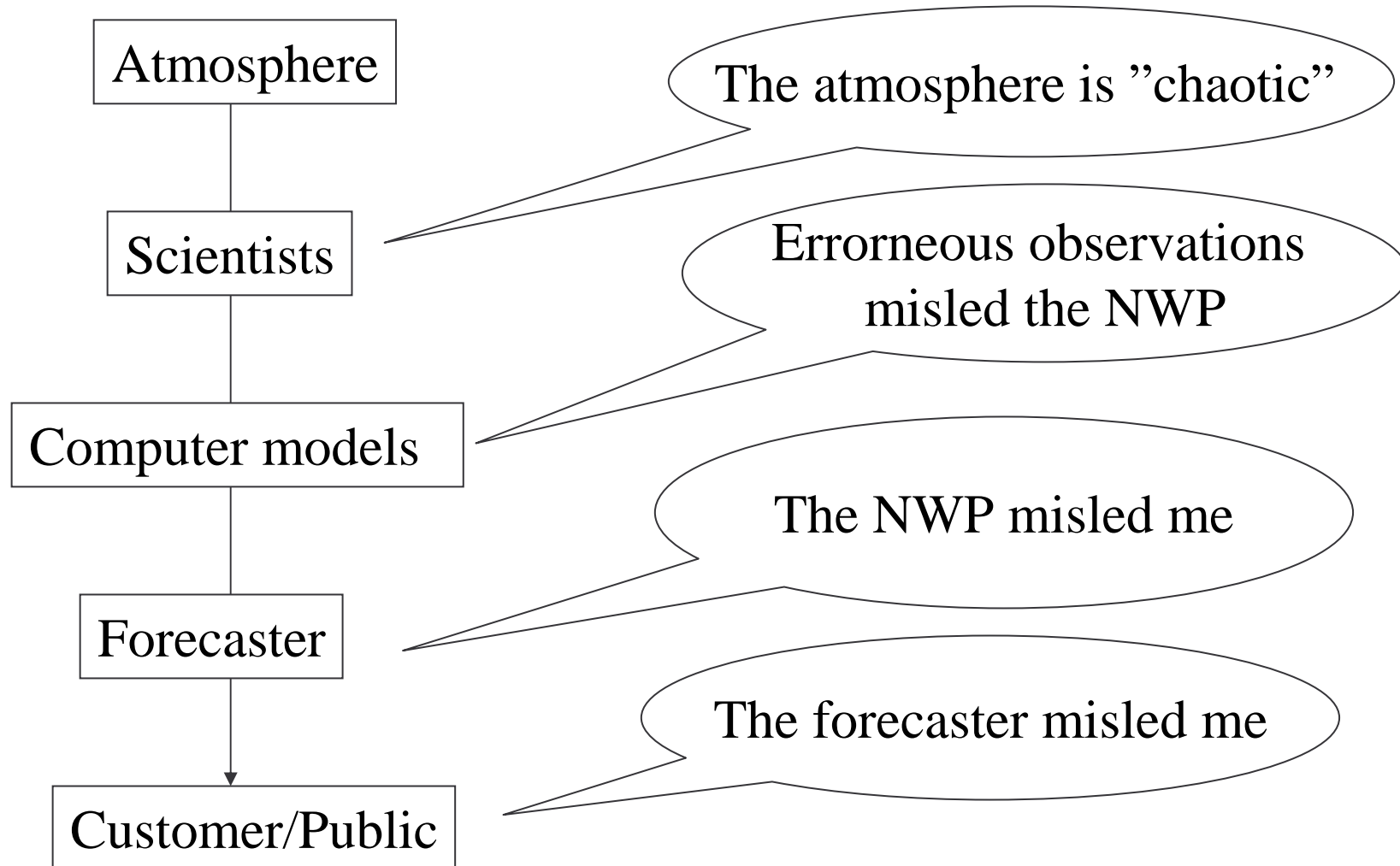


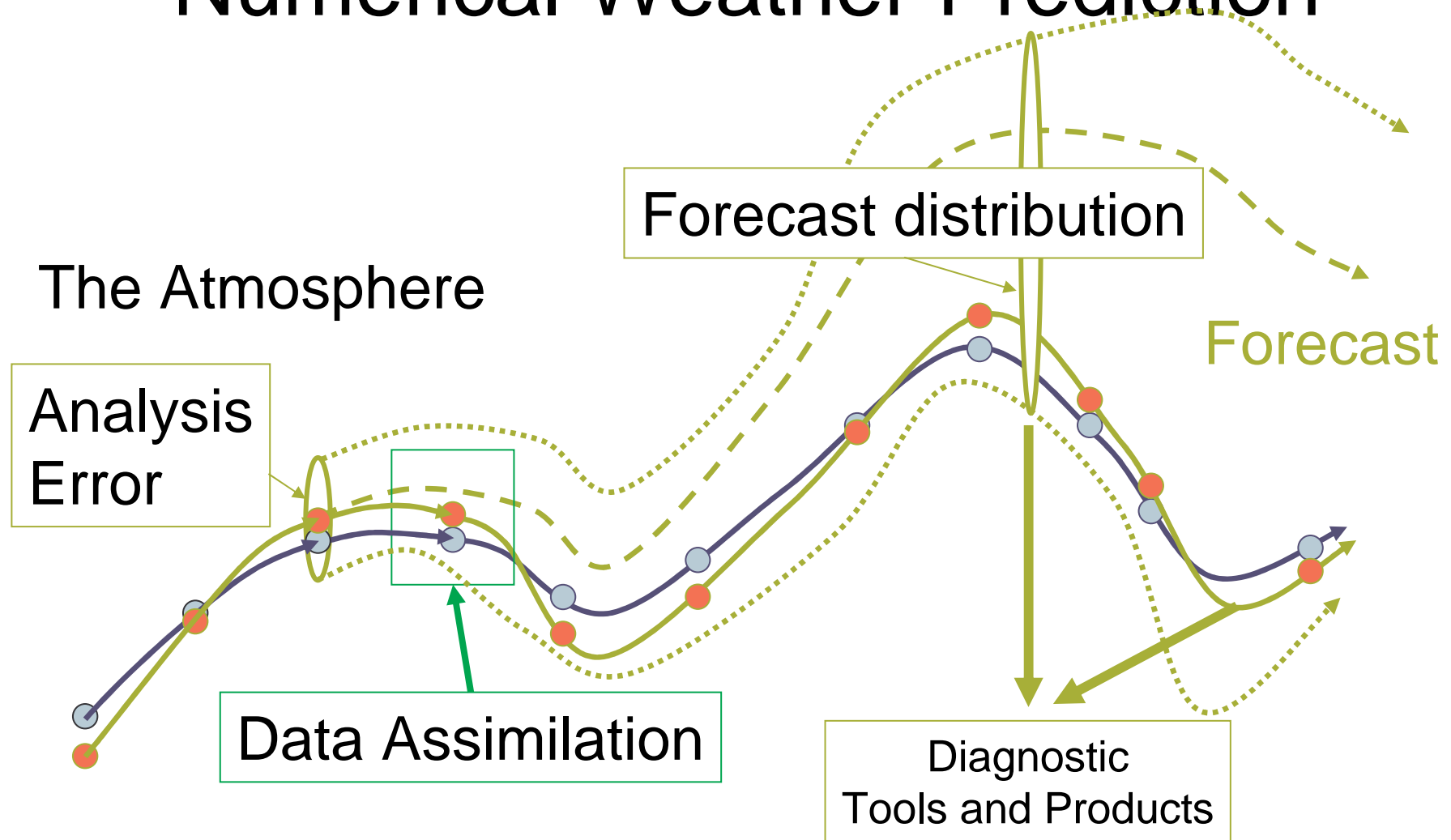
# Ensemble Prediction Systems and Probabilistic Forecasting

# "The Blame Game" or "The Passing of The Buck"



# Understanding chaos

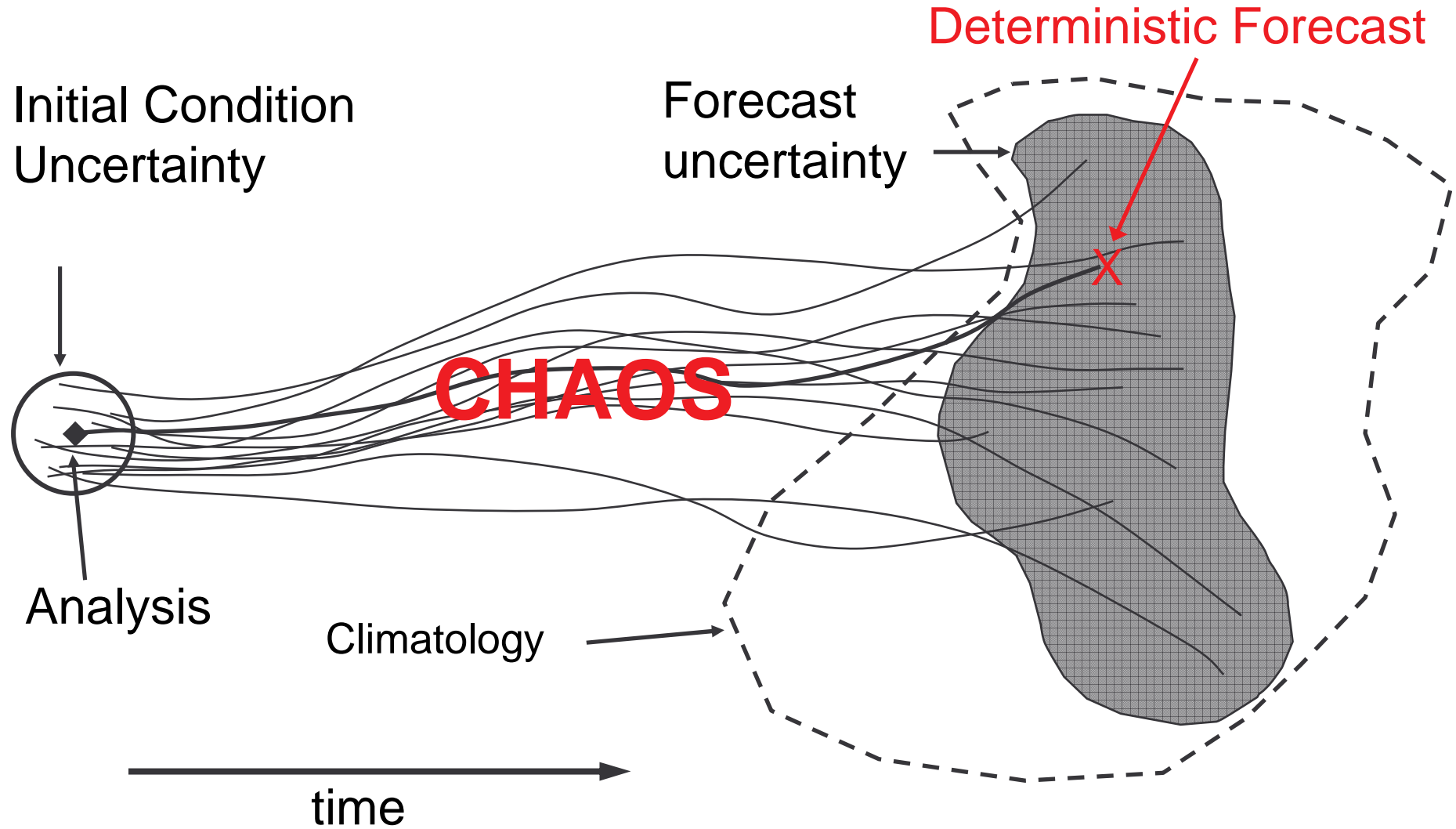
# Numerical Weather Prediction



Model System

2012-11-28

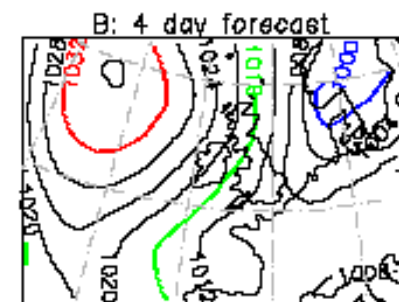
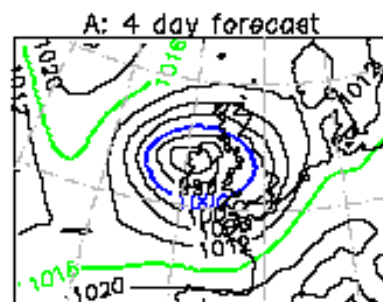
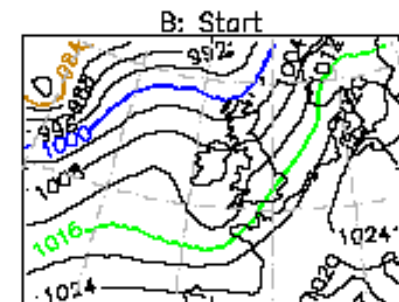
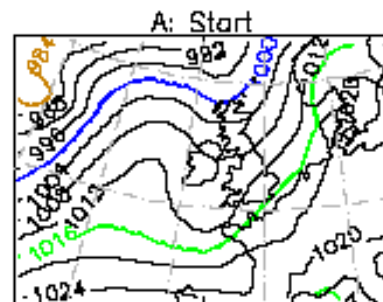
# Quantifying uncertainty with ensembles



