



# ECMWF 10<sup>th</sup> workshop on Meteorological Operational Systems

18th November 2005

# Monthly range prediction products: Post-processing methods and verification

Bernd Becker, Richard Graham.

- Met Office monthly forecast suite
- UK Products from the Monthly Outlook
- Standard Verification System

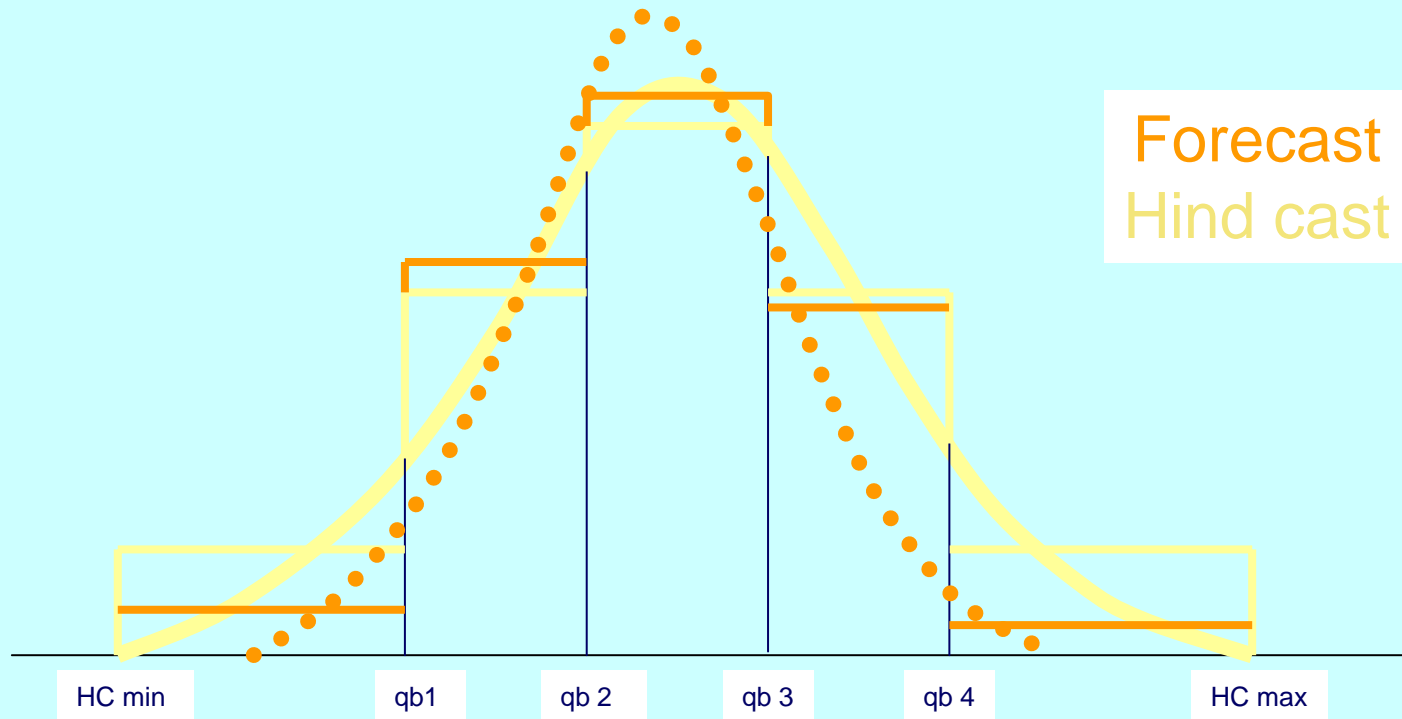
# Monthly Forecasting System



- Coupled ocean-atmosphere integrations: a **51-member ensemble** is integrated for 32 days every week.
- Atmospheric component: IFS with the latest operational cycle 29r3 and with a TL159L40 resolution (320 \* 161)
- Oceanic component: HOPE (from Max Plank Institute) with a zonal resolution of 1.4 degrees and 29 vertical levels
- Coupling: OASIS (CERFACS). Coupling every ocean time step (1 hour)
- Perturbations:**
  - Atmosphere: Singular vectors + stochastic physics
  - Ocean: SST perturbations in the initial conditions + wind stress perturbations during data assimilation.
- Hindcast statistics:**
  - 5-member ensemble integrated over 32 days during the past 12 years.
  - Representing a **60-member ensemble**.
  - Running every week

1. Data Volume reduction → Derive properties of the PDF
2. Interpolation to 10 UK climate regions → Down scaling
3. Calibration with historical data → Bias correction
4. Interpretation of the histogram → Deterministic terce/quint
5. Mapping → Deterministic value

# Properties of quintile PDF



FXmin	FXmean	FXmax	<b>Wk1</b> : d 5 – 11
gm1	gm2	gm3	<b>Wk2</b> : d 12 – 18
<u>well below</u> <u>below</u> <u>normal</u> <u>above</u> <u>well above</u>			<b>Wk3&amp;4</b> : d 19 - 32

FORMOST global PDF data

## 2. Interpolation (UK)

- Bilinear interpolation to representative points
- Averaged station data from 1971 to 2000 build the climatology

## 3. Calibration (UK)

- Quint boundaries are derived
- And swapped with the hindcast quint boundaries.

Takes care of

- Bias correction of the category boundaries
- Bias in the mean



## 4. Interpretation of the PDF

Many customers want **deterministic** answer.

How to deduce deterministic Forecast information from the PDF?

Ensemble mean, but!

If Spread > set threshold and  
most probable quint 5% more likely than 2<sup>nd</sup> most probable

Use Mode and

Issue Message: uncertain forecast, low confidence.

## 5. Mapping



Low spread, Ensemble mean a good “best estimate”, high confidence.

High Spread, ensemble mean misleading in many cases.

High Spread, delta probability > 5%.  
Most probable category “best estimate”.

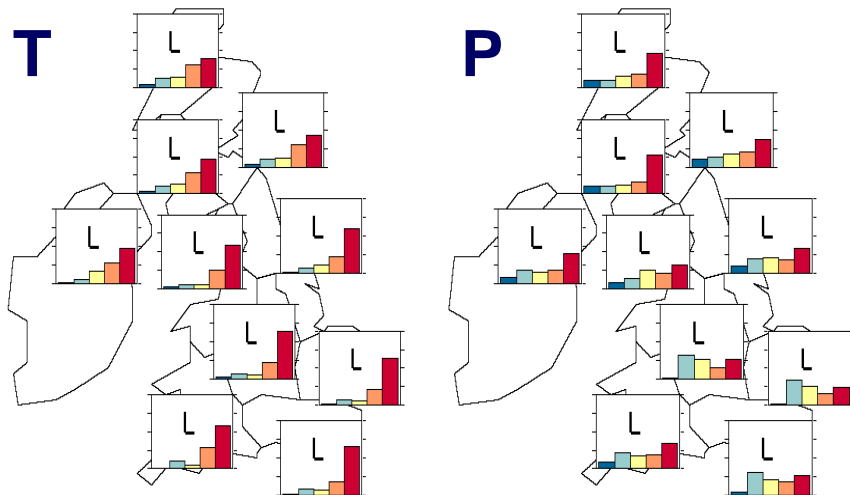
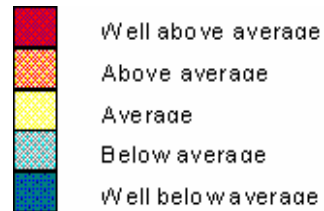
To derive a deterministic Temperature or Precipitation value, the predicted quintile/tercile category average value is mapped onto the Calibration PDF.



# Example UK 12-18 day temperature forecast for 10 climate districts

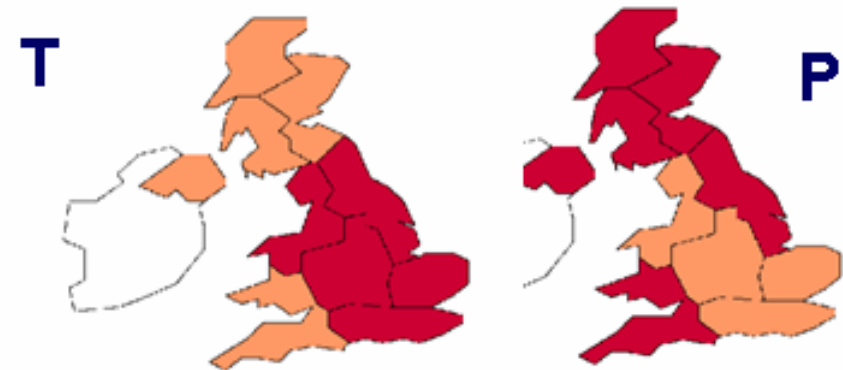


## Probability forecast

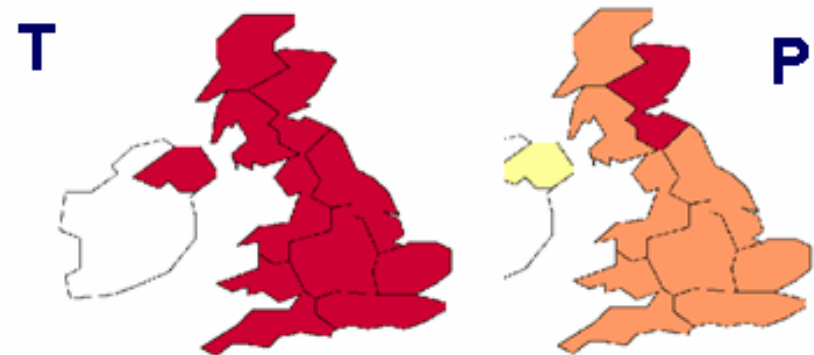


## Deterministic forecast

(based on most probable category or ensemble mean)



## Verification



“... A mild west to south-westerly airflow will dominate the weather during this period, and becoming rather wet at times...”

