

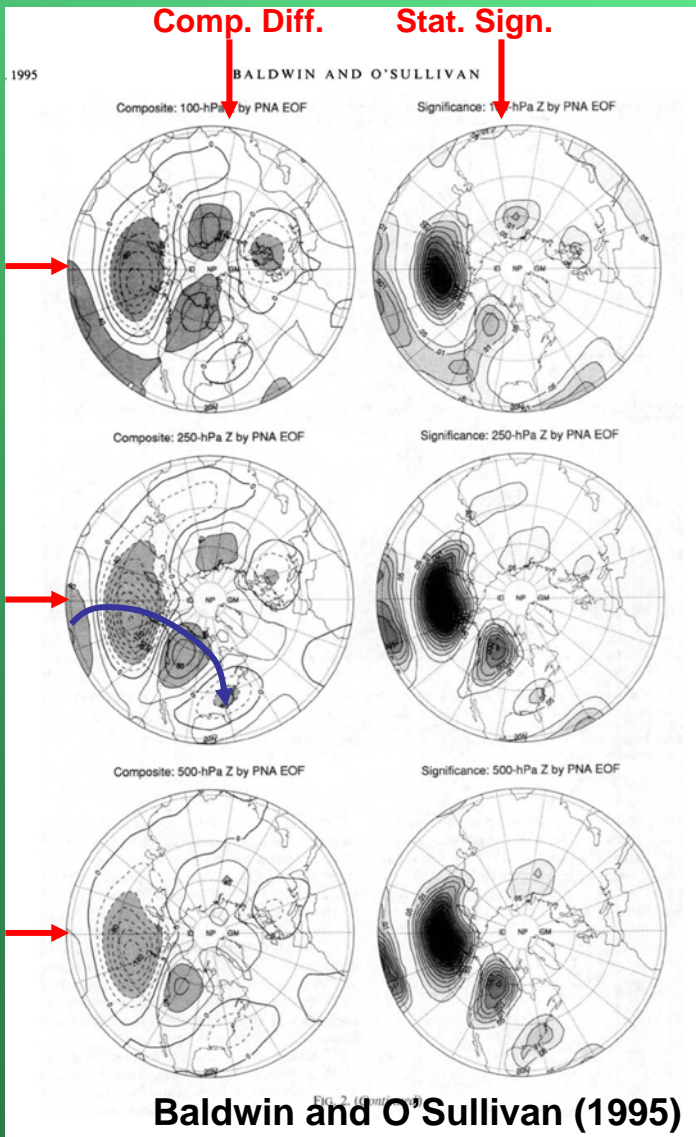
# THE EFFECT OF ENSO ON THE DYNAMICAL AND THERMAL STRUCTURE OF THE MIDDLE ATMOSPHERE

