We thank the reviewer for the time she/he took and for the comments provided, which will help us to improve the manuscript. A pointwise reply to the reviewer's comment is given below.

Methodology

1.) *The paper only very briefly describes SDAM. I do have many questions about the model, however, that the paper misses to address even briefly. Is this a dry model, or does it have some representation of moisture and clouds? How high is the model top? Is there a stratosphere? What about topography? All of these are important for the circulation, and it's unclear whether or not these factors are taken into account, and if so how?*

    We agree with the reviewer that the original manuscript was lacking some details in this respect. However, this can (and we will in a resubmission) be easily improved.
    Our model belongs to the class of statistical-dynamical atmosphere models (SDAM) and is called Aeolus 1.0. An outline of Aeolus 1.0 is given in the last paragraph of the introduction with references to earlier papers, which describe the model in more detail (in particular cloud parameterizations and synoptic parameterizations). We appreciate the questions by the reviewer and will add a separate model description section to the manuscript to enhance self-containedness.

    Aeolus 1.0 is a wet model. Clouds are represented in the cloud module as written in Molnos et al. (2016) and presented in Eliseev et al. (2013). The dynamical core is coupled with a convective plus 3-layer stratiform cloud scheme which includes low-level, mid-level and upper-level stratiform clouds developed by Eliseev et al. (2013).
    However, in this particular experiment, the surface humidity is prescribed to decouple the dynamics from changes in latent heating and associated temperature changes. This way, the dynamical core equilibrates to the prescribed surface temperature patterns without any additional complicating factors.

    The equation for humidity is a prognostic equation and described in Petoukhov et al. (2000).

    The model has 5 vertical levels in the troposphere with the model top at 10000m altitude. Aeolus 1.0 has a "dummy" stratosphere (i.e. its physics and dynamics are not resolved) to have a boundary condition at the top of the troposphere. In this experiment we excluded topographic influences and it is an atmosphere-only setup using prescribed sea level temperatures. For more information, we refer the reader to Molnos et al. (2016).

2.) *Temperature perturbations: are the temperature perturbations in the sense of Newtonian background relaxation temperatures, or is this the final temperature. If the latter, it seems the authors are prescribing the u-wind via thermal wind balance, and so prescribe the circulation. At which height are the perturbations applied? This is crucial given the ongoing debate on low-level versus high-level baroclinicity*

The temperature perturbation is the final temperature. The temperature perturbations are applied at sea level and propagate to the upper levels based on the lapse rate equation (as schematically shown in Fig. 1). We will add Figure 1 to the manuscript to clarify the process.

