5.4. The Extreme Forecast Index (EFI)

The extraction of extreme weather-related information from the ensemble is not always straightforward. For example, the probabilities themselves do not reveal whether a certain value is unusual or even extreme. A 30% probability of >20 mm rainfall in 6 hours in July would not be "extreme" in New Delhi, but would be in Cairo. The *Extreme Forecast Index* (EFI) has been developed to alert forecasters to anomalous or extreme events by relating the forecast probability distribution to the climatological one (Lalaurette, 2003; Zsótér, 2006).

5.4.1. The EFI reference climate

In EFI the forecast probability distribution is compared to the model climate (M-climate) distribution for the chosen location, time of year and lead time. The underlying assumption is that, if a forecast is anomalous or extreme with respect to the M-climate, the real weather is also likely to be anomalous or extreme compared to the real climate.

Since 12 May 2015 the M-climate has been based on 5 weeks of re-forecasts run every Monday and Thursday with 10 perturbed and 1 unperturbed member. Initial conditions come from ERA-Interim re-analyses for each of the last 20 years. Before 12 May 2015 the M-climate was constructed from 5 Thursday runs of a smaller ensemble that consisted of 4 perturbed and 1 unperturbed member. The resolution decreases with forecast range exactly as in the ENS. This procedure allows seasonal variations and model changes to be taken into account, as well as model drift. By construction the EFI compensates for systematic errors in the model climate.

The M-climate for the EFI computations on Saturday 31 October 2015 at 12 UTC is, for example, prepared from nine runs of the re-forecast suite within a 5-week time window centred on the preceding Thursday, 29 October, i.e. 15, 19, 22, 26, 29 October and 2, 5, 9 and 12 November for all the 20 years, totalling 1980 re-forecast values for each grid point (see Figure 51).

5.4.2. The cumulative distribution function

The EFI value is computed from the difference between two cumulative distribution function (CDF) curves: one for the M-Climate, and the other for the current ENS forecast distribution. The calculations are made so that more weight is given to differences in the tails of the distribution (see Figure 51).

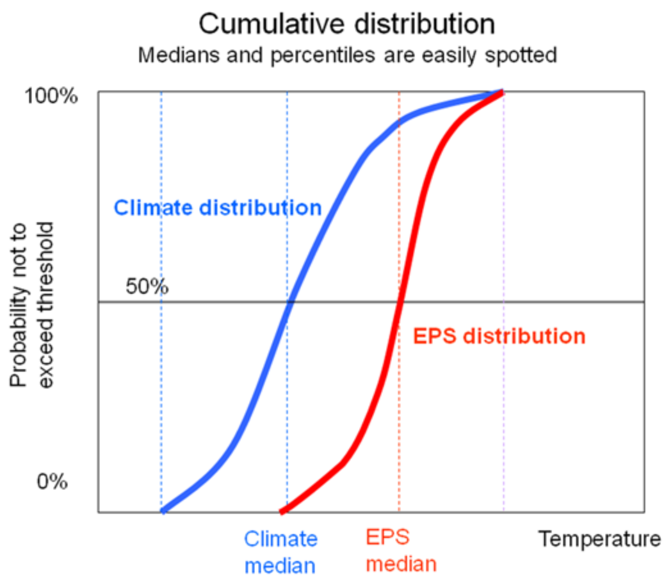

Figure 51: A schematic explanation of the principle behind the Extreme Forecast Index, measured by the area between the cumulative distribution functions (CDFs) of the M-Climate and the ensemble members. The CDF shows the probability (y-axis) against the exceedance threshold value (x-axis). The EFI is, in this case, positive (red line to the right of the blue), indicating higher than normal probabilities of warm anomalies.

From a CDF curve it is also easy to determine the median and any other percentiles as the point on the x-axis where a horizontal line intersects the curve. The most likely values are associated with those where the CDF is steepest. Another way to assess it is by the probability density function (pdf), which is a derivative of the CDF (i.e. the gradient of the curve). The highest probability intervals are easily recognised as the peaks in a pdf (see Figure 52).

