Predicting this year's European heat wave

**LINUS MAGNUSSON,
ALAN THORPE,
ROBERTO BUIZZA,
FLORENCE RABIER,
JEAN NICOLAU** (Météo-France)

A heat wave affected large parts of Europe during the summer of 2015. Records include an all-time high for Germany (5 July), an all-time high for Switzerland north of the Alps (7 July), a June record for Madrid (29 June) and a July record for the UK (1 July). The 2-metre temperature anomaly from ERA-Interim for the period 1 July to 15 August was more than 3 °C for large parts of central Europe as well as Spain. In this article we examine how successive ensemble forecasts for Paris picked up the onset of the heat wave increasingly well. On 1 July, the observed temperature at 12 UTC was between 35.5 °C and 36.8 °C among SYNOP stations in Paris, and later that day one station reached 39.7 °C, the second warmest temperature on record for the city. There are, of course, many other aspects of the heat wave worth discussing but not covered in this article.

Synoptic situation

The onset of the heat wave was associated with a ridge over western Europe, bringing hot tropical air from Africa. The amplification of the ridge started on the last days of June and coincided with the arrival of a Rossby wave train over western Europe. This Rossby wave had propagated from the west and could be traced back in the analysis to the Western Pacific, where it originated around 22 June.

Another synoptic-scale element was a cyclone that developed on 26 June over the eastern US and propagated eastward over the Atlantic. These dynamical ingredients probably contributed on different timescales to the establishment and predictability of the heat wave.

Ensemble visualisations

The ECMWF ensemble is designed so that its 51 members provide a set of scenarios consistent with our knowledge of the initial conditions and the laws of physics, bearing in mind the associated uncertainties. The ensemble forecast is typically represented in the form of probability distributions, based on the relative frequency of ensemble members making particular predictions. This can take the form of a probability distribution function (PDF), shown for Paris in the top-left panel, or of a cumulative distribution function (CDF), shown in the top-right panel, or of box-and-whiskers diagrams, as shown in the mid-left and mid-right panels. We also show 2-metre temperature anomaly forecasts for Europe initialised on 18 June (bottom-left) and 22 June (bottom-right) for the week starting on 29 June to highlight the spatial pattern of the anomaly.

The different PDFs and CDFs for 2-metre temperature in Paris at 12 UTC on 1 July represent consecutive forecasts. Each PDF has been estimated by calculating a histogram of ensemble members using bins of 1 °C and applying a smoothing function with a weight of 0.5 for the central bin and 0.25 for the neighbouring bins. We have also included the distribution for the model climate, which is a useful reference as it includes the same systematic errors as the forecasts.

Results

The longest lead time illustrated here is the forecast issued one month before the event, on Monday 1 June. For this lead time – the so-called monthly forecast – it is expected that, to isolate a predictable signal, it is necessary to average in time over periods such as a week (as shown in the mid-right and lower panels). However, it is interesting to ask at which lead time the extended-range forecast for a specific time (such as 12 UTC on 1 July) acquires predictive skill. In answering this question, it is important to consider the range of scenarios predicted within the ensemble forecast.

