Investigating the Assimilation of Geostationary Water Vapour Radiances to extract Wind Information with an Ensemble Kalman Filter

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Deutscher Wetterdienst
Wetter und Klima aus einer Hand

Abstract

Satellite observations of water vapour radiances not only contain information about the water vapour distribution in the atmosphere but also on the wind field through the displacement of the water vapour structures. This information can be exploited through the direct tracking of these movements, done *e.g.* in the derivation of so-called water vapour atmospheric motion vectors, but also in a data assimilation system. For 4Dvar it has been shown that through the so-called tracer effect meaningful wind increments are derived from assimilating a sequence of water vapour radiances benefitting the forecast quality.

The current study investigates whether such wind information can also be obtained in an ensemble assimilation system context. The study uses the clear-sky radiances (CSR) from the geostationary MSG/SEVIRI instruments in the global EnVAR and LETKF system of DWD. To analyze the behavior of and the results in the ensemble DA, first artificial data from a nature run are assimilated and background error covariances and analysis increments and their dependence on key parameters like observation and background errors and localization approaches are studied. In parallel, the system is prepared for the assimilation of real data, including aspects like data monitoring and bias correction.

Results of the nature run experiments and studies involving real data are presented.

I) Operational ensemble DA system at DWD

A fundamental upgrade of DWD's operational NWP system has taken place over the last three years, consisting of:

1) Global model **ICON (ICO**sahedral **N**on-hydrostatic modelling framework, developed in cooperation between DWD and the MPI Hamburg for climate research), operational since **January 2015**. The non-hydrostatic model is formulated on an **icosahedral grid,** runs currently at **13km** resolution with **90 vertical σ-z-levels** (model top at 70km/~2.6 Pa). Higher resolution forecasts are provided at **6.5 km for a European domain** using two-way nesting (ICON-EU, see Fig. 1).

2) Global EnVAR data assimilation, operational since **January 2016**: A global LETKF (following Hunt et al. 2007) ensemble data assimilation at lower resolution, providing flow dependent background errors, is coupled to a full resolution deterministic 3DVar. The current ensemble size is 40 members (to be increased in 2018). See **Fig 1**. for illustration of setup.

3) Global ensemble forecasts, the **ICON-EPS,** with 40 members based on the analysis ensemble are operational since **December 2017** and produce forecasts up to 120 h (00, 12 UTC) and additionally 3-hourly 24 h forecasts used as boundaries for the regional ensemble.