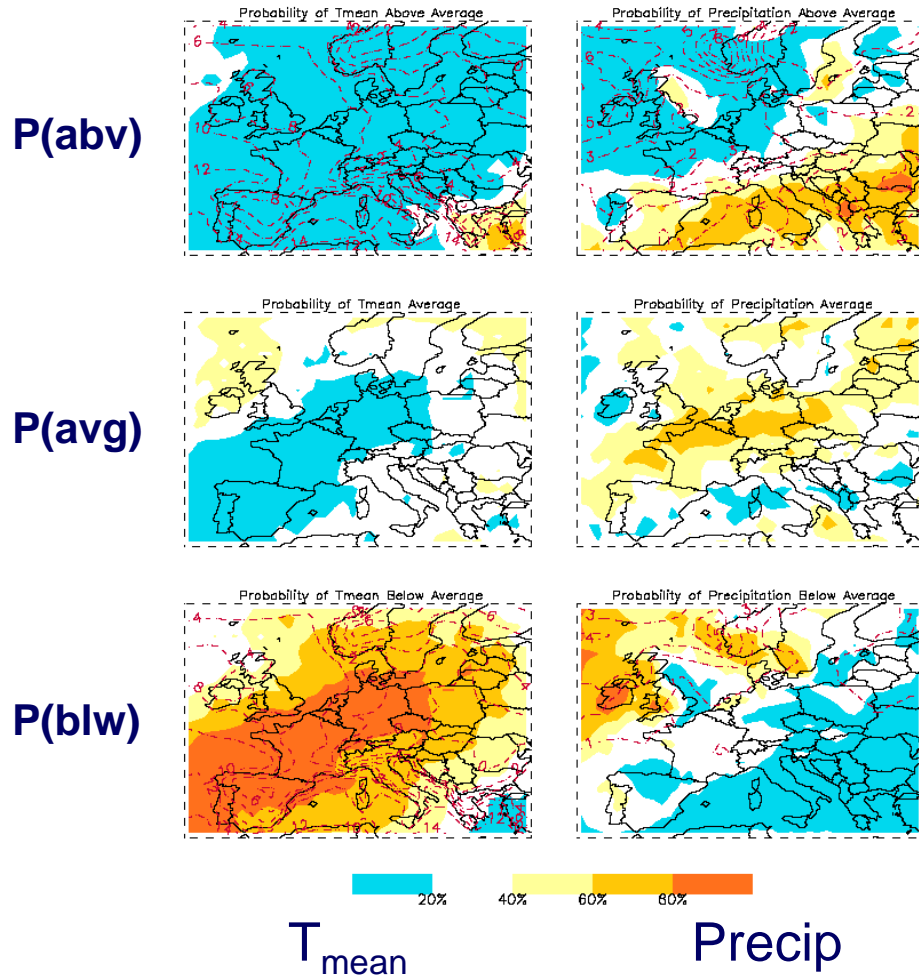
(Forecast text issued 13<sup>th</sup> Oct for week 24-30 of Oct)

# Example global capability tercile probability forecast – Europe, days 12-18



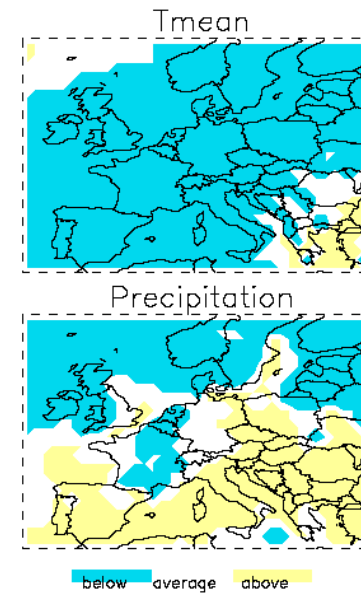
## The Monthly Outlook for Europe

Days 12–18: 21 February 2005 – 27 February 2005

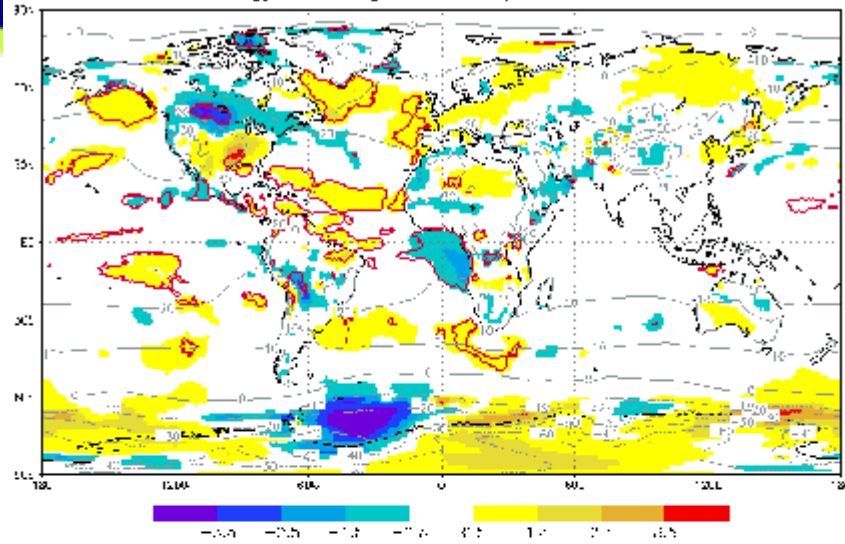


## Verification (ECMWF operations)

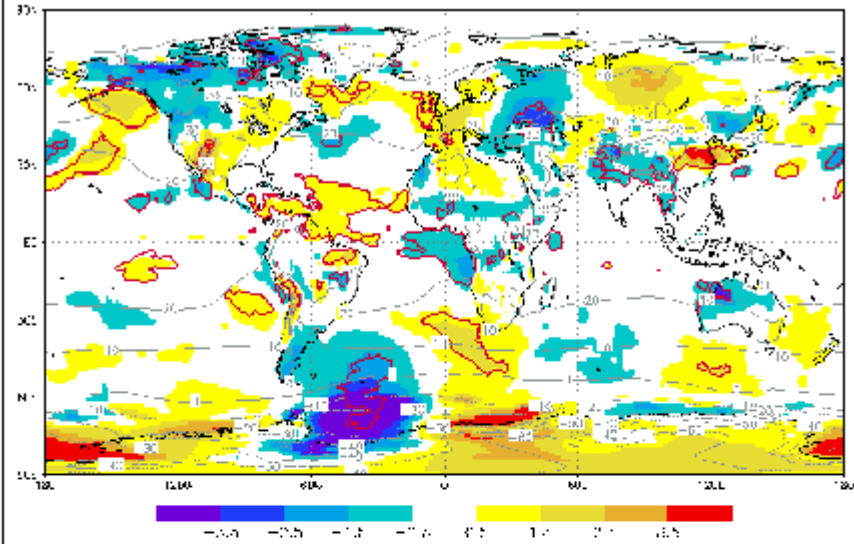
The Observed Tercile for Europe  
Days 12–18: 21 February 2005 – 27 February 2005



