ECMWF Severe Event Catalogue

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Background

The ECMWF Severe event catalogue was created in 2013 to collect material about severe weather cases. Since the start more than 150 cases has been added. The aims are to act as a starting point for further evaluation, pick cases for model testing, and simplify the writing of governance documents and external communication.

The catalogue uses the Confluence portal and is open to the public. Each case populates one page. Every quarter one case is selected for the ECMWF Newsletter, which has resulted in more than 40 articles so far.

https://confluence.ecmwf.int/display/FCST/Severe+Event+Catalogue

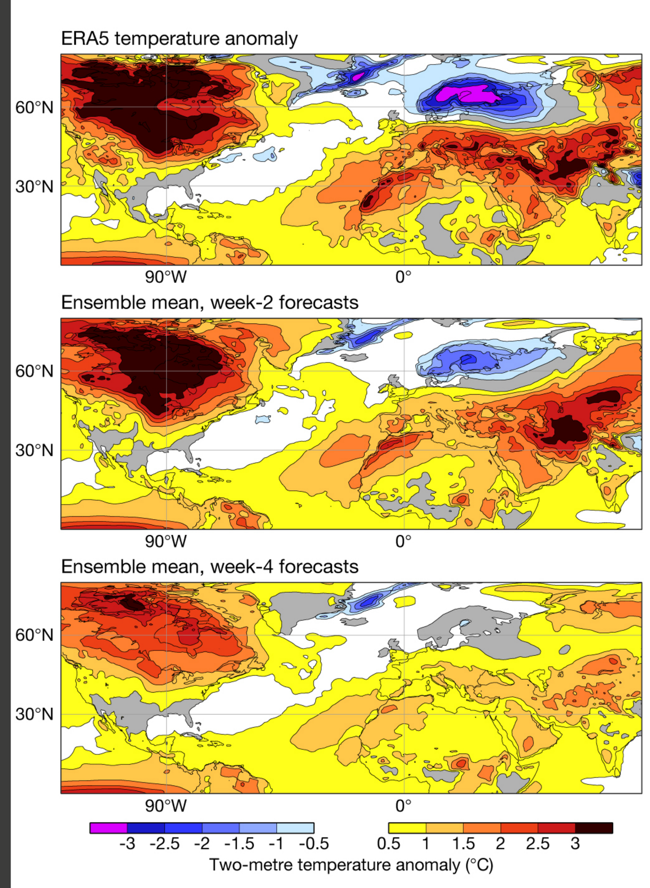
How to define a case?

- Case selection: No rigid selection criterion is used to decide to create a page for an event. Factors influencing the decision are (1) requests from external users, (2) severity of the event and news converge, (3) interesting forecasting aspects, (4) **availability of observations**, and (5) time available to work on the page.
- Event definition: For each event a definition in terms of area, period and key variable is needed. Several factors are coming into play here such as societal impact (i.e large cities are favourable), **available observations** and accumulation periods in observations and forecast products. The event is in most cases selected based on the outcome, by selecting the worst affected area.
- False alarms: So far the focus has been on event that happened and evaluation for the worst affected area (see above). False alarms are difficult to select in the sense that it depends on the user, i.e which probability threshold the user decides to act upon the forecast.

A cold winter in northern Europe

While the world as a whole experienced an unprecedentedly high average temperature in 2023, Northern Europe was one of the few areas that saw below-average temperatures compared to 1991–2020. Especially the autumn and the winter were dominated by cold anomalies as seen in the composite of weekly anomalies in ECMWF's ERA5 reanalysis from 2 October 2023 to 25 February 2024.

Composites of extended-range ensemble mean predictions of weekly mean 2-metre temperature anomalies for weeks starting on 2 October to 18 February, shows that the anomalies over Europe were **well captured in week-2 forecasts**. The longer forecast (week-4) had the warm signal present for continental Europe but was neutral for northern Europe. It still predicted that northern Europe would be colder than central Europe in terms of anomalies.

