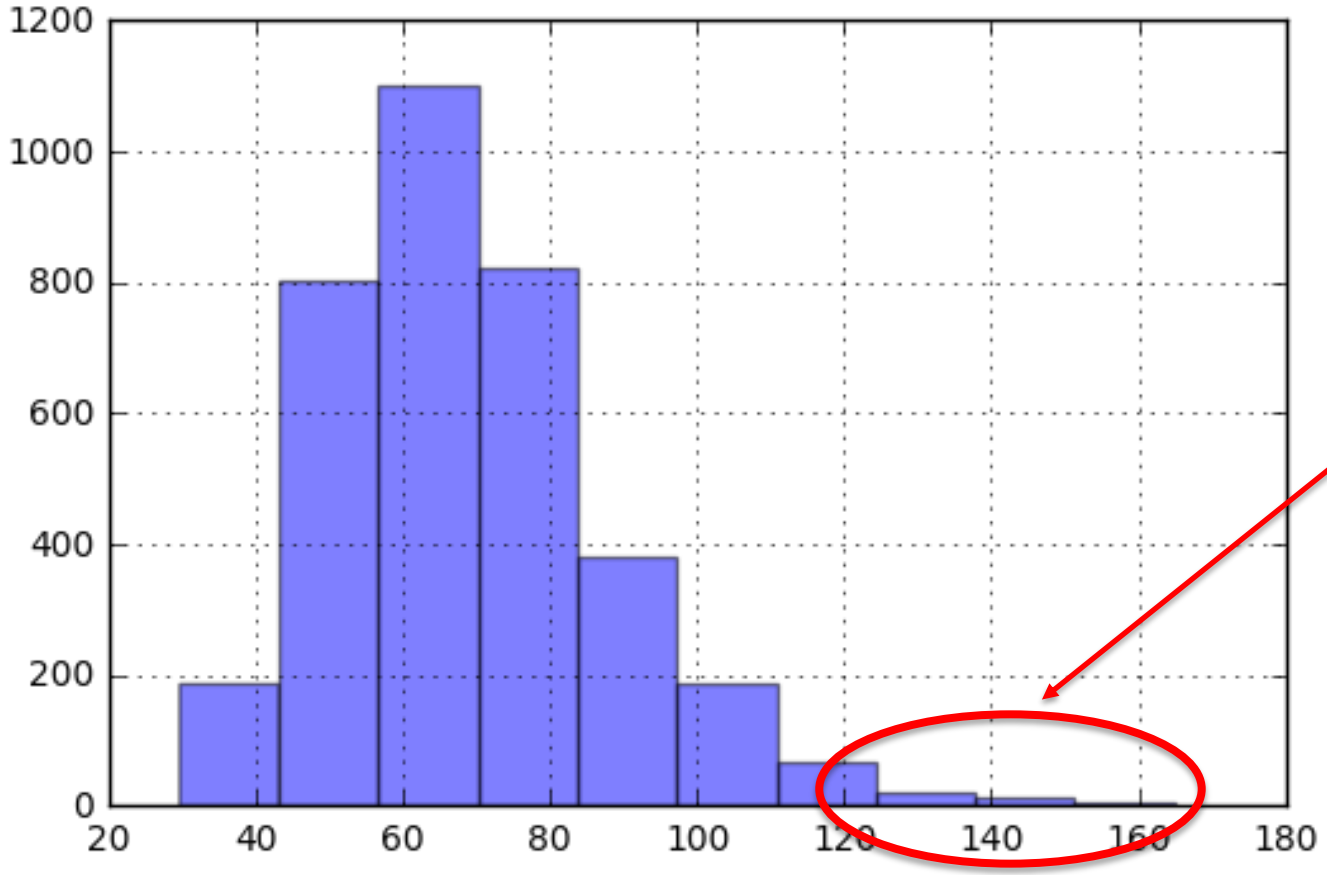
Diagnostic methods for understanding the origin of large forecast errors

