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INSAT-3D vertical profile retrievals at IMDPS, New Delhi : A preliminary evaluation

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सार – दिनांक 26 जुलाई, 2013 को विकसित मौसम विज्ञानिक पेलोड (Payloads) वाले स्वदेशी भूस्थैतिक उपग्रह इंसैट-3 डी के सफलतापूर्वक प्रक्षेपित किए जाने से भारतीय मौसम विज्ञानियों को नया अवसर मिला है। वायुमंडल के तापमान और आर्द्रता की ऊर्ध्वाधर प्रोफाइलें प्राप्त करने के लिए भारतीय उपग्रह में पहली बार एक नया पेलोड (Payloads), वायुमंडलीय ध्वनित्र (Sounder) लगाया गया है। इससे 30 × 30 कि. मी. के स्थानिक विस्तार और एक घंटे के कालिक विस्तार में ऊपरी स्तर के तापमान और नमी का लगातार प्रोफाइल्स प्राप्त करना और एक घंटे का कालिक विभेदन प्राप्त करना संभव हुआ है। इंसैट-3 डी से तापमान और नमी के आँकड़ों की पुन: प्राप्ति/इंसैट मौसम विज्ञान डेटा संसाधन प्रणाली (IMDPS) नई दिल्ली में संस्थापित ध्वनित्र डेटा संसाधन एल्गोरिथ्म के नेमी प्रयोग से प्राप्त किया गया है। इसकी तुलना उस पर लगे जी पी एस सौंदे प्रेक्षणों (GPOB) से की गई है, तथा राष्ट्रीय महासागरीय वायुमंडलीय प्रशासन (NOAA) के ध्रुवीय कक्षा में घूमते उपग्रहों (एन-18 एवं एन-19) से संशोधित आँकड़ों को पुन: प्राप्त किया गया है। इंसैट-3 डी के तापमान प्रोफाइल्स धरातल से 30 हे. पा. पर GPOB के विपरीत धनात्मक प्रवृति को दर्शाते हैं। समग्र रूप से तापमान आँकड़ों की सभी प्राप्तियों के बीच अधिकतर सभी स्तरों में एक क्रमानुगत त्रुटि की प्रवृति पाई गई है। इस त्रुटि प्रवृति का विस्तार 1000 से 100 हे. पा. स्तरों के बीच 2 से 4° सेल्सियस तक होता है। जहाँ इंसैट-3 डी के मान अत्यधिक ऊष्ण होते हैं वहाँ अधिकतम धनात्मक प्रवृति का स्तर सतह के नजदीक और 100 हे.पा. होते हैं। उच्च स्तरों पर आम असहमति होने के कारण क्षोभमंडल के ह्रास दर में थोड़ा परिवर्तन का पता लगाने में पुन: प्राप्ति योजना (रिट्रीवल स्कीम) की अक्षमता का लक्षण माना जा सकता है। यद्यपि नमी के प्रोफाइल्स कुछ हद तक GPOB के विपरित अल्पतम स्टीकता को दर्शाते हैं। इंसैट-3 डी और GPOB से प्राप्त किए गए कुल वर्षणीय जल (TPW) की भी तुलना की गई है और इंसैट- 3 डी टी पी डब्ल्यू के सहसंबंध GPOB TPW से कुछ हद तक विशिष्ठ LI स्तर की तुलना में मेल खाते हैं।

ABSTRACT. Successful launch of indigenous geostationary satellite INSAT-3D on 26 July, 2013 with advanced meteorological payloads onboard, has provided a new opportunity to the Indian meteorologists. A new payload, atmospheric sounder, has been launched for the first time in Indian satellite to provide the vertical profiles of temperature and humidity in the atmosphere. It is possible to obtain continuous upper level temperature and moisture profiles with a spatial resolution of 30 × 30 km and temporal resolution of one hour. The INSAT-3D temperature and moisture retrievals derived from routine application of sounder data processing algorithm installed at INSAT Meteorological Data Processing System (IMDPS), New Delhi were compared with collocated GPS sonde observations (GPOB), and National Oceanic and Atmospheric Administration (NOAA) polar orbiting satellites (N-18 and N-19) derived profiles to assess retrieval performance. The INSAT-3D temperature profiles show the positive bias throughout from surface to 30 hPa against the GPOB. The overall temperature between retrivals exhibited a systematic bias error at almost all the levels. Bias ranges from 2 to 4 °C between 1000 to 100 hPa levels. The levels of maximum positive bias, where INSAT-3D values are too warm, are near the surface and 100 hPa. This can be attributed to the inability of the retrieval scheme to precisely locate the change in the lapse rate associated with the tropopause due to general disagreement at higher levels. However, the moisture profiles showed somewhat lower accuracy against the GPOB. INSAT-3D and GPOB derived Total Perceptible Water (TPW) were also compared and showed that correlation of INSAT-3D TPW agree well with GPOB TPW to some extent than the level specific LI.

