The impact of dropsonde and extra radiosonde observations during the field campaigns NAWDEX and SHOUT in autumn 2016

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Thanks to Gabor Radnoti, Cristina Lupu, Massimo Bonavita, …

Motivation

NAWDEX campaign

- Diabatic processes disturbing waveguide
- Disturbances can grow, resulting in HIW affecting Europe
- Systematic errors in waveguide representation translate to errors in fc

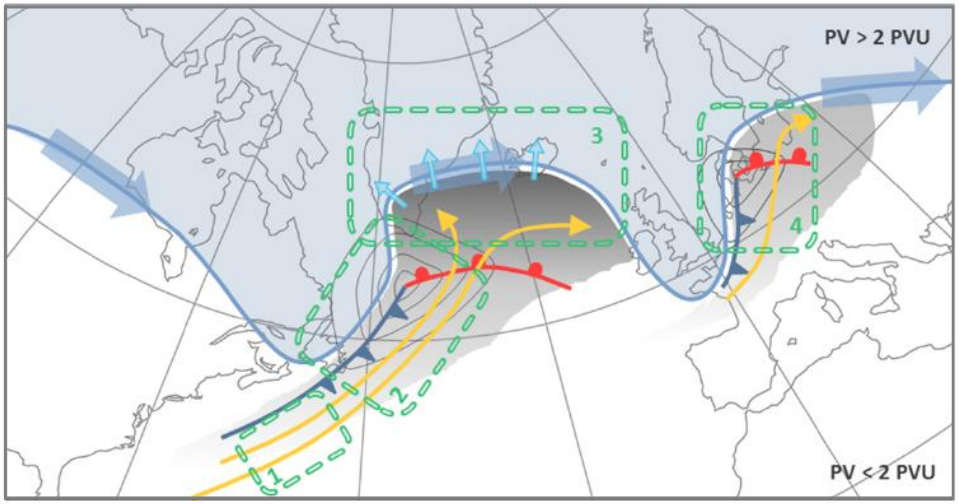

Figure 1: Idealized weather situation during NAWDEX (from Schäfler et al., 2018).

→ Gather comprehensive dataset

→ No objective targeting, but observations in synoptically sensitive regions

Motivation

Unique Dataset

- Dropsonde observations from four research aircrafts (N- and W-Atlantic)
- Additional radiosondes over CA and EUR
- Observations from cloud radars, radiometers, wind lidars… (not assimilated)

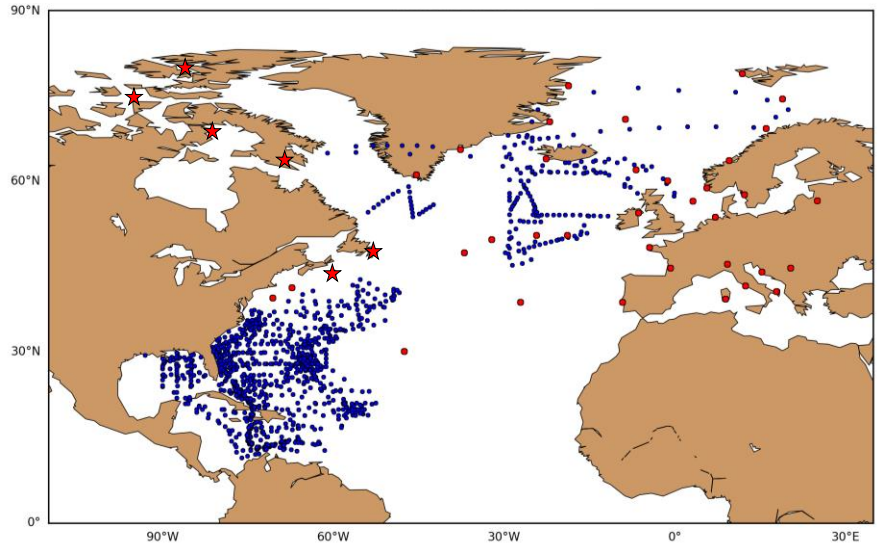

Figure 2: Dropsonde and radiosonde observations.

Favorable Conditions

- 13 intensive observation periods (IOPs)
- Events with low forecast skill and busts
- Increased frequency of relevant weather: Cyclones, WCBs, ETs, …

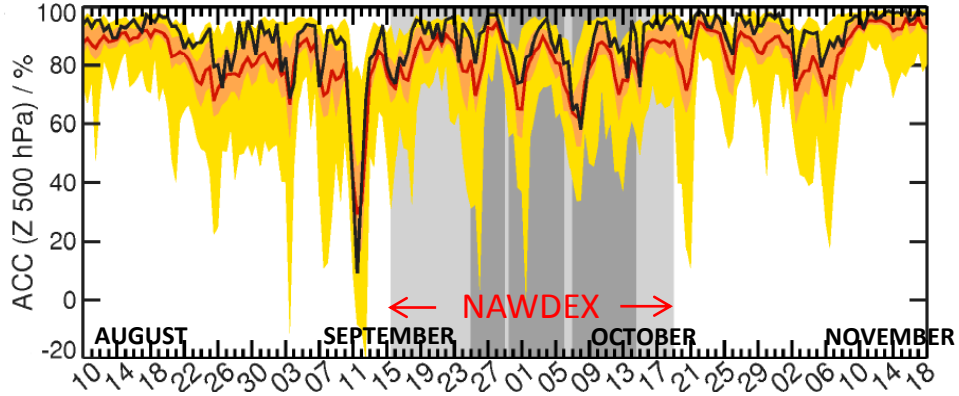

Figure 3: 5 day ACC for 500 hPa geopotential height, NA region (from Schäfler et al., 2018).

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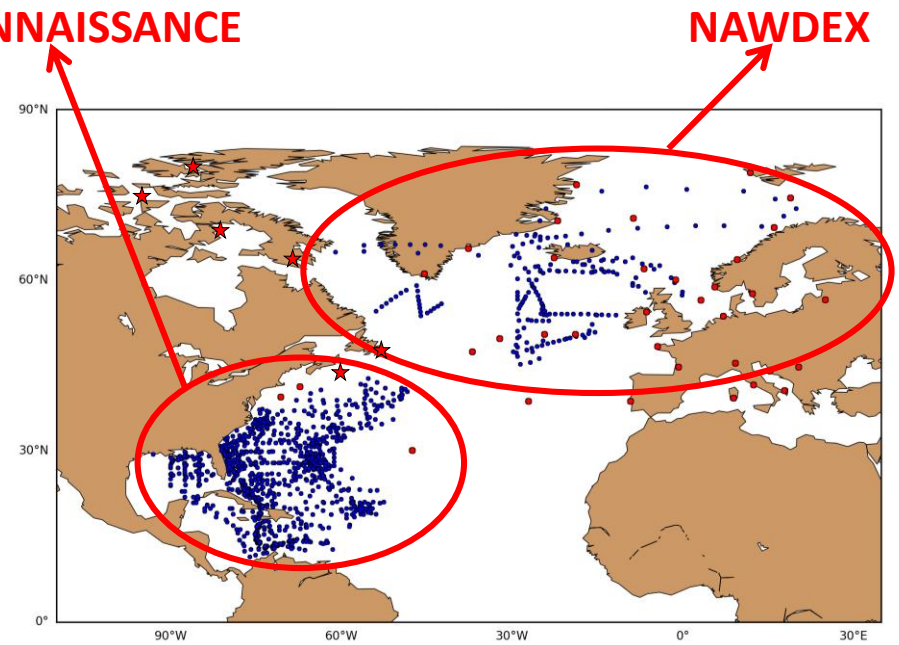

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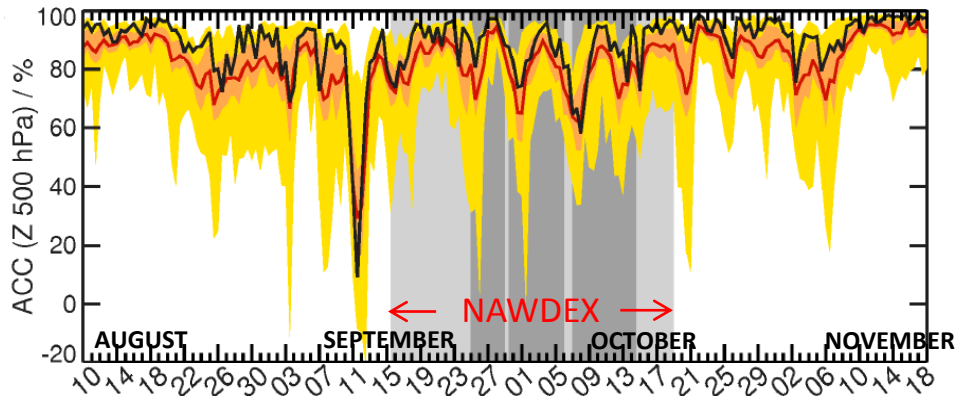

