Validating and Understanding Climate Feedbacks in the NCAR and GFDL Models

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Climate feedbacks determine the sensitivity of the climate system to an external perturbation, affect the mean climate, and control the amplitude of natural variability. Thus validating and understanding feedbacks in climate models are of critical importance. Here we compare the feedbacks in the two latest versions of the NCAR Community Atmosphere Model- -the NCAR CAM1 (CCM3) and the NCAR CAM2-- with those from observations over the equatorial Pacific cold-tongue. We also present some corresponding results from a preliminary analysis of a GFDL atmosphere model-- the GFDL "intermediate" globe atmosphere model (AM2). We obtain the strength of the feedbacks by measuring the response of the corresponding energy fluxes to El Nino warming/La Nina cooling.

The results show that the positive feedback from the greenhouse effect of water vapor in both CAM1 and CAM2 largely agrees with that from observations (8.2 $Wm^{-2}K^{-1}$ and 8.3 $Wm^{-2}K^{-1}$ respectively in the two models versus the observed 6.4 $Wm^{-2}K^{-1}$). CAM1 and CAM2 also both capture the strong negative feedback from the atmospheric transport (-13.2 $Wm^{-2}K^{-1}$ and -11.0 $Wm^{-2}K^{-1}$ respectively in the two models versus the observed value -14.8 $Wm^{-2}K^{-1}$). More significant errors are found in the cloud feedbacks. The feedback from the short-wave forcing of clouds in CAM2 appears to need particular attention. While observations show a strong negative feedback from the short-wave forcing of clouds (-7.8 $Wm^{-2}K^{-1}$), the feedback from the short-wave forcing of clouds in CAM2 is positive (+3.4 $Wm^{-2}K^{-1}$). The sign of the feedback from the short-wave forcing in CAM1 is correct, but the strength is less than half of the observed value (-3.0 $Wm^{-2}K^{-1}$). Consequently, the net atmospheric feedback in both CAM1 and CAM2 over the cold-tongue region is strongly positive (+5.1 $Wm^{-2}K^{-1}$ in CAM1 and +6.7 $Wm^{-2}K^{-1}$ in CAM2) while in the real atmosphere it is strongly negative (-6.4 $Wm^{-2}K^{-1}$).

The cloud feedbacks in the GFDL AM2 appear to have a better agreement with observations than the NCAR models. The negative feedback from the short-wave forcing of clouds from the GFDL AM2 is only slightly less negative than the observed value (-6.6 $Wm^{-2}K^{-1}$ versus -7.8 $Wm^{-2}K^{-1}$). The feedback from the long-wave forcing of clouds in AM2 is also closer to the observed value than that in either CAM1 or CAM2. Largely due to the improvement in the cloud feedbacks, the net atmospheric feedback over the cold-tongue region in AM2 is considerably closer to the observed value than in the NCAR models, though it is still significantly less negative than the observed value (-3.9 $Wm^{-2}K^{-1}$ in AM2 versus the observed -6.4 $Wm^{-2}K^{-1}$).

Possible causes for the differences in the feedbacks among these models are explored. The consequences of a less negative net atmospheric feedback in the Pacific cold tongue region upon the coupled simulation of the tropical Pacific climate are outlined.