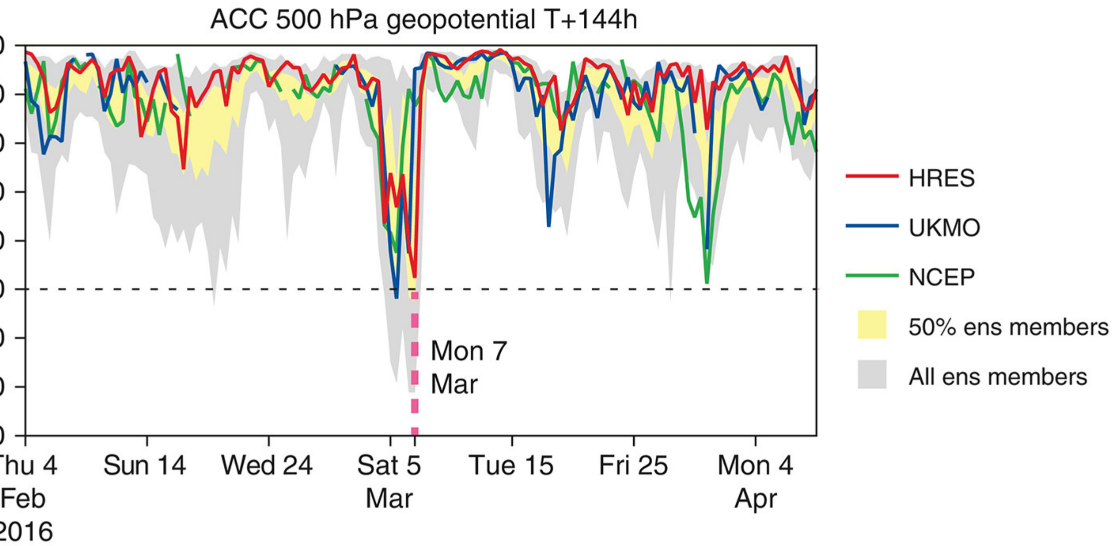
# Diagnostic methods for understanding the origin of forecast errors and uncertainties

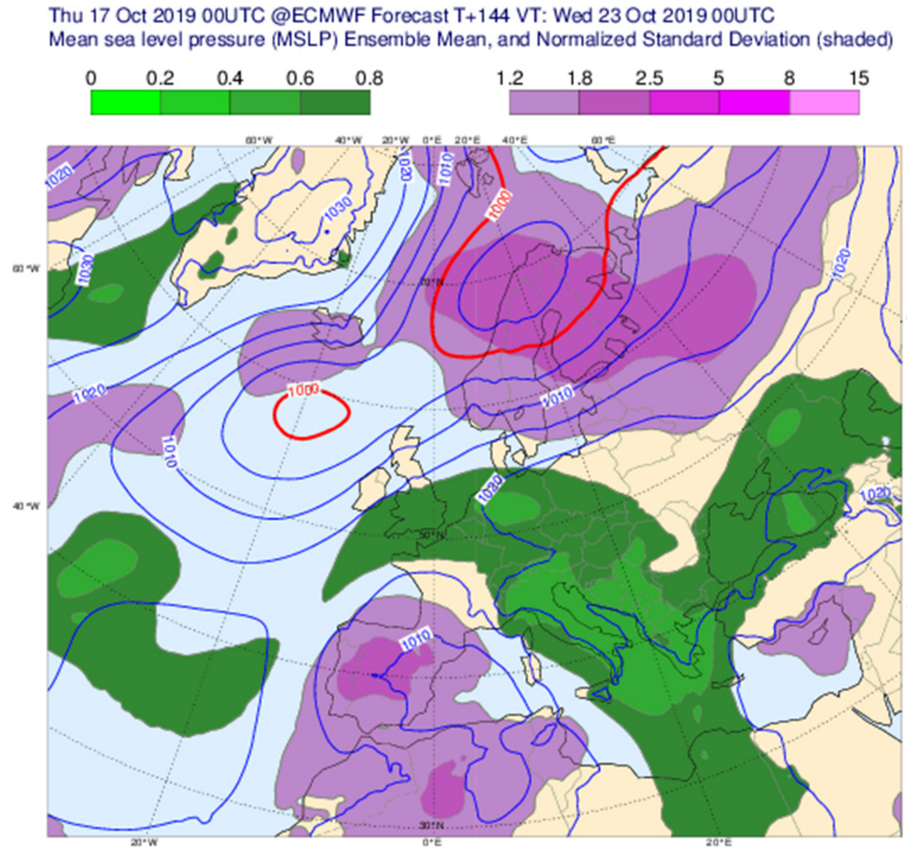
Linus Magnusson

Based on experiences from:
Rodwell, Magnusson, et al. (2013)
Magnusson (2017)
Grams, Magnusson and Madonna (2018)
Magnusson et al. (2019)

