Diagnosing the coupled stratosphere-troposphere stationary wave response to climate change in CCMs

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Outline

- Introduction;
- Stationary wave model validation;
- Diagnosing climate change simulations;
- Summary.

Introduction to stationary waves

- Stationary wave: zonally asymmetric component of the atmospheric climatological flow;

- Play a large role in stratospheric variability, transports of heat and momentum, and BDC (Rosenlof and Holton 1993, Yulaeva et al. 1994);

- Changes in stationary wave activity from climate forcing can potentially lead to changes in BDC. (McLandress and Shepherd, 2009)

Motivation

- Stationary wave field will be significantly influenced by climate change (e.g. as revealed by CMAM CCMVal-1 REF2 runs):

  Zonal mean basic state; Zonally asymmetric diabatic / transient-eddy forcing.

- Both **basic state** and **diabatic heating** account for the stationary wave response to climate change.

- First realistic stationary wave model attempting to capture both troposphere and stratosphere.

Stationary Wave Model and CCM Data

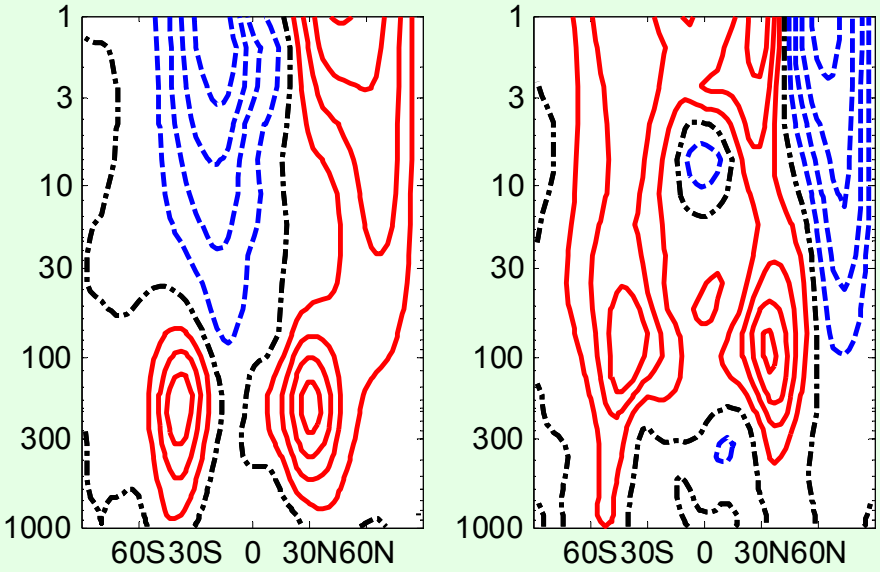
- We developed a nonlinear baroclinic stationary wave model (Ting and Yu, 1998) with a well-resolved stratosphere:
  - Based on GFDL dry dynamical core;
  - Stationary wave solution is obtained by imposing linear damping and increasing diffusion;
  - Zonal mean basic state is prescribed;
  - Zonally asymmetric forcing includes topography and diabatic heating.
- CMAM CCMVal-1 REF2 Simulation (Eyring et al. 2007): Januaries of 1960-1979 and 2080-2099, are chosen to represent **past** and **future** winter time climate, individually;
- AMTRAC3 CCMVal-2 REF-B2 Simulation (Austin, J. at GFDL): 1960-1979 and 2080-2099.

