The Concept of ‘Deterministic Limit’

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Structure of Talk

1. Definitions and Examples
2. Forecast Recalibration
3. Meteorological Complications

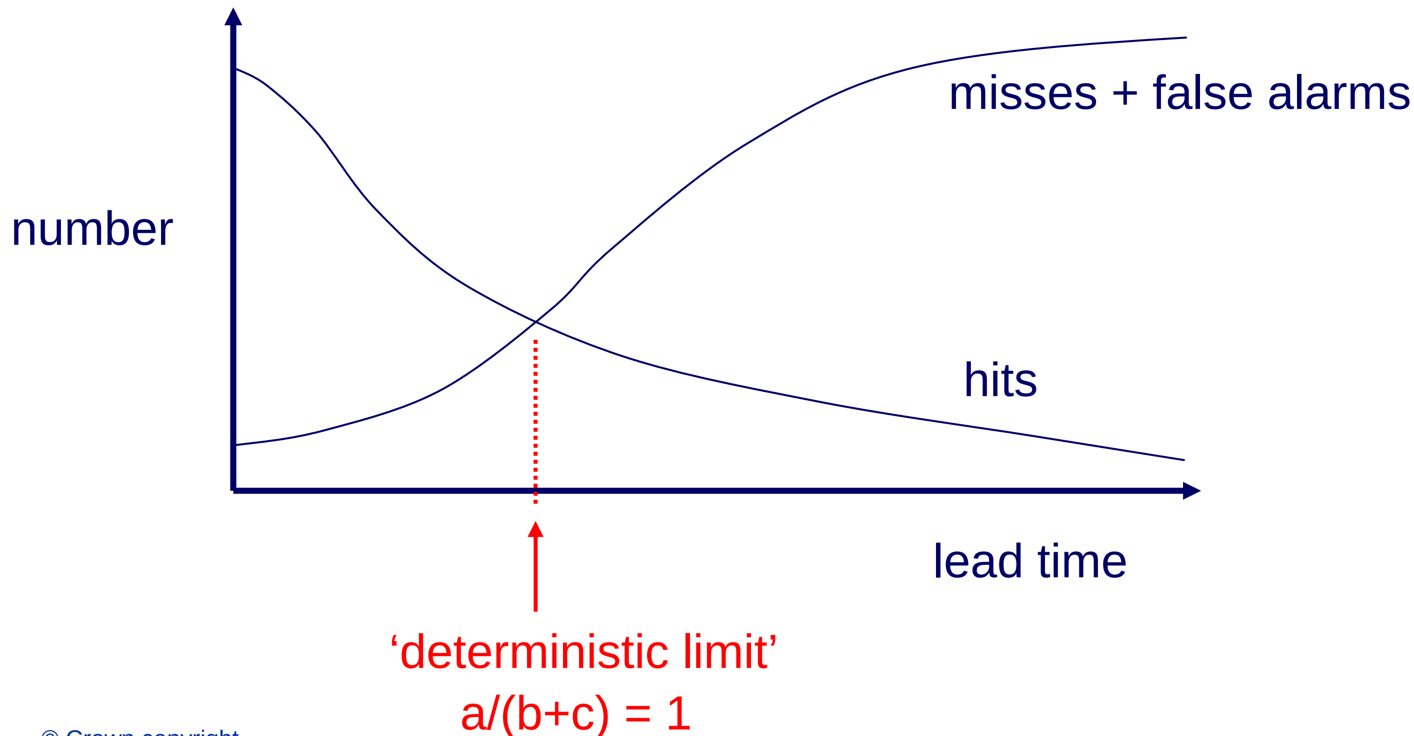
- real examples used here relate to strong wind events; concepts apply more generally, to many parameters

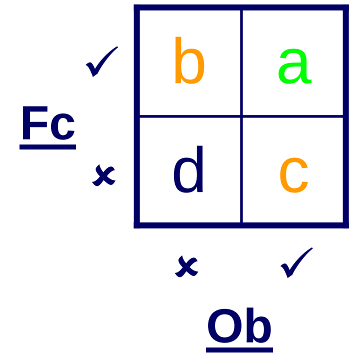
1. A New Verification Measure

- Conceptually there should be a ‘deterministic limit’ for predicting a **pre-defined meteorological event** (such as strong winds at a point)
- Simply defined this could be the point in lead time beyond which forecasts *concerning* that event are more likely, on average, to be wrong than right
- This can provides guidance on when to shift emphasis, in forecasts for particular events, from deterministic towards probabilistic
- For rare events at least, correct null forecasts – ie the majority - can be ignored as not relevant

Deterministic Limit

- The ‘deterministic limit’ for the event in question is then simply the lead time at which, over a suitably large forecast sample, *hits* equals the sum of *misses* and *false alarms* (or CSI = 0.5)

