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Modeling the Impact of the Solar Cycle and the QBO in the Atmosphere: Time-Varying vs. Constant Forcings

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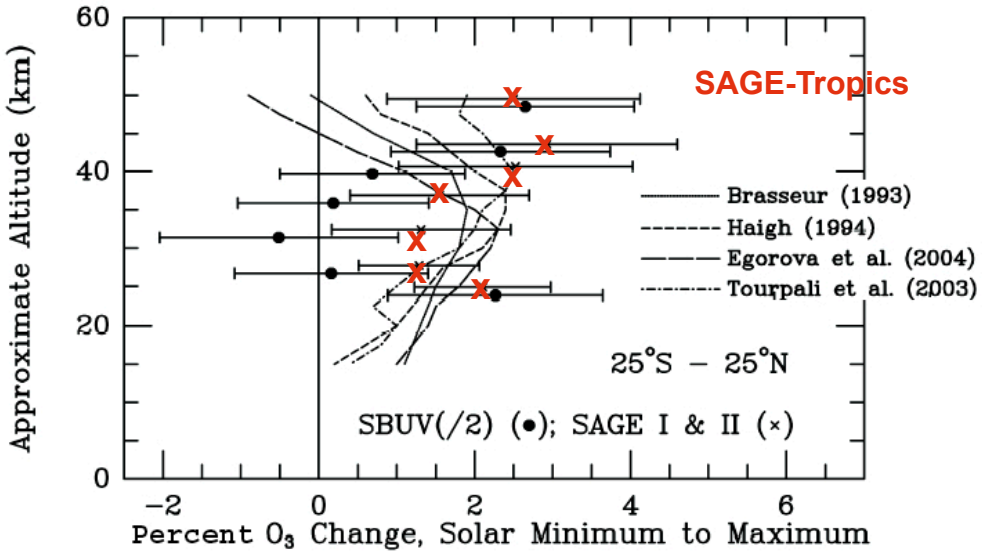
Outline

- Motivation
- Model and Experimental Description
- Results:
  1. Time-varying Solar and QBO Forcing Run
  2. Comparison to Constant Forcing Runs
- Summary and Outlook

