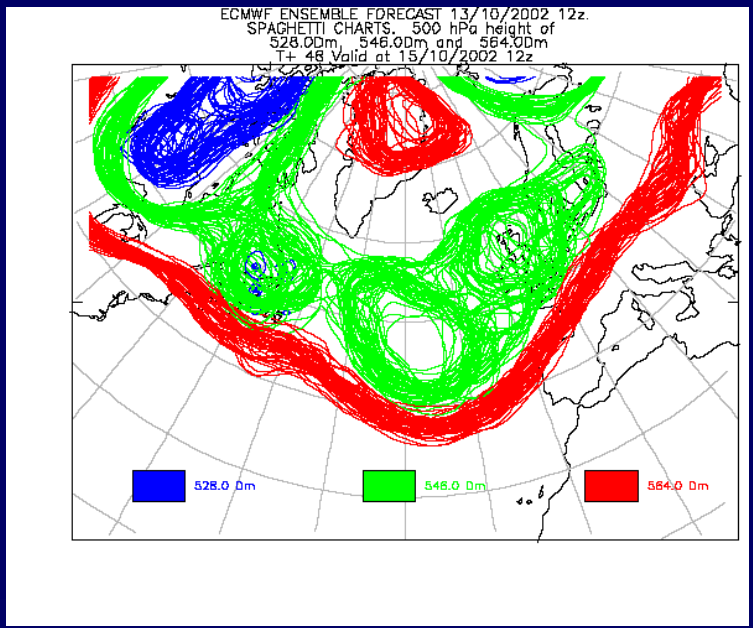
Probabilistic Early Warnings of Severe Weather based on the EPS

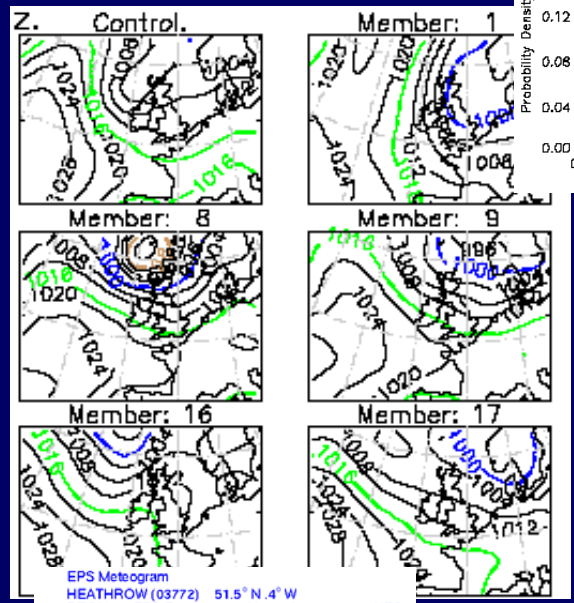
Ken Mylne and Tim Legg

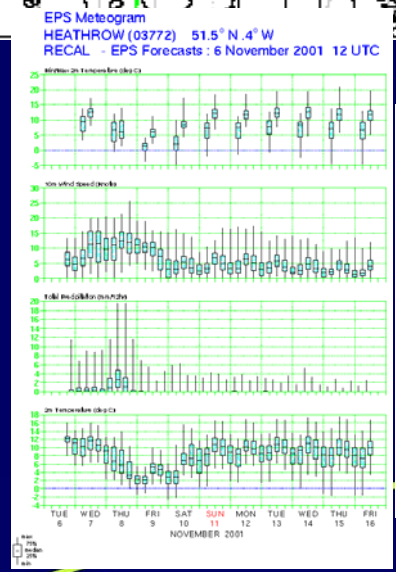
Met Office

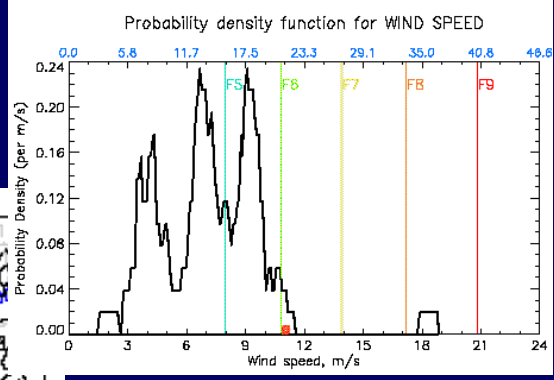
EPS Background

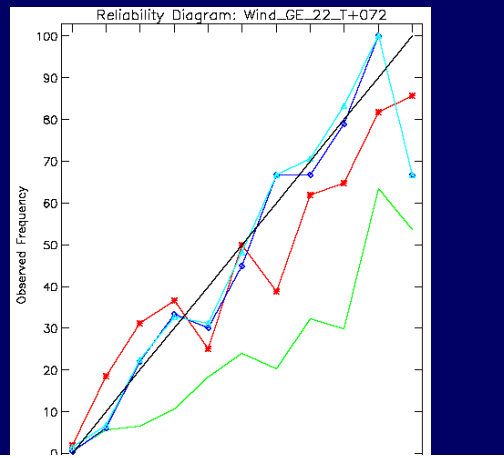
Met Office Previn system provides forecasters with many ensemble products.

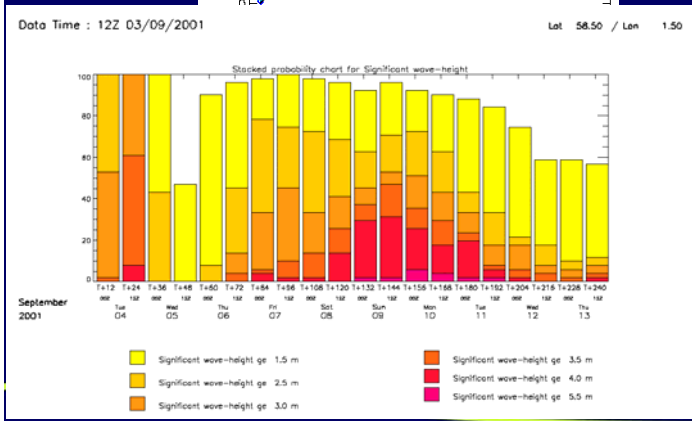












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And they do use them! Deputy Chief forecaster, NMC Exeter
Deputy
Chief Forecaster
Ensemble Charts

The Challenge of Predicting Hazardous Weather

Severe weather prediction difficult because:

- Model may not resolve severity of event
  - Limited model climatology
- Development often involves interaction of several elements
  - interactions are non-linear
  - elements are often small-scale (poorly resolved)
  - each element may be climatologically extreme - difficult
- Need to get all these right in combination
  - all sensitive to small errors so chance of deterministic success is low

Predictability of Extreme Events

- Hence “arbitrary changes to the trajectory of a system leading to an extreme event are likely to moderate (and not intensify) the extreme”
  Zhu and Toth (2001)

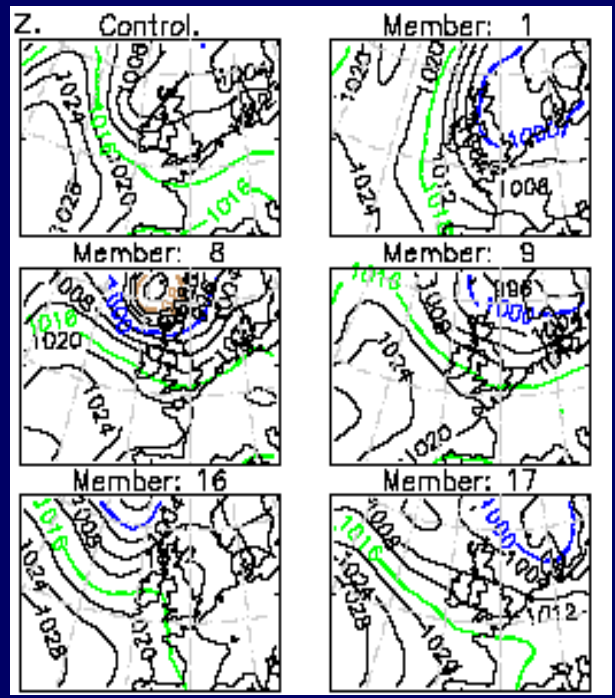
Ensembles for Severe Weather

Ensembles should be ideal for severe weather

- full account of non-linearity
- uncertainty in combination of small-scale processes

but

- model climatology may exclude extremes
- may require:
  - downscaling
  - calibration



