Assimilation of INSAT-3D Water vapor Imager radiances in the NCUM Assimilation system

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1. Introduction
2. Bias Correction
3. Single Observation Experiment
4. 1D-VAR Experiments
5. Global Assimilation and Forecast

INSAT3D/3DR :

Geostationary satellites (82 °E/74 °E) over India and surrounding oceanic regions.

19 channel sounder and 6 channel Imager

6 channel Imager
Spectral Bands (µm)

Visible : 0.55 - 0.75
Short Wave Infra Red : 1.55 - 1.70
Middle Infra Red : 3.80 - 4.00
Water Vapour : 6.50 -7.10
Thermal Infra Red-1 : 10.30 -11.30
Thermal infra Red-2 : 11.50 – 12.50

Resolution :
1 km VIS and SWIR
4 km MIR and TIR
8 km WV

19 channel Sounder
Spectral Bands (µm)

Short Wave Infra Red : 6 bands
Middle Infra Red : 5 bands
Long Wave Infra Red : 7 bands
Visible : 1 band

Resolution (km):
10 x 10 (all bands)

Water vapor channel (6.5 – 6.9 µm)

Water Vapor channel is used to sample the upper atmosphere. Water vapor and high clouds absorb the radiation in this spectral region so that the surface of the earth and low clouds are nearly obscured in water vapor images.

WV channel in both the imagers (INSAT-3D/3DR and MVIRI) are at the centre of the absorption band with strong absorption and consequently radiation only from higher levels come to the satellite.

WV radiance provides valuable information to the NWP in the upper tropospheric levels of the atmosphere, where the atmospheric motion vectors are less.

NCMRWF Unified Model (NCUM) System

NCUM used at NCMRWF for NWP is adapted from the Unified Model (UM) system of Met Office, UK.

The NCUM data assimilation system has mainly four components, Observation Processing System (OPS), Surface Data assimilation (SURF), Hybrid-4D-Variational assimilation (VAR or 4D-Var) and the model.

The OPS system mainly processes the data, does quality control of observations and prepares the observation for assimilation.

In this implementation, a low-resolution 4D-Var at N144 is run ahead of the main 4D-Var run at N320 resolution which leads to quicker convergence of the 4D-Var algorithm hence significant reduction in run-time 4D-Var at N320 resolution

SURF is the surface data assimilation component of NCUM

The non-linear forecast model used here (NCUM) has a resolution of 17 km (N768) in midlatitudes. The model has 70 levels in vertical reaching up to 80 km.

DATA QUALITY (Bias Correction)

In order to monitor the biases in the observations, measured satellite radiances are compared with their equivalents computed from short-term forecasts .

The assumptions made in this type of comparison are: the observed satellite radiances are free from calibration errors, the radiative transfer model is accurate, and the short-term forecast provided by NWP model is free from systematic errors.

These assumptions are not always valid. Biases vary with time (both diurnal and seasonal variations of biases), geography or air mass, scan position of satellite instrument and the position of the satellite in its orbit.

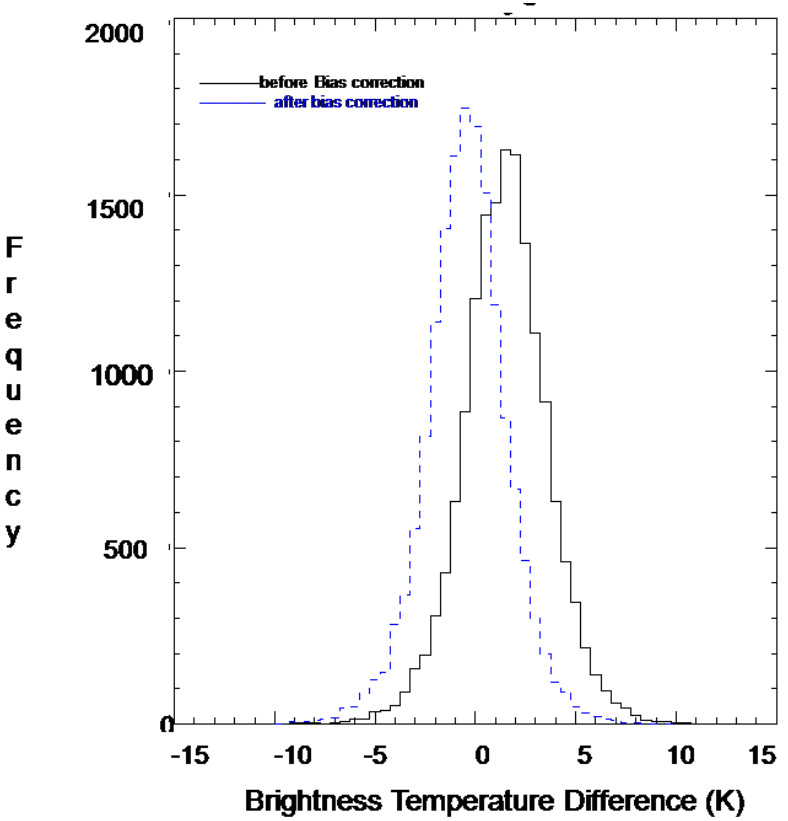
In this study, the model equivalents of the observed Brightness Temperatures (Tbs) are computed using a fast Radiative Transfer Model RTTOV-9.

Innovations, the differences between the observations (O) and simulations based on the forecast fields (B), are used to diagnose the errors in the observation.

In variational data assimilation, both the observation and background errors are assumed to be Gaussian and unbiased.

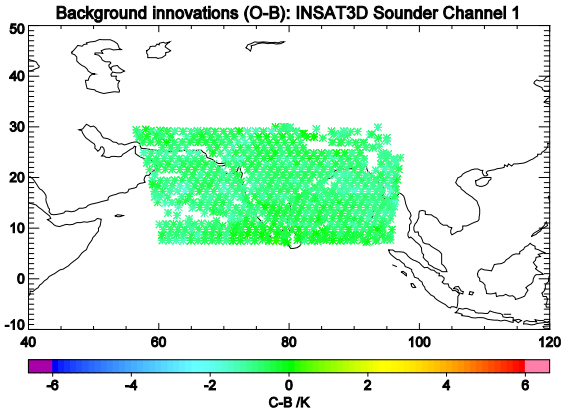
Histograms of innovations before and after the bias correction are indicative of how well the bias correction works.

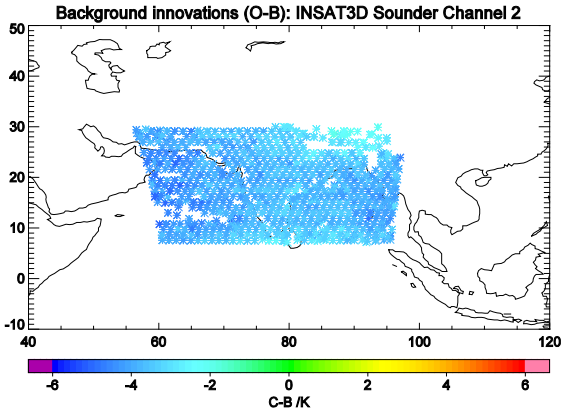
The bias correction works perfect, if the mean of the innovation shifts towards zero (very close to zero) in the distribution after bias correction.

