Dominant Subseasonal Variability Modes Over the Eastern Pacific ITCZ and their Representation in Climate Models

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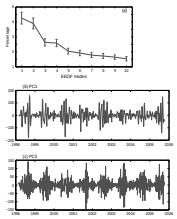
Abstract

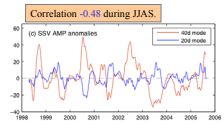
Our recent analysis of TRMM rainfall revealed two dominant subseasonal variability (SSV) modes over the eastern Pacific (EPAC) ITCZ during boreal summer, i.e., a 40-day mode and a 20-day mode. While the possible linkage between the 40-day mode and the MJO has been previously suggested, we found this mode to also exhibit northward propagation, an aspect that had only previously documented for SSV over the Asian monsoon region.

The second SSV mode (i.e., 20-day mode) associated with the EPAC ITCZ rainfall, to the best of our knowledge, is documented for the first time. While its strongest signals are present over the EPAC, the impacts of this mode are discerned over the North American Monsoon, the Gulf of Mexico, and Caribbean Sea.

Representation of these two dominant SSV modes over the EPAC ITCZ in six atmospheric general circulation models (GCMs) and three coupled GCMs are further examined, including one super-parameterized GCM (SPCAM) which utilizes embedded 2-D cloud resolving mode, and one recently developed high-resolution GCM (GFDL HIRAM) with horizontal resolution of about 50km.

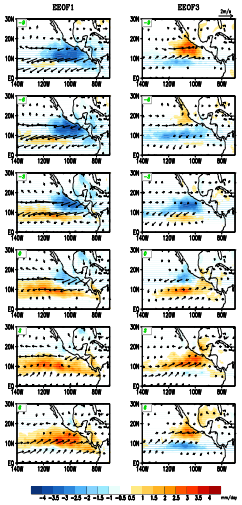
Two Dominant SSV modes over the EPAC ITCZ





Interannual variability of anomalous amplitudes of the 40-day (red) and 20-day (blue) modes.

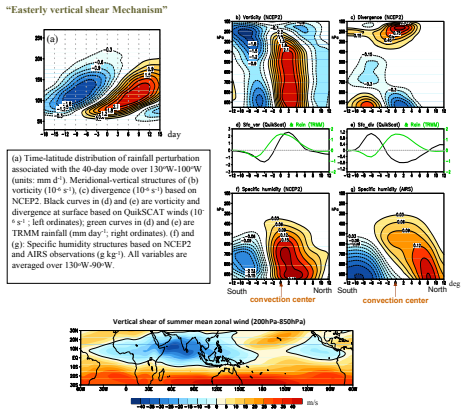
(a) EOF spectrum of TRMM rainfall over the EPAC in terms of the total variance explained by each EOF mode. Time series of temporal coefficients for the (b) $EEOF_1$ and (c) $EEOF_3$ modes.



Lagged regression patterns of TRMM rainfall (shaded) and NCEP/DOE 850hPa wind (vectors) versus the $EEOF_1$ (left) and $EEOF_3$ (right) modes during boreal summer (JJAS). The time interval between adjacent panels is 3 days.

- Two well separated SSV modes are identified based on an EEOF analysis of TRMM rainfall over the EPAC, e.g., a 40-day and a 20-day modes;
- Both of the SSV modes exhibit northward propagation over the EPAC with phase speed 0.6 versus 1.2 degree/day;
- Analysis of the low-frequency variability of these two SSV modes shows that they are anti-correlated on the interannual time scales.

Northward movement and vertical structures of the 40-day SSV Mode



(a) Time-latitude distribution of rainfall perturbation associated with the 40-day mode over 130°W-100°W (units: mm d^{-1}). Meridional-vertical structures of (b) vorticity (10^{-6} s^{-1}), (c) divergence (10^{-6} s^{-1}) based on NCEP2. Black curves in (d) and (e) are vorticity and divergence at surface based on QuikSCAT winds (10^{-6} s^{-1}; left ordinates); green curves in (d) and (e) are TRMM rainfall (mm day^{-1}; right ordinates). (f) and (g): Specific humidity structures based on NCEP2 and AIRS observations (g kg^{-1}). All variables are averaged over 130°W-90°W.

- The northward propagating 40-day mode exhibits very similar vertical structures with its counterpart over the Asian monsoon region.
- As both the EPAC and Asian monsoon region are characterized by the easterly vertical wind shear associated with monsoonal circulation, these results may provide additional independent evidence for the essential role that easterly vertical wind shear may be playing in the meridional propagation of SSV as previously proposed in *Jiang et al (2004)*.

