

Study of Quasi-Biennial Oscillation in WACCM

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National Center for Atmospheric Research

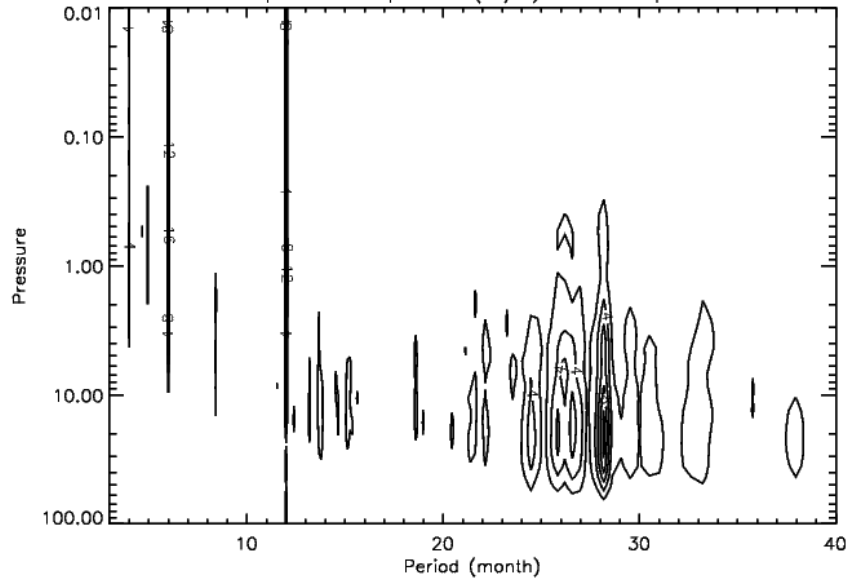
Acknowledgement: Xianghui Xue (Univ. of Science and
Technology of China), Mike Mills (Atmospheric Chemistry
Division, NCAR)

Overview

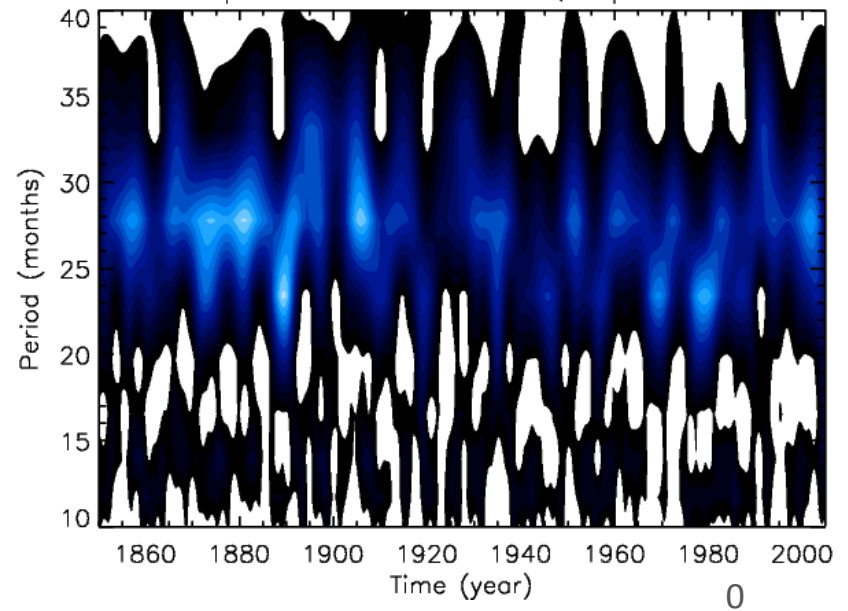
- Inertial gravity wave forcing likely important in driving QBO, but is poorly resolved and not parameterized in WACCM.
- IGW parameterization developed and implemented in WACCM (Xue et al., 2012).
- Evaluation of WACCM simulations with the IGW.
 - Zonal mean wind and forcing at the equator.
 - Extratropical effects and surface signatures.
 - Sensitivity QBO to wave spectrum.
 - WACCM simulations with coupled ocean and specified SST: filtering by tropopause wind?

Zonal Wind: Equator

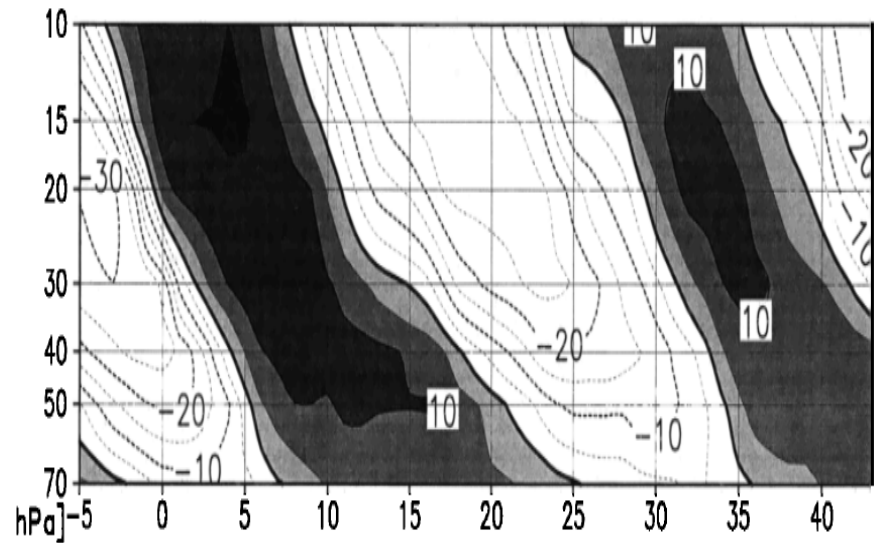
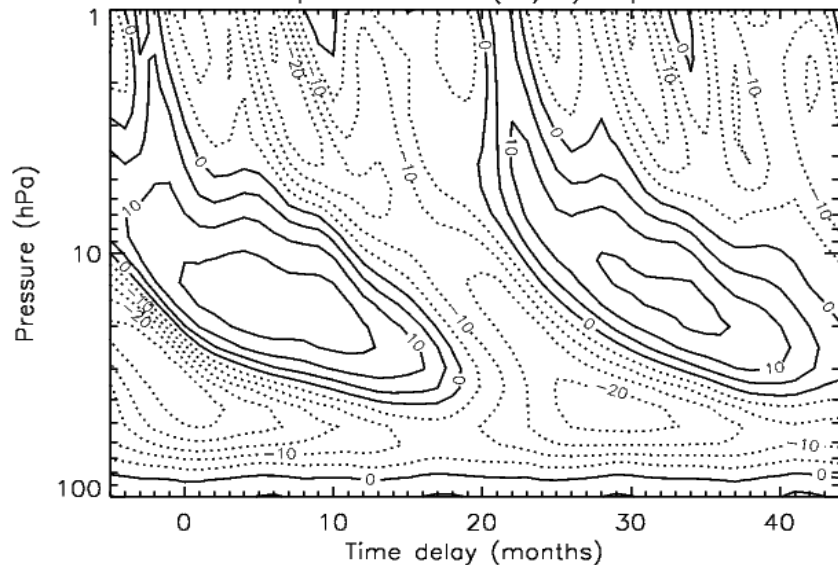
U spectral amplitude (m/s) at the Equator



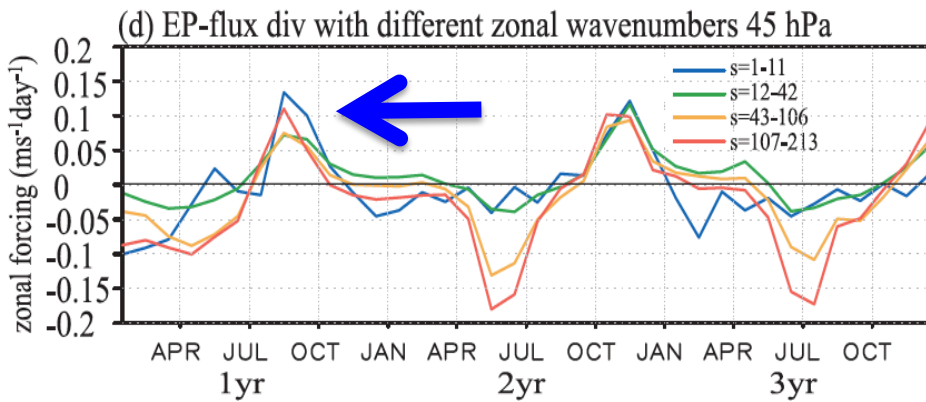
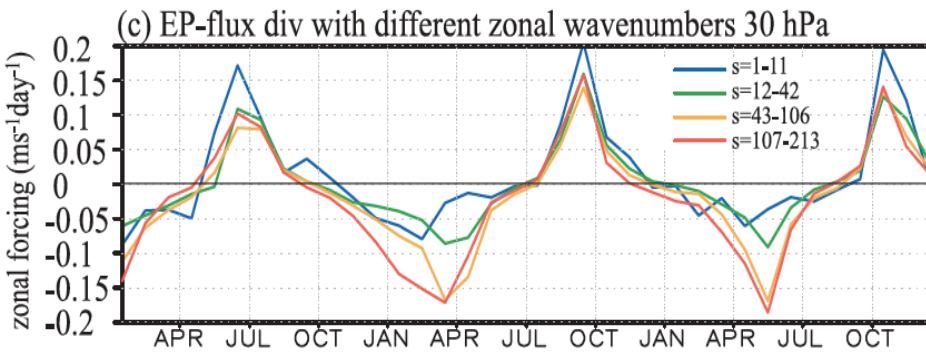
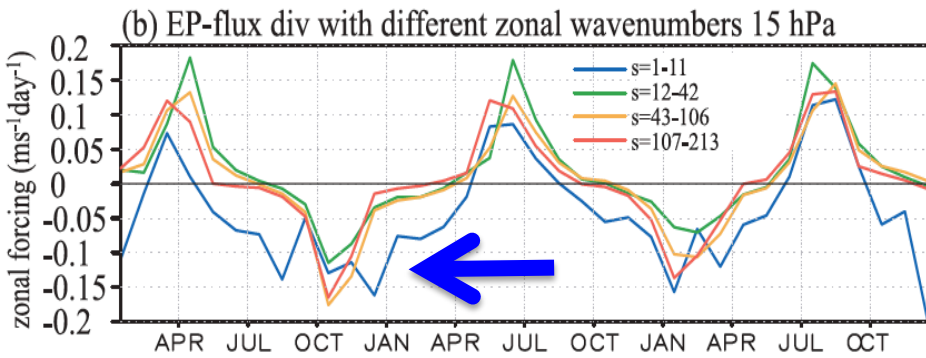
Wavelet power: zonal mean U, equator 10 hPa