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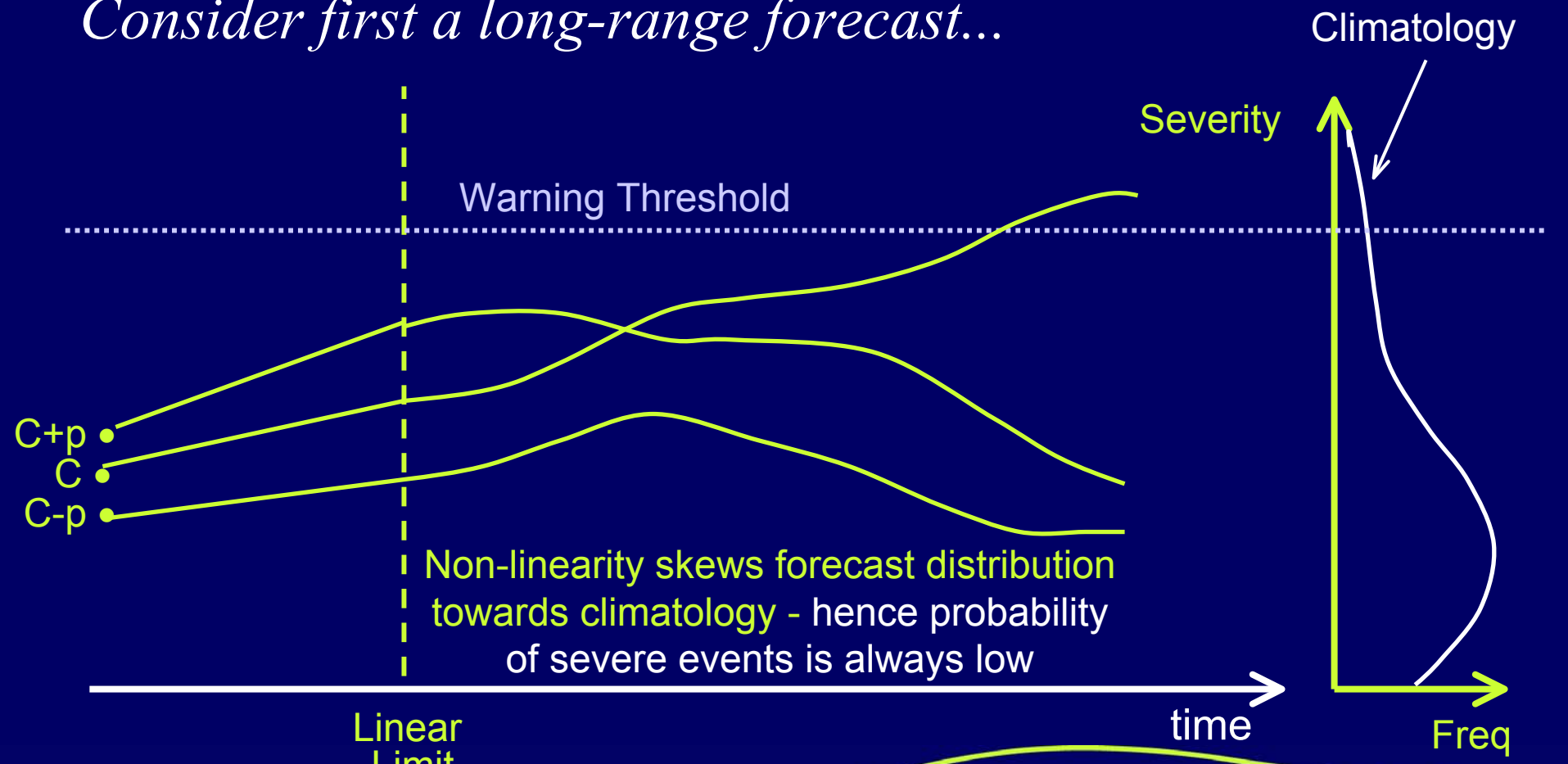
What can we expect of an ensemble in predicting severe weather? - *a thought experiment*

Ideally we would like high probabilities (e.g. >50%) - is this likely?

Consider first a long-range forecast...



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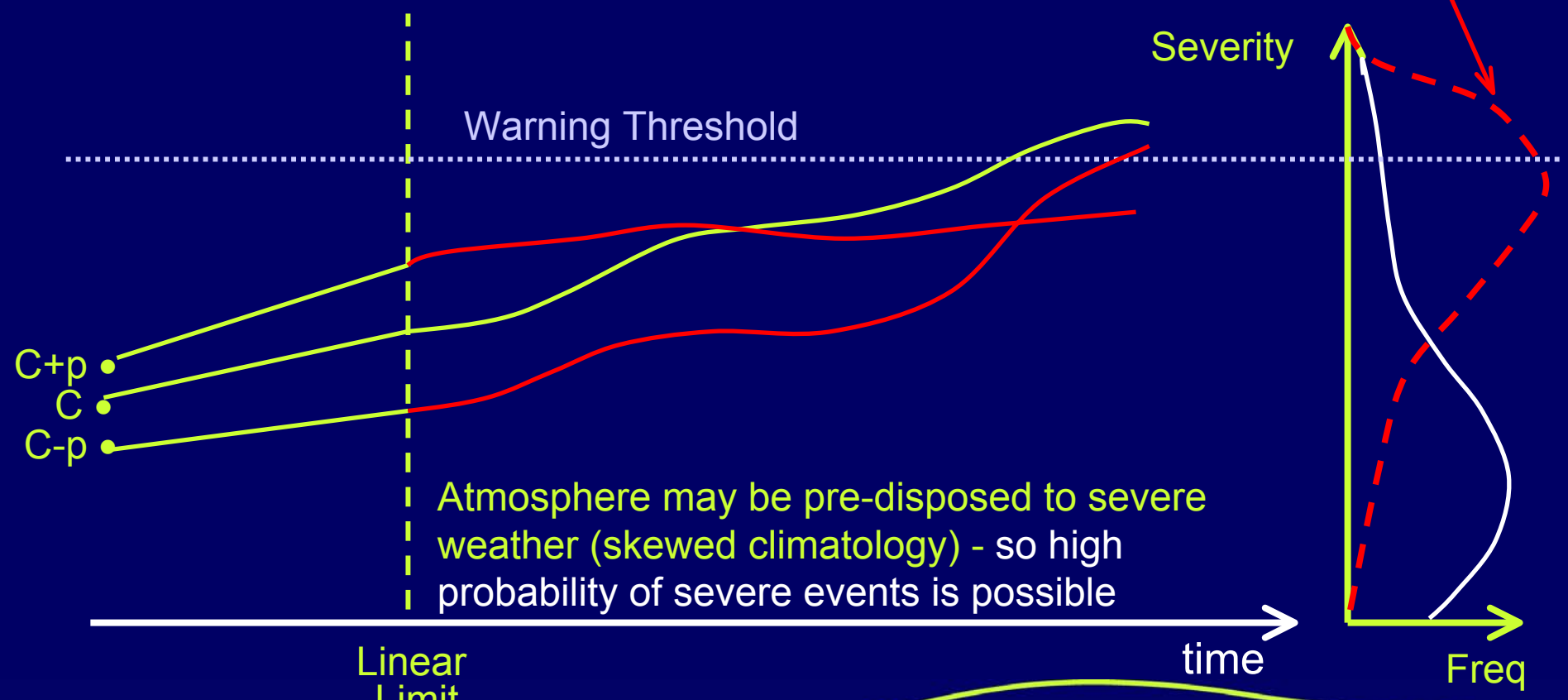
What can we expect of an ensemble in predicting severe weather? - *a thought experiment*

Ideally we would like high probabilities (e.g. >50%) - is this likely?

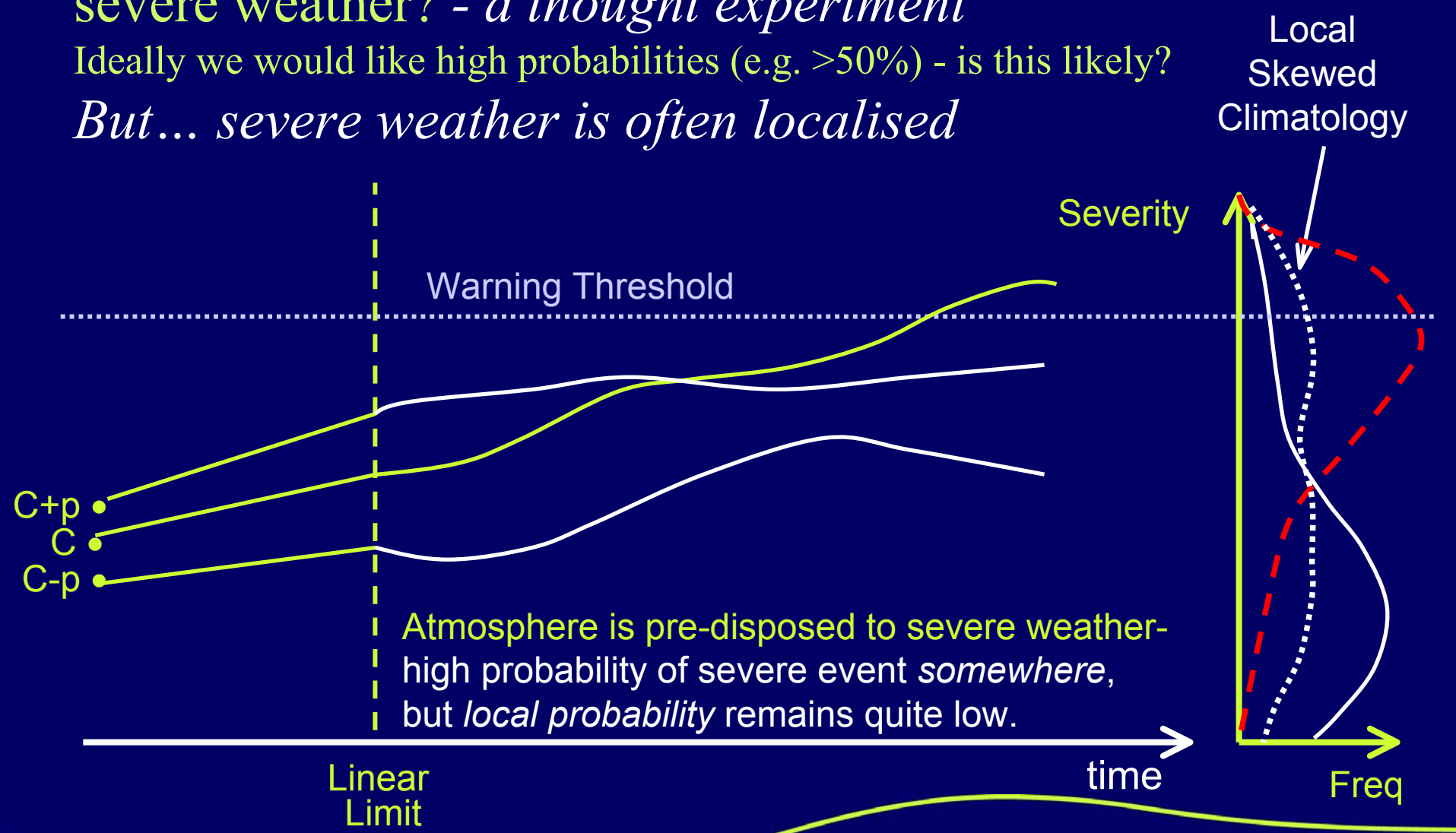
Now consider a short-range forecast...



