Meteorological Characteristics of Flood Producing Heavy Rainfall Event in December 2021 over Peninsular Malaysia

Liew Ju Neng

Department of Earth Sciences and Environment

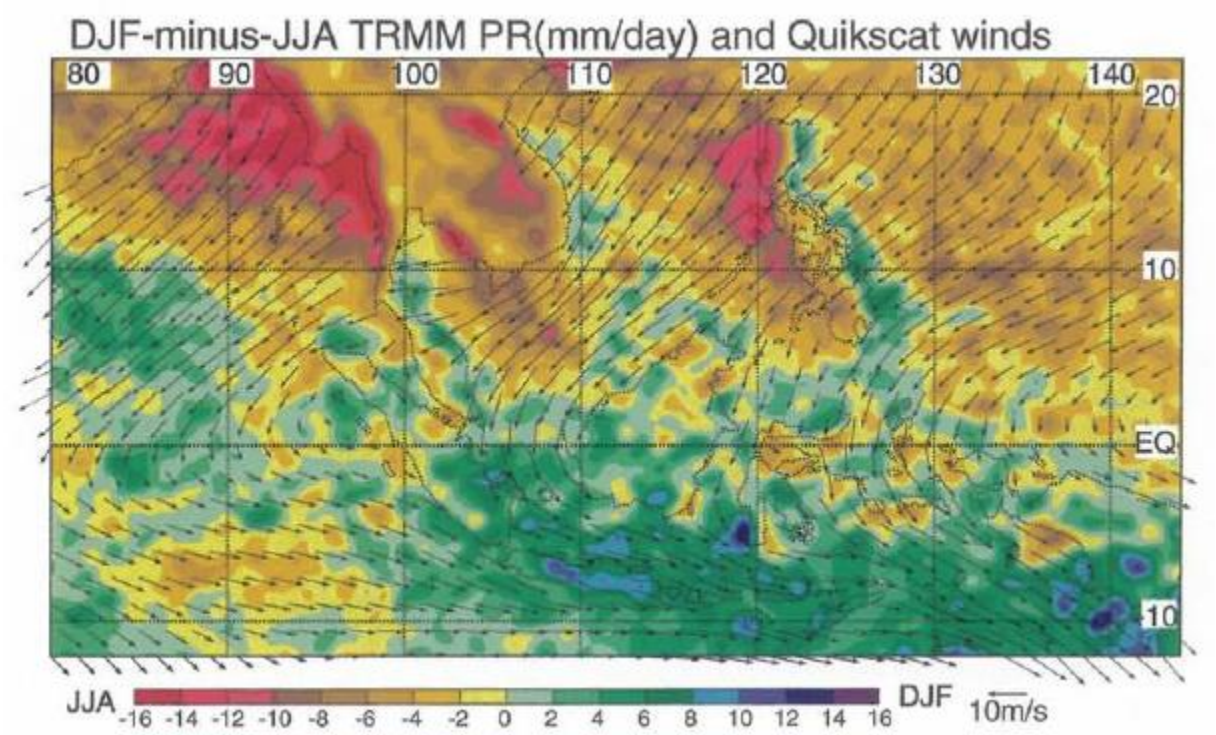
Faculty of Science and Technology

Universiti Kebangsaan Malaysia

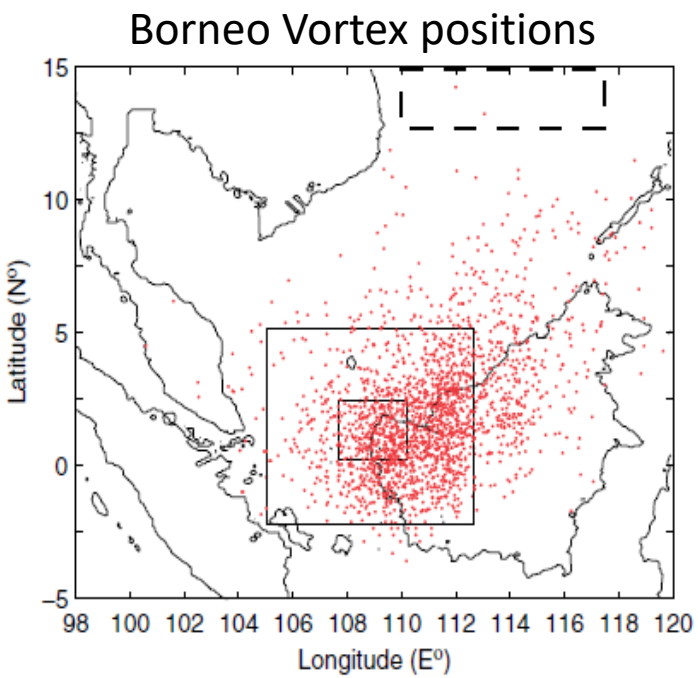
Outline

- The climate over Malaysia regions.
- Extreme rainfall event in December 2021 and its potential synoptic drivers.
- Some discussion.

Synoptic Characteristics



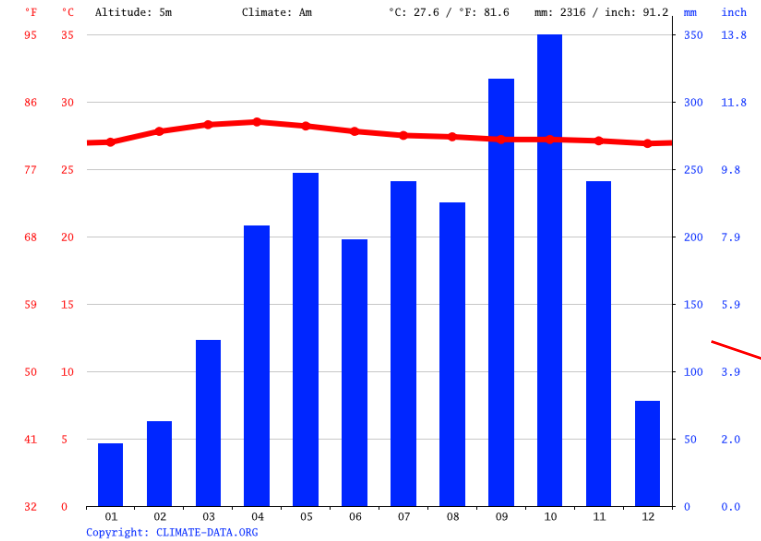
Source: Chang et al. 2005

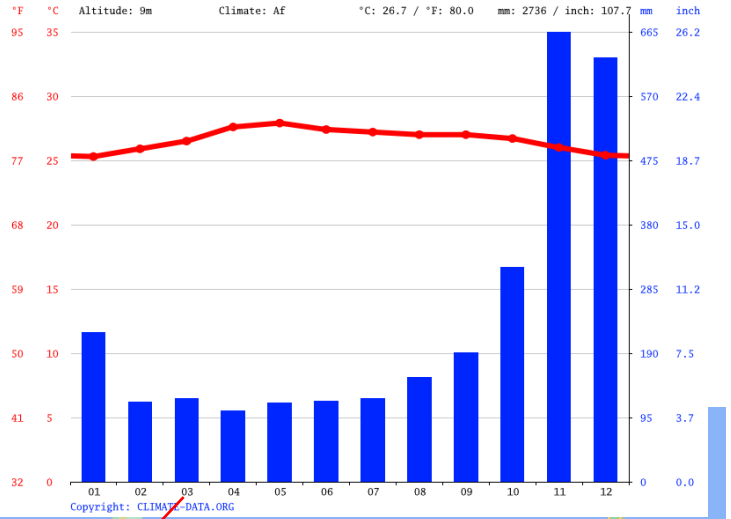


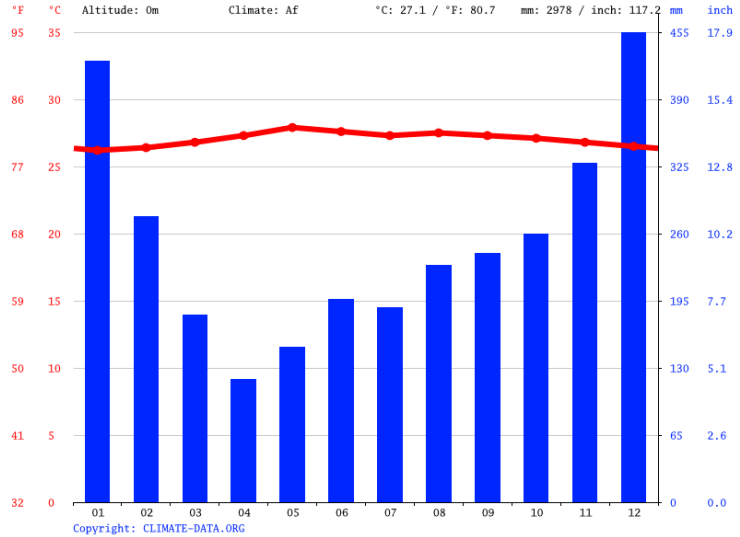
Source: Juneng and Tangang (2010)

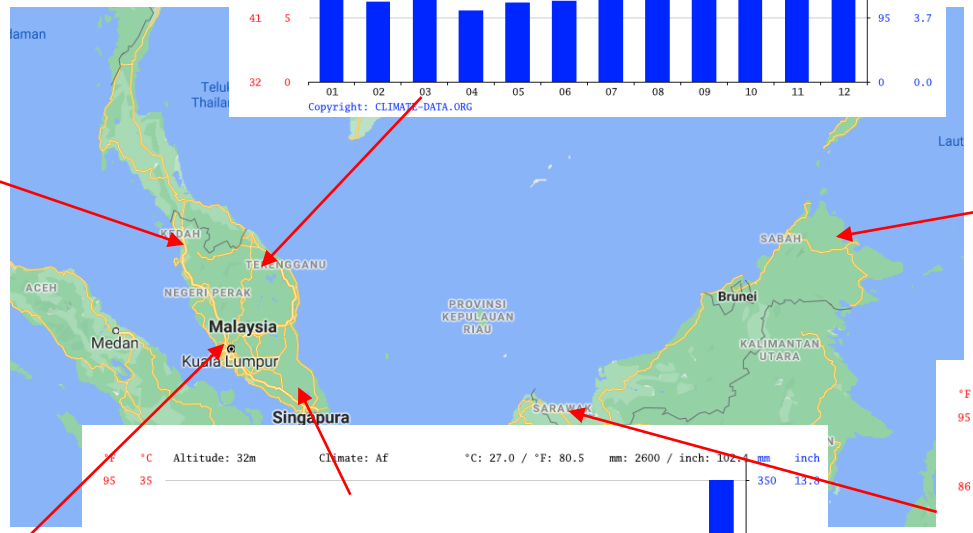
- Seasonal cycle are predominantly control by the Southeast Asia monsoon.
- Regional surface climate is controlled by synoptic scale features:
- Cold surge winds
- Borneo vortex - a synoptic-scale quasi-stationary low-level cyclonic circulation