Zonal mean response to climate change

Past

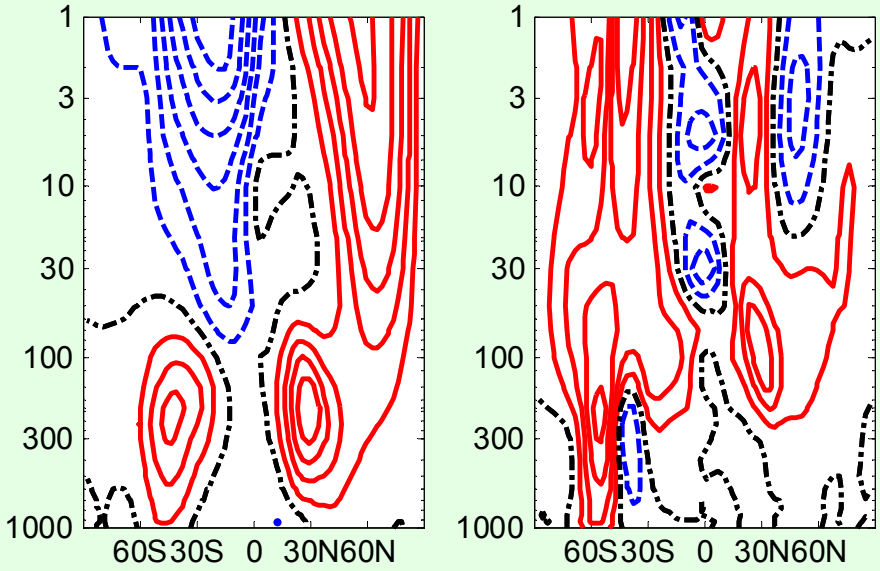
Change

CMAM



- Strengthening in the mid-lat. lower stratosphere zonal wind and poleward shift of tropospheric jet happen in both hemispheres and both CCMs;

AMTRAC3



- Weakening in NH high-lat. upper stratosphere is common in both CCMs (and among many other CCMVal2 models).