composite ubar (m/s) equator

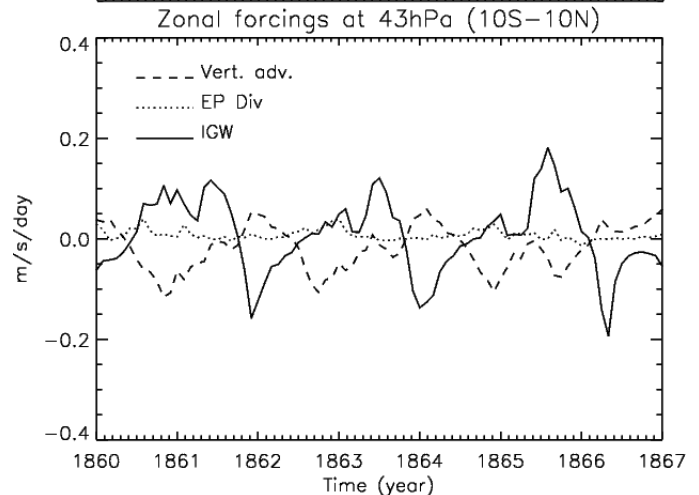
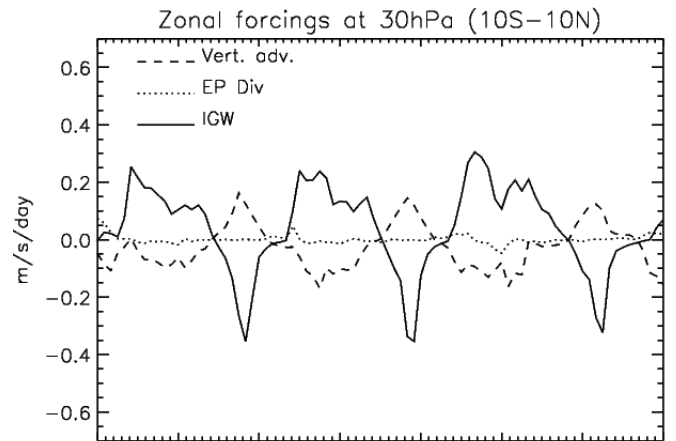
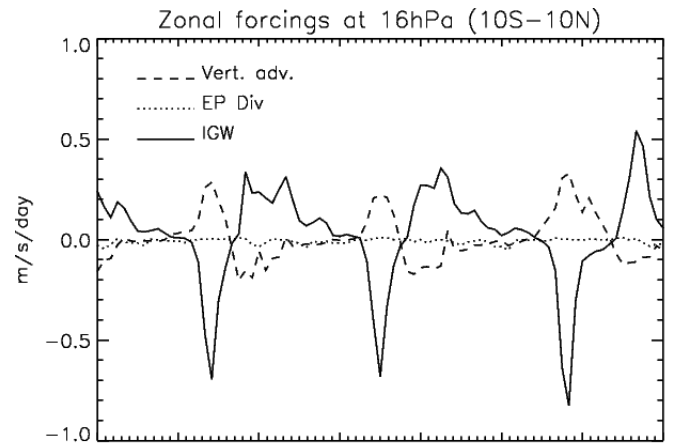


