



THE USE OF INFRARED RADIANCES FROM GEOSTATIONARY SATELLITES AT ECMWF

OPERATIONAL CHANGES AND RESEARCH DEVELOPMENTS

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EUMETSAT Fellowday 2026



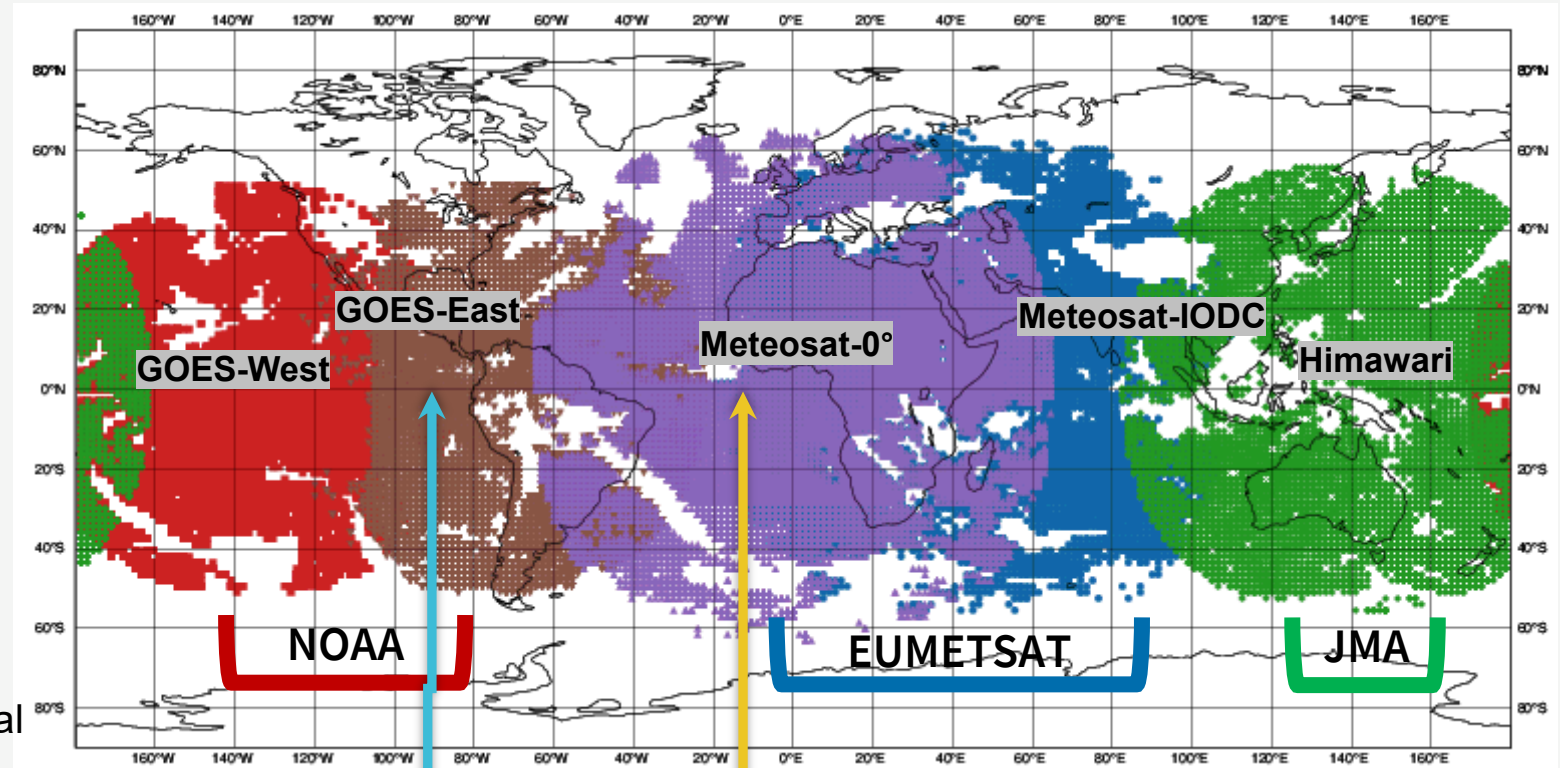
Updates since last fellowday: operational use of GEOS

Currently assimilated operationally

-  GOES-East | GOES-19 (ABI)
-  GOES-West | GOES-18 (ABI)
-  Meteosat IODC | Meteosat-9 (SEVIRI)
-  Meteosat 0° | Meteosat-12 (FCI)
-  Himawari-9 (AHI)

Changes in 2025

- March 2025: start monitoring pre-operational MET12-FCI L2 products.
- April 2025: GOES-East transitioned from GOES-16 to GOES-19.
- November: MET12-FCI L2 products operational assimilation.



GOES-16 ABI → GOES-19 ABI

Meteosat-10 SEVIRI → Meteosat-12 FCI

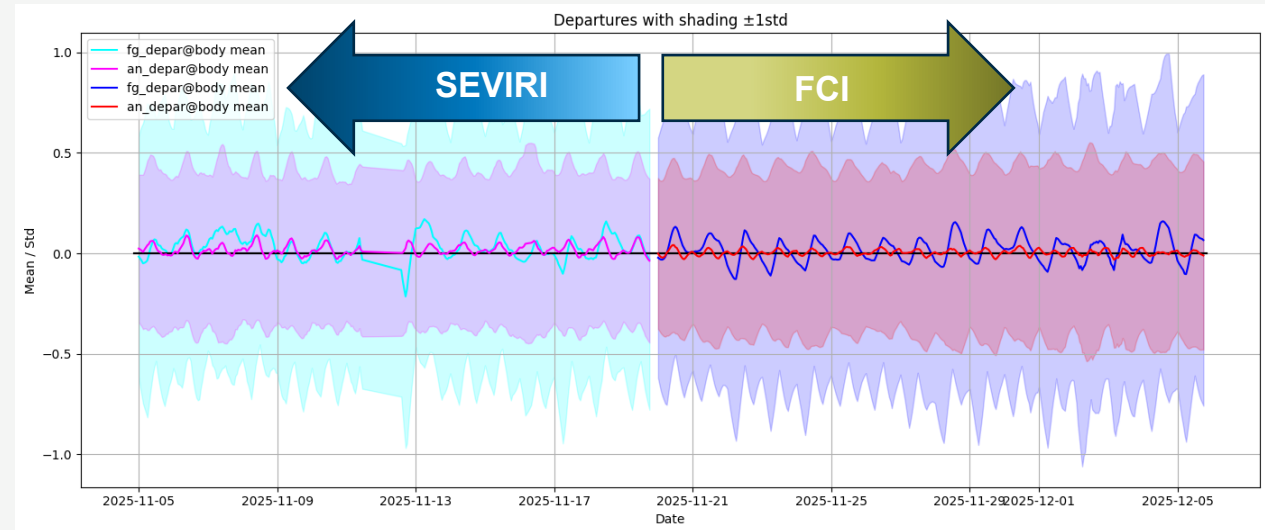
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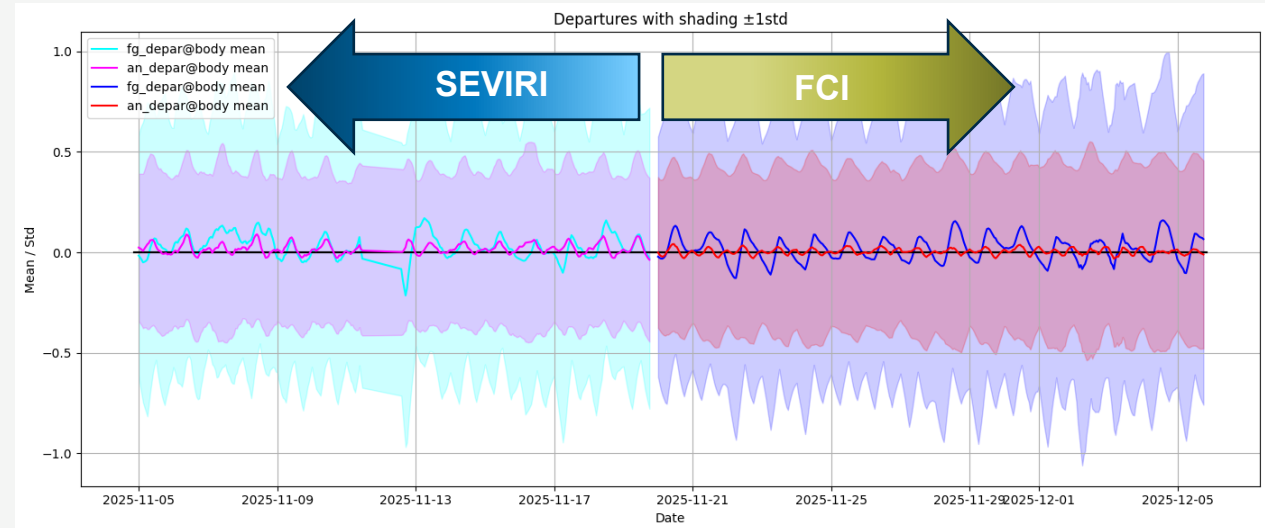
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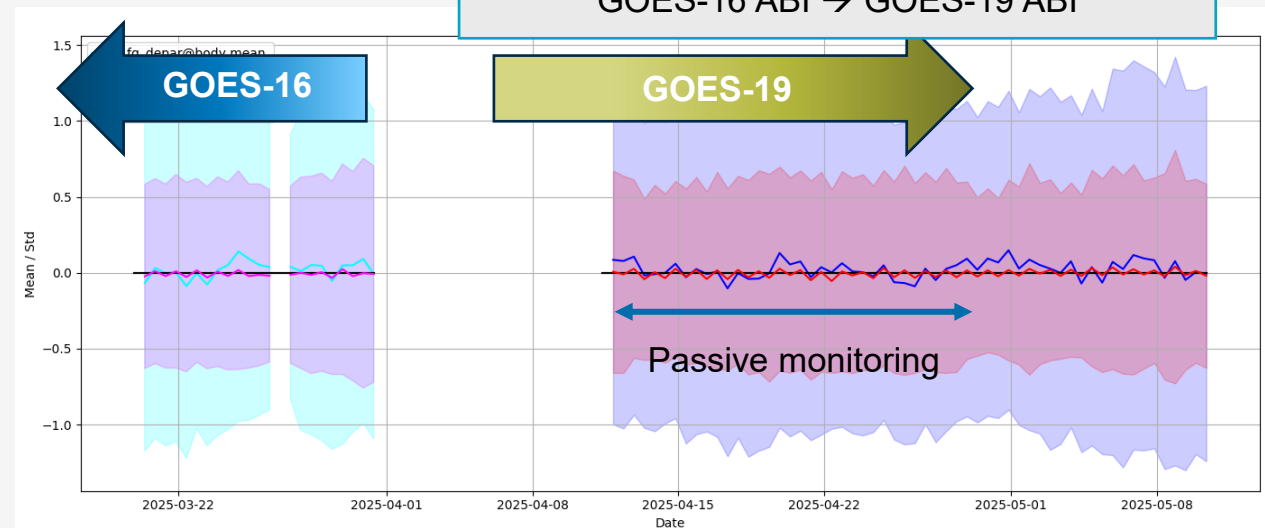
GOES-EAST:

- 1 April: preventive rejection of GOES-16.
- 7 April: GOES-19 becomes operational. Monitored in IFS from 10 April.
- 29 April: activation after varBC stabilisation.

Meteosat-10 SEVIRI → Meteosat-12 FCI



GOES-16 ABI → GOES-19 ABI

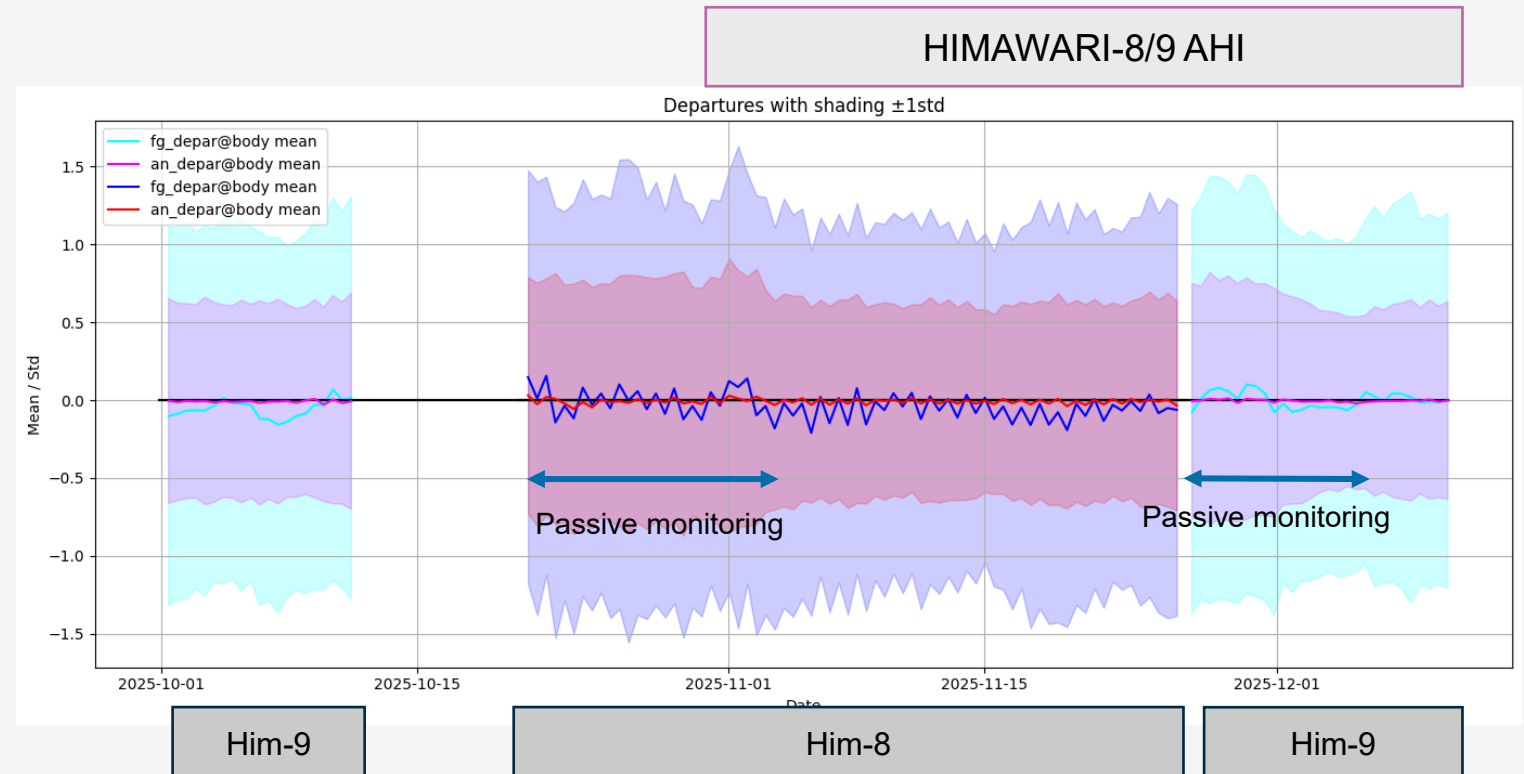


Updates since last fellowday: operational use of GEOS

HIMAWARI outage:

- 11 October: Him-9 unavailable, Him-8 reactivated to ensure continuity of service.
- 20 October: Him-8 passively monitored in IFS
- 3 November: Him-8 activated
- 26 November: Him-9 back, passive monitoring
- 3 December: Him-9 reactivated

Identified as telecommunication problem

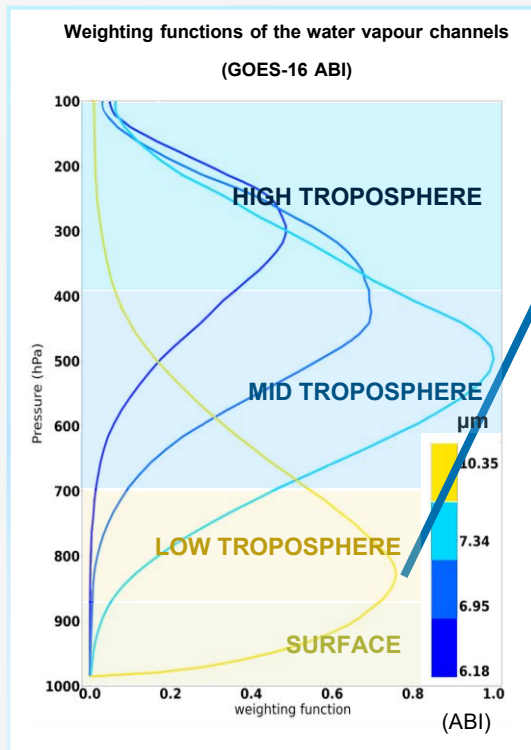


Update since last fellowday: GEO window channel

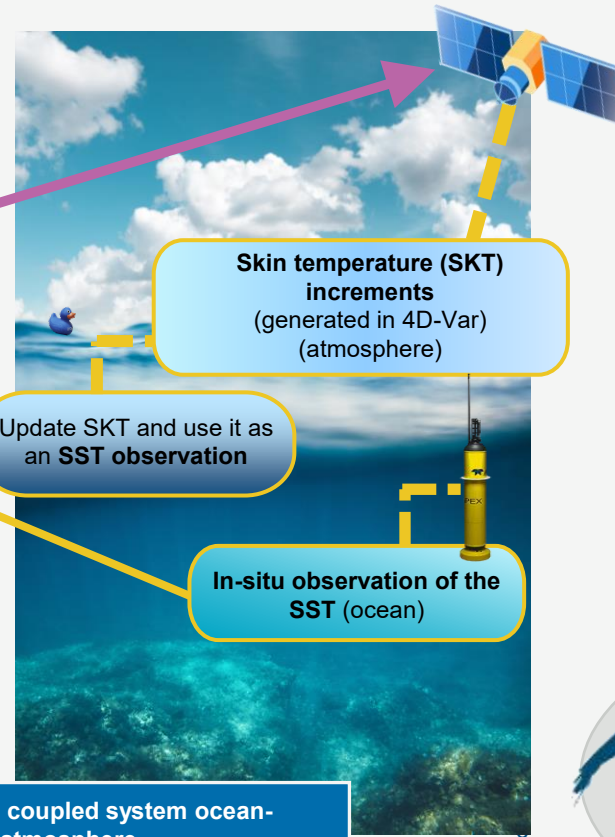
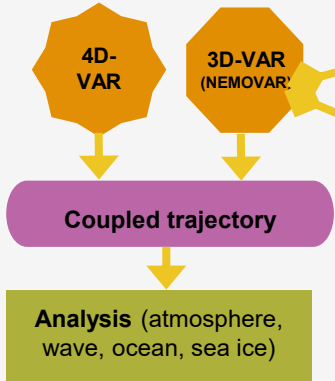
- Development and usage in coupled system: last year we have seen that the coupled assimilation of GEOS window channels are beneficial in the lower layers of the atmosphere and near-surface ocean temperature.
- **Issue found for AHI and FCI:** malfunctioning dust filter.

QUALITY CONTROL:

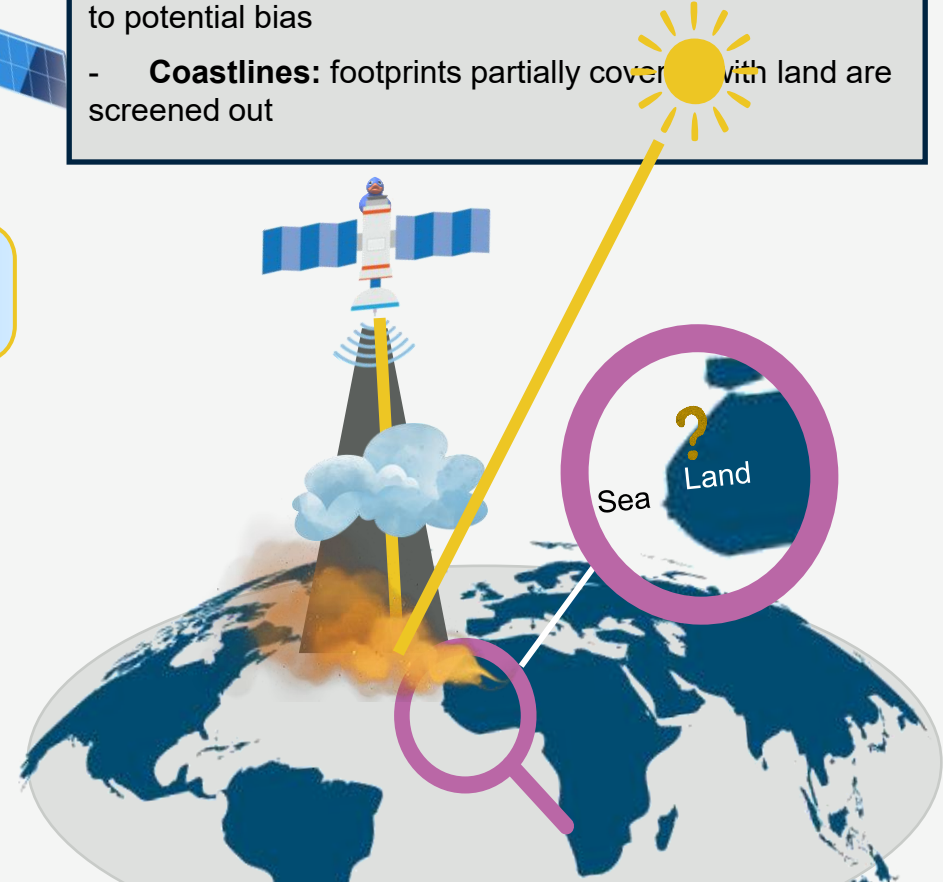
- **Clouds:** more stringent quality control on clouds.
- **Dust:** Use channel around 12 μm to help detect scenes potentially contaminated by dust.
- **Solar glint:** low solar glint angles screened out due to potential bias
- **Coastlines:** footprints partially covered with land are screened out



Exploiting the window channel in clear-sky = observing the surface



ECMWF-IFS coupled system ocean-atmosphere



GEO window channel (IR10.5 μ m): bug

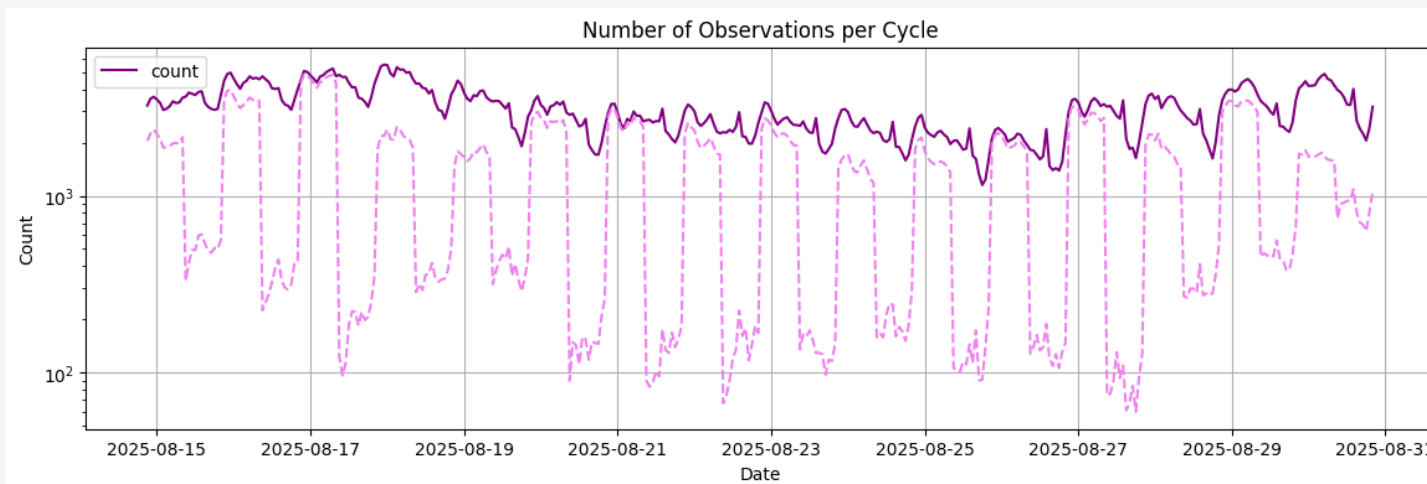
- Development and usage in coupled system: last year showed that the coupled assimilation of GEOS window channels are beneficial
- **Issue found for AHI and FCI:** malfunctioning dust filter.
- Massive drop in counts of used data coinciding with IFS assimilation windows.

The rejection is caused by false alarms in the dust detection.

In IFS, VarBC coefficients are computed within a given assimilation window and then applied to the next window. For Himawari-AHI, the LW00 window (21–09 UTC) corresponds to local daytime over Japan and the Pacific, whereas LW12 (09–21 UTC) corresponds to local nighttime.

As a result, bias correction estimated under daytime conditions are applied during nighttime. For the IR12 window channel used in dust detection, this leads to an incorrect increase of the bias during local nighttime, which in turn triggers false dust detections and a large rejection of observations.

For reliable dust detection, VarBC should therefore be deactivated for this channel.



Counts AHI window channel,
all data (purple) and used
(dashed pink)

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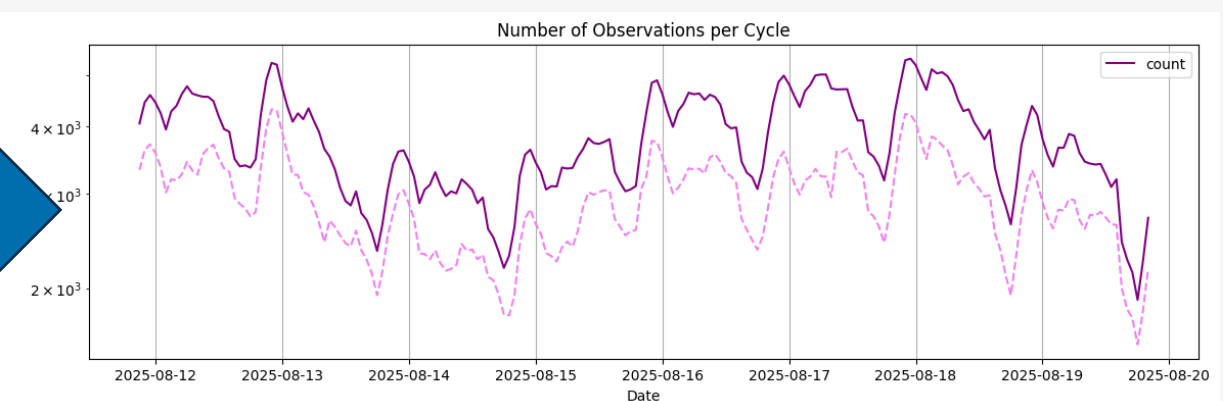
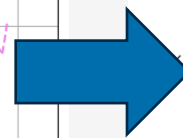
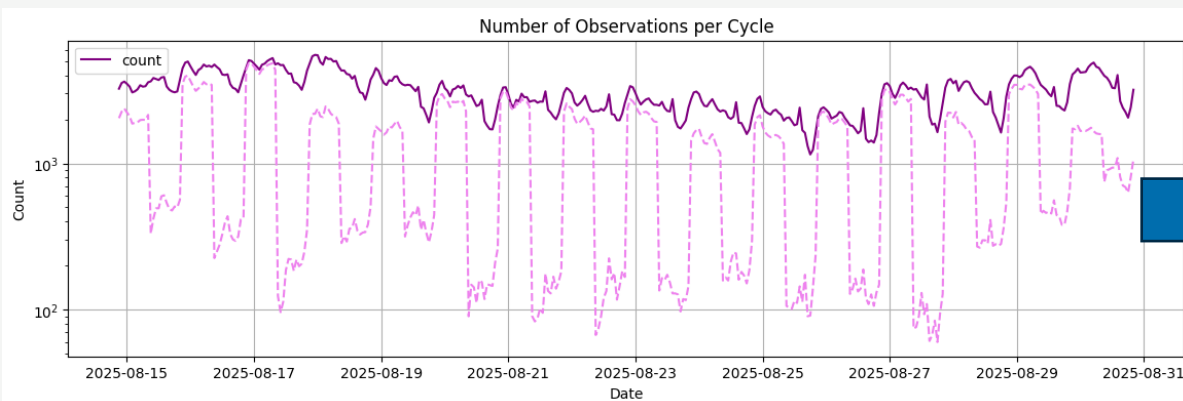
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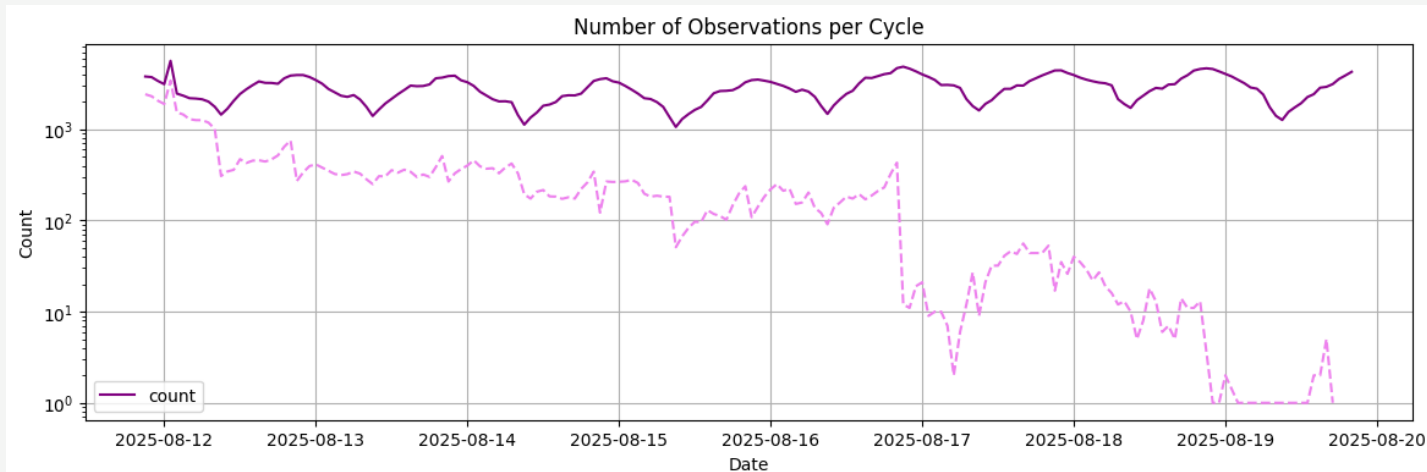
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GEO window channel (IR10.5 μm): bug

