Impact of Microwave Sounder Data from Polar-orbiting Satellites in NCMRWF Global Forecast System

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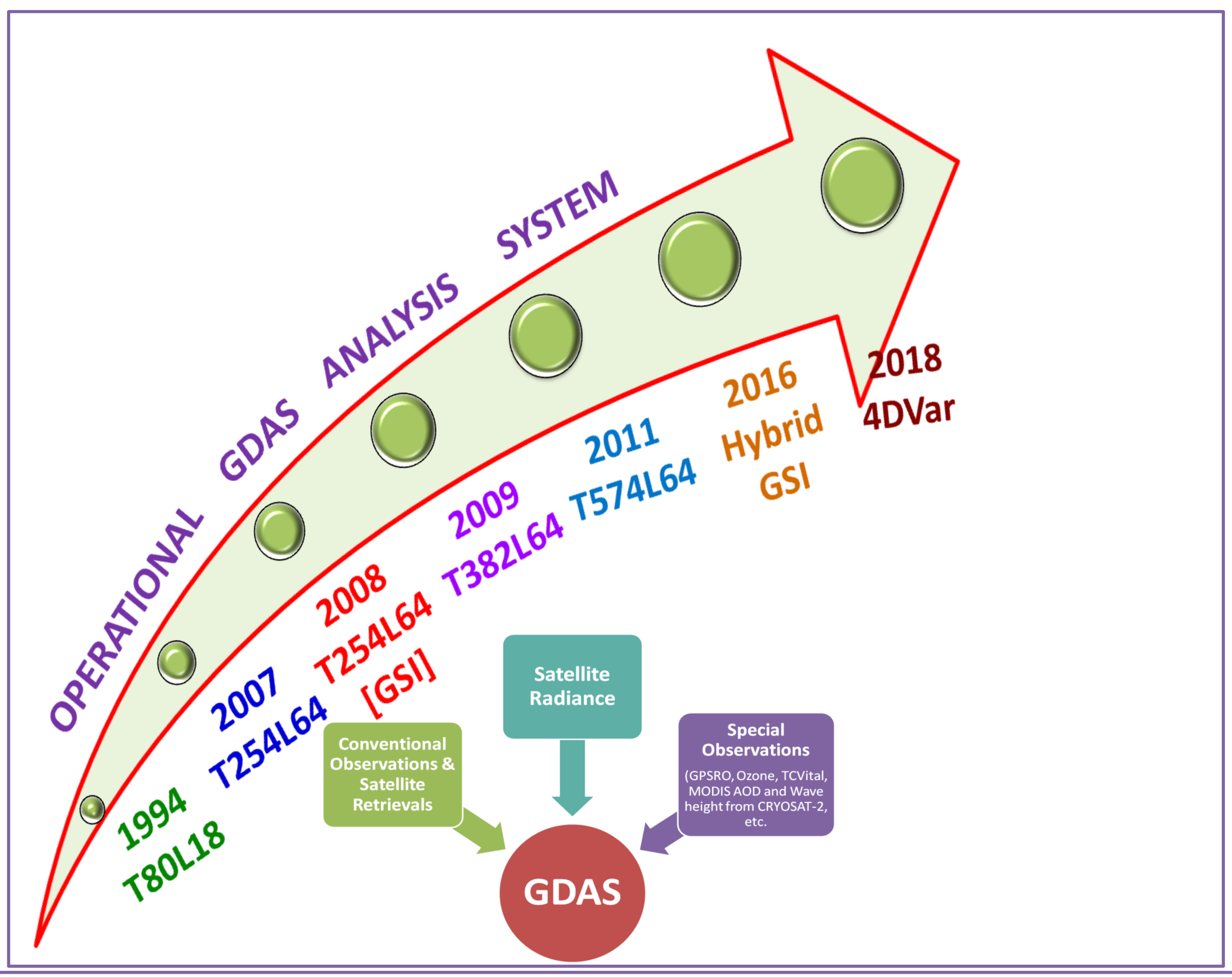
Introduction

