Quality and impact of GPSRO observations from Megha-Tropique satellite on NGFS model

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Megha-Tropique satellite mission launched in 2011 was aimed at providing more observations in the tropical region. In the initial phase of the mission, it was found that the quality of global positioning system radio occultation (GPSRO) observations was not satisfactory. The Indian Space Research Organisation (ISRO) took remedial measures in this regard by modifying the data processing algorithm and releasing the new version of data. In 2012, an observing system simulation experiment (OSSE) was done at National Centre for Medium Range Weather Forecasting (NCMRWF) using simulated data at Megha-Tropiques ROSA observation location with Global Forecast System (GFS) based model. As an extension of the previous study, the quality of new version of GPSRO bending angle observations and impact of assimilation of these observations in NCMRWF GFS (NGFS) model were studied. It was found that with the use of a new data processing algorithm, quality of bending angle observations improved and comparable with other GPSRO missions in the pressure range between 500 hpa and 200 hpa. Impact study shows that the new observations improved forecasts in the middle and upper levels in the tropics.

Keywords: Assimilation, bending angle, GPSRO, Megha-Tropiques, NGFS.

THE global positioning system radio occultation (GPSRO) is a limb sounding technique in which the signal emitted by GPS is tracked by a receiver on a low earth orbit satellite. Occultation event occurs when LEO satellite rises or sets behind the earth. GPSRO observations provide atmospheric information on temperature and humidity at good vertical resolution and in all weather conditions. There are numerous studies which envisaged the quality and applications of these observations in various weather and climate studies[1–8]. A major impact of GPSRO observations was seen in upper-tropospheric and stratospheric temperatures[9]. At present GPSRO observations are available from different platforms like COSMIC, METOP/GRAS, GRACE, SAC-D, C/NOFS and TerraSAR-X. As the COSMIC-1 mission is ageing, it provides fewer observations than its peak performance period.

GPSRO observations are routinely assimilated in all major operational numerical weather prediction (NWP) centres. European Centre for Medium Range Weather Forecasting (ECMWF) employs 2D operators for GPSRO observations while all other centres use 1D operators for GPSRO observations. Assimilation of radio occultation (RO) observations in NWP models produced positive impacts on global and regional scale predictions[10–14]. Unlike other satellite observations, GPSRO observations do not require bias correction and can be used for anchoring bias correction applied to satellite radiances[15]. GPSRO and conventional observations have the largest impact per observation basis in global NWP and GPSRO has the largest mean impact on global NWP analysis[16]. With the present set of GPSRO observations there is no saturation impact and error reduces with more number of observations. In NCEP, operational assimilation of GPSRO observations in GFS model started in 2007 with refractivity data from COSMIC[17]. In 2012 operational GPSRO assimilation algorithm was modified with the use of bending angle operator and new quality control procedures. Impact studies showed that both the changes improved forecast over existing model configuration. In NGFS model, assimilation of GPSRO observations started in 2010 with refractivity observations and upgraded to bending angle observations in 2014.

Megha-Tropiques, an Indo-French mission launched in 2011, is intended to provide frequent observations over tropical regions due to its low satellite orbit inclination. Inter-comparison studies done in the initial phase of the mission showed that GPSRO observations derived from Megha-Tropique satellite were not of adequate quality to be used in NWP models[18]. The study also showed improvement in forecast on using model simulated refractivity observations at positions of Megha-Tropiques observations. Corrective measures were taken in the new data processing algorithm by ISRO to make a new product. In this study we investigate the characteristics of the new derived product of GPSRO observations from Megha-Tropiques satellite. As a continuation of the previous observing system simulation experiment[18], assimilation impact was studied using real observations obtained using new data processing algorithm. Quality of these observations was studied using bending angle, as it is of much less refined product than refractivity. Refractivity computation from bending angle requires certain climatology details and under super refraction conditions, refractive computations show negative bias[19]. Again the bending angle measurement errors are vertically less correlated than errors in refractivity profile as Abel transform is not involved[20]. Impact of assimilation of these observations in NWP model was studied using NGFS model during May 2015.