What can we expect of an ensemble in predicting severe weather? - *a thought experiment*

Ideally we would like high probabilities (e.g. >50%) - is this likely?

But… severe weather is often localised



What can we expect of an ensemble in predicting severe weather? - *a thought experiment*

Ideally we would like high probabilities (e.g. >50%) - is this likely?

- When atmosphere is synoptically pre-disposed to severe weather (eg strong jet-stream or large CAPE) *high probability is possible* at short-range
  - possible to issue warnings of severe weather *somewhere*

But…

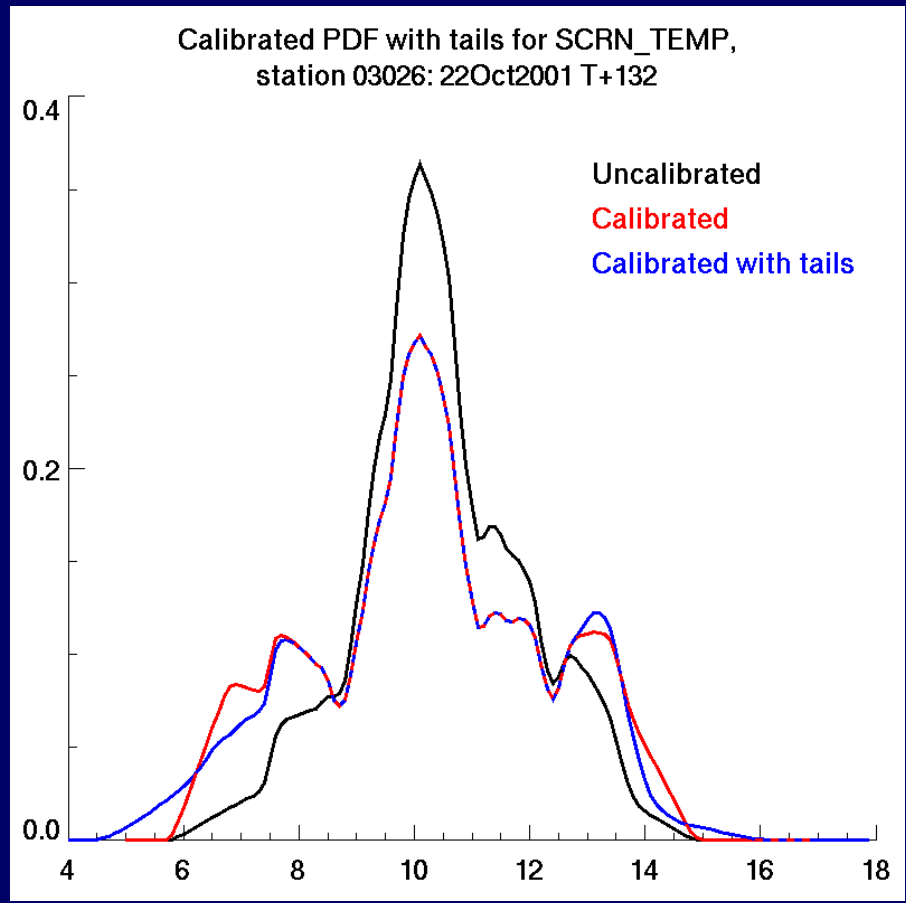
- How short is short-range?
  - Strong non-linearity in severe developments
- Most severe weather is relatively small-scale
  - local probabilities remain low

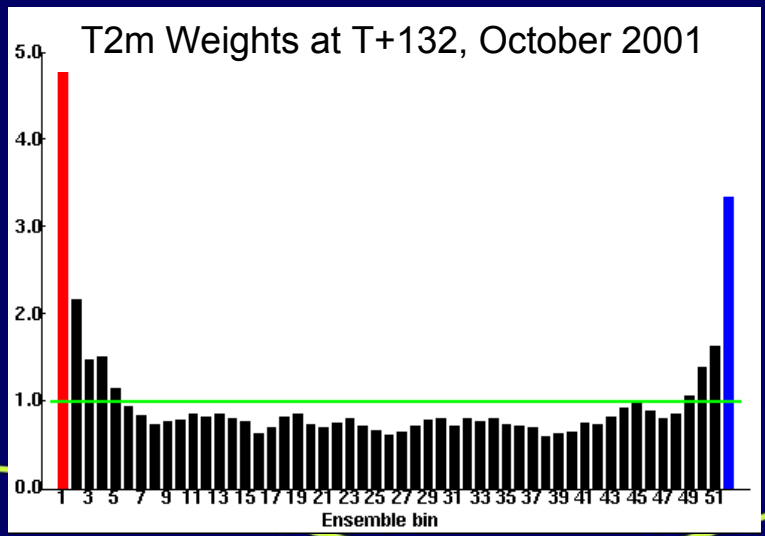
Site-specific probability forecasts

- The Met Office generates site-specific probability forecasts from the EPS (as described at 2001 Operations Workshop)
- How do these perform for severe weather events?

Calibrated probability distribution functions

- Ensemble members are re-weighted based on rank histogram verification
- Tails are added to increase overall spread





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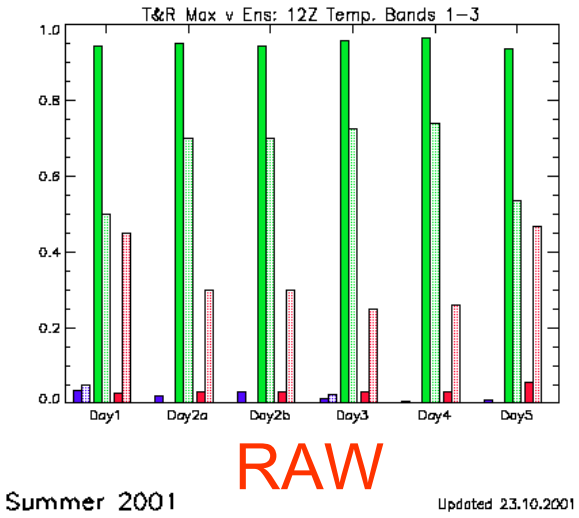
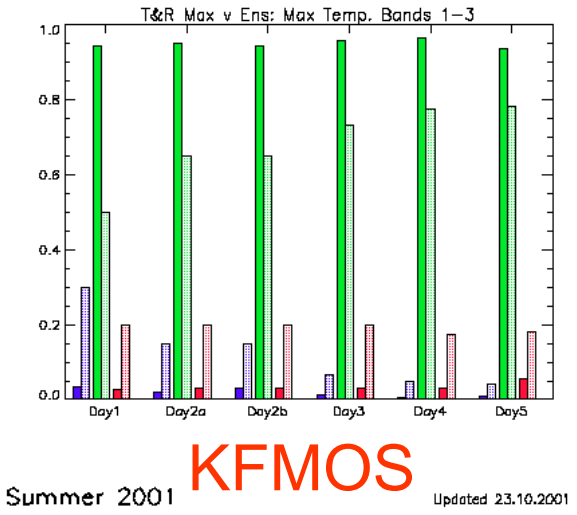
Outliers – 95% confidence Temp.

Dark colours forecasters

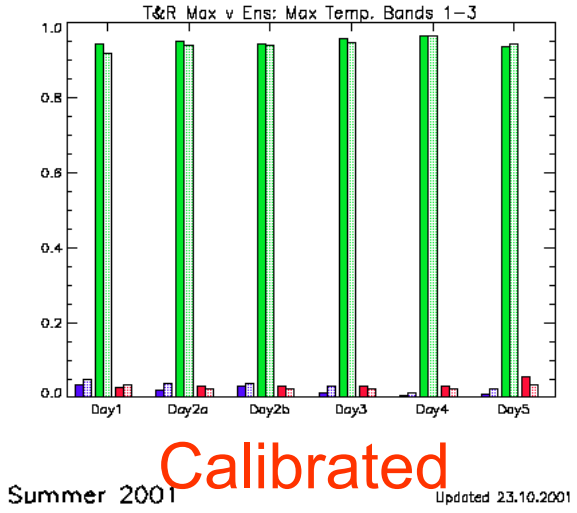
Pale colours EPS



RAW



KFMOS



Calibrated

Only after full calibration can EPS compete with forecasters.

