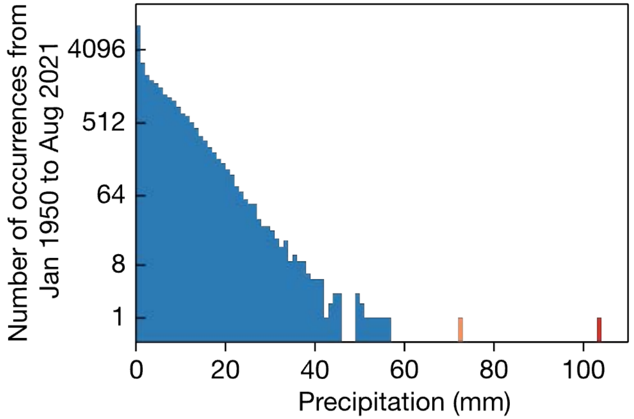
- Extreme rain in Germany and Belgium in July 2021







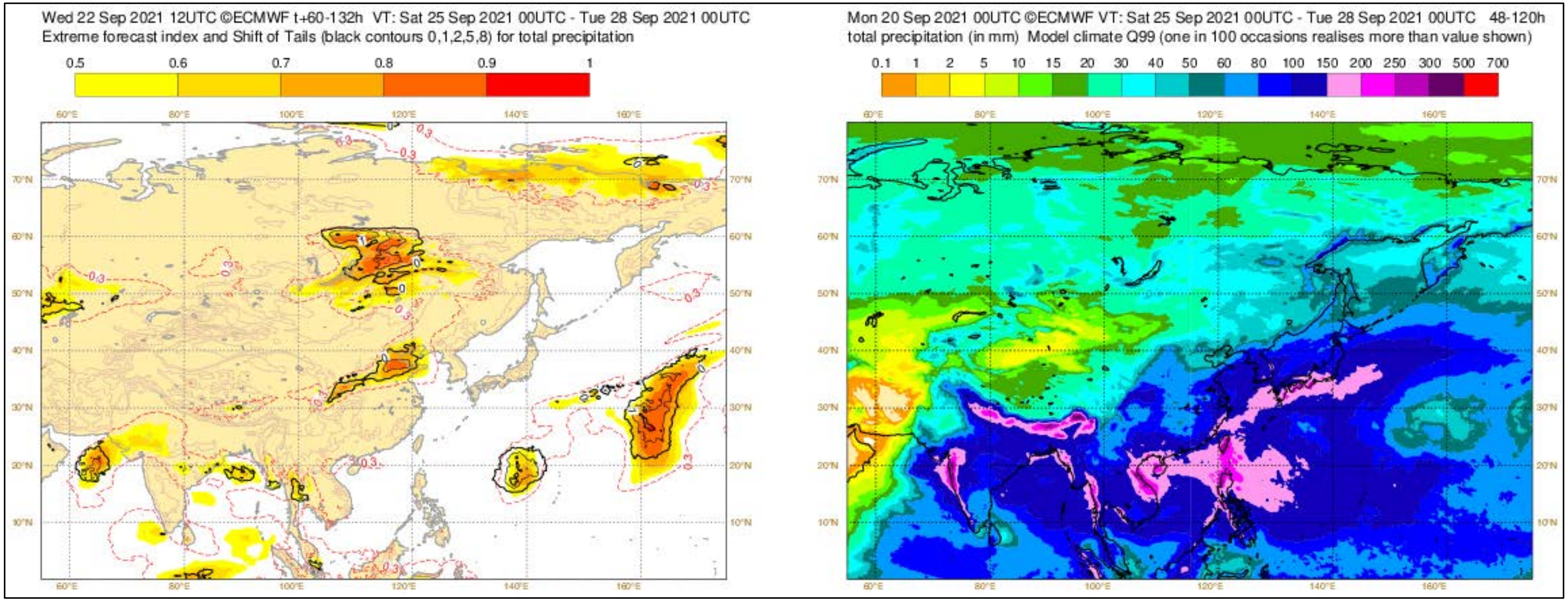




distribution of 48-hour ERA5 precipitation for all days from January 1950 to August 2021 in that area