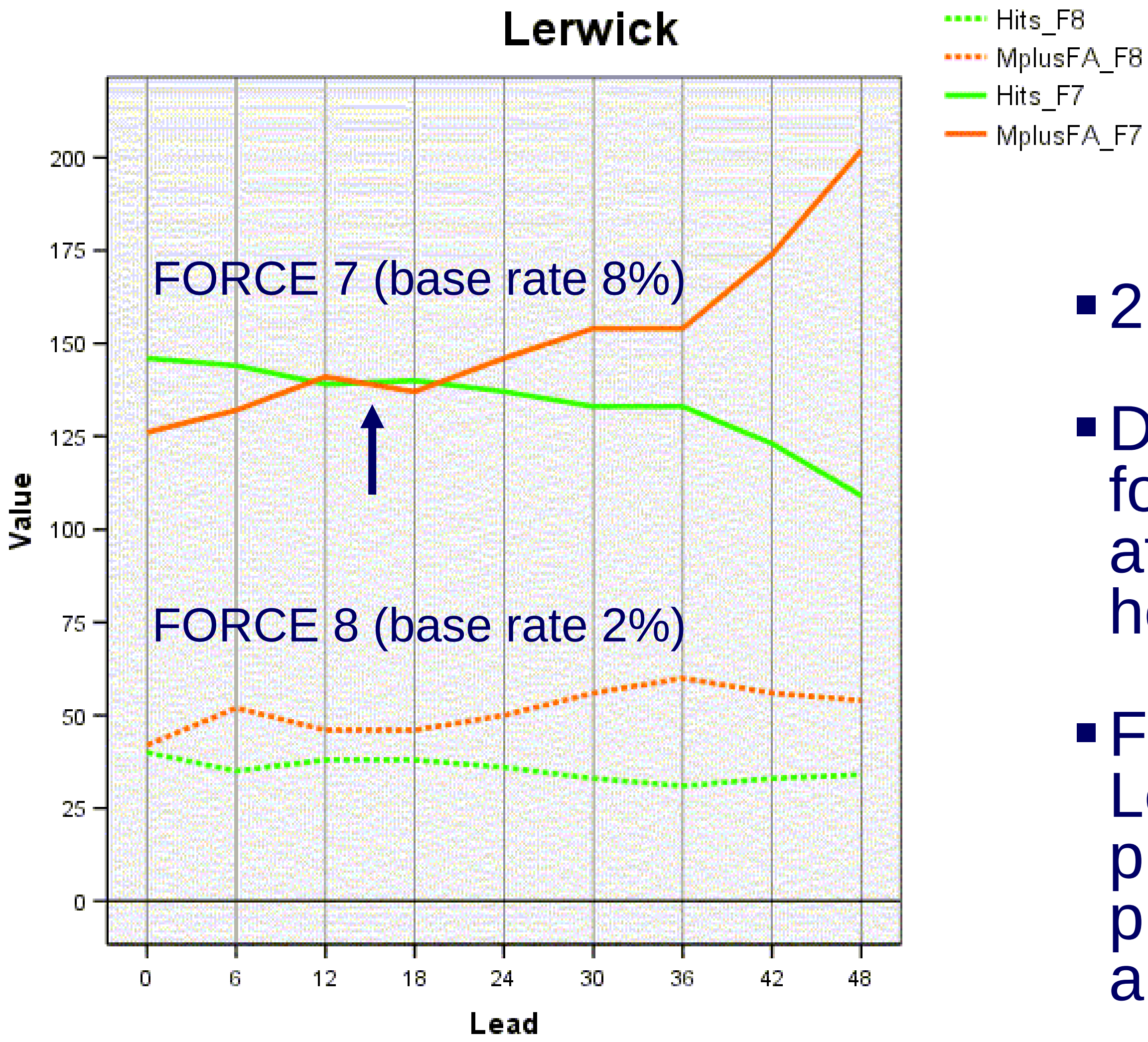




Event Examples (numbers are crude *estimates*)

- Tornado within 2km radius (deterministic limit ~ 5 mins)
- Snow falling at a point (~5 hours)
- Rain falling at a point (~18 hours)
- Gale force gusts at a point (~2 hours)
- Gale force gusts within a UK county (~6 hours)
- Rainfall >15mm in 3 hours somewhere in a UK county (2 hours)
- Cyclonic surface pressure pattern at a point (~120 hours)
- Atmospheric front within 200km of a point (~60 hours)
- Day with maximum above 30C in London (~96 hours)
- ‘Change of synoptic type’ for the UK (~4 days)

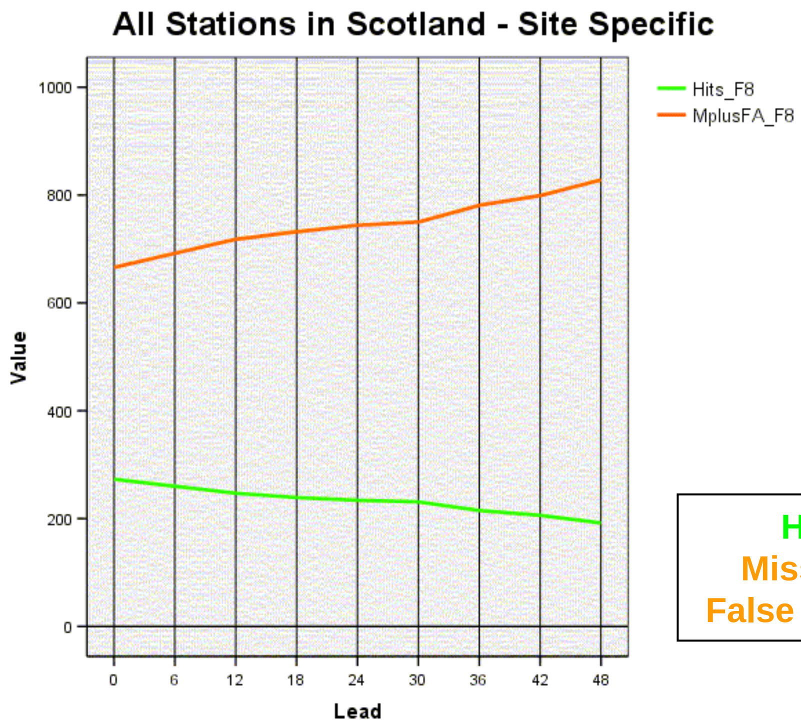
Site Specific Example – Mean Winds



Hits
Misses + False Alarms

- 2 years data
- Deterministic limit for F7 mean winds at Lerwick is ~15 hours
- F8 mean winds at Lerwick should be predicted probabilistically at all leads (DL<=0)

