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Optimizing the assimilation of radiances in the operational AROME-Arctic NWP system

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1: MET Norway

2: AEMET

3: SMHI

Content

- The AROME-Arctic Forecast model
- Recent updates of the satellite DA system
- OSE data denial
- Forecast verification
- Conclusions and future plans

The AROME-Arctic Forecast model

NWP forecast system:

HARMONIE-AROME

Domain: AROME-Arctic **(AA)**

2.5 km / 65 levels – Forecast up to 66h

Lateral Boundary Conditions provided hourly with IFS

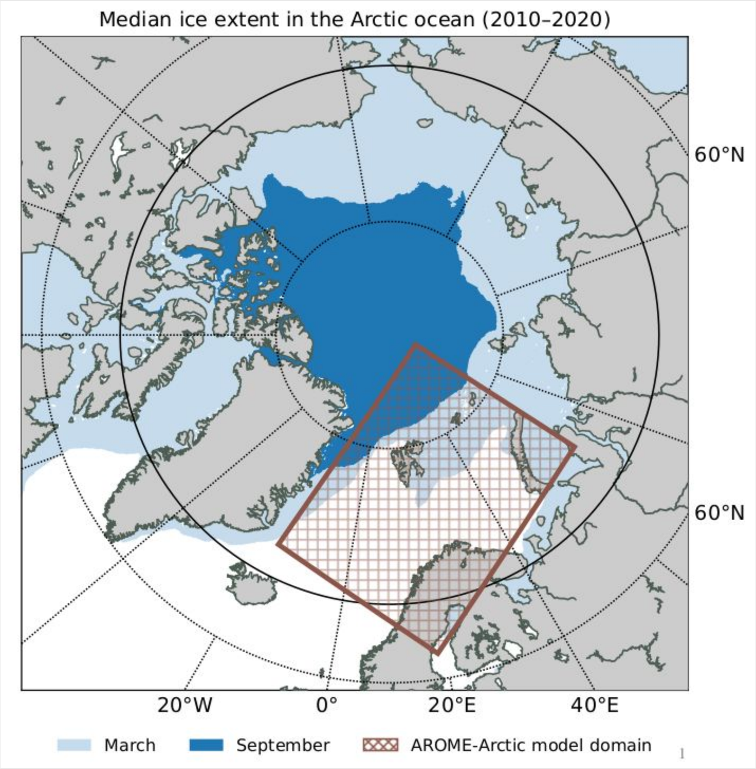
3D-Var DA system

OBS: synop, buoys, ship, radiosondes, SCATT,

Polar AMV and radiances (clear-sky only)

Prod: cy43

Preop: cy46



Courtesy of Yurii Batrak

Data assimilation experiments:

April 2024 & September 2024

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Recent updates of the satellite DA system in AA

Microwave radiances:

- AMSU-A Channel 5 to 9 (Metop-B & C + NOAA-15 & -18 & -19)
- MHS Channel 3 to 5 (Metop-B & C)
- ATMS Channel 6 to 10 & 18 to 22 (NPP & NOAA-20 + **NOAA-21**)
- MWHS-2 Channel 4 to 6 & 11 to 15 (FY-3D + **FY-3E**)

+ AWS offline monitoring

Infrared radiances:

- IASI ∽30 high peaking T & Q channels (Metop-B & C)
- CrIS ∽50 high peaking T & Q channels (**NOAA-20 + NOAA-21**)

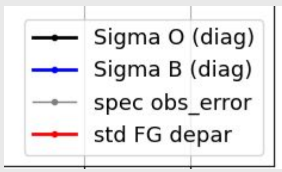
+ Fine tuning observation errors, new VARBC predictors, new blocklist
+ Bias correction of surface emissivity + other diagnostics updates (DFS, allobs …)

Recent updates of the satellite DA system in AA
Tuning observations errors

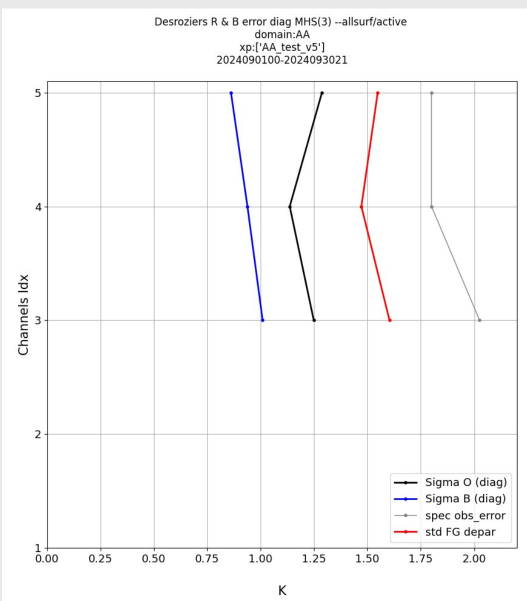
September 2024

=> Fine tuning of observation error for each instrument and each satellite to calibrate their weight in the analysis.

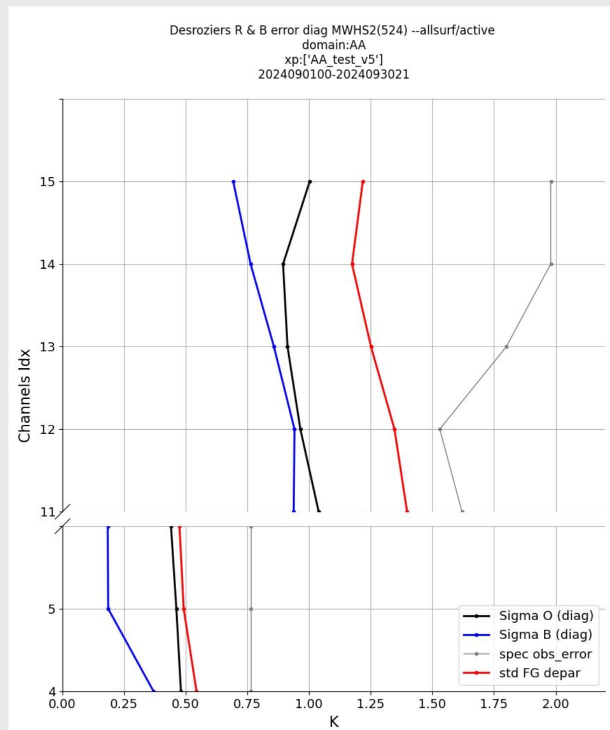
(See Jana's poster for more details on the Desroziers diagnostic)



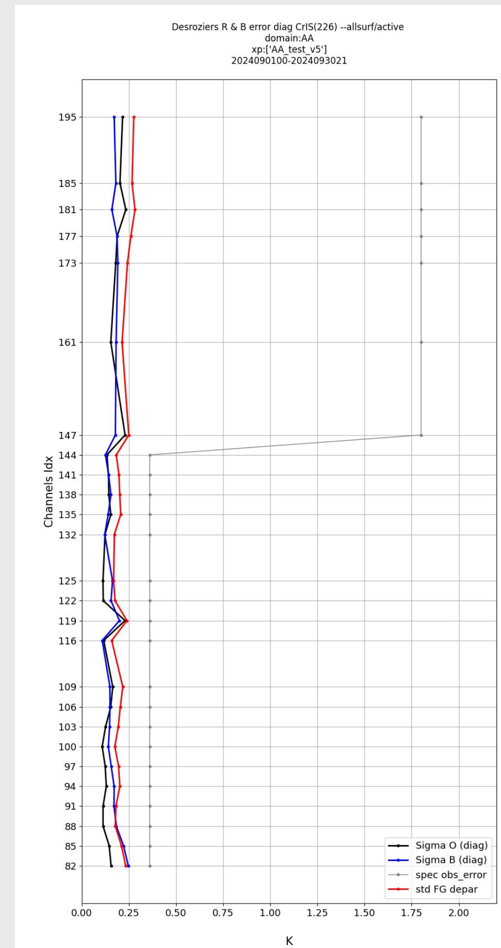
MHS (Metop-B)



MWHS-2 (FY-3E)



CrIS (NOAA-21)



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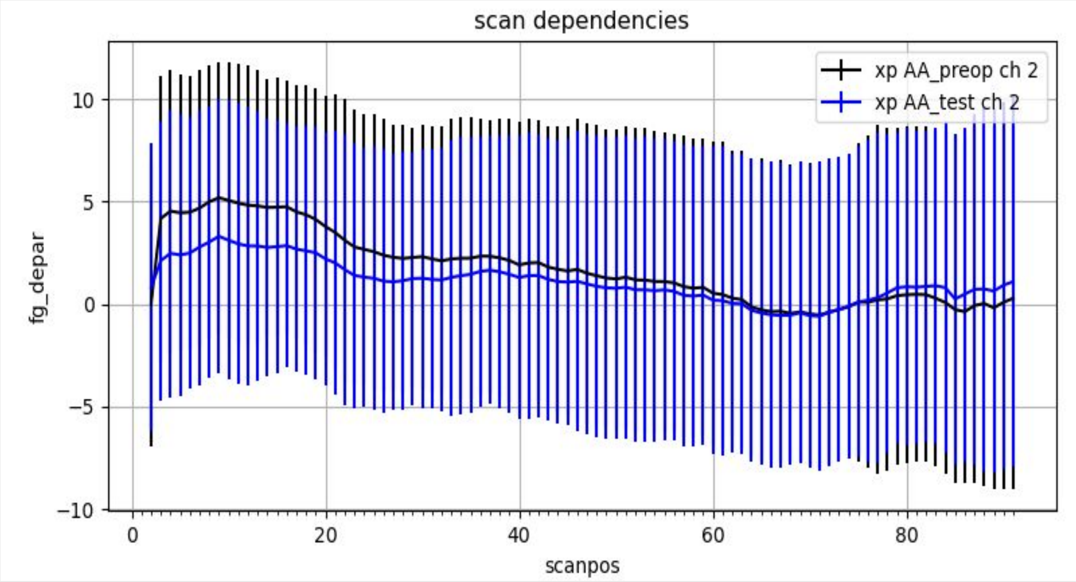
Recent updates of the satellite DA system in AA
Bias corrected emissivity retrievals