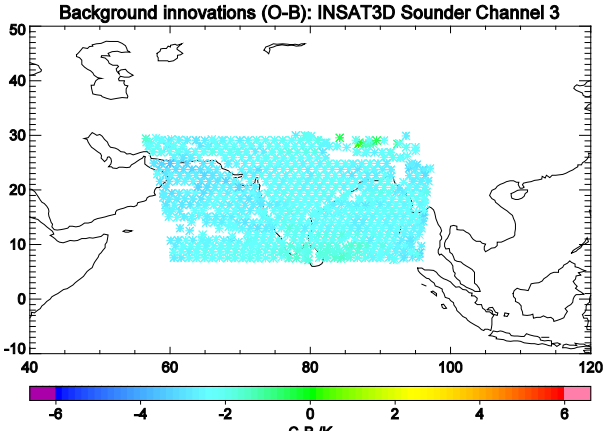


Bias Correction: INSAT3D

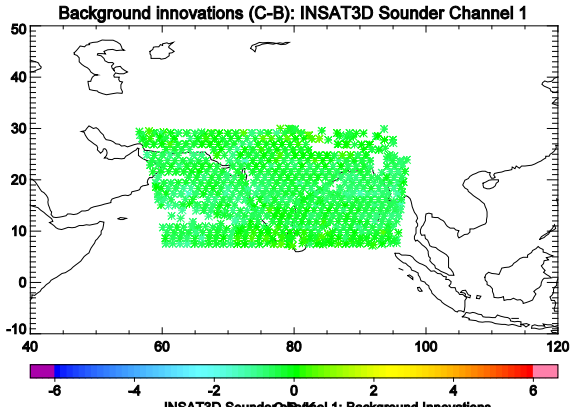
O - B

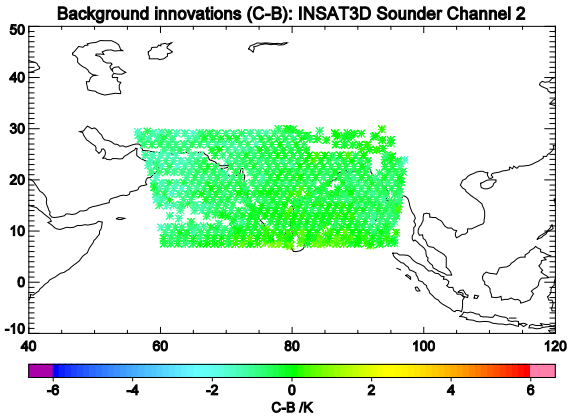


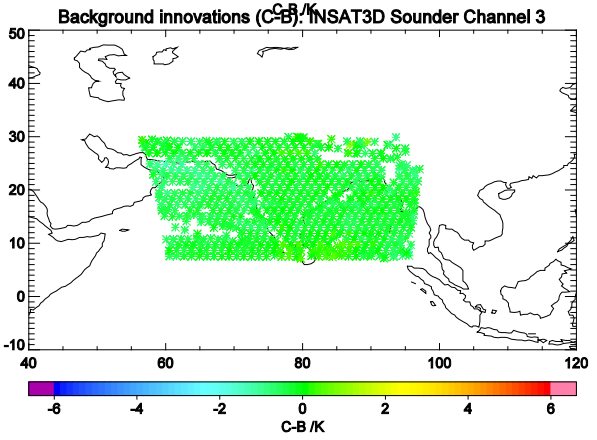




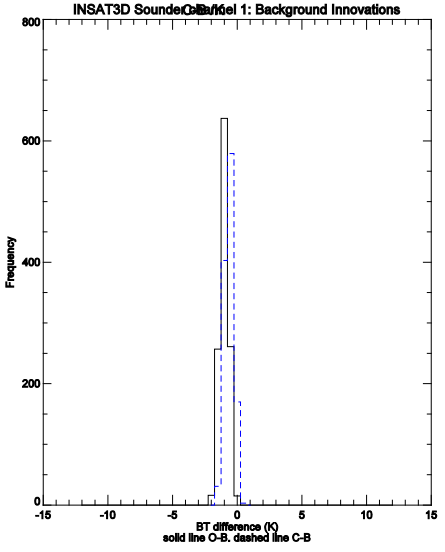
C - B

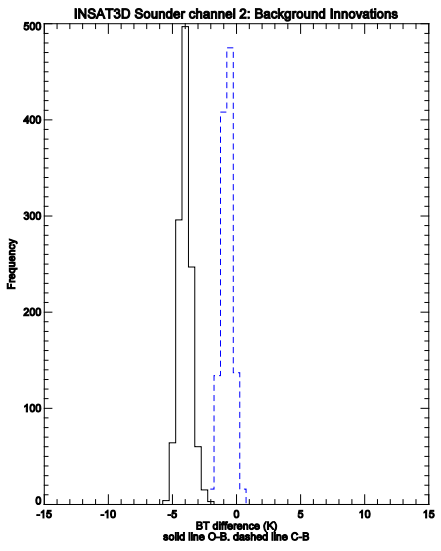


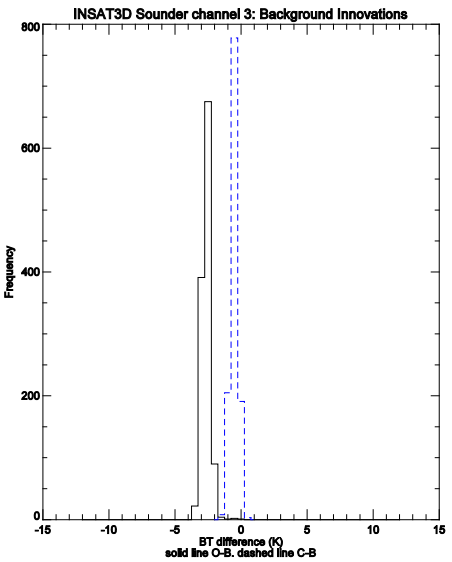




----------before
---------- after







Single Observation Experiment

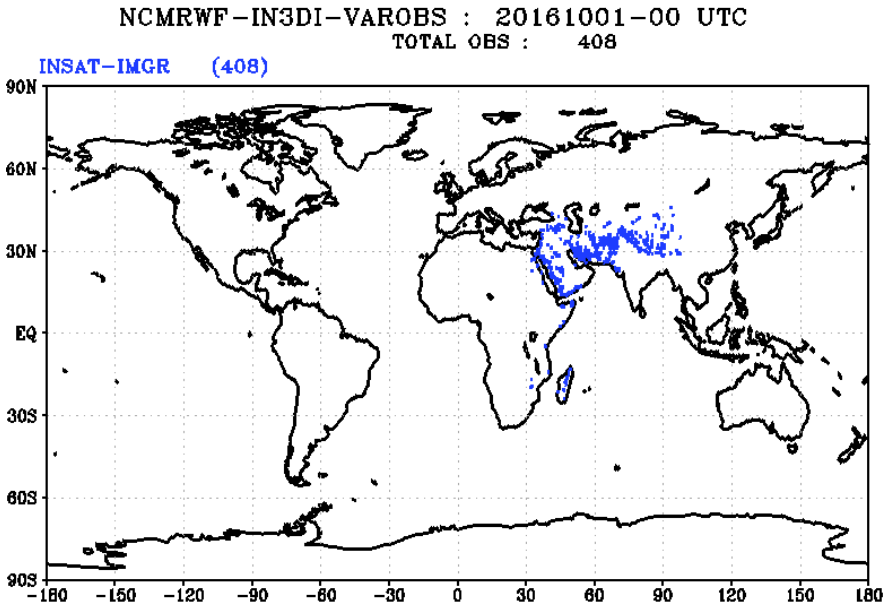
Single Observation Experiments (SOEs) are designed to assess the impact of INSAT-3D Imager and the imager onboard Meteosat-7 (MVIRI).

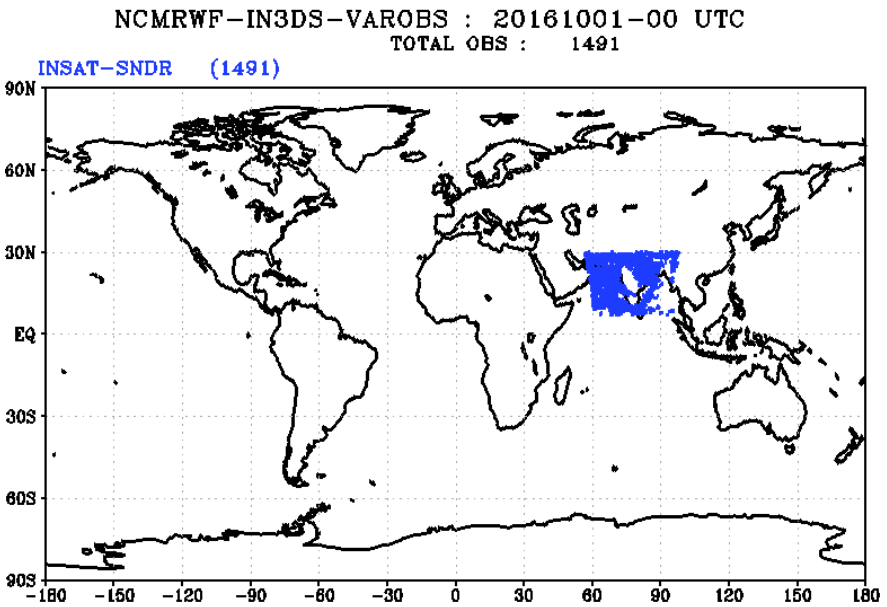
SOEs were conducted for different combinations of Imager and the corresponding channel from the INSAT-3D sounder (6.51 μ: channel 12).

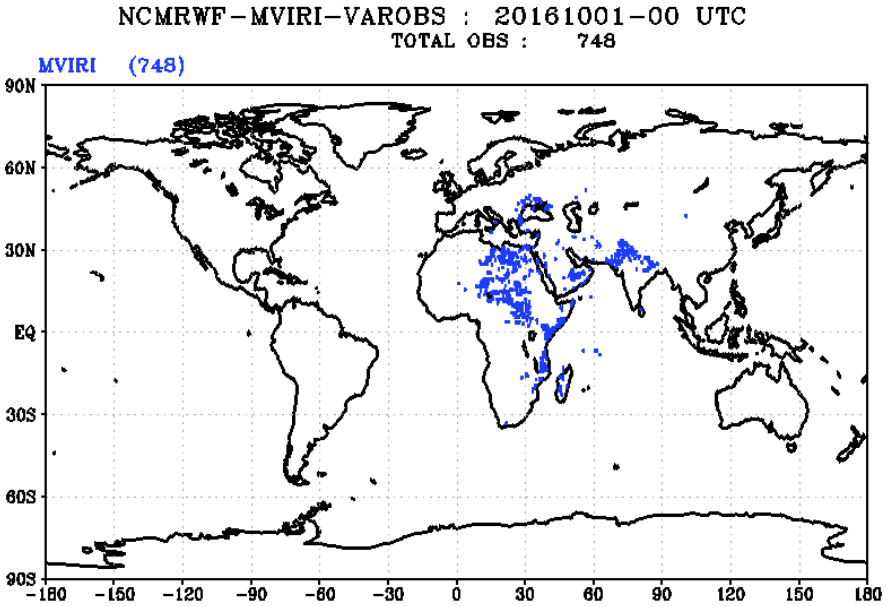
1. **INSAT-3D Imager**
2. **MVIRI**
3. **INSAT-3D Imager + MVIRI**
4. **INSAT-3D Sounder**
5. **INSAT-3D Sounder + Imager**
6. **INSAT-3D Sounder +MVIRI**
7. **All three**

Global experiments are also designed for the above combinations.

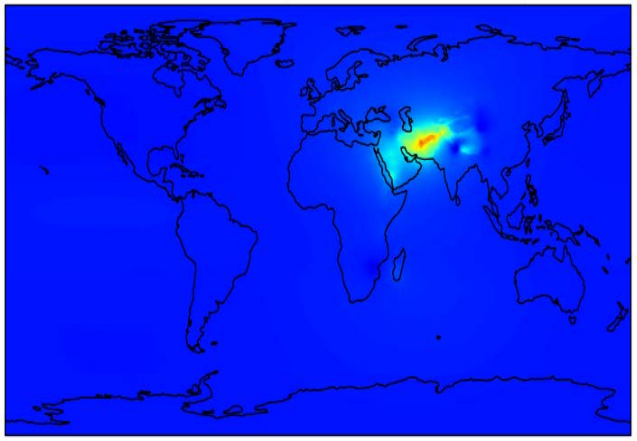
Data Used (Clear Sky radiances)



