Date: July 31, 2019
Location: CCRS, Singapore
Morning - Auditorium
Afternoon - Conference Room

Participants

MJOTF members: Charlotte DeMott, Samson Hagos, Xianan Jiang (remotely), Daehyun Kim, Hyemi Kim (remotely), Nicholas Klingaman, Tieh-Yong Koh, Eric Maloney (remotely), Tomoki Miyakawa, Donaldi Permana, Matthew Wheeler (remotely), Steve Woolnough (remotely), and Prince Xavier

Guests
Chidong Zhang (PMEL/NOAA), Andrew Robertson (IRI), Lucas Harris (GFDL), Jiwoo Lee (LLNL, remotely), Shuyi Chen (University of Washington), Raizan Rahmat, Thea Turkington, Muhammad Hassim, Joshua Qian (CCRS)

Opening Remarks

Erland KÄLLÉN (Director, CCRS): rely on international collaborations to get their work done. rely on ESMs for their work.

MJO Teleconnections

Eric Maloney: MJO ET teleconnections (TCs). TCs vary w/ MJO phase. Phases 2/3 and 7/8 exhibit better pattern agreement of Z500. RWS is critical for TC response. QBO strongly influences TC response. Developed empirical forecast model based on MJO, QBO phase. ML (machine learning) enhances this empirical model. CA water managers are quite interested. MJO in future climate is a big source of concern for Eric (TC response is projected to weaken with warming). Nick notes that he, Frederic, etc. are planning similar MJO-QBO experiments as Eric. Some discussion as to how well posed are these experiments.

Hyemi Kim: MJO TC (teleconnection) metrics. Many collaborators: DK, Stephanie Henderson, Cristiana Stan, Eric Maloney. Sensitivity of MJO TCs to MJO and basic state. Develop, apply metrics to TCs and ID sources of error. These will be great metrics to add to PCMDI. Sources of TC error can be 1) MJO-related or 2) basic state related. Shuyi notes that meridional structure (or path?) of MJO can have a large impact on TC response, so we should try to include such information in our metrics. Eric concurs.

Minutes Summary: Progress continues to be made in understanding and characterizing MJO interactions with the extratropics. TF member Eric Maloney summarized recent work by his group (with collaboration from Elizabeth Barnes at CSU). The MJO teleconnection response varies with MJO and QBO phase. Eric and his team have developed an empirical forecast model based on MJO and QBO phase, with additional improvements gained through machine learning approaches. A source of concern for the future is the projected reduction of the extratropical teleconneciton response with future warming: global effects of the MJO may become less predictable.

TF member Hyemi Kim summarized a collaborative effort between herself, TF members Daehyun Kim, Eric Maloney, and Steve Woolnough, plus Stephanie Henderson (UW Madison), and Cristiana Stan (GMU) to develop metrics to assess the MJO teleconnection response in general circulation models. Sources of teleconnection error can be 1) MJO-related or 2) basic state related. Guest attendee Shuyi Chen noted that the meridional structure (or path?) of the MJO can have a large impact on teleconnection response, and advised that we include such information in our metrics. Eric concurred that this would be a good idea.

MJO Prediction

Andy Robertson: 2nd phase is focused on drilling down to the science behind the forecast. ECMWF (for now) will start providing ocean output variables. BoM is also considering.

Hyemi Kim: MJO propagation processes and mean state biases in the SubX and S2S reforests. NCAR-CESM1 (run by Ben Kirtman) is 2nd performing model, after ECMWF, for MJO. Interestingly, the best MJO forecasts develop weak amplitude drift with lead time. She finds that the models precipitate too much at light rainfall rates to which she attributes the negative PW biases. This paper just came out and can be found here.

Shuyi Chen: MJO prediction in ECWMF. Rainfall feature tracking doesn't require anomaly calculation. Just pattern tracking. She argues that separating MJO from the mean state is artificial and hinders understanding.

