Satellite Observations and Coupled Atmosphere-Ocean Modeling of the MJO over the Maritime Continent

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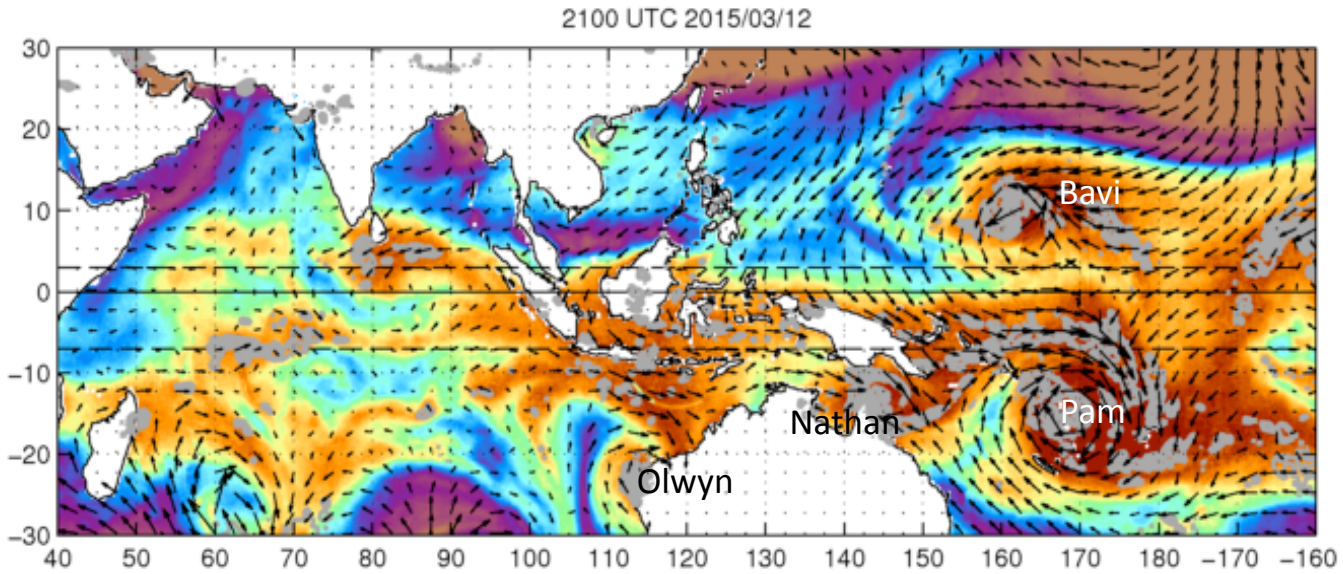
University of Washington

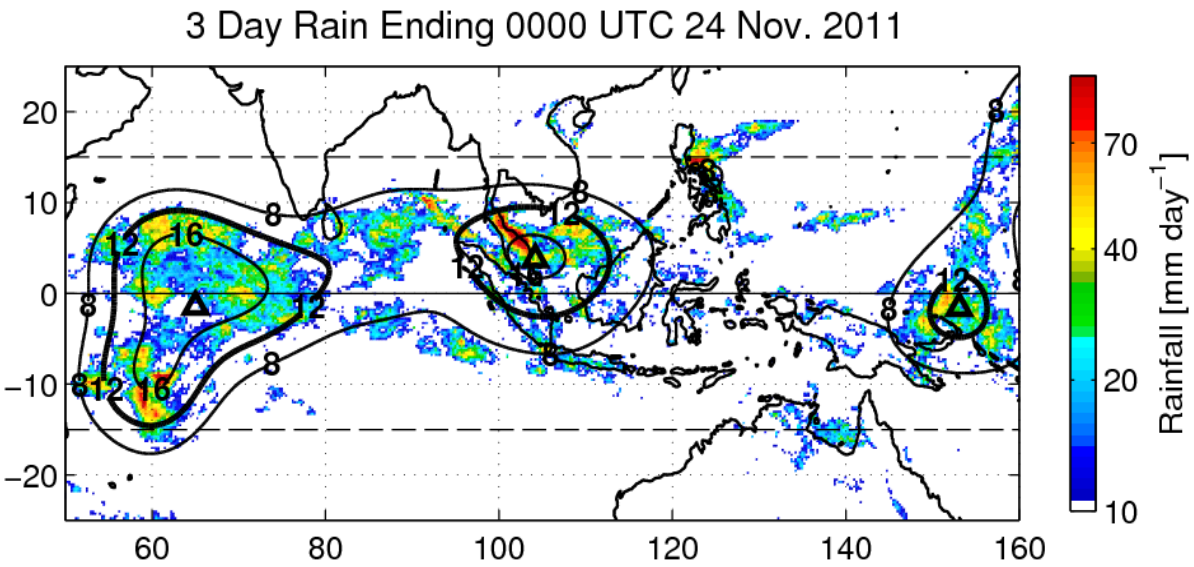


(4th International YMC Workshop, UP, Manila, Philippines, 26-28 Feb 2019)

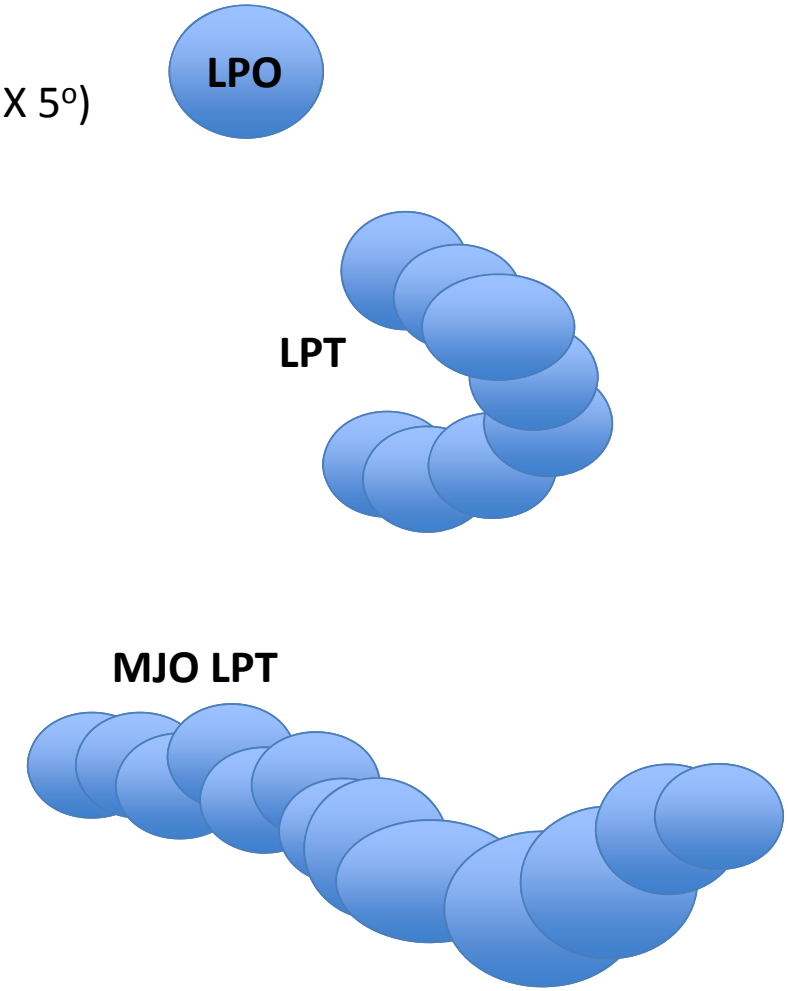
Hurricanes and Coupled Atmosphere-Ocean Systems

Data and Large-scale Precipitation Tracking (LPT):

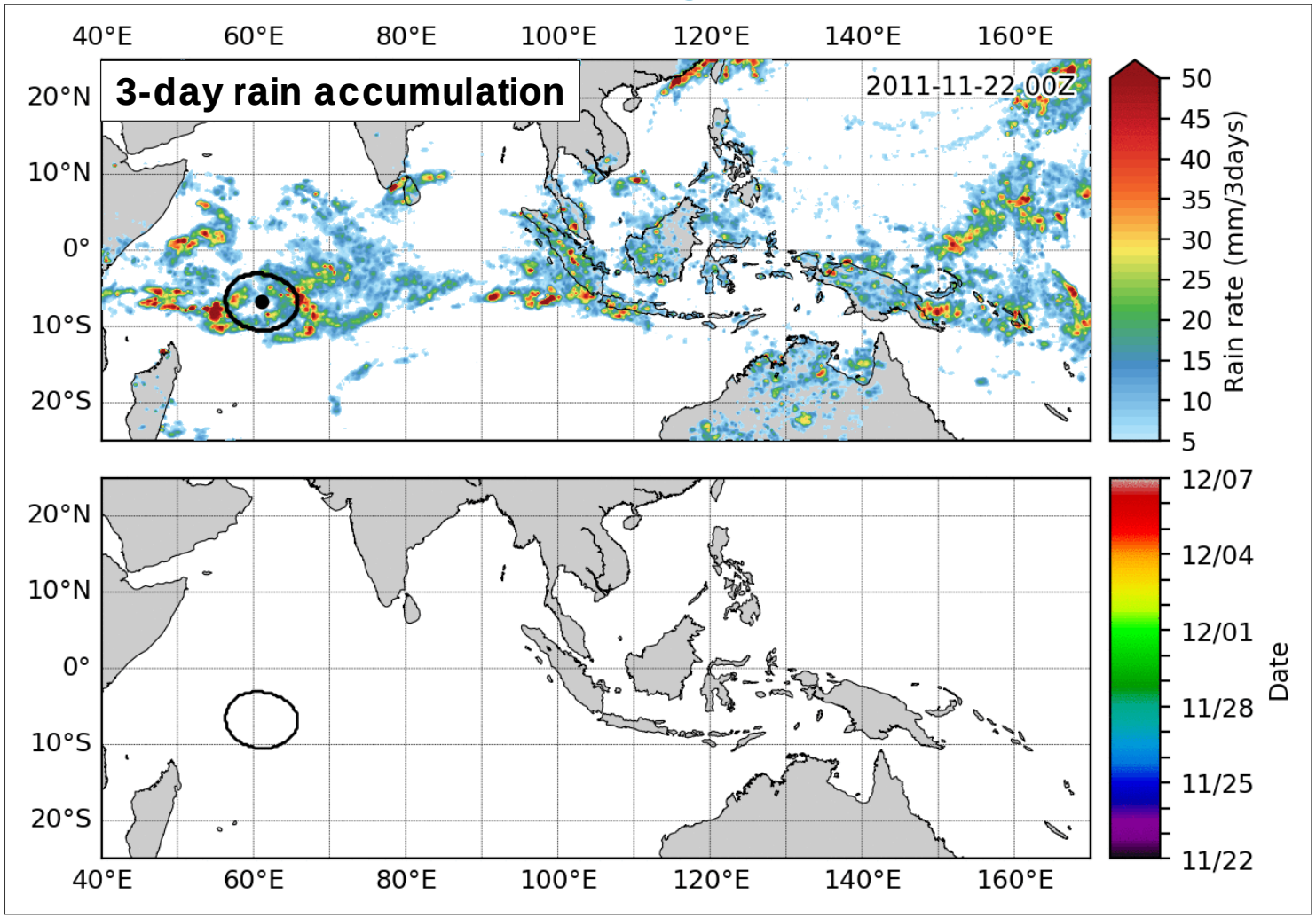
- TMPA 3B42 V7 data (0.25°, 3 hourly)
- **LP Object (LPO) :** 3-day accumulated rainfall with spatial filter (5° X 5°) area of > 12 mm day^{-1} (> 250,000 km^2)
- **LP Tracking (LPT)**: track LPO in time > 7 days
- **MJO LPT**: LPT > 10 days; eastward propagation speed > 0 m/s



Kerns and Chen (2016, JGR)

