

Impact of hyperspectral radiances in 4D-VAR data assimilation system



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Overview

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Introduction

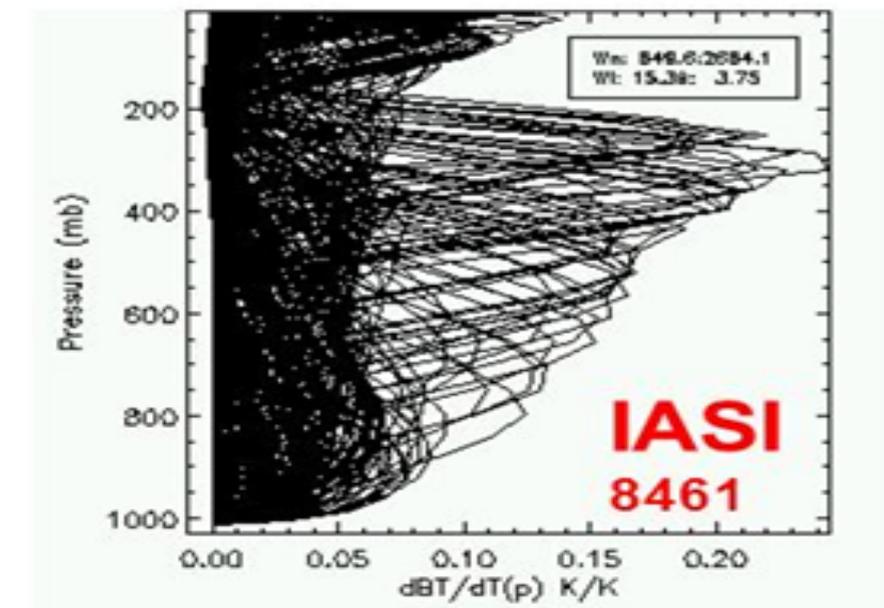
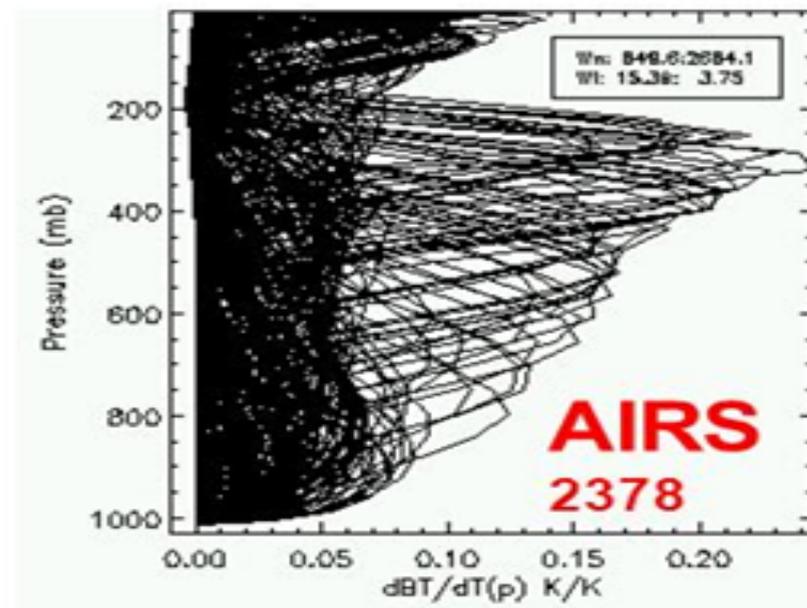
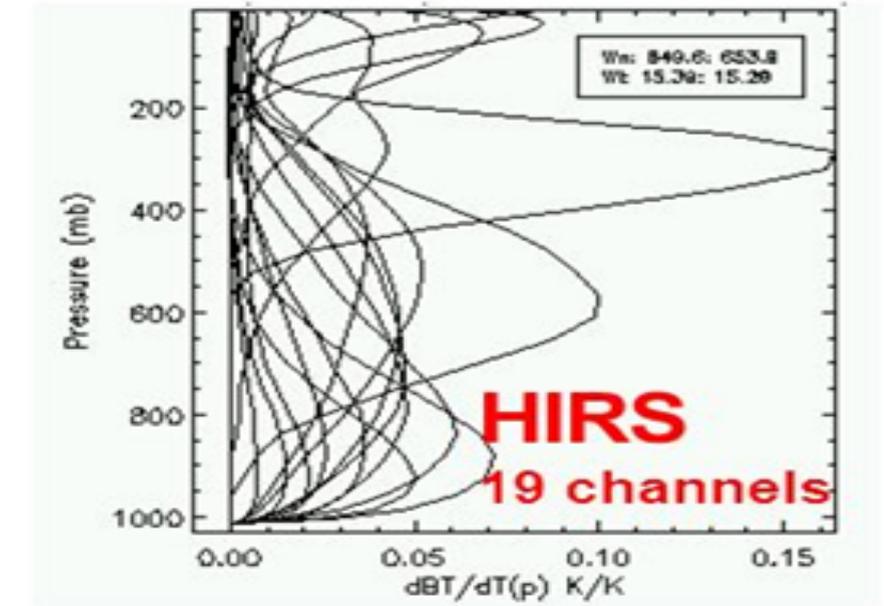
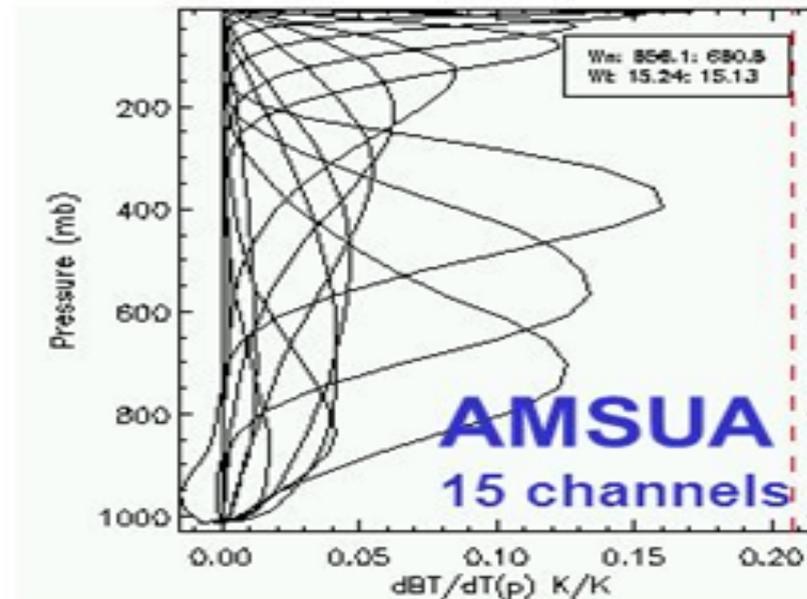
- Multispectral remote sensing is defined as the collection of reflected, emitted, or backscattered energy from an object or area of interest in about 3 to 20 multiple bands of electromagnetic spectrum; while Hyperspectral remote sensing involves data collection in hundreds or thousands of bands.
- Hyperspectral sensing improve both the spatial and spectral resolution.
- Hyperspectral imaging measures contiguous spectral bands, as opposed to multispectral imaging which measures spaced spectral bands.
- Example of multispectral sensor: Landsat Multispectral Scanner, NOAA Advanced Very High resolution radiometer, INSAT-3D Imager, etc.
- Example of Hyperspectral sensors: Atmospheric Infrared Sounder (AIRS) on-board NASA-AQUA satellite, Infrared Atmospheric Sounding Interferometer (IASI) aboard both MetOp-A and MetOp-B and Cross track Infrared Sounder (CrIS) on-board Suomi-NPP satellite



Credit: www.markelowitz.com

weighting function of multispectral and hyper-spectral sensors

- Weighting function of Multispectral Microwave AMSUA for 15 channels and Infrared HIRS for 19 channels
- Weighting function of Hyper-spectral AIRS for 2378 channels and IASI for 8461 channels
- All the channels are not used in assimilation
- Only those channels which contribute in NWP are used in assimilation
- channels selection depends on the sensitivity of channel



Design of experiment

- ❖ Two experiments are designed :
 - Assimilation and forecast system – NCMRWF's Unified Model (NCUM)
 - Resolution- 17 km
 - Experiment run- Assimilation of hyper-spectral radiances along with other conventional and satellite observations
 - Hyper-spectral radiances from AIRS, IASI and CrIS.
 - Wind from Satwind and Scatwind.
 - Radiances from Polar orbiting satellite sensor AMSR, MTSAPHIR, ATOVS, GMILOW, GMIHIGH, MWSFY3C, SSMIS.
 - Radiances from Geostationary satellite sensor INSAT-3D, SEVIRICLEAR, AHICLEAR, GOESCLEAR.
 - GPSRO
 - Conventional observations from AIRCRAFT, SONDE, SURFACE, GROUNDGPS.
 - Control run - Hyper-spectral radiances from AIRS, IASI and CrIS are denied.
 - Other conventional and satellite observations are assimilated.
 - Period- 1st May to 31st May 2018
 - 5-day forecasts are computed based on 00 UTC initial condition of each day.