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Experiments

Approach

- Cycled data denial exps with global model of ECMWF (current version, including EDA)
- Cycled over whole campaign period

  CNTRL: Assimilating oper obs + extra obs

  DNL: Assimilating oper obs
- Evaluation of data assimilation diagnostics (e.g. FSOI, First guess departure, SG, …)

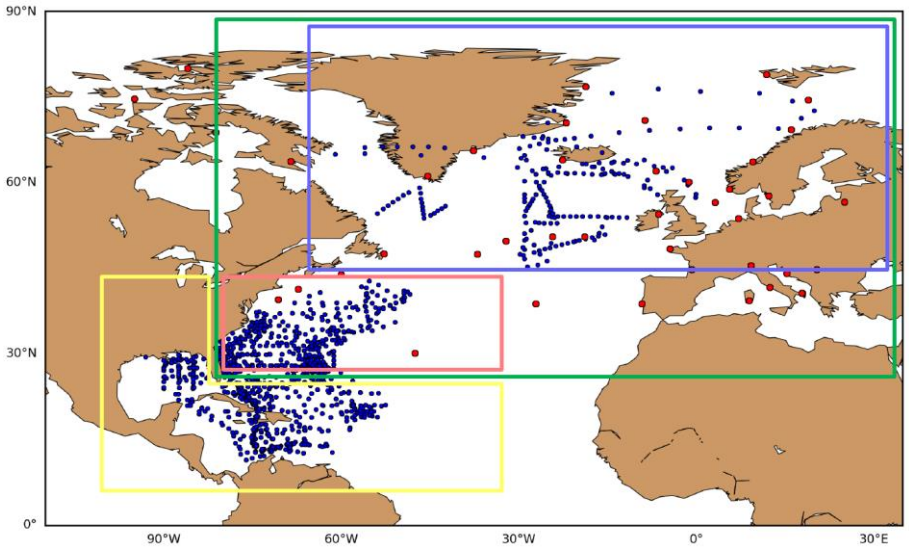


Figure 4: Dropsonde and radiosonde observations, denial: green box.

Goal

- Downstream impact of collected observations
- Model errors and their source as related to specific weather features

Mean absolute forecast error

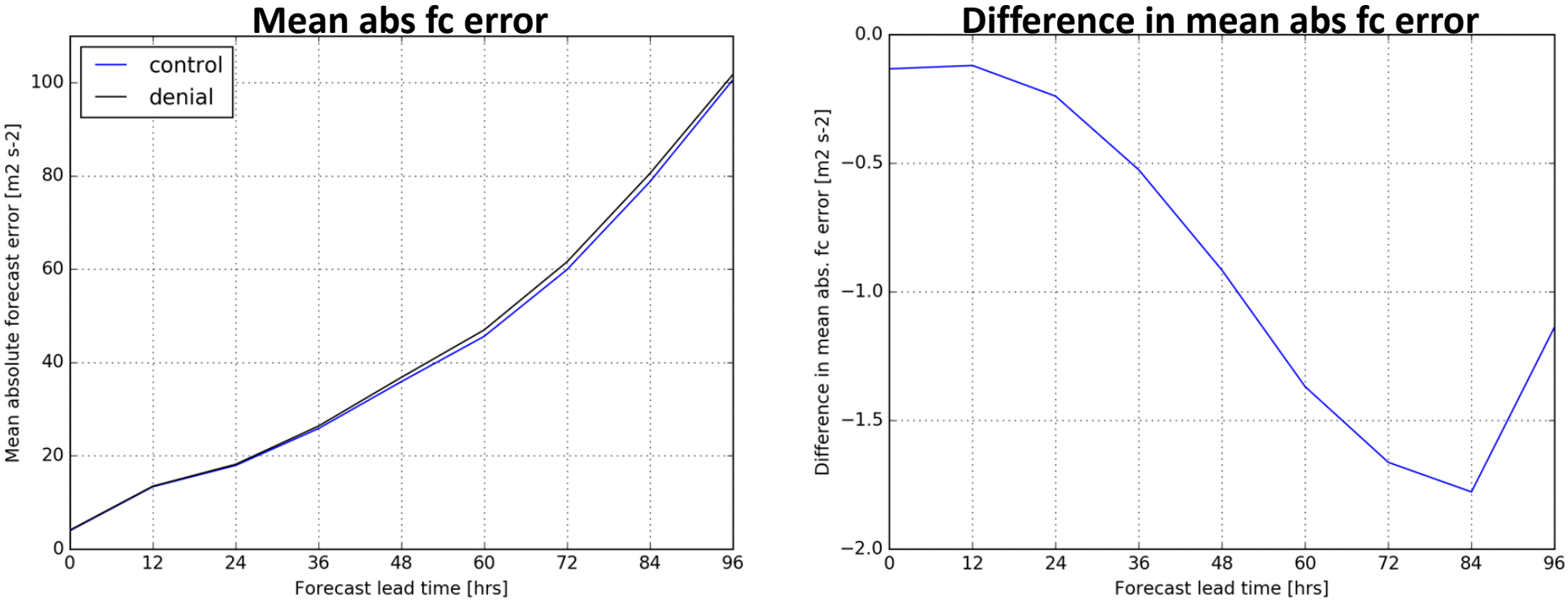


Figure 5: Mean abs. forecast error (left) and difference, 500 hPa geopotential, denial region

- Small improvement up to 96 hrs (denial region)
- Consistent for different levels and parameter

Timeseries of RMSE

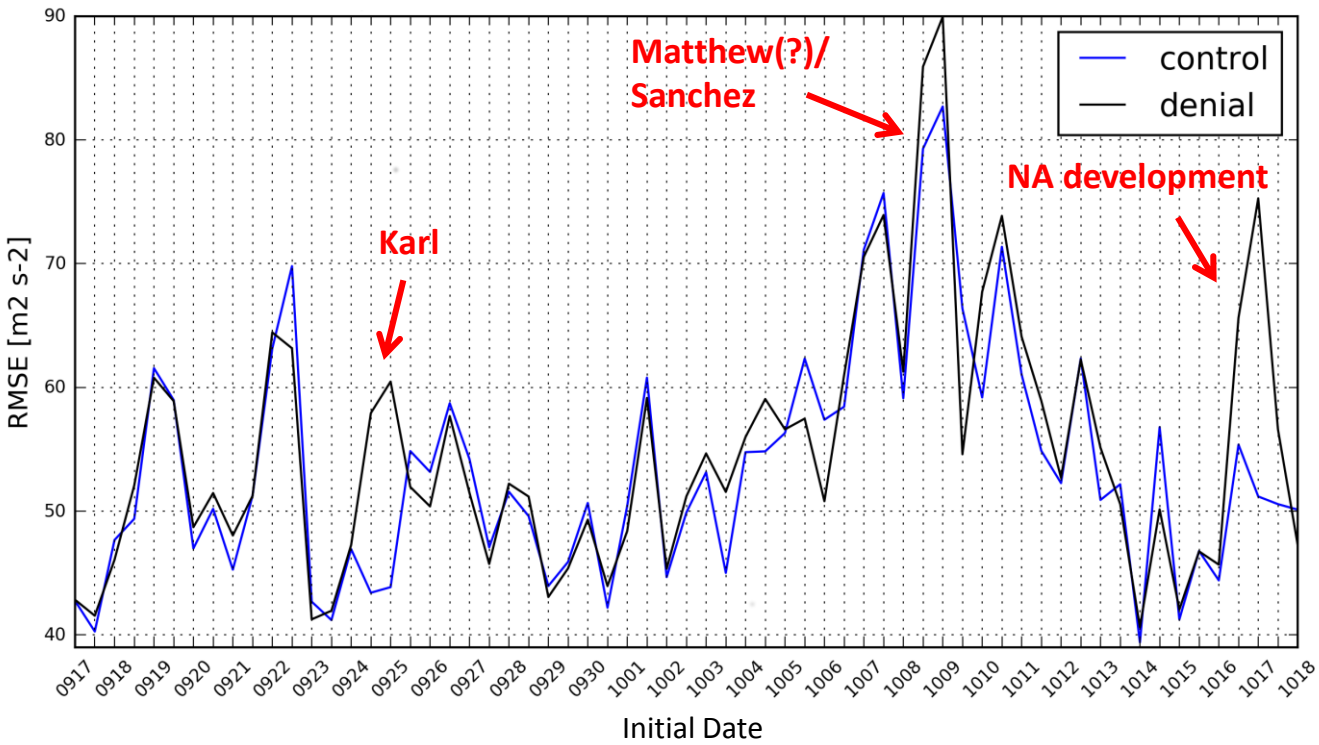


Figure 6: Timeseries of RMSE (500 hPa Geopotential), denial area, 48 hrs.

