Impact of Assimilation of Water vapor (WV) imager radiances from INSAT-3D and 3DR satellites in the NCMRWF Unified Model

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Abstract

This paper describes INSAT-3D and INSAT-3DR clear sky water vapor imager radiance assimilation in National Centre for Medium Range Weather Forecasting (NCMRWF) Unified Model (NCUM) assimilation and forecast system. Imagers onboard both INSAT-3D and INSAT-3DR have the same configuration and provide multi-spectral images of the earth and the atmosphere at every 30 minutes interval. The image dissemination time difference between INSAT-3D and INSAT-3DR is 15 minutes. Thus the combined images from both the satellites are of 15 minutes interval. 1D-VAR simulation over the Ocean shows the standard deviation of the retrieved humidity profiles are approximately same for both the imagers and is less than the standard deviation of the background profiles. The specific humidity analysis increment of INSAT-3D water vapor imager channel has similar behavior as that of MVIRI on board Meteosat-7 and both the water vapor channels have drying effect in the analysis, revealed from a set of single observation experiments. Hybrid-4DVAR assimilation system of NCUM is used in this global assimilation experiments. Hybrid-4DVAR and the combined high temporal resolution of 15 minutes of these two Indian geostationary satellite radiances can be explored to provide information on the tropospheric humidity as well as the wind field.

1. Introduction

Space Application Centre (SAC) of ISRO provided half hourly INSAT-3D and INSAT-3DR imager radiances in clear sky condition, Clear Sky Brightness Temperature (CSBT) for 15 days from 1 February to 15 February 2017. Both the imagers data contain the four channel brightness temperatures, viz., the middle Infra Red (MIR), the Water vapor channel (WV) and the thermal Infra Red channels, TIR-1 and TIR-2. NCMRWF processed this data and packed it into the required format for the data assimilation system.

WV channel CSBTs from the imagers onboard geostationary satellites are being assimilated in the NCMRWF Unified Model (NCUM) global data assimilation system (Hybrid 4D-Var system). WV channel provides valuable information of humidity in the upper tropospheric levels. In the present study, WV channel CSBTs from both INSAT-3D and INSAT-3DR imagers are assimilated in the NCUM system, whereas the three other spectral channels in the IR region viz., MIR, TIR-1 and TIR-2 are used for quality control of WV channel CSBTs.

Different experiments are conducted to analyze the characteristics of both INSAT-3D/3DR imager CSBTs. Single observation experiments are conducted to compare the characteristics of INSAT-3D/3DR imager CSBTs with that of other geostationary imagers over the same geographic coverage area. 1D-VAR retrieval experiments are conducted to examine the standard deviation and error in the retrieved products from both the imagers.

2. Single Observation Experiments

Before assimilation in the global data assimilation system, we compared the characteristics of the WV channel CSBT observations from INSAT-3D imager to that of Meteosat Visible and Infrared Imager (MVIRI) onboard Meteosat-7 through single observation experiments. Figure 1 shows the analysis increment in specific humidity from the single observation experiment. Results of the study show that the WV channel CSBTs from both INSAT-3D imager and MVIRI have drying effect in the analysis increment. From Figure 1 it is clear that the analysis increment in specific humidity is mostly driven by the INSAT-3D imager WV channel, when the WV channel CSBTs from both INSAT-3D imager and MVIRI are assimilated together.

Figure 2 shows the analysis increment in potential temperature (K) when WV channel CSBTs of both INSAT-3D imager and MVIRI are assimilated separately and together. Assimilation of WV channels CSBTs of both INSAT-3D imager and MVIRI show heating effect in the analysis increment. The increment in the potential temperature is also largely driven by the INSAT-3D imager WV channel CSBTs, when the WV channel CSBTs from both INSAT-3D imager and MVIRI are assimilated together. From Figures 1 and 2 it is clear that the WV channel CSBTs of both the imagers have similar impact in the humidity and temperature analysis increment, but with varying magnitude. When assimilated together, the increment is largely driven by the WV channel CSBTs from INSAT-3D imager.

