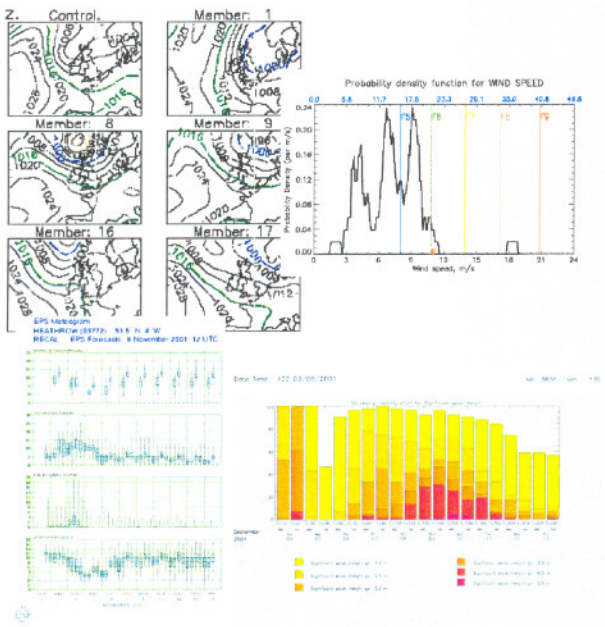
Probabilistic early warnings of severe weather based on the EPS

Ken Mylne and Tim Legg, Met Office

EPS background

Met Office Previn system provides forecasters with many ensemble products.



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

The challenge of predicting hazardous weather

Severe weather prediction is difficult because:

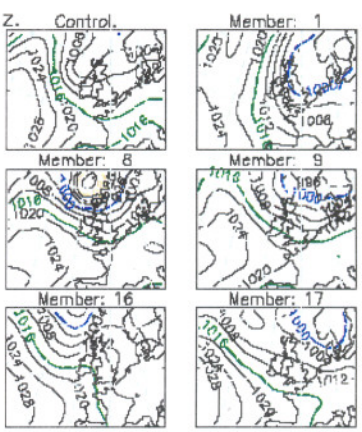
- Model may not resolve severity of event
  - Limited model climatology
- Development often involves interaction of several elements
  - interactions are non-linear
  - elements are often small-scale (poorly resolved)
  - each element may be climatologically extreme - difficult
- Need to get all these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

