Occurrence of extreme rainfall events associated with the Madden-Julian Oscillation

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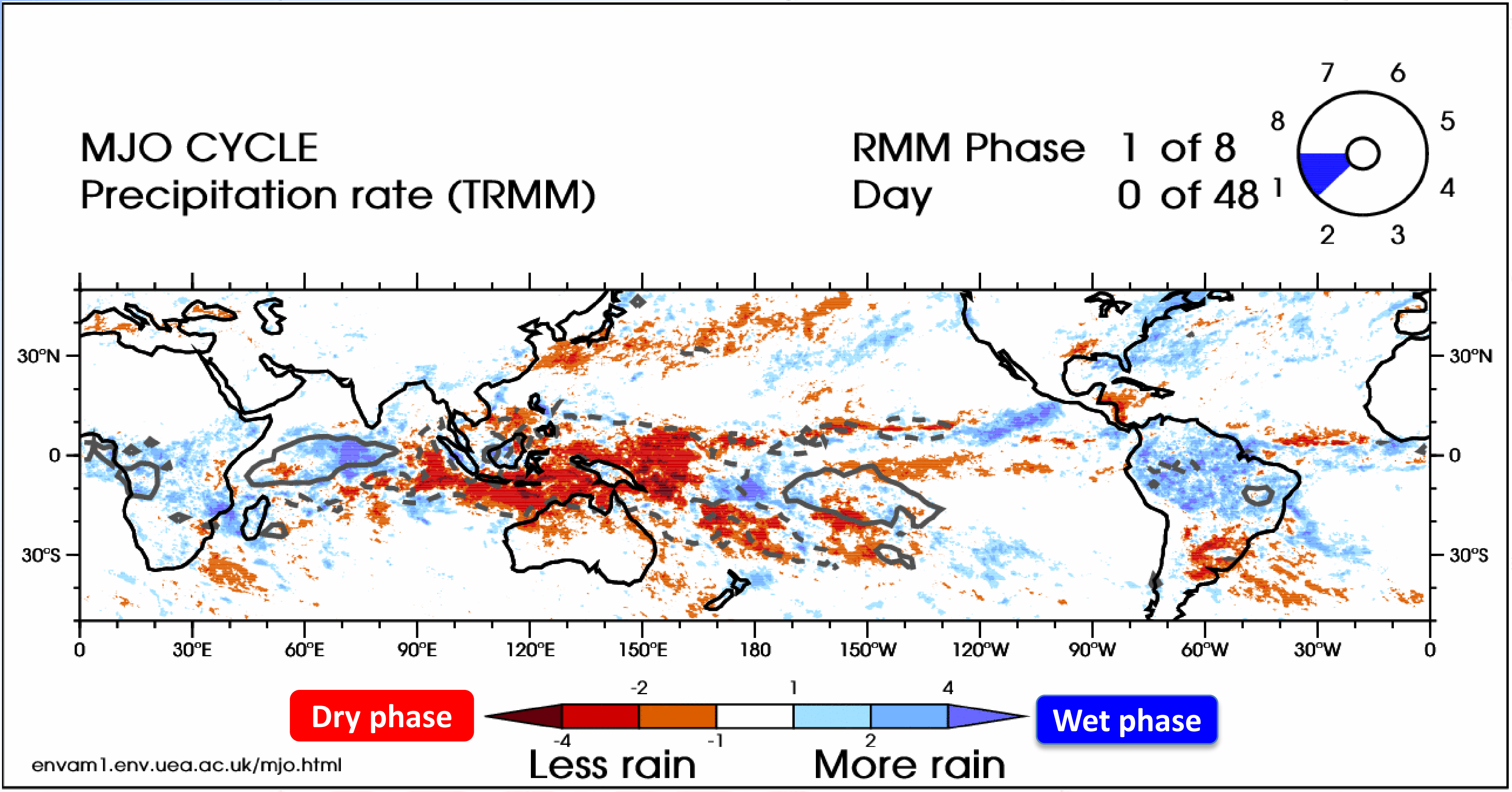
Background

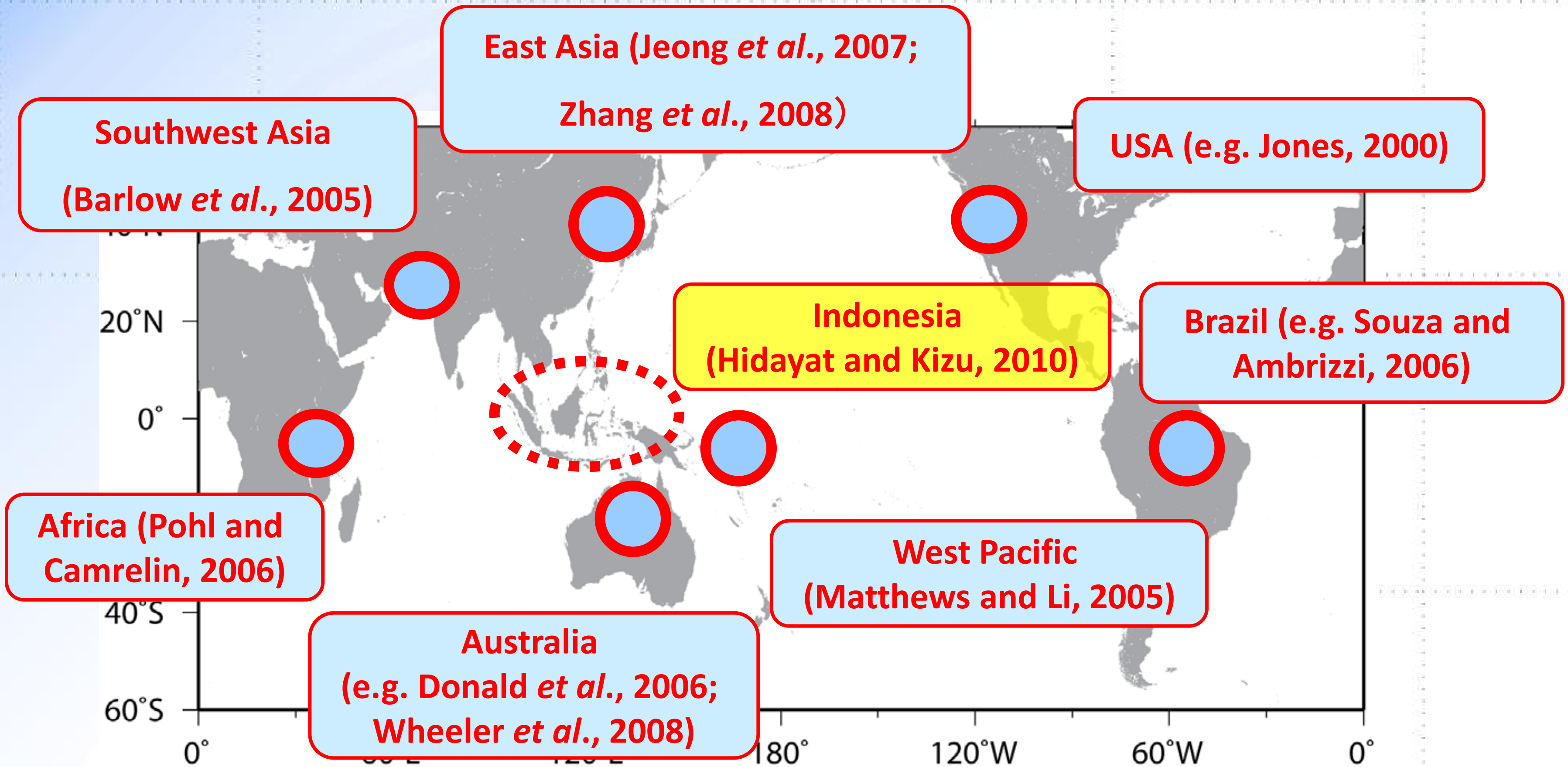
- Indonesia is vulnerable to climate variability and change. The occurrence of extreme climate events have caused serious impact in many sectors.
- Extreme climate events are strongly influenced by rainfall variability. → Extreme dry event leads to devastating drought with crop failure. → Frequent heavy rainfall can lead to severe floods.
- Understanding of rainfall variability and its impact to the region is essential in order to improve the quality of climate forecasting and to reduce the risk of natural disaster.
- Hidayat and Kizu (2010) have pointed out that rainfall variabilty over Indonesia is significantly modulated by the Madden-Julian Oscillation