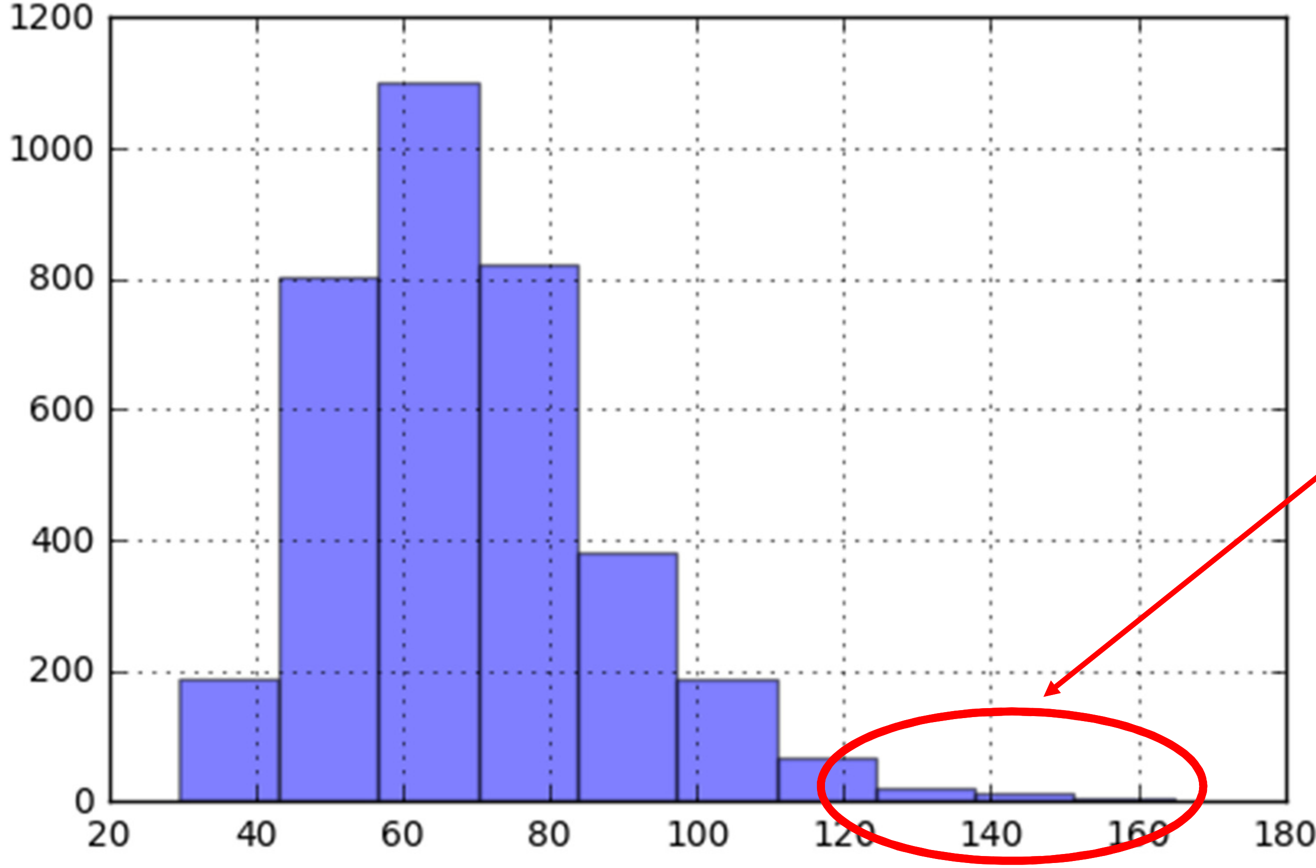
## Case of large forecast error




## Case of large forecast uncertainties



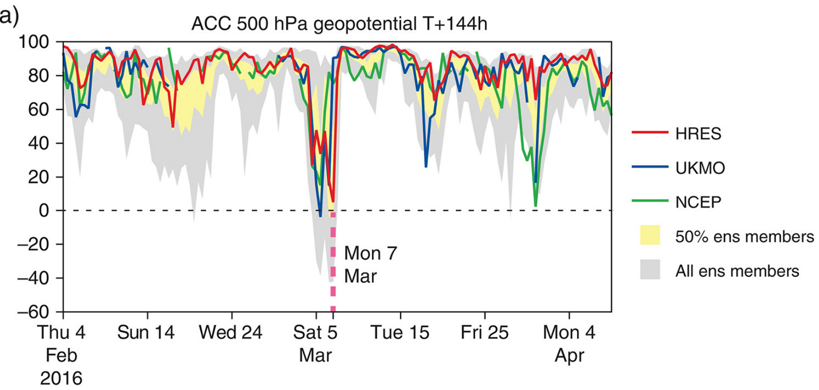
# Distribution of Day 6, z500 RMSE over 4 years

