

The Response of the QBO to Zonal-Mean Ozone Perturbations Consistent with the 11-Year Solar Cycle

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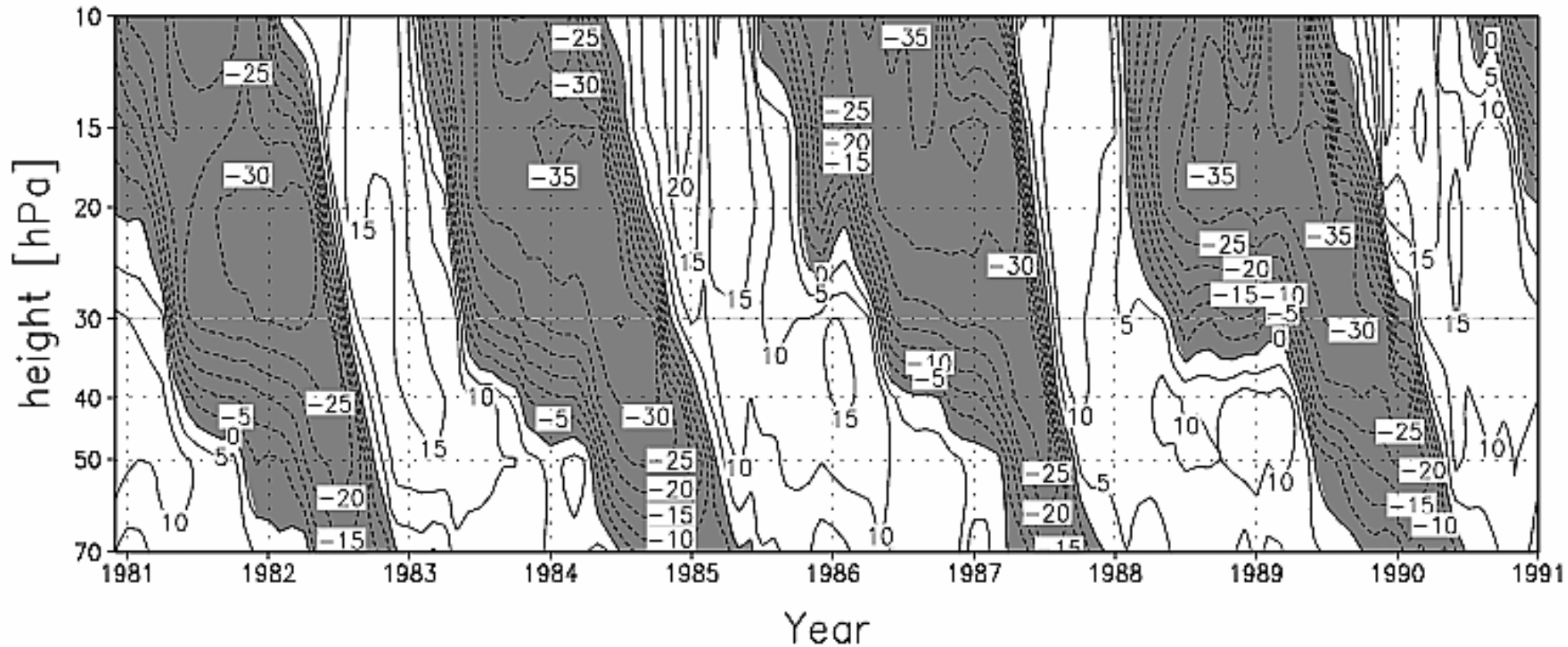
Outline

- QBO
- Ozone – Dynamics feedbacks
- Solar cycle - QBO

The QBO

- The Quasi-biennial Oscillation (QBO) is an oscillation of tropical stratospheric winds characterized by
 - alternating easterly and westerly wind regimes with an average period ~ 27 months

