Forecast and analysis sensitivity to *in situ* observations

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Overview

- Buoy data: introduction and O-B statistics
- Forecast and analysis sensitivity
  - Comparison with baroclinic development areas
  - Variation within assimilation time window
  - Aircraft/radiosonde analysis sensitivity
- Discussion and summary

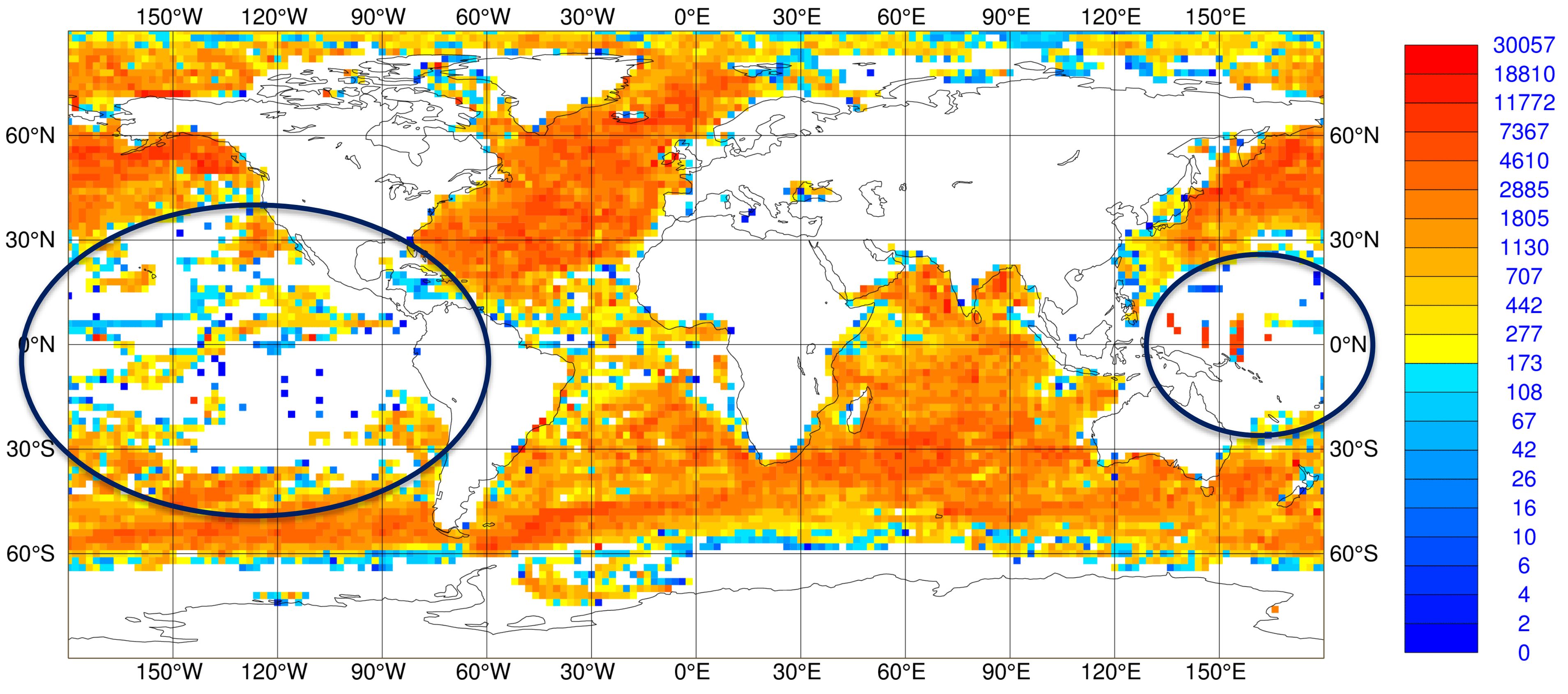
BUOY data

- Looking at alphanumeric BUOY data – mainly drifting buoys plus some tropical moored buoys
- Good quality Pmsl data (small percentage rejected or bias corrected)
- Background Pmsl over ocean also good quality in general
- Quasi-continuous in time
- Well distributed over most oceans – tropical Pacific gap
- Coverage in otherwise very sparse areas
- Ship results (not shown) broadly similar but noisier
- References include: Ingleby (Jtech, 2010), Centurioni et al (BAMS, 2016)

- NB. Need to use BUFR data now, most alphanumeric BUOY reports will stop 1 November 2016! https://software.ecmwf.int/wiki/display/TCBUF/

