All-sky Radiance Assimilation of INSAT-3DS Imager WV Channel in the WRF Model

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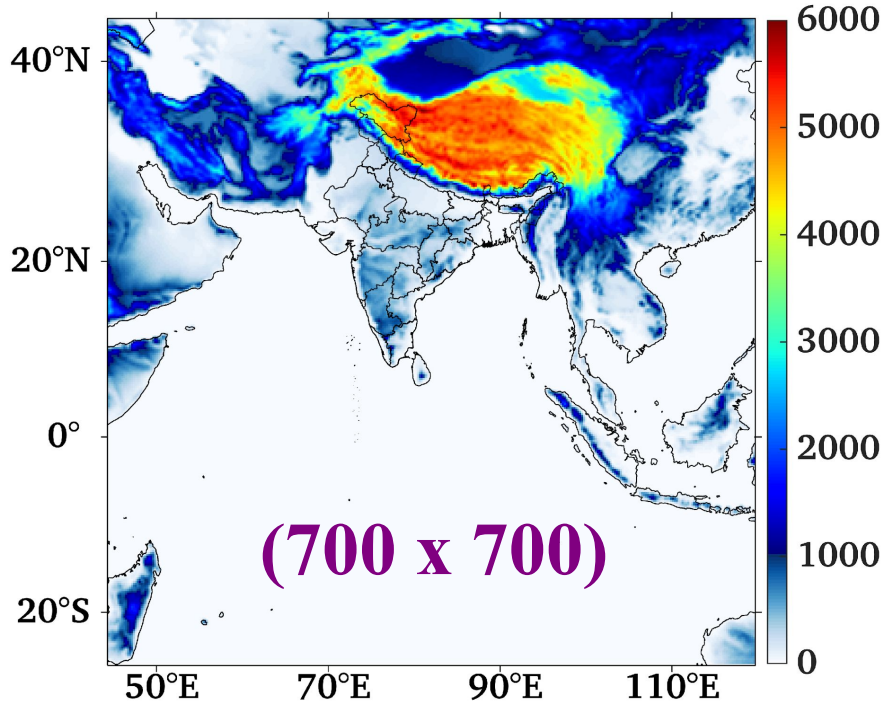
Background

- Generally, Infrared (IR) measurements are assimilated with **clear-sky limitations**, and **cloud removal or correction** for IR radiance became a critical step for operational assimilation.
- The restriction of clear-sky assimilation is not due to insignificance of cloud-affected measurements, but mainly due to **insufficient treatment of clouds in the first guess, RTM, constraints of DA techniques**, etc.
- Montmerle et al. (2010) emphasized the necessity of **background error modelling for clouds and precipitation parameters**.
- Geer et al. (2017, 2018) highlighted that the cloud and precipitation data cannot be assimilated when missing in model first guess due to the **zero gradient problem**.

Methodology



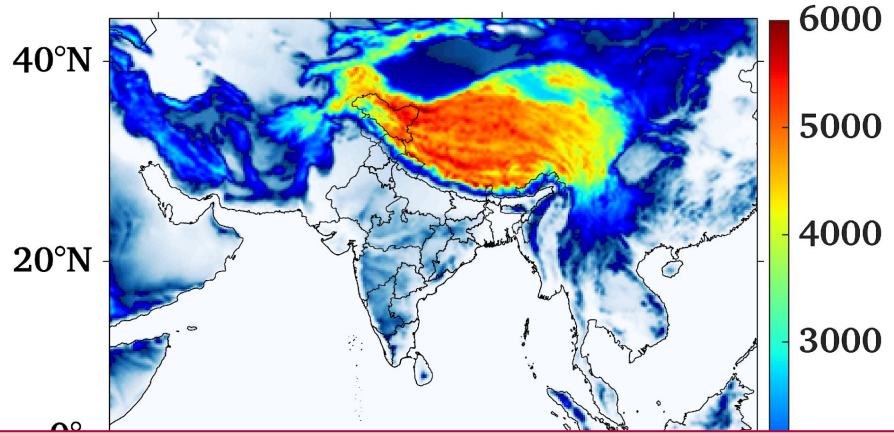
- WRF model version 4.6.0
- 3D-Var

Added INSAT-3DS in WRFDA code

- Domain 1: 12 km
- Period: 1-31 July 2024
- Forecast hours: 72 hours
- NMC method

- Additional control variables (CV) are **qc, qi, qr, qs, and qg** in generalized B using Descombes et al. (2015)
- The multivariate correlation of cloud and rain CV with moisture is considered.
- No cross-correlation is considered for the CV related to the mixing ratios of snow, ice, and graupel.

Methodology



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Need more research for B_{Gen}

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Data Used

- NCEP GFS for IC/LBC
- Conventional (Sonde, Synop, Metar, Buoy, Ship, Pilot, etc.)
- Scatterometer OSW and GEO AMVs
- GPS RO Refractivity

