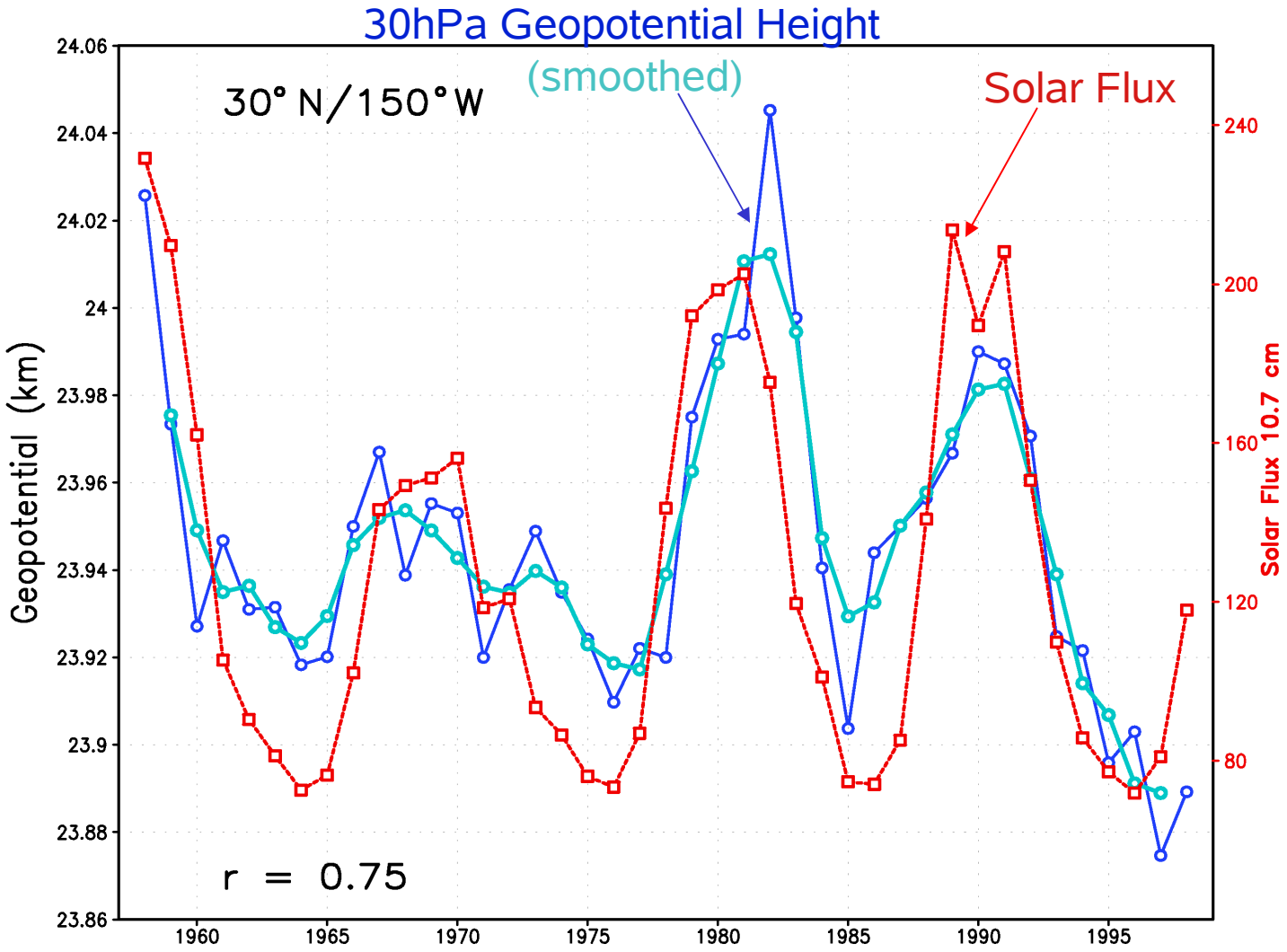
Solar Cycle Studies at the Freie Universität Berlin

Katja Matthes, Ulrike Langematz, Anne Kubin, and Karin Labitzke

Overview

- Motivation
- Modeling Results:
  1. Mechanistic Forcing Experiments
  2. Solar Cycle Time Slice Experiments
     - Time Varying Solar Cycle Experiments
- SOLARIS (SOLAR Influence for SPARC)

Positive Correlations Sun - Stratospheric Parameters



Labitzke and van Loon (1999)

MAECHAM5-MESSY

- Middle Atmosphere ECHAM5
- Based on ECHAM model family
- Horizontal resolution: T42 (2.8°x2.8°) (spectral model)
- Vertical resolution: L39 (L90)
- Model top: 80km (mesosphere)
- So far: non-interactive chemistry mode, no QBO
- high-resolution short-wave heating parameterization FUBRad (Nissen et al. 2007)

(Roeckner et al. 2003, Jöckel et al. 2005)

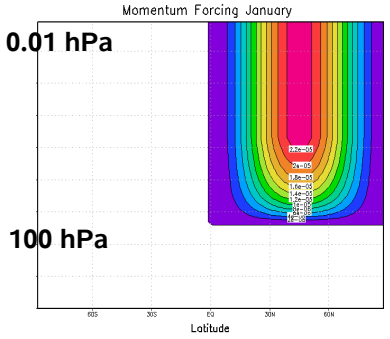
WACCM3

- Whole Atmosphere Community Climate Model
- Based on NCAR Community Climate Model family (CAM3)
- Horizontal resolution: 1.9˚x2.5˚(4° x 5°) (finite volume dynamics)
- Vertical resolution: L66
- Model top: 140km (thermosphere)
- Interactive chemistry, Mozart-3 package (Kinnison et al., 2007)
- Mesosphere-lower thermosphere processes from TIME-GCM