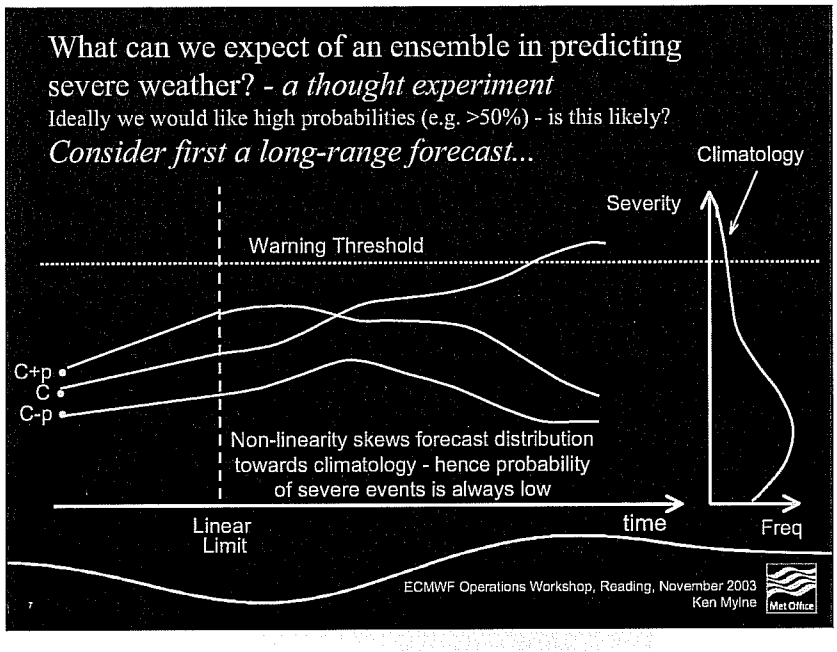
Predictability of extreme events

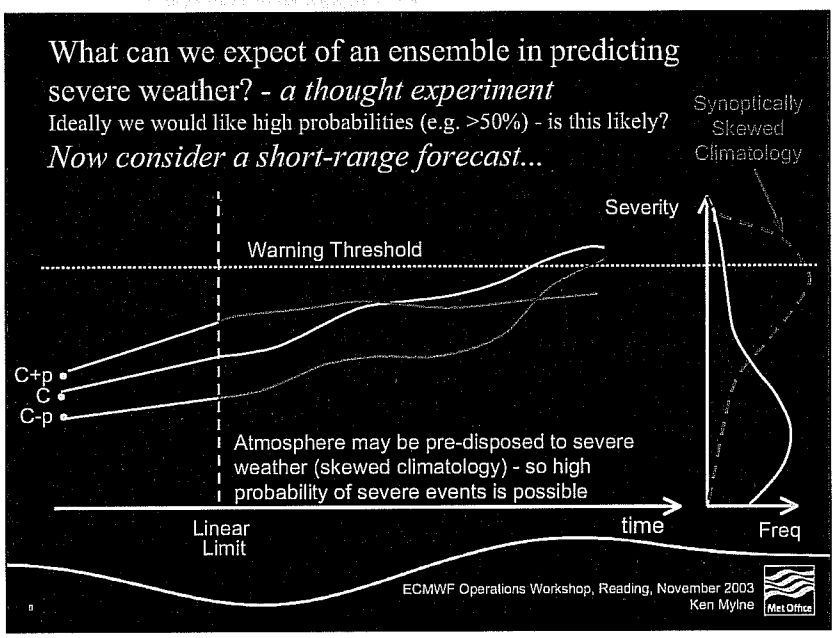
- Hence 'arbitrary changes to the trajectory of a system leading to an extreme event are likely to moderate (and not intensify) the extreme' *Zhu and Toth* (2001)

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 and calibration




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...
Climatology
Severity
Warning Threshold
C+p
C
C-p
Non-linearity skews forecast distribution towards climatology - hence probability of severe events is always low
Linear Limit
time
Freq
ECMWF Operations Workshop, Reading, November 2003
Ken Mylne
Met Office


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...
Synoptically Skewed Climatology
Severity
Warning Threshold
C+p
C
C-p
Atmosphere may be pre-disposed to severe weather (skewed climatology) - so high probability of severe events is possible
Linear Limit
time
Freq
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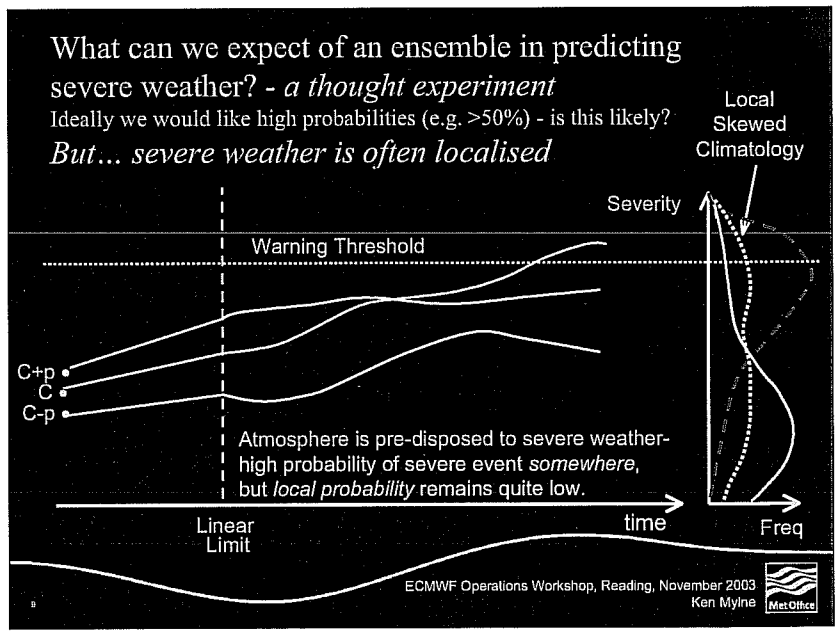
What can we expect of an ensemble in predicting severe weather? - a thought experiment
Ideally we would like high probabilities (e.g. >50%) - is this likely?
But... severe weather is often localised
Local Skewed Climatology
Severity
Warning Threshold
C+p
C
C-p
Atmosphere is pre-disposed to severe weather- high probability of severe event somewhere, but local probability remains quite low.
Linear Limit
time
Freq
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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?

