Norwegian Meteorological Institute

Impact of satellite data in an arctic regional reanalysis system

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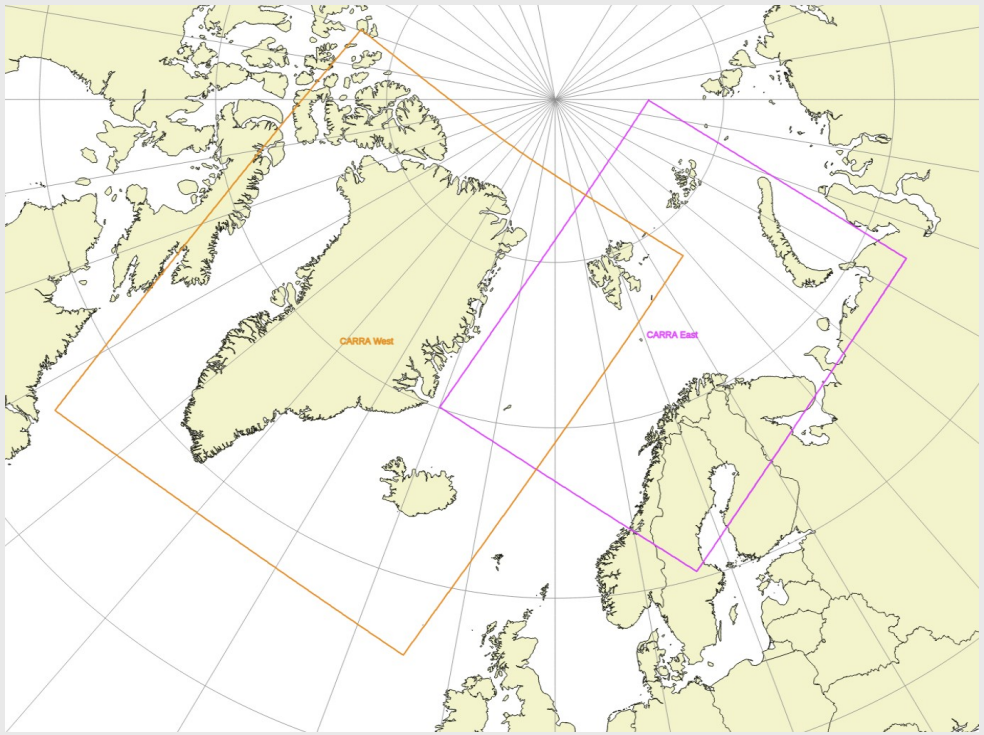
Outline

Context & objectives

- The CARRA regional reanalysis system
- Overview of experiments
- Observation impact on analysis (DFS)
- Observation impact on forecast (MTEN)
- Forecast verification statistics
- Summary

