Impact assessment approaches for field campaign data

M. Dahoui, T. McNally, L. Isaksen and L. Magnusson

Mohamed.Dahoui@ecmwf.int

ECMWF

Outline

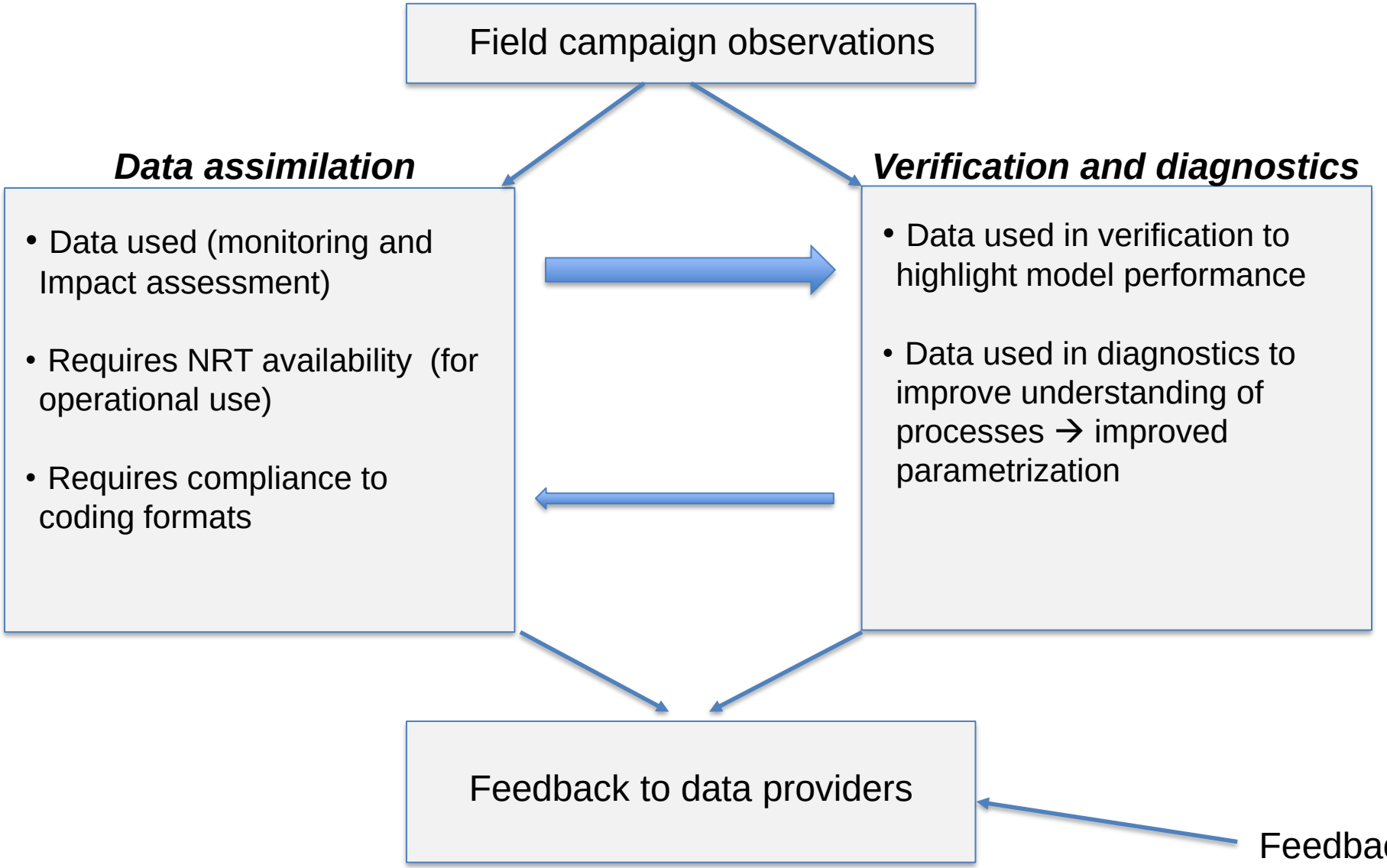
1. Introduction
2. Impact assessment approaches
3. Test cases
4. Conclusion

Introduction

Field campaigns are important for NWP to:

- Address scientific knowledge gaps (improve understanding and test of hypotheses):
  - Storms and Tropical cyclones initiation and evolution
  - Gravity waves initiation and propagation
  - Boundary layer processes
  - etc
- Demonstrate the benefit of extra/new observations:
  - Constrain the model in sensitive areas
  - Test coverage scenarios (e.g. dropsondes around TCs)
  - Test impact of new observations

Introduction



observations impact on forecasts?

Contribution of observations to the reduction/increase of the forecast error (to be *measured* against the *truth*)

- What is the truth ? Not known but proxies are used :

  - Conventional (in situ) Observations ? Poor spatial coverage (under-sampling) and have errors

  - Satellite Observations ? Excellent spatial coverage but limited vertical resolution and have errors

  - NWP analyses ? Perfect spatial coverage but have errors

- Impact measures :

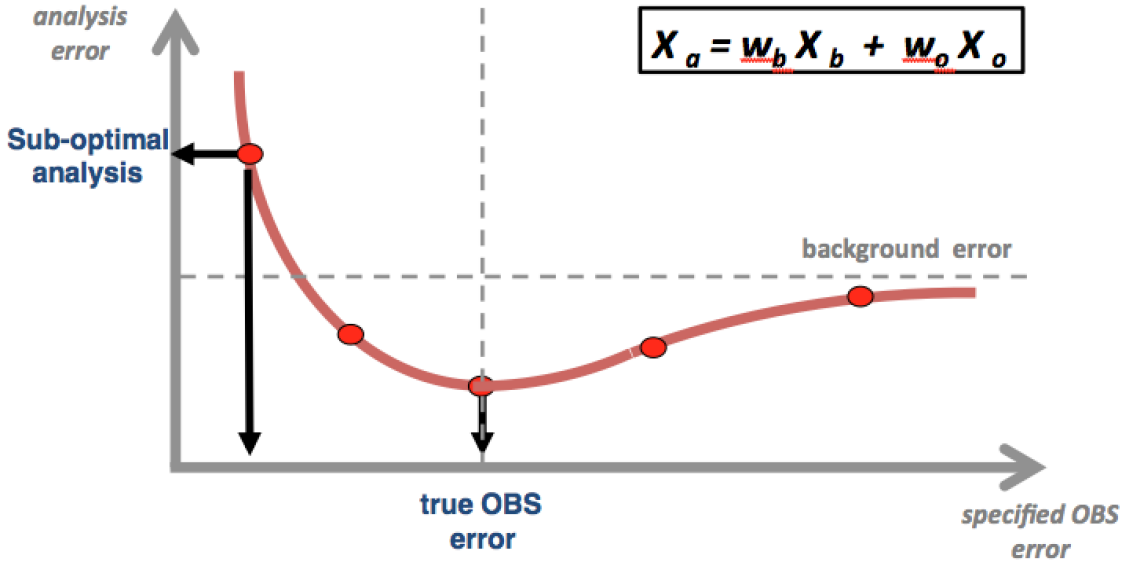
  - Statistical area averaged measures for selected parameters and levels (e.g. RMSE of Z500)

  - Statistical global measures combining impact on many parameters and atmospheric layers (e.g. dry energy norm)

  - Measures targeting high impact weather (e.g. TC track and intensity)

Factors that influence the impact ?

- Observed quantity (some parameters are more useful than others)
- Observation quality
- Observation usability (ambiguity)
- Observation spatial coverage
- Observation time (end of the DA window more influential)
- Tuning of the assimilation system (correct specification of B, R, BC, QC)

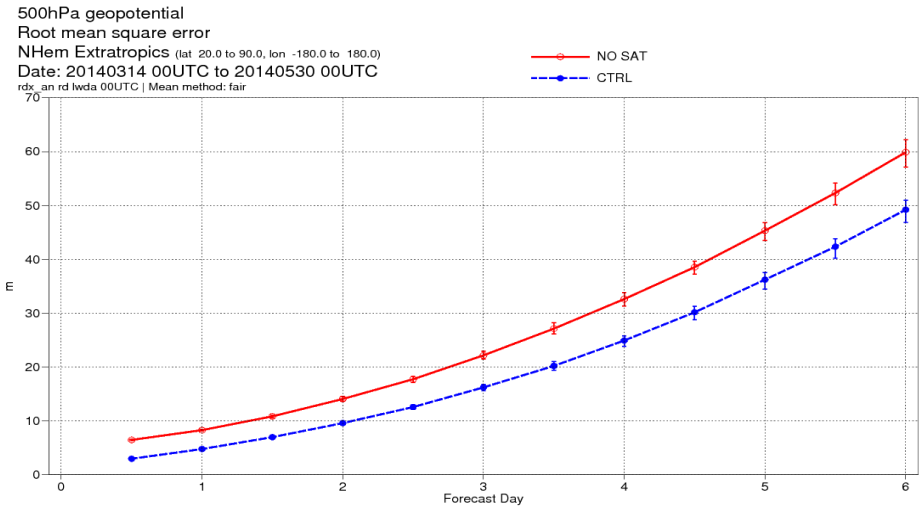


From: T. McNally, ECMWF

Impact assessment methods

Observing System Experiments (OSE)

- Denial or addition of sets of observations: running over a period of time
- Results are compared to a control experiment (with all observations)
- Changes of scores reflect the influence of the data (statistical evaluation for selected parameters/vertical levels over pre-defined areas).
- The approach is also used for case studies (high impact weather events).



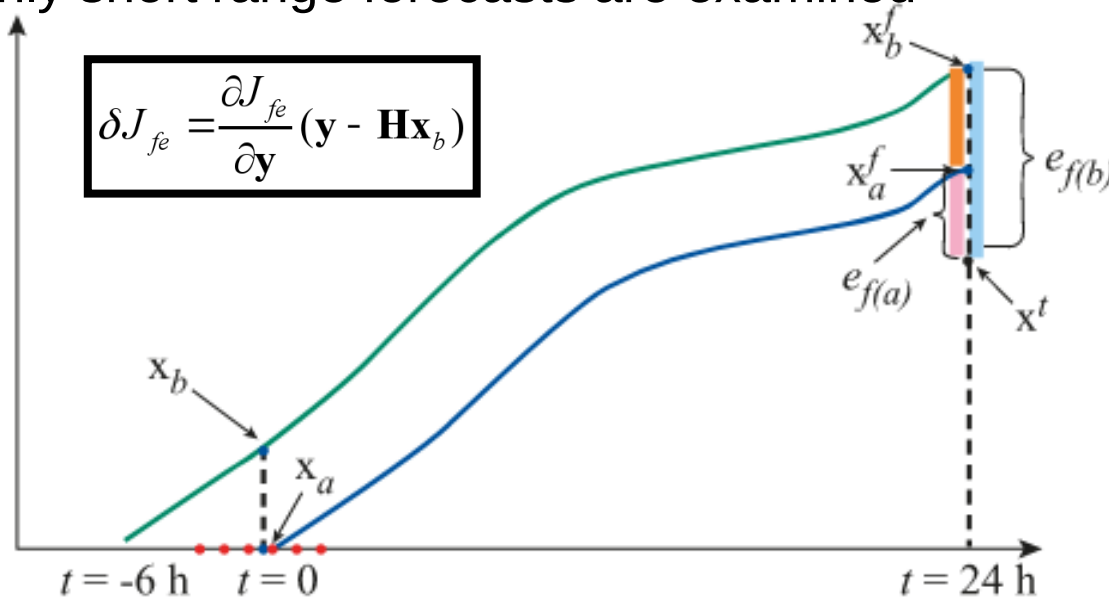
ECMWF

Impact assessment methods

Adjoint Sensitivity Diagnostics (FSOI)