- Difference between CNTRL and DNL relatively small
- However: several cases with significant differences (e.g. Karl)

IOP KARL

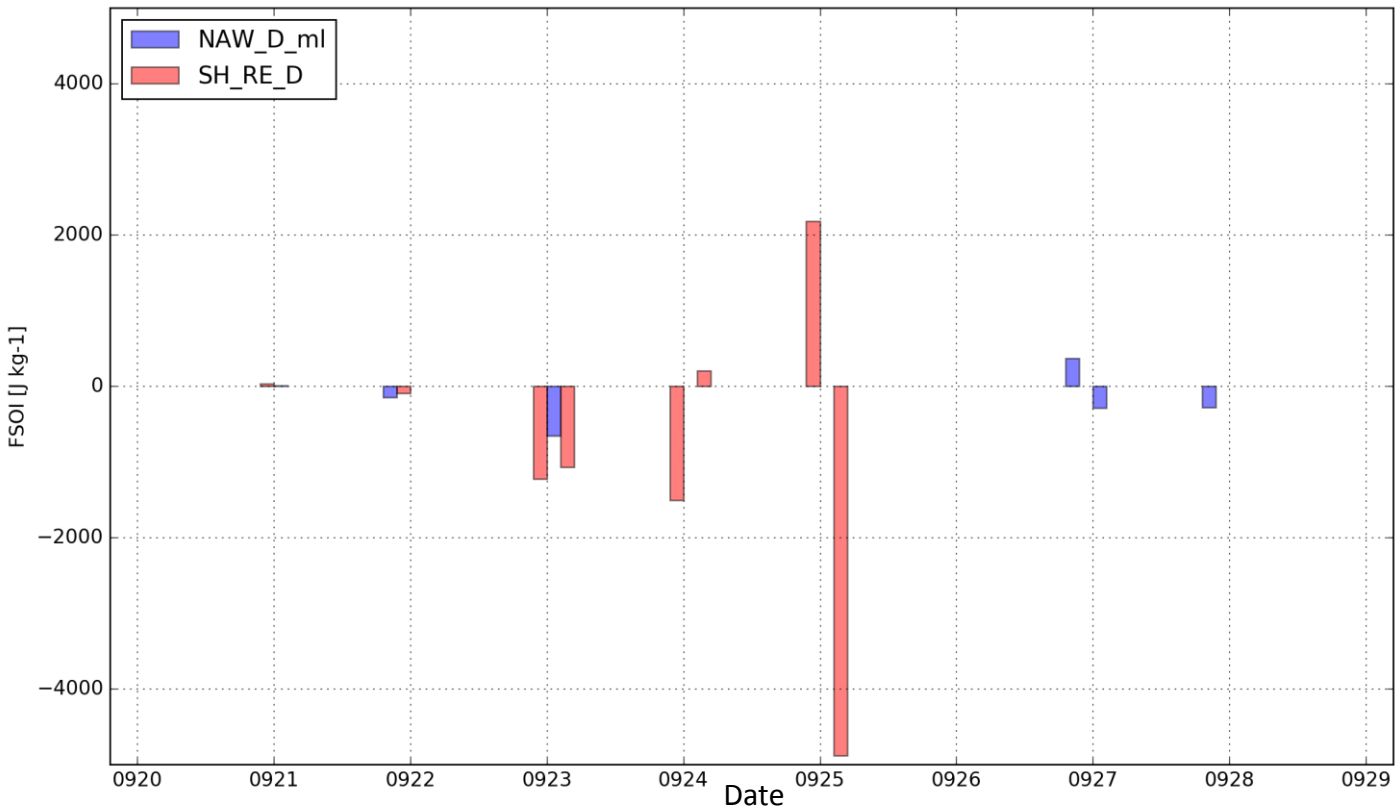
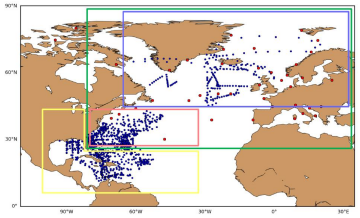


Figure 7: Timeseries of total FSOI and impact-coded dropsonde location.

- Significant number of beneficial SH dropsondes
- NAWDEX flight on 23.09. with beneficial impact



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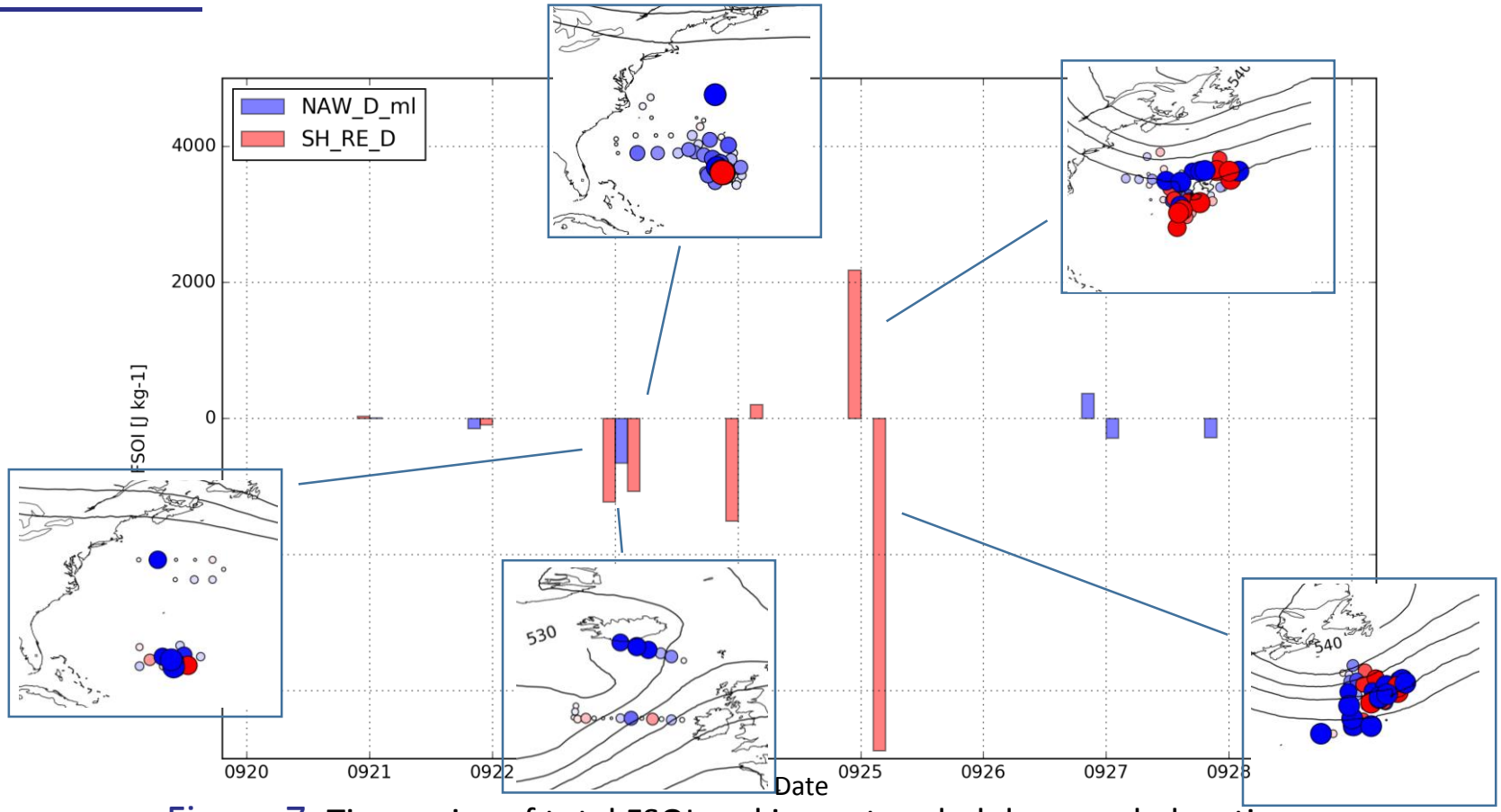

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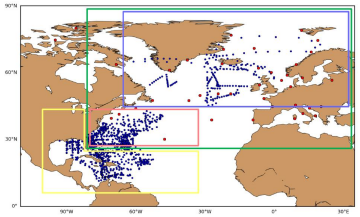

