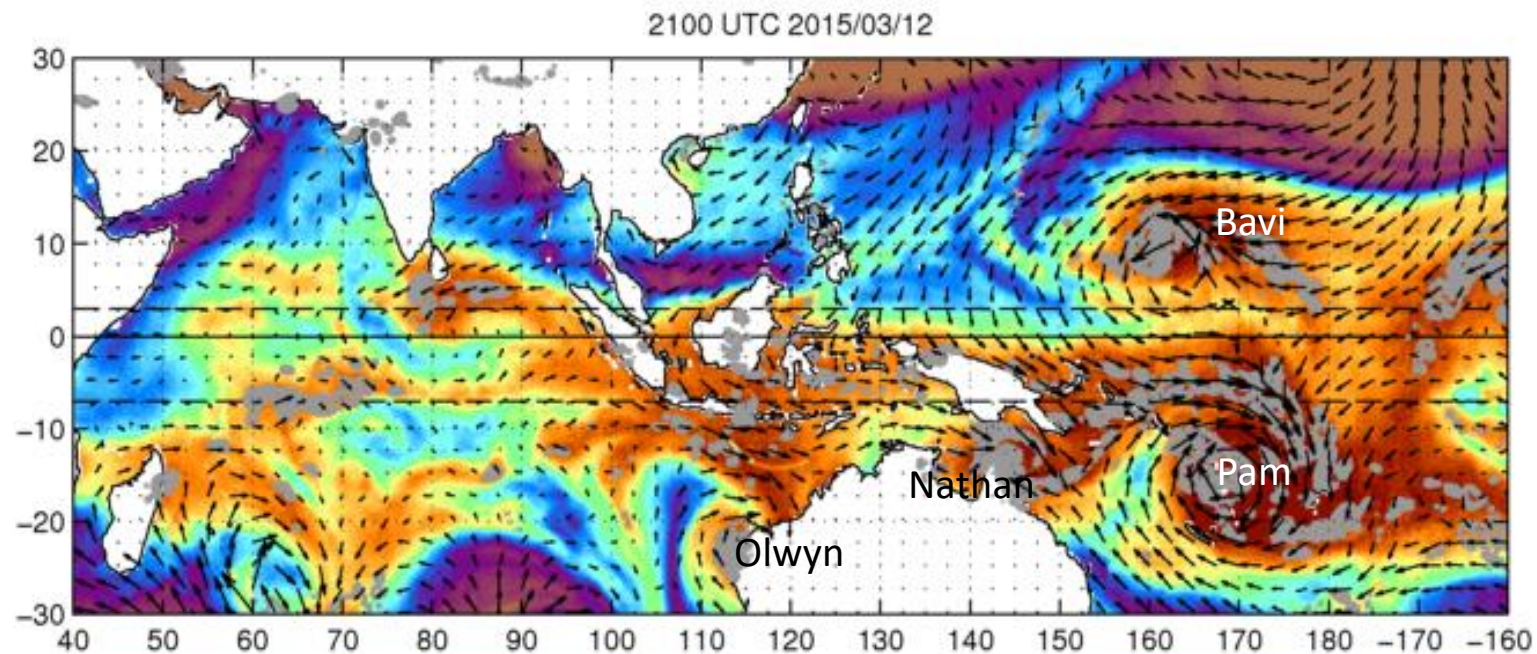# Understanding predictability of the MJO in ECMWF S2S Reforecast

Shuyi S. Chen, Yuanwen Zhang, Brandon Kerns, and Ajda Savarin
University of Washington

<u>Objectives</u>:

- Better understand and predict the Madden-Julian Oscillation (MJO) convective initiation and eastward propagation

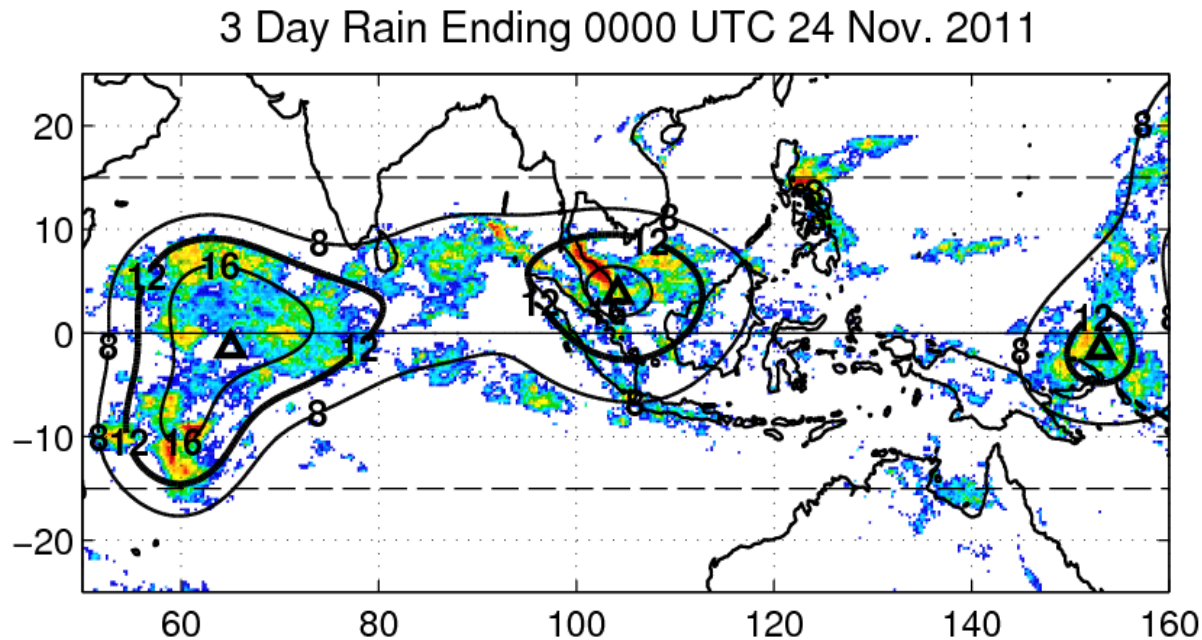- Assessing predictability and predictive skill of the MJO in the ECMWF S2S reforecast ensemble

<u>Data</u>:
- 20 years of the TRMM-GPM Precipitation from 1998-2018 (Kerns and Chen 2016, 2019)
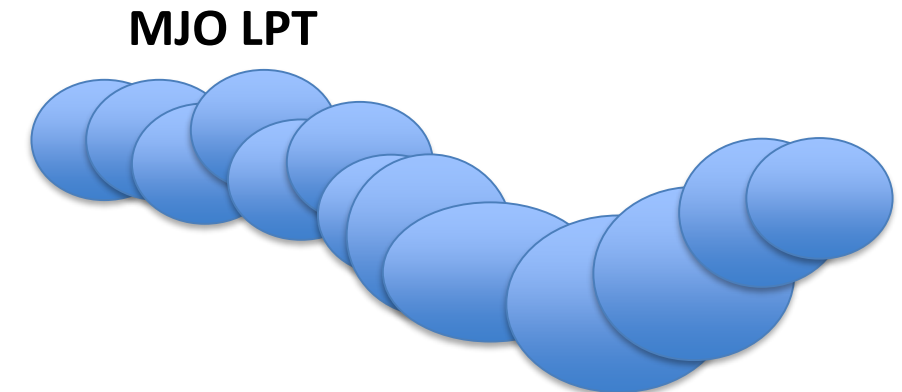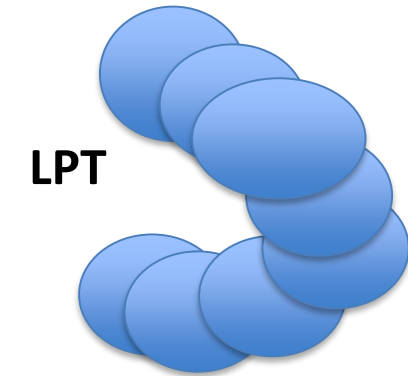- RMM (BoM)

<u>Model</u>:
- ECMWF S2S reforecast ensemble from 1998-2017
- ECMWF IFS ensemble experiments (IC + SPPT + SKEBS, 15-day forecast), four initial times: 18, 20, 22, 24 November 2011 (collaboration with Hannah Christensen)
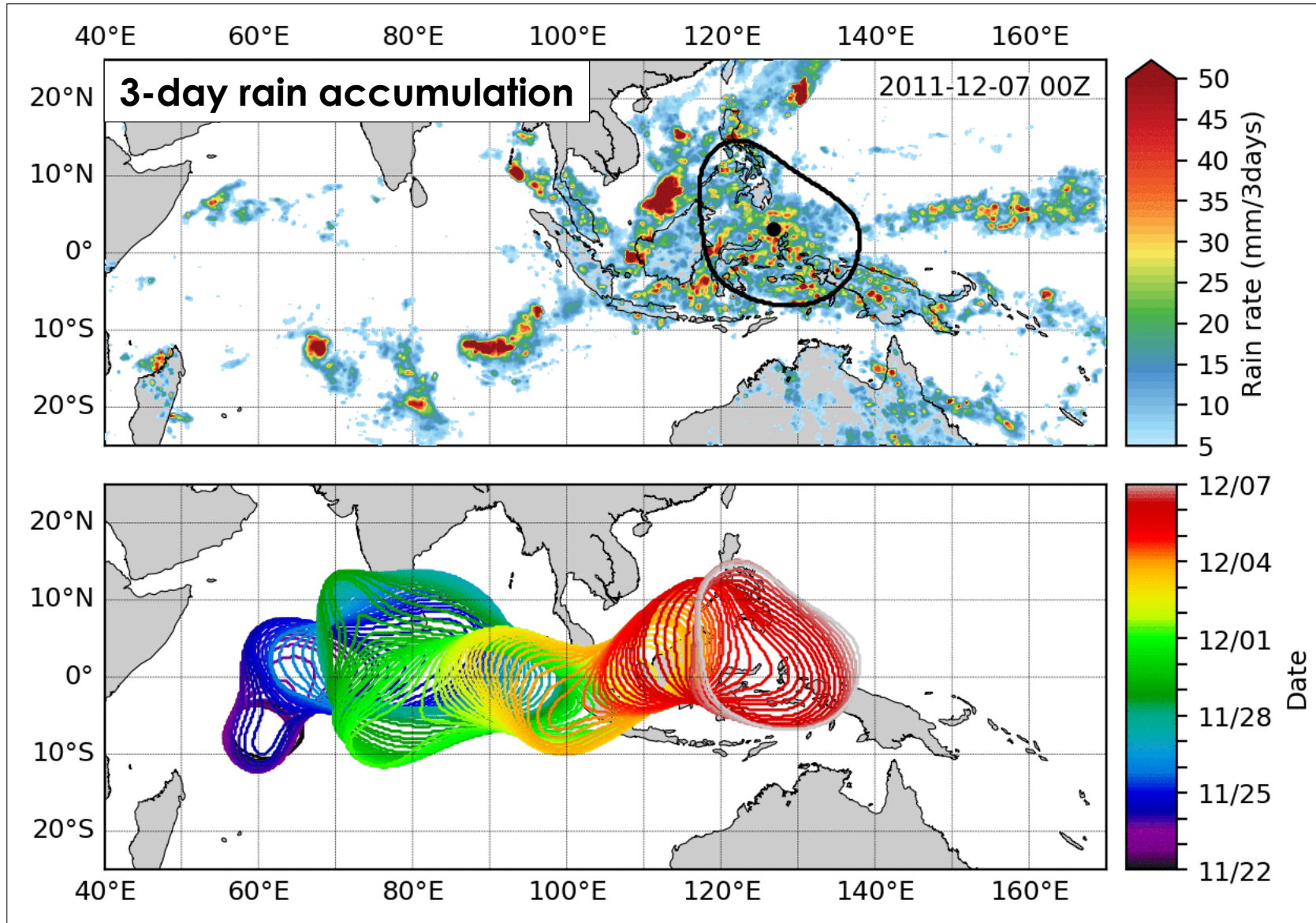
Data and Large-scale Precipitation Tracking (LPT):

- TMPA 3B42 V7 data (0.25^o, 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

3 Day Rain Ending 0000 UTC 24 Nov. 2011

Kerns and Chen (2016, JGR)

LPO

LPT

MJO LPT

Tracking the MJO

3-day rain accumulation

2011-12-07 00Z

- Traditional RMM index cannot provide spatial and temporal variation of the MJO.

