Warm Season Heavy Precipitation Observed from Satellite Earth Observations

Yukari N. TAKAYABU[1], Hiroki TSUJI[1], Chie YOKOYAMA[1], and Atsushi HAMADA[2]

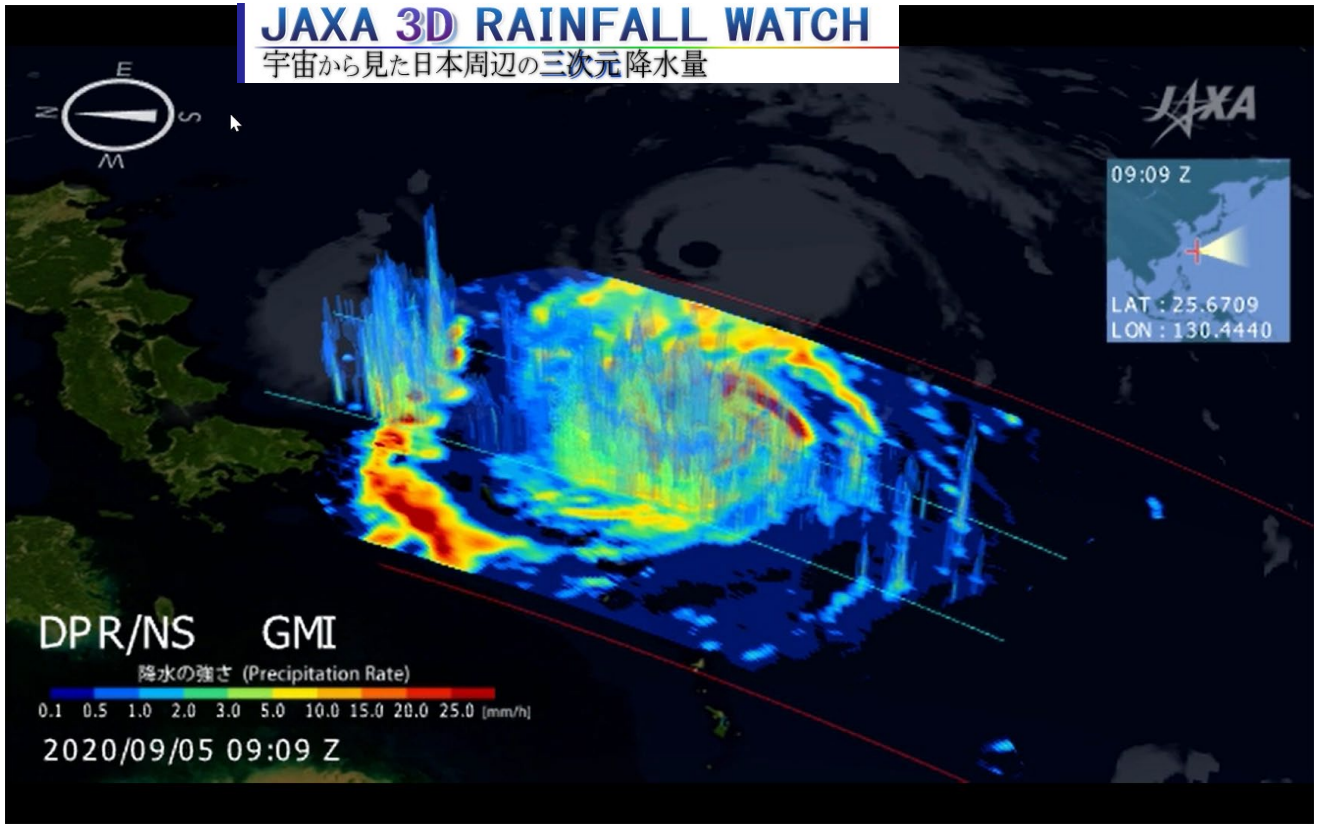
[1] The University of Tokyo

[2] University of Toyama

“July 2018 Flood” 7July2018 Mabi-cho, Kurashiki
(c)共同通信社/アマナイメージズ

In recent years, frequency of wide-area heavy rainfalls causing disastrous floods is increasing in Japan.