- Remote-sensing technologies have led to a paradigmatic shift in atmospheric observation, enabling the procurement of high-resolution, spatially and temporally explicit data across vast territorial expanses.
- Microwave sounding instruments on board Polar-orbiting Environmental Satellites (POES) deliver critical atmospheric observations that serve as essential inputs for Numerical Weather Prediction (NWP) models, thereby augmenting forecast precision and reliability.
- Microwave observations exhibit reduced susceptibility to cloud interference compared to infrared data, thereby providing crucial information in regions inaccessible to other nadir-viewing instruments.
- Effective utilization of ATOVS and ATMS data in NWP is critical for sustaining or enhancing forecast accuracy in future applications.

Salient Achievements in GDAS Assimilation System



Statistical Measurements for Analysis

Mean Error (ME)

$$\mathrm{ME} = \frac{1}{n}\sum_{i=1}^{n}(f_i - o_i) = \overline{f} - \overline{o}$$

Forecast standard deviation

$$SD_f = \sqrt{\frac{1}{T+1}\sum_{i=1}^{T}(f_i - \bar{f})^2} \qquad \overline{f} = \frac{1}{n}\sum_{i=1}^{n} f_i$$

Observation standard deviation

$$SD_o = \sqrt{\frac{1}{T+1}\sum_{i=1}^{T}(o_i - \bar{o})^2} \qquad \overline{o} = \frac{1}{n}\sum_{i=1}^{n} o_i$$

Pearson Correlation Coefficient

$$r = \frac{\sum_{i=1}^{T}(f_i - \overline{f})(o_i - \overline{o})}{\sqrt{\sum(f_i - \overline{f})^2}\sqrt{\sum(o_i - \overline{o})^2}}$$

Anomaly Correlation Coefficient

$$\text{Anomoly Correlation} = \frac{\sum(f_i - c)(o_i - c)}{\sqrt{\sum(f_i - c)^2}\sqrt{\sum(o_i - c)^2}}$$

The root mean square error (RMSE) can be defined as,

$$RMSE = \sqrt{\frac{1}{n}\sum(f_i - o_i)^2}$$

The Equitable Threat Score (ETS) can be defined as,

$$ETS = \frac{(a - a_r)}{(a + b + c - a_r)}$$

Where, $a_r = (a+b)(a+c)/n$

$a = hits; b = false\ alarms; c = misses;\ a_r =$

hits expected by chance

hits expected by chance

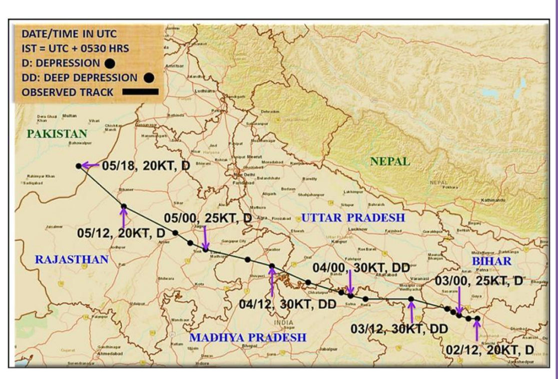
$= (total\ forecasts\ pf\ the\ event)$

$* (total\ observations\ of\ the\ event)/(sample\ size)$

Results and Discussion

Salient Features of Deep Depression (02-06 Aug 2024)