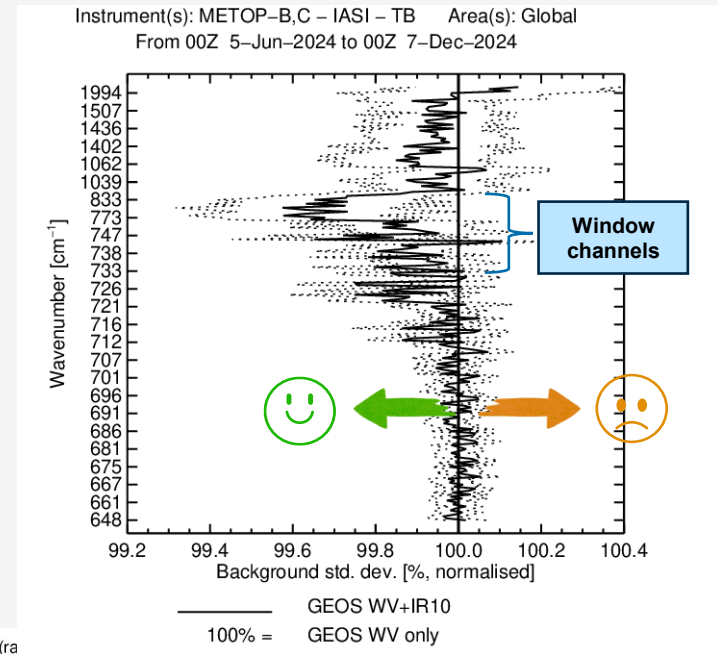
- A similar issue is observed for FCI, although the behaviour differs slightly. The bias correction applied to the IR12 channel increases the occurrence of dust false alarms within a given assimilation window, leading to rejection of observations.
- As a result, fewer observations are available for the following VarBC estimation. The bias correction is then computed from a reduced and potentially unrepresentative sample, which further degrades the correction. This creates a snowball effect: increased false alarms lead to more rejections, which in turn worsen the bias estimation in the next window. After a few cycles, the number of assimilated observations drops to zero in a couple of days.



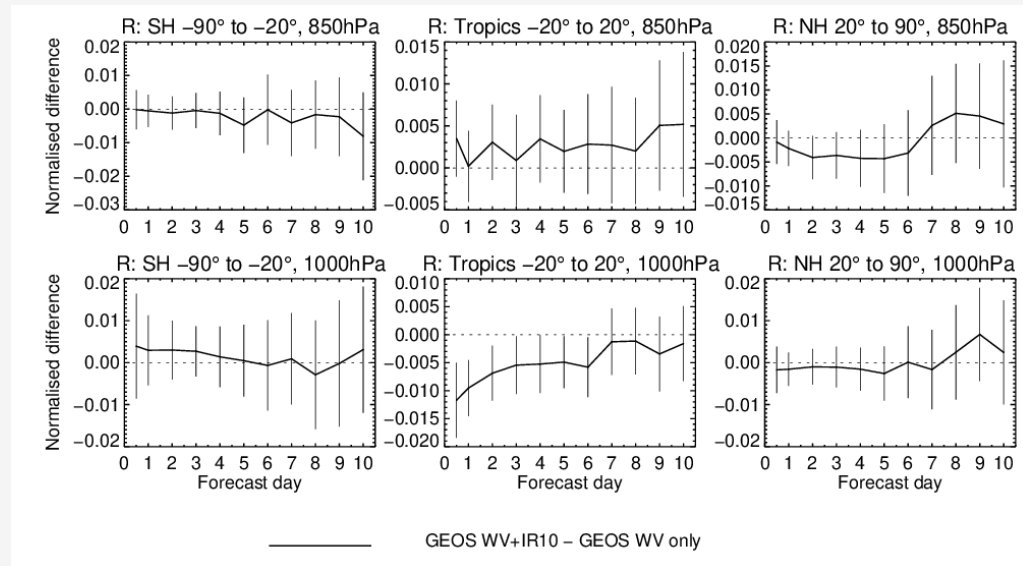
Counts FCI window channel,
all data (purple) and used
(dashed pink)

GEO window channel (IR10.5 μm): bug fixed

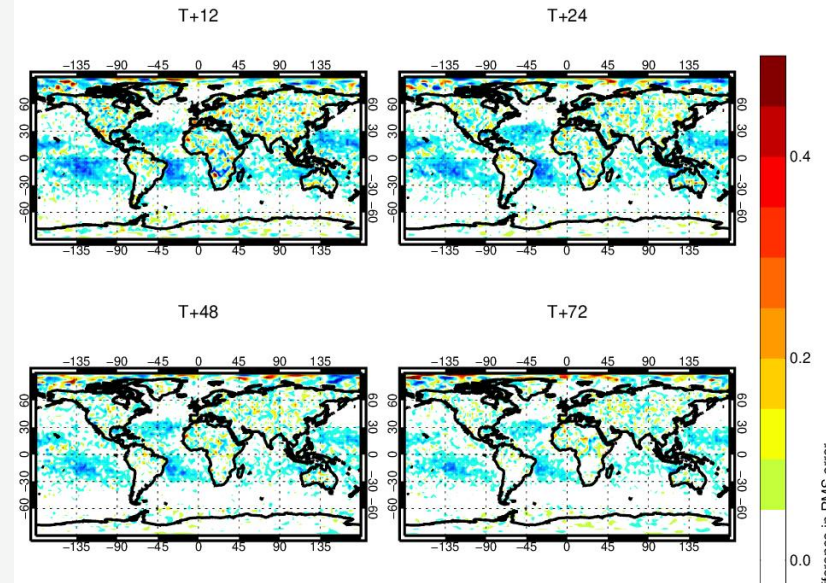
- With those additional fixes for AHI and FCI:
 - Improvements in humidity field at lower levels in Tropics and SKT, neutral impact elsewhere.
 - Improved fit to independent clear-sky window channels (IASI).
 - Improvements in fit to in-situ ocean temperature observation in the first layer of the ocean (up to 9m). Synergistic impact when used together with MW satellite observations (Tracy Scanlon's work, [Scanlon et al, 2026](#)).



Normalised difference in RMSE in R field by assimilating the GEOS window channel in addition the WV channels. June 2024 + December 2024.



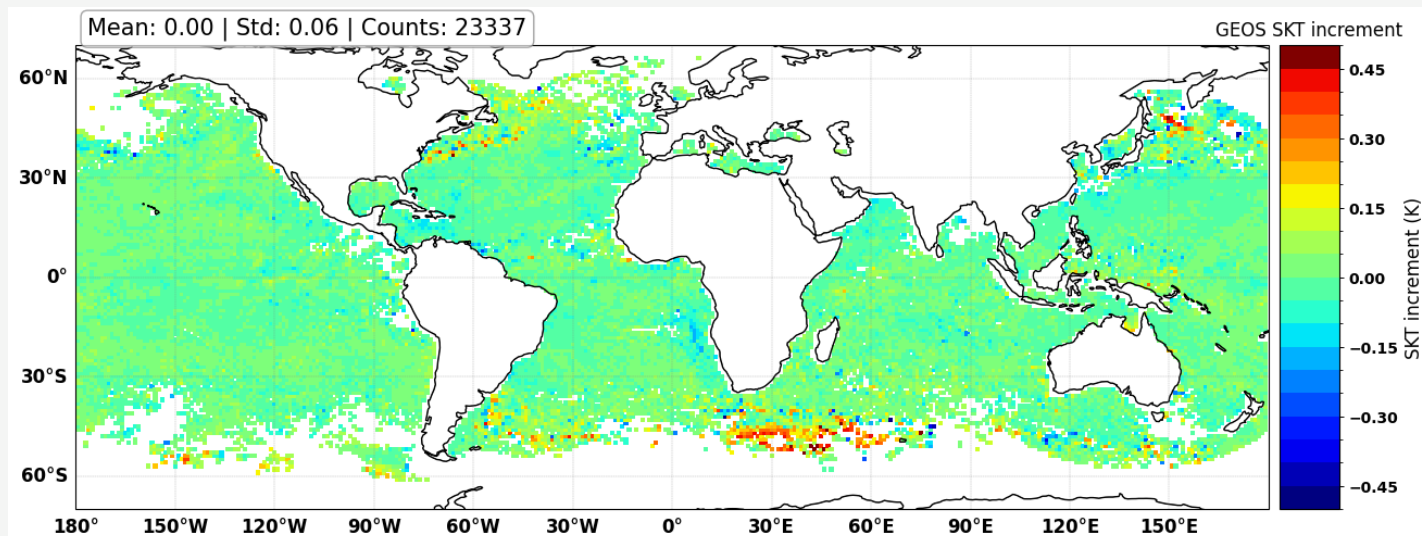
Change in RMS error in SKT (GEOS WV+IR10 (ra) 7-Jun-2024 to 9-Dec-2024 from 72 to 96 samples. Verified against own-analysis. No statistical significance testing applied.



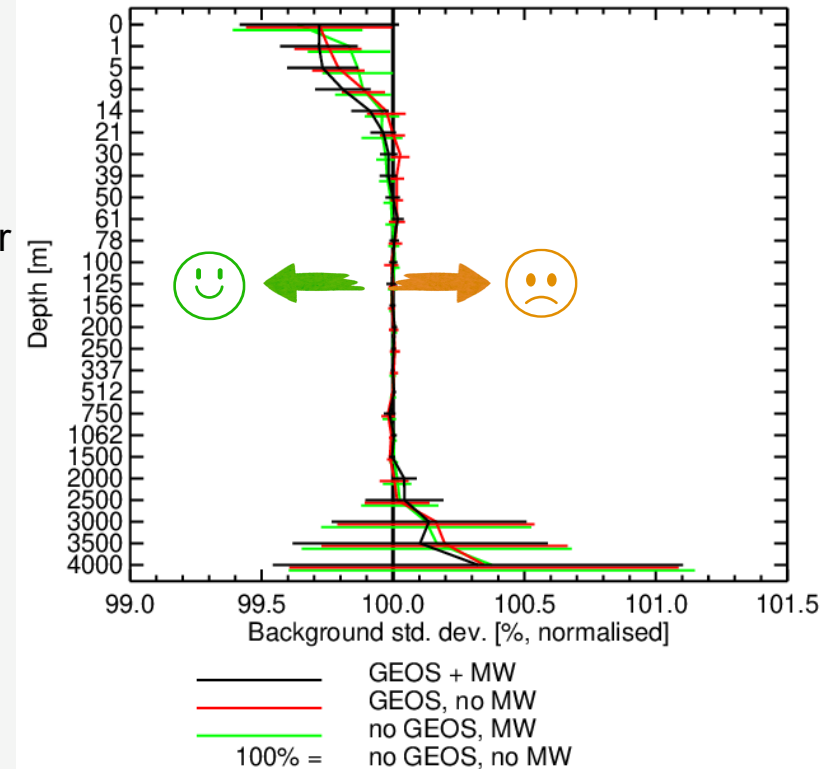
Normalised difference in RMSE in SKT field by assimilating the GEOS window channel in addition the WV channels. June 2024 + December 2024.

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 - Realistic ocean SKT increments.
- Paper on the way.