Regional Example, >= F8 winds



Hits
Misses +
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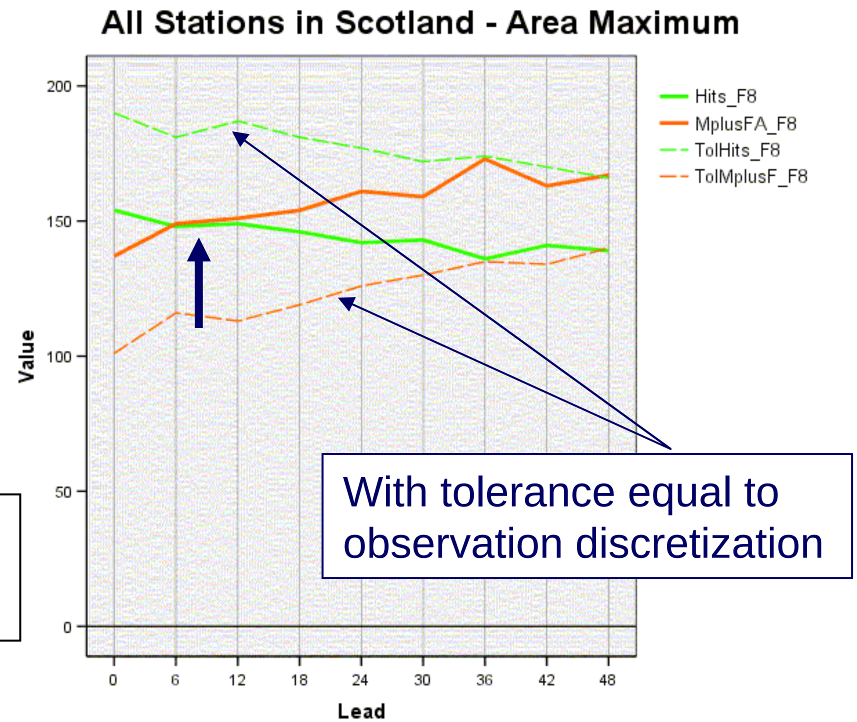


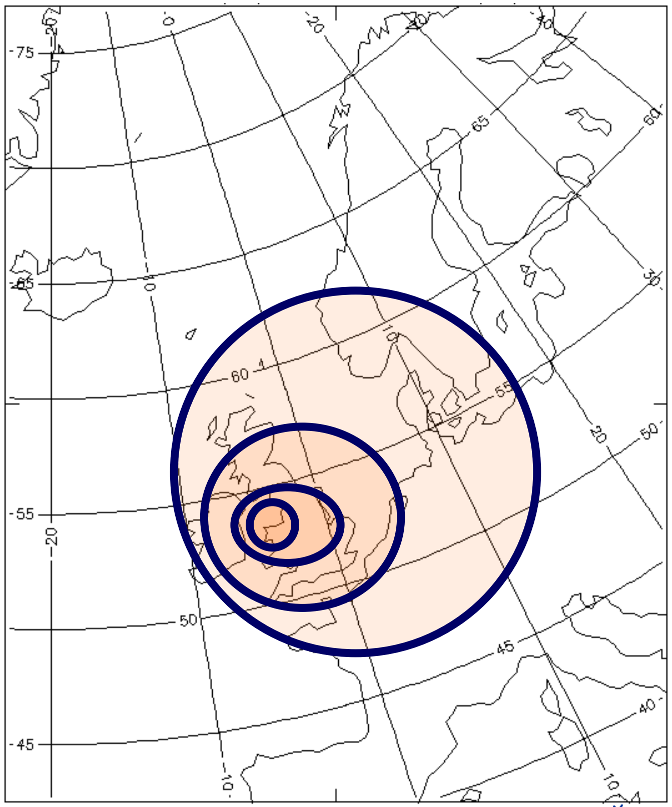
- Similar to Lerwick example, but for all Scottish sites considered collectively.
- Forecast event definition is: 'gales will occur at a particular site in Scotland, at a particular time'
- Deterministic limit << 0
- Base rate << 2%

- Forecast event definition is: 'gales will occur *somewhere* in Scotland, at a particular time'
- Deterministic limit ~8hours

- **Deterministic forecasts that are geographically less specific are much more valid**
- **Time-windowing should increase DL further**
- **Partly an impact of a higher base rate**

Some Implications for Windstorm Forecasts

- Deterministic Limit will decrease as areal specificity of the forecast increases
- Hence provides pointers to forecast and warning content, and suitable product development, as a function of lead time, eg:
    - day 5: part of continent
    - day 4: country groups
    - day 3: countries
    - day 2: extended regional
    - day 1: regional...



