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European Space Agency Project -Performance Evaluation of Arctic Weather Satellite Data

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Preparations of HARMONIE-AROME for the Arctic Weather Satellite

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Magnus Lindskog, Mats Dahlbom, Per Dahlgren, Stephanie Guedj, Máté Mile, David Schönach and other ESA-AWS project colleagues

The Team

Magnus Lindskog, Máté Mile, Mats Dahlbom, Patrick Eriksson, Stephanie Guedj, Per Dahlgren, David Schönach, Susanna Hagelin, Rasmus Tonboe, Roohollah Azad, Vasileios Barlakas, Hanna Hallborn, Ewan O'Connor, Bjarne Amstrup, Reima Eresmaa, Annakaisa von Lerber, Jani Tyynelä, Bengt, Rydberg, Adam Dybbroe

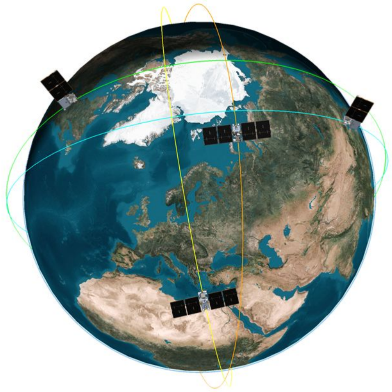
Outline

- The Arctic Weather Satellite (AWS)
- Preparation of HARMONIE-AROME for use of AWS data
- General enhancements made regarding use of MW radiances
- Conclusions

EPS-Sterna

- 6 satellites in 3 different orbital planes
- Complementing the Metop & JPSS
- Giving high temporal coverage - down to ~30 minute over the Arctic

EUMETSAT



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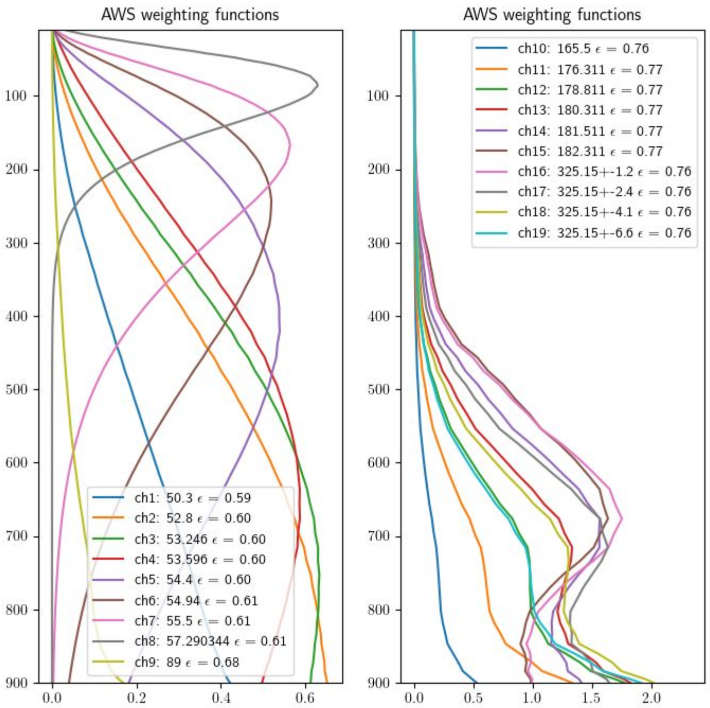
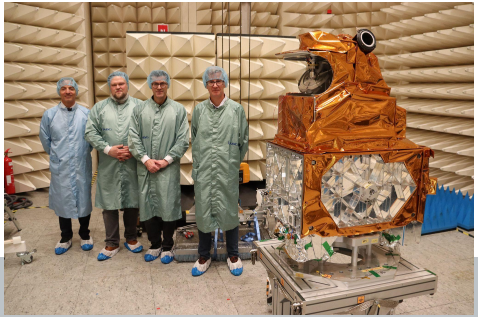
The AWS instrument

- Passive Microwave Radiometer
- Cross-track scanner (~2000 km swath)
- Strong heritage to MHS/AMSU-A and ATMS (and MWS)
- 19 channels for temperature and humidity sounding + clouds
- 4 new sub-mm bands around 325 GHz for humidity sounding and clouds

