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

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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 means 1958-2001
South Pole radiosonde ascents example 1999/2000

- 30 hPa
- Δ 50
- ◊ 70
- + 100

How to define the final warming date?
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

South Pole

Mean difference
30-100 hPa:

100 hPa
70
50
30

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

3 Sep 2008
Final warming dates (comparison of stations)

<table>
<thead>
<tr>
<th>Pressure</th>
<th>Correlation Coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>0.86</td>
</tr>
<tr>
<td>70</td>
<td>0.91</td>
</tr>
<tr>
<td>50</td>
<td>0.88</td>
</tr>
<tr>
<td>30</td>
<td>0.88</td>
</tr>
</tbody>
</table>
Multiple regression analysis: forcing indices
Regression results: de-seasonalised SAM index

bold: 5% signif
Labitzke (2004) correlation of 30hPa Z with solar activity

Multiple regression analysis: Solar*QBO index
Regression results (SAM): alternative indices
Regression results (SAM): alternative indices
Regression results: final warming dates from radiosonde data

<table>
<thead>
<tr>
<th>Pressure (hPa)</th>
<th>OMD</th>
<th>linear</th>
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<tbody>
<tr>
<td></td>
<td>Days (1998 cf pre-1980)</td>
<td>t-value</td>
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<tr>
<td>100</td>
<td>29</td>
<td>7.5</td>
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<tr>
<td>50</td>
<td>16</td>
<td>3.6</td>
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<tr>
<td>30</td>
<td>8</td>
<td>1.3</td>
</tr>
</tbody>
</table>

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)

Delay in Spring weakening

ω (Pa s\(^{-1}\))
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!)