Motivation: Discrepancy in Observed and Modeled Tropical Solar Ozone Signal

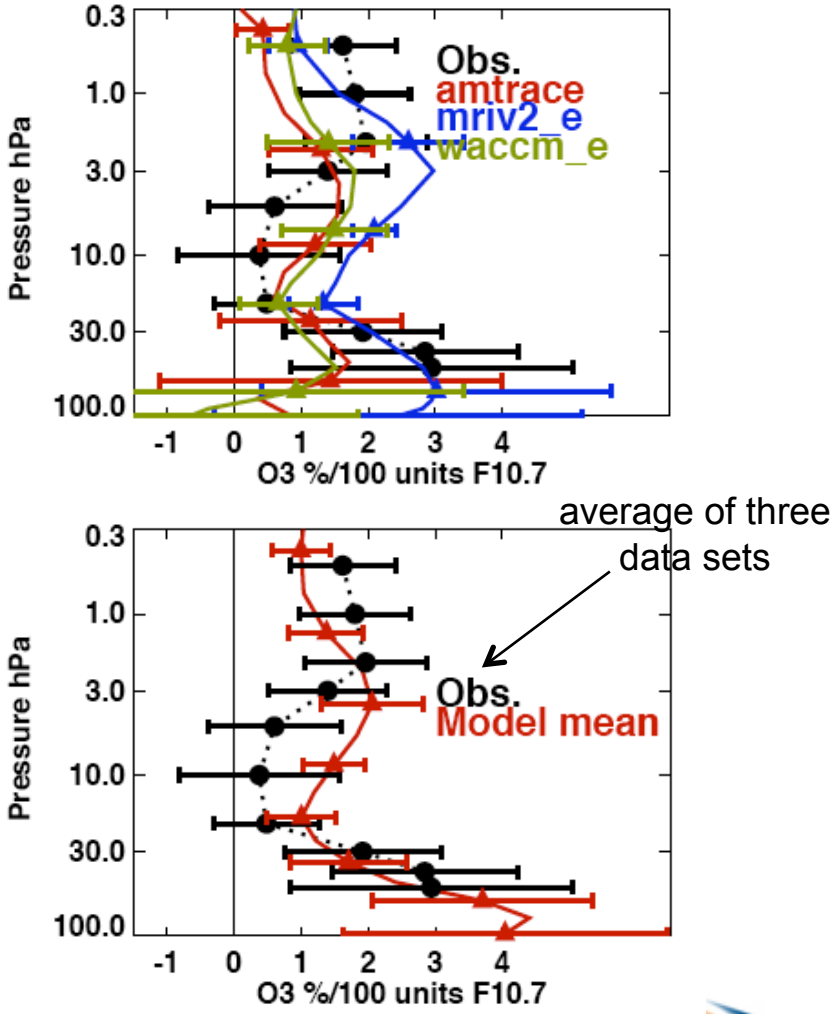
Observations and Models



WMO (2006)

Hypotheses:
Time-varying solar cycle?
Presence of a (prescribed/self-consistent) QBO?
SSTs?

Observations and REF1



Austin et al. (2008)

Whole Atmosphere Community Climate Model Version 3 (WACCM3)

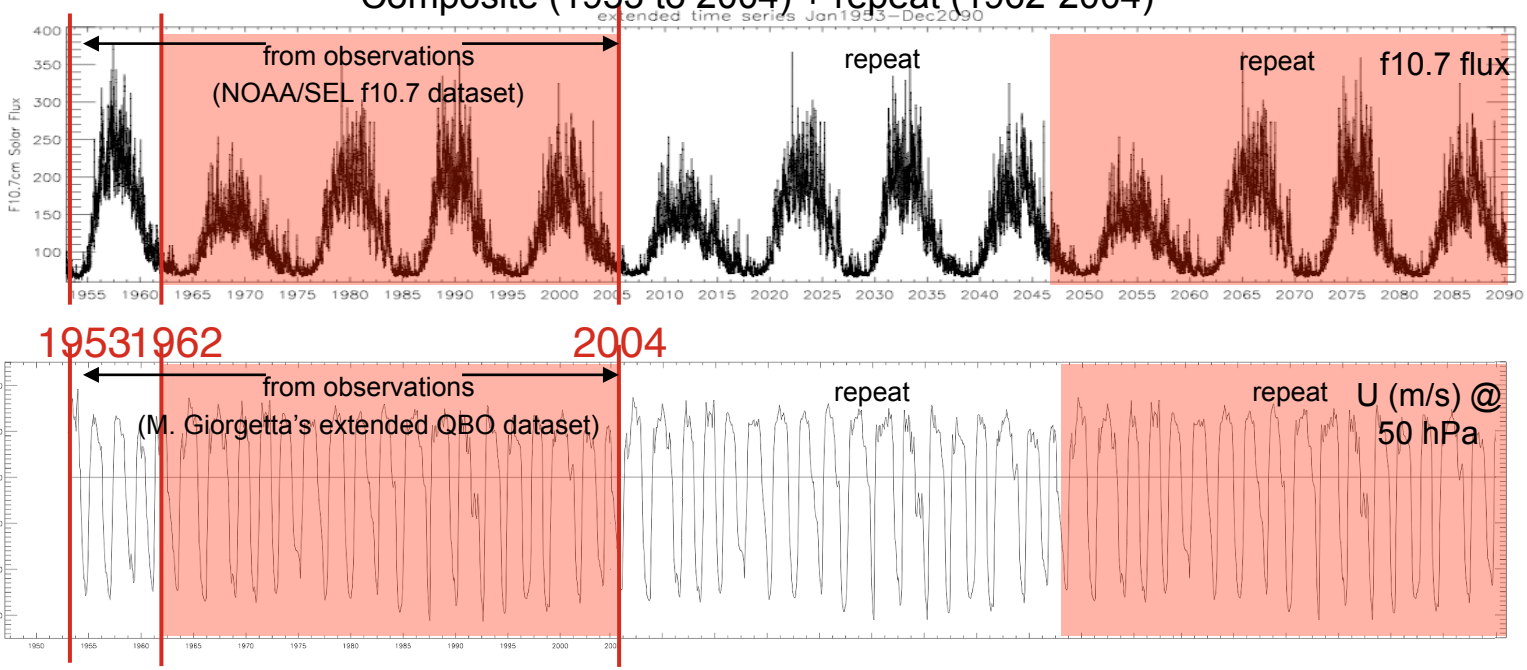
MODEL Framework	Dynamics	Tracer Advection	Resolution	Chemistry	Other Processes
Extension of the NCAR Community Atmosphere Model version 3 (CAM3)	Finite Volume Dynamical Core (Lin, 2004) Fully-interactive, i.e., consistent with model derived: O_3, CO_2, CH_4, N_2O, H_2O, CFC-11, CFC-12, O_2, NO. **WACCM does not produce a QBO spontaneously; a QBO may be forced by relaxing to observations in Tropics.**	Flux Form Finite Volume (Lin, 2004)	Horizontal: 1.9° x 2.5° or 4.0° x 5.0° (lat x lon) Vertical: 66 levels 0-140km • < 1.0km in UTLS • 1-2 km in mid-upper stratosphere • 3 km in M/LT	Middle Atmosphere Mechanism • 57 Species including Ox, HOx, NOx, BrOx, and ClOx • No NMHCs • Includes Het. Chemistry on LBS, STS, NAT, ICE • D-region Ion Chemistry	• GW Param. Internal and Orographically-generated • Molecular Diffusion (Banks and Kockarts, 1973) • Auroral processes, inc. ion drag, and Joule heating • Long-, short-wave, chemical potential heating

