Prepare For The Apocalypse. The largest coronal mass emission (CME) ever detected by scientists breaks off from the sun and hurtles toward the Earth. With temperatures soaring higher, the sky on fire and the continued existence of the human race in question scientists must explode the polar ice caps to stop the CME. Will it backfire or save life as we know it?

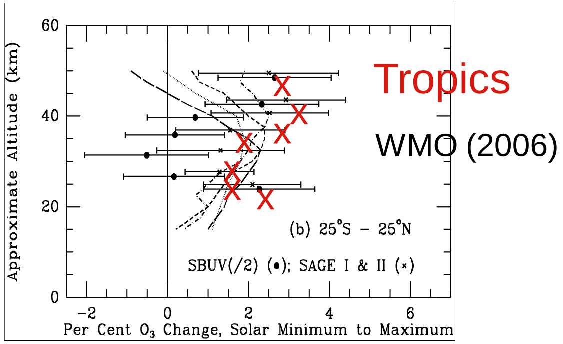
A whole-atmosphere modeling perspective on sun-climate effects

The WACCM Group*

* With contributions from Drs. K. Matthes (FUB), J. Jackman (NASA).

Motivation

- Understand tropical solar signal in O_3 and T:



- Understand observed solar-QBO relationship in the tropics and extratropics:

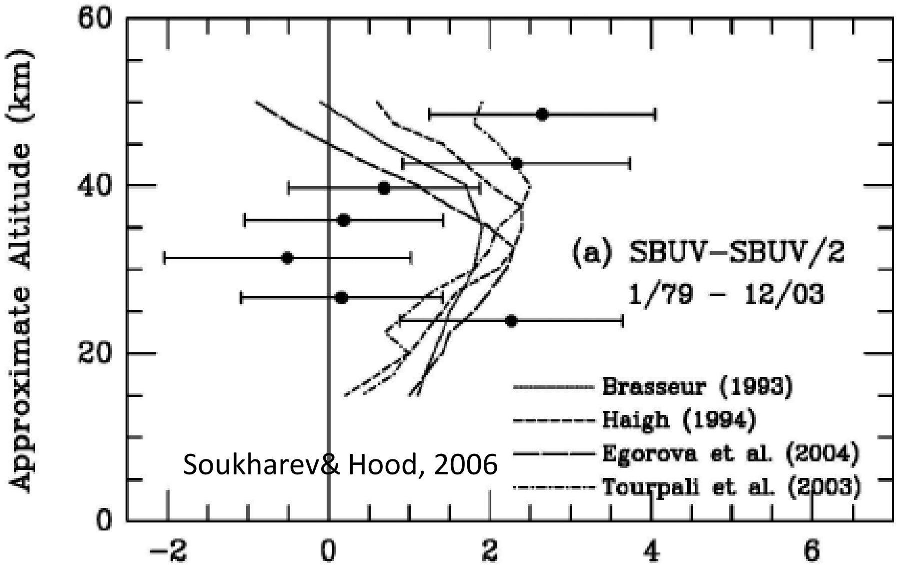
Holton and Tan (1980, 1982)

	Min	Max
East	W	C
West	C	W

Labitzke (1987), Labitzke and van Loon (1988)

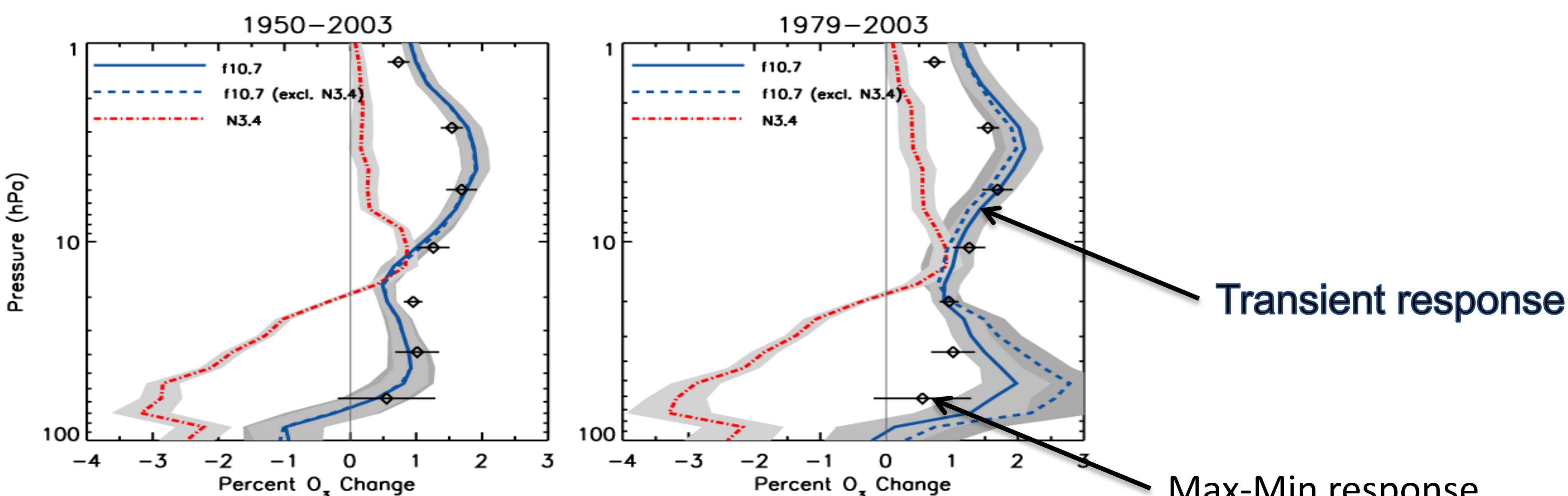
also Gray et al. (2001a,b), (2003); Camp and Tung (2007)

