Progress in Simulating Intraseasonal Variability in Climate Models

K. Sperber\textsuperscript{1}, H. Annamalai, D. Kim, and M.-P. Hung

\textsuperscript{1}Lawrence Livermore National Laboratory
Outline

- Observations and Models Used
- Literature/Results Used
- Boreal Winter Madden-Julian Oscillation
  - Dominated by eastward propagation of enhanced convection
- Boreal Summer Intraseasonal Variability
  - Eastward and northward propagation of enhanced convection
- Preliminary Conclusions/Ongoing Work
Observations, CMIP5, and CMIP3 Models

- Observations
  - CMAP, GOES Precipitation Index, GPCP, AVHRR OLR

- CMIP5 (27 models overall)

- CMIP3 (20 models overall)
  - bccr_bcm2.0, cccma_cgcm3.1, cccma_cgcm3.1_t63, ccsM3.0, cnrm cm3, csiro mk3.0, csiro mk3.5, gfdl cm2.0, gfdl cm2.1, giss aom, fgoals 1.0g, ingv-sxg, inmcm3.0, hadcm3, ipsl cm4, miroc 3.2 (hi-res), miroc 3.2 (med-res), miub echo-g, echam5/mpi-om, and mri_cgcm2.3.2a

- CMIP5 Historical vs. CMIP3 20c3m simulations
  - Modeling groups best estimates of natural and anthropogenic forcing
  - CMIP5 has higher horizontal resolution (most ~1° vs. ~2.5°)
  - CMIP5 has more complete representation of the Earth system and improved parameterizations
Boreal Winter Madden-Julian Oscillation


Boreal Summer Intraseasonal Variability

Boreal Winter Madden-Julian Oscillation: Precipitation Wavenumber-Frequency Power Spectrum

- Diagnostic promoted by the CLIVAR MJO Working Group (CLIVAR MJOWG 2009, Kim et al. 2009)
- East (West) sum of spectral power within box A (sum of spectral power within box B)
- E/W: East/West
- Wavenumbers 1-3, period 30-60 days
- Model data is interpolated into 2.5 x 2.5 degree resolution
- 20-year (1979-1998) period from CMIP3 and CMIP5
- GPCP data for 1997-2008 is used as reference
Boreal Winter Madden-Julian Oscillation: Precipitation
Wavenumber-Frequency East Power vs. West Power

- Wavenumbers 1-3, period 30-60 days
  - The majority of models have weak intraseasonal variance
  - The majority of models have eastward power that is underestimated relative to the westward power

CMIP3

CMIP5
Boreal Winter Madden-Julian Oscillation: Precipitation Wavenumber-Frequency East/West Ratio

- Wavenumbers 1-3, period 30-60 days
  - CMIP5: more models have a realistic East/West Ratio in the MJO band
    - 9/29 (31%) CMIP5 models have an E/W ratio >2, compared to 4/17 (24%) of the CMIP3 models

![CMIP3 models n=17, ave=1.86 vs. CMIP5 models n=29, ave=1.77](image)

GPCP=2.2
Boreal Winter Madden-Julian Oscillation Precipitation Variance (5°N-5°S average)

- Wavenumber 1-6, period 30-70 days
  - The majority of models underestimate MJO variance
  - The CMIP5 average is improved relative to the CMIP3 average
Boreal Winter Madden-Julian Oscillation Precipitation Variance (15°N-15°S, 65°E-185°E average): CMIP5 vs. CMIP3

- Wavenumber 1-6, period 30-70 days
  - Paired CMIP5 and CMIP3 models
  - Most CMIP5 counterparts have improved their MJO variance

<table>
<thead>
<tr>
<th>CMIP3</th>
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<tbody>
<tr>
<td>CCSM3</td>
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<tr>
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<td>MRI-CGCM2.3.2</td>
<td>MRI-CGCM3</td>
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![Graph showing MJO (mm/day)^2 vs. CMIP3 with models and their predecessors depicted.](image-url)
Boreal Winter Madden-Julian Oscillation: Outgoing Longwave Radiation (Wm\(^{-2}\))

- Unified Approach to Model Diagnosis
  - Regrid model data to AVHRR OLR grid, and apply 20-100 day bandpass filter
  - Project model filtered OLR onto the leading MJO EOF’s obtained from 20-100 day filtered AVHRR OLR (Sperber 2003, *Mon. Wea. Rev.*, 131, 3018-3037)
  - The resulting PC’s are used for lag regression to reconstruct the MJO Life-Cycle (the regression fit is for 1 standard deviation of the PC)
Boreal Winter Madden-Julian Oscillation using 20-100 day Filtered OLR (Wm\(^{-2}\)): AVHRR Observations

