EPS and EFI: Understanding and Interpretation

ADAPTED FROM DAVIES, 2012

South African Weather Service

The ensemble forecast

Ensemble Mean:

- The ensemble mean (EM) forecast is a simple but effective product. The averaging serves as a filter to reduce or remove atmospheric features that vary amongst the members and are therefore likely to be regarded as less predictable *at the time*. Such non-predictable features are effectively removed from the EM.
- Significant high-impact events are often weakened or absent in the EM. Use of probabilities is therefore essential in conjunction with the EM.
- The EM is most suited to parameters like temperature and pressure, which usually have a rather symmetric Gaussian distribution.
- It is less suitable for wind speeds and precipitation because of their skewed distributions. For these parameters, the *median* might be more useful. It is defined as the value of the middle ensemble member, if the members are ordered according to rising (ranked) values. Due to the anti-symmetry of the initial perturbations, the EM is very similar to the Control (or HRES) in the short range.
- The EM tends to weaken gradients: all members might forecast an intense low-pressure system with 15-20 m/s winds in different positions. These differences in position lead to a rather shallow low in the EM, which gives the impression of weak average winds.

The ensemble forecast

Ensemble Spread:

- The ensemble spread is a measure of the difference between the members and is represented by the standard deviation (Std) *with respect to the EM*. On average, small spread indicates high a priori forecast accuracy and large spread low a priori forecast accuracy.
- The ensemble spread is flow-dependent and varies for different parameters. It usually increases with the forecast range, but there can be cases when the spread is larger at shorter forecast ranges than at longer. This might happen when the first days are characterized by strong synoptic systems with complex structures but are followed by large-scale "fair weather" high pressure systems.
- The spread around the EM as a measure of a priori accuracy applies only to the EM forecast error, not to the median, the Control or HRES, even if they happen to lie mid-range within the ensemble. The spread of the ensemble, relative to a particular ensemble member is, for example, about 41% larger than the spread around the EM.
- The spread with respect to the Control is initially the same as for the EM, but gradually increases, ultimately reaching the same 41% excess as any member.

The ensemble forecast

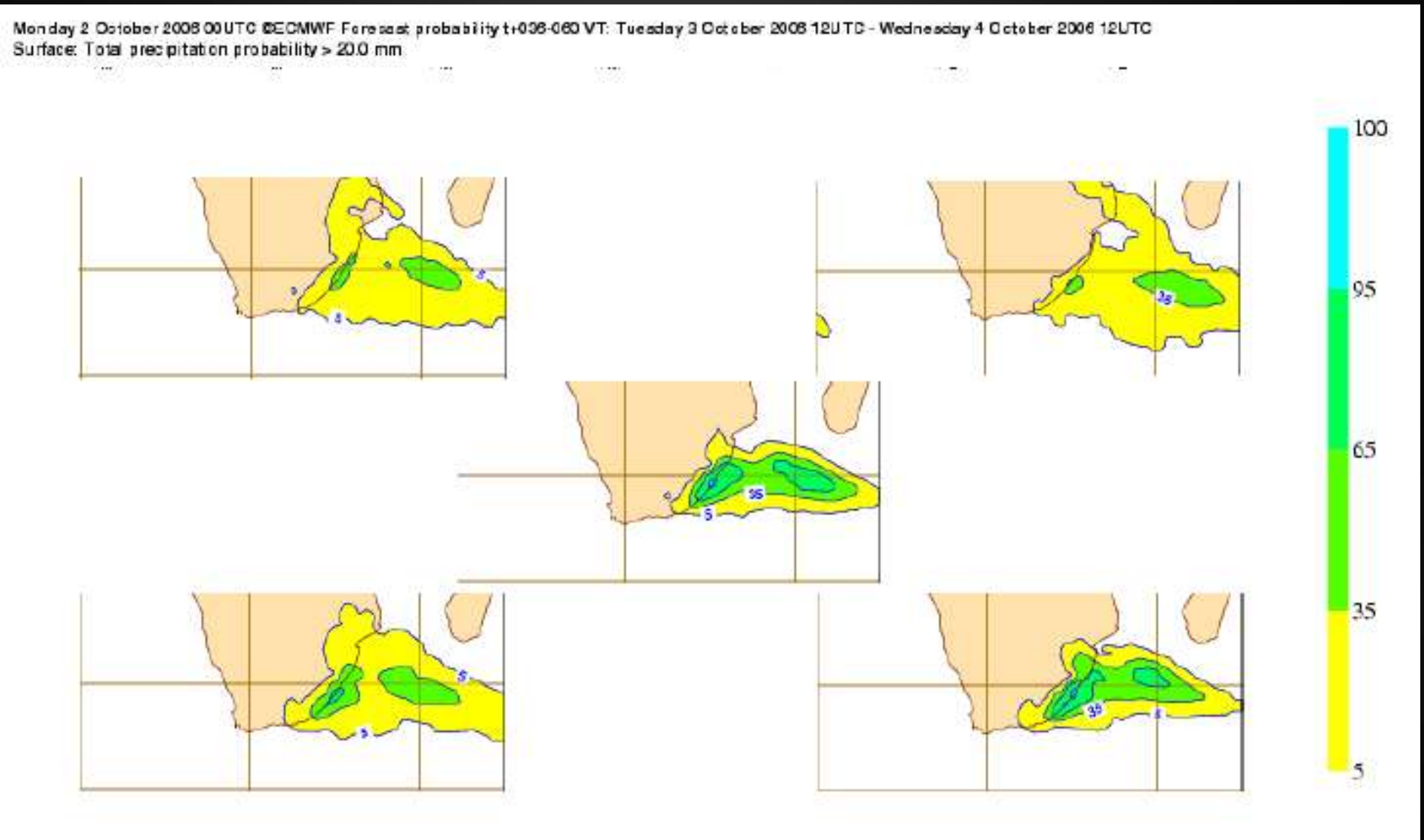
Probabilities:

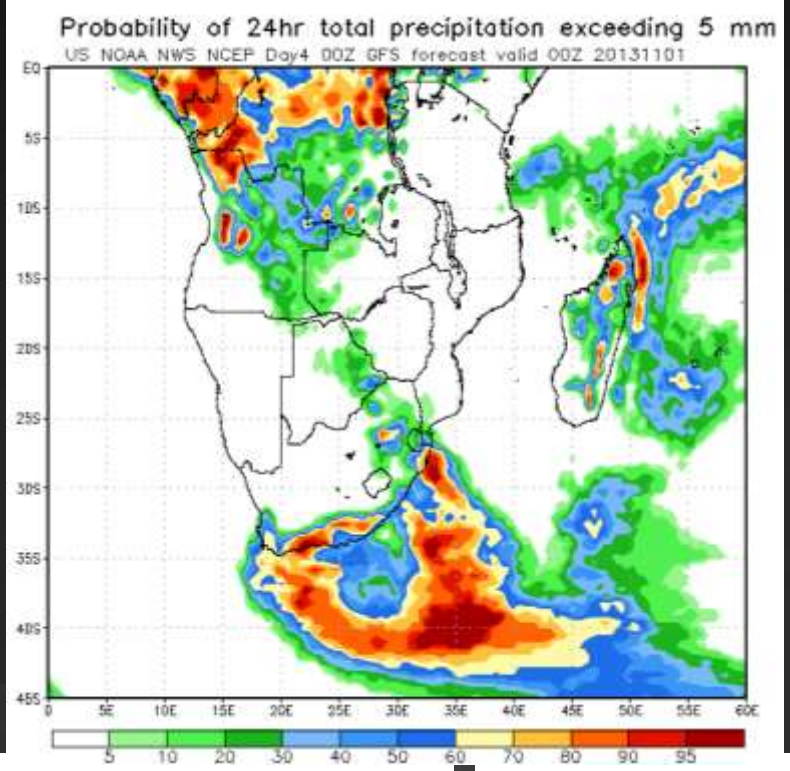
- The most consistent way to convey forecast uncertainty information is by the probability of the occurrence of an event. The event can be general or user-specific representing the exceedance of a threshold. The event threshold often corresponds to the point at which the user has to take some action to mitigate for the potential damage of a significant weather event.
- Probabilities can be instantaneous, such as 10 m wind probabilities. They can also be calculated over a time interval, for instance precipitation, because the values are themselves originally computed as values accumulated over some time interval. Probabilities for extreme wind gusts are computed as probabilities over 24 hours because it is considered more important to know that an extreme wind gust might occur than to know exactly when within a 24 h interval.
- Probabilities give no indication of the physical nature of the uncertainty. A 25% probability of precipitation >5 mm/24h might be related to a showery regime or to the uncertainty of the arrival of a frontal rain band. A 25% risk forecast for temperatures < 0°C might be related to the possible early morning clearing of low cloud cover or the possible arrival of arctic air.

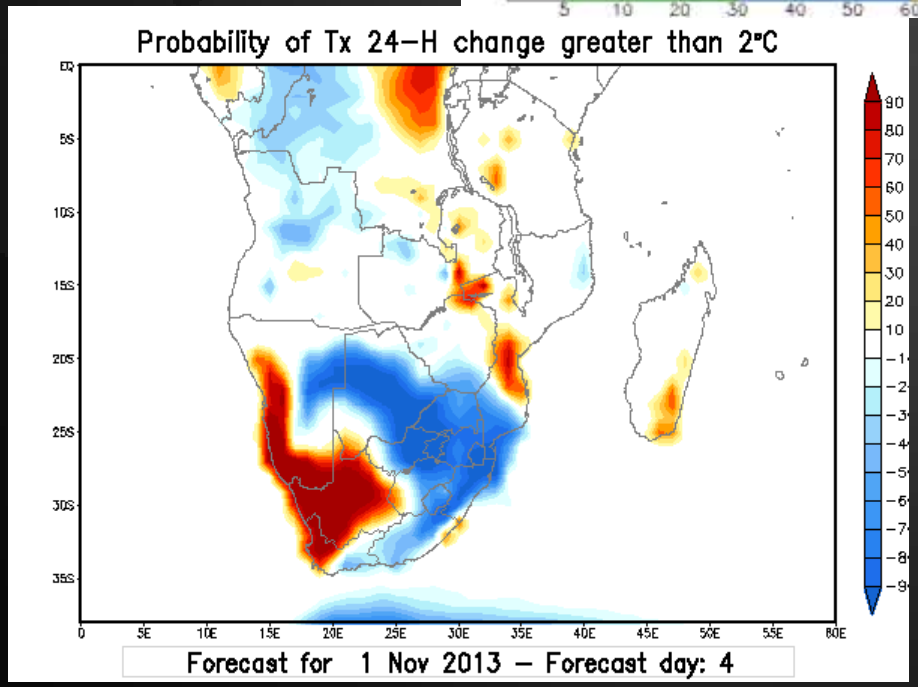
Using Probabilities

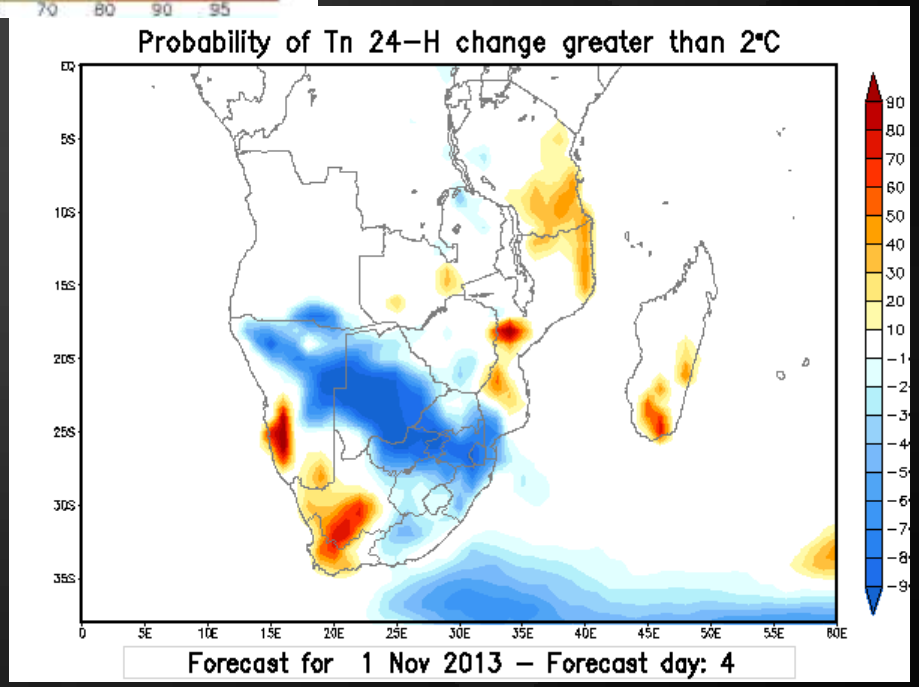
- Recipients of forecasts & warnings are sensitive to different levels of risk: reflecting cost of mitigation vs expected loss
- An intelligent response to forecasts & warnings depends on risk analysis, requiring knowledge of impacts probability
- Use of ensembles to estimate probability at longer lead times is well established in meteorology
- Ensemble mean acts as a dynamic filter and removes normally unpredictable features
- The removed features are put back in a consistent way as probabilities