The Copernicus Arctic Regional Reanalysis (CARRA) system

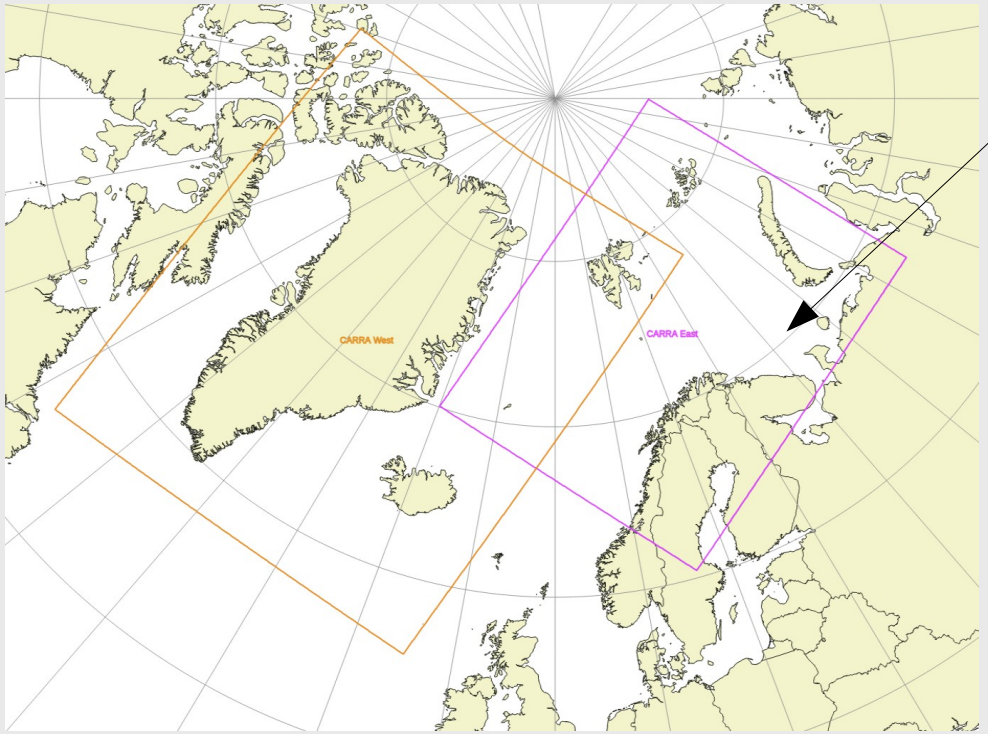
Implemented by ECMWF as part of The Copernicus Programme



- A Copernicus C3S service
- CARRA system built from Norwegian (MET) and Danish (DMI) operational HARMONIE-AROME systems
- 2 domains, reanalysis: 1991-near real time
- 3D-Var, full observing system assimilated:

  AMSU/MHS, IASI, AMV, Scatt, GNSS-RO
- 3 hour cycling
- +30h forecast at 00 and 12UTC
- Lateral boundaries: ERA5

