Lindzen and Choi Unraveled

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Guest Commentary by John Fasullo, Kevin Trenberth and Chris O'Dell

A recent paper by Lindzen and Choi in GRL (2009) (LC09) purported to demonstrate that climate had a strong negative feedback and that climate models are quite wrong in their relationships between changes in surface temperature and corresponding changes in outgoing radiation escaping to space. This publication has been subject to a considerable amount of hype, for instance apparently "[LC09] has absolutely, convincingly, and irrefutably proven the theory of Anthropogenic Global Warming to be completely false." and "we now know that the effect of CO_2 on temperature is small, we know why it is small, and we know that it is having very little effect on the climate". Not surprisingly, LC09 has also been highly publicized in various contrarian circles.

Our initial reading of their article had us independently asking, how we could have missed such explicit evidence of the cloud feedback as shown in LC09? Why would such a significant finding have gone undiscovered when these feedbacks are widely studied and recognised as central to the projections of climate change? We discovered these common concerns at a meeting last year and then teamed up to address these questions.

With the hype surrounding the manuscript, one would think that the article provides a sound, rock solid basis for a reduced climate sensitivity. However, our examination of the study's methods demonstrates that this is not the case. In an article in press (Trenberth et al. 2010 (sub. requ.), hereafter TFOW), we show that LC09 is gravely flawed and its results are wrong on multiple fronts. These are the major issues we found:

- **The LC09 results are not robust.**

  A goal of LC09 was to quantify the cloud feedback by examining variability in top-of-atmosphere (TOA) radiative fluxes in the tropics as it relates to variability in mean sea surface temperature (SST). To do this they examine only tropical data. In general, they find that during periods of higher-than-normal SST, the radiation emitted and reflected to space by the earth goes up as well, cooling the Earth and amounting to an overall negative climate feedback. To show this, they select intervals of warming and cooling (in a time series of monthly averaged values) and compare fluxes at their endpoints (see Figure). They didn't provide an objective criterion for selecting these endpoints and in some instances (see their Fig. 1), the selection of these intervals actually appears to be quite odd.

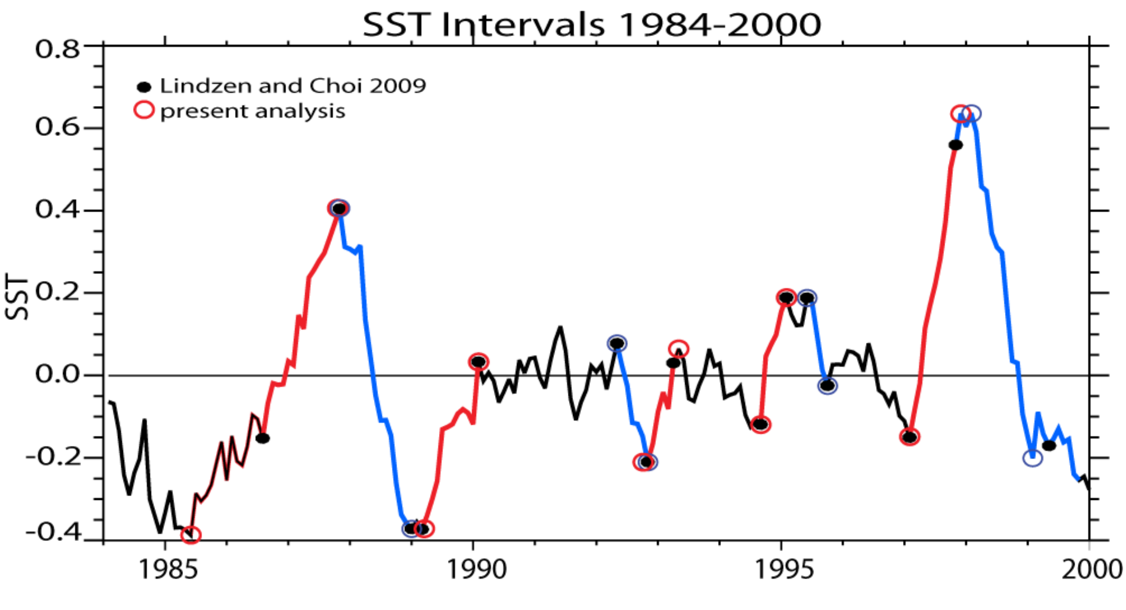

Fig. 1: Warming (red) and cooling (blue) intervals of tropical SST (20°N – 20°S) used by LC09 (solid circles) and an alternative selection proposed derived from an objective approach (open circles) (TFOW, 2010).