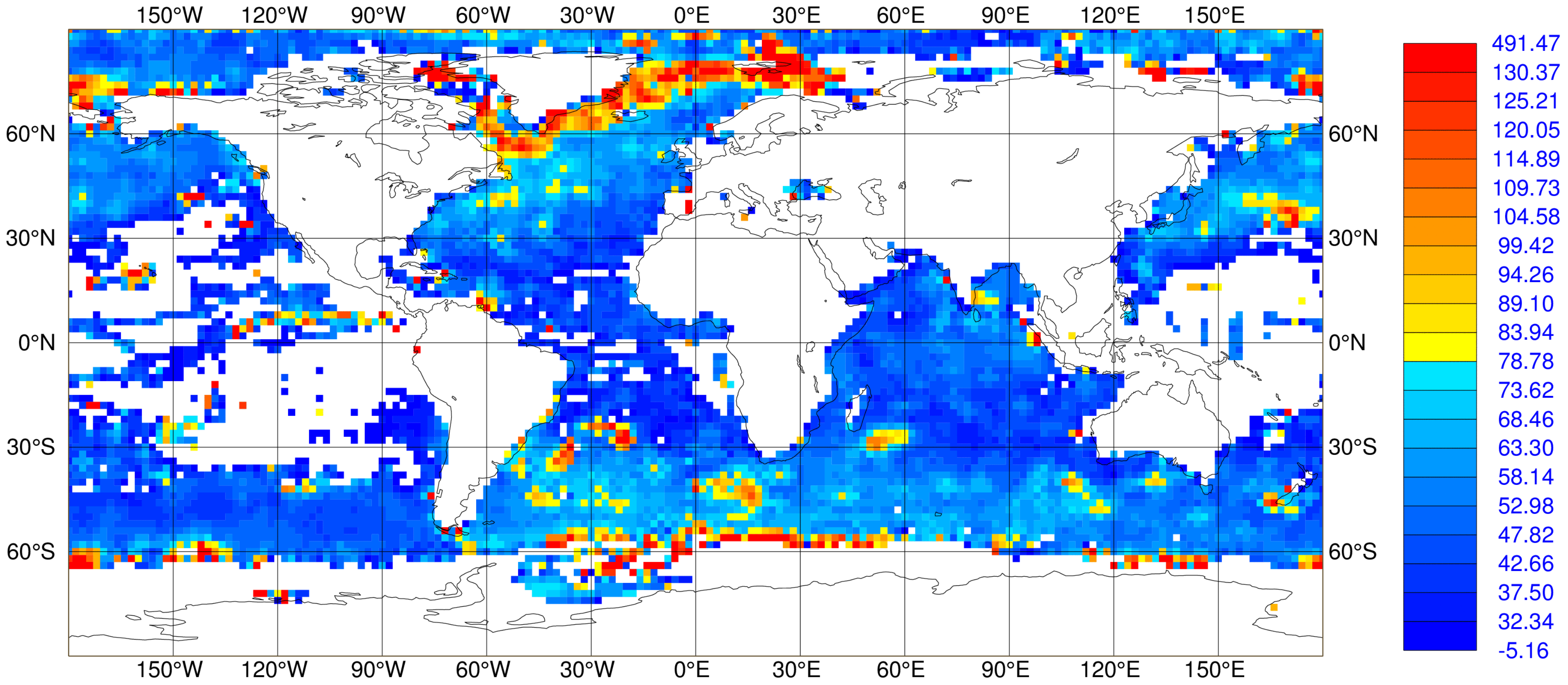
BUOY Pmsl data coverage, 2014-2015

- Numbers of reports used in operational system per 2° by 2° box
- Almost half of drifting buoys are SST+current only (esp. Tropical Pacific)



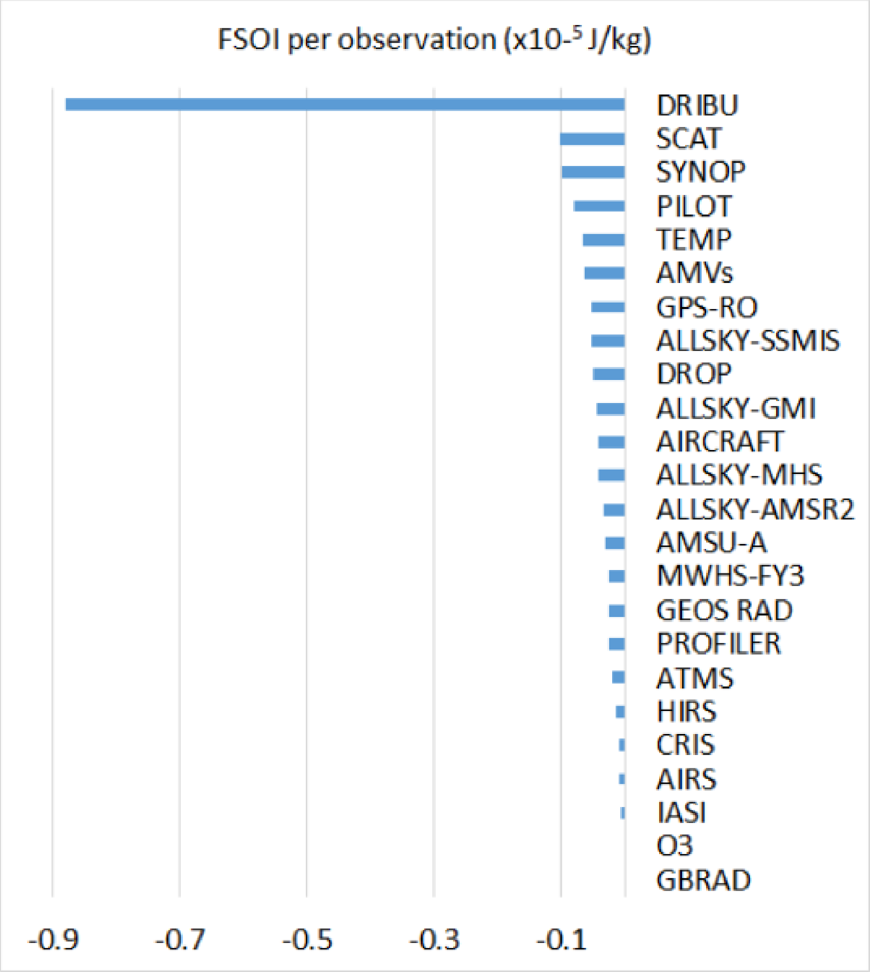
BUOY Pmsl StdDev(O-B), 2014-2015

- Generally very good fit, lowest in tropics
- Larger values at high latitudes – especially ice edge? Sensor icing?
- Some special ‘ice buoys’ in the Arctic.



