Quasi-Biennial Oscillation in WACCM: Parameterization and Evaluation

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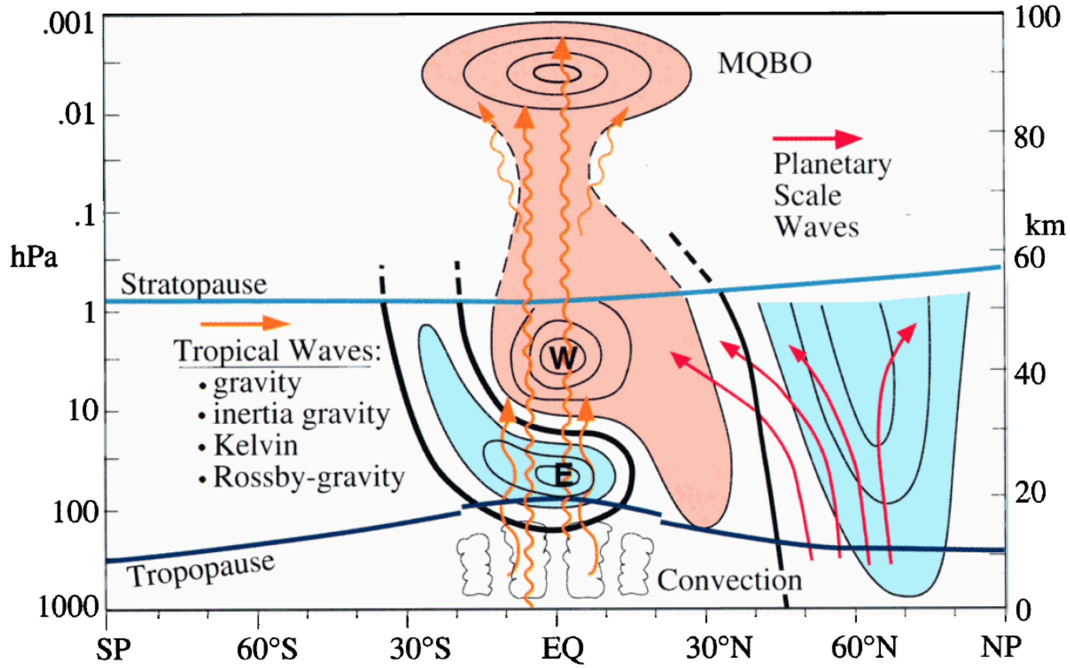
Overview

- Absence of QBO in WACCM and possible causes.
- Development of an inertio-gravity wave (IGW) parameterization scheme.
- Evaluation of WACCM simulations with the IGW.
  - Zonal mean wind, temperature, ozone at the equator.
  - Extratropical effects.
  - Surface signature.

Possible Driving Forces of QBO



Baldwin et al, 2001

- F(GW/IGW) likely much larger than F(PW)
- PW (Kelvin waves, Rossby-gravity waves) resolved by WACCM (albeit weak).
- Mesoscale GW parameterized, breaking mainly in mesosphere.
- IGW poorly resolved, and not parameterized.

Requirement for QBO Forcing

- QBO Acceleration rate:
  - 50m/s/14months~10^{-6}m/s^2
  - Q $\frac{\partial u}{\partial t} = -\frac{1}{\rho}\frac{\partial \tau}{\partial z} \approx -\frac{1}{\rho}\frac{\Delta \tau}{\Delta z}$

  $\therefore \Delta\tau \sim 10^{-3} Pa$ (ρ_{strat}~0.1kg/m^3, Δz~10km)
- For GW with such momentum flux to break in the stratosphere, the horizontal wavelength is ~1000 km according to linear saturation theory.
- Also possible: intermittent mesoscale GW with large momentum flux (e.g. t~10^{-2} Pa, occurring 10% of the time). Not considered in this study.

