Assimilation of GIIRS on-board FY-4B in the ECMWF IFS

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ECMWF

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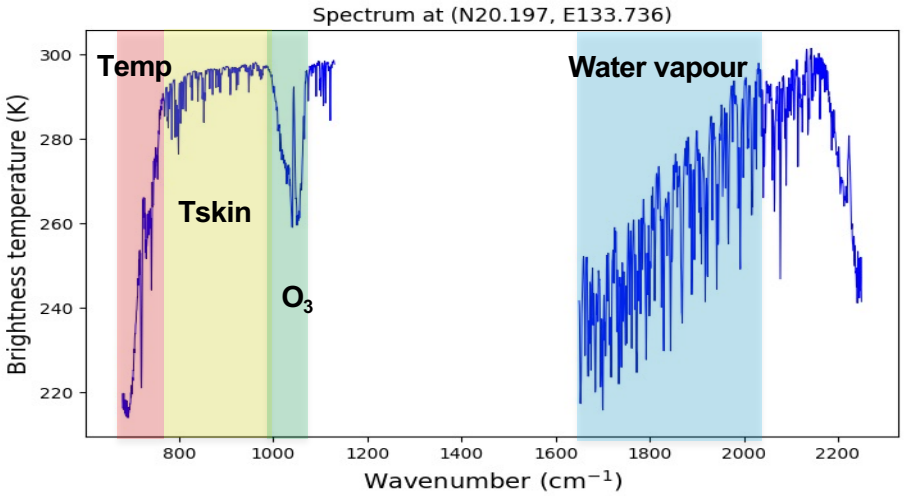
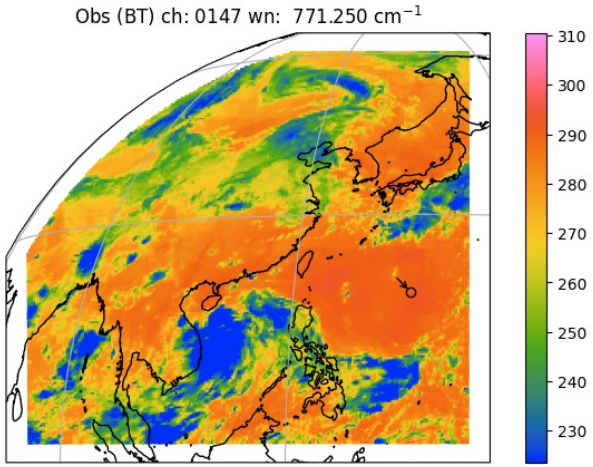
Overview of FY-4B GIIRS observations

FY-4B GIIRS: The first operational hyperspectral infrared sounder onboard Chinese geostationary satellite FY-4B

- Launch date: 3rd June 2021
- Observation area: east Asia
  - 79 -142E for longitude and 0 -70N for latitude (until Feb 2024)
  - 75-129E for longitude and 1-70N for latitude (after the relocation of FY-4B in Feb 2024)
- Observation wavenumber range
  - LWIR: 680-1130cm^{-1}, MWIR:1650-2250cm^{-1}
- Spectral resolution: 0.625cm^{-1}
- Time interval of full disk scan: 2 hours