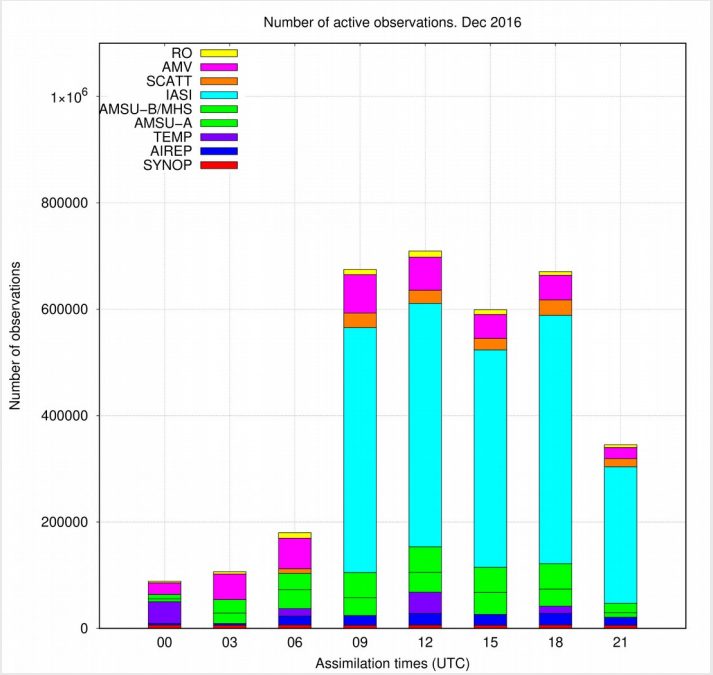
Observation Impact Experiments



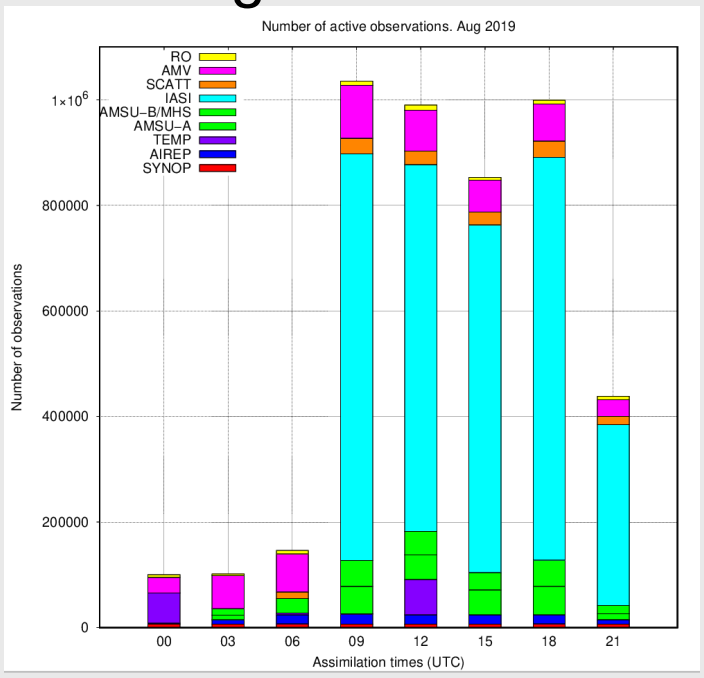
- East domain used
- Two periods
  - December 2016
  - August 2019
- Reference: Full observing system
- In the experiments we take out:
  AMSU/MHS
  IASI
- All runs start using 1:st guess and VARBC from the CARRA reanalysis

Observation Usage

December 2016



August 2019



Instrument	Satellites, December 2016	Satellites, August 2019
ATOVS AMSU-A	NOAA-15,18,19 METOP-1,2	NOAA-15,18,19 METOP-1,2,3
ATOVS AMSU-B	NOAA-18	
ATOVS MHS	NOAA-19 METOP-1,2	NOAA-19 METOP-1,2,3
IASI	METOP-1,2	METOP-1,2
SCATT	METOP-1,2	METOP-1,2,3
AMV	NOAA-15,18,19 NPP AQUA METOP-2	NOAA-15,18,19 NPP AQUA METOP-1,2 Dual-METOP
RO	METOP-1,2 GRACE-A COSMIC-1,6	METOP-1,2,3

Observation impact on the analyzed atmospheric state

- Methodology: Degrees of Freedom of Signal (DFS)
  1: Perform 3D-Var analysis
  2: Perturb all observations and do a second analysis
  3: Compare difference between analyses:

$$DFS = \sum_i \frac{\partial H_i(\boldsymbol{x}_a)}{\partial \boldsymbol{y}_i} \approx (\boldsymbol{y}^* - \boldsymbol{y})^T \boldsymbol{R}^{-1} (H(\boldsymbol{x}_a^*) - H(\boldsymbol{x}_a))$$