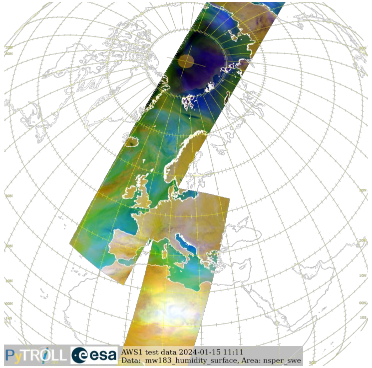


AWS satellite during cleanroom tests this year. Planned to be launched in July, 2024.



Preparations for handling of AWS radiances

- We have developed a Bator NetCDF interface that reads a sample file with synthetic AWS radiances and writes these observations into Observational Data Base (there is also an ASCII interface to Bator available).
- RTTOV coefficient file obtained from NWP-SAF (rtcoef_aws_1_aws.dat).
- AWS definitions included in arrays inside the code so that these data are recognized by the system
- AWS will then follow the same path through the source code as other MW data (AMSU-A/MHS/ATMS/MWHS2) and will be subject to:
    - First guess check
    - Spatial thinning
    - Blacklisting (set e.g. which channels to assimilate)
    - VARBC (Dee, 2005)
    - Cloud and rain check (mw_clearsky_screen_mfdecis.F90)



Use of 325 GHz radiances for cloud and rain check

A cloud and rain check needed for clear-sky assimilation of AWS radiances

- There will be separate cloud filterings for AWS 50 GHz and 183 GHz channels, following the present treatment of e.g. ATMS. As a first step, AWS undergoes a simple first guess departure check for window channels at 52.4GHz and 165.5GHz. Similar is done for AMSU-A and MHS.
- As a next novel step we will use the 325 GHz data will be applied for cloud filtering of AWS channels 32 to 36 (176.311 to 182.311 GHz) . The basic idea is that 183 and 325 GHz channel antenna temperatures follow each other relatively closely for clear-sky, and deviations from this pattern is a direct indication on an impact of clouds. A presence of clouds gives a considerably higher impact at 325 GHz than at 183 GHz (Eriksson et al. (2020) and Kaur et al. (2021)).

Handling of surface-sensitive low-peaking channels

$$
\left.\begin{aligned}
T_b(\theta) &= T_s\varepsilon(\theta)\Gamma + (1-\varepsilon(\theta))\,\Gamma T_a^{\downarrow}(\theta) + T_a^{\uparrow}(\theta) \\
\Gamma &= \exp\left(\frac{-\tau(0,H)}{\cos(\theta)}\right)
\end{aligned}\right\} \qquad (1)
$$

$$
\varepsilon(\nu,\theta) = \frac{T_b(\nu,\theta) - T_a^{\uparrow}(\nu,\theta) - T_a^{\downarrow}(\nu,\theta)\,\Gamma}{\left(T_s - T_a^{\downarrow}(\nu,\theta)\right)\Gamma} \qquad (2)
$$

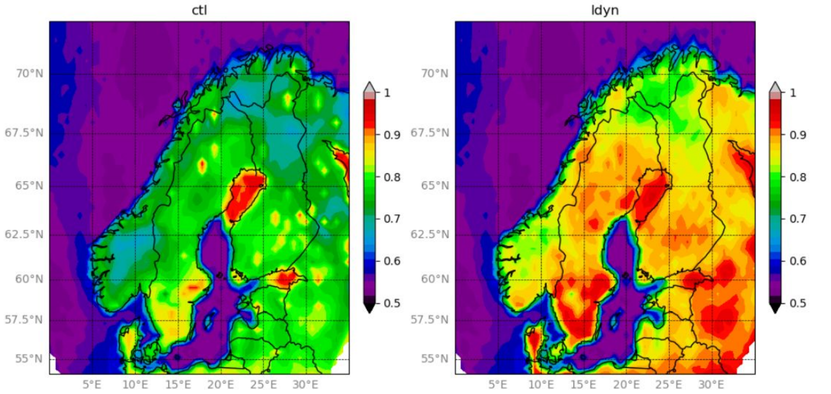


Table 2. Enhanced usage of low peaking channels from heritage channels and associated window channels.

