Application of large-scale precipitation tracking (LPT) to real-time MJO monitoring and forecasts

Chidong Zhang (NOAA/PMEL)
Wanqiu Wang (NOAA/NWS/NCEP/CPC)
Brandon Kerns (University of Washington)
Weiyu Yang (NOAA/NWS/NCEP/CPC, ERT)
Jieshun Zhu (NOAA/NWS/NCEP/CPC)

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Outline

Part 1

1. Description of LPT method
2. Demonstration of LPT skill scores using CFS reforecasts

Part 2

3. Real-time LPT monitoring and forecast at CPC
4. Comparison of LPT with other MJO indices
5. Evaluation of forecast skill of LPT and RMM
6. Future work
7. Summary

1. Description of LPT method

<u>Data</u>:

- TRMM-GPM Multi-satellite Precipitation Analysis (TMPA, 3B42) data from 1998-2020, 0.25^o, 3-hourly (Kerns and Chen 2016; 2020)
- IMERG (multi-satellite, NASA, 0.1^o, hourly), 1998-2020
- CMORPH (multi-satellite, NOAA, 0.1^o, hourly), 1998-2020

Large-Scale Precipitation Tracking (LPT) for Model Evaluation

Procedure:

1. Data Preparation

- Accumulate rain for **3 days**.
- Apply a spatial smoother (**Gaussian, stdev = 2.5 deg**)
- Determine an appropriate Feature threshold (e.g., **12 mm/**

day, contour)

JGR Atmospheres

RESEARCH ARTICLE

10.1029/2019JD032142

Special Section:
Years of the Maritime Continent

A 20-Year Climatology of Madden-Julian Oscillation Convection: Large-Scale Precipitation Tracking From TRMM-GPM Rainfall

Brandon W. Kerns[1] and Shuyi S. Chen[2]

[1]Applied Physics Laboratory, University of Washington, Seattle, WA, USA, [2]Department of Atmospheric Sciences, University of Washington, Seattle, WA, USA

Key Points:

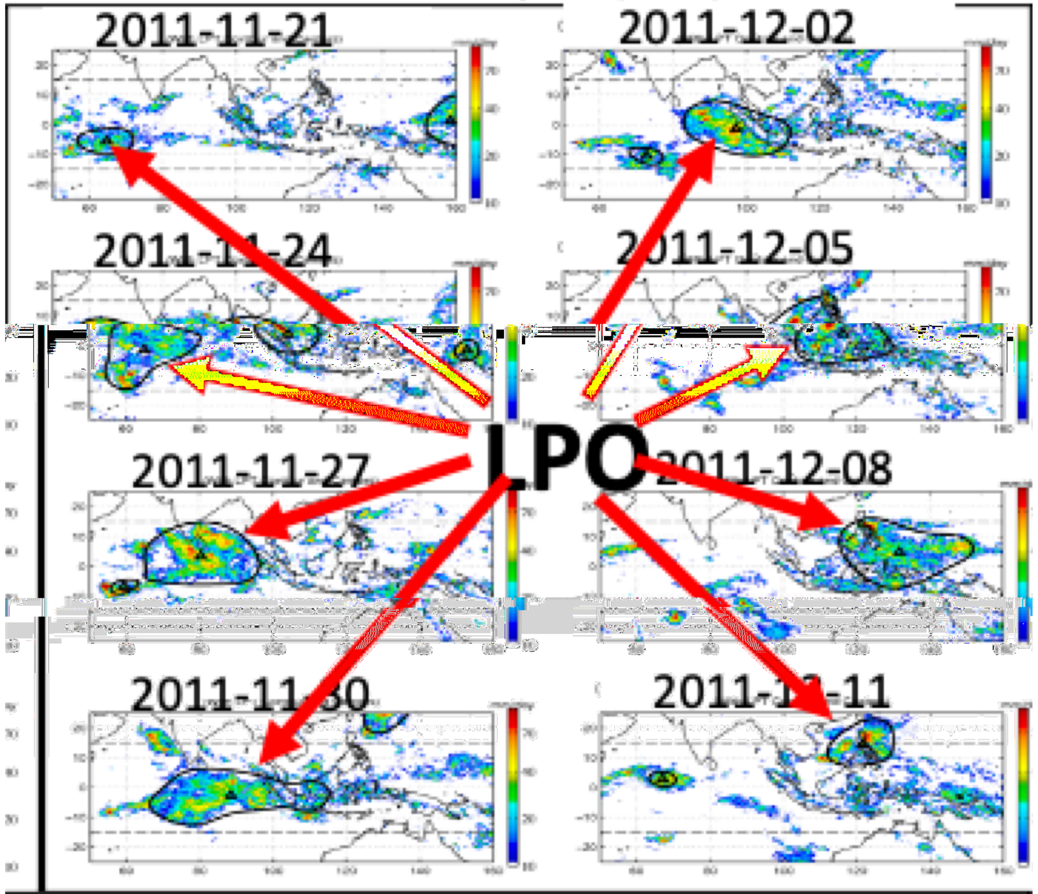
- The MJO accounts for 40–50% of the annual precipitation over the

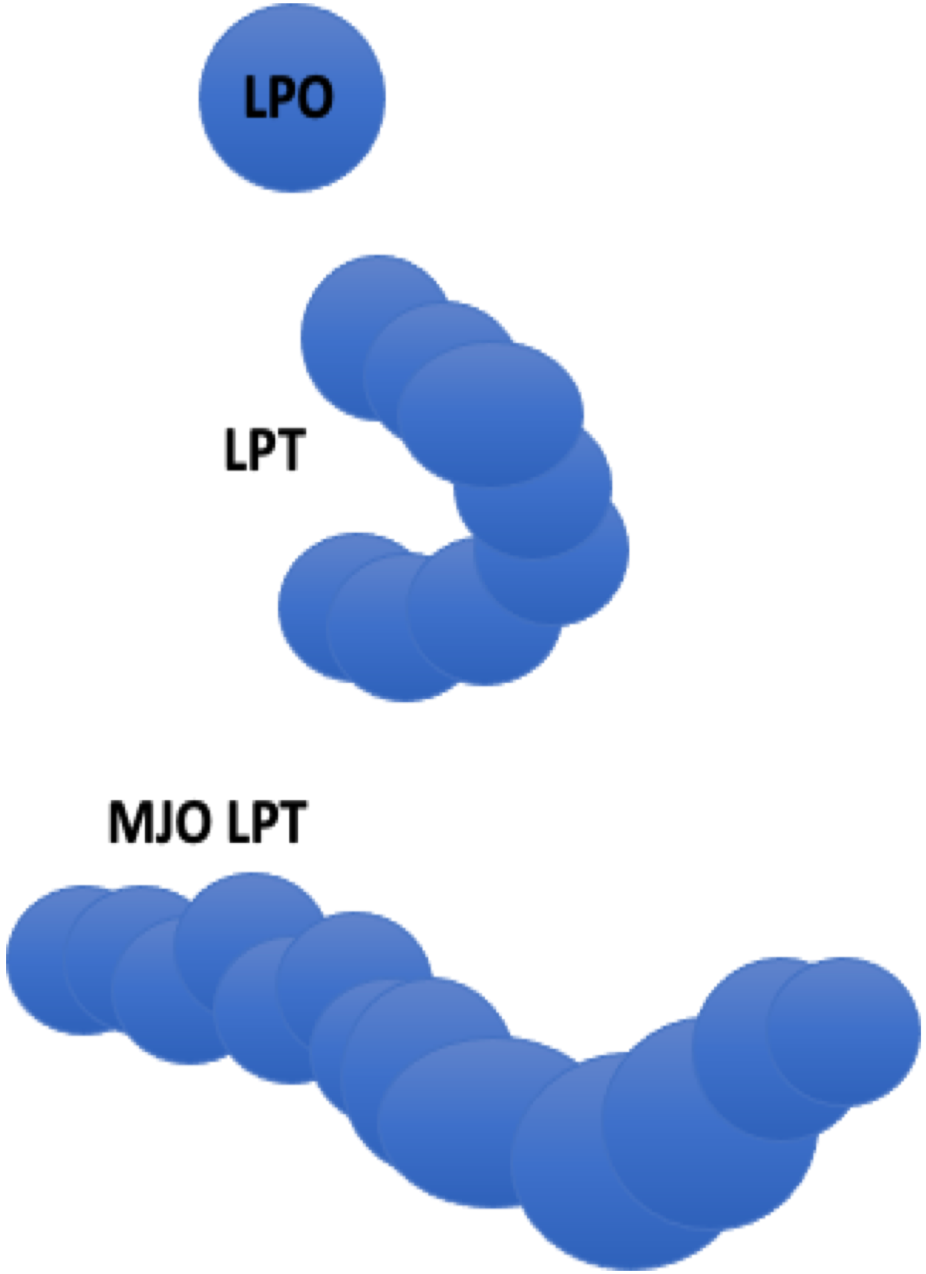
Large-Scale Precipitation Tracking (LPT) for Model Evaluation

2. Identify and Tracking

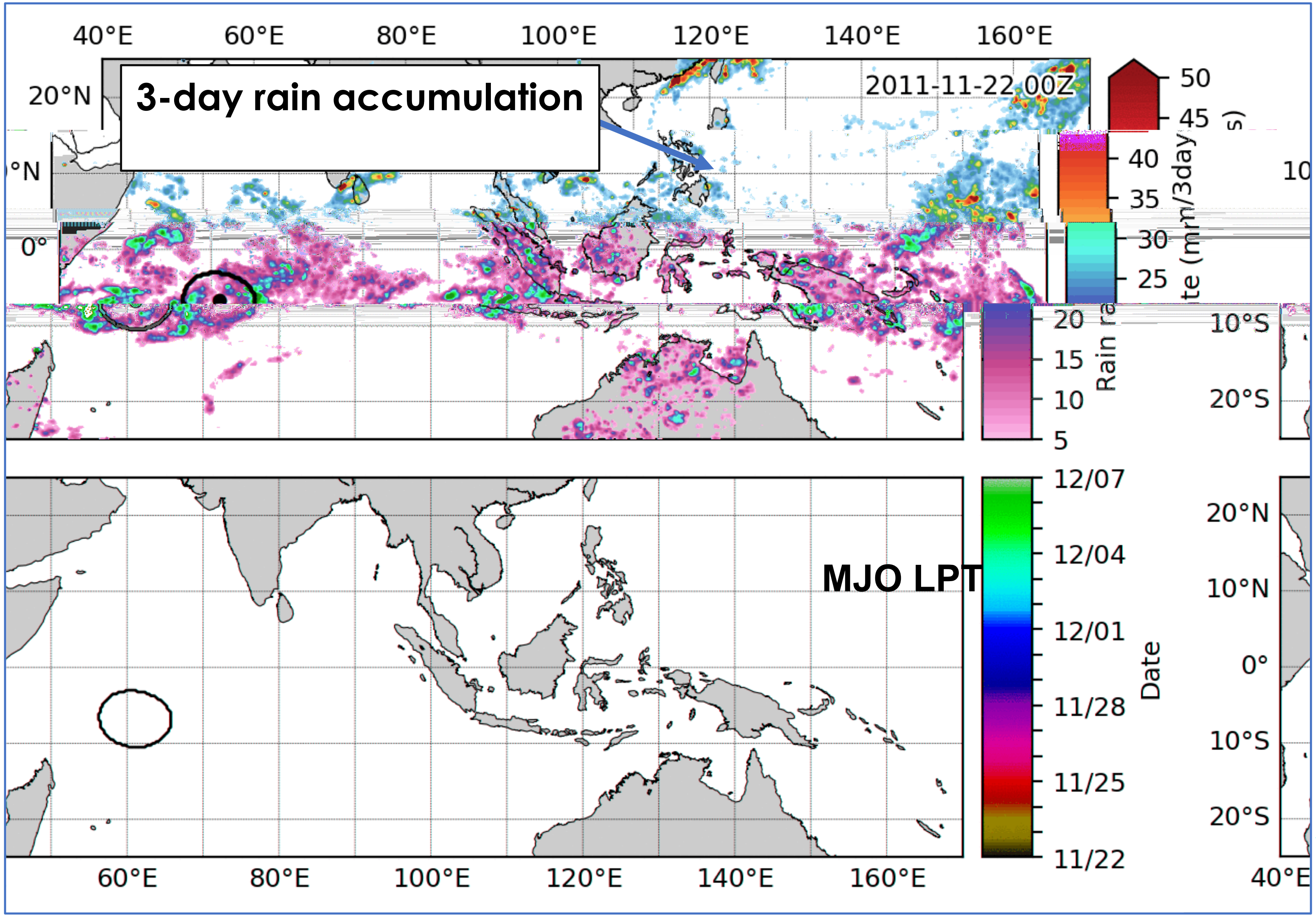
- <u>**Define LP Object (LPO)**</u> **:** 3-day accumulated rainfall with spatial filter (5° X 5°) area of **> 12 mm day^{-1}** (> 250,000 km^2)
- <u>**LP Tracking (LPT)**</u>: overlapping LPOs consecutively > 7 days
- <u>**MJO LPT**</u>: LPT longer than 10 days; eastward propagation speed > 0 m/s

▲ = ***LP Object (LPO)*** centroid.