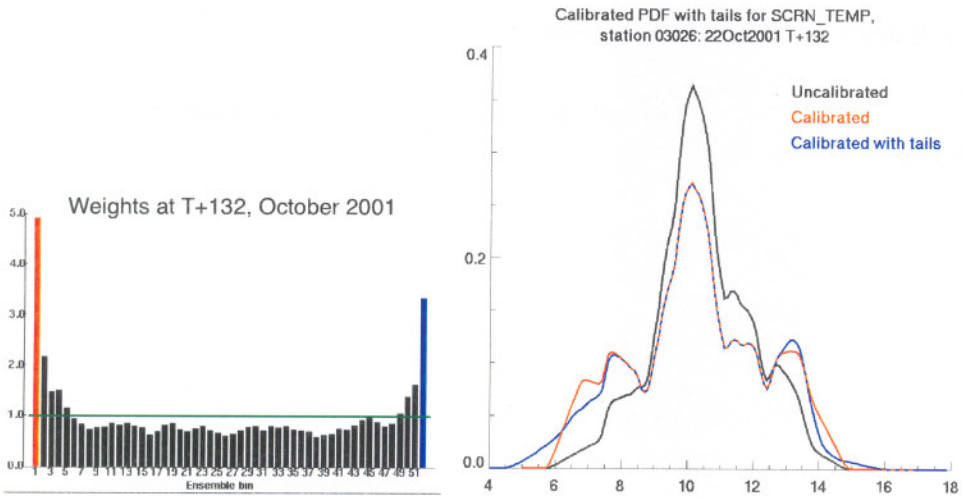
- When atmosphere is synoptically pre-disposed to severe weather (e.g. strong jet-stream or large CAPE) *high probability is possible* at short-range.
  - Possible to issue warnings of severe weather somewhere, but
- How short is short-range?
  - Strong non-linearity in severe developments.
- Most severe 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?

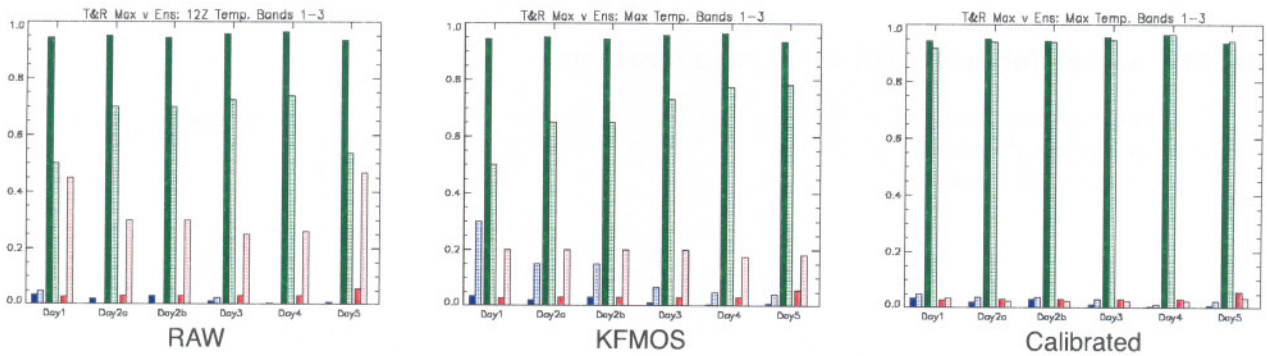
Calibrated probability distribution functions

