Influences of the 11-year sunspot cycle on the stratosphere – and the importance of the QBO

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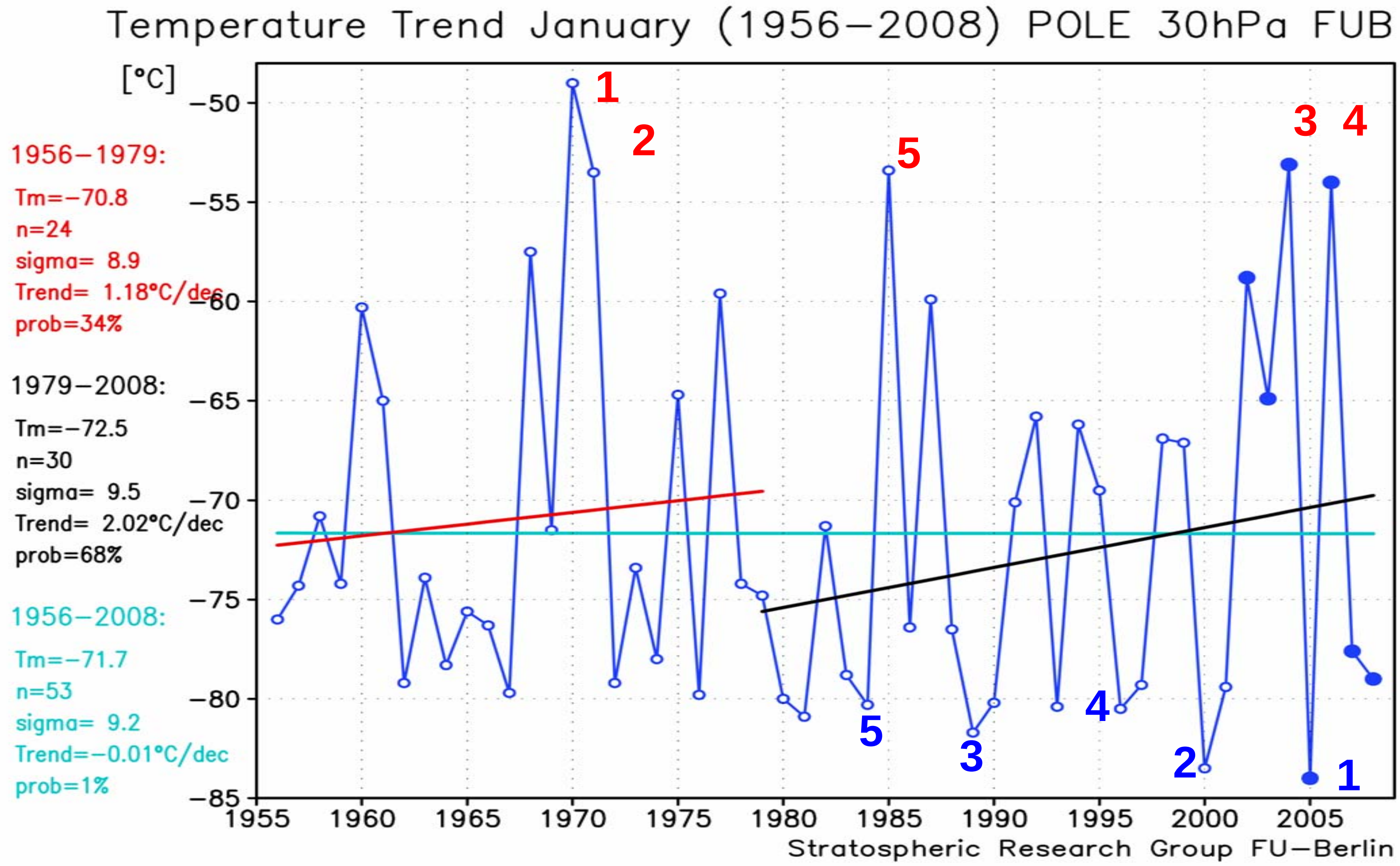
(Labitzke and van Loon, numerous papers, 1987 – 2006)

(UCD-Seminar-April-2008)

The topics of my lecture today are:

1) Variability of the Arctic Winters -- the Sun and the QBO

2) Solar Signals in Summer



1956 – 2008: trend = - 0.01 K/dec; sigma = 9.2K

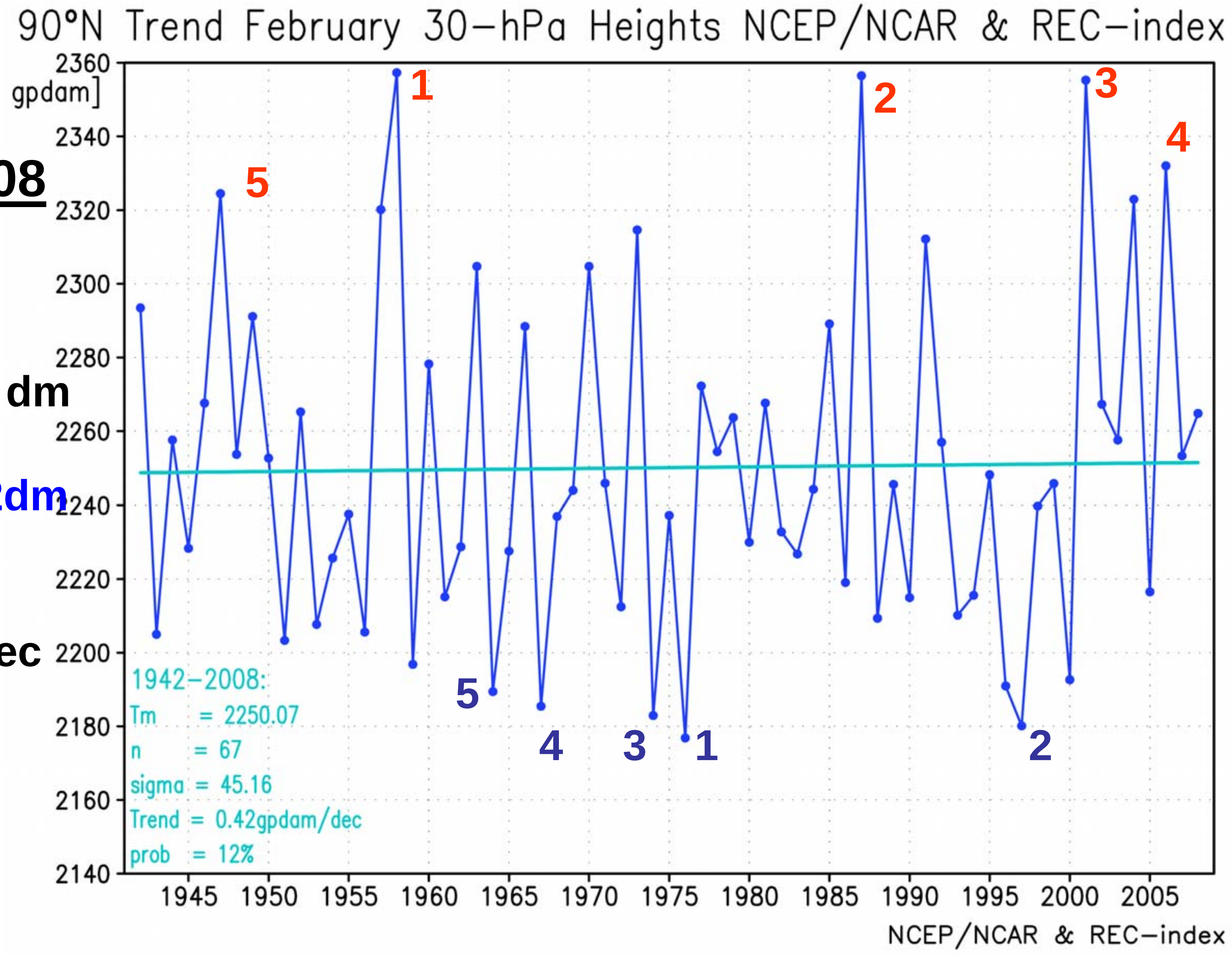
<u>1942 – 2008</u>

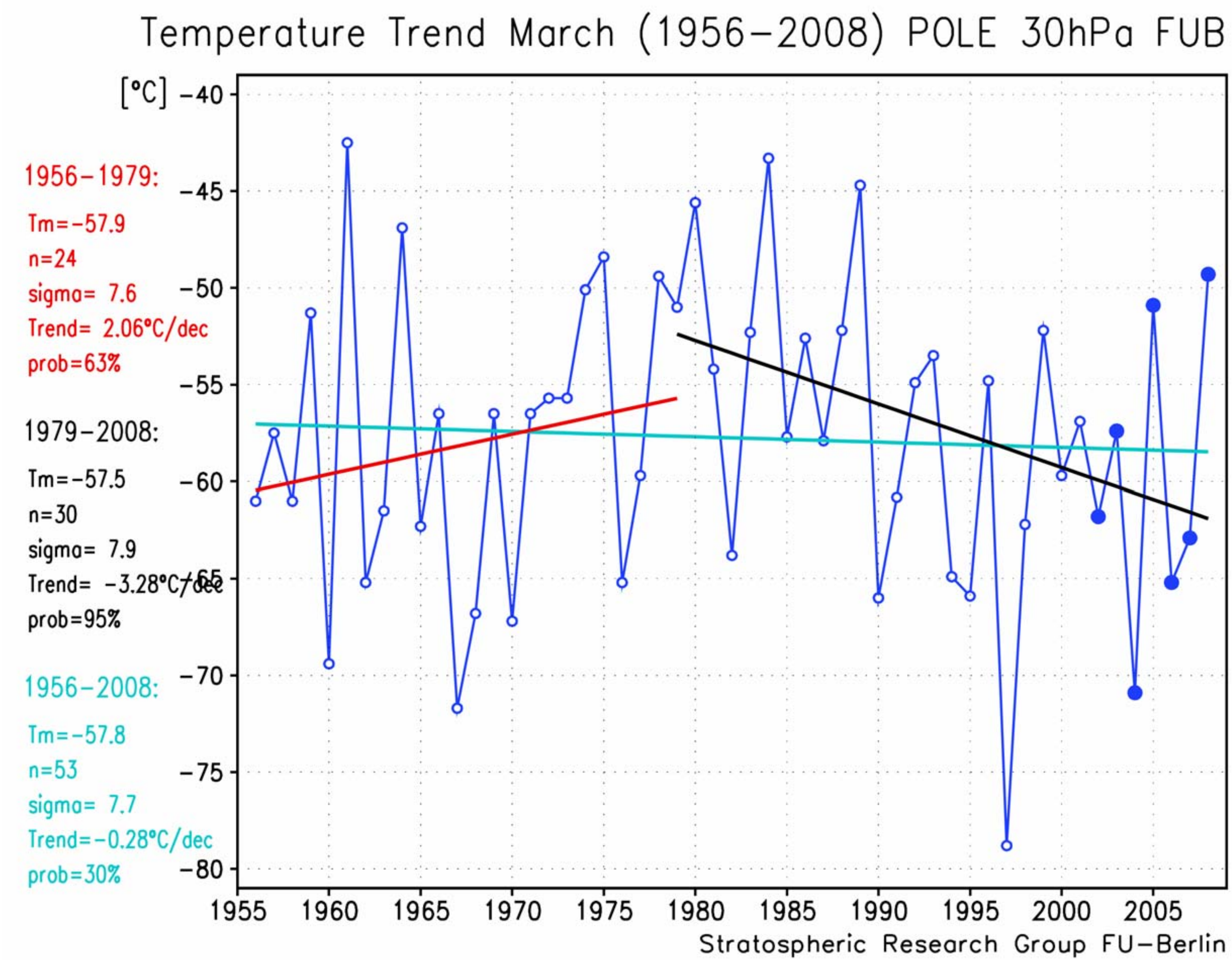
n = 67

Hm = 2250,1 dm

sigma = 45,2dm

trend =
+ 0.42 dm/dec
sign. 12 %

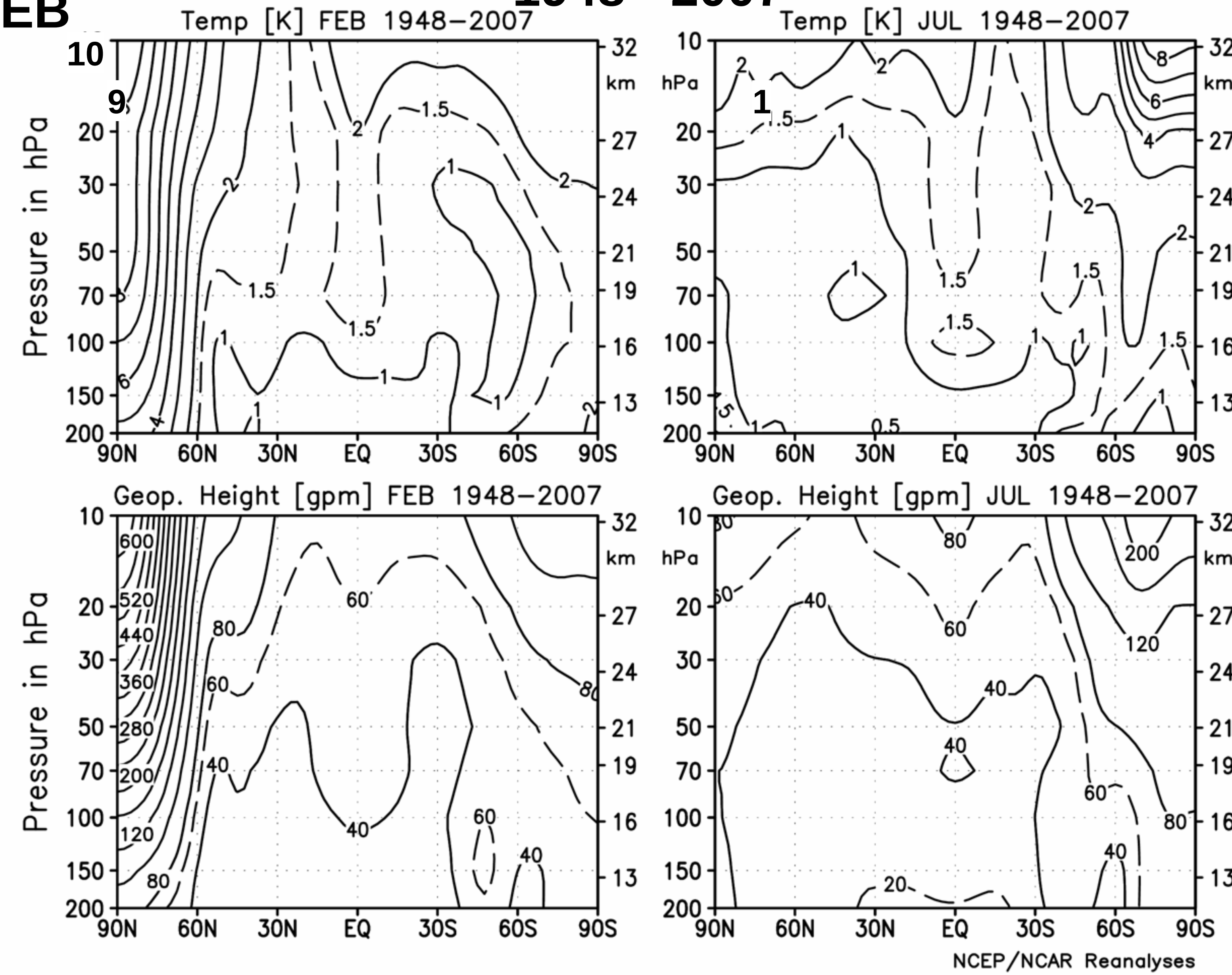




1956 – 2008: trend = - 0.28 K/dec; sigma = 7.7K

Standard Deviations for February and July 1948 - 2007

FEB **JUL**



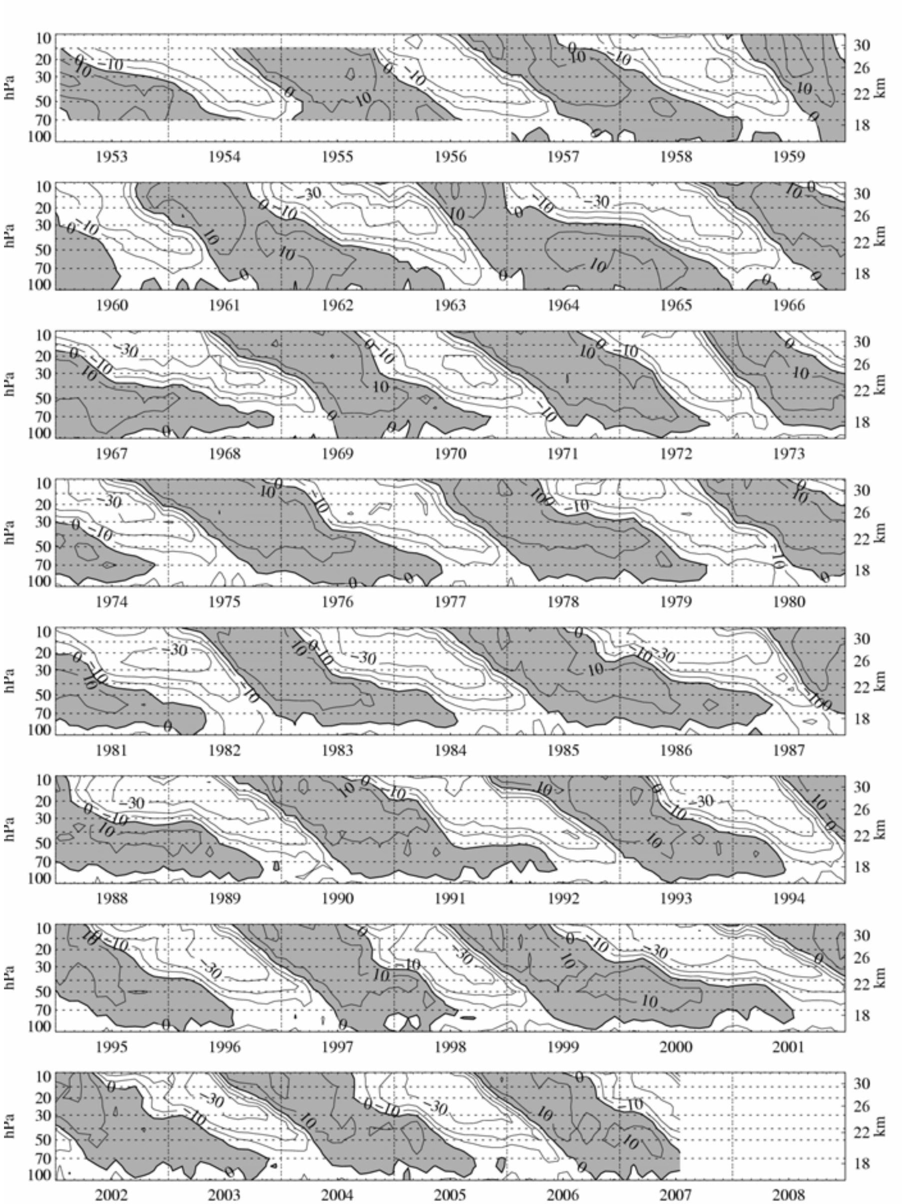
Temp

Height

Labitzke and Kunze, 2008)

SO	Cold event Warm event	**cold** and strong **warm** and weak	**(Labitzke and van Loon, 1987)**
QBO	Westphase Eastphase	**cold** and strong **warm** and weak	**(Holton and Tan, 1980; 1963-1978, n = 18)**
SUN	Solar min **Solar max**	like QBO **opposite to QBO**	**(Labitzke + van Loon, 1987 – 2006)**
AO	High index (+) Low index (-)	**cold** and strong **warm** and weak,	**(Baldwin and Dunkerton, 2001)**

Different forcings influencing the stratospheric polar vortex during the northern winters



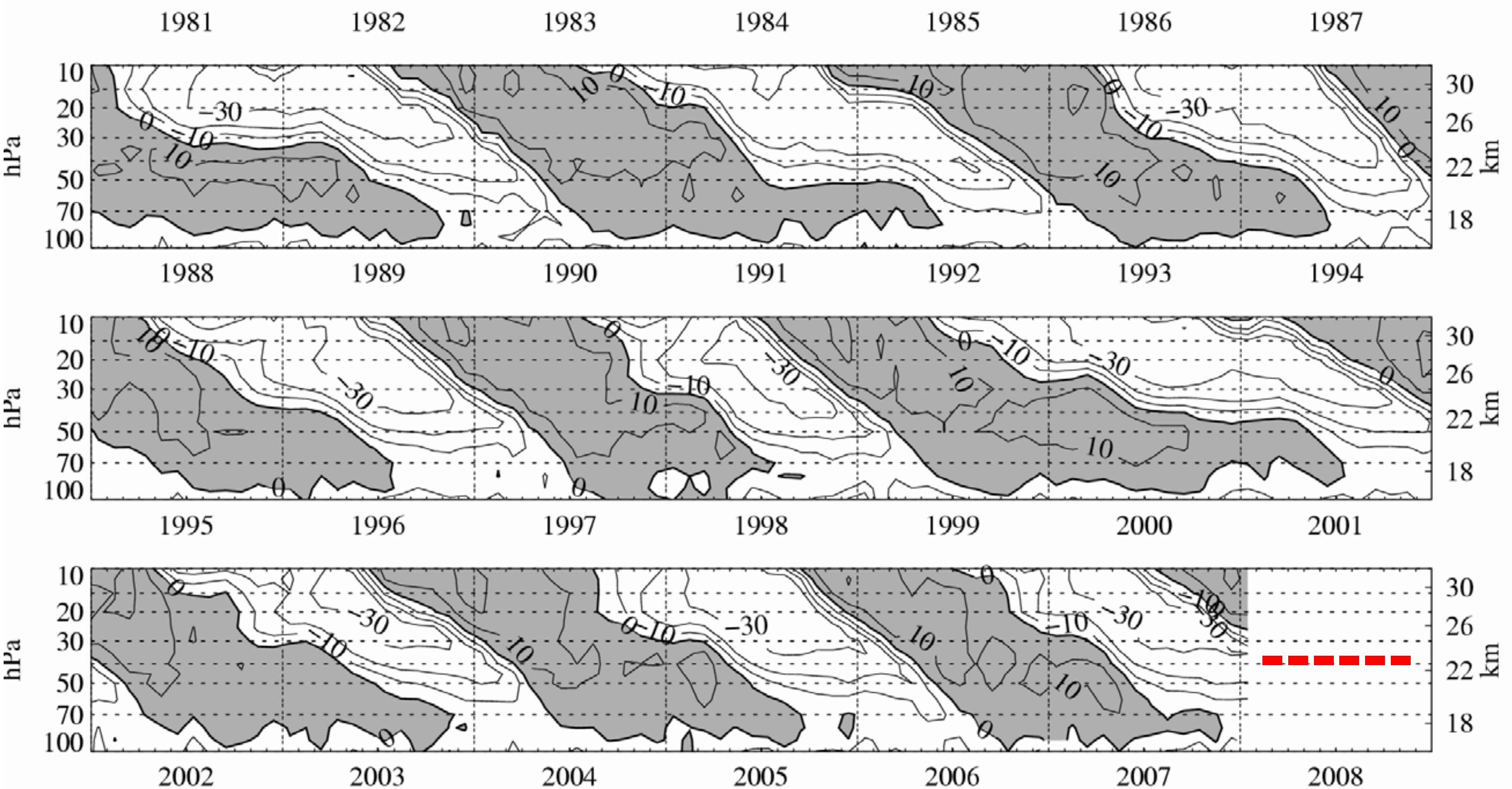
Quasi-Biennial Oscillation QBO

Time- height section of monthly mean zonal winds (m/s) at equatorial stations:
Canton Island (3°S / 172°W) (Jan 1953 – Aug 1967);
Gan/Maledive Islands (1°S /73°E) (Sep 1967 – Dec 1975);
Singapore (1°N /104°E) (since Jan 1976).
Isopleths are at 10 m/s intervals, westerlies are shaded ; (updated from Naujokat 1986).

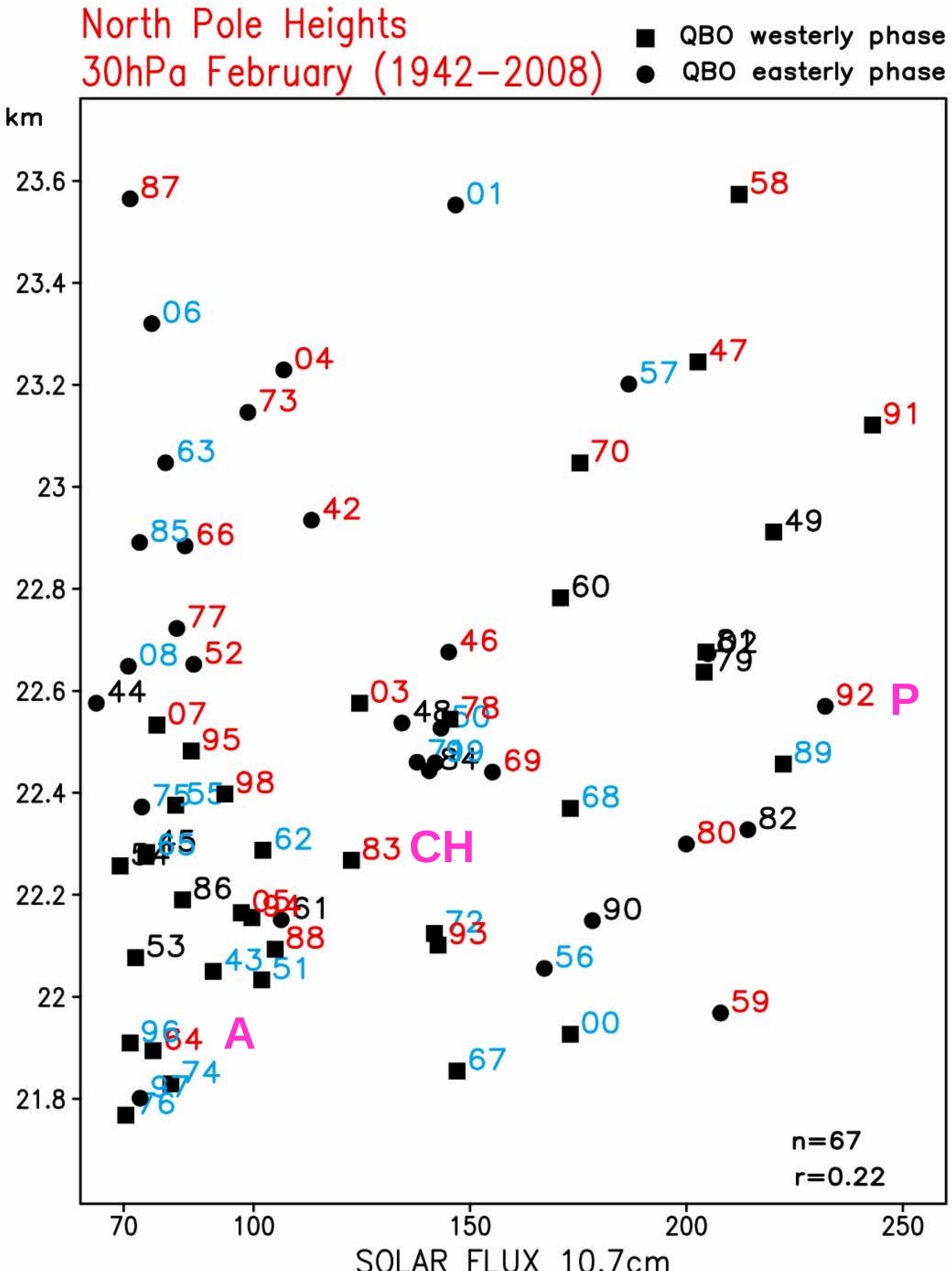
(grey = west; white = east)