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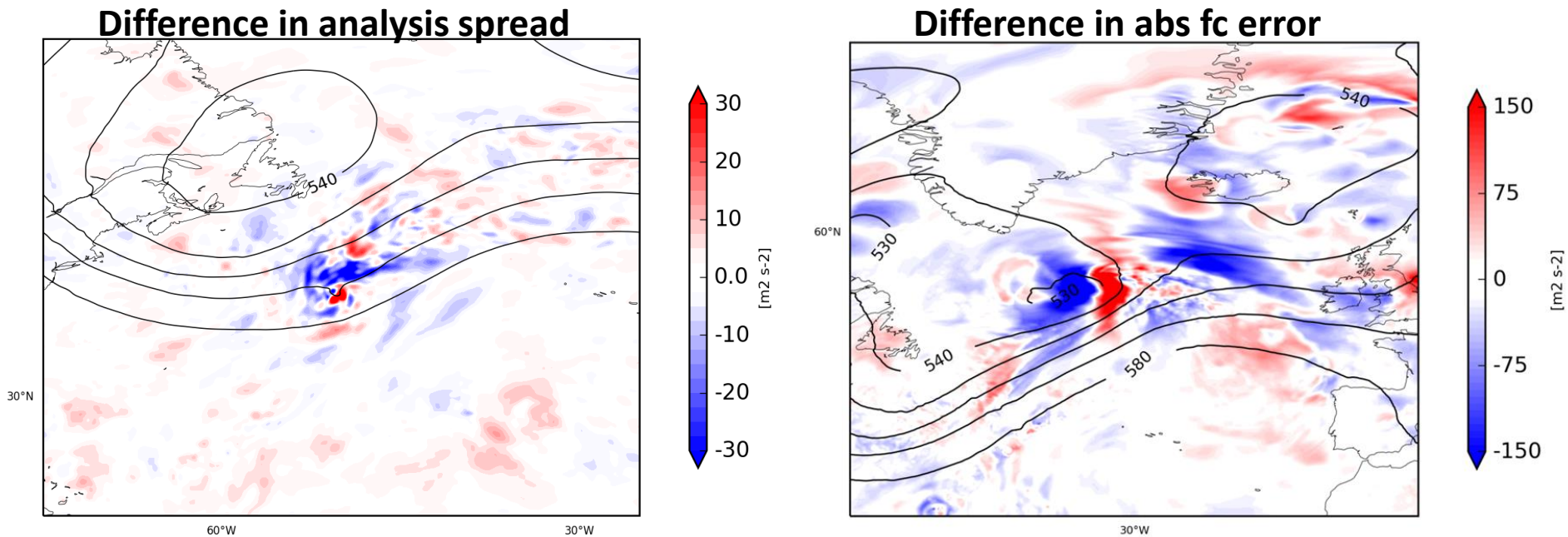


Figure 8: Difference in analysis spread and in absolute forecast error 12UTC, 24 hrs, 25.09.

- Reduced analysis spread for control, presumably related to cycled SH drops
- Smaller forecast error over widespread NA area

Mean impact per observation

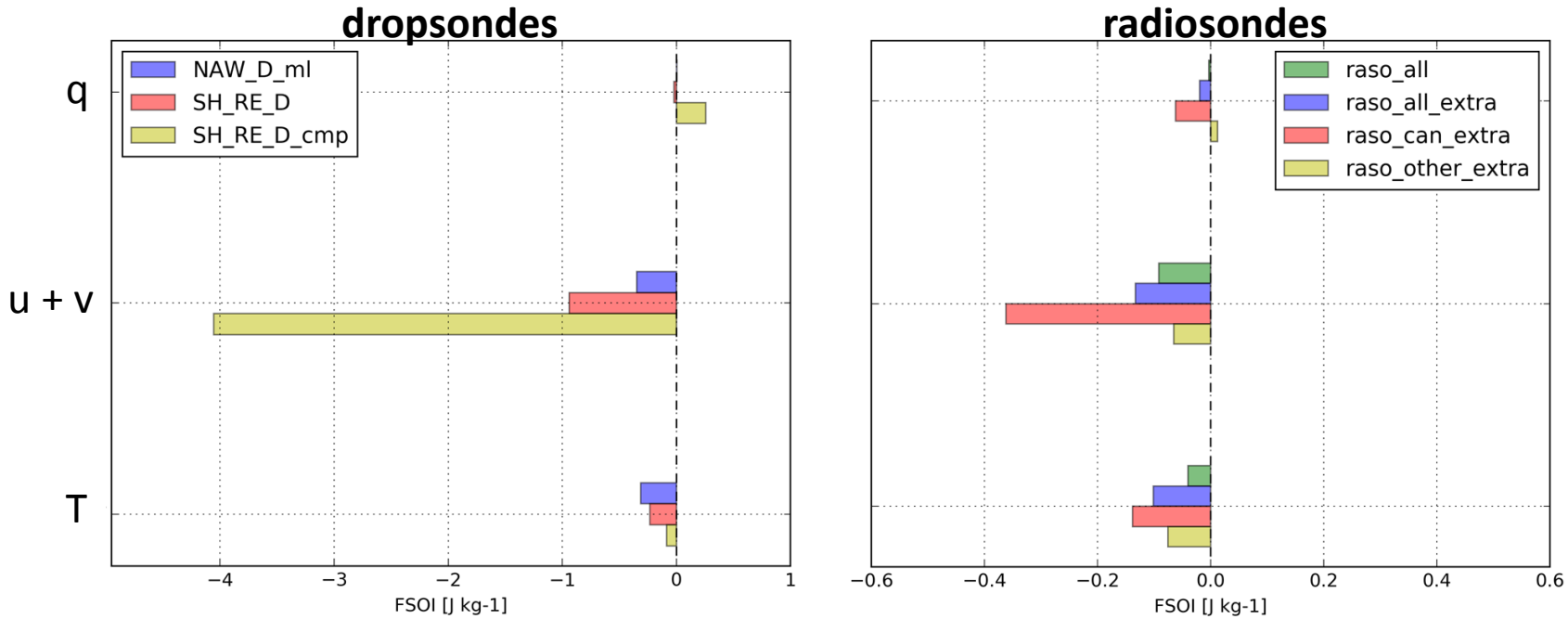
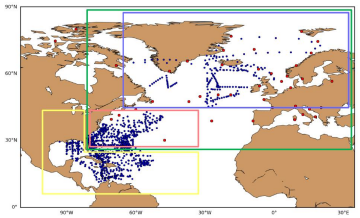


Figure 9: FSOI per observation for dropsondes (left) and radiosondes (right), whole campaign period.

- Beneficial impact of dropsonde observations in denial region
- Large beneficial impact on wind for SH/RE dropsondes
- Beneficial impact of extra radiosonde observations (Canadian, all)



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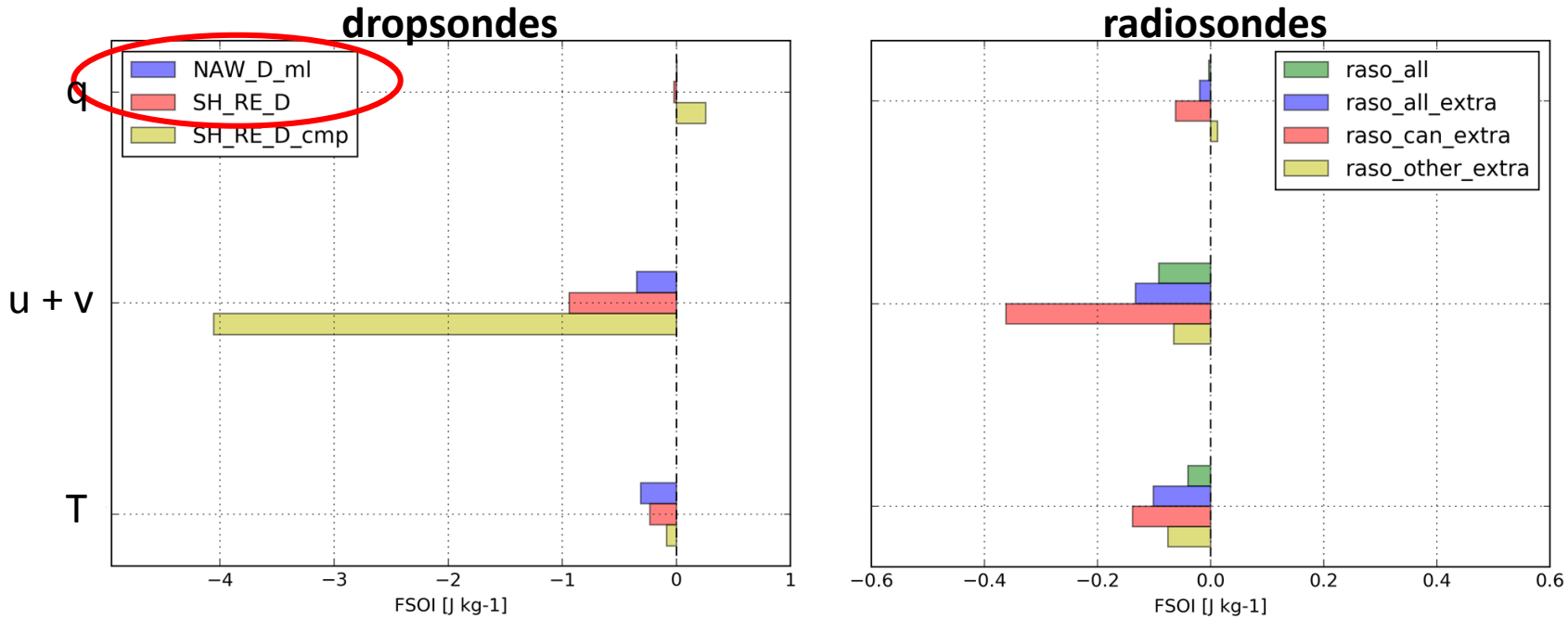