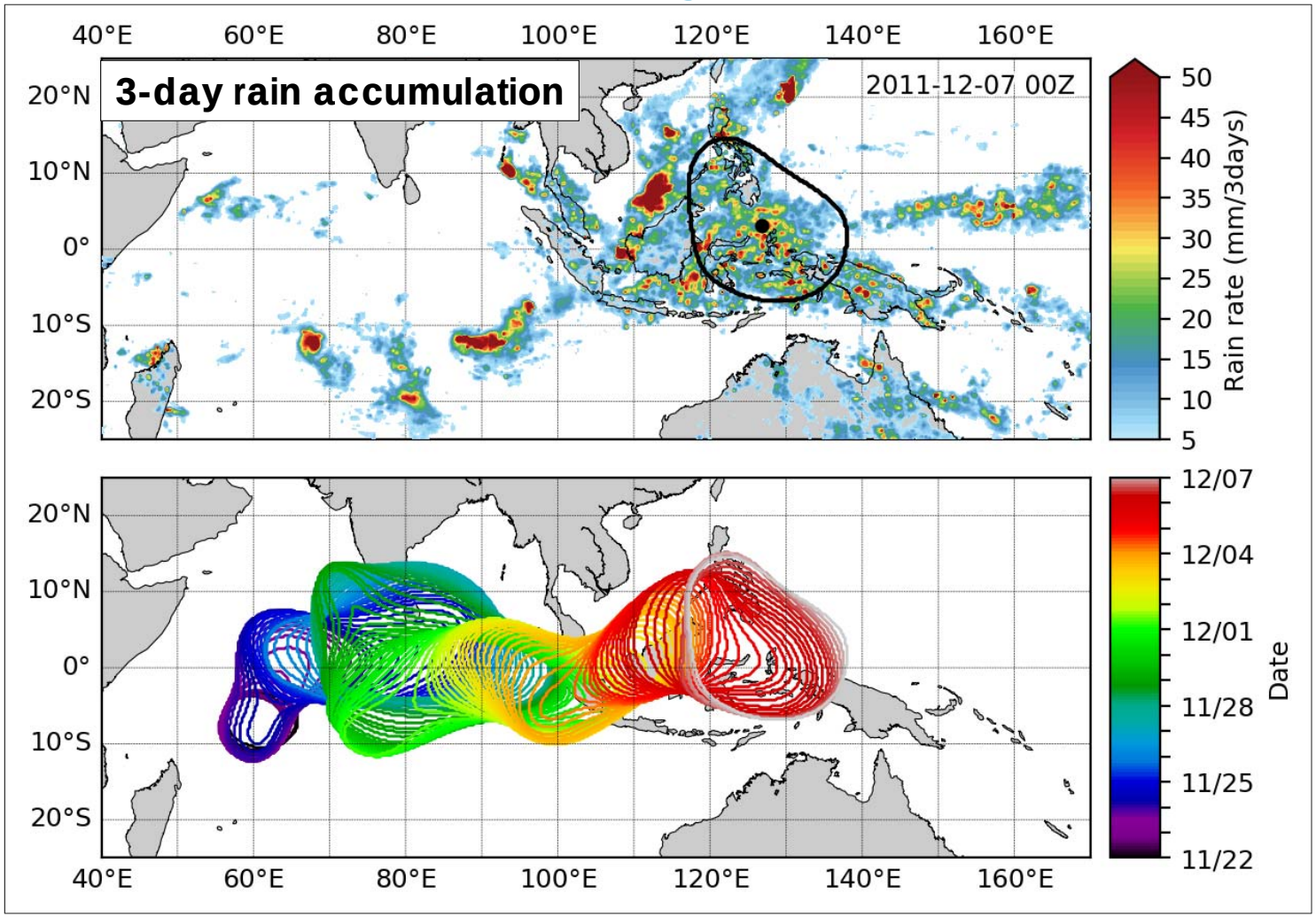


Tracking the MJO

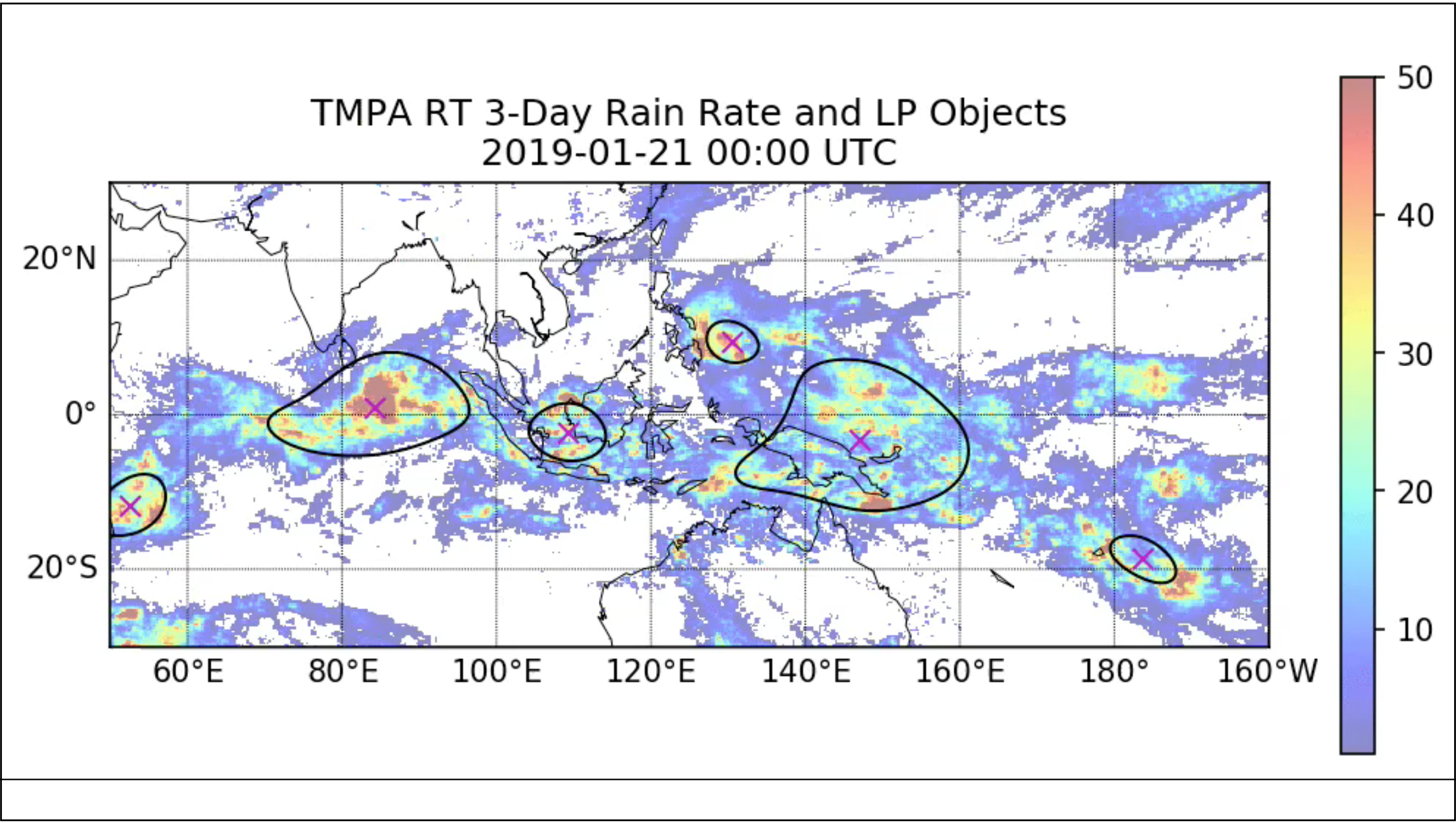


- Traditional RMM index cannot provide spatial and temporal variation of the MJO.
- LPT is used to track MJO precipitation. **(Kerns and Chen 2016)**

Tracking the MJO



- Traditional RMM index cannot provide spatial and temporal variation of the MJO.
- LPT is used to track MJO precipitation. **(Kerns and Chen 2016)**
- Challenge: majority of NWP and climate models cannot reproduce MJO precipitation patterns.

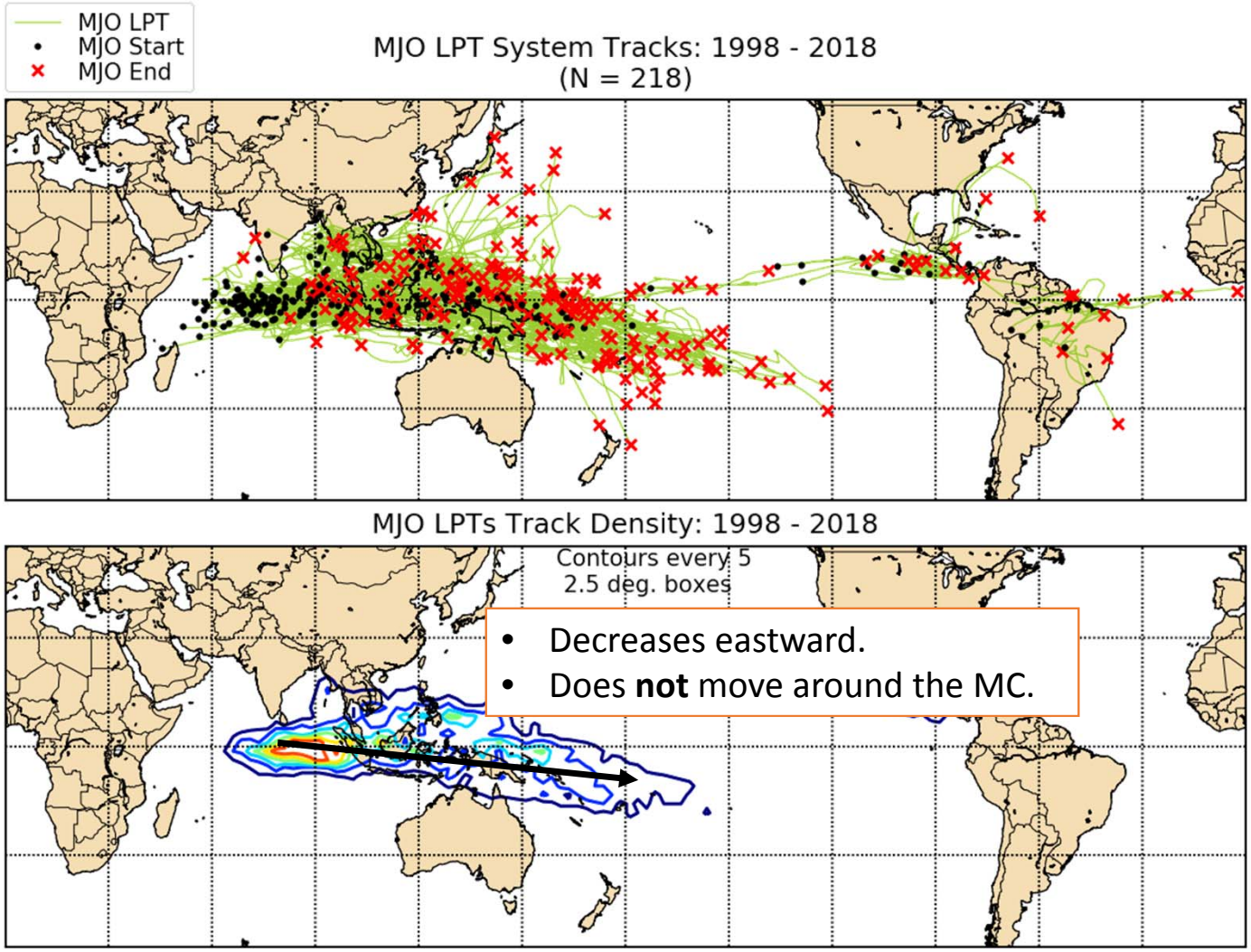

TMPA RT 3-Day Rain Rate and LP Objects
2019-01-21 00:00 UTC
20°N
0°
20°S
60°E
80°E
100°E
120°E
140°E
160°E
180°
160°W
50
40
30
20
10

