Imperial College London

Trends in, and influences on, the vertical structure and seasonal evolution of the Antarctic polar vortex

Joanna D. Haigh, Imperial College London, UK
Howard K. Roscoe, British Antarctic Survey, Cambridge, UK

Focus

- Seasonal evolution of Antarctic polar vortex: definition of final warming date
- Long-term variations in polar temperatures, SAM: role of polar ozone, influence of other factors (QBO, solar variability, volcanic aerosol, ENSO)

Data

- Radiosonde temperatures 100, 70, 50, 30 hPa:
  Halley (1957-2007), South Pole (1961-2007)
  (twice) daily (with gaps)

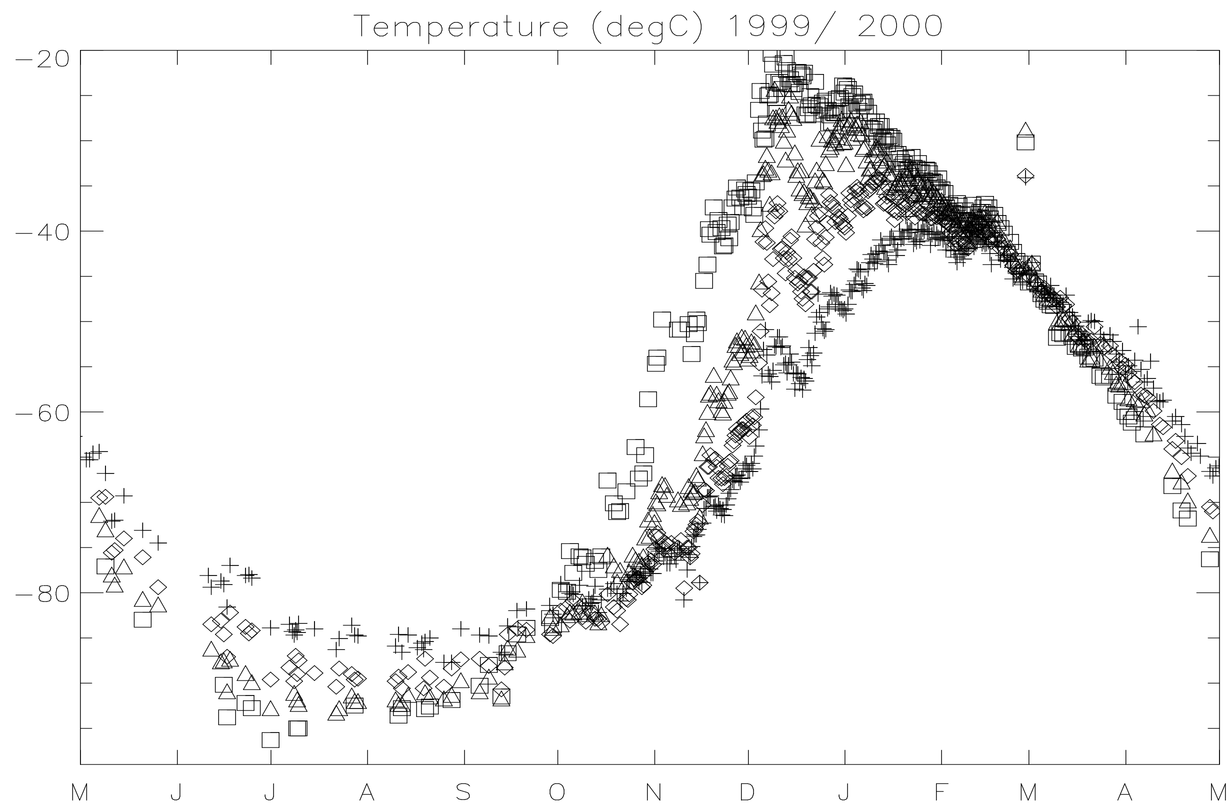
- NCEP Reanalysis: temperatures 700-30hPa
  60-90°S average, monthly means 1979-2005

- SAM index, time series of weighting of 1st EOF of NCEP geopotential heights 20-90°S, monthly means 1979-2005

- ERA-40 operational analysis pressure velocity at 500h Pa zonal mean, monthly means1958-2001

Vortex seasonal evolution

South Pole
radiosonde ascents
example
1999/2000



30 hPa
Δ 50
◊ 70
+ 100

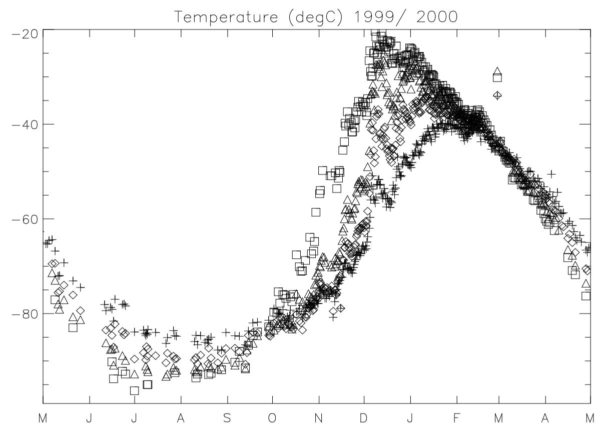
How to define the final warming date?

Waugh (1999), Zhou (2000), Karpetchko (2005): vortex spatial diagnostics

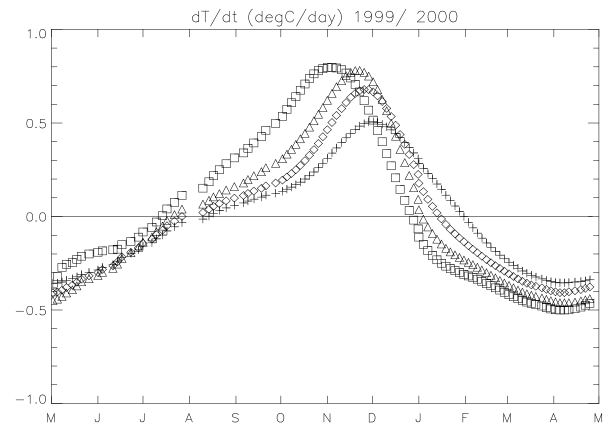
Black (2007): jet core zonal wind speed

All rely on thresholds – problem if in context of long term T trends ?

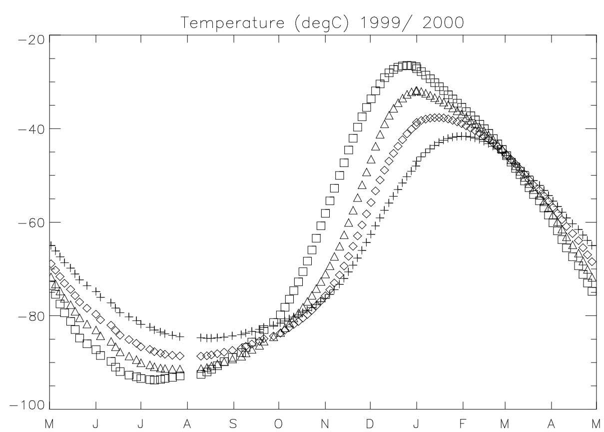
Final warming date definition



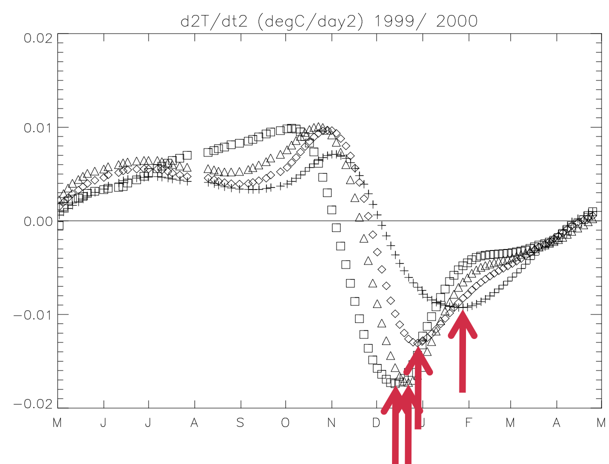
raw data



1st derivative (of smoothed data)