Linus Magnusson

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

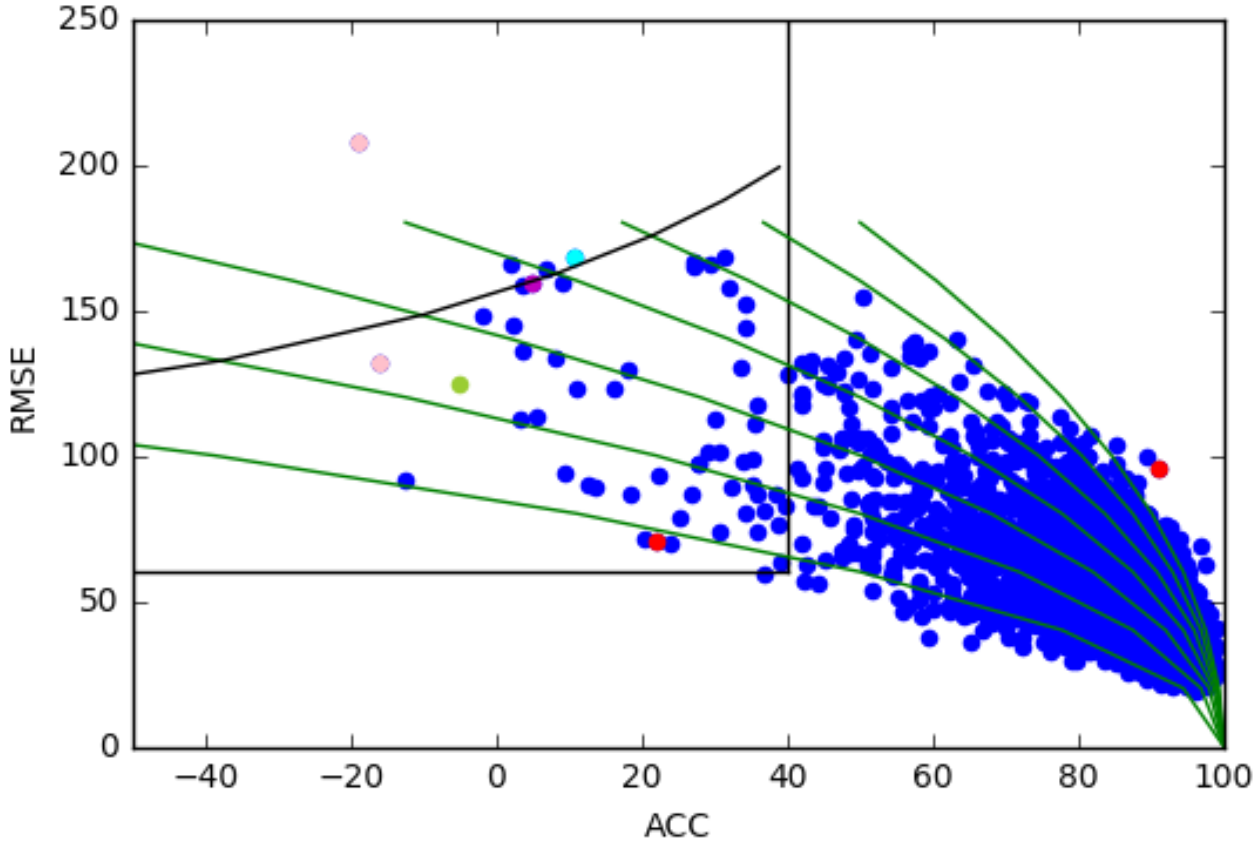
ECMWF

Distribution of Day 6, z500 RMSE over Europe based on 4 years



We will try to understand the origin of large errors

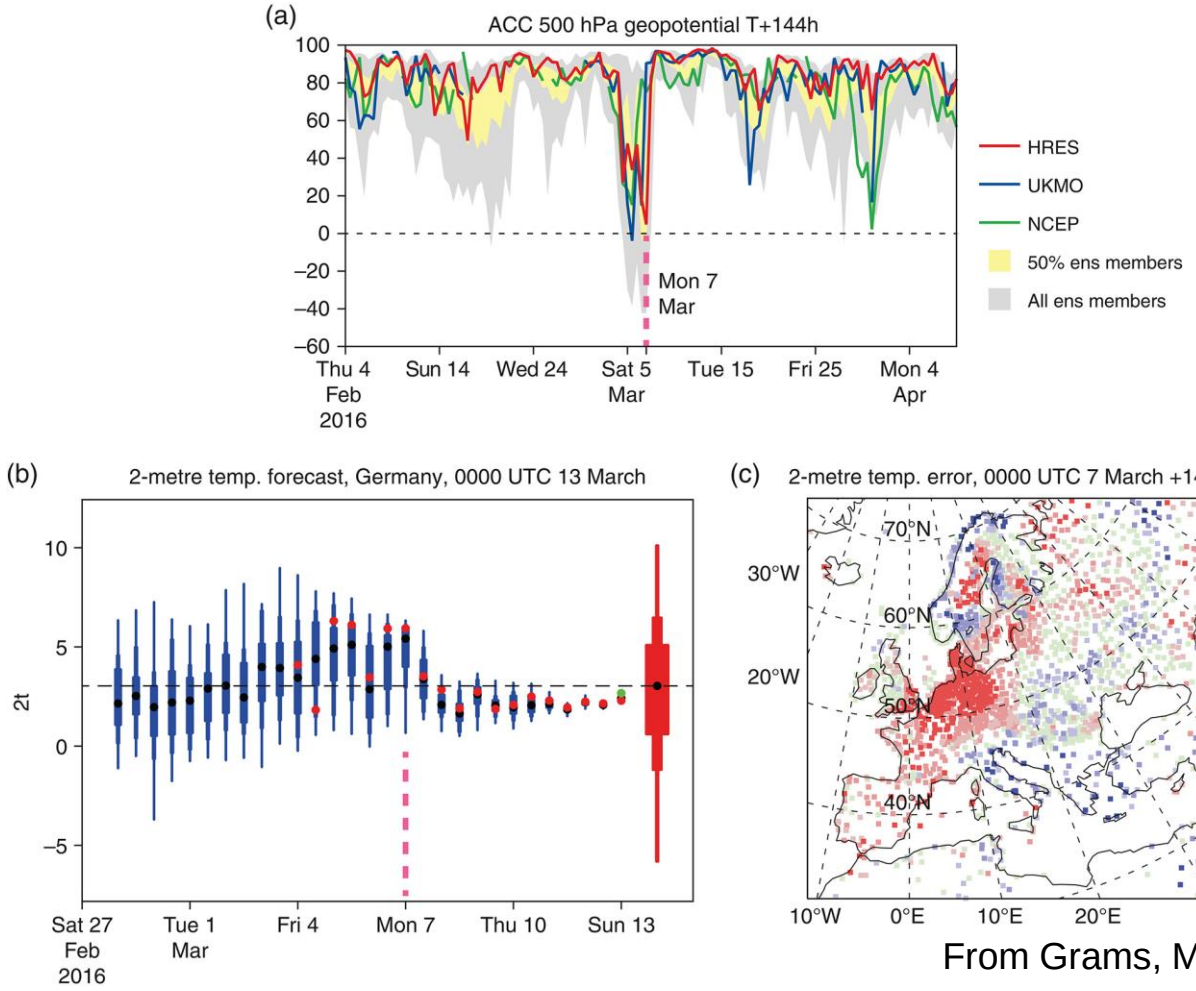
Definition of forecast busts



$$ACC \approx 1 - \frac{RMSE^2}{2ACT^2}$$

Green dot: Case from Rodwell et al.(2013)
Pink and purple dots: Cases from Magnusson (2017)
Black box: Bust definition in Rodwell et al. (2013)

Understanding forecast busts (“dropouts”) – example from March 2016

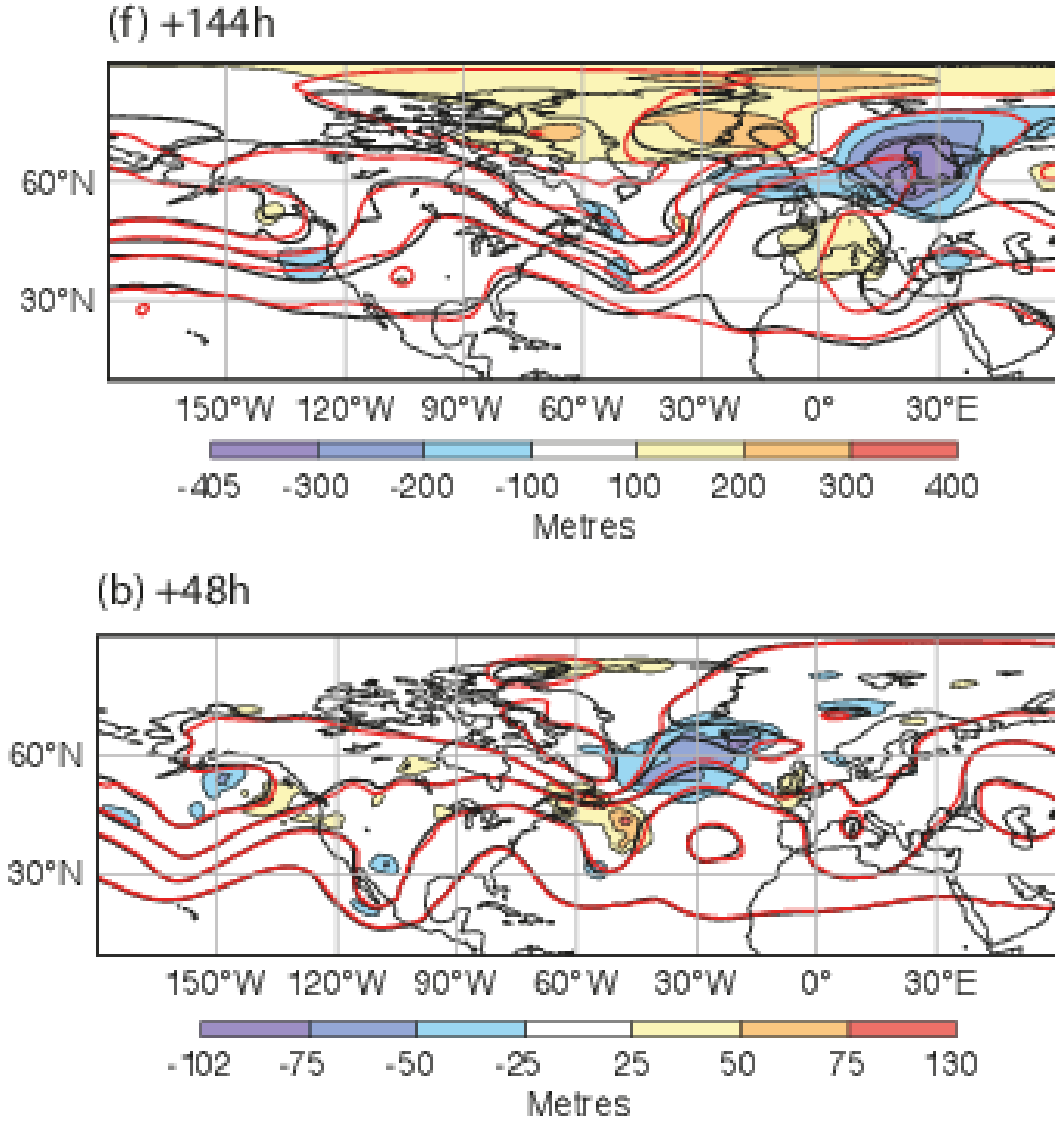


From Grams, Magnusson and Madonna (2018, QJRMS)

Do forecast busts appear from initial conditions and/or from model errors during the integration?

