# Forecast Inconsistencies

How often do forecast jumps occur in the models?

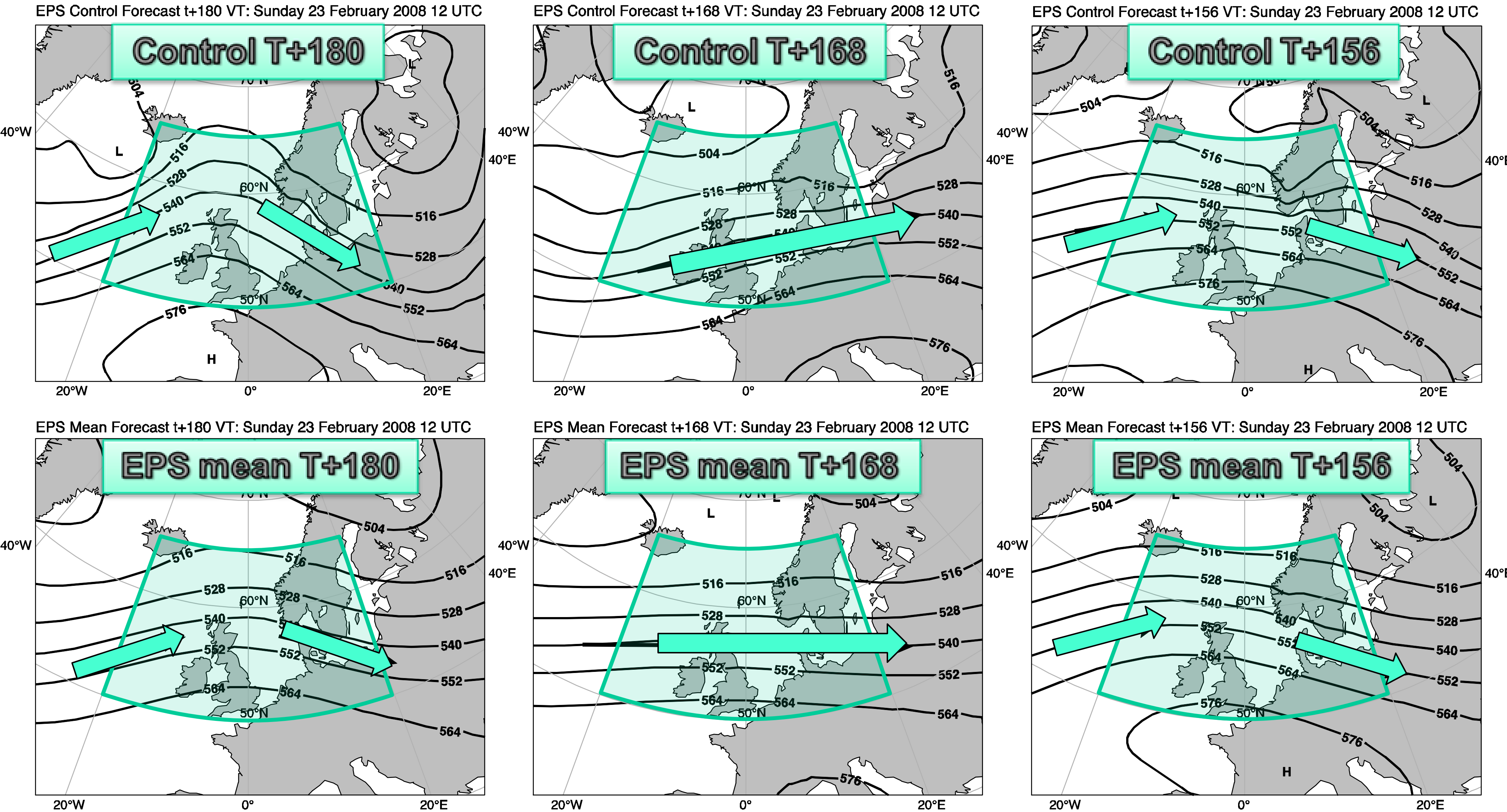
***Ervin Zsoter*** *(Hungarian Meteorological Service)*

*In collaboration with* ***Roberto Buizza*** *&* ***David Richardson*** *(ECMWF)*

# Outline

- Introduction – case study of a jumpy forecast period
- The inconsistency measures and the experiments
- Different inconsistency statistics
- Relationship between forecast jumps and forecast error
- Summary

