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TECHNICAL REPORT

NCUM Global DA System: Highlights of the 2021 upgrade

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September 2021

National Centre for Medium Range Weather Forecasting
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10	Abstract	Global NCUM operational global Data Assimilation (DA) system has been updated with a latest version of UM DA system of "UM Partnership". The new DA system has the capability to assimilate more new and novel satellite observations, especially the cloud-affected microwave humidity sounder radiance and horizontal line of sight (HLOS) wind profiles from Aeolus satellite. After extensive test runs, the new DA system with the compatible Observation Processing System (OPS) was made operational in June 2021. The in-house developed Observation Pre-processing System (OPpS), which processes and packs all types of observations, was also upgraded. The latest operational global NCUM Numerical Weather Prediction (NWP) system with improved DA, OPS and OPpS along with the existing Unified Model (UM 11.2) has been named as NCUM Global model system Version 7 (NCUM-G:V7). Surface data preparation system (SURF) with Land Data Assimilation System (LDAS) remains unchanged in this new upgrade as in the case of UM. The forecast skills of the previous operational global NCUM NWP system (NCUM-G:V6) and the new system (NCUM-G:V7) were compared based on commonly used metrics. The study clearly show that the new system (NCUM-G:7) is superior to NCUM-G:V6. The Forecast Sensitivity to Observation Impact (FSOI) system has also been improved and made it compatible with the new NCUM-G:V7. The high impact of the newly added observations in the NCUM-G:V7 DA system is clearly brought out by the FSOI study.
11	Security classification	
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Abstract

Global NCUM operational global Data Assimilation (DA) system has been updated with a latest version of UM DA system of "UM Partnership". The new DA system has the capability to assimilate more new and novel satellite observations, especially the cloud-affected microwave humidity sounder radiance and horizontal line of sight (HLOS) wind profiles from Aeolus satellite. After extensive test runs, the new DA system with the compatible Observation Processing System (OPS) was made operational in June 2021. The in-house developed Observation Pre-processing System (OPpS), which processes and packs all types of observations, was also upgraded. The latest operational global NCUM Numerical Weather Prediction (NWP) system with improved DA, OPS and OPpS along with the existing Unified Model (UM 11.2) has been named as NCUM Global model system Version 7 (NCUM-G:V7). Surface data preparation system (SURF) with Land Data Assimilation System (LDAS) remains unchanged in this new upgrade as in the case of UM. The forecast skills of the previous operational global NCUM NWP system (NCUM-G:V6) and the new system (NCUM-G:V7) were compared based on commonly used metrics. The study clearly show that the new system (NCUM-G:7) is superior to NCUM-G:V6. The Forecast Sensitivity to Observation Impact (FSOI) system has also been improved and made it compatible with the new NCUM-G:V7. The high impact of the newly added observations in the NCUM-G:V7 DA system is clearly brought out by the FSOI study.

1. Introduction

NCMRWF is operationally using NCUM global NWP system since 2012(Rajagopal et al., 2012). This system has been adapted from Unified Model (UM) seamless prediction system of “UM Partnership” and is being upgraded periodically to adapt new scientific and technological advancements. The major components of the NCUM global NWP system include components for data processing, data assimilation and forecast model (Brown et al., 2012, George et al., 2016). Observation pre-processing, observation processing and quality control components of the NCUM system prepare the quality-controlled observation for assimilation. (Buddhi et al., 2019, Sumit et al., 2020).There have been six significant upgrades of NCUM global NWP system since 2012 and the details of each system can be seen in NCMRWF technical reports (Sumit et al., 2020 and references therein). The current up gradation of the NCUM global NWP system is limited to the improvements in the data processing and data assimilation components, whereas the forecast model version remains unchanged. The surface analysis preparation system (SURF), that prepares the surface analysis of snow, sst, sea ice, soil moisture etc for the NCUM model remains the same in this up-gradation (SURF system includes Extended Kalman Filter based Land Data Assimilation System) (Sumit et al., 2020). Hence, this report focuses only on the changes made in the DA system for its improvements and its performance during a one-month trial period. Though the model and surface analysis system remain unchanged, DA changes are significant. The new assimilation system is capable to use quality observations from new sources/types, notably the Aeolus HLOS wind (Gibies et al., 2021) and has improved observation error variances for GPSRO (Bowler, 2020).Also the new NCUM DA system has the capability to assimilate cloud-affected microwave observations from ATOVS instruments.

NCMRWF initially adapted UM's advanced 4D-Var Data Assimilation (DA) system for its global NCUM system in 2012 (Rawlins et al., 2007, Rajagopal et al., 2012). One of the weaknesses of this system was the use of a climatologically average background error (Lorenc, 2003). So in 2016, NCUM DA system has been upgraded to “Hybrid 4D-Var”, which has the advantages of both traditional 4D-Var method and ensemble data assimilation approaches, providing flow-dependent forecast error covariances (Clayton et al., 2013). Another major change adopted in the past is the variational bias correction scheme for satellite radiance observations instead of a static bias correction scheme. The variational bias correction scheme implemented with the NCUM DA system follows quite closely the incremental formulation of Aulígné et al., 2007.

Various in-situ and remote-sensing observations are used in the NCUM DA system. New and novel observations are added to the data assimilation system after adapting/developing/enhancing the required capability in its pre-processing system (OPpS), the Observation Processing System (OPS), and data assimilation (Hybrid 4D-Var)from time to time. The changes to the operational system are made after carrying out Observing System Experiments (OSE) and Forecast Sensitivity to Observation Impact (FSOI) studies satisfactorily. Many new observations were added to the NCUM data assimilation system in the past along with the major system upgrades, but there were several additions of new observation types in the DA system in-between the major system upgrade. This major upgrade of the NCUM DA system has improved the capabilities of the DA system significantly and enabled the use of more types of observations in assimilation.

2. Observation Pre-processing System (OPpS) and Observation Processing System (OPS)

NCMRWF receives worldwide meteorological observations through Global Telecommunication System (GTS) via Regional Telecommunication Hub (RTH) at IMD, New Delhi. A large volume of satellite observations is being received through internet data services from various satellite data producers (NOAA/NESDIS, EUMETSAT, ISRO etc.) directly at NCMRWF. The NCUM Observation Pre-processing System (OPpS) packs all observations received at NCMRWF in a specific format known as “obstore”, which can be read directly by the Observation Processing System (OPS) of NCUM. The in-house developed OPpS system improved from time to time by the adding capabilities to process new types of observations. In this new up-gradation, the observation pre-processing system has been improved to process and pack the new observation types for its use in the DA system. Table 1 lists the observations assimilated in the latest version of the NCUM data assimilation system (NCUM-G:V7).The Observation Processing System (OPS) read the decoded observations packed by the OPpS. The OPS system has two components, the “extract” component of OPS retrieves the observations available in “obstore” format and calculates background values at the observation locations from the model background fields. The OPS also performs the quality control of observations and reformat the observations for its use in the Hybrid 4D-Var. The OPS system processes and packs observations for each 6 hourly window for the four data assimilation cycles in a day centred at 00, 06, 12 and 18 UTC.

Table 1: Types of observations assimilated in new NCUM DA system (NCUM-G:V7 DA)

Observation Type	Observation Description	Assimilated Variables
Surface	Surface observations over Land and Ocean (TAC & BUFR), TC bogus *(*Surface Pressure)	Wind, Temperature, Humidity, Surface Pressure
Sonde	Radiosonde (TAC & BUFR), Pilot balloons, Wind profiles &Radar VAD winds	Wind, Temperature, Humidity
Aircraft	Upper-air wind and temperature from aircraft (AMDAR & AIREP)	Wind, Temperature
GroundGPS	Ground based GPS observations	Zenith Total Delay
*Satellite:*GPSRO	Global Positioning System Radio Occultation observations from various satellites (Terra-Sar X, COSMIC (E1 to E6), FY3D, KOMPSAT, MetOp (A, B & C))	Bending Angle
*Satellite:*Satwind	Atmospheric Motion Vectors from geostationary and polar orbiting satellites (MSG, JMA, GOES,MetOp,INSAT-3D &INSAT-3DR, MODIS, NOAA)	Wind
*Satellite:*Scatwind	Advanced Scatterometer in MetOp-A & B, ScatSat-1, WindSat	Wind
*Satellite:*MicroWave Sounder/Imager	Microwave sounders / imagers ATMS,AMSU,GMI,MWHS,AMSR2,SAPHIR,SSMIS	Brightness Temperature
*Satellite:*Hyperspectral IR	Hyperspectral infrared sounders IASI,CrIS,AIRS	Brightness Temperature
Satellite: Geostationary Sounder/Imager	Sounder/Imagers from MSG,GOES,Himawari,INSAT	Brightness Temperature
*Satellite:*HLOS Wind	Mie-scattering and Rayleigh-scattering Horizontal Line-Of-Sight (HLOS) winds from AEOLUS satellite	HLOS wind
*Satellite:*Aerosol Optical Depth (AOD)	Dust aerosol optical depth from MODIS (Terra & Aqua) satellite	AOD

3. Hybrid 4D-Var Data Assimilation

In the conventional four-dimensional variational data assimilation method ("4d-Var")the optimal estimate of the “state of the atmosphere (called analysis)”, which is used as the model initial condition, is obtained by fitting the forecast (short forecast) to observations within a fixed time window. A weakness of the 4D-Var method is that it uses a static “climatological” forecast error covariance, which does not describe the flow-dependent errors of the day. To address this problem, hybrid-4DVar method was formulated (Clayton et al., 2013) for the UM system. Ensemble data assimilation attempts to circumvent the covariance modelling effort by making explicit use of flow-dependent forecast error information provided by ensemble prediction systems. The hybrid variational-ensemble DA approach merges the two sources of covariance information, climatological and flow-dependent, into the 4D-Var algorithm. NCUM "Hybrid 4D-Var" system uses the 22 member ensemble forecast from "NCMRWF Ensemble Prediction System (NEPS)" for determining the"day-to-day varying" flow-dependent errors. The hybrid variational- ensemble approach is particularly attractive for the operational NWP centres having sophisticated variational data assimilation systems like 4D-Var and ensemble prediction systems for probabilistic NWP.

