GSMaP
GLOBAL SATELLITE MAPPING OF PRECIPITATION

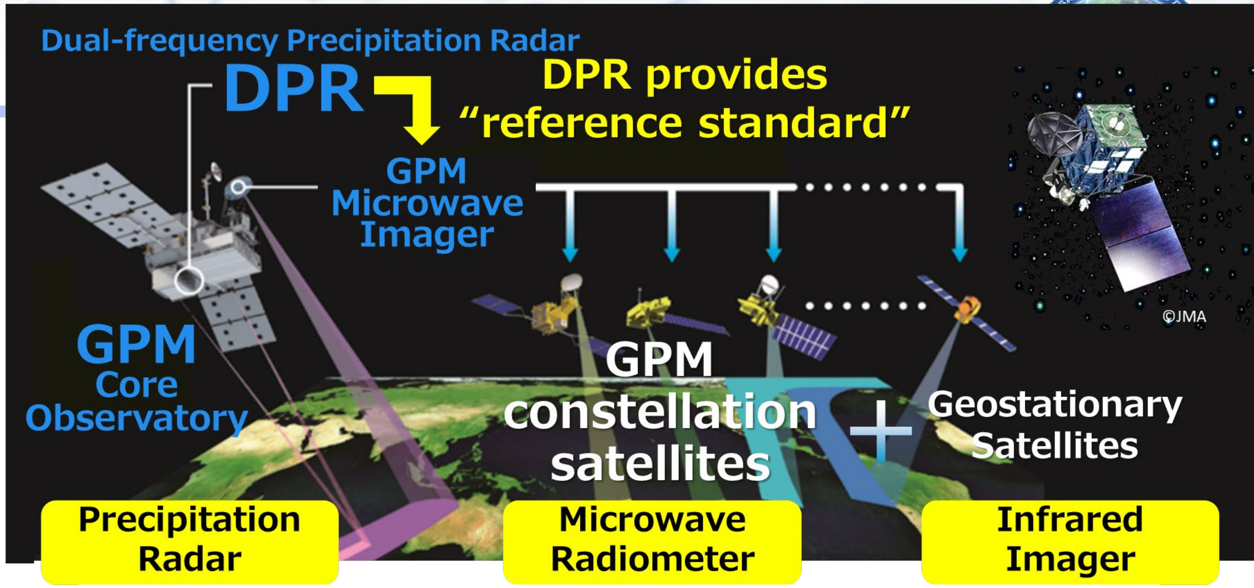
Orographic/nonorographic rainfall classification scheme in GSMaP

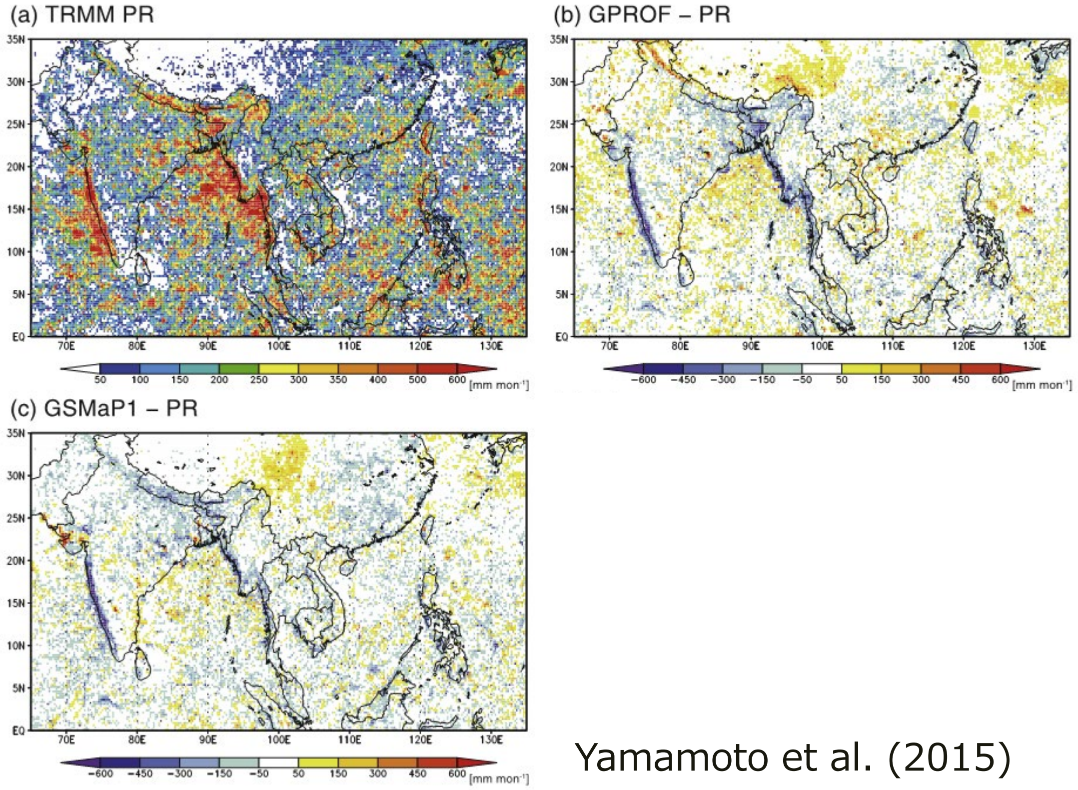
Munehisa K. Yamamoto[1], Masato Ito[2], Shoichi Shige[3], and Takuji Kubota[1]

1) Earth Observation Research Center, JAXA
2) Remote Technology Center of Japan
3) Graduate School of Sciences, Kyoto University

Introduction

- Precipitation estimates from PMW are often **underestimated** over mountainous regions such as **Western Ghats (WG)** due to presence of shallow but heavy precipitation associated with **warm rain processes**.
- To improve the underestimation of orographic precipitation, the **orographic/nonorographic rainfall classification scheme** has been implemented globally in the GSMaP algorithm.