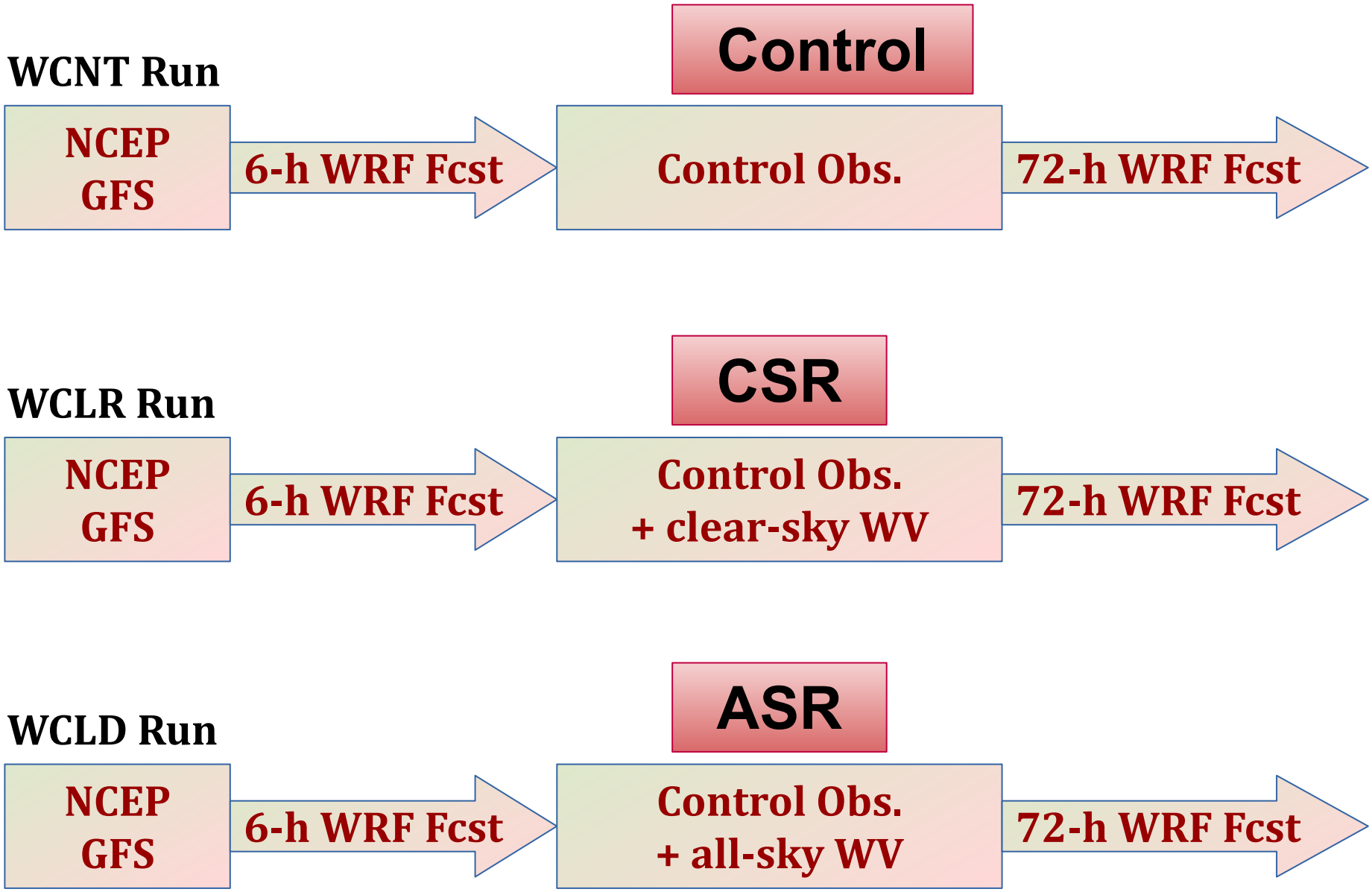
Channel	Spectral Band (μm)	Spatial Resolution at Nadir (km)
VIS	0.55-0.75	1 km
SWIR	1.55-1.68	1 km
MIR	3.80-4.00	4 km
WV	6.5-7.1	8 km
TIR-1	10.3-11.3	4 km
TIR-2	11.5-12.5	4 km

- WV radiance from INSAT-3DS Imager
- HIRS4, MHS, ATMS for analysis/forecast verification
- ERA5 reanalysis for analysis/forecast verification
- GSMaP_ISRO rainfall for forecast verification

Long-Term High-Resolution Gauge Adjusted Satellite Rainfall Product Over India

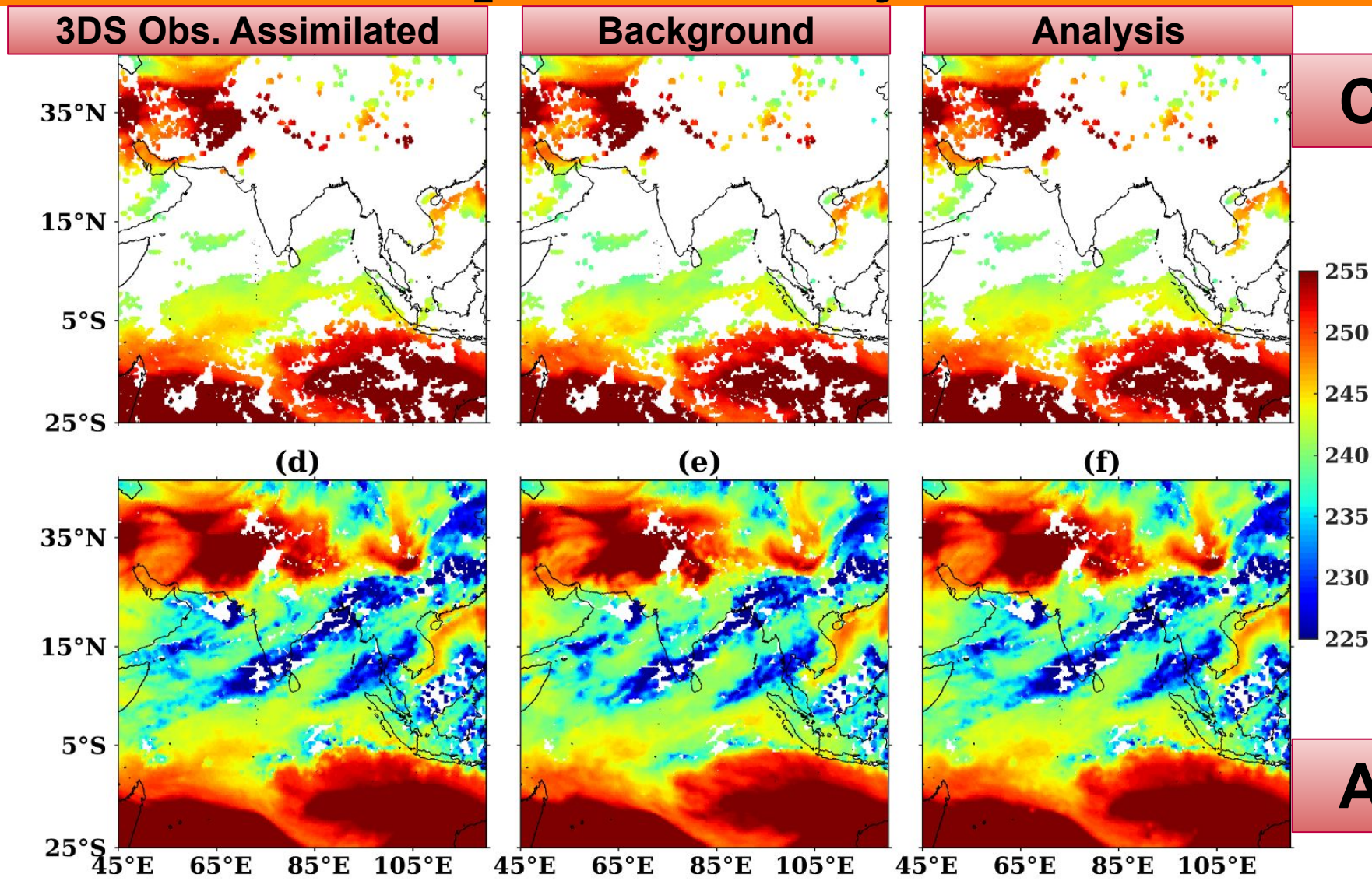
Prashant Kumar, Atul K. Varma, Takuji Kubota, Moeka Yamaji, Tomoko Tashima, Tomoaki Mega, Tomoo Ushio

