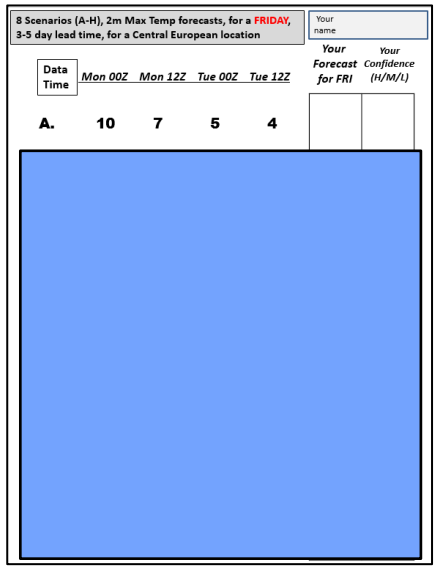
Each of the 8 scenarios (A-H) shows the maximum temperature forecasts, provided by a deterministic model, for a particular location, for a particular Friday.

The scenarios are all independent of one another.

For each scenario the successive columns show forecasts from 4 consecutive model runs earlier in the week (in deg C)

(you can assume that on average the model forecasts are unbiased)



<u>For each scenario:</u>

In the first box enter your forecast of 2m Maximum Temperature (half degrees are allowed) for the Friday, on the basis of the previous model forecasts

In the second box enter a confidence level for your forecast – high medium or low (H, M or L). You may prefer to complete all the first column first, then afterwards go back and do all the second column.

Put your name on the sheet (they can be returned!).

Forecast Jumpiness

Tim Hewson

Thanks to Ervin Zsoter, Ivan Tsonevsky and David Richardson

Motivation

- ECMWF quite often receives feedback regarding unwanted / unexpected ‘jumps’ in the forecast
- Commonly these refer to the HRES, but sometimes also to the ENS

- To what extent is the feedback justified ?
- Are there ways in which a forecaster can deal more effectively with apparent jumps in the forecast ?

Structure

- Example
- Related research results
- Comments on short range ‘instabilities’
- Summary

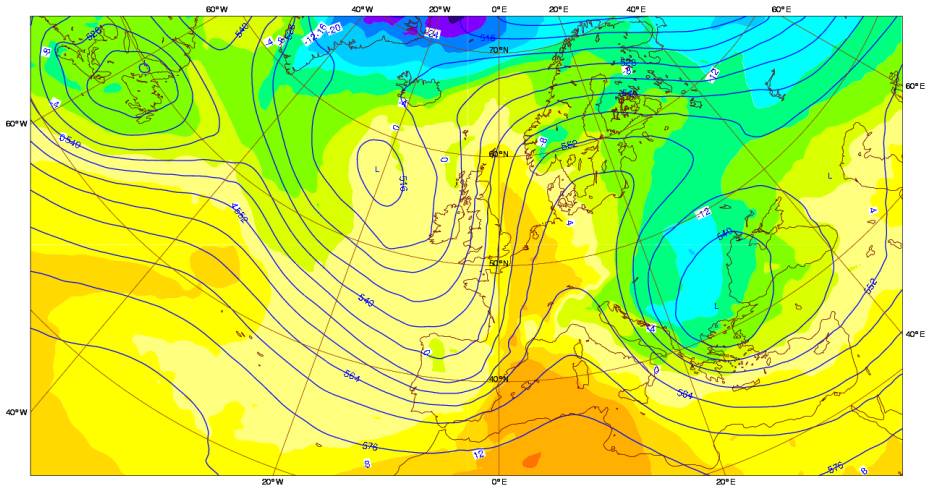
An Example

- Medium range forecasts for Belgrade
  - Christmas Day, 2012

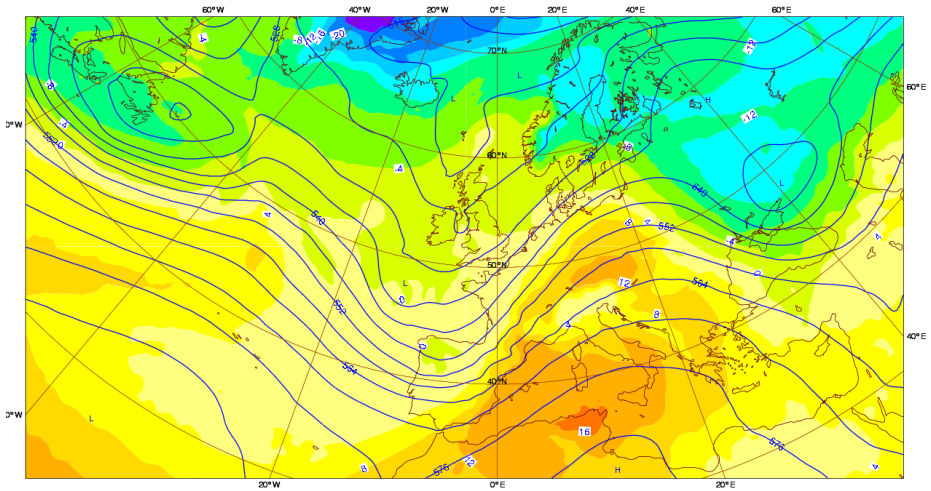
- Jump in HRES and ENS, at the 5 to 6 day lead time

VT: 25/12/2012 00UTC

Wednesday 19 December 2012 00UTC ©ECMWF Forecast t+144 VT: Tuesday 25 December 2012 00UTC
850 hPa Temperature / 500 hPa Geopotential



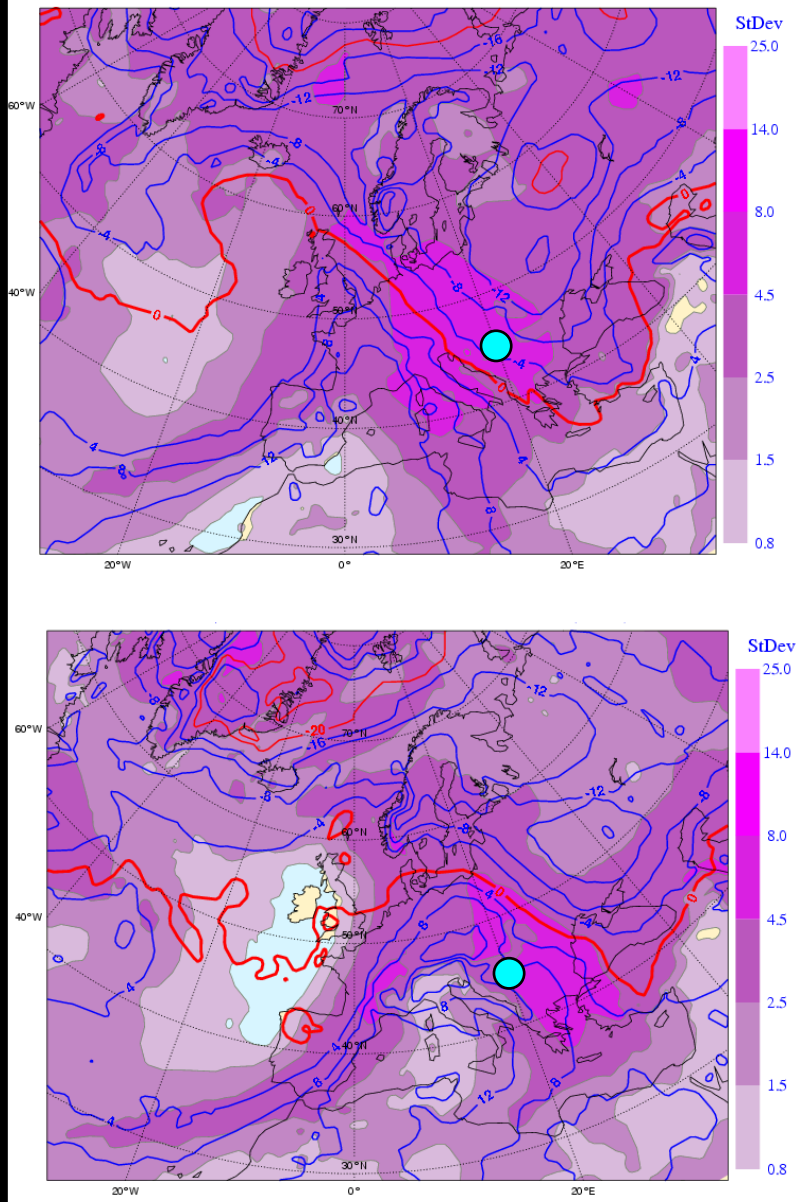
Thursday 20 December 2012 00UTC ©ECMWF Forecast t+120 VT: Tuesday 25 December 2012 00UTC
850 hPa Temperature / 500 hPa Geopotential



ECMWF

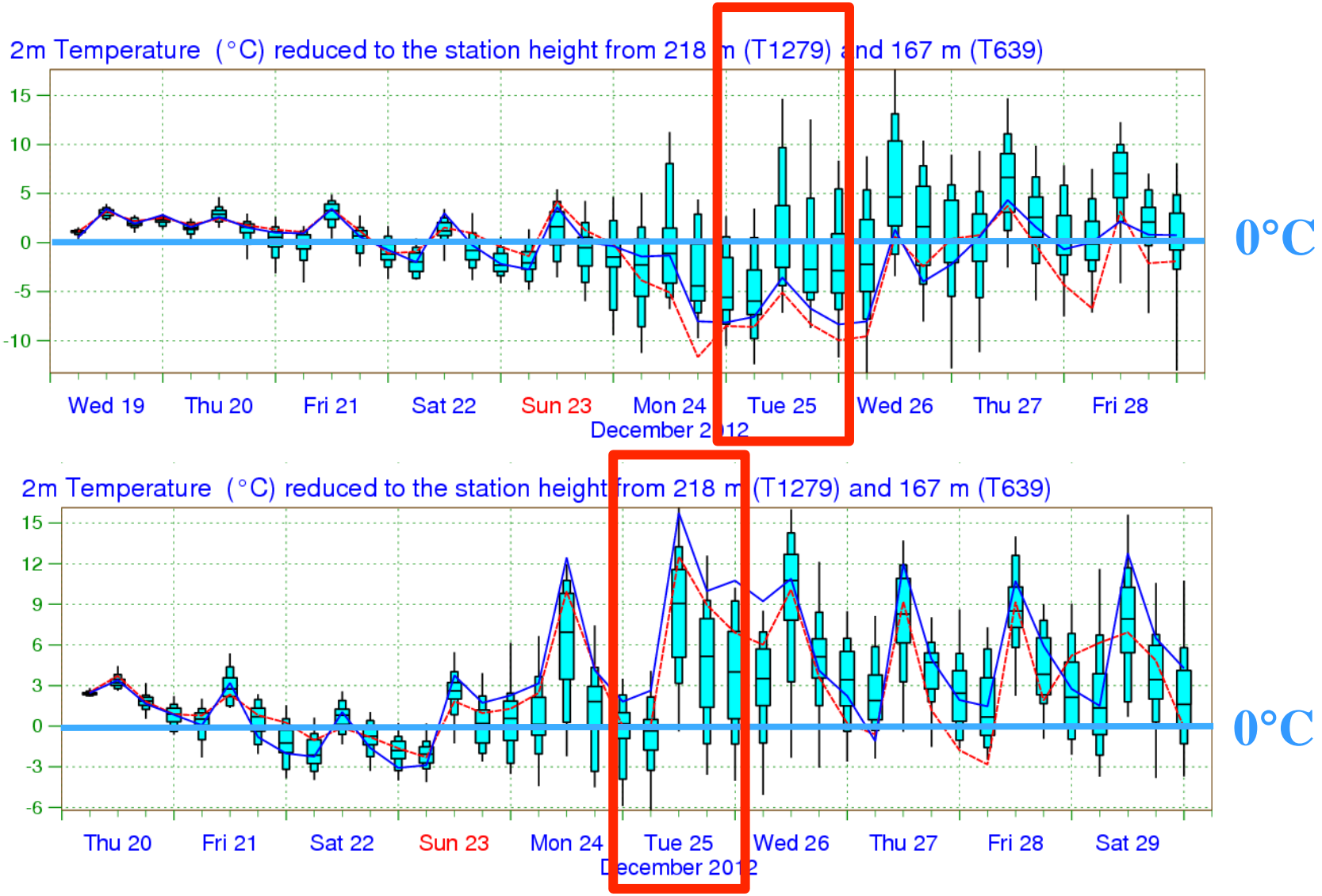
HRES (contours)

Actual ENS Spread (shading)