Attribution of decadal variability in lower-stratospheric tropical ozone



Marsh & Garcia, GRL 2007

Attribution of an ENSO-ozone signal as a solar-ozone signal may explain the apparent discrepancy between satellite observations and models



$\%\Delta O_3$/(100 units f10.7, N3.4)

Idealized Simulations: Time-Varying Solar Cycle & QBO

Solar Cycle & QBO — 110 years

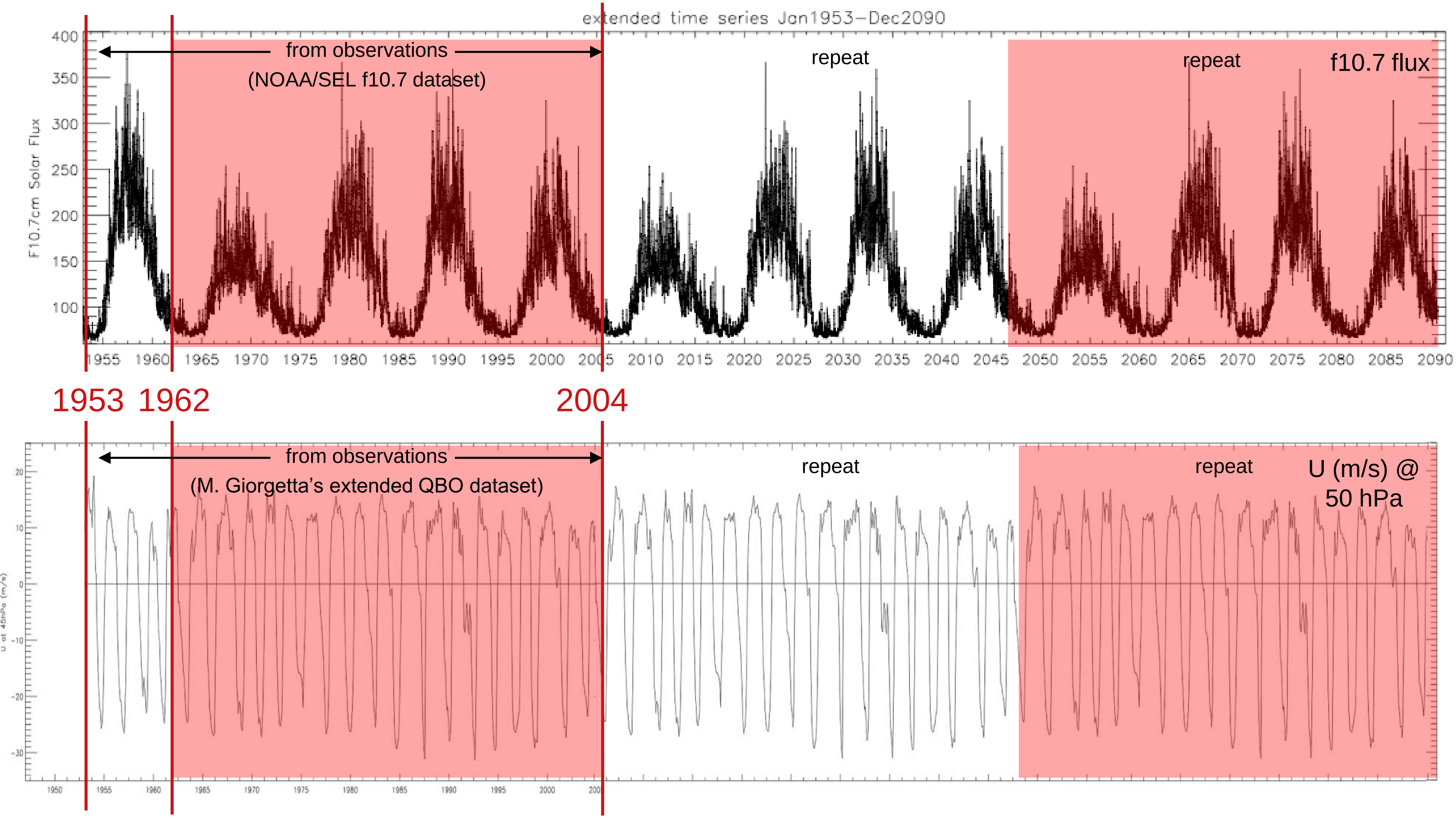
Solar Cycle Only (no QBO forcing) — 110 years