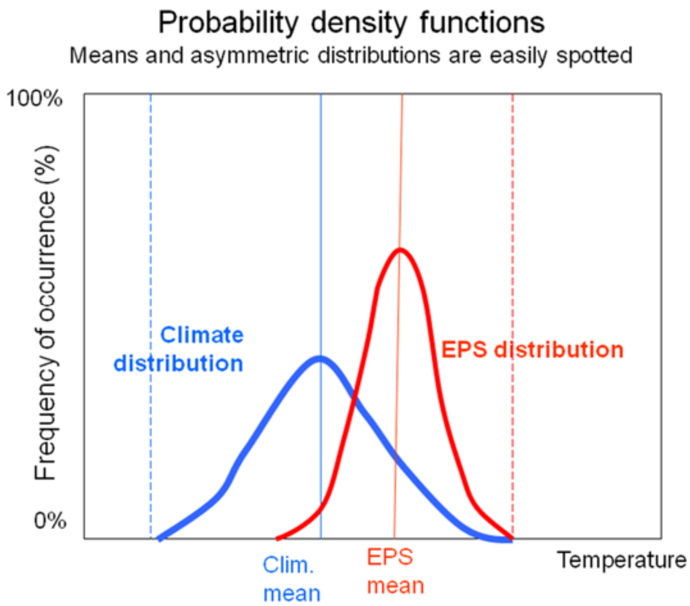

Figure 52: The temperature climatology (blue curve) and the forecast distribution (red curve) presented as probability density functions corresponding to the CDF curves in Figure 51. The pdf is the derivative of the CDF. Here the forecast pdf is to the right (red curve) of the M-climate pdf (blue

curve), indicating that the forecast predicts warmer than normal conditions with high probability, consistent with the conclusions on positive EFI from Figure 51.

The EFI can be understood and interpreted with both the CDF and pdf in mind; the former relates to the EFI value, the latter clarifies the connection to probabilities.

5.4.3. Calculating the EFI

The Extreme Forecast Index is calculated according to the formula

$$EFI = \frac{2}{\pi}\int_0^1 \frac{p-F_f(p)}{\sqrt{p(1-p)}}\mathrm{dp}$$

where $F_f(p)$ denotes the proportion of EPS members lying below the p quantile of the climate record. The EFI is computed for many weather parameters, for different forecast ranges and accumulation periods. Charts are accessible via the ECMWF web pages.