- LPT is used to track MJO precipitation. **(Kerns and Chen 2016)**
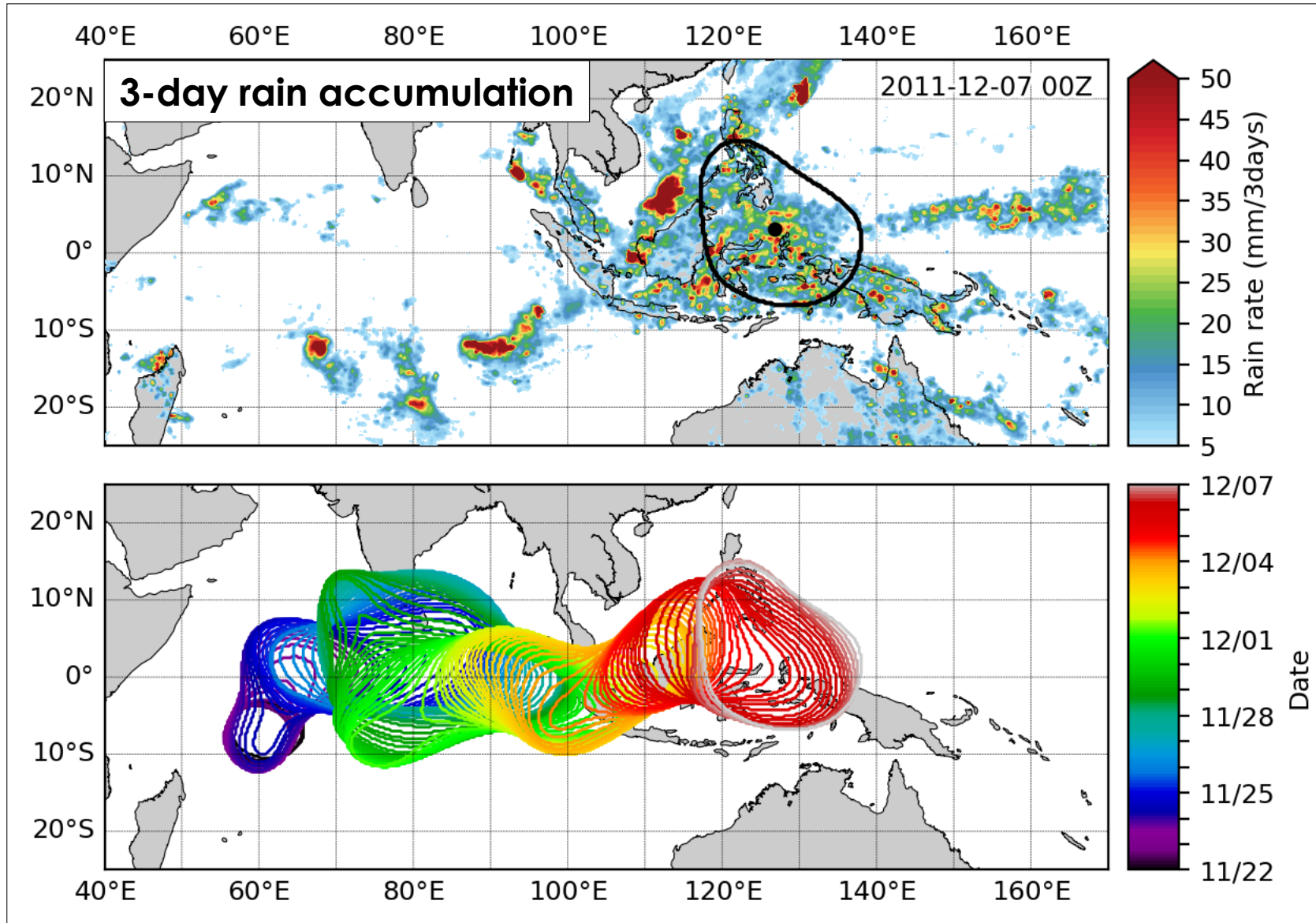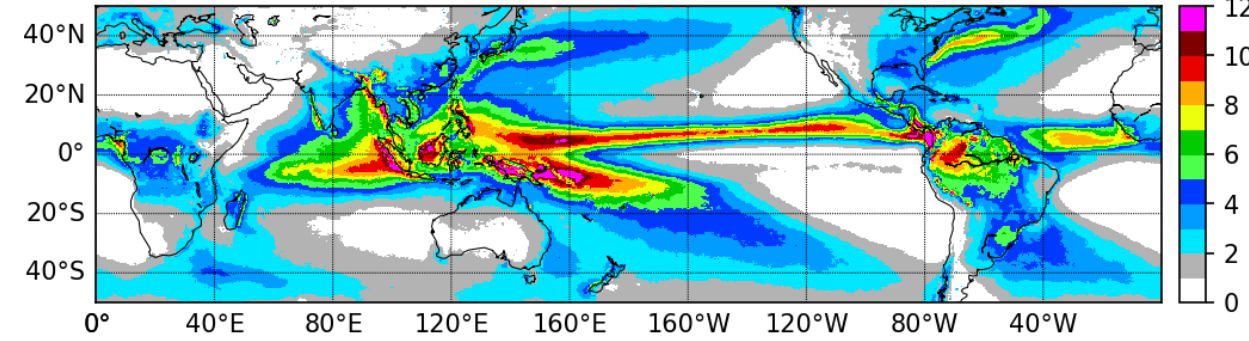
Tracking the MJO

3-day rain accumulation

2011-12-07 00Z

- 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.

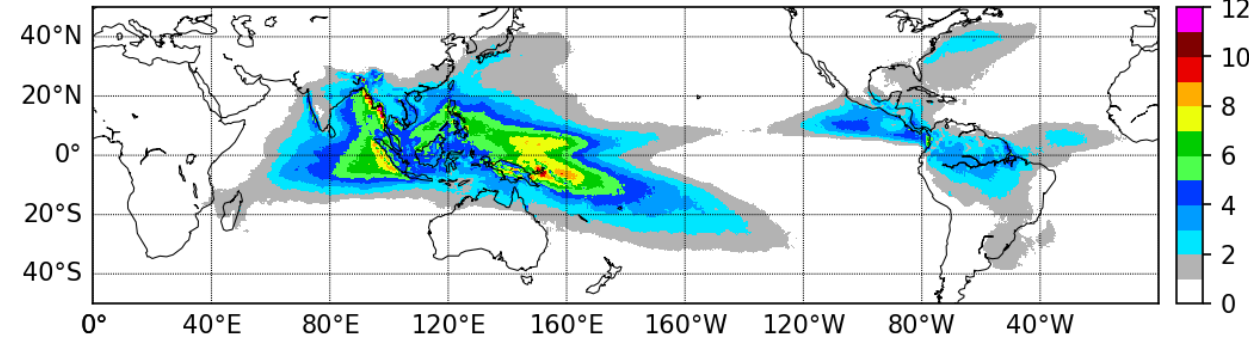# 20 Years Rainfall Climatology (TRMM-GPM 3B42 1998-2018)
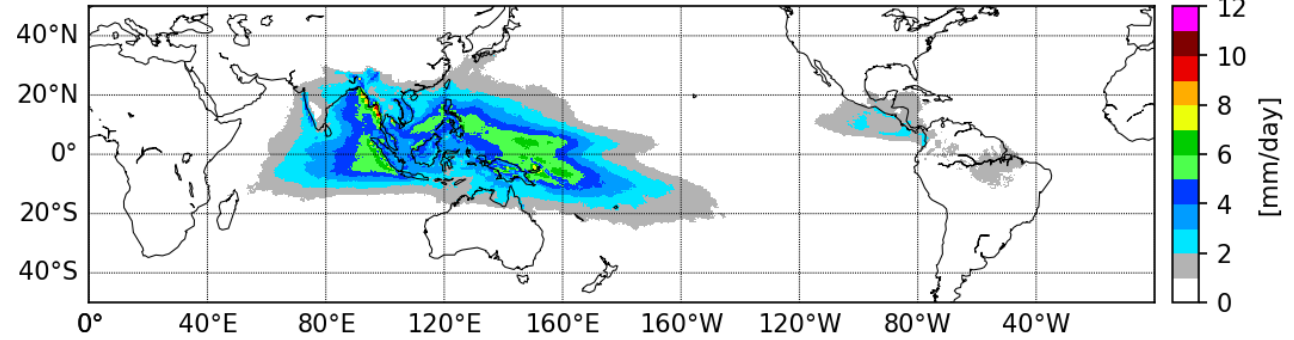
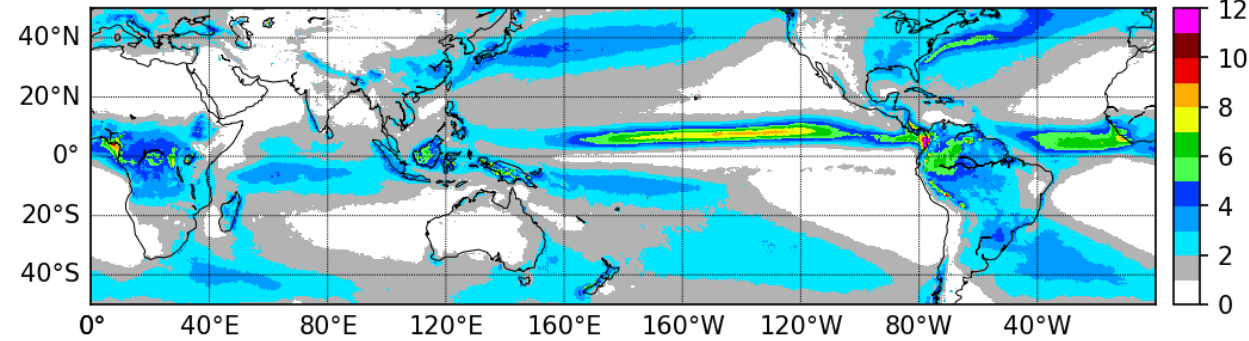Total Rainfall (TRMM)

LP Objects, Non-LPT Rainfall (TRMM)
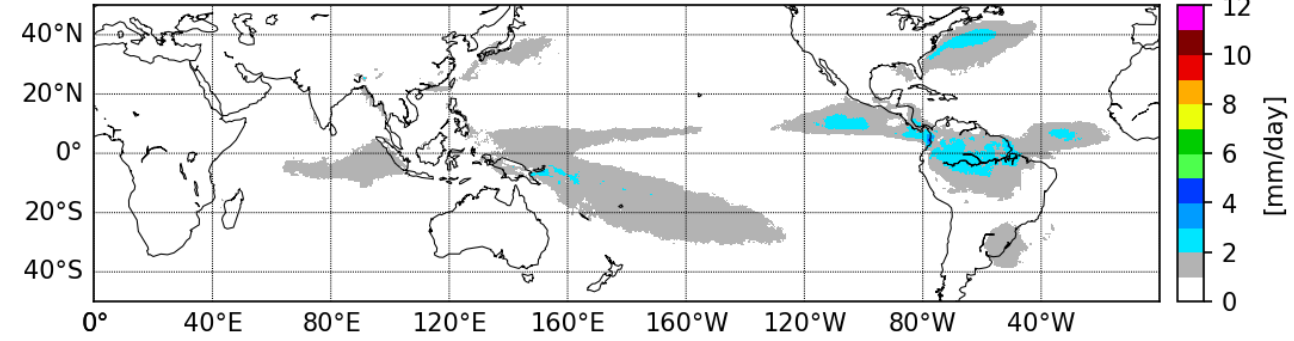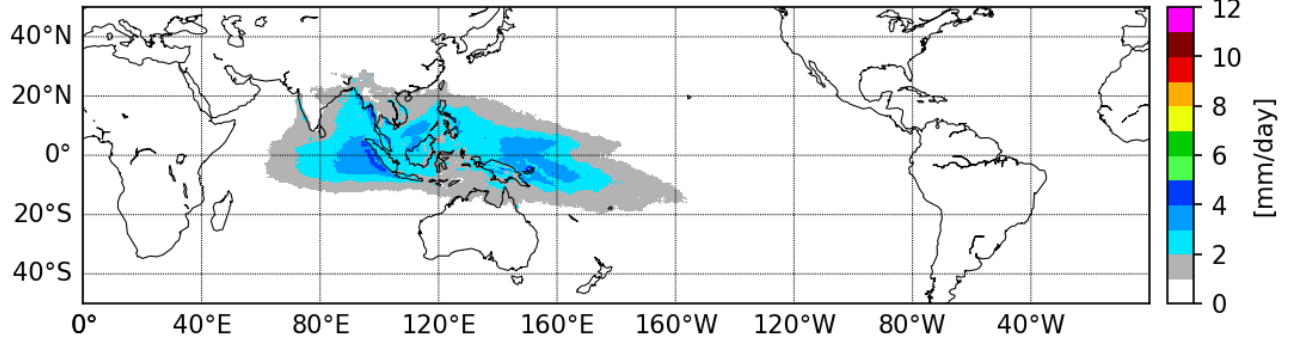
LP Objects Rainfall (TRMM)