- Partly hypothetical, requires testing!
- In reality, areas may overlap, disappear
- Aim of *using DL* is to *minimise overlap*

Benefit Summary

- Potential to provide a *meaningful succinct measure* of what to expect from, and therefore what to put into, a forecast. Too many forecast elements are deterministic.
- It is something that the public, other customers (and auditors!) could potentially relate to
- Provides a means for inter-comparing the relative merits of ‘operational’ and ‘ensemble’ runs (further work is required on ensemble application)
- As always extreme events would be more difficult to represent (though hindcasts from re-analyses are becoming increasingly tractable)
- Provides facility also to measure forecast improvements, compare systems, assess forecaster performance

Further thoughts – "Unbiased Forecasts"

- In the simple case of a fully reliable (unbiased) forecast system, no of false alarms (b) = no of misses (c)
- So the deterministic limit, where (a/(b+c)) = 1, becomes a = 2*b
- Number of events observed, O = a+b
- Thus O = 3b = 3a/2
- So the 'deterministic limit' for an unbiased forecast system is reached when the no of hits (a) drops to two thirds of the no of observed events (O)
- Frequency-preserving recalibration should be used to arrive at an unbiased forecast in most circumstances

3. Recalibration

- Recalibration is a fundamental requirement for model wind speed forecasts, due to biases and local effects. Without this the deterministic limit is less than zero.
- Example below is a contingency table for the windiest site in the UK (N Rona, an island NW of Scotland) for mean winds exceeding 30m/s (58kts), 2004-2006, based on T+0 mesoscale model (12km) data.

Key (Fc = forecast, Ob = observed):

Fc		
	FALSE ALARM	HIT
		MISS
		Ob

No recalibration

0	0
	15

Recalibration by linear regression

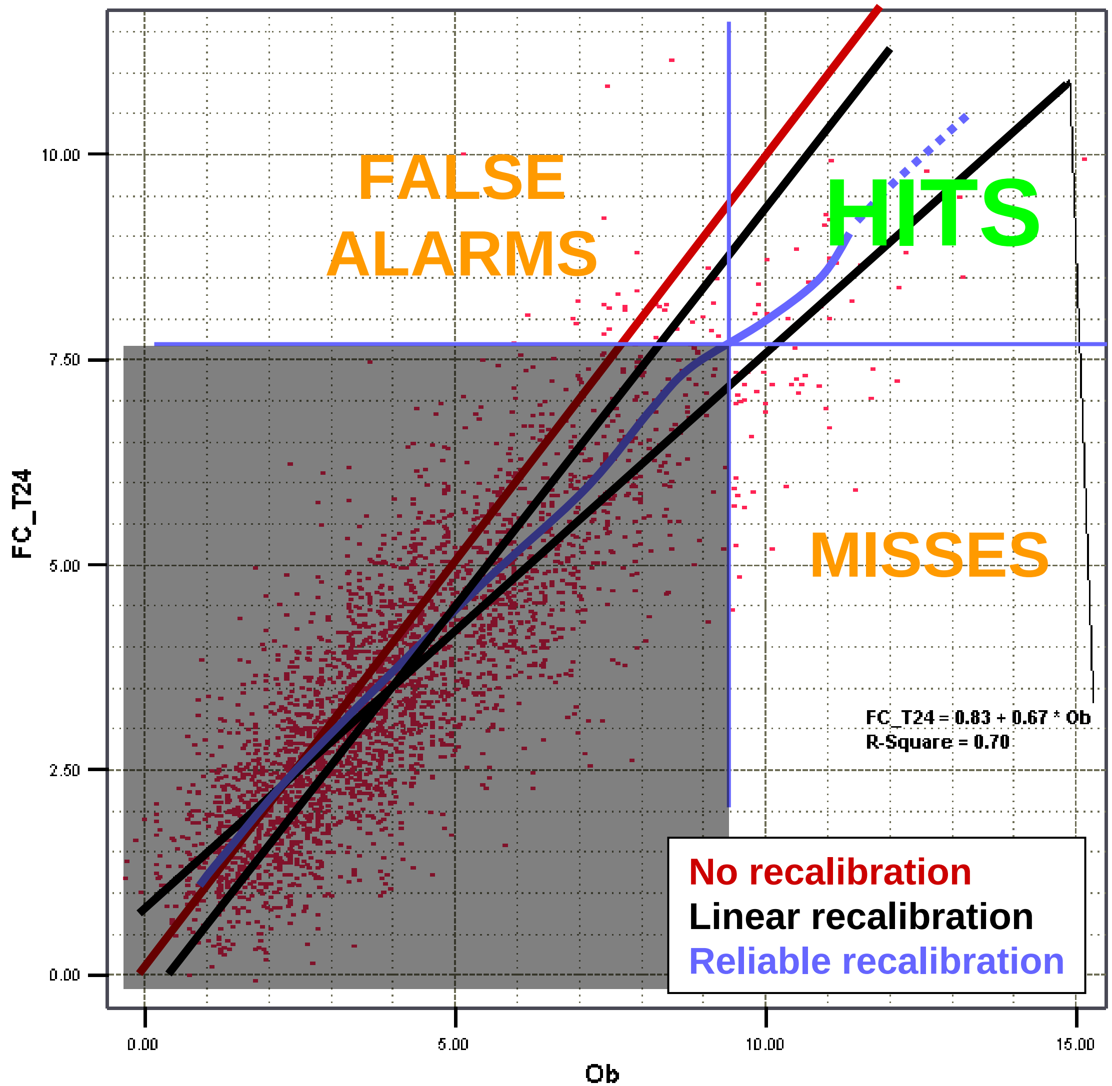
1 (4)	3 (4)
	12 (11)