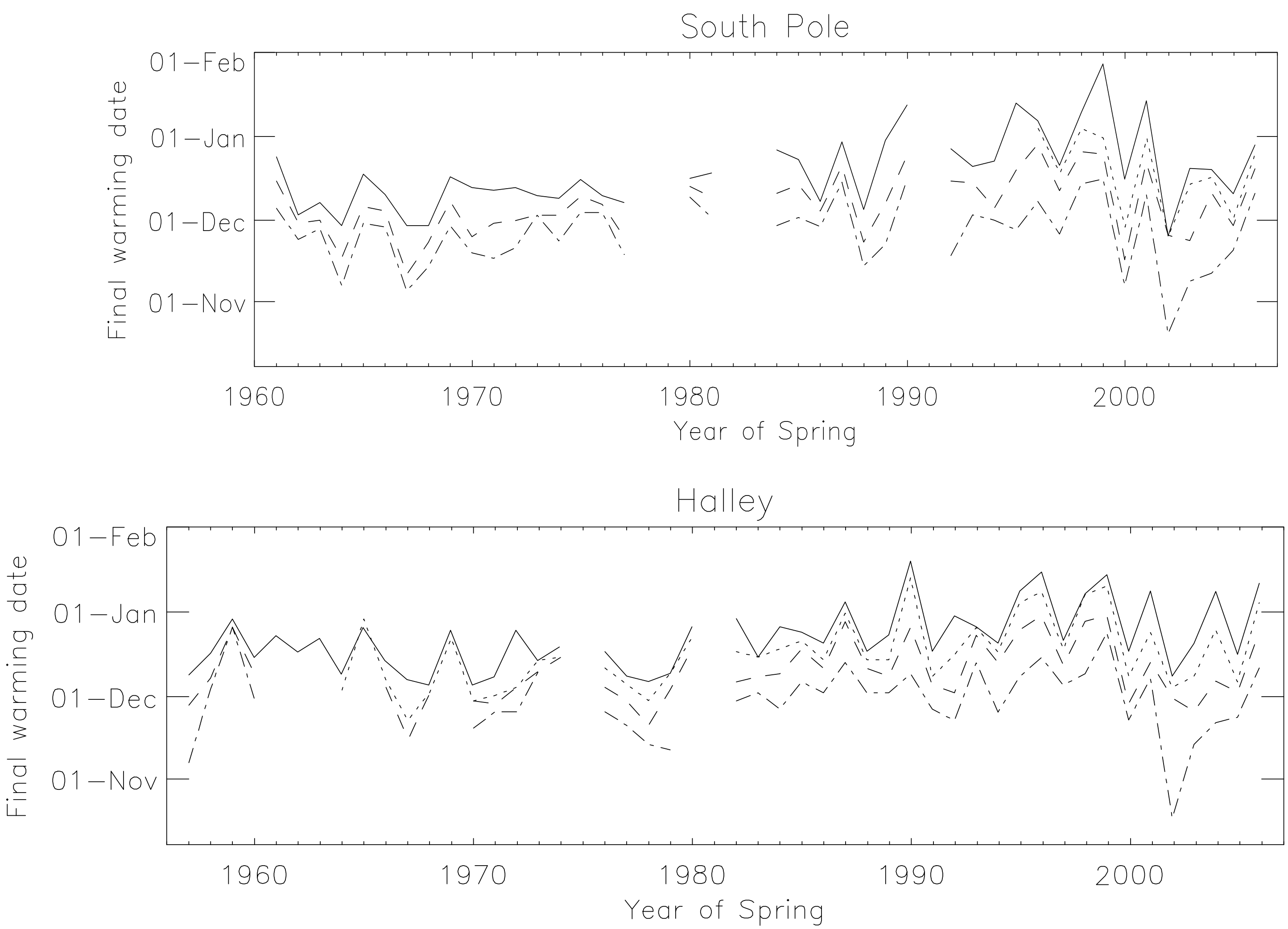
smoothed



2nd derivative

date of minimum

Final warming dates

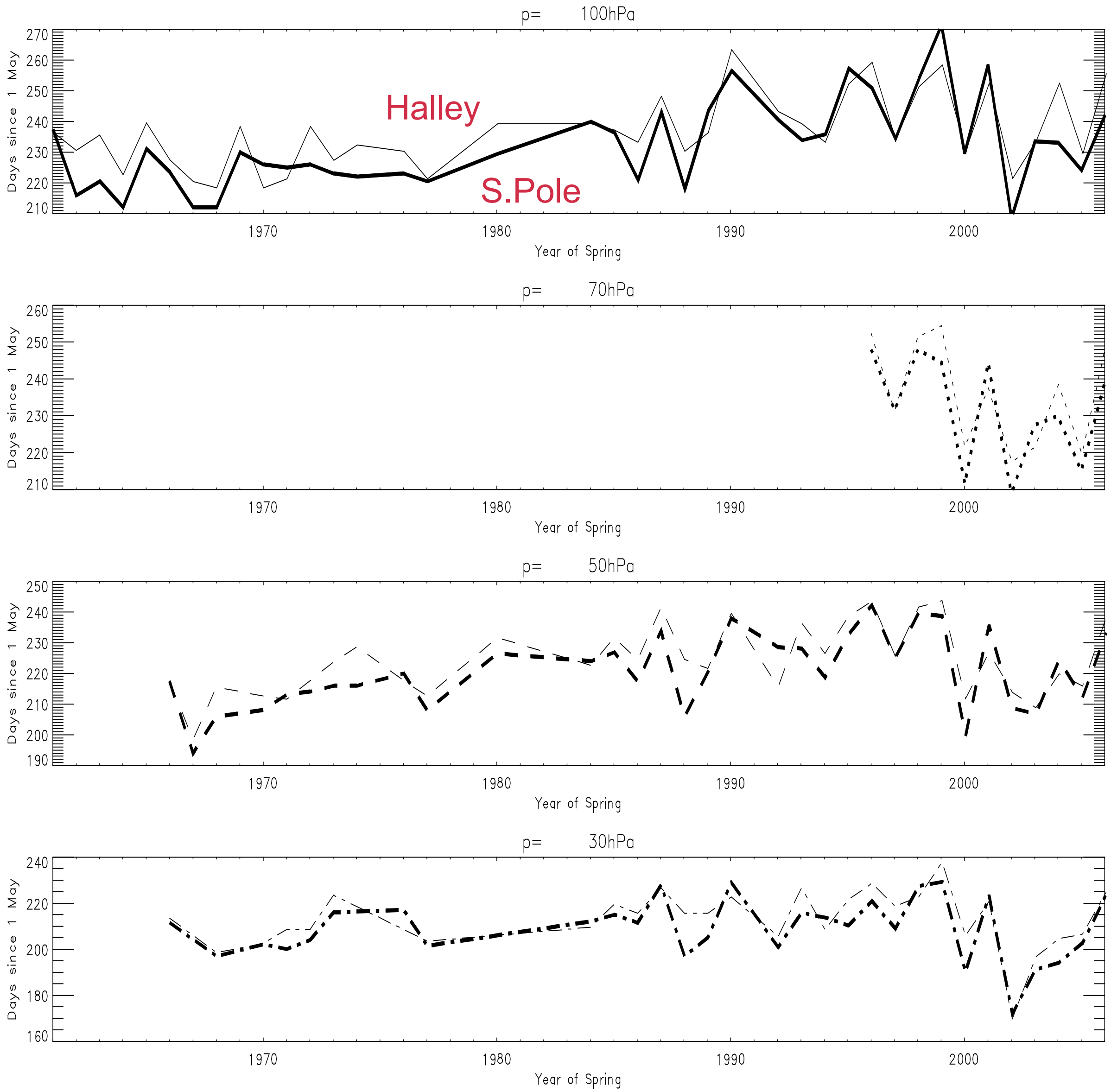


100 hPa
70
50
30

Mean difference
30-100 hPa:

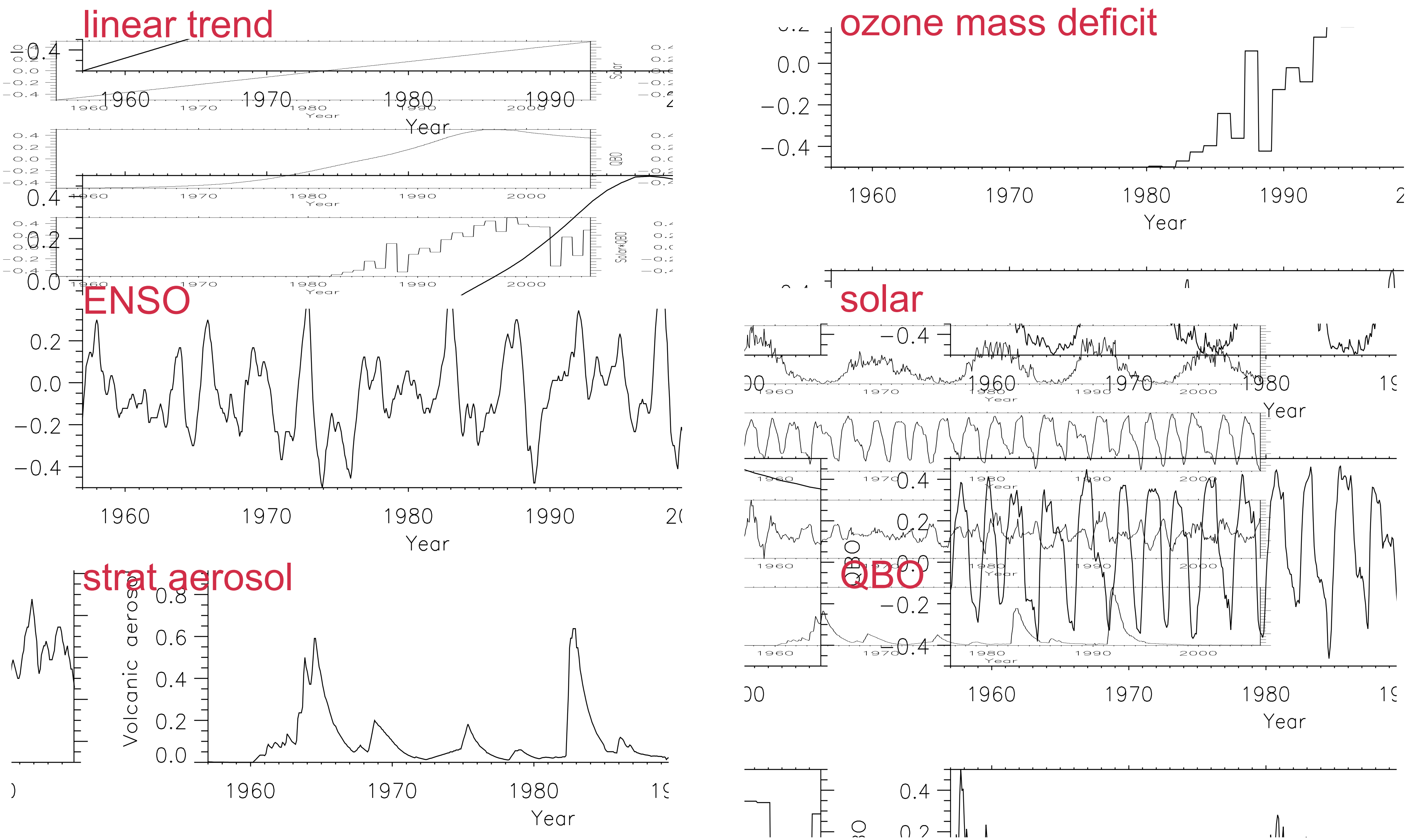
Ha 25.1 d (σ=10.8)
SP 23.4 d (σ=11.0)

Final warming dates (comparison of stations)