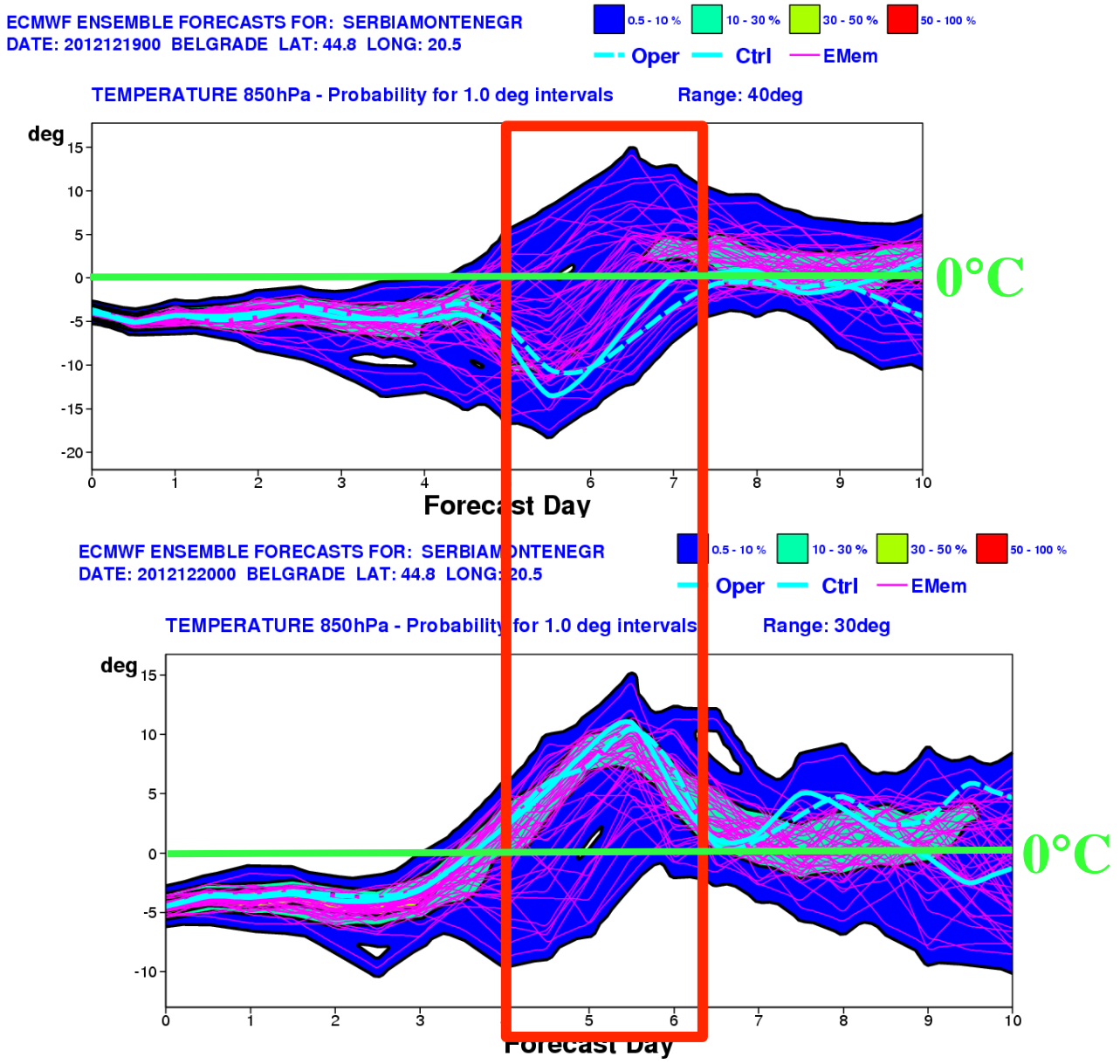


ECMWF

BELGRADE, SERBIA



ECMWF

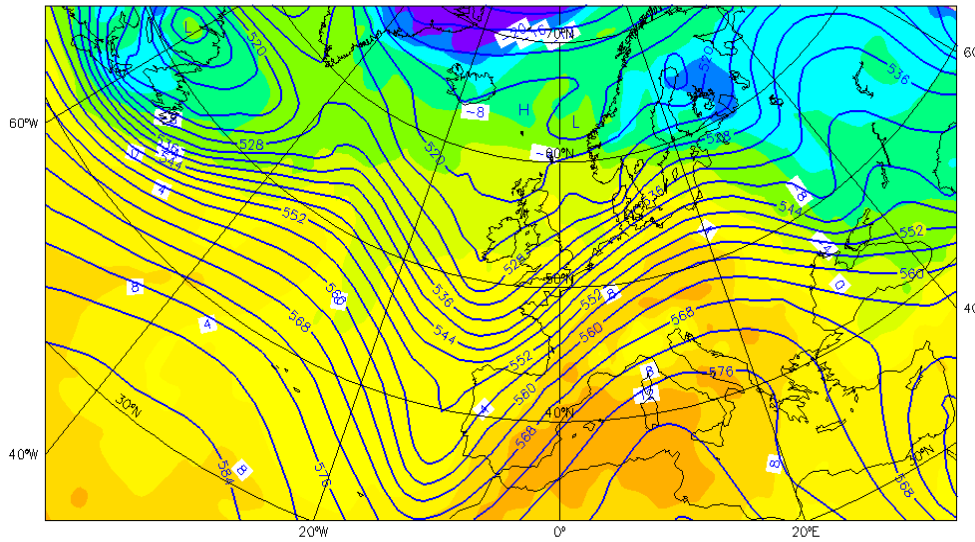


Bigger jumps in HRES and CONTROL than in the ENS Mean

Will this always be the case ?

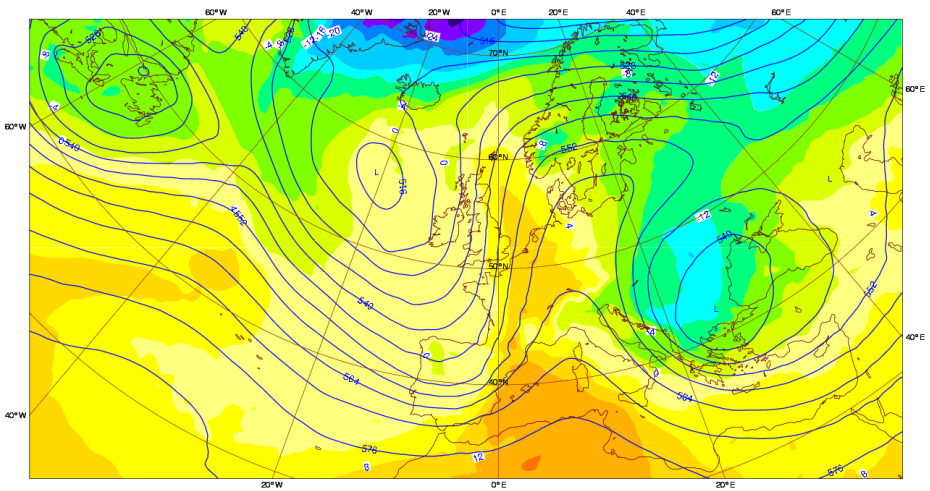
VT: 25/12/2012 00UTC

Tuesday 25 December 2012 00UTC ECMWF Forecast t+ 0 VT: Tuesday 25 December 2012 00UTC
500 hPa Height / 850 hPa Temperature

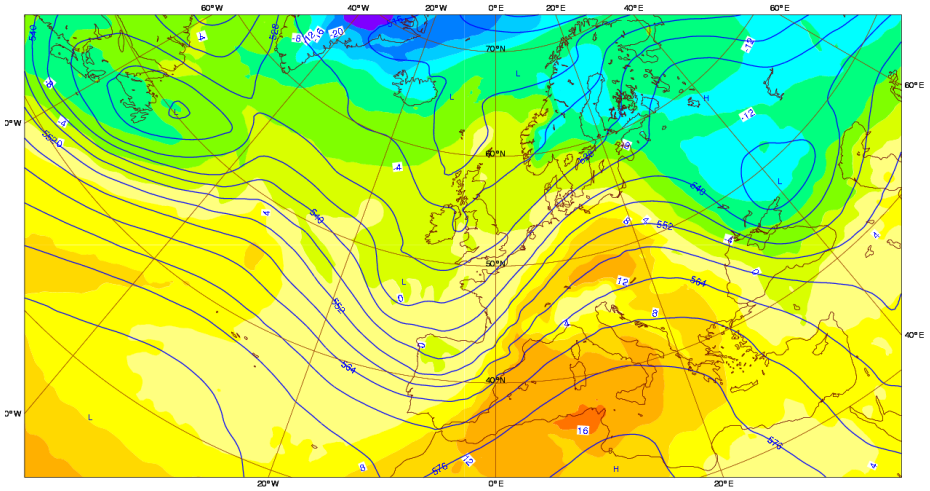


← ANALYSIS

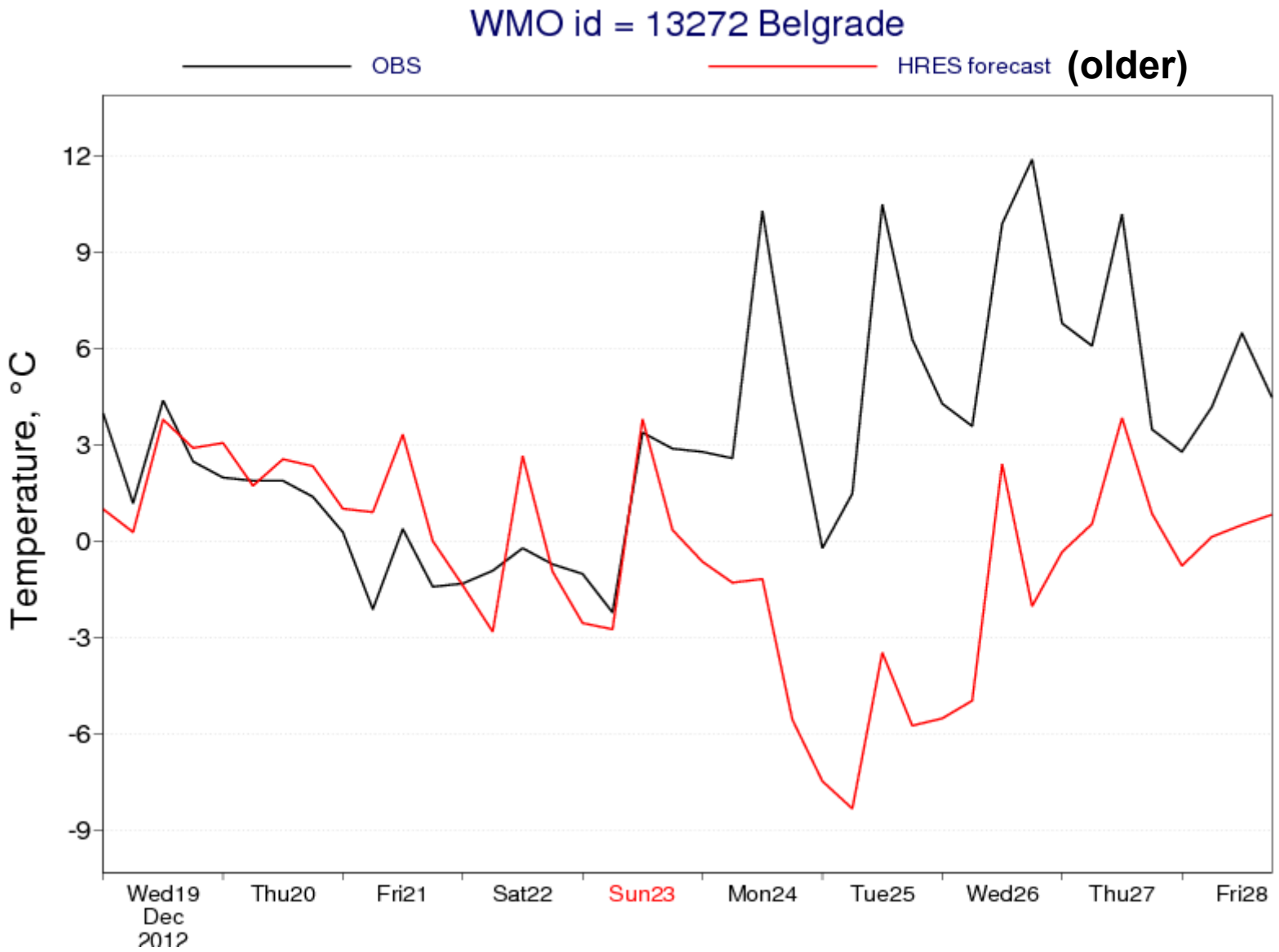
Wednesday 19 December 2012 00UTC ©ECMWF Forecast t+144 VT: Tuesday 25 December 2012 00UTC
850 hPa Temperature / 500 hPa Geopotential

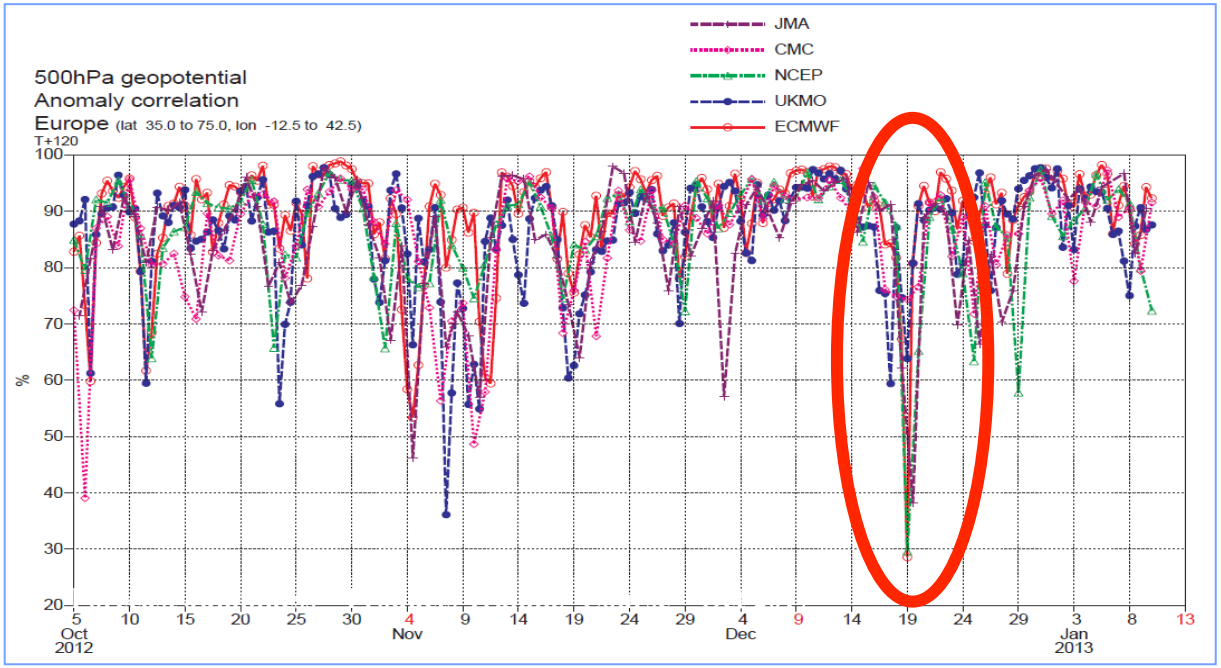


Thursday 20 December 2012 00UTC ©ECMWF Forecast t+120 VT: Tuesday 25 December 2012 00UTC
850 hPa Temperature / 500 hPa Geopotential