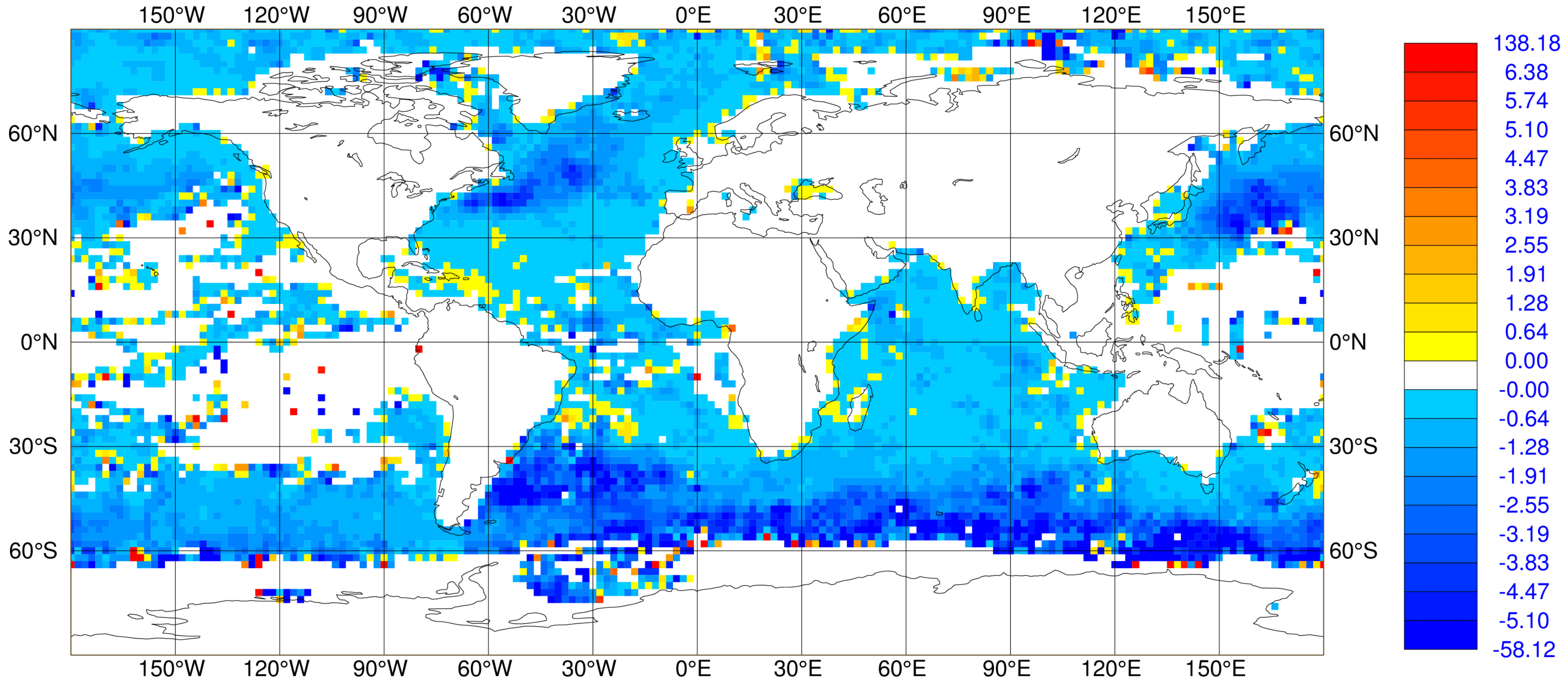
Forecast sensitivity

- FSOI: Forecast Sensitivity to Observation Impact
  - Uses a particular norm (usually energy) – dimensional
  - Negative values indicate smaller errors (at T+24)
- FSOI calculated for ECMWF operational system since 2012
- Drifting buoys have largest FSOI per datum, results for March 2016 (C Lupu, ECMWF) right