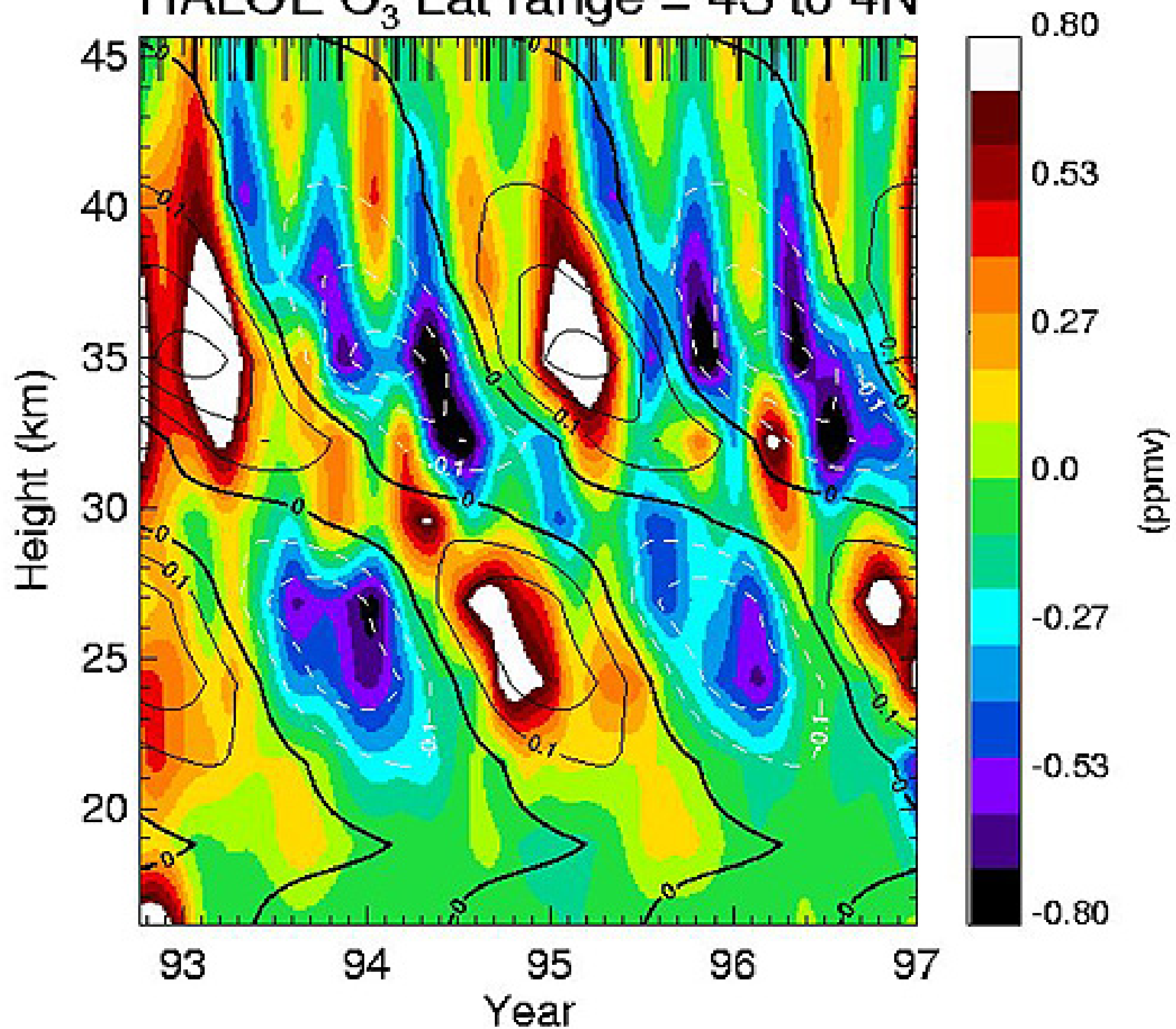
Tropical Zonal Wind



Dynamics of the QBO

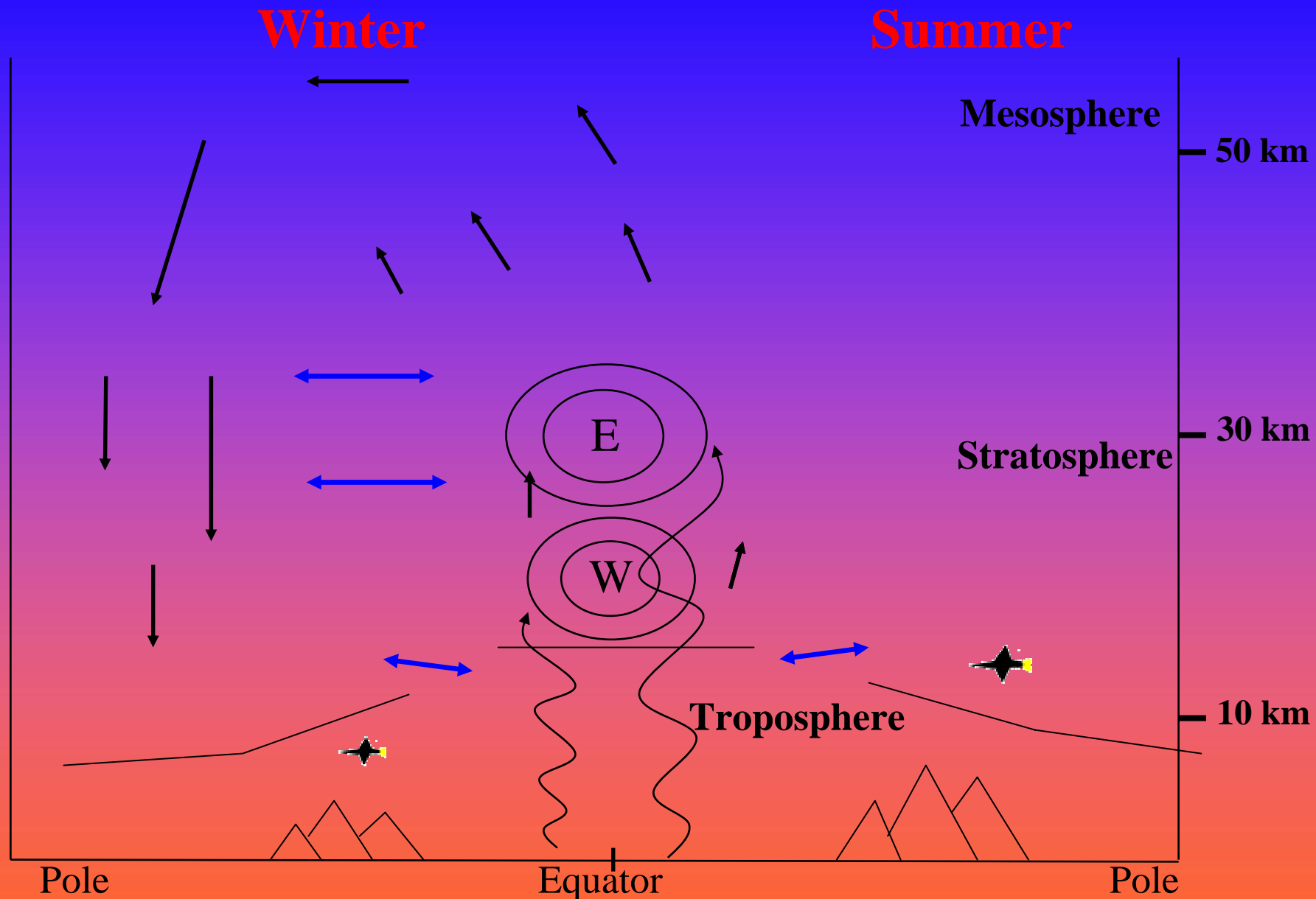
- The Quasi-biennial Oscillation (QBO) is an oscillation of tropical stratospheric winds characterized by
 - alternating easterly and westerly wind regimes with an average period ~ 27 months
- Wind QBO produces variations in tropical residual circulation
 - Ozone QBO

HALOE O₃ Lat range = 4S to 4N



Dynamics of the QBO

- The Quasi-biennial Oscillation (QBO) is an oscillation of tropical stratospheric winds characterized by
 - alternating easterly and westerly wind regimes with an average period ~ 27 months
- Wind QBO produces variations in tropical residual circulation
 - Ozone QBO
- QBO driven by vertically propagating equatorial waves
 - Kelvin wave, Rossby-gravity wave and other gravity waves.



