The Role of Ozone in Future IPCC (AR5+) Simulations

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Motivation

- IPCC AR4 simulations had very poor representation of the stratosphere; future (AR5+) simulations may include full stratospheric chemistry but this is expensive and there are many other competing factors
- Can we improve current IPCC low-top stratospheric representation and what is the impact on the troposphere?
- Ozone: mainly treated as a source of anthropogenic change (EESC trend); but what about its (natural) variability?

The talk

1. Model experiments: improvements in lower stratospheric ozone
2. Improved step-like feature in lower stratosphere temperature
3. Tropospheric impacts

The model

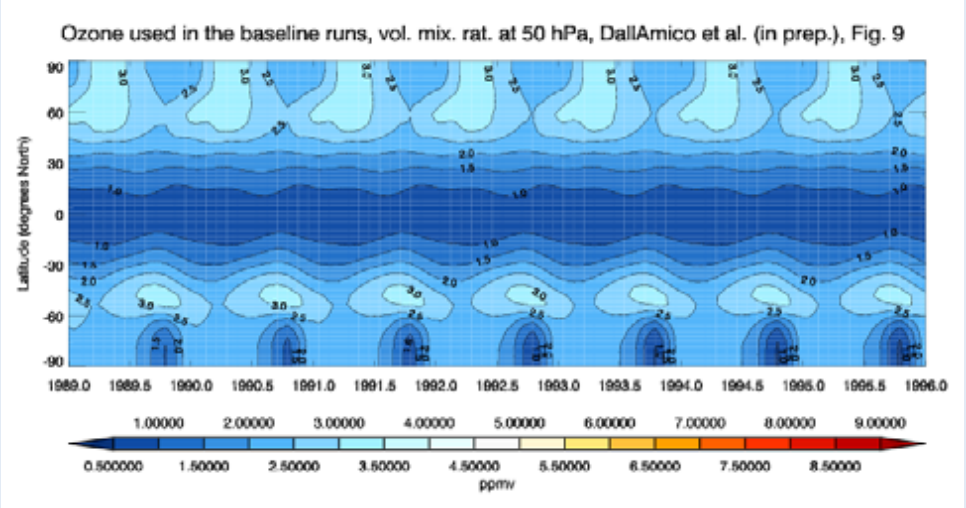
- UK Met Office Hadley Centre HADGEM1 model
- Coupled ocean-atmosphere model
- Atmosphere: 1.25 latitude x 1.875 longitude, 38 levels up to 5 hPa
- Ocean: 1 latitude x 1 longitude

The 'control' ensemble

- IPCC 'all-forcings' simulation (starting in 1859)
- Natural: solar irradiance + volcanic aerosol
- Anthropogenic: GHGs, CFCs, tropospheric aerosols, ozone
- N.B. only linear (EESC) trend in stratospheric ozone

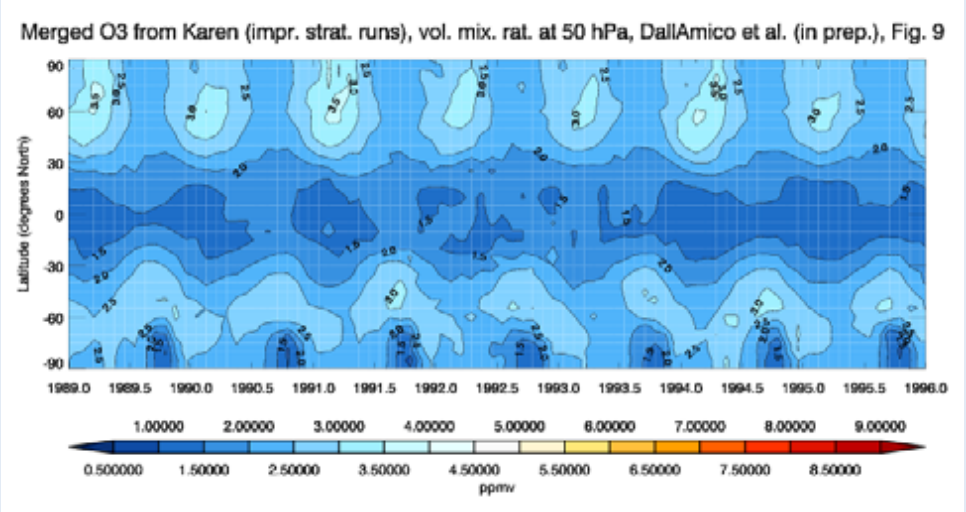
'Improved stratosphere' ensemble

- Realistic monthly ozone time-series from observations (Rosenlof) → 11-yr solar cycle + QBO + volcanic signal in ozone
- Relaxation of equatorial winds to ERA-40 → zonal wind QBO
- 3 x ensembles 1979-2003



Control run ozone: time-series at 50 hPa

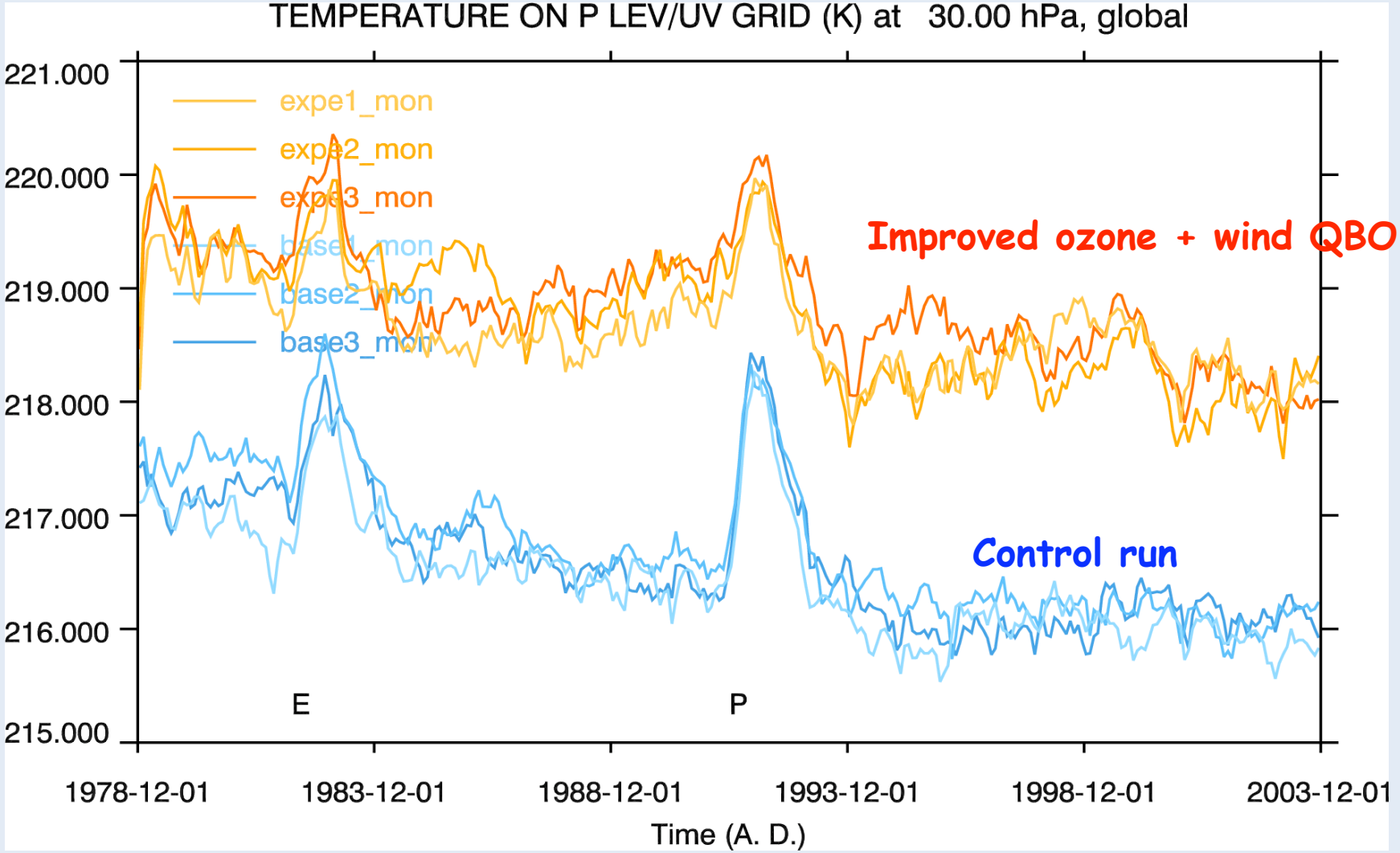
Monthly climatology + imposed EESC trend