MW low peaking channels are assimilated using the dynamic emissivity method (Karbou 2006)
(See Swapan's talk for more details on the dynamic emissivity in HARMONIE-AROME)

=> Activation and fine tuning of VARBC coefficients at window channels & application of bias correction before the emissivity retrievals (in collaboration with F. Baordo)
(See Reima's poster for more details on the 24h-cycled VARBC in HARMONIE-AROME)

Fg departures to MHS observations at channel 2
(with inclusion of new predictors for scan angles bias)



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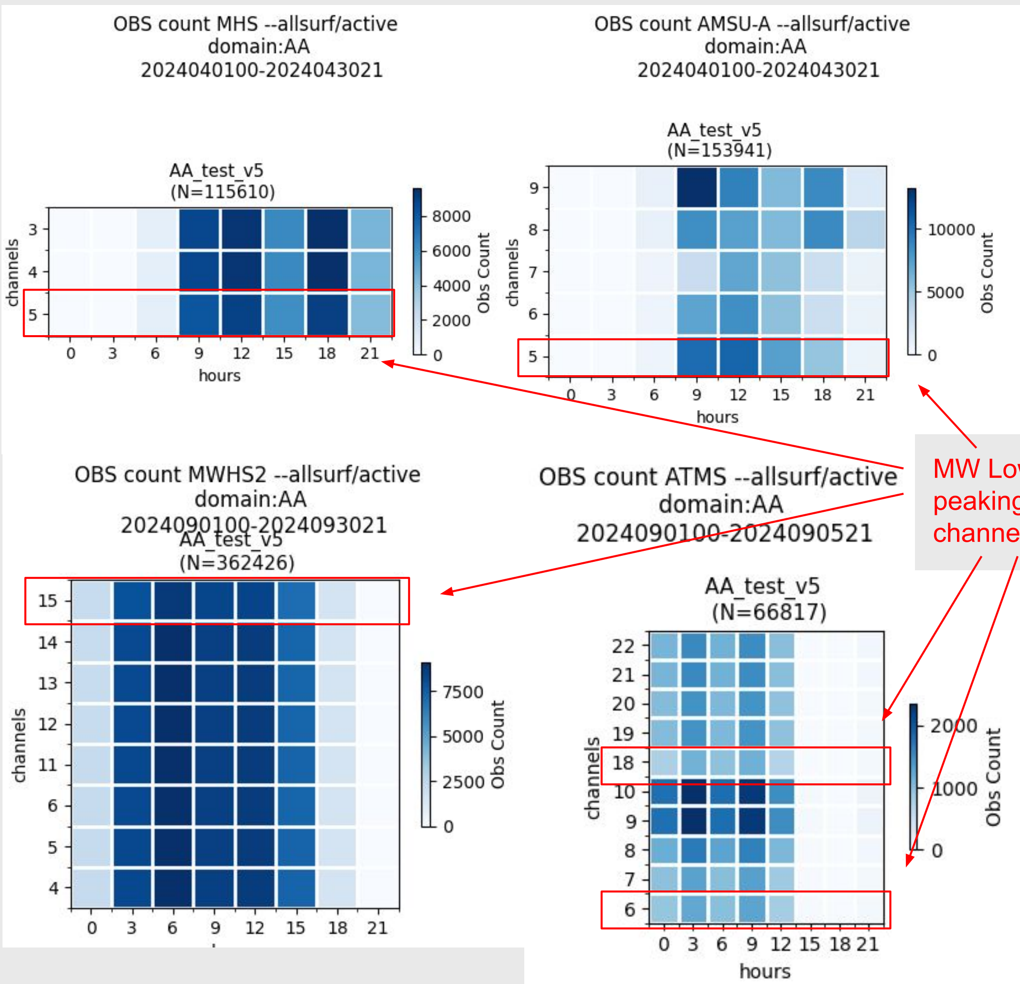
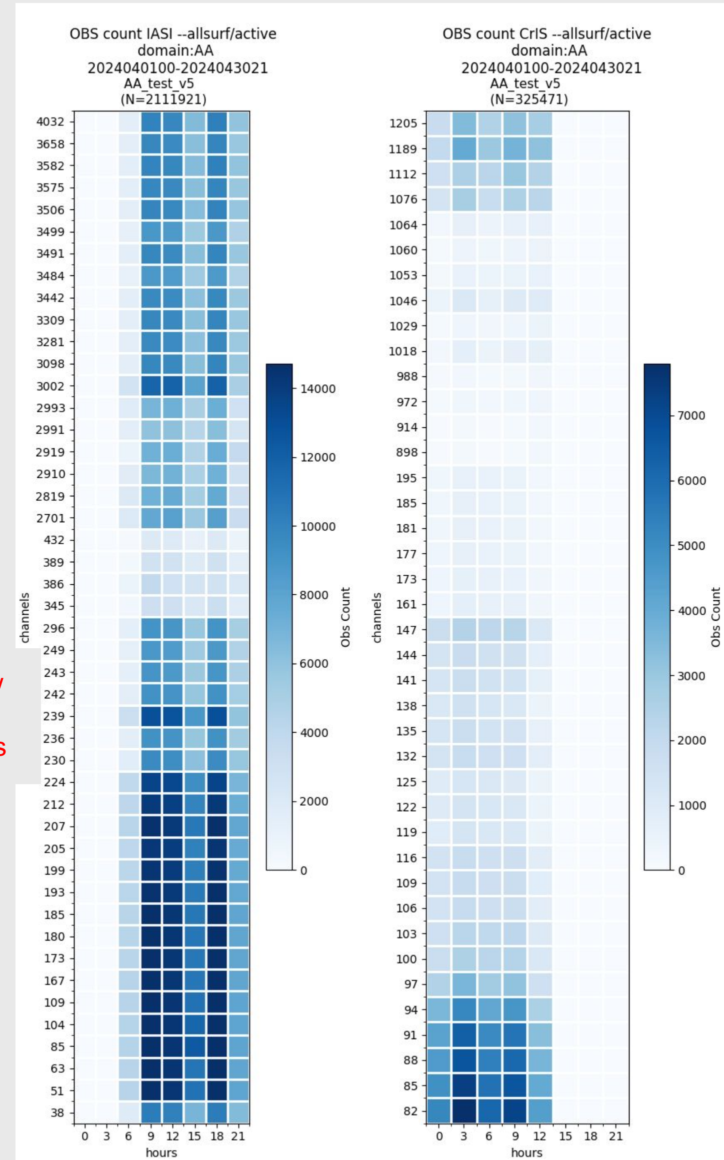
Recent updates of the satellite DA system in AA

2024

Active observations

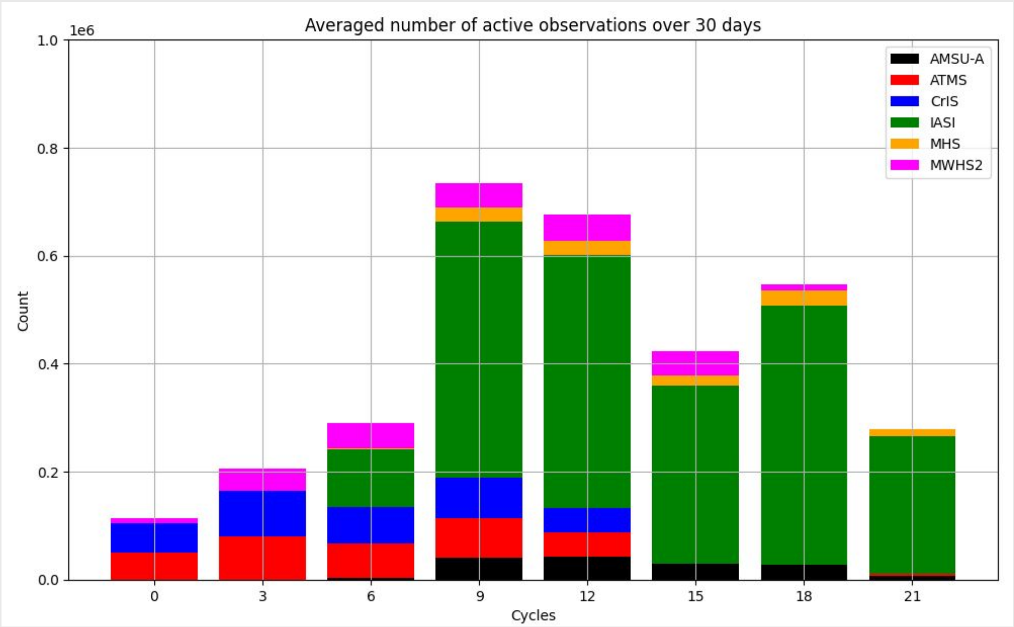
=> AMSU-A, MHS and IASI are covering from 9 to 21 UTC
=> MWHS-2 from 3 to 15 UTC
=> ATMS and CrIS from 0 to 12 UTC