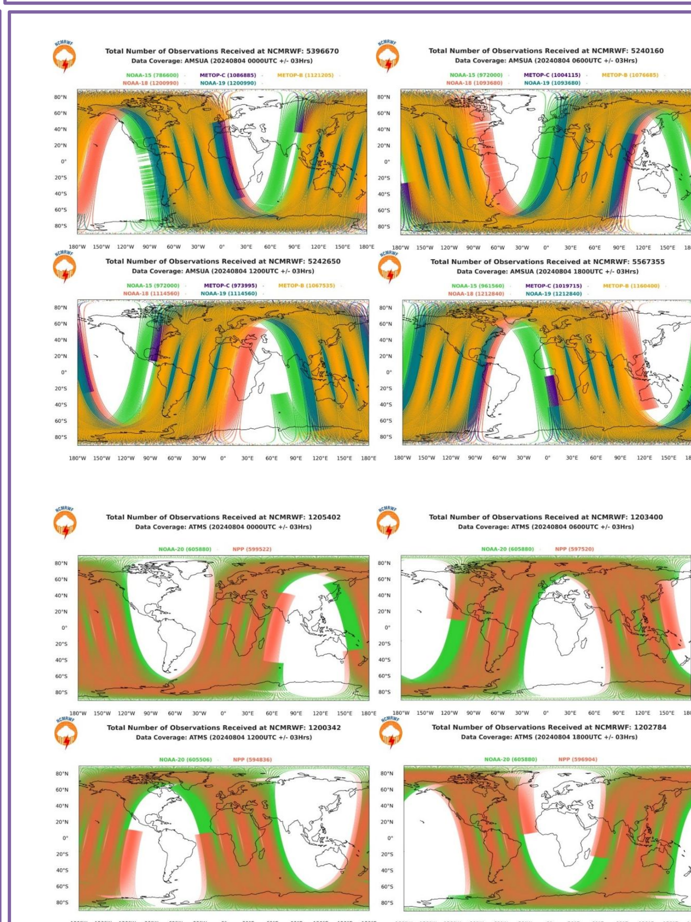
- A mid-tropospheric cyclonic circulation over Jharkhand on July 30, 2024, triggered a low-pressure system over Gangetic West Bengal on August 2, 2024 and intensified into a deep depression.



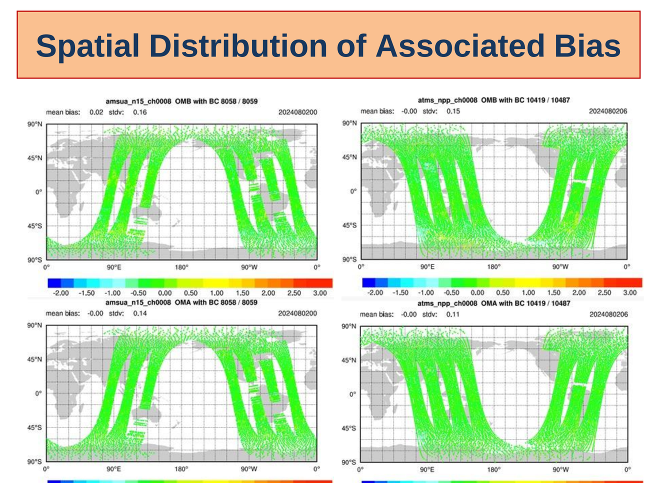
Observed track of the Deep Depression over North Jharkhand & neighbourhood (02 – 06 August, 2024)

- The system's west-northwestward trajectory was monitored using multi-platform observations, including INSAT-3D/3DR satellite imagery and polar-orbiting satellite data.
- As the system progressed, the vortex moved over Madhya Pradesh, Uttar Pradesh, and Rajasthan, with persistent intense convection.
- The system weakened sequentially, transforming into a depression over Northeast Rajasthan on August 5, 2024, and further dissipating into a well-marked low by August 6, 2024.
- The weakening trend was marked by diminishing convection, with moderate intensity persisting over North Gujarat and Southwest Rajasthan.