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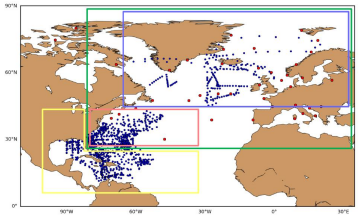

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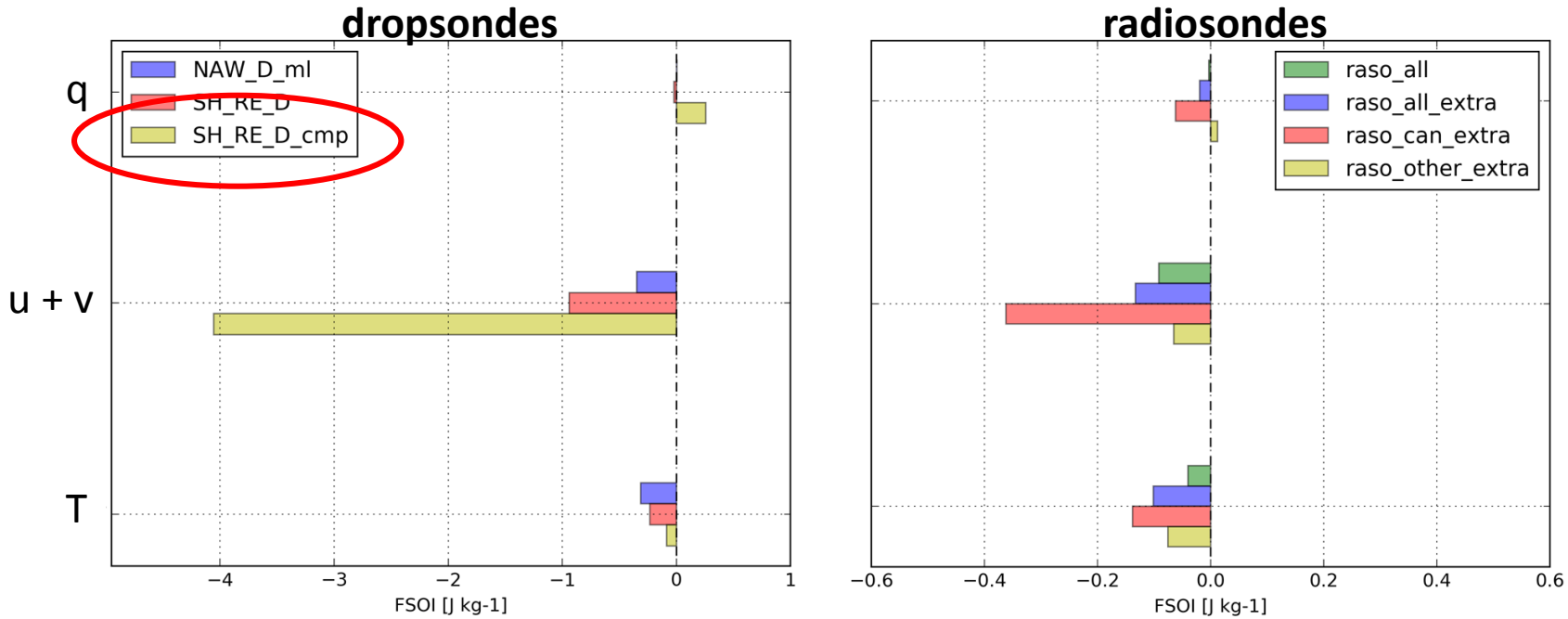

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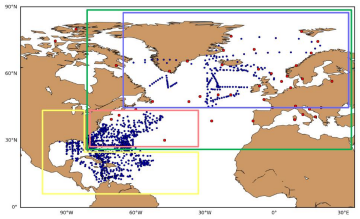

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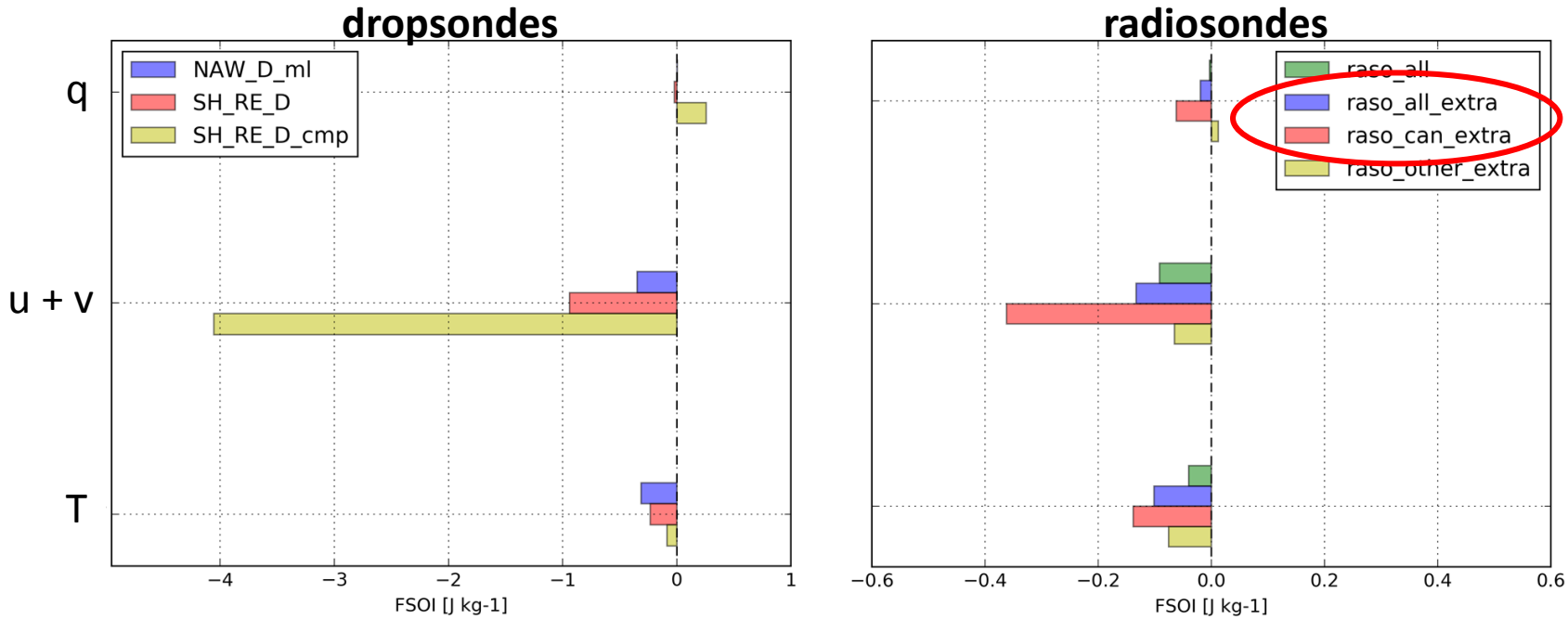

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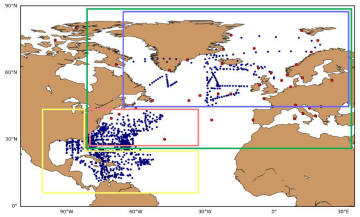


Modified Dropsonde QC (Bonavita et al. 2017)