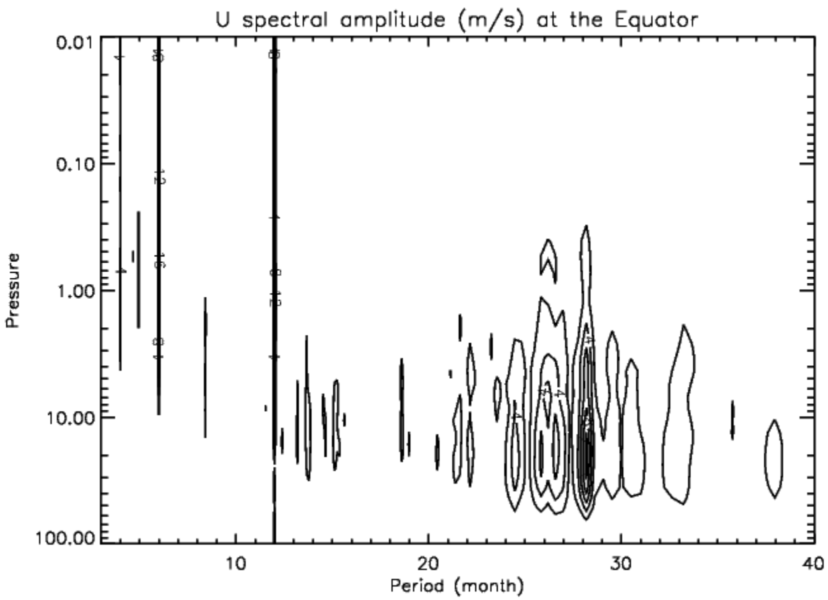
Parameterizing Inertia-GW

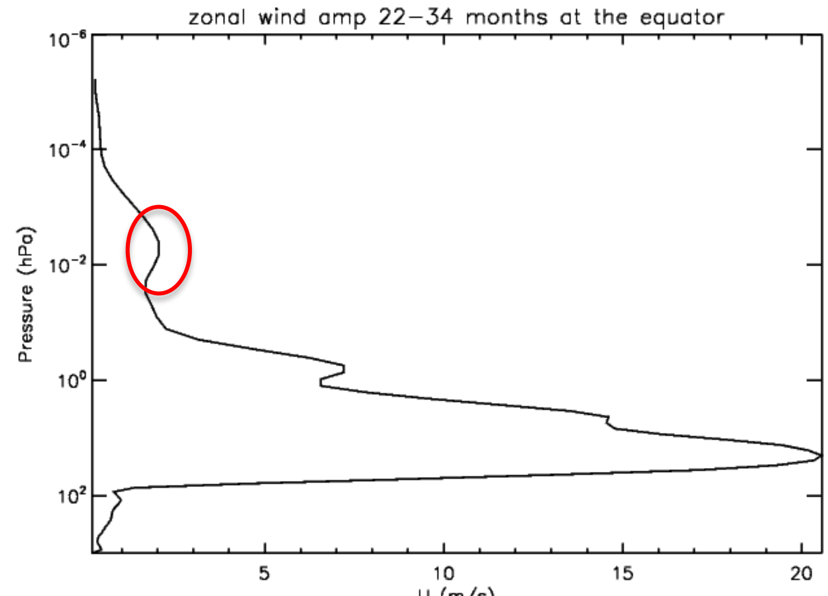
- Similar to Lindzen (1981), though considering Coriolis effect (Xue et al., 2011).

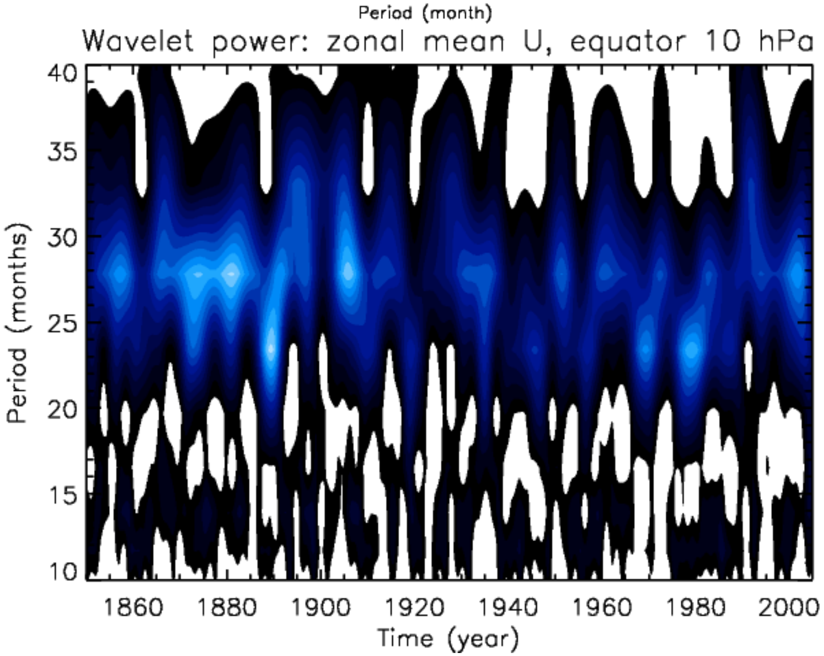
$$\frac{\partial u}{\partial t} = -\frac{1}{\rho_0}\frac{\partial \tau^*}{\partial z} = \frac{k[(c-u)^2 - f^2/k^2]^{1/2}(c-u)^2}{2NH}$$

