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Improvement of the Heavy Orographic Rainfall Retrievals for Microwave Radiometers

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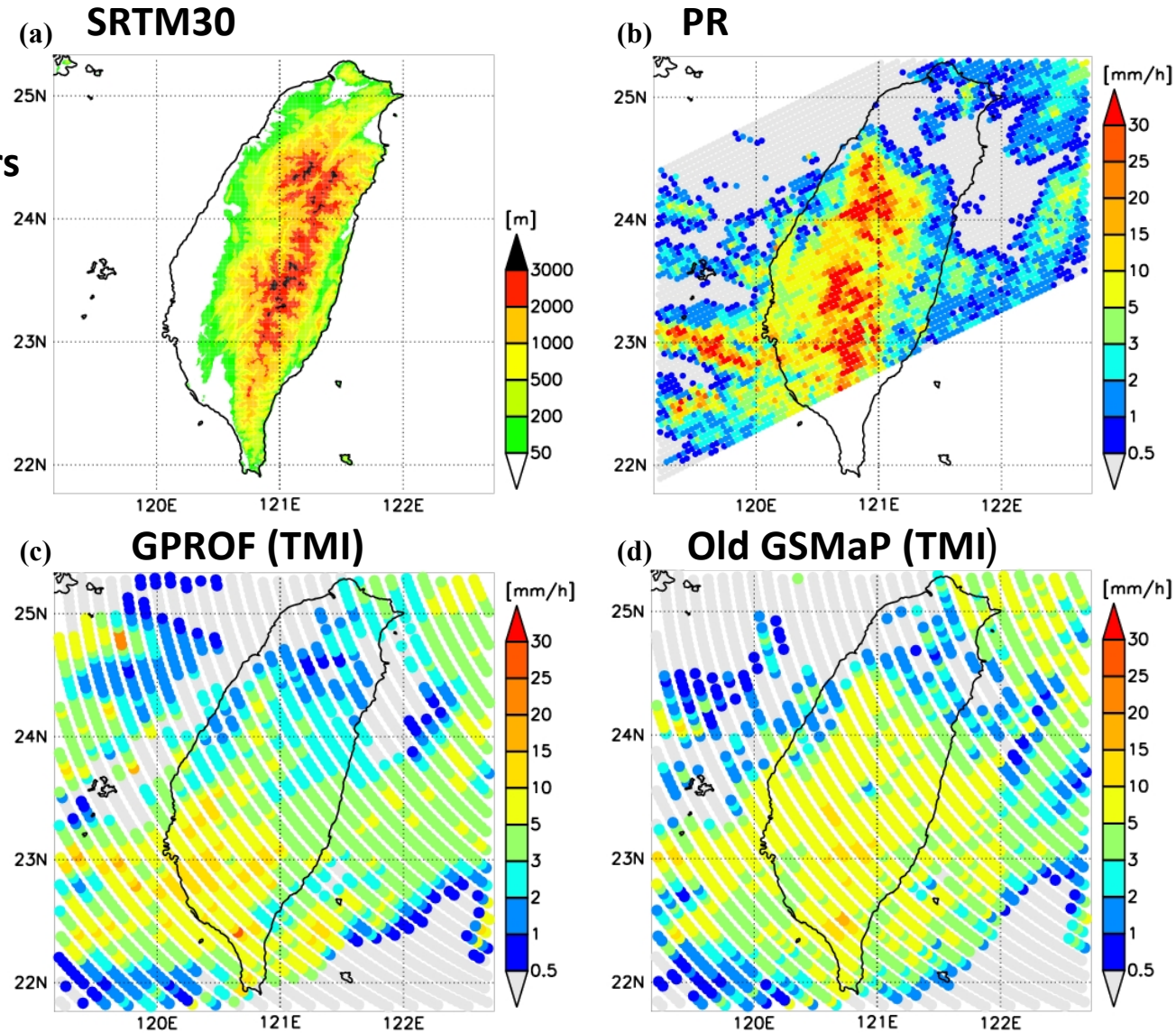
Typhoon MORAKOT observed by TRMM

Taniguchi et al. (2013, JHM)

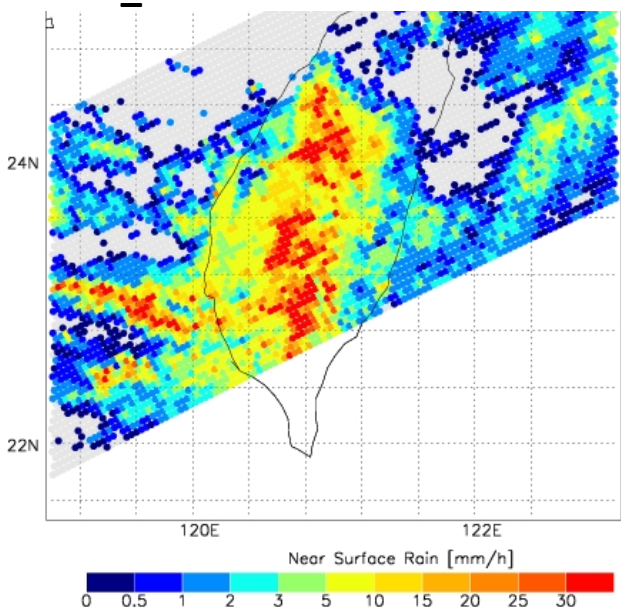
Aug 8 2009, orbit #66832

461 people dead & 192 others missing, most of whom are feared dead (Wikipedia)

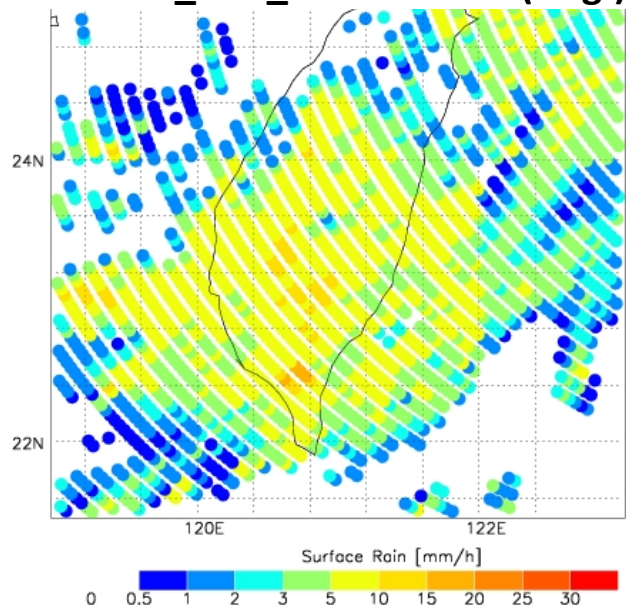


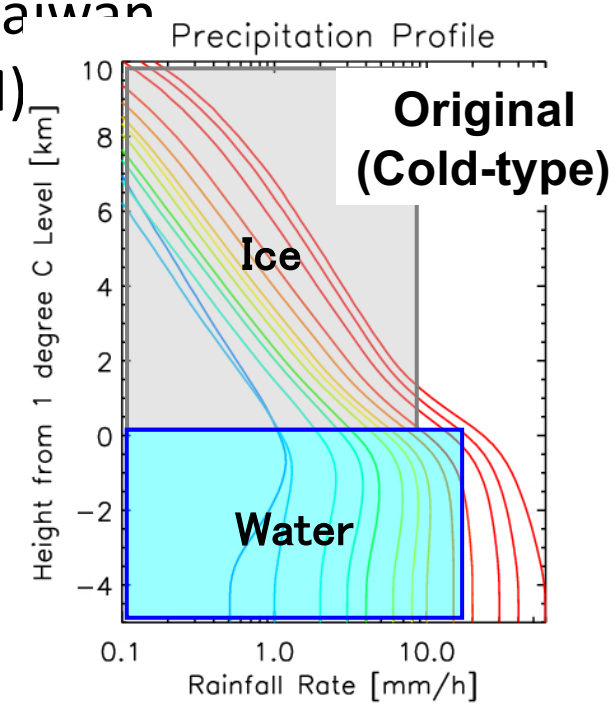
Typhoon Morakot (2009) over Taiwan
Taniguchi et al. (2013, JHM)

PR _ Near Surface Rain

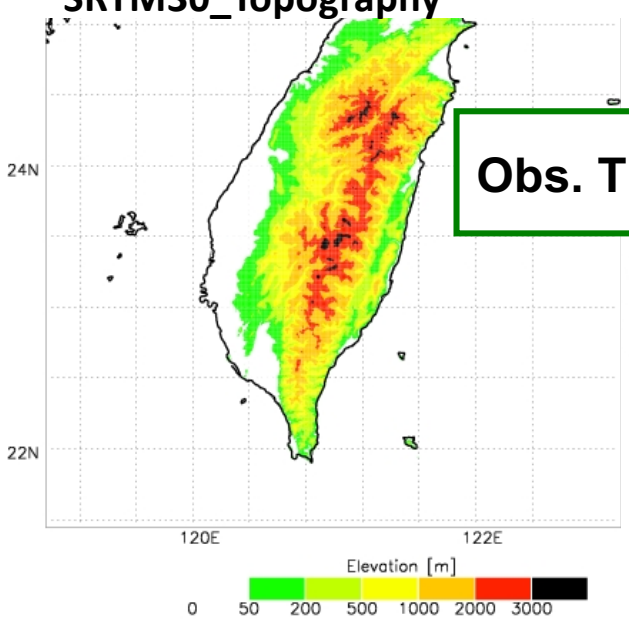


GSMaP_TMI_Surface Rain (orig.)



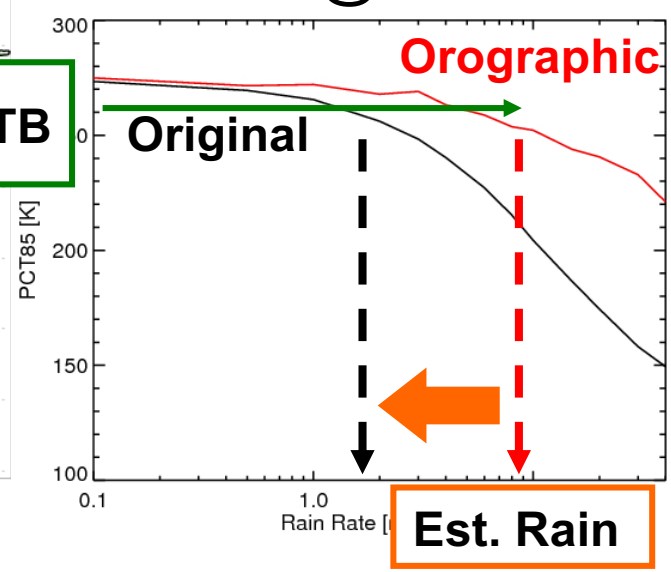


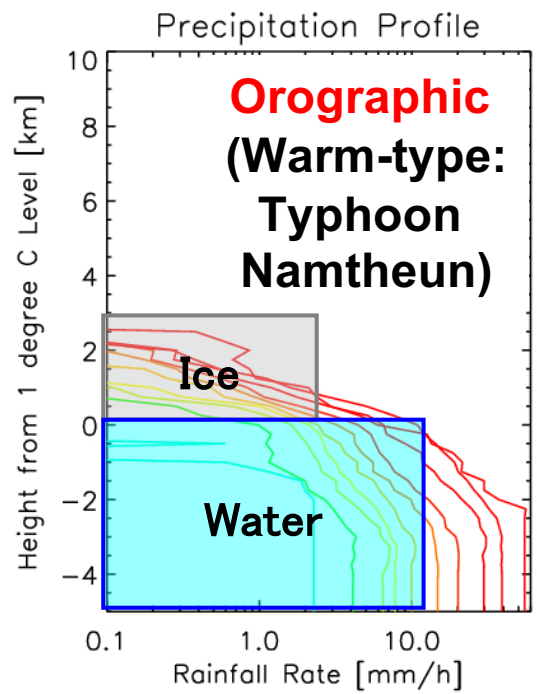
SRTM30_Topography



Obs. TB

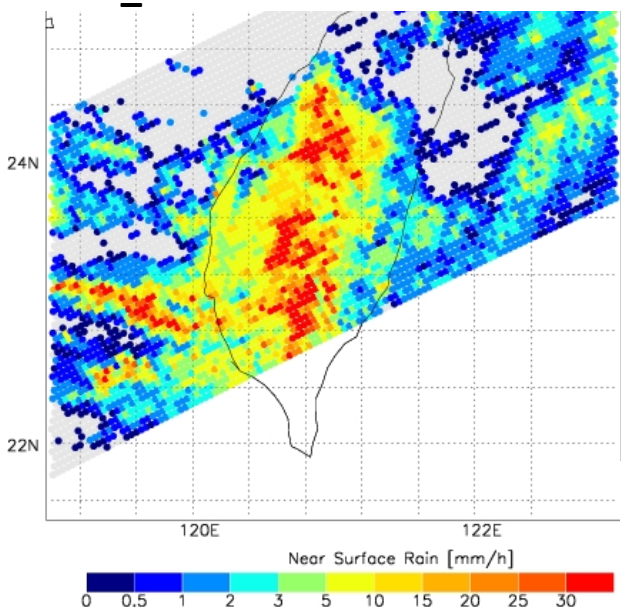
LUT@85 GHz



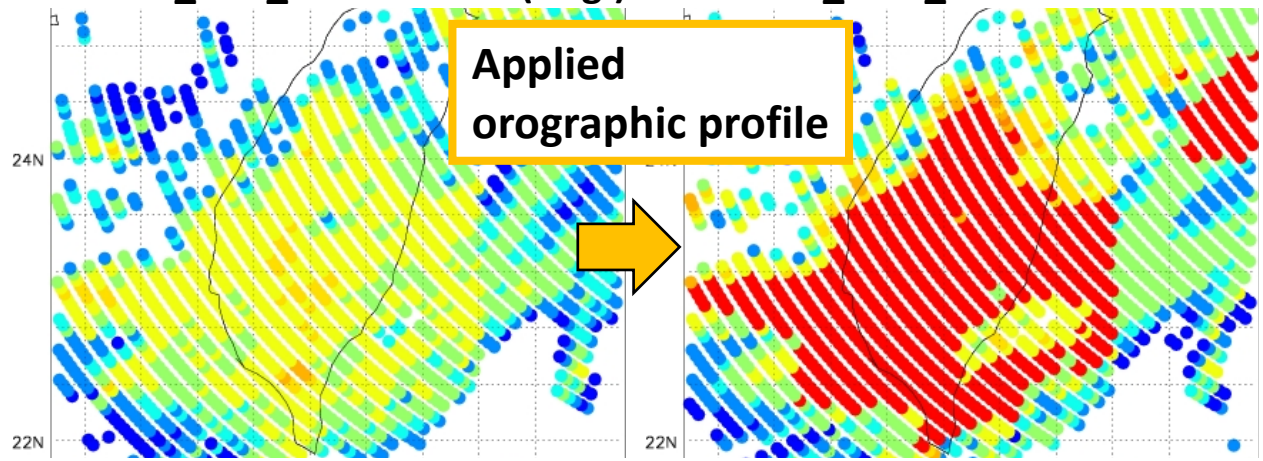


Typhoon Morakot (2009) over Taiwan
Taniguchi et al. (2013, JHM)