QBO Forcing

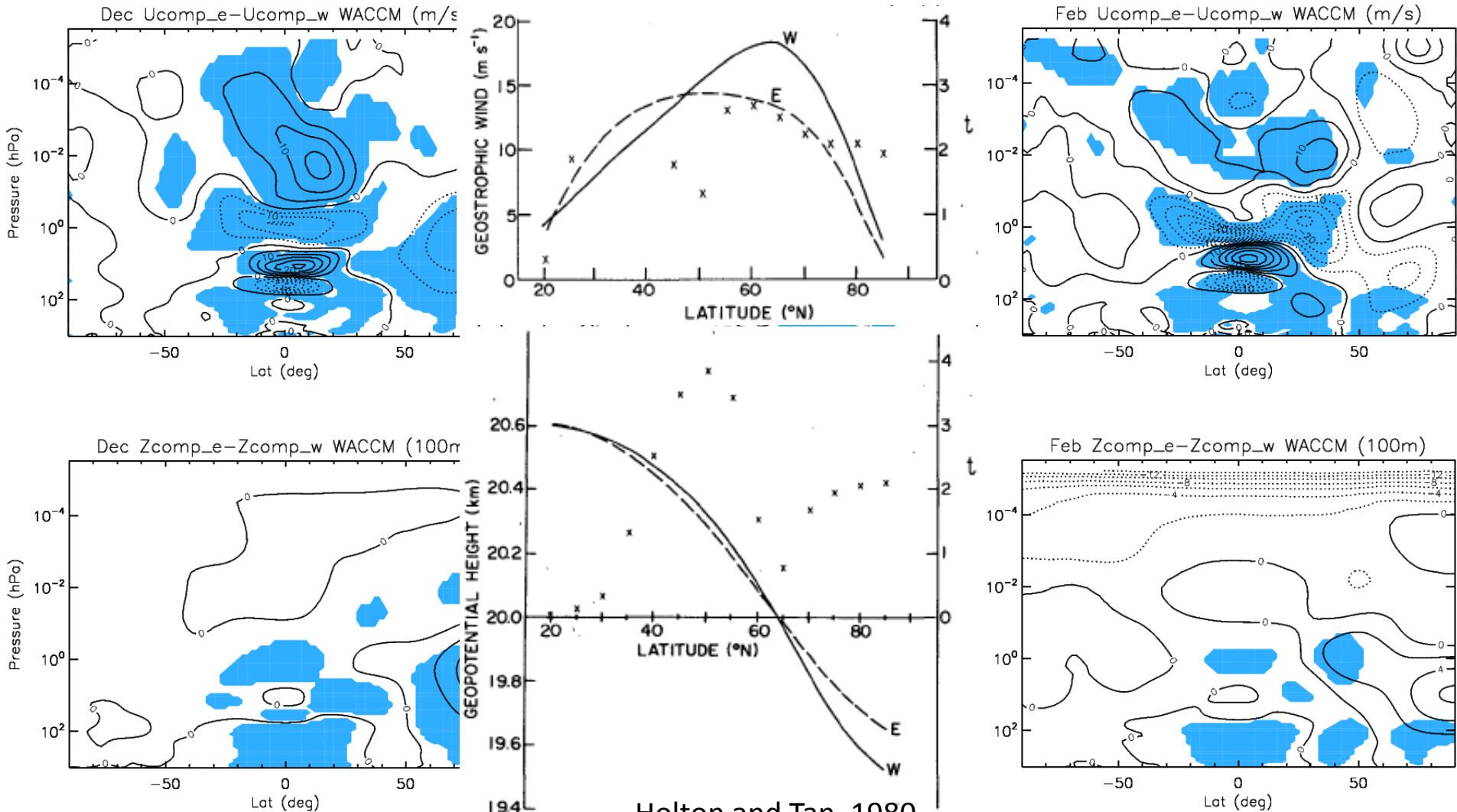


Kawatani et al, 2010

WACCM: IGW, Resolved Waves and Advection

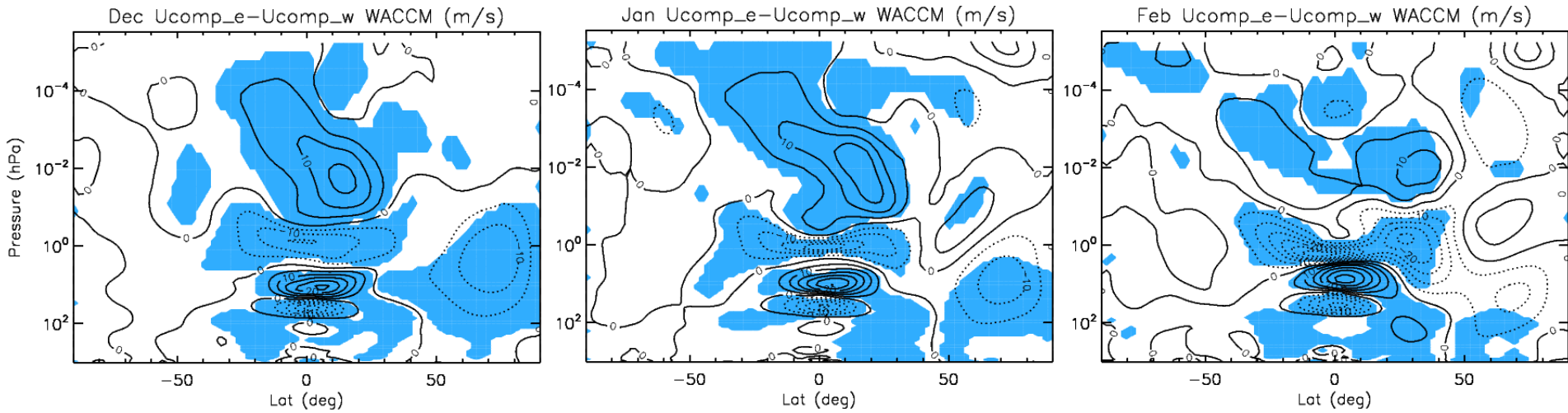


DJF Composite Diffs: E-W

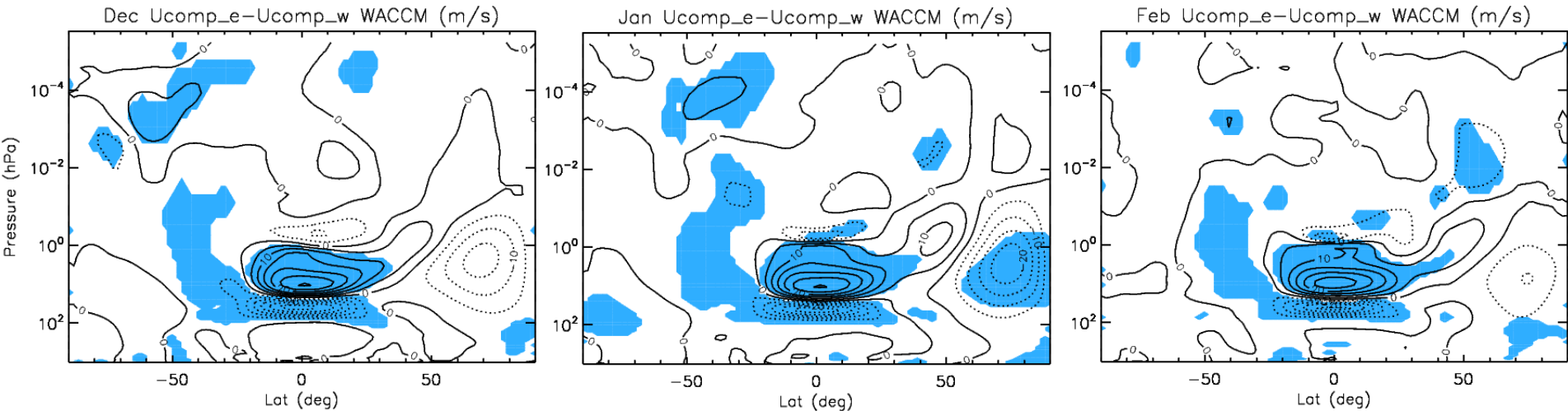


Holton and Tan, 1980

WACCM B1850-2005: QBO from IGW

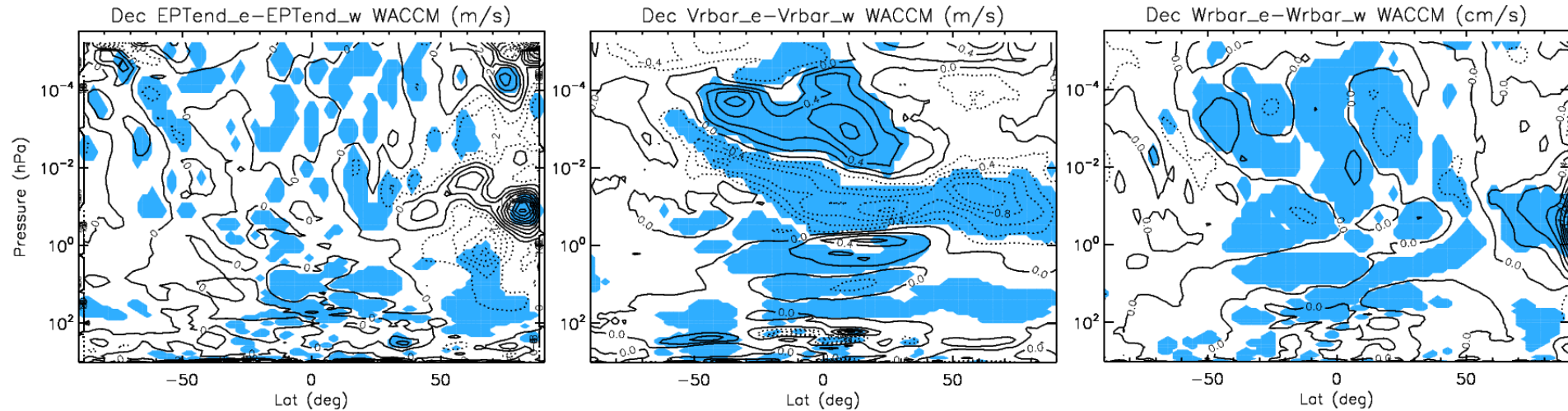


WACCM Refb1.2: Imposed QBO

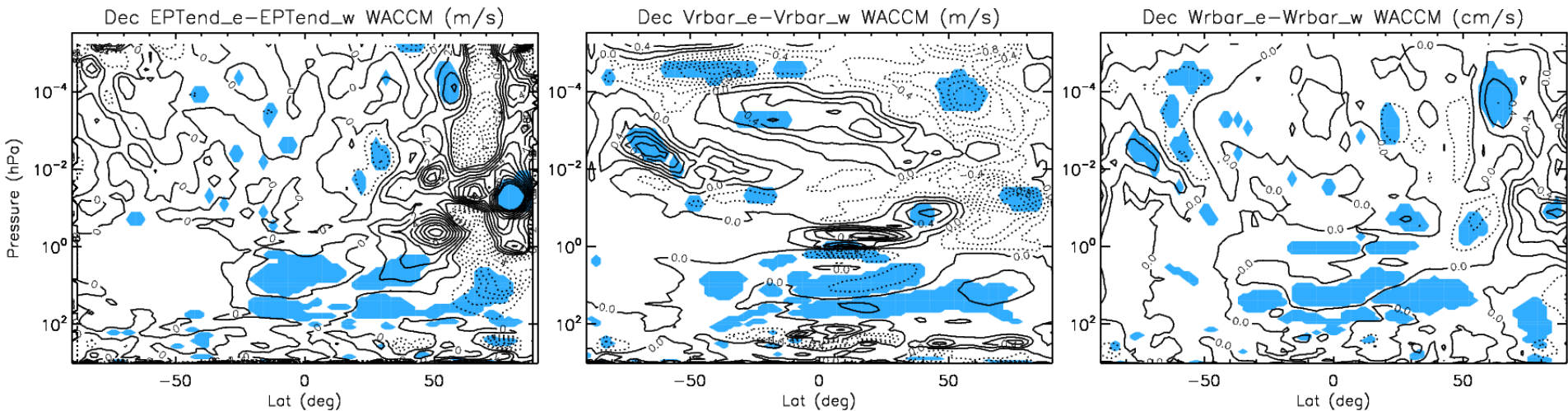


Forcing by PWs and Residual Circulation

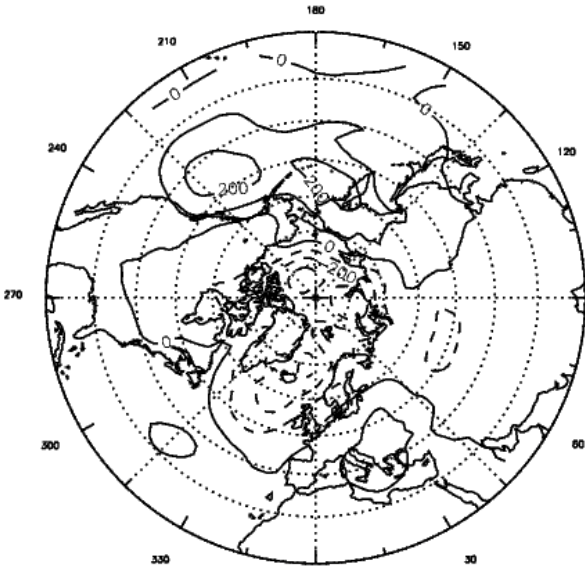
B1850-2005: QBO from IGW



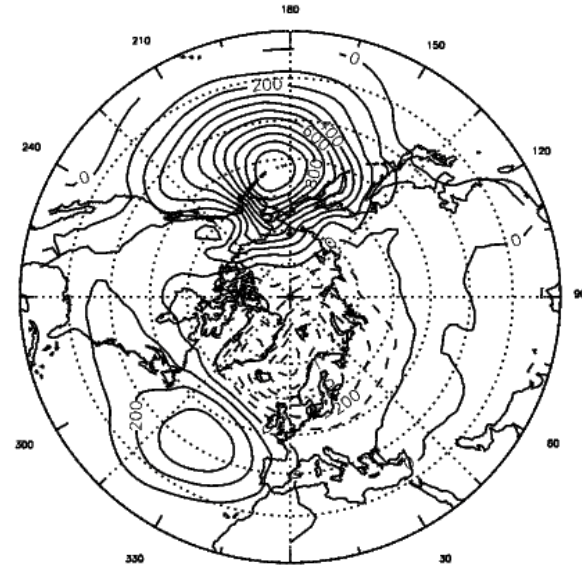
Refb1.2: Imposed QBO



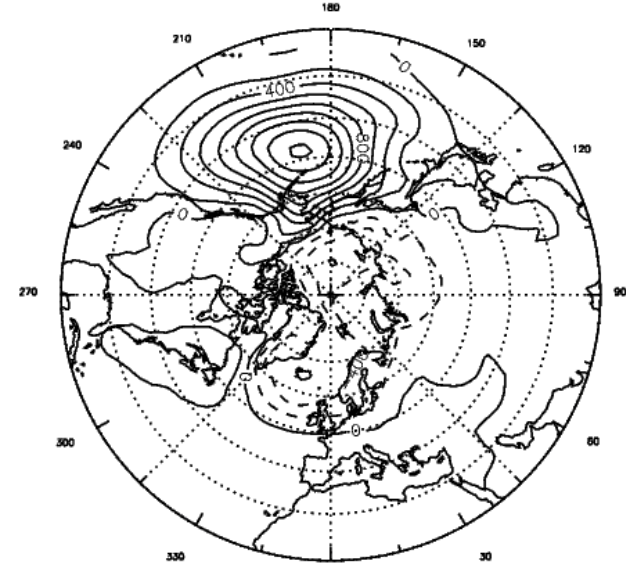
Surface Pressure: W-E



Longitude
Dec P_{Scomp_w} - P_{Scomp_e} (Pa)



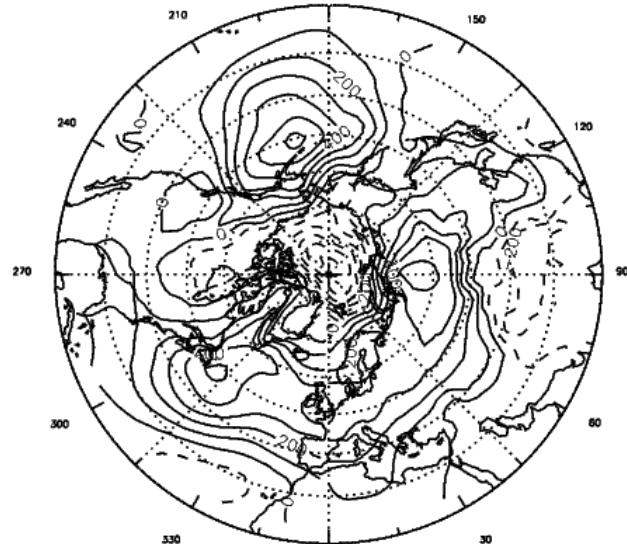
Longitude
Dec P_{Scomp_w} - P_{Scomp_e} (Pa)



Longitude
Feb P_{Scomp_w} - P_{Scomp_e} (Pa)