Precipitation Radar Observation from Space



2020.09.05 2020Typhoon#10

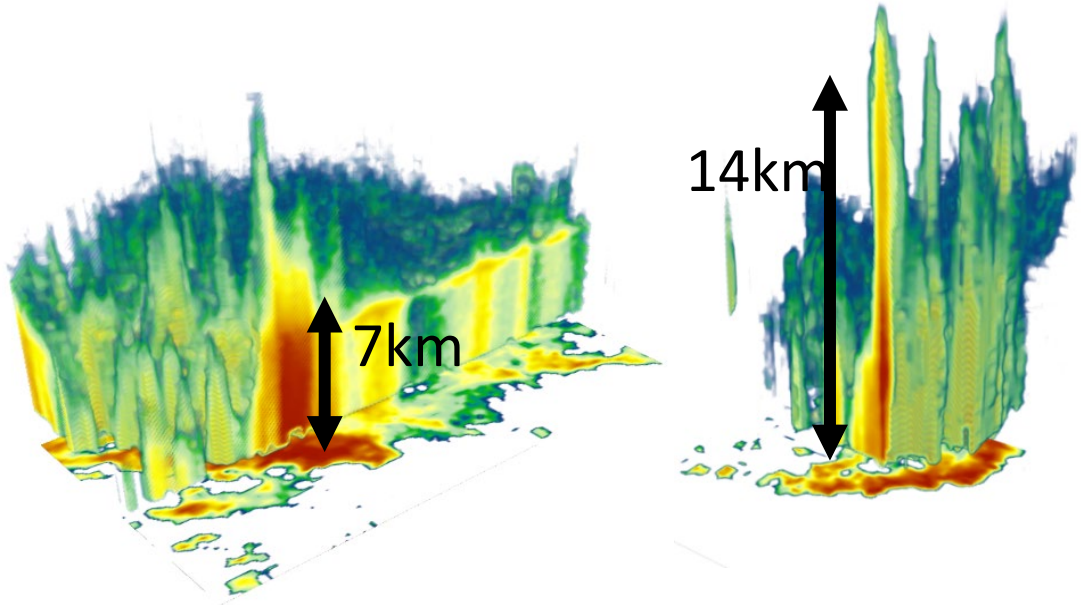
JAXA Web Page

Space-born Precipitation Radar
by JAXA&NICT

TRMM PR (Ku) 1997.11-2015.6

GPM DPR (Ku+Ka) 2014.2.28-Present

>24years

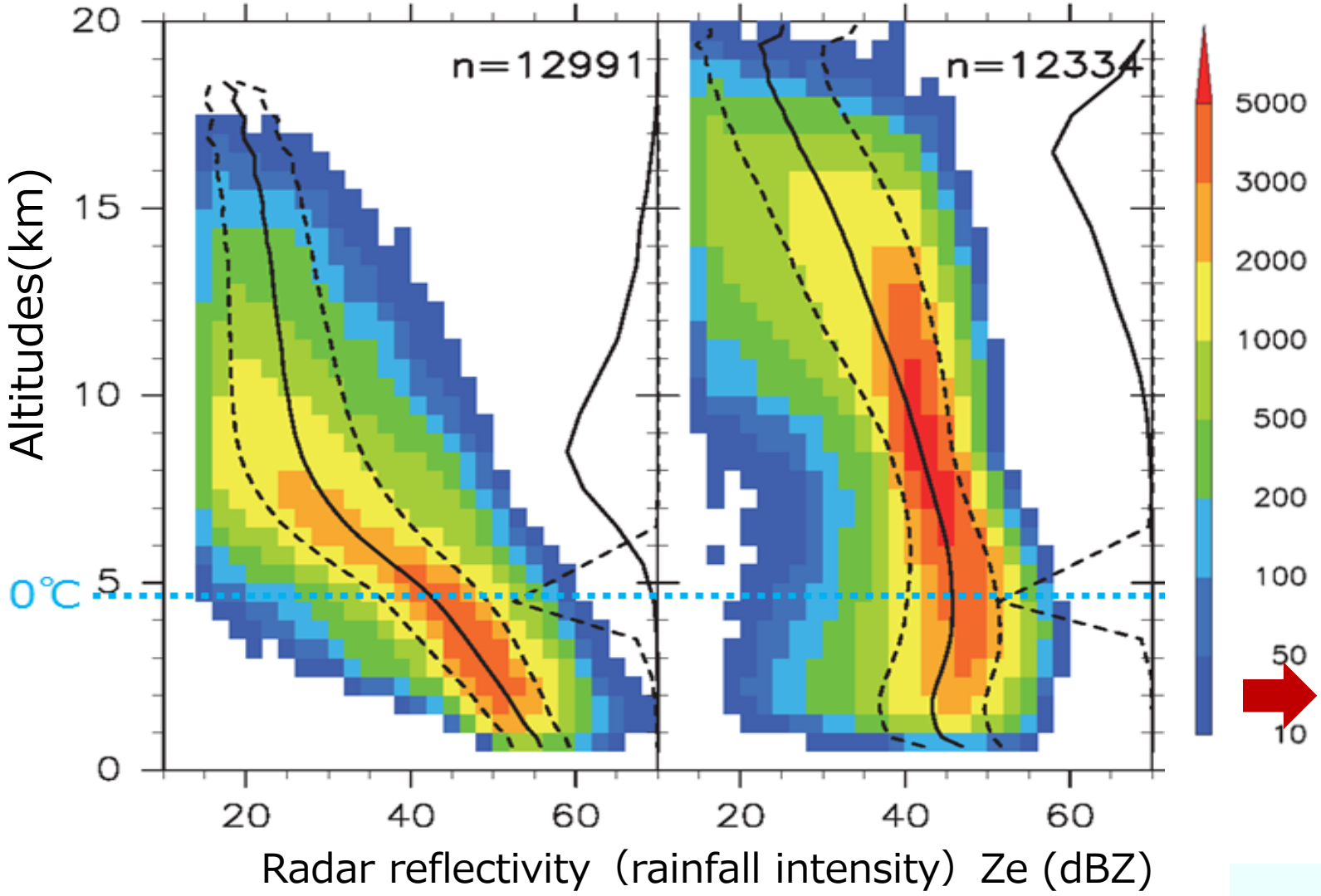


By capturing rainfall events in 3D, we can investigate “characteristics of rainfalls” with their height, area, stratiform/convective ratio, etc.

Extreme Rainfall and Extreme Convection (top 0.1%) Observed from TRMM PR (35N-35S)

(Hamada et al. 2015, Nature Comm)

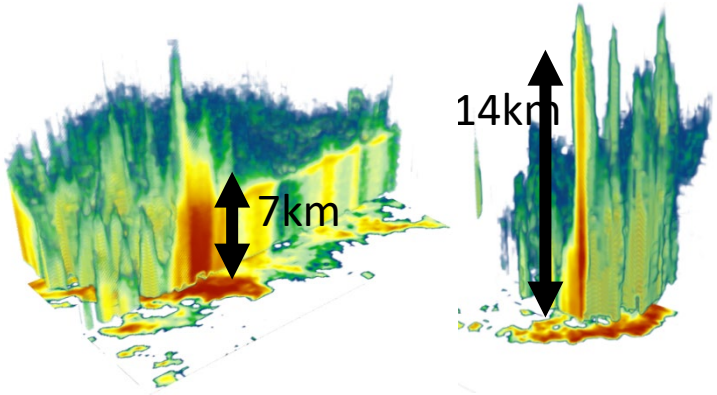
R-extreme | H-Extreme



Defined with Max. Near Sfc Rainfall Defined with max height of 40dBZ

←2D histograms of precipitating pixels over land for 35N–35S

Statistics at each 2.5° x2.5° lat-lon grid
2001.9-2012.8 total >85,000,000 rainfall events



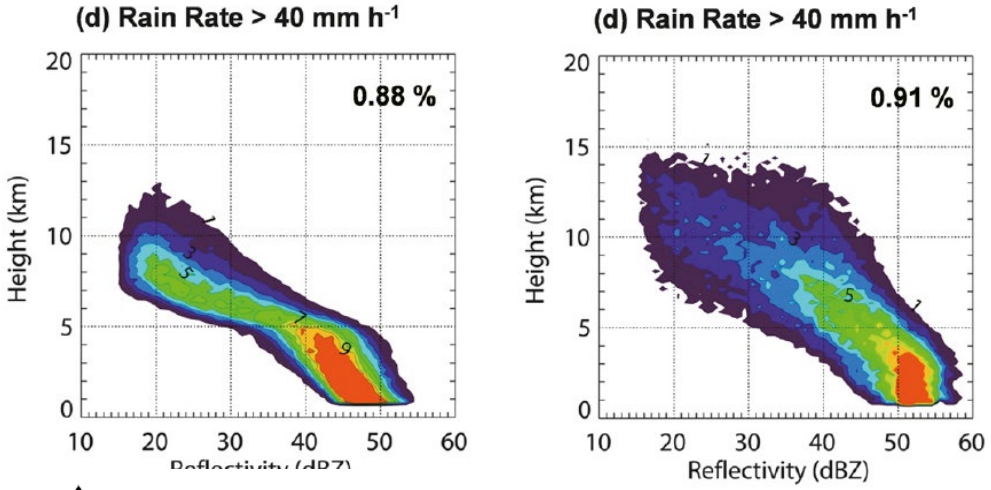
Heaviest Rainfall is not often accompanying tallest convection

In resonance with Dr. Yali Luo's talk (Yu et al. 2020) on Wednesday !

Heavy Rainfalls in Moist East Asia

(Sohn et al. 2013, MWR)

Korean Heavy Rain vs. Oklahoma Heavy Rain



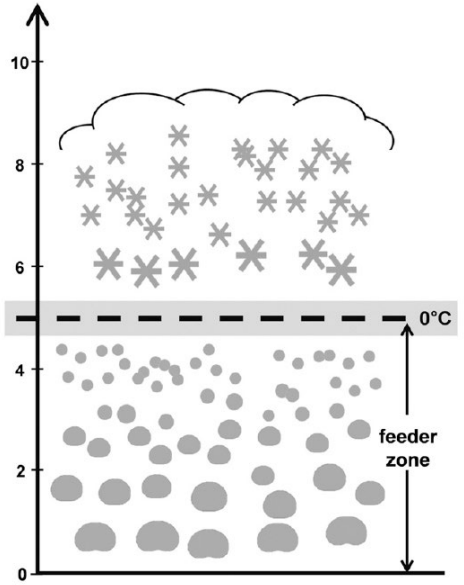
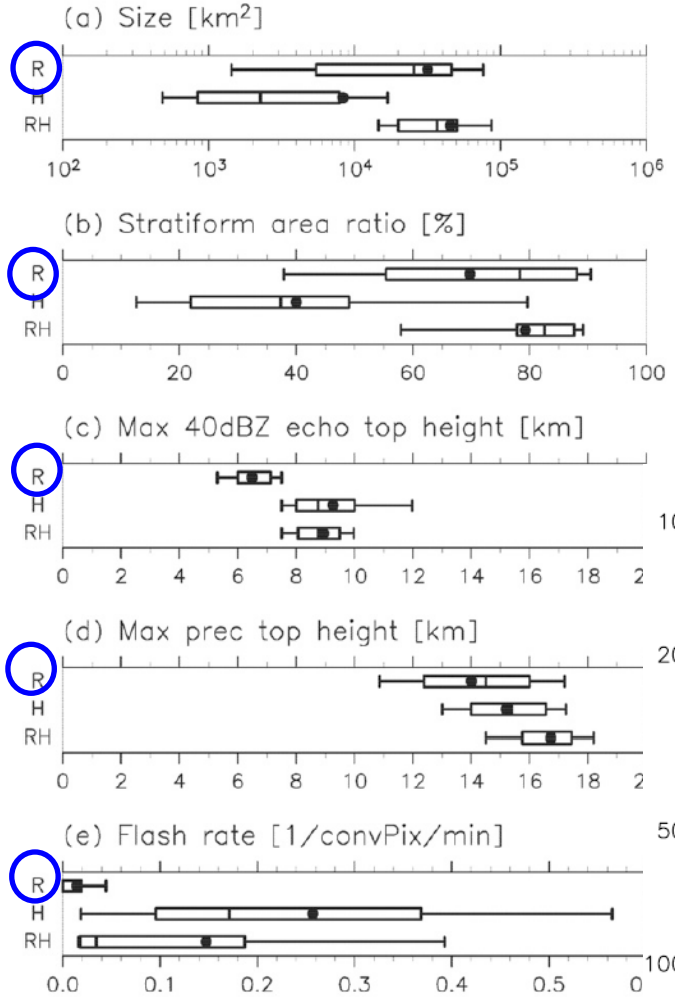
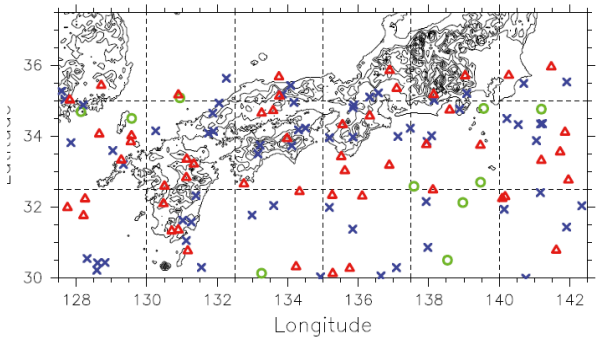