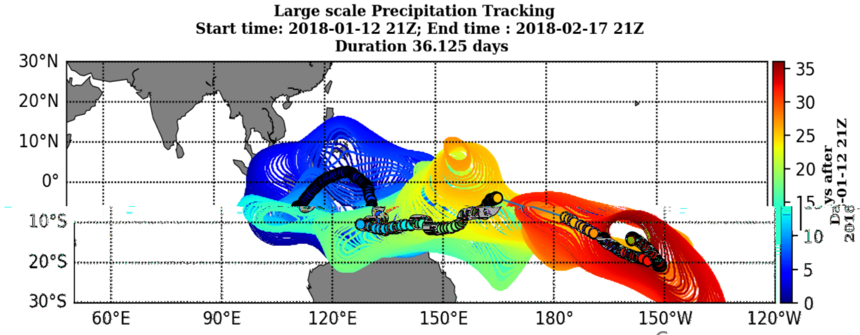




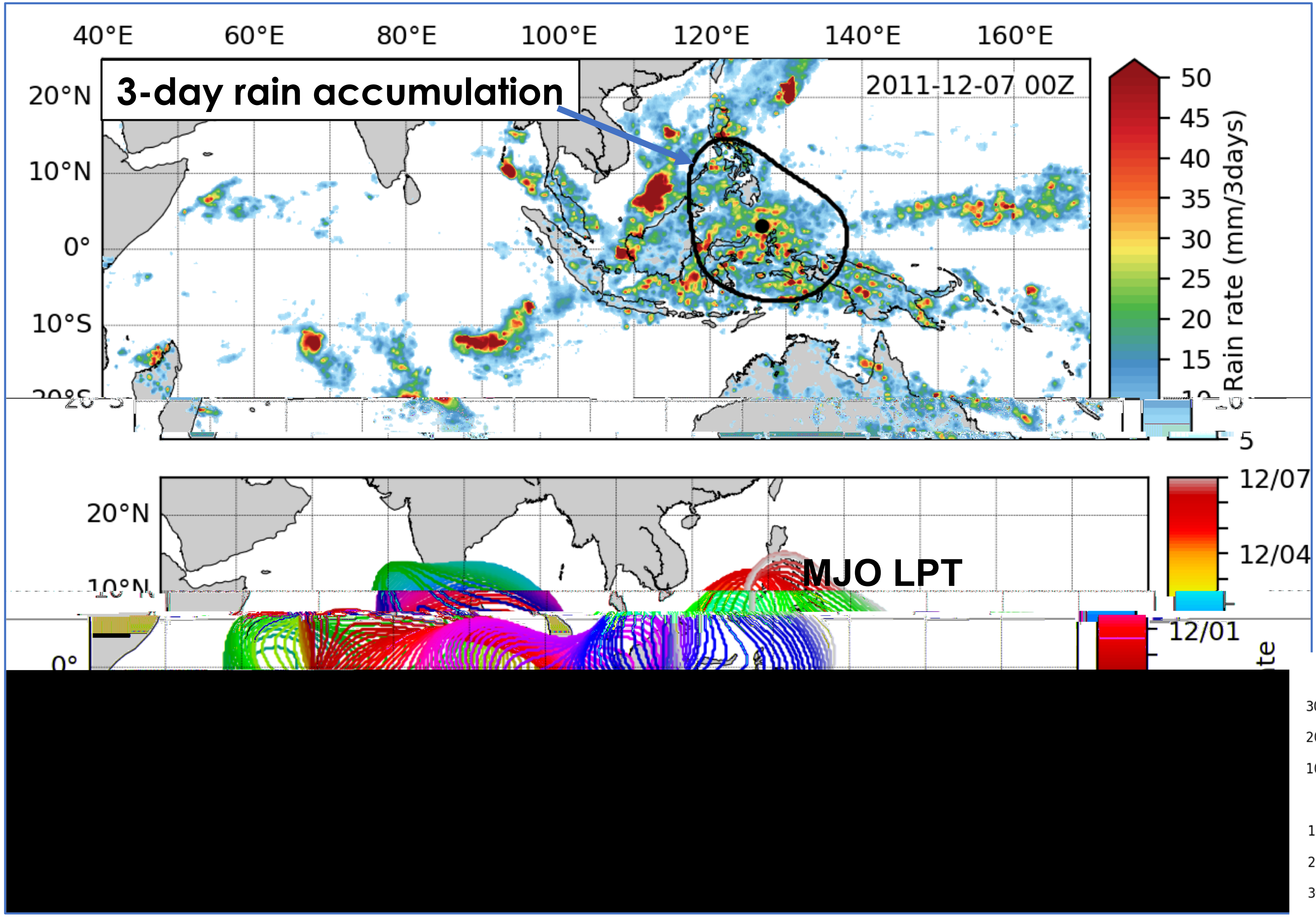
Tracking the MJO



- LPT is used to track MJO precipitation. **(Kerns and Chen 2016, 2020)**
- MJO LPTs provide both zonal and **meridional structure** that is important for global impact studies
- Challenge: many NWP and climate models cannot reproduce MJO convection/precipitation initiation, propagation, and spatial structure

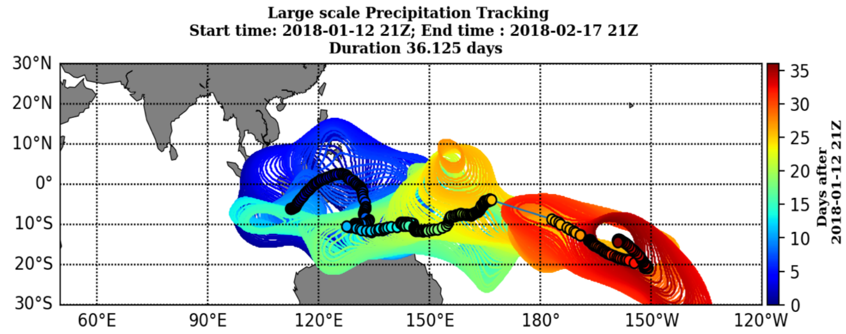


Tracking the MJO



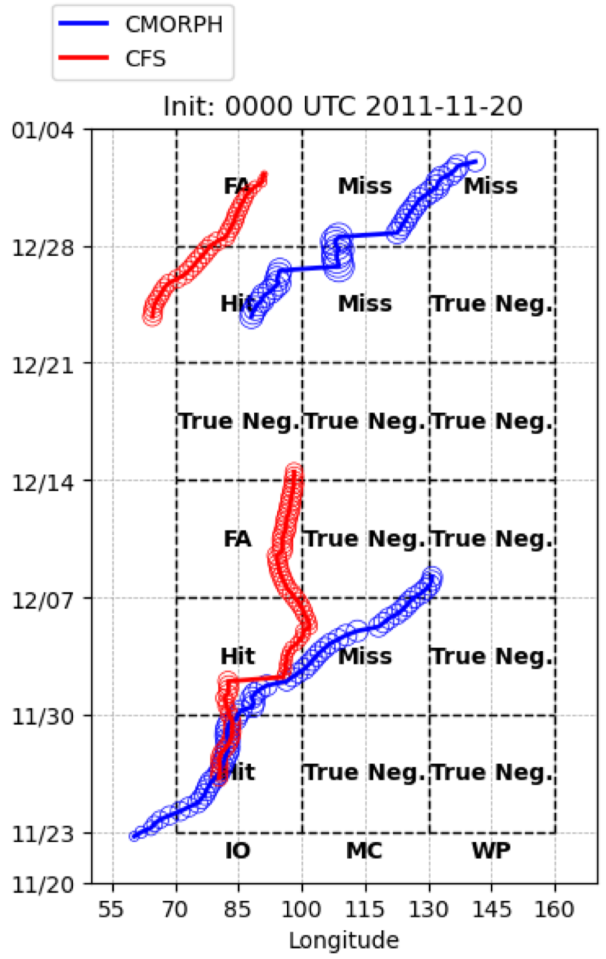
Tracking products:

- Individual MJO events
- Their initiation and termination locations
- Their longevity
- Their propagation speeds and patterns
- Their sizes (areal coverages)



2. Demonstration of LPT skill scores using CFS reforecasts

1. Treat the MJO as rare events and develop summary metrics based on contingency table for the Indian Ocean, Maritime Continent, and western Pacific



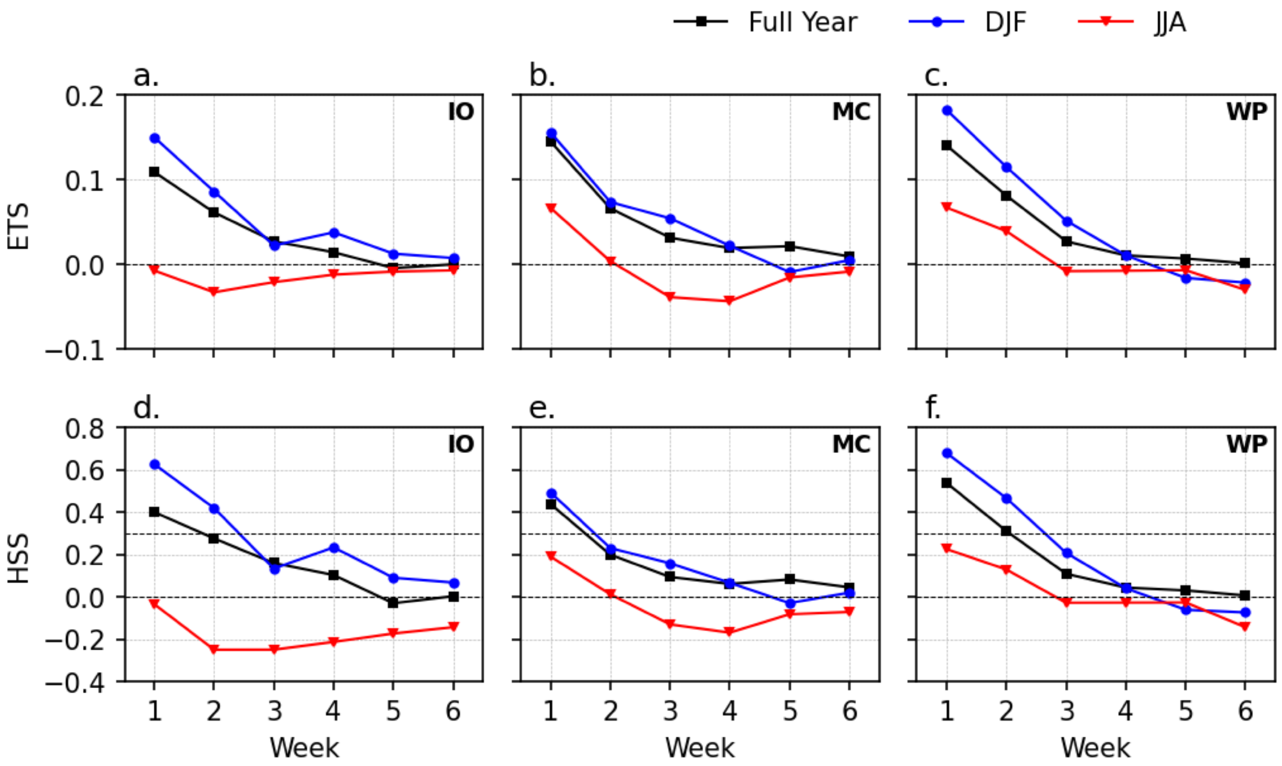
	Contingency Table for MJO LPT Verification		
		CMORPH MJO LPT (11 mm/day)	
		YES	NO
CFS MJO LPT	YES	H (hits)	F (False Alarm)
(13 mm/day)	NO	M (Misses)	N (True Negative)

Kerns et al. (2022)

Skill Metrics Using LPT (Kerns et al. 2022)