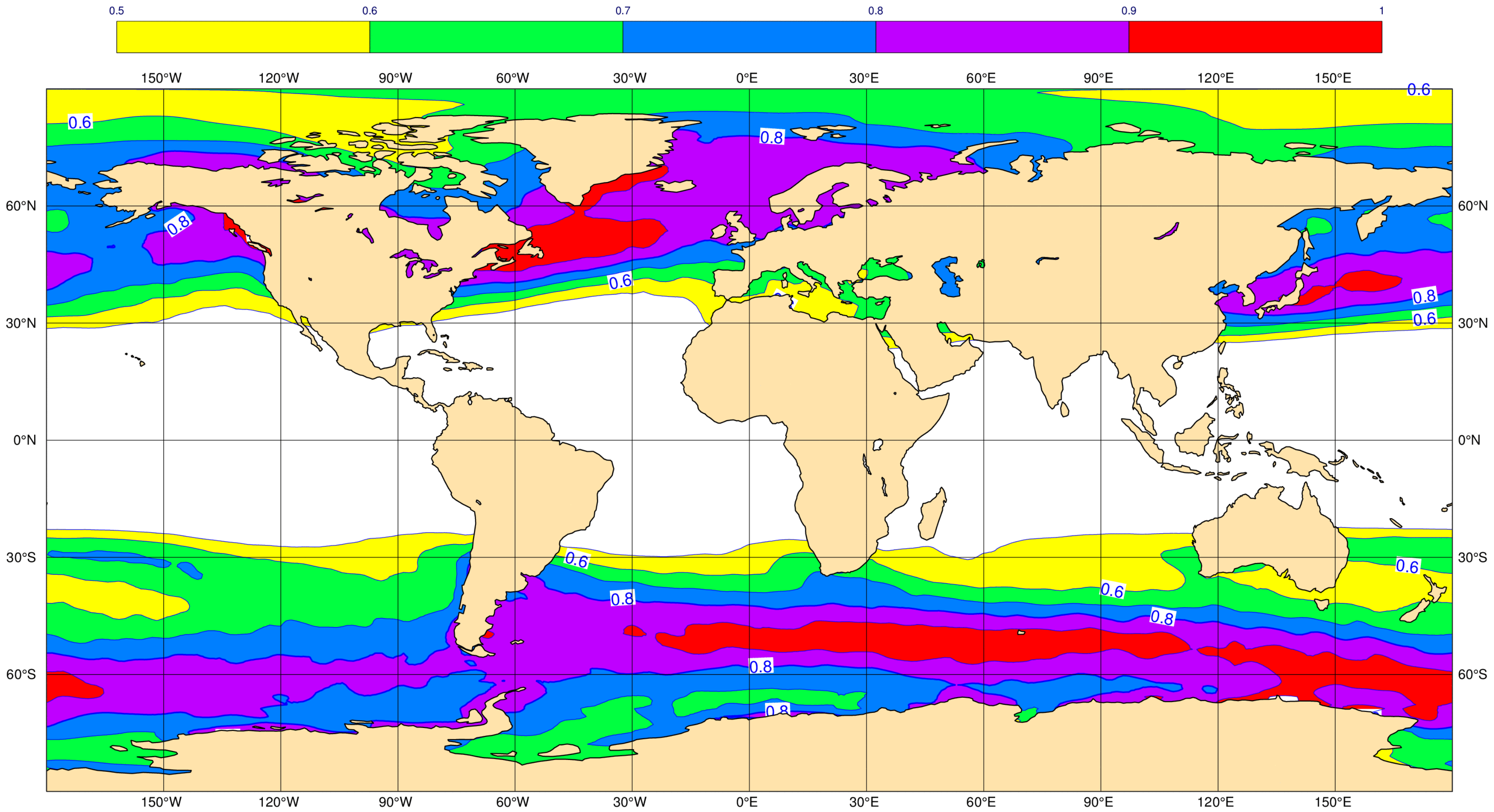
FSOI for BUOY Pmsl

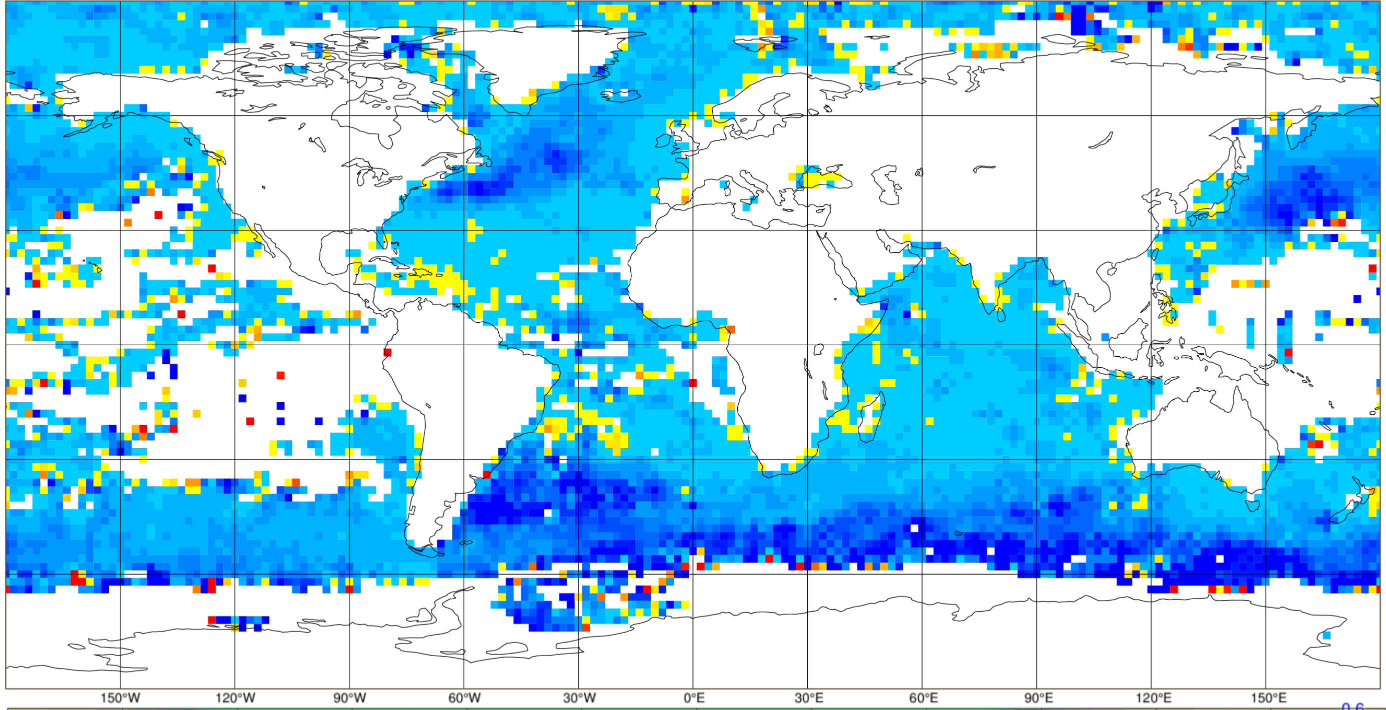
- Uses energy norm vs analysis at T+24
- Mean value -1.17 J
- Small sample points are noisy but clear overall pattern



