Earth Syst. Dynam. Discuss., 4, C137–C143, 2013
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Earth System Dynamics Discussions

Interactive comment on "Estimation of the climate feedback parameter by using radiative fluxes from CERES EBAF" *by* P. Björnbom

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Received and published: 25 March 2013

Subject: Comparison of my paper with Armour et al. (2012) gives a possible explanation to the observed time lag in global radiative thermal response.

Since the submission of my discussion paper the new important paper by Armour et al. (2012) has appeared. The purpose of this short comment is to discuss how their results may support some findings in my discussion paper. Thus their new regional approach to feedback may offer an explanation to the coherent oscillations in the temperature anomaly and the net radiative flux anomaly observed by me in CERES EBAF for the time interval mid-2006 to mid 2011. This especially concerns explanation of the lag between the radiative flux anomaly changes and the temperature anomaly changes.

General comments

Armour et al. (2012) suggest based on advanced climate model simulations that the local TOA net radiative flux satisfies the following linearized equation, where $\boldsymbol{r} =$ (latitude, longitude), $F(\boldsymbol{r}, t)$ denotes the local radiative forcing and $\Delta T(\boldsymbol{r}, t)$ the local surface temperature change:

$$N(\boldsymbol{r}, t) = F(\boldsymbol{r}, t) - \alpha(\boldsymbol{r})\Delta T(\boldsymbol{r}, t) \tag{1}$$

This appears to be a fruitful approach resulting in a possible explanation for the time dependence of the global climate feedback parameter, also called the thermal damping rate (Dessler 2013), observed in advanced climate model simulations. Armour et al. find that the time variations have to do with temporal changes in the relative importance of different regions with different values of the thermal damping rates.

I have used Eq. (1) for a simple reasoning in order to explain the time lag observed by me for the time interval mid-2006 to mid-2011 in the global radiative response to global temperature changes. See Fig. 1 in my discussion paper. The temperature anomaly is oscillating and the net radiative flux anomaly is varying coherently, but with a time lag of around seven months. It is assumed that the radiative flux anomaly changes due to the temperature response are dominating compared to the changes in radiative forcing.

My reasoning suggests that the lag may be explained as an effect of phase shifted temperature oscillations in regions with different values of the thermal damping rate. The proposed mechaninsm may of course also be combined with other mechanisms discussed in my discussion paper and other short comments here.

The mechanism presented here has the advantage that no lag is assumed between radiative feedback and temperature changes locally but the lag observed globally is the result of temperature oscillations being phase shifted in different regions. In the idealized example with two regions discussed in the following section, temperature oscillations were leading in the first region with a zero value of the thermal damping rate. In the second region similar temperature oscillations occurred but with a 15 months lag and with a thermal damping rate of 4.6 $\mathrm{W\,m^{-2}\,K^{-1}}$.

The remarkable result found was an oscillating response in the global radiative flux lagging the oscillating global temperature changes with seven months and, surprisingly, a thermal damping rate of 6 $\mathrm{W\,m^{-2}\,K^{-1}}$. Thus the value of the global thermal damping rate became higher than the values of the thermal damping rates in any of the two regions. The explanation for this is that the temperature changes in the two regions partly cancel giving a smaller amplitude in the global temperature changes than in the regional ones. This is further explained in the next section.

Specific comments

We assume that we have two regions of equal area. In the first region internal variability produces an oscillating temperature. In the second region the temperature changes in the first region produce a similarly oscillating temperature but with a lag of many months.

The first region has a low thermal damping rate while the second region has a high one.

$$N_1(t) = F_1 - \alpha_1 \Delta T_1(t) \quad (2)$$

$$N_2(t) = F_2 - \alpha_2 \Delta T_2(t) \quad (3)$$

$$\Delta T(t) = \frac{\Delta T_1(t) + \Delta T_2(t)}{2} \quad (4)$$

$$N(t) = F - \frac{\alpha_1 \Delta T_1(t) + \alpha_2 \Delta T_2(t)}{2} \quad (5)$$

$\Delta T(t)$ will have a lag between $\Delta T_1(t)$ and $\Delta T_2(t)$. Because $\alpha_1 < \alpha_2$ the net radiative flux $N(t)$ will be more lagged compared to $\Delta T_1(t)$ than to $\Delta T(t)$.

In Fig. 1 in this short comment this is illustrated using the following numerical example, assuming constant forcing and with time in months:

$$\Delta T_1(t) = 0.26 \sin(\pi \frac{t}{20}) \quad (6)$$

$$\Delta T_2(t) = 0.26 \sin(\pi \frac{t-15}{20}) \quad (7)$$

$$\alpha_1 = 0 \quad (8)$$

$$\alpha_2 = 4.6\,\mathrm{W\,m^{-2}\,K^{-1}} \quad (9)$$

As clearly seen from Fig. 1 this example produces a temperature anomaly and a net radiative flux anomaly numerically satisfying the following equation with $\alpha = 6\,\mathrm{W\,m^{-2}\,K^{-1}}$ and $t_{\mathrm{lag}} = 7$ months:

$$N(t) = F - \alpha \Delta T\,(t - t_{\mathrm{lag}}) \quad (10)$$

This is further demonstrated by the lagged phase plane plot in Fig. 2 in this short comment. In that diagram $-N(t)$ has been plotted versus the temperature anomaly with seven months lag $\Delta T(t-7)$.

Thus this numerical example produces a lagged thermal response of the radiative flux very similar to that observed by me in CERES EBAF data (see Fig. 1, Fig. 3 and Eq. (5) in my discussion paper).

References

Kyle C. Armour, Cecilia M. Bitz, Gerard H. Roe. Time-varying climate sensitivity from regional feedbacks. Journal of Climate 2012 ; e-View doi: http://dx.doi.org/10.1175/JCLI-D-12-00544.1

Dessler, A. E., 2013: Observations of climate feedbacks over 2000-10 and comparisons to climate models. J. Climate, 26, 333–342.

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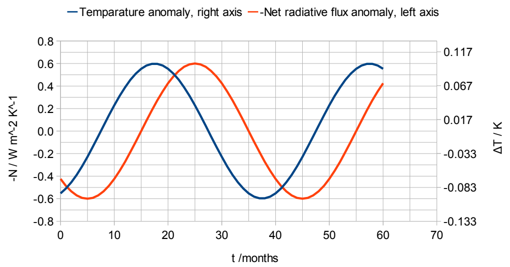

Fig. 1. Time series plot

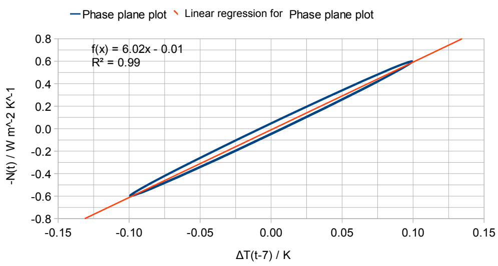

Fig. 2. Phase plane plot