
Solar and QBO Influence on the North Annular Mode

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in collaboration with

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The Key Elements

- ◆ Major Mode of Atmospheric Variability (NAM)
- ◆ Tropical Winds (QBO)
- ◆ Solar Variability (strongest in UV)
- ◆ Nonlinear Dynamics of Wind & Waves (mechanism)

Annular Modes

NAM and SAM

Ring-like patterns of wintertime climate anomalies with two states:

NAM > 0

high lat: low pressure, strong wind

low lat: high pressure, weak wind

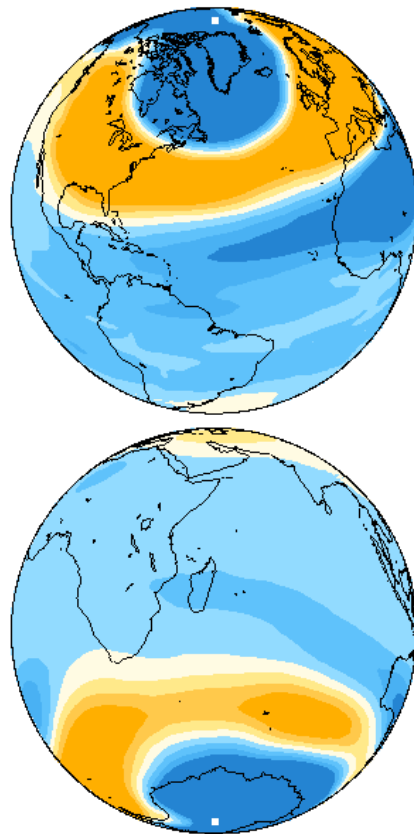
NAM < 0 the other way round

22% of variability at sea level

more in stratosphere

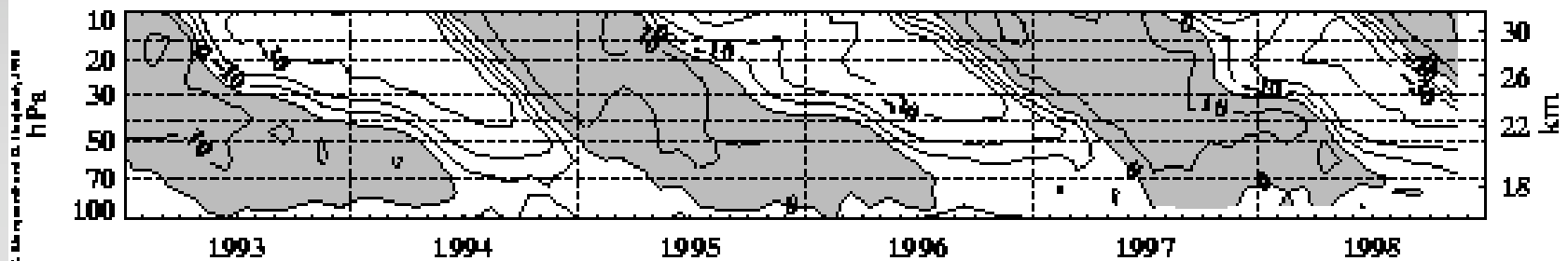
Thompson & Wallace (1998),

Baldwin & Dunkerton (1999)



MSU2LT data regressed on the JFM NAM index (top) and the SAM index (bottom). Contour interval 0.1 K/std.

Quasi-Biennial Oscillation (QBO)