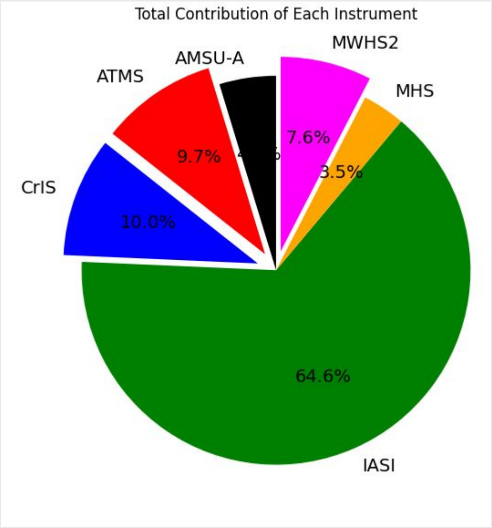


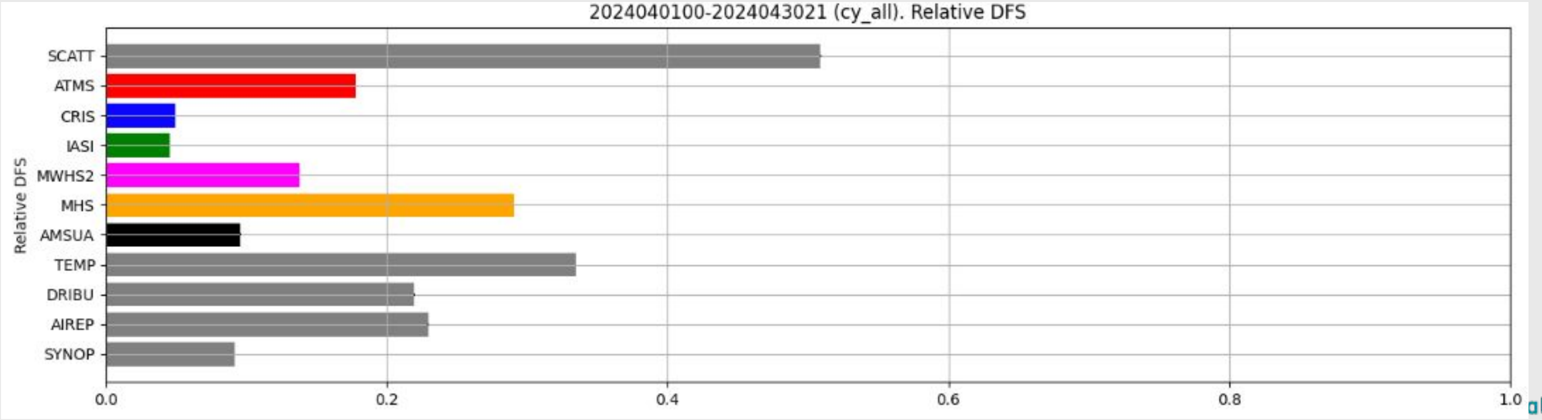
Recent updates of the satellite DA system in AA

Relative DFS



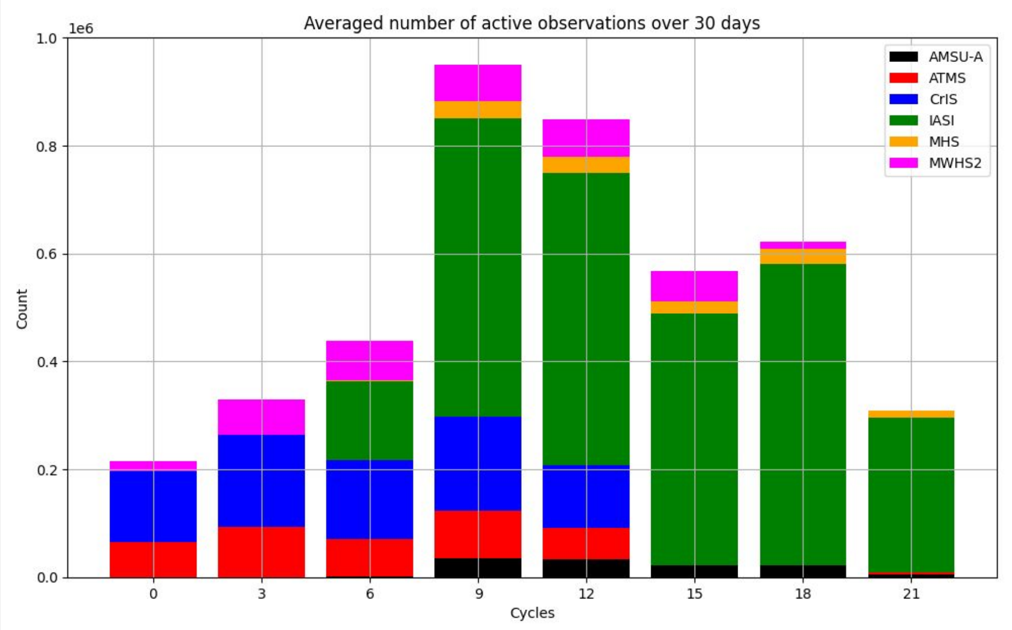
April 2024



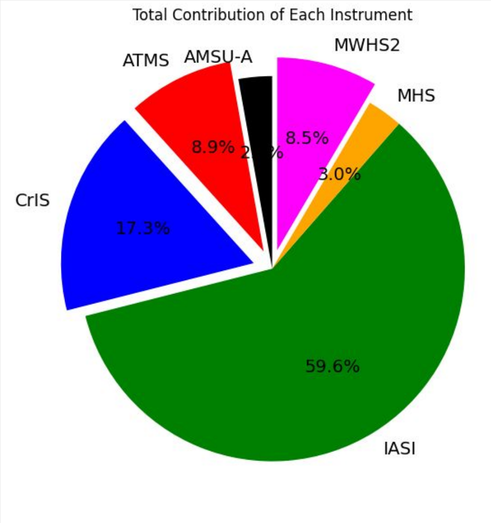


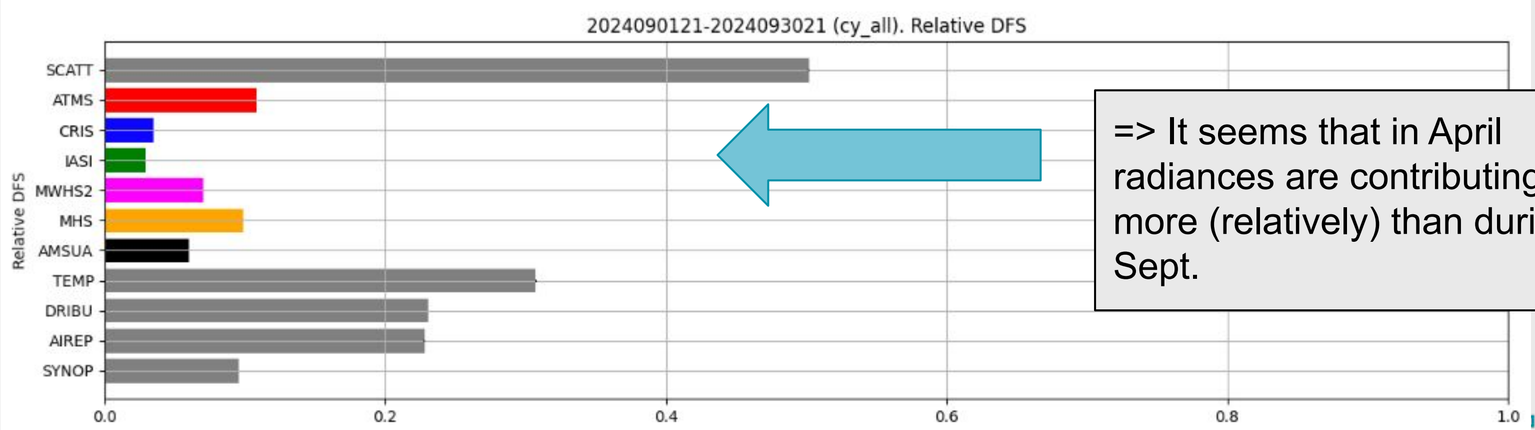
Recent updates of the satellite DA system in AA

