AMSU-A Window Channel Assimilation

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Abstract

AMSU-A channels 5-14 are assimilated in all-sky conditions at ECMWF since Oct. 2021[a]. AMSU-A also holds window channels with valuable all-sky information at 23.8, 31.4, 52.8, and 89.0 GHz. Some of these frequencies are assimilated already from imagers (e.g. GMI), so a strategy for using these channels on AMSU-A could significantly improve temporal sampling of all-sky radiances. In effect, AMSU-A represents several well-calibrated, mini-imagers that are under-exploited in the assimilation.

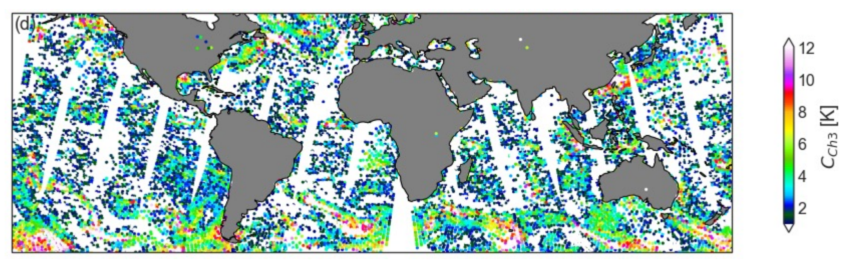
Assimilating AMSU-A window channels over sea improves short-range forecasts of low-level winds and humidity. This effect is largest in the tropics, where the five AMSU-A overpasses fill in temporal gaps left by the imagers. Forecast impacts are neutral to positive if adding channels 1 and 2 (23.8 and 31.4 GHz). Impacts are more mixed when also adding channels 4 and 15 (52.8 and 89.0 GHz); these have mixed surface and sounding sensitivity, and observation error modelling for these channels may require further attention. Assimilation of AMSU-A channels 1 and 2 will be a part of the future ECMWF upgrade to Cycle 49r1.

Observation error modelling

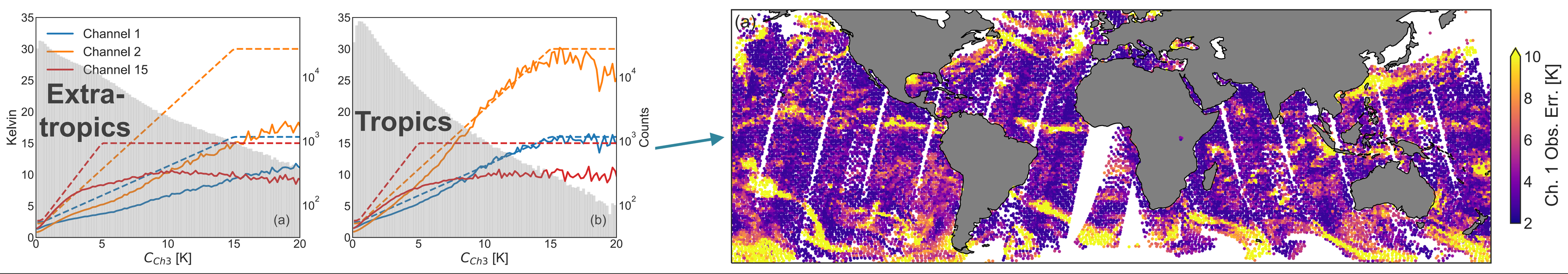
- All-sky assimilation uses a symmetric cloud predictor to assign observation errors
- AMSU-A channels 5-9 use liquid water path (LWP) retrieved with channels 1 & 2
- The window channels 1, 2, and 15 were tested using several cloud proxies, with a channel 3-based error model slightly favoured[b]:

Channel	Frequency [GHz]	Peak sensitivity [hPa]
1	23.8	Surface
2	31.4	Surface
3	50.3	Surface
4	52.8	920 - 810
5	53.596±0.115	650 - 530
15	89.0	Surface

$$C_{Ch3} = |O_3 - B_{3,clr}|/2 + |B_3 - B_{3,clr}|/2$$



- The channel 3 predictor has sensitivity to scattering and emission from precipitation and cloud, as well as surface emissivity errors
- For channel 4, the LWP predictor is retained, but a scattering index (SI) term derived from channels 1 & 15 is added to better account for frozen precipitation