ECMWF


WMO id = 13272 Belgrade
OBS
HRES forecast
(older)
Temperature, °C
12
9
6
3
0
-3
-6
-9
Wed19 Dec 2012
Thu20
Fri21
Sat22
Sun23
Mon24
Tue25
Wed26
Thu27
Fri28



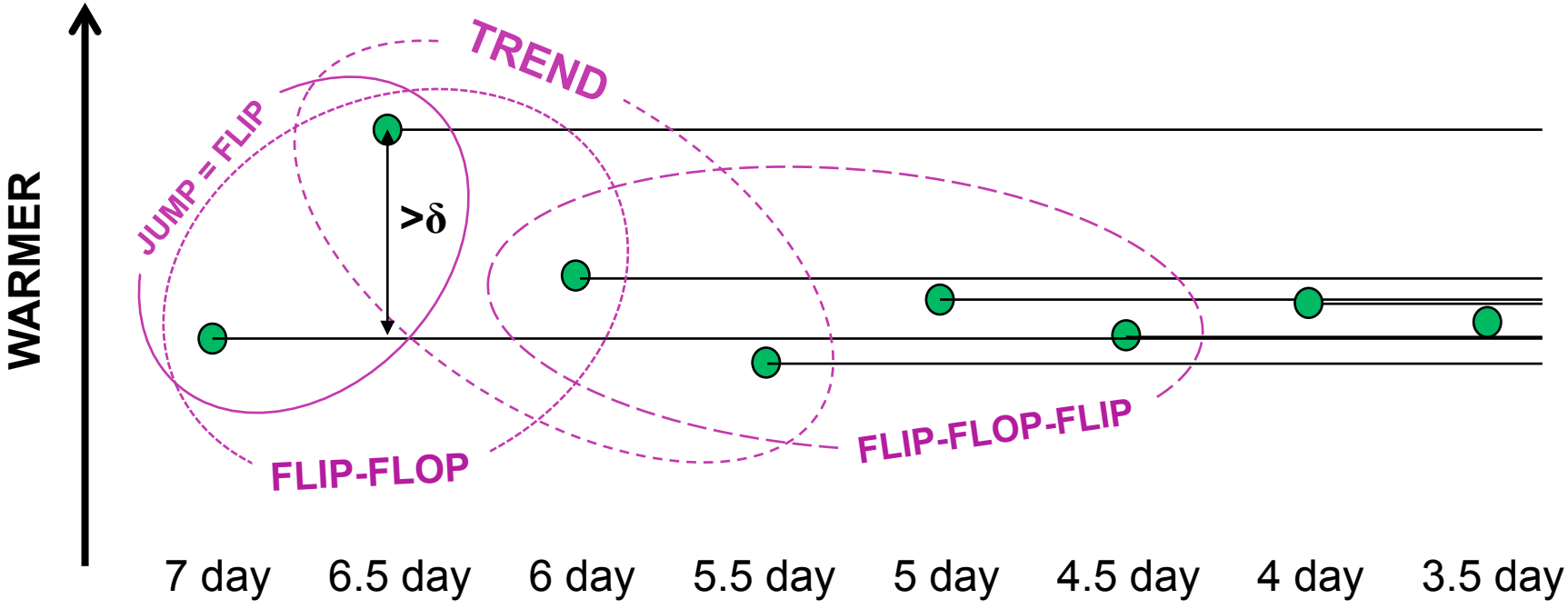
A big jump can mean that the forecast system is arriving more quickly at the right solution!

ECMWF

How '*should*' successive deterministic forecasts behave ?

- Consider successive HRES forecast of a single parameter (eg temperature) for a given time for a given location…

There should be convergence towards a particular solution – but this may involve jumps etc. along the way



Forecast lead time for a given date, time and location

ECMWF

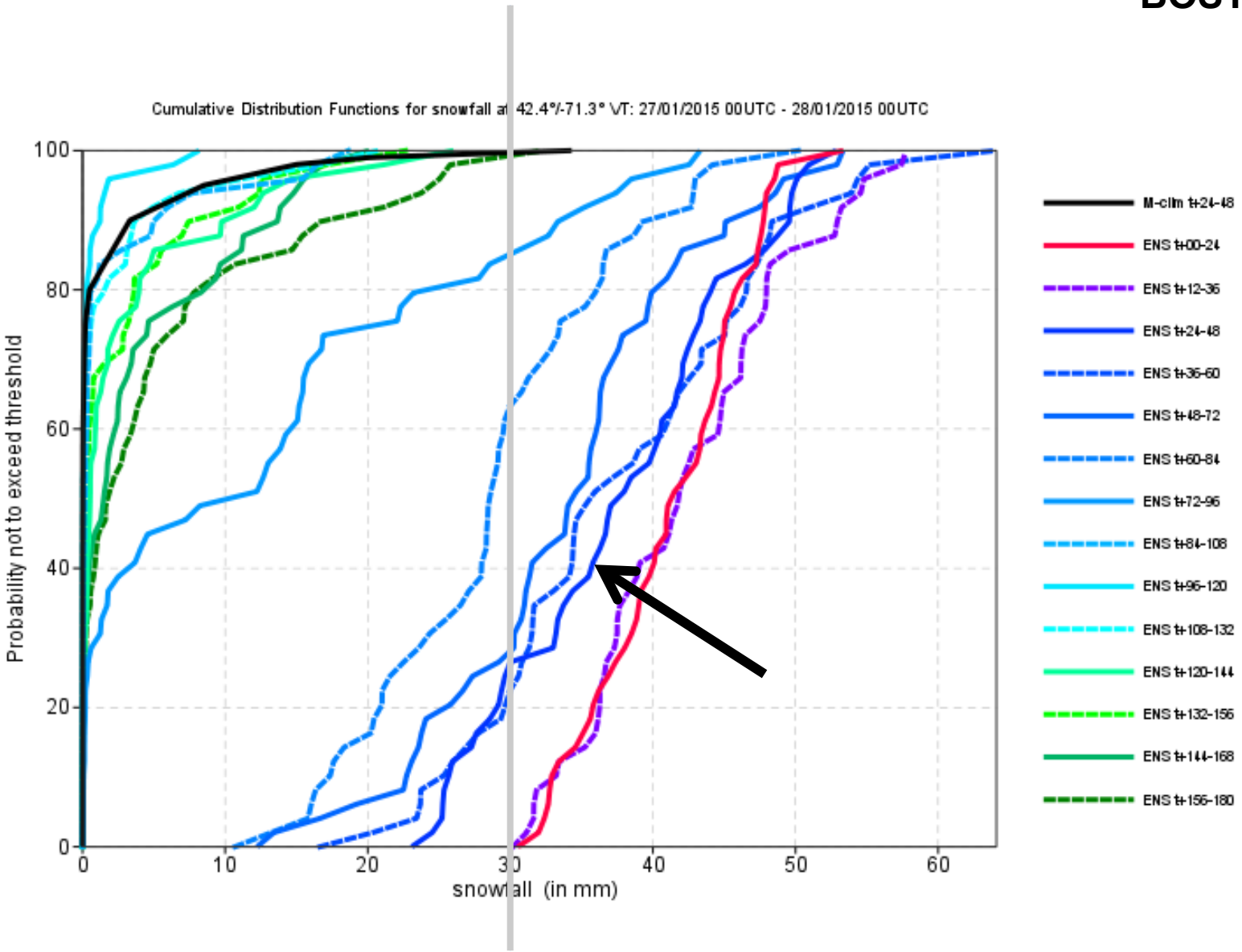
Dealing with jumps and trends…

- At the most basic level, given three consecutive forecasts:
  - "Flip-flops" will happen half the time
  - "Trends" will happen half the time

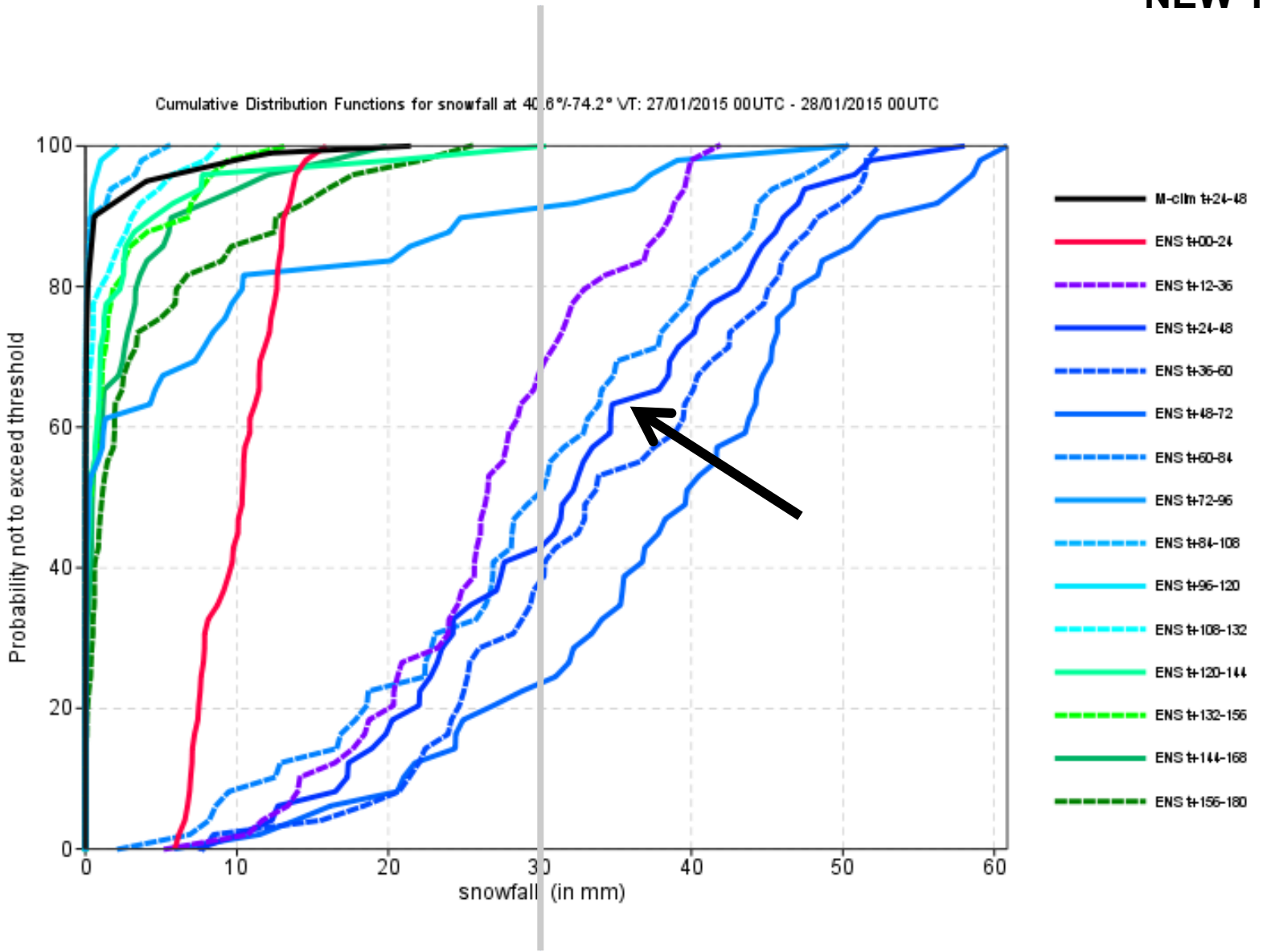
So neither should come as a surprise !!!

Whiteboard....