Garcia et al. (2007), Kinnison et al. (2007), Marsh et al. (2007)

Idealized Simulations: Time-Varying Solar Cycle & (Prescribed) QBO

Solar Cycle (SC) & QBO — 110 years

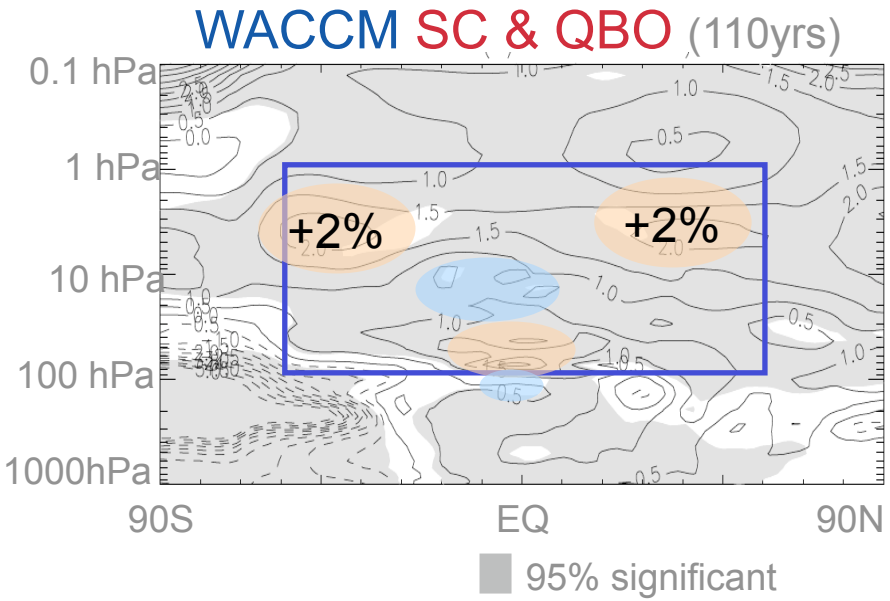
Composite (1953 to 2004) + repeat (1962-2004)