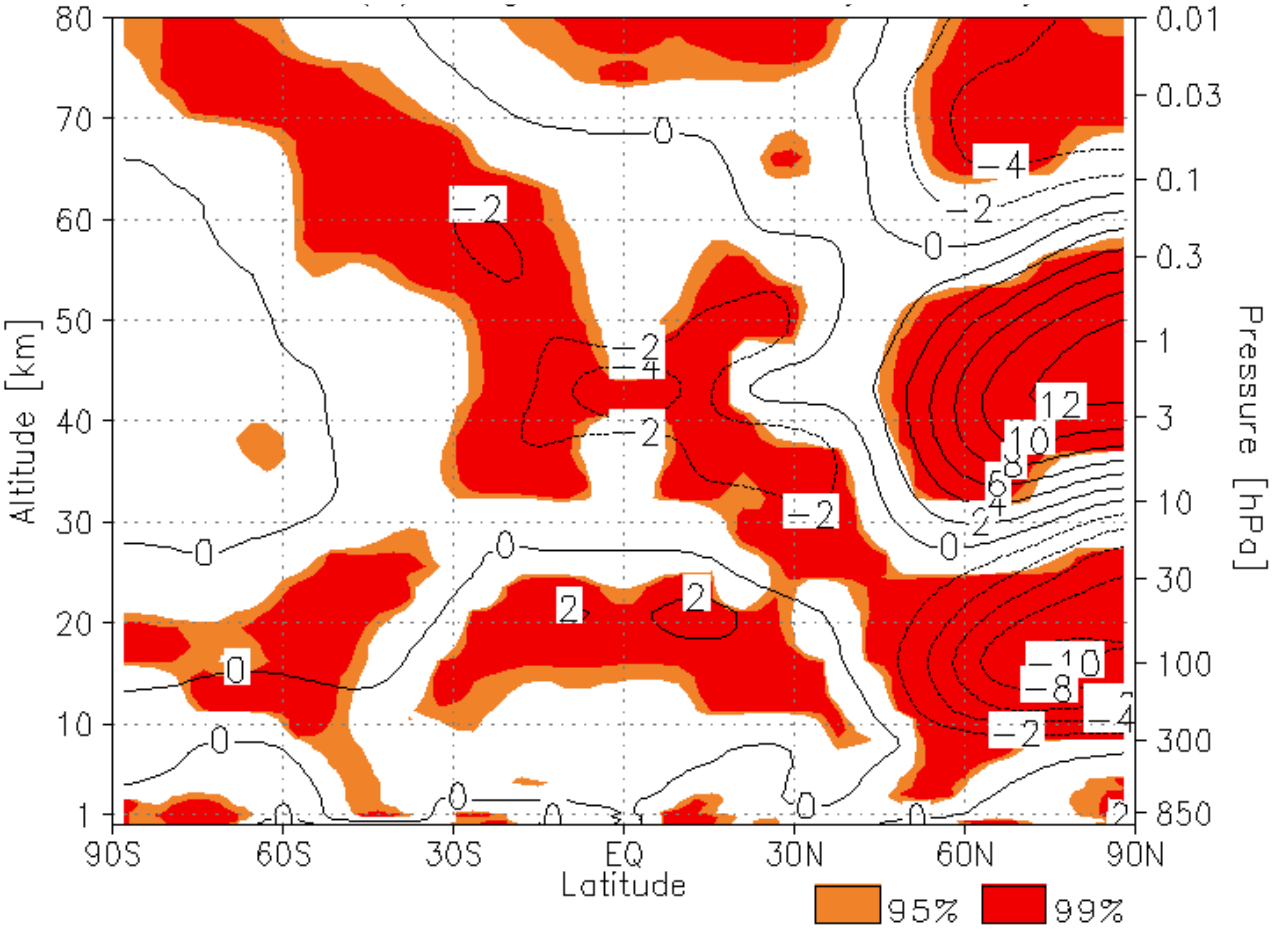
(Garcia et al., 2007)

Modeling Results
1. Mechanistic Forcing Experiments (MAECHAM5-MESSY)

- Mechanistic momentum forcing in the winter stratosphere
- 25 months perpetual January forcing versus control run



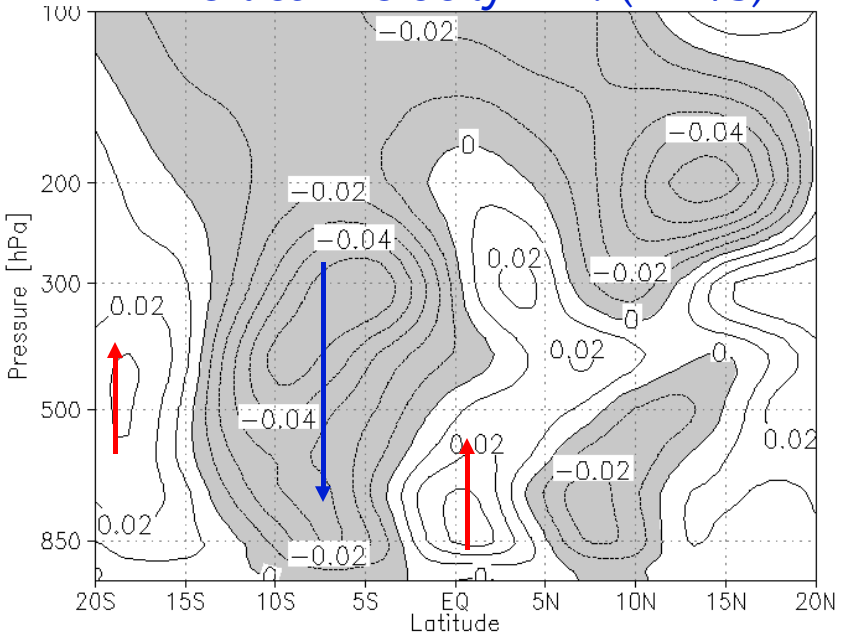
Temperature Differences (forc-ctrl) in Kelvin