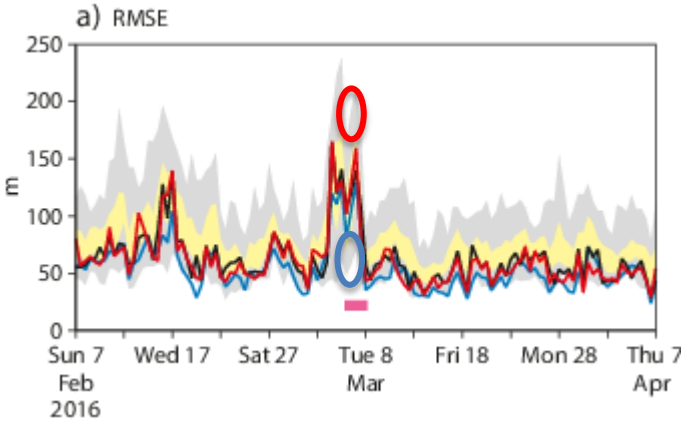
Which diagnostic methods can we apply?

Backward tracking of errors
Forecast errors, z500, 7 March 2016

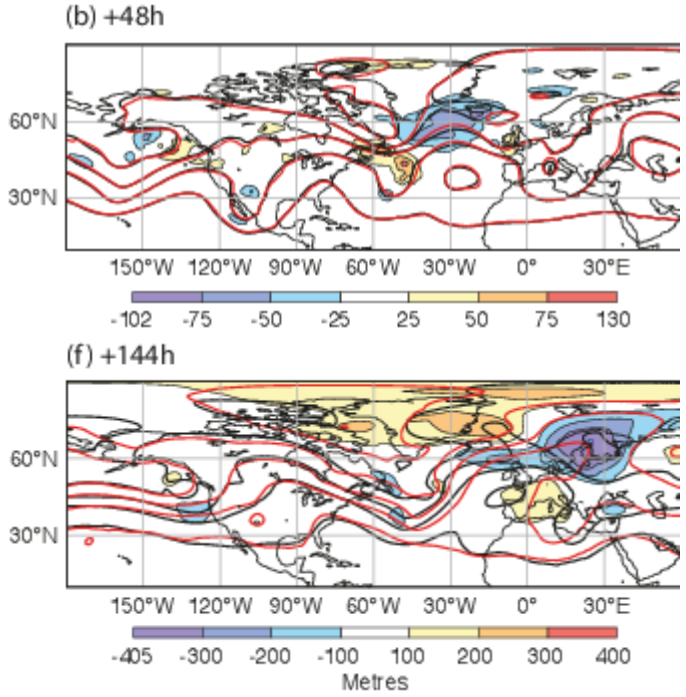


Forecast (black)
Analysis (red)
Error (shade)

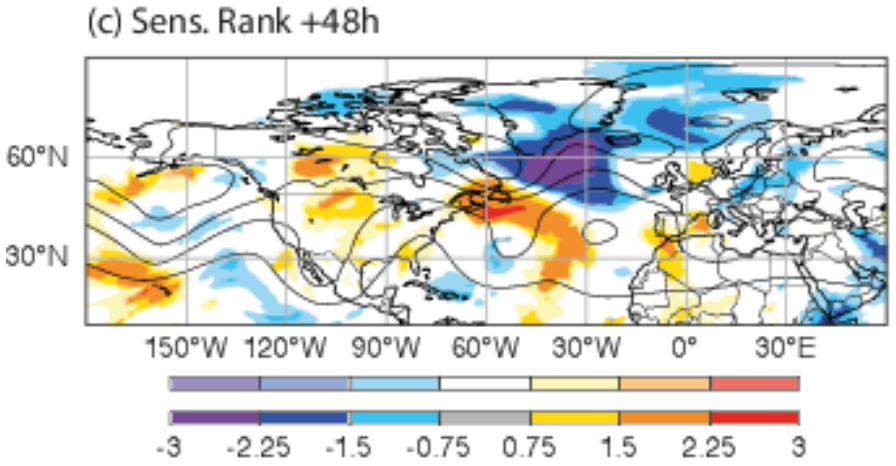
Ensemble sensitivity – rank method

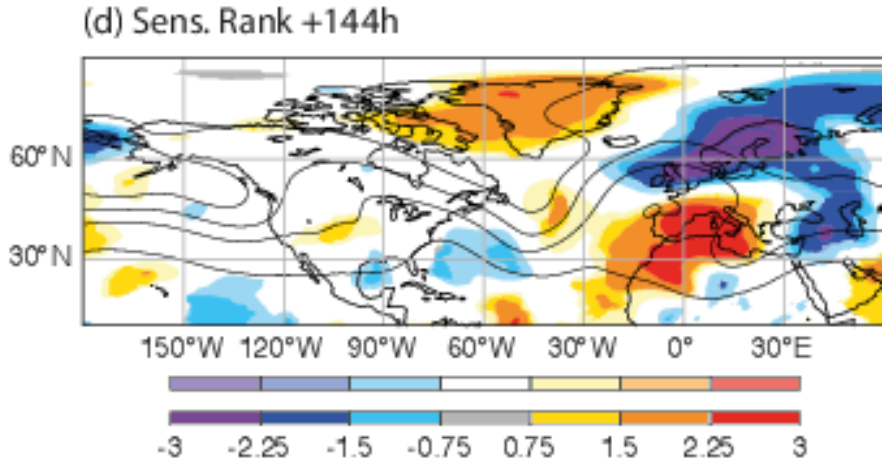


$$\frac{\text{mean(bad)} - \text{mean(good)}}{\text{stdev(all)}}$$



Z500 ensemble sensitivity





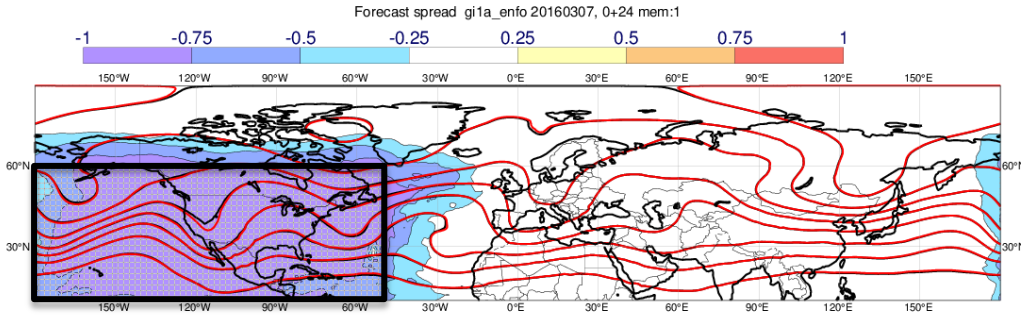
See:
Ancell and Hakim (2007)
Torn and Hakim (2008)
Zheng et al. (2013)
Torn et al. (2015)
Lamberson et al. (2016)
Magnusson (2017)