# The Effect of Chaos

- We can *usually* forecast the general pattern of the weather up to about 3 days ahead.
- Chaos then becomes a major factor

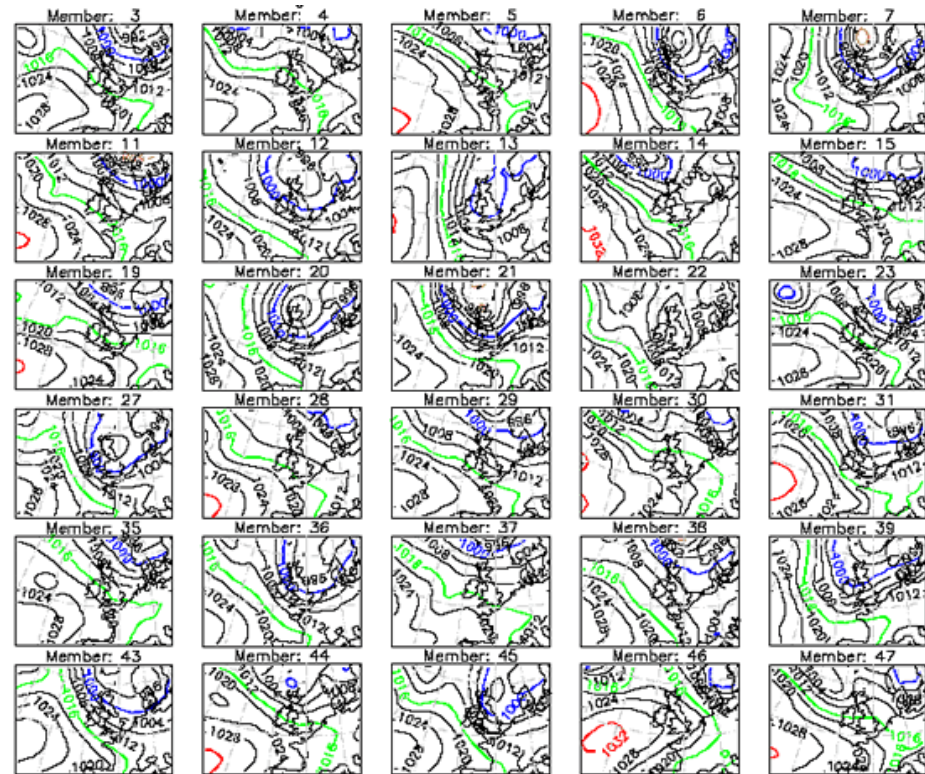
Tiny errors in our analysis of the current state of the atmosphere lead to large errors in the forecast – these are both equally valid 4-day forecasts.



- Fine details (eg rainfall) have shorter predictability

# Ensembles

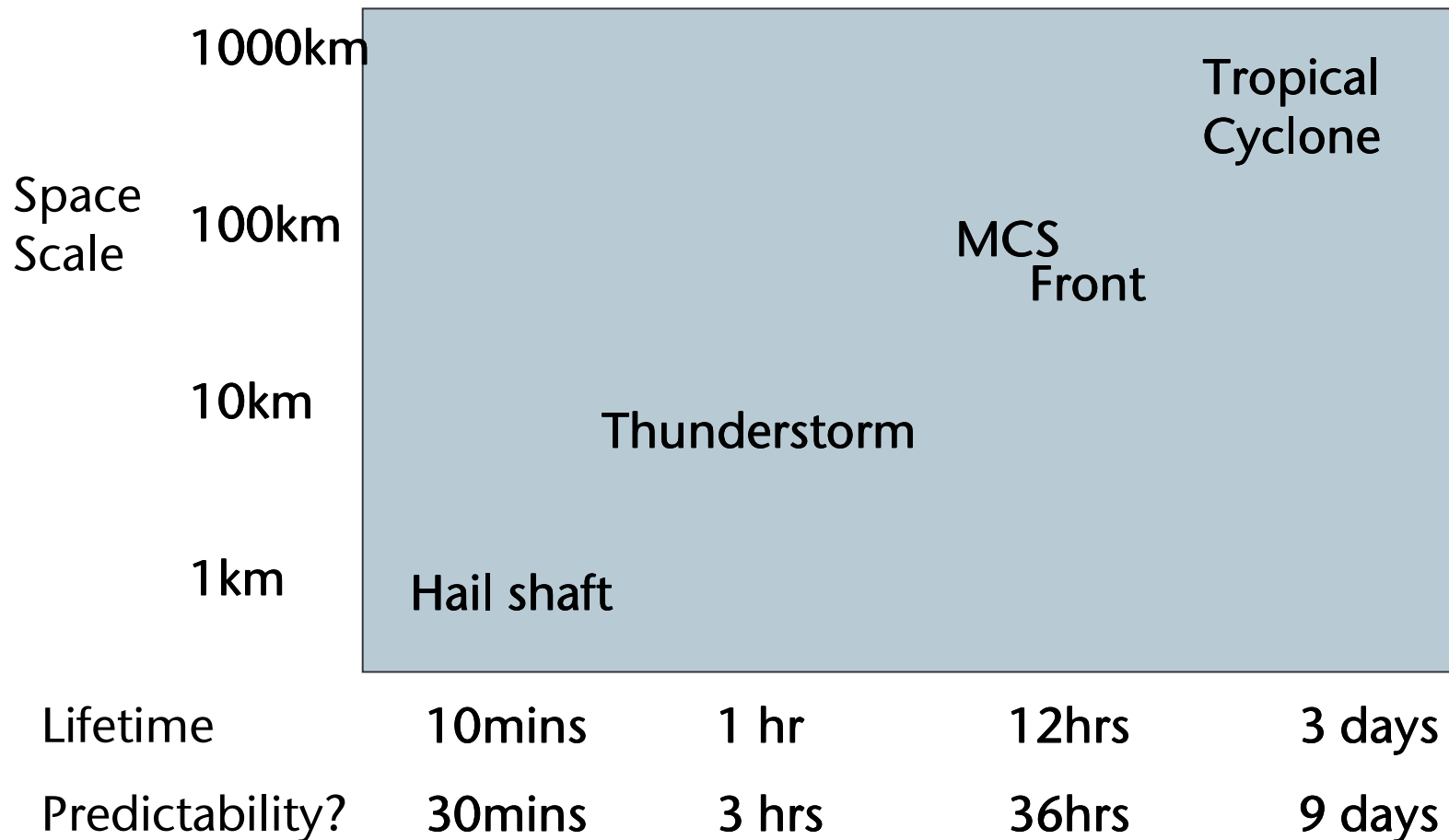
- In an ensemble forecast we run the model many times from slightly different initial conditions
- This provides a range of likely forecast solutions which allows forecasters to:
  - assess possible outcomes;
  - estimate risks
  - gauge confidence.



# Reminder on scales and predictability



# Temporal Resolution



# MOGREPS

# Short-range Ensembles

## **ECMWF EPS has transformed the way we do Medium-Range Forecasting**

- Uncertainty also in short-range:
  - Rapid Cyclogenesis often poorly forecast deterministically
  - Uncertainty of sub-synoptic systems (eg thunderstorms)
  - Many customers most interested in short-range
- Assess ability to estimate uncertainty in local weather
  - QPF
  - Cloud Ceiling, Fog
  - Winds etc

# Initial conditions perturbations

- Perturbations centred around 4D-Var analysis
- Transforms calculated using same set of observations as used in 4D-Var (including all satellite obs) within +/- 3 hours of data time
- Ensemble uses 12 hour cycle (data assimilation uses 6 hour cycle)

# Initial conditions perturbations

## Differences with ECWMF Singular Vectors:

- It focuses on errors growing during the assimilation period, not growing period:
  - Suitable for Short-range!
- Calculated using the same resolution than the forecast
- ETKF includes moist processes
- Running in conjunction with stochastic physics to propagate effect

# Model error: parameterisations

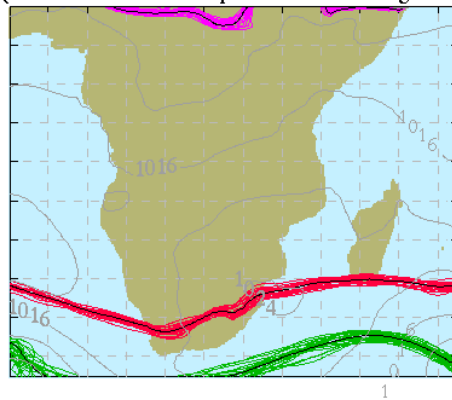
## Random parameters

- QUMP (Murphy et al., 2004)
- Initial stoch. Phys. Scheme for the UM (Arribas, 2004)

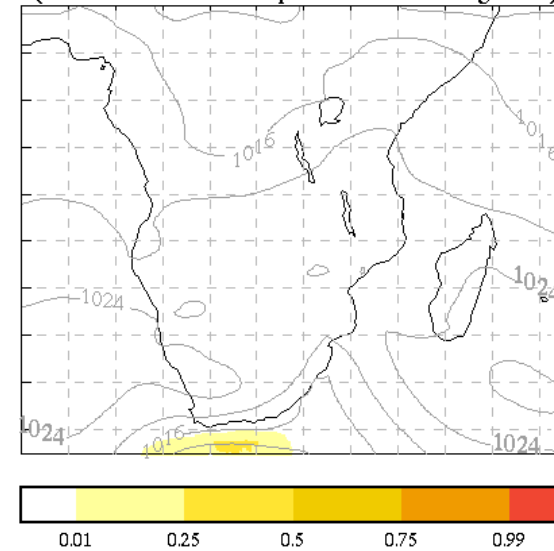
Parameter	Scheme	min/std/Max
Entrainment rate	CONVECTION	2 / 3 / 5
Cape timescale	CONVECTION	30 / 30 / 120
RH critical	LRG. S. CLOUD	0.6 / 0.8 / 0.9
Cloud to rain (land)	LRG. S. CLOUD	1E-4/8E-4/1E-3
Cloud to rain (sea)	LRG. S. CLOUD	5E-5/2E-4/5E-4
Ice fall	LRG. S. CLOUD	17 / 25.2 / 33
Flux profile param.	BOUNDARY L.	5 / 10 / 20
Neutral mixing length	BOUNDARY L.	0.05 / 0.15 / 0.5
Gravity wave const.	GRAVITY W.D.	1E-4/7E-4/7.5E-4
Froude number	GRAVITY W.D.	2 / 2 / 4