Methodology



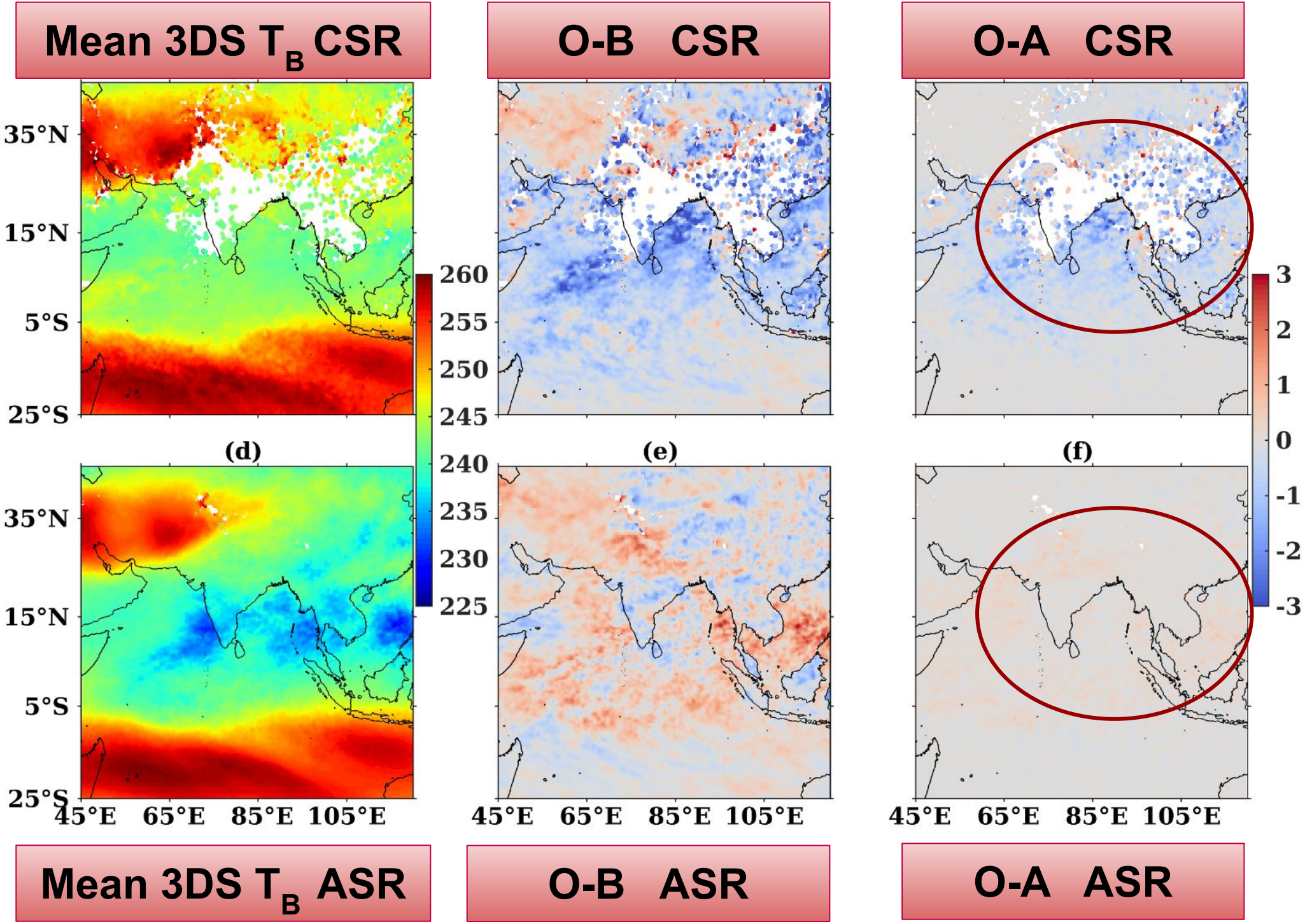
July 2024

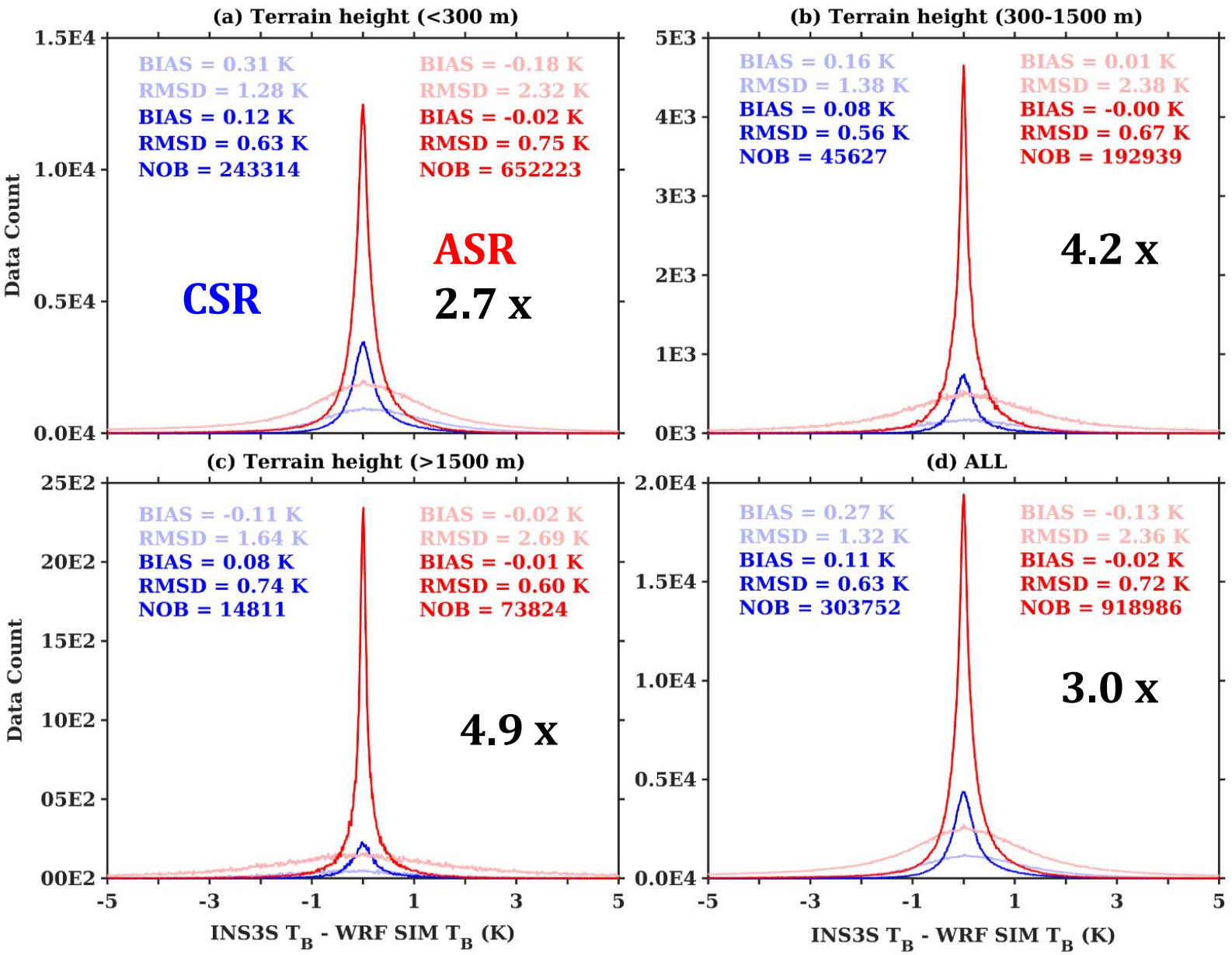
Impact in Analysis



INSAT-3DS WV T_B assimilated in the (a) CSR and (d) ASR runs, Simulated WV T_B from (b) CSR background, (c) CSR analysis, (e) ASR background, (f) ASR analysis

Sample day: 1 July 2024