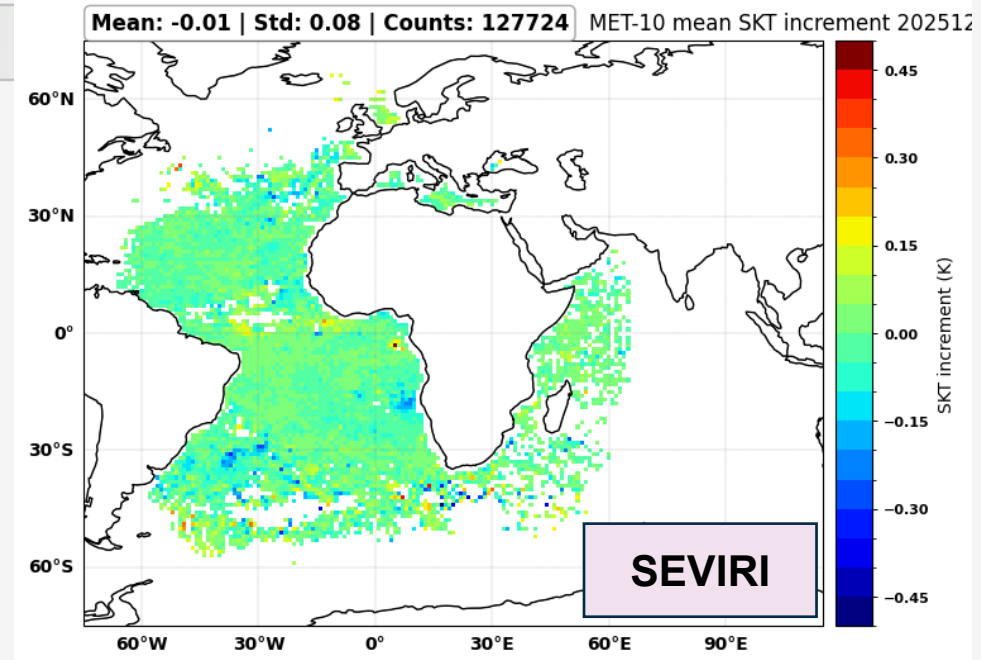
Instrument(s): ARGO – ARGO – POTM Area(s): Global
From 00Z 5-Jun-2024 to 00Z 7-Dec-2024



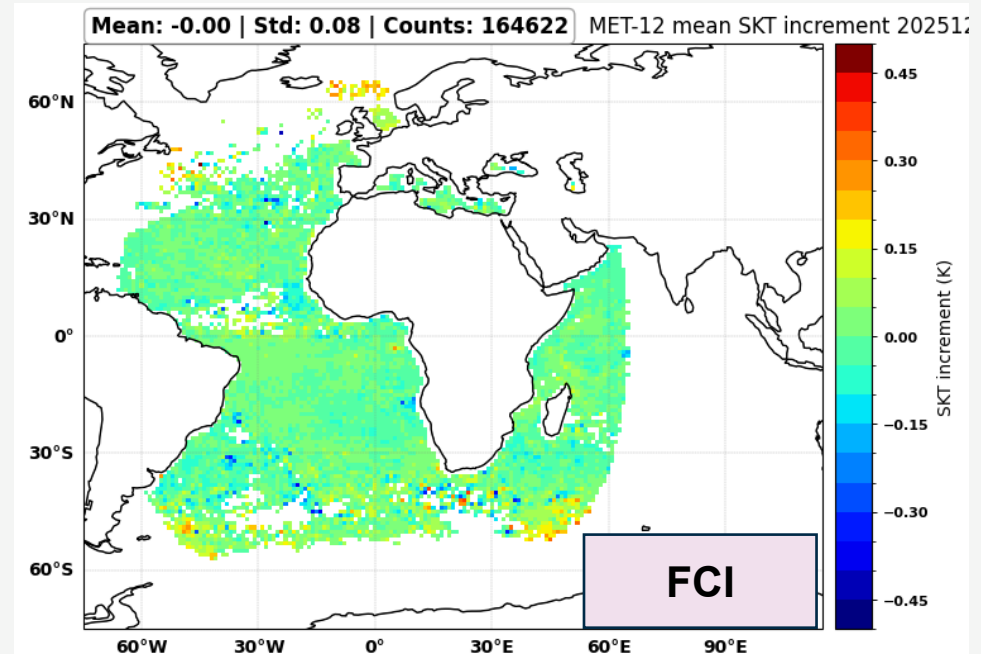
GEOS SKT increments
2024-06-07 to 2024-06-20

GEO window channel (IR10.5 μm): bug fixed

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 - Realistic SKT ocean increments.
- Paper on the way.
- FCI window channel assessment: similar signals to SEVIRI.

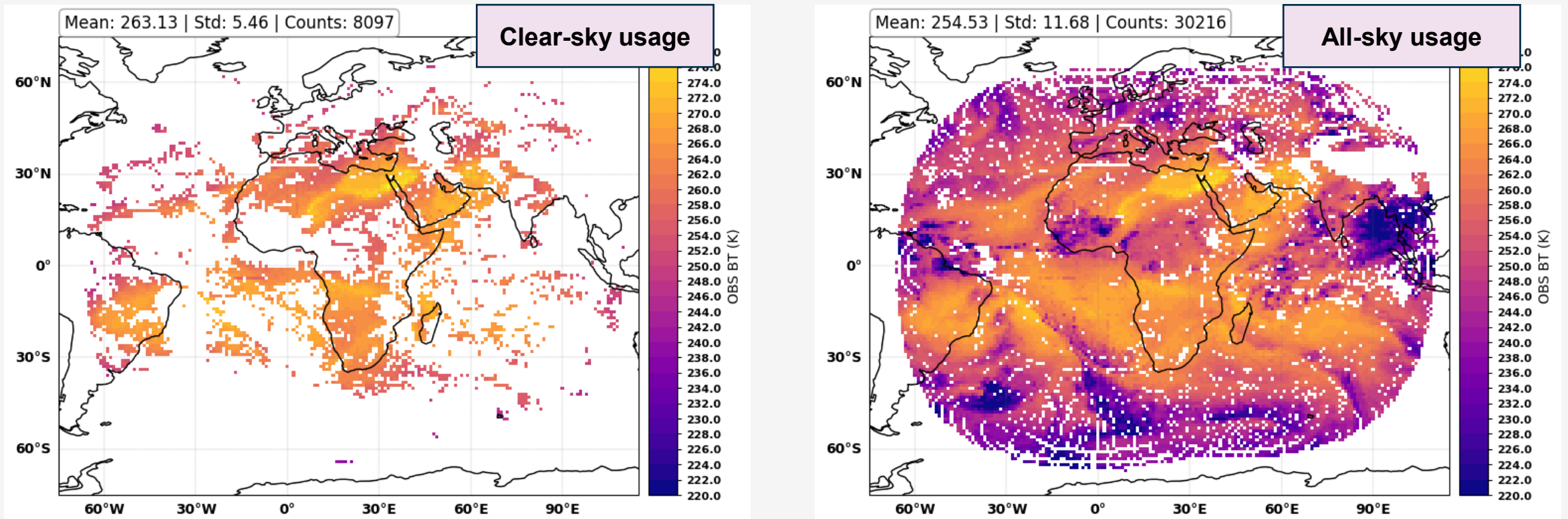


*MET10-SEVIRI (top) and MET12-FCI (bottom) SKT increments
2025-12-06 to 2025-12-16*



New developments: allsky IR assimilation

- Motivation: clear-sky vs allsky SEVIRI spatial coverage (+59% of used data for WV6.3 μm , more than 3x more used data for WV7.3 μm).
- Complementary with allsky MW observations already assimilated at ECMWF.



MET-9 and MET-10 SEVIRI WV7.3 observation BT on 2024-06-10 at 09:45 UTC : use in clear-sky (left) and all-sky (right)

GEOS IR radiances assimilation in allsky

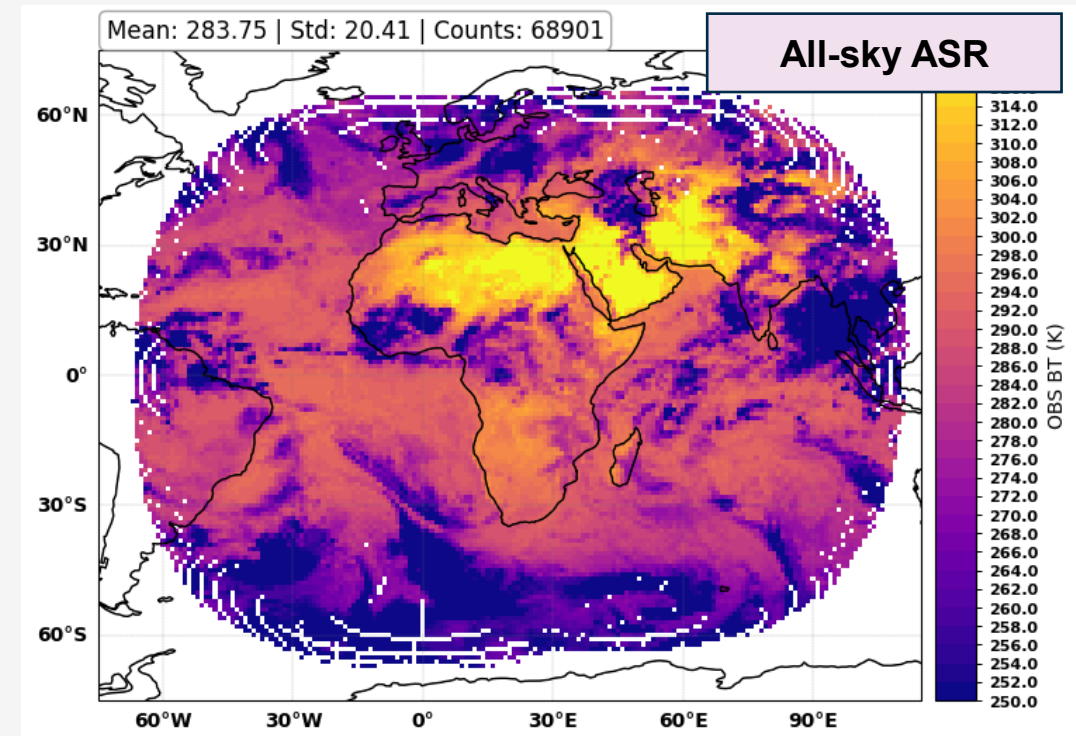
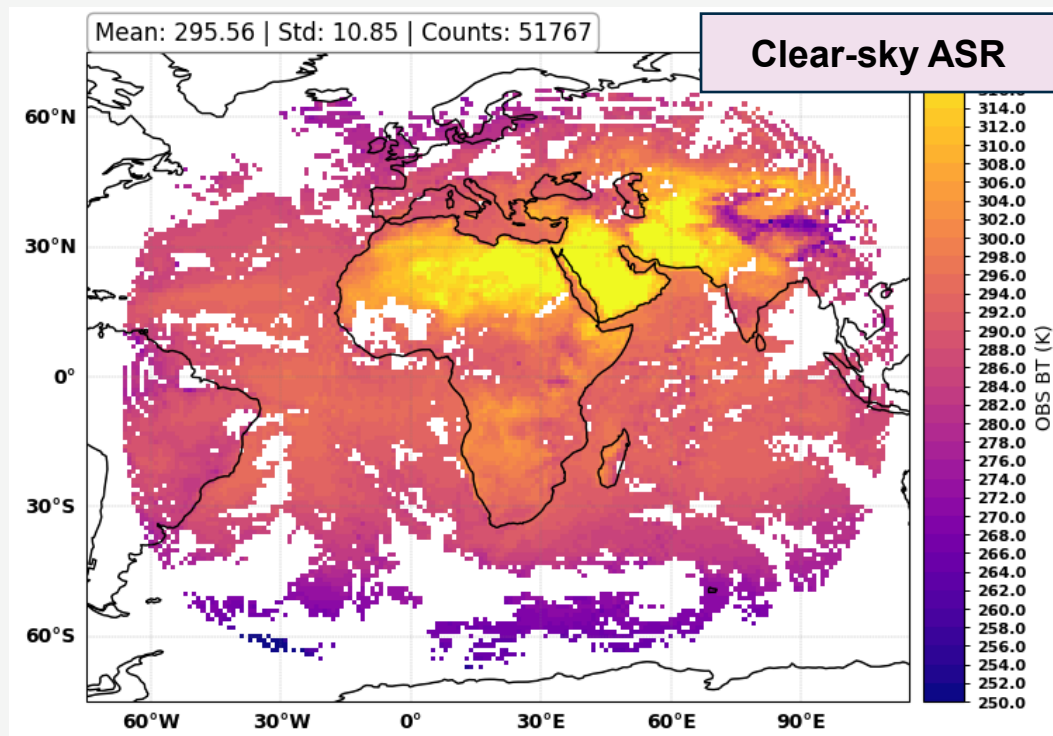
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Plan for GEOS all-sky IR assimilation:

Channels	Clearsky assimilation (operational use from CY50R1)	Allsky assimilation (plans)
WV 6.2 μm	CSR – assimilated	ASR – assimilated
WV 7.3 μm	CSR – assimilated	ASR – assimilated
IR 10.8 μm	CSR – ocean only assimilated Also assimilated for ocean temperature increments	ASR – ocean only , cloud screening (clear-sky) to keep supporting ocean temperature analysis
IR 12.2 μm	CSR – used for dust detection in the IR10.8 window channel	Probably not needed
IR 13.3 μm	CSR – monitored	ASR – assimilated (under investigation)

GEOS IR radiances assimilation in allsky

- As shown before, IR10.8 μm window channel is assimilated as an ocean-surface sensitive channel. To keep the benefits brought by the assimilation of this GEO channel, we need to keep using it over ocean in clear-sky only.
- Challenge in allsky assimilation context: previously we used the CSR product which is cloud-free but for allsky assimilation we need to move to ASR observation for all channels, even the ones we want in clear-sky.