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



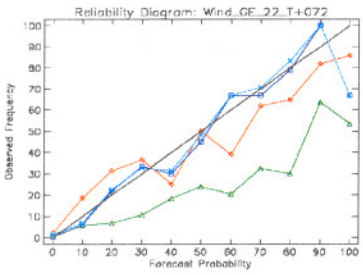
Outliers – 95% confidence temp.

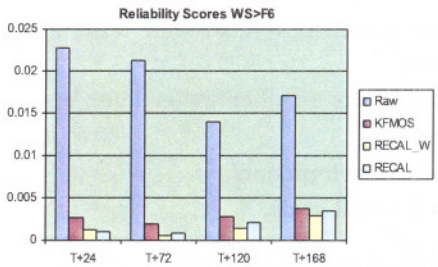
Dark colours forecasters, pale colours EPS. Only after full calibration can EPS compete with forecasters.

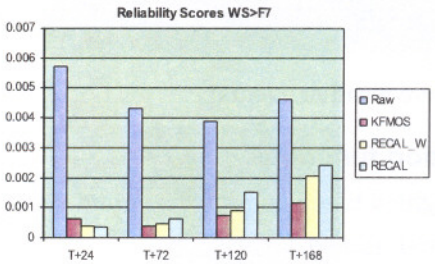


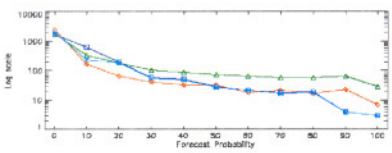
RAW KFMOS Calibrated

Verification – windspeeds at T+72



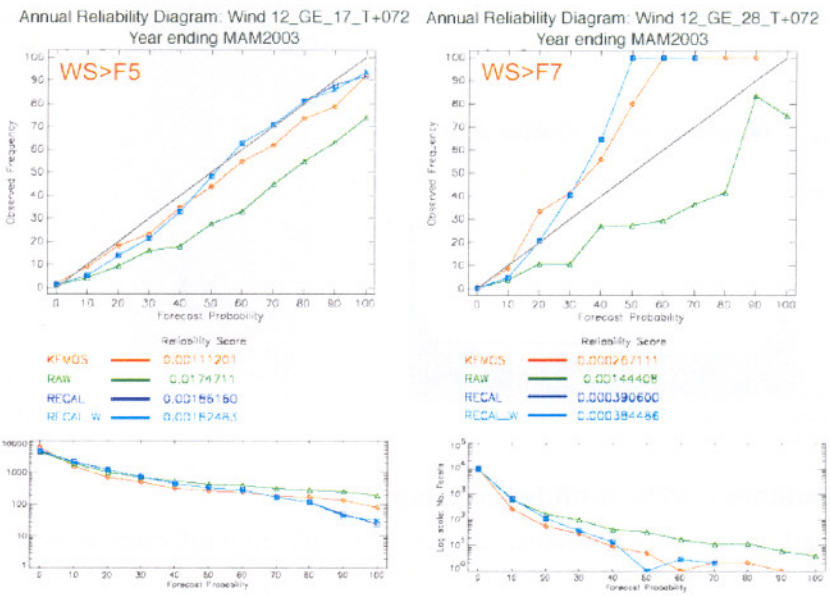






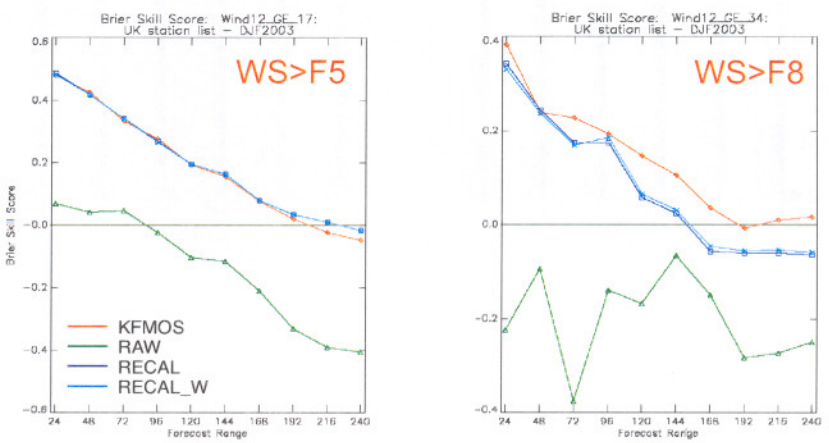
Reliabilty diagrams for calibrated windspeed forecasts