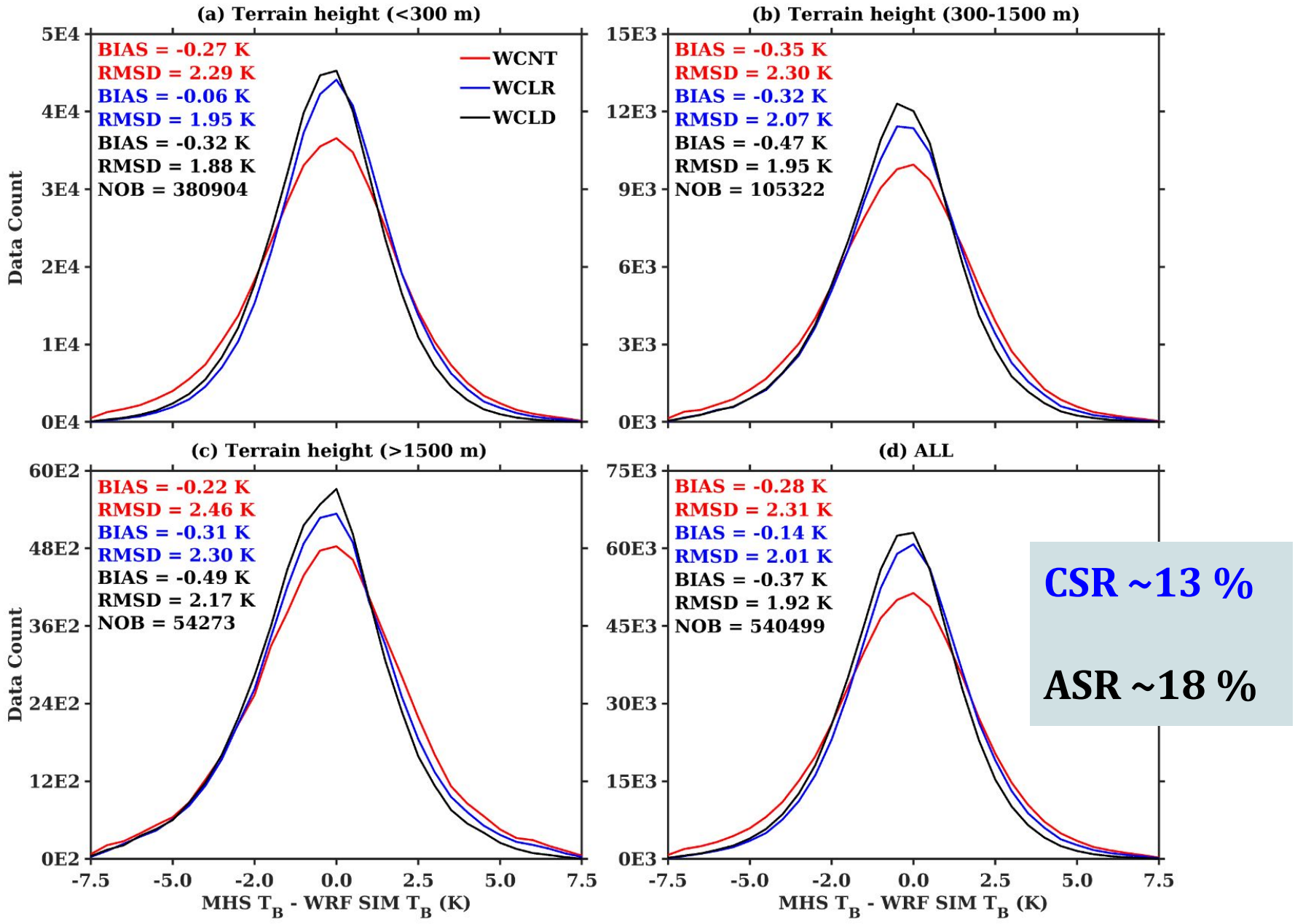

Mean 3DS T_B CSR
O-B CSR
O-A CSR
35°N
15°N
5°S
25°S
260
255
250
245
240
235
230
225
3
2
1
0
-1
-2
-3
(d)
(e)
(f)
45°E
65°E
85°E
105°E
Mean 3DS T_B ASR
O-B ASR
O-A ASR
July 2024



Background departure (light color)
Analysis departure (dark color)

Entire month of July 2024.