Table 2: Software details of NCUM DA system major up-gradations

Implementation Month/Year	**DA System Version (NCUM)**	**OPS (UKMO Version)**	**VAR (UKMO Version, Resolution and DA Method**	**SURF (UKMO Version)**	**UM (UKMO Version, Dynamical Core and Resolution)**
April-2012	NCUM-DA1	OPS 27.1	VAR27.1 (N216L70) (4D-Var)	UKMO Surface files	UM7.7 (ND) (N512 L70)
Dec-2012	NCUM-DA2	OPS 27.2	VAR27.2 (N216L70) (4D-Var)	SURF30.0	UM7.9 (ND) (N512 L70)
Nov-2015	NCUM-DA3	OPS 30.1	VAR30.0 (N320L70) (4D-Var)	SURF30.0.1 (Soil Moisture-EKF)	UM8.5(EG) (N768 L70)
Oct-2016	NCUM-DA4	OPS 32.1	VAR32.0 (N320L70) (Hybrid 4D-Var)	SURF32.0 (Soil Moisture-EKF)	UM10.2(EG) (N768 L70)
May-2018	NCUM-DA5	OPS 2017.07	VAR 2017.07 (N320L70) (Hybrid 4D-Var	SURF 2017.07 (Soil Moisture-EKF)	UM10.8(EG) (N1024L70)
June-2020	NCUM-DA6	OPS 2019.02.0	VAR 2019.02.01 (N320L70) (Hybrid 4D-Var	SURF 2019.02.0 (Soil Moisture-EKF)	UM11.2(EG) (N1024L70)
June 2021	NCUM-DA7	OPS2020.01.0	VAR2020.01.0(N320 L70) (Hybrid 4D-Var)	SURF 2019.02.0 (Soil Moisture-EKF)	UM11.2(EG) (N1024L70)

4. Major Changes to OPpS, OPS and Hybrid 4D-Var in NCUM-G:V7 DA

A list of observations and their subtypes incorporated in the latest DA system is described in Table-1. Table-2 presents a brief history of NCUM up-gradations since 2012.A brief description of the new NCUM global NWP system, including information about resolution, time step, physical parameterization version etc., is shown in Table-3.

Table 3: NCUM Global assimilation-forecast System (NCUM-G) of the new system up-grade

Model (NCUM-G:V7)	Atmospheric Data Assimilation	Surface analysis
Model: Unified Model; Version 11.2 **Domain:** Global **Horizontal Resolution:**12 km **Vertical levels:** 70 levels (model top at 80 km) **Time Step:** 5 minutes **Physical Parametrizations:** Based on GA7.2 **Dynamical Core:** ENDGame **Forecast length:** 10 days (based on 00 UTC and 12 UTC initial conditions)	**Method:** Hybrid incremental 4D-Var (Hybrid 4D-Var). Information on "errors of the day" is provided by NEPS (NCMRWF Ensemble Prediction System) forecast in all data assimilation cycles **Data Assimilation Cycles:** 4analyses per day at 00, 06, 12 and 18 UTC. Observations within +/- 3 hrs from the cycle time is assimilated in the respective DA cycle **Observations:** Observations received at NCMRWF from GTS (IMD) and various satellite data producers (NOAA/NESDIS, EUMETSAT, ISRO etc.) are used for assimilation. Observation Processing System does the quality control of observations. Variational bias correction is applied to satellite radiance.	**Soil Moisture analysis:** *Method:* Simplified Extended Kalman Filter *Analysis time:* 00, 06, 12 and 18 UTC *Observations assimilated:* ASCAT soil wetness observations, Screen Temperature and Humidity increments (pseudo observations from 3D-Var screen analysis) **SST**: Updated at 12 UTC DA cycle with OSTIA based SST and sea-ice analysis **Snow Analysis:** Satellite-derived snow analysis. Updated at 12 UTC DA cycle

There is no change in the data assimilation method or data assimilation resolution in the new NCUM system (NCUM-G:V7) compared to NCUM-G:V6 DA. The forecast model and its resolution is also same as in the previous system. Changes have been introduced in OPpS, OPS and Hybrid 4D-Var to include more observation types in the assimilation. List of new observations introduced in NCUM-G:V7 DA is given below:

(i) Mie-scattering and Rayleigh-scattering horizontal line of sight wind profiles from AEOLUS satellite.

(ii) Hyperspectral infrared sounder (IASI) and Microwave sounder (AMSU, MHS) radiance from MetOp-C satellite.

(iii) All-sky Microwave Humidity Sounder (MHS) radiance from various satellites.

(iv) Microwave sounder radiance (MWRI) from FY3D satellite.

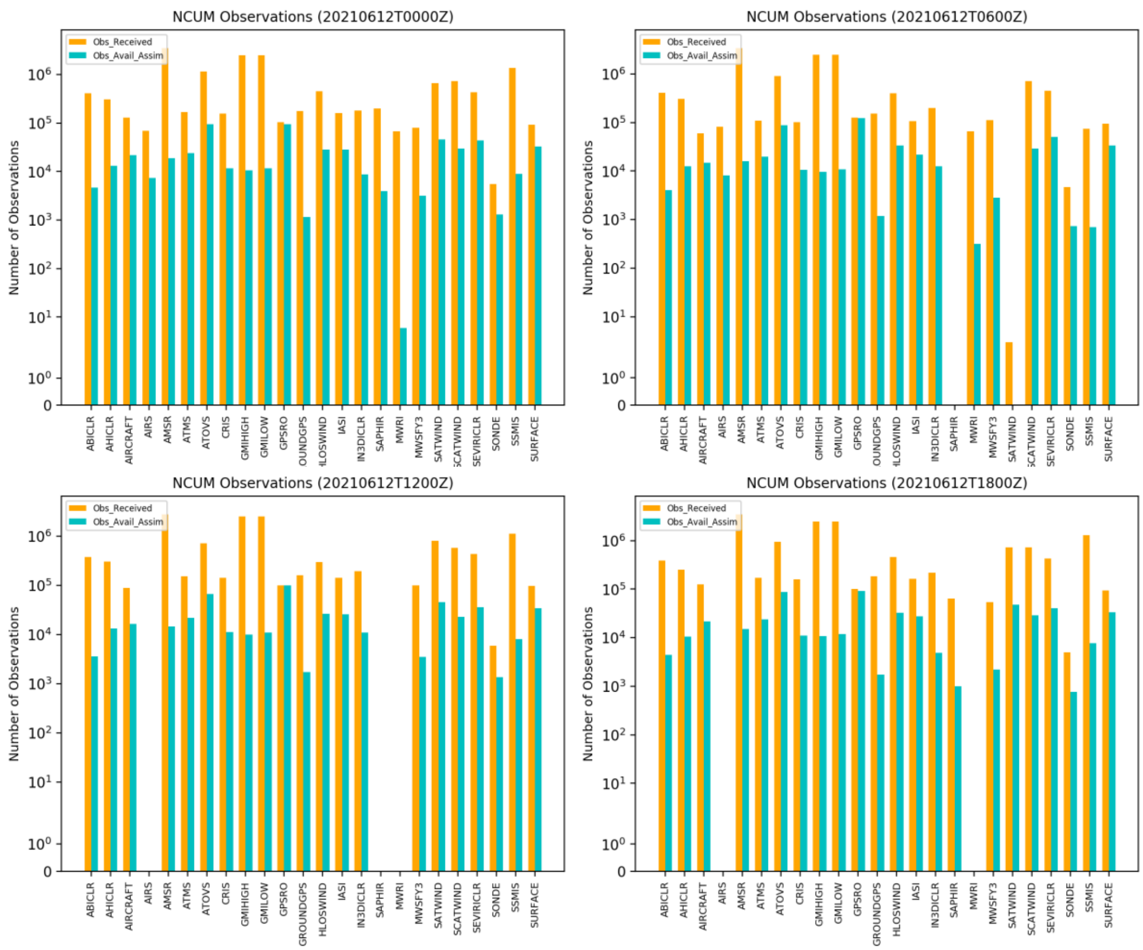

Figure 1: Number of observation received and assimilated in NCUM global NWP system on a typical day (all 4 DA cycles).

