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Earth System Dynamics Discussions

Interactive comment on “The energetics response to a warmer climate: relative contributions from the transient and stationary eddies” *by* D. Hernández-Deckers and J.-S. von Storch

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We thank Anonymous Referee #2 for the review and the points raised for discussion. As this referee points out, the strength of the mean circulation has dynamical effects that are not so well represented in the classical Lorenz Energy Cycle (LEC) formulation, which is more appropriate for describing the global energetics in terms of baroclinicity. In particular, eddy mean-flow interactions would be better represented using a Transformed-Eulerian-Mean (TEM) decomposition, which gives rise to the Eliassen-Palm flux formulation. Such a formulation of the energy cycle is possible (e.g., Plumb 1983). However, we use the classical formulation by Lorenz (1955), because we are

interested in quantifying the 2xCO$_2$ energetics response via baroclinic activity.

Nevertheless, certain terms of the LEC contain expressions related to changes in the mean circulation, which are worth discussing. One is the boundary flux of K_{se} that appears when splitting the atmosphere at an isobaric boundary. In particular the term including $[\omega^* z^*]$ (third term in eq. A25 in the manuscript). This term provides the largest contribution to this boundary flux, so it is the main cause for the change in $B(K_{se})$. Following Eliassen and Palm (1961), this term can be shown to be related to the mean flow and static stability, reflecting how vertical wave propagation depends on these properties of the mean state of the atmosphere. In our experiments, we find a decrease of 0.05 W m^{-2} in the upward boundary flux $B(K_e)$ when doubling CO$_2$ concentrations. In this context, this can be seen as a reduction in the upward wave propagation with two possible causes: (a) the enhanced mean flow—seen as the strong increase of K_m—and (b) the enhanced mean static stability due to the tropical upper-tropospheric warming. These two features would be expected to reduce the upward wave propagation, consistent with our results.

However, investigating the causes for the changes in these boundary fluxes is out of the scope of our study. We carry out the splitting of the LEC in order to verify that the energetic activity becomes stronger in the upper troposphere and weaker in the lower and middle troposphere. The fact that the responses of the boundary fluxes are small compared to the responses of the energy conversion rates allows us to do this, because we can consider the energetics changes in the upper and lower regions as approximately independent. Overall we are mostly interested in the globally-integrated LEC, in which boundary fluxes vanish. In this case, changes in the mean circulation would be relevant in terms of eddy-mean flow interaction in the K_e-to-K_m conversion rate (also in the P_m-to-P_e conversion rate, but in that case, baroclinic processes clearly dominate). In the classical LEC formulation, the conversion rate $C(K_e, K_m)$ is dominated by barotropic instability. Its largest contribution comes from the terms that are proportional to the horizontal shear in the mean flow (first terms in equations A11 and A12). The increase in the K_e-to-K_m conversion rate can be tracked down to the increase in the horizontal wind shear along the intensified jets. However, this conversion rate does not affect the main quantity that we are after: the global conversion rate between available potential energy and kinetic energy that describes the strength of the LEC. Furthermore, its changes are not as large as the changes along the $P_m \rightarrow P_e \rightarrow K_e$ path, suggesting that the response due to changes in the mean state of the atmosphere is not as large as the one related to baroclinicity. As the referee points out, this may become important when investigating larger climate contrasts.

Regarding the second point raised by this referee for discussion, it is indeed worth contrasting our results concerning mean static stability with similar studies (we will include a summary of the following discussion in the conclusions and discussion section of the revised manuscript). In our paper we are able to make a qualitative link between the energetics response—assuming that changes in P_m are good indicators for it—and (a) changes in mean static stability, and (b) changes in meridional temperature gradient. We infer these relationships based on a comparison between the vertical profiles of γ (the inverse mean static stability factor) and of P_m. O'Gorman and Schneider (2008) show that changes in K_e scale approximately linearly with changes in mean available potential energy (MAPE), which is very similar to the available potential energy we consider. This supports our assumption that changes in P_m reflect changes in energetic activity. Furthermore, they investigate how changes in the meridional temperature gradient and in dry static stability affect MAPE. In particular, they show that there is a strong dependence of MAPE on the meridional temperature gradient, partially counteracted by static stability changes. We further specify this dependence for different vertical layers of the troposphere. In a more recent study, O'Gorman (2010) describes how the seasonal features of the warming pattern can be linked to the seasonal changes in MAPE, bringing up again the effects of mean static stability and meridional temperature gradient changes. These results seem to suggest a stronger influence of mean static stability than previously thought, although it is not yet clear to what extent. These analysis—as well as ours—remain rather qualitative, in particular because it is

very difficult to separate the effects of mean static stability and meridional temperature gradient changes from each other. Determining the relative importance of these two effects on the global energetics response remains a topic for further research.

References

Eliassen, A. and Palm, E.: On the transfer of energy in stationary mountain waves, Geofys. Publ. 22 (3), 1–23, 1961.

Lorenz, E. N.: Available potential Energy and the Maintenance of the General Circulation, Tellus, 7, 157–167, 1955.

O'Gorman, P. A. and Schneider, T.: Energy of Midlatitude Transient Eddies in Idealized Simulations of Changed Climates, J. Climate, 21, 5797–5806, 2008.

O'Gorman, P. A.: Understanding the varied response of the extratropical storm tracks to climate change, Proc. Natl. Acad. Sci. (USA), 107 (45), 19176–19180, 2010.

Plumb, R. A.: A New Look at the Energy Cycle, J. Atmos. Sci., 40, 1669–1688, 1983.

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