Expanding All-sky AMSU-A Assimilation to Its Window Channels

BONUS: Initial evaluation of TROPICS Pathfinder CubeSat

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ECMWF

Background

All-sky AMSU-A was activated in ECMWF operations in October 2021 as part of IFS Cycle 47r3 upgrade, assimilating channels 5-14

Despite being a sounder, AMSU-A also holds 3 window channels

- Similar frequencies to assimilated “imager” channels on GMI, AMSR2, etc.
- We still have 5 active AMSU-A sensors, so assimilating these channels is like adding *2-3 more microwave imagers*, with additional overpass times
- Big potential benefit for *cloud analysis, columnar water vapour, low-level winds*

Compared to MW imagers the main differences are:

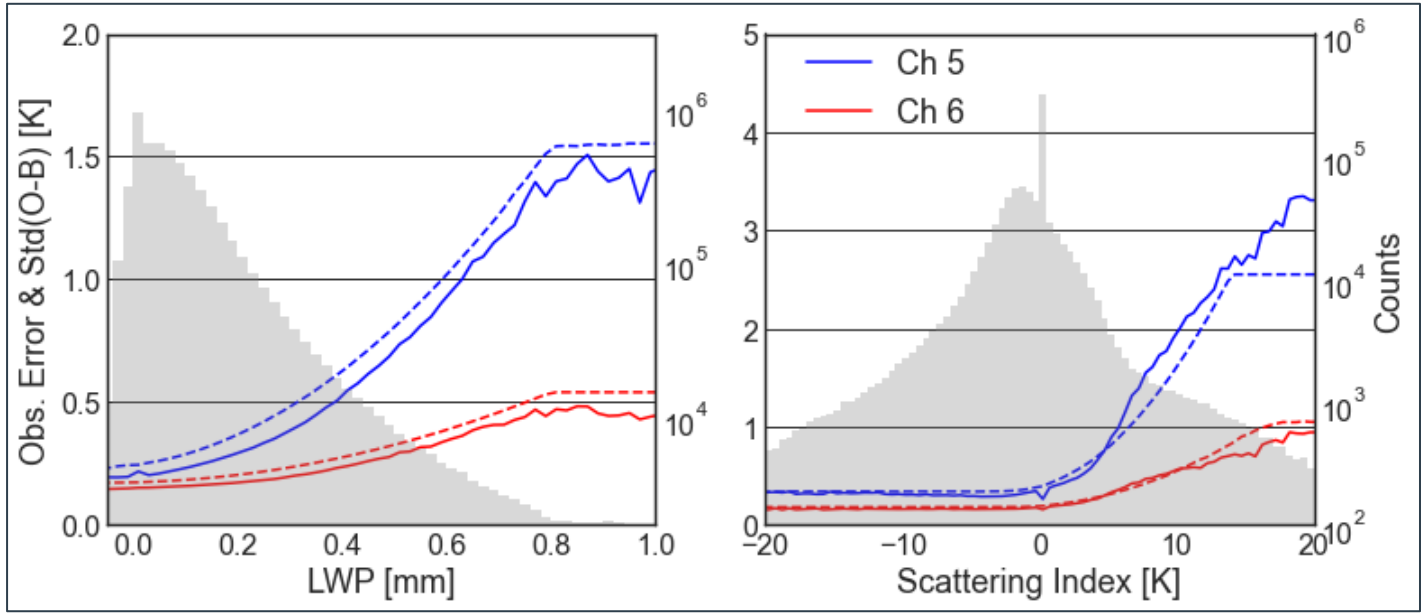
- Variable zenith angle due to cross-track scanning
- Imagers use a polarisation difference near 37GHz (P37) to inform the error model, but AMSU-A does not have this capability

New Error Model

All-sky error model concept is to assign errors that scale with a cloud predictor

For sounding channels we use a *LWP retrieval* over sea as cloud proxy

- This can *miss scattering signals* from graupel or snow aloft
- Scattering can impact 89GHz especially



From *Duncan et al. 2022* [https://doi.org/10.1175/MWR-D-21-0273.1]

	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
6	54.4	390 - 320
7	54.94	260 - 200
8	55.0	170 - 135
9	$57.29 = f_0$	85 - 70
10	$f_0 \pm 0.217$	50 - 40
11	$f_0 \pm 0.3222 \pm 0.048$	25 - 20
12	$f_0 \pm 0.3222 \pm 0.022$	10
13	$f_0 \pm 0.3222 \pm 0.010$	5
14	$f_0 \pm 0.3222 \pm 0.0045$	3
15	89.0	Surface

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We need to find a better predictor for window channels

- Channel 3 (50.3 GHz) sensitive to surface, temperature, water vapour, liquid cloud, precipitation
- A new error model for window channels:

$$C_{SYM} = |O - B_{clr}|/2 + |B - B_{clr}|/2$$

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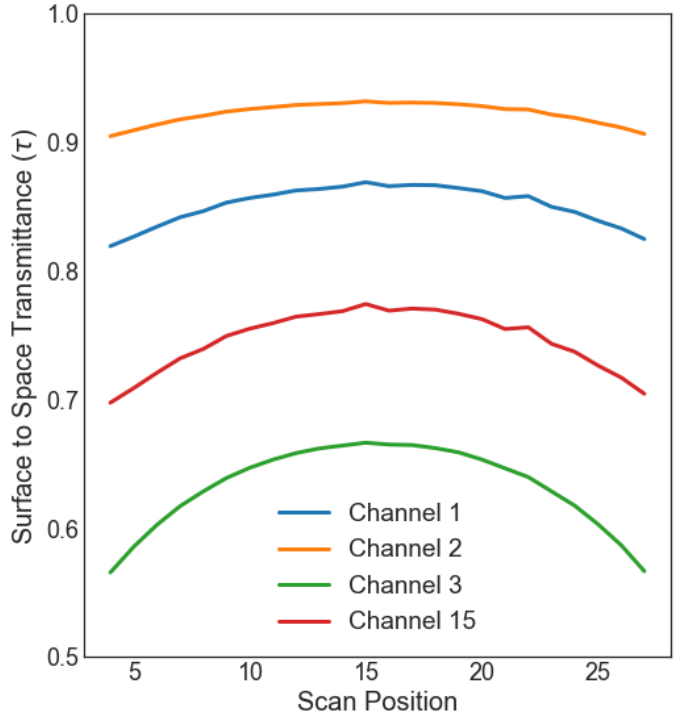