PR _ Near Surface Rain

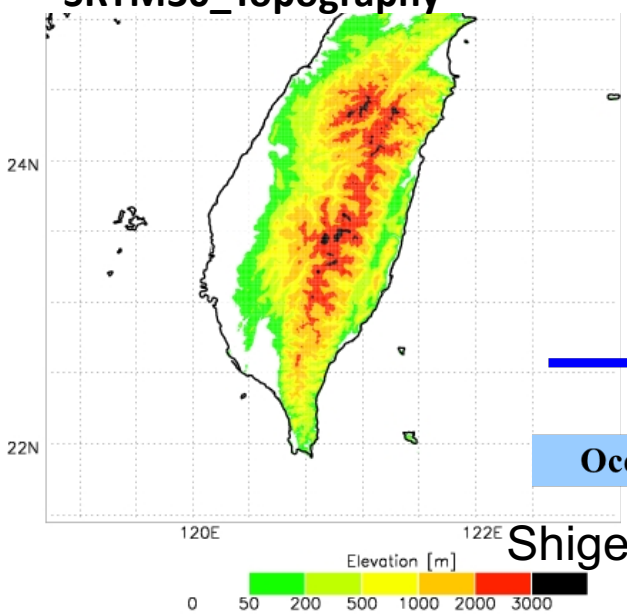


GSMaP_TMI_Surface Rain (orig.) **GSMaP_TMI _Surface Rain**



Orographic/Non-Orographic Rainfall Classification Scheme

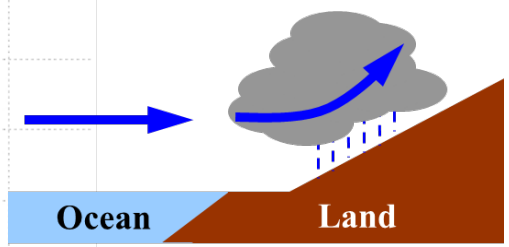
SRTM30_Topography



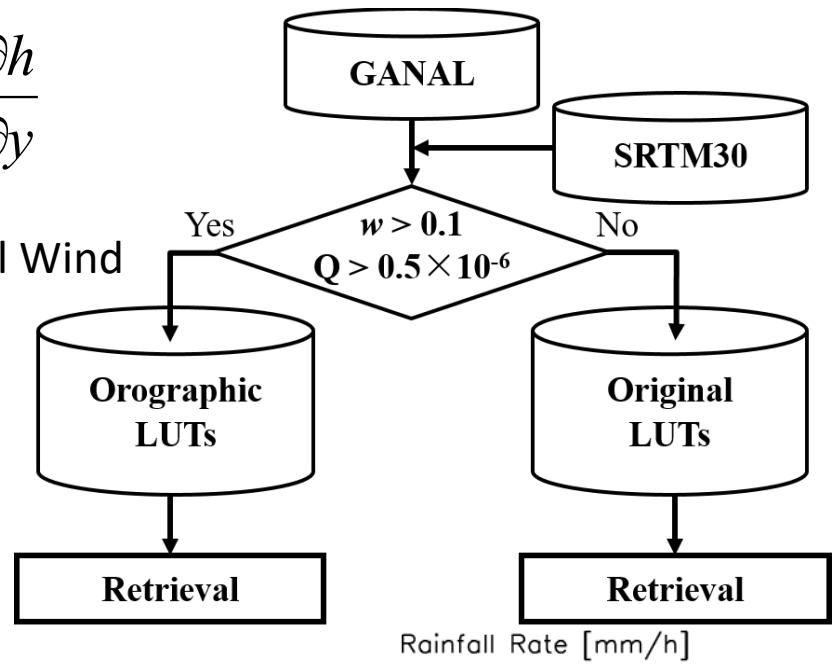
$$w = \frac{Dh}{Dt} = u\frac{\partial h}{\partial x} + v\frac{\partial h}{\partial y}$$

h : Terrain Height

u, v : Surface Horizontal Wind



Shige et al. (2013, JAMC)



Typhoon Morakot (2009) over Taiwan
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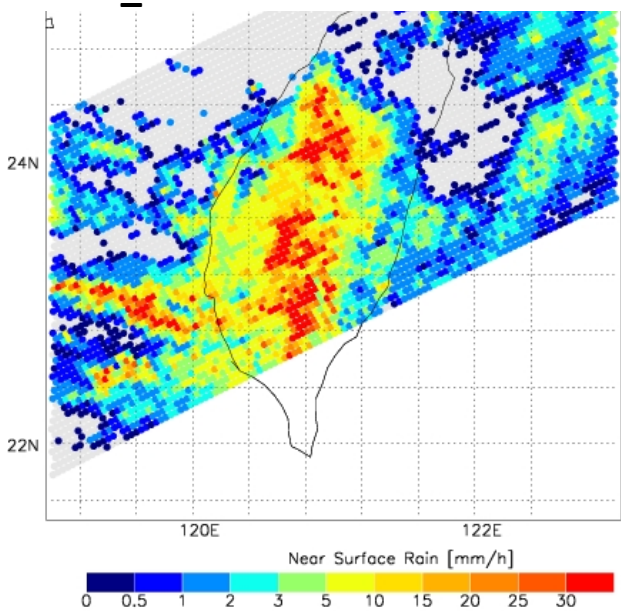
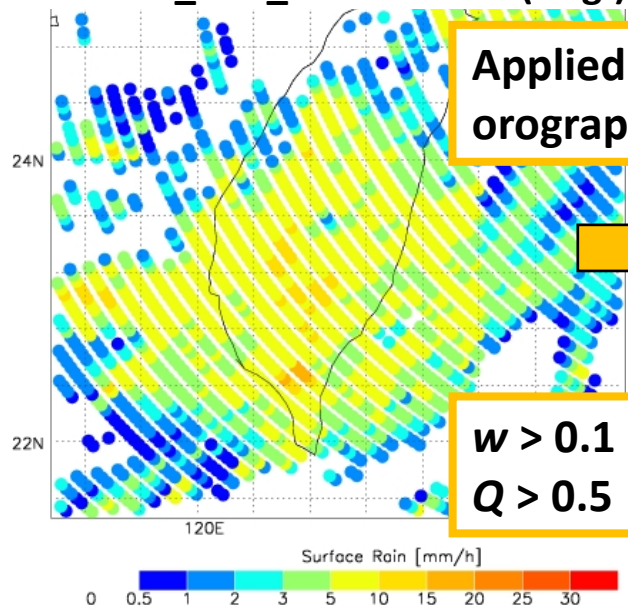
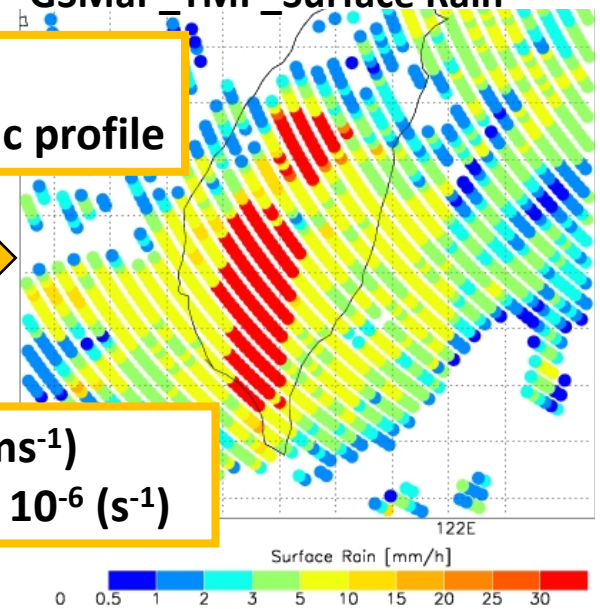
PR _ Near Surface Rain



GSMaP_TMI_Surface Rain (orig.)



GSMaP_TMI _Surface Rain

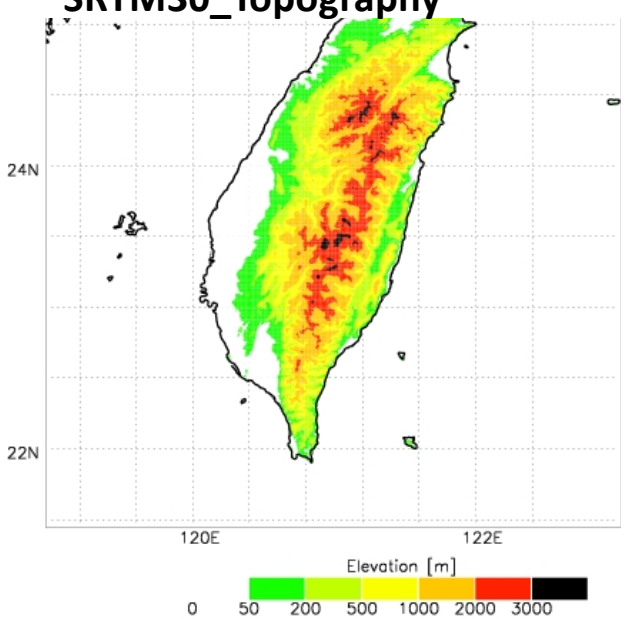


Applied orographic profile

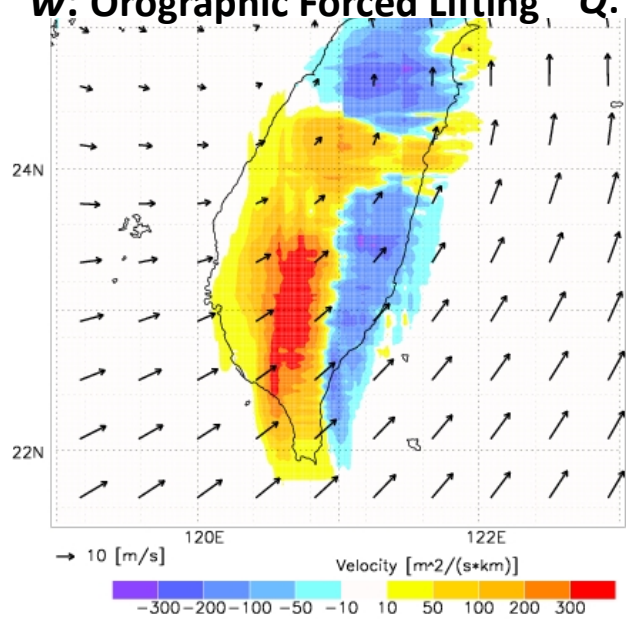
$w > 0.1$ (ms^{-1})

$Q > 0.5 \times 10^{-6}$ (s^{-1})

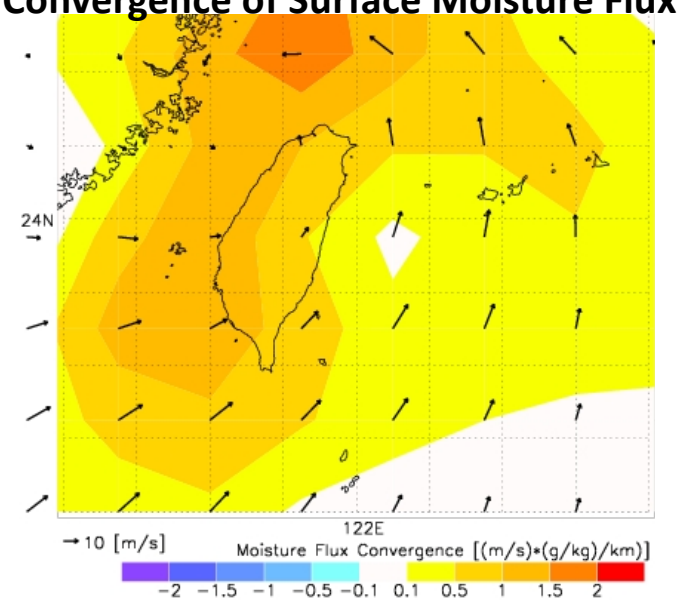
SRTM30_Topography



***w*: Orographic Forced Lifting**



***Q*: Convergence of Surface Moisture Flux**



Taniguchi et al. (2013, JHM)