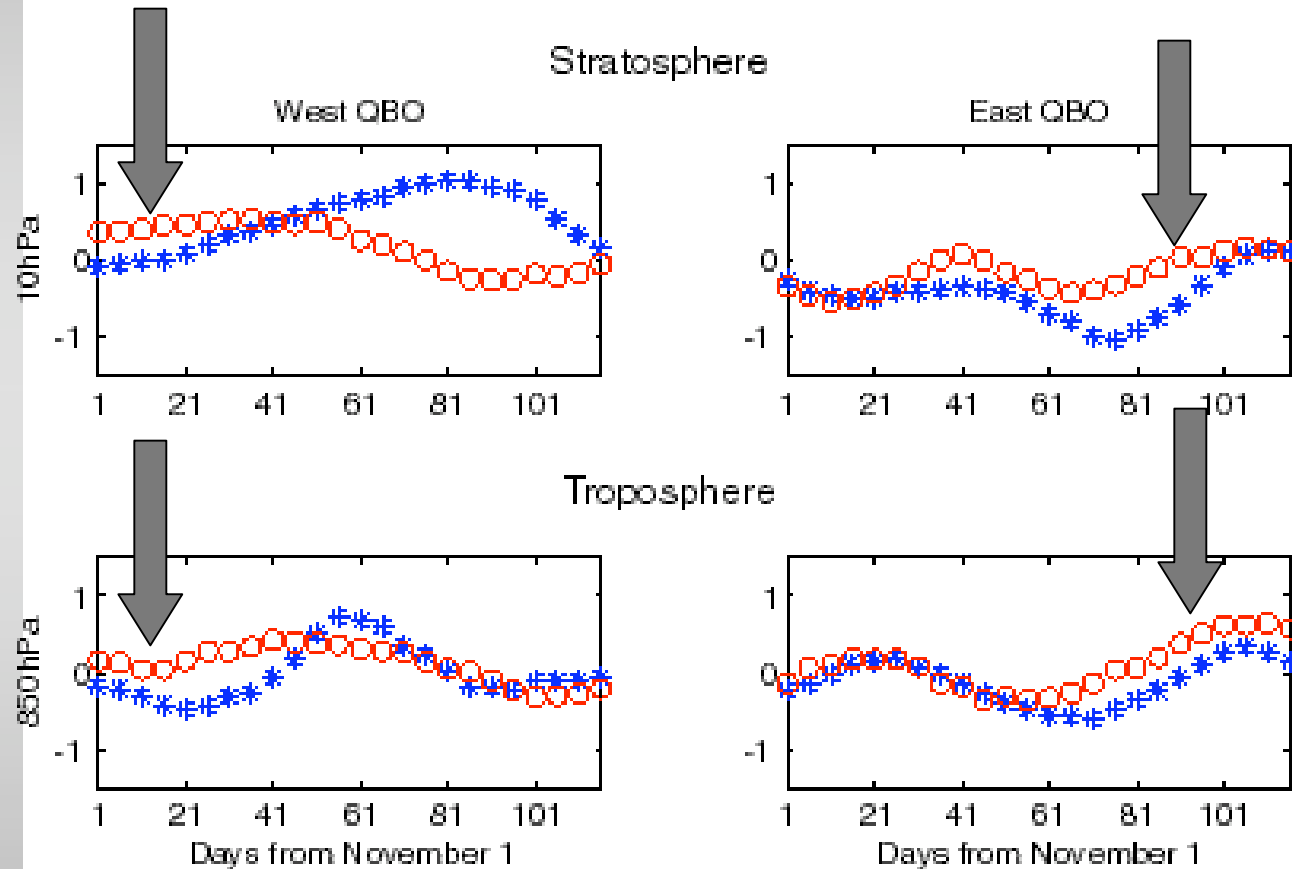
Alternate easterly - westerly tropical wind regimes (mean period 28mo)

Amplitude 40 - 50 m/s.

Appear above 30 km (~10 hPa) and propagate down 1 km/month.

Influences polar regions in the East phase (Holton-Tan effect)

Solar Influence on the North Annular Mode



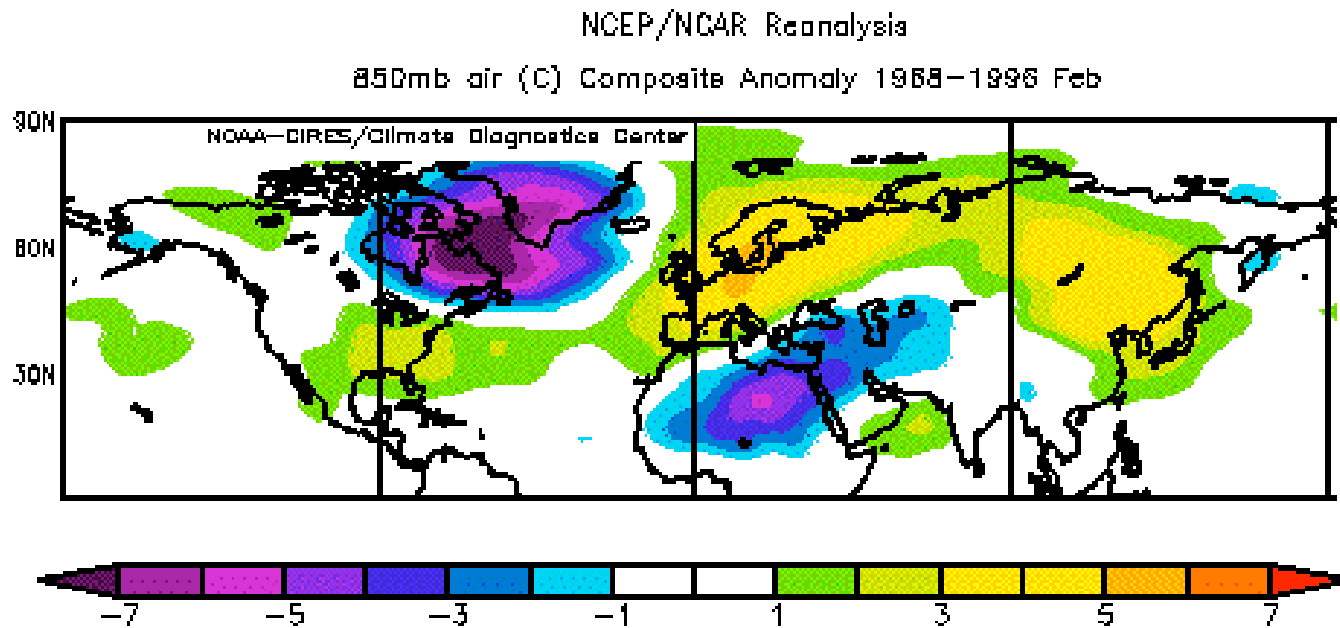
High UV flux - circles, Low UV flux - asterisks

