Norwegian Meteorological Institute

APPLICATE.eu
Advanced prediction in polar regions and beyond

Alertness

Improving the use of satellite radiances in high latitude regional NWP

Roger Randriamampianina,
Niels Bormann, Heather Lawrence, Irina Sandu, Morten A Ø Køltzow, Zheng Qi Wang, Máté Mile, Roohollah Azad, Yurii Batrak, Reima Eresmaa

Email: rogerr@met.no

ITSC-23, Virtual meeting, 24 - 30 June, 2021

Outline

- Motivation
- Observing System Experiment design
- Relative impact of observations in AROME-Arctic
- Few ways to enhance the use of satellite observations in a high latitude regional model
- Concluding remarks

Motivation

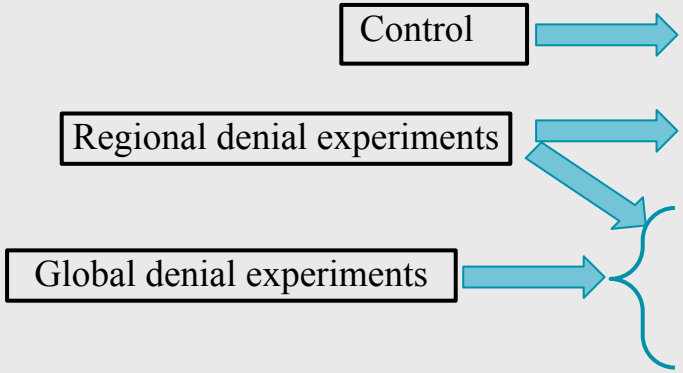
- In the Alertness project (2018-2021) we were originally planning to perform Observing System Experiments (OSE) at its final phase.
- Laurence et al. (2019) and Bormann et al. (2019) (ECMWF) conducted a global model with, respectively, Arctic and global OSEs in the framework of the APPLICATE project, and kindly provided us almost all their results to be used as lateral boundary conditions (LBCs) in our study.
- We decided to join this effort and performed the parallel OSEs

The Upper Air OSE

Experiments and naming: **G**= global NWP system, **R**= Regional NWP system , **all**= all observations, **noXX**= observation type XX is removed, **SOP1**= YOPP Special Observing Period 1, **SOP2**= YOPP Special Observing Period 2.

MW= microwave radiances, **MT**= microwave temperature sensitive radiances, **MH**= microwave humidity sensitive radiances, **IR**= Infrared radiances, **AM**= Atmospheric Motion Vectors, **CV**= all conventional observations, **RS**= all radiosonde observations, **PS**= all surface pressure observations, **S1**= all additional SOP1 observations.

The **Gall/Rall** experiment indicates for example the regional experiments in which all observations are assimilated in regional DA, which uses as LBCs the global experiment in which all observations are used. **GnoMW/RnoMW** indicates the regional experiment used while no MW sensitive observations are used either in the regional nor north of 60 N in the global DA.



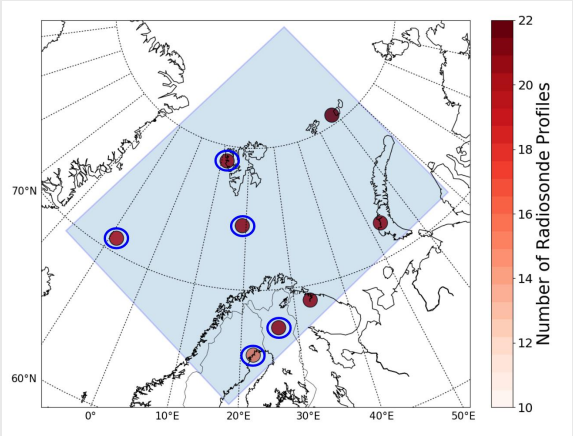
Global experiments used as LBC for regional experiments	Regional experiments	Observations
Gall	Rall	All obs included
Gall	RnoXX	**XX observations removed for SOP1**: MW, MT, MH, IR, AM, CV, RS, PS, S1 **XX observations removed for SOP2**: MW, IR, CV, AM
(Arctic) GnoXX	RnoXX	**XX observations removed for SOP1**: MW, MT, MH, IR, AM, CV, RS **XX removed for SOP2**: MW, IR, CV
(Global) GnoXX	RnoXX	**XX removed for SOP1**: MW, IR, AM, CV

The estimated relative impacts:

-- Through the regional DA: Gall(Arctic)/Rall and Gall(Arctic)/RnoXX
-- Through the LBCs : Gall(Arctic)/RnoXX and GnoXX(Arctic)/RnoXX
-- Total Arctic obs impact: Gall(Arctic)/Rall and GnoXX(Arctic)/RnoXX
-- Impact of mid-latitude obs: GallnoXX(Arctic)/RnoXX and GnoXX(global)/RnoXX