QBO Only (no 11-year solar variability) — 50 years

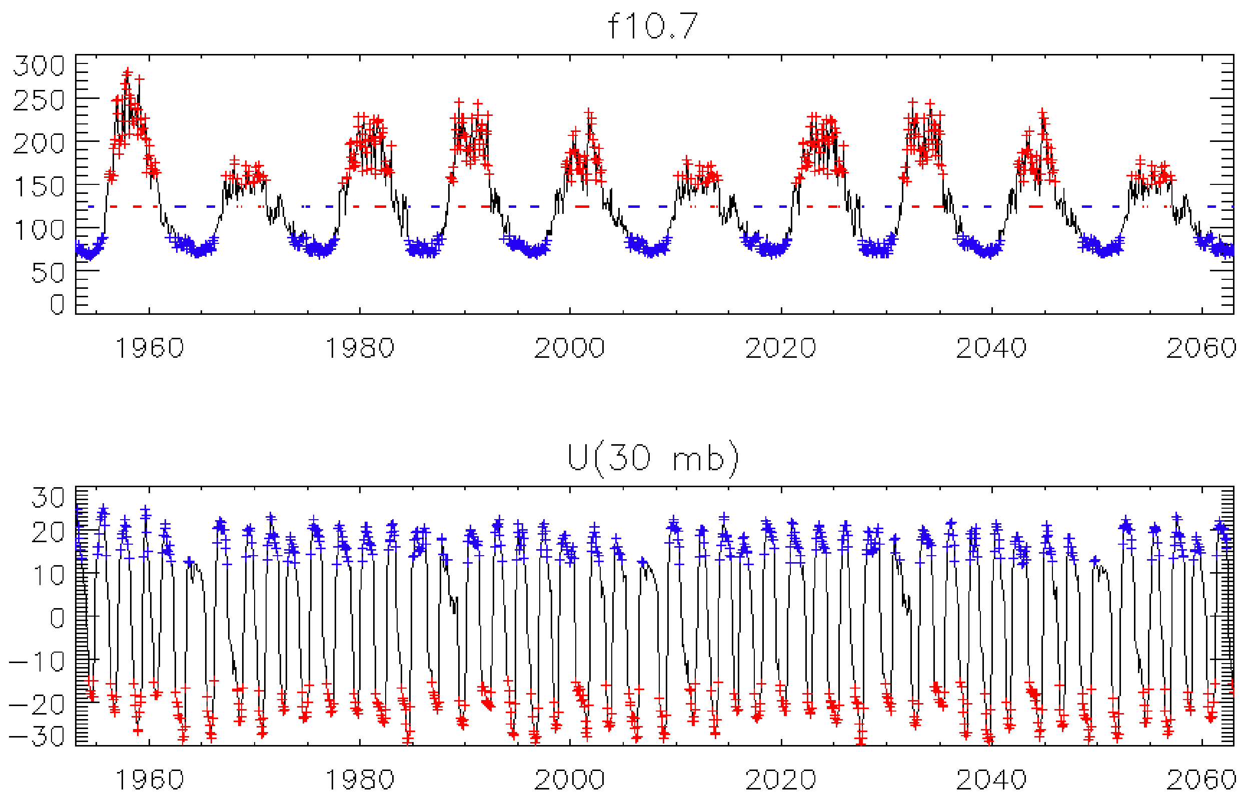
Constant 1995 GHG conditions, fixed SSTs

Forcing of 110 year run

Composite (1953 to 2004) + repeat (1962-2004)



Selecting Model Output for Stratification According to QBO phase



solar criteria (f107 cm flux)
smax: 150 units
smin: 90

qbo criteria (U @ 30 mb)
qbo-E: –15 m/s
qbo-W: 12

total years: 110

smax years: 32
smin years: 37

qbo-E years: 33
qbo-W years: 40

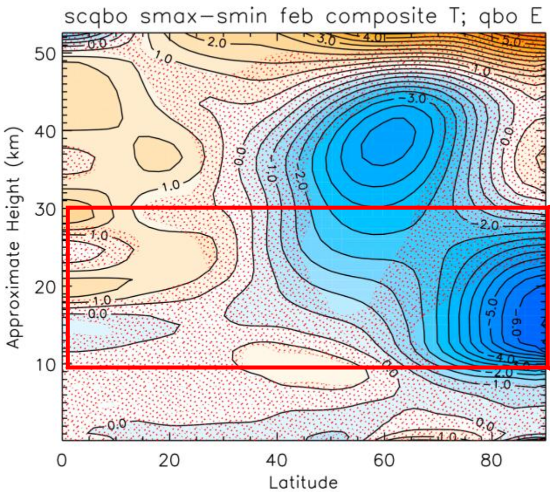
smax, qbo-E years: 11
qbo-W years: 13
smin, qbo-E years: 11
qbo-W years: 11

The 110-yr runs allow for selection of about a dozen smax and smin cases in QBO-E and QBO-W phases