LPT Rainfall (TRMM)

Non LP Rainfall (TRMM)

MJO Rainfall (TRMM)

20 Years Rainfall Climatology (S2S ECMWF Forecast Day 1-4)
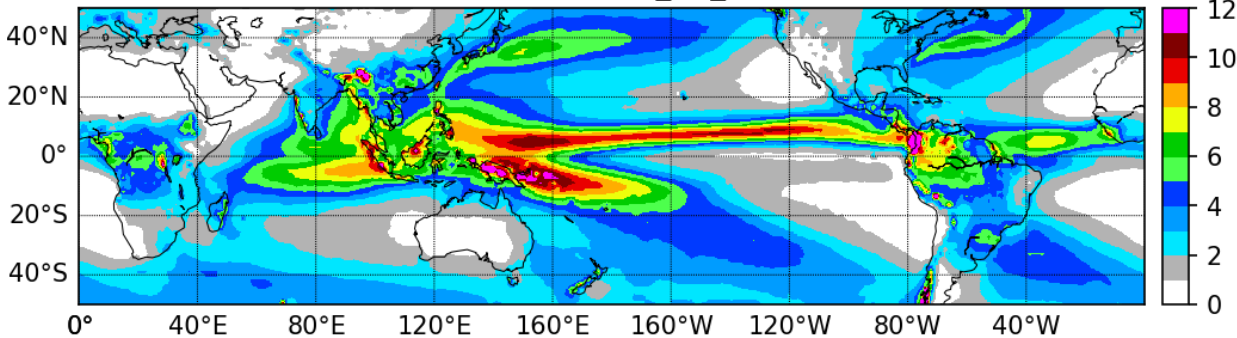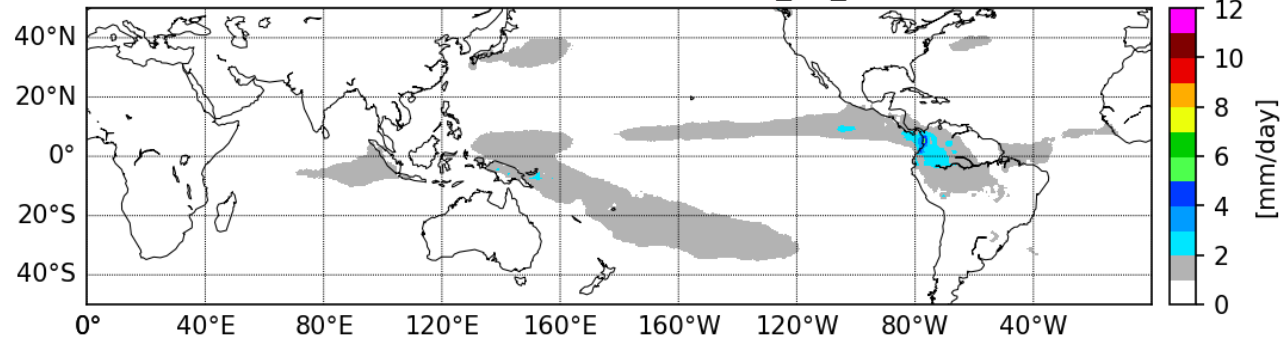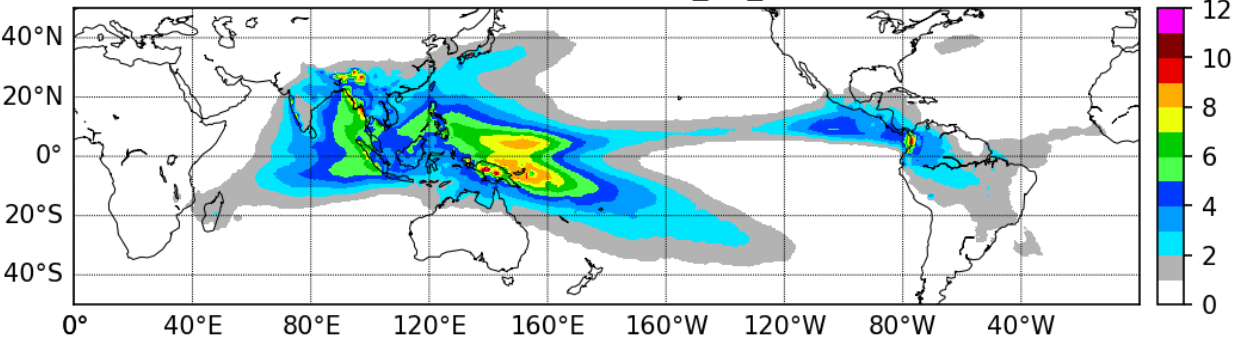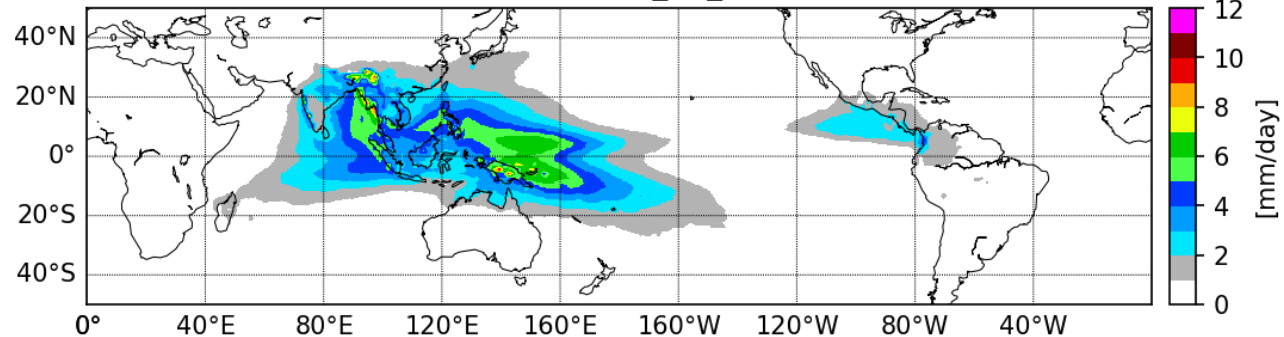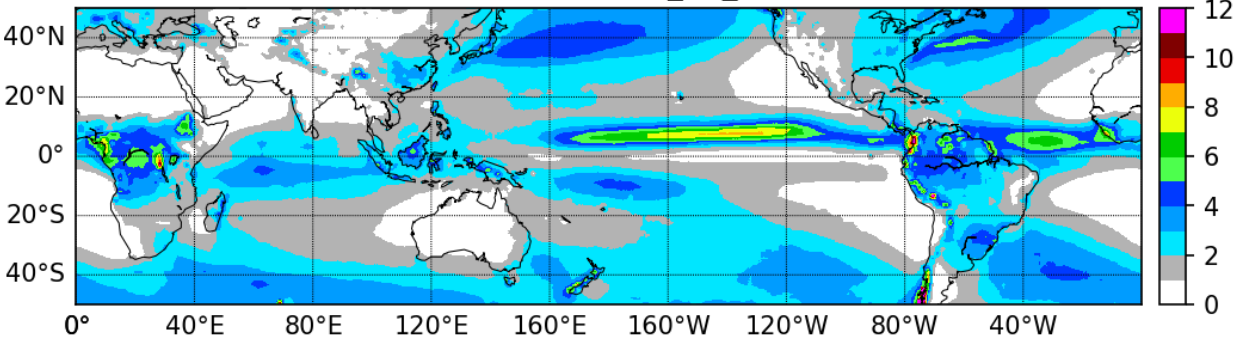
Difference: (S2S ECMWF Forecast Day 1-4) − (TRMM)
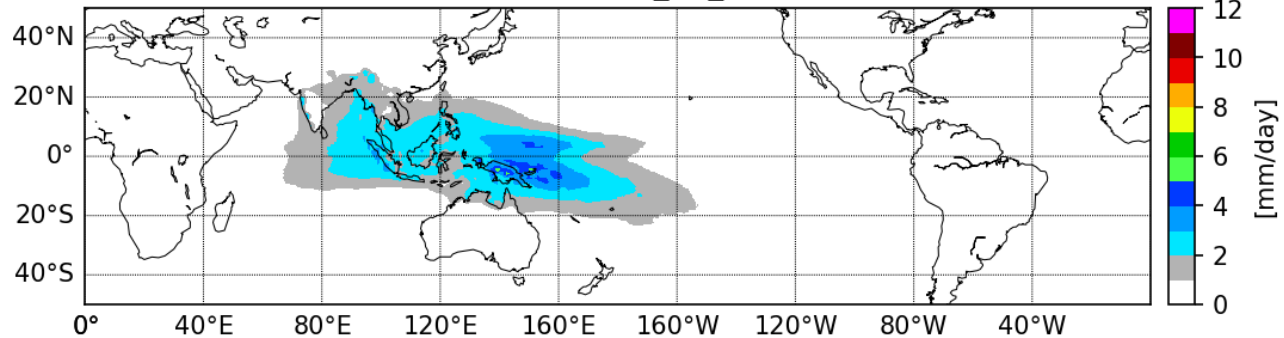
Difference: (S2S ECMWF Forecast Day 41-44) – (TRMM)

Total Rainfall Difference (S2S_EC_41-44day - TRMM)