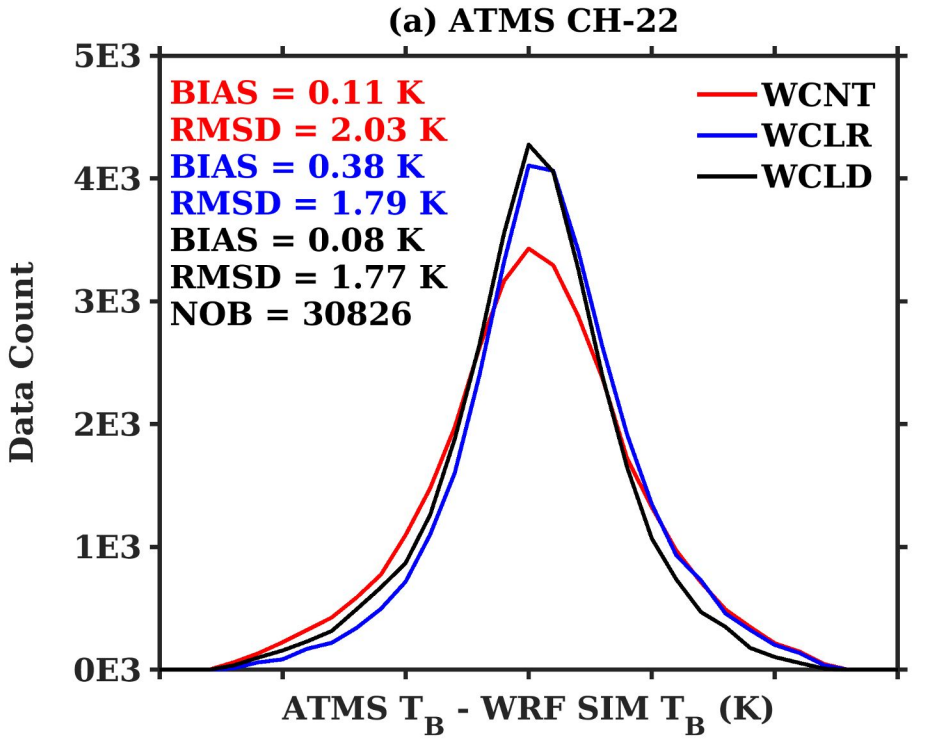
(a) low (<300 m),
(b) mid (300 to 1500 m),
(c) high (>1500 m),
(d) all terrain height

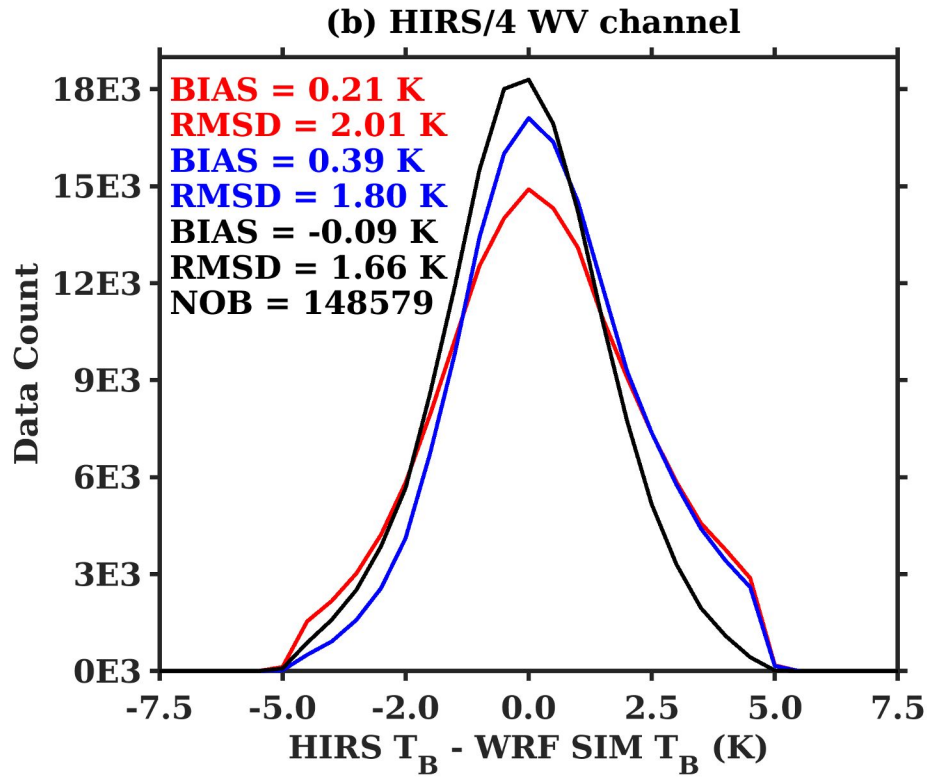


CSR ~13 %

ASR ~18 %

WRF simulated Analysis T_B against MHS channel-3 (183.31±1.0 GHz) T_B for (a) low (<300 m), (b) mid (300-1500 m), (c) high (>1500 m), (d) all terrain height.





