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Evaluation of Climate Models

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Monsoon Variability

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The Mean Monsoon: The global monsoon is the dominant mode of annual variation in the tropics (Wang and Ding 2008, Trenberth et al. 2000). Given the billions of people that fall under its influence, high fidelity simulation of the mean monsoon and its variability is of great importance (Wang 2006; Sperber et al. 2010). Assessment diagnostics and metrics of a model's ability to simulate the monsoon domain and its intensity were introduced by Wang and Ding (2008). As shown in Fig. 1, these measures are based on the hemispheric summer minus winter values, providing a large-scale view of the Earth's monsoon systems in terms of precipitation and circulation. The CMIP5 multi-model ensemble (MME) generally reproduces the observed spatial pattern but somewhat underestimates the extent and intensity, especially over Asia and North America. The best model has similar performance to the MME, whereas the poorest models fail to capture the monsoon precipitation domain and intensity over Asia and the western Pacific, Central America, and Australia. Metrics for the performance of the individual models are given in Fig. 2, which shows the circulation vs. precipitation plots for (a) the pattern correlation for intensity and (b) the threat scores for representing the monsoon domain (Kim et al. 2011). Relative to observations, Fig. 2a shows that the pattern correlation of intensity for the circulation is better simulated than the pattern correlation of precipitation intensity. Similarly, the Fig. 2b threat scores (a categorical metric, Wilks 1995) indicate that the circulation domain is better represented than is the precipitation domain. Consistent with previous generations of models (Sperber and Palmer 1995, Sperber et al. 1999), the circulation is better represented than the precipitation. Importantly, the results indicate that models with the greater skill in simulating the precipitation also have better skill at representing the circulation.

CLIVAR Asian-Australian Monsoon Panel is planning a series of papers that intercompare the CMIP5 and CMIP3 simulations of the Asian and Australian monsoons with the goal of providing the above metrics (and perhaps others) for the AR5.

Monsoon Intraseasonal Variability: Intraseasonal (ISO, 30-70 day) variations are a key component of the monsoon, modulating convection across the tropics. These variations are responsible for the active and break cycles that modulate precipitation over the monsoon. There is some evidence that models that are better able to simulate the seasonal mean climate tend to make better predictions of intraseasonal activity, indicating the seasonal mean is related to the intraseasonal activity over the season, particularly in the monsoon region (Sperber et al. 2000, Kim et al. 2008). During the boreal winter the eastward propagating ISO (known as the Madden-Julian Oscillation) predominantly impacts the deep tropics, while during the boreal summer there is also northward propagation over much of southern Asia (Annamalai and Sperber 2005). The simulation of the Madden-Julian Oscillation is still a challenge for climate models (Lin et al. 2006; Kim et al. 2009; Sperber et al. 2011). However,

contrary to a previous generation of models (Waliser et al. 2003), Sperber and Annamalai (2008) showed that the CMIP3 models were able to simulate eastward propagating intraseasonal convection over the Indian Ocean, though only two of seventeen were able to simulate the observed northward propagation during boreal summer, as seen in Figs. 3a, 3h, and 3i.

Coordinated efforts have been undertaken to improve our understanding of modelling monsoon intraseasonal variability (Sperber and Waliser 2008, Hendon et al. (2011) and to design diagnostics and metrics for model validation (CLIVAR MJOWG 2009, Kim et al. 2009). For example, using lead-lag temporal correlations of the two leading principal component time series, the maximum positive correlation and the time lag at which it occurs provides information about how well models simulate eastward propagation and its associated time scale. The maximum positive correlations presented in Fig. 4 indicate that all of the CMIP3 models have less coherent eastward propagation compared to observations and flux-adjusted versions of the ECHAM4 coupled models. Process-oriented diagnostics and metrics are in development, and they should provide insight in the reasons why simulation the MJO is challenging.

The YOTC MJO Task Force will be using the Fig. 4 metric using combined EOF's, and will be evaluating MJO/ISO in CMIP3 vs. CMIP5. When available I will provide the updated plot.