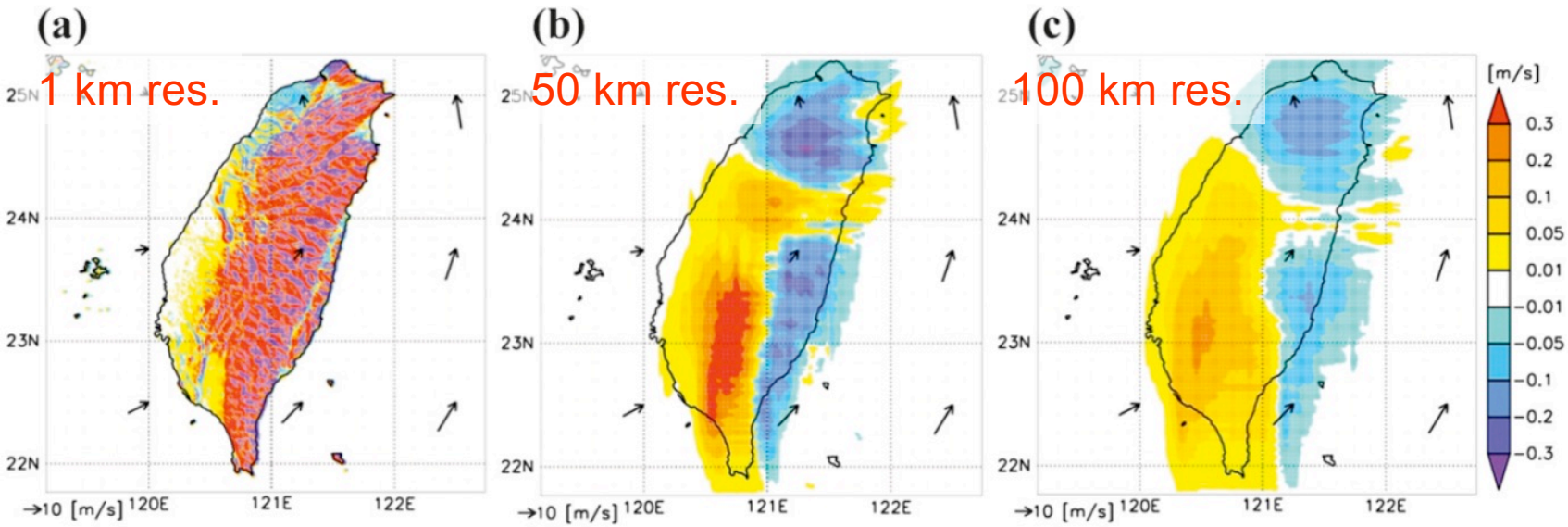
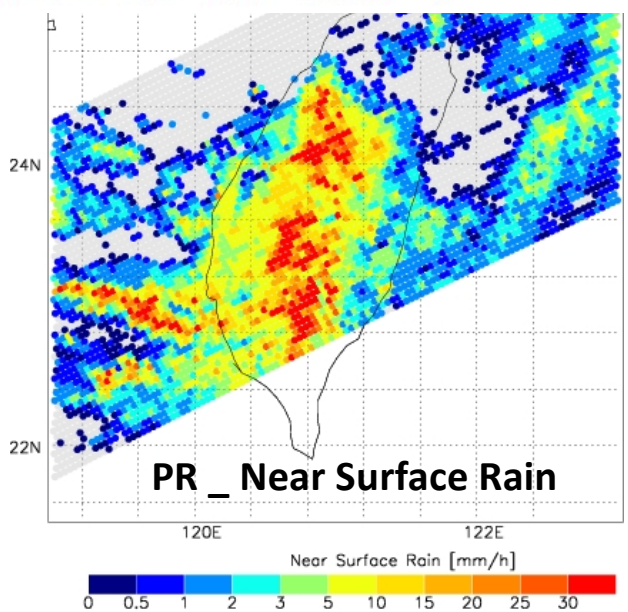


FIG. 4. Orographically forced upward motion w_{oro} ($m\,s^{-1}$) over Taiwan area estimated using Eq. (1) with surface wind data from JCDAS at 1800 UTC 8 Aug 2009 and SRTM30 data: (a) original, 1 km, and averaged within the horizontal length scale of (b) 50 km and (c) 100 km. Vectors are JCDAS surface wind ($m\,s^{-1}$).



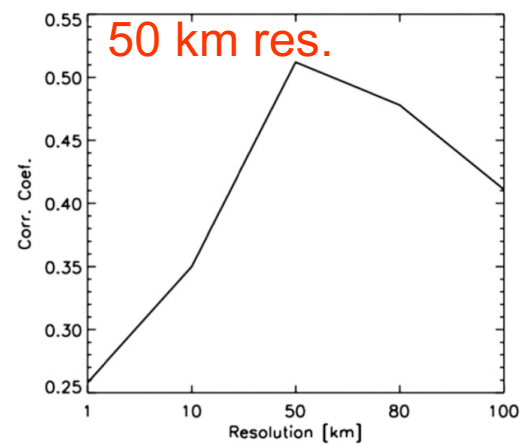
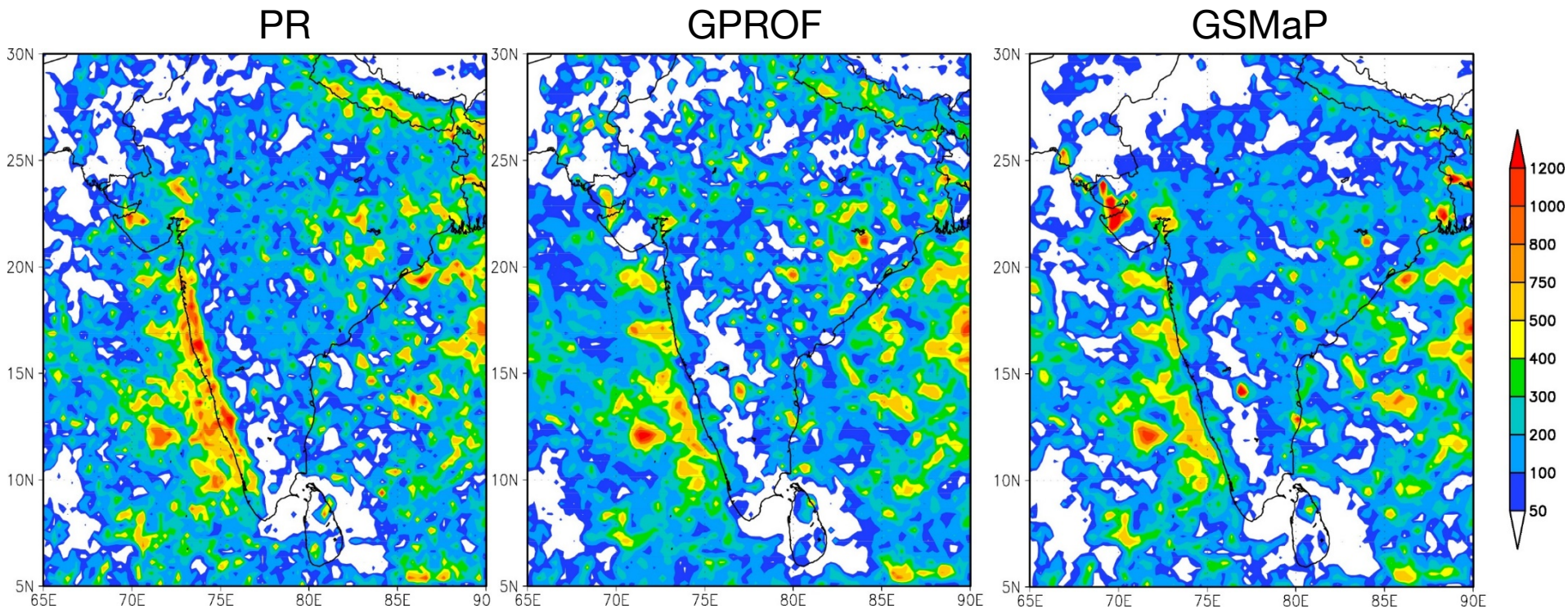


FIG. 5. Correlation coefficients between PR 2A25 near-surface rain shown in Fig. 1b and w_{oro} estimated using elevation data with five horizontal resolutions (1, 10, 50, 80, and 100 km). Calculations for correlation coefficients were made only for the upward motion regions.

Indian Subcontinent

Shige et al. (2014, AGU monograph)



Indian Subcontinent

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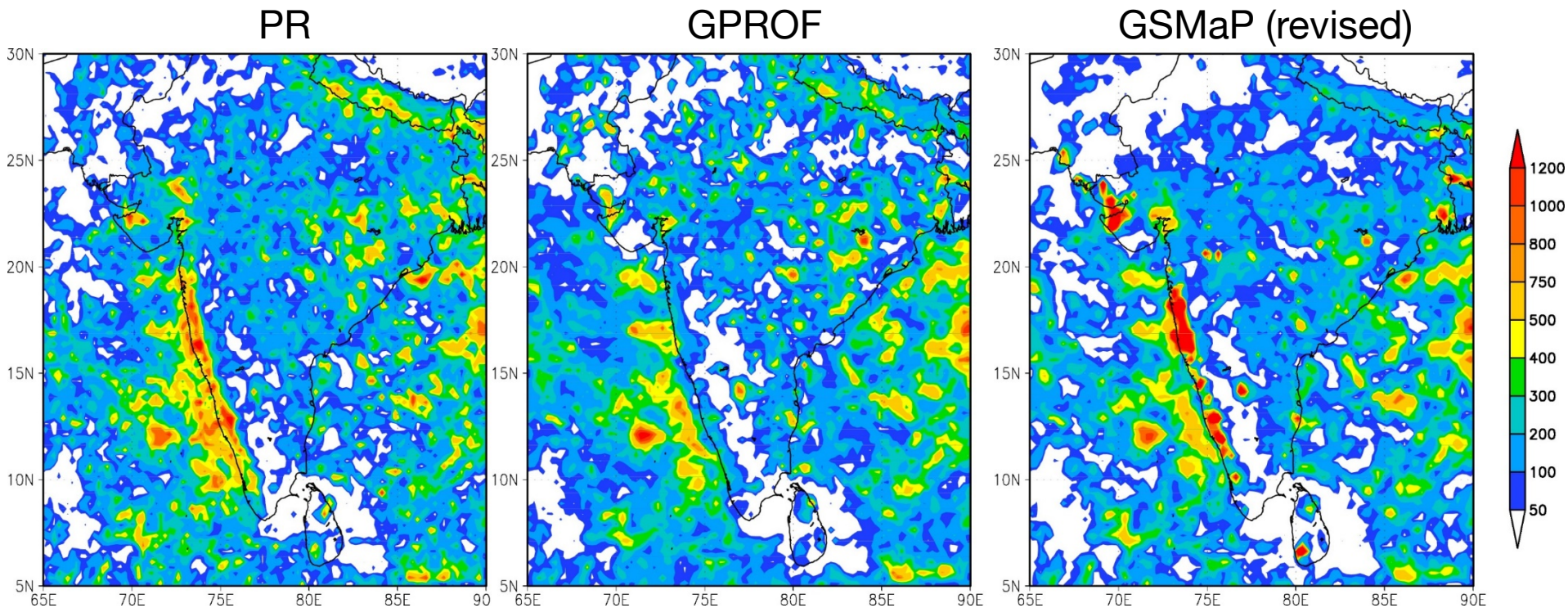
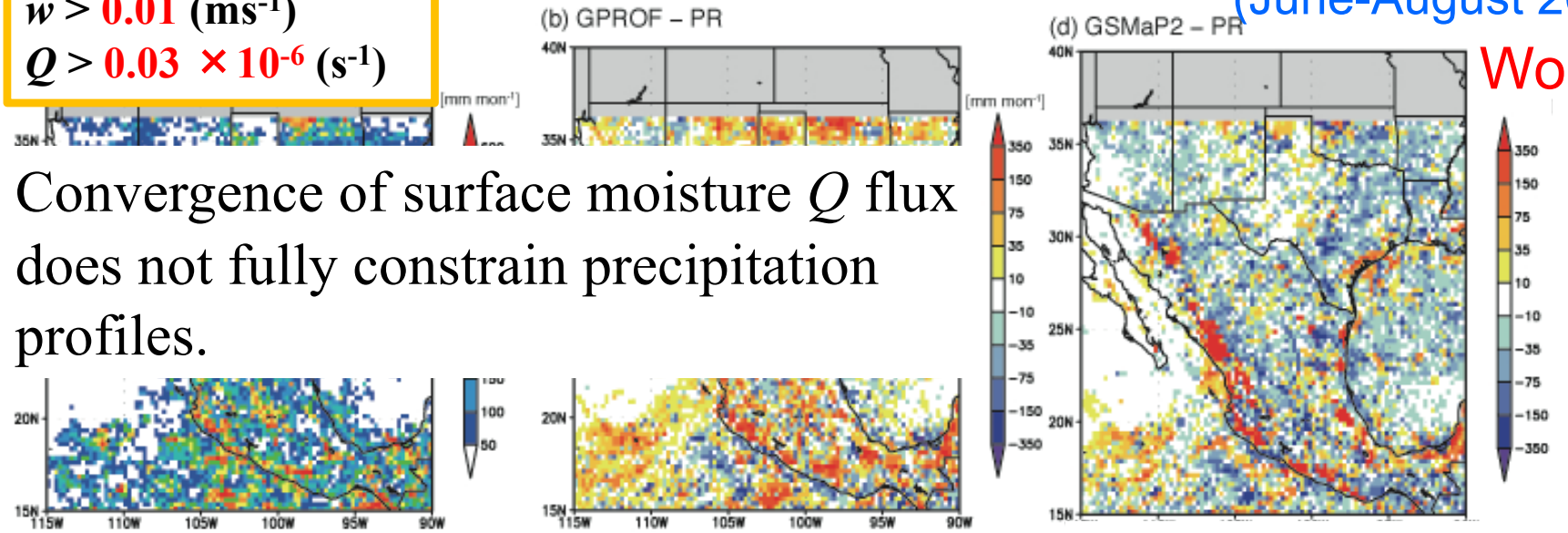


	Shige et al. (2013) Taniguchi et al. (2013)	Shige et al. (2014)
w [m s^{-1}]	**0.1**	**0.01**
Q [10^{-6} s^{-1}]	**0.5**	**0.1**

Global application of the scheme
(Yamamoto & Shige 2015, Atmos. Res.)