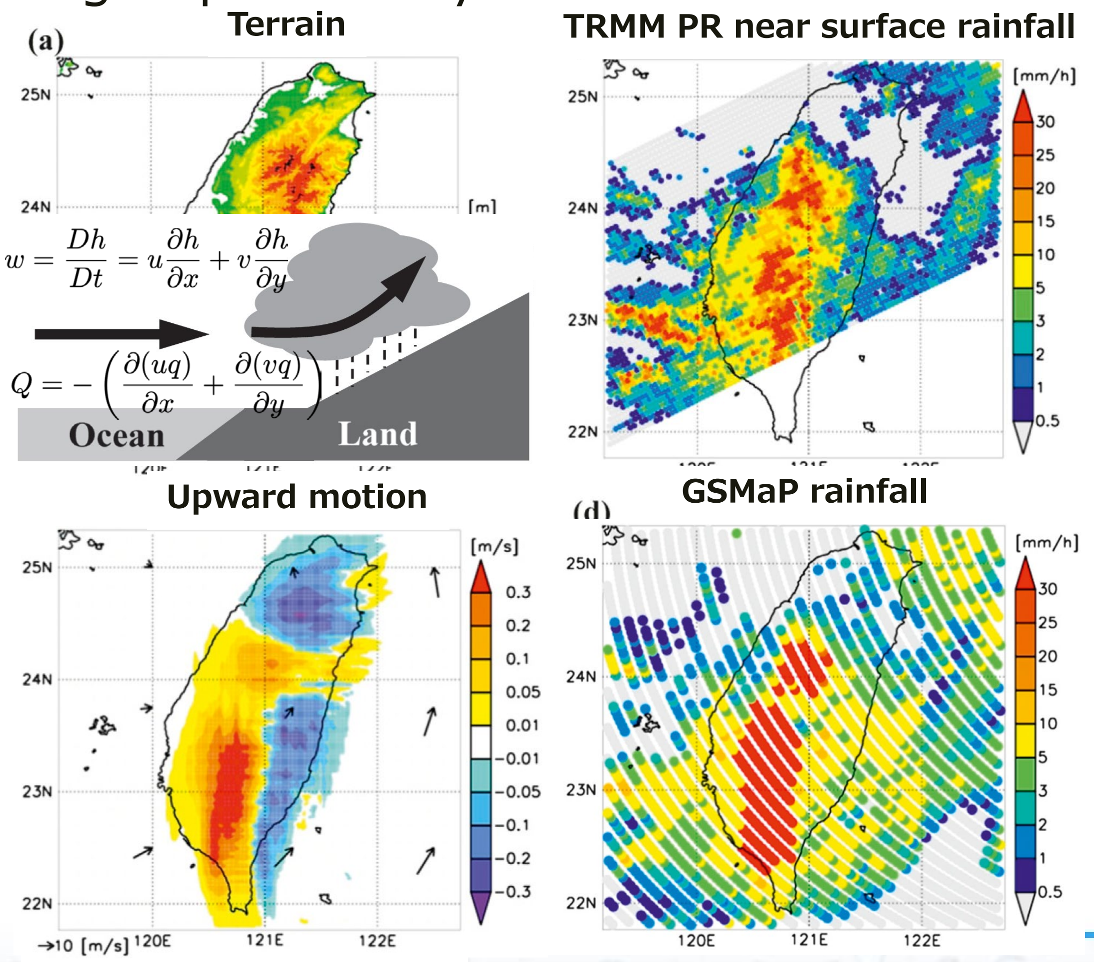


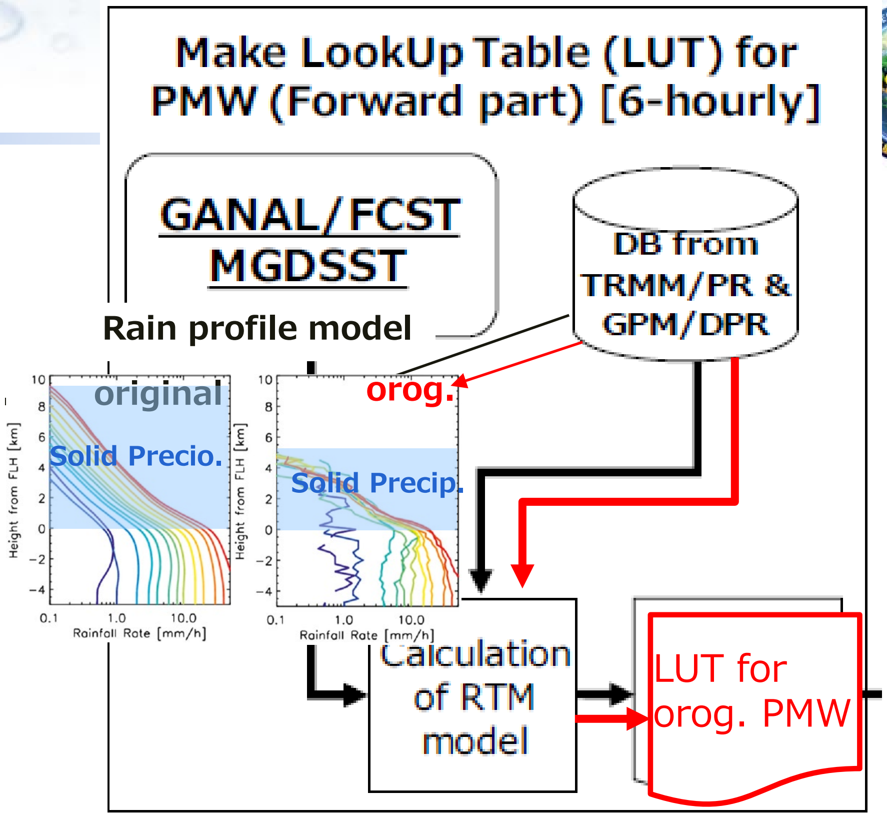


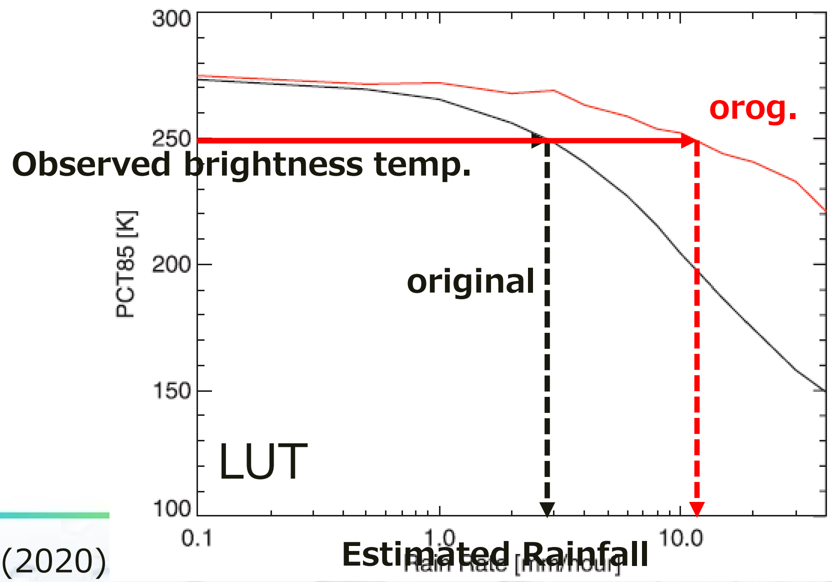
Yamamoto et al. (2015)

Orographic/nonorogrpahic rainfall classification scheme

- **Orographic rainfall condition** is detected from **<u>orographically forced upward motion</u>** and **<u>convergence of moisture flux</u>**.
- LUT and graupel density is switched in the condition.