FY-4B GIIRS Observation at 01UTC 24th Sep 2023

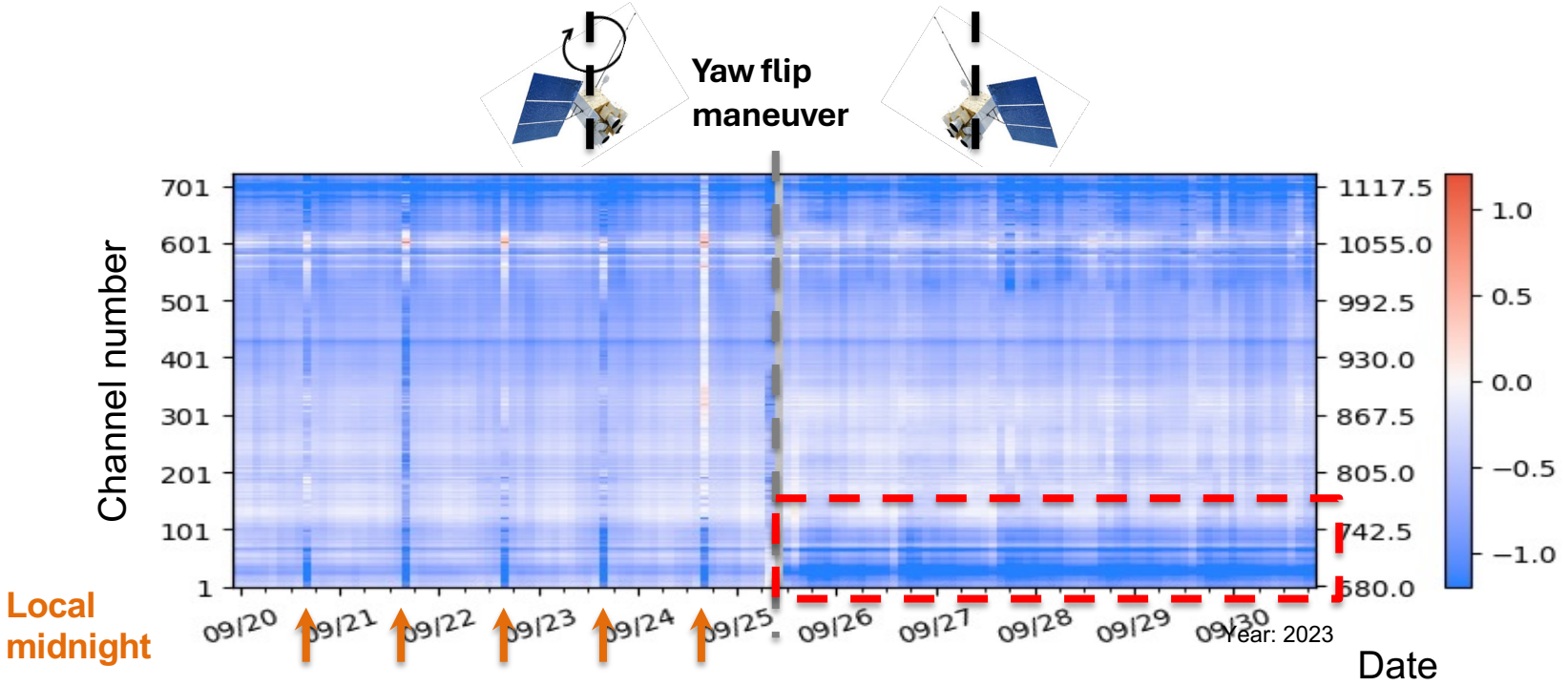


The circle denotes the location of the spectrum (left figure).

FY-4B GIIRS gives us detailed information on atmospheric structures (temperature, skin temperature, water vapour and ozone) both spatially and temporally. Assimilation of these data is expected to improve numerical weather prediction.

Data quality assessment

The averaged O-B binned by channel and date/time for long-wave band (after QC)



- **The bias is largely negative during local midnight due to solar intrusion.**
- **The bias of channels (< 742.5cm^{-1}) suddenly changes after the yaw flip manoeuvre.**

What causes the sudden change of bias?

- Yaw flip manoeuvre, in which the satellite rotates about the axis pointed towards the centre of the earth, is performed in March and September (twice a year) to prevent solar intrusion into the sensor.
- It is possible that the scanning mirrors are not cooled enough and emit thermally depending on solar intrusion. The thermal emission may not be accounted properly in the radiometric calibration.
- MTG IRS will also have yaw flip manoeuvres.

Assimilation setup

- Control
  IFS CY49R1 (ECMWF global DA system with TCo399 horizontal resolution(25km))

- FY-4B GIIRS assimilation
  Assimilation configuration for GIIRS
  - Assume clear-sky condition
    Cloud detection based on McNally and Watts (2003)
  - Assimilate 81 channels on 22 pixels of FY-4B GIIRS detector array
  - Exclude the data during local midnight (15-17UTC) due to solar intrusion
  - Use observation errors and correlation matrix
  - Apply the variational bias correction scheme
    Bias correction predictors: a constant, the layer thickness and a third-order polynomial of the nadir viewing angle

- Verification period
  - 8th June – 31st October 2023
  - 8th December 2023 – 29th February 2024

=> Total length is about 8 months.