Isentropic mixing
↔

Transport Circ. →

Simple QBO model

$$\frac{\partial \langle \bar{u} \rangle}{\partial t} = -\frac{1}{\rho} \frac{\partial \langle F_z \rangle}{\partial z} + K \frac{\partial^2 \bar{u}}{\partial z^2}$$

$$\frac{\partial \langle F_z \rangle}{\partial z} = A(z_0) m_i \exp\left(-2 \int_{z_0}^z m_i dz\right)$$

For the Kelvin wave

$$m_i = -c_1 \left[\alpha_N - \frac{A \bar{\gamma}_z}{N^2} \right]$$

m_i is the complex component of the vertical wave number

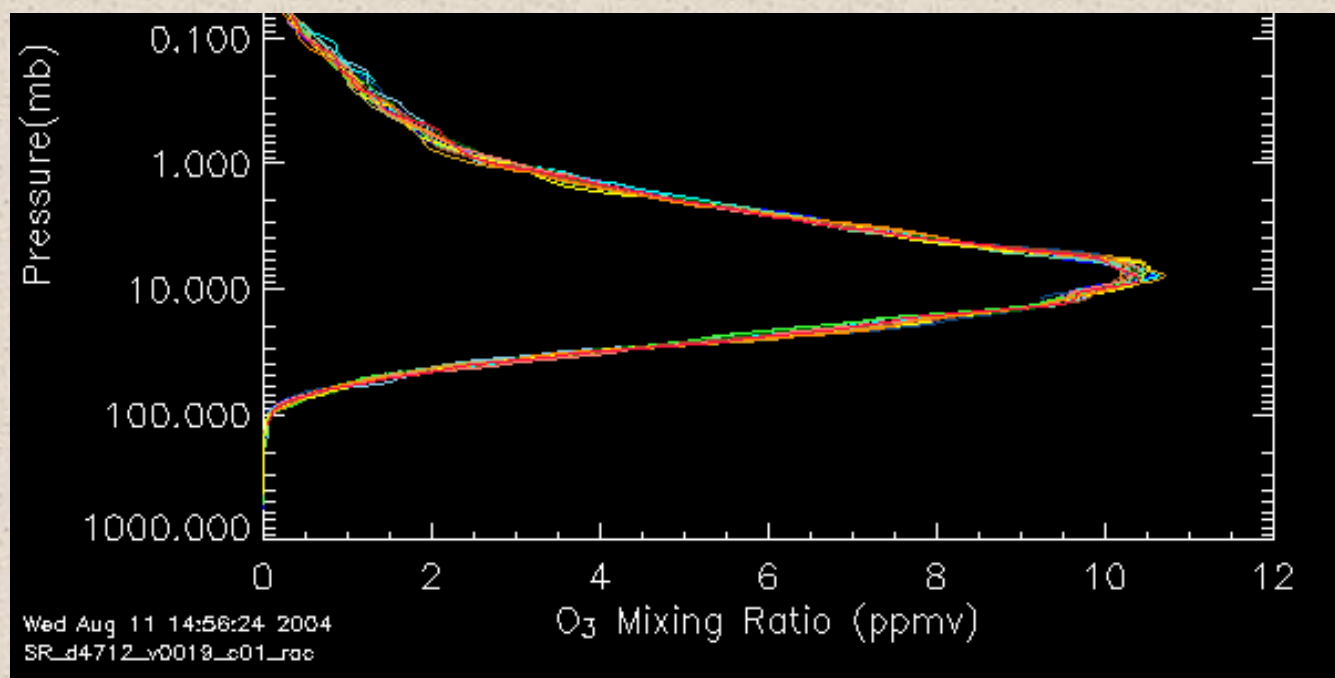
F_z is the vertical component of the Eliassen Palm Flux