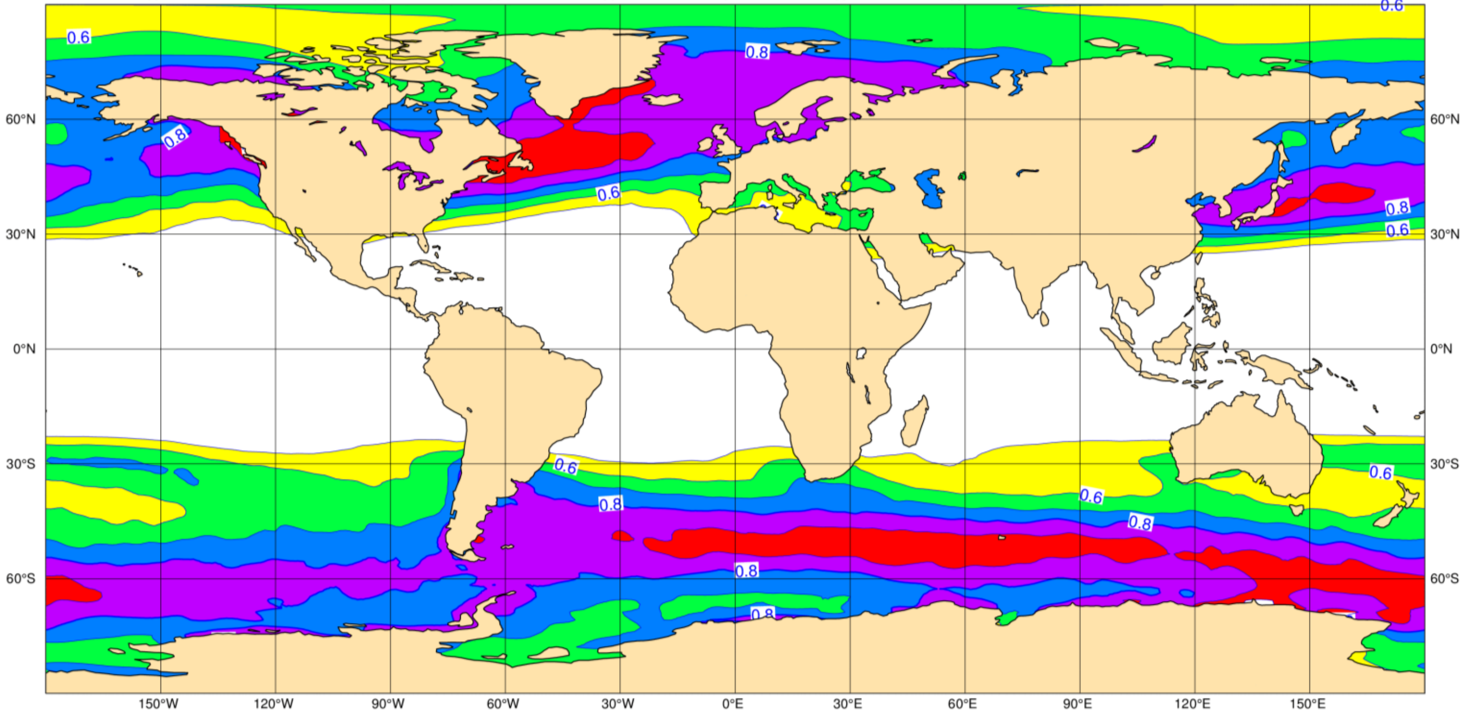
Baroclinic development (rms of Eady index, 2014-2015)

- Index calculated from 850 to 300 hPa. Hoskins and Valdes (JAS, 1990)
- NH maxima near Gulf Stream and Kuroshio (as for FSOI)





