On the onset of polar mesospheric cloud seasons

Susanne Benze[1,2], Cora E. Randall[1,2], Bodil Karlsson [3], V. Lynn Harvey[1], Matthew T. DeLand[4], Gary E. Thomas[1], Eric P. Shettle[4]

[1] Laboratory for Atmospheric and Space Physics, Univ. CO, Boulder, Colorado, USA
[2] Department of Atmospheric and Oceanic Sciences, Univ. CO, Boulder, Colorado, USA
[3] Department of Meteorology, Stockholm University, Stockholm, Sweden
[4] Science Systems and Applications, Inc., Lanham, Maryland, USA

Benze et al. [2012], On the onset of polar mesospheric cloud seasons as observed by SBUV, *JGR*, 117, D07104, doi:10.1029/2011JD017350.

Motivation: "dynamic" control

Smith *et al.* [2010], Lossow *et al.* [2012], Karlsson *et al.* [2011], Gumbel and Karlsson [2011]:

Antarctic O_3 hole influences the SH stratospheric winds.
SH stratospheric winds control timing of SH PMC onset dates.

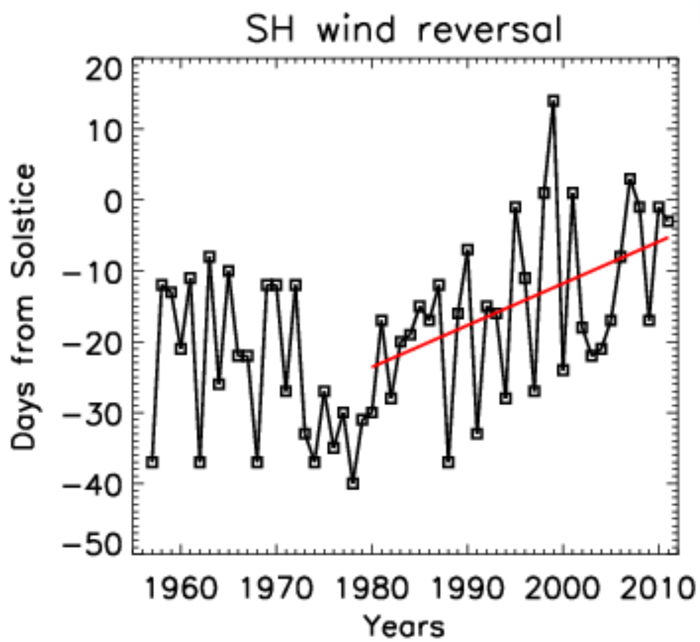
⇩

Does Antarctic O_3 hole control …

- **Season-to-season variability of SH PMC onset dates?**
- **Long-term trends in SH PMC onset dates = "dynamical" trends?**

What about "chemical" trends (CO_2, CH_4)?

SH wind reversal – trends?



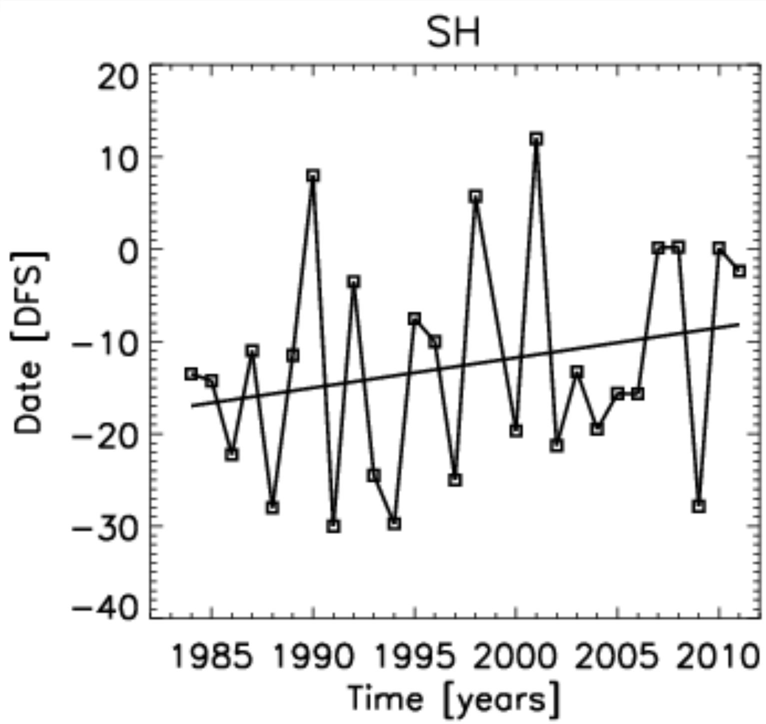
Daily mean stratospheric zonal mean zonal wind:

- ERA-40 and MetO
- 50 hPa and same hem. 65° lat
- 5-day running average

Wind "reversal": day of final decrease of the mean zonal wind below 10 m/s.