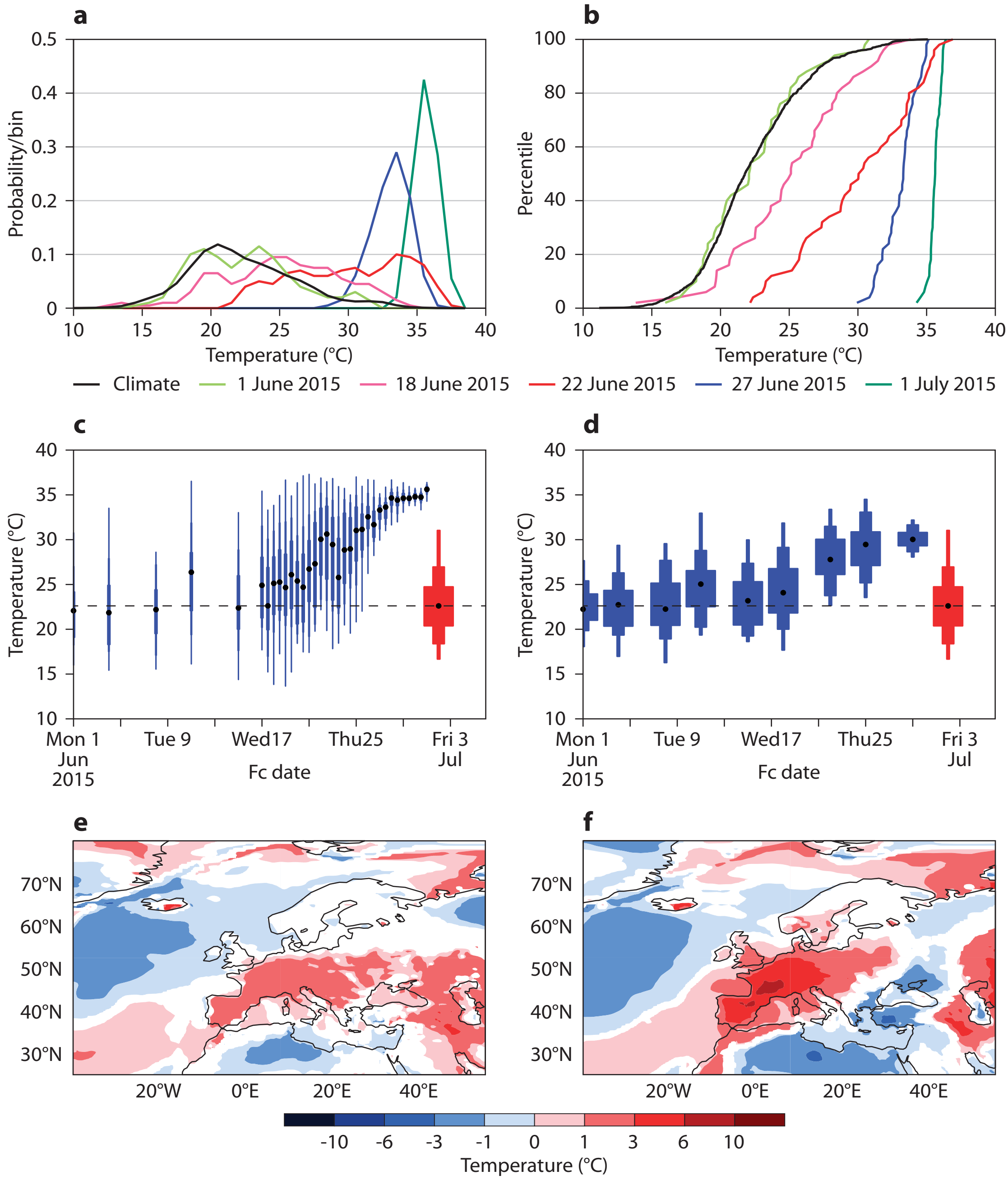
At a lead time of a month (and certainly for point values) we expect to see only very weak evidence of predictive skill if any, and indeed there is no visible distinction between the climate and forecast PDFs and CDFs. In the forecast from Thursday 18 June, the ensemble PDF is shifted towards warmer conditions, although the chance of near-record-breaking temperatures is still rather small. The shift in the PDF was due to a large-scale warm anomaly (covering most of Europe) for a longer period, and this anomaly put its stamp on the local PDF for Paris. The forecast from Monday 22 June has a peak in the PDF close to 34°C, indicating that several members are picking up the risk of extreme temperatures, although a cold tail is still present in the distribution. At this stage forecasters in France started to pay attention to the risk of a heat wave. In the weekly temperature anomaly map for this forecast, the strongest anomalies are present over Western Europe. One could speculate that this signal is connected to the presence of the Rossby wave packet in the initial conditions.

Forecasts change substantially from around 26 and 27 June: the signal of extreme temperatures is dominating and the cold tail in the distribution has vanished, although the predicted temperatures are still a little cooler than the observed 36 °C. From 27 June, the forecast is sufficiently sharp for the coolest ensemble members to exceed the 90th percentile of the climatology. As early as 26 June, Météo-France was able to put warnings on its website for the extreme temperatures. Synoptically, at this time the cyclone had formed over the eastern US and its further development was probably less uncertain than in earlier forecasts. Finally, the 12-hour short-range forecast from 1 July 00 UTC has a very sharp distribution as little uncertainty remains for this short lead time.

To summarize the evolution, the forecast PDF peak progressively shifts towards higher temperatures and the distribution sharpens and loses its asymmetric cold tail. These are characteristics that one would hope to see in an ensemble forecast that has increasing levels of skill relative to climatology as the event approaches.

'Ready-set-go'

This case illustrates rather well how the concept of 'ready-set-go' could be used by forecasters to warn users. The ensemble distribution evolves from a broad distribution indistinguishable from the climatology towards a very sharp distribution as the day of interest approaches. As valuable information is added to the initial conditions, the sharpness of the distribution increases, reducing uncertainty and increasing confidence. At the longer time range (2–3 weeks ahead), the ensemble provides an indication that the distribution is shifted towards warmer values – the forecaster can tell users to be ready for the possibility of an extreme weather event. At the medium range (e.g. ten days ahead), the forecaster can tell users that they are now more confident about the forecast and can suggest that they get set, i.e. start taking appropriate action that could help to manage the forthcoming weather conditions. Finally at short range (e.g. a few days ahead), forecasters can tell users that they are now very confident about the forecasts and can issue the warning: it is time to go and take action, since the extreme weather is coming.



Two-metre temperature forecasts. Ensemble forecasts valid 12 UTC on 1 July in Paris visualised by (a) probability density functions (PDFs) for forecasts initialised at 00 UTC on 1 June, 18 June, 22 June, 27 June and 1 July, (b) cumulative distribution functions (CDFs) for forecasts initialised at the same times and (c) a box-and-whisker plot for forecasts initialised at different times as shown, and for the model climate shown in red; also shown are (d) a box-and-whisker plot for ensemble forecasts of the average 2-metre temperature at 12 UTC for 29 June to 5 July in Paris, and for the model climate shown in red; and 2-metre temperature anomaly forecasts for 29 June to 5 July (shading in areas where the ensemble distribution is significantly different from climatology, significance level of 10%), initialised on (e) 18 June and (f) 22 June. The box-and-whisker symbols mark the 1st, 10th, 25th, 75th, 90th and 99th percentile and the median is marked with a dot. The dotted line represents the median of the model climate.