Key words – INSAT-3D, Radiosonde, GPOB, Vertical profile.

1. Introduction

India launched an exclusive meteorological satellite named, INSAT-3D, on 26th July, 2013 with advanced payloads of much better capabilities as compared to the earlier satellites of INSAT series. The ‘Sounder’ payload of the satellite carries a newly developed 19 channel atmospheric sounder, which is the first such payload to be flown on an Indian satellite mission. For the first time frequent temperature and moisture profiles data and derived products from these data over the Indian and the adjoining oceanic region are now possible with the INSAT-3D satellite sounder. The Sounder has eighteen narrow spectral channels in shortwave infrared, middle infrared and long wave infrared regions and one channel in the visible region. The ground resolution at nadir is 10 × 10 km for all nineteen channels. Specifications of sounder channels are given in Table 1.

Sounding system of the satellite provides vertical profiles of temperature (40 levels from surface to ~ 70 km), humidity (21 levels from surface to ~ 15 km) and integrated ozone from surface to top of the atmosphere. INSAT-3D provides continuity to earlier missions and further augments the capability to provide various meteorological products of better quality as well as search and rescue services. Vertical profiles of temperature and moisture can be derived from radiances in 18 channels, which are called ‘retrieval’, using the first guess from NWP data. Because of its higher temporal as well as horizontal resolution, these retrievals provide the valuable information on vertical structure of the atmosphere at higher frequency and with higher coverage over land and oceanic region, which is currently missing from conventional ground based methods of observations. The sounder retrieval scheme at India Meteorological Department (IMD), New Delhi, is adapted from the operational High resolution Infrared Radiation Sounder (HIRS) processing scheme and Geostationary Operational Environmental Satellites (GOES) algorithms developed by Cooperative Institute for Meteorological Satellite Studies (CIMSS), University of Wisconsin, USA (Ma *et al*., 1999 and Li *et al*., 2000), in which physical and regression based retrievals are employed. Spectral bands in and around the CO_2 and H_2O absorbing bands are designed to yield information about the vertical structure of atmospheric temperature and moisture.

In general, physical and regression retrievals or both have been used to generate the retrievals from the sounder radiance channels. Over last 30 years or so lots of theoretical work has been done in USA for processing of sounder data obtained from earlier satellites of NOAA and GOES series. Lee *et al*. (1983) first used a statistical regression procedure that incorporated surface observations with Visible and Infrared Spin Scan Radiometer (VISSR) Atmospheric Sounder (VAS) radiances to determine temperature and moisture profiles. On the other hand, Smith *et al*. (1985) and Hayden (1988) described a simultaneous physical algorithm for obtaining operational retrievals from VAS radiances and a first-guess temperature - dewpoint profile. Several studies have evaluated VAS retrievals with radiosonde observations (Velden *et al*., 1984; Hayden, 1988). Fuelberg and Olson (1991) compared VAS retrievals against collocated NWS RAOBs. Comparison between VAS and RAOB temperature showed correlation greater than 0.95 at most pressure levels. Magnitude of mean error was less than 1.5 ºC and standard deviations were small around 1.4 ºC to 2.2 ºC, but moisture showed much less agreement and did not correlates well as standard deviations ranging from 2.5 ºC to 6.9 ºC and biases as great as -3 ºC.

