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Constraining climate system properties using 20th century observations and the implications for the CMIP3 ensemble results

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Two characteristics of the climate system are often used as intercomparison metrics for the large-scale response of the climate system to global forcings: the climate sensitivity and the rate of heat uptake by the deep-ocean. We present revised probability distributions for these climate model properties (in addition to the strength of the net aerosol forcing) that are based on climate change observations from the 20th century. We compare observed changes in surface, upper-air, and deep-ocean temperature changes against simulations of 20th century climate in which the climate model parameters were systematically varied. The estimated 90% range of climate sensitivity is 2. to 5. K. The net aerosol forcing strength for the 1980s has 90% bounds of -0.70 to -0.27 W/m^2. The rate of deep-ocean heat uptake corresponds to an effective diffusivity, K_v, with a 90% range of 0.04 to 4.1 cm^2/s. We also estimate the effective climate sensitivity and rate of deep-ocean heat uptake for 11 of the IPCC AR4 AOGCMs in the CMIP3 archive. By comparing against the acceptable combinations inferred by the observations, we conclude that the rate of deep-ocean heat uptake for the majority of AOGCMs lie above the observationally based median value. Using these parameter distributions, we estimate the distributions for changes in global mean surface temperature for the IPCC SRES scenarios B1, A1B, and A2. The results are compared with the projections made by the IPCC AR4's multi-model ensemble. The multi-model ensemble systematically underestimates the warming, because it overestimates how rapidly heat is mixed into the oceans. For example, for the A2 (business as usual) scenario the multi-model ensemble gives a 5 % probability that the mean warming will

exceed 4.1 C by 2100, while the MIT analysis gives a 46 % probability.