US & Mexico
(June-August 2007)

$w > 0.01$ (ms^{-1})
$Q > 0.03 \times 10^{-6}$ (s^{-1})

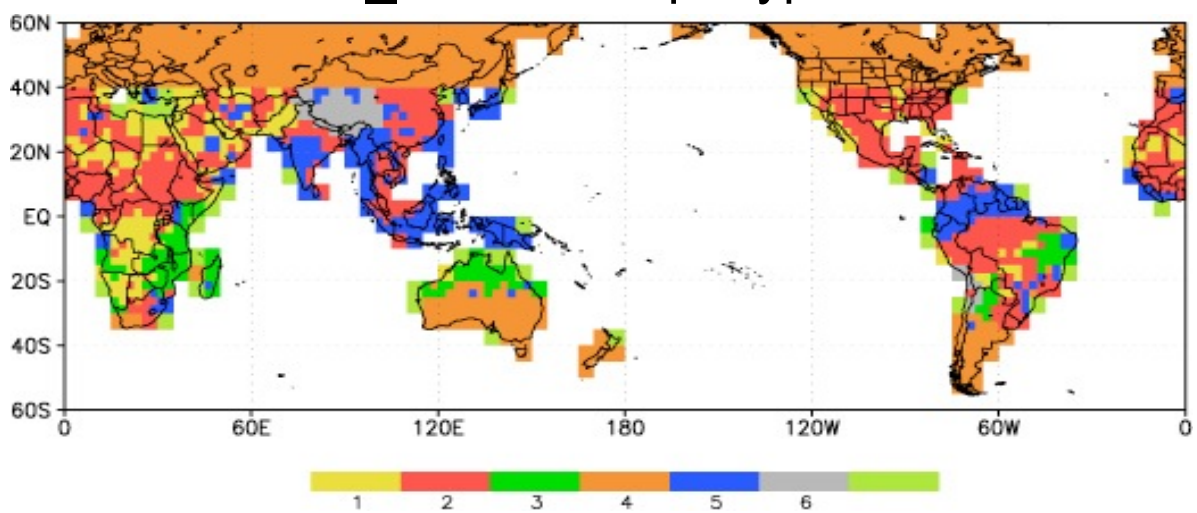


Worse!

Convergence of surface moisture Q flux does not fully constrain precipitation profiles.

(with orographic scheme)

GSMaP_MWR Precip. Type over land



Switch-off

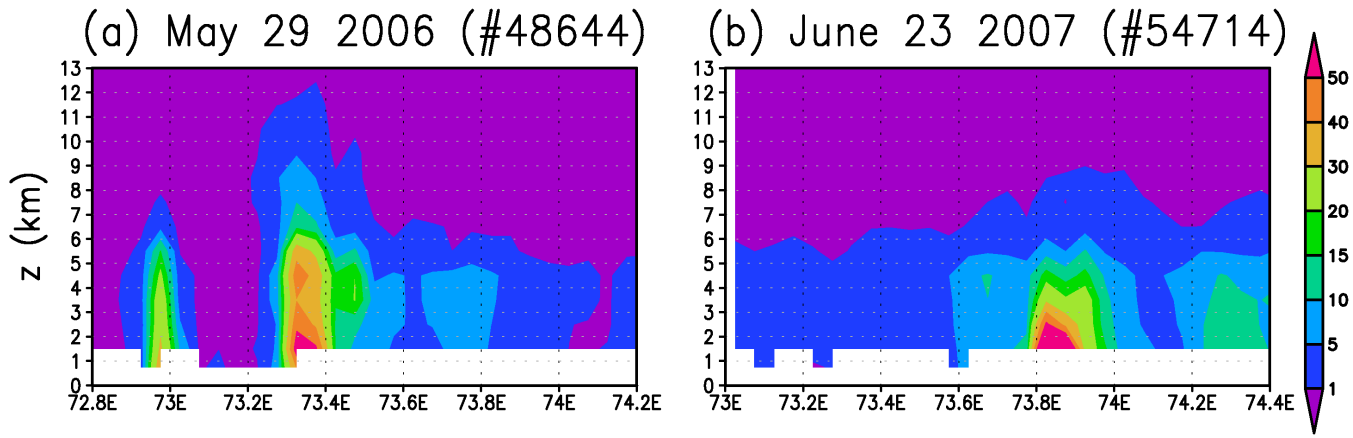
1: So[illegible]storm
2: Af[illegible]
3: Shallow rain
4: Extratropical frontal systems
5: Organized systems
6: Highland rain

What is the thermodynamic characteristics of the atmosphere that determine PTHs in tropical coastal mountains? (Shige and Kummerow 2016, JAS)

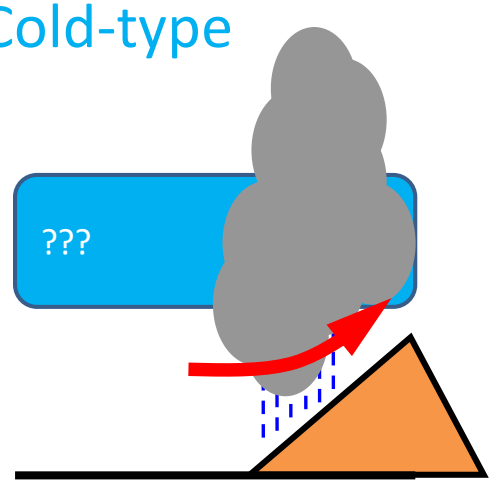
Heavy Orographic Rainfall Cases over the Western Ghats

R = 80 m/h, PTH = 12 km

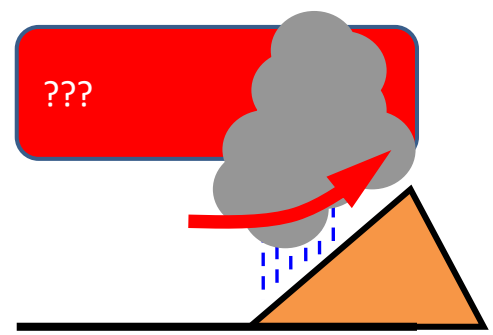
R = 110 m/h, PTH = 8 km



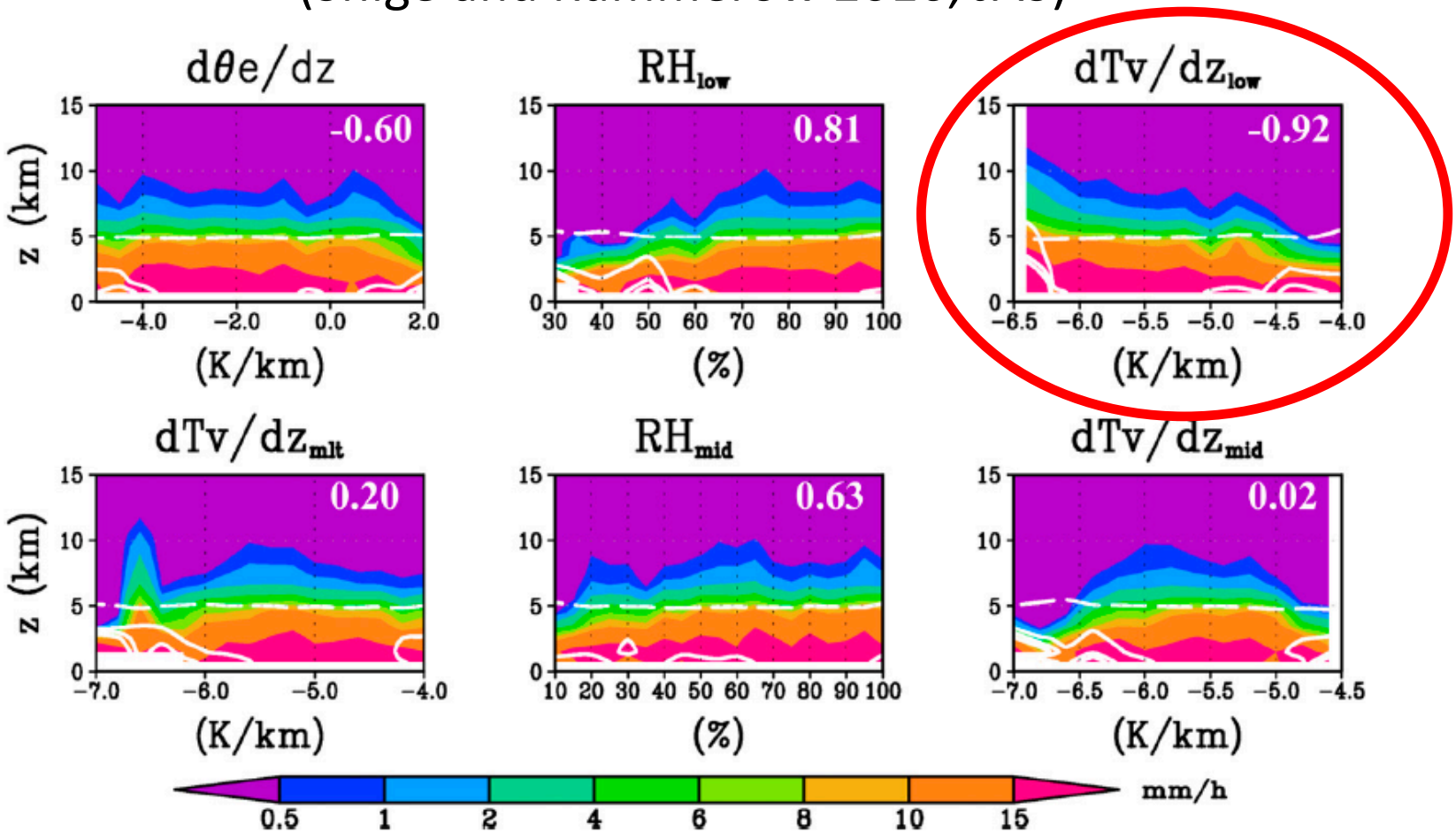
Cold-type



Warm-type



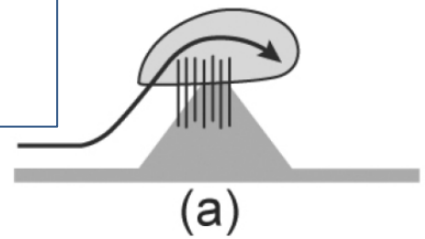
What is the thermodynamic characteristics of the atmosphere that determine PTHs in tropical coastal mountains? (Shige and Kummerow 2016, JAS)

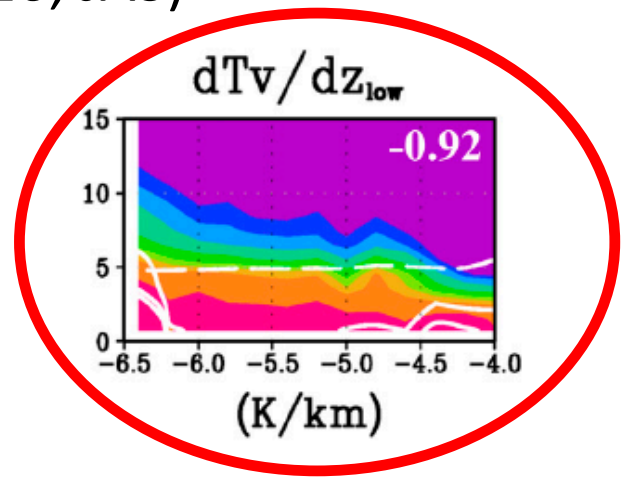


PR-observed precipitation profiles with near-surface rain rates of 10 mm $h^{-1} < R \leq 40$ mm h^{-1} and upward motion ($w_{oro} > 0$ m s^{-1}) as a function of candidate thermodynamic parameters over Annam Range for the transition from boreal summer to winter monsoon (Oct-Dec) during 2004-2008. Correlation coefficients for PTHs are indicated.

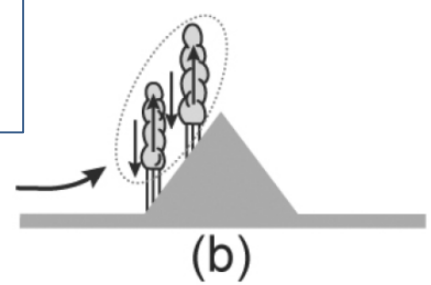
What is the thermodynamic characteristics of the atmosphere that determine PTHs in tropical coastal mountains? (Shige and Kummerow 2016, JAS)

Stable upslope mechanism
(Heavy Rainfall in Asia)





Unstable upslope mechanism
(Heavy convective rainfall)



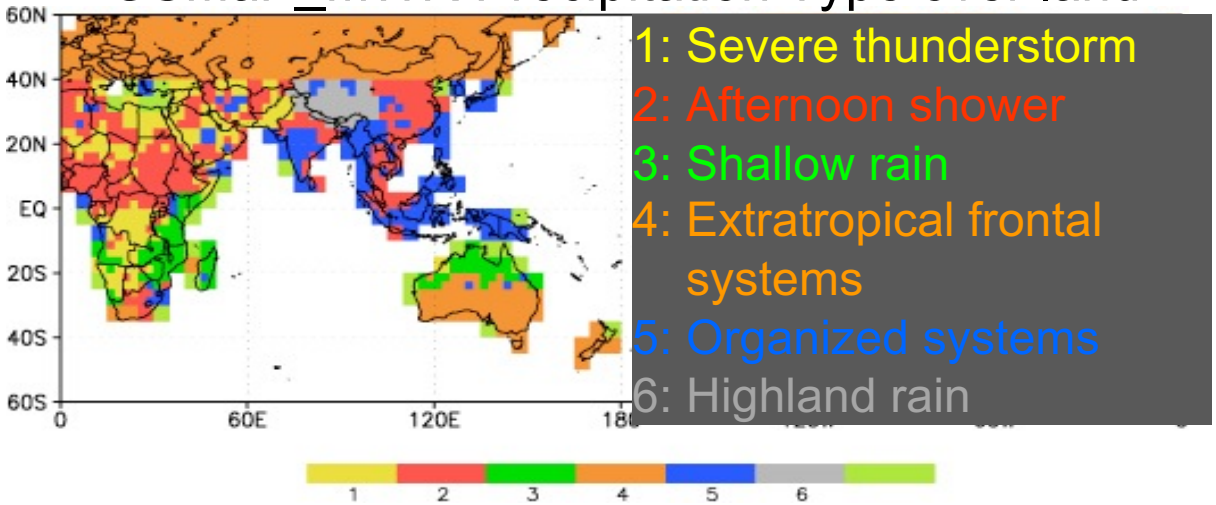
Houze (2012)

Low-level static stability is the key parameter determining precipitation top heights (PTHs).

