Stratosphere-troposphere coupling: Controls by the Zonal Mean Circulation on the Stationary Wave Response to Climate Change

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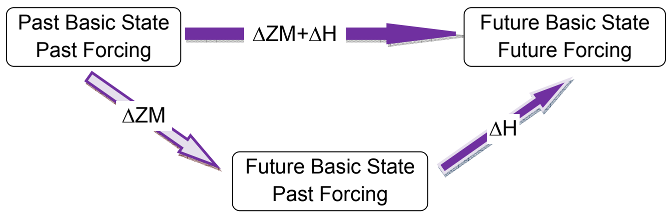
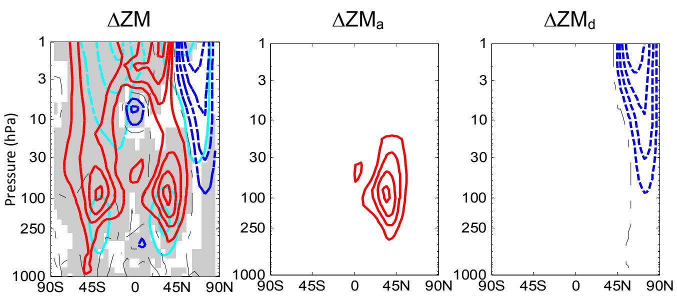
Background

Planetary stationary wave is an essential component of atmospheric general circulation and its response to climate change could have significant societal and ecological impact.

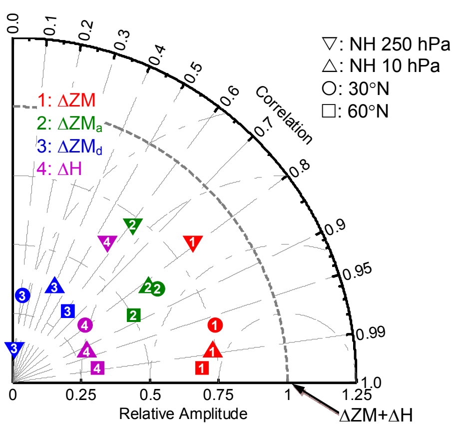
Both zonal mean circulation and zonally asymmetric forcing contribute to the response.

Lessons learned from CMAM (CCMVal-1 REF2) simulation





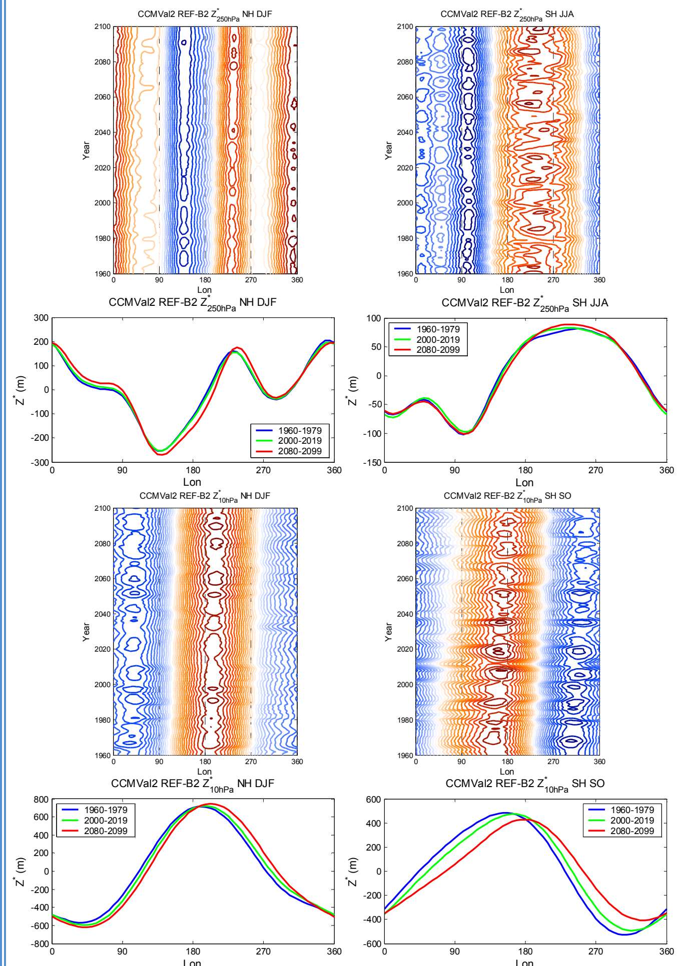
CMAM NH winter zonal mean zonal wind response to climate change (1960-1979 vs. 2080-2099). Contour interval is 2 m/s for response (red/blue) and 20 m/s for climatology (cyan). Grey shading represents the statistical significance at 5% level by *t*-test.