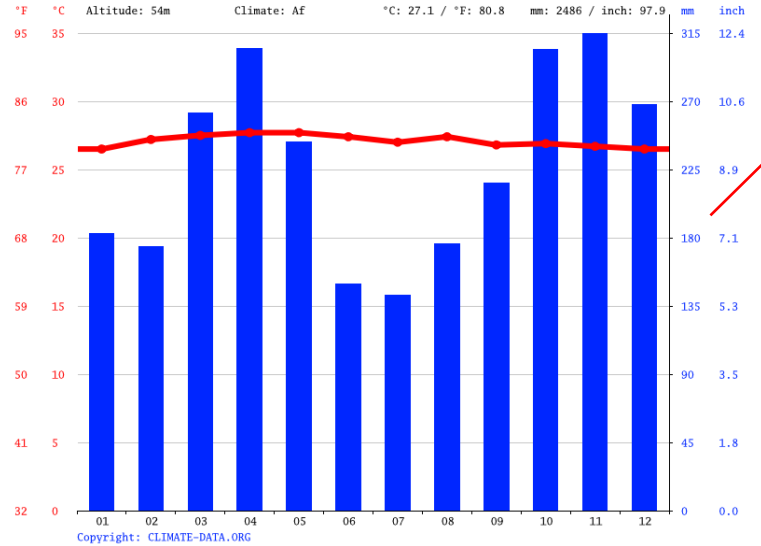
Rainfall Climatology

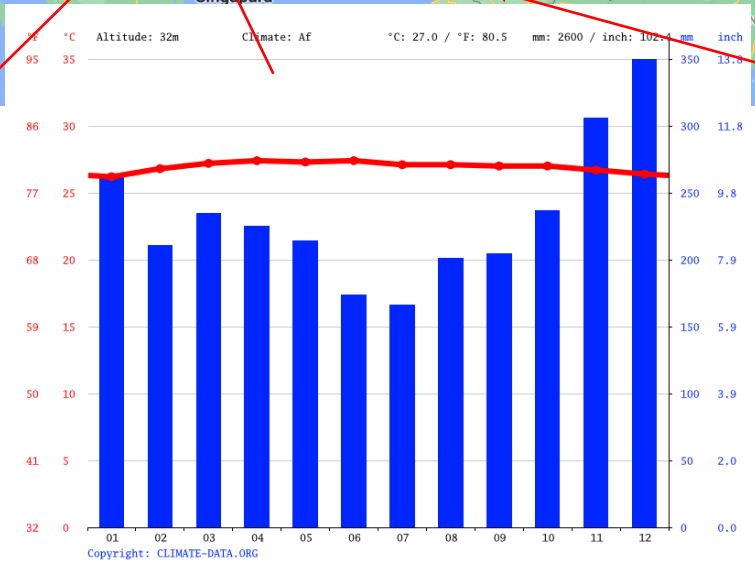


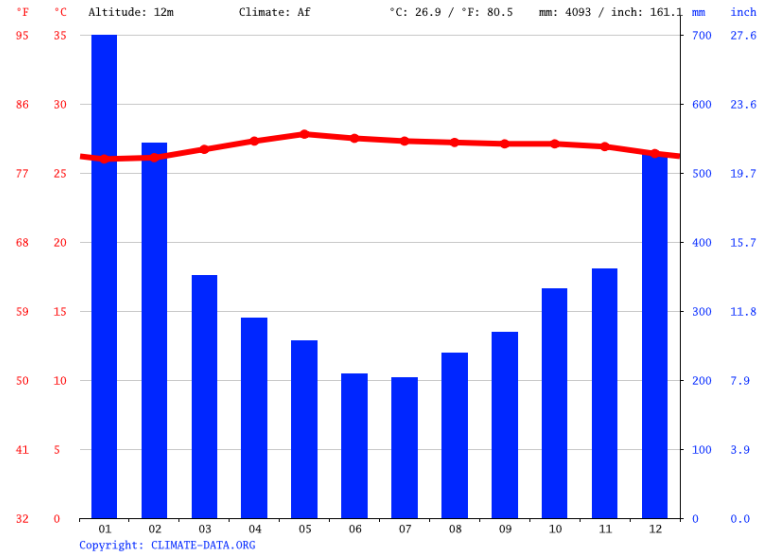




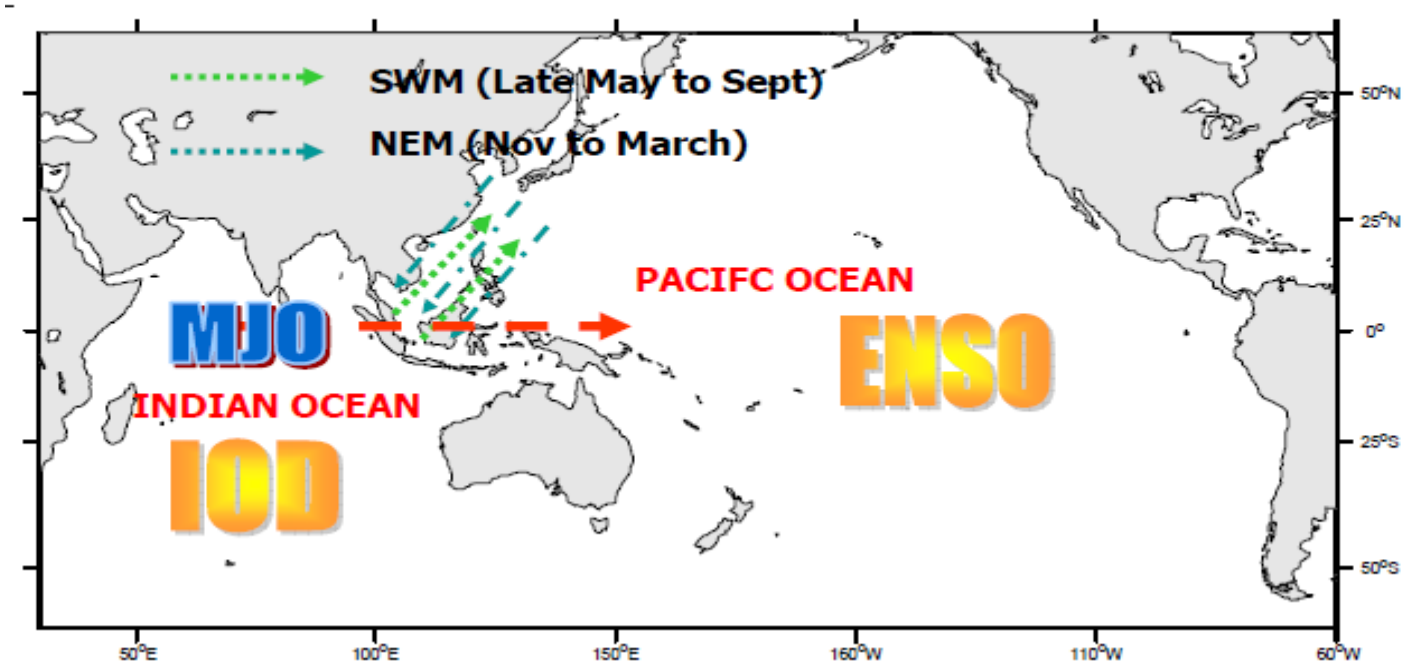






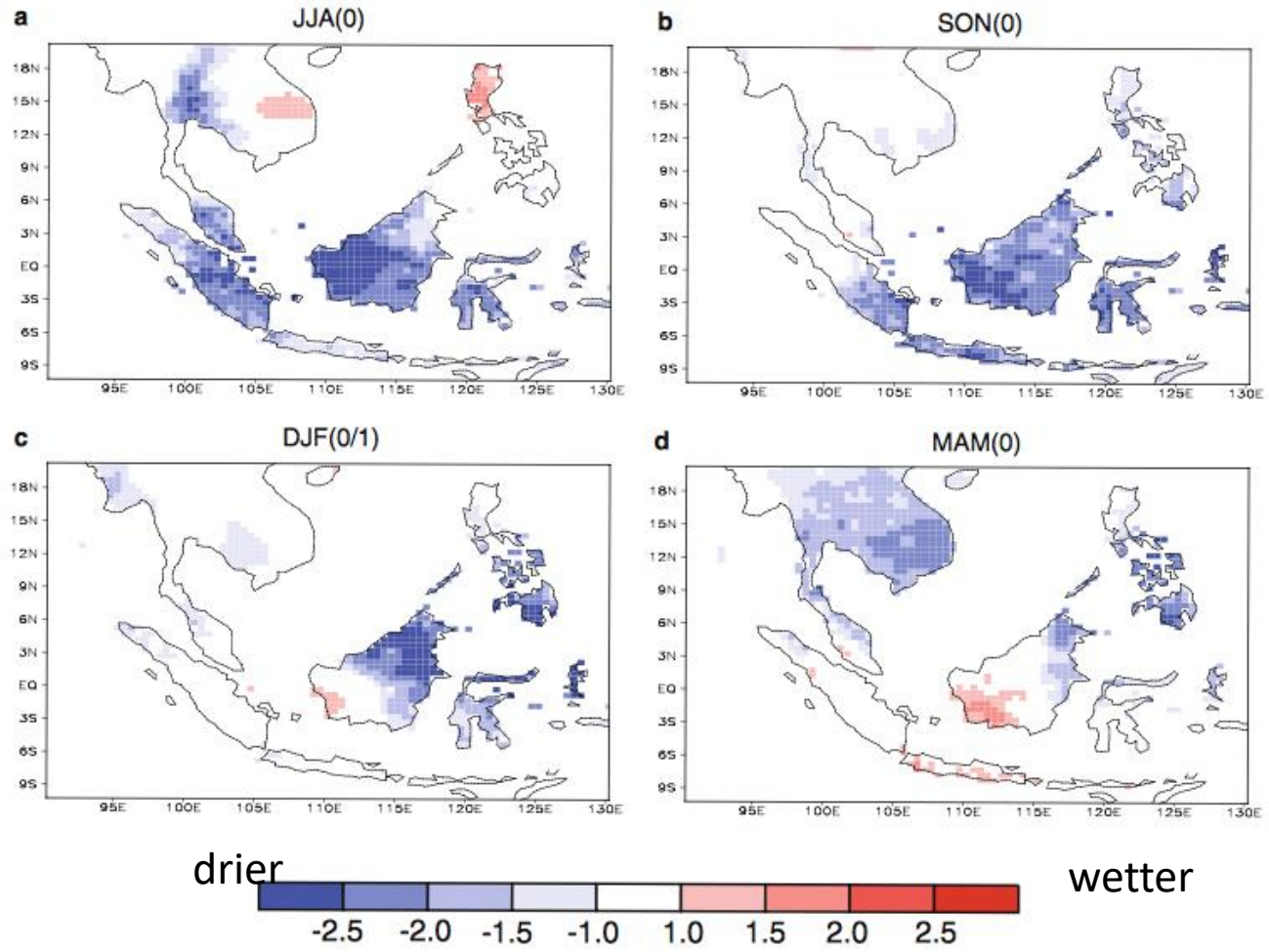


Monsoon & Dominant Modes of Climate Variability



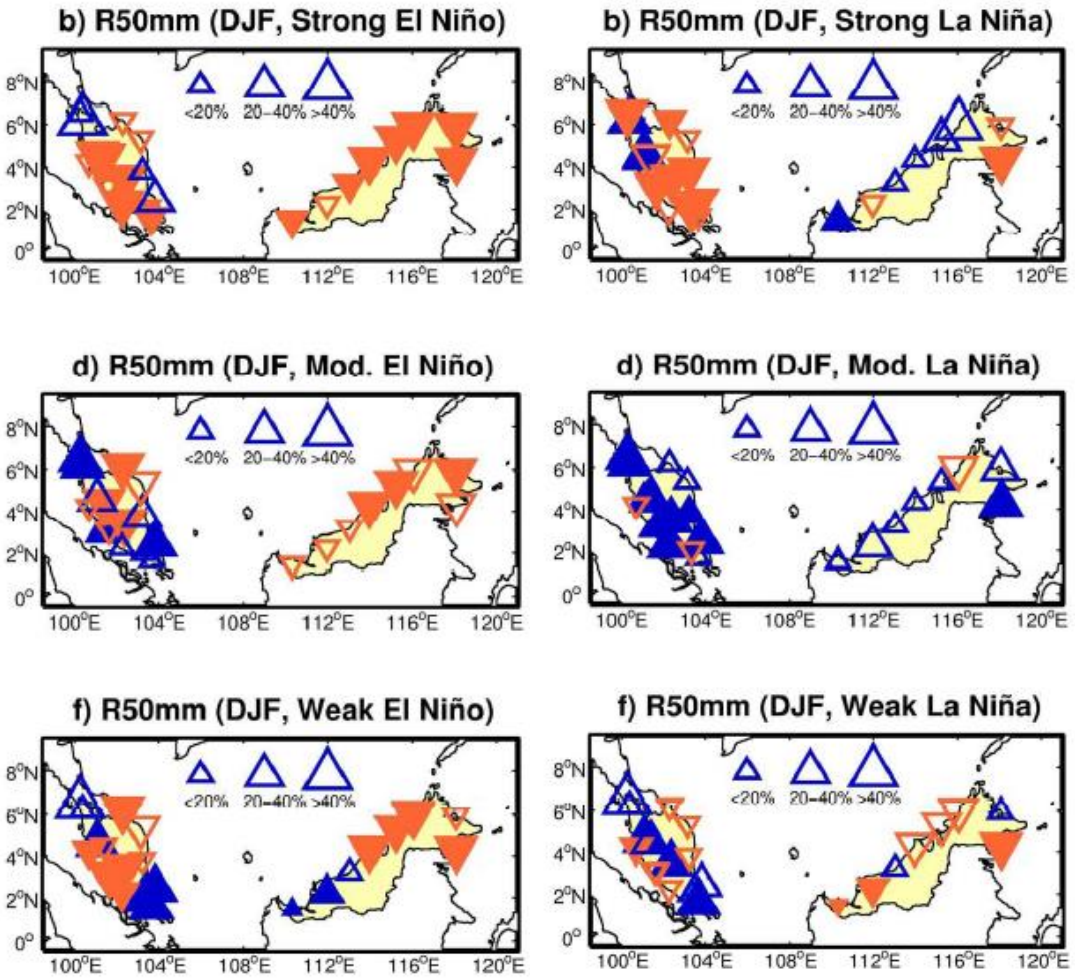
- Maritime continent climate – complex variations modulated by various large-scale climate modulators
  - El Niño – Southern Oscillation (ENSO)
  - Indian Ocean Dipole (IOD)
  - Madden-Julian Oscillation (MJO)
- Complex local topographic and coastline configurations.

ENSO and regional precipitation anomalies



- ENSO modulation – south to north/northeast following the reversal of monsoon winds

How does the strength of the ENSO influence the impact?