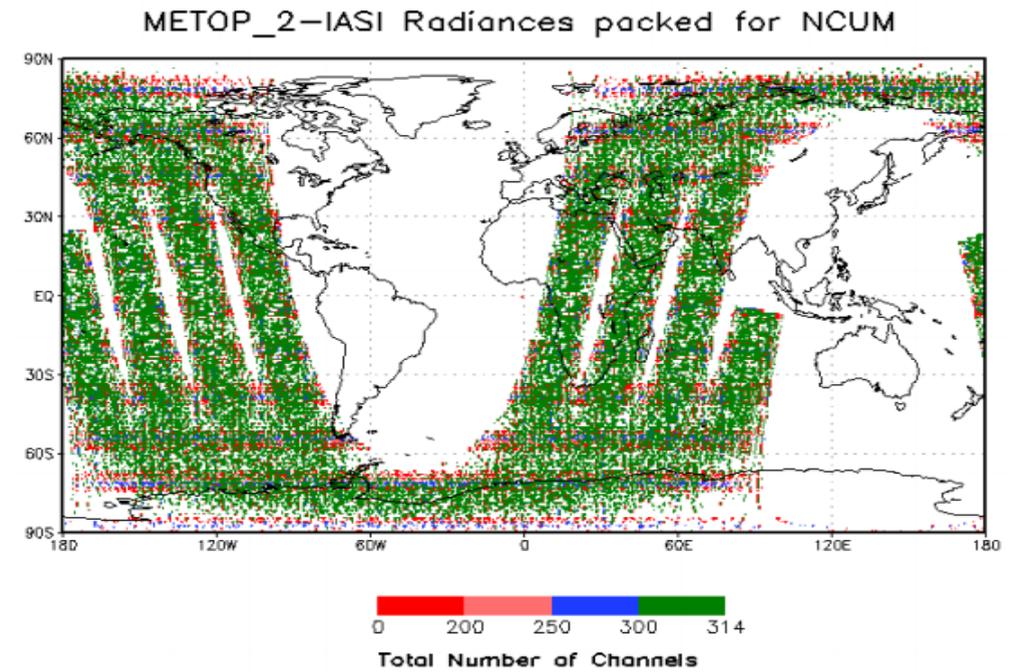
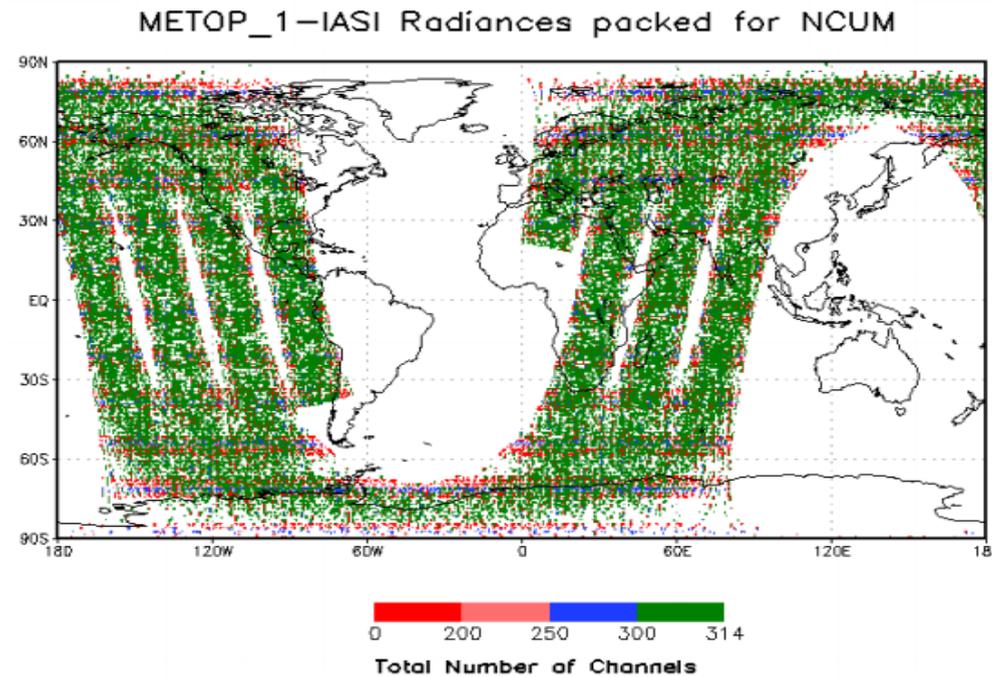
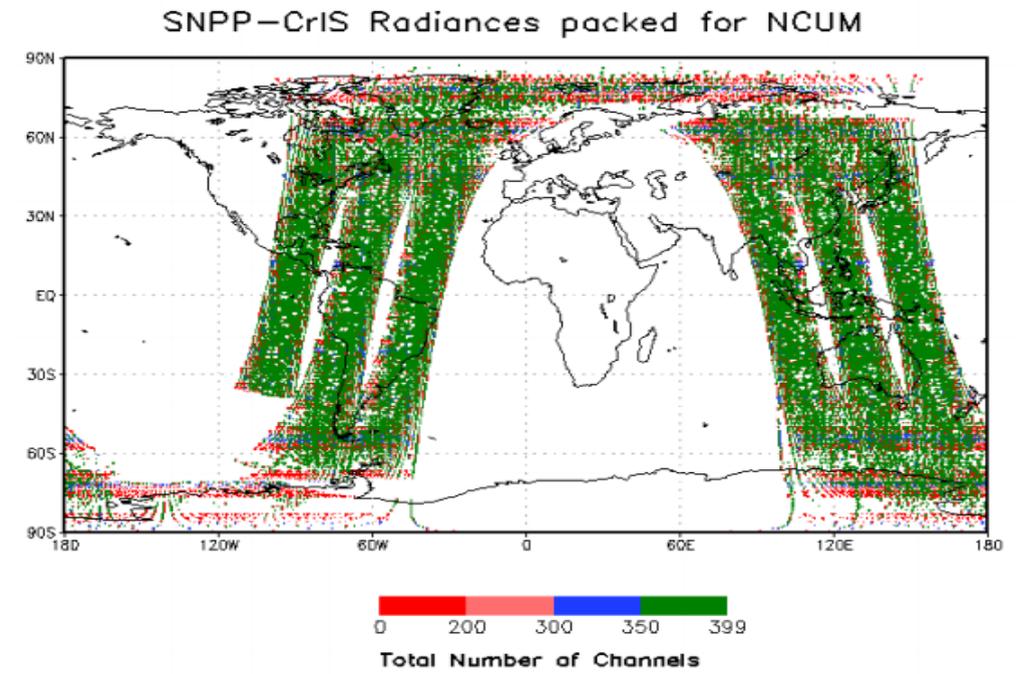
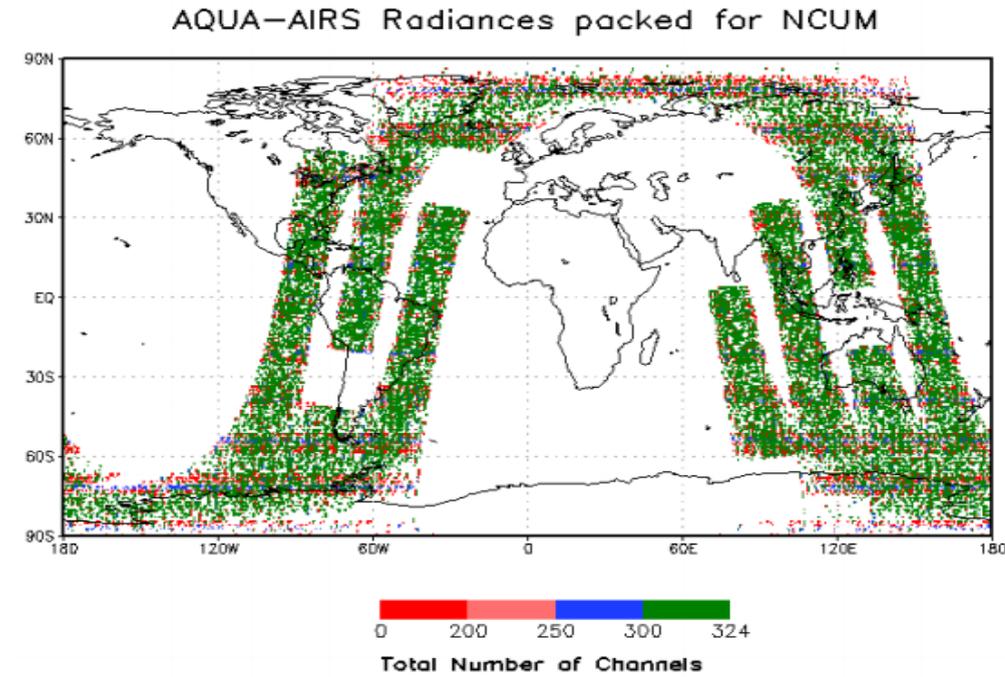
Hyper-spectral sensors used in 4d-var assimilation

- Hyperspectral radiances from Atmospheric Infrared Sounder (AIRS) on-board NASA-AQUA satellite, Infrared Atmospheric Sounding Interferometer (IASI) aboard both MetOp-A and MetOp-B and Cross track Infrared Sounder (CrIS) on-board Suomi-NPP satellite are assimilated. AIRS and CrIS have 2378 and 2211 spectral channels respectively, whereas IASI has 8461
- Out of thousands channels, only Few channels are selected for assimilation depending on the sensitivity to humidity, temperature and NWP contribution.