The AROME-Arctic model

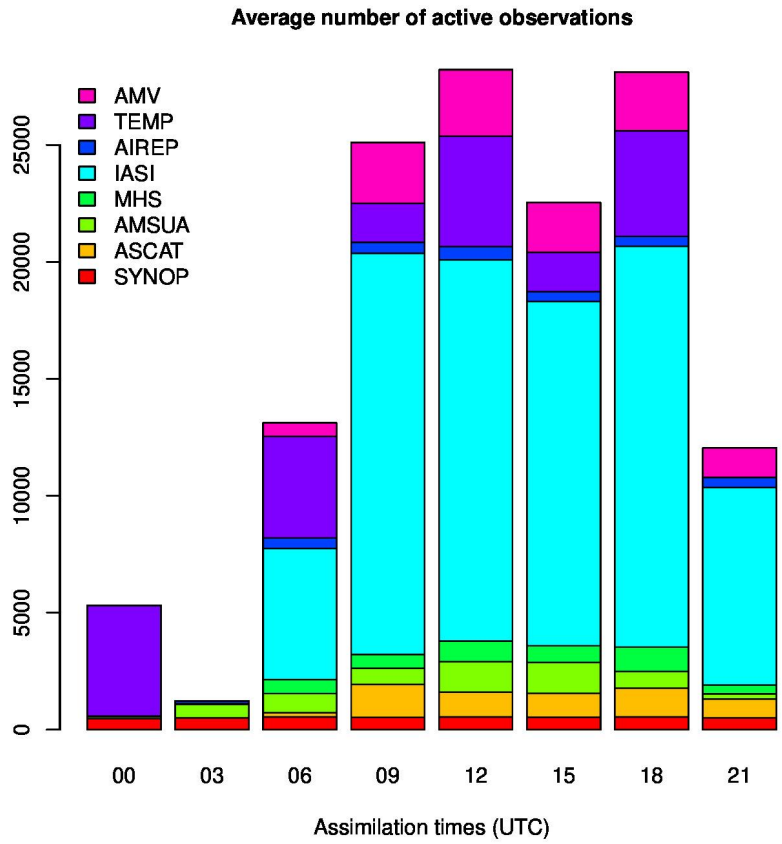
- Model upper-air physics: HARMONIE-AROME
- Model surface physics: SURFEX
- Upper-air assimilation: 3D-Var
- Surface assimilation: Optimum interpolation (OI)
- Update strategy: 3 hourly cycling (00, 03, 06, 09, 12, 15, 18, 21 UTC)
- Lateral boundary condition: ECMWF (in this study every 3 hour)
- Used model version: 40h1.2
- Forecast lengths: Long forecast (48 hours) twice a day (00, 12 UTC) for verification purposes
- Winter period (SOP1): 10 February - 31 March 2018
- Summer period (SOP2): 1 - 25 July 2018



The AROME-Arctic model domain with the available radiosonde stations counted during the summer (SOP2) study. Marked stations are those providing additional observations during the YOPP SOPs

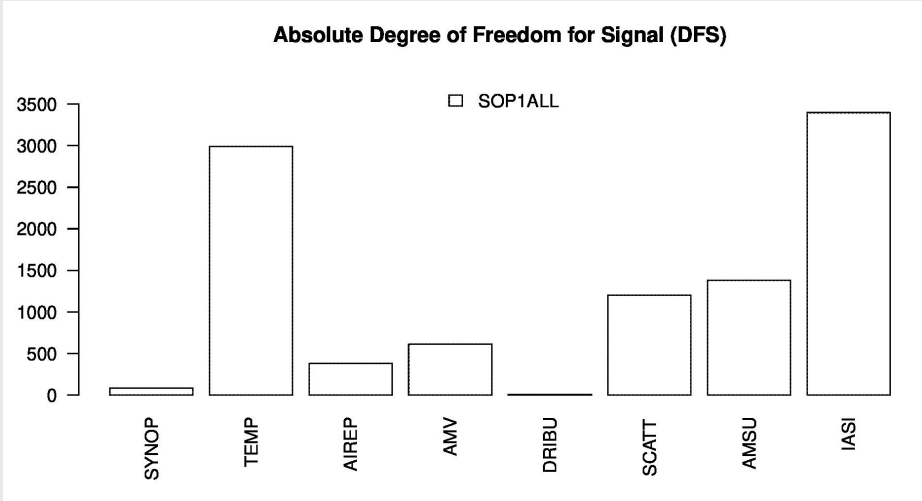
Norwegian Meteorological Institute

Arctic observations and their impact in DA



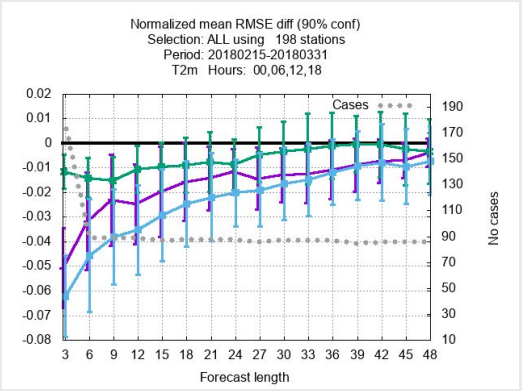
A ten-day averaged number of the assimilated observations per observation type