$A(z_0)$ is the wave amplitude at the lower boundary

α_N is the Newtonian cooling coefficient

γ_z is the vertical gradient of ozone

Tropical ozone from UARS



In the lower stratosphere

$$\bar{\gamma}_z > 0$$

$$w' > 0 \\ \gamma' < 0 \Rightarrow T' < 0 \text{ Cool}$$



$$w' < 0 \\ \gamma' > 0 \Rightarrow T' > 0 \text{ Warm}$$

Vertical ozone advection is **destabilizing**

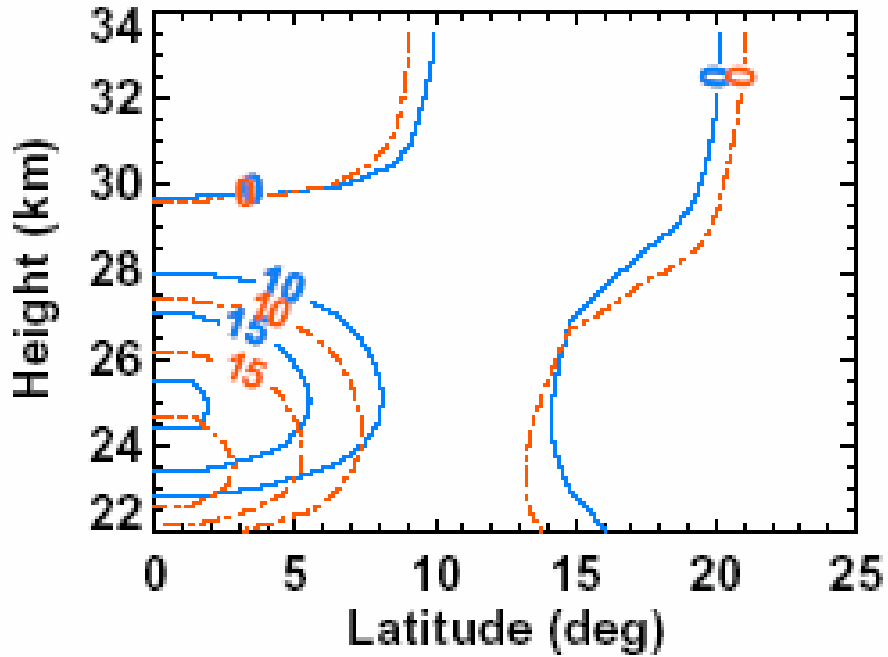
2-D QBO Model

- Constrained to tropical latitudes (equatorial β -plane).
- Driven by prescribed wave amplitudes at lower boundary (100hPa).
- Zonal mean and wave equations for wind, temperature and ozone mixing ratio.