Channel selection

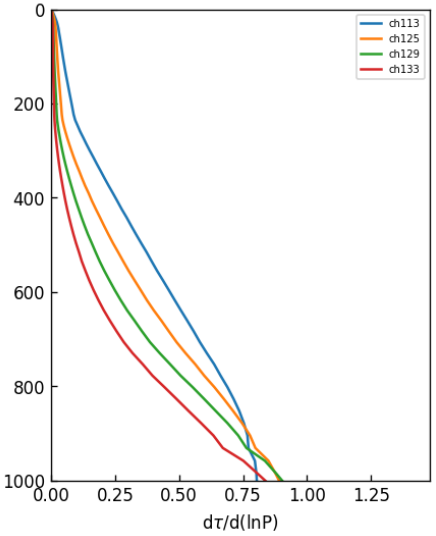
81 channels for assimilation are selected from channels with wavenumber larger than 742.5cm^{-1} to avoid the change of bias during the yaw flip manoeuvre.

Channels selection is based on the following method.

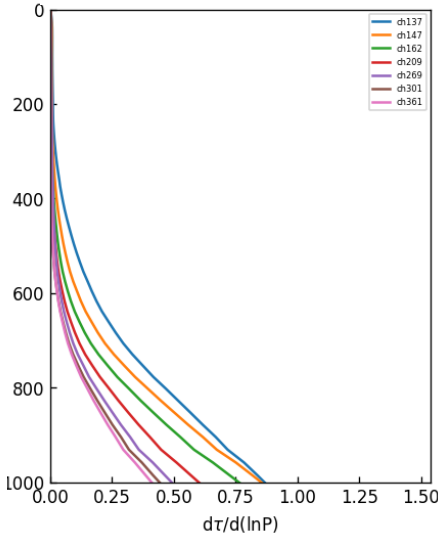
- For temperature, surface and ozone channels, select the same wavenumbers as CrIS.
- For water vapor channels, select based on the degree of freedom for the signal (DFS).

Weighting function of selected channels

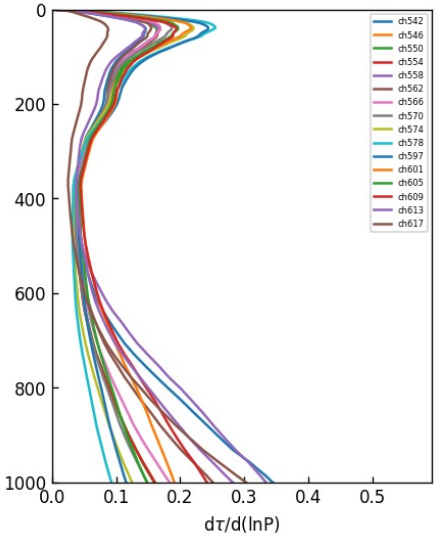
Channels sensitive to temperature (4 chs)



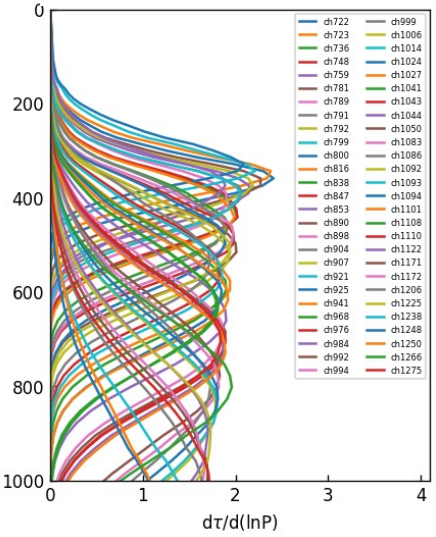
Channels sensitive to surface (7 chs)



Channels sensitive to O_3 (16 chs)



Channels sensitive to water vapour (54 chs)