The Madden-Julian Oscillation



The Madden-Julian Oscillation (MJO) has a strong influence on the atmospheric circulation in tropics during northern winter and early spring (e.g. Madden and Julian, 1974)

Studies on Rainfall variability and the MJO



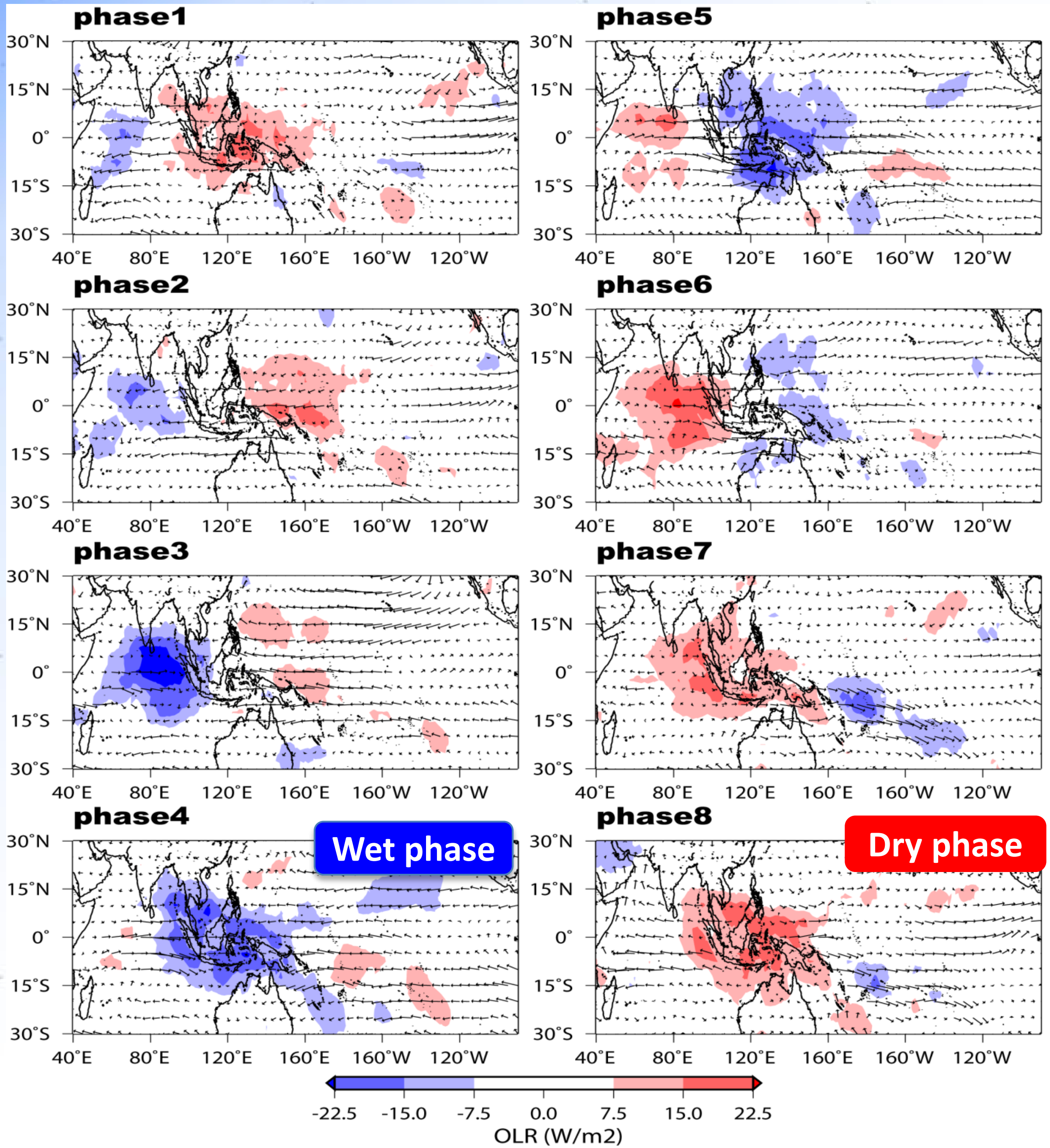
Purpose of study :

To investigate the role the Madden-Julian Oscillation in modulating occurrence of extreme rainfall events over Indonesia

Data

1. **3-hourly gridded (0.25^0 x 0.25^0) TRMM (Tropical Rainfall Measuring Mission) rainfall 3B42.**
2. **Daily Real-time Multivariate MJO (RMM) index** (Wheeler and Hendon, 2004).
3. **Daily gridded (2.5^0 x 2.5^0) zonal (u), meridional (v)** (NCEP 2 reanalysis; Kanamitsu *et al*., 2002)
4. **Daily gridded (2.5^0 x 2.5^0) Outgoing Longwave Radiation (OLR)** (NOAA; Liebmann and Smith, 1996).

MJO-related convection and circulation (u850 hPa)



Phase 8- 1

- **Indonesia is mostly covered by convectively-suppressed area.**

Phase 2 - 3

- **enhanced convection in western Indian Ocean → moves eastward as easterlies strengthened.**