# A prominent example – 20080223 12 UTC

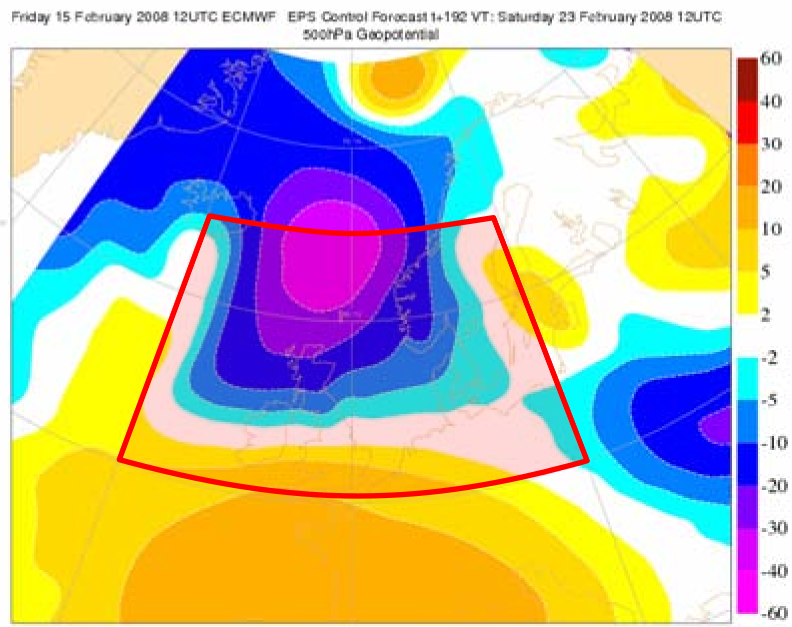



All Z500 forecasts verifying at 20080223 12 UTC

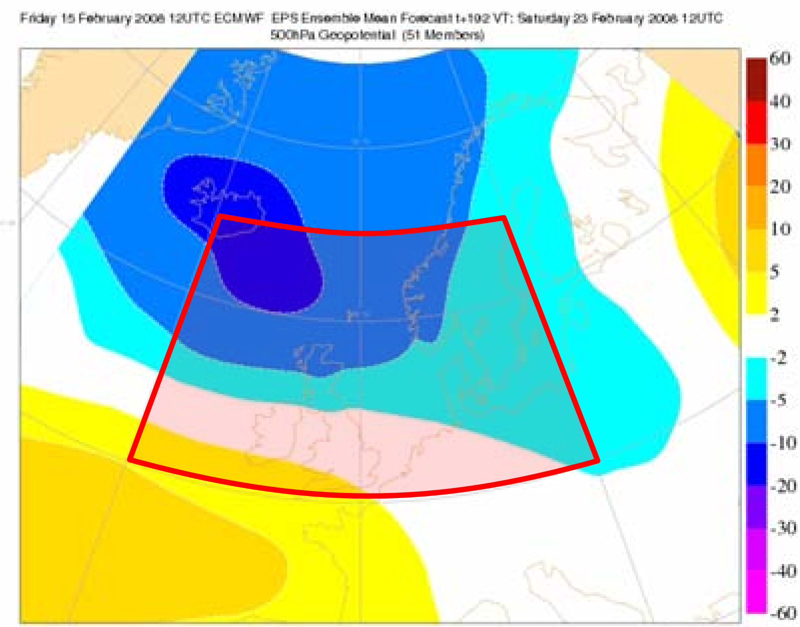
# A prominent example – 20080223 12 UTC

Difference of consecutive Z500 forecasts verifying
on 20080223 12 UTC

**T+192 – T+204**




**EPS Control**




**EPS Mean**

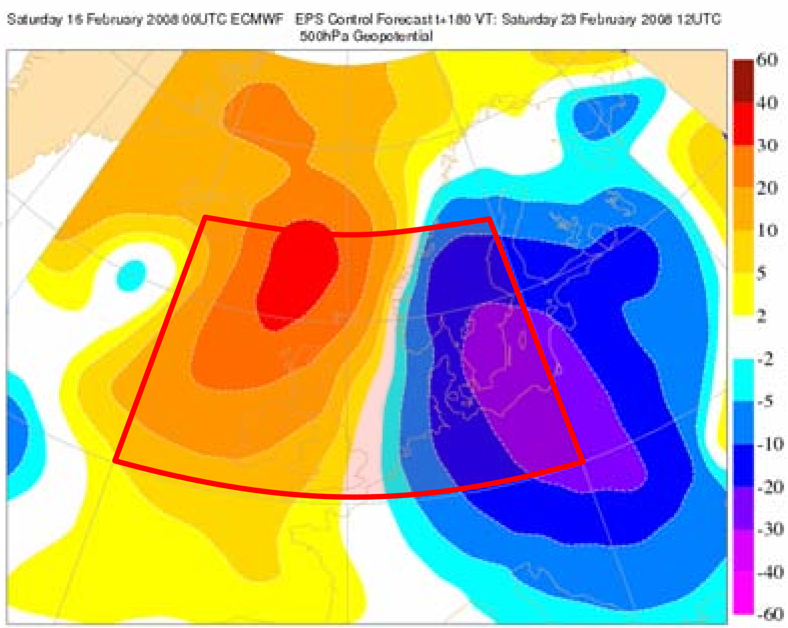


OMSZ

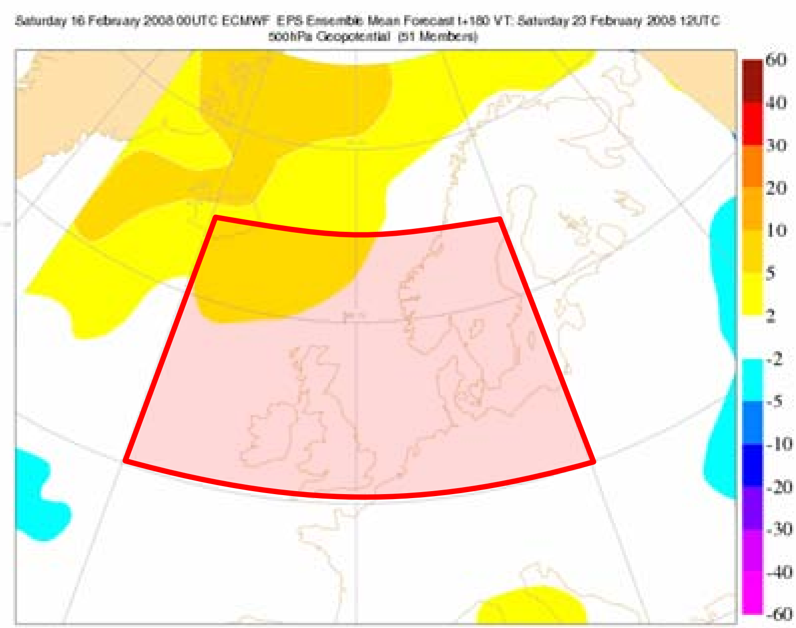
# A prominent example – 20080223 12 UTC

Difference of consecutive Z500 forecasts verifying on 20080223 12 UTC

T+180 – T+192




EPS Control

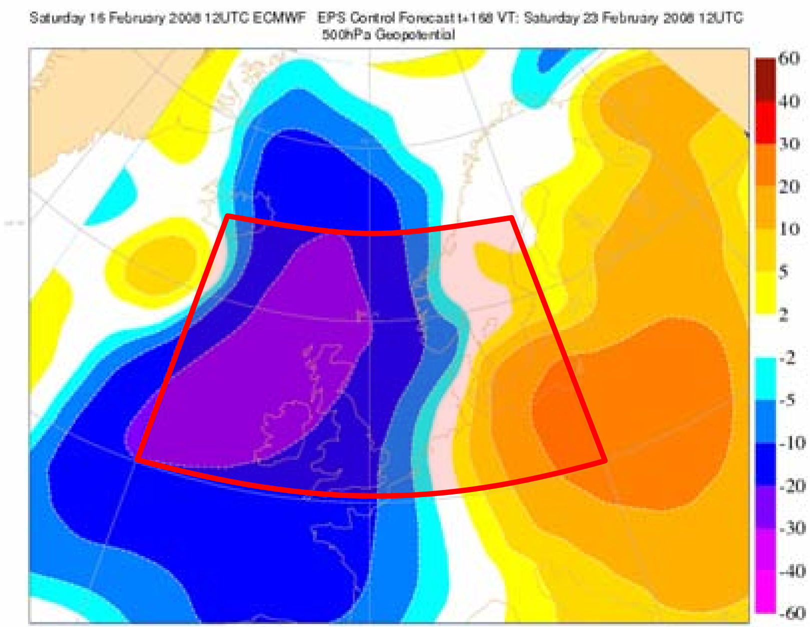



EPS Mean

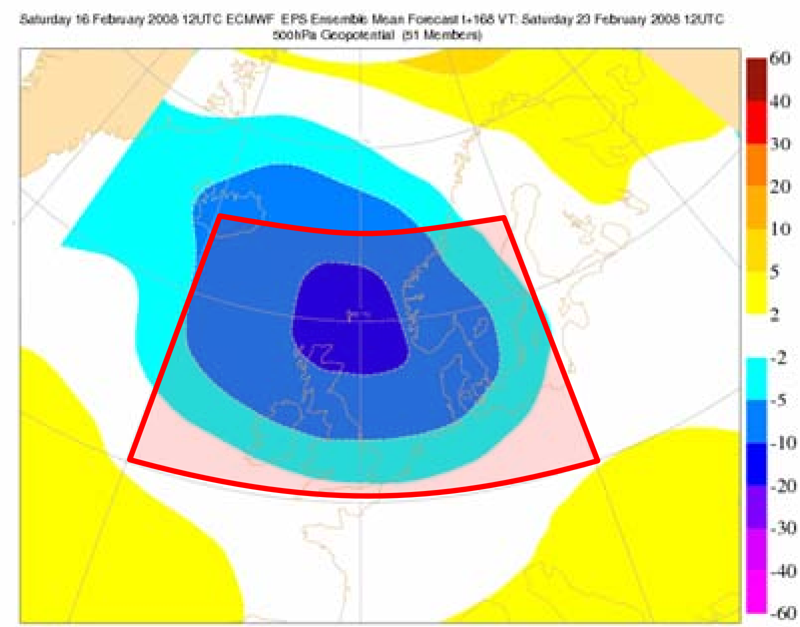
# A prominent example – 20080223 12 UTC

Difference of consecutive Z500 forecasts verifying on 20080223 12 UTC

**T+168 – T+180**




**EPS Control**

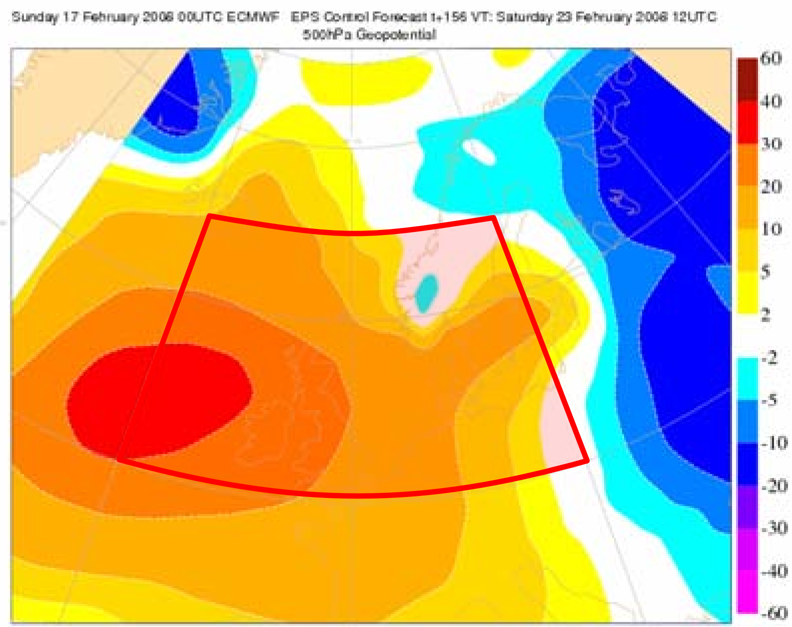



**EPS Mean**

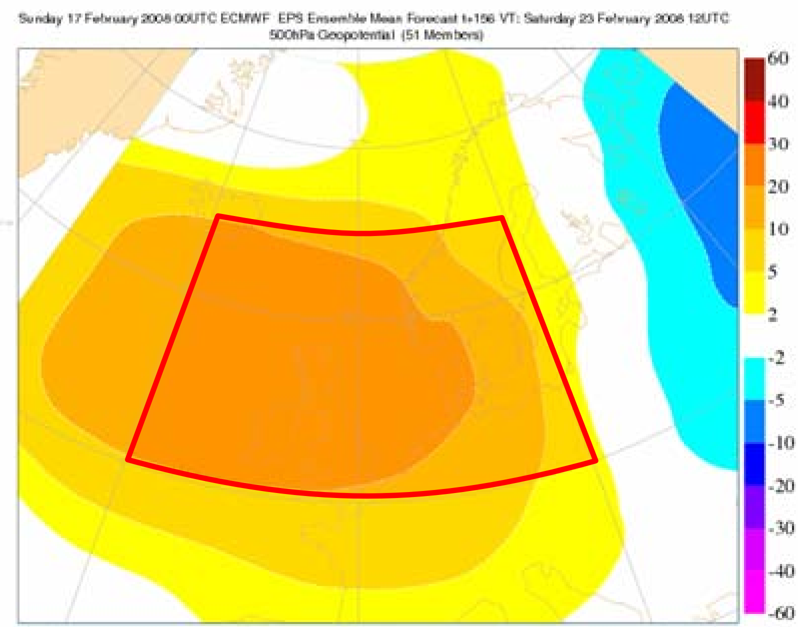