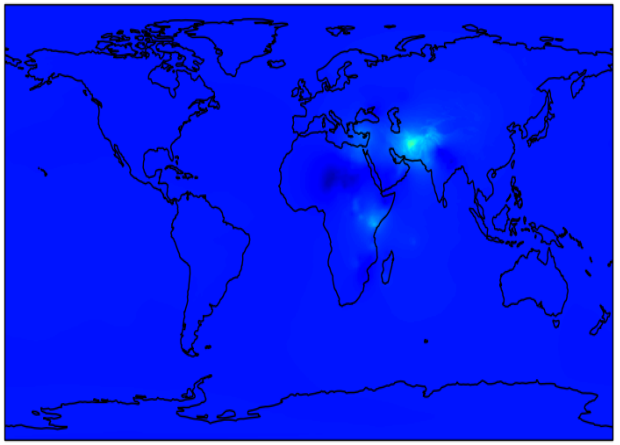




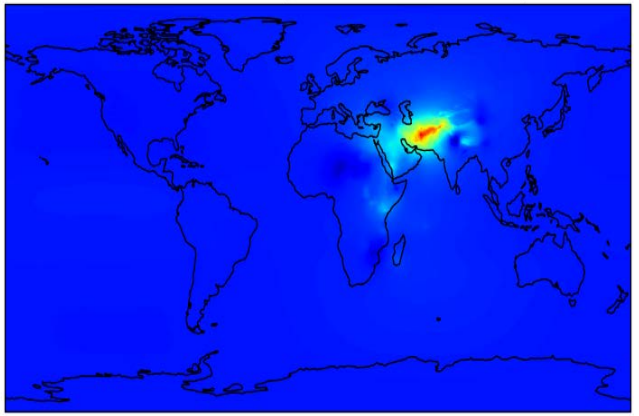
IN3DI



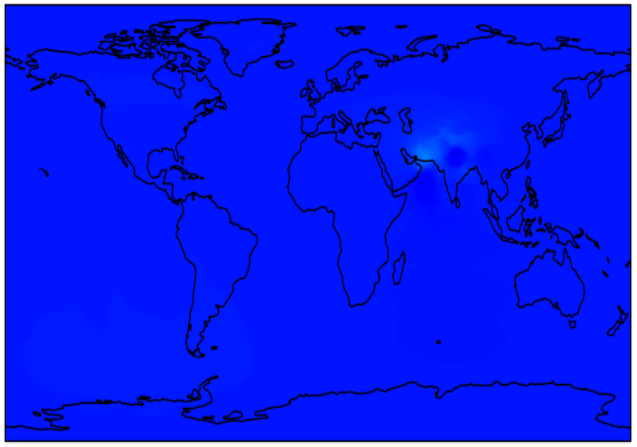
MVIRI



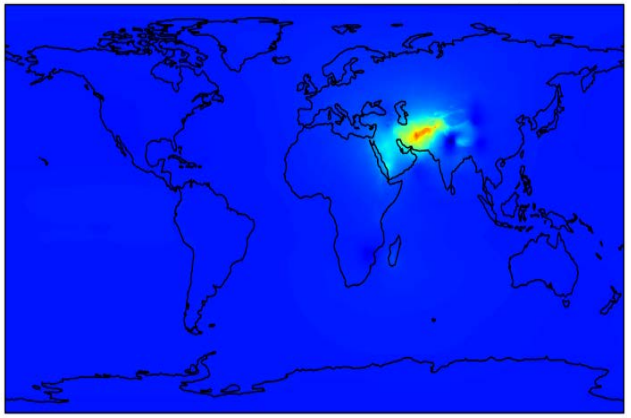
MVIRI + IN3DI



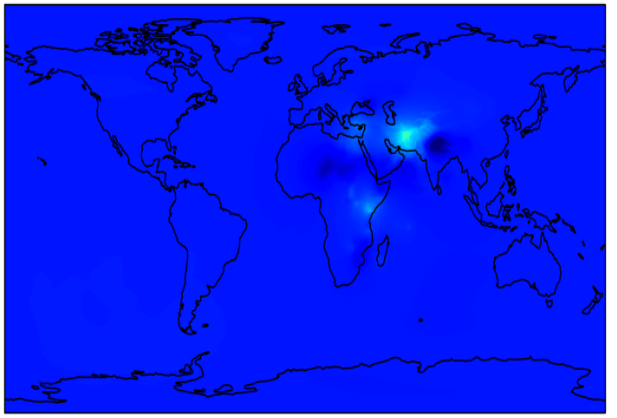
IN3DS



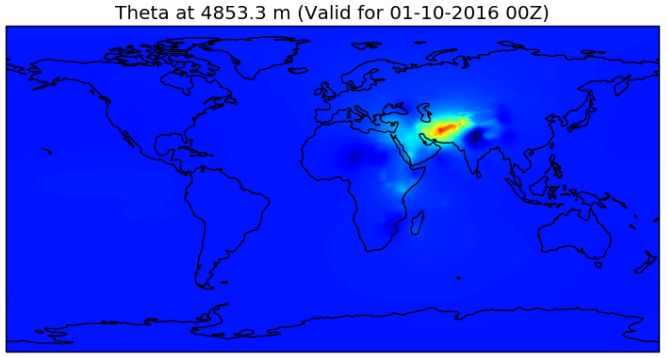
IN3DI + IN3DS

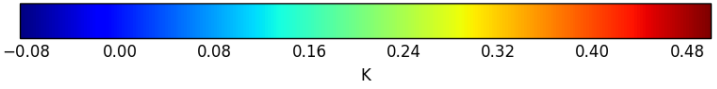


MVIRI + IN3DS



Analysis Increment in Potential Temperature (K)

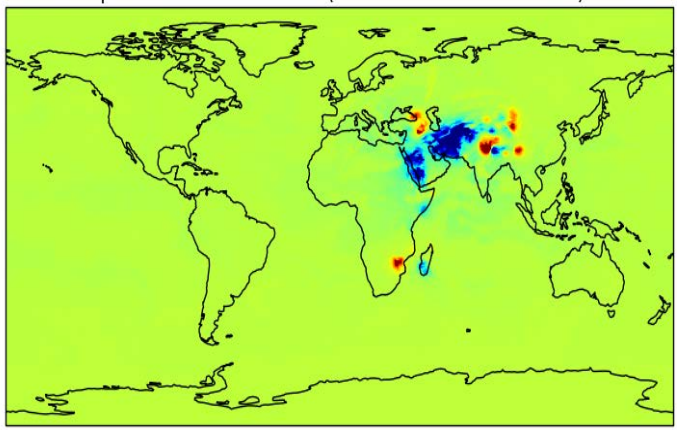




IN3DI + IN3DS+MVIRI

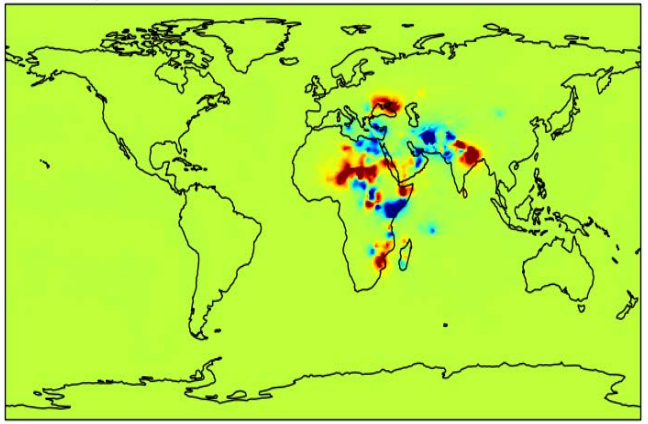
IN3DI

qT x10000 at 4853.3 m (Valid for 01-10-2016 00Z)



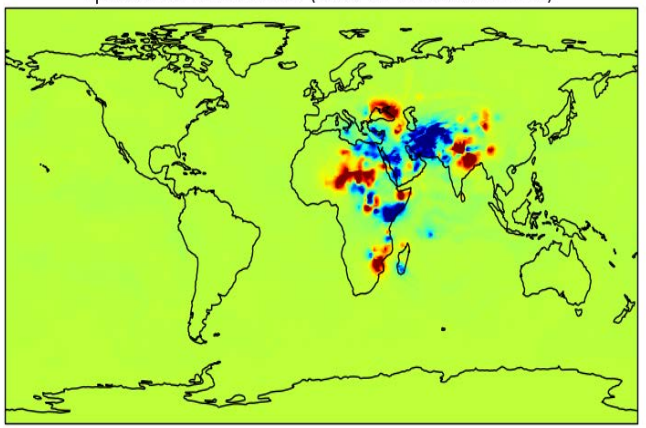
MVIRI

qT x10000 at 4853.3 m (Valid for 01-10-2016 00Z)



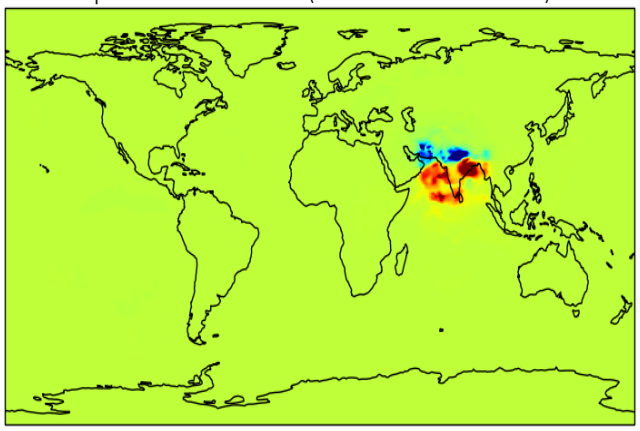
MVIRI + IN3DI

qT x10000 at 4853.3 m (Valid for 01-10-2016 00Z)



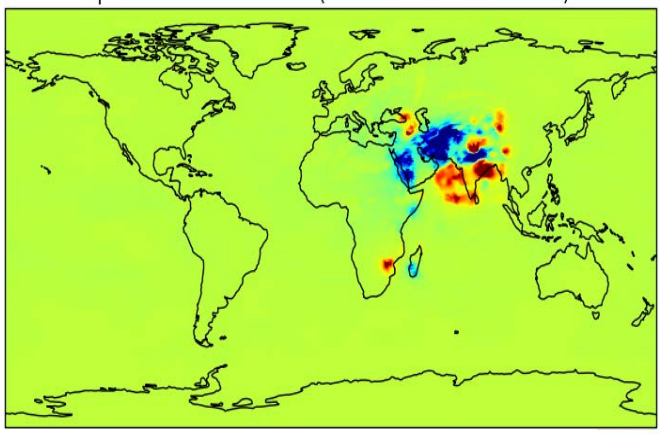
IN3DS

qT x10000 at 4853.3 m (Valid for 01-10-2016 00Z)



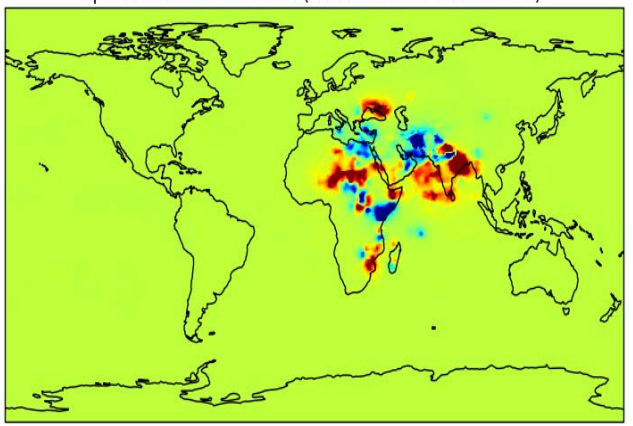
IN3DI + IN3DS

qT x10000 at 4853.3 m (Valid for 01-10-2016 00Z)