- Computes the variation of forecast error due to the assimilated observations
  - Positive variation means forecast error increase
  - Negative variation means forecast error decrease
- The forecast error measure is based on normalised difference of the forecast and a proxy to the truth (The analysis is used).
- Linearity assumption are applied and consequently only short range forecasts are examined
- Impact assessed without denial

$$\delta J_{fe} = \frac{\partial J_{fe}}{\partial \mathbf{y}} (\mathbf{y} - \mathbf{H}\mathbf{x}_b)$$



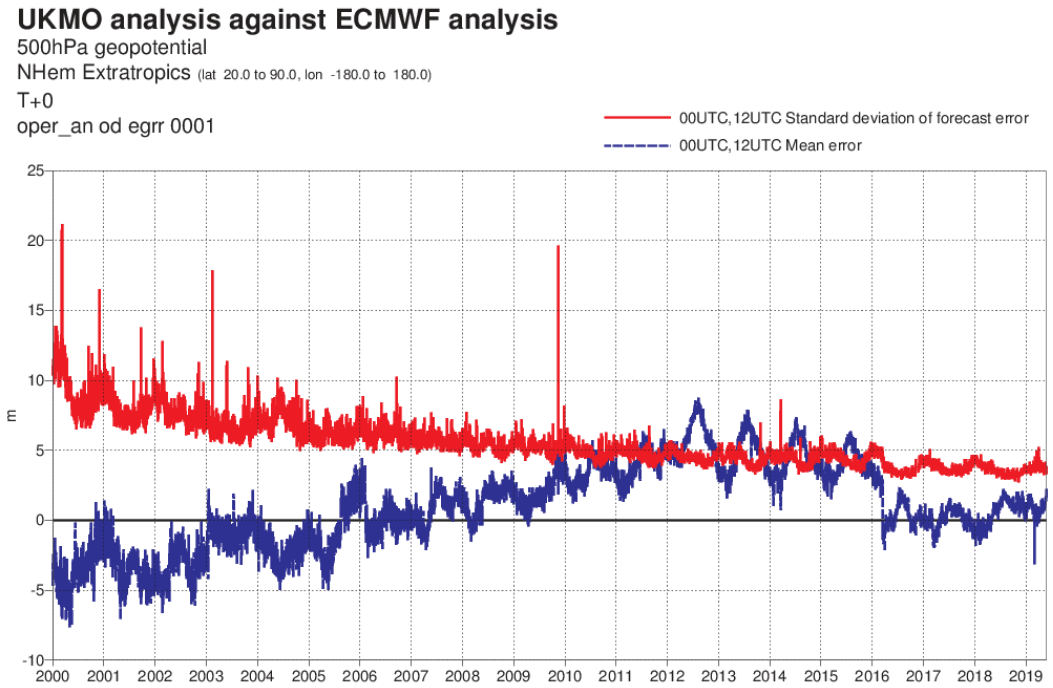
https://www.ecmwf.int/en/forecasts/quality-our-forecasts/monitoring-observing-system

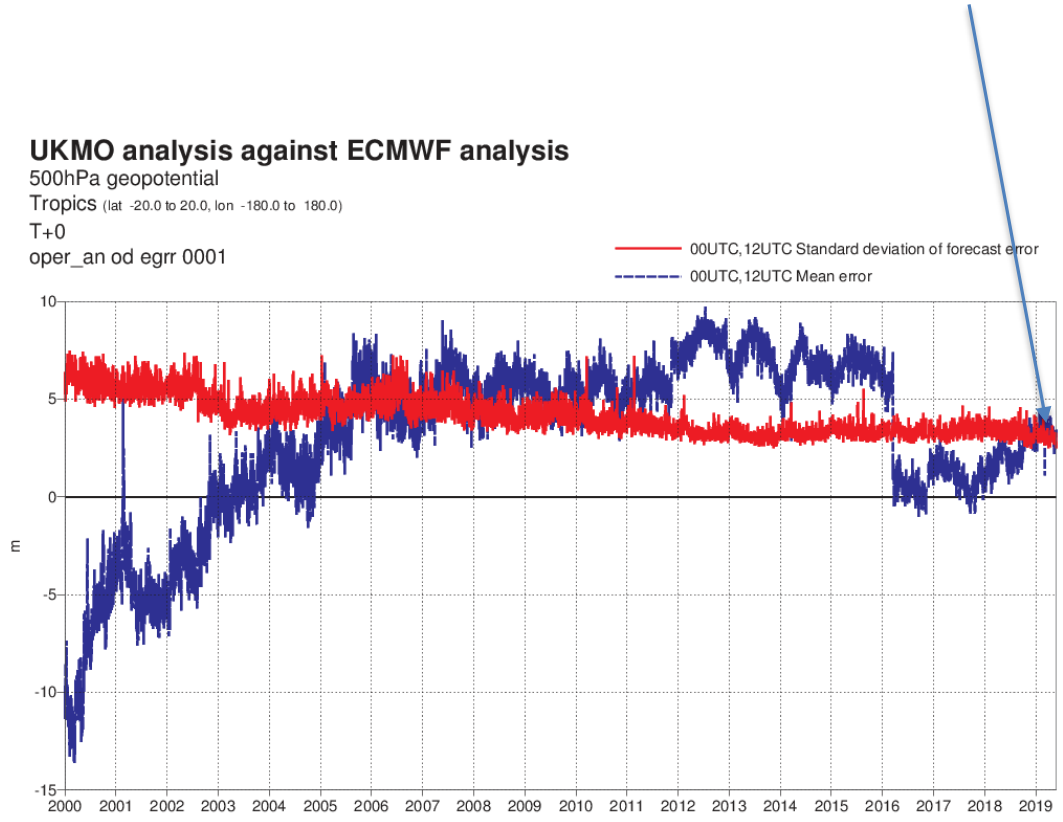
Langland and Baker 2004

Impact assessment methods

Both methods are reliable subject to :

- The accuracy of the verifying state (errors can mask small improvements)
- Sampling noise (for statistical evaluations)
- Correct specification of system parameters (B/R)
- Appropriate interpretation !





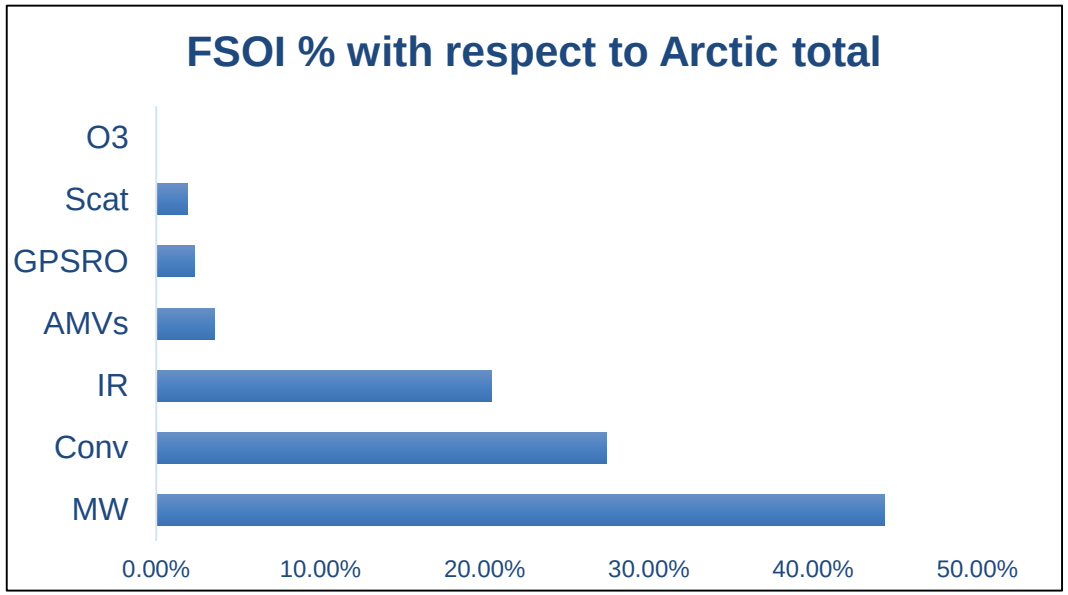
Comparing FSOI and OSE methods

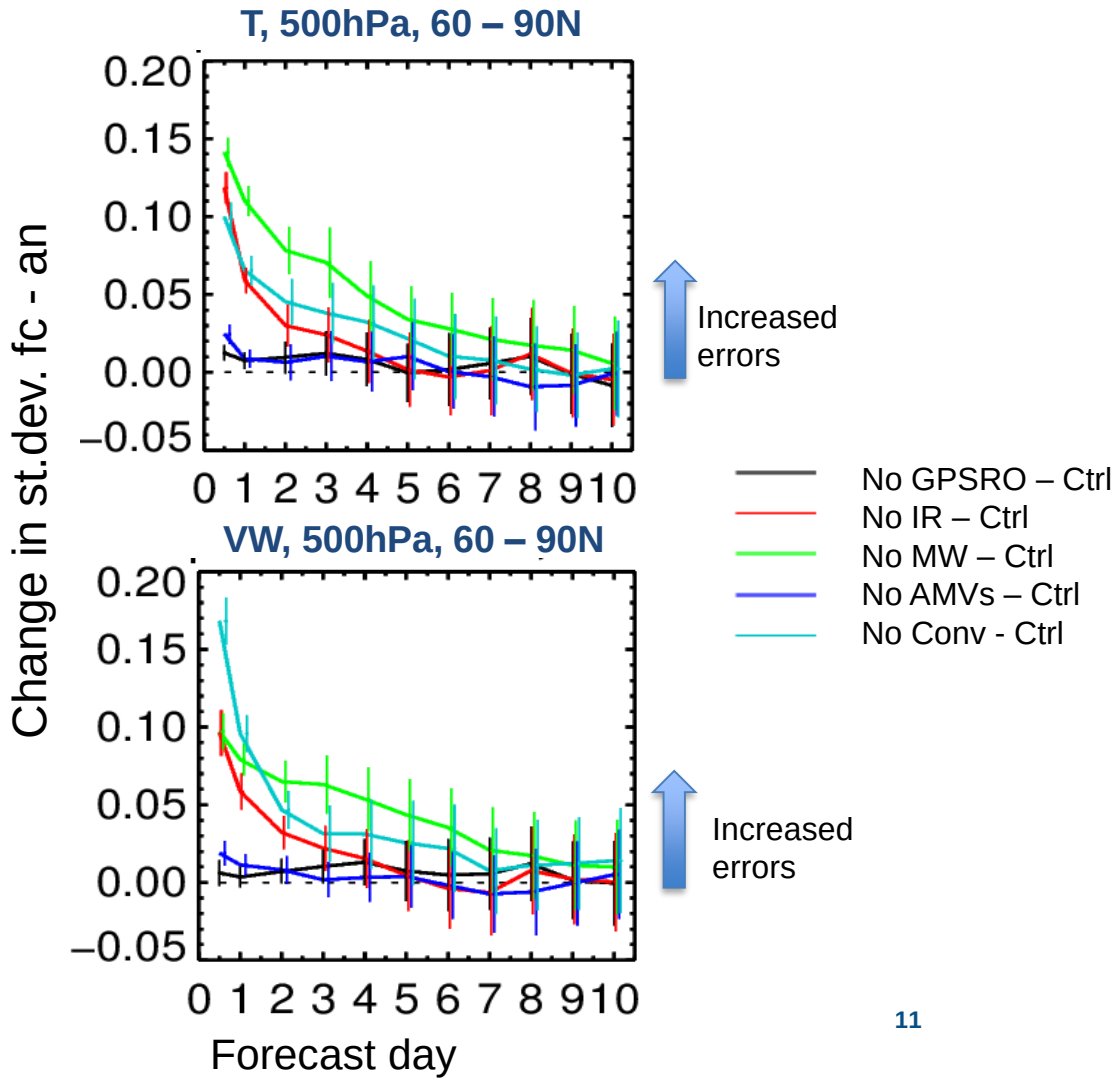
Observing System Experiment (OSE)	Forecast Sensitivity Observation Impact (FSOI)
Observing system modified "what if I did not have this data ?"	Measures the impact of obs when entire observation dataset is present using an adjoint based var. method Allows detailed evaluation of observation impact (e.g. by channels)
Effects of a single perturbation on all forecast metrics In most cases OSEs require long experimentation to evaluate impact (prohibitively expensive)	Measures the response of a single forecast metric to all perturbations of observing system. Ranking of observation impact depends on the norm used in the forecast error metric
Only way to measure data impact on long-range forecast, but denying a data type may require background errors (e.g own EDA)	
Accounts for the accumulated effects of observations assimilated in the previous analyses	Limited to short-range forecast (24-48hr) due to tangent linear assumption restrictions
Verifying short-range forecasts is less reliable	Poor observation error tuning can produce misleading results
Not suitable for small data samples unless used for case studies targeting specific weather events	Analysis and model errors can mask observations impact → produce misleading results

How do they compare ?

