Probabilistic products for NWP

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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)
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

![ EFI map for total precipitation](image1)

![ Precipitation map](image2)
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 (e.g., 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
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`

- **Day-1:**
  - All threshold versions are similar
- **Day-30:**
  - 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
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 90T (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 29 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
The Extreme Forecast Index for water vapour flux

David Lavers, Ivan Tsonovski, David Richardson, Florian Pappenberger

In the upgrade of ECMWF's Integrated Forecasting Systems (IFS Cycle 48/1), implemented in June 2019, the Extreme Forecast Index (EFI) for water vapour flux has been introduced. The new EFI parameter can provide an improved understanding of high-impact weather events. Following this implementation, EFI has proven to be highly useful in providing forecasts for high-impact events across various regions of the world.

 EFI is particularly effective in identifying regions with a high risk of excessive rainfall. The EFI is based on a combination of the background error covariances and the analysis error covariances, which are estimated from the ensemble of weather forecasts. This allows for a more accurate assessment of the predictability of extreme weather events.

An example in Italy

In 2019, Italy experienced a series of heavy rainfall events, which led to widespread flooding and landslides. The EFI was able to provide early warnings of these events, allowing for timely evacuation and mitigation efforts.

EFI and the Precipitation EFI

The EFI is closely related to the Precipitation EFI, which provides a direct measure of the potential for heavy rainfall. This relationship is illustrated in the diagram, showing the areas of highest EFI values correspond to areas of high precipitation potential.

Extreme Floods 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 26 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.

EFI for CAPE and CAPE-SHEAR

Convective activity for Friday 11 August 2017

ESWD+ATDnet lightning

ATDnet lightning flashes valid for 11/08/2017