Relaxation experiment

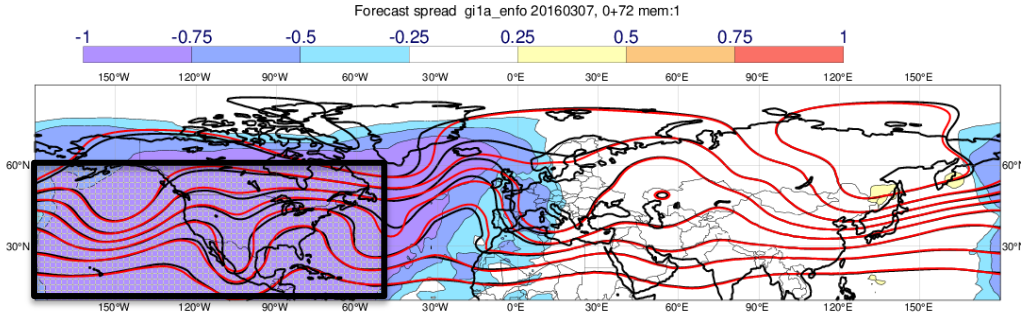
$-\lambda (x - x_{ref})$ 20 ensemble members

Reduction of ensemble spread

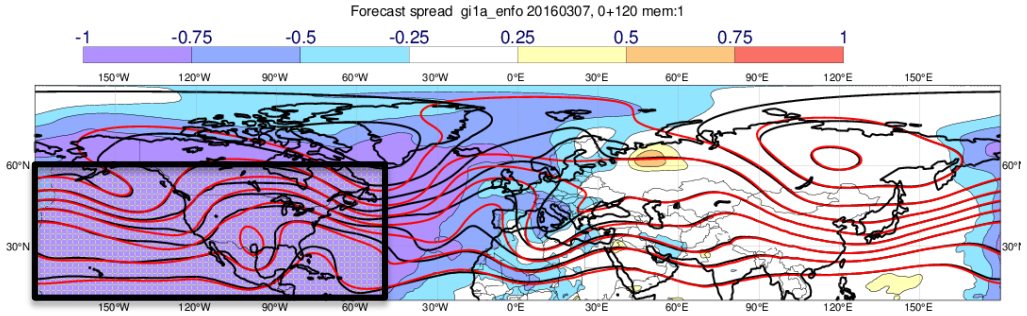
+24h



+72h

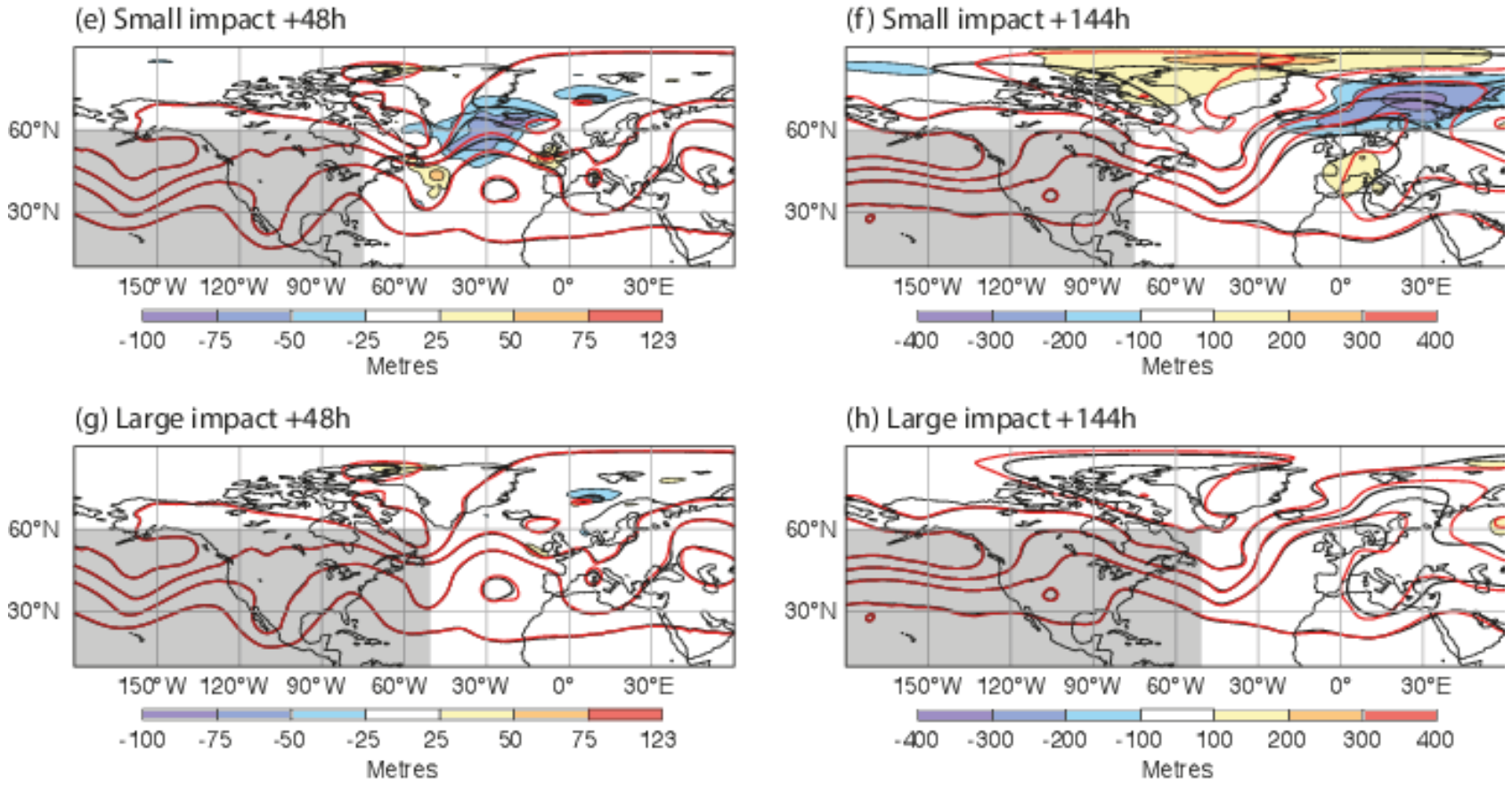


+120h



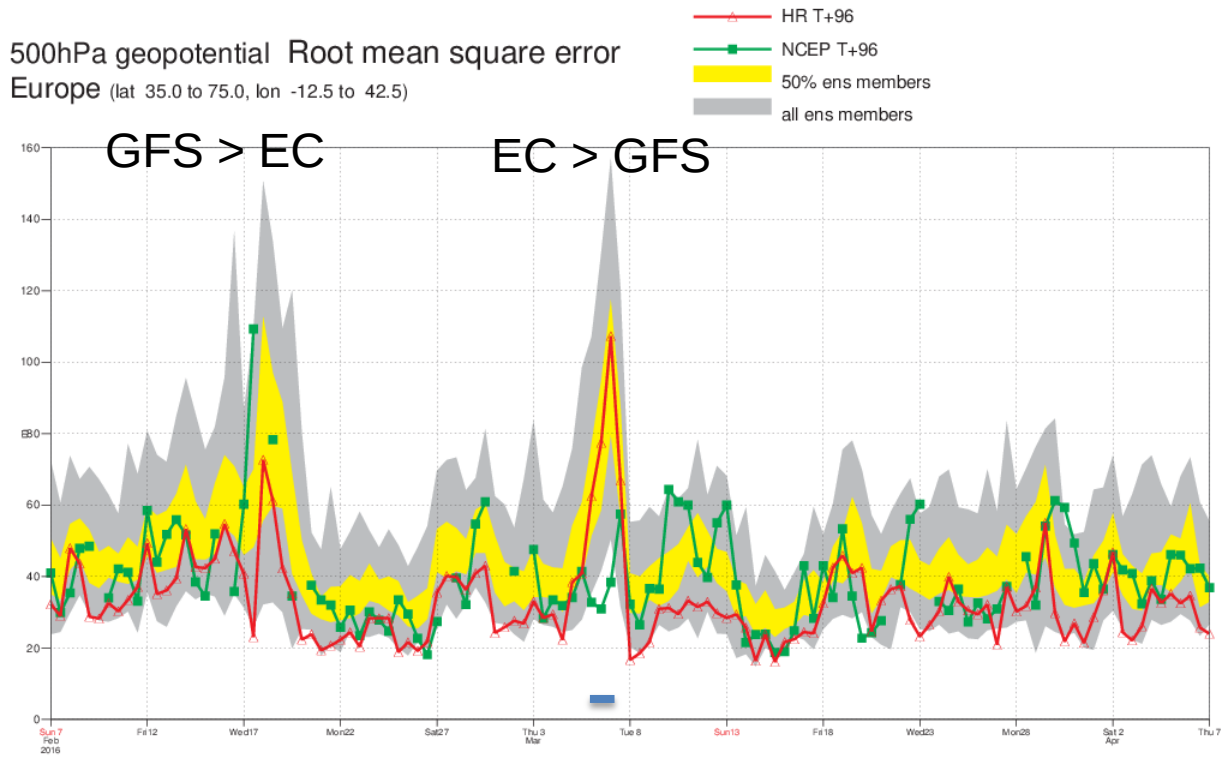
Magnusson (2017)

Errors in relaxation experiments



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

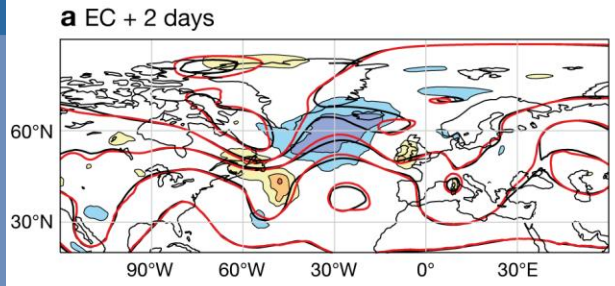
Comparison with other centres:
RMSE, day 4, Europe, February-April 2016

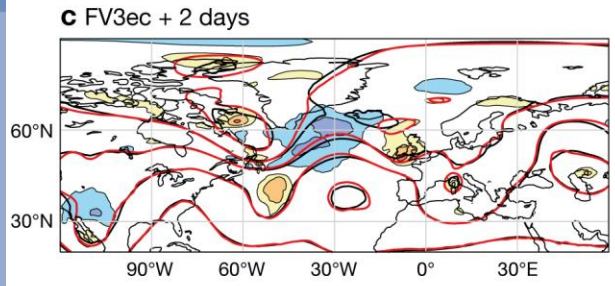


