

**Quasi-biennial Synchrony
of the
Extratropical Troposphere
and the
Solar Magnetic Field**

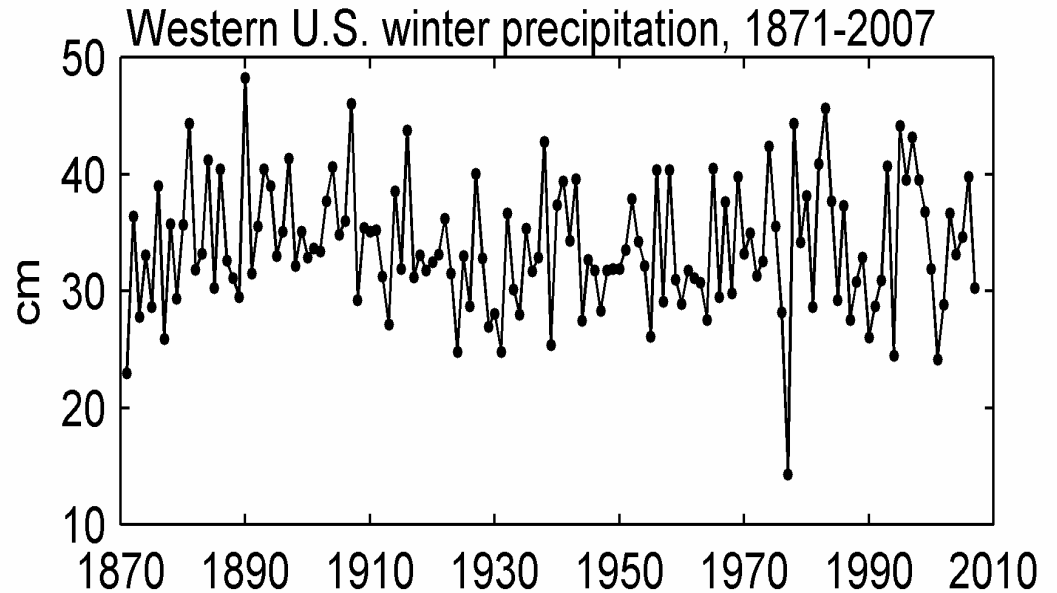
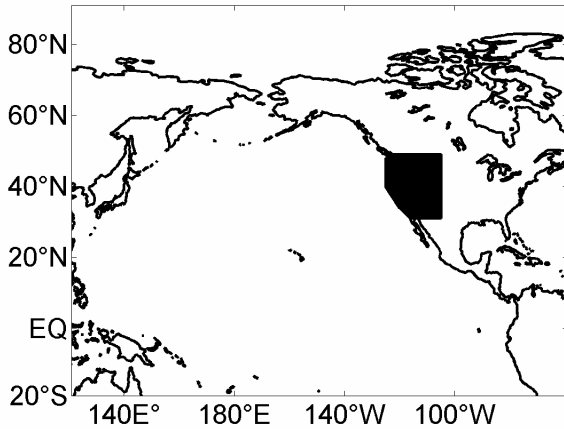
James A. Johnstone

Department of Geography

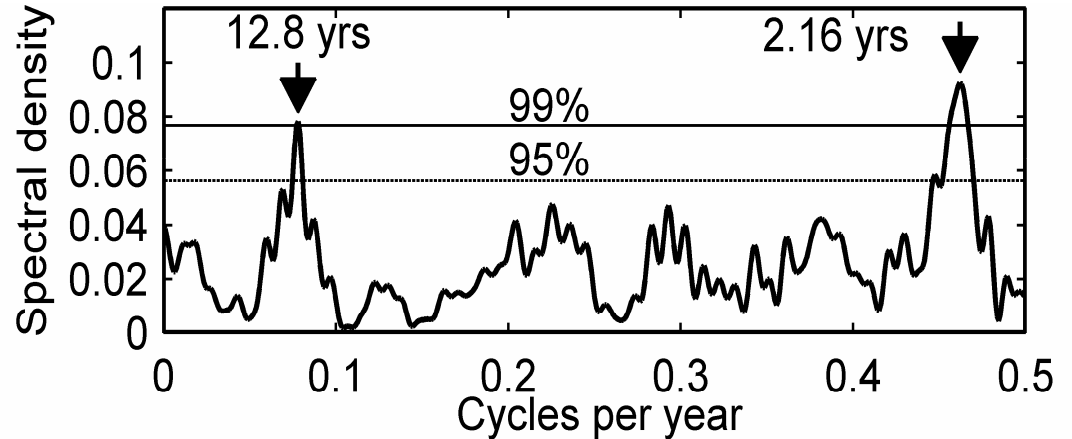
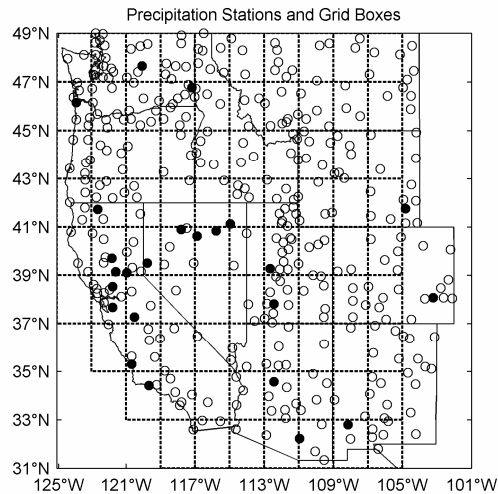
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Western U.S. Winter Precipitation



**Quasi-biennial
oscillation**



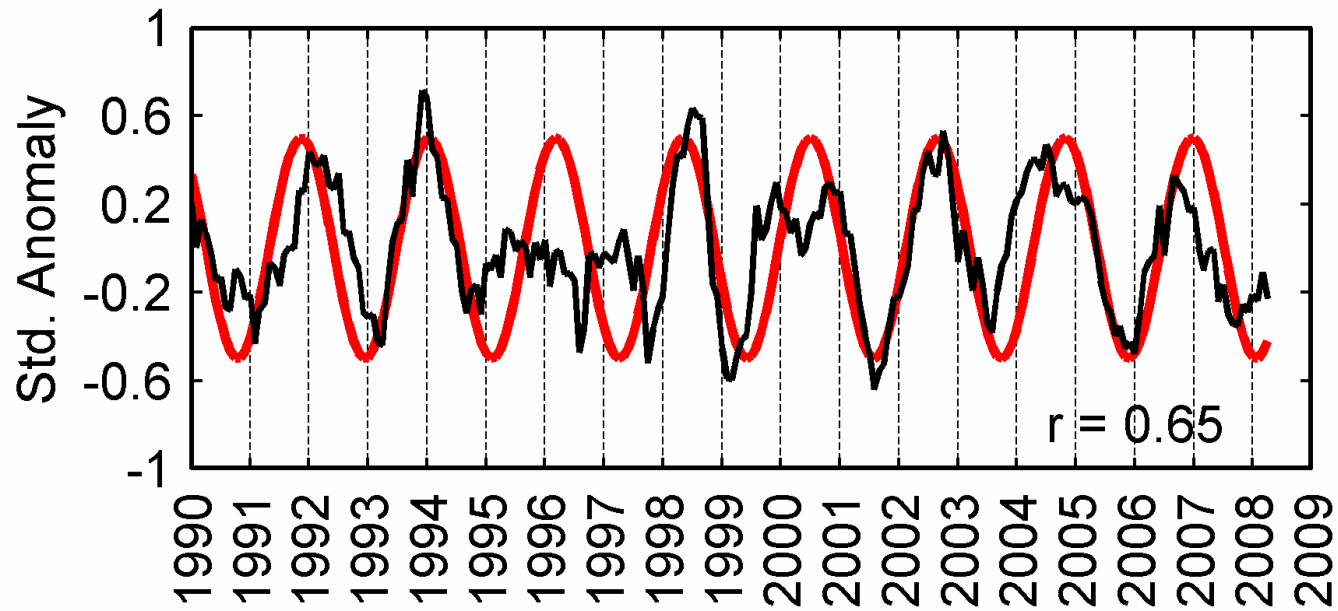
Corroborating evidence from the U.S.:

California	Precipitation	25-26 mo.	Granger 1977
N. America West Coast	Precipitation	25 months	McGuirk 1982
Western US	Precipitation	26 months	Dettinger et al. 1998
Great Salt Lake	Lake level	2.2 years	Mann, et al. 1995
United States	Temp., precip., pressure	2.2 years	Dettinger et al. 1995
United States	Temp., precip..	2.1 years	Walsh and Mostek 1980
NE, SW US	Temperature	25.6 mo	Rasmusson et al. 1981, p.594
United States	Pressure, Temp.	25 months	Clayton 1884

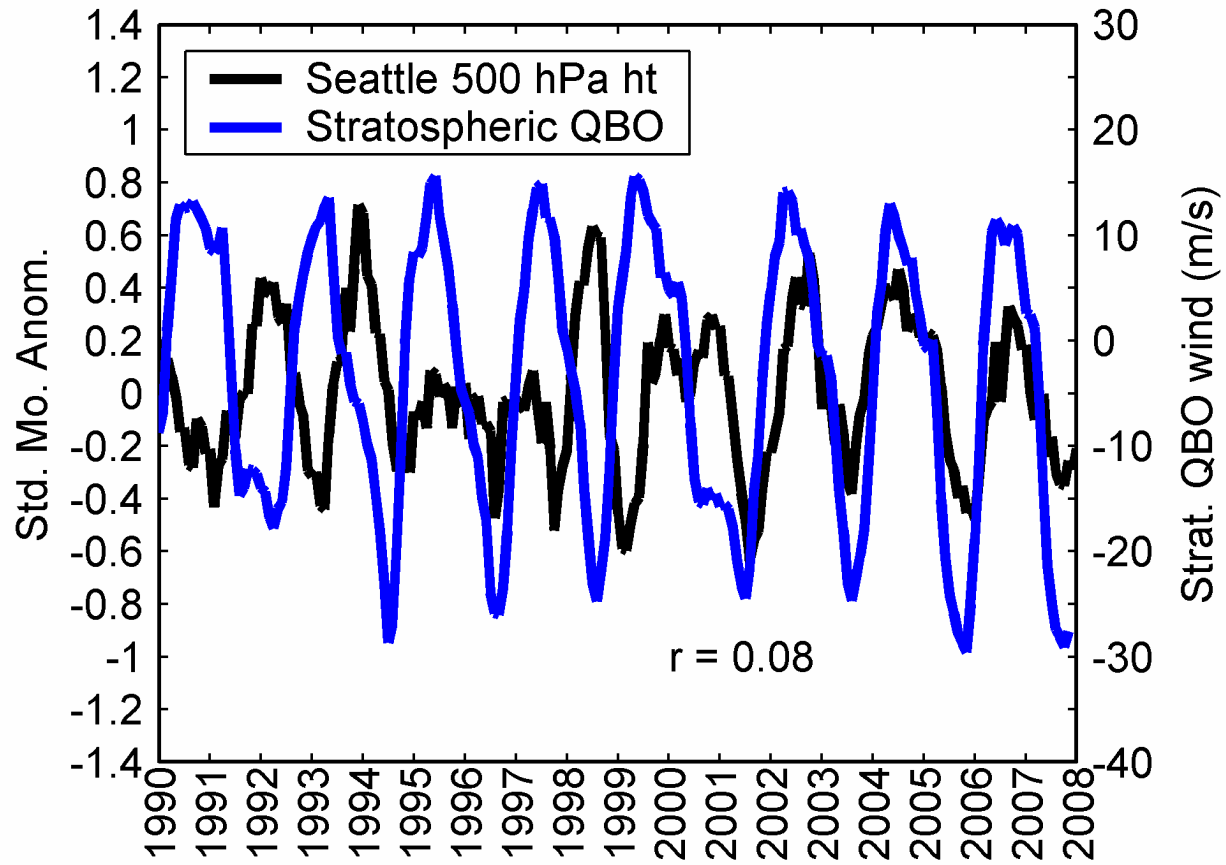
Consistently reported at 25-26 months / 2.1-2.2 years

Red curve: Monthly 25.9-month (2.16-yr) sinusoid

Seattle 500 hPa geopotential height, PSIN 1990-2007



Uncorrelated with the stratospheric QBO (shorter QB period)