Instrument	Channel numbers of the new channels assimilated	Central Frequencies of new channels assimilated (GHz)	Frequency of Window channel (GHz)
AMSU-A	5	53.596 ± 0.115	52.8
ATMS	6,18	53.596 ± 0.115,183.31 ± 7.0	52,8; 88.2
MHS	5 over land	190.311	89
MWHS-2	11 over land	183.31 ± 7.0	89

Instantaneous land surface emissivity maps for AMSU-A Channel 5 (53.6 GHz), as derived from channel 3 (50.3 GHz) and for 20210215 09 UTC. This is the way dynamical emissivity approach is used in nordic operational systems and is illustrated here for the MetCoOp domain.

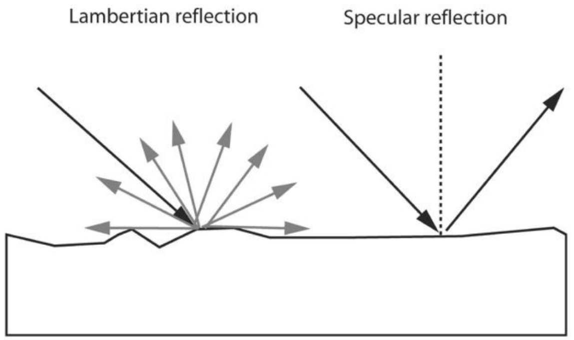
Handling of surface-sensitive low-peaking channels

Special handling over sea-ice and snow

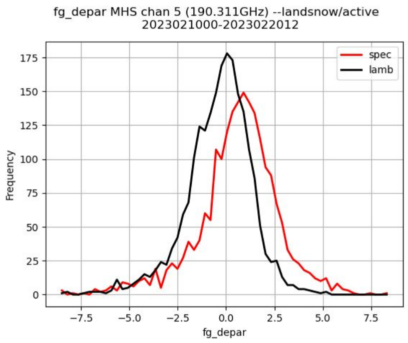
For MHS, the emissivity is retrieved at channel 1 (89 GHz) and propagated at channel 2 (157 GHz) using a **linear regression method** as follow:

$$\varepsilon(157,\theta)_e xtr = \varepsilon(89,\theta) - \frac{T_b(157,\theta) - T_b(89,\theta)}{T_s} \quad (3)$$

Activation of **Lambertian** reflection instead of specular:



Surface scattering: Lambertian (or diffuse) and specular (from Fig.2 in Guedj et al. (2010)).

