Recent Developments in Atmospheric Motion Vectors at ECMWF

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EUMETSAT Fellow Day, Darmstadt

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With thanks to Katie Lean, Francis Warrick and Niels Bormann

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ECMWF

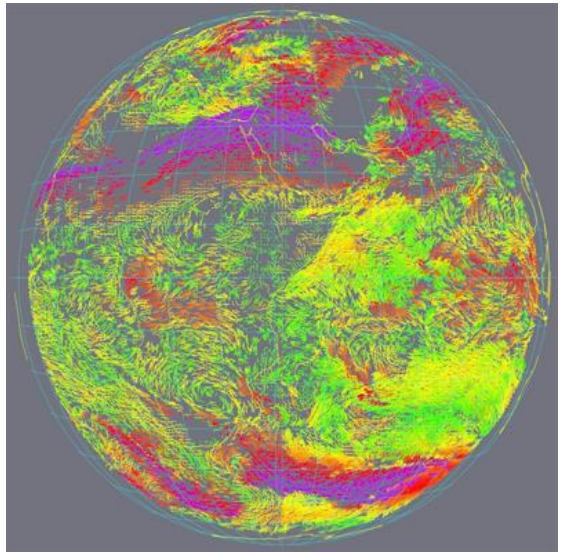
Talk Overview

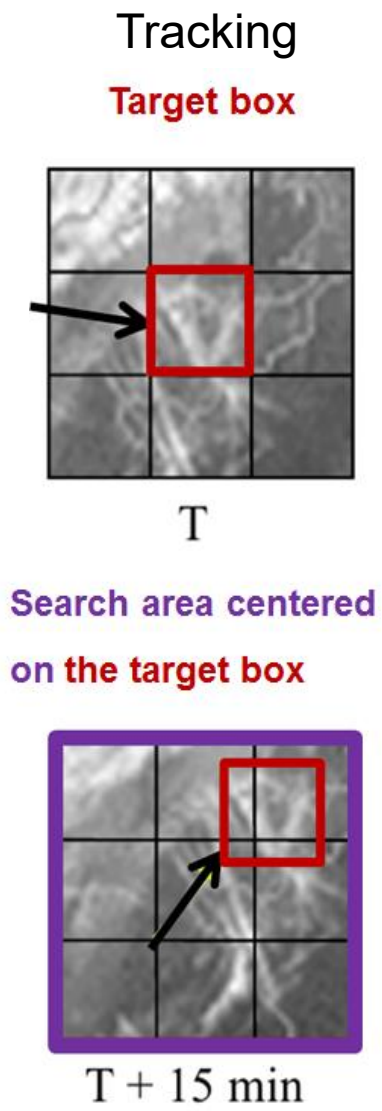
- Introduction to AMVs at ECMWF
- Extending use of AMV IR channels
- EUMETSAT Dual-Sentinel SLSTR AMVs
- Future plans

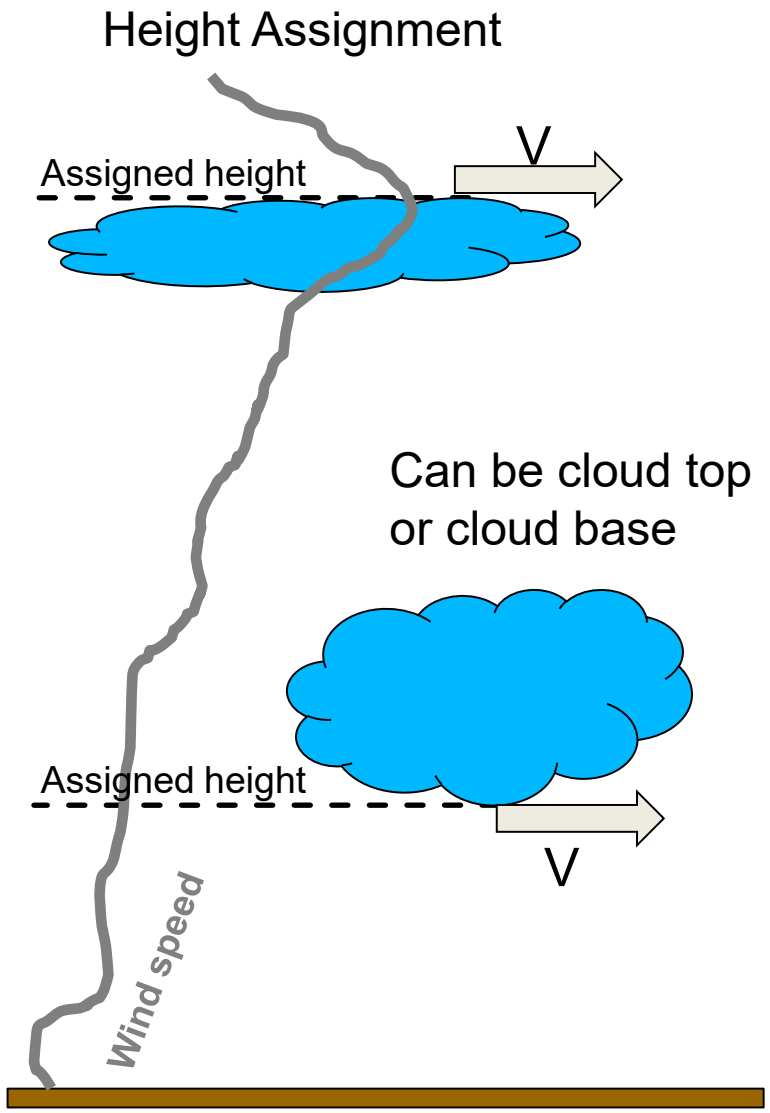
What are AMVs?

- **Wind observations produced by tracking clouds or water vapour features in consecutive satellite images.**

- Both geostationary and polar.
- Channels: infrared, visible, water vapour.



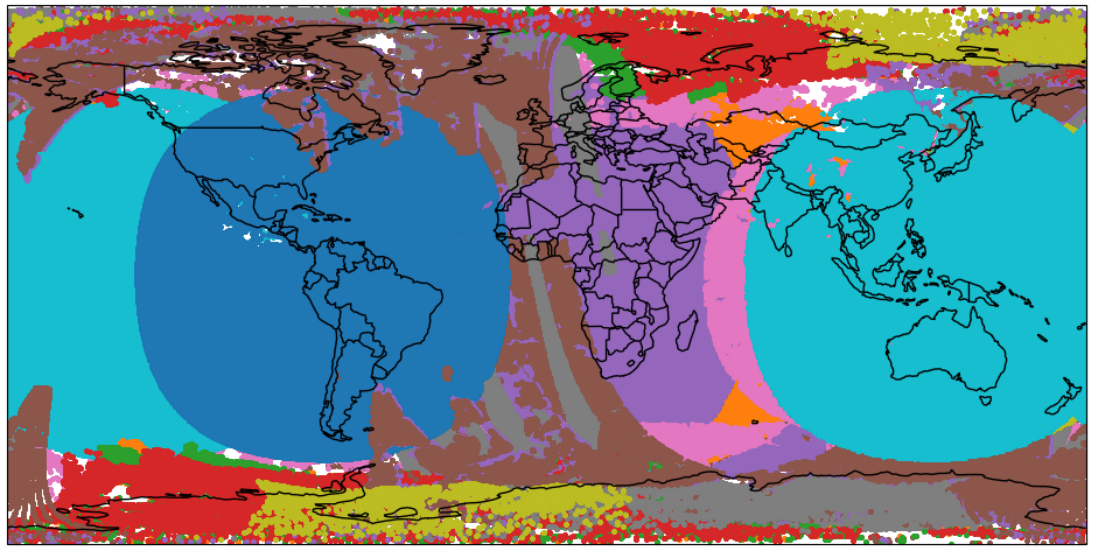


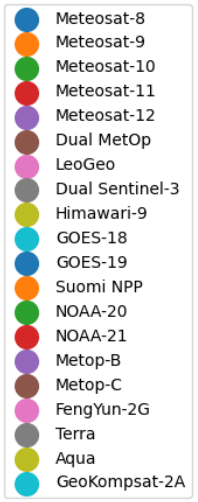


Current AMV Usage at ECMWF

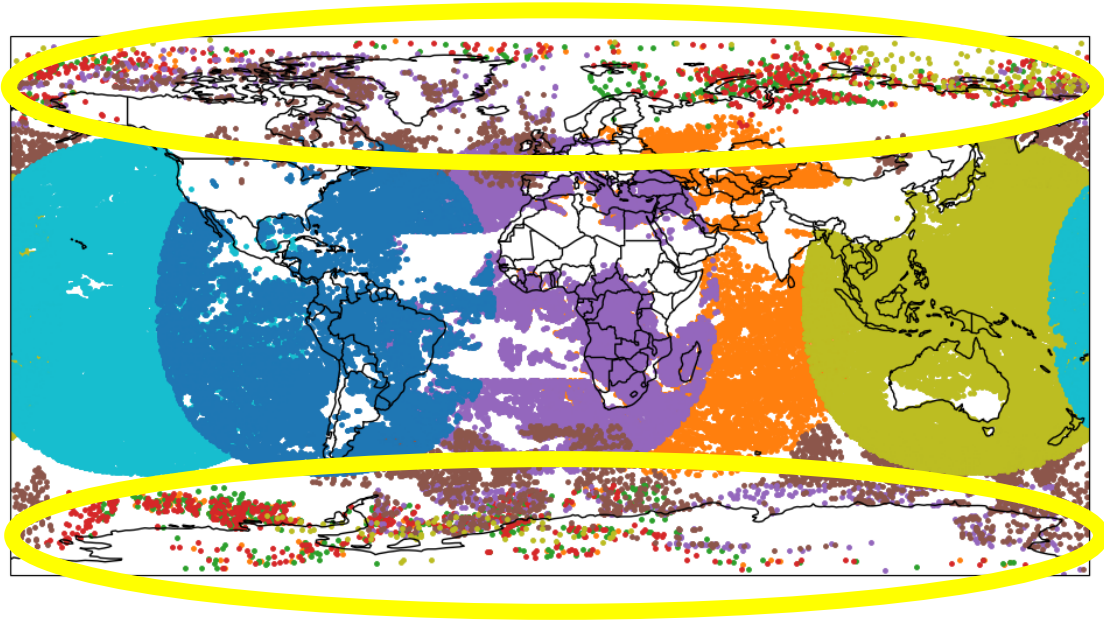
20260213 00Z cycle

Monitoring **49,965,150** winds in this 12-hour cycle.





