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

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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° × 5°) area of > 12 mm day⁻¹ (> 250,000 km²)
- **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)
Traditional RMM index cannot provide spatial and temporal variation of the MJO.

LPT is used to track MJO precipitation. (Kems and Chen 2016)
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Challenge: majority of NWP and climate models cannot reproduce MJO precipitation patterns.
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 LPT System Tracks: 1998 - 2018 (DJF)
(N = 73)

MJO LPT System Tracks: 1998 - 2018 (JJA)
(N = 69)
Boreal Winter
Oct - Mar

Boreal Summer
Apr - Sep

Savarin and Chen (2018, AGU)
20 Year Climatology of Westward LPTs

Westward LPT System Tracks: 1998 - 2018
(N = 454)

Westward LPTs Track Density: 1998 - 2018
Contours every 5 2.5 deg. boxes
Seasonality of Westward LPTs

Westward LPT System Tracks: 1998 - 2018 (DJF)
(N = 126)

Westward LPT System Tracks: 1998 - 2018 (JJA)
(N = 166)
Evaluation of ECMWF 20 years S2S reforecasts

- Very good overall MJO numbers
- Poor MJO convective initiation timing over Indian Ocean
- Little skill in convection over the Maritime Continent
- Double ITCZ problem
No skill over the Maritime Continent
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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- **Experiments:**
  - **CTRL**
  - **FLAT:** MC terrain leveled to 10 m, land use 100% evergreen rainforest

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![Map Diagram](image-url)
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• **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.
High resolution atmosphere-ocean coupled modeling for high impact weather – the MJO

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

Oceanic convection with night-morning maximum!
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.