Improved stratosphere ozone (Rosenlof): time-series at 50 hPa

Merged data from: SAGE-II, HALOE, MLS, SBUV, SME, TOMS

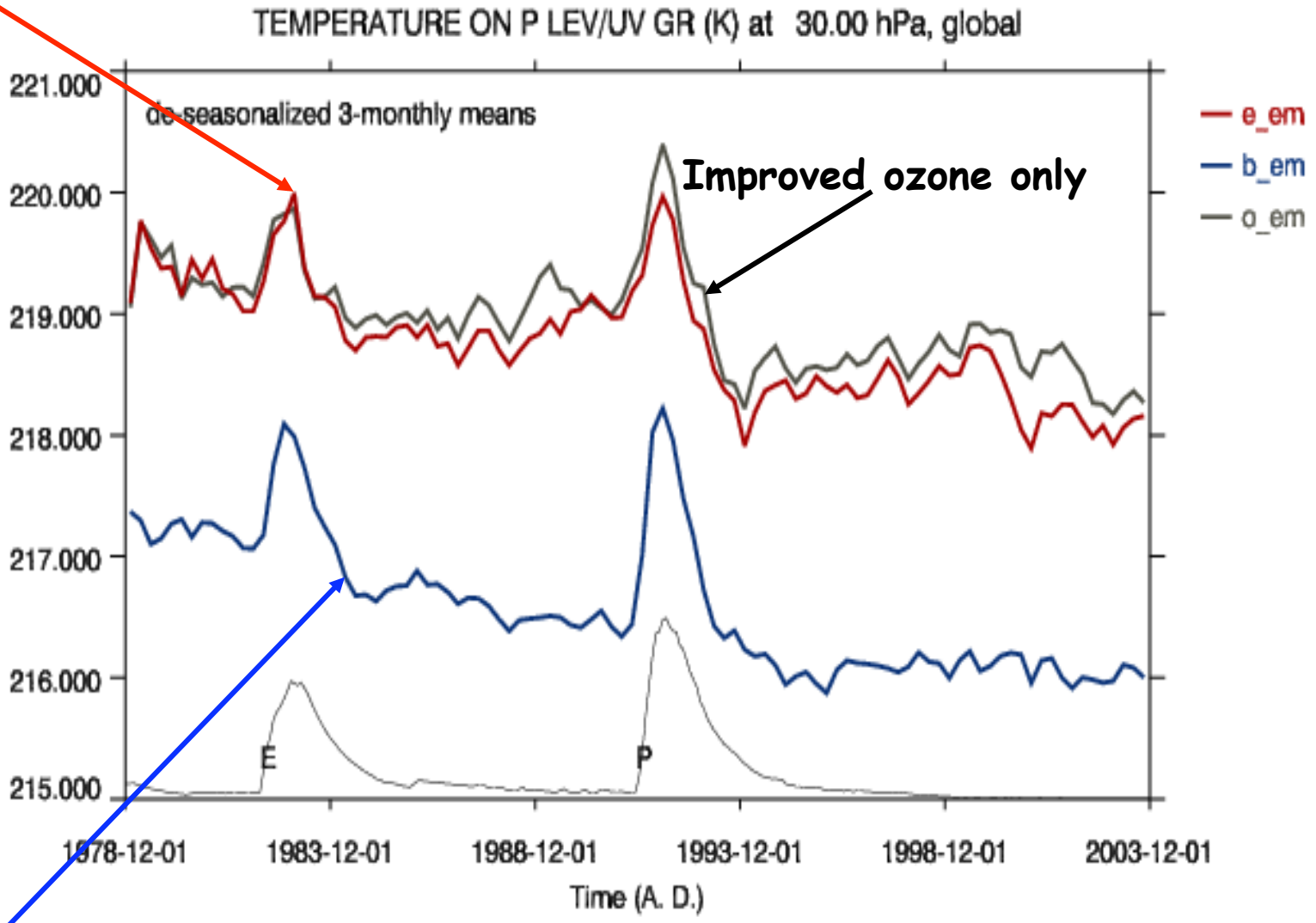
Modelled 30 hPa global temperatures



Dall'Amico et al. 2009 (submitted)