Taylor diagram of CMAM (CCMVal-1 REF2) NH winter stationary wave (streamfunction) response to the changes in (1) zonal mean basic state (ΔZM), (2) tropospheric jet (ΔZM_a), (3) stratospheric jet (ΔZM_d), and (4)diabatic heating (ΔH) compared with the total response (ΔZM + ΔH, the target) diagnosed by the stationary wave model.

- ΔZM dominates the total response;
- Zonal mean dominance can be further narrowed down to ΔZM_a;
- ΔZM_d and ΔH also contribute to the total response and all components reinforce each other.

Results



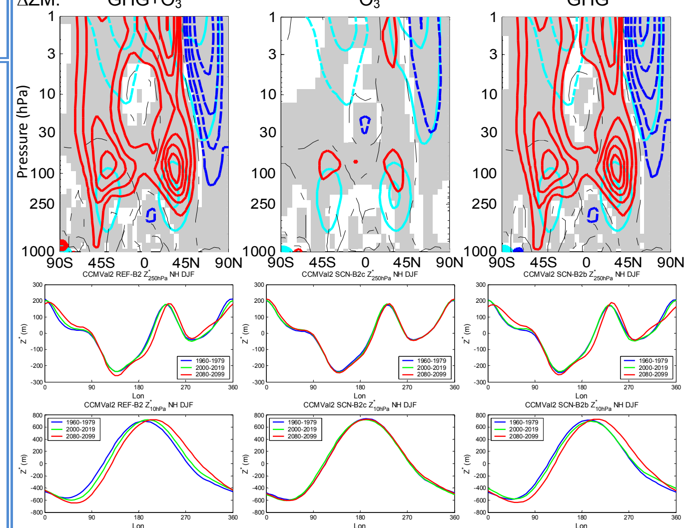
Hovmöller diagrams of ensemble mean (20 members from 14 models) stationary wave (geopential height) evolution in CCMVal-2 REF-B2 (GHG + O_3 forcings) simulations.

- Stationary wave pattern shifts eastward in time except for SH troposphere;
- Stationary wave amplitude increases in NH troposphere and stratosphere, but decreases in SH stratosphere.

Summary

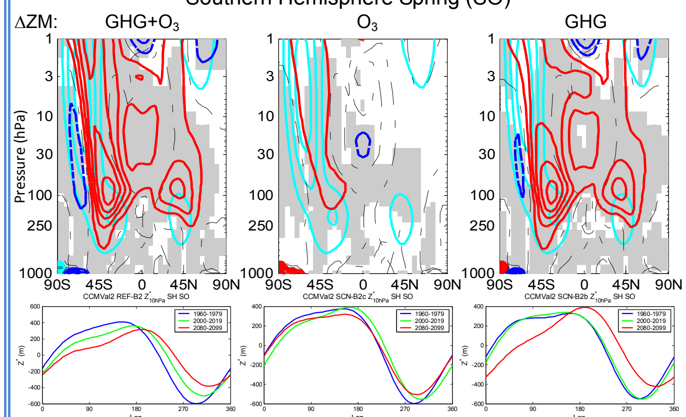
- Stationary wave response to climate change is controlled by the changes in zonal mean circulation in most cases;
- Generally there is an eastward drift of the wave pattern, largely due to GHG increasing;
- Wave amplitude trends are due to collaboration between GHG and O_3 forcings.

Scenario comparison based on 5 ensemble members from 3 models: Northern Hemisphere Winter (DJF)



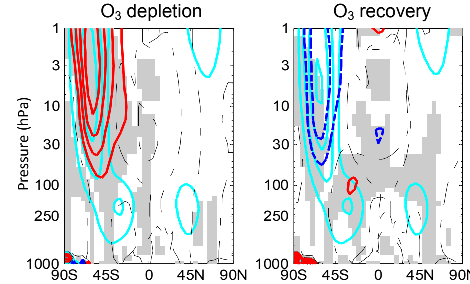
- GHG forcing is responsible for the NH stationary wave responses.

Southern Hemisphere Spring (SO)



Over the whole 140-year period (focus on blue and red lines):

- GHG increasing is responsible for the eastward shift;
- Both GHG and O_3 forcings weaken the stationary wave amplitude.



Comparing O_3 depletion and recovery (focus on green lines):

- O_3 depletion can produce an eastward shift and O_3 recovery reverses it;
- O_3 recovery forcings weakens the stationary wave amplitude, likely due to reduced zonally asymmetry in radiative cooling.

Reference: (1) Ting and Yu, 1998, JAS.; (2) Held et al., 2002, J. Clim.; (3) Joseph et al., 2004, J. Clim.; (4) Brandefelt and Körnich, 2008, J. Clim.; (5) Acknowledgements to CMAM and CCMval-2 modeling groups for providing data for this study.