

1. Overview

A dry dynamical core of idealized global atmospheric models with spectral dynamics of the GFDL first introduced by Held and Suarez (1994, hereafter HS) and it has been widely used. The basic idea is to isolate the dynamics from the complicated physical parameterizations, such as radiation, clouds, moist convection, etc., using analytically prescribed equilibrium temperatures and a certain relaxation time scale. Held and Suarez described equilibrium temperature (T_{eq}) and relaxation time (τ) just for troposphere. Later, many researches focus on developing T_{eq} and τ for the stratosphere (Polvani and Kushner, 2002; Gerber and Polvani, 2009; Jucker et al., 2014). However, these simulations are still highly idealized. For example, they use either no topography or Gaussian mountains in the model. Meanwhile, T_{eq} and drag are zonally symmetric and deficit in representing the thermal contrast between land and ocean and in boundary-layer friction.

In the present research, we want to make the model producing earth-like circulation in both troposphere and stratosphere, while keeping it simple. Circulations in the troposphere and stratosphere are attributed to the thermal wind balance and the wave activity. In order to make the dry dynamical core more earth-like, we modify equilibrium temperature (T_{eq}) and add the smoothed realistic orography to represent zonally thermal contrast and wave generation. Further, we add zonal drag asymmetry to mimic different friction above land and ocean.

2. Methodology

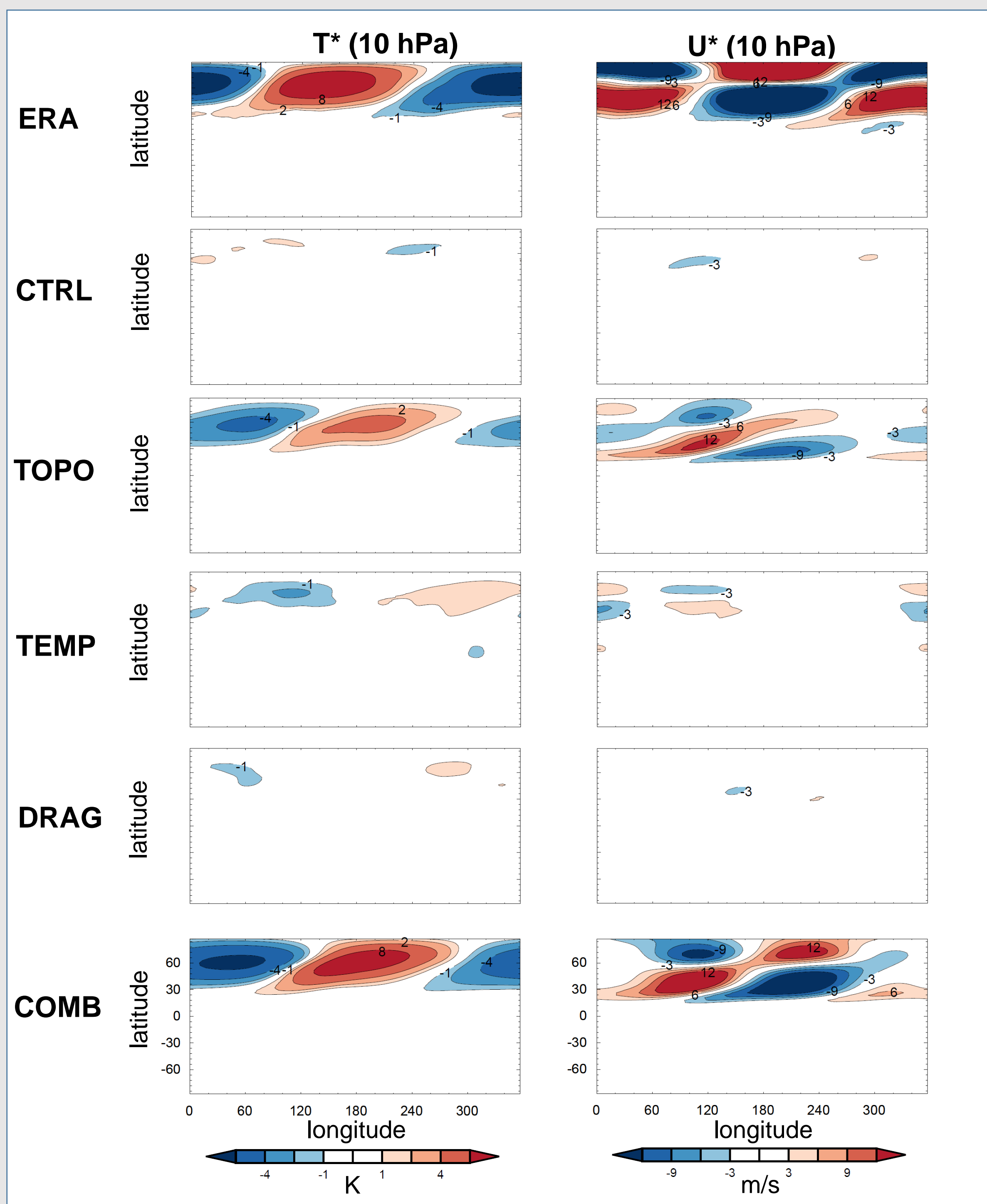
We use the spectral dynamical core of the GFDL FMS model with a resolution of T42 and 40 hybrid sigma levels. All experiments are integrated for 60 years with an equilibrium temperature that varies only by season. We discard the first year of model spin-up. All results are for January and are compared against ERA-40 reanalysis.