FIG. 11. A schematic diagram showing the growing processes for warm-type rain over the Korean peninsula during summer. The

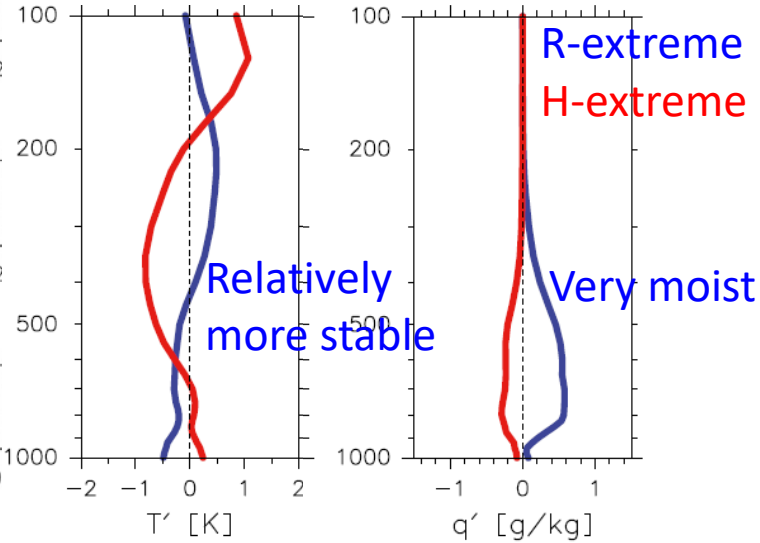
Defined as "Warm type" and "Cold type" extremes in Sohn et al. 2013.

(Hamada and Takayabu, 2018, J. Clim)





Env. Anomalies from the Clim.



Rainfall-extreme systems have larger-size, larger stratiform ratio, relatively low convection, less lightnings, indicating organized systems.

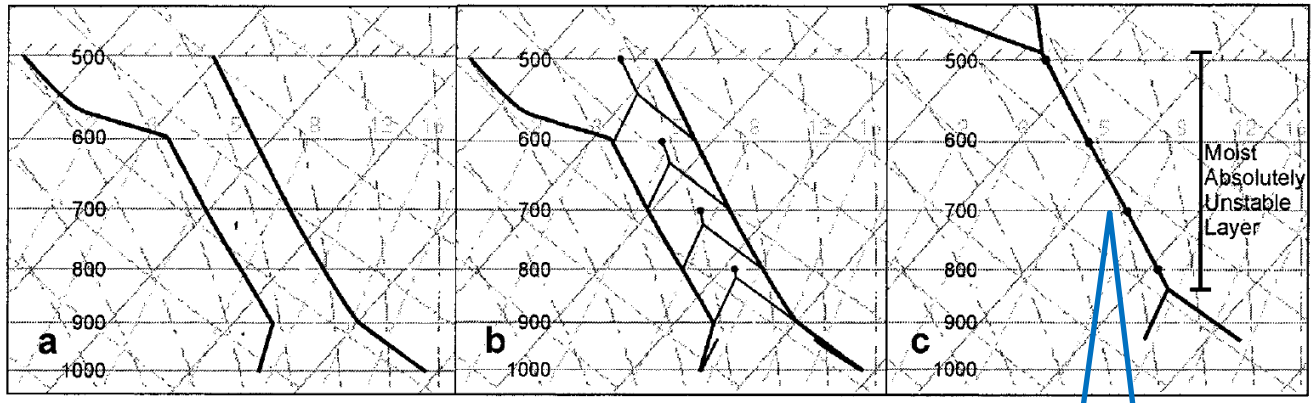
What causes heavy rainfalls ?

Moist Absolutely Unstable Layer (MAUL)

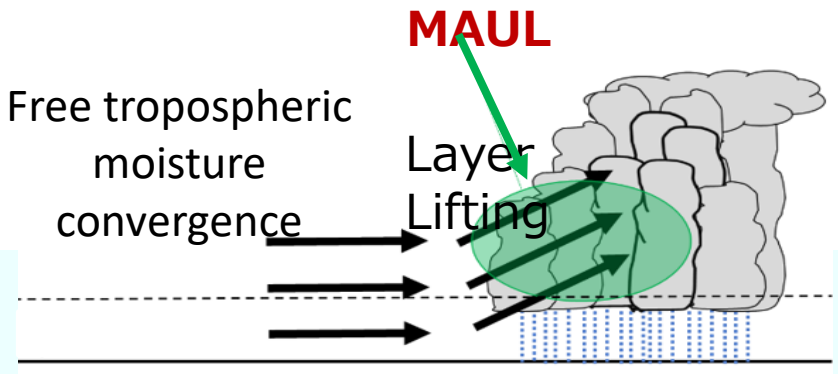
(Bryan and Fritsch 2000)