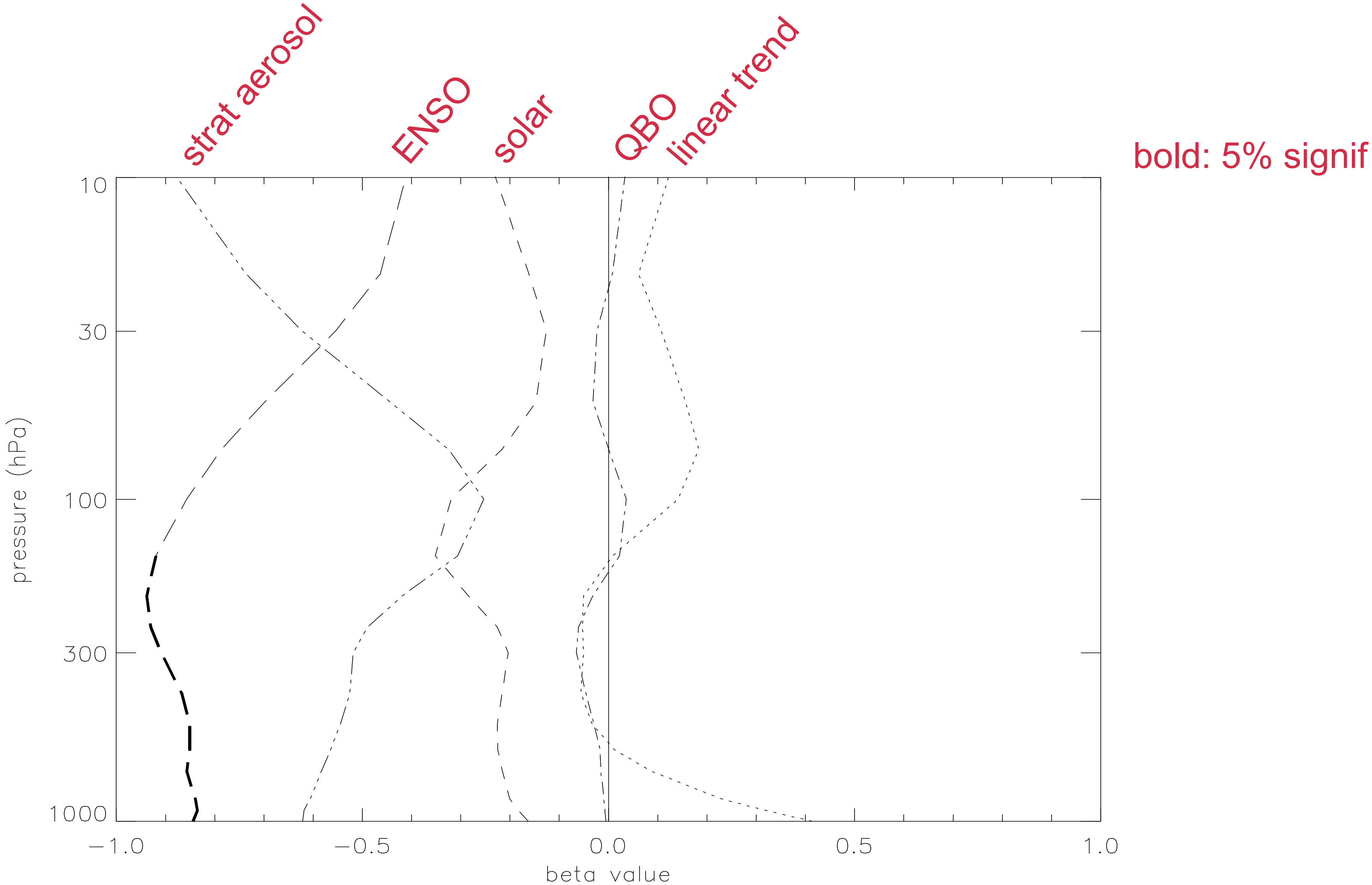


pressure	correlation coefficient
100	0.86
70	0.91
50	0.88
30	0.88

Multiple regression analysis: forcing indices

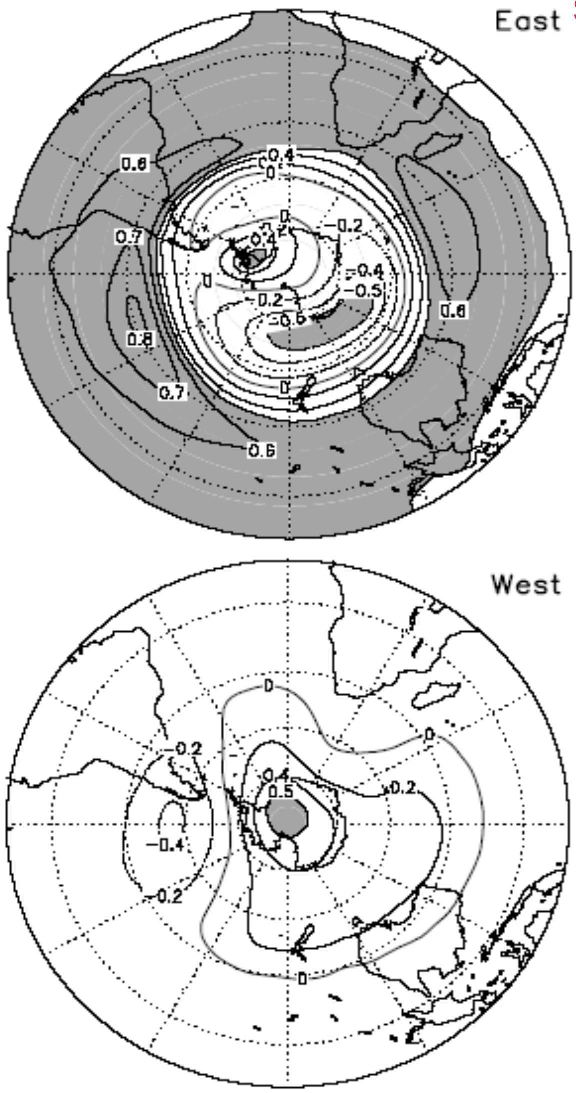


Regression results: de-seasonalised SAM index



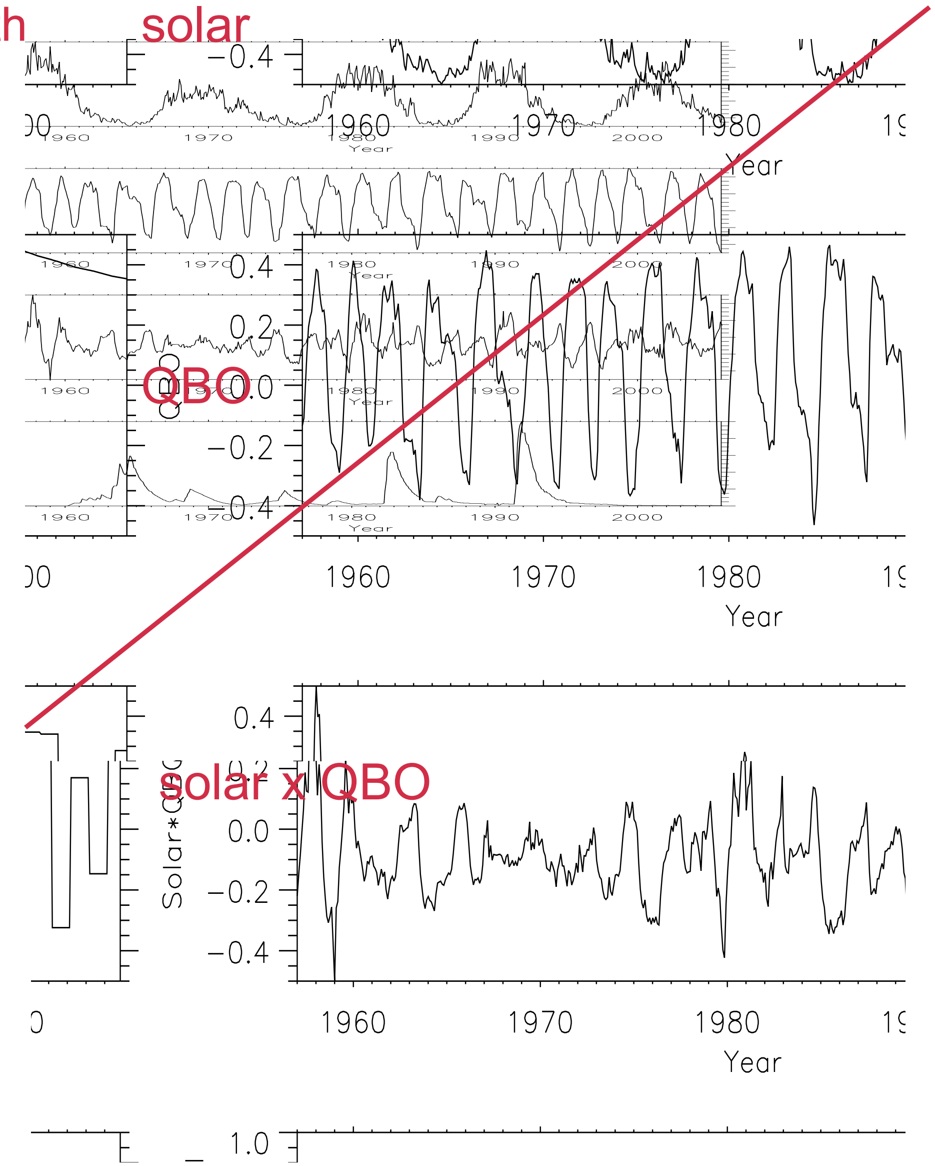
Multiple regression analysis: Solar*QBO index