In early (late) winter for West (East) QBO UV effect on NAM is not damped 10-850hPa

NAM index is persistently low in troposphere during Maunder Minimum

Ruzmaikin & Feynman (2002)

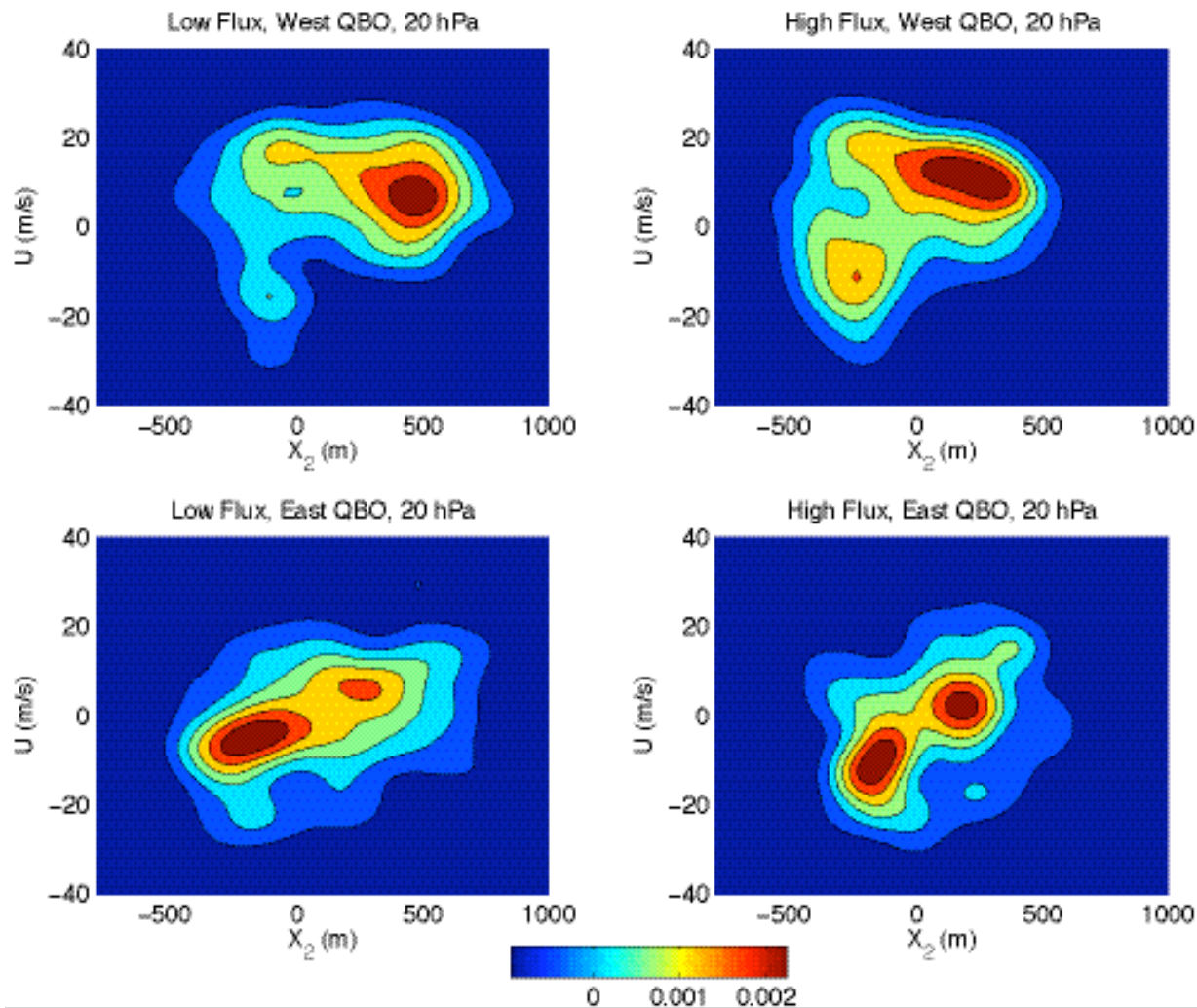
NAM Temperature Anomaly sol max - sol min



