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Earth System Dynamics
Discussions

Interactive comment on "Temperatures from Energy Balance Models: the effective heat capacity matters" *by* Gerrit Lohmann

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Thanks for the quick response to my comment.

Answer to 1

Thanks for your comment on this. I see that I shall describe the energy balance

$$\epsilon\sigma T^4(\Theta,\varphi) \quad = \quad (1-\alpha)S \quad \cos\varphi \quad \cos\Theta \quad \times \quad 1_{[-\pi/2<\Theta<\pi/2]}(\Theta)$$

in more detail. $\cos\Theta \quad \times \quad 1_{[-\pi/2<\Theta<\pi/2]}(\Theta)$ reflects the longitude dependent part which is rotating on the daily time scale. For clarification, I shall reformulate this.

The fact that I can ignore for a moment the Sun's declination angle is that for the global

temperature, it does not matter (Berger and Loutre 1991; 1997; Laepple and Lohmann 2009). Later in the paper, the seasonal cycle is explicitly used.

Answer to 2

Indeed, my argument goes that $\overline{T^4}$ is not the same as $\overline{T}^4$. This is essential. When using the EBM, the global temperature is calculated to be

$$\overline{T} = 0.4\sqrt{2}\sqrt[4]{\frac{(1-\alpha)S}{4\epsilon\sigma}} = 0.566\sqrt[4]{\frac{(1-\alpha)S}{4\epsilon\sigma}}$$

This is the result without the heat capacity. When I use the heat capacity and a weak day-to-night cycle, then (my equation (12) in the manuscript) I obtain

$$\overline{\tilde{T}} = 0.989\sqrt[4]{\frac{(1-\alpha)S}{4\epsilon\sigma}}$$

The numerical solution confirms this and is shown in Fig. 3. As seen in the figure, the solution depends heavily on the heat capacity.

In your comment to my comment, you provide a calculation that you describe with the words "we can show by using" that you probably use a different model, namely the linear EBM. Then, you can obtain a similar result than mine. This is exactly what I wrote "The linearization of the long wave radiation in several models (North et al., 1975a, b; Chen et al., 1995) implicitly assumes the above heat capacity and fast rotation arguments. " Indeed, the linearized version can give a reasonable zonal mean climate.

In your new comment, you said that "Further, the role of heat capacity should be compared and contrasted with that of heat redistribution (not only in the meridional direction but also in the zonal direction), since the latter is already proven to produce reasonable temperature distribution on the surface of the earth."

As an answer, the heat transport has no influence on the global mean temperature (as in my equation (15) and following text), but of course to the local one. The order of arguments is important:
1) heat capacity and fast rotating Earth (implicitly included in the linearized version)
2) heat transport, seasonal cycle, feedbacks (as mentioned in the manuscript)

I will clarify this in order to avoid misunderstandings.

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