Holton and Tan, 1980



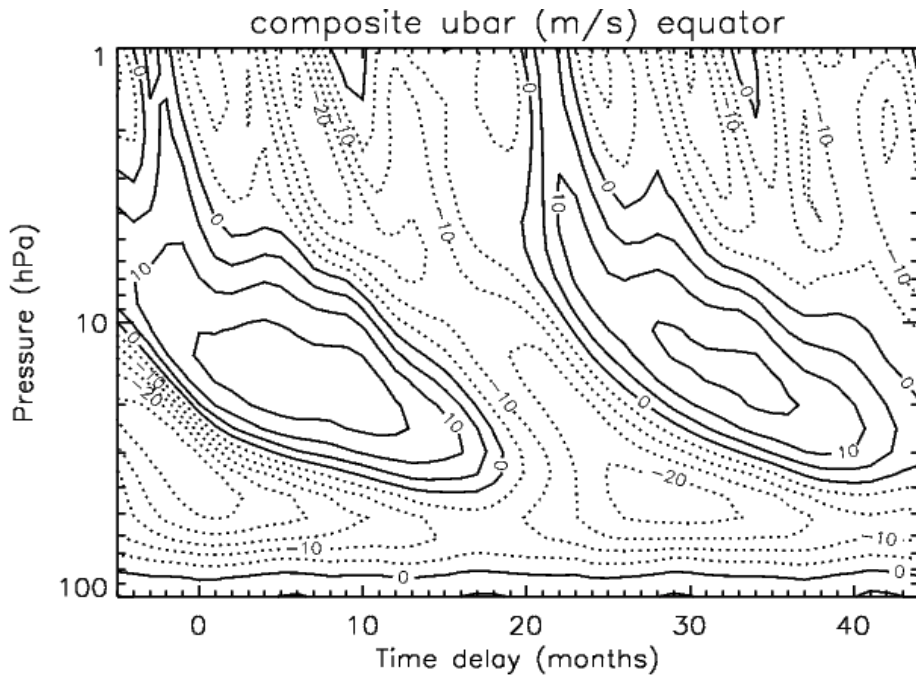
Longitude
Jan P_{Scomp_w} - P_{Scomp_e} (Pa)

Jan, Refb1.2 imposed QBO

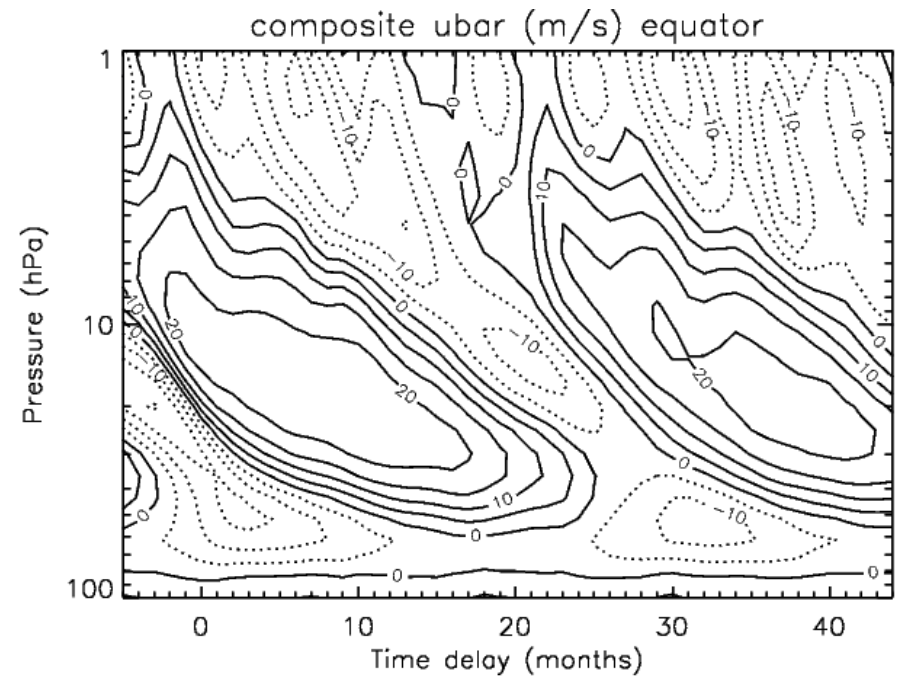
WACCM Experiments

- WACCM with coupled ocean:
 - Transient run: Anisotropic IGW spectrum (shifted westward by 5m/s).
 - Transient run: Isotropic IGW spectrum.
 - Perpetual run (1850): Anisotropic IGW spectrum.
- WACCM with specified SST:
 - Transient run: Anisotropic IGW spectrum (1955-1976).
 - Perpetual run (1850): Anisotropic IGW spectrum. (21 years)
 - Perpetual run (2000): Anisotropic IGW spectrum. (21 years)

