



NASA's GMAO Atmospheric Motion Vectors Simulator

Description and Application to the MISTiC Winds Concept

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Why simulate AMVs?

- In the recent past, significant efforts have been made to estimate the potential added value of new observations to the present Earth observing system by quantifying their expected impact on the current weather forecasting skills.
- OSSEs (Observation System Simulation Experiments) are an essential tool for this. A key aspect is that the envisioned observations are realistically simulated (mainly in terms of **spatial and temporal distributions, and errors**), for the DAS to show a similar behavior when applied to real observations.
- A code was designed to simulate cloud and water vapor features tracking AMVs using as an atmosphere the GEOS-5 Nature Run (G5NR), to be later used as simulated AMVs in OSSEs. The simulated wind observations are taken at G5NR gridpoints where clouds and water vapor gradients exist.
- Similarly to what is done in the GMAO OSSE framework, all simulated observations are drawn from the G5NR:
 - 7 km horizontal resolution
 - 72 vertical levels
 - Output every 30 mins



How to simulate AMVs?

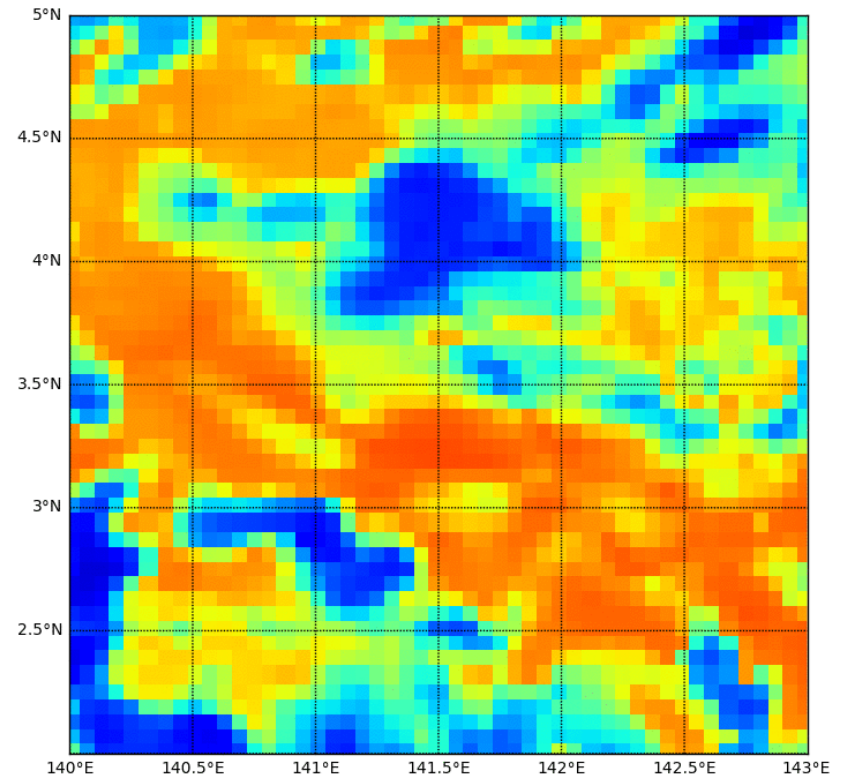
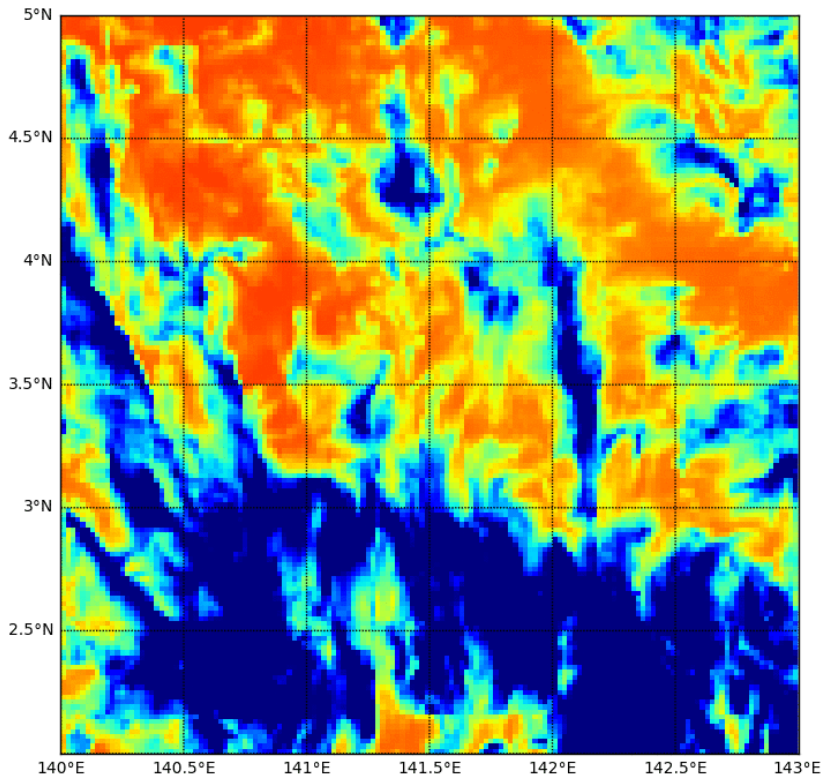
- However, feature tracking on a model grid such as the G5NR is not a reasonable option...
 - Coarse spatial resolution compared to satellite imagery (7 km vs. ~2-5 km)
 - Temporal resolution is also insufficient (30 mins vs. 10-15 mins)
 - G5NR does not have clouds and water vapor fields, but cloud fractions and humidity fields (not exactly the same...)