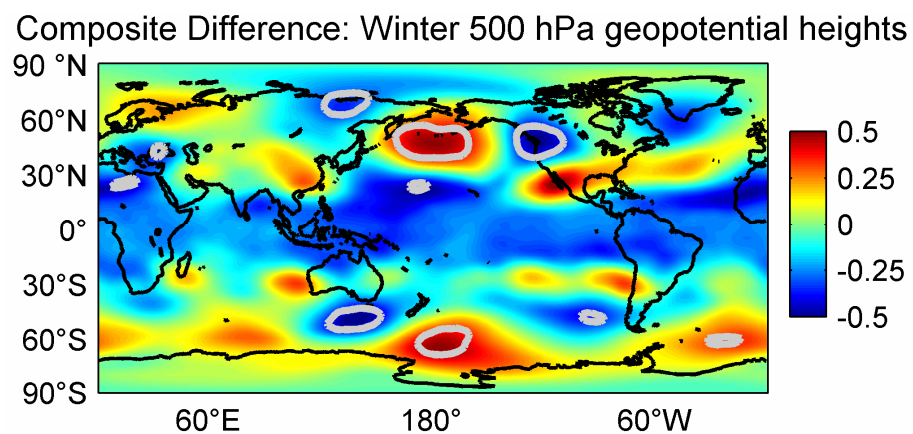
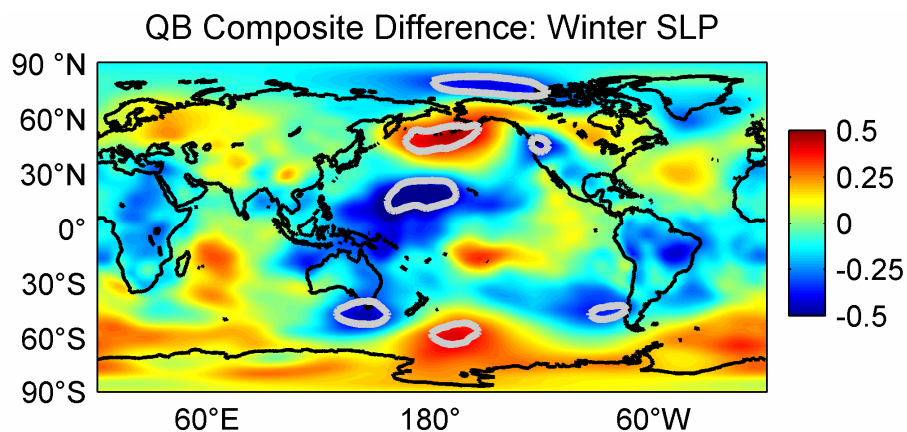
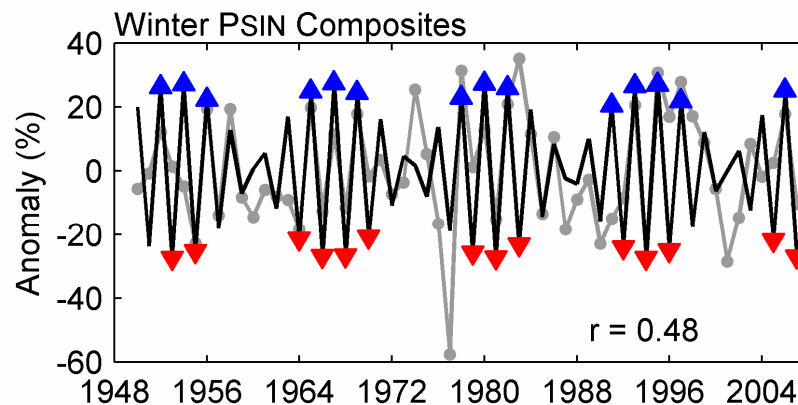
**Upper, lower QB
quartiles**