Sensor	Total No. of Channels	Selected channels for data Assimilation	Assimilating Channels
IASI	8461	314	135
AIRS	2378	324	128
CrIS	2211	399	132

Spatial coverage plot for hyper-spectral instruments

➤ Spatial coverage plot for particular assimilation cycle of AIRS, CrIS and IASI

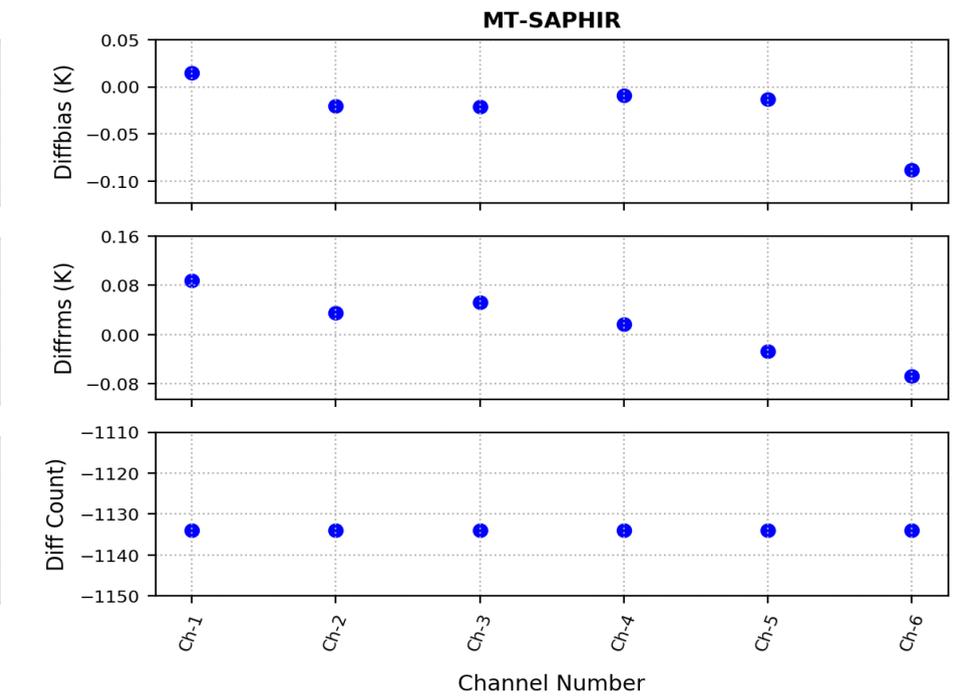
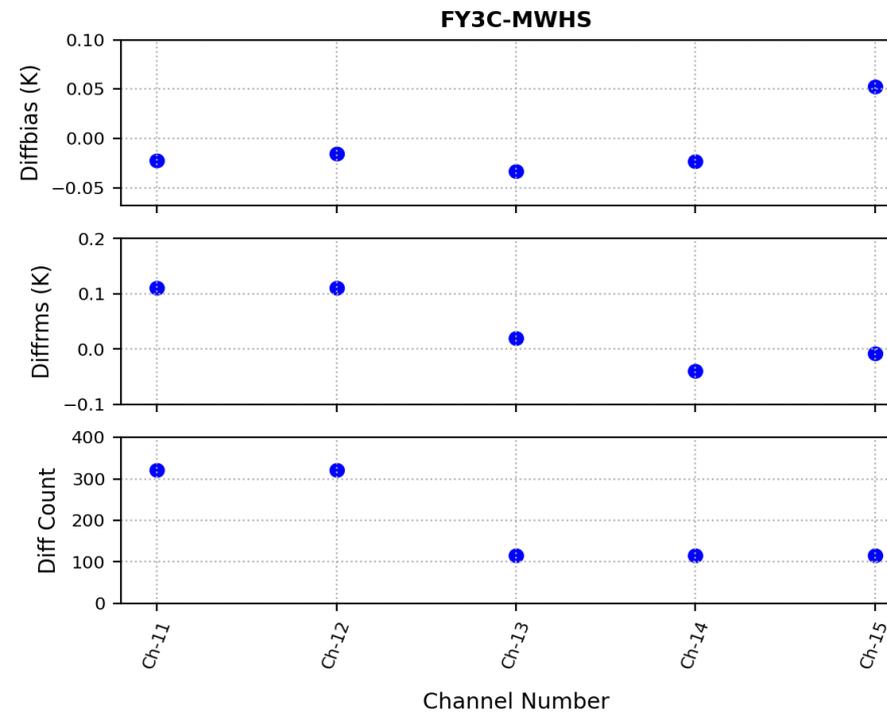
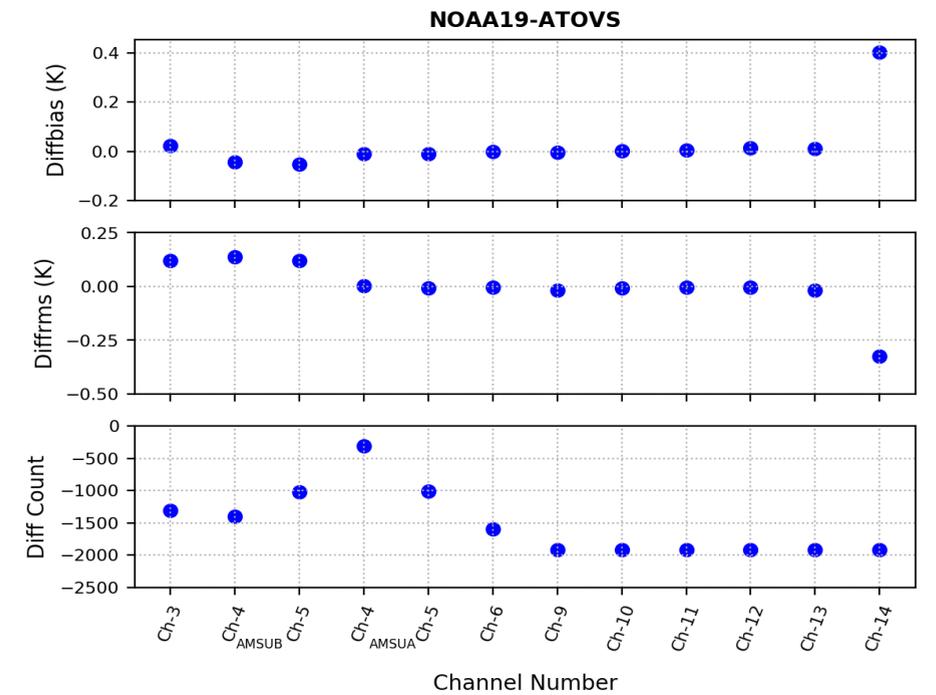
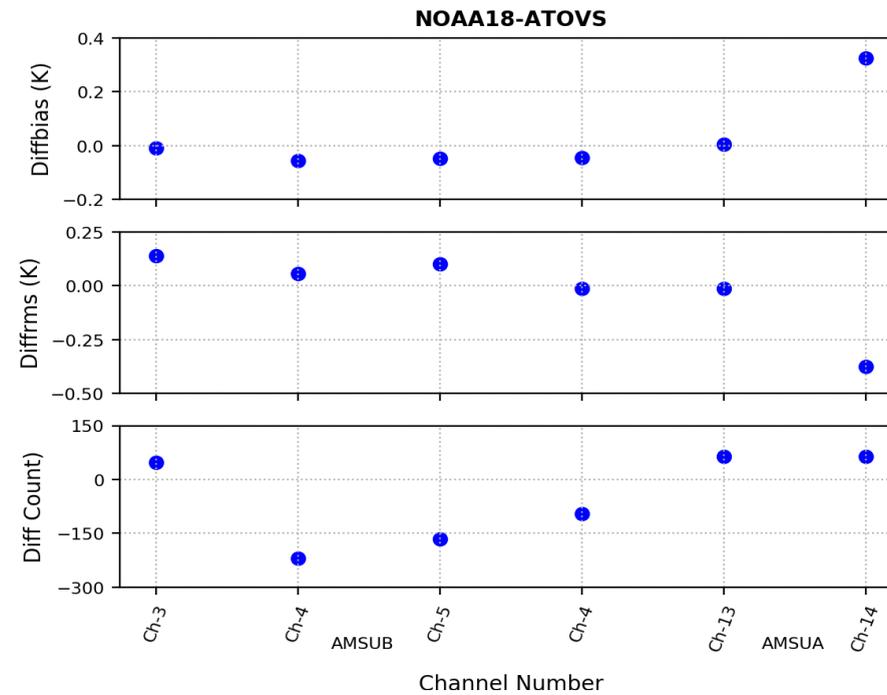