2. Define skill scores

- Probability of Detection (POD) = H / (H + M)
- False Alarm Rate (FAR) = F / (F + N)
- Accuracy (AC) = (H + N) / (H + F + M + N)
- Threat Score (TS) = H / (H + F + M)
- **Equitable Threat Score (ETS) = (H - Href) / (H – Href + F + M), where Href = ((H + M)(H + F)) / (H + F + M + N)**
- **Heidke Skill Score (HSS) = 2(HN – FM) / ((H + M)(M+N) + (H + F)(F + N))**



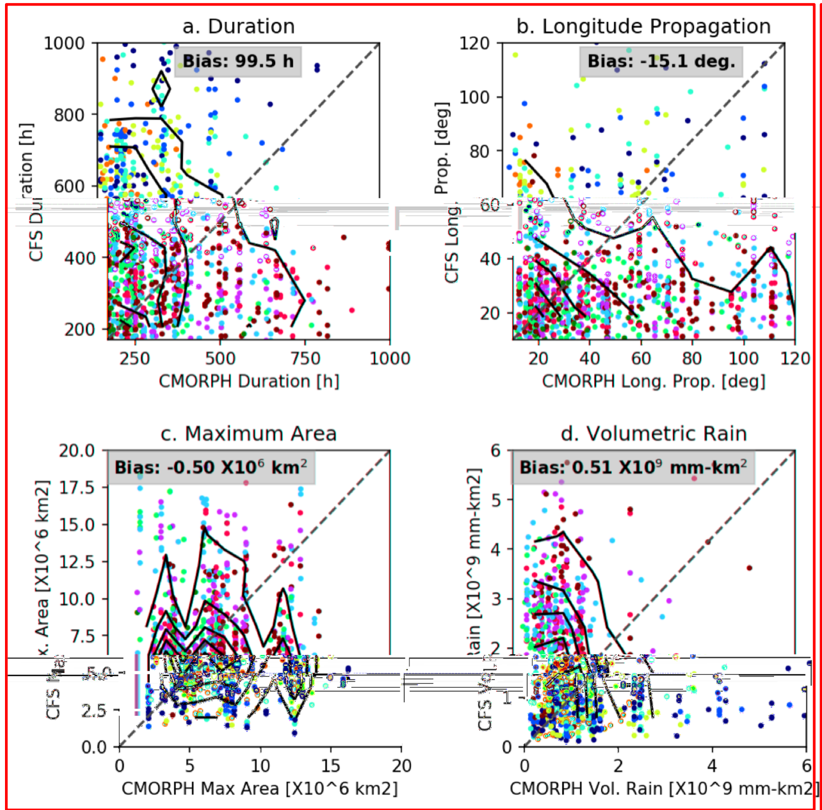
Skill Metrics Using LPT (Kerns et al. 2022)

3. Forecast accuracy of MJO properties for the captured events

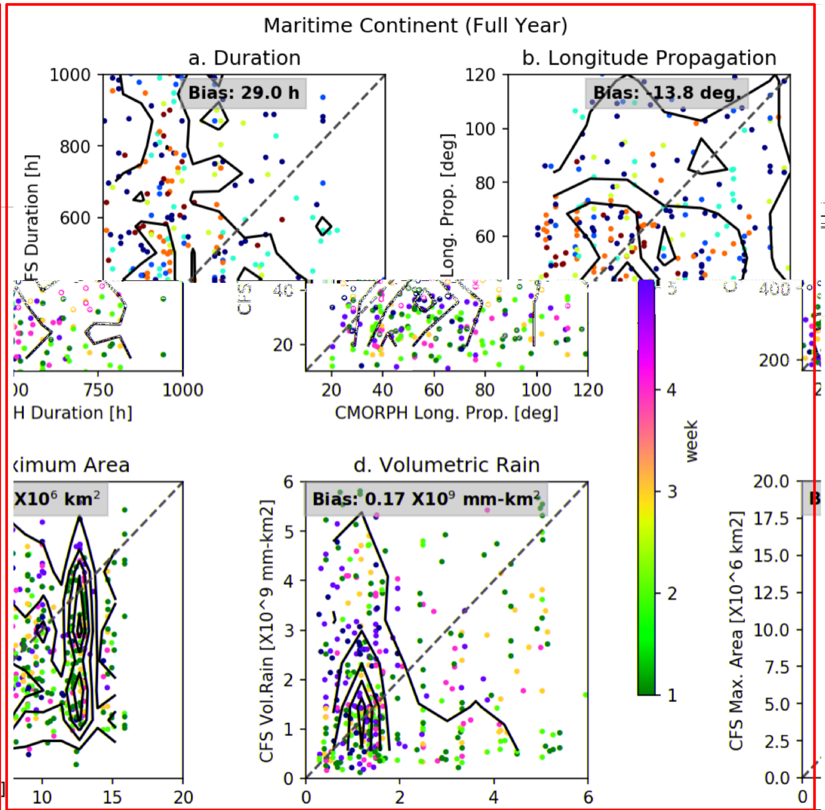
- Duration
- Longitudinal Range
- Scale (maximum areal coverage)
- Strength (volumetric rain)

- A few patterns (CFS overestimates the strength and duration of short and weak events but underestimates the propagation range over the Indian Ocean)
- No dependence on forecast lead time!!!!

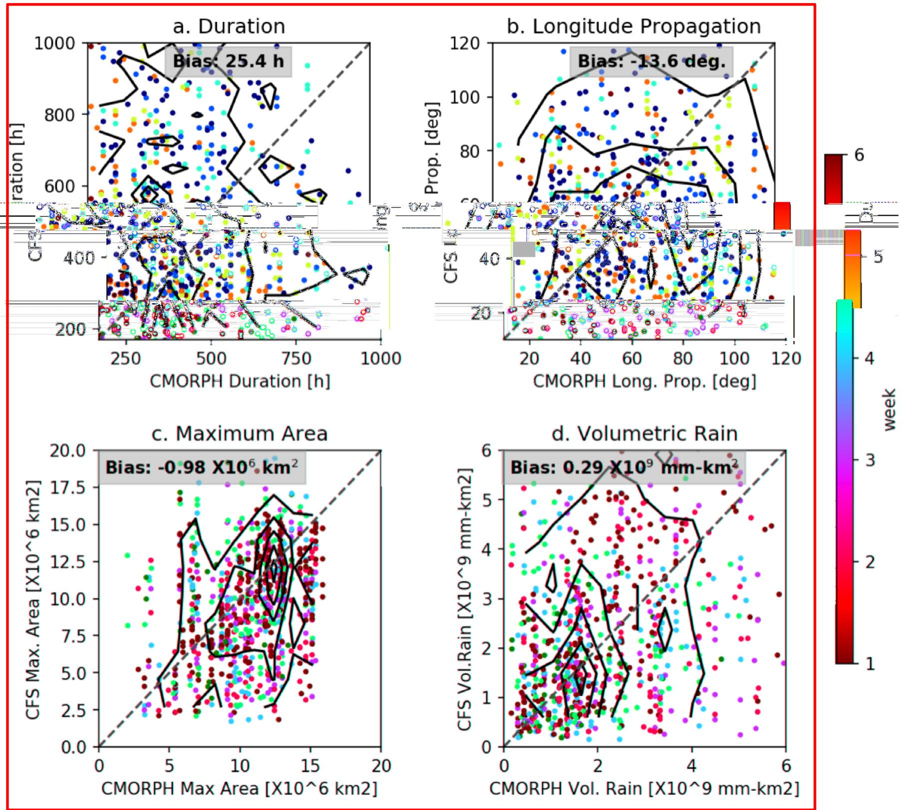
Indian Ocean



Maritime Continent



Western Pacific

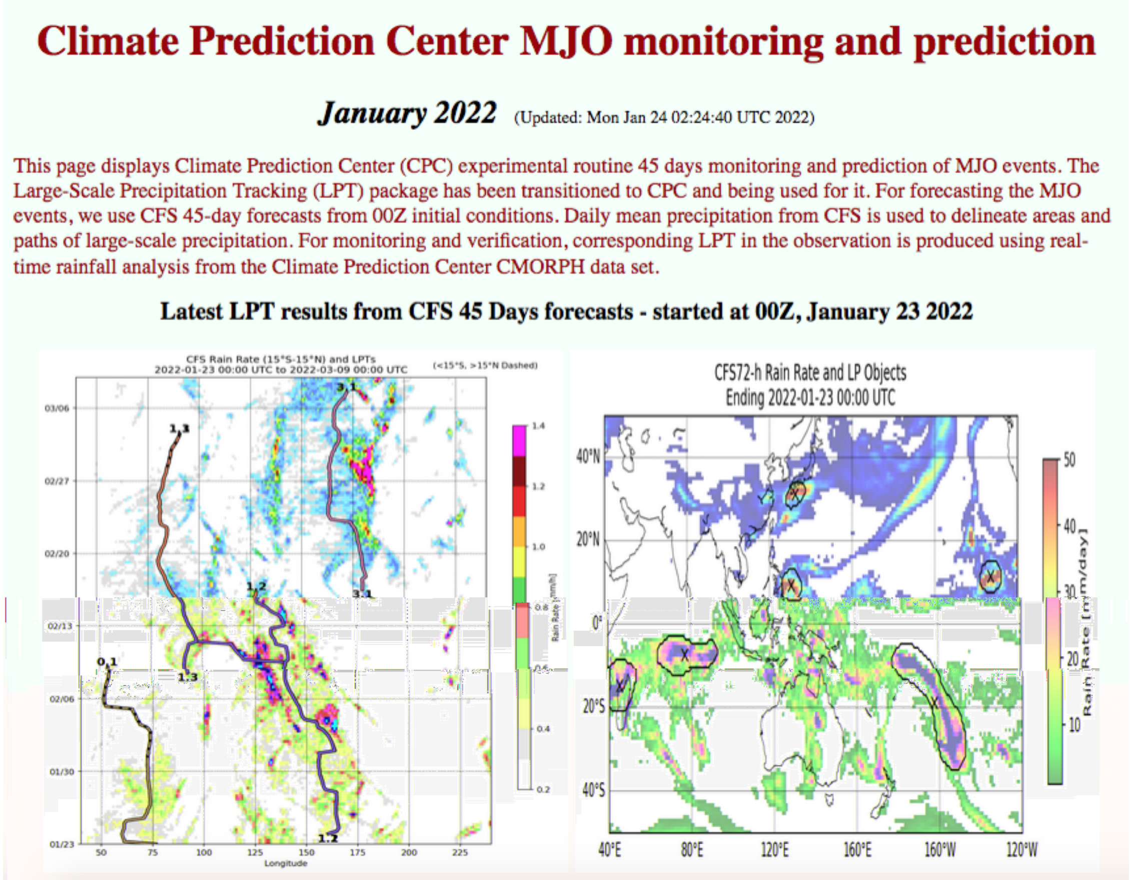


3. Real-time LPT monitoring and forecast at CPC

- Computer system
  - CPC Linux workstations
  - Computer language: Python
- CFS forecast
  - One 00Z forecast run each day; 6-hourly output
- Observation
  - CMORPH: hourly analysis
- Experimental routine update
  - Started May 2020
  - Display

Experimental Routine update of CFS forecast

https://origin.cpc.ncep.noaa.gov/products/people/wyang/MJO_LPT_45days/index.html



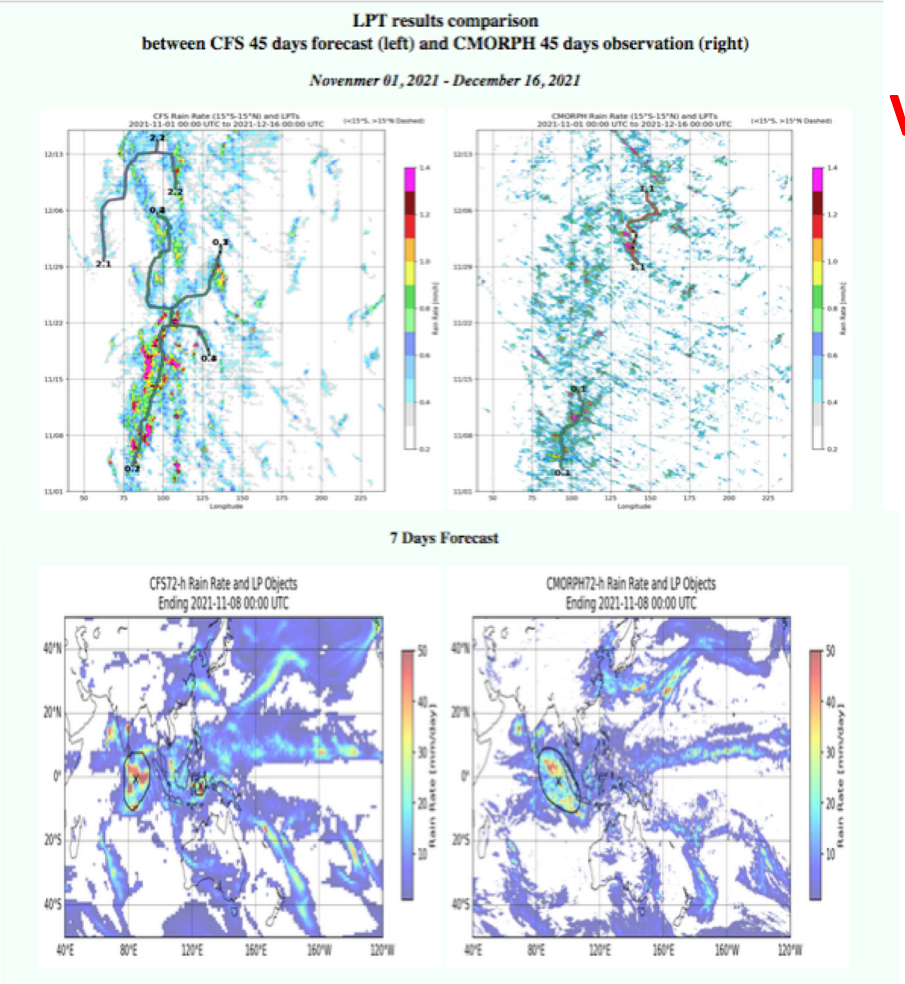
Climate Prediction Center MJO monitoring and prediction

