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ENSO representation in climate models: from CMIP3 to CMIP5

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We analyze the ability of CMIP3 and CMIP5 coupled ocean-atmosphere general circulation models (CGCMs) to simulate the El Niño Southern Oscillation (ENSO) and the tropical Pacific mean state. The large spread in ENSO amplitude is reduced by a factor of 2 in CMIP5 and the ENSO life cycle (seasonal phase locking, location of surface temperature anomalies) are slightly improved. Other fundamental ENSO characteristics as its spectrum and central Pacific precipitation anomalies however remain poorly represented. Our analyses however reveal that CMIP5 displays an encouraging 30% reduction of the cold bias in the west Pacific. The Bjerknes and shortwave-surface temperature feedbacks, previously identified as major sources of model errors, do not improve in CMIP5. The slightly improved ENSO amplitude therefore might results from error compensations. CMIP3 and CMIP5 can thus be considered as one ensemble (CMIP3+CMIP5). The ability of CMIP models to simulate the observed nonlinearity of the shortwave feedback is assessed. This nonlinearity arises because the real atmosphere switches from subsident (positive feedback) to convective (negative feedback) regimes under the effect of seasonal and interannual variations. Only one third of CMIP3+CMIP5 models reproduce this regime shift, with the remaining models always locked in one of the two regimes. We suggest that an improved mean state results in an improved shortwave feedback non-linearity, and an improved modeled ENSO amplitude. This provides guidance on how to improve the modeled ENSO in CGCMs in a process-based way, avoiding error cancellation. In order to help choosing appropriate models for studying ENSO, we also provide a summary assessment of CMIP3 and CMIP5 models performance in terms of ENSO characteristics and key feedbacks.