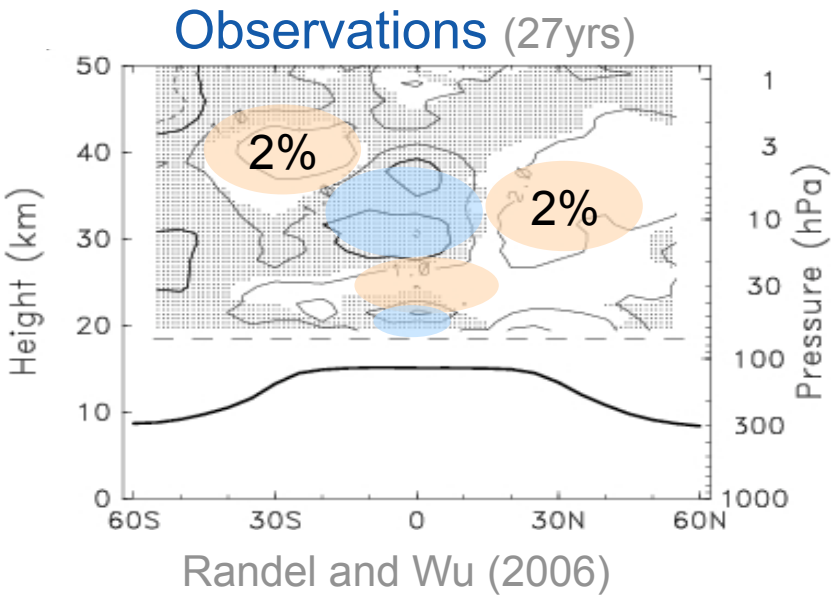


Constant 1995 GHG conditions, fixed SSTs

Solar Signal in Ozone (%/100 f10.7)

WACCM vs. Observations – Annual Mean





- Variable SC & QBO experiment close to response determined from observations

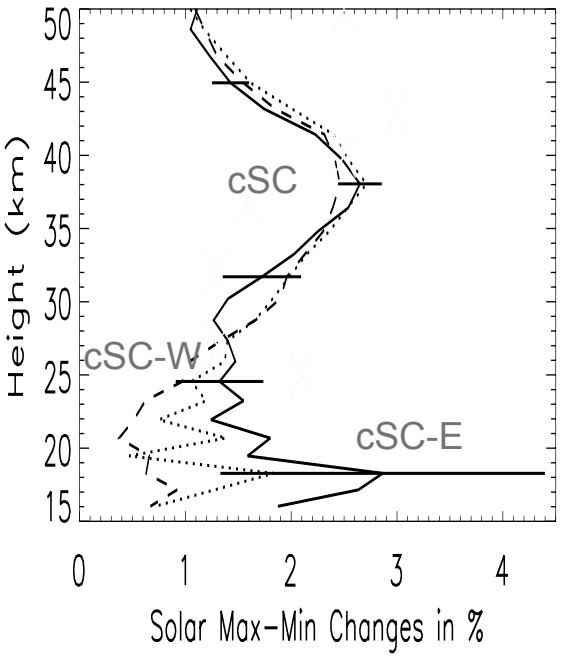
Overview of SC/QBO Experiments

Constant Forcings		Variable Forcings
Solar Cycle (SC) (Max/Min)		SC
SC and QBO	Constant SC and Variable QBO	SC and QBO