TABLE 1

INSAT-3D Sounder channel specification

Channels	Spectral range microns	Resolution
VISIBLE(1)	0.67 – 0.72	10 × 10 kms
SWIR(6)	3.67 – 4.59	10 × 10 kms
MIR(5)	6.38 – 11.33	10 × 10 kms
LWIR(7)	11.66 – 14.85	10 × 10 kms

After the launch of new generation of GOES satellites from 1994, Hayden *et al*. (1996); Gray *et al*. (1996) and several other scientists have done lot of additional work on improving the quality of retrieval and its products from sounder data. Since 1994 the GOES Sounders (GOES-8/9/10/11/12/13) have been measuring radiances in 18 infrared (IR) spectral bands, ranging from approximately 3.7 to 14.7 µm, on an hourly basis over North America and adjacent oceanic regions (Menzel *et al*., 1998). Derived products generated operationally by NOAA/NESDIS, include clear-sky radiances, atmospheric temperature (T) and moisture (Q) profiles, TPW, cloud-top pressure, and water-vapor atmospheric motion vectors. The root mean error differences, with respect to radiosonde observations, GOES temperature retrievals were shown to be approximately 1 K from the surface to 200 hPa from 72 concurrent radiosonde observations (Timothy *et al*., 2002). Currently (Yong-Keun *et al*., 2014) at National Environmental Satellite, Data and Information Service (NESDIS, USA) operational GOES-13 temperature retrieval shows very small differences less than 0.1 K (standard deviation and mean bias) against either ARM (Atmospheric Radiation Measurement) RAOB or conventional RAOB. Whereas, the GOES-13 relative humidity standard deviation and bias is well below 15% and 18% between 300 hPa and the surface compared with the ARM RAOB and with the conventional RAOB respectively.

Main objective of this paper is to evaluate the quality of temperature and moisture retrievals of INSAT-3D for use by the forecasters or meteorological community as the same has not yet been reported in the literature so far. The current paper would be of interest to those who plan to use INSAT-3D retrievals in diagnostic studies or in NWP models because it provides a detailed evolution of operational INSAT-3D retrievals by comparing them against RAOBs and NOAA satellites retrievals. Other sections describe the quantitative analysis correlation, standard deviation and slope between INSAT-3D retrievals and GPOBs. Finally, INSAT-3D sounder derived parameters commonly used in delineating possible areas for development of convection, such as LI and TPW were assessed with GPOB and NOAA derived indices.

During last three decades, the use of satellite observations for meteorological applications has increased tremendously. However, the systematic errors and uncertainties inherent in the satellite measurements have also been of concern. These arguments can also be extended to some extent with global radiosonde observations. While comparing RAOB with satellite derived wind products, Tomassini *et al.* (1999) have reported that the radiosondes themselves are known to have wind errors ranging from roughly 2 m/s to 4 m/s. Similarly, the root-mean-square (RMS) errors as large as 0.8 °C and 20% have been reported for sonde-derived temperature and relative humidity, respectively by Pratt (1985). Apart from this, radiosonde data have various types of inherent errors and uncertainties. The meteorological agencies use radiosonde instruments of different makes and designs, and employ different ground computation procedures. This requires them to undertake rigorous inter-comparisons periodically so as to maintain compatibility amongst the instruments and uniformity in the global synoptic observations. In addition, the time lag between the temperature and humidity measurements and errors in pressure measurement add further to the overall errors and uncertainties (McMillin *et al.*, 1988).

Due to various factors, there can be some discrepancies between GPOBs and retrievals values at the same point-location in the atmosphere. These can be attributed to measurement techniques, sampling of the atmosphere by different ways and physical retrieval scheme at lower level atmosphere (Mitra *et al.*, 2010). In this regard, Fuelberg and Olson (1991) gave a more detailed discussion that measurement errors are caused by inherently different ways that satellites and RAOBs sample the atmosphere. Radiosondes are direct sensors, providing point-source measurements whereas satellites provide volume-averaged data, that is, each channel measures the brightness temperature within a layer and over a horizontal area (FOV) of the atmosphere. Alternative solution given by Menzel and Purdom (1994) that since radiances are averaged over an array of FOVs to reduce random error, this "smoothing" can increase the difference between the retrieval and RAOB at a specific point. The cloud clearing procedure used to remove cloud-contaminated radiance data also is a possible source of error, as are the algorithm's various physical and numerical approximations (Hayden 1988, Li *et al.* 2008).