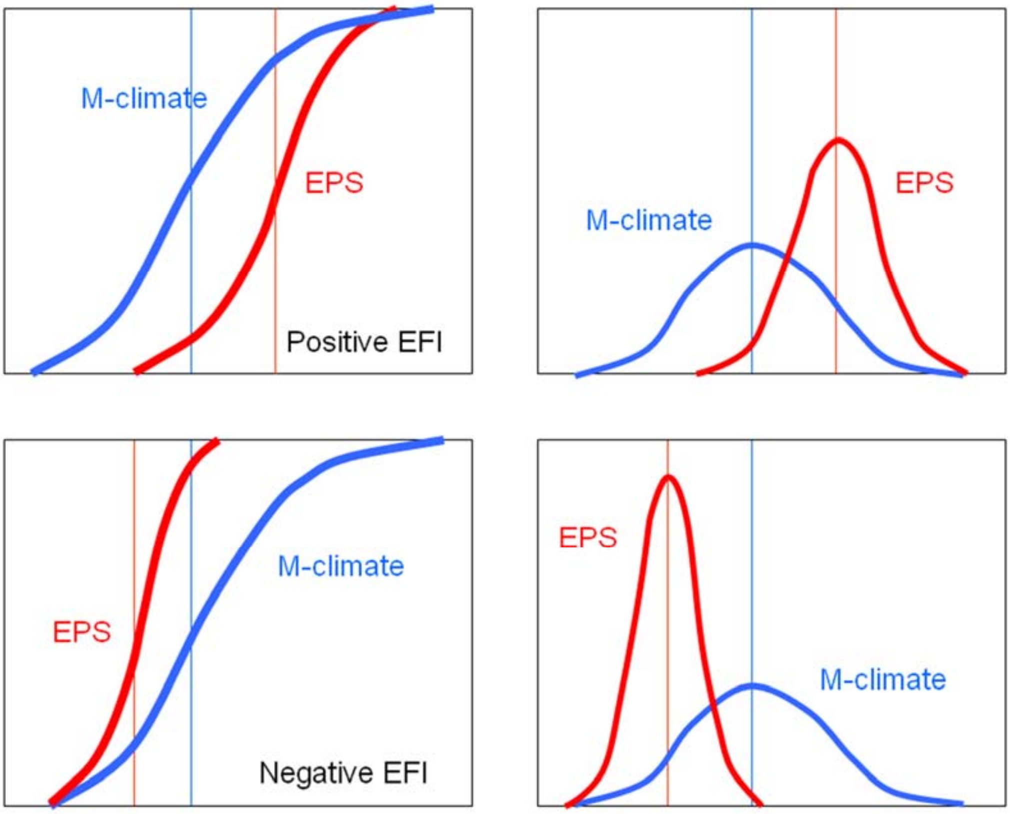

Figure 53: The EFI can have both negative and positive values: positive for positive anomalies (upper figures) and negative for negative anomalies (lower figures).

If the forecast probability distribution agrees with the M-climate distribution then EFI = 0. If the probability distribution (mean, spread and asymmetry) does not agree with the climate probability distribution, the EFI takes non-zero values. In the special case where all the members forecast values above the absolute maximum in the M-climate, the EFI = +1; if they all forecast values below the absolute minimum in the M-climate the EFI = -1 (see Figure 53).

Experience suggests that EFI values of 0.5 - 0.8 (irrespective of sign) can be generally regarded as signifying that “unusual” weather is likely and values above 0.8 as usually signifying that “very unusual” or extreme weather is likely.

A convenient way to depict the current forecast together with previous runs verifying at the same time (“lagged ensembles”) is to depict the CDF from previous runs (see Figure 54).

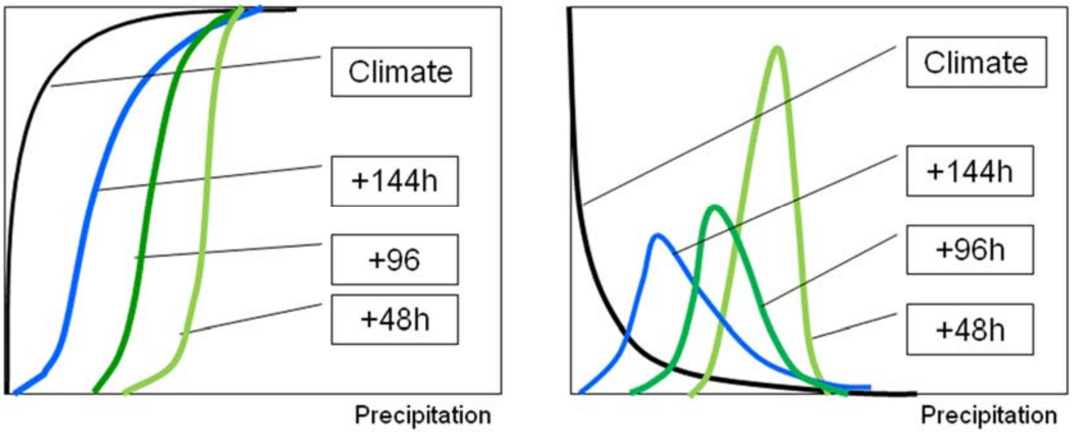

Figure 54: A schematic illustration of the CDF (left) and pdf (right) for forecasts of 12-hour accumulated precipitation. The last EPS forecast +48 hour ahead (light green curves) is presented together with the climate (black curves) and the EPS forecasts four (dark green) and six days back (blue curves).

5.4.4. The interpretation of the EFI

Although a high EFI value indicates that an extreme event is more likely than usual, the values do not represent probabilities. Any forecasts or warnings must be based on a careful study of probabilistic and deterministic information in addition to the EFI.

Since potentially extreme situations (wind storms, for example) are characterized by high dynamical instability in the atmosphere and large spread, EFI users should be aware that it is not uncommon for an extreme event to be preceded by wide-ranging shallow slope CDFs, yielding EFI values that are not particularly high. CDFs should be directly referenced. If, for example, the EFI indicates to forecasters that anomalous wind speeds or rainfall rates are more likely than normal, they have to find out from the CDF diagram what this means for a specific threshold, e.g. 5 mm/12 hours. If the climatological risk is 5% and the predicted probability is 20%, the risk is four times larger than normal. Any action will, however, depend on whether this 20% is high enough for a specific end-user to undertake protective action.

Finally, another key issue of the EFI is that members well beyond M-climate extremes contribute no more to the EFI than members matching the M-climate extreme. Recently the ‘Shift of Tails’ has been developed to address this, and is offered as an additional product (Tsonevsky and Richardosn 2012).