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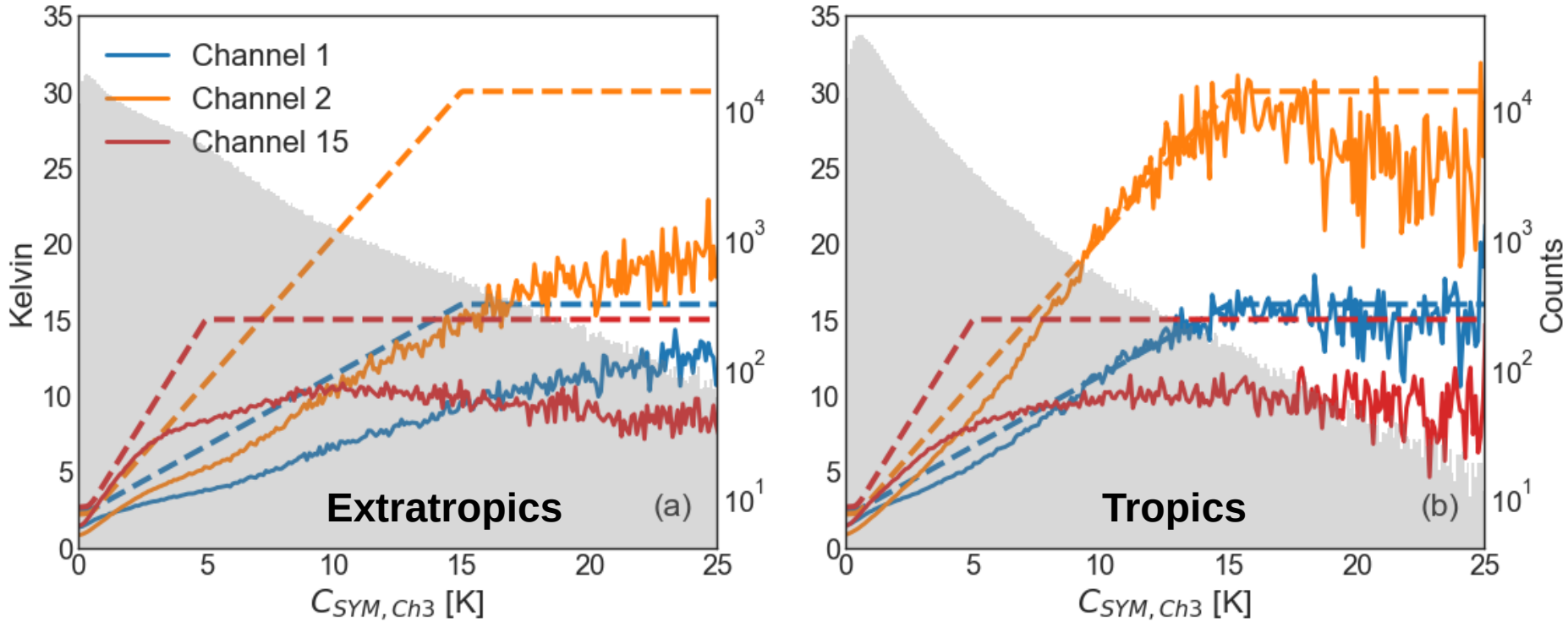
New Error Model

Follow philosophy of symmetric error model *(Geer and Bauer 2011)*

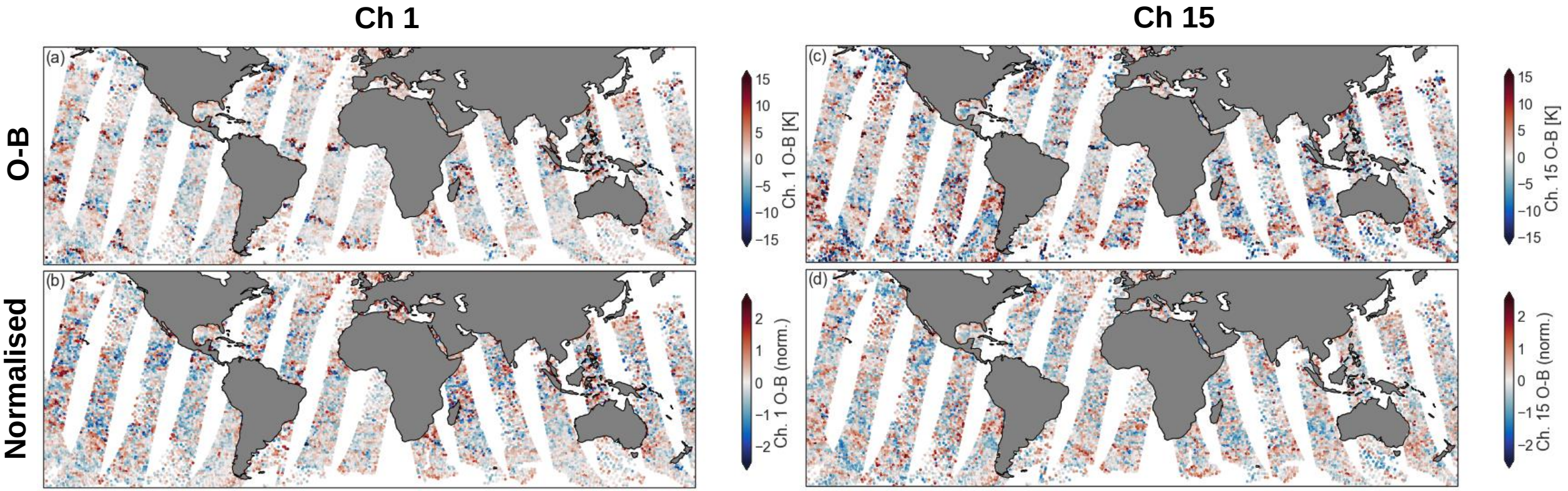
- Tune Ch3-based predictor to observed O-Bs
- *Conservative in extratropics, more tightly tuned in tropics*
- O-Bs quite linear with channels 1 and 2



New Error Model

Ch3 model picks up largest departures well

- Normalised departures well-behaved at 23 and 89 GHz
- Produces rather Gaussian PDFs