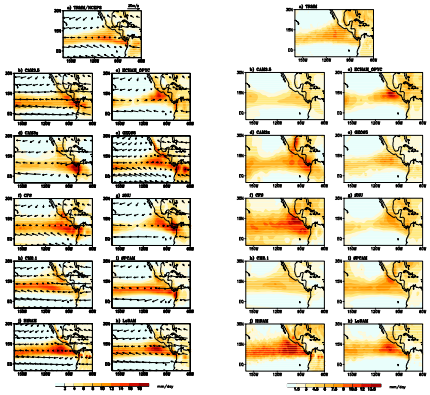
Participating Models

Model (group)	Horizontal Resolution -AGCM	Vertical Resolution (top level) -AGCM	Cumulus parameterization	Integration	Reference
CAM3.5 (NCAR)	1.9° lat x 2.5° lon	26 (2.2hPa)	Mass flux (Zhang and McFarlane 1995)	20 years 01JAN1986-31DEC2005	Neale et al. (2007)
CAM3z (SIO)	T42(2.8°)	26 (2.2hPa)	Mass flux (Zhang and McFarlane 1995)	15 years 29JAN1980-23JUL1995	Zhang et al. (2005)
CFS (NCEP)	T62(1.8°)	64 (0.2hPa)	Mass flux (Hong and Pan 1998)	20 years	Wang et al. (2005)
CM2.1 (GFDL)	2° lat x 2.5° lon	24 (4.5hPa)	Mass flux (RAS; Moorthi and Suarez 1992)	20 years	Delworth et al. (2006)
ECHAM4 /OPYC (PCMDI)	T42(2.8°)	19 (10hPa)	Mass flux (Tiedtke 1989, adjustment closure Nordeng 1994)	20 years	Roeckner et al. (1996), Sperber et al. (2005)
GEOS5 (NASA)	1° lat x 1.25° lon	72 (0.01hPa)	Mass flux (RAS; Moorthi and Suarez 1992)	12 years 01DEC1993-30NOV2005	To be documented
SNUAGCM (SNU)	T42(2.8°)	20 (10hPa)	Mass flux (Numaguti et al. 1995)	20 years 01JAN1986-31DEC2005	Lee et al. (2003)
SPCAM (CSU)	T42(2.8°)	26 (3.5hPa)	Superparameterization (Khairoutdinov and Randall 2003)	19 years 01OCT1985-25SEP2005	Khairoutdinov et al. (2005)
HiRAM (GFDL)	0.5° lat x 0.6° lon 2.0° lat x 2.5° lon	32 (4.5hPa)	Mass flux (Bretherton et al. 2004)	19 years 01JAN1990-31DEC2008	Zhao et al. (2009)

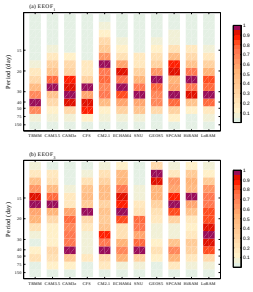
Summer (Jun-Oct) Mean State and Standard Deviations

Summer mean rainfall (shaded) & 850hPa winds (vectors)

STDs of summer rainfall

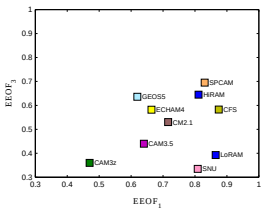


Spectra of $EEOF_1$ & $EEOF_3$ of EPAC Rainfall



Normalized spectral density of time series corresponding to (a) $EEOF_1$ and (b) $EEOF_3$ based on TRMM and GCM simulated rainfall over the EPAC.

Pattern Correlations of $EEOF_1$ & $EEOF_3$ between OBS and GCMs

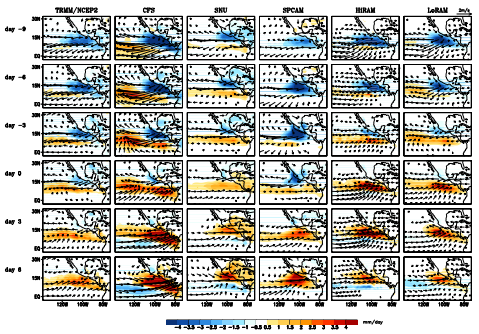


Pattern correlation coefficients of $EEOF_1$(x-axis) and $EEOF_3$(y-axis) of rainfall over the EPAC between TRMM observations and GCM simulations

