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On constraining climate system properties using observed and modeled climate changes

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To quantify uncertainty in climate model properties, the basic method requires two parts: simulations of the 20^{th} century climate record and the comparison of the simulations with observations using optimal fingerprint diagnostics. First, a large sample of simulated records of climate change are created in which climate parameters have been systematically varied. This requires a computationally efficient model with variable parameters as provided by the MIT 2D statistical-dynamical climate model. Second, a method of comparing model data to observations that appropriately filters "noise" from the pattern of climate change is required. The variant of optimal fingerprinting proposed by Allen and Tett (1999) provides this tool and yields detection diagnostics that are objective estimates of model-data goodness-of-fit. The primary goal has been to quantify the joint uncertainty in S, K_v, and F_{aer}, by exploiting the surface, upper-air and deep-ocean temperature records.

The two major findings from Forest et al. (2002, Science, v295, p113-117) are (1) an estimate of the uncertainty range for the climate sensitivity and (2) an estimated range for the uncertainty in the net aerosol forcing. These objective pdf estimates are based on climate observations from multiple data sources (upper-air, surface, and deep-ocean temperatures) and attempt to take into account uncertainties in these data where possible. The method also permits the use of *a priori* information outside the scope of the analysis and thereby, can assess the relative importance of the diagnostics and external information. Forest et al. (2002) estimated the climate sensitivity 5-95% confidence interval of 1.4-7.7 K with uniform priors and 1.3-4.2 K with an expert prior. For the net aerosol forcing, the 5-95% confidence interval is -0.3 to -0.95 W/m^2 with uniform priors.

The Forest et al. (2002) method has been updated to include a more complete set of forcings for the 1860-1995 period. In addition to changes in greenhouse gases, sulfate aerosols, and ozone concentrations, changes in solar irradiance (Lean, 2000), volcanic aerosols (Sato et al., 1993) and land-surface vegetation (Ramankutty Foley, 1999) were included. The solar and volcanic forcings are external natural forcings while the land-surface vegetation represents an additional anthropogenic forcing. As previously done, we performed a systematic scan of the model parameter space using the reference settings of the land-surface vegetation, solar, and volcano forcings. The additional forcings have two major effects. First, the inclusion of the volcanic aerosol forcing provides a net cooling during the latter 20th century and thus the MIT 2DLO climate model requires a higher climate sensitivity and weaker deep-ocean heat uptake to remain consistent with the historical climate record. Second, the median net aerosol forcing is partially reduced from -0.6 to -0.4 W/m^2 but there is little change in its uncertainty ($\pm \sim$0.3 W/m^2). This reduction is partially because the net forcing uncertainty no longer includes the volcanic term. However, the net aerosol forcing remains a cooling effect. These distributions differ from Forest et al. (2002) results in both the climate sensitivity and Kv distributions. The range of effective ocean diffusivities for the existing AOGCMs is 4-25 cm^2/s and represents a fundamental uncertainty in the large-scale behavior of the climate system. We compare these results with the recent pdf from the GSOLSV results and discuss methods for constraining additional feedbacks.