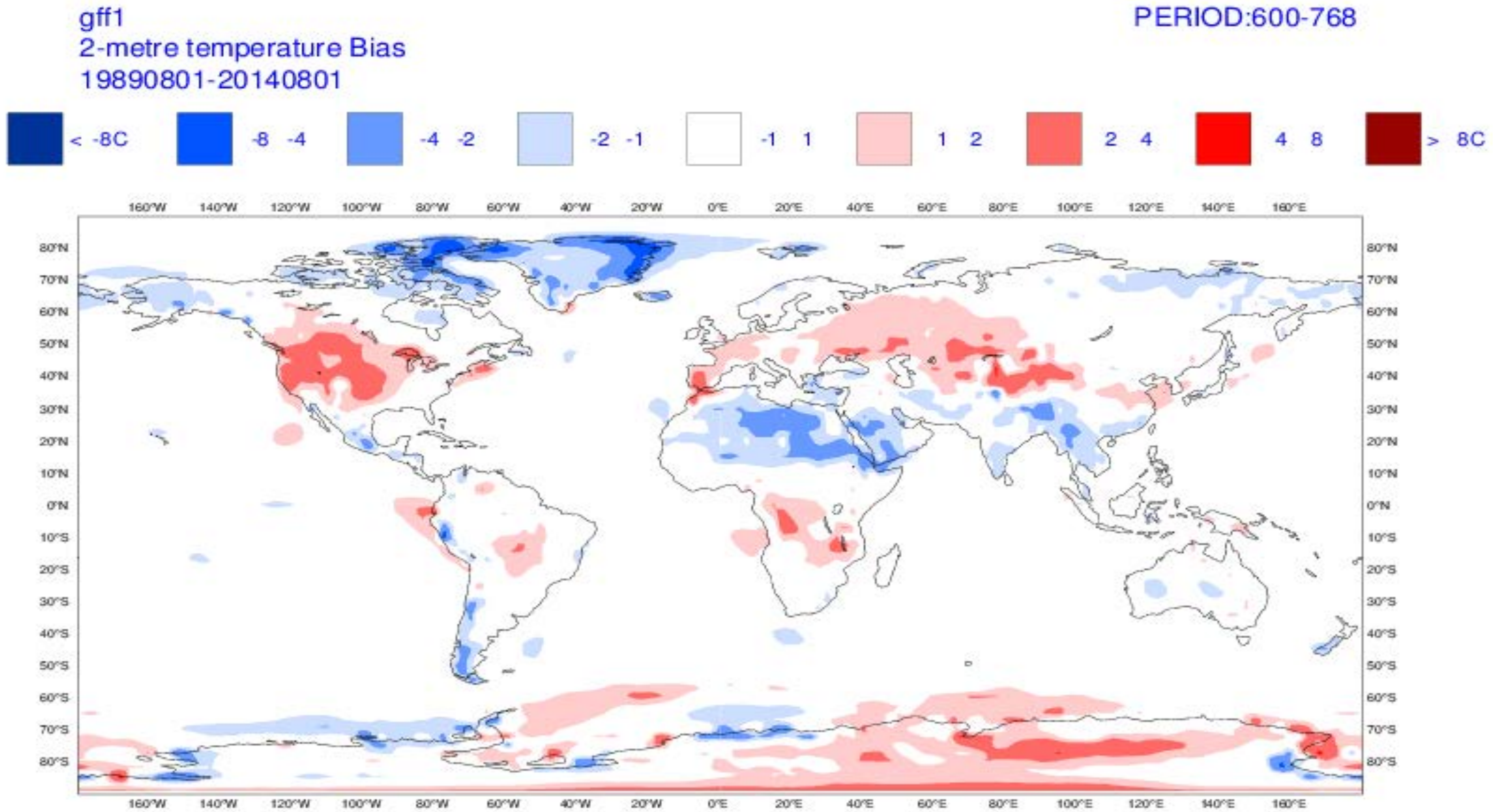
Forecasting extreme events

- Extreme forecast index (EFI) indicates places where the ENS distribution is towards the extreme of the climate distribution



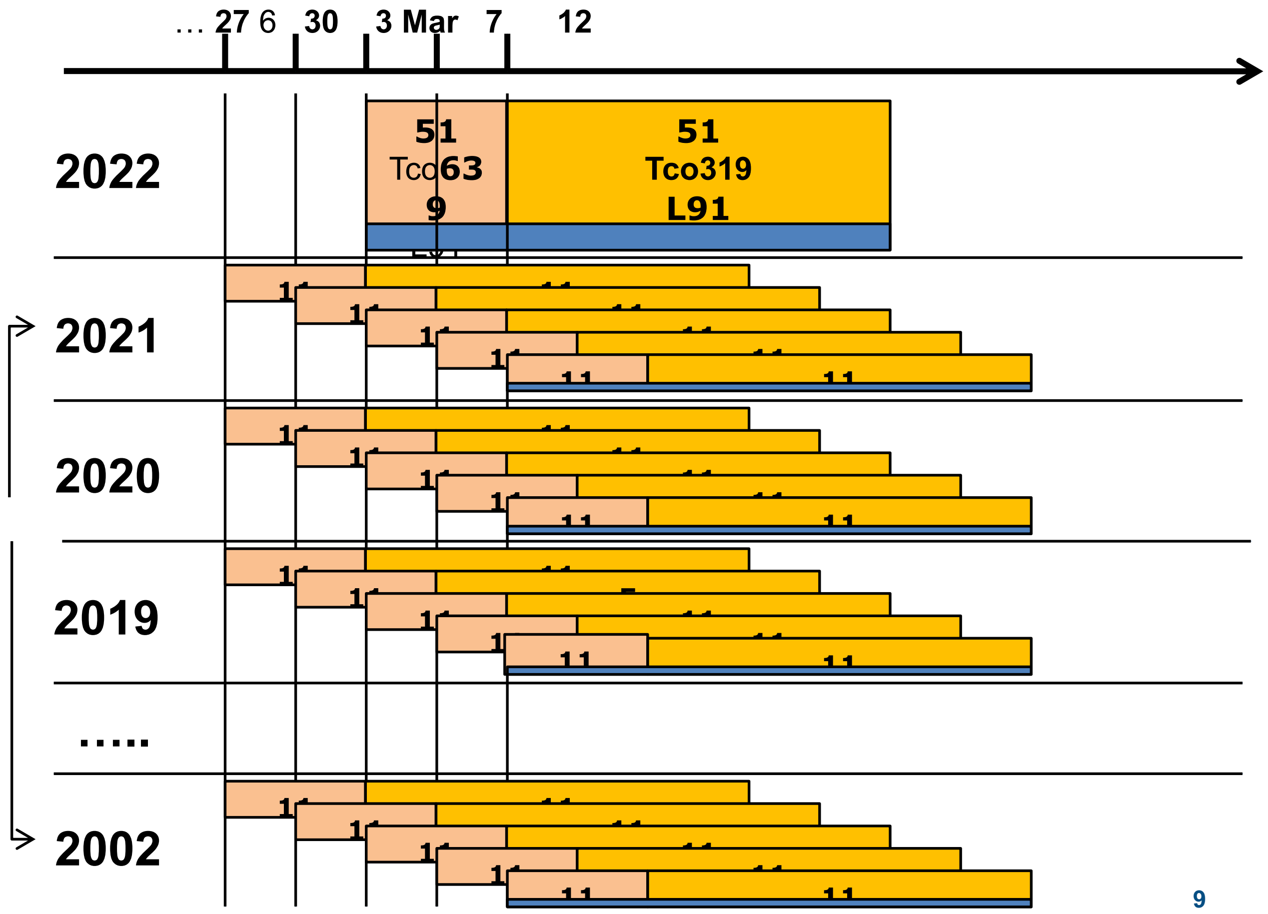
Extended-range forecast – model bias

- Biases (eg 2mT as shown here) are often comparable in magnitude to the anomalies which we seek to predict
- To make useful products we need to calibrate the model – we need a model climate