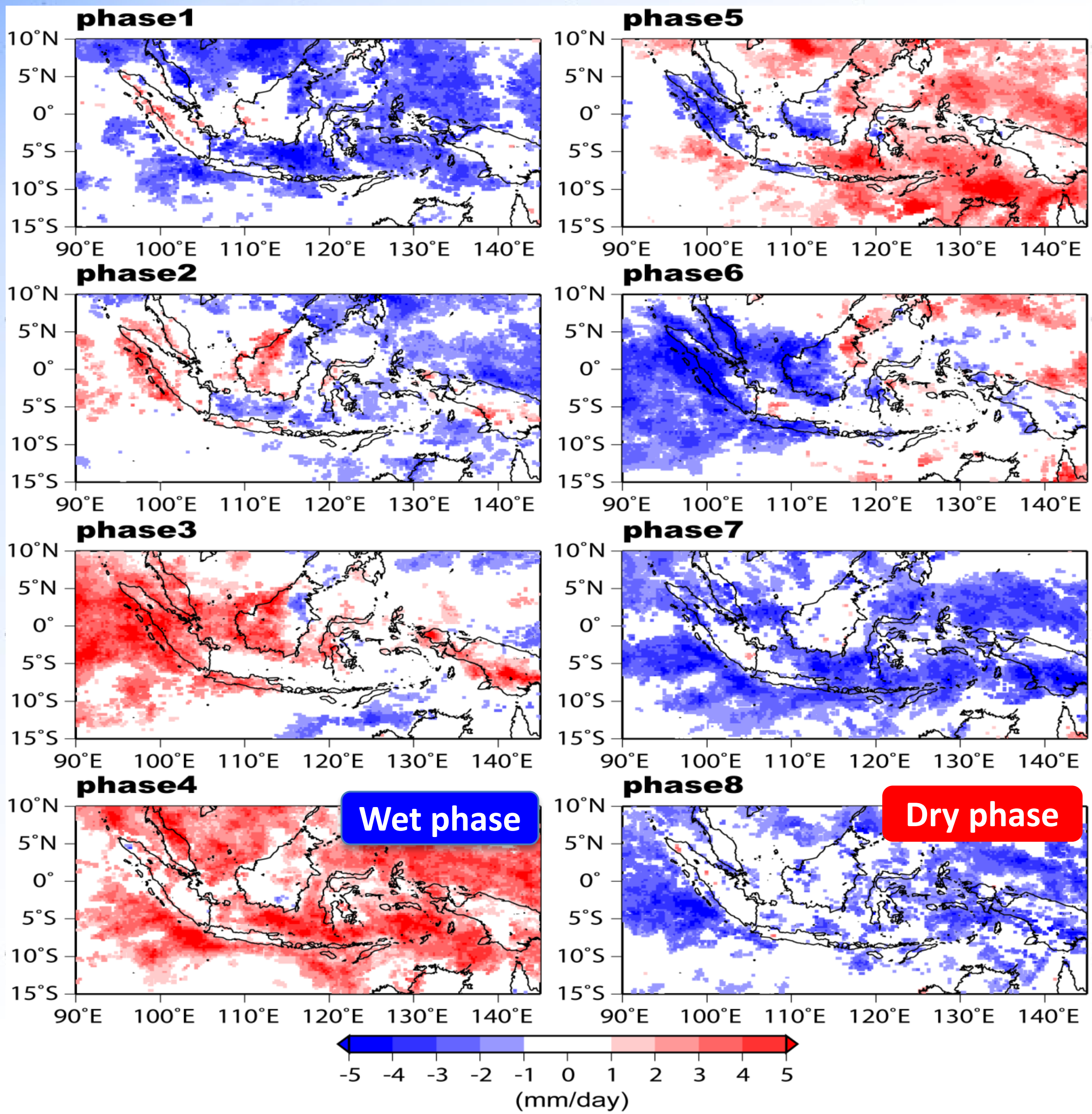
Phase 4 - 5

- **organized convection reached maximum over Indonesia.**

Phase 6 - 7

- **Suppressed convection in Indian Ocean →center of convection migrates eastward.**

MJO impacts observed by TRMM

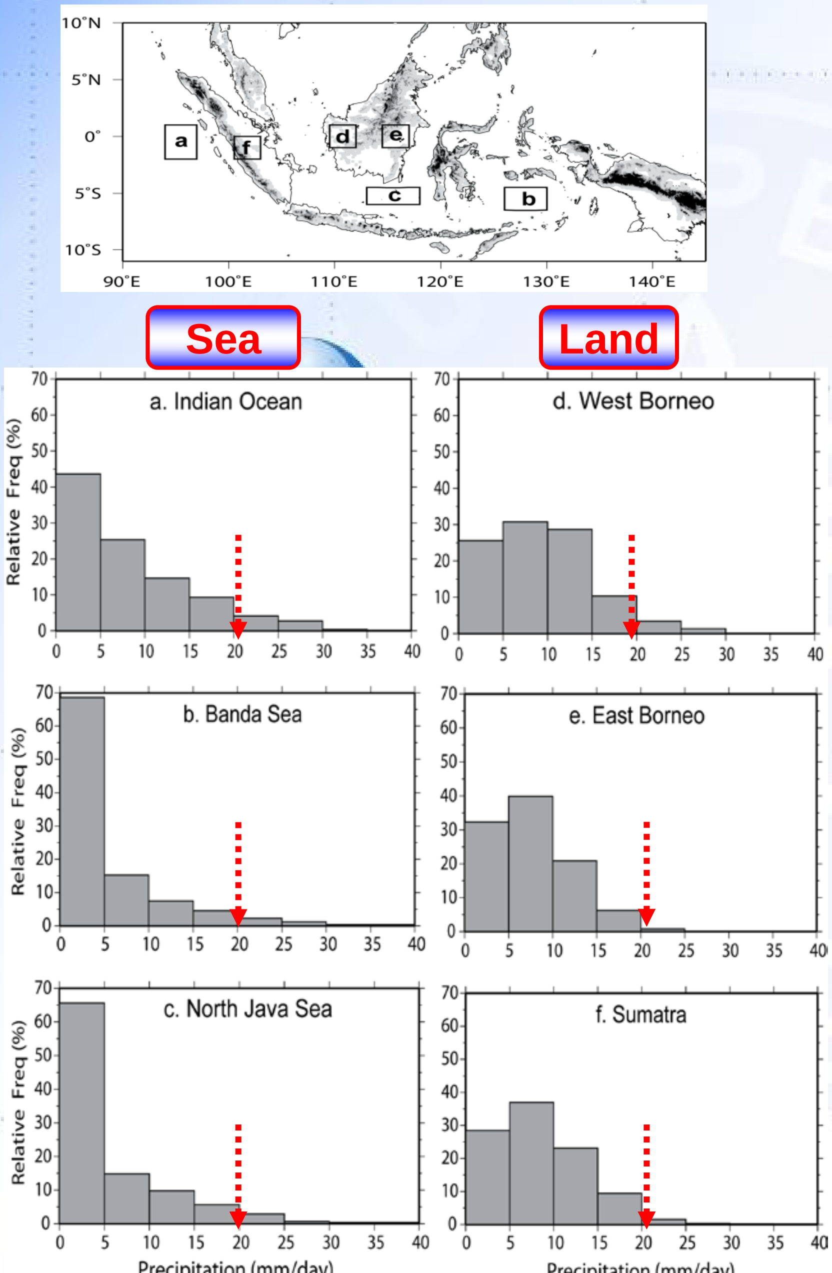


16 MJO events (1998 - 2006)

- ✓ Spatially-coherent pattern of rainfall anomaly.
- ✓ Eastward propagation of rainfall anomaly.
- ✓ MJO phase reflects in rainfall variation.
- ✓ Land and seas contrast.