- Eastward propagation of convective anomalies from the Indian Ocean to the Central Pacific Ocean

![Day -20](image)
- ![Day -15](image)
- ![Day -10](image)
- ![Day -5](image)
- ![Day 0](image)
- ![Day 5](image)
- ![Day 10](image)
- ![Day 15](image)
- ![Day 20](image)
Boreal Winter Madden-Julian Oscillation using 20-100 day Filtered OLR (Wm\(^{-2}\)): NorESM1-M

- Eastward propagation of convective anomalies from the Indian Ocean to the Central Pacific Ocean (curiously, during boreal summer this model is dominated by westward propagation!)

a) Day -20
b) Day -15
c) Day -10
d) Day -5
e) Day 0
f) Day 5
g) Day 10
h) Day 15
i) Day 20
Boreal Summer Intraseasonal Variability (BSISV): 20-100 day Variance ($Wm^{-2}$)$^2$

- CMIP3 and CMIP2+ discussed in detail in Sperber and Annamalai (2008)
  - Only 1 model, ECHAM4/OPYC, gave a high-quality representation of the BSISV
- Variance of 20-100 day bandpass filtered OLR (JJAS)
  - Includes propagating and standing components of intraseasonal variability

![Maps showing spatial patterns of intraseasonal variability](image-url)
BSISV Life-Cycle: Outgoing Longwave Radiation (Wm$^{-2}$)

- Unified Approach to Model Diagnosis
  - Regrid model data to AVHRR OLR grid, and apply 20-100 day bandpass filter
  - Project model filtered OLR onto the Day 0 Cyclostationary EOF pattern obtained from 20-100 day filtered AVHRR OLR (Annamalai and Sperber 2005, JAS, 62, 2726-2748)
  - The resulting PC is used for lag regression to reconstruct the BSISV Life-Cycle (the regression fit is for 1 standard deviation of the PC)
BSISV Life-Cycle using 20-100 day Filtered OLR (Wm$^{-2}$): AVHRR Observations

- Eastward and northward propagating OLR anomalies (Annamalai and Sperber 2005, JAS, 62, 2726-2748)
- The Day 10 tilted rainband is a key component of the BSISV
BSISV Life-Cycle using 20-100 day Filtered AVHRR OLR (Wm\(^{-2}\)):
MIROC5

- Similar evolution as observed, but the anomalies are weaker
- Only non-ECHAM-4 based model to “reasonably” simulate BSISV
  - MRI-CGCM3, and to a lesser extent GFDL-ESM2G, have the tilted rainband
Despite the poor simulation of the BSISV by the vast majority of models, the MMM gives a good representation of the BSISV life-cycle, and the MMM’s exceed that skill of the individual models.
Skill: 20-100 day Variance vs. BSISV Life-Cycle

- For both CMIP3 and CMIP5, the BSISV is better simulated in models that have a better pattern correlation in their simulation of the 20-100 day filtered variance (the linear regression fits are significant at better than the 1% level)
- This suggests that the location and strength of the filtered variance maxima are largely determined by the propagating BSISV
Preliminary Conclusions/Ongoing Work

- **MJO/BSISV**: Signal in OLR better represented than that in precipitation
- **MJO/BSISV**: Intraseasonal variance improved in CMIP5 compared to CMIP3, though most models still underestimate the observed magnitude
- **MJO/BSISV**: Most models simulate near-equatorial eastward propagation from the Indian Ocean to the Maritime Continent, but have difficulty in exhibiting eastward propagation over the Pacific Ocean
- **BSISV**: MIROC5 (and to a lesser extent MRI-CGCM3 and GFDL-ESM2G) exhibit northward propagation. This is the first time that non-ECHAM4 based models have shown this capability
- **MJO/BSISV**: Improvement suggests possible importance of diluted convective updrafts, convective momentum transport (CMT), and moisture-convergence-type convective closure/trigger
- **MJO/BSISV**: The CMIP5 multi-model mean (MMM) gives a good representation of the life-cycle of the MJO, suggesting a multi-model approach to forecasting the intraseasonal variability could be fruitful
- **MJO**: The Year of Tropical Convection (YOTC) MJO Task Force is applying MJO process-oriented diagnostics and the CLIVAR MJO Working Group diagnostics to develop a more complete investigation of MJO skill in the CMIP5 models