Denial of the main observing systems at lat>60N and lat<-60N (Polar Observing System Experiments**):**

Summer: June – September 2016, cycle 43R3
Winter: December 2017 – March 2018, cycle 45r1





From: H. Lawrence, ECMWF

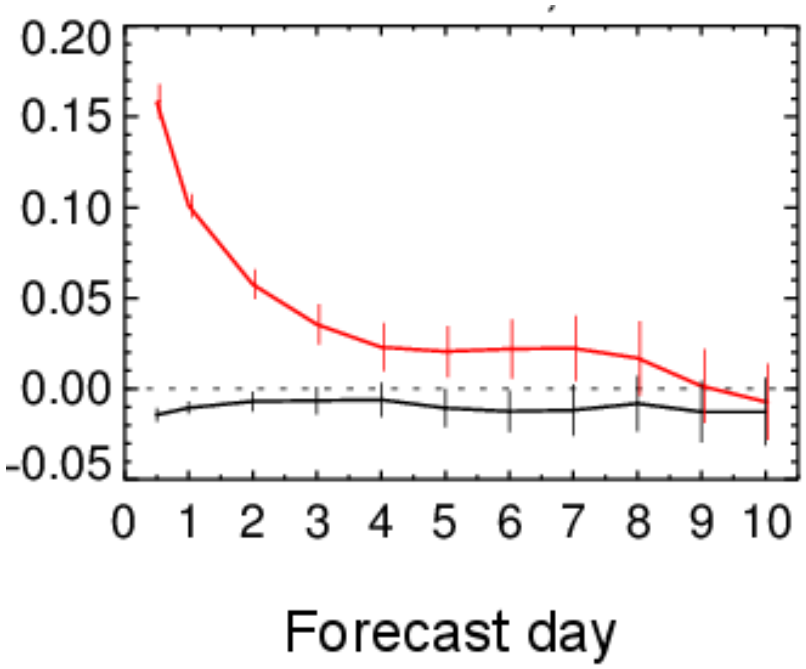
How do they compare ?

Impact measured using operational observation error model (values 0.4K to 2K)

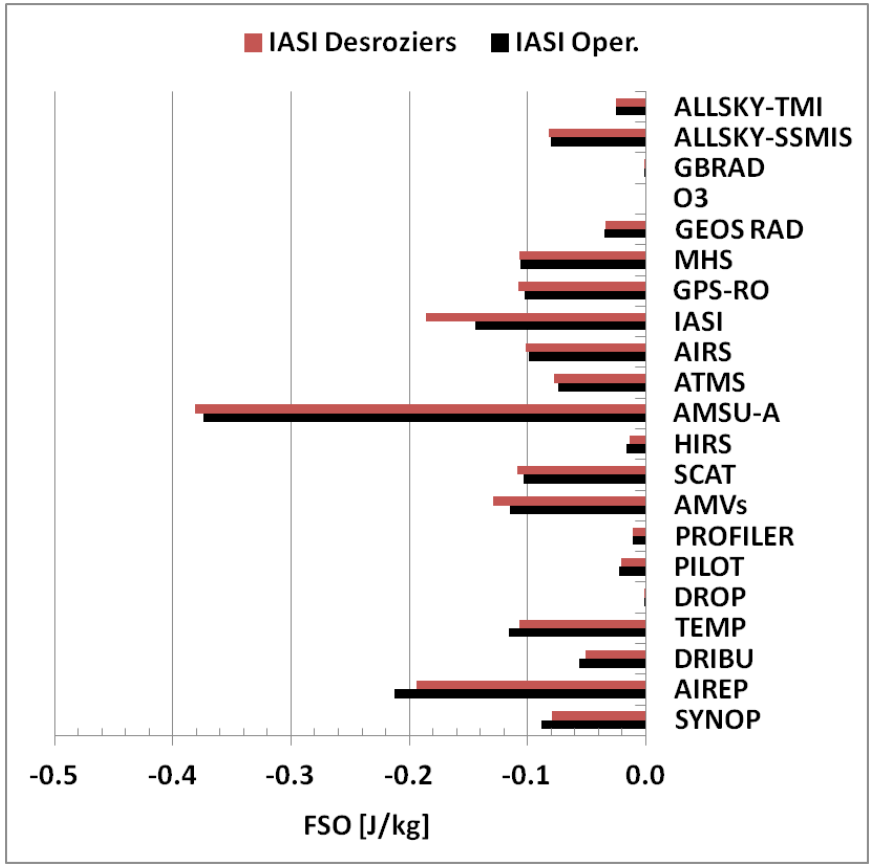
Impact measured using unrealistic observation error model (unscaled Desrosier values)