Our control experiment (CTRL) uses a zonally symmetric T_{eq} and τ (Jucker et al., 2014) and flat topography. We then perform three single-forcing experiments: TOPO has realistic topography; TEMP has longitudinal temperature variations derived from reanalysis to mimic diabatic heating anomalies between land and ocean; DRAG has longitudinal drag variations in the boundary layer between land and ocean (Chang, 2005). Finally, we perform an experiment (COMB) with all three forcings combined.

	topography	temperature asymmetry	damping asymmetry
CTRL	-	-	-
TOPO	✓	-	-
TEMP	-	✓	-
DRAG	-	-	✓
COMB	✓	✓	✓

4. Eddies at 10 hPa

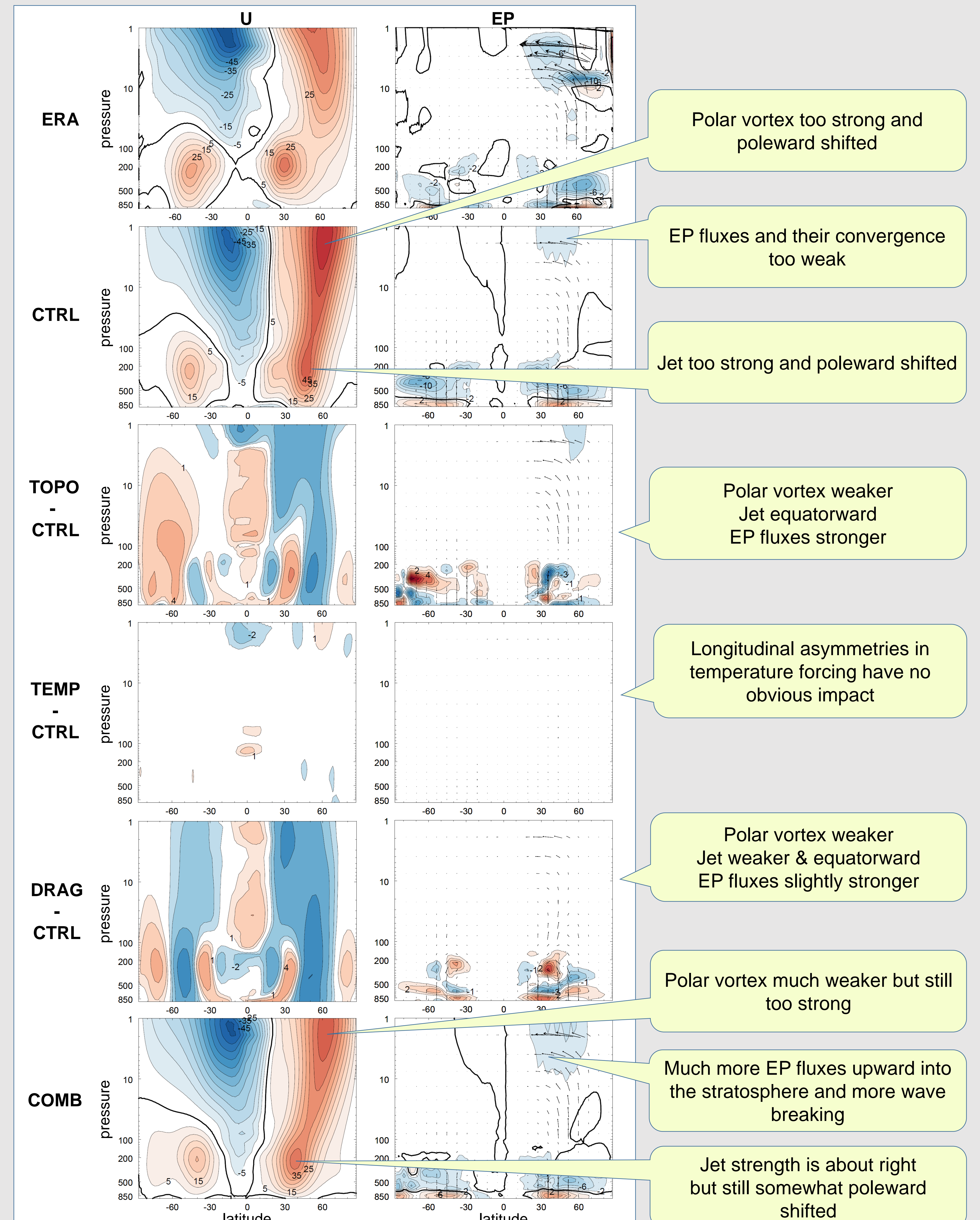
From the eddies, we can see the structure of planetary waves in the stratosphere in different experiments.