Sensitivity to Source Spectrum

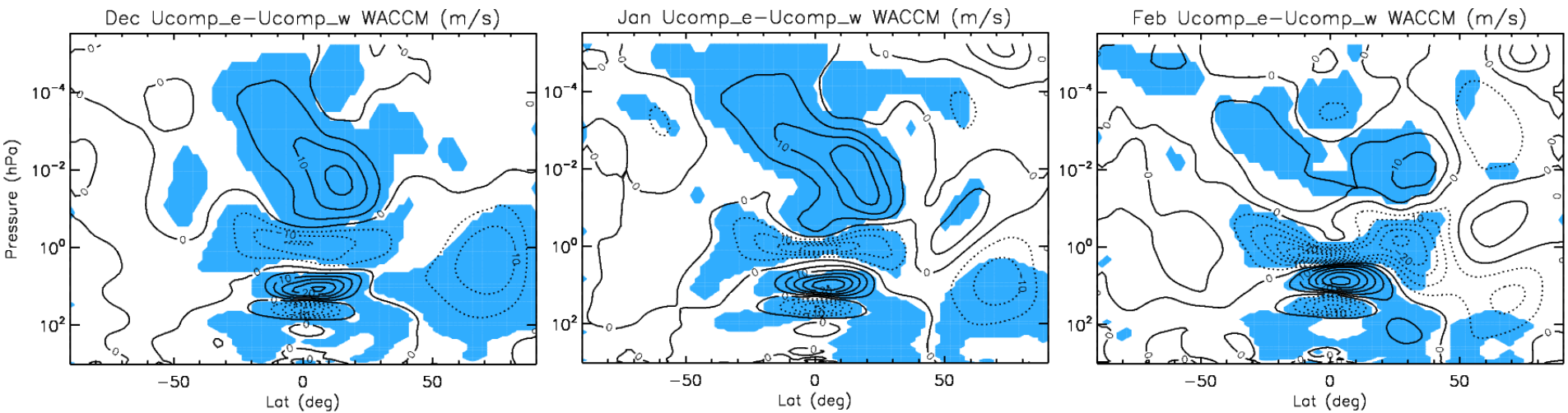


Source spectrum: West 25m/s to East 15m/s

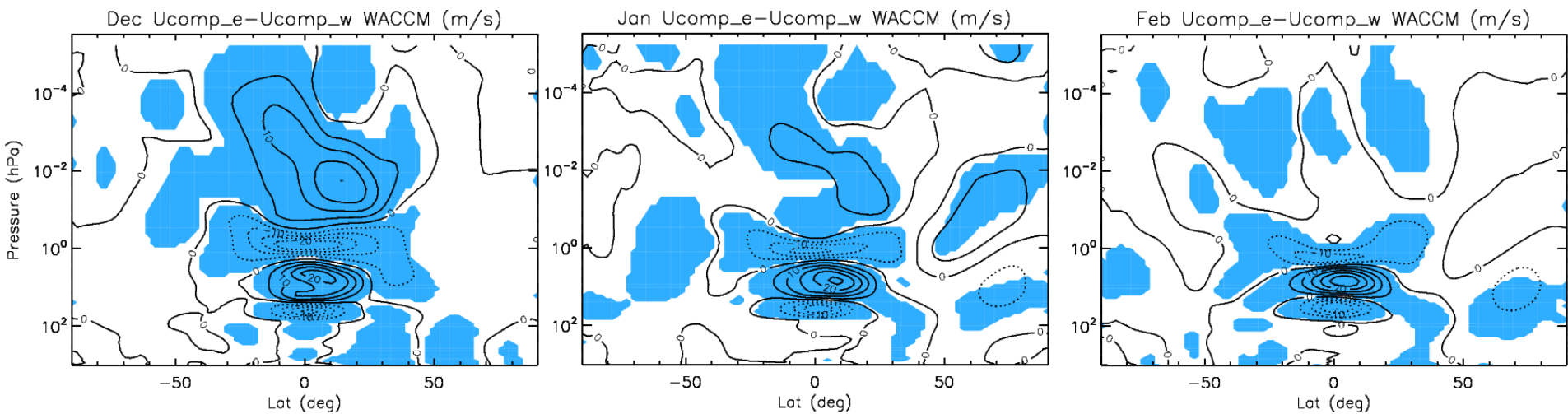


Source spectrum: West 20m/s to East 20m/s

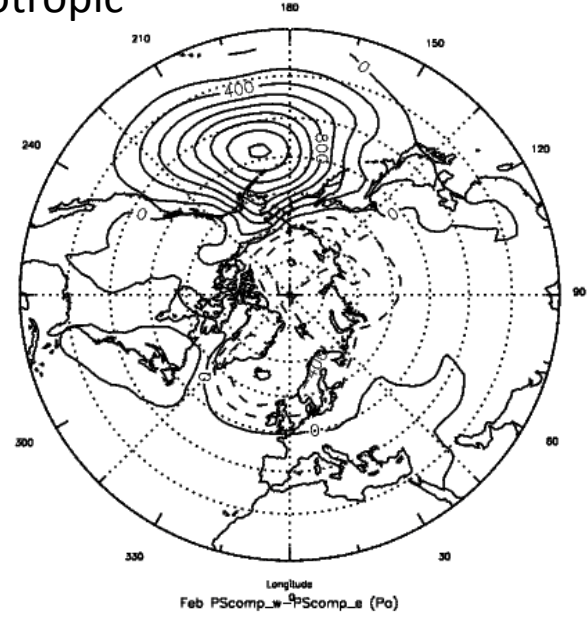
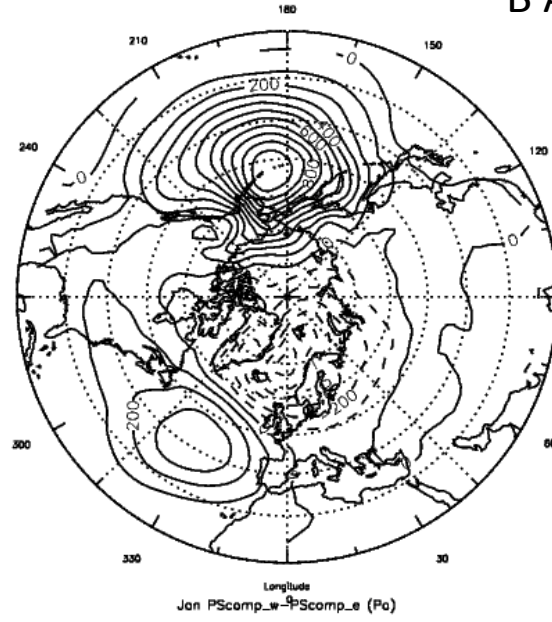
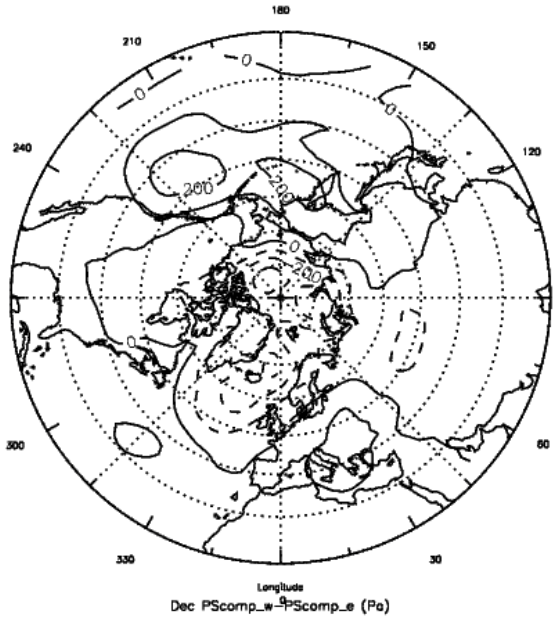
“B” run with anisotropic source spectrum



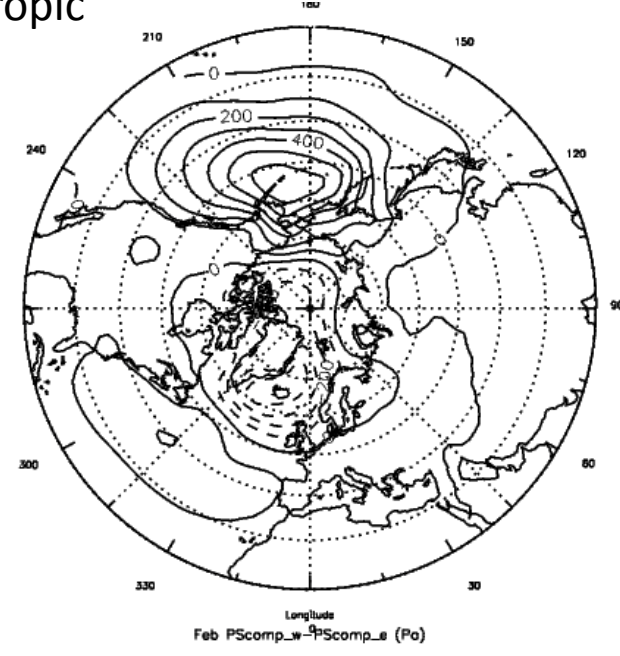
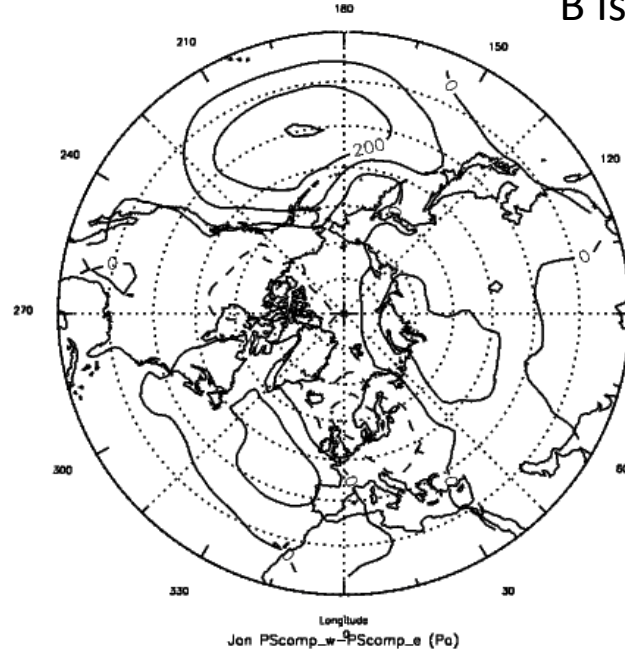
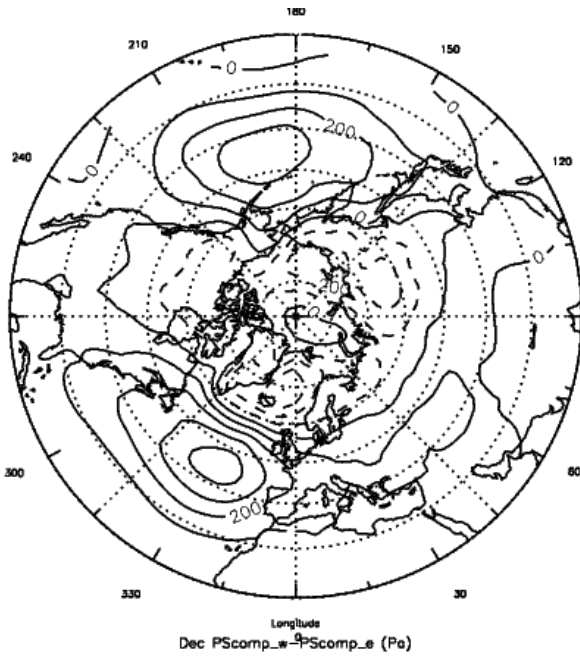
“B” run with isotropic source spectrum