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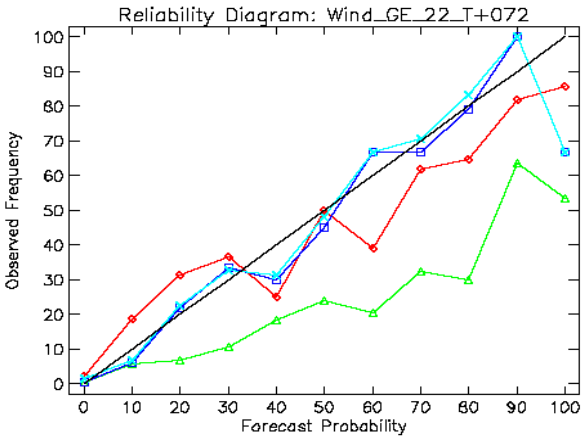
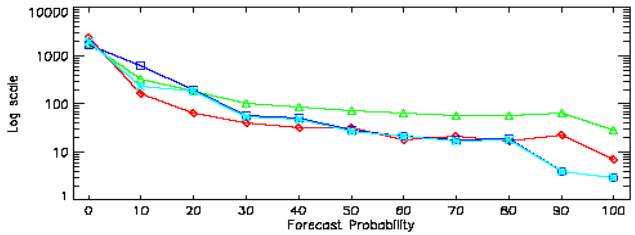
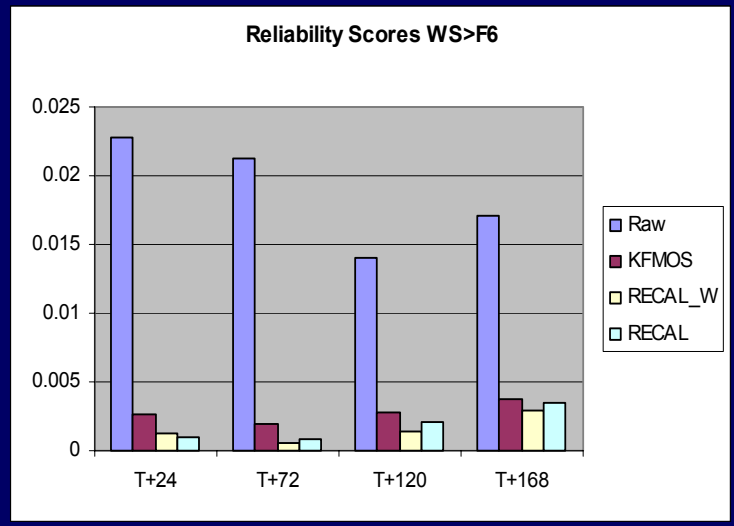
Verification -windspeeds at T+72

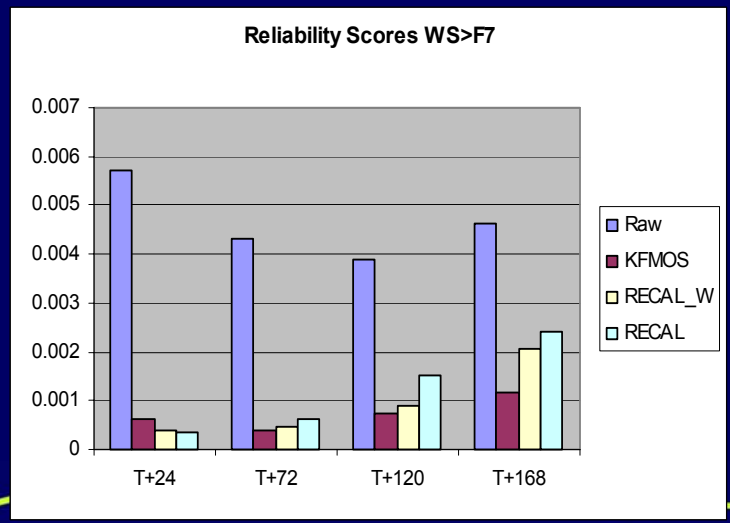


Reliability Score

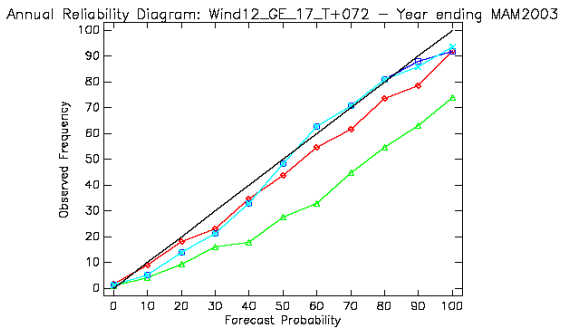
KFMOS	0.00201257
RAW	0.0213004
RECAL	0.000799934
RECAL_W	0.000624931



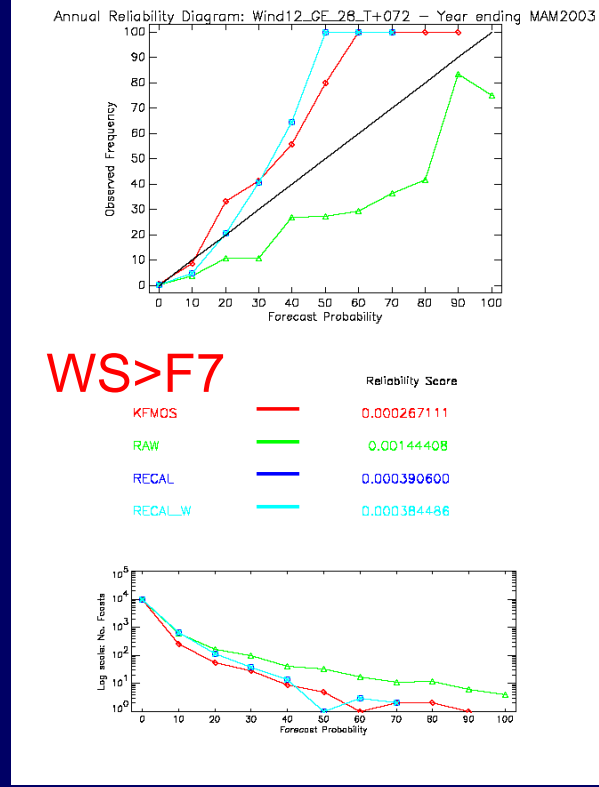




Reliabilty Diagrams for Calibrated windspeed forecasts



- Calibration of winds can improve forecasts at low thresholds but degrades at high thresholds



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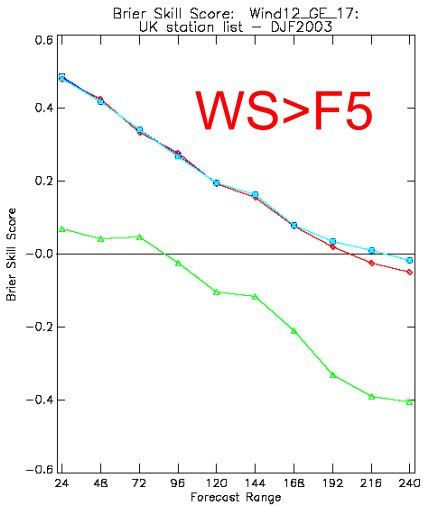
Brier Skill Scores for Calibrated windspeed forecasts



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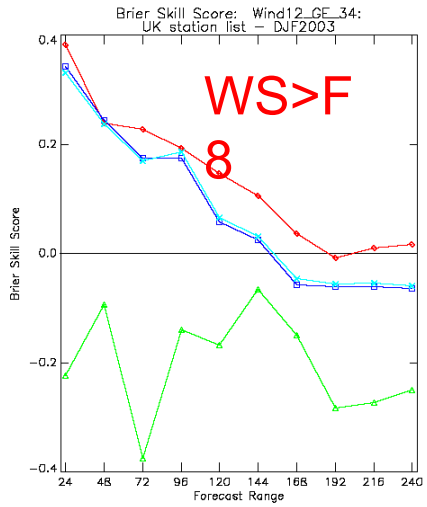

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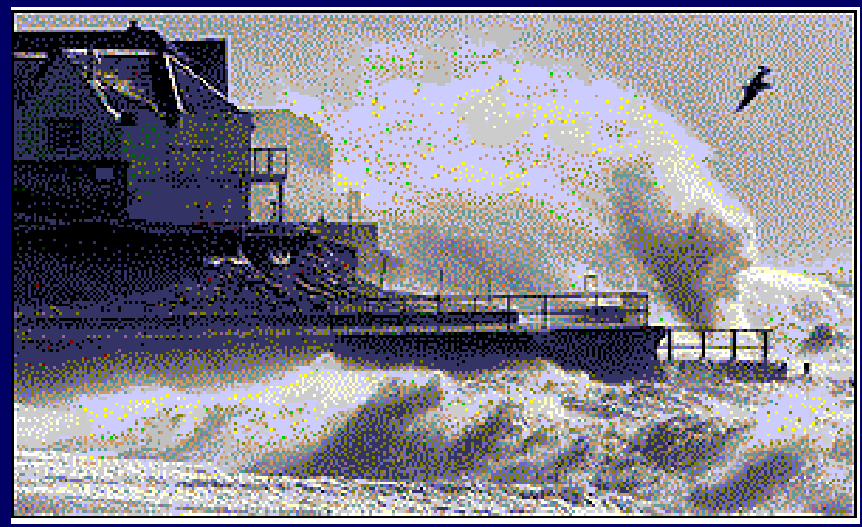
First Guess Early Warnings Project