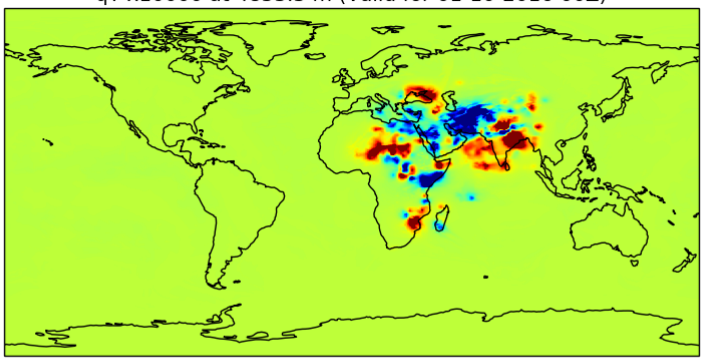


MVIRI + IN3DS

qT x10000 at 4853.3 m (Valid for 01-10-2016 00Z)

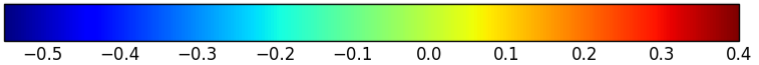


qT x10000 at 4853.3 m (Valid for 01-10-2016 00Z)

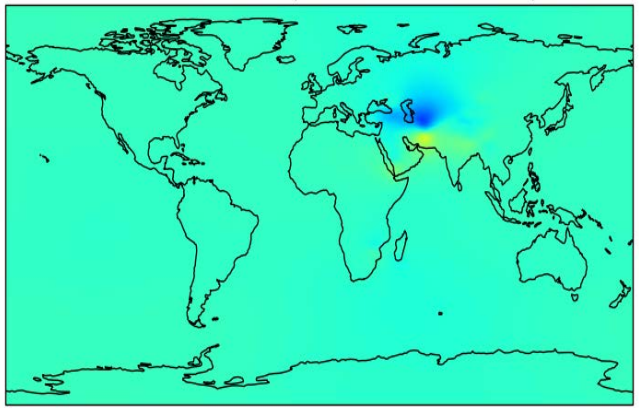


IN3DI + IN3DS+MVIRI

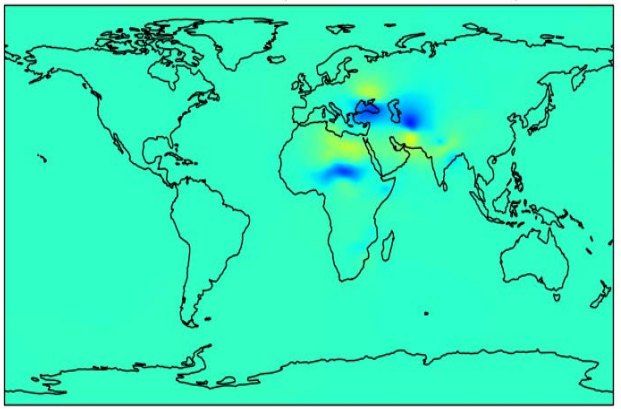
Analysis Increment in Specific Humidity (kg/kg)



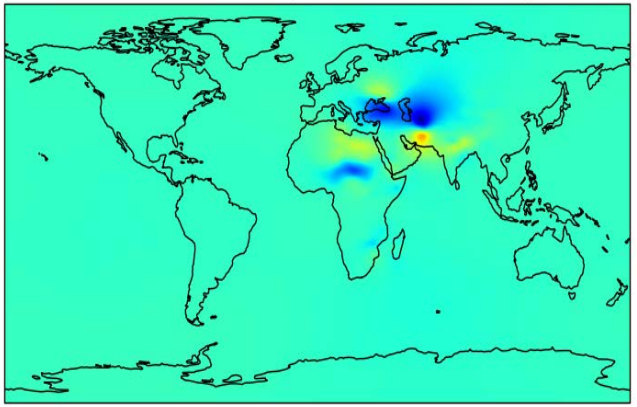
IN3DI



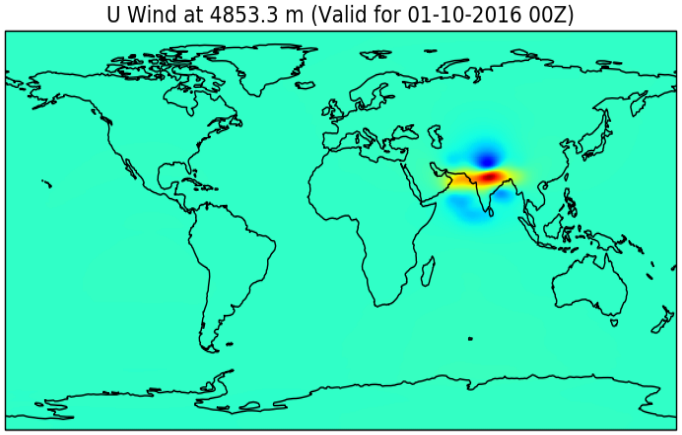
MVIRI



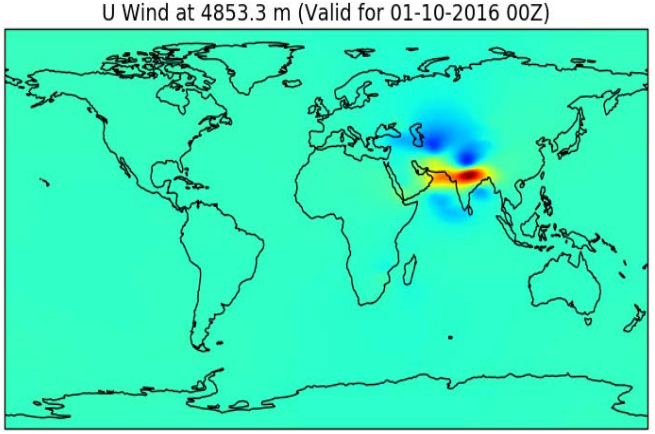
MVIRI + IN3DI



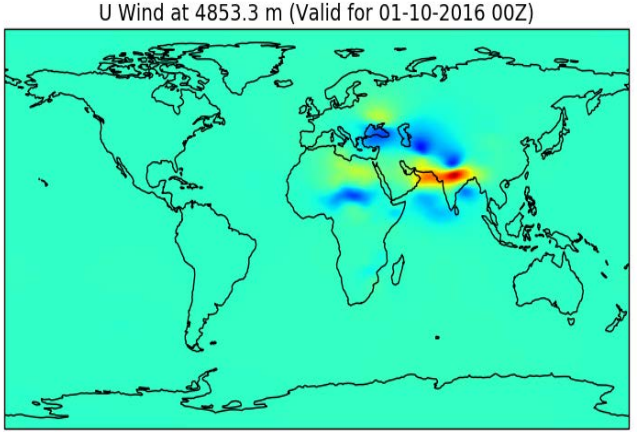
IN3DS



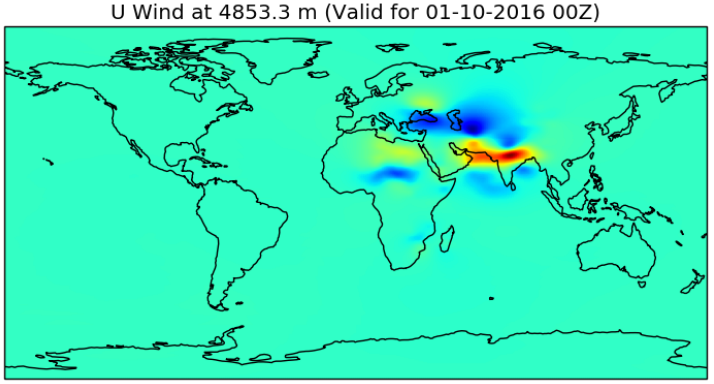
IN3DI + IN3DS

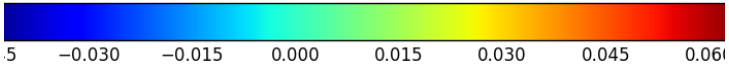


MVIRI + IN3DS



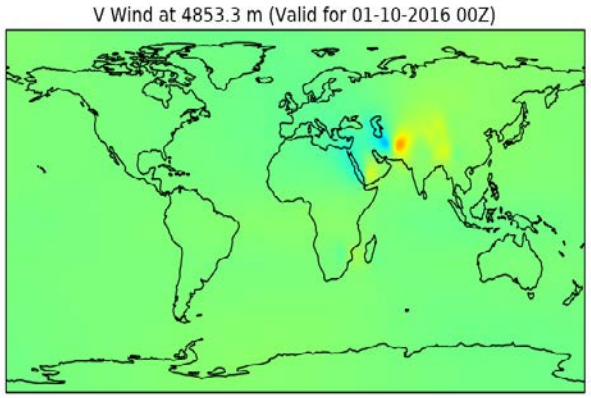
Analysis Increment in Zonal Winds (m/s)