# A prominent example – 20080223 12 UTC

## Difference of consecutive Z500 forecasts verifying on 20080223 12 UTC

**T+156 – T+168**




**EPS Control**

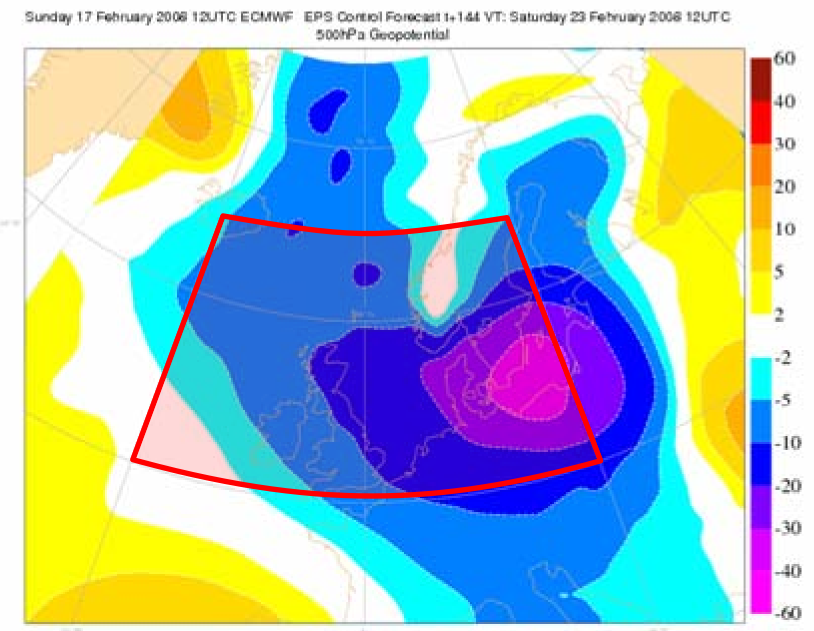



**EPS Mean**

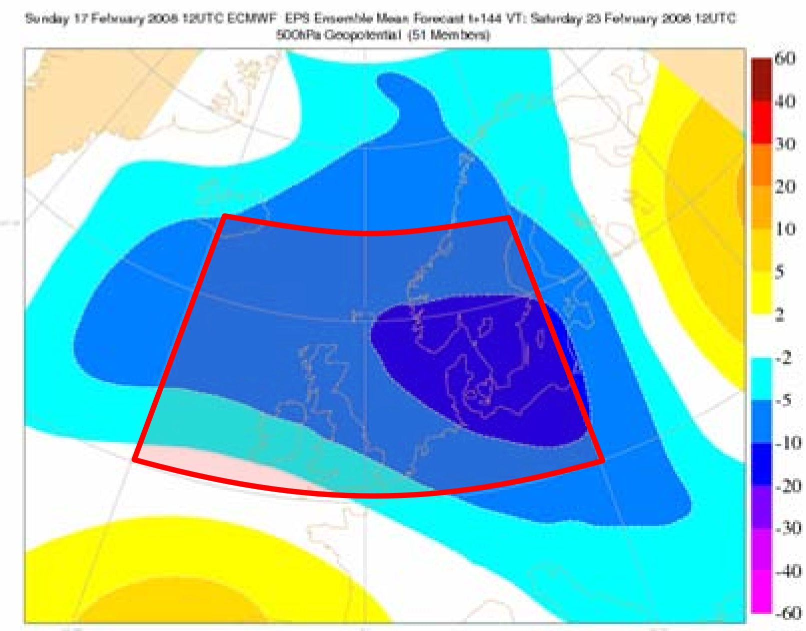
# A prominent example – 20080223 12 UTC

## Difference of consecutive Z500 forecasts verifying on 20080223 12 UTC

**T+144 – T+156**




**EPS Control**

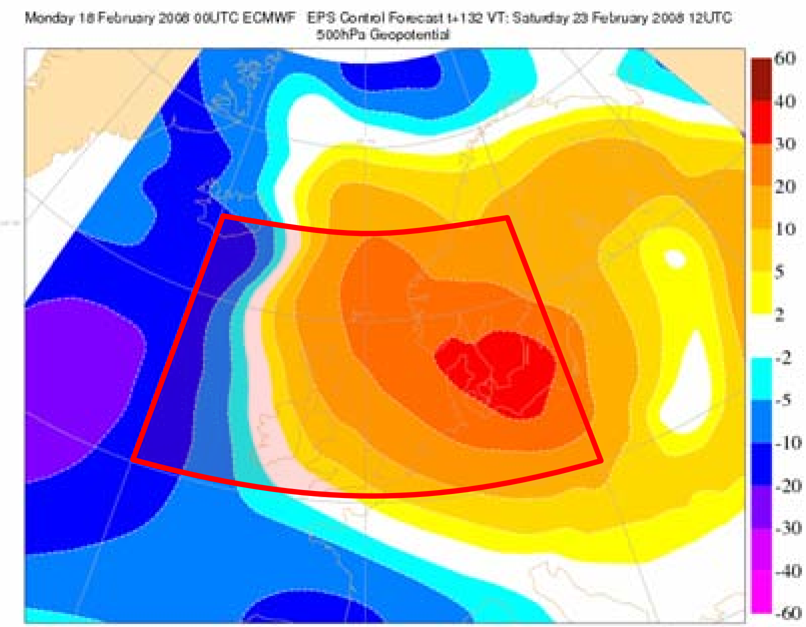



**EPS Mean**

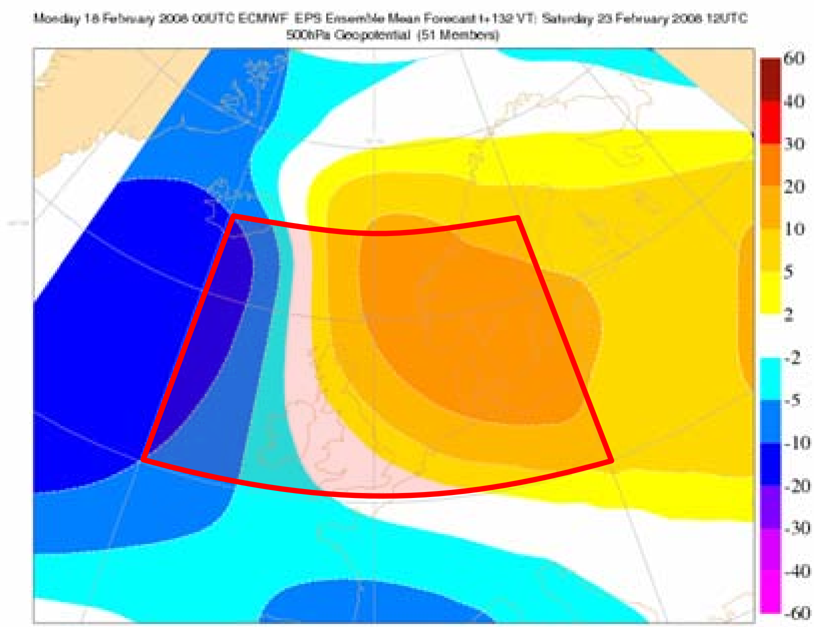
# A prominent example – 20080223 12 UTC

Difference of consecutive Z500 forecasts verifying
on 20080223 12 UTC

**T+132 – T+144**



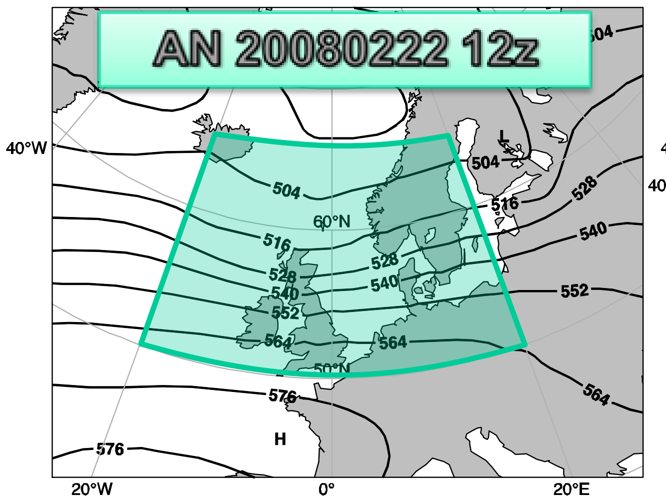

**EPS Control**



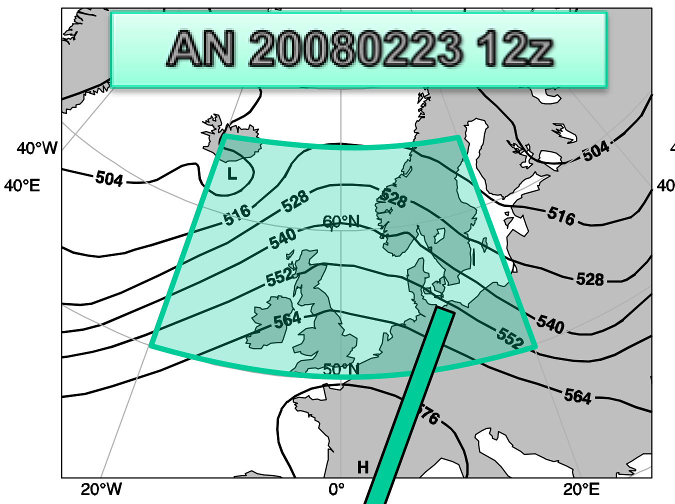

**EPS Mean**

# A prominent example – 20080223 12 UTC

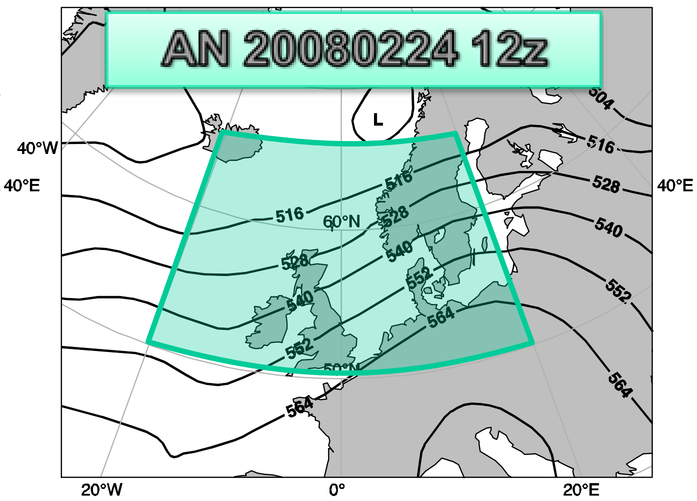
500hPa Geopotential Analysis VT: Saturday 22 February 2008 12 UTC