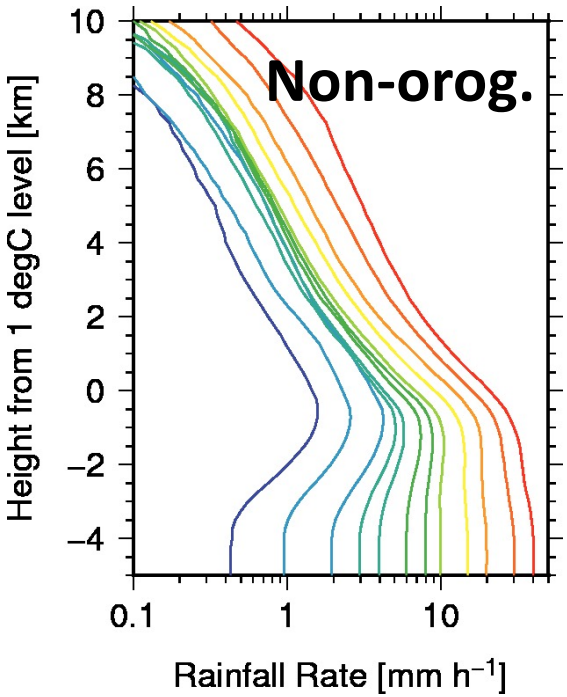
Heavy orographic rainfalls with low PTHs correspond to stable upslope mechanisms, which has been considered to produce weak stratiform rainfall in the midlatitudes (US and Europe).

Vertical profile model (severe thunderstorm)

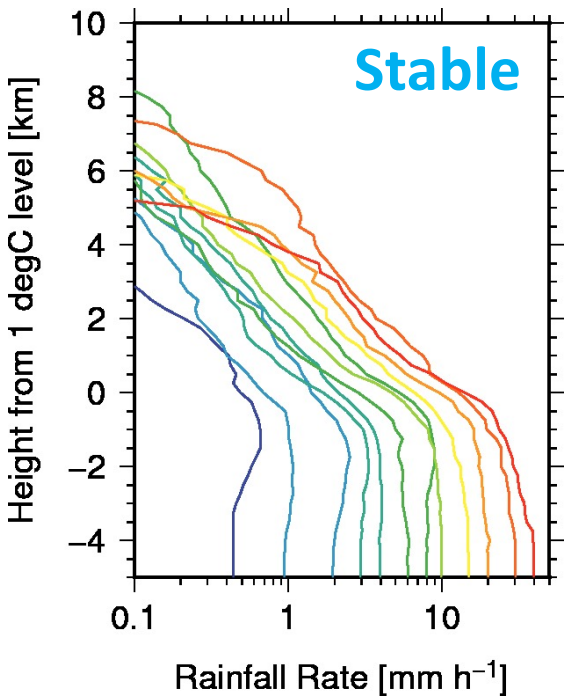
GSMaP_MWR Precipitation Type over land

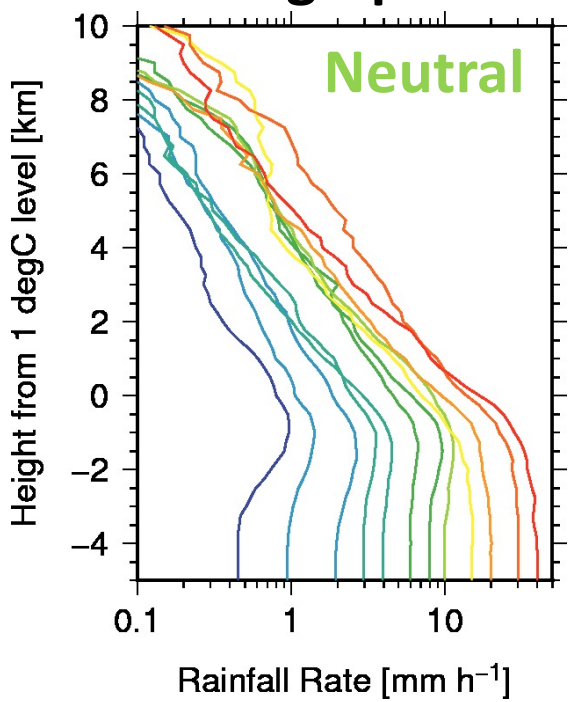


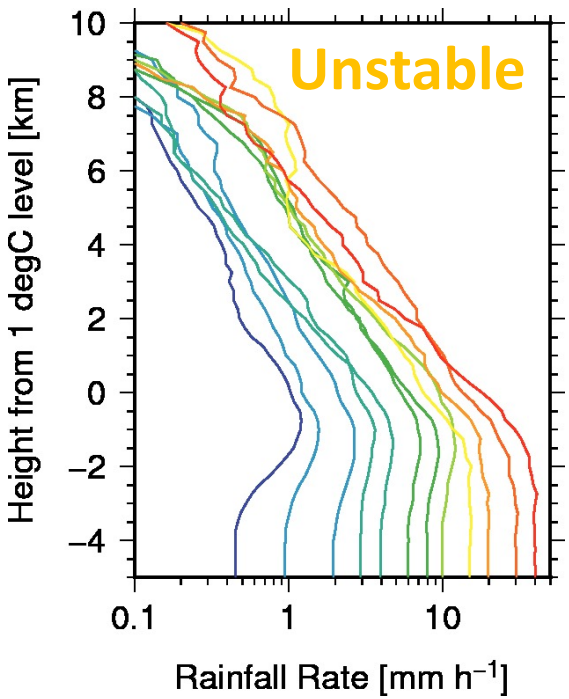
1: Severe thunderstorm
2: Afternoon shower
3: Shallow rain
4: Extratropical frontal systems
5: Organized systems
6: Highland rain



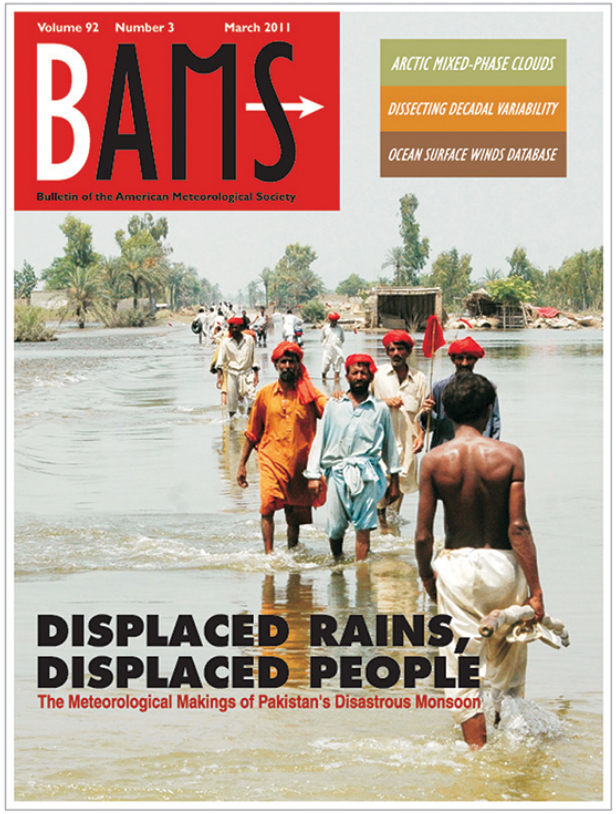
Orographic







TRMM data for 28 Jul. 2010 Pakistan rainstorms (Houze et al. 2011, BAMS)



ON THE COVER. Houze et al. (beginning on page 291) describe the unusual character of the monsoon storms that flooded Pakistan last year, affecting more than 20 million people. (PHOTO: World Vision)

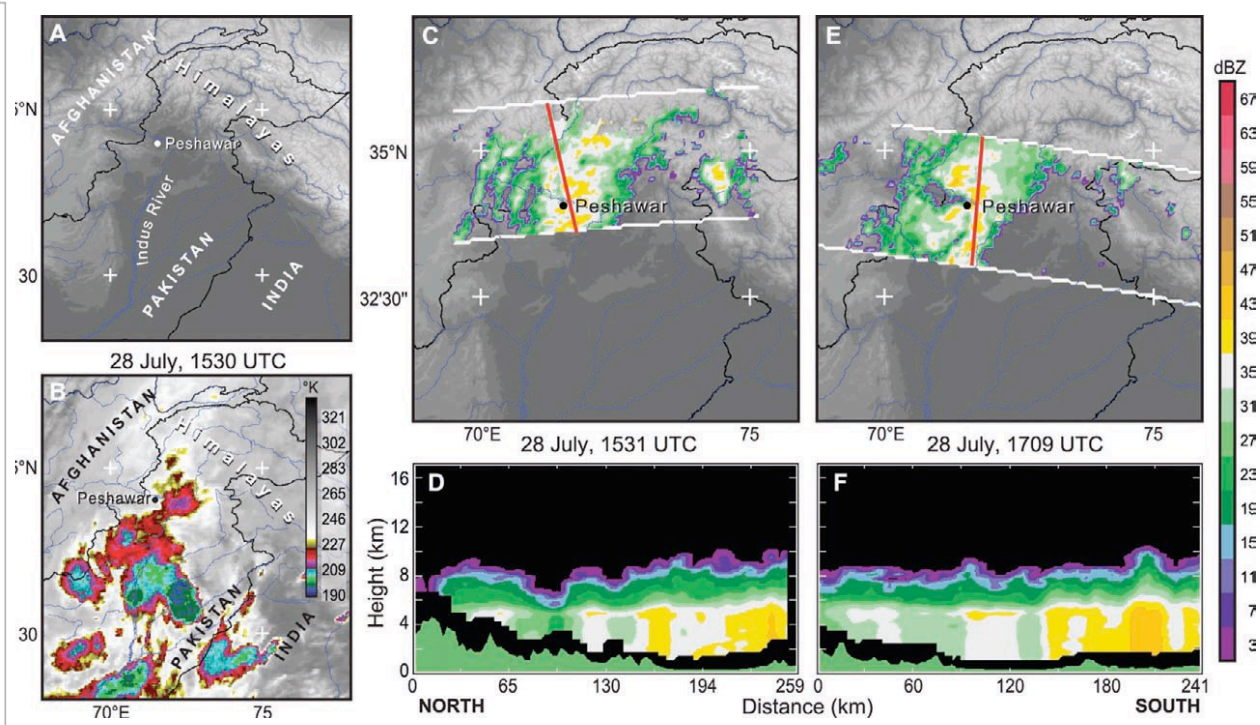
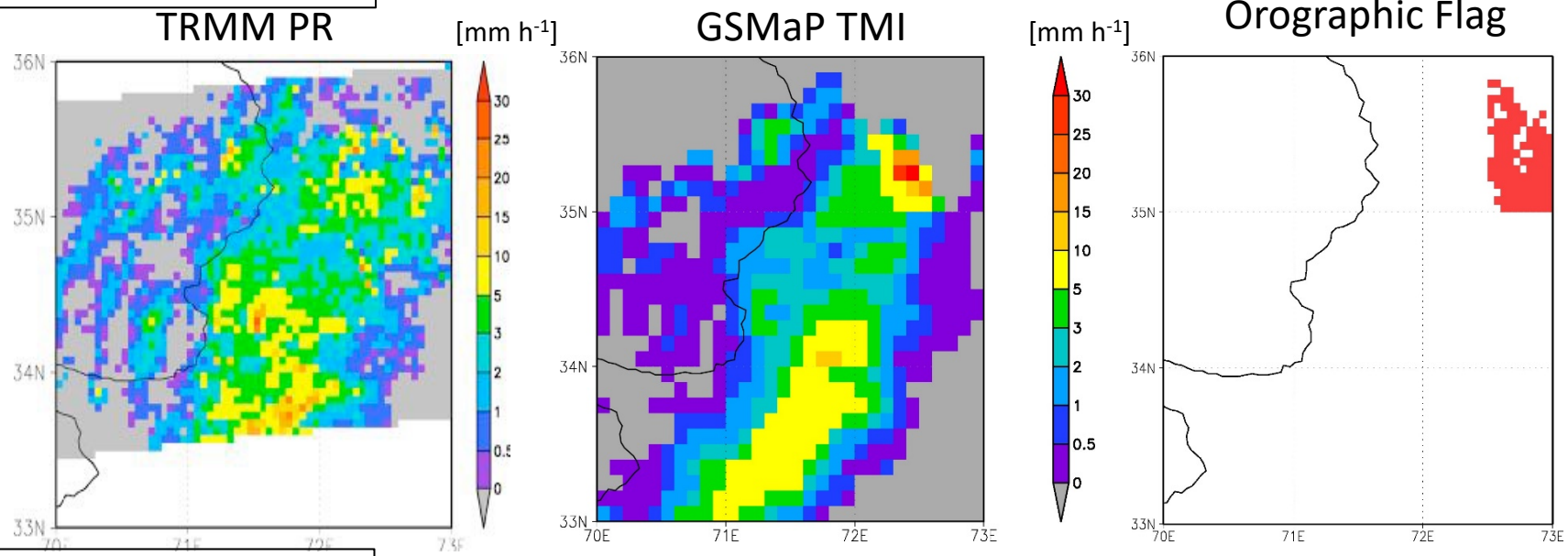


Fig. 5. (a) Topography and (b)-(f) satellite data for 28 Jul 2010 Pakistan rainstorms; (b) infrared satellite image (K) from the METEOSAT 7 image for 1530 UTC 28 Jul; (c)-(f) reflectivity from the TRMM satellite radar in dBZ; (c)-(d) TRMM radar overpass at 1531 UTC 28 Jul; (e)-(f) TRMM radar overpass at 1709 UTC 28 Jul. Horizontal cross sections are at 5-km altitude. Red lines in (c) and (e) indicate the location of the vertical cross sections in (d) and (f), respectively.