BOSTON

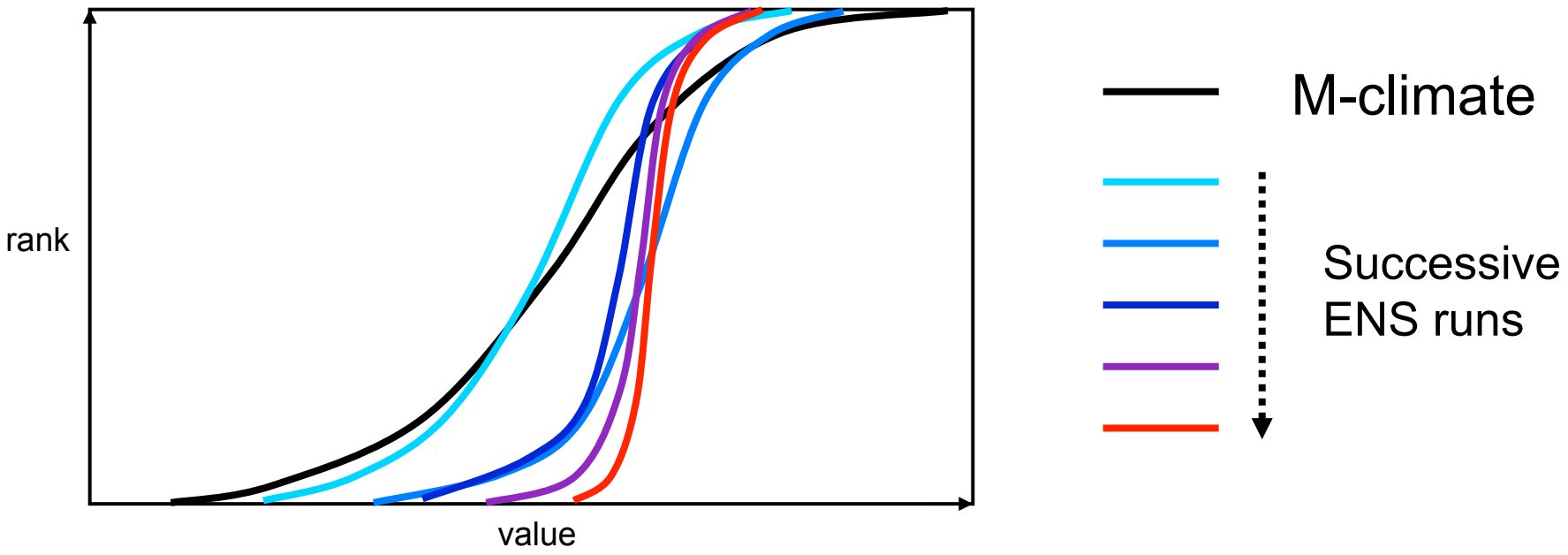

Cumulative Distribution Functions for snowfall at 42.4°/-71.3° VT: 27/01/2015 00UTC - 28/01/2015 00UTC
Probability not to exceed threshold
100
80
60
40
20
0
0
10
20
30
40
50
60
snowfall (in mm)
M-clim t+24-48
ENS t+00-24
ENS t+12-36
ENS t+24-48
ENS t+36-60
ENS t+48-72
ENS t+60-84
ENS t+72-96
ENS t+84-108
ENS t+96-120
ENS t+108-132
ENS t+120-144
ENS t+132-156
ENS t+144-168
ENS t+156-180

NEW YORK



ECMWF

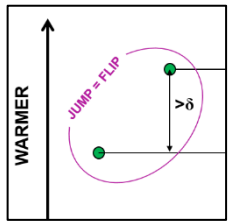
How '*should*' CDFs behave in successive ENS runs?



- At long lead times forecast CDF may be similar to the M-climate
- Lateral variations in CDF position between successive runs should, mostly, become less (with time), implying ***consistency***
- CDF will tend to become steeper (with time), implying higher ***confidence***

Dealing with jumps and trends…

- At the most basic level, given three consecutive forecasts:
  - "Flip-flops" will happen half the time
  - "Trends" will happen half the time
- However we can classify jumpy behaviour to only be when the magnitude of jumps exceeds certain thresholds δ (making frequencies less)

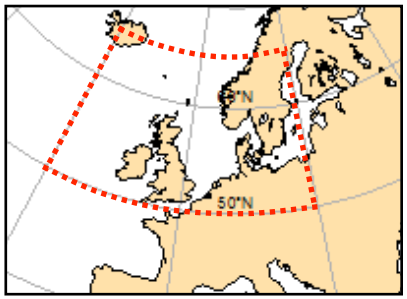


- So what do we forecast, given a "jump" ?
- And what do we forecast, given a "trend" ?
- <u>Is the forecast more likely to be right if there is a trend or if there is a jump ?</u>
- <u>How can the ensemble help ?</u>

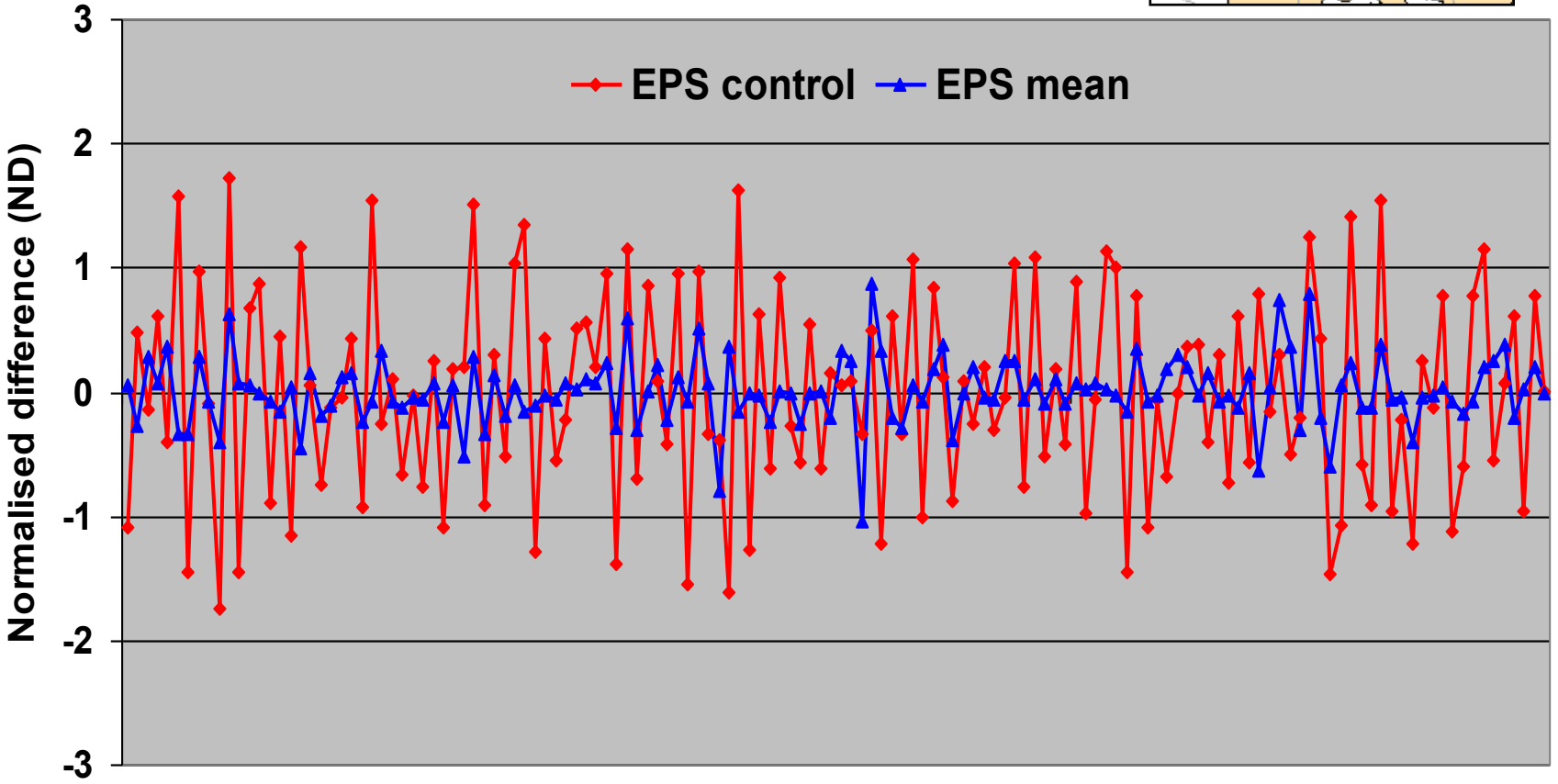
This topic has been studied in detail..

- Some results from:
  - Zsoter, Buizza and Richardson; *Monthly Weather Review*; 2009; "Jumpiness of the ECMWF and Met Office EPS Control and Ensemble-Mean Forecasts"

T+348 - T+360



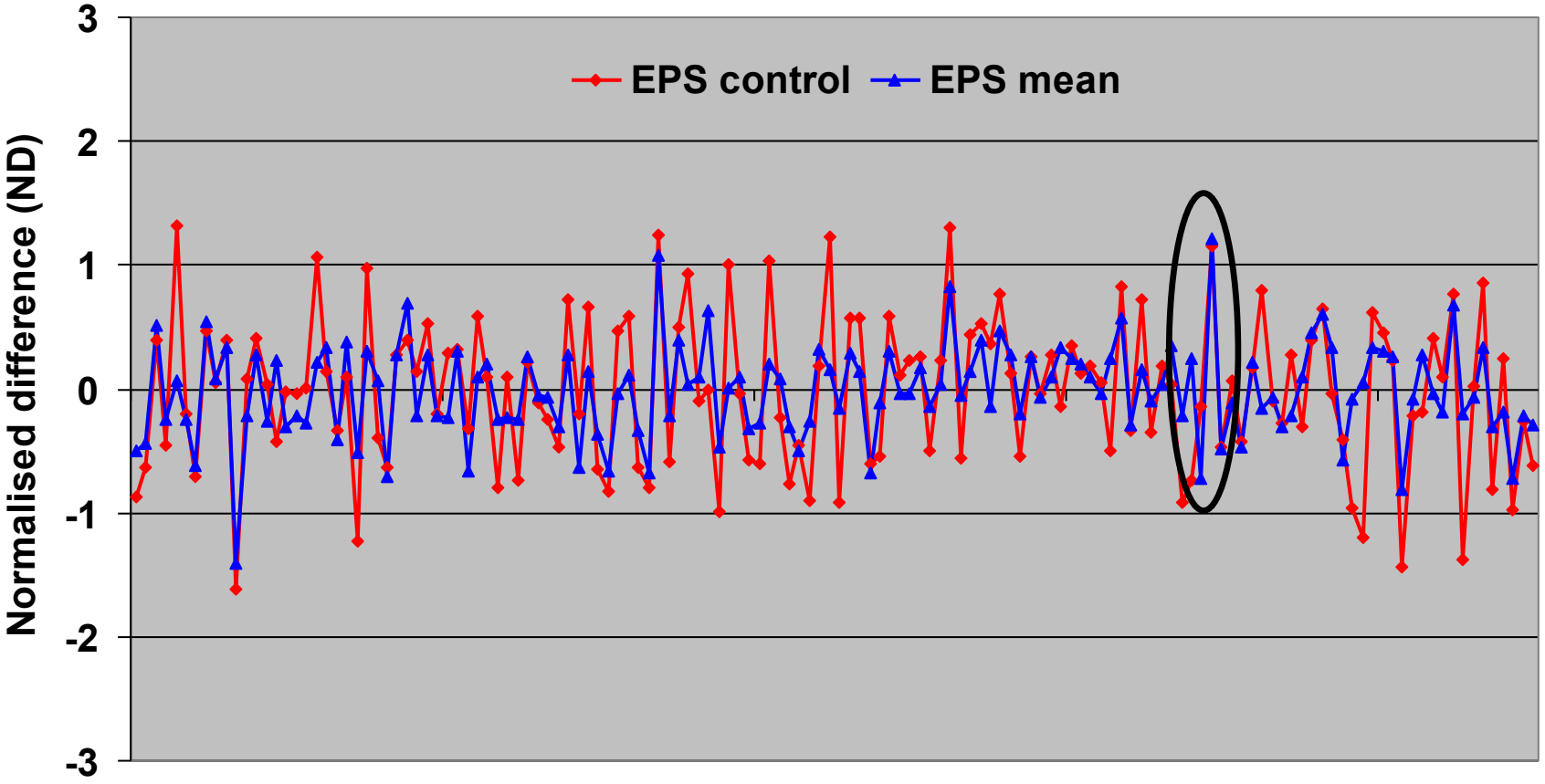
500mb ht. Area: [50N, 20W, 65N, 20E]
Period for plot : Jan/Feb 2008