CSR ~12 %

ASR ~13 %

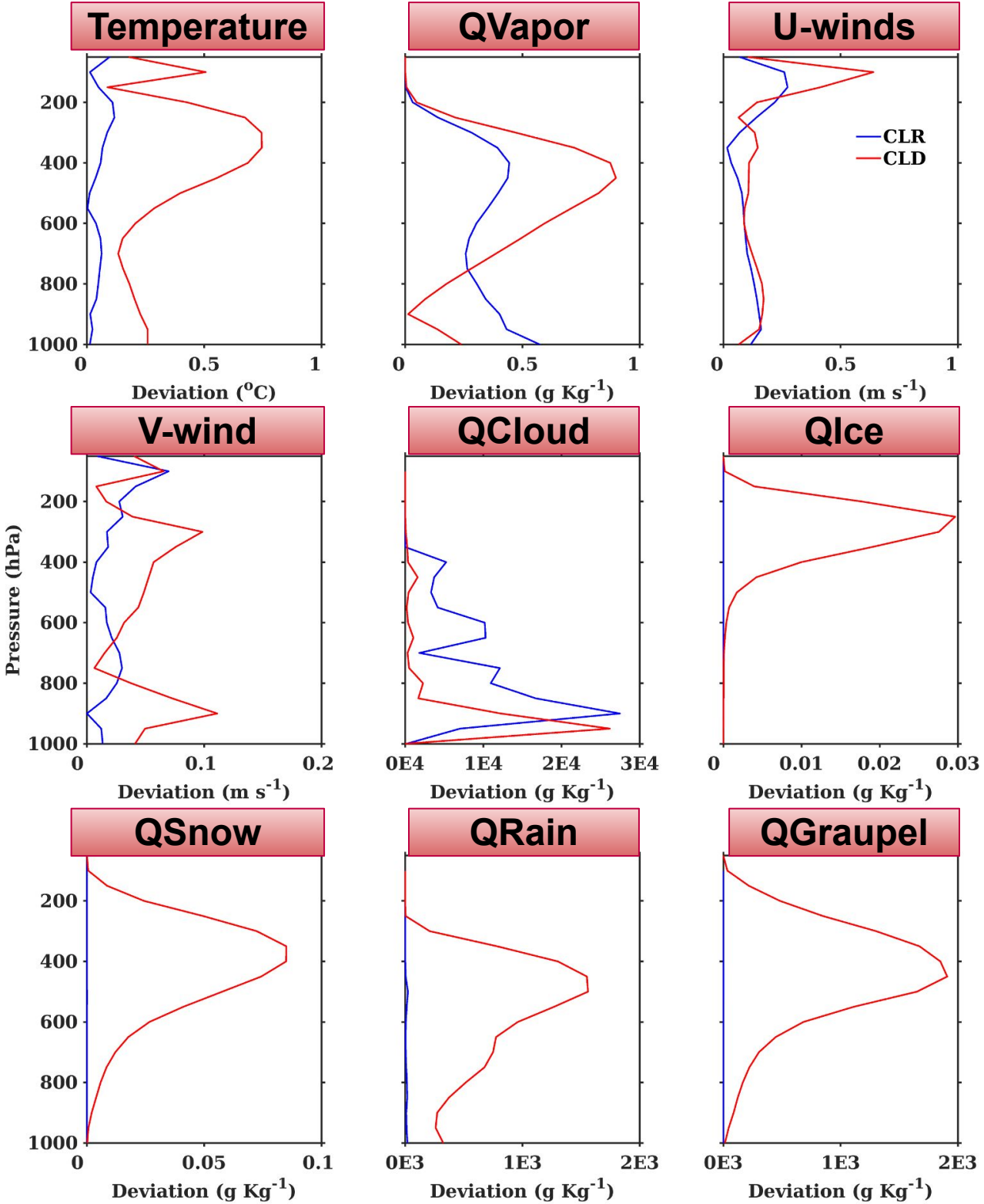
WRF simulated T_B against

(a) ATMS channel-22 (183.31 ±1.0 GHz) T_B ,

(b) HIRS/4 channel-12 (6.52 μm) during July 2024.