- Instead, ***trackable clouds and water vapor features*** are identified in the G5NR:
 - **Trackable cloud**
 - ✓ a “cloudy layer”: a set of adjacent vertical levels with a combined cloud fraction in the range of 20-80%
 - ✓ below the tropopause
 - ✓ not stationary
 - ✓ able to be seen by the instrument (not substantially covered by higher clouds above)

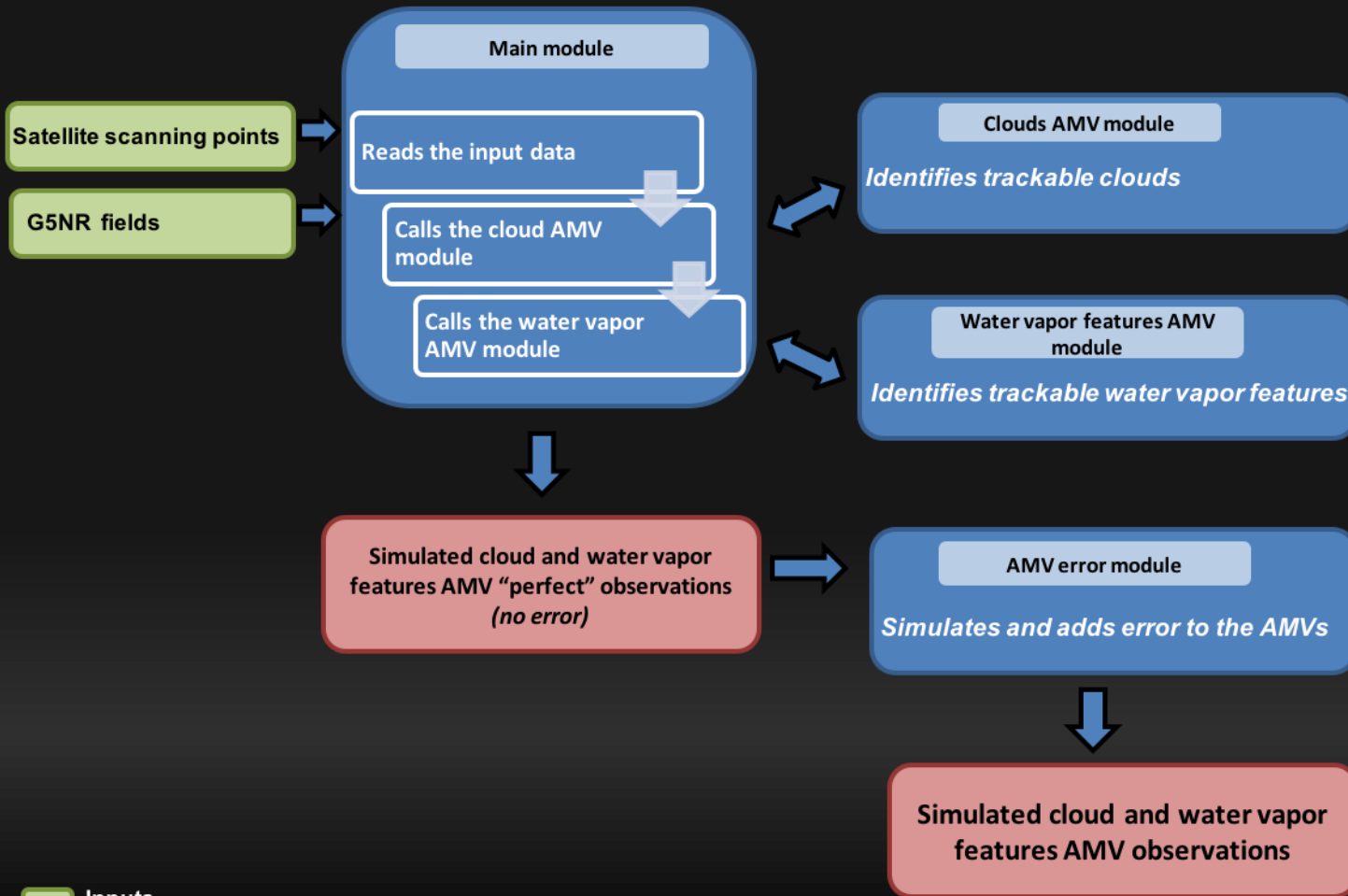
 - **Trackable water vapor feature**
 - ✓ Points in the G5NR where humidity gradients are high
 - ✓ below the tropopause
 - ✓ not stationary
 - ✓ not significantly covered by clouds above