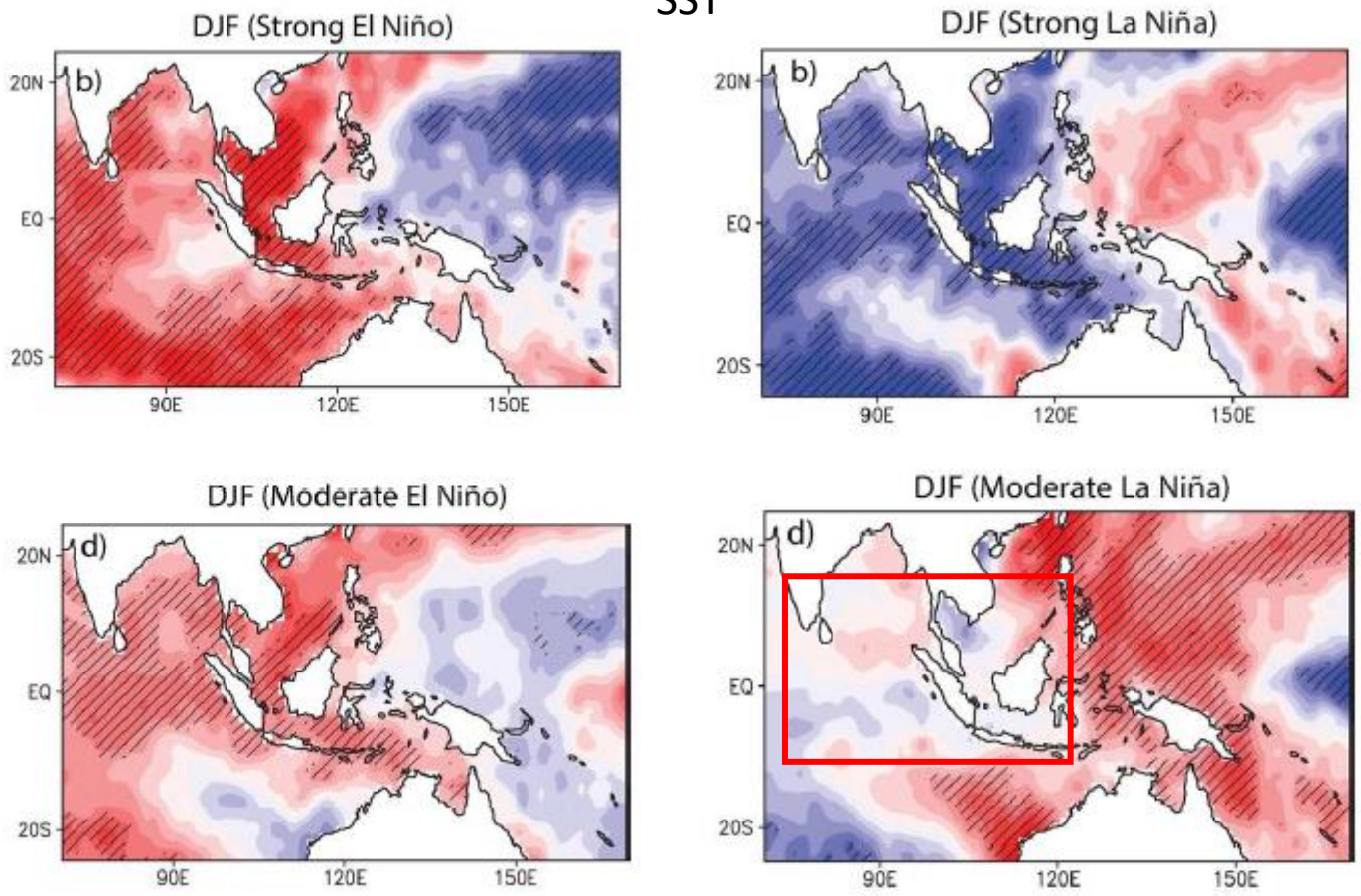


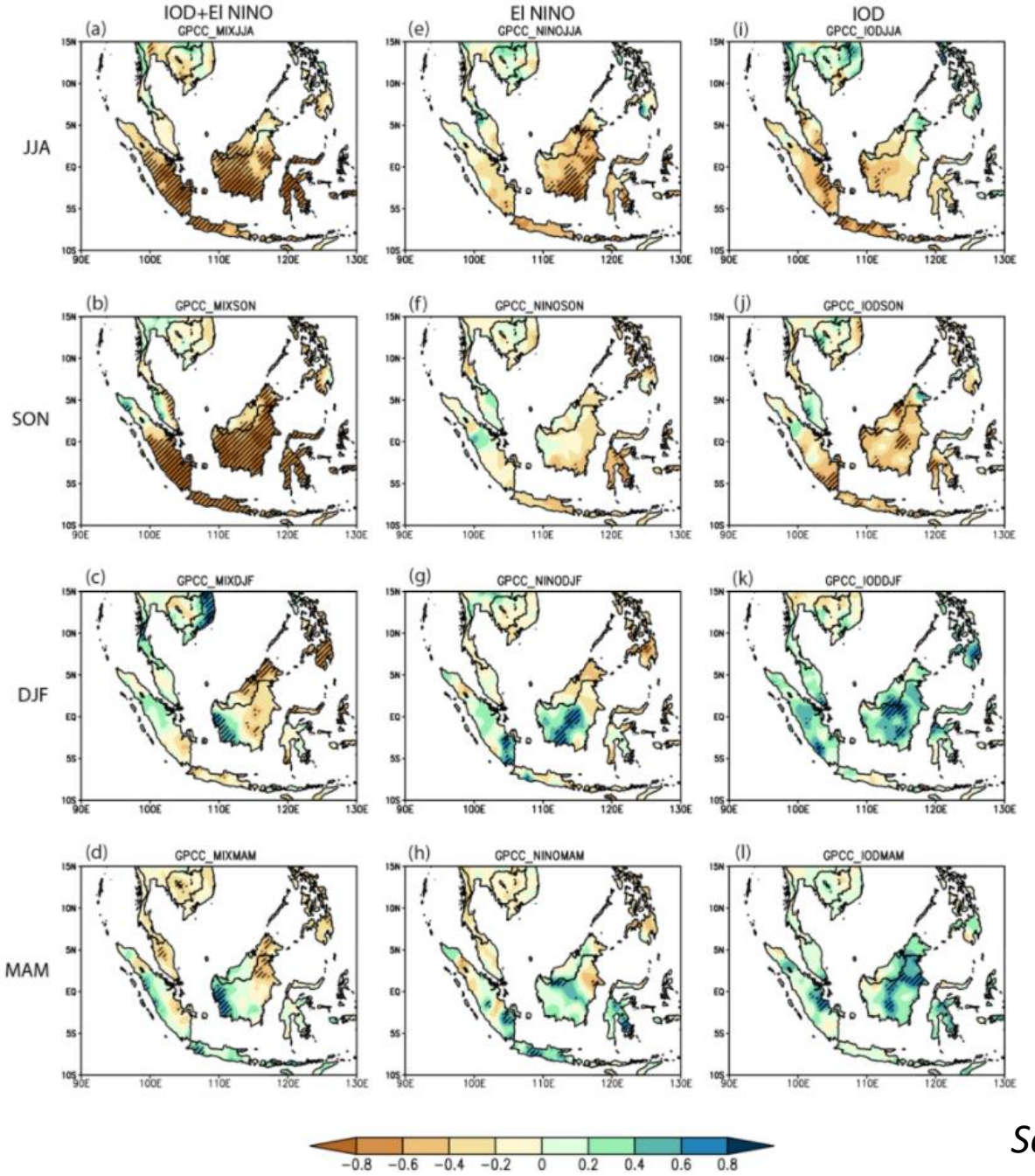
- El Nino: generally coherent over different intensity (over northern Borneo)
- La Nina: Strongest impact during moderate La Nina, but not during the strong La Nina.

What causes the differences.

- The regional SST and circulation. The Rossby wave response is different for different La Nina strength.

SST

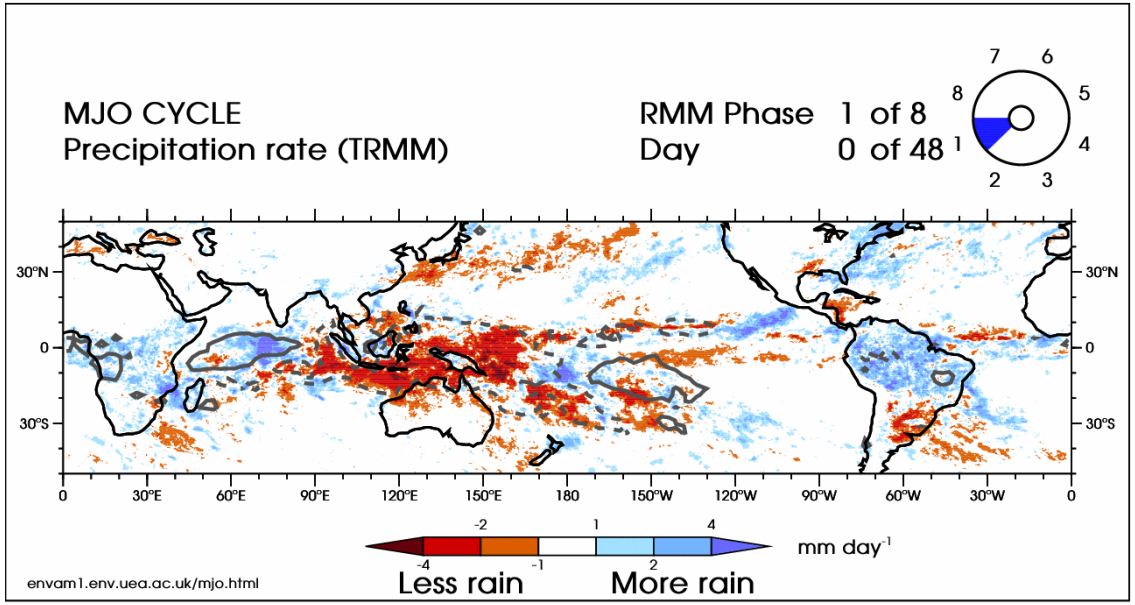


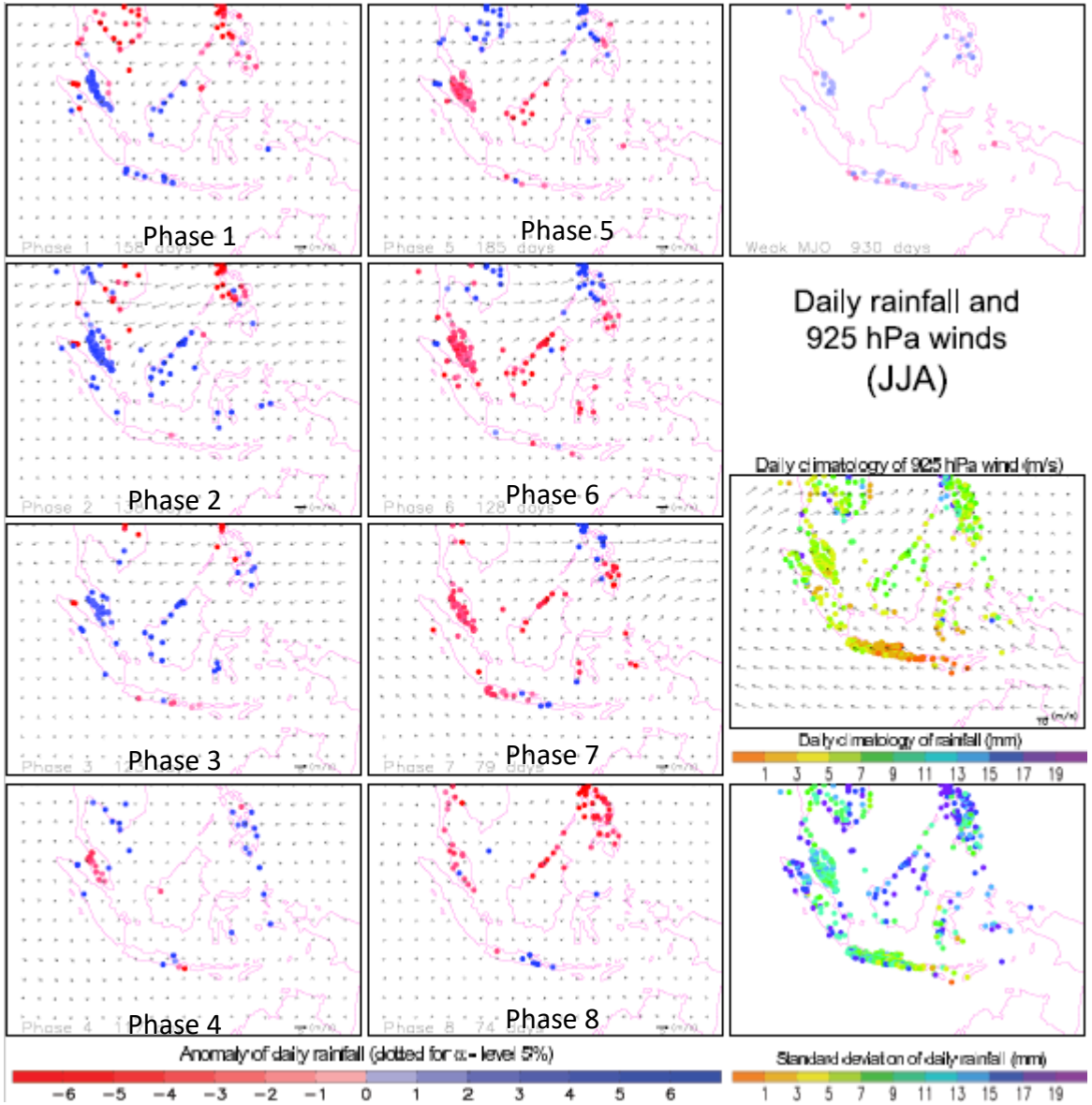


- The occurrence of IOD and ENSO has larger impact on the rainfall anomalies over Southeast Asia.

Source: Amirudin et al. (2020)

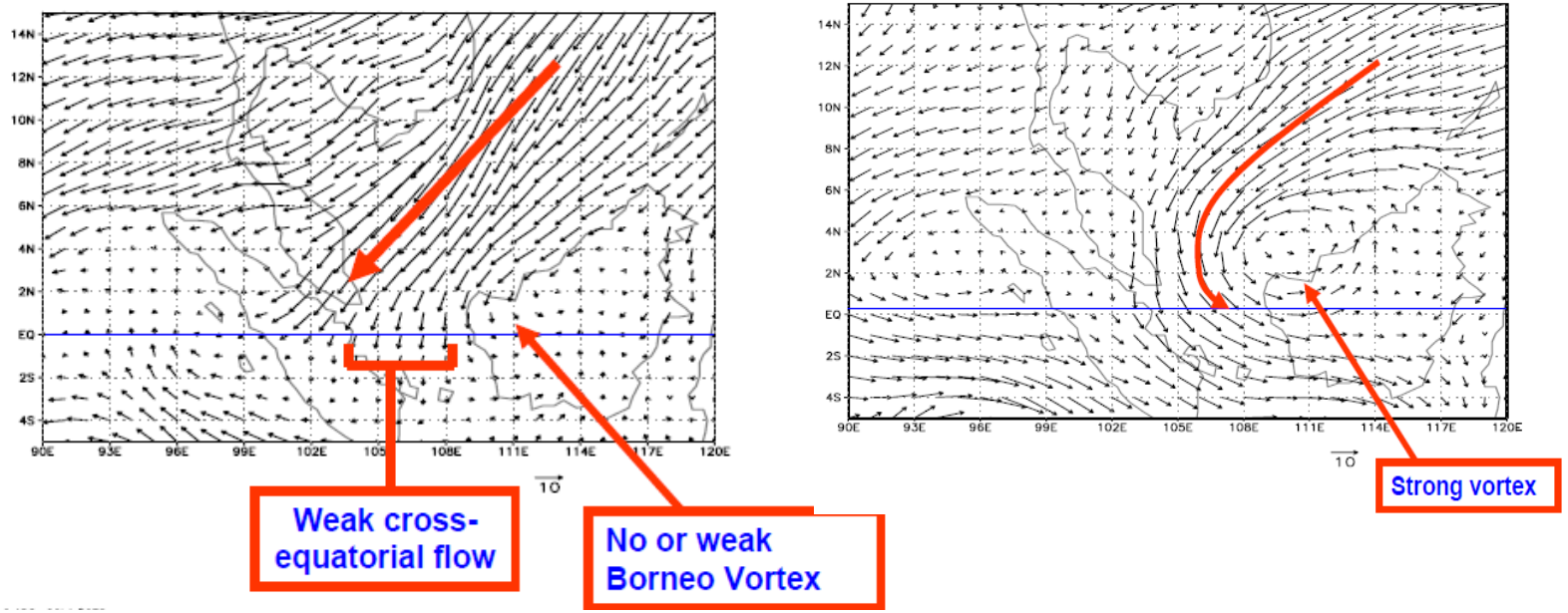
- The MJO signature is prominent over western coastal areas over the Peninsular Malaysia.





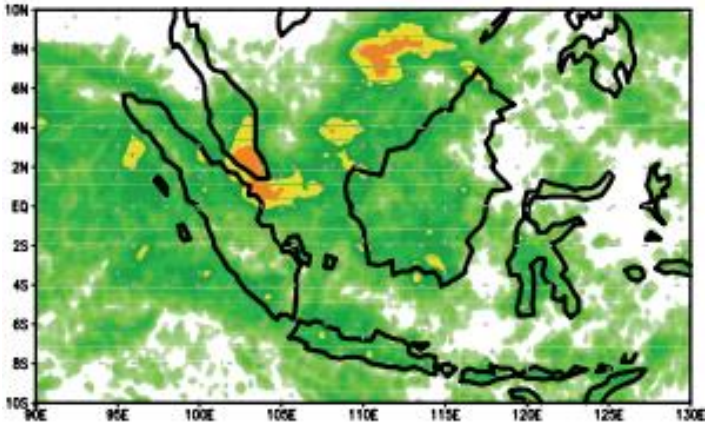
Source: Jamaluddin et al.

MJO, cold surges and Borneo vortex interaction may associate to extreme rainfall events



- MJO induced deep convection over the eastern Indian Ocean may weaken the cross-equatorial low and inhibit the Borneo vortex.
- May also strengthen the north easterlies cold surge winds.