1950-2007

**Wet-minus-dry
quartile differences**

**Sea-level
pressure**

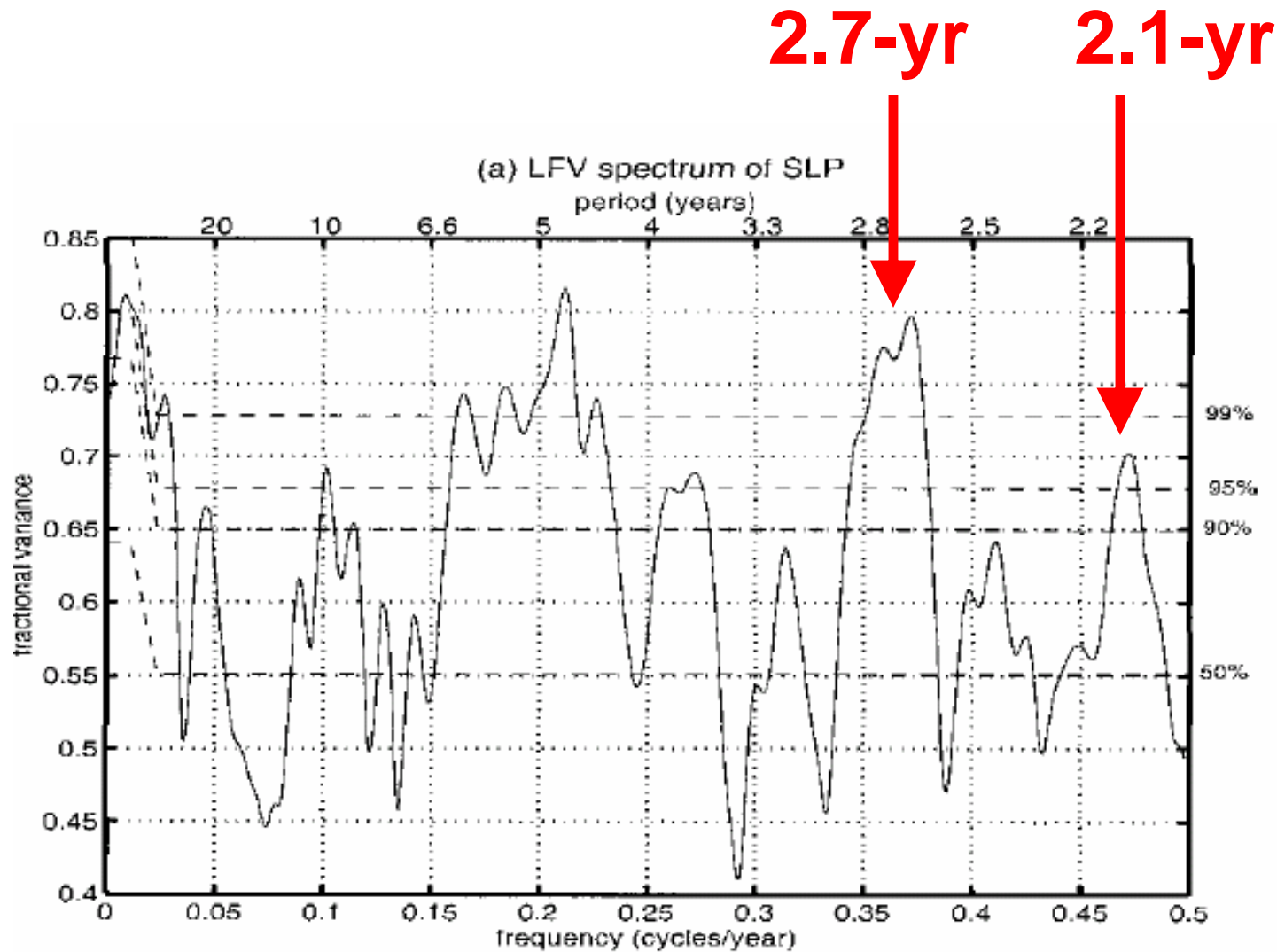
**500 hPa
geopotential
height**



Gray contours: 95% significance

Arctic Pressure Oscillations

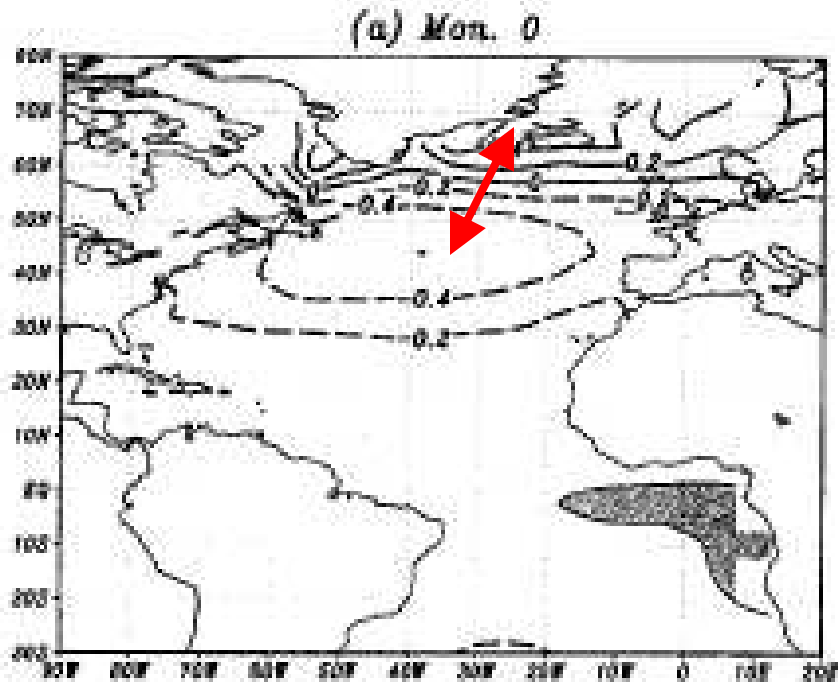
Venegas & Mysak JCLim 2000



North Atlantic Pressure Oscillations

Tourette et al. JCLim1999

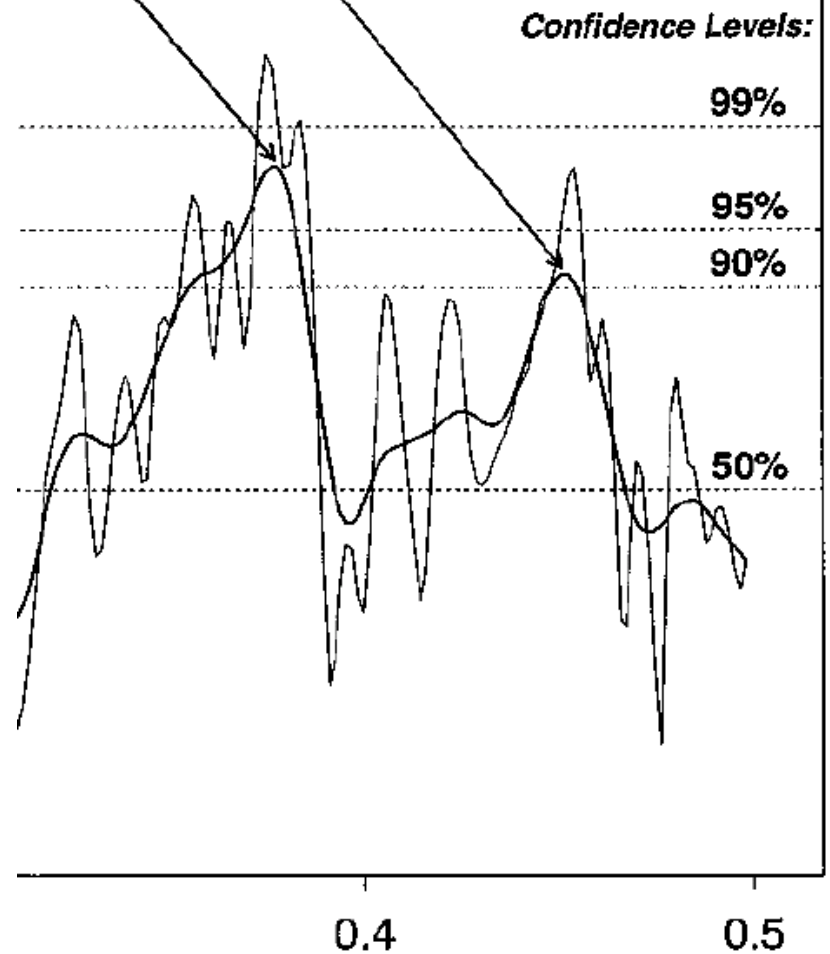
Meridional Dipole



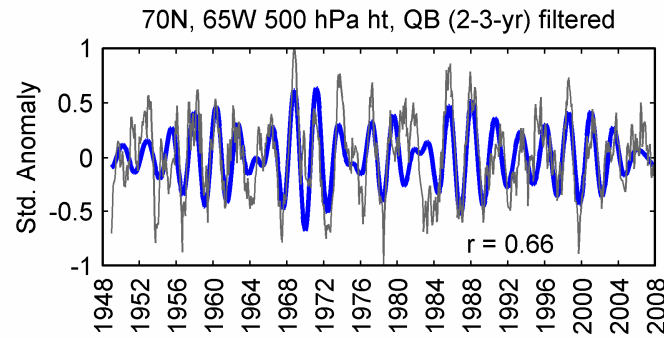
2.7-yr **2.2-yr**

2.7-year period

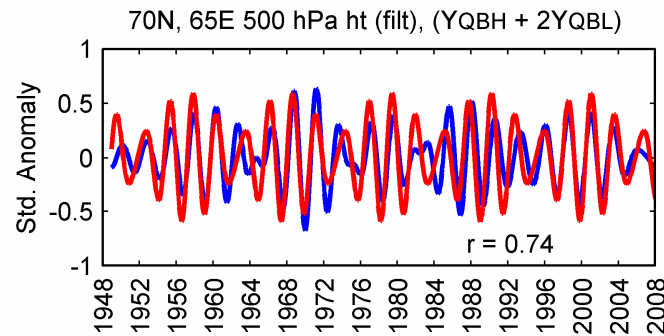
2.2-year period



Arctic 500 hPa
geopotential height
(70N, 65W)

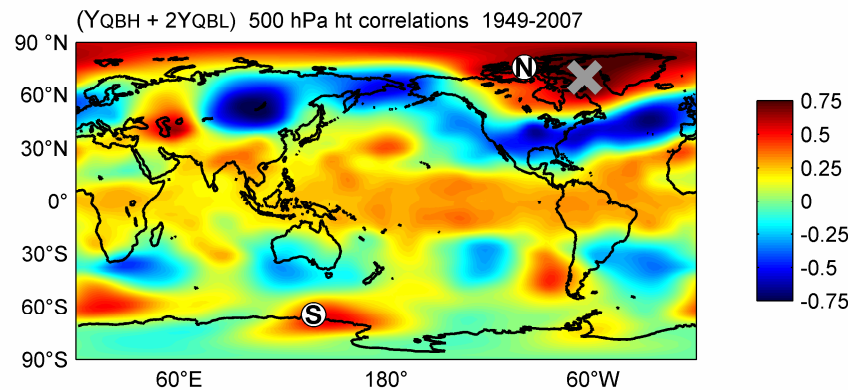


Red: Sum of 2.16-
and 2.7-yr sinusoids
Produces a 10.8-yr
beat frequency



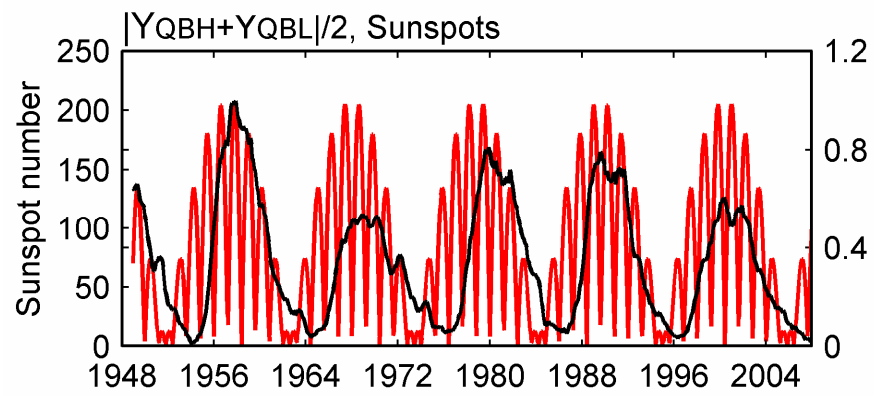
$$2.16^{-1} - 2.7^{-1} = 10.8^{-1}$$

Correlations with
500 hPa heights



coherent
QB signal
over both
magnetic
poles

QB amplitude increases during solar max



Questions:

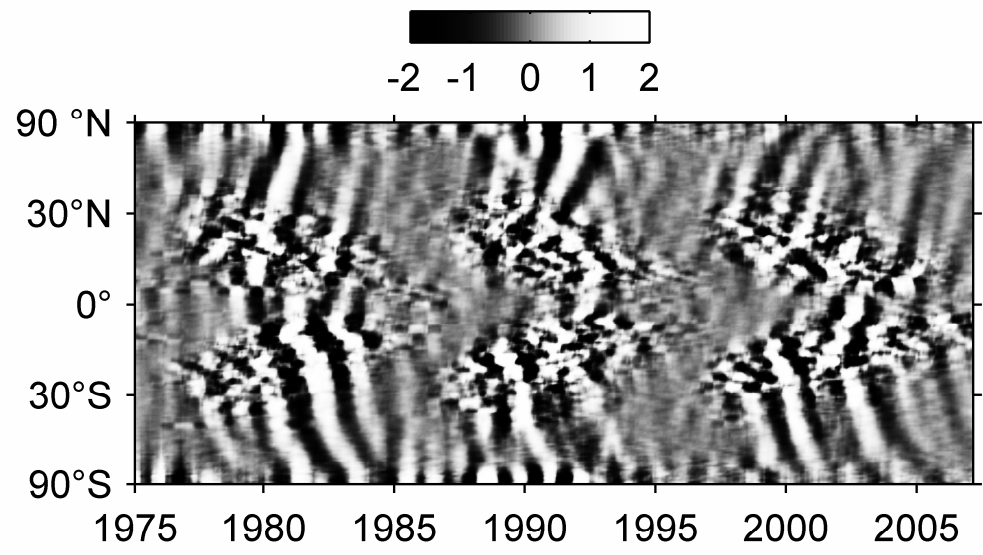
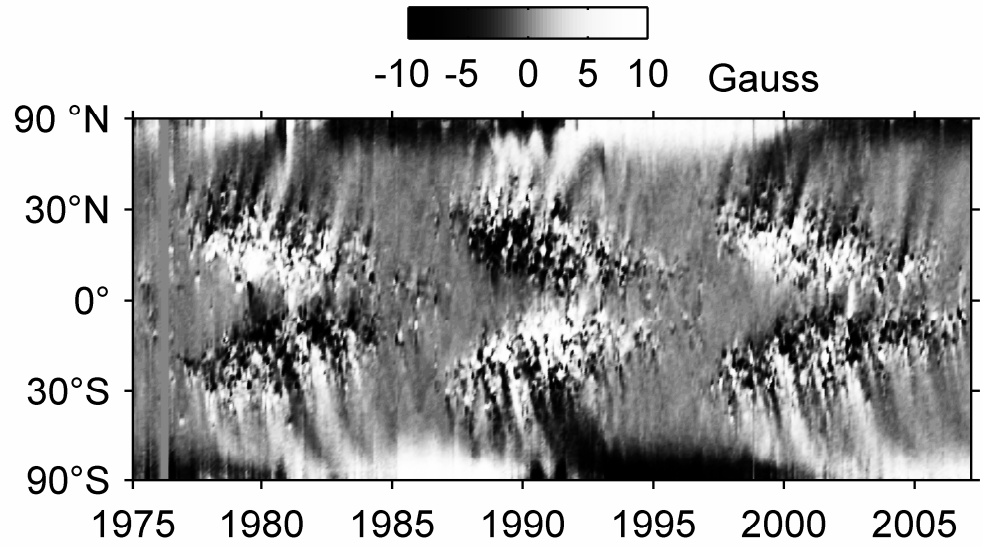
Why such persistent nonseasonal QB signals?

Why coherent over both (magnetic) poles?

Why is the QB amplitude in phase with the solar cycle?

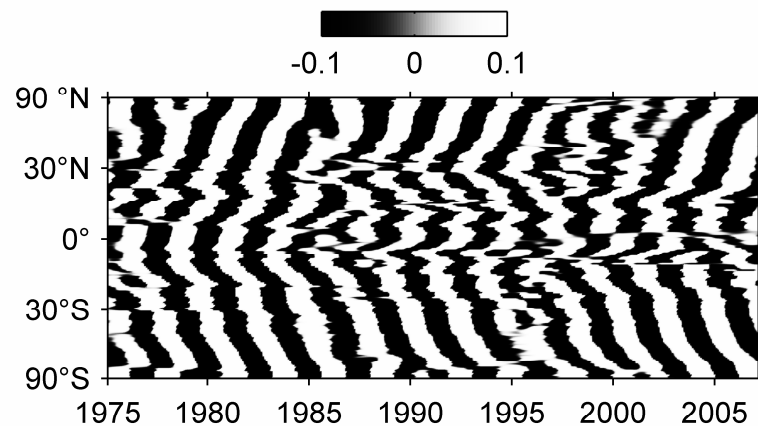
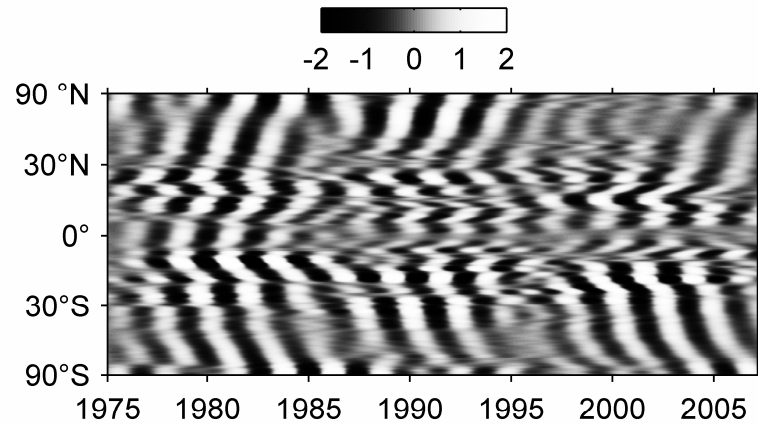
Some external forcing mechanism??