The quality of Megha-Tropique GPSRO bending angle observations was studied by comparing observations with bending angle simulated from NGFS model background. Secondly, the impact of these observations on model forecasts was studied by assimilating observations in the

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NGFS model. This was done by performing two numerical experiments, one with the inclusion of Megha-Tropique observations (Megha-Tropiques) and the other without Megha-Tropique observations (NGFS). NWP model NGFS used in the study is a three-dimensional hydrostatic global spectral model adopted from NCEP GFS and runs operationally at the centre near real time. The model uses grid point statistical (GSI) analysis system and in this study we employed 3D Var assimilation technique. The details of the model setup in the centre and the working procedure can be seen in Prasad *et al.*[21]. In the numerical experiments, model version GFS 3.1 and GSI 3.3 (ref. 22) were used. Although the model was capable of using hybrid assimilation technique, we employed 3D Var considering computational requirements. Numerical experiments were not performed in real time and were done at a horizontal resolution of T-574 with 64 vertical layers. Megha-Tropiques GPSRO observations within the altitude range 1.5–23 km were only included in the assimilation system. Assimilation was done 4 times a day corresponding to 00, 06, 12 and 18 UTC and forecast was done at 00 UTC only with the forecast integration

Table 1. Incremental bending angle (observation-back ground/observation; in %)

Pressure (hpa)	COSMIC and METOP	Megha-Tropiques
700–850	3.02	10.39
550–700	1.43	2.64
500–550	0.71	1.13
400–500	0.38	0.44
350–400	0.19	0.21
300–350	0.15	0.20
100–300	0.13	0.28
50–100	0.24	0.34
10–50	0.13	0.16

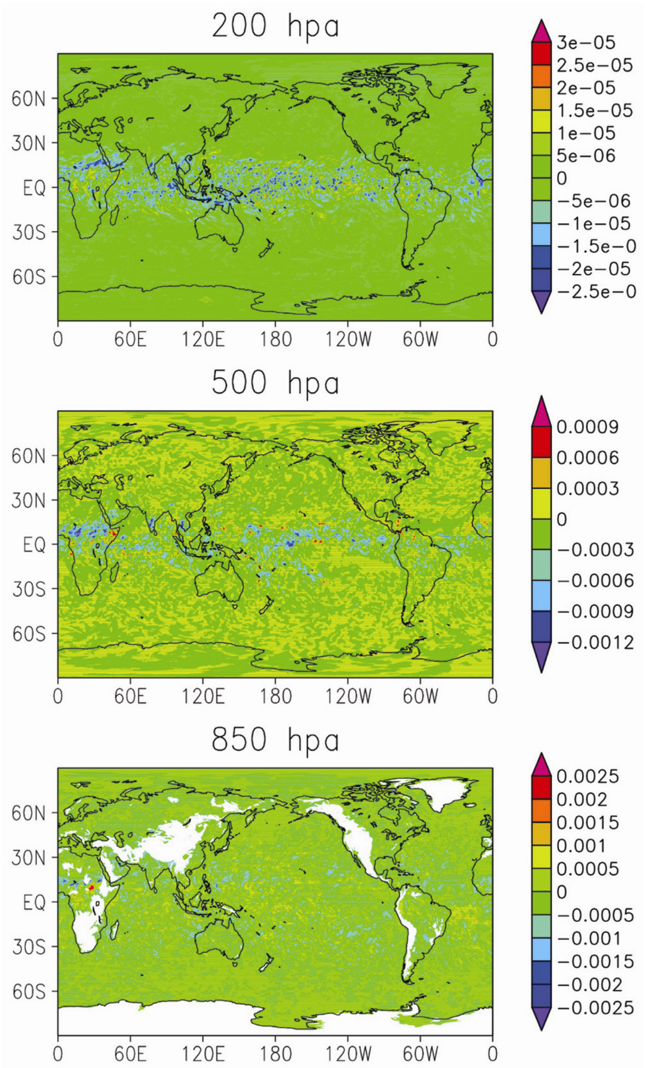

Figure 1. Mean difference (Megha-Tropiques–NGFS) in specific humidity (g/kg) between model analyses of the numerical experiments.