Z500 error pattern for bust case

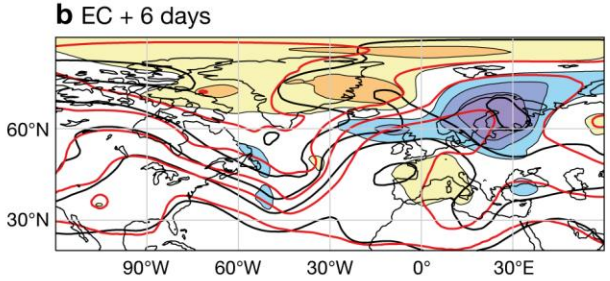
ECMWF initial conditions

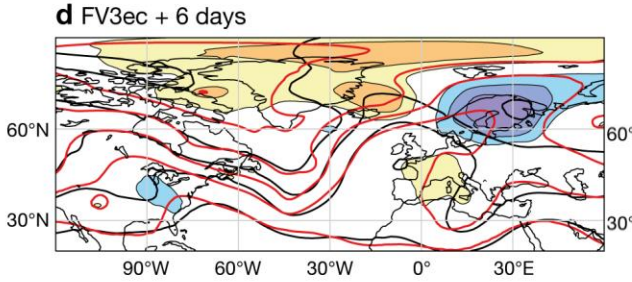
2-day error





6-day error

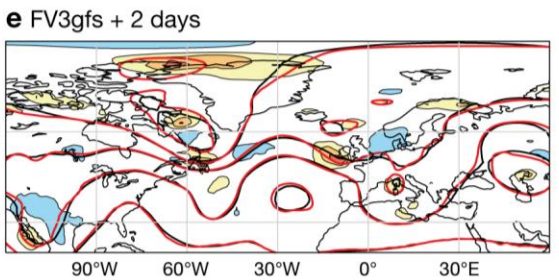


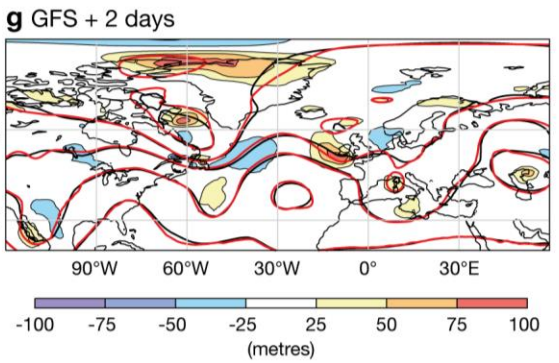


- Initialisation scheme developed at GDFL to initialise FV3 from GFS and IFS initial conditions (Chen et al., AMS Hurricanes 2017)
- Create opportunity to compare forecasts with “same” initial conditions but different models: Compare model biases, predictability, etc