Averaged DFS over four distant assimilation times

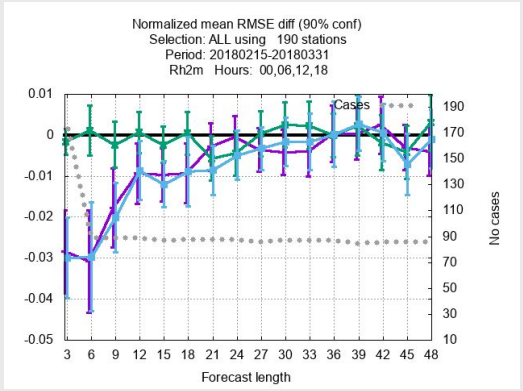


Relative impact of observations on the surface fields

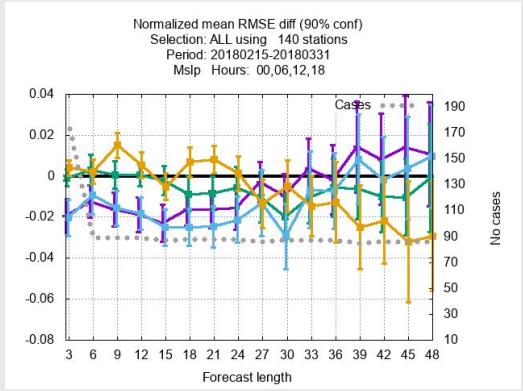
Impact of Arctic obs Through:
LBCs
Regional DA
Total impact