TABLE 2

GPS radiosonde stations of IMD in 2014

S. No.	Stations
1.	Portblair
2.	Goa
3.	Minicoy
4.	Thiruvananthapuram
5.	Hyderabad
6.	Vishakhapatnam
7.	Mohanbari
8.	Patna
9.	Srinagar
10.	Chennai

2. Data and methodology

INSAT-3D retrieval algorithm at IMDPS, New Delhi, is designed for retrieving vertical profiles of atmospheric temperature and moisture in the atmosphere from clear sky infrared radiances in different absorption bands observed through the various sounder channels on an hourly time scale. The algorithm includes generation of the hybrid first guess atmospheric profiles using a linear combination of regression retrieval and NWP model forecast. This is followed by a non-linear physical retrieval procedure (Li *et al.*, 2000; Ma *et al.*, 1999) to make the first guess consistent with the Sounder observations. The pressure layer fast algorithm for atmospheric transmittances (PFAAST) radiative transfer model (Hanon *et al.*, 1996) has been used for the forward computation of sounder channel radiances alongwith the Jacobians, which is used in the physical retrieval. More details can be found at http://www.imd.gov.in/section/ satmet/ dynamic/INSAT3D_Catalog.pdf.

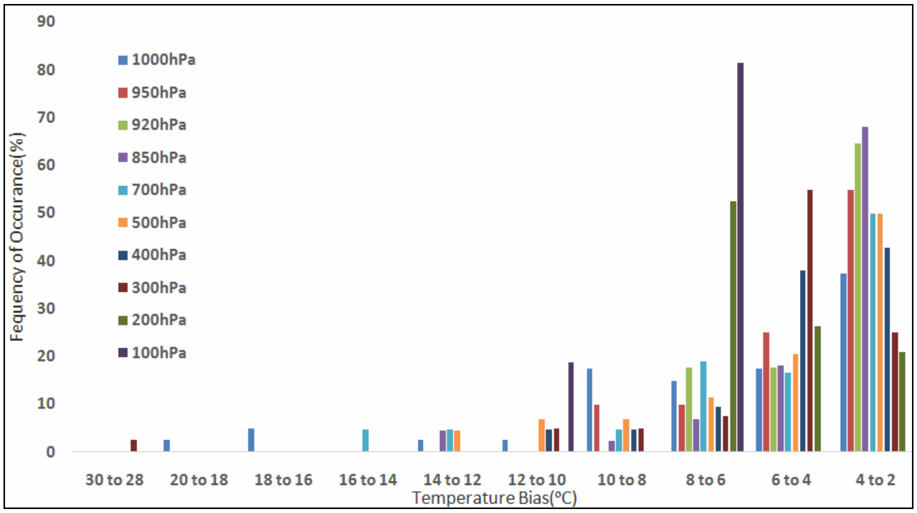


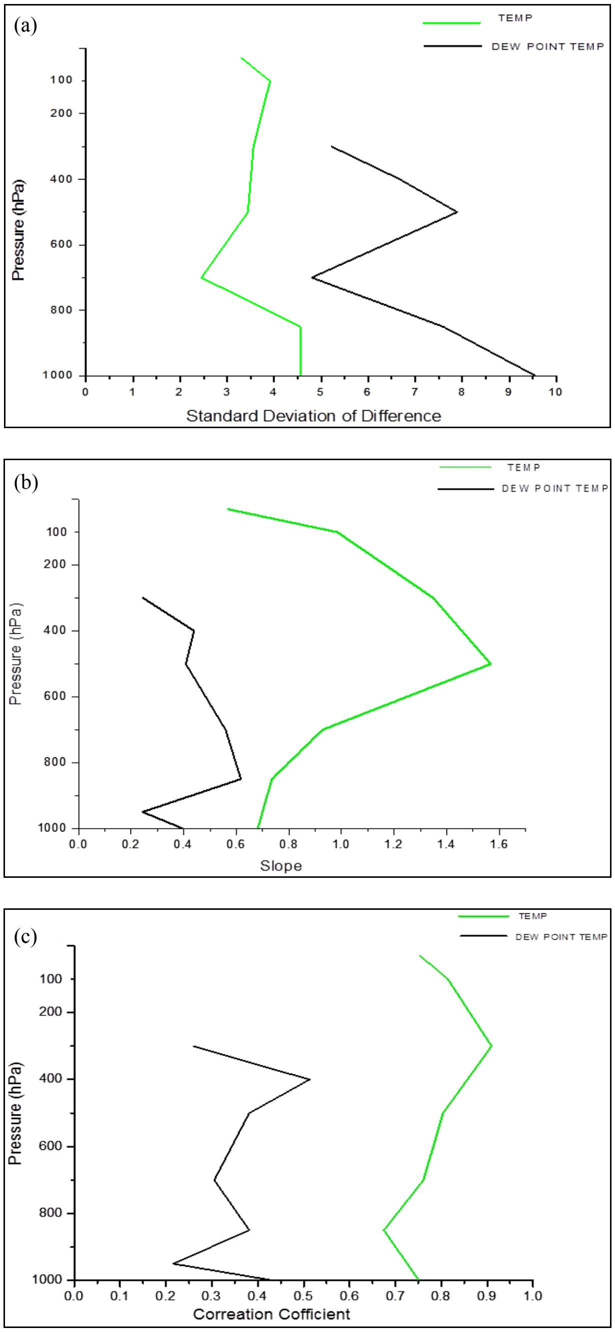
Fig. 1. Bias frequency distribution of INSAT-3D *vs* GPOB from surface to 100 hPa level