- After 1980: 5.9 ± 2.0 days/decade
- Before 1980: no significant trend

SH PMC onset



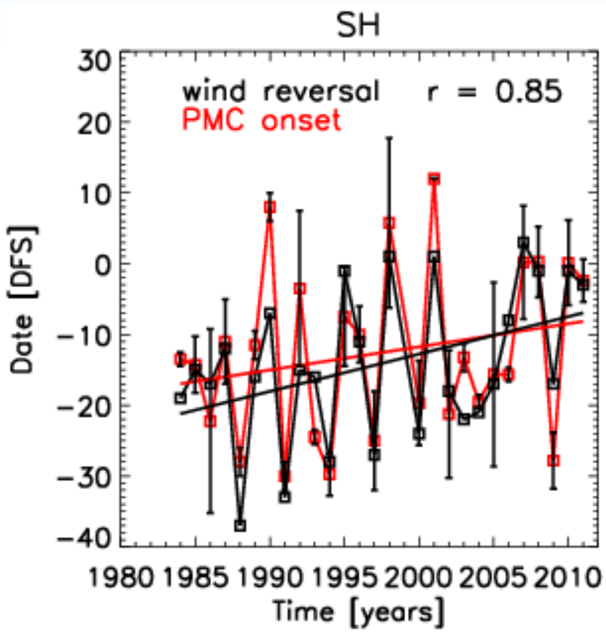
SBUV frequency between 75° and 85° lat, asc and desc node separated.

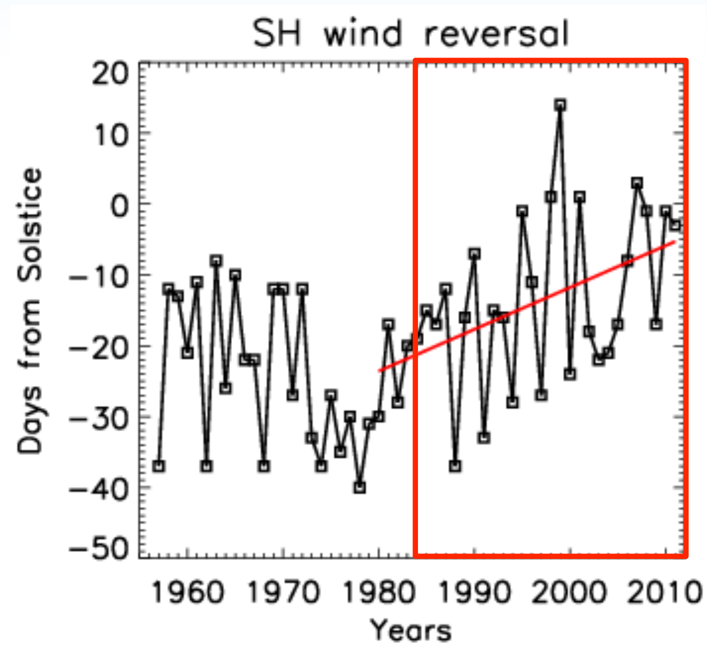
Season start: day on which 5-day mean frequency is above 1.5% for at least seven consecutive days for the first time.

28 continuous years of SBUV data spanning more than two solar cycles in both hemispheres