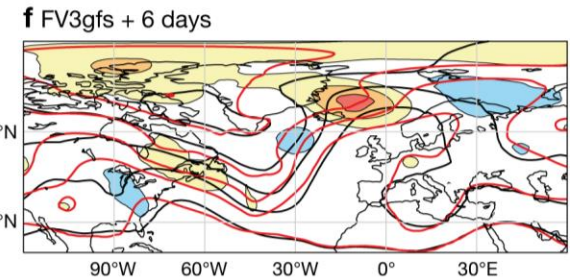
GFS initial conditions

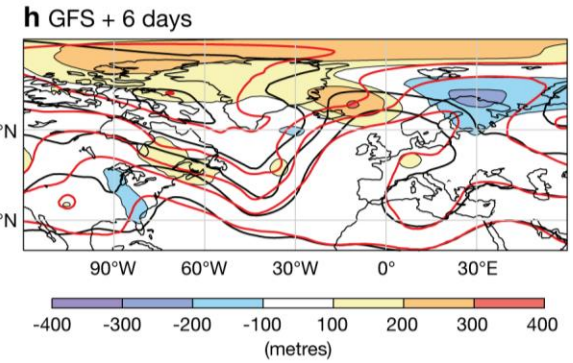
2-day error





6-day error

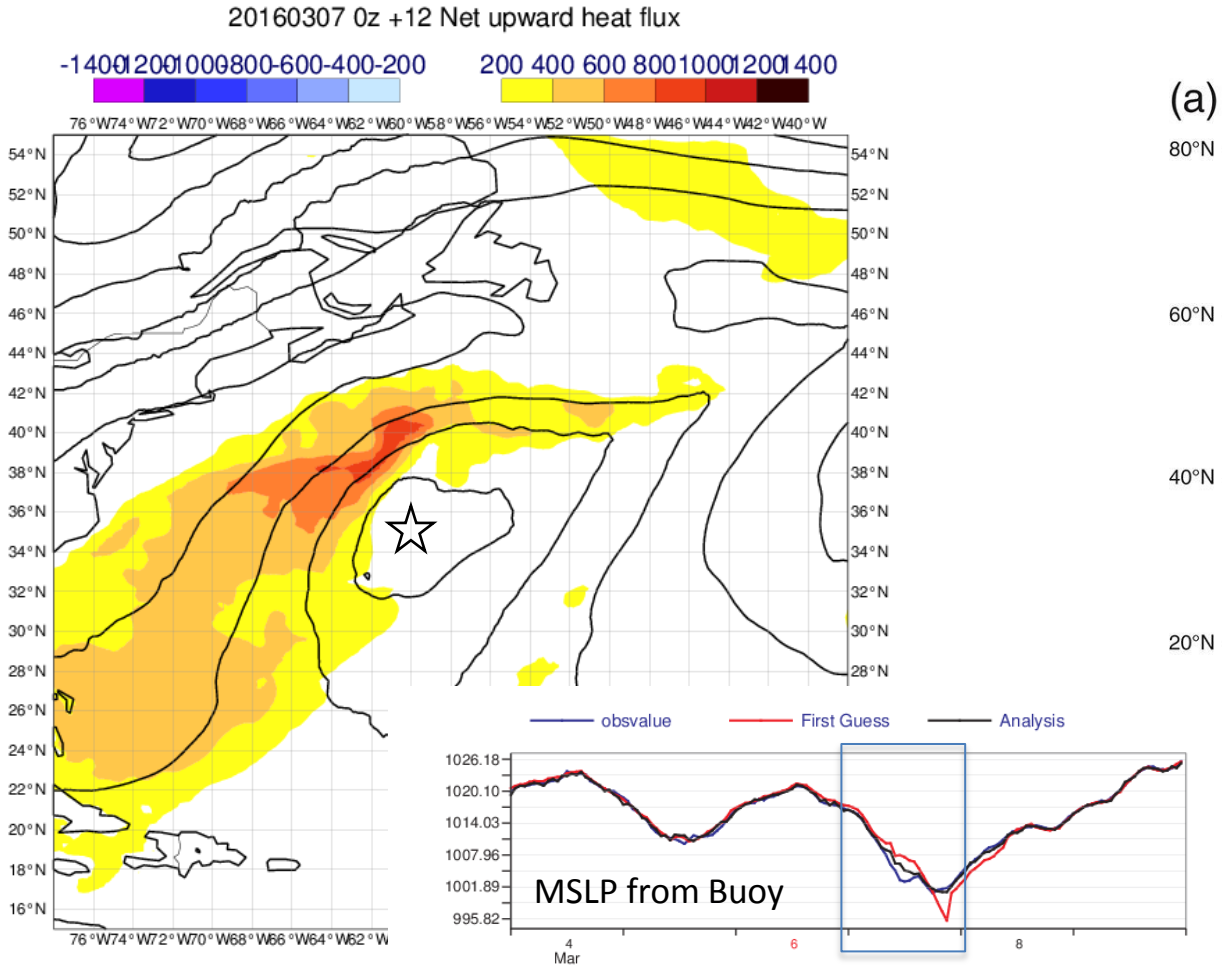




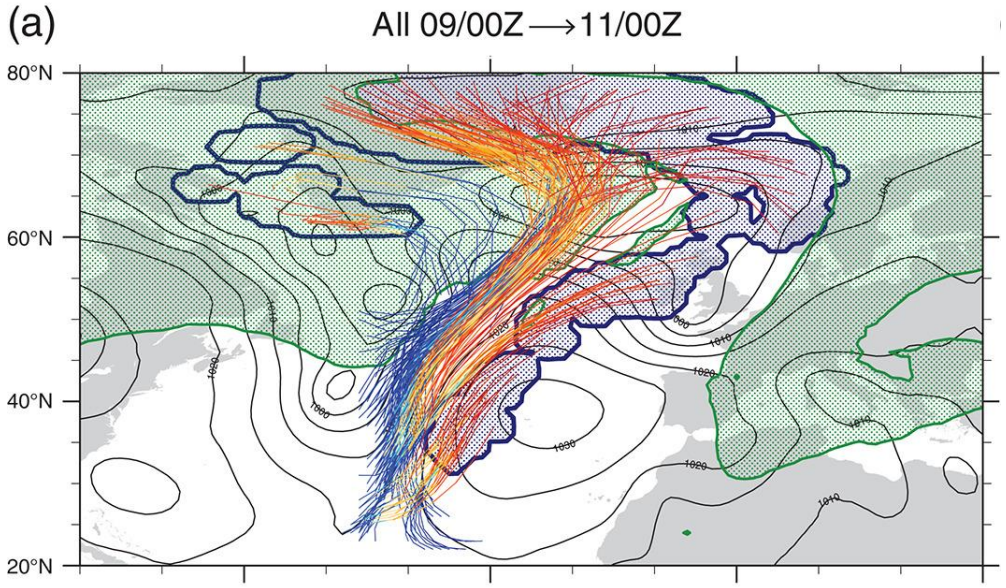
From Magnusson et al. (2019)

Synoptic evolution

Cyclogenesis on 7 March



Warm-conveyor belt associated with cyclone



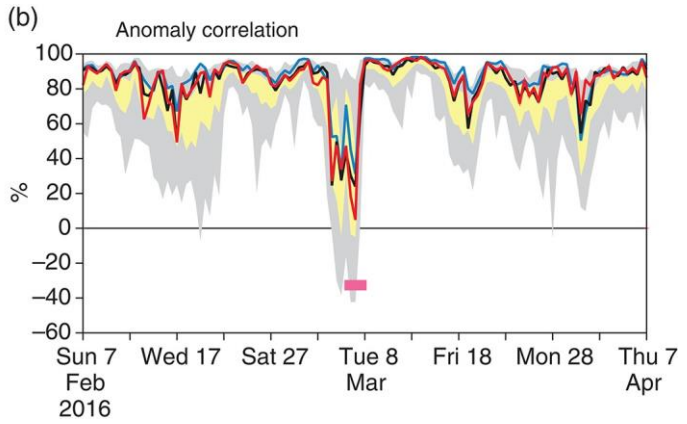
From Grams, Magnusson and Madonna (2018, QJRMS)

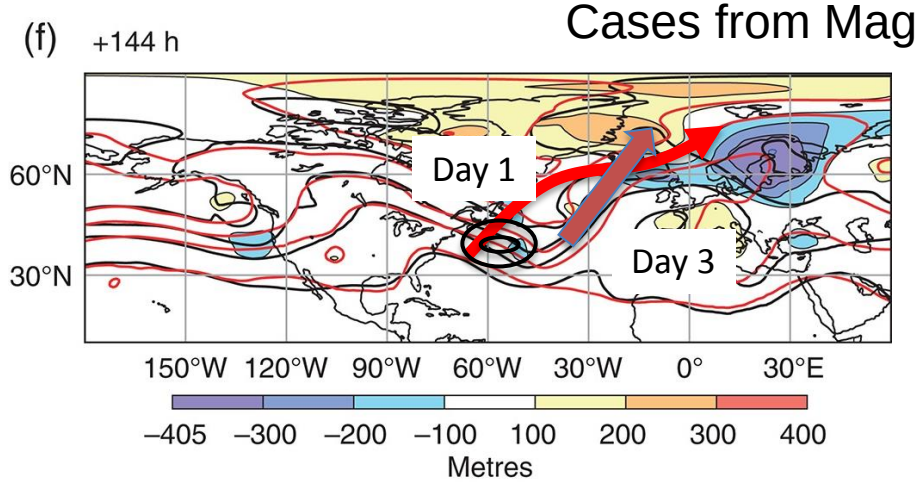
Observation statistics from data assimilation

