WGNE MJO Task Force

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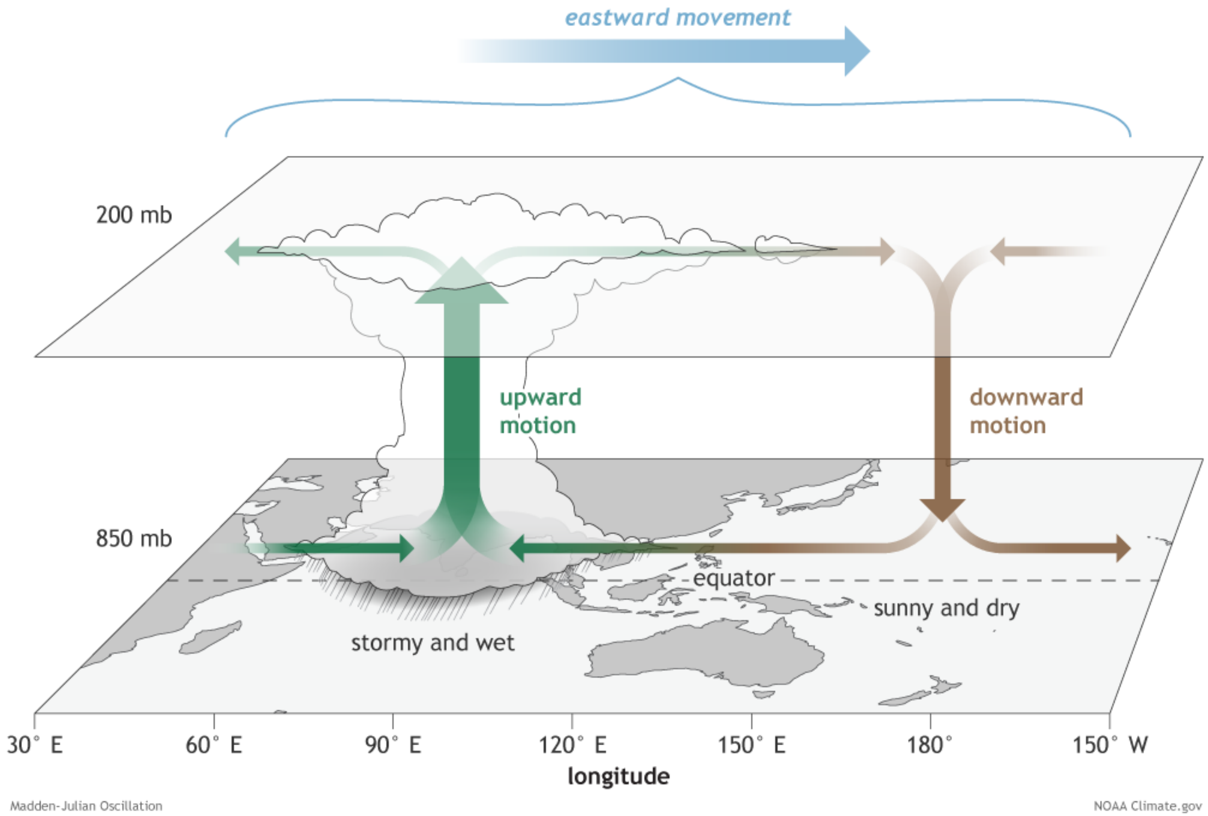
on Behalf of the WGNE MJO Task Force

WGNE-34, DWD, Offenbach

September 24, 2019

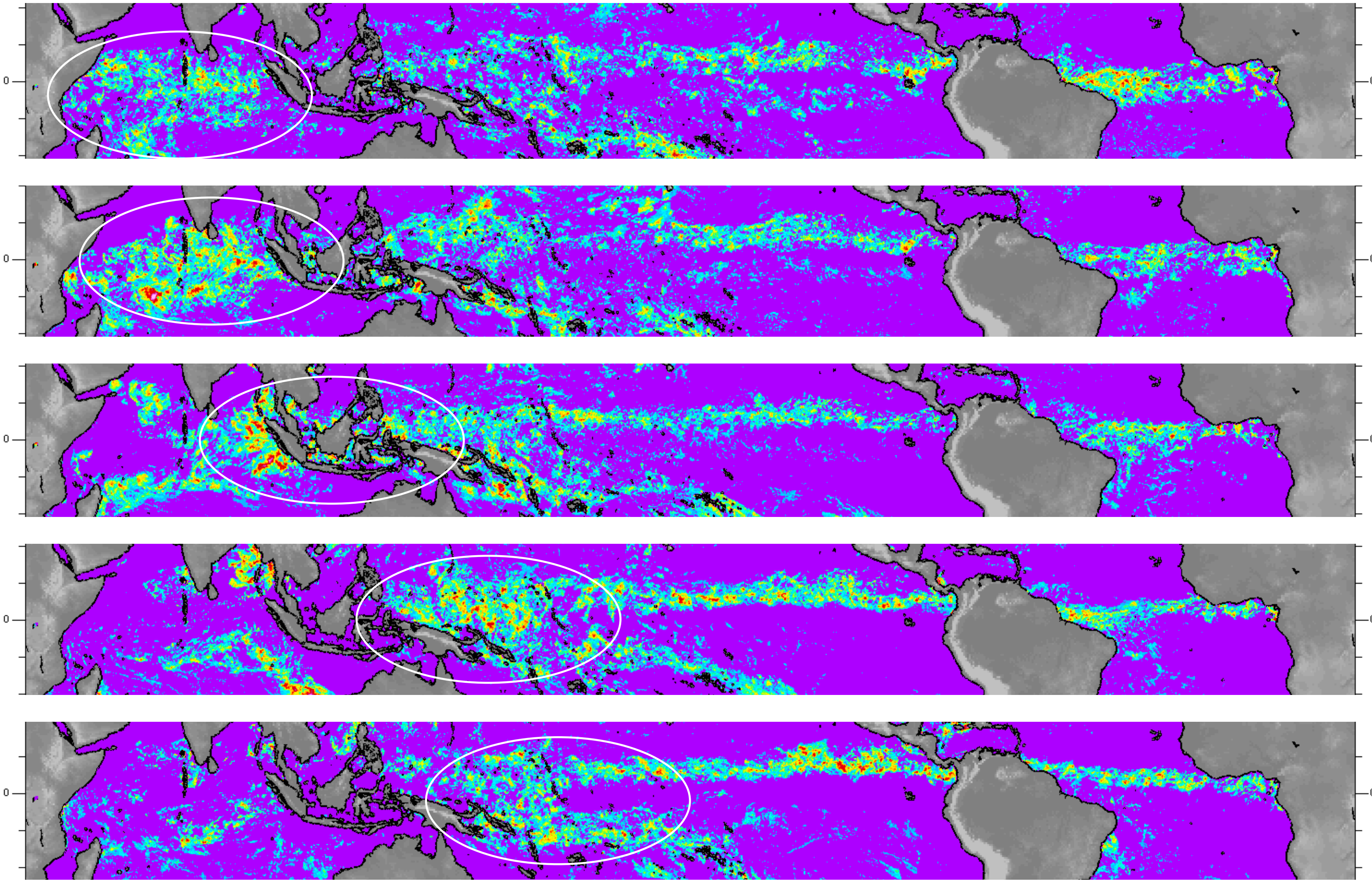
Madden-Julian Oscillation (MJO)

Rolald Madden

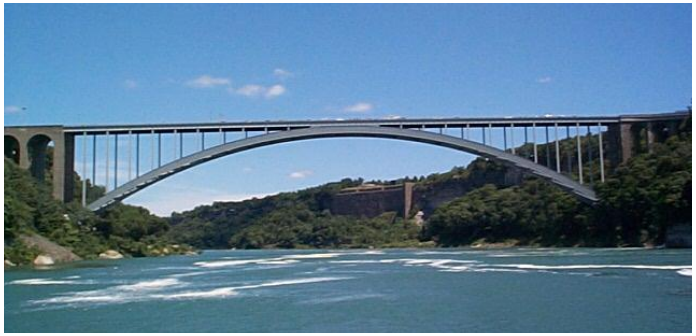


- Discovered in the early 70's by Madden and Julian
- Planetary-scale envelop of cumulus clouds that are coupled to circulation
- Propagates eastward at a 5 m/s phase speed over the warm pool
- Dominant mode of tropical intraseasonal variability that affects the global weather-climate-environment system (e.g., TCs, extreme precipitation events)

Satellite view of an MJO event (SSM/I Precip, April 20-May 25, 2002)



MJO provides the dominant source of predictability in the intraseasonal time scale, bridging the gap between weather and seasonal prediction