'Reliable' recalibration

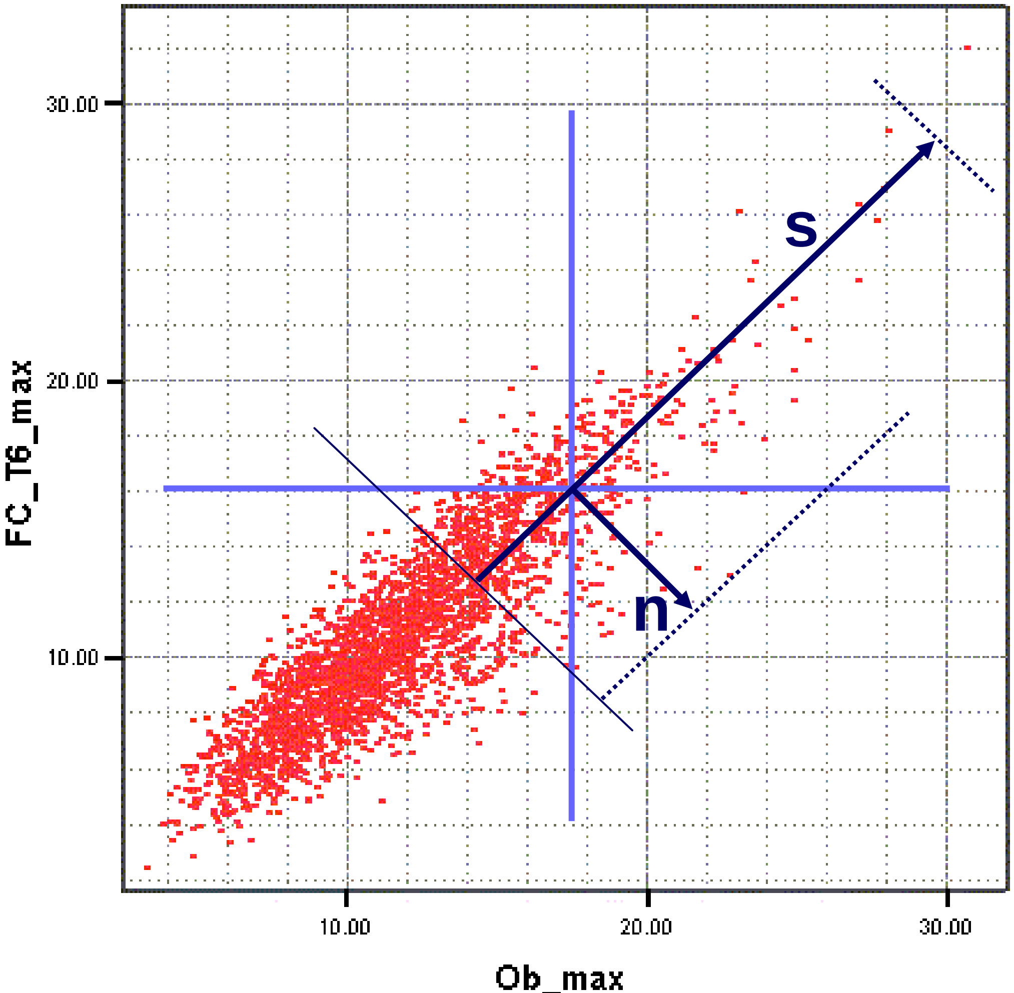
5	10
	5

Meaning of ‘Reliable Recalibration’

- Example is for London Heathrow T+24 forecasts
- ‘Reliable’ recalibration is so-named because it is frequency preserving. Percentile matches are used to ascertain whether a forecast is above threshold.
- Misses = False Alarms
- Problems can occur (as always!) with model changes
- See Casati et al (2004)



Scatterplot characteristics and the deterministic limit



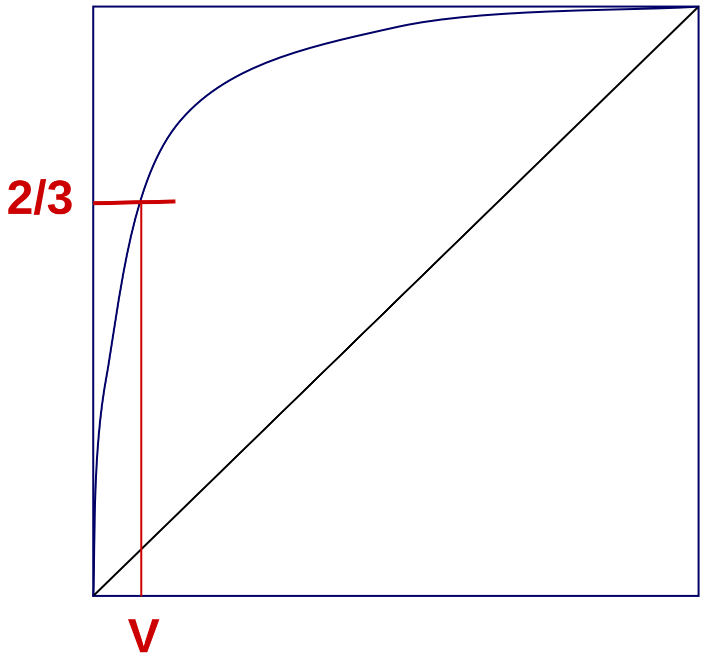
- By making a first order assumption of a linear reduction in point density in the two directions shown (s,n), relative box populations can be computed geometrically
- This leads to the result that for the DL to be greater than the lead time to which the plot corresponds (ie hits > misses + false alarms), requires