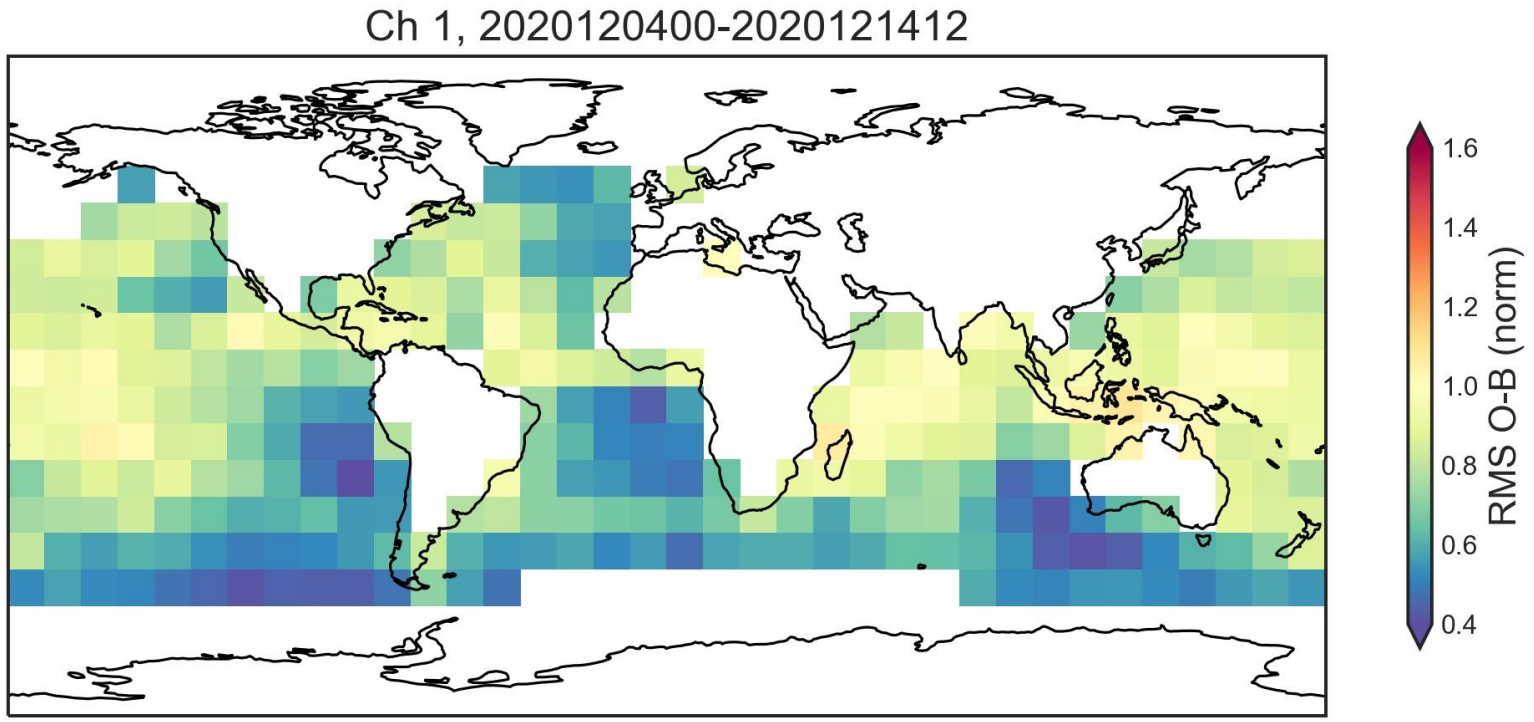


Metop-C AMSU-A, 15th Dec 2020 12Z

New Error Model

Ch3 model retains impact in Tropics

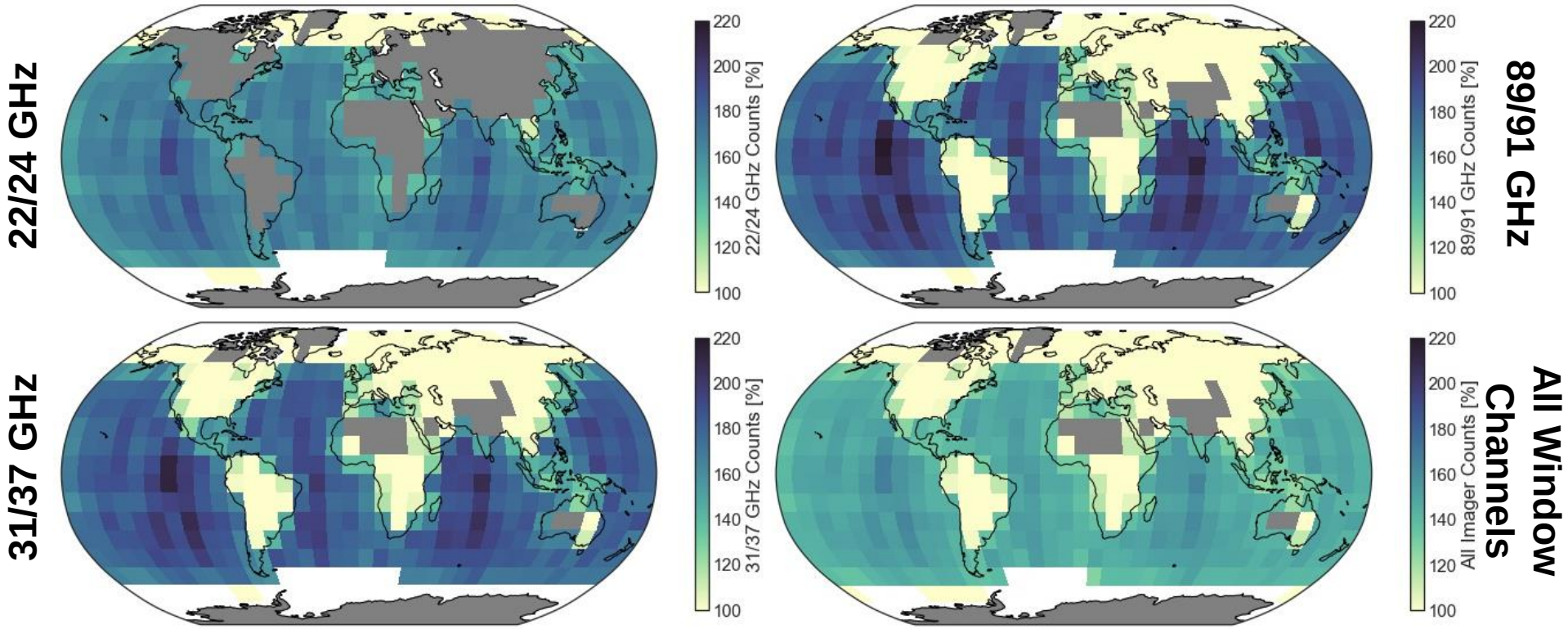
- It down-weights stratocumulus areas and Southern Ocean where window channel assimilation is more problematic



Results

Adding AMSU-A 1/2/15 is significant gain of data

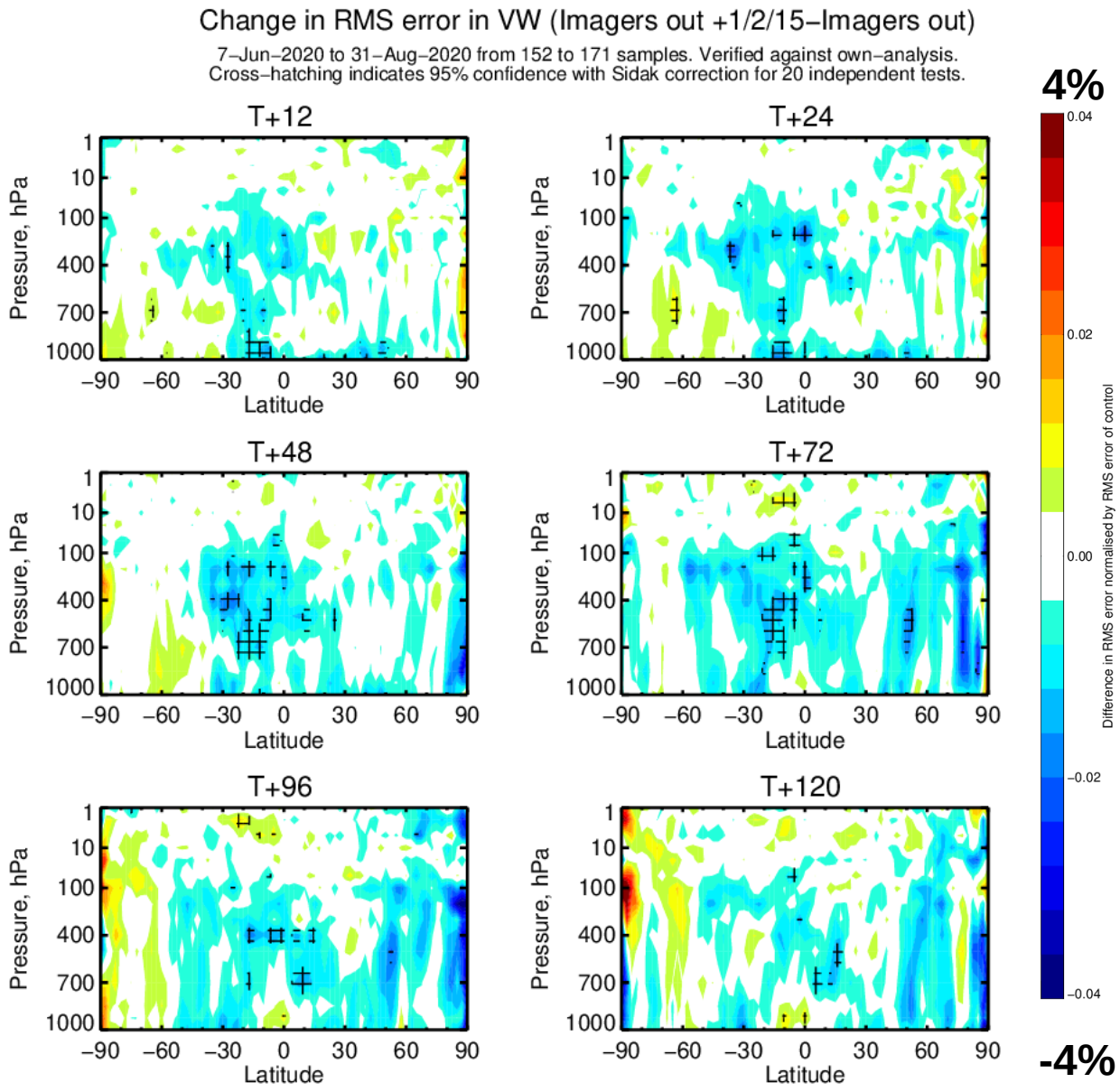
- Nearly double radiances assimilated at 31/37 GHz and 89/91 GHz
- About 40% increase on top of all 18-91 GHz channels from GMI, AMSR2, SSMIS, & MWRI



Results

Compare to denial of all MW imagers (3 mo.)