(Hidayat and Kizu, 2010)

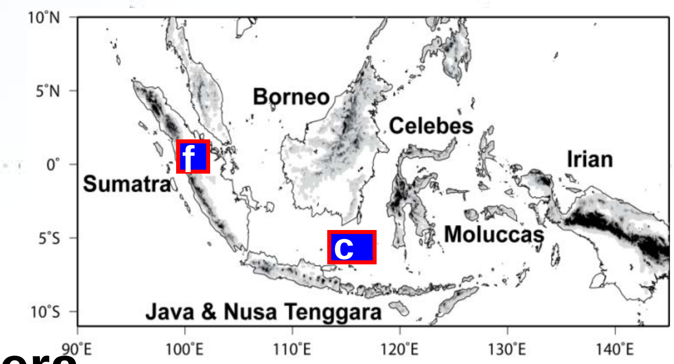
Definition of extreme rainfall events (ERE)



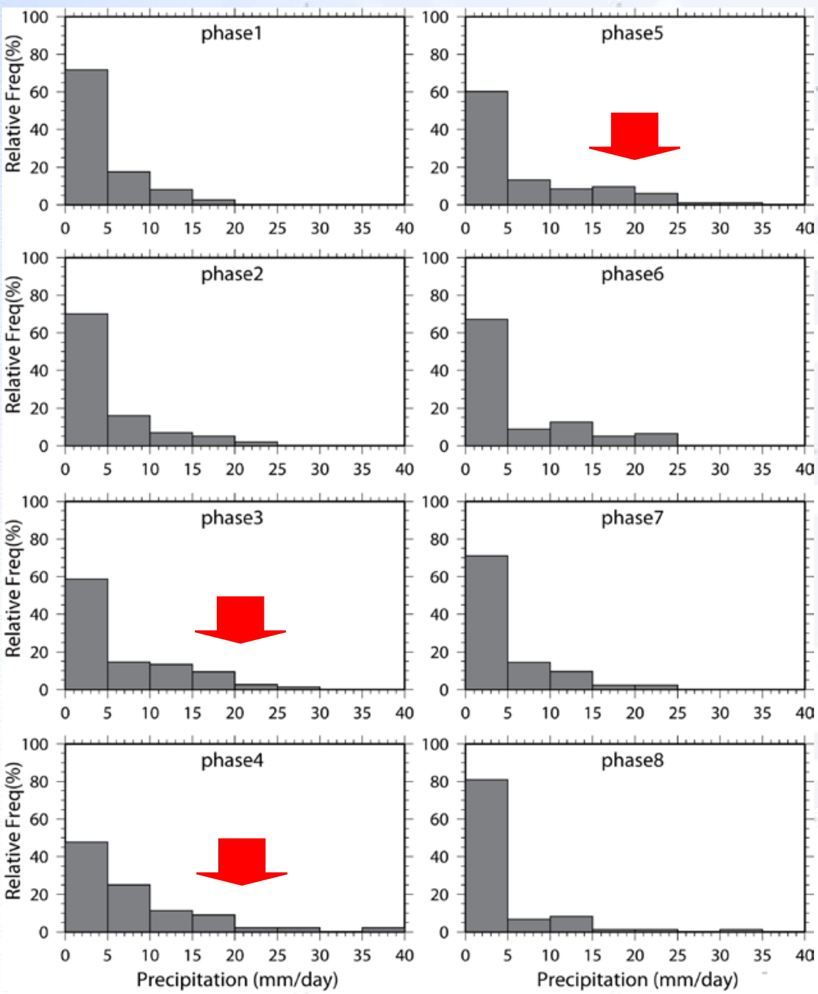
- Extreme rainfall events are defined by choosing **20 mm/day** as a threshold value for pentad mean rainfall by TRMM data at each grid.
- The threshold value is chosen to ensure that **ERE occur rarely**.

✓ Frequencies of identified extreme events (i.e. **20 mm/day**) are **lower than 5% of the total occurrence** in any given locations.