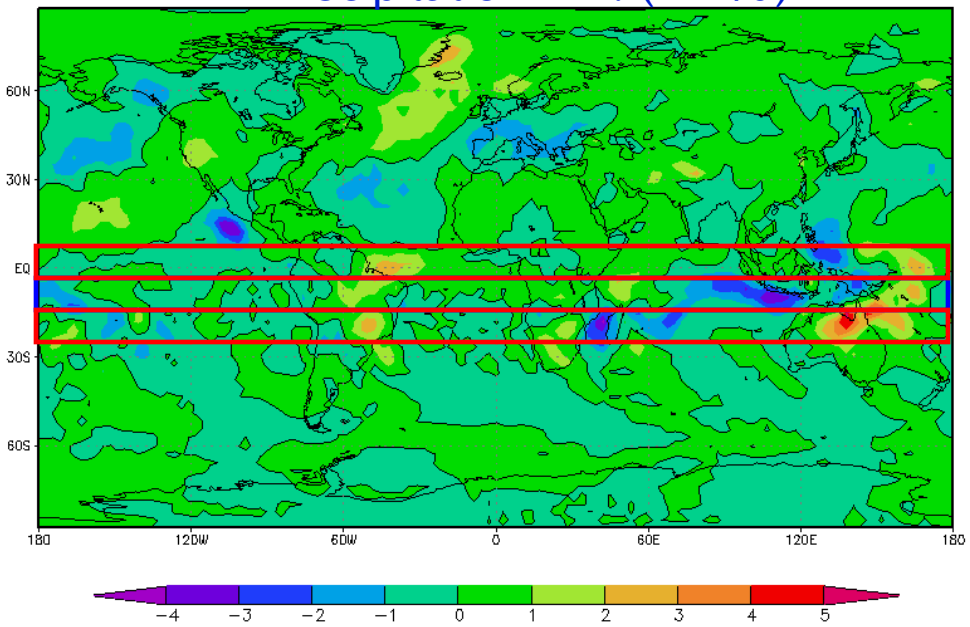
Dynamically induced significant relative warming in the tropical lower stratosphere.

Tropical Tropospheric Response (forc-ctrl)

Vertical Velocity Diff. (mm/s)



Precipitation Diff. (mm/d)



Weaker tropical upwelling

Consistent precipitation changes

⇒ Response consistent with observational response to solar cycle, e.g. Kodera (2004).

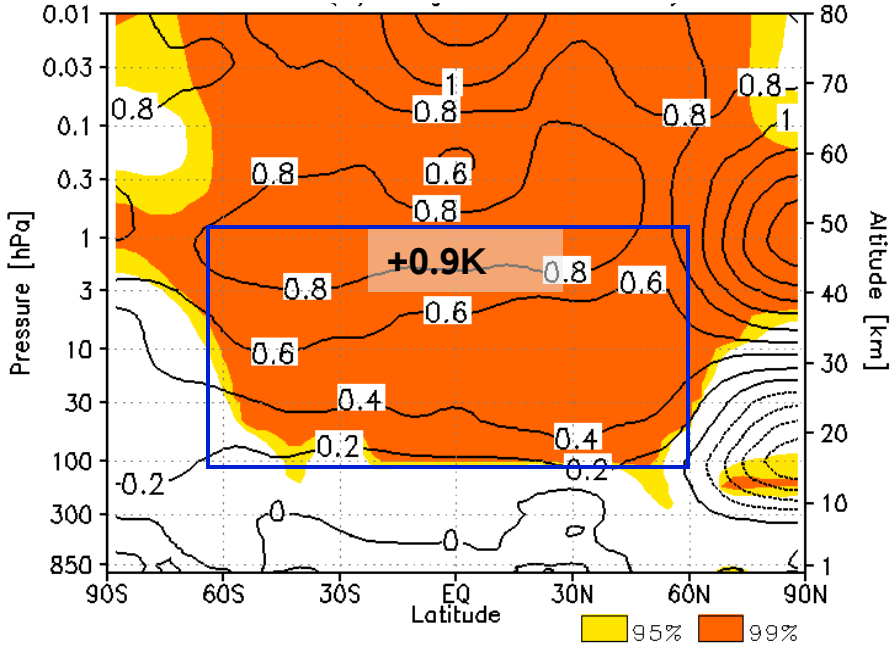
Modeling Results
2. Solar Cycle Time Slice Experiments (MAECHAM5-MESSY)

- Prescribed spectral irradiance (Lean et al.1997) and ozone changes (Haigh, 1994)
- climatological SSTs
- 25 years under perpetual solar maximum and minimum conditions

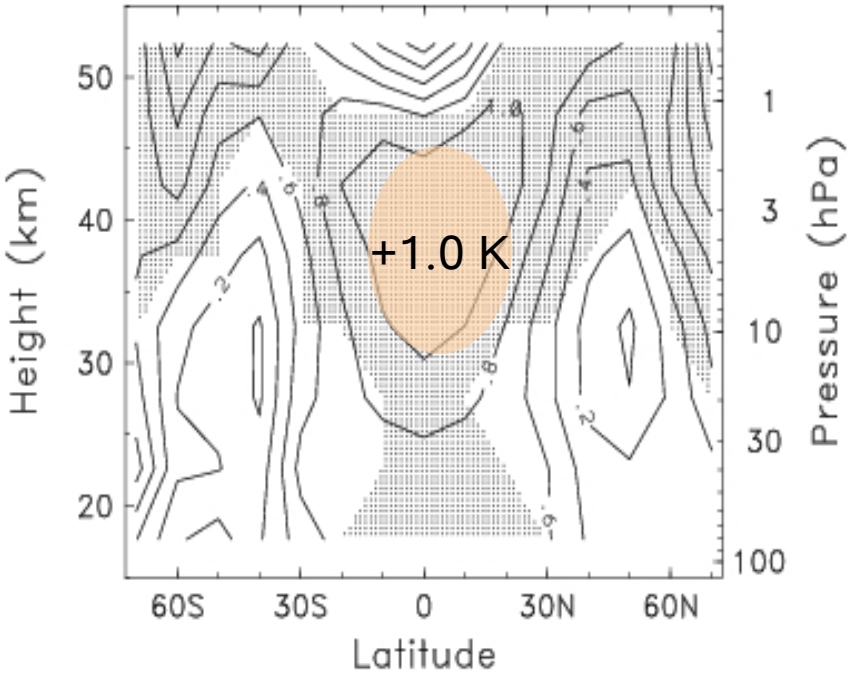
Observed vs. Modeled Solar Signal in Temperature