Probability maps

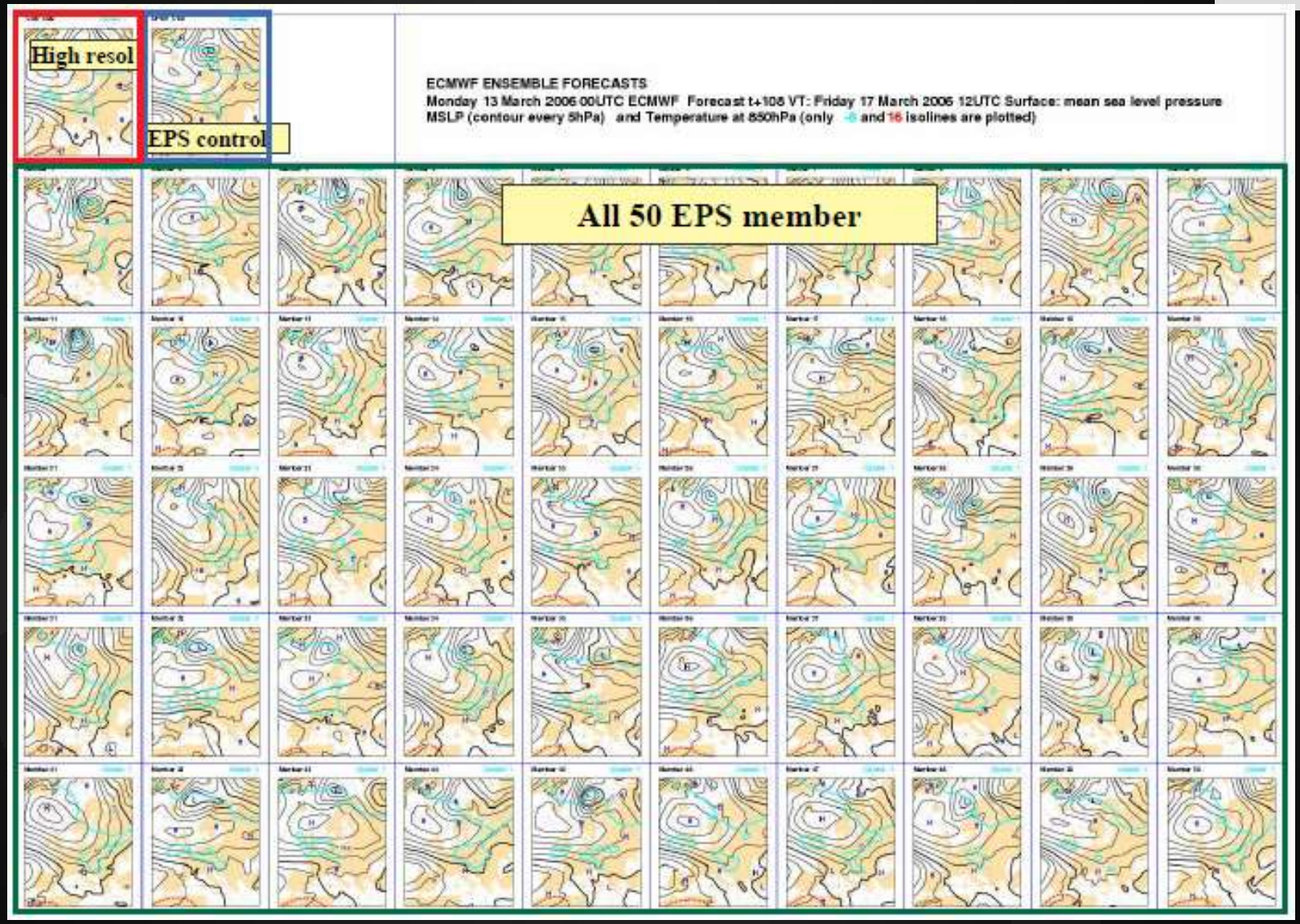



Probability of 24hr total precipitation exceeding 5 mm
US NOAA NWS NCEP Day4 00Z GFS forecast valid 00Z 20131101
5 10 20 30 40 50 60 70 80 90 95


Probability of Tx 24-H change greater than 2°C
Forecast for 1 Nov 2013 – Forecast day: 4


Probability of Tn 24-H change greater than 2°C
Forecast for 1 Nov 2013 – Forecast day: 4