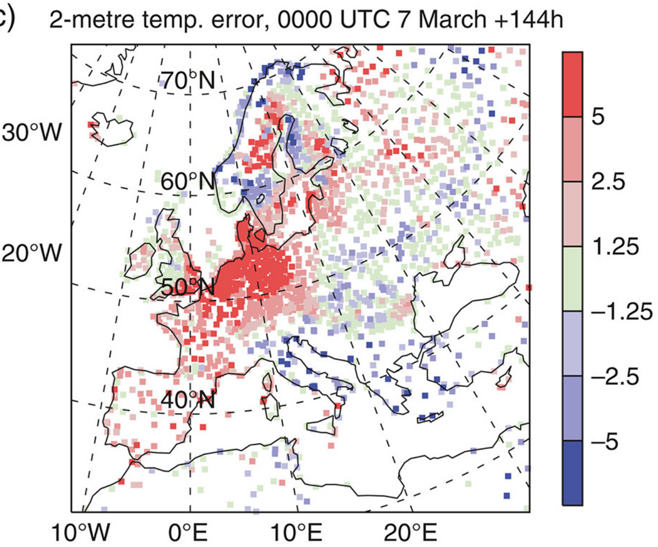



We will try to understa
the origin of large erro

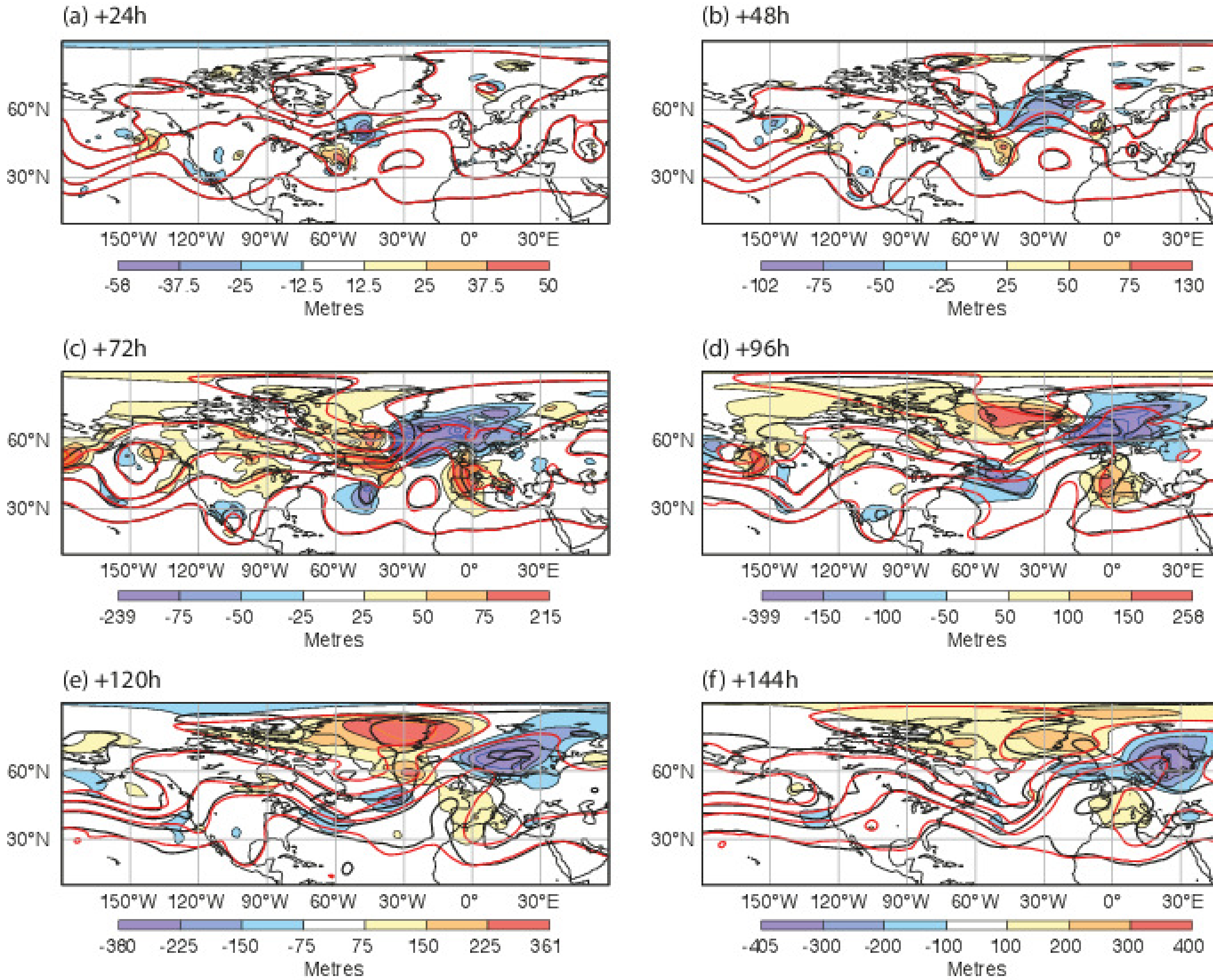
# Case March 2016

Magnusson (2017, QJ



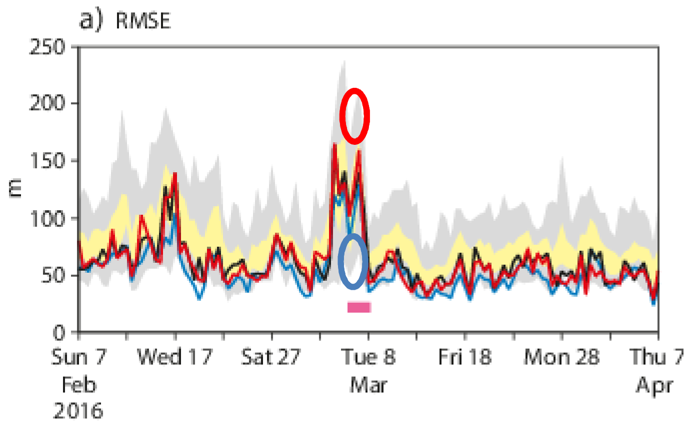




## Errors in z500 forecasts from HRES

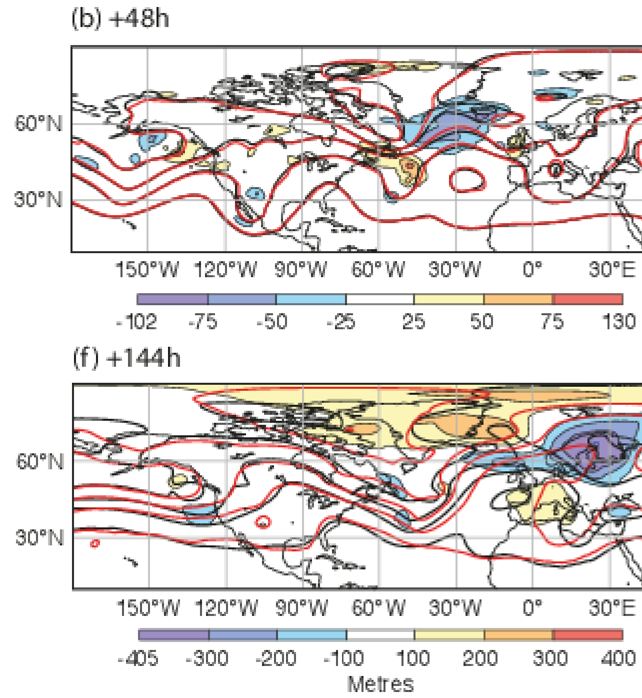



Black – forecast, red – analysis (EC), error - shade

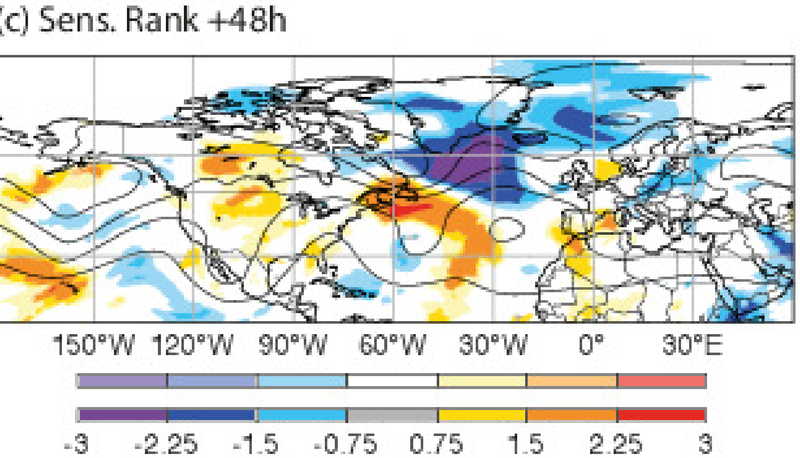
# Ensemble sensitivity – rank method

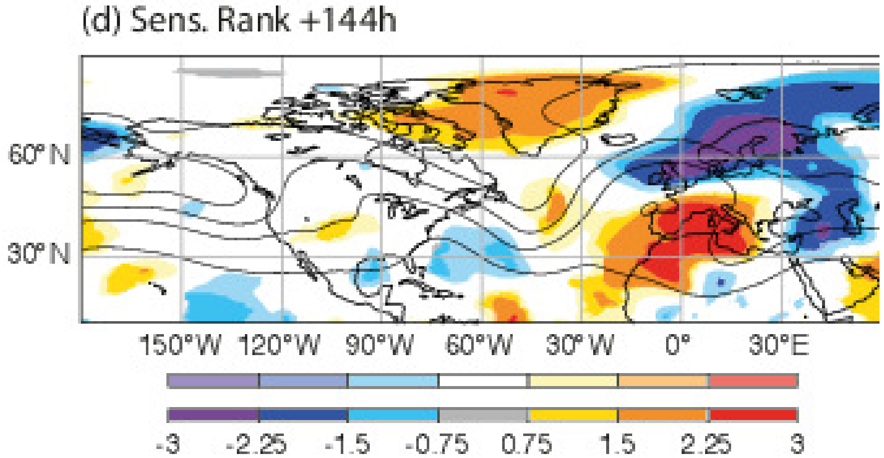



$$\frac{\text{mean(bad)} - \text{mean(good)}}{\text{stdev(all)}}$$




Z500 ensemble sensitivity

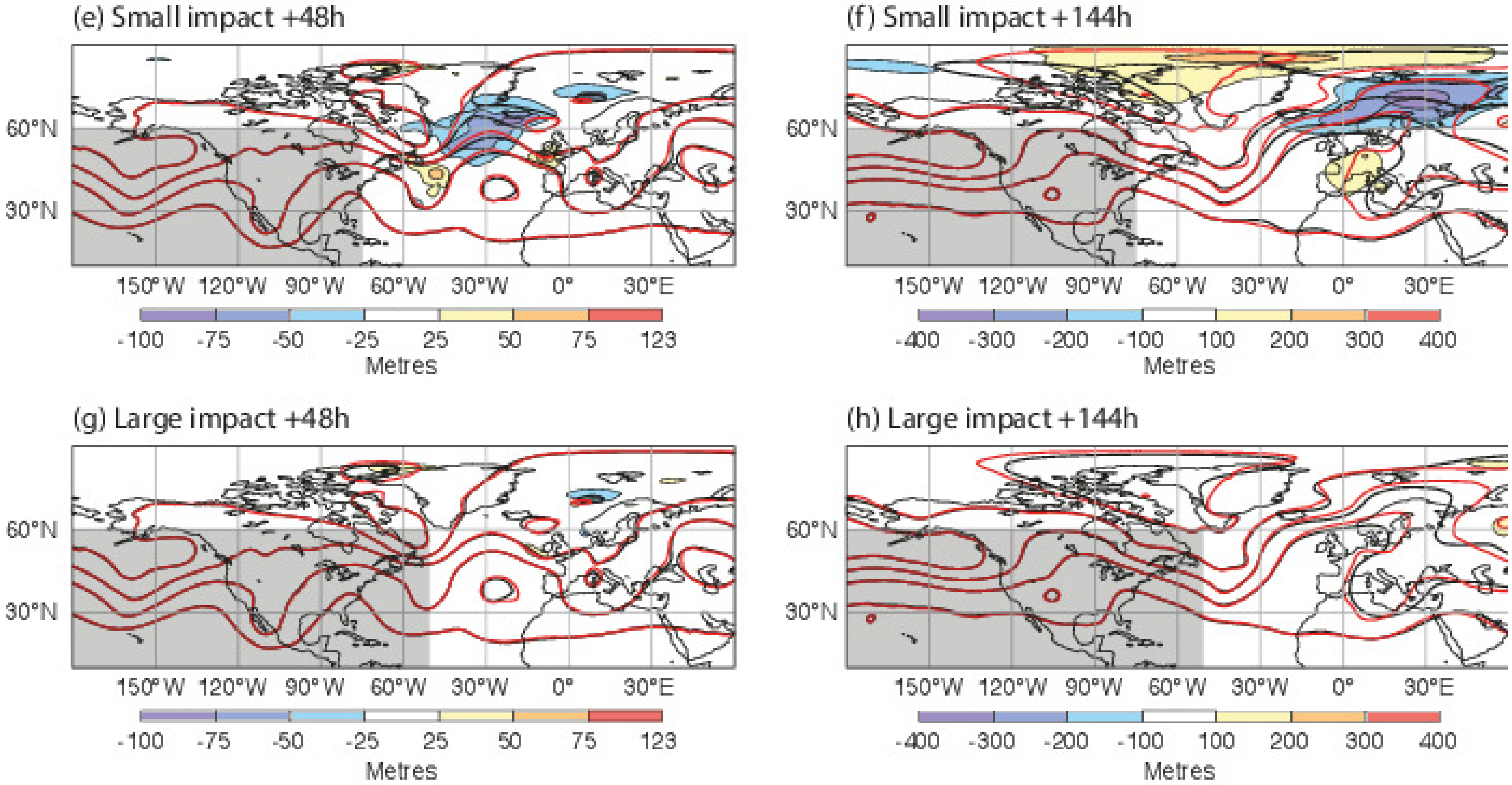



See:
Ancell and Hakim (20
Torn and Hakim (2008
Zheng et al. (2013)
Torn et al. (2015)
Lamberson et al. (201
Magnusson (2017)