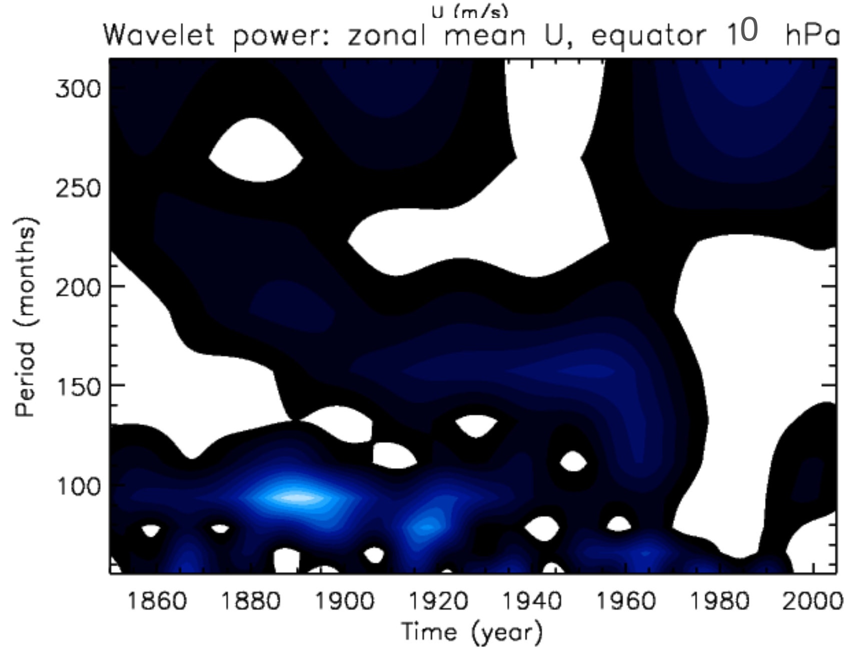
- A discrete spectrum of IGWs is launched at each grid point from tropopause between 30S-30N. Uniform longitudinal distribution.
- Implemented in CESM/WACCM4 and made a simulation 1850-2004.