20 years of the TRMM-GPM Precipitation from 1998-2018
(Kerns and Chen 2019, JGR)

and

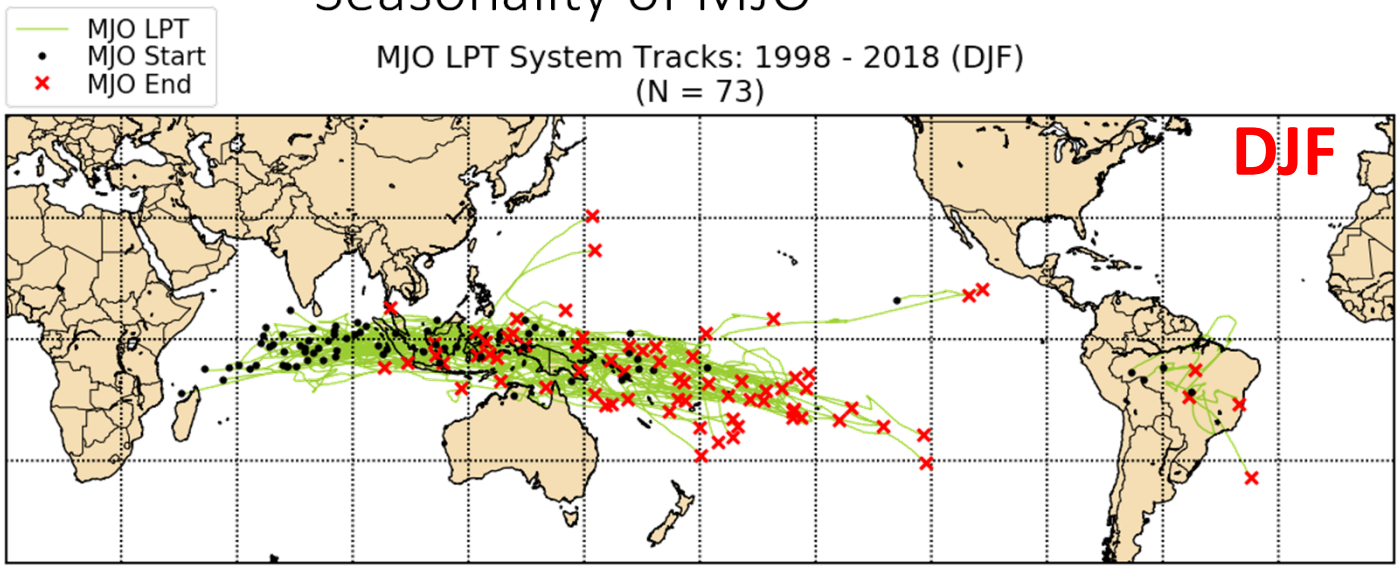
ECMWF S2S Reforecast from 1998-2017

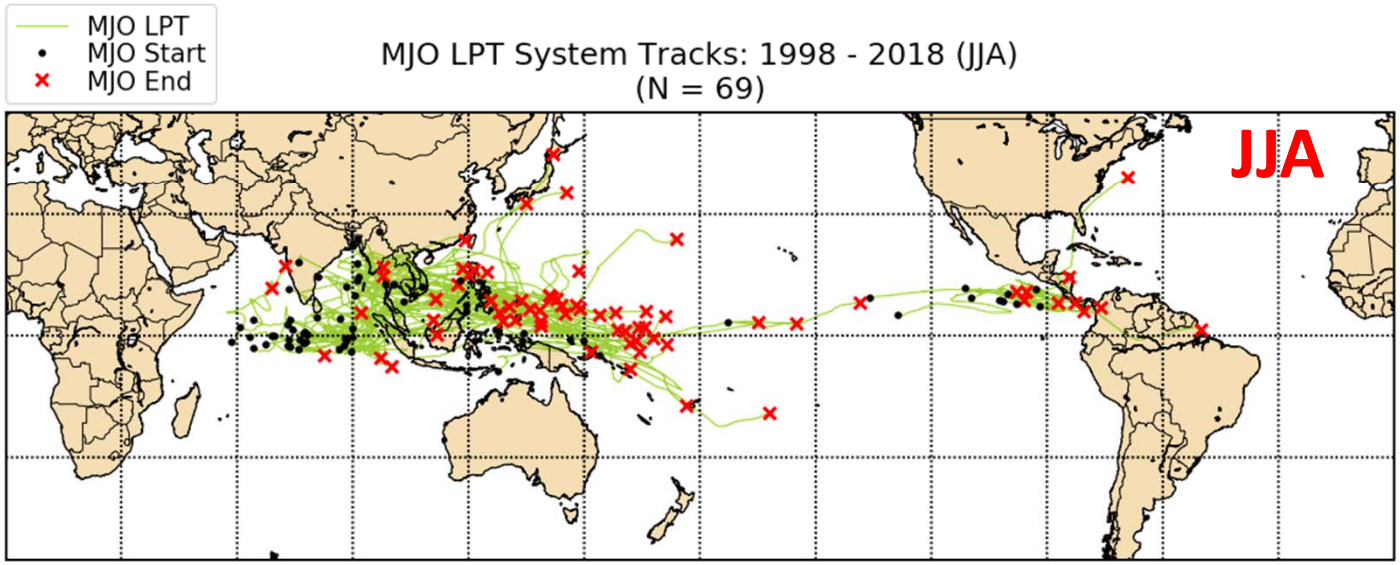
20 year MJO climatology

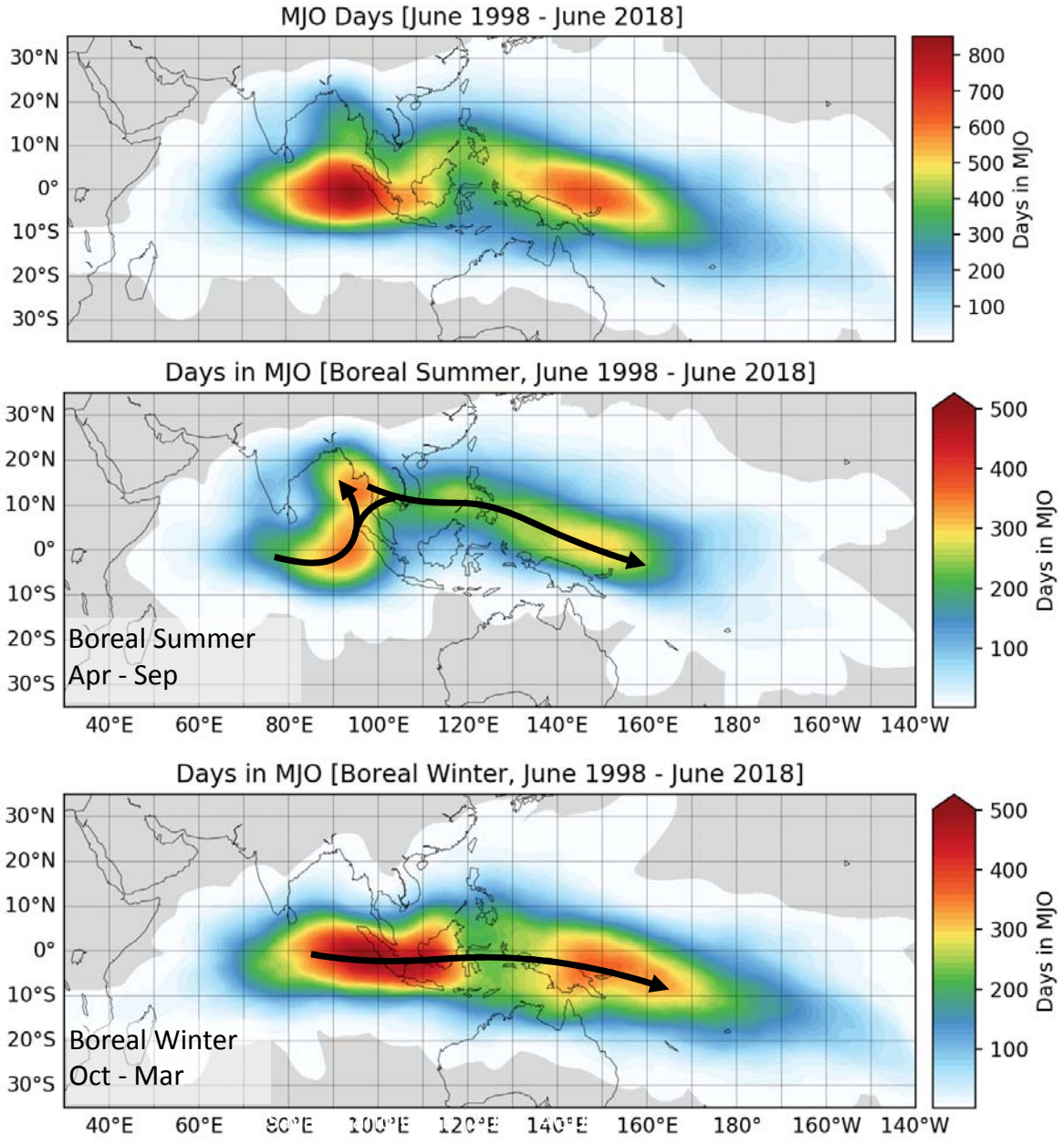


- Decreases eastward.
- Does **not** move around the MC.