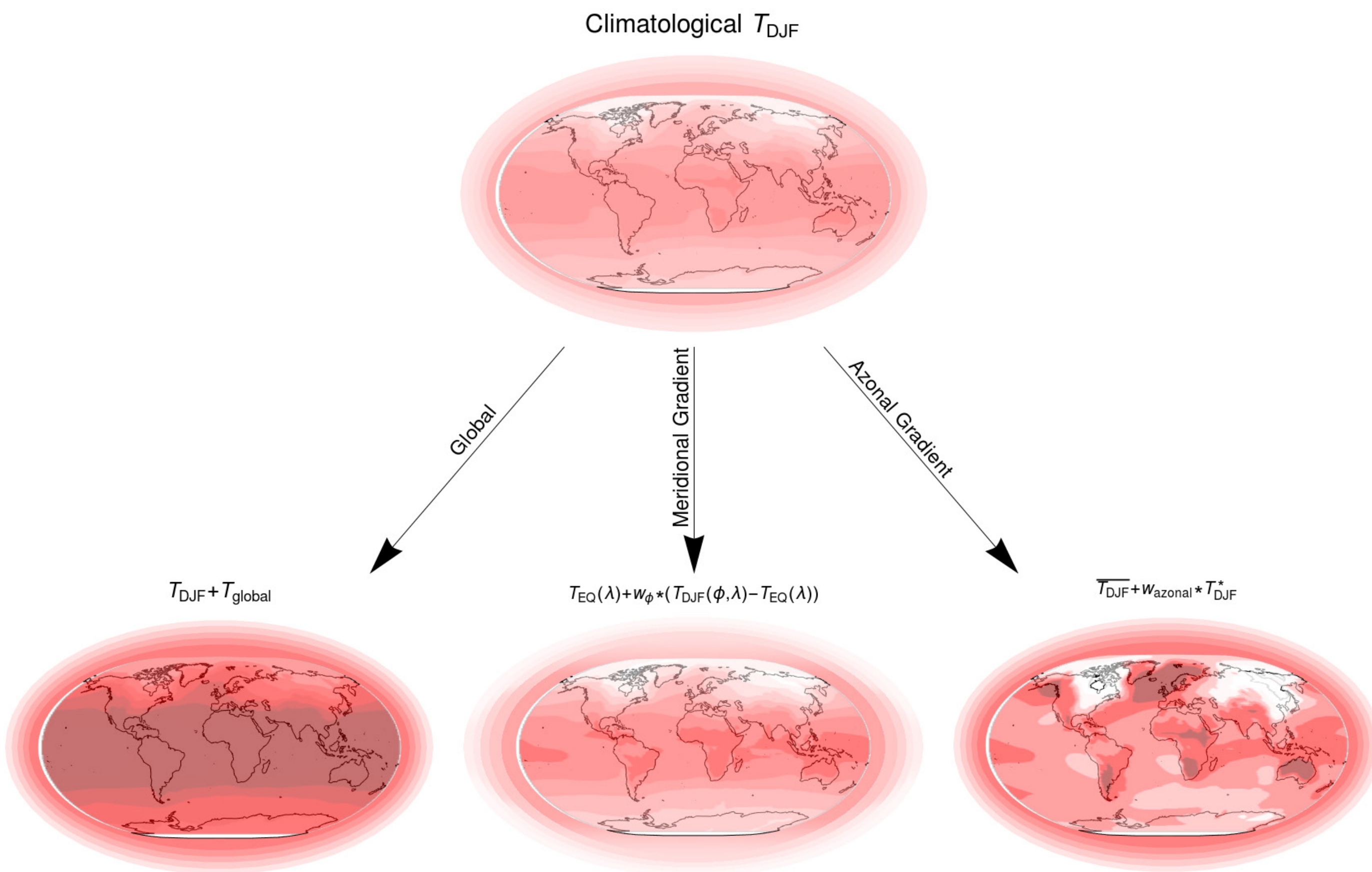

Figure 1 Schematic plot of the temperature perturbations

3.) *Circulation metrics: the chosen circulation metrics are unusual, to say the least. This is problematic as it will make comparison to other studies and models difficult, or might even inhibit such comparisons. Two examples: i) the jet stream strength is defined as the meridional average of u between 10N-80N at 9000mb (Fig.5). Why such a choice? Normally it's defined as the maximum zonal wind in the upper troposphere (for the subtropical jet) or the lower troposphere (for the midlatitude eddy-driven jet). ii) the Hadley cell strength is defined as the mass flux between the surface and 500mb. Why,* *and at which latitude? Normally it is defined as the maximum of the mass stream function. If the mass stream function maximum moves vertically, the the metric of the authors will be unable to take such a shift into account.*

Unfortunately, there has been some confusion on the chosen metrics, and we will improve this throughout the manuscript.

In the following, we explain what metrics we choose and why we choose them:

i.) We calculated the subtropical jet stream as the *maximum* between 10°N-80°N at 9000m altitude. That was phrased incorrectly in Figure 5 and will be corrected. We decided to use 9000m, which corresponds to the 300mb pressure level, since the subtropical jet stream should be located there. This is thus quantitatively in agreement with the reviewer's suggestions.

ii.) The strength of the Hadley cell is defined as the absolute maximum zonal mean integrated mass flux over several latitudes. We believe this is the most appropriate measure and point out that also in the literature there is no consensus on the best metric to use (D'Agostino and Lionello, 2016; Trenberth et al., 2000).