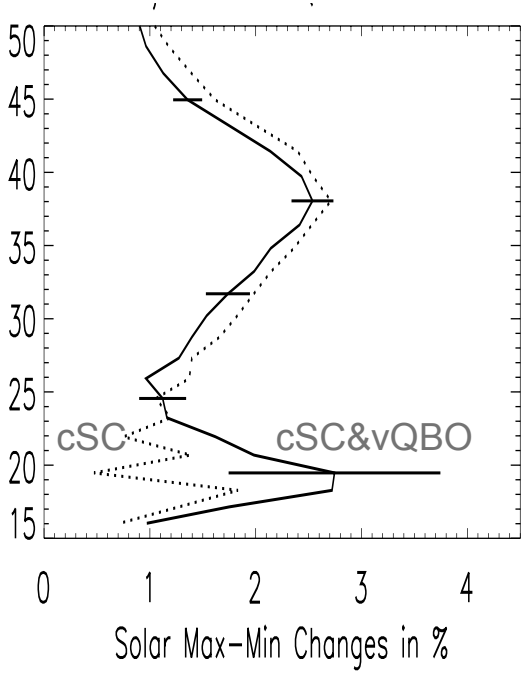
Tropical Solar Ozone Signal

Constant vs. Variable Forcing Runs (Max-Min)%

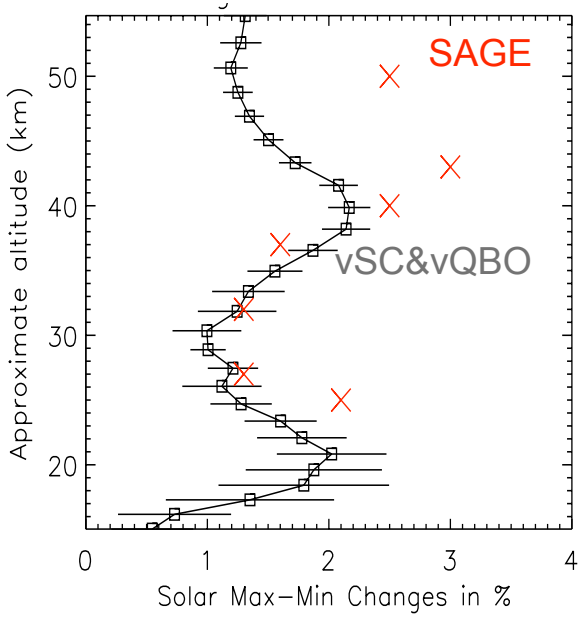
Constant SC and QBO



Constant SC and variable QBO



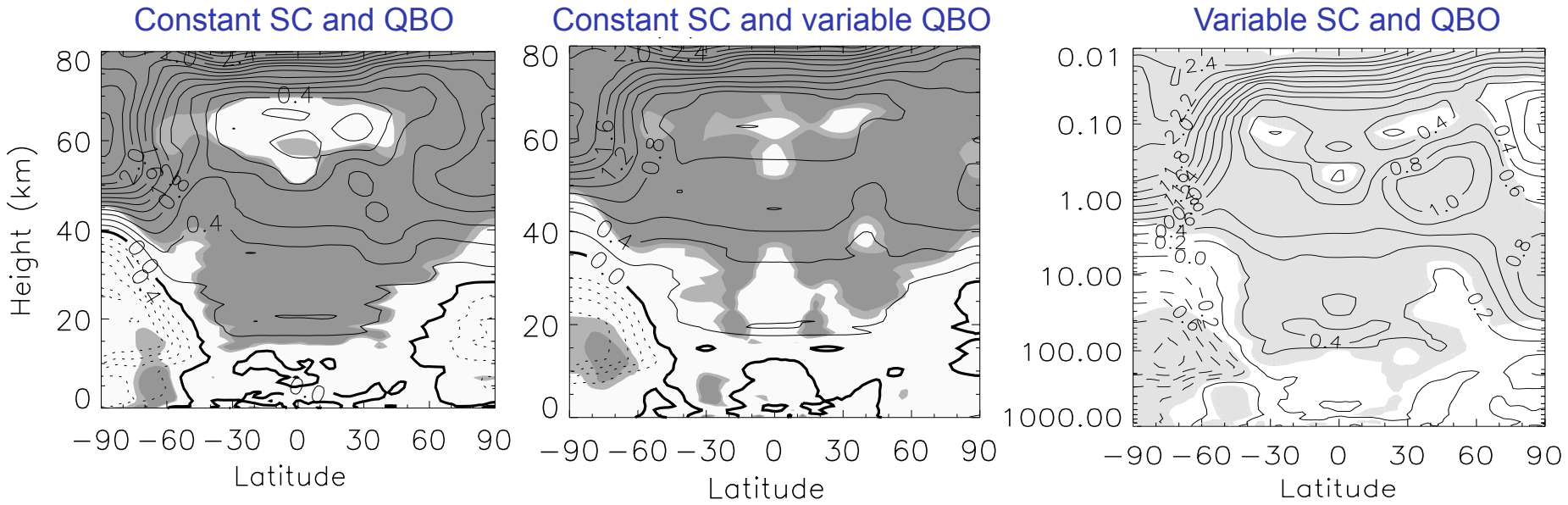
Variable SC and QBO



- solar response larger for constant (cSC) forcing
- response in upper stratosphere similar regardless of QBO
- QBO modifies vertical structure of the response in the lower stratosphere (~ 20-25 km)
- constant SC and QBO east experiment and constant SC and variable QBO experiment closest to the response determined from observations
- response below ~18 km is not significant in any of the simulations

Annual Mean Solar Temperature Signal

Constant vs. Variable Forcing Runs



Matthes et al. (2008), in preparation

- no large differences in the annual mean between constant and variable forcing runs!
- Variable SC and QBO experiment generates slightly larger response in the tropical to mid -latitude lower stratosphere as compared to constant forcing runs

