Forecast impact expected from EPS-Sterna’s 325 GHz channels

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1) Introduction

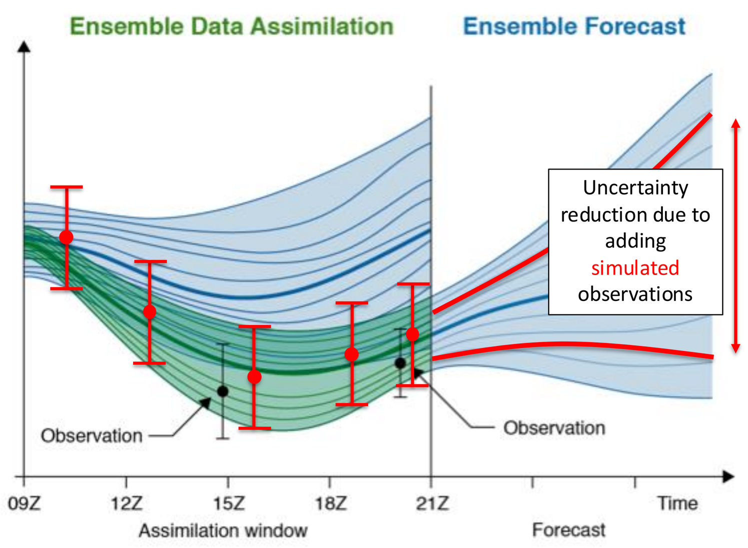
EPS-Sterna is a constellation of 6 small-satellites with 19-channel passive MW sounders proposed by EUMETSAT. The instrument is the same as for the Arctic Weather Satellite (AWS) and includes a novel set of 325 GHz channels not previously available from space. Here we develop an approach to assimilate these new channels and assess their expected impact using simulated data and the Ensemble of Data Assimilations (EDA) technique. See also [4].

EDA method to evaluate new observations:

- Monte-Carlo approach to estimate the forecast uncertainty in data assimilation.
- 10 independent 4D-Var assimilation systems with members generated through perturbations to the observations, model and SSTs.
- Benefit from changes to the observation use (real or simulated observations) measured by reductions in the EDA spread.

Model resolution used: $T_{CO}399$ (28 km)

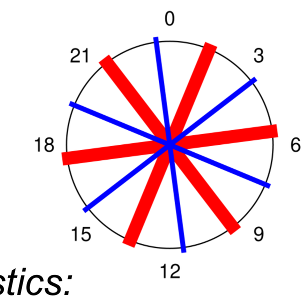
Study period: 1 – 28 July 2019.



Focus is on 12h forecasts, for which the signal due to observation changes is more robust.

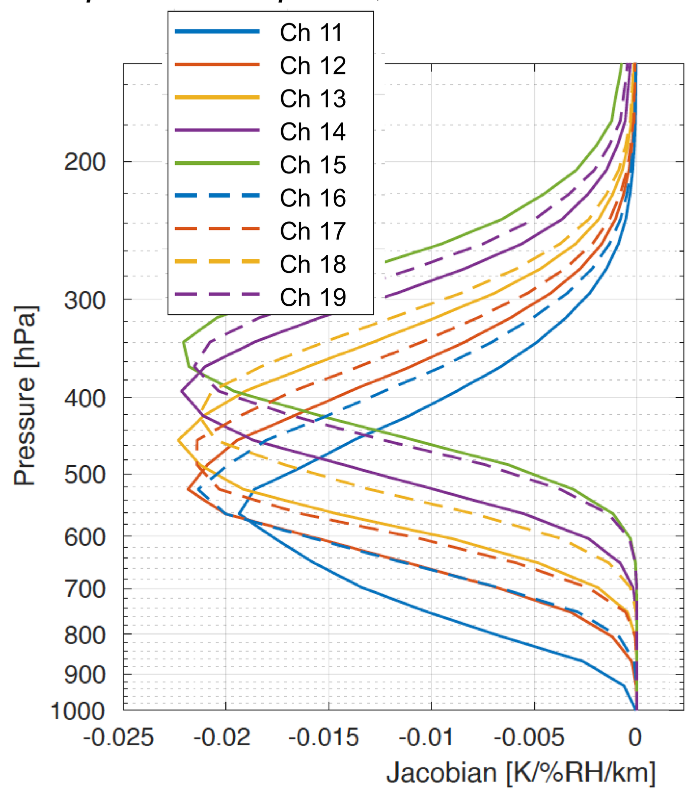
2) EPS-Sterna, simulation and assimilation

EPS-Sterna comprises 6 satellites in 3 polar-orbiting planes (blue), complementing the backbone 3-orbit CGMS constellation (red):



EPS-Sterna observations are simulated in all-sky conditions from ECMWF high-resolution analysis trajectories using RTTOV-SCATT v13.