In the present study, we have used advanced GPOBs for pairing with their closest INSAT-3D temperature and moisture retrievals. The GPOBs provide temperature and dew point as functions of pressure at both mandatory and significant levels and these data were obtained from IMD's network. Prior to use of GPOB data for comparison, GPOB data were filtered using the following two criteria's: (a) the temperature must be taken at least upto 100 hPa levels, (b) As we reach above 100 hPa, the amount of water vapour becomes low and the sensor used for humidity measurement (hygrister) is not very reliable. Due to these reasons, we have fixed the upper level up to 300 hPa for moisuture retrievals (Elliot and Gaffen, 1991). The performance of IMD`s GPS radiosonde stations has been very well examined using ECMWF global data monitoring report by Gajendra Kumar *et al*. (2011). The period of the current study was 15th January, 2014 to 31st May 2014 using data from 10 GPS radiosonde stations over the Indian region (Table 2).

In the retrieval process of INSAT-3D, the regression coefficients are computed for 150 zenith angle classes [0 to 65° with increment of Δsec (θ) = 0.01] from radiosonde database (SeeBor dataset, University of Wisconsin at http://cimss.ssec.wisc.edu/training_data/) separately for land and ocean. The set of predictors include sounder channel brightness temperature (T_b) and its quadratic term (T_b^2) along with the surface pressure (P_s). The first-guess input to the retrieval algorithm is taken from National Center for Environmental Prediction (NCEP) Global Forecast System (GFS) consisting of 12-h forecast. Therefore, the atmospheric profiles obtained from regression retrieval is combined with the NWP forecast profiles to generate a hybrid regression profile that is used as first guess for the physical retrieval. Similar to GOES-8 satellite sounding retrievals scheme, to reduce the random errors, INSAT-3D sounder channels brightness temperature values are averaged over a number of field of view (FOVs) prior to application of retrieval algorithm. Based on this, retrieval algorithm has option for retrieving the vertical profiles at 30 km (3 × 3 pixels) and 10 km resolution (each pixel).

In our evolution methodology, each GPOB was paired with closest INSAT-3D retrievals and patterned according to criteria suggested in Fuelberg and Olson (1991). The collocation criteria for INSAT-3D retrievals with GPOB data are based on the following: (1) The absolute distance between the position (latitude and longitude) of the GPOB and the INSAT-3D retrievals has been considered as 0.5° (50 km) (2) The INSAT-3D/GPOBs were matched at 0000 and 1200 UTC. But results for only 0000 UTC comparisons are presented here. (3) The temporal difference between two sets of data is around 60 minutes depending on retrievals and location of the GPOB station. A total of 986 pairs of observations taken at 0000 UTC have been used in the study.

Since INSAT-3D retrievals are based on only clear sky condition (limitation of Infra-red sounder sensors), the number of field of view (FOV) comprising each pixel retrievals is very much important. Retrievals from partial cloud contaminated pixels may exhibit large discrepancies between INSAT-3D and GPOB comparisons. An attempt has been made to minimize the errors through the use of methodology described above but this discrepancy cannot be avoided completely. In this paper we have presented a simple and objective scheme for those who can use the INSAT-3D retrieval for research or operational use for weather related studies.