Linear trend in SH PMC onset: 3.3 ± 2.8 days/decade

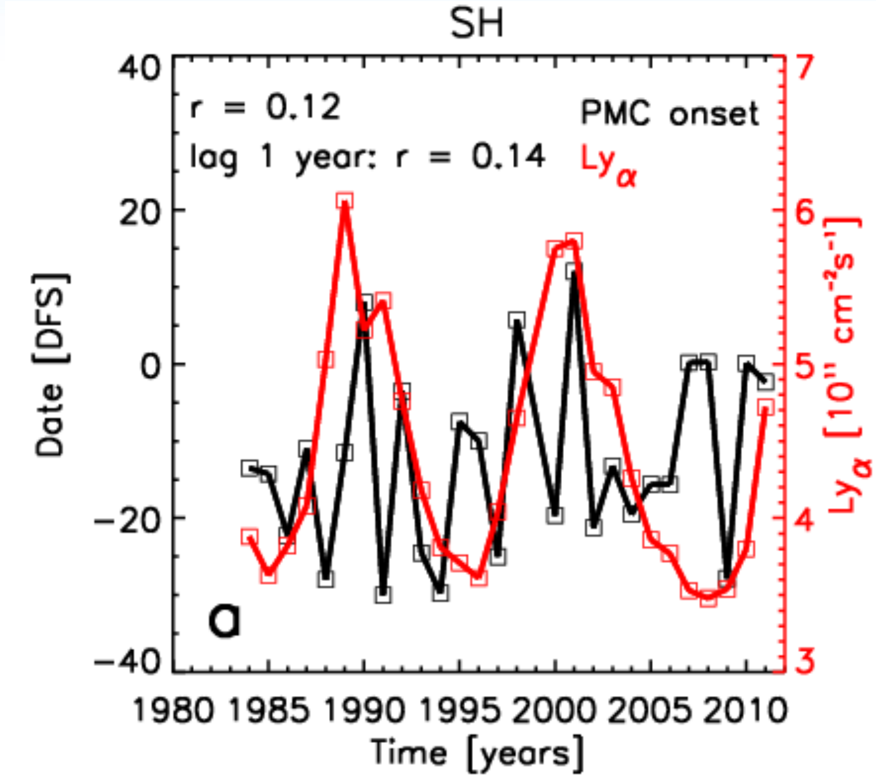
SH PMC onset: correlations and trends





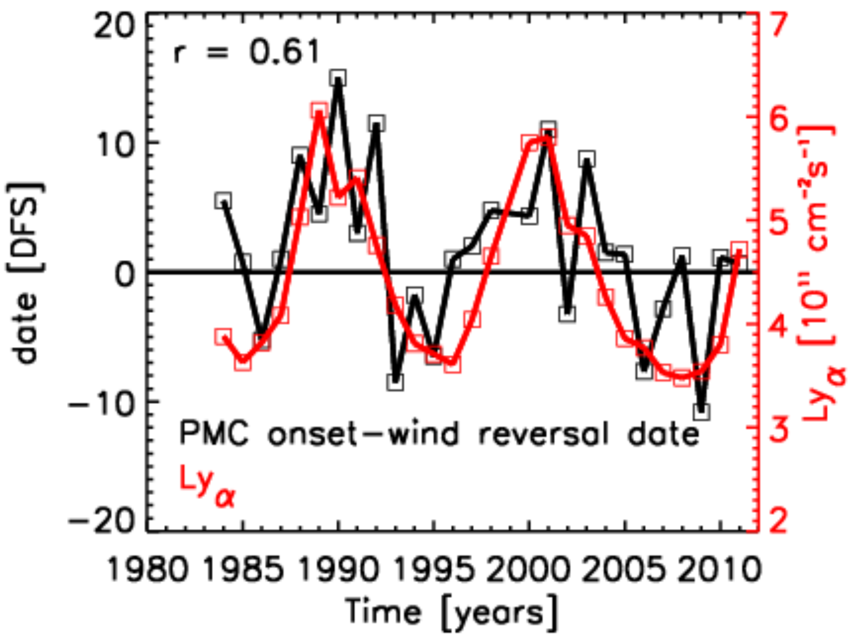
- **SH PMC season onset dates and wind reversal dates are highly correlated: r = 0.85.**
- **Trend in wind reversal after 1984 bigger (5.3 ± 2.3 days/decade) than trend in PMC onset dates (3.3 ± 2.8 days/decade)**
- **"Dynamical" trend counteracting "chemical" trend?**

SH PMC onset & solar cycle



SH: small correlation: r = 0.12, but low frequency variation?