# MOGREPS products

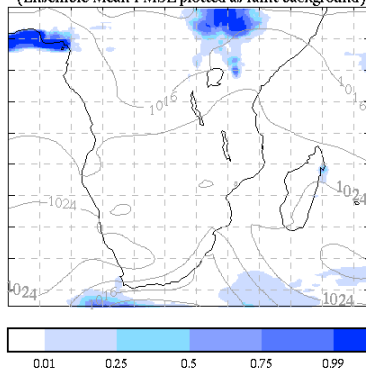
MOGREPS (Global) Spaghetti chart for 1000-500hPa Thickness  
 DT 00Z on 04/07/2006 VT 18Z on 04/07/2006 lead time 18h  
 510/528/546/564/582 dam (Black lines represent Control member)  
 (Ensemble Mean PMSL plotted as faint background)



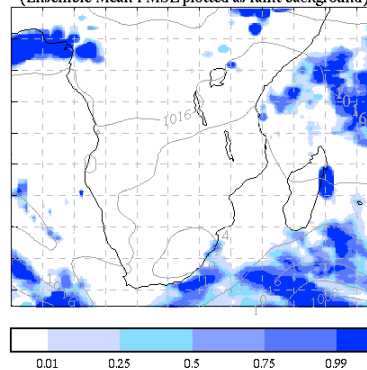
MOGREPS (Global) Probability map for 10m WindSpeed > 34.0knots  
 DT 00Z on 04/07/2006 VT 06Z on 06/07/2006 lead time 54h  
 (Ensemble Mean PMSL plotted as faint background)



MOGREPS (Global) Probability map for 24HourPrecip > 10.0mm  
 DT 00Z on 04/07/2006 VT 06Z on 06/07/2006 lead time 54h  
 (Ensemble Mean PMSL plotted as faint background)



MOGREPS (Global) Probability map for 6HourPrecip > 0.3mm  
 DT 00Z on 04/07/2006 VT 06Z on 04/07/2006 lead time 06h  
 (Ensemble Mean PMSL plotted as faint background)



# Using probabilities



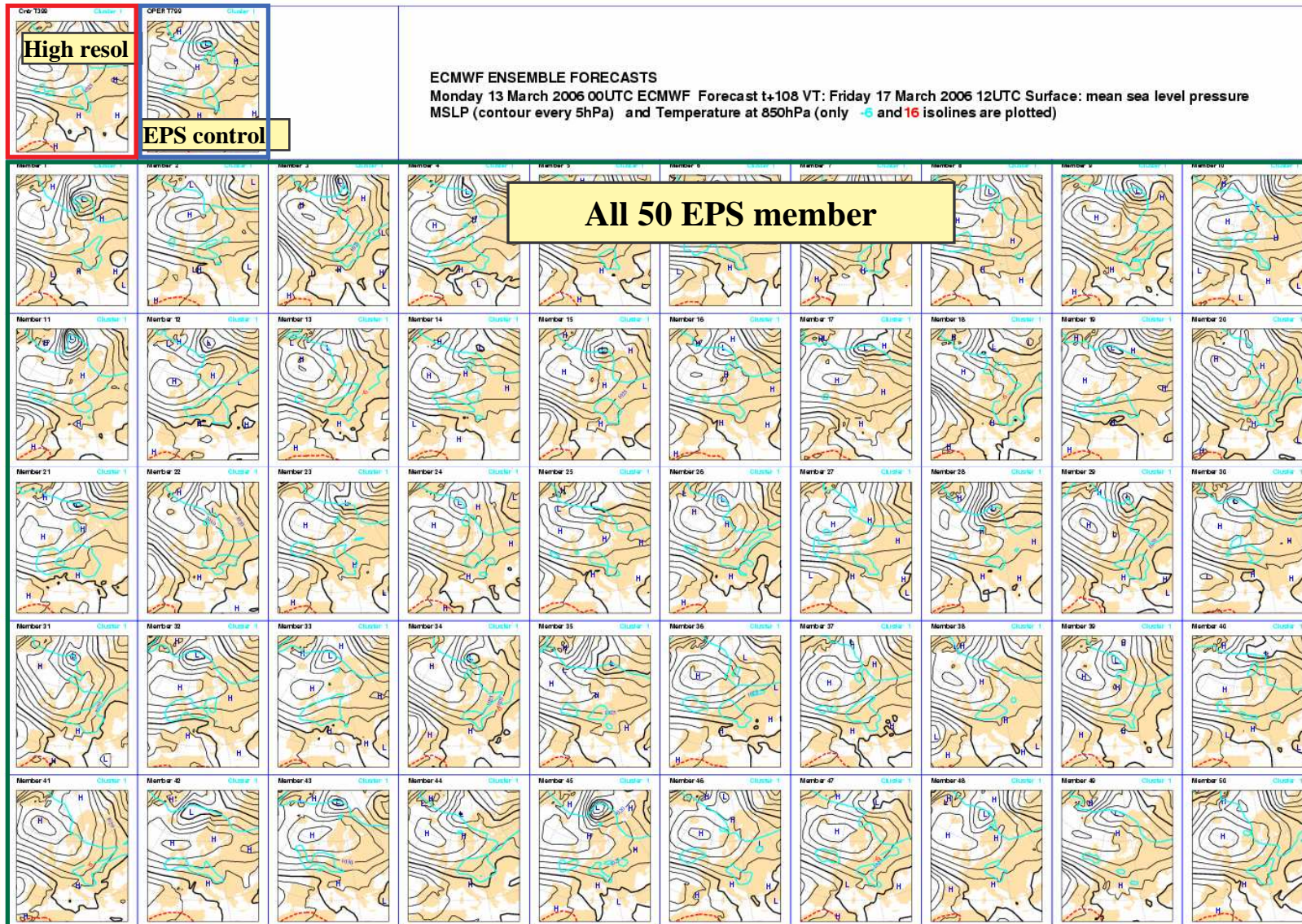
# Using probabilities

- 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 impact probability
- Use of ensembles to estimate probability at longer lead times is well established in meteorology

# Ensemble forecast products

# Stamp maps and clusters

# Products: Stamp maps



# ECMWF Ensemble Forecast Clusters

Wednesday 17 October 2007 00UTC  
500hPa Geopotential

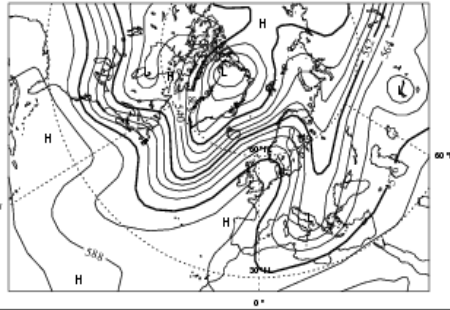
# Operational Forecast in cluster 2

# Control Forecast in cluster 1

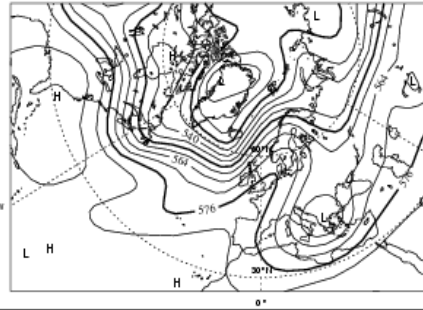
- Cluster 1 : 30 Forecast(s)
- Cluster 2 : 21 Forecast(s)
- Cluster 3 : 0 Forecast(s)
- Cluster 4 : 0 Forecast(s)
- Cluster 5 : 0 Forecast(s)
- Cluster 6 : 0 Forecast(s)

> 0001

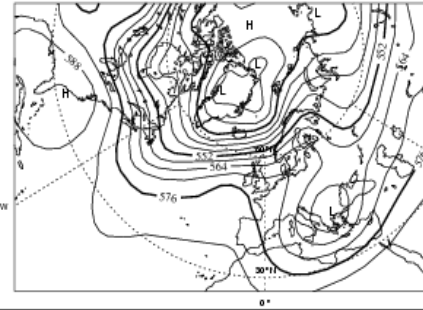
Wednesday 17 October 2007 00UTC ECMWF EPS Cluster Mean Forecast (1+66/17): Sunday 21 October 2007 00UTC  
500hPa Geopotential - Cluster Number 1 (20 members) of 2  
Reference step is 1200m, Domain is 200000000, Op FC in d.us, Clr FC in d.us 1



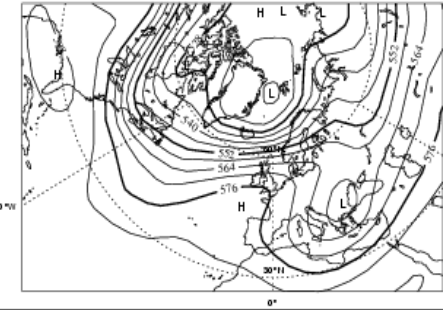
Wednesday 17 October 2007 00UTC ECMWF EPS Cluster Mean Forecast (1+20/17): Monday 22 October 2007 00UTC  
500hPa Geopotential - Cluster Number 1 (20 members) of 2  
Reference step is 1200m, Domain is 200000000, Op FC in d.us, Clr FC in d.us 1



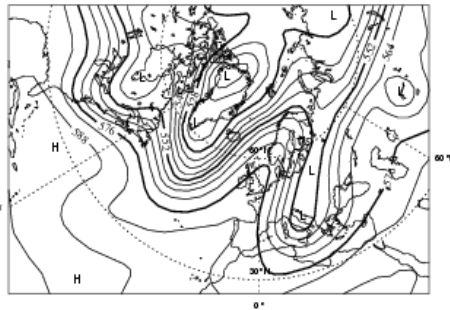
Wednesday 17 October 2007 00UTC ECMWF EPS Cluster Mean Forecast (1+11/17): Tuesday 23 October 2007 00UTC  
500hPa Geopotential - Cluster Number 1 (20 members) of 2  
Reference step is 1200m, Domain is 200000000, Op FC in d.us, Clr FC in d.us 1



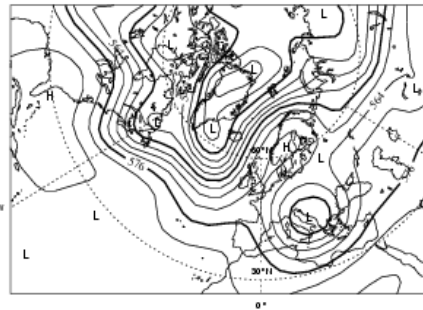
Wednesday 17 October 2007 00UTC ECMWF EPS Cluster Mean Forecast (1+14/17): Wednesday 24 October 2007 00UTC  
500hPa Geopotential - Cluster Number 1 (20 members) of 2  
Reference step is 1200m, Domain is 200000000, Op FC in d.us, Clr FC in d.us 1



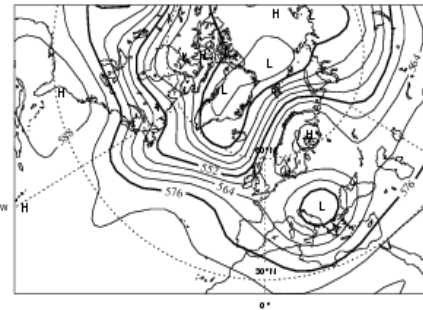
Wednesday 17 October 2007 00UTC ECMWF EPS Cluster Mean Forecast (1+20/17): Sunday 22 October 2007 00UTC  
500hPa Geopotential - Cluster Number 2 (21 members) of 2  
Reference step is 1200m, Domain is 200000000, Op FC in d.us, Clr FC in d.us 1