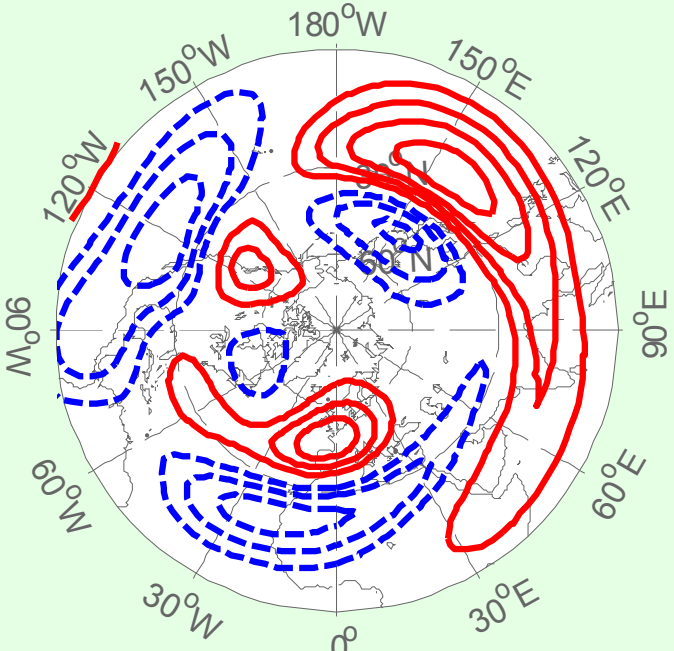
Contour Interval: 10, 2 m/s

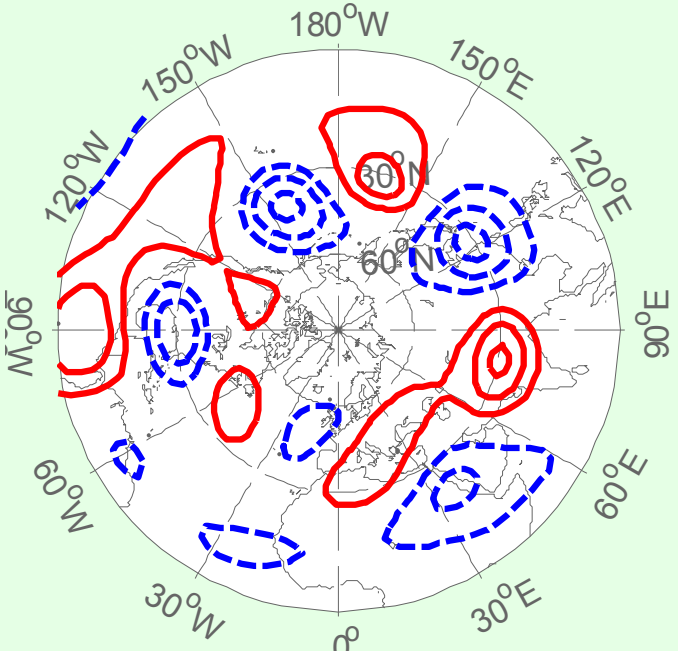
Past

Change