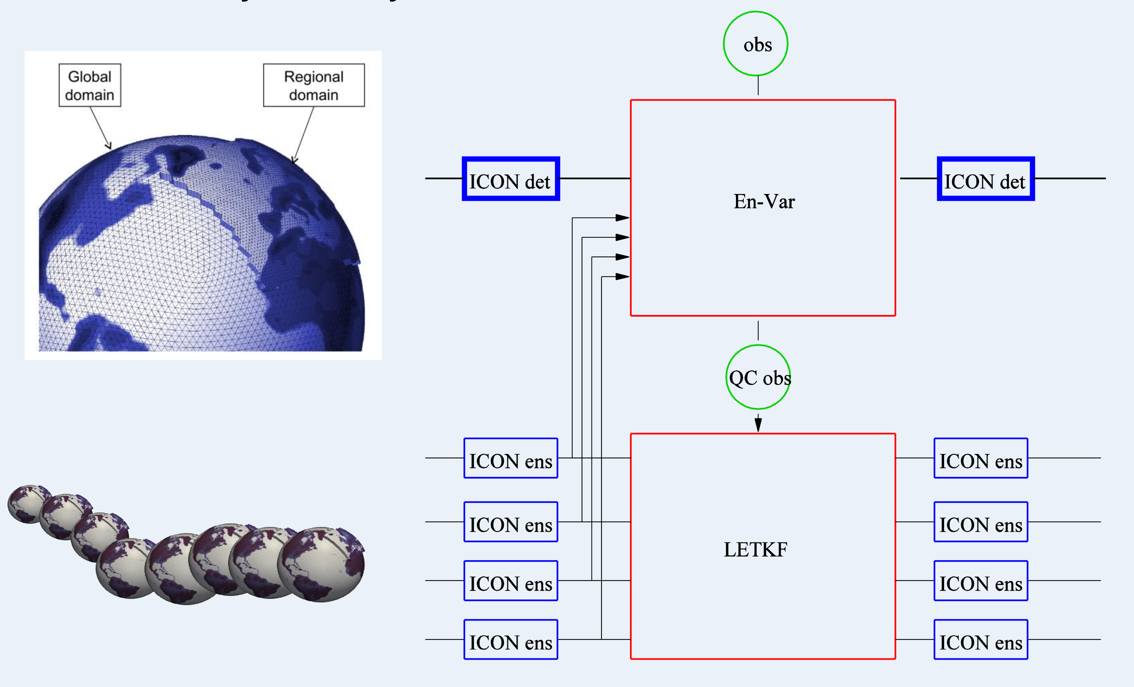

Fig. 1: Schematic diagram of the global NWP system: Interaction between global ensemble prediction (ICON ens, 40 km/20 km resolution) using LETKF ensemble analysis and the higher resolution deterministic forecast (ICON det, 13 km global/6.5 km Europe nest) using the EnVar analysis.
The EnVar uses the flow-dependent background errors from the ensemble blended with climatological covariances (70% ensemble-B/30% clim.-B). The observation processing and quality control (QC) are performed only once by the EnVar and used in the ensemble LETKF analysis.

II) Setup of idealised experiments

The Integration of the model (01-16.08.2017) is performed undisturbed (i.e. without an assimilation cycle). This model run is denoted as nature run and regarded as the truth in subsequent assimilation experiments. In this nature run a trajectory of the atmospheric development fully consistent with the model formulation is generated and all available observations (conventional and remote sensing) are processed by the observation operator. The results of the observation operator applications (model equivalents of the nature run) are then used as synthetic observations with added observation error (consistent with the assumed observation error in the DA) in a subsequent experiment.

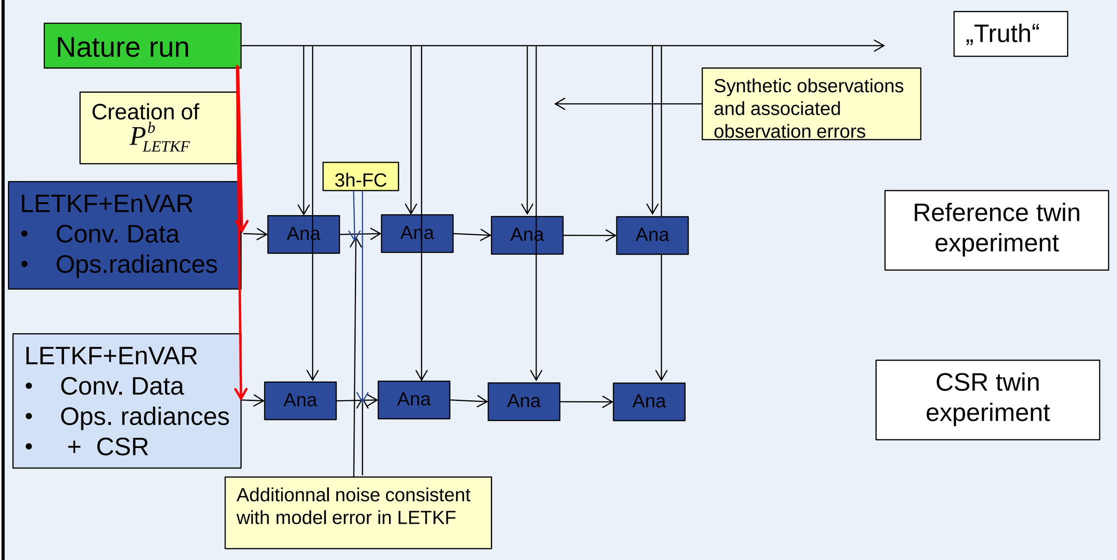

Fig. 2: The subsequent assimilation twin experiments (LETKF and EnVar) are performed using the synthetic (conventional and satellite) observations from the nature run. In the reference experiment all operational data are used. In the CSR twin experiments, MSG/SEVIRI observations are assimilated.
Before using the data in the assimilation system they are disturbed with random noise consistent with the assumed observational error.
The short range model forecasts (deterministic trajectory and ensemble mean) providing the background in the assimilation experiment is disturbed with noise consistent with the assumed model error in the LETKF.