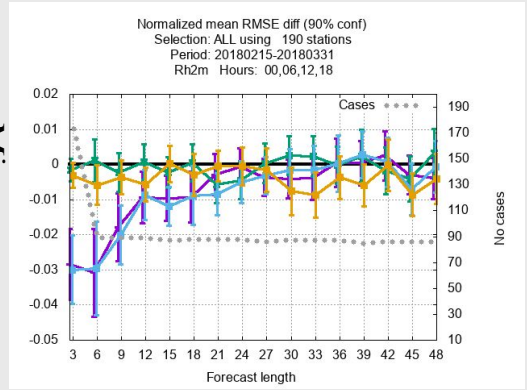
Conventional



Microwave ATOVS



Microwave ATOVS

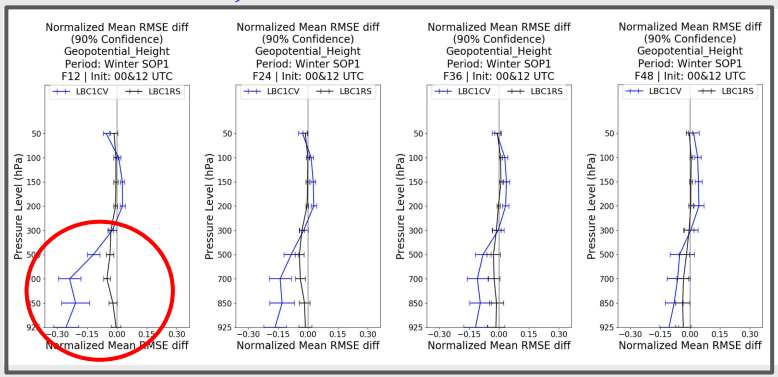


Impact of microwave radiance:
Arc LBCs
Regional DA
Arc total impact
Mid-latitude

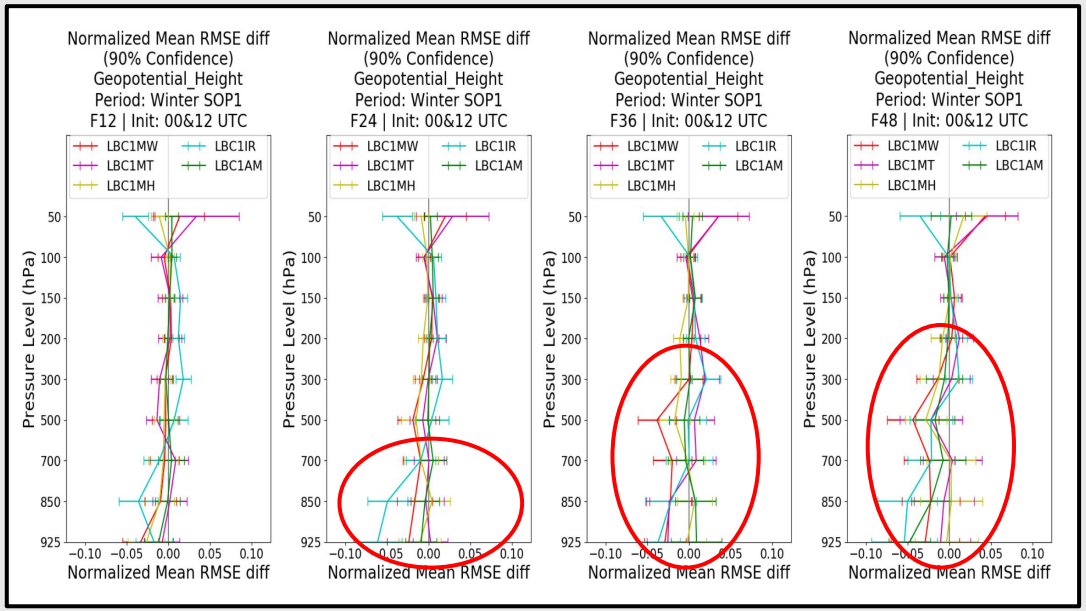
Norwegian Meteorological Institute

Impact of Arctic obs through LBCs

Conventional, Radiosonde

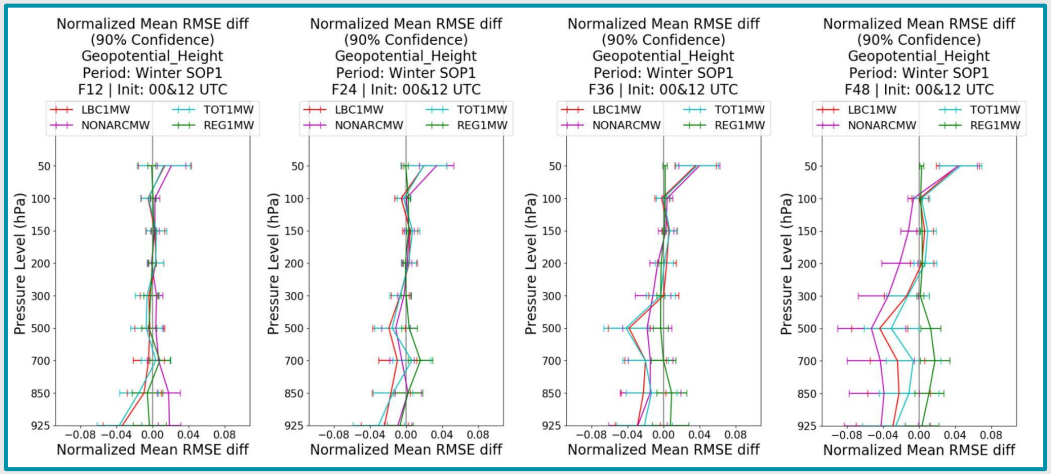


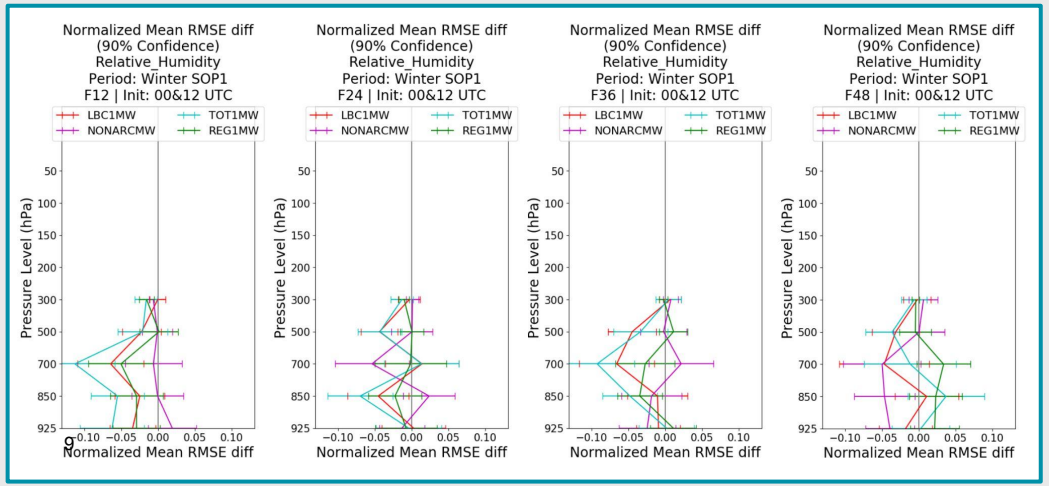
ATOVS, IASI, AMSU-A, MHS, AMV



Norwegian Meteorological Institute

Total impact of the Arctic observations





Impact of microwave radiance:

Arctic MW through LBCs

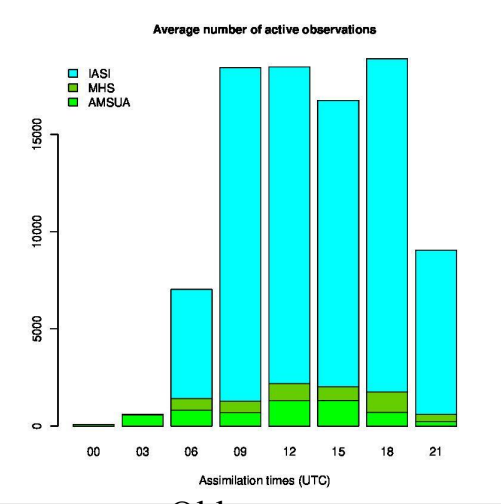
Arctic MW through regional DA

Arctic MW total impact

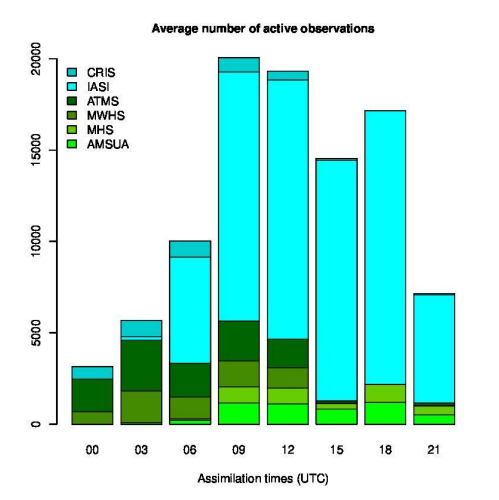
Impact of Mid-latitude WM

Norwegian Meteorological Institute

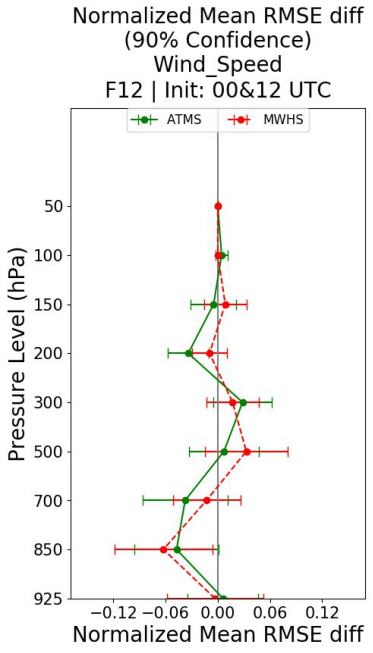
Using more radiances in early morning DA



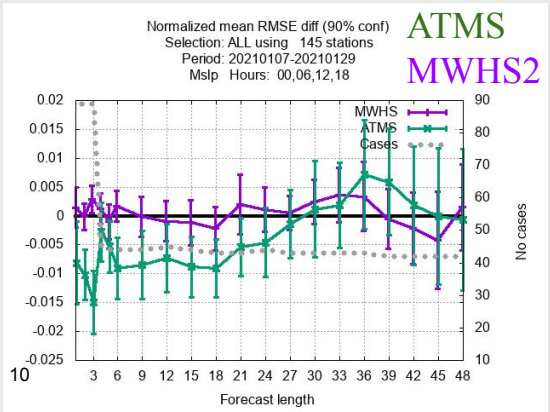
Old

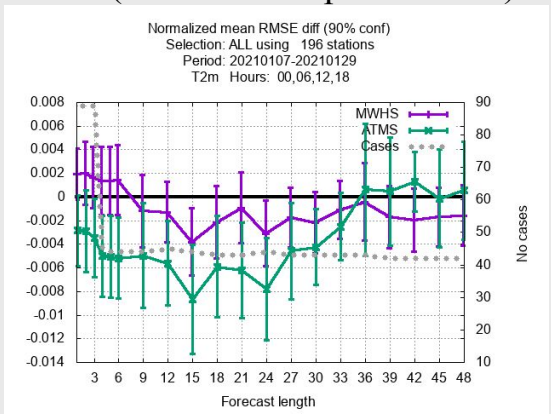


New (without Metop C ATOVS)