Challenges in simulating AMVs from model output

- In the real atmosphere, a cloud or water vapor feature is *trackable* if it maintains its shape or appearance. That doesn't happen with cloud fraction or humidity fields in the NR.




GMAO AMV simulator



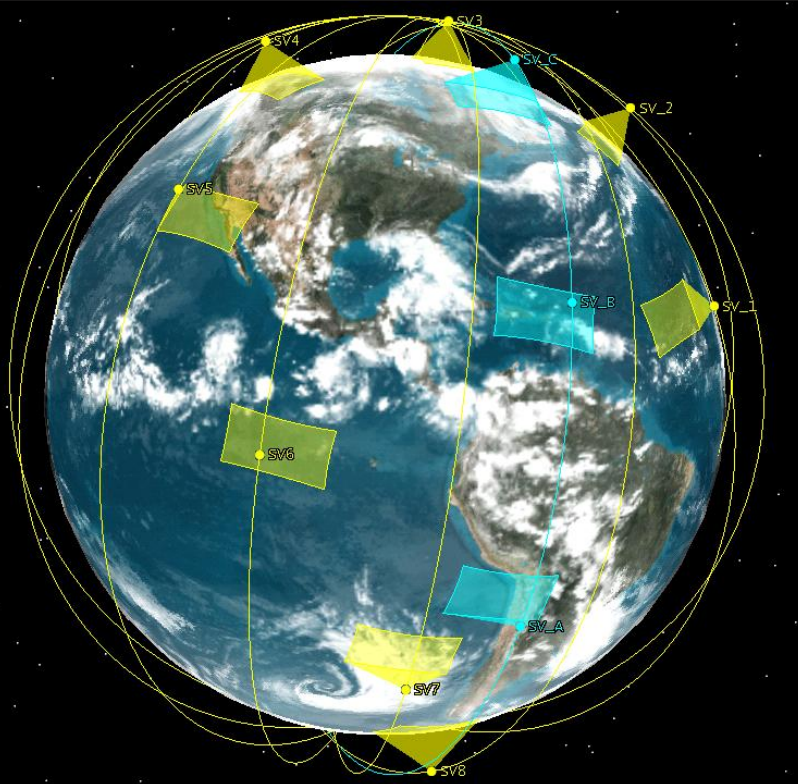
 Inputs

 Code

 Outputs

- ❖ A proxy instrument, or a set of assumptions, have to be considered to tune the code in order to derive the expected observation counts and spatio-temporal distributions.

MISTiC Winds observing system concept: a case study



➤ NASA mission concept consisting of a constellation of low Earth orbit (LEO) MicroSats.