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



Brier skill scores for calibrated windspeed forecasts

- Calibration of winds improves forecasts at low thresholds but degrades at high thresholds

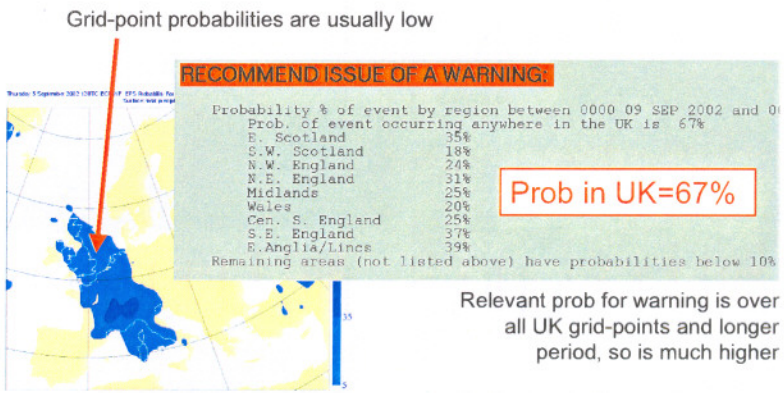


First guess early warnings project

Met Office issues Early Warnings up to 5 days in advance – when probability ≥60% of, for example: severe gales, heavy rain, heavy snow

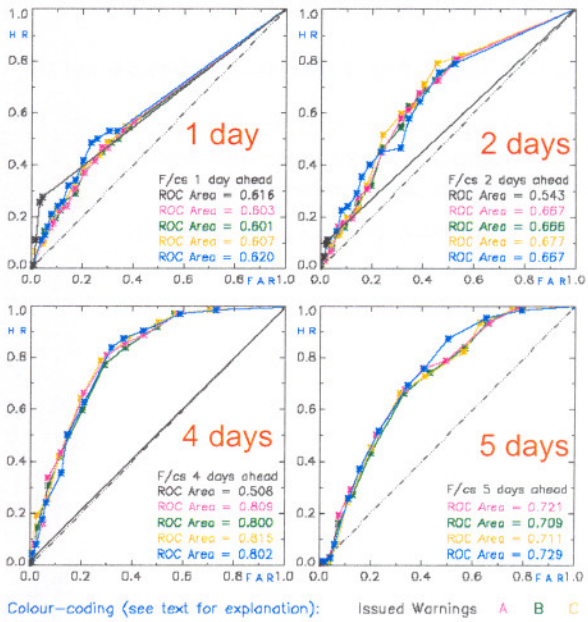
- Developed a system to provide forecasters with alerts and guidance from the EPS
- Verified against short-period, high certainty warnings