Time-series 30 hPa Global Temperatures

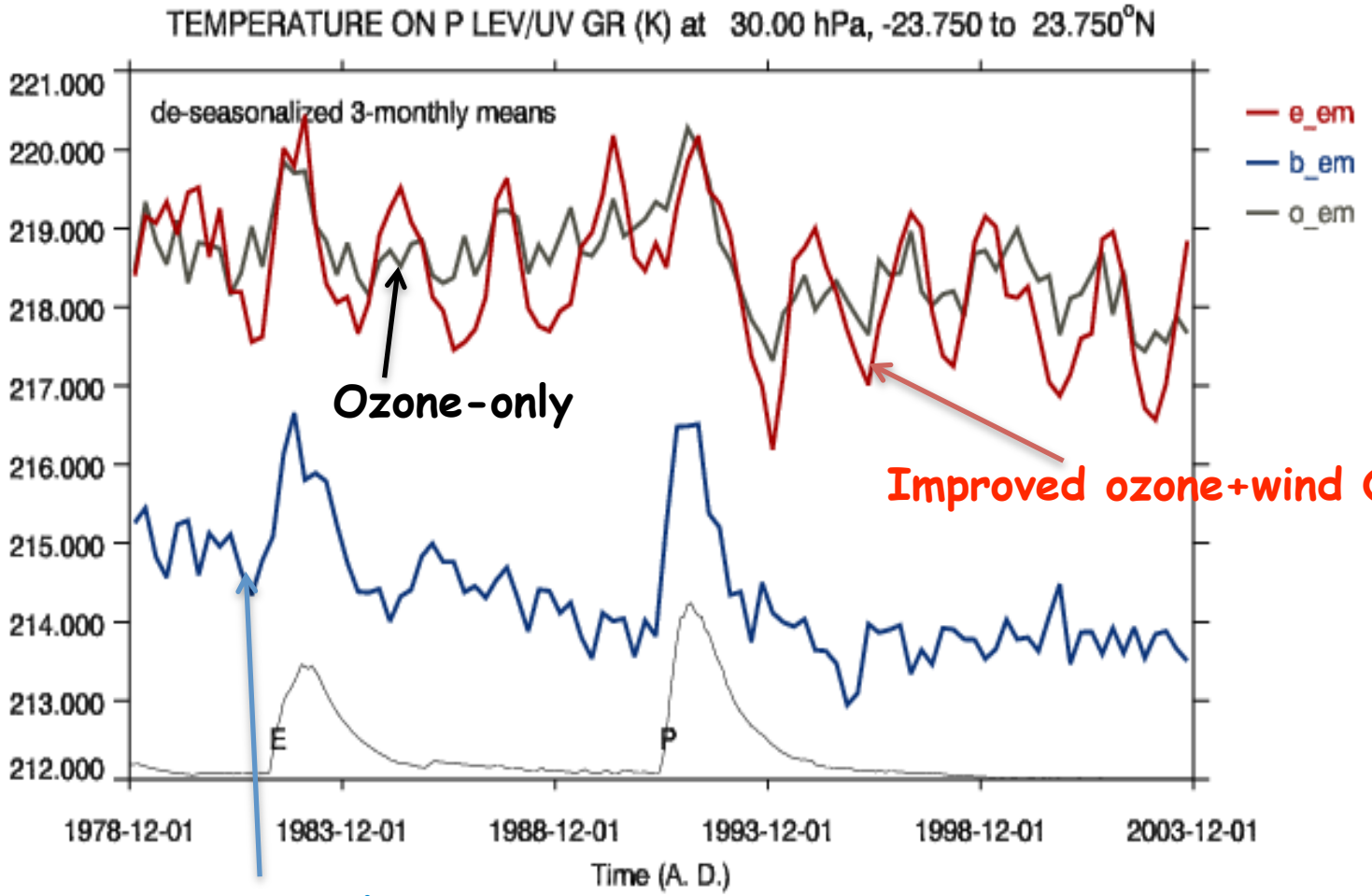
Improved ozone + wind QBO



Control run

Dall'Amico et al. 2009 (submitted)

Time-series 30 hPa equatorial temperatures

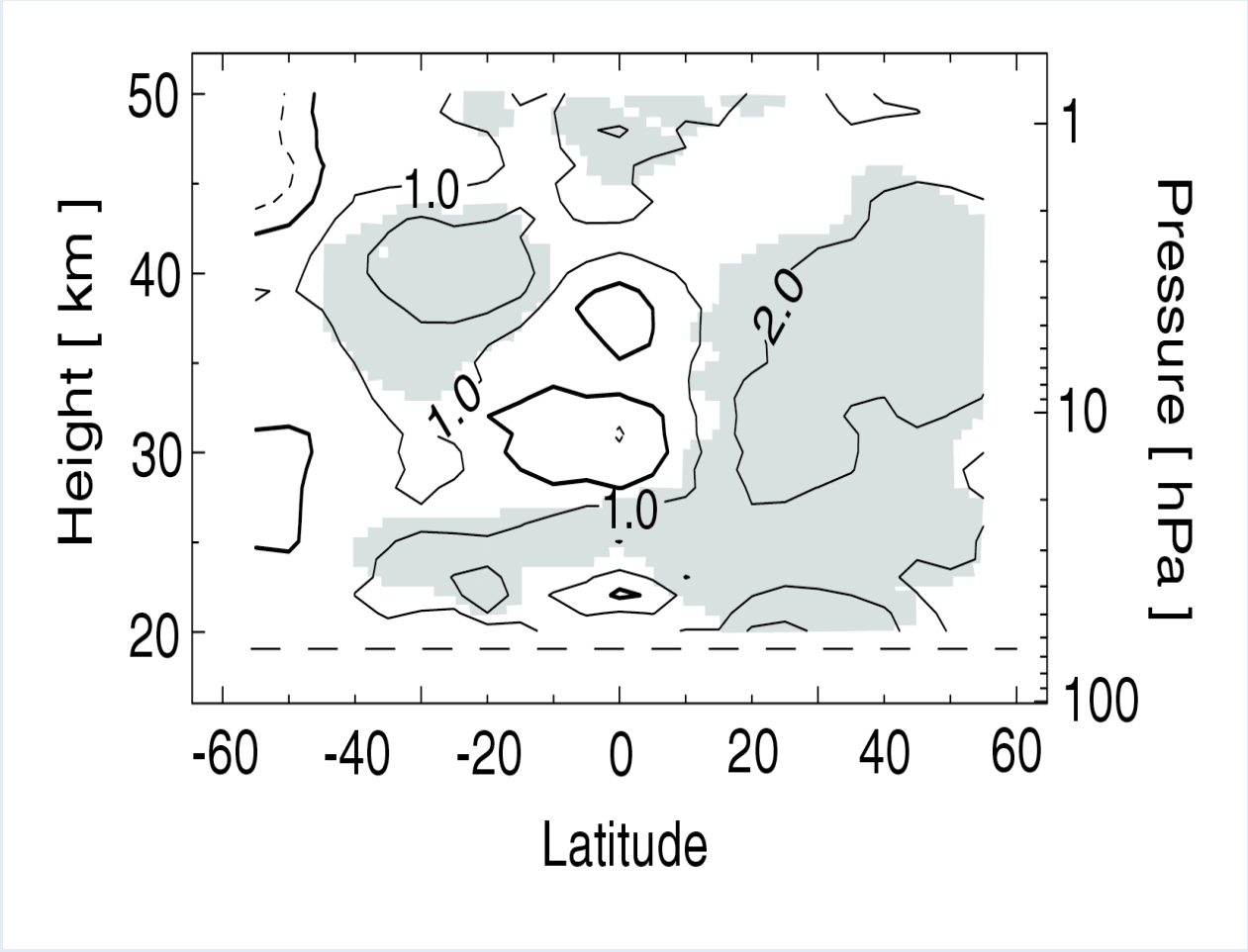


Dall'Amico et al. 2009 (submitted)