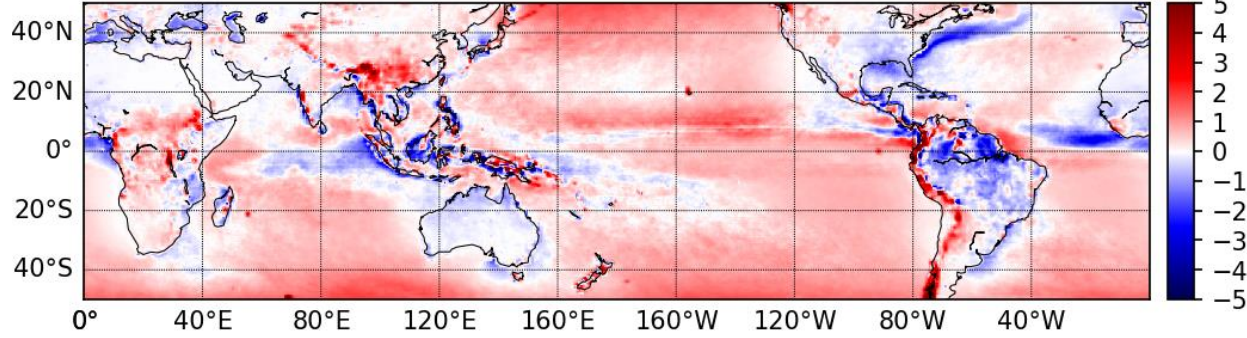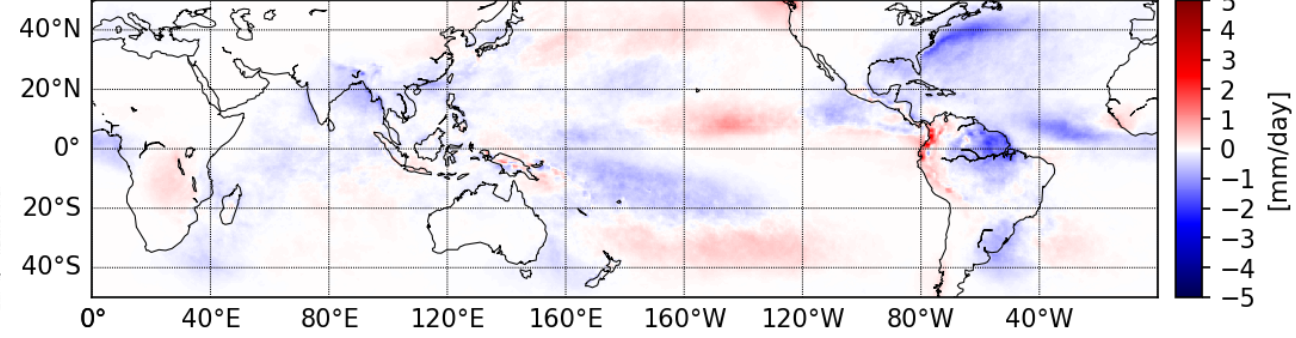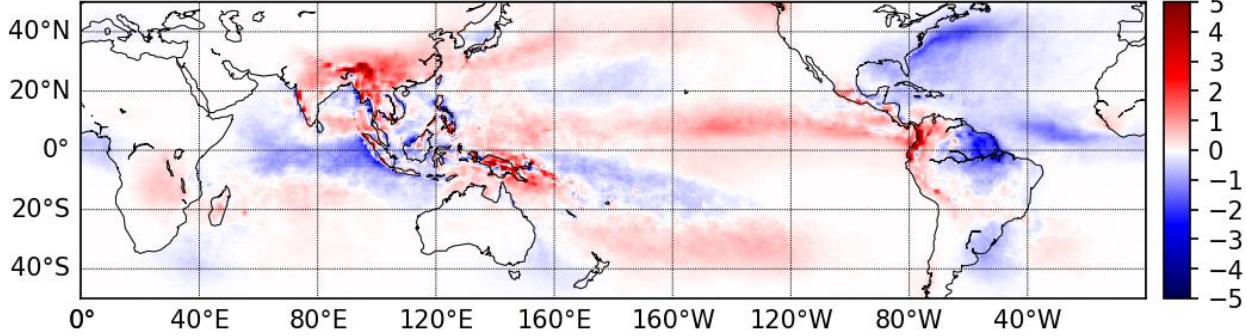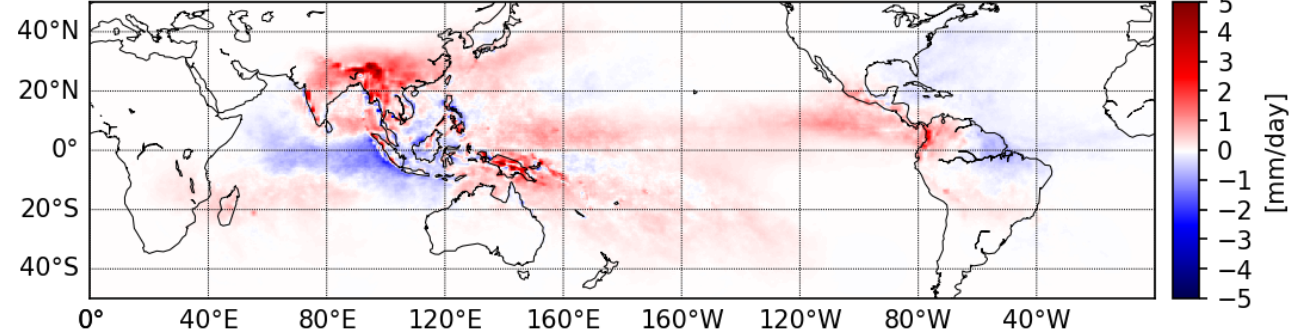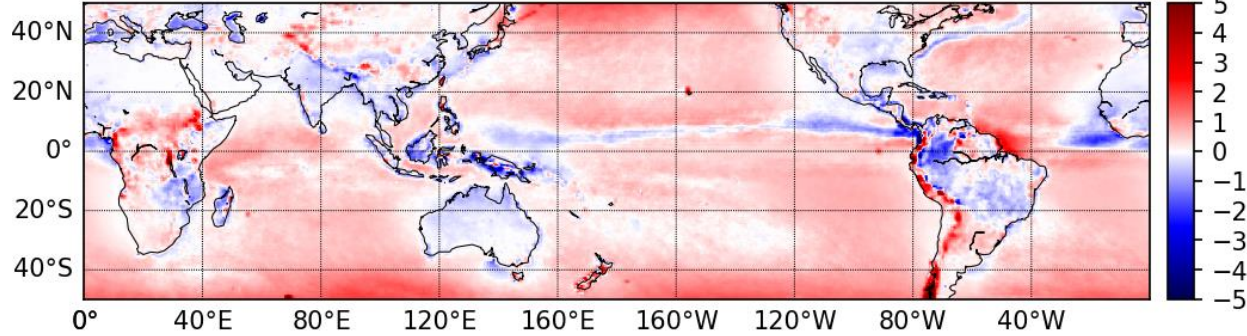LP Objects, Non-LPT Rainfall Difference (S2S_EC_41-44day - TRMM)

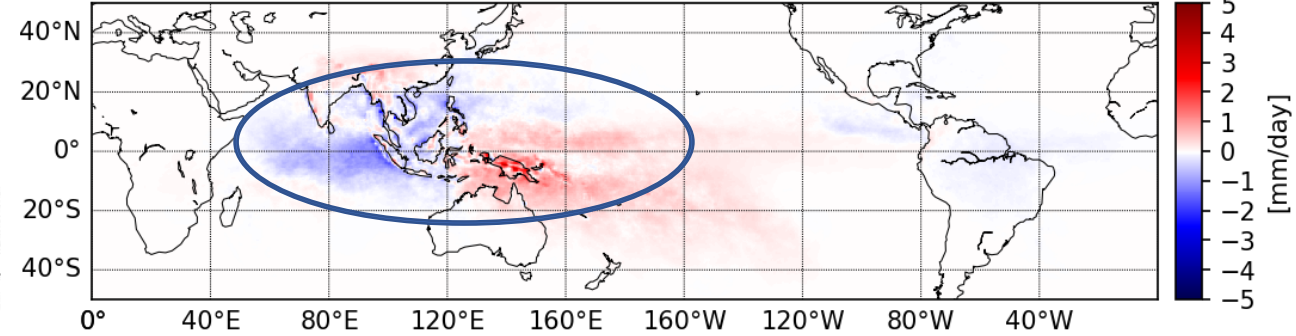LP Objects Rainfall Difference (S2S_EC_41-44day - TRMM)

LPT Rainfall Difference (S2S_EC_41-44day - TRMM)
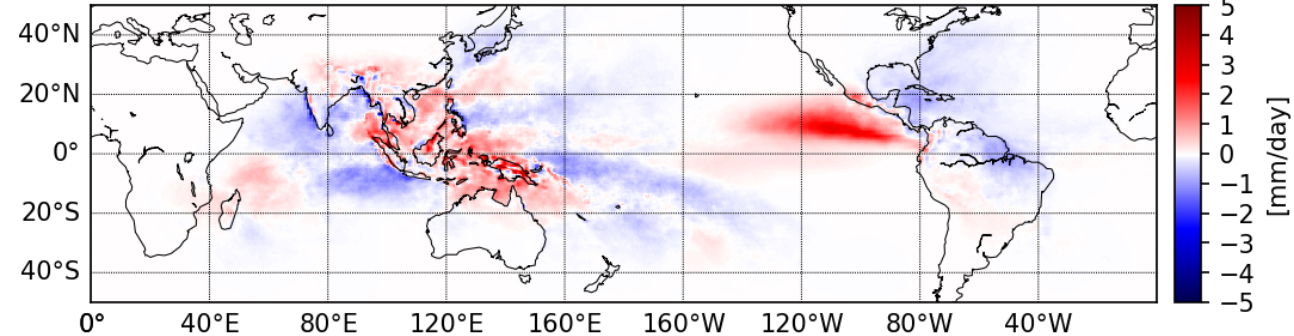
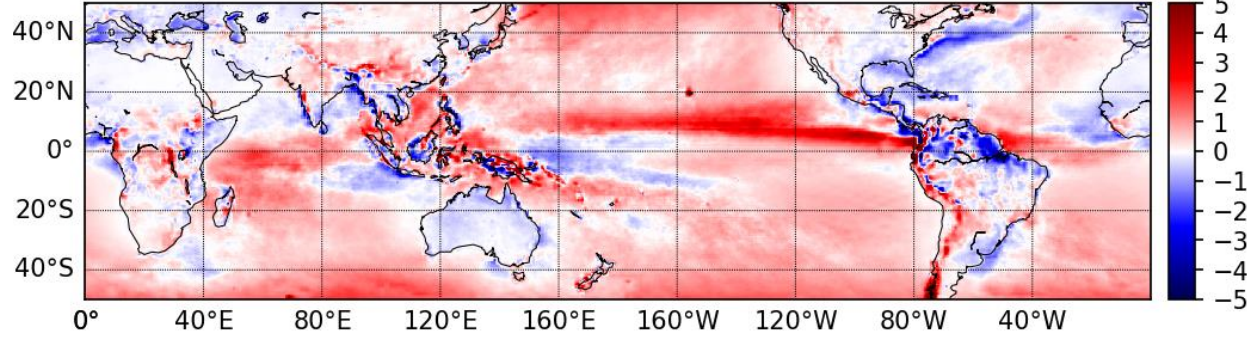Non LP Rainfall Difference (S2S_EC_41-44day - TRMM)