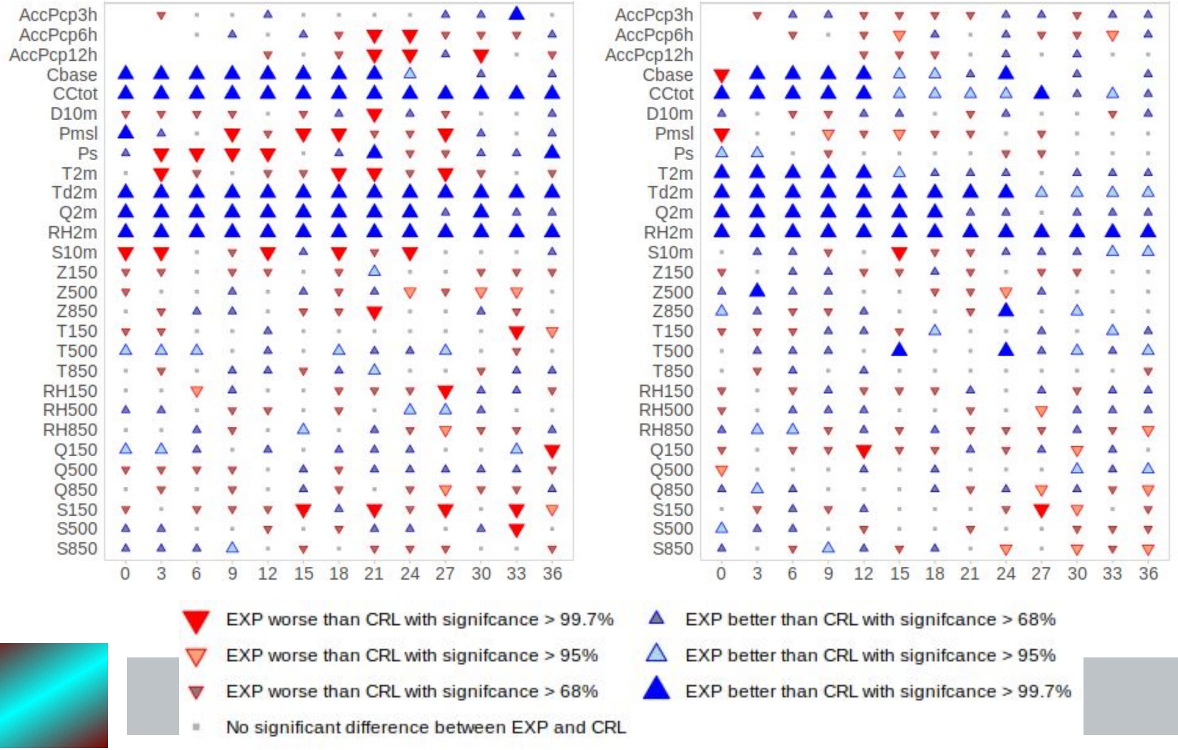


Histograms of first guess departures (observation minus model equivalent) of MHS channel 5 close to nadir brightness temperatures and over land–covered snow. For a 10 day winter period and with specular (red) and Lambertian (black) emissivity assumption.

Handling of surface-sensitive low-peaking channels

CRL: reference experiment using conventional and various types of satellite-based observations.

EXP: Like in CRL and in addition the surface sensitive channel 5 the surface sensitive channel 5 on AMSU-A and channel 5 on MHS are used over land and sea-ice with a dynamic emissivities approach.



Forecast impact experiments using dynamical emissivity method over MetCoOp domain

One month winter period February, 2021.

Scorecards for EXP-CRL RMSE forecast differences and for various parameters and forecasts lengths for 3D-Var (left) and 4D-Var (right) framework.

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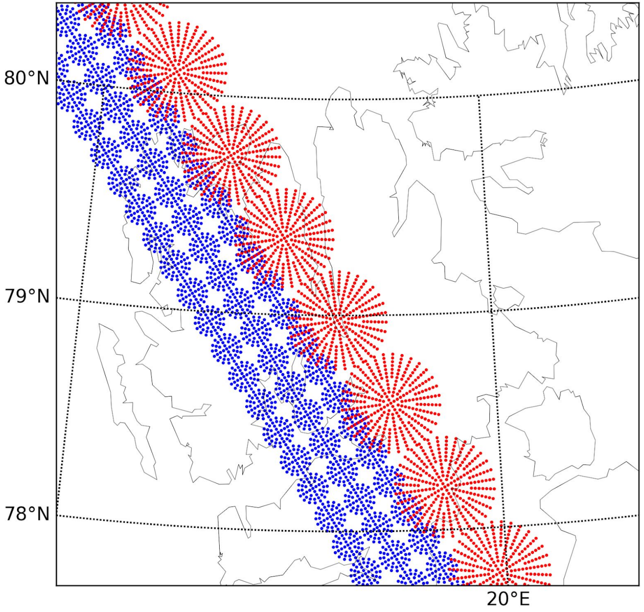
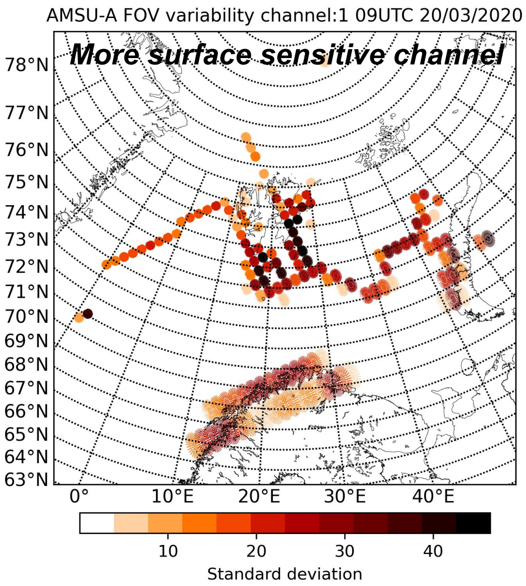
A footprint operator allows fort handling of observation and model scale differences