Re-forecasts

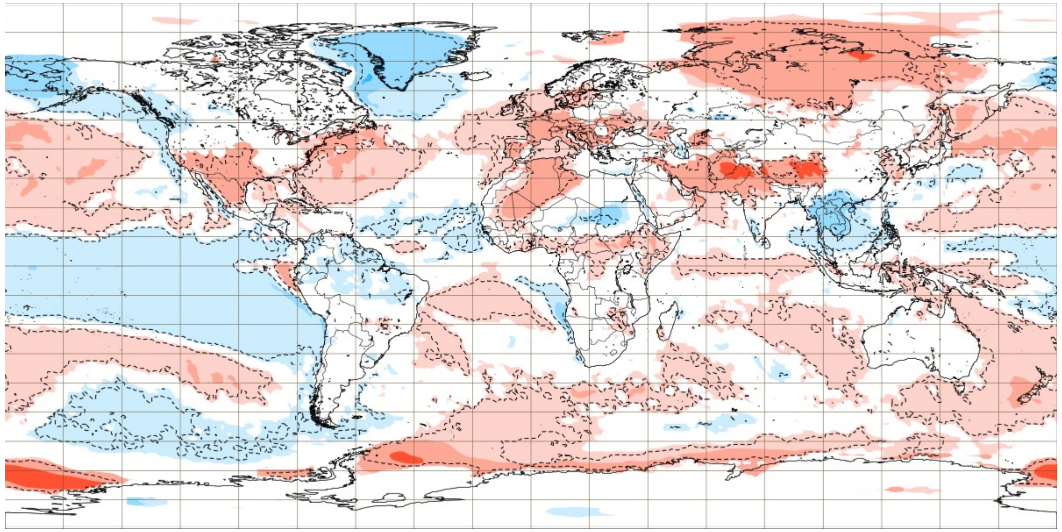
- Provide model climates for the medium-range and the extended-range (monthly) products
- Run with operational IFS version (for start dates from previous 20 years)
- twice a week, for Mondays and Thursdays (11 members)



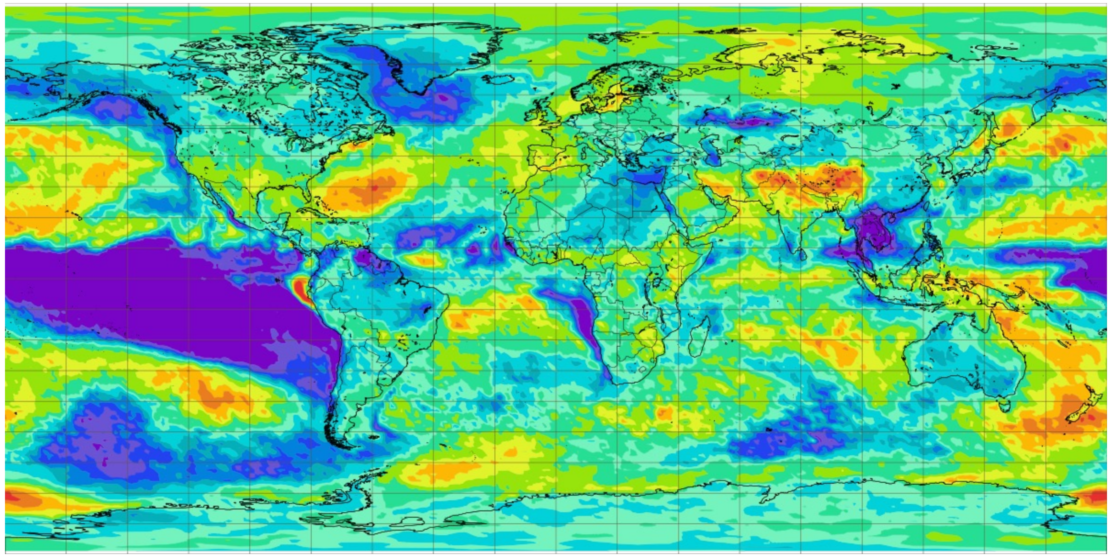
Extended-range products

- Average conditions over a period of time (eg 5-7 days)
- Expressed as a departure from climate values for that period