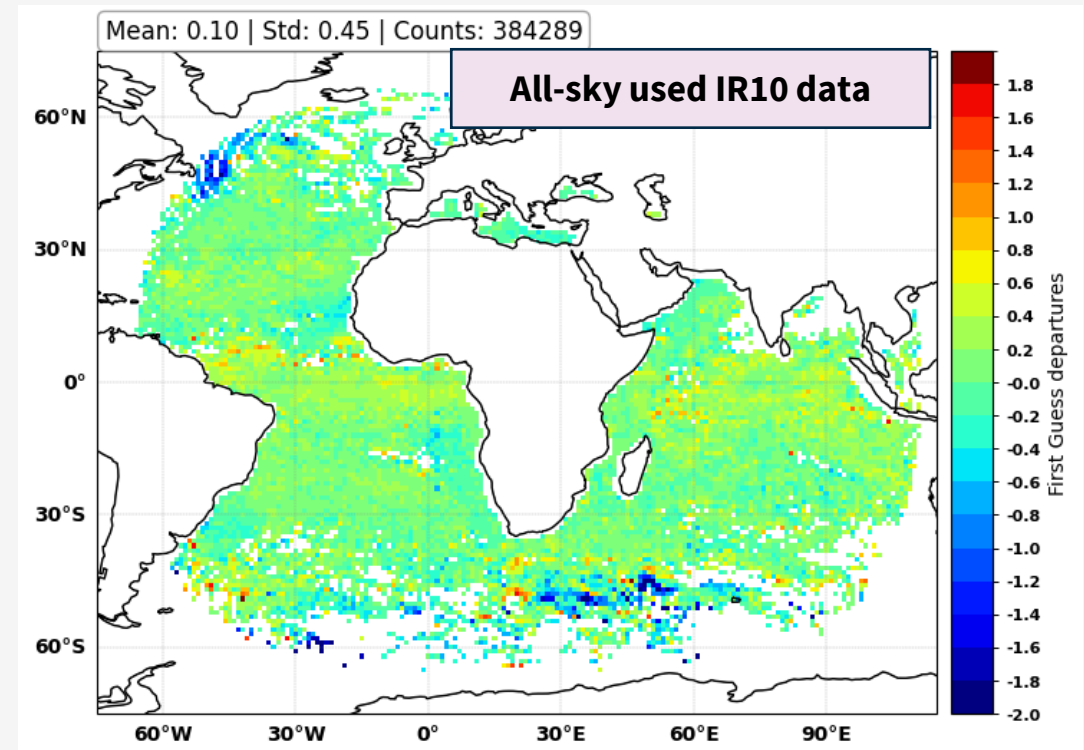
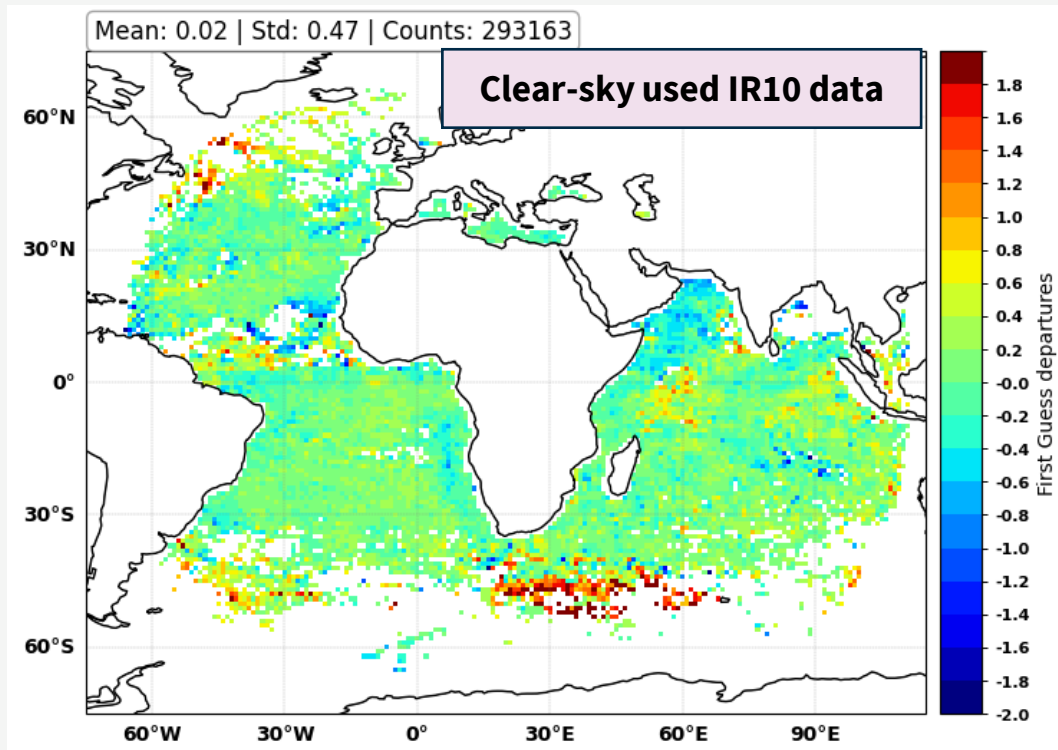


GEOS IR radiances assimilation in allsky: **IR10 in clear-sky**

- **Clear-sky quality control for CSR** used for coupled assimilation presented before would not work in allsky assimilation pathway: both observation clouds and model clouds need to be detected and screened to ensure assimilating only clear-sky departures.
- Cloud detection **in allsky framework** can make use of RTTOV simulated brightness temperature. RTTOV simulates the brightness temperature in clear-sky (BT_clr) in addition to the one simulated including the impact from clouds in radiative transfer (BT_all).
 - Model cloud detected: $BT_clr - BT_all > 0.6 \text{ K}$
 - Observation cloud detected: $BT_clr - OBS_all > 0.8 \text{ K}$
 - Data screened when a cloud is detected in model and/or observation => around 93% of the data appear as cloud contaminated.

GEOS IR radiances assimilation in allsky: IR10 in clear-sky

- Allsky experiment : IR10.8 observation error is larger than in clear-sky setup.
- Allsky background simulation still exhibits some missed low clouds. Work in progress to have a clear-er use of the IR10.8 channel in allsky (varQC implementation helps handling outliers, introduction of another low tropospheric peaking channel helps also with cloud detection, RTTOV hydrometeor settings).

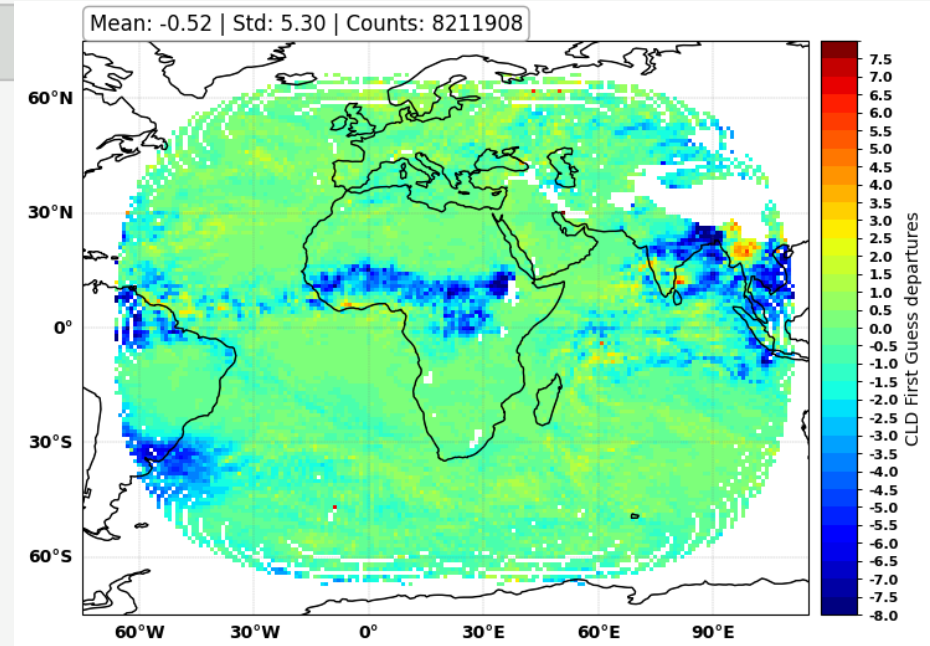


GEOS IR radiances assimilation in allsky: WV channels

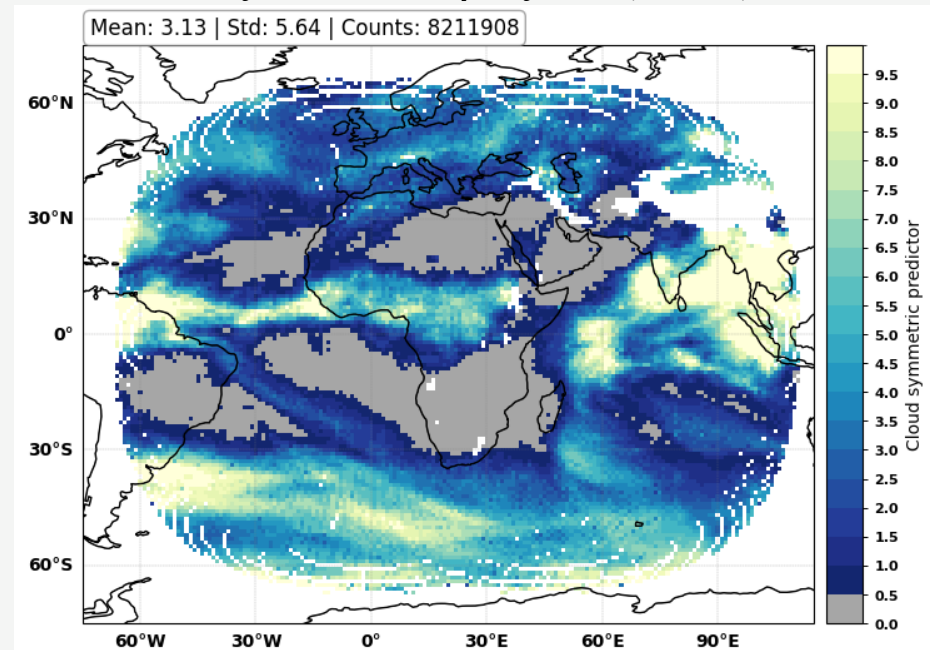
- Allsky assimilation of the water vapour channels:
 - Observation errors are higher over cloudy scenes, important to take this into account.
 - MW allsky observation are assimilated with scene-dependent observation error. The scene is characterised with a cloud proxy to assess the cloudiness.
 - IR allsky assimilation studies (e.g. Okamoto et al. 2014, 2023; Geer et al. 2019) have shown that the following cloud proxy quantifies well the cloud impact on IR channels:

$$\text{CSYM} = \frac{\overbrace{(\text{FG_clr} - \text{FG_all})}^{\text{Cloud impact on first guess}} + \overbrace{(\text{FG_clr} - \text{OBS_all})}^{\text{Cloud impact on observation}}}{2}$$

- High values indicates a high cloud impact on the channel, The observation error value needs to be higher than clear-sky.

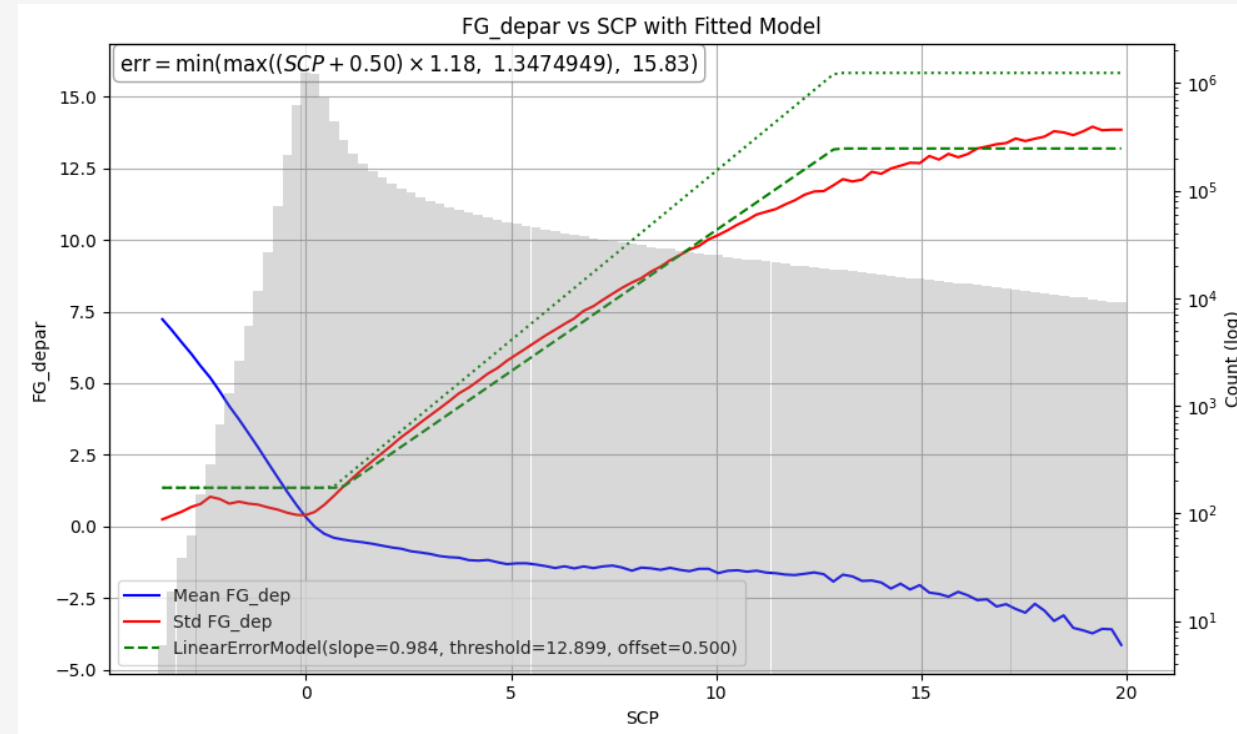


MET-9 and MET-10 SEVIRI WV7.3 used first guess departures (top) and symmetric cloud proxy value (bottom)



GEOS IR radiances assimilation in allsky: WV channels

- Following MW developments (Geer and Bauer, 2010), the observation error is diagnosed starting from a linear fit to **stdev error of the first guess (red line)** departures as a function of the symmetric cloud proxy.
- For clear scenes (low cloud proxy values), the observation error is inflated to a fixed minimum value (here we use the operational clear-sky observation error value).
- Then, the observation error grows linearly until we reach a plateau.
- This diagnosed **observation error model** is then inflated (factor of 1.2 for WV channels) : dotted green line.