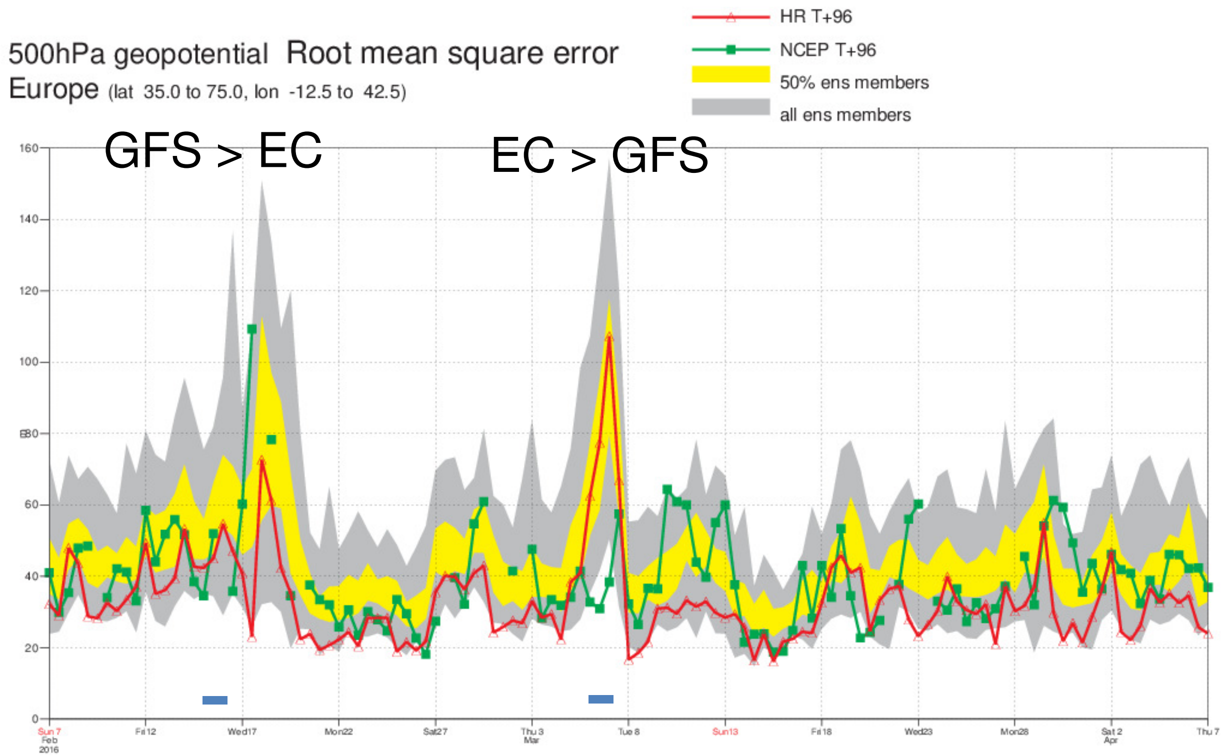
# Errors in relaxation experiments

$-\lambda\,(x - x_{ref})$ 20 ensemble members




Black – ensemble mean, red – analysis, error - shade

# RMSE, day 4, Europe, February-April 2016



# Comparison between FV3, GFS and IFS

- Initialisation scheme developed at GDFL to initialise FV3 from GFS and IFS initial conditions (Chen et al., AMS Hurricanes 2017)

- Create opportunity to compare forecasts with "same" initial conditions but different models: Compare model biases, predictability, etc

| | GFS | FV3, 2018 GFDL version | IFS |
|---|---|---|---|
| Dynamical core | Spectral, Hydrostatic, S-L advection | Finite-volume, Non-hydrostatic, cube-square grid | Spectral, Hydrostatic, S-L advection |
| Physics | GFS | Modified GFS (GFDL microphysics, YSU PBL scheme, mixed-layer ocean model | IFS |
| Resolution | 13 km / 64 levels | 13 km / 91 levels | 9 km / 137 levels |
| Initial conditions | GFS | GFS, IFS | IFS |

Same initial condition    Same model    Same initial condition

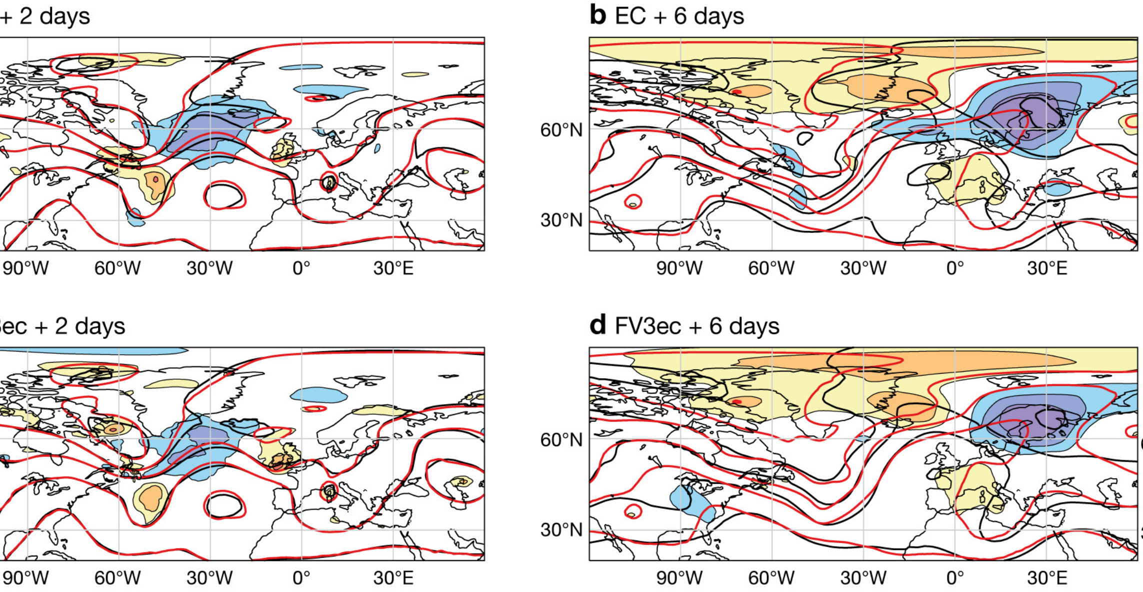
1-year sample: Initialised every 5th day from 15 August 2015 to 15 August 2016
Hurricane season: Initialised every 12th hour from 1 August to 30 October 2017