Scatterometer quality control (QC) is also improved (in OPS) in new system. This new QC system allows the use of scatterometer sea surface winds that are closer to the coasts. Other significant improvements in the DA system include:

- Up gradation of RTTOV fast radiative transfer model version (to RTTOV12.3)
- SatRad coefficient update for GOES ABI channels.

- Updated observation error variances for GPSRO (Bowler, 2020).

Number of observations received for assimilation (observations “received”) and final number used in the assimilation system after quality control and thinning (observations “”assimilated”) are presented in Figure 1.

5. Performance of NCUM-G:V7 DA System

A month-long observing system experiments (OSEs) was conducted to evaluate the impact of enhanced DA system of NCUM (NCUM-G:V7) from 01 July 2020 to 31 July 2020.The NCUM-G:V6(PS43) operational assimilation-forecast system is considered as a “control” system. Various verification statistics were generated to assess the experimental system analysis and forecast (the new DA system) against the “control” system (PS43) analysis and forecast (hereafter called “experiment” and “control” analysis and forecast).

The verification metrics are prepared mainly using NOAA’s standard operational verification statistics database (VSDB) system (Johny et al., 2020). Here we present some of the VSDB results for day-1–5 forecast from the control, and experiment runs. The day-1 to day-5 forecasts from the control and experiment are validated against their respective analysis. Important forecast verification scores such as anomaly correlation (AC), root-mean-square error (RMSE), and bias are presented here. Experimental forecast shows (Figure 2) lower RMSE for Geopotential Height (HGT), Temperature (T) and Wind at 500 hPa level over the global domain (G) for all the 5 days of the forecast (during the one month study period of 01-31 July, 2021) considered in this study. The pattern of RMSE is more or less similar (not presented here) for other levels too. Figure 3 shows the 500 hPa level global anomaly correlation for HGT, T and Wind (during the study period). Improved anomaly correlation values (higher values of anomaly correlation) are obtained from the experimental forecast for all the three forecast variables considered here at 500 hPa level for all the 5 days of forecast (day 1 to day 5), which is mostly similar in other levels too. Figure 4 shows the Global RMSE of HGT variable at 850 hPa, 500hPa and 250 hpa levels. In all the three levels the experiment (new DA) shows a reduction in RMSE globally at all the lead-time (upto day 5) forecasts for one-month study period. Figure 5 is similar to Figure 4 but for Temperature (T). Here also, in all three levels and all lead-time forecasts, the global RMSE is less in experimental forecast compared to the control forecast. In the case of Wind, global RMSE is less at850, 500 and 200 hPa levels and for all lead-time forecasts (Figure 6).Northern Hemisphere Wind RMSE for 850, 500 and 200 hPa level forecasts are presented in Figure 7. Even though the magnitude of the RMSE reduction in the experiment over Northern Hemisphere is less than the global domain results, a consistent decrease in RMSE can be noticed in the experimental forecast. However, over RSMC (IMD) region, at 850 hPa levels beyond 2 days of forecast lead-time, experimental RMSE are slightly higher (Figure 8). Other levels show improved (less) RMSE in Wind over the RSMC region in the experimental forecasts.

5.1. Comparison of Rainfall forecast

Model rainfall forecasts are verified against IMD-NCMRWF merged rainfall analysis (Mitra et al. 2009). Figure 9 presents the 5-days rainfall analysis over the Indian region and day 1 to day 5 forecast valid for 00 UTC 09 from experimental and control NWP system. Oceanic rainfall is nearly similar in both sets of forecast for all lead-times considered here, with slight improvement seen in experimental forecasts. Over the Indo-Gangetic plain, the experimental forecast shows some over prediction of rainfall in day 1 forecast, which is improved in other lead-time forecasts. The bias of the forecast with respect to the rainfall analysis is presented in Figure 10. It is difficult to conclude the quality of rainfall forecast obtained with the changes in the data assimilation system from this lone case study. However, this case study indicates that the up-gradation of the NCUM assimilation-forecast system is not showing any significant improvement or deterioration of rainfall forecasts. Biases of rainfall forecast (day 1 to day 5) for 29th July 2020 in Figure 11 also gives the same conclusion of no significant improvement or deterioration in rainfall forecast due to the changes made in the NCUM system in this up gradation (DA improvements).

5.2. Impact of observations

The assessment of observation contribution to the analysis and forecast is one of the most challenging diagnostics in data assimilation and NWP (Cardinali, 2009). Observing System Experiments (OSEs) is the traditional tool for estimating data impact in an NWP system (Bauer, 2009). NCMRWF started using the new adjoint-based technique, known as Forecast Sensitivity to Observation Impact (FSOI), to estimate the observation impact on the forecast (24 hr forecast) in the last few years (Kumar et al., 2018). The advantage of FSOI is that it measures the impact of observations on the forecast when the entire observation dataset is present in the assimilation system, while the observing system in the OSE gets modified. The operational FSOI system is also improved to include more observation types/subtype (all new observations like AEOLUS HLOS) along with this DA up-gradation in NCUM:G-V7. The FSOI statistics for the one-month period (June, 2020 for Control and June, 2021 for Experiment) is presented in Figure 12.The major conclusion from the FSOI study is listed below:

- An increase is observed in ATOVS impact in the experimental forecast. This may be attributed to the use of all-sky MHS (ATOVS) observations in the new system.
- Slight decrease in IASI impacts is noticed in experiment forecast despite considerable increase in assimilated observations counts (These results need a large dataset to make a reliable conclusion.)
- A large positive impact is seen in the experimental forecast due to the use of AEOLUS HLOS wind profiles observations (both Rayleigh and Mie types) and is comparable with other wind observations. The height-wise impact of both Rayleigh and Mie wind is presented in Figure 13.Rayleigh wind impact is higher than Mie wind observations, primarily due to more number of observations available for assimilation after quality control. Also, the vertical extent of the availability of Rayleigh wind observation is more than that of Mie observation, which is due to retrieval methodology (i.e. Rayleigh and Mie channels, represent molecular (clear air) and particulate (aerosol and clouds) backscatter, respectively)
- Many newly added observations also show beneficial impact on the forecast in the experimental forecast (Figure 12).