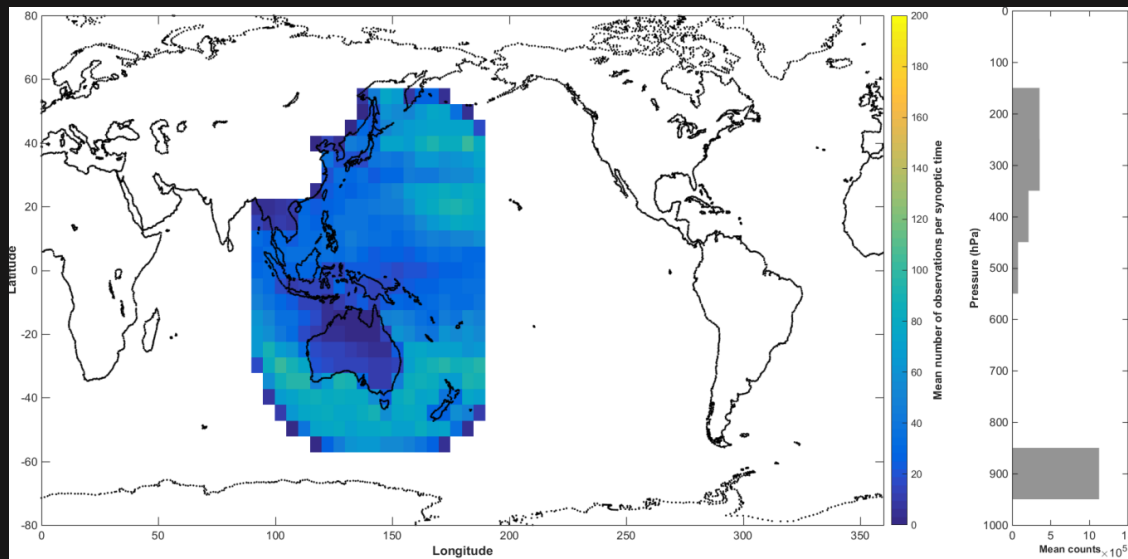
➤ Designed to provide temperature and humidity soundings of the atmosphere with high spatio-temporal resolution, providing radiances and AMV retrievals globally (including in the AMV latitudinal gap, 55-70 deg. N and S).

➤ The AMVs simulator was used to synthesize the AMVs expected to be derived from the MISTiC instruments, to be later used in OSSEs to assess the impact of these new observations.

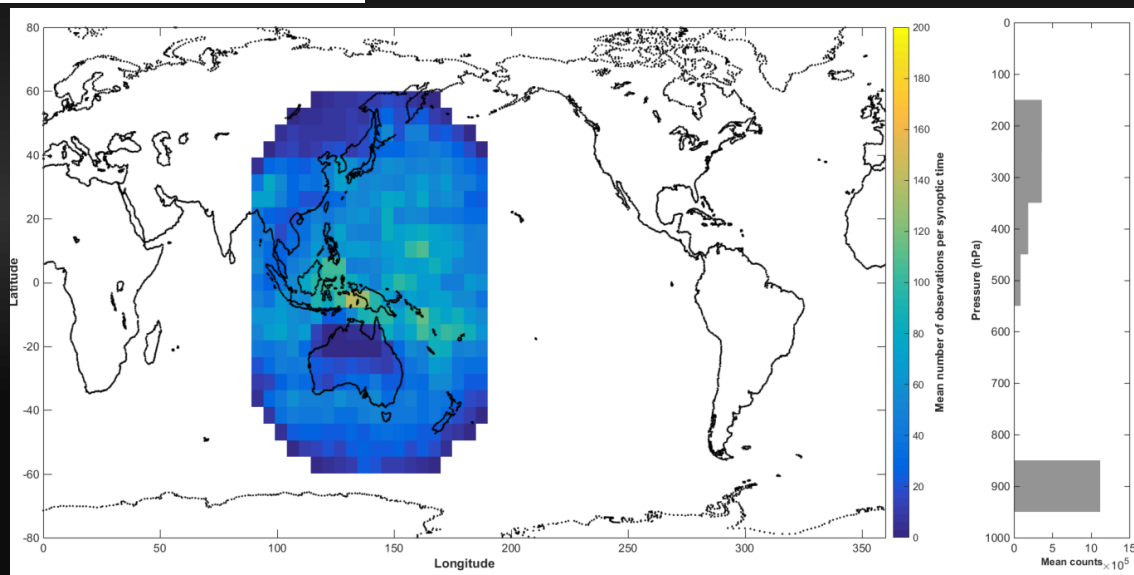
➤ The Himawari-8 Advanced Imager (AHI) was considered as a proxy instrument to tune and validate the AMVs simulator when applied to MISTiC.

- ❑ The approach is to tune the code to match the real AHI AMVs counts and distributions taking as input the Himawari-8 scanning points, and then use that configuration (with some changes specific to MISTiC instruments) to simulate MISTiC AMVs considering the satellite constellation scanning points.