- Winds improved particularly in Tropics
- Nice signal out to day 5



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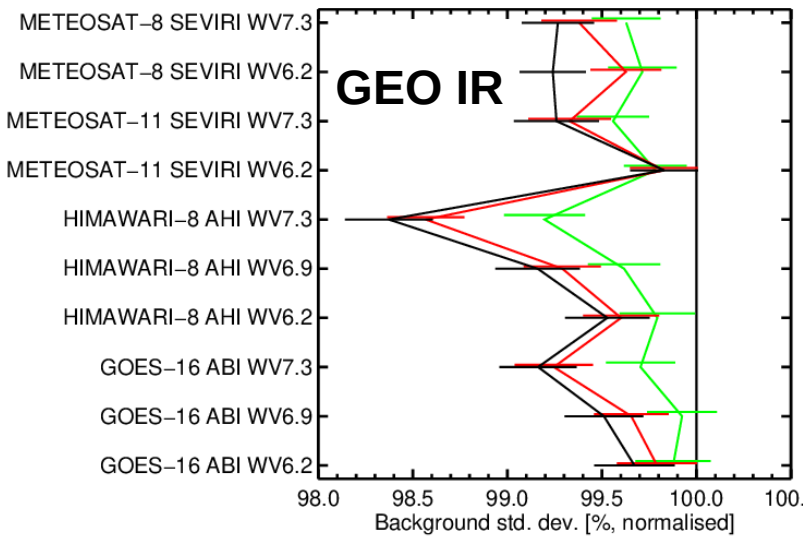
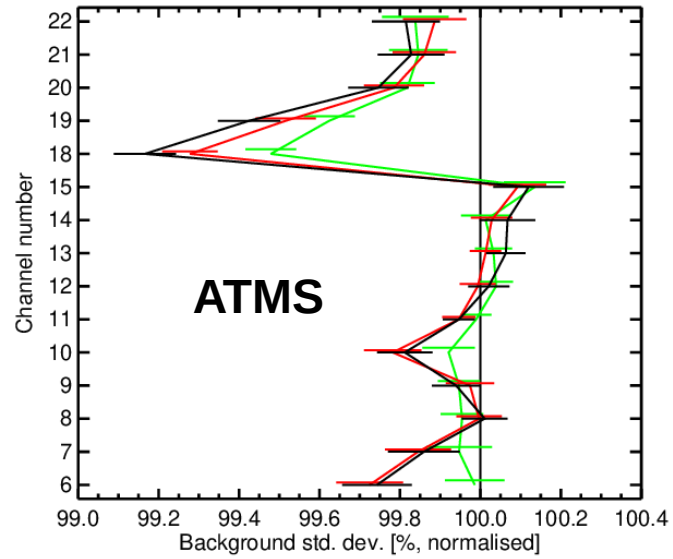
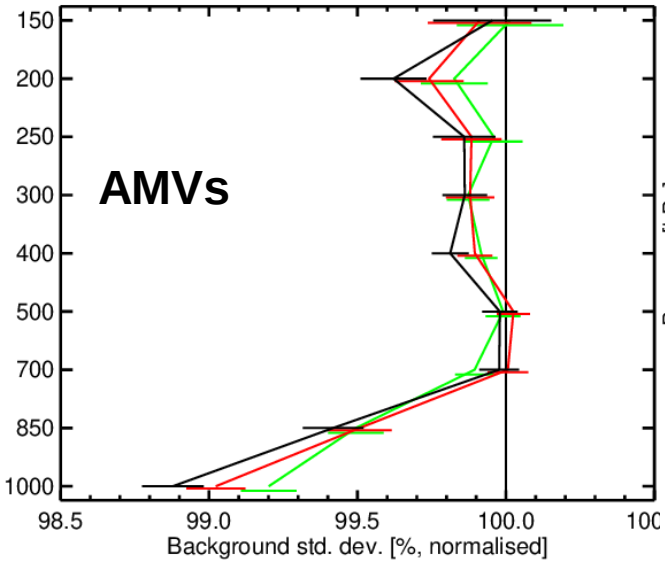
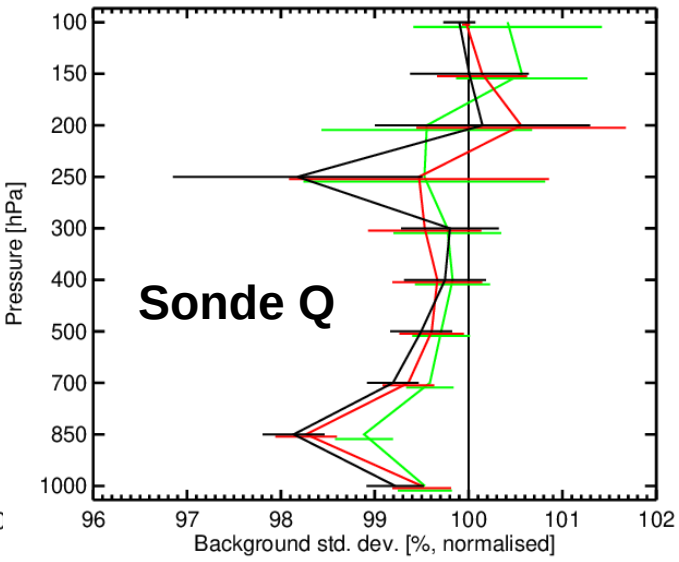


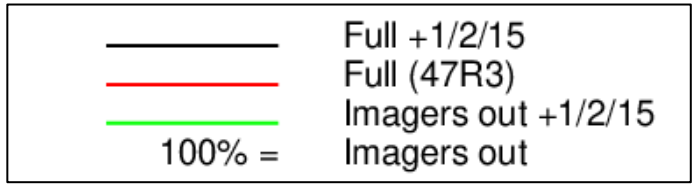






Compare to denial of all MW imagers (3 mo.)

- Global fits to observations improve for humidity and winds
- Impact largest in Tropics
- AMSU-A can provide large fraction of total imager impact