ATMS
MWHS2
12 hours forecast from 00&12 UTC runs

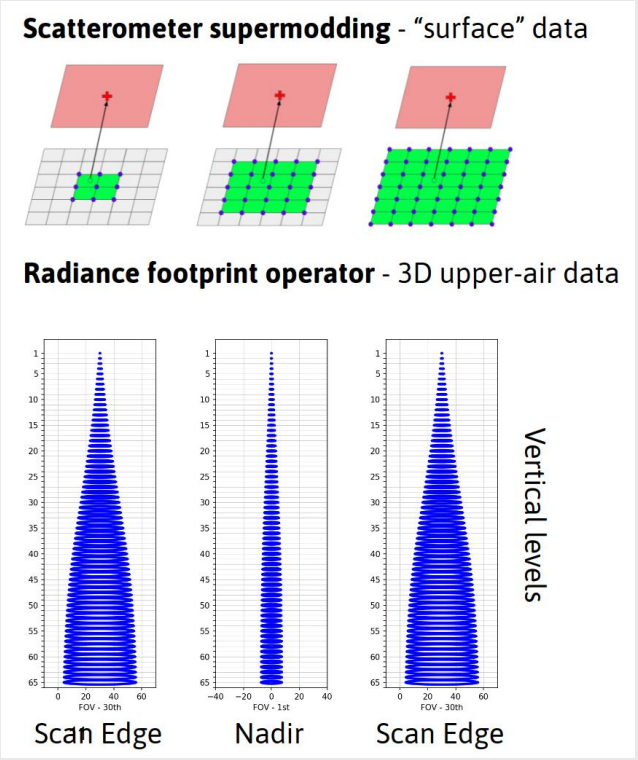


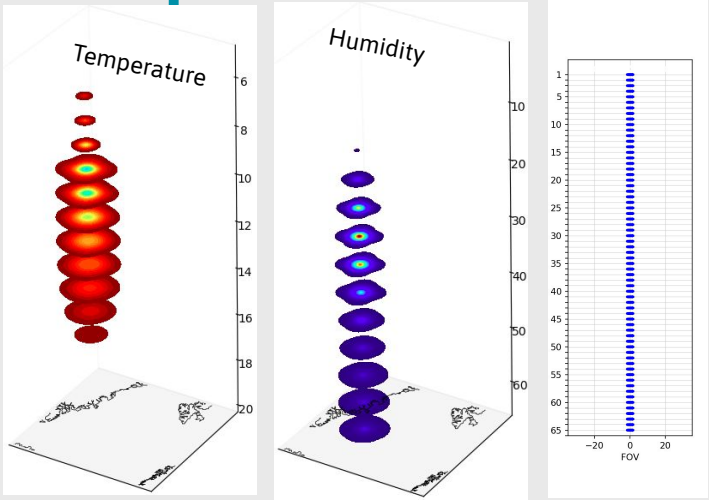


Very promising results from first test. Tuning is required. CrIS data needs more work.

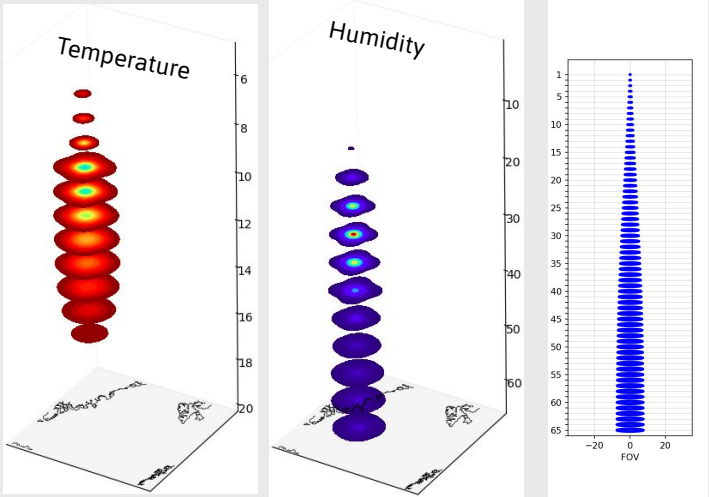
Accounting for the footprint of the instruments

The design of the footprint operator
Mile et al. (2021)





Old Obs operator:
4 points bilinear interpolation



Obs operator:
Nadir footprint size is relatively small i.e., single obs gives very very small differences
From **12 to 60 km averaging** was tested

Norwegian Meteorological Institute

Weak coupling between surface and upper air

- The surface and upper air assimilation are decoupled since no information from surface assimilation is used in the upper air assimilation.
- Therefore, in order for the surface assimilation results to be used by 3D-Var (or later 4D-Var) at least the skin temperature needs to be updated in the upper air model file before the quality control and data screening.
- Tested in the context of assimilation of sea ice temperature in AROME-Svalbard (Fig. 1)