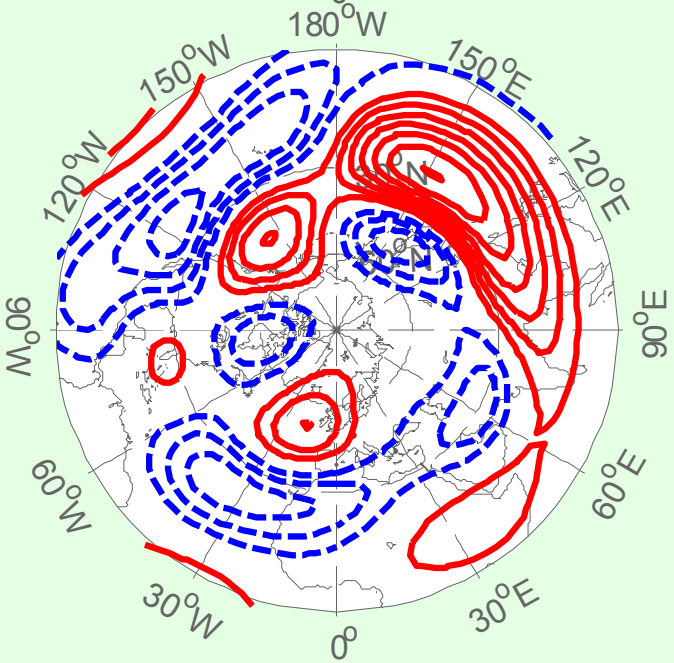
250hPa

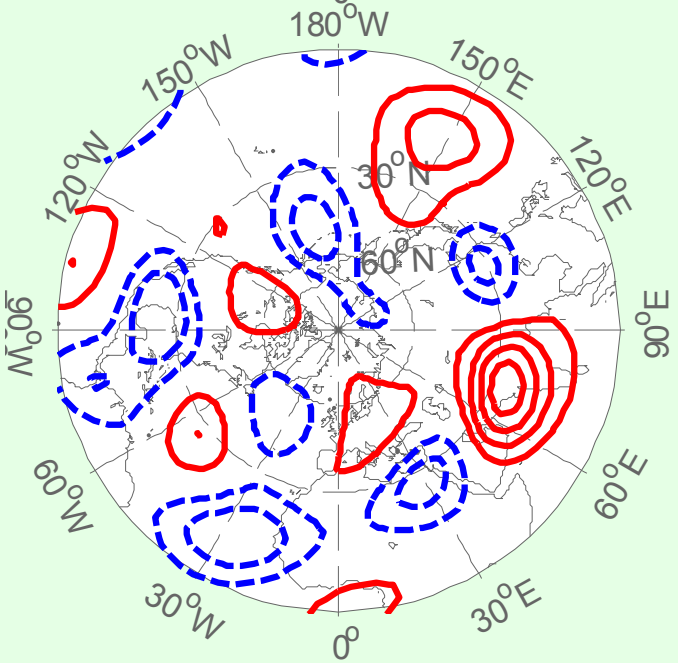
CMAM





SWM





Contour Interval: $6{,}3\times10^{6}\,m^{2}/s$