(50 + 40hPa in Jan + Feb)/4

The Quasi - Biennial Oscillation (1988 – 2007)



QBO-definition:
40+50hPa in Jan+Feb)/4



solar min solar max

February

red = warm event

~ El Nino

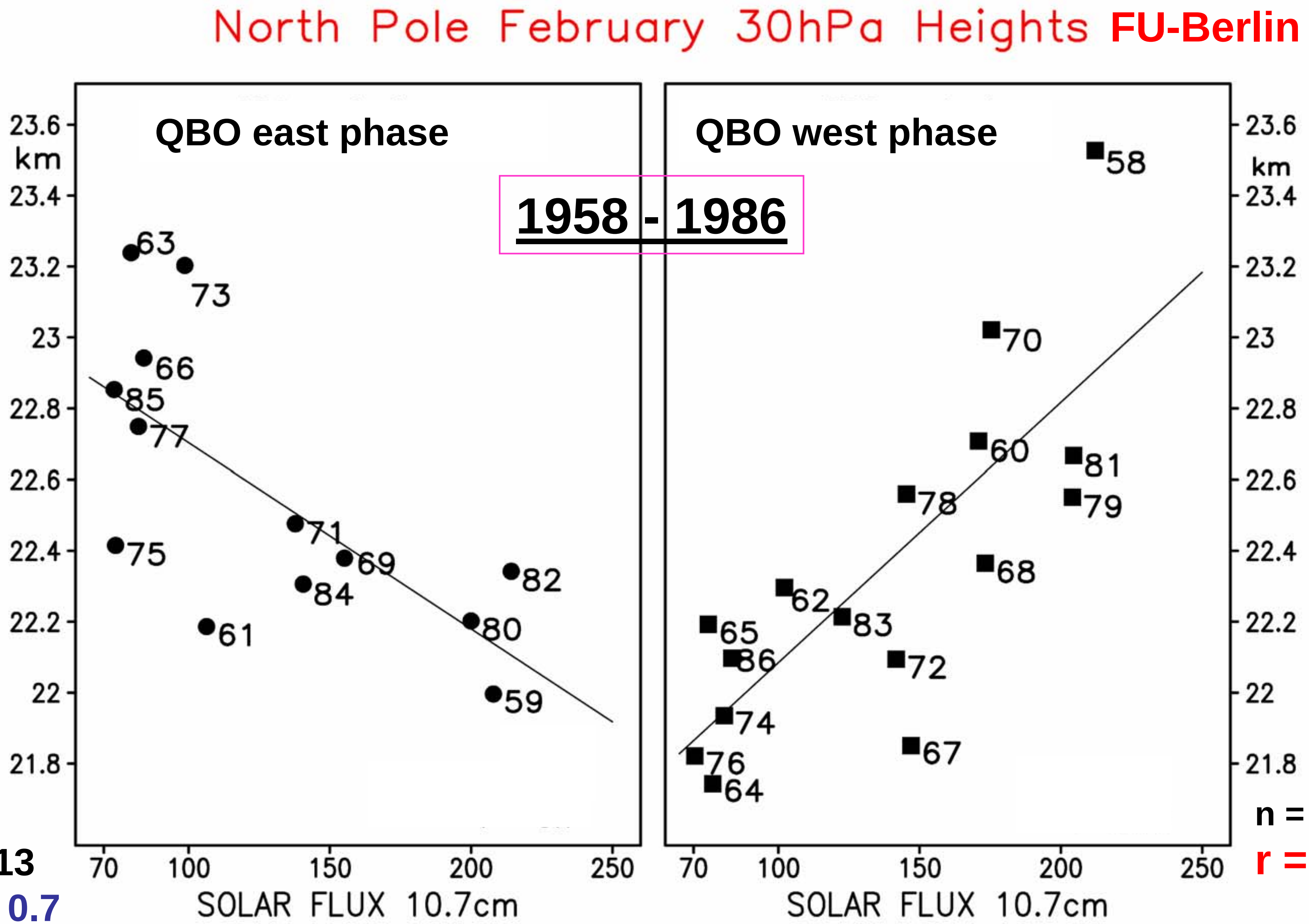
blue = cold event SO

no correlation with

11 year solar cycle

r = 0.22 (n = 67)

Tropical volcanoes
W: Agung March 1963
E: Chichon March 1982
E: Pinatubo June 1991



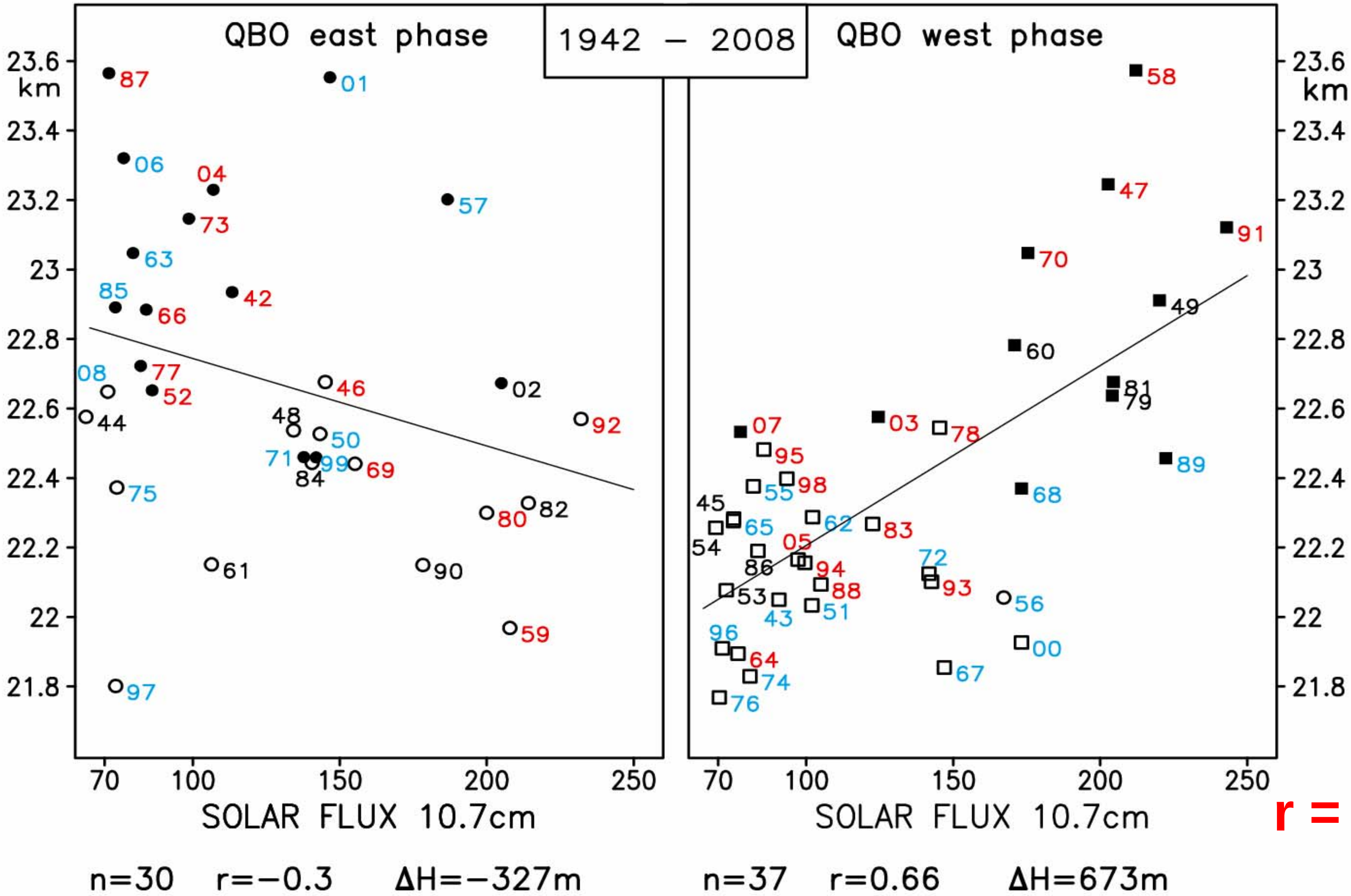
n = 13
r = - 0.7

n = 16
r = 0.78

Correlations between 30-hPa Heights and the Solar Flux

1. 1958 -1986, (n = 29 years ~3cycles; Labitzke (1987)

North Pole February 30 – hPa Heights, NCEP/NCAR + Rec.



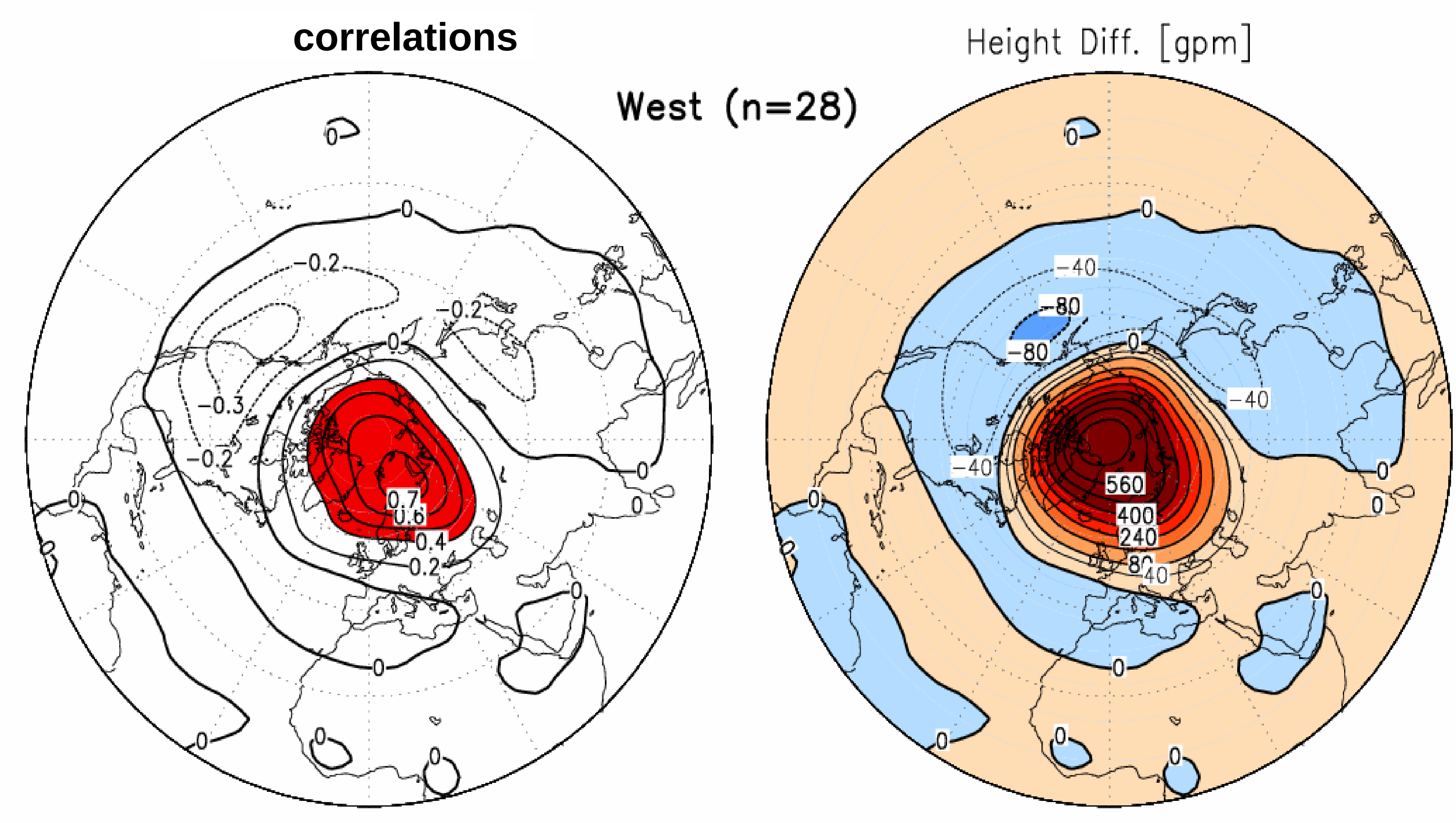
r = 0.66

22 years later and 16 years back; filled symbols = MMWs; n = 67

6.5 solar cycles; WE in red, CE in blue; van Loon and Labitzke (1994), updated)