January 2022 (Updated: Mon Jan 24 02:24:40 UTC 2022)

This page displays Climate Prediction Center (CPC) experimental routine 45 days monitoring and prediction of MJO events. The Large-Scale Precipitation Tracking (LPT) package has been transitioned to CPC and being used for it. For forecasting the MJO events, we use CFS 45-day forecasts from 00Z initial conditions. Daily mean precipitation from CFS is used to delineate areas and paths of large-scale precipitation. For monitoring and verification, corresponding LPT in the observation is produced using real-time rainfall analysis from the Climate Prediction Center CMORPH data set.

Latest LPT results from CFS 45 Days forecasts - started at 00Z, January 23 2022

Latest forecast



Verification

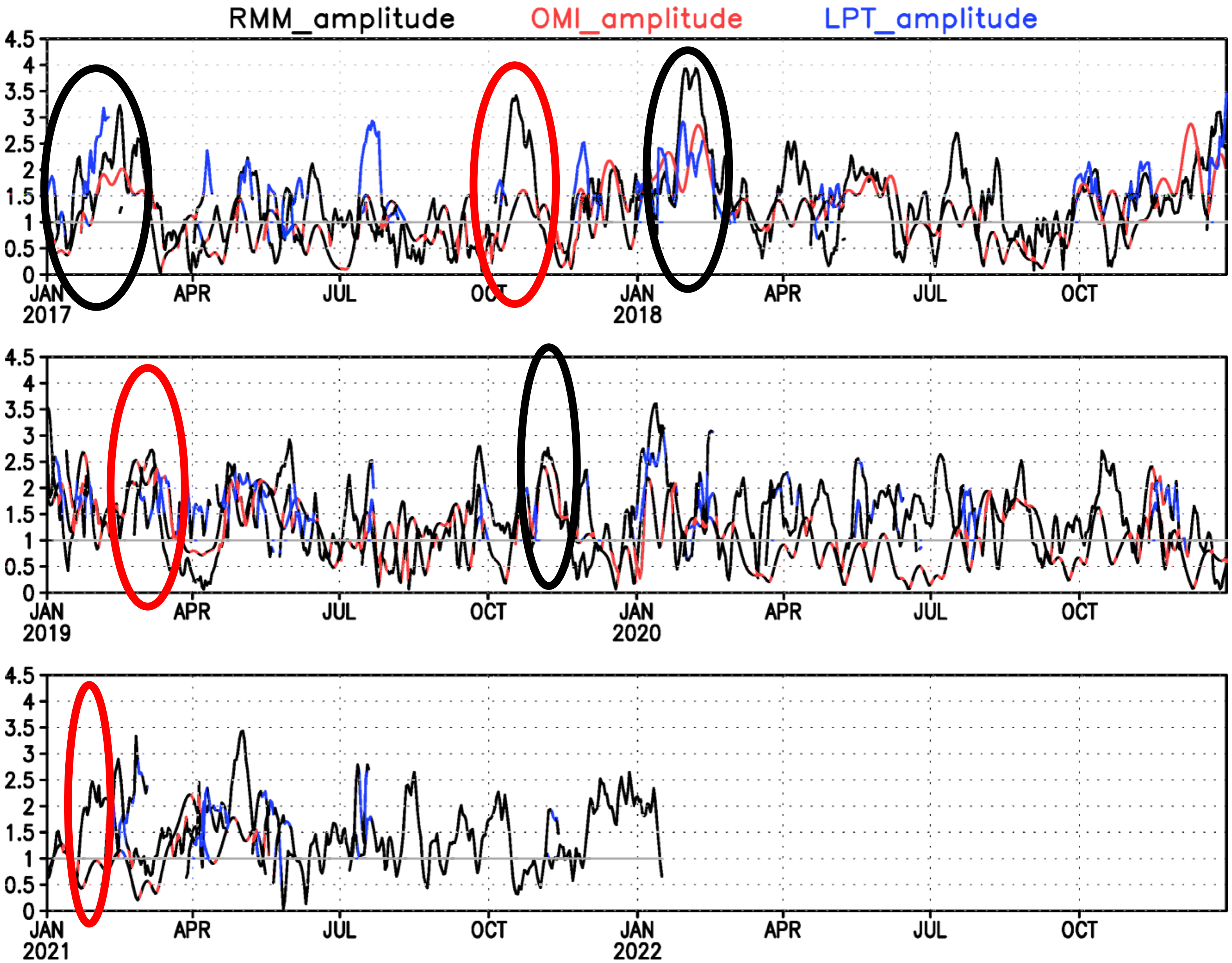
Tracking

7-day Rainfall forecast; 14-day forecast.

4. Comparison of LPT with other MJO indices

- Time series of RMM, OMI, LPT
  - **RMM**: Real-time Multivariate MJO Index
  - **OMI**: OLR MJO Index
  - **LPT**: Large-scale Precipitation Tracking
- Comparison for individual cases
  - Observation
    - Phase diagrams
    - LPT tracking and evolution of LPT areas
  - Forecast
    - Phase diagrams (RMM & LPT)

Time series of RMM, OMI, LPT

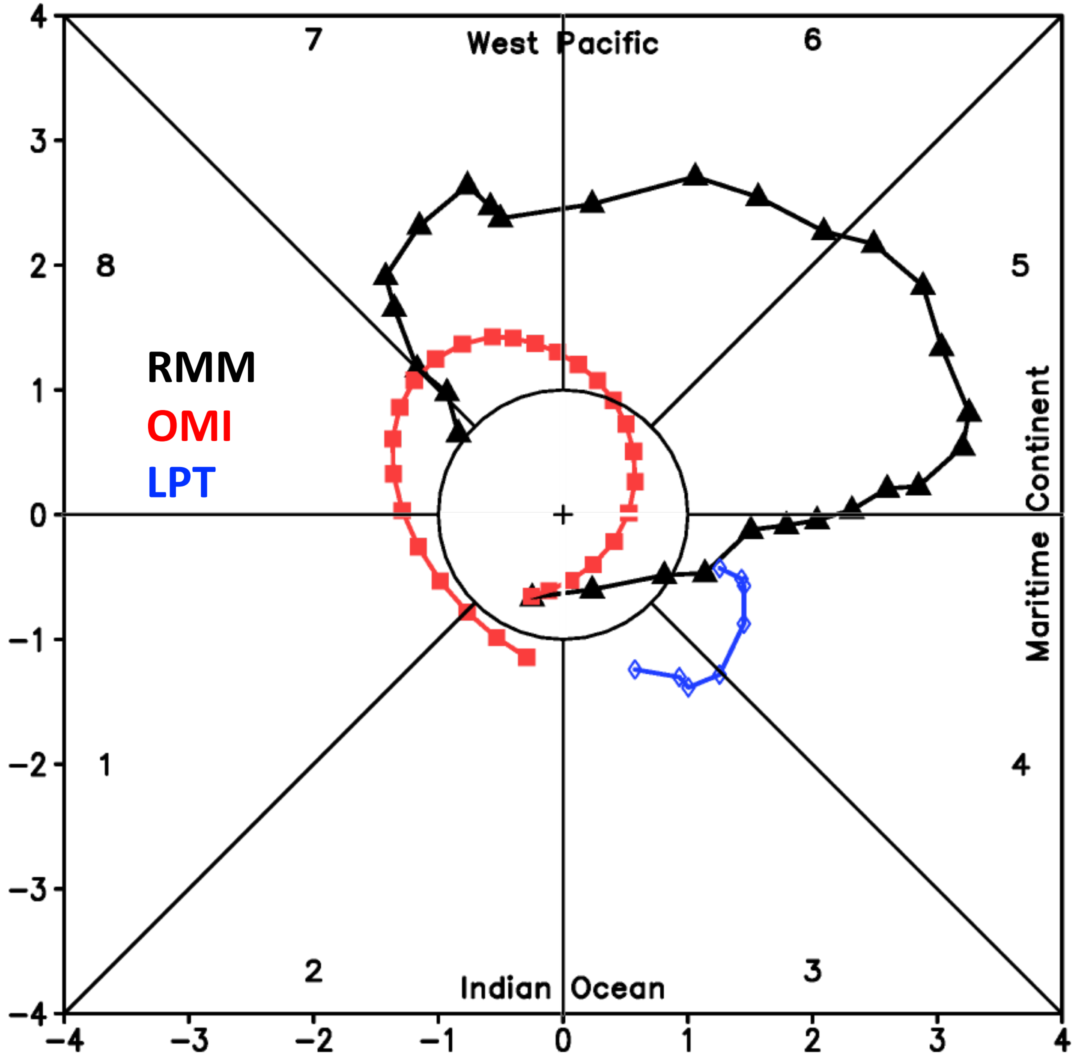


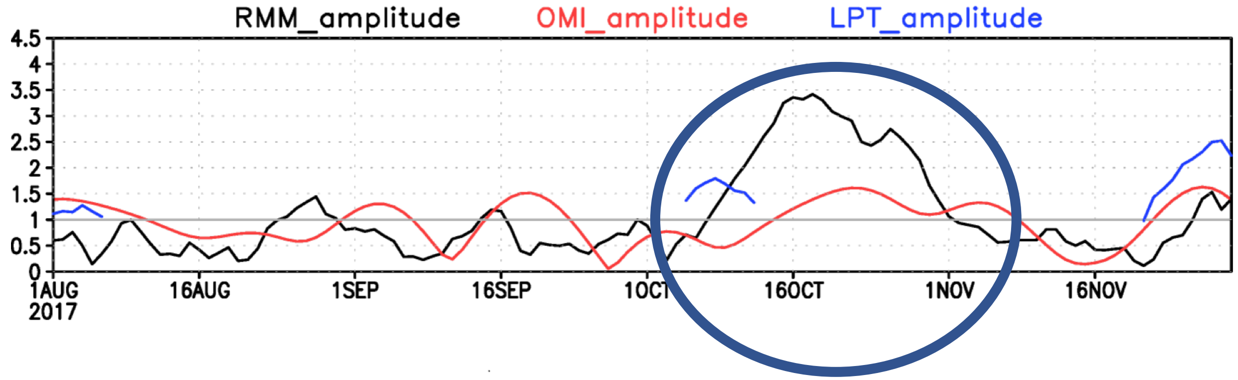
- **RMM**: Winds and convection; Global modes; No intraseasonal filtering
- **OMI**: Convection; Global modes; Intraseasonal filtering
- **LPT**: Convection; No intraseasonal filtering

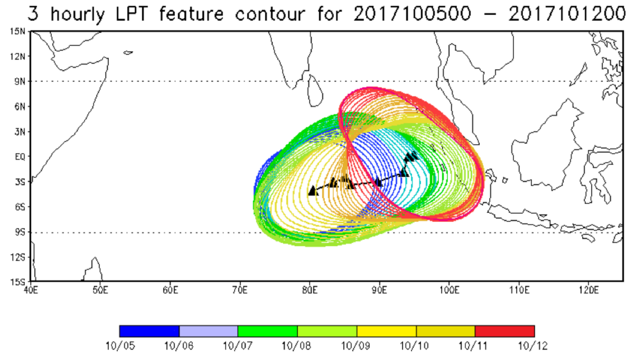
- Periods of reasonable correspondence among three indices, e.g., Jan-Feb 2017, 2018
- Periods of good correspondence between RMM and OMI, e.g., Nov 2019
- Periods of mismatch among indices
  - Jan-Feb 2020: Strong RMM, weak OMI, missing LPT
  - Oct 2017: Strong RMM, Short LPT, weak OMI
  - Feb-Mar 2019: Shorter RMM and OMI, longer LPT

LPT provides important convection information on MJO activities.