Differences between two consecutive forecasts, for the same validity times

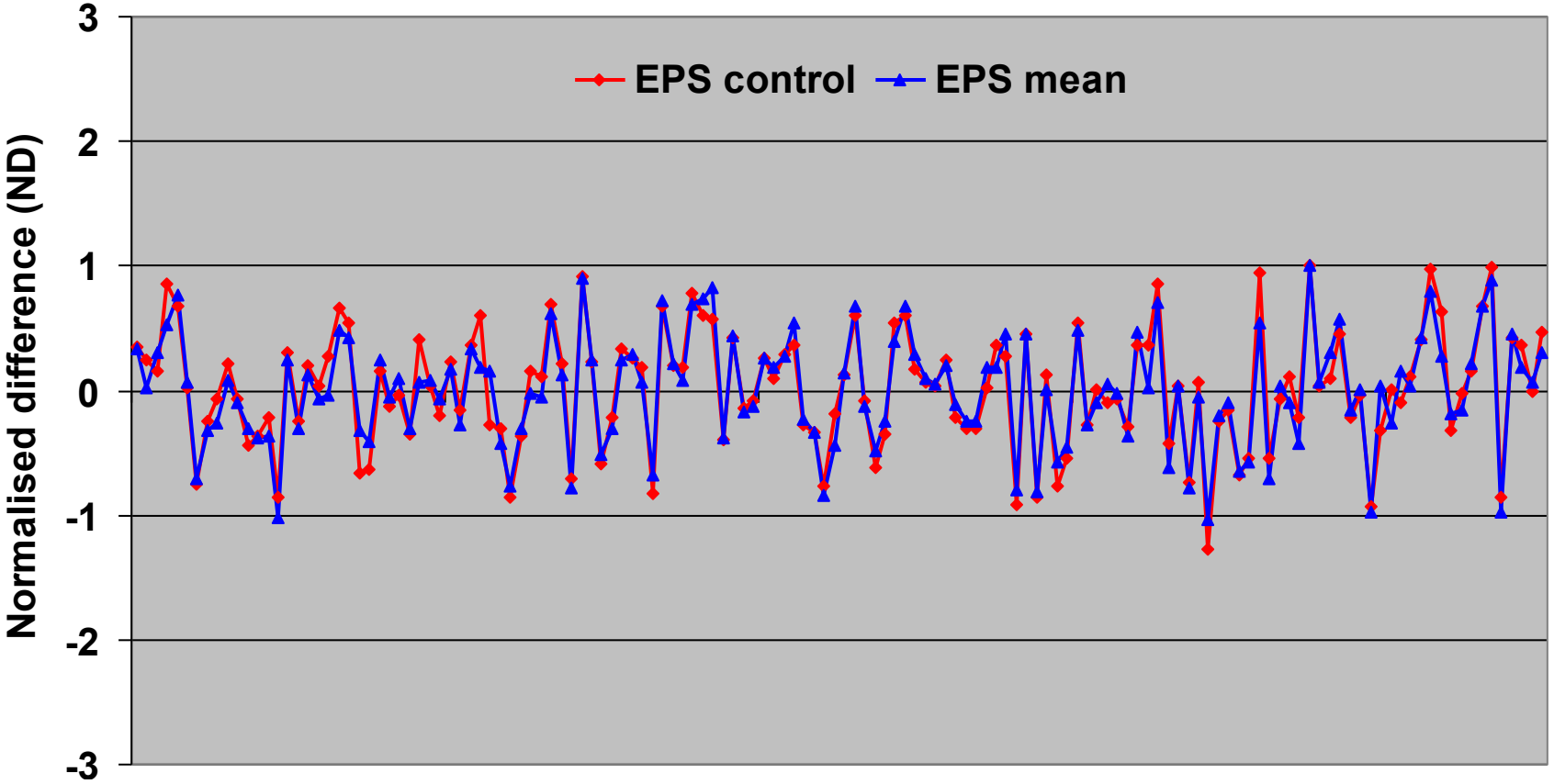
ECMWF

T+156 - T+168



Differences between two consecutive forecasts, for the same validity times

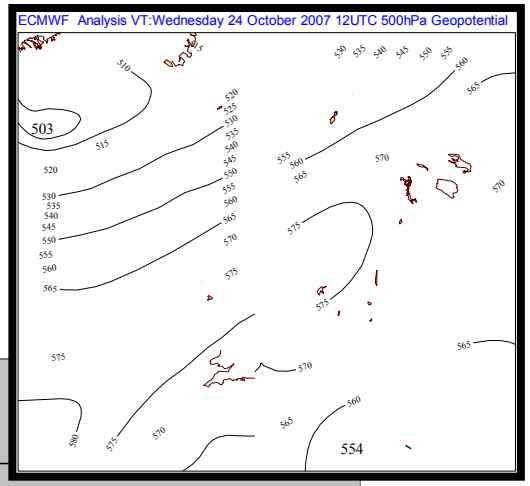
T+60 - T+72



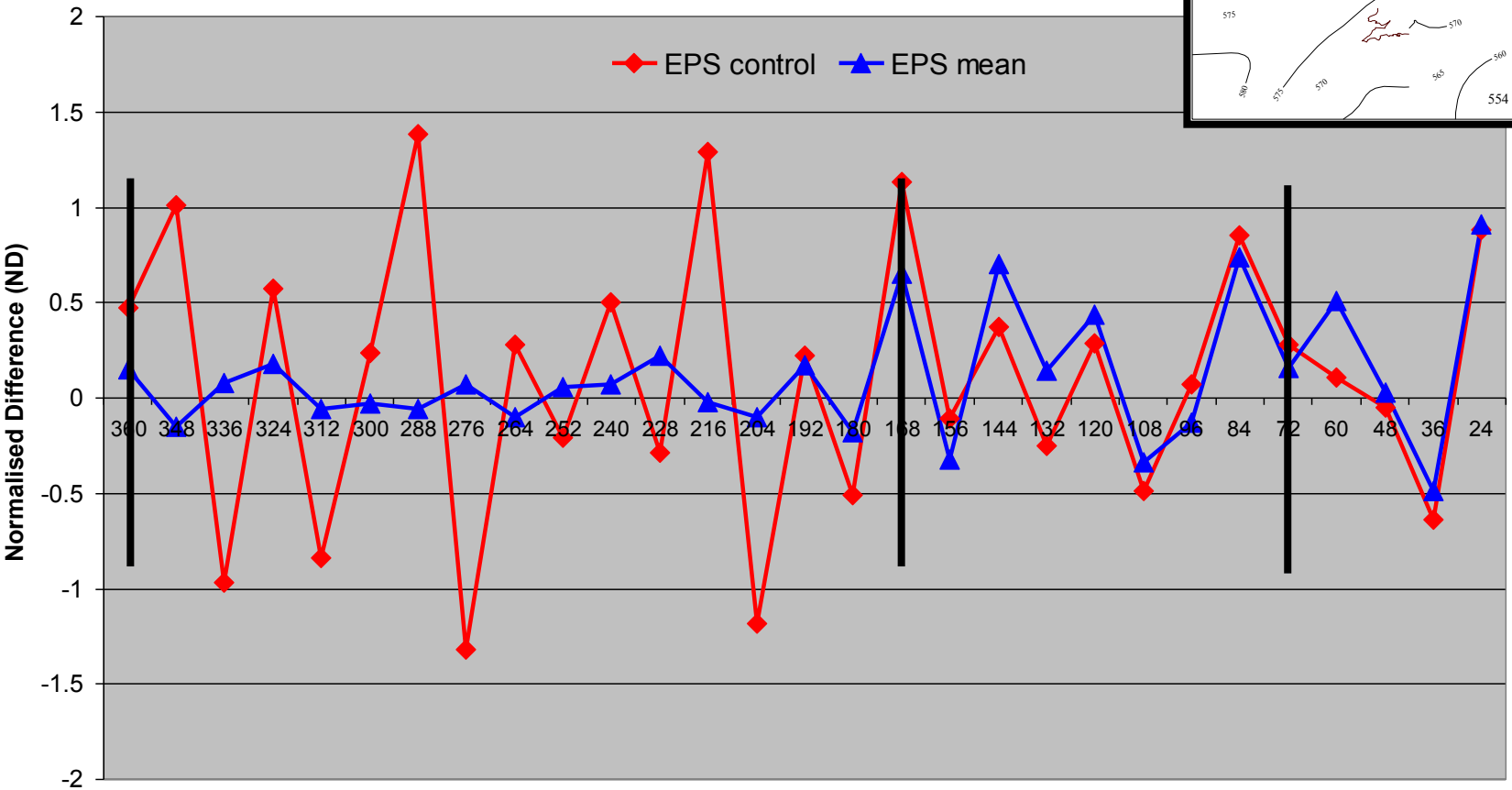
Differences between two consecutive forecasts, for the same validity times