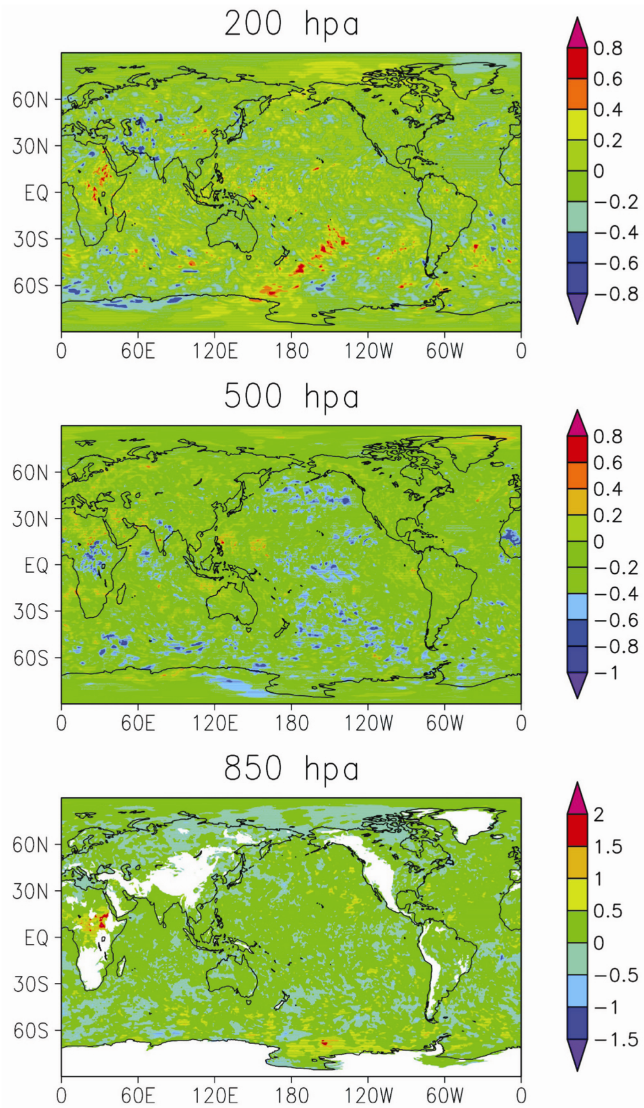

Figure 2. Mean difference (Megha-Tropiques–NGFS) in temperature (K) between model analyses of the numerical experiments.

time of 5 days. Conventional and satellite observations including satellite radiances were used in the assimilation system. In addition to other GPSRO observations, Megha-Tropiques mission provided ~250 profiles per day.

A comparison during the initial phase of the mission showed that Megha-Tropiques GPSRO refractivity observations were not of comparable quality with other GPSRO missions like COSMIC[18]. In order to address this issue ISRO modified the data processing algorithms and produced new set of observations. In this study, the quality of new GPSRO bending angle observations was verified against NGFS model background. Comparison was performed for 12 days from 1 to 12 May 2015 and bending angle observations below 23 km only was used for comparison. Table 1 shows incremental bending angle (in %) of Megha-Tropiques and other GPSRO missions with the model background. It is seen that except in the pressure range 500–850 hpa, Megha-Tropiques bending angle observations were comparable with other GPSRO missions like COSMIC and METOP. Widely accepted observation error characteristic of GPSRO observations in