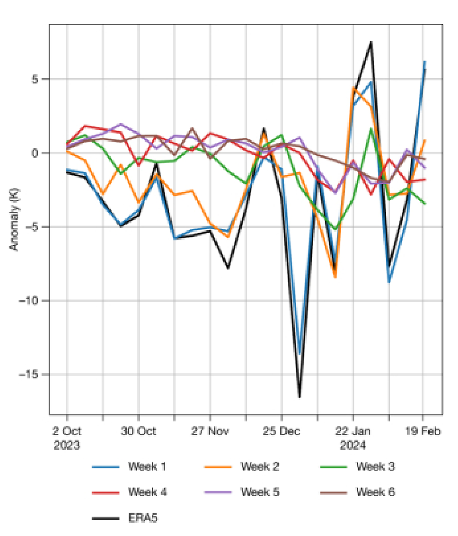


Weekly anomalies of 2-metre temperature over parts of Finland and north-eastern Sweden. The chart shows weekly anomalies in the ERA5 reanalysis and according to ECMWF extended-range ensemble mean forecasts one to four weeks ahead, over land points inside the box in the third figure.

Predicting week-to-week variations of extended-range ensemble mean predictions for a box over Finland/Sweden proved difficult. This resulted in a **negative correlation with the outcome for week-4 forecasts** (–0.3) and for week-3 forecasts was 0.22. **The week-2 forecast captured well the week-to-week variability (correlation of 0.65) except for the coldest week of the period**, starting on 1 January, which had a weekly anomaly of –16° in the box in the ERA5 analysis.

On 3–5 January, the coldest temperatures since 1999 were measured in both Sweden and Finland (–44.6°C and –44.3°C), and two stations in Sweden had a 3-day mean temperature below –40°C (2–4 January). According to the ECMWF analysis of 2-metre temperature, large parts of central Finland had a 3-day mean temperature below –30°C. The forecast evolution of 2-metre temperature inside the box (top panel of the last figure), based on the daily extended-range ensemble, shows that the **signal for the extreme cold appeared between 26 and 28 December**. The day-6 forecast from 25 December as well as earlier forecasts included **large errors over Europe**. Predictability experiments using the nudging technique pointed to **short-range errors on the downstream side of a trough over the central U.S**. These affected the subsequent development of storm Geraldine, which hit France. Once the uncertainties in this development were overcome, medium-range predictions captured the extreme cold.

Predicting very cold temperatures during calm conditions has been a long-standing challenge for ECMWF's forecasts as well as other models. It is believed that this issue is due to a **combination of several model deficiencies** that need to be tackled separately. Looking at the spatial pattern of the 9 km control forecast averaged over the first 72 hours for 3 January 00 UTC, we see that the forecast underestimated the coldest extreme, such as the region where temperatures were below –30°C (brown shading). In the upcoming Cycle 49r1 planned for late 2024, several changes are targeting 2-metre temperature.



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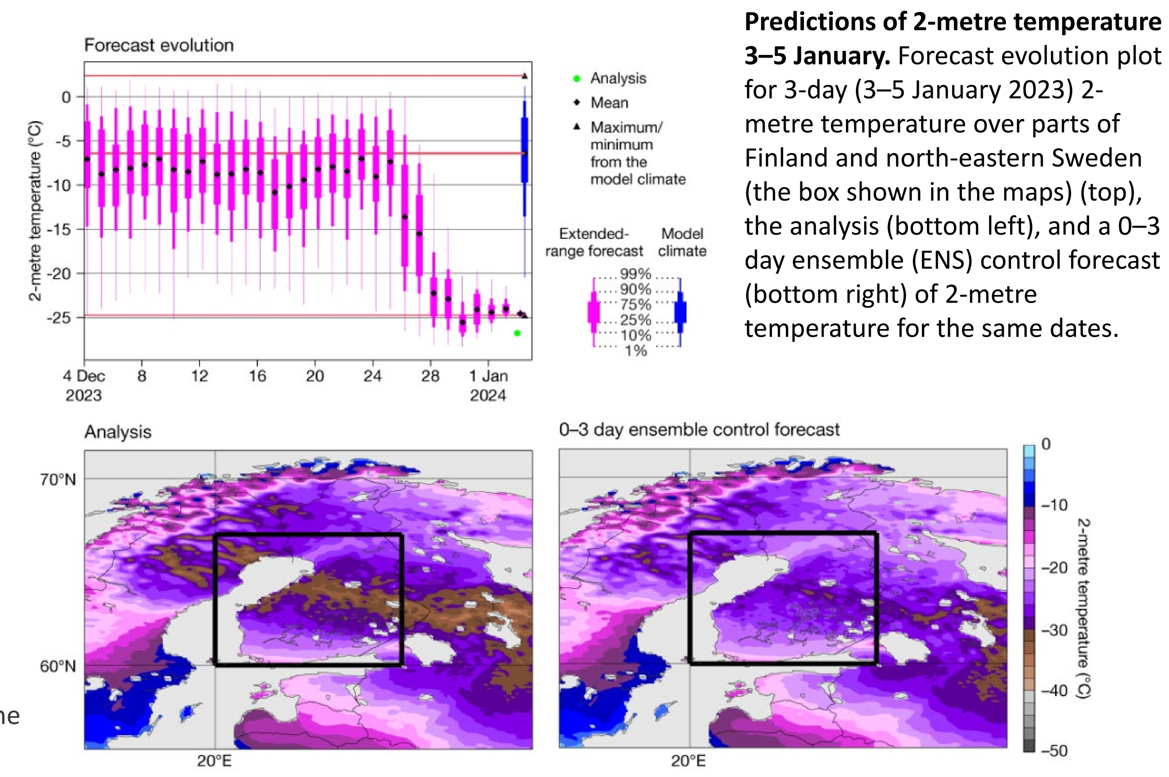