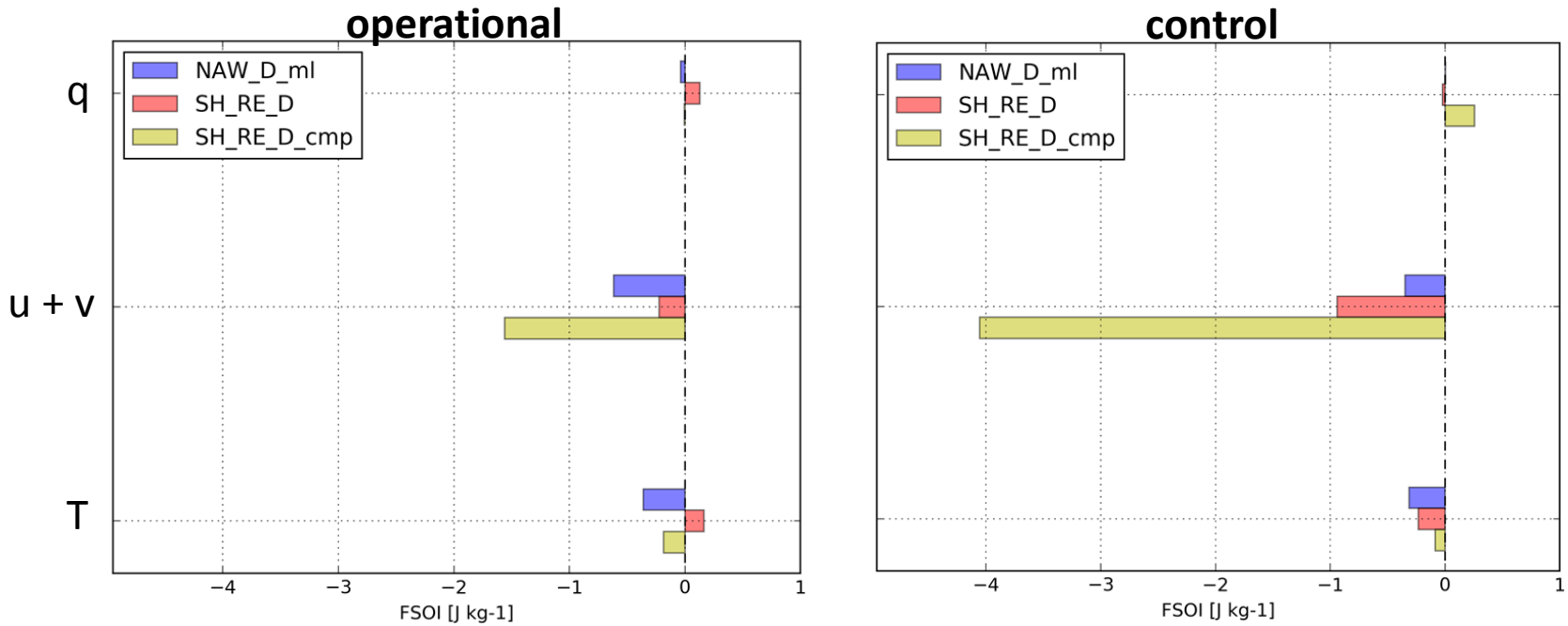
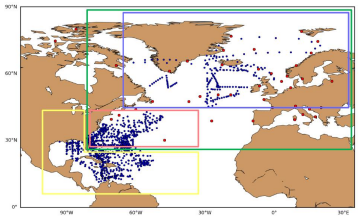


Figure 10: FSOI for dropsondes: operations (left), control exp (right).

- ECMWF's modified dropsonde quality control
- QC changes with significant influence on wind
- However: horizontal drift not yet taken into account!



Relative total impact

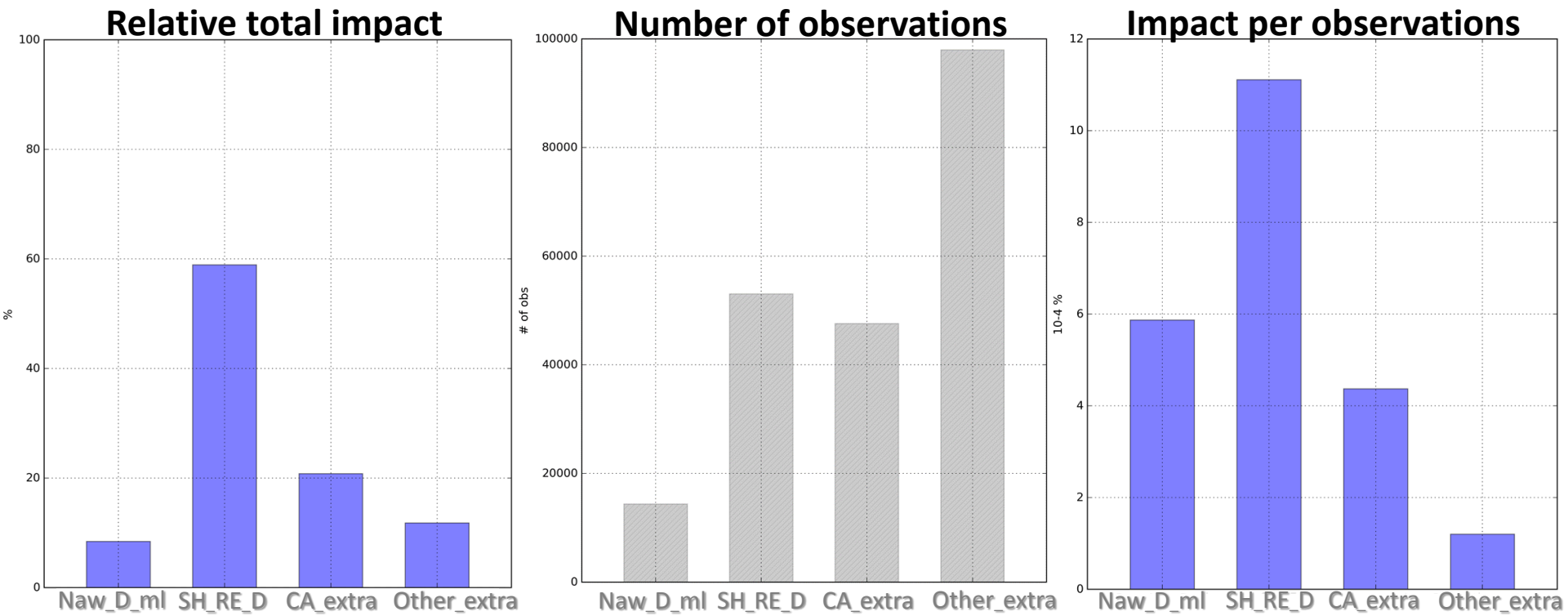


Figure 11: Relative total impact (left), number of observations (middle) and impact per observation (right).

- Largest impact by SH/RE dropsondes and CA radiosondes
- Largest impact per observation: SH/RE dropsondes > NAW dropsondes > CA radiosondes
- Small impact by European extra radiosondes

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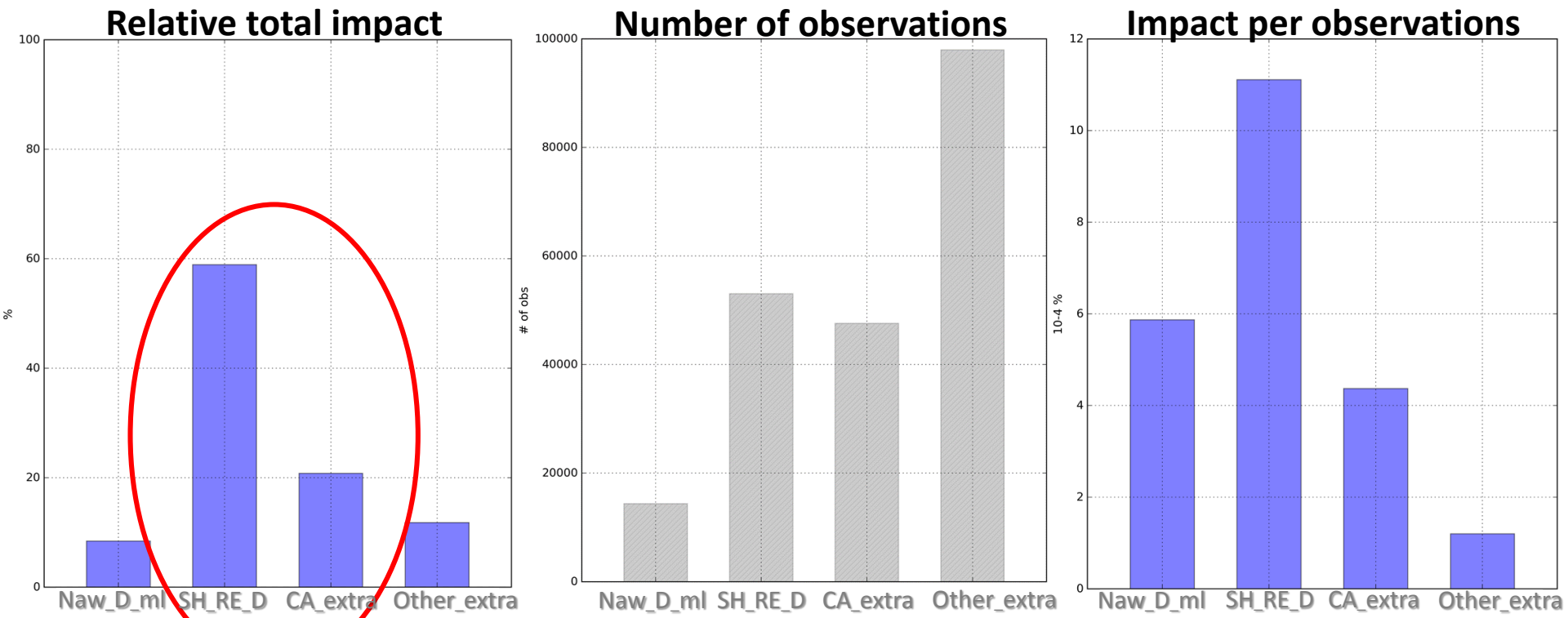