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## OUTLINE

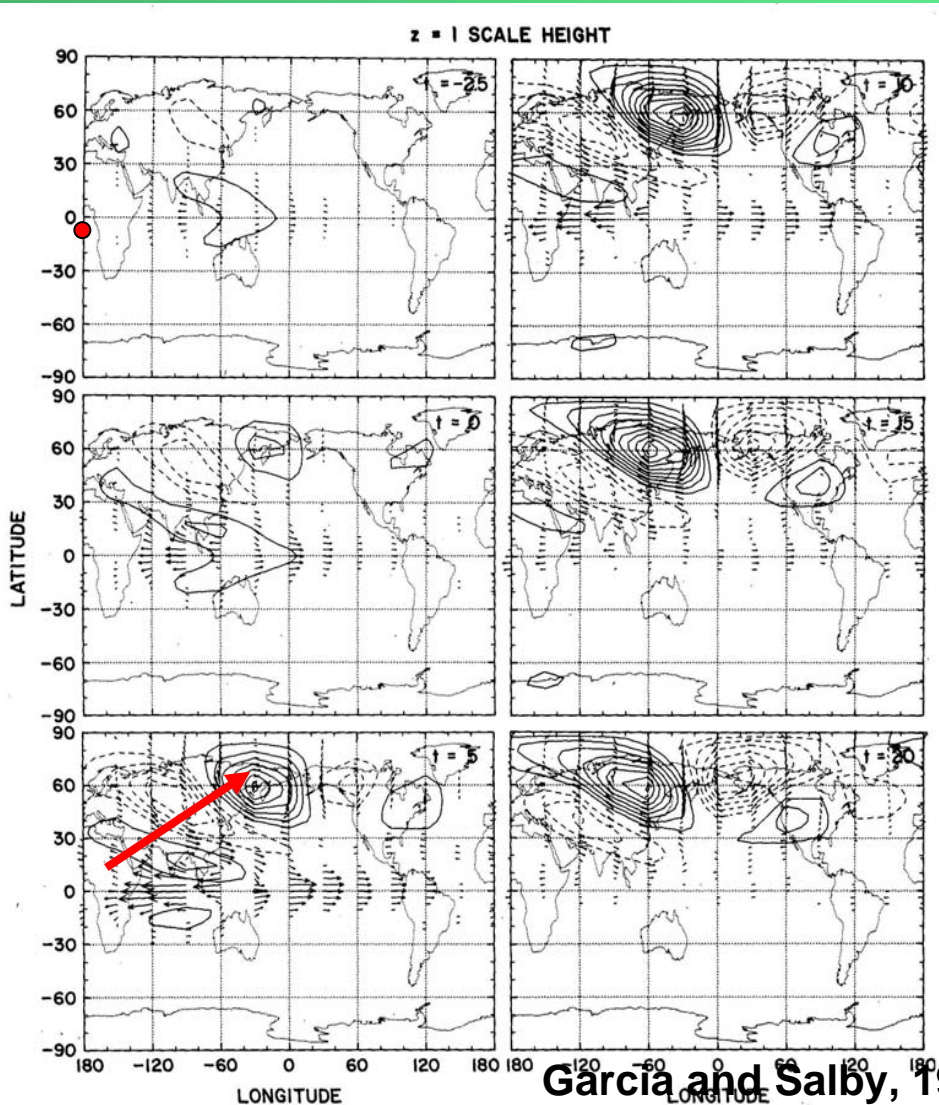
1. Background/review
2. Model and simulation description
3. ENSO influences:
  - Dynamical and thermal effects: Statistical significance
  - Water vapor in stratosphere
  - Annular mode
4. Conclusions

# Background/Review



- El Niño and Southern Oscillation (ENSO) impacts significantly tropospheric climate.
- A PNA-like pattern emerges clearly.
- Patterns of statistical significance highlight the PNA signature throughout the troposphere.