Predictions of 2-metre temperature 3–5 January. Forecast evolution plot for 3-day (3–5 January 2023) 2-metre temperature over parts of Finland and north-eastern Sweden (the box shown in the maps) (top), the analysis (bottom left), and a 0–3 day ensemble (ENS) control forecast (bottom right) of 2-metre temperature for the same dates.

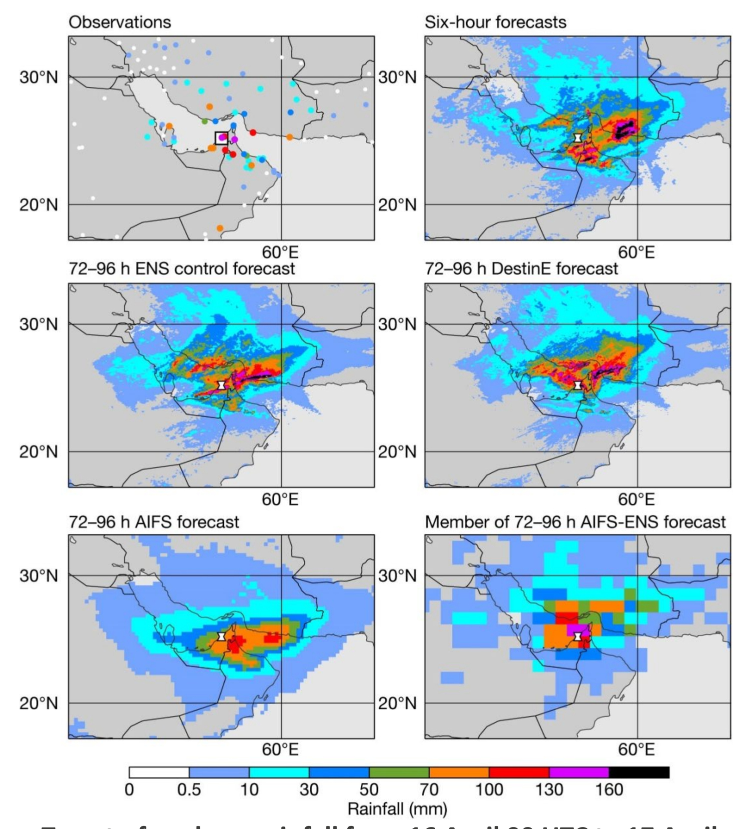
Unprecedented rainfall in the United Arab Emirates

On 16 April 2024, the United Arab Emirates (UAE) experienced unprecedented rainfall. The highest 24-hour rainfall recorded was 259.5 mm, reportedly setting a new all-time UAE record. Many stations exceeded 100 mm, e.g. Dubai Airport with 144 mm, corresponding to 1.5 years' worth of rain.

Here we focus on precipitation from 16 April 00 UTC to 17 April 00 UTC over Dubai. We find that a wide region was affected by the rainfall, but with **significant local variations in the magnitude**, which is also hinted at in the sparse observations . The analysis proxy for Dubai was 48 mm compared to 144 mm in the SYNOP weather station report from Dubai Airport, but there are values above 160 mm in the proxy analysis to the south.