References

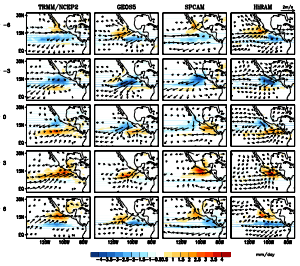
- Jiang, X., T. Li, and B. Wang (2004), Structures and Mechanisms of the Northward Propagating Boreal Summer Intraseasonal Oscillation, *J. Clim.*, *17*, 1022-1039.
- Jiang, X., and D. E. Waliser (2008), Northward propagation of the subseasonal variability over the eastern Pacific warm pool, *Geophys. Res. Lett.*, *35*.
- Jiang, X., and D. E. Waliser (2009), Two Dominant Subseasonal Variability Modes of the Eastern Pacific ITCZ, *Geophys. Res. Lett.*, *36*.
- Jiang, X., and coauthors: Simulation of the intraseasonal oscillation over the Eastern Pacific ITCZ in climate models, in preparation.

Spatial Evolution of Observed & Simulated 40-day SSV mode



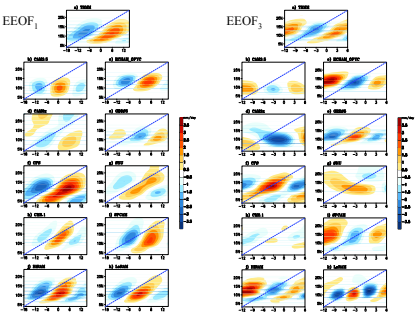
Lagged regression patterns of Rainfall (shaded) and 850hPa winds (vectors) against the standardized time series of PC_1 during boreal summer (JJAS) based on TRMM / NCEP2 observations and CFS, SNU, SPCAM, HiRAM, and LoRAM simulations.

Spatial Evolution of Observed & GCM Simulated 20-day SSV mode



Same as above, except for rainfall and 850hPa winds patterns associated with PC_3 based on (a) TRMM /NCEP2 observations, and GOES5, SPCAM, and HiRAM simulations.

Meridional movement of EPAC rainfall associated with $EEOF_1$ & $EEOF_3$



Shading: rainfall averaged over 130°-100°W. Slopes of dash lines in left and right panels represent phase speed of 0.6 and 1.2 deg/day, respectively.

Summary

- Based on an EEOF analysis of the TRMM rainfall over the EPAC, two dominant SSV modes, a 40-day and a 20-day mode, are identified by two well-separated leading pairs of EEOFs.
- Consistent with the presence of easterly vertical shear during boreal summer over the EPAC, as well as a hypothesis for the key role of easterly vertical shear for the northward propagation of the SSV based on Indian Ocean sector, a prominent northward propagation of the 40-d SSV is also observed over the EPAC with very similar vertical structure as its counterpart over the Asian monsoon region. Thus, the present study provides another independent example of the essential role that easterly vertical wind shear may be playing in regulating the meridional migration of the SSV.
- The second SSV mode associated with the eastern Pacific ITCZ rainfall, which is documented for the first time to the best of our knowledge, could exert influences on the regional climate, including the North American monsoon region, the Gulf of Mexico, and Caribbean Seas.
- The activities of the two SSV modes over the EPAC are anti-correlated on seasonal-to-interannual time scales. A similar feature has been suggested for the SSV over the South China Sea.
- It remains challenging for current GCMs to faithfully depict both of these two SSV modes over the EPAC, including their amplitude, periodicity, and evolution patterns. In contrast to the observed 40-day period of the first SSV mode, the model simulated counterparts generally display slightly higher frequency, with a 30-day spectral peak. Meanwhile, only about half of the GCMs tend to capture the observed bi-weekly period of the second mode.
- While a few of GCMs (e.g., CFS, SNU, GEOS5) reasonably capture the evolution patterns of either the first or second SSV mode, two models, SPCAM and GFDL HIRAM, show superior skills in simulating both of these two modes. Despite of a shift to higher frequency in the spectrum of the first SSV mode in the model, some observed details in evolution patterns of this mode are well captured in GFDL HiRAM. Moreover, a coarse resolution run of the HiRAM fails in capturing the second SSV mode, which indicates the importance of fine horizontal resolution in simulating both of these two dominant SSV modes over the EPAC. The relatively good performance of SPCAM, despite its coarse resolution at 2.5°, may suggest the importance of representation of cumulus processes on the other hand. Thus, these results may reflect two directions for improvement in representing regional climate variability over the EPAC in GCMs.