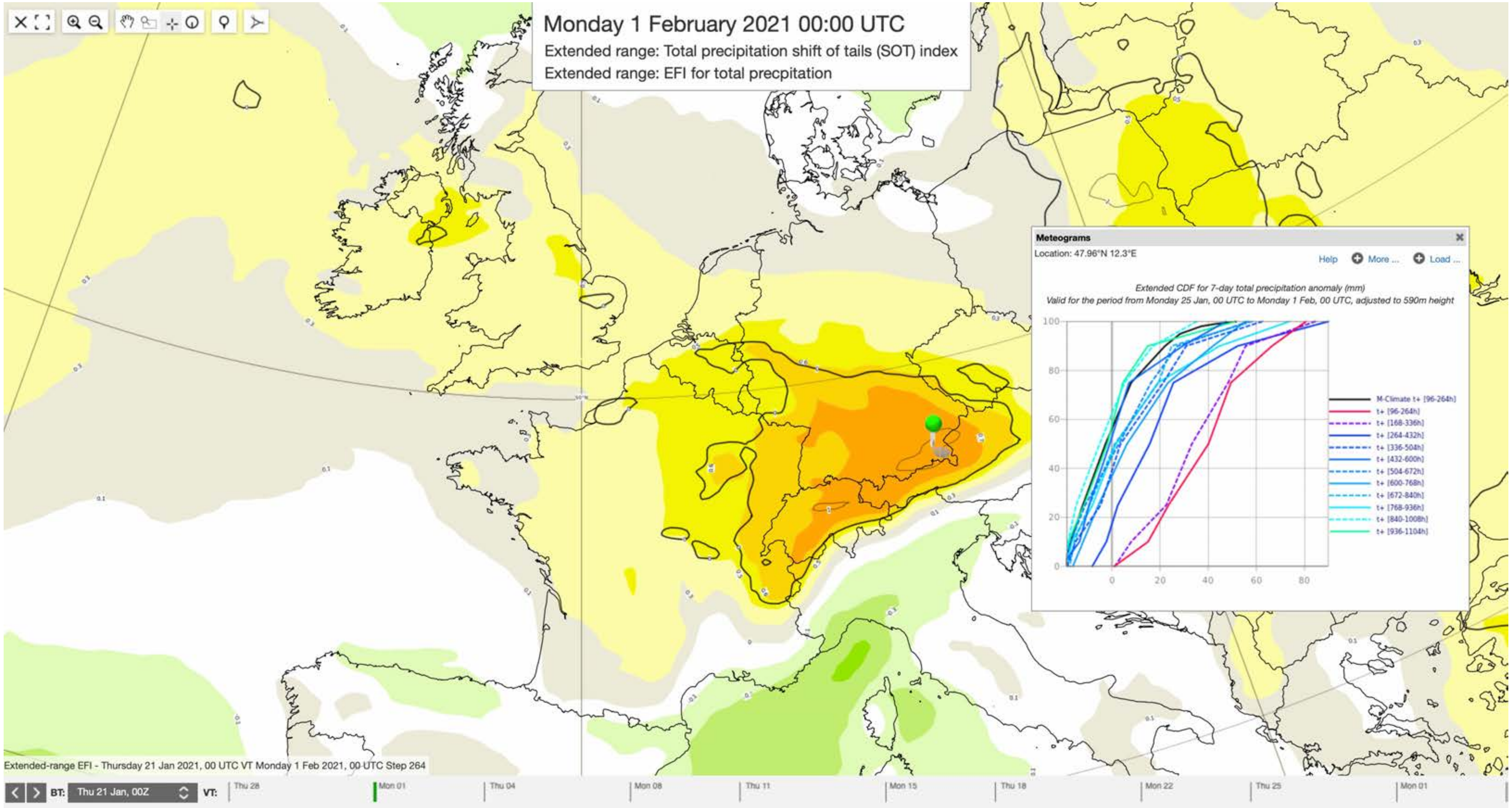
2-metre temperature anomalies
10 March 2022 - Week 4



Probability of 2-metre temperature in upper tercile
10 March 2022 - Week 4



Extended-range EFI and CDFs



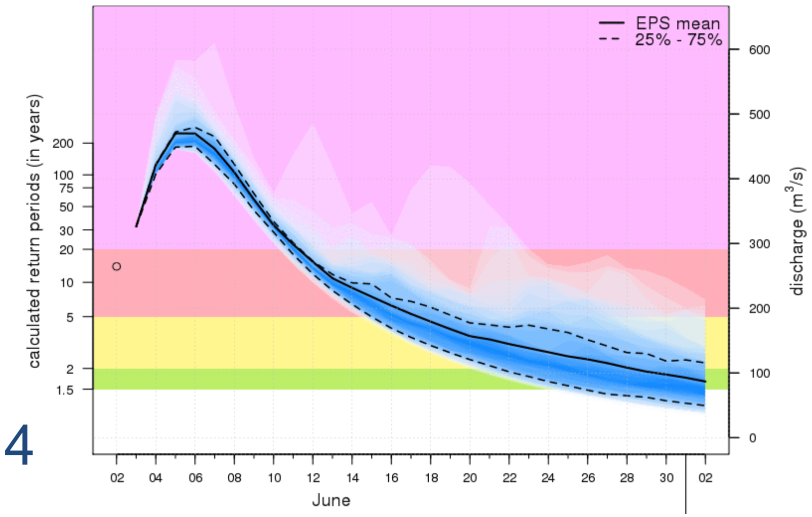
ECMWF

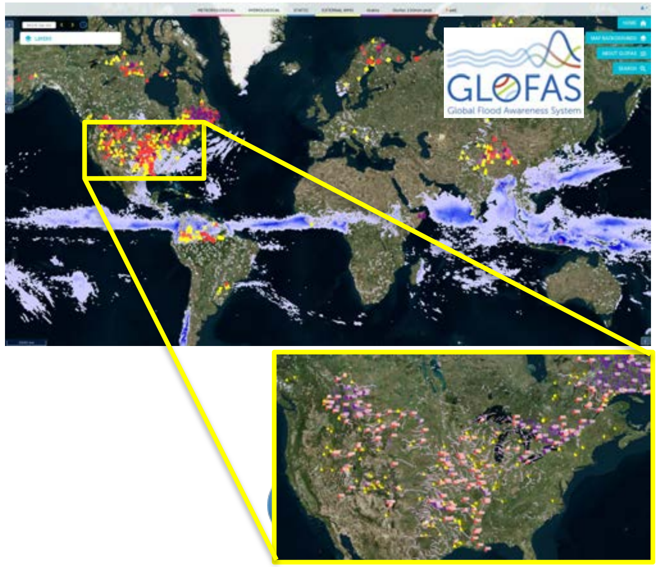
EFAS/GloFAS at a glance

- Early probabilistic flood warnings
- Transboundary system

- In Europe (EFAS), ~ 70 partners (restricted) who provide:
  - Observations
  - Feedback on warning performance
  - Service delivered by the Joint Research Centre (JRC) and 4 centres