B Anisotropic

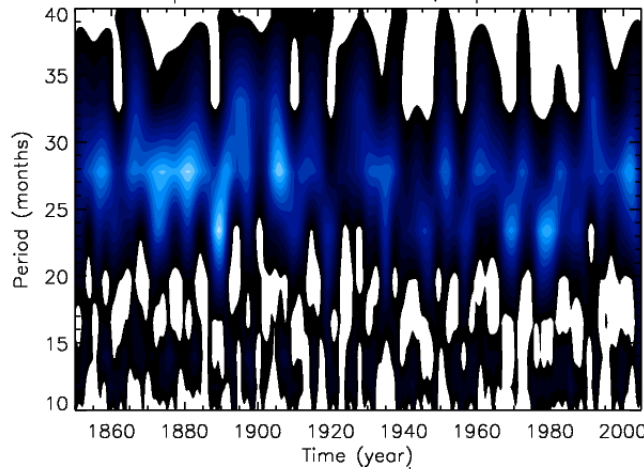


B Isotropic

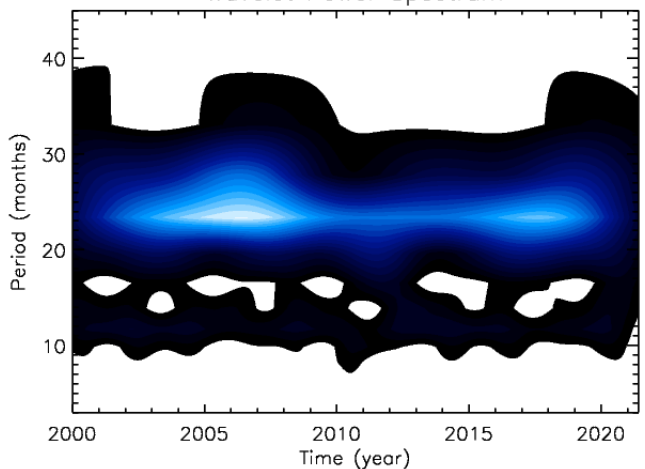


Wavelet power: zonal mean U, equator 10 hPa

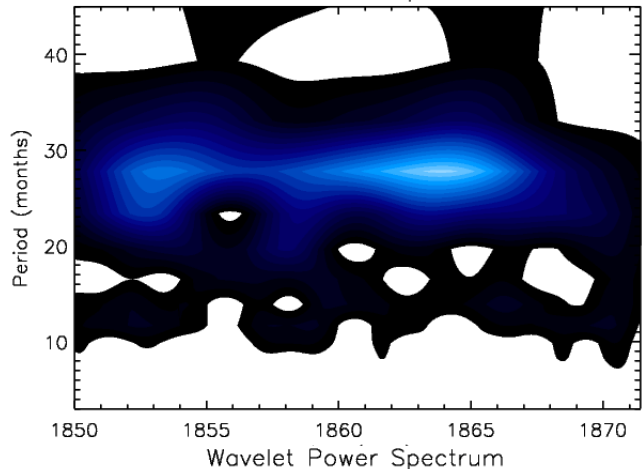
B1850-2005



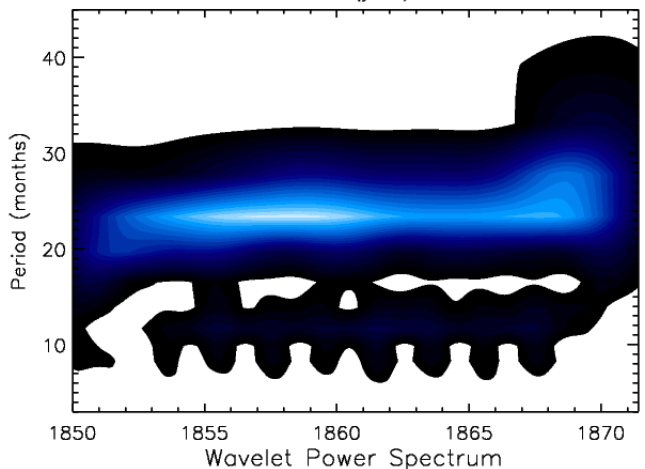
F2000



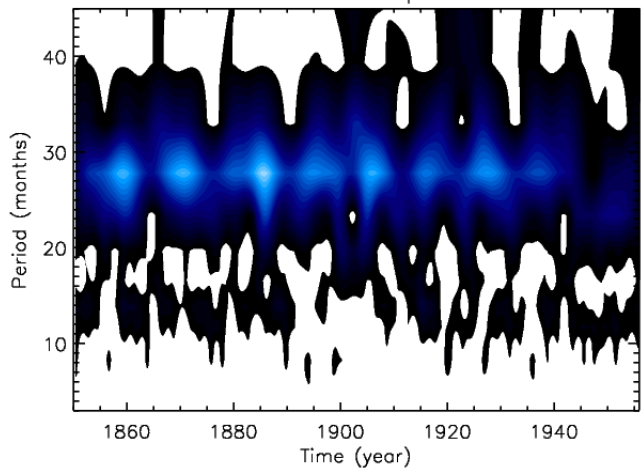
B1850



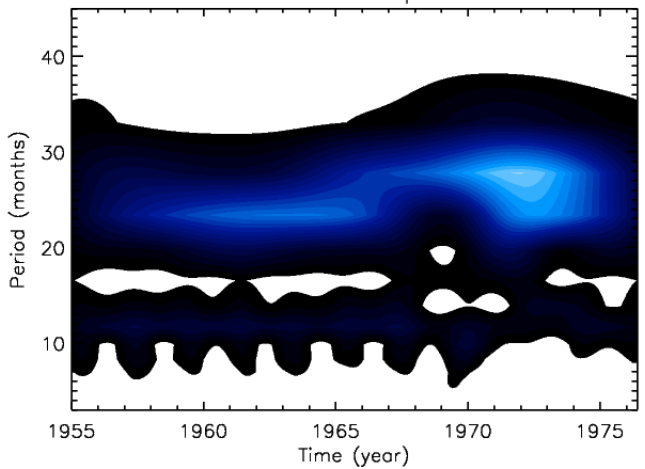
F1850



B1850-1955
"isotropic spectrum"

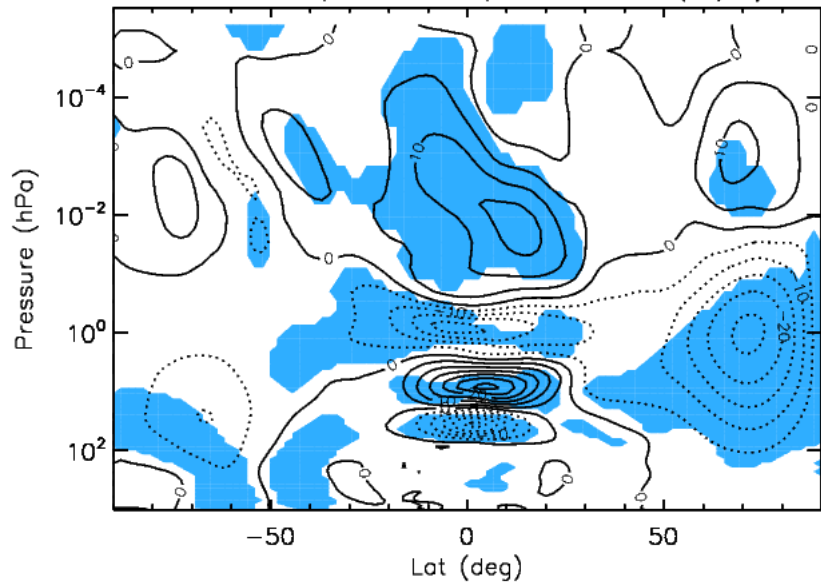


F1955-1976

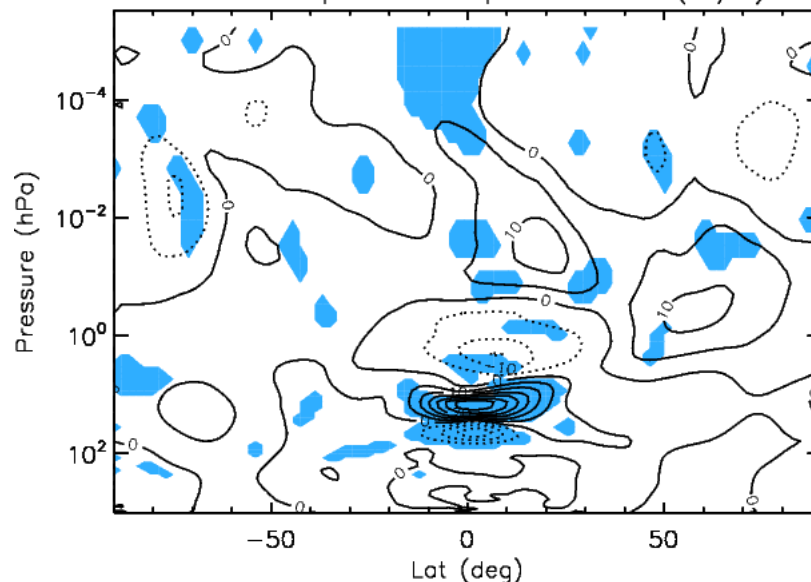


B1850

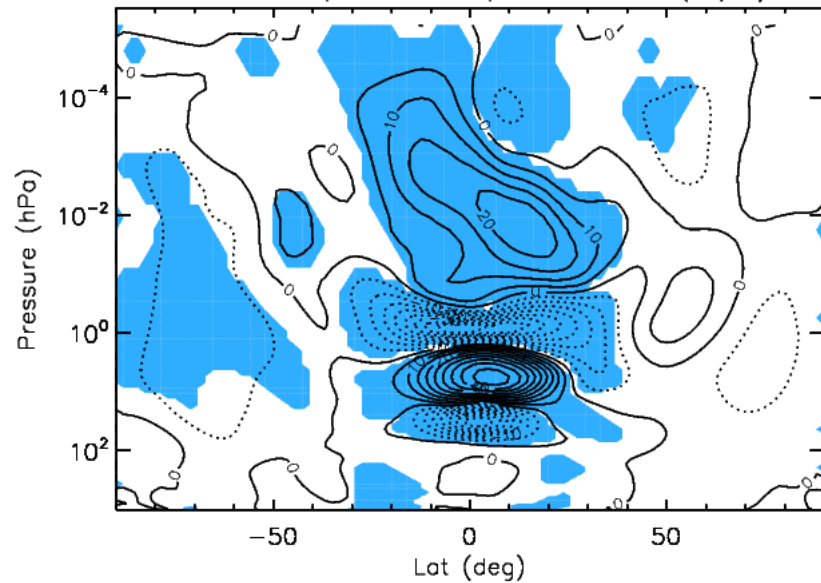
Dec Ucomp_e-Ucomp_w WACCM (m/s)

**F1850**

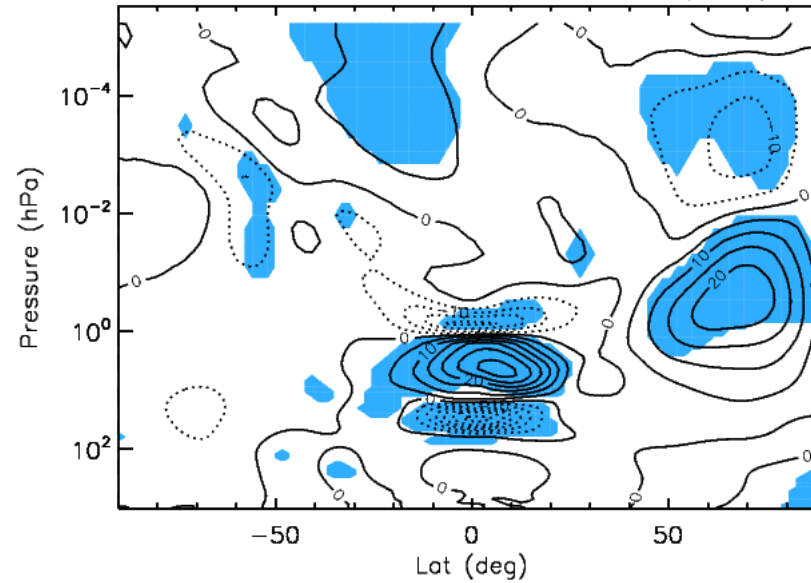
Dec Ucomp_e-Ucomp_w WACCM (m/s)

**F2000**

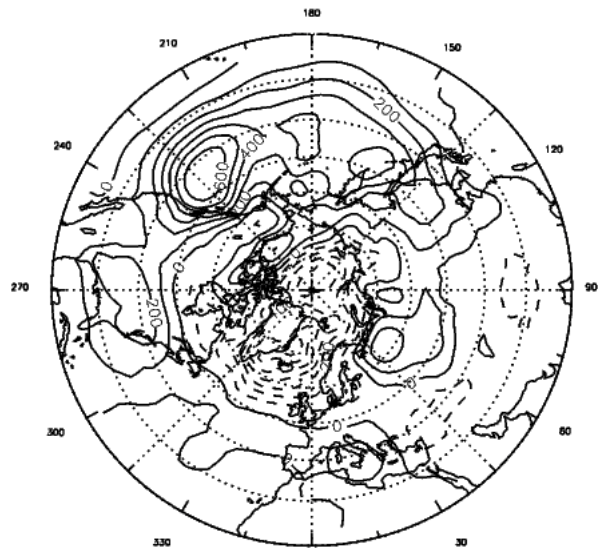
Dec Ucomp_e-Ucomp_w WACCM (m/s)

**F1955-1976**

Dec Ucomp_e-Ucomp_w WACCM (m/s)