Content concerns:

1. *There is very little new results in this paper that are of interest beyond the documentation of the SDAM behaviour for this specific setup. Most prominently this is reflected in the abstract, where only three out of 15 sentences are devoted to new results (lines 24-27)*

The new findings in our manuscript are the following:

- To our knowledge we are the first who systematically sample the global mean temperature and the meridional and azonal temperature gradient in order to receive 3D plots for different investigated variables depending on all three temperature components. Most other studies analyzed the combined effect, e.g. under greenhouse gas scenarios, making it difficult to disentangle cause-effect relationships.
- Although different authors already addressed the question of separating the impact of different precursors, to our knowledge no author used our approach to directly change the global mean temperature, meridional temperature gradient and the azonal temperature gradient as final temperature. Our approach is shown in Fig. 1.
    - Most of the analyzed variables have only a very weak dependence on the azonal component except planetary waves and the width of the

Hadley cell. For that reason it could be that the Hadley cell can widen even though the meridional gradient is the same and only the global temperature changes (Fig. 2).

- Jet stream, storm tracks & Hadley strength in dependence on the meridional gradient show similar results as found in the literature and are explained in the discussion section, which confirms already existing results. However, in addition, we can find a global temperature dependency in our model.
- Planetary waves depend on all three temperature components and those results can give one explanation why no significant changes in observational analyses were found by Barnes et al. (2013), since increased global mean temperature and decreased meridional temperature have contrary effects on the strength of planetary waves.

The results in the abstract are only explained briefly. In the revised manuscript we will point out the novelty of our research.

2. *The authors claim that they can clearly separate the impact of global, meridional and zonal temperature changes, and that previous studies were unable to do so. But they entirely neglect the rich literature using dry GCMs that has looked at exactly this question (e.g., papers by Amy Butler, Jian Lu, Janni Yuval, and many more)*

We agree with the reviewer and do not want to claim to be the first to do so. Other authors changed either the CO2 concentration or added a heat source. However, for example using a heat source in the upper troposphere alters not only the global mean temperature but also the azonal and meridional temperature gradient.

Since all below mentioned papers examine either different variables or attributes of the variables (Brewer-Dobson-Circulation, shift of jet streams and shift of storm tracks) or different warming effects (changes in the vertical structure of baroclinicity), we cannot directly compare their results with our results, and cannot include those in the discussion, but we will add the following text in the introduction:

Different studies examined the influences of different temperature sources on the mid-latitude circulation. Butler et al. (2010) addresses the idea to separate the temperature effects by using different heating sources ((1) enhanced warming in the troposphere, (2) enhanced cooling in the stratosphere, (3) enhanced warming at the surface over the polar region). With their approach Butler et al. can attribute which forcing has the most important influence on the shift of jet streams, storm tracks etc. In a study from 2011 Butler et al. presented an alternative perspective on the response of the mid-latitude tropospheric circulation to zonal-mean tropical heating. The projection of the heating onto the isentropic surfaces at extratropical latitudes drive the poleward shift in wave generation at lower levels. In addition, the poleward shift in the heat fluxes within the troposphere and the diffusive nature of eddy fluxes of the polar vortex lead to a poleward shift in wave breaking near the tropospause.

In addition, Yuval and Kaspi (2016) investigated changes in the vertical structure of baroclinicity to the magnitude of eddy kinetic energy and eddy fluxes using an idealized global circulation model. This is especially interesting, since new studies indicate that under increasing CO2 concentrations the lower-tropospheric temperature gradient will decrease whereas the upper tropospheric temperature gradient will increase with counteracting effects on eddy activity. The results demonstrate that eddy activity is more sensitive to temperature gradient changes in the upper troposphere.

Moreover, Shaw and Voigt (2015) examined the radiative changes of clouds and water vapour for two different aquaplanet climate models and found that they are important to the regional response of precipitation and atmosphere circulation. They concluded that uncertainty in circulation is linked to uncertainty in the behaviour of clouds and water vapour.

We will add the following text in the discussion:

Lu et al. (2007) found a robust weakening and a poleward expansion of the Hadley circulation in response to increased GHG forcing in simulations of the 21st century climate taken from the A2 scenario of the IPCC AR4 project (Lu et al., 2007). Lu et al. (2008) analyzed the change in the zonal mean atmospheric circulation under global warming in comparison with the response to El Niño forcing, by examining the CMIP5 model simulations. They used again the A2 scenario to simulate global warming. Under global warming due to higher CO2 concentrations the Hadley cell weakens and expands northwards together with a poleward shift of the jet stream.