III) Ensemble spread for temperature humidity and wind

At the end of each experiment, the ensemble spread has been computed for the variables temperature, humidity and wind at different layers and for vertical cross sections. The assimilation of MSG/SEVIRI CSR leads to a significant reduction of the ensemble spread. Some similar patterns in the spread of wind and humidity fields and cross sections (SH) may be due to wind information derived from the hunmidity data through the LETKF correlations.

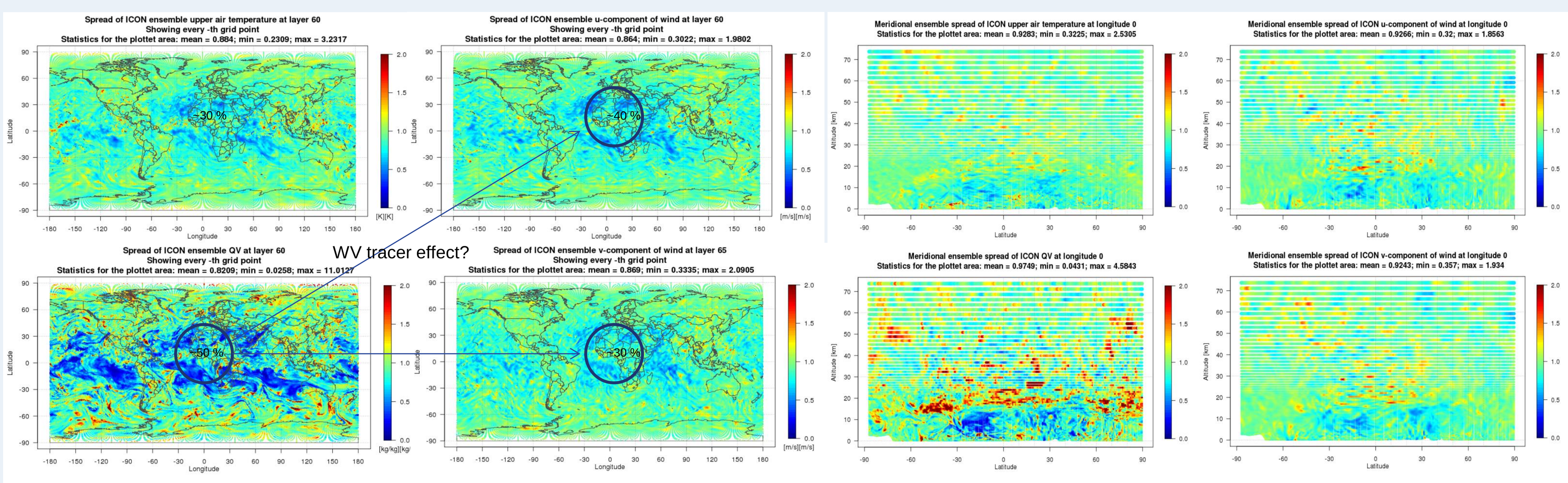

Fig. 3: Relative spread (ratio of the CSR forecast ensemble spread divided by the reference forecast ensemble spread) computed at the end of the twin experiments. A strong correlation between the patterns of humidity ensemble spread and wind ensemble spread can be observed in the scanning area of MSG/SEVIRI on the fields (left) as well as on the cross sections (right).

IV) Verification of CSR twin experiment vs nature run

The assimilation of MSG/Seviri clear sky radiances improves the skills of the LETKF/EnVar assimilation system in terms of scores as shown in figure 4, especially for the humidity and (to a lesser extend) wind, in the area and pressure range at which MSG/SEVIRI clear sky radiances are the most sensitive to a change in the water apour content.

