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INFORMATION PAPER

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Agenda Item 6: Research, development and other initiatives

DEVELOPMENT OF RECONSTRUCTED RADAR REFLECTIVITY FOR CONVECTIVE STORM MONITORING OVER INDIA

(Presented by India Meteorological Department)

SUMMARY

This information paper describes the development of reconstructed radar reflectivity by integrating Dual-frequency Precipitation Radar (DPR) observations on-board Global Precipitation Mission (GPM) with the storm index from INSAT3D. Performance of the derived product was tested against the independent DPR observations. A correlation coefficient of 0.81 is reported between the reconstructed radar reflectivity and the radar reflectivity from DPR observations. Derived reconstructed reflectivity is shown to be an excellent aviation product for the storm monitoring over the regions without radar coverage.

1. INTRODUCTION

1.1. Convective storms are potential aviation hazards. These storms are associated with hazardous conditions in the form of heavy winds, hails, lightening, flash floods and low visibility. India is one of the most vulnerable countries against extreme weather events including convective storms.

1.2. Precise monitoring of such storms has applications in various fields including disaster management, aviation meteorology and weather forecasting. Ground based weather radars are very useful for the precise monitoring of storms but have limited spatial and temporal coverage. Space borne radars available from space have very narrow swaths and limited passes (two time a day over India).

1.3. Study described in this paper focuses on the development of reconstructed radar reflectivity by integrating observations from DPR onboard GPM with recently developed storm index using Outgoing

Longwave Radiation (OLR) from Indian geostationary satellite INSAT3D. The developed reconstructed radar reflectivity from the satellite observations can be used by aviation forecasters for the identification of convective weather occurrences over regions without radar coverage.

2. DISCUSSION

<u>Data and Method</u>

2.1. For this study, storm index derived from current operational Indian Satellite INSAT3D is used for the period 2014-2021. Storm index has been derived at every 15 minutes at spatial resolution of 8km by integrating Outgoing Longwave Radiation (OLR) from INSAT3D and radar reflectivity from PR. Storm signature represented by low OLR values was compared against high radar reflectivity from PR for a large dataset to establish a linkage between reflectivity and OLR which was used for the derivation of storm index.

2.2. Shallow and convective storms were identified with reflectivity thresholds of 17 dBZ and 30 dBZ, respectively from PR observations. OLR threshold for storm detection was derived from reflectivity threshold using collocated dataset. Storm index was derived as OLR threshold divided by actual OLR value. Severity of the storms was detected by the depression below OLR threshold. Validation results reported a good consistency between storm index and space based radar reflectivity in monitoring storm events at near-real time.

2.3. Quantitative linkage between storm index and radar reflectivity from DPR is investigated. This relationship is depicted in figure 1. For this purpose, 5690 data points (collocated at 8km spatial resolution) have been used during storm cases of different seasons in 2014-2021. A nonlinear regression relationship is observed using curve fitting and a coefficient of determination of about 0.88 is reported between storm index and reflectivity factor. Following relationship is obtained

$$RR = RR_0+\alpha\times SI+\beta\times SI^2 \quad (1)$$

Where RR= Radar Reflectivity (in dBZ), SI = Storm Index, RR_0, α and β are coefficients derived from the nonlinear fit. Standard error of estimate of about 5.14 dBZ has been reported. Linear fit was also attempted while establishing relationship between radar reflectivity and storm index. However, non-linear fit showed least error and was given preference over linear fit.

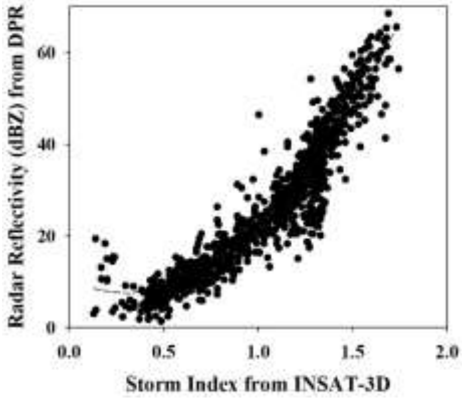

Figure 1: Quantitative linkage between radar reflectivity from DPR and storm index from INSAT3D

Relationship expressed in equation (1) is used to estimate reconstructed reflectivity by using derived coefficients and Storm Index from satellite.

Results:

2.4. Usefulness of the developed reconstructed reflectivity is examined by testing the performance for a few case studies of storm events during various seasons. A case study of a recent cyclonic storm is depicted in figure 2. A Low Pressure Area (LPA) was formed over North Andaman Sea and Southeast Bay of Bengal (BoB) during early morning (0000 UTC) of October 20, 2022. LPA was concentrated into a depression over South-east and adjoining East-central BoB close to Andaman Islands under favorable condition on October 22, 2022. This Depression moved towards north-west and intensified into a deep depression over West-central BoB on October 23, 2022 by 0000 GMT and finally concentrated into a cyclonic storm 'Sitrang' on the same day by 1200 UTC. Figure 2b shows reconstructed radar reflectivity depicting the structure and intensity of the cyclonic storm on October 24, 2022 at 0000 GMT.