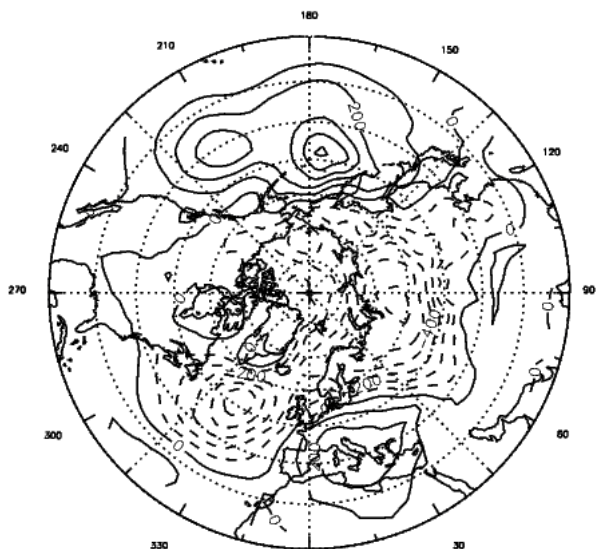


B1850



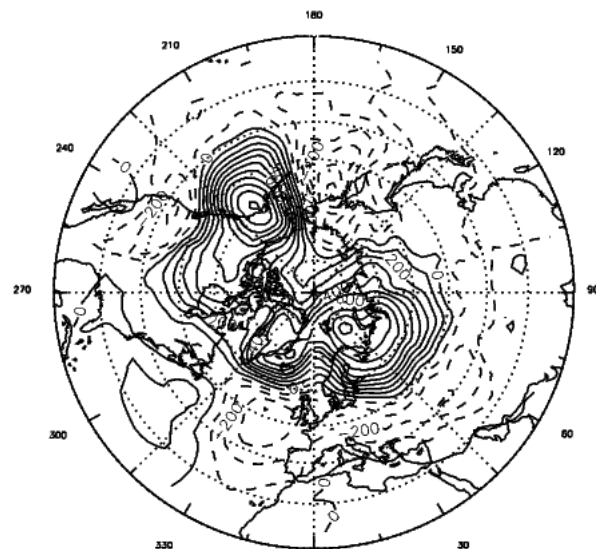
Longitude
Dec PScomp_w - PScomp_e (Pa)

F2000



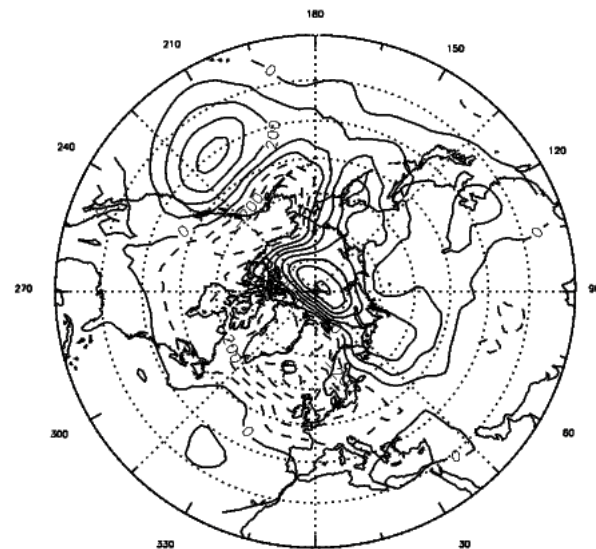
Longitude
Dec PScomp_w - PScomp_e (Pa)

F1850



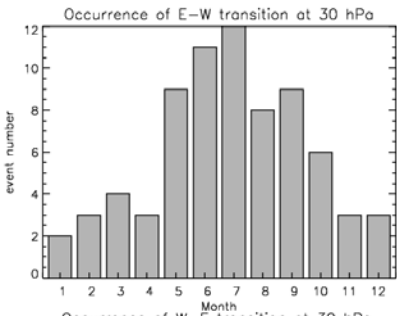
Longitude
Dec PScomp_w - PScomp_e (Pa)

F1955-1976

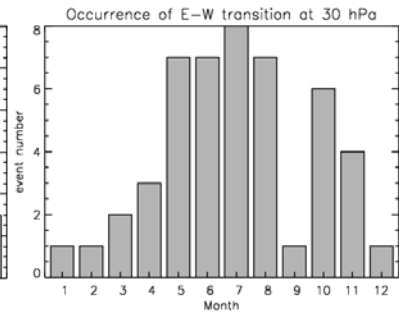


Longitude
Dec PScomp_w - PScomp_e (Pa)

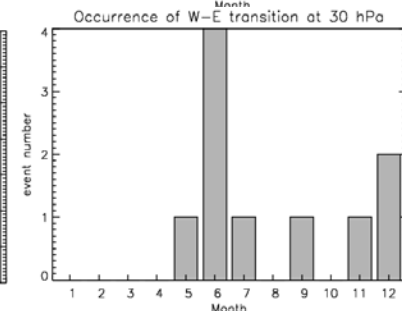
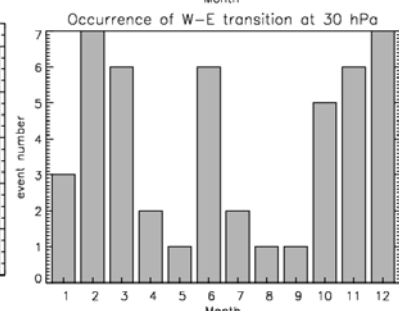
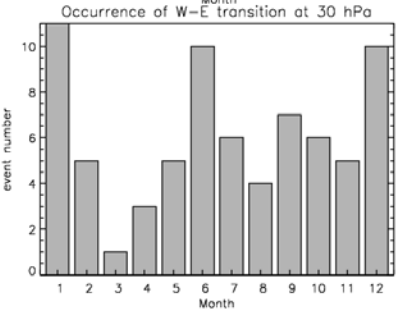
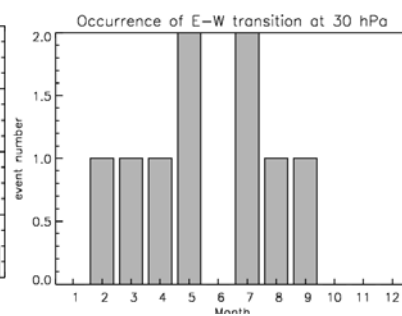
B1850-2005



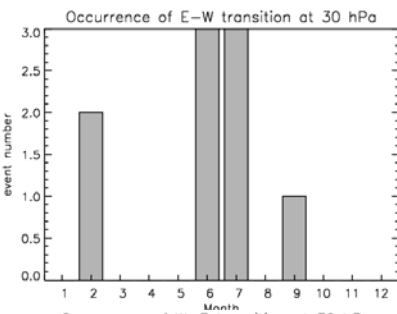
B1850-1955



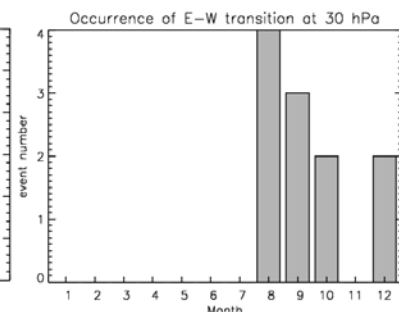
B1850



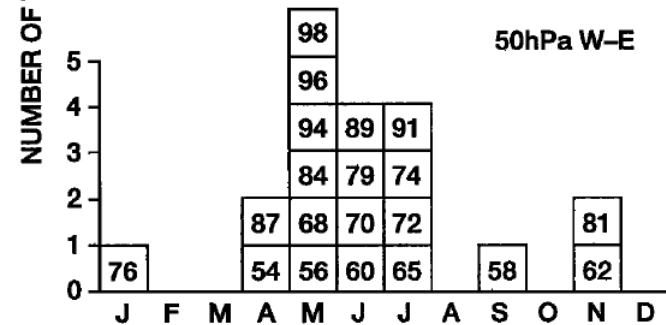
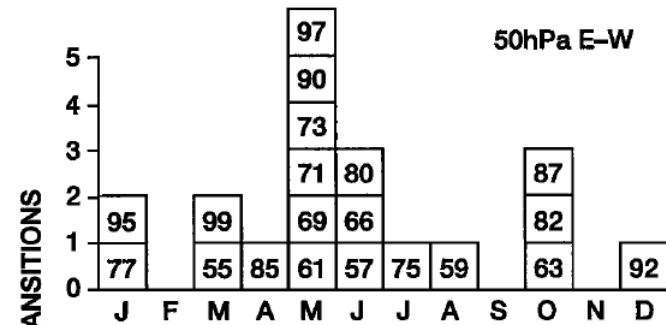
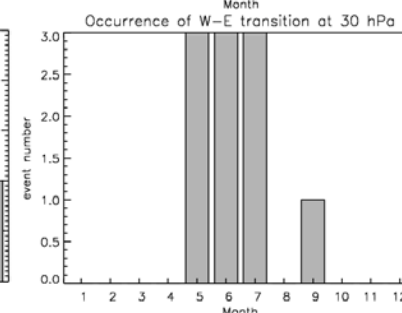
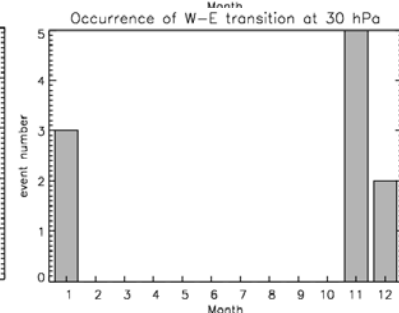
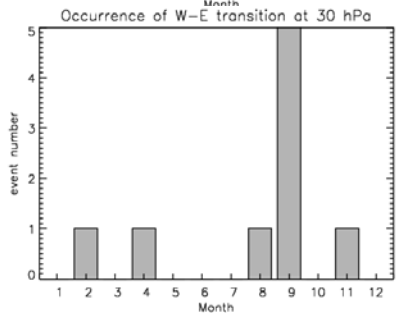
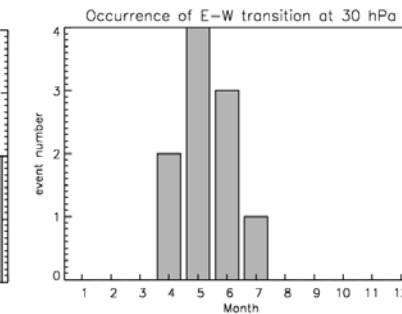
F1955-1976