CASE STUDY – I

Permanent ridge



Forecasts verifying on **<u>24 Oct 2007</u>**

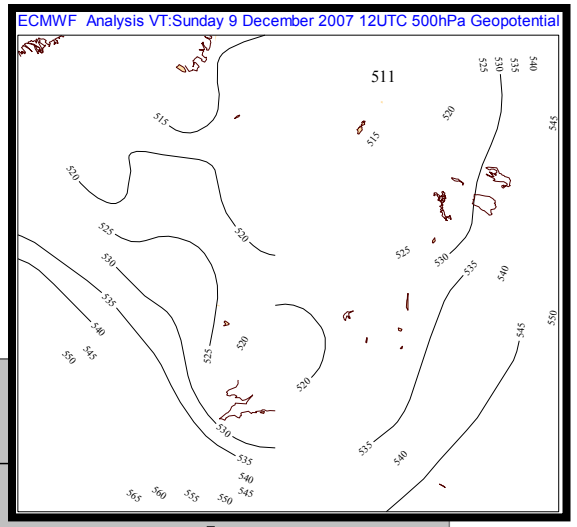


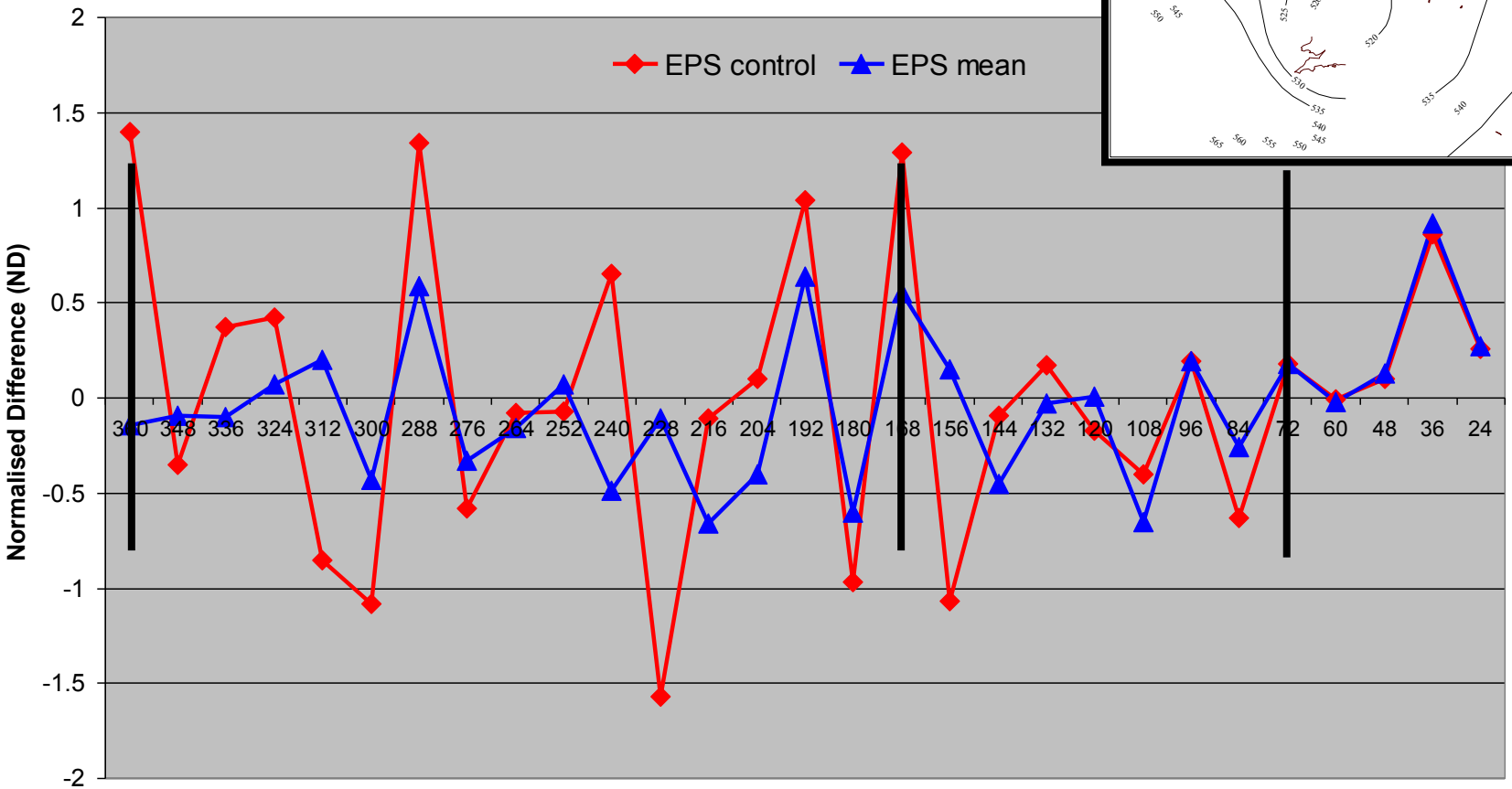
ECMWF

CASE STUDY – II

Intense low

Forecasts verifying on **9 Dec 2007**



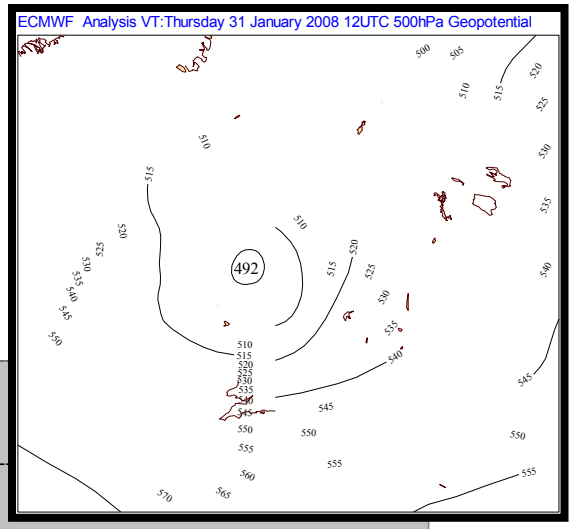


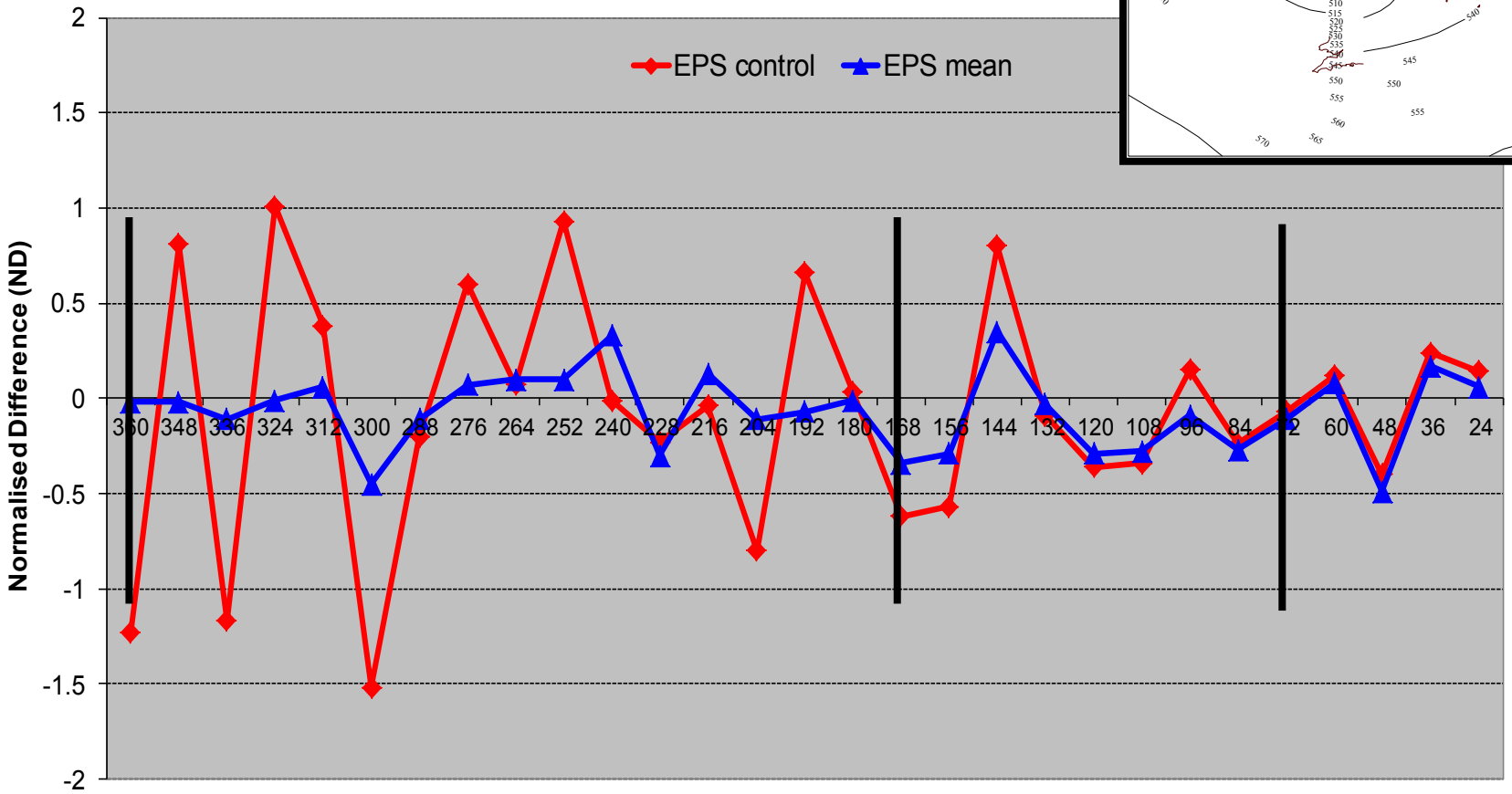
ECMWF

CASE STUDY – III

Very intense, fast moving cyclone

Forecasts verifying on **31 Jan 2008**





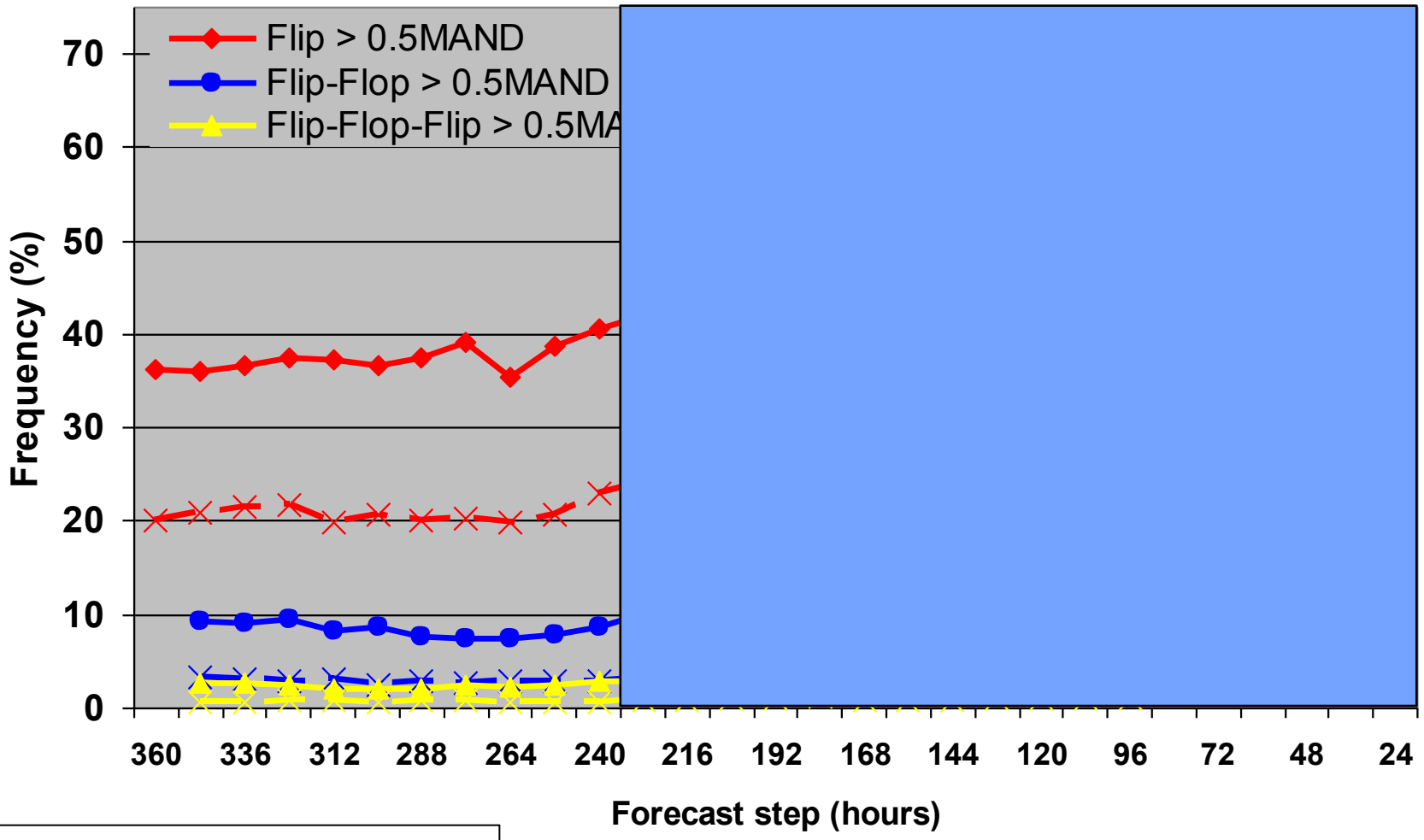
ECMWF

Lesson

- Make more use of the Ensemble mean, rather than the Control (or HRES)
- Especially at longer lead times (say ≥ ~ 4 days)
- Forecasts will then be less jumpy
- Beware however that strong gradients are always weakened in the ensemble mean

- At short lead times the picture is more complicated..

How often do the ENS mean and Control jump together?



Period 2007+, NW Europe

ECMWF

At short ranges…

- ENS Mean and Control tend to “jump together” more often
- This makes the strategy of following the ENS mean, rather than Control or HRES, less beneficial
- Though it is probably still advantageous

An explanation

- The behaviour we see at both short and long ranges seems to be an inevitable (and necessary) consequence of ensemble design
- Perturbations, *positive and negative*, spread the ensemble forecasts either side of the Control early on, so any jumps in Control (and HRES) will likely be reflected in ENS also (at time zero ENS mean = Control)
- Later on in the forecast non-linearity becomes more important, and so the ENS members are less of a slave to the Control (and HRES), making the forecasting strategy of following the ENS mean (with the usual caveats) result in a less jumpy and more reliable forecast, on average

Should we be more cautious about following a jumpy forecast ?

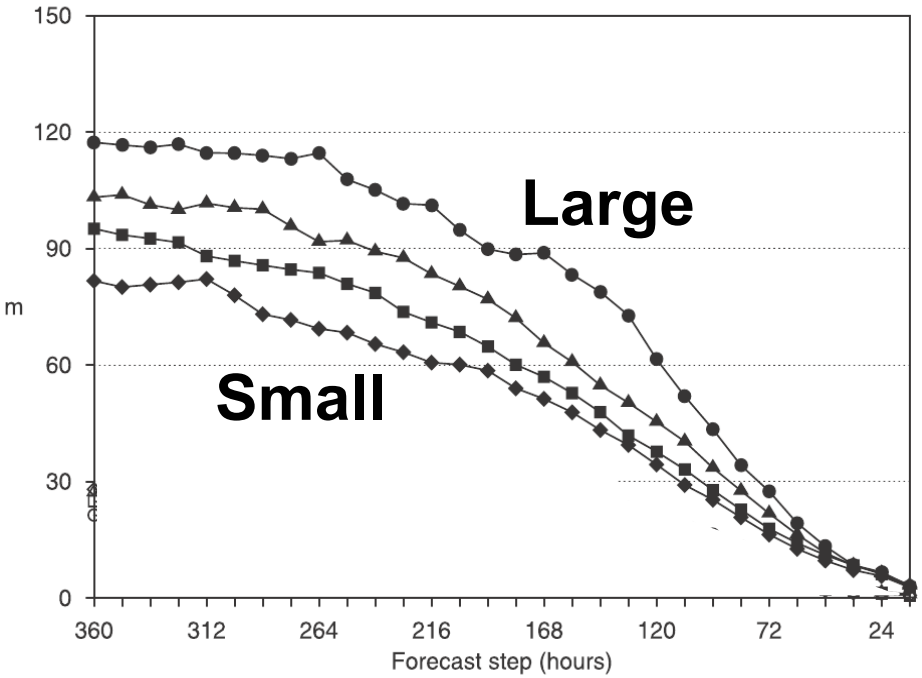
- From a psychological and customer perspective, we don't want to give out forecasts that jump around
- But at the same time it is likely that in absolute terms forecasts that *don't* get adjusted whenever there is a jump will average out to be more accurate in the long term
- Remember that, strictly, flip-flops occur half the time!
- We have seen that we should not extrapolate a trend, but nor should we revert back if we see a jump
- This is a difficult area, affected by customer perception…

- So is there any evidence to say that jumpiness means forecasts are likely to be less accurate?

Jumpiness/Spread relationship

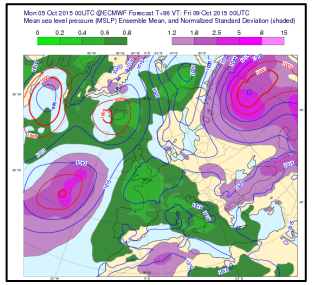
Error statistics for Z500 for NW Europe
- Error of the most recent forecast..

"Small", "Small-medium", "Medium-large" and "Large" spread



ECMWF

Errors



- The average error of the ENS mean relates quite strongly to the absolute spread in the ensemble, as one would hope and expect. Larger spread implies larger errors, on average.
- However errors show only a very weak dependance on whether or not the ensemble mean forecast has been jumpy

So is there any evidence to say that jumpiness means forecasts are likely to be less accurate?

No, not really

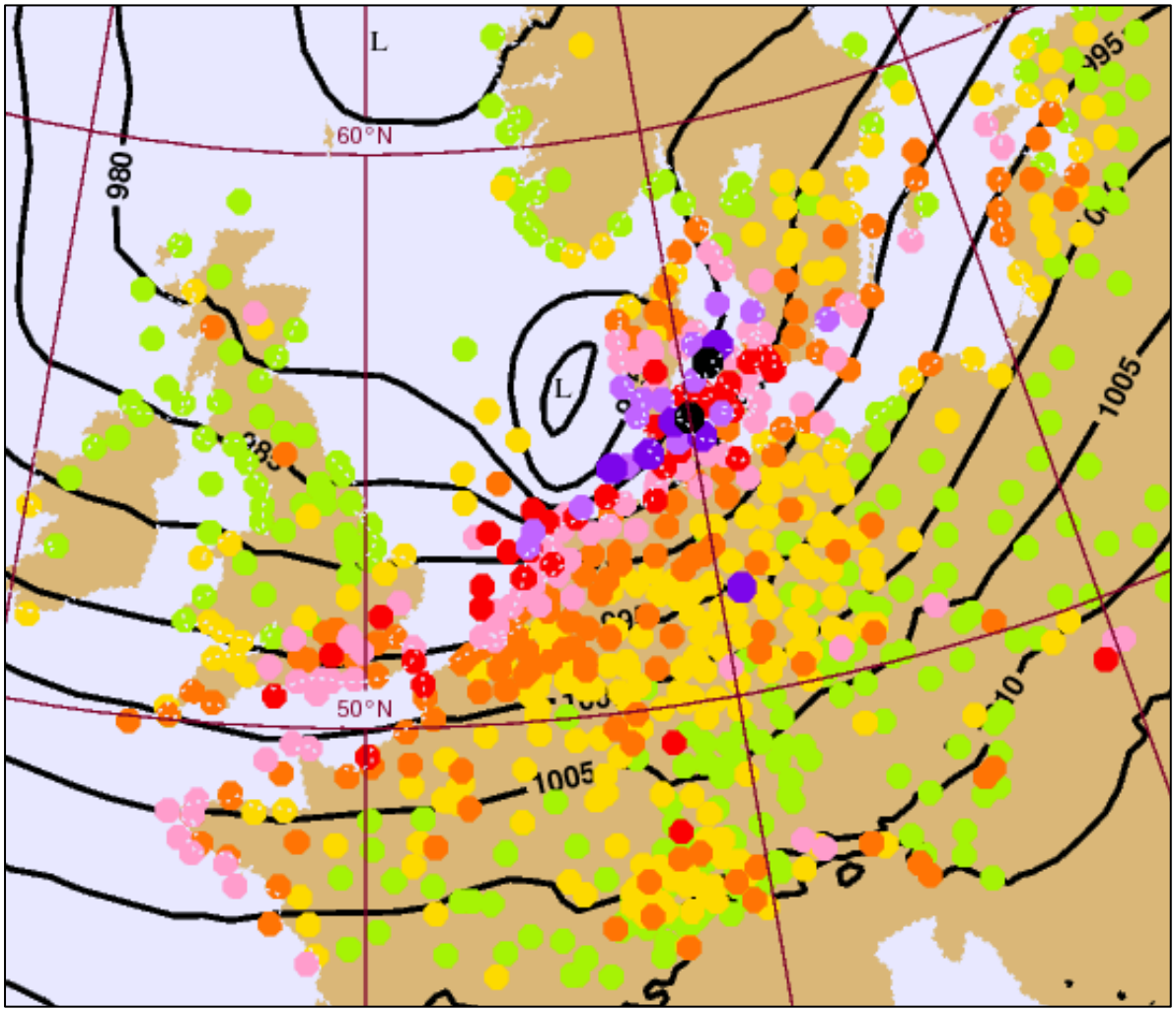
Think back to the exercise at the beginning –
did you use the same strategy for the jumpy forecasts?