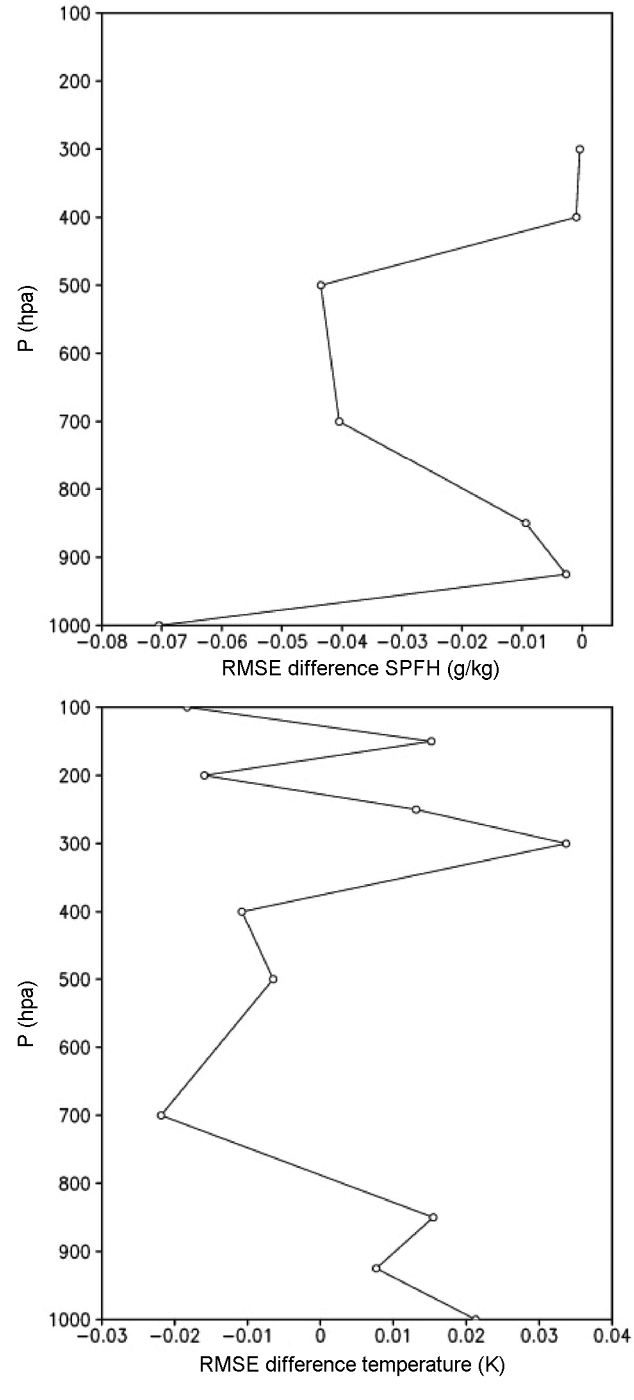

Figure 3. RMSE difference (Megha-Tropiques–NGFS) in analysis specific humidity (g/kg) and temperature (K) against radiosonde observations.

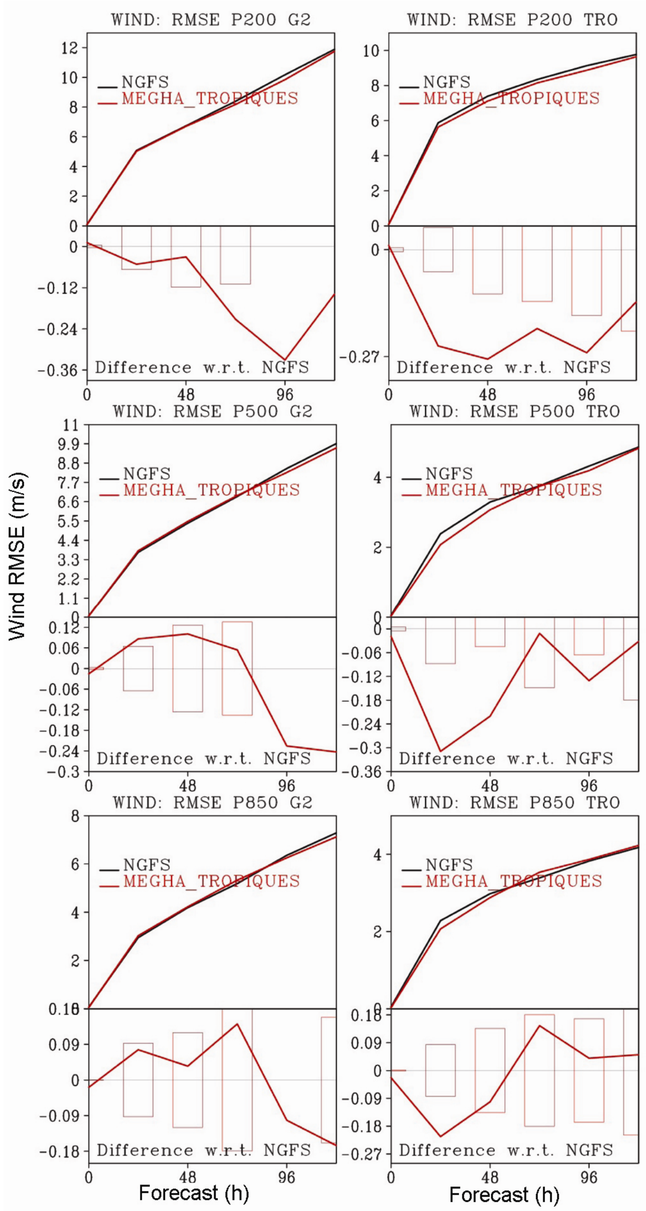

Figure 4. RMSE dieoff plots of wind (m/s) forecasts against respective analysis over the domains global (G2) and tropics (TRO).