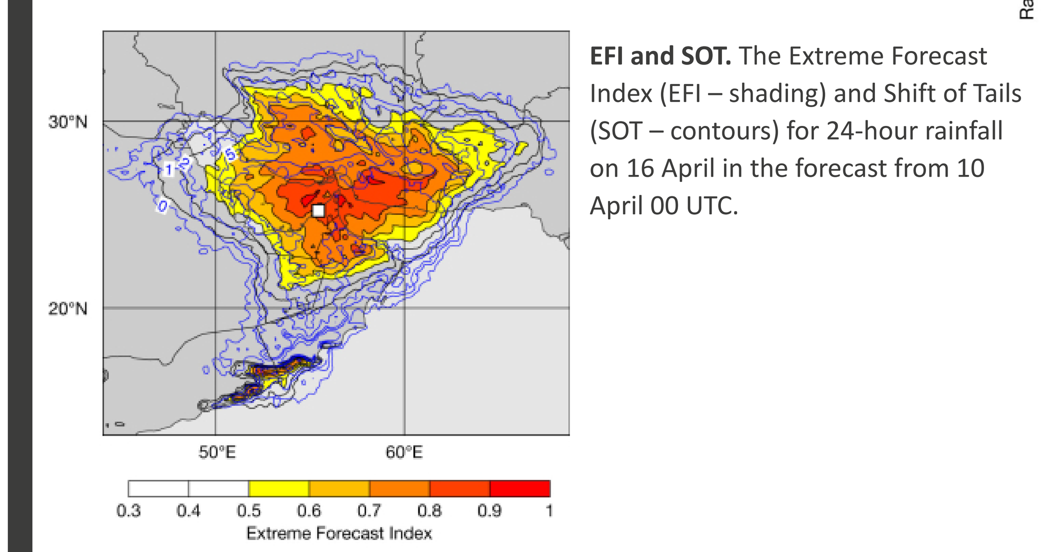
Looking at the forecasts issued on 13 April 00 UTC from the ENS 9 km control, 4.4 km forecasts produced for the EU's Destination Earth (DestinE) initiative, and 28 km forecasts of the Artificial Intelligence Forecasting System (AIFS), we find that **all forecasts predicted the rainfall region well**. ENS control and DestinE had **large variability around the UAE**, causing large local deviations from the SYNOP observations. **AIFS producing a much smoother field**, this model also predicted the region of the rainfall well, although it missed the extension to the northwest.

The forecast evolution plot for 24-hour rainfall over the gridbox including Dubai shows that even down to the **shortest range (00–24 h) the uncertainty remained large**, with IFS ensemble members ranging from 20 to almost 200 mm. The ensemble mean was around 80 mm, which is about four times the maximum in ECMWF re-forecasts (valid day 5) for this time of the year. The ensemble mean was stable at around 70–80 mm/24 h from **7-8 days before the event**. This early signal can also be seen in the Extreme Forecast Index (EFI) from 10 April (6–7 days before the event).

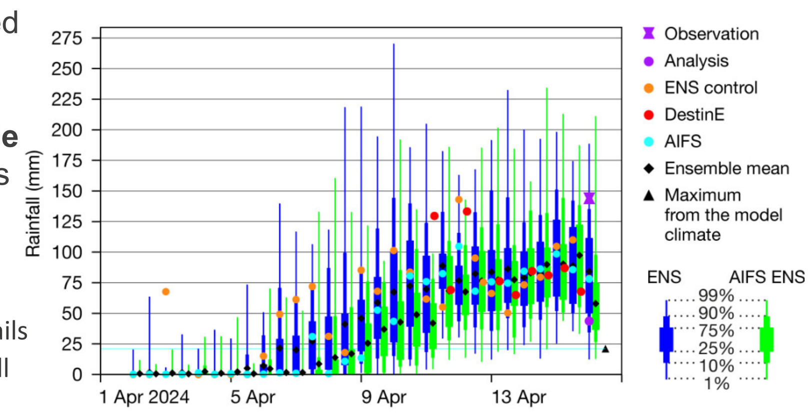


Twenty-four-hour rainfall from 16 April 00 UTC to 17 April 00 UTC. The charts show observations (top left); concatenated 6-hour forecasts (top right); 72–96 h forecasts from the ENS control at 9 km (middle left), DestinE at 4.4 km (middle right), and the AIFS at 28 km (bottom left); and the first perturbed member from the AIFS-ENS at 111 km (bottom right).