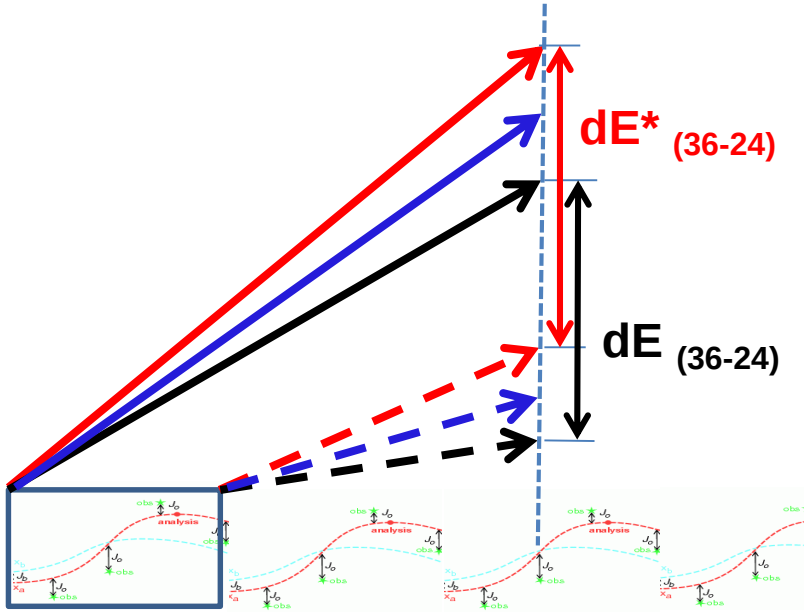
IASI minus NO-IASI

IASI unscaled minus NO-IASI



Similar FSOI results



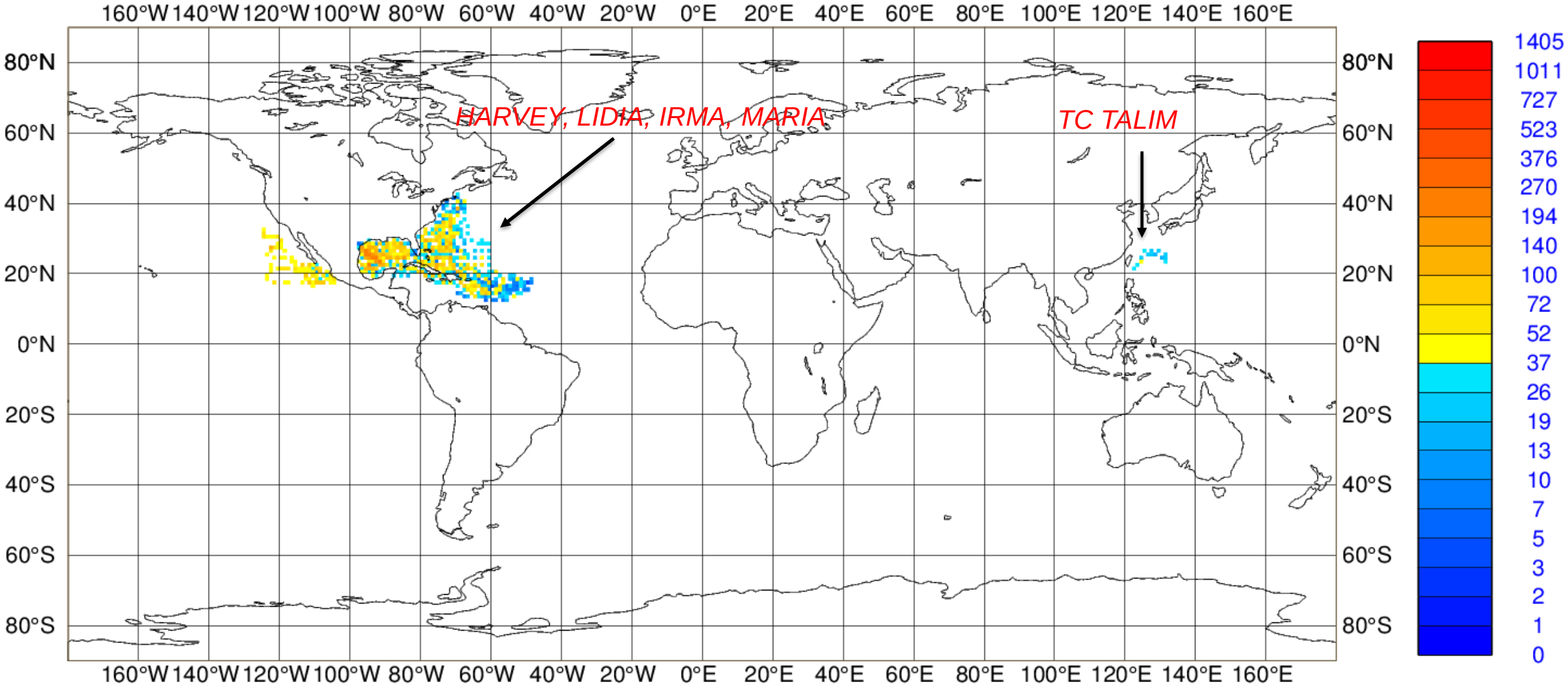


ECMWF

From: T. McNally, ECMWF

Dropsondes

Counts (1x1) 20170814 to 20171001



Dropsondes

- Dropsondes Denial experiment 14 August 2017 to 01 Oct 2017
- FSOI results

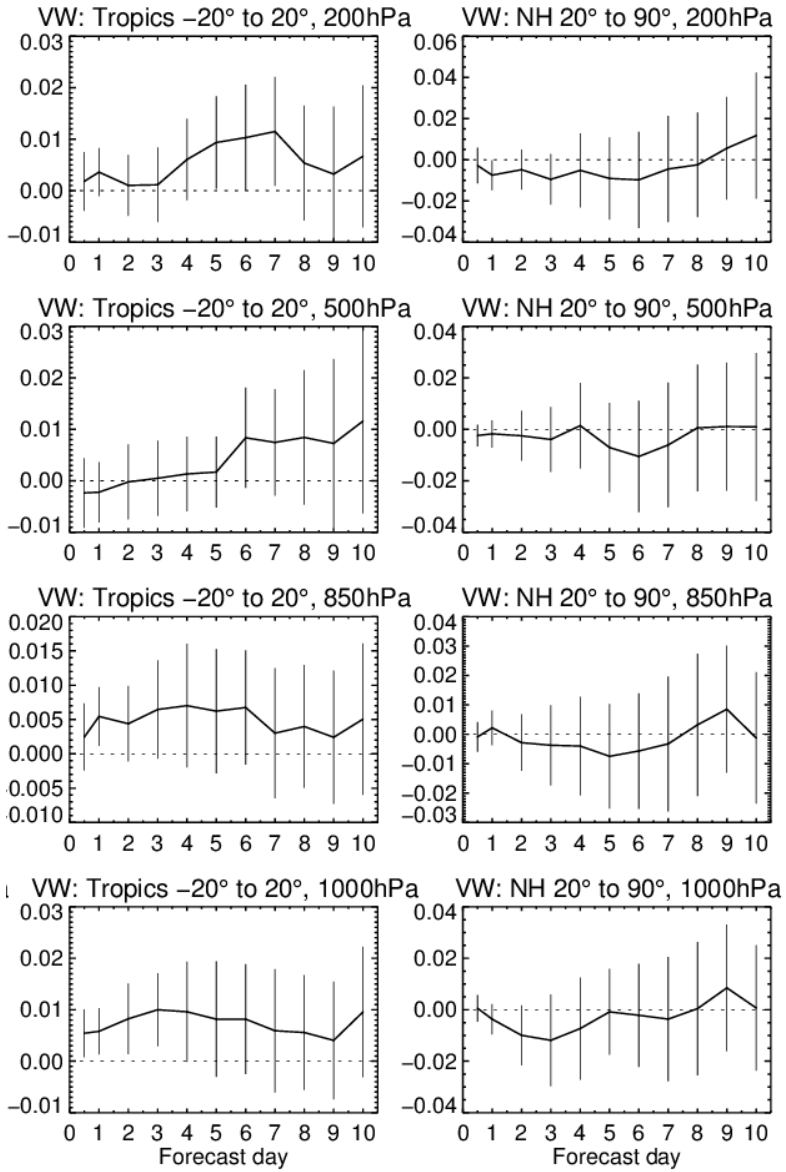
Dropsondes

OSE (scores per area)

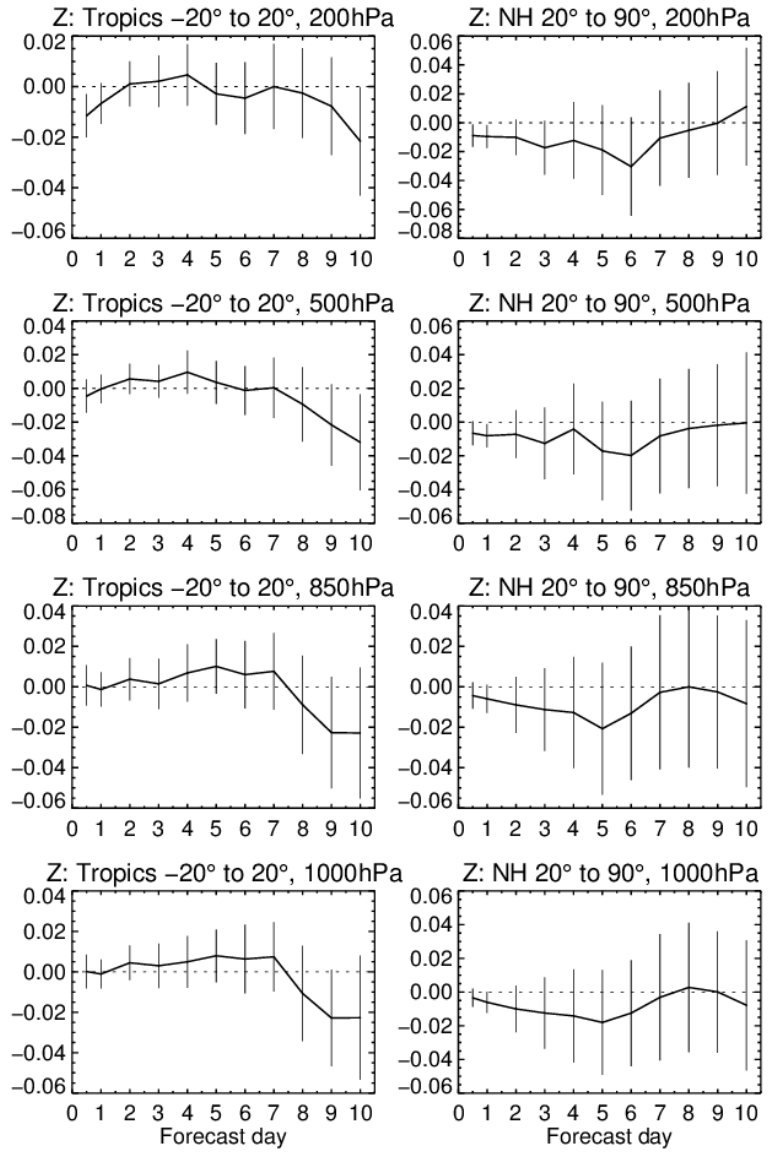
- No statistically significant impact for most parameters and atmospheric layers (expected given the small number of dropsondes).

RMSE (No drop minus oper)

Wind



Z



ECMWF

Dropsondes

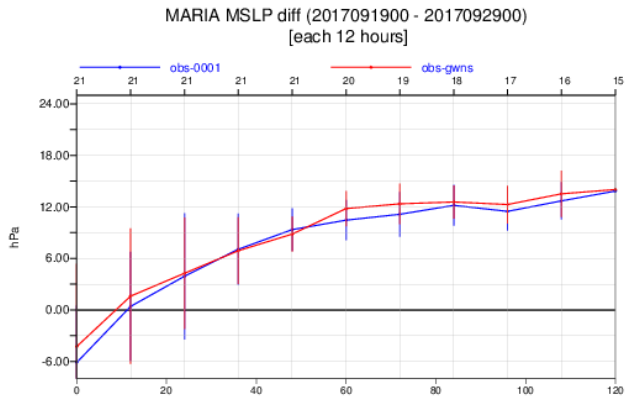
OSE (TC intensity and position)

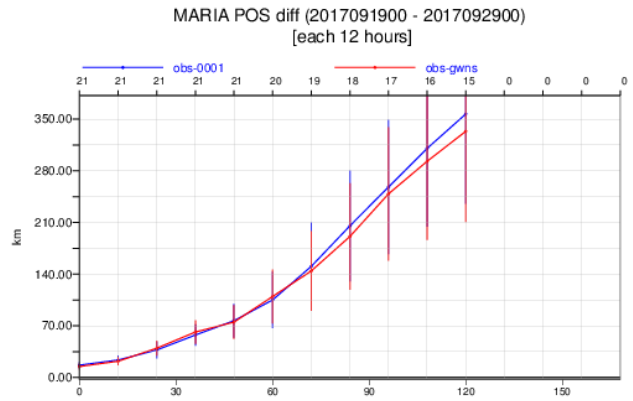
- No statistically significant impact on TC track/intensity.