Very Moist Atmosphere → Organized System

Convectively Unstable | Layer Lifting | Moist Absolutely Unstable Layer



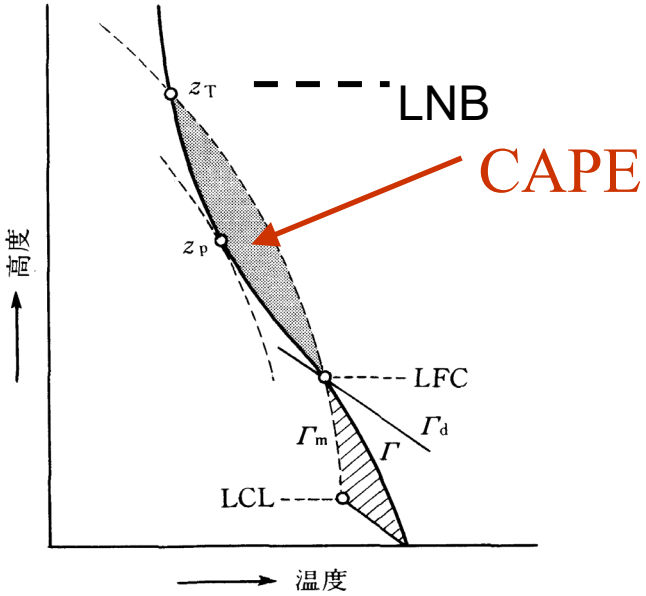
An example of profiles with MAUL

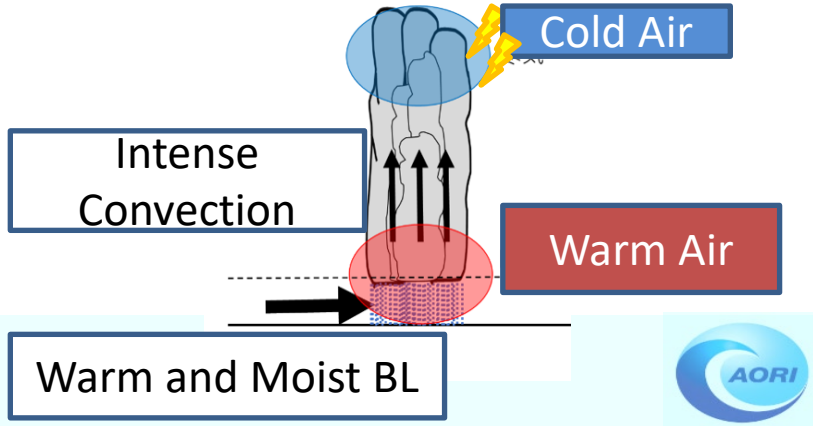


Immediate Convection

CAPE

Unstable Atmosph → Severe convection

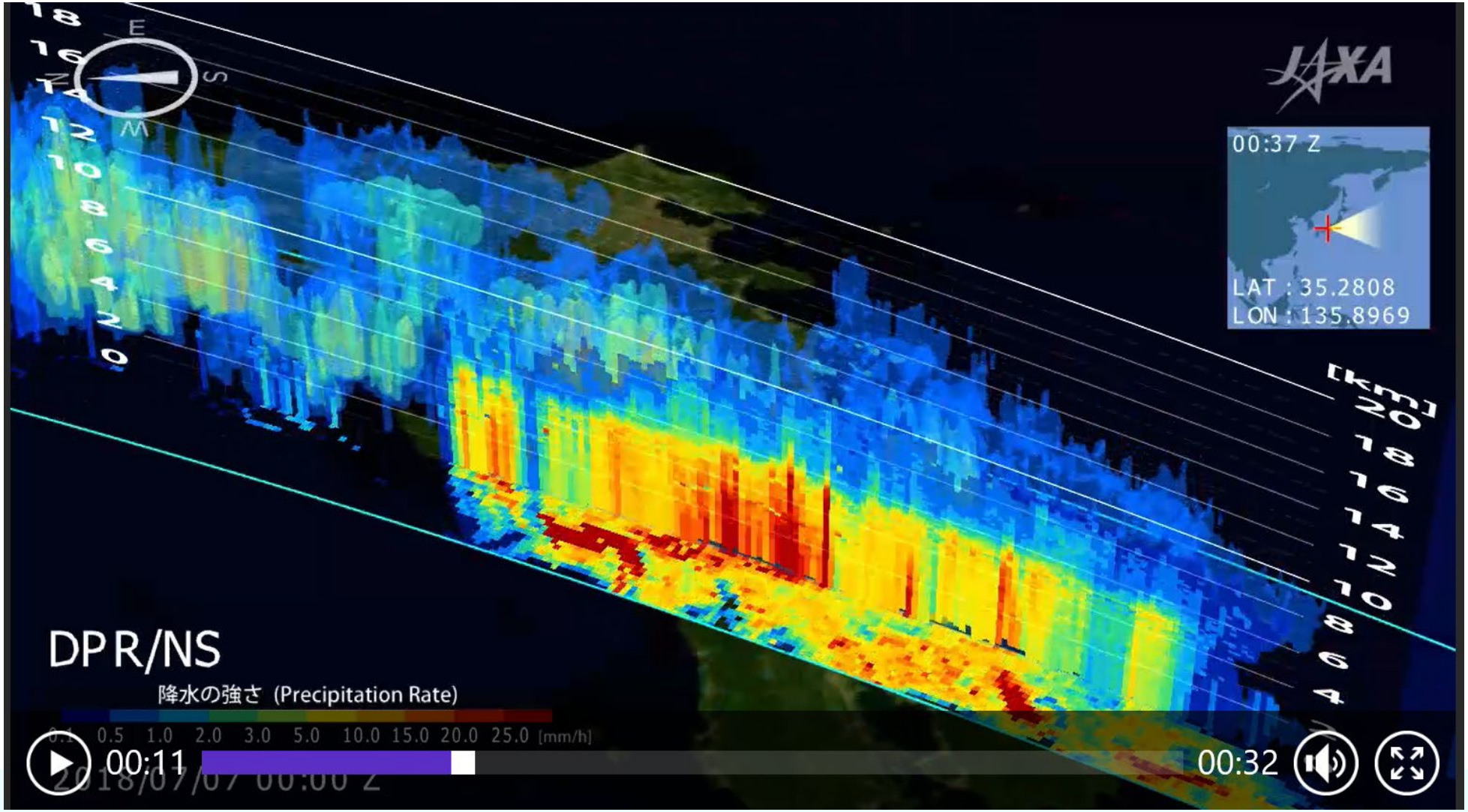


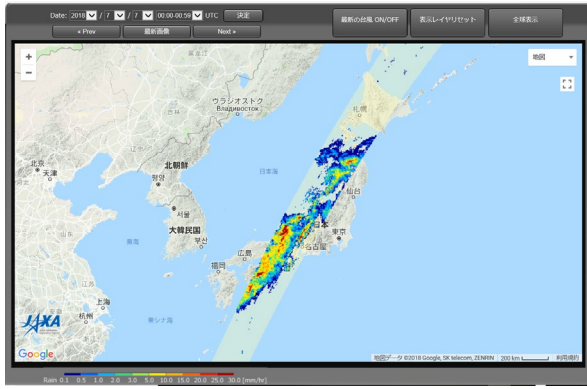


Schematics by H. Tsuji

The July 2018 Heavy Rainfall Event Observed by GPM DPR

9:38JST 7 July 2018





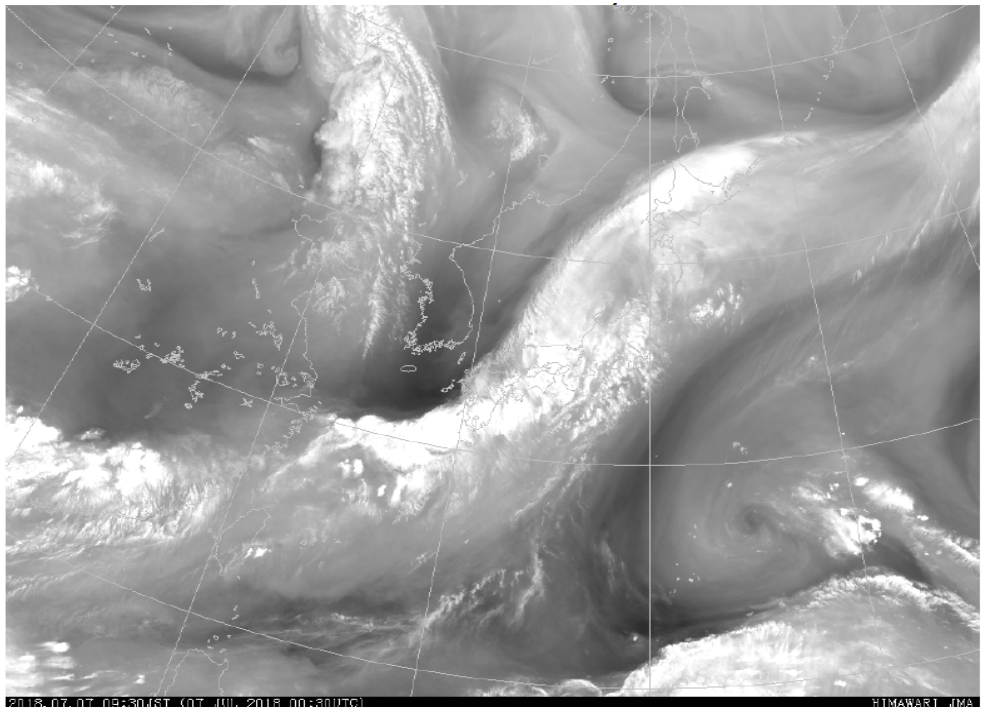
Despite the record-breaking rainfall amount, rainfall height over 10km is scarcely observed.

Plot by JAXA

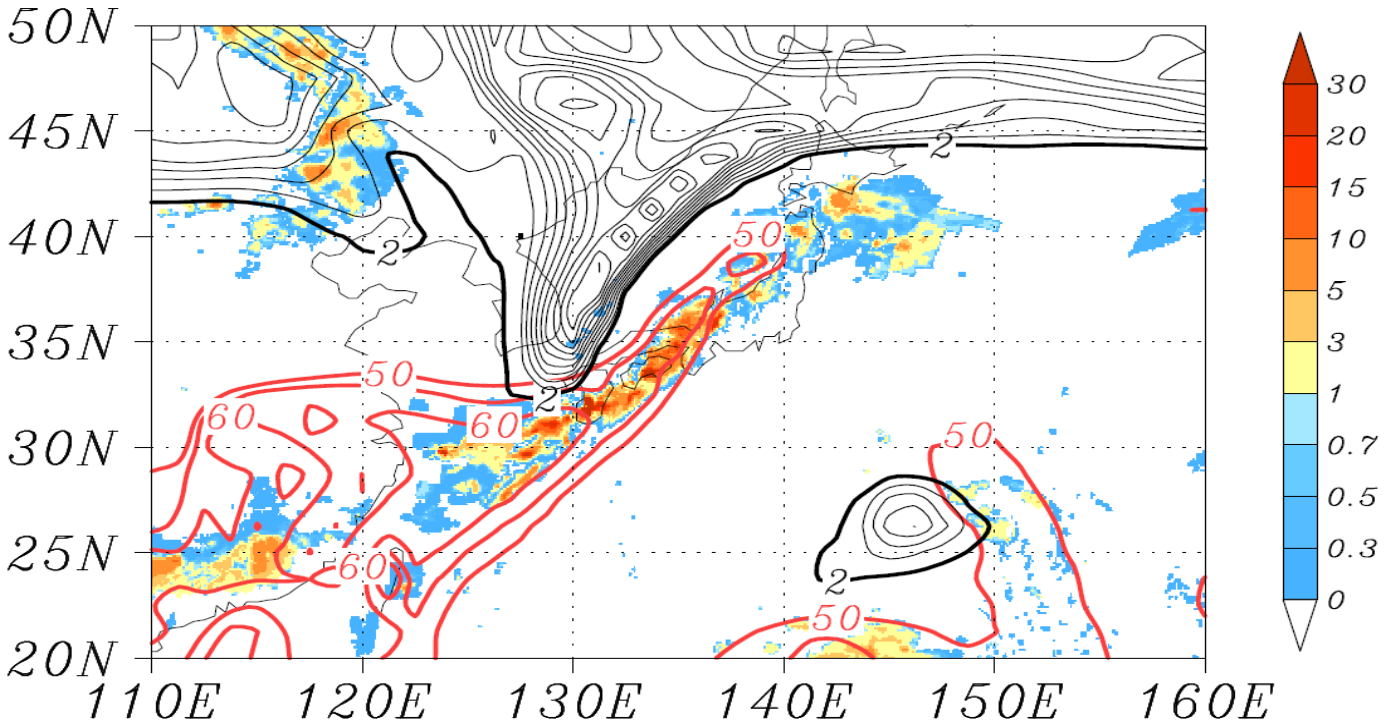
Large-scale environment for the July 2018 Heavy Rainfall Event

0900 JST 7 July 2018

Himawari-8 water vapor image (provided by JMA)



Rainfall (color), potential vorticity at 350K (black cnt.), precipitable water (red cnt.)