# Background/Review

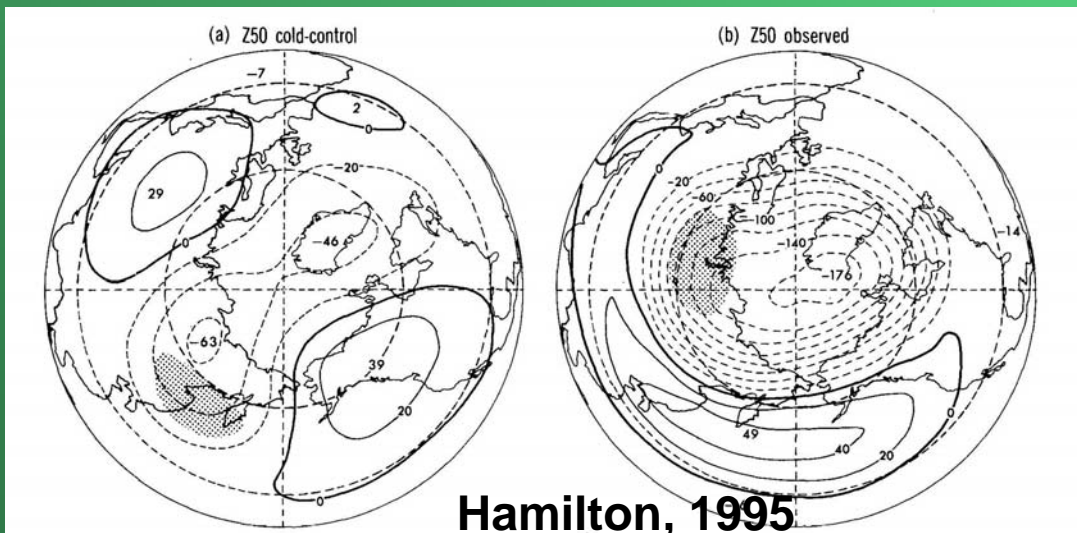
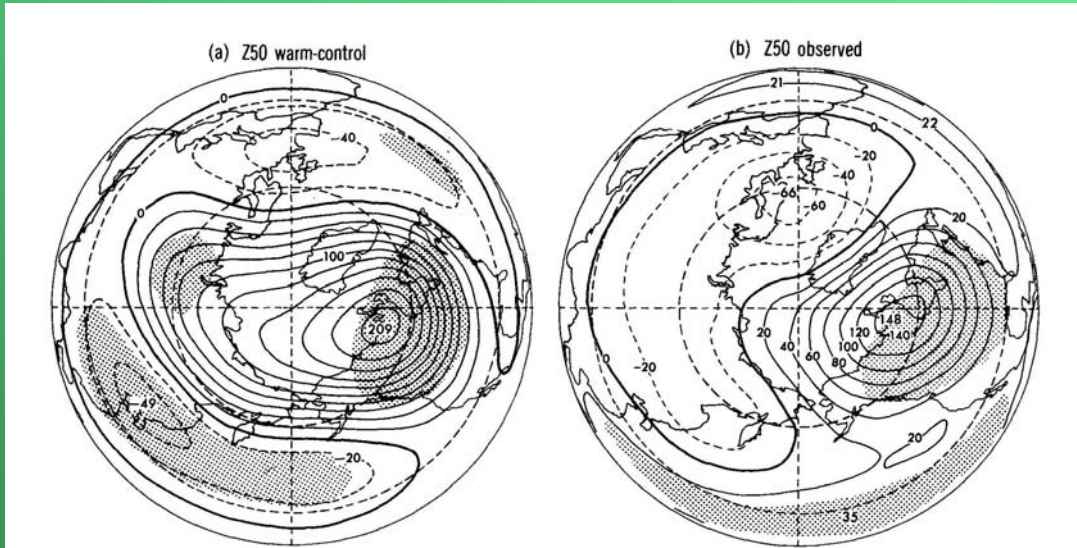


- Heat sources in the Tropics produce both tropically confined responses and laterally propagating wave-trains (PNA-like pattern).
- In the numerical experiment shown on the lhs, transient heat source is located off the equator.
- Barotropic Rossby-wave packets propagate laterally toward the extra-tropics.
- The signature is typical of observed teleconnection patterns (e.g., Horel and Wallace, 1981).

# Background/Review



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Hamilton, 1995

- The barotropic response emerges in stratosphere as planetary waves 1&2 which dominate the difference patterns between cold/warm phases.
- Pattern of cold phases is uncorrelated to warm phases.
- Anomalies of the cold phase are weaker than during warm phase.
- Statistical significance is limited.