Met Office issues Early Warnings up to 5 days in advance - when probability ≥60% of, eg:

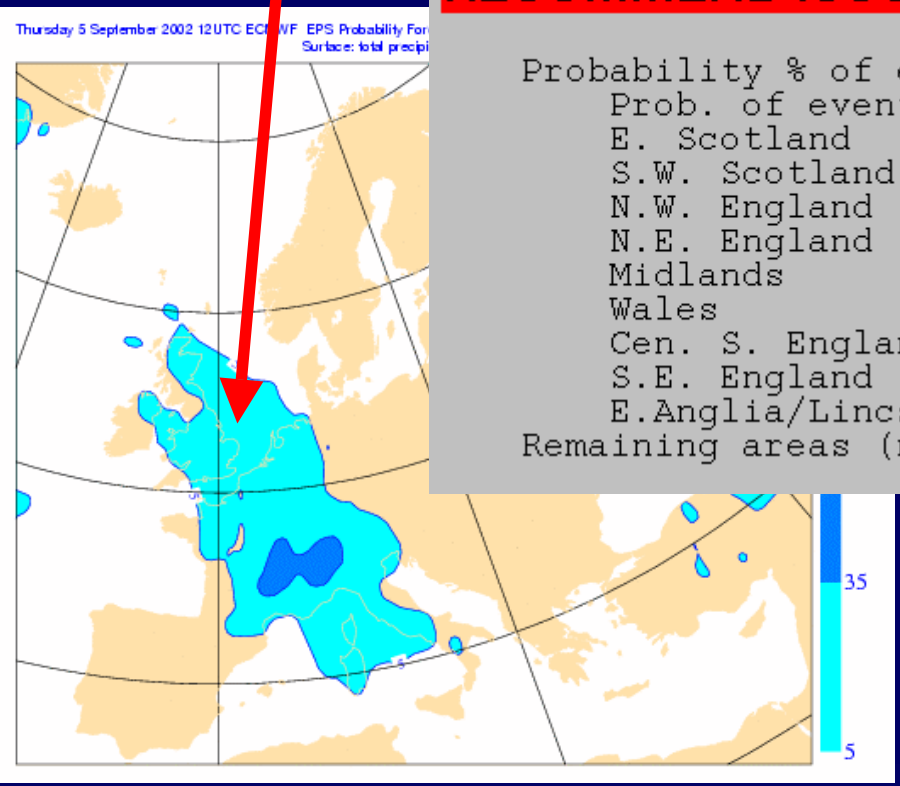
- **Severe Gales**
- **Heavy rain**
- **Heavy Snow**



- Developed a system to provide forecasters with alerts and guidance from the EPS
- Verified against short-period, high certainty warnings

Calculation of Relevant Probs

Grid-point probabilities are usually low



RECOMMEND ISSUE OF A WARNING:

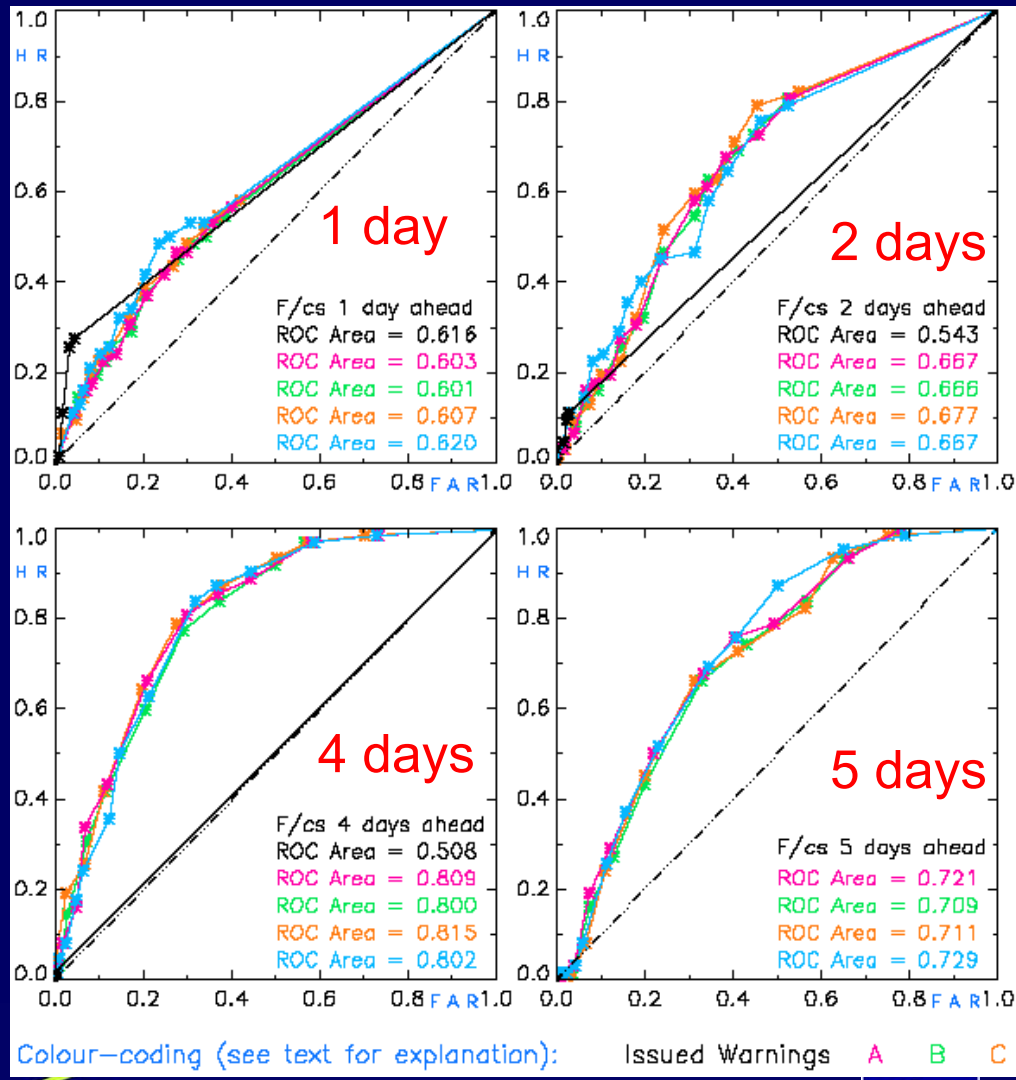
```
Probability % of event by region between 0000 09 SEP 2002 and 0
    Prob. of event occurring anywhere in the UK is  67%
    E. Scotland                35%
    S.W. Scotland              18%
    N.W. England               24%
    N.E. England               31%
    Midlands                   25%
    Wales                      20%
    Cen. S. England            25%
    S.E. England               37%
    E.Anglia/Lincs             39%
Remaining areas (not listed above) have probabilities below 10%
```

Prob in UK=67%

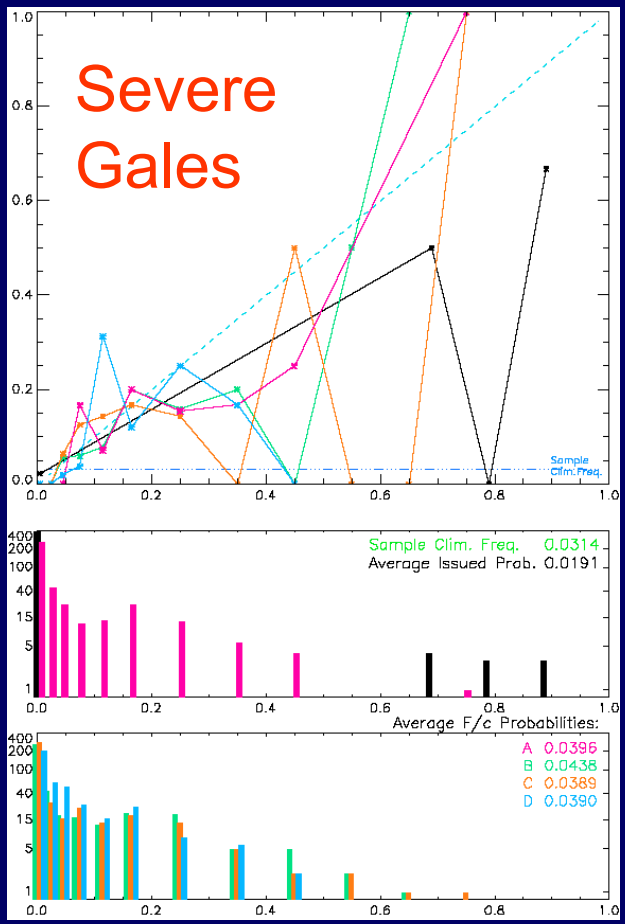
Relevant prob for warning is over all UK grid-points and longer period, so is much higher