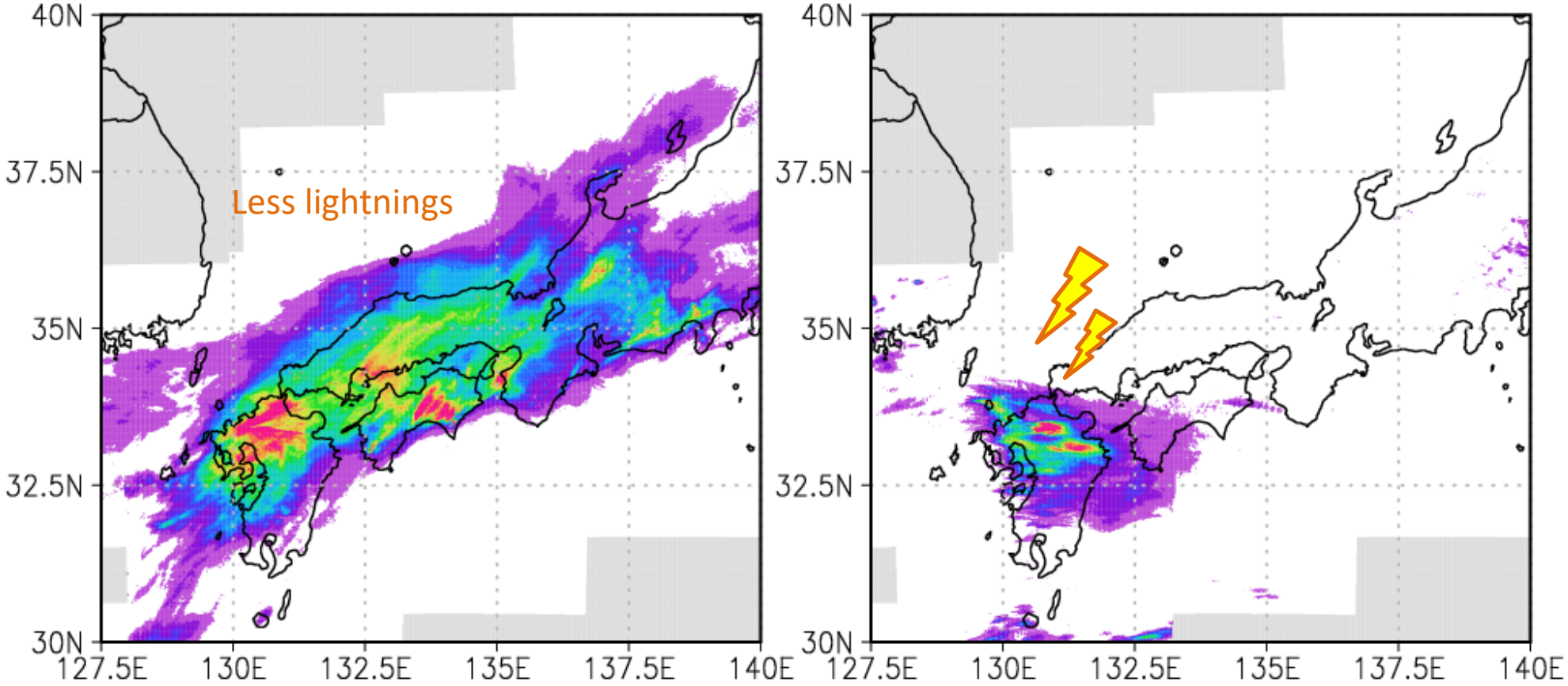


Yokoyama et al. 2020, JMSJ

Accumulated rainfall (24 hours): Comparison with the 2017 Northern Kyushu heavy rainfall in Japan