Stamp maps and clusters



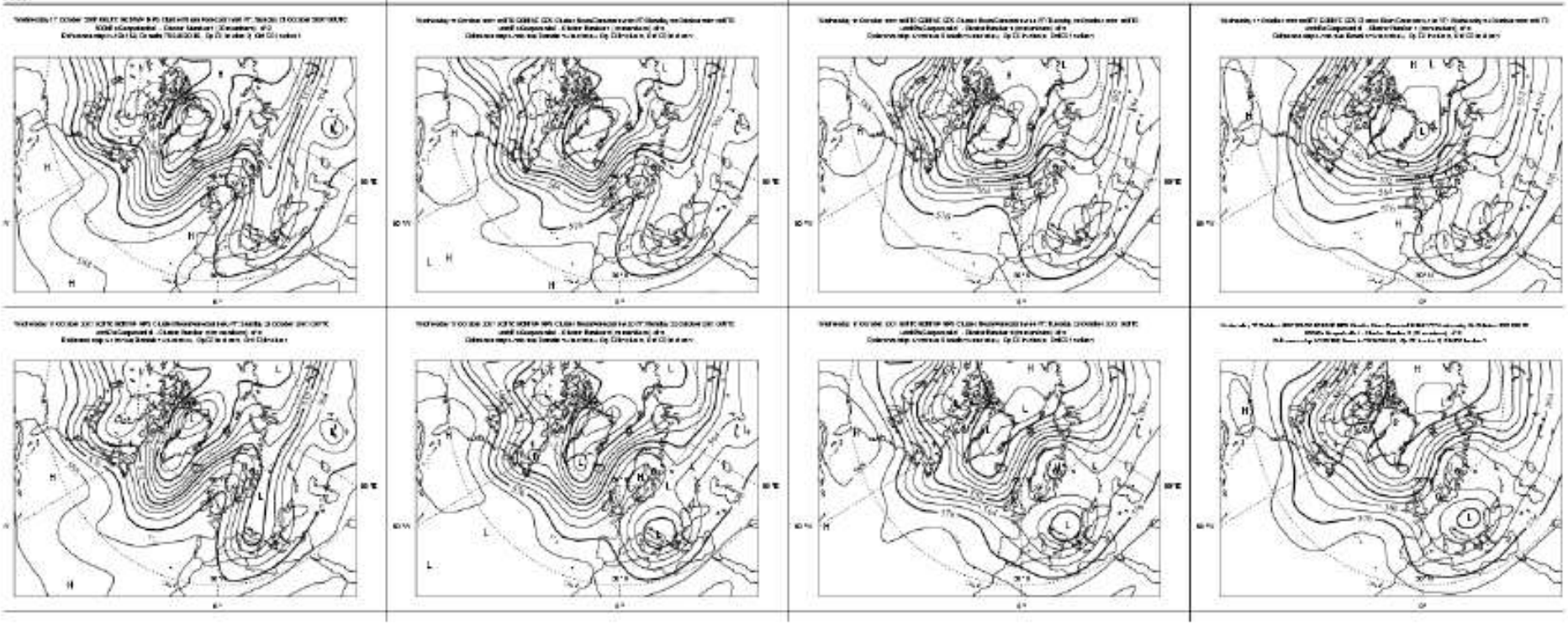
ECMWF Ensemble Forecast Clusters

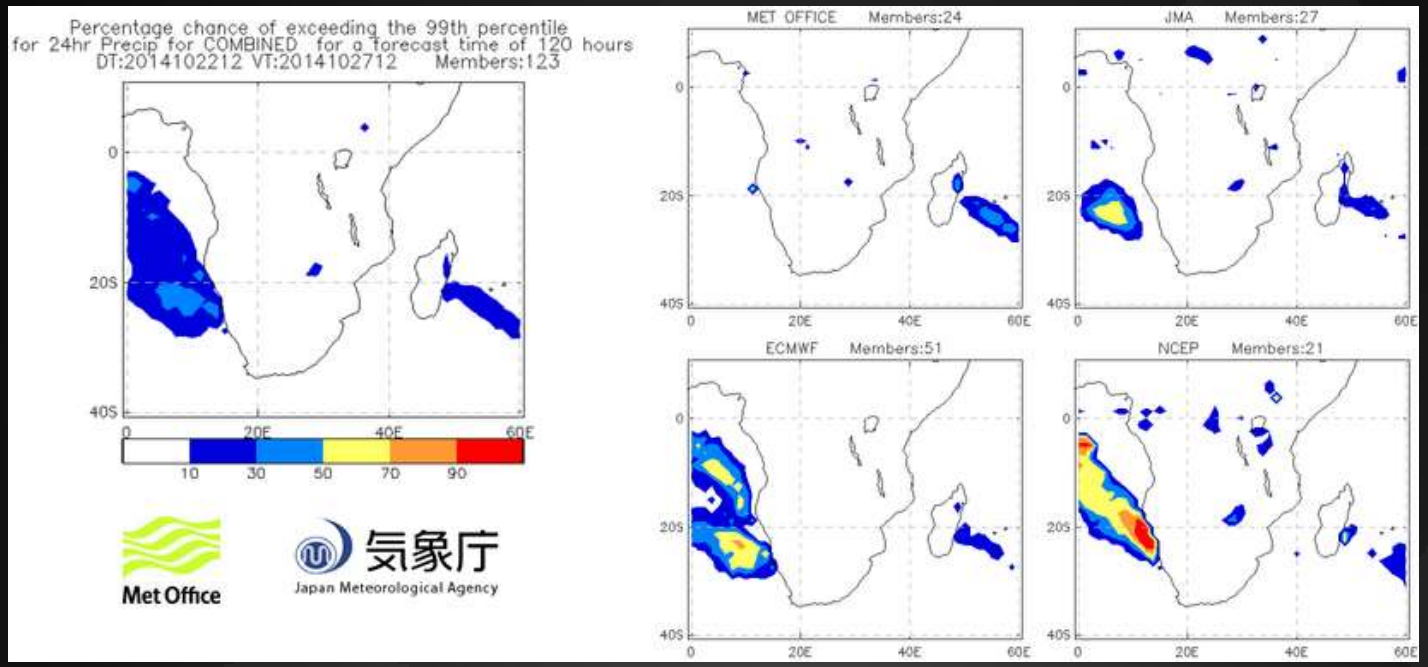
Wednesday 17 October 2007 00UTC
500hPa Geopotential