Dynamical sensitivities = extra jumpiness?

- Should we expect more jumps in potential severe weather situations, at *short lead times*, because of 'dynamical sensitivity' ?
- By dynamical sensitivity we mean 'finely balanced' situations, where slight changes can have a big impact:
  - eg – precise phasing of upper and lower levels needed for explosive cyclogenesis
  - eg – high precipitation intensities can turn rain into (surprise) snow, due to cooling through melting
- Illustrate, briefly, with a windstorm example (Christian, St Jude: 28 October 2013)

Further discussed in ECMWF Newsletter Spring 2014

Windstorm ‘St Jude’ / ‘Christian’

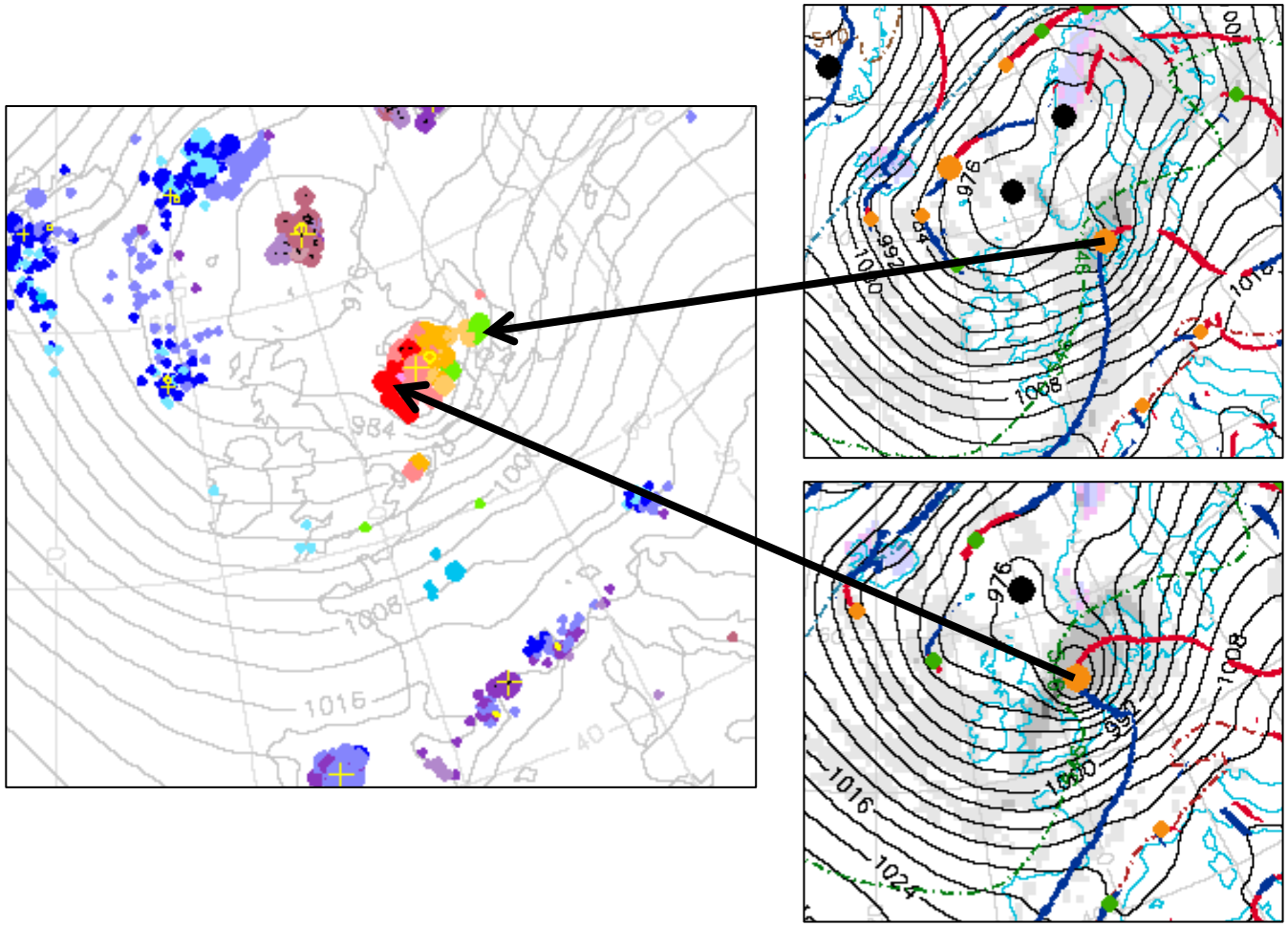


MAX GUSTS

m/s

ECMWF

36h forecast for “Christian” – Valid 12UTC Oct 28th 2013

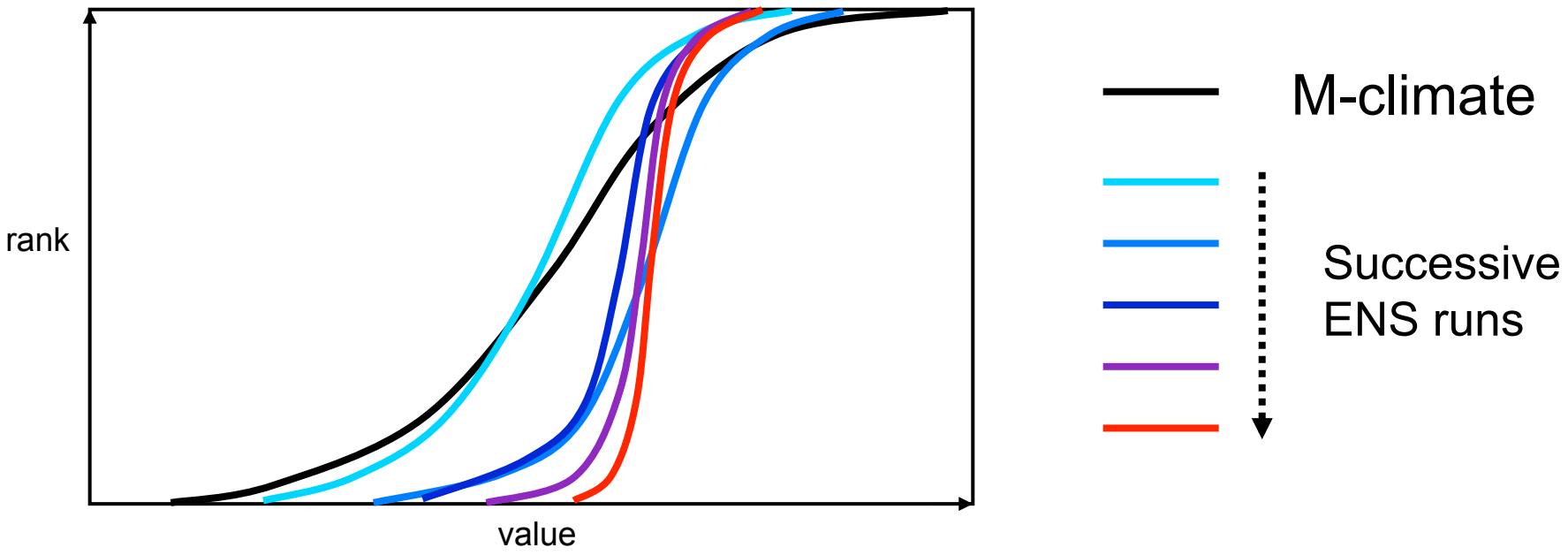


Large spread
=
Large uncertainty

Is this OK at short lead times ?

ECMWF

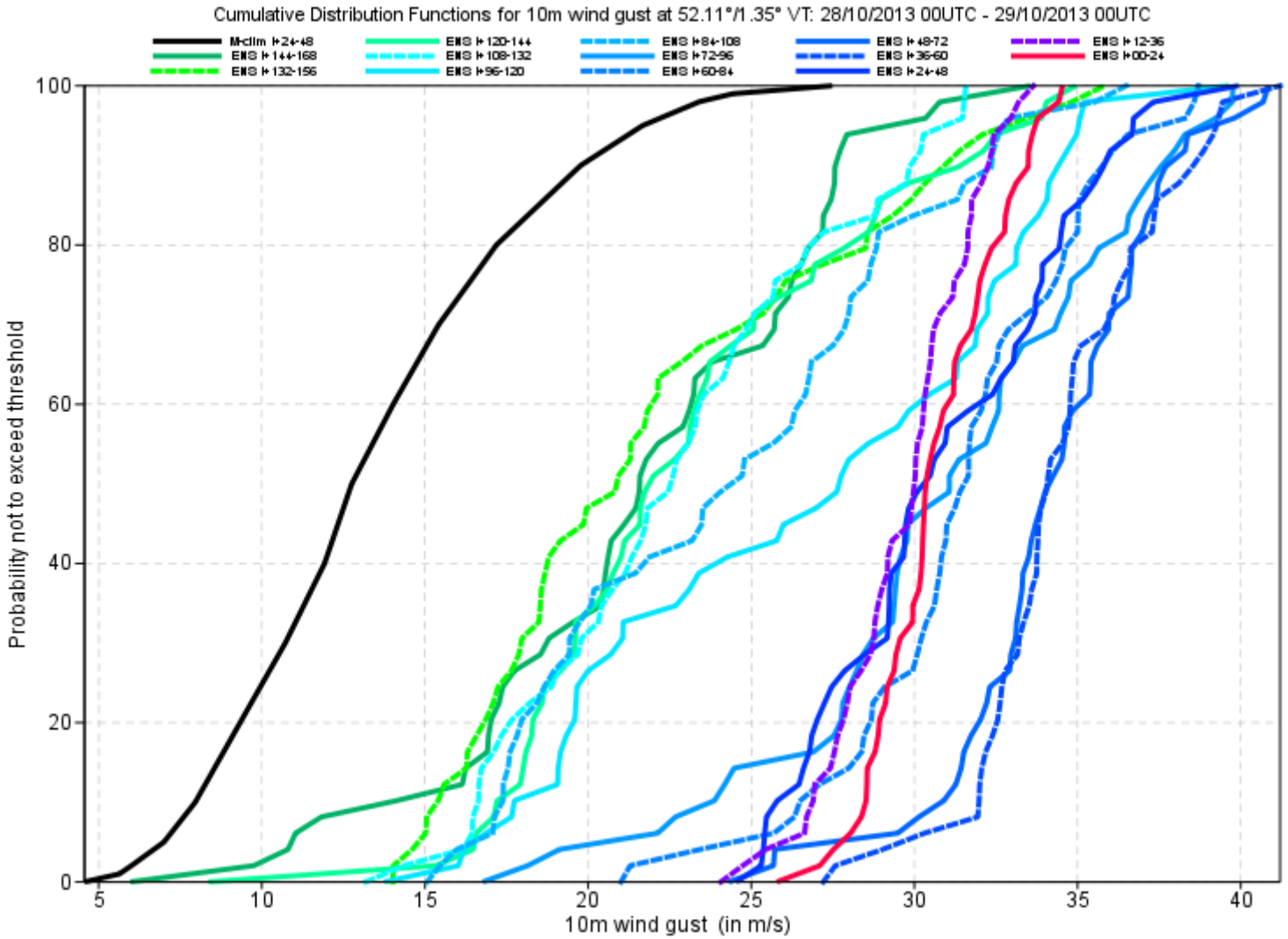
How ‘should’ CDFs behave in successive ENS runs?



- At long lead times forecast CDF may be similar to the M-climate.
- Lateral variations in CDF position between successive runs should, mostly, become less (with time).
- CDF will tend to become steeper (with time), implying higher confidence.