July 2018 Heavy Rainfall Event over W. Japan

July 2017 Heavy Rainfall Event in N. Kyushu

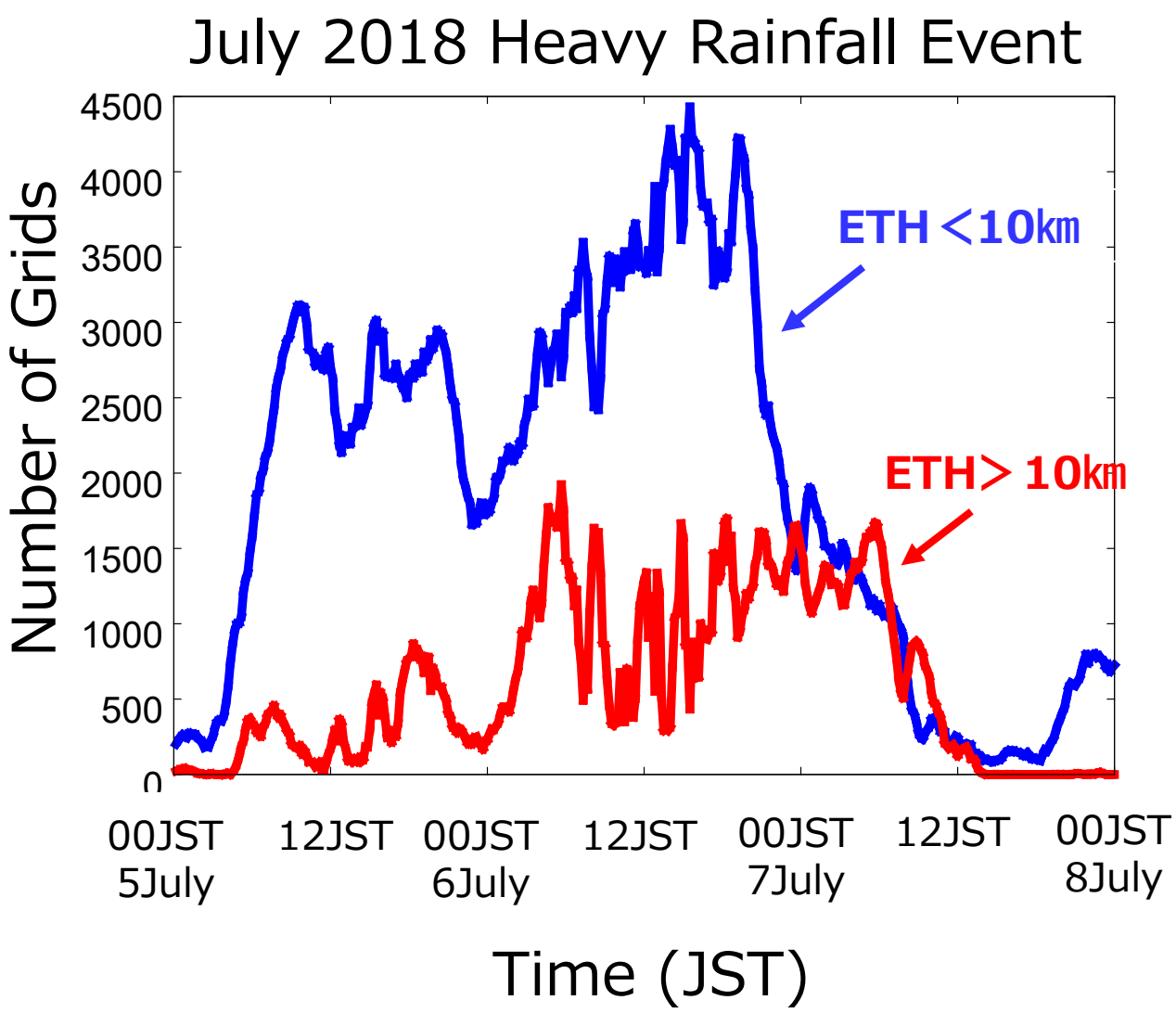


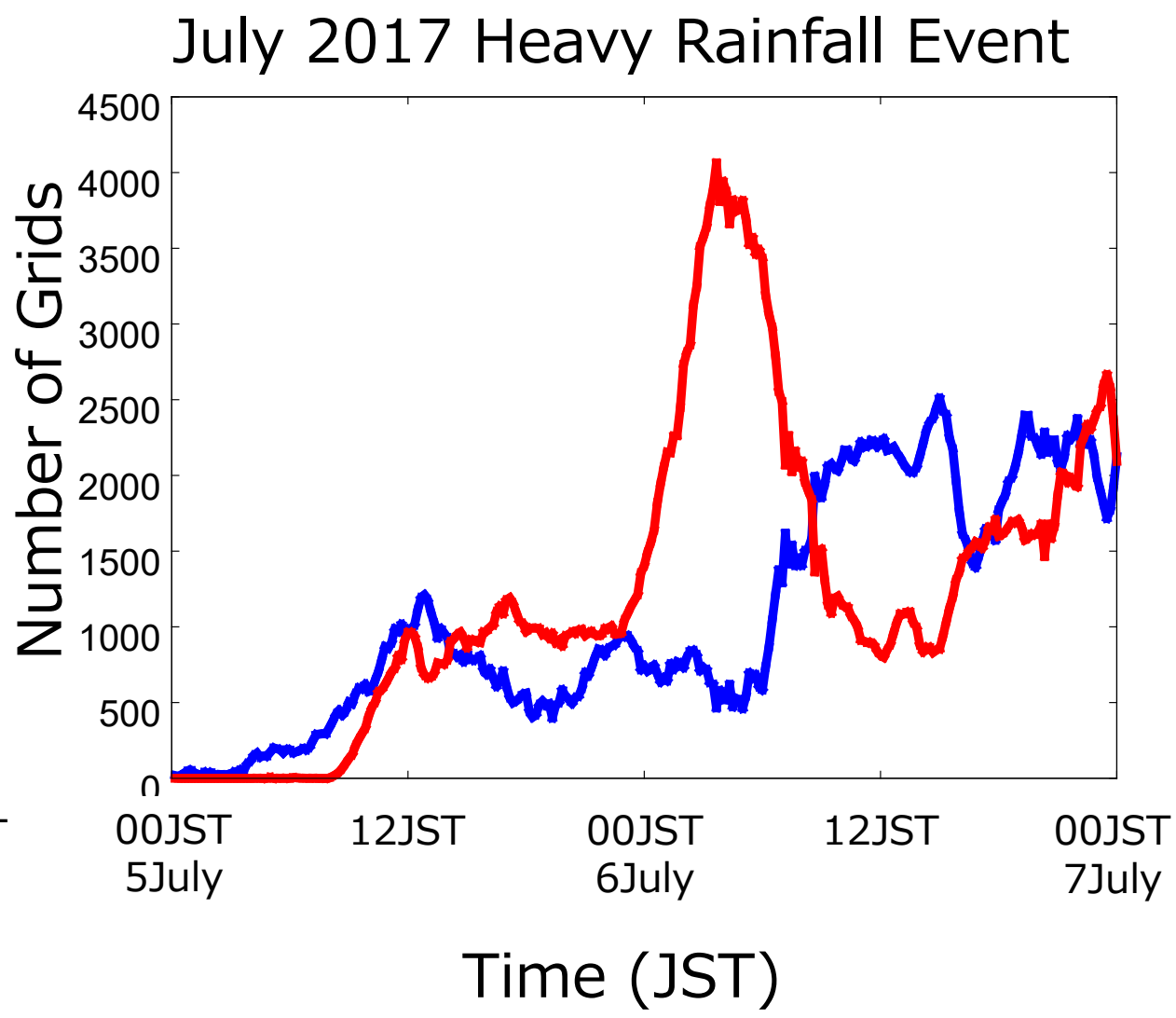
00 JST 6 July~00 JST 7 July

12 JST 5 July~12 JST 6 July

Tsuji et al. 2020, JMSJ

Time series for very tall rain grids and moderate-height rain grids for heavy rainfall events (JMA N. Kyushu Radar)





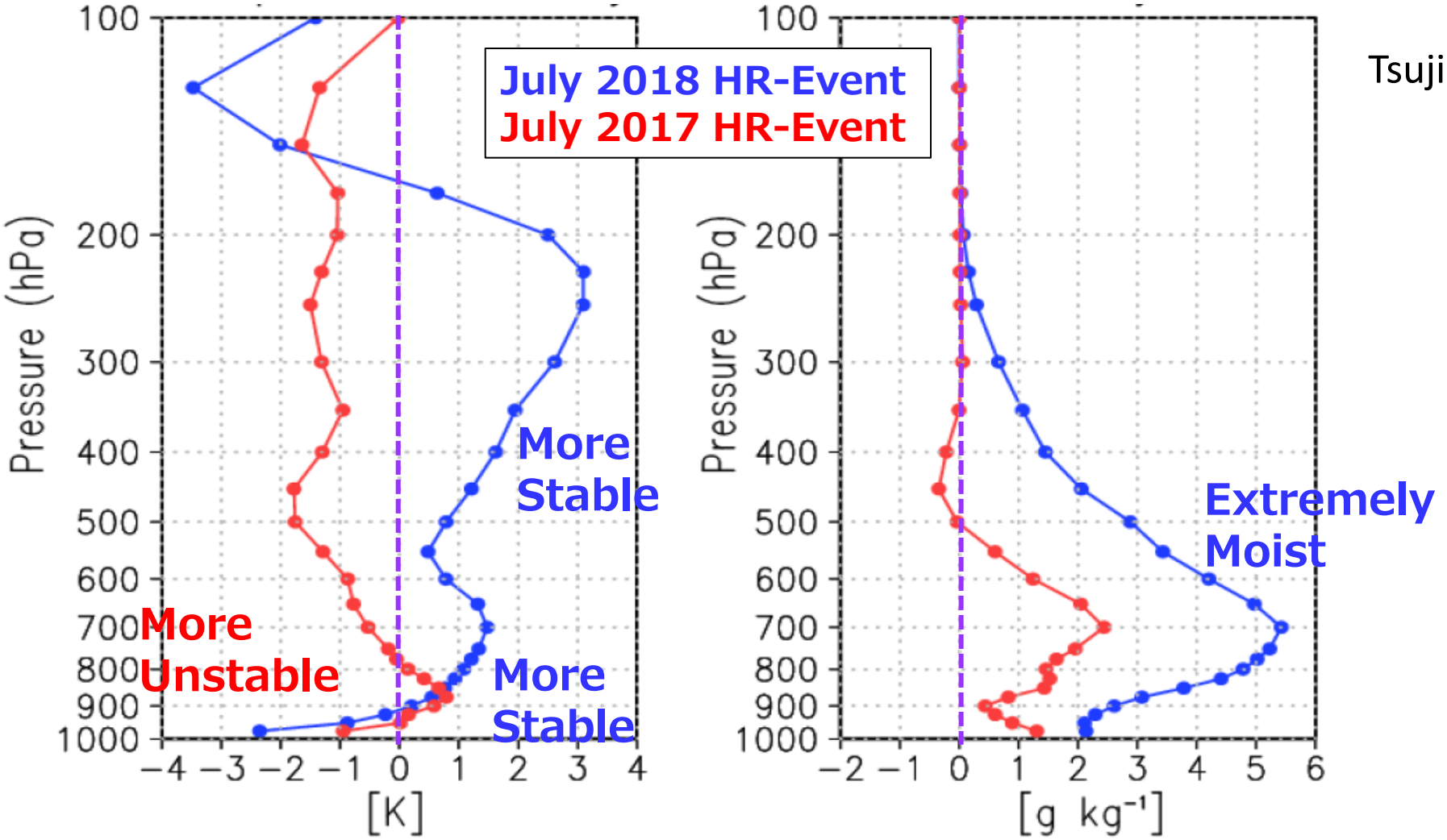
Red : Echo top height >=10 km
Blue : Echo top height <10 km

Tsuji et al. 2020, JMSJ

Comparison of Environments
in anomalies from the climatology

Temperature Anom

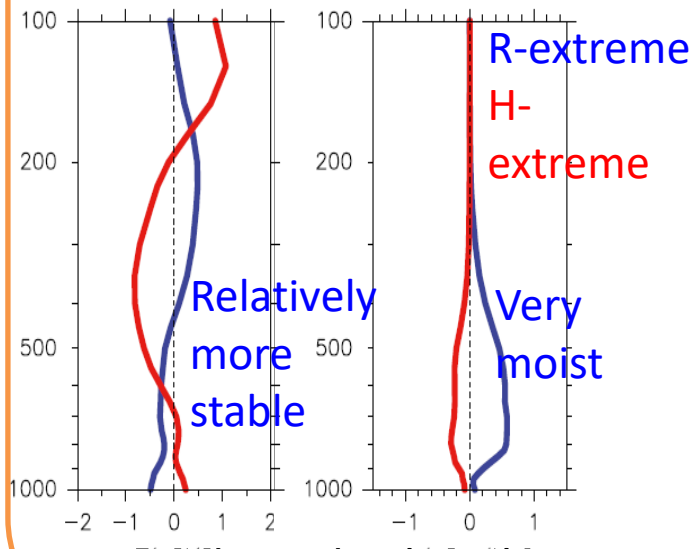
Specific Humidity Anom



Tsuji et al. 2020, JMSJ

Env. Anomalies from the Clim.