Weather forecast
(0-14 day)
- Atmospheric initial condition

Subseasonal prediction
(2-8 weeks)
- Madden-Julian Oscillation

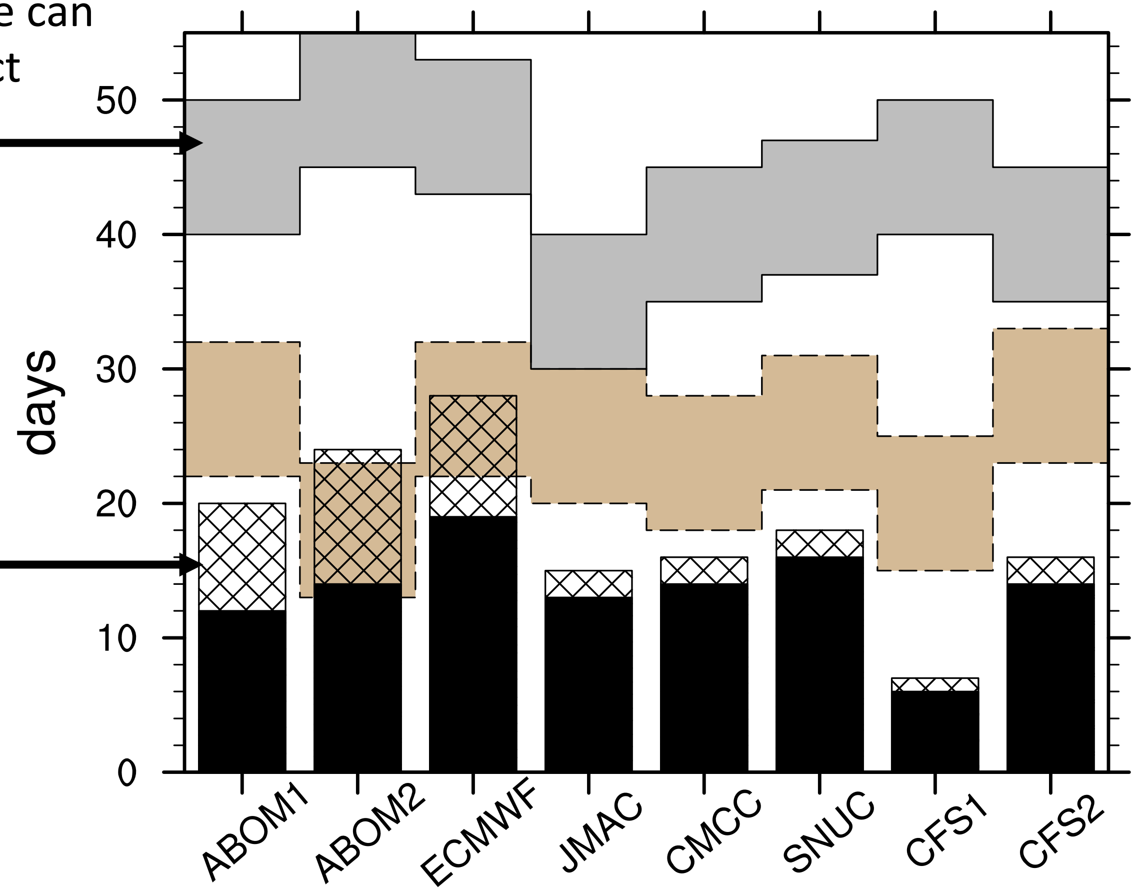
Seasonal prediction
(2-6 month)
- El Niño

Significant untapped predictability exists in the MJO prediction

(hypothetical) prediction skill we can achieve if our models are perfect

Untapped predictability due to model biases

Actual prediction skill



Neena et al. 2014

WGNE MJO Task Force

Goal

Facilitate improvements in the representation of the MJO in weather and climate models in order to increase the predictive skill of the MJO and related weather and climate phenomena.

Historical Background

- CLIVAR MJO working group (2006-2009)
- MJO Task Force established in 2010 within the framework of WCRP-WWRP/THORPEX YOTC activity (2010-2012)
- MJO Task Force was reformulated under WGNE in early 2013 (2013-present)

Members (as of September 2019)

Daehyun Kim[@]	University of Washington **(co-chair)**
Charlotte DeMott	Colorado State University **(co-chair)**
Samson Hagos	Pacific Northwest National Laboratory
Xianan Jiang[@]	University of California, Los Angeles
Hyemi Kim[@]	Stony Brook University
Nick Klingaman[@]	University of Reading
Tieh-Yong Koh	Singapore University of Social Sciences
Eric Maloney	Colorado State University
Adrian Matthews	University of East Anglia
Tomoki Miyakawa[@]	University of Tokyo
Richard Neale	National Center for Atmospheric Research
Donaldi Permana[@]	Badan Meteorologi, Klimatologi, dan Geofisika (BMKG)
Matthew Wheeler	Bureau of Meteorology
Steve Woolnough	University of Reading
Prince Xavier[@]	UK Met Office

[@]: joined as an early-career scientist

*WGNE MJO Task Force Website: http://wgne.meteoinfo.ru/activities/on-going-activities/wgne-mjo-task-force/

Goal

Facilitate improvements in the representation of the MJO in weather and climate models in order to increase the predictive skill of the MJO and related weather and climate phenomena.

Current Subprojects

- **MJO Mechanisms and Simulations**

  Develop diagnostics and experimental designs to elucidated key mechanisms for MJO and its simulation in models

- **MJO Prediction** (in collaboration with **S2S**)

  Perform evaluation of real-time forecasts and hindcasts of tropical intraseasonal variability, including assessment of hindcasts in the S2S model database

- **MJO-Extratropics Interactions** (in collaboration with **S2S**)

  Develop, coordinate, and promote analyses of MJO interactions with the extratropics in climate model simulations and hindcasts

- **MJO and the Maritime Continent** (in collaboration with **S2S** and **YMC**)

  Advance understanding of MJO interactions with the Maritime Continent (joint activity with S2S and YMC)

MJO Mechanisms and Simulations – Role of the Mean State

Action items

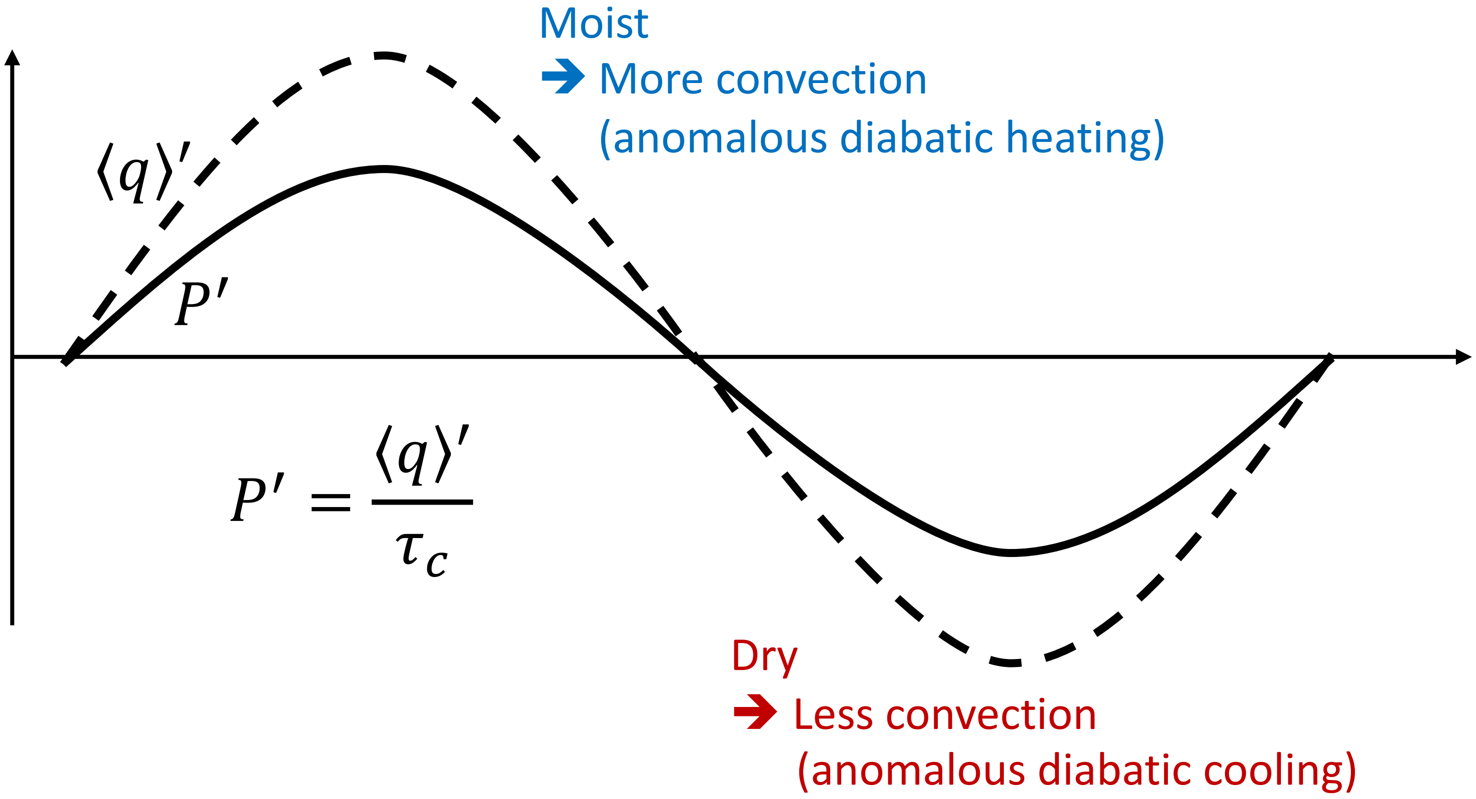
- Continue to develop diagnostics to elucidated key mechanisms for MJO and its simulation in models, including
  - Sensitivity to parametrized physics (including impact of explicit representations)
  - Role of air-sea interaction including biases in "coupling strength"
- Understanding interannual variability in MJO
  - Role of interannual modes of variability (ENSO, QBO)
  - Impact of simulated interannual variability on metrics of MJO activity