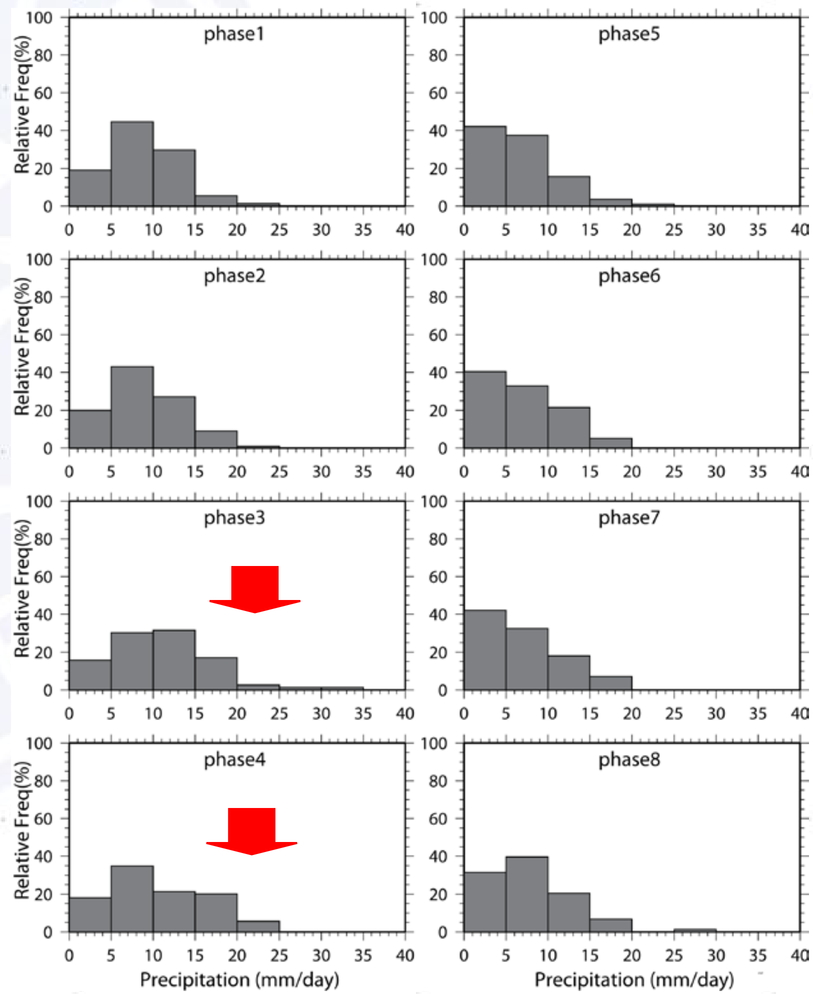
MJO impact on occurrence of ERE



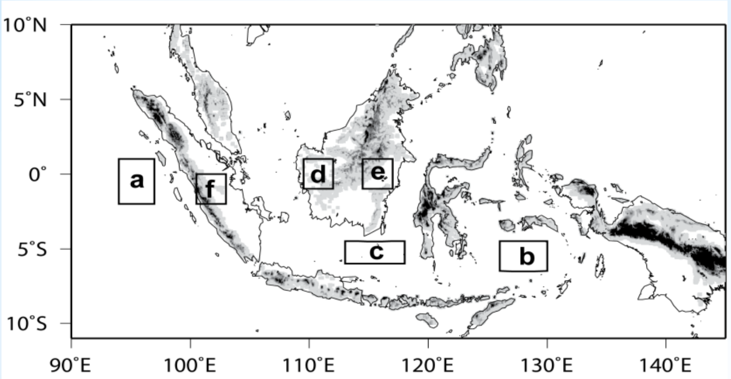
c. Java Sea



f. Sumatera



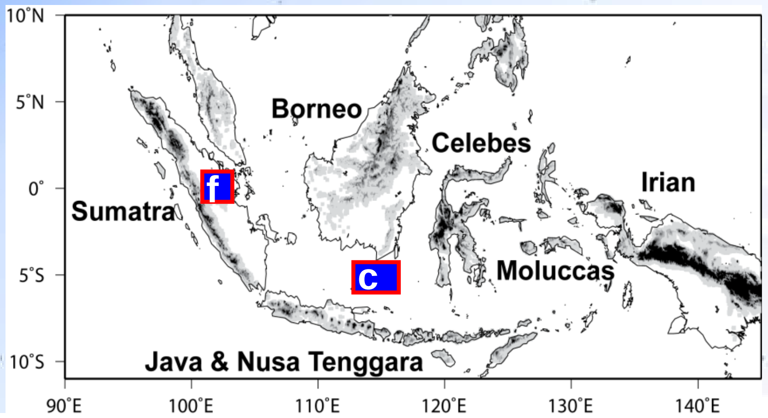
MJO impact on occurrence of ERE



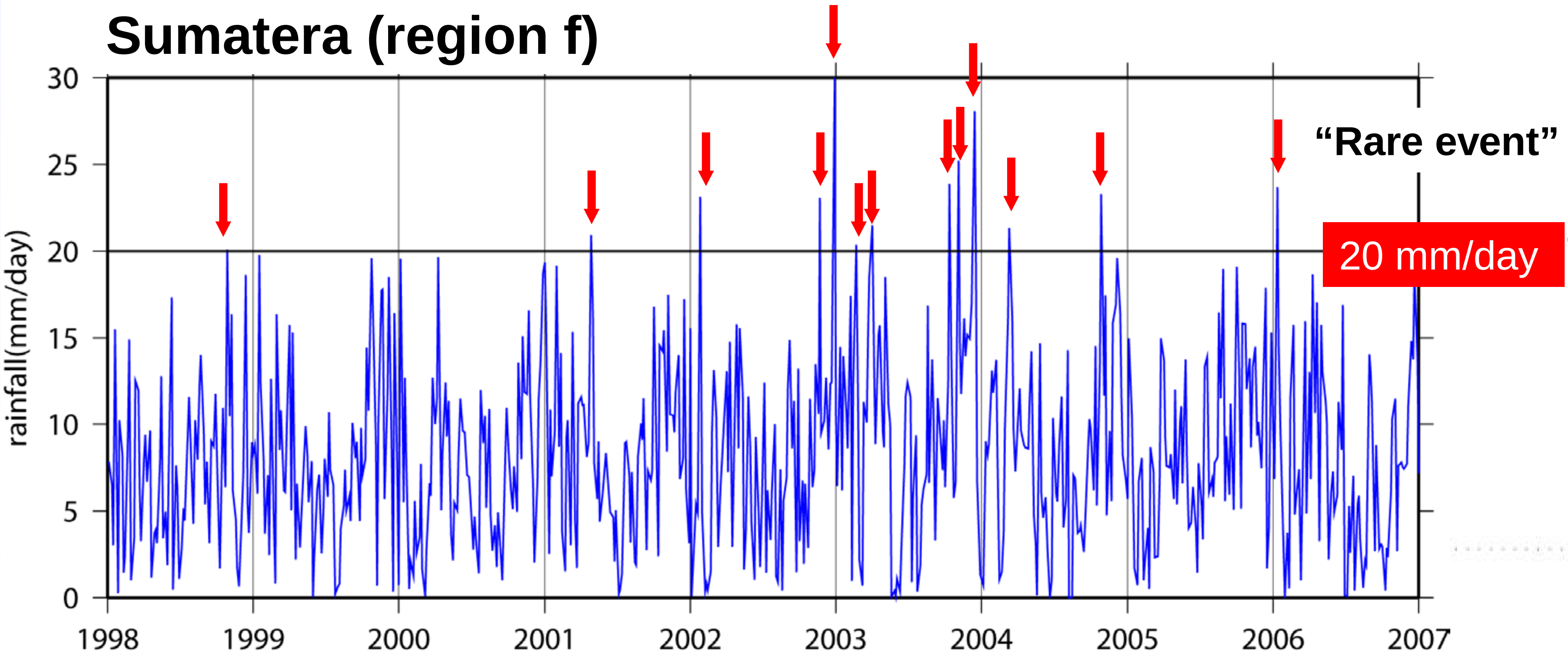
Relative frequency of extreme rainfall events (i.e. **over 20 mm/day**) observed in each MJO phase at each location. Unit is percentage.

	Phase 1	Phase 2	Phase 3	Phase 4	Phase 5	Phase 6	Phase 7	Phase 8
a) Indian Ocean	4	11	11	15	5	2	2	3
b) Banda Sea	2	3	5	10	10	5	0	2
c) Java Sea	0	3	5	8	10	6	3	2
d) West Borneo	4	6	6	8	4	4	2	2
e) East Borneo	0	0	2	4	2	1	1	0
f) Sumatra	2	2	5	8	2	0	0	2

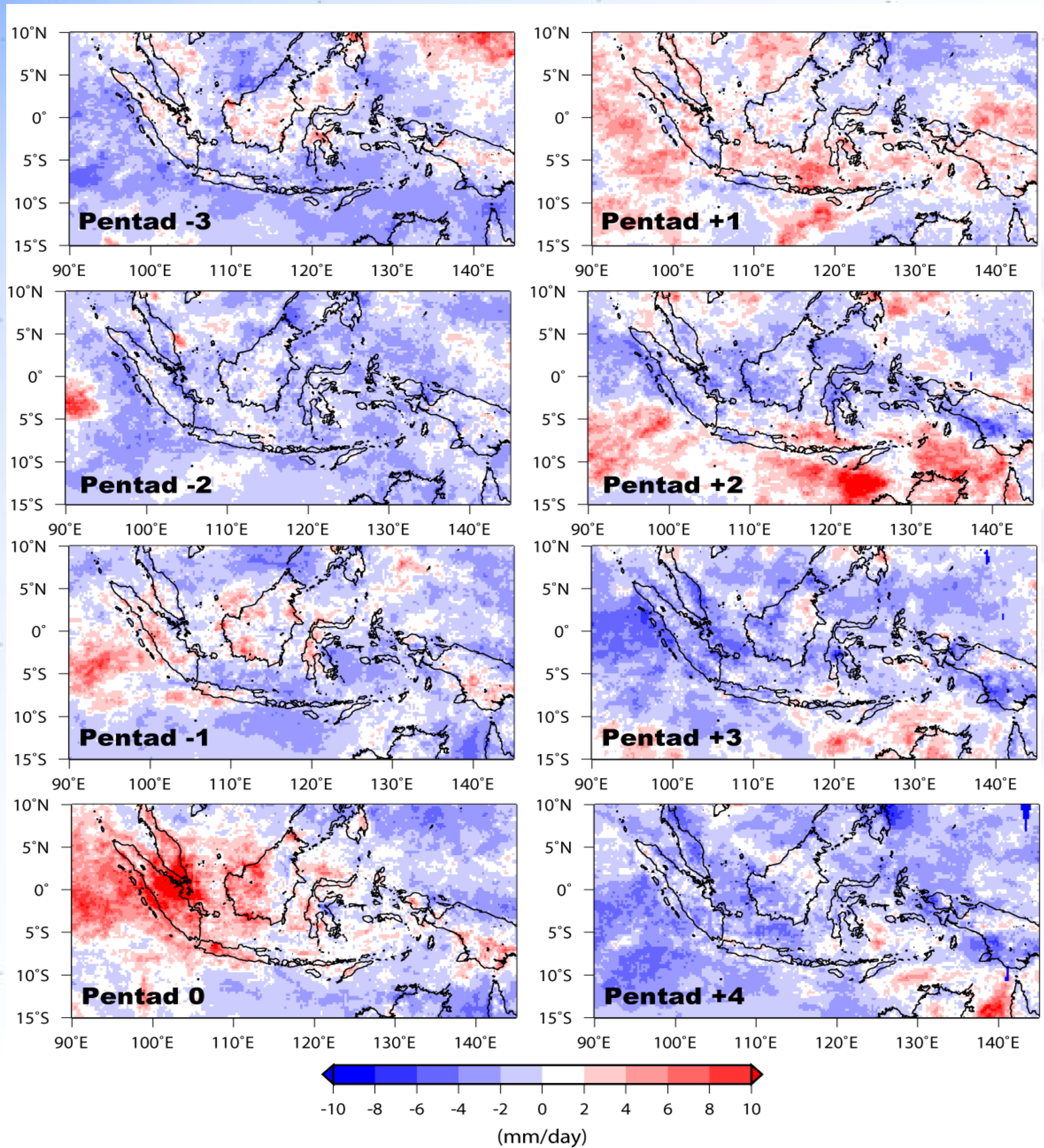
Eastward propagation of occurrence of ERE