# Z500 error pattern for bust case

## ECMWF initial conditions

2-day error

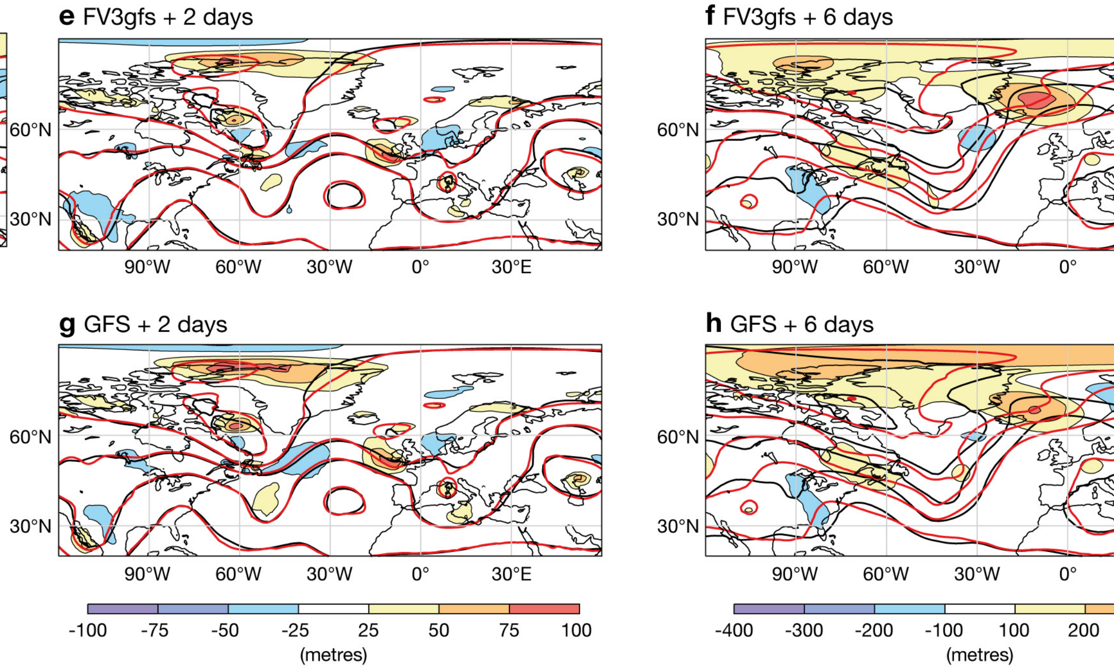
6-day error




## GFS initial conditions

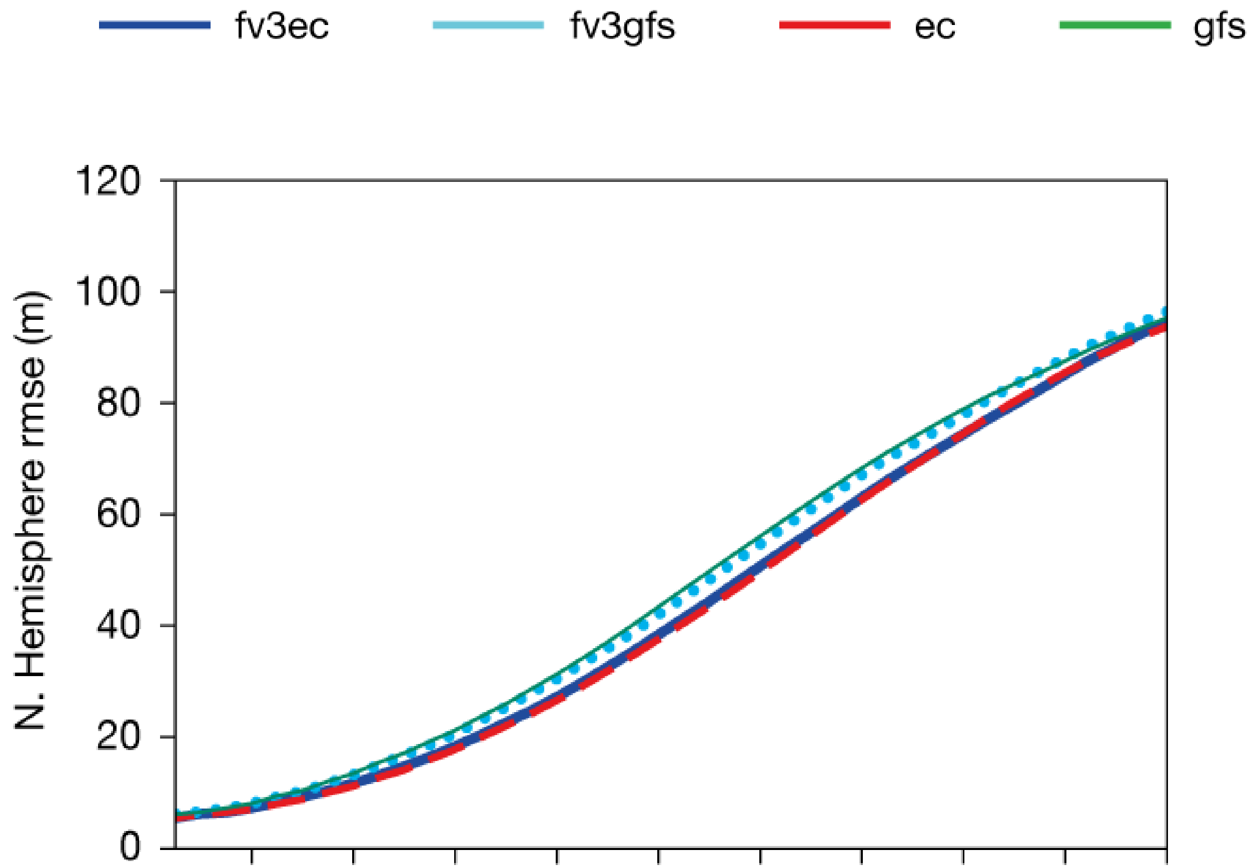
2-day error

6-day error



# MSE for z500, Northern hemisphere

1 year sampled every 5th day, Verified against UKMO analysis



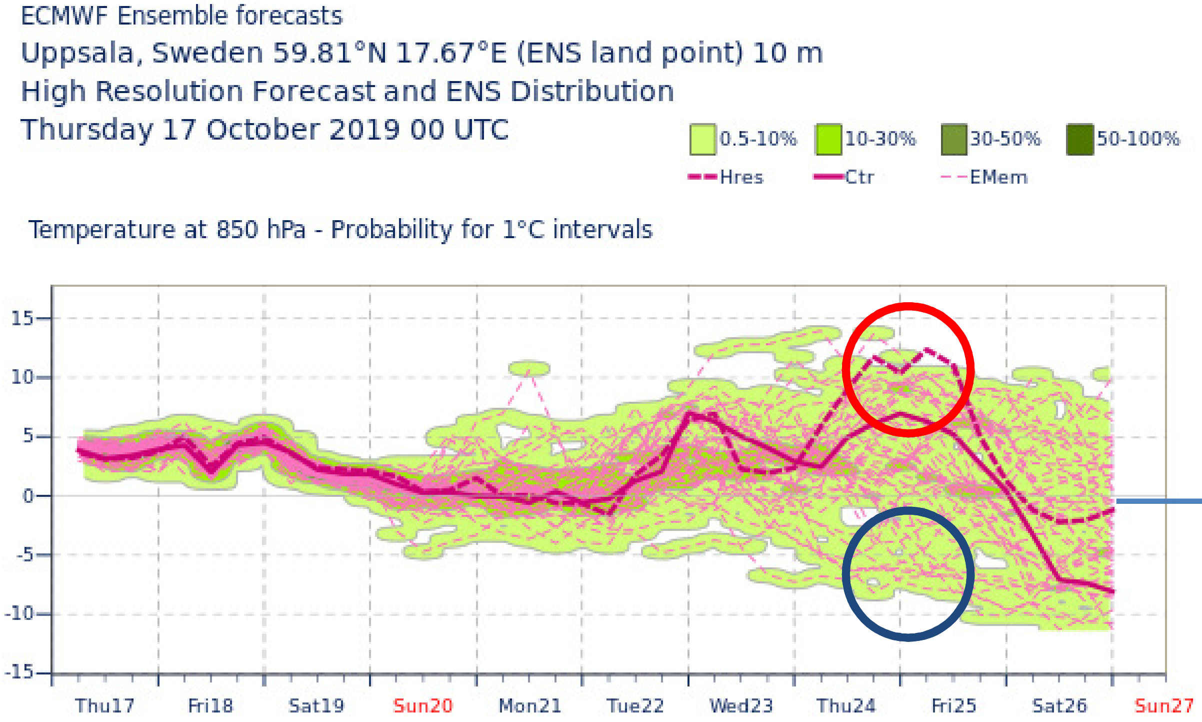

Magnusson et. al. (2019, Q.