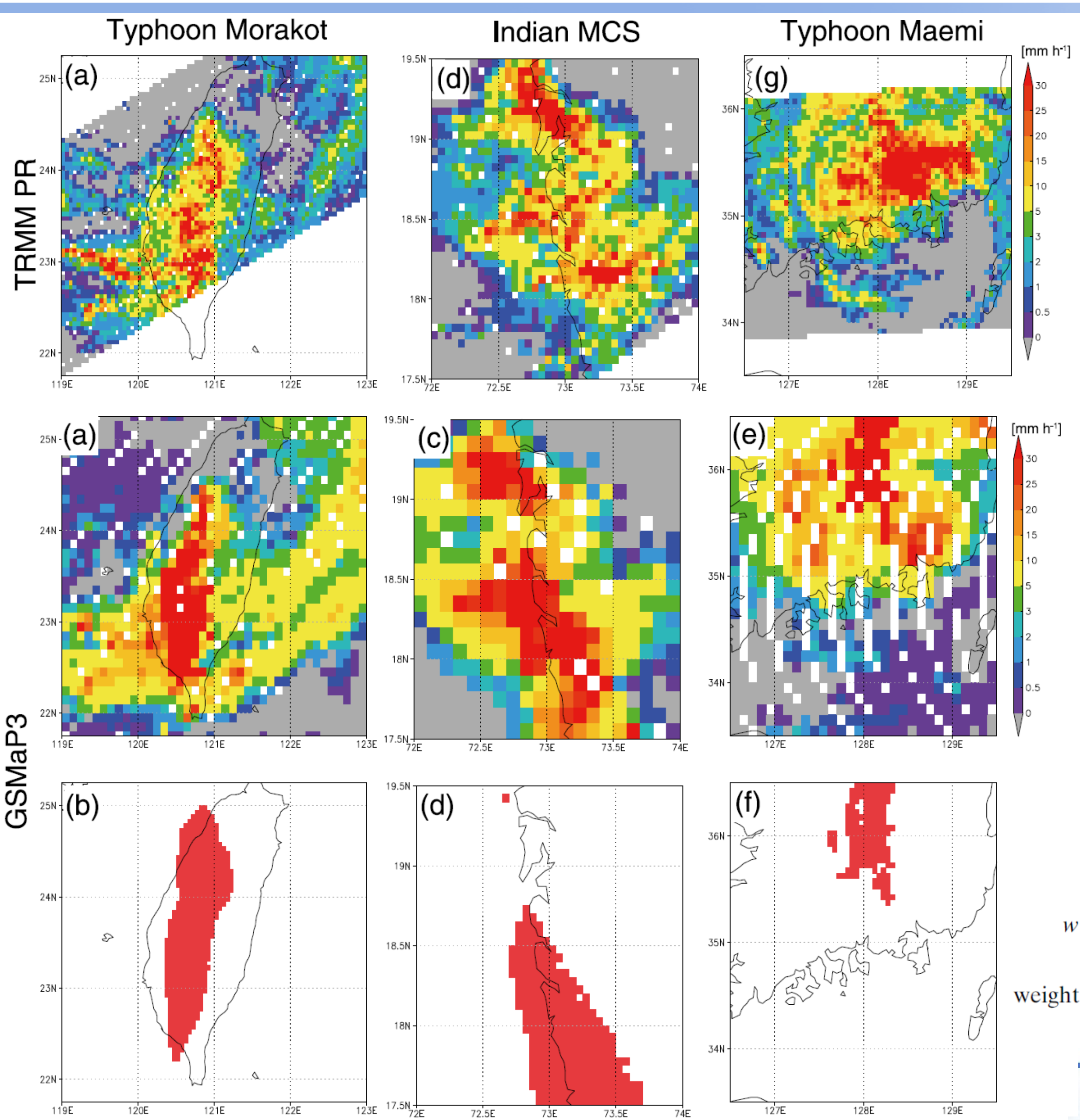




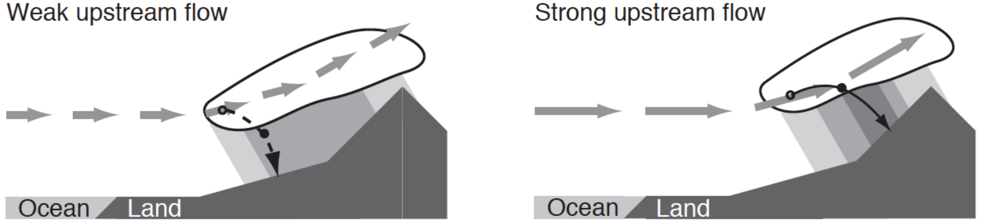


Taniguchi et al. (2013), Shige et al. (2013), Kubota et al. (2020)

Orographic rainfall scheme updates (previous ver.)



- V03 (released in 2014)
  - Newly implemented globally
    - ☺Improvement of rainfall underestimation around WG
    - ☹False alarm/overestimation for orographic rainfall detection/estimation
- V04 (released in 2017)
  - Considered rainfall enhancement by low-level upslope wind
  - Modification of rain amount using 37 GHz information
    - ☺ Improvement of false alarm/overestimation
    - ☹ No detection over in land region/convective rainfall type



$$w = 0.01 + \text{weight} \times 0.19 \quad \text{and}$$

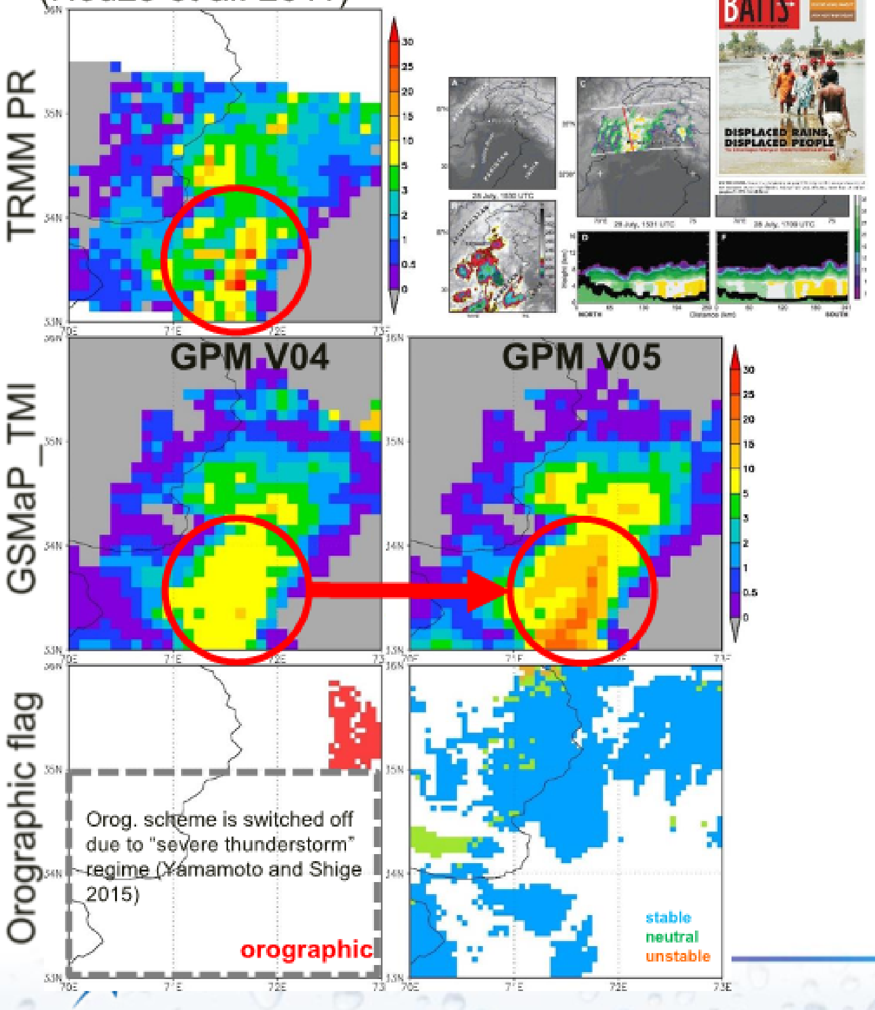
$$\text{weight} = \begin{cases} 0 & \text{for} \quad U < 10\,\text{m s}^{-1} \\ (U - 10)/10, & \text{for} \quad 10 \le U \le 20\,\text{m s}^{-1} \\ 1 & \text{for} \quad U > 20\,\text{m s}^{-1} \end{cases}$$

$$\text{rainpct3785} = \text{weight} \times \text{rainpct37} + (1.0 - \text{weight}) \times \text{rainpct85} \quad \text{and}$$

$$\text{weight} = \begin{cases} 0 & \text{for} \quad \text{rainpct85} < 1\,\text{mm h}^{-1} \\ (\text{rainpct85} - 1.0)/(10.0 - 1.0) & \text{for} \quad 1 \le \text{rainpct85} \le 10\,\text{mm h}^{-1} \\ 1 & \text{for} \quad \text{rainpct85} > 10\,\text{mm h}^{-1} \end{cases}$$

Orographic rainfall scheme updates (current ver.)

Pakistan Heavy rainfall event in 28 Jul. 2010
(Houze et al. 2011)



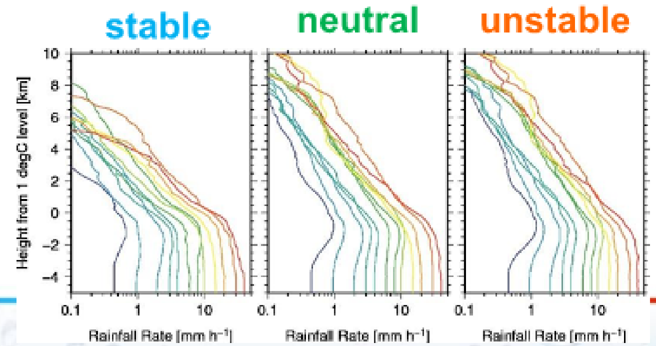
Issues of orographic rainfall scheme in GPM V04:
Switching off of the scheme over the regions with strong lightning activity results in underestimation of warm orographic rainfall such as Pakistan Heavy rainfall event in 28 Jul. 2010.