Discussion

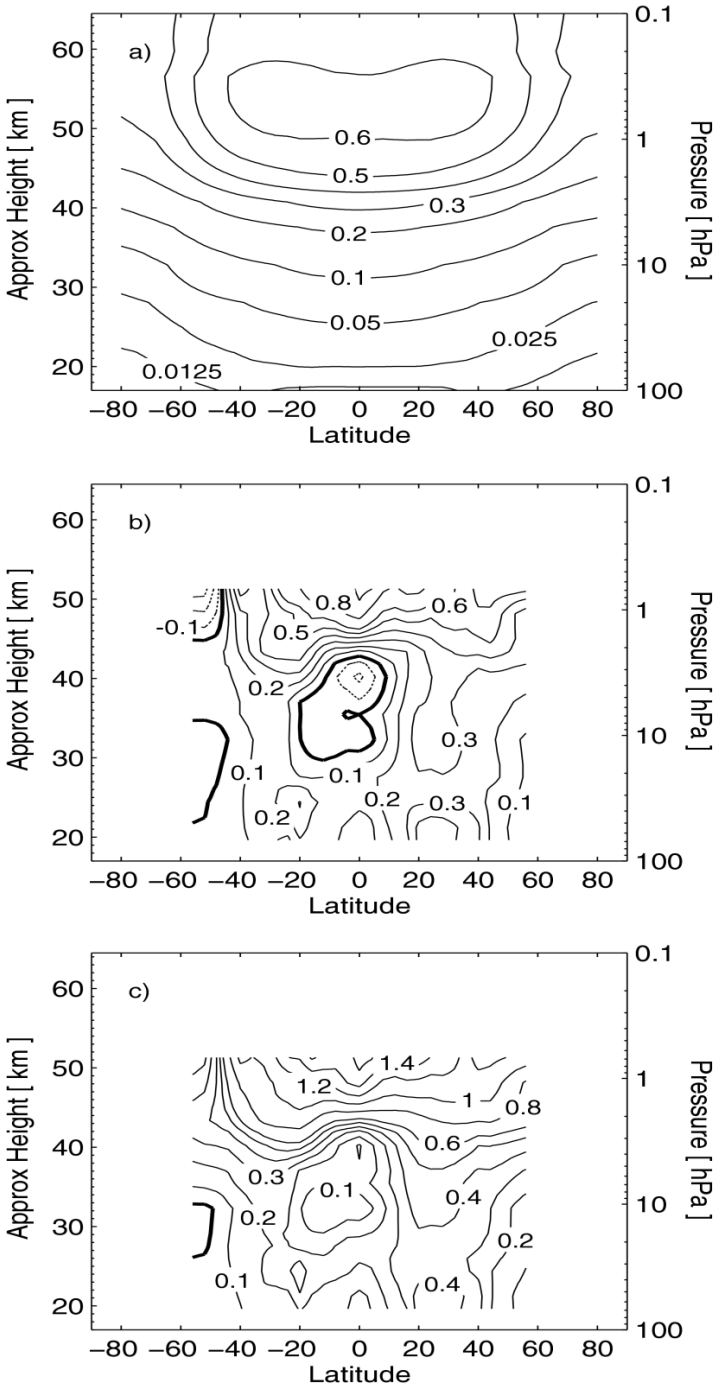
- Improved step-like feature lower stratospheric temperature is due to the improved ozone time-series: consistent with observational analysis of Thompson and Solomon 2008.
- Our results are similar to those of Ramaswamy et al. (2006). They suggest thermal inertia of oceans as possible cause + possible role of solar cycle; our results do not support a role for oceans (also present in control run).
- Thompson and Solomon (2008) suggest role for volcanic impact on ozone variations.
- Our ozone time-series includes both solar + volcanic effects but Ramaswamy et al. ozone included solar effect only (Randel and Wu ozone excluded 2 years after each eruption). This suggests that solar influence may be important factor.

Regression analysis: 11-yr solar cycle in ozone (% per 100 units F10.7cm flux)



Randel and Wu 2007

Estimated 11-yr solar cycle temperature changes (K)



Irradiance Changes only

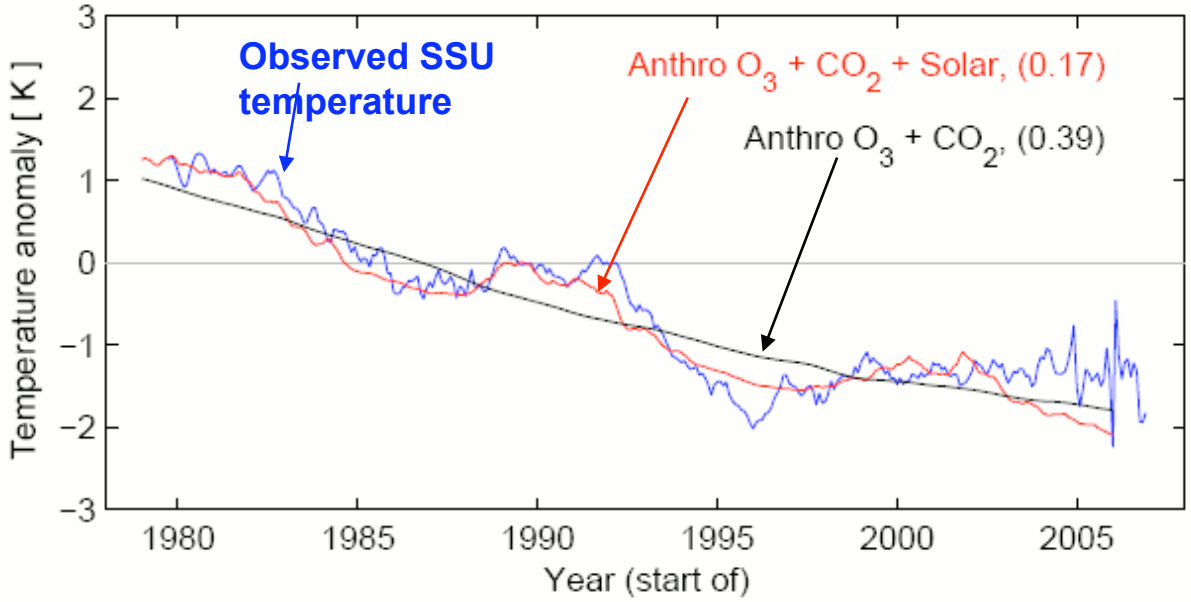
Ozone changes only (from Randel and Wu 2007)