Chapnik, 2006
Q. J. R. Meteorol. Soc

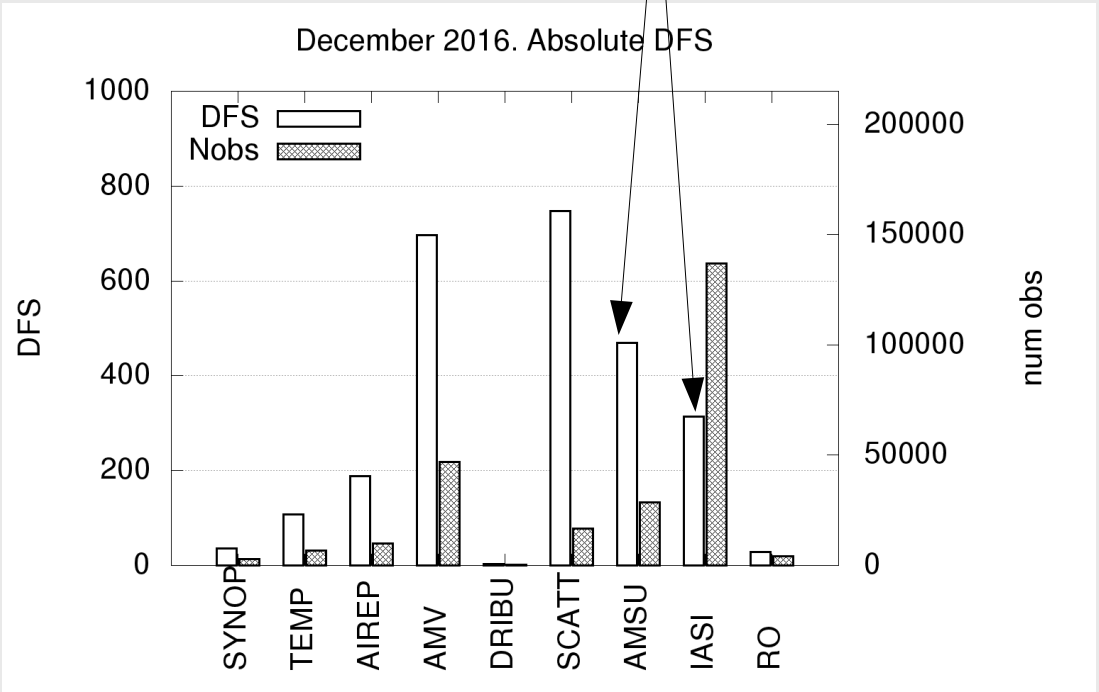
- Calculate DFS for all cycles in two separate days
- Average results

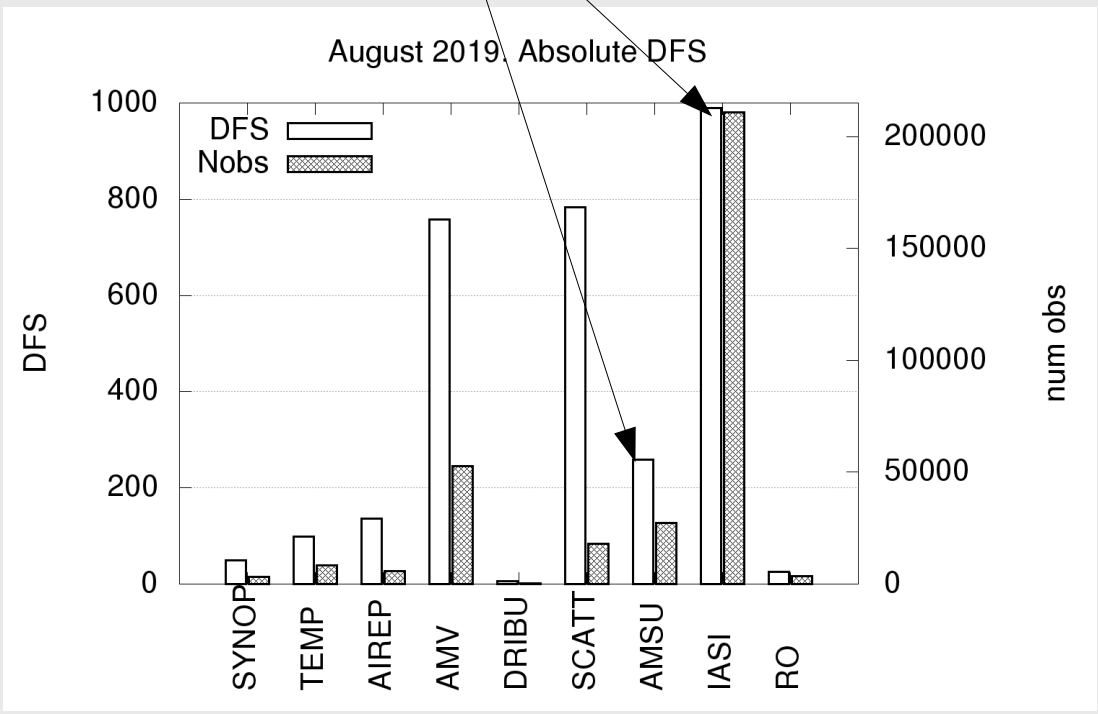
Observation impact on the analyzed atmospheric state