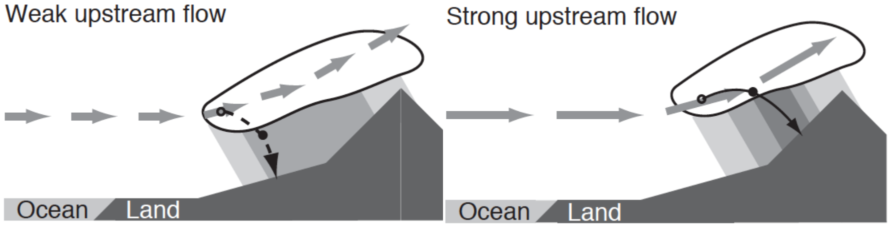
↓

Low-level static stability (Shige and Kummerow 2016) enable the scheme to detect warm orographic rainfall over the regions with strong lightning activity

- Stable upslope: -5.5 < dTv/dz
- Neutral upslope: -6.5 < dTv/dz ≤ -5.5
- Unstable upslope: dTv/dz ≤ -6.5

dTv/dz: raplse rate of virtual temperature < 1.5 km above surface [K km^{-1}]





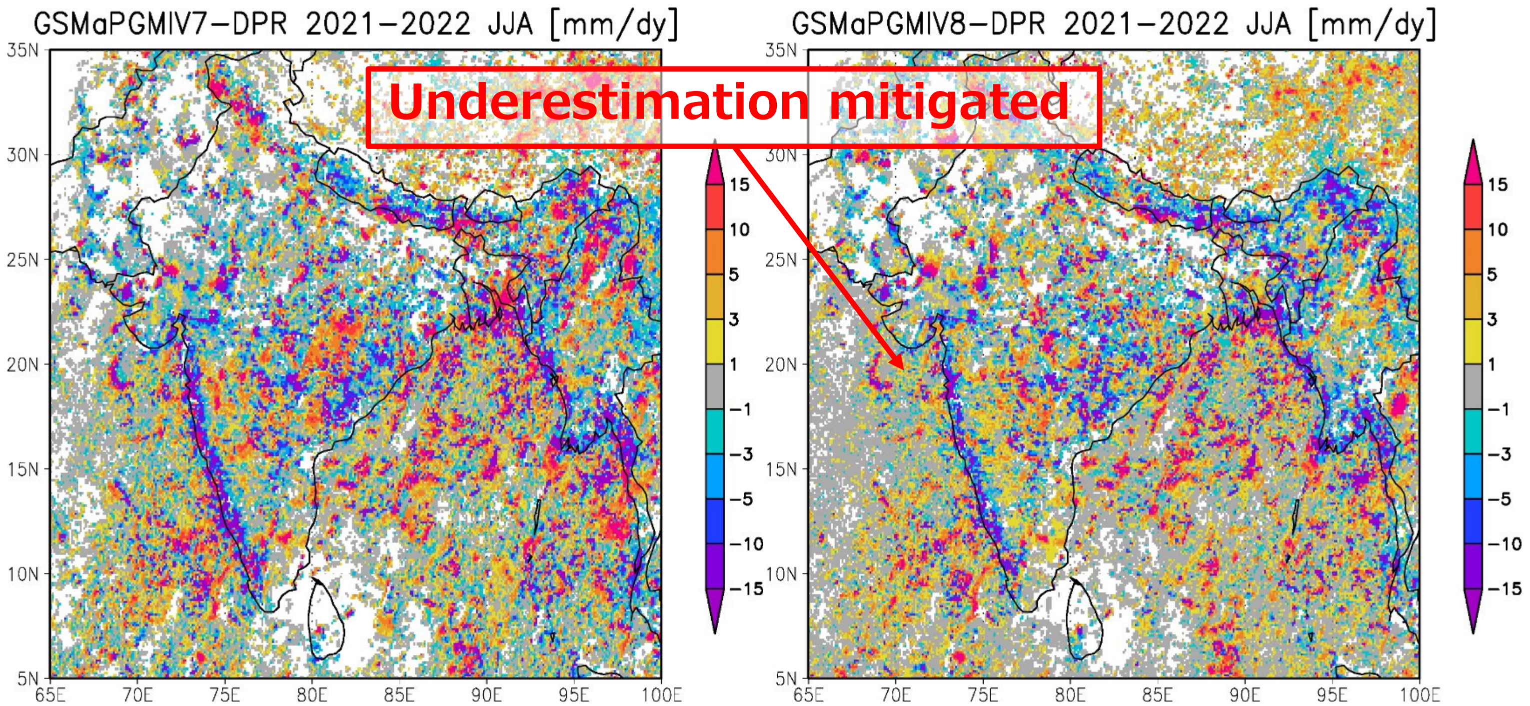
$$w = 0.01 + \text{weight} \times 0.19 \quad \text{and}$$

$$\text{weight} = \begin{cases} 0 & \text{for} \quad U < 10\,\text{m}\,\text{s}^{-1} \\ (U - 10)/10, & \text{for} \quad 10 \le U \le 20\,\text{m}\,\text{s}^{-1} \\ 1 & \text{for} \quad U > 20\,\text{m}\,\text{s}^{-1} \end{cases}$$

$$\text{rainpct3785} = \text{weight} \times \text{rainpct37} + (1.0 - \text{weight}) \times \text{rainpct85} \quad \text{and}$$

$$\text{weight} = \begin{cases} 0 & \text{for} \quad \text{rainpct85} < 1\,\text{mm}\,\text{h}^{-1} \\ (\text{rainpct85} - 1.0)/(10.0 - 1.0) & \text{for} \quad 1 \le \text{rainpct85} \le 10\,\text{mm}\,\text{h}^{-1} \\ 1 & \text{for} \quad \text{rainpct85} > 10\,\text{mm}\,\text{h}^{-1} \end{cases}$$

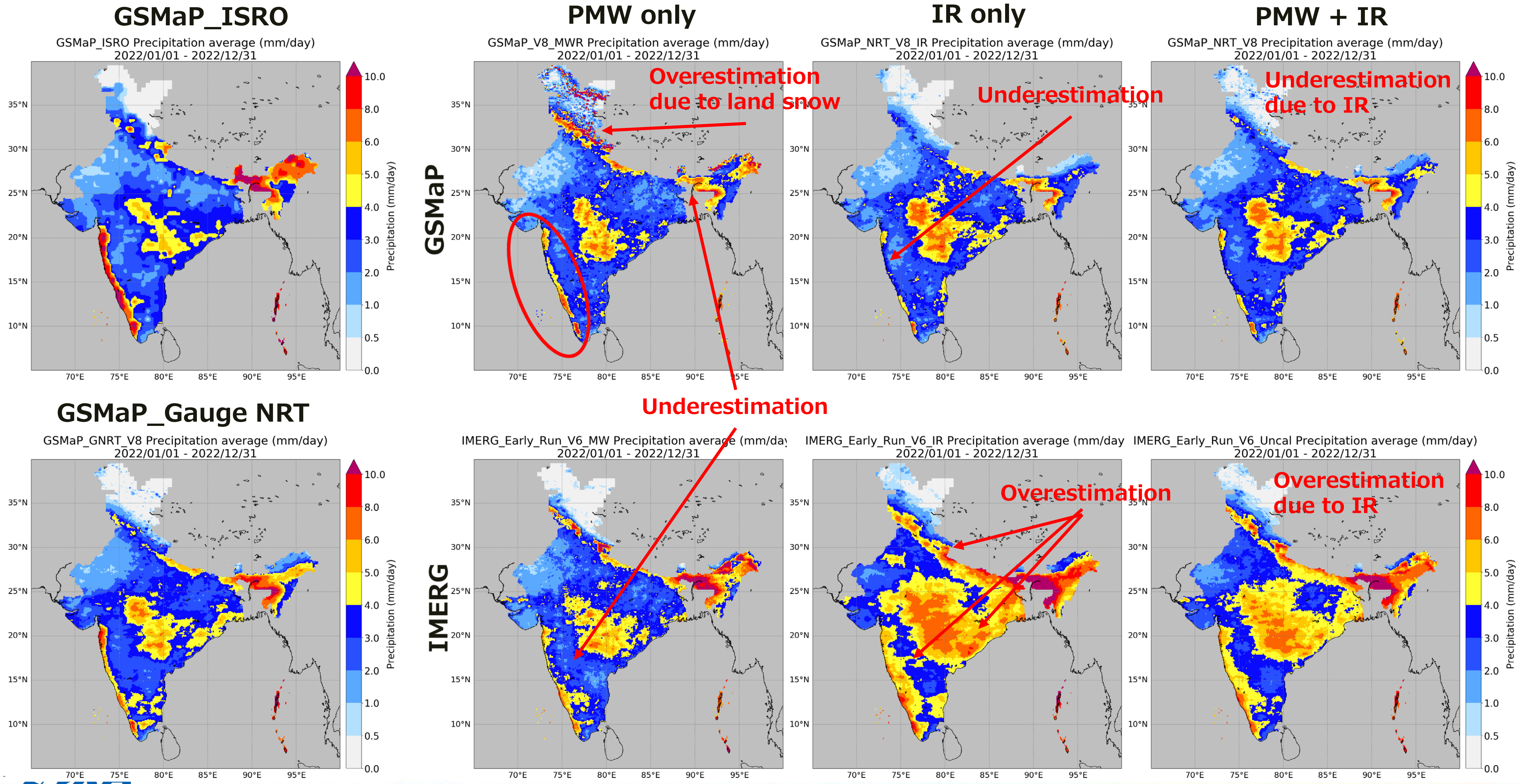
Evaluation of GSMaP GMI against DPR/GSMaP_ISRO