Since June 2024, ECMWF has also been running a real-time ensemble version of the AIFS. This first version has the output on a 1x1 degree grid. Looking at the spatial pattern of the first perturbed member from the we see extreme rainfall (> 70 mm/24 h) in the region, but the low resolution (111 km grid spacing) is very apparent. **Despite the low resolution, we see that the ensemble mean for precipitation over Dubai is of a similar magnitude** as the IFS ensemble mean from 12 April onwards.



EFI and SOT. The Extreme Forecast Index (EFI – shading) and Shift of Tails (SOT – contours) for 24-hour rainfall on 16 April in the forecast from 10 April 00 UTC.



Forecast evolution plot for Dubai. The plot shows the evolution of 24-hour rainfall forecasts on 16 April over the grid box including Dubai. The model climate is about zero precipitation, with a maximum of less than 25 mm based on 1,800 forecasts (marked by the black triangle).

Different categories of forecast errors

The catalogue has given insights of different kind of forecast error than needs different approaches:

	Cause	Mitigation
Synoptic non-systematic errors	Mainly initial condition errors with some model error component	Ensemble forecasts
Non-growing model biases*	Model errors (often diagnostic variables)	Post-processing based on observation datasets
Growing model biases*	Model errors (often difficult to find the source)	Bias-correction using reforecasts
Representation errors*	Insufficient resolution	Ensemble spread inflation e.g by EcPoints
Interpretation errors	Over-simplification of products and messages	Education
Technical errors	Faulty observations, ..	Continuously. Monitoring for the forecasts

* Conditional errors

ECMWF Newsletter articles based on cases:

- 139 - Windstorms in northwest Europe in late 2013
- 140 - Forecasting the severe flooding in the Balkans
- 141 - Recent cases of severe convective storms in Europe
- 142 - Forecasts for a fatal blizzard in Nepal in October 2014
- 143 - Forecasts for US east coast snow storm in January 2015
- 144 - ECMWF forecasts for tropical cyclone Pam
- 145 - Predicting this year's European heat wave
- 146 - Forecasting flash floods in Italy
- 147 - Wind and wave forecasts during Storm Gertrude/Tor
- 148 - Forecasts showed Paris flood risk well in advance
- 149 - Predicting heavy rainfall in China
- 150 - Flash floods over Greece in early September 2016
- 151 - The cold spell in eastern Europe in January 2017
- 152 - ECMWF supports flood disaster response in Peru
- 153 – Predictions of tropical cyclones Harvey and Irma
- 154 – Two storm forecasts with very different skill
- 155 – Predicting extreme snow in the Alps in January 2018
- 156 – Forecasting convective rain events in late May
- 157 – Forecasting the 2018 European heatwave
- 158 – Predicting multiple weather hazards over Italy
- 159 - Forecasts of freezing rain in Romania
- 160 - ECMWF works with universities to support response to tropical cyclone Idai
- 161 - The 2019 western European heatwaves
- 162 - Challenges in forecasting Hurricane Lorenzo
- 163 - Forecasting February's wet and stormy weather in parts of Europe
- 164 - Warm intrusions into the Arctic in April 2020
- 165 – Hurricane Laura and its threat to the United States
- 166 - Windstorm Alex affected large parts of Europe
- 167 - Unusual snowfall in Madrid in January
- 168 - Saharan dust events in the spring of 2021
- 169 - Extreme rain in Germany and Belgium in July 2021
- 170 - Heavy snowfall in Denmark and Sweden at the start of December
- 171 - Wind gust predictions for storm Eunice
- 172 - Spring heatwave in India and Pakistan
- 173 - Predicting the heat over western Europe in the summer of 2022
- 174 - The deepest extratropical cyclone of modern times?
- 175 - Predicting extreme precipitation over California
- 176 - Predicting tropical cyclone Mocha in the Bay of Bengal
- 177 - Heatwave over southwest Europe in August 2023
- 178 - Capturing extreme rainfall events
- 179 - A cold winter in northern Europe
- 180 - Unprecedented rainfall in the United Arab Emirates
- 182 - Severe rain in central Europe from Storm Boris
- 183- Forecasts for Storm Éowyn
- 184 - Prediction of precipitation contrasts over western Europe during spring 2025