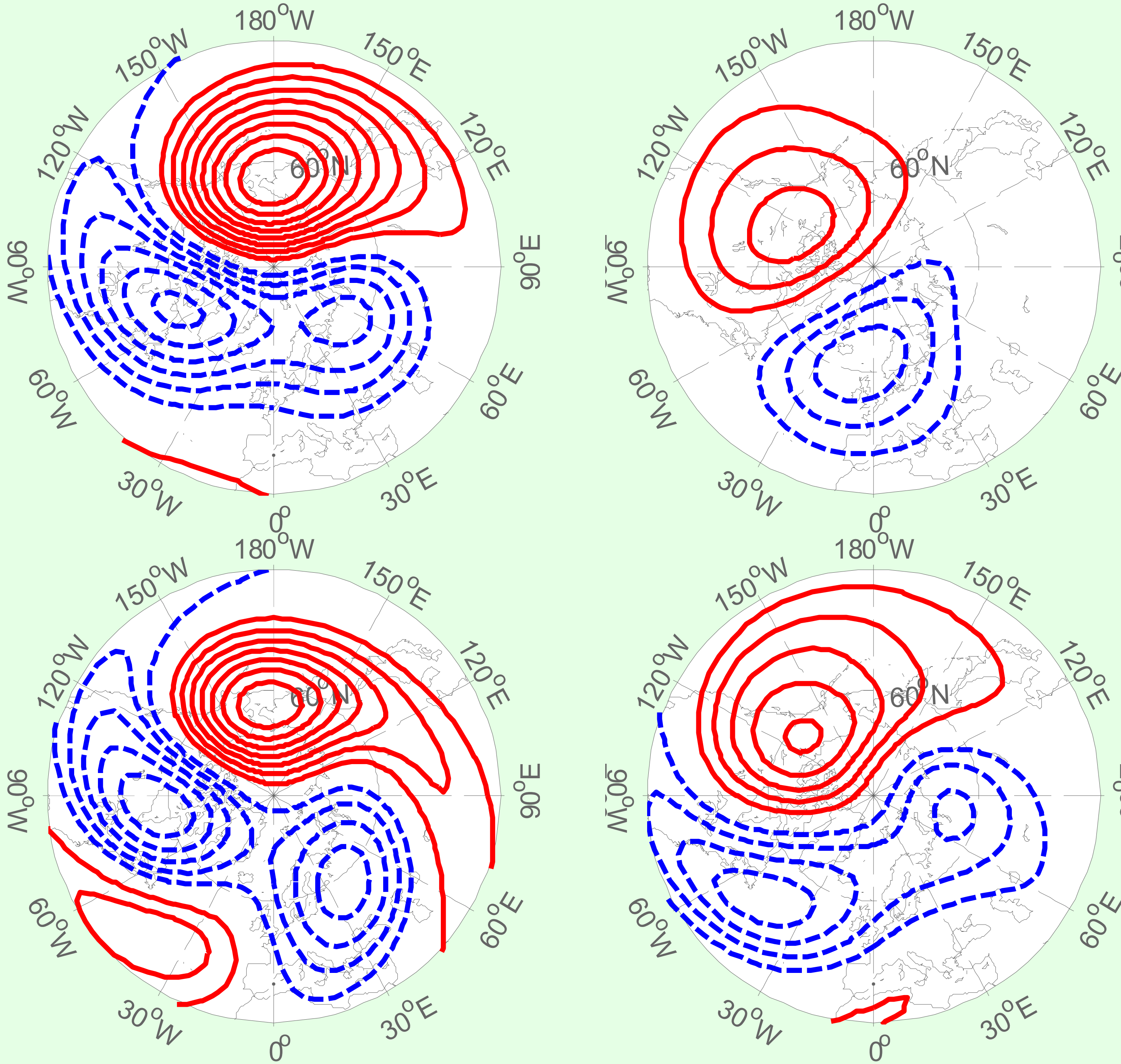
Past | Change

10hPa

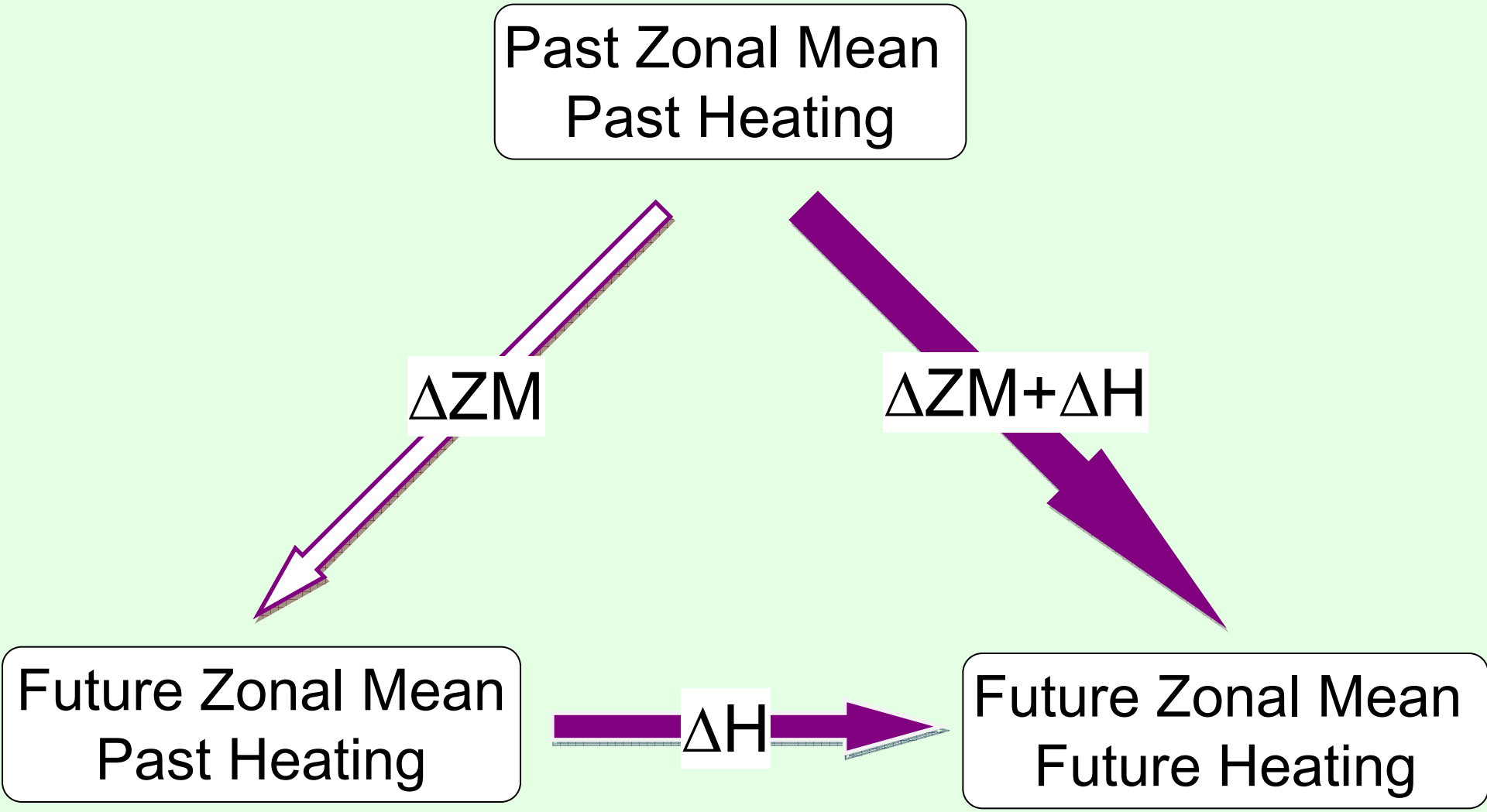
CMAM

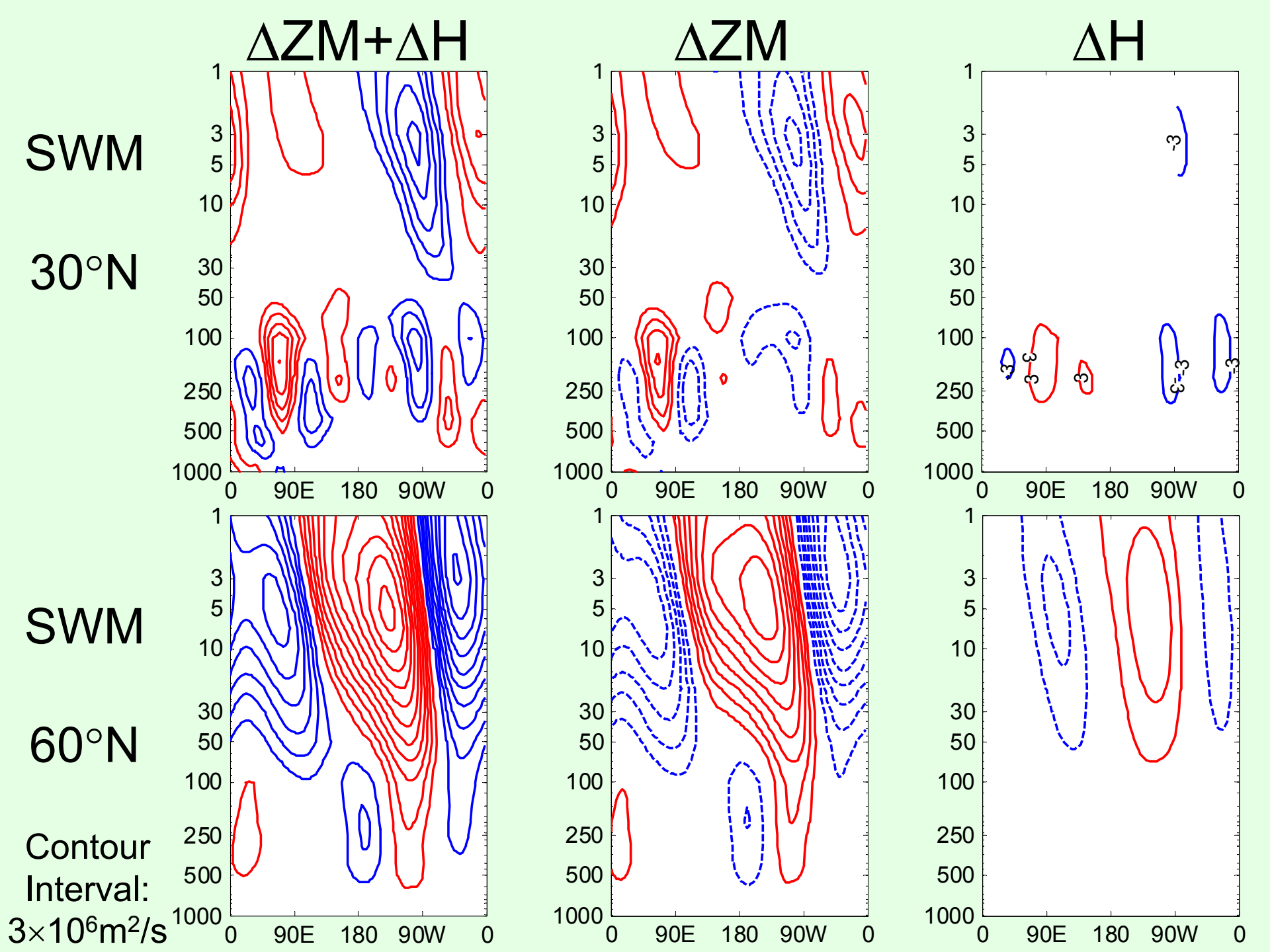