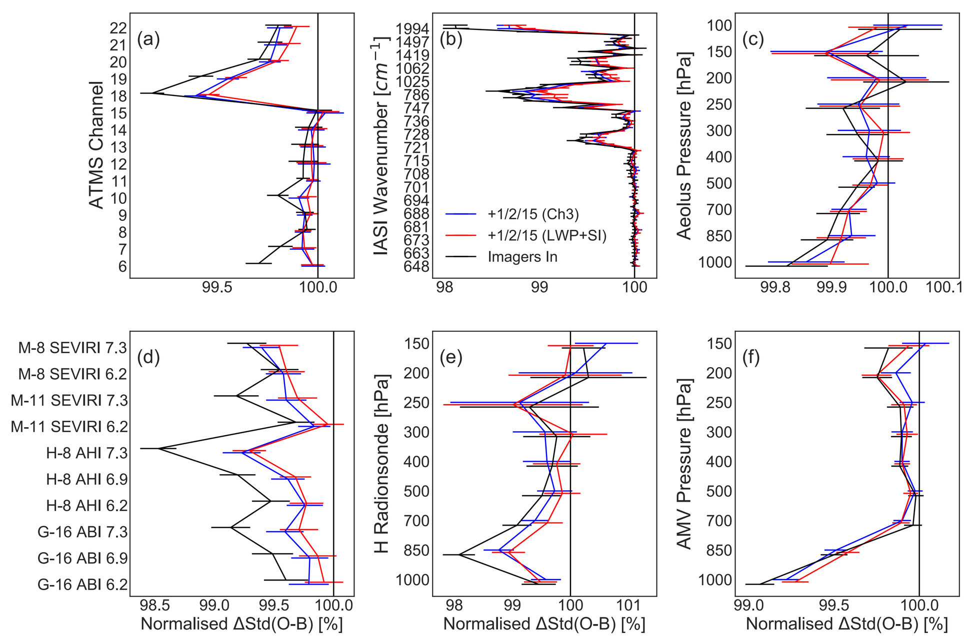


Comparison to impact from imagers

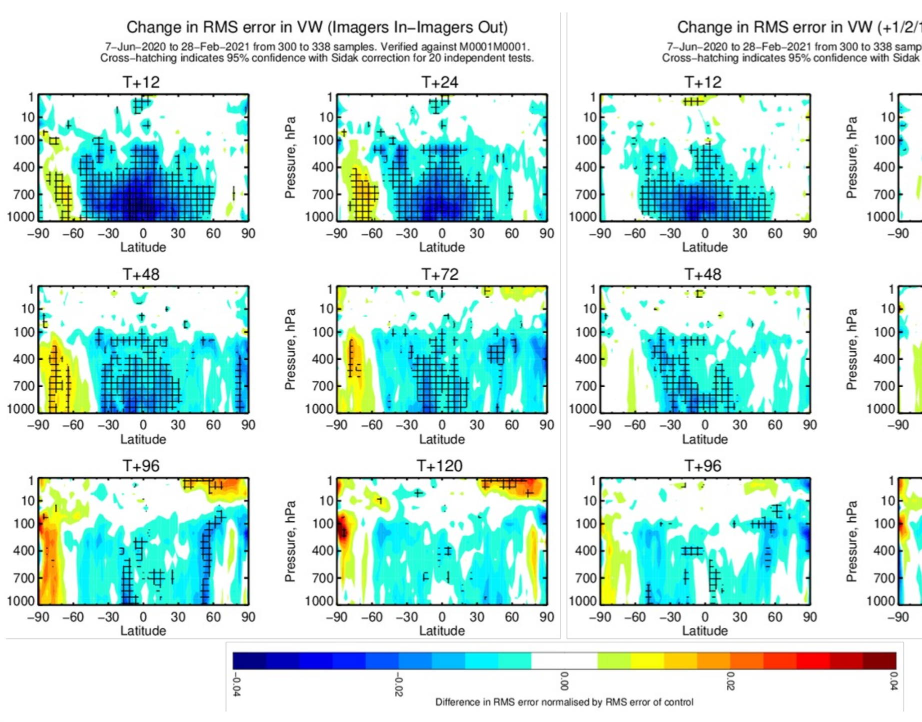
Test assimilation of 16 window channels (Chs. 1, 2, 15) across 6 AMSU-As in 2020. How does this compare to the cumulative impact of all-sky imagers in the IFS (AMSR2, GMI, F17 SSMIS, FY-3D MWRI)?