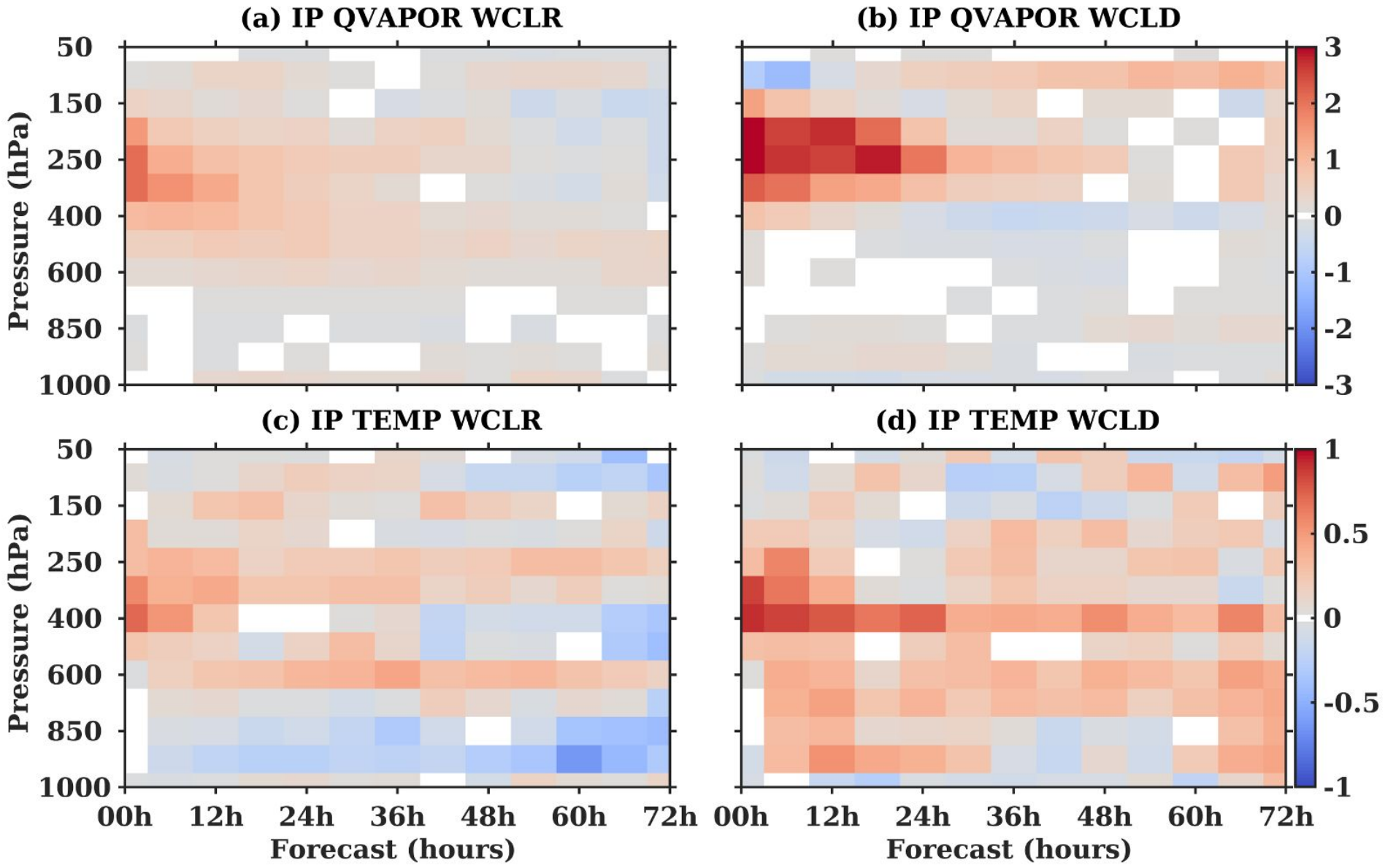
CSR ~10 %

ASR ~17 %



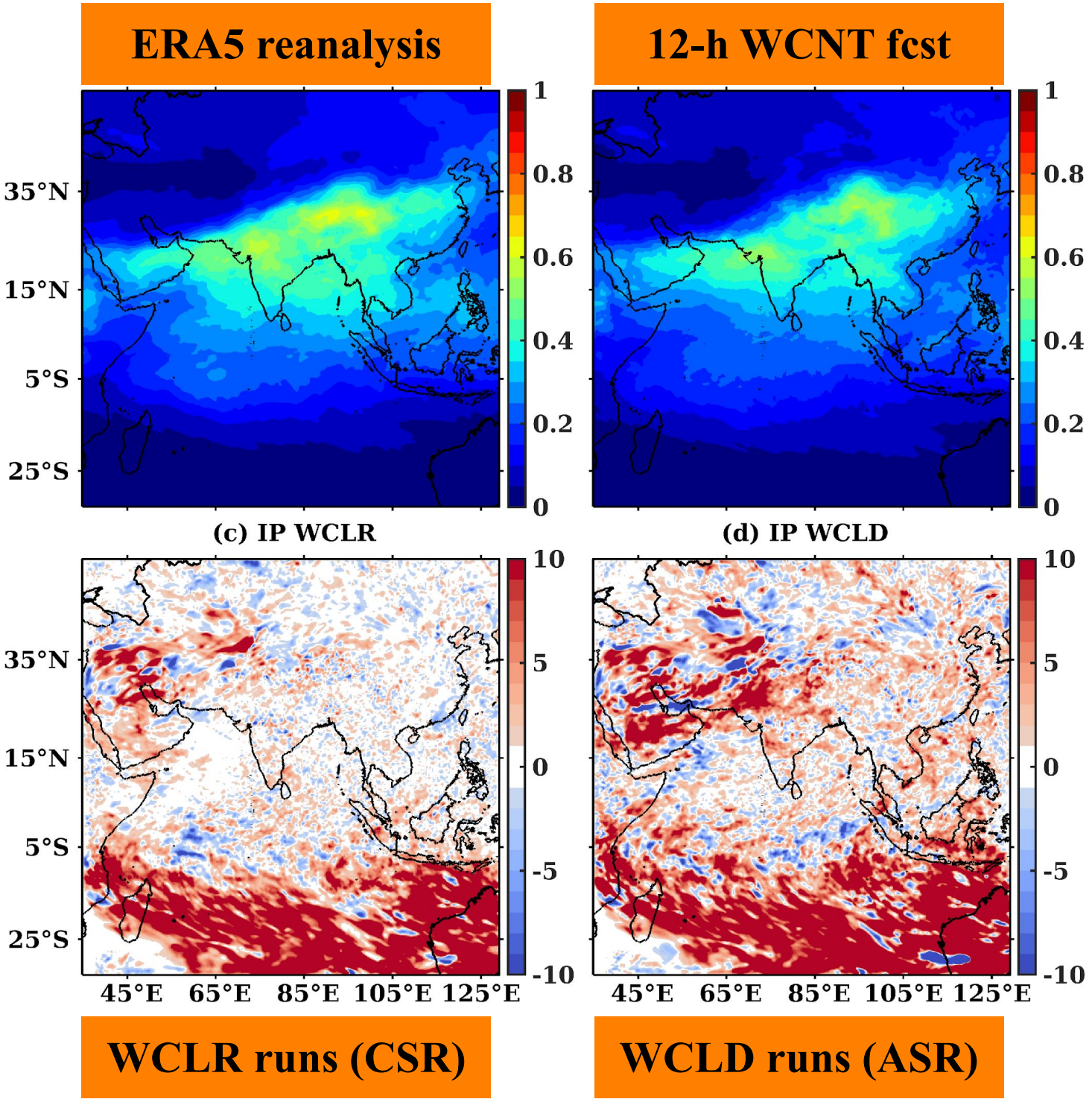
Vertical profile of mean deviation in CSR and ASR runs compared with WCNT runs during July 2024.

Impact in Forecast



Improvement parameter (IP) for the humidity (QVAPOR; **upper**) and temperature (TEMP; **below**) forecasts, **ERA5 reanalysis as reference**