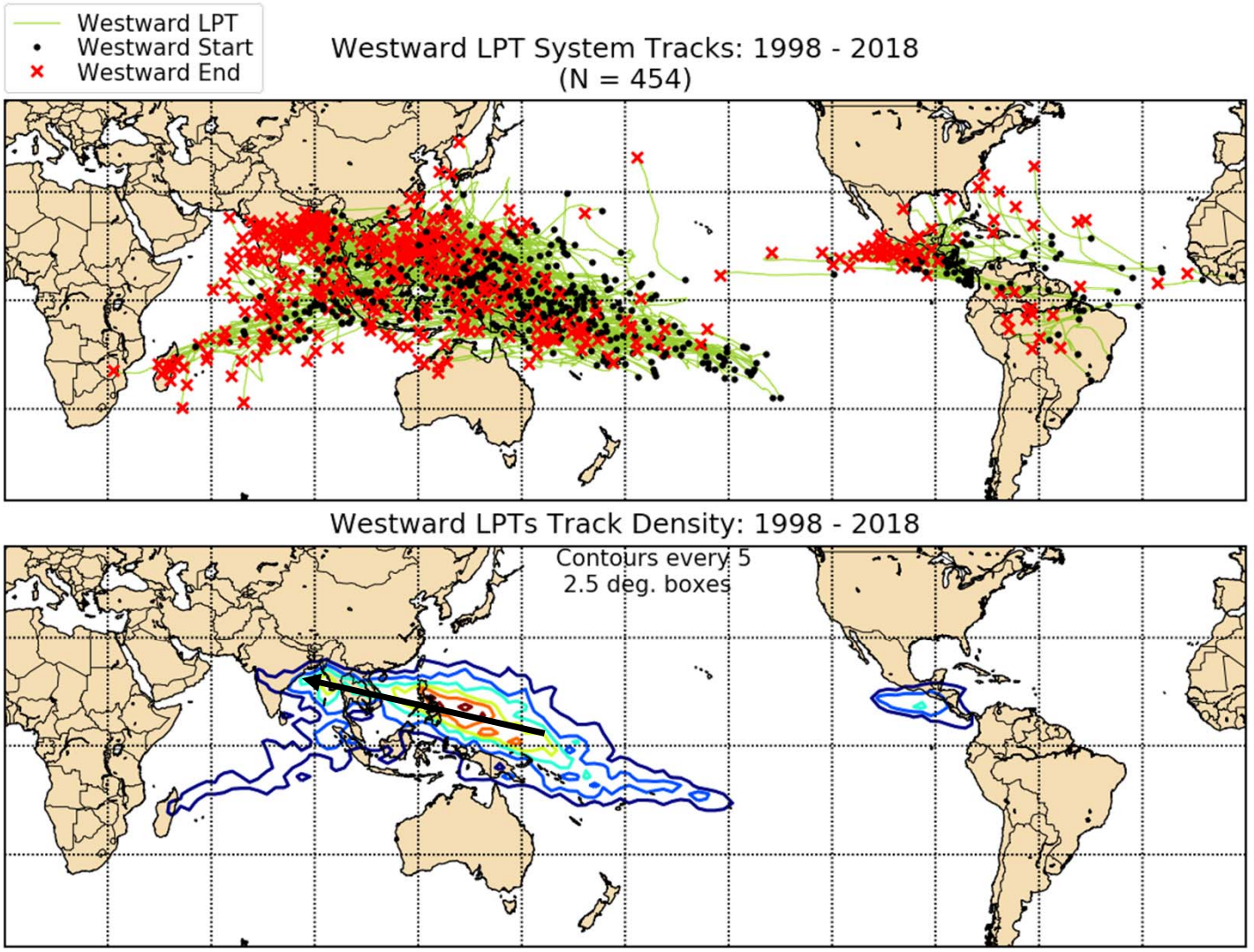
Seasonality of MJO



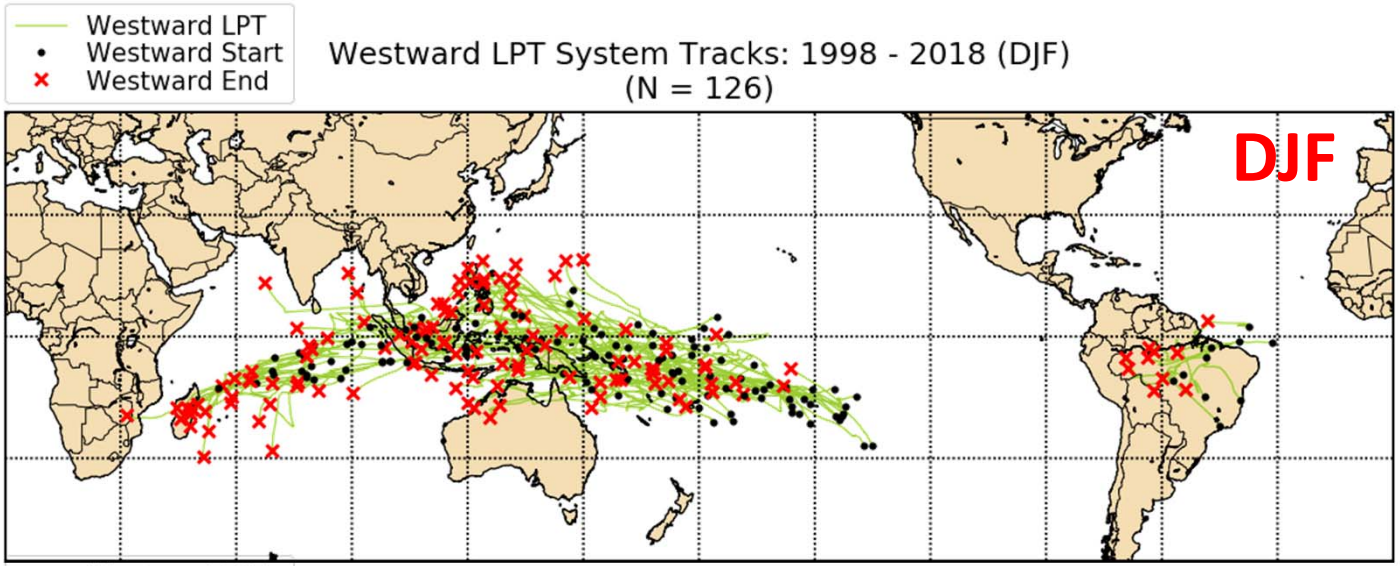


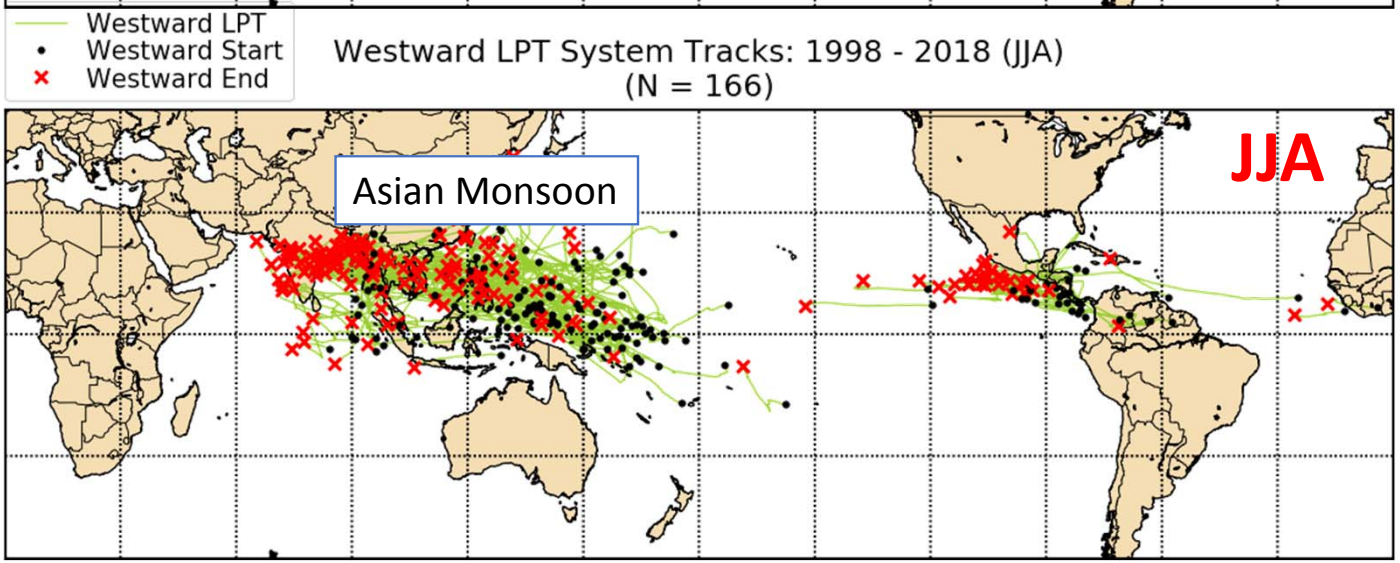

MJO Days [June 1998 - June 2018]
30°N
20°N
10°N
0°
10°S
20°S
30°S
800
700
600
500
400
300
200
100
Days in MJO
Days in MJO [Boreal Summer, June 1998 - June 2018]
Boreal Summer
Apr - Sep
40°E
60°E
80°E
100°E
120°E
140°E
160°E
180°
160°W
140°W
500
400
300
200
100
Days in MJO
Days in MJO [Boreal Winter, June 1998 - June 2018]
Boreal Winter
Oct - Mar

20 Year Climatology of Westward LPTs

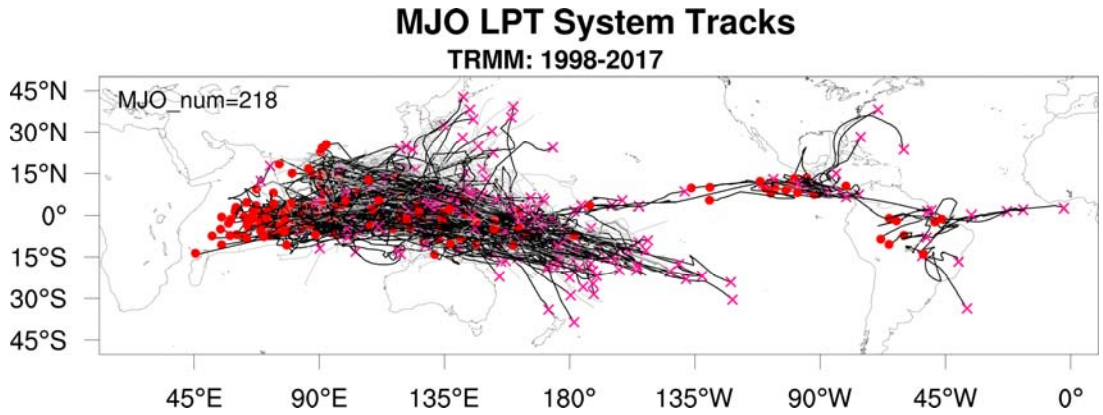


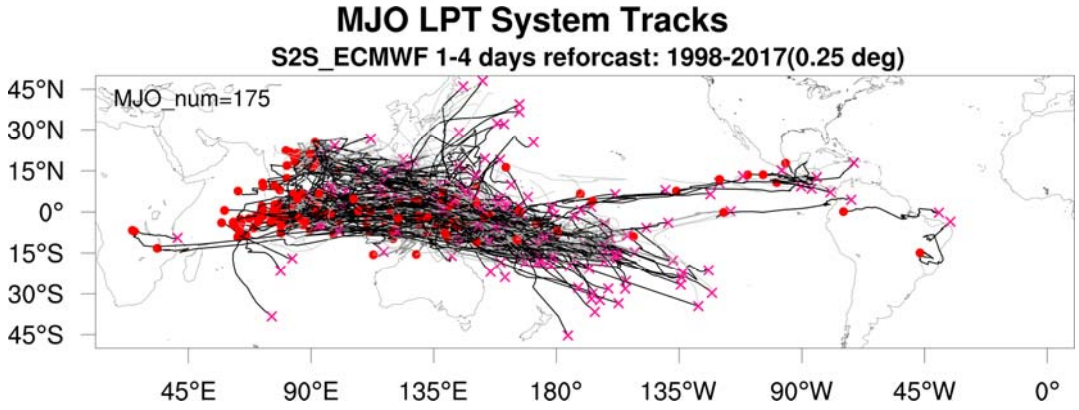
Seasonality of Westward LPTs

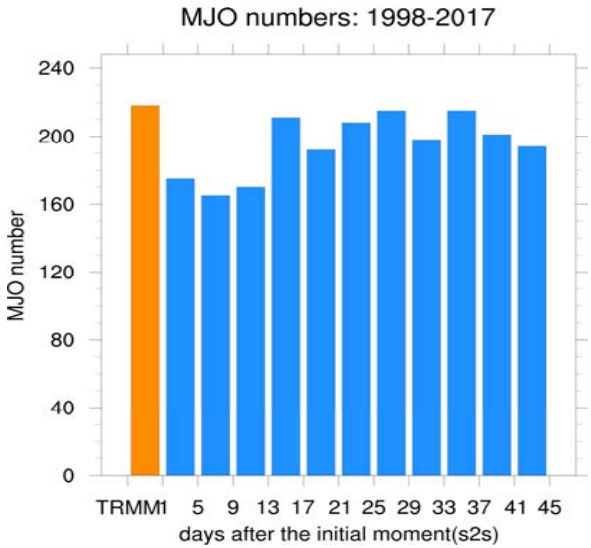




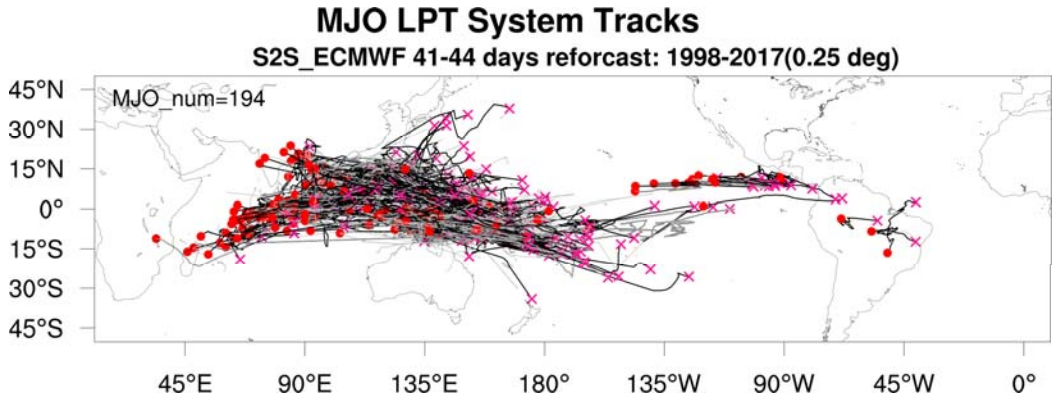
Evaluation of ECMWF 20 years S2S reforecasts