Comparison for individual cases
Observation (Oct 5-22, 2017)

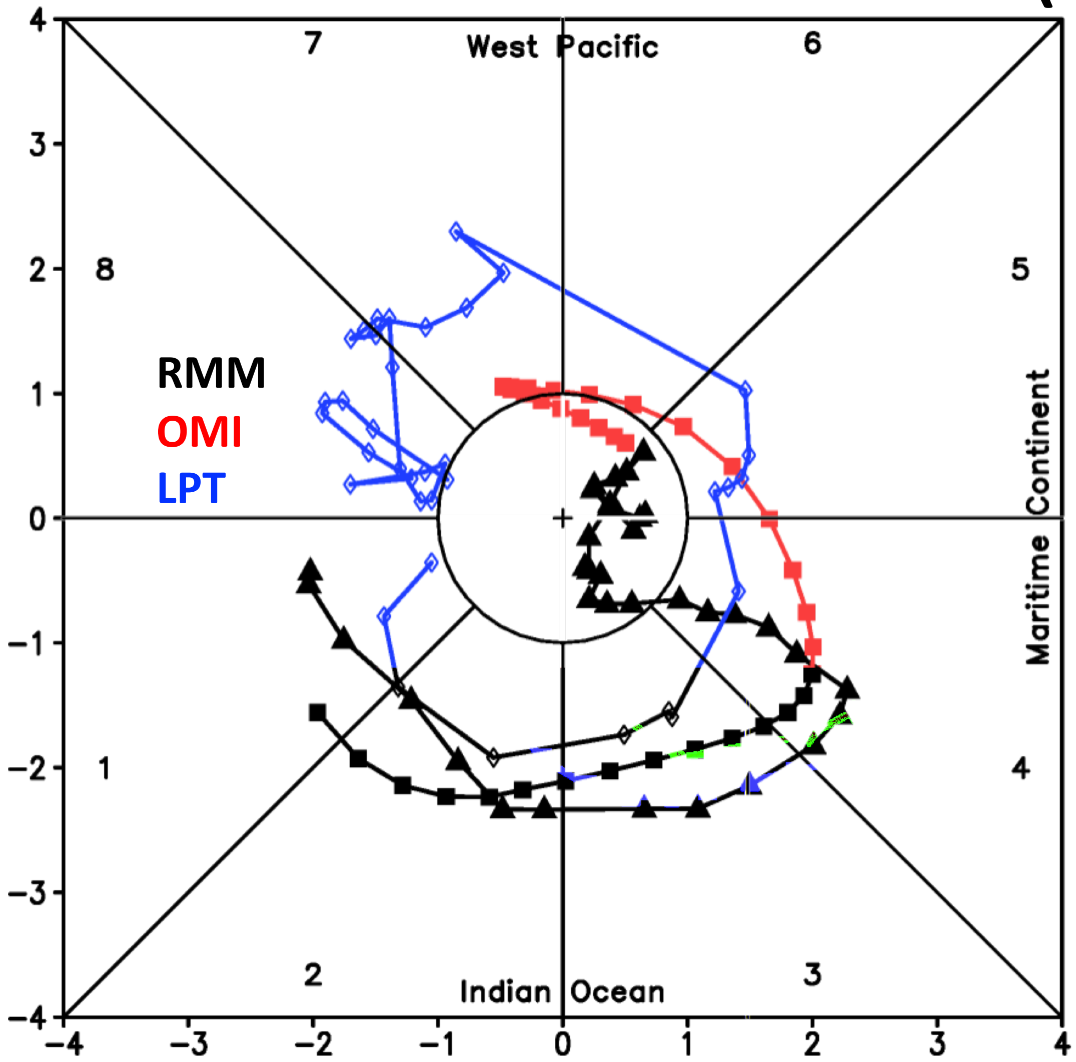


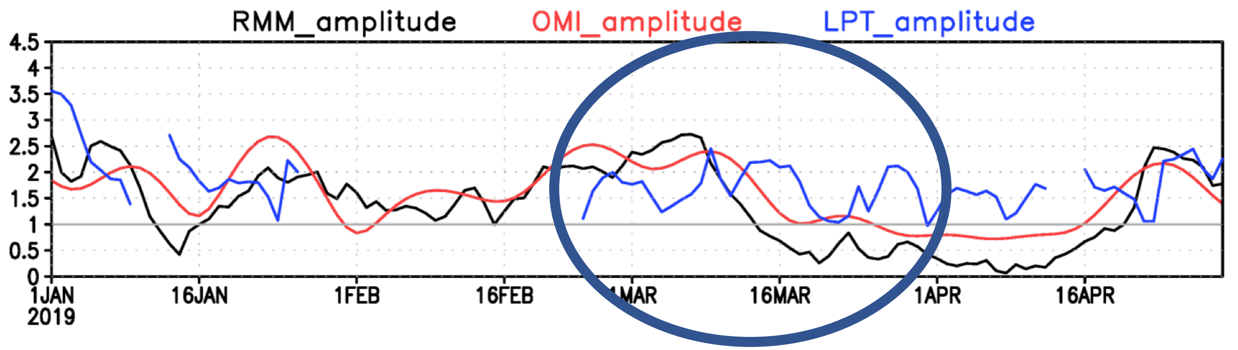


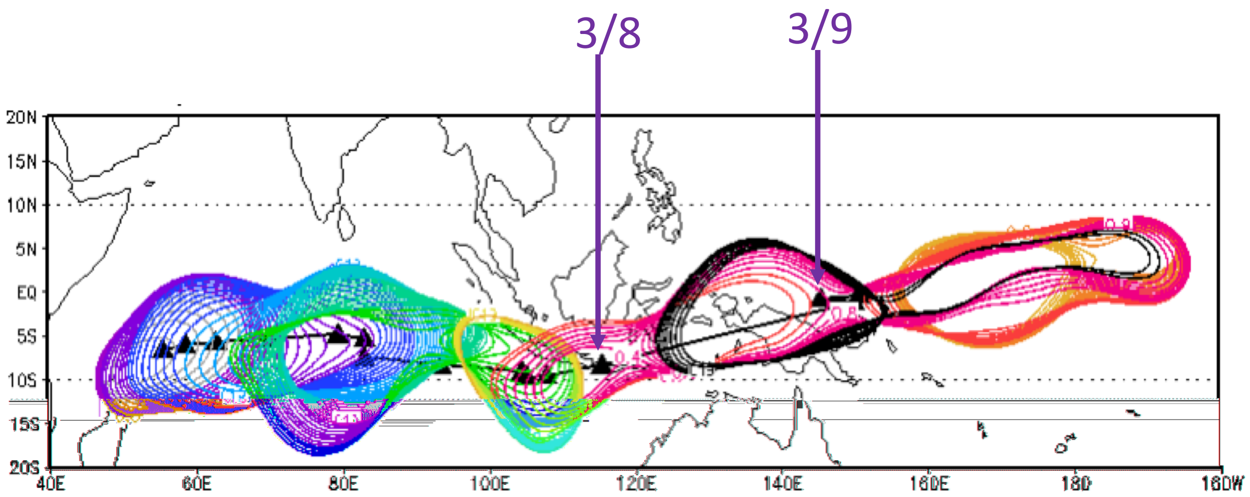


- Strong MJO signal in RMM
- Weak MJO signal in OMI when RMM signal weakened
- Much shorter MJO signal in LPT when RMM amplified

Comparison for individual cases Observation (Feb 24 – Mar 31, 2019)

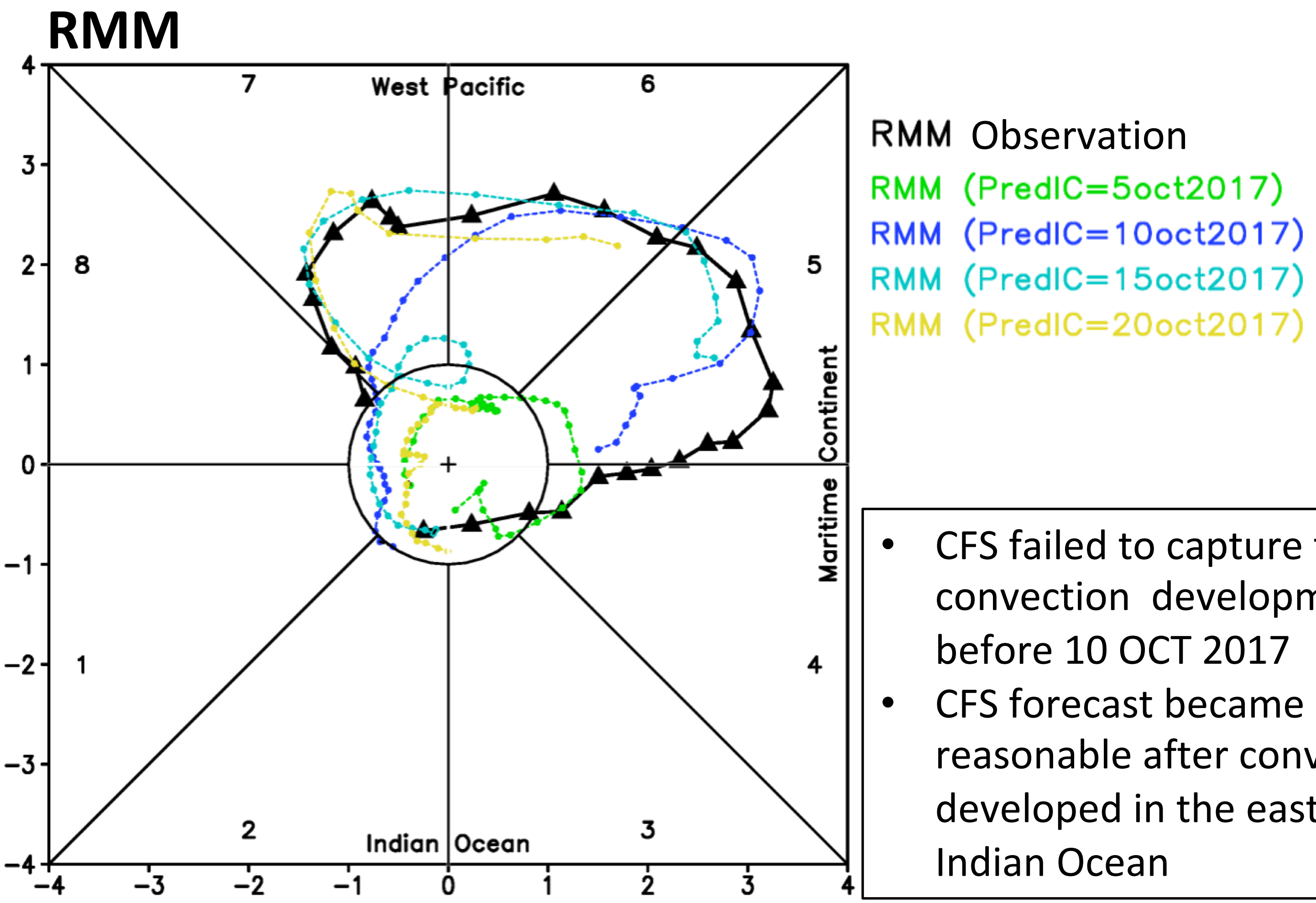




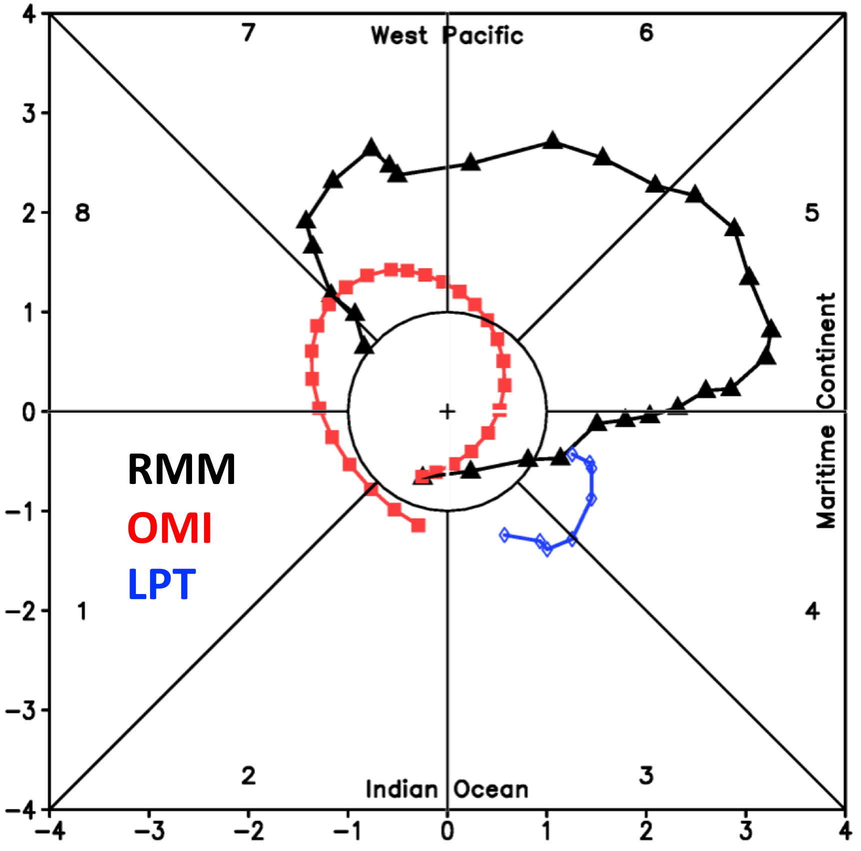


- LPT showed two convection episodes
- Only the first episode is seen in RMM
- Longer MJO period in OMI than in RMM