Assimilating **256,740** winds in this 12-hour cycle.



Data rejected by:

- Thinning (200km, 30 minute, 50-175 hPa boxes)
- First-guess check
- Data selection choices: regional, satellite, channel, quality indicators…

Operational developments since last Fellows Day

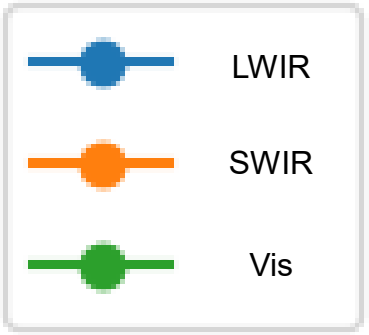
- Replaced GOES-16 AMVs with GOES-19 AMVs *(April 2025)*
- Reintroduction and active assimilation of Aqua MODIS AMVs *(April 2025)*
- Replaced **Meteosat-10 AMVs with Meteosat-12 AMVs** *(June 2025)*
- Reject AMVs from NOAA-18,-19 due to their decommissioning *(June 2025)*
- Briefly switched from Himawari-9 to Himawari-8 due to outage *(October 2025)*

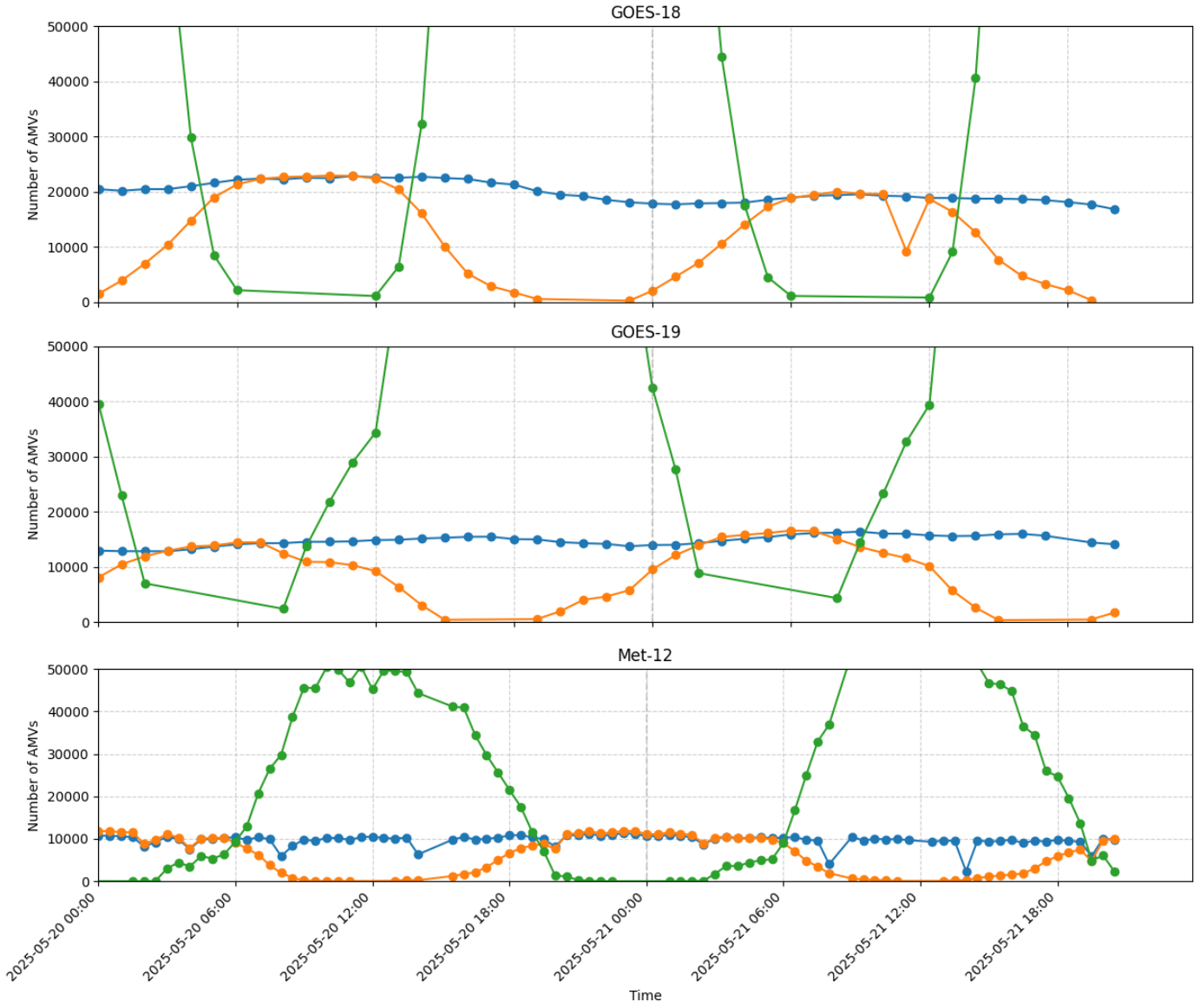
Short-wave IR

- GOES-18/-19 3.9μm, Meteosat-12 3.8μm
- Low levels,
  - SWIR can detect the contrast between the low clouds and surface better than LWIR,
  - sensitive to low, stratocumulus cloud - found west of continents.
- Generally low quality due to the nosier channels. The detector technology is less sensitive to SWIR channel than the LWIR.
- Night-time only.
- Lean & Bormann 2023 - height re-assignment for low level AMVs in the tropics using model cloud information.

Short-wave IR - Night-time only

- Low-level (>700hPa).





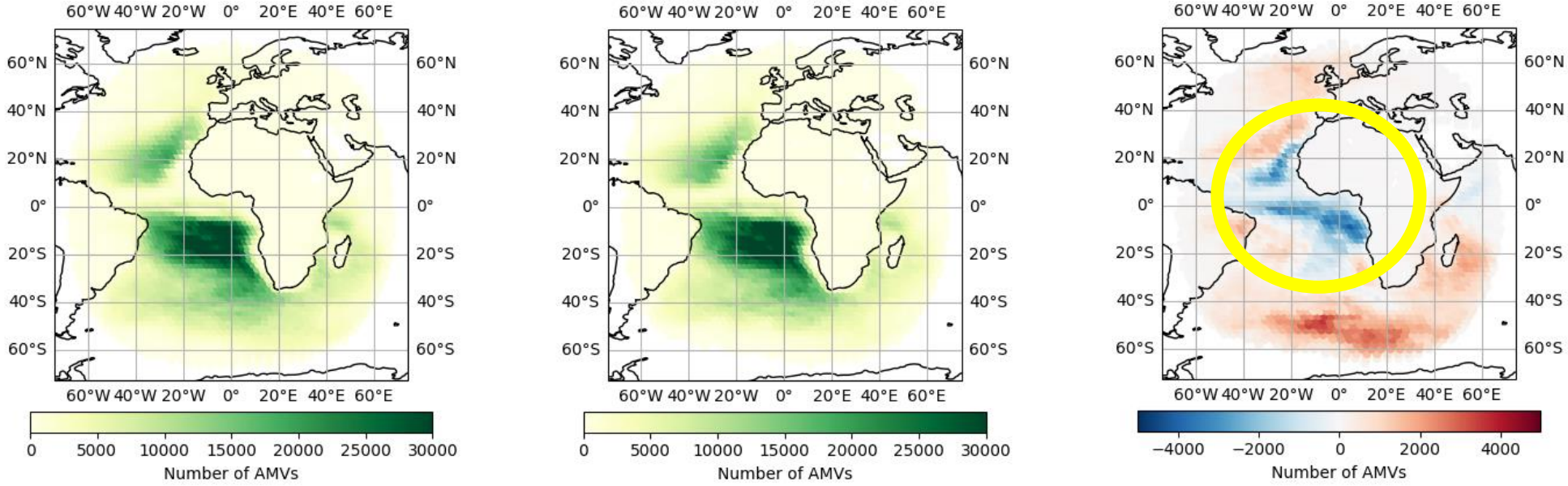
Locations of SWIR compared to LWIR

- Number of AMVs from 6pm to 6am for Met-12 (and 6am to 12pm for GOES).
- Low-level (>700hPa).
- QI>85, passing first guess check.