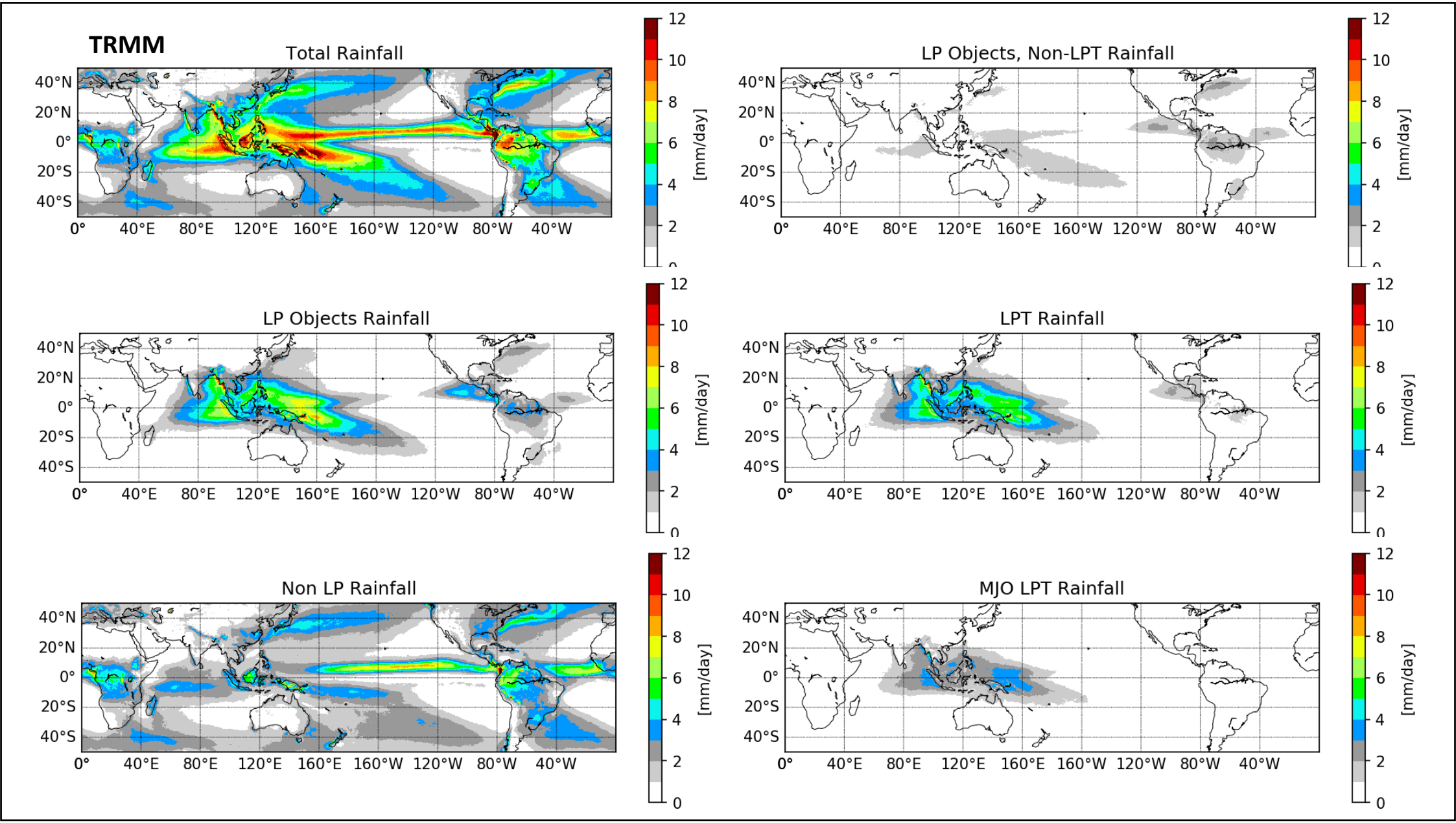


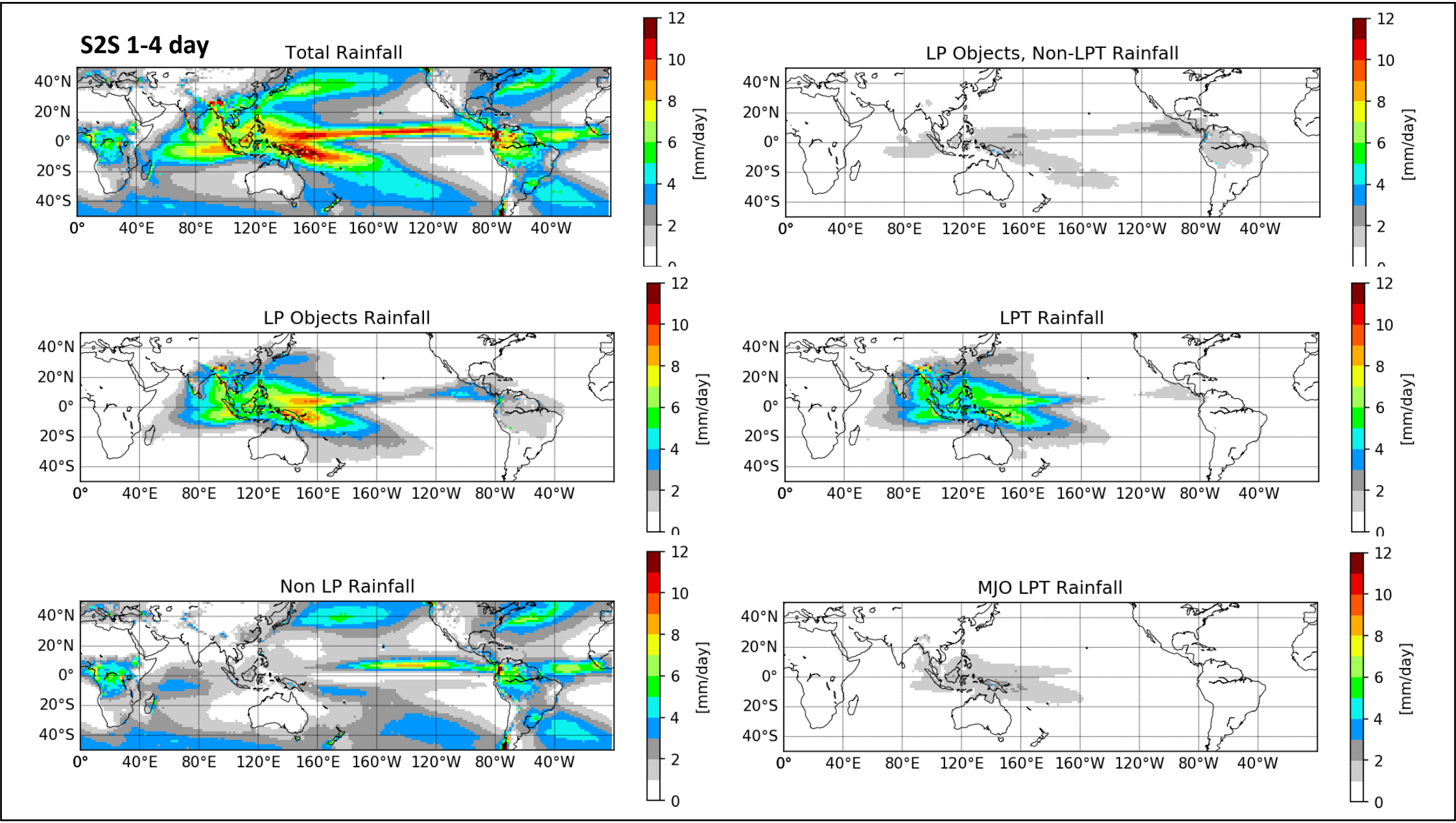


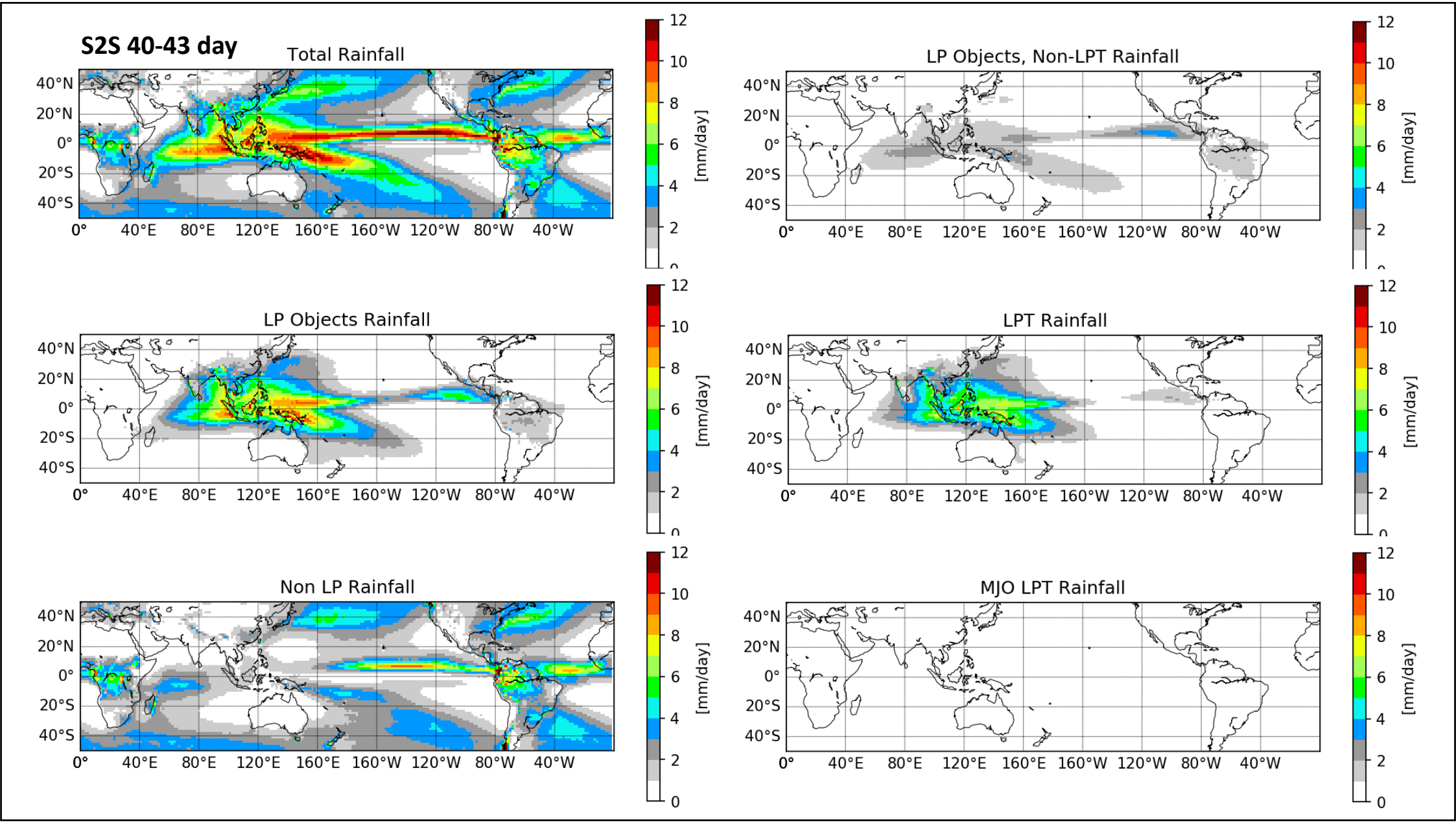
Forecast lead time

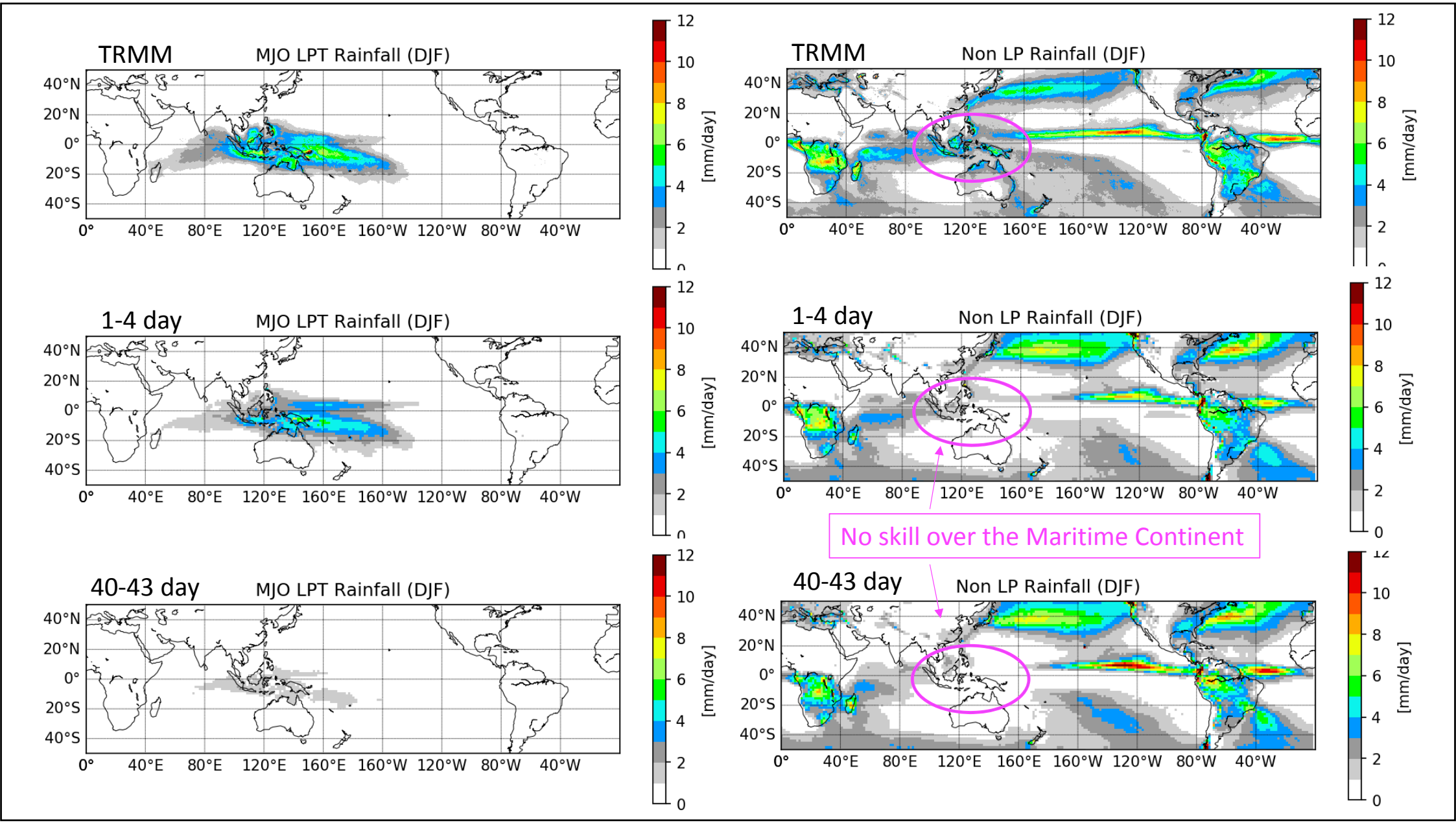


- Very good overall MJO numbers
- Poor MJO convective initiation timing over Indian Ocean
- Little skill in convection over the Maritime Continent
- Double ITCZ problem

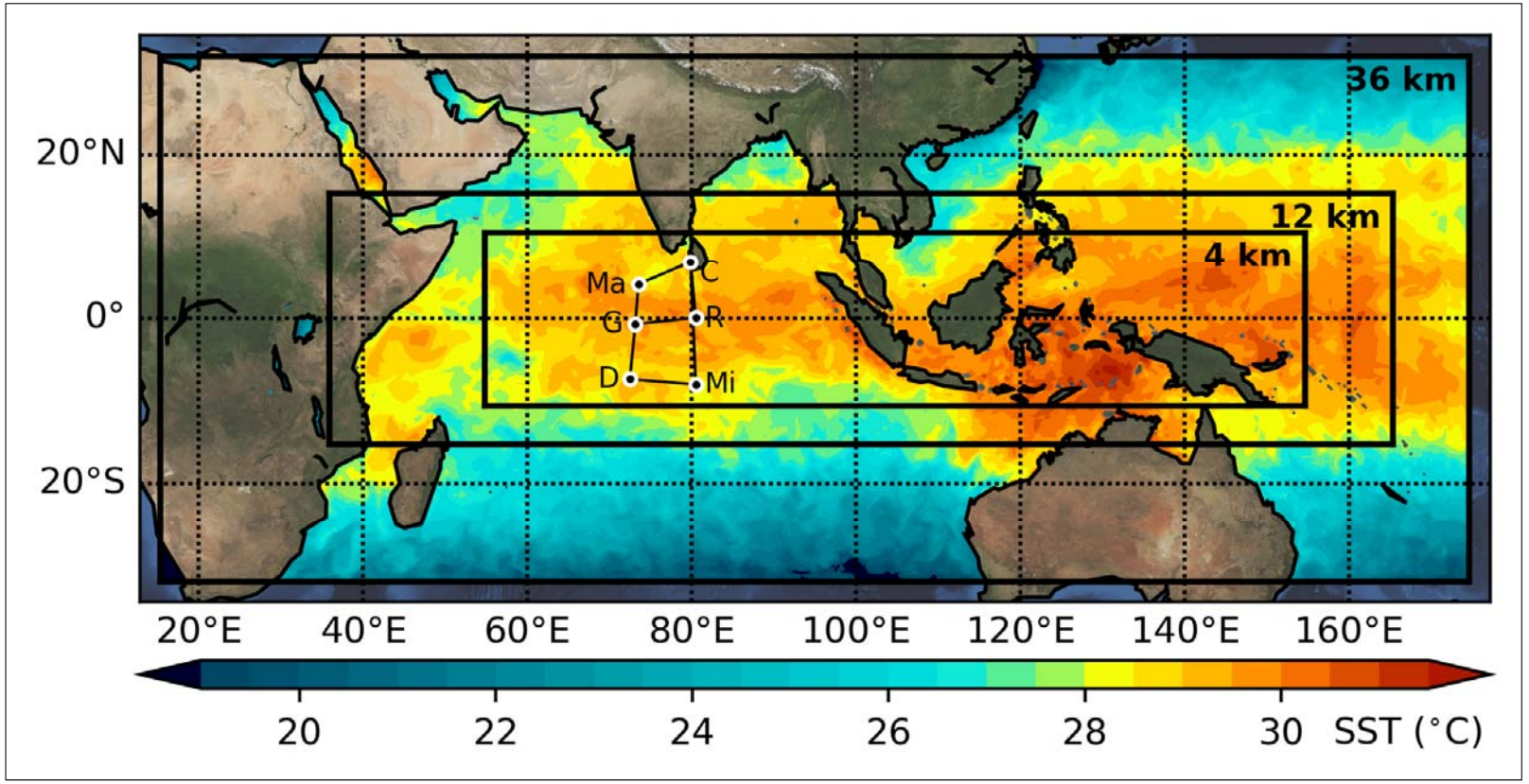

TRMM
Total Rainfall
LP Objects, Non-LPT Rainfall
LP Objects Rainfall
LPT Rainfall
Non LP Rainfall
MJO LPT Rainfall
40°N
20°N
0°
20°S
40°S
0°
40°E
80°E
120°E
160°E
160°W
120°W
80°W
40°W
12
10
8
6
4
2
0
[mm/day]


S2S 1-4 day
Total Rainfall
LP Objects, Non-LPT Rainfall
LP Objects Rainfall
LPT Rainfall
Non LP Rainfall
MJO LPT Rainfall
40°N
20°N
0°
20°S
40°S
0°
40°E
80°E
120°E
160°E
160°W
120°W
80°W
