Vol. 22: 187–188, 2002 | CLIMATE RESEARCH Clim Res | Published September 6

REPLY COMMENT

Modeling climatic effects of anthropogenic carbon dioxide emissions: unknowns and uncertainties. Reply to Risbey (2002)

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Our review article (Soon et al. 2001) highlighted the limitations of utilizing the current generation of General Circulation Models (GCMs) in estimating the effects from added anthropogenic CO_2, because of major uncertainties and unknowns about the basic working of the Earth's climate system. As emphasized in our paper, our discussion is necessarily incomplete because of practical constraints. However, to pejorate our discussion as a 'dirty laundry list' is to ignore the care exercised in selecting quite specific examples of the limitations of GCMs, each directly related to the clearly stated purpose of estimating the interdecadal timescale effects of anthropogenic CO_2 forcing or any number of external forcings. Furthermore, the limitations we discussed lead us not to sweeping conclusions about invalidating GCM results, but only to the scientist's standard conservative caution on the lack of reliable, meaningful answers from GCMs given both the present level and future scenarios of CO_2 or other external forcings. In addition, even a mere 'dirty laundry list' can serve the crucial purpose of provoking constructive discussion on improving the science of climate forecasting.

We restrict our response to 4 of Risbey's complaints:

(1) '*…one can generate such lists in any complex modelling endeavour ...Soon et al. (2001) make a set of general claims on the basis of the laundry list, mostly without relating function to process, variable, or scale.*'

The issue under examination is not about 'any complex modelling endeavour.' Instead, we focused on the specific basis of future modelling efforts, namely, an understanding of forced and unforced change of specific climate variables on specific regional and global spatial scales, from interannual to century time scales. From that standpoint, we logically extended the topic to the ability of GCMs to explain, through quantitative understanding of well-documented features of the climate system (rather than ambiguous statistical arguments alone). The GCMs cannot be validated by any other means than to compare forced and unforced results to observed climate variability. In that context, our review cited important systematic deficiencies for current GCMs in simulating basic climatic variables such as surface temperature, atmospheric temperature and precipitation. Admittedly, it is far easier to obtain data with which to validate weather GCMs than climate models, but unless Risbey is willing to argue either that the climate GCMs are immune to the same scientific validation process, or that the expert opinions accumulated in our review are incorrect, Risbey's metacriticism is both biased and irrelevant.

(2) '*In several places Soon et al. (2001) cite flux errors in the energy budget in GCM simulations compared to observations, generally taking the presence of such errors to imply that GCM simulations are unreliable. The presence of such errors may or may not be important depending on what one wishes to simulate ... Without such analysis a list of flux errors in models is just that.*' (see the complete paragraph in Risbey 2002).

Risbey (2002) suggests that GCMs can somehow be correct in assessing the small climate perturbations in response to the approximately 4 W m^{-2} net infrared flux change caused by anthropogenic greenhouse gases, while important flux adjustments more than 10 × larger shuttle through the calculation! This is an attempt to bypass the scientific process of model validation.

Risbey (2002) argues that some research suggests that GCM validation is irrelevant, even in the presence

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of large flux adjustments, because the large flux adjustments are of no consequence. We agree with Risbey (2002) that flux adjustments are important for simulation (e.g. of the thermohaline circulation) but how a large flux adjustment can be truly insignificant for problems of regional or global climatic change on decadal to century timescales has never been demonstrated. Quite the contrary, in many contemporary GCMs, artificial energy or heat flux adjustments as large as 100 W m^{-2} are used to minimize unwanted drift in the ocean-atmosphere coupled system, apart from nonphysical flux adjustments for freshwater, salinity and wind stress (momentum). Models that attempt to avoid artificial heat flux adjustments fare no better because of other substantial biases, including major systematic errors in the computation of sea-surface temperatures and sea ice over many regions, as well as large salinity and deep-ocean temperature drifts. For example, another GCM's high-latitude southern ocean suffered a large drift (Cai & Gordon 1999): within 100 yr after coupling the atmosphere to the ocean, the Antarctic Circumpolar Current was noted to intensify by 30 Sv (from 157 to 187 Sv) despite the use of flux adjustments. Cai & Gordon (1999) identified the instability of convection patterns in the Southern Ocean to be the primary cause of this drift problem. These are specific citations of problems with GCMs.

(3) *'…the models are sometimes impugned on the basis of specious reasoning. In their Fig. 3, they show ...'* (see the complete paragraph in Risbey 2002).

We impugn neither the models nor modellers. We merely cite numerous, specific limitations of the current generation of climate models in relation to the problem of predicting the climate response to anthropogenic greenhouse gases (see the paragraph above). The problems we cite are not vague editorial statements, but documented problems from peer-reviewed literature.

We do not know why Risbey imagined that Soden (2000) made the simple error of comparing the interannual variability of the ensemble average of 30 different precipitation time series, on one hand, with observed interannual variability of tropical-mean precipitation, on the other. In fact, Soden did not make this error. On the contrary, he clearly stated that he followed the correct procedure of finding the variance of each series, individually, and then comparing their average of 0.06 mm yr^{-1} with the observed value of 0.18 mm yr^{-1} (Soden 2000, p. 541) and drew the obvious conclusion that the variability was underestimated by a factor of 3. In any case, Risbey will need to raise this issue (if he believes he still has one) with Soden, not with us.

(4) *'…the Soon et al. (2001) review cites shortcomings of GCM simulations of the El Niño Southern Oscillation (ENSO). By and large, GCM modellers have been quite forthcoming and candid about these…'*

We did not state that ENSO models have hidden their inadequacies. Further, we have no interest in claiming that GCM modellers have not been forthcoming or candid about weaknesses or inadequacies of GCMs in representing any physical phenomena. However, it is a relevant scientific matter to point out the fact that current GCM simulations of ENSO and related variabilities are still less than adequate, and are therefore unable to render either meaningful or consistent predictions of ENSO characteristics under, for example, the high CO_2 loading scenario (i.e. 4× the current concentration of CO_2) adopted by some simulations.

We conclude by restating 2 important points from our article: (1) 'Our review points out the enormous scientific difficulties facing the calculation of climatic effects of added CO_2 in a GCM, but it does not claim to disprove a significant anthropogenic influence on global climate'; and that (2) 'the proper use of a climate model is to challenge existing formulations (i.e. a climate model is built to test proposed mechanisms of climate change) rather than to predict unconstrained scenarios of change by adding CO_2 to the atmosphere.

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