Accomplishments/Findings

- Models with a good representation of the mean moisture (gradients) tend to have a good simulation/prediction skill of the MJO (e.g. Jiang, 2017; Gonzalez and Jiang, 2017; Kim, H. 2017; Lim et al., 2018; Kim, H. et al. 2019)
  - Relation to moist static energy budget of the MJO and "moisture mode" theories for the MJO (Adames and Kim 2016)
  - Importance of horizontal advection of the mean moisture by the MJO winds in MSE budget
- Ocean feedbacks improve MJO propagation by affecting convective moistening profiles and sharpening meridional moisture gradients (DeMott et al. 2019; Kim, D. et al. in prep)

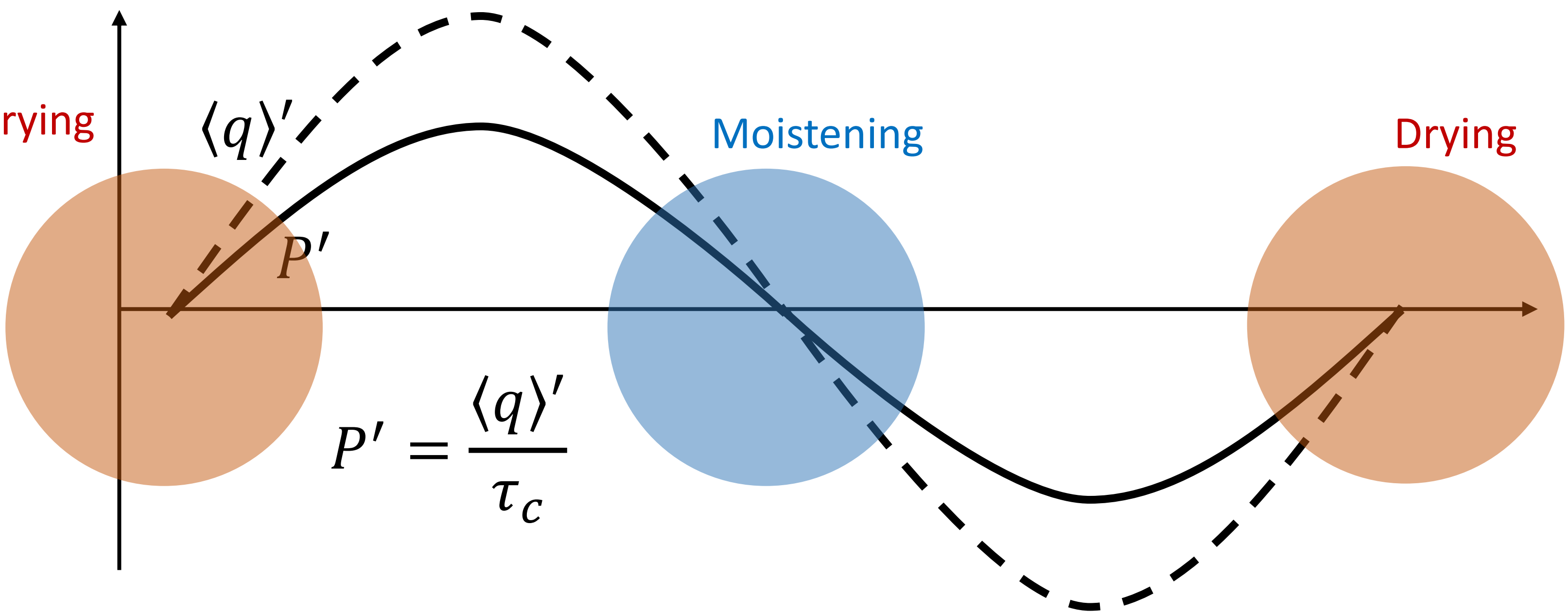
MJO as a "moisture mode"

1. Deep convection occurs preferentially over the area of high column moisture

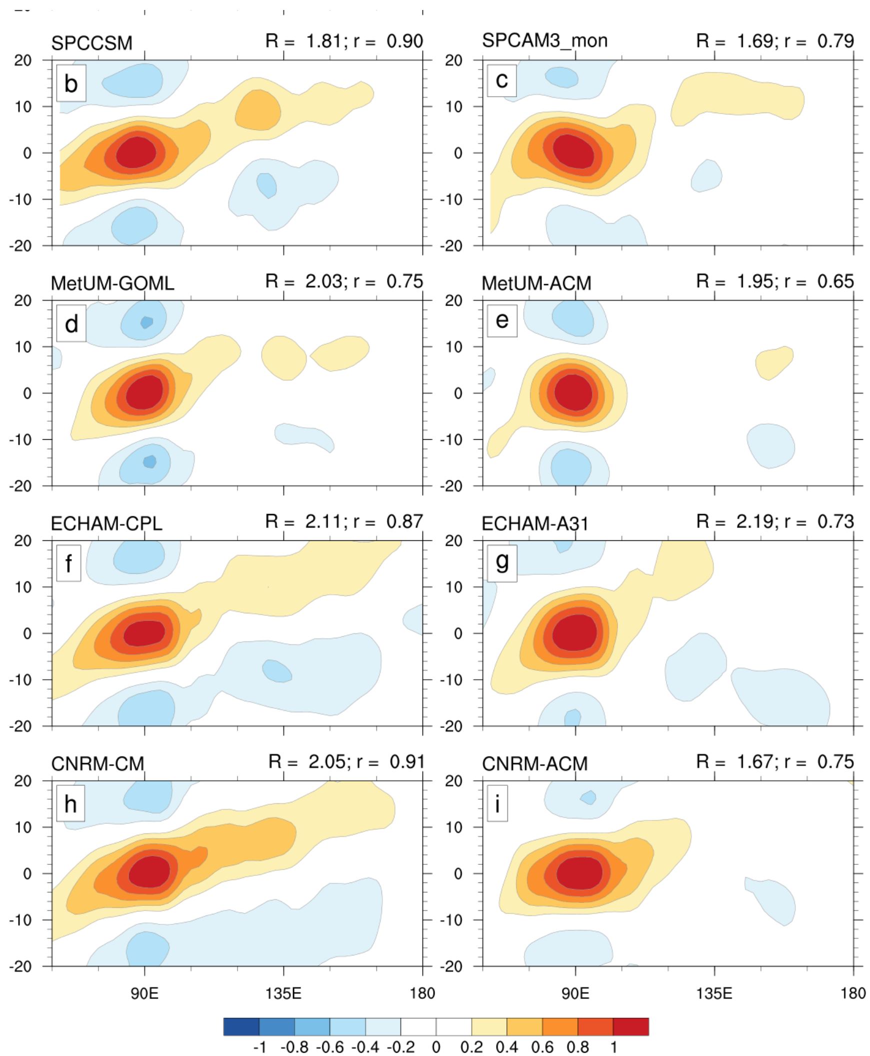


MJO as a "moisture mode"

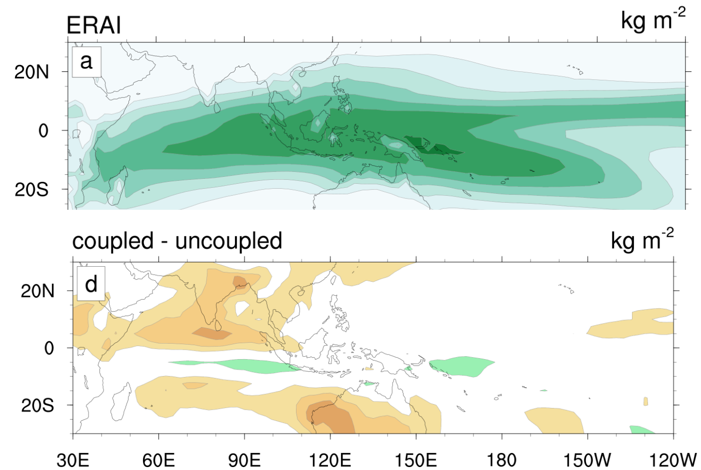
2. Tropical atmosphere responds to diabatic heating anomalies in the form of the Matsuno-Gill response, re-distributing moisture by acting upon the mean state moisture gradient