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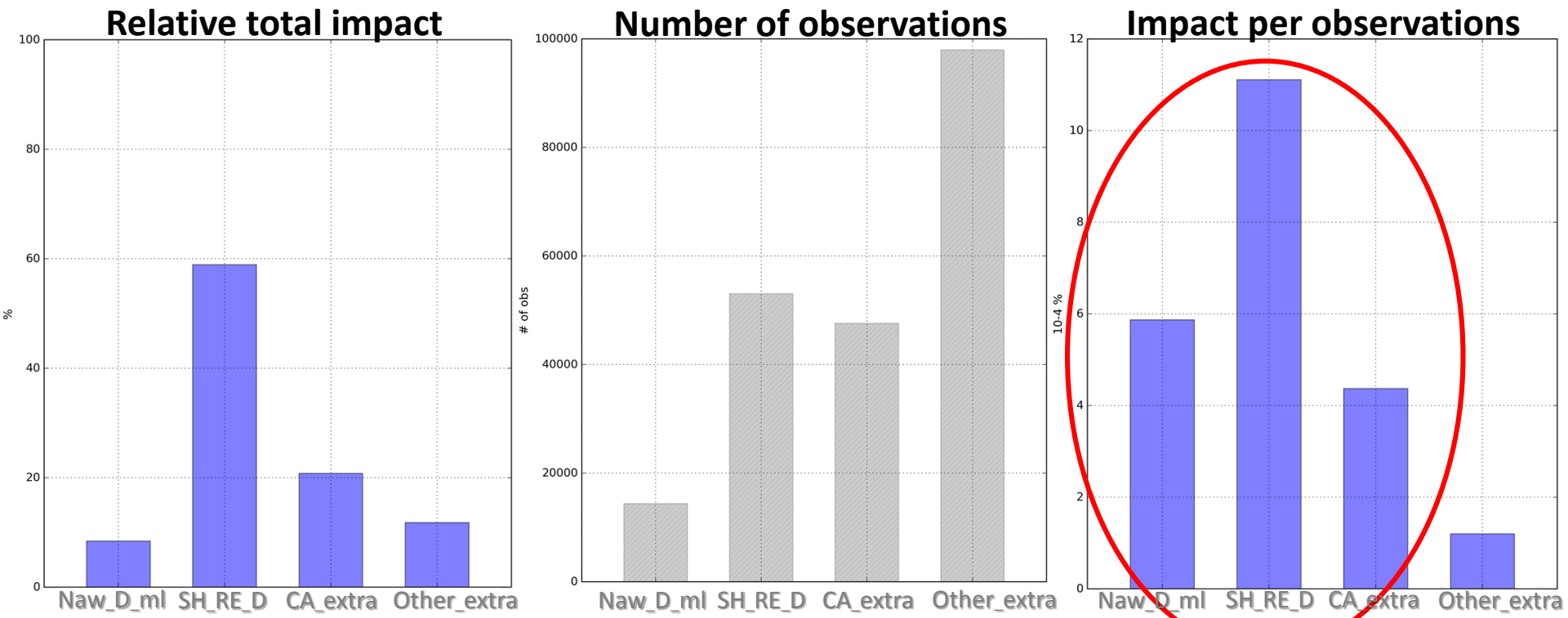

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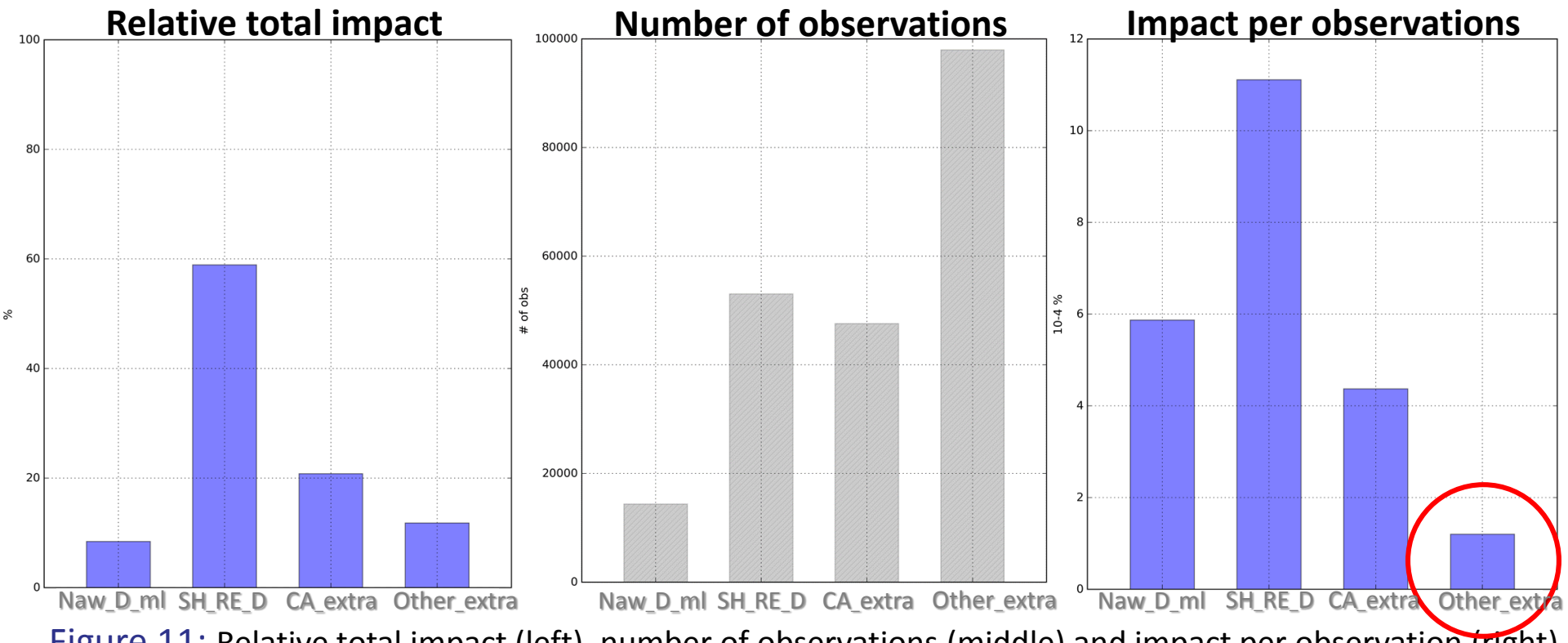

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…some work in progress

The concept of targeted observations:

- Predict location of high-impact observations, gain a lot from few adaptive observations
- Limited success in pratice during several expensive aircraft field campaigns

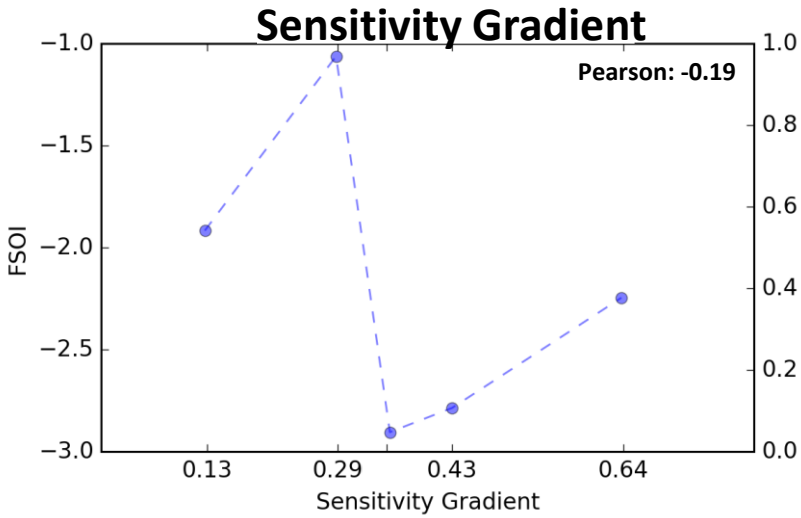
➡ What determines observation impact?