Calculation of relevant probs



ROC – heavy rain

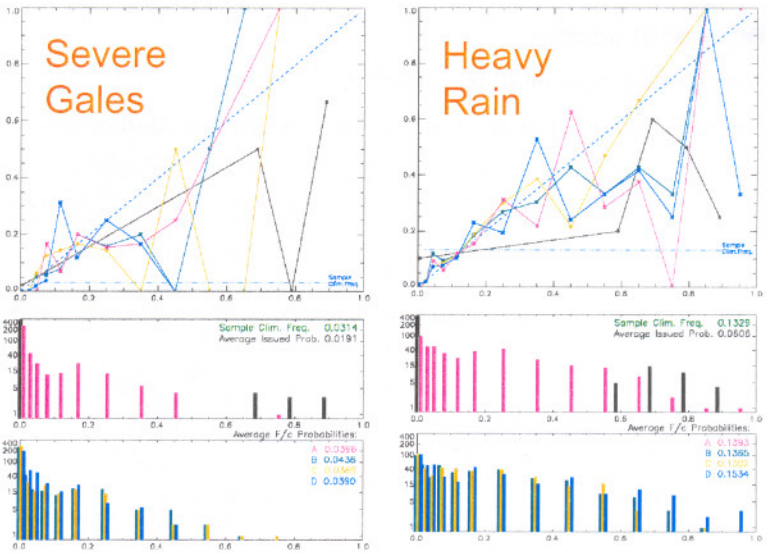
- Verification is difficult due to small samples, but warnings do have skill in discriminating severe events
  - Skill is best at 4 days
  - Severe gales results similar



Reliability 4-day forecasts whole UK

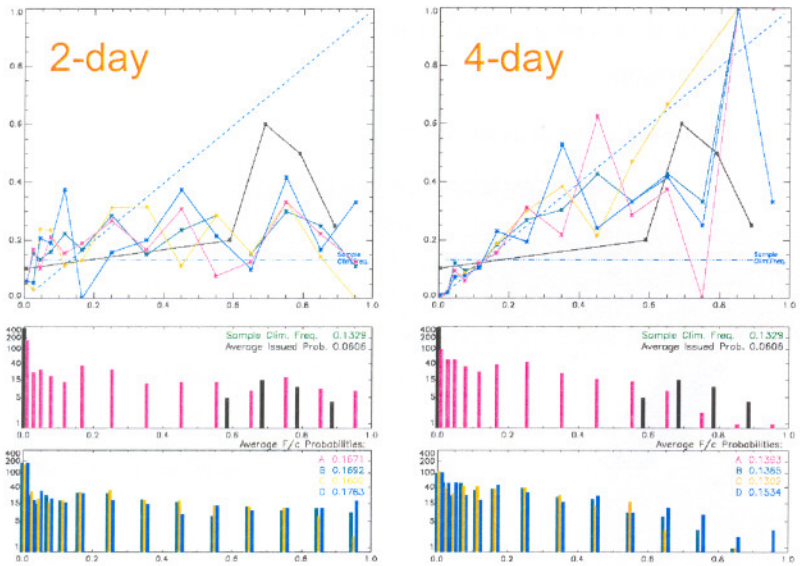
Small samples make verification noisy, but

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



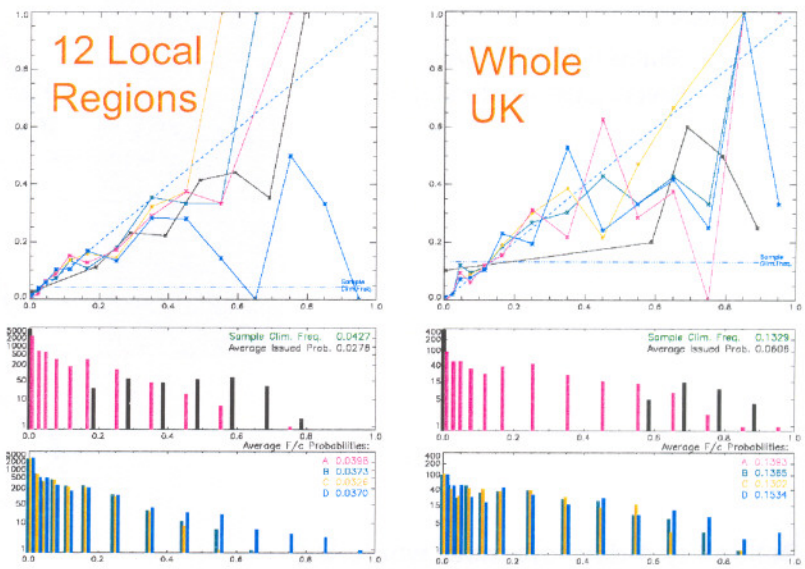
Reliability 2 and 4-day heavy rain – whole UK