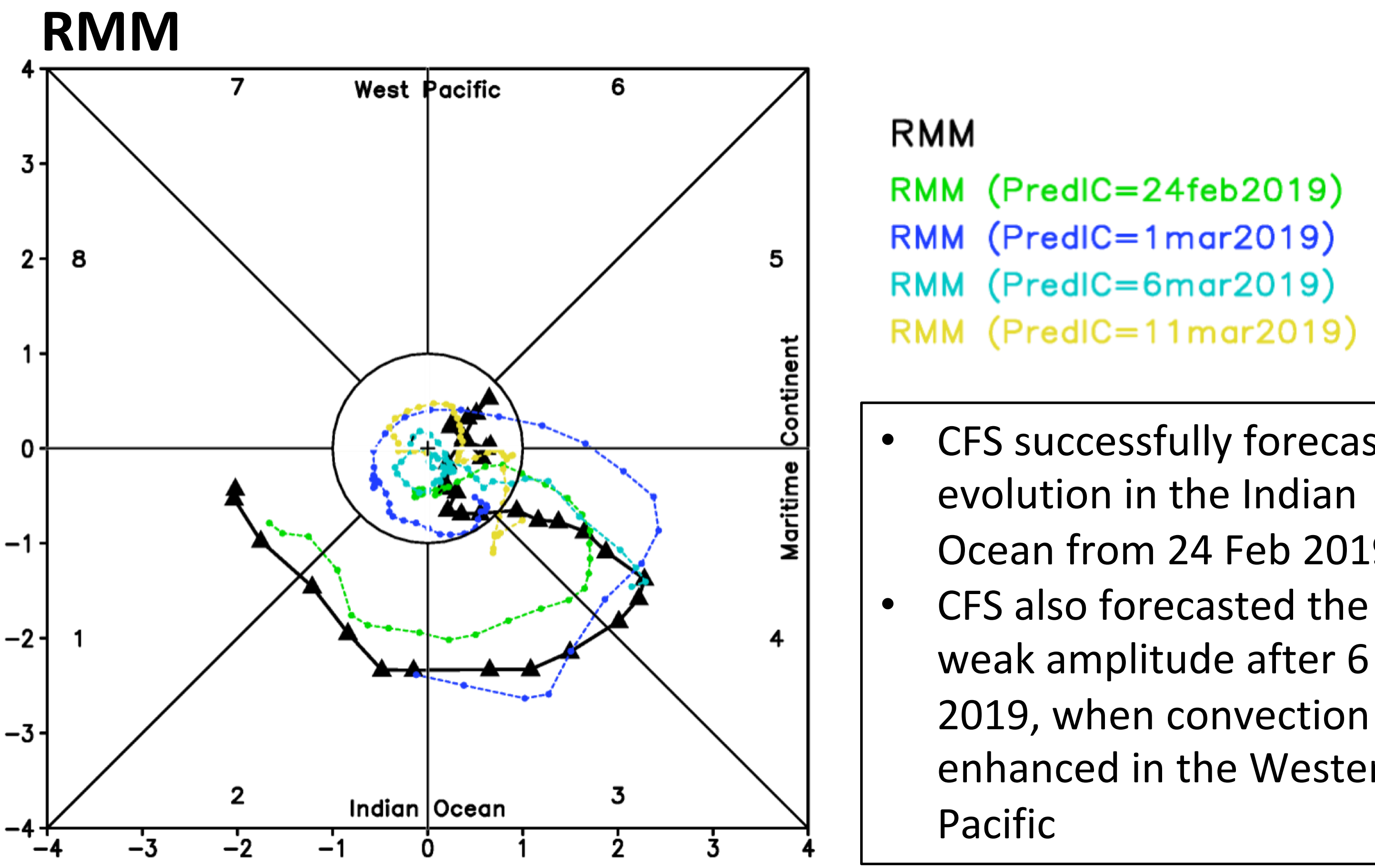
Comparison for individual cases Forecast (Oct 5-22, 2017)



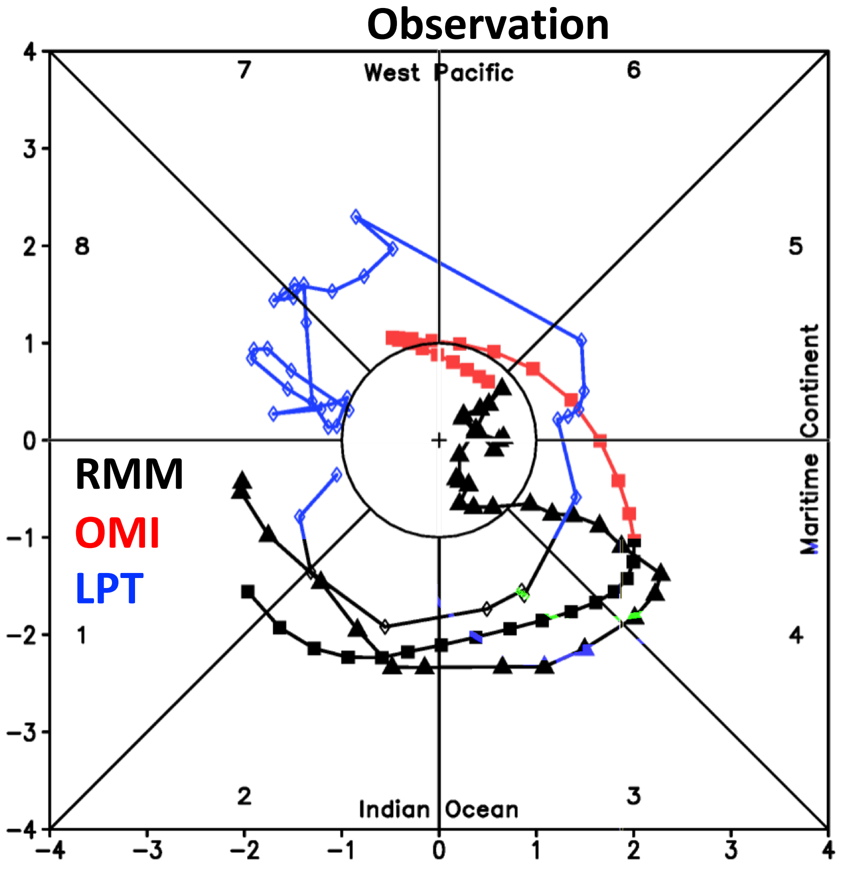
- CFS failed to capture the convection development before 10 OCT 2017
- CFS forecast became more reasonable after convection developed in the eastern Indian Ocean



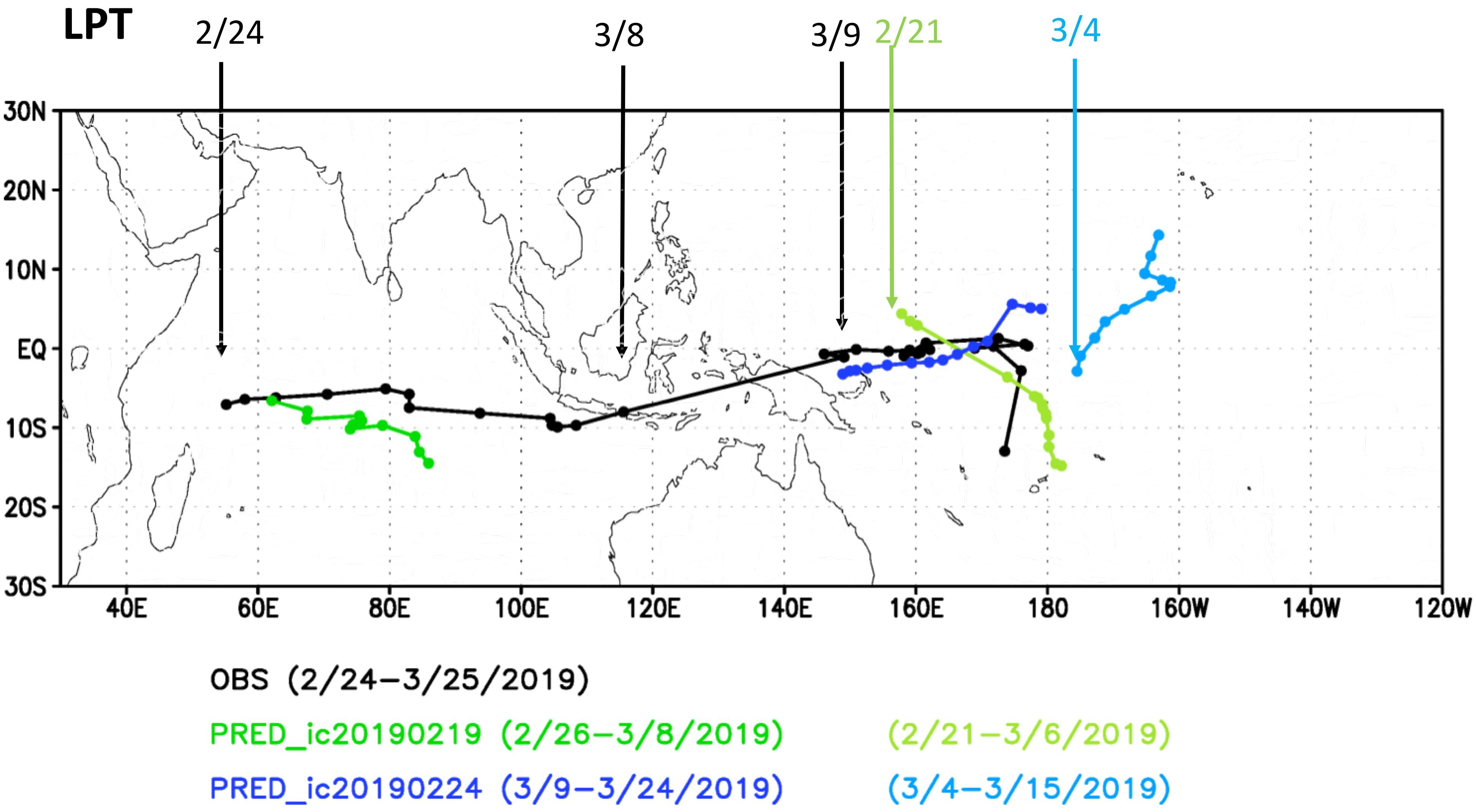
Comparison for individual cases Forecast (Feb 24 - Mar 31, 2019)



- CFS successfully forecasted evolution in the Indian Ocean from 24 Feb 2019
- CFS also forecasted the weak amplitude after 6 Mar 2019, when convection was enhanced in the Western Pacific



Comparison for individual cases Forecast (Feb 24 Mar 31, 2019)