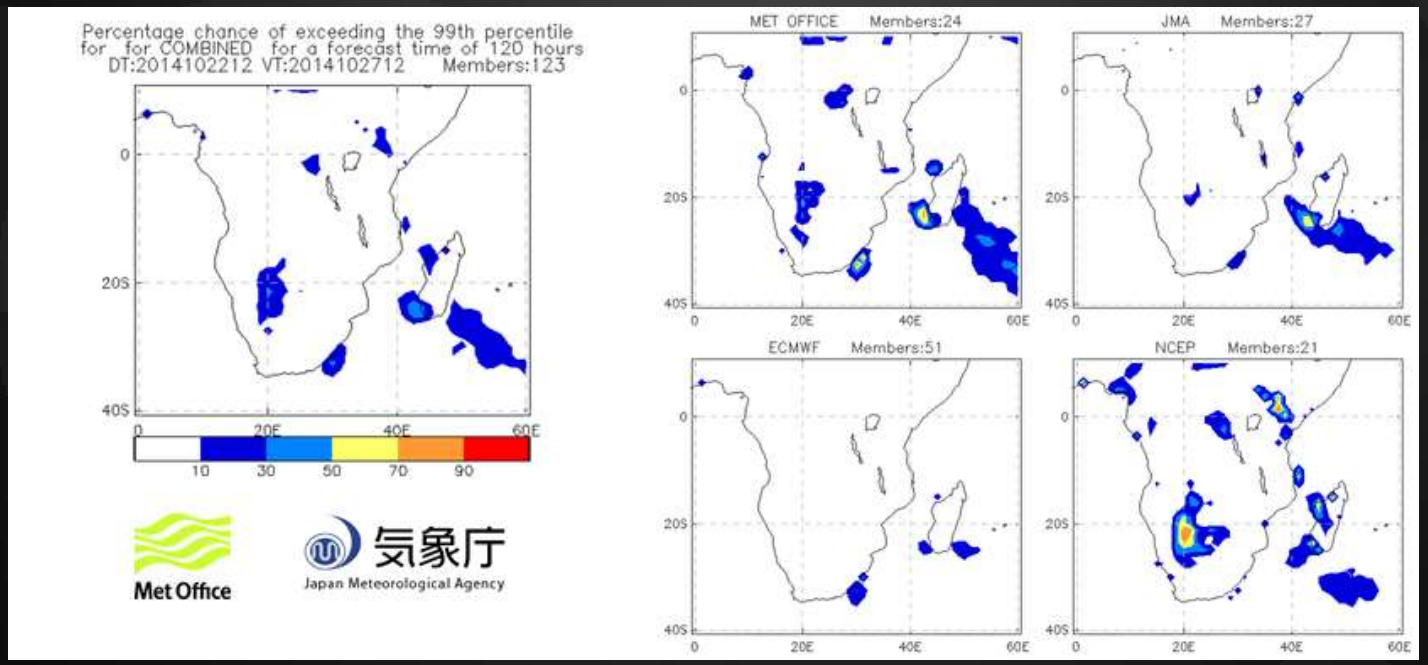
Operational Forecast in cluster 2

Control Forecast in cluster 1

Cluster 1 : 30 Forecast(s)
Cluster 2 : 21 Forecast(s)
Cluster 3 : 0 Forecast(s)
Cluster 4 : 0 Forecast(s)
Cluster 5 : 0 Forecast(s)
Cluster 6 : 0 Forecast(s)




Percentage chance of exceeding the 99th percentile
for 24hr Precip for COMBINED for a forecast time of 120 hours
DT:2014102212 VT:2014102712 Members:123
0
20S
40S
0
20E
40E
60E
10
30
50
70
90
Met Office
気象庁
Japan Meteorological Agency
MET OFFICE Members:24
JMA Members:27
ECMWF Members:51
NCEP Members:21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DT:2014102212 VT:2014102712 Members:123
0
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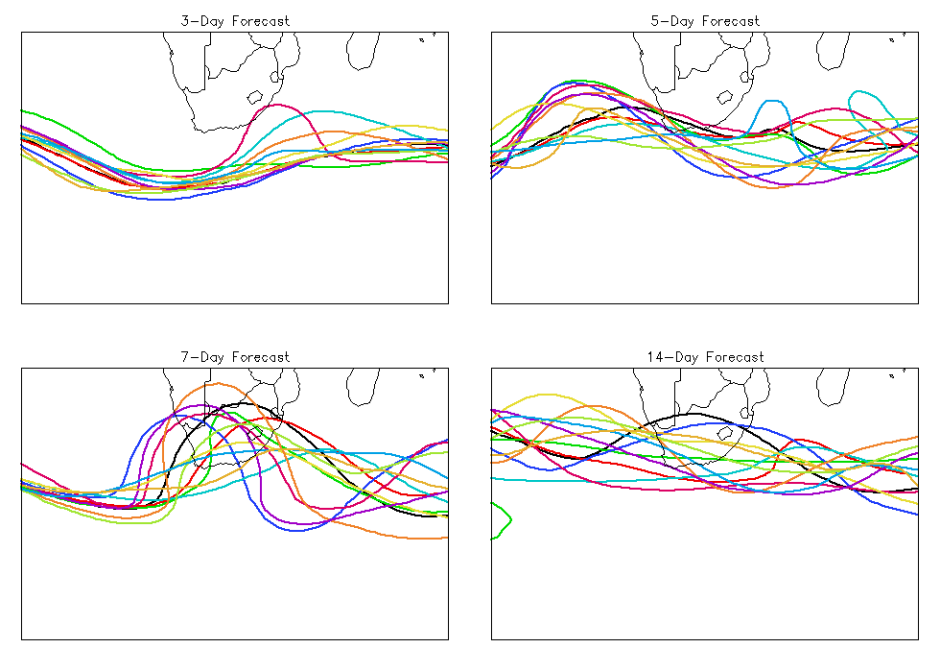
Spaghetti diagram example



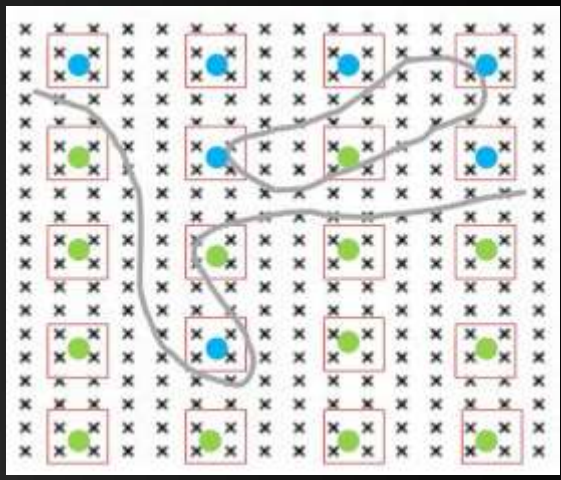
Spaghetti diagrams display certain pre-defined isolines (for a specific value of geopotential or temperature at 850 hPa or 500 hPa, for example) drawn for each member. While the isolines are initially very tightly packed, they spread out more and more with increasing lead time, reflecting the flow-dependent increase in forecast uncertainty.