Labitzke (2004) correlation of 30hPa Z with solar activity



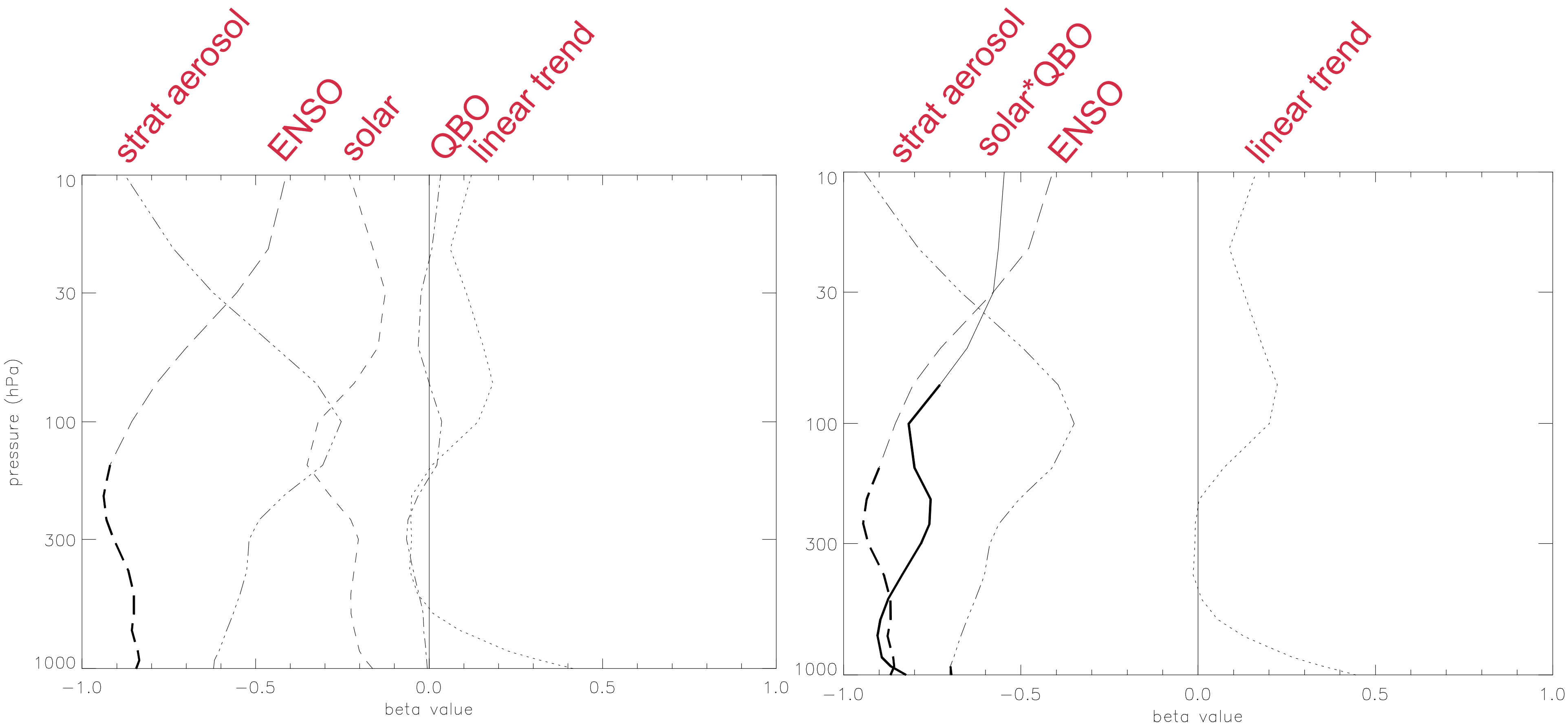
QBO E

QBO W

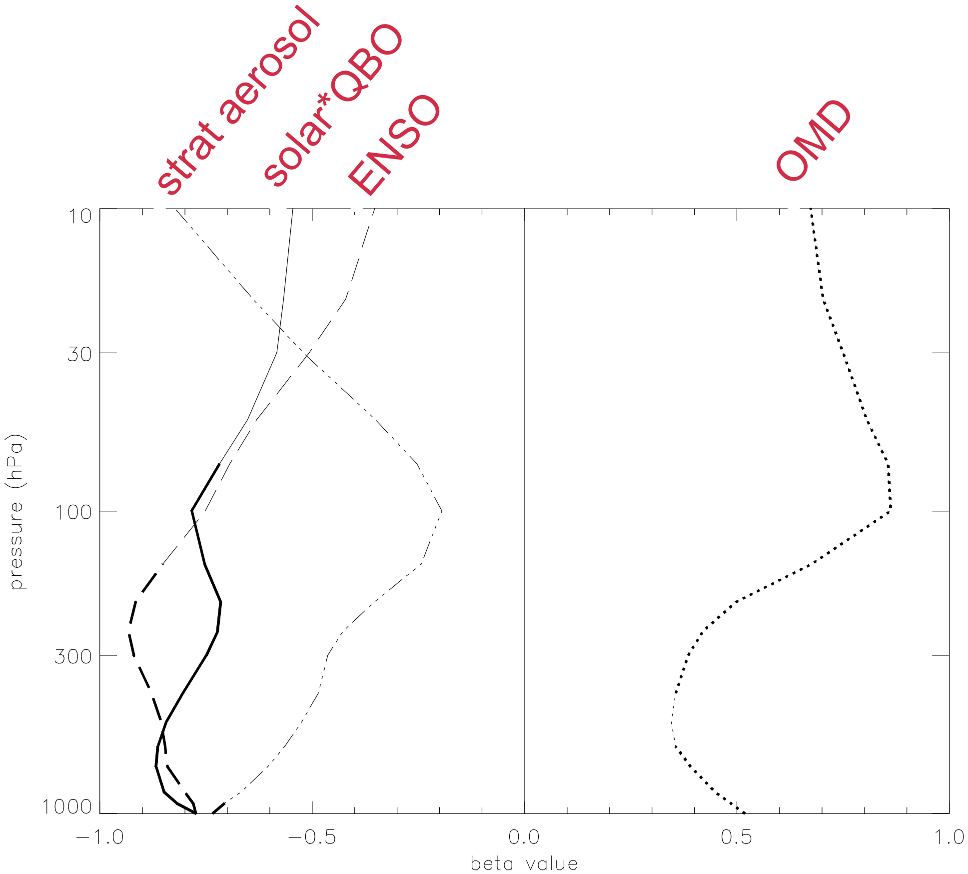


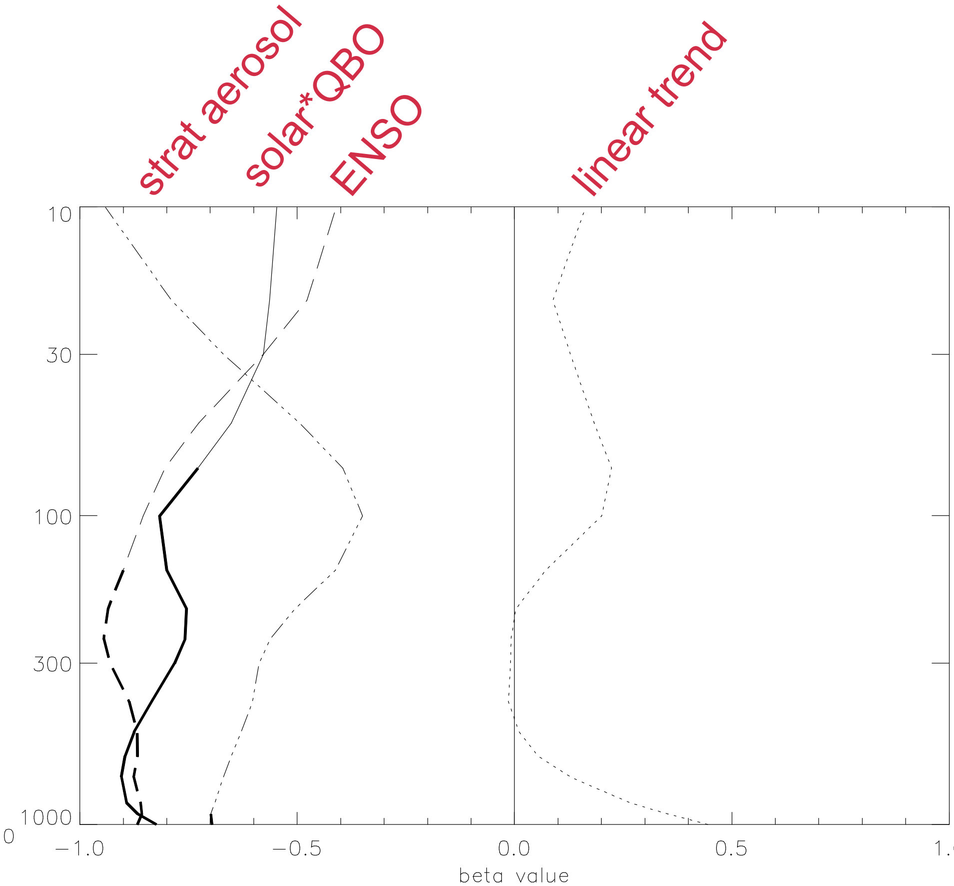
College London

Regression results (SAM): alternative indices

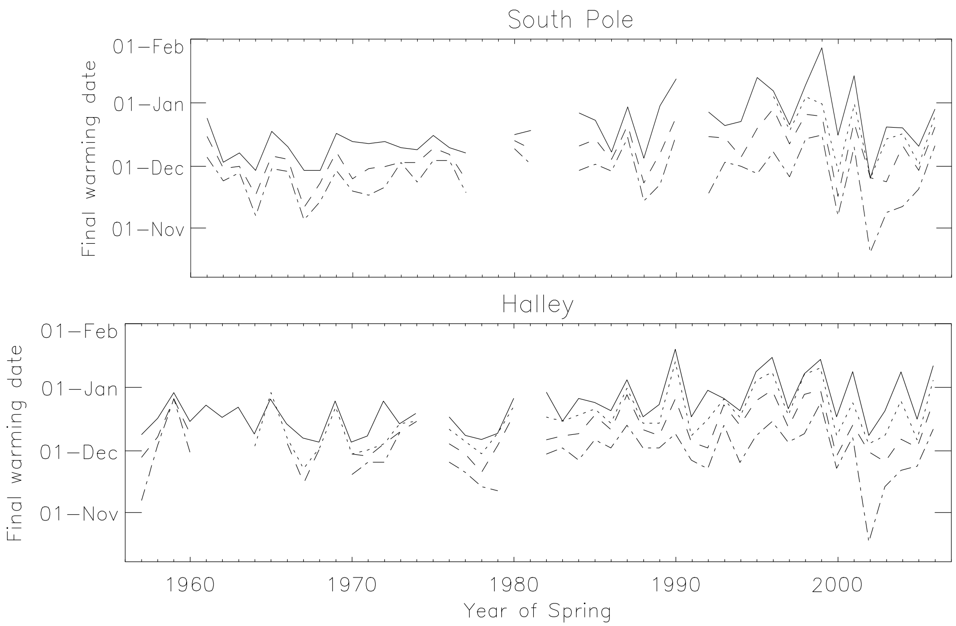