Coupled | Uncoupled



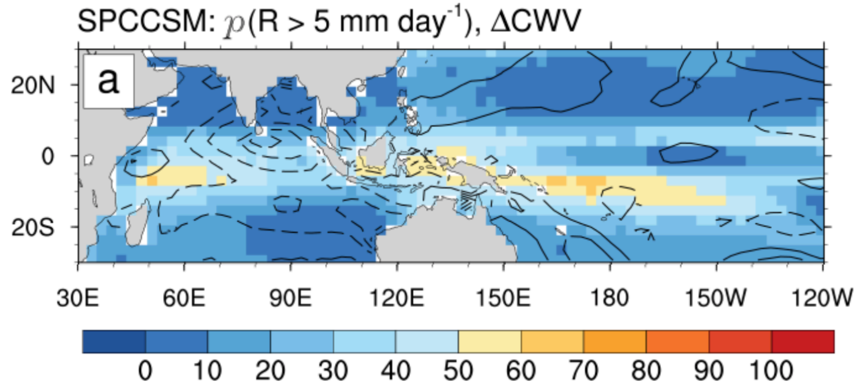
Mean CWV (Nov-Apr)



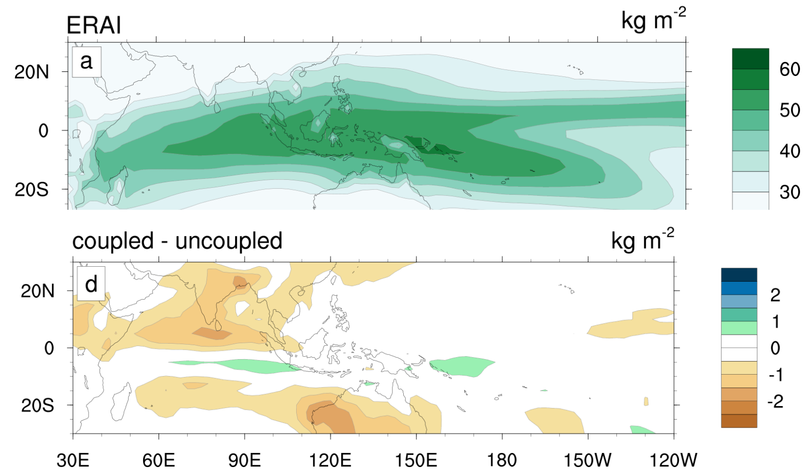
- monthly SSTs from CGCM prescribed to AGCM: identical SST climatology and low-frequency variability.
- coupling improves MJO propagation in all four models
- coupling sharpens meridional moisture gradients
- improved MJO propagation arises from enhanced meridional moisture advection

DeMott et al. (2019)

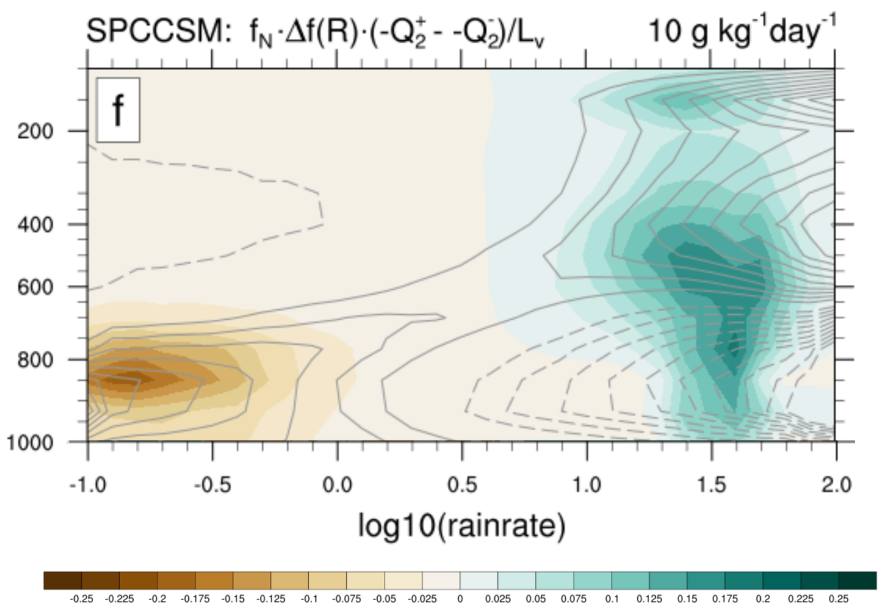
Coupled – Uncoupled: p(R > 5 mm/day)



Mean CWV (Nov-Apr)



Coupled – Uncoupled: Net moistening



- Coupling sharpens mean meridional moisture gradients, which aid MJO propagation.
- Coupling changes the distributions of rainfall rate and convective moistening (i.e., -Q2/Lv) such that low-level moistening is enhanced at high rainfall rates.
- High rainfall rates, and hence enhanced moistening, are most common near the Equator.

DeMott et al. (2019)

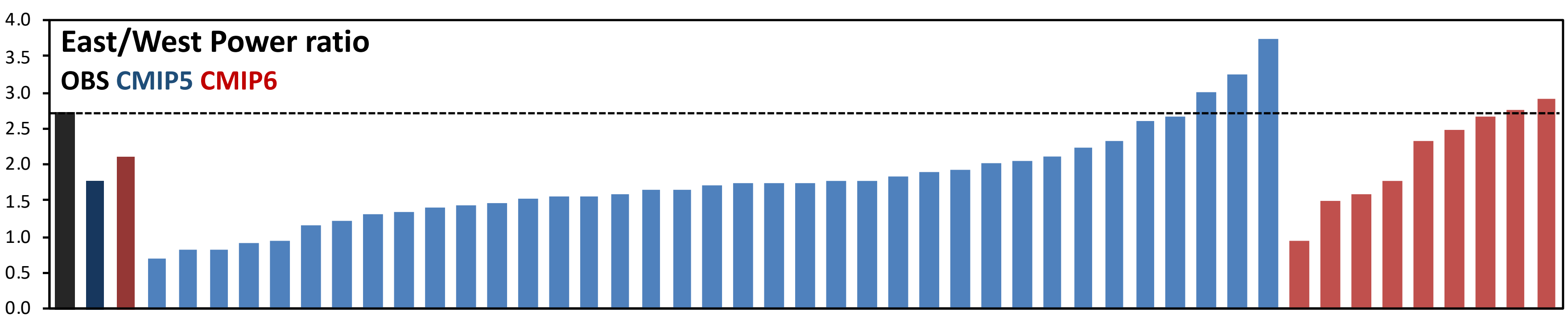
MJO Mechanisms and Simulations – Diagnostics and Evaluations

Action items

- Continue developing process-oriented MJO simulation diagnostics
- Application of existing and new process-oriented diagnostics and air-sea interaction diagnostics to CMIP6

Accomplishments/Findings

- Leading model analysis of MJO in CMIP6 models including application of MJO process diagnostics (Ahn, D. Kim et al. in prep)
- Collaborating with Peter Glecker's team at PCMDI in implementing basic MJO metrics into PCMDI Metrics Package
- Led the development of the MJO Diagnostics for the NOAA MAPP Model Diagnostics Task Force to develop and implement a process oriented model national modeling center diagnostics package