- Radiances, and other satellite based observations, all have big influence on the analyzed atmospheric state

AMSU/MHS bigger impact than IASI in winter

...and vice versa in summer





Observation impact on forecast

-

Propagation of Information

- Methodology: Moist Total Energy Norm (MTEN)

  1: Perform analysis and forecast

  2: Withdraw one observation type

  3: Redo analysis and forecast

  4: Compare difference between forecasts

$$MTEN = \int_D \left[u'^2 + v'^2 + \frac{c_p}{T_r} T'^2 + RT_r \left(\frac{p'_s}{p_r} \right)^2 + \frac{L^2}{c_p T_r} q'^2 \right] dD$$

Ehrendorfer, 1999
J. Atmos. Sci.

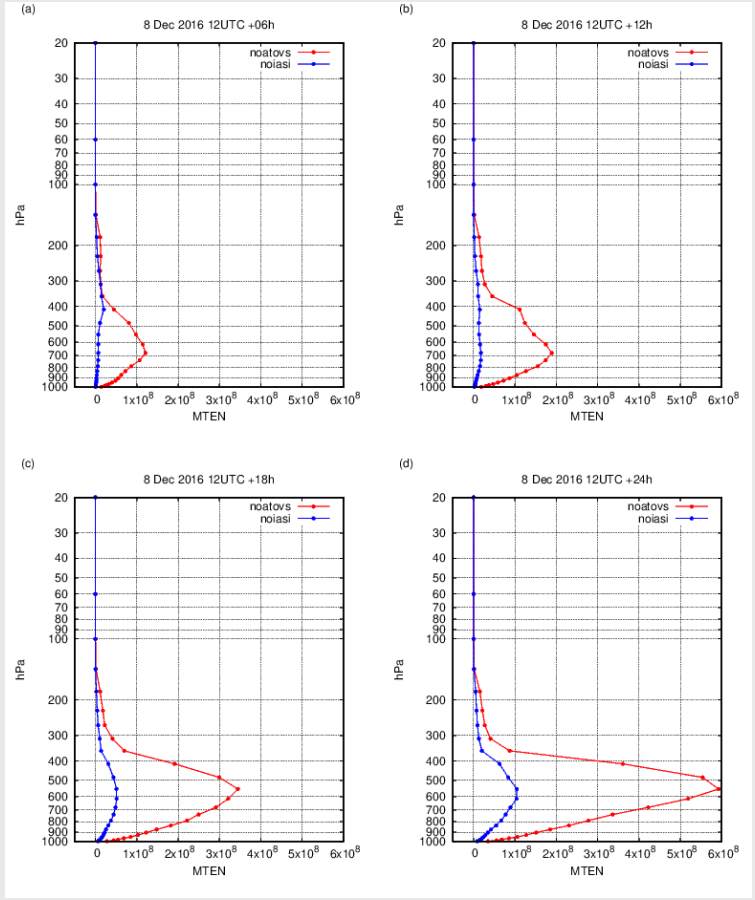
Storto,, 2010
Atmos. Sci. Lett.