$$\boxed{s > 3n}$$

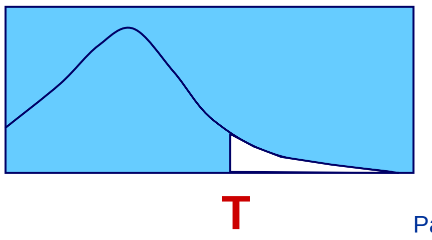
- Could be used to instantly assess the validity of making deterministic categorical forecasts for rarer values of a particular parameter at a particular lead time (based on past performance)

ROC curves

- Intersection of Y=2/3 with ROC curve corresponds to Deterministic Limit = plot lead time
- Thus a ROC curve (for a particular lead) will tell you the base rate of the event for which the DL equals that lead time
- Event threshold (T) then relates directly to base rate
- Assumes recalibration incorporated



Base rate = 3V/(3V+1)

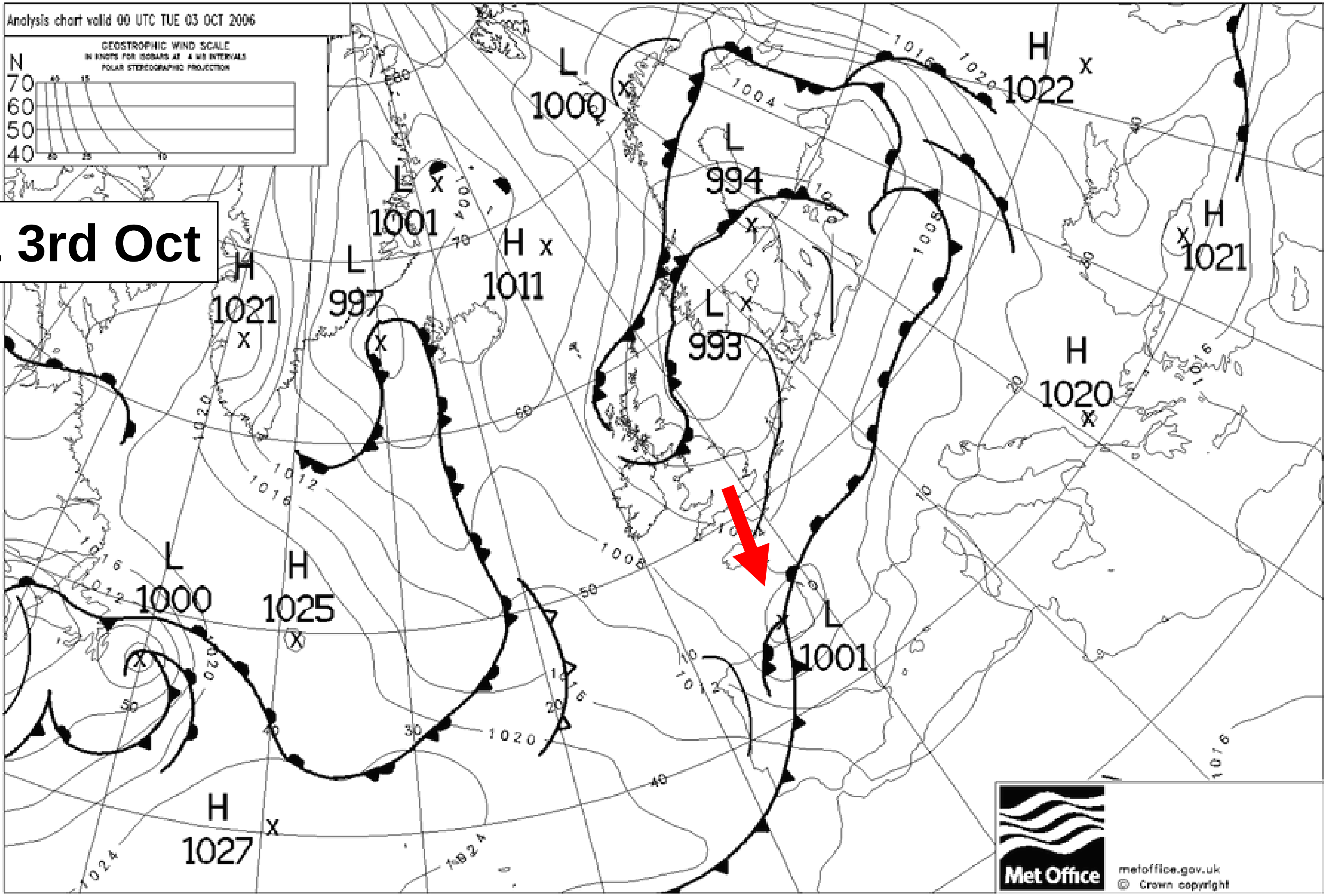


Meteorological Complications

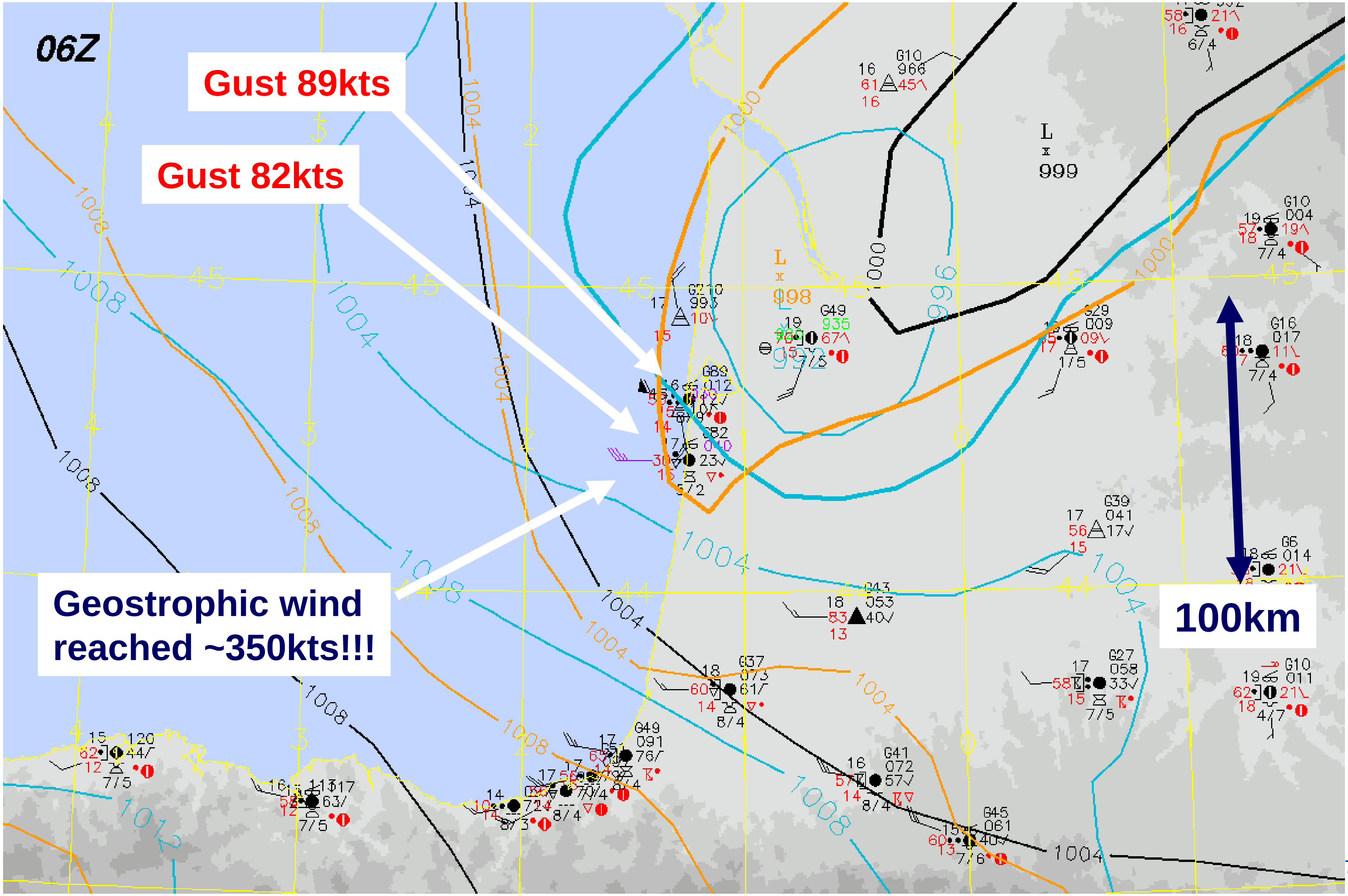
- Example…
- ‘Most severe’ windstorm of the 2006/7 European winter period so far (highest gusts anyway!)
- Not forecast
- Recalibration would not help