17 December 2006

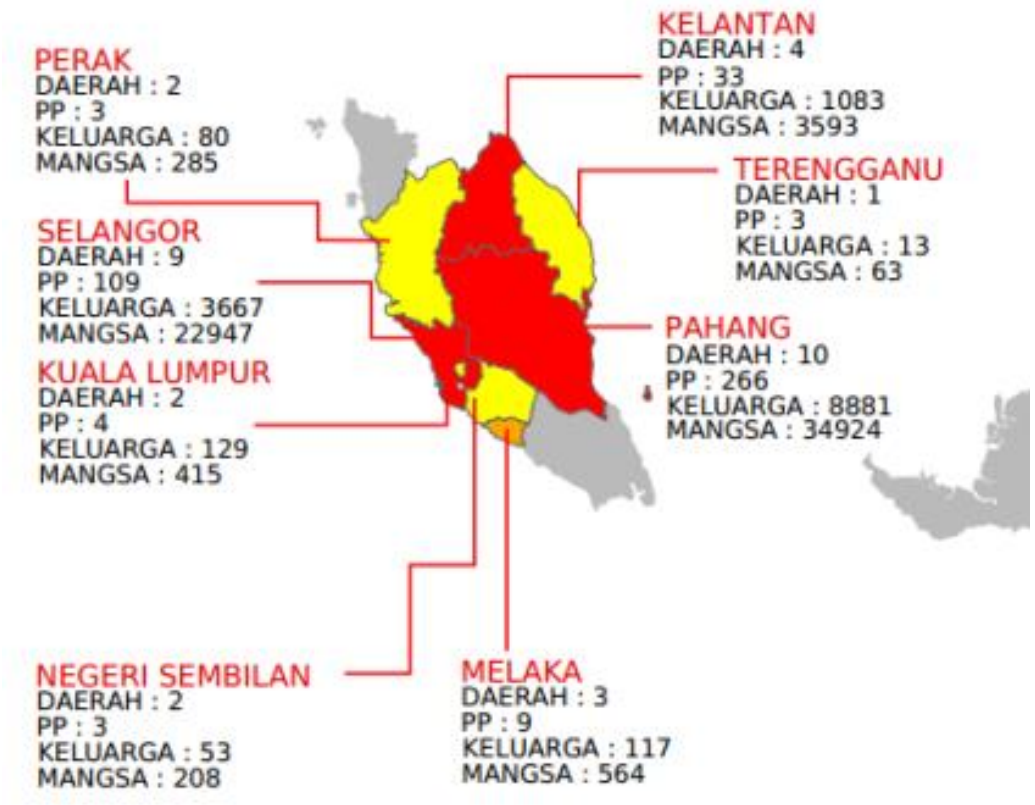


Source: Tangang et al. (2008)

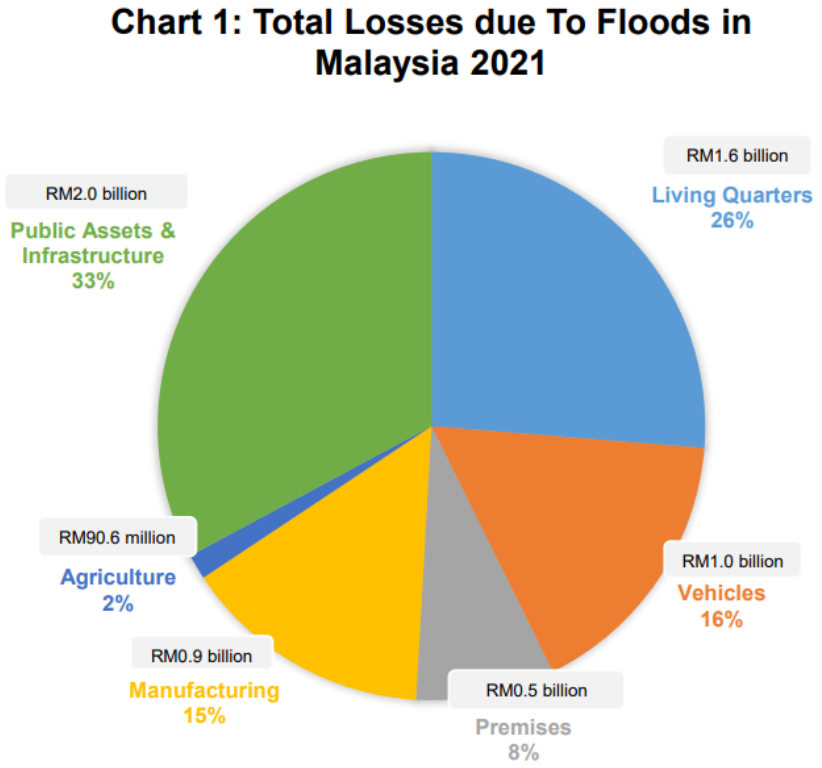
Extreme rainfall event in December 2021 and its potential synoptic drivers.

Reported Damages of the Flood Event

- Heavy rainfall 17-18 December 2021
- > 63K displaced (majority from the Selangor and Pahang state)
- Total loss: ~6.1 Billion (~0.4% nominal GDP)



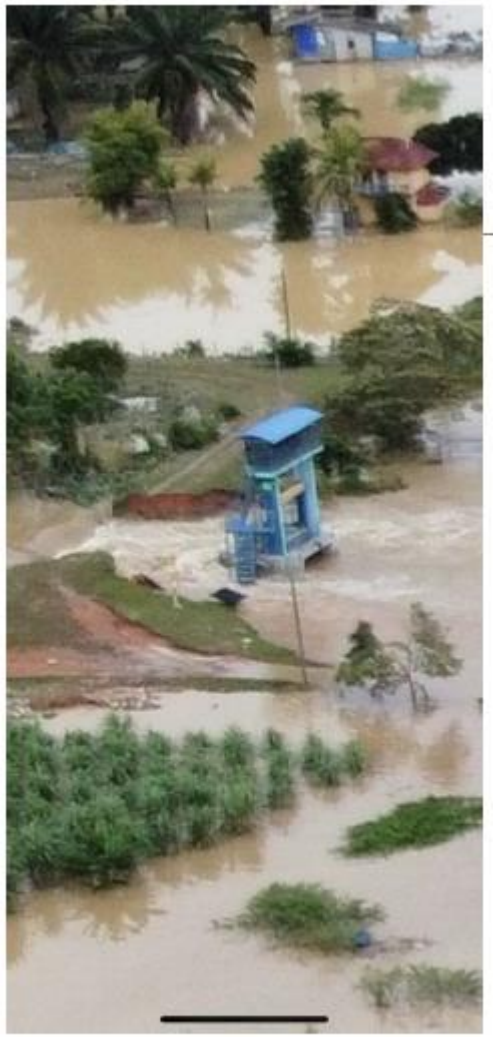
Source: National Disaster Management Agency, Malaysia



Source: Department of Statistics Malaysia

Dataran Merdeka, Kuala Lumpur

Kg. Periuk, Kg. Baru



Pintu Air Kg. Lombong, Klang

Seksyen 13, Shah Alam

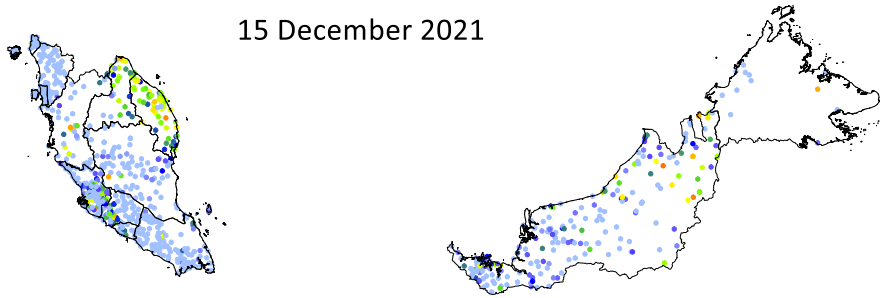
Sg. Sekamat, Hulu Langat

Saujana Aman, Kuala Selangor

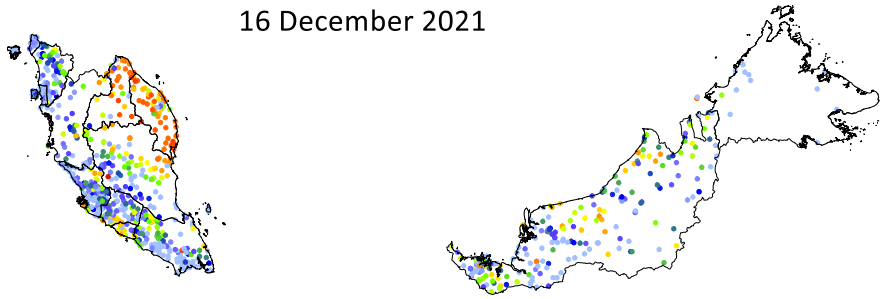
Source: Malaysia Drainage and Irrigation Department

Spatial Rainfall Distribution (15-20 Dec 2021)