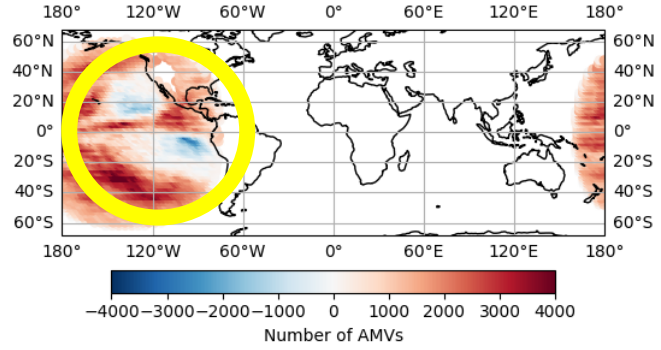
Red – More LWIR than SWIR
Blue – More SWIR than LWIR

LWIR | **SWIR** | **LWIR - SWIR**

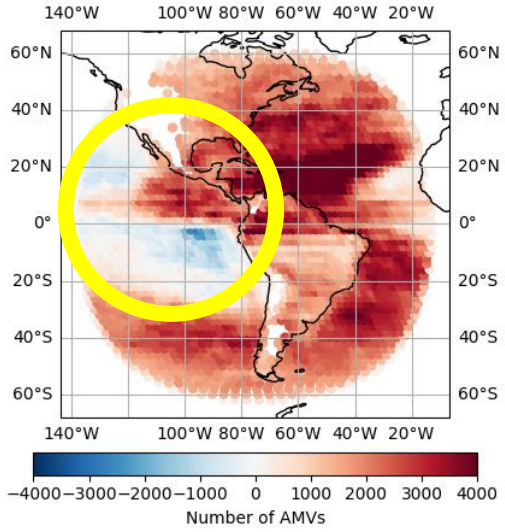
Meteosat-12



GOES-18



GOES-19



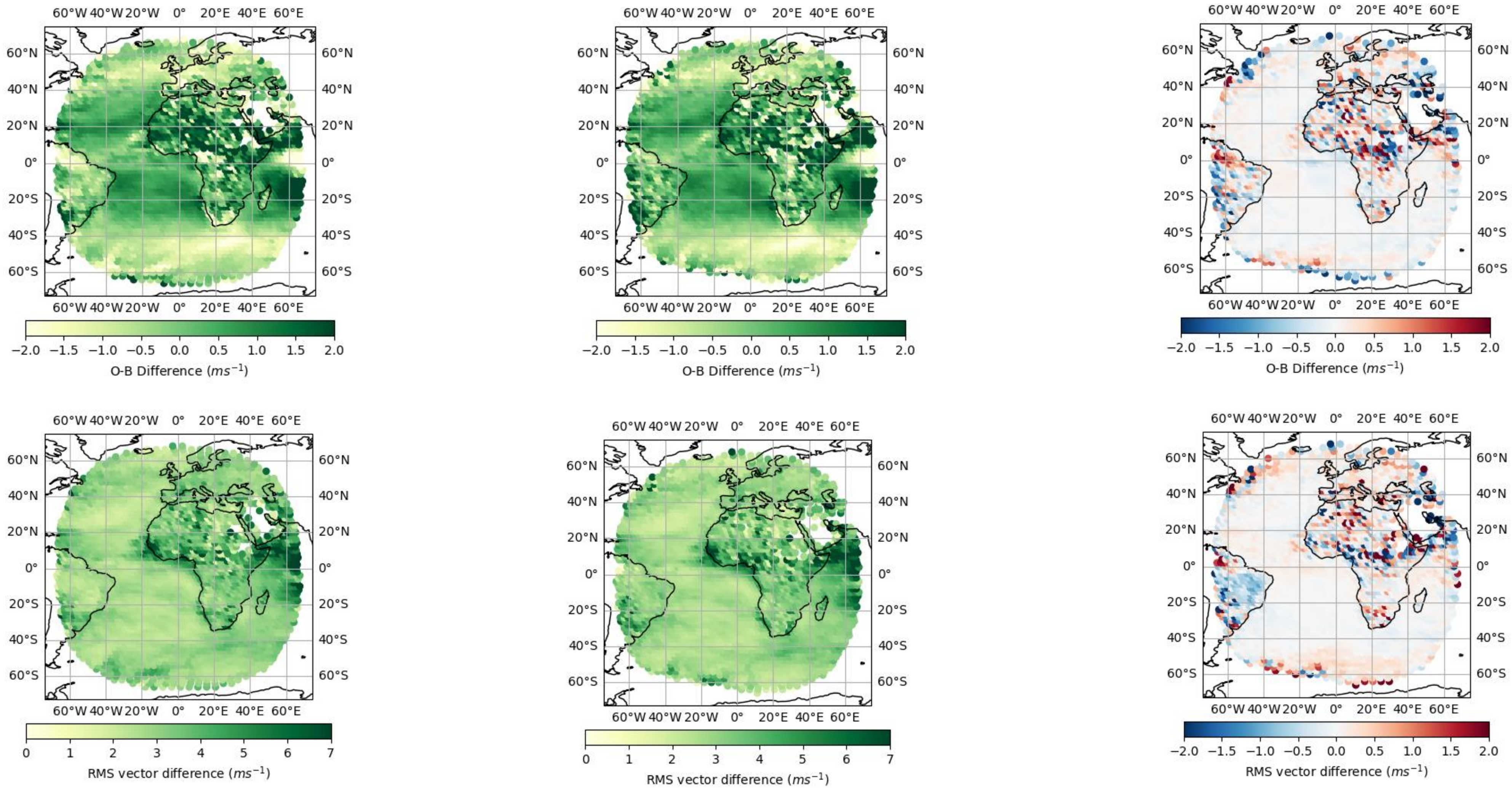
Short-wave IR O-B statistics – Meteosat-12

- Night-time.
- Low-level (>700hPa).
- QI>85, passing first guess check.
- 2.5 months of data.