Solar magnetic 'Butterfly' chart



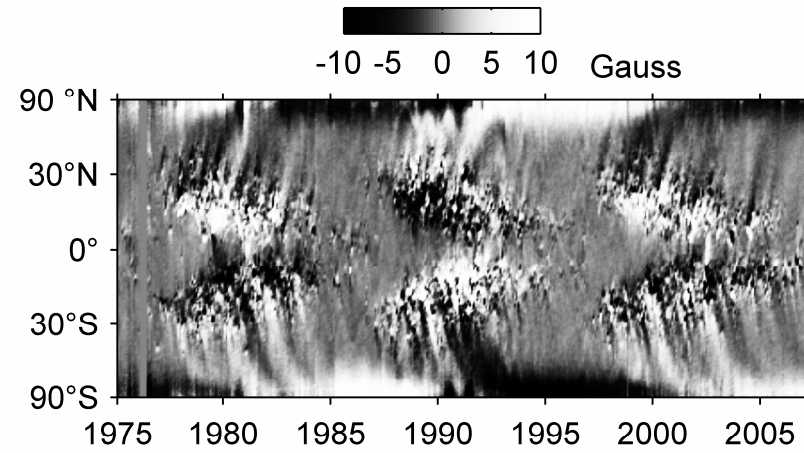
**High-Frequency
(~1-5 yrs)**

Quasi-biennial oscillations of the solar magnetic field

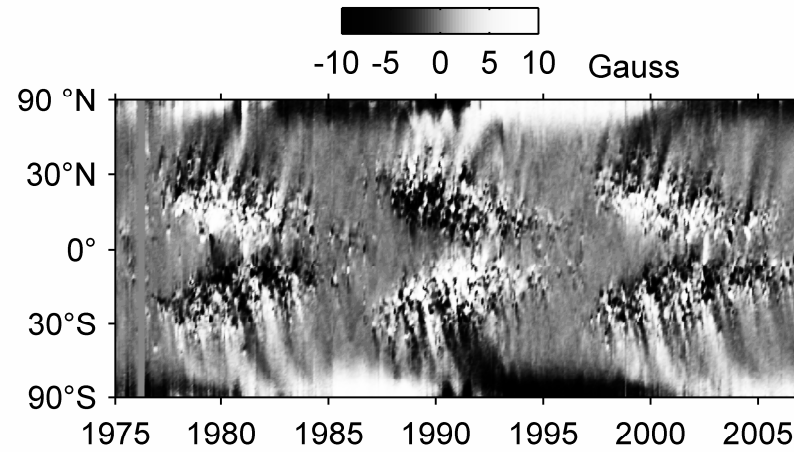


- Badalyan, O. G., et al. (2005), Quasi-biennial oscillations of the north-south asymmetry, *Astron. Rep.*, *49*, 659-670.
- Bazilevskaya, G. A., et al. (2000), Structure of the maximum phase of solar cycles 21 and 22, *Sol. Phys.*, *197*, 157-174.
- Bazilevskaya, G. A., et al. (2006), Gnevyshev gap effects in solar energetic particle activity, *Adv. Space Res.*, *38*, 484-488.
- Benevolenskaya, E. E. (1995), Double Magnetic Cycle of Solar-Activity, *Sol. Phys.*, *161*, 1-8.
- Benevolenskaya, E. E. (1996), Origin of the polar magnetic field reversals, *Sol. Phys.*, *167*, 47-55.
- Benevolenskaya, E. E. (1998), A model of the double magnetic cycle of the Sun, *Astrophys. J.*, *509*, L49-L52.
- Benevolenskaya, E. E. (2003), Impulses of activity and the solar cycle, *Sol. Phys.*, *216*, 325-341.
- Ivanov-Kholodny, G. S. (2000), Solar EUV quasi-biannual variations, *Physics and Chemistry of the Earth Part C-Solar-Terrestrial and Planetary Science*, *25*, 433-435.
- Ivanov-Kholodny, G. S., and V. E. Chertoprud (1992), Analysis of extrema of quasi-biennial variations of the solar activity, *Astron. Astrophys. Trans.*, *3*, 81-84.
- Ivanov-Kholodny, G. S., et al. (2000), Quasi-biennial oscillations in total solar irradiance and in the Earth's ionospheric parameters, *Geomagn. Aeron.*, *40*, 565-569.
- Ivanov-Kholodny, G. S., et al. (2003a), Heliolongitudinal effect in the solar and ionospheric quasi-biennial variations, *Geomagn. Aeron.*, *43*, 151-155.
- Ivanov-Kholodny, G. S., et al. (2003b), Spatial relations of quasi-biennial oscillations of the solar magnetic field, *Geomagn. Aeron.*, *43*, 673-679.
- Ivanov-Kholodny, G. S., et al. (2004), Quasi-biennial oscillations of the solar magnetic field and heliogeomagnetic activity, *Geomagn. Aeron.*, *44*, 265-269.
- Knaack, R., et al. (2004), Periodic oscillations in the north-south asymmetry of the solar magnetic field, *Astronomy & Astrophysics*, *418*, L17-L20.
- Knaack, R., et al. (2005), Evolution and rotation of large-scale photospheric magnetic fields of the Sun during cycles 21-23 - Periodicities, north-south asymmetries and r-mode signatures, *Astronomy & Astrophysics*, *438*, 1067-1082.
- Obridko, V. N., and B. D. Shelting (2001), Quasi-biennial oscillations of the global solar magnetic field, *Astron. Rep.*, *45*, 1012-1017.
- Stenflo, J. O., and M. Gudel (1988), Evolution of Solar Magnetic-Fields - Modal Structure, *Astron. Astrophys.*, *191*, 137-148.
- Stenflo, J. O., and M. Vogel (1986), Global Resonances in the Evolution of Solar Magnetic-Fields, *Nature*, *319*, 285-290.

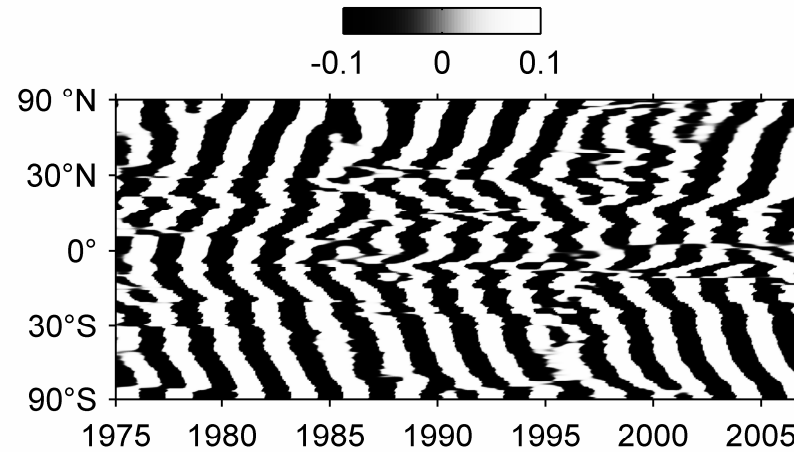
An 11-yr magnetic butterfly....