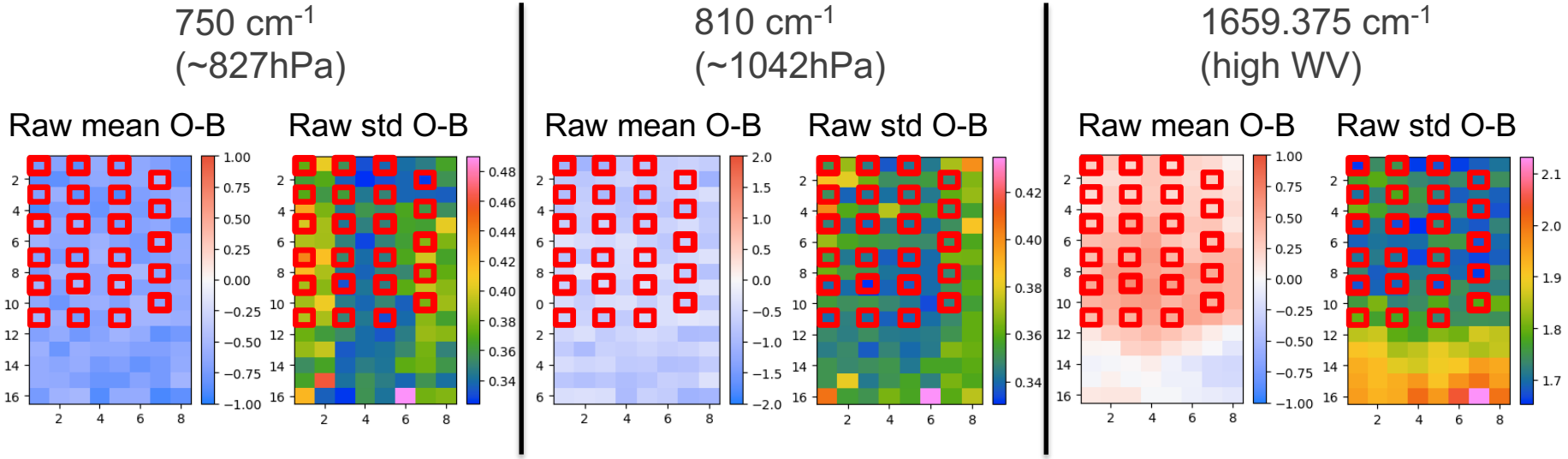


Pixel selection

The sensor of GIIRS is a 16x8 detector array. In clear-scene pixels, the means show some concentric/diamond patterns in water vapour channels.

22 pixels with similar bias and small observation error are selected for assimilation.

The statistical period: July 2023



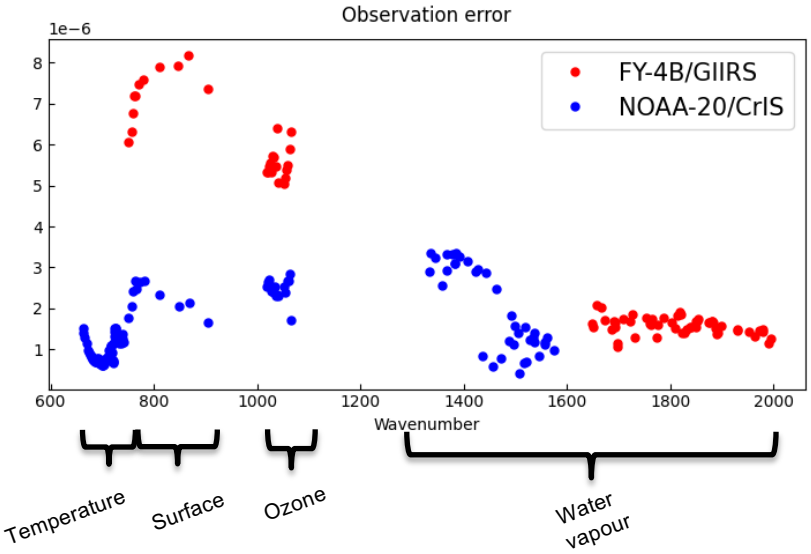
Red square : selected pixels

Observation errors and correlation matrix

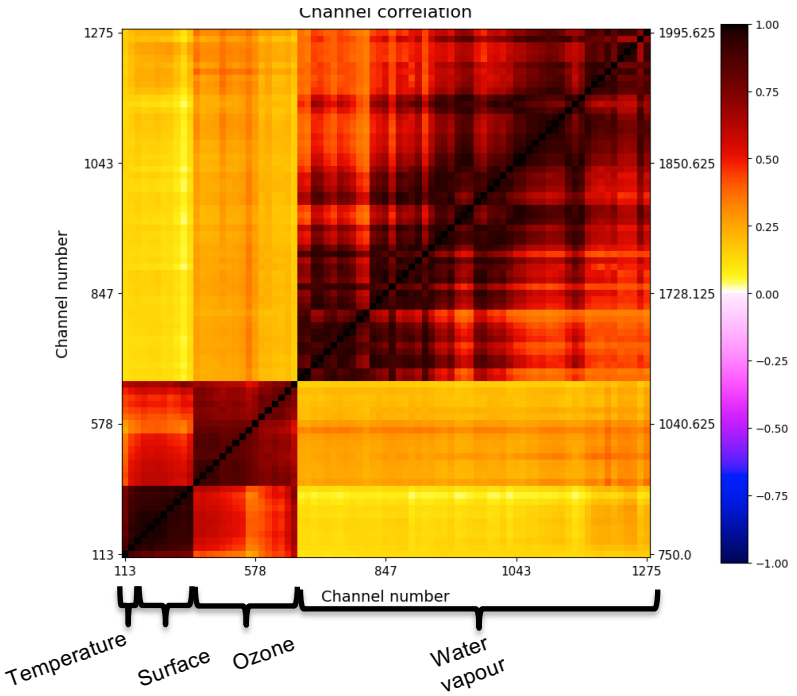
Observation errors and inter-channel observation-error correlation matrix are diagnosed based on Desroziers et al. (2005). FY-4B GIIRS has larger observation errors than NOAA-20 CrIS in temperature, surface, and ozone channels.