- 2-day forecasts clearly have no significant discrimination



Reliability 4-day forecasts – heavy rain

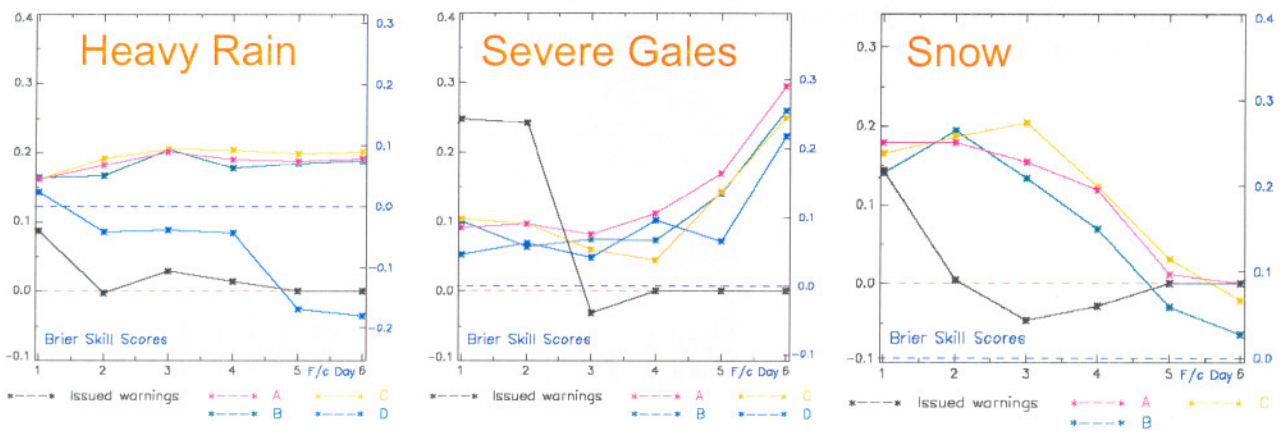
- Larger sample size for local regions reduces noise (but note sample is not independent)
- Otherwise performance is similar



Brier skill scores

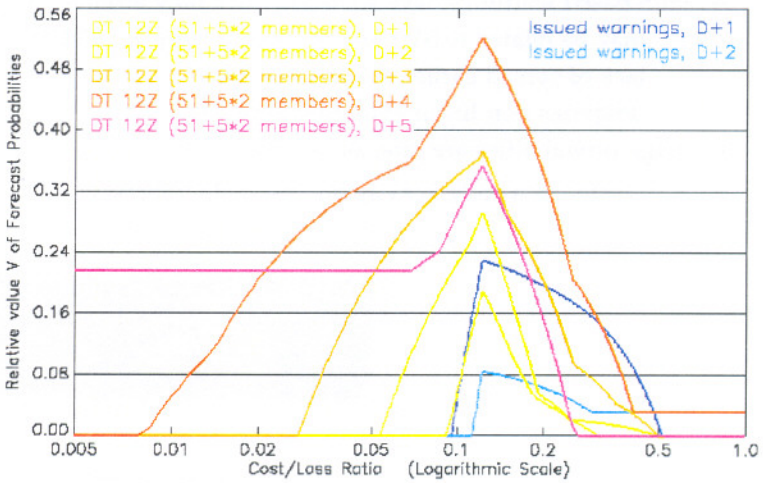
- Skill scores small but positive.