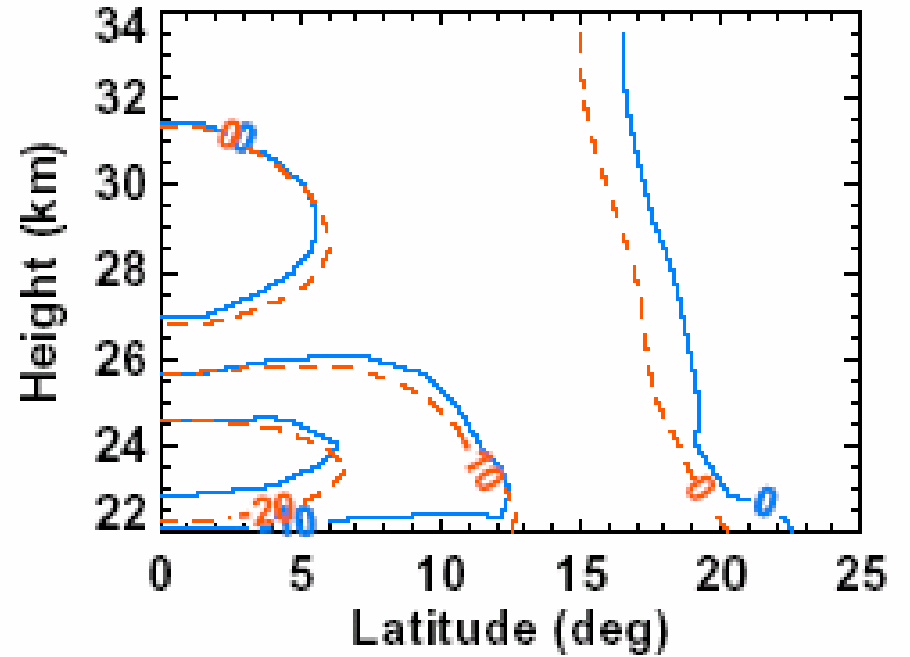
2D Model Experiments

- **Include ozone feedbacks**

Descending Easterlies



Descending Westerlies

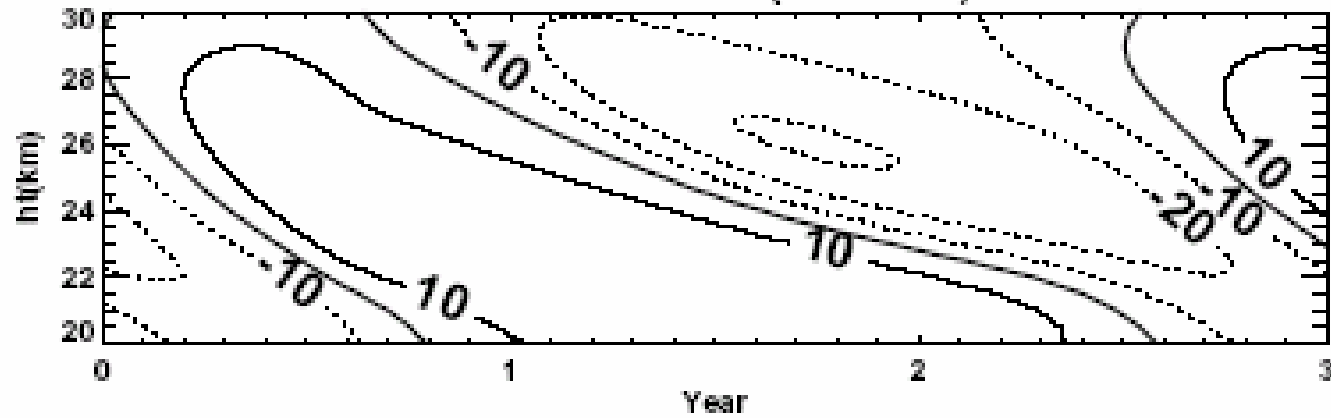


- Reference
- - - With ozone feedbacks

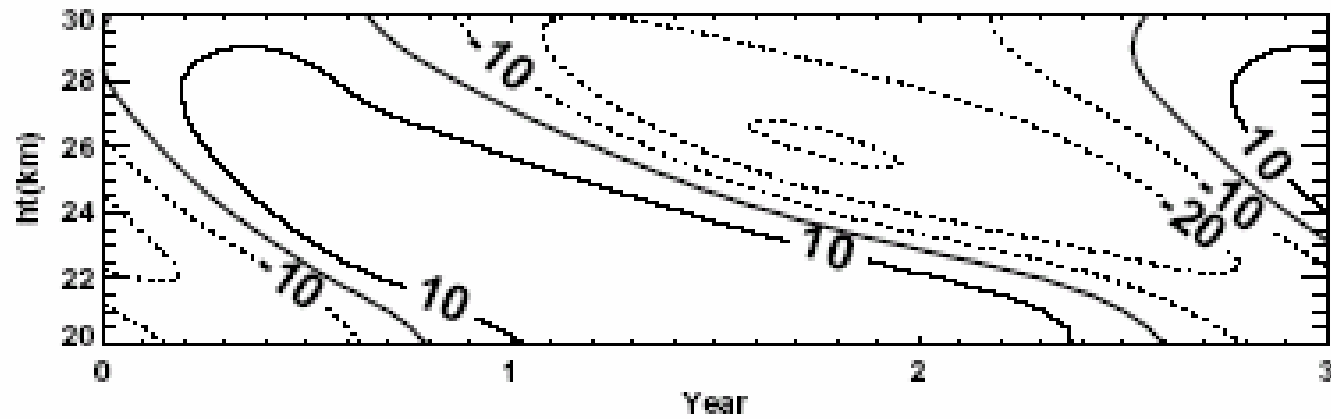
2D Model Experiments

- Include ozone feedbacks