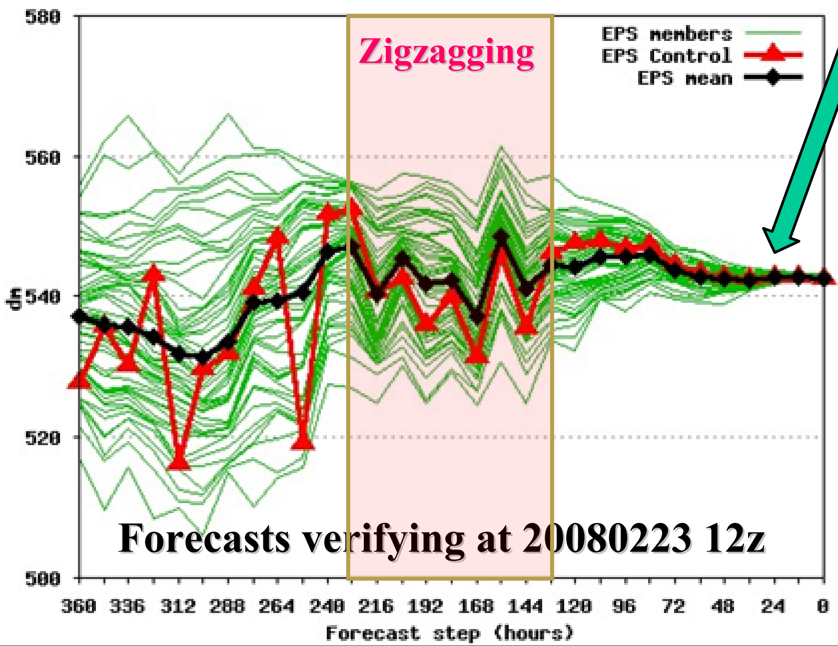



500hPa Geopotential Analysis VT: Sunday 23 February 2008 12 UTC

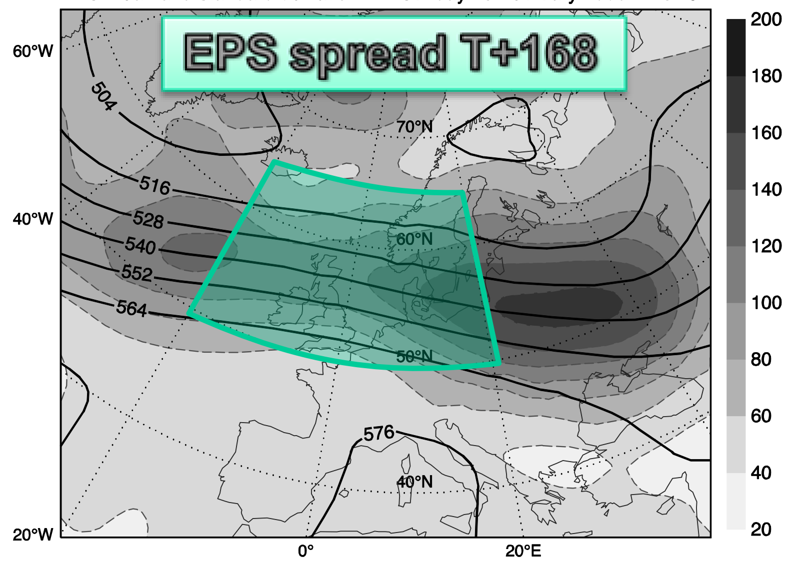



500hPa Geopotential Analysis VT: Monday 24 February 2008 12 UTC

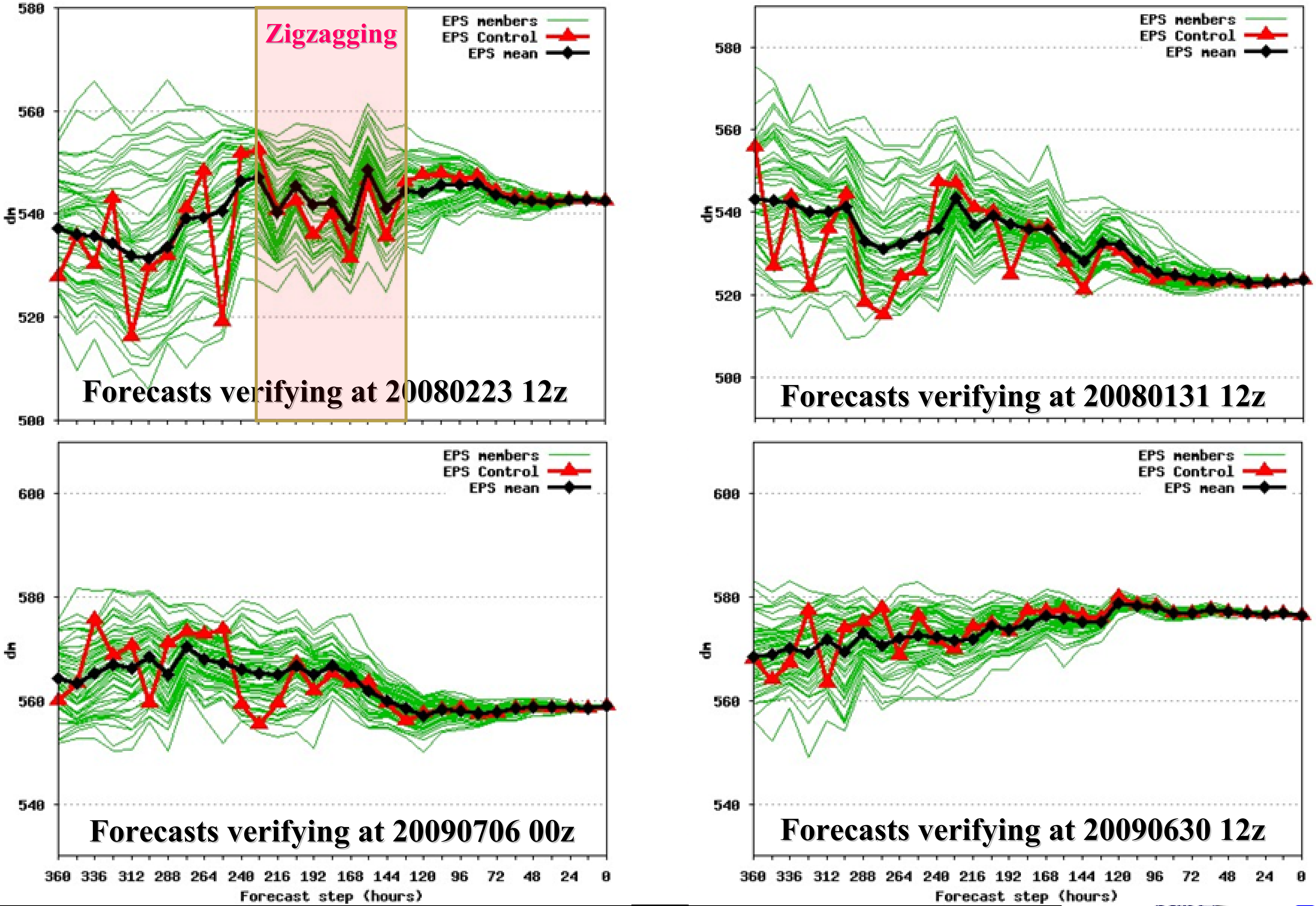



EPS mean and standard deviation VT: Sunday 23 February 2008 12 UTC



# Other examples



# Questions for answering

• How do the EPS-mean forecasts (representing the whole EPS distribution) and the single forecasts (high resolution deterministic & EPS-control) relate in terms of day-to-day consistency/inconsistency ?

• If the EPS-control forecast jumps, how closely does the EPS-mean forecast follow the control forecast ?

• What is the relationship between forecast jumps and forecast error ?

# Framework of the forecast inconsistency experiments

• We have investigated the behaviour of the EPS control vrs. EPS mean regarding day-to-day consistency based on the operational ECMWF and Met Office EPS forecasts for the period of February 2007 to August 2009 (~ 2.5 years).

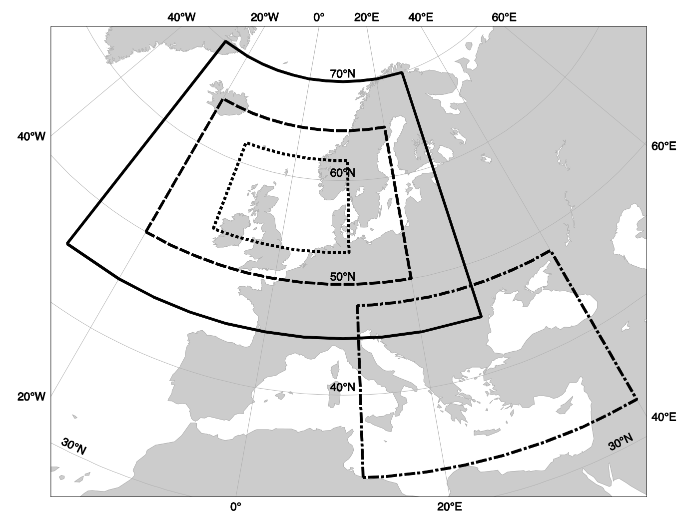
• The inconsistency indices were computed based on consecutive (12 and 24-hour apart) runs all verifying at the same date. Forecasts starting at 00z and 12z were also considered. We processed all possible forecast ranges from T+0 (compared with T+12) to T+348 (compared with T+360).