# Tracking uncertainties in ensemble forecasts
# - Use of ensemble sensitivities

- From where originates the uncertainties in the forecast? When can we expect the uncertainties to be eliminated?

ean(upper tail) – mean(lower tail)
stdev(all)

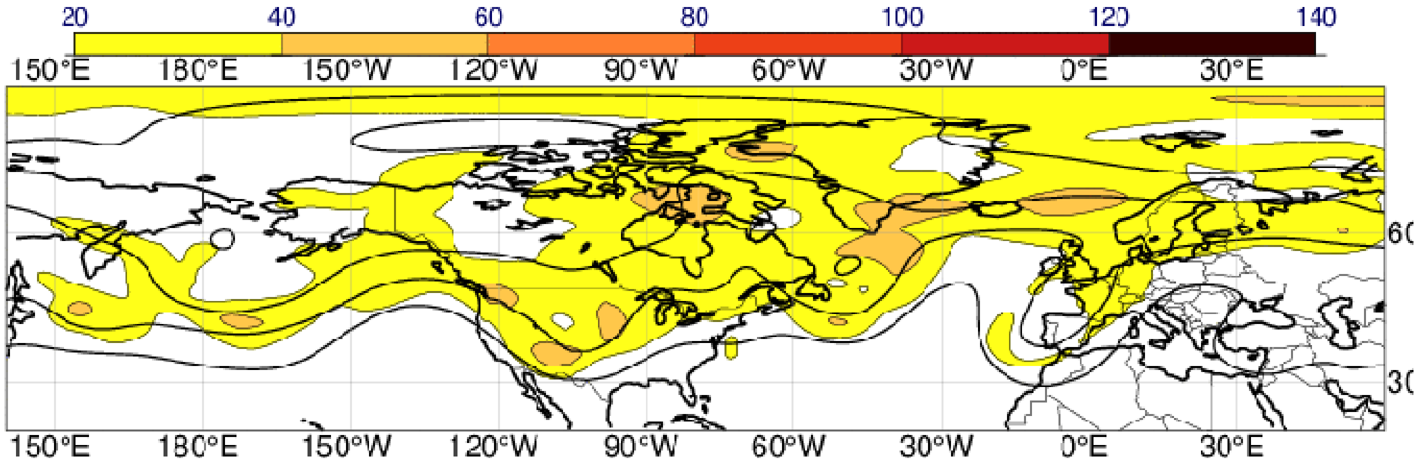
For example:
Mean of the 5 coldest members minus the mean of the 5 warmest members



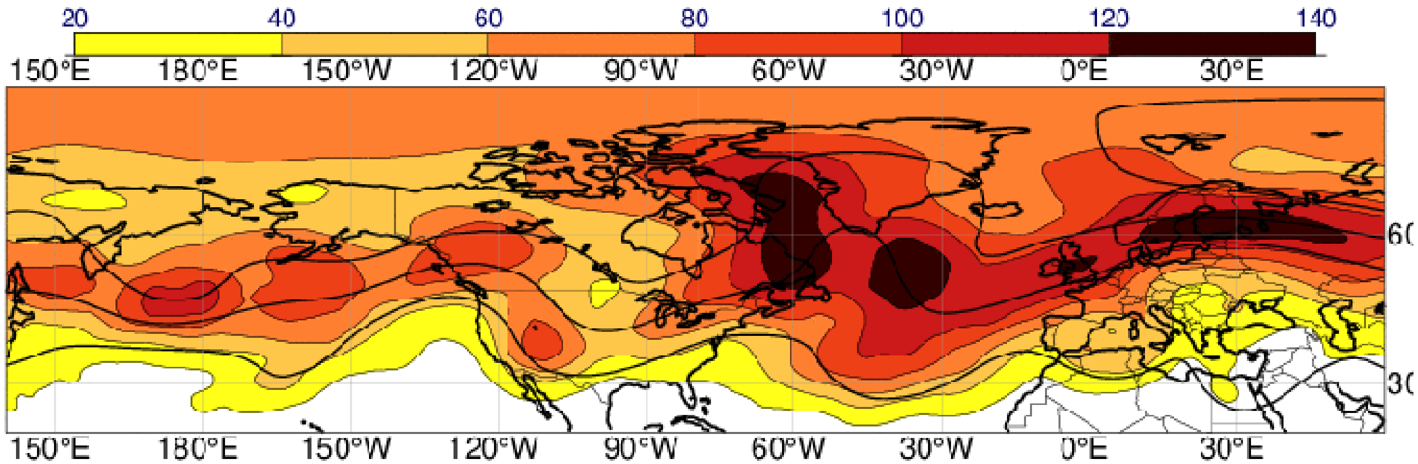

Map into another variable, are the groups separated?

# Z500 ensemble spread in forecast from 17 Oct 12UTC + 18 Oct 12UTC

Ensemble spread 72




Ensemble spread 168




mean(upper tail) – mean(lower tail

stdev(all)

Define a metric e.g:

Temperature in Uppsala

Forecast error (in hindsight)

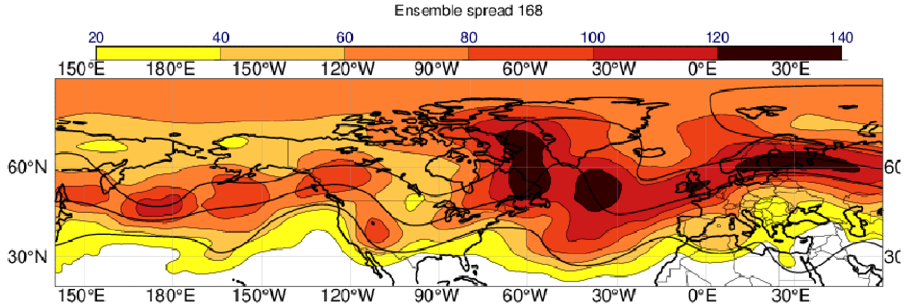
Tropical cyclone track

….