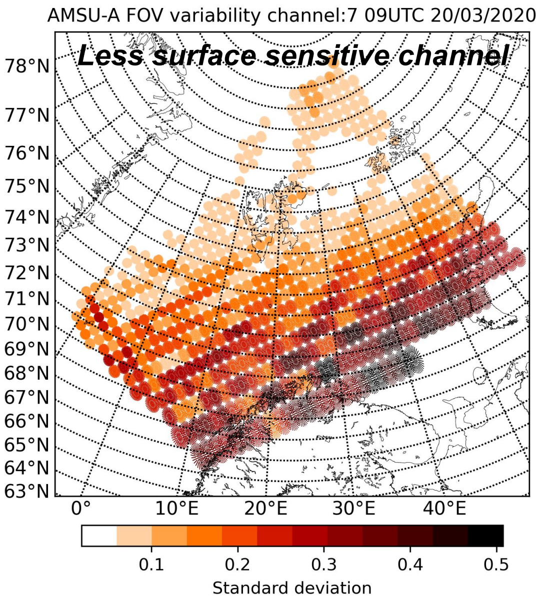


AMSU-A (red) and MHS footprints (blue) for one particular satellite passage.

Handling of observation and model scale differences by using a footprint operator

The in-footprint variability of brightness temperatures is larger for surface sensitive channels and in areas of heterogeneous surfaces.





In the situations of high variability we can expect more impact from the footprint operator.

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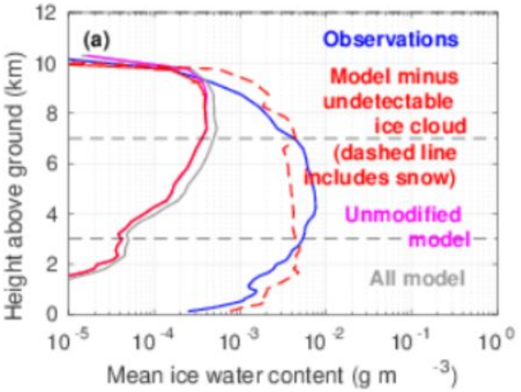
Towards use of satellite MW radiances from all-sky conditions

6 months of HARMONIE-AROME +3h ice water content forecasts has been evaluated against Cloudnet cloud profiling instruments

Ground-based cloud remote sensing instruments, clockwise from top left: cloud radar, ceilometer, multi-channel microwave radiometer. b) Locations: Lindenberg, Germany; Norunda, Sweden; Hyytiälä, Finland.



Evaluation of mean ice water content of +3h forecasts against cloud profiling data from Norunda; Observation (blue), full model equivalents (grey), model equivalents without (solid red) and with graupel included (dashed red).

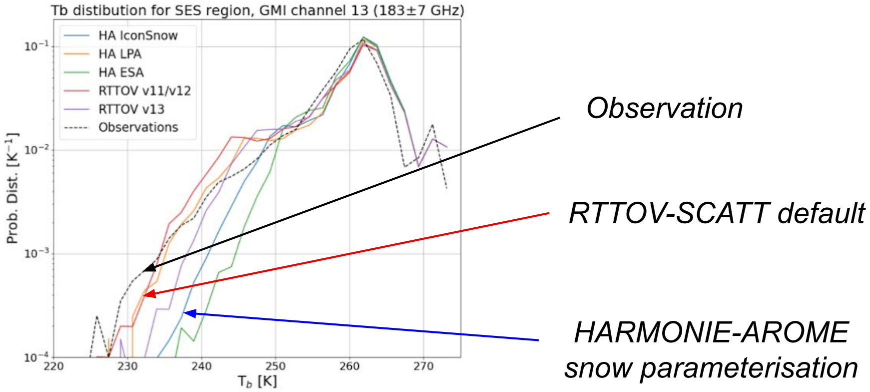
Graupel added to total ice water content in HARMONIE-AROME RTTOV-SCATT interface.