LWIR **SWIR** **LWIR - SWIR**

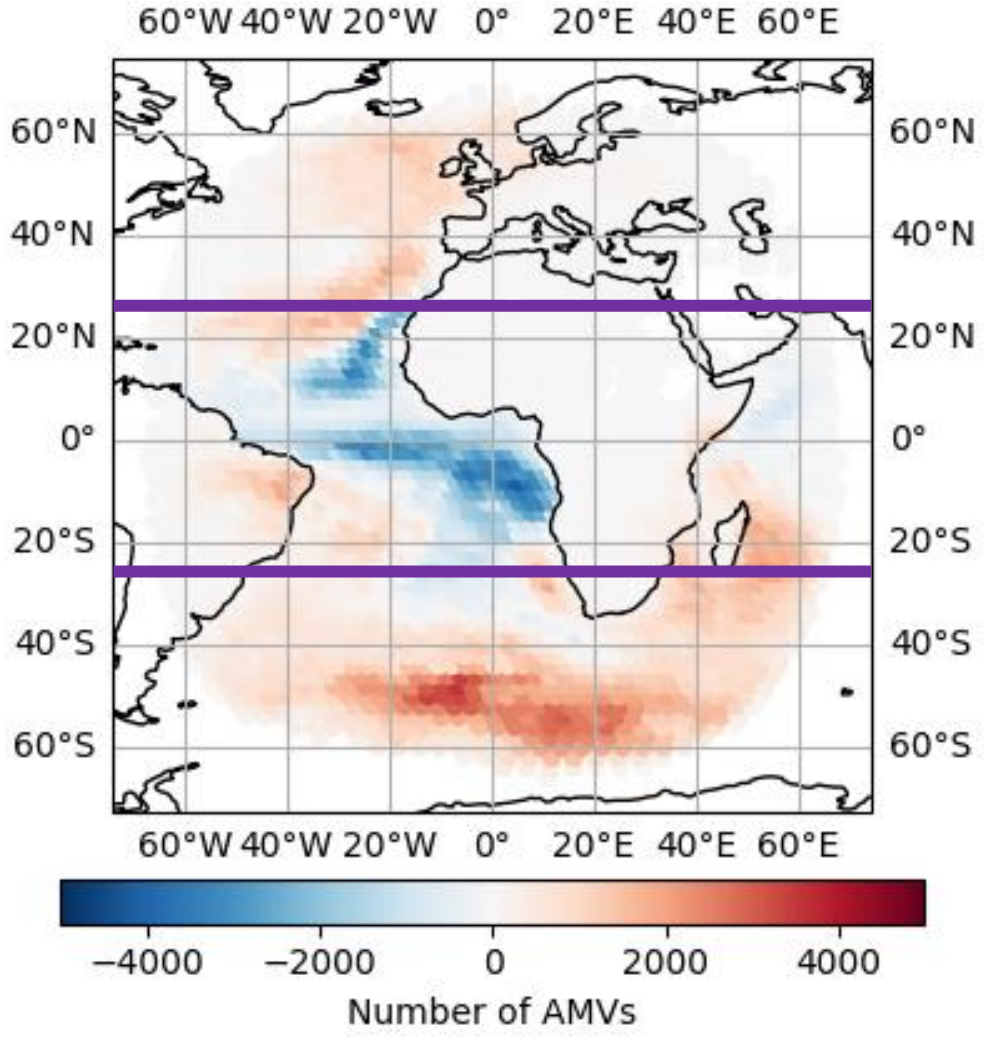
Bias

RMSVD

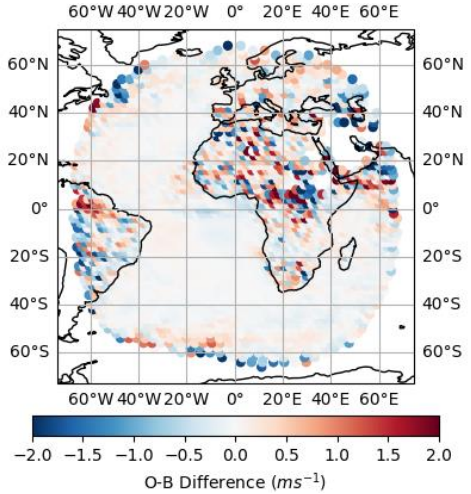


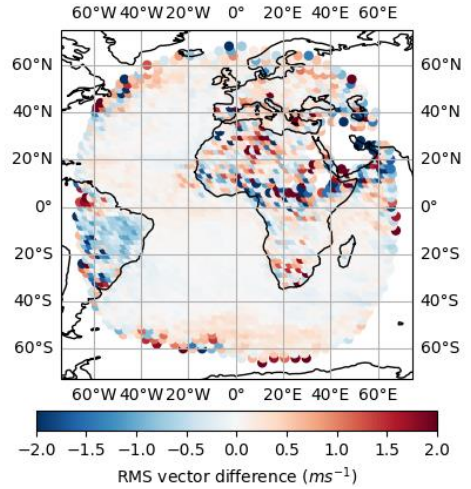
SWIR is improving
SWIR is degrading

Short-wave IR O-B statistics – Meteosat-12



LWIR - SWIR

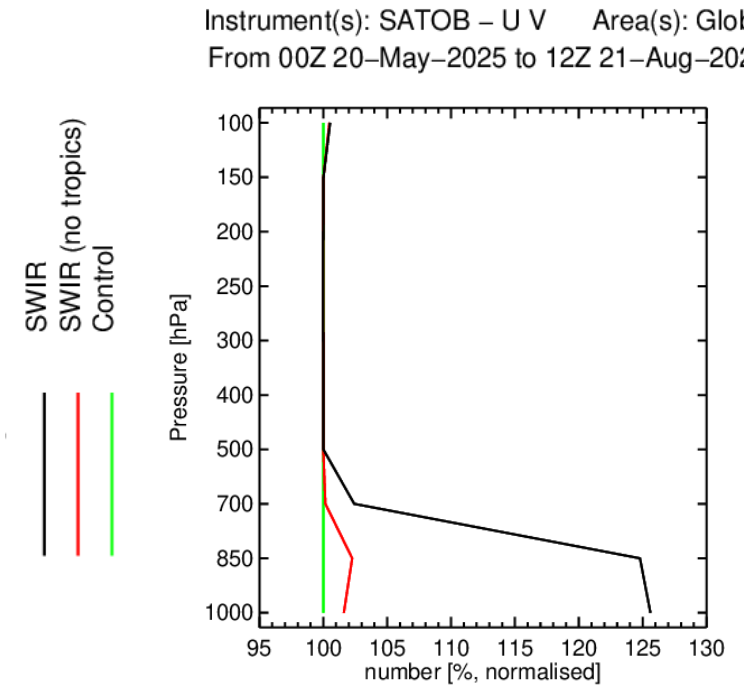


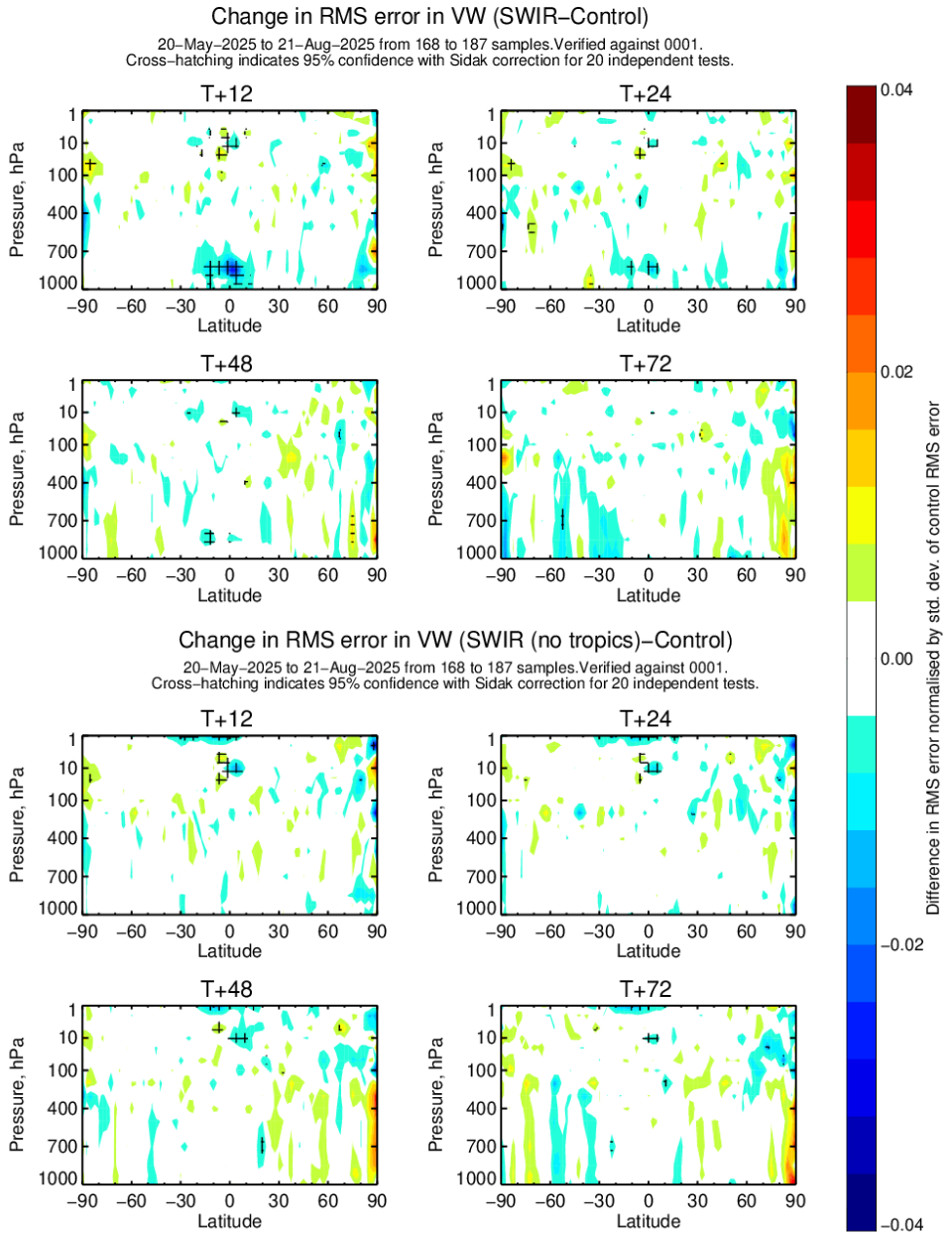


SWIR is improving
SWIR is degrading

SWIR Assimilation Experiment

Experiment (3 months)	Details
Control	Current ECMWF assimilation set-up
SWIR	Inclusion of the GOES-18/-19 and Meteosat-12 SWIR channels at low levels (> 700 hPa)
SWIR (no tropics)	Inclusion of the GOES-18/-19 and Meteosat-12 SWIR channels at low levels (> 700 hPa) only in the extra-tropics