Performance indices against GSMaP_ISRO (IMD gauge corrected GSMaP)

	NUM			RAIN AMOUNT	
	POD	FAR	MISS	/ISRO	MISS
GMIV04	0.22	0.04	0.78	1.44	0.53
GMIV05	0.23	0.04	0.77	1.01	0.51

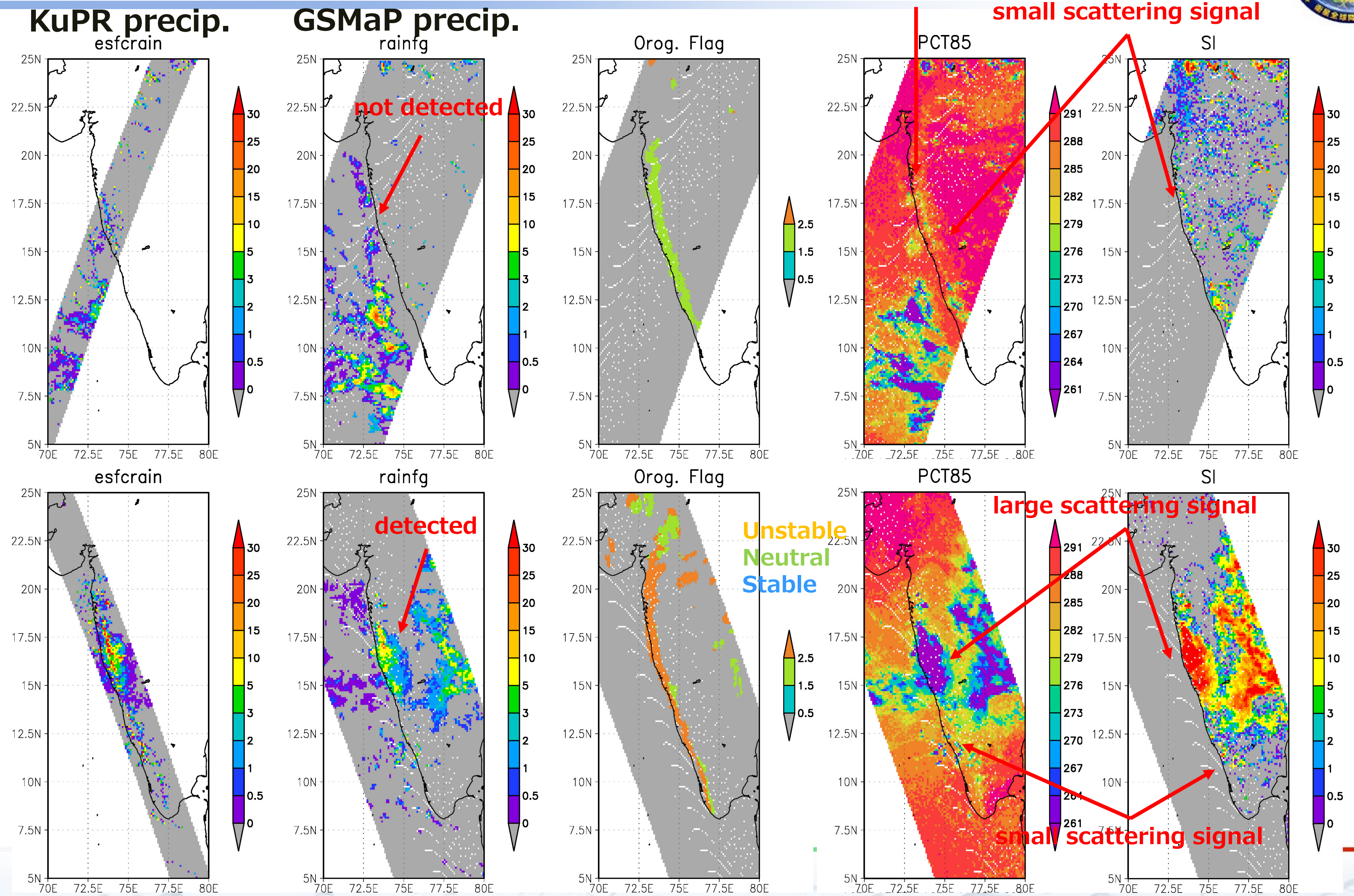
Evaluation of GSMaP_NRT V8 / IMERG Early Run V6 (Annual precip in 2022)