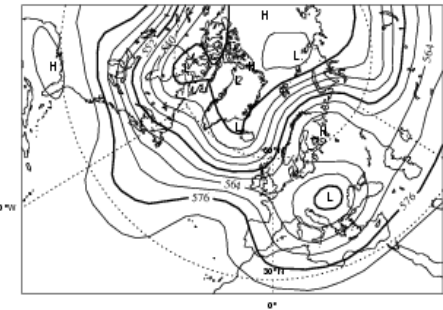
Wednesday 17 October 2007 00UTC ECMWF EPS Cluster Mean Forecast (1+20/17): Monday 22 October 2007 00UTC  
500hPa Geopotential - Cluster Number 2 (21 members) of 2  
Reference step is 1200m, Domain is 200000000, Op FC in d.us, Clr FC in d.us 1



Wednesday 17 October 2007 00UTC ECMWF EPS Cluster Mean Forecast (1+11/17): Tuesday 23 October 2007 00UTC  
500hPa Geopotential - Cluster Number 2 (21 members) of 2  
Reference step is 1200m, Domain is 200000000, Op FC in d.us, Clr FC in d.us 1



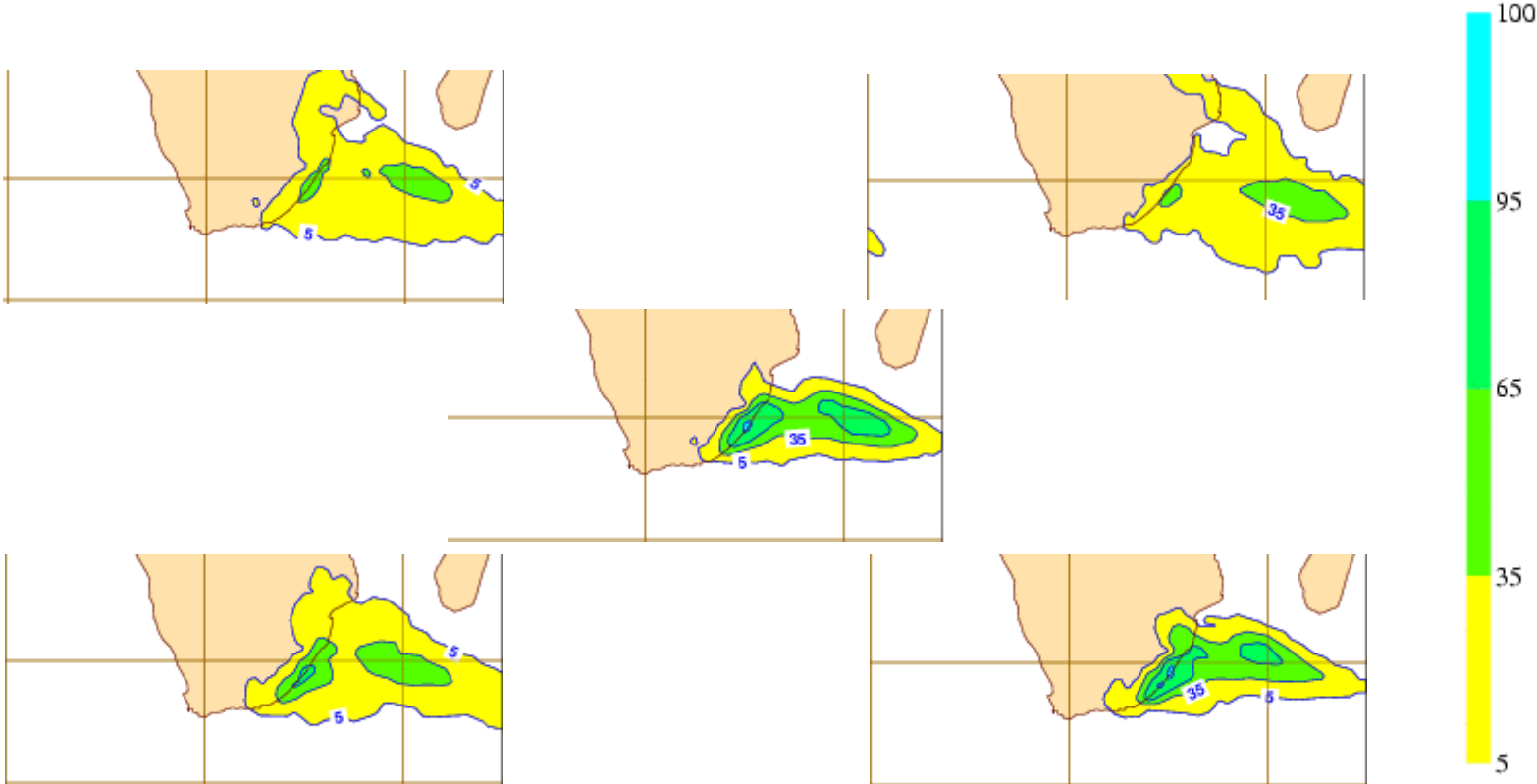
Wednesday 17 October 2007 00UTC ECMWF EPS Cluster Mean Forecast (1+14/17): Wednesday 24 October 2007 00UTC  
500hPa Geopotential - Cluster Number 2 (21 members) of 2  
Reference step is 1200m, Domain is 200000000, Op FC in d.us, Clr FC in d.us 1



# Probability maps

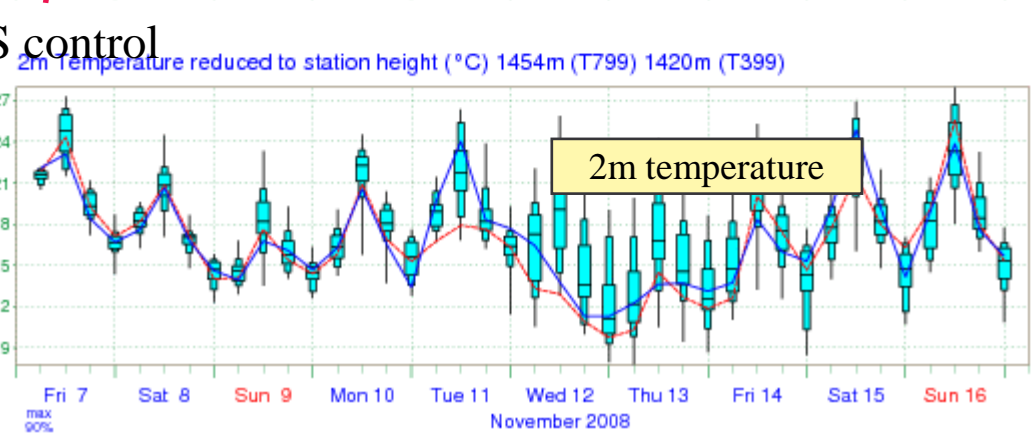
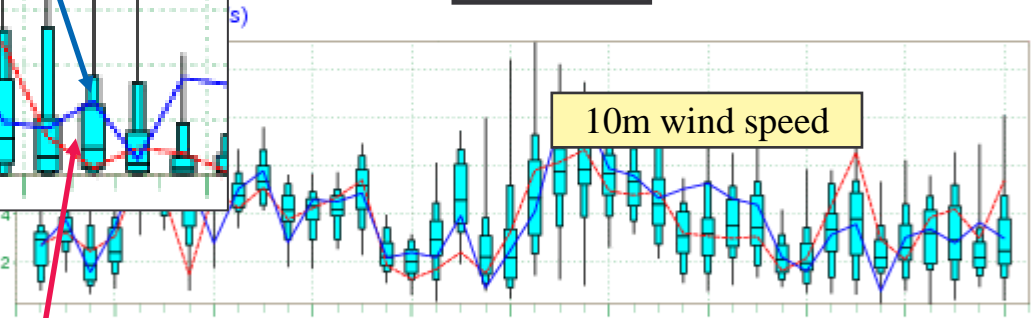
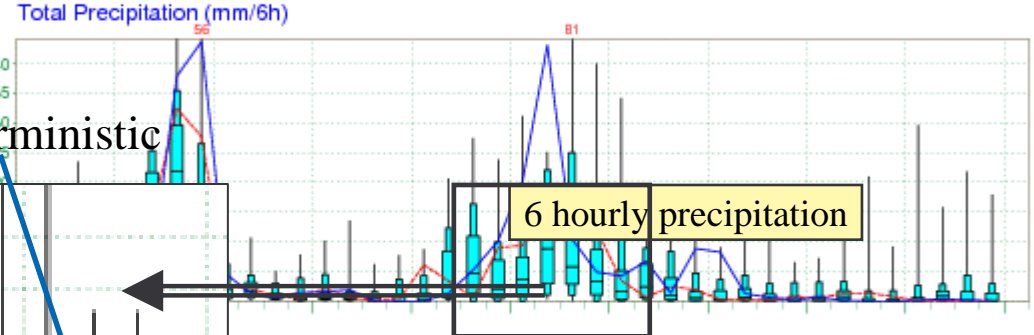
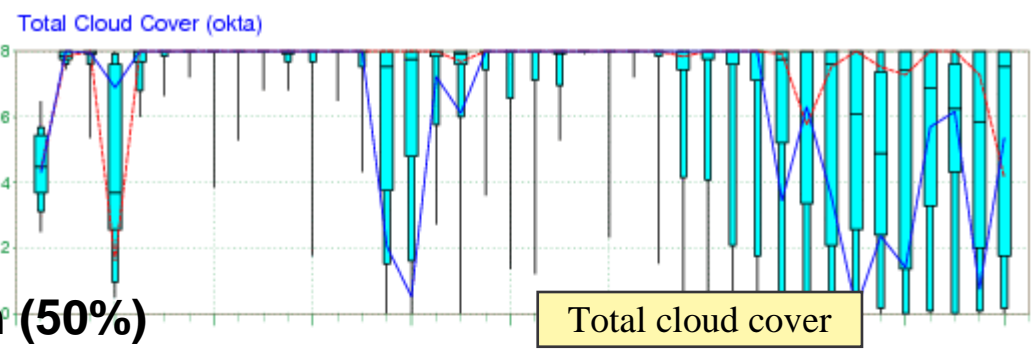
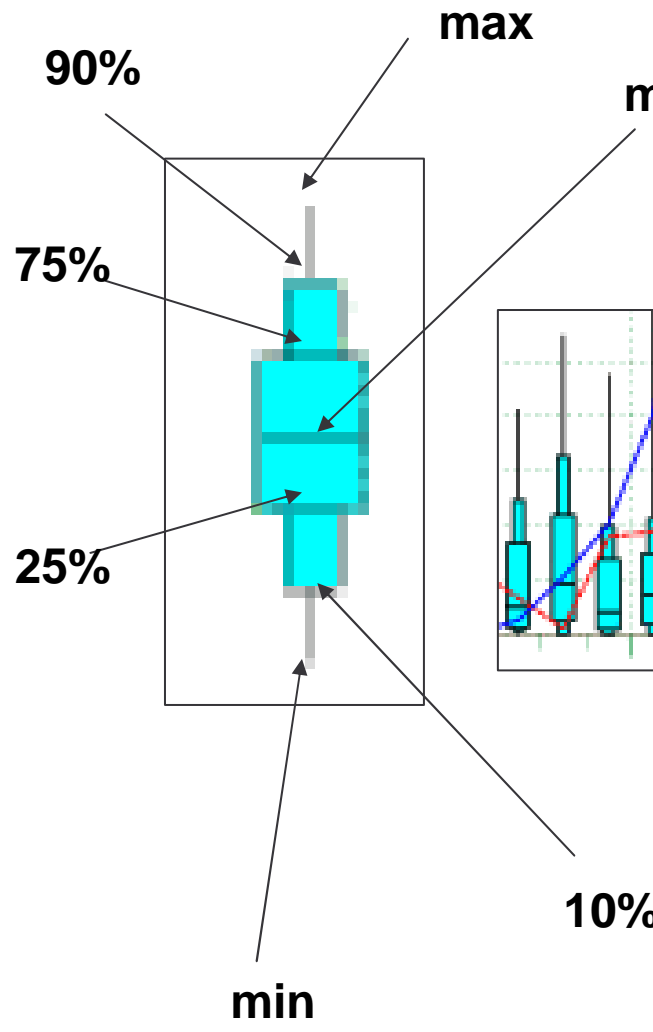
# EC Total ppn prob > 20mm 12z Tue – 12z Wed