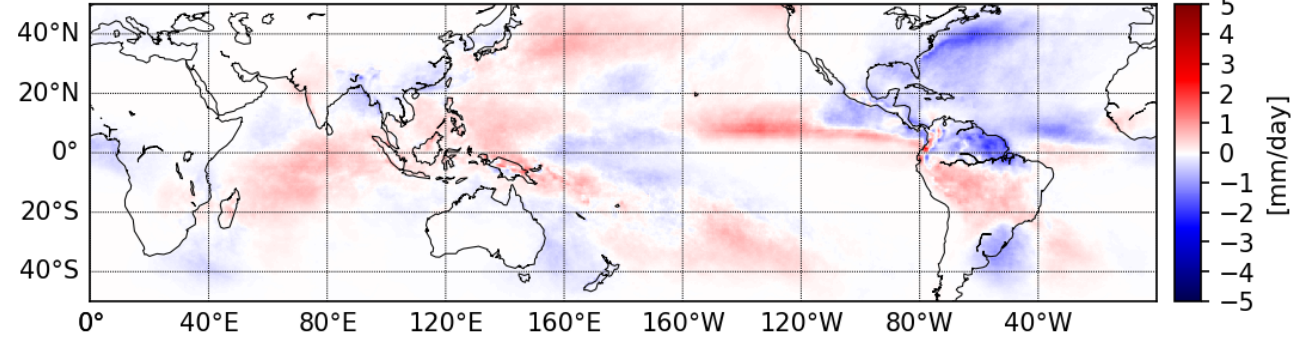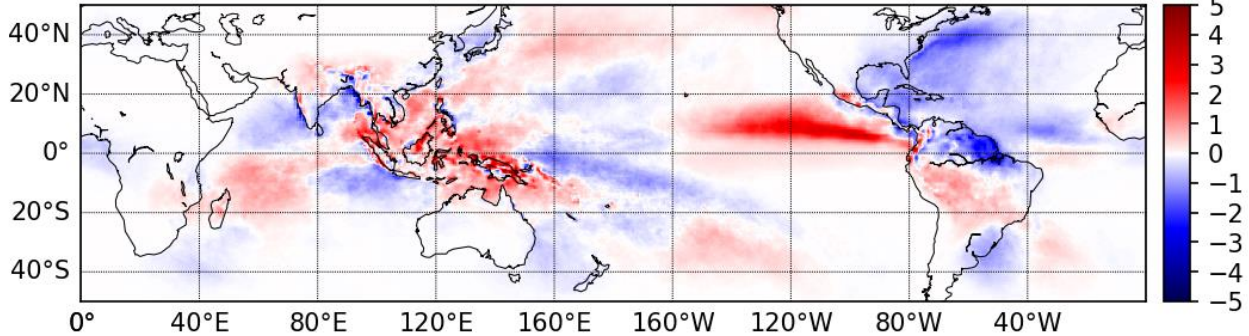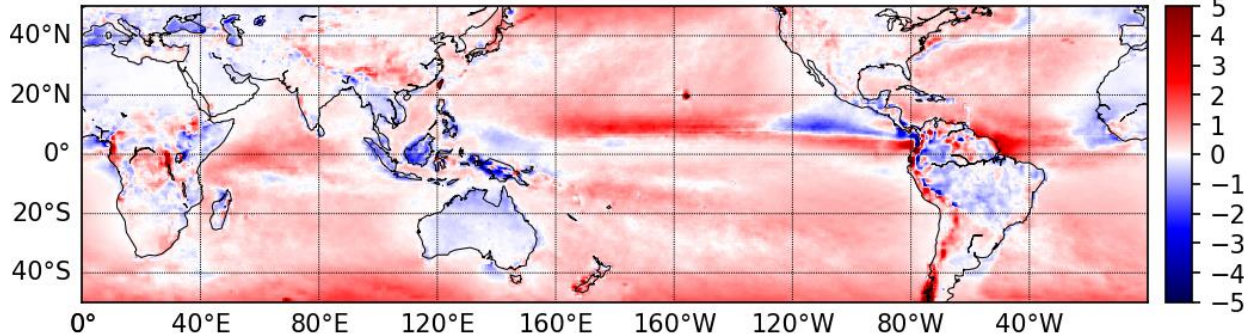MJO Rainfall Difference (S2S_EC_41-44day - TRMM)
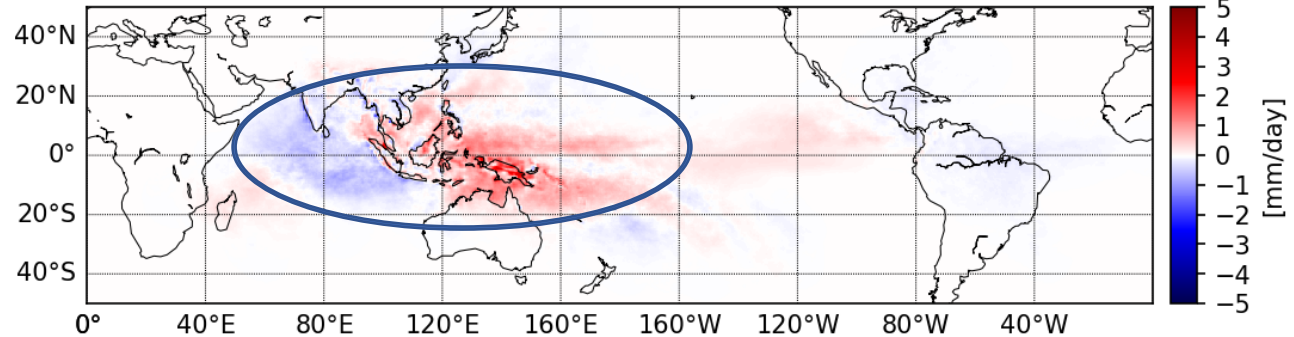
20 year MJO climatology

MJO LPT System Tracks: 1998 - 2018
(N = 218)

MJO LPTs Track Density: 1998 - 2018

Contours every 5
2.5 deg. boxes
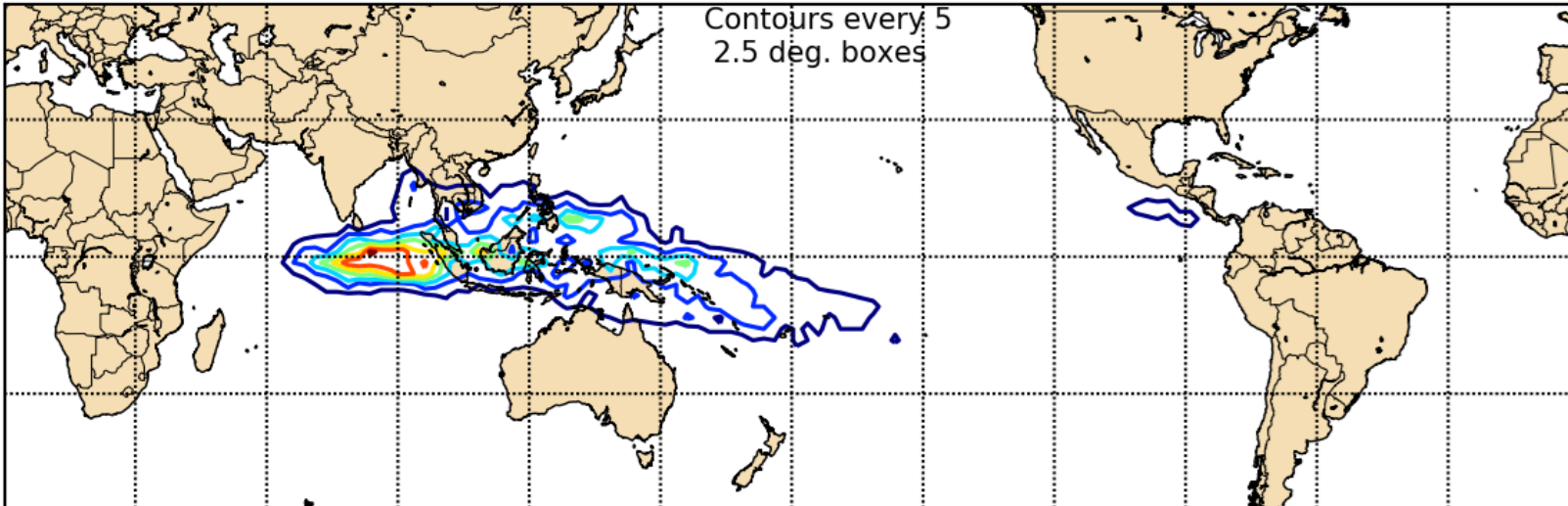
Seasonality of MJO

MJO LPT System Tracks: 1998 - 2018 (DJF)
(N = 73)

- MJO LPT
- MJO Start
- MJO End

DJF
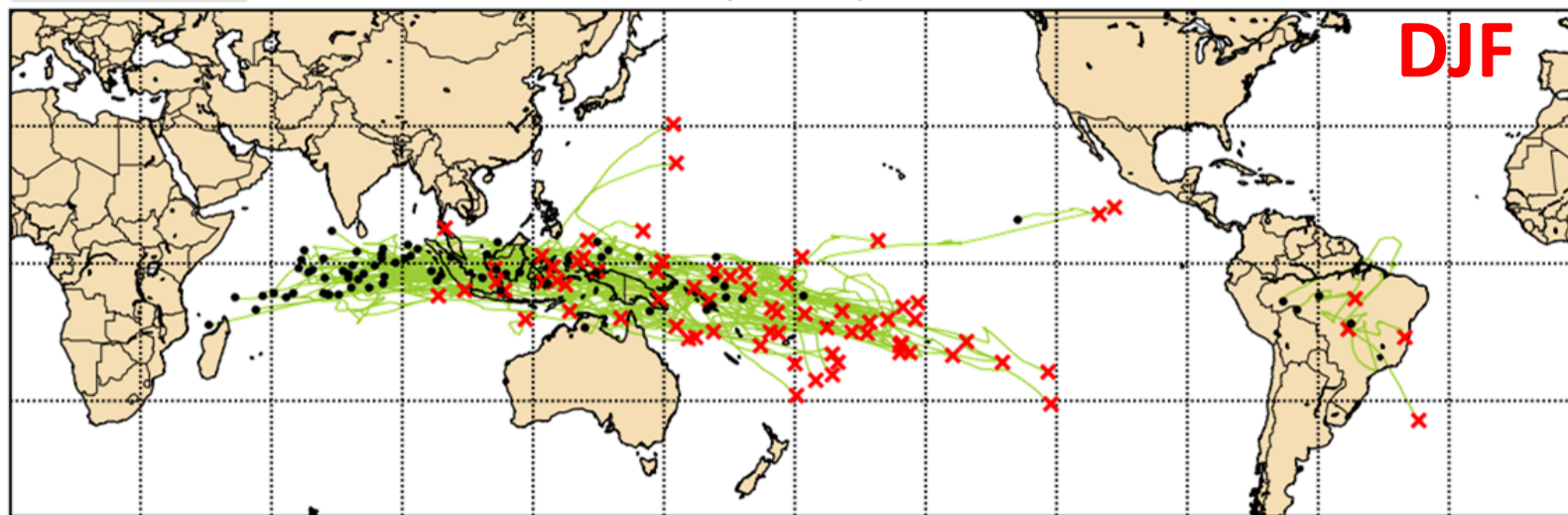
MJO LPT System Tracks: 1998 - 2018 (JJA)
(N = 69)

- MJO LPT
- MJO Start
- MJO End

JJA
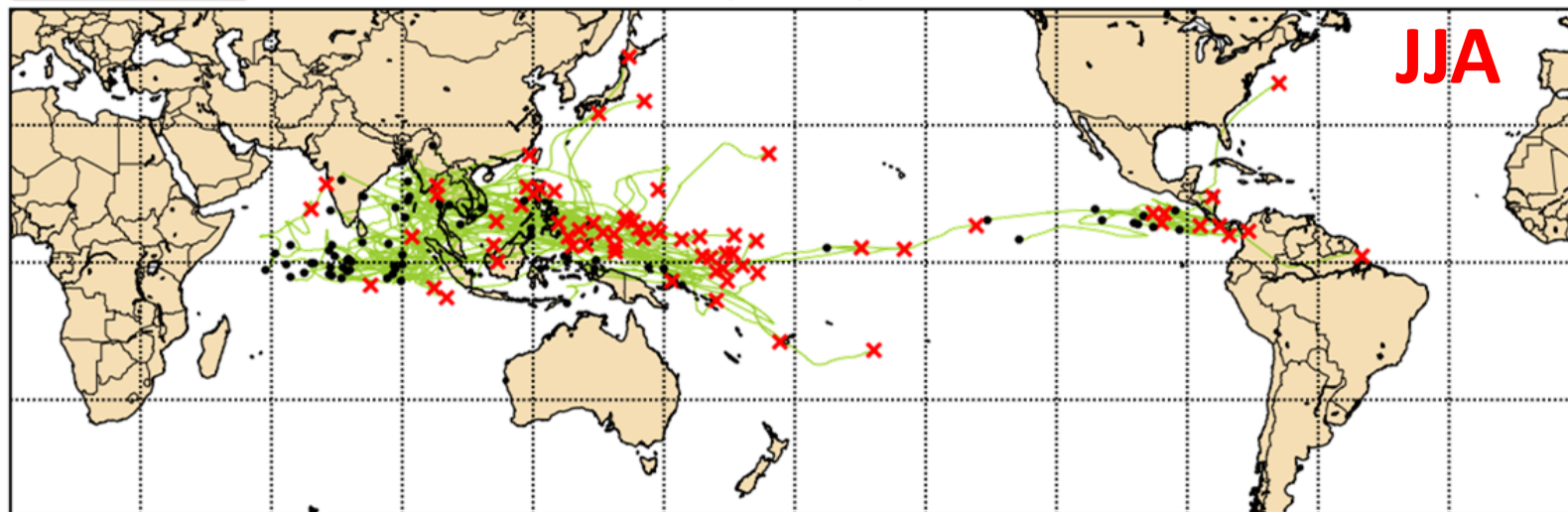
Evaluation of S2S ECMWF reforecast (1998-2017)