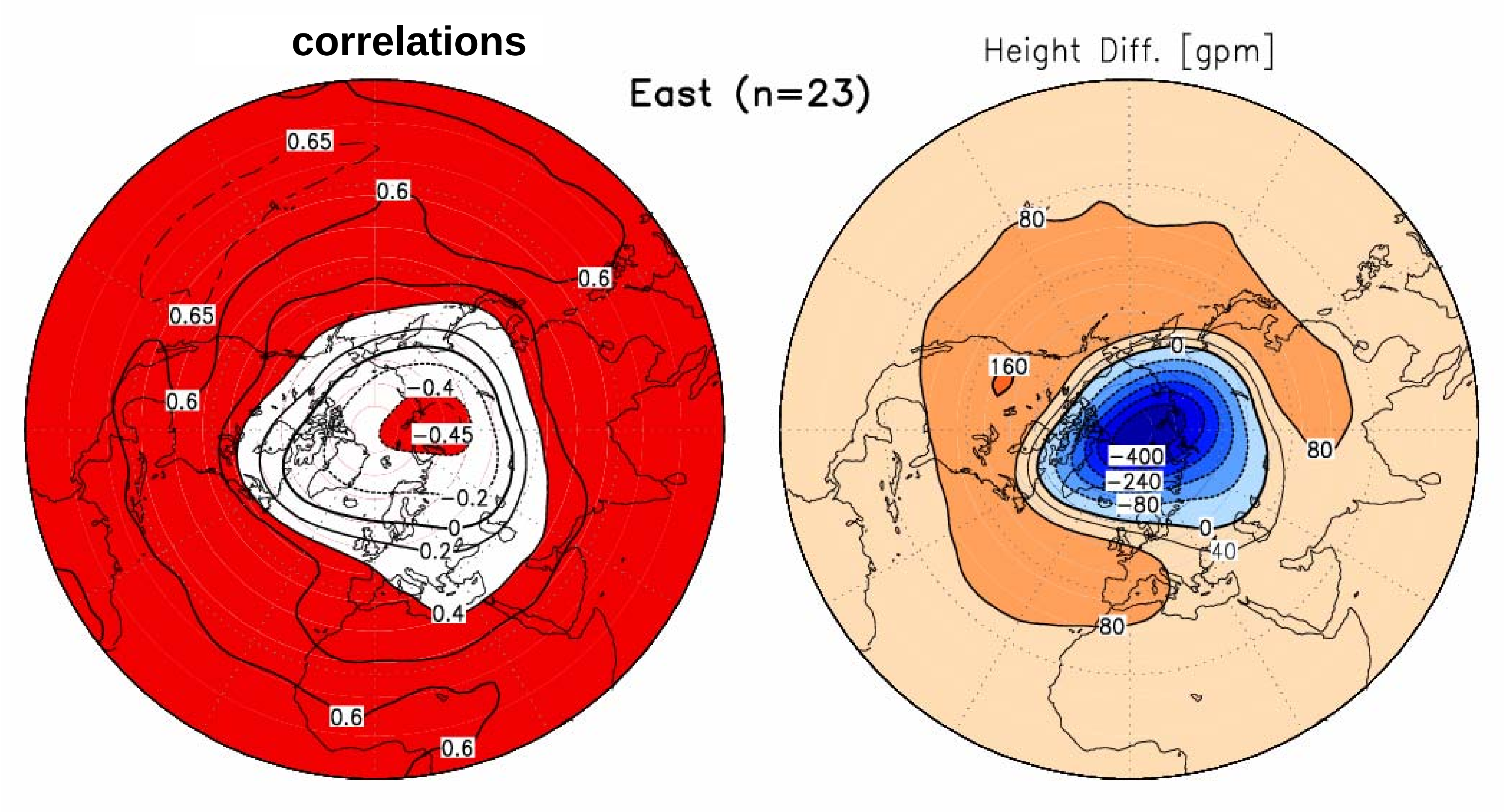
A Stratospheric Major Midwinter Warming (MMW) is defined by a reversal of the temperature gradient (at the 10hPa level) between the North Pole and 60°N (i.e., polar region warmer) – and
by a reversal of the normal westerlies to easterlies (winds from the east), i.e. a negative AO.

Solar Cycle; detrended 30hPa Height; WEST/QBO
February 1958 – 2008; (n=51); NCEP/NCAR



min = - 0.34; max = 0.75; 5 solar cycles; max height diff. 640 m (~1.5 sigma)

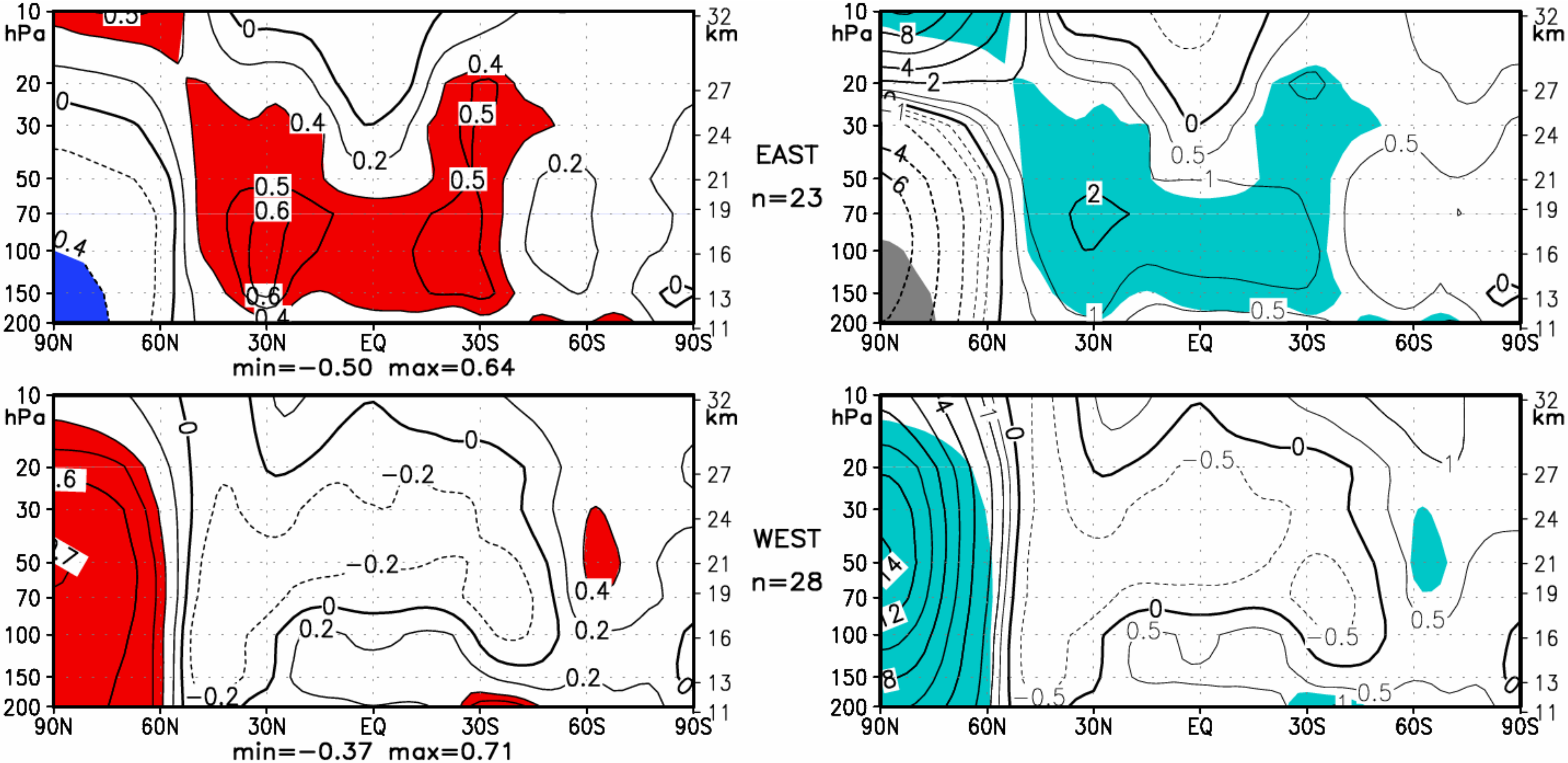
Solar Cycle; detrended 30hPa Height; EAST/QBO
February 1958 – 2008 (n=51) NCEP/NCAR



min = - 0.47; max = 0.67; 5 solar cycles; height diff. 440 m

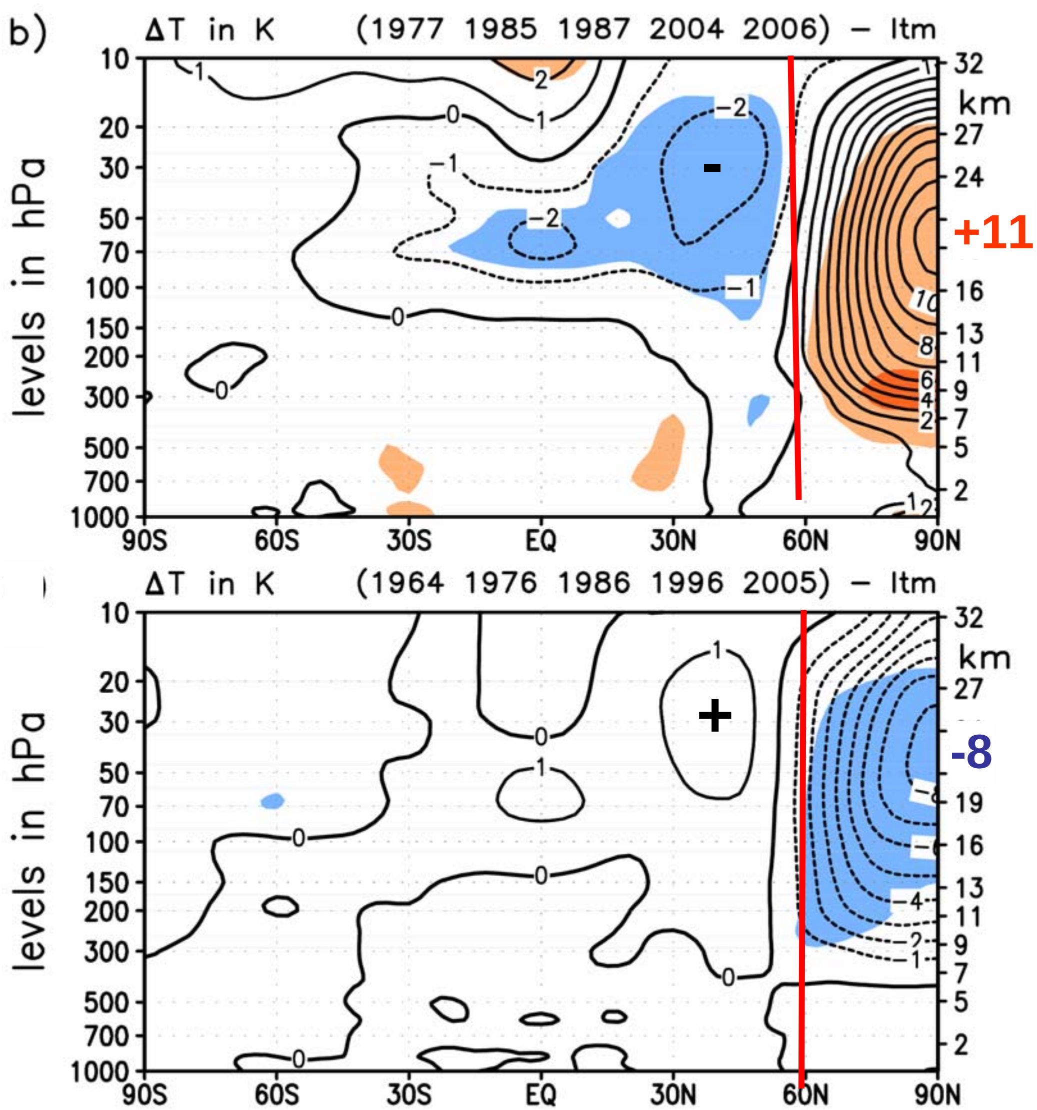
Detrended Temp., February, NCEP/NCAR, 1958- 2008

solar max – solar min



(shading = corr >+/- 0.4)

n = 51, ~ 5 solar cycles



5 strongest MMWs
in
east min

☆

nodal points:
~ 30S and ~ 55N
in both cases

5 coldest winters
in
west min

Deviations of the zonal mean temperatures (K) in (Jan+Feb)/2
from the long-term mean (1968 through 2002);
(shading larger than 1 (2) standard deviations)