Figs. 2(a-c). (a) Standard Deviation, (b) Slope of INSAT-3D *vs* GPOB temperature/moisture Profile (c) CC of INSAT-3D *vs* GPOB temperature/moisture profile

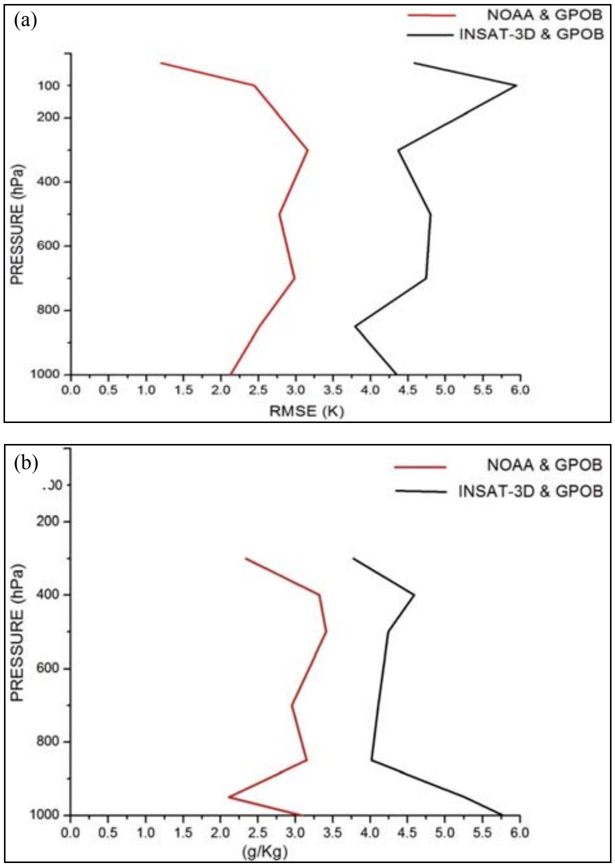
2.1. *Temperature bias distribution between INSAT-3D and GPOB profiles*

The bias distribution for INSAT-3D with GPOB at different pressure levels, *viz*., 1000, 950, 920, 850, 700, 500, 300, 200, 100 hPa has been attempted and is shown in Fig. 1. Here bias is calculated from INSAT-3D-GPOB data at different levels. In this distribution, INSAT-3D temperature profile always showed positive bias compared to GPOB throughout from 1000 to 100 hPa levels. The levels of maximum positive bias, where INSAT-3D values are too warm, are in the lower trpospheric levels and at 100 hPa. This can be attributed to inability of the retrival scheme to precisely locate the change in the lapse rate associated with the tropopause and uncertainties in retrievals at lower levels. Li *et al*. (2000) have also pointed out that the retrieval could have large errors especially in the lower atmospheric levels due to some uncertainties, such as the failure of low-level cloud check, surface type uncertainty and emissivity errors. At lower trpospheric levels, frequency distribution of bias (2 to 4 °C) amounts to the total of 37% from overall samples. Similarly, 55 to 65% of these positive biases, from surface to 500 hPa, are also around 2 to 4 °C. The overall retrivals exhibited almost systematic errors at all the levels and falls between 2 °C to 8 °C from 1000 to 100 hPa.