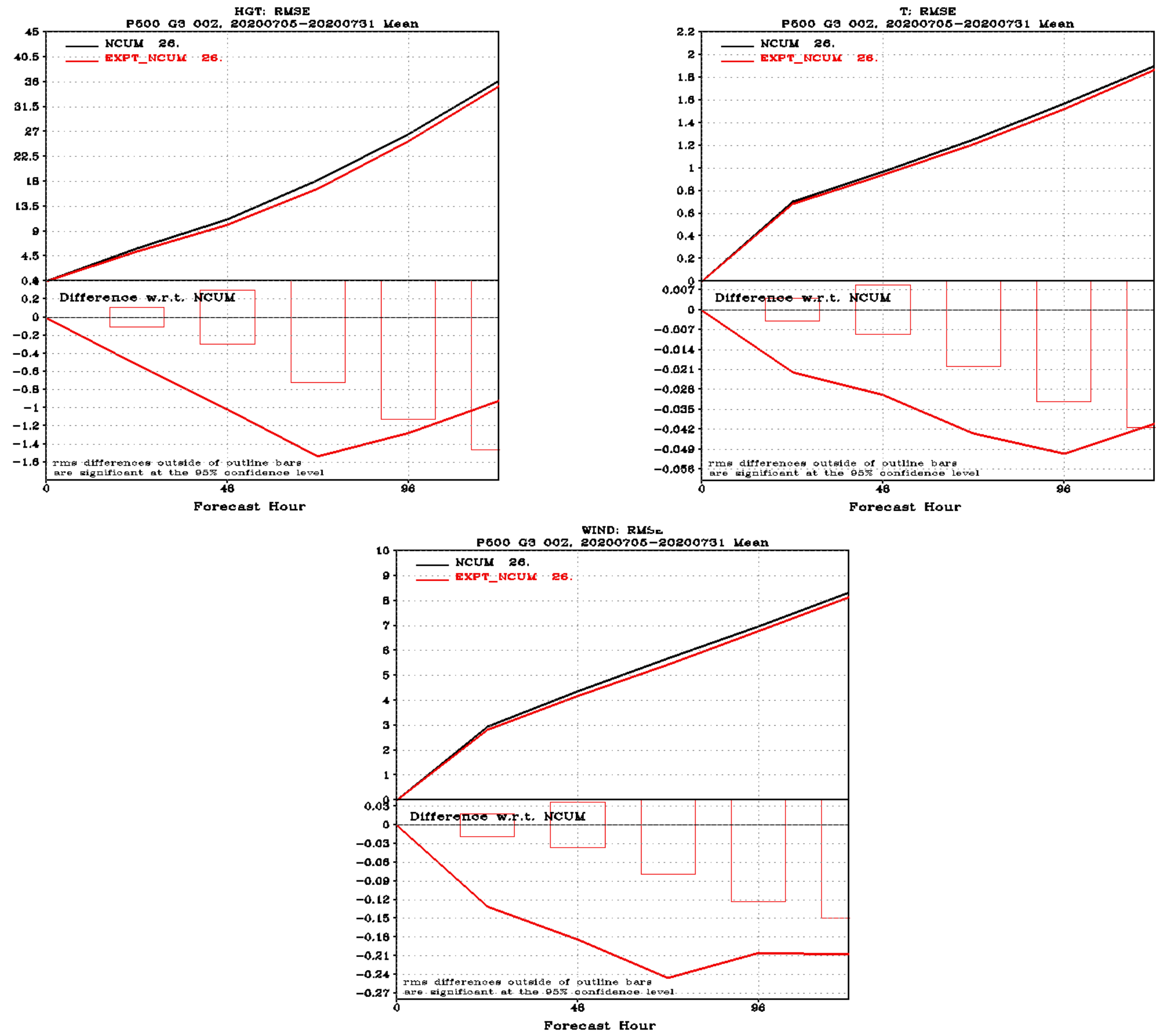

Figure 2:500-hPa level global mean RMSE of Geopotential Height, Temperature and Wind forecast (up to day 5 forecasts) during 06 July– 31 July, 2020 for the control and experiment. The scores outside of the boxes in the bottom panel are statistically significant at the 95% confidence level.

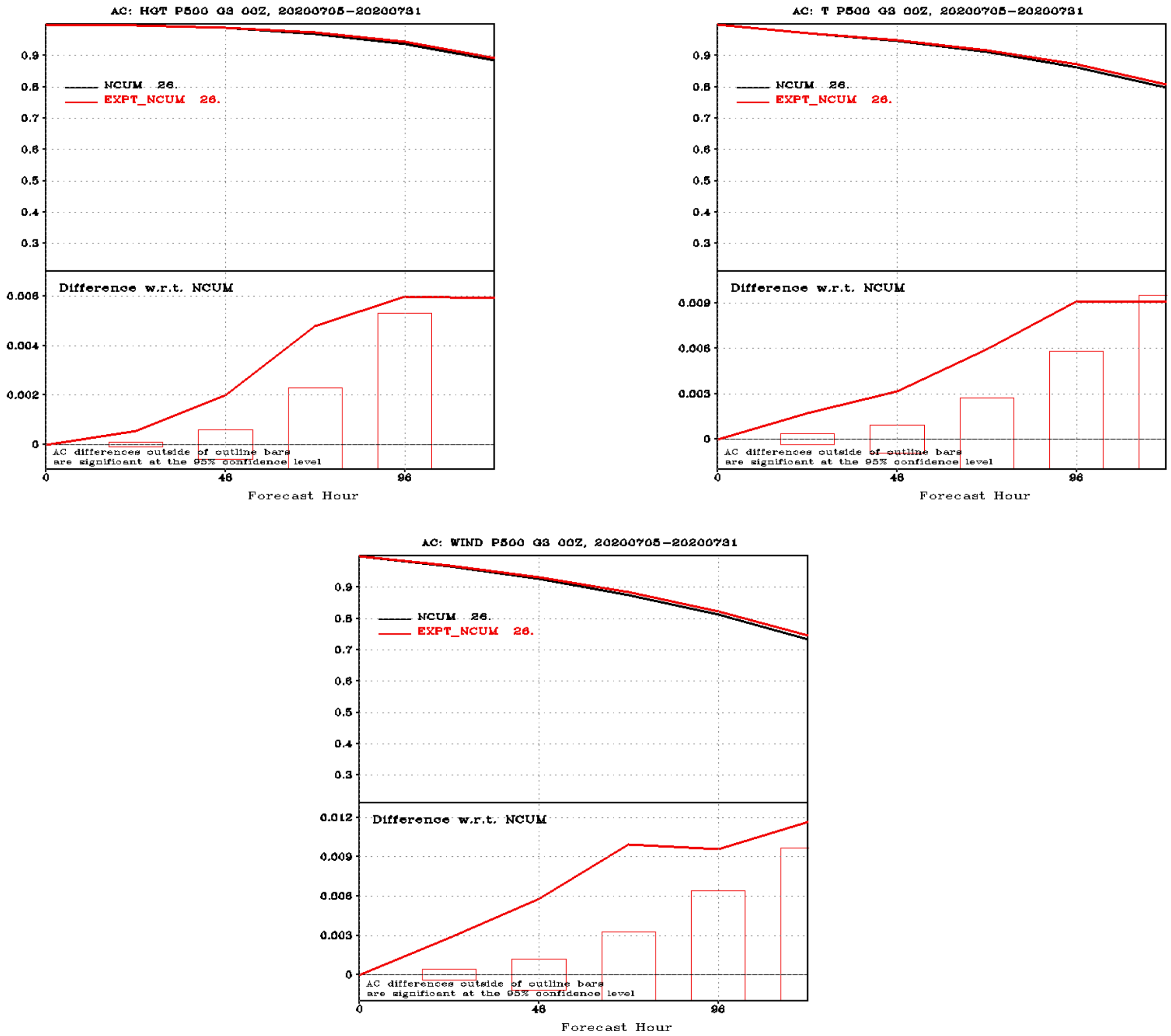

Figure 3:500-hPa level global mean Anomaly Correlation (AC) of Geopotential Height, Temperature and Wind forecast (up to 5 day forecasts) during 06 July– 31 July, 2020 for the control and experiment. The scores outside of the boxes in the bottom panel are statistically significant at the 95% confidence level.

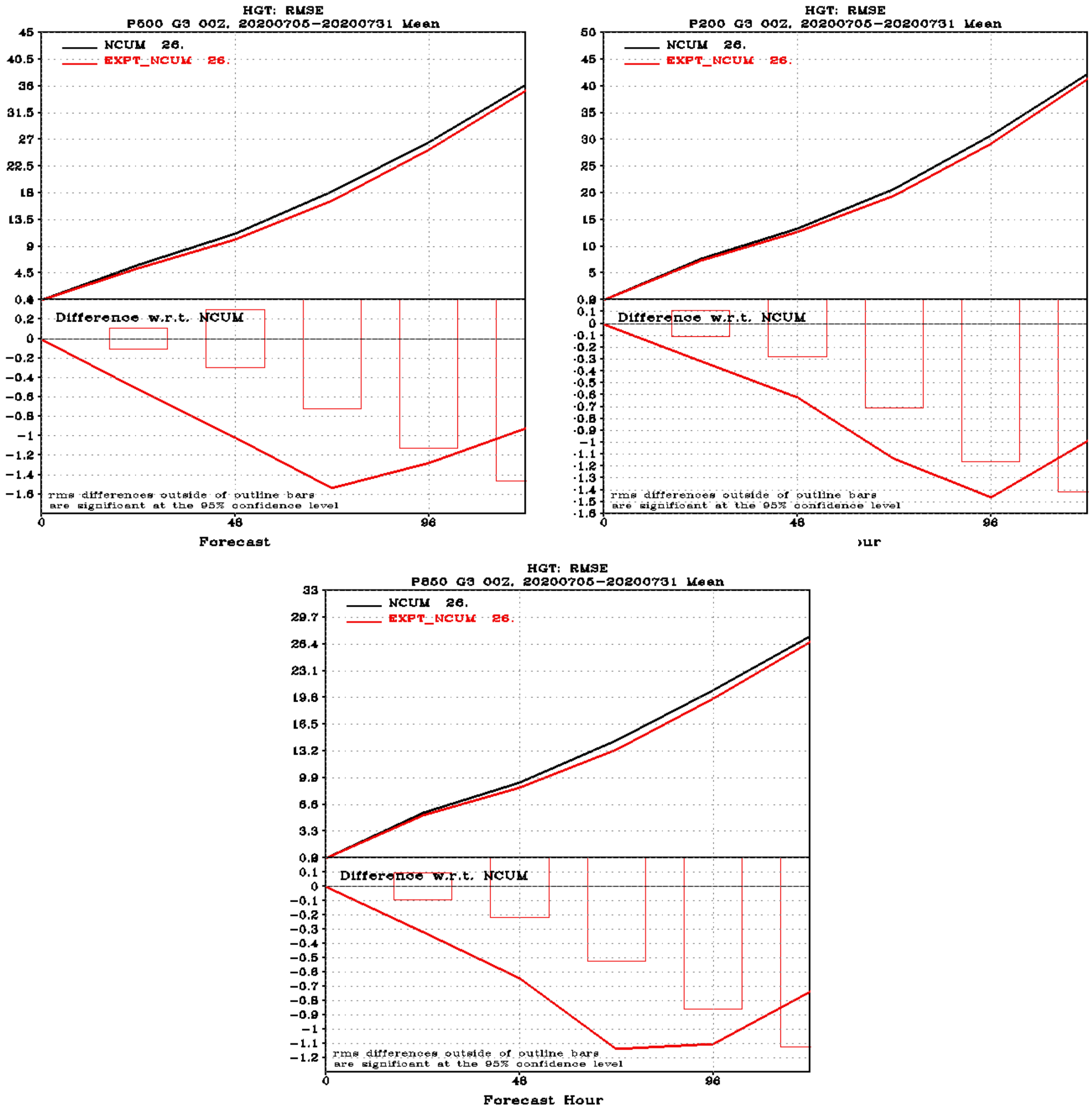

Figure 4:RMSE of Global mean Geopotential Height forecast (up to day 5 forecasts) at 200, 500 and 850 hPa pressure levels during 06 July– 31 July, for control and experiment.