# Summary of Review and outstanding questions



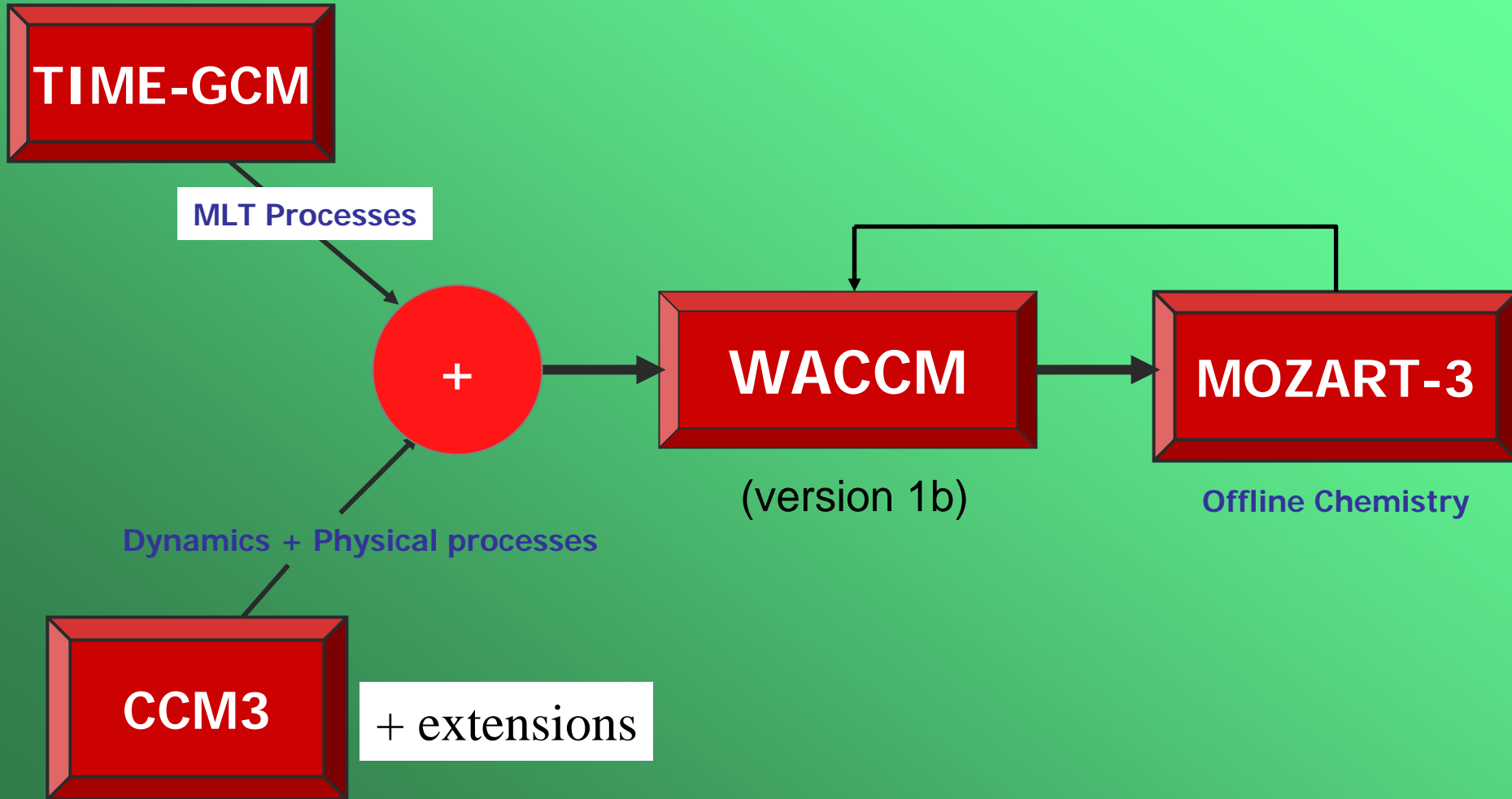
- Observations show a strong connection between ENSO and tropospheric climate.
- Connection between ENSO and stratospheric structure is suggestive but not strong.
- One problem is that in the real atmosphere ENSO variability is small compared to other sources of variability, principally those associated with the QBO. Other contributions include solar cycle, increase in greenhouse gases, and chemistry.
- In a model *with* no QBO, nor solar cycle, nor increasing greenhouse gases, and with fixed chemical composition but with time dependent SST the only low frequency variability is associated with ENSO, aside from model's internal variability.