NH Winter Signal (Solar Max-Min) in Zonal Mean T
WACCM vs. Observations

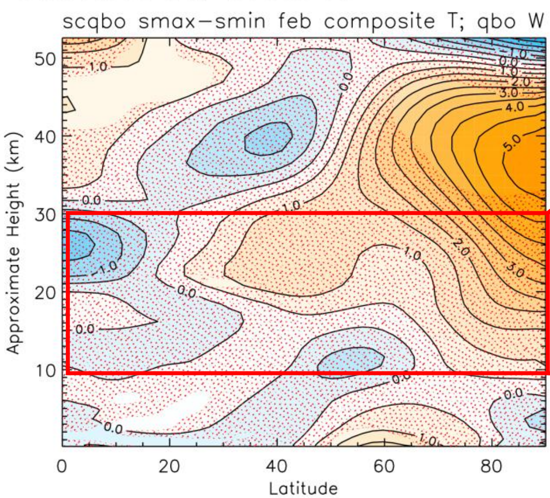
WACCM February

QBO-E



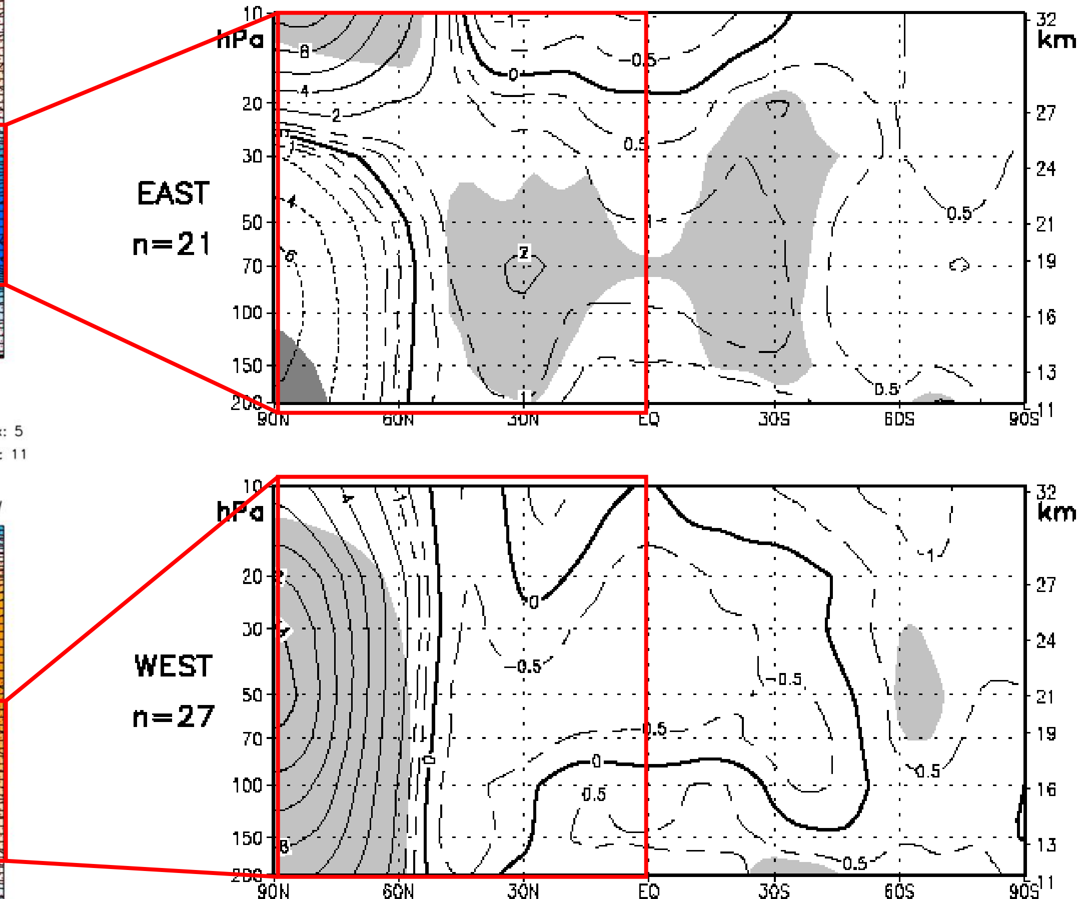
solar criteria: max = 150; min = 90 f10.7 units   no. smax: 5
qbo criteria: east = −15; west = 12 ms^{-1} no. smin: 11
Shaded areas are not significant at 90% level.

QBO-W



solar criteria: max = 150; min = 90 f10.7 units   no. smax: 8
qbo criteria: east = −15; west = 12 ms^{-1} no. smin: 11
Shaded areas are not significant at 90% level.

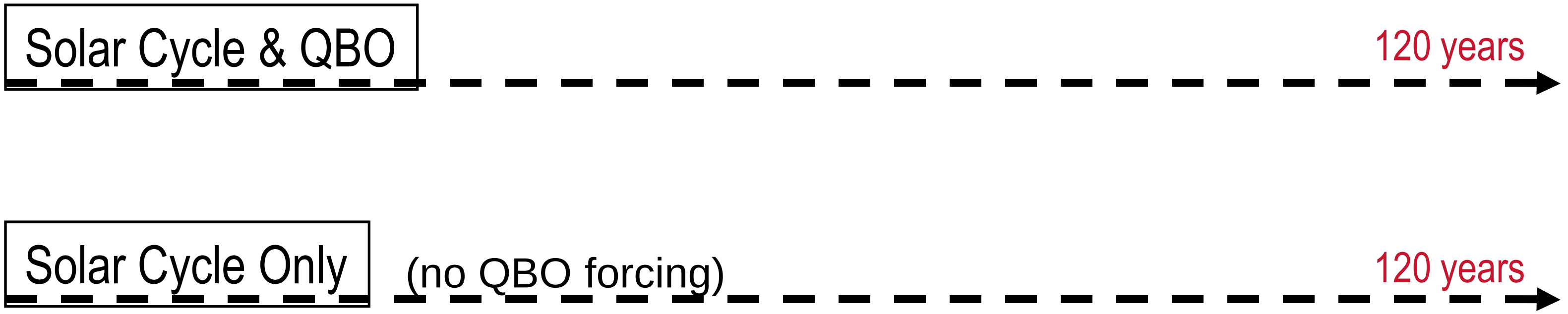
February



Labitzke, *Sp. Sci. Rev.*, 2006 (NCEP/NCAR reanalysis)