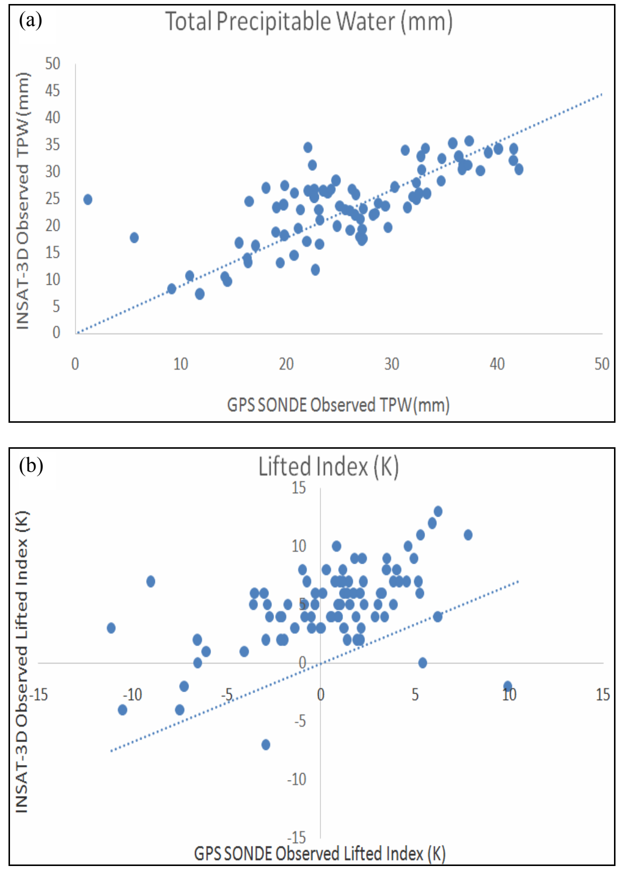
2.2. *INSAT-3D temperature and moisture profile evaluations*

Prior to the utilization of INSAT-3D sounder derived products, it is important to examine its temperature and moisture data since it would be used as an input for those parameters. It can be observed (green line is temperature and black line is dew point temperature) from Fig. 2(a) that standard deviation (SD) of INSAT-3D/GPOB temperature comparison at 0000 UTC approximately as function of pressure are 4.5 °C from the surface to 900 hPa, showing some improvement from 900 to 500 hPa levels, 2.2 °C at 700 hPa. But above this level of 500 hPa values are nearly constant (3.5 °C) and showing little variation with height. A possible reason for this is that at middle levels around 850 to 500 hPa, the SD of temperature profiles are less than that at surface and upper levels. In contrast, SD values for moisture profiles are on the higher side but following the general pattern of temperature profiles with lower values near 700 hPa.

In Fig. 2(b), a least-squares procedure has been used to calculate linear best-fit regression lines between INSAT-3D and GPOB temperatures. A slope of 1.0 indicates that INSAT-3D values agree to some extent with the sonde-derived versions or that they are uniformly warm or cold biased over all temperature ranges. Slopes not equal to 1.0 imply the existance of differential bias. It can be interpreted from Fig. 2(b) that if the slopes exeed 1.0, INSAT-3D values are too warm at cold GPOB temperature and/or too cold at warm GPOB temperature. The moisture profile slope ranging between 0.23 to 1.58 °C, means that differential bias is not pronounced. In contarst, the temperature profile slope exceeds 1.0 from 700 hPa to 100 hPa exhibiting differntial bias at these levels.



Figs. 3(a&b). RMSE of (a) Temperature and (b) Moisture profile between INSAT-3D with GPOB and NOAA



Figs. 4(a&b). INSAT-3D derived (a) TPW and (b) LI

Linear correlation coefficients (CC) between INSAT-3D and GPOB profiles have been calculated and dipicted in Fig. 2(c). The temparature CC values [Fig. 2(c)] are quite large, varying from 0.7 at 850 hPa level upto 0.9 at a pressure level around 300 hPa. After this it decreases with height upto 0.7 near the tropopause. However, dew point CC are very less as compareed to temparatue CC and agreement with GPOB is not so good. The overall dewpoint CC are not exceeding the value of 0.5.

2.3. *Error statistics of INSAT-3D profiles with GPOBs and NOAA derived retrievals*

The root mean square error (RMSE) of temperature and moisture profiles has been computed between INSAT-3D with GPOB and at same location between NOAA derived retrievals against GPOB from March 2014 to June 2014 [Figs. 3(a&b)]. RMSE of temperature profile from INSAT-3D was found to be higher compared to the NOAA temperature retrievals. Although the pattern was matching but the magnitude of the error at surface as well as upper levels is much higher for INSAT-3D shown in Fig. 3(a). Higher differences at upper levels may probably be attributed to inability of INSAT-3D retrievals to properly resolve the altitude of tropopause and the associated change in lapse rate around 100 hPa. RMSE of moisture profile from INSAT-3D were found to be around 5 to 6 g/kg in the lower levels as compared to those from NOAA profile which were around 2 to 3 g/kg [Fig. 3 (b)]. The errors above 850 hPa and upto 300 hPa were almost constant around 4 g/kg. At these levels the magnitude of the RMSE is comparable with NOAA retrievals and exhibiting little change with height. The total collocation points for both the sources are 1110 and 934 for temperature and moisture data respectively.