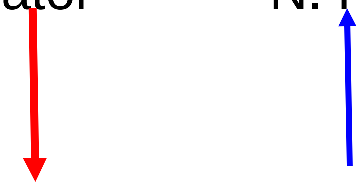
Teleconnections – QBO – Solar Cycle
(in the middle stratosphere/ upper troposphere)

Solar MIN – QBO **West,**

northern winter:

weakening of BDC (Holton + Tan)

Equator N. Pole



COLD vortex

Solar MIN – QBO **East**,

northern winter:

intensification of BDC (Holton + Tan)

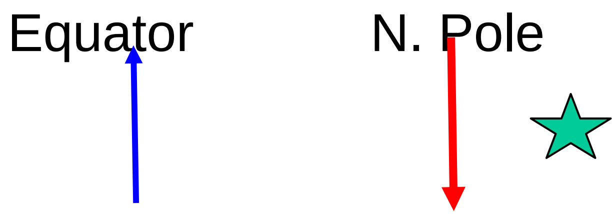
Equator N. Pole

Teleconnections – QBO – Solar Cycle
(in the middle stratosphere/ upper troposphere)

Solar MAX – QBO **West**,

northern winter:

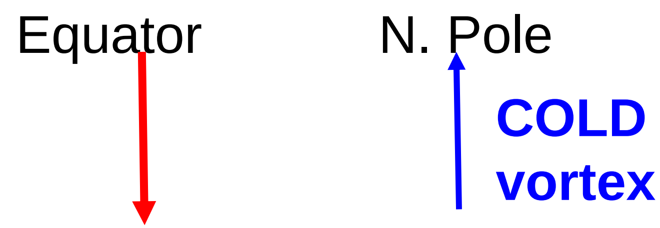
intensification of BDC



Solar MIN – QBO **West**,

northern winter:

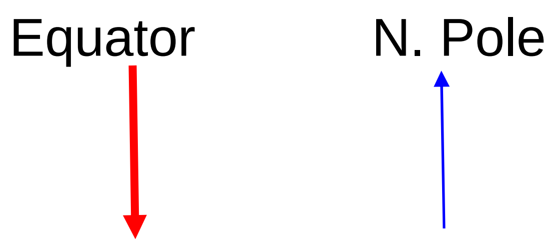
weakening of BDC (Holton + Tan)



Solar MAX – QBO **East**,

northern winter:

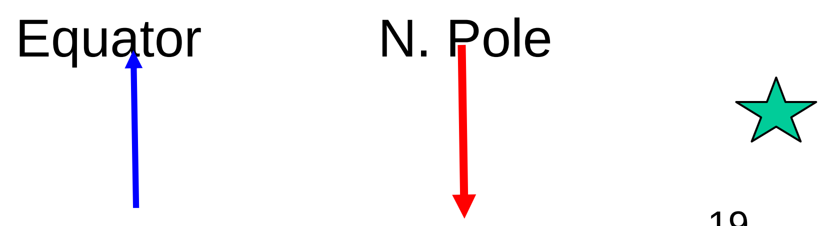
some weakening of BDC



Solar MIN – QBO **East**,

northern winter:

intensification of BDC (Holton + Tan)



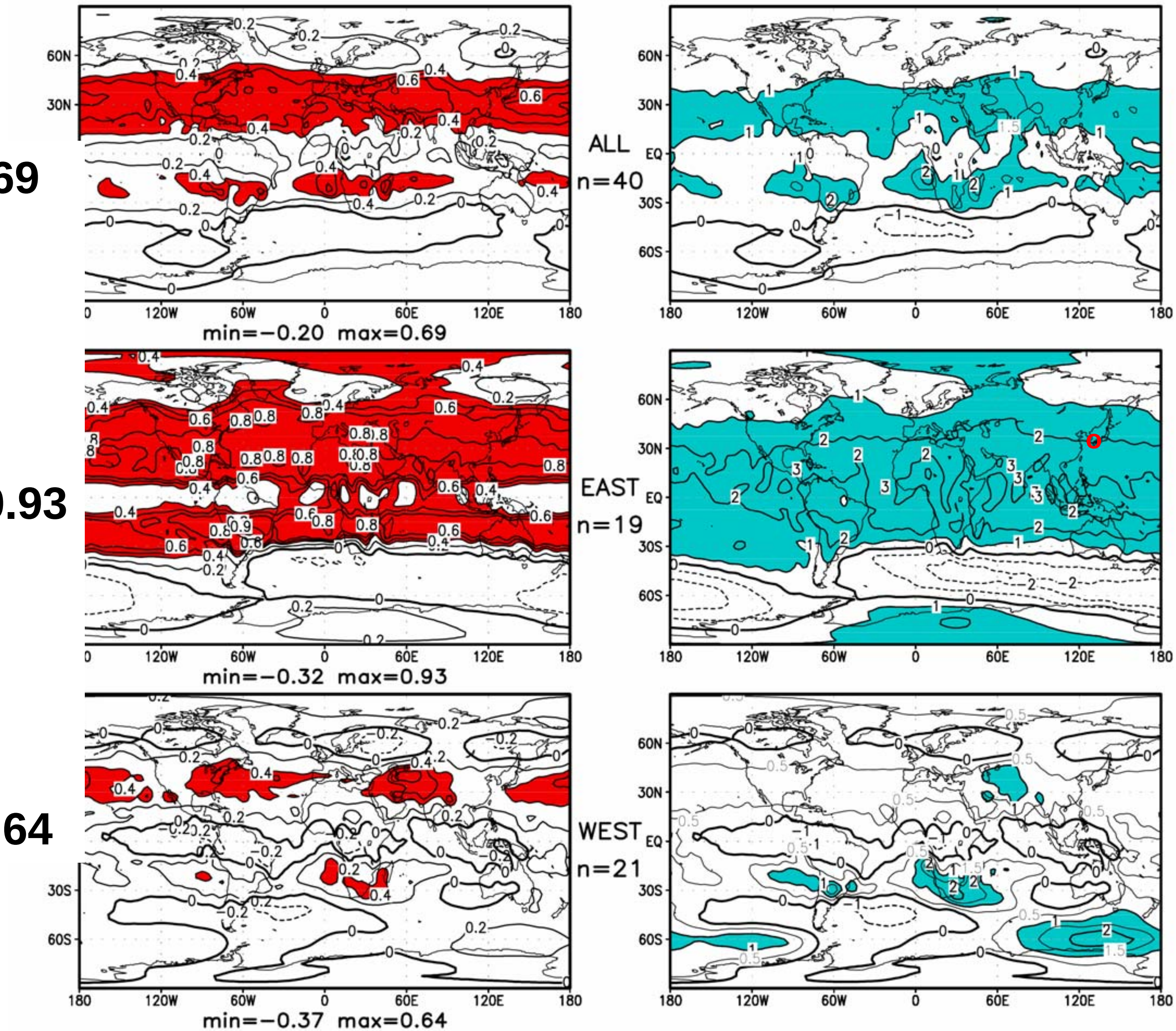
July, Northern Summer,

the dynamically least disturbed season

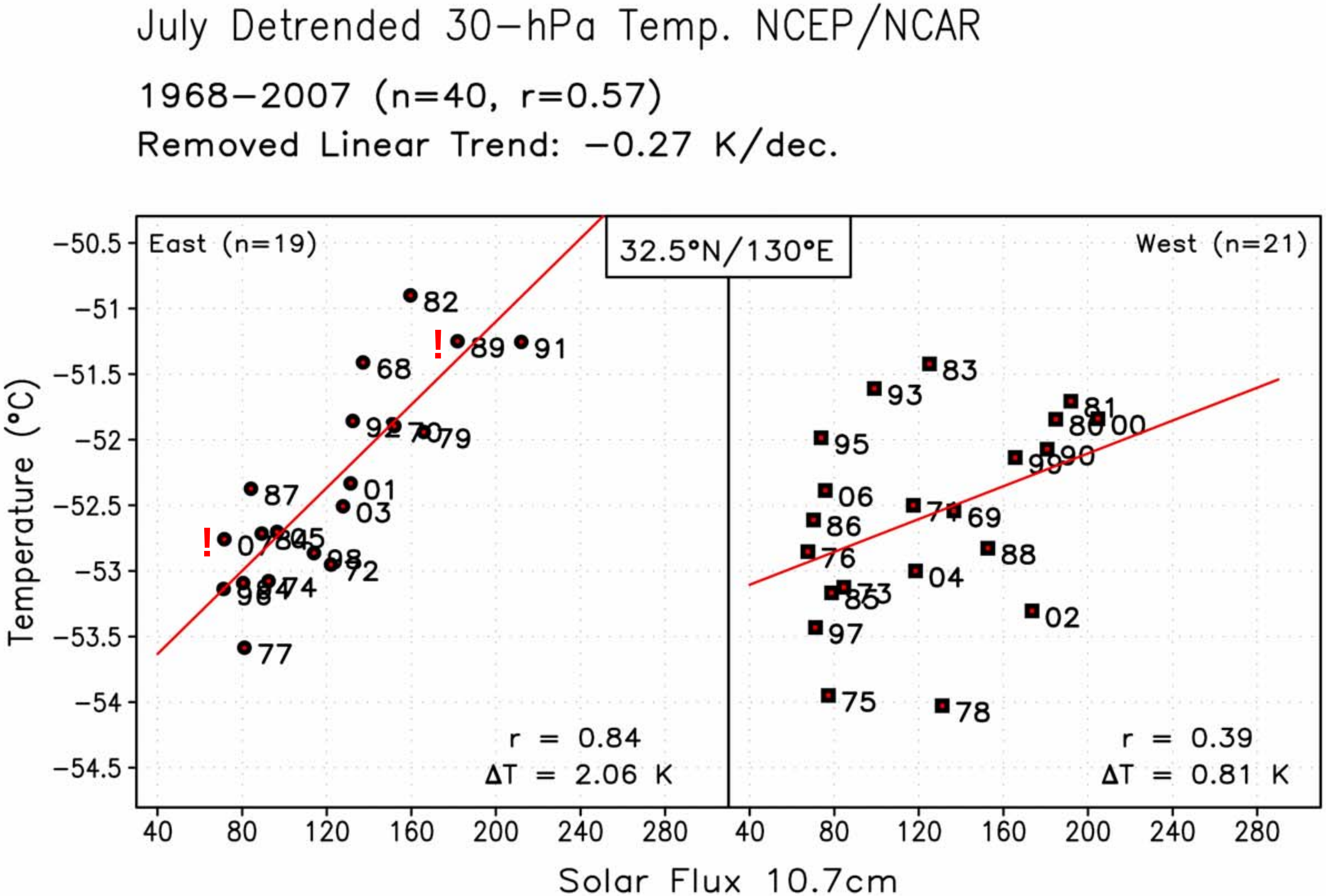
all; r_{max} = 0.69

east; r_{max} = 0.93

west; r_{max}=0.64



Correlations between the solar flux and the detrended 30-hPa temperatures in July (1968 -2007); red = corr. > 0.4; blue is temp. diff. > 1K



r = 0.84, T_{diff} = 2.1 K **r = 0.39, T_{diff} = 0.8 K**

(sigma = 1K)

(near Nagasaki)

(Chichon = March 82/ east; Pinatubo = June 91/east)