Zonal Wind Spectrum: Equator

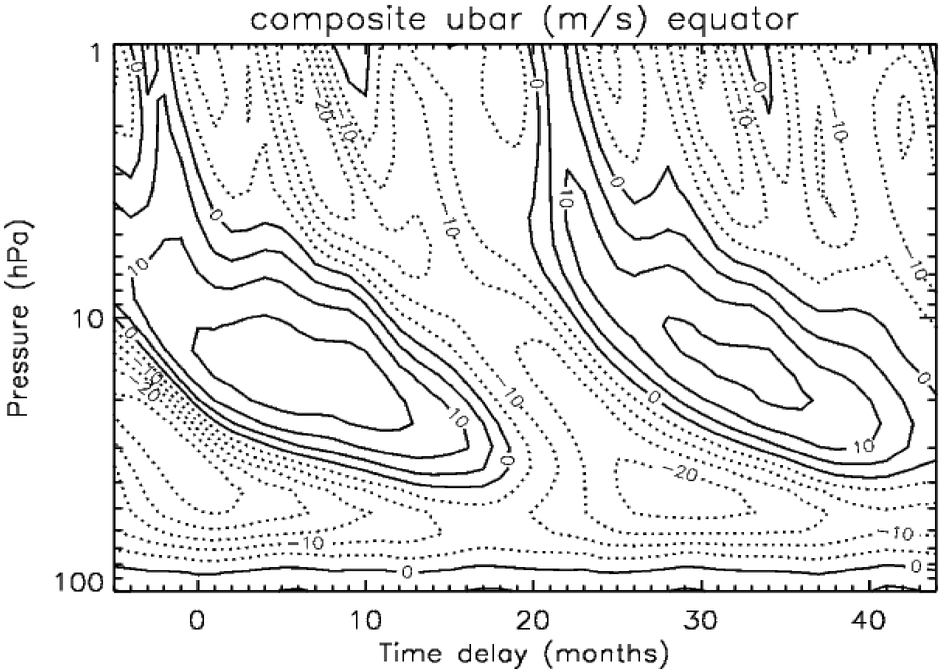


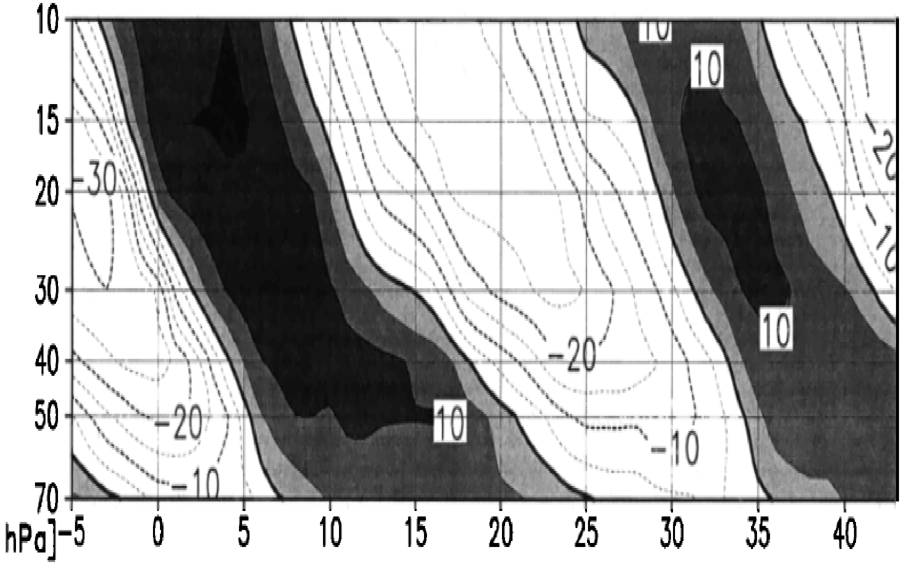






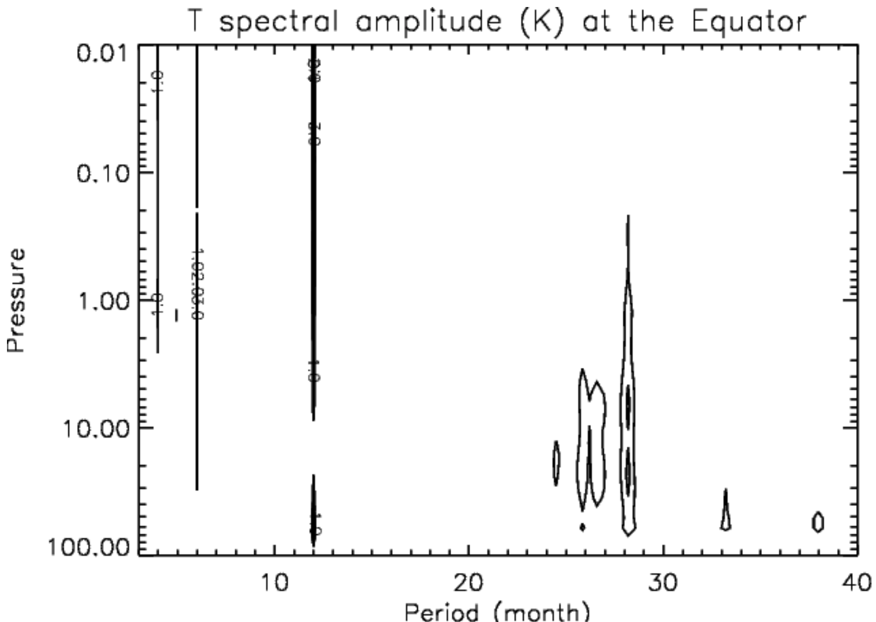
Composite Zonal Mean U: Equator

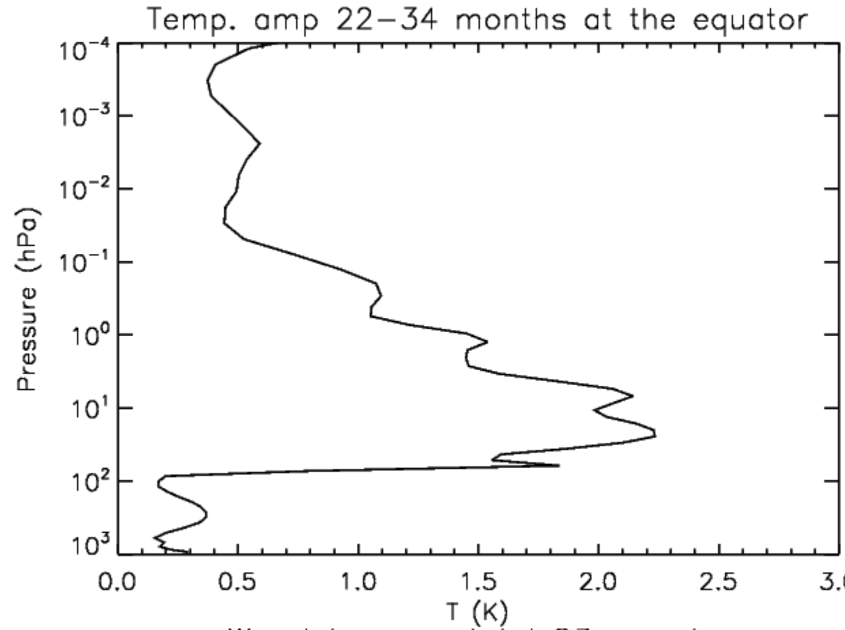