Agrees well with irradiance sensitivity at periods of low solar output

Ruzmaikin et al. (2004)

Observed Basins of Attractors

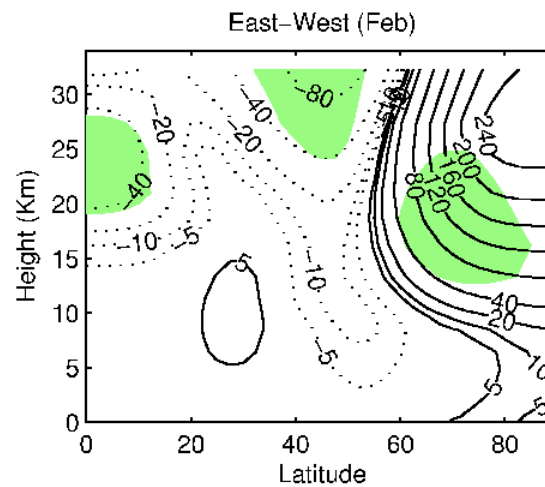
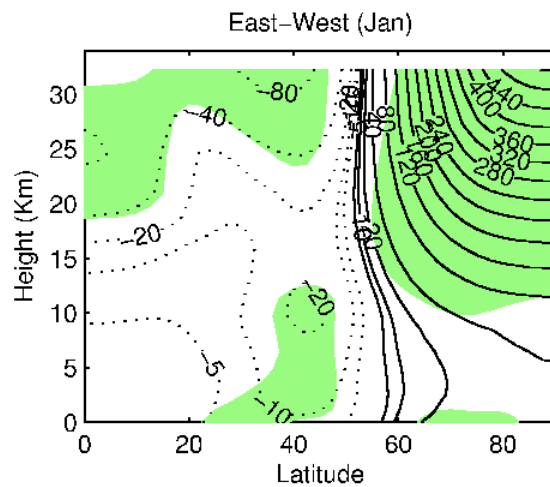
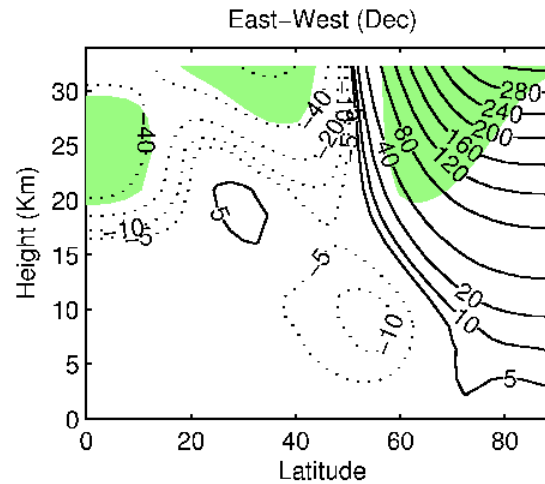
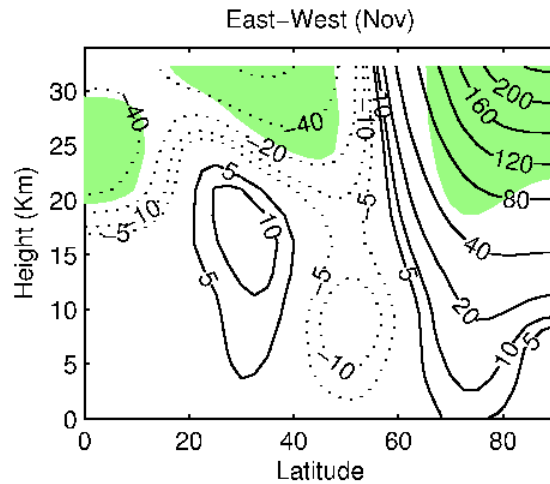