- Annual Mean

MAECHAM5-MESSY



SSU/MSU4 (1979-2005)

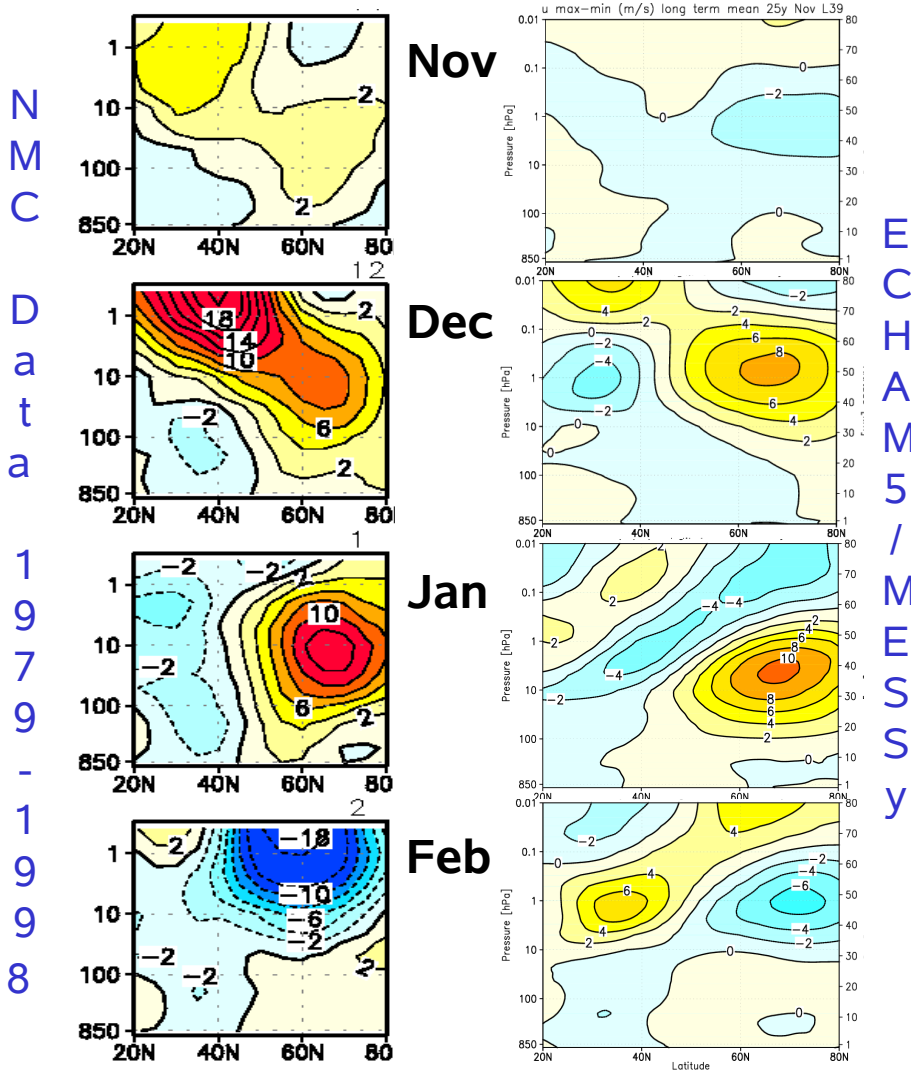


Courtesy of W. Randel (2006)

Qualitative correspondence with observations

Observed vs. Modeled Solar Signal in Zonal Mean Wind

- NH Winter

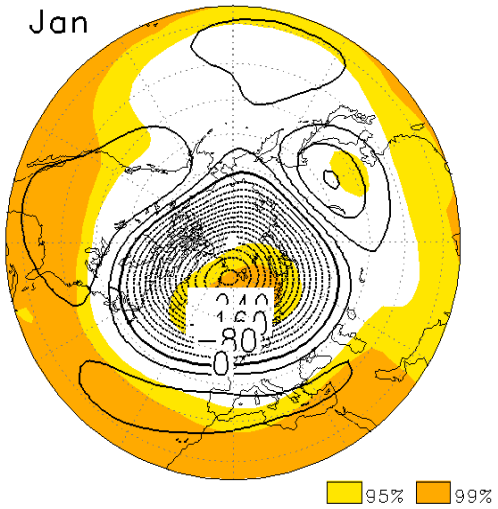


Obs. poleward -downward movement (Kodera and Kuroda, 2002) reproduced in the model

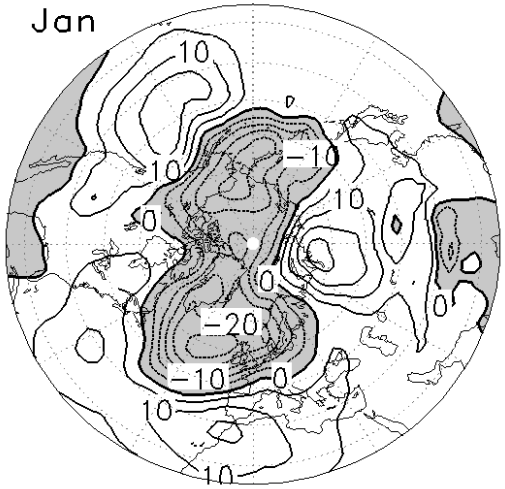
update of Kodera (1995), Matthes et al. (2003)