SWM

Contour Interval: $6\times10^6 m^2/s$



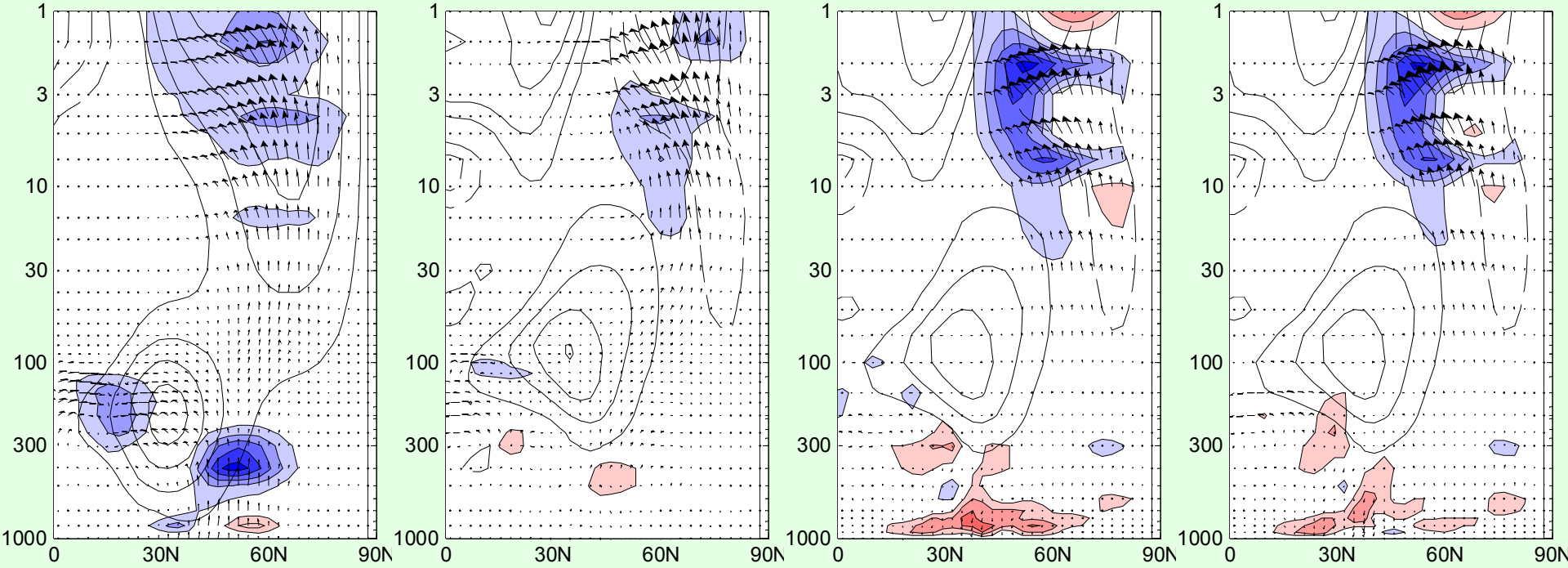
Zonal Mean Basic State vs. Diabatic Heating