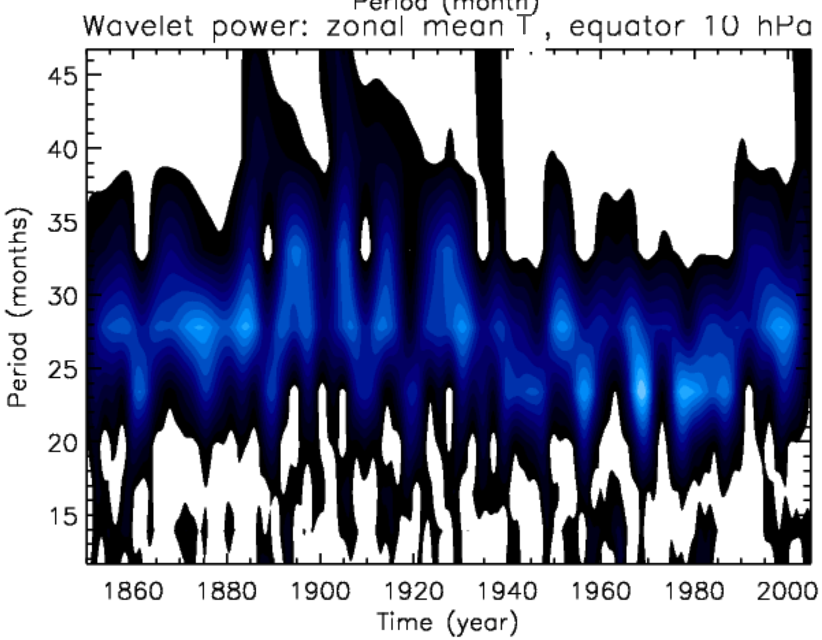


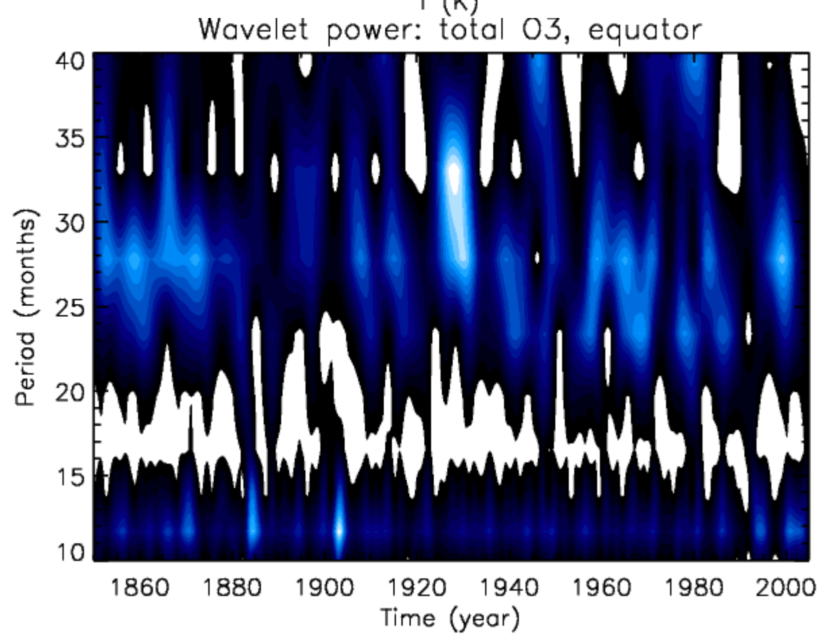
- 10 hPa: Westerly phase 18 mon. in WACCM, compared with 10 mon. in reanalysis.
- Westerly phase becomes shorter at lower altitude, opposite to the reanalysis.
- Westerly phase stops at 40 hPa.