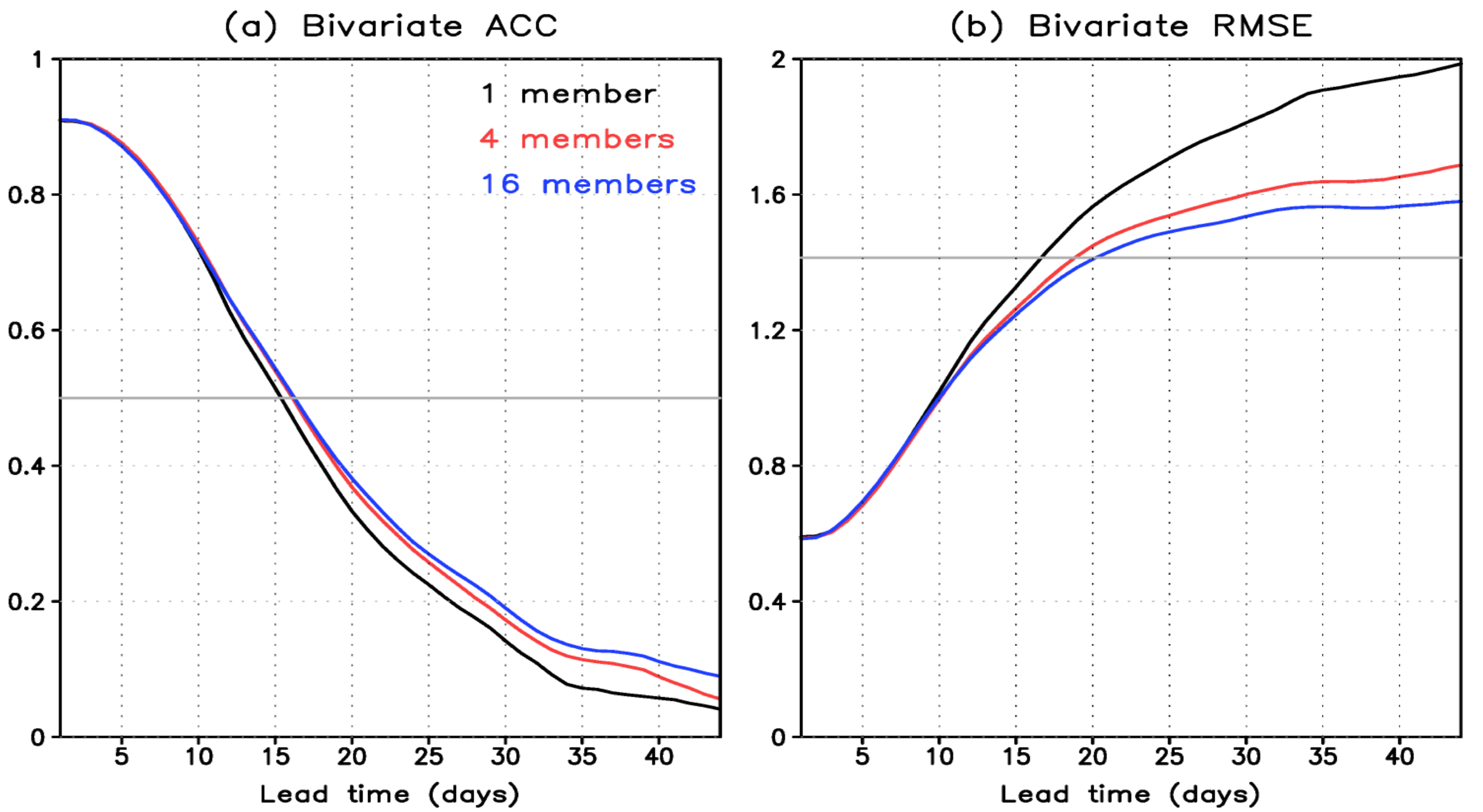


- CFS from Feb 19 forecasted parts of the evolution in the central Indian Ocean. The LPT in the Western Pacific developed too early, though.
- CFS from Feb 24 forecasted parts of the evolution in the Western Pacific. with a false alarm LPT to the east of Date Line.

5. Evaluation of forecast skill of LPT and RMM

- RMM
  - ACC/RMSE
  - HSS
- LPT
  - HSS
  - Impact of precipitation threshold

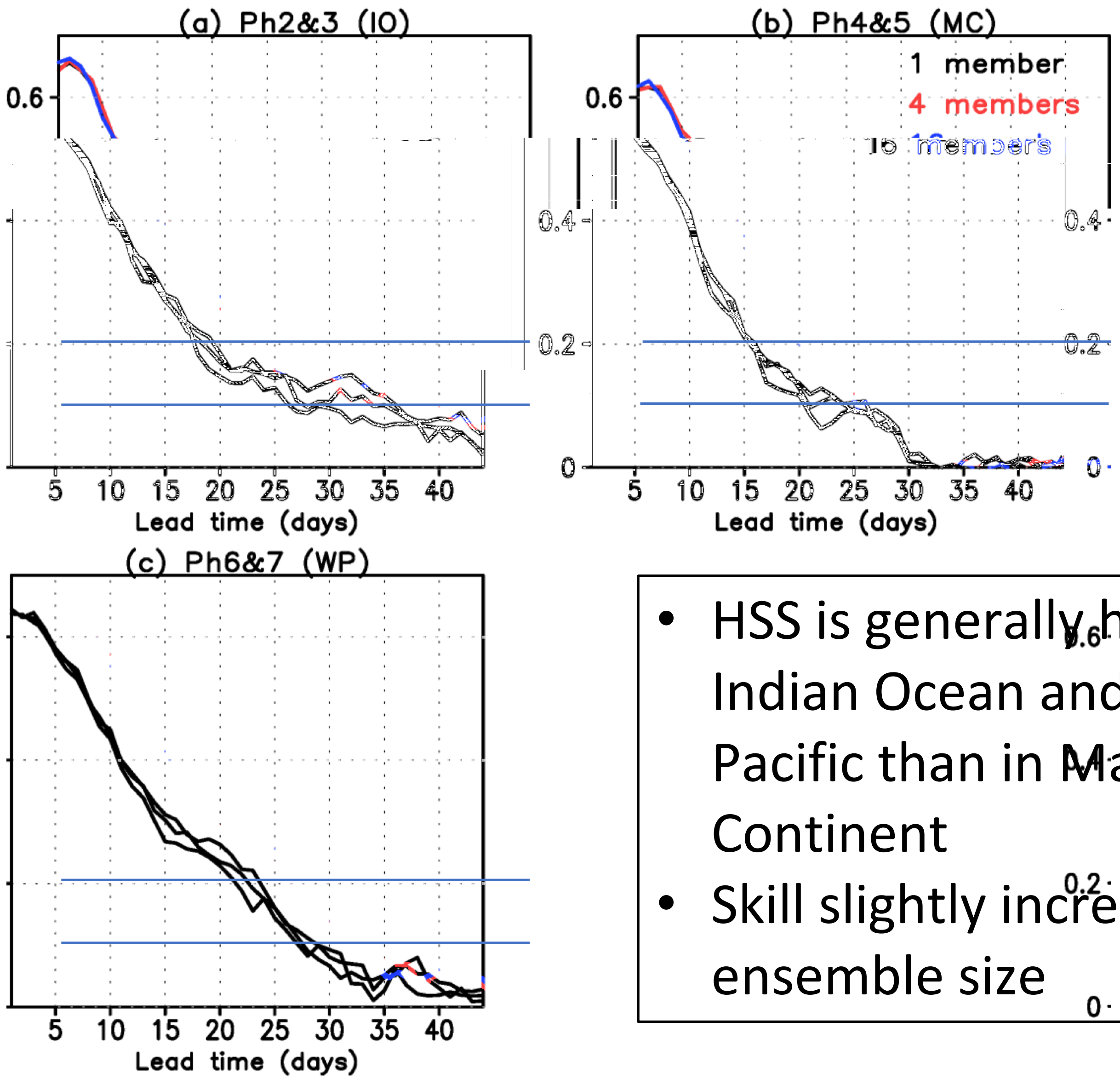
RMM prediction skill during 2012-2020



- ACC decreases to 0.5 at days 15-16; RMSE increases to 1.414 at days 16-20
- Skill improves with ensemble size at longer lead time

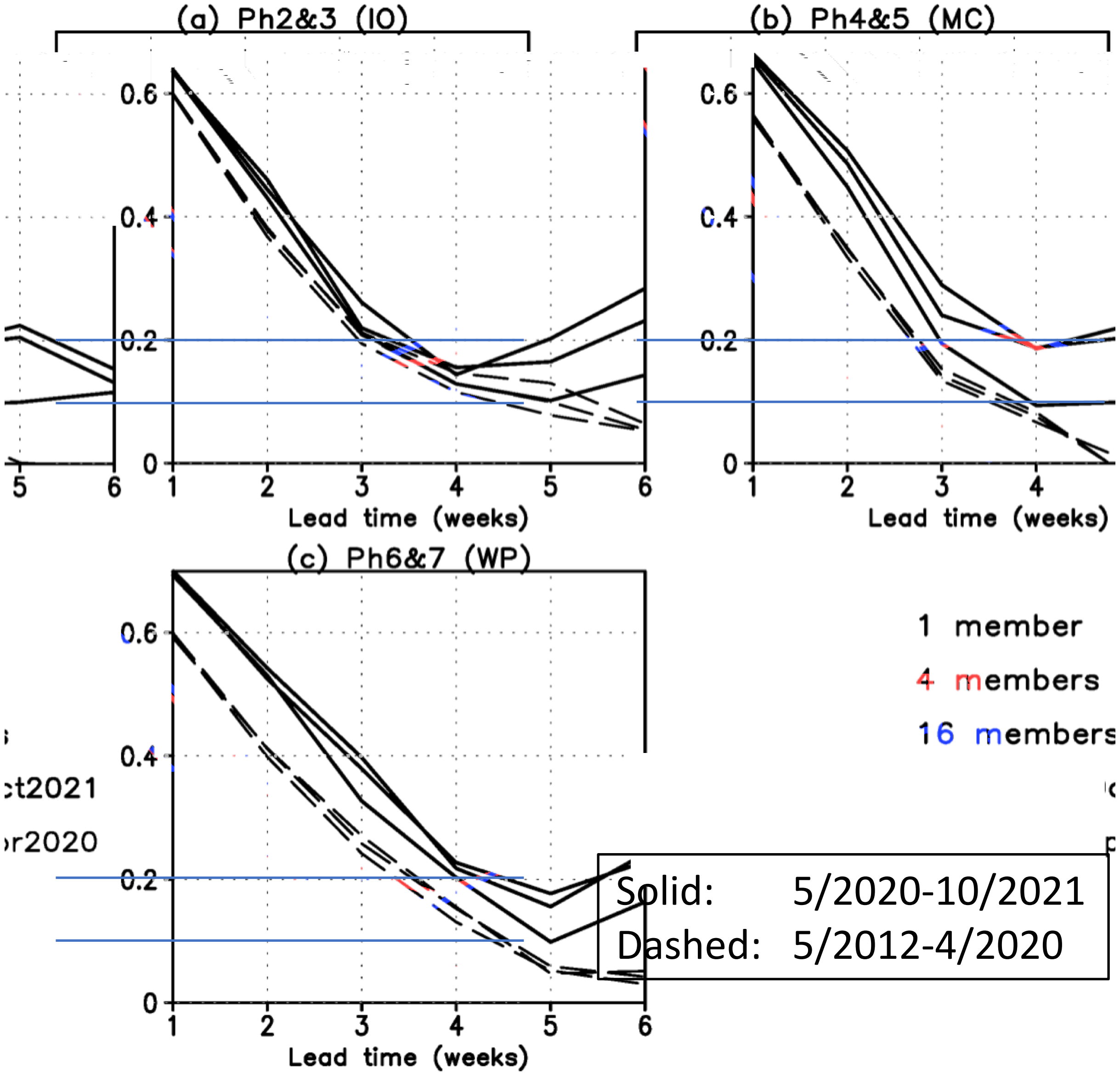
Verified against R1-based RMM (from BOM)