ΔZM+ΔH
ΔZM
ΔH
SWM
30°N
SWM
60°N
Contour Interval:
3×10⁶m²/s
1
3
5
10
30
50
100
250
500
1000
0
90E
180
90W
0

Wave forcing response to climate change

CMAM CMAM SWM SWM



Past Change ΔZM+ΔH ΔZM

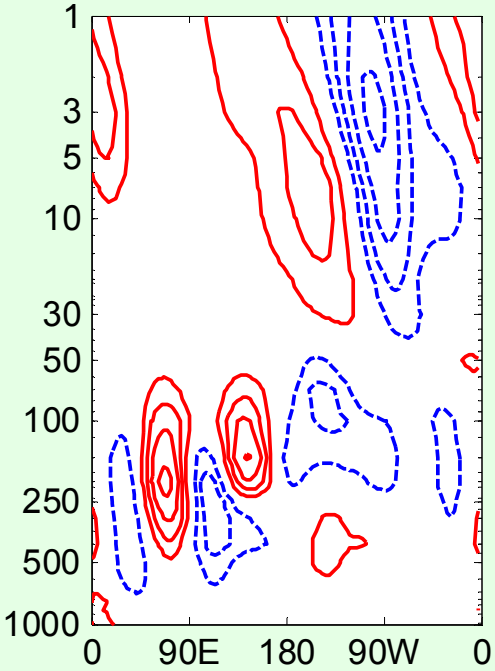
AMTRAC3

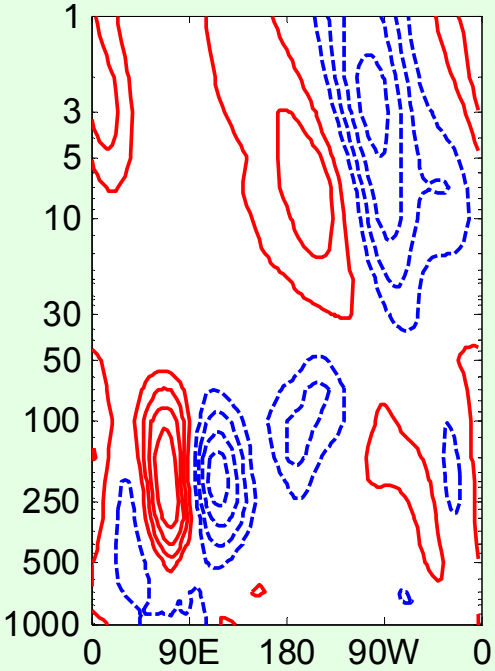
ΔZM+ΔH

ΔZM

SWM

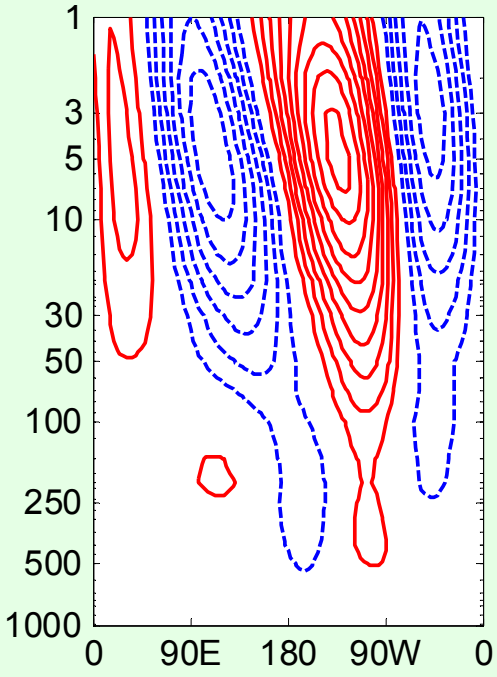
30°N

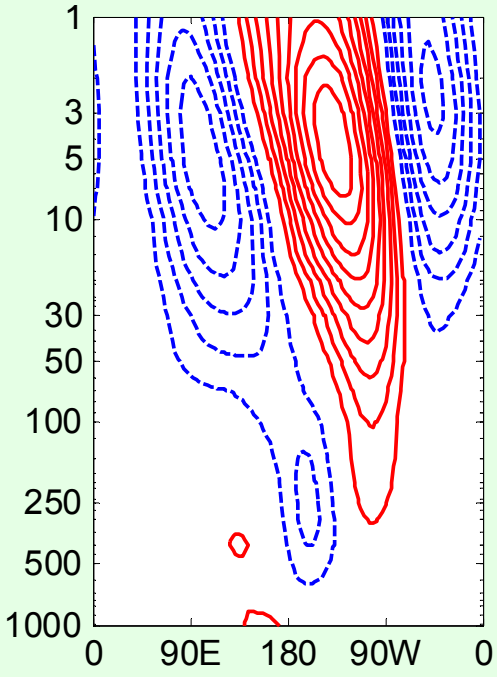




SWM

60°N

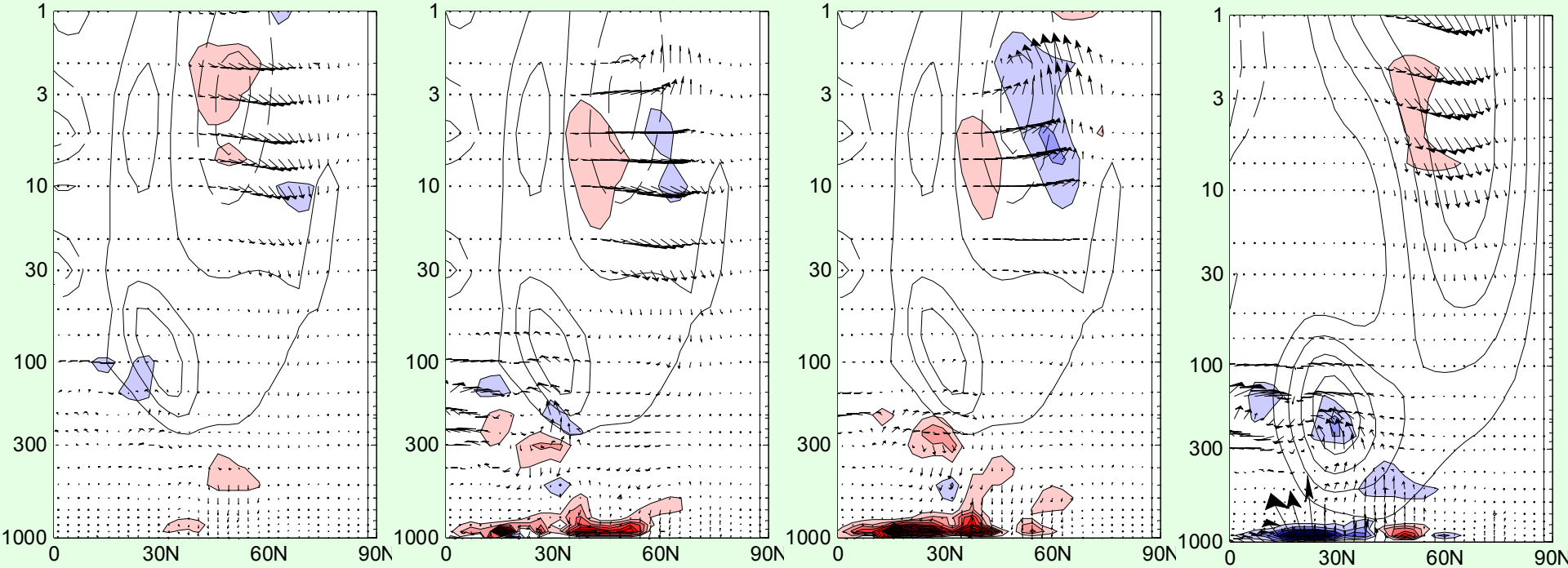




Contour Interval: $3\times10^6 m^2/s$

Wave forcing response to climate change

AMTRAC3 SWM SWM SWM



Change ΔZM+ΔH ΔZM ΔH

Summary

- A stationary wave model is tested with CCM data, and is able to largely reproduce stationary waves in CCMs when forced by zonal mean states, topography, and zonally asymmetric diabatic heating.

- This diagnostic tool is used to decompose the stationary wave response to climate change. Changes in the zonal mean state play a major role in explaining the total response.