Clear-sky humidity Jacobians for channels 11-19 for a tropical atmosphere; from Eriksson et al 2020 [2]

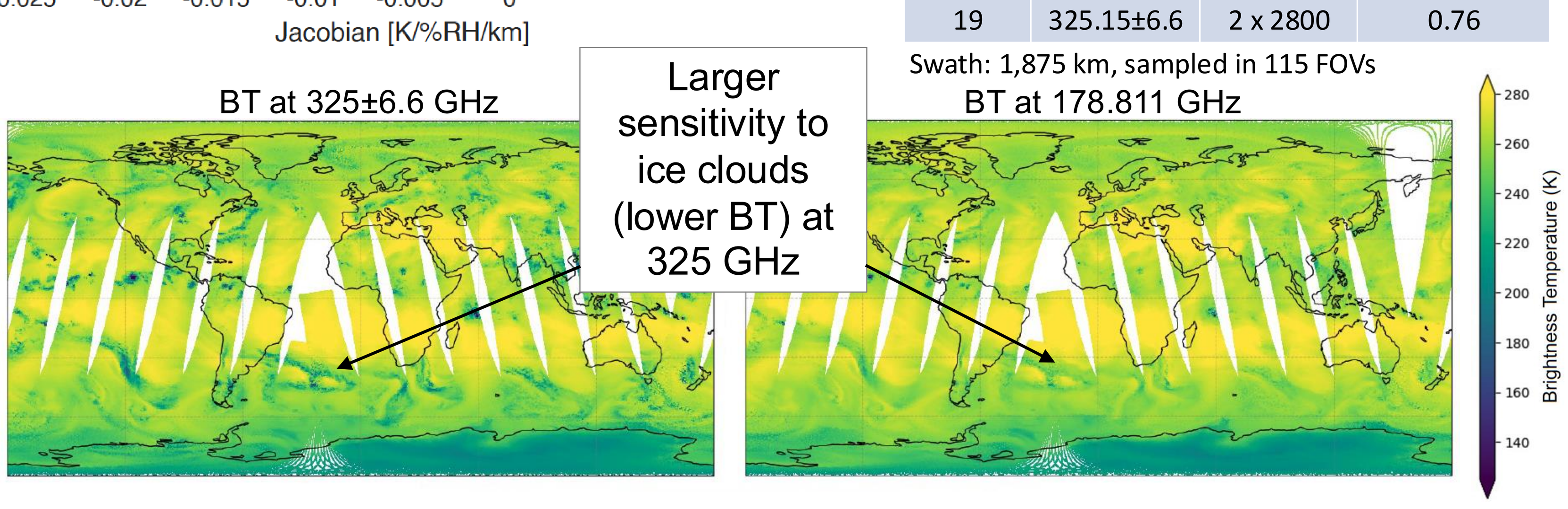


325 GHz channels (16-19) peak at similar altitudes as corresponding 183 GHz channels (11-14).

Key channel characteristics:

Channel number	Frequency (GHz)	Bandwidth (MHz)	Sample NEDT (K)
1	50.3	180	0.987
2	52.8	400	0.641
3	53.246	300	0.641
4	53.596	370	0.658
5	54.4	400	0.606
6	54.94	400	0.606
7	55.5	330	0.641
8	57.290344	330	0.658
9	89.0	4000	0.269
10	165.5	2800	0.53
11	176.311	2000	0.53
12	178.811	2000	0.53
13	180.311	1000	0.74
14	181.511	1000	0.74
15	182.311	500	1.04
16	325.15±1.2	2 x 800	1.42
17	325.15±2.4	2 x 1200	1.16
18	325.15±4.1	2 x 1800	0.95
19	325.15±6.6	2 x 2800	0.76