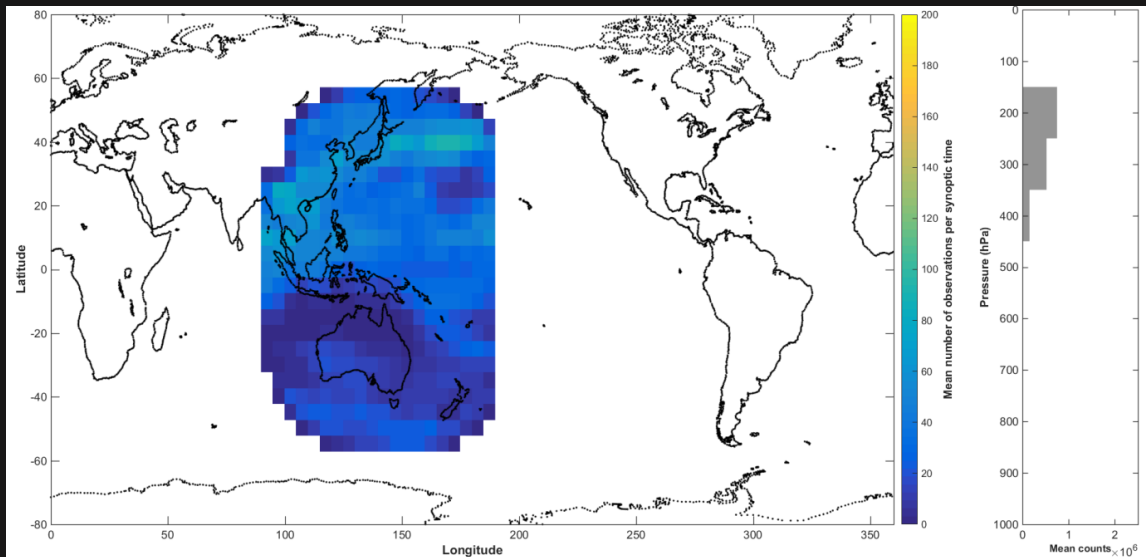
MISTiC Winds: simulated vs. real AHI cloud AMVs



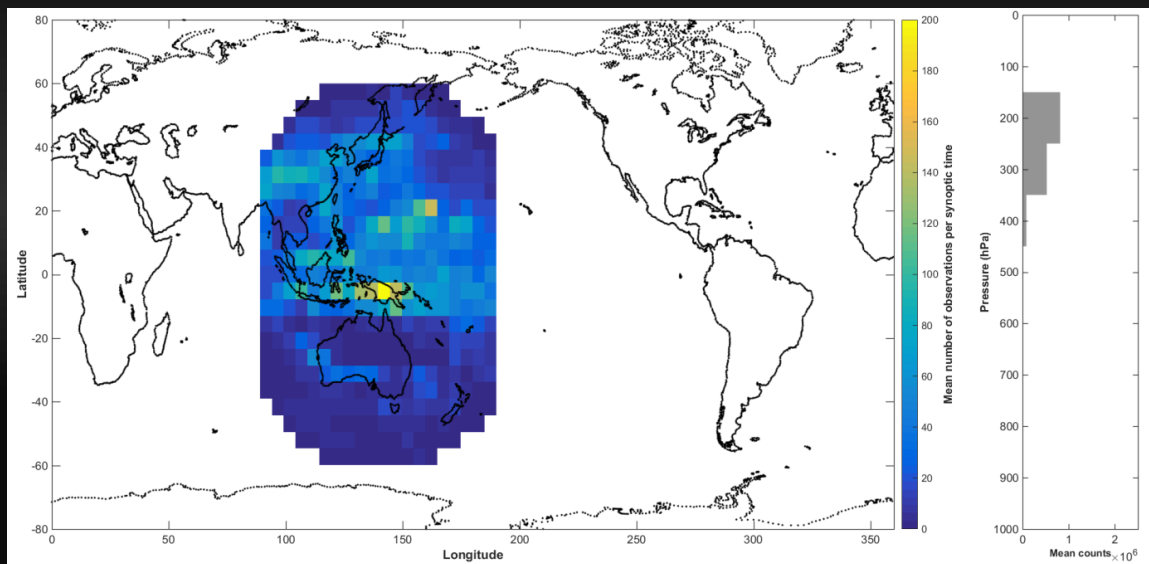
- ❑ Simulated Himawari-8 AHI cloud AMVs vertical distribution and number of obs match the real ones (~17,400 simulated vs. ~17,300 real average counts per synoptic time)
- ❑ Horizontal distribution not so much... Differences between the real and G5NR meteorology and cloud fields (?)