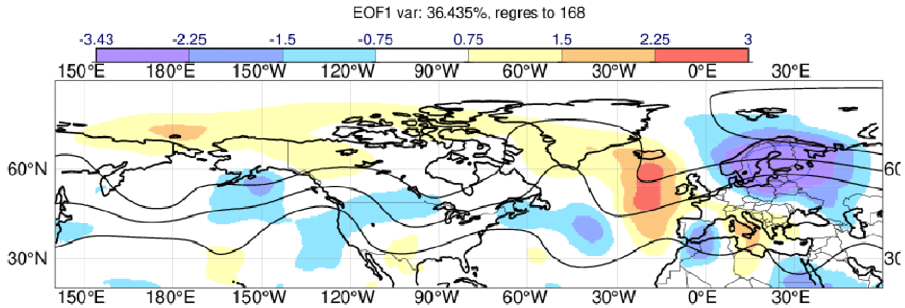
Projection on leading spread EO

# 18 October 00UTC +168h and 17 October 12UTC +190h

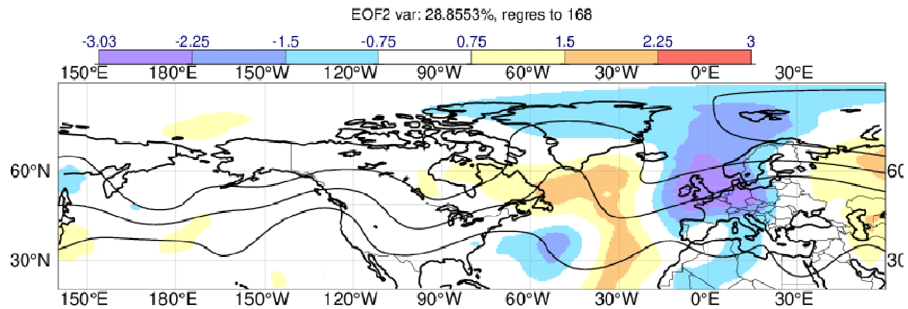
spread

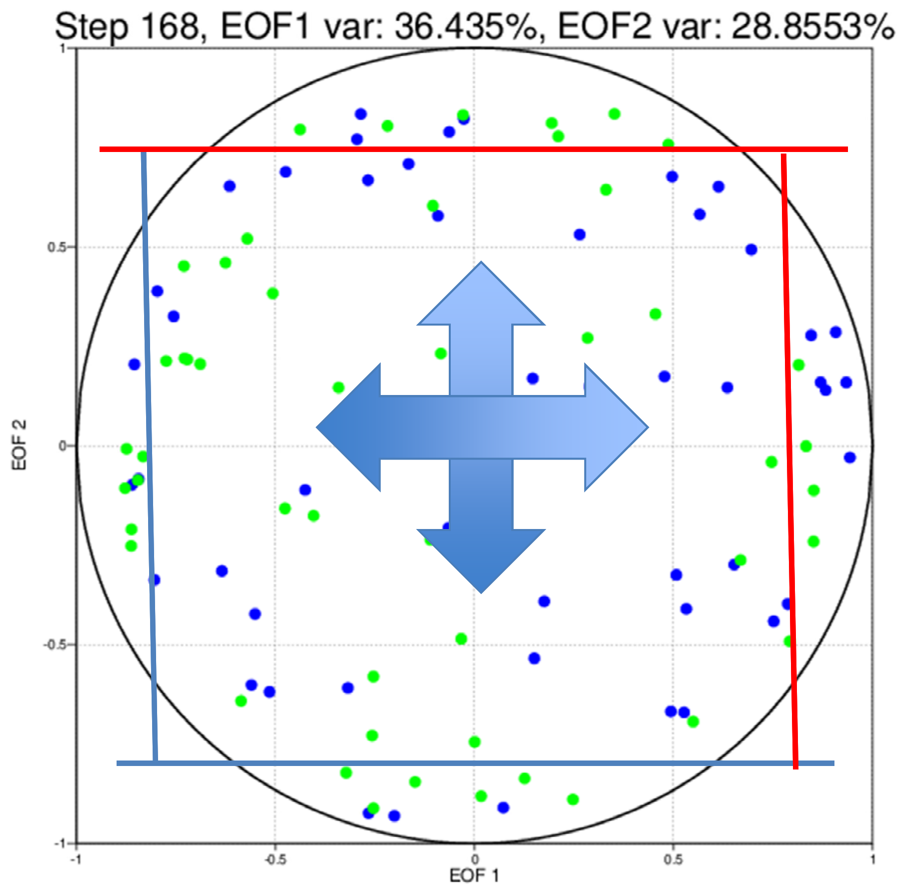



ster
erence
F1

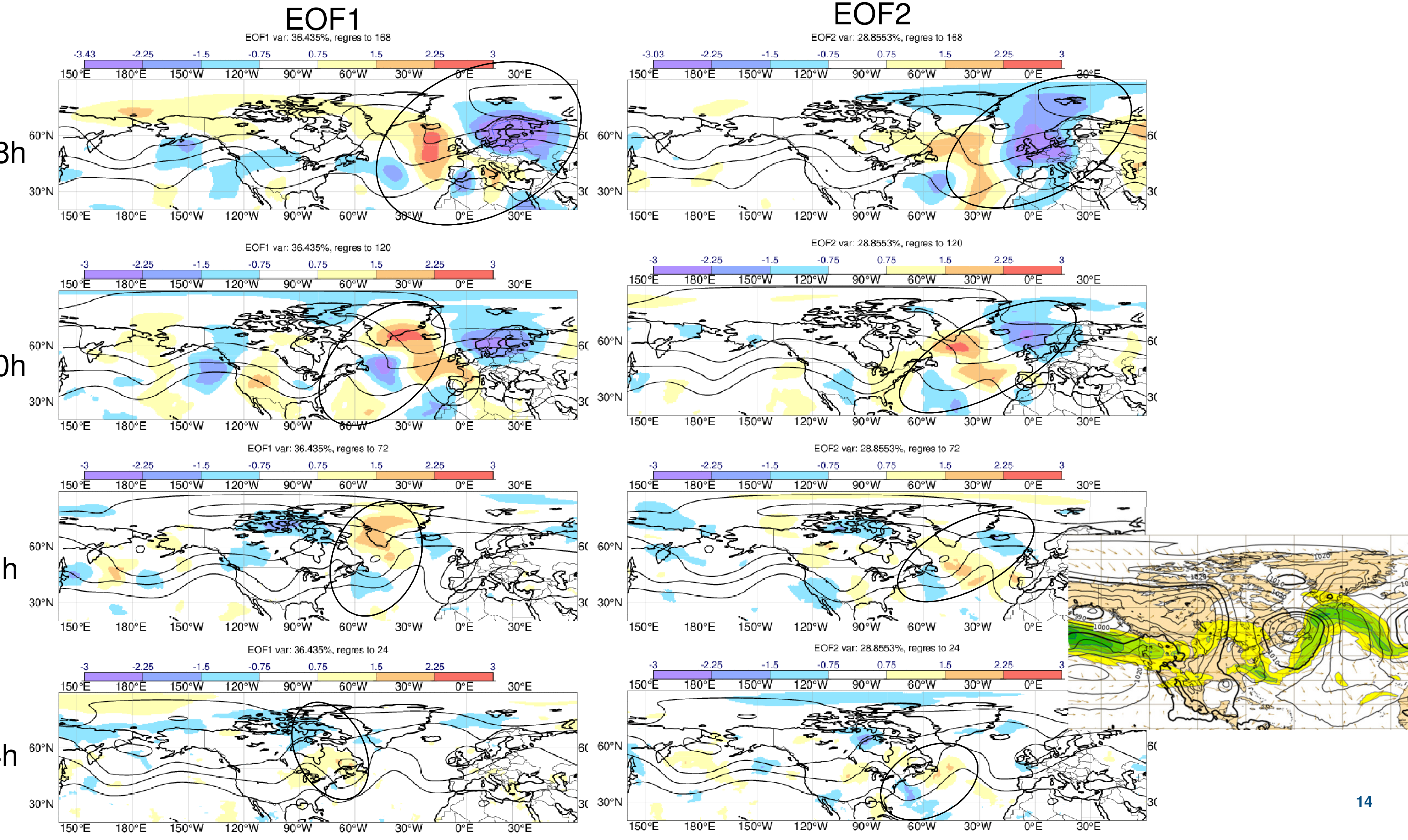



ster
erence
F2

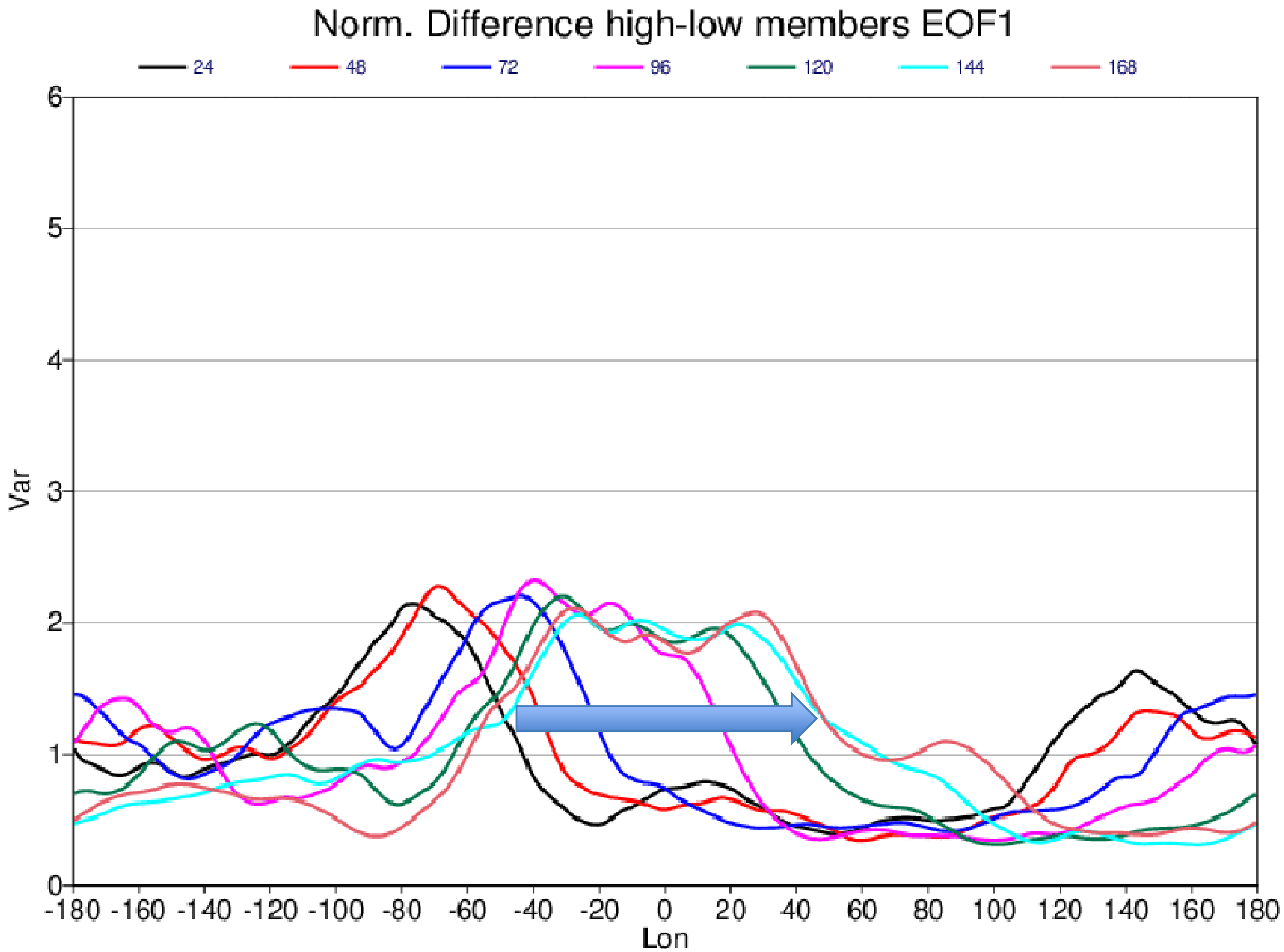


# Ensemble sensitivities for different lead times



# Meridional propagation of ensemble