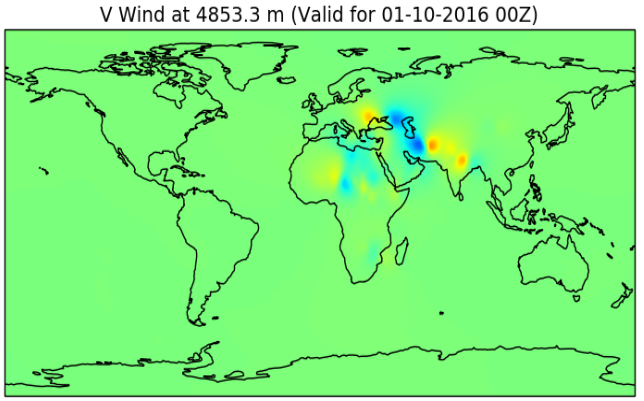


IN3DI + IN3DS+MVIRI

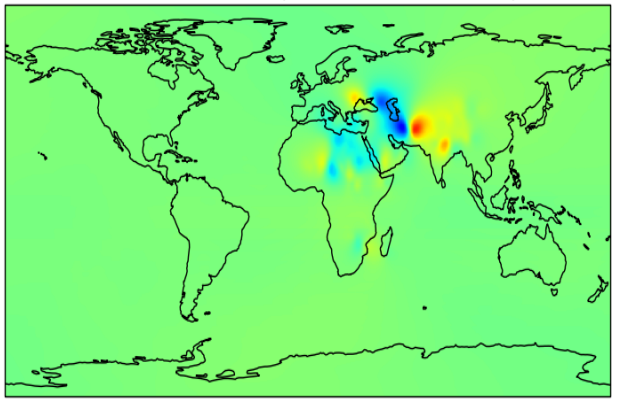
IN3DI



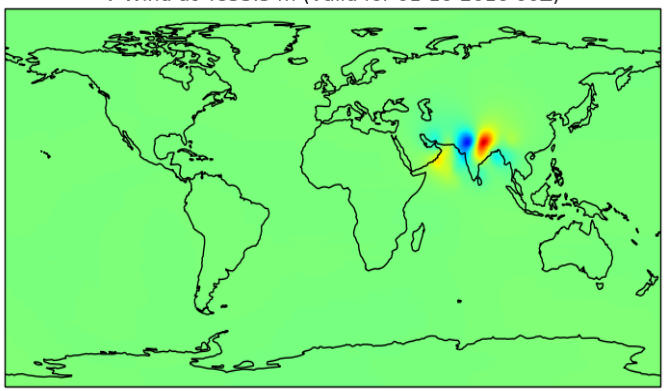
MVIRI



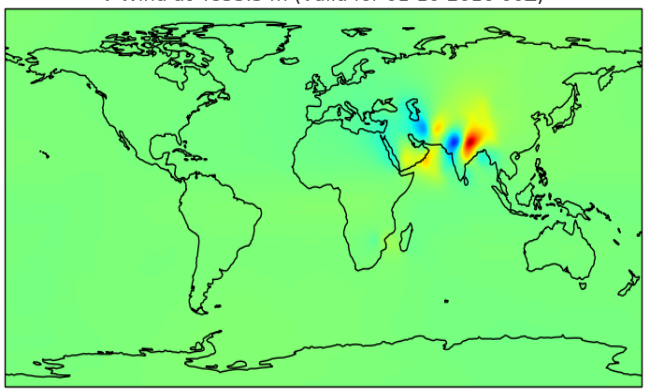
MVIRI + IN3DI



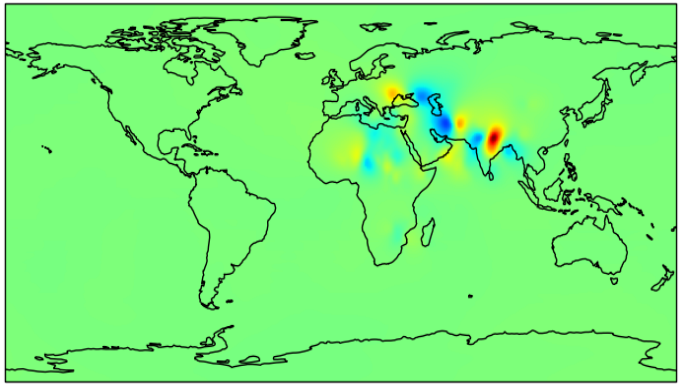
IN3DS



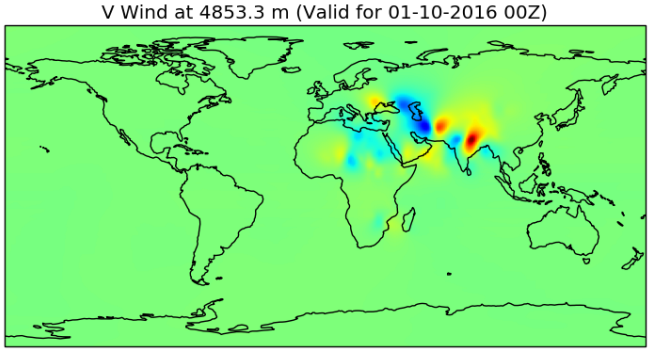
IN3DI + IN3DS

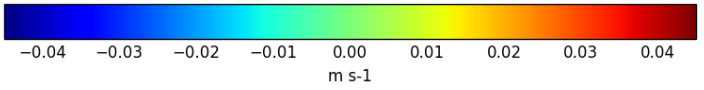


MVIRI + IN3DS



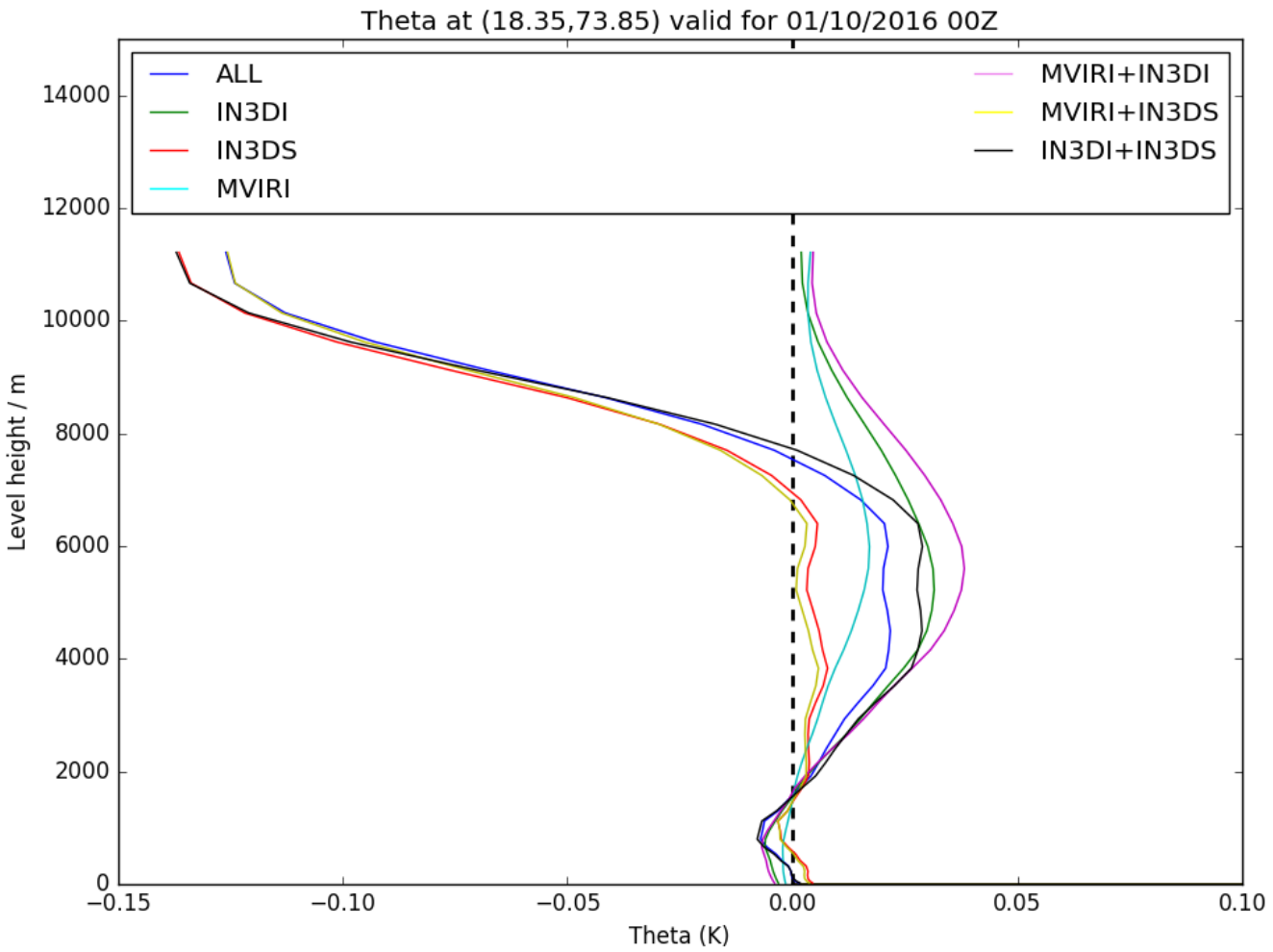
Analysis Increment in Meridional Winds (m/s)