Impact of Hyper-spectral radiances on other satellite instruments

➤ Figure shows the average differences between control and experiment (c-e) in bias, rmse and counts of Observation (O)-Analysis(A)

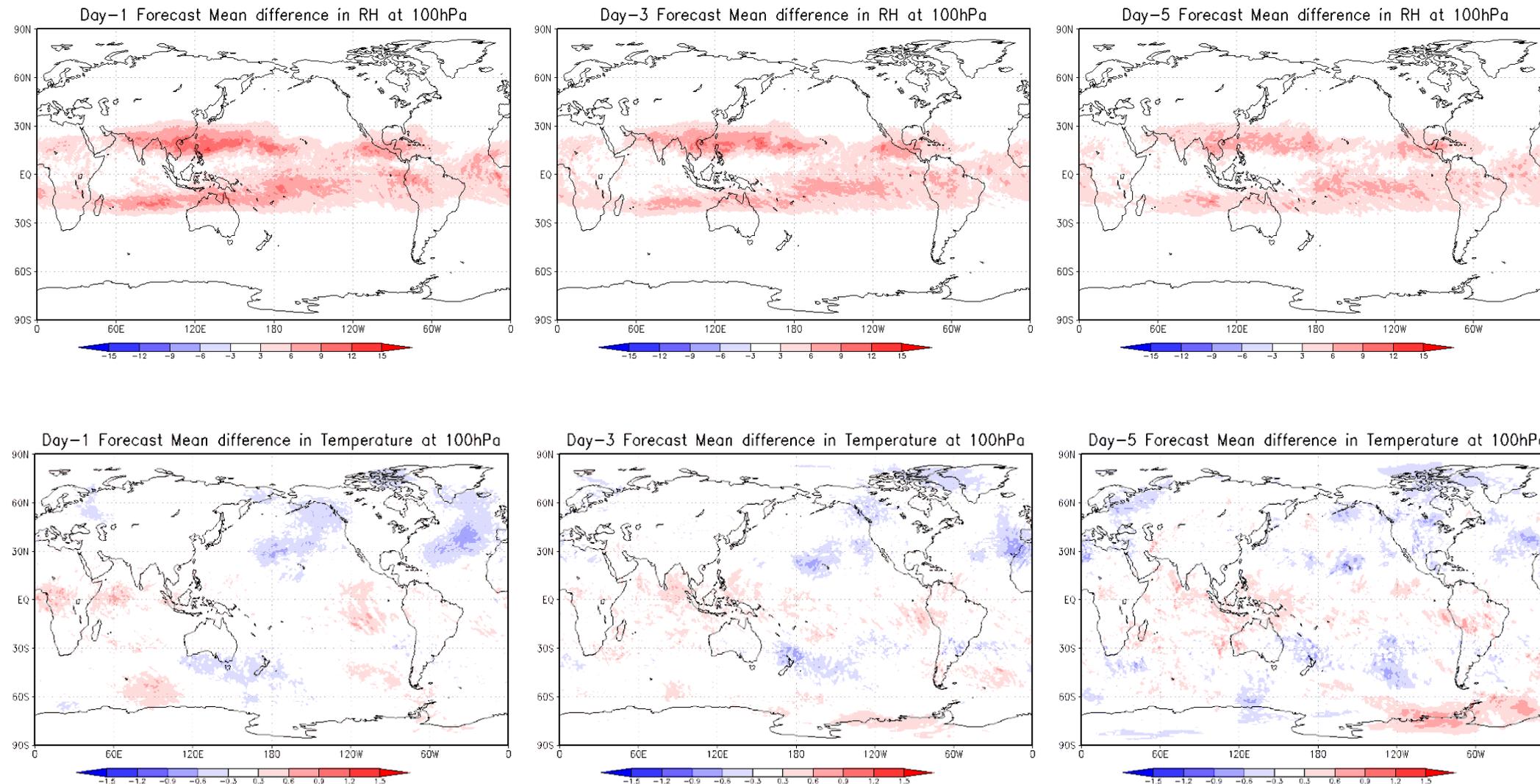
➤ Positive difference means higher the control value and negative difference means higher the experiment value.

➤ Positive rms difference shows the better impact of hyper spectral radiances simulation on other satellite.



Global assimilation and forecast

❖ Relative humidity and temperature forecast plot at 100 hPa for day-1, day-3 and day-5 forecast



➤ Top Figures show the forecast mean differences (c-e) in Relative Humidity (RH) and bottom figures show the forecast mean differences (c-e) in temperature at 100 hPa for Day-1, Day-3 and Day-5.

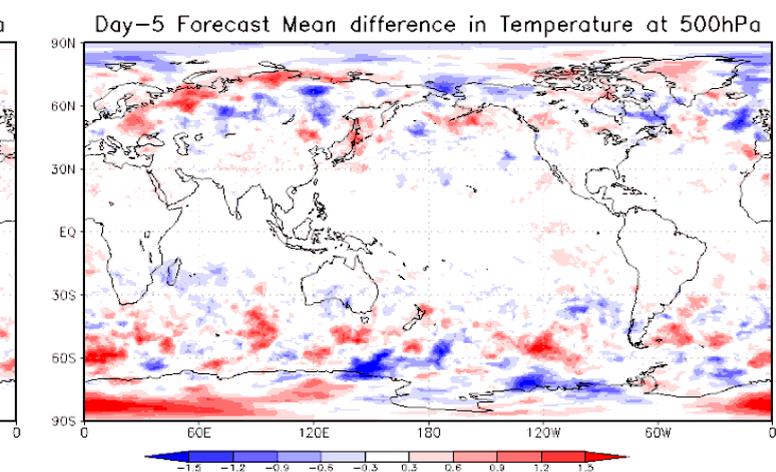
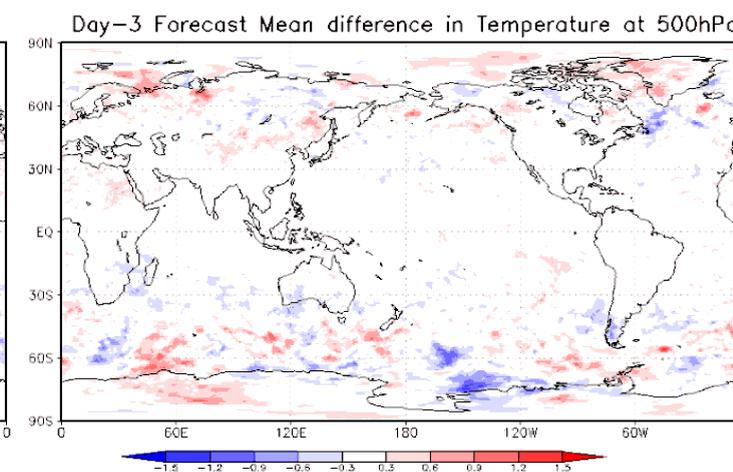
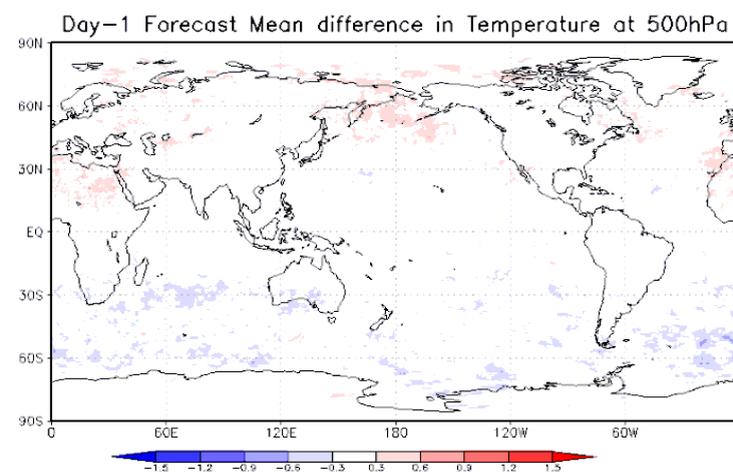
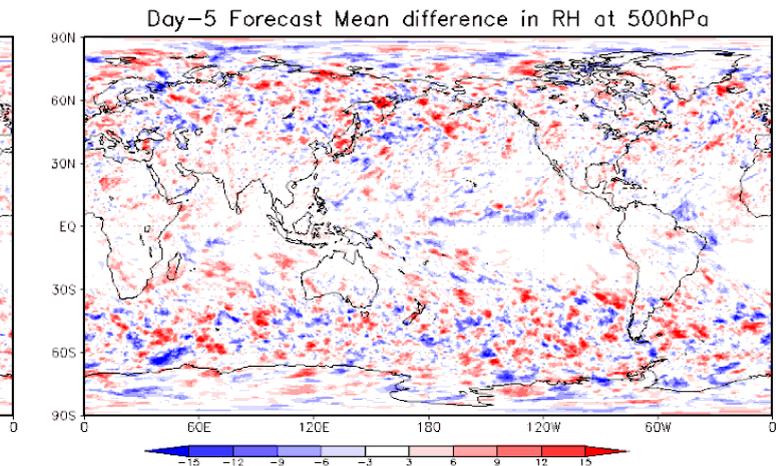
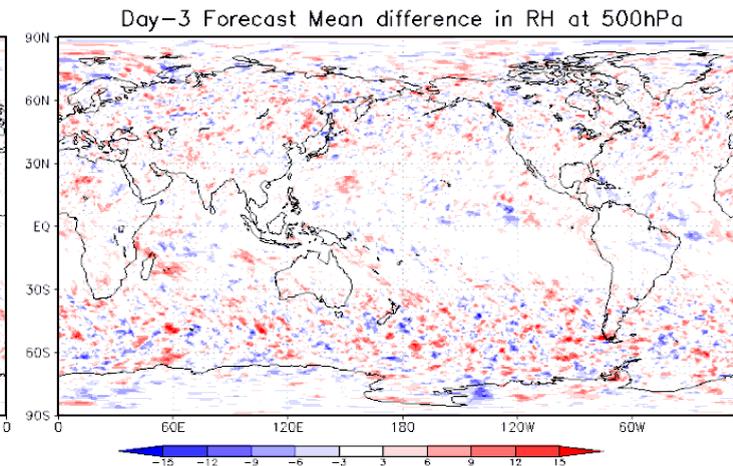
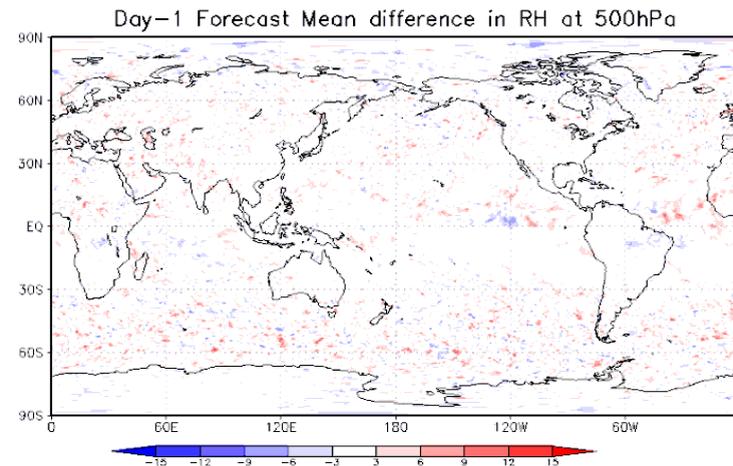
➤ Forecast mean differences in (i) RH are large positive over tropics, whereas, (ii) Temperature are positive over near equatorial region and near the Australia while negative above 30° N for day-1, day-3 and day-5 at 100 hPa.