• The inconsistency behaviour was investigated on 4 parameters: z500, z1000, t500 and t850.

• The inconsistency between two forecasts was computed for an area based on the grid point values inside the area, using a unified 1*1 degree grid.

• We used four areas to asses the sensitivity of the inconsistency indices to the area.

• Seasonal and annual differences were also investigated.



# Inconsistency Index

• For two forecasts (*f(d,t)* with run date *d* and forecast step *t*), $\delta$-hour apart, verifying on the same date ($d+t$), over an area ($\Sigma$):

$$INX_{\Sigma}[f(d,t),\delta]=\frac{d_{\Sigma}[f(d,t),f(d-\delta,t+\delta)]}{0.5\{std_{\Sigma}[f(d,t)]+std_{\Sigma}[f(d-\delta,t+\delta)]\}}$$

difference between the two fields, averaged over the area ($\Sigma$)

Average of the standard deviations of the values in the two fields inside the area ($\Sigma$)

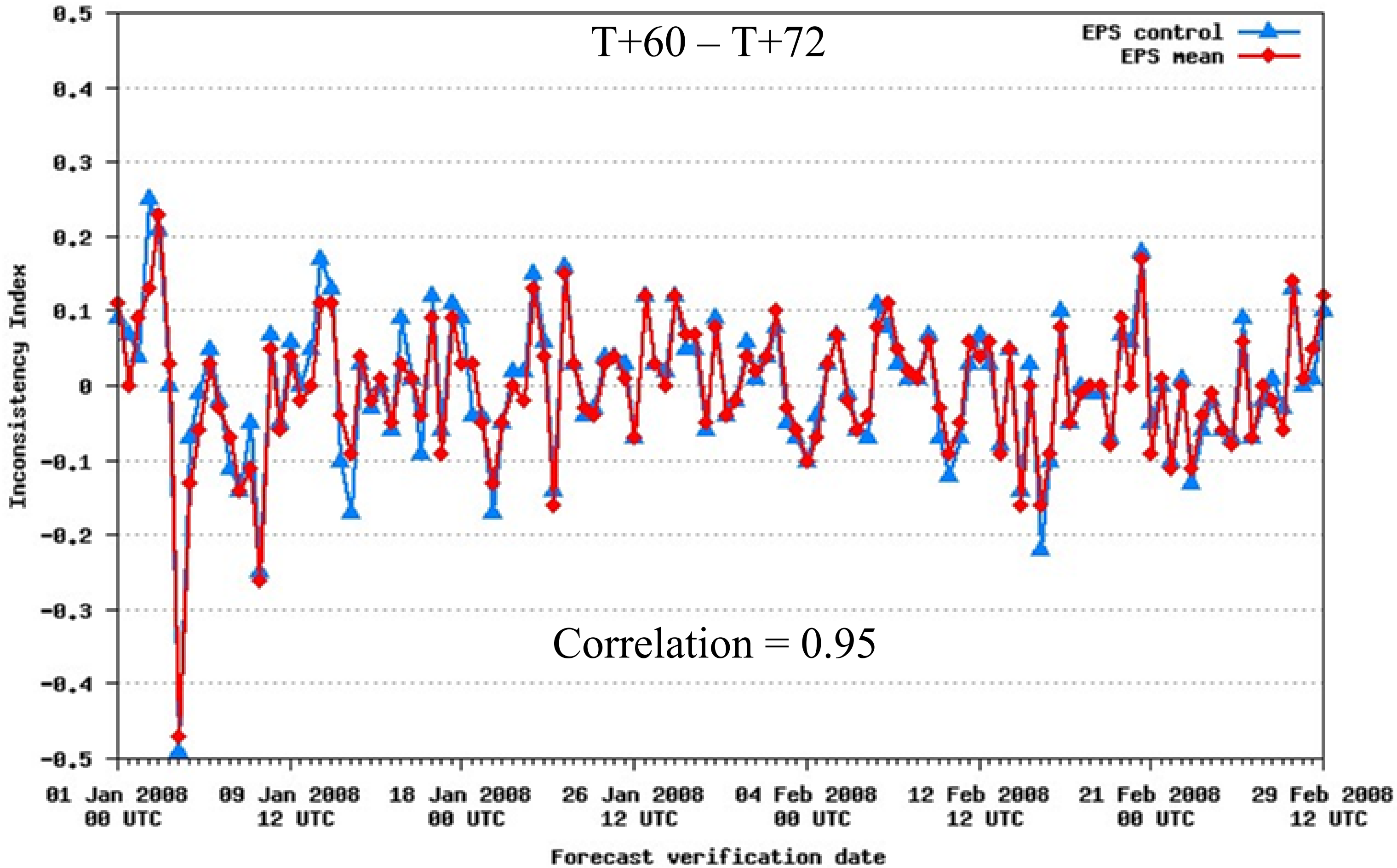
• Forecast *f(d,t)* can be any of the **four forecast versions**: EPS control or EPS mean of both the ECMWF or the Met Office.

• We tried to account for the fact that the EPS mean fields can be much smoother than the corresponding EPS control fields by normalising the differences (both EPS mean and EPS control) by the **Standard Deviation of the** forecast fields' **grid values inside the area**.

• Therefore the EPS-control forecasts, normally showing more details than the EPS-mean over an area, will have in general larger normalising factor which should compensate the larger field difference.

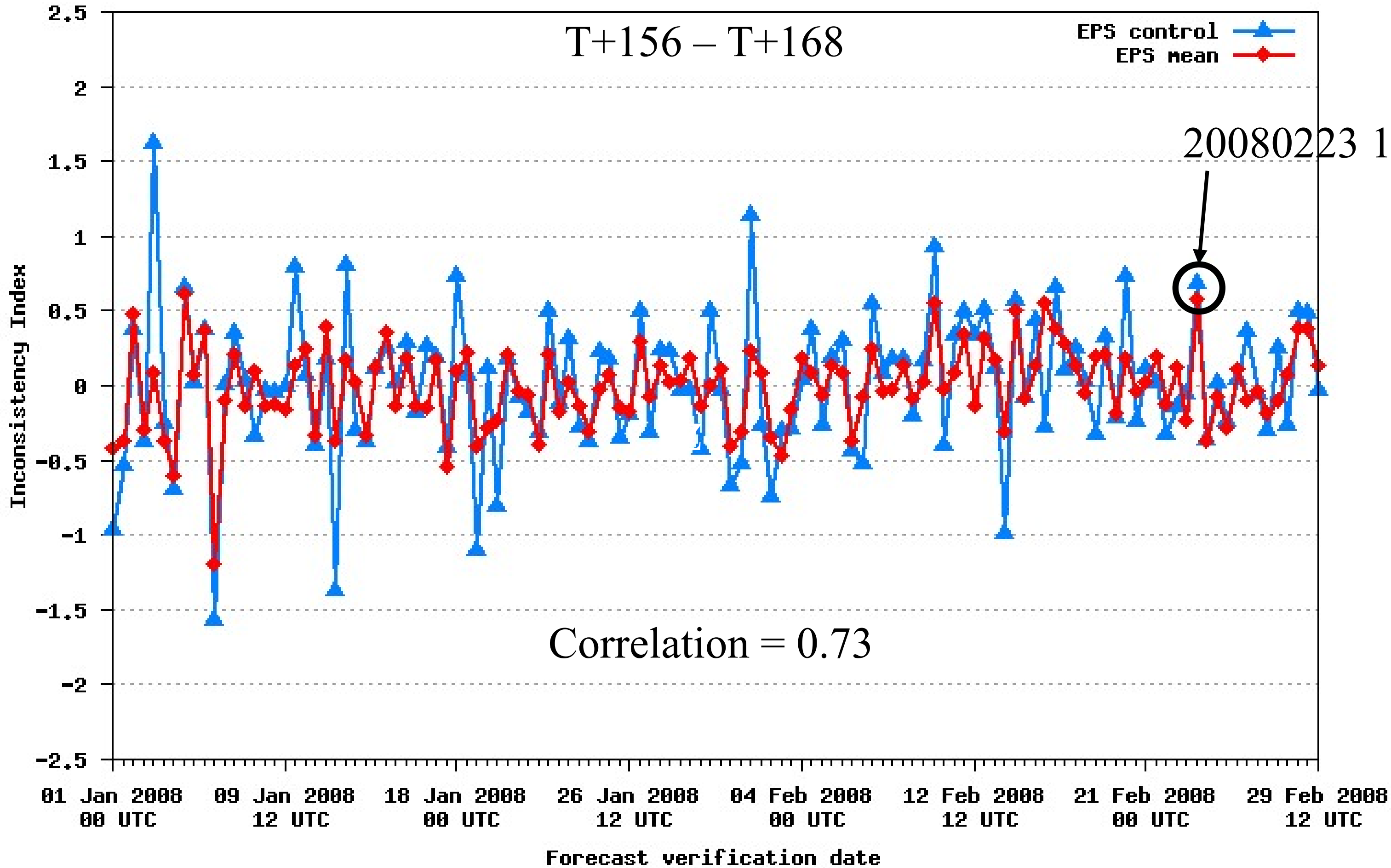
# Inconsistency index time series T+60

Parameter: Z500
Area: Northwest Europe [50N, 20W, 65N, 20E]
Sample period: 1 January 2008 – 29 February 2008