IN3DI + IN3DS+MVIRI

Single Observation Experiment: Potential Temperature

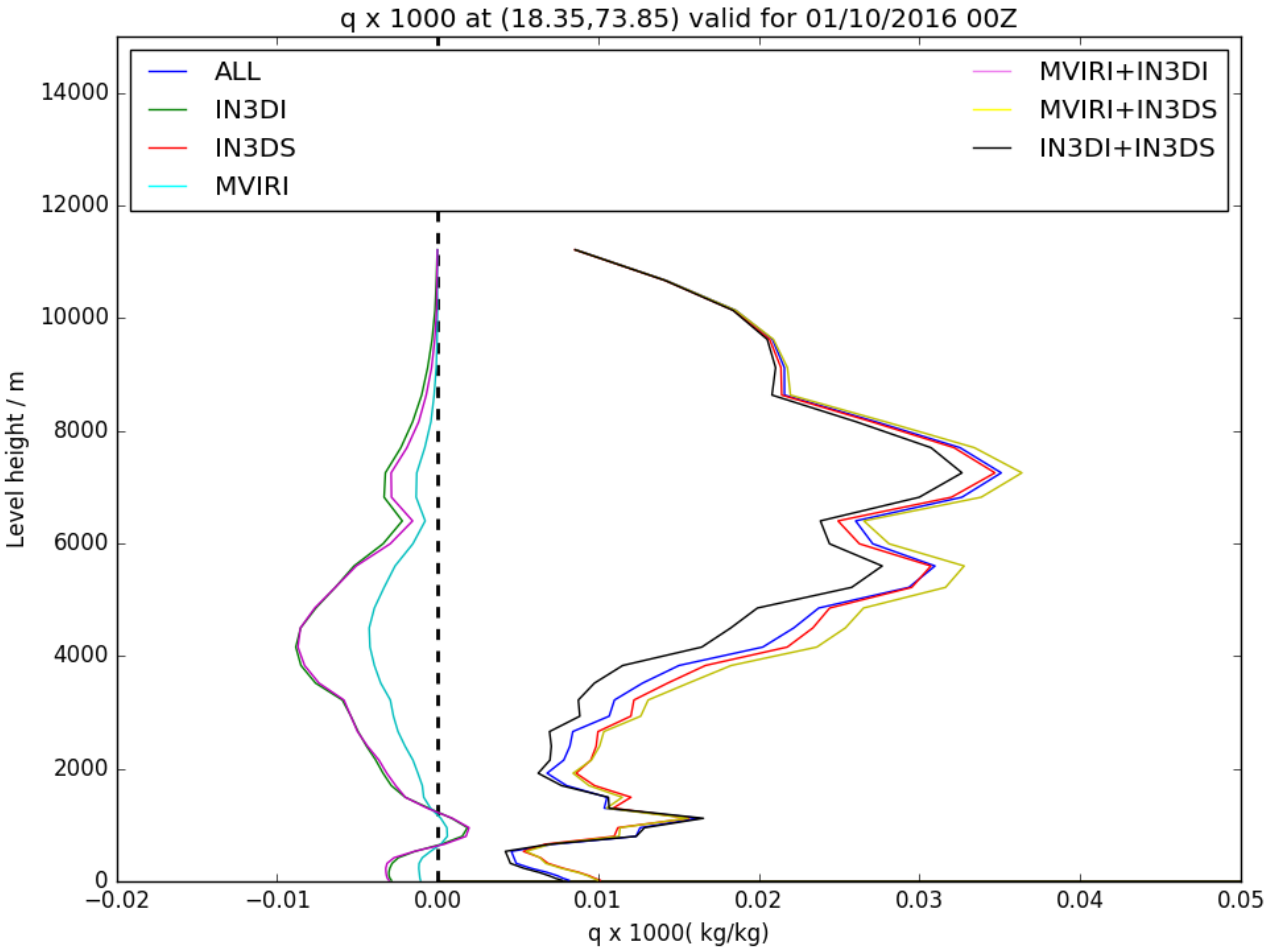


Imagers radiance assimilation show similar trend in the analysis increment

Addition of sounder radiances modifies the increment

Cooling in the lower levels (upto 1.5 km), and heating above

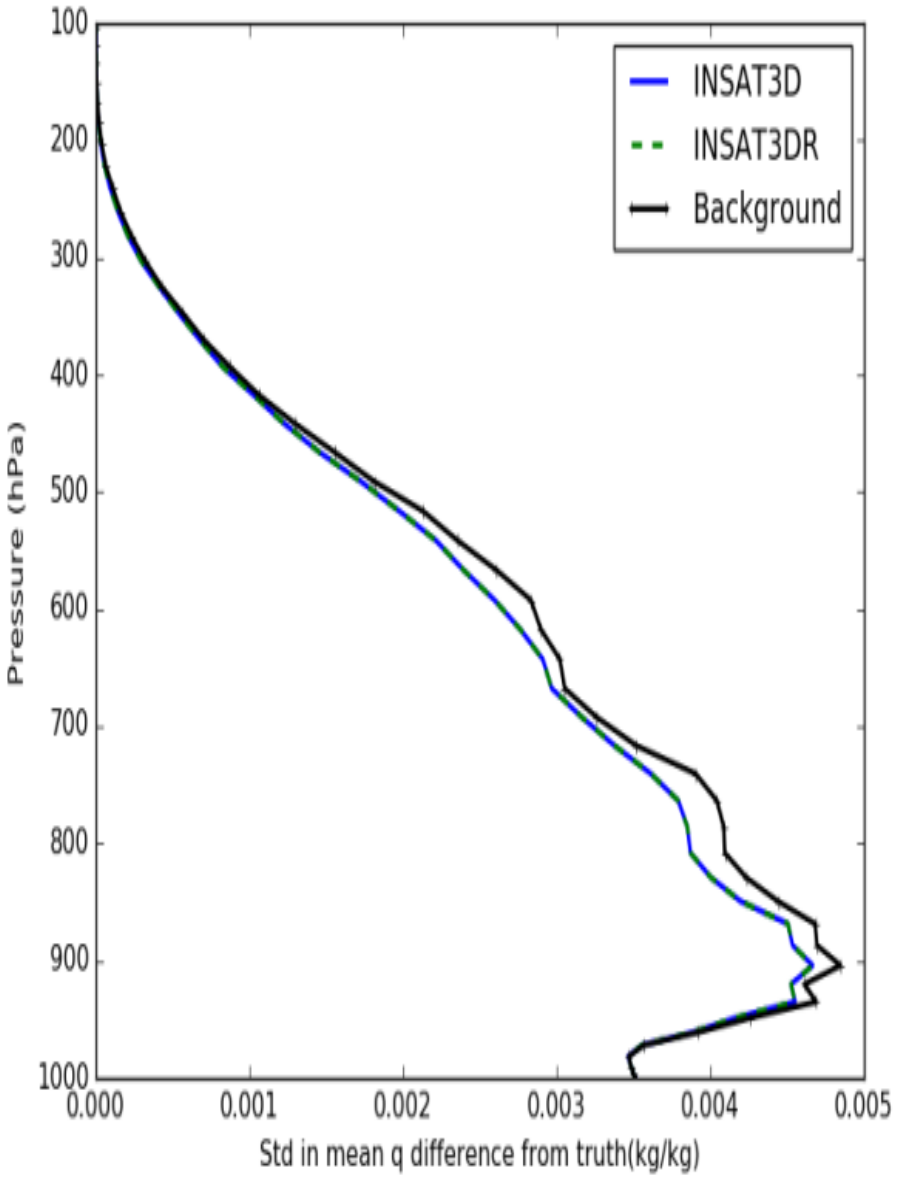
Single Observation Experiment: Specific Humidity

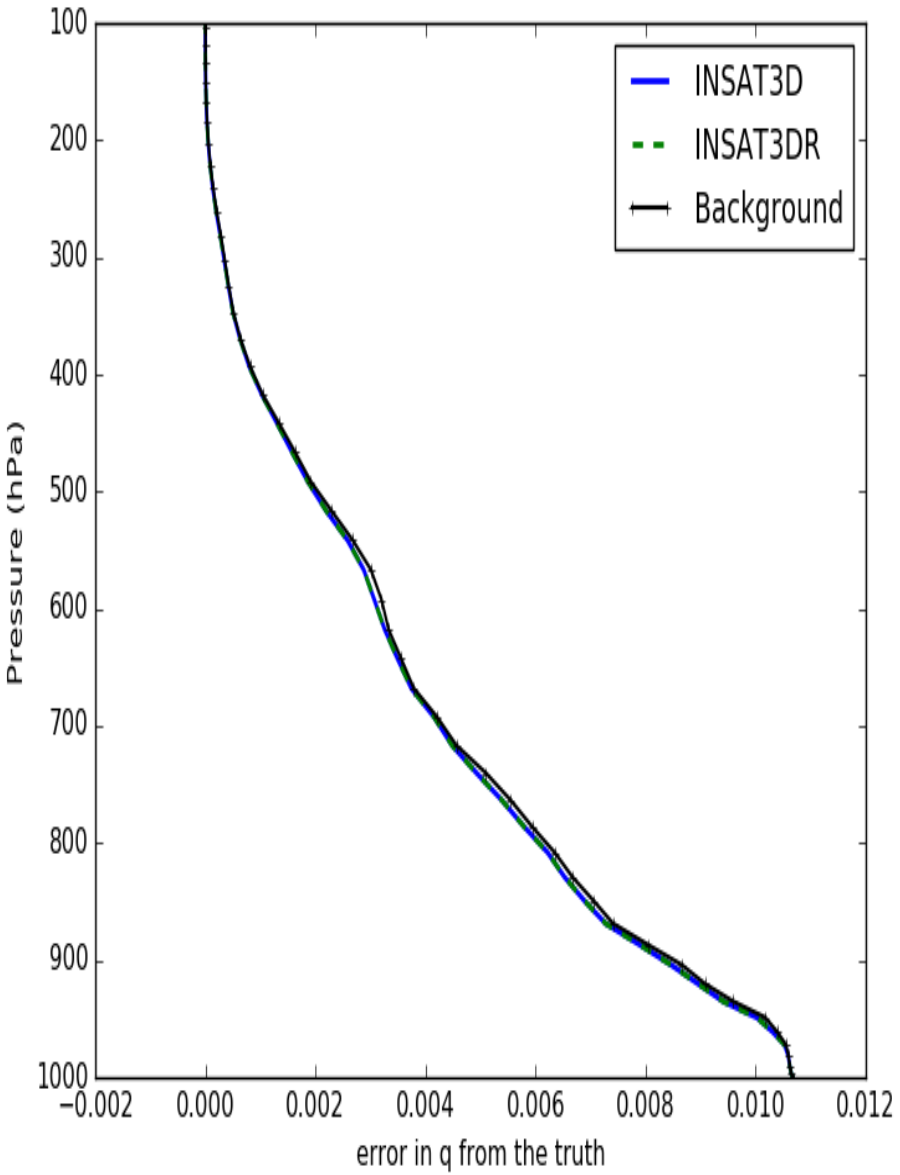


Imager radiance assimilation drying the atmosphere throughout from surface to above 10 km

Sounder modifies the analysis increment, moistening the atmosphere throughout

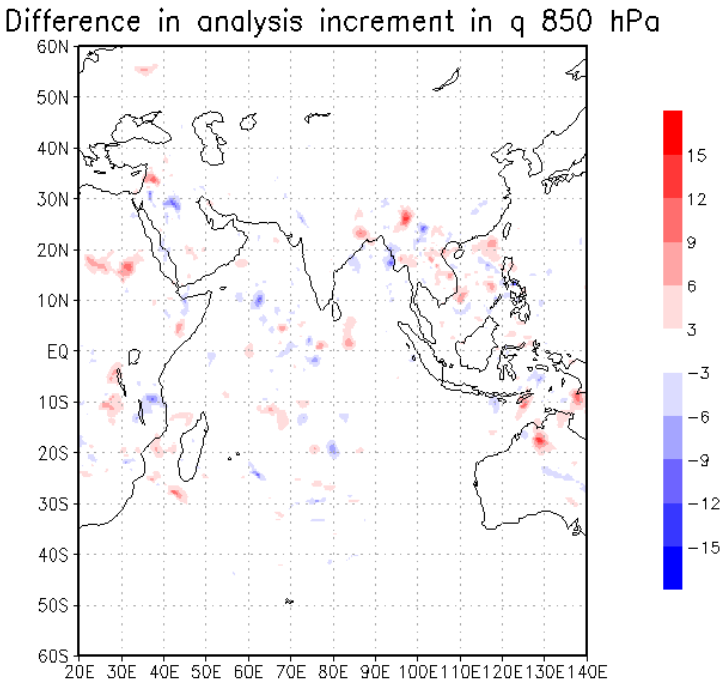
1D-VAR simulation of INSAT-3D and 3DR Imager Water Vapor Channel