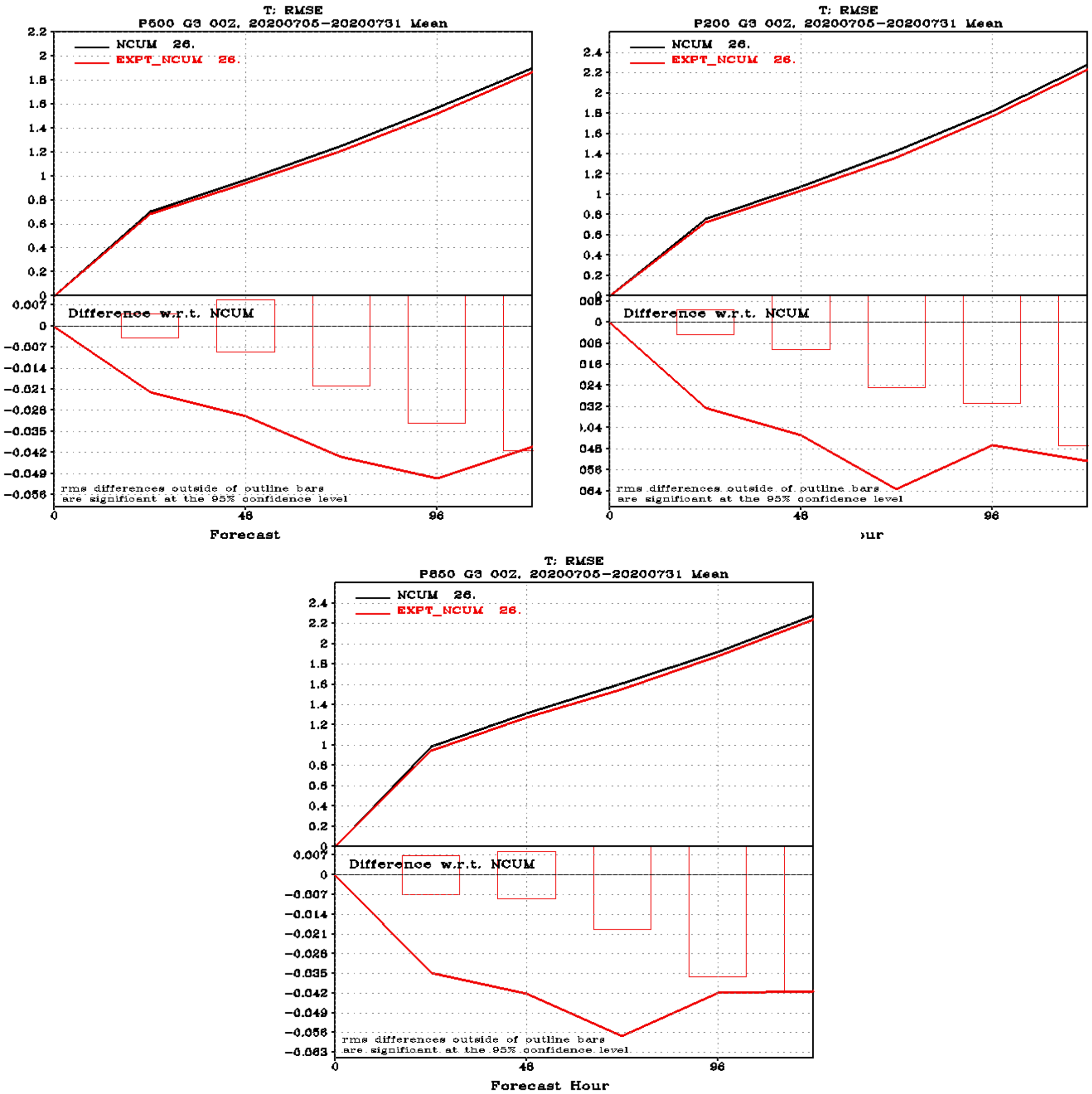

Figure 5: Same as Figure 4 but for Temperature.

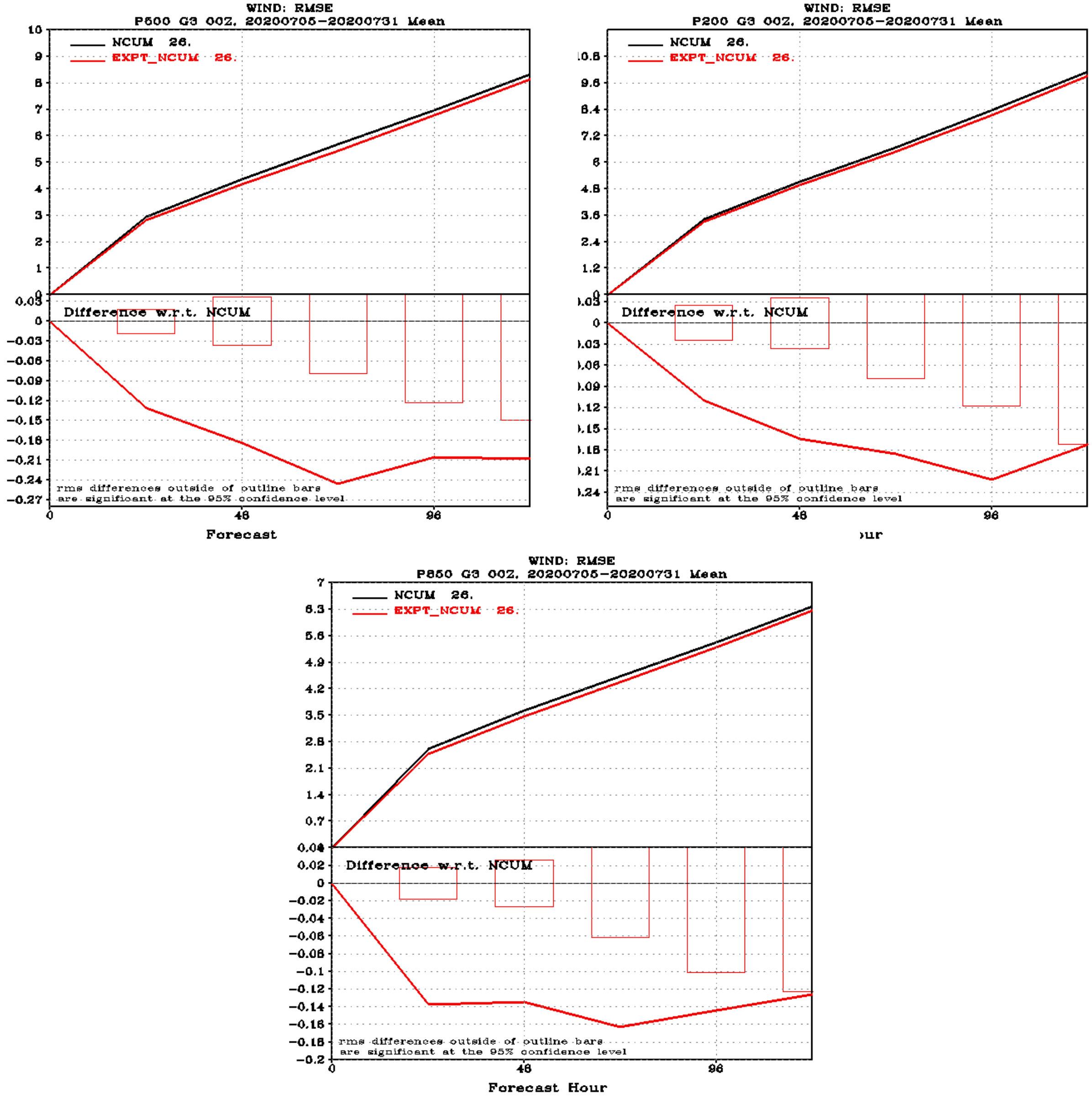

Figure 6: Same as Figure 4 but for Wind.