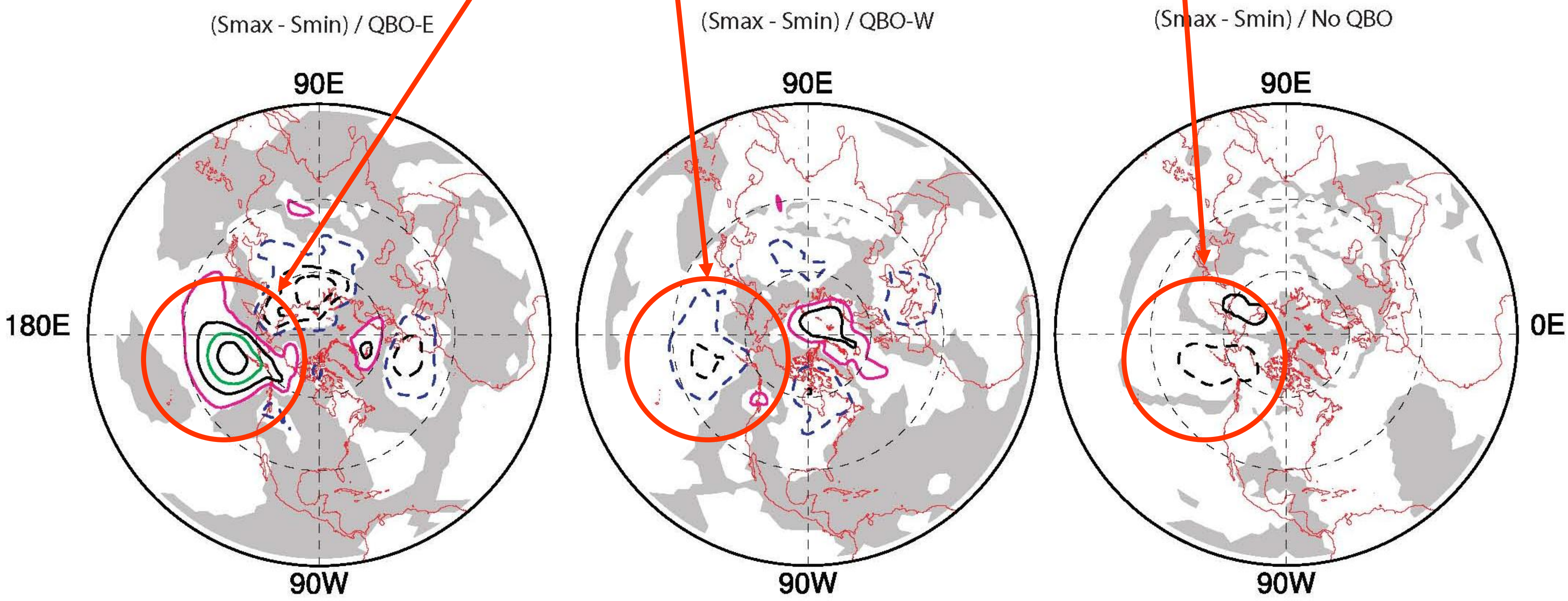
Ongoing Solar Studies

- WACCM coupled to a full depth ocean/sea-ice/land.
- Present day chemical composition.
- Same QBO forcing as previously, but F107 “scrambled”.
- The motivation is to look for solar/QBO signals in the troposphere in an unconstrained climate.



Mid-Winter Sea Level Pressure response to decadal variations (February)