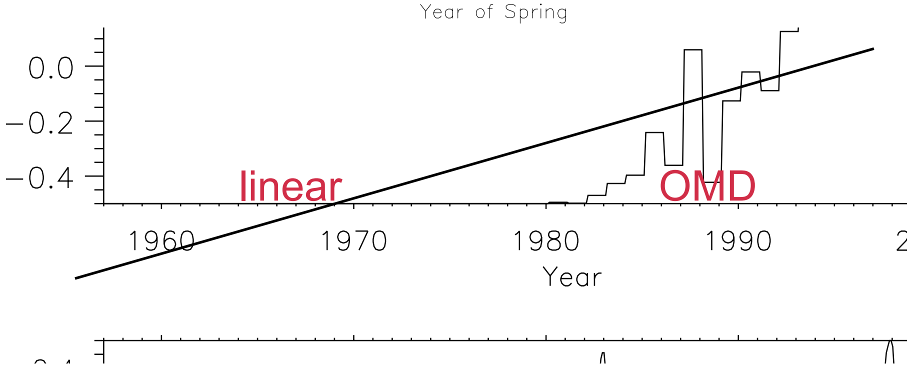
Regression results (SAM): alternative indices





Regression results:
final warming dates from radiosonde data





S.Pole

Pressure (hPa)	OMD		linear	
	Days (1998 cf pre-1980)	t-value	Days (over 49 years)	t-value
100	**29**	7.5	**32**	4.5
50	**16**	3.6	**17**	2.4
30	8	1.3	-1	0.2