PDF(U, X_2)

NCEP data
1948-2003
60° lat, 20 hPa

Ruzmaikin, Cadavid &
Lawrence (2004)

Imprint of the QBO in Extratropics



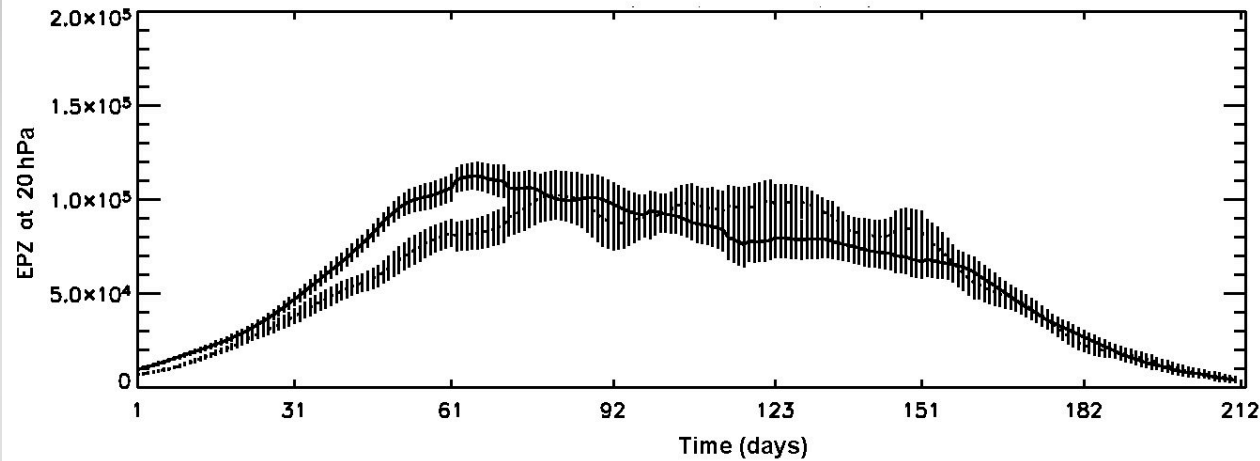
Geopotential height anomalies Nov-Feb

NCEP1 1958-78
NCEP2 1979-02

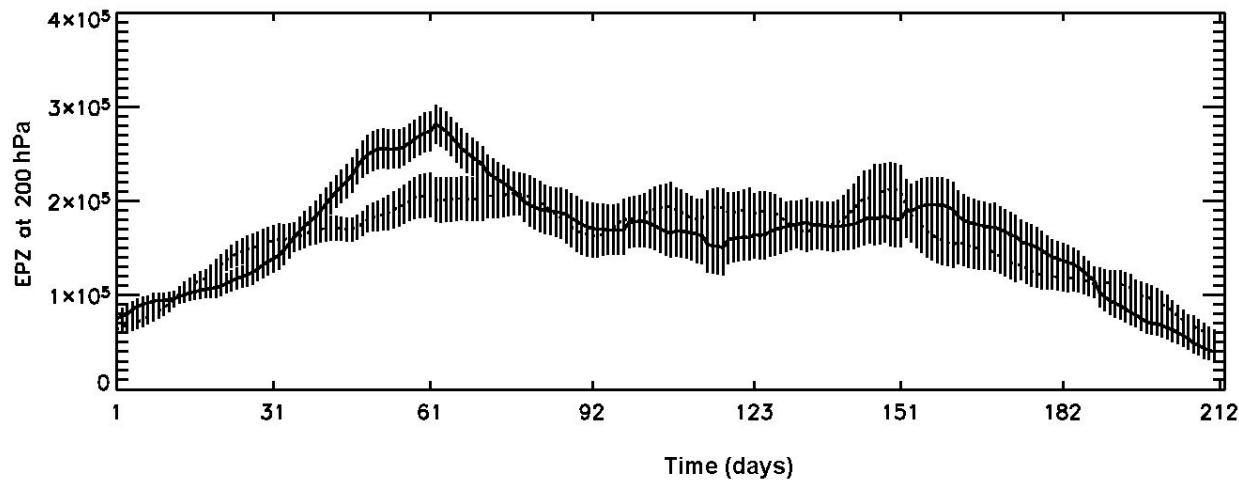
QBO at 40 hPa

QBO Modulation of the EP flux

(Holton-Tan)