Lucas Harris: The MJO in GFDL Shield (new version of the wx prediction model). Uses FV3 dycor. Many changes wrt previous model: microphysics, PBL scheme, SAS convection (scale aware "does not suck"), ML ocean w/ 15-day relaxation timescale. Question: what is ocean vertical resolution? Gets pretty good MJO and diurnal cycle over land and ocean. Improved propagation with nested grid over MC. Also large improvements of diurnal cycle over MC. He reports that this model's MJO is highly sensitive to ocean feedbacks.

Mohammed Hassim: Studied frequency of 8 weather regimes (determined by K-means clustering algorithm of T, Q, u, v, profiles from Singapore) over MC as a function of MJO phase. How predictable are these phase? Local weather is linked to prevailing large-scale state. Regimes correspond to seasonal ITCZ movement. Find potential predictability of weather types is 2-3 weeks.

Thea Turkington: Outreach activities at CCRS. "Regional capability." They use model output from other centers and tailor ("calibrate") it to their region. Main goal is to investigate the usefulness of S2S projections. Currently constrained by the 3-week delay in releasing S2S output. Project involves national and regional end users. Spent time developing rainfall indices based on user needs (i.e., "monsoon break" index).

Minutes summary:

Several TF members and guest presenters provided updates on MJO prediction research. **Andy Robertson** (IRI) updated us on Phase II of the S2S project, which seeks a deeper understanding of physical mechanisms associated with prediction skill (or lack thereof). In support of this effort, ECMWF, and possibly BoM, will be providing enhanced ocean model output fields to help better delineate whether sources of model bias or skill arise from atmospheric or oceanic components.

Hyemi Kim reported on her analysis of mean state biases in S2S and SubX forecast models as they relate to MJO prediction. NCAR-CESM1 (run by Ben Kirtman) is 2nd performing model, after ECMWF, for MJO. Interestingly, the best MJO forecasts develop weak amplitude drift with lead time. She finds that the models precipitate too much at light rainfall rates to which she attributes the negative PW biases. It is suspected that these biases are rooted in convective parameterization schemes. Here paper on this topic just came out and can be found here.

Shuyi Chen (U. Washington) briefed us her evaluation of MJO prediction in ECWMF using a precipitation tracking approach. Rainfall feature tracking doesn't require anomaly calculation, a practice that she argues hinders understanding by imposing an artificial separation of the MJO from the mean state.

Lucas Harris (GFDL) reported the state of MJO simulation in the new GFDL Shield weather prediction model. Shield uses the FV3 dynamical core and includes many changes compared to the previous model, including updates to microphysics, PBL scheme, SAS convection (scale aware; "does not suck"). The model is coupled to a mixed-layer ocean with a 15-day relaxation timescale toward climatology. (Question: what is ocean vertical resolution?) Shield simulates a pretty good MJO and diurnal cycle over land and ocean. MJO propagation improves with the addition of a nested grid over the MC. Also large improvements of diurnal cycle over MC. He reports that this model's MJO is highly sensitive to ocean feedbacks.

Muhammad Hassim (CCRS) provided T, Q, u-, and v-wind soundings from Singapore to a K-means clustering algorithm to identify 8 weather regimes over MC. Regime frequency is modulated by MJO phase. How predictable are these regimes as a function of phase? Local weather is linked to prevailing large-scale state. Regimes correspond to seasonal ITCZ movement. He finds potential predictability of weather types is 2-3 weeks.

Thea Turkington (CCRS) talked to us about uutreach activities at CCRS focused on "Regional capability." Her team uses model output from other centers and tailors ("calibrates") it to their region. The main goal is to investigate the usefulness of S2S projections. They are currently constrained by the 3-week delay in releasing S2S output. The project involves national and regional end users. An example effort is their development of rainfall indices based on user needs (i.e., "monsoon break" index).

Maritime Continent Interactions

Chidong Zhang: Provided an overview of upcoming field campaigns. Targeting Jan 2021 for multinational field campaign (US, China, Japan, Australia). TerraMaris is UK campaign. Also collecting data from local observing networks.