Despite the limited skill in simulating the MJO/ISO, dynamical prediction of the MJO has been improved in recent years with a dynamical prediction system now able to predict the MJO for up to 20 days (Rashid et al. 2009; Kang and Kim 2010; Gottschalck et al. 2010), which is longer than that of the best statistical models.

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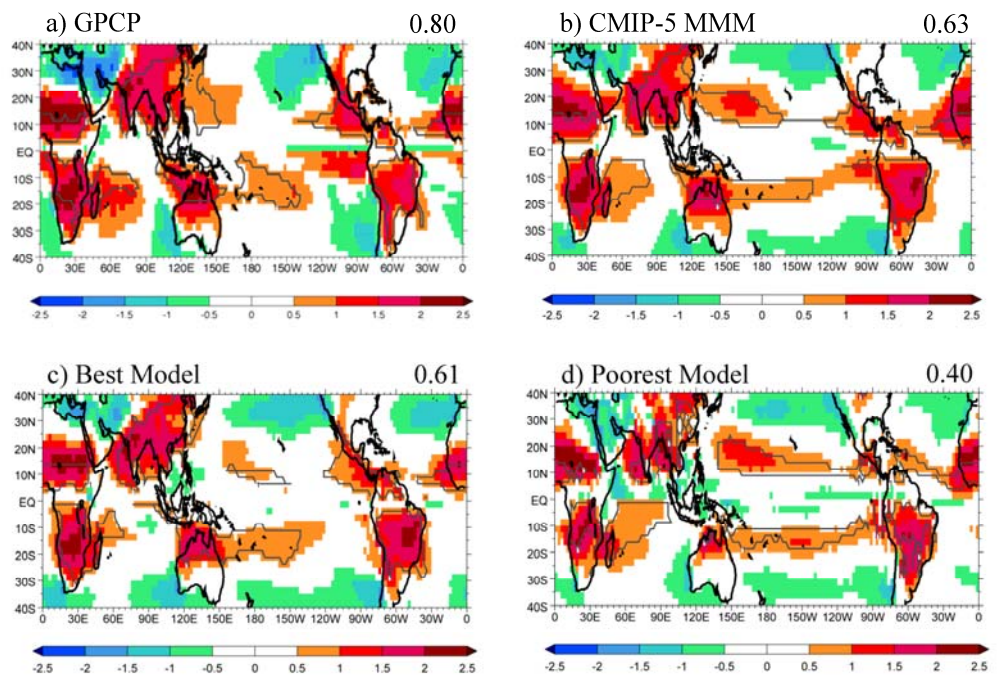


Figure 1: Monsoon precipitation intensity (shading, mm/day) and monsoon precipitation domain (isoline) are plotted for (a) GPCP, (b) the CMIP-5 multi-model mean, the best model, and (d) the worst model in terms of the threat score for this diagnostic. The threat scores indicate how well the models represent the monsoon precipitation domain compared to the GPCP data. The threat score in panel (a) is between GPCP and CMAP rainfall to indicate observational uncertainty. A threat score of 1.0 would indicate perfect agreement between the two datasets. See Wang and Ding (2008), Wang et al. (2010), and Kim et al. (2011) for details of the calculations.