MISTiC Winds: simulated vs. real AHI WV AMVs

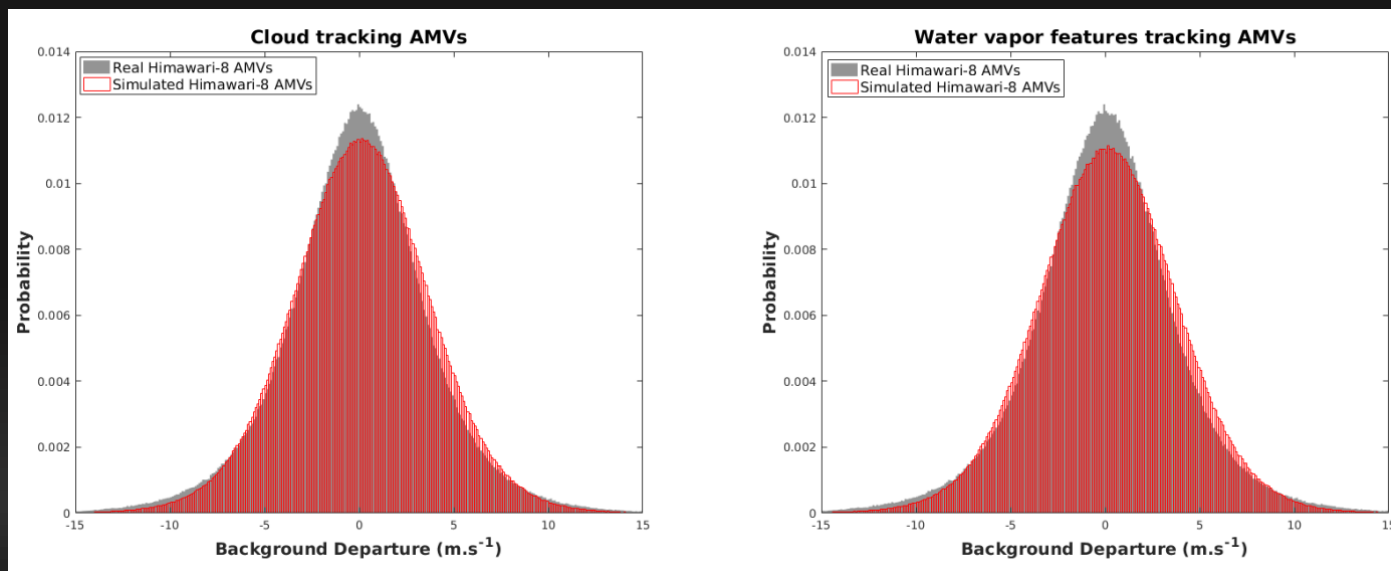


- ❑ Simulated Himawari-8 AHI water vapor AMVs vertical distribution and number of obs match the real ones (~11,450 simulated vs. ~11,500 real average counts per synoptic time)
- ❑ Again, horizontal distribution not so much... Differences between the real and G5NR meteorology and relative humidity fields (?)



MISTiC Winds: simulated vs. real AHI AMVs - Errors

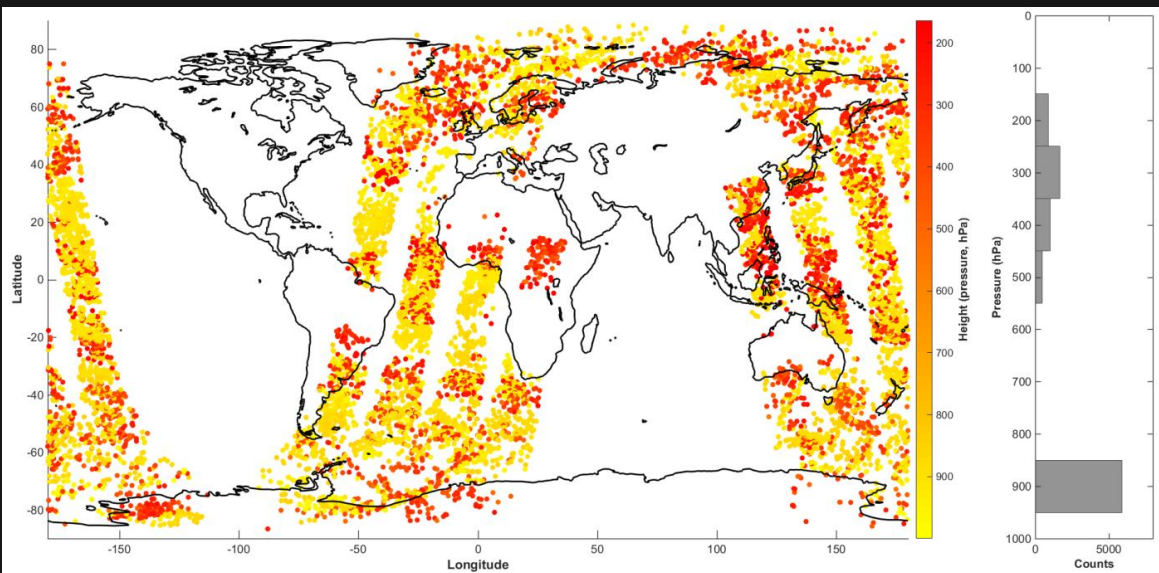
- For the DAS to show a similar behavior when applied to simulated observations, the differences between the observations and the background fields (background departures) have to be realistic >> similar to the real obs.
- Simulated AHI obs. error (following Errico et al., 2016) was added to the simulated AHI AMVs (random and correlated error).