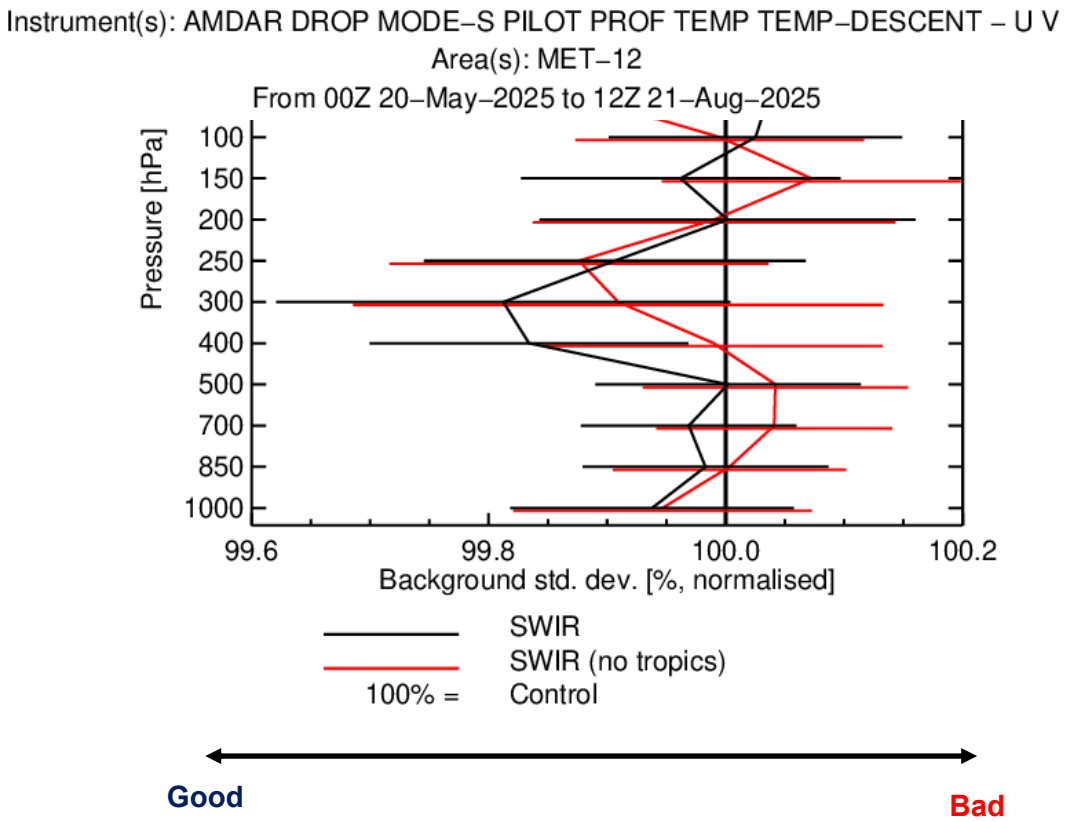
Bad

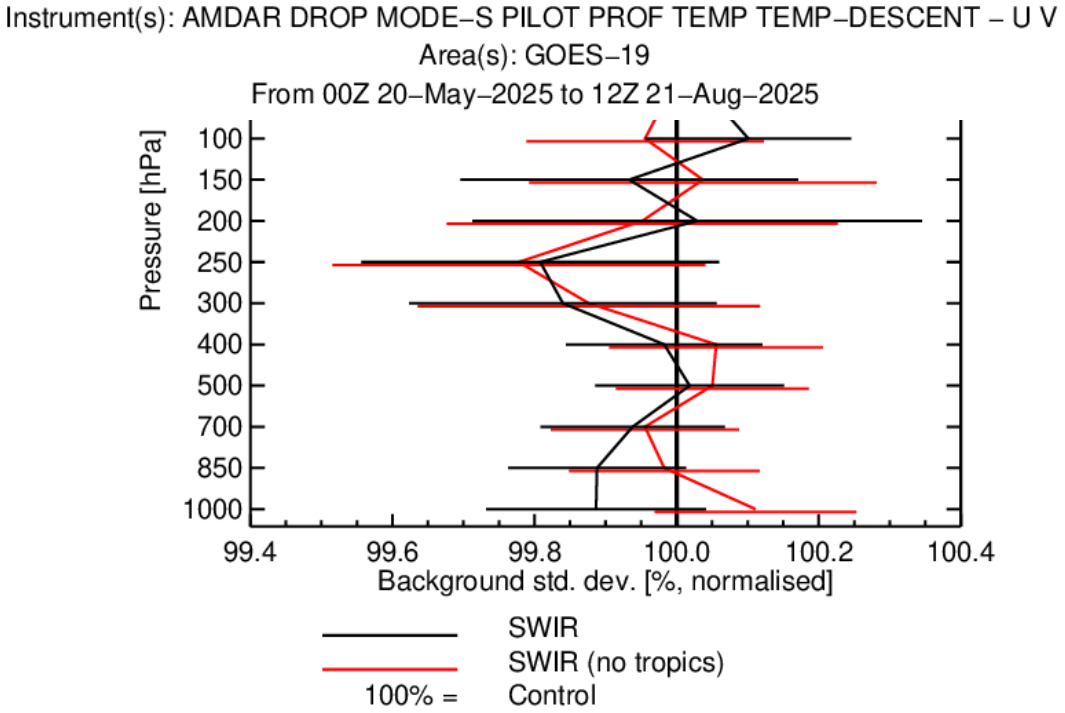
Good

SWIR Assimilation Experiment

- Improvement of the background fit to other observations.
- Other observations: **IN-SITU WIND**

Experiment	Details
Control	Current ECMWF assimilation set-up
SWIR	Inclusion of the GOES-18/-19 and Meteosat-12 SWIR channels at low levels (> 700 hPa).
SWIR (no tropics)	Inclusion of the GOES-18/-19 and Meteosat-12 SWIR channels at low levels (> 700 hPa) only in the extra-tropics.



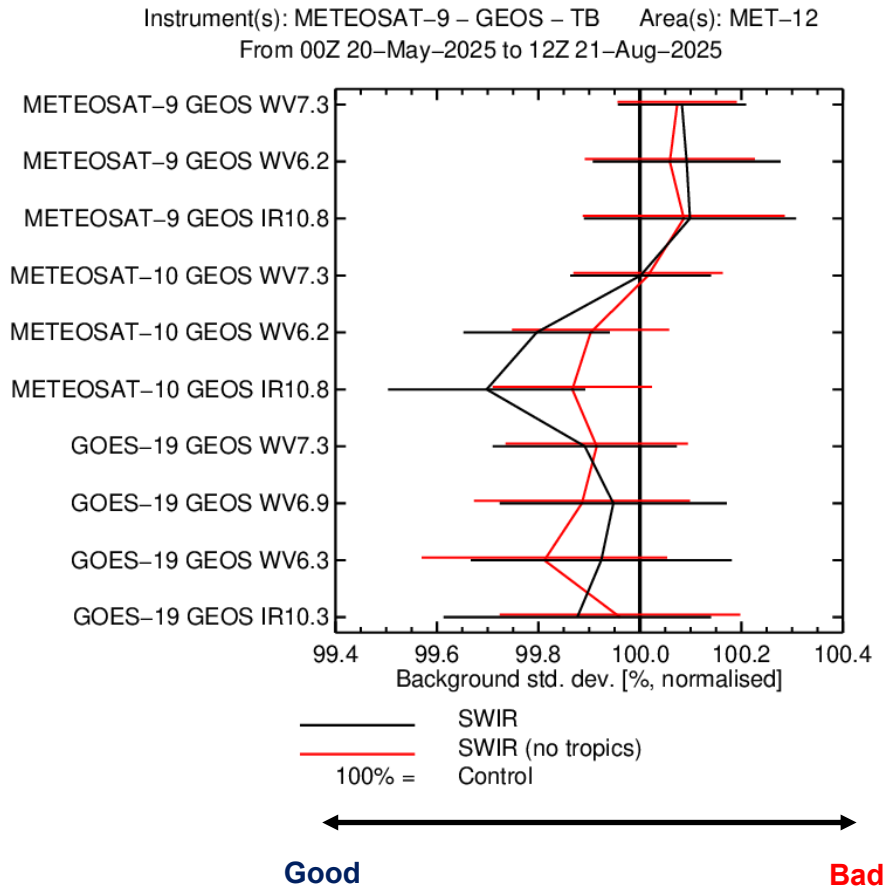


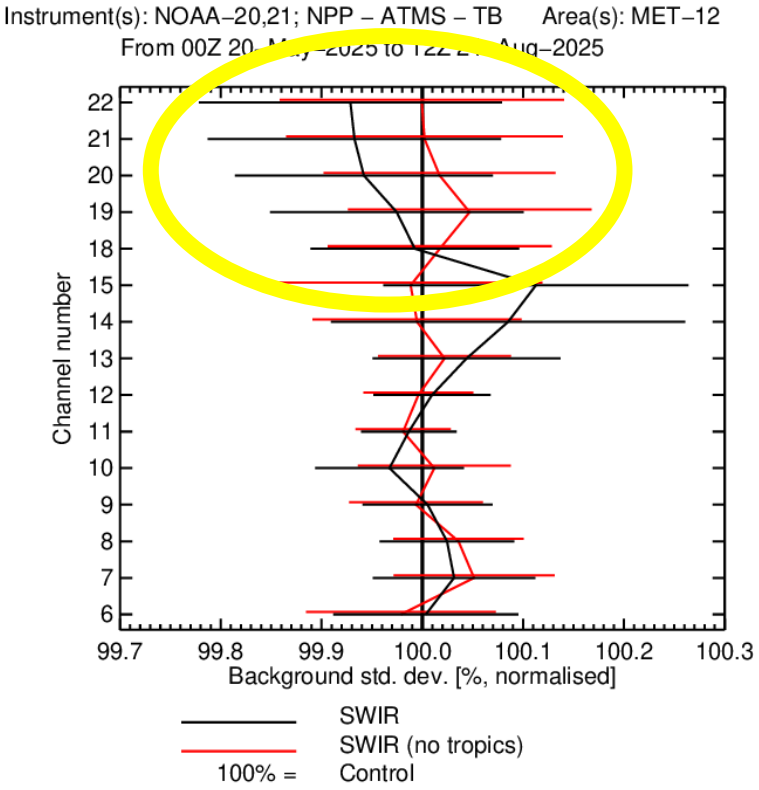
Area	Latitude	Longitude
Met-12	$-75 < \varphi < 75$	$-140 < \lambda < 0$
GOES-19	$-75 < \varphi < 75$	$-80 < \lambda < 80$