NWP is such that it linearly varies from 20% at 0 km to 1% at 10 km and, above 10 km, 1% is considered.

Model initial conditions (analysis) in numerical experiments were compared to determine the influence of Megha-Tropiques GPSRO observations on temperature and specific humidity. Temperature and humidity were chosen for comparison as the variables directly benefited by assimilation of GPSRO observations. Figure 1 shows the mean difference in specific humidity analysis between numerical experiments at different pressure levels averaged over the entire study period. Figure 2 shows a similar plot for temperature. In the case of humidity, major difference between analyses occurred at locations of Megha-Tropiques observations at 500 and 200 hpa level. However, in 850 hpa the difference between models was much smaller. But in the case of temperature, the regions of large difference between analyses do not co-locate with Megha-Tropique observation locations. Analysis of temperature and specific humidity was compared against radiosonde observations used in the assimilation system. On considering the global domain, difference between the numerical experiments was very small. Figure 3 shows the RMSE difference between numerical experiments (Megha-Tropiques-NGFS) in analysis specific humidity and temperature, in tropics computed against radiosonde observations. In tropics RMSE computations showed that specific humidity analysis from Megha-Tropiques experiment was closer to observations at all vertical levels, while in the case of temperature results were not definite.

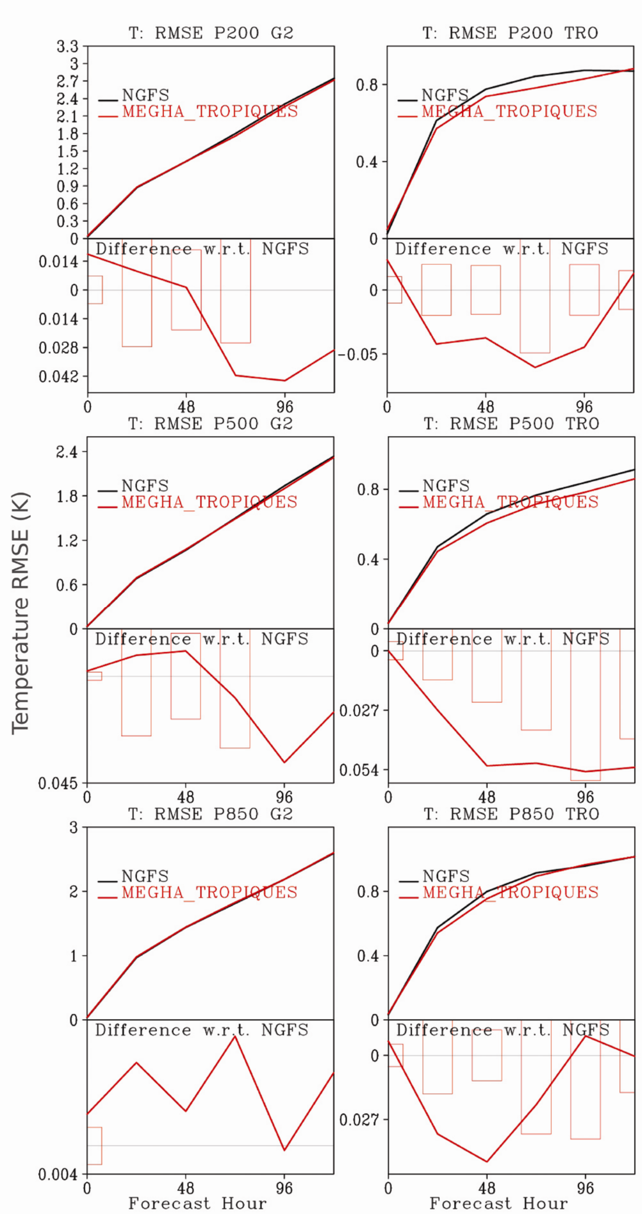

Figure 5. RMSE dieoff plots of temperature (K) forecasts against respective analysis over the domains global (G2) and tropics (TRO).