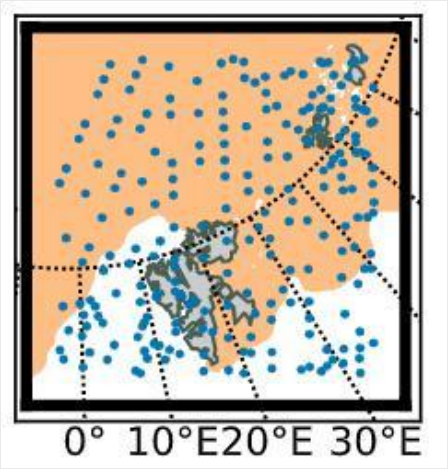


Figure 1: AROME-Svalbard with satellite radiance assimilation

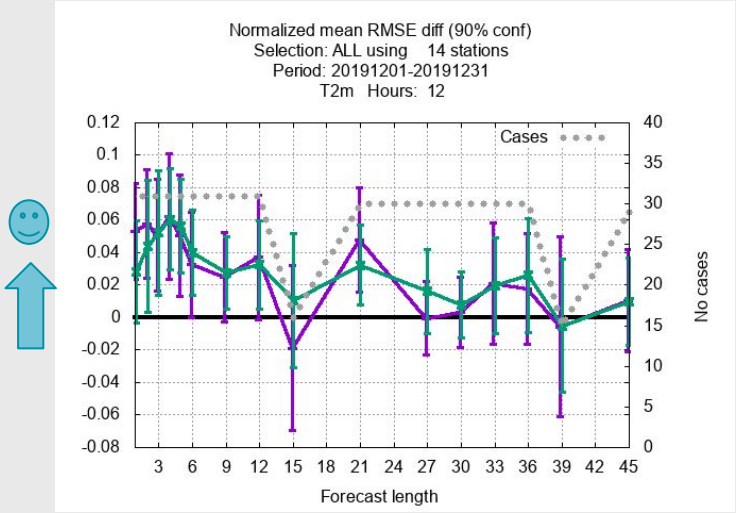


Figure 2: With & without weak coupling of skin temperature

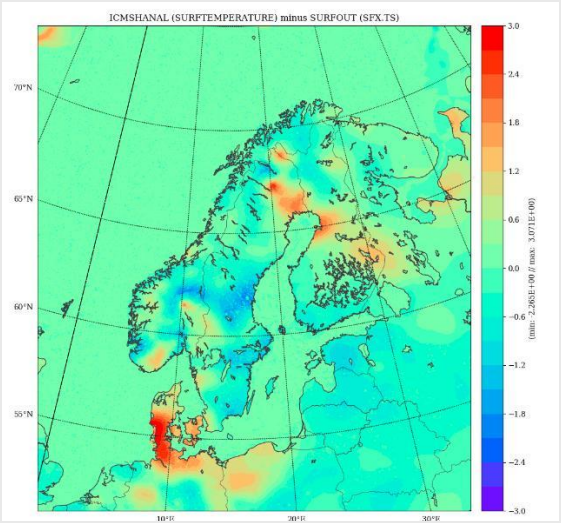


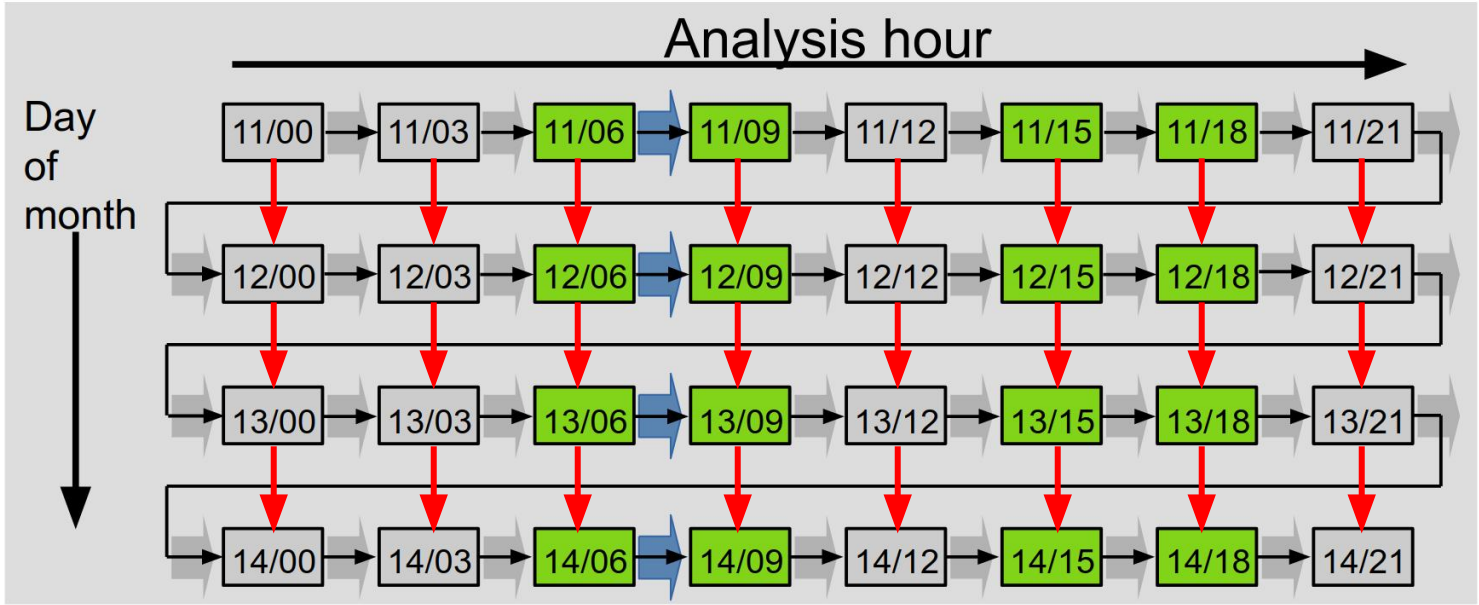
Figure 3: Skin temperature difference (original input minus the updated one).

