

Author's Response

Abstract:

Reviewer's Comments (RC): Line 13: “..infrared radiances”

Author's Response (AR): This has written in line no. 13.

Introduction:

RC: Be consistent in using AMT reference style.

AR: AMT reference style has been incorporated in entire manuscript.

RC: Section 2. “Datasets”

AR: Replaced with “Datasets”, refer line no. 80

RC: 2.1 Remove “in IMD”

AR: Removed “In IMD” refer line no. 81

RC: 2.4 Description of NOAA satellite data is too short and inadequate. Provide more information on the dataset, the retrieval procedure with appropriate references.

AR: The NOAA (National Oceanic and Atmospheric Administration) Satellite and Information Service provides timely access to global environmental data from satellites. In this study, we used blending TPW from two satellite sources, one from the Advanced Microwave Sounding Unit (AMSU) instruments on NOAA satellites (Ferraro et al., 2005), and the other from the Special Sensor Microwave Imager (SSM/I) instruments on Defence Meteorological Satellite Program (DMSP) satellites. In the blended Total Precipitable Water (TPW) product, individual biases of the data sources have been mitigated to produce a more meteorologically significant product. Blending retrieval procedure has detailed (Kidder et al., 2007) and methodology provides seamless global coverage without gaps to allow for the analysis of atmospheric moisture over land and ocean (Schmit et al., 2002 and Smith et al., 2007). The products are on a Mercator projection with 16 km resolution at the equator. The products are hourly in HDF-EOS file format. These operational products were produced by the NOAA/NESDIS (National Environmental Satellite, Data, and Information Service) Office of Satellite and Product Operations (OSPO). Refer line no 130-143.

RC: Figure 2. Areas marked with ellipses represent different sub-division scale. Mention it in the caption.

AR: Replaced by “Figure 2. Radiosonde Stations (red dots) of IMD over India. Areas marked with ellipses represent different sub-divisions.” Refer line no. 110-111 and 118-119.

Section 3. Methodology:

RC: Line 151-153: Provide appropriate references.

AR: It has been mentioned. Refer line no. 163-165.

RC: g is the gravity constant. Consider sentence restructuring

AR: The sentence has restructured, refer line no 182.

Section 4. Result and Discussion:

RC: Section 4.1 “...Sub Division Scales”

AR: Refer line no. 194-195

RC: Figure 3 caption: “Comparison of INSAT-3D derived TPW with that from RS network..”

AR: Replaced by “Figure 3. Comparison of INSAT-3D derived TPW with RS observed TPW from May to September 2016”. Refer line no. 204-205

RC: Expand the discussion little more. Describe the overall uncertainty in the TPW retrievals and associated sources of errors.

AR: INSAT-3D TPW is able to measure the synoptic features of weather phenomena at monthly scale over the Indian region very well. However magnitude differs, it can be termed as source of error due to registration and navigation issues during the night time. The consistent and better correlation has seen above 40 mm of TPW values, whereas for less than 40 mm TPW values, INSAT-3D underestimates slightly. This is due attributed to seasonal variation, orographic of the region and different climatic zone over India. Refer line no 207-213.

The mean difference between RS and INSAT-3D TPW is much higher in the month of July 5.57 mm. It is due to the substantial rainfall during the monsoon season and in the subsequent months August and September 5.24, 5.3 mm respectively. It was also reported by Ratnam et al., 2016 that mean difference in the water vapor is as high as 20-30%. The dry bias of 10-25% in INSAT-3D channel compare to similar satellite and reanalysis dataset was also noted. Refer line no 224-229.

RC: Figure 4. Instead of denoting each sub-plot with a), b), c)...denote it with the actual month of observations; it increases the readability of the plot.

AR: Replaced “Figure 4. INSAT-3D sounder TPW with RS for May, June, July, August and September 2016” Refer line no 242-243.

RC: INSAT-3D TPW is consistently lower for values < 40 mm for which some discussion is needed.

AR: INSAT-3D TPW is able to measure the synoptic features of weather phenomena at monthly scale over the Indian region very well. However magnitude differs, it can be termed as source of error due to registration and navigation issues during the night time. The consistent and better correlation has seen above 40 mm of TPW values, whereas for less than 40 mm TPW values, INSAT-3D underestimates slightly. This is due attributed to seasonal variation, orographic of the region and different climatic zone over India. The largest differences are observed mainly over mountainous areas and/or near the sea, which reveal differences in representativeness. Good confidence in INSAT-3D TPW estimates is gained during periods of moderate to heavy rain. Refer no 207-215.

RC: Figure 5. Improve the caption

AR: Written “Figure 5. Comparison of INSAT-3D derived with RS and NOAA observed TPW sub-division scales NI, WI, CI, WI& PS from May to September 2016”. Refer line no 267-268.

RC: Section 4.2 “Comparison of INSAT-3D TPW with Actual Rainfall Observations”

AR: Replaced by “Comparison of INSAT-3D TPW with Actual Rainfall Observation”. Refer line no. 272

RC: Figure 6. Showing the data as “box and whisker” plot would enhance the readability of the plot. The data arranged in Figure 6 is somehow unclear. What is the area coverage considered for such comparison? Over the entire Indian sub-continent? It must be stated in the text as well as in the figure caption.