MJO Prediction

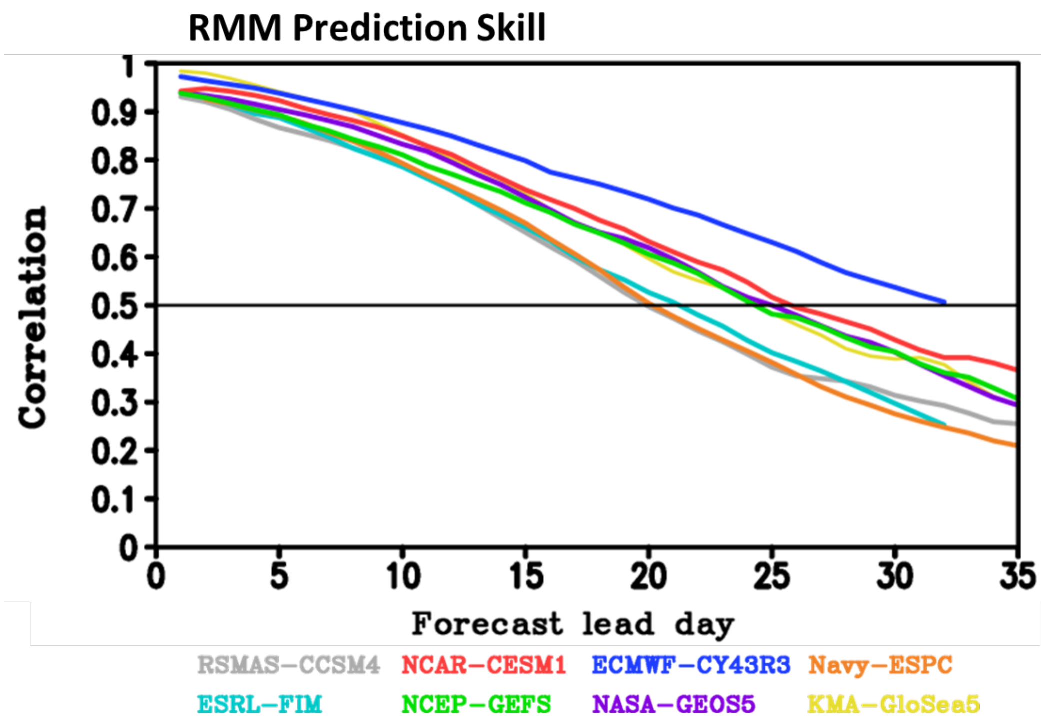
Action items

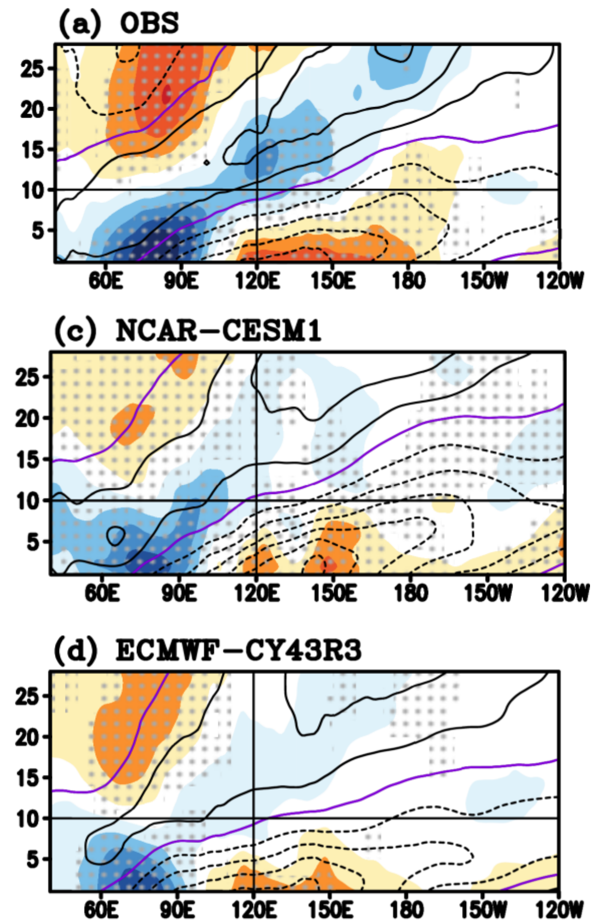
- Continued analysis of MJO Prediction skill and its dependence on variability of e.g. MJO, basic state; and model configuration
- Explore relationships between ensemble spread and skill
- Representation of MJO impacts in prediction systems

Accomplishments/Findings

- Participated in the development of global cloud resolving model and led its evaluation in terms of prediction skill (Satoh et al, 2017)
- Assessment of the MJO prediction skill in the S2S database (Lim et al 2018) and SubX (Kim, H et al. 2019), including the analysis of the relationship between prediction skill and the mean moisture and cloud long-wave feedback (Kim, H. 2017, Lim et al 2018; Kim, H. 2019)
- Led a review paper and book chapter on MJO prediction and predictability (Kim, H. et al. 2018)
    - Variable MJO prediction skill across models
    - MJO predictions are under-dispersive
    - Better skill for initially strong MJO events
    - Maritime Continent is probably a prediction barrier rather than predictability barrier

MJO prediction skill in S2S and SubX reforecasts

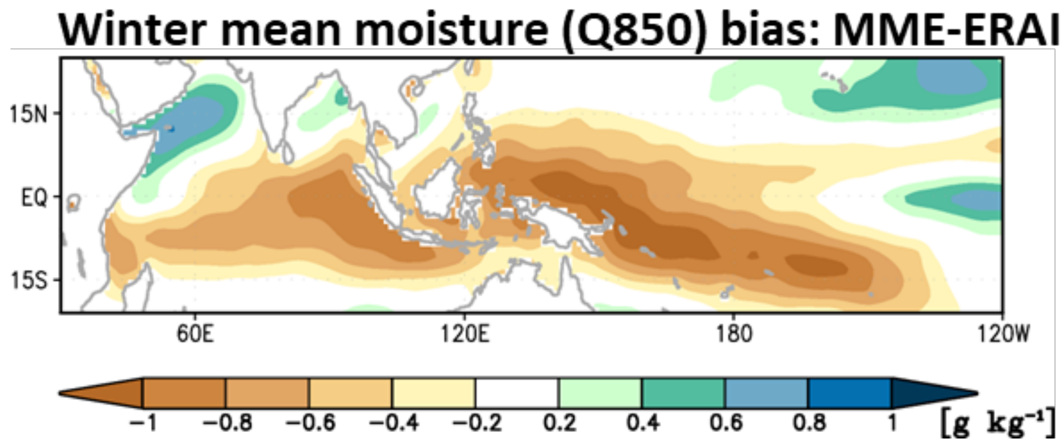


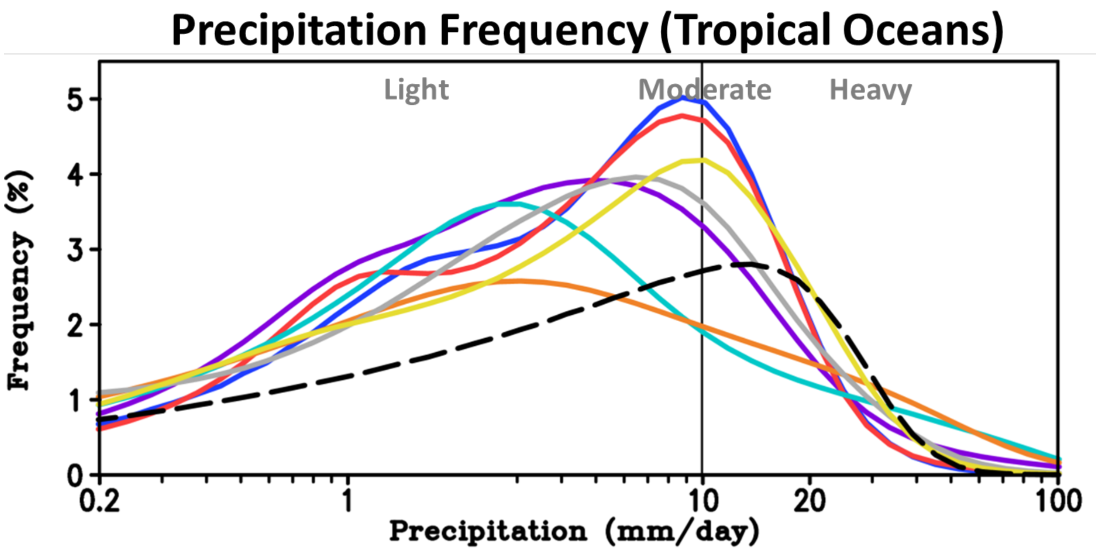


- Range of “skill” from 3-4.5 weeks
- Most models biased weak and slow

Kim, H. et al. (2019)

MJO prediction skill in S2S and SubX reforecasts





Kim, H. et al. (2019)

- Common biases in SubX and S2S reforecasts:
  - Convection starts too early in the low moisture regime
  - Light precipitation occurs too frequently
- Excess of surface precipitation & Drier lower troposphere