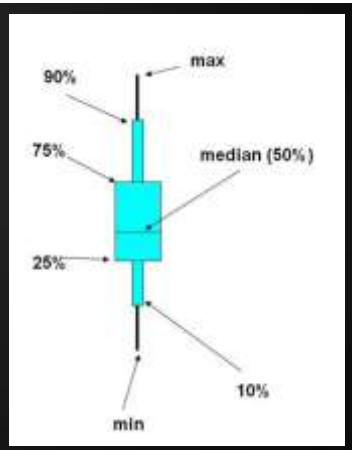
Being visual images, "spaghetti diagrams" are sensitive to gradients. In areas of weak gradient they can show large isoline spread, even if the situation is highly predictable. On the other hand, in areas of strong gradient they can display a small isoline spread, even if there are important forecast variations.

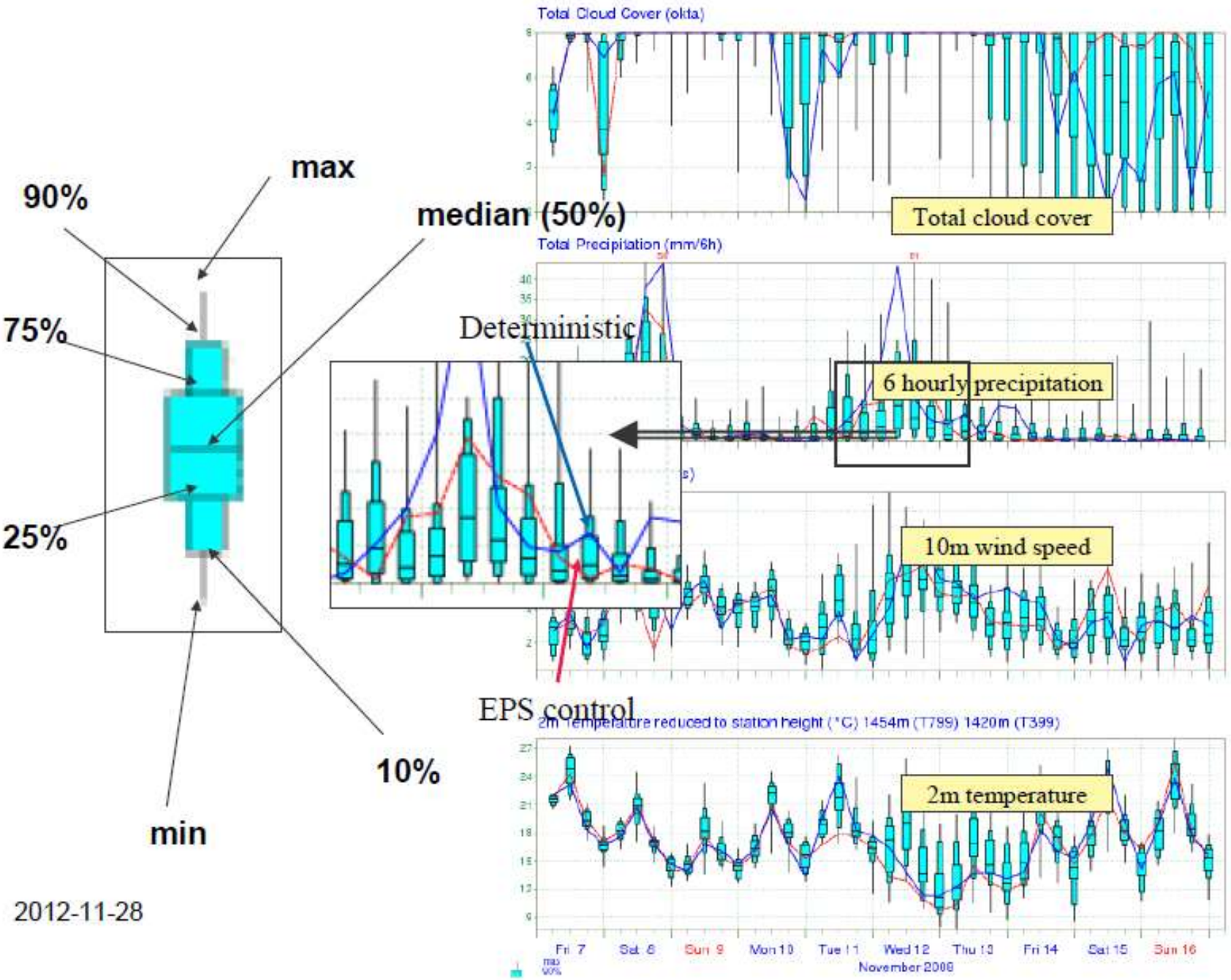
- Drop in forecast confidence with increasing lead-time

EPS-grammes

- The EPSgram provides a probabilistic interpretation of the ENS for specific locations. It displays the time evolution of the distribution of several meteorological parameters from the ensemble at each forecast range by a box and whisker plot.
- Common to all versions is the title section, which gives the name (unless overwritten by the user) and height of the chosen location and the co-ordinates of the grid point used, based on the ENS resolution.
- When creating an EPSgram for a specific location, the four surrounding grid points are considered. If there is at least one land grid point within these four, then the nearest land point will be chosen. Otherwise, if only sea points are available, the nearest sea grid point will be chosen. This situation is noted in the EPSgram title section by the words "EPS sea point".
- For each 6-hour time interval, forecast distributions are displayed using a box and whisker plot which shows the median (short horizontal line), the 25th and 75th percentiles (wide vertical box), 10th and 90th percentiles (narrower boxes) and the minimum and maximum values (vertical lines). The HRES is interpolated onto the ENS grid (meteorological fields and the model orography) from the four nearest grid points in this model to the location of the selected grid point.
- The ensemble can only predict severe weather events of the kind that the model can resolve. The HRES has a small advantage over the ENS with respect to rainfall rate or wind speed. This is another good reason to consider the last HRES together with the ENS in a mini-ensemble.
- When the HRES deviates systematically from the ENS, forecasters, relying on their experience or local knowledge, have to decide which information is the more realistic or representative and, if necessary, adjust one to the other. In such circumstances, it may be appropriate to give more weight to HRES.