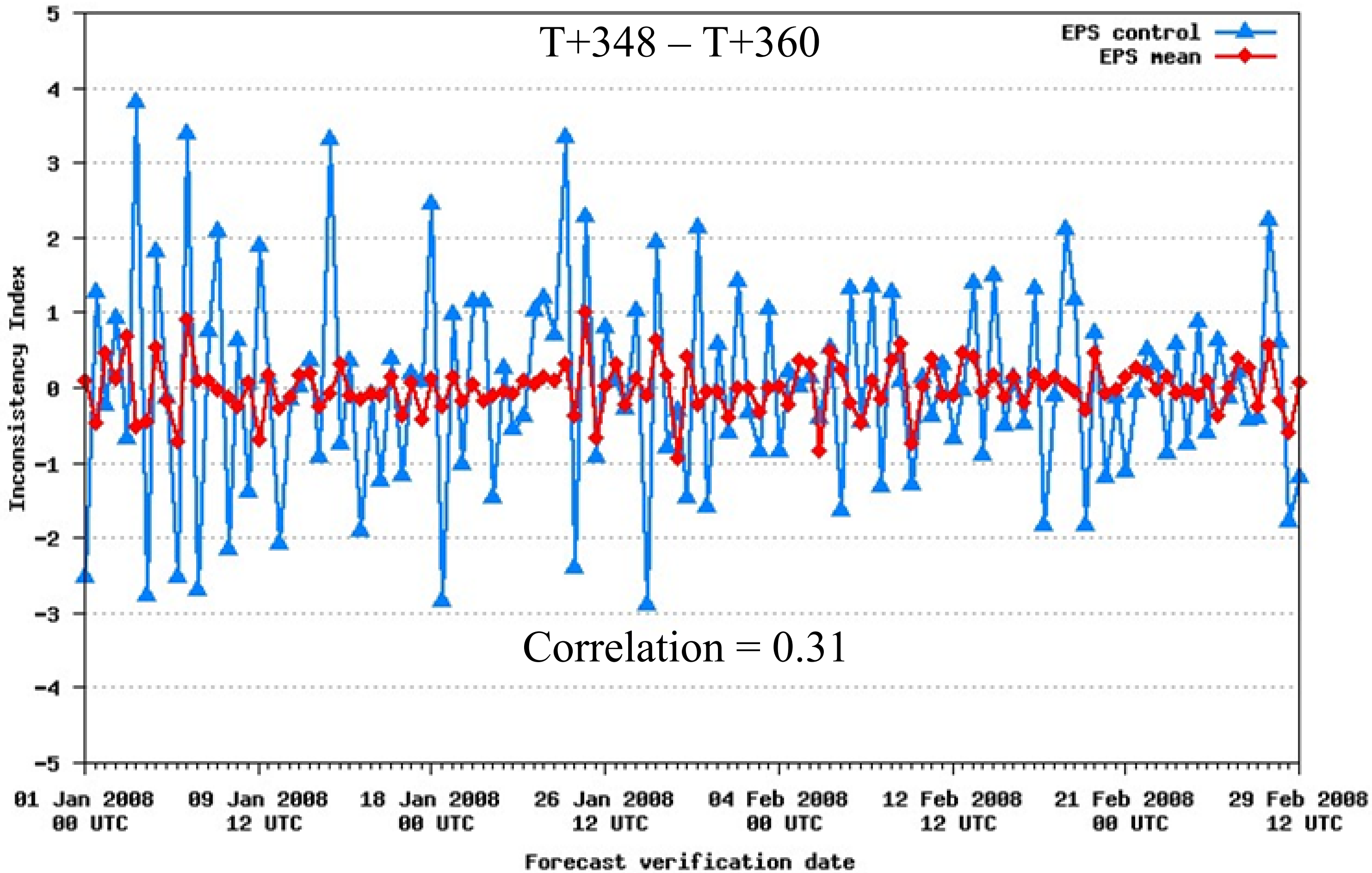
# Inconsistency index time series T+156

Parameter: Z500
Area: Northwest Europe [50N, 20W, 65N, 20E]
Sample period: 1 January 2008 – 29 February 2008



# Inconsistency index time series T+348

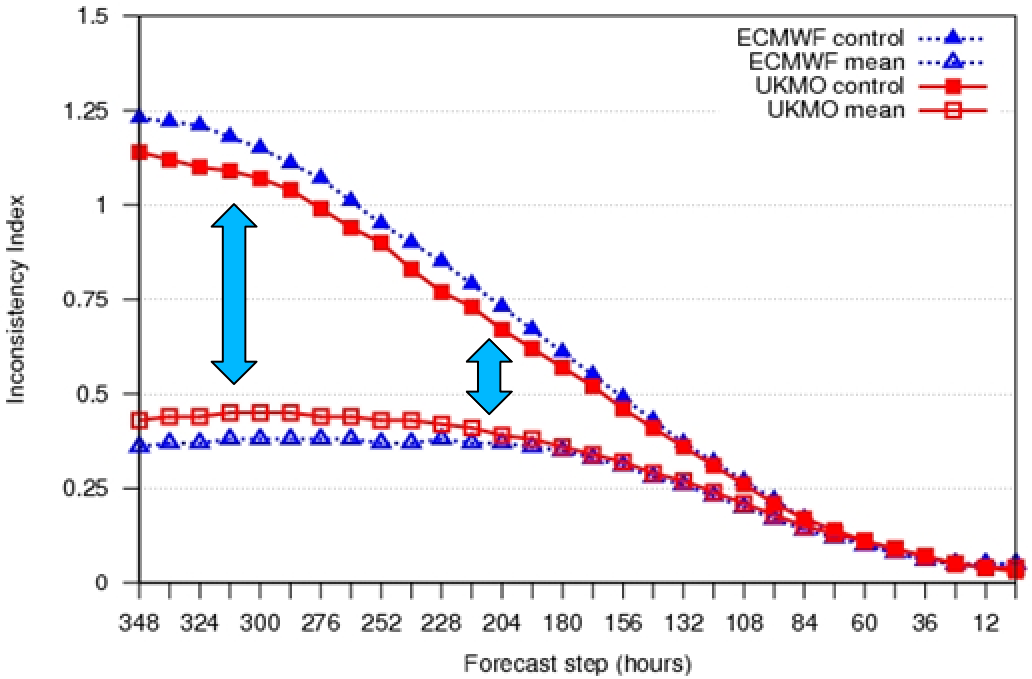
Parameter: Z500
Area: Northwest Europe [50N, 20W, 65N, 20E]
Sample period: 1 January 2008 – 29 February 2008



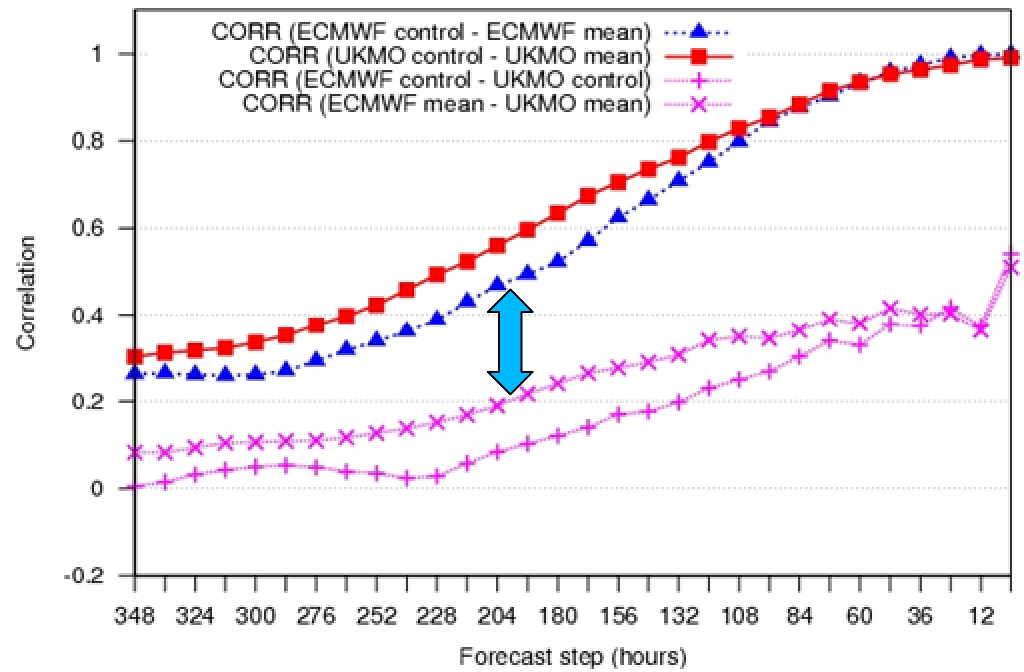
# Inconsistency index statistics

Parameter: Z500, Area: Northwest Europe, Sample period: 16 February 2007 – 31 August 2009 (~2.5 years)