The statistical period: July 2023

Observation errors (in radiance unit)



FY-4B GIIRS
inter-channel observation-error correlation matrix

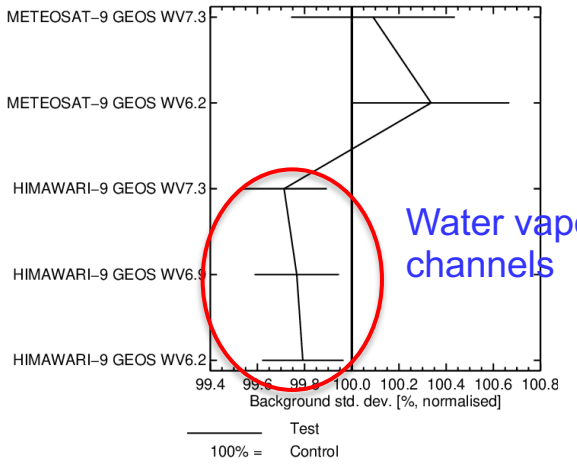


Forecast impact; short-range forecast

First guess fits better to other observations sensitive to temperature, humidity and wind in middle troposphere. Assimilation of FY-4B GIIRS results in short-range forecast improvement over the GIIRS domain.

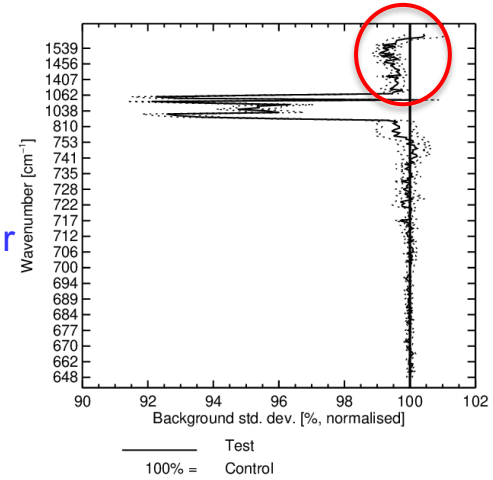
Verification area: over the GIIRS domain