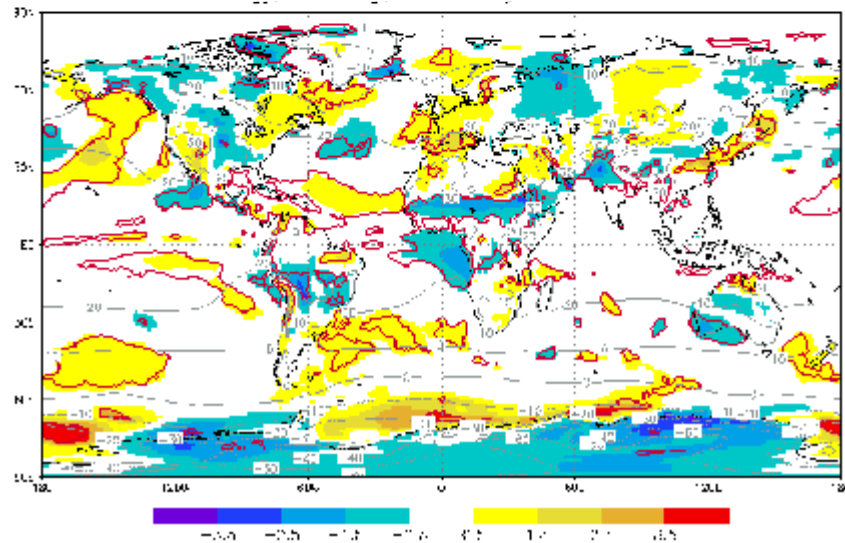
# WK 3&4



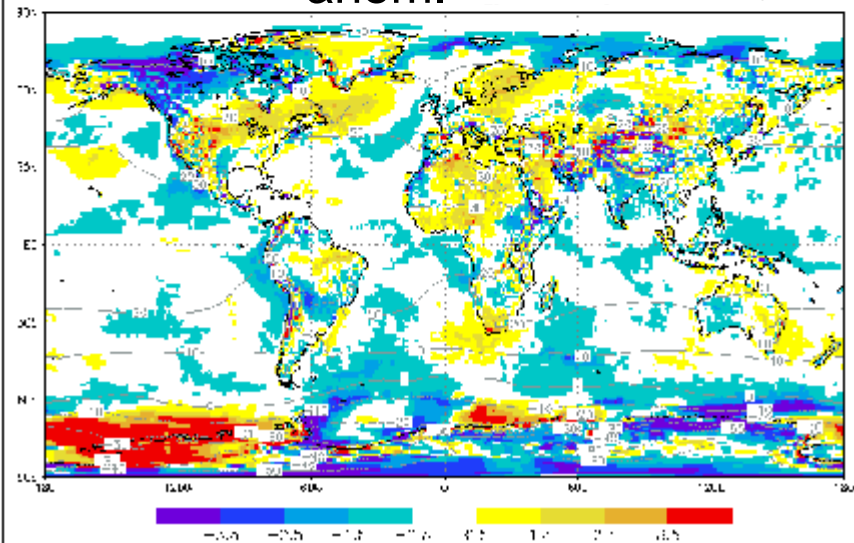
# WK 2



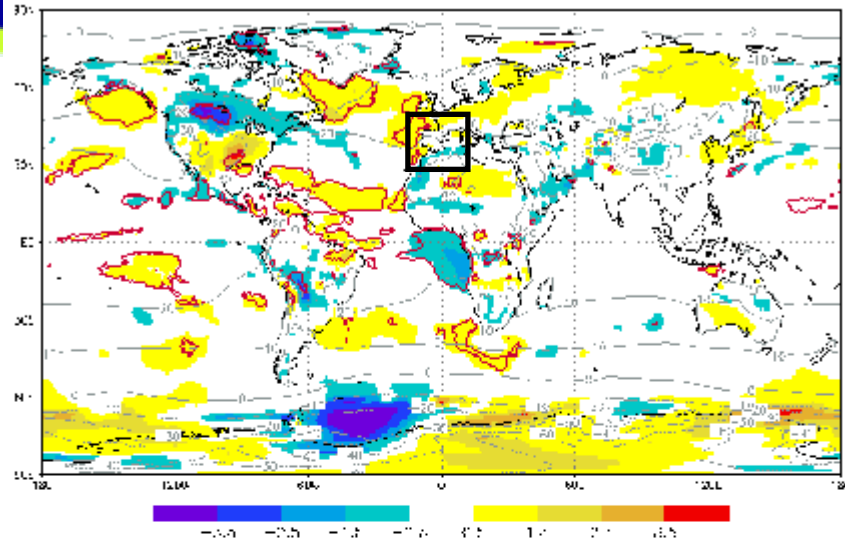
# WK 1



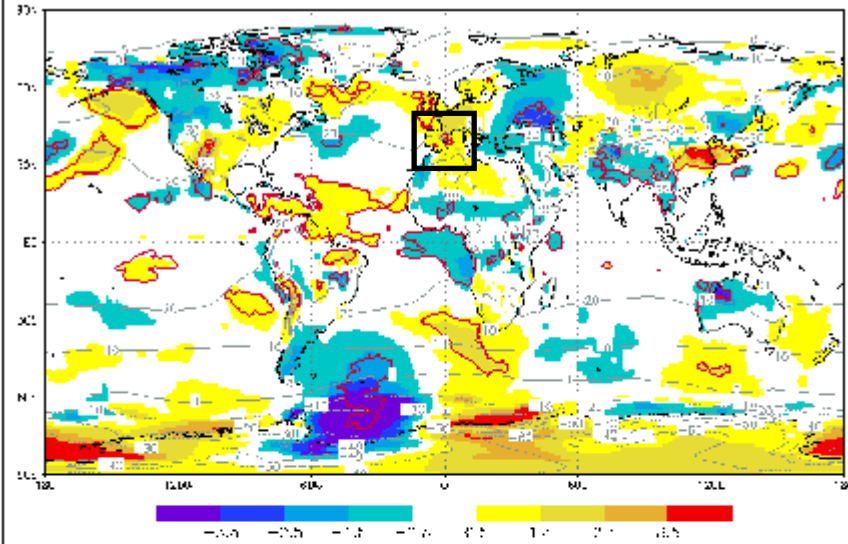
# Obs. T<sub>anom.</sub> 4-10. July



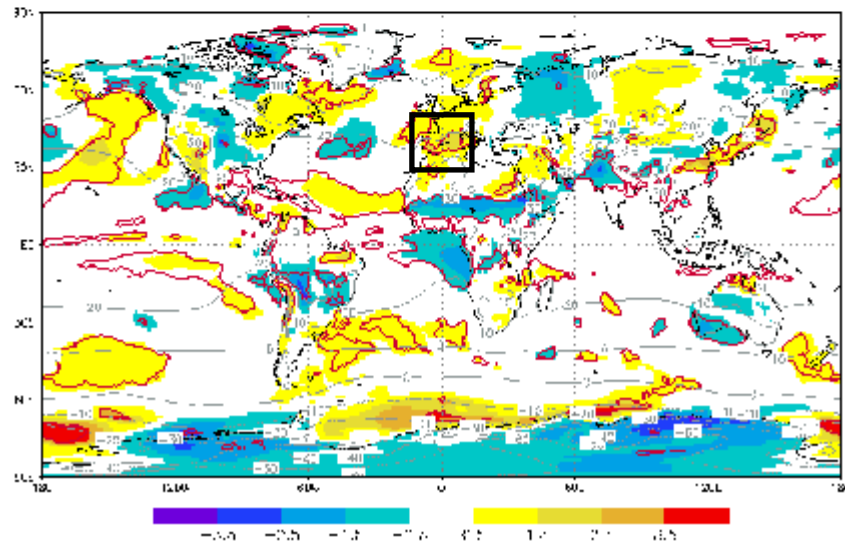
# WK 3&4



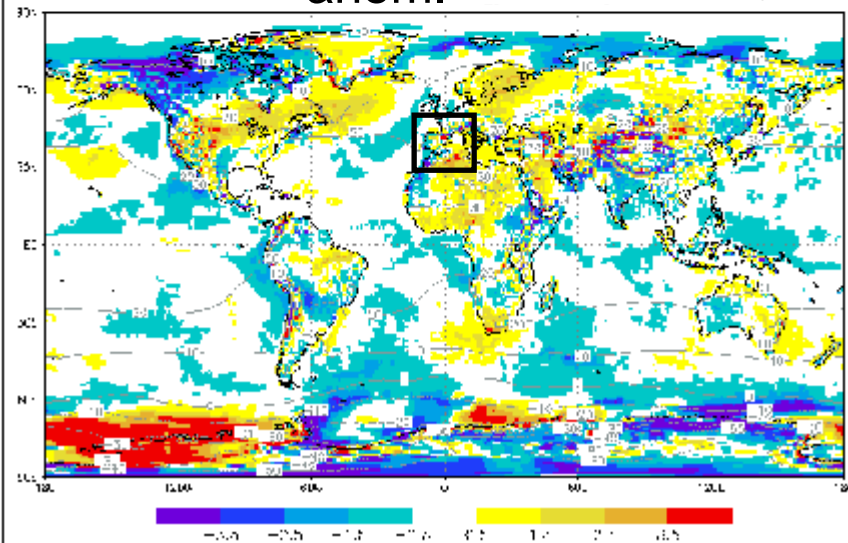
# WK 2



# WK 1



# Obs. $T_{anom.}$ 4-10. July



# Recap: Post processing and Products



- Data Volume reduction before transfer to The Met Office: Calculate
  1. Tercile/Quintile boundaries from the Hindcast ensemble
  2. Tercile/Quintile populations from the Forecast ensemble
  3. Maximum, Mean and Minimum from Forecast and from Hindcast
  4. Forecast Tercile/Quintile averages
  5. Average in time to week 1, 2 and 3&4.
  
- UK Forecast: [http://www.bbc.co.uk/weather/ukweather/monthly\\_outlook.shtml](http://www.bbc.co.uk/weather/ukweather/monthly_outlook.shtml)
  1. Interpolation to points representing UK climate regions
  2. Calibration with historical UK climate region observations
  3. Interpretation of the Histogram, Ensemble mean or Mode in cases with large spread,
    - derive deterministic forecast tercile/quintile
  4. Mapping Tercile/Quintile average onto calibration PDF
    - to derive deterministic forecast value
  
- Global Forecast:
  1. Tercile/Quintile probabilities
  2. Calibrate by overlaying Tercile/Quintile boundaries derived from 1989 – 1998 ERA40 data

# Verification May 2002 - October 2005



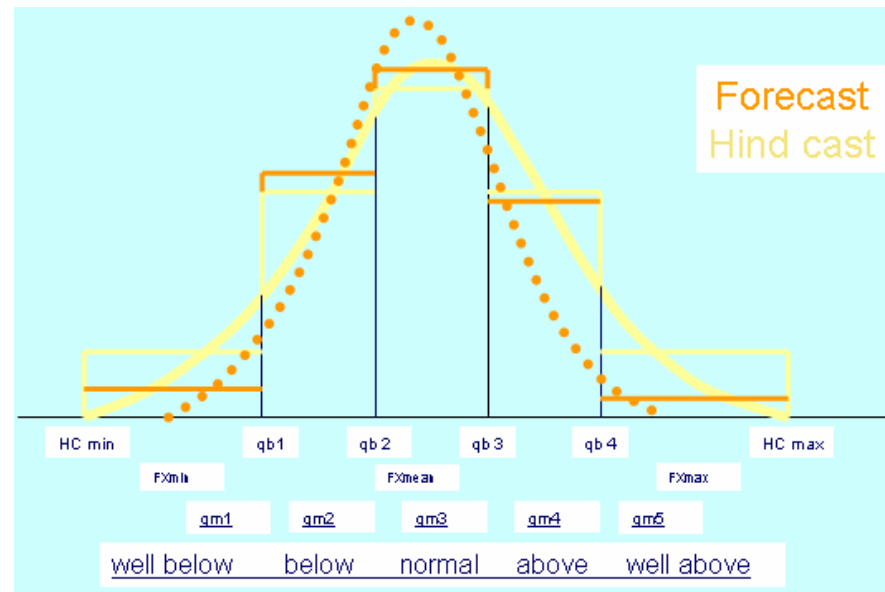
- Focus on periods beyond the medium range, days 12-18
- 115 forecast/ observation pairs of Temperature and Precipitation
- Verifying Observations:
  - Station observations averaged in each UK climate region

- Remember: Weekly averages  
5 class histogram

**Wk1** : d 5 – 11

**Wk2** : d 12 – 18

**Wk3&4** : d 19 - 32



Compare the following forecasts:

- Based on past experience
  - Climate Mean                      Scores Zero by design
  - Climate Histogram                Scores Zero by design
  - Persistence
  
- Dynamical ensemble forecasts
  - Most Probable Quintile category
  - 5 class histogram

With respect to skill scores.

# Skill scores...

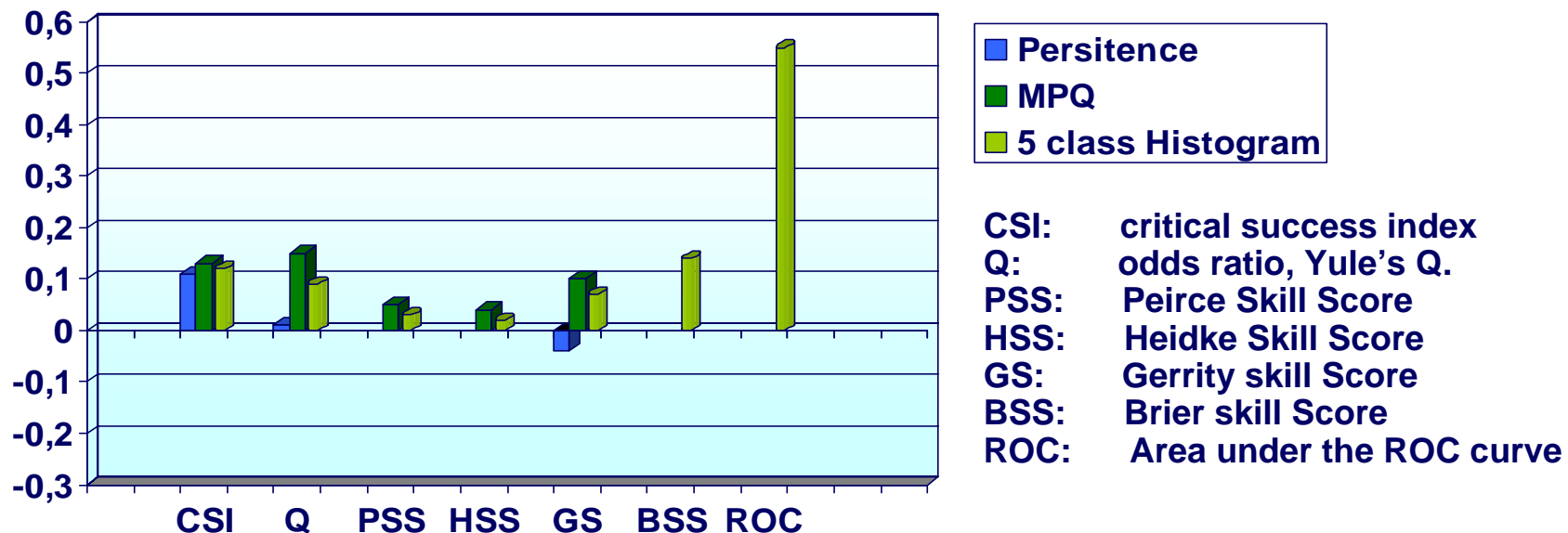


..are derived from a 5 \* 5 \* 10 contingency table.  
Each cell records matching:

$T_{\text{mean}}$ , days 12 - 18

- Observation / Forecast category and
- the probability with that the category was predicted

Scores are calculated per category, figures in graph below are averaged over 5 categories.