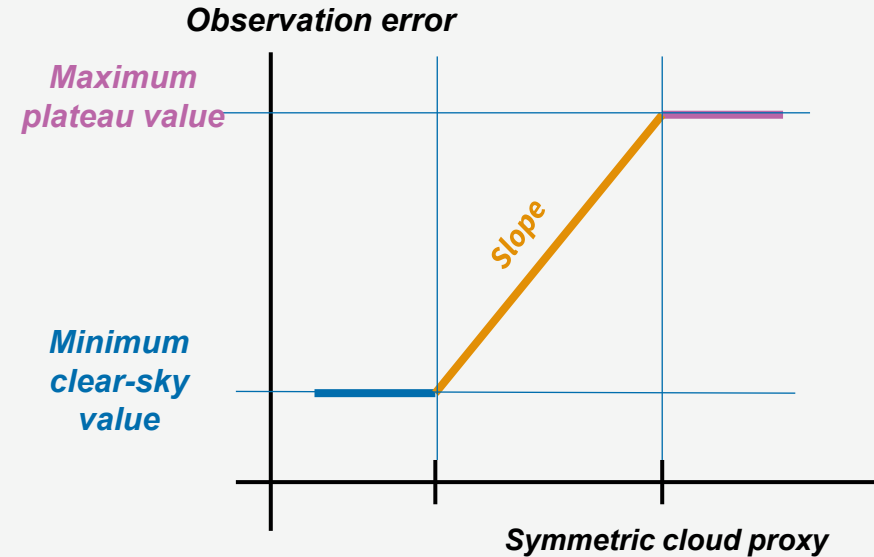


MET-9 and MET-10 SEVIRI WV7.3 scene-dependent observation error model

$$CSYM = \frac{(FG_{clr} - FG_{all}) + (FG_{clr} - OBS_{all})}{2}$$

GEOS IR radiances assimilation in allsky: WV channels

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- Then, the observation error grows linearly until we reach a plateau.
- This diagnosed **observation error model** is then inflated (factor of 1.2 for WV channels) : dotted green line.
- Can also be surface-type dependent, observation errors over land are often higher than over sea



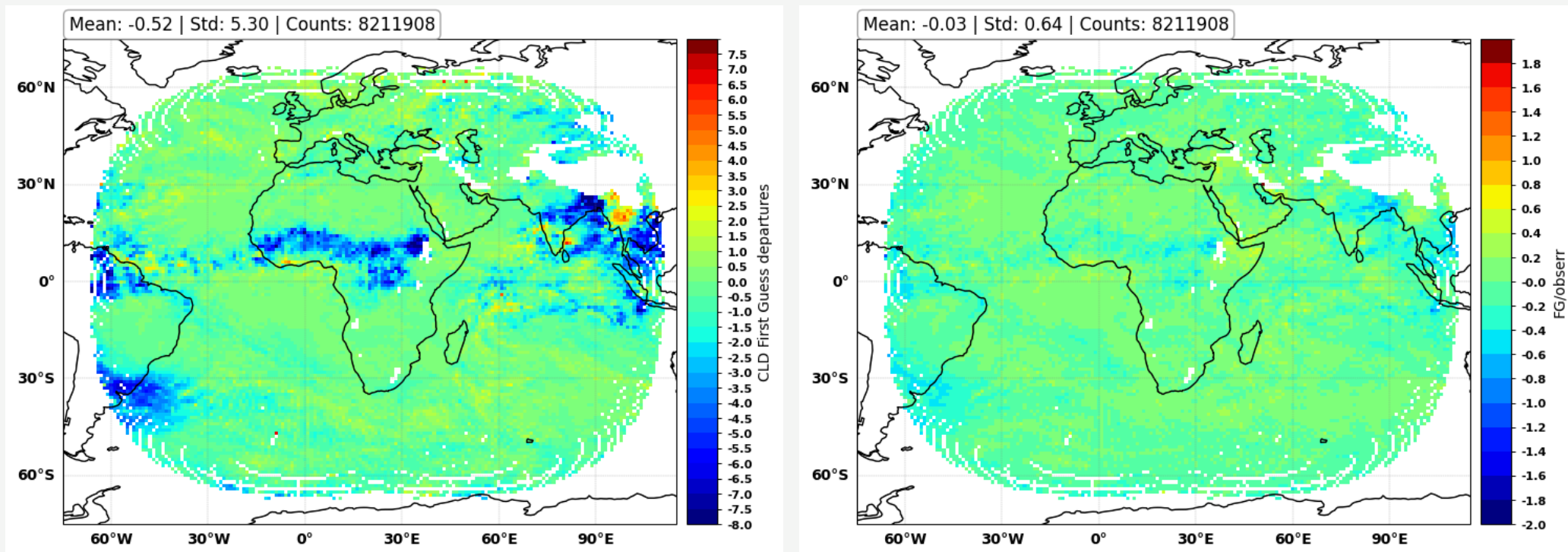
$$\text{obserror} = \text{MIN}(\text{MAX}(\text{min_clr}, (\text{CSYM} * \text{slope})), \text{max_cld})$$

WV7.3	ALL	SEA	LAND
MIN	1.35	1.35	1.35
SLOPE	1.17	1.12	1.29
MAX	15.72	13.81	20.18

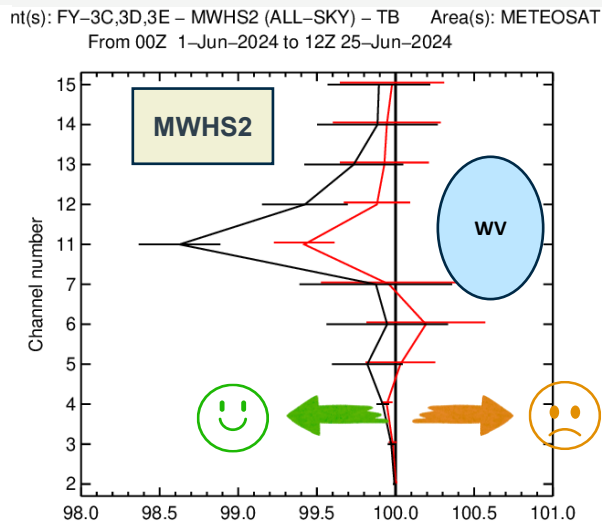
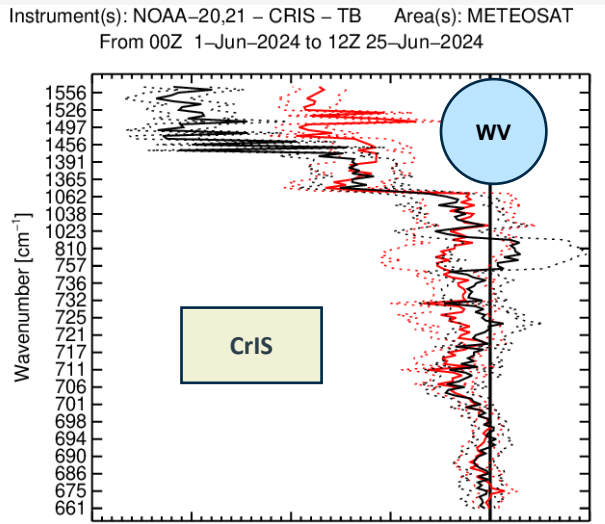
GEOS IR radiances assimilation in allsky: WV channels

To assess if the observation error model captures well cloud uncertainties, the normalised first-guess departures ($FG_departure / obs_error$) indicate whether the departures are statistically consistent with the prescribed observation errors.

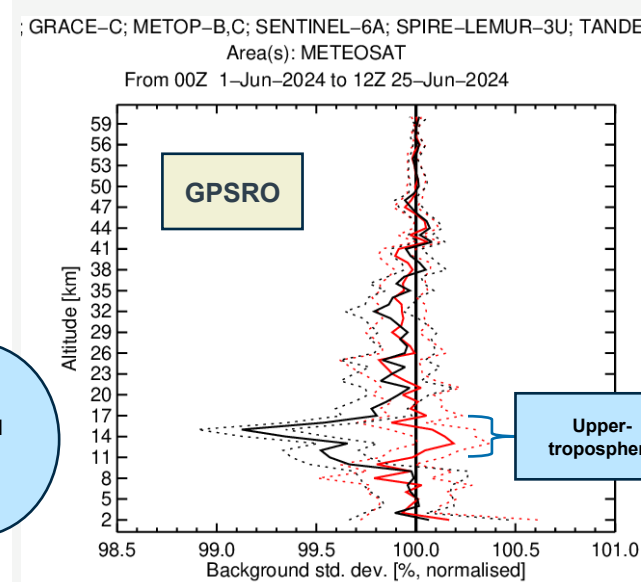
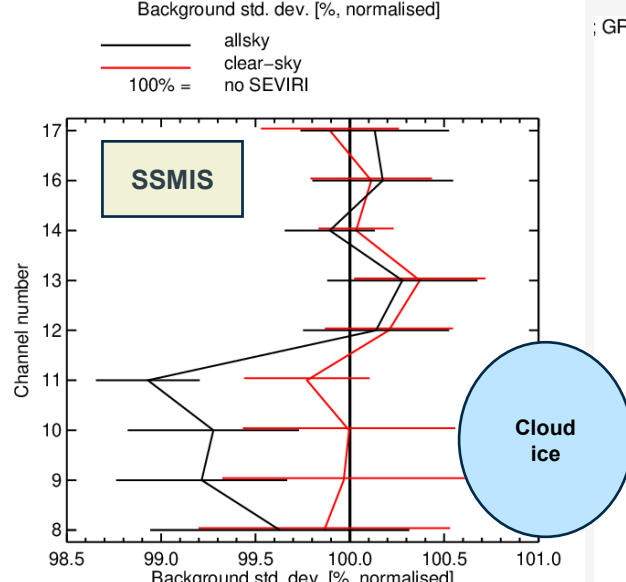
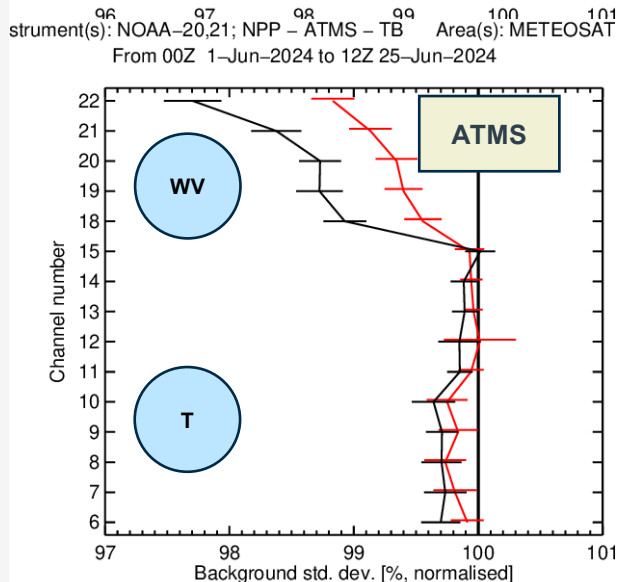
MET9 and MET-10-SEVIRI WV7.3 used first guess departures (left) and normalised first guess departures by their observation error (right)



GEOS IR radiances assimilation in allsky: WV channels



- Control (100%) is an experiment where SEVIRI is fully rejected
- Red line: Control + SEVIRI assimilated in clear-sky
- Black line: Control + SEVIRI assimilated in all-sky
- Improved fit to clear-sky (CrIS, ATMS) and allsky (MWHS2, SSMIS) observations.



Assimilating WV channels in allsky improves significantly the fit to independent satellite (clear-sky and allsky) observations compared to assimilating them in clear-sky only.

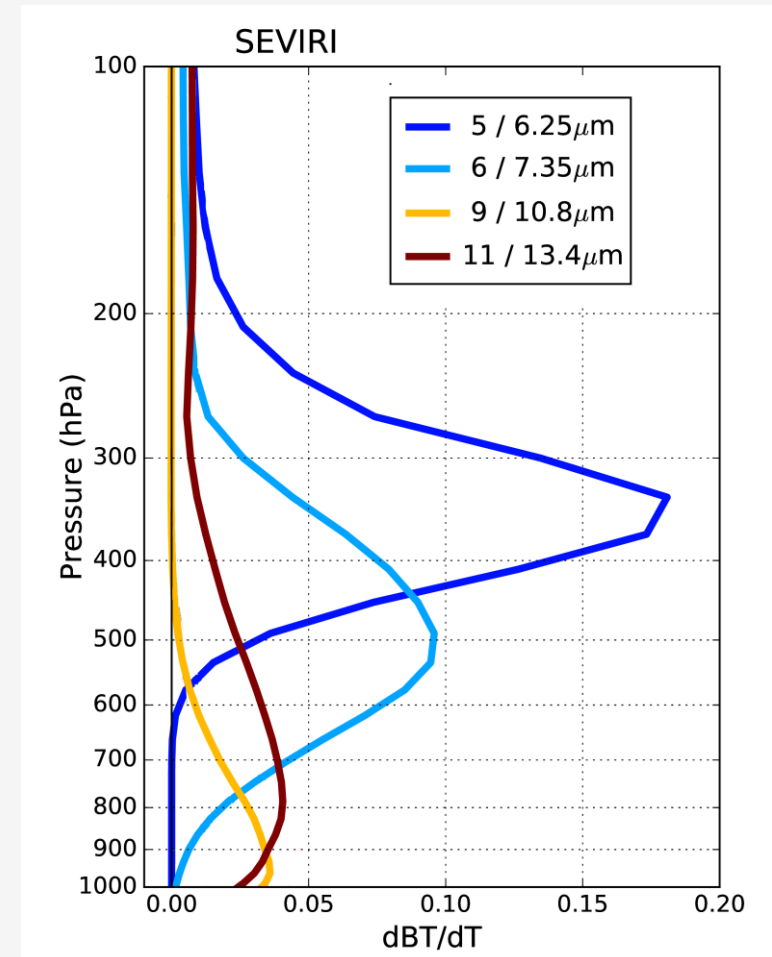
— allsky
— clear-sky
100% = no SEVIRI

— allsky
— clear-sky
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— allsky
— clear-sky
100% = no SEVIRI