# Model and Simulation description

**WACCM:**

**Whole Atmosphere Community  
Climate Model**

# Model/Simulation description



# Model/Simulation description



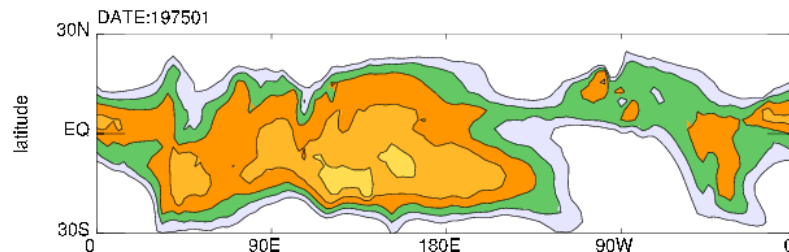
- Based on NCAR Community Climate Model v.3 (CCM3)
- T63 resolution (128 x 64 grid points)
- 0-150 km (66 levels;  $\Delta z = 1.3$  km in lower stratosphere to 3 km in thermosphere)
- Semi-Lagrangian dynamics
- 30 minute time step
- Upper atmosphere extensions:
  - Lindzen GW parameterization
  - Short-wave ( $\lambda < 200$  nm) heating rates from TIME-GCM
  - Parameterized ion-drag
  - non-LTE long-wave heating in the  $15 \mu\text{m}$  band of CO<sub>2</sub>
  - Interactive LW cooling (GHG), but SW heating from specified O<sub>3</sub>

# Model/Simulation description

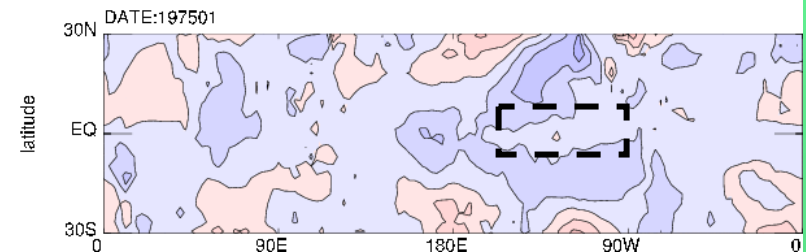


Three 50-year simulations from 1950 throughout 2000 using observed sea surface temperature (SST) from NCEP Reynolds SST data set, <http://podaac.jpl.nasa.gov/reynolds>.