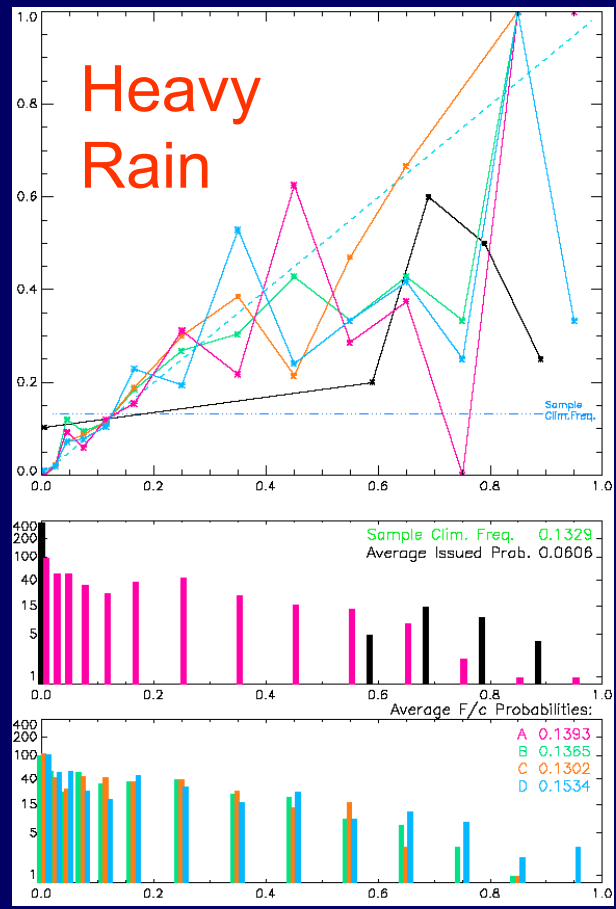
ROC - Heavy Rain

- Verification is difficult due to small samples, but...
  - Warnings *do* have skill in discriminating severe events
  - Skill is best at 4 days
  - Severe gales results similar



Reliability
4-day forecasts
Whole UK





Small samples make verification noisy, but

- There is clearly some probabilistic discrimination & skill
- Reliability is best at low probabilities - high probs are rare

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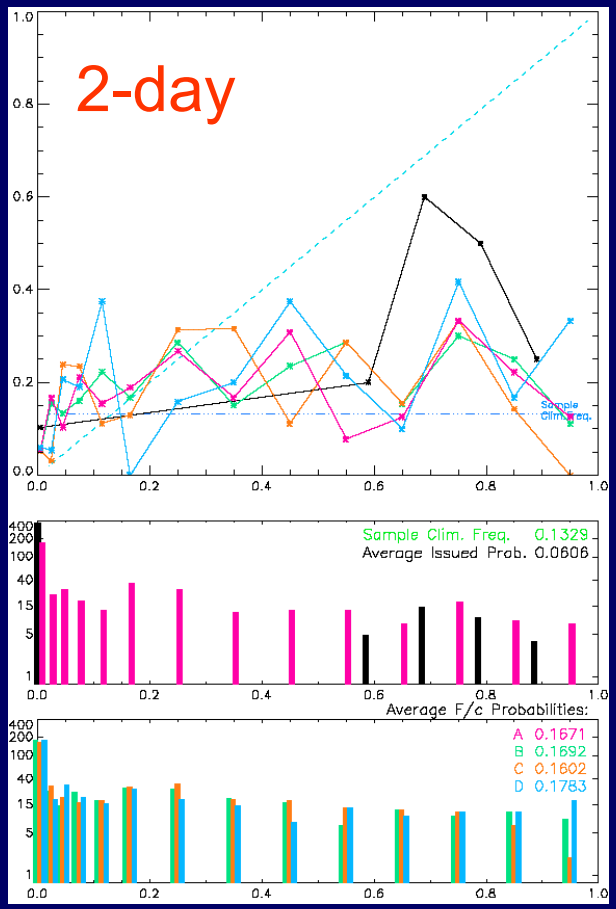
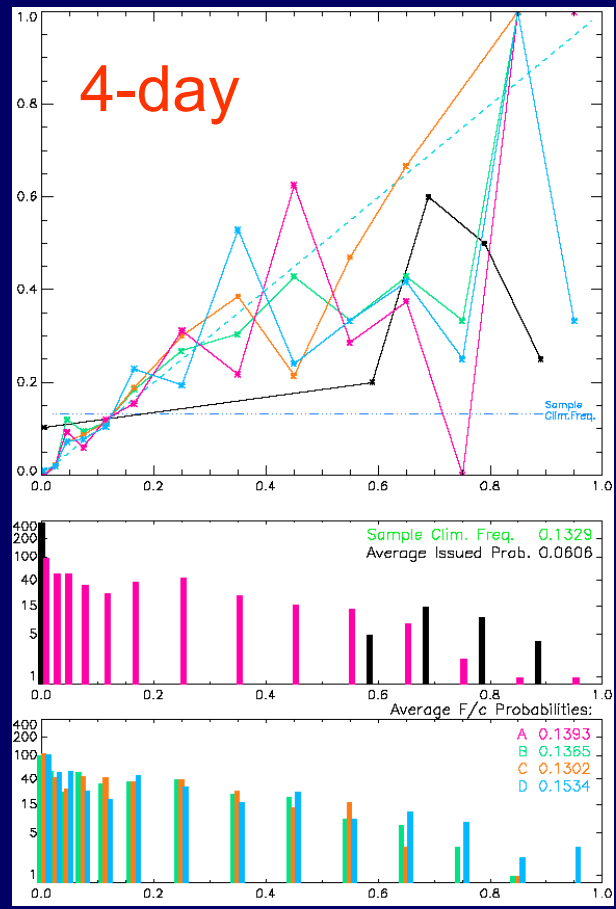
Reliability

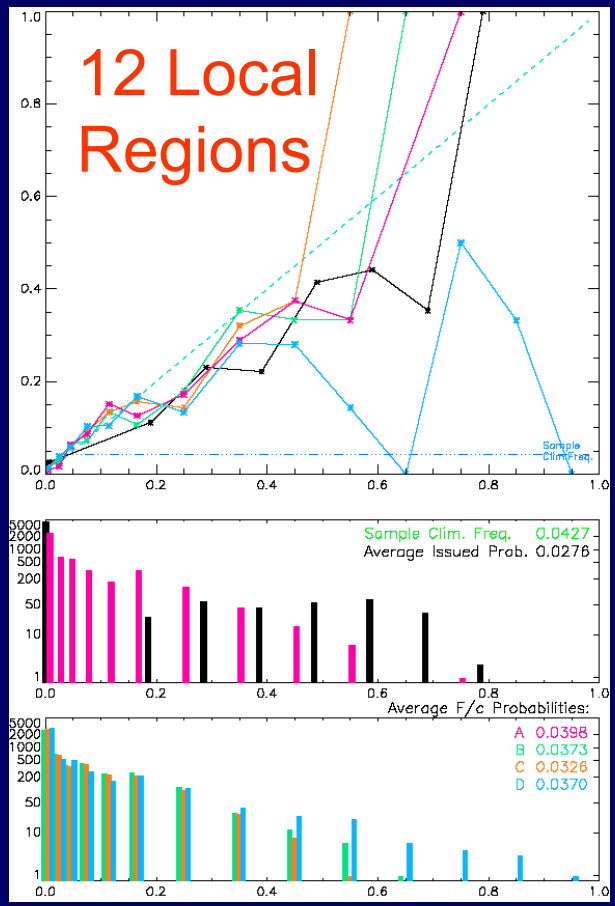
2 and 4-day heavy rain Whole UK

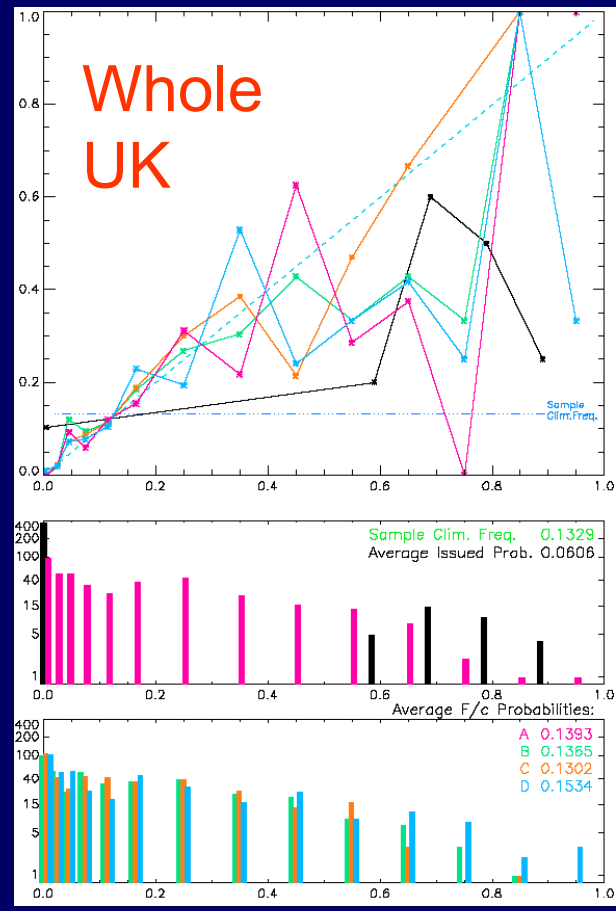




- 2-day forecasts clearly have no significant discrimination

Reliability
4-day forecasts
Heavy Rain





- Larger sample size for local regions reduces noise (but note sample is not independent)
- Otherwise performance is similar