Seasonal Evolution of the Solar Signal

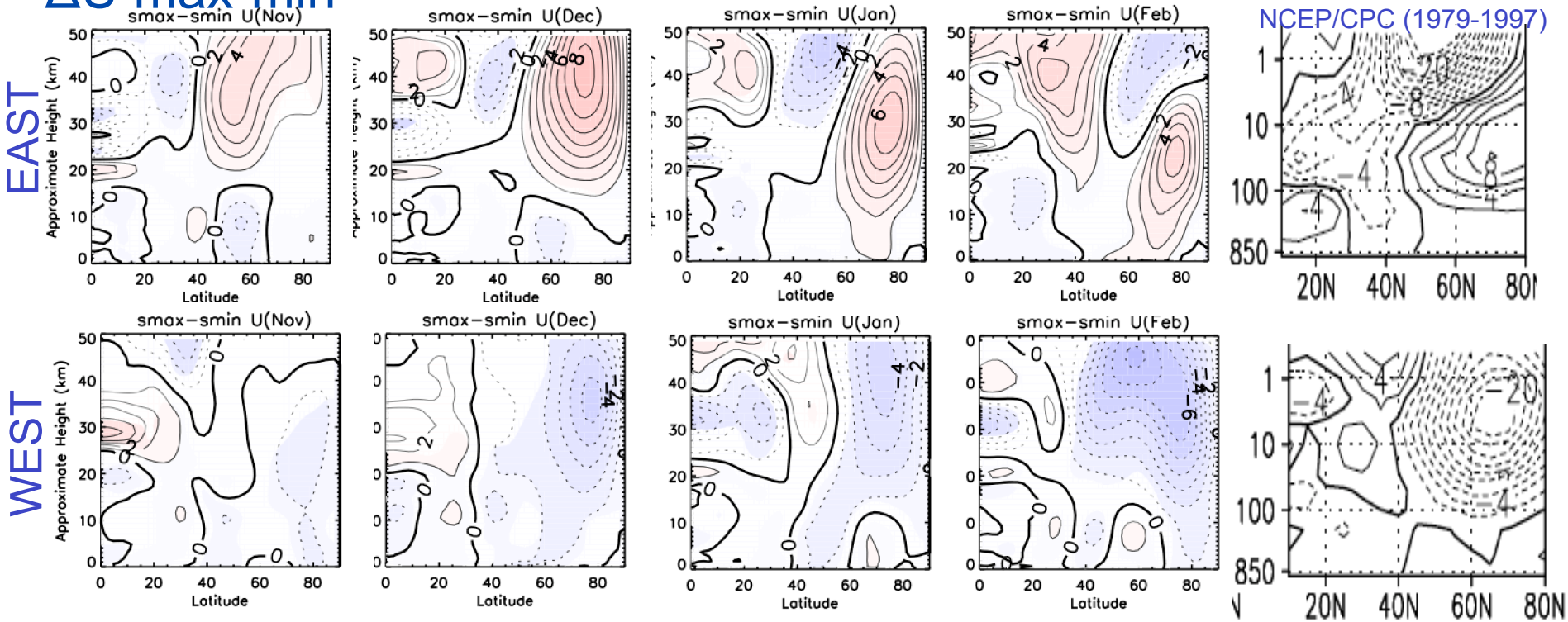
(van Loon and Labitzke/Kodera mechanism?)

Constant Forcings		Variable Forcings
Solar Cycle (SC) (Max/Min)		SC
SC and QBO	Constant SC and Variable QBO	SC and QBO

- Variable SC and QBO experiment closest to observations, shows modulation of the polar night jet, Brewer Dobson circulation and dependence of polar vortex on solar/QBO phase
- all other experiments fail to show this

QBO Impact – SC&QBO vs. Obs.