ATOVS and ATMS Data Coverage and Associated Errors

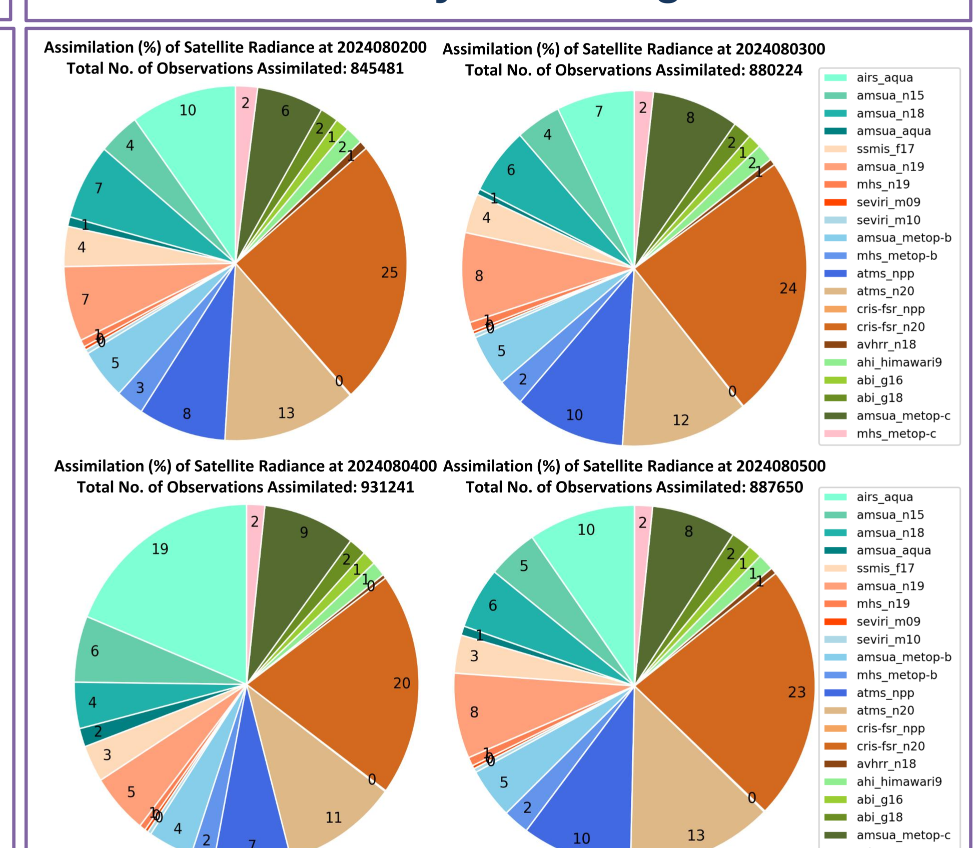


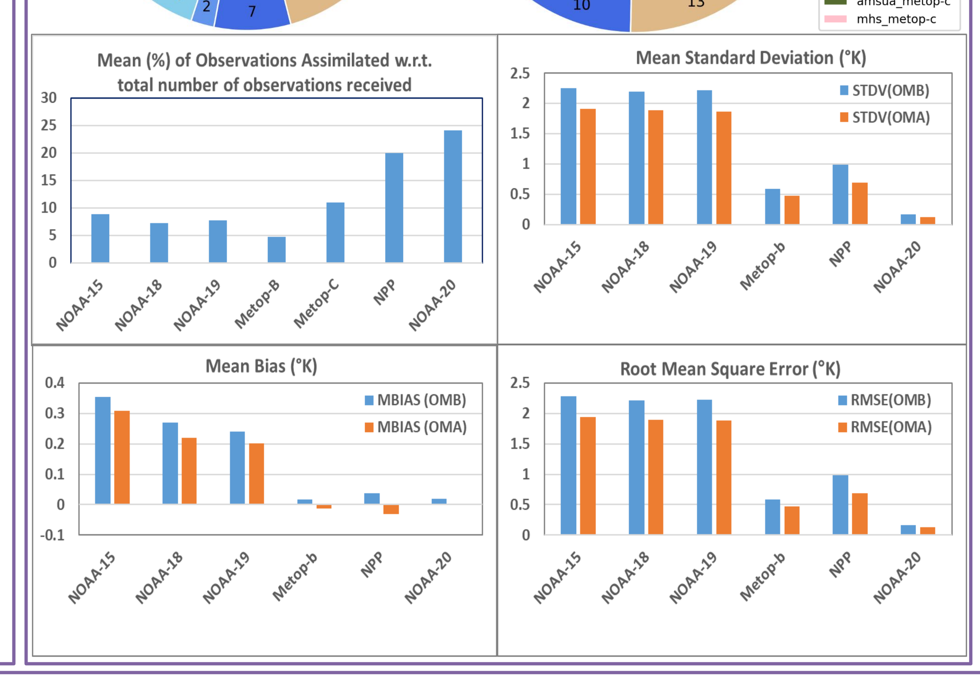
Spatial Distribution of Associated Bias



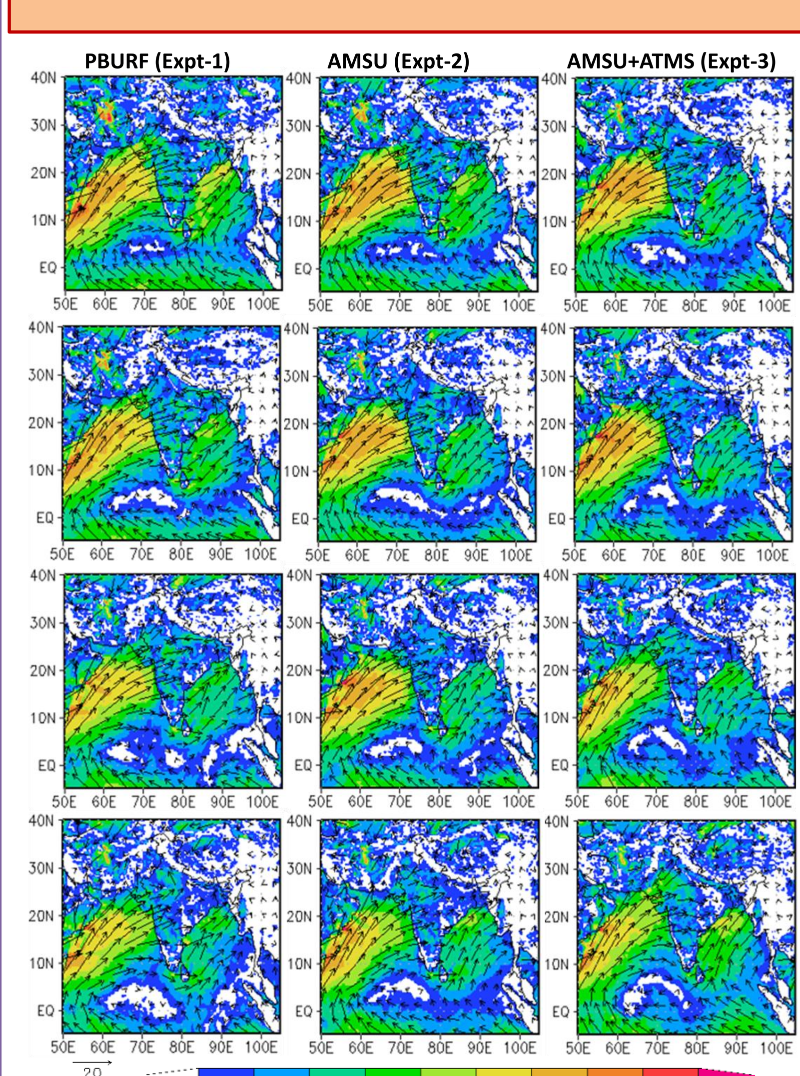
- AMSU-A has 15 channels, each sensitive to different frequencies, providing temperature sounding data for various atmospheric layers.
- The wide swath and global coverage enable AMSU-A to capture large-scale weather patterns and atmospheric phenomena in each cycle.
- Similarly, ATMS is a microwave radiometer with 22 channels, divided into two main groups: temperature sounding channels (1-15) and humidity sounding channels (16-22), providing full coverage in all cycles.
- The RMSEs are computed between the bias-corrected analysis and the bias-corrected background. The bias associated with the analysis varies from -2 °K to + 2° K.