Monday 2 October 2006 00UTC ©ECMWF Forecast probability t+036-060 VT: Tuesday 3 October 2006 12UTC - Wednesday 4 October 2006 12UTC  
Surface: Total precipitation probability > 20.0 mm



# EPSgrammes

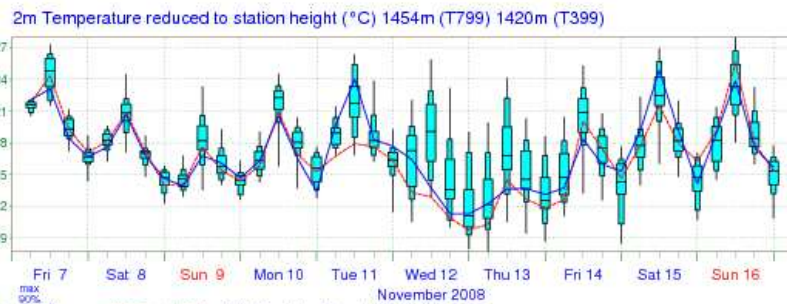
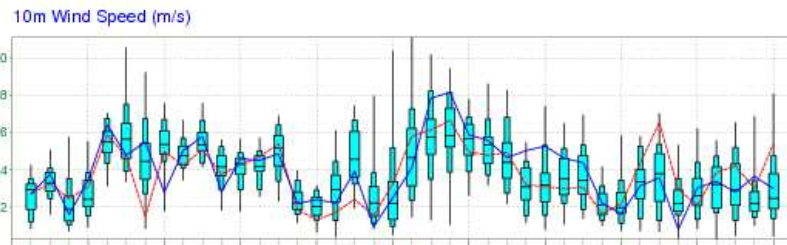
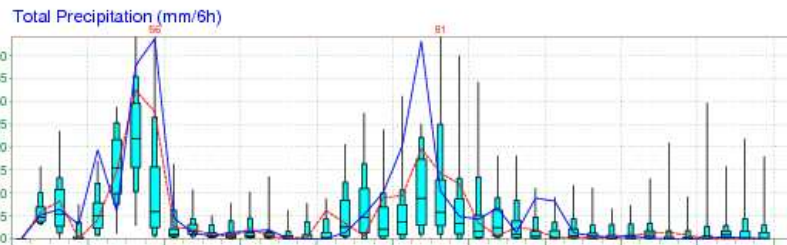
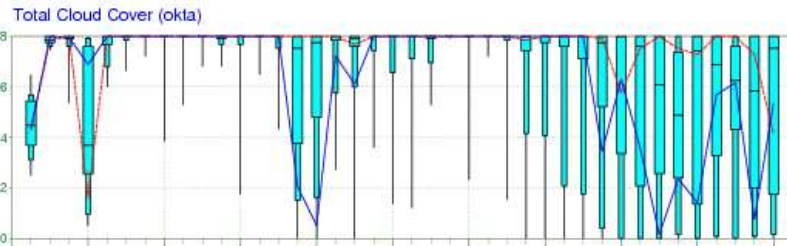




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# Pretoria

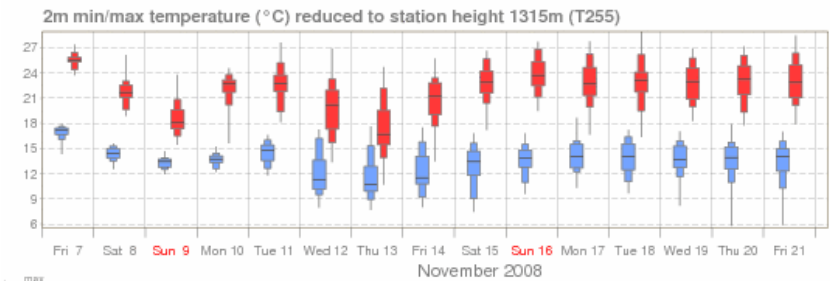
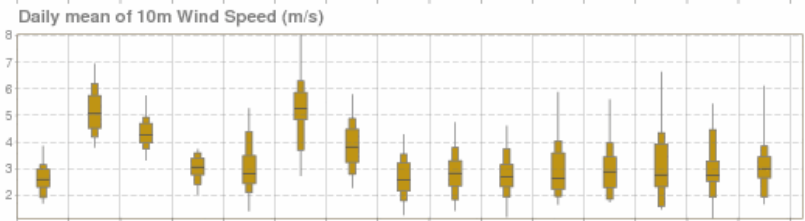
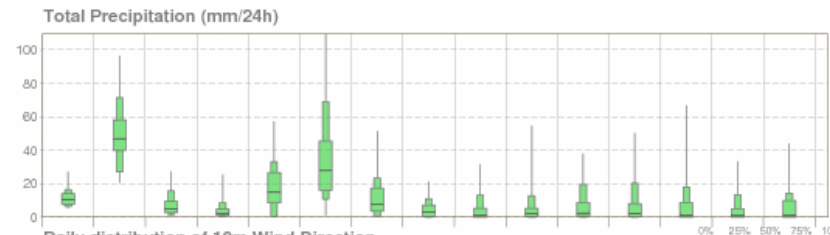
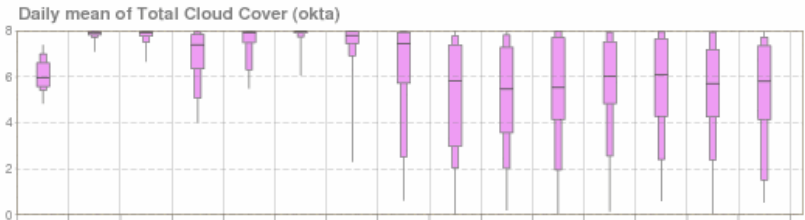
EPS Meteogram  
 Pretoria (1282m) 25.84°S 28.32°E  
 Deterministic Forecast and EPS Distribution Friday 7 November 2008 00 UTC



EPS Control(50 km) High Resolution Deterministic(25 km)

2012-11-28

EPS Meteogram  
 Pretoria (1282m) 25.61°S 28.5°E  
 Extended Range Forecast based on EPS Distribution Friday 7 November 2008 00 UTC



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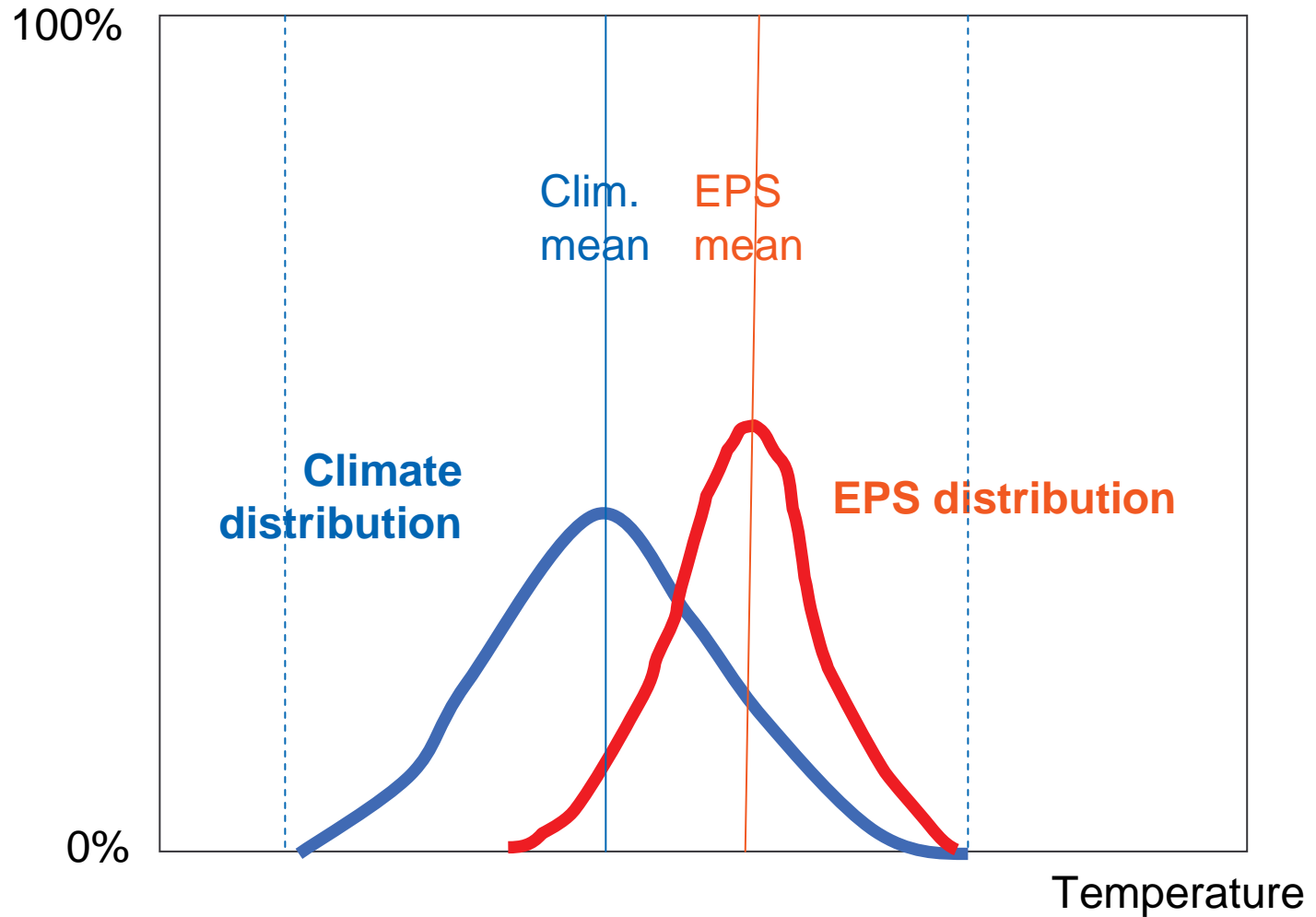
# **The Extreme Forecast Index (EFI)**

# Extreme forecast index (EFI)

- **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)**
- **The main idea is to have an index that can be conveniently mapped – removing the effect from different climatologies – to use as an “alarm bell”**