# Skill scores...

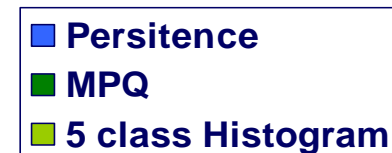
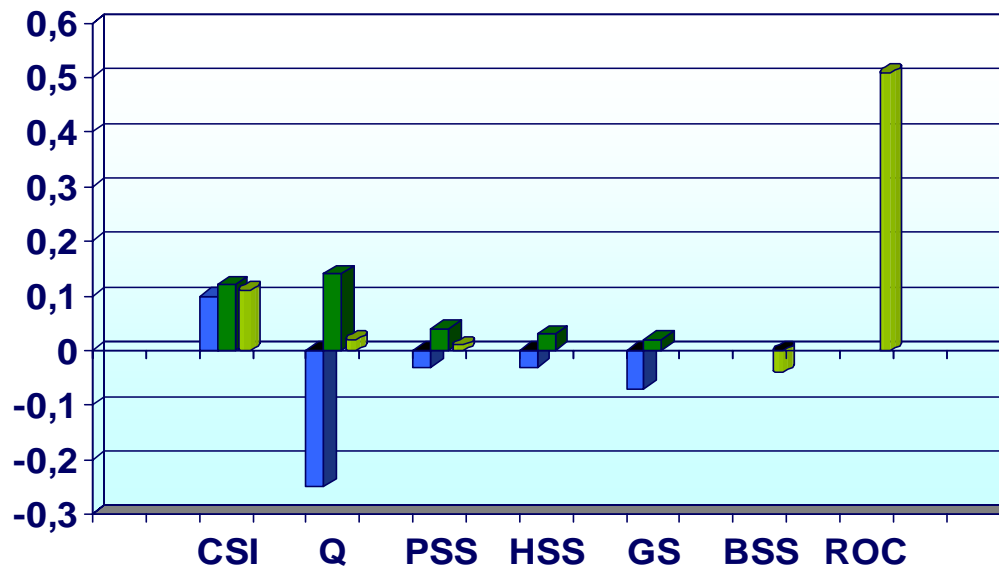


..are derived from a 5 \* 5 \* 10 contingency table.  
Each cell records matching:

$T_{\text{mean}}$ , days 19 - 32

- Observation / Forecast category and
- the probability with that the category was predicted

Scores are calculated per category, figures in graph below are averaged over 5 categories.

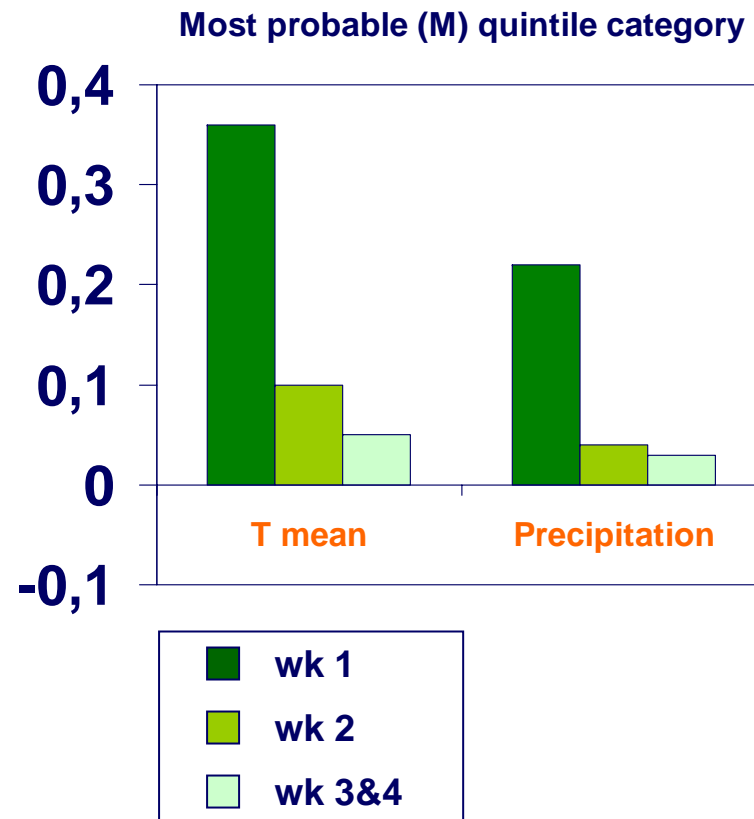
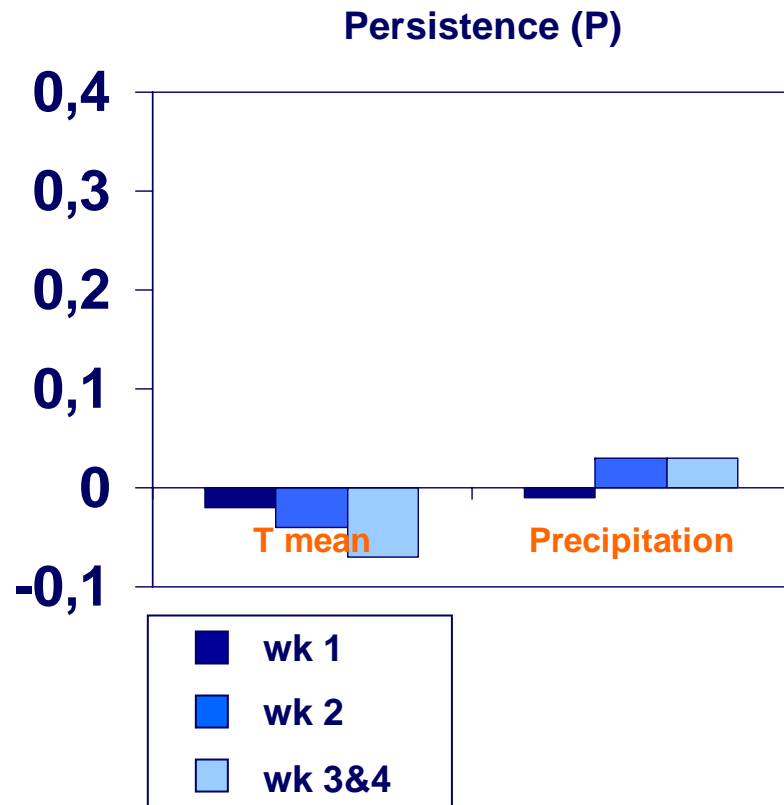


CSI: critical success index  
Q: odds ratio, Yule's Q.  
PSS: Peirce Skill Score  
HSS: Heidke Skill Score  
GS: Gerrity skill Score  
BSS: Brier skill Score  
ROC: Area under the ROC curve

# Gerrity Scores for monthly-range forecasts for the UK districts: 5 categories



Total of 115 forecasts



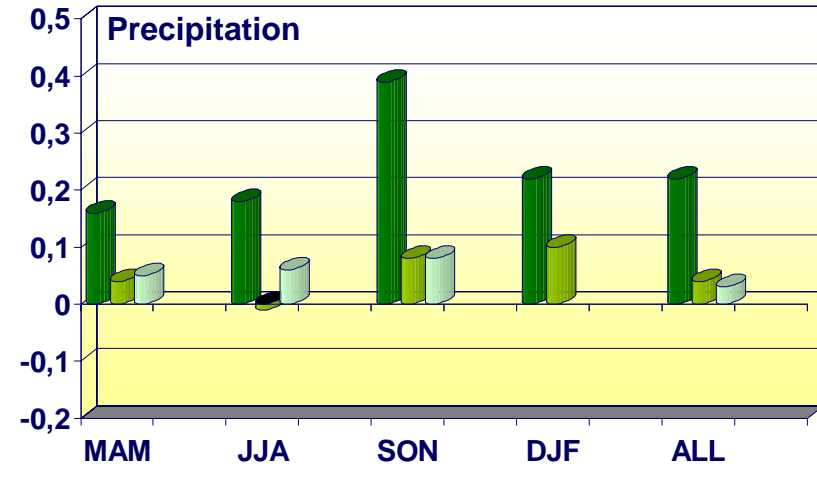
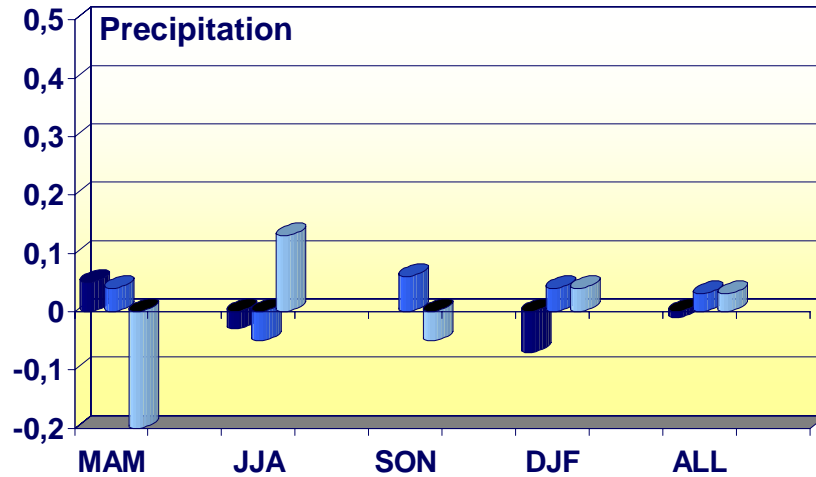
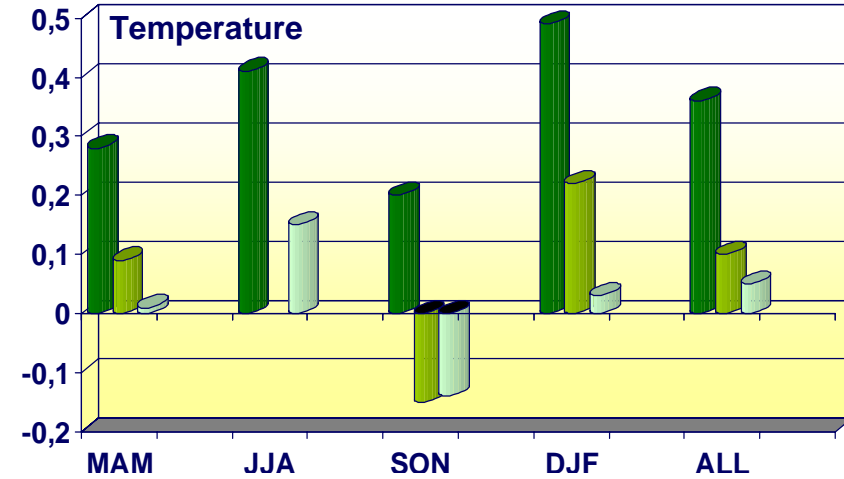
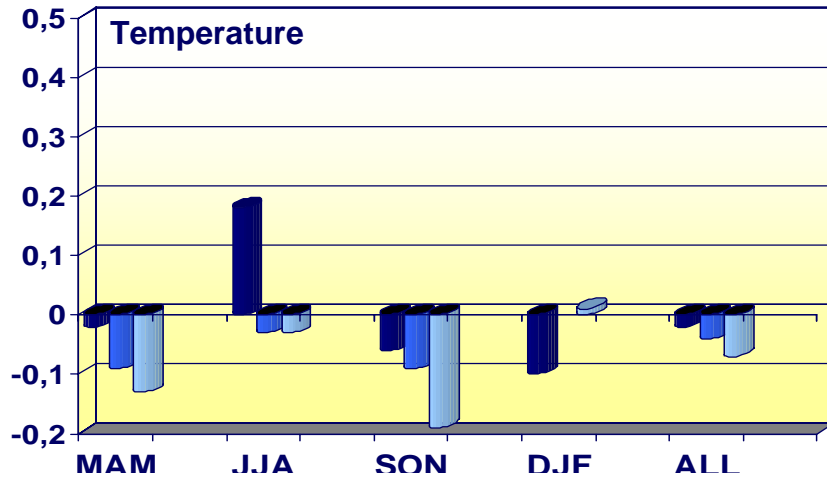
Persistence: conditions will be the same as observed in period prior to forecast