- **Include ozone perturbations representative of the solar cycle**
 - A. Perpetual solar max conditions - ozone**

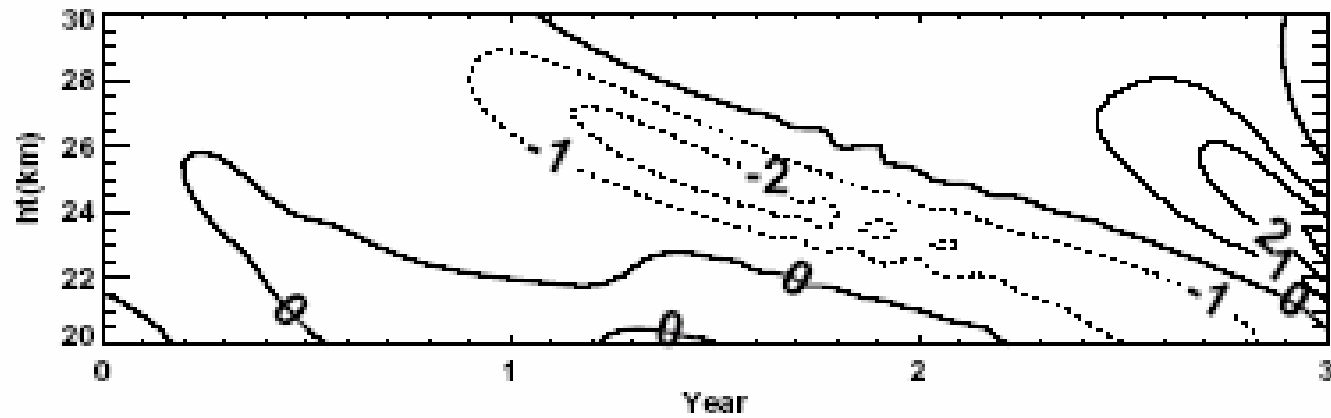
Ozone Perturbed (Solar Max)

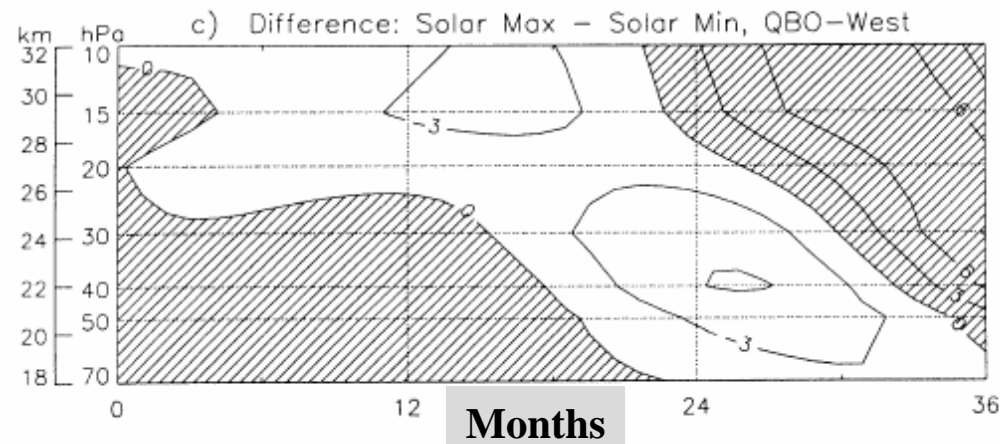
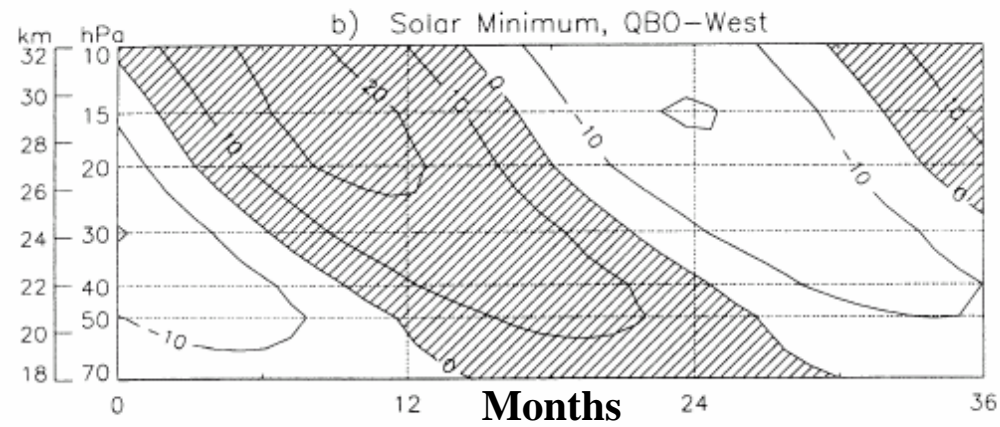
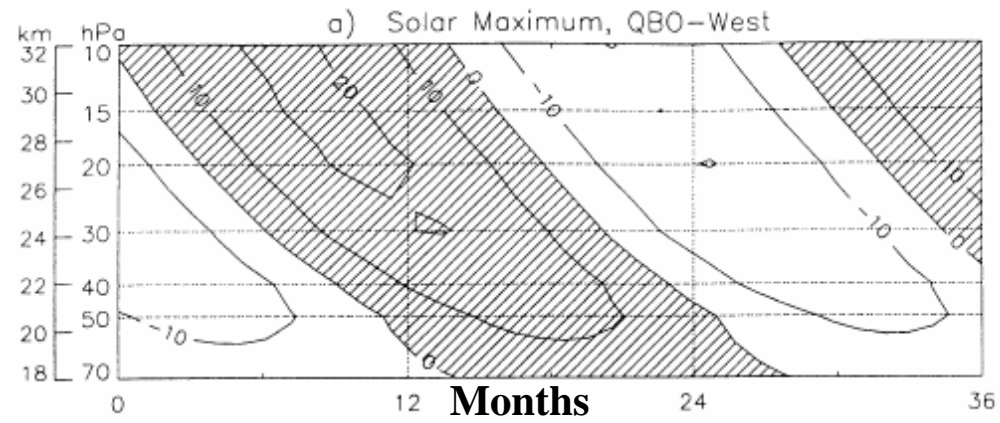