- GEO IR



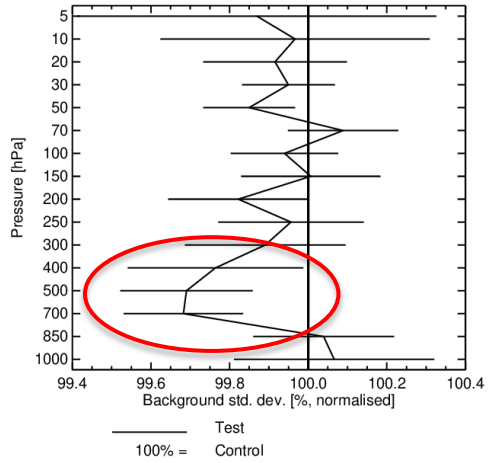
Water vapour channels

- IASI

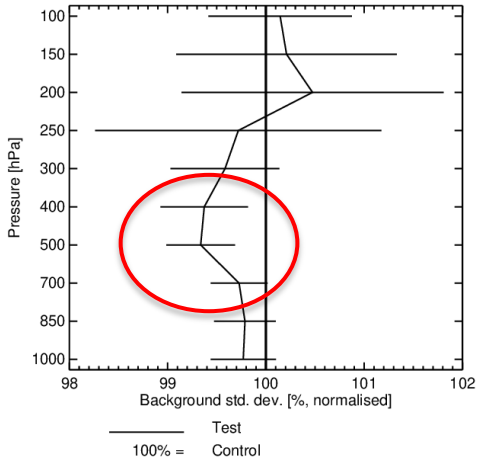


Water vapour channels

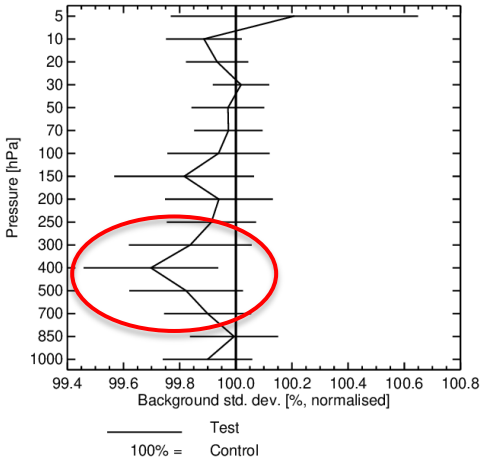
- TEMP-T



- TEMP-Q



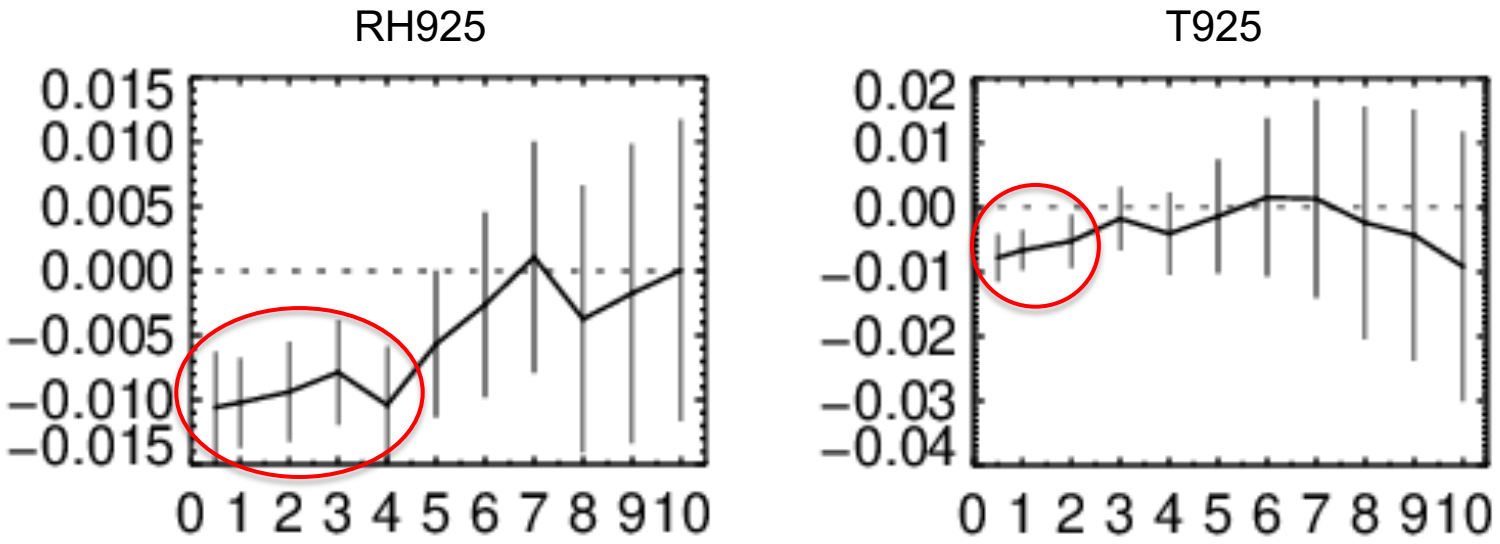
- Aircraft wind



Forecast impact; long-range forecast

Assimilation of FY-4B GIIRS leads statistically significant forecast improvement of temperature and relative humidity in lower troposphere over sea of the GIIRS domain until forecast day 4 due to lower troposphere channels.
The other elements of long-range forecast are almost neutral.

Timeseries of change in RMS of forecast error over the GIIRS domain



Summary

- FY-4B GIIRS gives us detailed information on atmospheric structures over east Asia.
- There are still some issues in FY-4B GIIRS, including sudden change of bias, systematic differences in the pixels across the detector and horizontally-correlated observation errors in high-peaking temperature channels.
- Selection of channels and pixels enables to avoid these issues and get forecast improvement from FY-4B GIIRS assimilation.
- FY-4B GIIRS assimilation leads forecast improvement of temperature, humidity and wind.
- The investigation of FY-4B GIIRS is also beneficial to learn how best to exploit observational data from geostationary hyperspectral infrared instrument such as MTG IRS.

Thank you for your attention!

Any questions?