Geopotential Height and Temperature Differences (Max-Min) - January NH

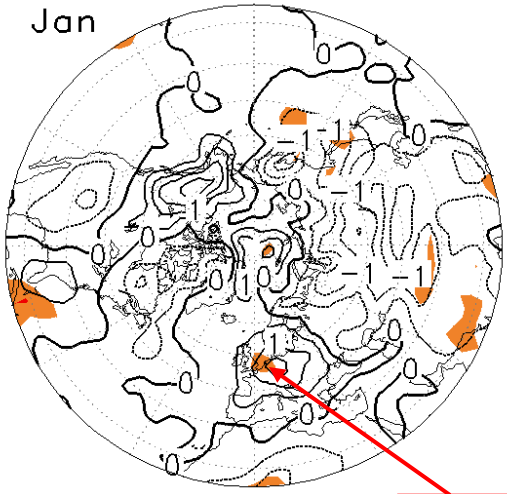
ΔZ 10 hPa



ΔZ 1000 hPa



ΔT 1000 hPa

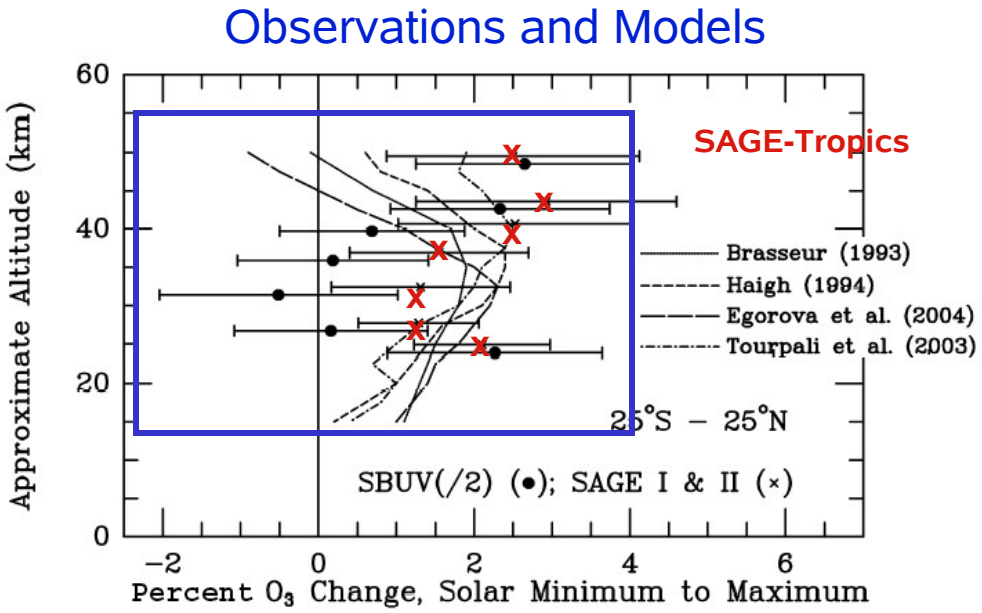


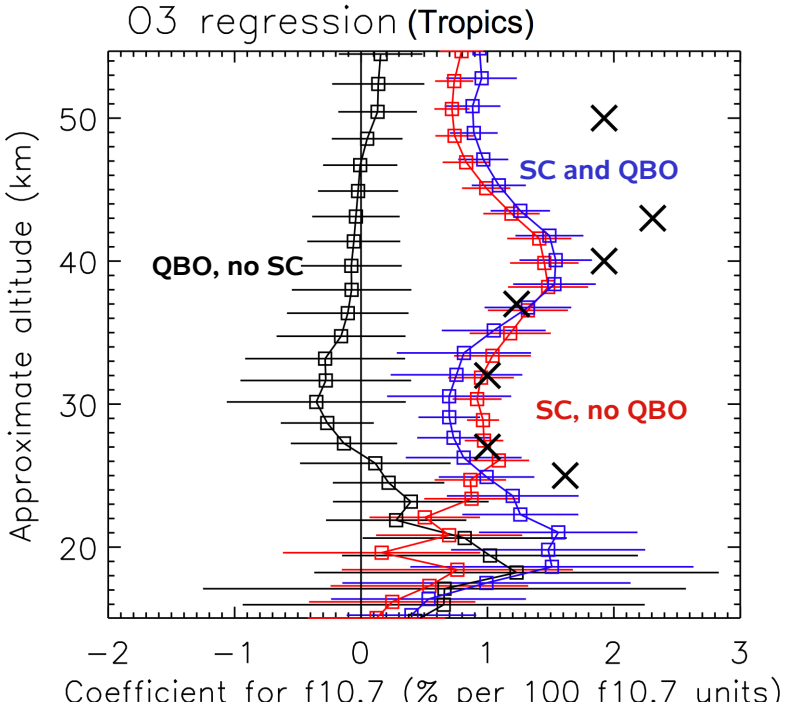
Significant AO-positive signal in the stratosphere and in the troposphere, in agreement with observations (Kuroda and Kodera, 2002).

Modeling Results
3. Solar Cycle Time Varying Experiments (WACCM3)

- Time-varying solar cycle and/or time-varying (prescribed) QBO:
  - 110yrs solar cycle + QBO
  - 110yrs solar cycle (no QBO forcing)
  - 50yrs QBO (no solar forcing)
- Constant 1995 GHG conditions, climatological SSTs

Observed vs. Modeled Solar Signal in Ozone (%)
Annual Mean -Tropics





WACCM time-dependent runs
[SAGE (black crosses) scaled by 100/130]