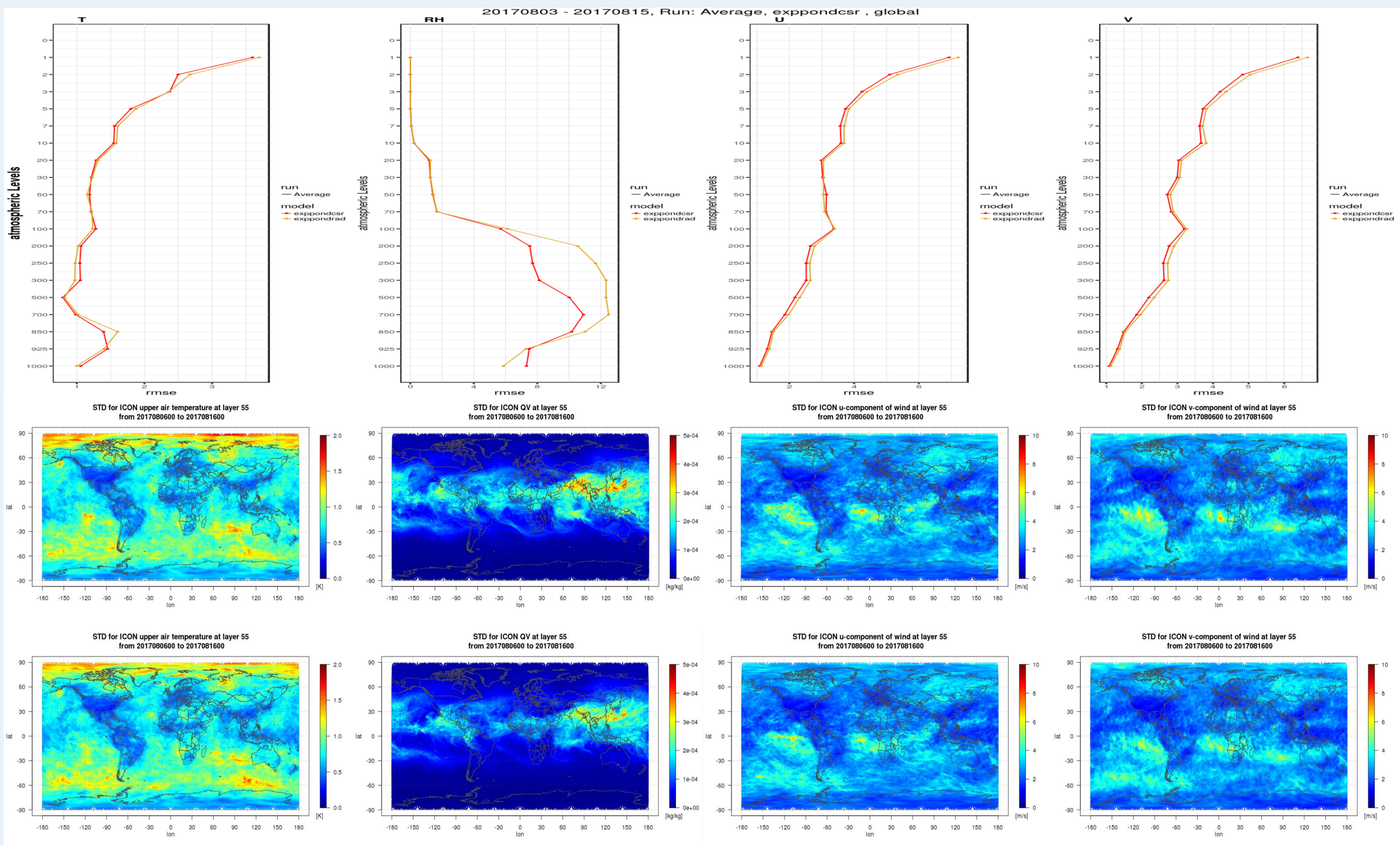

Fig. 4: Twin experiment statistics (with respect to nature run) plotted vertically (global height profile RMSE, top panel) and horizontally (STD of reference, top panel, and CSR, bottom panel) at 270 hPa for temperature, humidity and wind. With the inclusion of MSG/SEVIRI clear sky radiances into the EnVar/LETKF assimilation system, the forecast error in the mid troposphere is greatly (~35%) reduced, which leads to a slight improvement of wind forecasts.

