Solar and QBO Influence on the North Annular Mode

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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

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

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,X₂)

NCEP data
1948-2003
60º 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

\[ \bar{\rho}_0 w^* \cos \phi = \partial \frac{\partial}{\partial y} \]

\[ \bar{\rho}_0 v^* \cos \phi = - \partial \frac{\partial}{\partial z} \]

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

\( \frac{\partial}{\partial t} q + w^* q = -q + \bar{Q}_0 \)

Cap-average \( \bar{q} \) (\( f \) to \( \pi/2 \))

\( \frac{\partial}{\partial t} \langle \bar{q} \rangle + \bar{q} \langle \bar{q} \rangle = \frac{\bar{Q}_0 z}{a(1 - \cos \bar{q})} + \bar{Q}_0 \)

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

(Gillett, Baldwin & Allen, 2001)

(Newman, Nash & Rosenfeld, 2001)
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