- Java Sea (c) : 20 ERE
- Sumatera (f) : 13 ERE



Lagged/lead composite of TRMM (Sumatera)



- Composite mean of **13 ERE cases.**
- Extreme rainfall event for pentad means centered on the period from pentad -3 to pentad +4.

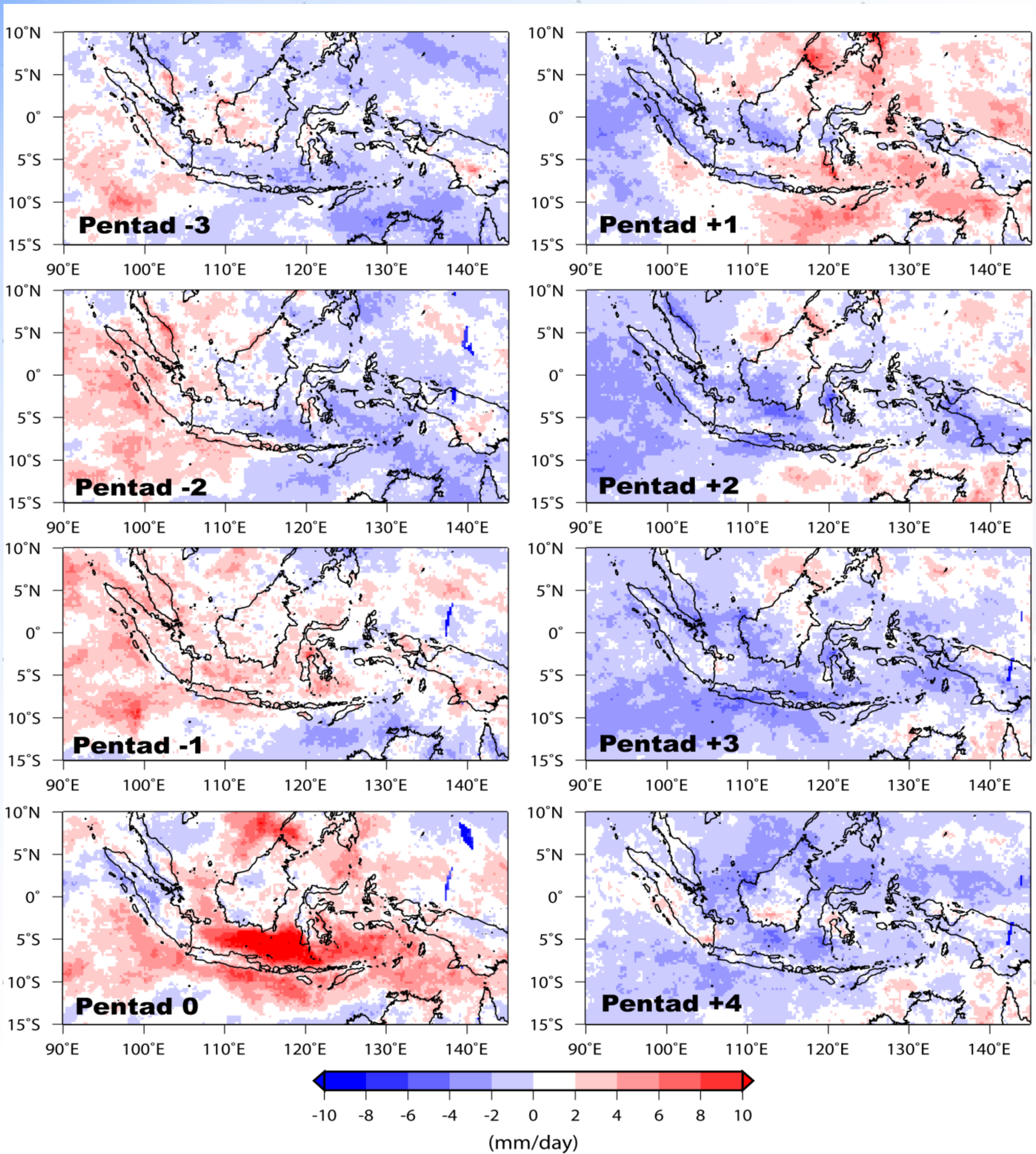
➢ Life cycle has a period of approximately 40 days.

➢ Spatially-coherent pattern of rainfall anomaly.

➢ Clear eastward propagation of ERE.

"MJO-like event"

Lagged/lead composite of TRMM (Java Sea)