Irradiance plus ozone changes

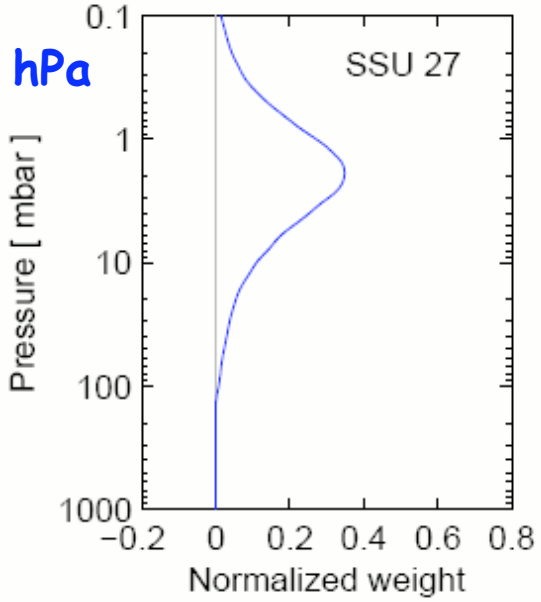
Fixed dynamical heating (FDH) approach

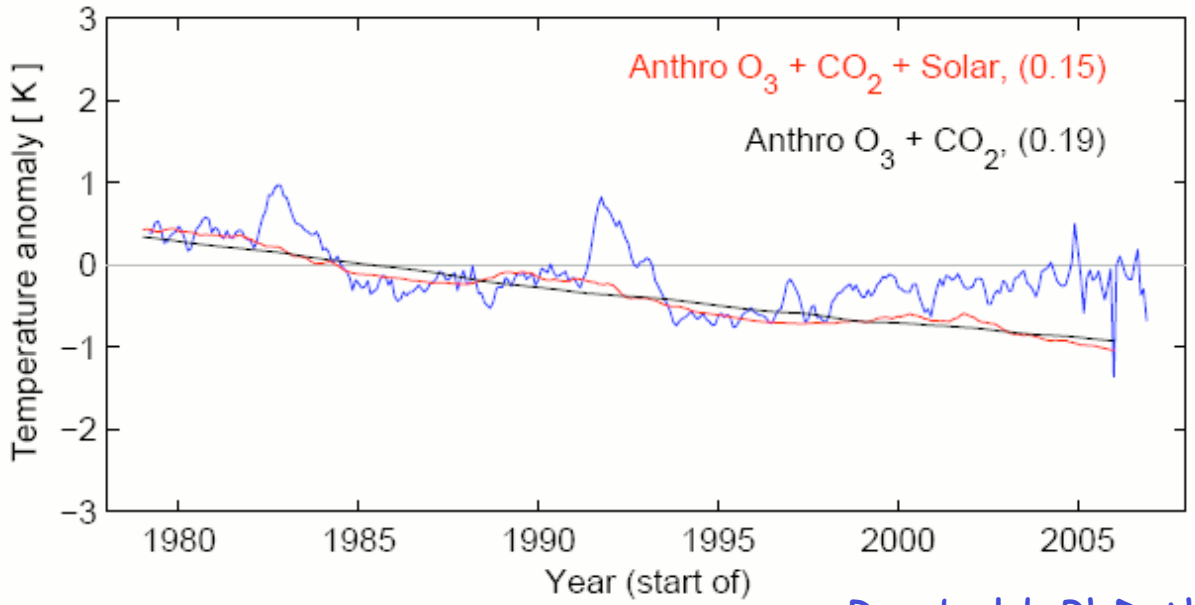
Rumbold, PhD thesis, 2008
Gray et al. 2009 submitted