## Sea Surface Temperature



## Difference from long term average



# Model/Simulation description



Red = December Blue = January  
Green = February Black = March

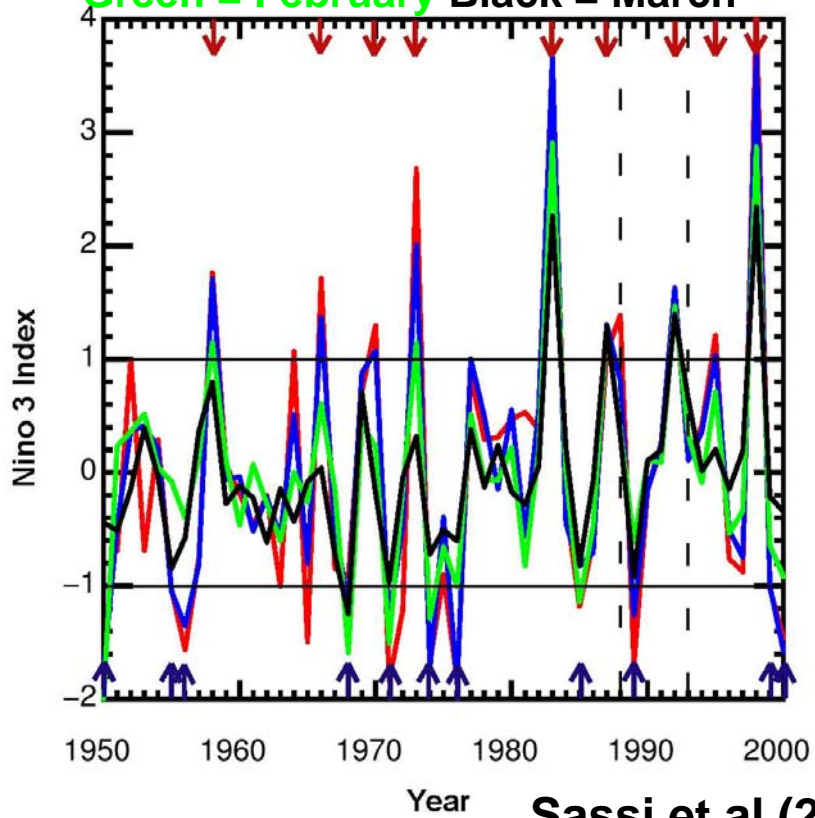


Table 1

El Niño	La Niña
1957-1958	1949-1950
1965-1966	1954-1955
1969-1970	1955-1956
1972-1973	1967-1968
1982-1983	1970-1971
1986-1987	1973-1974
1991-1992	1975-1976
1994-1995	1984-1985
1997-1998	1988-1989
	1998-1999
	1999-2000

# Model/Simulation description



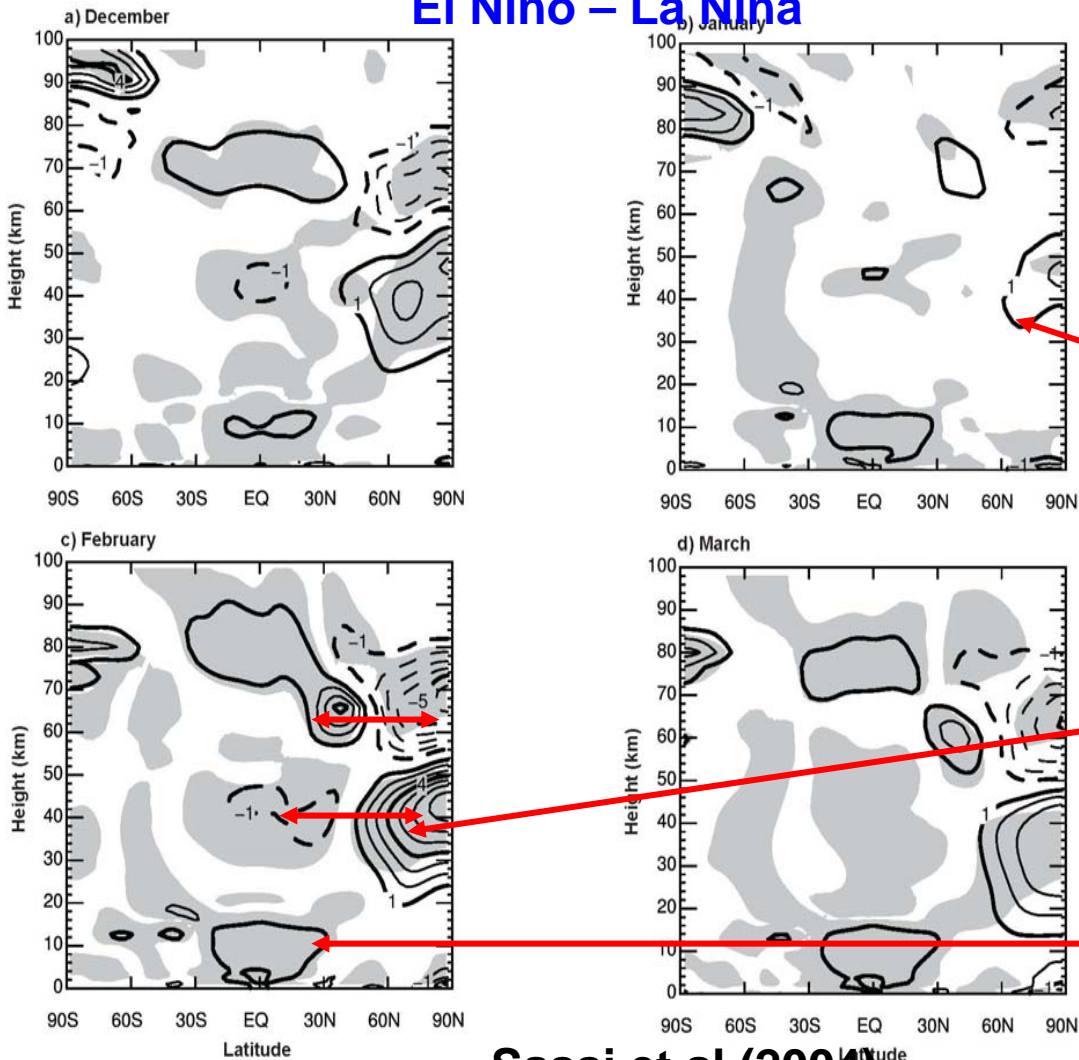
- Three 50-year simulations contain 27 (=9x3) El Nino and 33 (=11x3) La Nina.
- Composite differences of the extreme events are calculated
- Statistical significance is determined from a Monte Carlo analysis and EOF.
- Results are shown for temperature only.