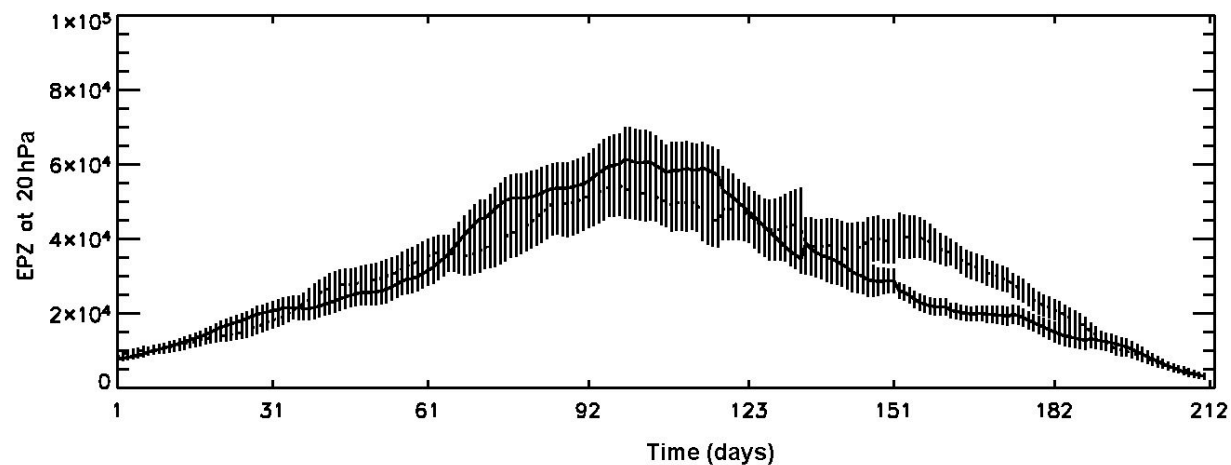


Wave 1
EP flux for East
and West QBO
(Oct-Mar)
at 20 and 200 hPa

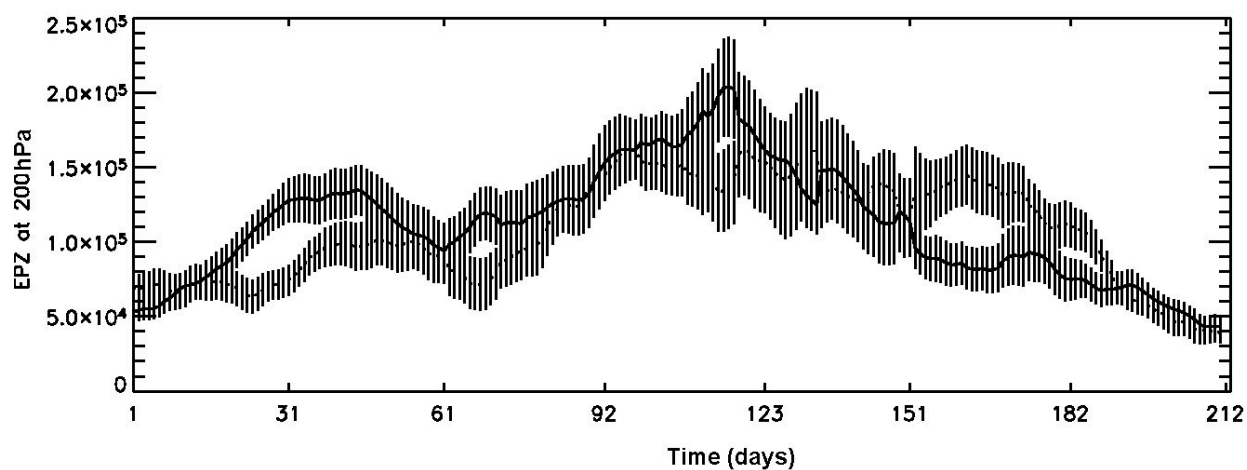


NCEP1 1958-78,
NCEP2 1979-2002

QBO Modulation of the EP flux



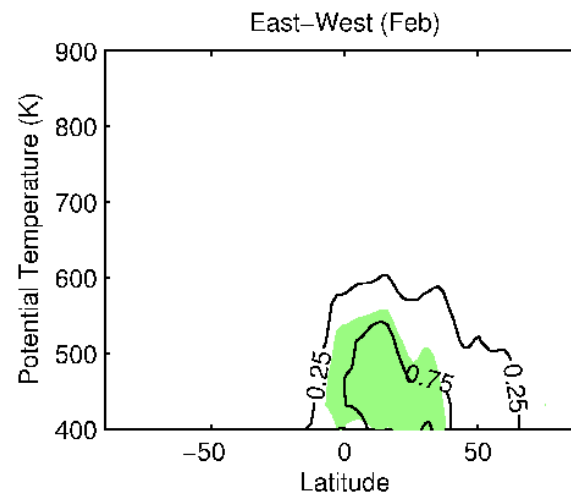
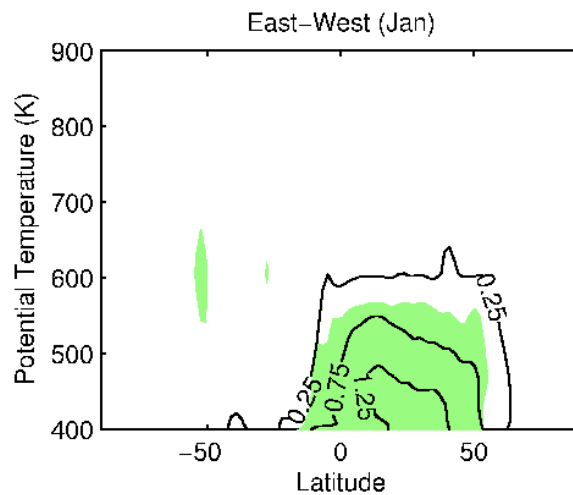
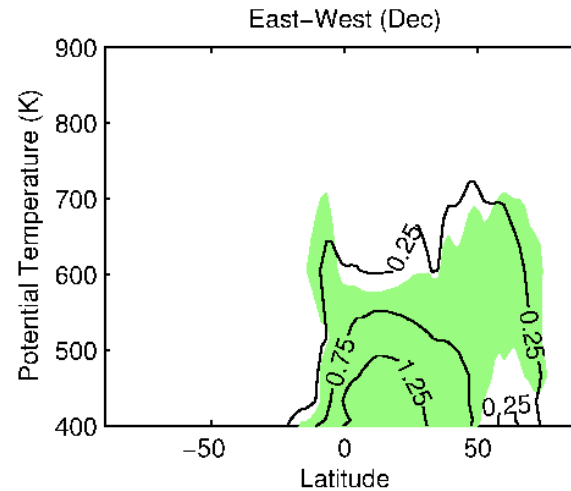
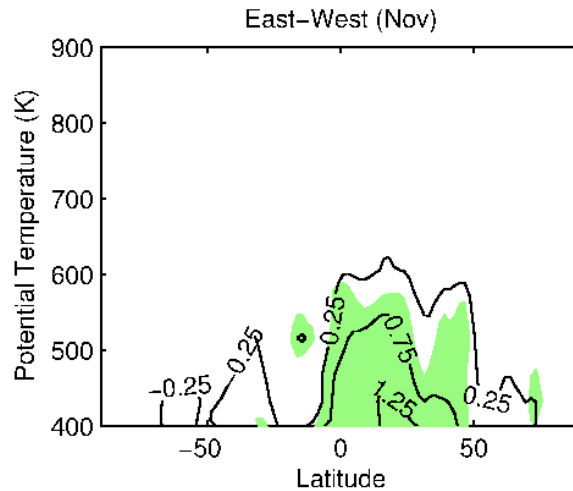
Wave 2
EP flux for East
and West QBO
(Oct-Mar)
at 20 and 200 hPa



NCEP1 1958-78,
NCEP2 1979-2002

QBO Circulation Anomaly

(Kinnersley-Tung)



Stream Function

$$\int_0^{\theta} w^* \cos \theta = \partial_{\theta} \psi,$$

$$\int_0^{\theta} v^* \cos \theta = -\partial_z \psi$$

NCEP1 1958-78

NCEP2 1979-02

QBO at 40 hPa

Polar Temperature as Proxy for the NAM

Polar temperature is strongly anti-correlated with the NAM
(Gillett, Baldwin & Allen, 2001)

$$\partial_t \bar{\theta} + w^* \bar{\theta} = -\bar{\theta} \bar{\theta} + \bar{\theta}_0 Q_0$$