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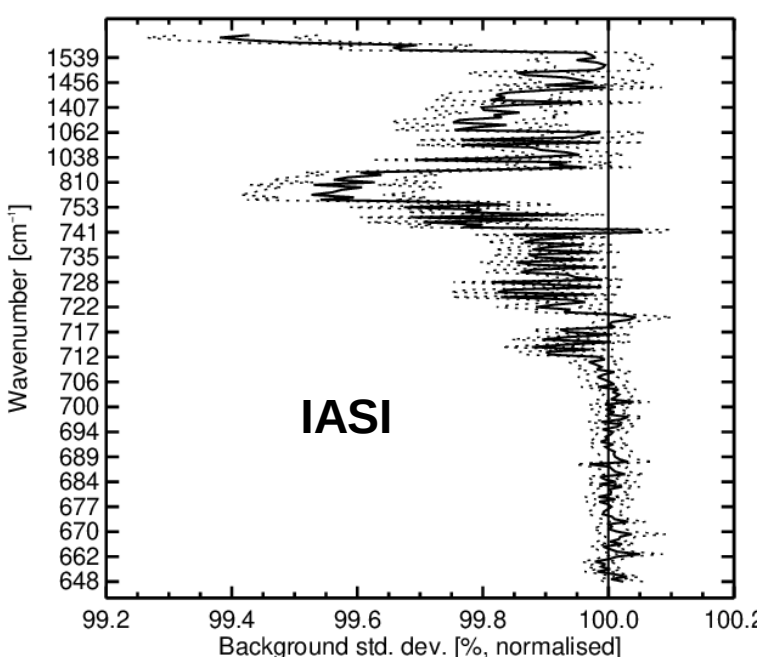
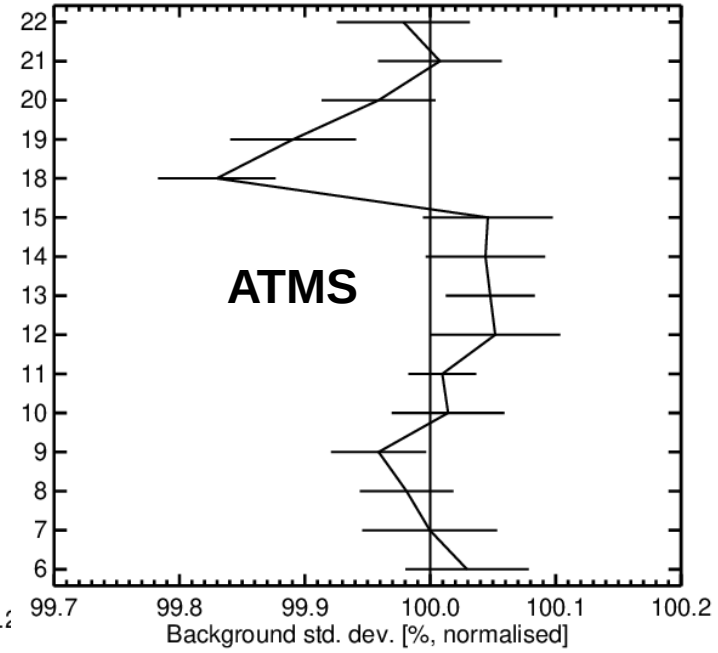
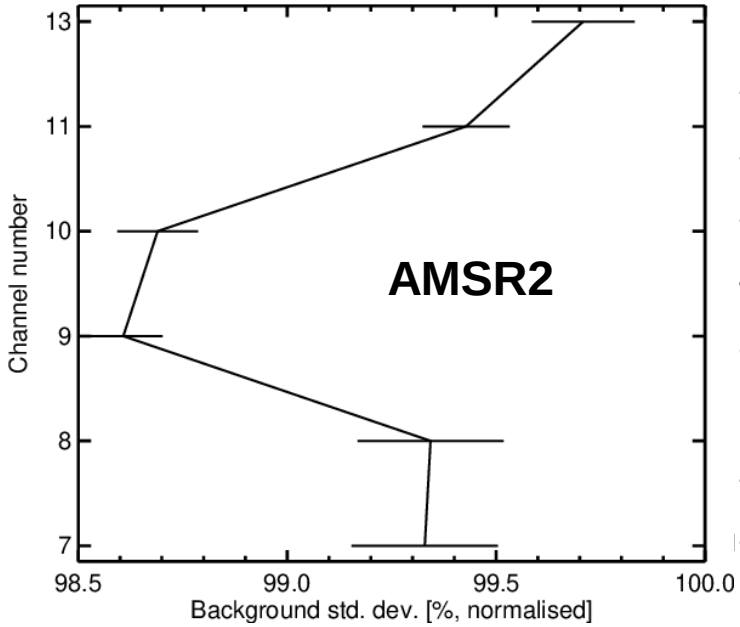
Results

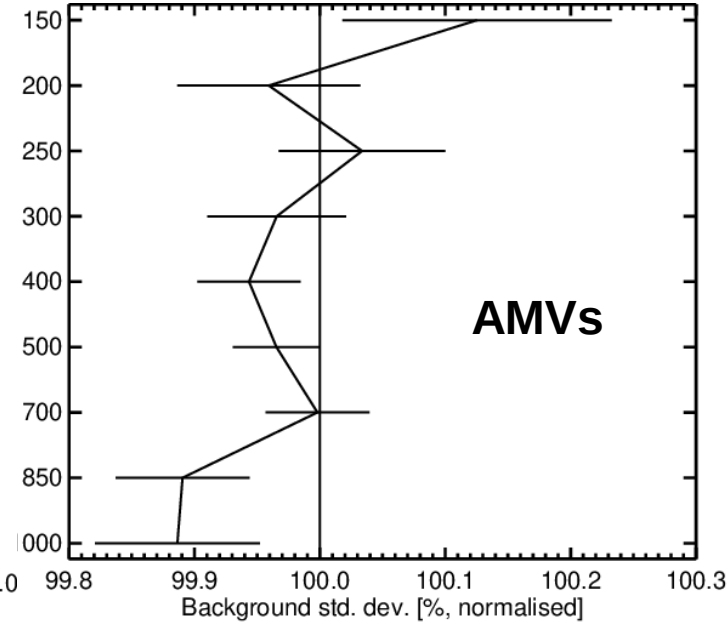
Compare to full system (6 mo.)

- Still see improvement for humidity and wind observations
- Imager channel std(O-B) 1-2% better especially in Tropics
- Increase of up to 1.5% in used data from tropospheric IASI & CrIS channels -> improved cloud fields









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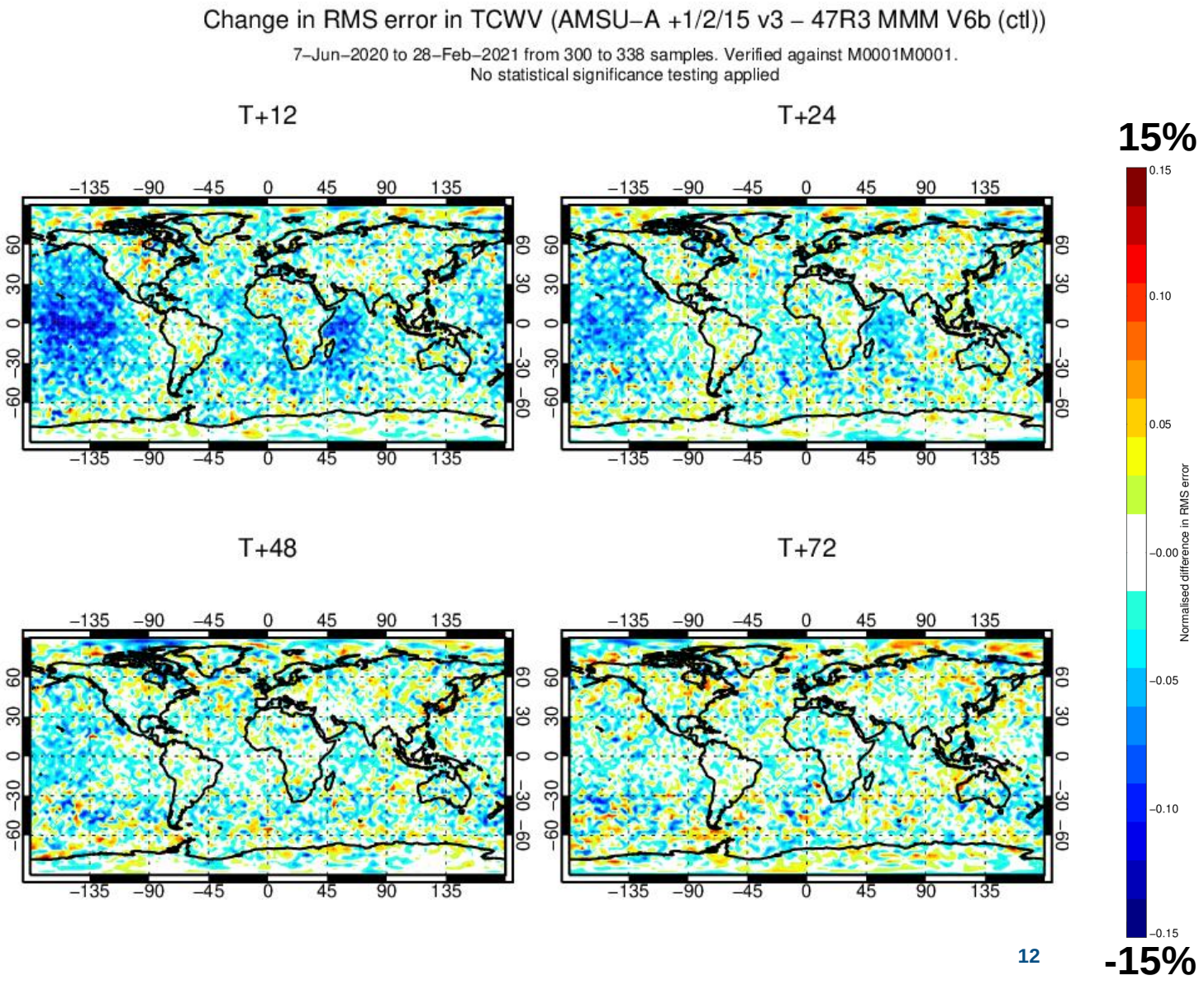
Results