Case study

08 Aug. 2021
(neutral case)

22 Aug. 2021
(unstable case)



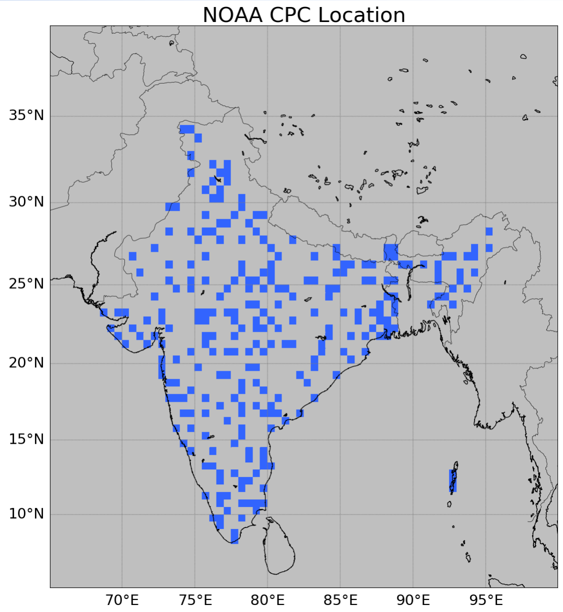
Summary

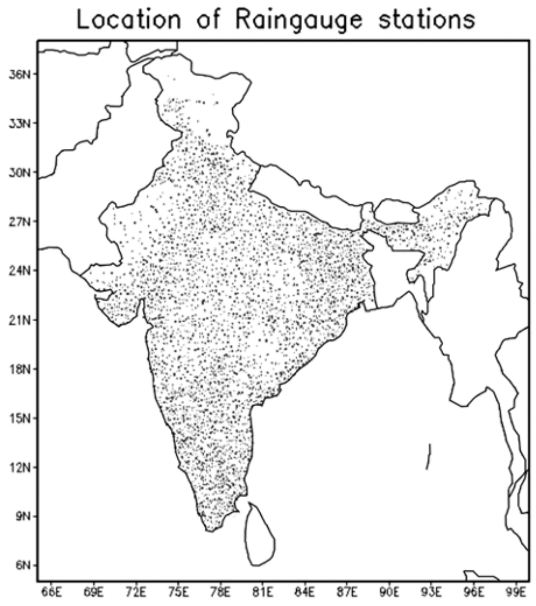
- Orographic/nonorographic rainfall classification scheme was updated in the latest version (V05) of GSMaP, changing classification factor from moisture flux to static stability to detect inland orographic rainfall.
- GSMaP GMI V04/V05 is evaluated against GPM DPR and IMD rain gauge corrected data (GSMaP_ISRO).
  - Bias of monthly mean rainfall for GSMaP GMIV05 is mitigated compared to V04.
  - Overestimated tendency of orographic rainfall is also mitigated in hit cases (> 0 mm h^{-1} both GMI and DPR/IMD)
  - Rainfall detection remains issue due to small scattering signals
- Orographic rainfall is classified into PMW and IR estimation in GSMaP/IMERG

	PMW	**IR**
GSMaP	light underestimation	underestimation
IMERG	underestimation	overestimation

Data, Period, and Research area

- Period
  - January-December 2022
- Area
  - Indian mainland (partly WG only)
- Ground Truth
  - GSMaP_ISRO (Kumar et al. 2022)
- Data

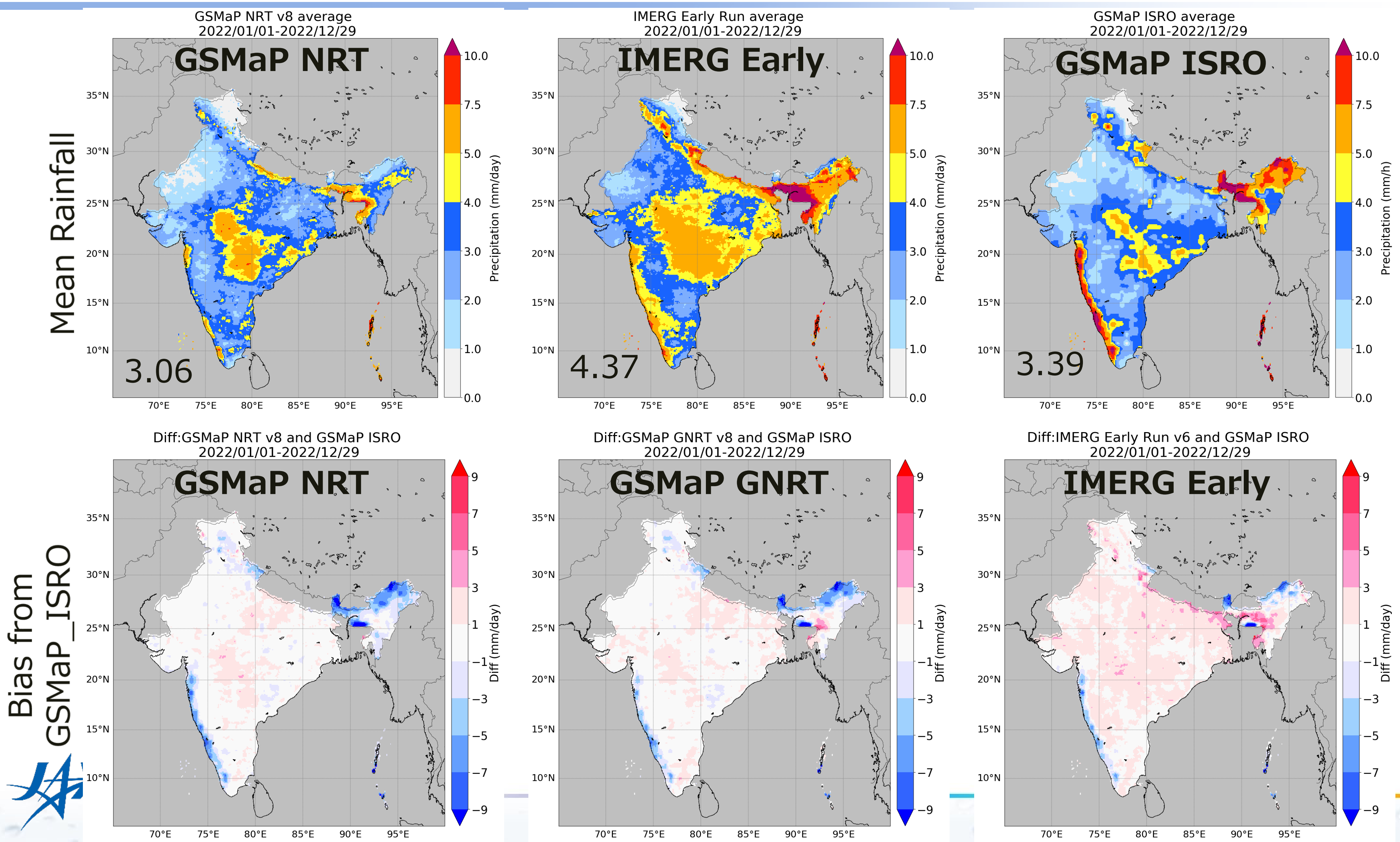




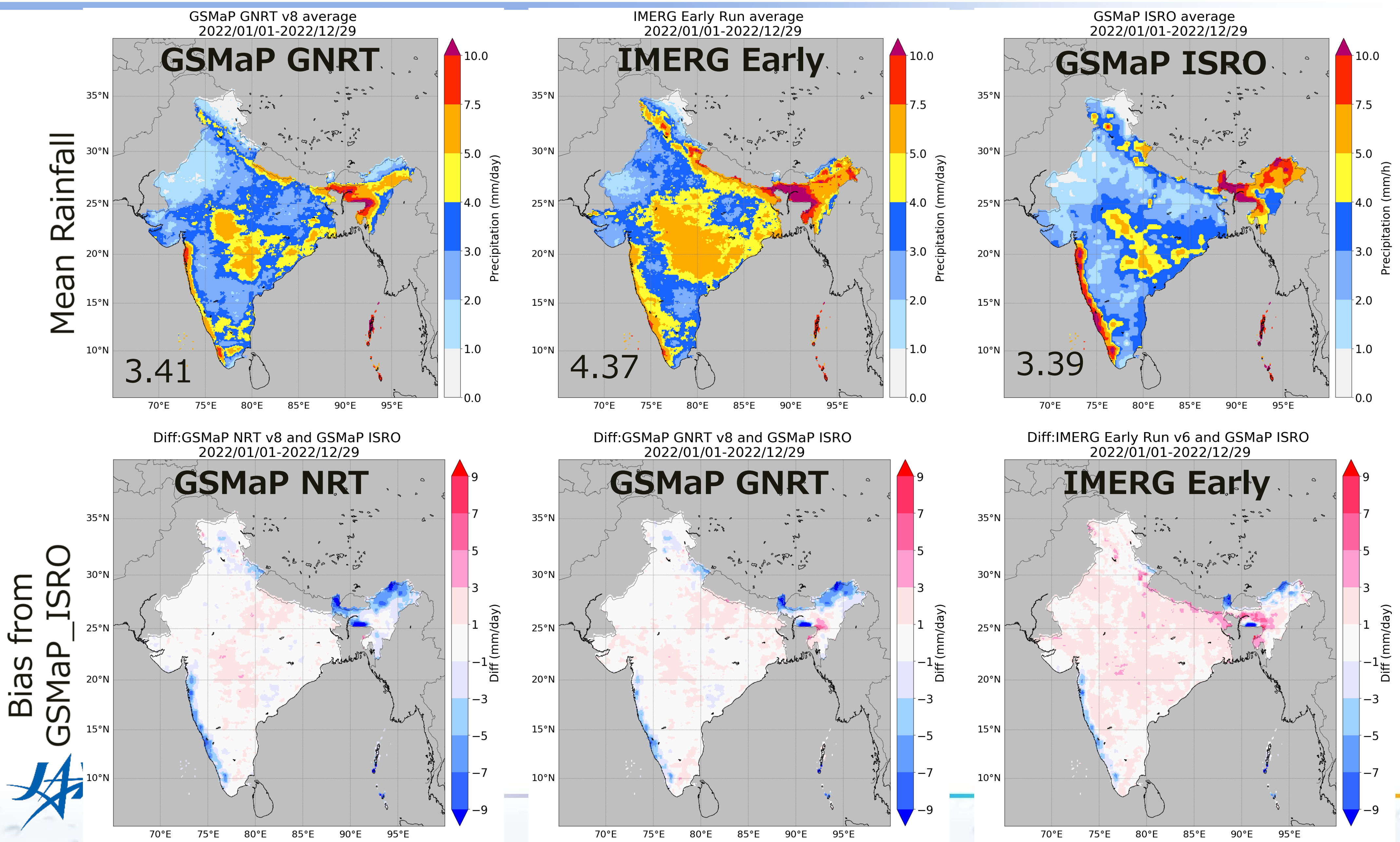
IMD rain gauge
Pai et al. (2014)