Reference



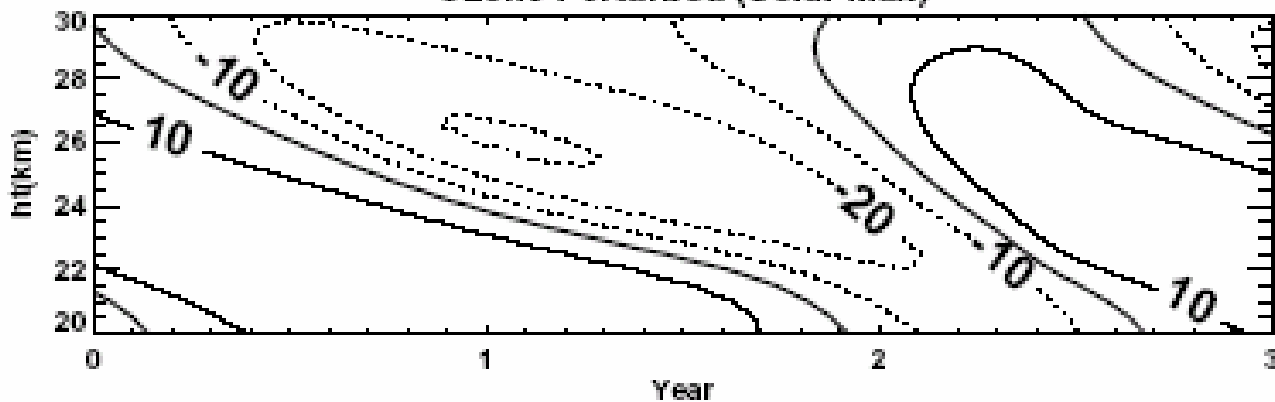
Difference



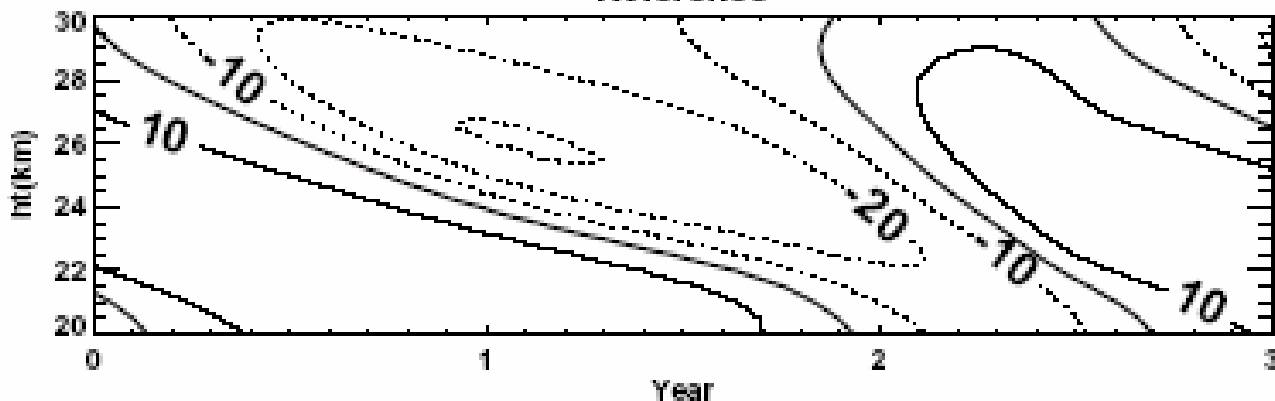


*Soukharev and
Hood, 2001 JGR*

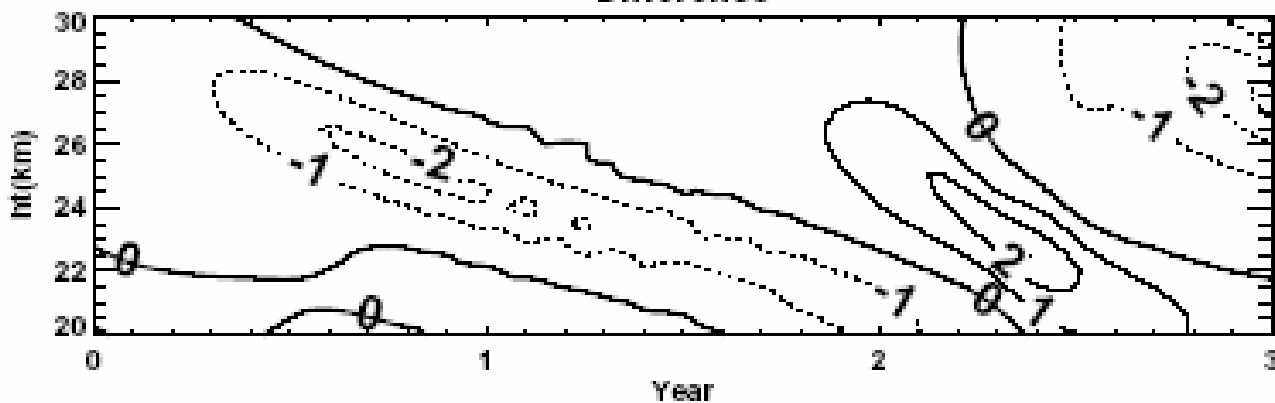
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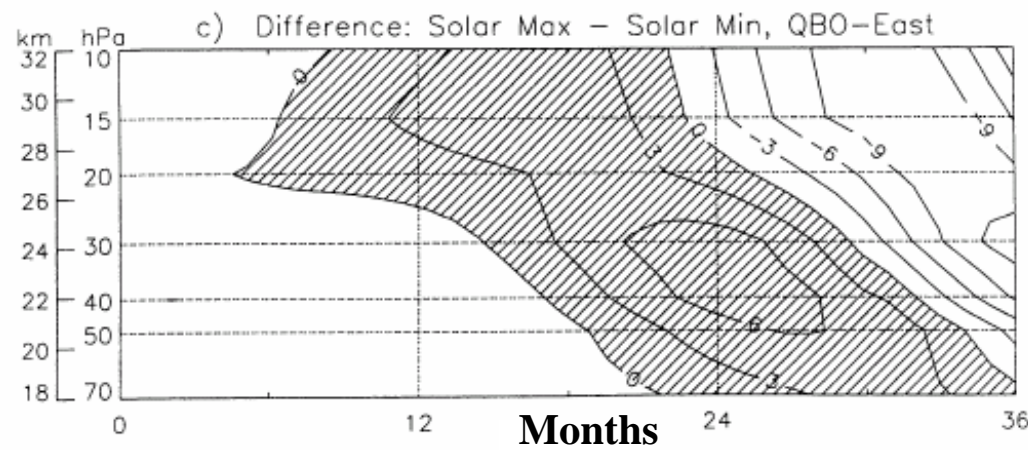
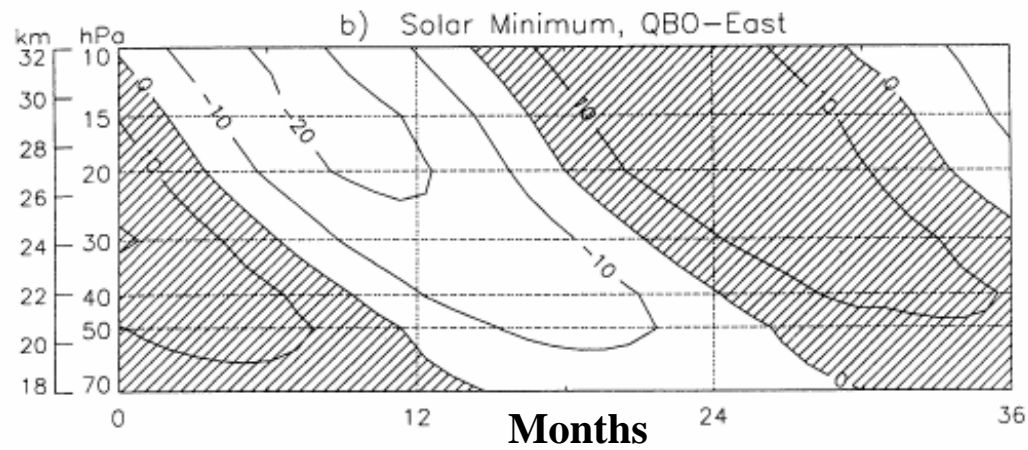
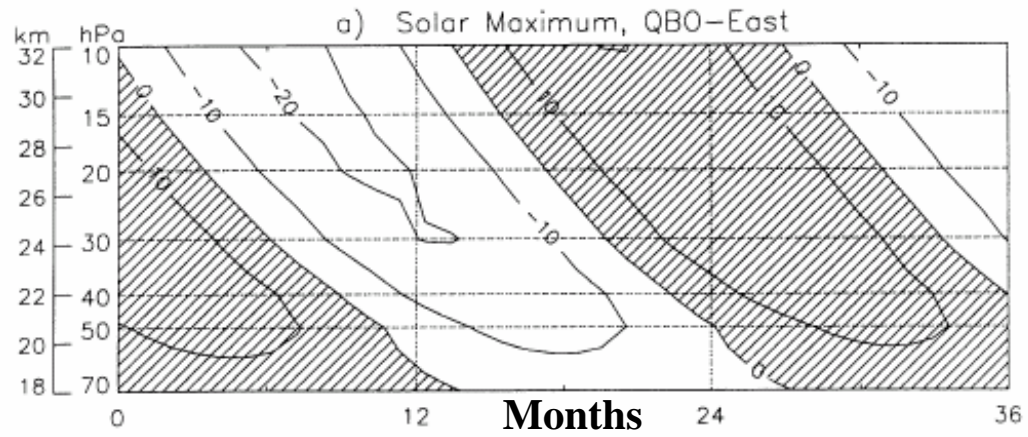