❖ Relative humidity and temperature forecast plot at 500hPa for day-1, day-3 and day-5 forecast

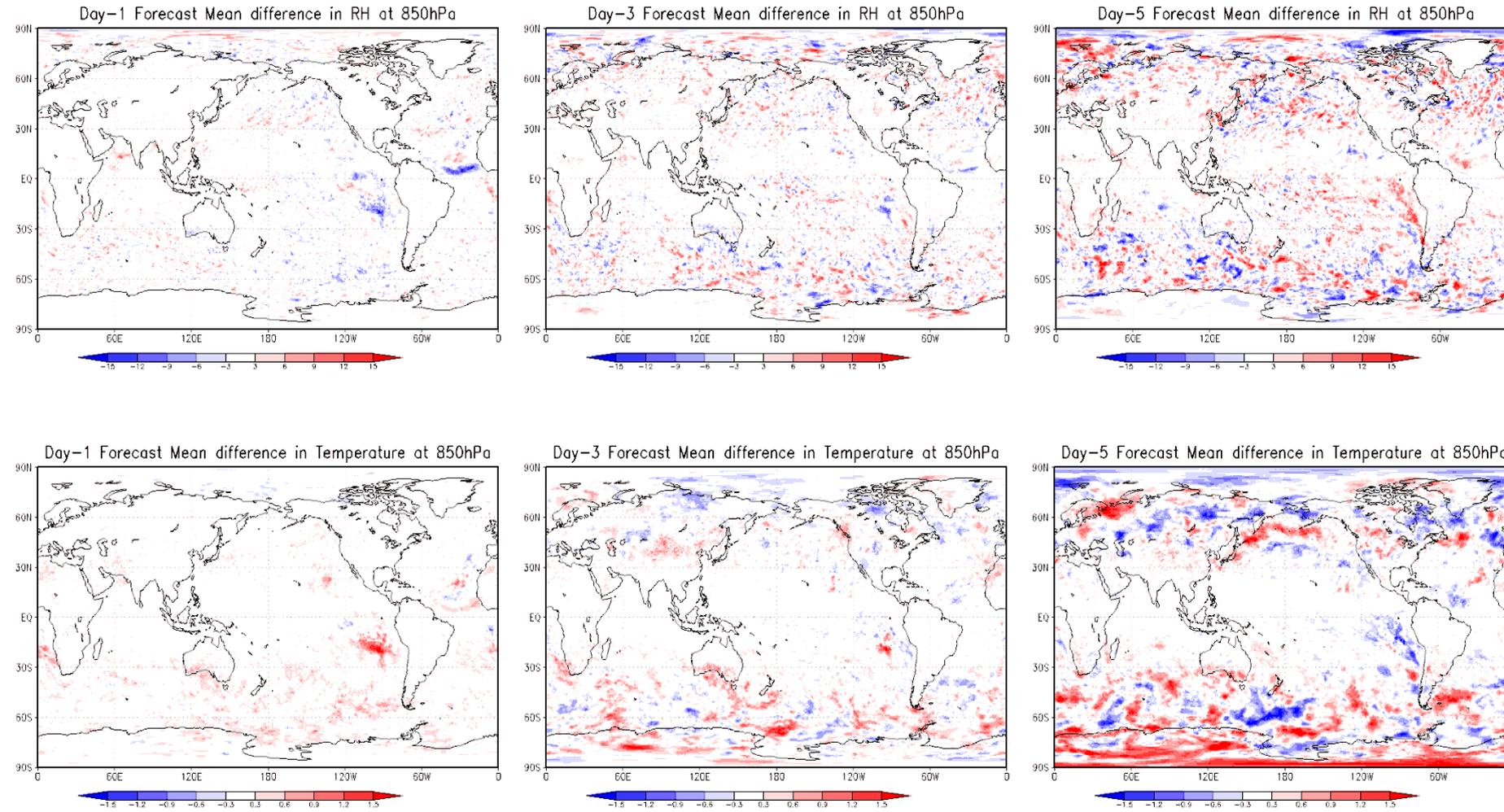
➤ Positive differences in RH over Indian Land Mass, Arabian Sea and Bay of Bengal for day-1.

➤ Mixed type of both positive and negative differences can be seen in RH for day-3 and day-5.

➤ Larger negative differences in temperature can be seen over extra tropics in southern hemisphere for day-1 while both positive and negative differences over extra tropics in both the hemisphere for day-3 and day-5.



❖ Relative humidity and temperature forecast plot at 850 hPa for day-1, day-3 and day-5 forecast



➤ Largely positive differences in RH over Arabian sea at lower level for Day-1 and Day-3 forecast.