Oper

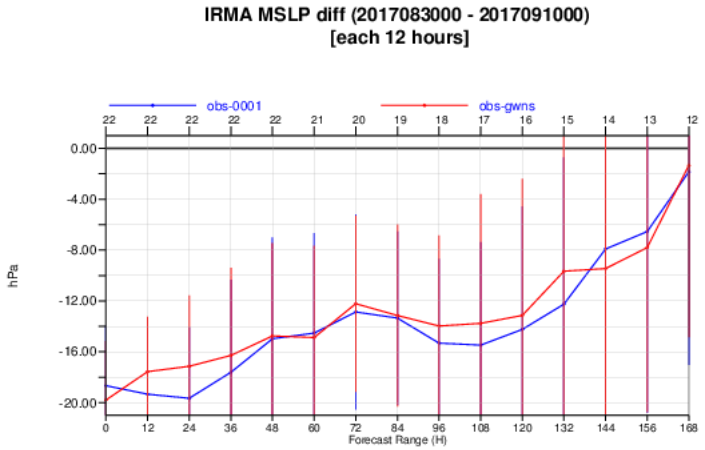
No drop

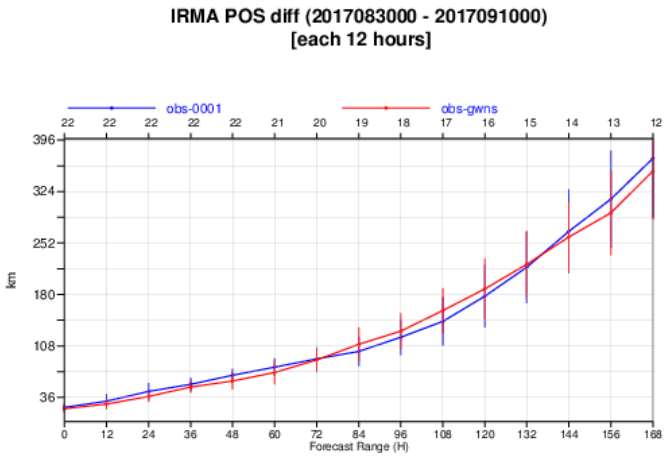
MARIA



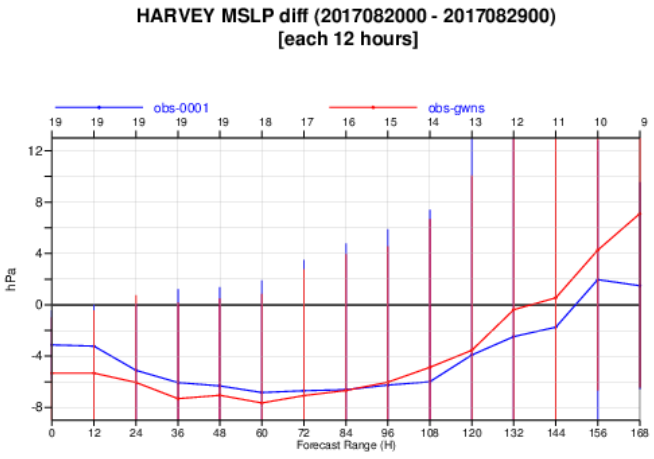


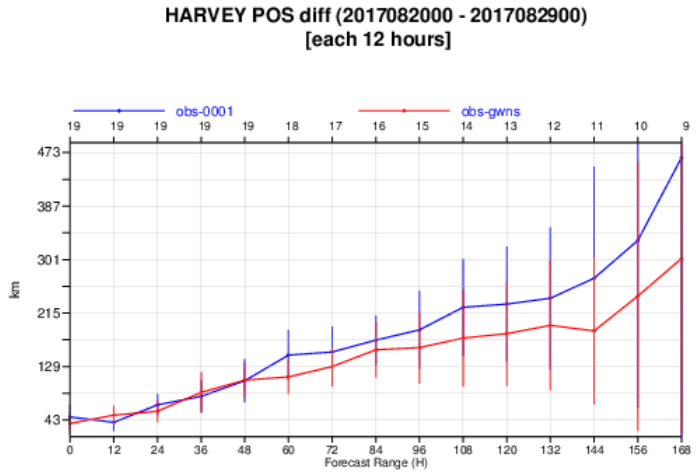
IRMA





HARVEY





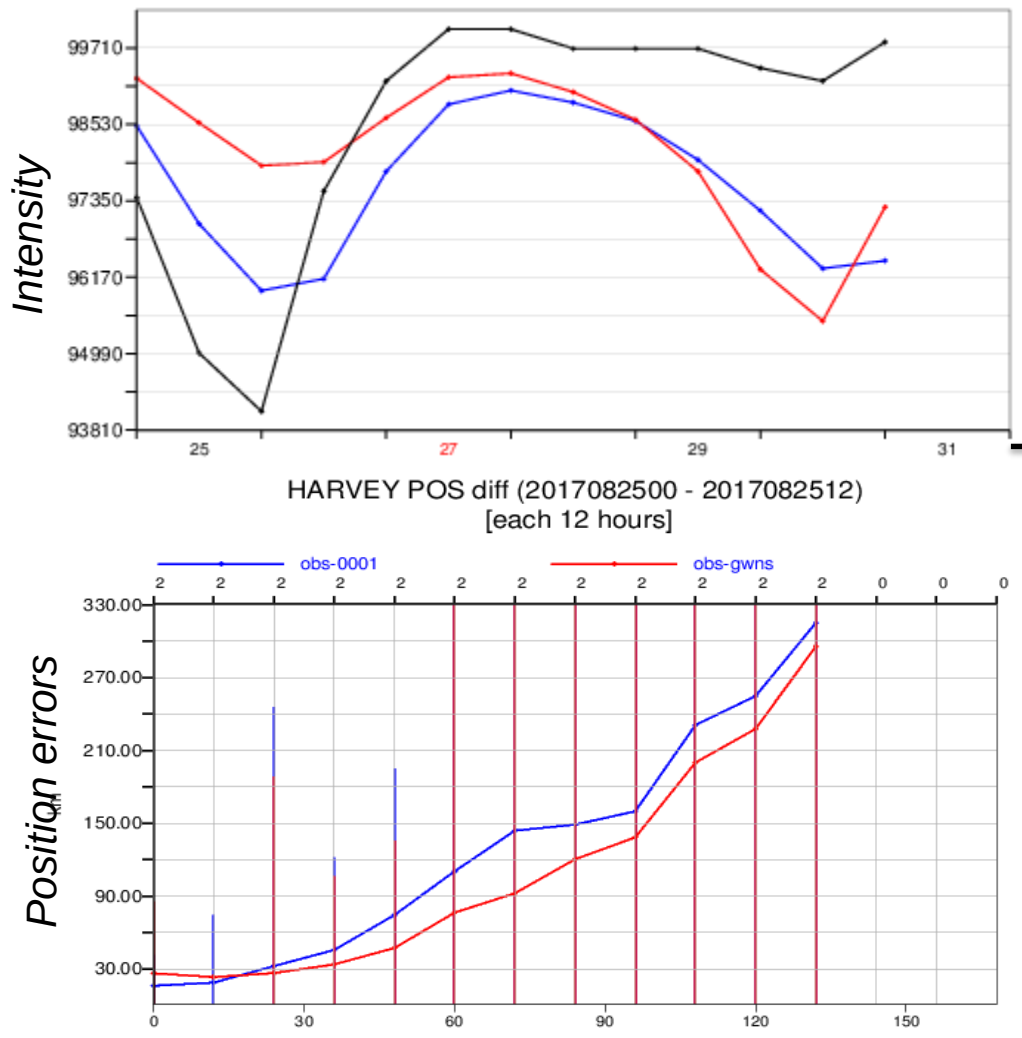
ECMWF

Dropsondes

OSE (TC intensity and position)