- As a first guess, the simulated AHI errors were used as proxy for the MISTiC AMVs errors and added to the MISTiC "perfect" obs.

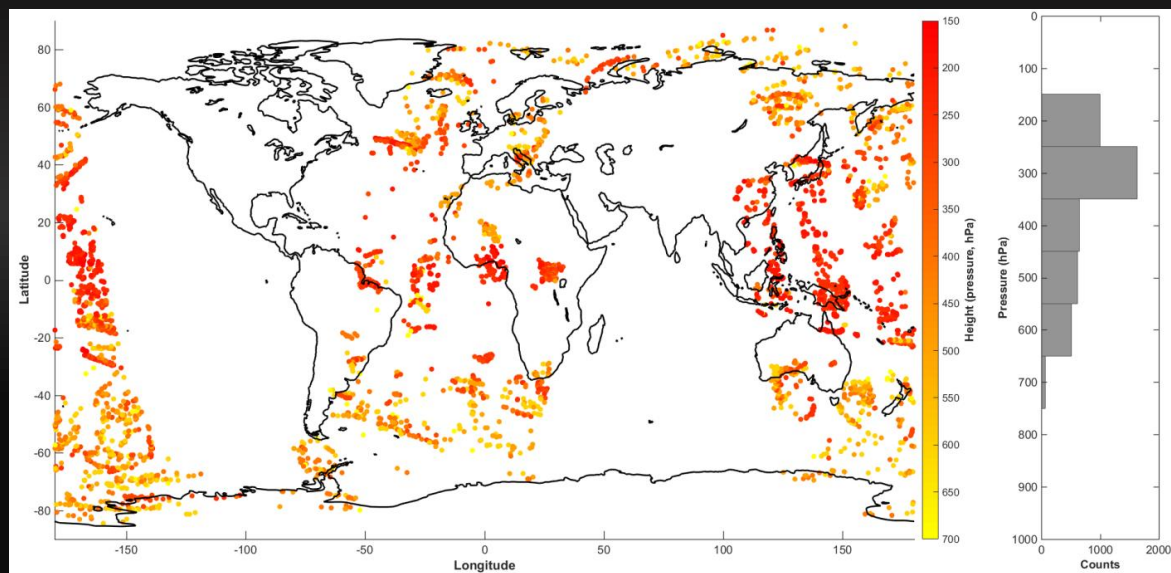
✓ **Despite the differences, the simulated AHI AMVs show a high degree of realism in terms of obs counts, spatial distributions and errors**