FDH calculations: relative contributions of CO2, ozone, solar influence

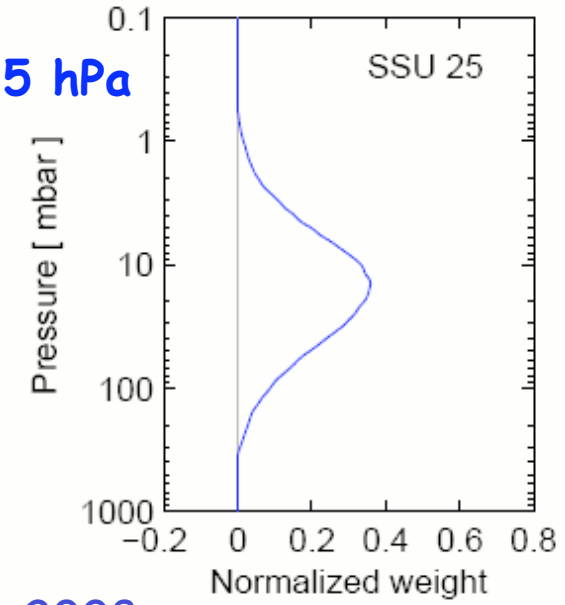


~3 hPa





~15 hPa

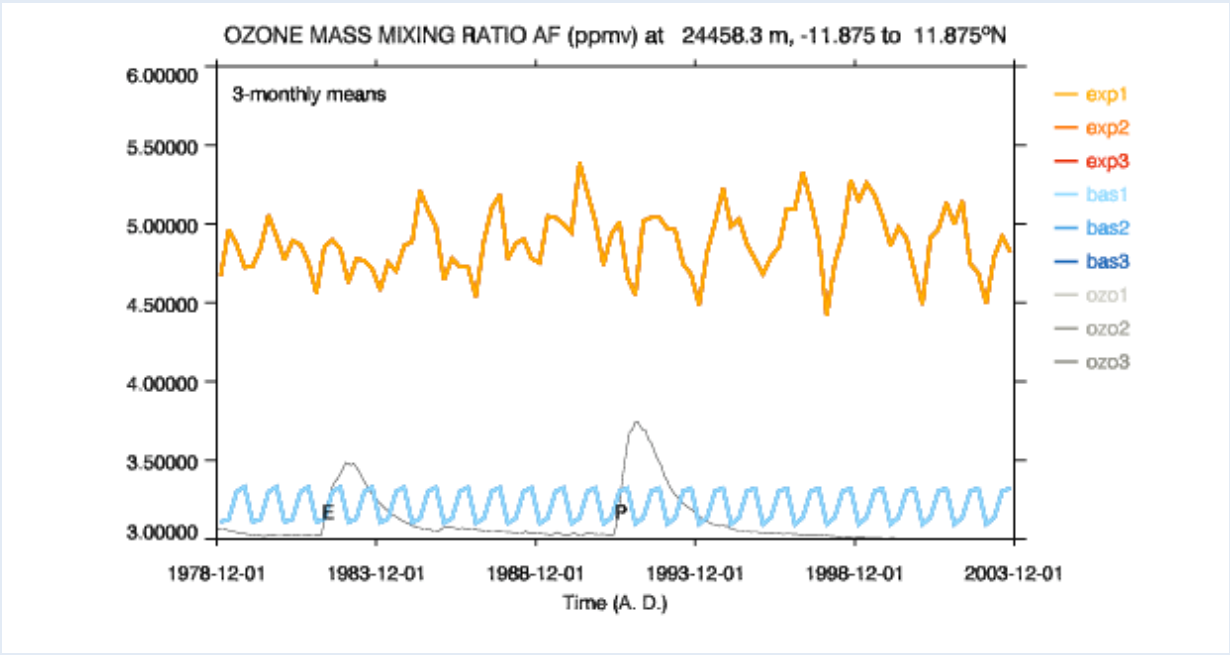


Rumbold, PhD thesis,2008

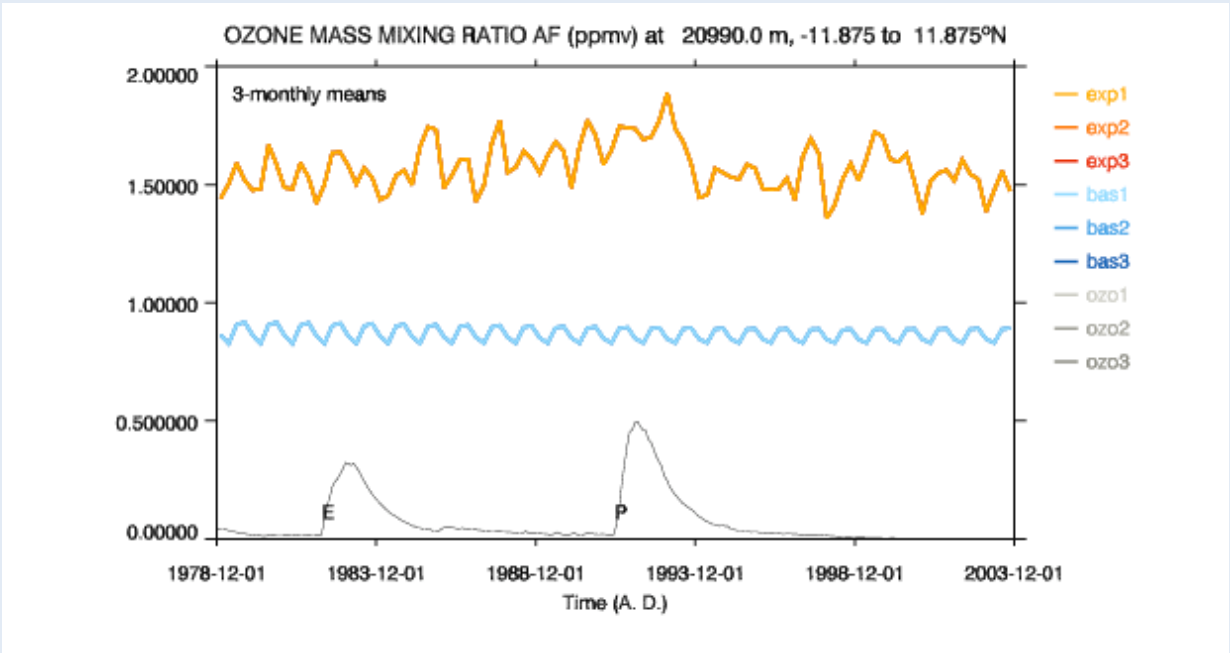
Tropospheric Impacts

- Surface global warming trend not affected but variance is substantially increased.
- NH high-latitude warming trends increased.
- Increased tropopause cooling and slightly reduced warming trends in upper tropical troposphere
- Improved near-surface response to volcanic eruptions
- Positive SAM trend is increased and is statistically more significant.

Main conclusion: Important to improve stratospheric ozone in AR5 IPCC runs and, if possible, include variability in addition to the simple EESC simple trend.

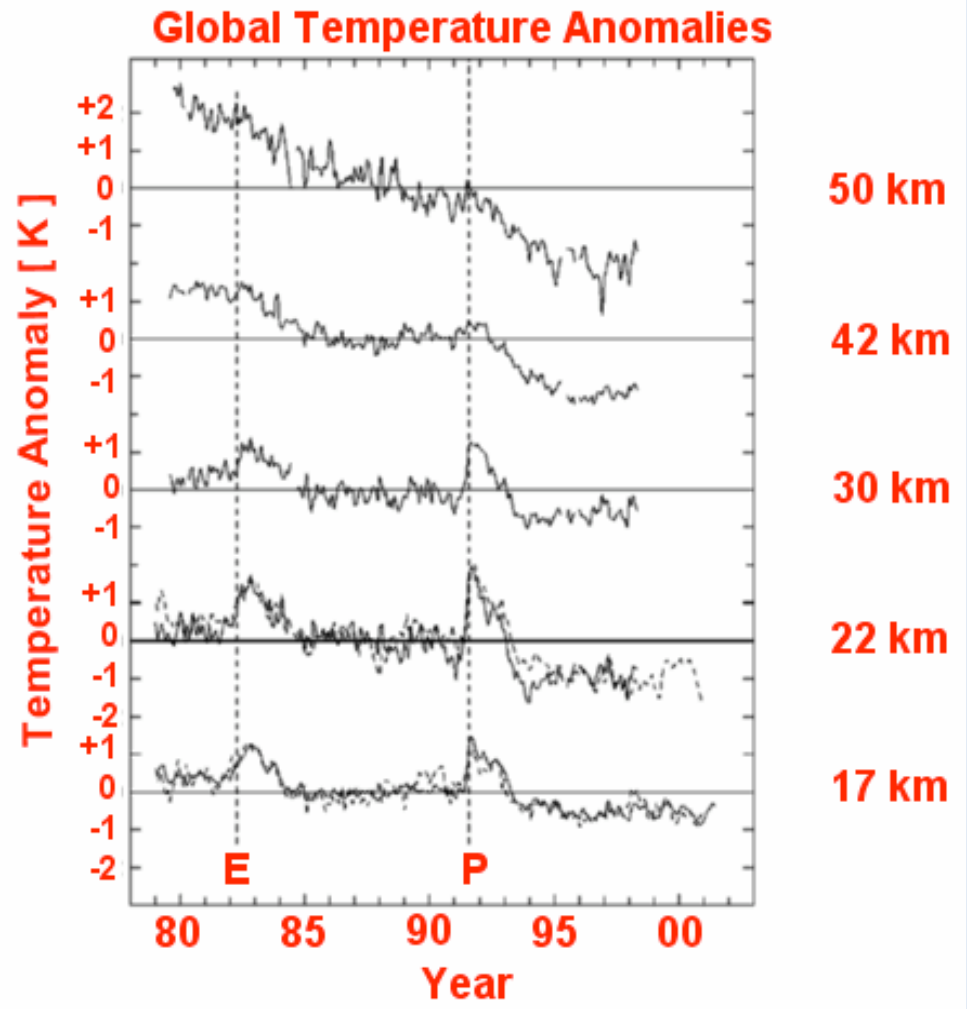

OZONE MASS MIXING RATIO AF (ppmv) at 24458.3 m, -11.875 to 11.875°N
3-monthly means
6.00000
5.50000
5.00000
4.50000
4.00000
3.50000
3.00000
E
P
1978-12-01
1983-12-01
1988-12-01
1993-12-01
1998-12-01
2003-12-01
Time (A. D.)
exp1
exp2
exp3
bas1
bas2
bas3
ozo1
ozo2
ozo3