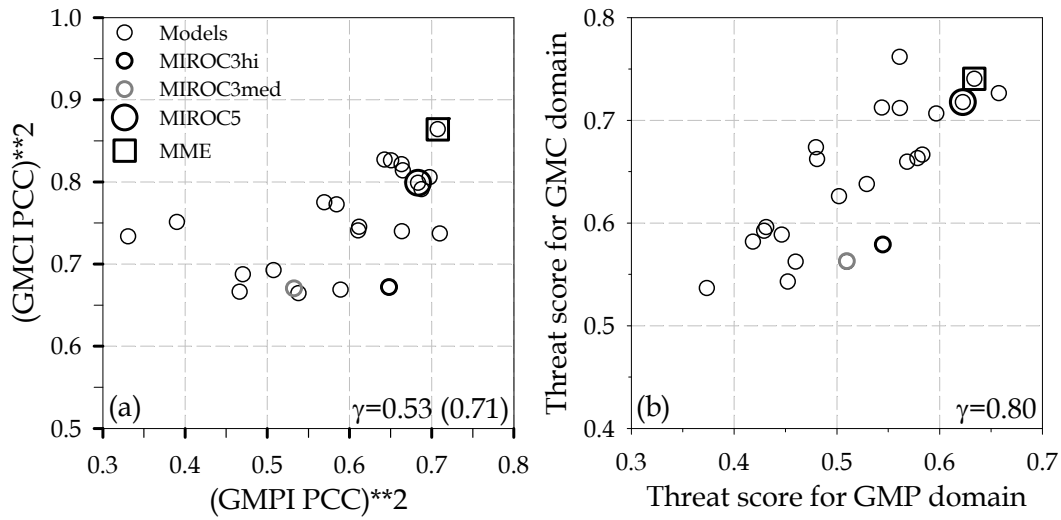


Figure 2: Evaluation of the CGCMs' performance on the climatological global monsoon intensity (left) and domain (right). The regression coefficient is shown in lower-right corner of each panel. The domain used is 0° - 360° E, 40° S- 45° N. The threat score has a range of 0-1, with 1 indicating perfect agreement with observations. After Kim et al. (2011).