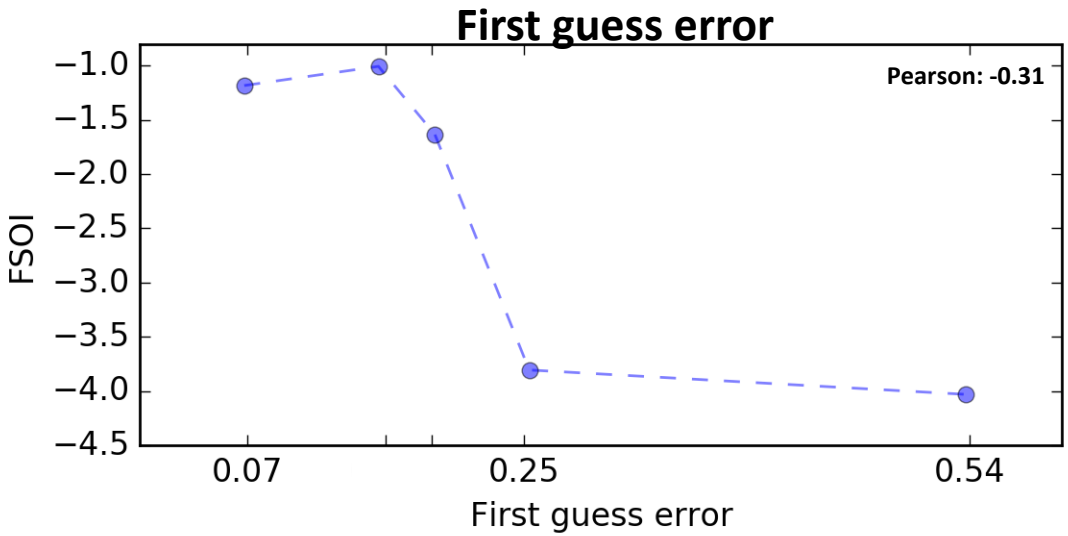
➡ What is needed for predicting observation impact?

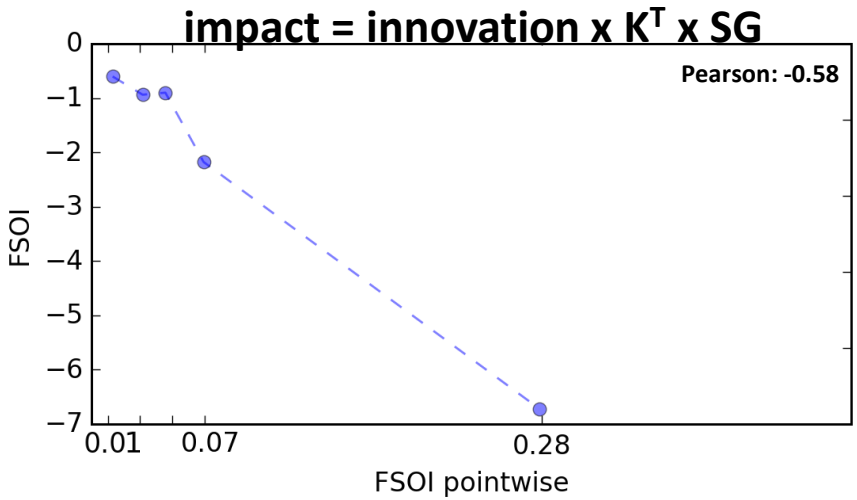
For this we investigate:

- Relative importance of the two components (SG and fg error) determining impact
- Role of ignoring covariances, just targeting at the location of maximum sensitivity/fg error

...some work in progress







Samplesize > 400
beneficial dropsondes

Figure 12: FSOI binned for pointwise vertically integrated SG, fg error and approximated FSOI.

Summary and Outlook

Summary

- Slightly lower mean error of control
- Large differences for Karl (and two further cases)
- Overall beneficial impact of dropsondes and radiosondes
- Largest impact by SHOUT dropsondes (TC and ET)
- Followed by midlatitude NAWDEX dropsondes and CA radiosondes
- Small impact of European extra radiosondes
- Indication for weak correlation between FSOI and pointwise SG
- Better (but imperfect) correlation for pointwise approximated FSOI

Next steps

- FSOI comparison with NRL and Environment Canada
- Single cycle experiments (detailed case studies)
- Link impact to weather features

References

[1] Quantifying Observation Impact for a Limited Area Atmospheric Forecast Model
Amerault et al., *Data Assimilation for Atmospheric, Oceanic and Hydrologic Applications Vol. II*, 2013

[2] On the initialization of Tropical Cyclones
Bonavita et al. et al., *ECMWF Technical Memorandum 810,* 2017

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Cardinali, *Quarterly Journal of the Royal Meteorological Society,* 2009

[4] Estimation of observation impact using the NRL atmospheric var. data assimilation adjoint system
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[5] The North Atlantic Waveguide and Downstream Impact Experiment
Schäfler et al., *Bulletin of the American Meteorological Society,* 2018

FSOI Basics

Concept

- diagnostic tool to monitor obs impact
- information on error of new obs type, relative importance of obs etc.

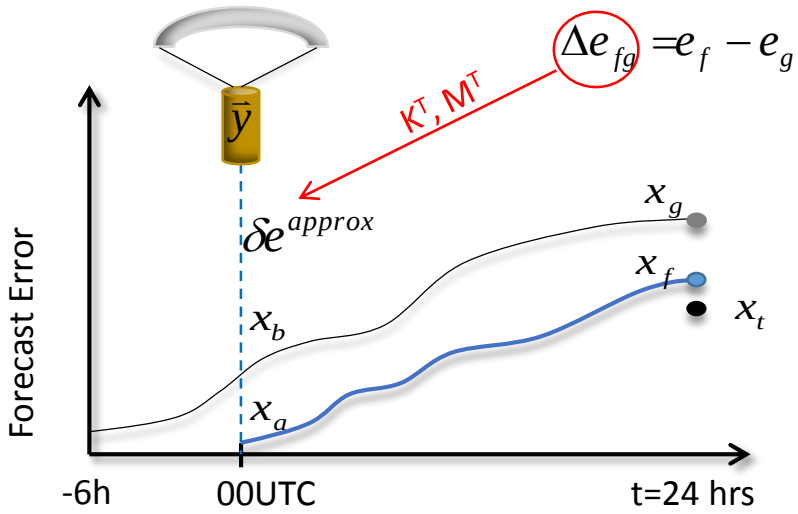

Figure 9: FSOI schematic (as in Langland and Daley, 2004).

Theory (adjoint-based)

- Quadratic energy weighted forecast error

$$\left.\begin{aligned} J_f &= \frac{1}{2} e_f = \frac{1}{2}\langle (\vec{x}_f - \vec{x}_t), C(\vec{x}_f - \vec{x}_t) \rangle \\ J_g &= \frac{1}{2} e_g = \frac{1}{2}\langle (\vec{x}_g - \vec{x}_t), C(\vec{x}_g - \vec{x}_t) \rangle \end{aligned}\right\} \Delta e_{fg} = e_f - e_g$$

Δe_{fg} → < 0 : obs improve fc

Δe_{fg} → > 0 : obs degrade fc

- Using adjoint of NWP and DA scheme to approximate Δe_{fg}

$$\delta e^{approx} = \left\langle (\vec{y} - H\vec{x}_b), K^T \left(\frac{\partial J_f}{\partial \vec{x}_a} + \frac{\partial J_g}{\partial \vec{x}_b} \right) \right\rangle = \left\langle (\vec{y} - H\vec{x}_b), \frac{\partial J}{\partial \vec{y}} \right\rangle$$

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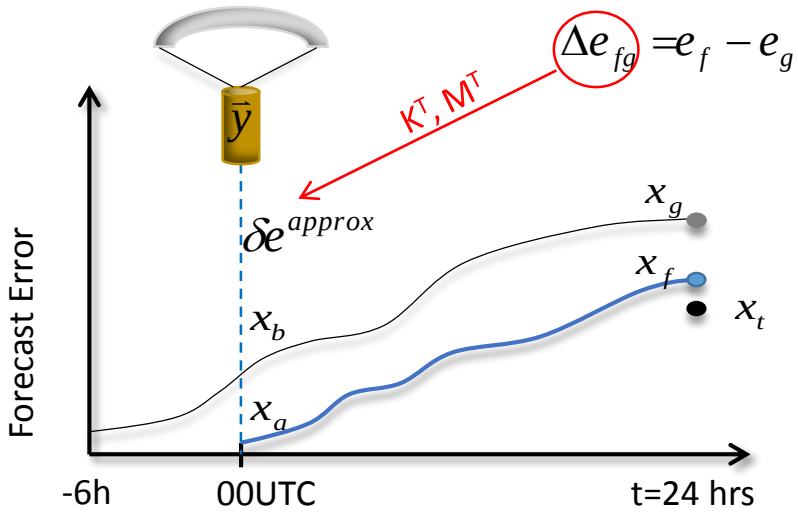

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impact = innovation x K^T x sensitivity gradient