→ Assessed in an OSE from JJA 2020 and DJF 20-21 against 'Imagers Out' control (depleted observing system)

- Overall impact on medium-range is comparable
- Similar but smaller magnitude impact on fits to independent observations such as AMVs, radiosondes, and infrared radiances
- Nice result as AMSU-A window channel radiances assimilated are ~50% of imager radiances in total



Changes in global background fits to other observations: ATMS (a), IASI (b), Aeolus (c), geostationary infrared (d), humidity radiosondes (e), and AMVs (f). The 100% line here represents the depleted system, i.e. Imagers Out. Two observation error predictors tested: Ch3-based model and LWP+SI model.

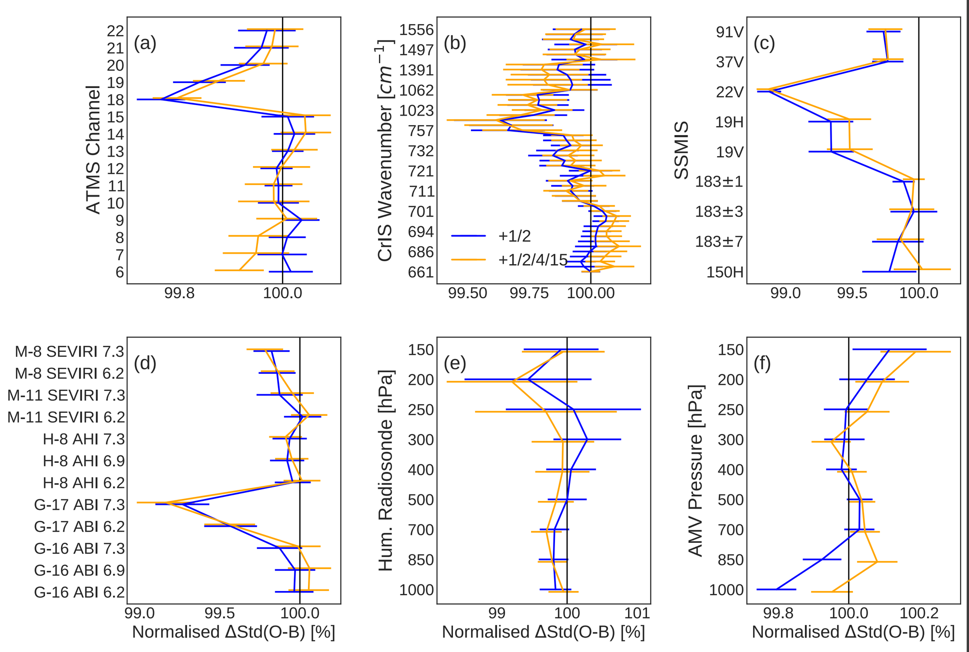


Changes in RMS vector wind forecast errors from lead time +12hr to +120hr. Imagers In on the left, AMSU-A Window Channels On is on the right. Control is Imagers Out with verification against operational analysis.