40°W
12
10
8
6
4
2
0
[mm/day]


S2S 40-43 day
Total Rainfall
LP Objects, Non-LPT Rainfall
LP Objects Rainfall
LPT Rainfall
Non LP Rainfall
MJO LPT Rainfall
40°N
20°N
0°
20°S
40°S
0°
40°E
80°E
120°E
160°E
160°W
120°W
80°W
40°W
12
10
8
6
4
2
0
[mm/day]


TRMM
MJO LPT Rainfall (DJF)
TRMM
Non LP Rainfall (DJF)
1-4 day
MJO LPT Rainfall (DJF)
1-4 day
Non LP Rainfall (DJF)
40-43 day
MJO LPT Rainfall (DJF)
40-43 day
Non LP Rainfall (DJF)
No skill over the Maritime Continent
40°N
20°N
0°
20°S
40°S
0°
40°E
80°E
120°E
160°E
160°W
120°W
80°W
40°W
0
2
4
6
8
10
12
[mm/day]

High-resolution Coupled Atmosphere-Ocean Modeling



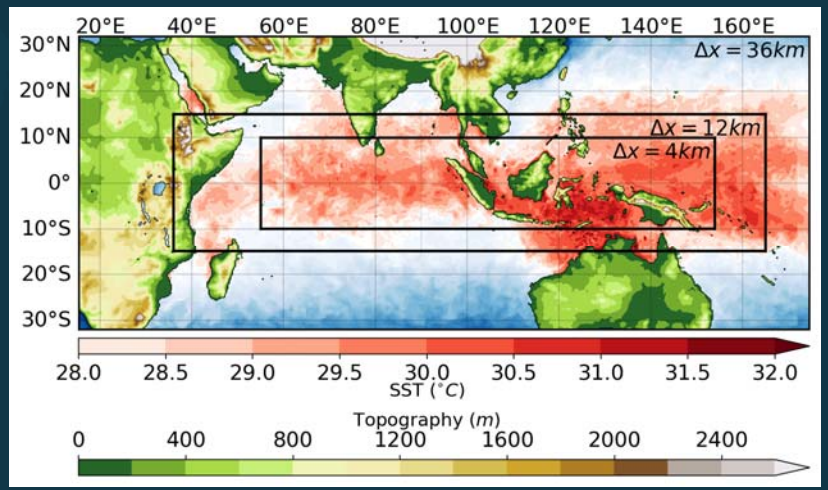
1) Sensitivity to model resolution (parameterized v. explicitly resolved convection).

2) Effect of air-sea coupling on MJO prediction.