Relative DFS



September 2024

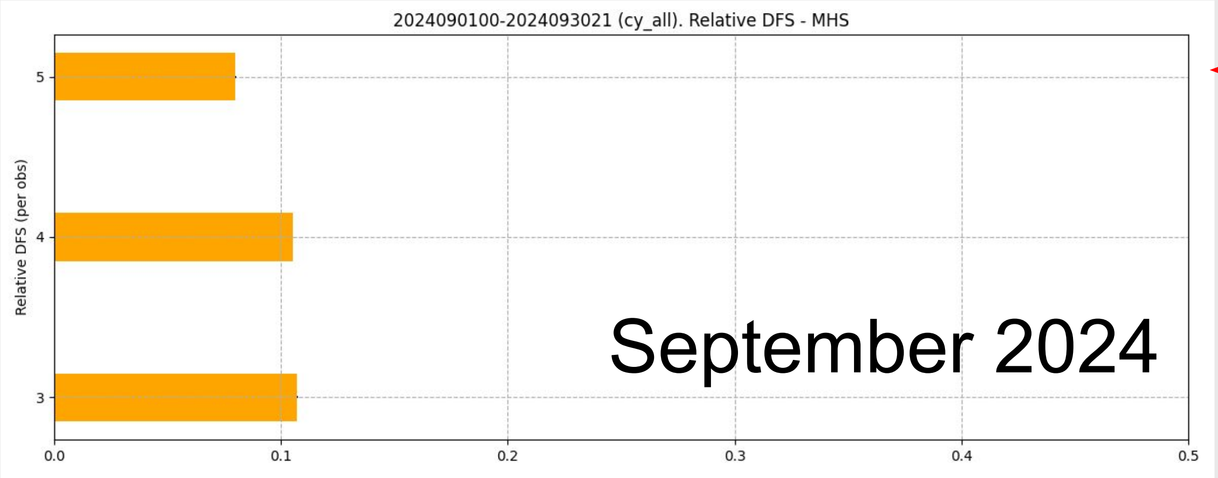




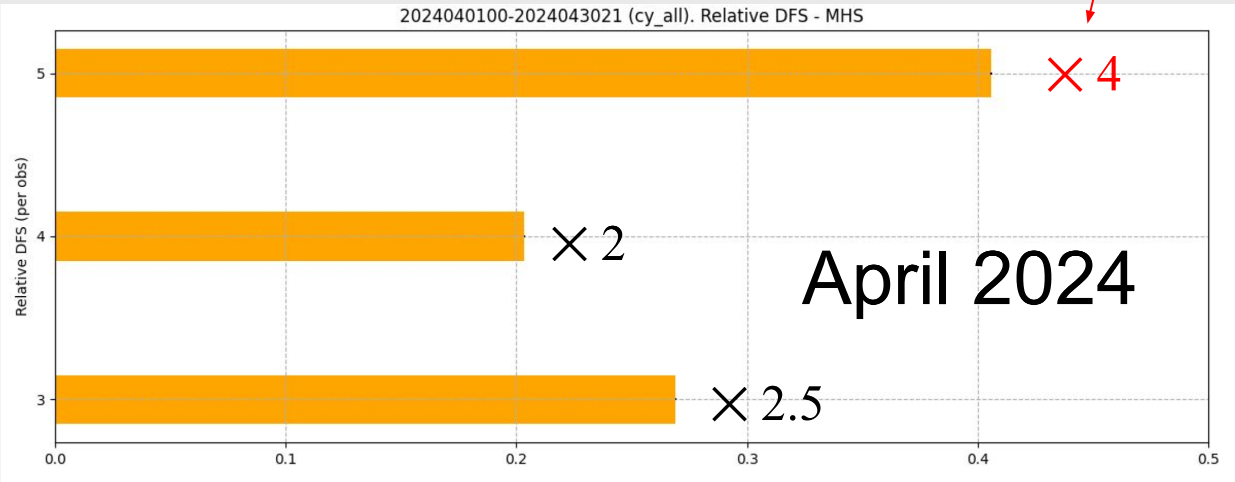
=> It seems that in April radiances are contributing more (relatively) than during Sept.

Recent updates of the satellite DA system in AA
DFS per channel

Relative DFS per MHS observation per channel



Low peaking channels



Larger portion of the domain is covered by sea-ice in April

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OSE data denial

Very few verification data are available in Polar region, especially over sea-ice …

Idea: Data denial to evaluate how the fit to other observations is changing

AA Control experiment (preop - cy46):

Conv + polarAMV + SCATT + AMSU-A + MHS + ATMS + MWHS-2 + IASI + CrIS

Microwave denial xp:

- xp_noLP => Control - All low-peaking channels
- xp_noAMSUA => Control - AMSU-A
- xp_noMHS => Control - MHS
- xp_noATMS => Control - ATMS
- xp_noMWHS-2 => Control - MWHS-2

Infrared denial xp:

- xp_noIASI => Control - IASI
- xp_noCRIS => Control - CrIS

Forecast Verification
Vs conventional obs

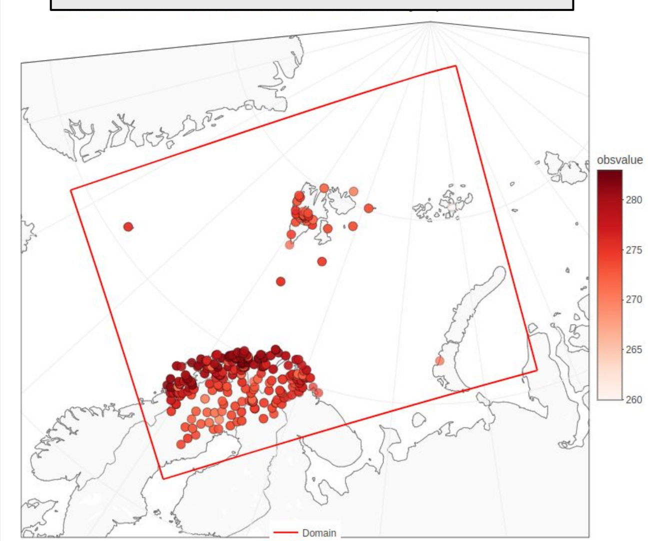
Impact of removing low-peaking channels (September 2024)

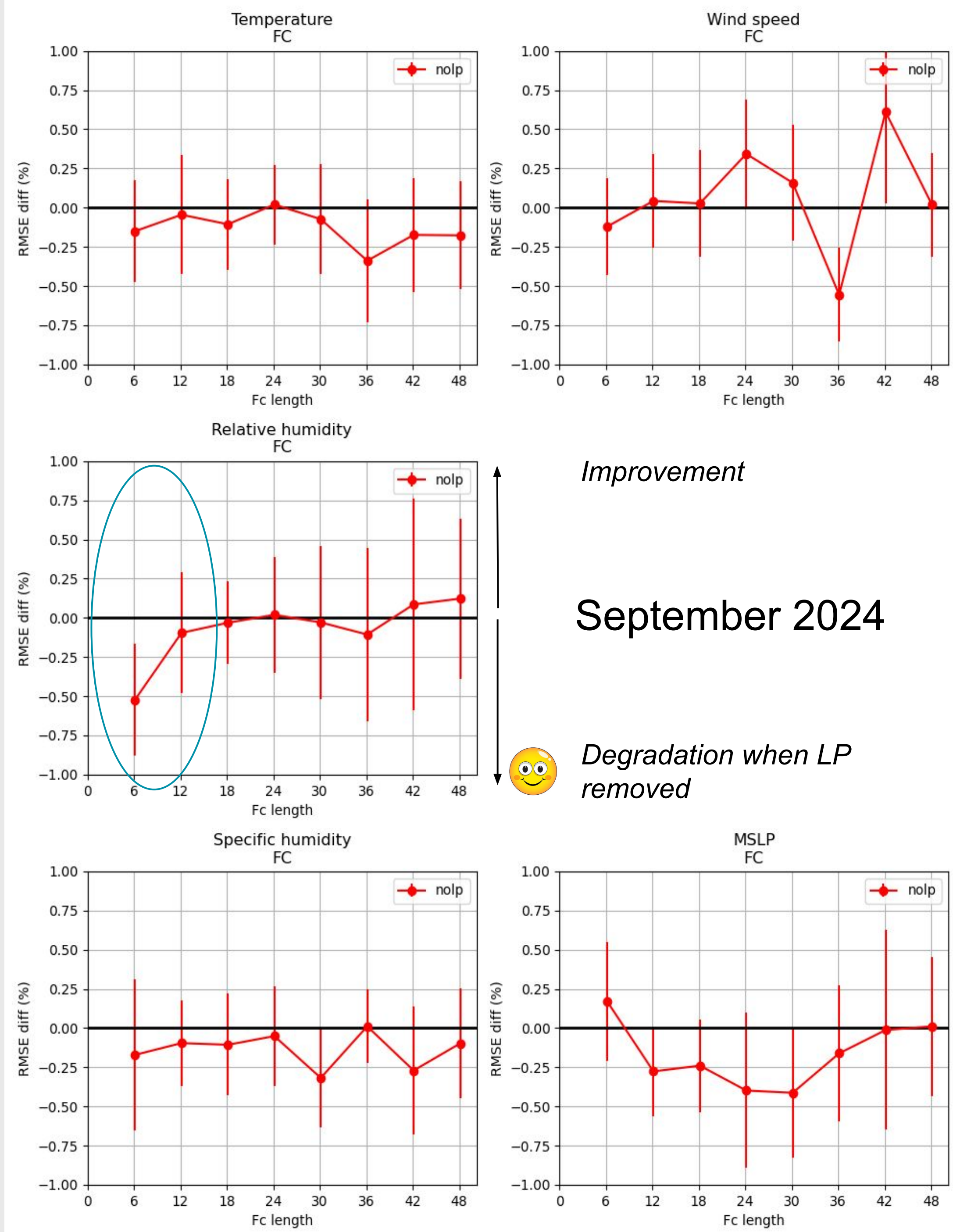
=> Mostly not significant over land …

7 radiosondes available giving mostly insignificant results as well …

What about sea-ice ?