Based on our results, we can assume that “El Niño–like” enhanced warming leads to a stronger meridional temperature gradient (and a higher global mean temperature) resulting in a stronger Hadley cell, whereas the CO2 concentration leads to a weaker meridional temperature gradient (and a higher global mean temperature) and as a consequence the Hadley cell weakens. This can also explain the widening of the

Hadley cell, which we observe in our experiments as well: A stronger meridional temperature gradient can lead to a smaller width of the Hadley cell and vice versa.

Editorial concerns:

1. *The paper reads like a rushed and, to be honest, quite careless write-up. Most figures follow the same layout as if they were all produced with the same script, labels are missing (e.g., y-label in Fig. 5), and the choice of the colormap in the contour plots is poor. There is unnecessary line breaks in the text (e.g., see the introduction). Normally I would not mind, but this slopiness strengthens my feeling that this paper was done in a rush.*

The label mentioned in Fig.5 (a) was added incorrectly. The y-label should occur only in the center figure.

We will improve the colorbar and plot 3D plots to visualize the experiments (Fig 2 - 6).

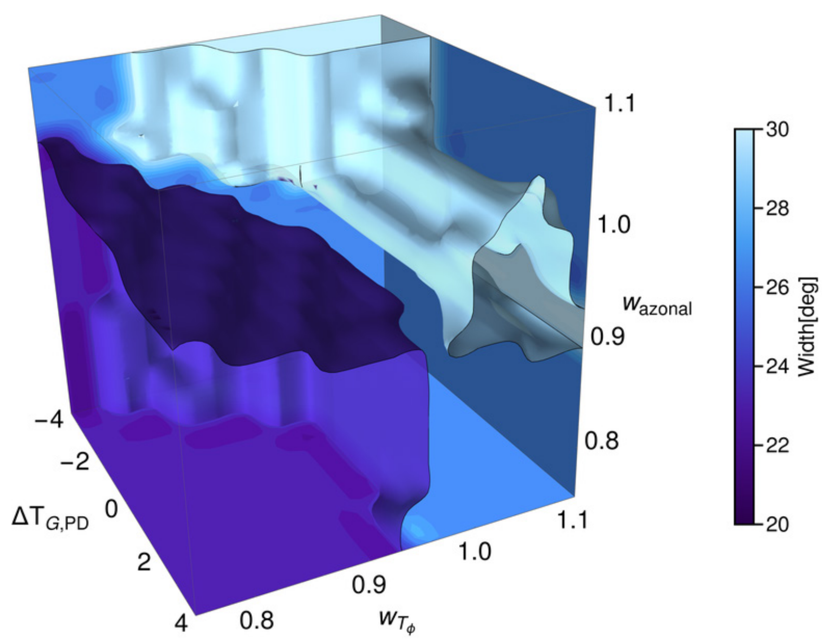

Figure 2 Width of the Hadley cell in dependence of w_{T_ϕ} and w_{azonal} and $\Delta T_{G,PD}$, whereby $\Delta T_{G,PD}$ is the difference between the present day temperature and the changed global mean temperature.