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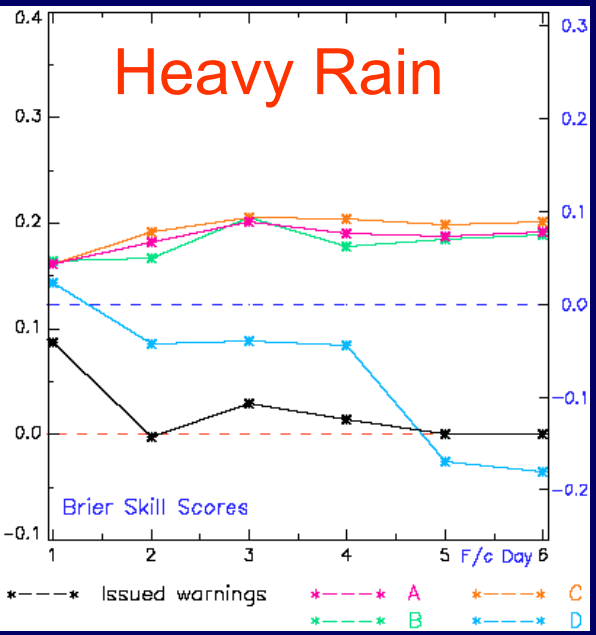
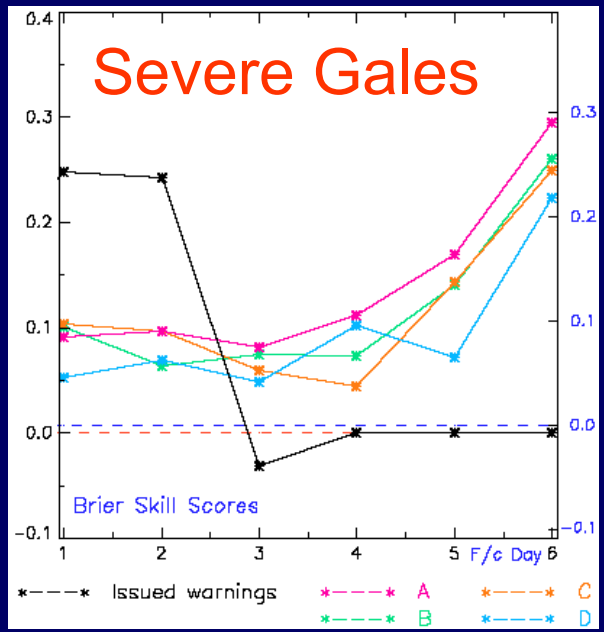
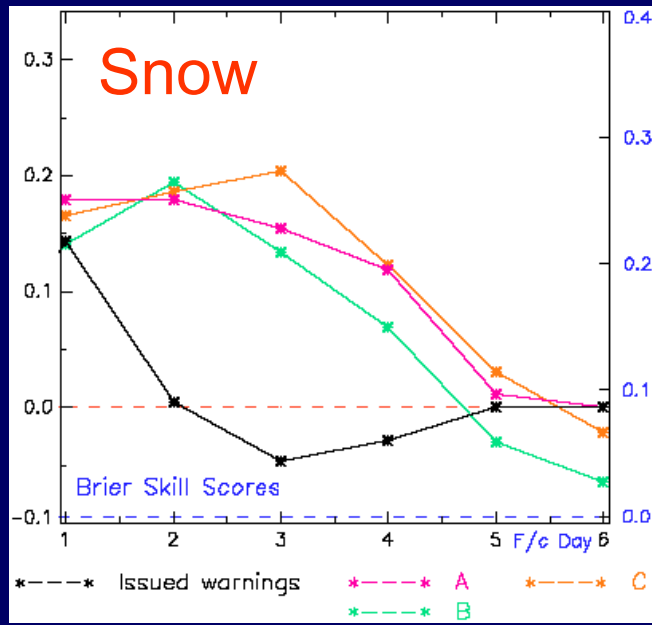
Brier Skill Scores

- Skill scores small but positive.







Left axis: skill relative to “null” forecasts

Right axis: skill relative to prior sample climatology (small sample)

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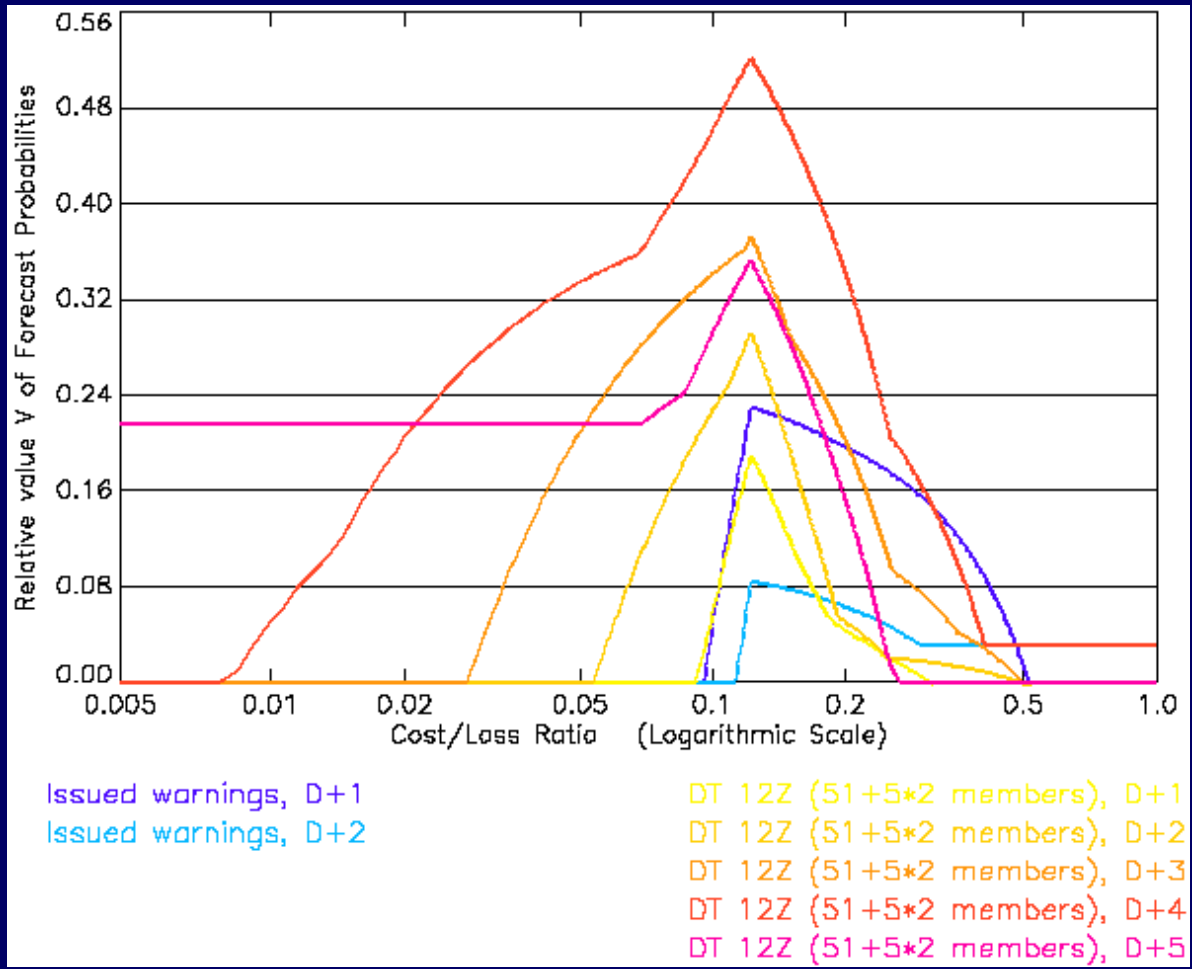
Verification - Relative Economic Value

- Estimates value of forecasts to users making decisions with different cost-loss ratios C/L
- Relative to value of perfect forecast
- Much value for users with small C/L
  - low probabilities



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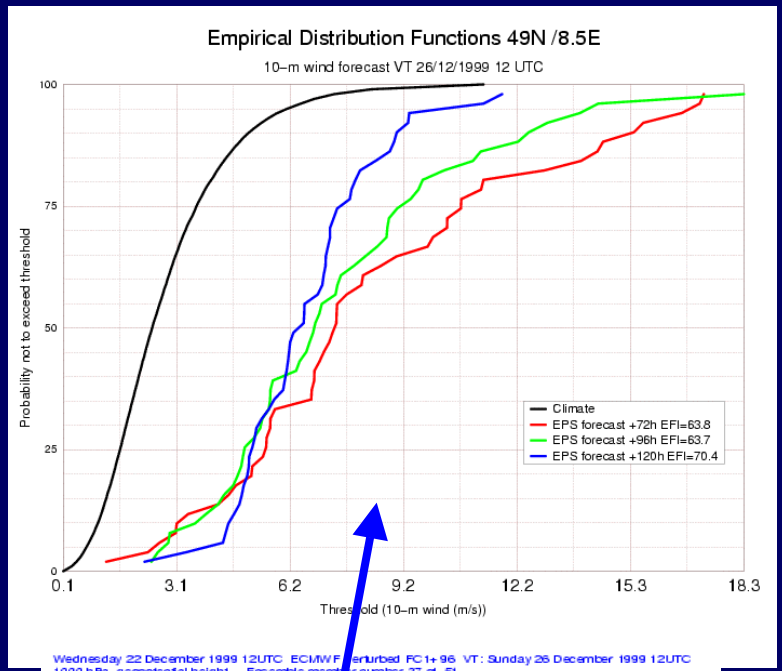
New ideas for Calibration



- Calibration of warnings is difficult due to small samples of past cases for tuning
- Model climatology of extremes may be very different from real atmosphere
  - ECMWF uses EFI to relate forecasts to model climatology
- EFI is useful as an alerting system but does not provide probabilities of severe weather
- Can we use EFI climatology to calibrate warning thresholds?