SH PMC onset & solar cycle

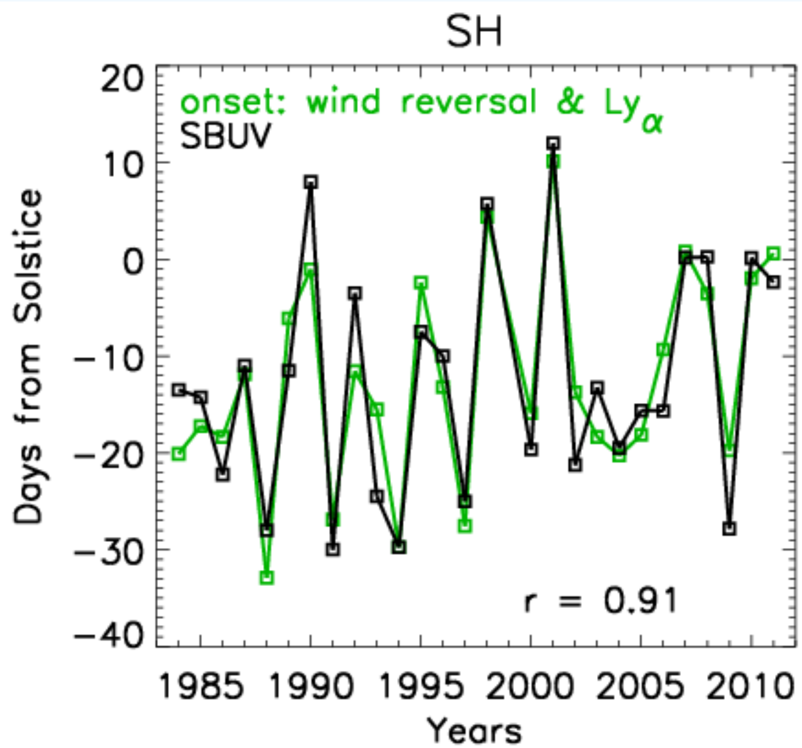


Black: SH PMC onset – SH wind reversal date
Red: solar cycle

Residual (onset - wind) is correlated with solar cycle, r = 0.61.

Variations in SH PMC season onset date dominated by timing of stratospheric wind reversal, with additional modulation from the solar cycle.

SH PMC onset regression



D_{on} = a·W + b·Lyα

D_{on} = regressed SH PMC onset date

W = SH stratospheric wind reversal date

a = 1.03 ± 0.10 days per day delay in the wind reversal

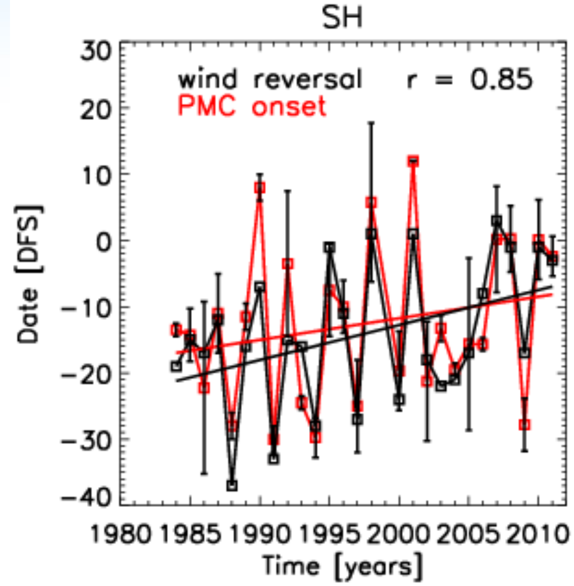
b = 5.00 ± 1.34 days per unit of Ly-α equal to 10^{11} $cm^{-2}s^{-1}$

What does that mean?

a=1.03 ± 0.10 days per day delay in the wind reversal

⇨ For every day delay in the wind reversal, the season onset date is delayed by 1.03 days