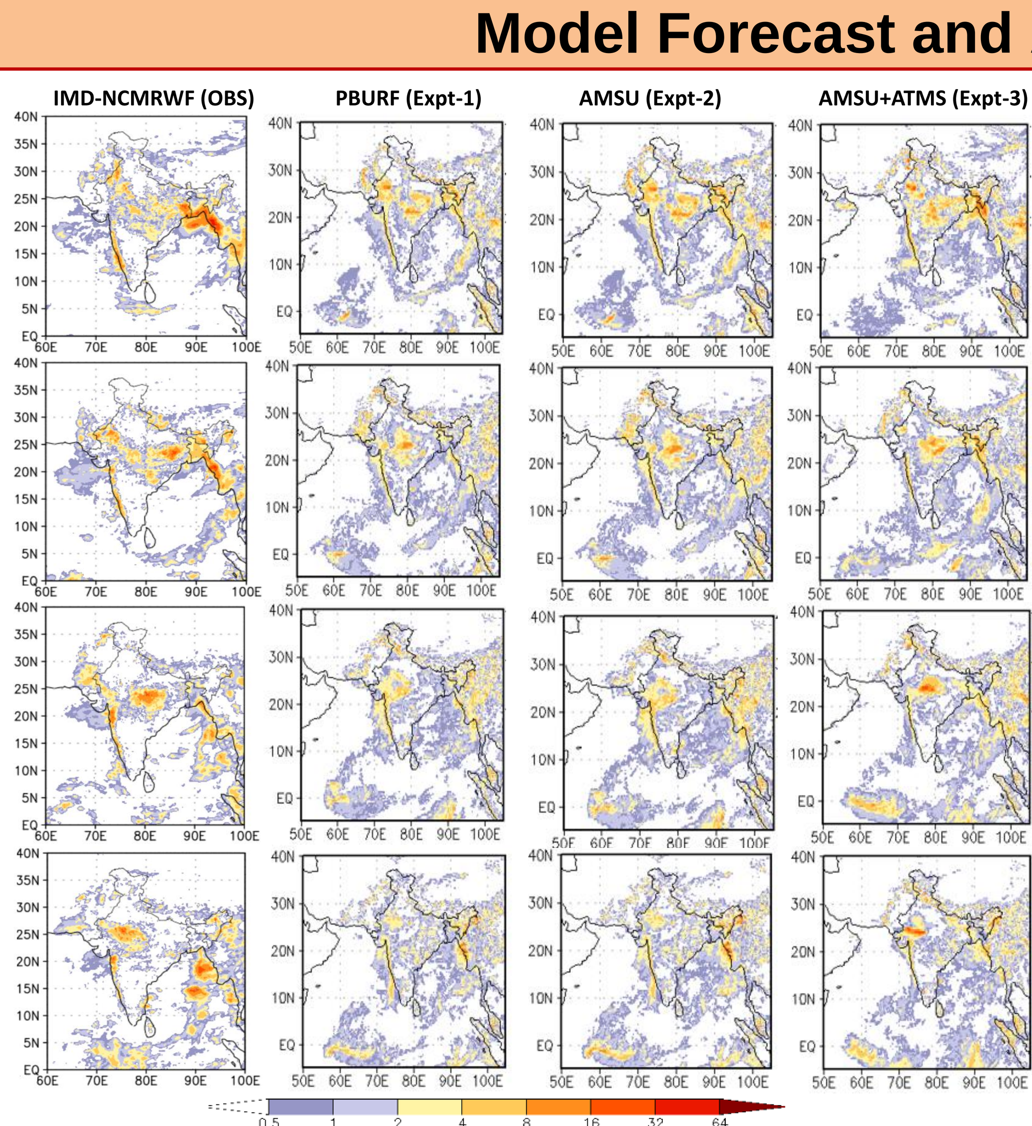
Statistical Analysis during the Event

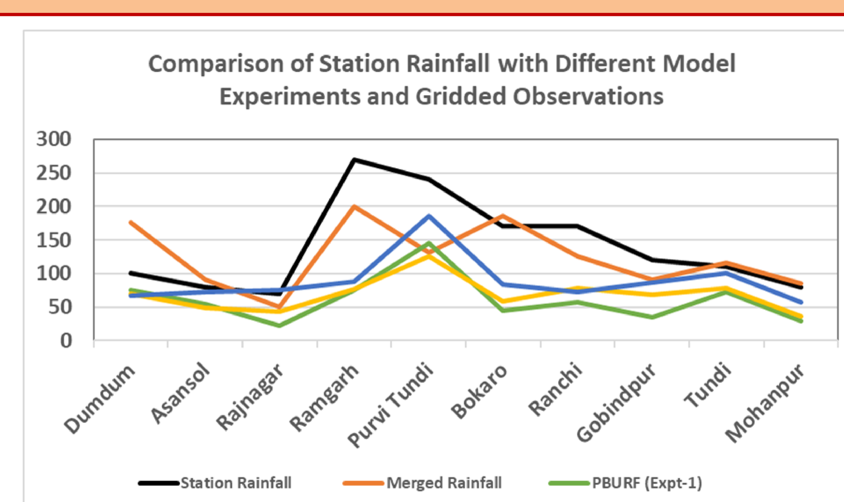


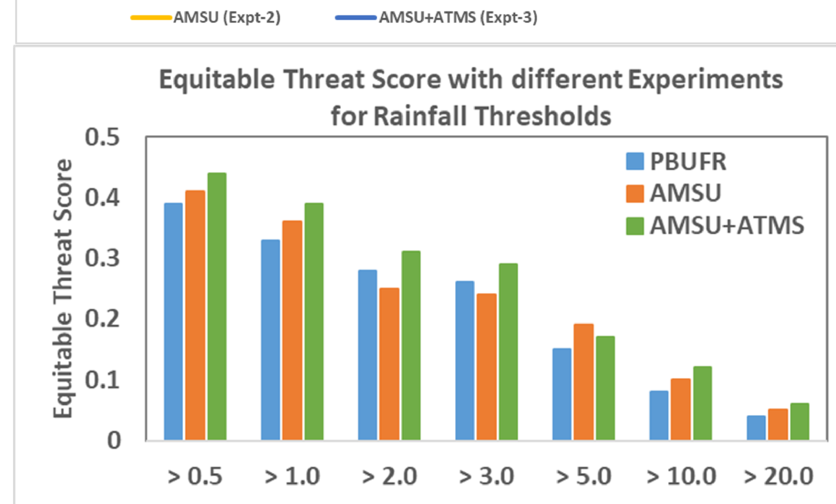


Model Forecast and Associated Skill









- The cyclonic circulation was evident in the wind fields from 10 meters above the surface to 500 hPa, however the system's intensity resulted in relatively weak spatial winds near the center.
- The 10-meter wind observations revealed strong surface winds in proximity to the system center, indicative of its intense dynamics.
- The model could simulate station rainfall, exhibiting good correspondence with observed rainfall and gridded data.
- The rainfall associated with the deep depression is relatively improved in assimilation experiments with higher ETS, less bias and high co-relation coefficient.

Conclusions

- Microwave sounder data from polar-orbiting satellites profoundly influence operational data assimilation, and analysis suggests that about 25% of observations were assimilated, with a substantial portion coming from water vapor channels, significantly contributing to the GDAS.
- Analysis and forecast indicate that the assimilation of ATOVS and ATMS observations positively impacts the global analysis field, thereby enhancing the accuracy and reliability of the forecast system.