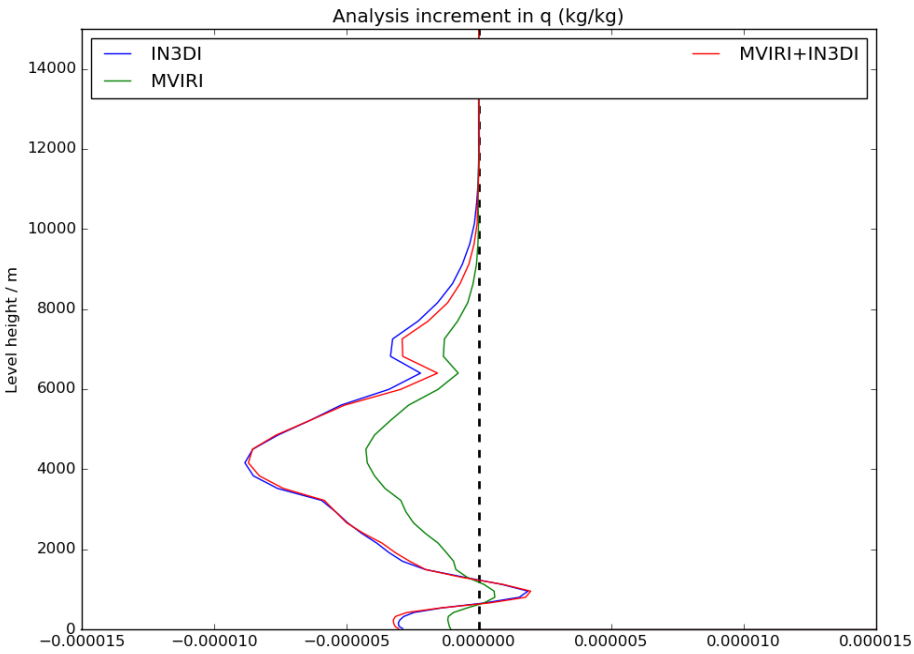

Figure1: Analysis increment in specific humidity (kg/kg) due to the assimilation of WV channel CSBT from INSAT-3D imager and MVIRI, when assimilated separately and together through single observation experiments.

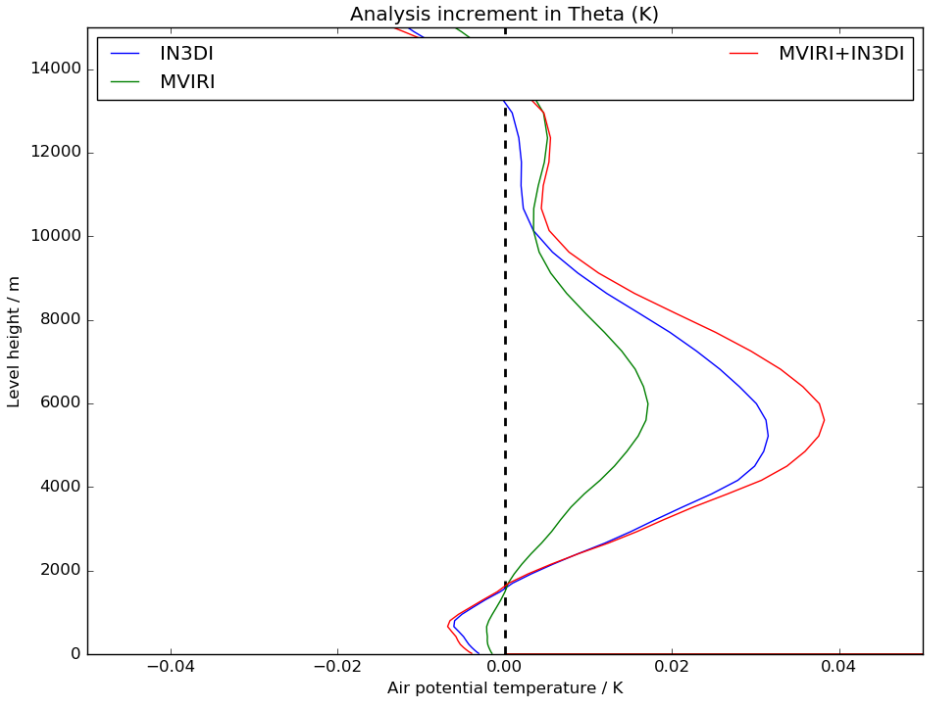

Figure 2: Similar to Figure 1, but for potential temperature (K).