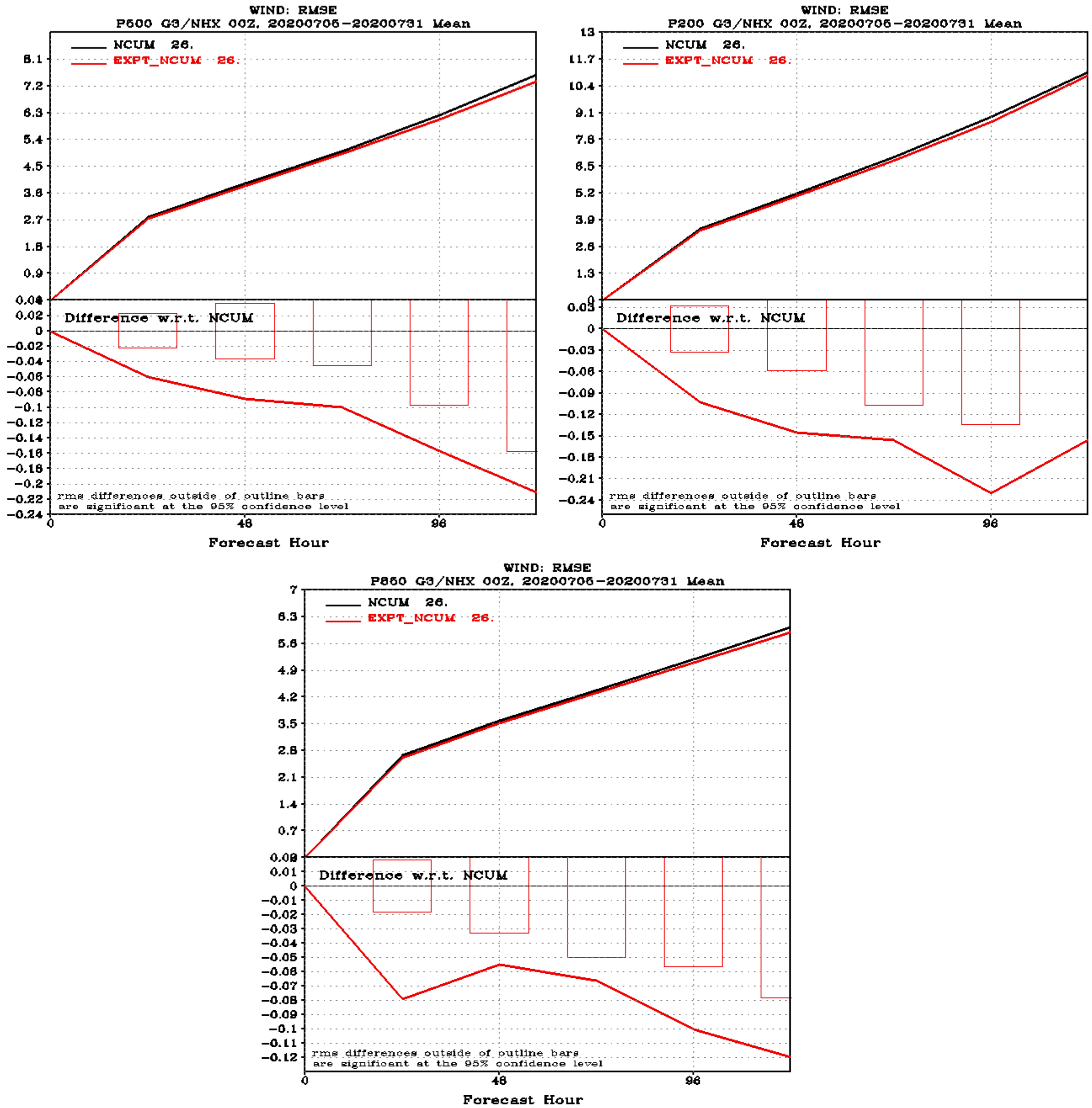

Figure 7:RMSE of Wind forecast (upto day 5 forecasts) over Northern Hemisphere at 200, 500 and 850 hPa pressure levels during 06 July– 31 July, for the control and experiment forecast.

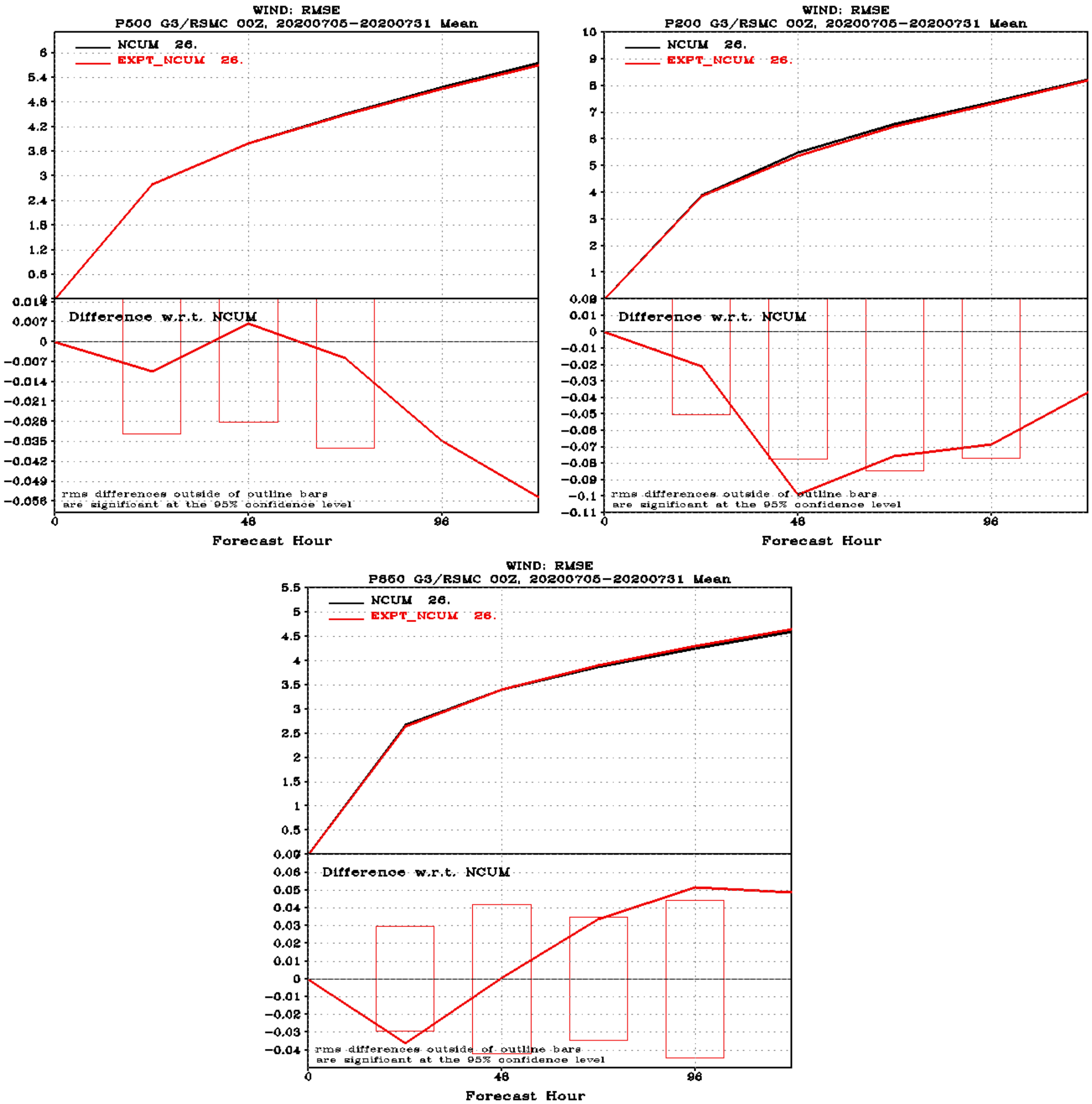

Figure 8:RMSE of Wind forecast (up to day 5 forecasts) over RSMC Region at 200, 500 and 850 hPa pressure levels during 06 July– 31 July, for the control and experiment forecast.