Donaldi Permana: Diurnal cycle of MC as observed by the Bengkulu radar (SW Sumatra), Surabaya (Java), and Papua (New Guinea).. ~200 days of 10-minute radar data. Topography, distance inland, island orientation all influence diurnal cycle variations throughout MJO lifecycle. During an oral session later in the week, Tieh-Yong noted that the high spatial and temporal resolution of the radar data reveal subtle differences between TRMM 3-hourly resolution diurnal cycle that he feels are worthy of further exploration.

Samson Hagos: Seasonality of MJO propagation from the perspective of insolation and soil moisture. MJO RMM amplitude is strongest over MC during March and September (shoulder seasons). MJO signal over land is strongest in March when soil moisture is a maximum. Experiments: CTRL, low soil moisture (DRYSOIL), high insolation (HINSOL), DRYSOIL+HINSOL. Both experiments increase precipitation over land. Apparent MJO stalling over MC is related to tendency for MJO rainfall to remain locked over islands during HINSOL. Surmises that observed MJO stalling/weakening over MC arises due to enhanced MJO-DC interaction during "vanguard" phase.

Josuah Qian (Jian-Hua; MSS): Mechanisms for the vanguard associated with eh MJO. Weak wind speed is associated with enhanced DC over land. El Nino over Java reduces mean wind speed, so increases DC. Generally more rainfall on lee side of mountain. Narrow islands: monsoon damping effect. Wide islands: monsoon wake effect. Large scale wind anomalies are key to understanding MJO-DC variations.

Minutes summary:

Chidong Zhang (NOAA PMEL) summarized recent and upcoming field campaigns in the MC region. January 2021 is targeted for multinational campaign (US, China, Japan, Australia). TerraMaris is the UK campaign. He would also like to see a "MC field campaign data hub" website similar to that developed for the DYNAMO campaign. This greatly simplifies data discovery and access for researchers wanting to use observations who may not have been directly involved in its collection.

Donaldi Permana presented his research on the diurnal cycle of MC rainfall as observed by the Bengkulu (SW Sumatra), Surabaya (Java), and Papua (New Guinea) radars. Each site has collected O(100) days of 10-minute radar data. Topography, distance inland, island orientation all influence diurnal cycle variations throughout MJO lifecycle. During Donaldi's oral presentation later in the week, Tieh-Yong noted that the high spatial and temporal resolution of the radar data reveal subtle differences between TRMM 3-hourly resolution diurnal cycle that he feels are worthy of further exploration.

Samson Hagos reported on a WRF modeling study focused on the seasonality of MJO propagation from the perspective of insolation and soil moisture. MJO RMM amplitude is strongest over MC during March and September (shoulder seasons). The MJO rainfall signal over land is strongest in March when soil moisture is a maximum. Experiments: CTRL, low soil moisture (DRYSOIL), high insolation (HINSOL), DRYSOIL+HINSOL. Both experiments increase precipitation over land. Apparent MJO stalling over MC is related to tendency for MJO rainfall to remain locked over islands during HINSOL. He surmises that observed MJO stalling/weakening over MC arises due to enhanced MJO-diurnal cycle interactions.

Josuah Qian (MSS) studied mechanisms for vanguard rainfall associated with the MJO. Weak wind speed is associated with an enhanced diurnal cycle over land. El Nino reduces mean wind speed over Java, so increases the diurnal cycle there. There is generally more rainfall on the lee side of mountains. Narrow islands provide a monsoon damping effect. Wide islands lead to a monsoon wake effect. Large scale wind anomalies are the key to understanding MJO-diurnal cycle variations.

MJO Mechanisms and Simulations

<u>Daehyun Kim</u>: Application of E-W power ratio, lag-regression pattern correlation metric to CMIP5 and 9 CMIP6 models (PCMDI metrics package). Preliminary results suggest improved MJO simulation with CMIP6, but it is still too early say anything conclusively. What metric can described the MC detour? He presented some "timing over MC wrt lag-regression" analysis for the Equatorial and southern MC regions. This provides a nice visual summary of how long and when precipitation resides over the MC. How can this be reduced to a single metric? Also some mean state metrics (pattern correlation with OBS for a given regions and season; do these overlap with work by Angie Pendergrass?)