3. 1D-VAR Experiments

1D-VAR retrieval experiments are conducted to analyze the differences, if any, in the retrieved specific humidity from the WV channels of INSAT-3D and INSAT-3DR imagers. Figure 3 shows the standard deviation and error in the 1D-VAR retrieved specific humidity profiles from the WV channel of INSAT-3D and INSAT-3DR imagers and the same in the background specific humidity profiles over the Ocean. From Figure 3, it is clear that the error and standard deviation in the retrieved specific humidity from the WV channels of both INSAT-3D and INSAT-3DR imagers are same and it is less than the background values. Since both INSAT-3D and INSAT-3DR imager WV channel characteristics are same, for the time being only the INSAT-3D imager WV channel CSBTs for the period 1-15 February, 2017 are assimilated in the NCMRWF assimilation and Forecast system.

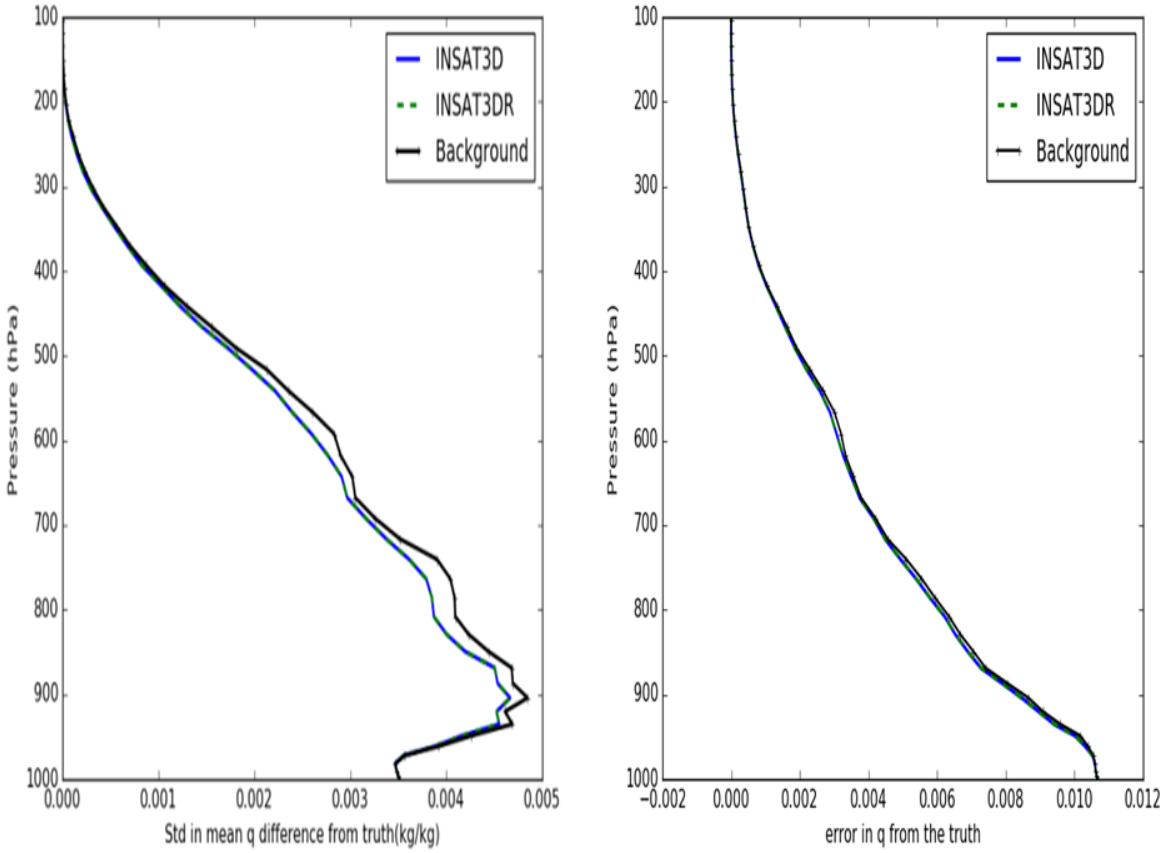

Figure 3: Standard deviation and error in the 1D-VAR retrieved specific humidity profiles from the WV channels of INSAT-3D and INSAT-3DR imagers and the same in the background profile.