Temperature Spectrum: Equator

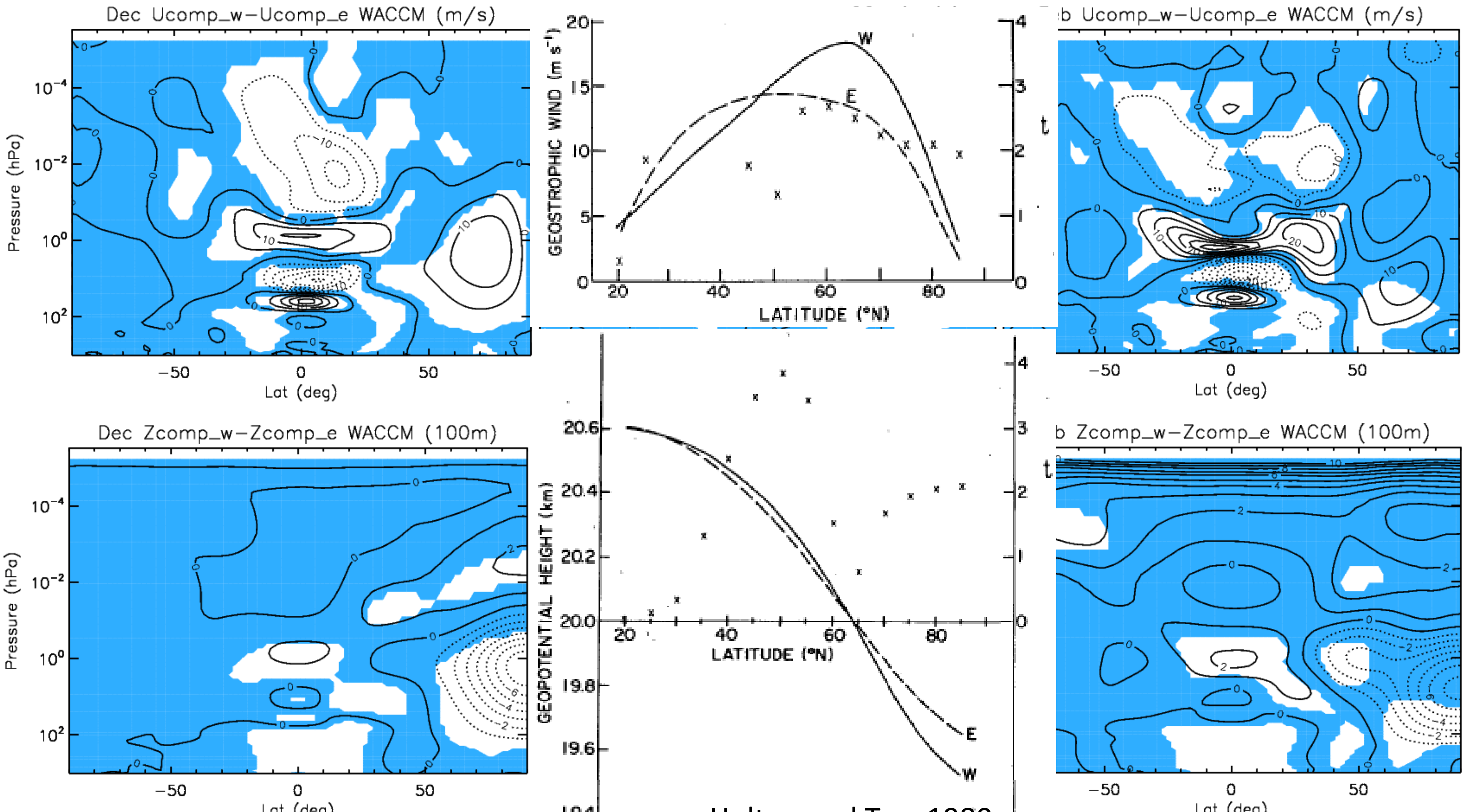






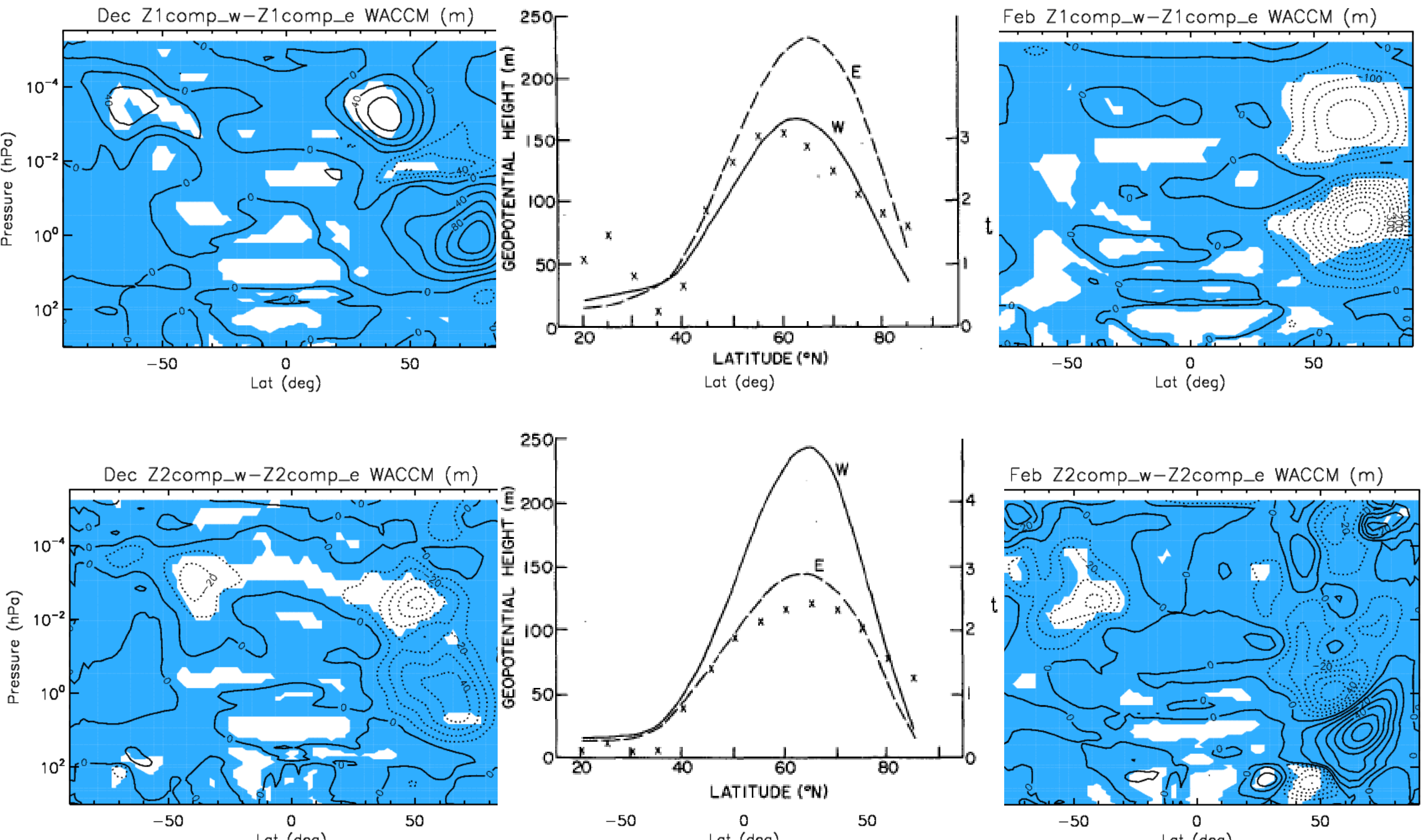


DJF Composite Diffs: W-E



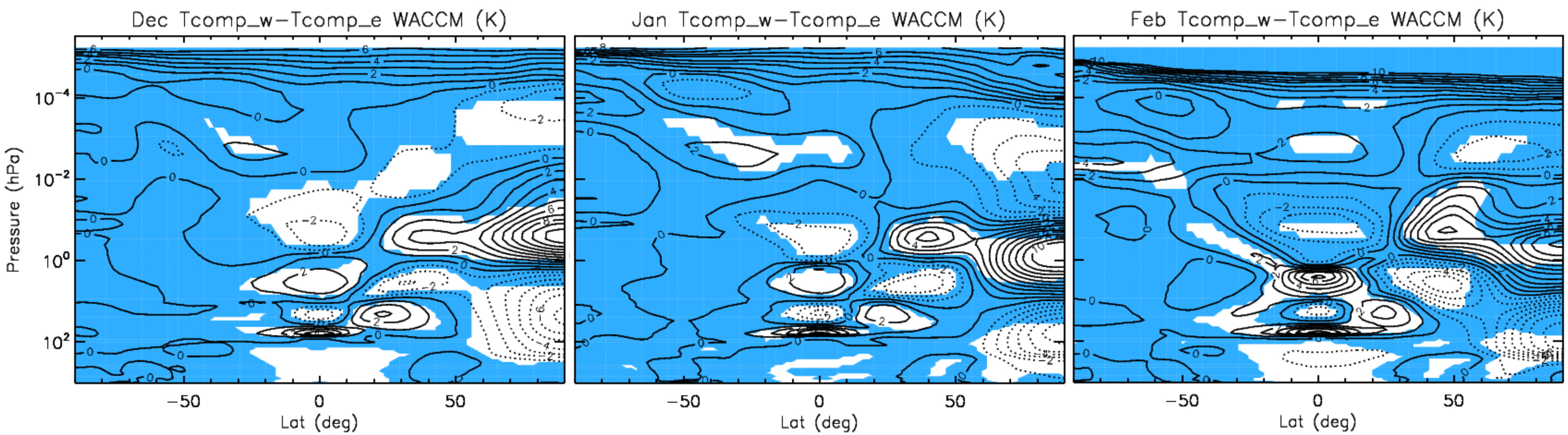
Holton and Tan, 1980

Planetary waves (1-2): W-E

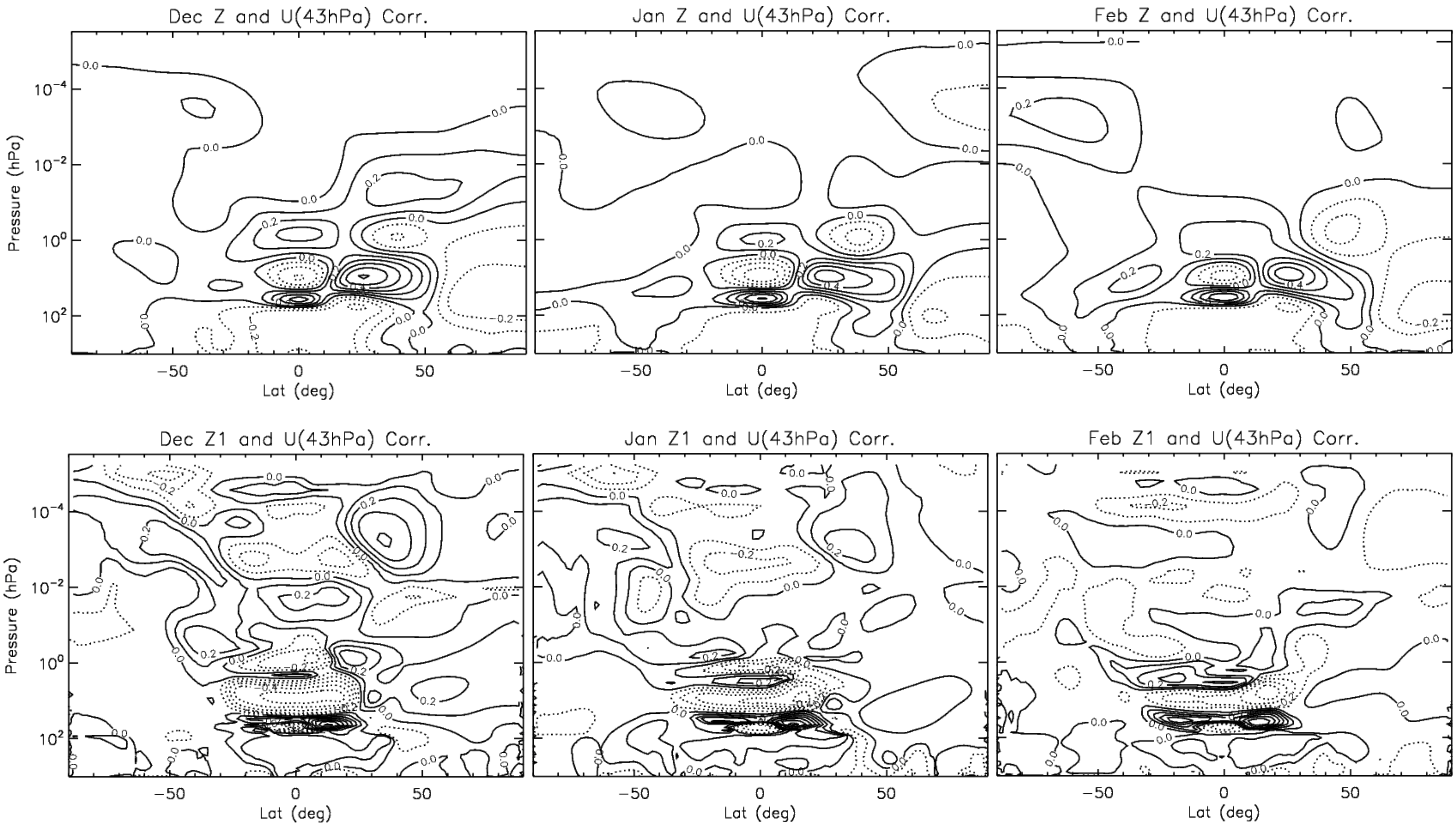


Holton and Tan, 1980

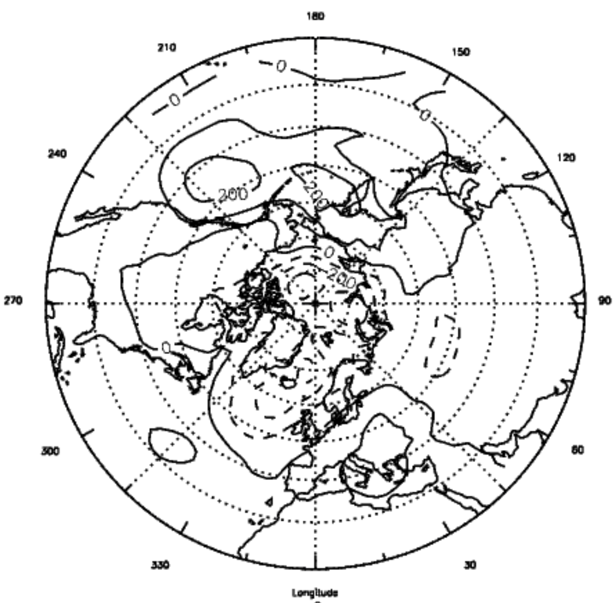
DJF Composite T Diff: W-E



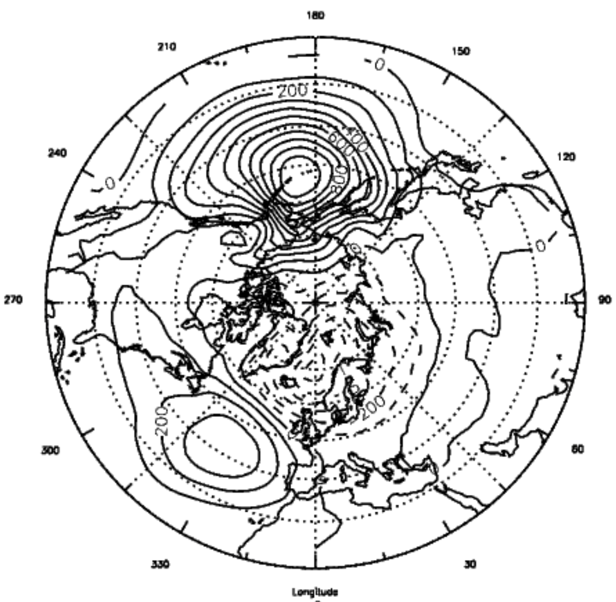
Correlation Between Z/Z1 with U(43hPa)