V) Assimilation experiment with real SEVIRI/CSR data

- Assimilation method: EnVar
- Time period: 01.06.2017 – 31.08.2017
- Reference experiment:
  - Assimilation of operational data
  - Assimilation of IASI, MHS and ATMS water vapour channels
- Assimilation of SEVIRI CSR:
  - Channel 2: 6.2 µm
  - Channel 3: 7.3 µm

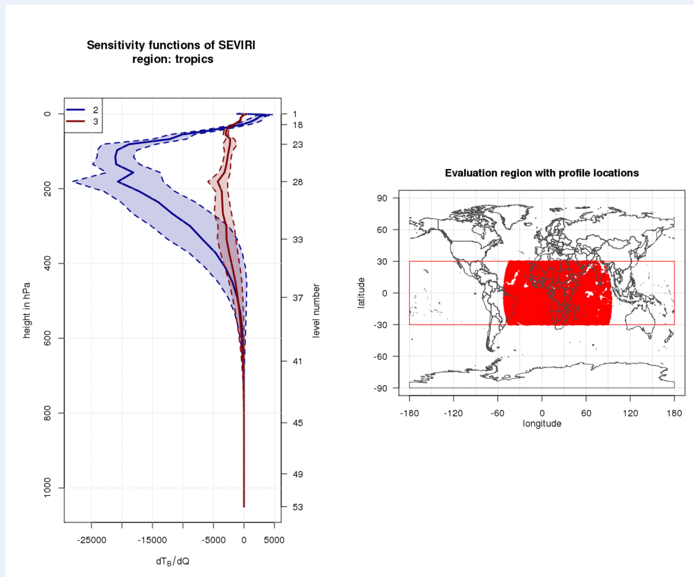

Fig. 5: SEVIRI/CSR Jacobians for Q.