# Deterministic Skill: UK Gerrity Skill Score



**Blues: Persistence (P)**

**Greens: Most probable (M) quintile category**



■ Week 1   ■ Week 2   ■ Week 3&4

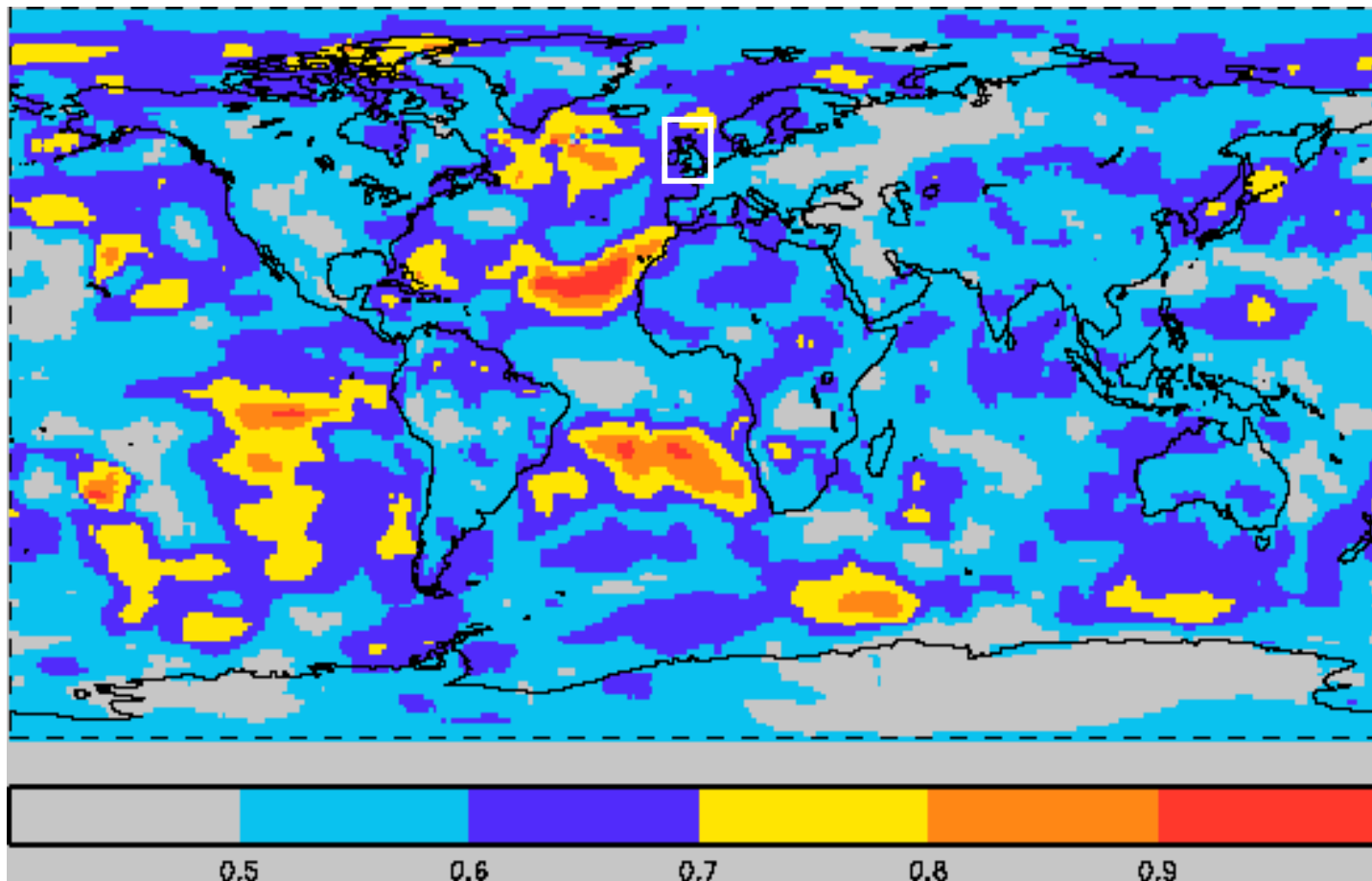
■ Week 1   ■ Week 2   ■ Week 3&4

- 115 forecast/ observation pairs of Temperature and Precipitation
- Verifying Observations:
  - ECMWF short range (12-36 hrs) forecasts over the period
- Global Forecasts:
  - Relative Operating Characteristics for quintile forecast
  - Reliability Diagram
  - Brier skill score decomposition

# ROC Map



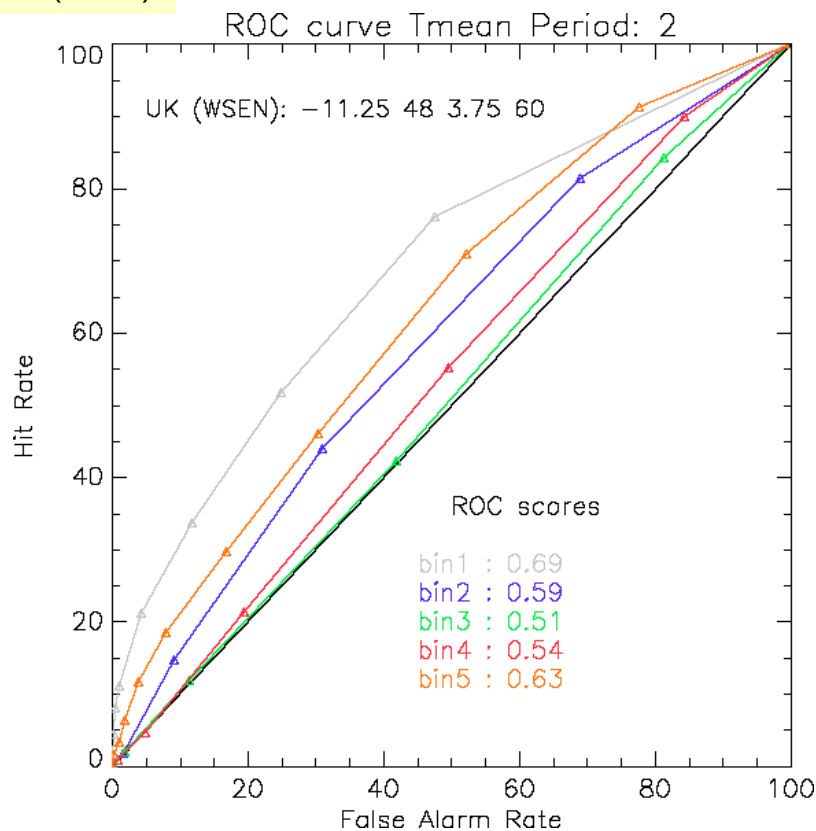
ROC Score for Temperature well below normal  
19 to 32 days ahead



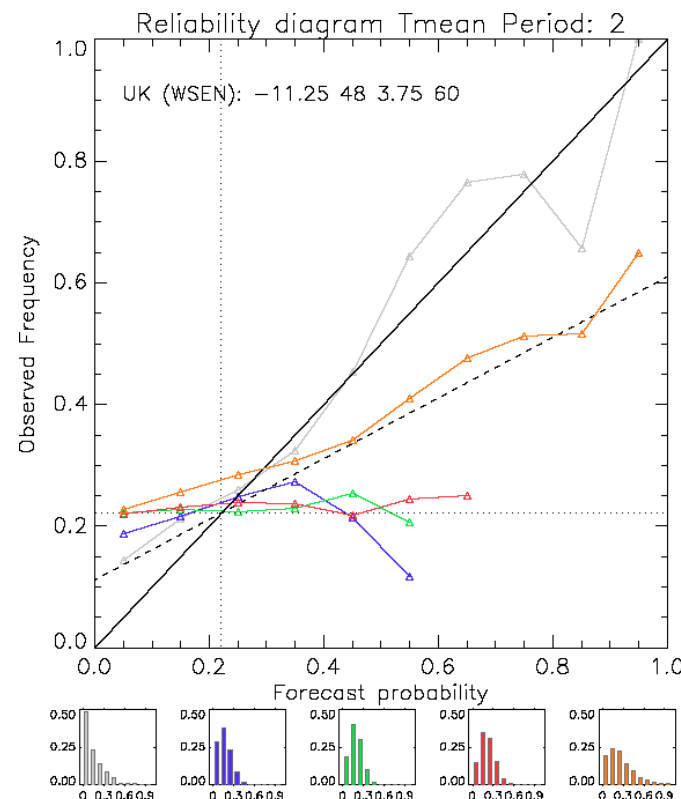
# Monthly Verification (UK): $T_{\text{mean}}$ ROC & reliability, all seasons, days 12-18



$POD = H / (H + M)$



$HR = H / (H + FA)$



Rel. frequency of use vs probability category (sharpness)

	Brier Score (skill)	Reliability	Resolution	Uncertainty
BIN1	+0.11 (+0.07)	+0.00 (+0.98)	+0.01 (+0.10)	+0.12
BIN2	+0.15 (-0.00)	+0.00 (+0.98)	+0.00 (+0.02)	+0.15
BIN3	+0.18 (-0.05)	+0.01 (+0.95)	+0.00 (+0.00)	+0.17
BIN4	+0.18 (-0.04)	+0.01 (+0.95)	+0.00 (+0.01)	+0.17
BIN5	+0.18 (-0.02)	+0.01 (+0.93)	+0.01 (+0.05)	+0.18