4. Global Assimilation and Forecasts

A pre-processing system is developed for the assimilation of INSAT-3D imager CSBT data and the data is packed into the required format for Observation Processing System (OPS) of the NCUM global data assimilation system. OPS does the quality control and thinning of observations. INSAT-3D imager WV channel CSBTs were assimilated in a baseline system, which assimilates all satellite and conventional observations those are being operationally assimilated at NCMRWF. Two data assimilation experiments were conducted, one with all observations used operationally (Control), and the second with INSAT-3D imager CSBTs along with other observations used in the control run (Experiment). Using the NCMRWF Hybrid-4DVAR assimilation system, continuous four cycles of assimilations (00, 06, 12, and 18 UTCs) per day were conducted for 15 days. Forecasts for five days were made from the 00UTC assimilation of each day from both the runs. An average of approximately 540, 1320, 1180 and 420 numbers of INSAT-3D imager WV channel CSBTs were assimilated in the assimilation cycles of 00, 06, 12 and 18 UTCs. Figure 4 shows the spatial plot of INSAT-3D imager WV channel CSBT observations assimilated in different cycles in a typical day during the study period.

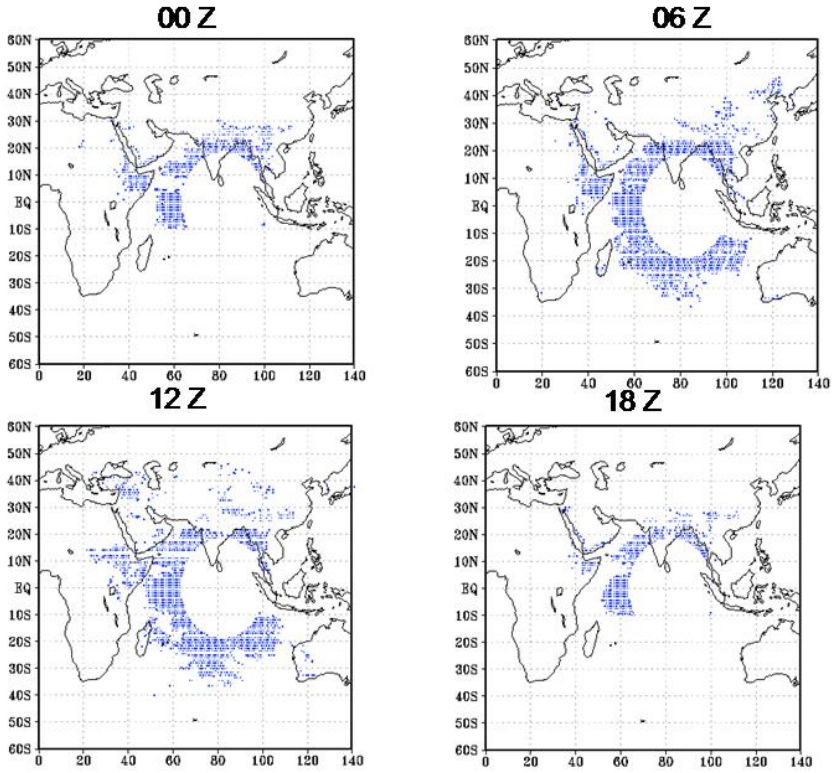

Figure 4: Geographical plot of INSAT-3D imager WV channel CSBT observations assimilated in different assimilation cycles on a particular day during the study period.

Figure 5 shows the difference in the analysis increment in specific humidity between the experiment and control run at three different levels, 850 hPa, 500 hPa and 200 hPa respectively for a particular cycle and also the geographical plot of INSAT-3D imager WV channel CSBT observations assimilated in that particular cycle. From figure 5, the impact of the assimilation of INSAT-3D imager WV channel CSBTs is clearly seen at different model levels. Assimilation of INSAT-3D imager WV channel CSBTs added moisture in the lower (850 hPa) and middle (500 hPa) levels of the model atmosphere, while it removed moisture from upper levels (200 hPa).