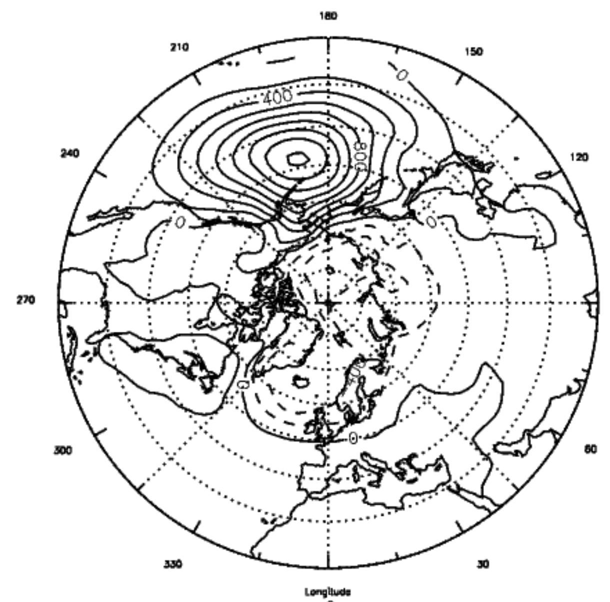
Surface Pressure: W-E



Dec PScomp_w-PScomp_e (Pa)



Jan PScomp_w-PScomp_e (Pa)



Feb PScomp_w-PScomp_e (Pa)

Holton and Tan, 1980

Summary

- The new IGW parameterization scheme produce QBO-like oscillations in CESM/WACCM4 simulation (1850-2004).
- Stratosphere zonal mean zonal wind around equator oscillates with a mean period of 28 months. Wavelet analysis shows that the period and strength of the oscillation vary with time.
- Lengths of QBO W/E phase differ from observations.
- Mesosphere QBO weak compared with observations.
- Holton-Tan relation reproduced: W phase -> lower geopotential/temperature, stronger jet at high latitudes of winter hemisphere.
- Surface pressure change consistent with reanalysis. W phase -> low pressure anomaly over winter pole and high pressure anomaly over northern Pacific (50N) and Atlantic (40N) oceans.