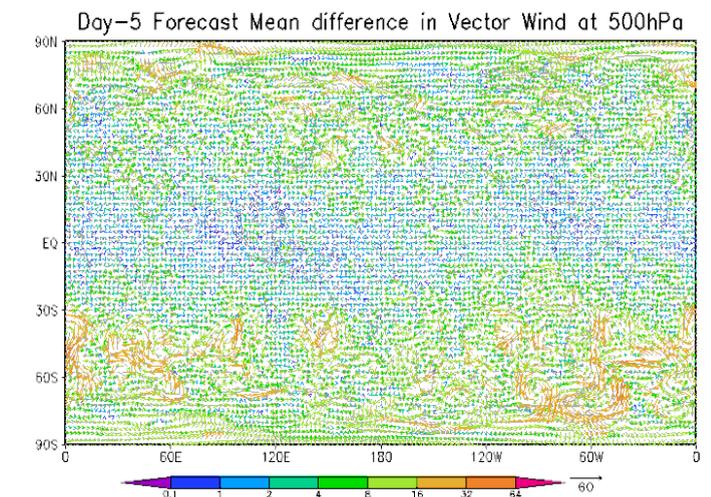
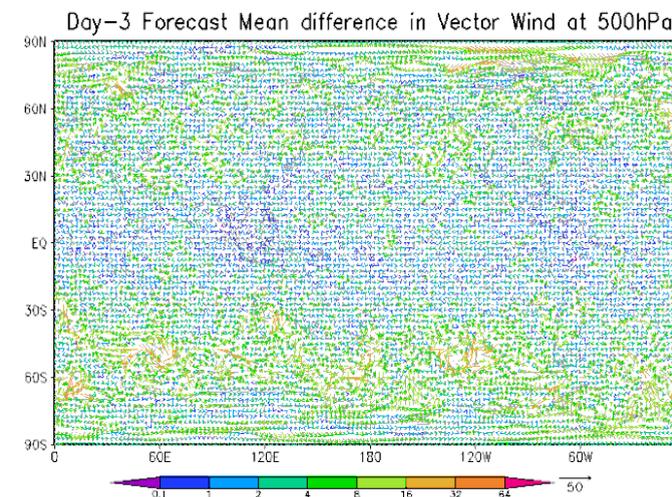
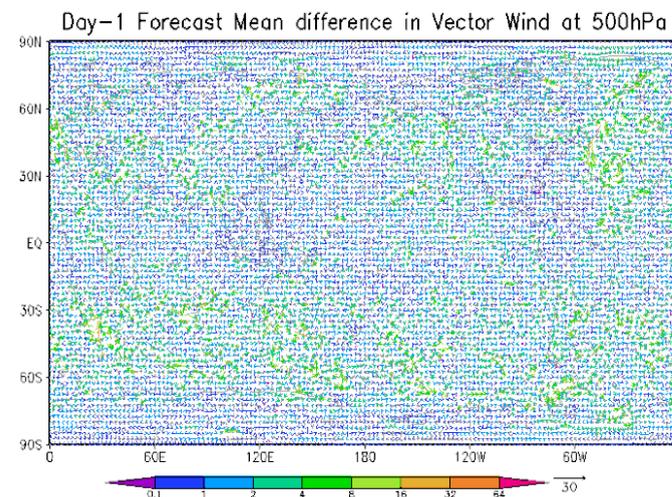
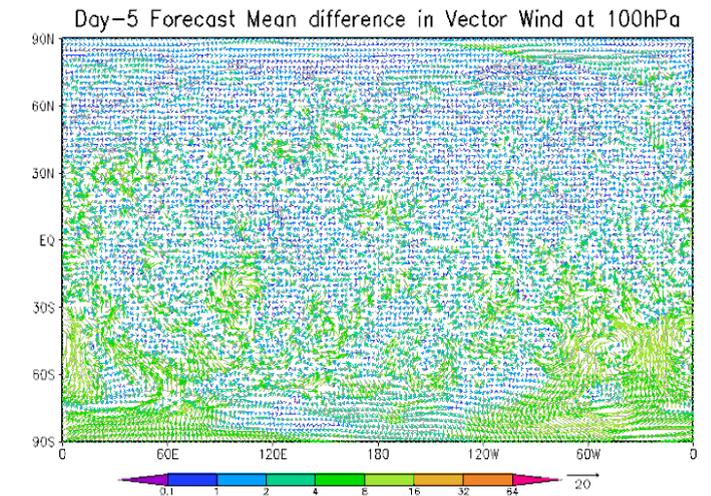
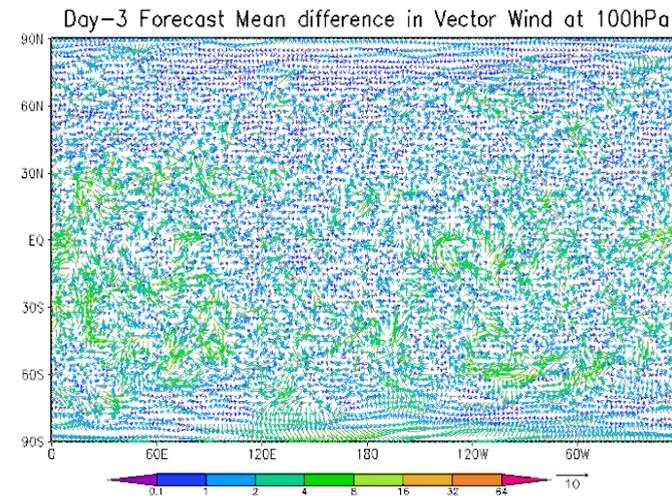
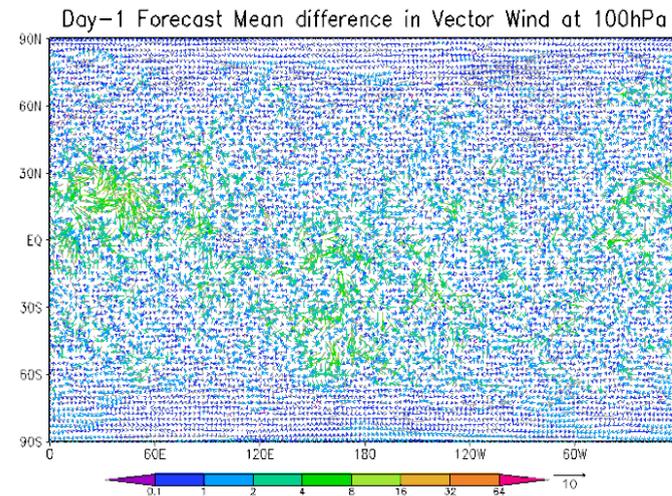
➤ Mainly, Higher positive differences in temperature can be seen for day-1, day-3 and day-5 forecasts.

Wind forecast plot at 100 hPa and 500 hPa for day-1, day-3 and day-5 forecast

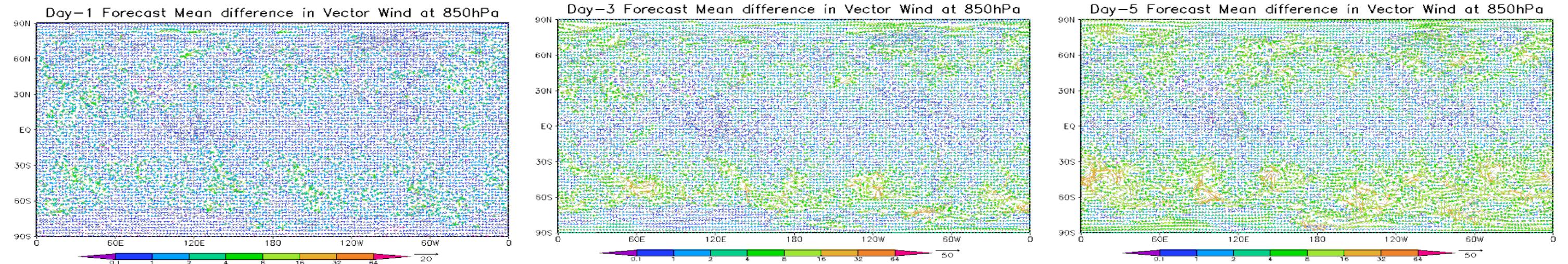
➤ Figures show the forecast mean difference of control and experiment (c-e) in wind field at 100 hPa and 500 hPa

➤ At 100 hPa, wind field changes is more over tropics for day1, day3 .

➤ At 500 hPa pressure level, wind field changes are less over tropics but more over extra tropics for day1, day3 and day5.



❖ Wind forecast plot at 850 hPa for day-1, day-3 and day-5 forecast

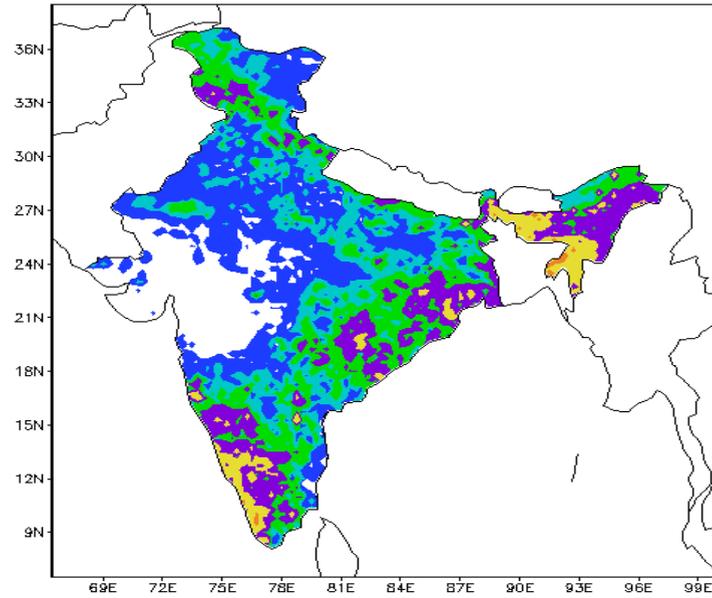


➤ Figures show the forecast mean difference of control and experiment (c-e) in wind field at 850 hPa.