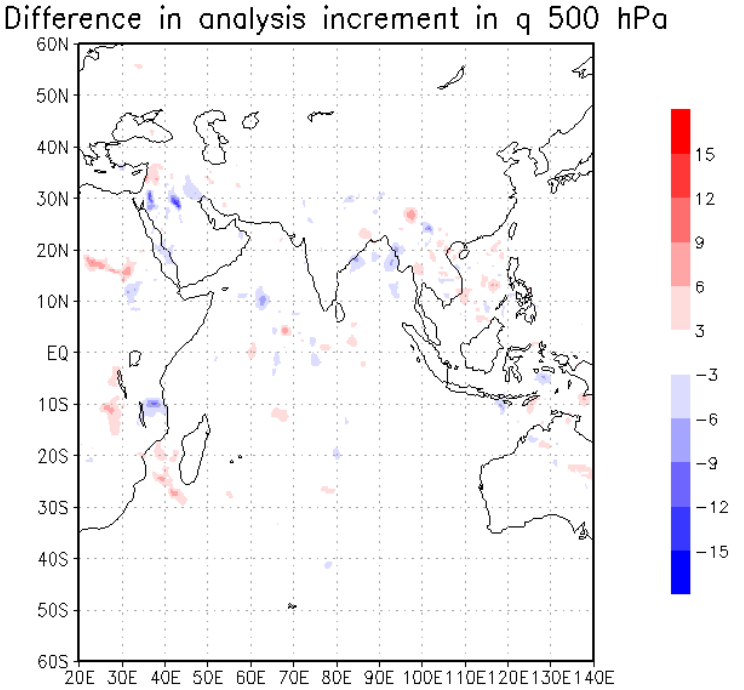


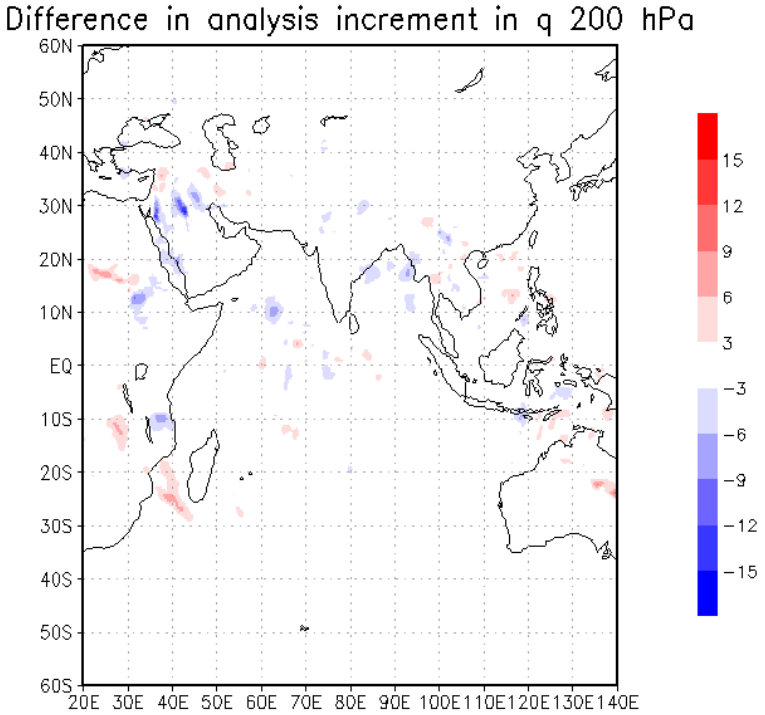


The errors and standard deviation are same for both WV channels

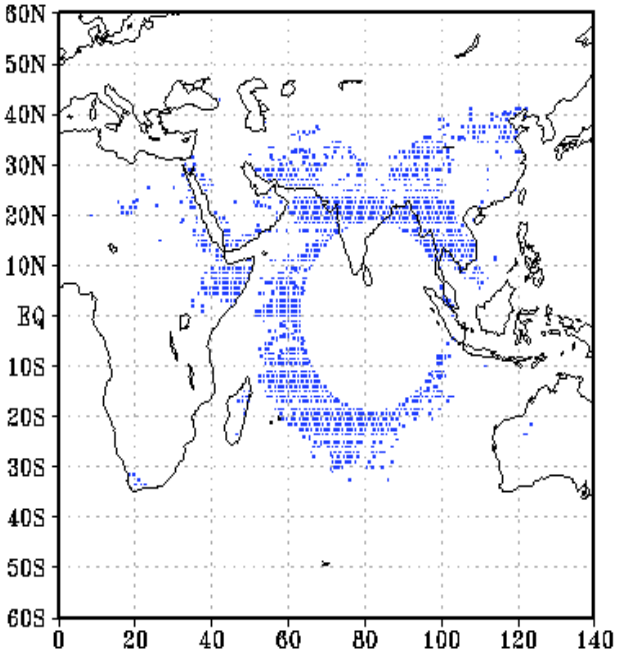
Analysis increment in Specific Humidity (*10000)