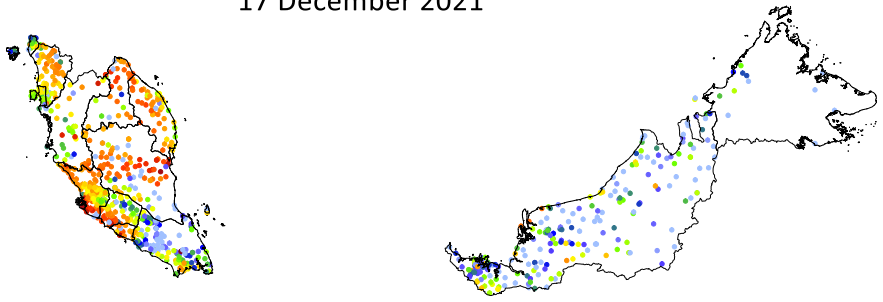
15 December 2021



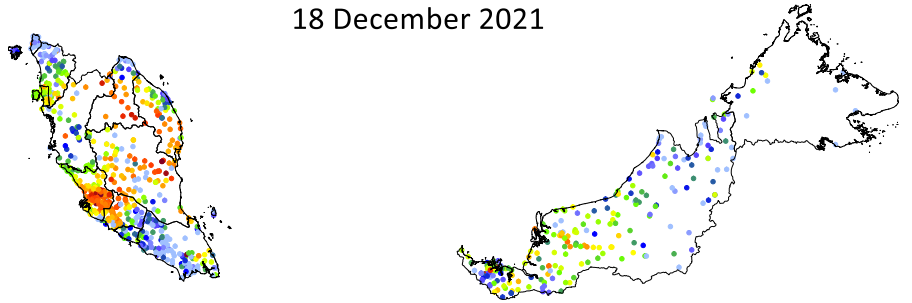
16 December 2021



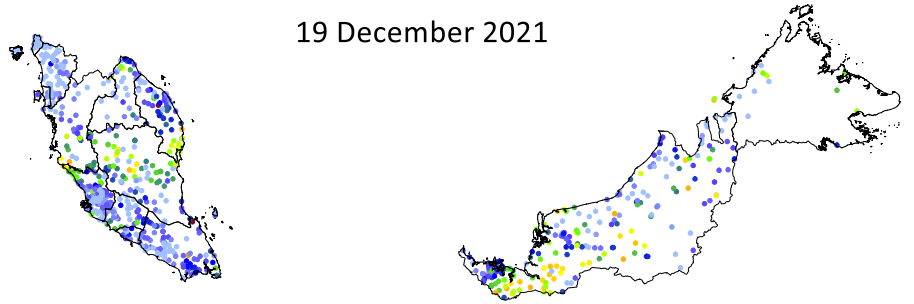
17 December 2021



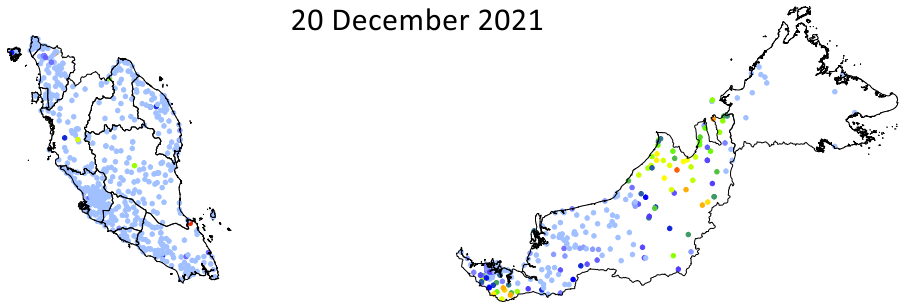
18 December 2021

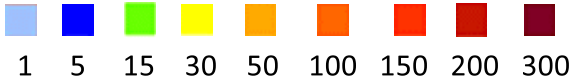


19 December 2021

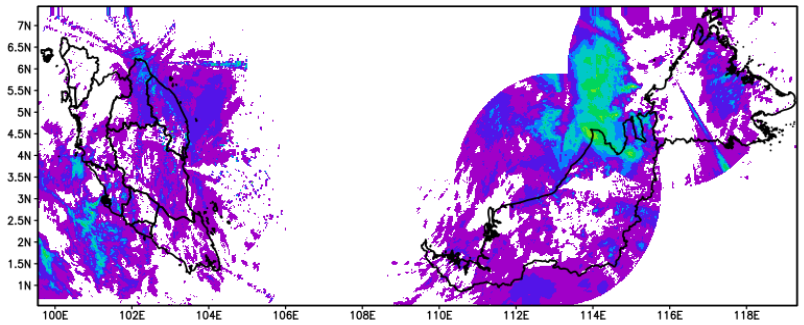


20 December 2021

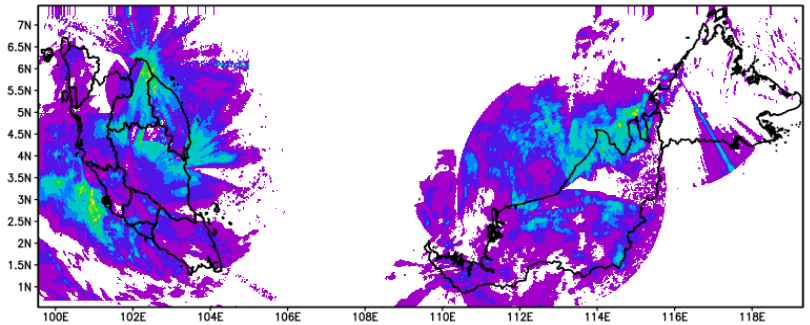




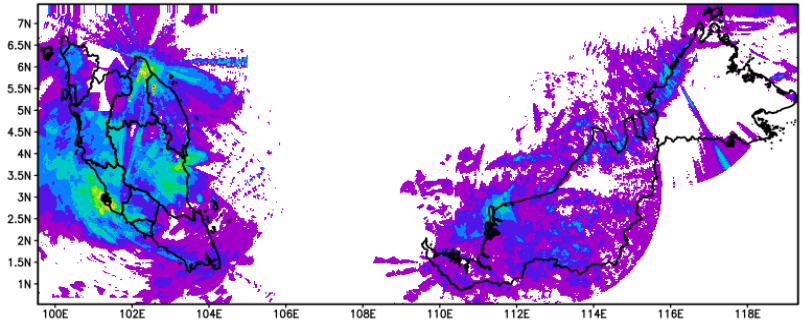
2021:12:15:11



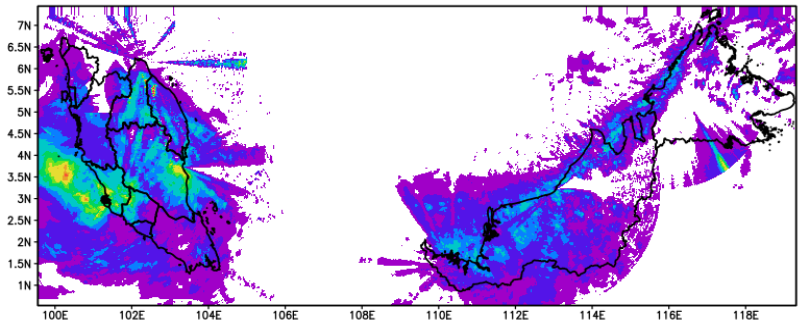
2021:12:16:11



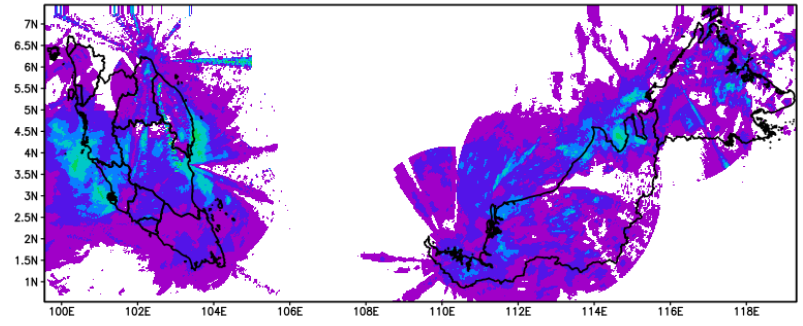
2021:12:17:11



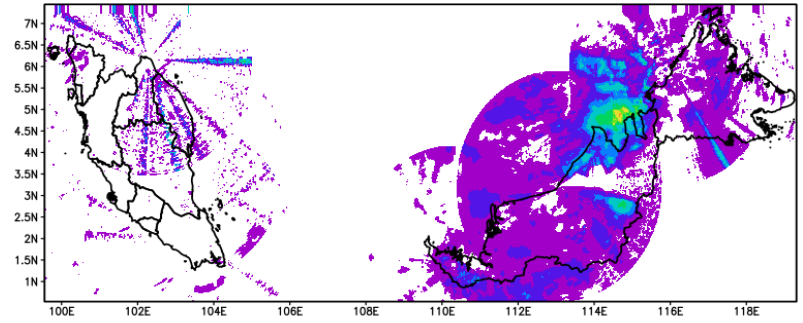
2021:12:18:11

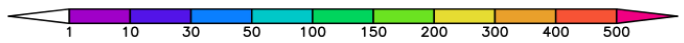


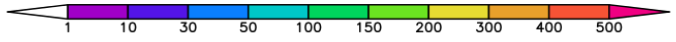
2021:12:19:11

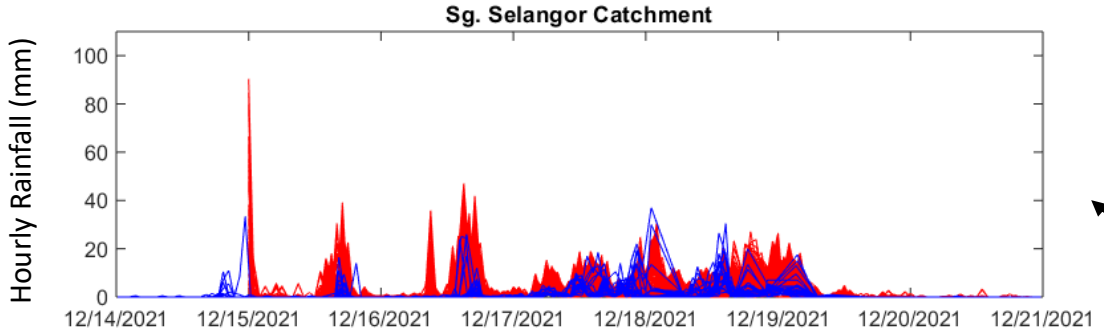


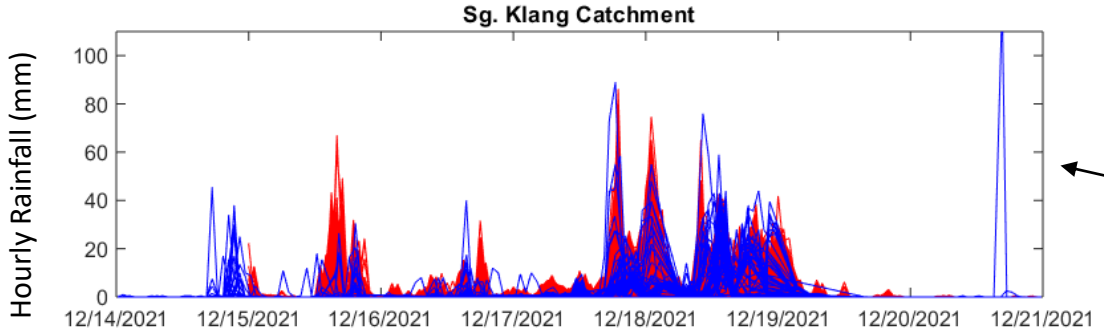
2021:12:20:11

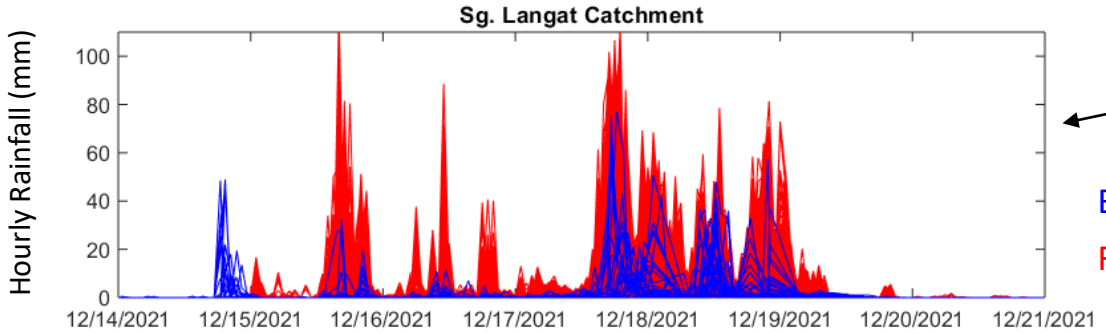