Location of surface observations (for verification)





First-guess fit to observations

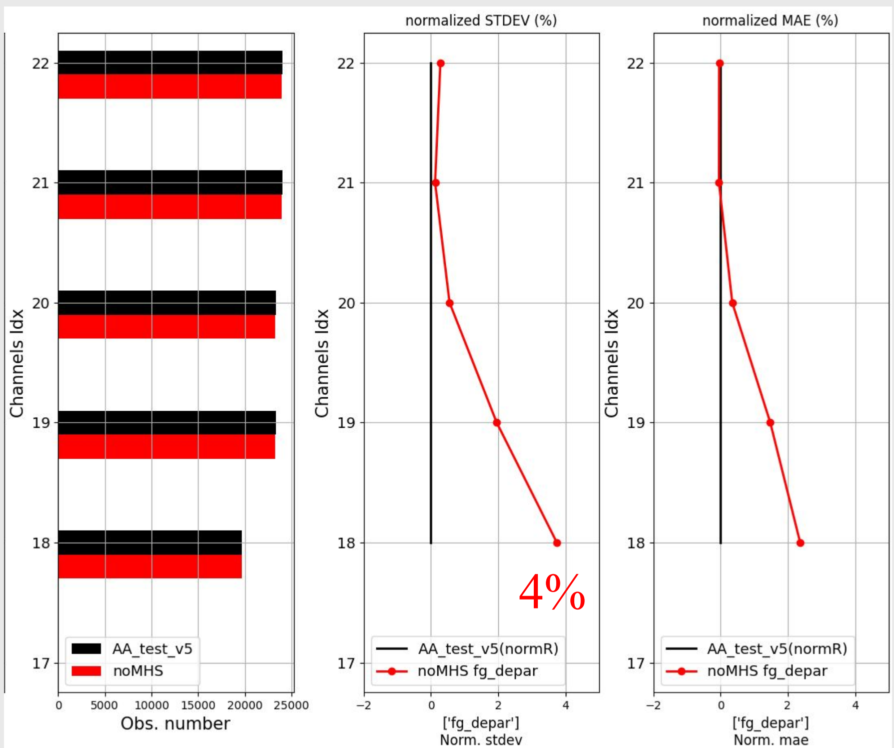
Humidity

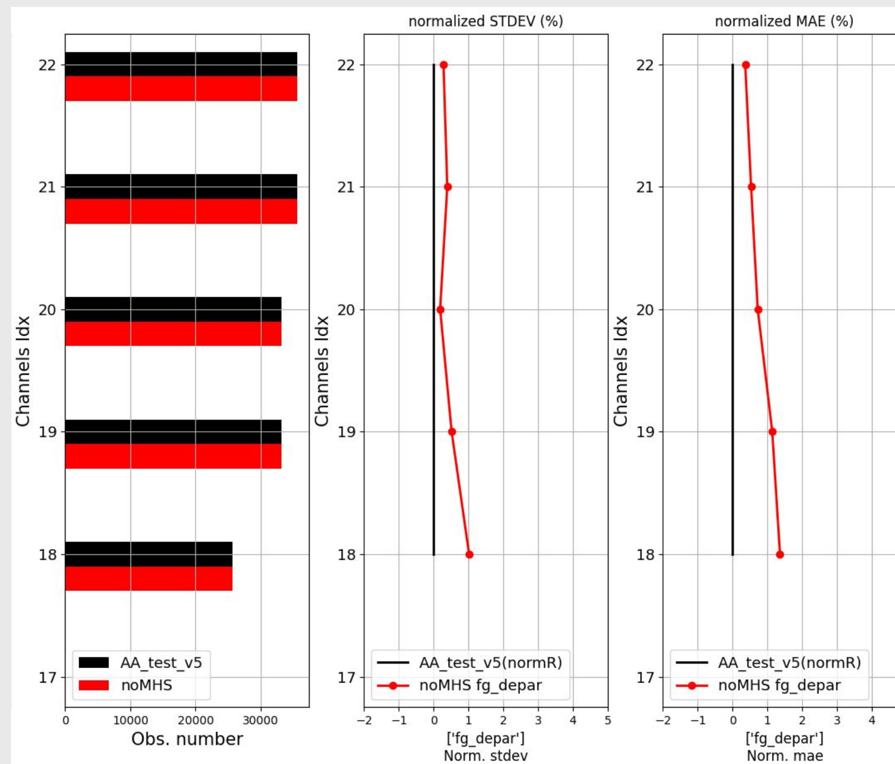
Fit to ATMS observations if MHS is removed: CTL vs xp_noMHS

Degradation when MHS removed

April 2024

September 2024





=> Normalized Fg departures to active ATMS observations increase when MHS is removed

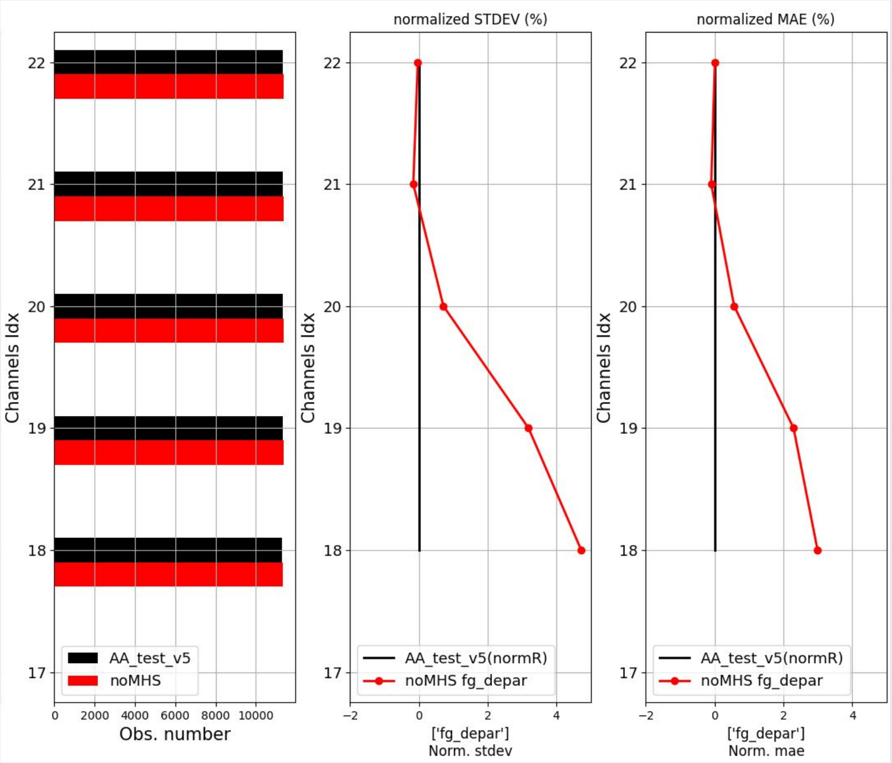
April 2024

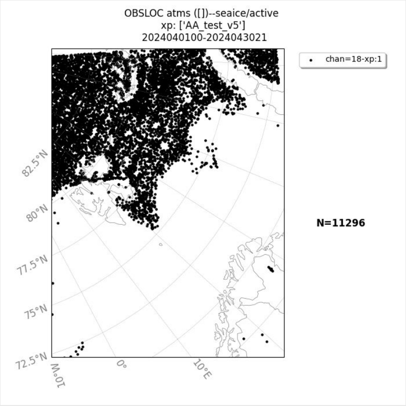
First-guess fit to observations

Humidity

Fit to ATMS observations if MHS is removed: CTL vs xp_noMHS

Sea-ice





Degradation of the fit to ATMS low-peaking channels observations
=> Assimilation of MHS is beneficial

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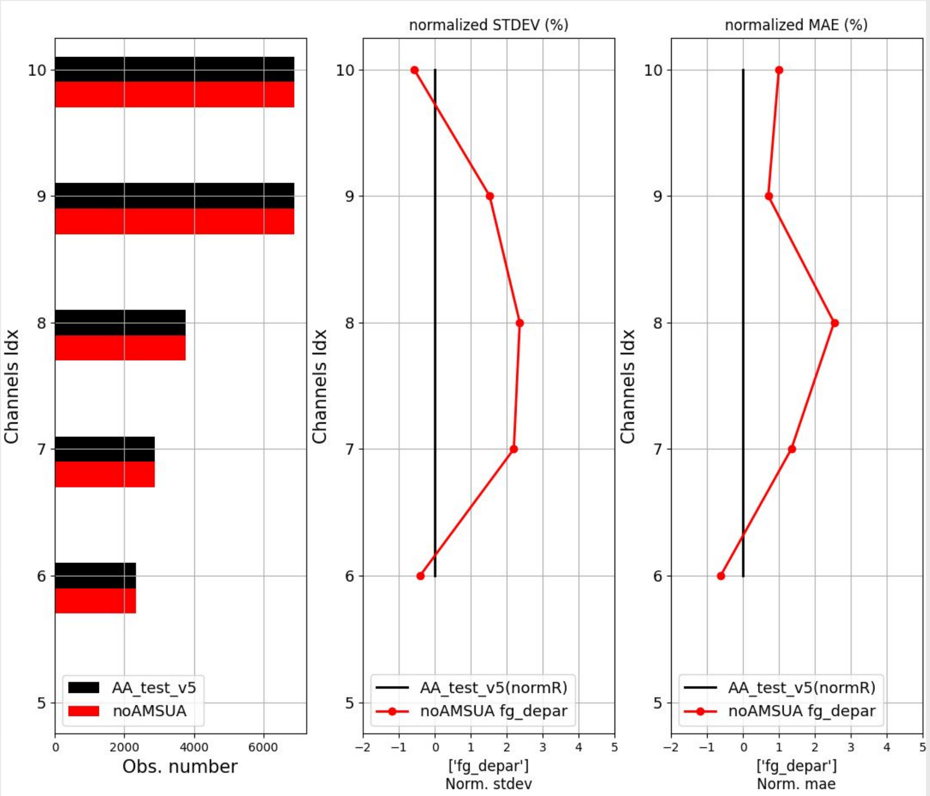
April 2024