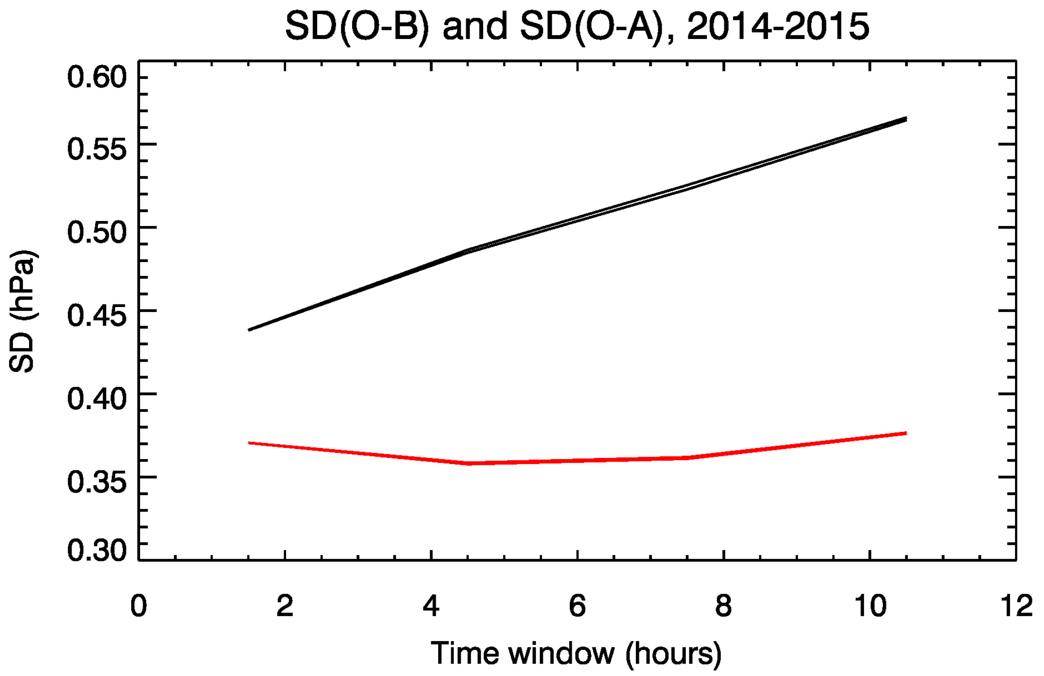
FSOI

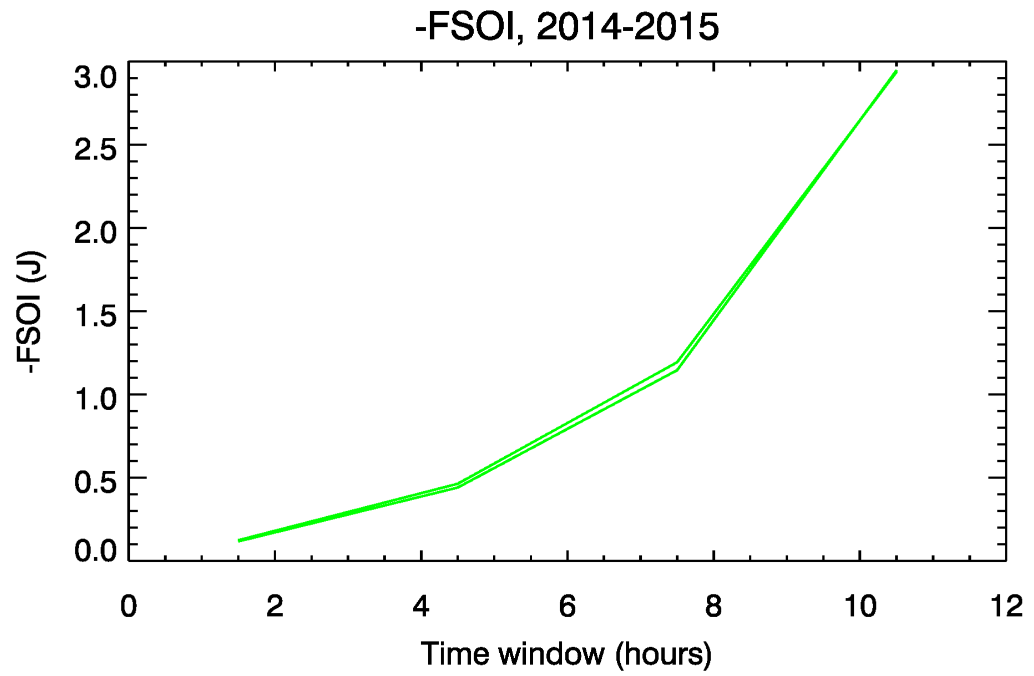


Eady Index

Fit to data and FSOI

- ECMWF uses strong constraint 4DVar with 12 hour window (21-09 and 09-21Z)
- Statistics for 3-hour sub windows, both 00 and 12Z windows shown but lines overlap
- SD(O-B) increases into the window, SD(O-A) shows slight minimum in middle – well known features
- FSOI near zero at start of wind increases sharply near end
- Partly expected. Gauthier (2013, presentation) and McNally (2016, presentation) have related results.



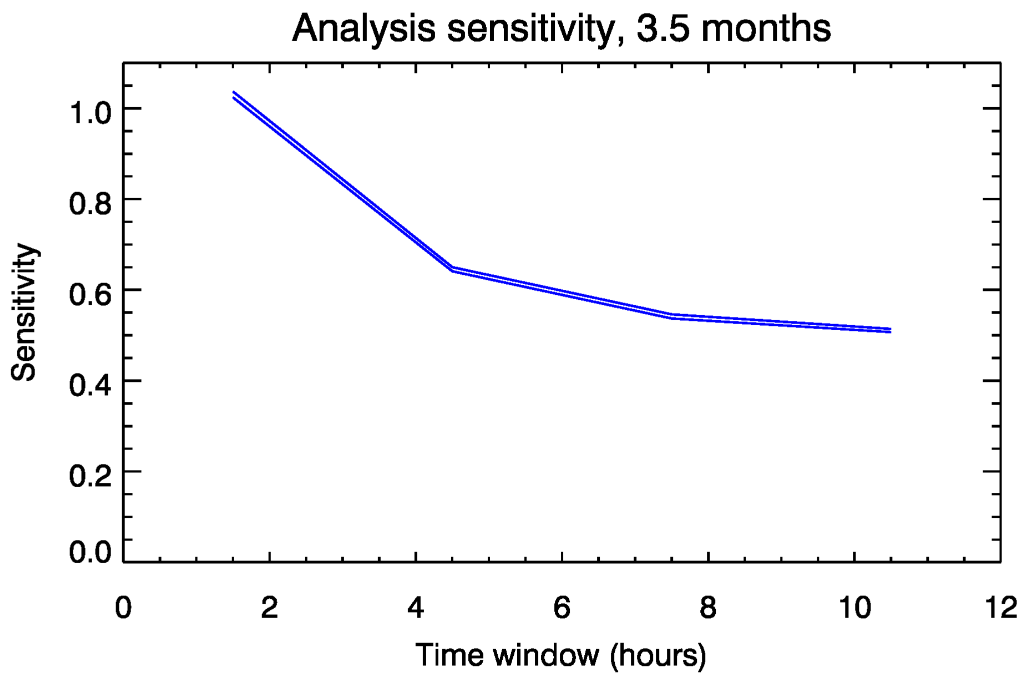


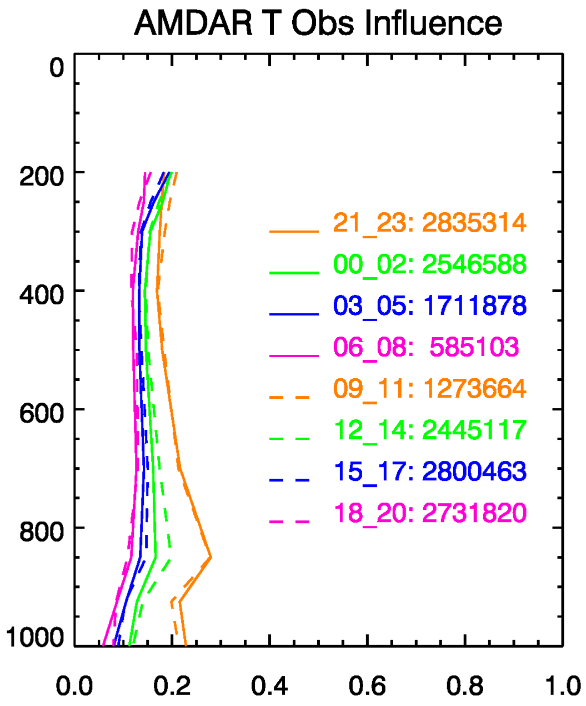
Forecast and analysis sensitivity

- FSOI: Forecast Sensitivity to Observation Impact
  - Uses a particular norm (usually energy) – dimensional
  - Negative values indicate smaller errors (at T+24)
- FSOI calculated for ECMWF operational system since 2012
- Analysis sensitivity (‘observation influence’)
  - Analysis increment projected to observation time and variable normalised by observation increment (Cardinali, 2013, in Park and Xu book)
  - Non-dimensional, generally between 0 and 1. ~ ‘Effective weight’.
  - Depends on σ_o/σ_b and observation density
  - Less used than FSOI
- Both require extra computation (vs standard 4DVar)
- Analysis sensitivity only available from trials with particular options – 3.5 month trial used