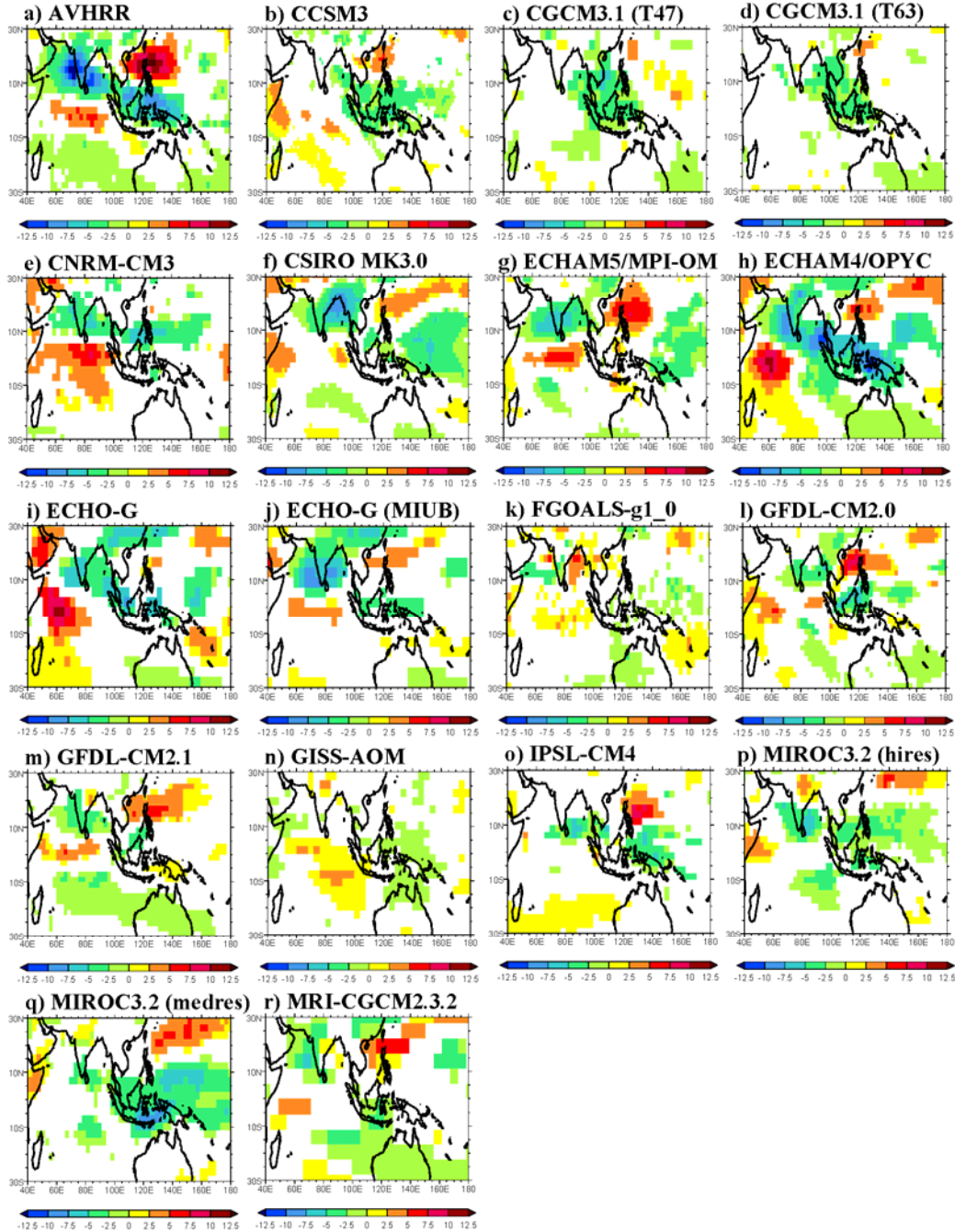


Figure 3: Simulated boreal summer intraseasonal convective anomalies relative to the observed day10 pattern. (a) observations (AVHRR outgoing longwave radiation), (b) CCSM3, (c) CGCM3.1 (T47), (d) CGCM3.1 (T63), (e) CNRM-CM3, (f) CSIRO MK3.0, (g) ECHAM5/MPI-OM, (h) ECHAM4/OPYC, (i) ECHO-G, (j) ECHO-G (MIUB), (k) FGOALS-g1_0, (l) GFDL-CM2.0, (m) GFDL-CM2.1, (n) GISS-AOM, (o) IPSL-CM4, (p) MIROC3.2(hires), (q) MIROC3.2 (medres), and (r) MRI-CGCM2.3.2. After Sperber and Annamalai (2008).

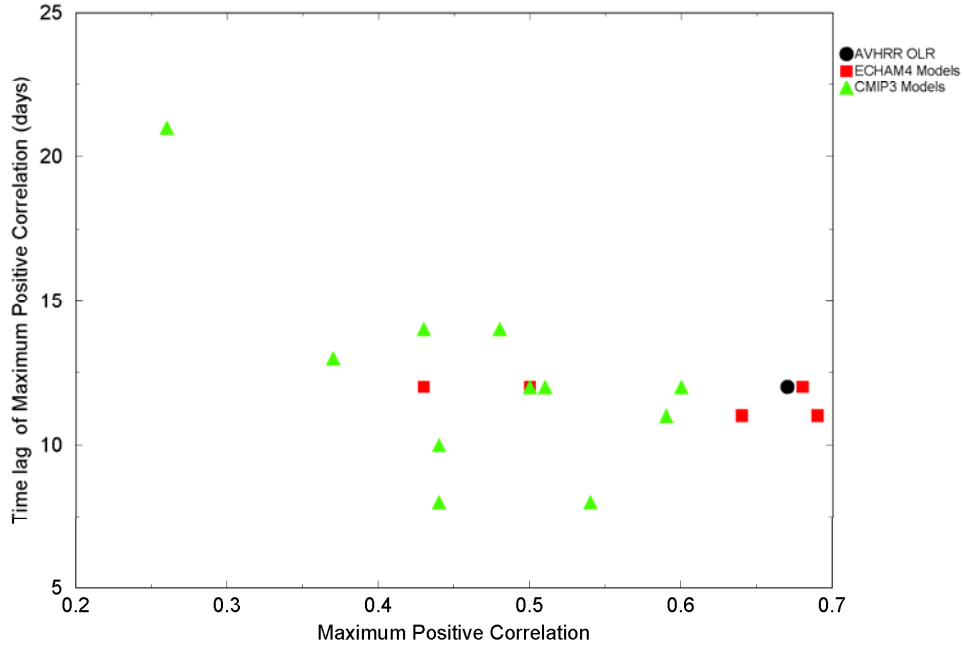


Figure 4: Maximum positive correlation and the time lag at which it occurred based on lead-lag correlations of the principal components (PC's) from the two leading modes of 20-100 day filtered outgoing longwave radiation that capture the MJO. The model data were projected onto the observed EOF's to obtain model PC's. The maximum positive correlation is a measure of how coherently the MJO convection propagates from the Indian Ocean to the Maritime Continent/west Pacific. The time-lag is approximately equivalent to one-quarter of the period of the MJO. Figure courtesy of K. Sperber.