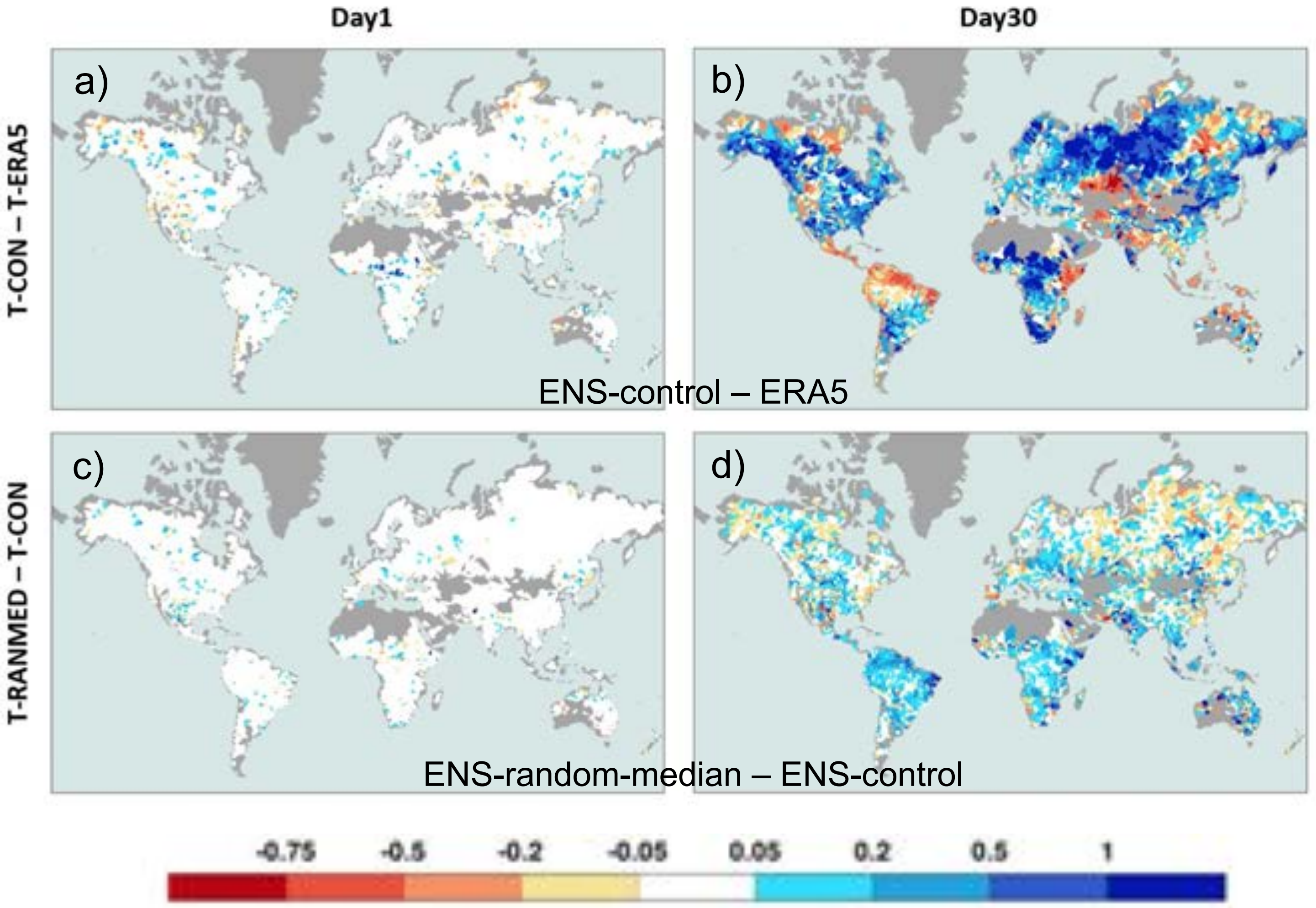
- In the world (GloFAS)
  - Over 2000 registered users
  - Special partners providing observation data
  - Service delivered by JRC and ECMWF





How similar are the flood thresholds?

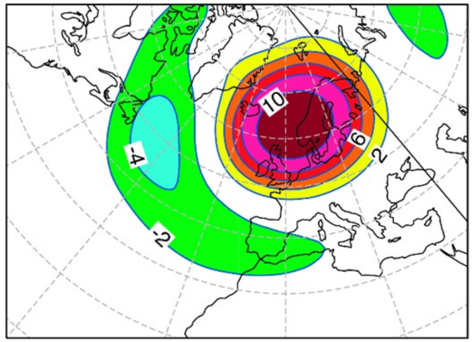
%-difference between thresholds for 10% AEP



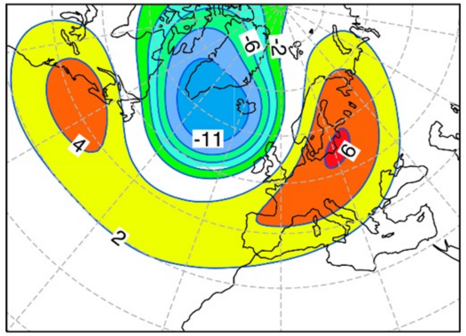
- **<u>Day-1</u>**:
  - All threshold versions are similar
- **<u>Day-30</u>**:
  - Differences can grow very large
  - T-ERA5 becomes very different to the reforecast-based thresholds
  - Using only control member alone still produces different thresholds than using the full ensemble