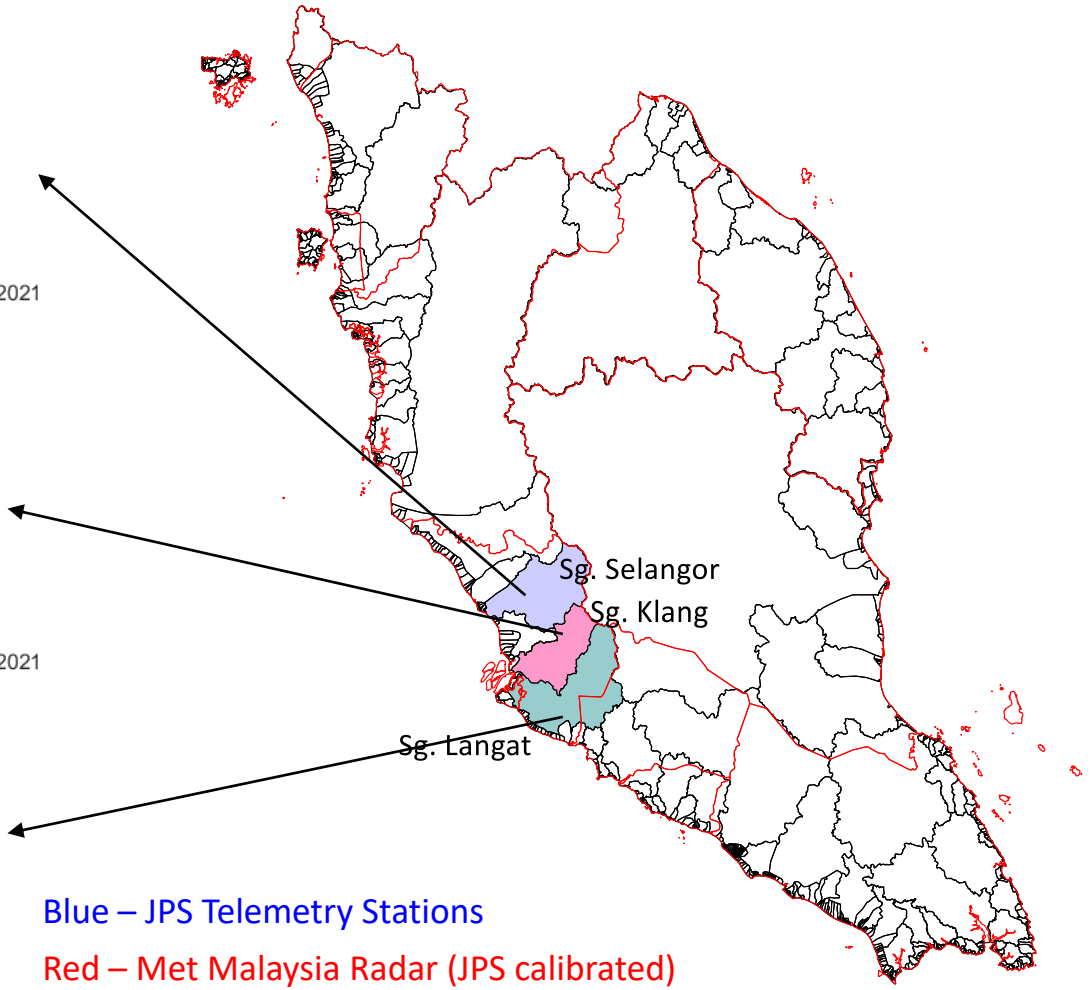






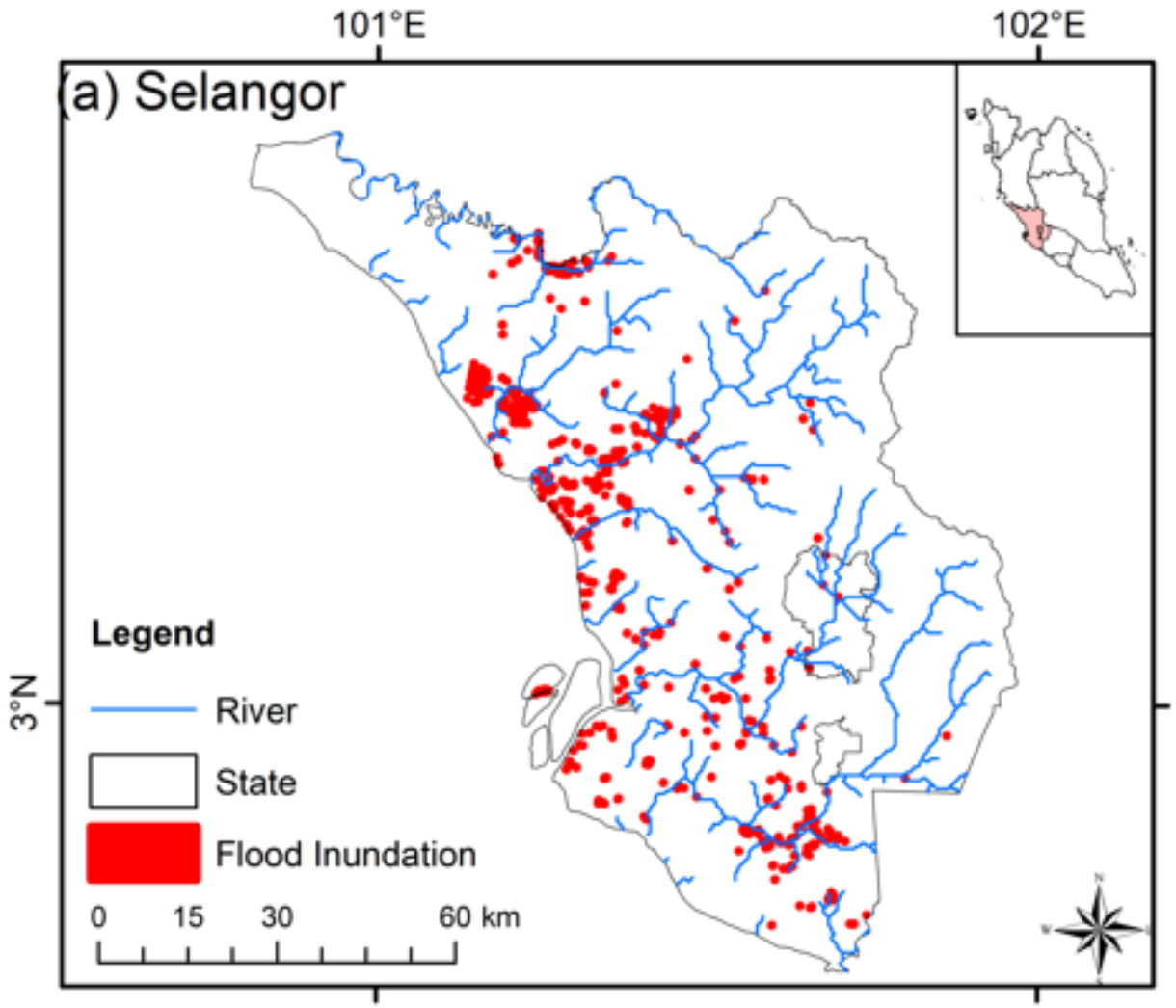


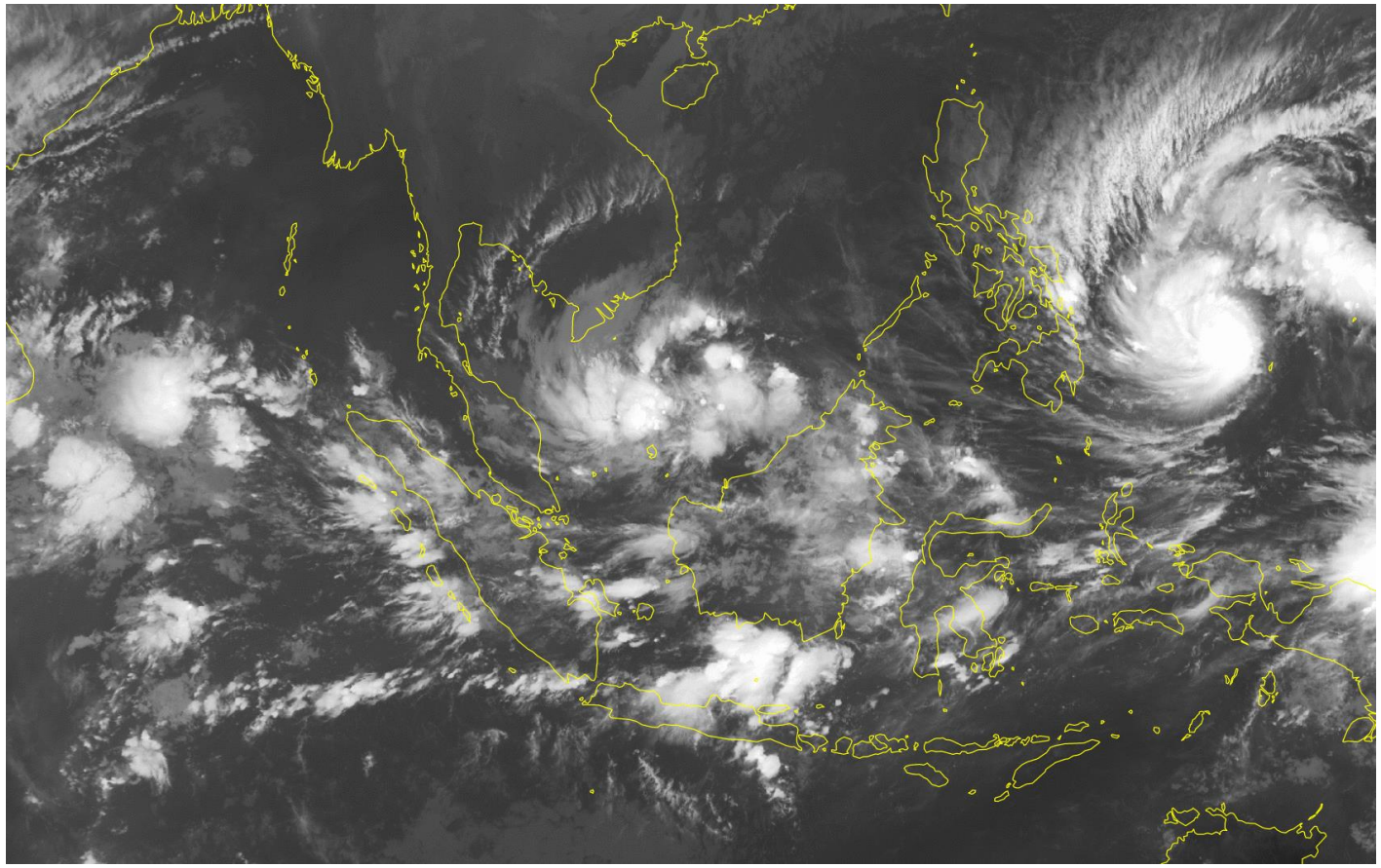


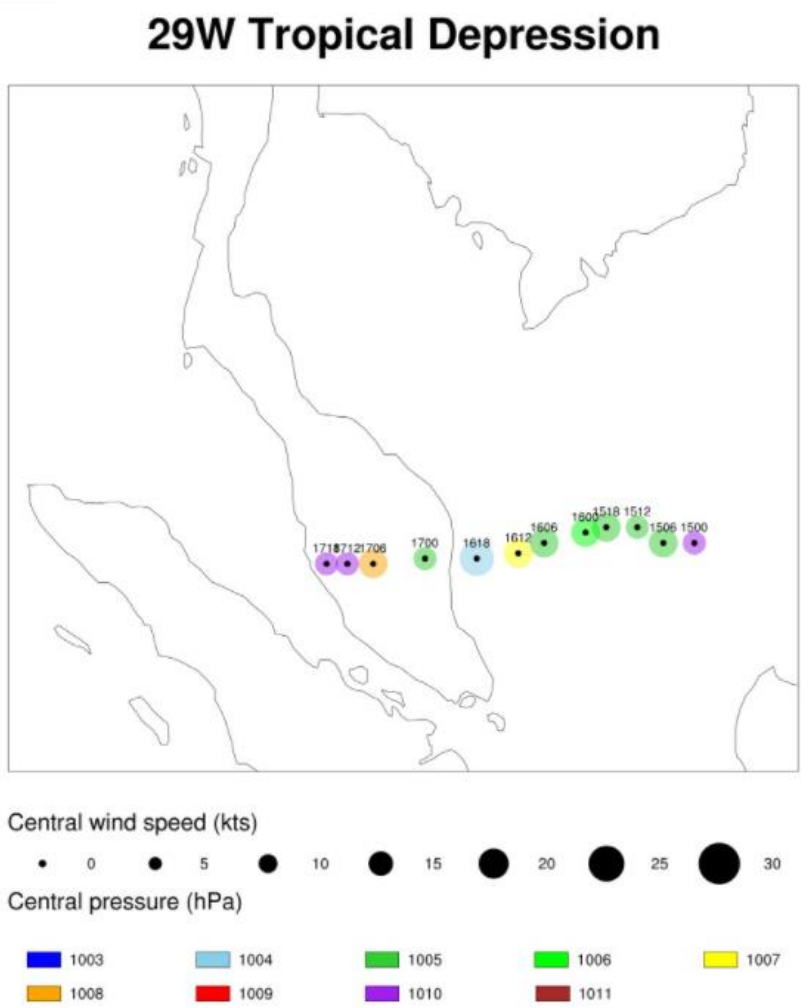


- Comparable Radar and stations rainfall, but slightly higher radar rainfall in the south.
- Hourly rain rate > 60 mm/h in some areas. Radar estimated 80-100 mm/h in some areas.

Flood locations from Sentinel Satallites data

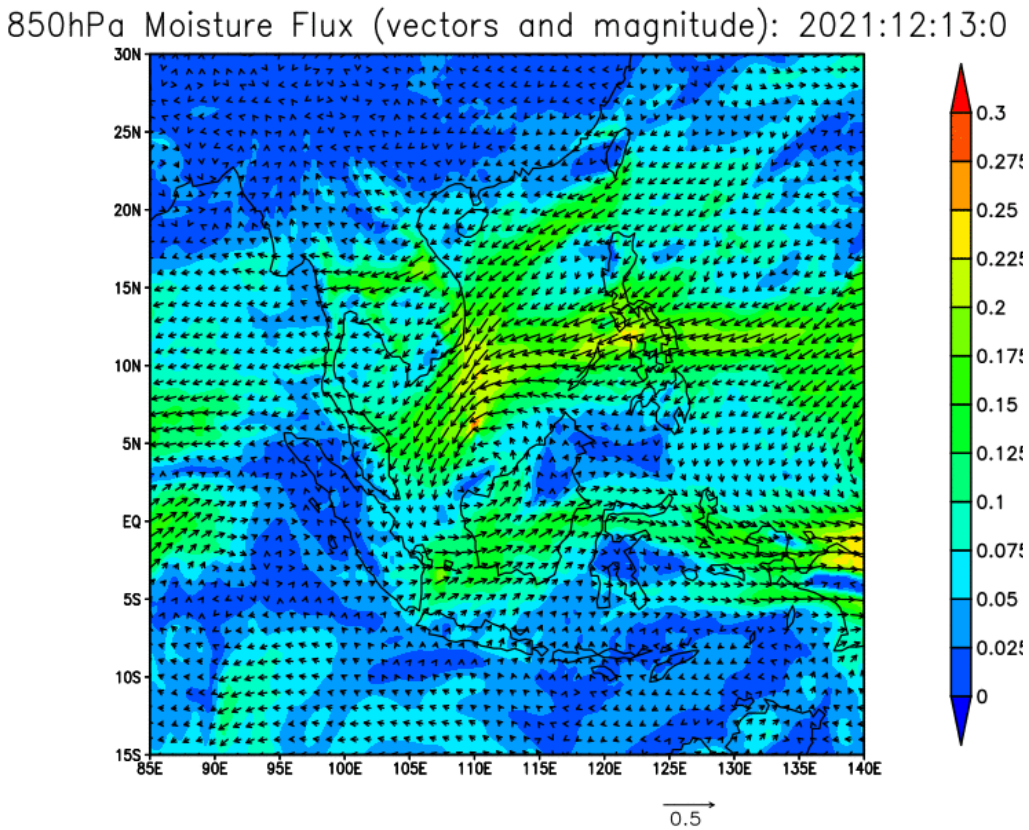


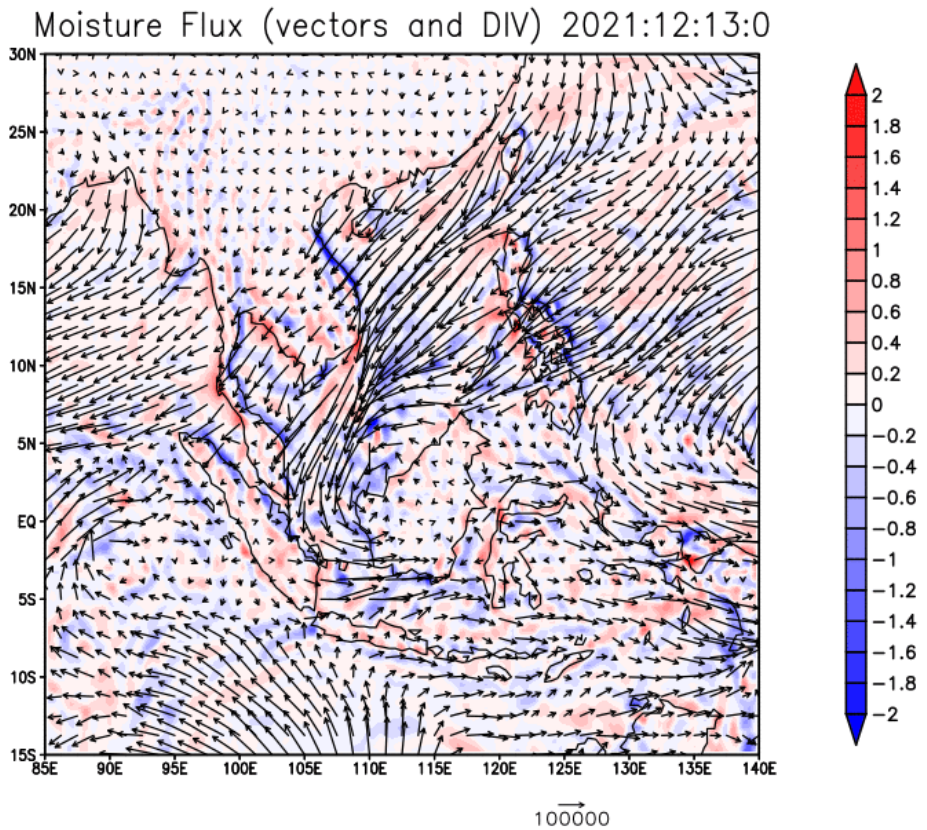




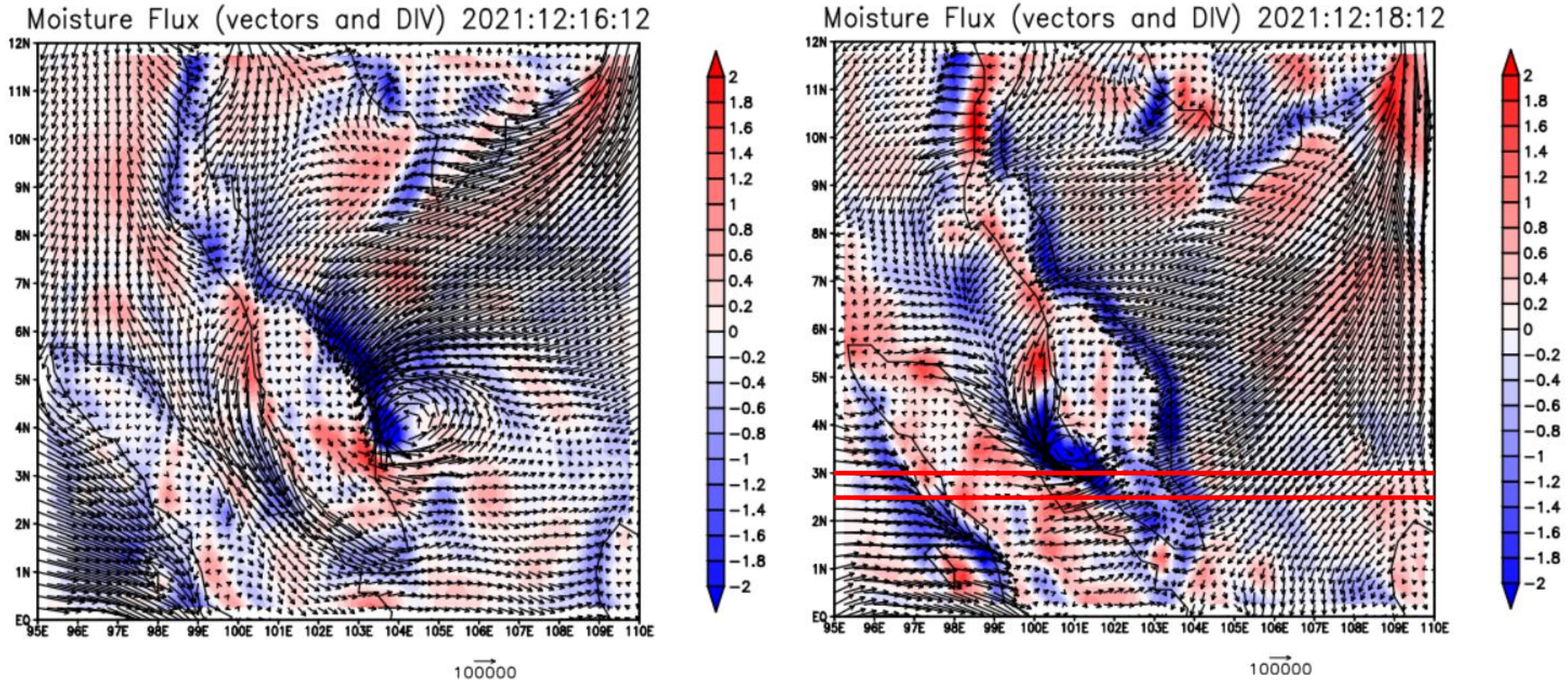
- On the 14th December 2021 a westward propagating low pressure system Borneo vortex) was identified at the equatorial South China Sea
- JTWC upgraded the system to a tropical depression, assigning it the designation 29W on 16th December 2021.
- Re-intensification over the Strait of Malacca (short period).