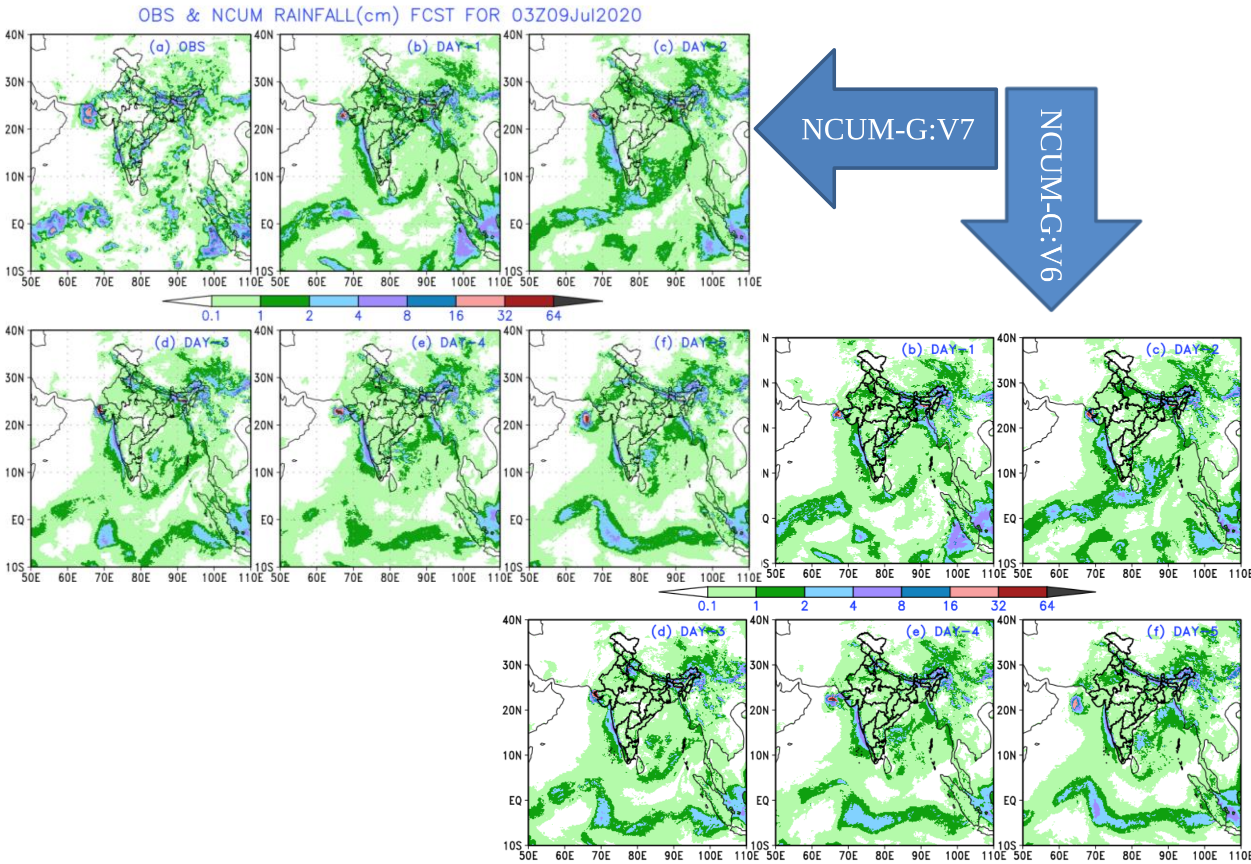

Figure 3: Day-1 to Day-5 Rainfall forecast (from control and experiment) and verifying rainfall analysis produced from observation (IMD-NCMRWF merged product labeled here as "Obs") over Indian region for d typical day

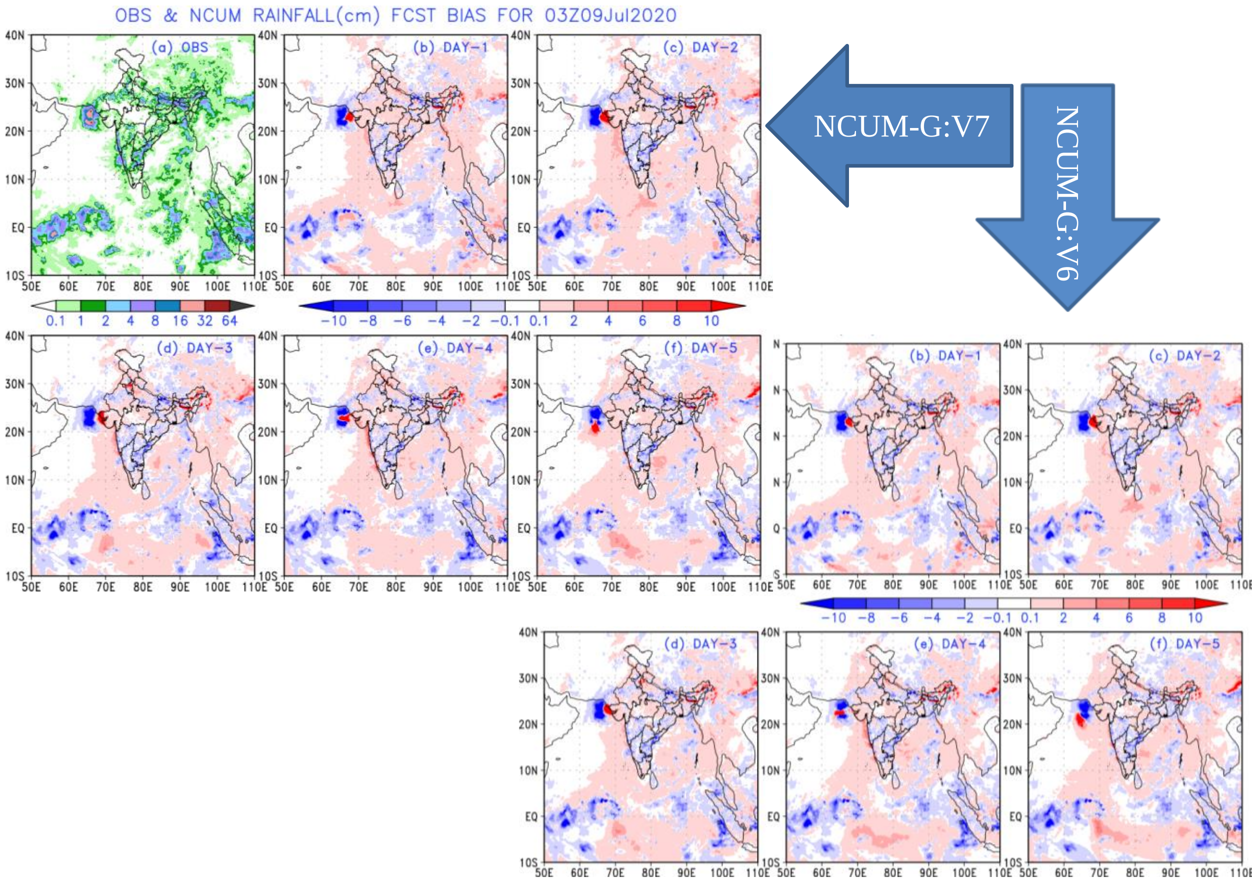

Figure 4: Day-1 to Day-5 forecast Bias (against IMD-NCMRWF rainfall analysis) of Rainfall (control and experiment) over Indian region on typical day (valid for 03Z09July2020)