First-guess fit to observations

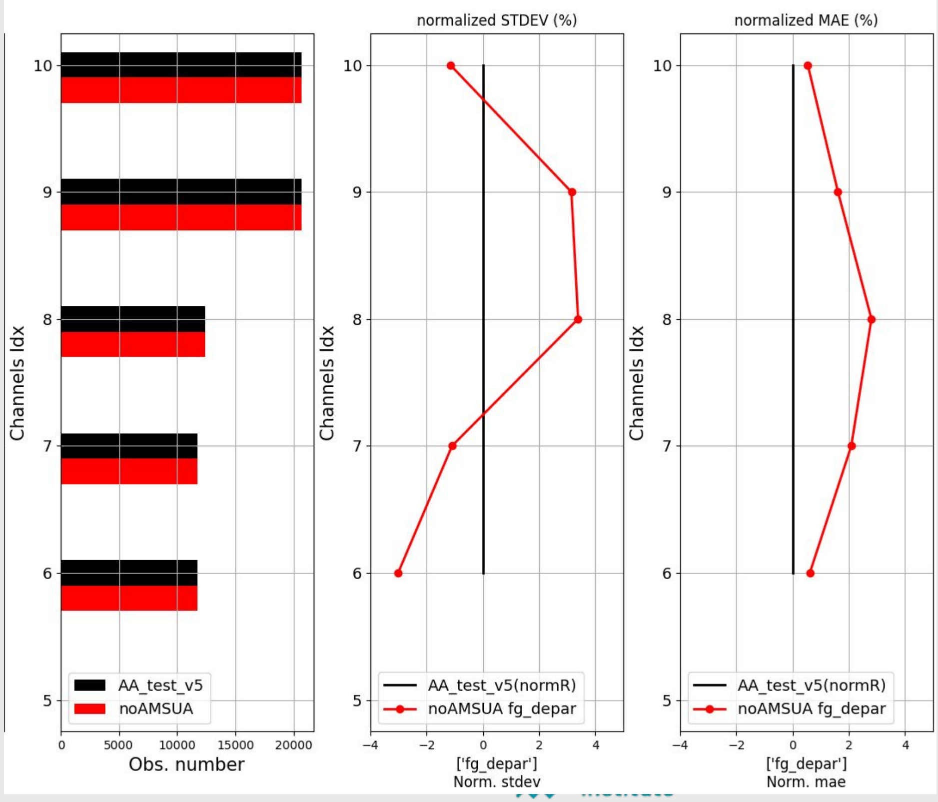
Temperature

Fit to ATMS observations if AMSU-A is removed: CTL vs xp_noAMSUA

Land



Sea-ice



Conclusions

- Several recent updates of the satellite DA system in AROME-Arctic permits to optimize the use of radiances.

  => additional instruments, adjusted bias correction & blocklist …

- It seems that in April, radiances (and particularly the MW low-peaking channels) are contributing more (relatively) than in september.

- Data denial experiments:
  - Low peaking channels have impact on short range forecast
  - Overall degradation of the fit to ATMS when removing humidity channels (ex:MHS).
  - But the opposite was observed close to the surface when removing temperature channels (AMSU-A);

- It remains very difficult to characterize the impact of radiances over Polar regions, partly due to the lack of verification data.

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Plans

- Compute forecast scores in radiances space (ex: 24h forecast fit to observations)
- Diagnose background error in radiance space (BGOS tools presented in Jana’s poster)
- Start the operational assimilation of AWS in AA (Per’s poster on the AWS Cal/Val)
- Extend MW radiance DA in all-sky conditions
- Coupled DA via skin temperature retrievals …

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Thank you

Recent updates of the satellite DA system

	Instrument	WF	FOV	Channel & frequency [Ghz]	Snow-free land	Snow-covered land	Sea-ice	Open ocean	Coast*	Channel emiss retr (LDYN)
	AMSU-A (on NOAA-18, -19, Metop-B,-C)	L L M M H	4-27	5 (53.596±0.115) 6 (54.4) 7 (54.94) 8 (55.5) 9 (57.290344)	yes3,4 yes5 yes yes yes	yes3,4 yes5 yes yes yes	yes1 yes yes yes yes	yes1 yes yes yes yes	no yes yes yes yes	3 (50.3)
T	ATMS (NPP,NOAA-20,-21)	L L M M H	8-89	6 (53.596±0.115) 7 (54.4) 8 (54.94) 9 (55.5) 10 (57.290344)	yes3 yes5 yes yes yes	yes3 yes5 yes yes yes	yes yes yes yes yes	yes yes yes yes yes	no yes yes yes yes	3 (50.3)
	MWHS-2 (FY-3D,3E)	H H M	6-94	4 (118.75±0.3) 5 (118.75±0.8) 6 (118.75±1.1)	yes5 yes5 yes4	yes5 yes5 yes4	yes1 yes1 yes1	yes1 yes1 yes1	yes yes yes	1 (89)
	MHS (Metop-B,-C)	H M L	10-81	3 (183.31 ±1) 4 (183.31 ±3) 5 (190.311)	yes5 yes4 yes2,4	yes5 yes4 yes2,4	yes1 yes1 yes1	yes1 yes1 yes1	no yes yes	1 (89)
Q	ATMS (NPP,NOAA-20,-21)	L L M H H	8-89	18 (183.31 ±7) 19 (183.31 ±4.5) 20 (183.31 ±3) 21 (183.31 ±1.8) 22 (183.31 ±1)	yes2,4 yes4 yes4 yes5 yes5	yes2,4 yes4 yes4 yes5 yes5	yes yes yes yes yes	yes yes yes yes yes	no yes yes yes yes	16 (89.5)
	MWHS-2 (FY-3D,3E)	H H M L L	6-94	11 (183±1) 12 (183±1.8) 13 (183±3) 14 (183±4.5) 15 (183±7)	yes5 yes4 yes4 yes4 yes2,3	yes5 yes4 yes4 yes4 yes2,3	yes1 yes1 Yes1 yes1 yes1	yes1 yes1 Yes1 yes1 yes1	yes yes yes yes no	1 (89)

Optimizing the assimilation of radiances in the operational AROME-Arctic NWP system

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Abstract

The AROME-Arctic forecast system has been running operationally at MET Norway since November 2015. To compensate for the lack of conventional/radiosondes observations in the Arctic, an optimal use of satellite observations from polar-orbiting satellite instruments is crucial.
Currently, the operational suite is assimilating level 1 radiances from AMSU-A, MHS, IASI, ATMS and MWHS-2. Radiances from CrIS are presently monitored and some preparatory work is ongoing for the assimilation of Arctic Weather Satellite.

This work aims at optimizing the use and documenting the impact of radiances in these complex polar regions, focusing on low-peaking channels. To carefully tune the system, the Desroziers diagnostic has been used to estimate the optimal observation errors and their correlations for each instrument. Then, extensive Observing System Experiments (OSE) have been run in which each instrument separately has been denied from the 3D-Var data assimilation system over both winter and summer periods. Objective forecast scores against conventional and radiances (AllObs) together with diagnostics such as Degree For Signal (DFS) and Moist Total Energy Norm (MTEN) are used to tune once again the system and document the impact of each instrument over the AROME Arctic domain. A case study of an extreme event will be presented.

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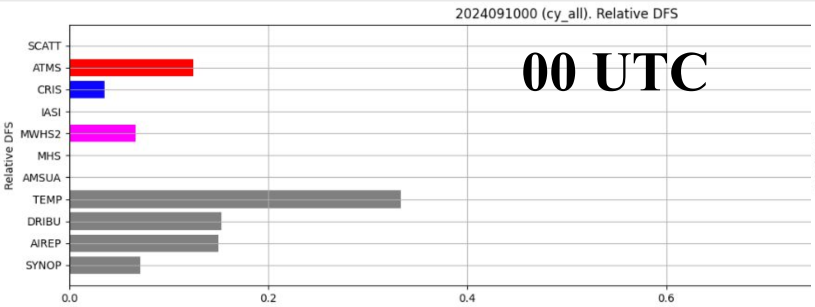
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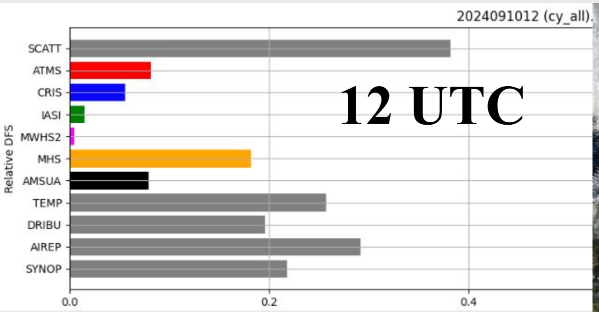
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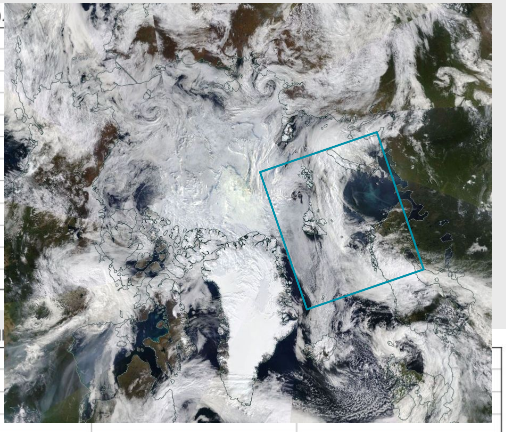