MISTiC Winds: simulated MISTiC AMVs

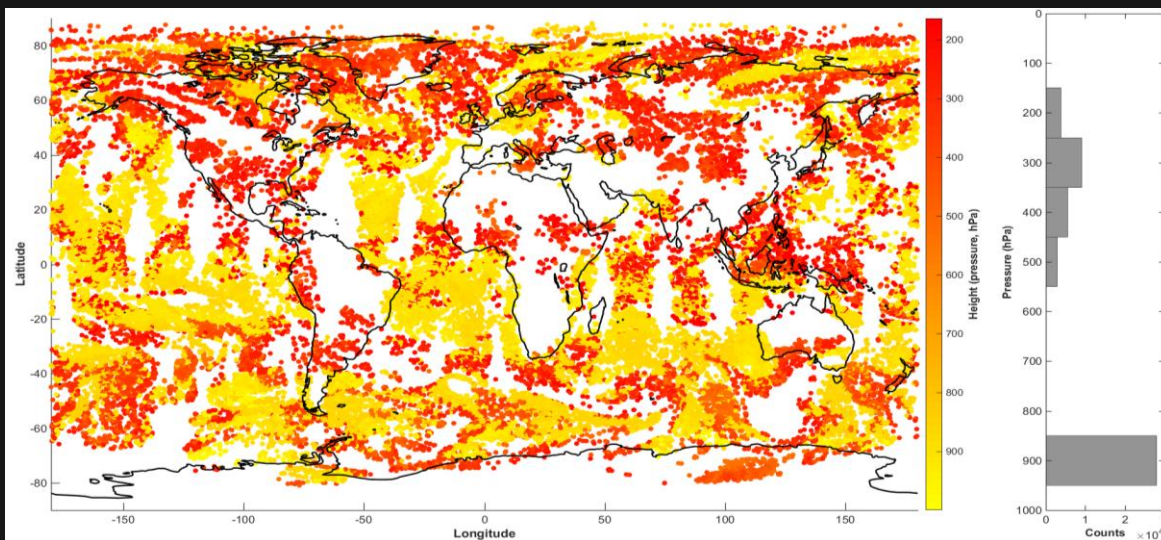


- Considering only one orbital plane (3 satellites), MISTiC Winds is able to collect approximately **13,000 cloud AMV observations** and **5,000 water vapor AMVs** every 6 hours.

- The simulated WV AMVs vertical distribution reflect one of the expected added-value of MISTiC Winds, being able to derive AMVs below 500-400 hPa, an unique feature among the water vapor AMVs derived from the current Earth observing system.

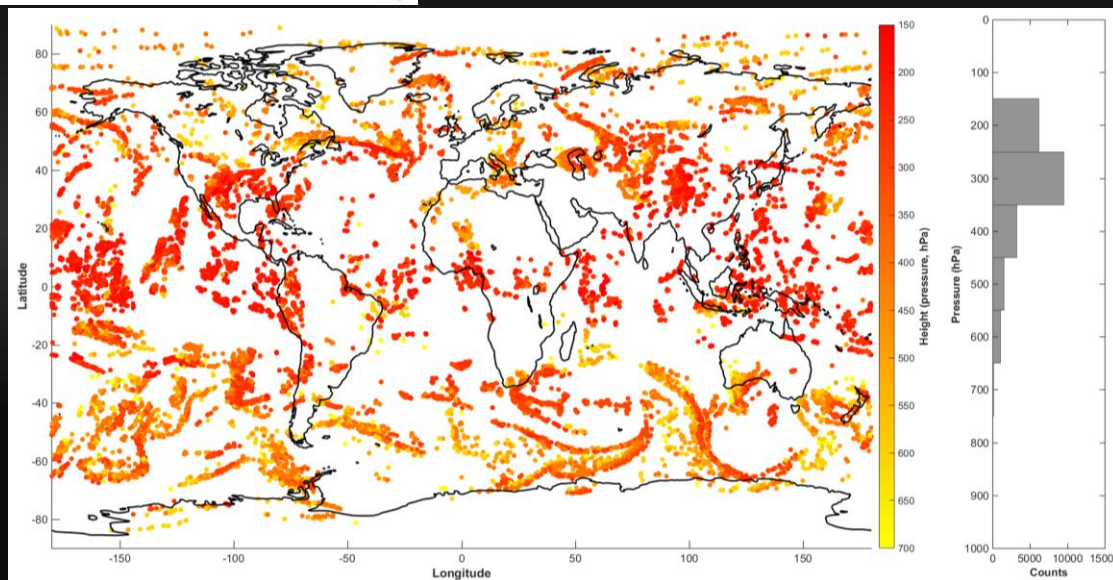


MISTiC Winds: simulated MISTiC AMVs



➤ If 4 orbital planes are considered, a **full global coverage** could be obtained every 6 hours, collecting ~ 74,000 AMV observations.

➤ Another unique advantage of MISTiC is that it can cover the **current AMV latitudinal gap**.





Conclusions

- ✓ An AMVs simulator was developed to simulate AMVs from future satellite constellation concepts, which can be later used in OSSEs to estimate the potential added value of new observations to the Earth observing system.
- ✓ The designed code identifies trackable clouds and water vapor features in the G5NR considering its cloud fraction and humidity fields.
- ✓ As a case study and application example, NASA's GMAO AMV simulator was used to simulate AMVs expected to be collected by a NASA mission concept – MISTiC Winds, a constellation of satellites equipped with infrared spectral midwave spectrometers.
- ✓ A tuning and validation considering a proxy instrument to MISTiC Winds (Himawari-8 AHI) showed that the AMVs simulator synthesizes AMVs with enough quality and realism to produce a response from the DAS equivalent to the one produced with real observations (the main goal of an OSSE).
- ✓ When applied to MISTiC Winds, it can be expected that a full global coverage will be obtained every 6 hours with approx. 74,000 wind observations, if considering a constellation composed of 12 satellites (4 orbital planes).
- ✓ The GMAO AMV simulator is a tunable and flexible code that can be easily adapted and applied to AMVs simulation expected to be derived from different instruments and satellite orbit configurations.