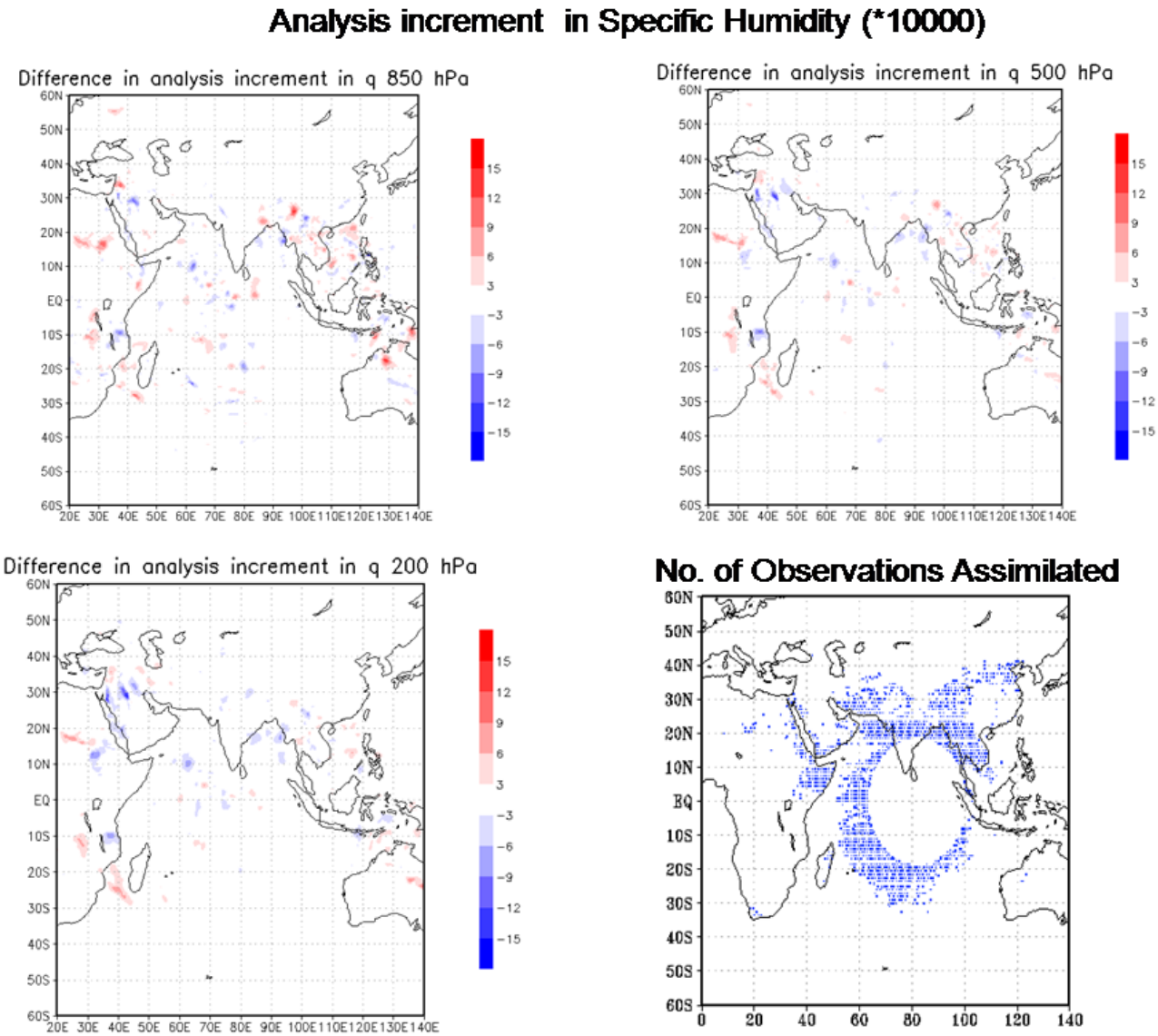

Figure 5: Difference in analysis increment in specific humidity between the experiment and control run for a particular assimilation cycle at three different levels,850 hPa, 500 hPa, and 200 hPa, and the spatial plot of INSAT-3D imager WV channel CSBT observations assimilated.

Figure 6 shows the mean difference in the relative humidity in day-1, day-3 and day-5 forecast between experiment and control run for the study period. In figure 6, first row is the mean difference in day-1 relative humidity forecast at 850 hPa, 500 hPa and 200 hPa, respectively. Similarly the second and third rows show the mean difference in day-3 and day-5 relative humidity forecast at different levels.