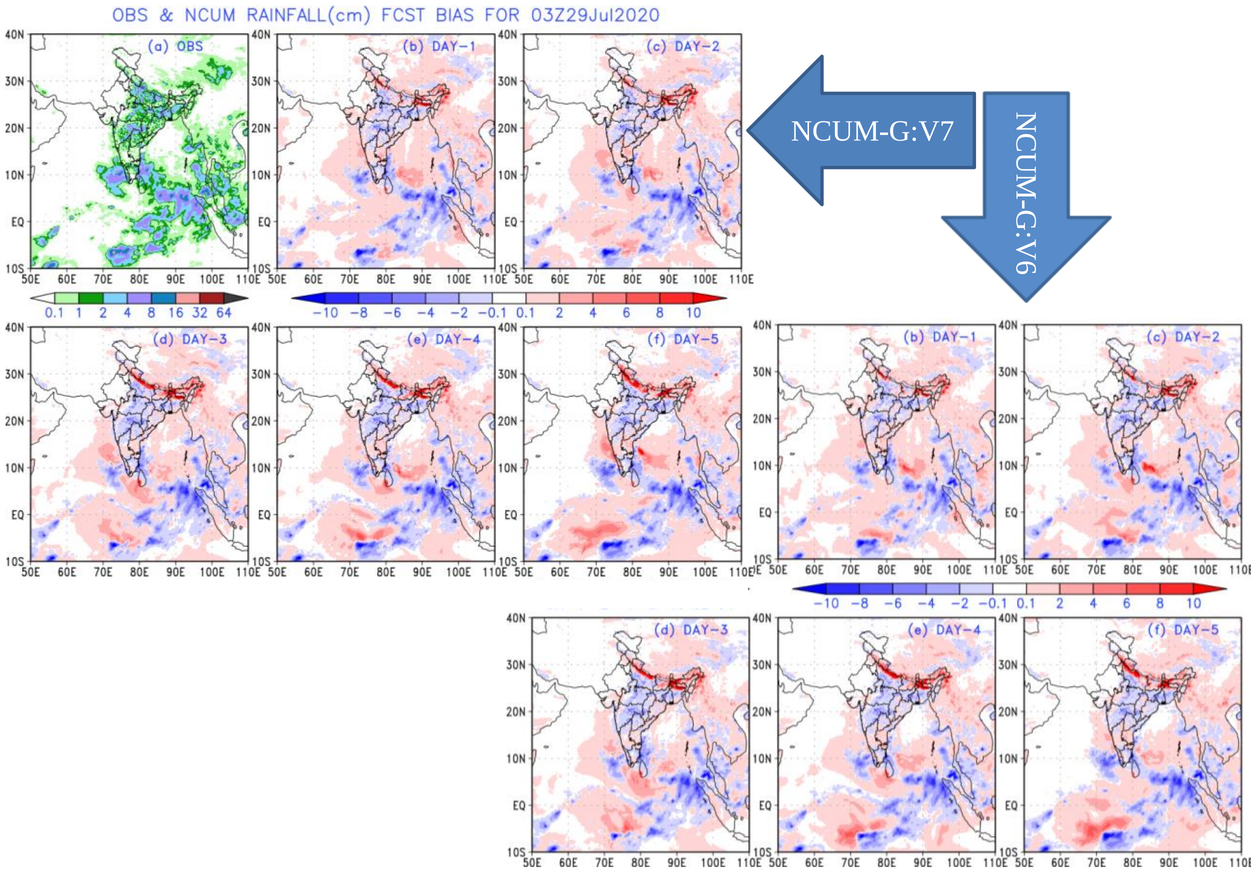

Figure 51: Day-1 to Day-5 forecast Bias (against IMD-NCMRWF rainfall analysis) of Rainfall (control and experiment) over Indian region on another day (valid for 03Z29July2020)

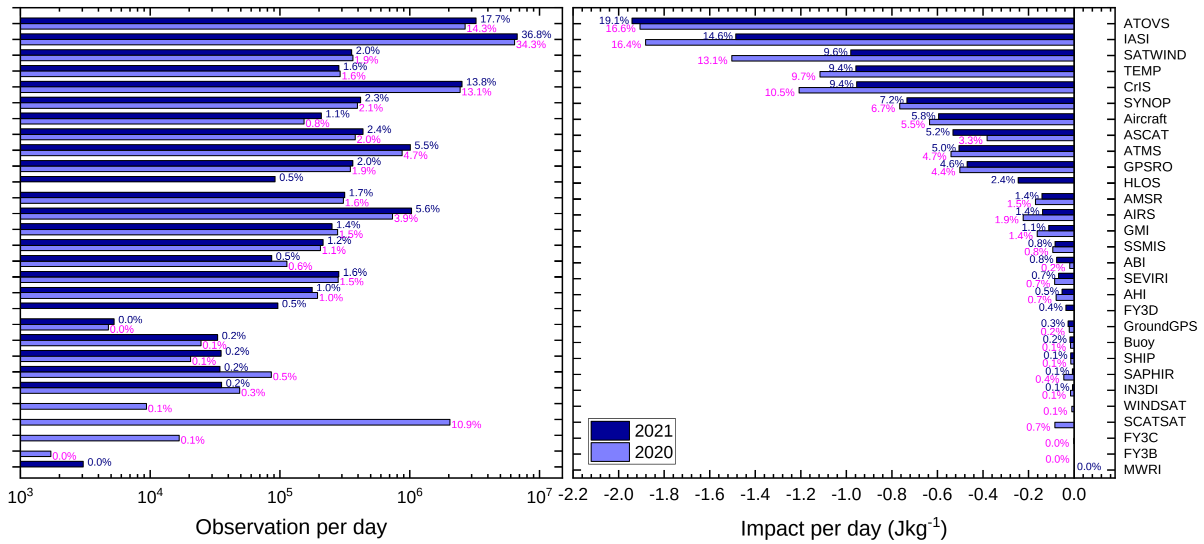

Figure 6: Number of assimilated observation per day and its impact on the 24 hr operational NCUM forecast during June, 2020 and 2021. 2020 forecast is generated using NCUM-G:V6 system and 2021 forecast is generated using NCUM-G:V7 system.

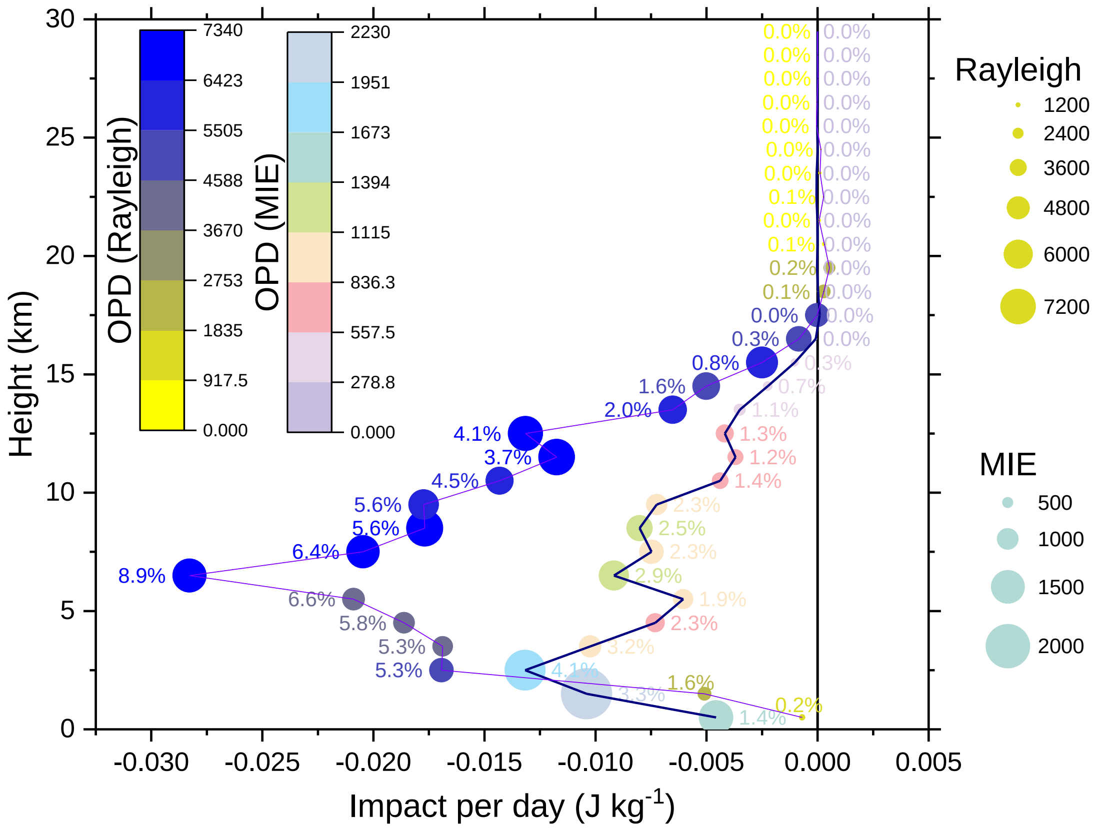

Figure 7: Vertical profile of the 24hr forecast impact of Aeolus HLOS wind observations (Rayleigh and Mie) during July 2020

Summary & Conclusion

NCUM global NWP system has been updated with the latest version of UM DA system and made it operational after extensive comparison and verification studies. The major highlight of the new DA system is the capability to assimilate cloud-affected microwave humidity sounder observations from MHS (ATOVS), novel horizontal line of sight (HLOS) observations from the Aeolus satellite etc. The in-house developed Observation Pre-processing System (OPpS) has been improved to process all new types of observations. The latest upgrade of the NCUM system with enhanced DA, OPS, and OPpS and the existing (old) Unified Model (UM 11.2) is named NCUM Global Version 7 (NCUM-G:V7) for easy reference. The new system has been made operational in place of NCUM-G:V6 system in June, 2021.

Results of the one month comparison (July, 2020) of analysis and forecast of the new system (NCUM-G:V7) with the previous operational system (NCUM-G:V6) is also presented in this report. The analysis and forecast comparison clearly shows that the medium-range forecast with the new NCUM NWP system (NCUM-G:V7) is improved, both globally and regionally (Indian region). The Forecast Sensitivity to Observation Impact (FSOI) system has been improved and made operational with the new NCUM-G:V7 system. Some of the major conclusions drawn from the comparison and FSOI results (experiment and control forecast) are listed below:

- Assimilation of new and novel observations and improvement in quality control have resulted in an overall decrease of global and regional forecast RMSE of geopotential height, temperature and wind at various levels in the new NCUM system (NCUM-G:V7). The Anomaly correlation also shows a similar improvement in the new system, both globally and regionally.
- A good increase is noticed in various types of satellite data assimilated in the new NCUM compared to the old NCUM system.
- Aeolus HLOS wind profiles (both Rayleigh and Mie winds) assimilation in NCUM show that this data set has beneficial impact on the forecast.
- AMV datasets with improved quality control have become more beneficial to improve forecast skill in the new NCUM system.

- Rainfall forecast doesn't show any appreciable changes due to up gradation although spatial distribution/ spread over the oceanic region, in general, is narrower in the new NCUM forecast.

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