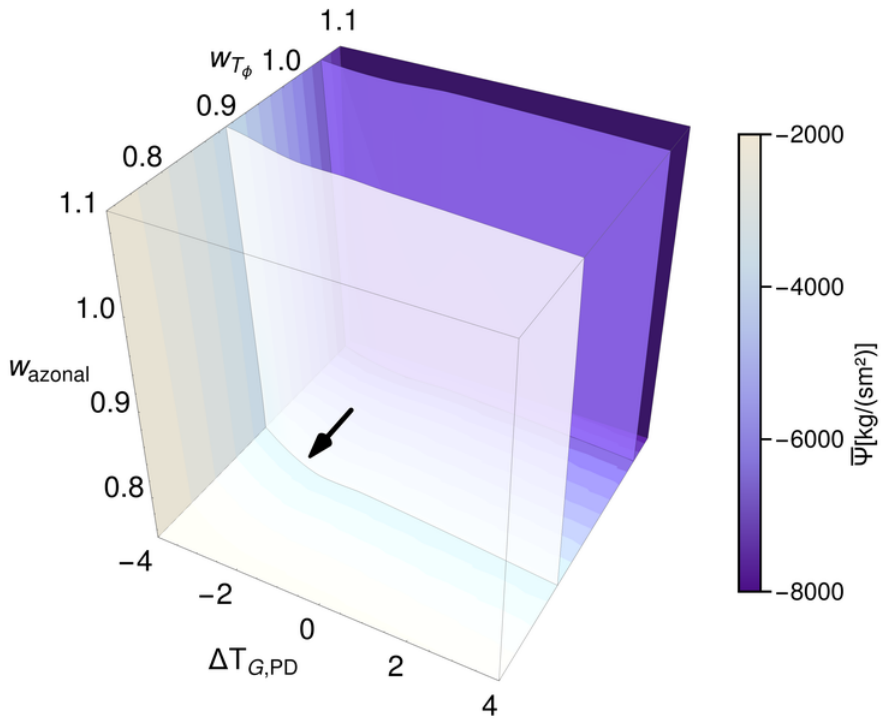

Figure 3 Strength of the Hadley cell in dependence of w_{T_ϕ} and w_{azonal} and $\Delta T_{G,PD}$, whereby $\Delta T_{G,PD}$ is the difference between the present day temperature and the changed global mean temperature. The arrow points in the direction of the strongest gradient.

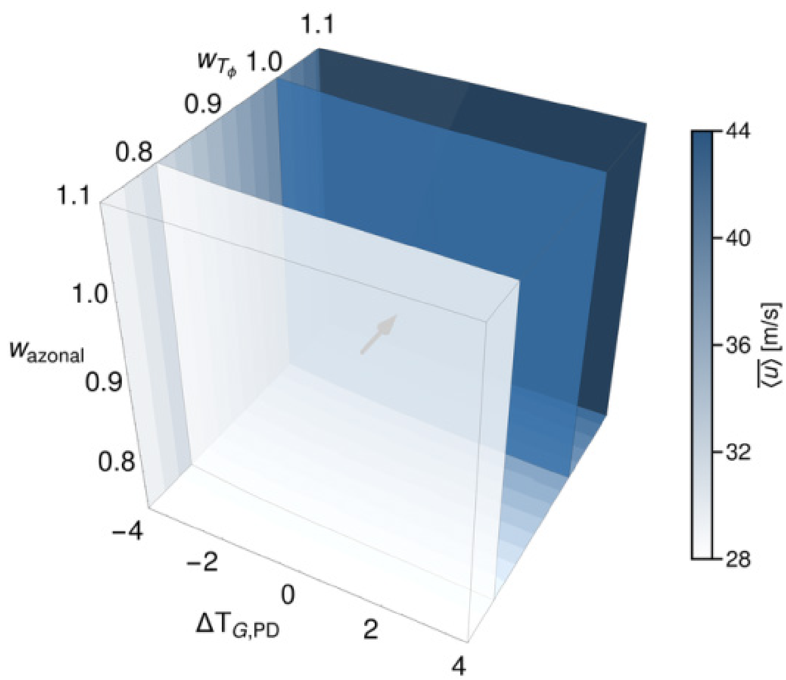

Figure 4 Jet stream strength defined by the meridional average of the zonal mean zonal wind velocity ($\overline{\langle u \rangle}$) between 10°N and 80°N at a height of 9000 m in dependence of w_{T_ϕ} and w_{azonal} and $\Delta T_{G,PD}$, whereby $\Delta T_{G,PD}$ is the difference between the present day temperature

and the changed global mean temperature. The arrow points in the direction of the strongest gradient.