RMM prediction skill during 2012-2020: Heidke Skill Score



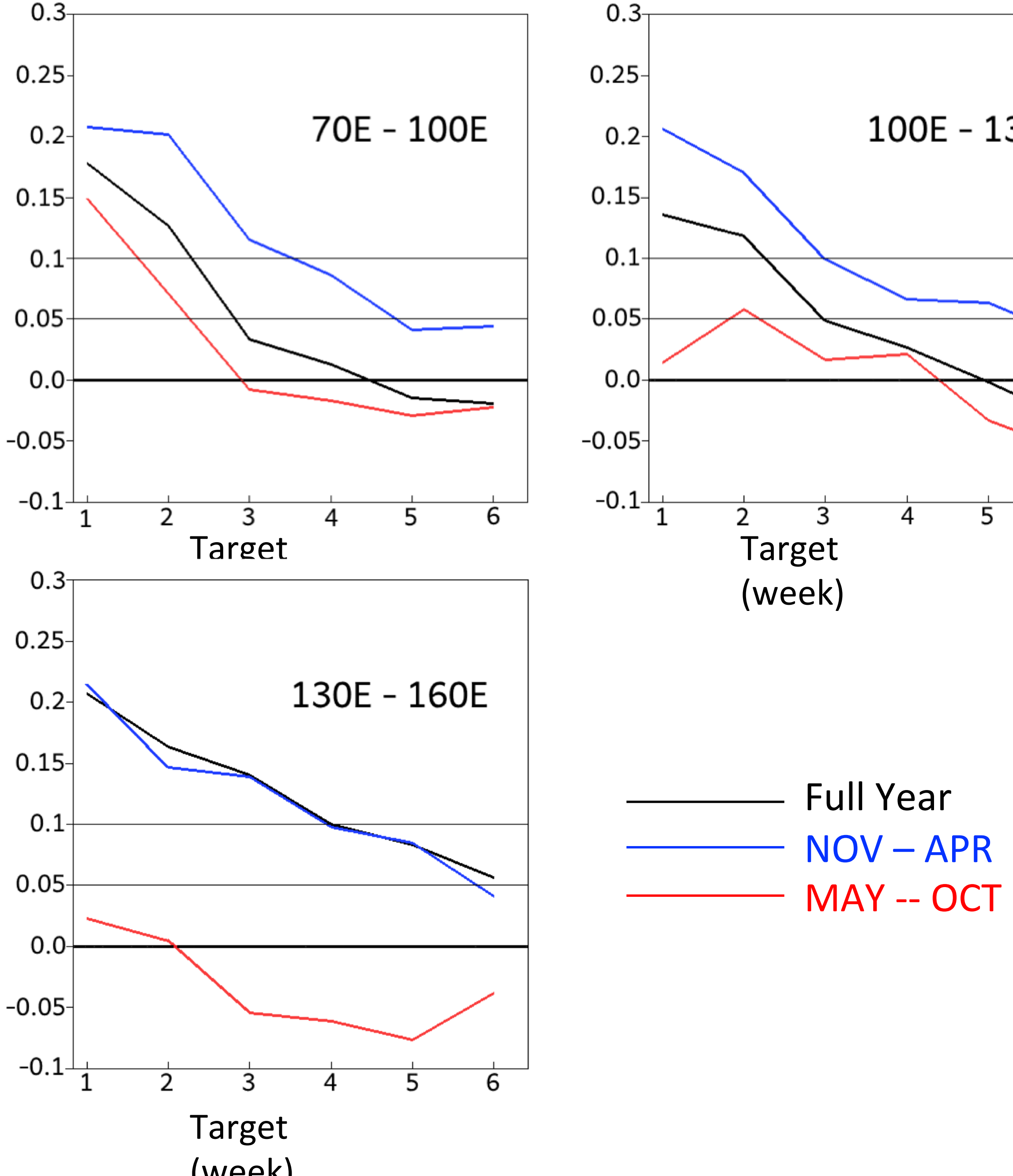
- HSS is generally higher in Indian Ocean and Western Pacific than in Maritime Continent
- Skill slightly increases with ensemble size

RMM prediction skill: Heidke Skill Score



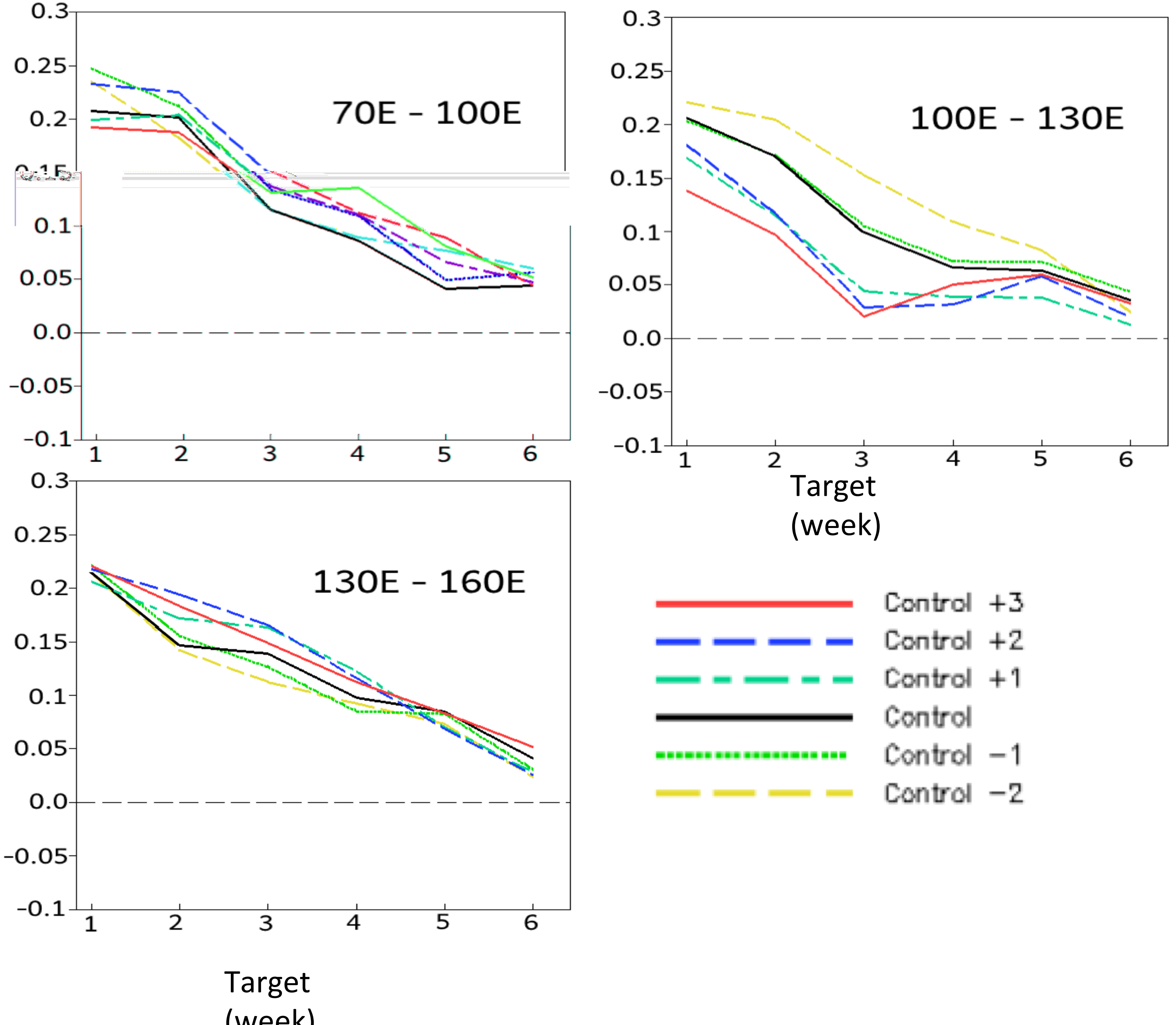
- HSS is generally higher in Indian Ocean and Western Pacific than in Maritime Continent for May 2021-Apr 2020
- Skill for latest years higher
- Impact of ensemble size

LPT prediction skill during May 2012-Apr 2020: Heidke Skill Score



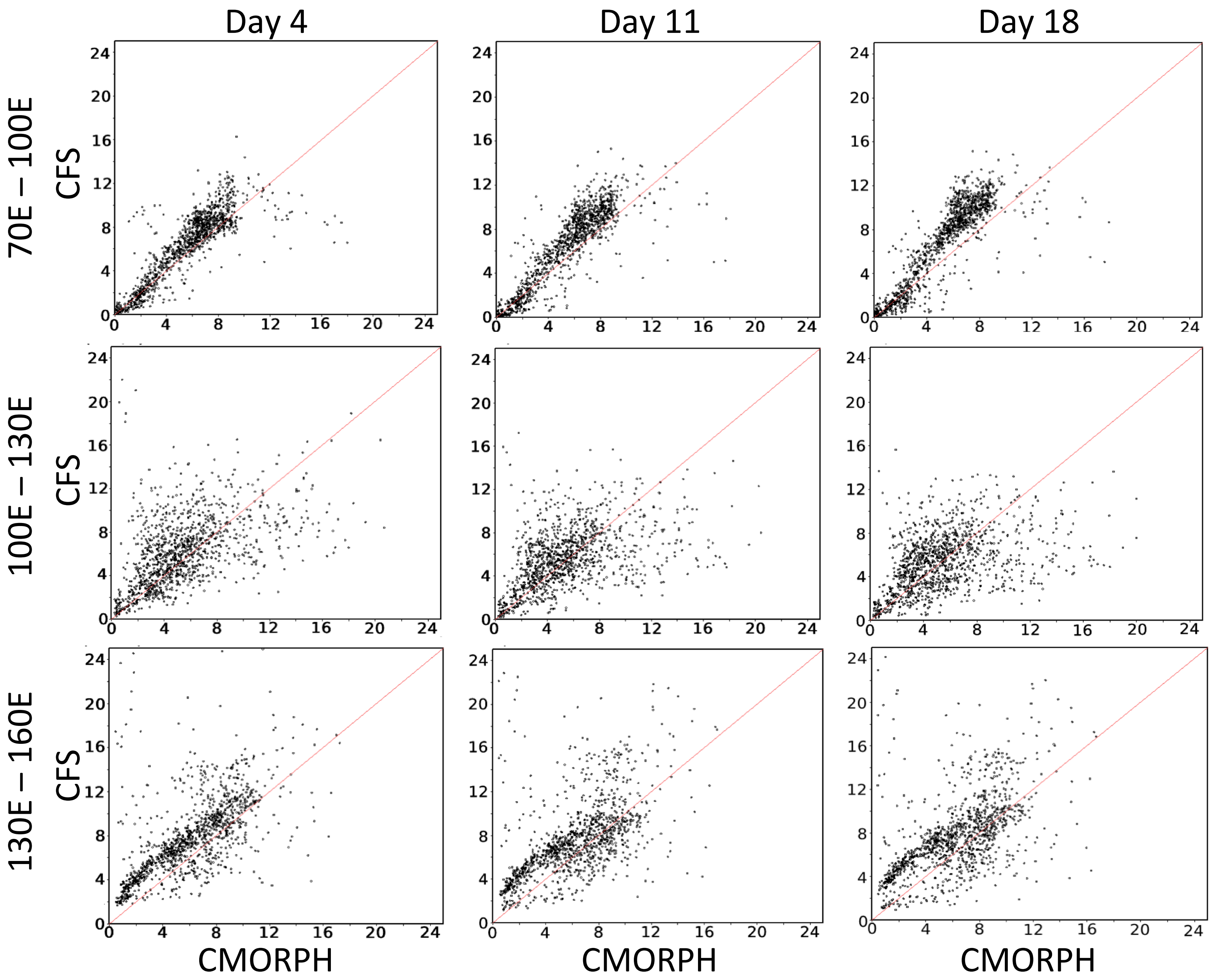
- Strong seasonality in LPT HSS skill, higher skill during boreal winter than during boreal summer
- During boreal winter, the skill is highest in Western Pacific and lowest in Maritime Continent for most of the target period

LPT prediction skill: Impact of precipitation threshold (201205 --- 202004 NOV -- APR)



- Use of alternative threshold values may lead to better forecasts
- The optimal threshold is lead-time dependent
- Overall, a higher (lower) threshold would result in better forecast skill for Indian Ocean and Western Pacific (Maritime Continent)

Precipitation bias in CFS (Nov – Apr)



- Bias is lead-time and amplitude dependent
- CFS rainfall tends to be higher for larger rainfall rate in Indian and western Pacific Oceans
- CFS rainfall tends to be lower for large rainfall rate in over Maritime Continent
- A lead time and amplitude dependent rainfall bias correction is required to improve LPT forecast

6. Future work

- Bias correction to forecast rainfall
  – PDF correction/quantile mapping before LPT processing
- Ensemble CFS forecasts
  – Include 16 daily forecast runs
  – Tracking from each member
  – LPT tracking density
- Addition of other models
  – GEFS12
- Improve real-time display
  – Addition of phase diagrams
  – Evolution of tracking areas

7. Summary

- A LPT method was developed and demonstrated for real-time monitoring and CFS forecast
- The LPT is being tested at CPC
- Preliminary evaluation indicates the impact of precipitation threshold on LPT forecast and the need for bias correction in CFS
- Future work required to further enhance the real-time application