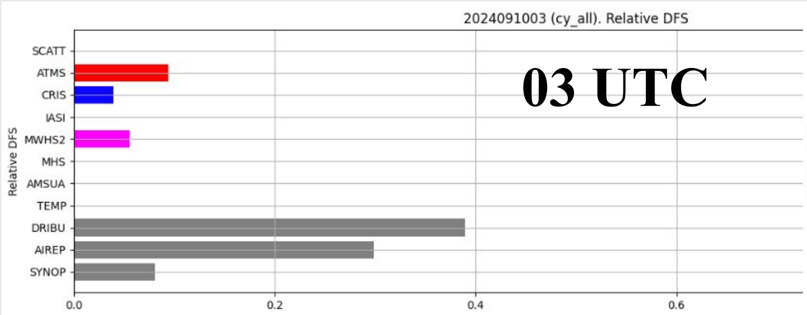
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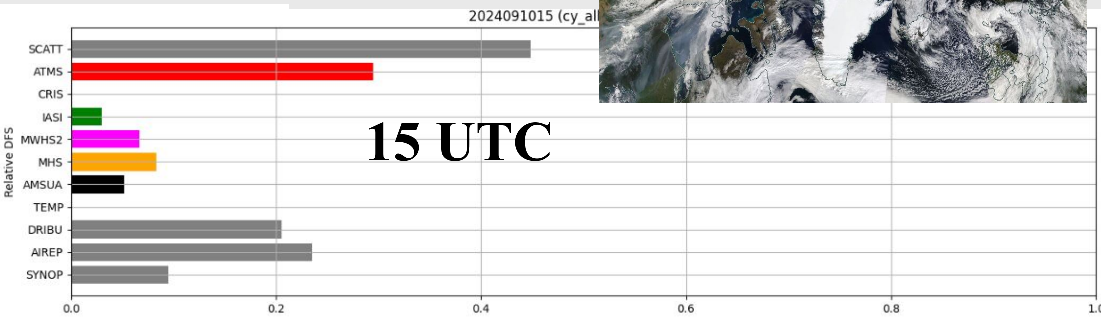
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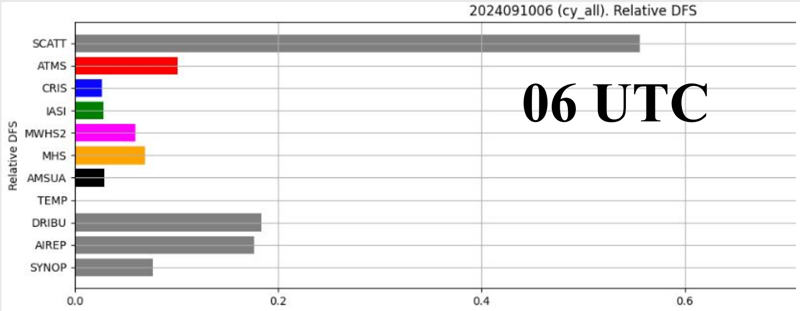
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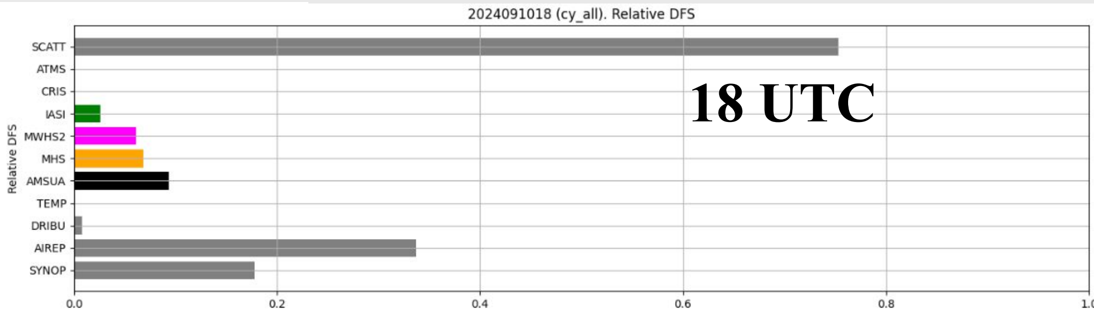
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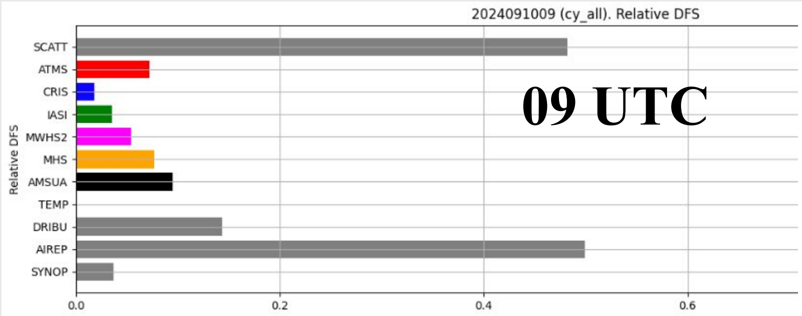
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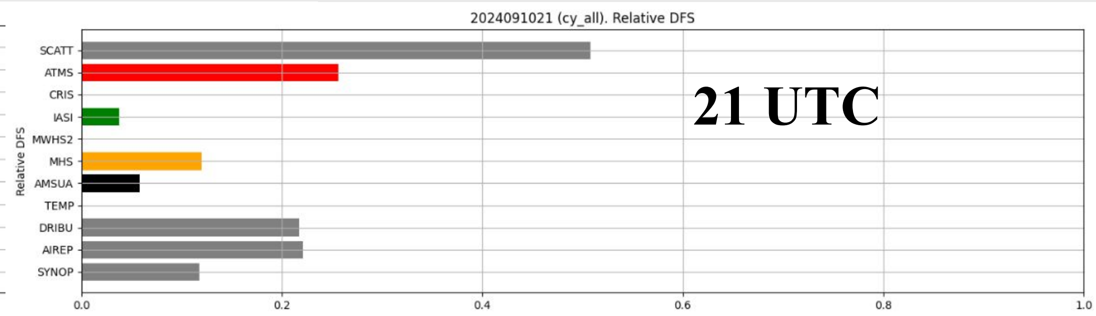
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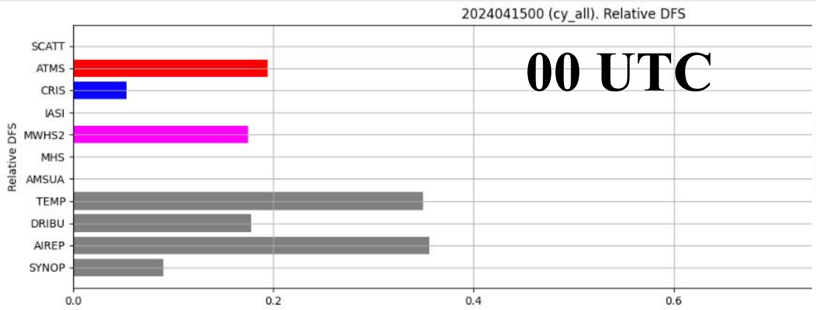
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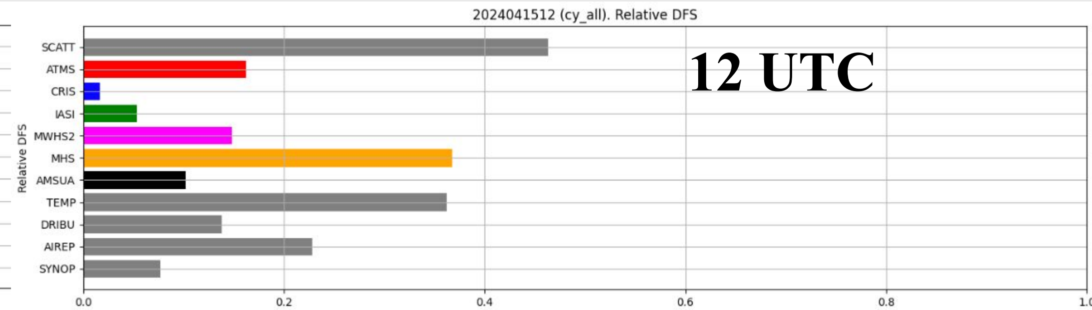
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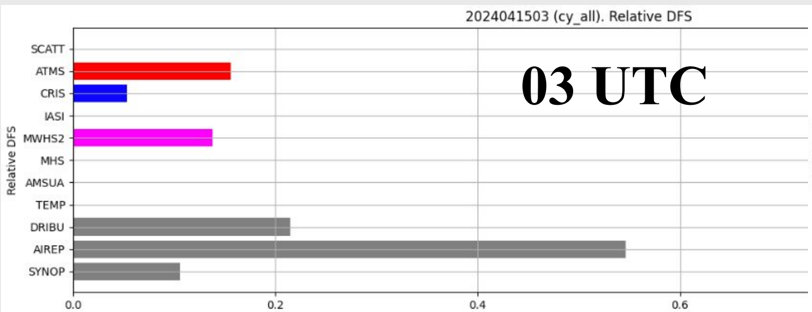
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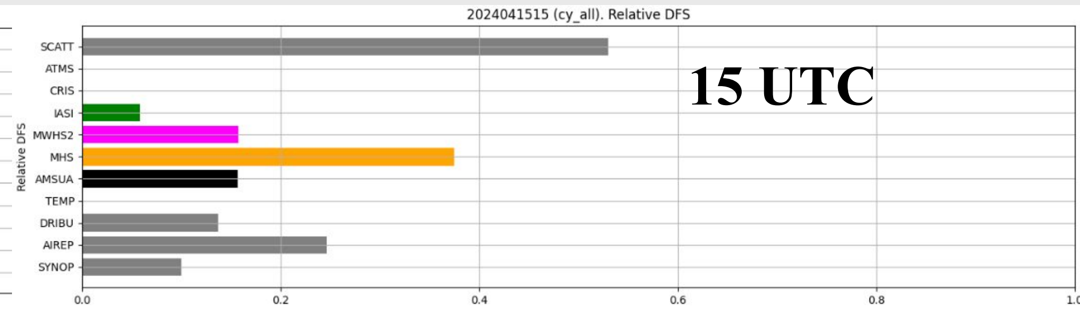
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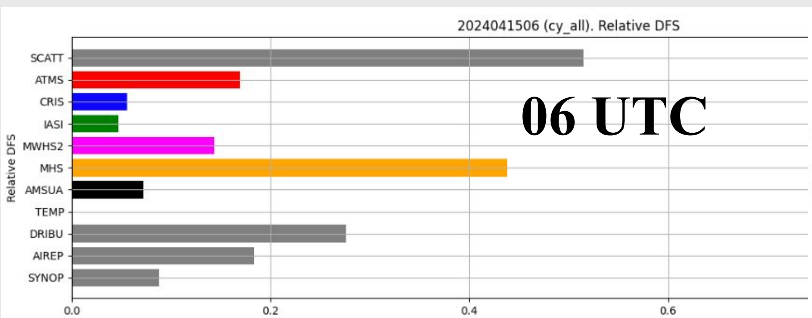
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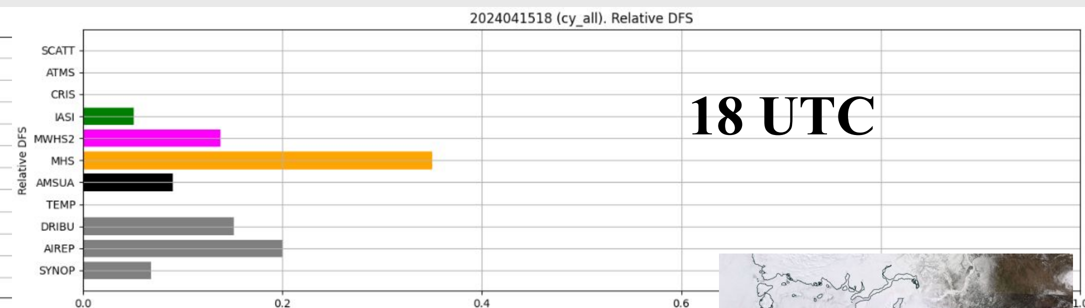
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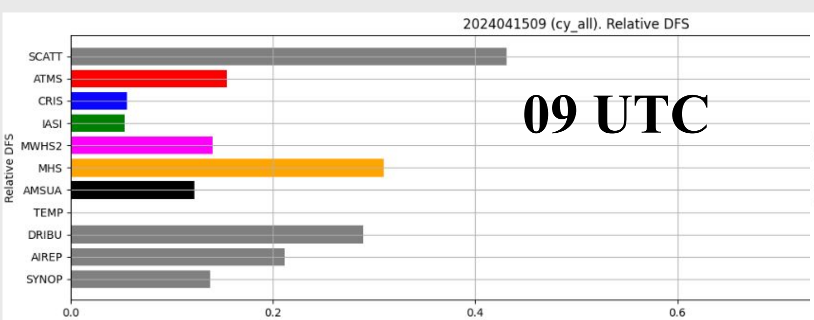
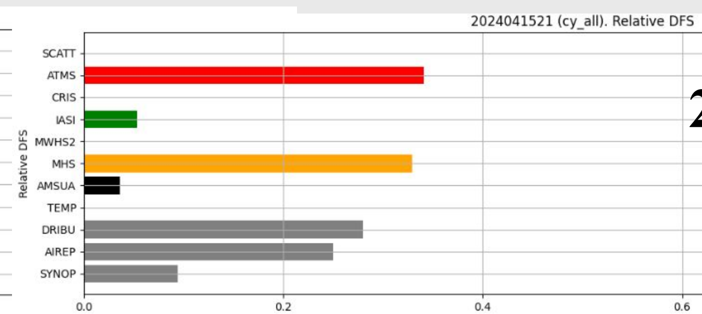
Relative DFS
SCATT
ATMS
CRIS
IASI
MWHS2
MHS
AMSUA
TEMP
DRIBU
AIREP
SYNOP
0.0
0.2
0.4
0.6