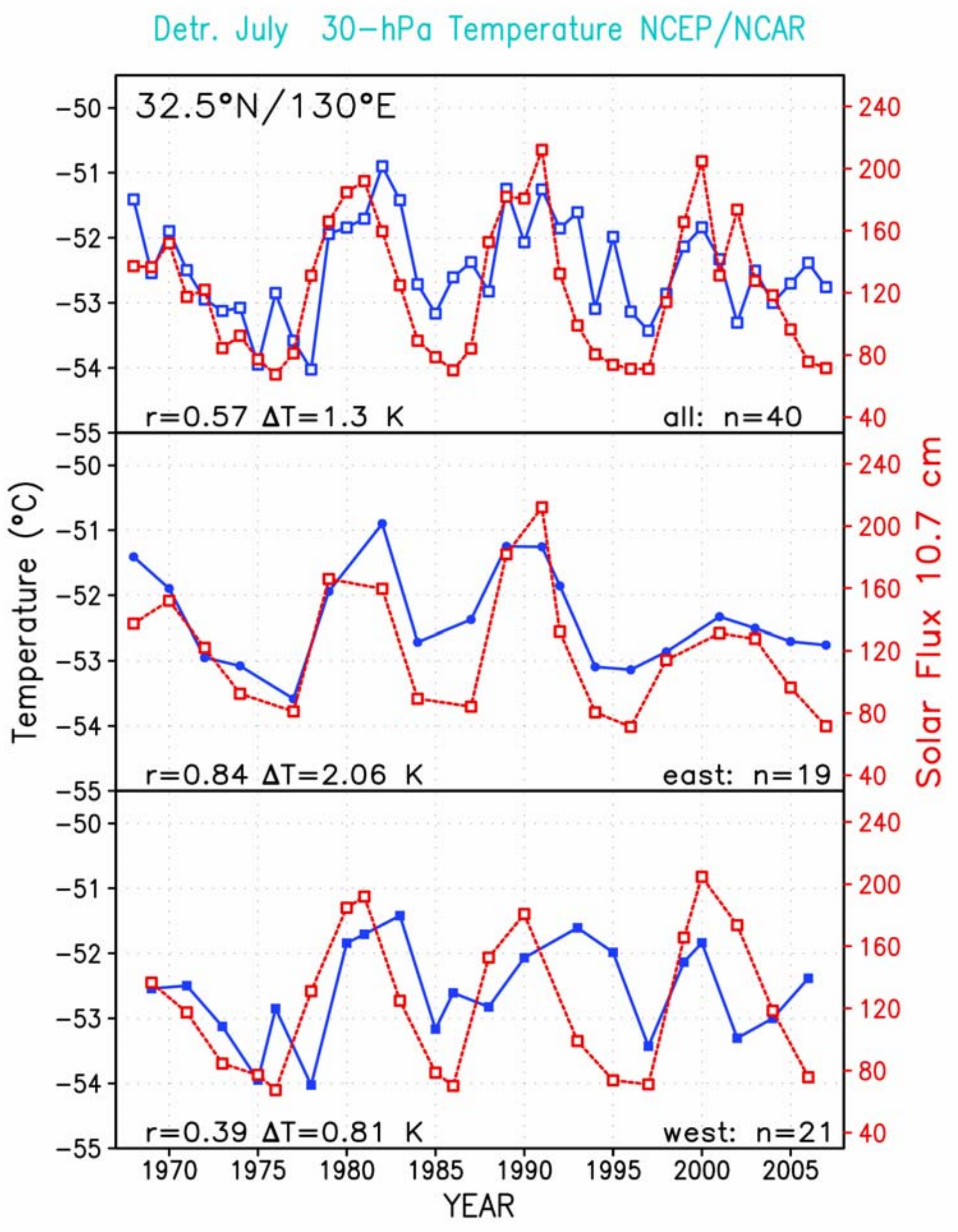
near Nagasaki

(1968 – 2007, n = 40)

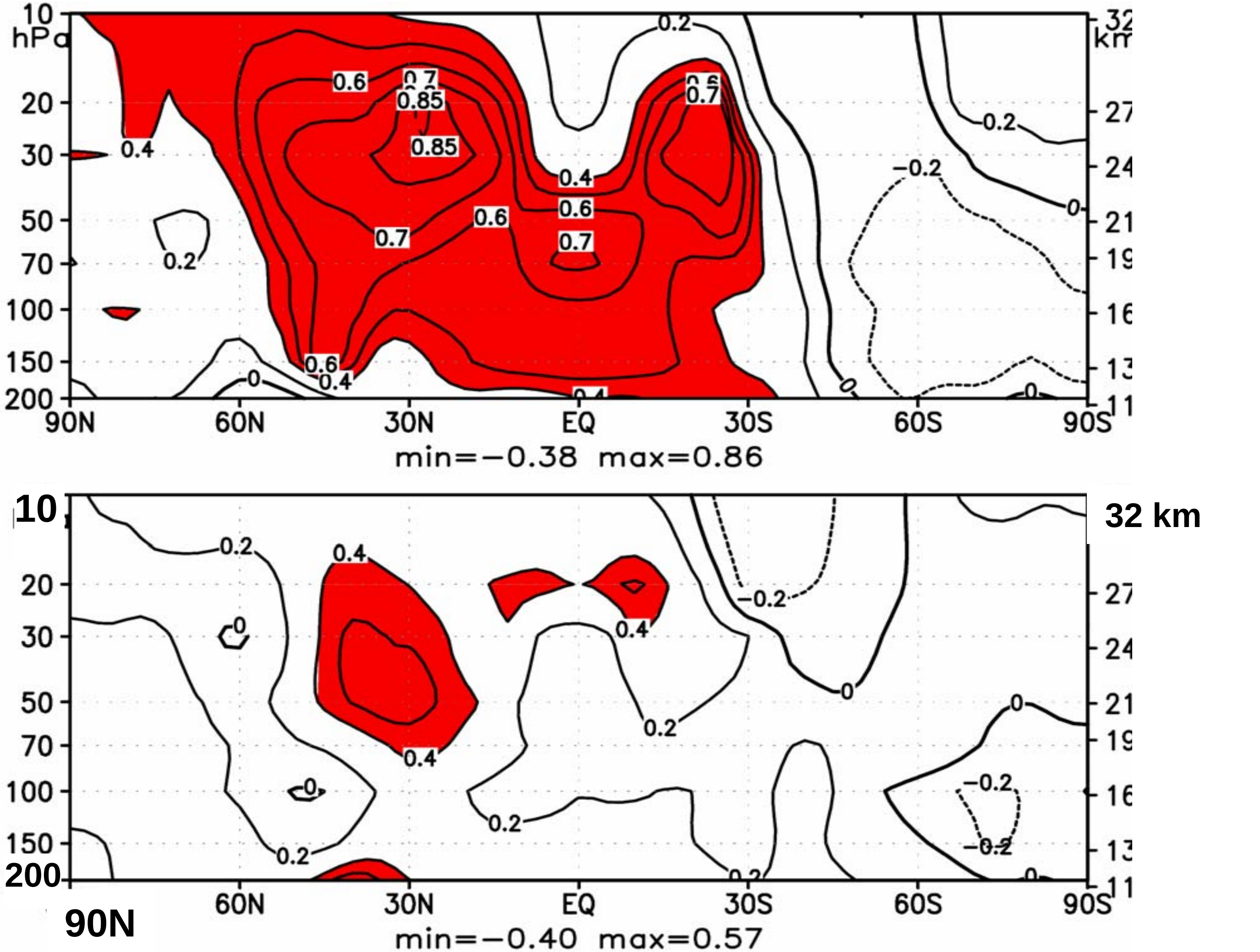
all
r = 0.57

east
r = 0.84

west
r = 0.39



July, 1968 – 2005: Detrended Temperature Correlations (NCEP/NCAR)



East: n = 18
r max = 0.86
> 99 %

West: n = 20
r max = 0.57

(4 solar cycles)

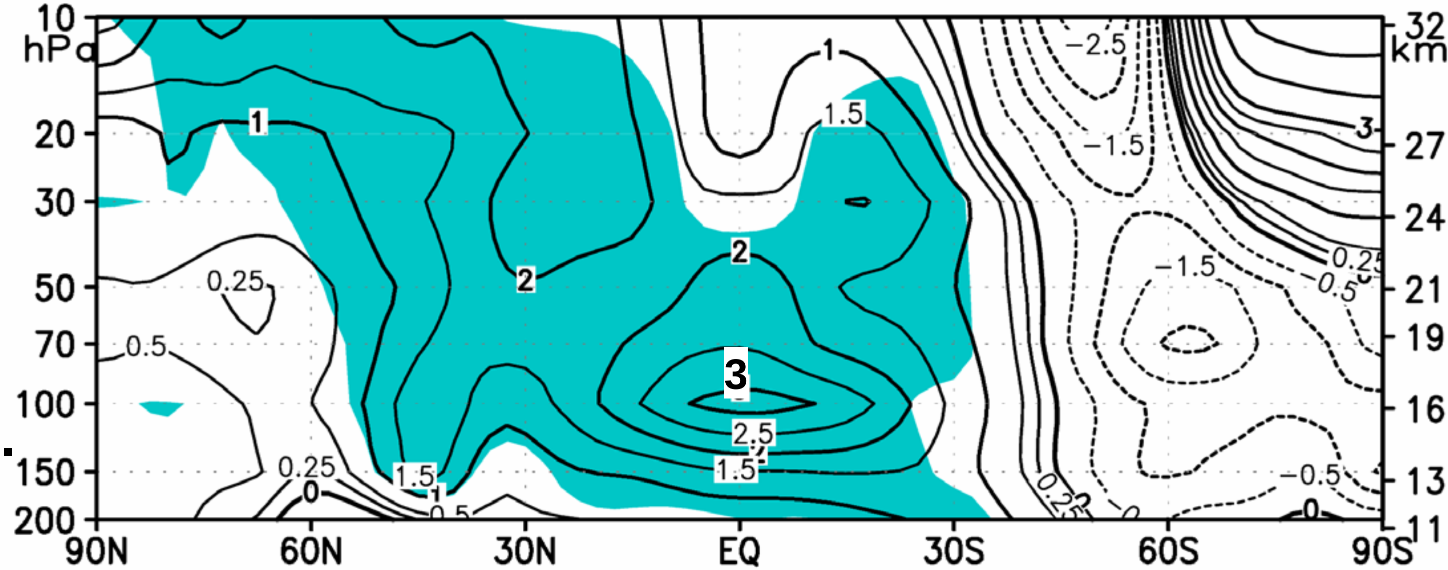
(Labitzke 2003, updated)

Temperature Differences, (solar max – min) July, 1968 - 2005

East
n = 18

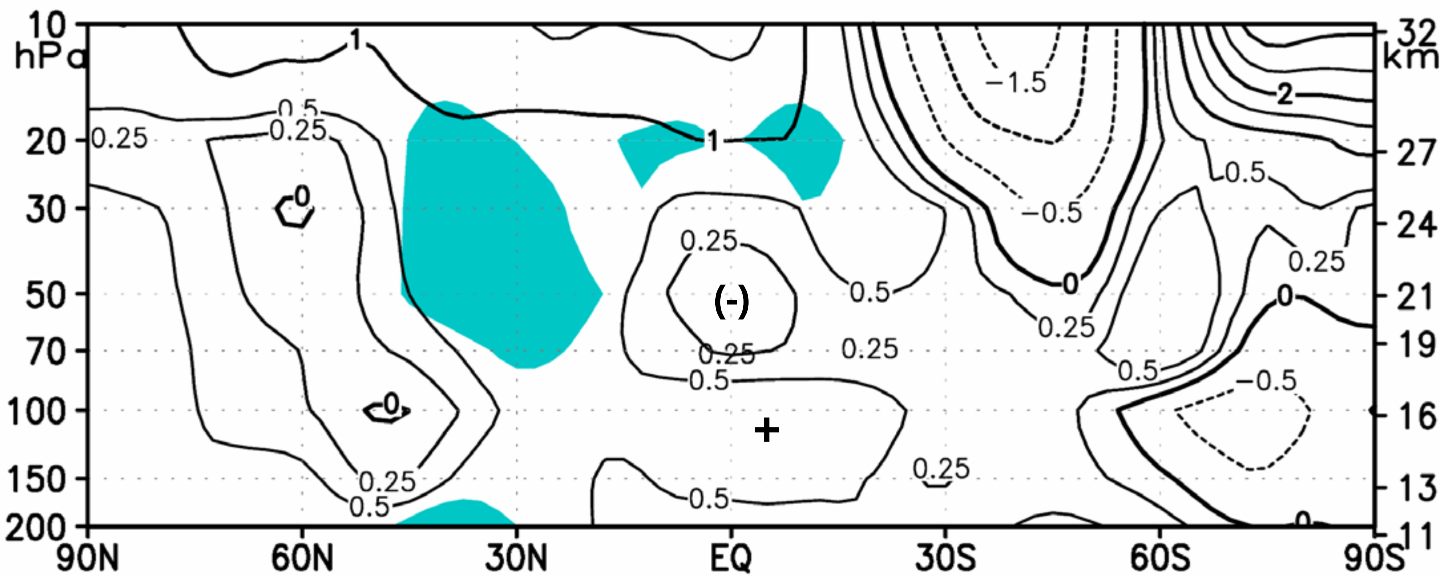
tropical warming = downwelling

= weakening of Brewer-Dobson C.



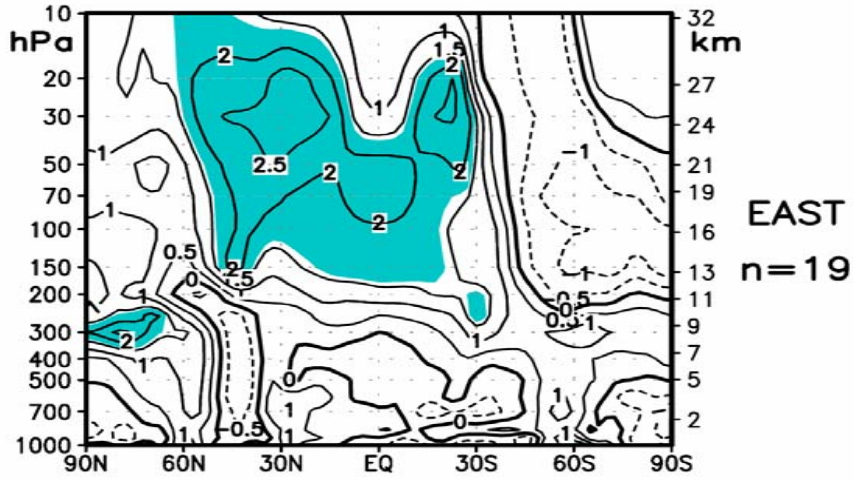
West
n = 20

Intensification of Hadley Circulation? More convection over equator?