Method – Coupled Modeling Framework

The Unified Wave Interface – a Coupled Model (UWIN-CM)

- Weather Research and Forecasting (WRF v3.6.1)
  - 36-, 12-, 4-km nested domains, 36 vertical levels
  - Initial, lateral BCs: ECMWF analysis
  - Key parameterizations: YSU PBL, WSM5 microphysics, Tiedtke cumulus parameterization
- HYbrid Coordinate Ocean Model (HYCOM v2.2.98)
  - 0.08° resolution, 32 vertical levels
  - Initial, lateral BCs: HYCOM analysis



- Initialization: 22 Nov. 2011 00 UTC
- Integration time: 15 days
- Coupling frequency: 3 minutes
- Experiments:
  - CTRL

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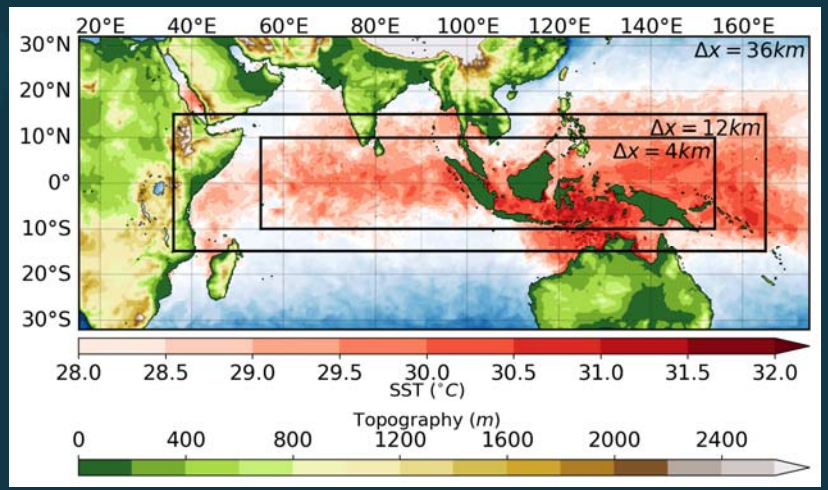

- Initialization: 22 Nov. 2011 00 UTC
- Integration time: 15 days
- Coupling frequency: 3 minutes
- Experiments:
  - **CTRL,**
  - **FLAT:** MC terrain leveled to 10 m, land use 100% evergreen rainforest

Method – Coupled Modeling Framework

The Unified Wave Interface – a Coupled Model (UWIN-CM)

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  - 36-, 12-, 4-km nested domains, 36 vertical levels
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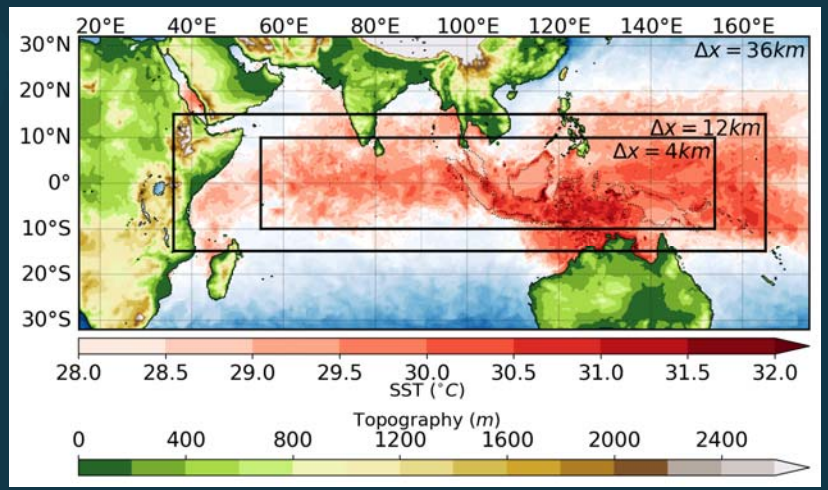
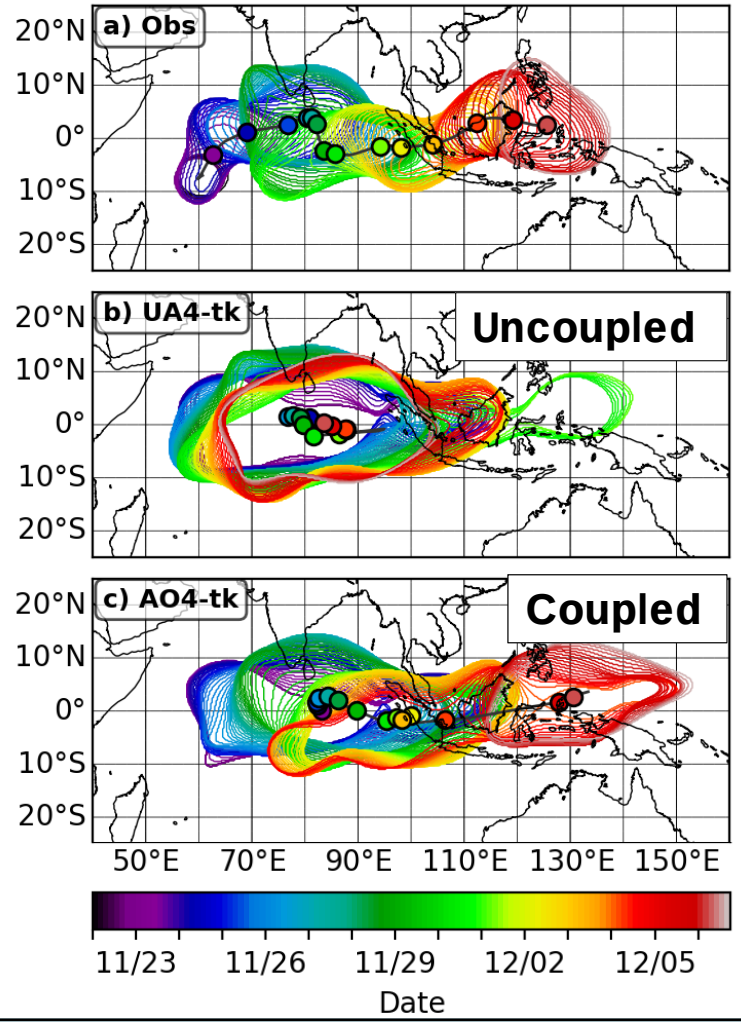


- Initialization: 22 Nov. 2011 00 UTC
- Integration time: 15 days
- Coupling frequency: 3 minutes
- Experiments:
  - **CTRL, FLAT,**
  - **WATER:** MC land replaced with water, surface temperature evolves with surrounding seas

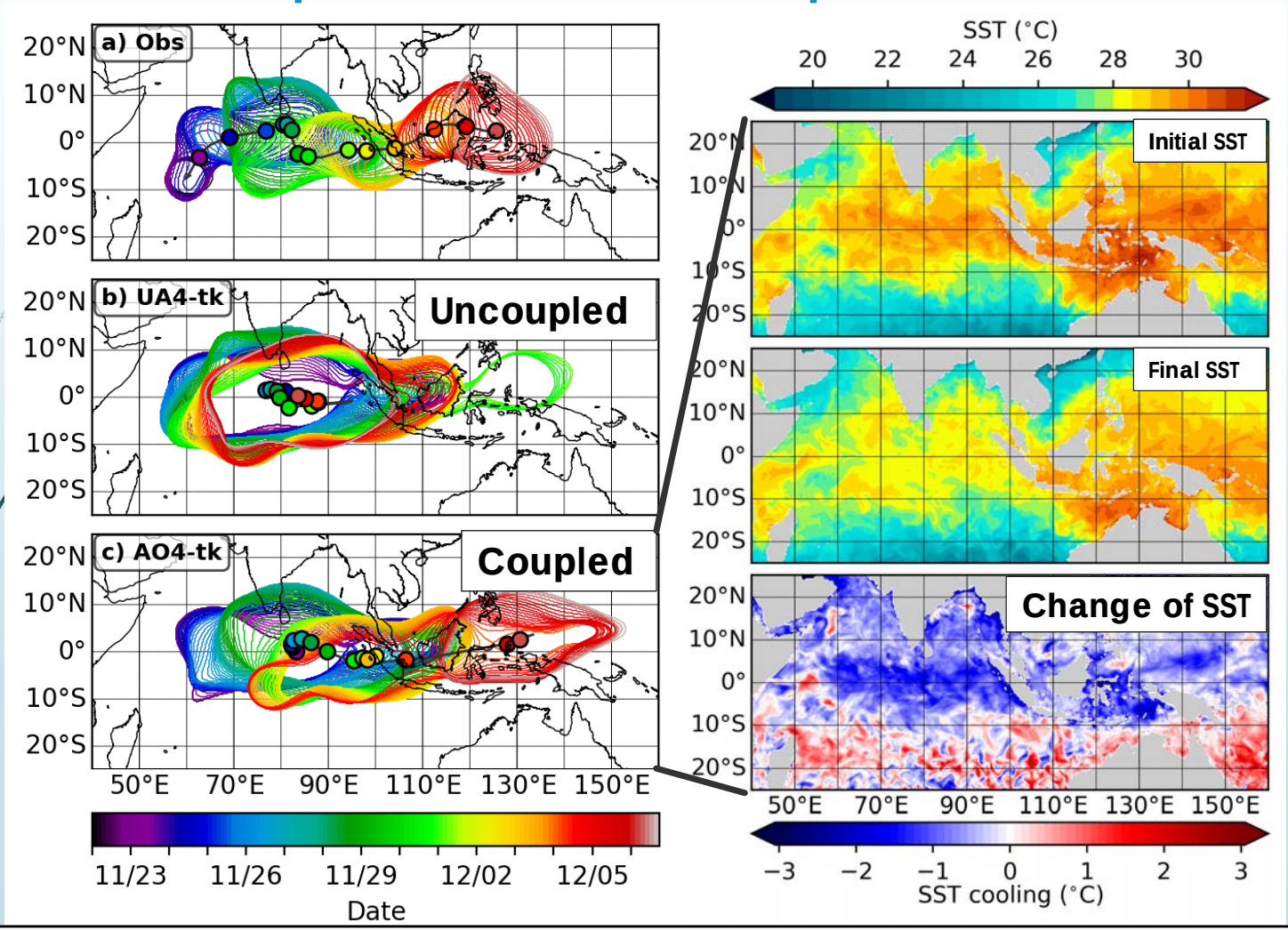
Impact of atmosphere-ocean coupling



(Savarin and Chen 2019b)

- Uncoupled model produces stationary “MJO”. Coupled model produces clear eastward propagation, as observed.

Impact of atmosphere-ocean coupling

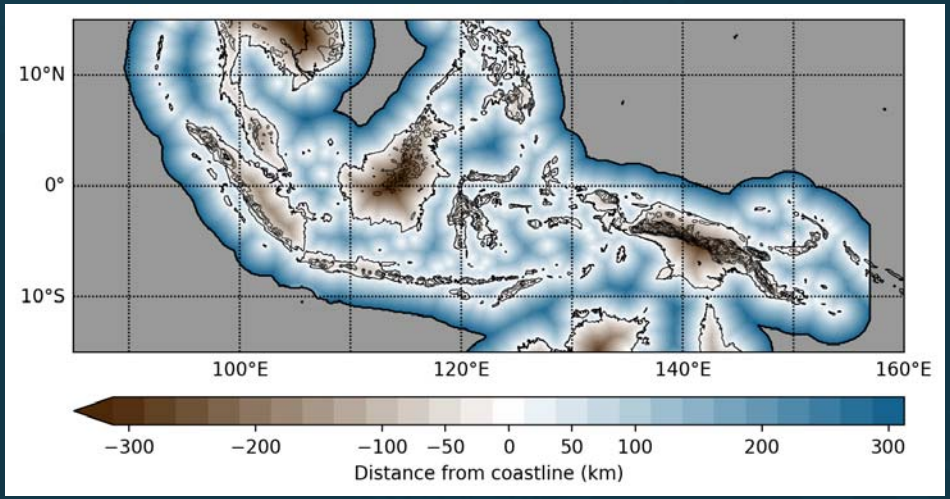


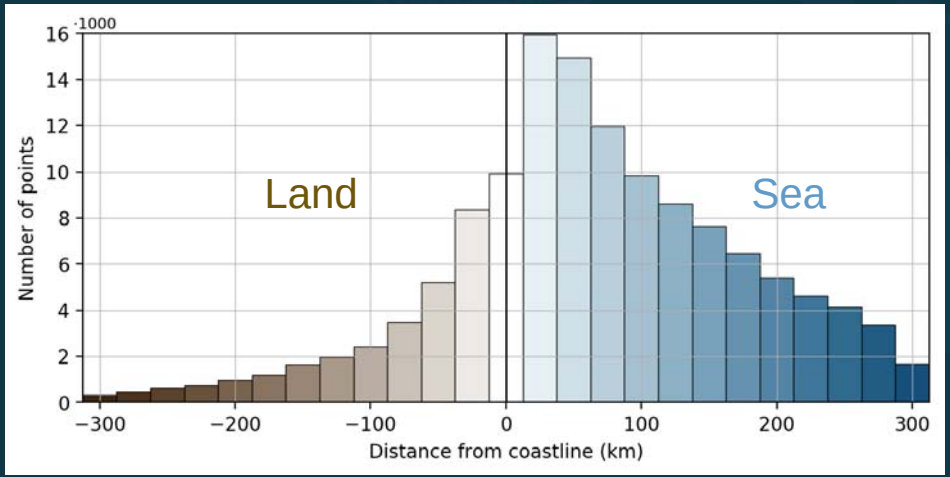
- Uncoupled model produces stationary “MJO”. Coupled model produces clear eastward propagation, as observed.
- Reason for this difference is the SST cooling induced by the MJO.