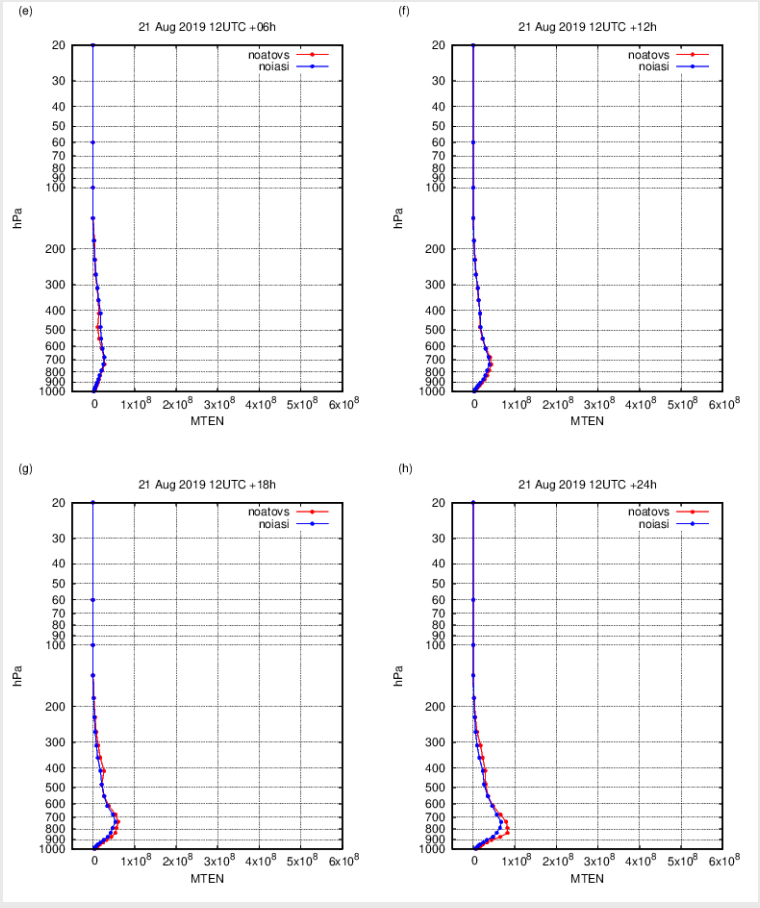
- Here the integral is per level, i.e. a profile is obtained
- **OBS!!** Only one case per study period

Observation impact on forecast

Propagation of Information

- Stronger MTEN response in winter than in summer
- AMSU/MHS (red) bigger impact than IASI in winter
- AMSU/MHS and IASI comparable in summer
- MTEN value dominated by wind (in these cases):
  - Dec case involved a strong cyclonic vortex