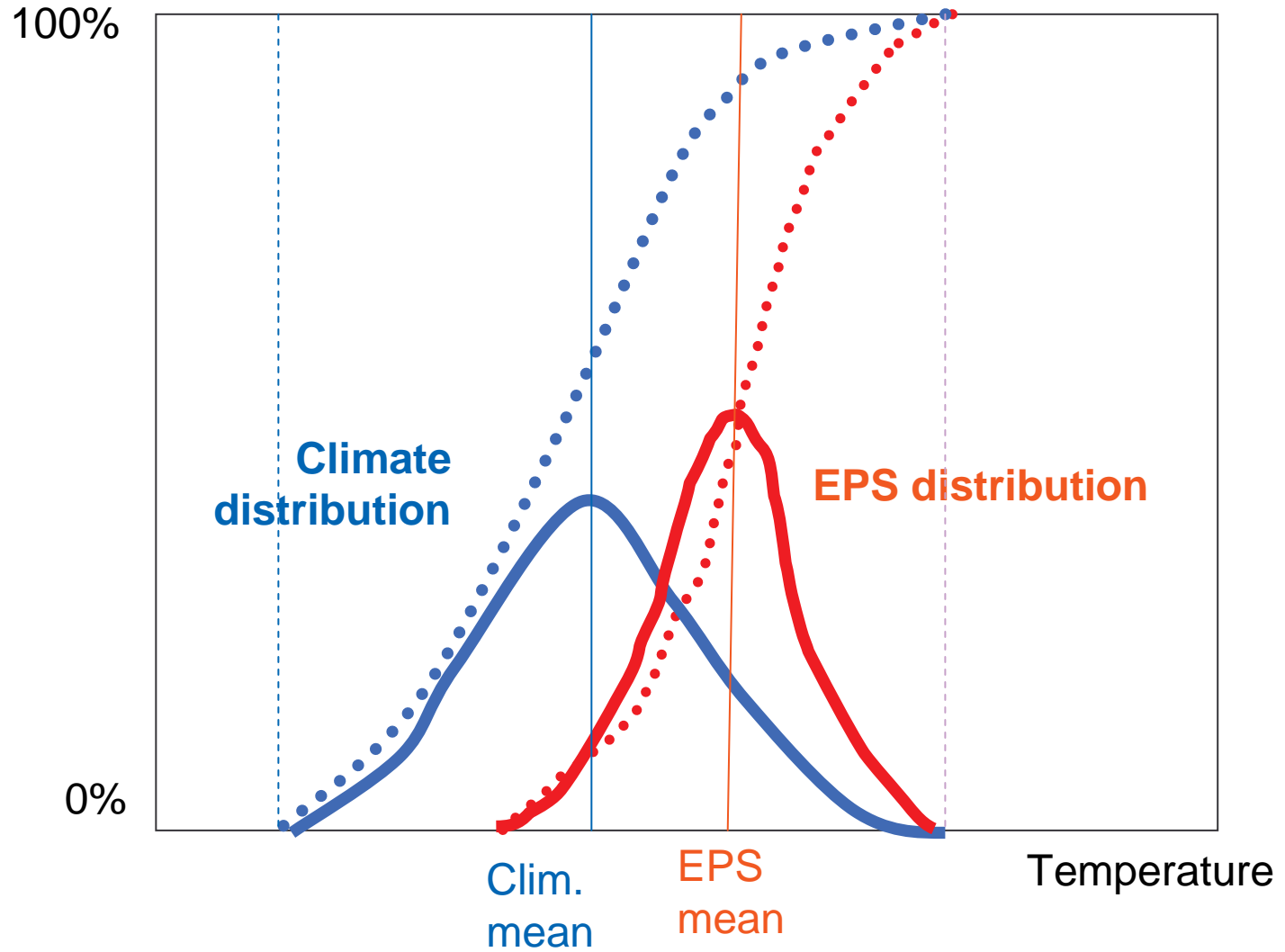
# Advantages with probability density functions

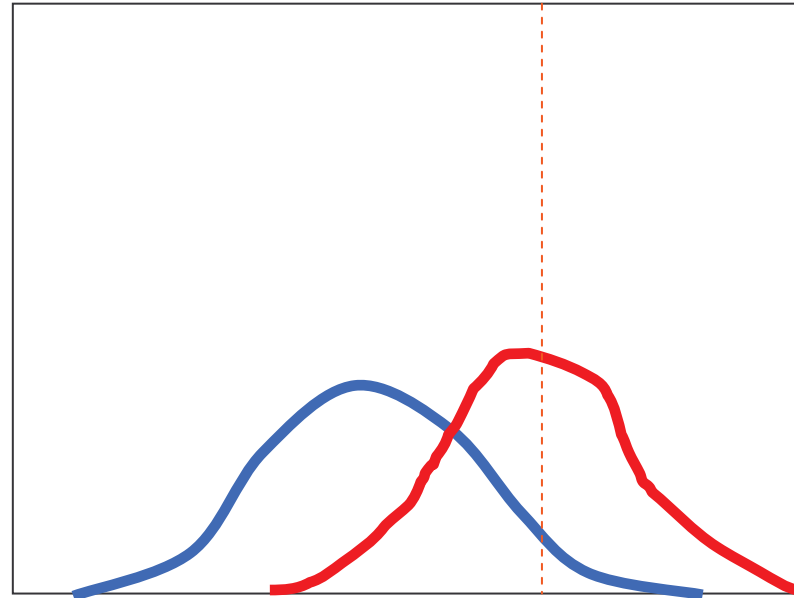
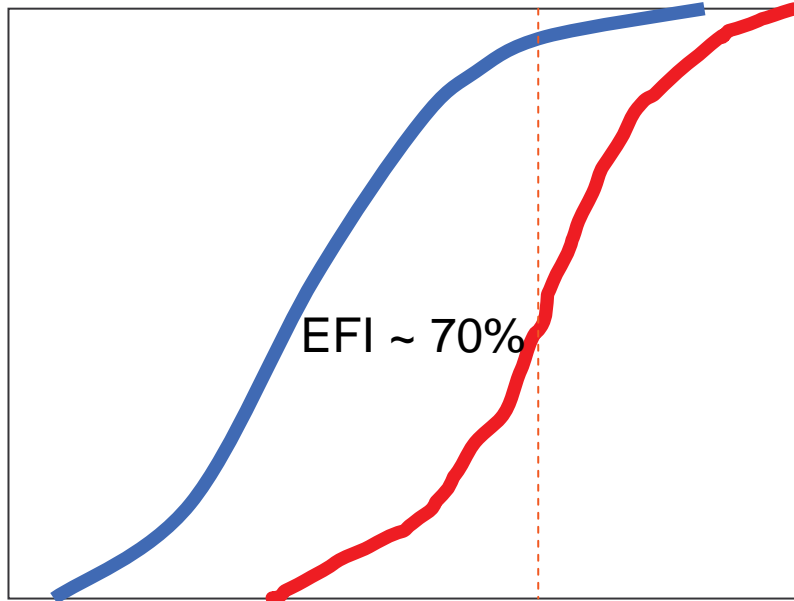
Means and asymmetric variances are easily spotted



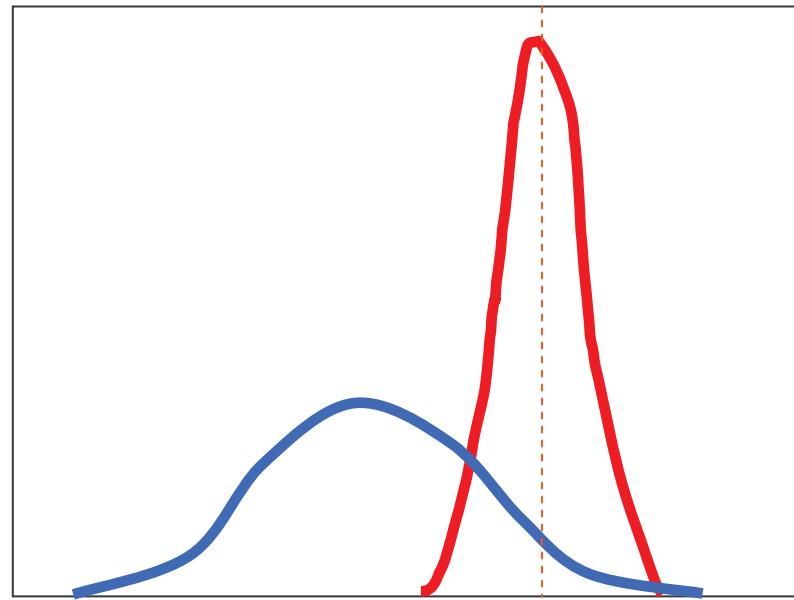
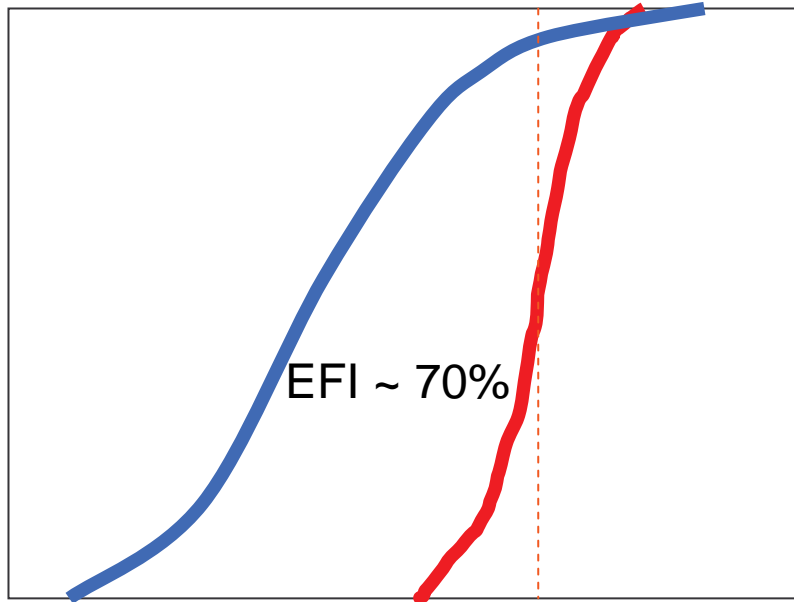
# Advantages with probability density functions

Means and asymmetric variances are easily spotted



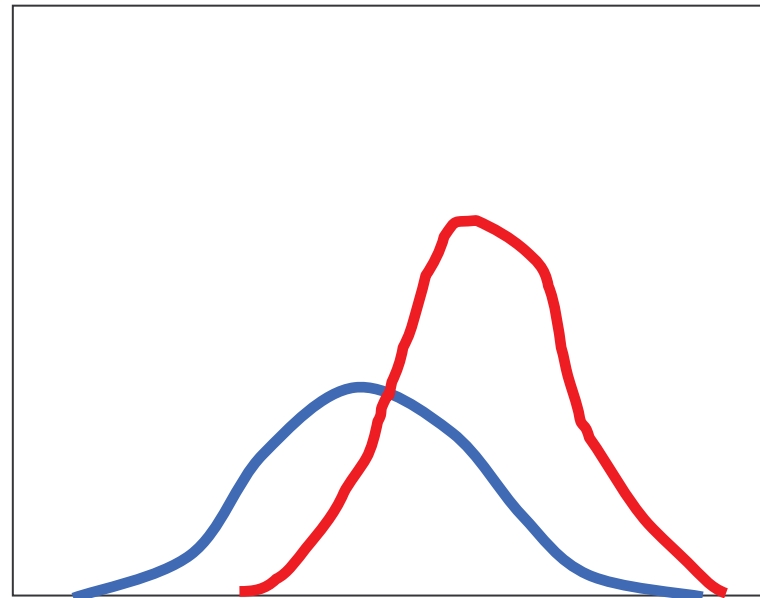
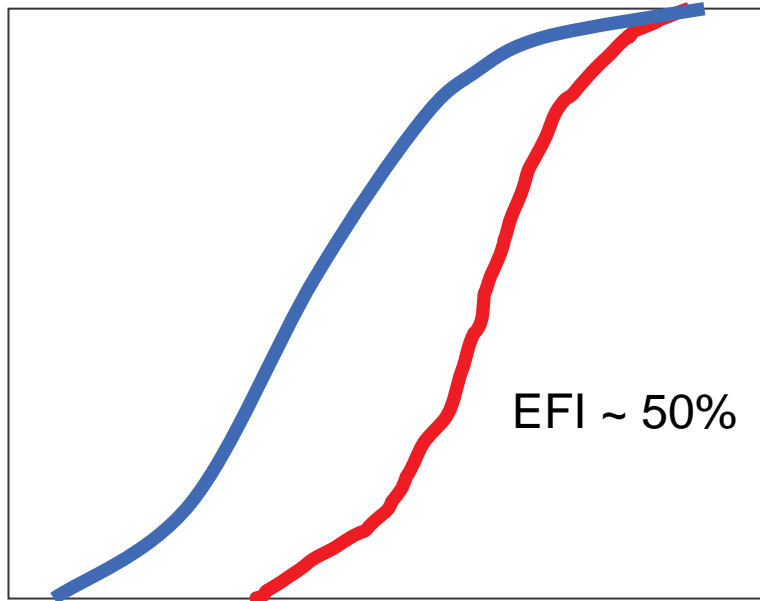