<u>Charlotte DeMott:</u> Summary of ocean feedback mechanisms for MJO propagation. Experiments: Monthly mean SST from four CGCMs are prescribed to respective AGCMs (identical SST climatology and low-frequency variability). MJO is uniformly better in CGCMs due to sharpened meridional moisture gradients. Conditional sampling of convective moistening (-Q2/Lv) profiles as a function of rainfall rate and sign of SST anomaly (warm or cold) suggests that coupling enhances low-level moistening at rainfall rates greater than about 5 mm/day. Because these rainfall rates are most frequent near the Equator, the coupled feedbacks help maintain the sharper meridional moisture gradients in CGCMs. This partitioning of -Q2 profiles,

combined with warm-minus-cold distributions of rainfall rate as a function of CWV fraction can "illustrate" how parameterized convection interacts with its environment.

Nicholas Klingaman: Analysis of mean state bias-MJO feedbacks in MetUM GC2 to GC3. GC3 mean state encourages MJO propagation. Some resolution dependence (improvement) in GC3 for observed state. Model wet biases are generally consistent with their SST biases. Mean state changes with increased resolution are not sufficient to explain improved MJO propagation, so some of the improvement must arise from resolution, likely over the MC.

Minutes summary:

Daehyun Kim introduced us to a preliminary assessment the MJO in CMIP5 and nine CMIP6 models. This work is supported through a DOE grant, and the diagnostics are being added to the PCMDI metrics package. Metrics shown include the E-W power ratio, lag-regression pattern correlation metric, and timing and duration of rainfall over the MC following the eastern IO MJO rainfall maximum, and an "MC detour" metric. Preliminary results suggest improved MJO simulation with CMIP6, but it is still too early say anything conclusively. Additional metrics are planned, and further input from the TF was discussed.

Charlotte DeMott provided a summary of ocean feedback mechanisms for MJO propagation. Experiments: Monthly mean SST from four CGCMs were prescribed to their respective AGCMs (identical SST climatology and low-frequency variability). Findings: MJO is uniformly better in CGCMs due to sharpened meridional moisture gradients. Conditional sampling of convective moistening (-Q2/Lv) profiles as a function of rainfall rate and sign of SST anomaly (warm or cold) suggests that coupling enhances low-level moistening at rainfall rates greater than about 5 mm/day. Because these rainfall rates are most frequent near the Equator, the coupled feedbacks help maintain the sharper meridional moisture gradients in CGCMs. The take-home message is that coupling improves the MJO by making mean state moisture more favorable for MJO propagation via horizontal moisture advection.

Nicholas Klingaman presented his analysis of mean state bias-MJO feedbacks in the MetUM GC2 and GC3 (latest) model configurations. The GC3 mean state encourages MJO propagation. There is some resolution dependence (improvement) in GC3 for the observed state. Coupled model wet biases are generally consistent with their SST biases. Mean state changes with increased resolution are not sufficient to explain improved MJO propagation, so some of the improvement must arise from resolution, likely over the MC.

Rich Neale reported on a series of model experiments with CESM2. Coupled (C) MJO is much better than uncoupeld (UC). CESM2 was developed with little regard to CAM6 MJO performance, and he notes that the MJO was slightly better in development versions than in the official release. A similar experiment to that done by C. DeMott yields a similar result: the MJO is better with coupling, even when mean state and low-frequency SSTs are identical. The CESM2 SST mean state also improves the MJO in CAM5, suggesting that the poor MJO in

CAM5 is directly related model physics, but indirectly related to model physics through their affect on the mean state. Note that CEMS2 has warm SST bias on the Equator from IO to WPac. (Suspect the mean state SST bias leads to similar mean state CWV bias that improves MJO propagation?). He has also performed MC island experiments, and gets the best MJO simulation when MC islands are removed. This is consistent with Samson's MC diurnal cycle interference paper, i.e., the diurnal cycle appears to interfere with MJO propagation. Rich would like to propose some YMC experiments where many models perturb the MC as he has done.