MJO LPT System Tracks
TRMM: 1998-2017

MJO_num=218
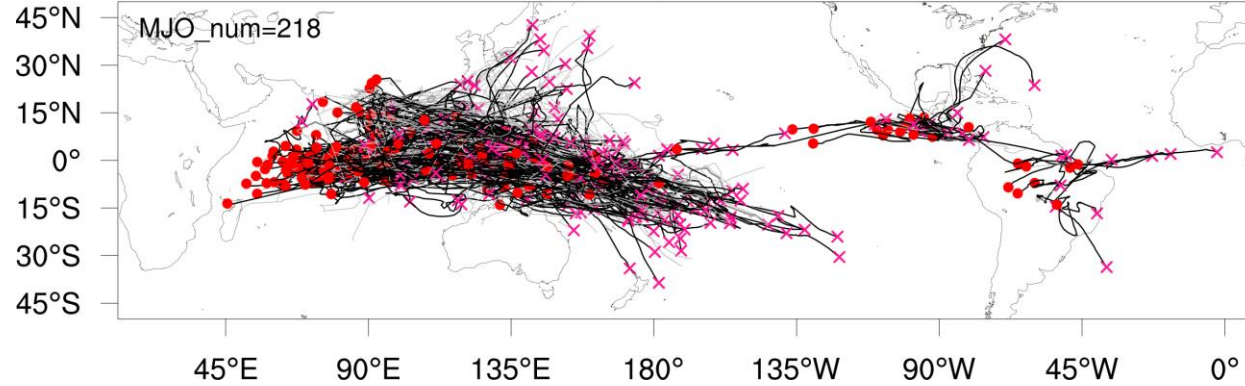
MJO LPT System Tracks
S2S_ECMWF 1-4 days reforecast: 1998-2017(0.25 deg)

MJO_num=175
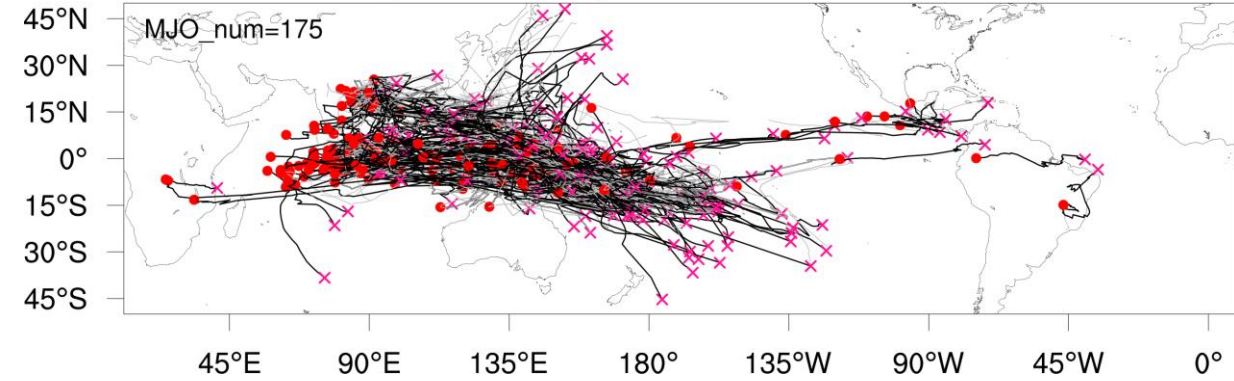
MJO LPT System Tracks
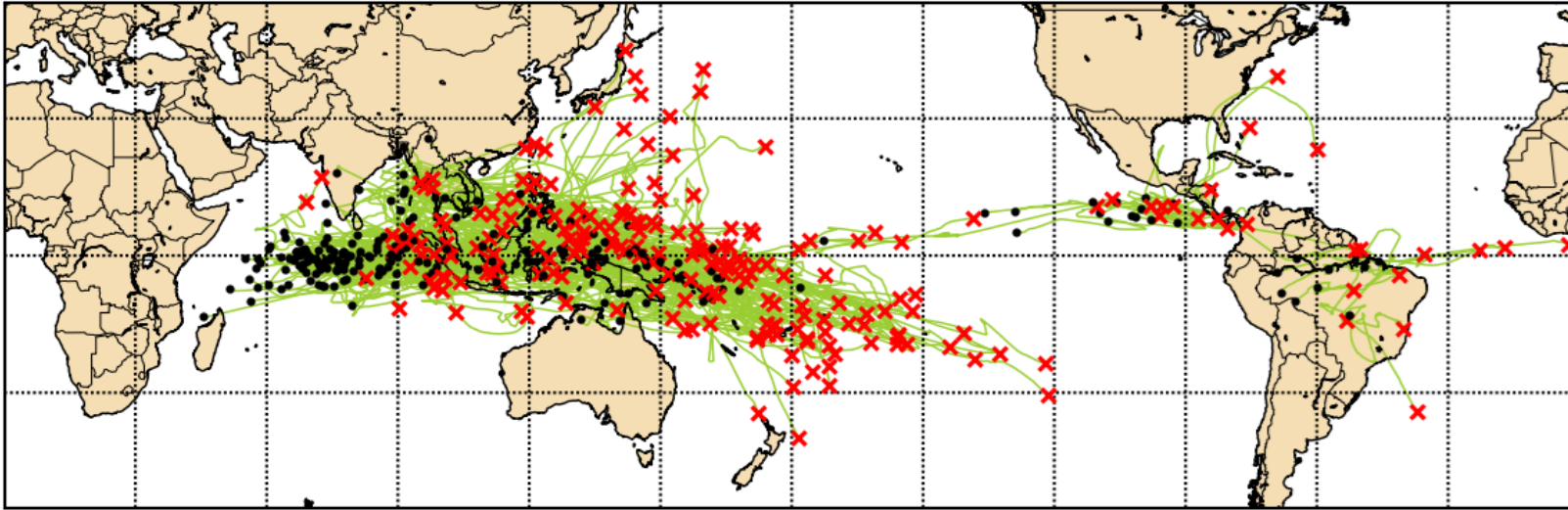S2S_ECMWF 41-44 days reforecast: 1998-2017(0.25 deg)

MJO_num=194

- Very good overall total MJO numbers and general tracks
- Hint of double ITCZ problem in the model

MJO LPT "Density"

MJO Days [June 1998 - June 2018]

Days in MJO [Boreal Summer, June 1998 - June 2018]

Days in MJO [Boreal Winter, June 1998 - June 2018]

All

Boreal Summer
Apr - Sep

Boreal Winter
Oct - Mar
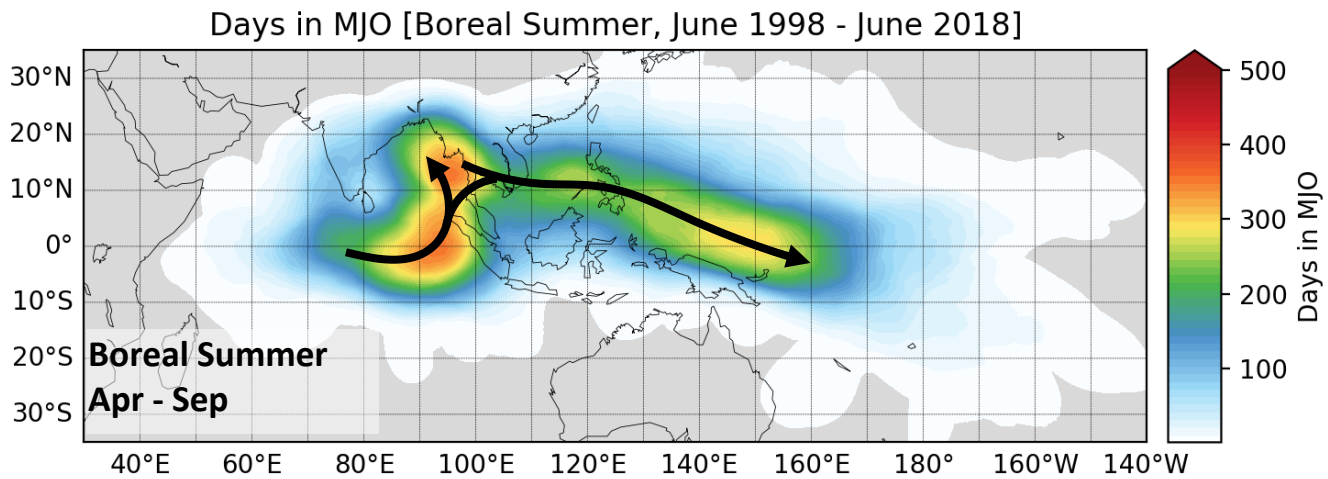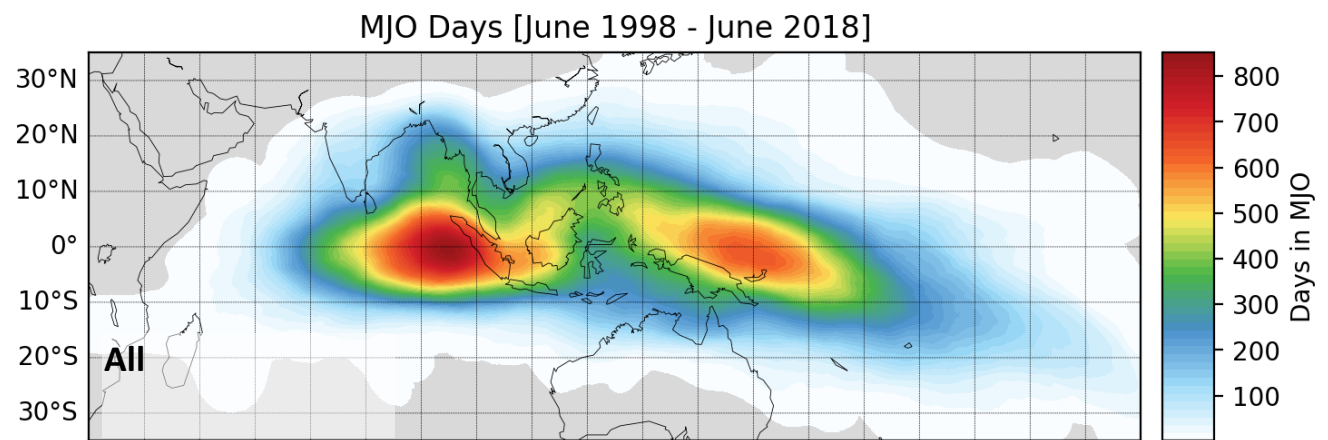
Forecast day 1-4