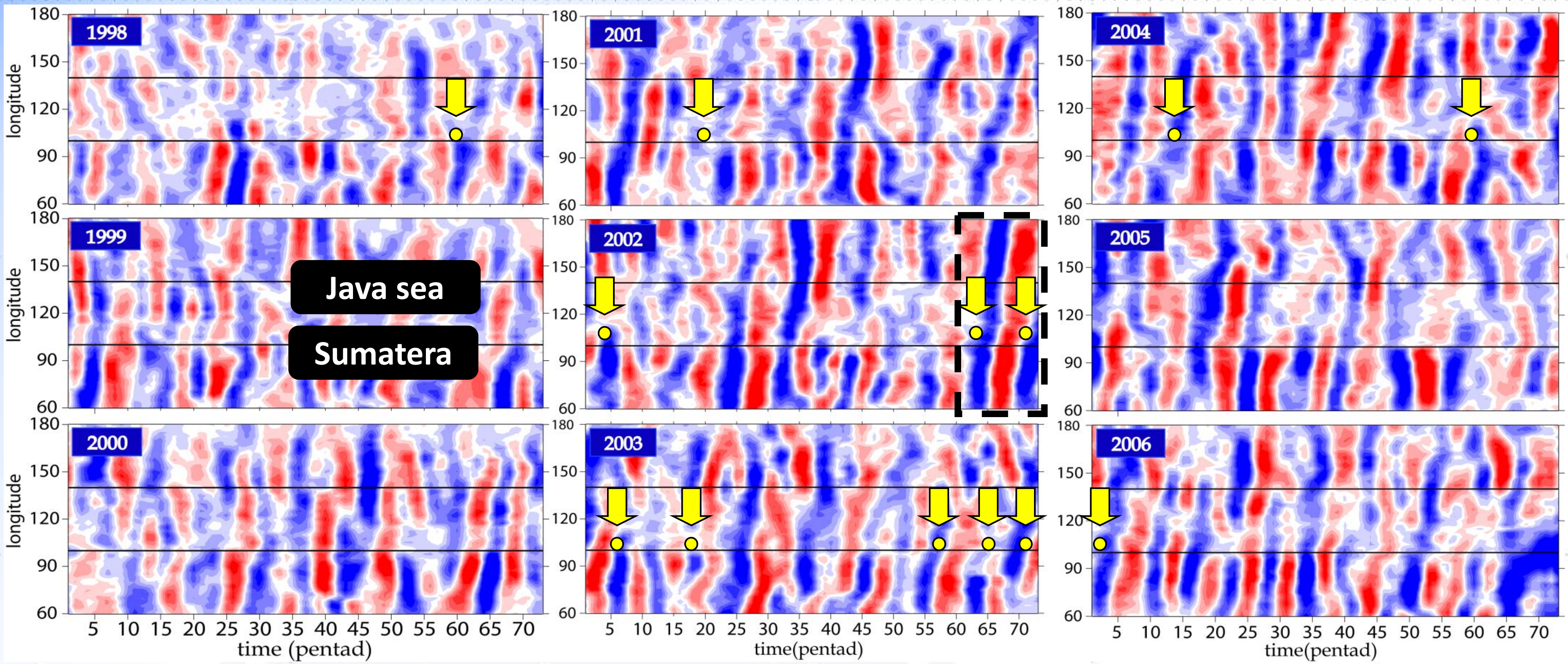
- Composite mean of **20 ERE cases.**
- Extreme rainfall event for pentad means centered on the period from pentad -3 to pentad +4.

➢ Spatially-coherent pattern of rainfall anomaly.

➢ Clear eastward propagation of ERE.

Hovmöller diagram of OLR (5^0N - 5^0S)

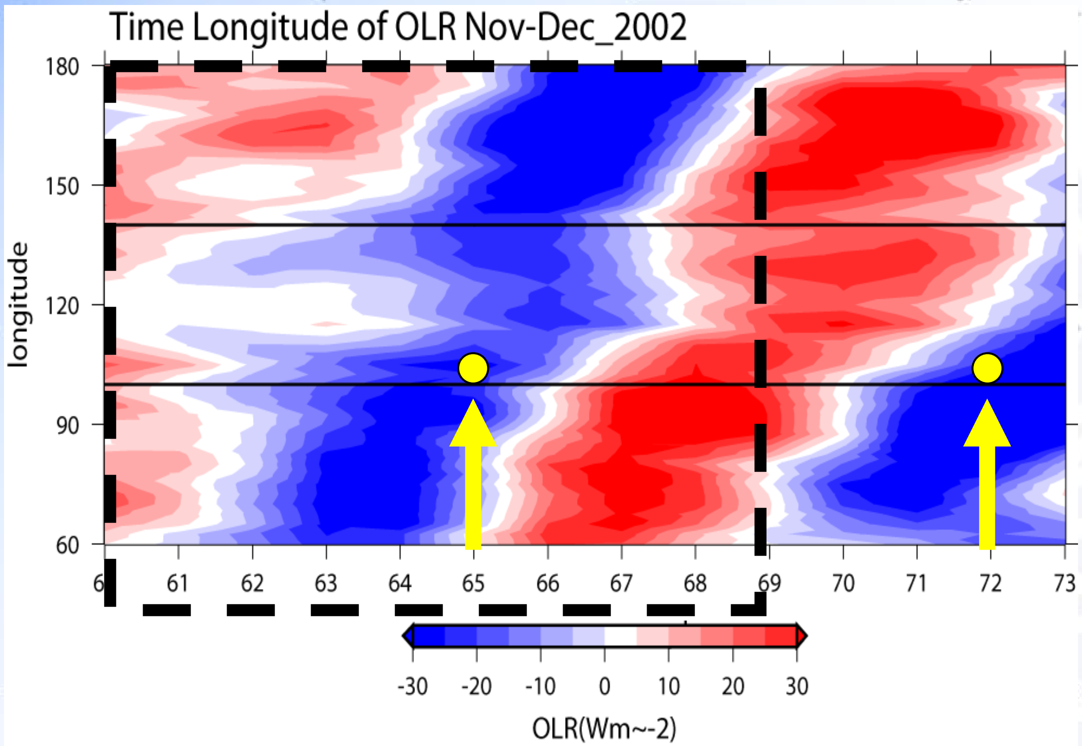
Band pass-filter with cutoffs at 20-90 days to obtain the MJO signal.



- Strong MJO-related signals are clearly observed over the Indian Ocean.
- Decay/weak MJO signals tend to be observed over the Maritime Continent.

- **13 Peaks of ERE fall into convective bands (wet phase) of the MJO cycle.**

A case of ERE during Nov-Dec 2002



Strong MJO event

- High amplitude
- Phase systematically propagates eastward (phase 1 to 8)

- MJO event at pentad 60th – 69th of Nov-Dec 2002 (10 pentads or 50 days)
- Peak of ERE : pentad 65th

Rainfall features and evolution of circulation anomalies field of ERE are further investigated during this MJO event.