However the impact of dropsondes is large at times

Dropsondes denial (25/08 00) *HARVEY*

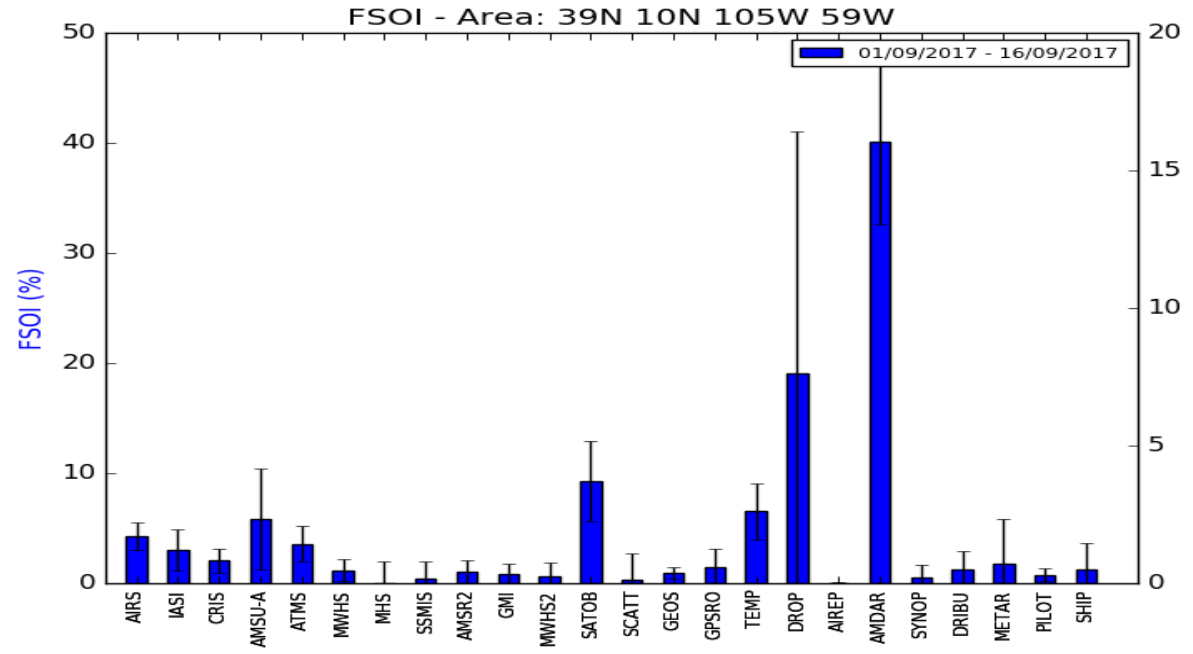


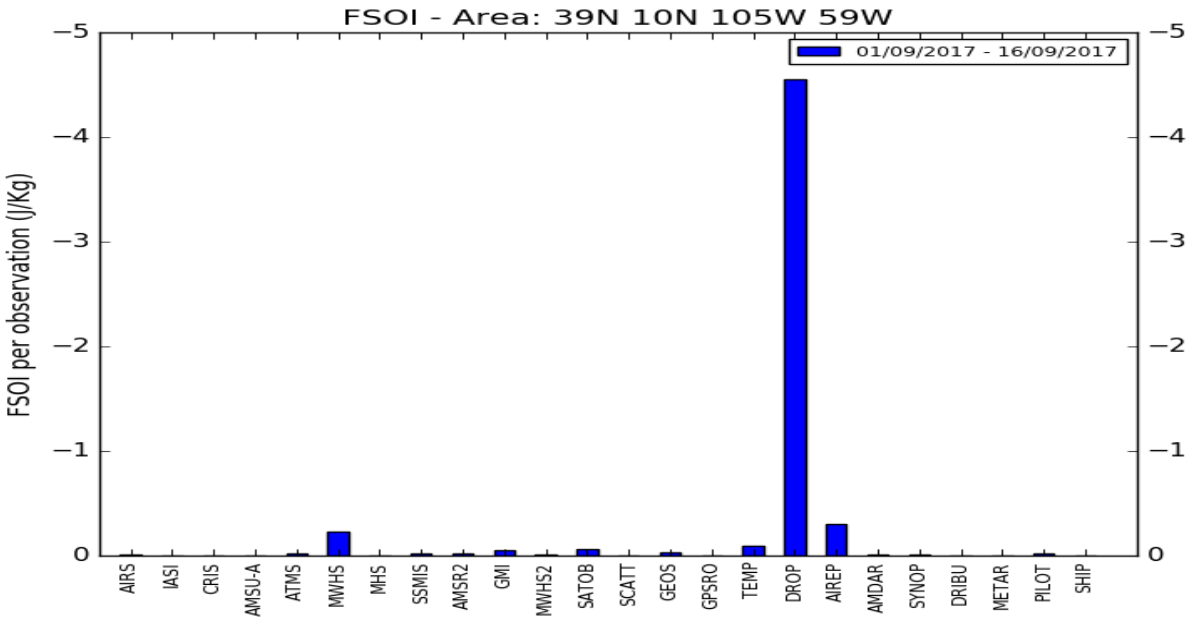
ECMWF

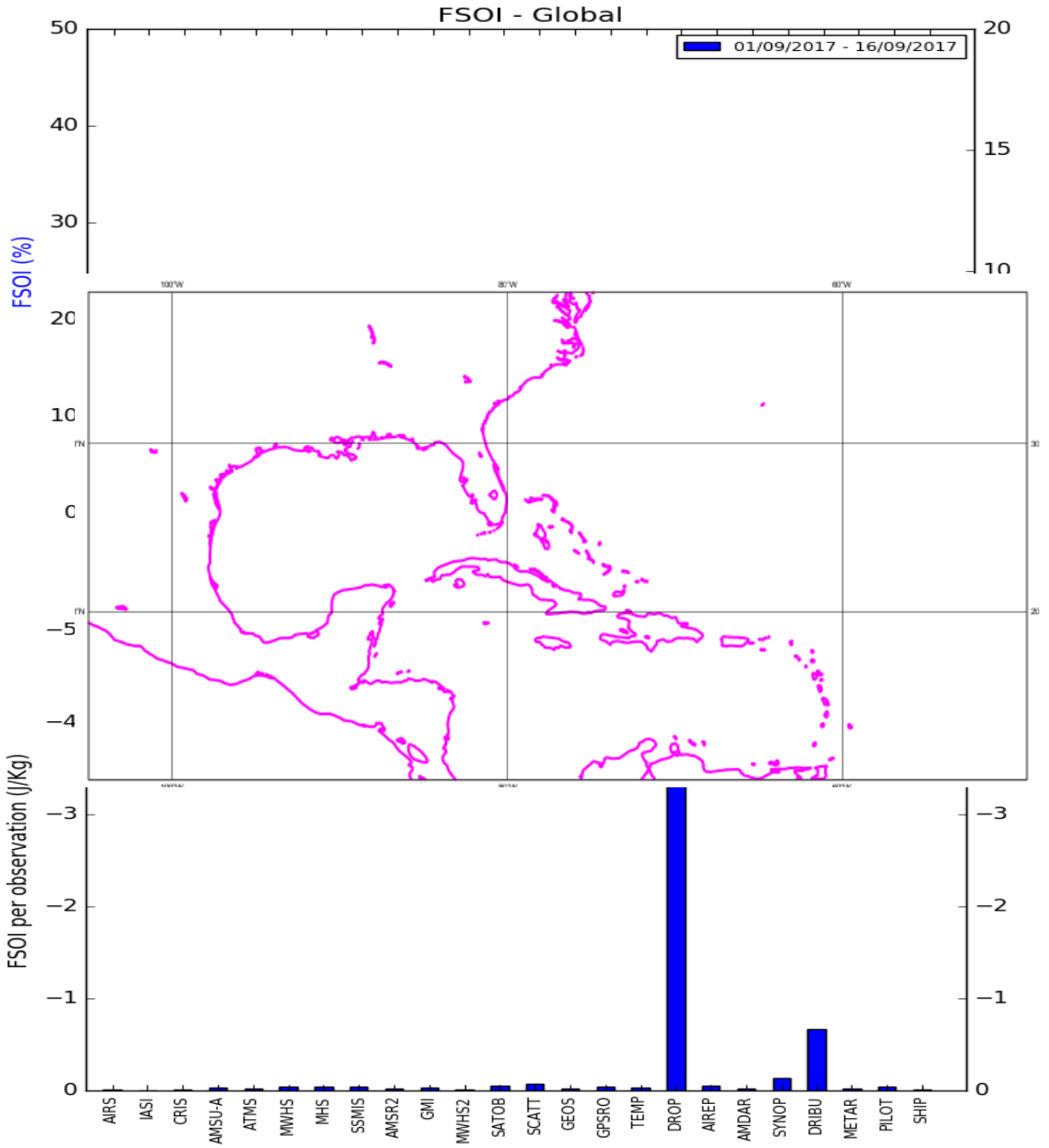
FSOI

Dropsondes

Global statistics



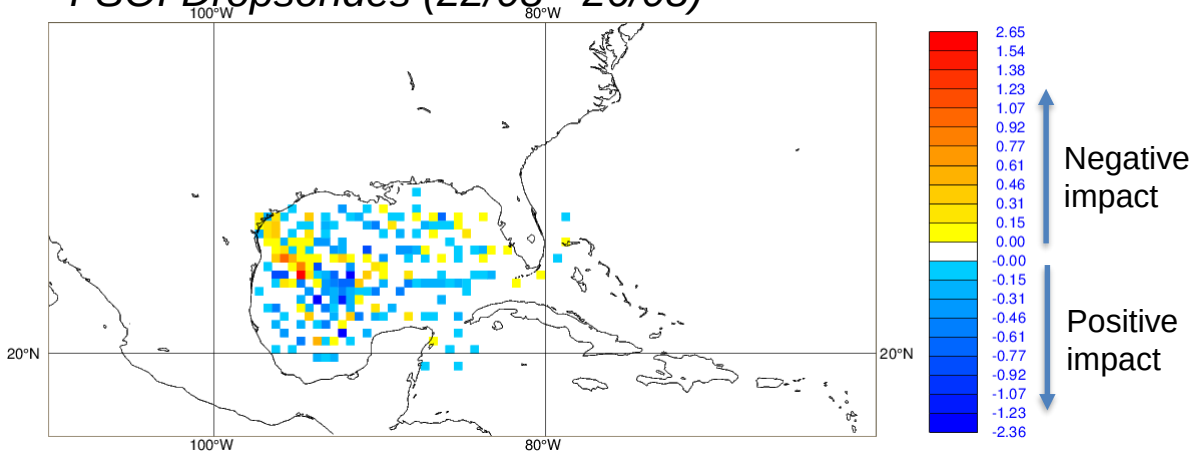




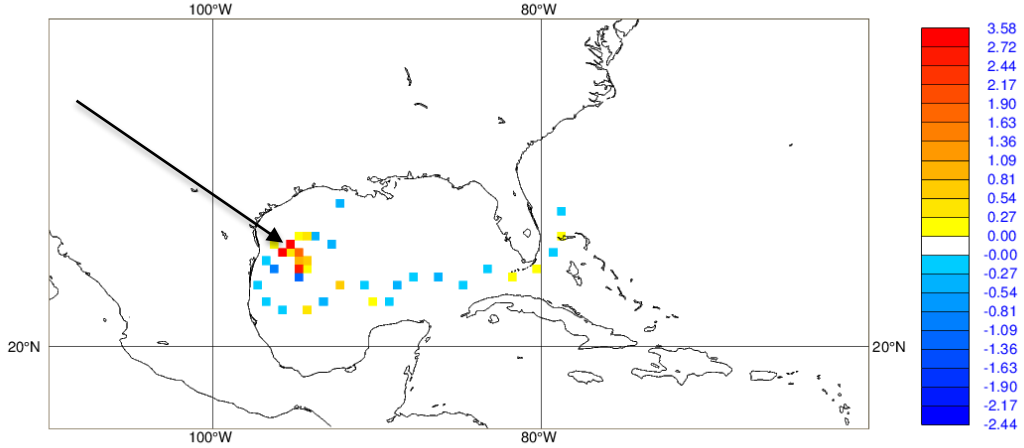
TC HARVEY

18 – 31 August 2017

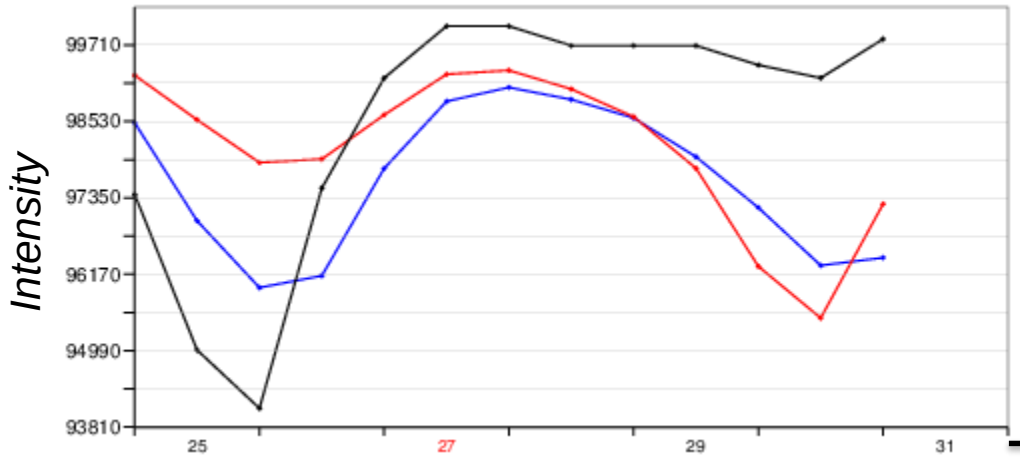
FSOI Dropsondes (22/08 - 26/08)

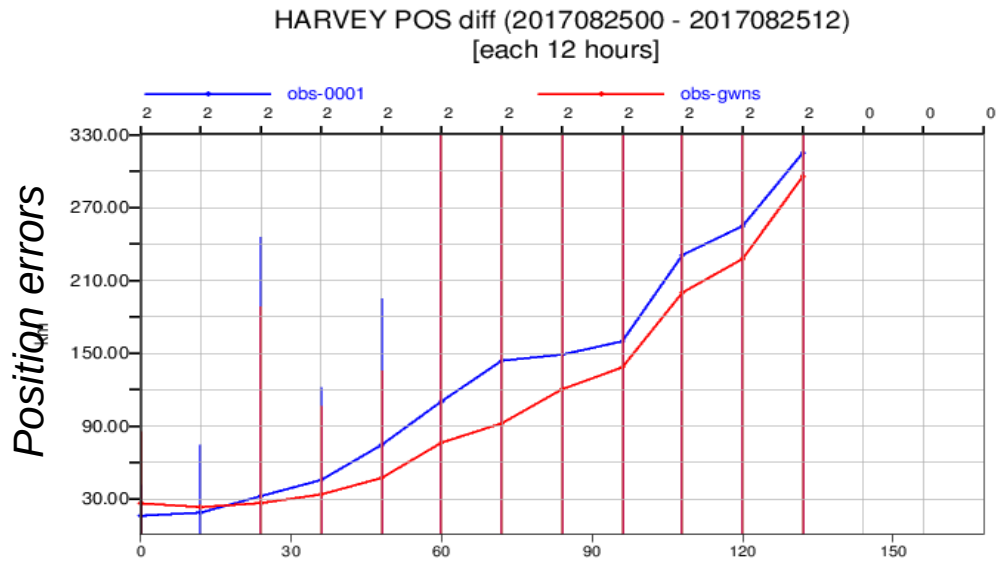


FSOI Dropsondes (25/08)



Dropsondes denial (25/08 00)



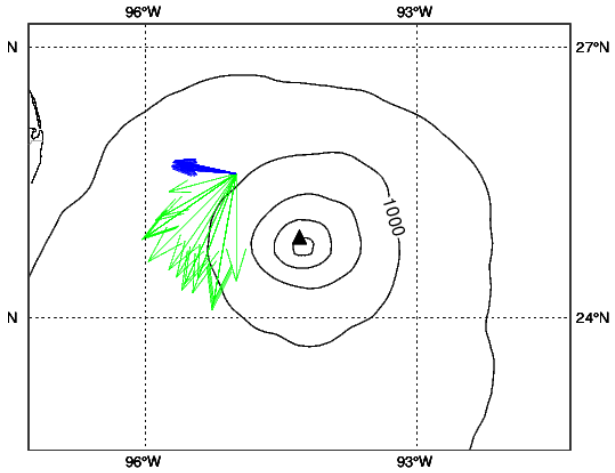


ECMWF

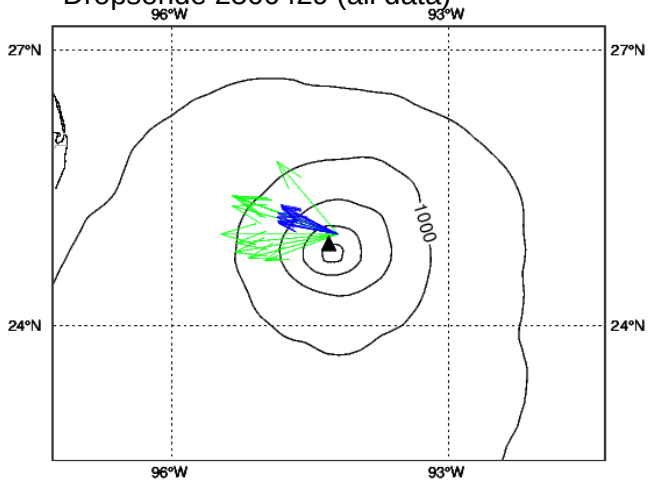
TC HARVEY

18 – 31 August 2017

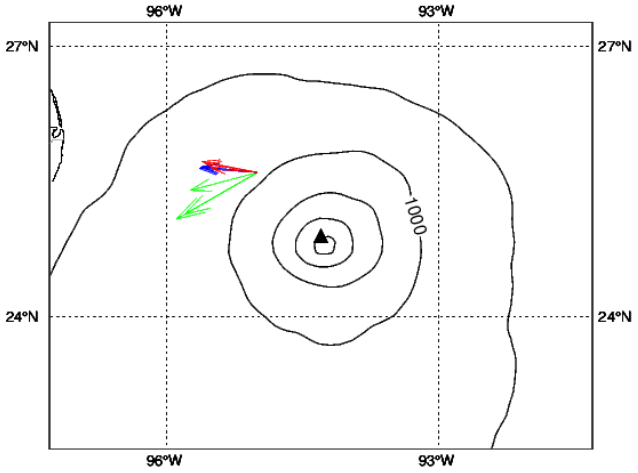
Dropsonde 25600950 (all data)



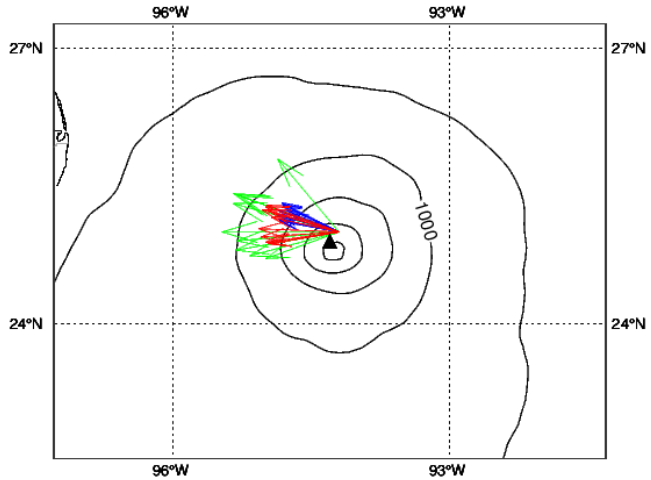
Dropsonde 2500429 (all data)