Compare to full system (6 mo.)

- Total column water vapour is most improved field
- Acting on model bias in some regions, random errors generally
- Impact felt out to day 2-3 (verified against ECMWF operations)
- Some short range degradation in Southern Ocean low levels



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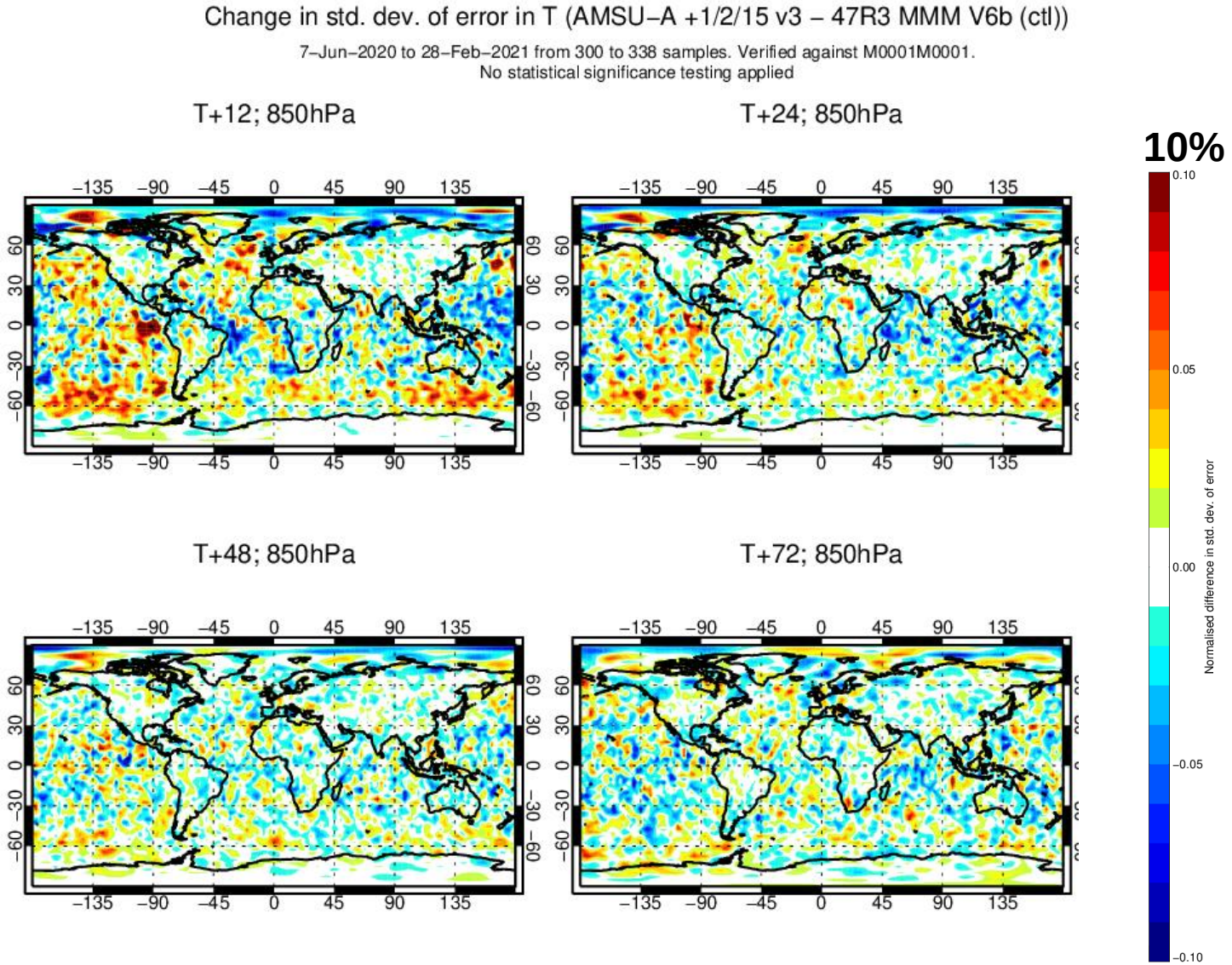


Summary

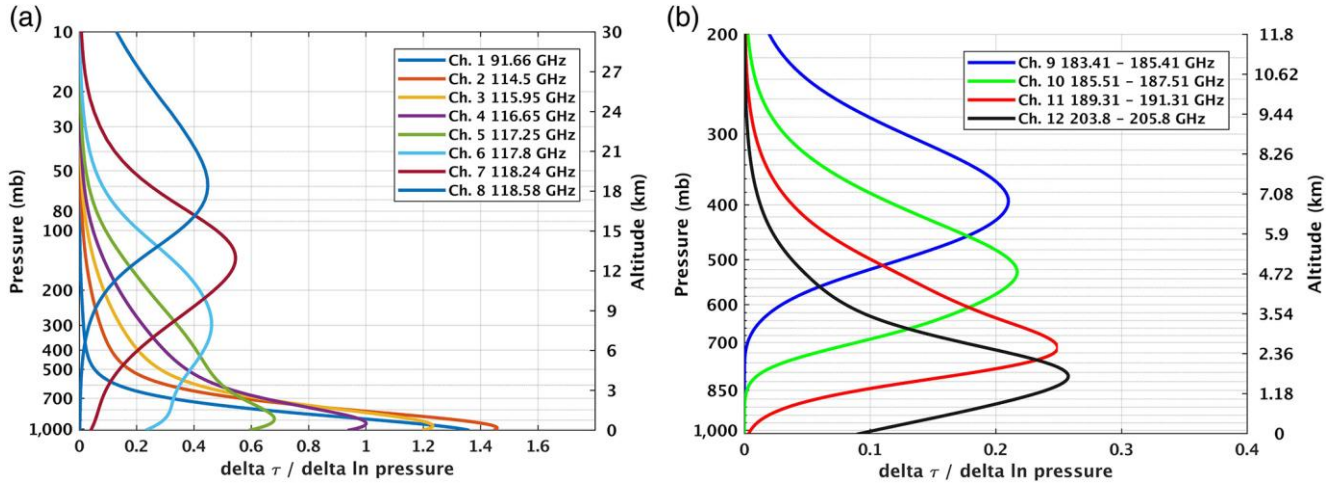
- AMSU-A holds *more cloud and humidity information* in its window channels
- Many potential upsides:
  - These channels exist *on ATMS too*
  - Offers nice *redundancy* if any current imagers are lost
  - Long data record makes greater utilisation appealing *for reanalysis*
- Ch3-based predictor works well for 23, 31, 89 GHz error modelling
- Benefit relative to a depleted system is very clear
- Even after 20+ years, we can still get more out of AMSU-A for NWP!