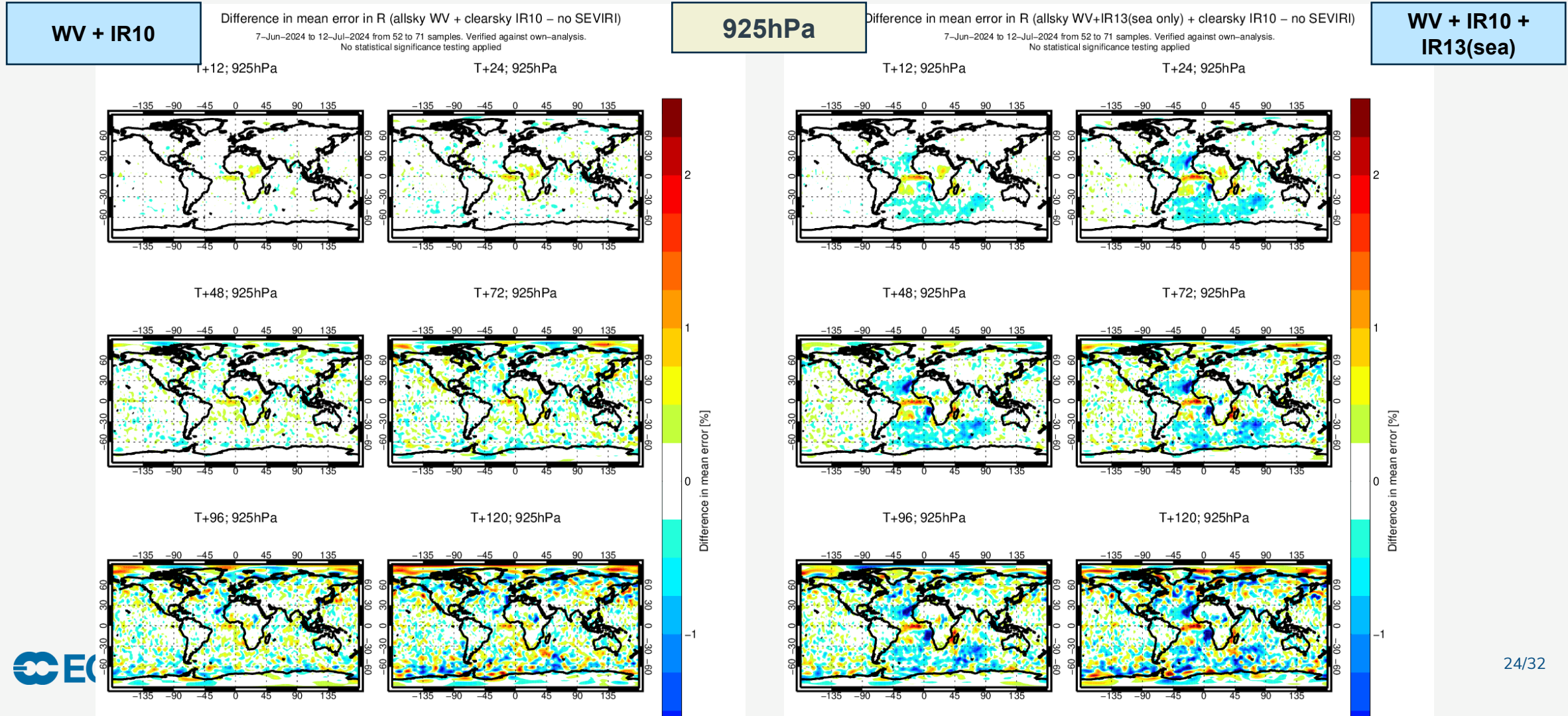
GEOS IR radiances assimilation in allsky: IR13.3 microns

- Investigation on assimilation of IR13.3 channel peaking low troposphere in allsky.
- Sensitive to low troposphere humidity and temperature, less to surface emissivity than other window bands.
- Same method as WV channels: observation error diagnostic.
- First tests over ocean only, extended to land as well.



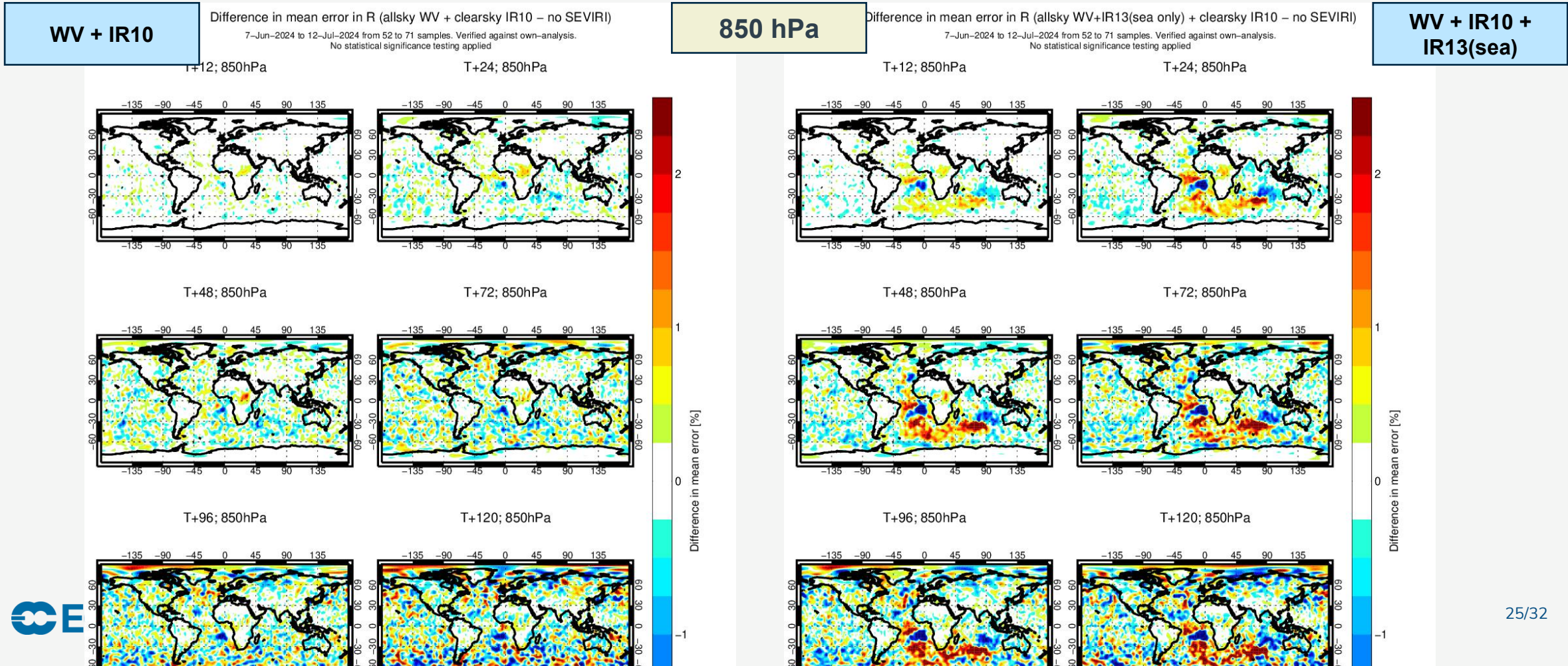
GEOS IR radiances assimilation in allsky: IR13.3 microns

- **Over sea only**: Add low-troposphere information over sea over Atlantic



GEOS IR radiances assimilation in allsky: IR13.3 microns

- Add low-troposphere information over sea over Atlantic
- Degradation observed at 850 hPa



GEOS IR radiances assimilation in allsky: IR13.3 microns

- Add low-troposphere information : **sea AND land**
- Degradation observed at 850 hPa: reduced when using IR13.3 over land as well

WV + IR10

error in R (allsky WV + clearsky IR10 – no SEVIRI)
 2024 from 52 to 71 samples. Verified against own-analysis.
 No statistical significance testing applied

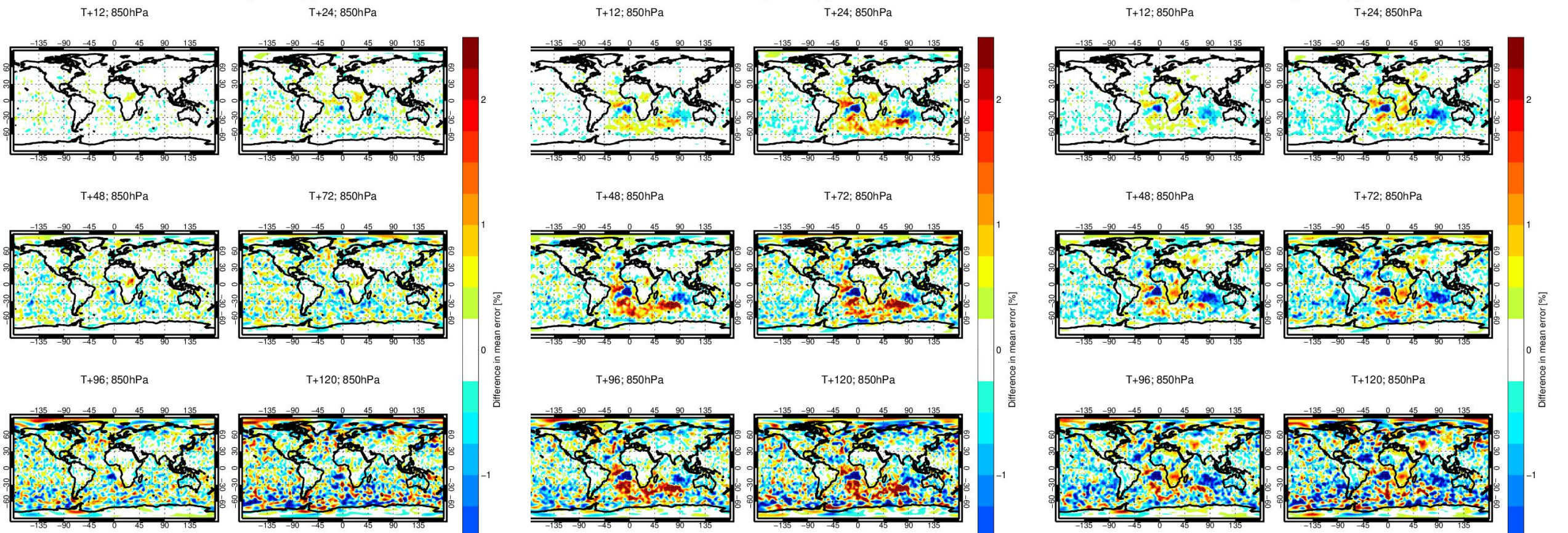
WV + IR10 + IR13(sea)

850 hPa

error in R (allsky WV+IR13(sea only) + clearsky IR10 – no SEVIRI)
 2024 to 12-Jul-2024 from 52 to 71 samples. Verified against own-analysis.
 No statistical significance testing applied

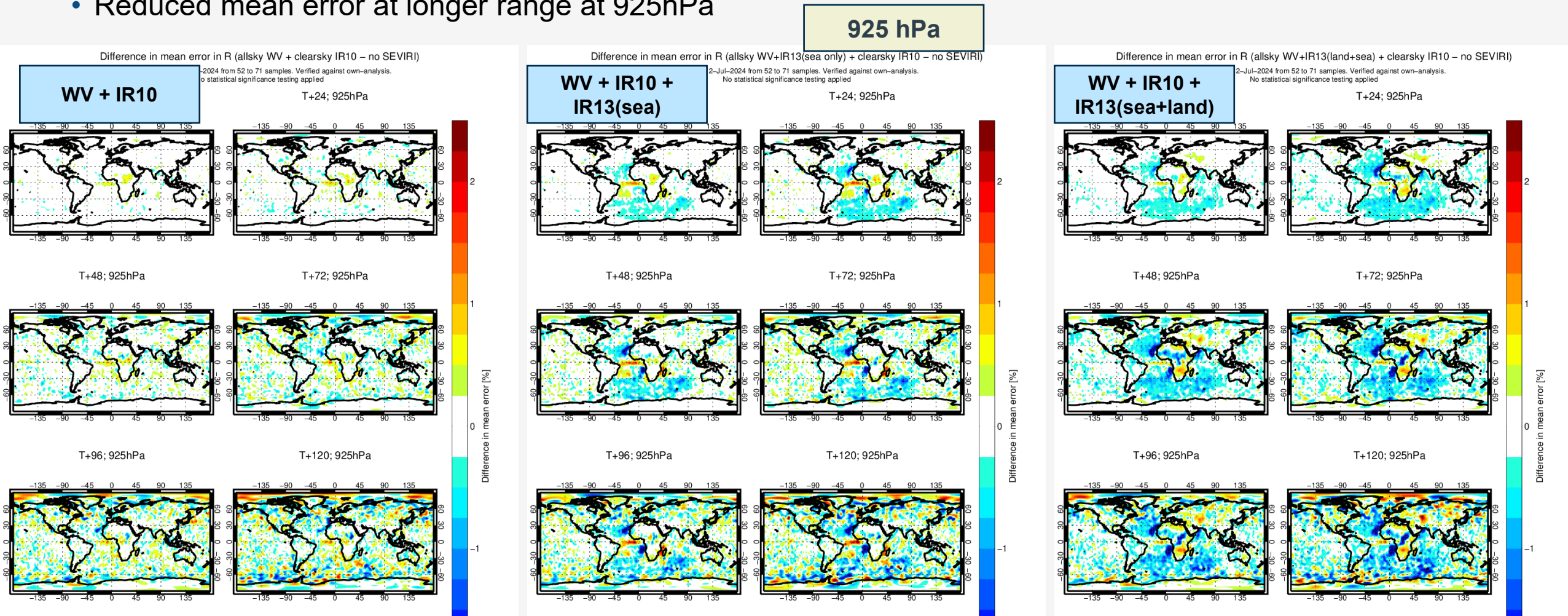
WV + IR10 + IR13(sea+land)

error in R (allsky WV+IR13(land+sea) + clearsky IR10 – no SEVIRI)
 12-Jul-2024 from 52 to 71 samples. Verified against own-analysis.
 No statistical significance testing applied