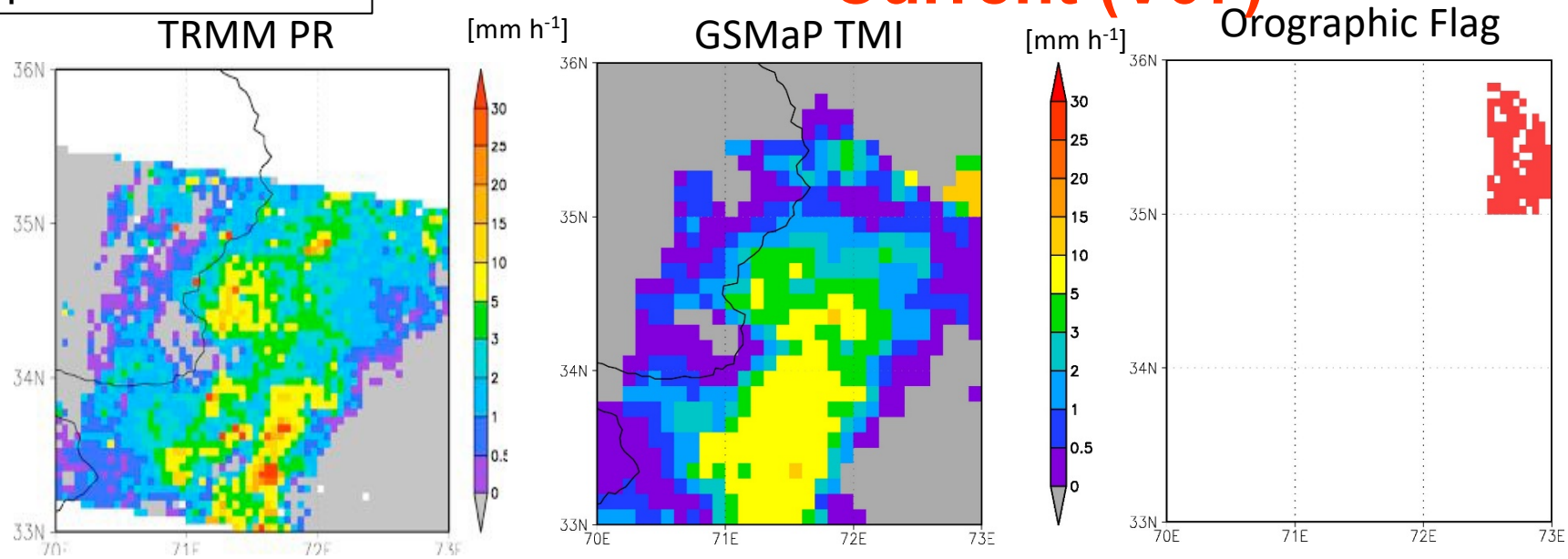
GSMaP TMI for 28 Jul. 2010 Pakistan rainstorms

Overpass at 1531UTC



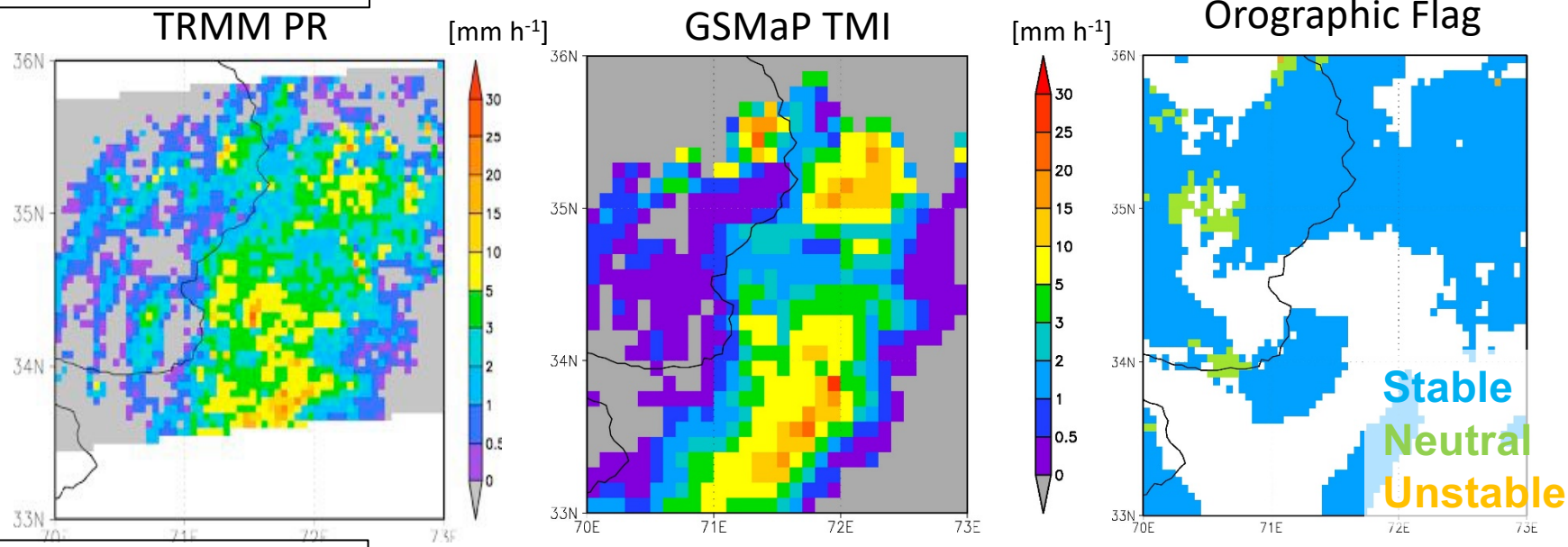
Overpass at 1709UTC

Current (V07)



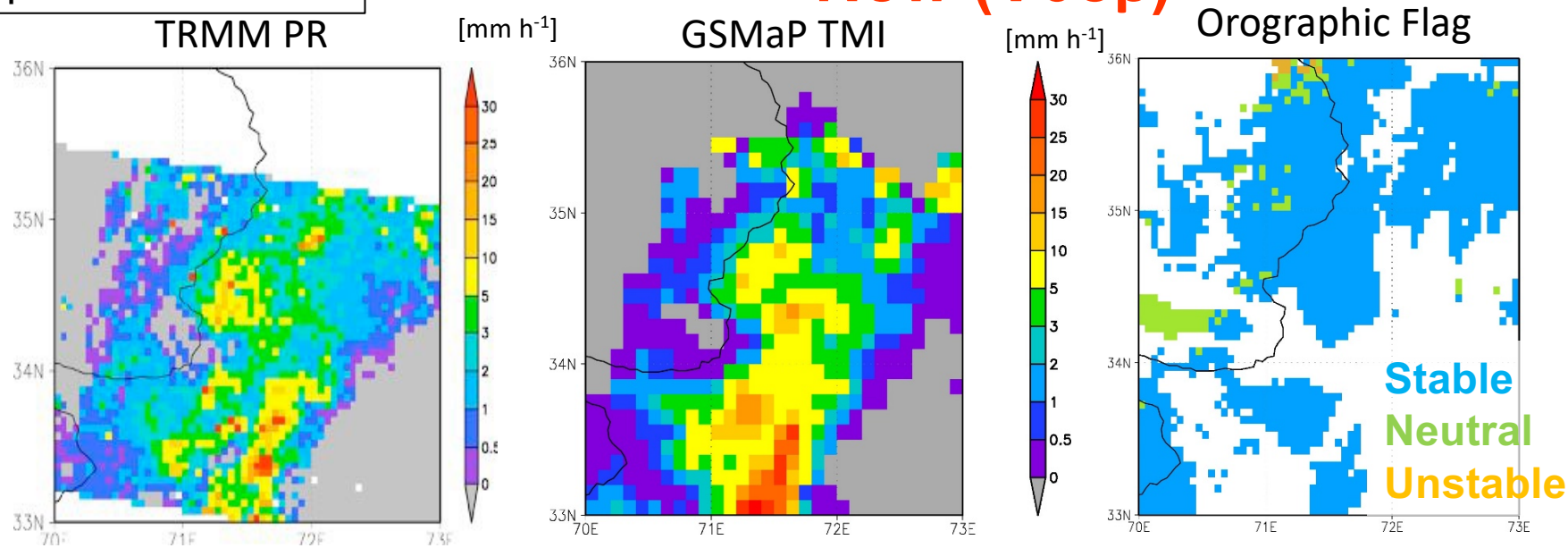
GSMaP TMI for 28 Jul. 2010 Pakistan rainstorms

Overpass at 1531UTC



Overpass at 1709UTC

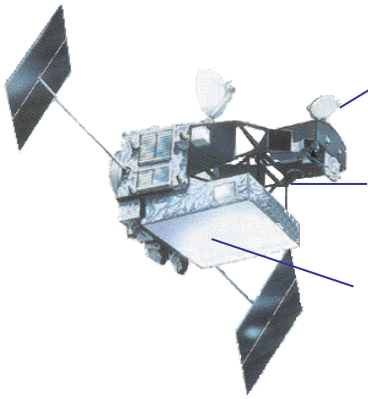
New (V08β)



Summary

- A dynamic selection of lookup tables (LUTs) appropriate for heavy orographic rainfall, based on topographic forced upward vertical motion & convergence of surface moisture flux, has been introduced in the GSMaP MWR algorithm (Shige et al. 2013, 2014, Taniguchi et al. 2013, Yamamoto & Shige 2015, Yamamoto et al. 2017).
- Use of low-level static stability (Shige and Kummerow 2016) instead of convergence of surface moisture flux could lead to "real" global application of the scheme (no switch-off for Severe thunderstorm & Afternoon shower) and contribute to not only improvements of **coastal** orographic rainfall but also **inland** orographic rainfall.
- Issues of orographic snowfall still remain.

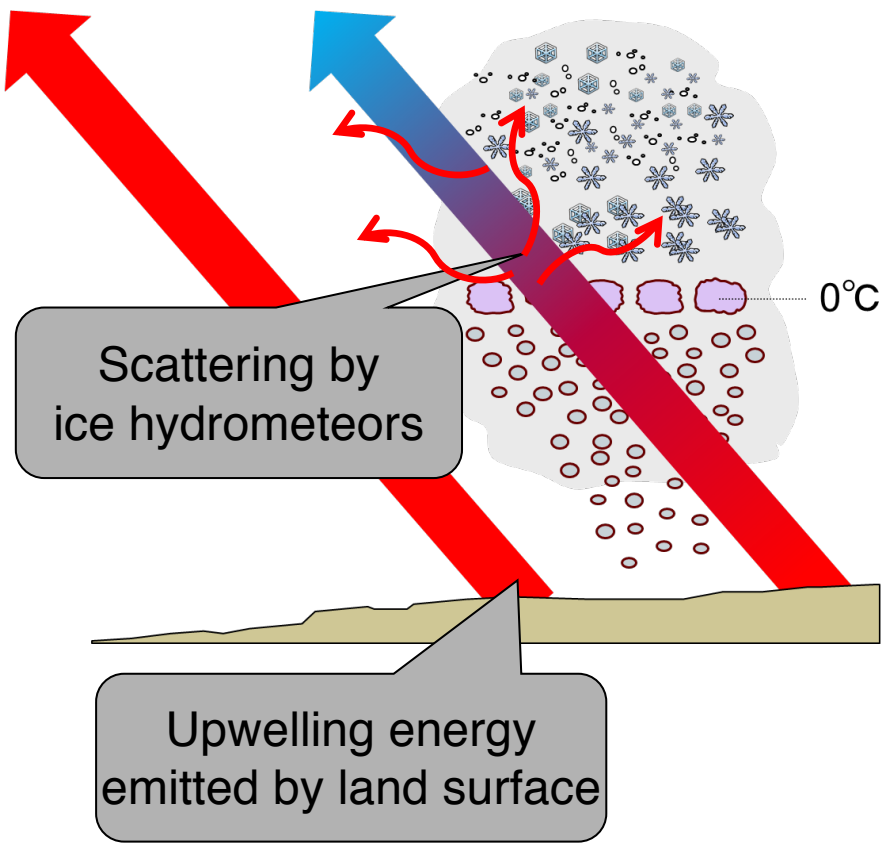
Typhoon Morakot over land observed by TRMM