T-anom SpHum-anom



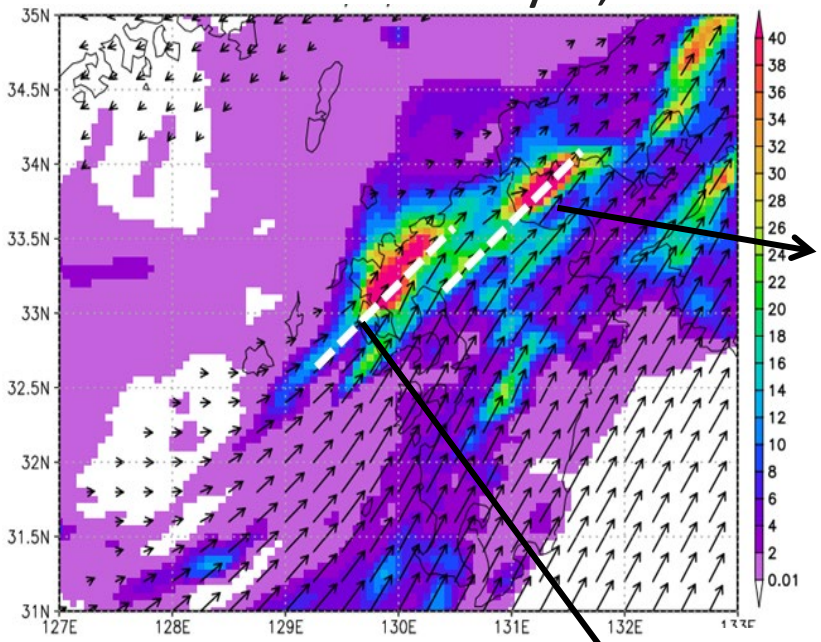
Hamada and Takayabu, 2018

➡These contrasts well corresponds to the statistics for the Extreme Rainfalls and Extreme Convection around Japan (Hamada and Takayabu, 2018)

Vertical Cross Sections of Deep Inflow Layer in 2018 Case

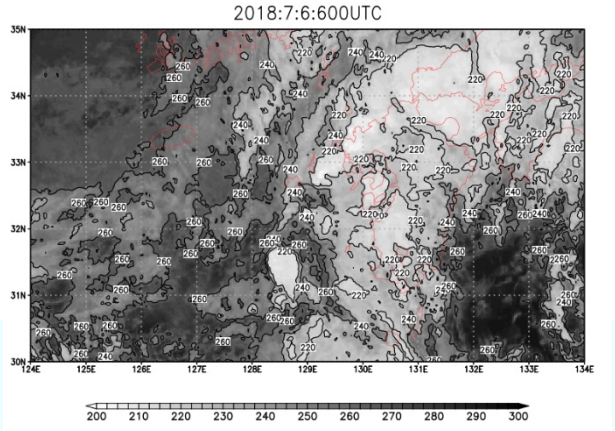
06UTC July 6, 2018

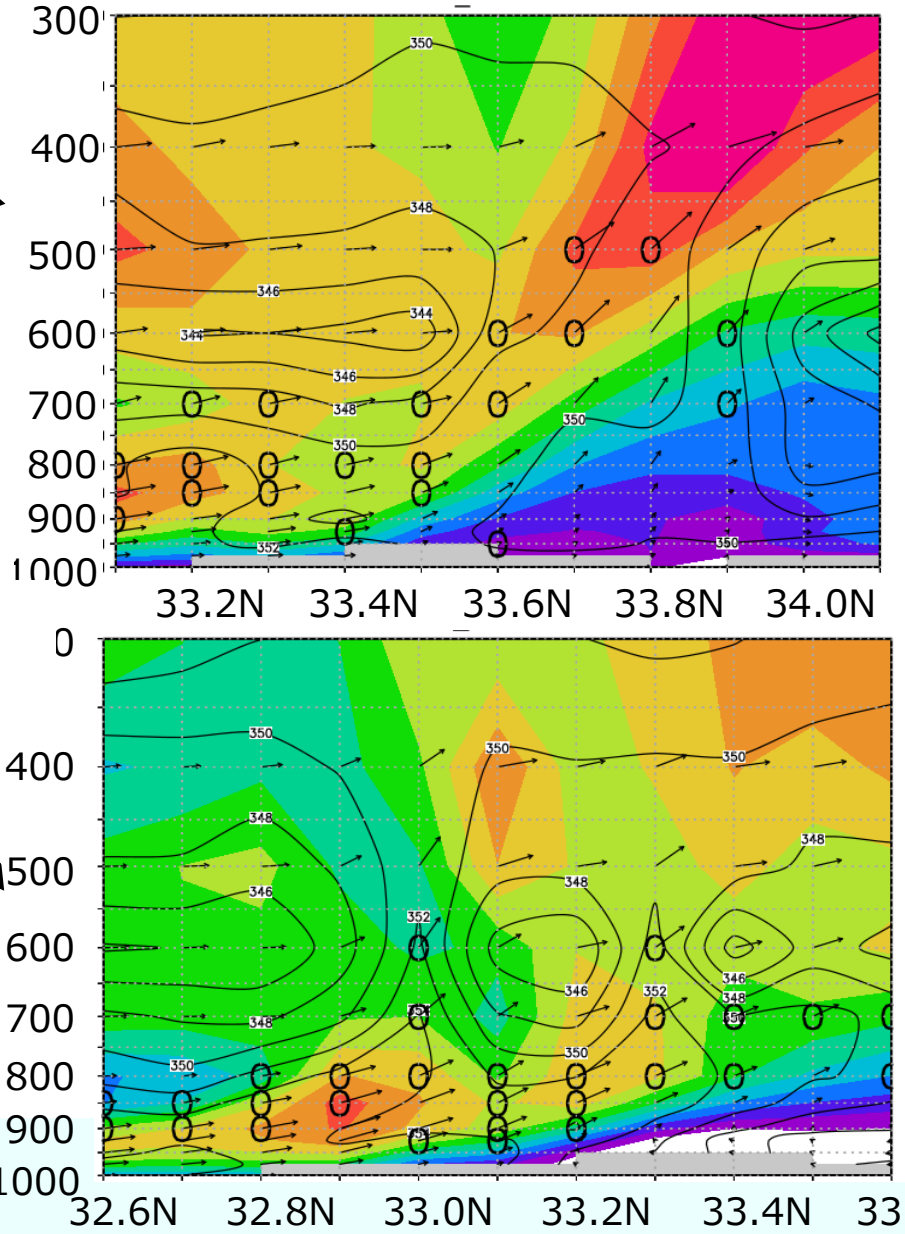
Same as Tsuji et al. 2021, but for a different case



Color: Precipitation

Vectors: Vertically Integrated Moisture Flux (kg m^{-1} s^{-1})





Black Open **O**s: **MAUL** cond.