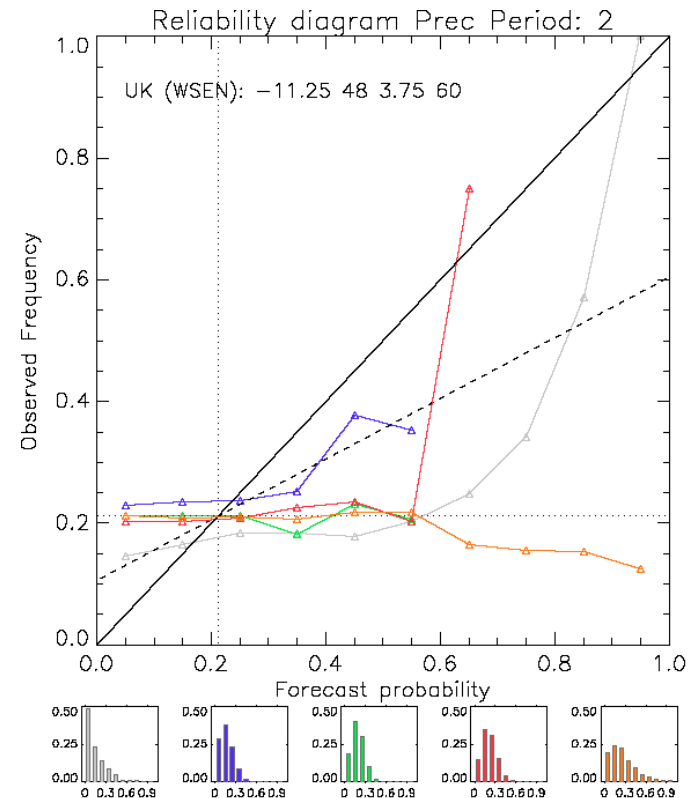
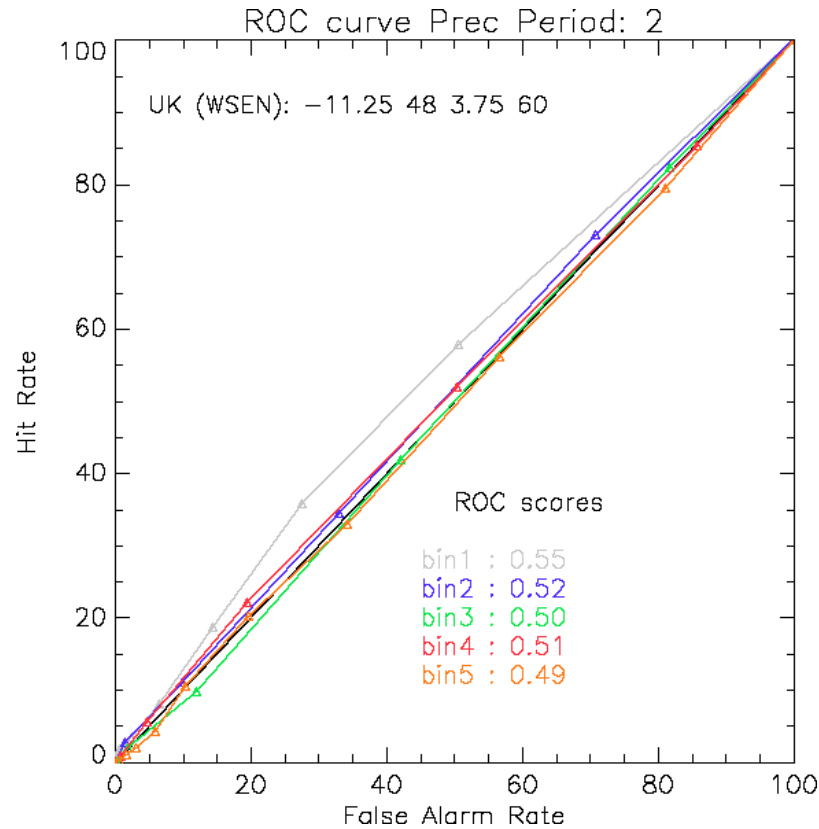
- Based on 115 operational forecasts (all seasons)
- Verification data = ECMWF  $T+12-36$
- outer Quintiles better than inner

# Monthly Verification (UK): Precip ROC & reliability, all seasons, days 12-18



$POD = H / (H + M)$

$HR = H / (H + FA)$



Rel. frequency of use vs probability category (sharpness)

	Brier Score (skill)	Reliability	Resolution	Uncertainty
BIN1	+0.14 (-0.11)	+0.01 (+0.88)	+0.00 (+0.01)	+0.12
BIN2	+0.19 (-0.06)	+0.01 (+0.93)	+0.00 (+0.00)	+0.18
BIN3	+0.18 (-0.06)	+0.01 (+0.94)	+0.00 (+0.00)	+0.17
BIN4	+0.17 (-0.06)	+0.01 (+0.94)	+0.00 (+0.00)	+0.16
BIN5	+0.20 (-0.23)	+0.04 (+0.77)	+0.00 (+0.00)	+0.17

$POFD = FA / (FA + CR)$

# Holiday planner for November 2005



## The Most likely Quintile category for Europe

Monthly Forecast Issued 10 November 2005

### Mean Temperature

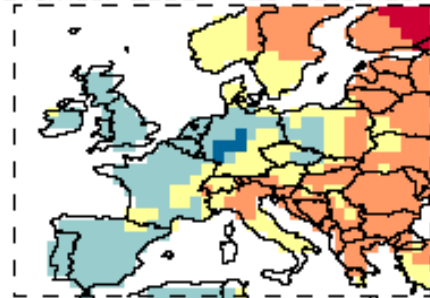
### Precipitation

### Wind

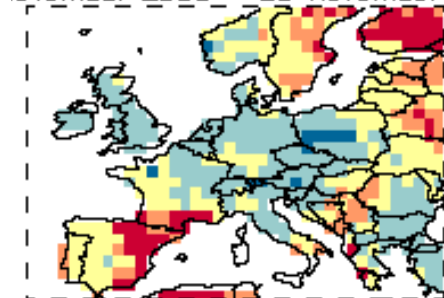
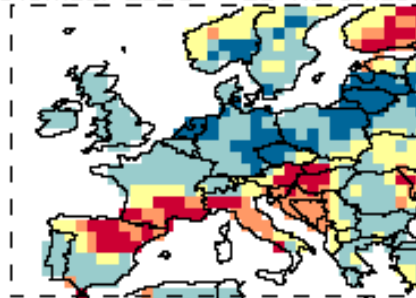
14 November 2005 – 20 November 2005

14 November 2005 – 20 November 2005

14 November 2005 – 20 November 2005



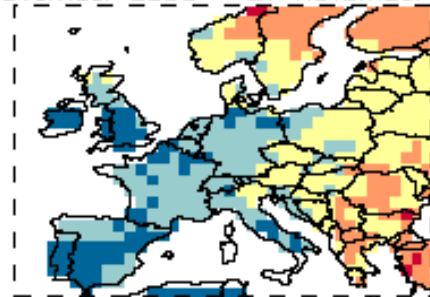
Wk 1



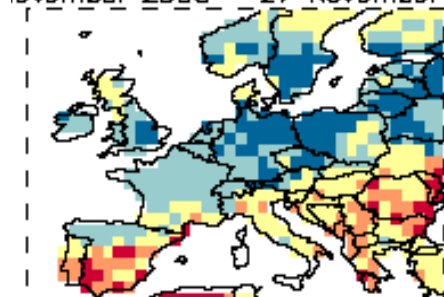
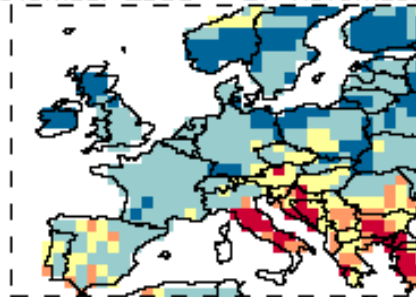
21 November 2005 – 27 November 2005

21 November 2005 – 27 November 2005

21 November 2005 – 27 November 2005



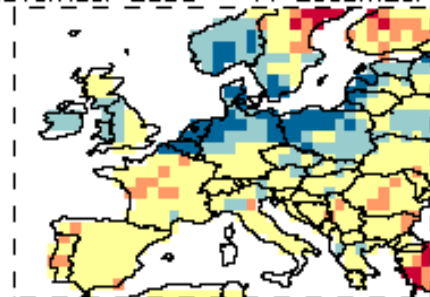
Wk 2



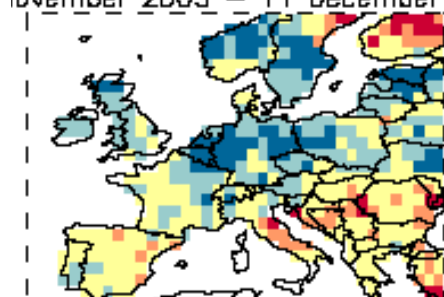
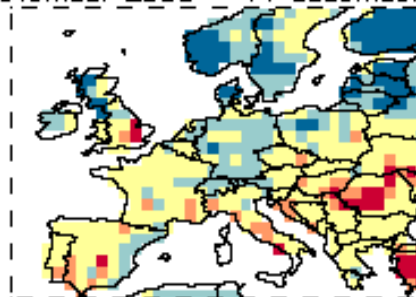
28 November 2005 – 11 December 2005

28 November 2005 – 11 December 2005

28 November 2005 – 11 December 2005



Wk 3&4





- port Standardised Verification system (SVS) to R, compare with other verification packages
  - More streamlined
  - More communication
  - More efficient
  
- Exploit daily data:
  - Environmental Stress index (Heat stress)
  - Monsoon onset
  - Period statistics, days above a threshold
  
- Description of the histogram/PDF in an analytical form, derived from Mean, Standard Deviation, Skewness and Kurtosis
  - More complete description of the PDF
  - Less data to carry around

# Conclusion



- ❑ The monthly forecasts model runs are produced at ECMWF, products are derived at the Met Office, operationally.
- ❑ Standardised Verification system (SVS) for Long-range Forecasts (LRF) is taking shape.
- ❑ Forecasts for day 19-32 are as useful as climatology.
- ❑ Predictions of Quintile 1 and 5 are more skilful than of Quintiles 2 to 4
- ❑ Europe is a difficult region to predict at long time range.
- ❑ The Monthly Outlook is a powerful tool to provide forecast guidance up to a month ahead in many areas.

# THANK YOU!



- Richard Graham
- Margaret Gordon
- Andrew Colman



We are one of the world's leading providers of environmental and weather-related services.

Our solutions and services meet the needs of many communities of interest...from the general public, government and schools, to civil aviation and almost every industry sector around the world.

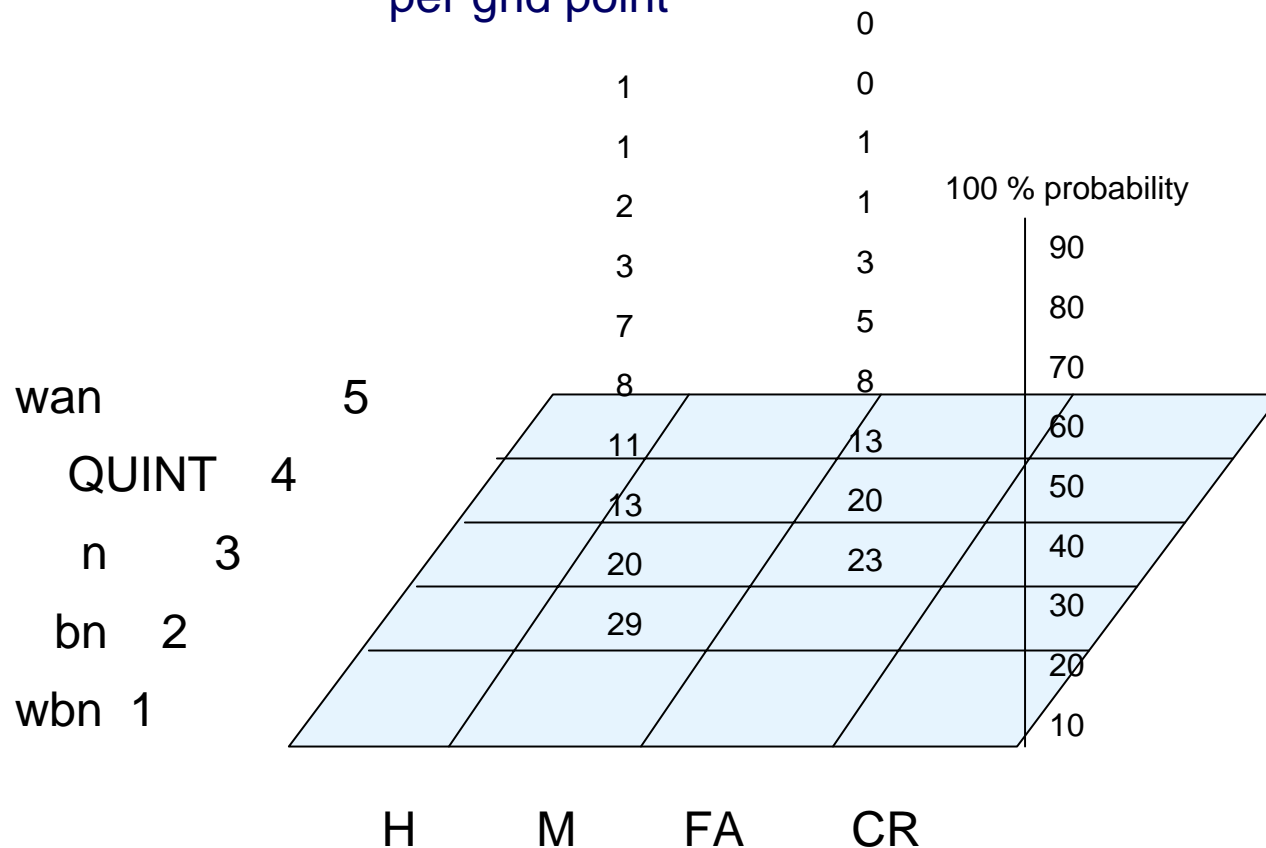


- [http://www.metoffice.gov.uk/research/seasonal/monthly\\_forecasts/headline.html](http://www.metoffice.gov.uk/research/seasonal/monthly_forecasts/headline.html)