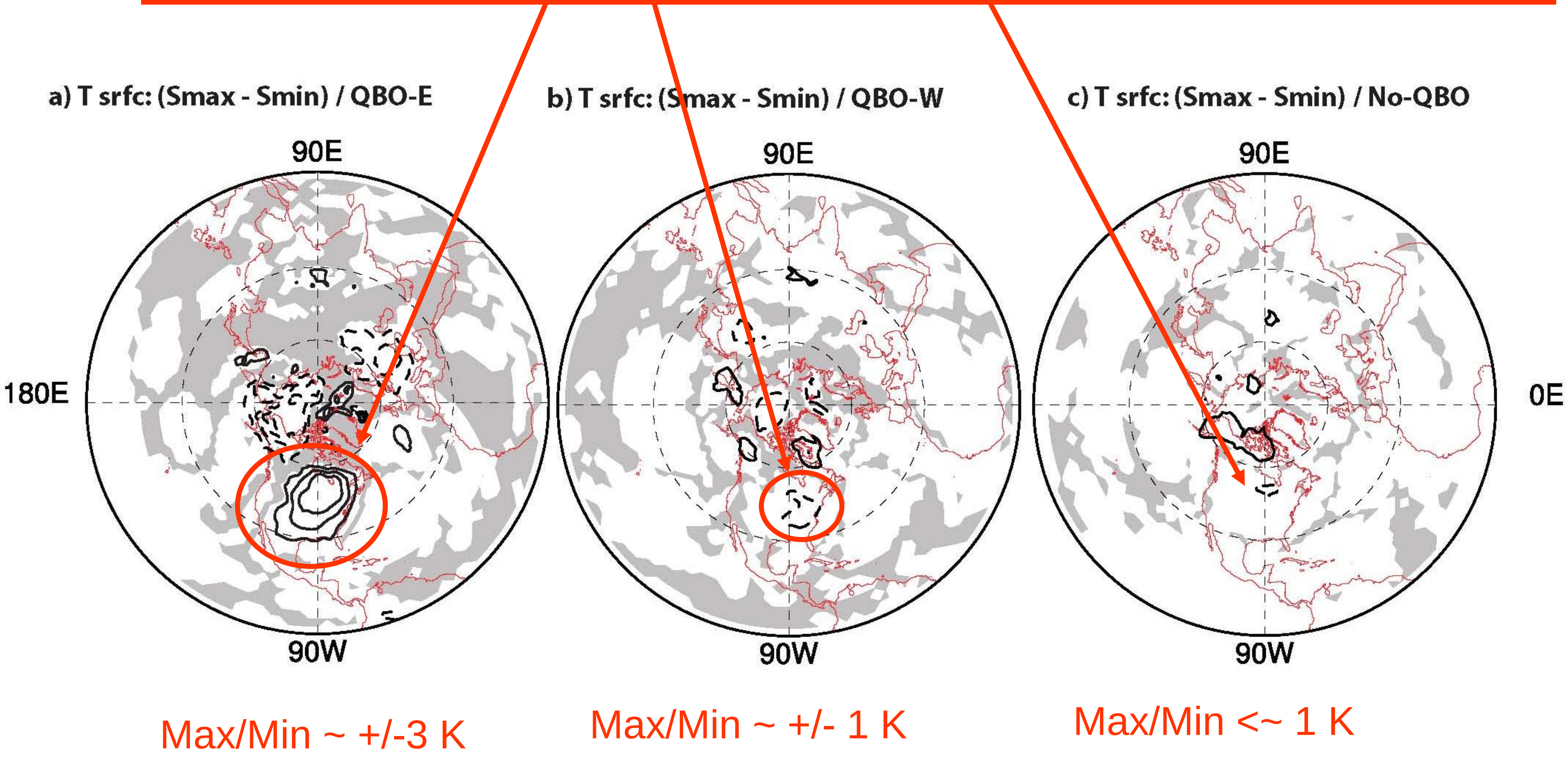
Surface pressure changes in the north Pacific basin are opposite between QBO-E and QBO-W, and they are substantially smaller when no QBO is used.



Max |ΔPSL| ~ 800 Pa   Max |ΔPSL| ~ 400 Pa   Max |ΔPSL| ~ 200 Pa

Surface Temperature response to decadal variations (March)

Large continental surface temperature differences between Solar-max and Solar-min are found in data stratified according to the QBO phase. No correspondingly large signals are found in the case w/out QBO (Solar Cycle only) – unshaded areas are statistically significant at 90% level.