Regime transitions

- Early warnings of cold spells

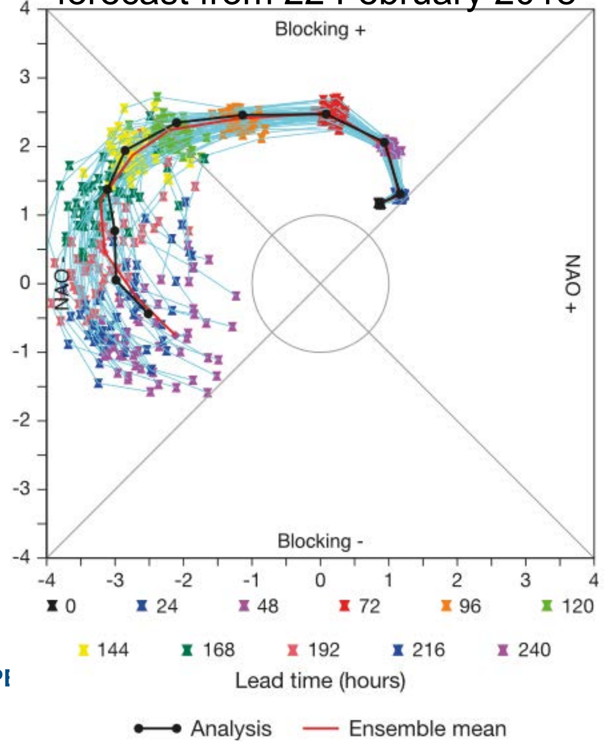


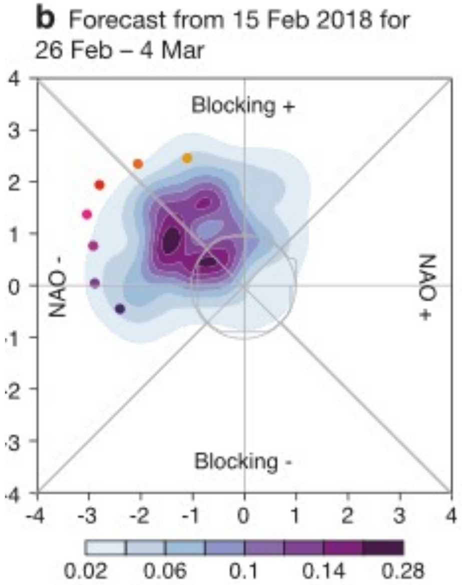
EOF2/BLO



EOF1 /NAO

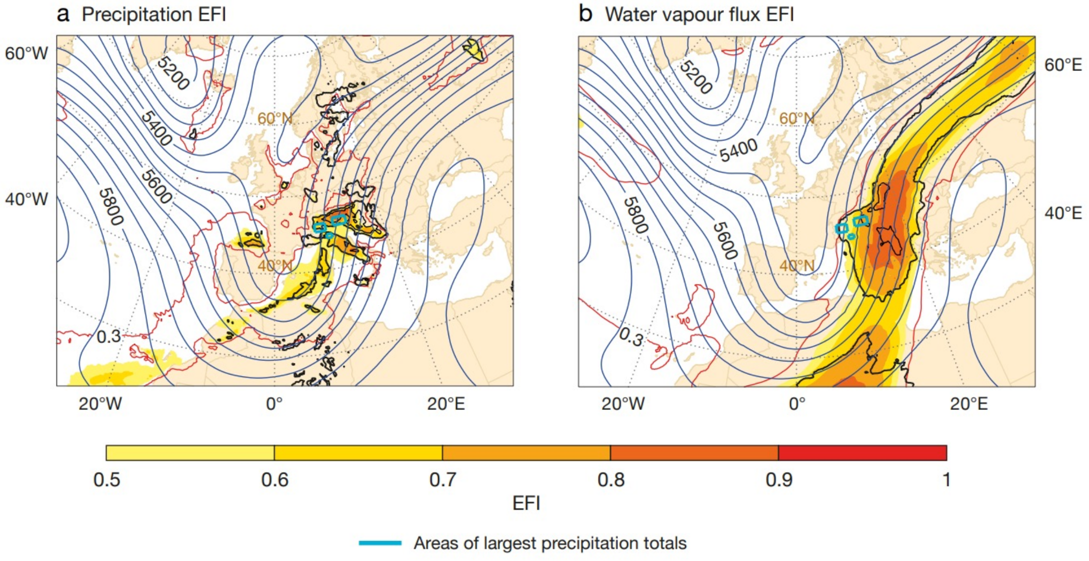
forecast from 22 February 2018





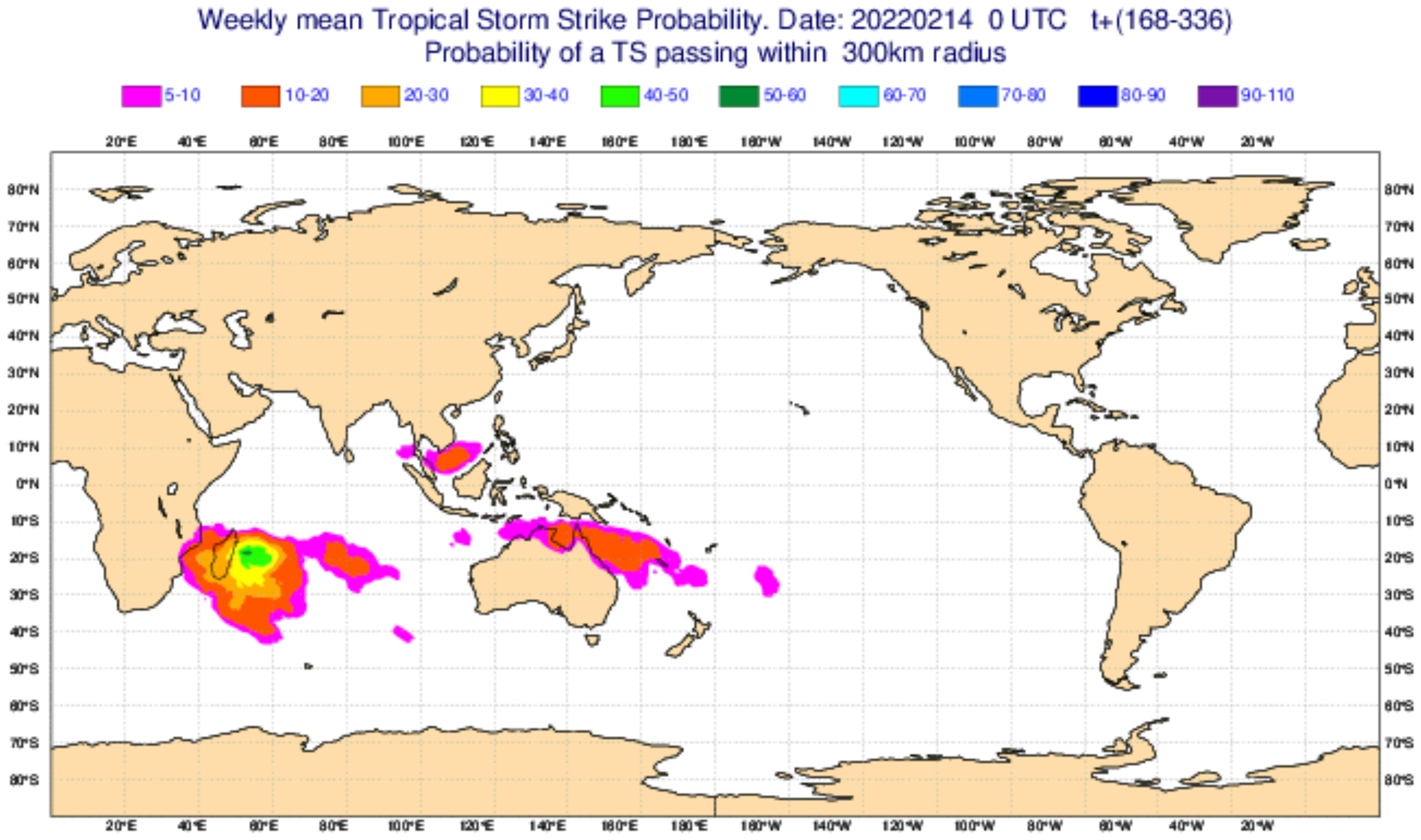
Summary

- For ECMWF and its users reforecasts bring many benefits for enhanced forecast products
- Medium-range
  - Put the current forecast in context of model climate – especially important for forecasting extreme events
- Extended range
  - Essential to account for (significant) model systematic error
- Many other applications (verification, case studies, model understanding)
- Why reforecasts?
  - Observations do not have complete coverage