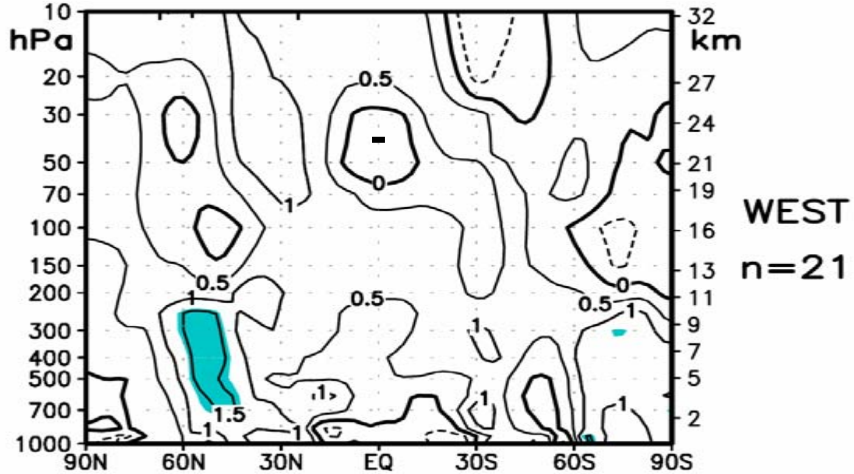


Temperature Differences, (solar max – min) standardized: July, 1968 – 2007, n = 40

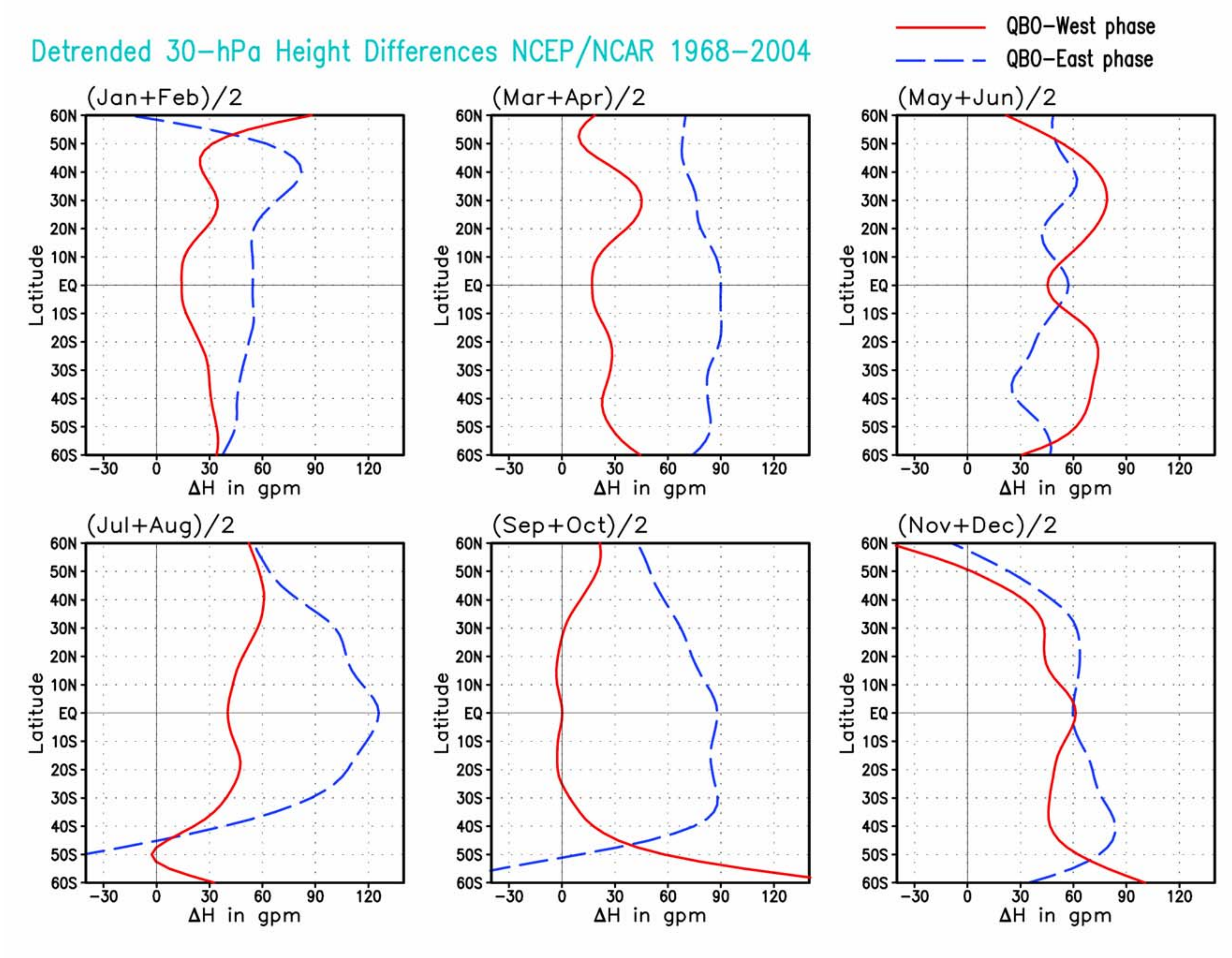
QBO/east



QBO/west

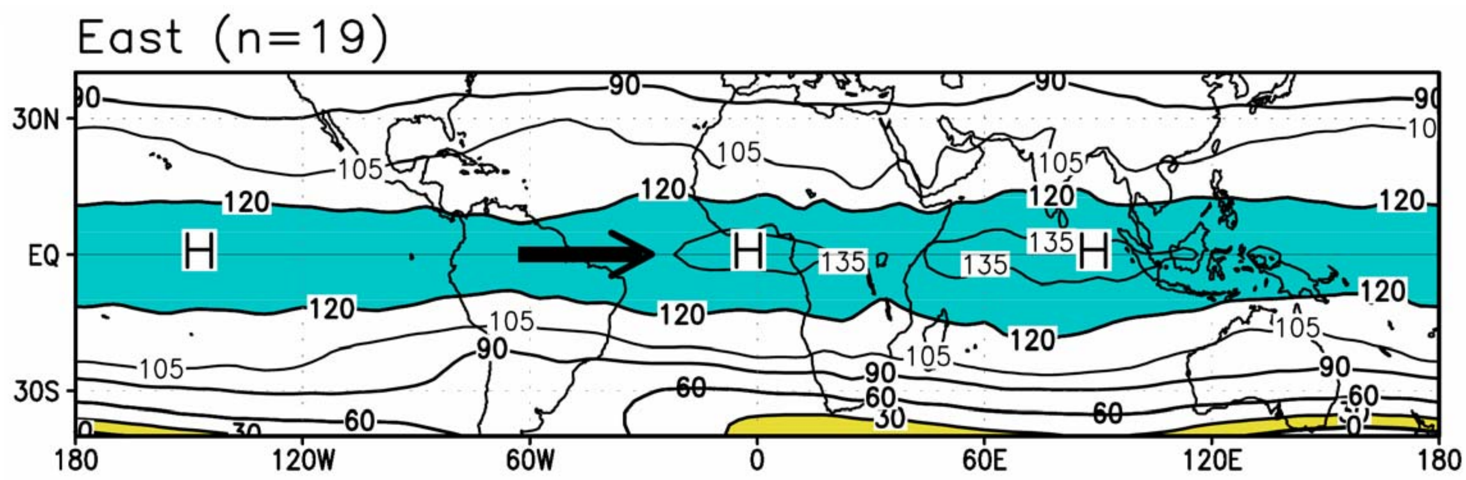


30-hPa Heights, solar max – solar min, bi-monthly through the year

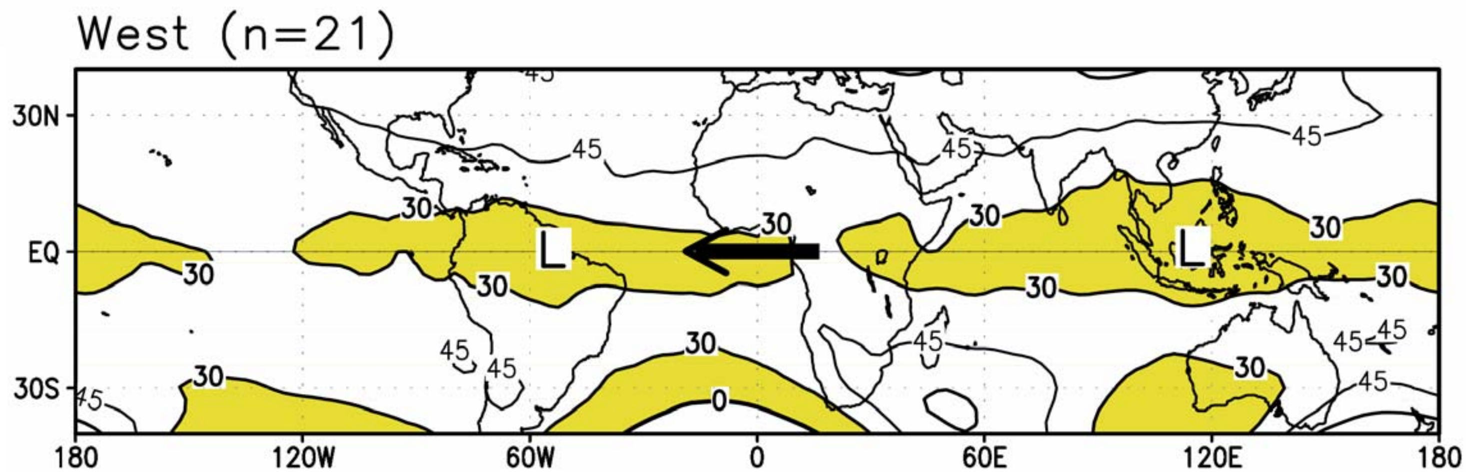


30-hPa heights, solar max – solar min, (Jul + Aug)/2

anomalous wind from the west in solar max, i.e. weaker QBO/East in solar max

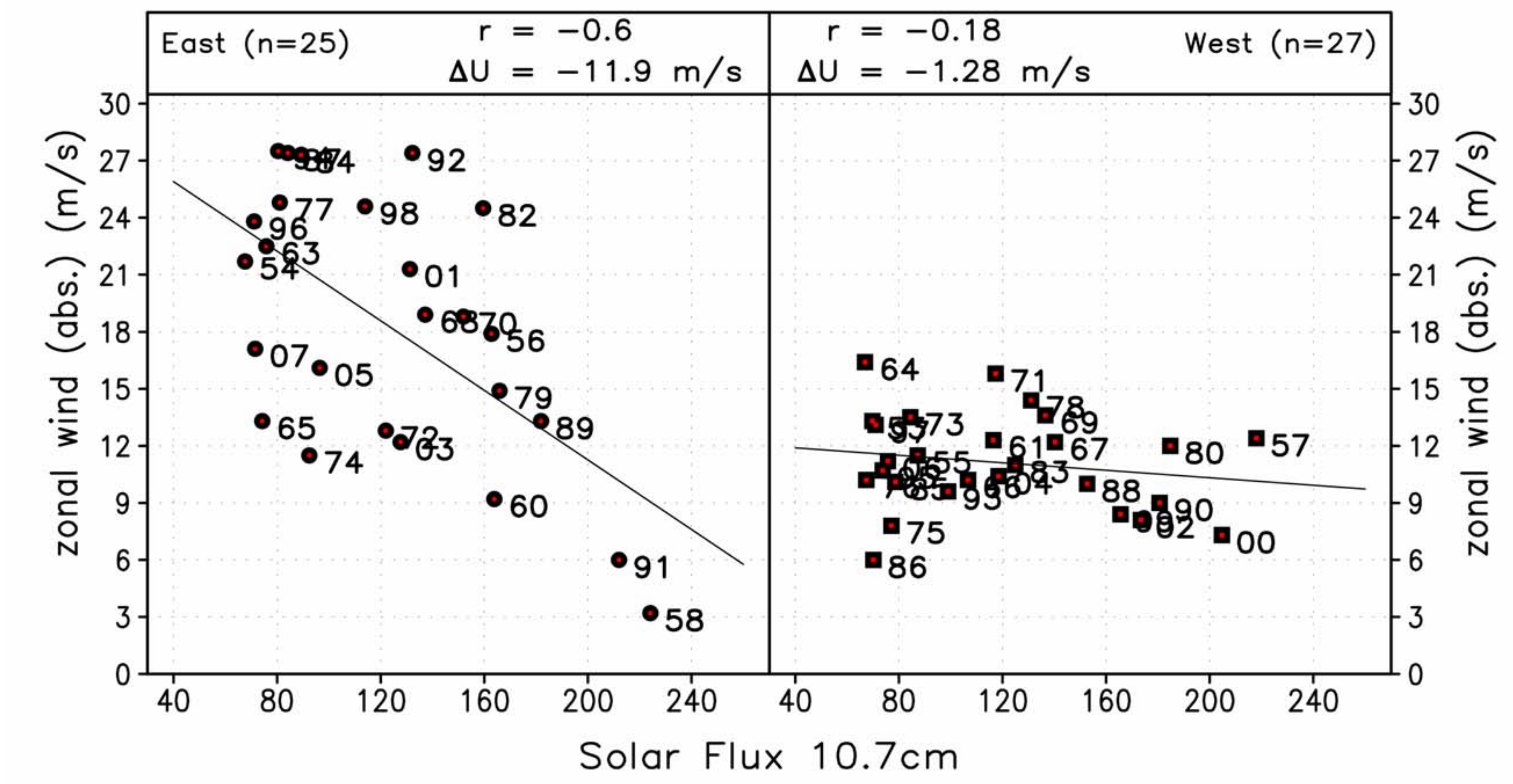


anomalous wind from the east in solar max, again weaker QBO/West in solar max



Scatter diagrams of the zonal wind (m/s) over the equator at (40+50 hPa)/2 in July (absolute values) against the 10.7 cm solar flux.
Period: 1953 – 2007 (n = 55, r = 0.07, Data set Fu-Berlin)
Left: years in the east phase of the QBO (n = 25).
Right: west phase

The QBO is weaker in solar max and stronger in solar min!