Analysis sensitivity

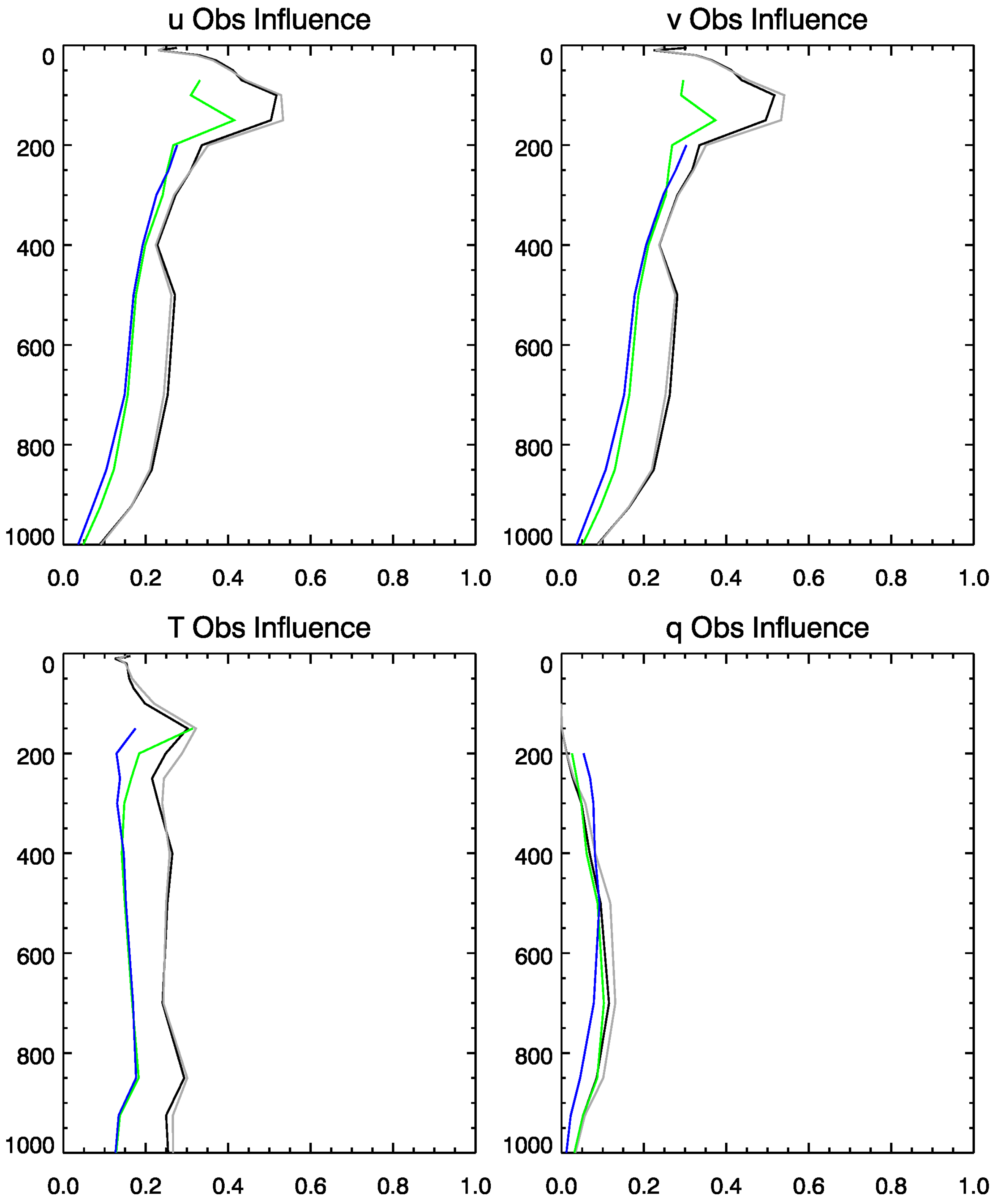
- Trial April to mid-July 2014
- Buoy sensitivity ~1 near start of window but drops with time
- New result, surprising at first – ‘opposite’ to FSOI
- First noted for radiosonde/aircraft data (bottom plot) – lower sensitivity/ influence than BUOY data, but highest at the start of the window





Variation with height/variable

- Radiosonde (black) and aircraft (green/blue) results
- Wind sensitivity low near surface increases with height (relative minimum at flight levels)
- Temperature sensitivity approximately constant with height
- Humidity sensitivity largest in mid-troposphere; small (~0.1) partly due to large σ_o in ECMWF system
- Larger wind/temperature sensitivity to sonde than aircraft data – most radiosondes 2 or 3 hours into window (also data density)