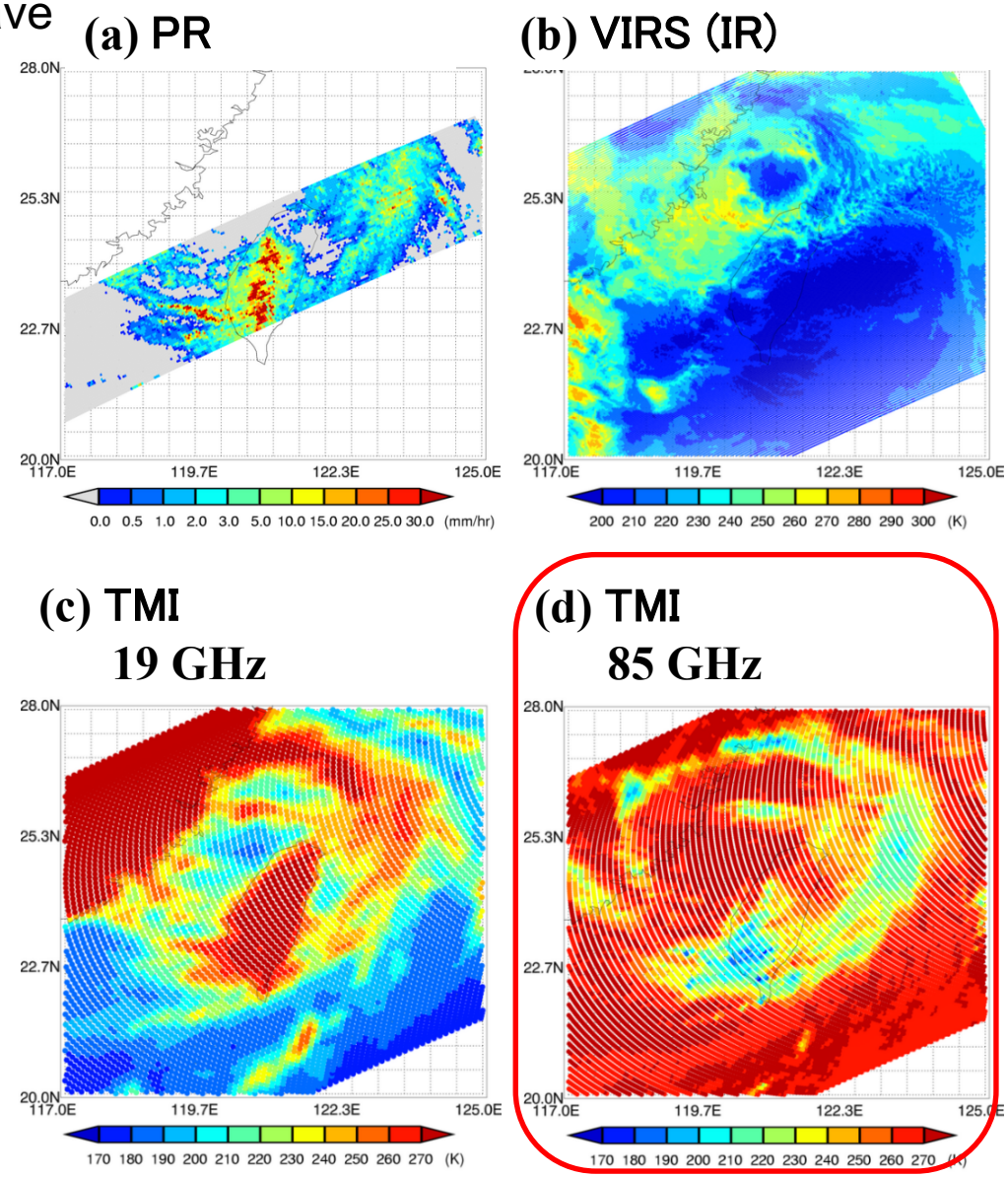


TMI passive microwave radiometer

VIRS visible/infrared radiometer

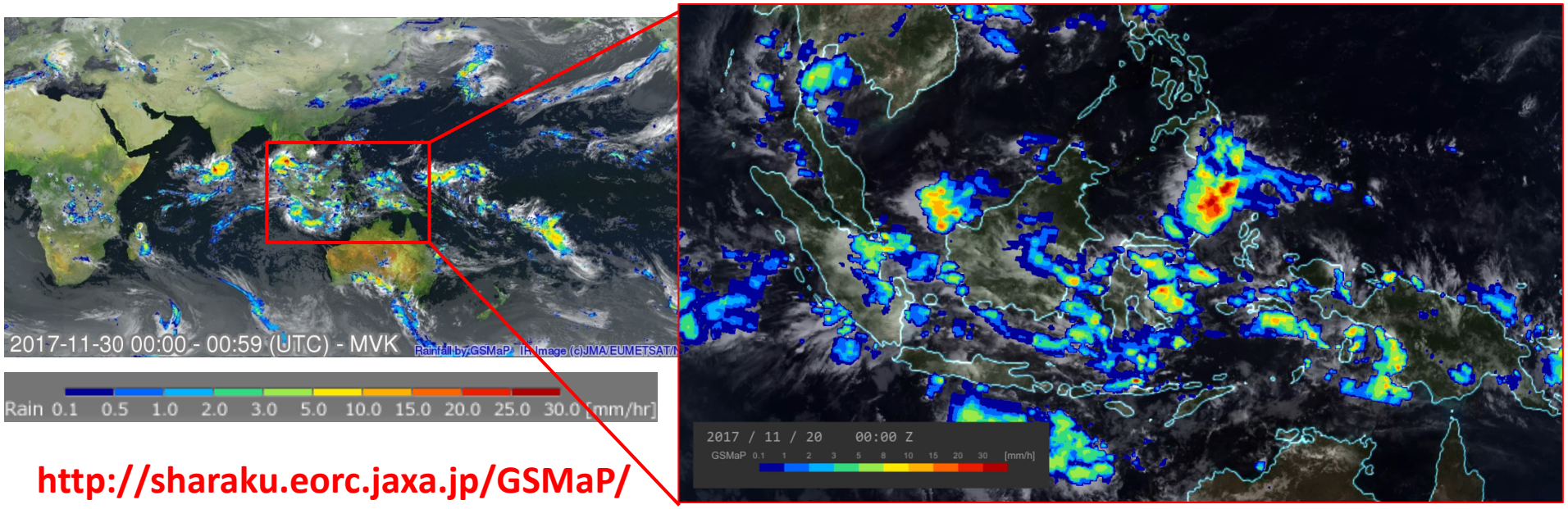
PR radar





Global Satellite Mapping of Precipitation (GSMaP)

GSMaP hourly rain with Himawari-8 cloud (20-30 Nov 2017)



http://sharaku.eorc.jaxa.jp/GSMaP/

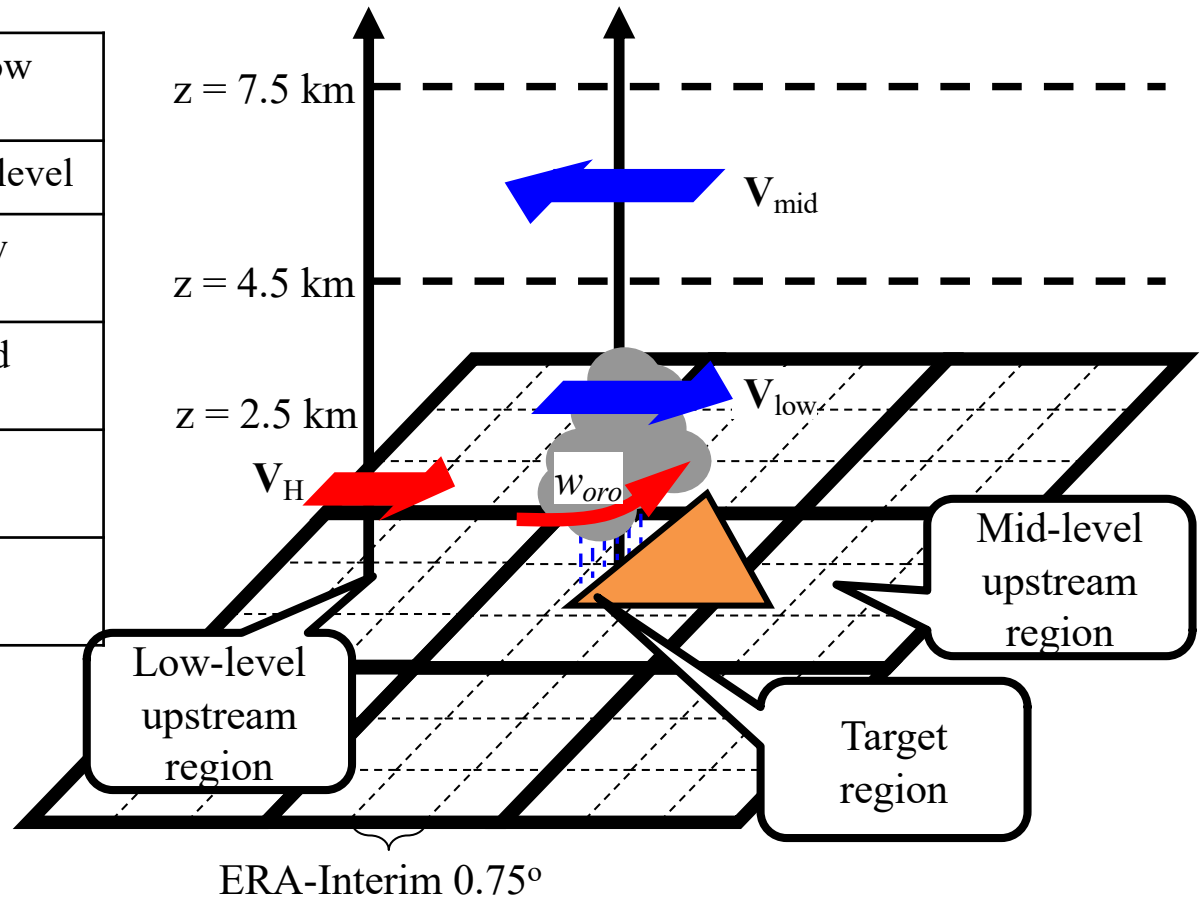
- GSMaP is a multi-satellite product from a blended passive microwave radiometer-IR algorithm and has been developed in Japan toward the GPM mission. (IMERG in US)
- GSMaP is now being used operationally by meteorological agencies in Southeast Asia such as Indonesia, Philippines, and Vietnam.
- We have improved the GSMaP passive microwave radiometer algorithm for heavy orographic rainfall using space-borne radar data.

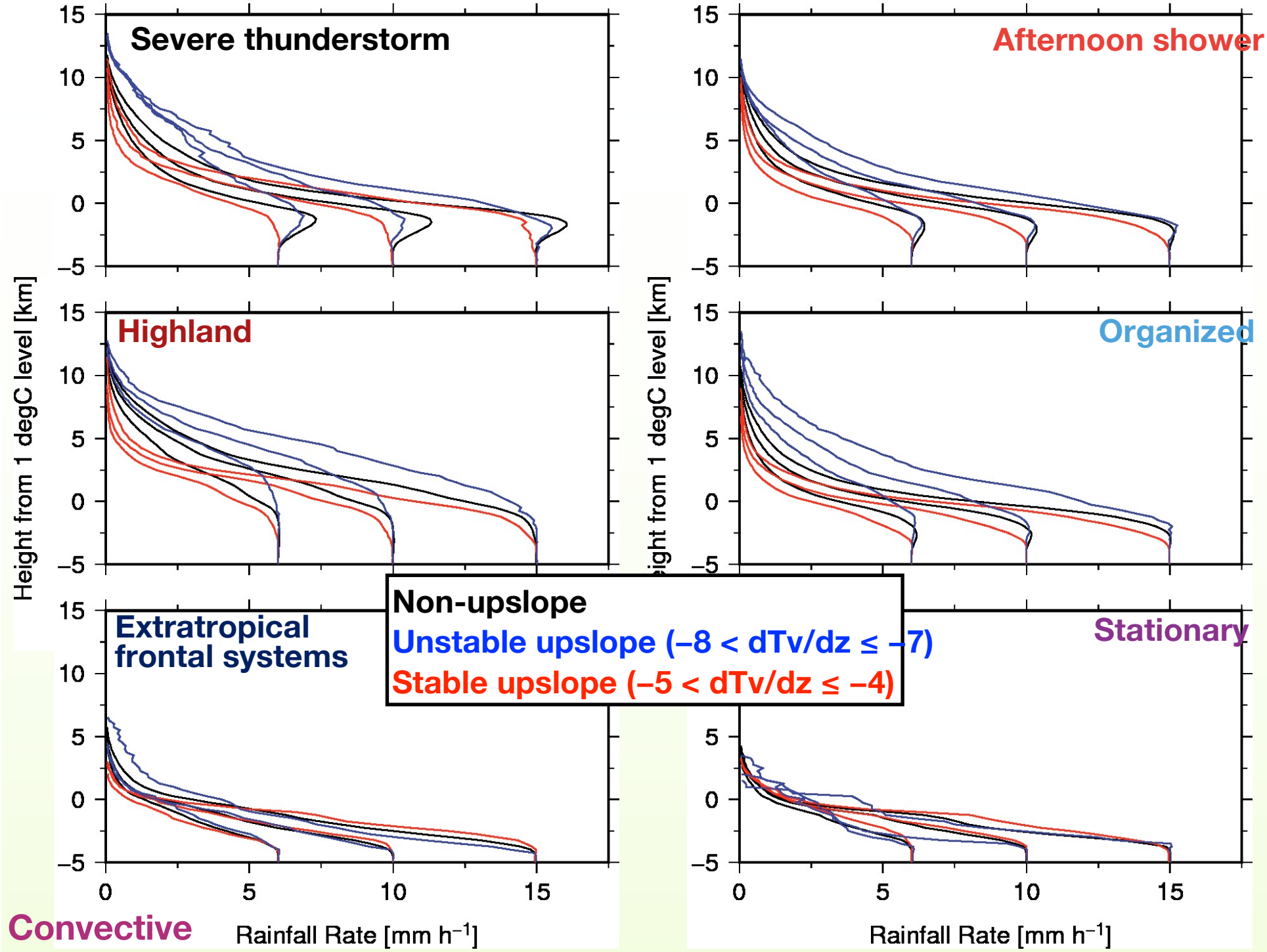
What is the thermodynamic characteristics of the atmosphere that determine PTHs in tropical coastal mountains? (Shige and Kummerow 2016, JAS)

Thermodynamic parameters examined in this study

$d\theta_e/dz$	Potential instability of the low troposphere
dT_v/dz_{mlt}	Static stability near the 0°C level
RH_{low}	Relative humidity of the low troposphere
RH_{mid}	Relative humidity of the mid troposphere
dT_v/dz_{low}	Static stability of the lower troposphere
dT_v/dz_{mid}	Static stability of the mid troposphere

Schematic of the target region with low- and mid-level upstream regions.