  - Some model parameters not directly observed
  - Model climate different to observed climate
    - representativeness (shorter range),
    - model drift (systematic error) at longer range
  - So need reanalyses, but also need reforecasts

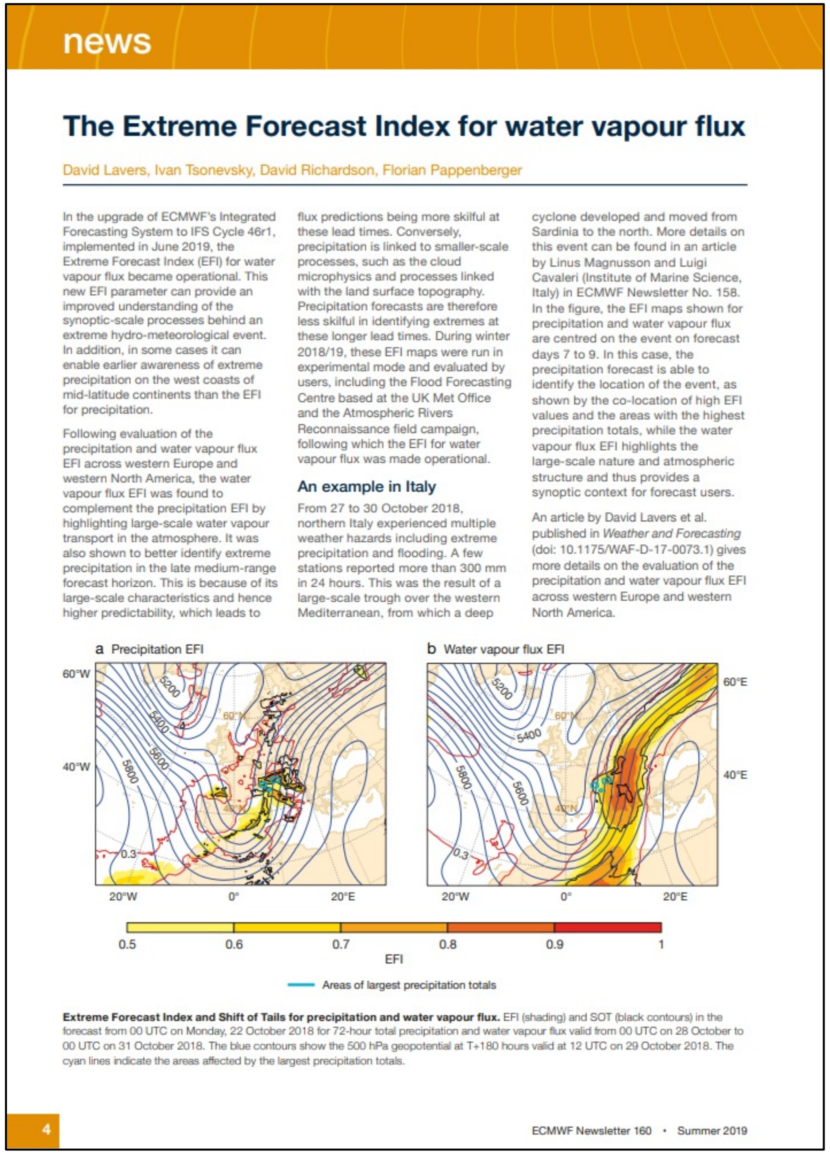


Extreme Forecast Index and Shift of Tails for precipitation and water vapour flux. EFI (shading) and SOT (black contours) in the forecast from 00 UTC on Monday, 22 October 2018 for 72-hour total precipitation and water vapour flux valid from 00 UTC on 28 October to 00 UTC on 31 October 2018. The blue contours show the 500 hPa geopotential at T+180 hours valid at 12 UTC on 29 October 2018. The cyan lines indicate the areas affected by the largest precipitation totals.