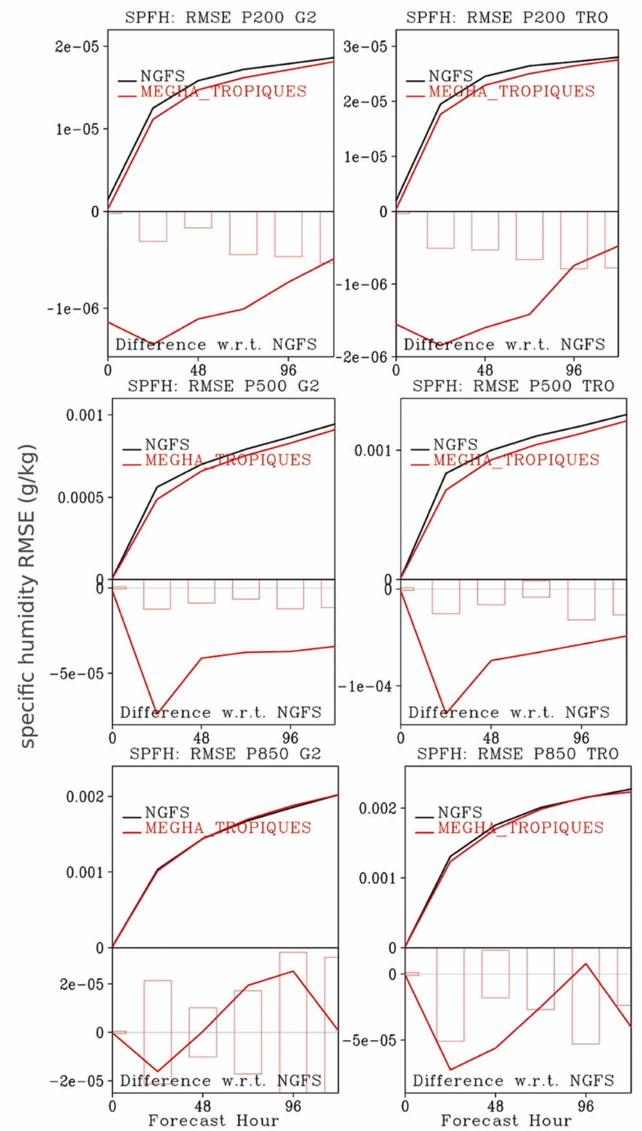

Figure 6. RMSE dieoff plots of specific humidity (g/kg) forecasts against respective analysis over the domains global (G2) and tropics (TRO).