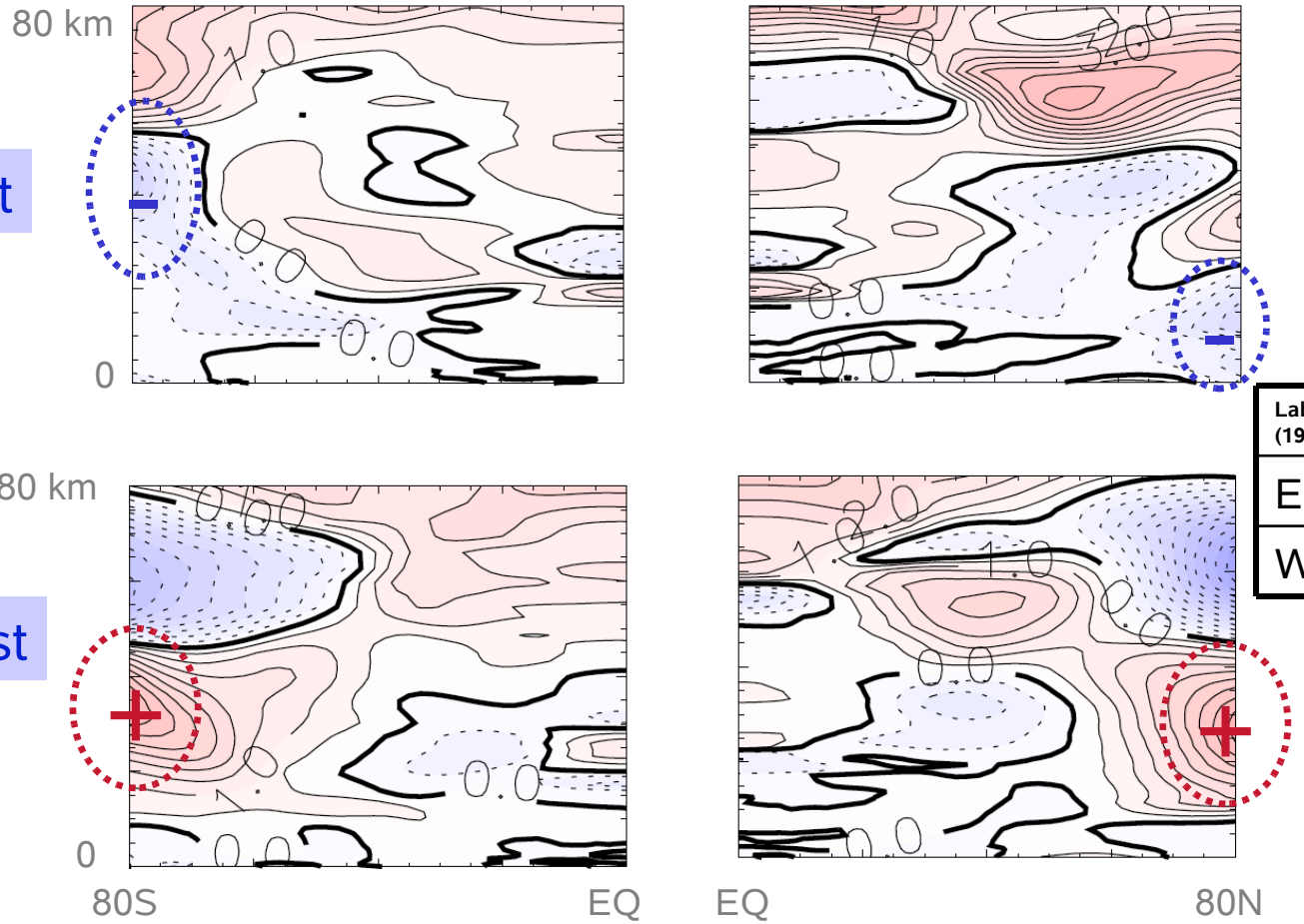
- response to SC in the upper stratosphere similar regardless of QBO
- QBO modifies vertical structure of the response in the lower stratosphere (~ 20-25 km)
- Solar + QBO experiments closest to the response determined from observations
- response below ~18 km is not significant in any of the simulations

Winter Signal in Zonal Mean Temperature

SH (August) NH (February)

QBO East

QBO West



Labitzke (1987)	Min	Max
E	W	C
W	C	W

Out-of-phase response for QBO phases agrees with observations (LvL).

SOLARIS
(SOLAR Influence Study Group for SPARC)

coordinated by K. Kodera, K. Matthes and L. Gray

- Follow on of solar intercomparison for GRIPS (Kodera et al., 2003, Matthes et al., 2003)
- Collaborative activity with the SCOSTEP CAWSES activity (Theme 1: Solar Influence on Climate)

http://www.geo.fu-berlin.de/en/met/ag/strat/research/SOLARIS/index.html

Coordinated Specific Studies

I) TMST-Model:
Thermospheric and mesospheric response in high top models, precipitating particles (WACCM, HAMMONIA, CMAM)

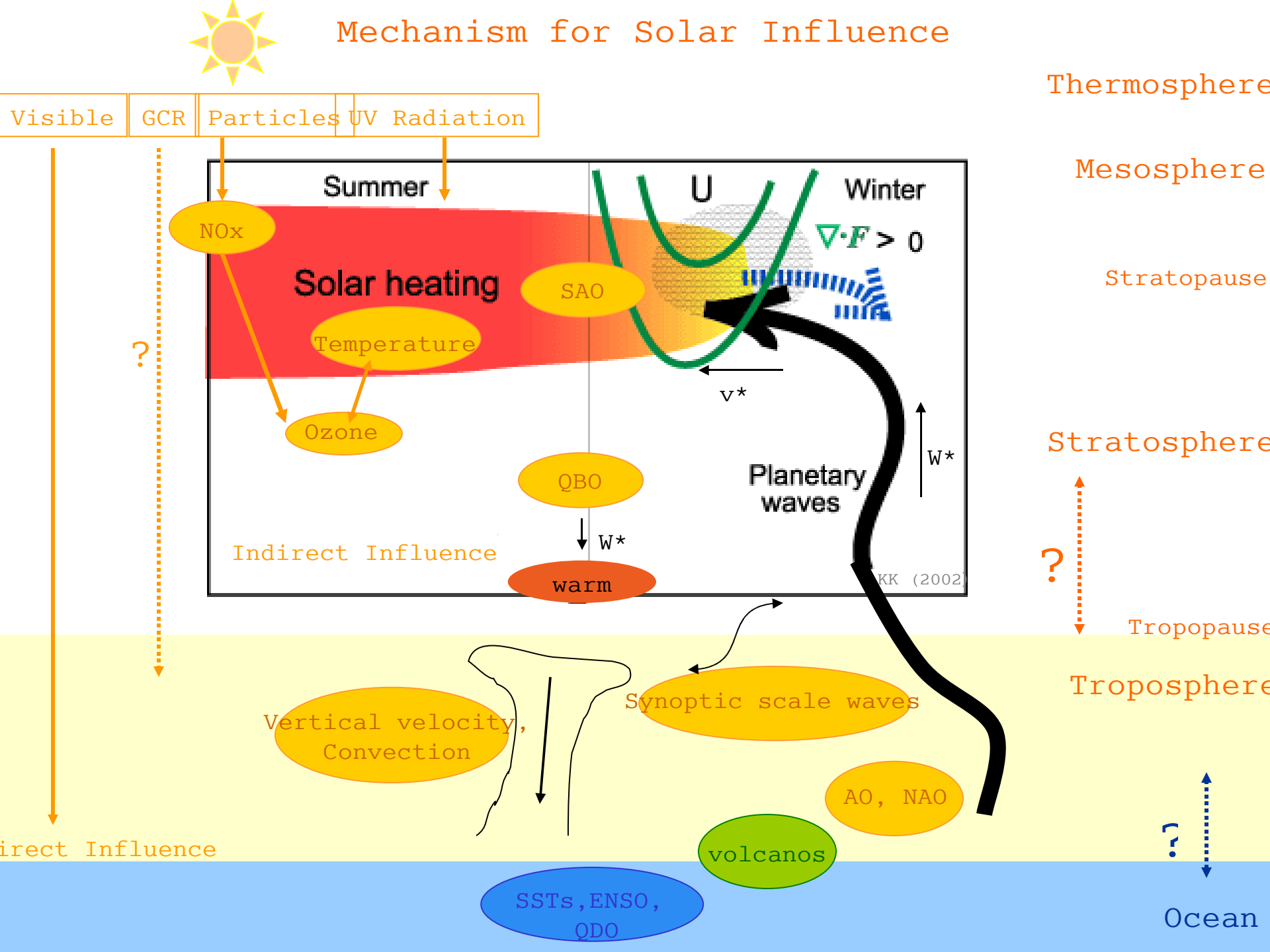
- Chemistry Climate Models (CCMs):
  Ozone and Temperature Response
- Atmospheric GCM (A-GCM):
  Role of Dynamics Including the Role of the QBO
- A-GCM:
  Stratosphere-Troposphere Coupling
- Atmosphere-Ocean coupled models (AO-GCM):
  Role of the ocean and paleoclimate (Maunder Minimum)