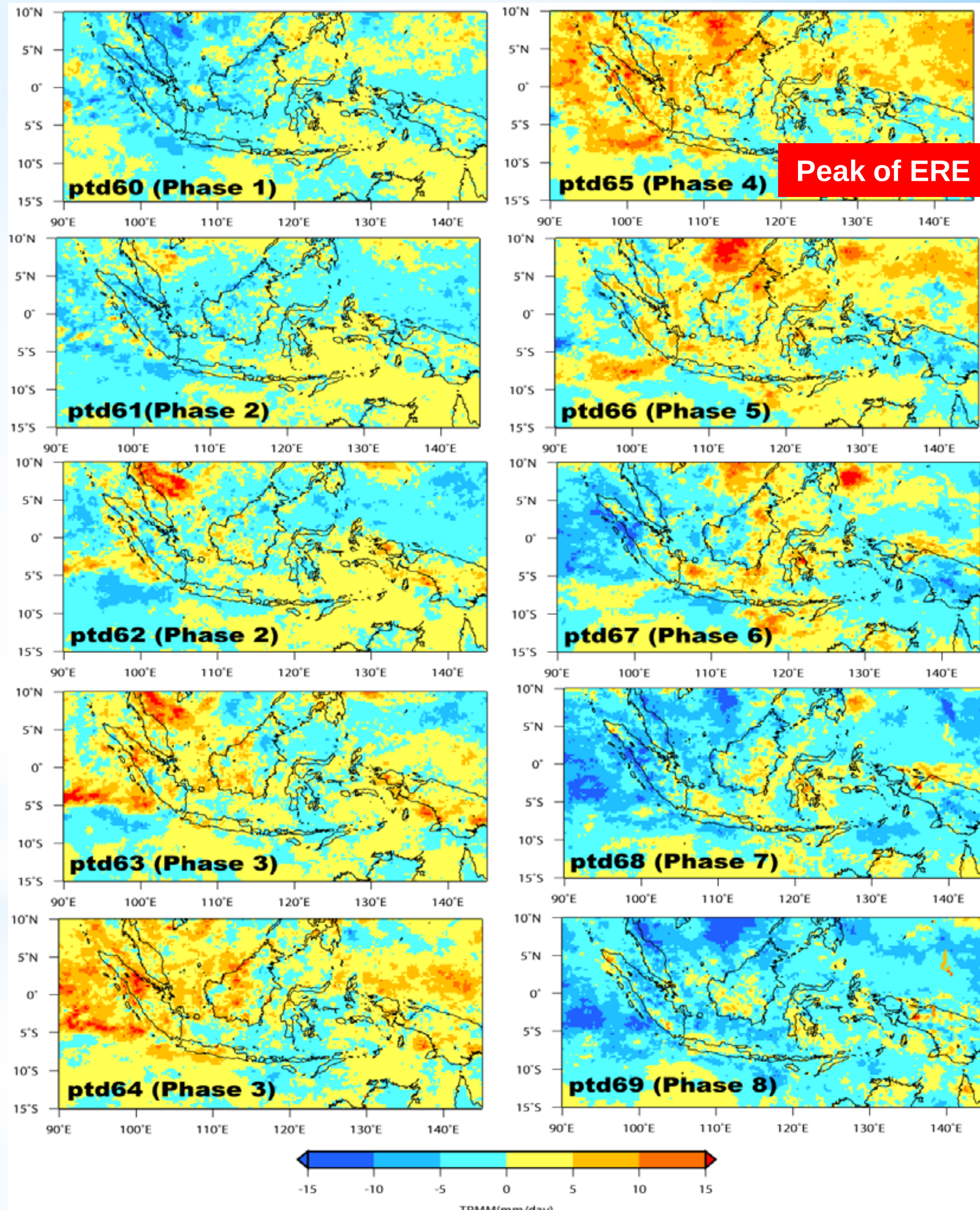
Features of TRMM in Nov-Dec 2002

Positive rainfall anomalies are observed over the western coast of Sumatera :

- pentad 62^{th} (phase 2 of MJO index)
- Pentad 65^{th} : peak of ERE (phase 4 of MJO index)
- Decay in pentad 68^{th}.

Clear eastward propagation of rainfall

※ Phase 1 - 8 based on RMM index



Evolution of OLR and u850 in Nov-Dec 2002

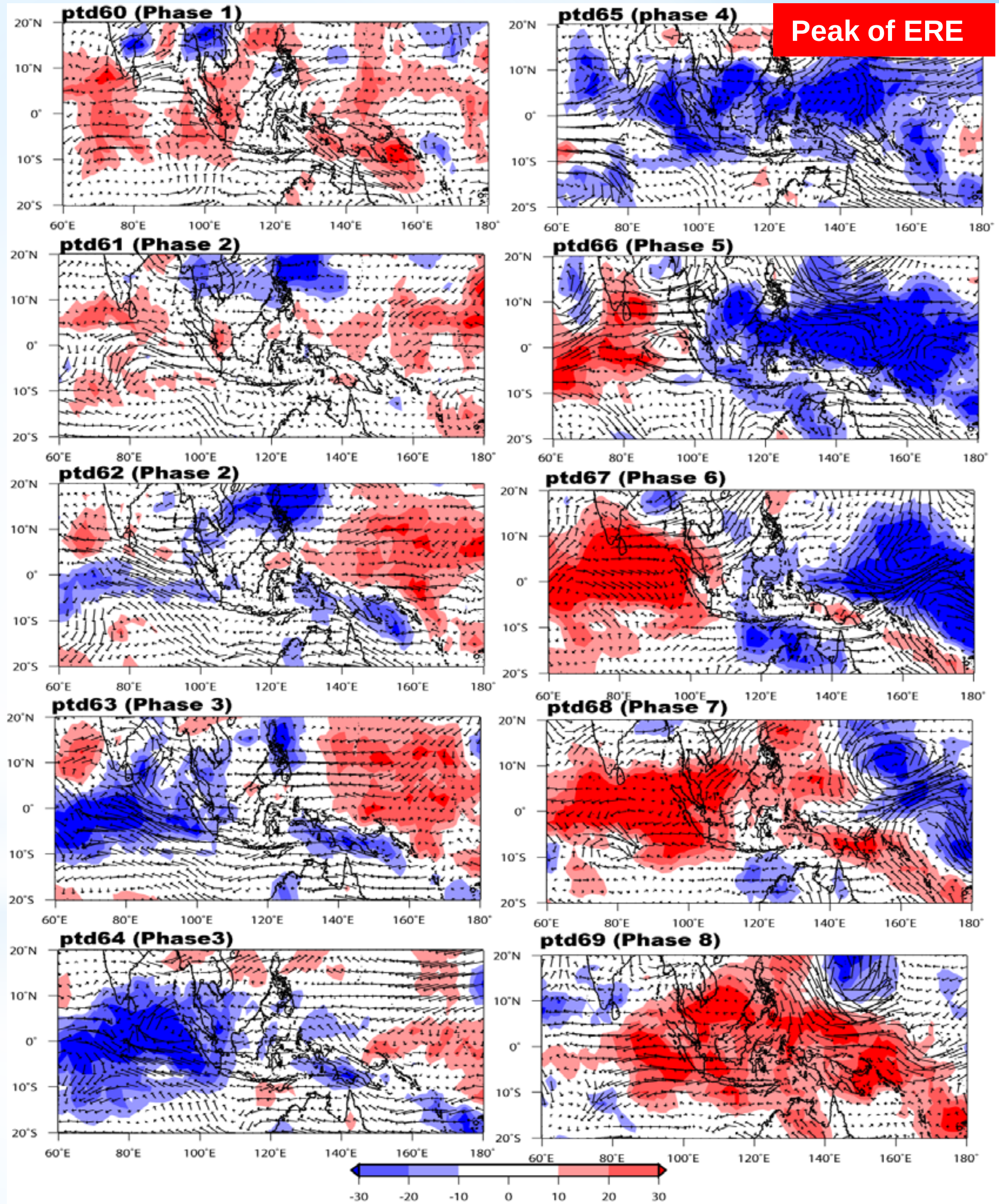
MJO event pentad 60th – 69th of Nov-Dec 2002

Active phase of MJO → pentad 65 (phase 4) → ERE peak

Eastward propagation of convective activities

Wet phase (phase 4) :

Enhanced convection ← changing low-level westerly and easterly anomalies.



Summary

- The modulation of occurrence of extreme rainfall event over Indonesia by eastward-propagating MJO-related large-scale convective activity is clearly observed by lagged/lead composite of TRMM rainfall and OLR.
- During the **wet phase**, the frequency of occurrence of extreme rainfall is about **10-15%** over the seas and **4-8%** over the land masses. During the **dry phase**, they are about **2-3%** over the seas and **0-2%** over the land masses.
- Typical extreme rainfall event during the period of Nov-Dec 2002 is clearly modulated by the activity of the MJO.

Thank You

ありがとうございました

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