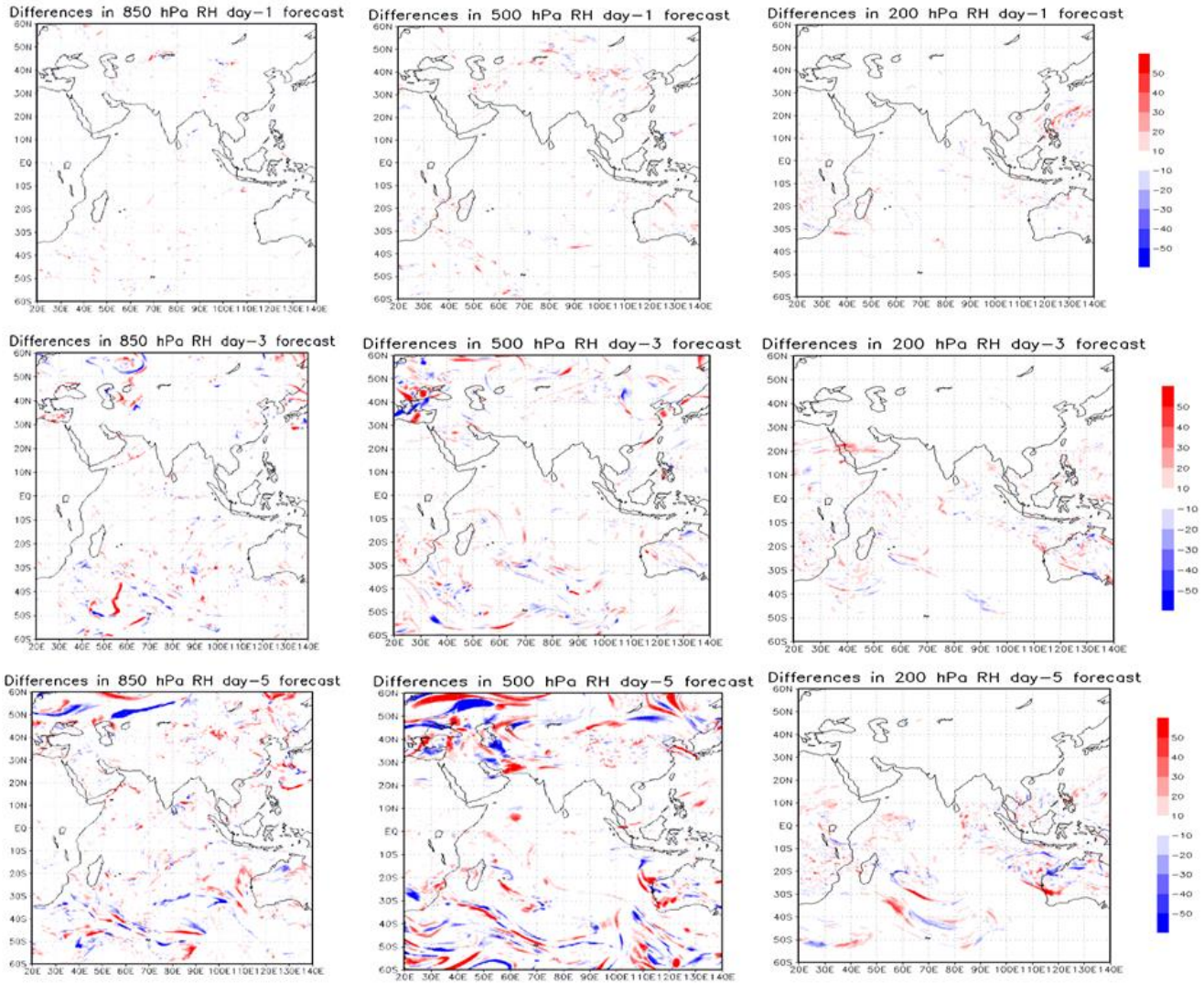

Figure 6: Mean difference in the relative humidity forecast between experiment and control run in day-1, day-3, and day-5 forecasts at 850 hPa, 500 hPa and 200 hPa during the study period.

5. Conclusions:

Impact of INSAT-3D (and INSAT-3DR) imager WV channel CSBT observations in the NCUM analysis and forecast system is studied. Single observation experiments show that the WV channel

CSBTs from both INSAT-3D imager and MVIRI have similar impact in the analysis increment of specific humidity and temperature. When assimilated the WV channel CSBTs from both the instruments, the analysis increments are mostly governed by the INSAT-3D imager WV channel. 1D-VAR experiments show that both INSAT-3D and INSAT-3DR imager WV channels have similar characteristics as seen in the bias and standard deviation in the retrieved specific humidity. Five day forecast presented above clearly shows the impact of the assimilation of INSAT-3D imager WV channel CSBTs in the forecast.

Assimilation of 15 days of INSAT-3D imager WV channel CSBT observations clearly shows its impact in the analysis and forecast in this study. The study also shows both positive and negative bias with respect to the control run. Moreover 15 days of data is not enough to quantitatively summaries the impact of a particular dataset in a global assimilation and forecast system. This experiment shows NCMRWF assimilation-forecast system is responding to the INSAT-3D imager WV channel CSBT observations and the analyses and forecasts are reasonable when compared against the control run.