AR: Replaced Figure 6 caption “Figure 6. The Box-Whisker plot for comparison of INSAT-3D TPW with actual rainfall over Indian region” Refer line no 299-300.

The box-whisker plot shown in the Figure 6 compares the actual rainfall observation and INSAT-3D TPW for different values during June to September 2016. This figure is constructed from the daily rainfall observation between 0 to 140 mm occurring over the 34 stations and collocated mean INSAT-3D TPW values between 0 to 90 mm over the entire Indian region. It can be seen from the Figure 6, that TPW is binned for the ranges 0-20, 21-40, 41-60, 61-81 and >80 . As seen from the whiskers, the rainfall has least scatter for the 0-20 bin, while for TPW >80 it shows most scatter. The mean and median are almost same for all the TPW bins, except for the TPW >80 . There exist exponential behavior between rainfall amounts with higher INSAT-3D

TPW values. However, further analysis with more number of observations is required for the quantification of non-linear/exponential relationship. Refer line no 273-282.

RC: Line 265: Remove “during summer monsoon season”

AR: It has removed.

RC: The rainfall-TPW relationship appears to exhibit an exponential behavior, which author completely misses to mention in the discussion. Does any other paper explore such relation or already noted such behavior?

AR: The mean and median are almost same for all the TPW bins, except for the TPW >80. There exist exponential behavior between rainfall amounts with higher INSAT-3D TPW values. However, further analysis with more number of observations is required for the quantification of non-linear/exponential relationship. Refer line no 276-282.

RC: Also, author should mention here that TPW corresponds to the cloud-free observations and rainfall measurements are for cloudy atmosphere.

AR: The TPW corresponds to the cloud-free observations and rainfall measurements are for cloudy atmosphere. Refer line no 285-286.

RC: Section 4.3, Provide latitude & longitude in parenthesis

AR: Pune, Kochi and Dibrugarh respectively latitude and longitude 18.52°E 73.85°N on June 3, 2017 at 1200UTC, 9.93°E 76.26°N on June 6, 2017 at 0600UTC and 27.47°E 94.91°N on June 9, 2017 at 0000UTC. Refer line no. 304-306.

RC: Line 282: Can author provide the URL link to the satellite images referred here?

AR: Further details can be found at <http://gnss.imd.gov.in/TrimblePivotWeb/>. Refer line no 307-308

RC: Line 284: “Figure 7” (not figure-7)

AR: Replaced by “Figure 7”. Refer line no 313.

RC: Line 299: “...compares reasonably well with the GNSS TPW observations”

AR: Refer line no 331-332.

RC: Indicate dates in this format throughout the manuscript: Jan 1, 2018

AR: Yes. Date formats are incorporated in whole manuscript. Refer line no 330.

RC: Please explain the sudden dive in TPW from ~50 mm to 20~ over Dibrugarh?

AR: At 0000 UTC of thunderstorm over Dibrugarh city was reported. The initial convection development started at 1800 UTC with values around 53 mm in comparison with GNSS TPW of

58 mm at 1800 UTC. It can be very well seen from Figure 7, there has been noted at 1400 UTC with values 24 mm from 50 mm. This is due to less precipitation occurred in Dibrugarh while 1400 to 1800 UTC, no precipitation has been noted due to cloudy sky. Refer line no. 324-328.

Conclusion:

RC: Line 311-314: Rephrase the sentence something like “In the present study, we have assessed the retrieval performance of INSAT 3D TPW by comparing it with corresponding observations from radiosonde network and NOAA’ GNSS network over the Indian region”.

AC: Sentence has been incorporated, refer line no 343-345.

RC: Line 320: “...TPW product in forecasting advancement of monsoon precipitation over the Indian region”

AR: Refer line no. 354-355.

RC: Line 322-324: “INSAT 3D TPW product offers near-real time availability over the Indian region with higher spatial and temporal resolution compared to the other derived from polar orbiting satellites”

AR: INSAT 3D TPW product offers near-real time availability over the Indian region with higher spatial (resolution 10 km) and temporal resolution (60 min) compared to the other derived from polar orbiting satellites. Refer line no. 358-359.

RC: Mention here the spatial and temporal resolution of INSAT 3D TPW product.

AR: Refer line no 358-359.

RC: The write up for Conclusion seems short. Author needs to discuss the comparison results in little more details.

AR: Refer line no. 348-349 and 361-363.

Acknowledgments:

RC: Authors are grateful to Dr. K. J. Ramesh, the Director General of Meteorology IMD for offering valuable suggestions.

AR: Refer line no 365-366.

RC: Rephrase the sentence as “We appreciate the work of C. M. Kistawal and P. Thapliyal of applying GSCIS correction at IMDPS for improving sounder retrievals. We thank both them for providing their technical inputs.”

AR: Refer line no 366-368.

RC: The first author also thanks NOAA for providing satellite data of TPW used in the comparison against that of INSAT 3D sounder.

AR: Refer line no 368-369.