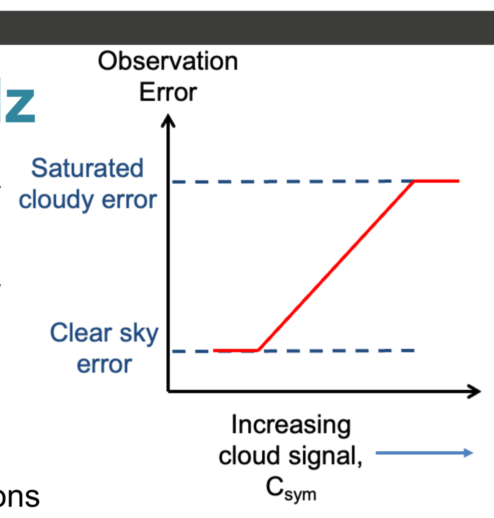
Swath: 1,875 km, sampled in 115 FOVs



- The simulated data are perturbed according to the expected noise characteristics after 3x3 super-obbing, and then sub-sampled to a spacing of ~110 km in half-hour slots.
- The all-sky framework is used for assimilation. Established choices are adapted for 50 and 183 GHz channels [3].
- Screening choices for 325 GHz are the same as for corresponding 183 GHz channels.

3) Observation error modelling for 325 GHz

The all-sky observation error model [1] is adapted to account for larger ice cloud sensitivity. The 89/165.5 scatter index (cloud-indicator for the 183 GHz channels) was found to be inadequate for the 325 GHz channels. Instead, the following cloud indicator is used:

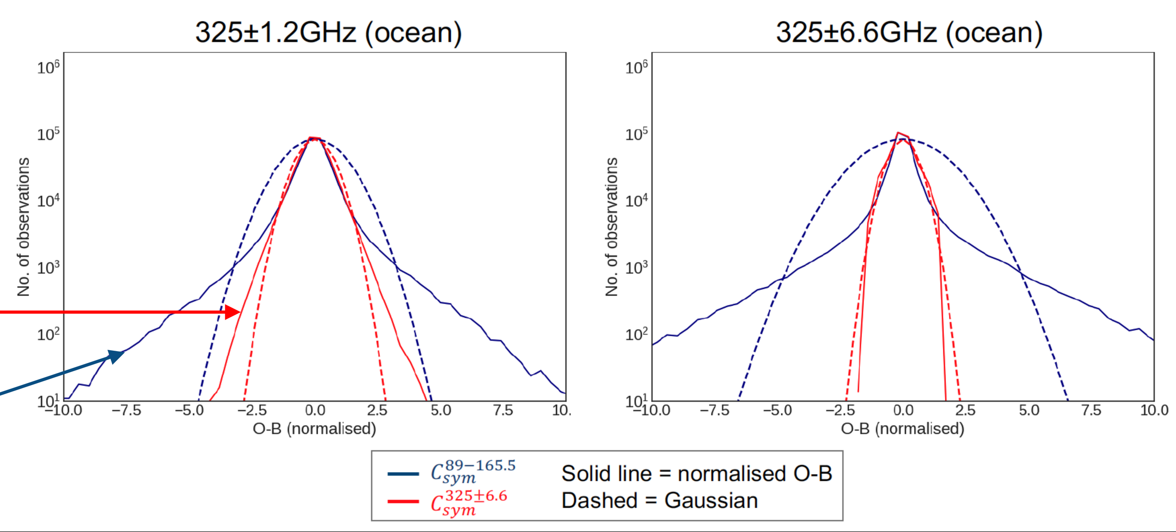


$$C_{sym}^{325\pm6.6} = \left(|(BT_{obs} - BT_{bkclr})| + |(BT_{bkcld} - BT_{bkclr})|\right)/2$$

BT_{obs} – observations; $BT_{bkclr/cld}$ – clear/cloudy background simulations

Clear-sky errors are calculated from the NEDT using empirical formulae as for the 183 GHz channels. For the cloudy errors, values are taken from corresponding 183 GHz channels from heritage sensors, scaled by the ratio of standard deviations of cloud-affected background departures for the 325 and 183 GHz channels.

Background departures normalised with the assigned observation error are close to Gaussian for new error model, using $C_{sym}^{325\pm6.6}$, compared to using the 89/165.5 scatter index, $C_{sym}^{89-165.5}$



4) Relative impacts of 183 and 325 GHz

EPS-Sterna observations are added to a **Baseline** system of real observations: the full observing system used operationally in July 2019, but with MW-sounding only from: 2 Metop satellites, 2 ATMSs, AMSU-A on NOAA-15, 183 GHz channels from SSMIS on F17 and GMI.