Severe thunderstorm
Afternoon shower
Highland
Organized
Extratropical frontal systems
Stationary
Convective
Non-upslope
Unstable upslope (–8 < dTv/dz ≤ –7)
Stable upslope (–5 < dTv/dz ≤ –4)
Height from 1 degC level [km]
Rainfall Rate [mm h⁻¹]
15
10
5
0
–5
0
5
10
15

Large-scale process control moist-convection processes in "Extratropical frontal systems" and "Stationary"?

Arakawa (1993)

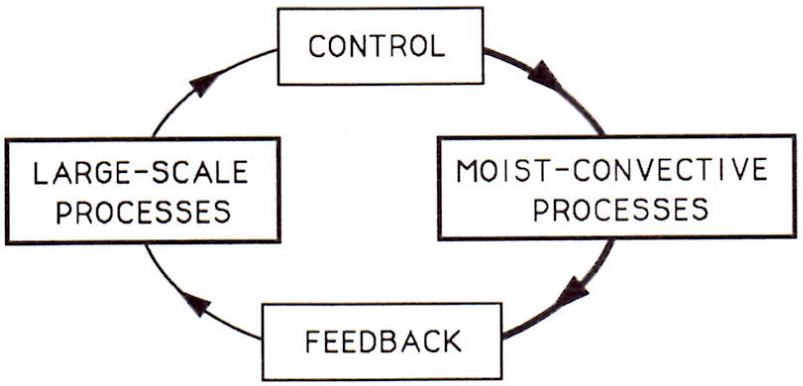
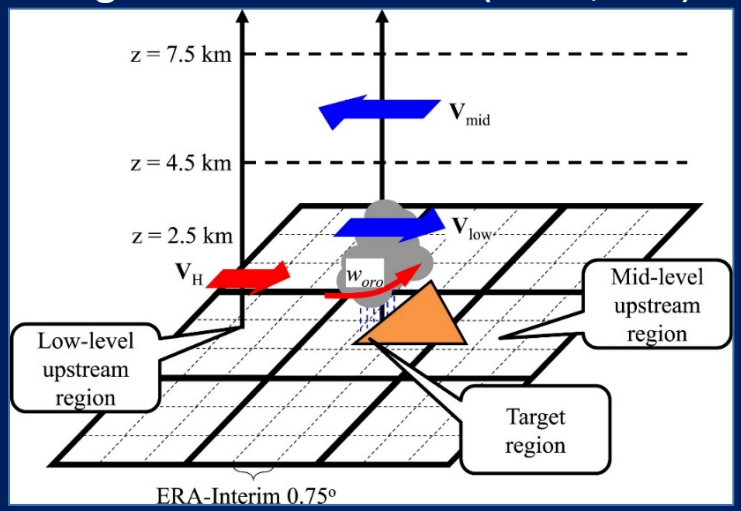
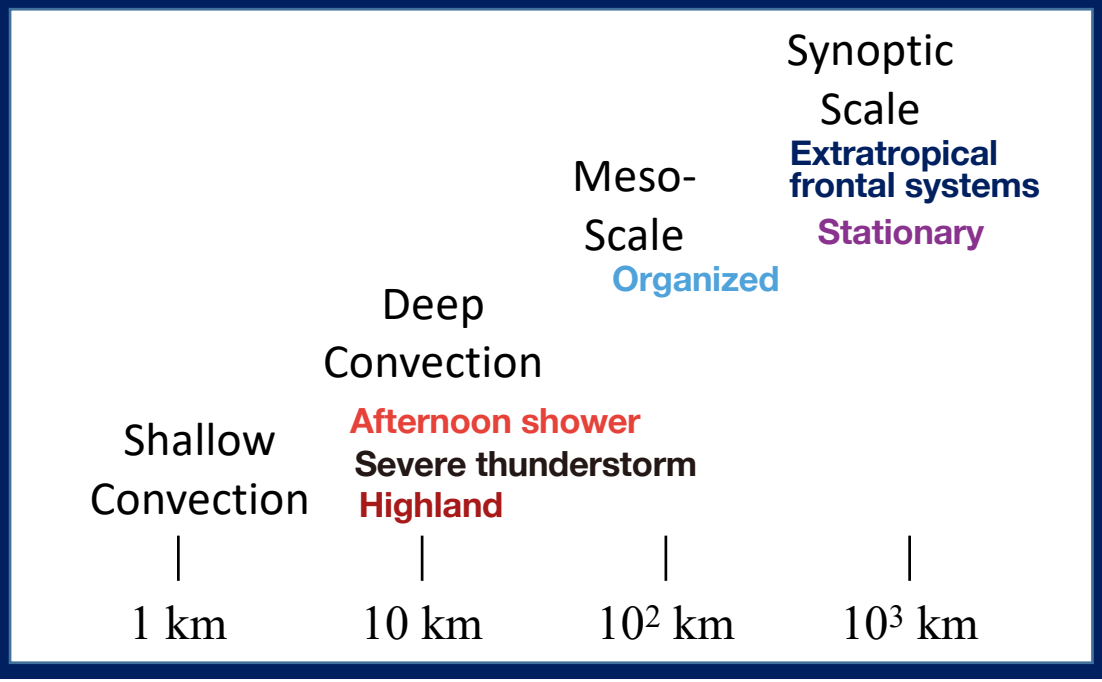


FIG. 1.1. A schematic figure showing the interaction between large-scale and moist-convective processes.

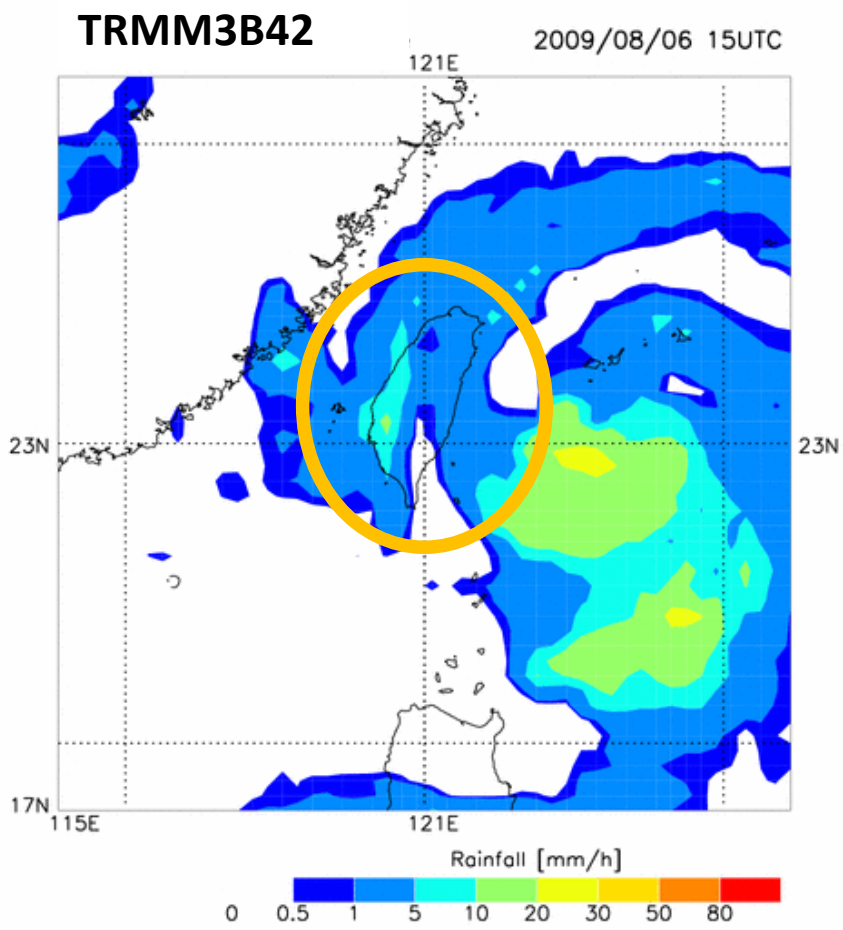
Shige and Kummerow (2016, JAS)

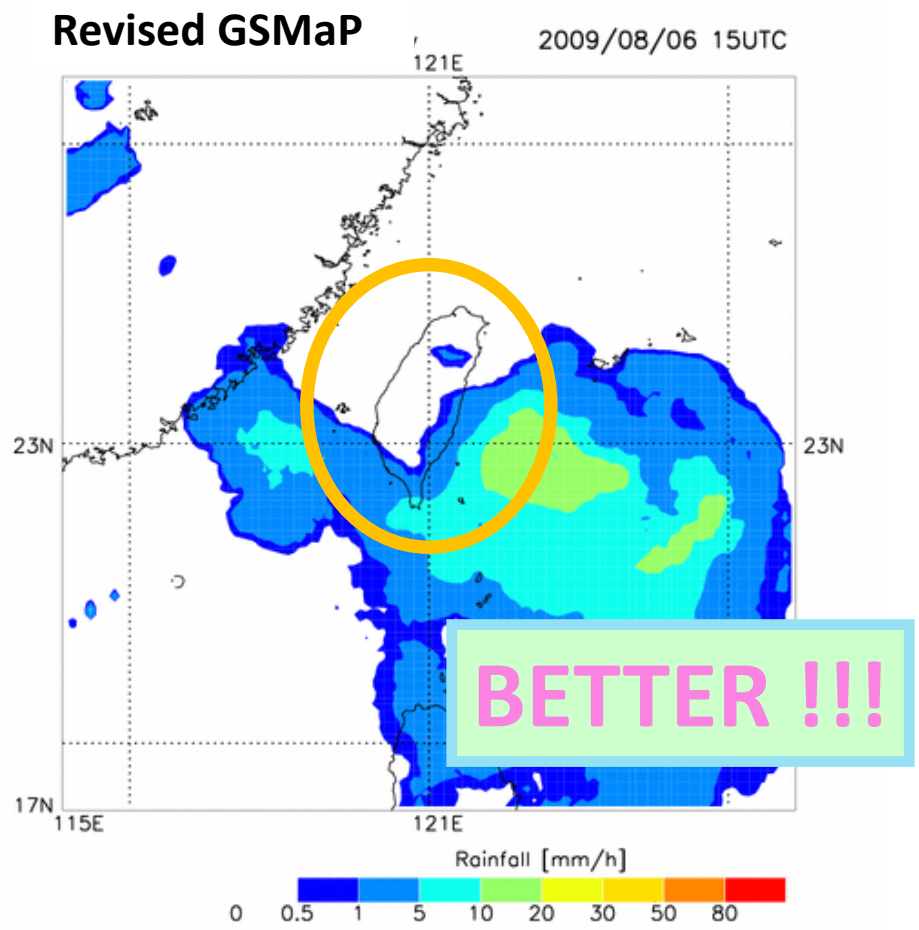




TRMM 3B42 vs. Revised GSMaP

15UTC 6 August 2009～ 15UTC 9 August 2009 3hourly

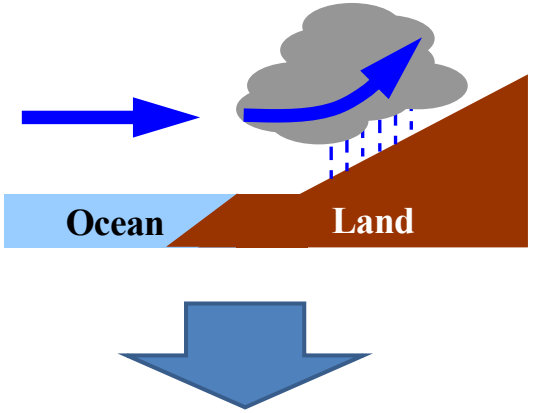




Summary

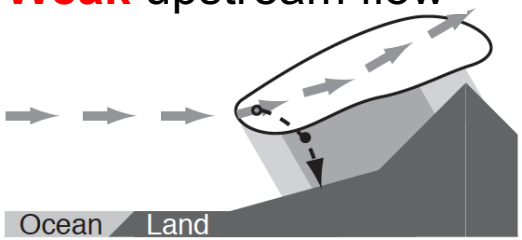
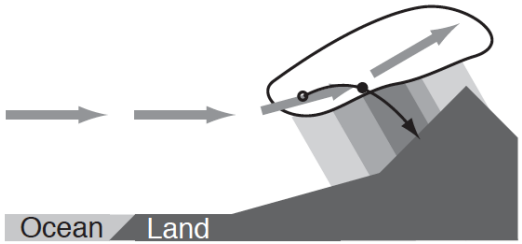
- A dynamic selection of lookup tables (LUTs) appropriate for heavy orographic rainfall, mainly based on topographic forced upward vertical motion, has been introduced in the GSMaP MWR algorithm.
- We improved the conceptual model of the warm-rain process for considering **the strength of the upstream flow** of the low-level troposphere (Yamamoto et al. 2017, JAMC). **GSMaP V7 (Current Version)**
- Use of low-level static stability (Shige and Kummerow 2016) instead of convergence of surface moisture flux may contribute to not only improvements of **coastal** orographic rainfall but also **inland** orographic rainfall.

Shige et al. (2013)



Yamamoto et al. (2017)

Weak upstream flow



Strong upstream flow