Activities

- Summary of first SOLARIS workshop in SPARC Newsletter (Matthes et al., 2007)
- Analysis of solar signal in REF1 simulations (Austin et al., 2007)

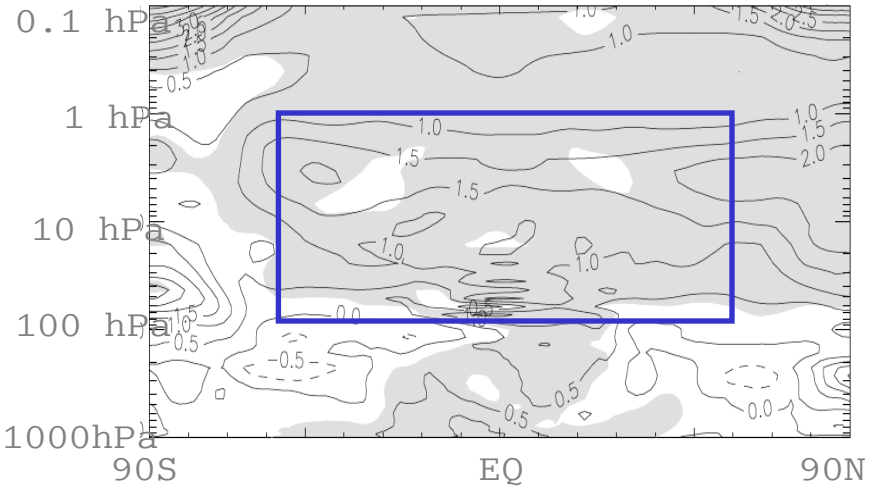
=> Start to understand which processes are important to simulate the solar signal

Mechanism for Solar Influence

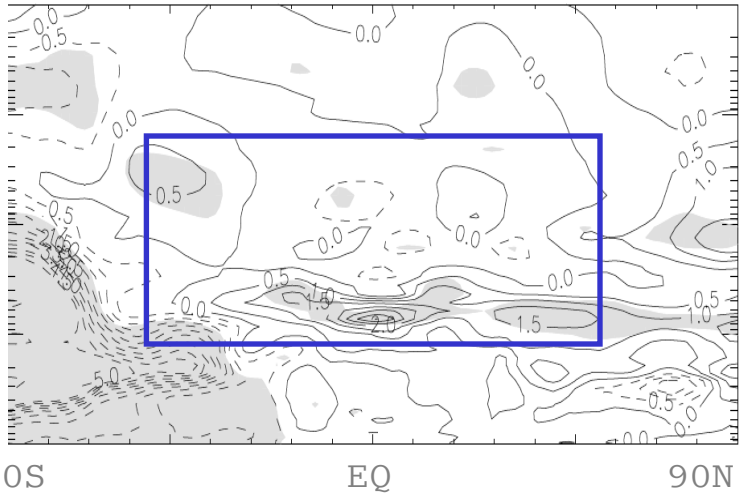


Solar Signal in Ozone (%/100 f10.7)

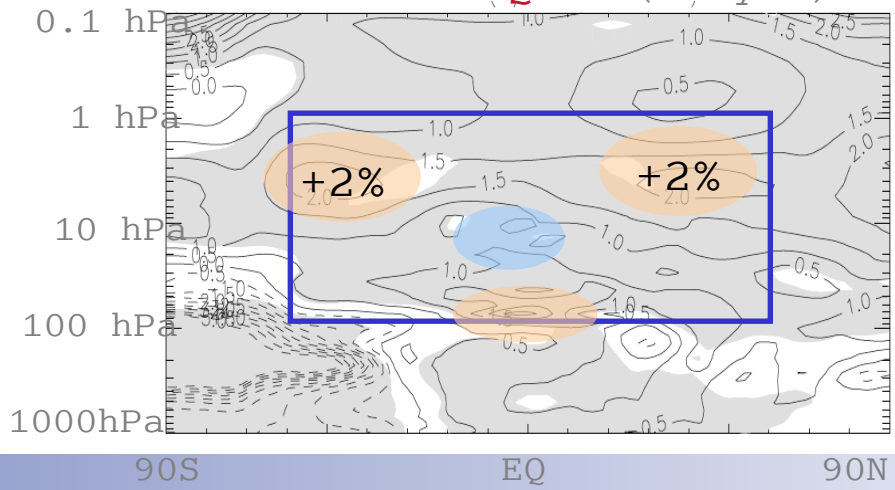
WACCM Solar (110yrs)