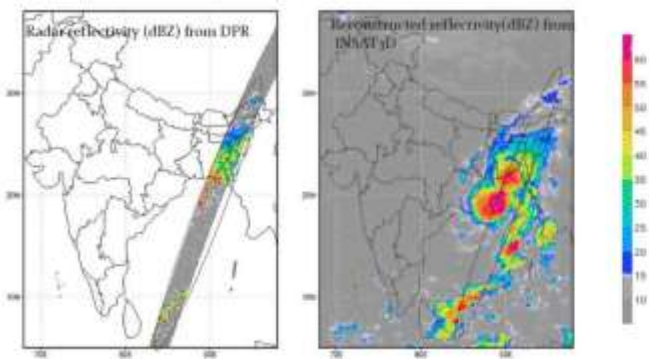

Figure 2: Comparison of radar reflectivity for a cyclonic storms on October 24, 2022 at 0000 GMT from (a) DPR and (b) reconstructed radar reflectivity from INSAT-3D

Structure and spiral bands of the system are very well captured by the derived reconstructed radar reflectivity. DPR had a partial coverage of the storm and thus can be used to evaluate the performance of reconstructed radar reflectivity against radar reflectivity from DPR. Region of maximum reflectivity (concentrated near 19N, 89E and 21N 90E) associated with the storm shows consistency from both the observations. Maximum reconstructed radar reflectivity of about 60 dBZ is observed near 19N and 89E which is consistent with DPR observation. Location and intensity of a spiral band, located below 10N and 82E, are consistent in both the observations. Similarly, regions of low to moderate reflectivity (30-45 dBZ) associated with outer bands centered at 23N and 93E match well from both the observations. A slight aerial overestimation from derived reconstructed radar reflectivity may be attributed to a number of factors including uncertainty due to the use of different sensors from different platforms, different foot prints of Satellite and Radar data, poor relationship between shallow storms and storm index, and weak characterization of shallow storms originating from complex topography.

2.5. For quantitative validation, we have considered a total of 11134 data points (collocated at 8km spatial resolution) during storm events of various seasons in 2014-2021. Figure 3 shows the scatter plot between the reconstructed radar reflectivity from Satellite and the radar reflectivity from DPR observations. Satellite based reconstructed radar reflectivity shows a very good agreement with DPR observations. A correlation coefficient of 0.81 is observed between reconstructed radar reflectivity and observations from DPR. A bias of 2.28 dBZ and rmse of 6.97 dBZ have been reported between the two observations. Slender disagreement between derived reconstructed radar reflectivity and DPR observations may arise due to the use of different sensors from different platforms and poor characterization of shallow storms in Geostationary Satellites.

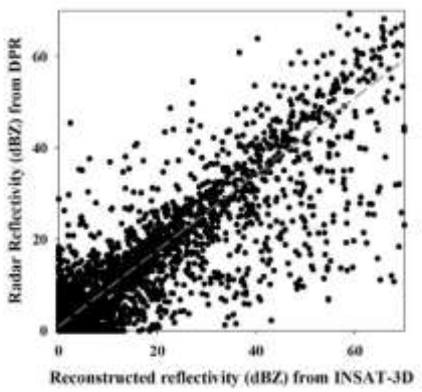

Figure 3: Scatter plot between the reconstructed radar reflectivity from Satellite and the radar reflectivity from DPR

2.6. Figure 4a shows range wise comparison of the reconstructed radar reflectivity with DPR observations. While averaging the radar echoes, the number of points were kept nearly constant in each range, so that statistical weight remained same. The vertical bars show the standard deviation of radar reflectivity. It can be seen that reconstructed radar reflectivity is in very good agreement with DPR observations at each range. Probability distribution of the data from both the observations is also identical (figure 4b). Validation results indicate that derived reconstructed radar reflectivity can be used as an excellent indicator of storms and provide reliable crucial information over the regions where the coverage of radar is not good.

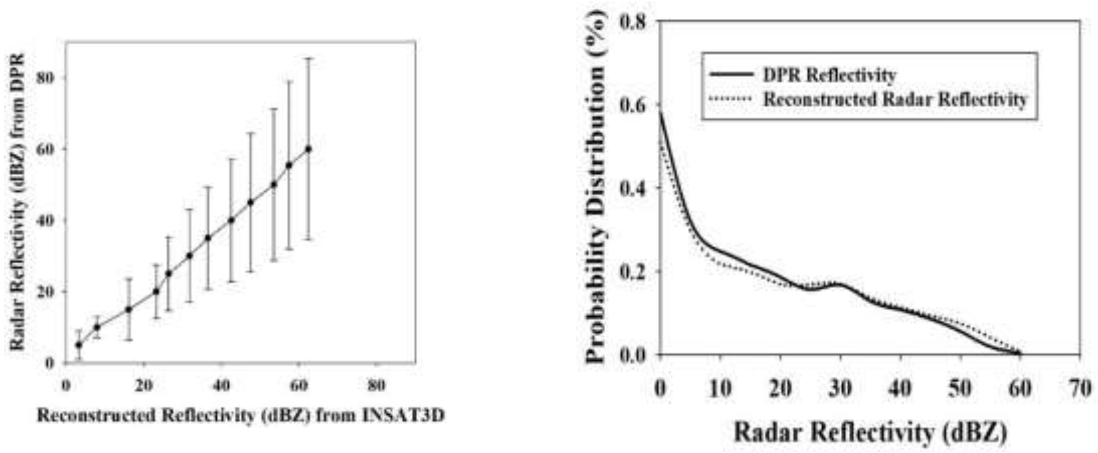

Figure 4 (a) Range wise comparison of the reconstructed radar reflectivity with DPR observations, vertical bars represent the standard deviation (b) Comparison of probability distribution of reconstructed radar reflectivity and DPR observations.

2.7. Derived reconstructed radar reflectivity is very useful for aviation forecasters and disaster managers. Future efforts will be focused on the improvement of reconstructed radar reflectivity especially for the shallow storms through building a more representative input datasets and including cloud microphysics from the Satellite and NWP models.

3. ACTION BY THE MEETING

3.1 Note the information contained in this paper.

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