Batrak (2021), *submitted JAMES*

Proposal for VarBC update strategy (applicable to NOAA-19)

Old:
Red arrows
Coefficients are updated daily for each assimilation time

Proposed:
Cycled, but updated with strict condition that full path is available with enough anchoring observations



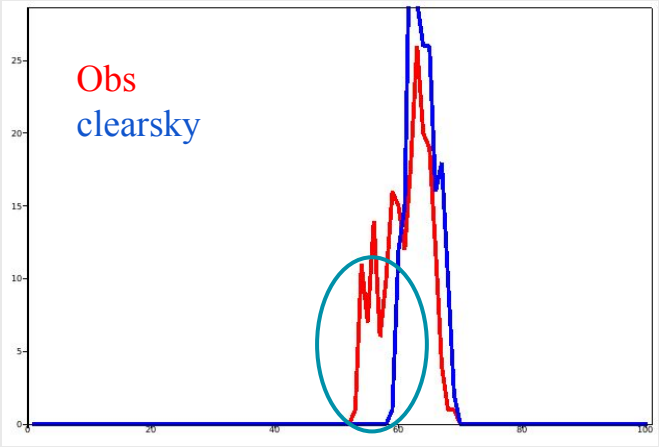
Assimilation of radiances in all-sky

The cost function in variational assimilation:

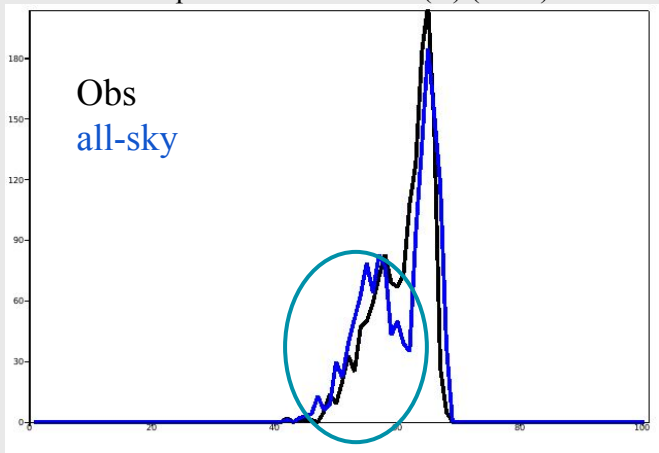
$$J(\mathbf{x}) = (\mathbf{x}-\mathbf{x}_b)^T\mathbf{B}^{-1}(\mathbf{x}-\mathbf{x}_b) + (\mathbf{y}-H(M(\mathbf{x})))^T\mathbf{R}^{-1}(\mathbf{y}-H(M(\mathbf{x})))$$

[obs Tb] - [model Tb] { rttov clearsky / rttov_scatt all-aky

-- Implementation of the IFS all-sky approach in the HARMONIE-AROME data assimilation system is ongoing with very good progress
-- Still a lot needs to be done
-- We started with MHS instrument
-- Here we present the simulation of channel 5 in both clearsky (top) and all-sky (bottom) conditions



Temperature distribution (K) (200+)



Temperature distribution (K) (200+)

Concluding remarks(1)

- More satellite observations are available in the Arctic for assimilation compared to conventional ones.
- The DFS diagnostic showed that both radiosonde and IASI data are the most contributing observations in the AROME-Arctic DA, followed by microwave, and scatterometer data.
- Arctic observations impact the quality of the AROME-Arctic forecasts both through regional DA and through LBCs.
- The total impacts of observations on the surface fields are dominated by the impacts through regional DA (e.g. winter case), while in the upper-air the total impacts are dominated by the impacts through LBCs.
- Mid-latitude observations impact the quality of day-2 AROME-Arctic forecasts through LBCs.
- The conventional observations are the most impacting observations, followed by IASI radiances. The microwave radiances are third impacting observations over our region of interest.
- An article on this study is available in Q. J. R. Meteorol. Soc.

Concluding remarks(2)

- Adding more infrared (IASI, CrIS) and microwave (ATOVS, ATMS, MWHS2) data using Metop-C, NOAA-20, SNPP and FY-3D closed the gap of both microwave and infrared radiance data in the early morning data assimilation.

- Under the Alertness project we are improving the representation of the sea ice cover by implementing an assimilation approach and improved interaction between surface and upper-air DA systems.

- We hope that the ongoing work on accounting for the footprint of satellite instruments together with improved updating procedure of the VarBC coefficients and the use of more observations through assimilation in all-sky condition will bring further improvement in our data assimilation system.

Thank you for your attention!

Norwegian Meteorological Institute

Backup slides

The design of the footprint operator

Implementation phase 3.