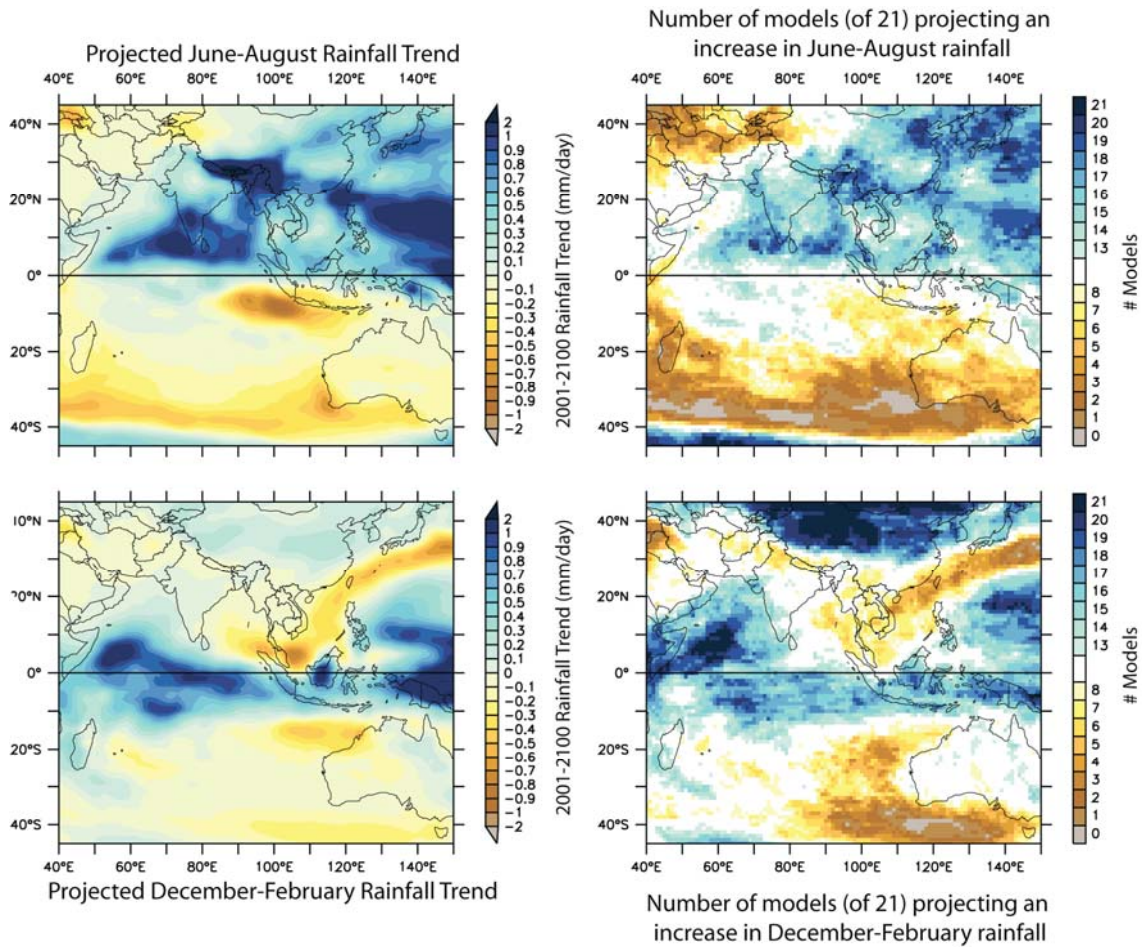


Fig. 6: Projected change in precipitation over the Asian-Australian monsoon region in June-August (top row) and December-February (bottom row) for the SRES-A1B scenario using the CMIP-3 models. The left panels show the 2001-2100 trend in mm/day (21-model average), and the right panels show the number of models (of 21) that have an increasing trend. The figure is adapted from Christensen et al. (2007).