‘Arcachon Windstorm’ - 4 hours before hitting French coast

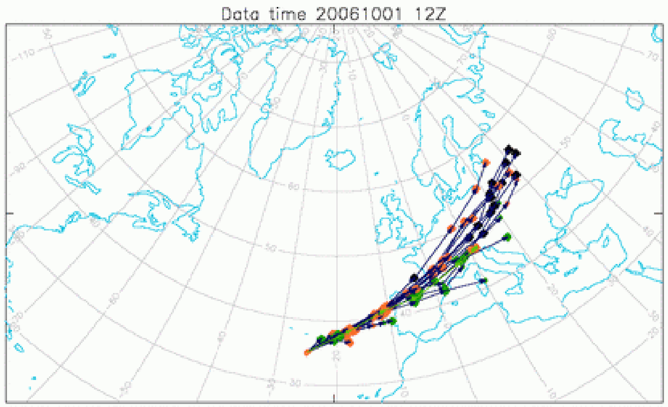
00Z 3rd Oct



O6Z Synops – 'on-screen' analysis in blue

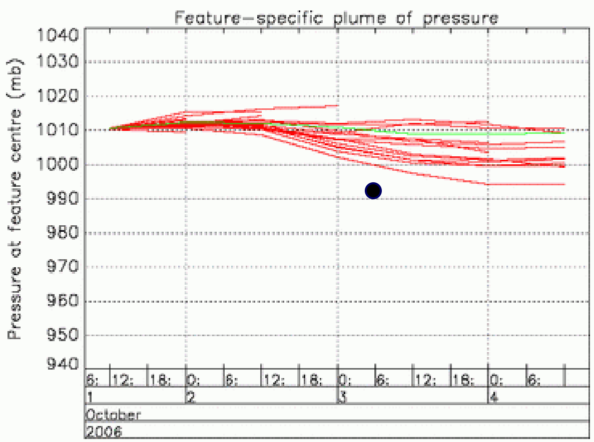


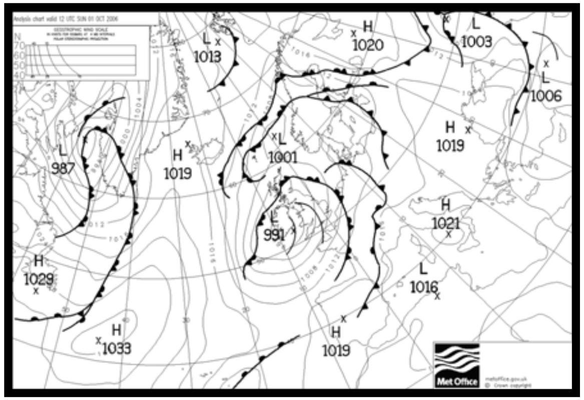
42-hour lead – feature tracks & feature plumes



Percentage of members in track, and a list of the member numbers:

T+ 0:	100.00%	0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
T+ 12:	91.67%	0 1 2 3 4 5 6 7 8 10 11 12 13 14 16 17 18 19 20 21 22 23
T+ 24:	70.83%	0 1 2 7 8 10 11 12 13 14 16 17 18 19 20 21 23
T+ 36:	62.50%	0 1 2 7 8 10 11 12 13 14 17 18 19 20 23
T+ 48:	58.33%	0 1 7 8 10 11 12 13 14 17 18 19 20 23
T+ 60:	58.33%	0 1 7 8 10 11 12 13 14 17 18 19 20 23
T+ 72:	45.83%	0 1 7 10 11 13 14 18 19 20 23

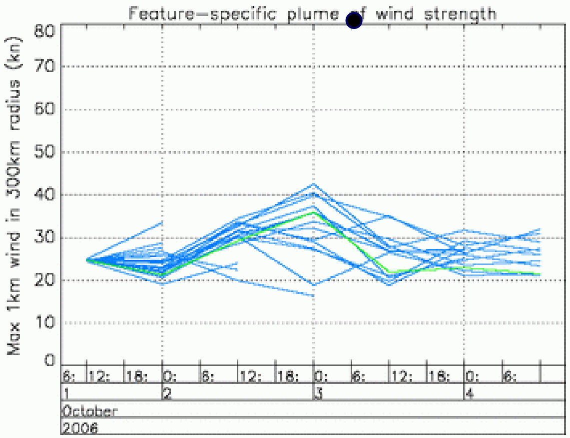


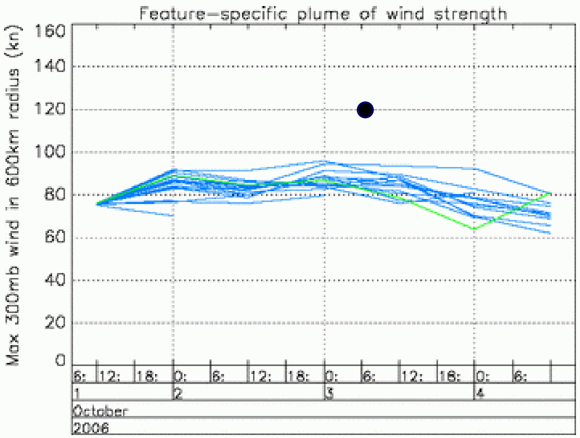


Central Pressure

Low level wind max

Upper level wind max





Summary

- New verification concept introduced – the ‘deterministic limit’ (DL)
- Examples, for strong wind exceedances in the UK, illustrate that DL depends on:
  - Base rate
  - Areal (and temporal) specificity
  - Tolerance when judging hits
- Examples also illustrate the requirement for recalibration
- ‘*Reliable*’ recalibration is needed to maximise forecast information utilisation (maximising DL)
- Scatterplot structure relevant for ascertaining ‘deterministic forecastability’
- DL values denote when to move from deterministic to probabilistic forecasts
- Requirement for expanding sample size, of ‘adverse weather’ events, is clear:
  - Improve model diagnostics (eg multi time-step interrogation for winds)
  - Improve verification data storage (archive all observations of all relevant events)
  - Reserve supercomputer time to perform re-runs of past events with new model versions
- **NEXT**: need to define more user-relevant events, and compute DL for these…. Leading to a **catalogue of DL values for a wide range of weather events**.

Challenges

- Accounting for observational error
  - e.g. Fewer gales occur than are reported!
- Performing reliable recalibration when observational error has been accounted for
- Performing reliable recalibration in real time
- Data collection needs to be improved
- Meteorological complexity – never forget the physics!
- Extreme events

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