Radiative Feedback Signatures in AMSR-E Sea Surface Temperatures Versus Tropospheric Temperatures

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Radiative feedbacks in the climate system are the primary uncertainty affecting estimates of anthropogenic global warming and climate change (Knutti & Hergerl, 2008; IPCC, 2007). While the feedbacks of most interest are on the long time scales associated with anthropogenic greenhouse gas forcing – decadal or longer – our most accurate satellite measurements of global radiative fluxes are closer to ten years in length. As a result, only short term climate variability can be analyzed and related to short term variability in climate models as part of the model testing and validation process.

But as time scales are decreased, the observed behavior of the climate system – at least in terms of identifying and quantifying feedbacks -- changes markedly. Feedbacks are traditionally referenced to surface temperature changes. But AMSR-E data shows that as time scales are shortened, there exists very little correlation between global, monthly average SST data and radiative fluxes measured by CERES on NASA's Aqua or Terra satellites.

This decorrelation is due to the fact that there are episodic variations in global-average convective heat transport from the surface to the troposphere (Spencer et al., 2007). These variations, which are usually on the order of weeks to a few months, exhibit either SST warming and tropospheric cooling during less convective periods, or SST cooling and tropospheric warming during more active periods. This negatively correlated behavior means that when radiative flux changes are quantitatively divided by temperature changes in order to estimate a feedback parameter, results with opposite signs can be experienced depending upon which temperature is used. Obviously, as time scales increase to yearly or longer, this effect gradually goes away since there is an average long term convective coupling of the surface to the troposphere which is believed to change very little over time.

When lag correlations are computed for global averages on daily time scales, one sees that correlations between daily radiative flux variations and SST variations are close to zero, maybe even slightly negative. But in contrast, tropospheric temperatures from AMSU-A reveal quite high correlations with radiative flux. For the total radiative flux (the sum of the reflected shortwave, SW, and emitted infrared or longwave, LW flux anomalies), a correlation approaching 0.70 is found at zero days lag. Within the forcing-feedback paradigm of natural climate variability, this is a clear 'feedback' relationship since and radiative forcing (e.g. quasi-random cloud cover variations not due to feedback) will precede temperature by 90 degrees in phase.

This feedback relationship at zero days lag is made up of a SW component which peaks several days before the tropospheric temperature peak, while the LW component peaks several days after the temperature peak. The sum of the two radiative components then has a peak correlation with radiative flux at zero days lag. This behavior is consistent with the conceptual view of convective events, probably driven by intraseasonal oscillations in the tropics, as starting out with an increase in low clouds initially, then a gradual enhancement of deep convection, and then a dissipating stage where the anomalously warm upper troposphere loses excess infrared energy to space.

We find evidence of considerable internal radiative forcing in the satellite data, that is, non-feedback variations in clouds causing temperature changes. These events are best revealed with phase space plotting, there the time history of radiative flux versus temperature in graphs is indicated by connecting successive data points with lines. A simple forcing-feedback model (Spencer & Braswell, 2008) shows that internal radiative forcing causes a decorrelated relationship between radiative flux and temperature, whereas feedback reveals a highly correlated relationship. The internal radiative forcing tends to obscure the signature of feedback, adding another dimension of uncertainty to the diagnosis of feedbacks from satellite data.

These results suggest that feedback studies must be very careful about the time scale of averaging employed when attempting to infer feedbacks from global satellite data.

References

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