F1850



F2000

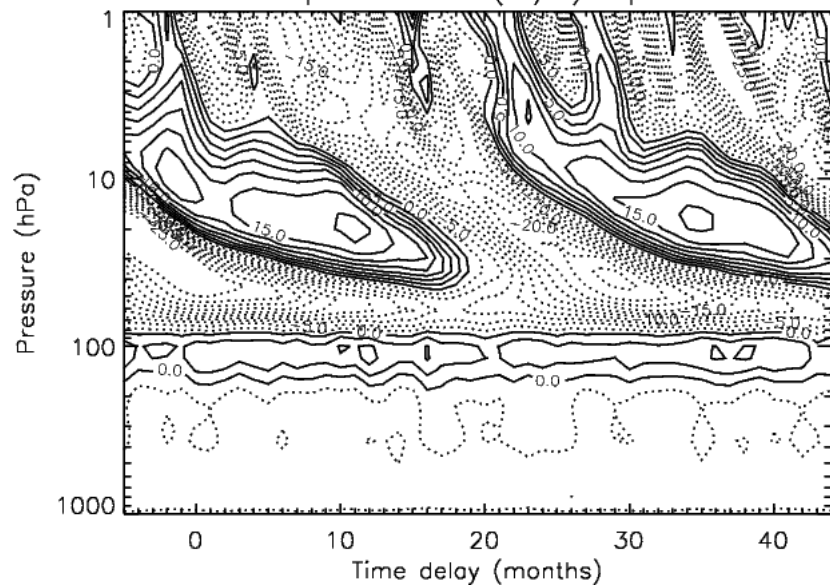


Pawson et al, 1993

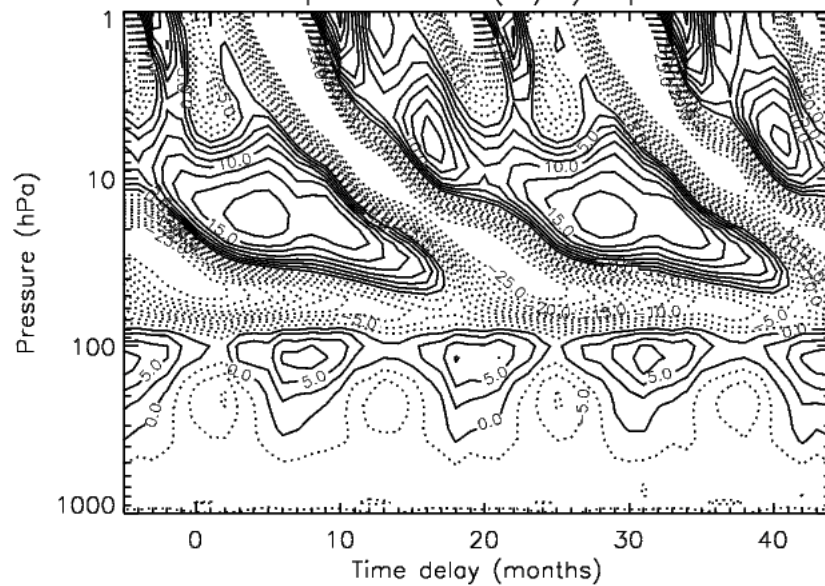
Causes?

- F2000: Solar maximum. Holton-Tan doesn't hold?
 - F1850 and B1850 both under solar medium condition. Holton-Tan relation significant in latter but not in former.
 - F1955-1976 went through 2 solar cycles. Winter stratospheric wind differences opposite to Holton-Tan.
- F1850 or F2000 SST may have a somewhat artificial annual periodicity (as a pace-maker)?
 - B1850 may also have that.
 - F1955-1976 wouldn't have the problem.

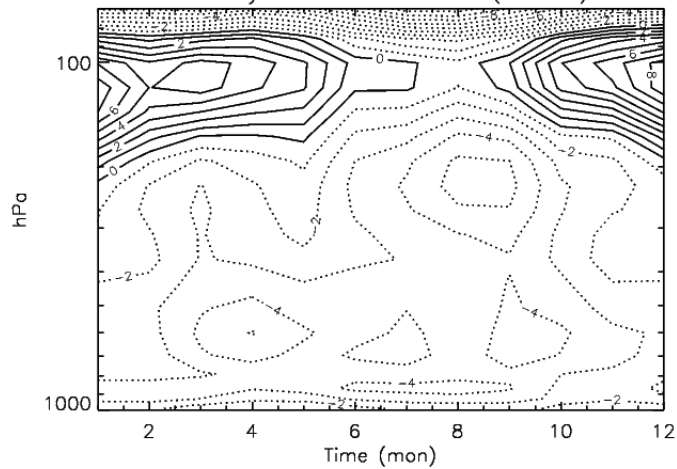
composite ubar (m/s) equator



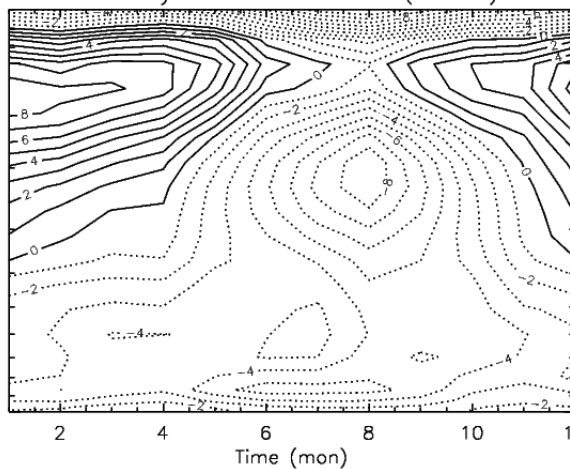
composite ubar (m/s) equator



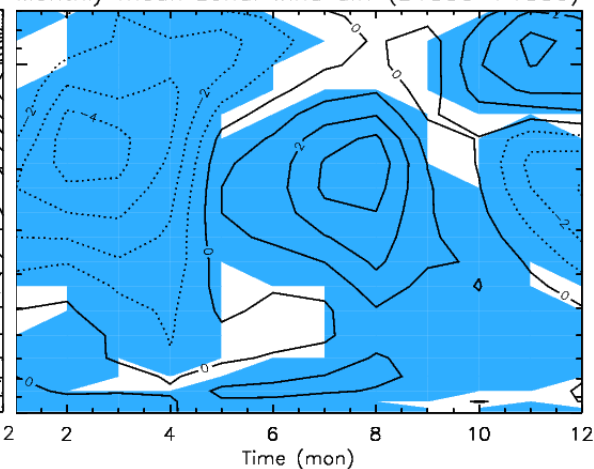
Monthly mean zonal wind (B1850)



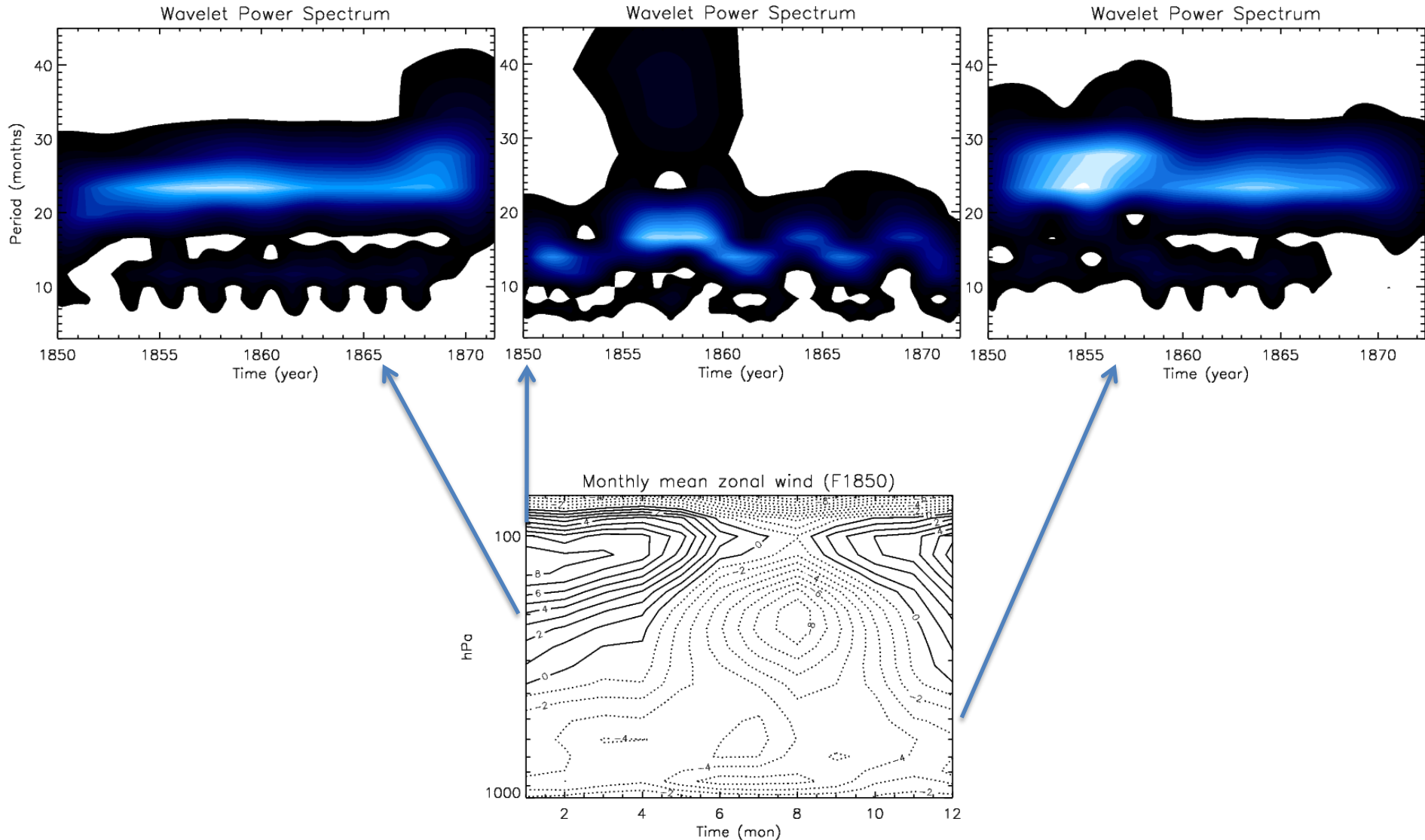
Monthly mean zonal wind (F1850)



Monthly mean zonal wind diff (B1850-F1850)



IGW Launch Level Dependence



Summary

- The new IGW parameterization scheme produce QBO-like oscillations in CESM/WACCM4 simulation.
- QBO period:
 - ~28 months with coupled ocean and perpetual 1850 condition.
 - 24-33 months with coupled ocean and 1850-2005 run.
 - 24 months with specified SST and perpetual conditions. Show some variation in transient simulation.
- QBO phase:
 - At middle stratosphere westerly phase too long, opposite lower down.
 - In simulations with ocean coupling, wind phase transition time agrees with climatology, though W-E also occurs frequently around northern winter.
 - In SST simulations, wind phase transition time nearly locked to certain months. The actual timing differs in cases.
- QBO forcing:
 - Parameterized GW forcing in general agreement with high-resolution GCM results.
 - PW forcing, particularly westward forcing, around equator very small. May explain the short easterly phase in middle stratosphere.
- Extra-tropical and surface modulation (Holton-Tan relation) significant in simulations with ocean coupling. Insignificant or significant in opposite sense in SST simulations.