  ➔ Weaken the moisture advection process

  ➔ Weaken the MJO eastward propagation signal

  ➔ Limit MJO prediction skill

MJO and the Maritime Continent

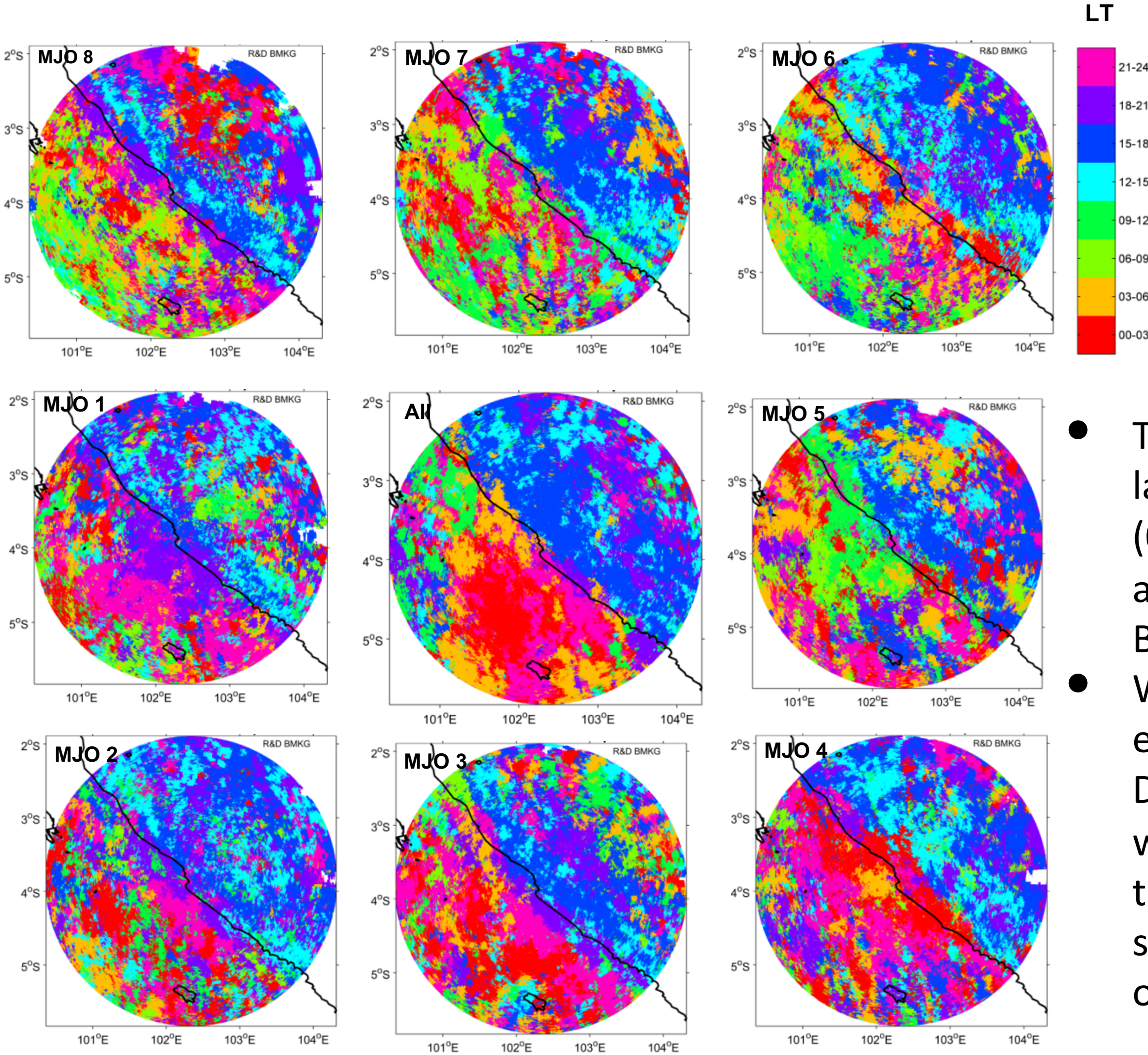
Action items

- Continued analysis of representation of key physical processes for simulation of MJO propagation in Maritime Continent
- Exploit observations and modelling efforts from YMC

Accomplishments/findings

- Leading ongoing or planned field campaigns within YMC activity
- Analysis multi-scale interactions between the diurnal cycle and MJO in BMKG radar observations (Permana et al. in prep)
- Interaction of the MJO with seasonal cycle and NE cold surges in the Maritime Continent (Lim et al, 2017; Xavier et al, 2019)
- Led a review book chapter on MJO interactions with the Maritime Continent for “The Global Monsoon” (Kim, D et al, in press)
- Sensitivity to strength of MC land convection in a GCM and relationship to mean moisture basic state (Ahn, D. Kim et al, accepted)
- Mechanistic Analysis and Experiments of MJO propagation through Maritime Continent (Neale et al. in prep)

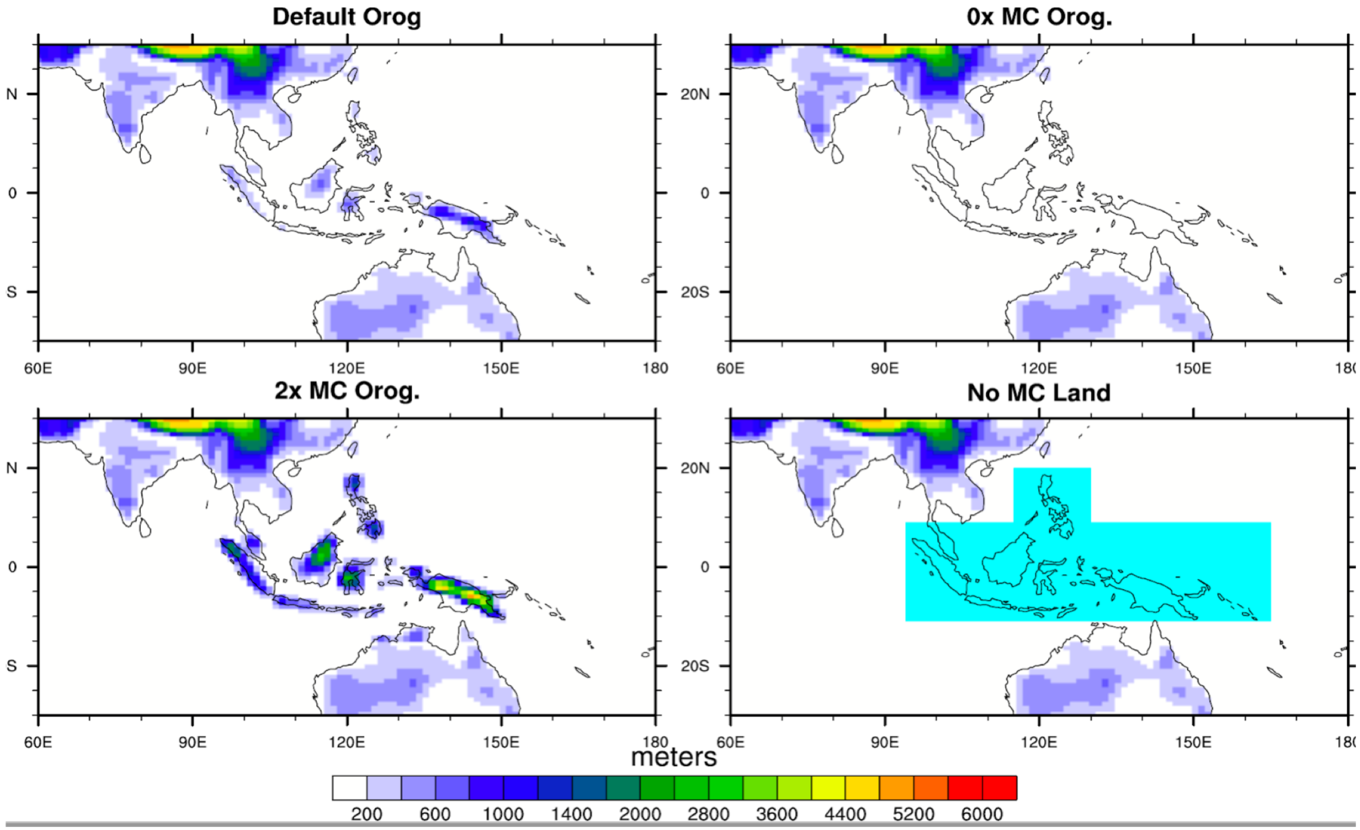
Impacts of the MJO on the Spatial Distribution of Diurnal Rainfall Peak near Bengkulu (SW Sumatra)



- The DC rainfall peaked between the late night (21-24 LT) to early morning (00-06 UTC) over the Indian Ocean and in the afternoon (12-21 LT) over Bengkulu.
- When the MJO wet phase moves eastward over the Indian Ocean, the DC peak migration tended to migrate westward (offshore). While during the dry phase, the peak of DC rainfall shifted into the morning (06-12 UTC) over the Indian Ocean

Permana et al. (in prep)