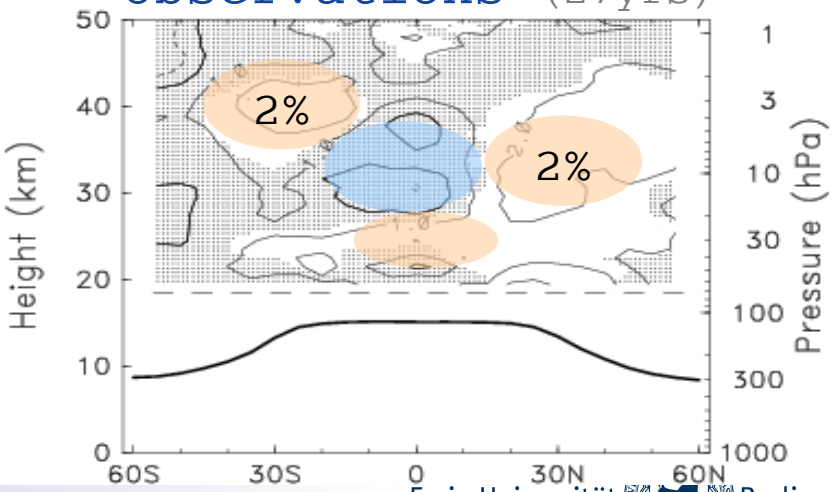
WACCM QBO (50yrs)



WACCM Solar & QBO (110yrs)



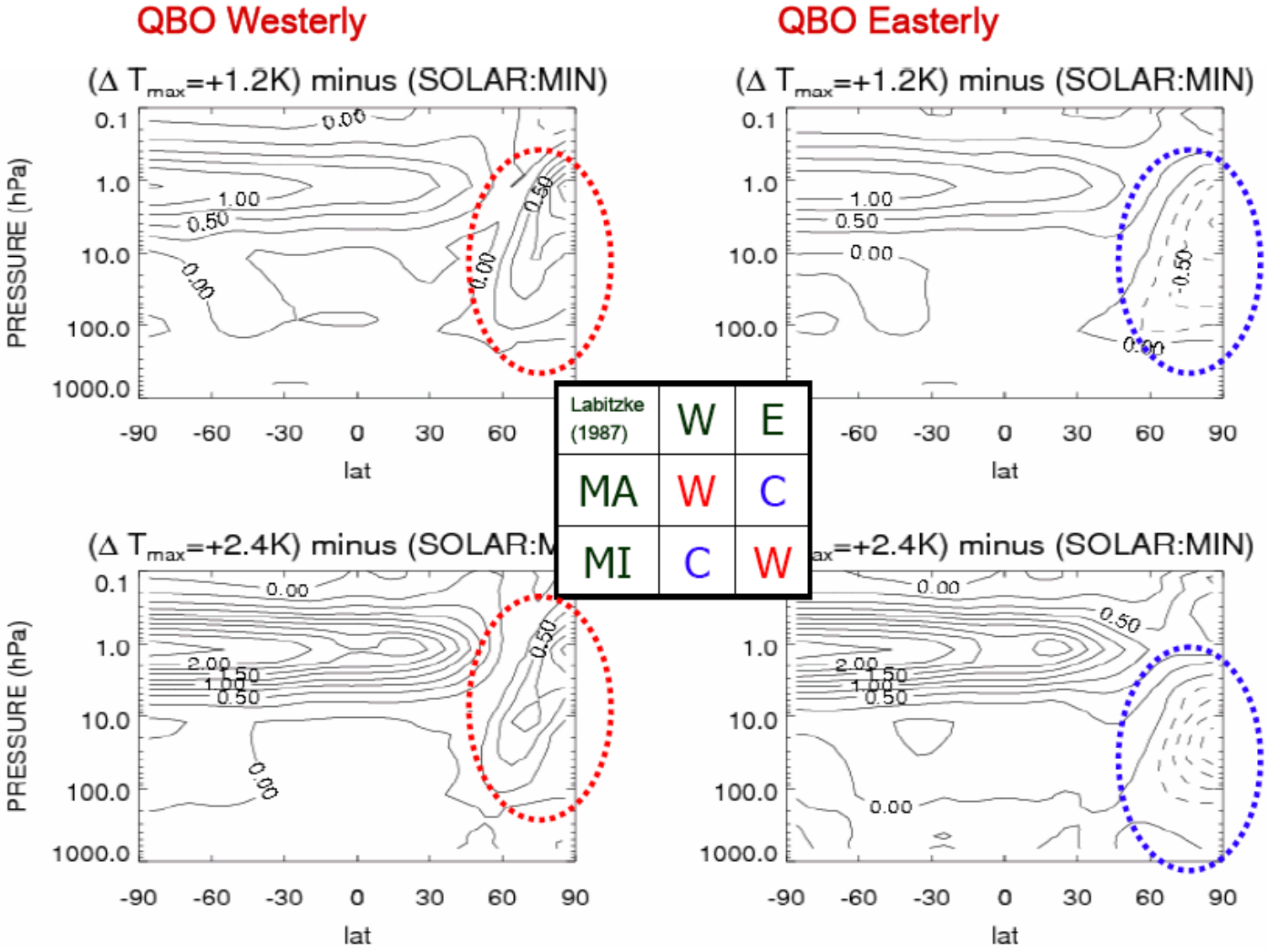
Observations (27yrs)



95% significant

Randel and Wu (2006)

Comparison with Observations and Mechanistic Model Studies



Courtesy of S. Yoden (2007)