Forecast day 41-40

MJO Density - ECMWF S2S lag 01 11 mm   day 1-4

MJO Density - ECMWF S2S 11 mm days 41-44

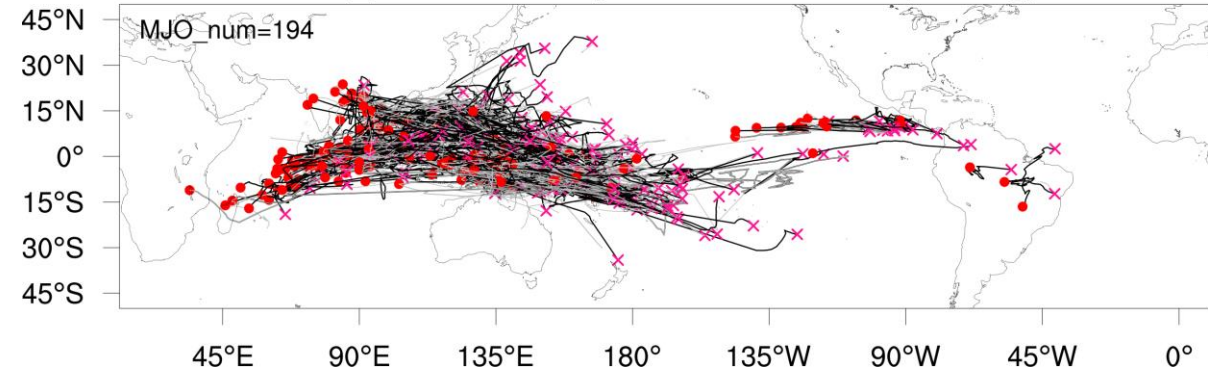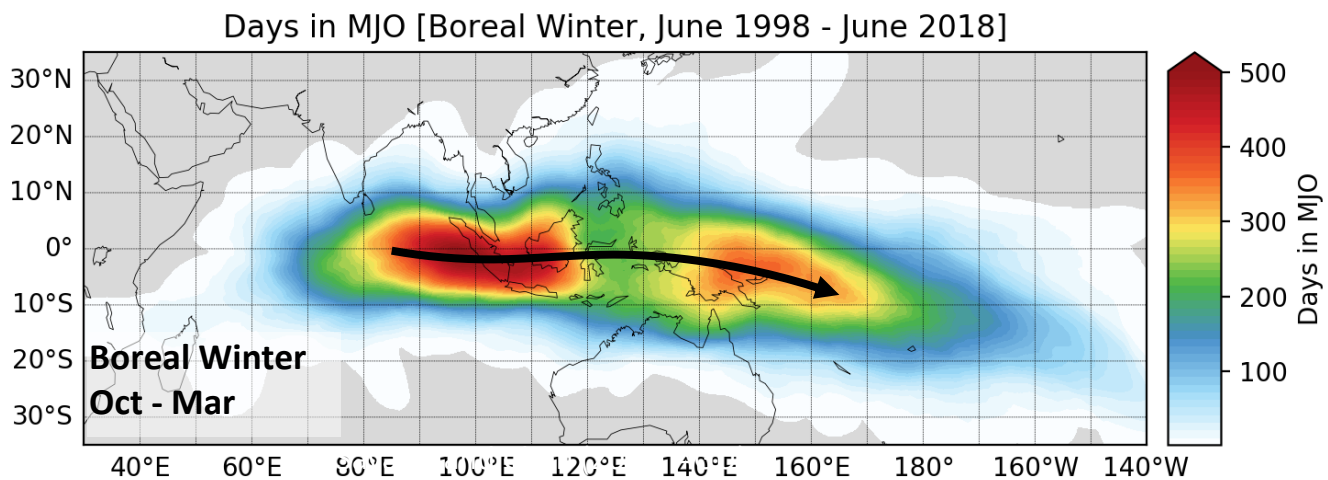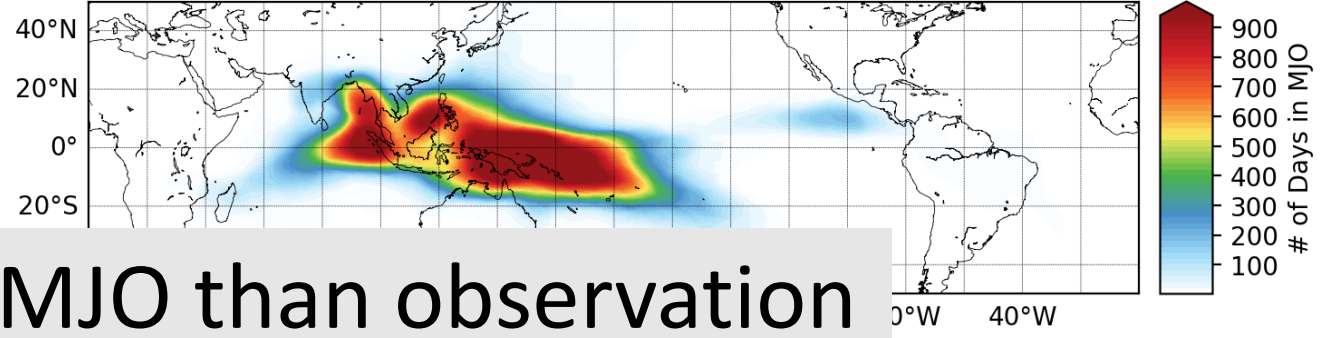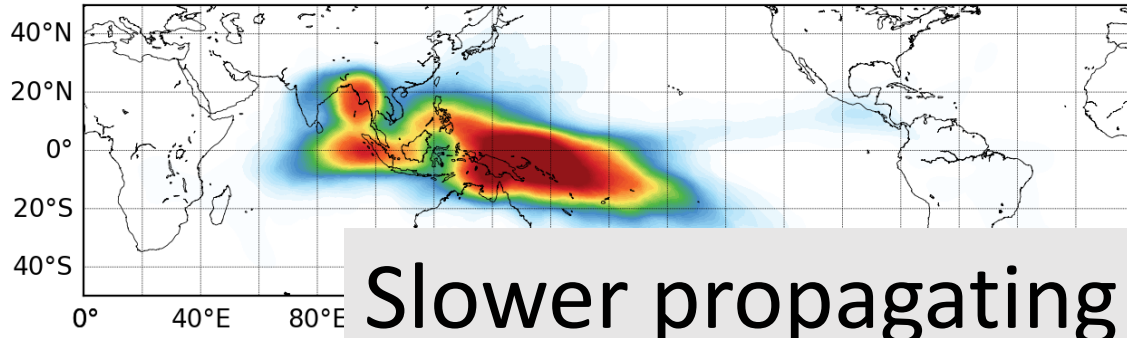**Slower propagating MJO than observation**

MJO Density - Boreal Summer (Apr - Sep) - ECMWF S2S lag 01 11 mm

MJO Density - Boreal Summer (Apr - Sep) - ECMWF S2S 11 mm days 41-44
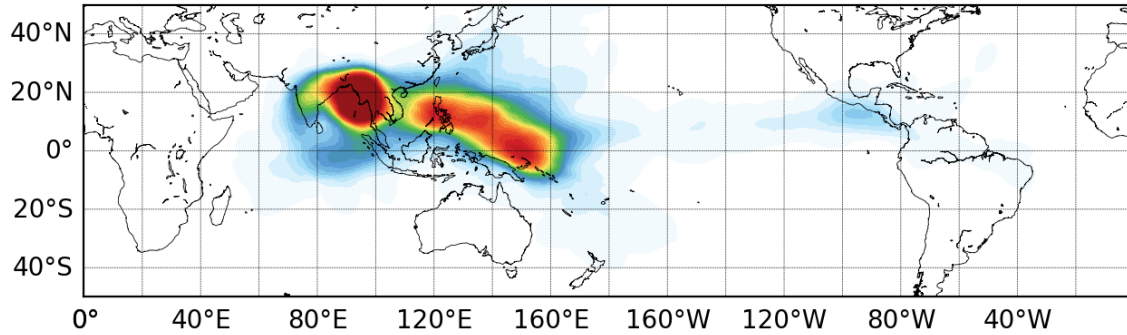
MJO Density - Boreal Winter (Oct - Mar) - ECMWF S2S lag 01 11 mm

MJO Density - Boreal Winter (Oct - Mar) - ECMWF S2S 11 mm days 41-44
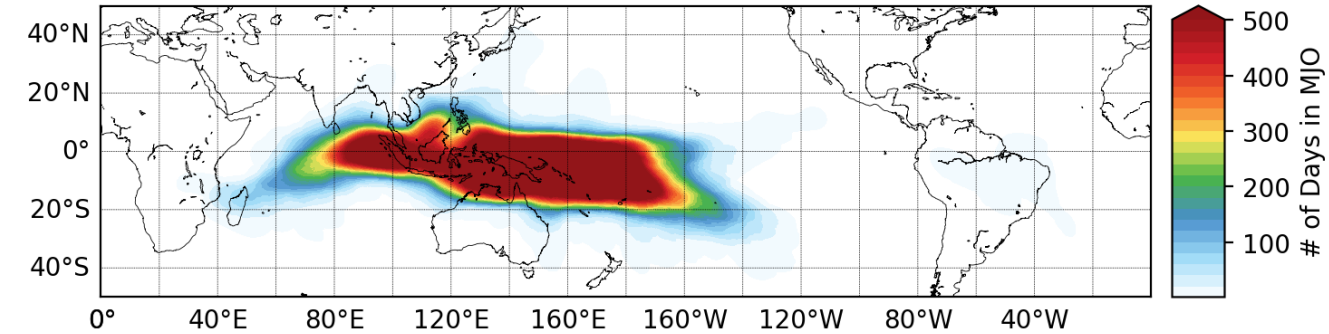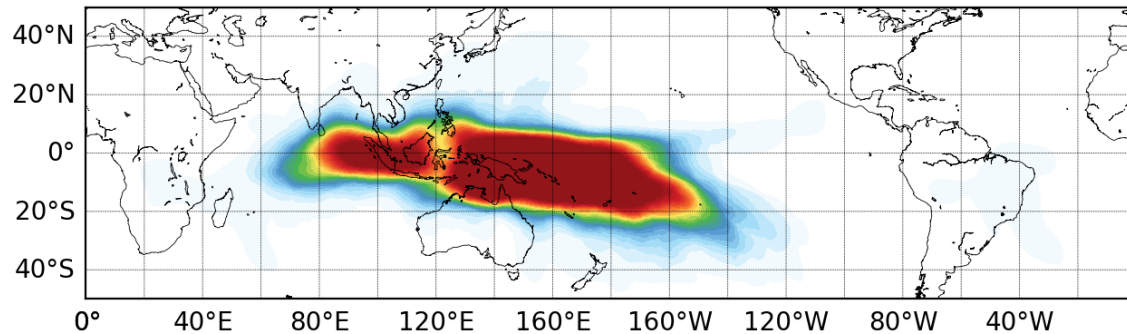
All MJO events ("climate")

MJO Numbers (based on RMM Indexes) : 1998-2017

RMM

MJO Numbers and Mean Volrain : 1998-2017
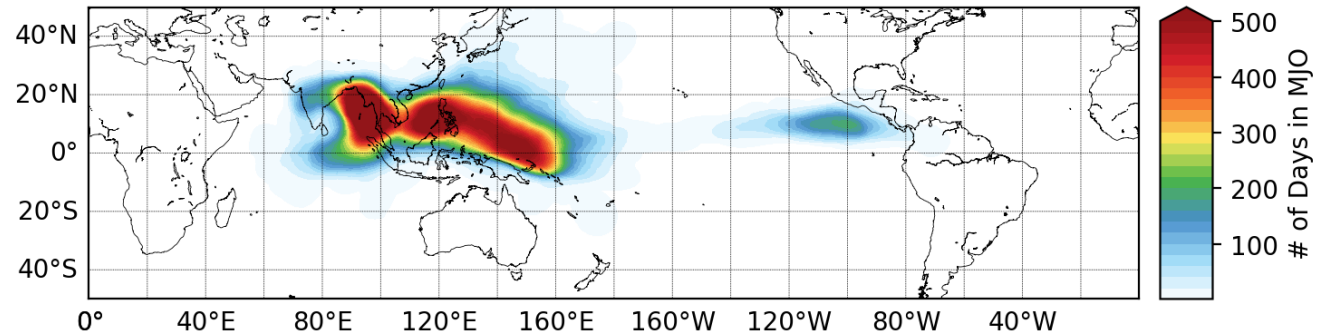
LPT

Matching MJO events in time + space

MJO Numbers (RMM Indexes) of S2S_EC that match OBS: 1998-2017

RMM

> 50% time and longitude overlap
> 25% time and longitude overlap
> 0% time and longitude overlap
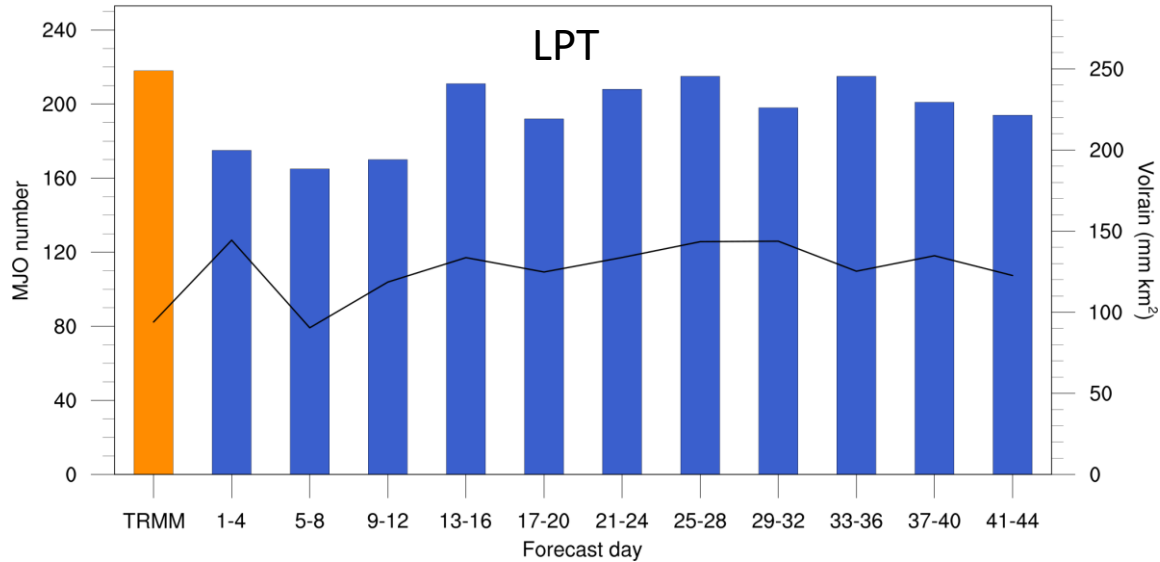
MJO Numbers of S2S_EC that match TRMM: 1998-2017