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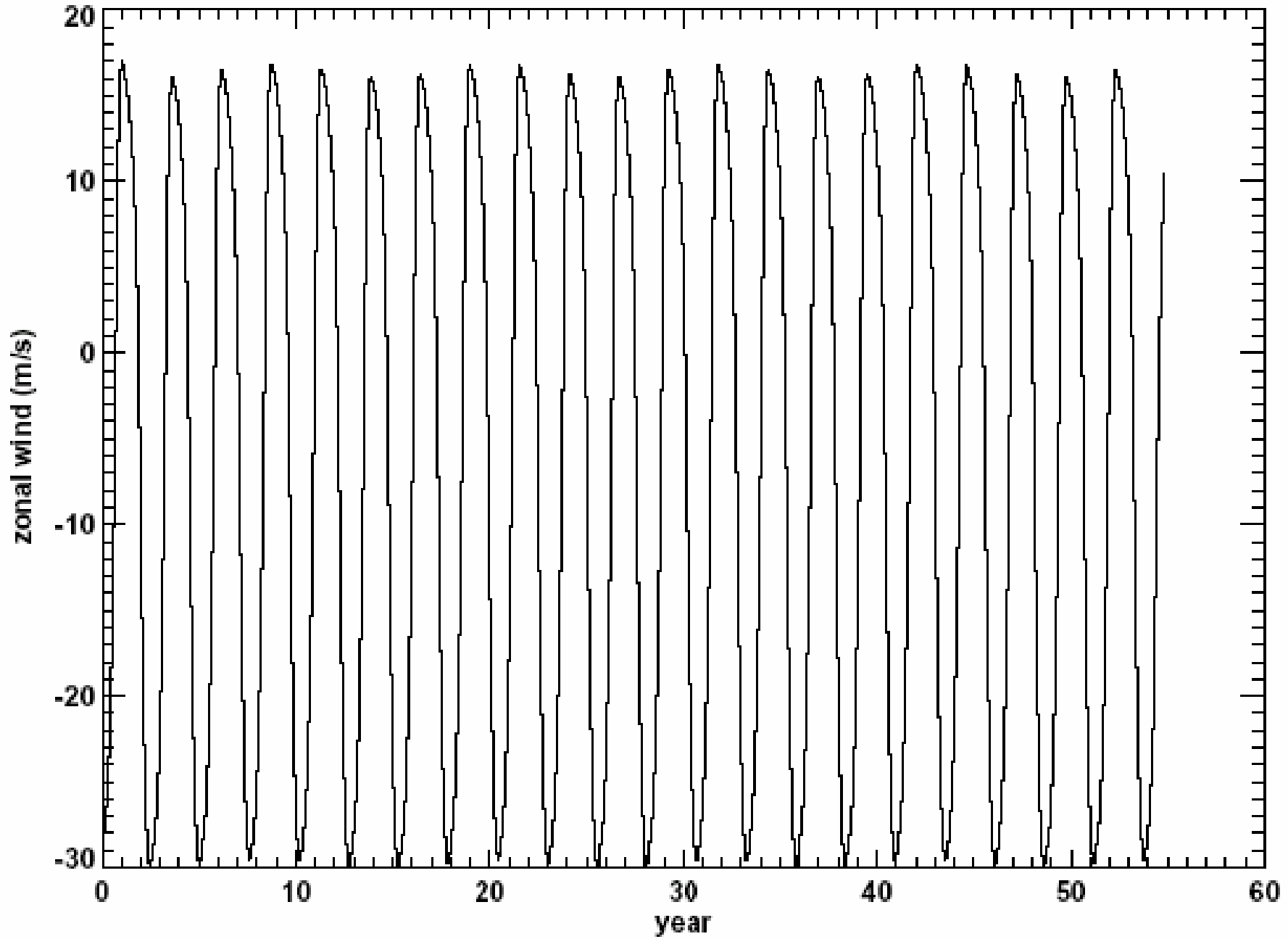


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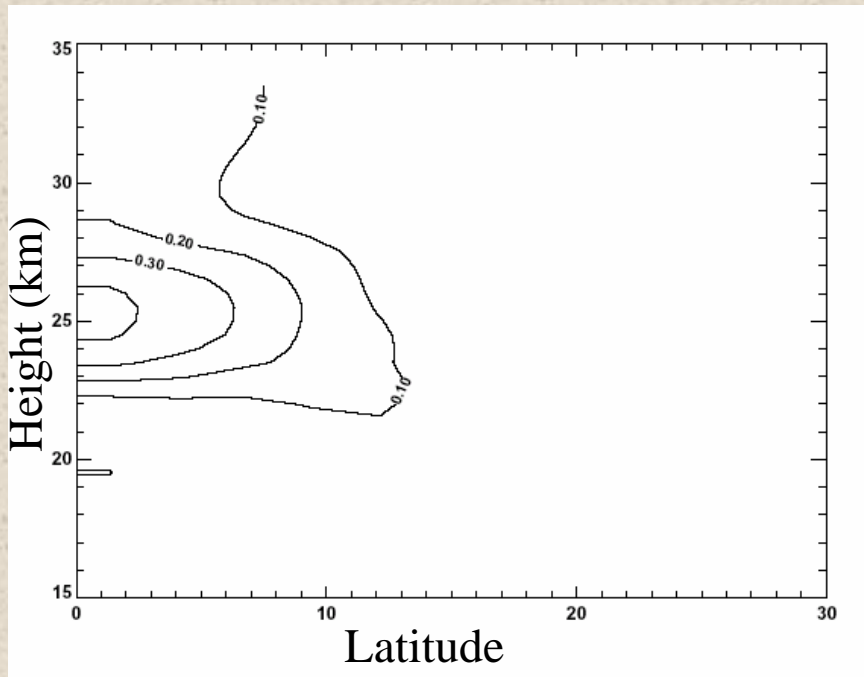
2D Model Experiments

- Include ozone feedbacks
- **Include ozone perturbations representative of the solar cycle**
 - A. Perpetual solar max conditions – ozone
 - B. Solar cycle in ozone**

Equatorial Wind at 25 km



FFT reconstruction for 11 year bin



Quasi-decadal variations alter zonal wind by 3-5% in the tropical stratosphere.

Conclusions

- Solar cycle-like perturbations to the ozone field affect the QBO in a way that resembles observations.
- Wave induced ozone perturbations are responsible for a majority of these changes.
- **Future Work**
 - Current model only includes lower stratosphere; upper stratospheric response also important.
 - Future model simulations will include annual cycle and expanded to a global model.