RTTOV-SCATT optional configurations compared

Snow Particle Size Distributions and Snow Particle Habits

Snow Model	Particle Size Distribution	Particle Habit
HA IconSnow	Modified Gamma Distribution (MGD)	Icon Snow
HA LPA	Modified Gamma Distribution (MGD)	Large Plate Aggregate (LPA)
HA ESA	Modified Gamma Distribution (MGD)	Evans Snow Aggregate (ESA)
RTTOV v11/v12	Field et al., 2007	Liu Sector Snowflake (LSS)
RTTOV v13	Field et al., 2007	Large Plate Aggregate (LPA)

Example of snow Particle Habits



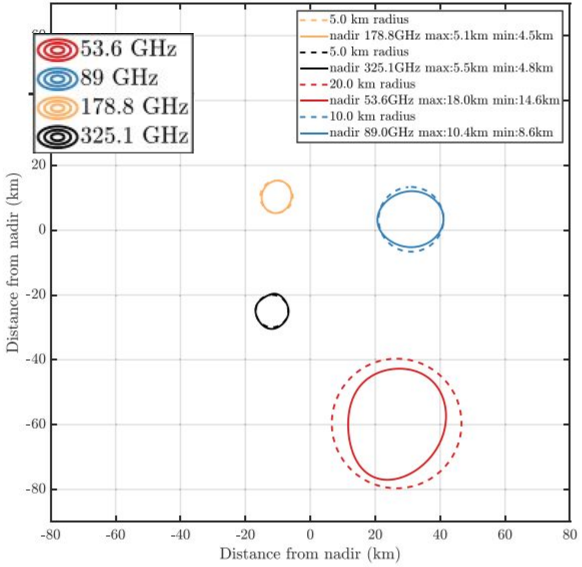
Brightness temperature (Tb) distributions for for GMI channel 13.

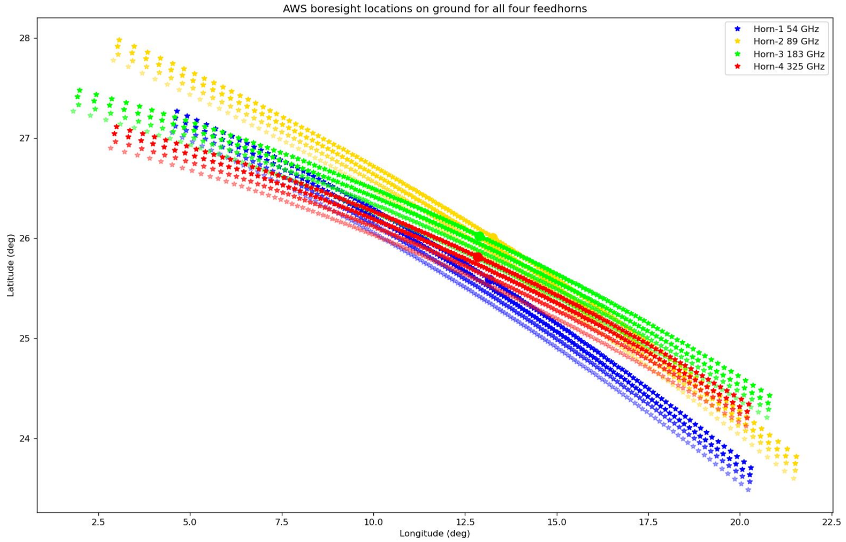
Radiative transfer simulations indicate that there is no specific reason to mimic the **HARMONIE-AROME snow model**.

The RTTOV-SCATT default configuration provides simulations in best agreement with **radiance observations**.

Challenge with AWS

Different footprints and locations of different frequencies for AWS.





Differences in location handled by remapping of data to positions of 183 GHz radiances.

Conclusions

- The HARMONIE-AROME system is prepared for AWS radiances.
- Cal/Val will start when satellite is launched in July, 2024.
- Several general enhancements regarding use of MW radiances in nordic conditions have been exploited.
- Preparations for all-sky.
- Novel use of 325 GHz channel for cloud detection planned for.