The <u>Constructed Annual Mean</u>

of the differences between

solar max and solar min for

the 30-hPa temperature

and

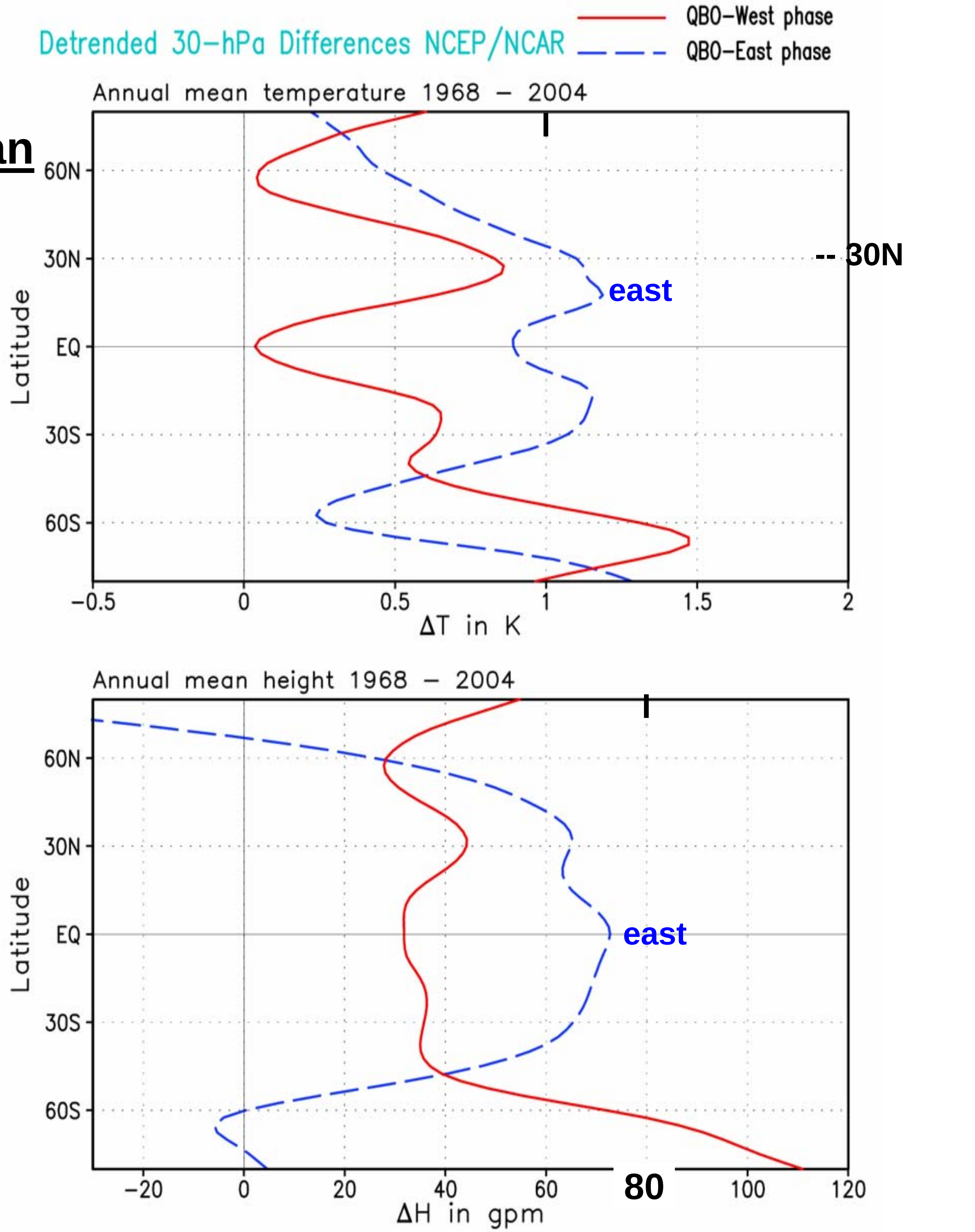
for the 30-hPa height,

separately for the

QBO east and west phases

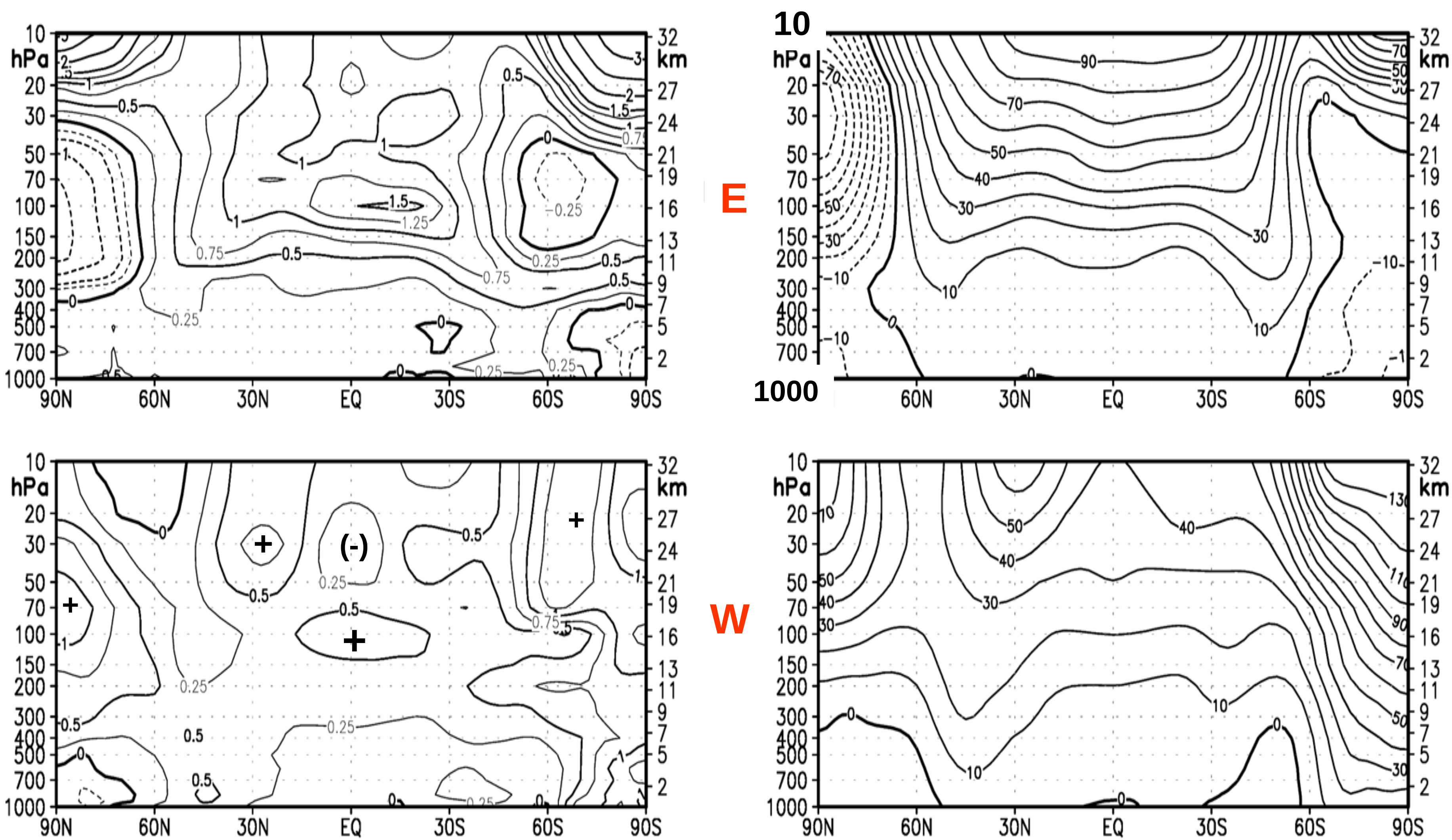
(1968 – 2004)

(QBO/east is weaker in max)



The Constructed Annual Mean Differences,
(solar max - solar min), separately for QBO east and west

Temperature differences (K) **Height differences (m)**



solar min **(H+T)**

QBO east is **stronger**

and

polar vortex is

warmer/weaker

QBO west is **stronger**

and

polar vortex is

stronger/ colder

But:

solar max

QBO east and west are weaker in max and the condition of the polar vortex is opposite to solar min (and to H+T)

Weaker QBO in Solar Max

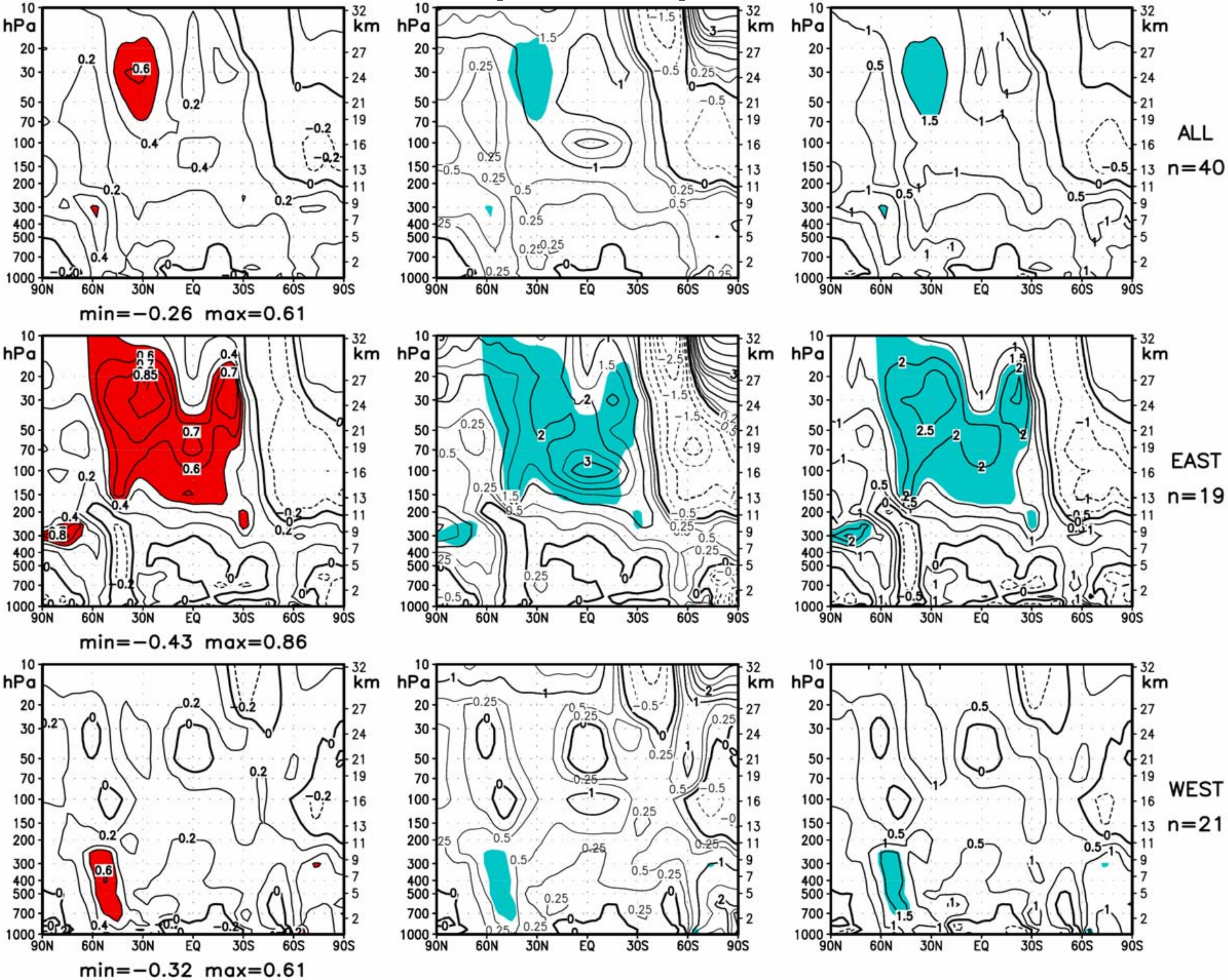
Thank you for your attention

July: **correlations** **T (max-min)** **standardized**

all

east

west



(1968 – 2007)