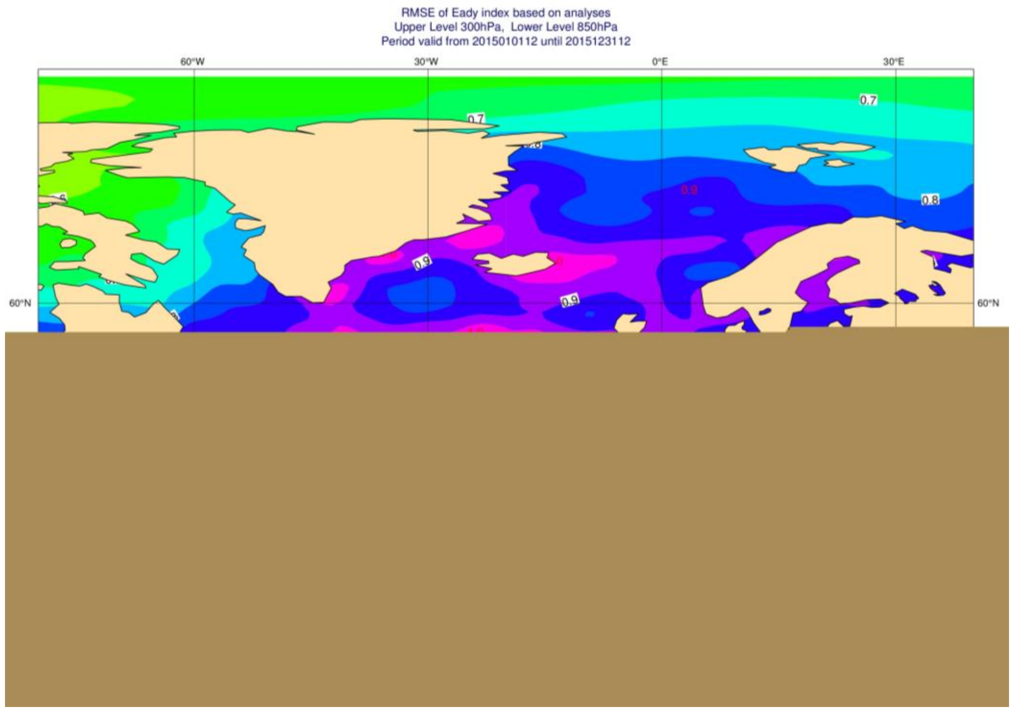
Discussion and summary

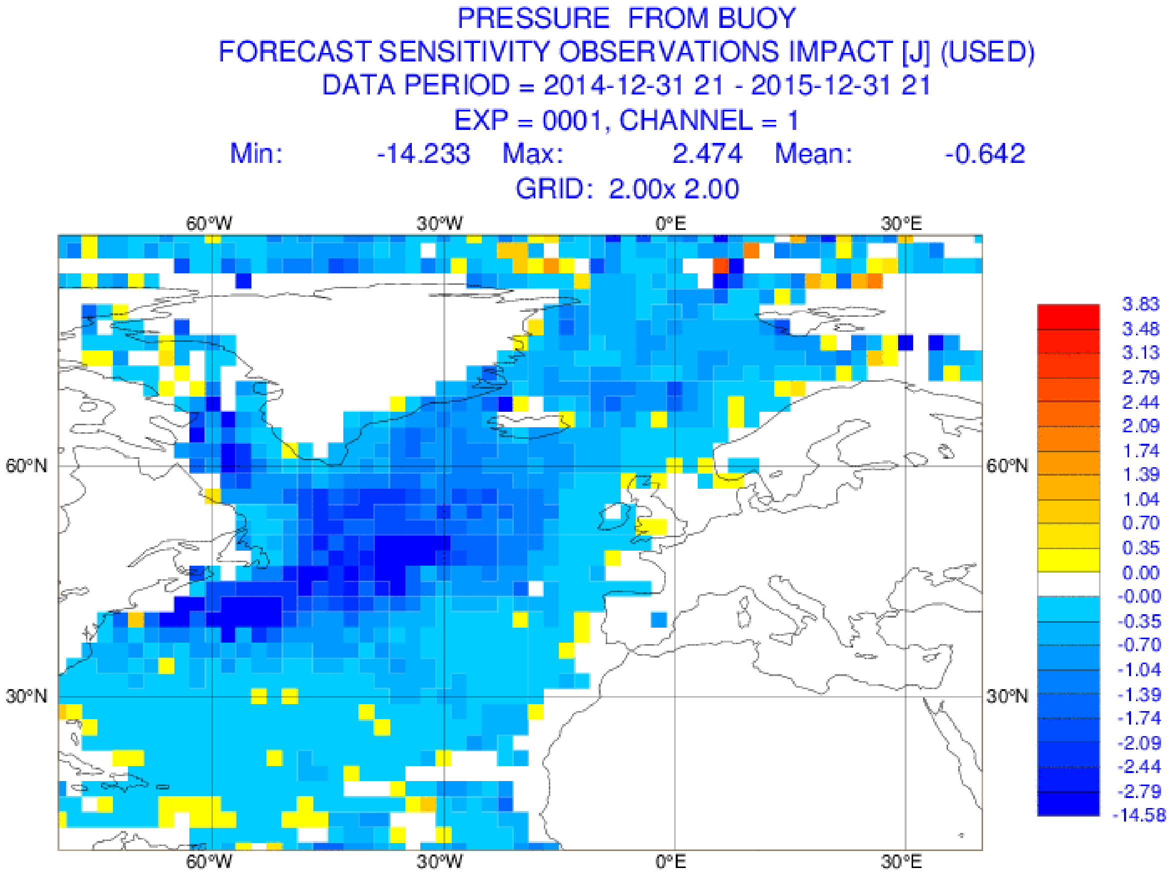
- FSOI ~0 at start of window but large at end (overstated or not?)
- Analysis sensitivity high at start of window then decreases
    - Sampling effects may affect results for some observations/orbits
    - We need timely data (near end of window) for best forecasts
- Hypothesis: near-start observations project mainly onto decaying modes, near-end observations project mainly onto growing modes. Consistent with Singular Vector view of Johnson et al (MWR, 2006)
- Weak constraint 4DVar offers prospect of fitting the observations more evenly through the window (more constant analysis sensitivity). Effect on FSOI is less clear and may depend on the flavour of weak constraint.

- FSOI for BUOY observations is largest (-ve) in areas of baroclinic instability – need to make sure those areas are well observed (synoptic common sense)

FSOI vs Eady index (Hoskins and Valdes, 1990)

- Calculated between 850 and 300 hPa for 2015
- Links to SST gradient (Gulf Stream)





Standard deviation of Pmsl O-B

- Highest SD in ‘baroclinic area’, to S of this ships worse than buoys
- Some large (ice-related?) SDs in North for buoys