sensitivities



## Summary ensemble sensitivities

1. Select function for calculating the sensitivities (rank method, correlation, linear regressior
2. Define final metric (e.g EOFs of ensemble spread)
3. Select parameter to follow the sensitivities

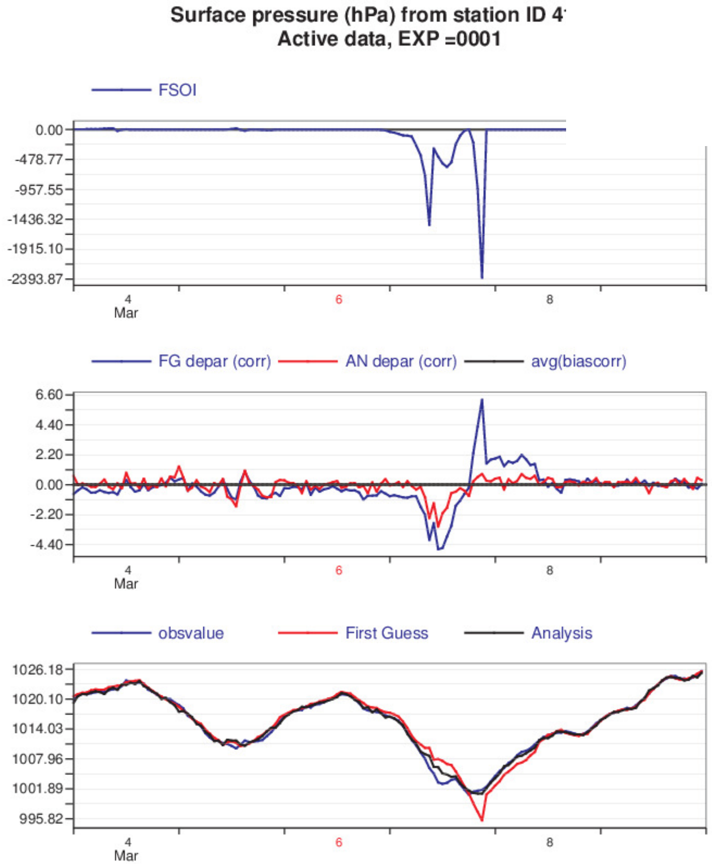
# Observation impact

One SYNOP

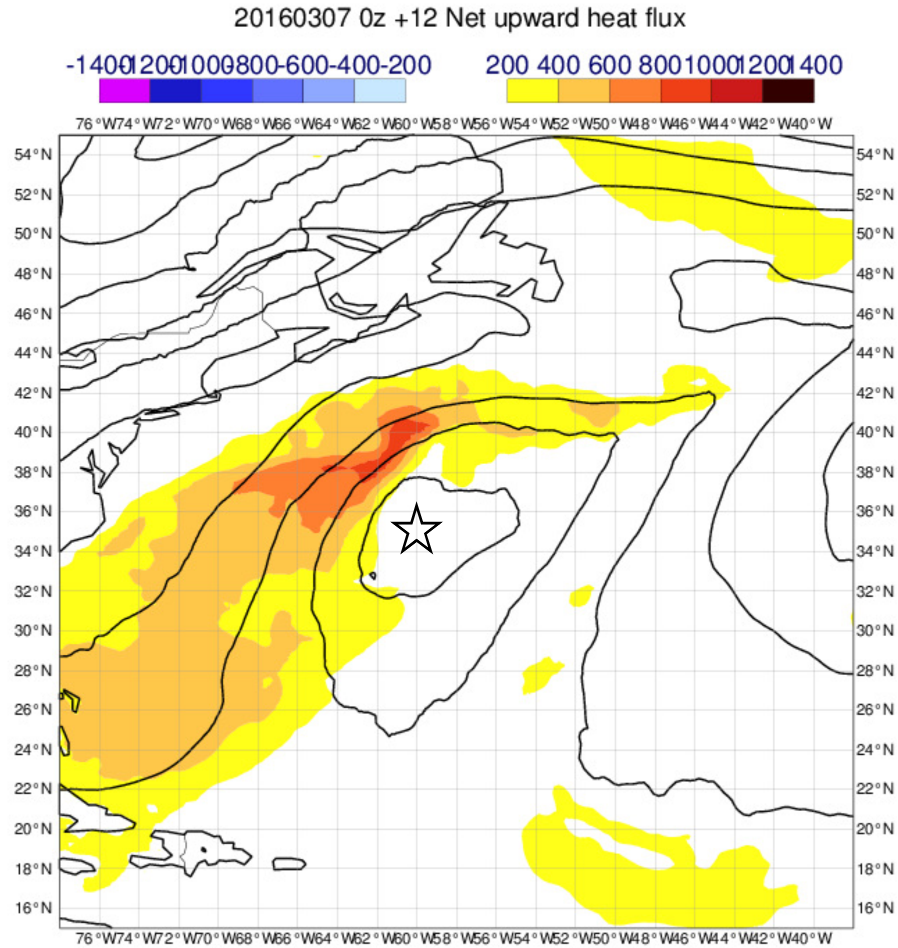
FSOI

Departures

Values




MSLP and surface heat-flux




ECMWF