Synoptic Configuration

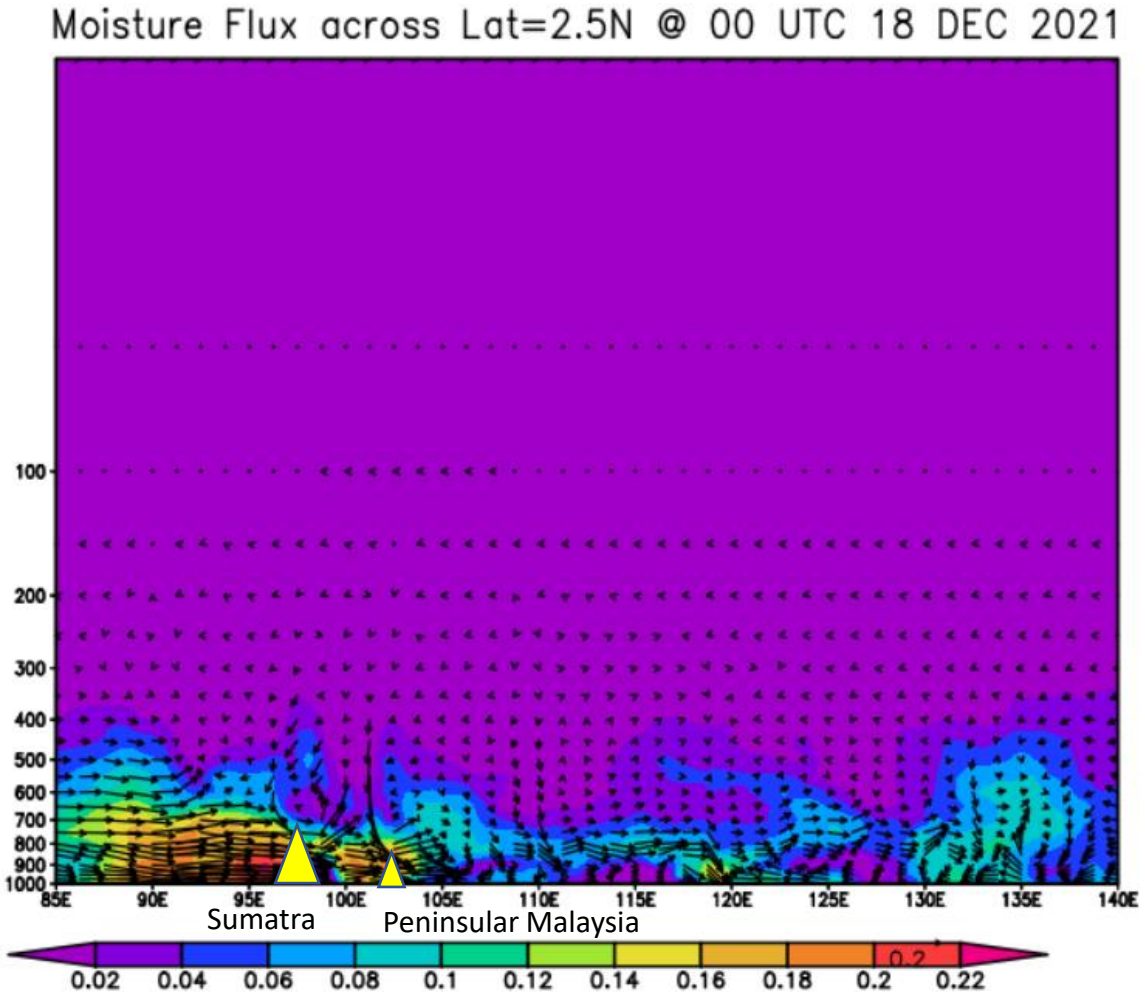


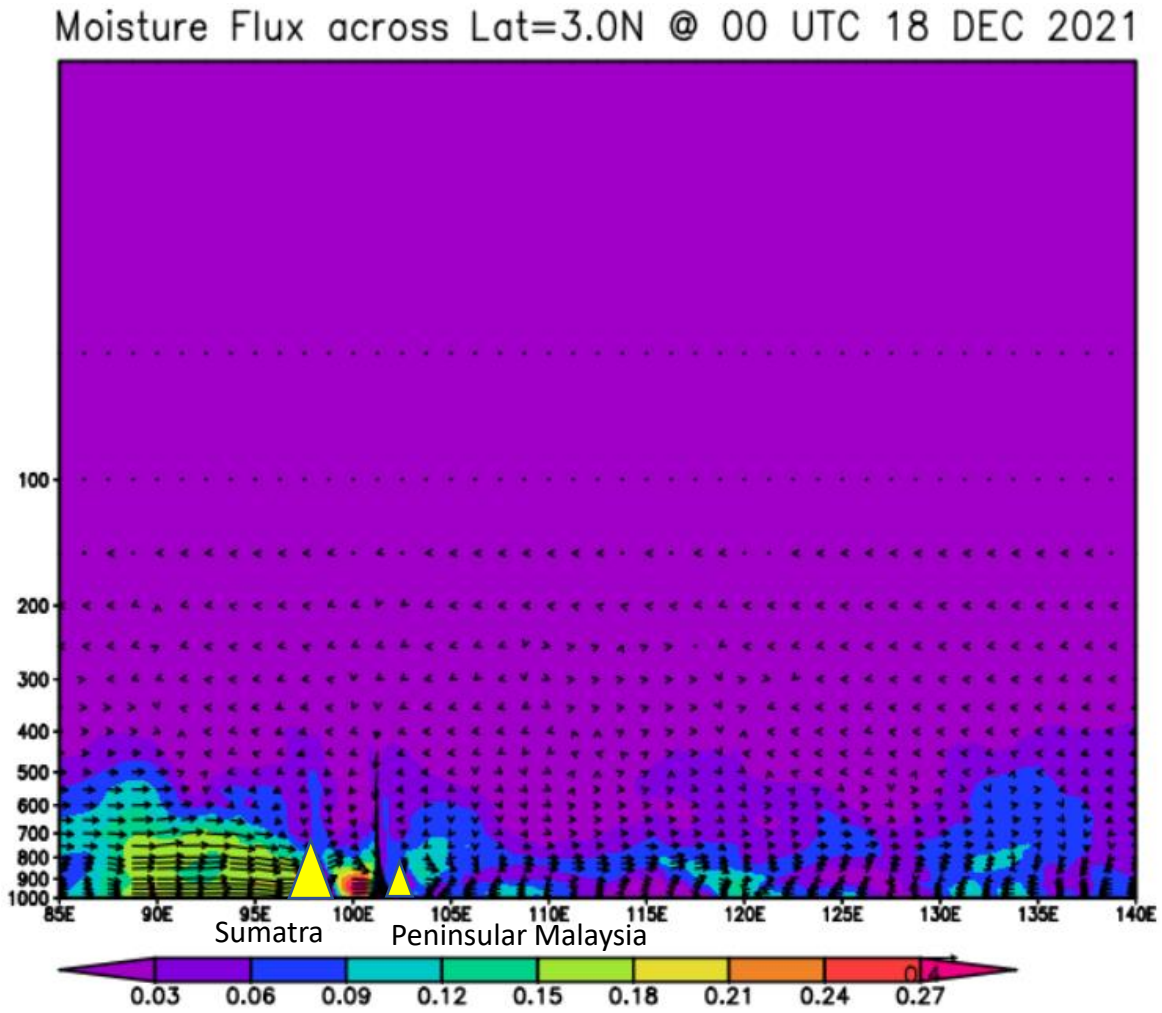


- The moisture flux patterns suggest that the heavy rainfall over the east coast is mainly associated to the tropical depression.
- Note that there was an approaching westerly moisture flux from the eastern Indian Ocean around late 16th Dec 2021 that crossed the Sumatera, and interacted with the northeasterlies associated to the tropical depression 29W.



- On the 16th Dec 2021, the moisture convergence is mainly a result of direct impinge of tropical depression circulation over the coastal areas.
- On the 18th Dec 2021, when largest amount of rainfall is received over the central west coast, the moisture flux converge as a result of intensified local cyclonic system.
- Potentially a result of the remnant of the 29W and the environmental flow.



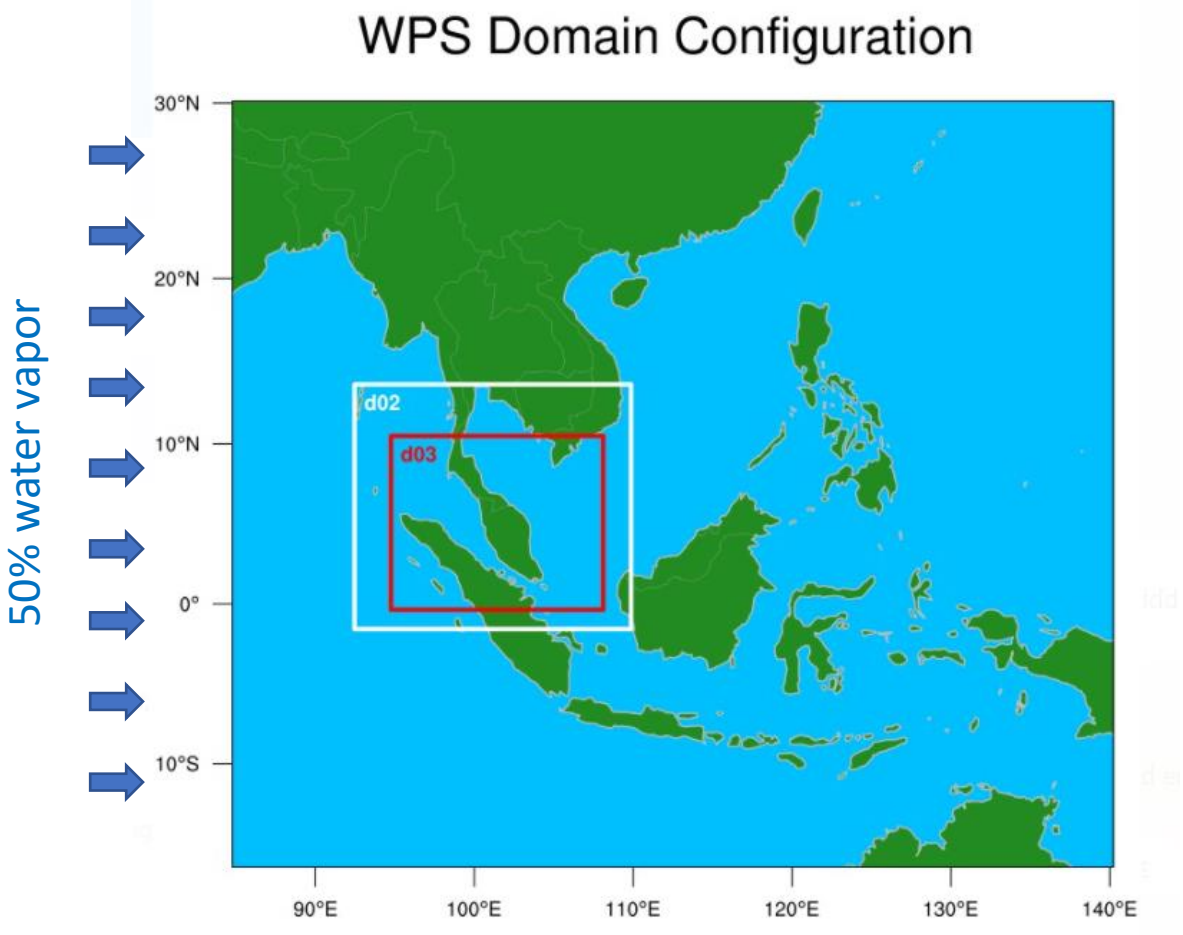


Contour/Shade
mag(u*q,v*q)

Vectors
skip(q*u,5,0);q*w*10

- The moisture is largely from the Indian Ocean and fuel the tropical depression.
- The moisture supply to the heavy rain center was via the cyclonic vortex, mainly from the northwest quadrant, from offshore to the coastal region.

WRF experiment



- 27km > 9km > 3 km.
- Tropical Suite:

Radiation: RRTM scheme for both longwave and shortwave.

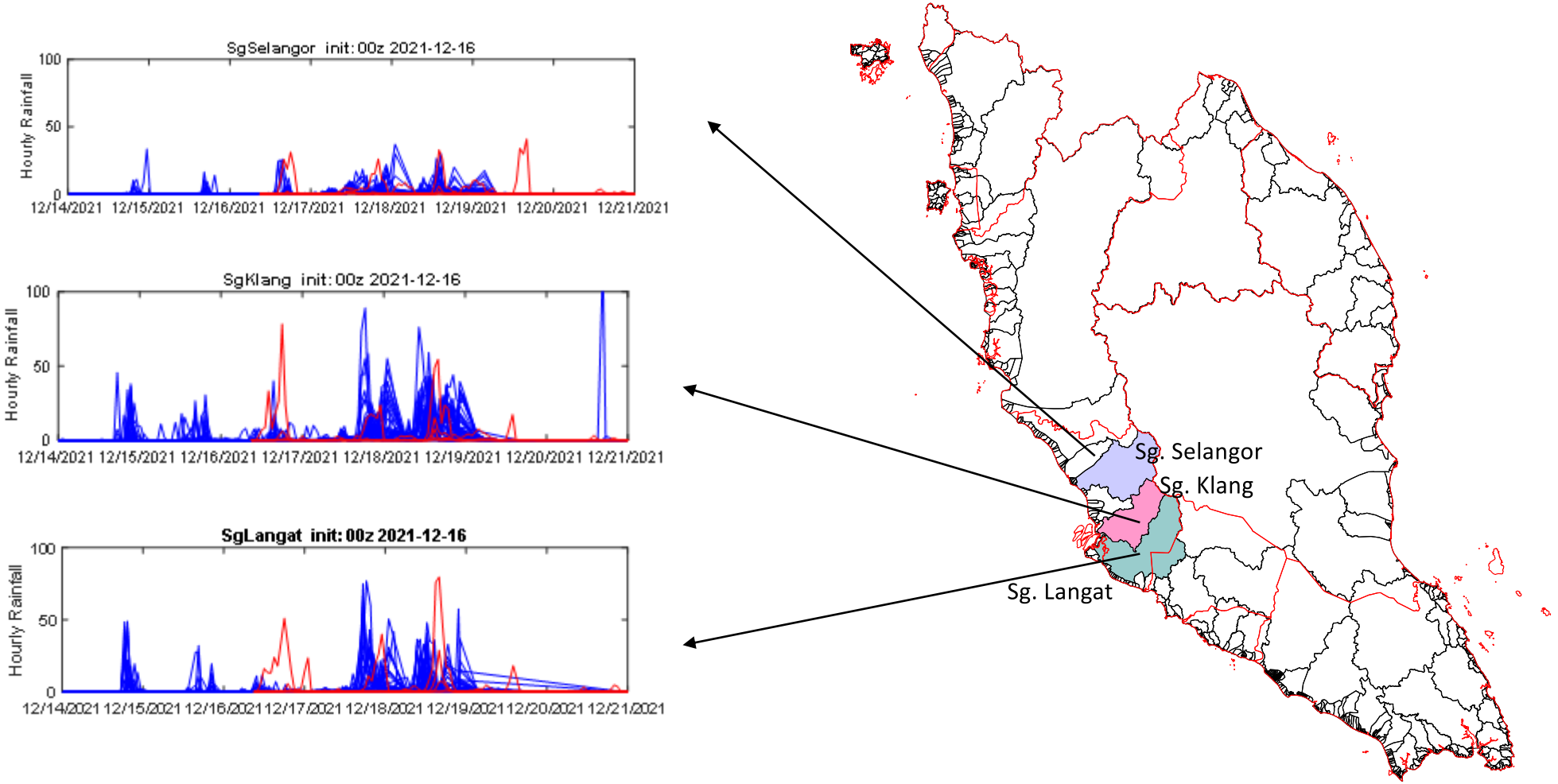
PBL: Yonsei University scheme.

Cumulus: new Tiedke scheme

Microphysics: WSM6 scheme.

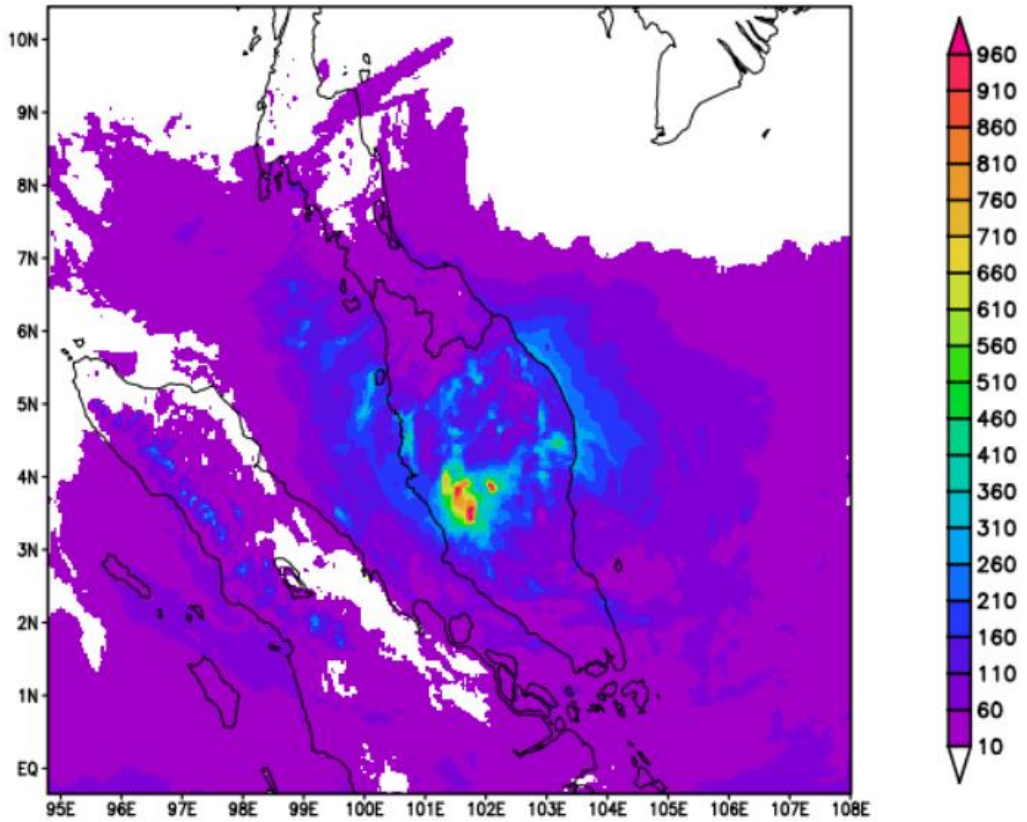
- Initial and boundary condition from NCEP FNL at 6-hourly interval.
- Initialized 0 UTC 16 December 2021.
- Experiment: The moisture from the western boundary is reduced by 50%.