ECMWF

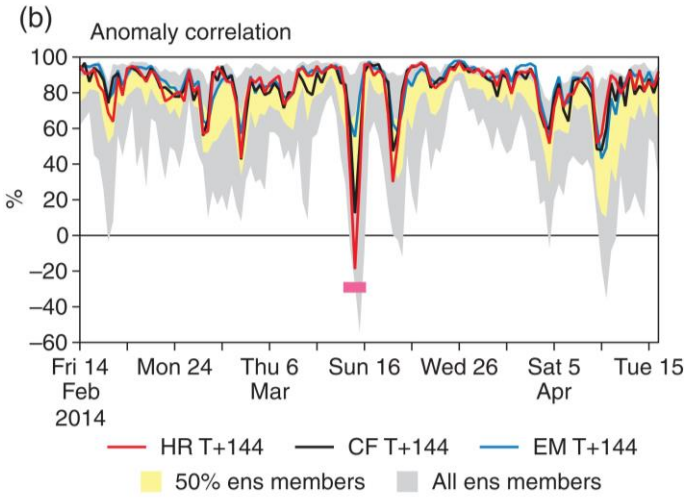
Cases from Magnusson (2017)

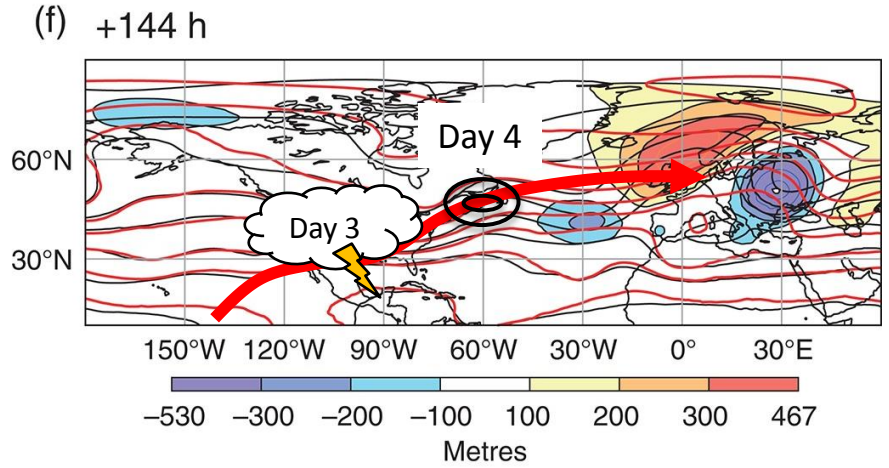
7 March 2016



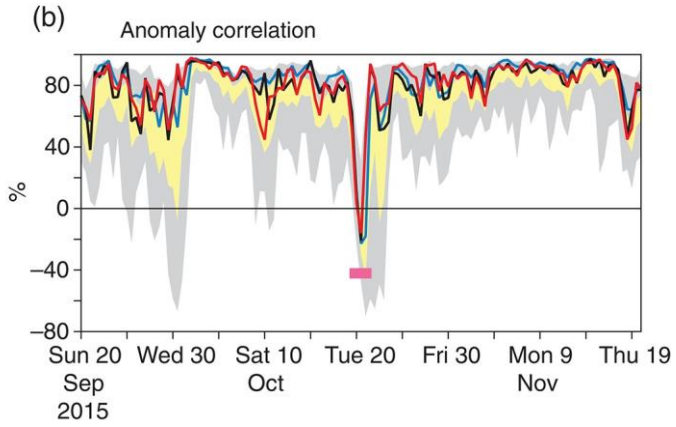


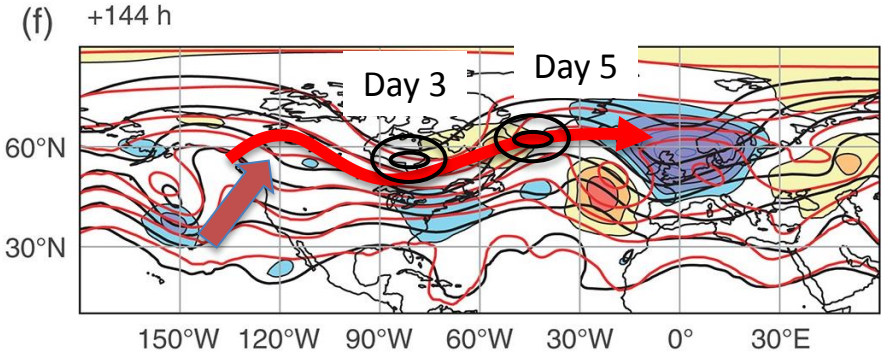
14 March 2014





20 Oct 2015



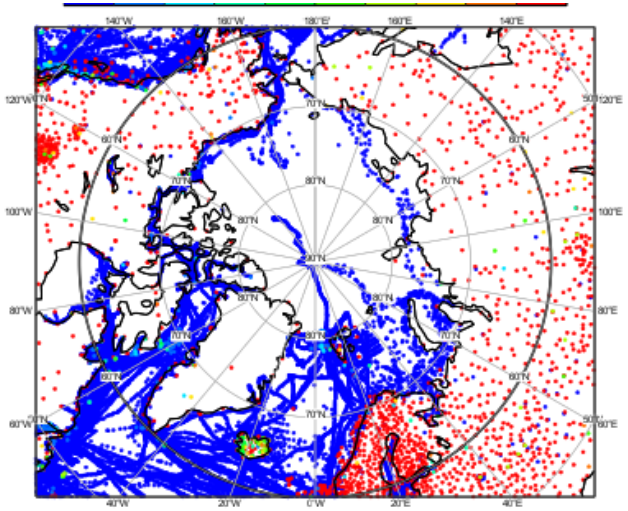


Impact of different observations in the Arctic: Observing System Experiments (OSEs)

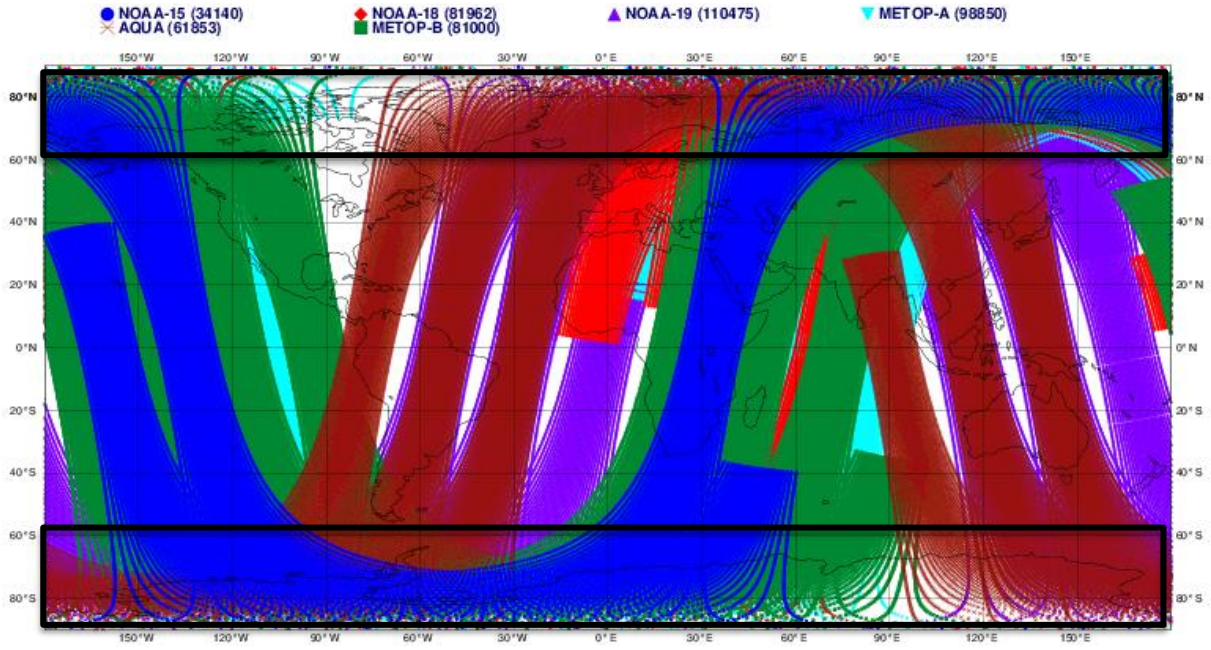
APPLICATE.eu
Advanced prediction in polar regions and beyond