TROPICS Initial Evaluation in the IFS

First look at CubeSat microwave sounder

- 3U CubeSat launched in summer 2021 – ECMWF is an ‘early adopter’
- Initial data from pathfinder satellite, with constellation scheduled for launch later this year
- TROPICS microwave sounder has 12 channels from 91 to 204 GHz
- TROPICS team is currently working on calibration aspects such as antenna pattern correction – results shown are using provisional radiances, with updates expected soon

Its suite of channels and small size make TROPICS a useful test case for future sensors in the pipeline (AWS, MWS, INCUS, etc.)

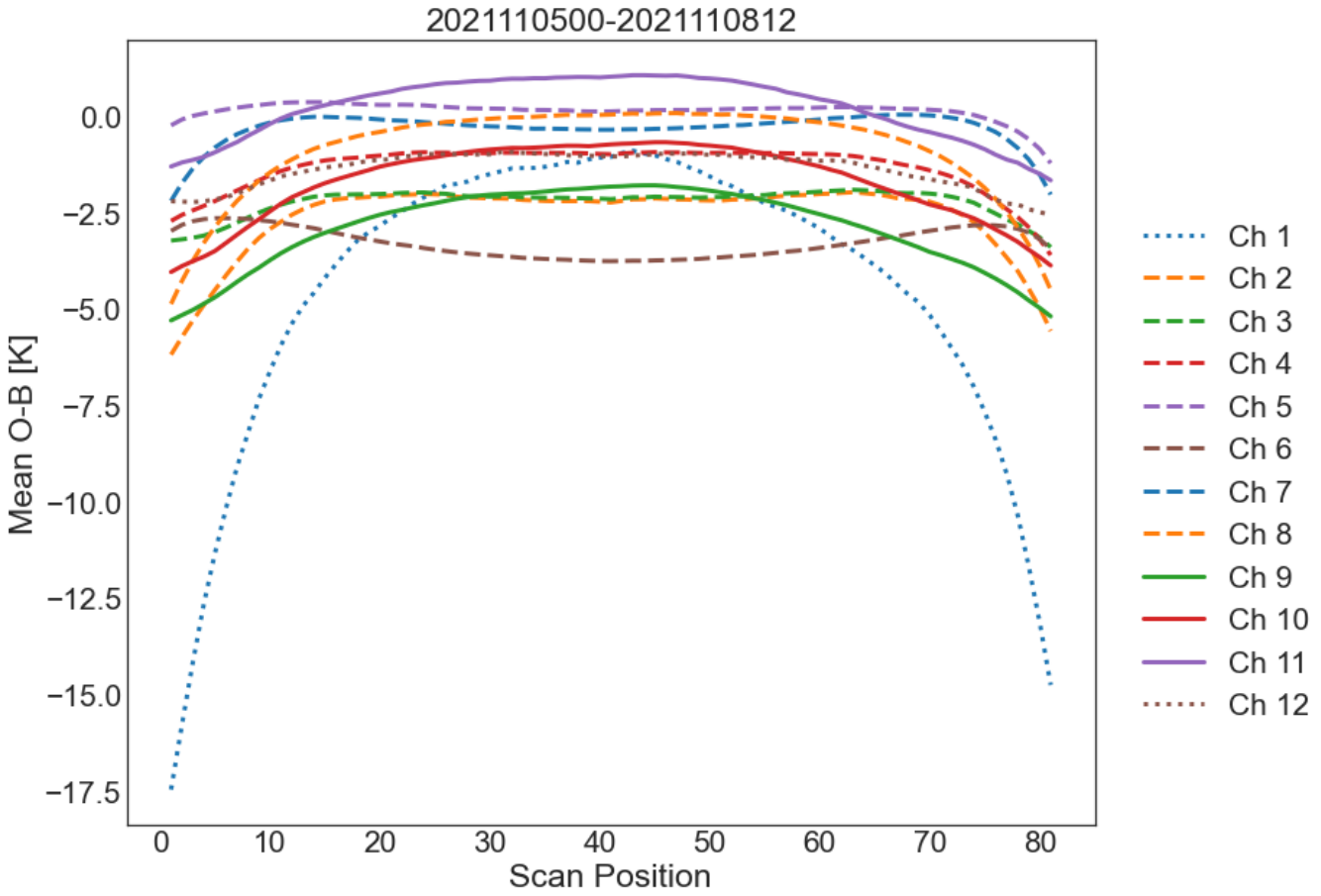


Blackwell et al (2018)

TROPICS Initial Evaluation in the IFS

First look at CubeSat microwave sounder

- Bias characteristics show generally negative bias compared to RTTOV-SCATT v13.0
- Stronger biases near scan edge
- Ch 1 (91GHz) is an outlier, but large bias is mostly handled by VarBC



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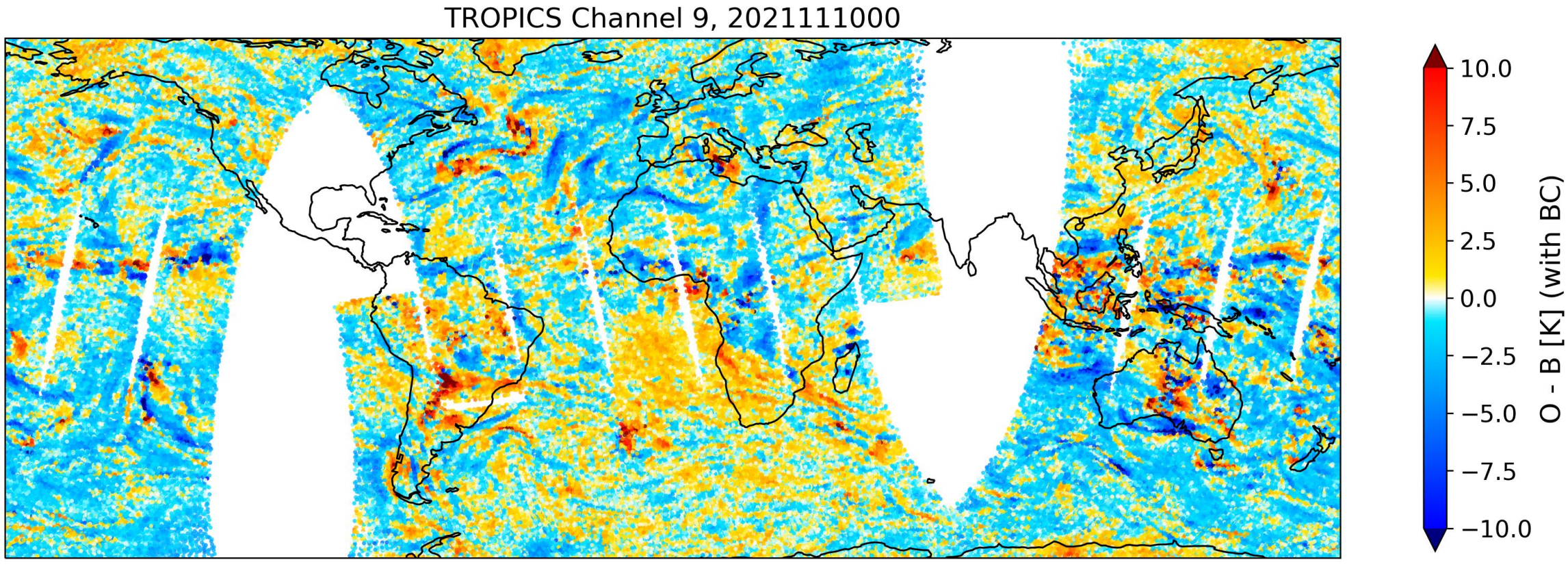
TROPICS Initial Evaluation in the IFS