2.4. *Comparison of INSAT-3D sounder derived products with GPOB*

INSAT-3D sounder derived products such as Total Precipitable Water (TPW) and Lifting Index (LI) have been comapred with GPOB derived TPW and LI from March to June, 2014 and results of comparison are shown in Figs. 4(a&b). The details of these INSAT-3D products and their algorithms can be found at http://www.imd.gov.in/ section/satmet/dynamic/INSAT3D_Catalog.pdf.

The error comparison statistics in Figs. 3(a&b) shows that temperature and moisture data at middle level compared favorably to some extent as far as pattern is concerned. Fuelberg and Olson (1991), have suggested that satellites measure upwelling radiation from atmospheric layers and not at specific levels. It is therefore reasonable to assume that vertically integrated satellite sounder derived parameters will compare more favorably with their corresponding radiosondes derived counterparts rather than retrieved data at individual levels. To verify this, INSAT-3D derived TPW and LI has been evaluated with GPOB derived TPW and LI. In Figs. 4(a&b), scatter plots are shown between GPOB and INSAT-3D derived TPW and LI respectively. In the evaluation of Figs. 4(a&b), the figures included best-fit linear regression line obtained from the least squares method. TPW exhibit a good linear relationship with little scatter, and this is evident in the correlation co-efficient of 0.73 with standard deviation of 5.96. This implies that there may be less amount of differential bias. In LI scattered plot, INSAT-3D exhibit somewhat less agreement with GPOB. There is good linear fit but scatter is more as reflected in lower correlation co-efficient of 0.48 but for TPW the standard deviation seems good which are around 3.95. This implies occurrence of the differential bias.

3. Conclusions

In the current study, the evaluation of INSAT-3D temperature and moisture retrievals from routine application of operational algorithm in use at IMDPS has been performed. The overall data set consisted of retrievals for the period January 2014 to May 2014 and collocated with GPOB to within 60 km over the Indian region. The temperature and moisture profiles were compared to the GPOB and NOAA retrievals. The comparison results show that the RMSE of temperature profile from INSAT-3D is quite high as compared to the NOAA temperature retrievals specifically the magnitude of the error at near surface levels as well as upper levels is 4.5 to 5 °C. The RMSE of moisture profile from INSAT-3D exhibits higher values at surface level around 5 to 6 g/kg as compared to error with reference to NOAA`s moisture profile of 2 to 3 g/kg. Above 850 hPa to 500 hPa the errors are showing almost a constant value of around 4 g/kg.

The temparature CC values with respect to only GPOB are quite large, varying 0.7 °C at 850 hPa and increasing upto 0.9 °C at a height around 300 hPa. After this there is a decrease upto 0.7 °C near the tropopause level. The linear best-fit regression lines between the INSAT-3D and GPOB temperatures show that between 700 hPa to 100 hPa differntial bias exist. Similarly, the SD of temperature profiles is lesser than surface and upper level around middle level 850 to 500 hPa. The overall temperature bias retrivals exhibited almost systematic error at all the levels and falls between 2 to 4 °C from 1000 to 100 hPa. The INSAT-3D temperature profile always shows the positive bias throughout from 1000 to 30 hPa against GPOB. The level of maximum positive bias, where INSAT-3D values are too warm, are near the surface level and 100 hPa.

The retrieval results presented in the paper reflect the overall performance of retrieval scheme for accurate upper level temperature and moisture profile observations. There is a need for further improvments in the processing or retreval scheme at IMDPS in order to improve the accuracy of retrievals. To have high quality of retrievals both, the retrieval scheme and the NWP system (first-guess) should be well performed. Image navigation, calibration and radiance bias correction coeffciants, all are imporatnt issues which affect retrieval performance. INSAT-3D retrieval scheme of IMD is currently in developing stage and still requires improvements in its sub-schemes. Therefore, it is important to make continuous effort to improve its quality. A superior transmittance model even on future versions may also improve results. However, in future, the present work would be extended to use the bias corrected INSAT-3D reterivals covering various seasons and geographical regions over the Indian sub-continent to provide the reasonable interpretation and quantitative benefit to NWP.

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