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Discussions

Interactive comment on "The influence of internal variability on Earth's energy balance framework and implications for estimating climate sensitivity" *by* Andrew E. Dessler et al.

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In this paper, the authors present an interesting result. Based on both historical observations and analyses of results from an advanced climate model they found that $\Delta(R-F)$ correlates much better with changes in the mean tropical tropospheric temperature ΔT_A than with changes in the mean global surface temperature ΔT_S. Thus, the linearised equation for the TOA radiative flux imbalance

$$R = F + \Theta T_A \tag{1}$$

gives a more precise representation of $R-F$ than the traditional linearised equation

that has frequently been used for determining ECS from historical observations

$$R = F + \lambda T_S \tag{2}$$

Consequently, the climate feedback parameter Θ can be determined more precisely than the traditional climate feedback parameter λ.

However, this paper also raises a question of a fundamental character concerning how regional versions of Eqs. (1) and (2) relate to the original global ones. The authors have discussed regional versions of Eqs. (1) and (2) in the paper

$$R_r = F_r + \lambda_r T_{S,r} \tag{3}$$

$$R_r = F_r + \Theta_r T_{A,r} \tag{4}$$

and found from the observations of the TOA imbalance that the three different regions NH, EQ and SH exhibited different values of λ_r and Θ_r (see Fig. 5 in the paper). This raises a fundamental question about the compatibility of Eqs. (2) and (3) or (1) and (4) that may be illustrated by an example with a planet being described using three regions with the surface area fractions a_1, a_2 and a_3. By using the three equations corresponding to Eq. (3) and applying $R = a_1R_1 + a_2R_2 + a_3R_3$, $F = a_1F_1 + a_2F_2 + a_3F_3$, $\lambda = a_1\lambda_1 + a_2\lambda_2 + a_3\lambda_3$ and $T_S = a_1T_{S,1} + a_2T_{S,2} + a_3T_{S,3}$ we get the following equivalent expressions for the TOA radiative flux imbalance

$$R = F + \lambda_1 T_S + a_2(\lambda_2 - \lambda_1)T_{S,2} + a_3(\lambda_3 - \lambda_1)T_{S,3} \tag{5}$$

$$R = F + \lambda_2 T_S + a_1(\lambda_1 - \lambda_2)T_{S,1} + a_3(\lambda_3 - \lambda_2)T_{S,3} \tag{6}$$

$$R = F + \lambda_3 T_S + a_1(\lambda_1 - \lambda_3)T_{S,1} + a_2(\lambda_2 - \lambda_3)T_{S,3} \tag{7}$$

$$R = F + \lambda T_S + a_2a_1(\lambda_2 - \lambda_1)(T_{S,2} - T_{S,1}) + +a_3a_1(\lambda_3 - \lambda_1)(T_{S,3} - T_{S,1}) + a_3a_2(\lambda_3 - \lambda_2)(T_{S,3} - T_{S,2}) \tag{8}$$

Similar equations are obtained with T_A instead of T_S and Θ instead of λ. The result of this analysis is that the linearised regional TOA imbalance equations are not in general compatible with the linearised global TOA imbalance equation. If Eq. (3) is satisfied for each region, then Eq. (2) is in general not satisfied globally. While Eq. (2) expresses $R - F$ as a function of T_S alone, according to Eqs. (5)–(8) $R - F$ in general is a function three temperatures.

The authors have demonstrated the estimation of the regional climate feedback parameters, both λ_r and Θ_r, from Eqs. (3) and (4). The values of those parameters given in Fig. 5 in their paper show that the differences between the Θ_r-values are less than the differences between the λ_r-values. From the form of Eq. (8) this suggests that Eq. (1) should give a better correlation than Eq. (2), in agreement with the author's results.

In the example given here regional ECSs could be calculated as ECS$_r$ $= \Delta T_{S,r} = -\Delta F_{2\times CO2,r}/\lambda_r$. Then, the global ECS simply equals ECS$=$ $a_1\Delta T_{S,1} + a_2\Delta T_{S,2} + a_3\Delta T_{S,3}$. Perhaps informed choices of regions could produce regional climate feedback parameters that allow ECS values more adapted to the effects of warming patterns and internal variability? Perhaps it is better to characterize the sensitivity of the climate for radiative forcing by several regional climate feedback parameters and regional ECS values, instead of only by one global climate feedback parameter and by one global ECS?

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