## Period average inconsistency index (A-INC)




## Inconsistency correlation (CORR)



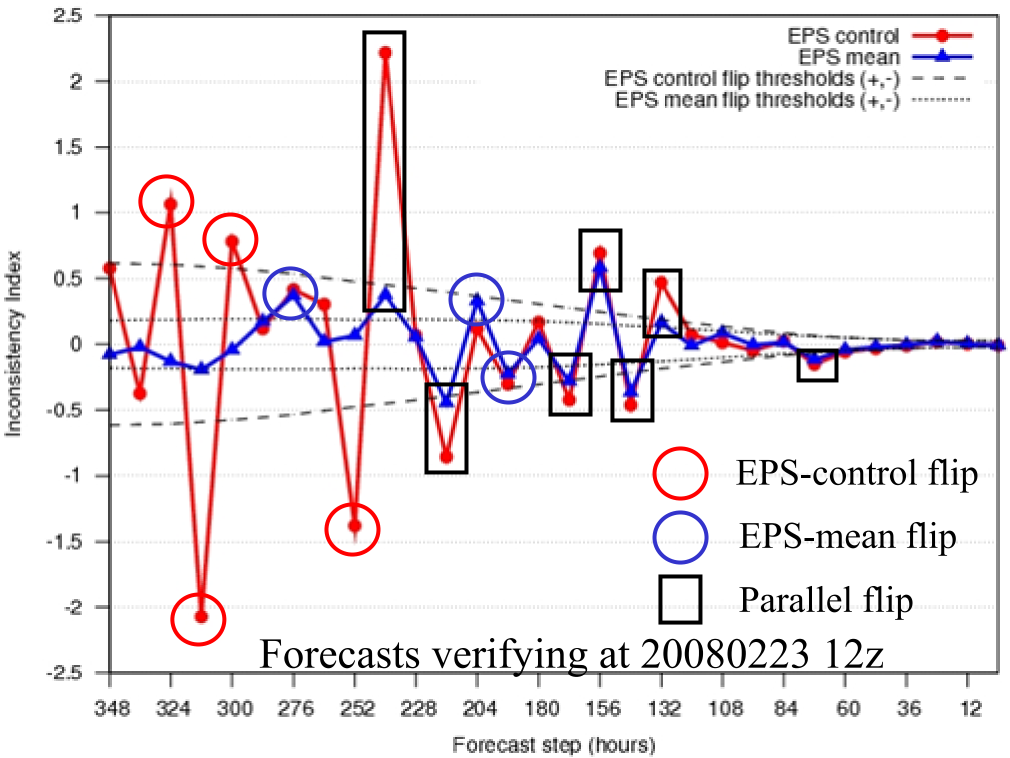

- A-INC = average of the inconsistency index values over a sampling period
- EPS-mean is increasingly more consistent than EPS-control for longer lead times

- CORR = correlation between two inconsistency index time series over a sampling period
- The correlation drops back from ~1 to ~0.3 by day 15 between inconsistency index time series of EPS-control and ESP-mean of the same forecast system
- Correlations are significantly lower between different forecast systems

# Forecast jumps / flip-flops

• We define the significant/large inconsistencies, i.e. **forecast jumps (flips)**, as inconsistencies (INC) over half the period average inconsistency (1/2*A-INC) with both positive and negative signs.

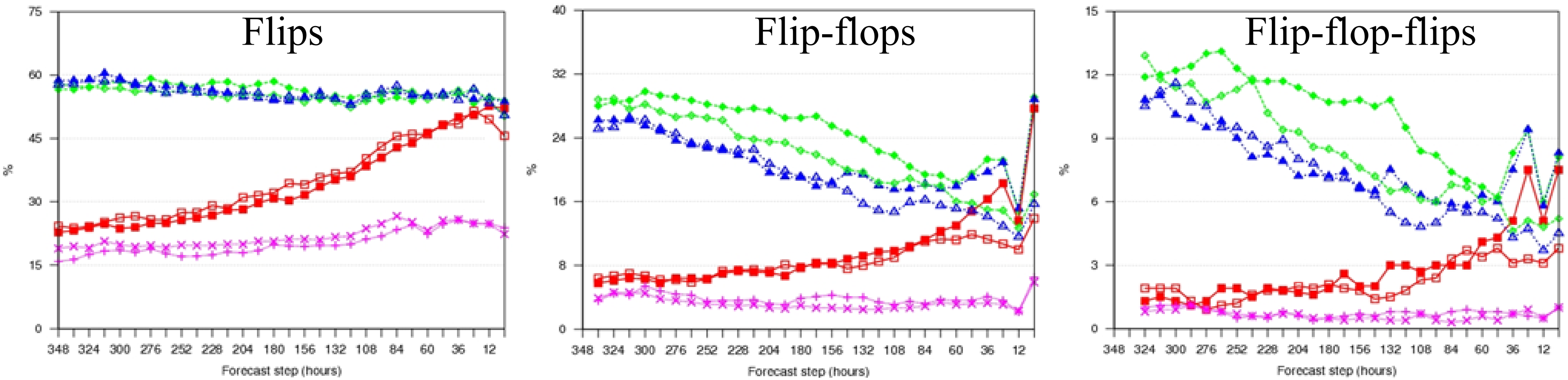
• There is a **flip threshold** for each forecast step and for each forecast versions (e.g. for EPS-control dashed lines, for EPS-mean dotted lines on the diagram).

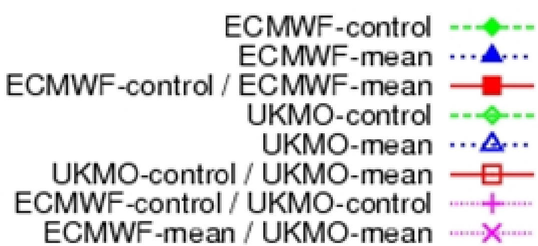



• When a forecast makes more than one consecutive flips with alternating signs (ups and downs) we call these events flip-flop, flip-flop-flip, etc.

• When two forecast versions are investigated in combination, and they make flips, flip-flops, etc. in phase, we call these events **parallel flips**, **parallel flip-flops**, etc., (e.g. the EPS control and the EPS mean on the diagram).

# Forecast jump statistics



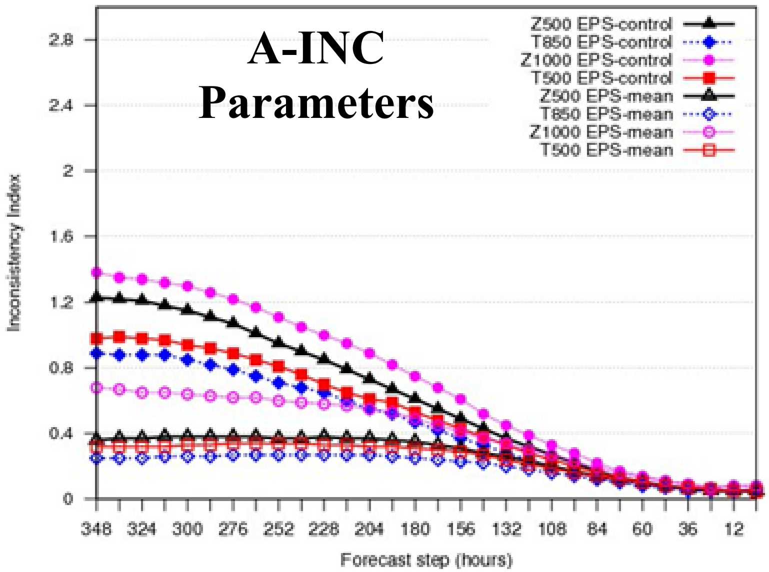

Parameter: Z500

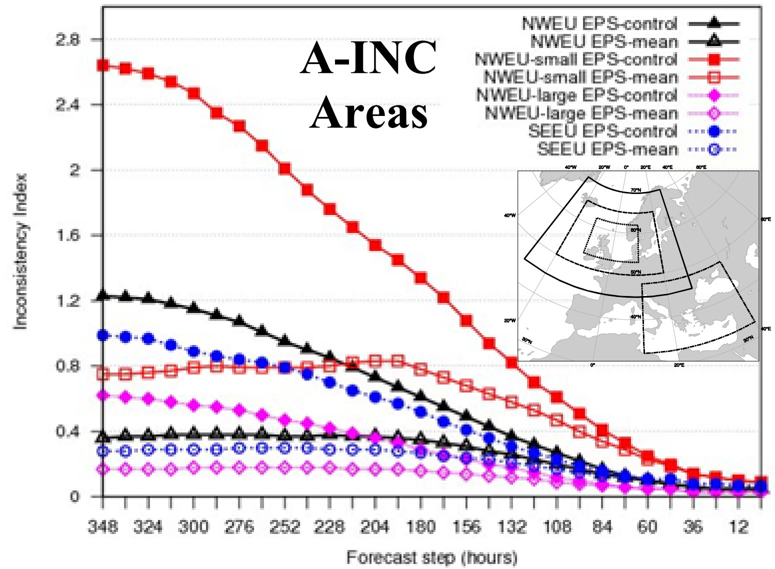
- The frequency of single jumps is the same for both the EPS-control and the EPS-mean throughout the 15-day forecast period

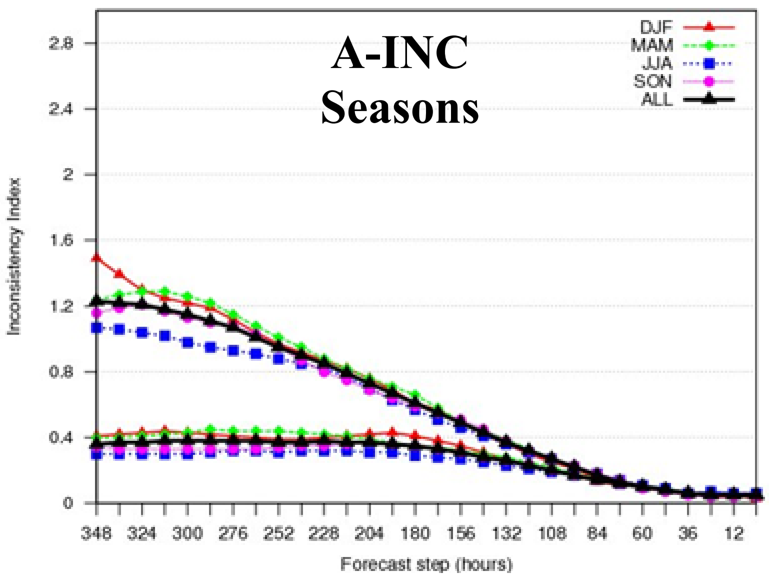
- In the contrary, the two and three consecutive alternating jumps occur clearly less often in the EPS-mean, confirming that the EPS-mean is not only more consistent on average but also zigzag less often than the control.