# Grid point diagnostics

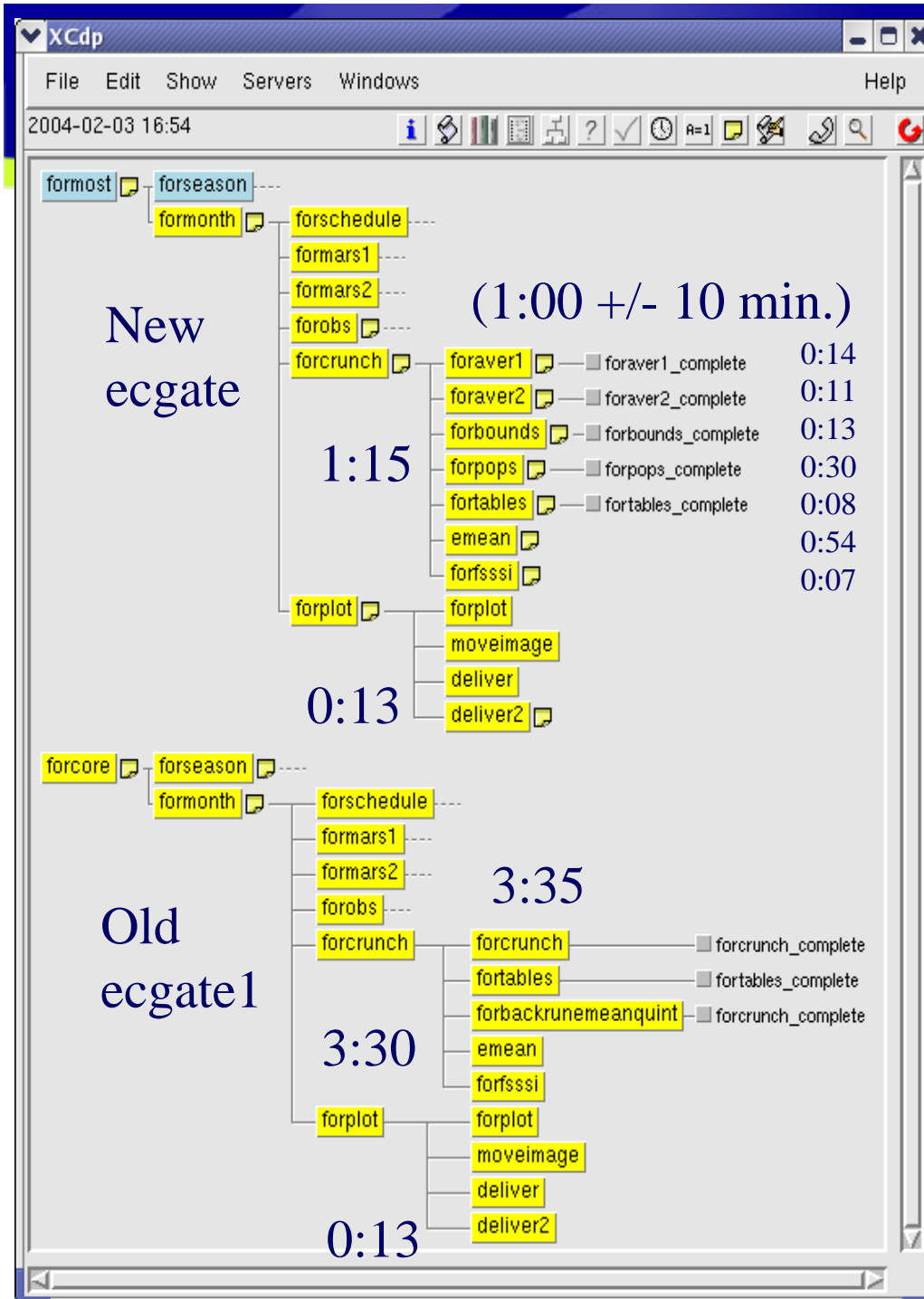


## Properties of a contingency table per grid point



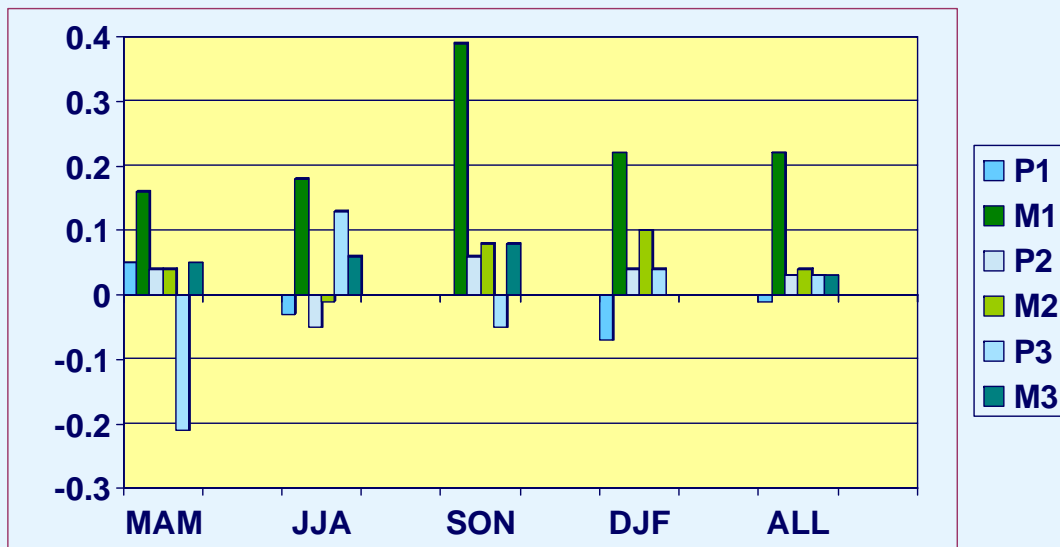
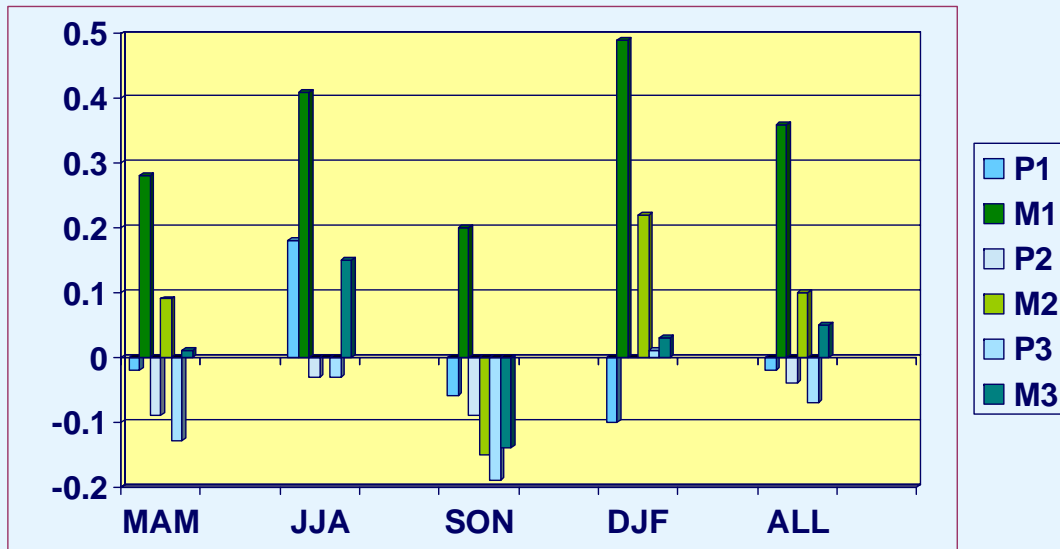
Stratify by magnitude of the probability at each grid point

- Hit :  $Q = Q_{obs} \ \& \ P(Q) \geq P_{thresh}$
  - Miss:  $Q = Q_{obs} \ \& \ P(Q) < P_{thresh}$
  - False Alarm:  $Q \neq Q_{obs} \ \& \ P(Q) \geq P_{thresh}$
  - Correct rejection:  $Q \neq Q_{obs} \ \& \ P(Q) < P_{thresh}$
- $POD = H / (H+M)$  conditioned on Observations
  - $POFD = FA / (FA+CR)$
  - Hit Rate =  $H / (H+FA)$  conditioned on Forecasts



Foraver 1 and 2 is followed by:  
 forbounds,  
 forpops and  
 fortables,  
 and emean is followed by:  
 forfsssi.  
 The 2 strands are run in parallel.