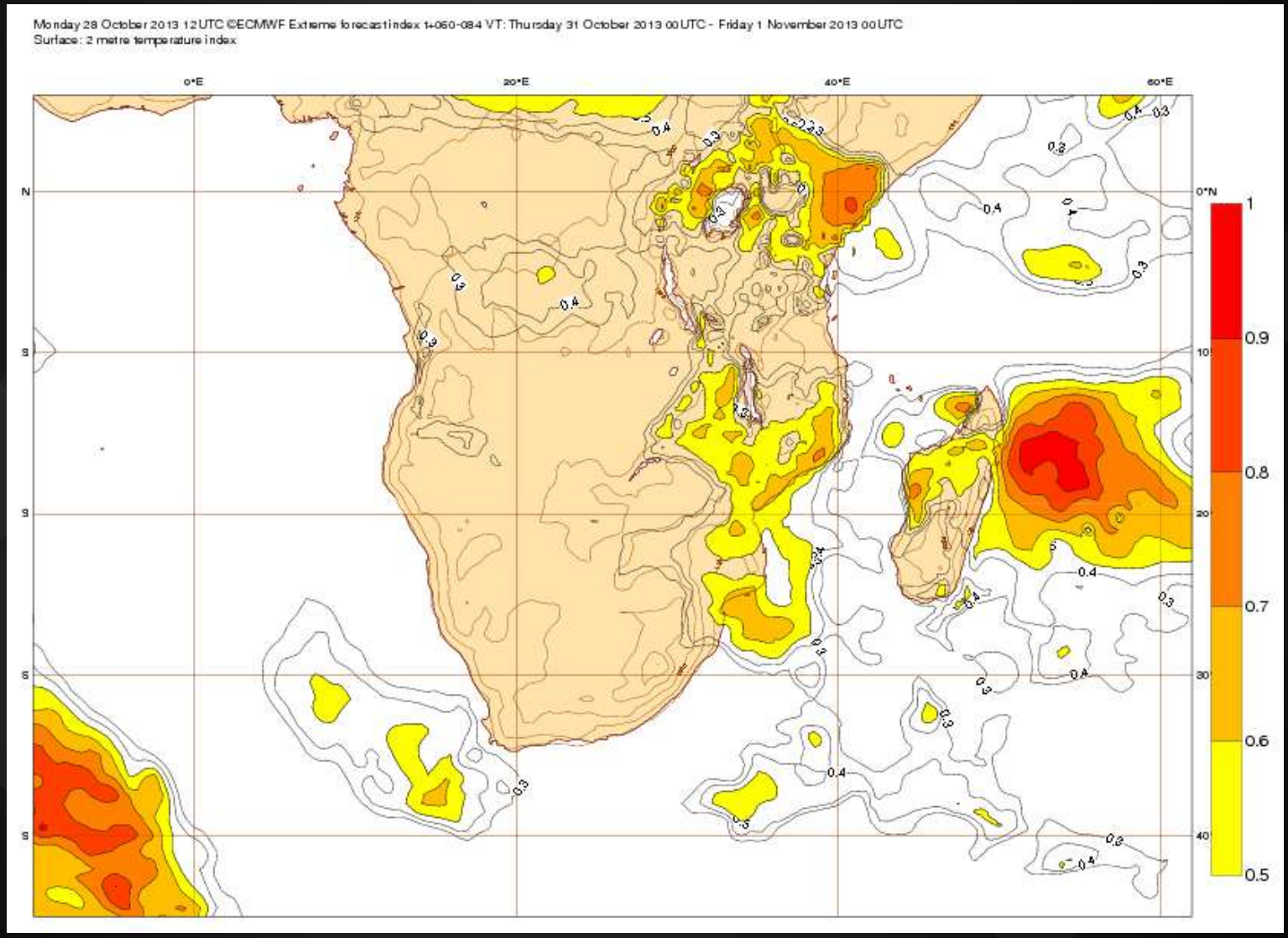





max
90%
median (50%)
75%
25%
10%
min
Deterministic
EPS control
Total Cloud Cover (okta)
Total cloud cover
Total Precipitation (mm/6h)
6 hourly precipitation
10m wind speed
2m Temperature reduced to station height (°C) 1454m (T799) 1420m (T399)
2m temperature
Fri 7
Sat 8
Sun 9
Mon 10
Tue 11
Wed 12
Thu 13
Fri 14
Sat 15
Sun 16
November 2008