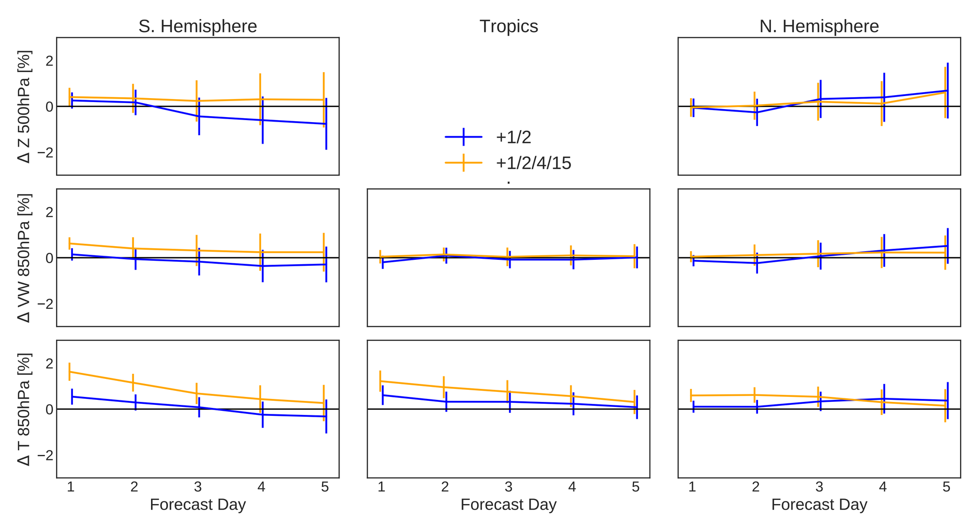
Impact in full system

Channels 1/2 & 1/2/4/15 added to the full observing system

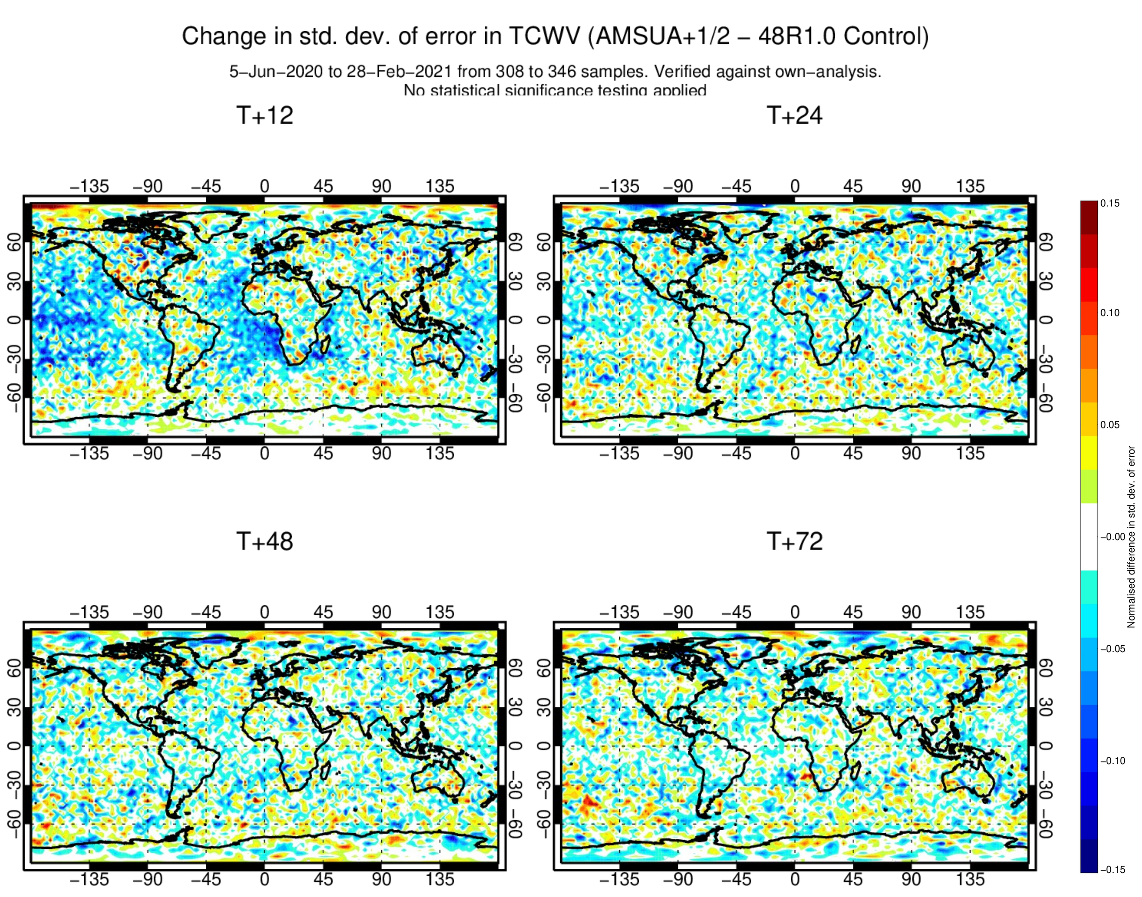
- Low-frequency channels 1 & 2 improve humidity at low levels
- Fits to other humidity channels generally improved
- Small impact on winds through 4D-Var tracer effect
- Biggest positive impact is on TCWV in the tropics
- Channels 4 & 15 have little extra impact, but we see significantly degraded T850 in southern hemisphere → further work likely needed on error modelling



Changes in global background fits to other observations caused by window channel assimilation: ATMS, CrIS (b), SSMIS (c), geostationary infrared (d), radiosonde humidity (e), and AMVs (f). The 100% line here represents the full observing system.