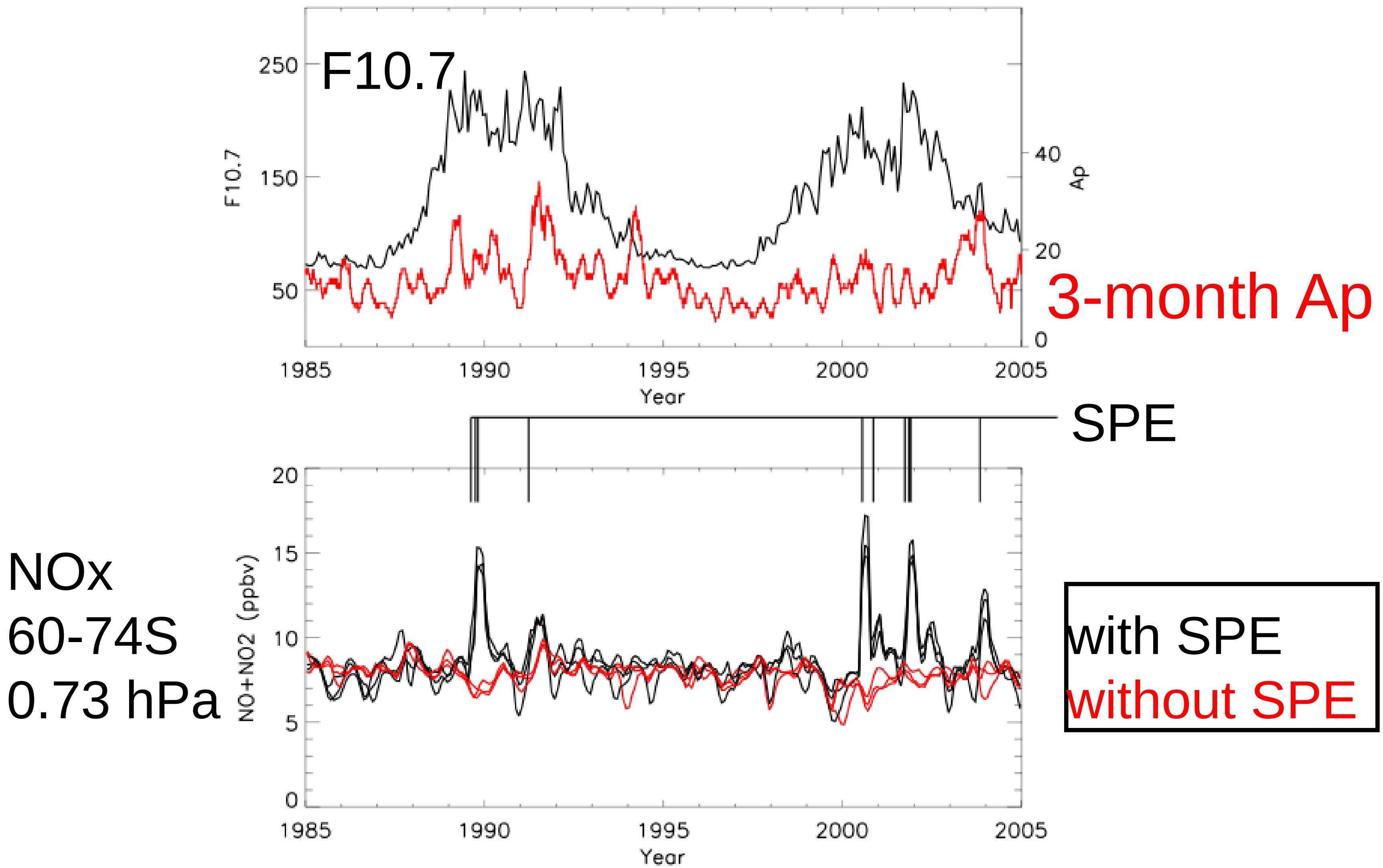
Solar Proton Events

Largest 15 Solar Proton Even Periods in the Past 45 years

Date of SPE(s)	***Rank***	***Computed NO_y Production In Middle Atmosphere (Gigamoles[1])***
October 19-27, 1989	1	11.
August 2-10, 1972	2	6.0
July 14-16, 2000	3	5.8
October 28-31, 2003	4	5.6
November 5-7, 2001	5	5.3
November 9-11, 2000	6	3.8
September 24-30, 2001	7	3.3
August 13-26, 1989	8	3.0
November 23-25, 2001	9	2.8
September 2-7, 1966	10	2.0
January 15-23, 2005	11	1.8
Sep. 29 – Oct. 3, 1989	12	1.7
Jan. 28 – Feb. 1, 1967	13	1.6
March 23-29, 1991	14	1.5
September 7-17, 2005	15	1.5
[1]Gigamole = 6.02×10^{32} atoms and molecules		