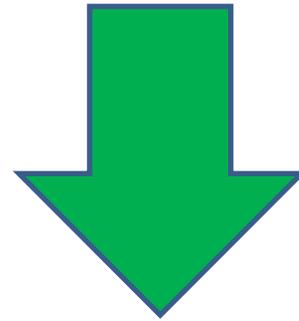
➤ At 850 hPa pressure level, wind field changes are less over tropics but more over the extra tropics for day1, day3 and day5.

Comparison of Rainfall forecast with IMD gridded Rainfall

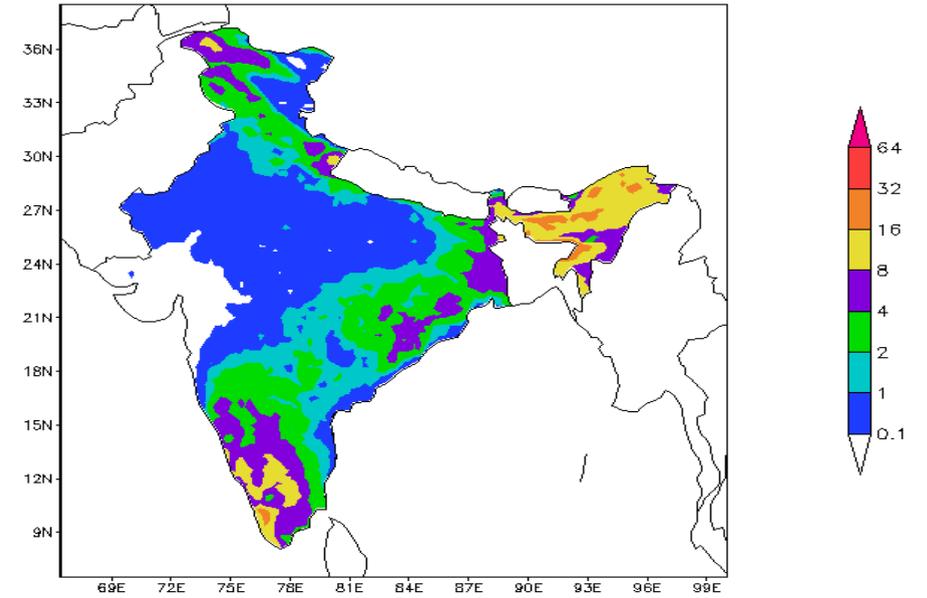
OBS



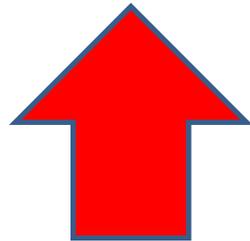
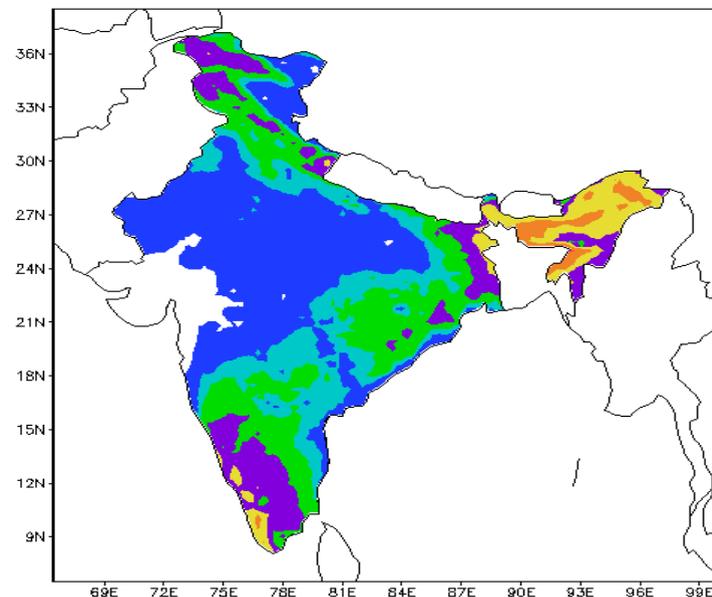
Monthly average
of EXP over India



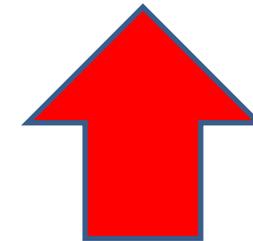
CNTL



EXP



IMD 0.25 degree
gridded rainfall
monthly average over
India

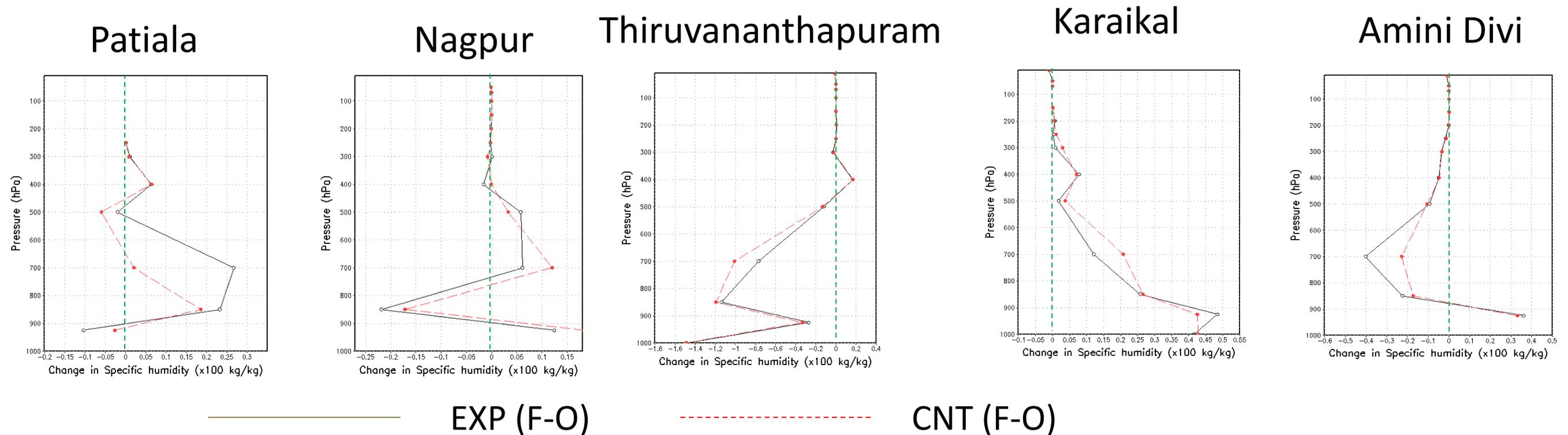


Monthly average
of CNTL over India

Comparison with Radiosonde Observations

S. No.	Station	Station ID	LAT (°N)	LON (°E)
1.	Patiala	42101	30.33	76.47
2.	Nagpur	42867	21.10	79.05
3.	Thiruvananthapuram	43371	9.95	76.27
4.	Karaikal	43346	10.92	79.83
5.	Amini Divi	43311	11.12	72.73