⇨ Range of wind reversal dates: ~40 days

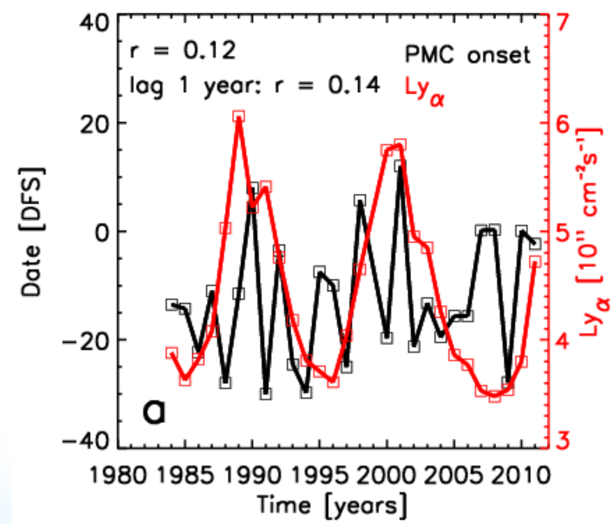


Delay of SH PMC onset by 40 ± 4 days through delay in SH wind reversal only

b=5.00 ± 1.34 days per unit of Ly-α

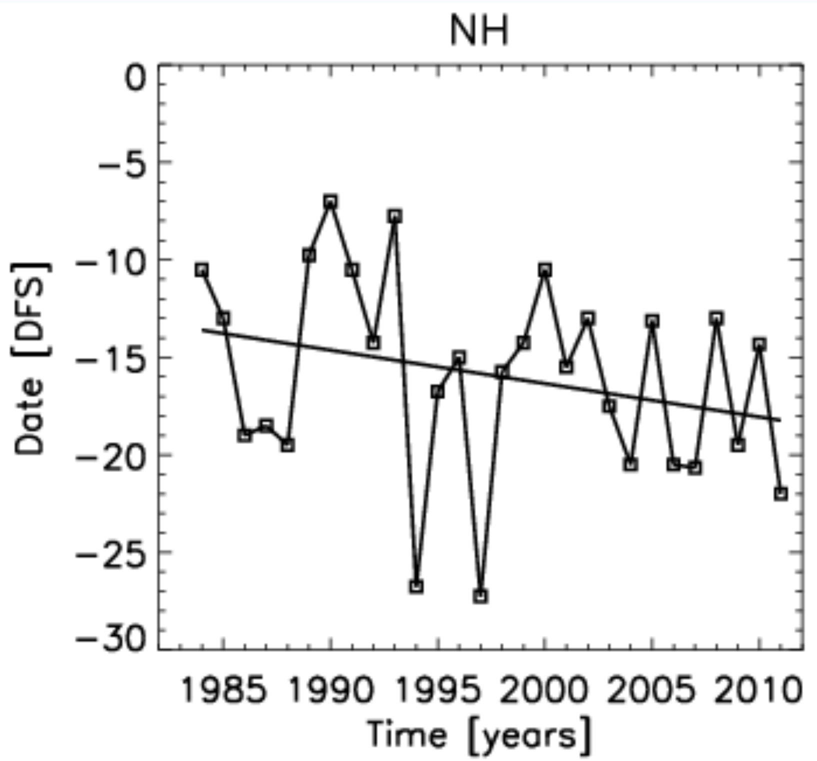
⇨ For every increase in Ly-α by 10^{11} $cm^{-2}s^{-1}$, the season onset date is delayed by 5.0 days

⇨ Range of Ly-α: ~$2 \cdot 10^{11}$ $cm^{-2}s^{-1}$



Delay of SH PMC onset by ~10 ± 3 days at solar max compared to solar min

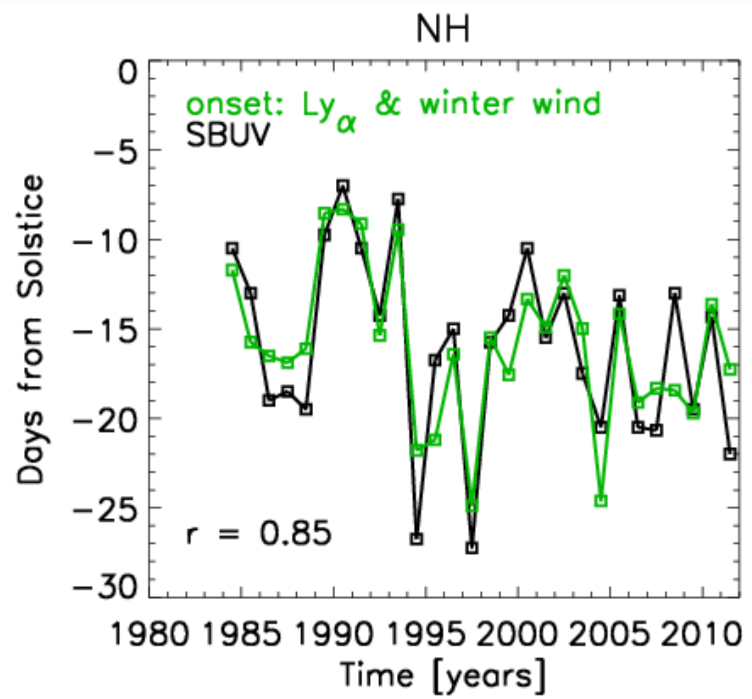
NH PMC onset



NH stratospheric winds reverse two months before PMC onset (not shown)
→ no effect