2024041509 (cy_all). Relative DFS
09 UTC
Relative DFS
SCATT
ATMS
CRIS
IASI
MWHS2
MHS
AMSUA
TEMP
DRIBU
AIREP
SYNOP
0.0
0.2
0.4
0.6


2024041521 (cy_all). Relative DFS
2
Relative DFS
SCATT
ATMS
CRIS
IASI
MWHS2
MHS
AMSUA
TEMP
DRIBU
AIREP
SYNOP
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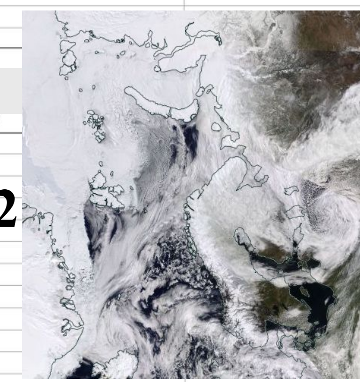
0.2
0.4
0.6
0.8
1.0



Institute

Recent updates of the satellite DA system in AA Preop

Monitoring

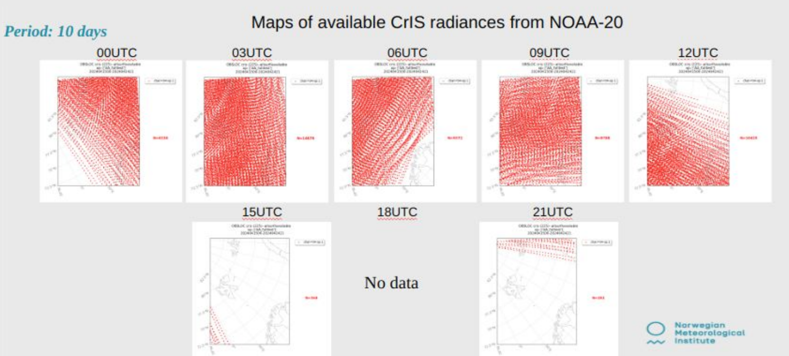
CrIS channel 94

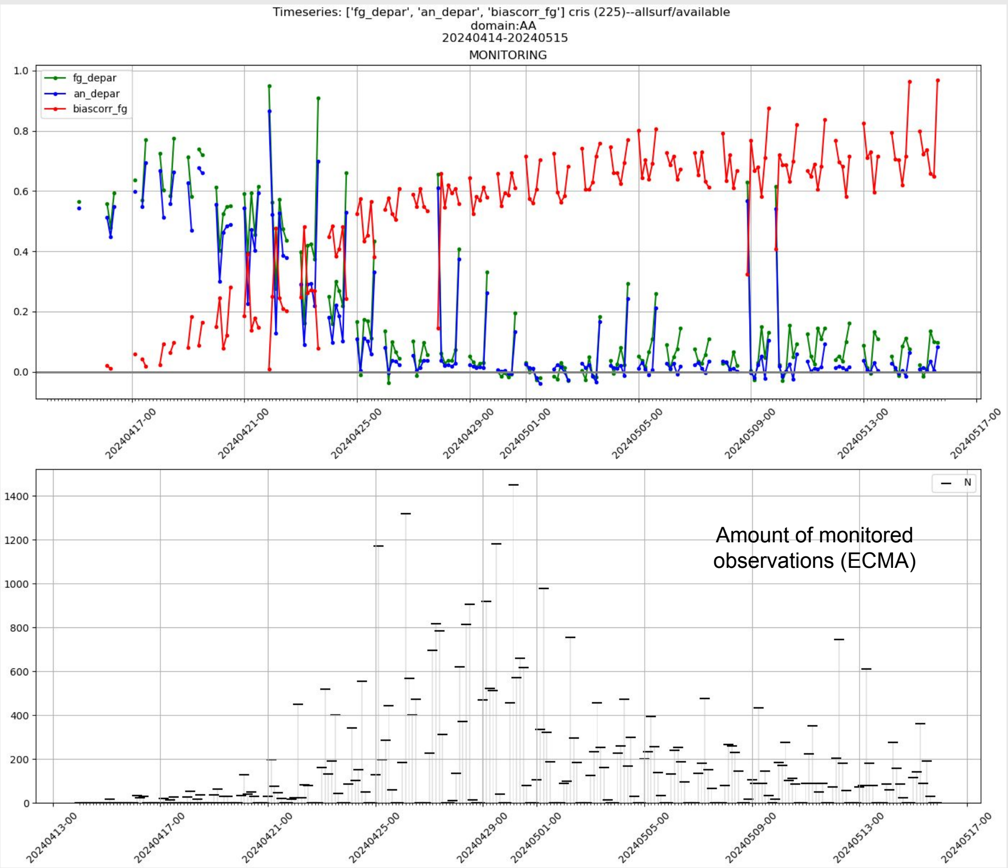
Variational Bias Correction (VARBC)

=> warm-up coefficients in monitoring mode takes around **15 days for MW** sounders and about **20 days for IR** hyperspectral sounders

Peaks in time series are due to a poor coverage of the domain …

=> VARBC is failing => Blocklisting





Norwegian Meteorological Institute