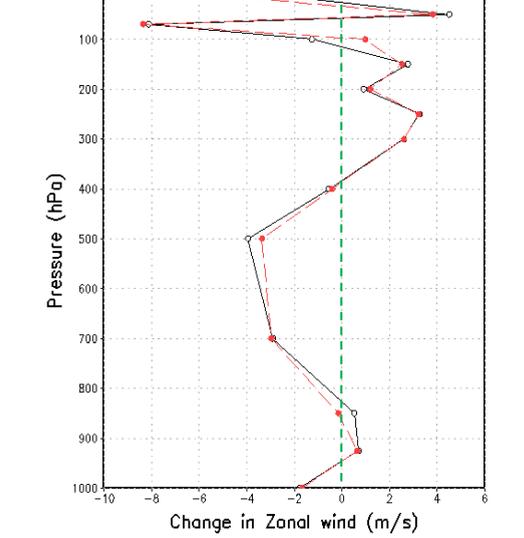
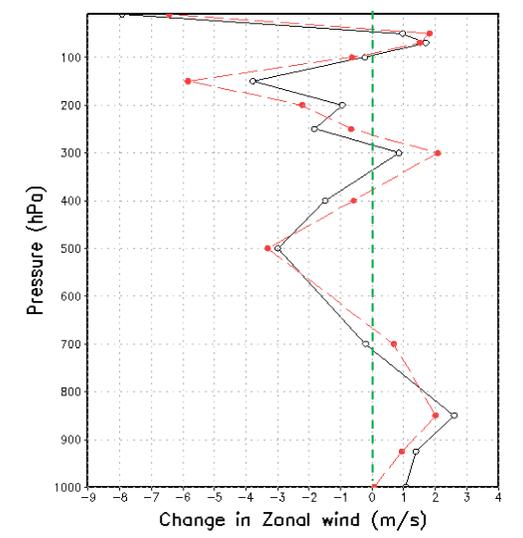
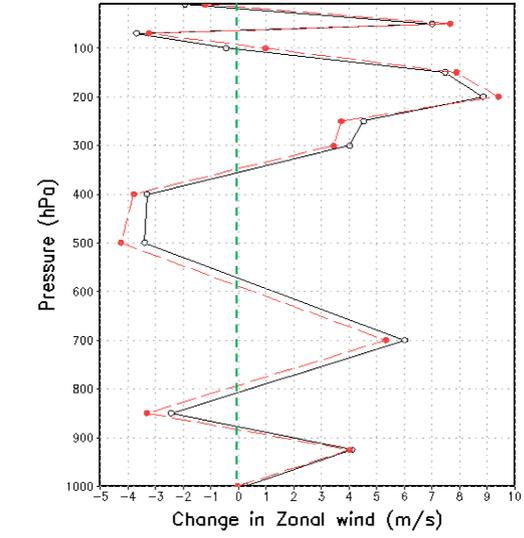
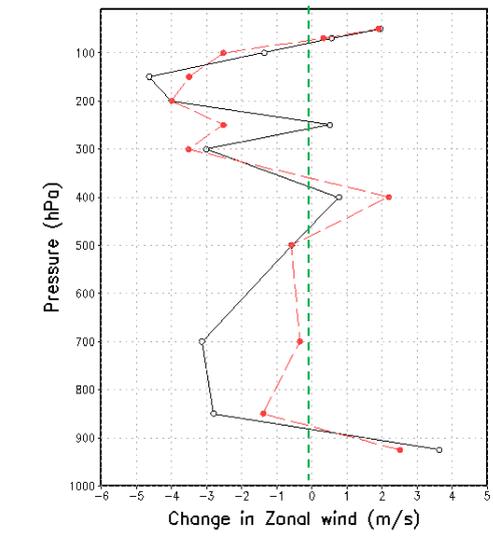
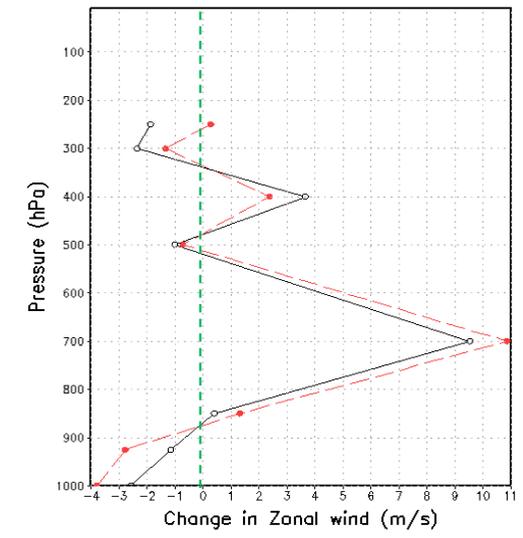
Validation of Specific Humidity with Radiosonde Observation at different locations



Validation of Zonal wind and potential temperature with Radiosonde Observation at different locations

EXP (F-O)

CNT (F-O)



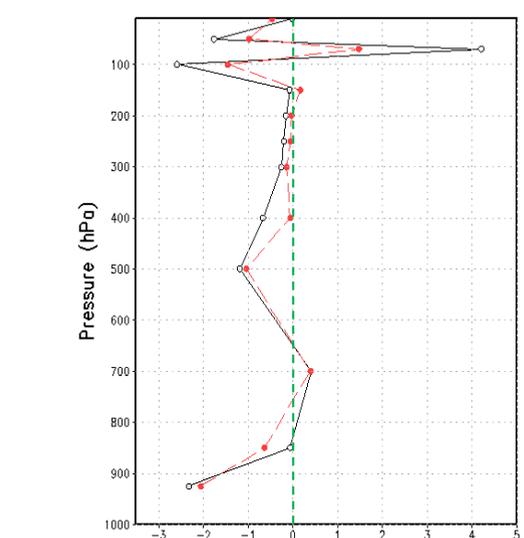
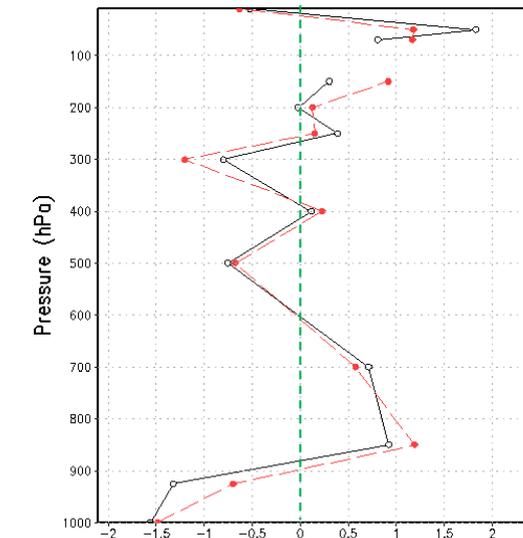
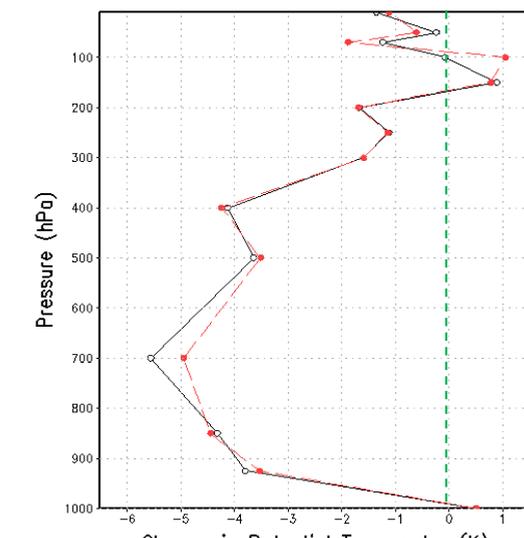
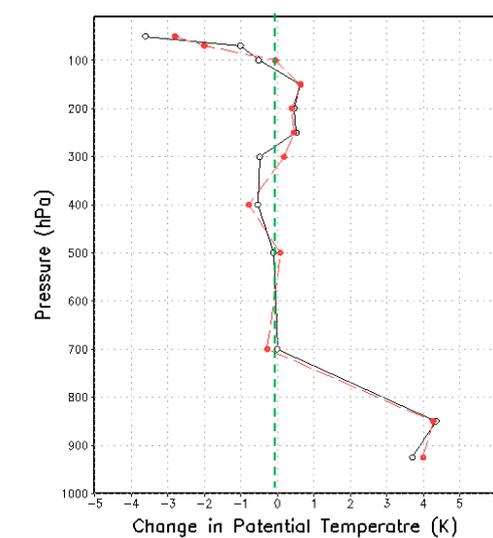
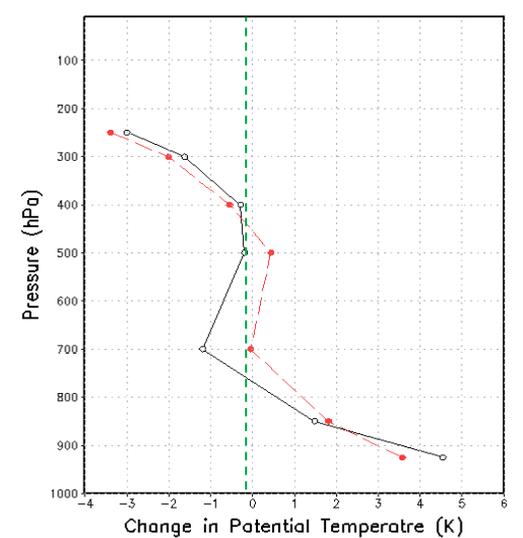
Patiala

Nagpur

Thiruvananthapuram

Karaikal

Amini Divi



Change in Potential Temperature (K)

Summary

- Channel-3,4,5 of AMSU-B in ATOVS NOAA-18 and NOAA-19 shows the more impact by the hyper-spectral radiances assimilations, whereas, Channel-4 and 13 of NOAA-18 AMSUA and channel 4-13 of NOAA-19 AMSUA has neutral impact and Channel-14 of both NOAA-18 and NOAA-19 shows negative impact of hyperspectral assimilation.
- Channel 11, 12, 13 of MWHS and channel 1-4 of MT-Saphir are positively influenced by hyperspectral assimilation, while channel 14,15 of MWHS and channel 5,6 of MT-Spahir are negatively influenced.
- At higher level, RH shows large positive differences over tropics means EXP forecasted dry weather for day-1, day-3 and day-5, whereas EXP forecasted cold temperature over arabian sea and Southern India Ocean and warm temperature near the Australia.
- At 500 hpa, EXP forecasted both dry and moist weather for all days, whereas EXP forecasted cold temperature over Indian ocean.
- At lower level, EXP shows warm temperature and both dry and moist weather.

- **At higher level, changes in wind field are more over tropics for day-1 and day-3**
- **At 500 and 850 hPa, difference in wind vector is less over tropics and more over extra tropics for day-1, day-3 and day-5.**
- **CNT and EXP both shows over-prediction in rainfall forecast.**

Thank you for kind Attention