5.4.5. *EFI maps*

On the ECMWF web site, the EFI is presented in maps, either for each parameter separately or on a composite map for temperature, precipitation and wind (see Figure 55)

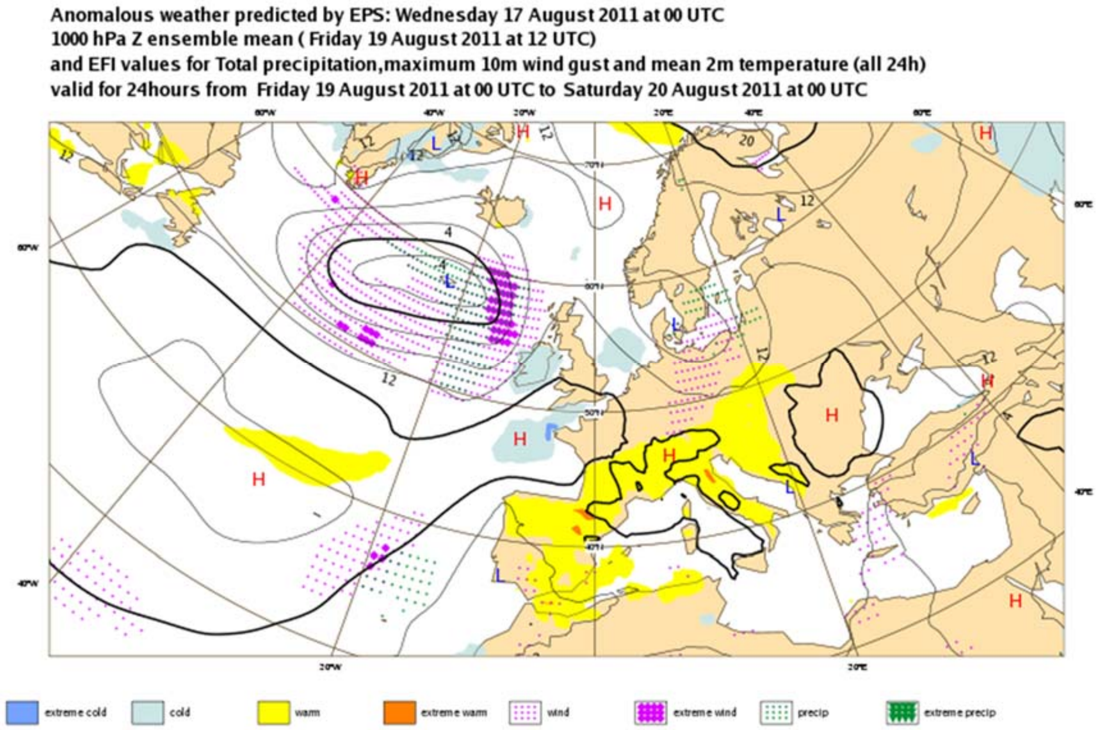

Figure 55: The global "anomalous weather" or "interactive EFI" chart from 17 August 2011, 00 UTC between +48 and +72 hours. It shows the geographical distribution of the EFI of the principal weather parameters: maximum wind gust, 24 h precipitation and 2 m temperature, overlaid with the ensemble mean of the 1000 hPa geopotential field.

Attached to each grid point of the global EFI maps there is a CDF diagram for each of the EFI parameters, with information on climate at the grid point and the available forecast distributions, including the corresponding EFI values. These diagrams can be displayed interactively by clicking on the desired location.

5.5. Tropical cyclone diagrams

The ECMWF tropical cyclone forecast products are designed to provide both deterministic and probabilistic information on the movement and intensity of individual tropical cyclones.

a) **Cyclone position:** Once official reports signify the existence of a tropical cyclone, it is automatically tracked. The tracking algorithm is based on the extrapolation of past movement and of the mid-tropospheric steering flow to obtain a first-guess position. The *actual position* is determined by searching for mean sea level (MSL) pressure and 850 hPa vorticity extremes around the first-guess position. In some circumstances the thickness maximum, the central MSL pressure and the orography are also considered in the evaluation.

b) **Strike probability charts:** Strike probability is defined as the proportion of members that predict that the tropical cyclone will pass within a 120 km radius of a given location at