	GSMaP		IMERG	
	NRT	Early Run	Late Run	Final Run
Non Gauge Correction	NRT v8	PrecipitationUncal	PrecipitationUncal	PrecipitationUncal
Gauge Correction	GNRT v8			PrecipitationCal
Latency	4 hours	4 hours	12 hours	3.5 months

Mean & Bias of annual rainfall



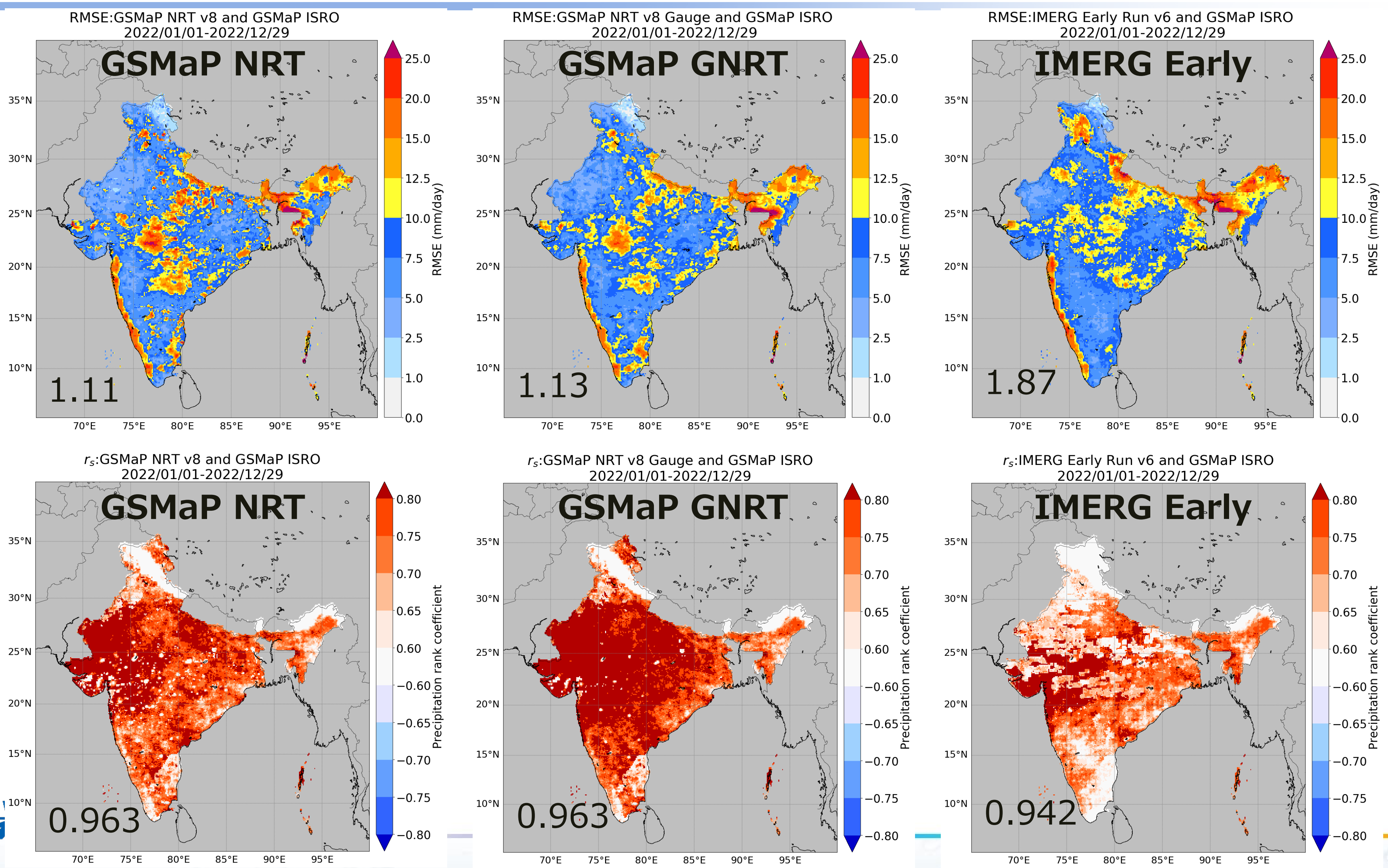
Mean & Bias of annual rainfall



RMSE & Spearman's rank correlation coefficient (r_s)

RMSE

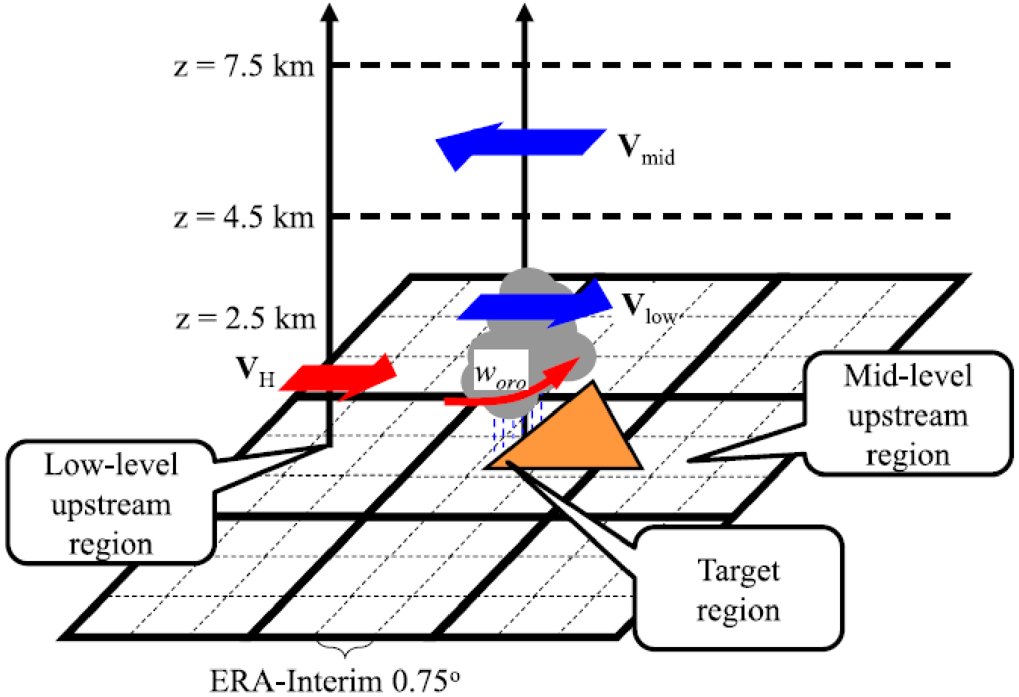
r_s



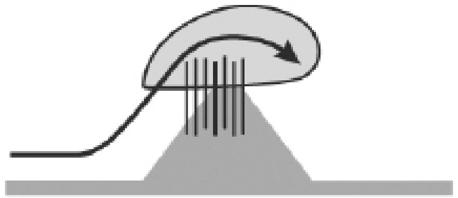
$$r_s = 1 - \frac{6\sum d_i^2}{n(n^2-1)},$$

$$d_i = \mathrm{R}(X_i) - \mathrm{R}(Y_i)$$

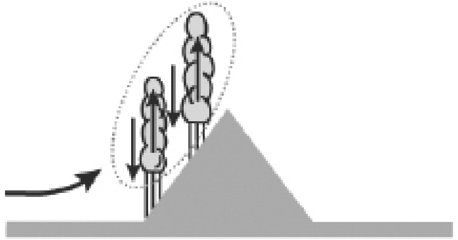
Relationship between thermodynamic parameters and precipitation top height