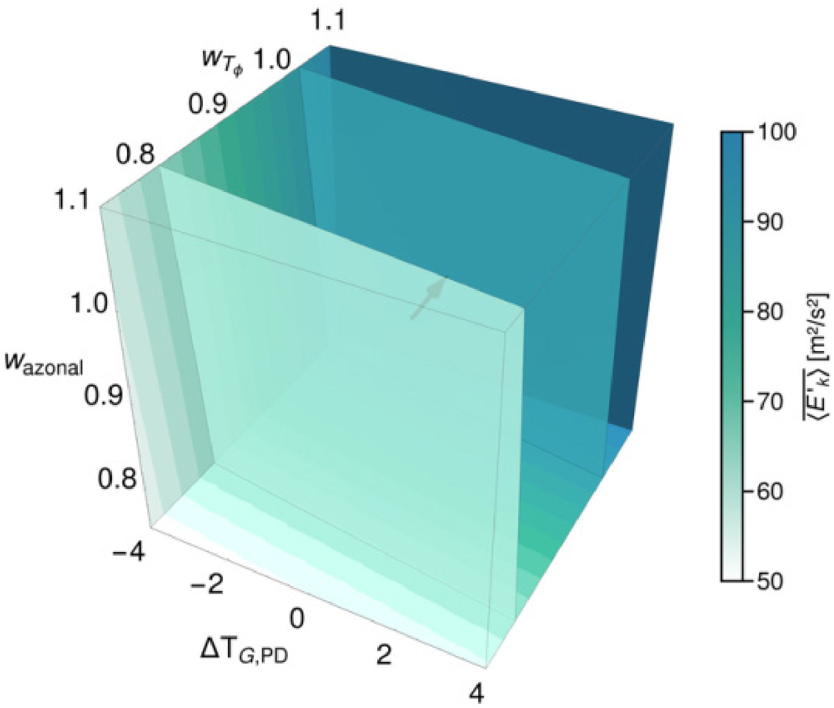

Figure 5 Strength of storm track activity in dependence of w_{T_ϕ} and w_{azonal} and $\Delta T_{G,PD}$, whereby $\Delta T_{G,PD}$ is the difference between the present day temperature and the changed global mean temperature. The arrow points in the direction of the strongest gradient.

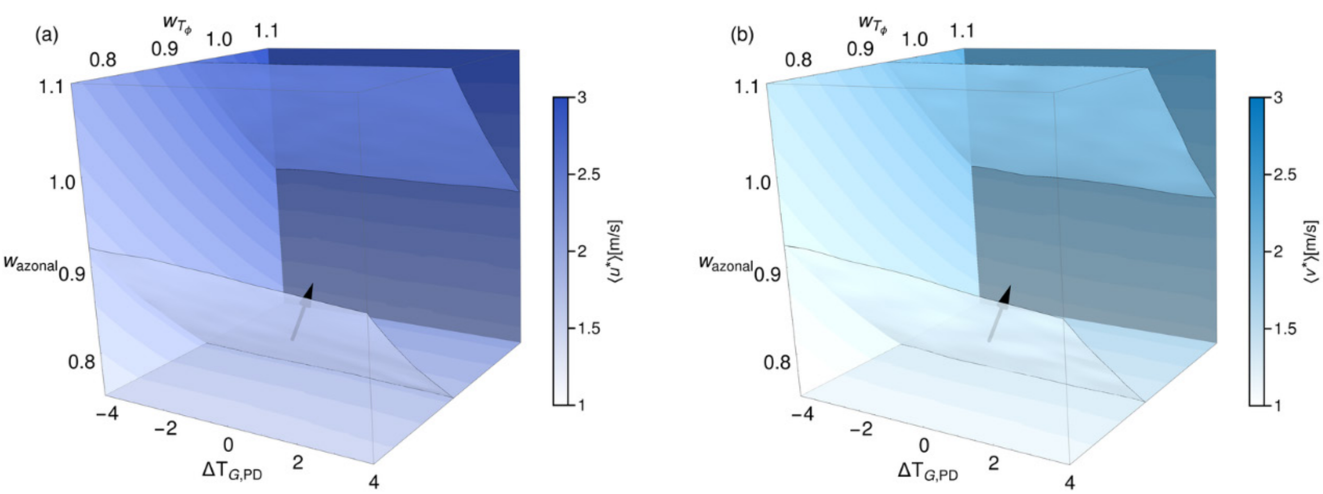

Figure 6 Strength of planetary waves $\langle u^* \rangle$ and $\langle v^* \rangle$ in dependence of w_{T_ϕ} and w_{azonal} and $\Delta T_{G,PD}$, whereby $\Delta T_{G,PD}$ is the difference between the present day temperature and the changed global mean temperature. The arrow points in the direction of the strongest gradient.

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