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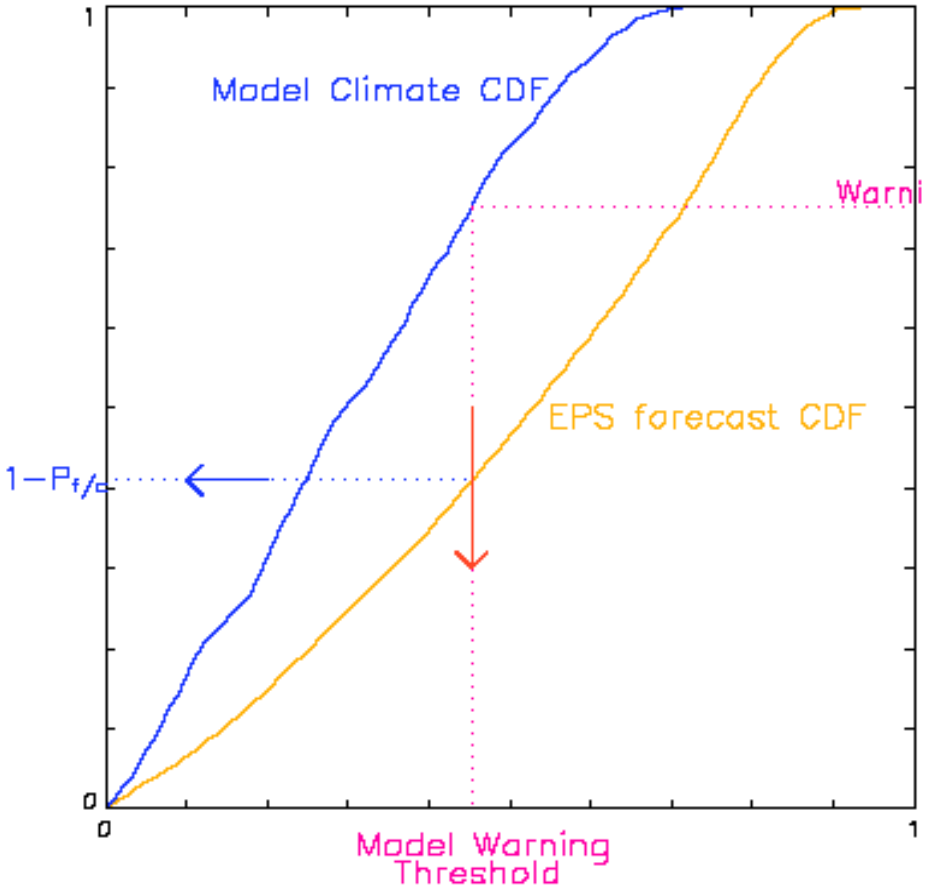
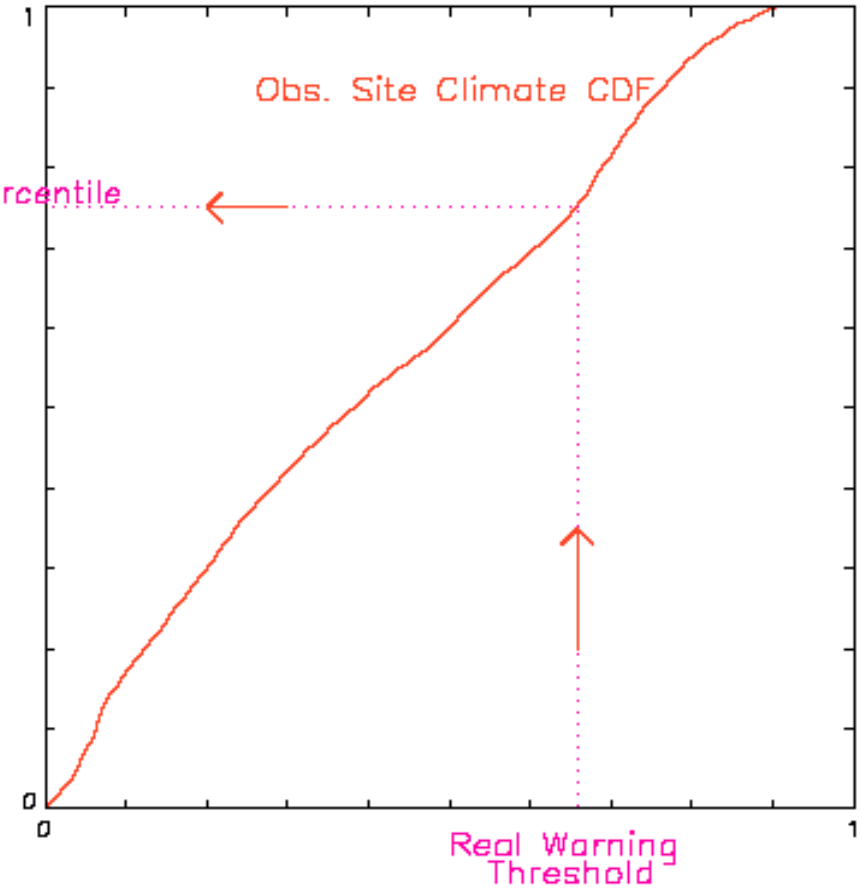
Calibration of Warnings using the EFI Climatology

Model Climate



Real Climate



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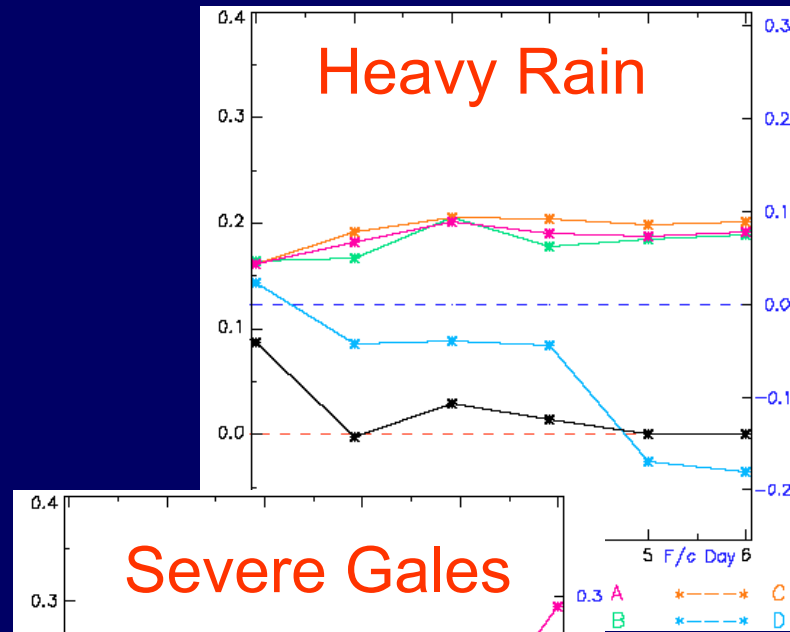
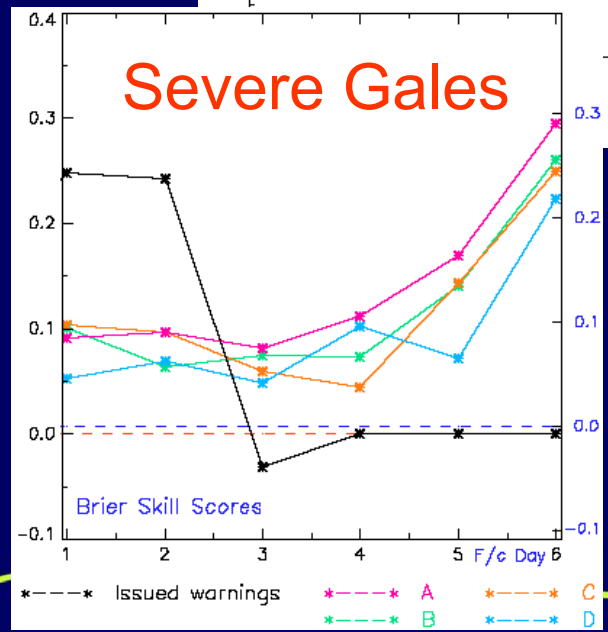
Calibration using site climatologies

- Alternative version of Early Warnings system calibrated by relating site climatologies to real site climatologies has been tested
- Results (pale blue on above verification results) are not quite as good as the fully tuned version, but provide a useful first estimate
- This will allow:
  - application to any site worldwide
  - application to any user's required warning thresholds





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Conclusions

- EPS-based warnings have some skill, but only around day 4
  - may be related to SV perturbation strategy at ECMWF
    - » lack of spread earlier in forecast?
    - » Requires non-linear evolution period?
- High probabilities are rare, as expected
- Forecasters now rely heavily on Ensemble forecasts

Questions?

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