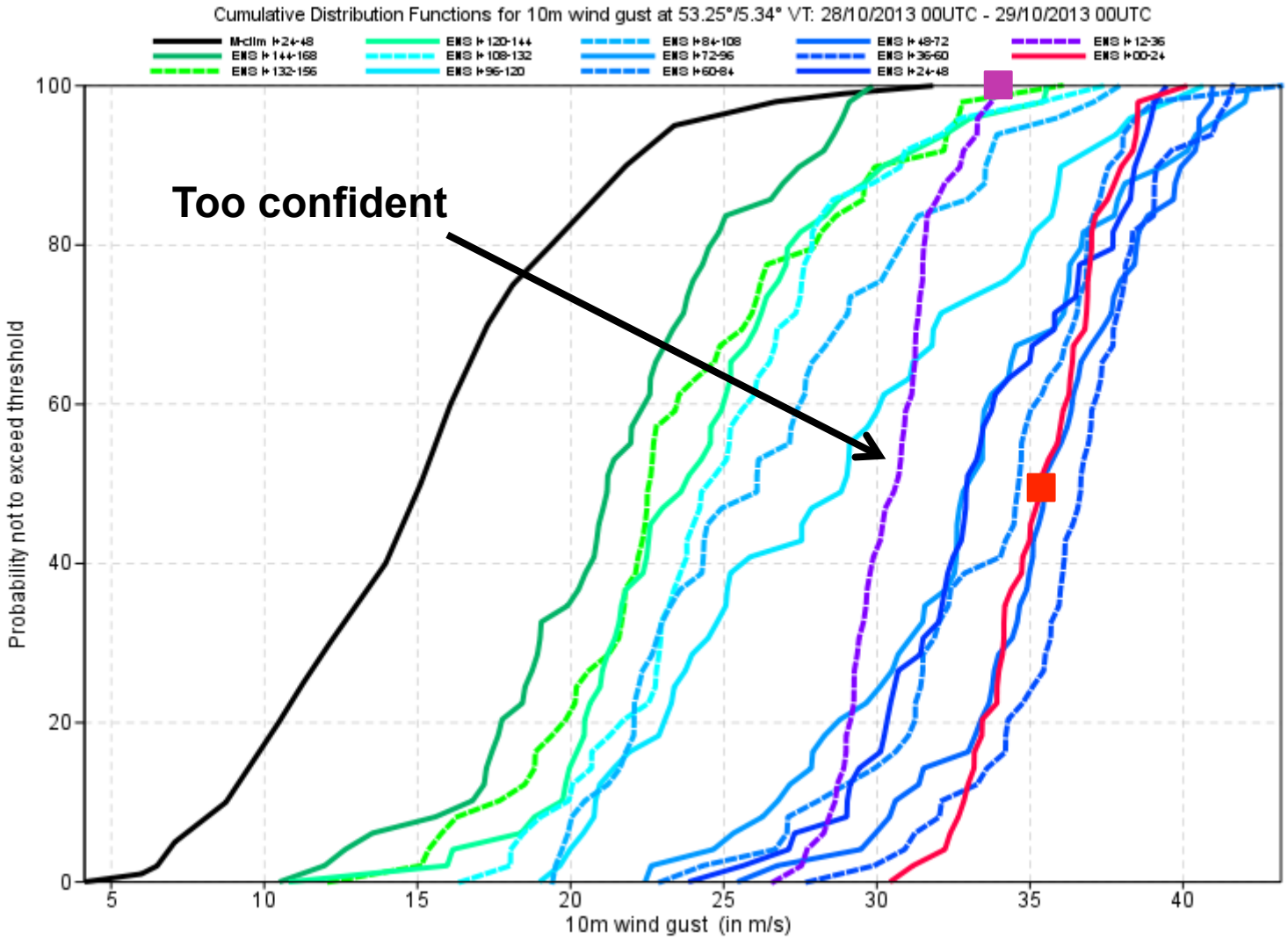
Wind Gust CDFs - E England

OK!



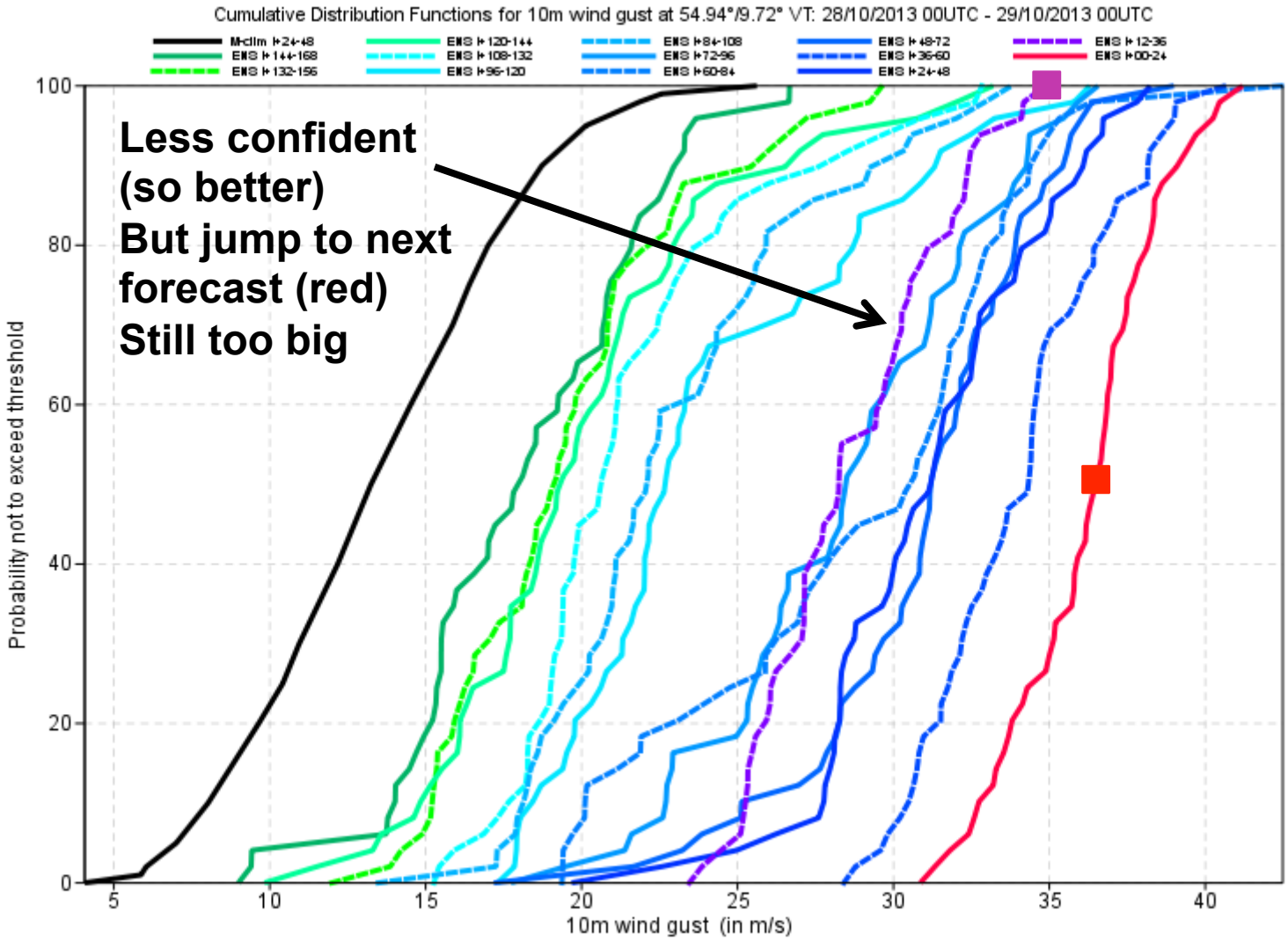
ECMWF

Wind Gust CDFs - Netherlands



ECMWF

Wind Gust CDFs - Denmark



ECMWF

What can we learn?

- Spread was high (eg from Dalmatian chart, but also other measures)
  - So this highlights uncertainty

- BUT, from the CDFs, it seems that for this case the spread was probably not great enough (using a simple metric of “median > extreme of previous forecast”)

- The fine scale nature (sting jet?) and small lateral extent of the very strong winds was probably pushing the IFS to its limits!

Conclusions

- Jumpiness is not a good indicator of likely error, but spread is
- We have to expect some jumpiness, otherwise there would be something intrinsically wrong with the forecasting system
- There are however probably too many jumps, in general, which probably relates to a (slight) lack of spread in the ensemble system
- The fact that the ENS mean and Control (or HRES) jump together more at short ranges is very probably due to ensemble design
- Customer aversion to jumpy forecasts is a very difficult hurdle to overcome; however broadly following the ensemble mean pattern, particularly at longer ranges, will help
- Dynamical sensitivity – related for example to strong jets - can unfortunately increase jumpy behaviour at short ranges in severe weather situations – beware!

A note on assimilation...and forecast trends

- Before 4D-Var, or even 3D-Var, numerical models were less responsive, in general, to observations
- As a result they were sometimes playing catch up
- This made trends more likely, and jumps less likely (?)
- It also meant that there could actually be merit in extrapolating a trend

- Now that we have 4D-Var, and indeed EDA (ensemble of data assimilations), this is no longer the case
- One could even argue that the word ‘trend’ is inappropriate
- Phrases such as ‘the forecasts are moving towards a less cyclonic outcome’ are entirely inappropriate, because they implant ‘trend extrapolation’ into the mind of the customer

Recent and Future developments

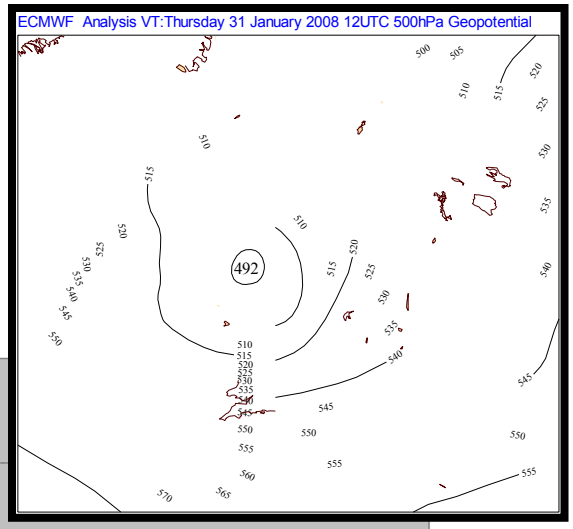
- Land surface analysis perturbations
- More use of EDA..
- Stochastic physics enhancements..
- Ocean coupling from day 0 (SSTs differ between runs)

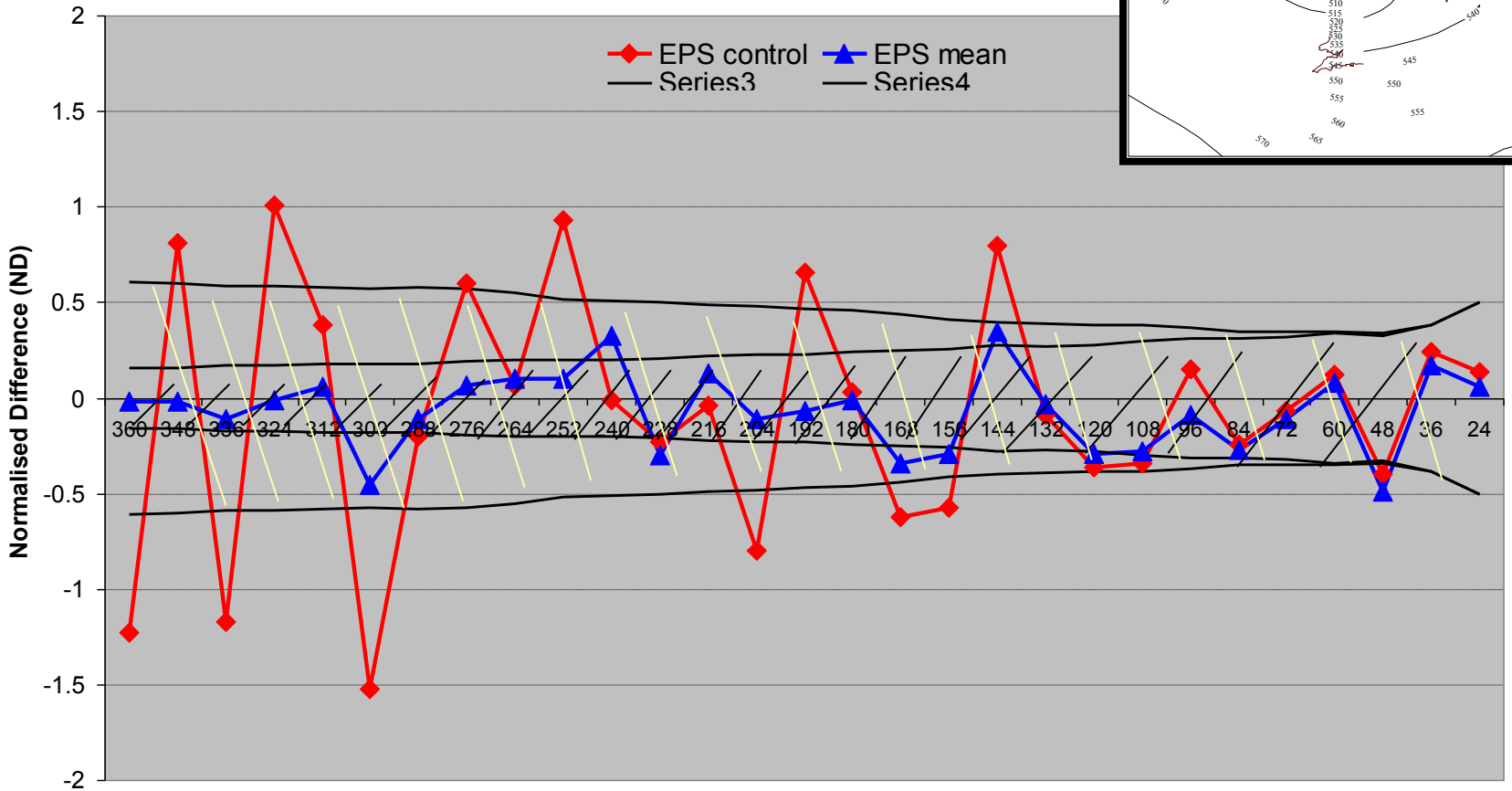
- All designed to improve the quality of the ensemble
  - Should reduce jumpiness

CASE STUDY – III

Very intense, fast moving cyclone

Forecasts verifying on **31 Jan 2008**





ECMWF