SWIR Assimilation Experiment

Other observations: **GEOSTATIONARY RADIANCES, ATMS (Channels >15)**

Area	Latitude	Longitude
Met-12	$-75 < \varphi < 75$	$-140 < \lambda < 0$



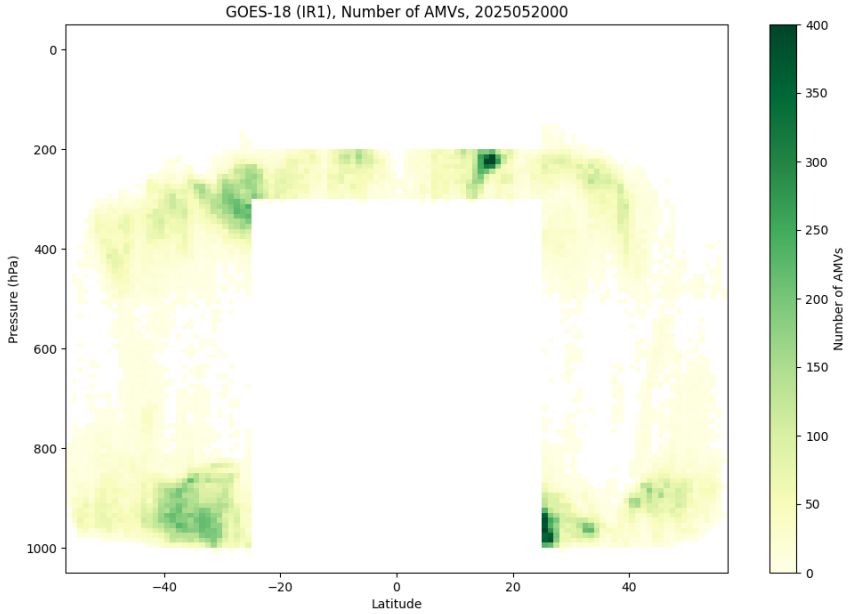


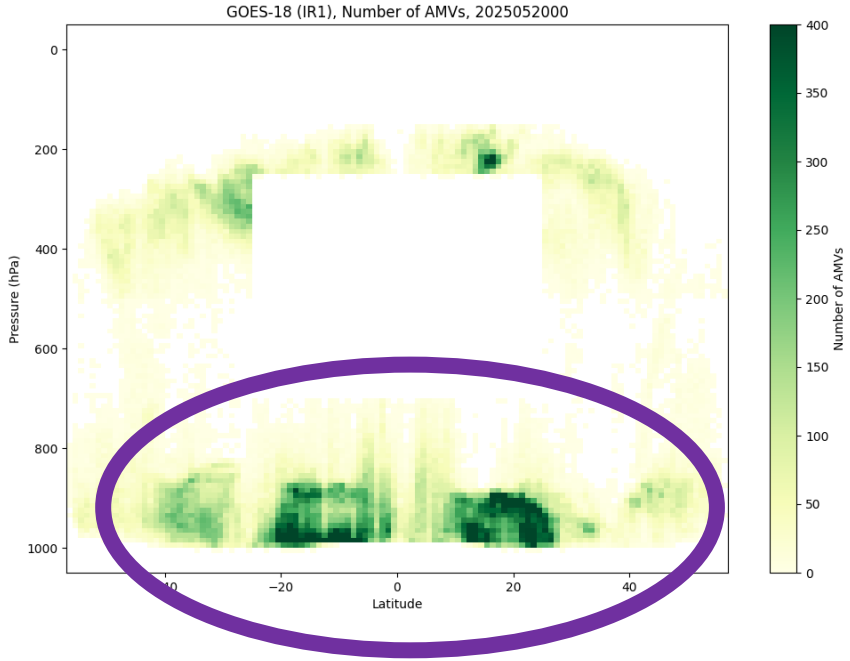
Summary:

- Overall, a mix of neutral and positive results
- Indication these winds may be helpful, especially in the tropics
- Will continue experiment for another 3 months before making any operational recommendations

Long-wave IR

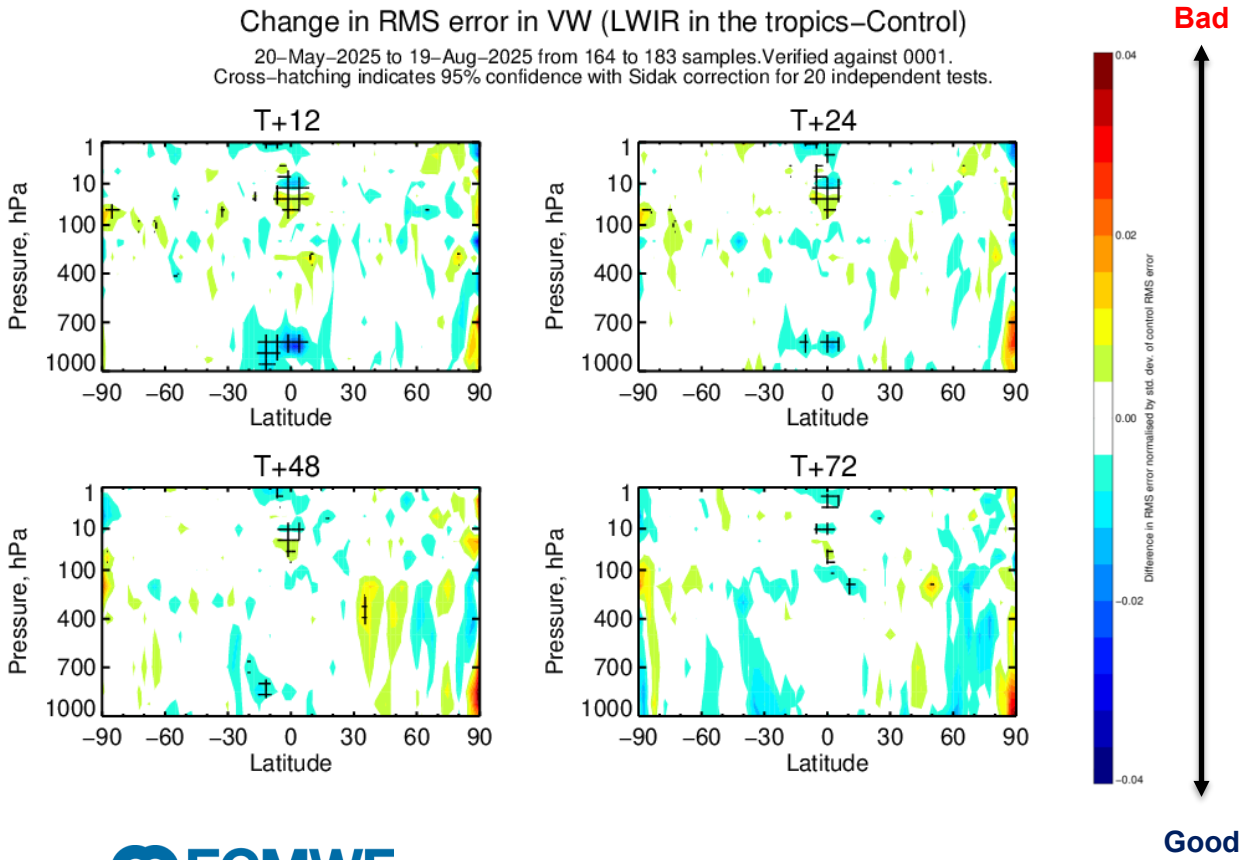
- GOES-18/-19 10.8μm, Meteosat-12 10.5μm
- LWIR is currently not assimilated at low-levels in the tropics at ECMWF.
- Lean & Bormann 2023 - height re-assignment for low level AMVs in the tropics using model cloud information.