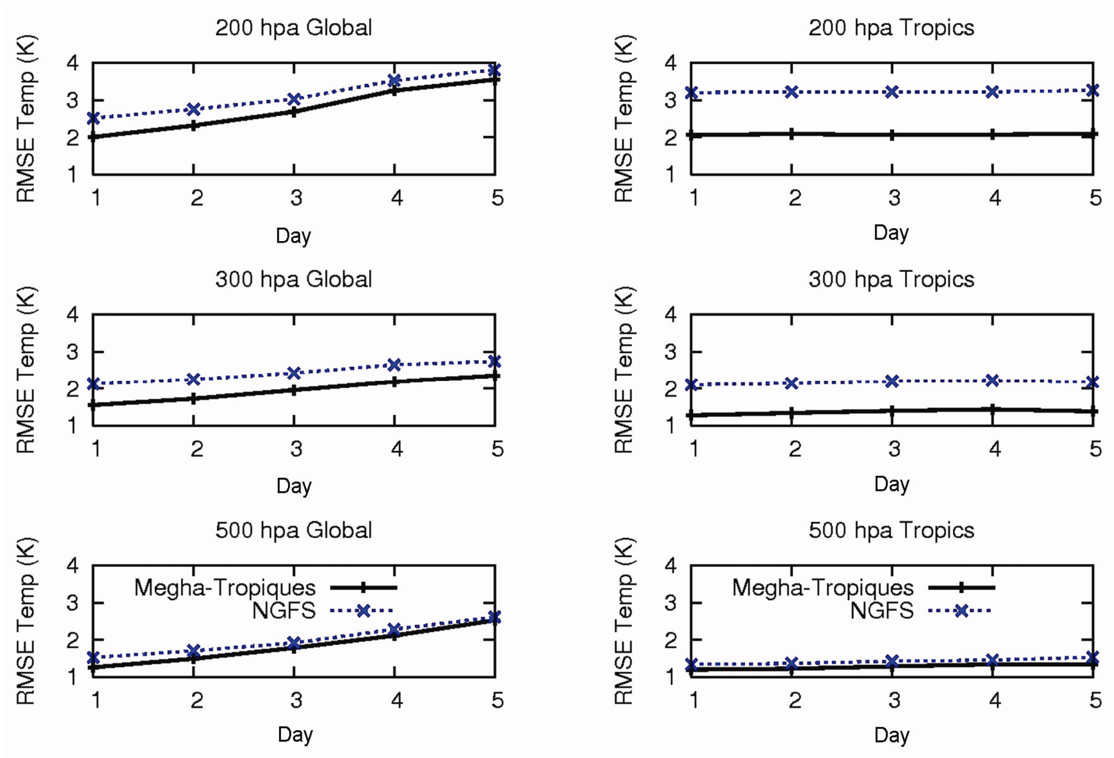

Figure 7. RMSE in temperature (K) forecasts against radiosonde observations in global and tropics.

Model forecasts of wind, temperature and specific humidity were verified against the respective analysis. Figure 4 shows RMSE plots of wind forecasts against respective analysis over the domains global and tropics. Significant improvement in forecasts was seen at 500 and 200 hpa pressure levels in all the forecasts in tropics. A similar plot for temperature is shown in Figure 5. Here also significant improvement with GPSRO observations was seen at 500 and 200 hpa pressure levels in all the forecasts in tropics. Comparison of specific humidity forecasts with analysis is shown in Figure 6. Significant improvement with inclusion of GPSRO observations was seen in 500 and 200 hpa pressure levels in both the regions. But in the case of specific humidity at 200 hpa level, improvements were small in the day 4 and day 5 forecasts. Forecasts were verified against radiosonde observations used in the assimilation system. Figure 7 shows RMSE in temperature forecasts computed against radiosonde observations in global and tropics at the middle and upper levels. It is seen that the temperature forecast shows large improvement at 200 hpa with new observations in both global and tropics.

This study is an extension of a previous OSSE experiment[18] using real observations obtained with modified data processing algorithm. The quality of GPSRO observations from Megha-Tropiques mission with the new data processing algorithm was found to be comparable with other GPSRO missions in the pressure range 500 hpa–200 hpa. The impact study shows an improvement in forecast with the new data set in middle and upper troposphere. Results were in concurrence as Megha-Tropiques observations in the assimilation system do not contain data in lower levels. The impact of new observations on model analysis was mainly seen in tropics and on specific humidity than other variables.

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Comparative analysis of grain quality and nutraceutical properties of selected rice varieties from Kerala

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Kerala, the land of rich biodiversity, is a treasure of land races of many crops. The speciality rice varieties of Kerala include Pokkali (organic rice), Jeerakasala and Gandhakasala (scented rice varieties), Black Njavara and Golden Njavara (medicinal rice varieties). A study on the nutraceutical properties of these speciality rice varieties was made to understand their health benefits. Oil content in the rice bran and antioxidants like oryzanol, tocopherol and tocotrienol in the rice bran oil (RBO) of these rice varieties were estimated and compared apart from the quality and nutritional analysis of both rice and bran. The study revealed that the bran is rich in RBO and antioxidants like oryzanol, tocopherol and tocotrienol which may contribute to its high therapeutic value. The study recommends minimum polishing of these rice varieties during milling for consumption purpose. As the bran is rich in fibre and micronutrients like Fe, Cu, B and S, it should be utilized for the preparation of value-added products like biscuits, baby foods, breads, etc. for healthy human consumption. The study envisages an urgent need for the utilization of the huge quantity of rice bran oil and as component of other food products.

Keywords: Antioxidants, grain quality, nutraceutical property, rice varieties.

RICE is the most important tropical cereal and staple food of about half the human population in the world. Starch constitutes the bulk of rice grain and it contains amylose and amylopectin. The human body can digest and absorb the carbohydrates in rice relatively quickly. The protein content of rice is lower than that of wheat, but is of superior quality and utilized better by the body than wheat protein. It contains all the eight essential amino acids in delicately balanced proportion[1].

Rice bran, the brown outer layer of the rice kernel is mainly composed of pericarp, aleurone/sub-aleurone layers and germ. Currently, it is discarded as waste product during the process of rice milling in this part of the world[2]. Godber *et al.*[3] have shown that rice bran and rice bran oil (RBO) have potential health benefits in the prevention of diseases such as cancer, kidney stones, heart diseases and hyperlipidaemia. This is attributed to the

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