Color: Horizontal Wind Speed

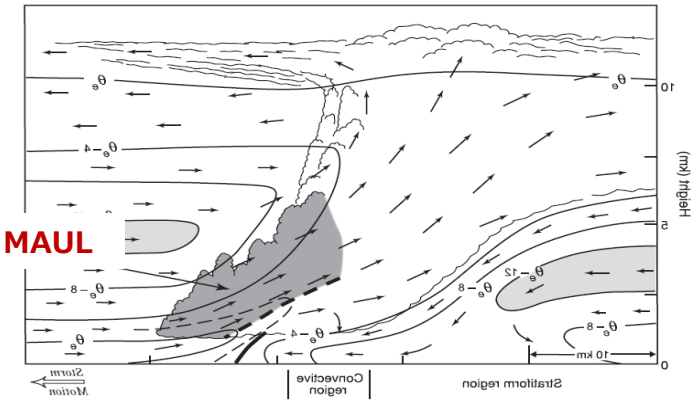
Vectors: Wind Vectors

20 (m/s, Pa/s)

* MAUL condition

$\partial\theta_e/\partial z < 0$ and RH>99%

(Takemi and Unuma 2020)



MAUL condition similar to (Bryan and Fritsch, 2000) is diagnosed

Contrasting Heavy Rainfall Events and their Environments

Tsuji et al. 2020, JMSJ

July 2018 Event

Deep trough

Warm

Relatively Stable

Very moist

MAUL

Dynamically induced ascent

Cold

Well Organized system

Long-lasting precipitation with extended areas

July 2017 Event

Shallow trough

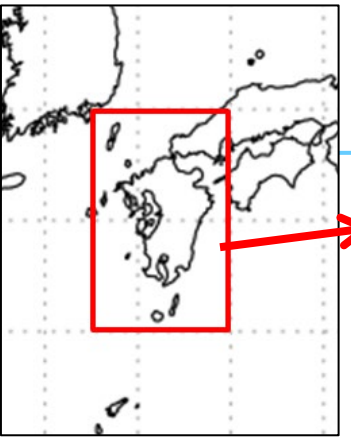
Cold

Unstable

Tall system

Warm

Short-term precipitation with narrow areas

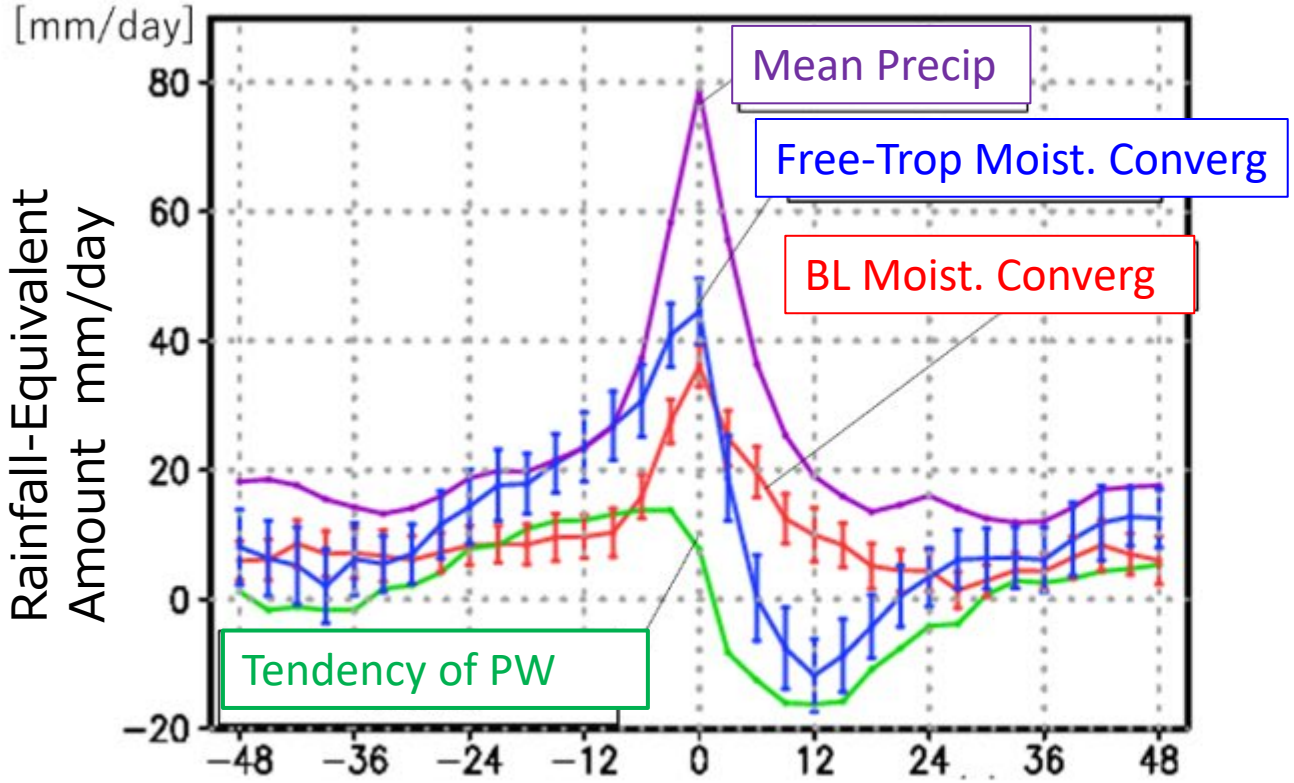


Composite Time Series for Heavy Rainfalls

Regional Mean Rainfall＞60 mm/day (62cases) Jun-Aug 2006-2020

Data: JMA MSM Initial Values, AMeDAS raingauge (Tsuji et al. *GRL, 2021)*

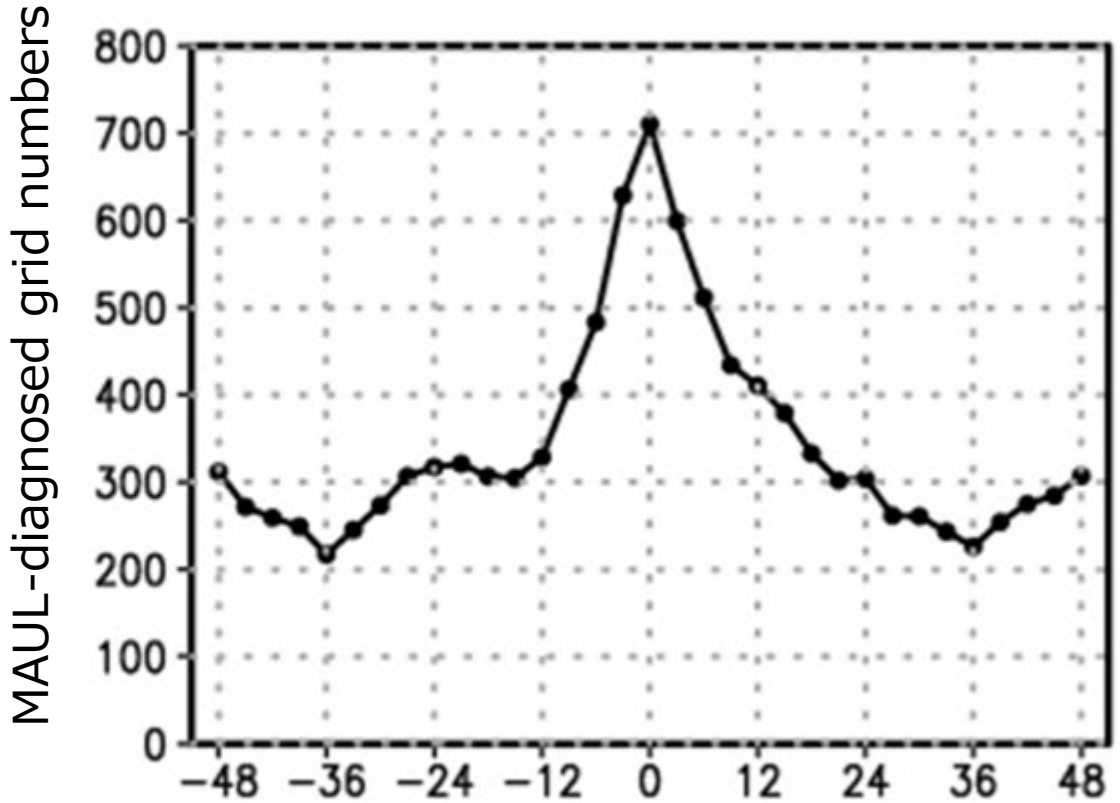
(a) Precipitation and Moisture Convergence



Relative hours from the Heavy Precipitation Peak

Bars : 95% Confidence

(b) Grid numbers satisfying the **MAUL condition**



Relative hours from the Heavy Precipitation Peak

- Free Tropospheric moisture convergence precedes
- MAUL condition is prepared

Summary

- In recent years, frequency of wide-area heavy rainfalls causing disastrous floods are increasing in Japan.
- Statistical studies of rainfall events observed from space-borne precipitation radars revealed that extremely heavy rainfalls do not often accompany extremely tall convection. Environments for heavy rainfalls show relatively stable but extremely moist condition.
- There are two types of heavy rainfalls, one is with CAPE-type instability, another is with Moist Absolute Stable Layer (MAUL).
- Wide area heavy rainfalls are associated with free tropospheric moisture convergence preparing MAUL environments favorable for organized convection.
- Atmospheric water vapor amount has been significantly increasing in past 30 years with the global warming. We should prepare for a further increase of MAUL-type heavy rainfalls in the warmer climate.

Thank you !