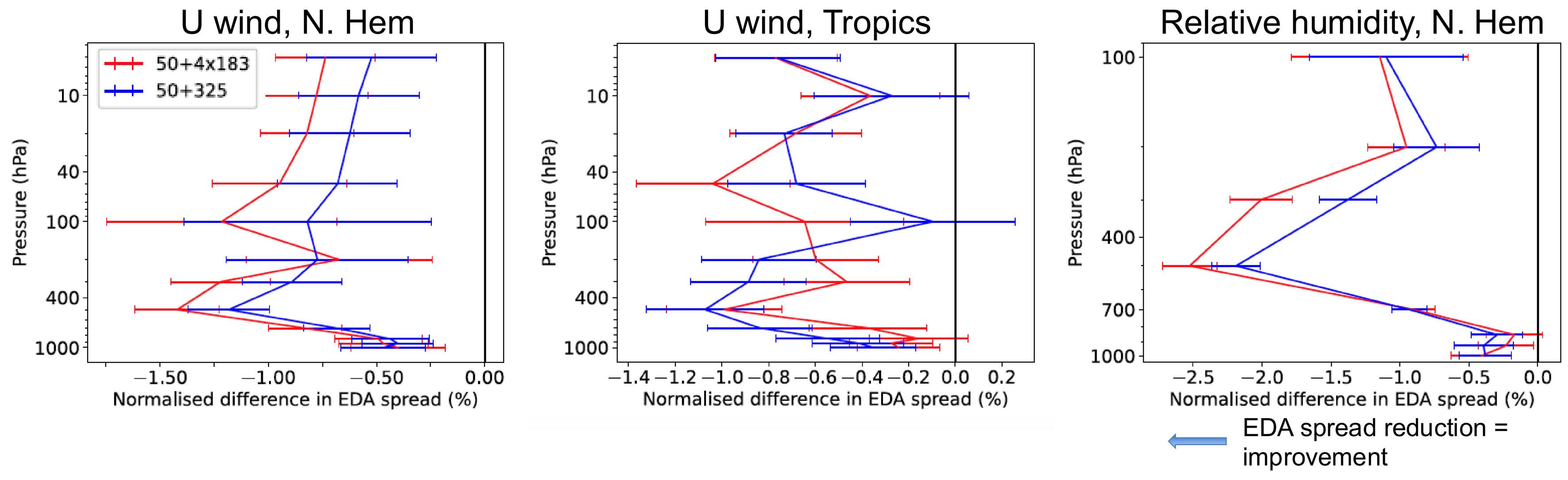
EDA experiments testing the impact of 183 or 325 GHz as the only humidity channels:

50only: Baseline real observing system plus the 50 GHz temperature-sounding channels from the 6-satellite nominal EPS-Sterna constellation.

50+325: As 50only, plus the four 325 GHz humidity-sounding channels from EPS-Sterna

50+4x183: As 50only, plus the highest-peaking four of the five 183 GHz channels from EPS-Sterna.

Added separately, the 183 and 325 GHz channels show a similar positive forecast impact, as suggested by the EDA spread reductions shown. The impact for humidity is a little lower, possibly due to the large sensitivity to ice clouds of the 325 GHz channels.



Normalised difference in EDA spread compared to the ***50only*** *experiment for the* ***50+4x183*** *(red) and* ***50+325*** *(blue) experiments. Data for 8 – 28 July 2019, horizontal bars indicate 95 % statistical significance.*

5) Combined impact of 50, 183 and 325 GHz

EDA experiments to test the impact of adding 325 GHz channels on top of the 50 temperature-sounding and 183 GHz humidity-sounding channels:

Baseline: Baseline real observing system

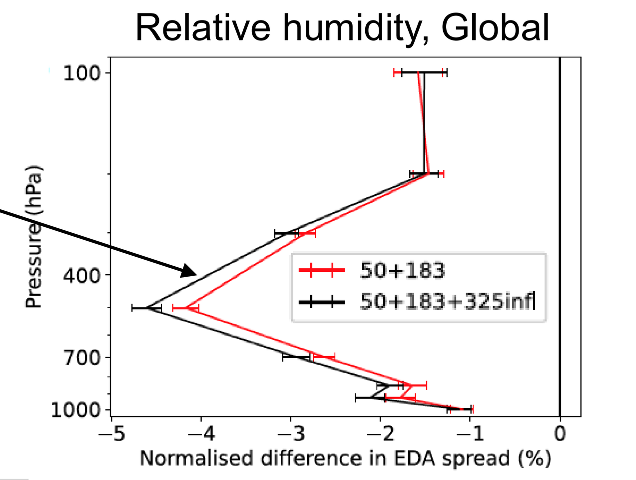
50+183: Baseline real observing system plus the 50 GHz channels and the 183 GHz channels from the 6-satellite nominal EPS-Sterna constellation.