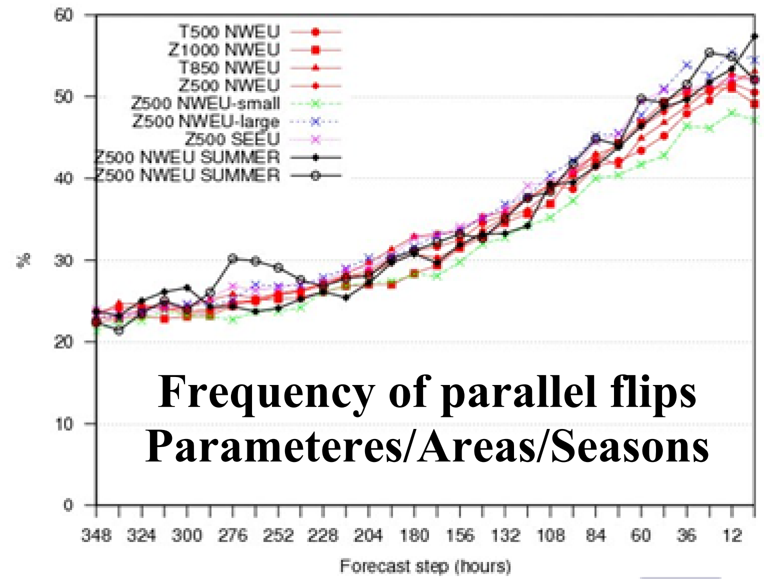
- It is also important to notice that the EPS-mean and the control forecasts from one system (the ECMWF and also the Met Office) follow each other more closely than the control or the EPS-mean of two different ensemble systems follow each other (red curves vrs. purple curves).

# Inconsistency measure sensitivity (ECMWF)



# Forecast error statistics

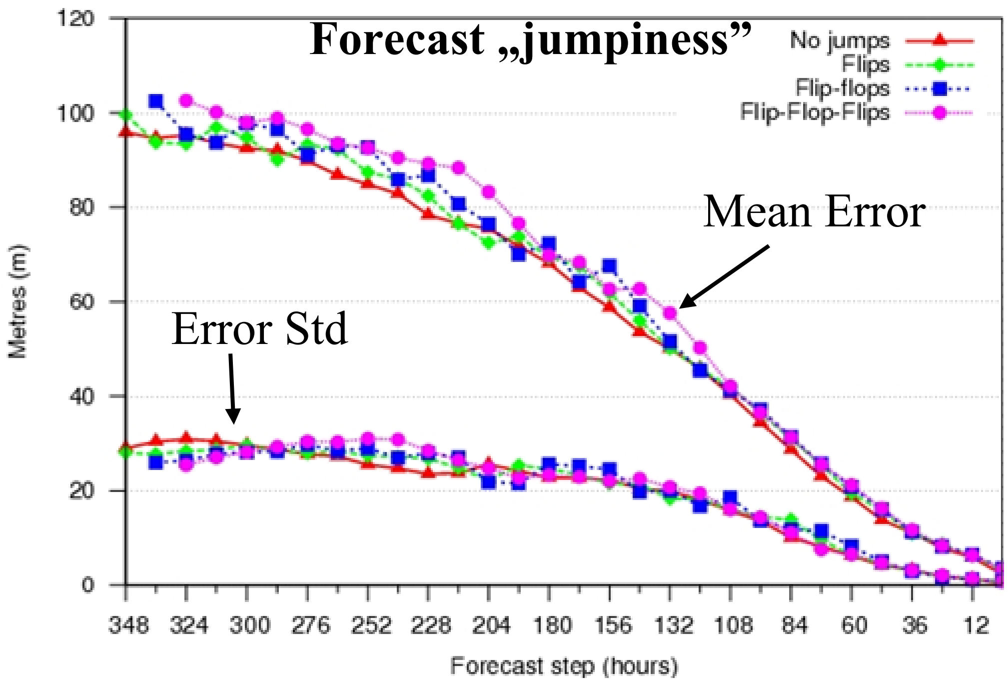
• The relationship between the EPS-mean error and the EPS-mean “jumpiness”, and similarly between the EPS error and EPS spread was investigated on seasonal subsets of the ~2.5 years sampling period.

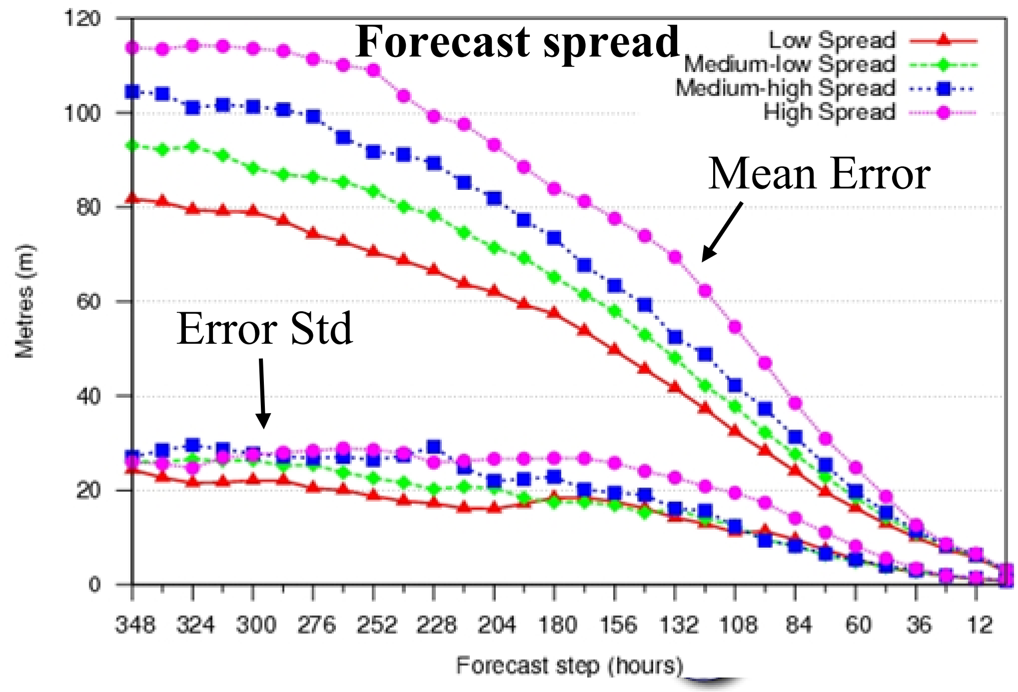
• The relationship between error and “jumpiness” seems to be week as the error characteristics in subgroups of 0, 1, 2 or 3 consecutive flips are rather similar. Forecasts having increasing number of consecutive flips seem to show, on average, only a bit larger error.

• In contrary, when we stratificatify the forecasts into four subgroups based on the EPS spread (small, medium small, medium large and large), we get a solid relationship, i. e. forecasts with larger spread are, on average, more likely to produce larger forecast errors

• The same conclusion applies for all investigated paramters, areas and seasons.

<u>Parameter</u>: Z500
<u>Period</u>: Summer (JJA)



# Summary - 1

- We defined an inconsistency index for a given area and also some other related indices to investigate the inconsistency behaviour of the ECMWF and UK Met Office EPS-control and EPS-mean forecasts with special emphasis on forecast “jumpiness”.
- We found that:
  - The EPS-mean provides more consistent forecasts than the control from about T+72, and this benefit gradually increases with forecast range to day-15.
  - An other aspect of the higher consistency of the EPS-mean is that although the flip frequencies (single jumps) are very similar for both the control and the EPS-mean, the zigzagging occurs clearly less frequently with the EPS-mean.
  - Although the inconsistency index is highly dependent on the area size, the sensitivity seems to be moderate on the parameters and rather small on the seasons. Besides, the number of expected jumps (all kinds) is rather similar with all investigated sample versions.
  - The relationship between the EPS-control and the EPS-mean of the same ensemble system is much stronger than the relationship between forecasts of two different ensemble systems.
  - This suggests that the forecast uncertainty is not sufficiently well sampled in either EPS. This could be because the ensemble size is not large enough, or because the EPS perturbations do not adequately represent the initial and model uncertainties.
  - This also seems to suggest that (e.g.) the 2-3% parallel flip-flop-flip frequency (control and mean zigzagging together) we found for Z500 is likely to be higher than an optimal frequency.

# Summary - 2

- We also found that:
  - The connection between forecast inconsistency and forecast error is week, however, there is a more substantial relationship between ensemble spread and forecast error.
  - This should be seen as a further evidence of the superiority of the EPS system compared to the lagged ensembles of the latest available forecasts.
- Plans for the future:
  - We would like to extend the concept of inconsistency measures onto the EPS in the probabilistic sense, and use the EPS probabilities or rather the whole EPS distribution in the inconsistency computations.
  - An other interesting area to step forward is to apply the diagnostic measures to all the ensemble forecasts available within TIGGE.


• Further reading

Zsoter, E., R. Buizza, D. Richardson, 2009. ‘Jumpiness’ of the ECMWF and the UK Met Office EPS control and ensemble-mean forecasts. *Mon. Wea. Rev.*, **137**, 3823-3836.