GEOS IR radiances assimilation in allsky: IR13.3 microns

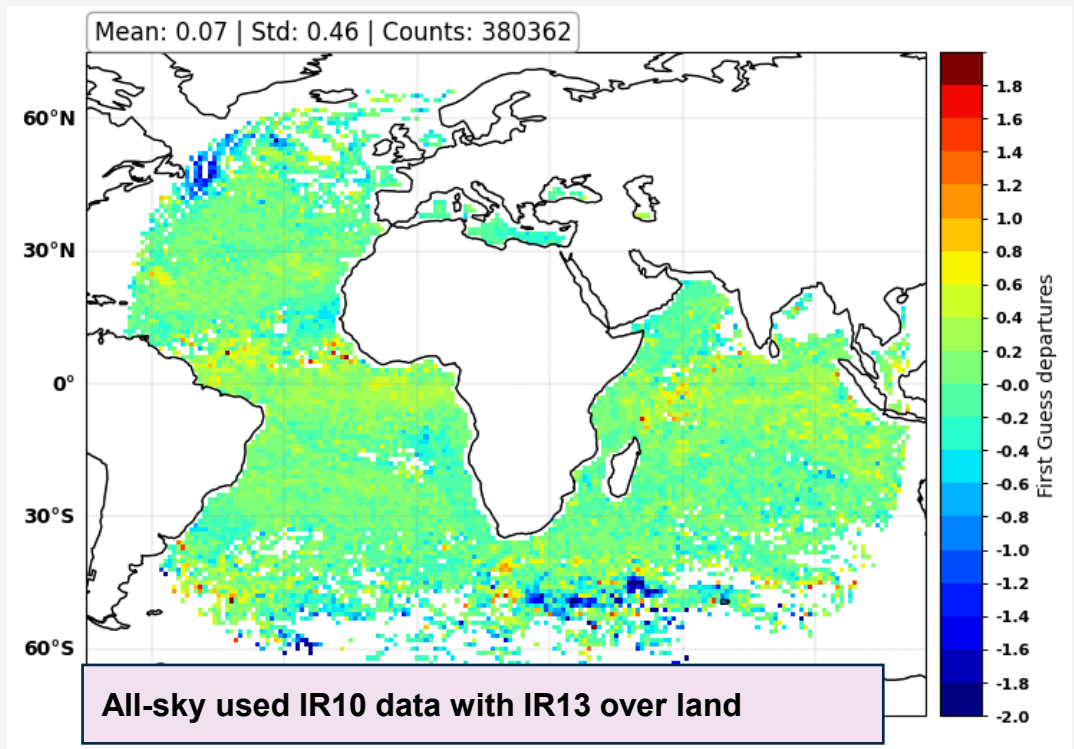
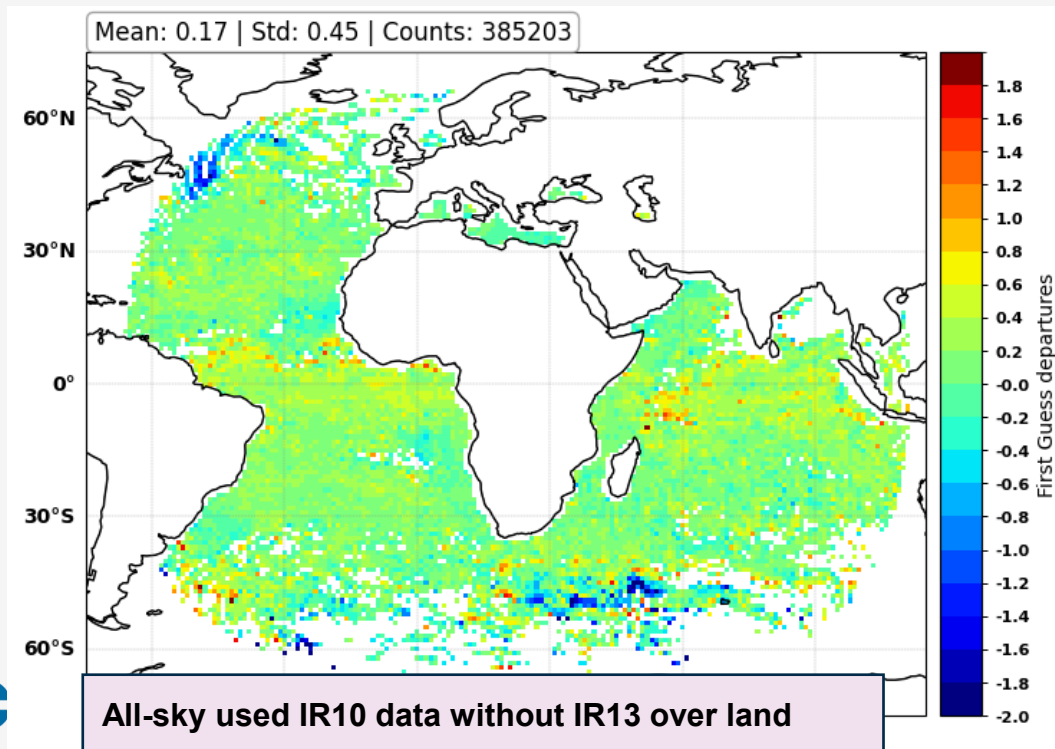
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- Degradation observed at 850 hPa: reduced when using IR13.3 over land as well
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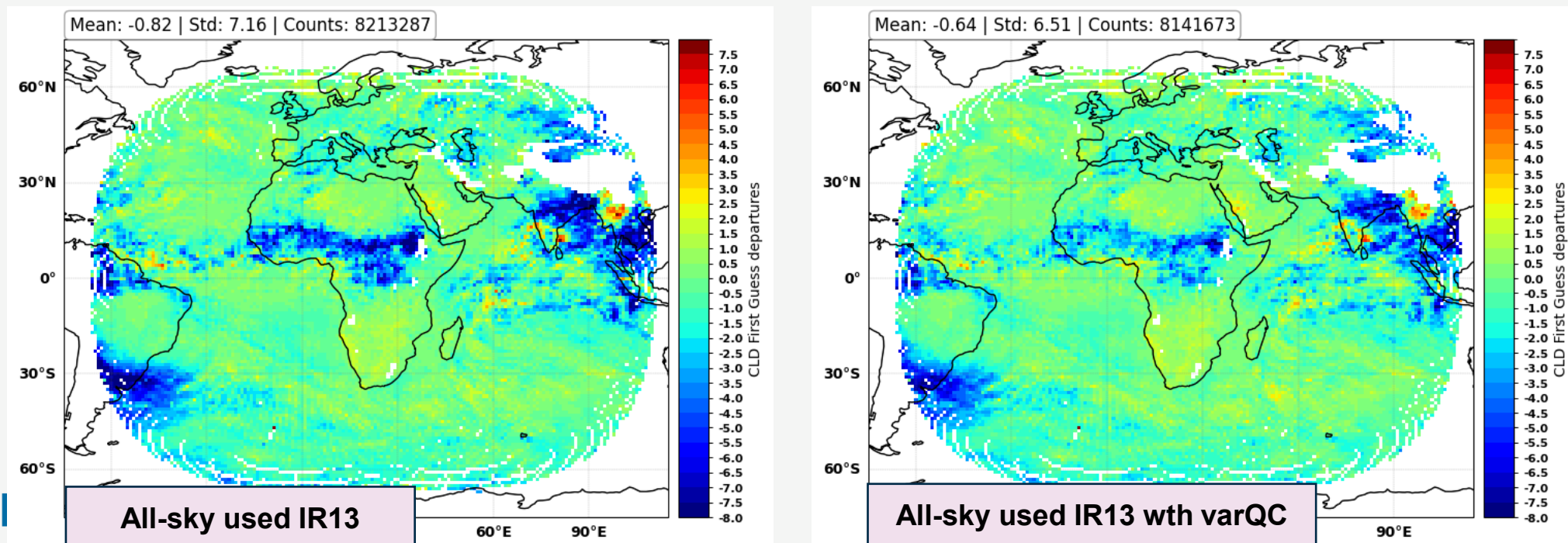
MET-9 and MET-10 SEVIRI IR10.8 used first guess departures



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- VarQC: variational quality control

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GEOS IR radiances assimilation in allsky – summary

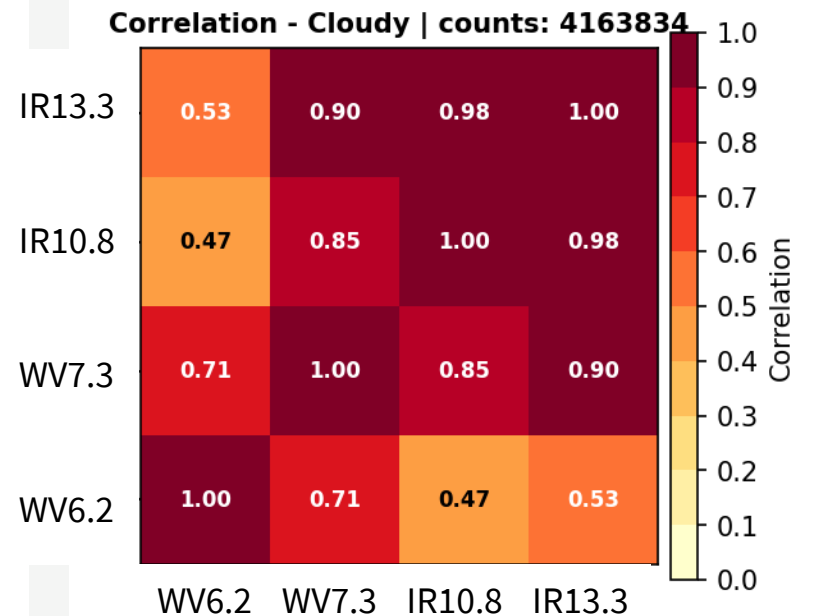
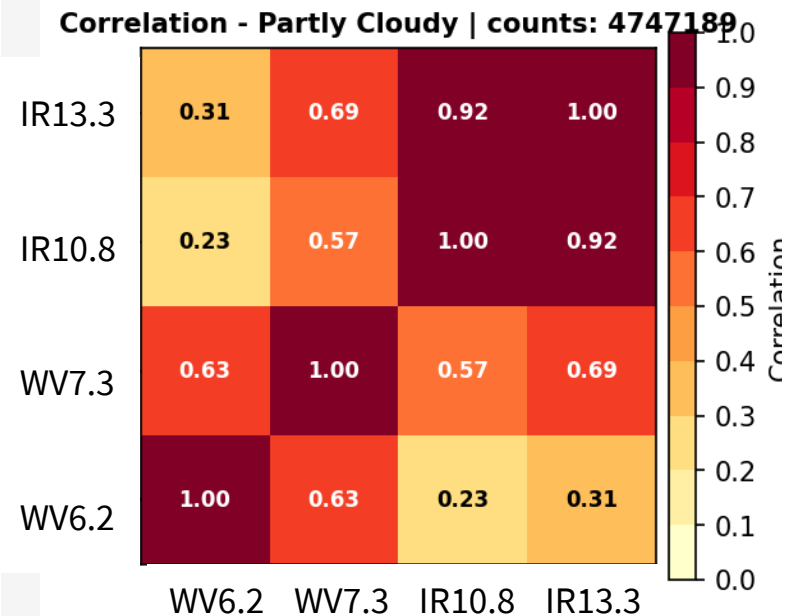
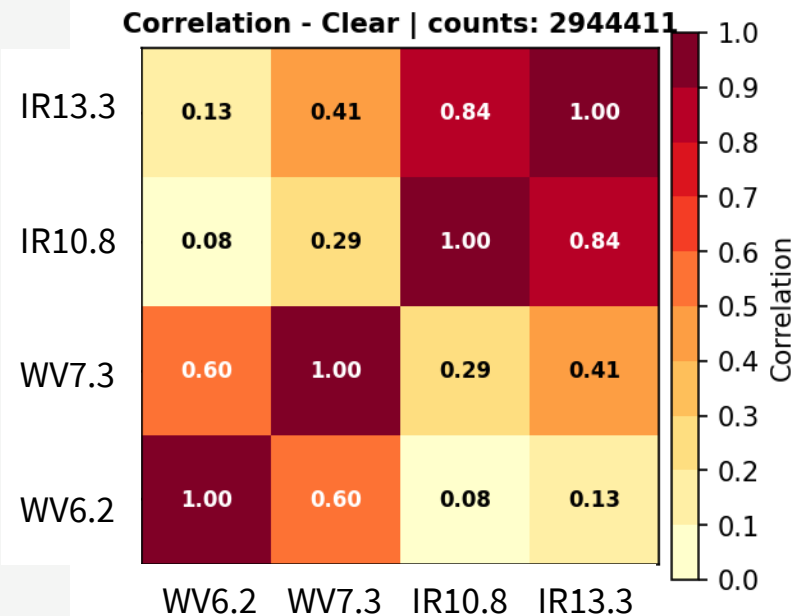
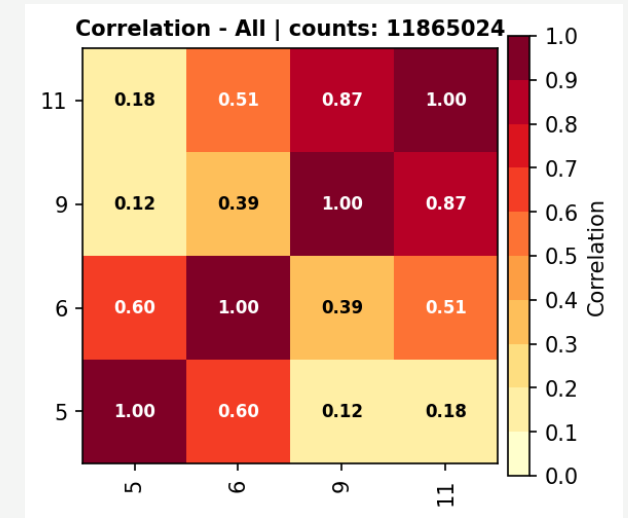
- **Water vapour sensitive channels** (6.2 μm and 7.3 μm) assimilated in allsky lead to significant improvements in the fit to other observations, when observation errors are specified accordingly to the cloudiness of the scene.
- **Surface sensitive window channel** (10.8 μm) will still be used in clear-sky over ocean with an efficient cloud screening based on background simulation in clear-sky and all-sky.
- **Low tropospheric channel** (13.3 μm) adds valuable information over ocean. The assimilation over land still needs to be improved but provides lower cloud information and leads to a smaller first guess departure error in the window channel meant to be assimilated in clear-sky.
- The addition of **varQC** helps handling outliers that remain in lower peaking channels (IR10.8, IR13.3) despite a tuned observation error model.

GEOS IR radiances assimilation in allsky – future plans

- Interchannel correlation errors are not accounted for in the allsky experiments.
- Clearsky framework: fixed value of 0.56 between the two WV channels. A fixed diagnosed value in allsky assimilation did not show any impact as they vary a lot with the cloudiness of the scene.
- Scene-dependent interchannel correlation matrices:

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- Technical developments in IFS source code to run independently the clearsky and allsky IR assimilation.
- Visible + IR allsky experiments.
- Address degradation at 850hPa (RTTOV hydrometeor input settings, tuning varqc, data selection, observation error model).
- Extension to other GEOS (MTG-FCI, GOES-19 ABI).

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