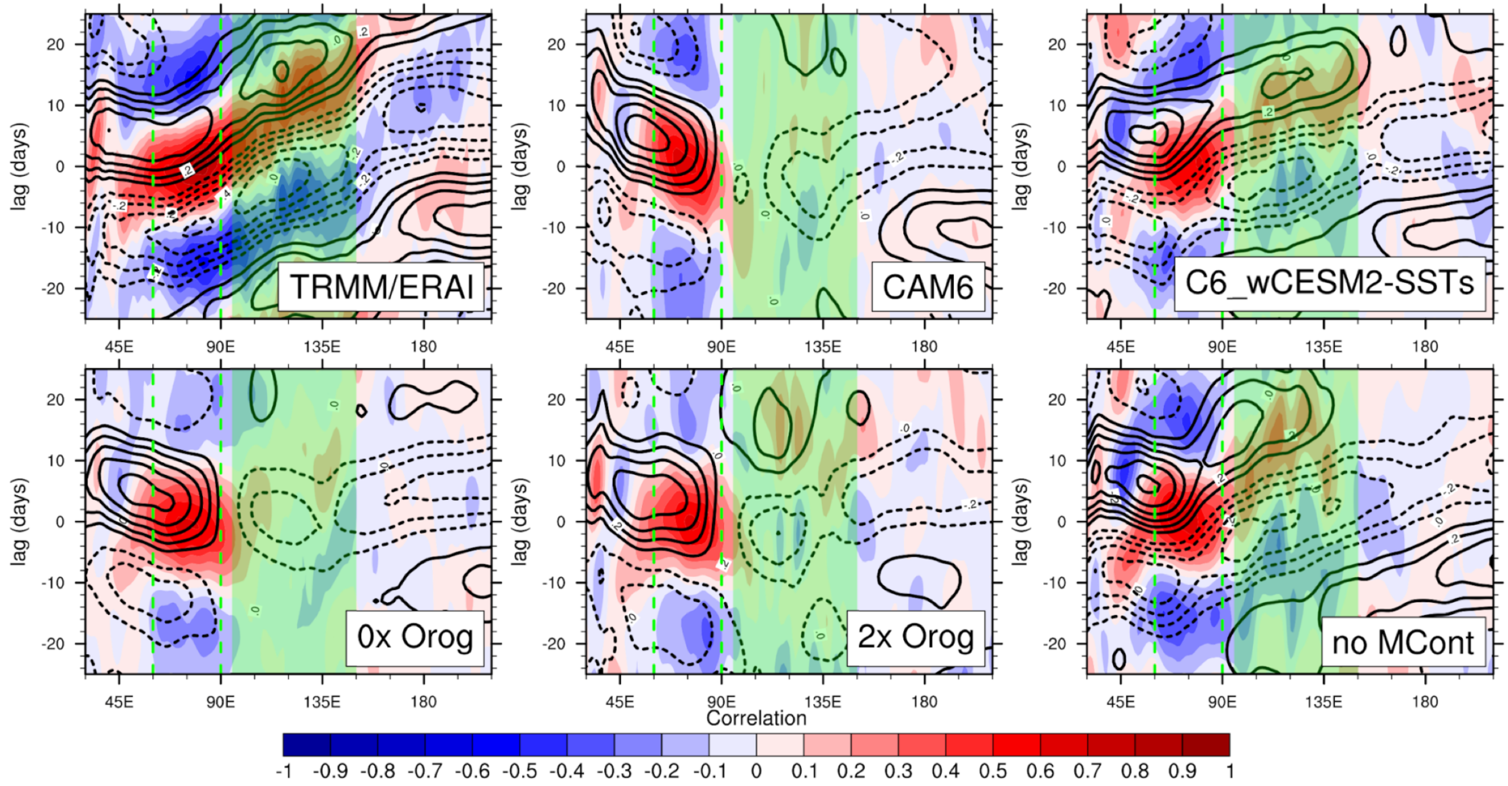
Regional Maritime Continent Characteristics and the MJO



- Community atmosphere model in CESM (CAM6)
- Poor MJO in AMIP, good in coupled
- Maritime continent (MC) AMIP sensitivity experiments
  - 0x orography and 2x orography height
  - Replace MC with SSTs
  - Replace obs. SSTs with coupled SSTs

Neale et al. (in prep)

Regional Maritime Continent Characteristics and the MJO



- No impact on MJO into W. Pacific with orography changes
- Barrier effect enables MJO to propagate
- Coupled SSTs lead to stronger MJO; more like coupled model
- Surface forcing larger role the barrier of MC

Neale et al. (in prep)

MJO-Extratropics Interactions

- Joint activity with new S2S teleconnections sub-project

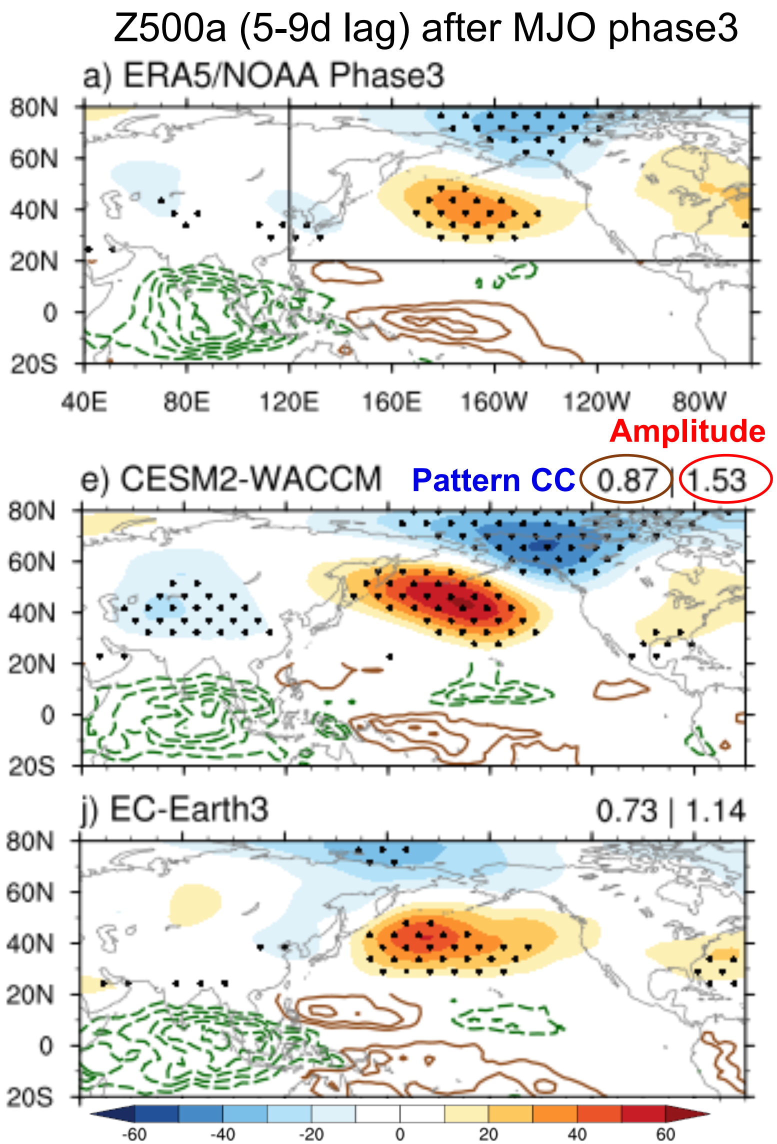
Action items

- Continued analysis of sensitivity of MJO teleconnections to details of MJO and basic state
- Develop and apply metrics for MJO teleconnections and sources of error in their representation in models
- Assess impact of MJO teleconnections on predictability and prediction skill for Extra-tropics

Accomplishments/Findings

- A number of studies looking at MJO teleconnections to the Northern Pacific, N America and Northern Atlantic and the dependence on the slowly varying background state
- MJO-NAE regimes MJO-NAO+ teleconnection stronger in El Niño and barely present in La Niña (Lee et al, 2019)
- Development of MJO teleconnection metrics for Climate Models and S2S models highlighting importance of both basic state and MJO heating (Henderson et al, 2017; Wang et al. 2019a, b)

MJO teleconnection metrics (over the PNA region)



- Joint activity with S2S and YTMIT
- Develop a "standardized MJO teleconnection metrics" for i) objective evaluation of model simulations, ii) fair model-to-model comparison, iii) consistent tracking of model improvement
- MJO teleconnection metrics include:
  - Five performance-based metrics: Z500 anomaly pattern, amplitude, east-west position, etc.
  - Two process-oriented metrics: Rossby wave source pattern and amplitude
- MJO teleconnection biases (in 29 CMIP5 & GASS/YOTC): Larger amplitude/Eastward shift/Longer persistence of MJO teleconnections
- Sources of errors (GCMs and LBM test)
  - Less coherent MJO propagation
  - Large amplitude in basic state (Westerly Jet)
  - Biases in jet position

Wang et al. (2019a, b)

Summary of MJO TF connections to other WMO groups

Subseasonal-to-seasonal (S2S) project

- A past outcome of the MJO-TF has been in implementation of MJO monitoring and prediction at many operational centres (e.g. NCEP, ECMWF, BoM), and an associated improvement of forecast models based on this MJO focus.
- Charlotte DeMott is co-leading a S2S-oceans focus group within the S2S Working Group.
- MJO TF members (Hyemi Kim, Daehyun Kim, and Eric Maloney) are leading the effort on developing standardized MJO-teleconnection metrics with S2S working group

Years of Maritime Continent (YMC)

- Matt Wheeler is co-leading the YMC cruise of the RV Investigator, during Oct-Dec 2019.
- Adrian Matthews, Steve Woolnough, Nick Klingaman and Prince Xavier are part of TerraMaris, the UK contribution to YMC, with Adrian as the overall PI.
- Daehyun Kim, Eric Maloney, Xianan Jiang, and Samson Hagos are PIs performing research under the NOAA CVP YMC program
- YMC has accounted MJO TF to cover its modeling theme

Tropical Pacific Observing System (TPOS) 2020

- Charlotte DeMott and Nick Klingaman have provided input (a 2-page letter) to the TPOS2020 group for design considerations that could improve observations of MJO air-sea interactions.