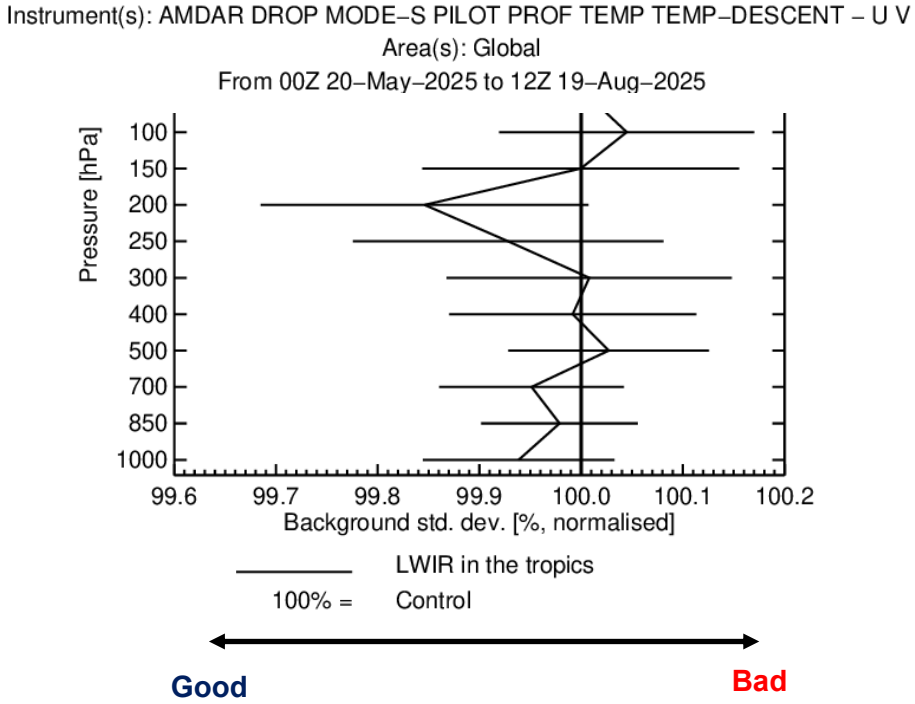


LWIR assimilation experiment

Experiment (3 months)	Details
Control	Current ECMWF assimilation set-up
LWIR in the tropics	Inclusion of the GOES-18/-19 and Meteosat-12 LWIR channels at low levels (> 700 hPa) in the tropics.



Other observations: **IN-SITU WIND**



LWIR assimilation experiment

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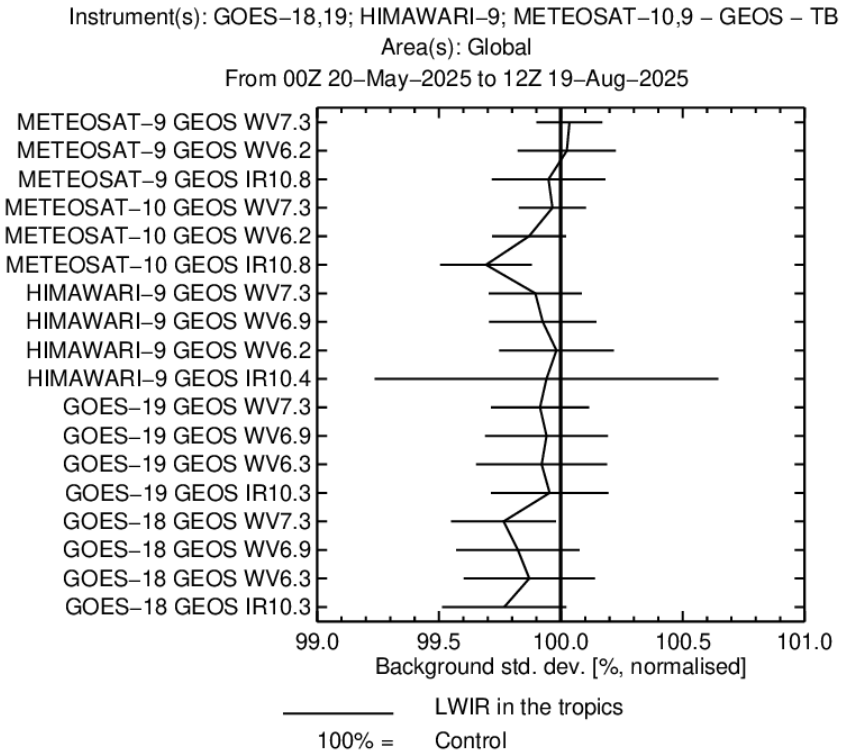
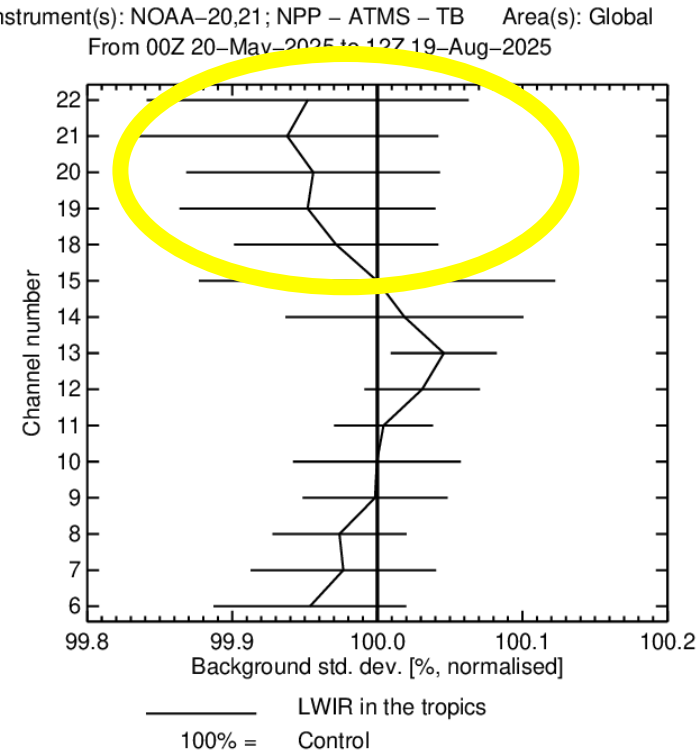
Other observations: **GEOSTATIONARY RADIANCES, ATMS (Channels >15)**



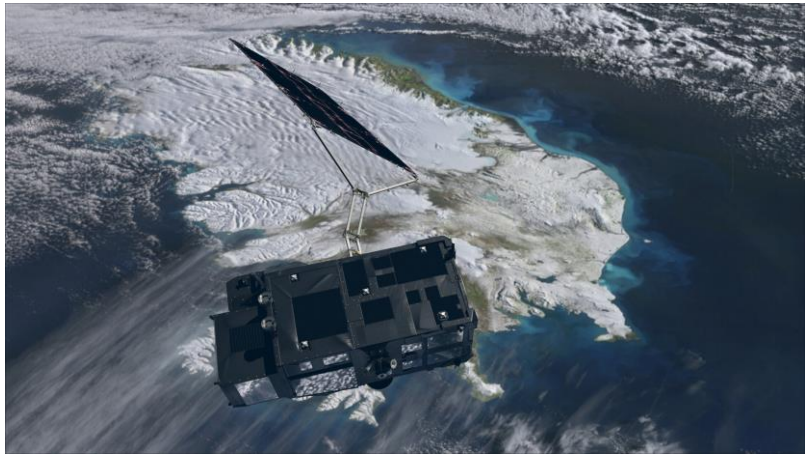


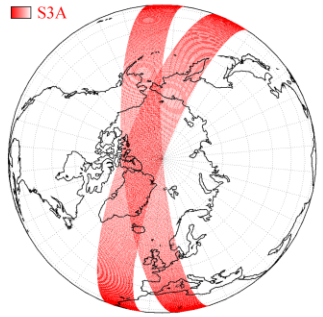
Summary:

- More mixed results than the SWIR experiments
- Will continue experiment for another 3 months before making any operational recommendations

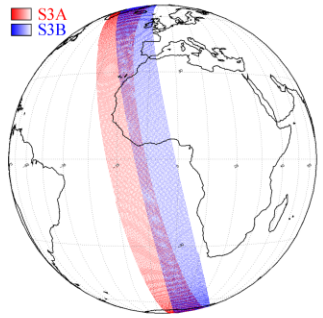
EUMETSAT Dual-Sentinel SLSTR AMVs

- SLSTR: Sea and Land Surface Temperature Radiometer
- Atmospheric Motion Vectors (AMVs) derived from Sentinel-3A and Sentinel-3B
- Sentinel-3B flies ~140° out of phase with Sentinel-3A
- Swath coverage: ~1420 km
- Two Dual-Satellite AMV products

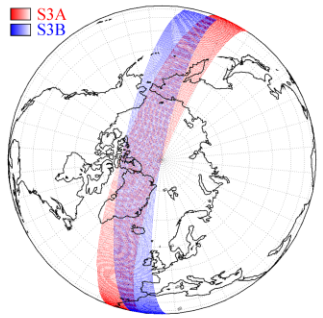




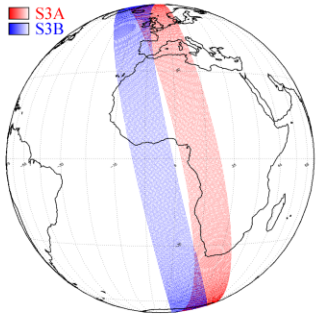
(**a**) Trace of two successive overpasses of Sentinel-3A, 101 min apart, over the North Pole.



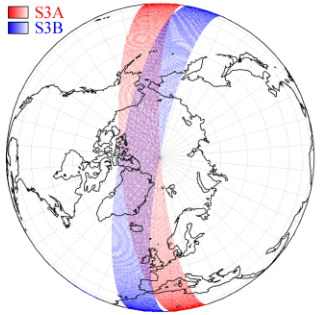
(**b**) S3B overpass, followed by a S3A overpass 39.5 min later, seen at the equator.



(**c**) S3B overpass, followed by a S3A overpass 39.5 min later, seen at the pole.



(**d**) S3A overpass, followed by a S3B overpass 61.5 min later, seen at the equator.



(**e**) S3A overpass, followed by a S3B overpass 61.5 min later, seen at the pole.