Dropsonde 25600950 (used data)



Dropsonde 2500429 (used data)

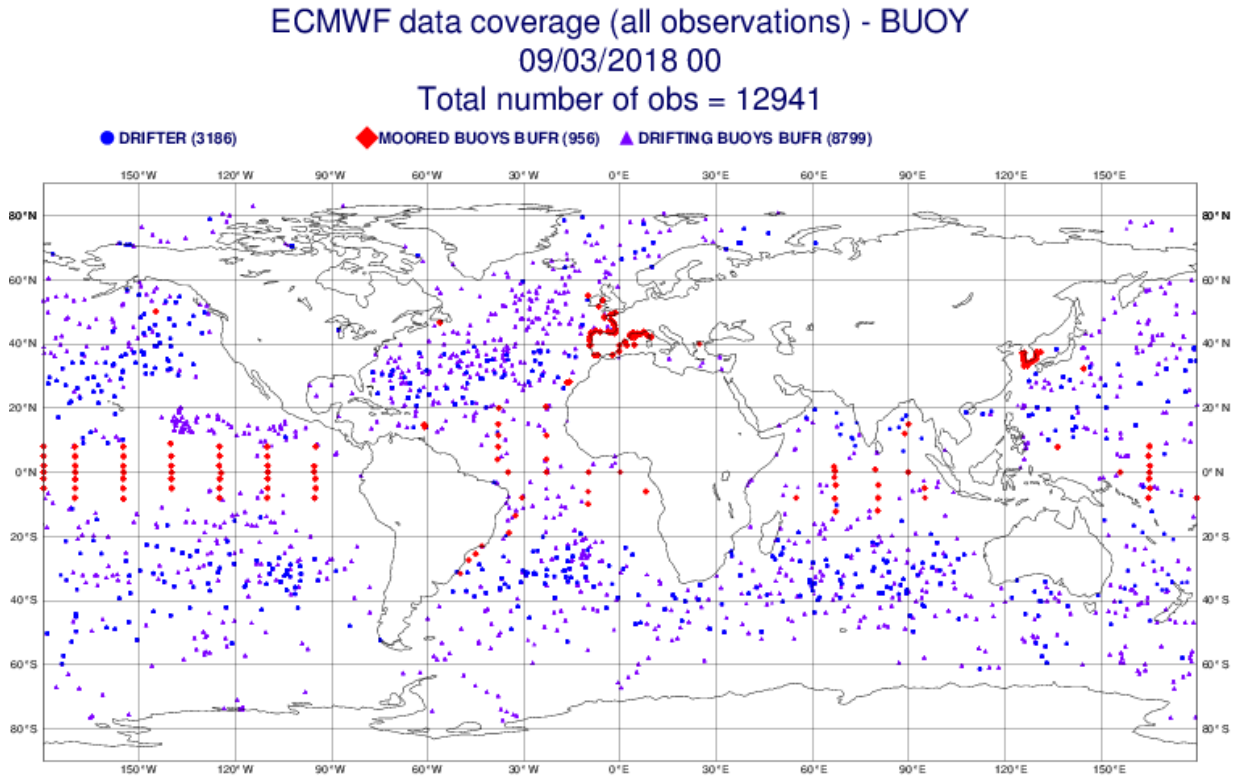


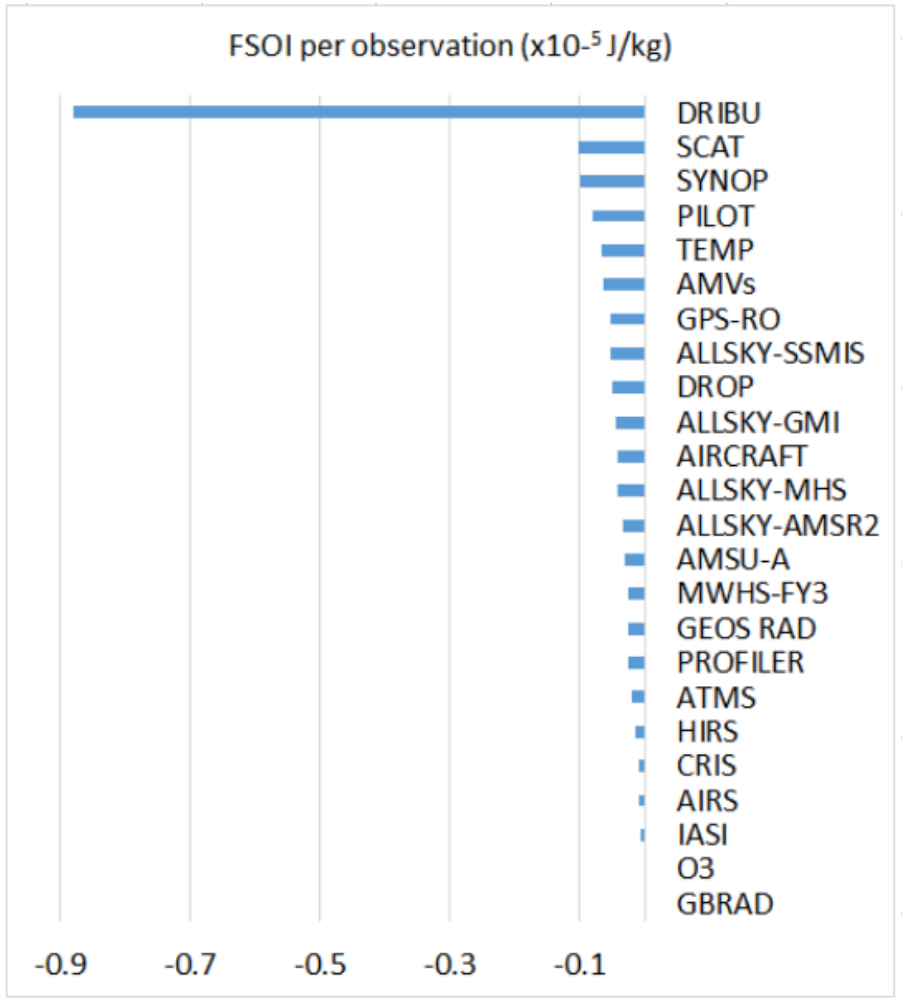
- Non handling of dropsondes drift can lead to data rejection and potentially degradation of the analysis
- Deployment pattern is also a potential factor of improvement
- Upcoming IFS cycles will be able to handle the drift of dropsondes if the data are available in BUFR

ECMWF

Forecast sensitivity per observation – drifting buoys vary valuable

- FSOI: Forecast Sensitivity to Observation Impact
- Drifting buoys have largest FSOI per observation
- Good quality data from remote areas, means high value

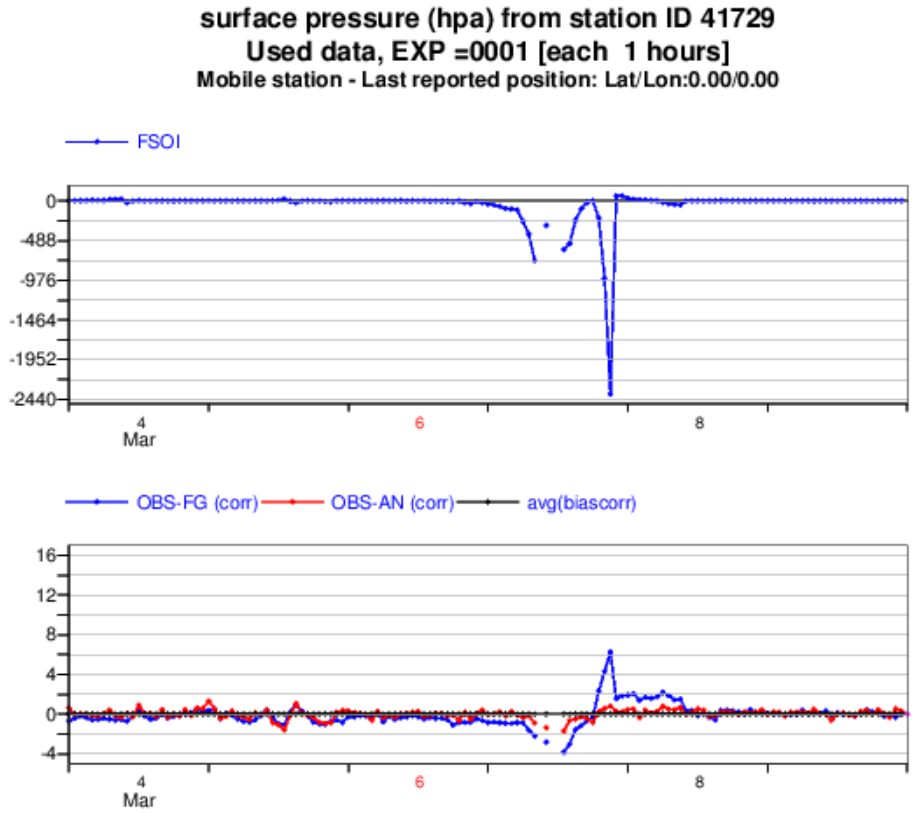




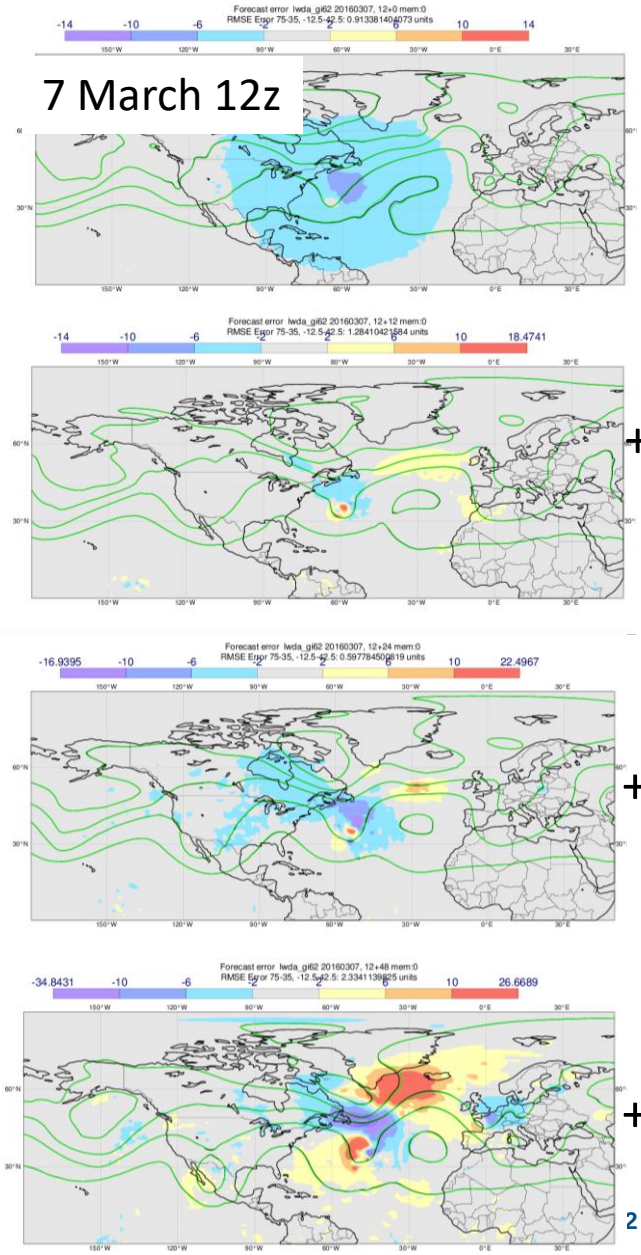
C Lupu, ECMWF

Other cases of impact monitoring (1/3)