Simulated Rainfall over the 3 selected catchments

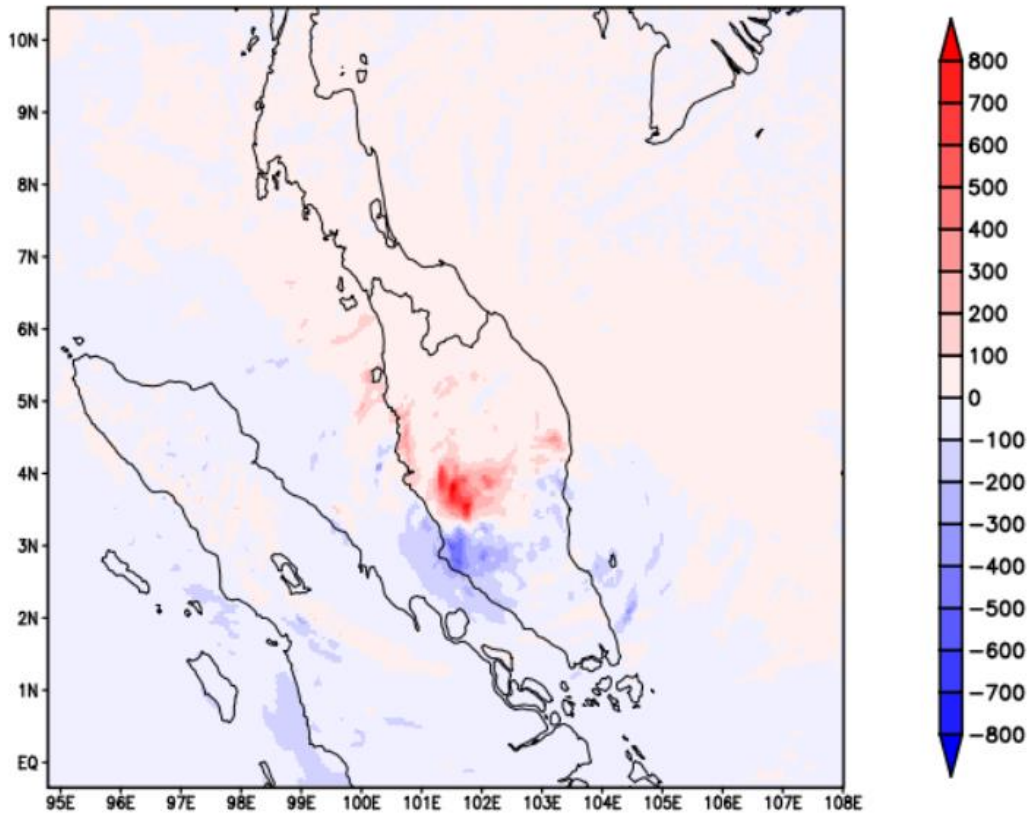


Figures show the observation (blue) vs the simulated rainfall values (100th, 75th, 50th and 25th percentile across the catchment.

Total rainfall accumulated 16-18 December 2021



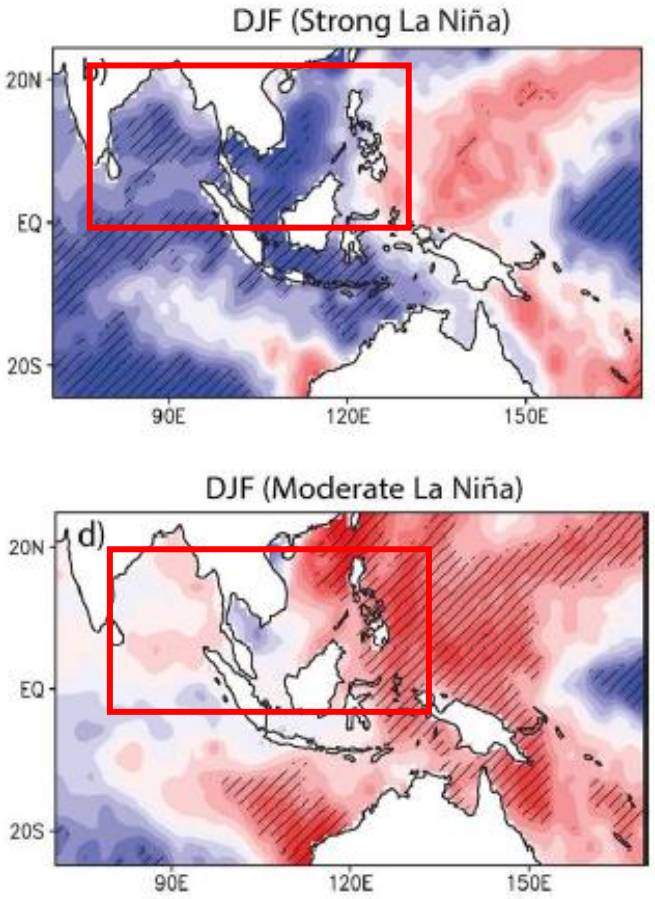
Control – Experiment (50% Q reduction)



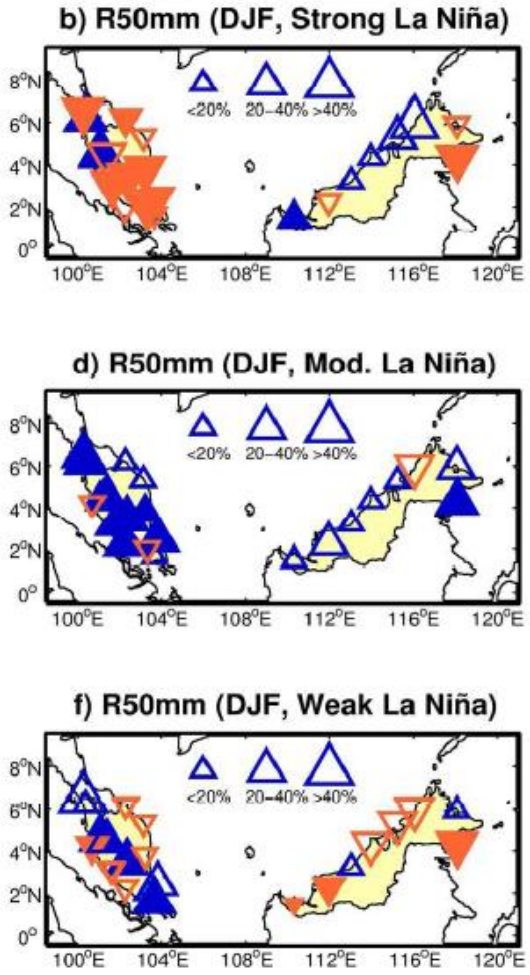
- The moisture from the western boundary is crucial for the received rainfall amount over the rainfall center.
- Crucial for local vorticity and moisture convergence.

Discussion: Potential La Nina modulation

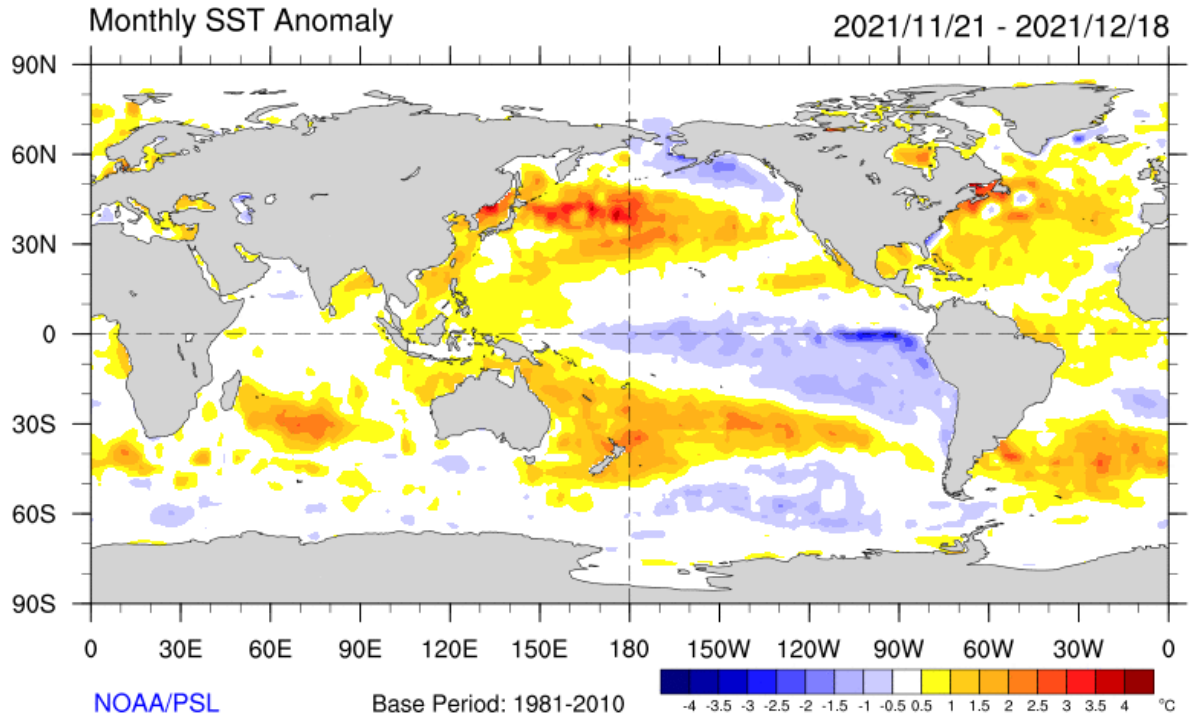
SST anomalies composite



R50mm during La Nina

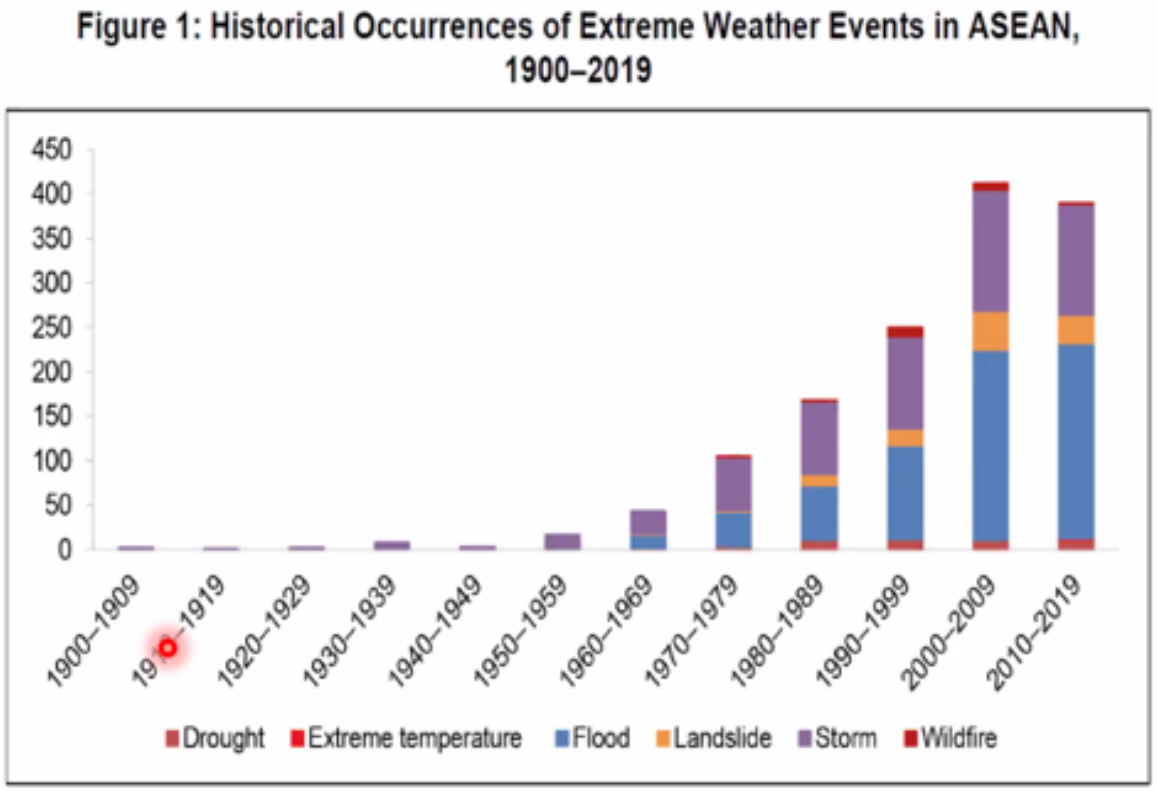


- La Nina (weak > moderate, Nov-December 2021

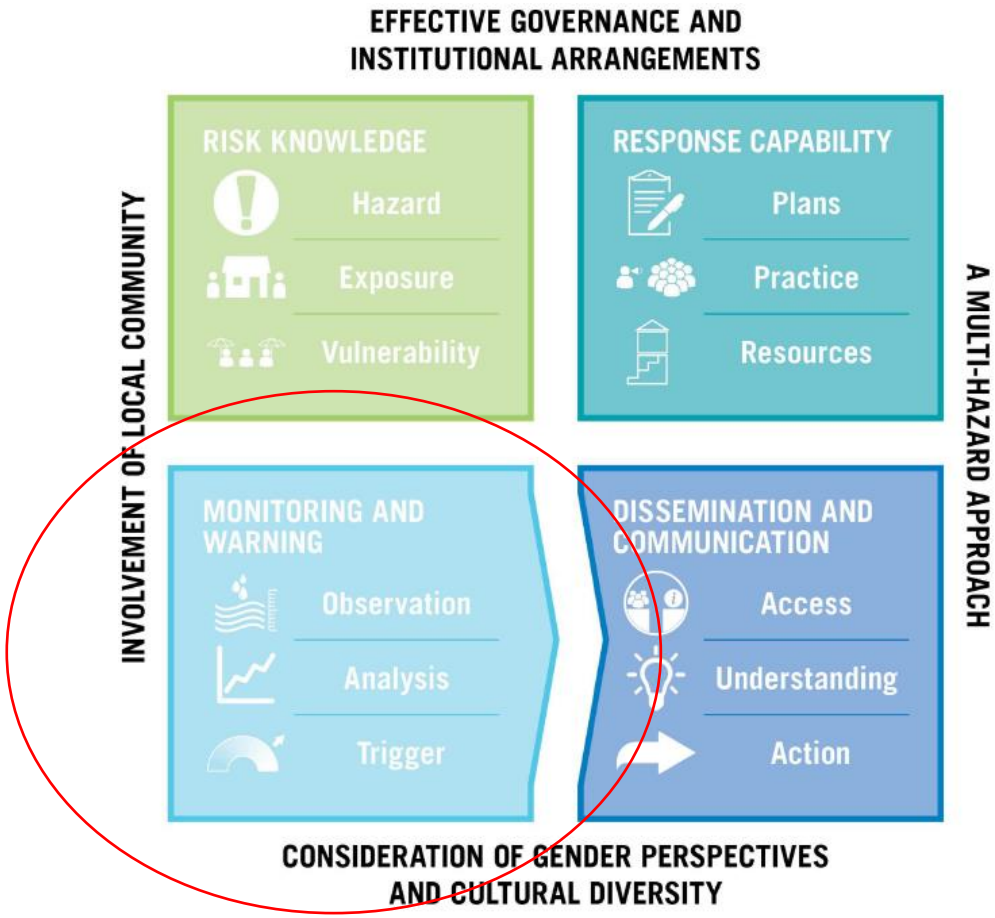


Source: psl.noaa.gov

Discussion: Current approach weighted much on “Monitoring and Warning”.



Beirne & Renzhi (2021)



- Early Warning System is an integral part of natural disaster management as well as climate change adaptation.
- Required proper integration with other management components.

Remarks

- The flood-producing heavy rainfall event in Dec 2021 over Peninsular Malaysia has very strong large scale environmental control.
- Over the east coastal, the heavy rainfall is mainly a result of the direct impingement of the tropical depression with the coastal areas.
- Over the western coast, the heavy rainfall appeared to a result of localized vortex that intensified over Strait of Malacca.
- The moisture sources from the Indian Ocean maybe a crucial factor for the western coast of Peninsular Malaysia.