184.41GHz (Ch 9) is a well-characterized upper tropospheric channel

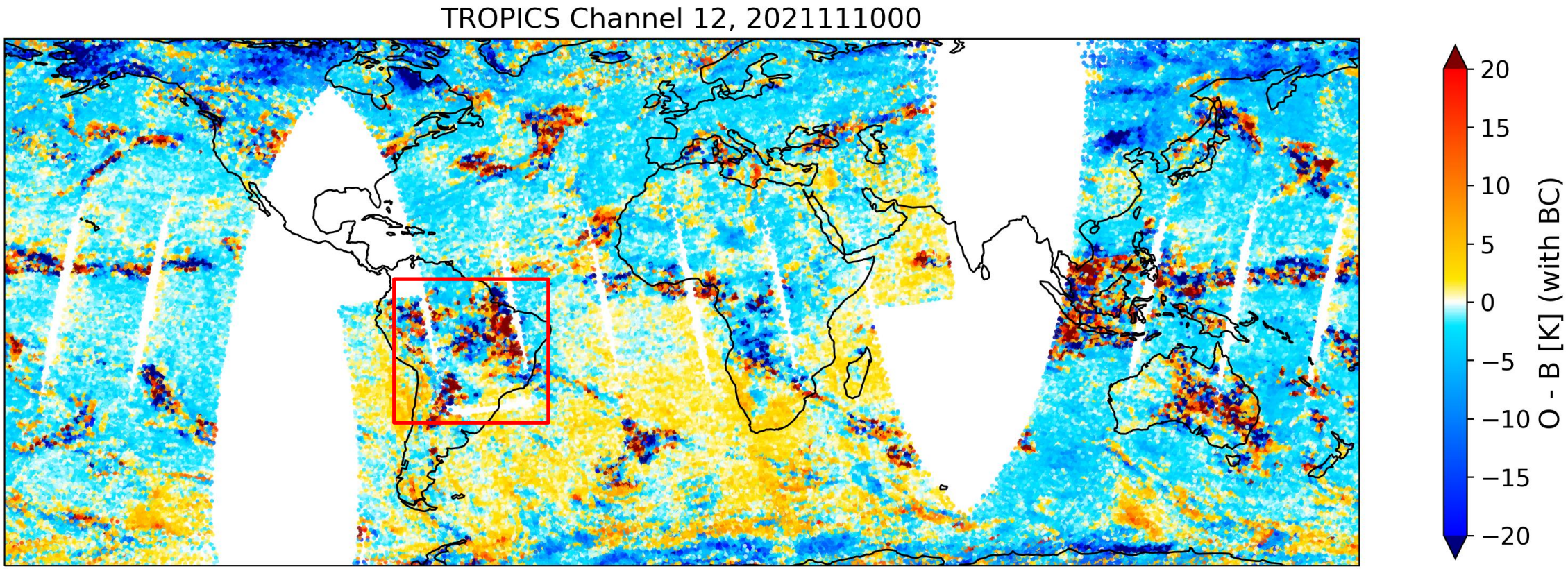
- Some orbital biases present
- Encouraging quality considering no averaging applied yet



TROPICS Initial Evaluation in the IFS

204.8 GHz (Ch 12) is an exciting new channel

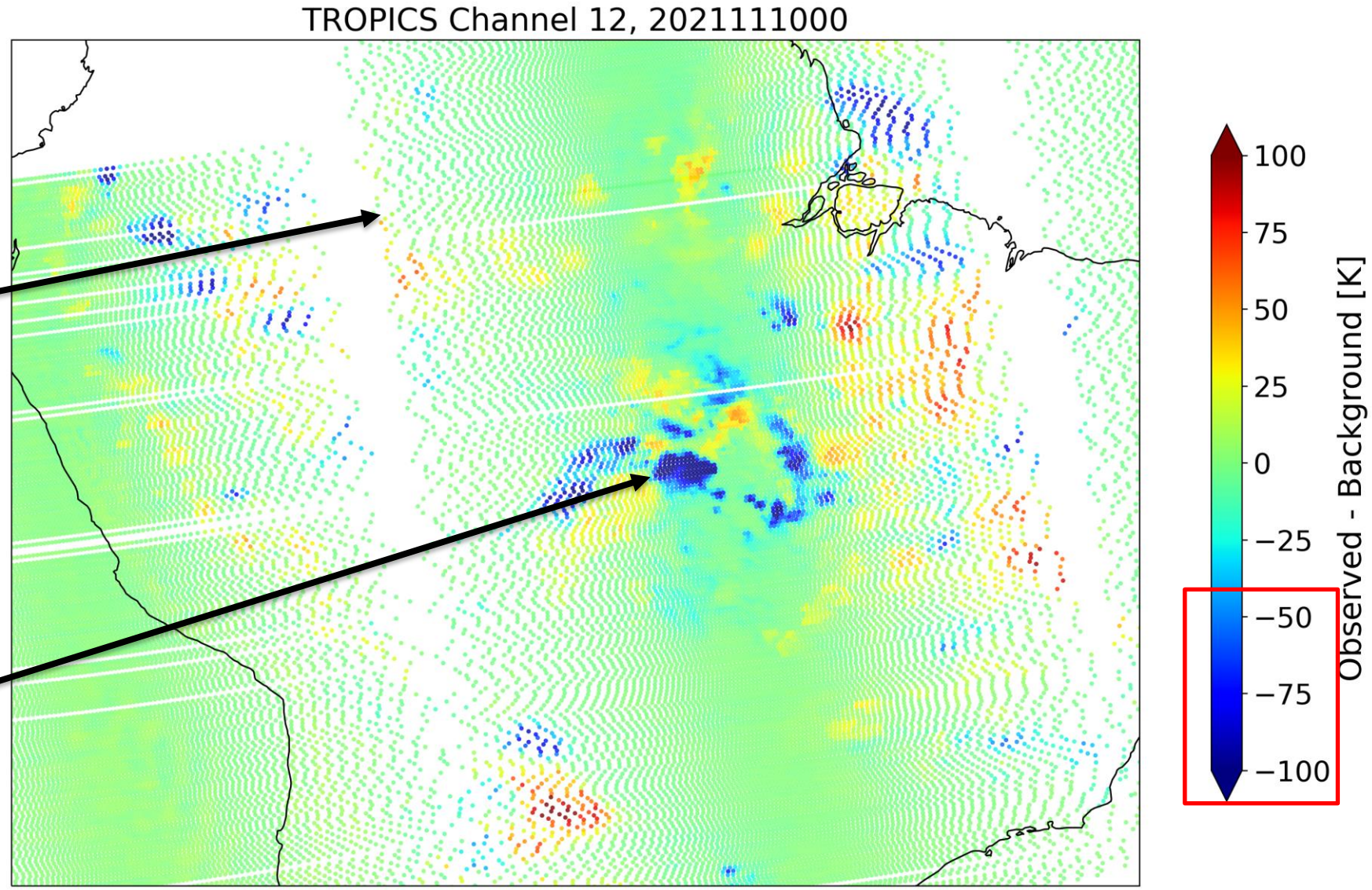
- This window channel sees more scattering from frozen hydrometeors than any sensor flown before – a preview of MWS (229 GHz) and ICI (243+ GHz)
- Good test of scattering for RTTOV-SCATT



TROPICS Initial Evaluation in the IFS

204.8 GHz (Ch 12) zoomed in

- ‘Wobble’ of TROPICS platform seen at scan edges
  - Geolocation within spec (0.94km bias and 2.68km 1-sigma at nadir)
- Very large cloud signals
- Fine resolution (no averaging)
- 100K scattering (!)



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Thanks!

Questions?