Abstract

The underrepresentation of the Madden-Julian Oscillation (MJO) in climate models remains a challenge, limiting our ability to improve medium- to extended-range atmospheric prediction. Motivated by recent work identifying the importance of the ratio of equatorial Rossby (ER) to Kelvin wave circulations in MJO propagation, this study examines MJO dynamics in 25 climate model simulations. We find that poor MJO models simulate anomalously large ER wave circulations to the west and small Kelvin and ER wave circulations to east of the convective center. To quantify the role of circulation asymmetries in MJO propagation, we formulate a new west/east (W/E) zonal wind speed ratio. Our W/E ratio differs from other similar metrics in that it implicitly accounts for the ER wave gyres and it can be applied at all levels. Poor model ER wave biases are associated with excessive 700–1000-hPa convergence, convection, and vertical moisture advection co-located and west of the convective center while Kelvin and ER wave biases to the east are associated with a weaker dry anomaly and smaller horizontal moisture advection at 450–750-hPa. Together, these biases help explain the stationary and slight westward MJO propagation in poor models. Space-time spectral analyses of the zonal wind and precipitation confirm that good models produce realistic power, coherence, and phase for the MJO while poor models vastly underrepresent Kelvin waves and the MJO. Even thought Kelvin waves are more realistic in good models, there are still model-wide biases in circulation-convection coupling for ER waves and Kelvin waves.

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Table 1. A list of participating models in the 20-yr climate simulations.

Model Name	Institution	Reference
ACCESS1	Centre for Australian Weather and Climate Research, Australia	(Zhu et al., 2013)
BCC_AGCM2.1	Beijing Climate Center, China Meteorological Administration	(Wu et al., 2010)
CCCma_CanCM4	Canadian Centre for Climate Modelling and Analysis, Canada	(Merryfield et al., 2013)
CNRM_ACM	Centre National de la Recherche Scientifique/Météo-France, France	(Voldoire et al., 2013)
CNRM_AM		
CNRM_CM		
CWB_GFS	Central Weather Bureau, Taiwan	(Liou et al., 1997)
EC_GEM	Environment Canada, Canada	(Côté et al., 1998)
IAP_FGOALS_s2	Institute of Atmospheric Physics, Chinese Academy of Sciences, China	(Bao et al., 2013)
ISU_GCM	Iowa State University, United States	(Wu & Deng, 2013)
LLNL_CAM5ZM	Lawrence Livermore National Laboratory, United States	(Song & Zhang, 2011)
MIROC5	Atmosphere and Ocean Research Institute (AORI)/ National Institute for Environmental Studies (NIES)/ JAMSTEC, Japan	(Watanabe et al., 2010)
MPI_ECHAM6	Max Planck Institute for Meteorology, Germany	(Stevens et al., 2013)
MRI_AGCM	Meteorological Research Institute, Japan	(Yukimoto et al., 2012)
NASA_GEOS5	NASA Global Modeling and Assimilation Office, United States	(Molod et al., 2012)
NASA_GISS_E2	NASA Goddard Institute for Space Studies, United States	(Schmidt et al., 2014)
NCAR_CAM5	NCAR Community Atmospheric Model 5	(Neale et al., 2012)
NCAR_SPCCSM	George Mason University, United States	(Stan et al., 2010)
NCEP_CFSv2	NOAA/NCEP Climate Prediction Center, United States	(Saha et al., 2014)
NCHU_ECHAM5_SIT	Academia Sinica, Taiwan	(Tseng et al., 2015)
NRL_NAVGEM1	U.S. Naval Research Laboratory, United States	
PNU_CFS	Pusan National University, South Korea	(Saha et al., 2006)
SMHI_ECEarth3	Rossby Centre, Swedish Meteorological and Hydrological Institute, Sweden	
TAMU_CAM4	Texas A&M University	(Lappen & Schumacher, 2012)
UCSD_CAM3	Scripps Institution of Oceanography, United States	(Zhang & Mu, 2005)

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