Positive (negative) —- improvement (degradation) **Period - July 2024**

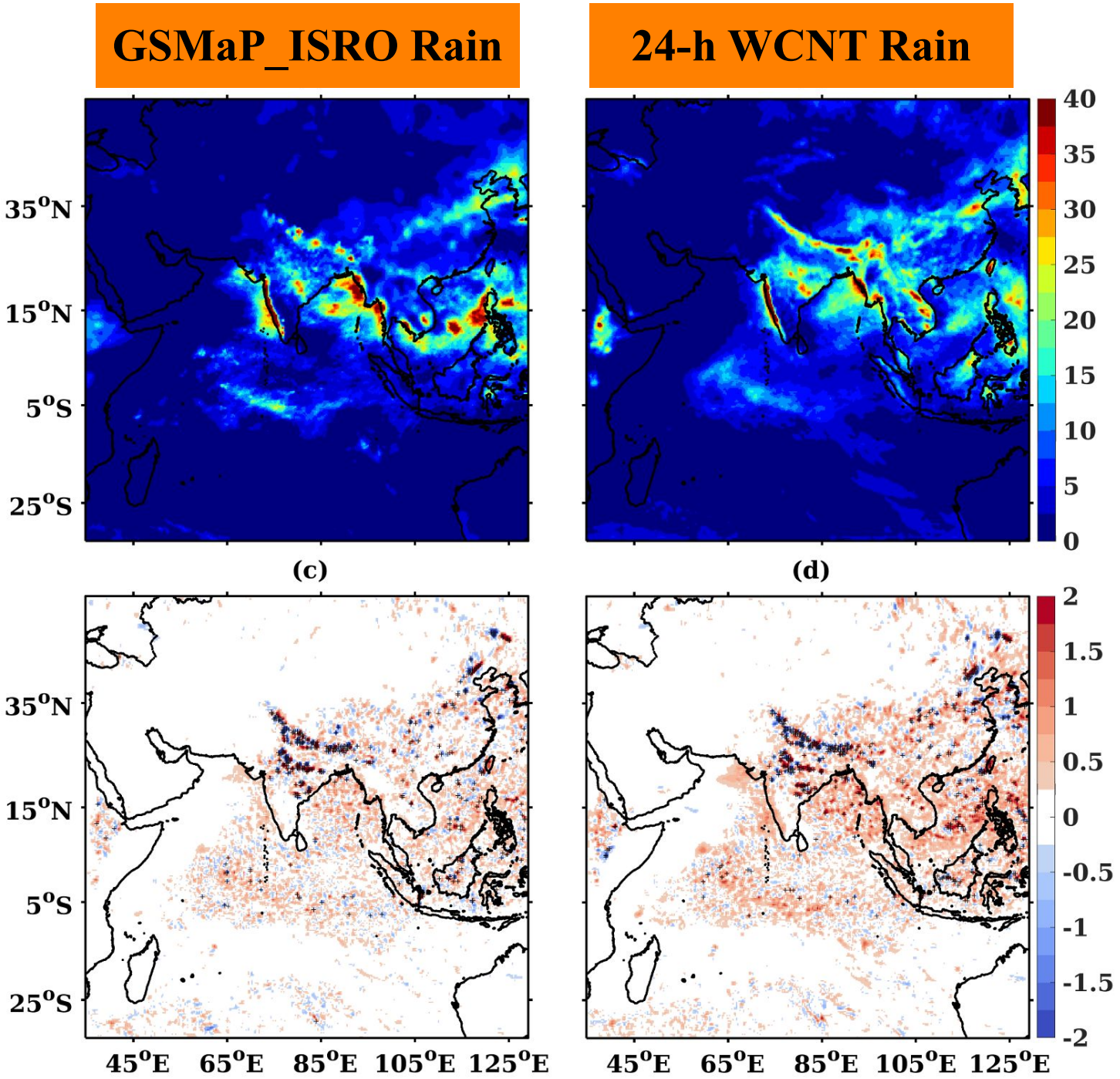


Mean humidity (g/Kg) at 250 hPa

% improvement during July 2024

improvement

degradation



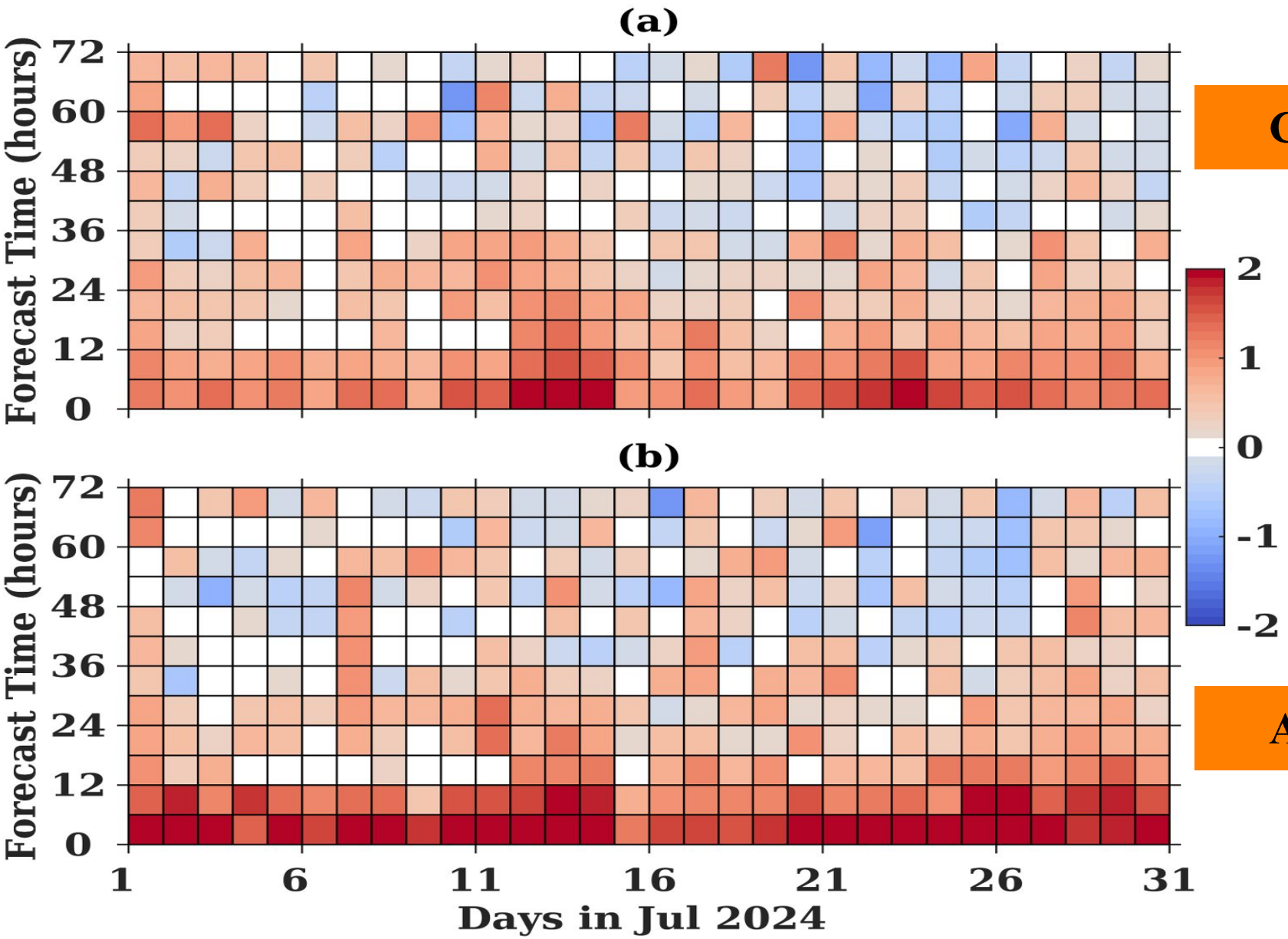
Mean rainfall (mm/day)

% improvement

July 2024

improvement

degradation



Improvement parameter in (a) WCLR and (b) WCLD INSAT-3DS WV T_B against WCNT simulated T_B, **INSAT-3DS WV T_B observations as reference**

improvement
degradation

Conclusion

- **The number of assimilated WV radiance increased by ~3 times in ASR runs compared to CSR runs.**
- **The ASR analyses are more consistent with independent satellite observations, particularly in the upper atmospheric levels where the maximum variation in hydrometeor profiles was observed.**
- **The positive impact of all-sky assimilation extends beyond the analysis stage, leading to improved short-range predictions of moisture, temperature, and T_B fields.**
- **Overall, this study demonstrates that assimilating all-sky WV radiance from the recently launched INSAT-3DS geostationary satellite proves both analyses and short-range forecasts.**

Way Ahead

- ★ The impact of frequent temporal sampling from INSAT-3DS is not considered
- ★ Fixed Value of R for clear and cloudy conditions
- ★ Correlation of CVs in generalized B
- ★ …

Thank you