The result one obtains in estimating the feedback by this method turns out to be heavily dependent on the endpoints chosen. [edit] In TFOW we show that the apparent relationship is reduced to zero if one chooses to displace the endpoints selected in LC09 by a month or less. So with this method the perceived feedback can be whatever one wishes it to be, and the result obtained by LC09 is actually very unlikely. This is not then really indicative of a robust cloud feedback.

- **LC09 misinterpret air-sea interactions in the tropics**

  The main changes in tropical SST and radiative fluxes at TOA are associated with El Niño-Southern Oscillation (ENSO) and are not necessarily indicative of forced variability in a closed system. ENSO events cause strong and robust exchanges of energy between the ocean and atmosphere, and tropics and subtropics. Yet LC09 treat the tropical atmosphere as a closed and deterministic system in which variations in clouds are driven solely by SST. In fact, the system is known to be considerably more complex and changes in the flow of energy arise from ocean heat exchange through evaporation, latent heat release in precipitation, and redistribution of that heat through atmospheric winds. These changes can be an order of magnitude larger than variability in TOA fluxes, and their effects are teleconnected globally. It is therefore not possible to quantify the cloud feedback with a purely local analysis.

- **More robust methods show no discrepancies between models and observations**

  In TFOW, we compute correlations and regressions between tropical SSTs and top-of-atmosphere (TOA) longwave, shortwave and net radiation using a variety of methods. LC09 found the observed behavior to be opposite from that of 11 atmospheric models forced by the same SSTs and conclude that the models display much higher climate sensitivity than is inferred from ERBE. However, in our analysis comparing these relationships with models, we are unable to find any systematic model bias. More importantly, the nature of these relationships in models bears no relationship to simulated sensitivity. That is, the metric developed by LC09 is entirely ineffective as a proxy for simulated sensitivity.

- **LC09 have compared observations to models prescribed with incomplete forcings**

  The AMIP configuration in the model simulations used by LC09 have incomplete forcings. The AMIP protocol started off a test only of how an atmospheric model reacts to changes in ocean temperatures, and so models often only use the ocean temperature change when doing these kinds of experiments. However, over the period of this comparison, many elements – greenhouse gases, aerosols, the sun and specifically, volcanoes changed the radiative fluxes, and this needs to be taken into account. Some models did this in these experiments, but not all of them.

  For instance, the dominant source of variability in the reflected solar flux arises from aerosols associated with the eruption of Mount Pinatubo in June of 1991 yet all but 2 model simulations examined by LC09 omit such forcings entirely. Other radiative species are absent from the models altogether. It is thus obviously inappropriate to expect such model simulations to replicate observed variability in TOA fluxes.

- **LC09 incorrectly compute the climate sensitivity**

  By not allowing for the black body radiation (the Planck function) in their feedback parameter, LC09 underestimate climate sensitivity. Using the correct equations, LC09 should obtain a feedback parameter and climate sensitivity of -0.125 and 0.82 K, respectively, rather than their values of -1.1 and 0.5 K. In contrast, TFOW results yield a positive feedback parameter and greater sensitivity estimate, though we also caution that this approach is not a valid technique for estimating sensitivity, as a closed and therefore global domain is essential (though not by itself sufficient). Lastly, LC09 fail to account for variability in forcings in estimating sensitivity.

While climate models are known to struggle with many aspects of tropical climate, especially in regards to its coupled variability, the problems claimed by LC09 are not among them. Forster and Gregory [2006] and Murphy et al. [2009] address changes in the energy budget with surface temperatures for a much larger domain and present a much more complete and defensible analysis and discussion of issues. They demonstrate that recent observed variability indeed supports a positive shortwave cloud feedback. So the feedbacks from processes other than the Planck function response are clearly positive in both observations and models, in contrast to LC09's conclusions. Moreover, it is not appropriate to use only tropical SSTs and TOA radiation for feedback analysis as the transports into the extratropics are substantial. Any feedback analysis must also recognize changes in ocean heat storage and atmospheric energy transport into and out of the tropics which are especially large during ENSO events. While the tropics play an important role in determining climate sensitivity, simplistic and arbitrary analyses of tropical variability can be grossly misleading.

References

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