# Deterministic Skill



Gerrity Skill Score:

- Blues: Persistence (P)
- Greens: Most probable (M) Quintile category



# Most probable Category for September 2005

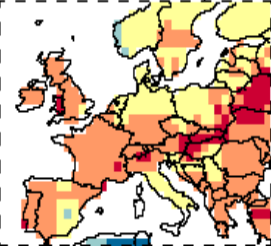


## The Most likely Quintile category for Europe

Monthly Forecast Issued 08 September 2005

### Mean Temperature

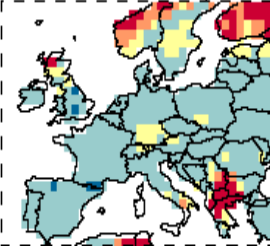
12 September 2005 – 18 September 2005



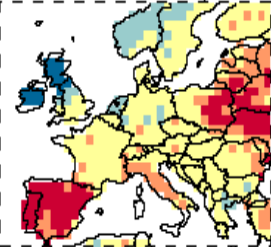
wk 1

### Precipitation

12 September 2005 – 18 September 2005

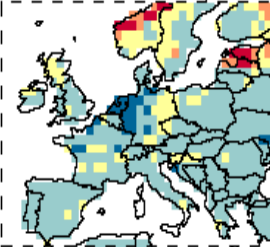


19 September 2005 – 25 September 2005

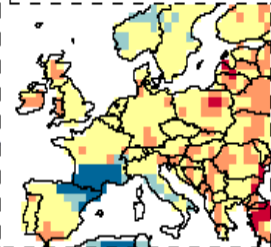


wk 2

19 September 2005 – 25 September 2005

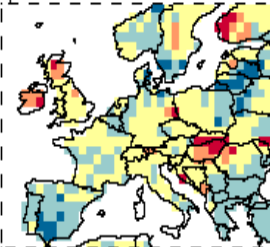


26 September 2005 – 09 October 2005



wk 3&4

26 September 2005 – 09 October 2005



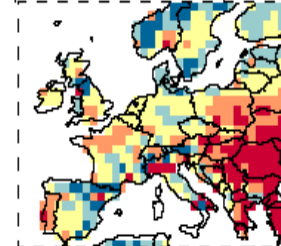
**Forecast**

## The Observed Quintile category for Europe

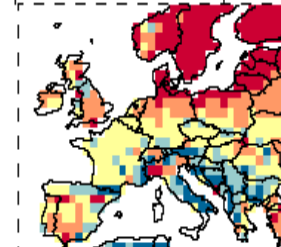
Monthly Forecast Issued 08 September 2005

### Mean Temperature

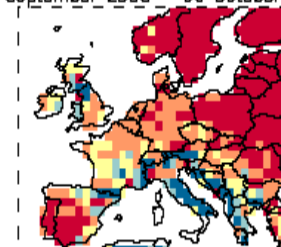
12 September 2005 – 18 September 2005



19 September 2005 – 25 September 2005

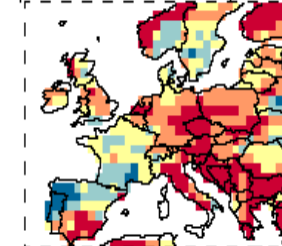


26 September 2005 – 09 October 2005

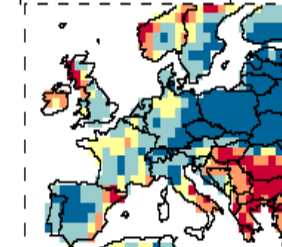


### Precipitation

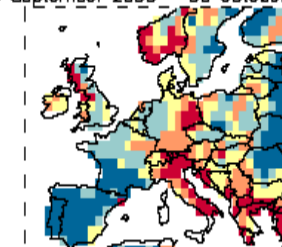
12 September 2005 – 18 September 2005



19 September 2005 – 25 September 2005



26 September 2005 – 09 October 2005

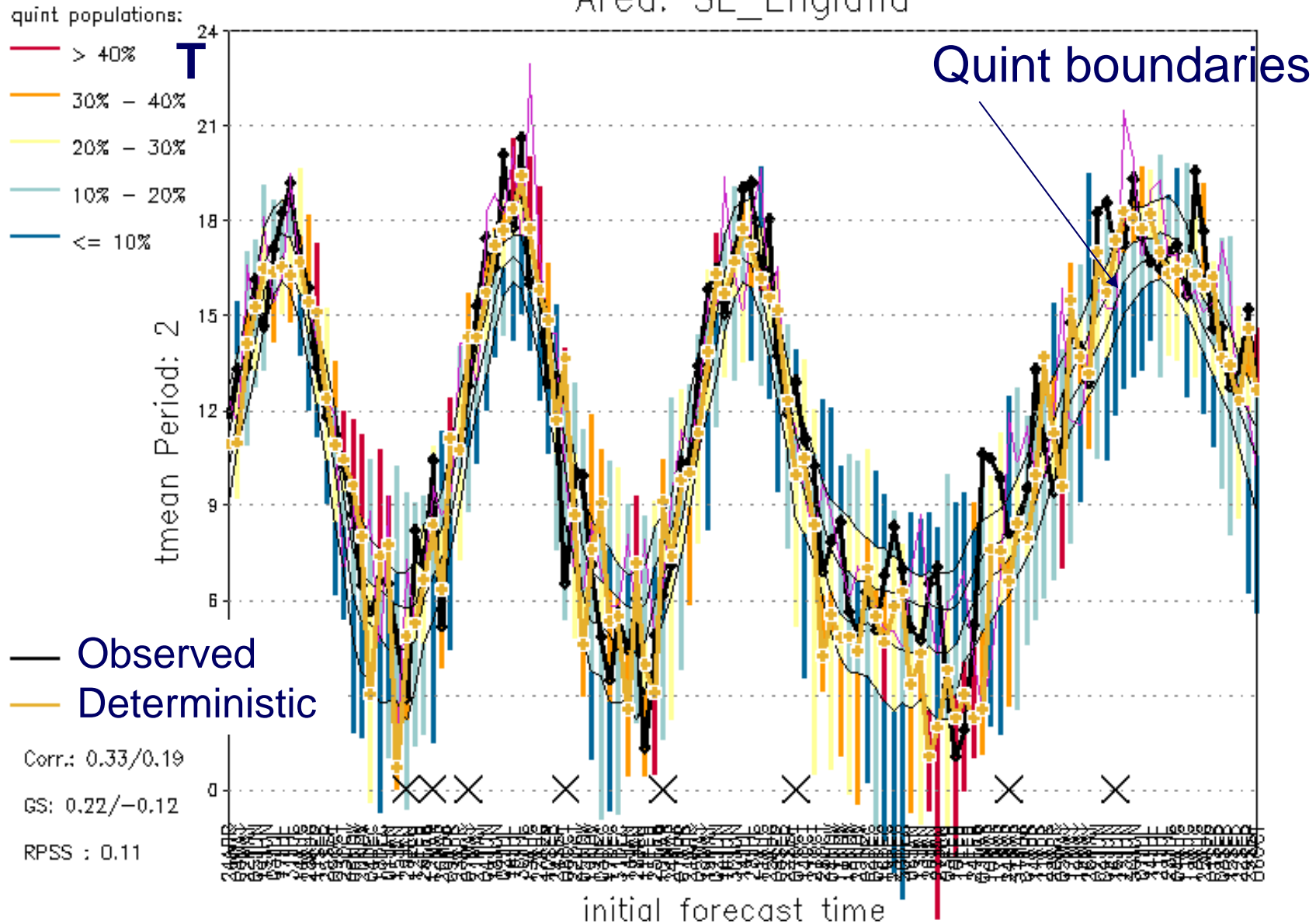


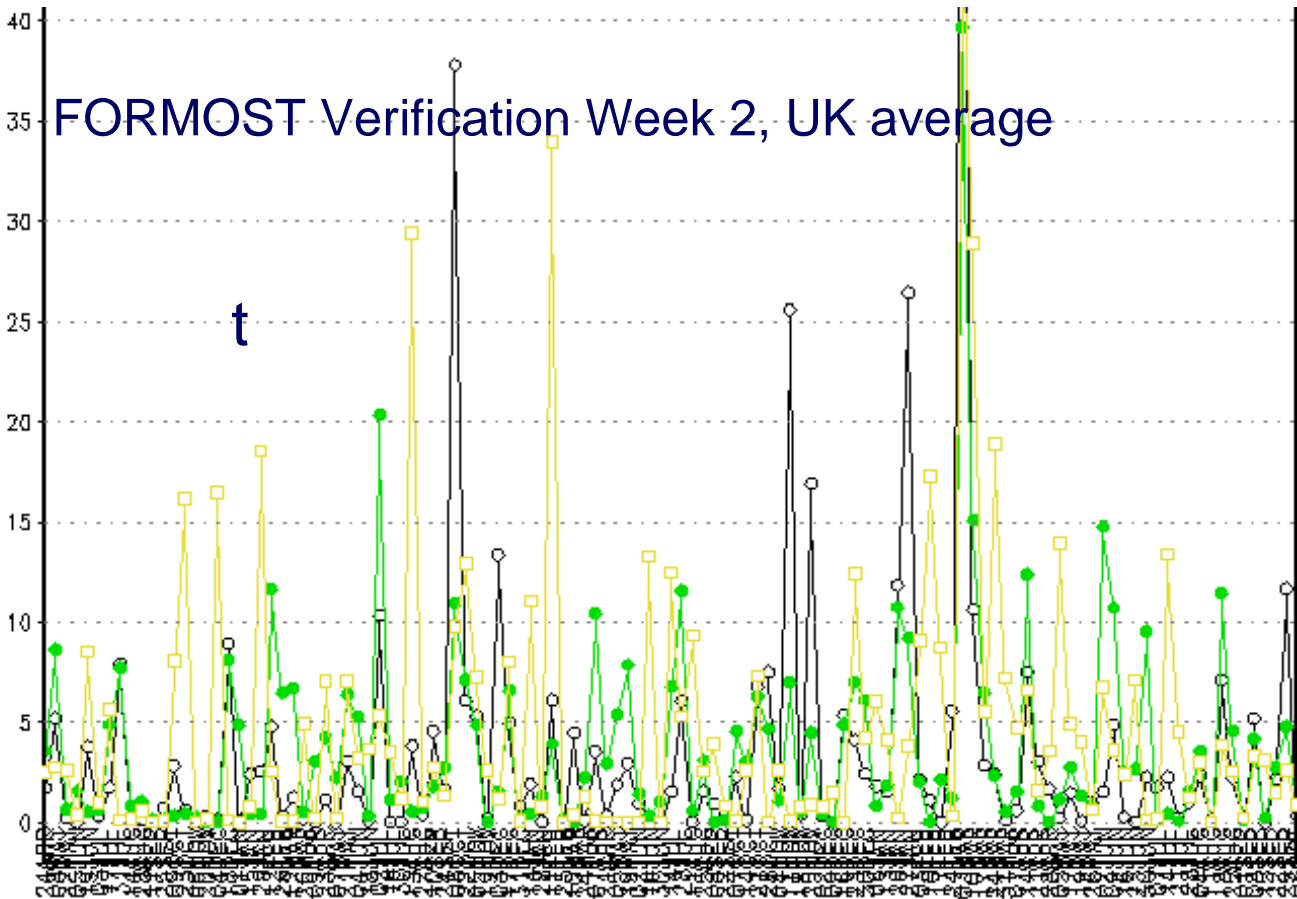
**Verification**

# FORMOST Verification Week 2

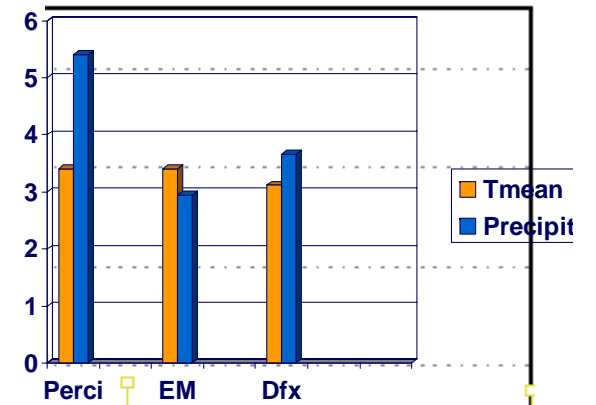


Area: SE\_England





Mean error



Green:  
Ensemble mean  
Yellow:  
Persistence  
Black: Forecast