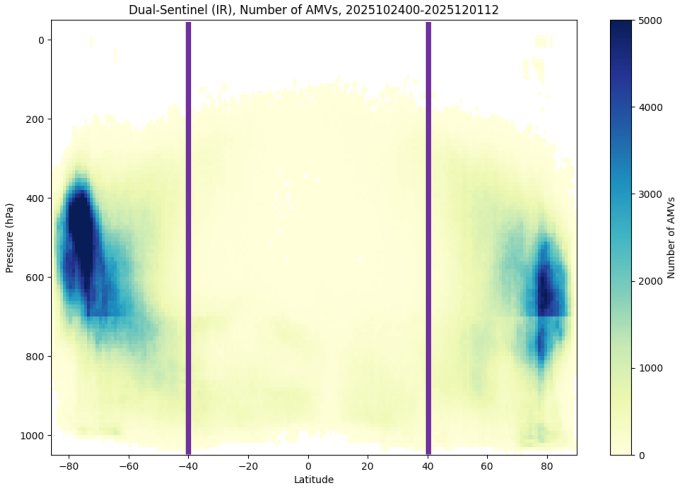
Barbieux, K., Hautecoeur, O., De Bartolomei, M., Carranza, M. and Borde, R., 2021. The Sentinel-3 SLSTR atmospheric motion vectors product at EUMETSAT. *Remote Sensing*, *13*(9), p.1702.

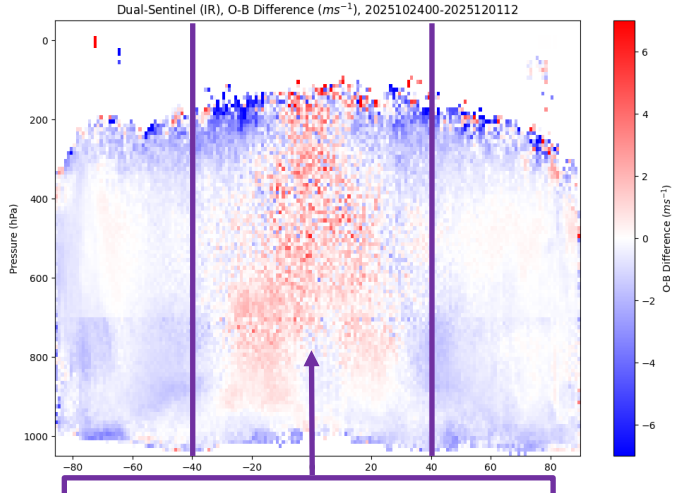
EUMETSAT Dual-Sentinel SLSTR AMVs

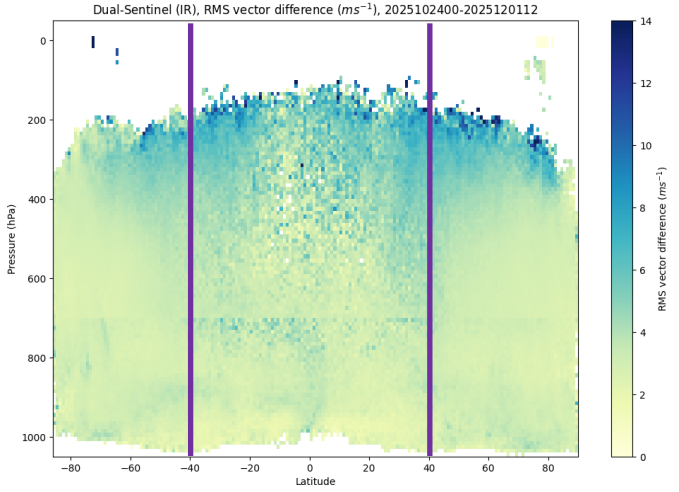
- QI>85, passing first guess check

Number | **Bias** | **RMSVD**

Dual-Sentinel

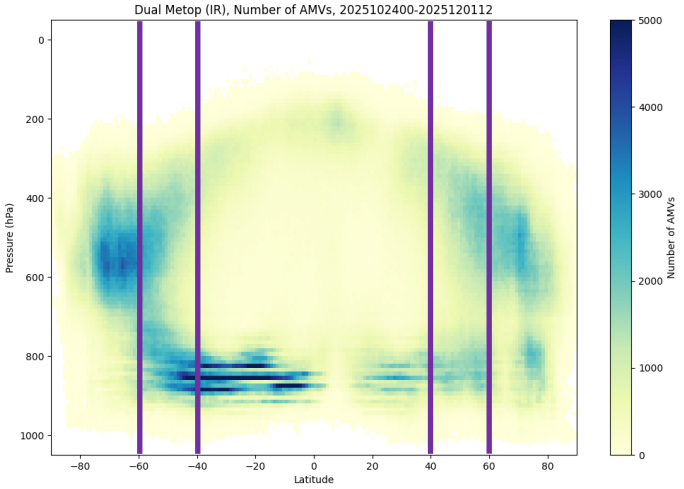


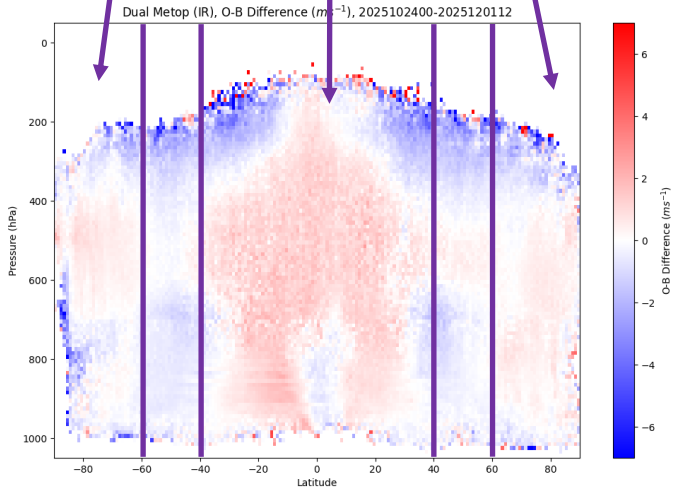


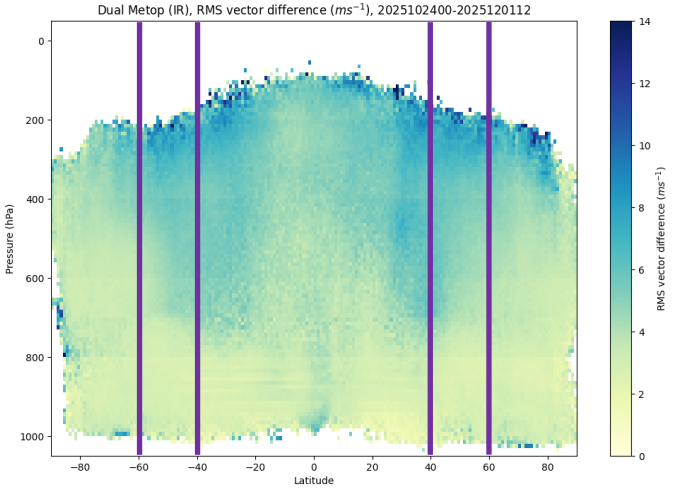


Won't assimilate in these regions

Dual-Metop







Summary

- **SWIR** channels add information at low levels at night-time in the tropics, west of continents. Initial assimilation results show promise.

- **LWIR** channels, previously excluded in the tropics at low levels, merit re-evaluation, due to recent improvements in height assignment.

- EUMETSAT **Dual-Sentinel** SLSTR AMVs give sensible statistics compared to Dual-Metop, supporting progression to full assimilation experiments.

- Assimilation experiment results are preliminary at this stage as experiments are on-going and a longer period is needed to establish more robust results.

Future plans

- Continue to evaluate the new EUMETSAT **Dual-Sentinel** SLSTR AMVs, with a view towards operational assimilation.

- Complete investigation on the use of AMVs derived from **short-wave IR** channels and **low level long-wave IR in the tropics**, providing operational recommendations.

- Assess the sensitivity and impact of **AMVs on AI-DOP**.

- Explore methods to better exploit the **spatial information in AMVs**, such as spatially correlated observation errors, superobbing, and spatially dependent thinning, and assess the feasibility and benefit of each approach. This would further benefit the use of AMV products from EUMETSAT.

Thank you for listening!

References

- Barbieux, K., Hautecoeur, O., De Bartolomei, M., Carranza, M. and Borde, R., 2021. The Sentinel-3 SLSTR atmospheric motion vectors product at EUMETSAT. *Remote Sensing*, *13*(9), p.1702.

- Lean, K. and Bormann, N., 2023. Using Model Cloud Information to Reassign Low-Level Atmospheric Motion Vectors in the ECMWF Assimilation System. *Journal of Applied Meteorology and Climatology*, *62*(3), pp.361-376.

- Warrick, F. and Bormann, N., 2022. Prospects for Improving AMV Spatial Coverage between geostationary and polar AMVs: LeoGeo and Dual-Sentinel. *EUMETSAT/ECMWF Fellowship Programme Research Report*, No.60

- Warrick, F., 2025. Quality Assessment and Assimilation of Meteosat-12 FCI AMVs. *EUMETSAT/ECMWF Fellowship Programme Research Report*, No.67