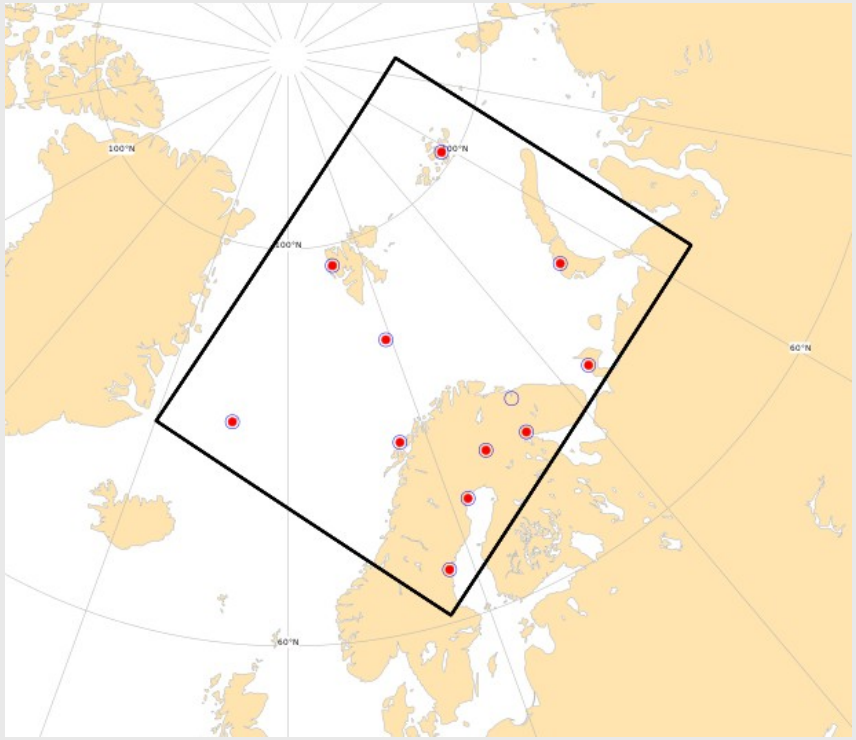


Impact on forecast verification statistics

TEMP stations used for verification

Blue rings: Dec 2016

Red dots: Aug 2019

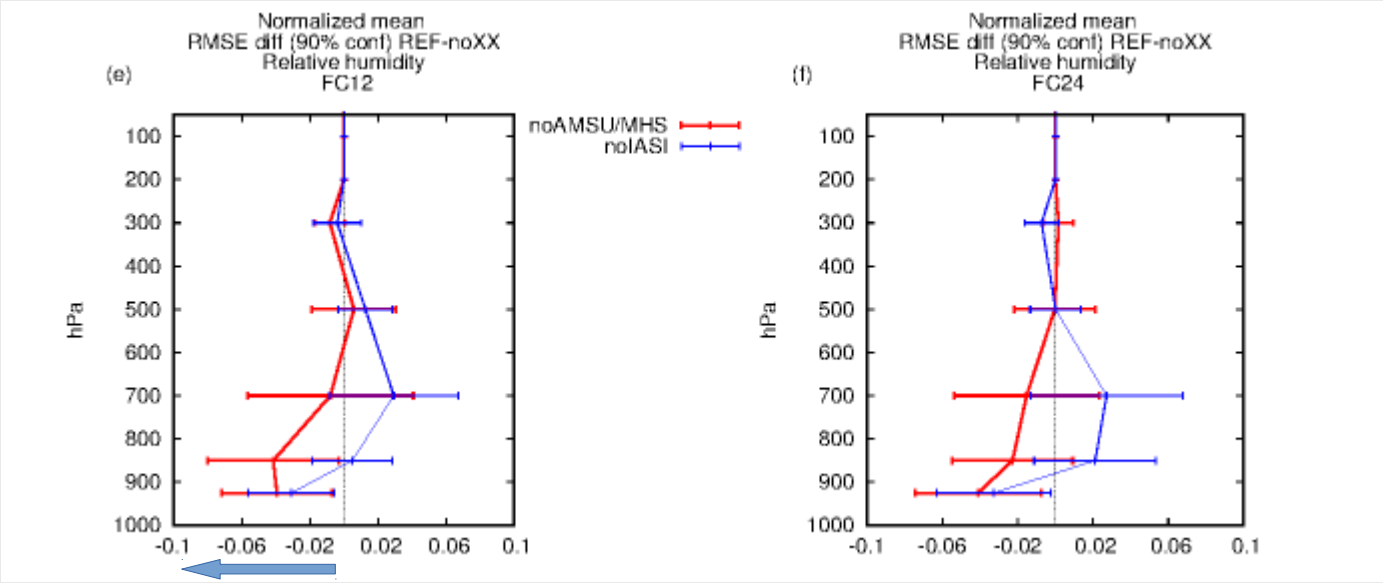


- Upper-air forecasts are verified against radiosonde observations
- Only forecast ranges +12h and +24h are verified (not the analysis)
- Significance test computed on normalized RMSE differences
- Impact generally quite small