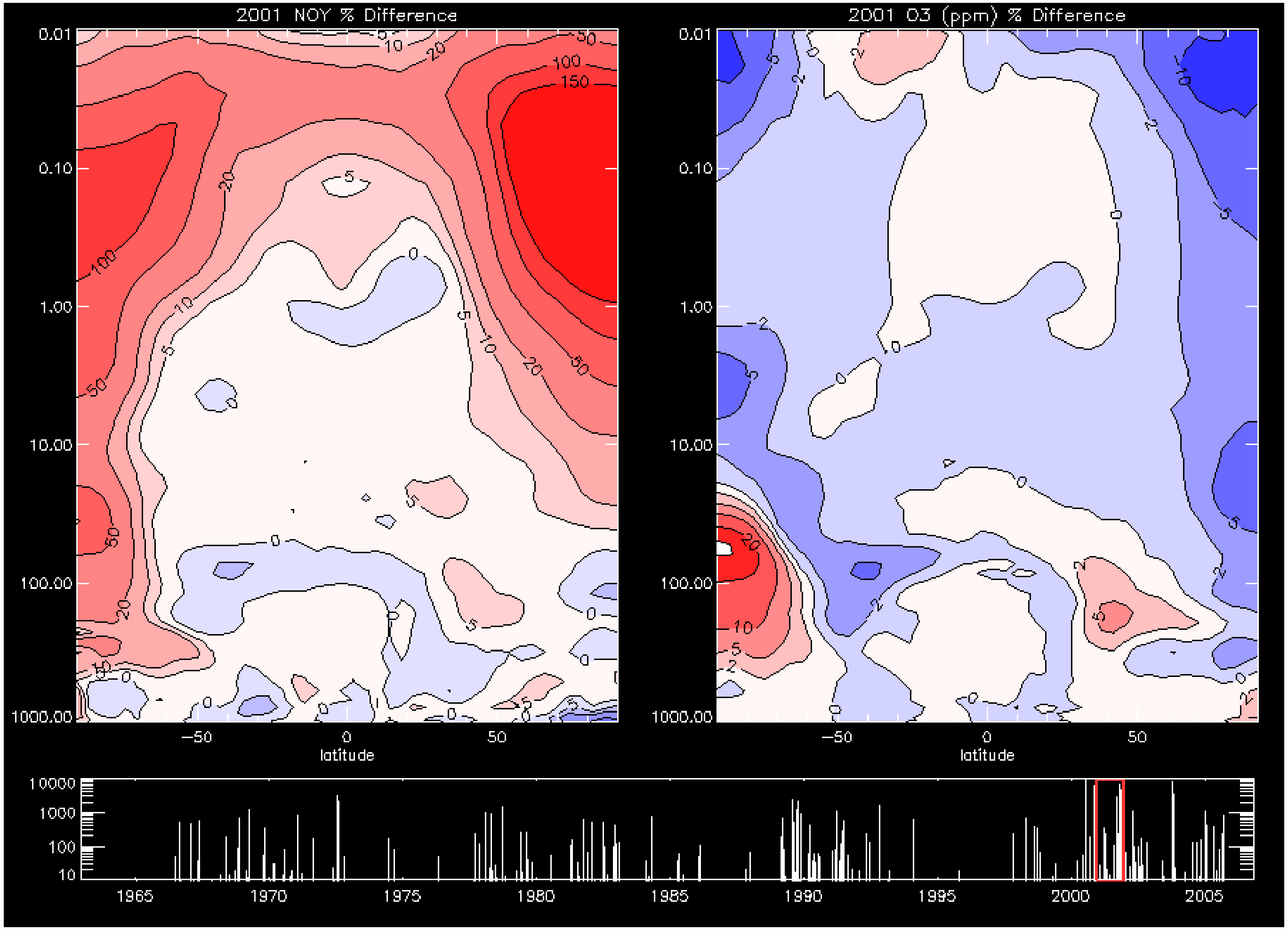
Jackman et al., 2007 ACPD

Time series of solar proxies & WACCM NOx

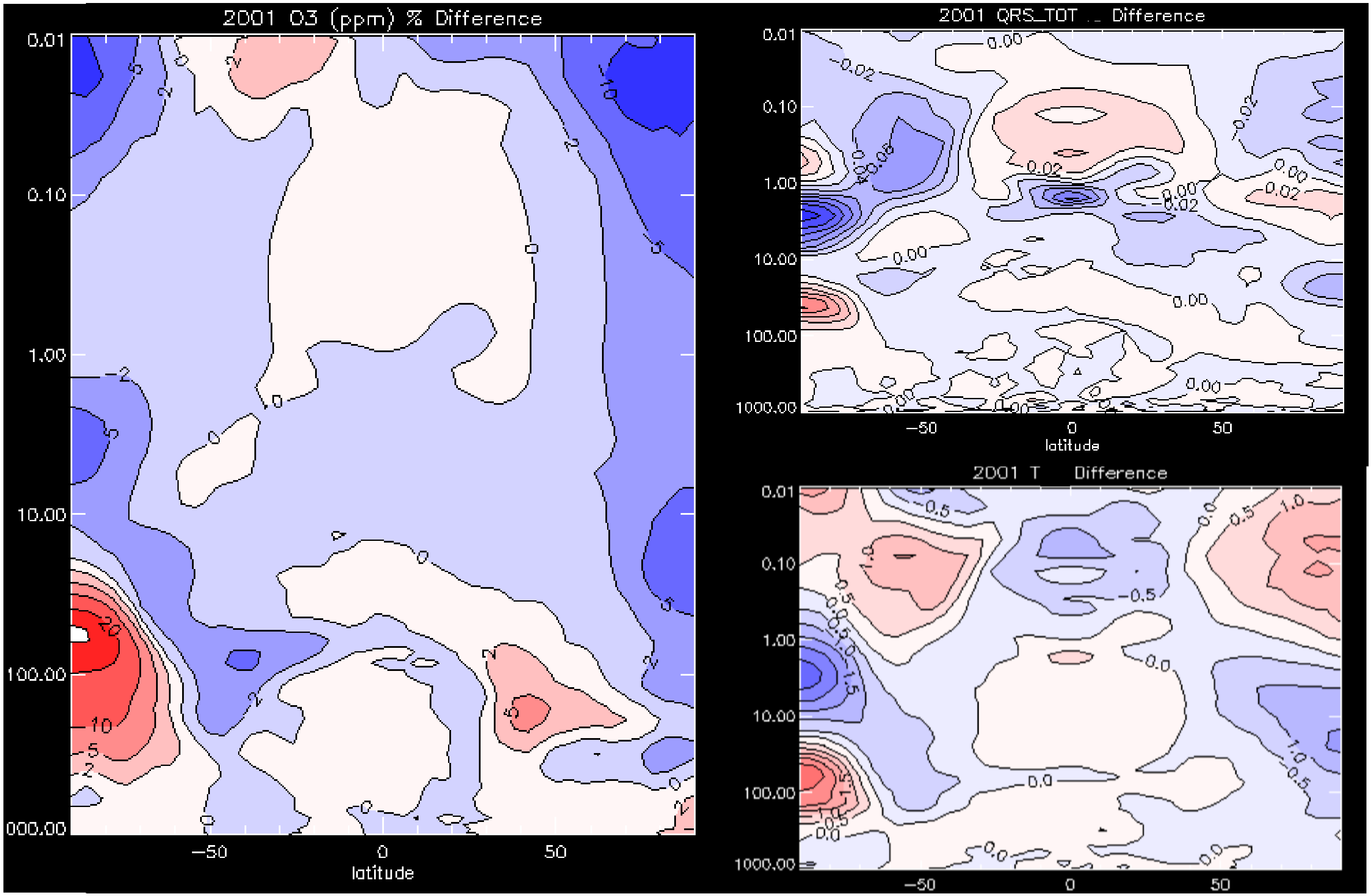


WACCM 2001

NOy % Difference Ozone % Difference



2001 ozone, SW heating & temperature changes



Final Thoughts

- The questions surrounding the effect of decadal solar variability on the atmospheric system are still wide open.
- We can assert a substantial and significant effect of decadal solar variation in the upper atmosphere.
- On shorter time scale, particle effects can be reproduced by our state-of-the-art models and have been shown to affect composition/thermal structure down to the lower stratosphere.
- In the lower stratosphere, the effect of decadal solar variations can be easily confused with other natural signals, like ENSO.
- In the troposphere, conclusions are not definitive yet, but new model capabilities offer hope for improved understanding.