Linear trend in NH PMC onset: -1.7 ± 1.2 days/decade

NH PMC onset regression



D_{on} = c·W + d·Lyα

D_{on} = regressed NH PMC onset date

W = SH winter stratospheric wind [m/s]

c = 0.72 ± 0.13 days per m/s

d = 3.51 ± 0.79 days per unit of Ly-α equal to 10^{11} $cm^{-2}s^{-1}$

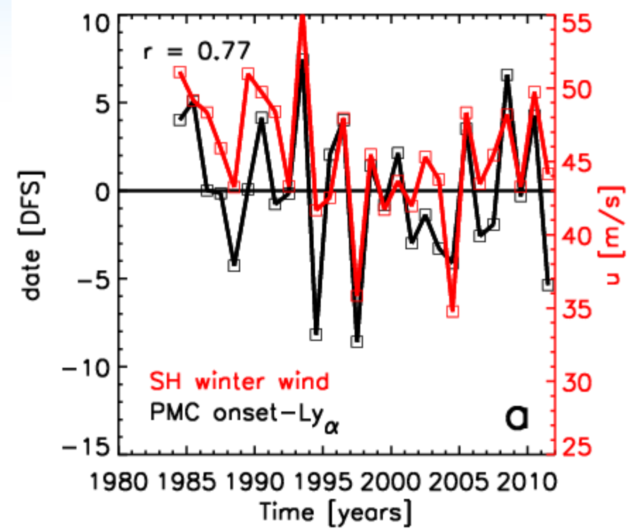
What does that mean?

c = 0.72 ± 0.13 days per m/s

⇨ For every increase in opposite hemisphere winter wind strength by 1 m/s, the NH season onset date is delayed by 0.72 days.

⇨ Range of SH winter wind: ~21 m/s

Delay of NH PMC onset by ~15 ± 3 days at maximum wind speeds compared to minimum wind speeds

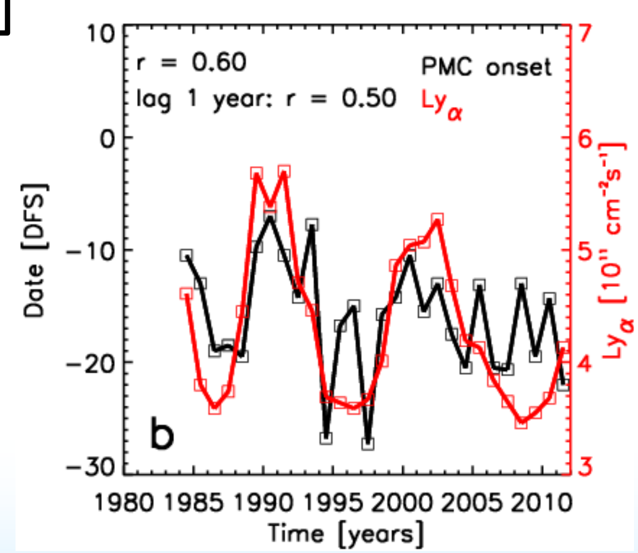


d = 3.51 ± 0.79 days per unit of Ly-α

⇨ For every increase in Ly-α by 10^{11} $cm^{-2}s^{-1}$, the season onset date is delayed by 3.51 days.

⇨ Range of Ly-α: ~ $2 \cdot 10^{11}$ $cm^{-2}s^{-1}$

Delay of NH PMC onset by ~7 ± 2 days at solar max compared to solar min



Summary I

Season-to-season variability in PMC onset dates strongly influenced by dynamics.

<u>Variability in NH PMC onset date</u>:

- **dominated by variability in SH *fall/winter* stratospheric wind speed, modulated by variability in solar cycle**
- **NH trend towards earlier PMC onset dates: "chemical" trend?**

<u>Variability in SH PMC onset date</u>:

- **dominated by variability in SH *winter-to-summer* transition of stratospheric wind reversal, modulated by variability in solar cycle**
- **trend towards later PMC onset dates due to deepening Antarctic O_3 hole**
- **currently, "dynamical" trend seems to counteract expected "chemical" trend**

Summary II

- "chemical" changes: increasing CO_2 and CH_4 concentrations in mesosphere → cooling, higher H_2O concentrations
- "dynamical" changes from deepening O_3 hole: colder Antarctic stratosphere → stronger polar vortex → GW & PW filtering → weaker residual circulation → warmer summer T and decreasing H_2O
- Climate change can also cause "dynamical" changes: changing T distribution → wind distribution, PW & GW filtering → residual circulation → …