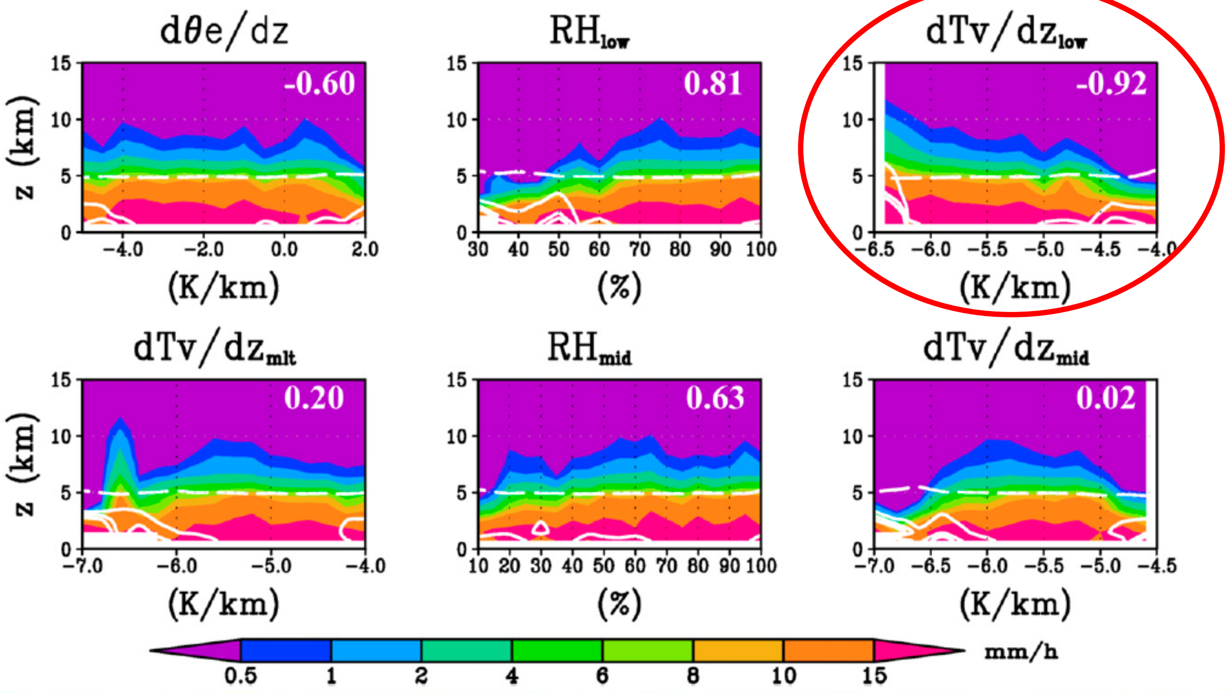
- Low-level static stability is the key parameter determining precipitation top heights
- Heavy orographic rainfall wigh low PTHs correspond to stable upslope mechanisms



Stable upslope mechanism



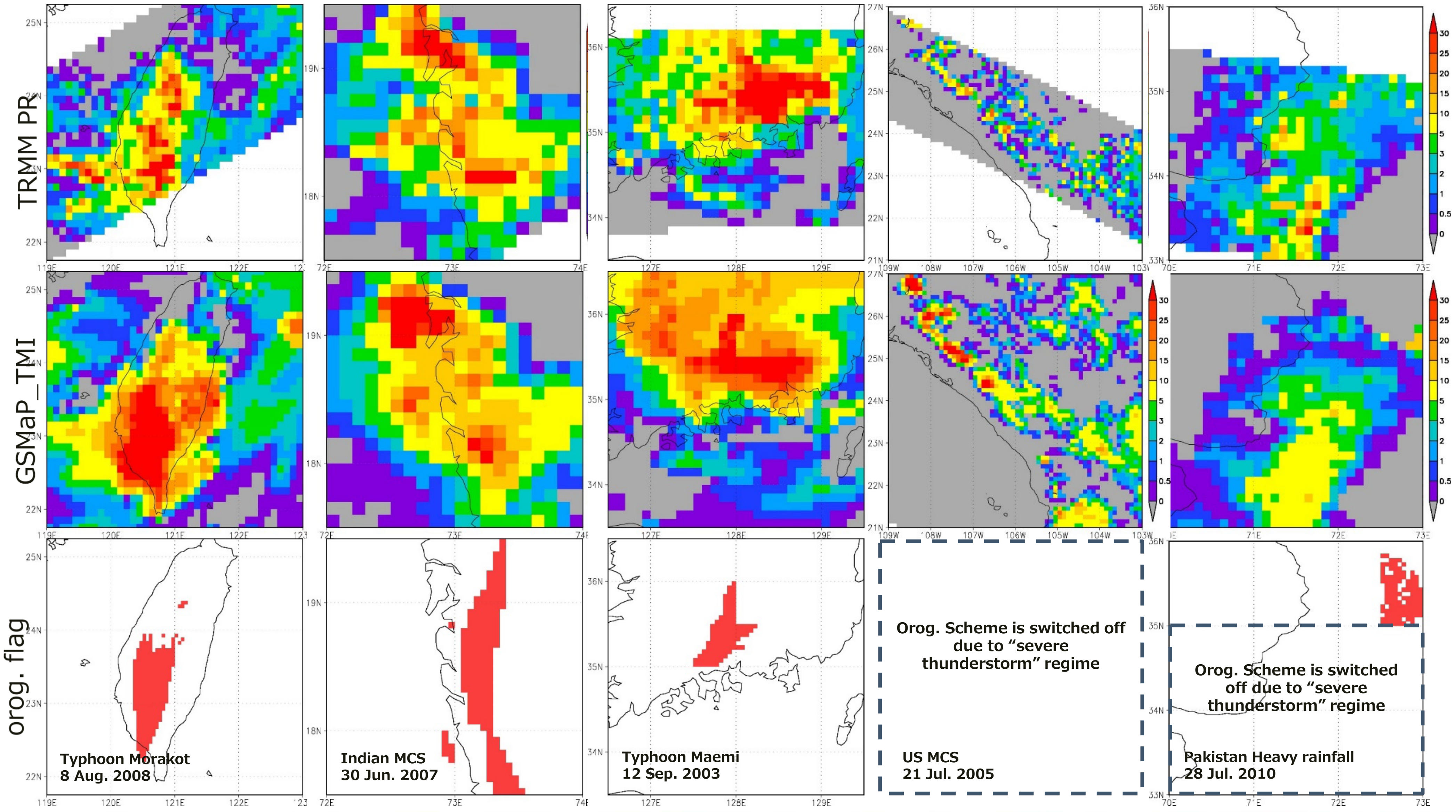
Unstable upslope mechanism



Houze (2012)

Shige and Kummerow (2016, JAS)

GSMaP V04 (previous ver.)



GSMaP V05 (current ver.)