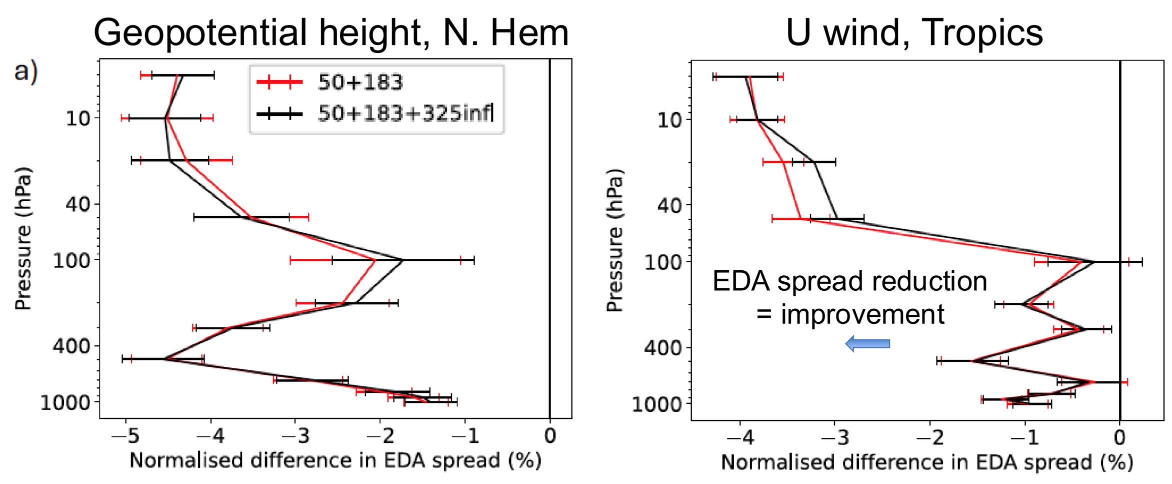
50+183+325: As 50+183, but with the four 325 GHz channels from EPS-Sterna added.

50+183+325infl: As 50+183+325, but with the maximum cloudy observation error assigned to the 325 GHz channels inflated by a factor 1.5.

Compared to using just 50 and 183 GHz, adding 325 GHz channels shows a small benefit for humidity, possibly due to better discrimination between humidity and ice-cloud signals.

Otherwise, the impact of adding 325 GHz is neutral. Error inflation is useful to achieve this (not shown).





Normalised difference in EDA spread compared to the ***Baseline*** *experiment for the* ***50+183*** *(red) and* ***50+183+325infl*** *(black) experiment. Data for 8 – 28 July 2019, horizontal bars indicate 95 % statistical significance.*

Using the three channel sets together, EPS-Sterna has a very clear positive impact, though the contribution of the 325 GHz channels is comparatively small. Further enhancements of the assimilation approach may improve the impact of the 325 GHz channels.

6) Conclusions

An approach to assimilate the 325 GHz channels of EPS-Sterna has been developed and evaluated in the EDA. This includes the adaptation of an adequate observation-error model tailored to the 325 GHz channels. The main findings of the study are (full details in [4]):

- EPS-Sterna is expected to have a significant positive impact when the 50, 183, and 325 GHz channels are used together.
- Used as the only set of humidity-sounding channels, the 325 GHz channels achieve a similar impact as the equivalent four 183 GHz channels.
- When added on top of the 50 and 183 GHz sounding channels, the impact of the 325 GHz channels is relatively small and primarily confined to tropospheric relative humidity.

Several avenues exist to enhance the impact of the 325 GHz channels, such as accounting for inter-channel error correlations or the use of a cloud control variable to better benefit from the additional ice-cloud capabilities.

References

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4. Lean, K. and Bormann, N. (2024): Evaluation of the EPS-Sterna 325 GHz channels in the Ensemble of Data Assimilations. EUMETSAT Contract Report, 39pp, doi: 10.21957/f53d05c057