The EFI generally does not take the probability into account

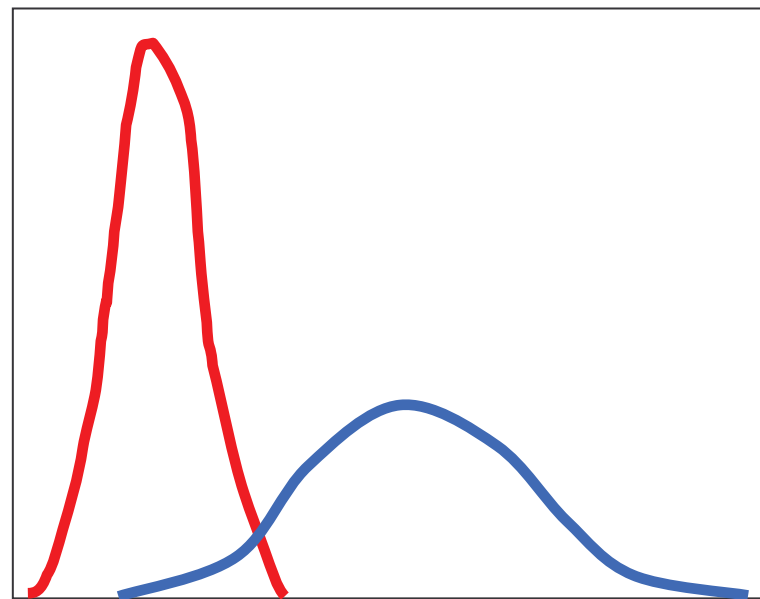
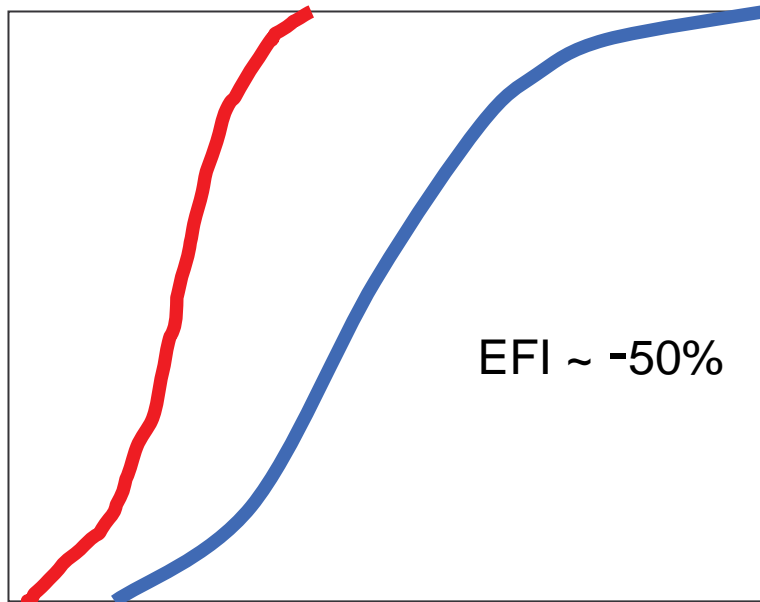


2012-11-28

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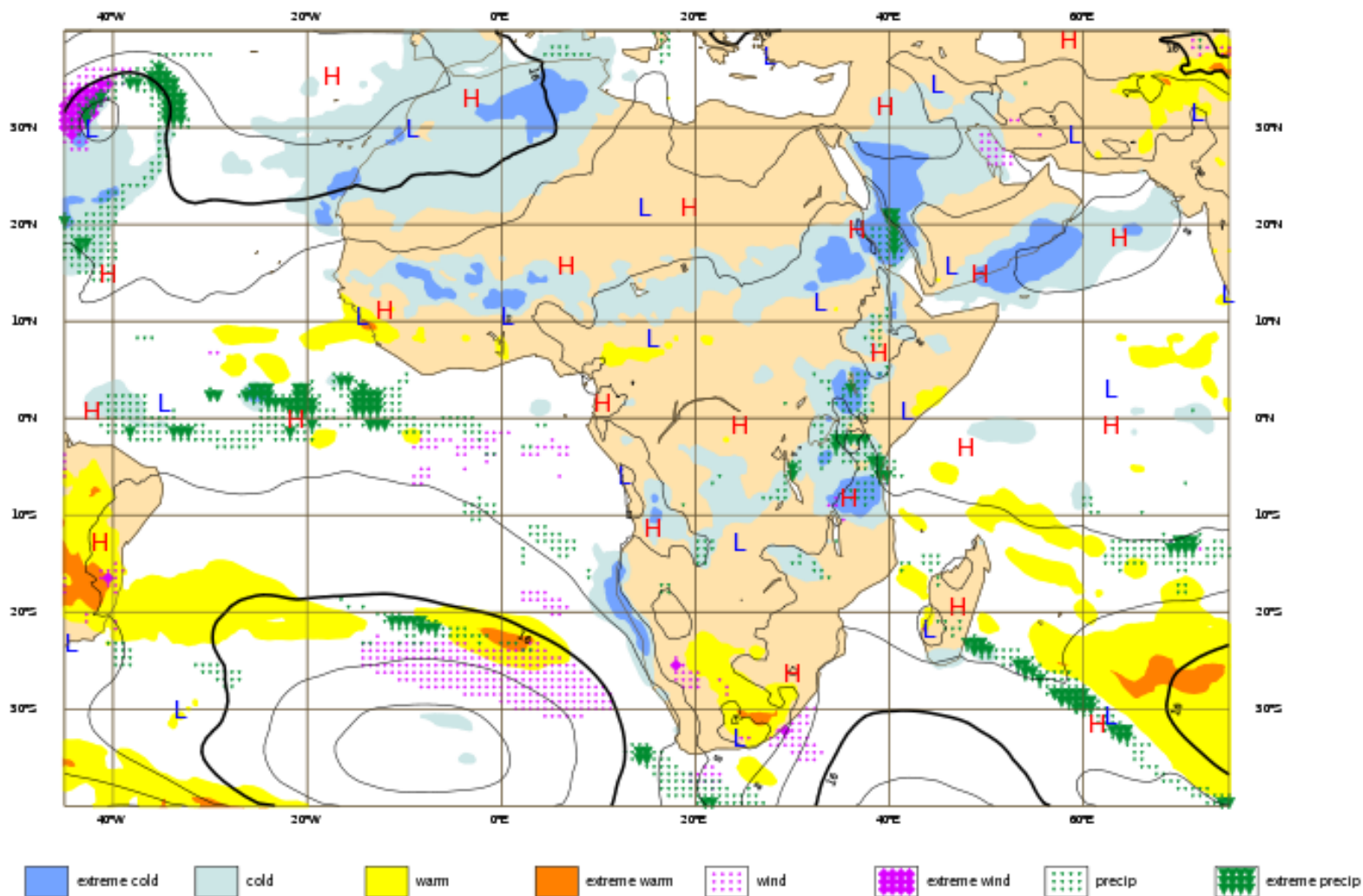
For temperature the EFI can take values  $< 0$



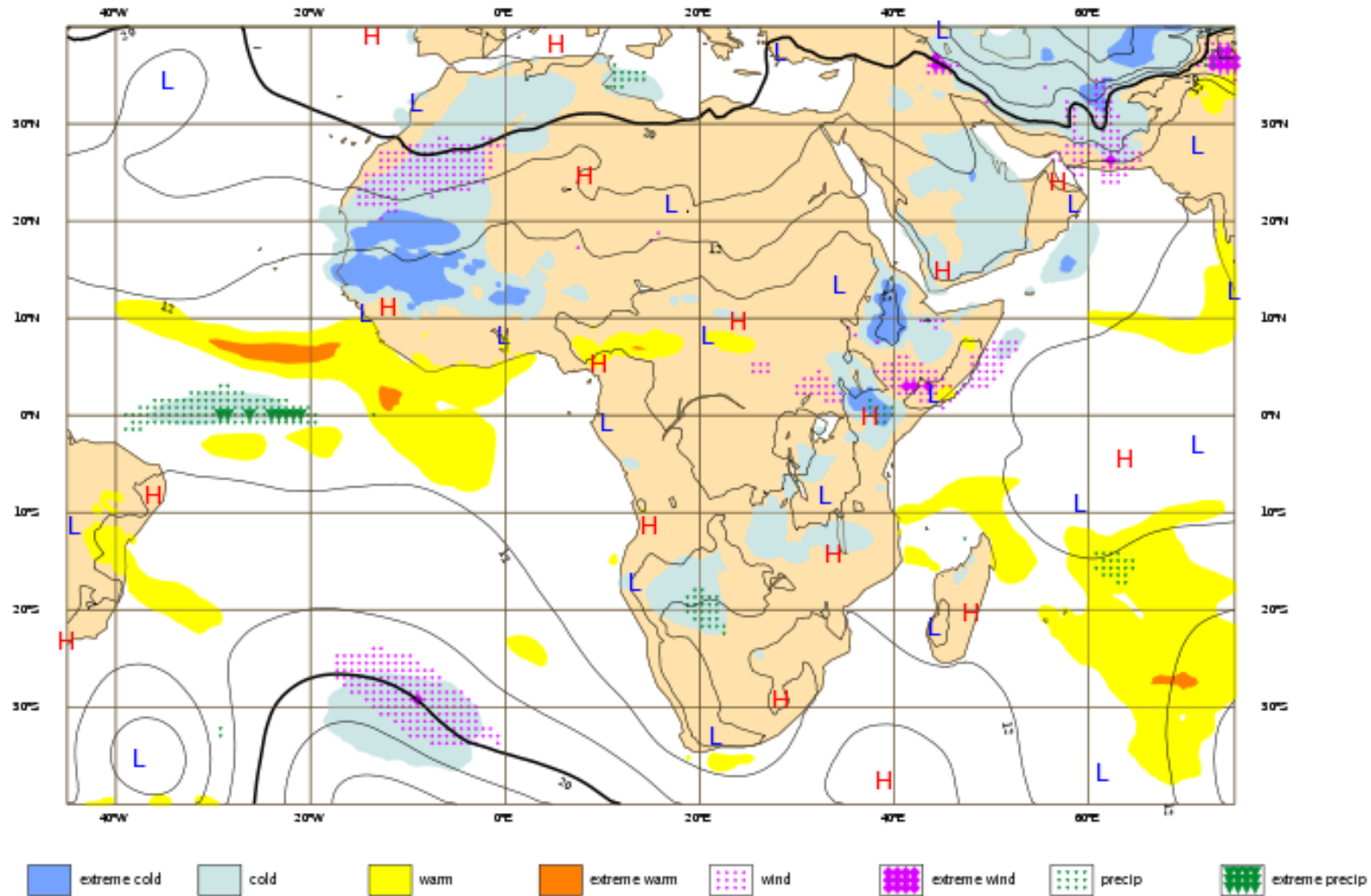
2012-11-28



Weather anomalies predicted by EPS: Thursday 06 November 2008 at 00 UTC  
 1000 hPa Z ensemble mean ( Thursday 06 November 2008 at 12 UTC)  
 and EFI values for 24h TP, 10m wind gust and 2m temperature  
 valid for 24hours from Thursday 06 November 2008 at 00 UTC to Friday 07 November 2008 at 00 UTC