One buoy had a huge benefit impact (from FSOI and denial)

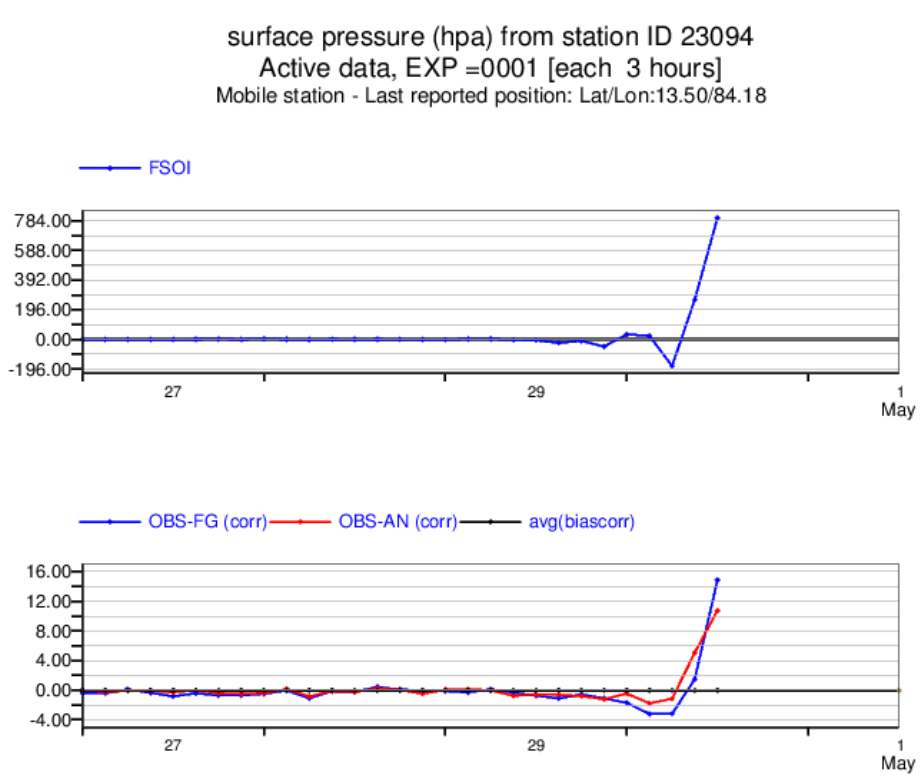


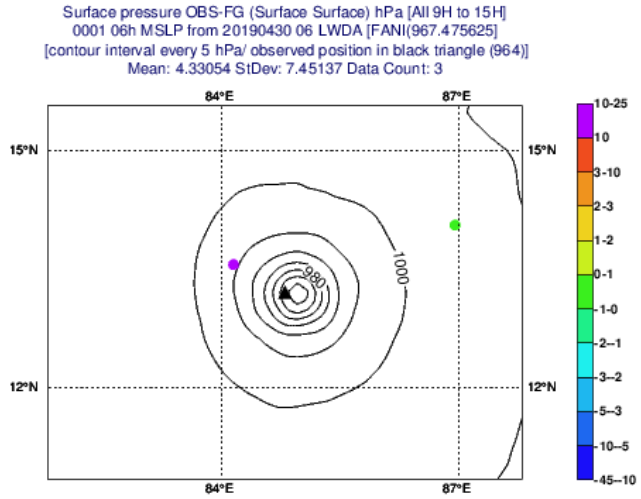
Z500 increment propagations from 41729 (MSLP)

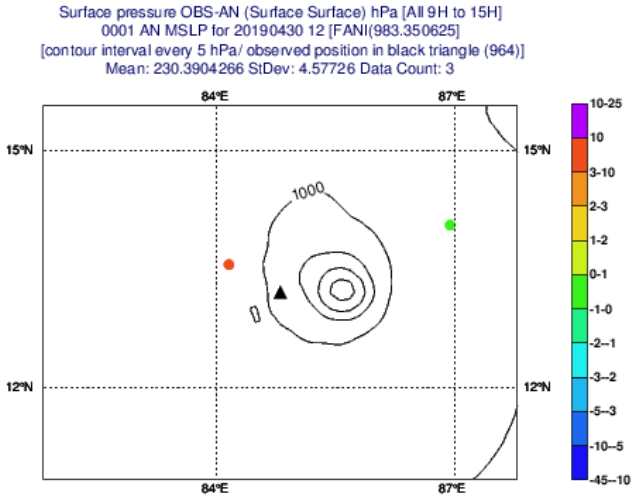


Other cases of impact monitoring (2/3)

One buoy had a significant negative impact (from FSOI and denial)

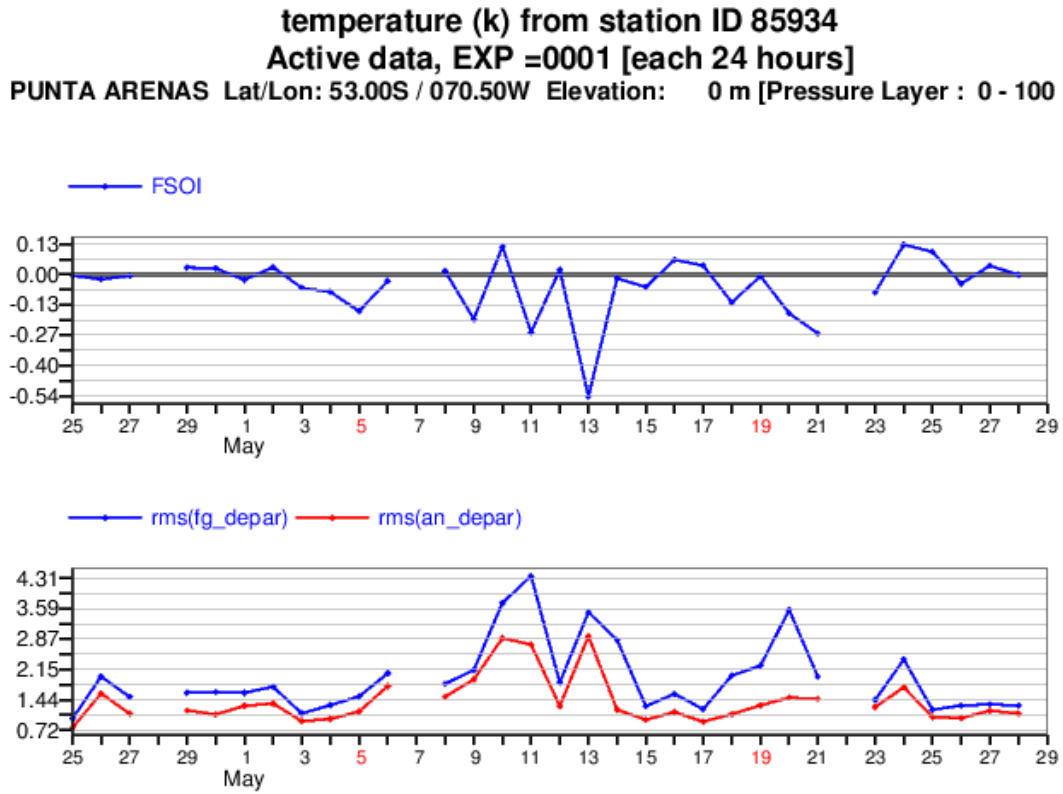


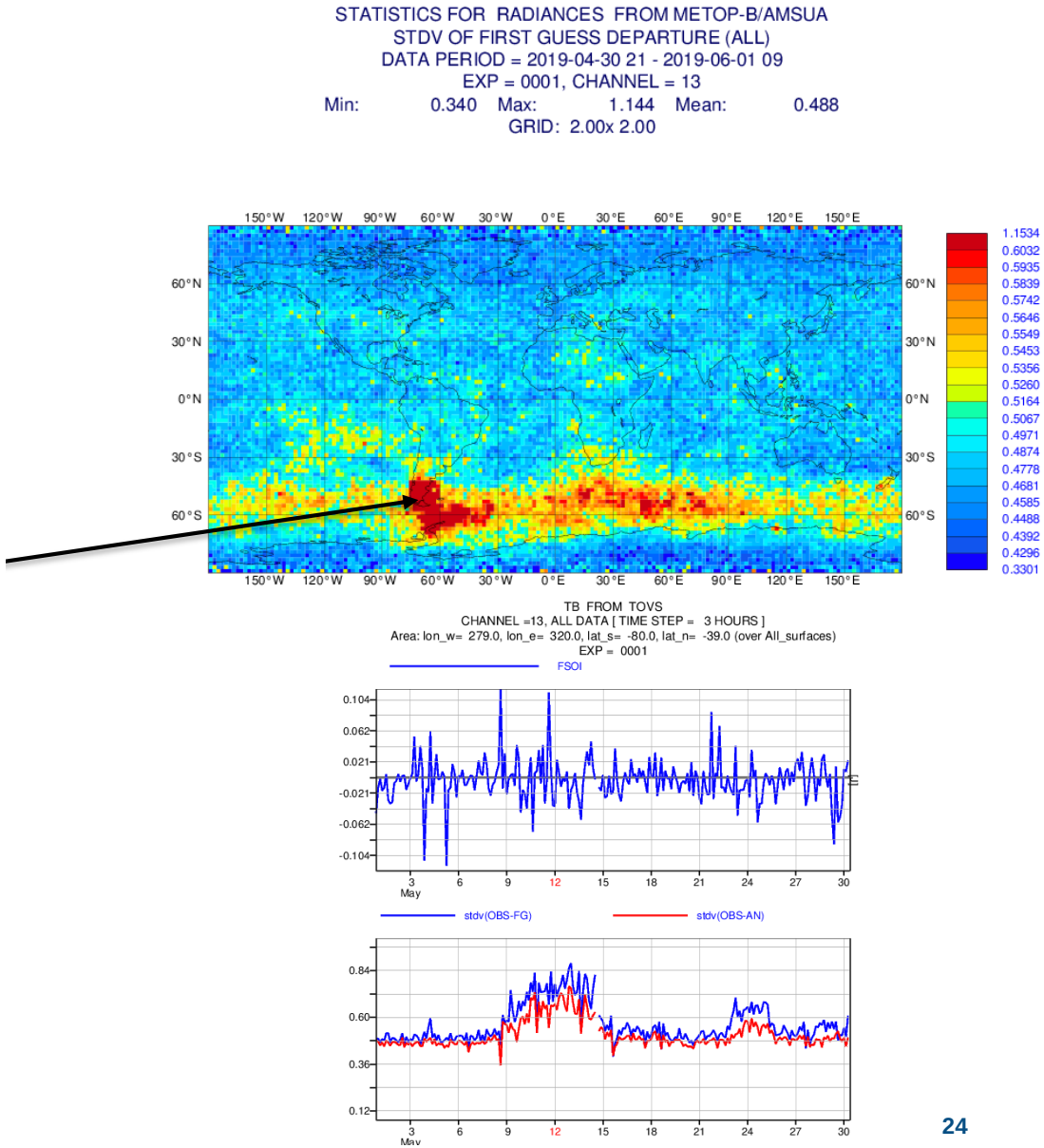




Other cases of impact monitoring (3/3)

Positive impact of isolated radiosonde near Orographic Gravity Waves





Conclusions

- Observations impact is very depended on the forecasting system being used. Apparent negative impact might be related to sub-optimal use of the data
- Two approaches being used to assess observations impact.
- Denial experiments used for statistical impact measure and in case studies (high impact weather)
- FSOI are very informative of day to day impact on the short range forecasts. Require careful interpretation
- FSOI usefulness would be enhanced if complemented by verification against observations