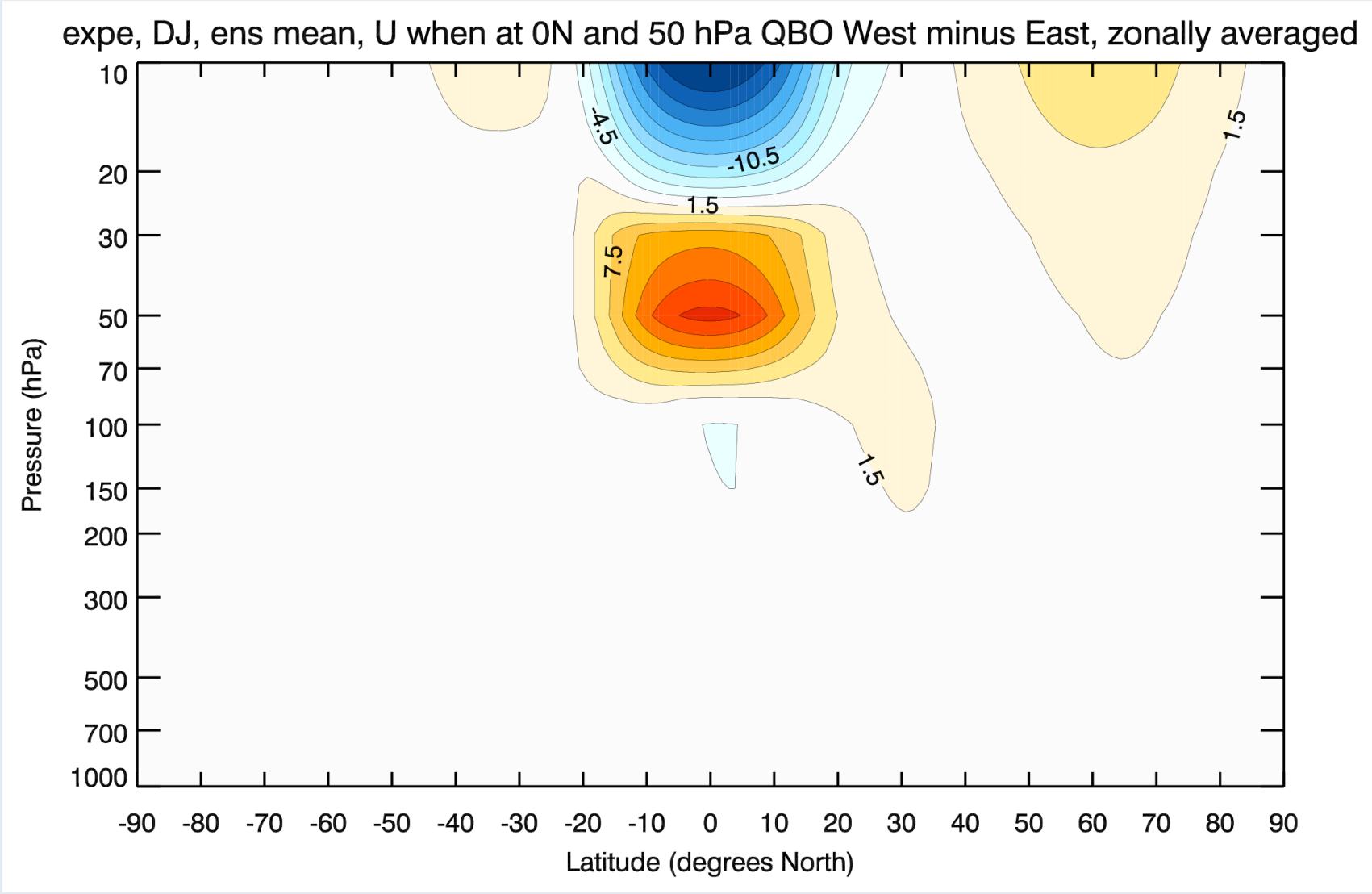
24.5 km

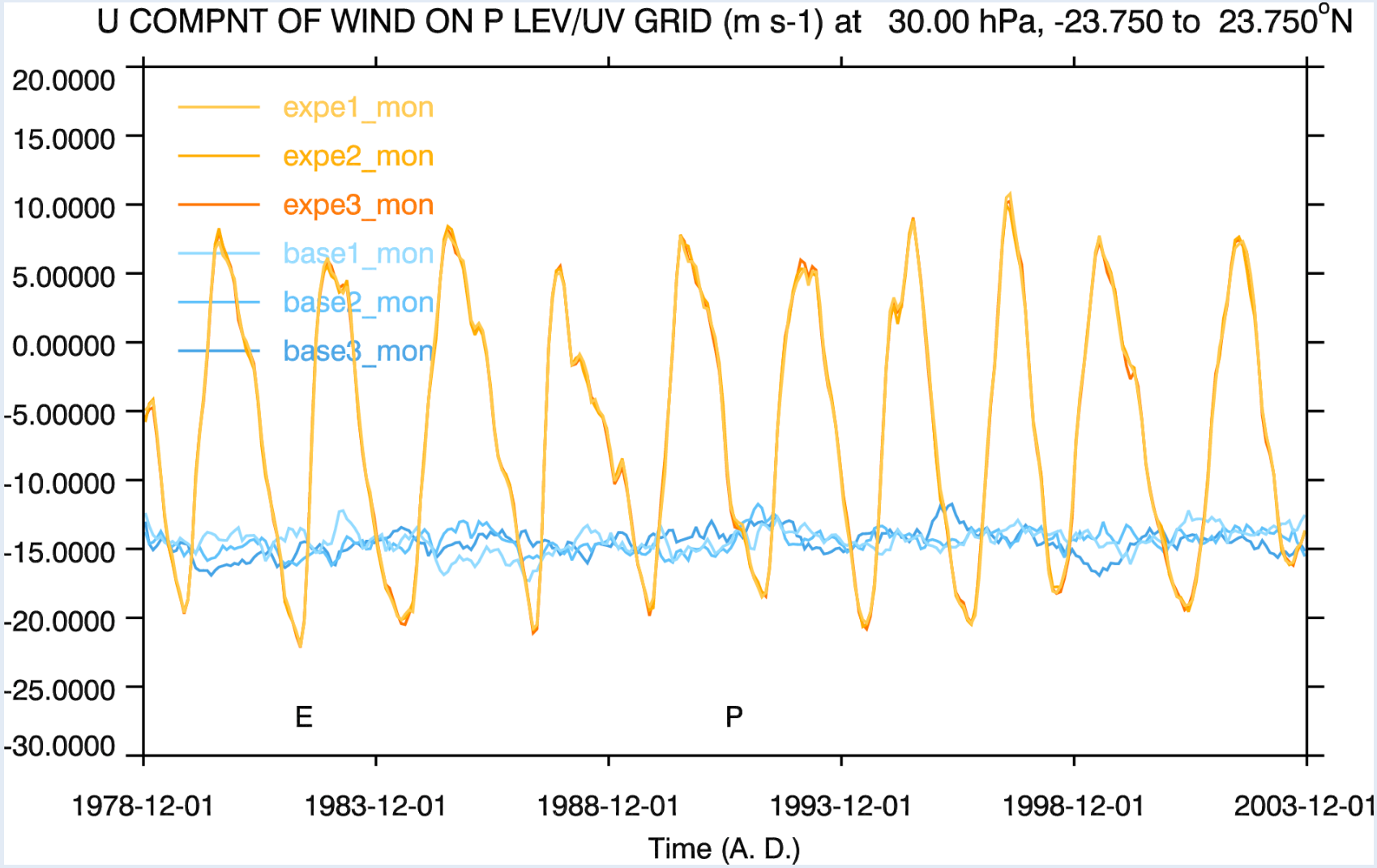

OZONE MASS MIXING RATIO AF (ppmv) at 20990.0 m, -11.875 to 11.875°N
3-monthly means
2.00000
1.50000
1.00000
0.500000
0.00000
E
P
1978-12-01
1983-12-01
1988-12-01
1993-12-01
1998-12-01
2003-12-01
Time (A. D.)
exp1
exp2
exp3
bas1
bas2
bas3
ozo1
ozo2
ozo3

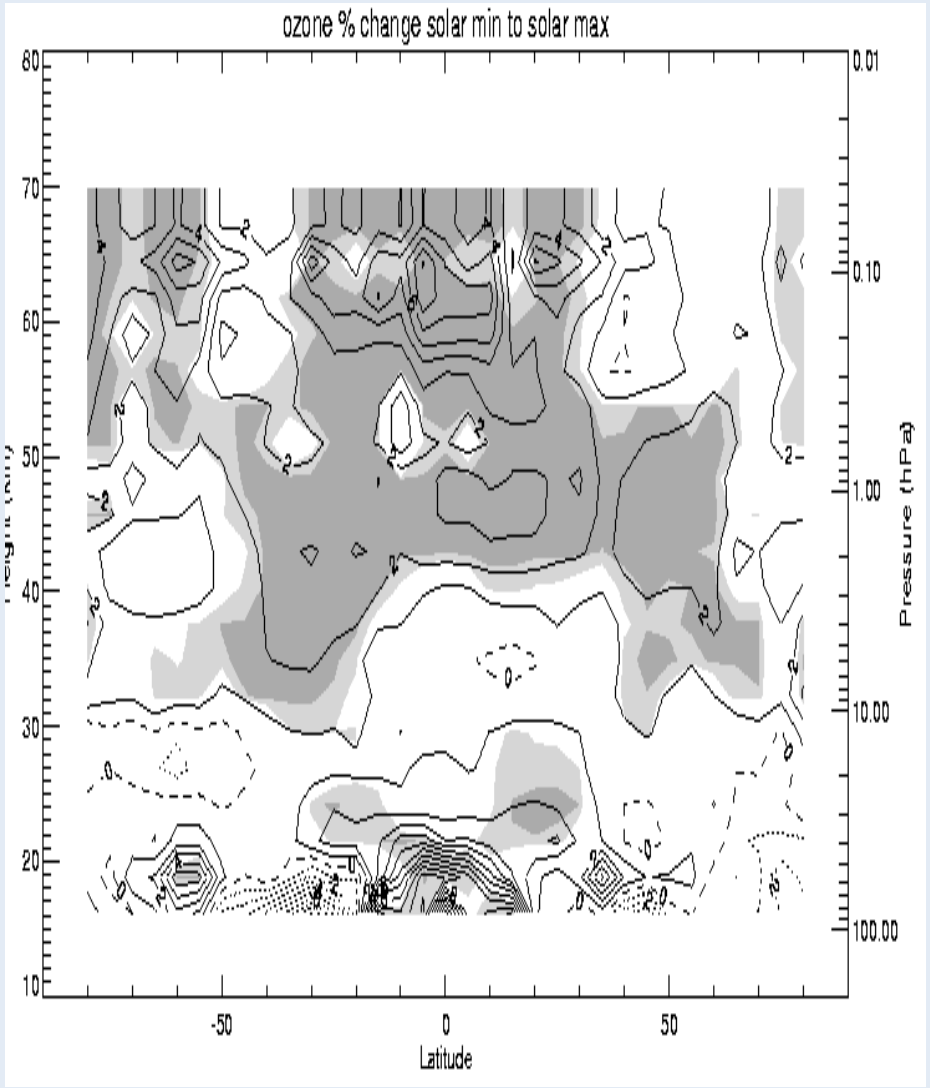
21 km

Observed SSU temperature anomalies




expe, DJ, ens mean, U when at 0N and 50 hPa QBO West minus East, zonally averaged
Pressure (hPa)
10
20
30
50
70
100
150
200
300
500
700
1000
-4.5
-10.5
1.5
7.5
1.5
1.5
-90 -80 -70 -60 -50 -40 -30 -20 -10 0 10 20 30 40 50 60 70 80 90
Latitude (degrees North)


U COMPNT OF WIND ON P LEV/UV GRID (m s-1) at 30.00 hPa, -23.750 to 23.750°N
20.0000
15.0000
10.0000
5.00000
0.00000
-5.00000
-10.0000
-15.0000
-20.0000
-25.0000
-30.0000
expe1_mon
expe2_mon
expe3_mon
base1_mon
base2_mon
base3_mon
E
P
1978-12-01
1983-12-01
1988-12-01
1993-12-01
1998-12-01
2003-12-01
Time (A. D.)


ozone % change solar min to solar max
80
70
60
50
40
30
20
10
-50
0
50
Latitude
0.01
0.10
1.00
10.00
100.00
Pressure (hPa)