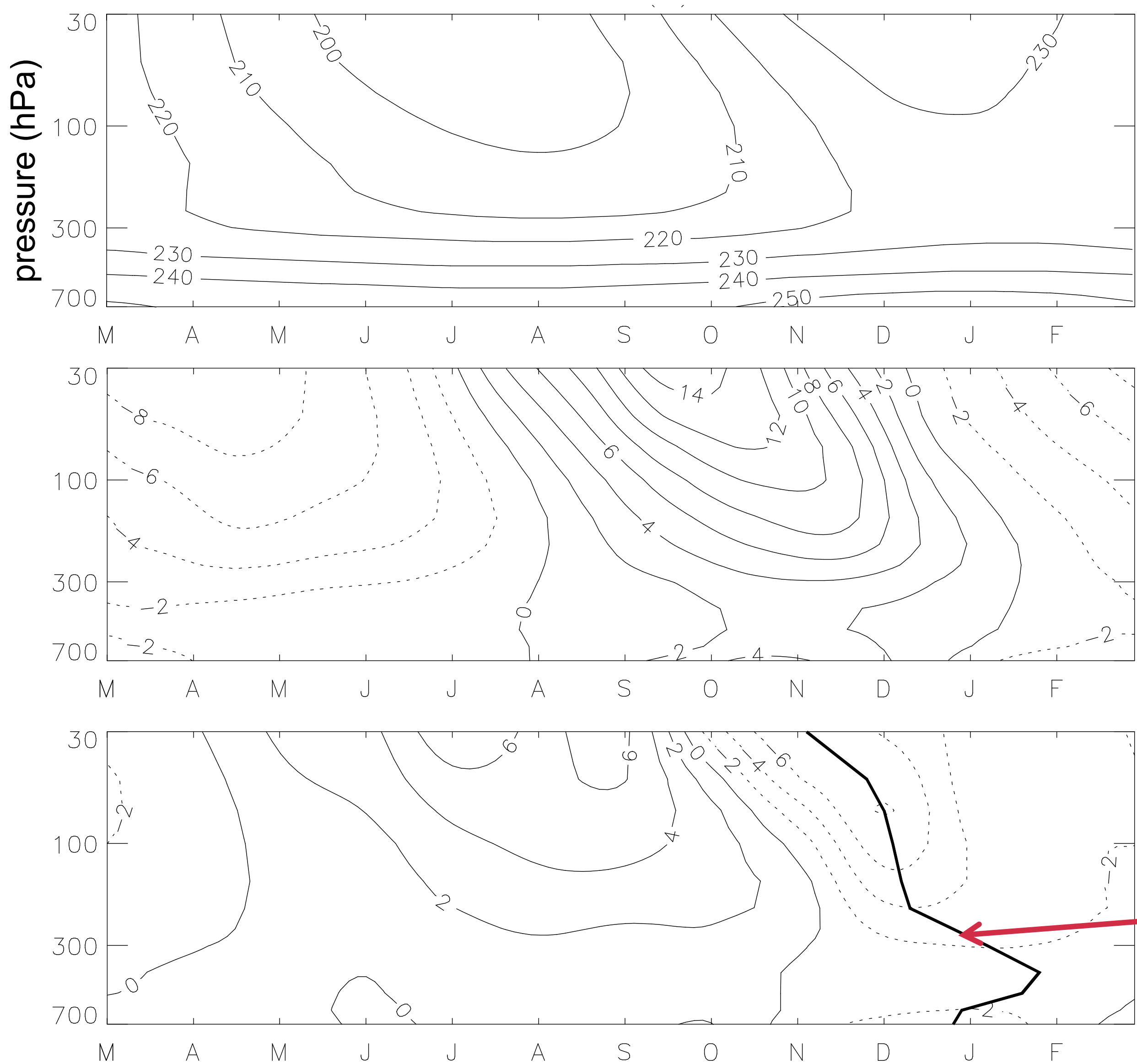
Halley

Pressure (hPa)	OMD		linear	
	Days (1998 cf pre-198 0)	t-value	Days (over 49 years)	t-value
100	**20**	5.9	**19**	3.8
70	**21**	4.4	**21**	2.6
50	**18**	3.0	13	1.5
30	**17**	2.3	2	0.2

bold = 5% signif

No other index produced significant results

Final warming dates:
monthly zonal mean NCEP temperatures 60-90°S



Mean 1979-2005

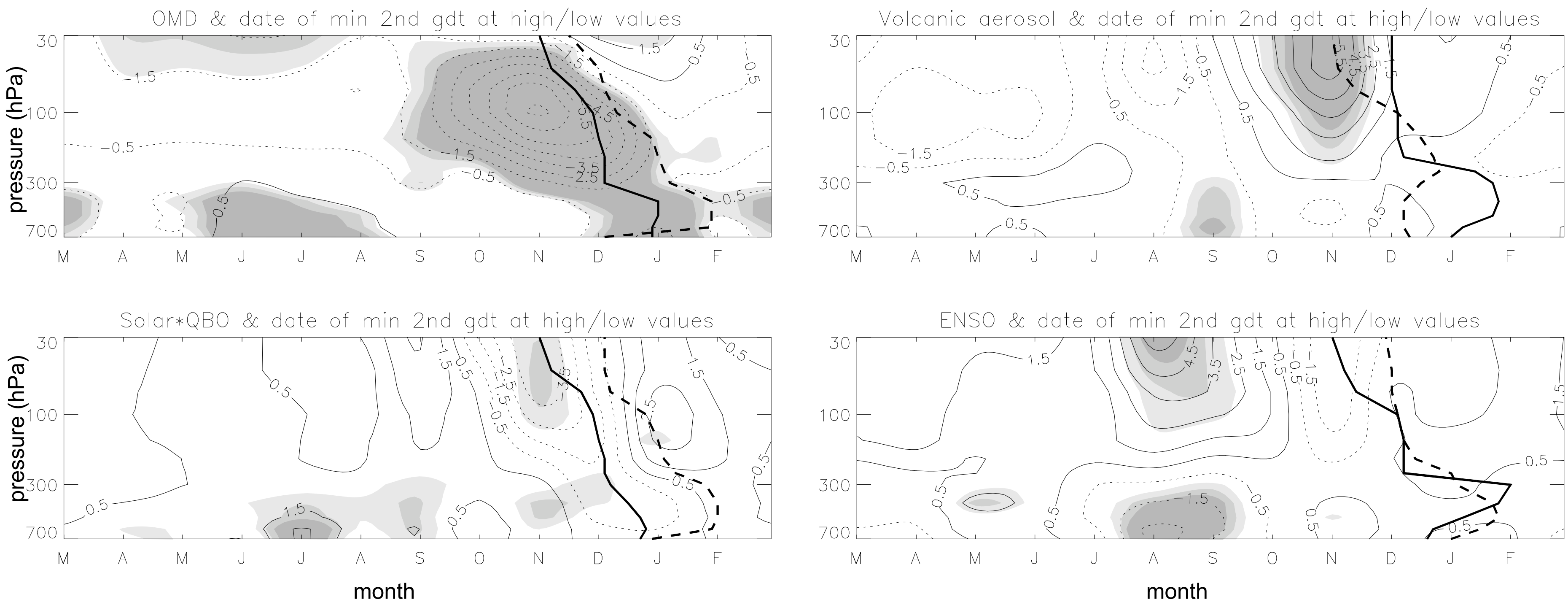
1st derivative
(K/month)

2nd derivative
(K/month/month)

date of minimum

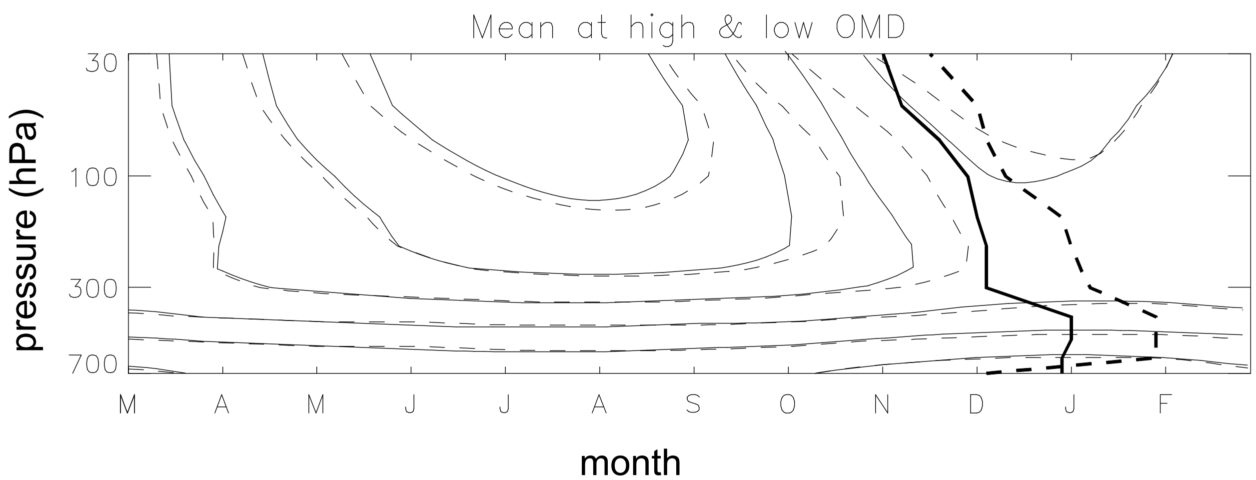
SPARC 3 Sep 2008

Regression results:
monthly zonal mean NCEP temperatures 60-90°S



Contours: signal derived for given forcing index
Shading: 5,10, 20% significance levels
Bold lines: "final warming date" at high (dashed) and low (solid) value of index