2012-11-28

Extreme Forecast Index



Extreme Forecast Index

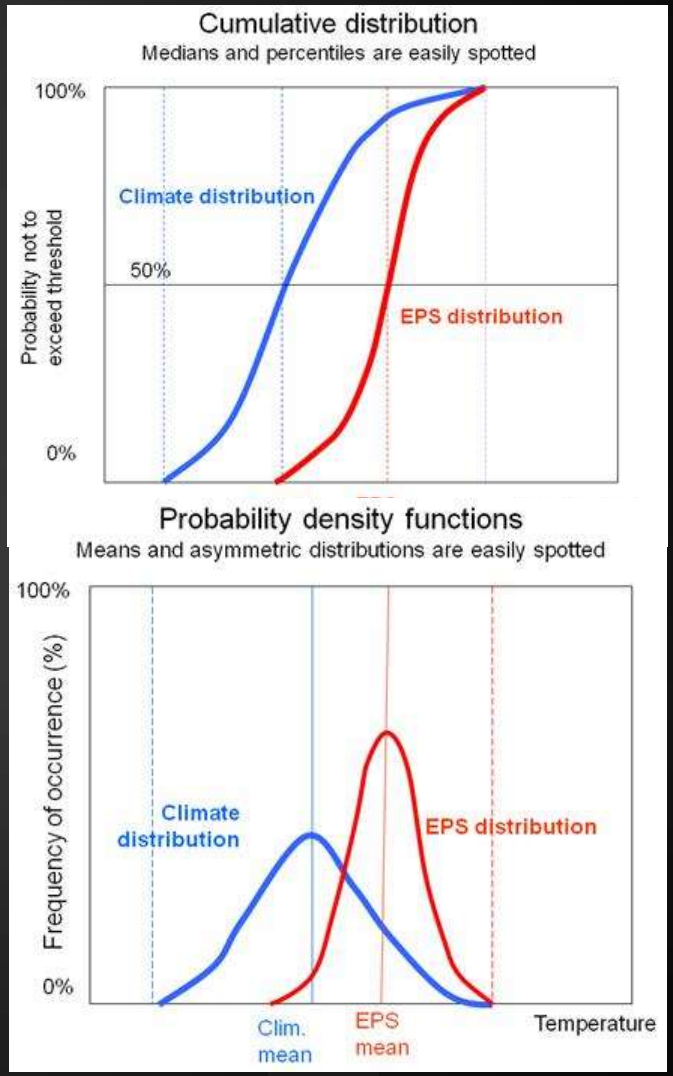
The extraction of extreme weather-related information from the ensemble is not always straightforward. For example, the probabilities themselves do not reveal whether a certain value is unusual or even extreme. A 30% probability of >20 mm rainfall in 6 hours in July would not be "extreme" in New Delhi, 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.

Model Climate (reference climate):

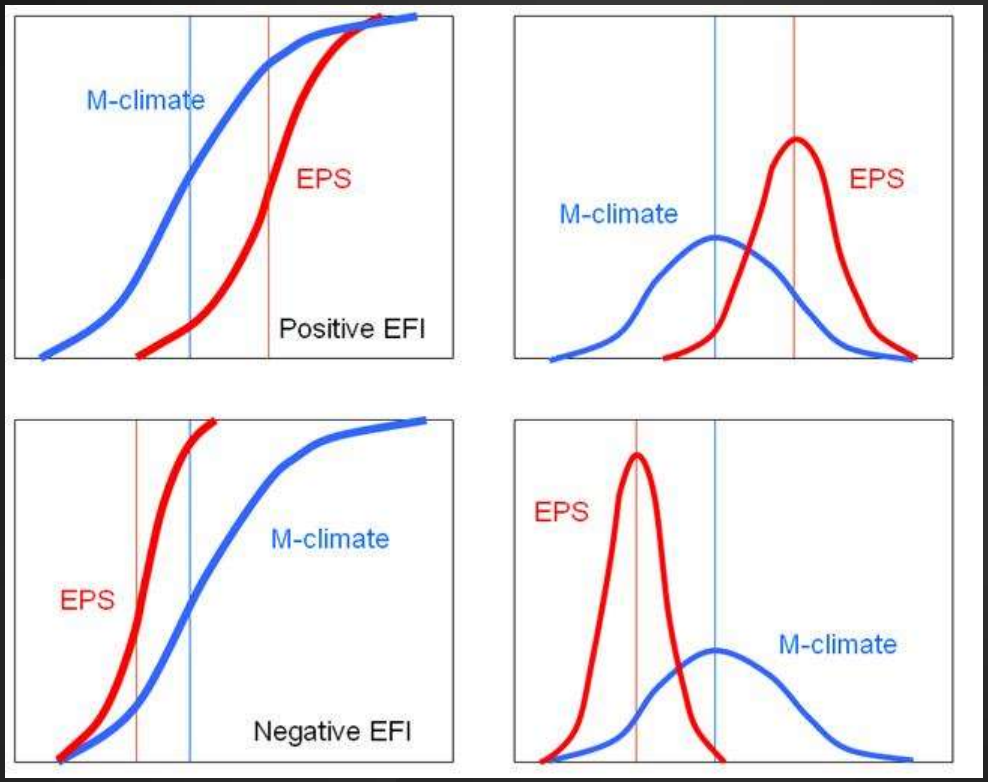
1. forecast probability distribution is compared to the model climate (M-climate) distribution for the chosen location, time of year and lead time.
2. The M-climate is based on five consecutive weekly 32-day re-runs of the ENS, with four perturbed and one unperturbed initial conditions and started from ERA-Interim re-analyses from each of the last 20 years.
3. The model climate for the EFI calculations on Sunday 31 October 2010 at 12 UTC is, for example, prepared from five re-runs of forecast from five Thursdays, centred on the 28 October, i.e.14, 21 and 28 October and 4 and 11 November, for all the 20 years, totalling 500 re-forecasts.

Extreme Forecast Index

- EFI measures the distance between the EPS cumulative distribution and the model climate distribution
- Takes values from –1 (all members break climate minimum records) and +1 (all beyond model climate records)



Extreme Forecast Index



EFI ~ +50%

EFI ~ -50%

Using & Interpreting EFI

- If the EPS 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 EPS 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.
- Negative EFI values are only really of interest for temperature anomalies, since temperature is the only variable which is of particular interest when it has negative anomalies, such as cold spells. Absence of precipitation might be important for certain agricultural activities, similarly weak winds are of significance for sailing; however, although such weather may be regarded as "unusual" in some locations, it is not catered for in the EFI.
- 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.

Using & Interpreting EFI

Although higher EFI values indicate that an extreme event is more likely than usual, the values do not represent probabilities, as such. Any forecasts or warnings must be based on a careful study of probabilistic and deterministic information.

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. Although the EFI index is a useful tool that allows the easy identification of extremes with respect to location and season, its simplicity is achieved by a rather complex mathematical treatment and should only serve as an "alarm bell", a warning of potentially extreme events.

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Questions and Answers?