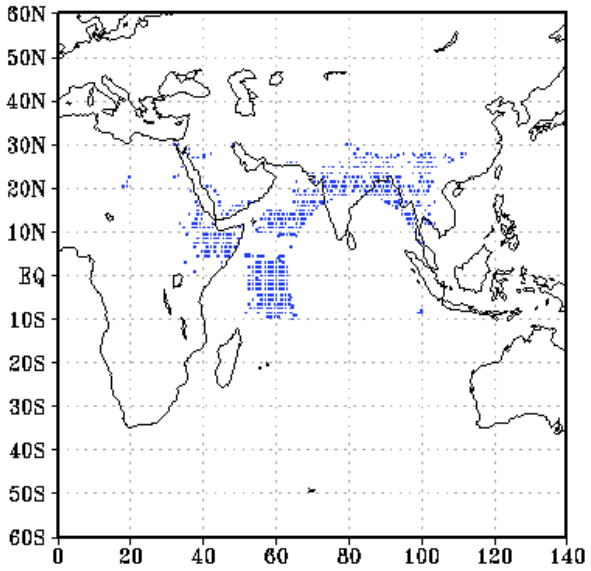


No. of Observations Assimilated

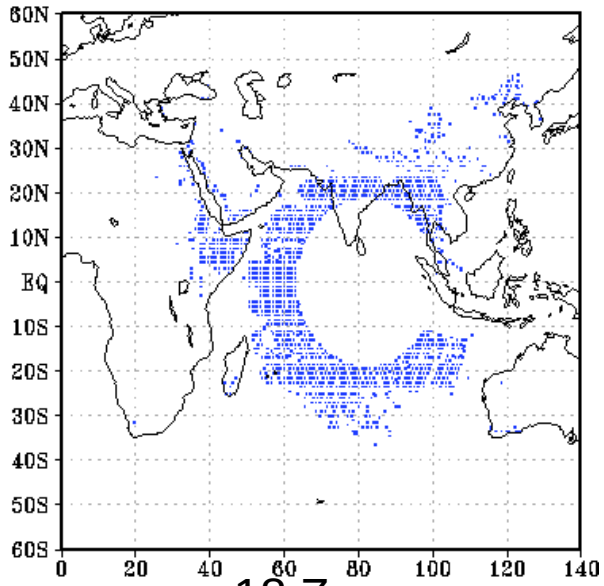


Average number of observations assimilated in different cycles

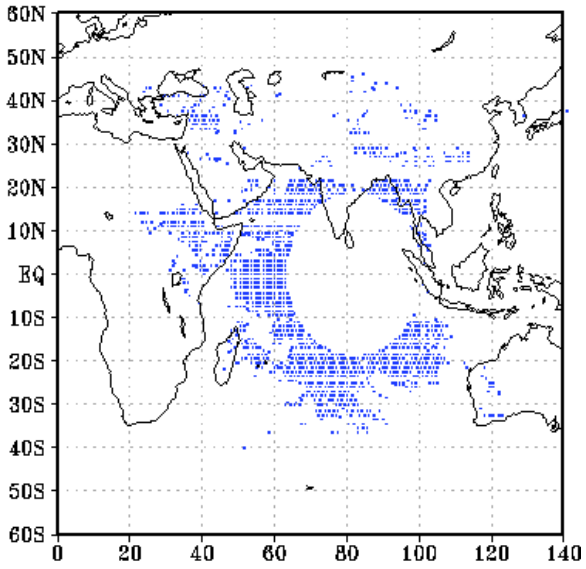
00 Z



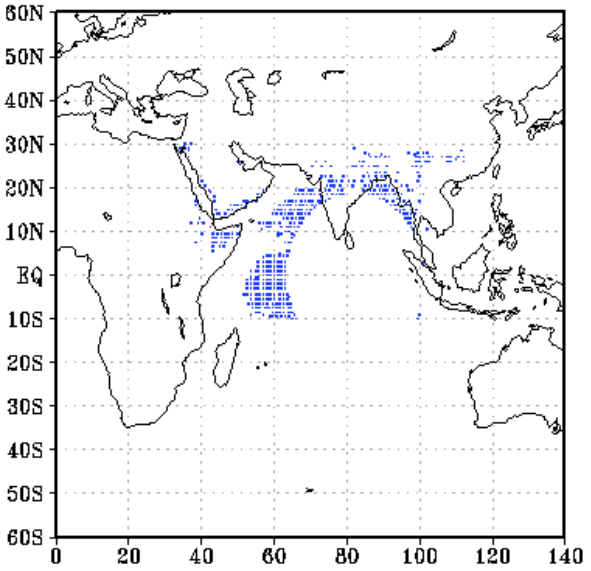
06 Z



12 Z



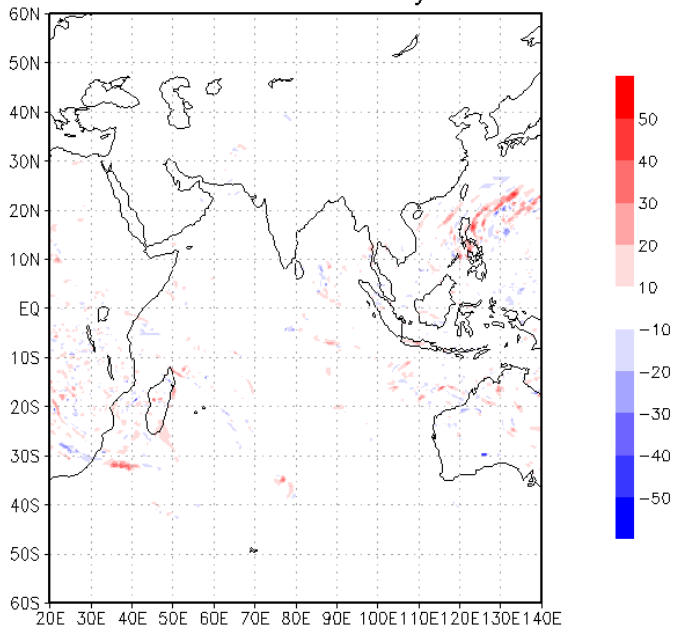
18 Z



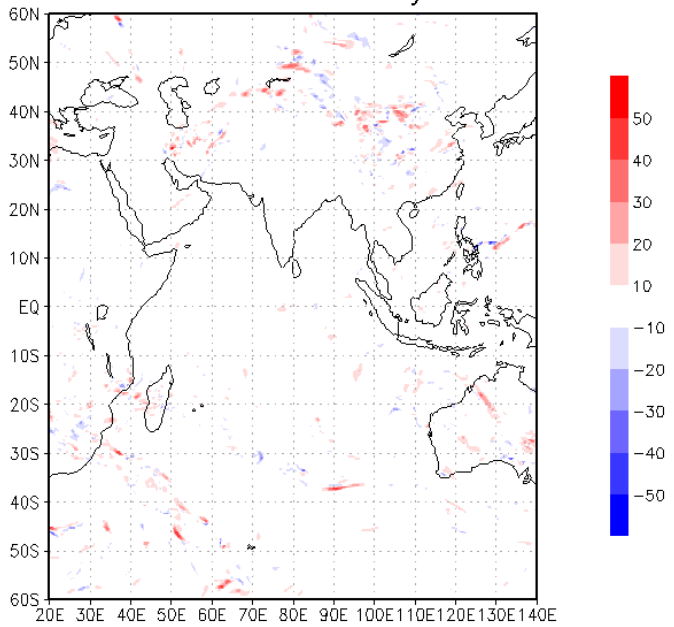
00	06	12	18
540	1320	1180	420

DAY-1 Forecast

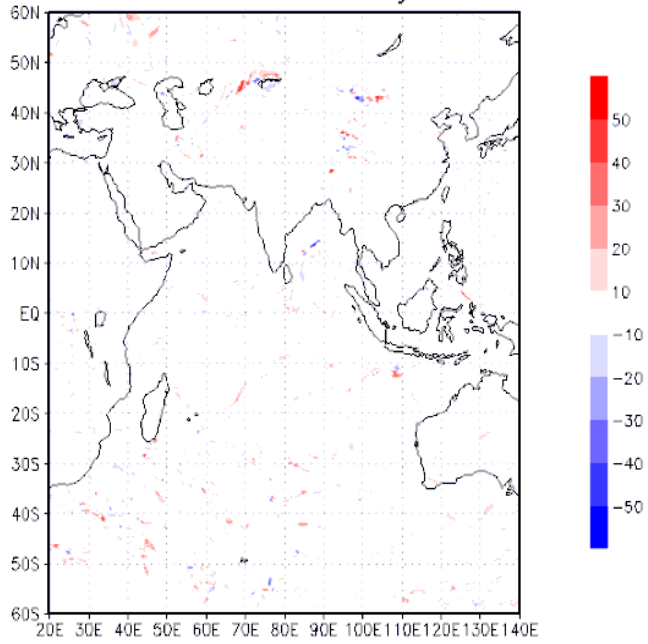
Differences in 200 hPa RH day−1 forecast



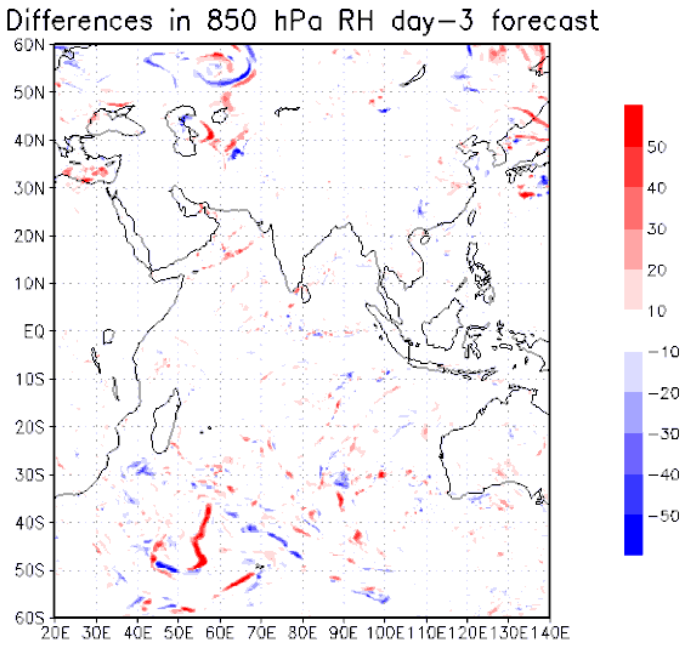
Differences in 500 hPa RH day−1 forecast

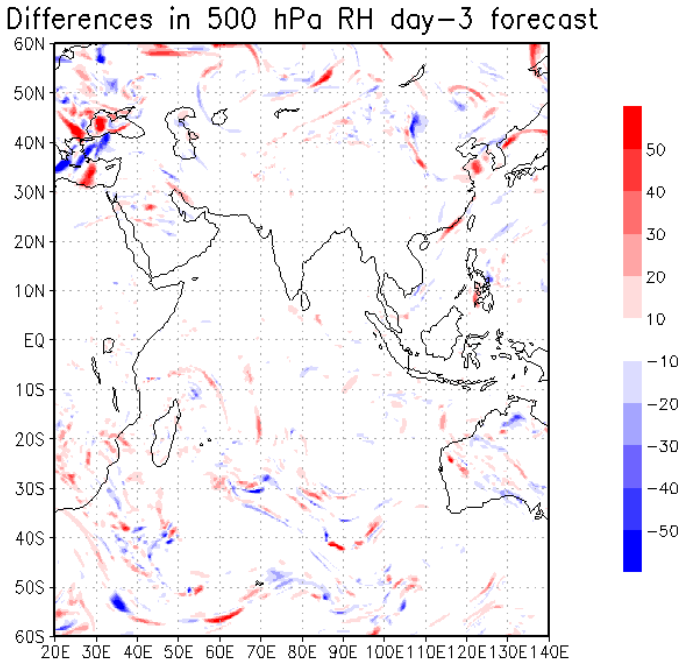


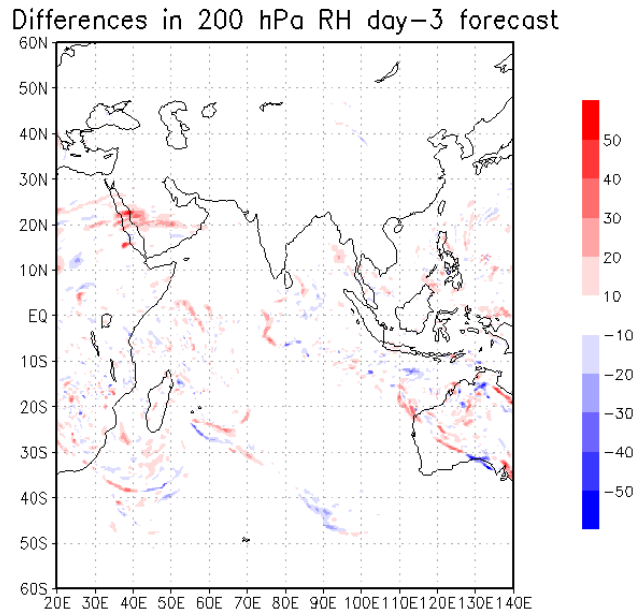
Differences in 850 hPa RH day−1 forecast



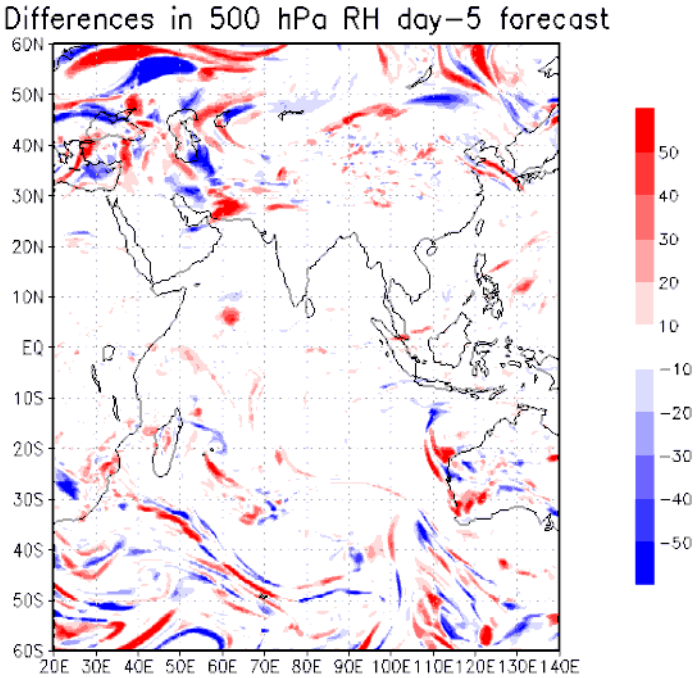
DAY-3 Forecast

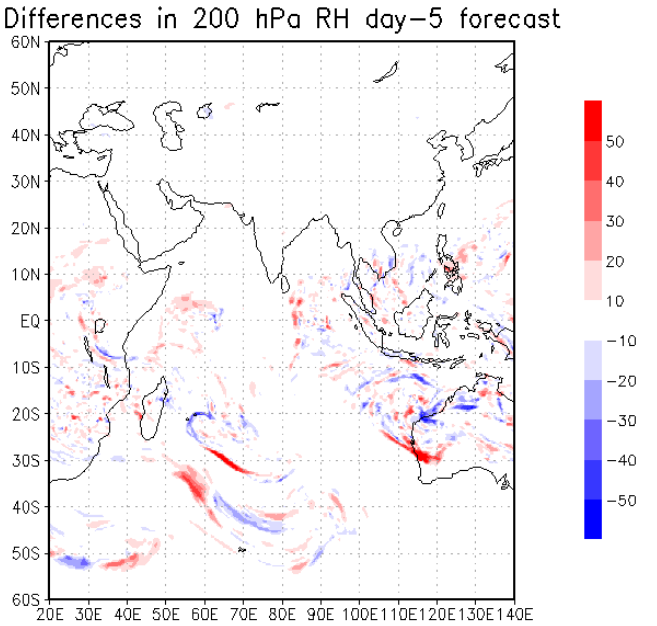


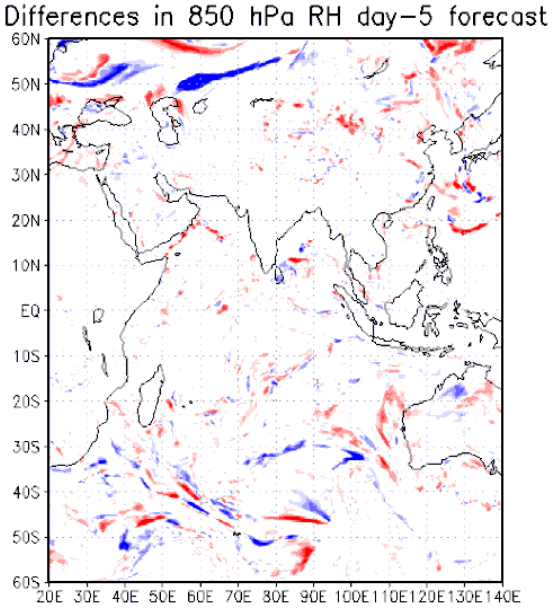




DAY-5 Forecast







Conclusions

Single Observation experiments show that

- WV imagers (INSAT3D and MVIRI) have similar impact in the temperature analysis increment
- Both the imagers shows drying effect in the analysis increment as against the moistening effect produced by sounder radiance

1D-VAR experiments shows that the errors and standard deviation in specific humidity are same for both INSAT-3D and 3DR WV channel

Global assimilation and forecast experiments show the impact of WV imager radiance in the medium range.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THANKS