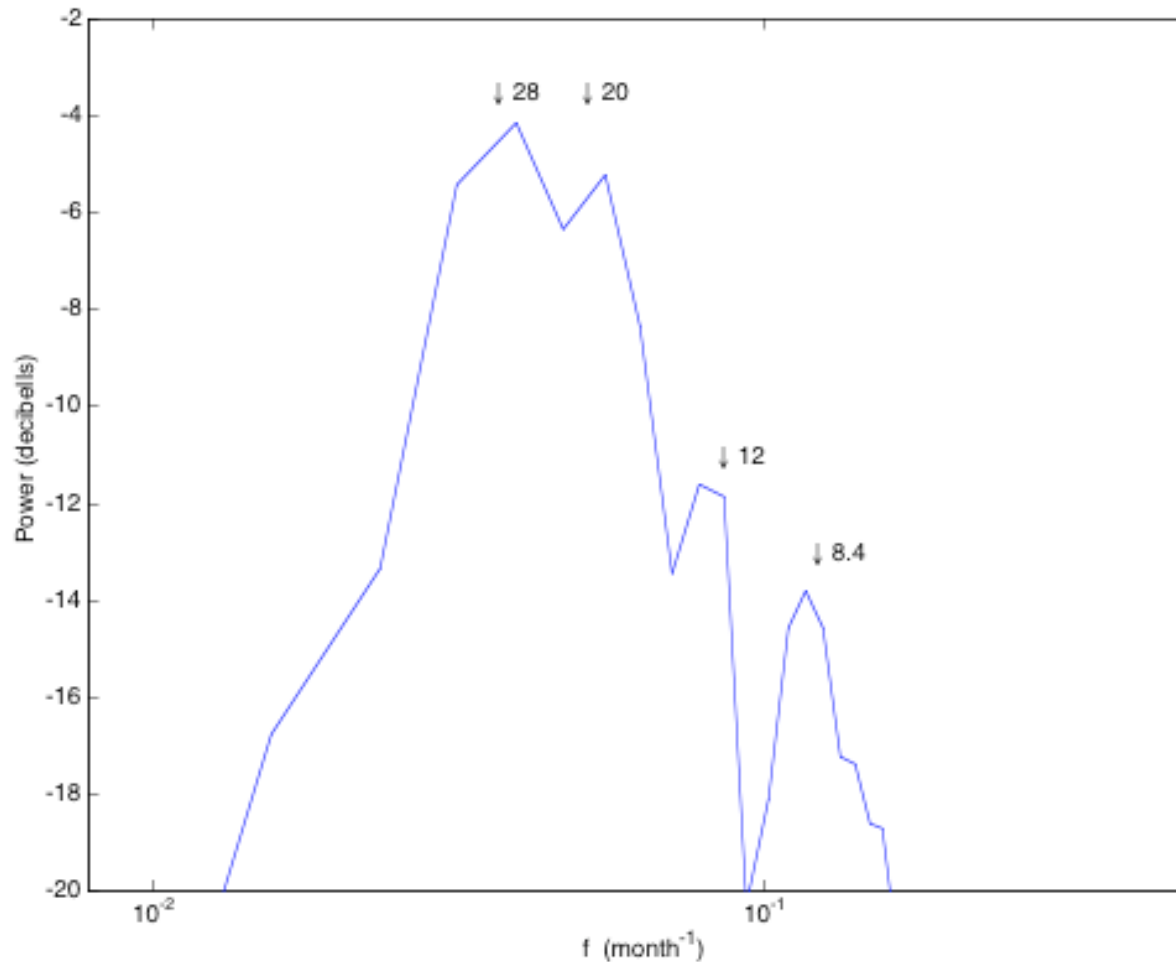
Cap-average $\bar{\theta}$ (θ to $\theta/2$)

$$\partial_t \langle \bar{\theta} \rangle + \bar{\theta} \langle \bar{\theta} \rangle = \bar{\theta}_{0z} \bar{\theta}_0 / a(1 - \cos \theta) + \bar{\theta}_0 Q_0$$

(Newman, Nash & Rosenfeld, 2001)

$$\bar{\theta} = \bar{\theta}_0 (B + \cos \bar{\theta}_a t) [1 + \bar{\theta} \cos(\bar{\theta}_Q t + \bar{\theta})]$$

Spectrum of Polar Temperature (and NAM)



NCEP data 1958-2002
Annual frequency is
mostly filtered out

Conclusions

- ◆ QBO and solar variability affect NH dynamics through the North Annual Mode
 - ◆ Changes occur in occupation frequencies and positions of the two states of the NAM
 - ◆ The mechanism operates through nonlinear wind-wave dynamics
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