Changes in RMSE for 500hPa geopotential (Z), vector winds (VW) and temperature (T) at 850hPa.

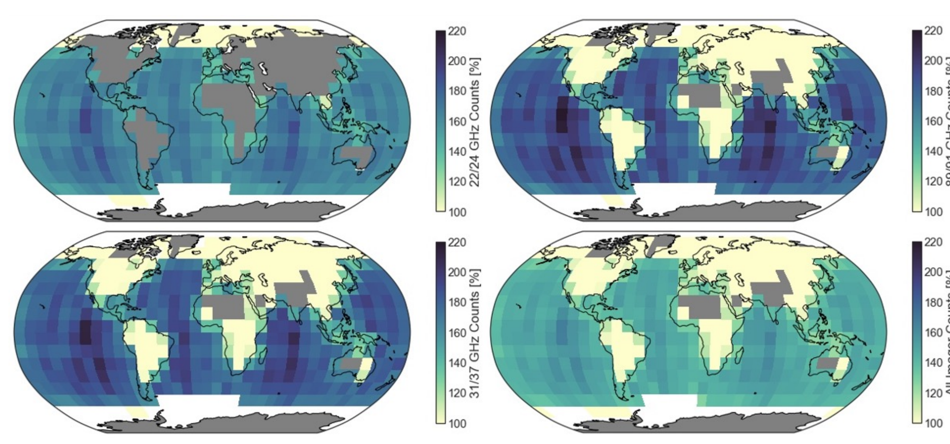


Total column water vapour (TCWV) change in standard deviation of error, from T+12 to T+72 hrs. Assimilation of AMSU-A channels 1 & 2 decreases short-range forecast errors for column water vapour in the tropics.

How much data?

Most AMSU-As maintain excellent window channel performance

- Channel 1, 2, and 4 are within specification on 5 satellites in 2023
- Channel 3 has high noise on Metop platforms, but this is sufficient for emissivity retrieval and error modelling



Increase in window channel radiances assimilated in the IFS, with 100% signifying the current usage from AMSR2, GMI, SSMIS, and MWRI. Data from July 1-10 2020.

Channel	Satellites with channel in spec.*	Max. active
1	Metop-A, -B, -C, NOAA-15, -18, -19	6
2	Metop-A, -B, -C, NOAA-18, -19	5
3	NOAA-15, -18, -19	3
4	Metop-A, -B, -C, NOAA-15, -18, -19	5
15	Metop-A, -C, NOAA-15, -18, -19	5

**Exceptions are Metop-B-15 (failed 2016) and NOAA-15-2 (asymmetric scan bias). The Metop-B failure precludes use of ch4, as the error model uses ch15.*

Conclusions

After years of use at ECMWF, there is more to exploit from AMSU-A

- Window channels 1 & 2 show benefit in the IFS when assimilated with appropriate error modelling and QC, even in a full observing system
- Greater temporal sampling in the tropics is perhaps biggest benefit for NWP, given limited temporal sampling from current imagers
- Results are more mixed when assimilating channels 4 & 15 as well, pointing to more complex error characteristics from combined sounding/imaging channels
- Channels 1 & 2 will be assimilated over sea with the upgrade to IFS Cycle 49r1
- This methodology can be applied to other temperature sounders like ATMS, MWTS-3, and MWS

References

a. Duncan, D. I., Bormann, N., Geer, A. J. and Weston, P. (2022). Assimilation of AMSU-A in all-sky conditions. *Mon. Weather Rev.*, 150(5), 1023 – 1041, https://doi.org/10.1175/MWR-D-21-0273.1

b. Duncan, D. I., Bormann, N., Geer, A. J. (2022), All-sky Assimilation of AMSU-A Window Channels, *EUMETSAT/ECMWF Fellowship Programme Research Report 59*, https://www.ecmwf.int/node/20457.