Remove (satellite and conventional) observations at lat>60N and lat<-60S:

Summer pressure obs



Red – regular stations
Blue – moving stations



3 months winter (including YOPP 1st SOP)

3 months summer (including YOPP 2nd SOP)

Analyse the increase in forecast error when observations are removed from the Arctic

ECMWF

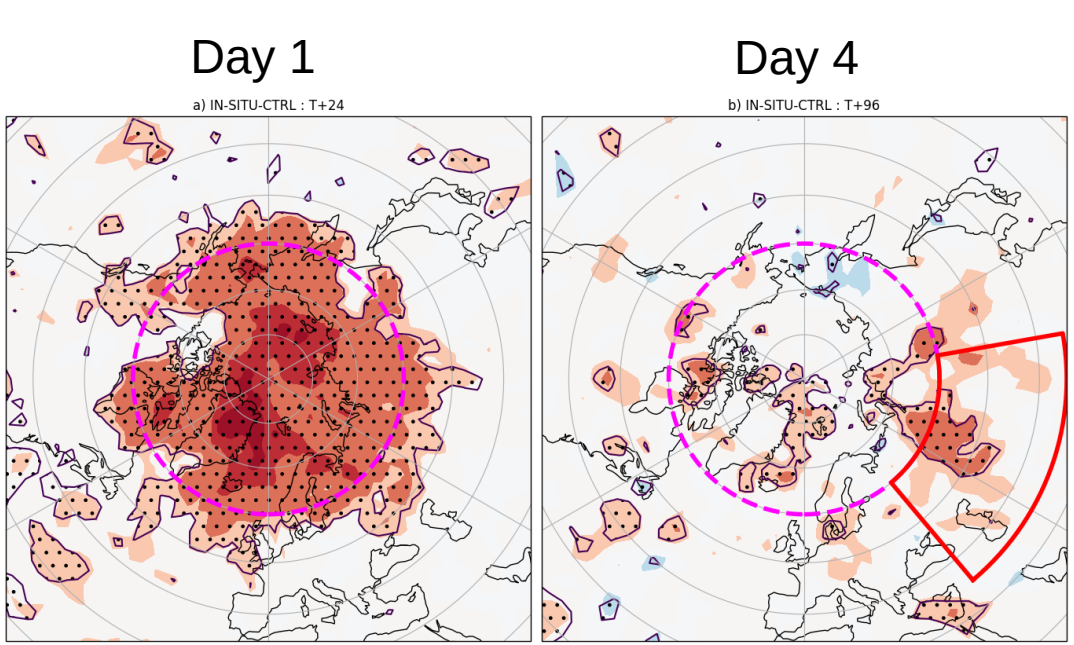
Lawrence et al., QJRMS, 2019

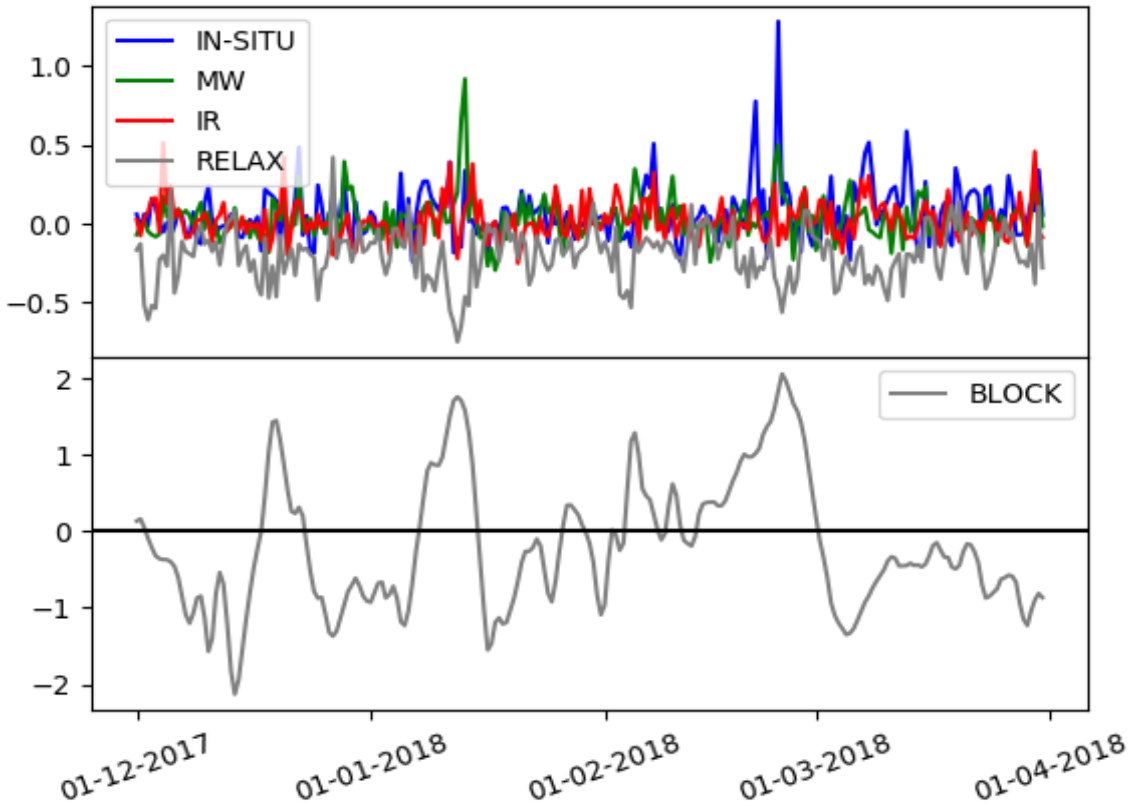
Impact on the midlatitudes & Arctic – midlatitude linkages

APPLICATE.eu
Advanced prediction in polar regions and beyond

Error increase without in-situ obs

Day 1 Day 4





removing Arctic in-situ or satellite observations from the data assimilation system, used to create the initial conditions for the forecasts, deteriorates mid-latitude synoptic forecast skill in the medium-range, particularly during Scandinavian Blocking episodes

Day et al, 2019, QJRMS

ECMWF

Diagnostic tools for finding source regions for errors

- Simple error tracking
- Ensemble sensitivity
- Relaxation experiments
- Compare with other centres
- Swap initial conditions
- Evaluate data assimilation statistics
- Observation system experiment

Challenges

- Role of intrinsic error growth
- Causality
- How do we use the results? (Increased knowledge base, obs usage, education)