Tropical cyclone activity



Water vapour flux EFI/SOT



news

The Extreme Forecast Index for water vapour flux

David Lavers, Ivan Tsonevsky, David Richardson, Florian Pappenberger

In the upgrade of ECMWF's Integrated Forecasting System to IFS Cycle 46r1, implemented in June 2019, the Extreme Forecast Index (EFI) for water vapour flux became operational. This new EFI parameter can provide an improved understanding of the synoptic-scale processes behind an extreme hydro-meteorological event. In addition, in some cases it can enable earlier awareness of extreme precipitation on the west coasts of mid-latitude continents than the EFI for precipitation.

Following evaluation of the precipitation and water vapour flux EFI across western Europe and western North America, the water vapour flux EFI was found to complement the precipitation EFI by highlighting large-scale water vapour transport in the atmosphere. It was also shown to better identify extreme precipitation in the late medium-range forecast horizon. This is because of its large-scale characteristics and hence higher predictability, which leads to flux predictions being more skilful at these lead times. Conversely, precipitation is linked to smaller-scale processes, such as the cloud microphysics and processes linked with the land surface topography. Precipitation forecasts are therefore less skilful in identifying extremes at these longer lead times. During winter 2018/19, these EFI maps were run in experimental mode and evaluated by users, including the Flood Forecasting Centre based at the UK Met Office and the Atmospheric Rivers Reconnaissance field campaign, following which the EFI for water vapour flux was made operational.

An example in Italy

From 27 to 30 October 2018, northern Italy experienced multiple weather hazards including extreme precipitation and flooding. A few stations reported more than 300 mm in 24 hours. This was the result of a large-scale trough over the western Mediterranean, from which a deep cyclone developed and moved from Sardinia to the north. More details on this event can be found in an article by Linus Magnusson and Luigi Cavaleri (Institute of Marine Science, Italy) in ECMWF Newsletter No. 158. In the figure, the EFI maps shown for precipitation and water vapour flux are centred on the event on forecast days 7 to 9. In this case, the precipitation forecast is able to identify the location of the event, as shown by the co-location of high EFI values and the areas with the highest precipitation totals, while the water vapour flux EFI highlights the large-scale nature and atmospheric structure and thus provides a synoptic context for forecast users.

An article by David Lavers et al. published in *Weather and Forecasting* (doi: 10.1175/WAF-D-17-0073.1) gives more details on the evaluation of the precipitation and water vapour flux EFI across western Europe and western North America.

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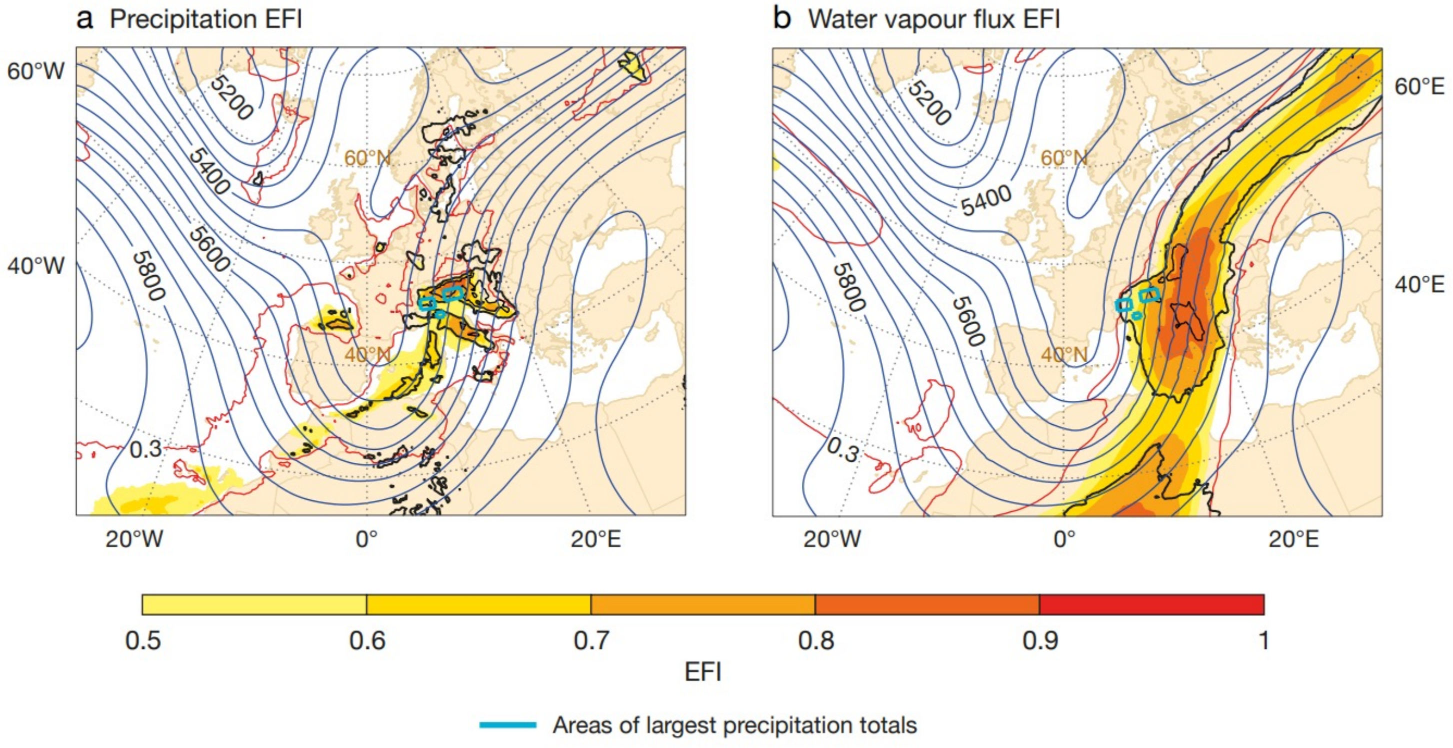
4 ECMWF Newsletter 160 • Summer 2019



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Lavers, D., I. Tsonevsky, D. Richardson, F. Pappenberger, 2019: The Extreme Forecast Index for water vapour flux, *ECMWF Newsletter*, **160**, 4.

EFI for CAPE and CAPE-SHEAR