  - Robust system; REF assimilates full observing system

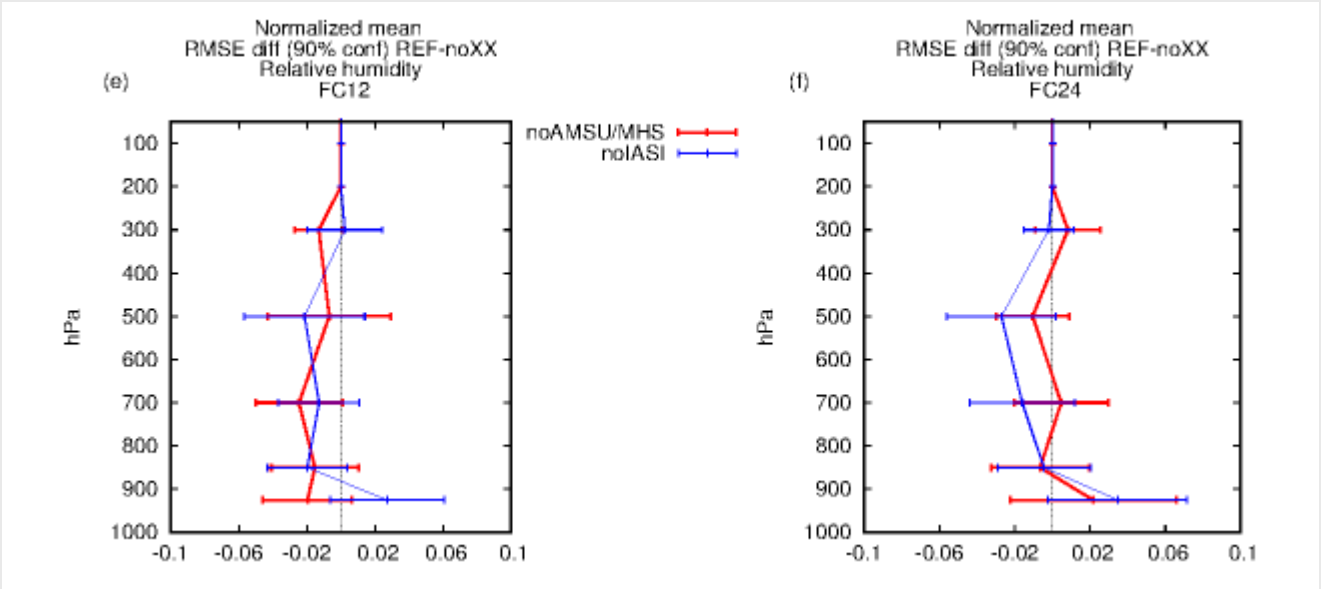
Impact on forecast verification statistics

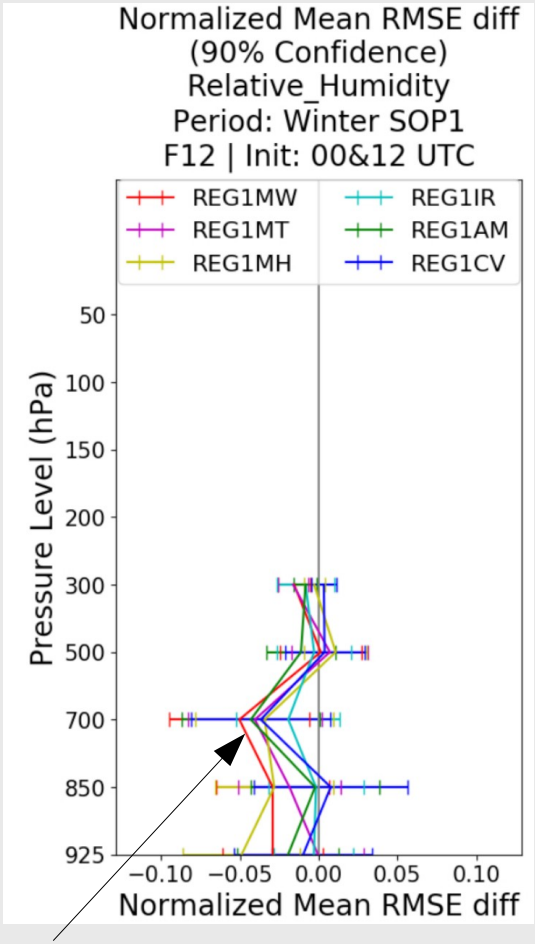
December 2016



Positive impact

August 2019





Randriamampianina 2021, QJRMS

Summary

- Radiances, and other satellite based observations, have big impact on the analyzed atmospheric state
- The increments from radiances propagates forward in time via forecast model integration.
  - How much is situation dependent
- MW and IR radiances improves low level humidity;
  - in line with other studies
  - IR did not improve humidity in winter, see bullet below
- We have identified some issues regarding AMSU-A and IASI that are under investigation