ΔU max-min



Matthes et al. (2008), in preparation

Shading indicates 95% significance

Obs. - Feb

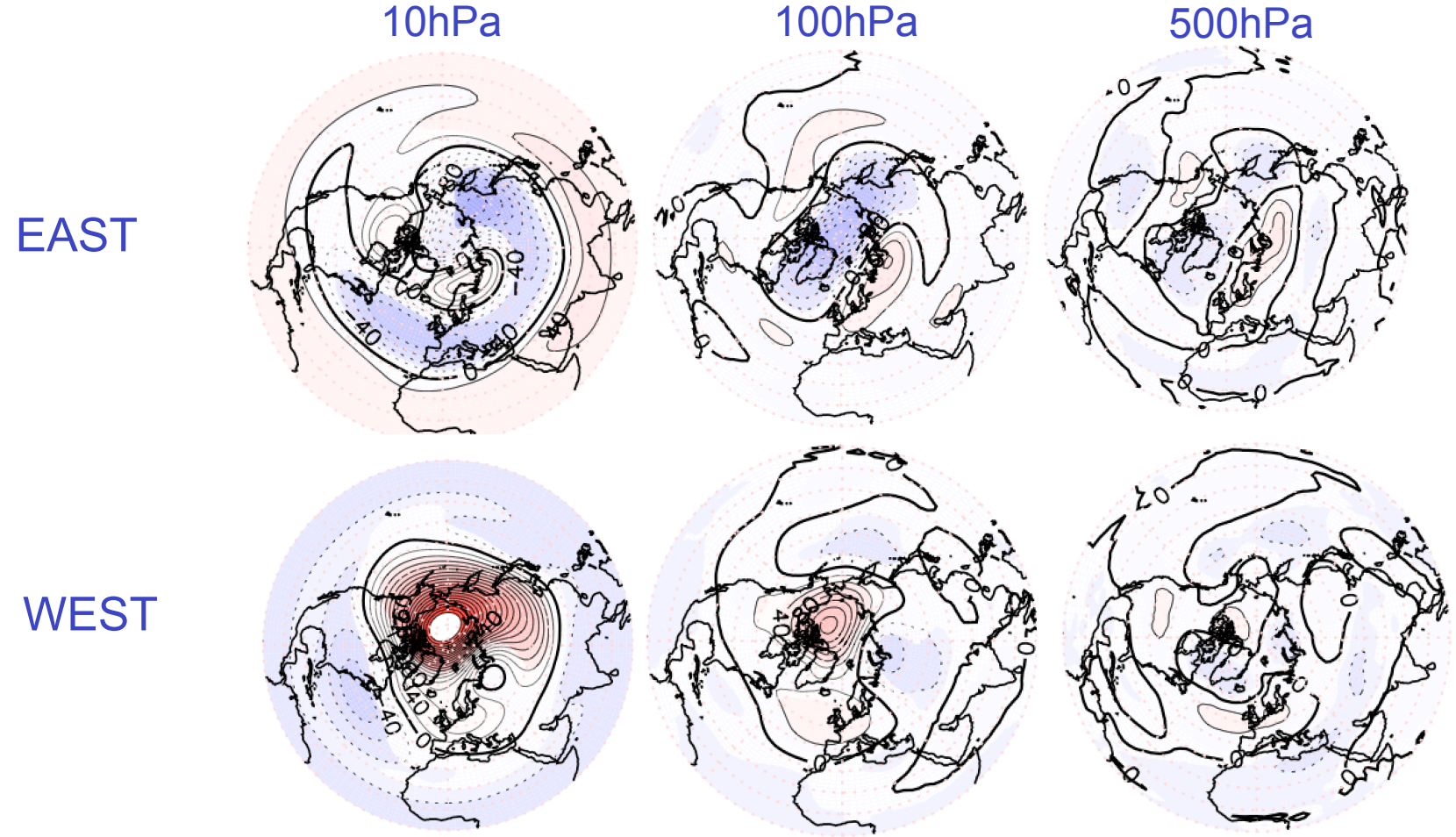
NCEP/CPC (1979-1997)

Matthes et al. (2004)

- poleward-downward propagation (Kodera and Kuroda, 2002)
- out-of-phase signal for QBO East and West
- qualitative agreement with observations and other mechanistic model studies (Labitzke and van Loon, 1988; Yoden, pers. comm., 2007)

Stratospheric and Tropospheric AO signal

February - ΔZ max-min



Matthes et al. (2008), in preparation

- AO-like signal all the way down to the troposphere (confirms Matthes et al., 2006)
- out-of-phase signal for QBO phases

Summary and Outlook

- Constant forcing runs show larger tropical solar ozone response than variable forcing run
- Although differences in the annual mean solar signal are small between constant and variable forcing, the variable SC and QBO forcing run is the only that shows the observed seasonal evolution of the solar signal
- QBO influences vertical structure of the solar signal in the tropical middle to lower stratosphere
- WACCM needs time varying SC and QBO forcing to show observed solar response. Is this true for other models as well (SOLARIS)?
- What is the impact of SSTs (variable vs. fixed vs. interactively calculated) (SOLARIS)?