LPT

> 50% time and longitude overlap
> 25% time and longitude overlap
> 0% time and longitude overlap
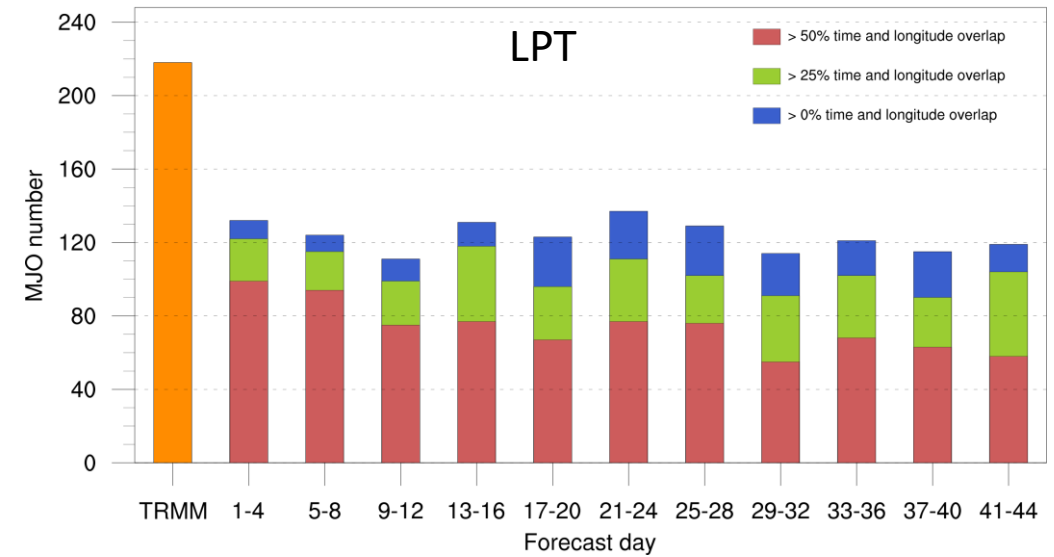
Where the MJO form?

Starting Longitude : 1-4 days
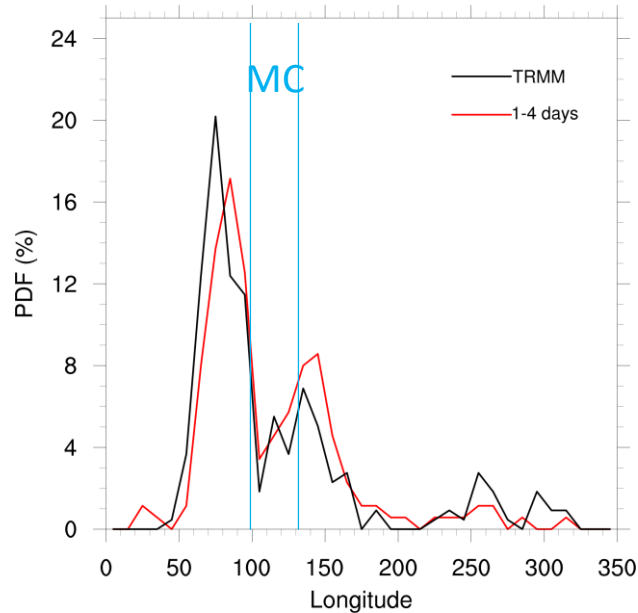
Starting Longitude (> 50% matching): 1-4 days
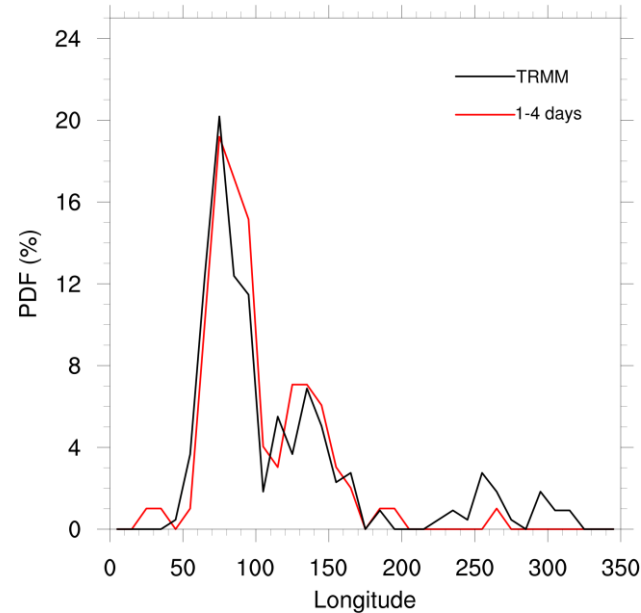
Starting Longitude : 37-40 days
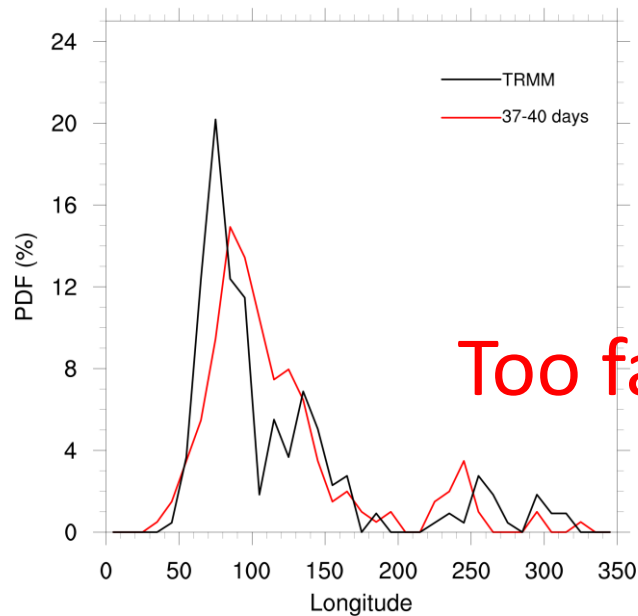
Starting Longitude (> 50% matching): 37-40 days
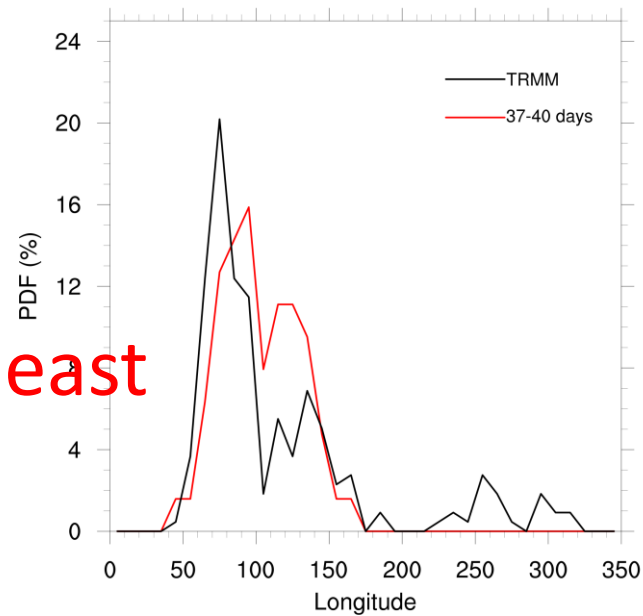
How the MJO propagate?

MJO Eastward Propogation Speed: 1-4 days
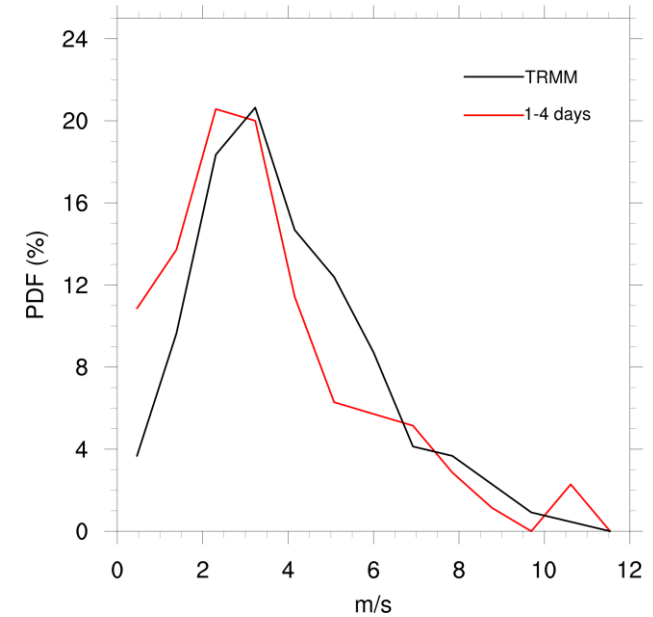
MJO Eastward Propogation Speed: 37-40 days

MC

Too far east

Too slow
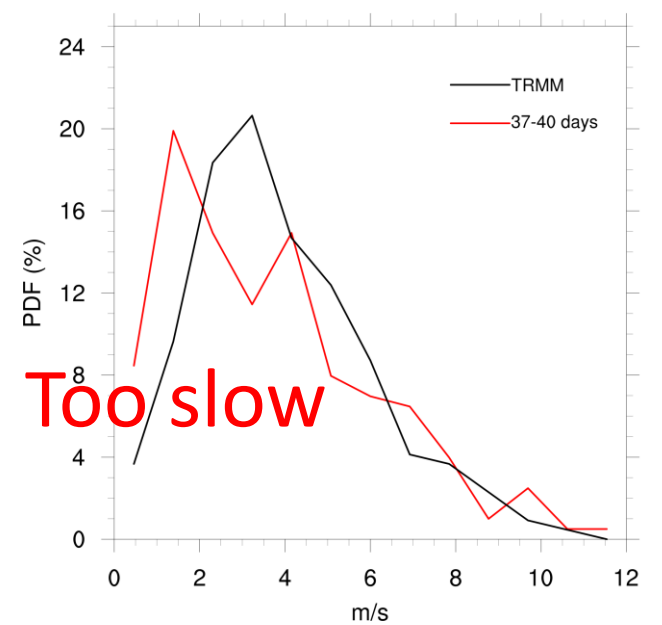
Assess Predictability of MJO RMM and LPT using ECMWF IFS ensemble experiments
(IC + SPPT + SKEBS) 15-day forecast, 4 initial times: 18, 20, 22, 24 November 2011

LPT for ECMWF CY41R1 IC+SPPT+SKEBS Ensemble

RMM

LPT

(a) RMM Index of IC+SPPT+SKEBS ens. Init. 20111118 1200 UTC — 18 Nov

(b) RMM Index of IC+SPPT+SKEBS ens. Init. 20111120 1200 UTC — 20 Nov

(c) RMM Index of IC+SPPT+SKEBS ens. Init. 20111122 1200 UTC — 22 Nov

(d) RMM Index of IC+SPPT+SKEBS ens. Init. 20111124 1200 UTC — 24 Nov

Init: 1200 UTC 18 November 2011

Init: 1200 UTC 20 November 2011

Init: 1200 UTC 22 November 2011

Init: 1200 UTC 24 November 2011

Legend:
- Ensemble Members
- Ensemble Mean
- EC Analysis
- NCEP Reanalysis
- BOM Official

SUMMARY

➢ **Large-scale Precipitation Tracking (LPT) provides a robust and direct measure of MJO convection/precipitation, which capture the spatial structure and its variability**

➢ **ECMWF S2S reforecast has very good skill in predicting the total number of MJO regardless lead time, but poor MJO initiation in Indian Ocean**

➢ **ECMWF S2S forecast skill in predicting RMM and MJO LPT decreases with lead time, more so in LPT than RMM**

➢ **Predictability of the MJO convective initiation over the Indian Ocean is relatively low as indicated by the ECMWF stochastic ensemble forecasts (similar results in S2S reforecast)**