Left axis: skill relative to 'null' forecasts. Right axis: skill relative to prior sample climatology (small sample)



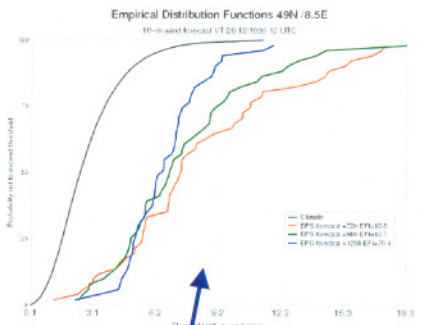
Verification – relative economic value

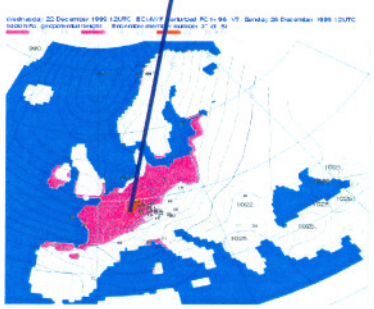
- Estimates value of forecasts to users making decisions with different cost-loss ratios C/L
- Relative to value of perfect forecast
- Much value for users with small C/L – low probabilities



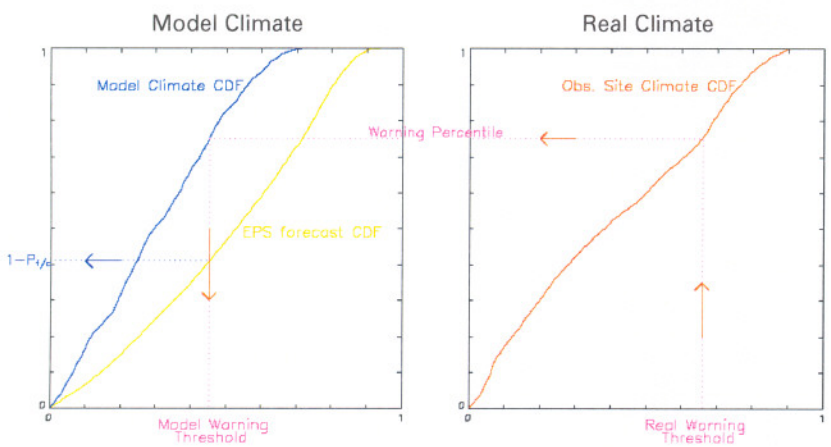
New ideas for calibration

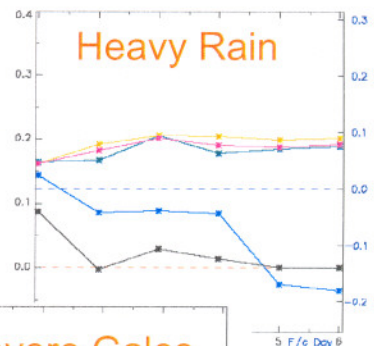
- Calibration of warnings is difficult due to small samples of past cases for tuning
- Model climatology of extremes may be very different from real atmosphere
  - ECMWF uses EFI to relate forecasts to model climatology
- EFI is useful as an alerting system but does not provide probabilities of severe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

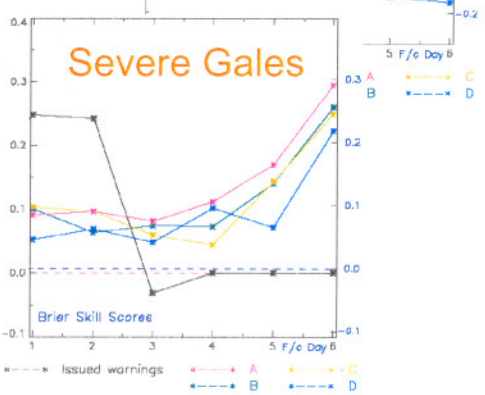




Calibration of warnings using the EFI climatology







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 and application to any user's required warning thresholds

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