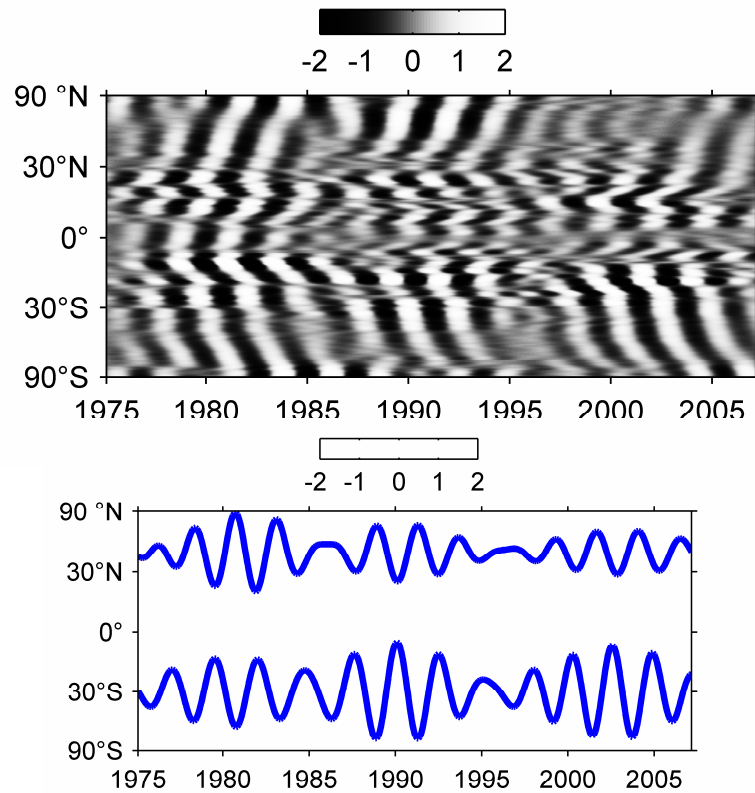


An 11-yr magnetic butterfly....



...and a quasi-biennial magnetic zebra





Quasi-biennial
(2-3 yr band pass)

Plotted for
42N, 30S

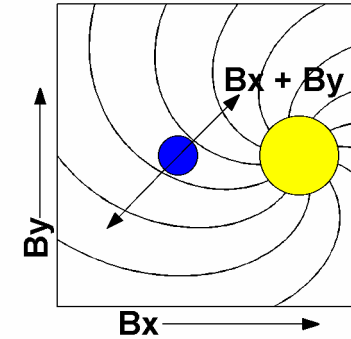
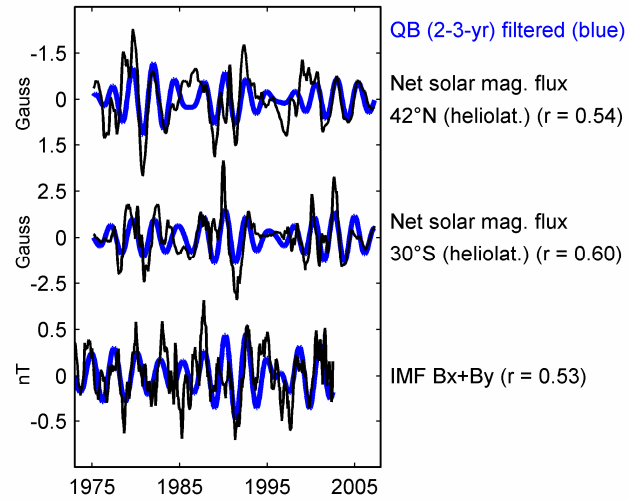
QB amplitude increases during solar max

Previously observed:

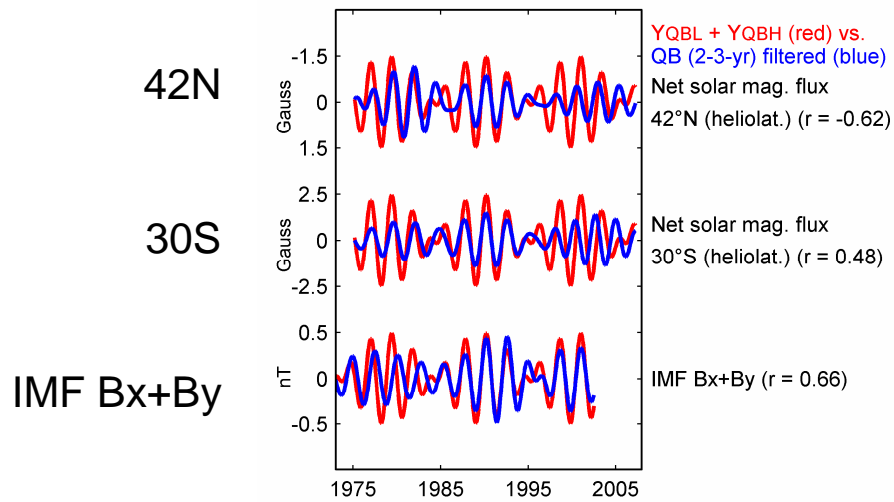
Stenflo and Vogel 1986

Obridko and Shelting 2001

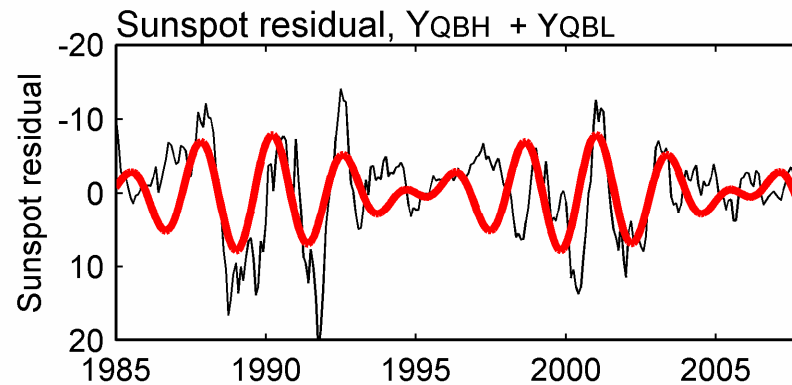
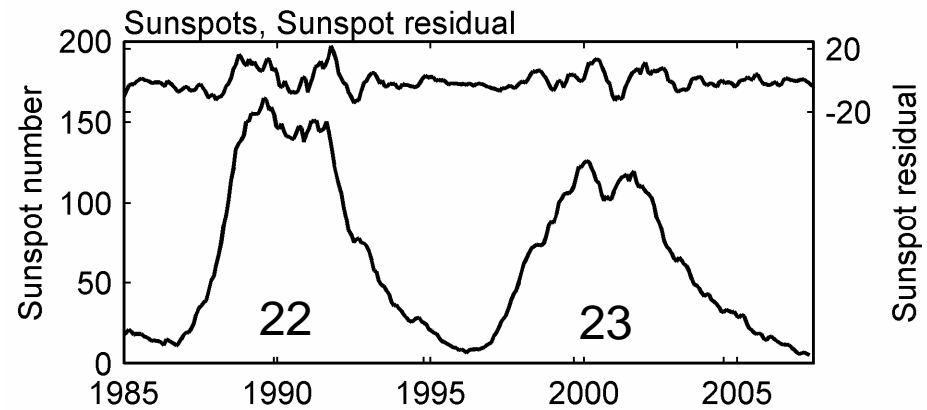
Knaack et al. 2005