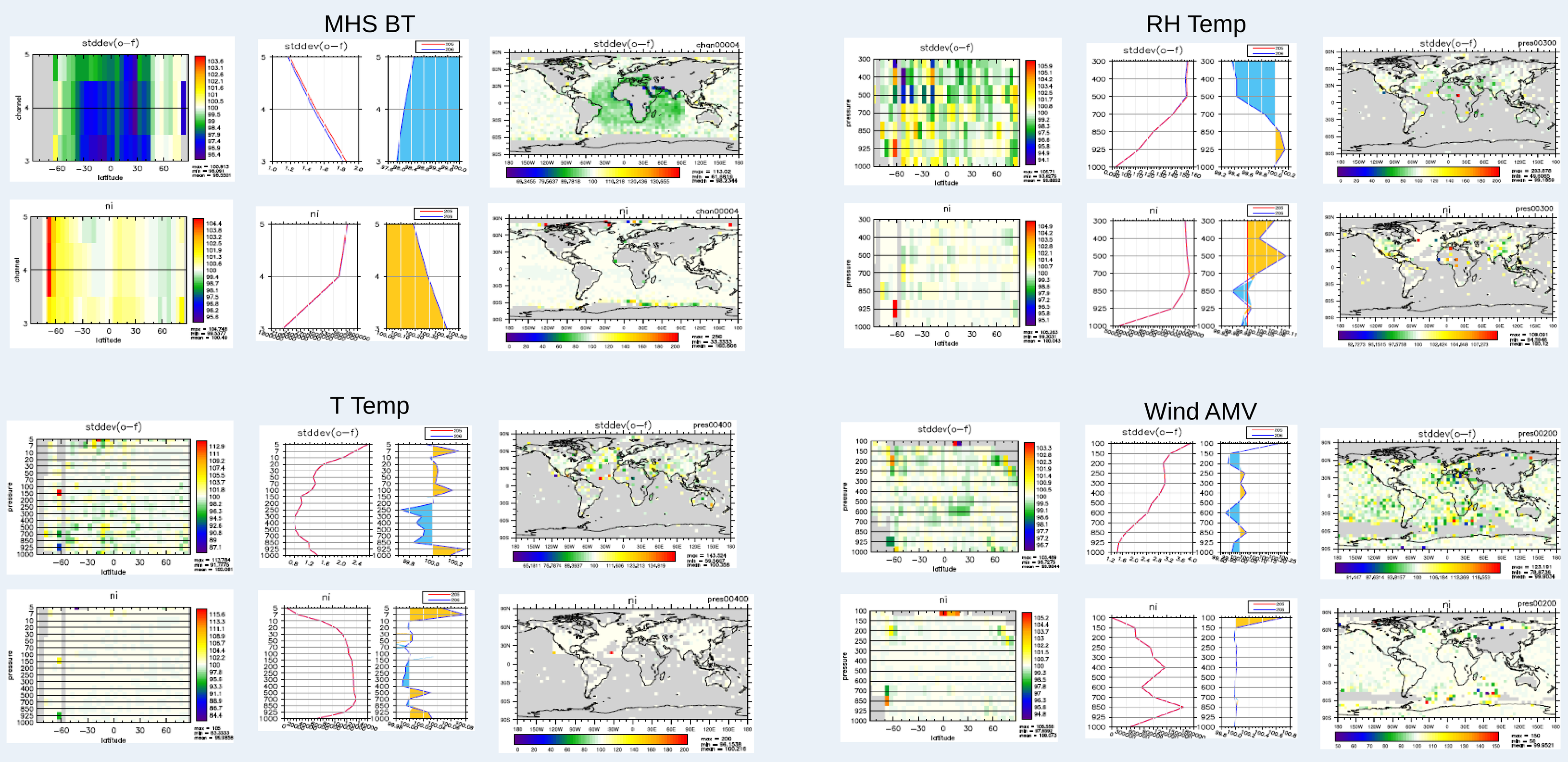

Fig. 6: Relative difference of stdv (OBS-FG) and number of used data between CSR assimilation and reference experiment for selected other assimilated data types: MHS ch. 3-5 (top left panels); radiosonde humidity (RH, top right panels); radiosonde T(bottom left panels); AMV (bottom right panels).

VI) Outlook

- Nature run setup:
  - Further evaluation of increment
  - Tuning of localisation in LETKF
- Real data:
  - Comparison with other humidity sounder experiments is ongoing (Fig. 7)
  - Extension of assimilation to GOES and Himawari CSR (implementation started)

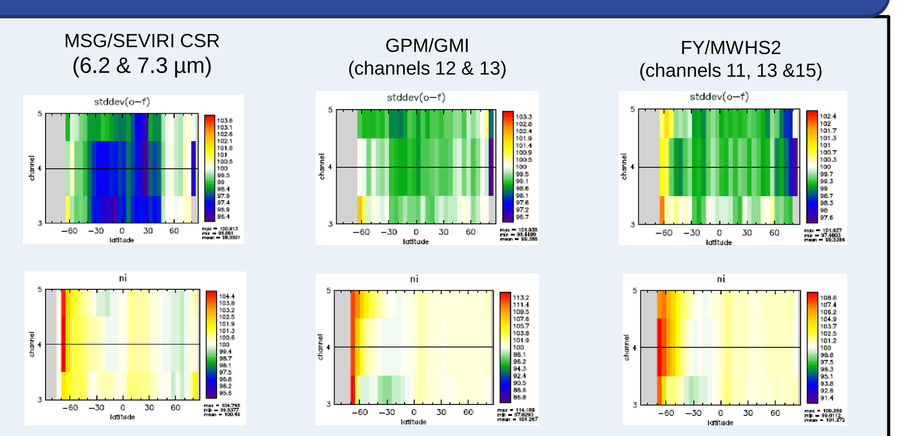

Fig. 7: Same as Fig. 6 but comparing results for three humidity sounder experiments using SEVIRI/CSR, GMI or MWHS-2.

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