Method – Diurnal Cycle Classification

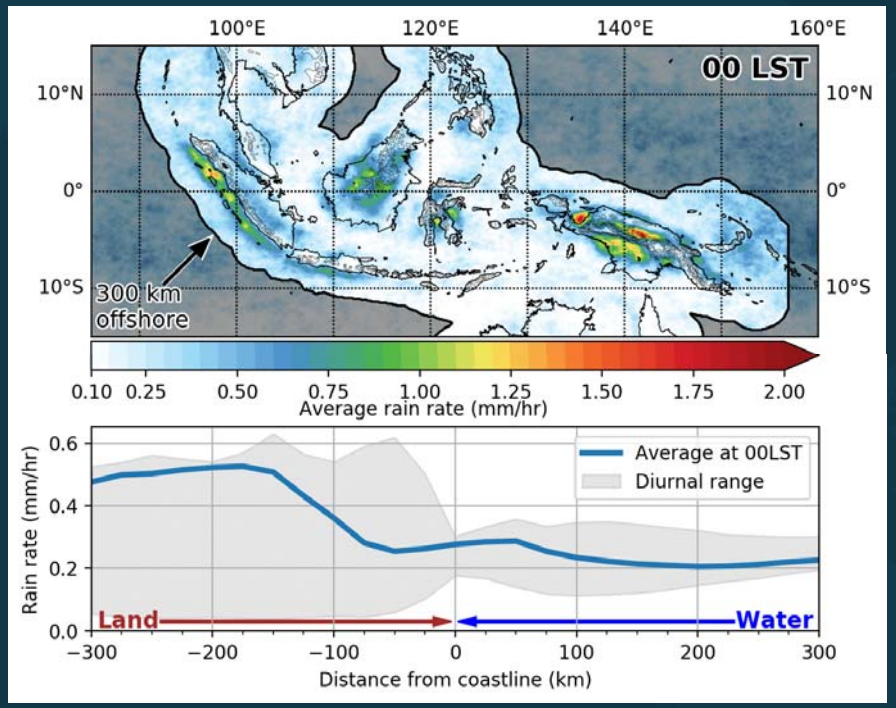
Compositing across Distance from Coastline

- Calculate distance of every point from its nearest coastal point
  - Positive values over water, negative values over land
- Composite precipitation across the distance from coastline in 25-km bins
  - Results shown within 312.5 km from the coast
  - One bin straddling the coastline to account for cross-sampling
  - 0.1° resolution



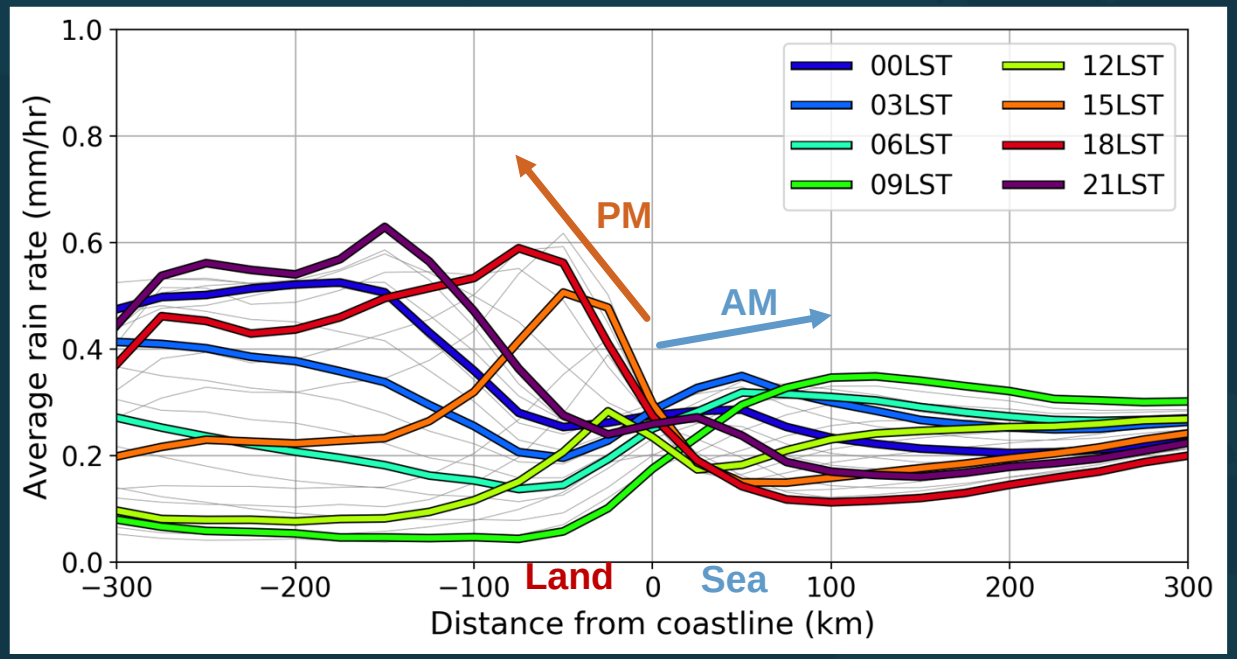


Results – Diurnal Cycle of Convection



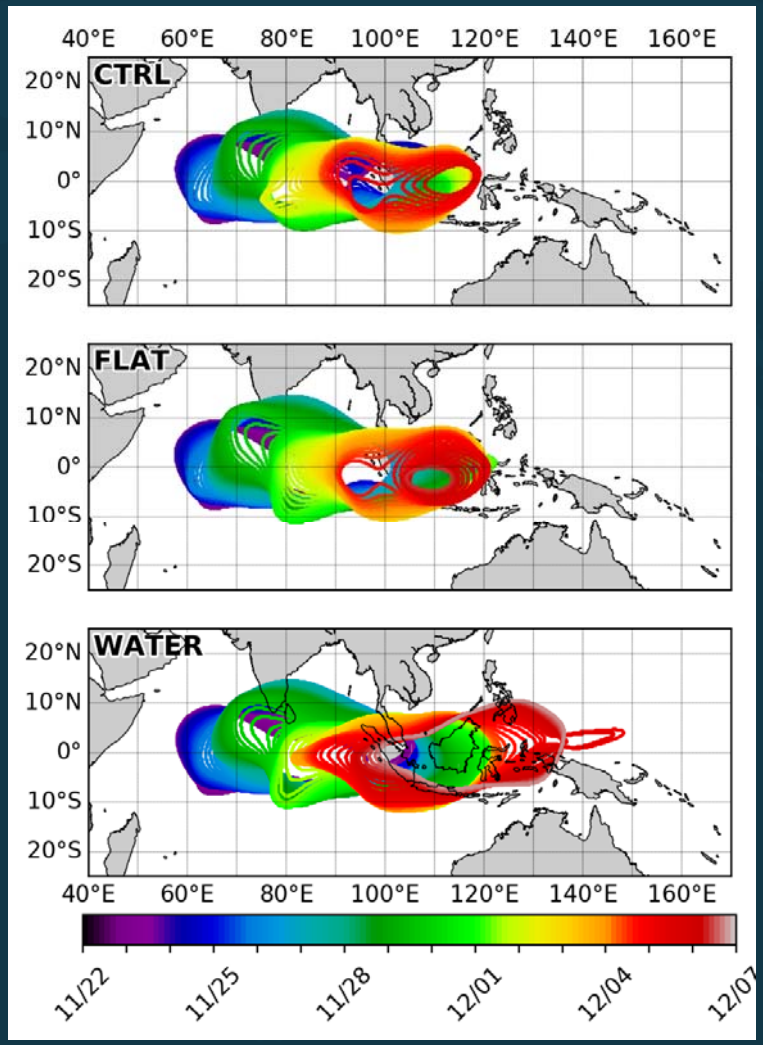
- DC of precipitation in GPM-IMERG, June 2014 – May 2017, 0.1° resolution.
  - Morning precipitation maxima over water, suppressed over land
  - Afternoon/evening precipitation maxima over land, suppressed over water

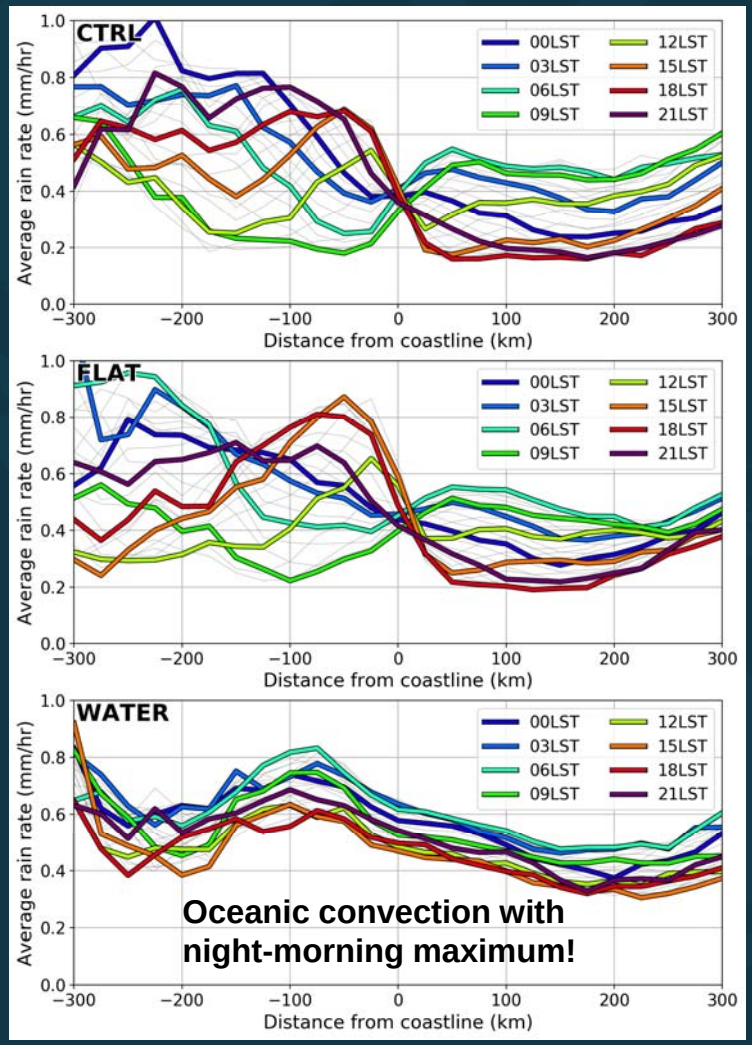
Results – Diurnal Cycle of Convection



- DC of precipitation in GPM-IMERG, June 2014 – May 2017, 0.1° resolution.
  - Morning precipitation maxima over water, suppressed over land
  - Afternoon/evening precipitation maxima over land, suppressed over water

MJO propagation with real, flat-land, and all-water MC





SUMMARY

- **Large-scale Precipitation Tracking (LPT) provides a robust and direct measure of MJO convection, which capture the spatial structure and its variability**
- **LPT can be used for verification of the MJO prediction in both global and regional models**
- **Predictability of the MJO convective initiation over the Indian Ocean is relatively low as indicated by the ECMWF stochastic ensemble forecasts**
- **S2S ECMWF reforecast has almost no skill in predicting convection over the Maritime Continent regardless leadtime**
- **Higher resolution and atmosphere-ocean coupling improve MJO initiation and its eastward propagation.**