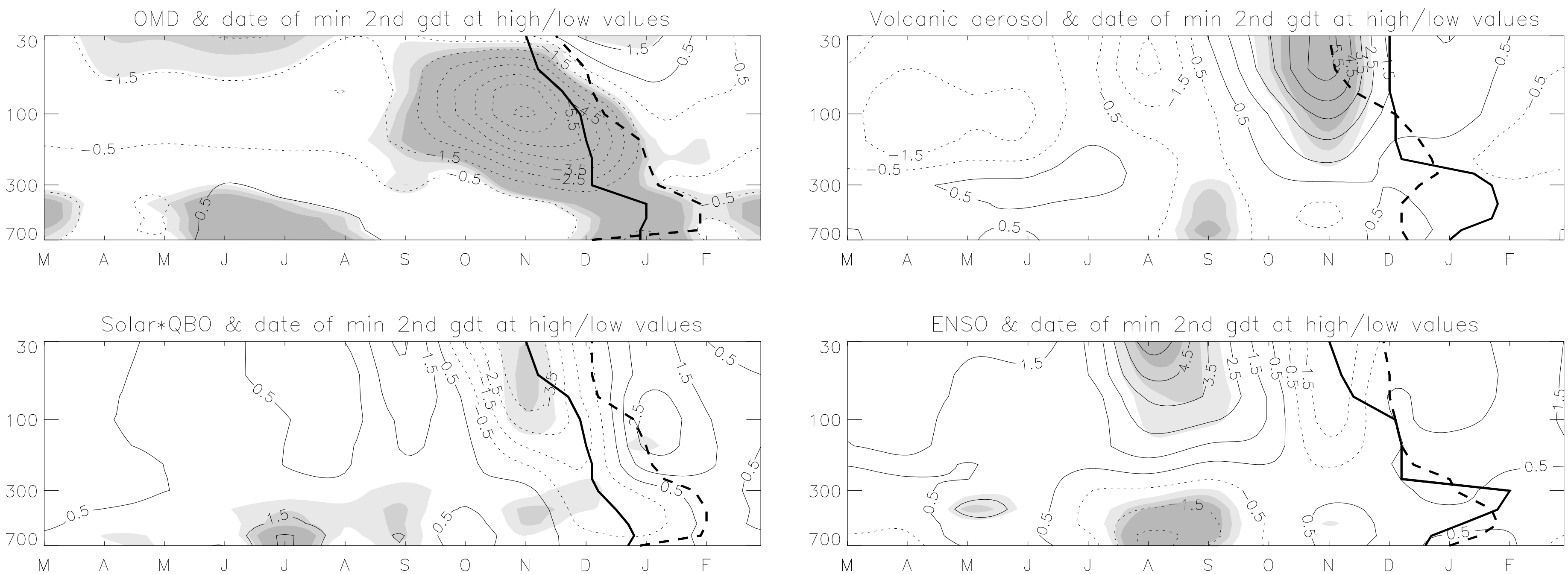
Temperatures at high and low OMD states



Contours: temperature at high (dashed) and low (solid) value of index
Bold lines: “final warming dates”

Higher values of OMD result in later warming from middle stratosphere through to mid-troposphere

Regression results:
monthly zonal mean NCEP temperatures 60-90°S

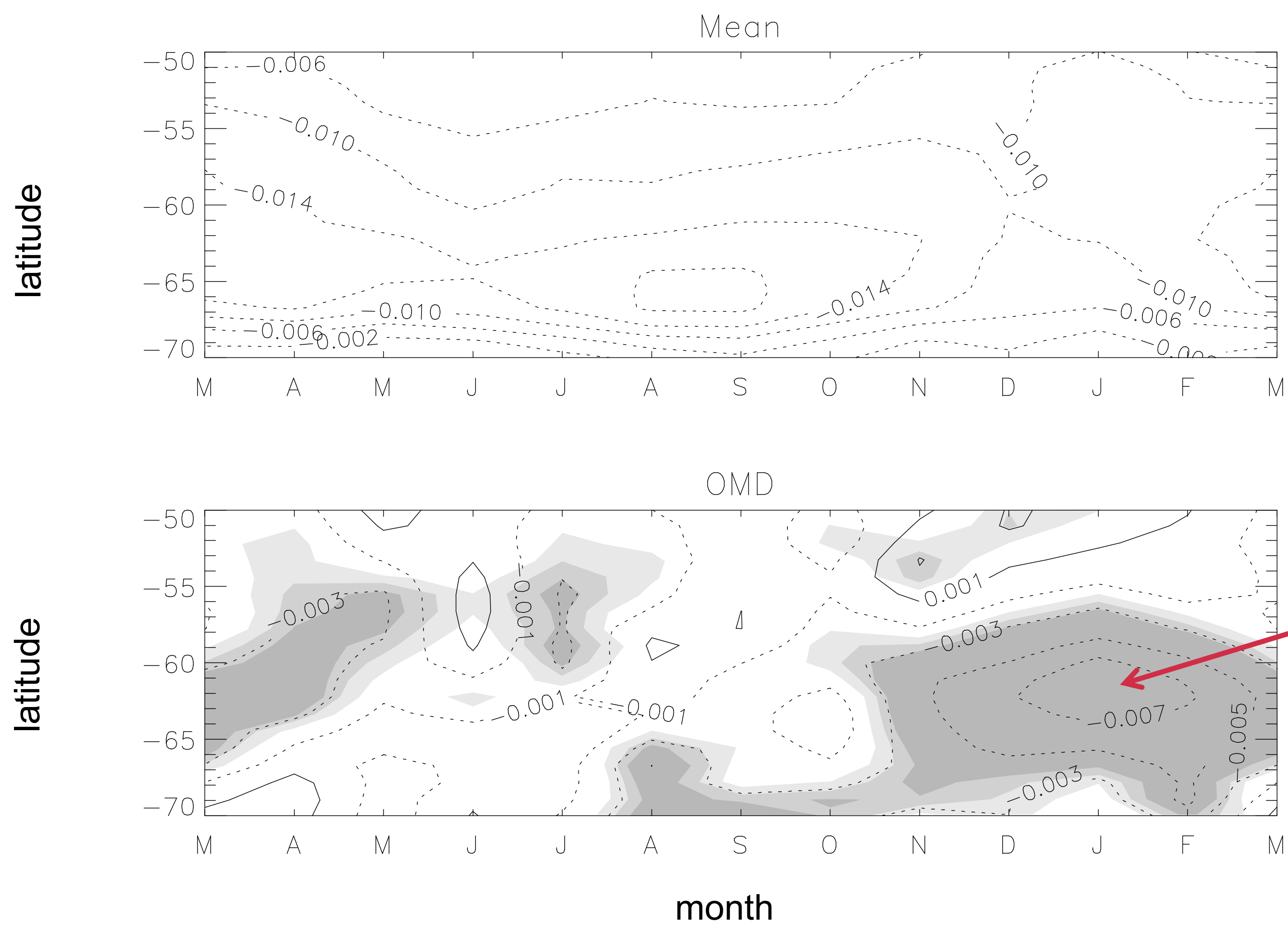


Contours: signal derived for given forcing index

Shading: 5,10, 20% significance levels

Bold lines: “final warming date” at high (dashed) and low (solid) value of index

OMD signal in zonal mean pressure velocity (500 hPa)



ω (Pa s^{-1})

Delay in Spring weakening

Summary

- Simple definition of final warming date based on temporal evolution of temperature.
- Final warming dates show response to ozone recovery.
- Long-term trends more strongly related to stratospheric ozone depletion than to linear climate change.
- Stronger response to compound solar*QBO index than to these factors separately.
- Delay in final warming date due to ozone depletion (and also to solar*QBO) from mid-stratosphere to mid-troposphere:

  not downward propagation of an anomaly but delay in normal behaviour (but need to understand that!)