MJO TF Publications (since 2016)

Ahn, M.-S., **D. Kim**, **K. R. Sperber**, I.-S. Kang, **E. Maloney**, D. Waliser, and H. Hendon, 2017: MJO simulation in CMIP5 climate models: MJO skill metrics and process-oriented diagnosis. Clim. Dyn., 49, 4023–4045.

Ahn, M.-S., **D. Kim**, et al. Examination of the Maritime Continent barrier effect on MJO propagation in a GCM, Accepted pending minor revision.

Baggett, C. F., E. A. Barnes, **E. D. Maloney**, and B. D. Mundhenk, 2017, Advancing Atmospheric River Forecasts into Subseasonal Timescales. Geophys. Res. Lett., 44, 7528-7536.

Baranowski, D. B., D. E. Waliser, **X. Jiang**, J. Ridout, and M. K. Flatau, 2019: Contemporary GCM fidelity in representing the diurnal cycle of precipitation over the Maritime Continent. Journal of Geophysical Research: Atmospheres, 124, 747– 769.

DeMott, C. A., J. J. Benedict, **N. P. Klingaman**, **S. J. Woolnough**, and D. A. Randall, 2016: Diagnosing ocean feedbacks to the MJO: SST-modulated surface fluxes and the moist static energy budget. JGR, 121, 8350-8373.

DeMott, C. A., and **N. P. Klingaman**, 2018: Air-sea interactions in the Madden-Julian oscillation. Under review.

DeMott, C. A., **N. P. Klingaman**, W.-L. Tseng, M. A. Burt, D. A. Randall, 2018: Beyond surface fluxes: How ocean coupling changes the Madden-Julian oscillation in four GCMs, in preparation.

Fonseca, R.M., **T.-Y. Koh,** and C.-K. Teo, 2018: Multi-Scale Interactions in a High-Resolution Tropical-Belt Experiment using WRF Model. Clim. Dyn. (in press).

Gonzalez, A. O. and **X. Jiang**, 2017: Winter Mean Lower-Tropospheric Moisture over the Maritime Continent as a Climate Model Diagnostic Metric for the Propagation of the Madden-Julian Oscillation. Geophys. Res. Lett., 10.1002/2016GL072430.

Gonzalez, A. O., and **X. Jiang**, 2019: Distinct propagation characteristics of intraseasonal variability over the tropical west Pacific. Journal of Geophysical Research: Atmospheres, 124, 5332– 5351.

Henderson, S. A., **E. D. Maloney**, and E. A. Barnes, 2016: The influence of the Madden-Julian oscillation on Northern Hemisphere winter blocking. J. Climate, 29, 4597-4616.

Henderson, S. A., **E. D. Maloney**, and S.-W. Son, 2017: Madden-Julian oscillation teleconnections: The impact of the basic state and MJO representation in general circulation models. J. Climate, 30, 4567–4587.

Henderson, S. A., and **E. D. Maloney**, 2018: The impact of the Madden-Julian Oscillation on high-latitude winter blocking during El Niño-Southern oscillation events. J. Climate, 31, 5293–5318.

Jiang, X., M. Zhao, **E. D. Maloney**, and D. E. Waliser, 2016: Convective Moisture Adjustment Time-scale as a Key Factor in Regulating Amplitude of the Madden-Julian Oscillation. Geophys. Res. Letters, 43, 10,412–10,419.

Jiang, X., 2017: Key processes for the eastward propagation of the Madden-Julian Oscillation based on multi-model simulations. Journal of Geophysical Research: Atmospheres, 10.1002/2016JD025955.

Jiang, X., Á. F. Adames, M. Zhao, D. Waliser, and **E. Maloney**, 2018: A Unified Moisture Mode Framework for Seasonality of the Madden–Julian Oscillation. J. Clim., 31, 10.1175/jcli-d-17-0671.1, 4215-4224.

Jiang, X., **D. Kim,** and **E. Maloney**: Progress and status of MJO simulation in climate models and process-oriented diagnostics, Under review.

Jiang, X., H. Su, and D. Waliser, 2019: A Damping Effect of the Maritime Continent for the Madden-Julian Oscillation. Journal of Geophysical Research - Atmosphere, revised.

Kim, D., M.-S. Ahn, **C. DeMott**, **X. Jiang**, **N. Klingaman**, **H. Kim**, J. Lee, Y. Lim, S.-W. Son, **S. Woolnough**, **P. Xavier**, Basic state lower-tropospheric humidity distribution: key to successful simulation and prediction of the Madden-Julian oscillation, 2017 AGU fall meeting, New Orleans

Kim, D., H. Kim, and M.-I. Lee, 2017: Why does the MJO detour the Maritime Continent during austral summer? Geophys. Res. Lett., 44, 2579–2587.

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Kim, H. M., **D. Kim**, F. Vitart, V. Toma, J. Kug, P. J. Webster, 2016: MJO propagation across the Maritime Continent in the ECMWF ensemble prediction system, J. Climate, 10.1175/JCLI-D-15-0862.1.

Kim, H. M., 2017: The impact of the mean moisture bias on the key physics of MJO propagation in the ECMWF reforecast, JGR-Atmospheres, 122, 7772–7784

Kim, H. M., F. Vitart, D. E. Waliser, 2018: Prediction of the Madden-Julian Oscillation: A Review, J. Climate, DOI: 10.1175/JCLI-D-18-0210.1

Kim, H. M., F. Vitart, D. E. Waliser: MJO Prediction: Current status and future challenges, Book chapter in "The Multi-Scale Global Monsoon System" (under review)

Kim, H.-M., M. A. Janiga, K. Pegion, 2019, MJO propagation processes and mean biases in the SubX and S2S reforecasts. JGR-Atmos,

MJO TF Publications (since 2016) - continued

Koh, T.-Y. and R.M. Fonseca, 2016: Rainfall-Based Convective Cloud Scheme applied to the BMJ Scheme in WRF Model. Q. J. R. Meteorol. Soc., 142, 989-1006.

Lee, R. W., **S. J. Woolnough,** A. C. Charlton-Perez, F. Vitart: ENSO modulation of MJO teleconnections to the North Atlantic (in preparartion)

Lim, S. Y., C. Marzin, **P. Xavier** and C-P. Chang, Bertrand Timbal, 2017: Impacts of Boreal Winter Monsoon Cold Surges and the Interaction with MJO on Southeast Asia Rainfall, J. Climate, 30, 4267-4281, doi: 10.1175/JCLI-D-16-0546.1.

Lim, Y., S.-W. Son, and **D. Kim**, 2018: MJO Prediction Skill of the Subseasonal-to-Seasonal Prediction Models. J. Clim., 31, 4075–4094.

Miyakawa, T., H. Yashiro, T. Suzuki, H. Tatebe, M. Satoh, 2017: A Madden-Julian Oscillation event remotely accelerates ocean upwelling to abruptly terminate the 1997/1998 super El Nino. Geophys. Res. Lett., doi:10.1002/2017GL074683.

Mundhenk, B. D., E. A. Barnes, and **E. D. Maloney**, 2016: All-Season Climatology and Variability of Atmospheric River Frequencies over the North Pacific. J. Climate, 29, 4885–4903.

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Permana, D. S., T. D. Hutapea, J. A. I. Paski, A. S. Praja, H. Harsa, D. E. Nuryanto, R. Kurniawan, E. E. S. Makmur, and D. Ardiansyah. 2019. Interaction of MJO and diurnal cycle observed by radiosonde data during the first YMC campaign in Bengkulu (November 2017-January 2018). In *IOP Conference Series: Earth and Environmental Science* (Vol. 303, no. 1, p. 012058). IOP Publishing.

Satoh, M., Tomita, H., Yashiro, H., Kajikawa, Y., Miyamoto, Y., Yamaura, T., **Miyakawa, T.**, Nakano, M., Kodama, C., Noda, A. T., Nasuno, T., Yamada, Y., Fukutomi, Y., 2017: Outcomes and challenges of global high-resolution non-hydrostatic atmospheric simulations using the K computer. Progress in Earth and Planetary Science, 4, 13, doi:10.1186/s40645-017-0127-8.

Stan, C., Straus, D. M., Frederiksen, J. S., Lin, H., **Maloney, E. D.**, & Schumacher, C., 2017: Review of tropical-extratropical teleconnections on intraseasonal time scales. Reviews of Geophysis, 55, 902–937.

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