Same pair of QB
functions (red)



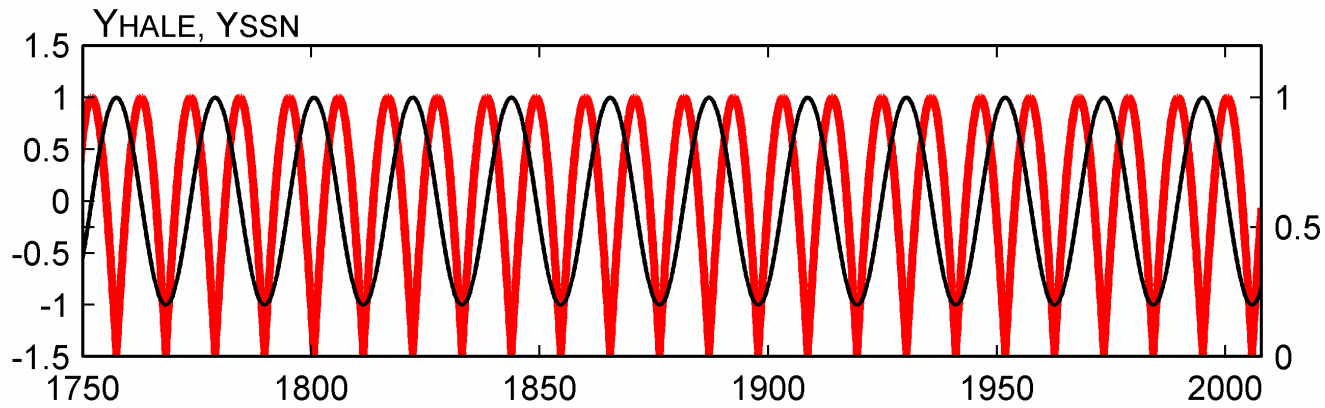
Same pair of QB functions correlates with high-frequency sunspot variations



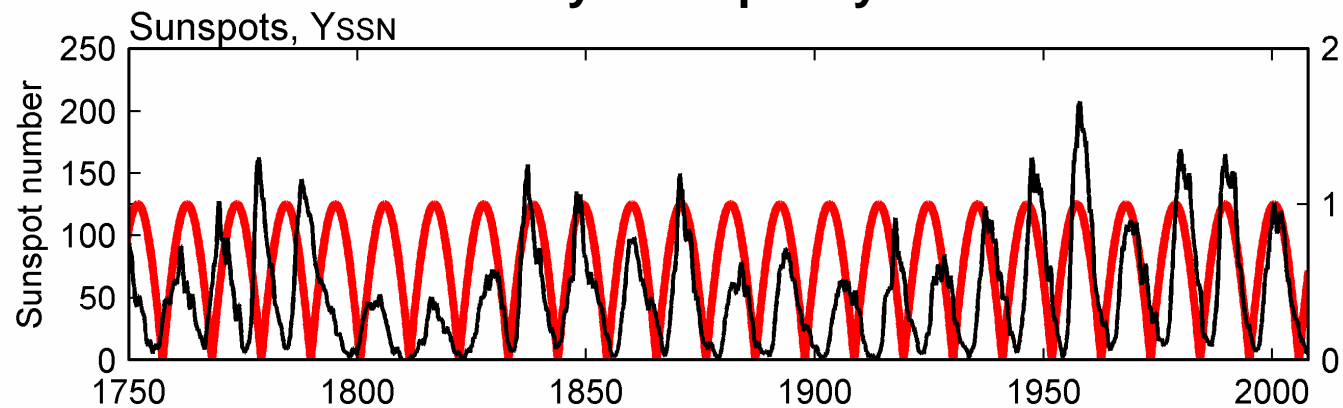
QB harmonics of a 21.6-yr Hale Cycle?

$$2.16 \cdot 10 = 21.6$$

$$2.7 \cdot 8 = 21.6$$



10.8-yr sunspot cycle



QB harmonics of a 21.6-yr Hale Cycle?

$H = 259.2$ months (21.6-yr Hale cycle)

$t(0) = \text{June, 1946}$ (months)

Hale cycle (21.6 yrs)

$$Y_{\text{HALE}} = \sin(2\pi / Ht)$$

Sunspot cycle (10.8 yrs)

$$Y_{\text{SSN}} = |\cos(2\pi / Ht)|$$

International sunspot number 1750-2007:

Mean length 10.90 ± 0.32 yrs (1 std. error)

Median length 10.58 yrs

QB cycles:

2.7-yr QB (32.4 mos.):

$$Y_{\text{QBL}} = \sin[2\pi / (H/8)t]$$

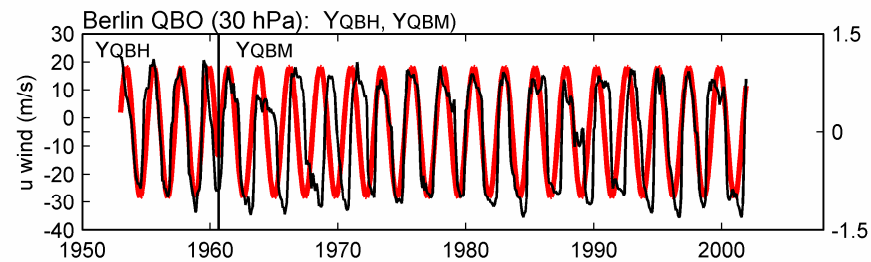
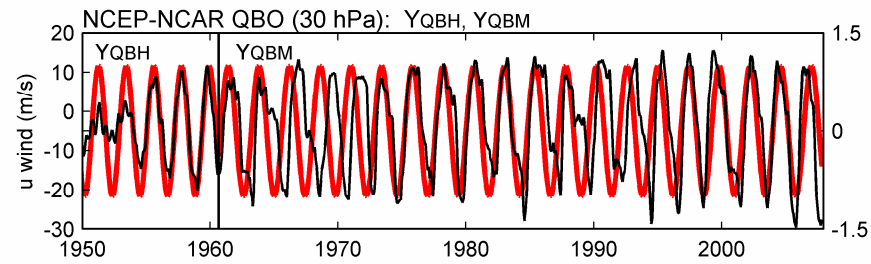
2.16-yr QB (25.92 mos.)

$$Y_{\text{QBH}} = \sin[2\pi / (H/10)t]$$

2.4-yr QB (28.8 mos.)

$$Y_{\text{QBM}} = \sin[2\pi / (H/9)t]$$

The stratospheric QBO: The 9th harmonic of the Hale cycle? (28.8 months)



Conclusions:

The atmosphere possess a harmonic series of three QB cycles (2.16, 2.4, and 2.7 yrs) which can be described as harmonics of the Hale cycle.

Two of these QB oscillations in combination (2.16 & 2.7-yr) are also apparent in the solar magnetic field and IMF orientation.

Question?

Physical sun-climate connection via the solar wind-IMF?

Global electrical circuit? (Tinsley et al. 2007)

Particle precipitation?