With zonal symmetry and without topography, no eddies

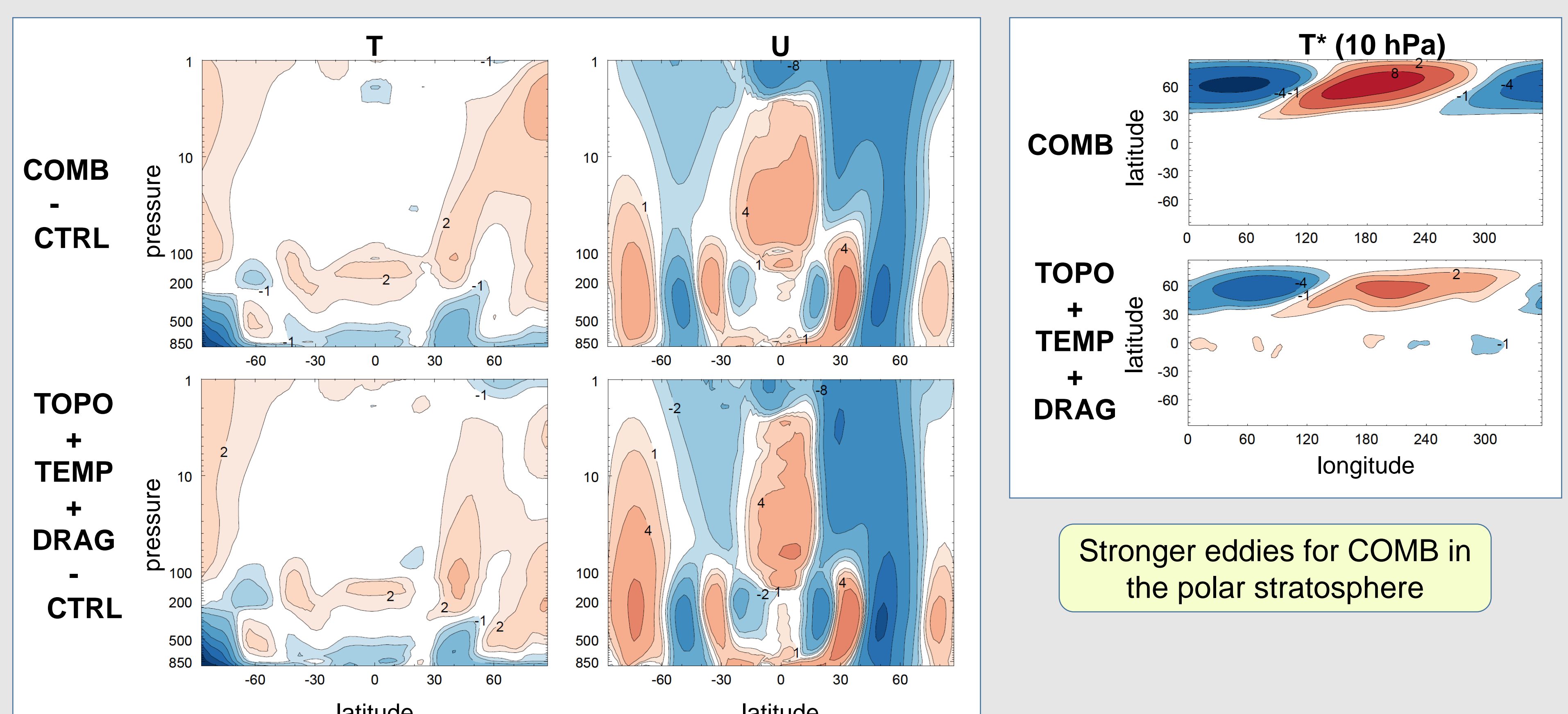
Similar to reanalysis but eastward shifted by $\sim 30^\circ$

3. Zonal mean U and EP-fluxes



5. Linearity of the response

To first order, the effects of the individual forcing experiments add almost linearly up to the effect seen in the combined forcing experiment. The only location where there is some indication of non-linear behavior is the polar stratosphere.



7. References

- Chang E. K. M., 2006: An idealized nonlinear model of the northern hemisphere winter storm tracks. J. Atmos. Sci. 63: 1818–1839.
- Gerber, E. P., and L. Polvani, 2009: Stratosphere–troposphere coupling in a relatively simple AGCM: The importance of stratospheric variability. J. Climate, 22, 1920–1933.
- Held, I. I. M., and Suarez, M. M. J., 1994: A proposal for the intercomparison of the dynamical cores of atmospheric general circulation models. Bull. Amer. Meteor. Soc., 75, 1825–1830.
- Jucker, M., S. Fueglistaler, and G. K. Vallis, 2014: Stratospheric sudden warmings in an idealized GCM. J. Geophys. Res. Atmos., 119, 11,054–11,064.
- Polvani, L. M., and P. J. Kushner, 2002: Tropospheric response to stratospheric perturbations in a relatively simple general circulation model. Geophys. Res. Lett., 29, 40–43, doi:10.1029/2001GL014284.

6. Summary

Out of our five simulations, the control run (CTRL) produces the least realistic circulation, including a much too strong polar vortex, a poleward shifted jet and too weak EP fluxes in the stratosphere.

With topography (TOPO) the model produces a more realistic (weaker) polar vortex and more wave activity in the stratosphere. With longitudinally varying drag (DRAG) the model also produces a more realistic circulation. Even though the effect of adding longitudinal temperature asymmetries (TEMP) is not obvious, the combined simulation (COMB) is the most realistic out of our five experiments.

The overall effect of the combined forcings (COMB) is very similar to applying the three forcings individually. However, there is indication that non-linear effects are important in the polar stratosphere, where COMB shows more realistic (section 4.) and stronger (section 5.) eddies.