

Response to Editor

Dear Tim Dunkerton, we acknowledge your comments and provide responses below. We hope you find the paper ready for publication after addressing these comments.

Comments to the Author:

1. The relation between surface temperature and shallow BDC highlighted toward the end of the paper appears to be a simple form of “statistical attribution” which I describe, whenever encountered on Twitter, as “rubbish” because correlation is not causation. The extent to which statistical attribution has been stretched in public discussion is simply ludicrous, e.g., in the attempt to anticipate regional climate change from past statistical associations. The attribution of shallow BDC trend to surface temperature suggest common underlying dynamical mechanisms. This suggestion is implicit, but extremely important, as we attempt to construct a dynamical framework for climate change, particularly in zonally averaged metrics. I hope that authors will find suitable wording to be compatible with this comment.

We agree that correlation does not imply causation, and of course we base our conclusion on the robust dynamical mechanism connecting tropical surface temperature with the acceleration of the shallow branch. We thank the Editor for realizing that this mechanism was not explicitly stated, and we have now discussed it in lines 314-316: “This statistical relationship reflects an underlying dynamical mechanism: tropical surface warming leads to tropical upper tropospheric warming, which modifies meridional temperature gradients and thus wind shear (e.g. Garcia and Randel 2008), altering the wave propagation and dissipation conditions (Shepherd and McLandress 2011).”

2. For “direct” measurement of tropical upwelling, the classic tape recorder signal of tracers in HALOE provide strong constraints on the vertical profiles of upwelling, vertical diffusion, and lateral in-mixing; see Dunkerton (1997 JGR) for references and application to QBO wave driving. Later authors attempted to tease seasonal variation of upwelling also. These estimates nicely compliment age of air and provide, as it were, a local rather than time-integrated metric of BD transport.

We are aware that the tape recorder provides constraints on tropical upwelling (e.g. Mote et al. 1996). However, as you highlight, these measurements provide a measure of “effective” upwelling, which cannot be directly compared with w^* from models, due to the role of horizontal and vertical mixing and diffusion. Unfortunately, tracer output, which would allow for more detailed comparisons of the net local tracer transport, is not generally available in these CMIP6 simulations.

3. As for the TEM statistics I’d like reassurance that daily or 4x daily fields were used for wave fluxes.

The TEM diagnostics used are monthly averages computed from daily averages (i.e., averages of each time step over a day).