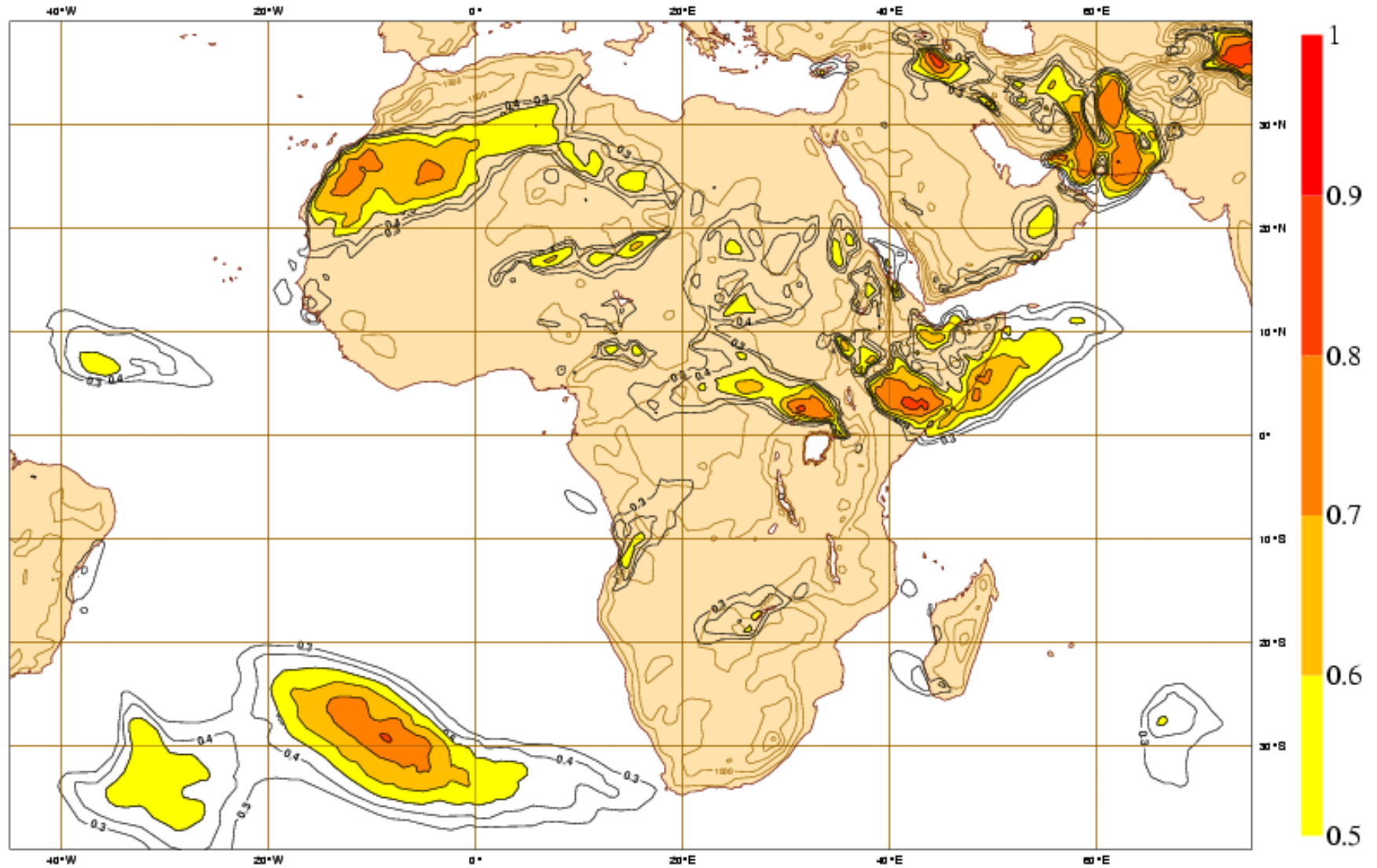


Weather anomalies predicted by EPS: Thursday 06 November 2008 at 00 UTC  
 1000 hPa Z ensemble mean ( Monday 10 November 2008 at 12 UTC)  
 and EFI values for 24h TP, 10m wind gust and 2m temperature  
 valid for 24hours from Monday 10 November 2008 at 00 UTC to Tuesday 11 November 2008 at 00 UTC



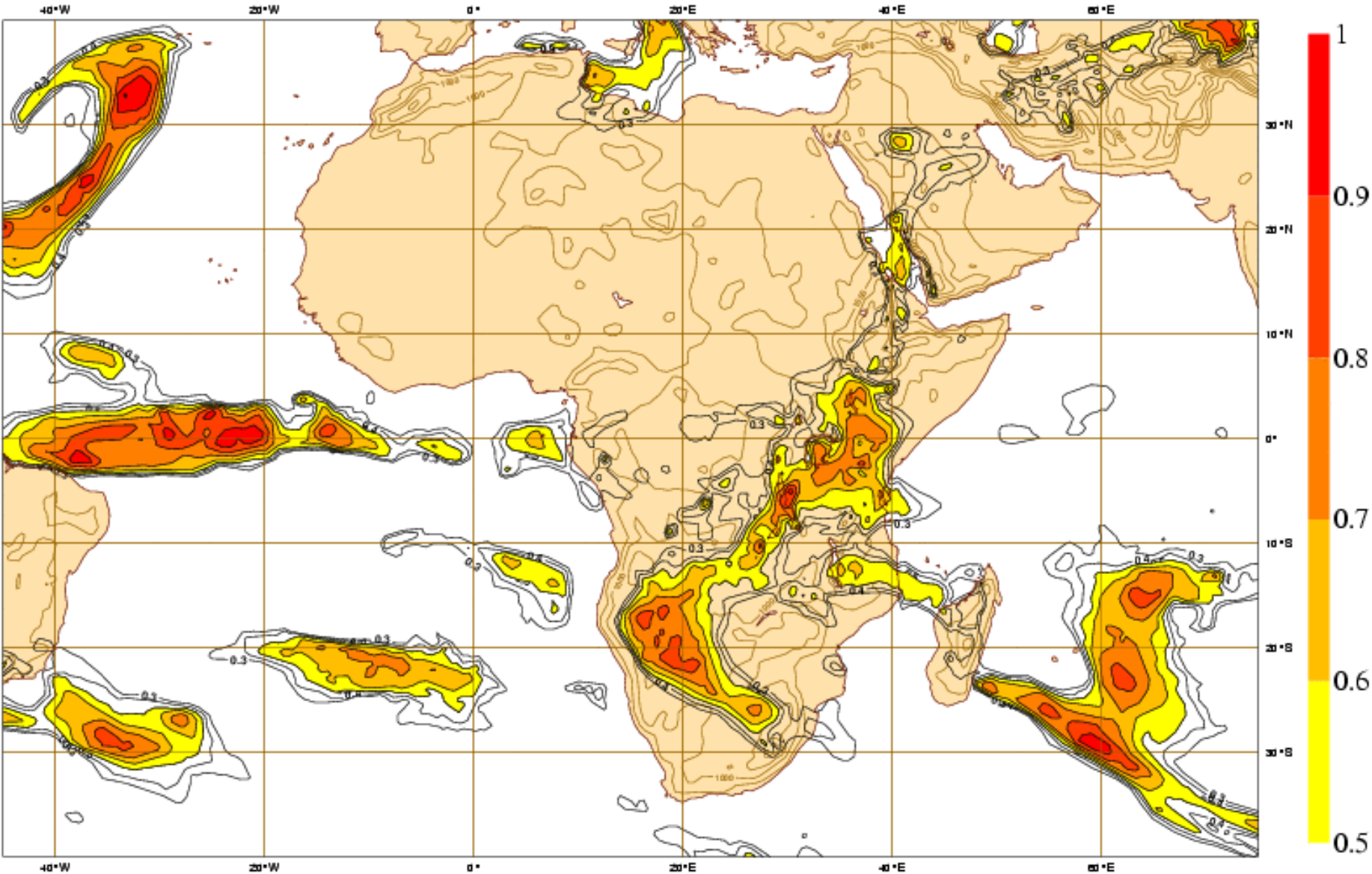
# Product under development

Thursday 6 November 2008 00UTC ©ECMWF Extreme forecast index t+096-120 VT: Monday 10 November 2008 00UTC - Tuesday 11 November 2008 00UTC  
Surface: 10 metre wind gust index



# Product under development

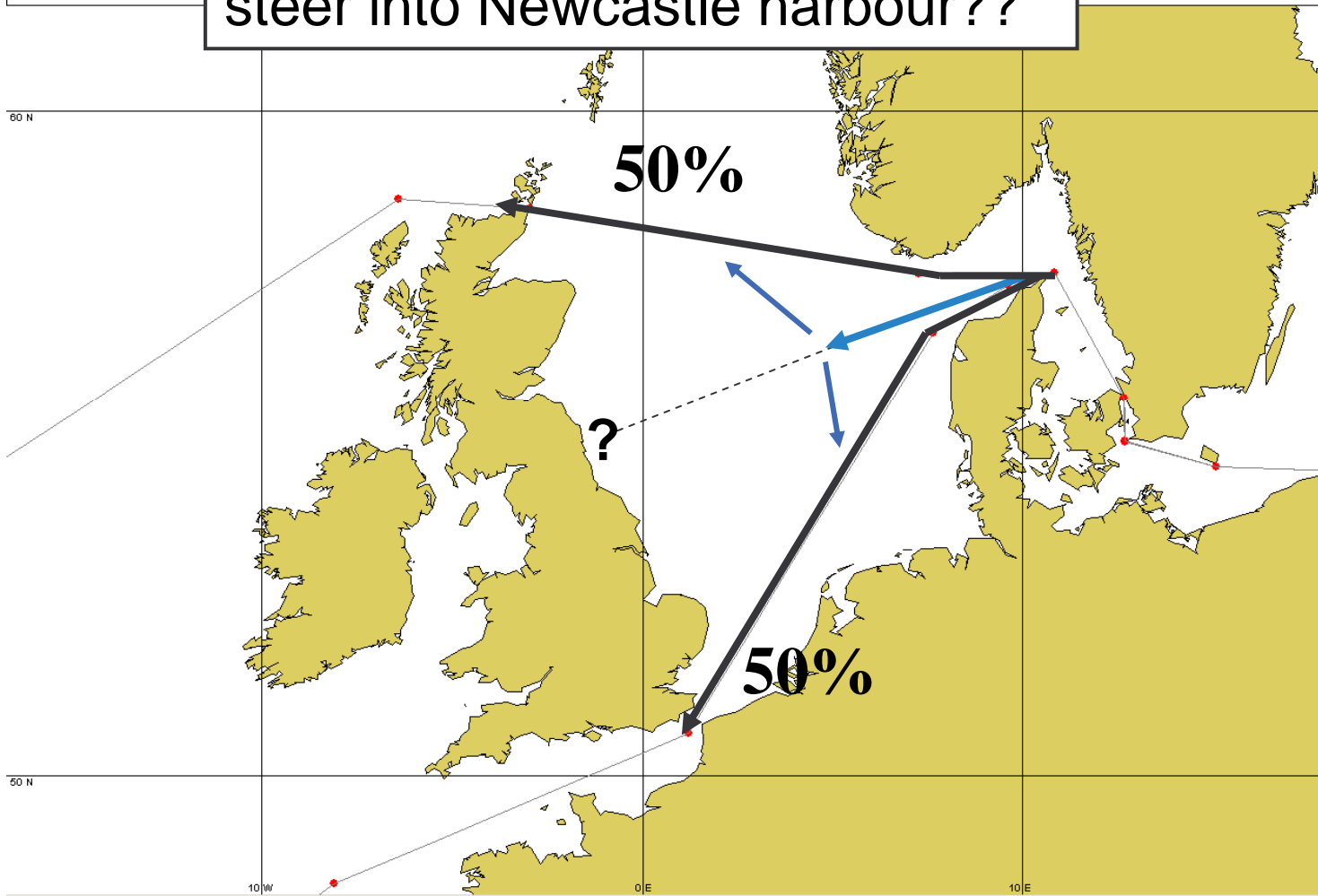
Thursday 6 November 2008 00UTC ©ECMWF Extreme forecast index t+000-120 VT: Thursday 6 November 2008 00UTC - Tuesday 11 November 2008 00UTC  
Surface: Total precipitation index



# Working with the EPS

- Ensemble mean acts as a dynamic filter and removes normally unpredictable features
- The removed features are put back in a consistent way as probabilities

Would you guide the ships to go  
steer into Newcastle harbour??



# Questions & Answers