# ENSO Influences:

Thermodynamic effects

# Thermodynamic Effects

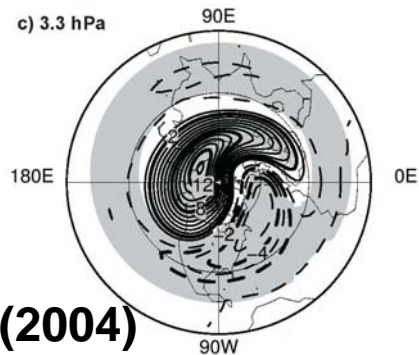
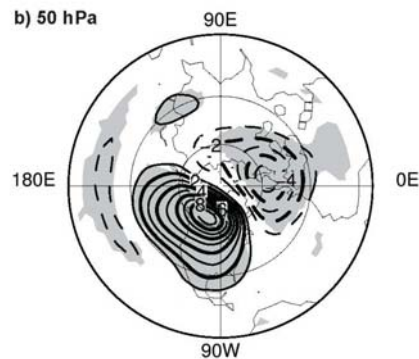
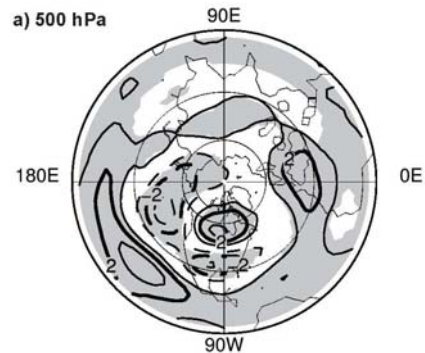
## El Nino – La Nina



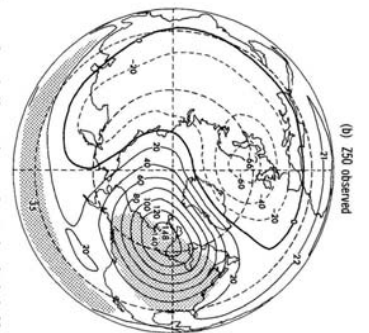
Sassi et al (2004)

- High latitude zonal mean anomalies are significant (shading) at least at 95% level based on a  $t$ -test of a Monte Carlo analysis.
- Smallest significance levels are in mid-winter.
- Note the quadrupoles of positive/negative pairs in stratosphere/mesosphere.
- Largest anomalies (and regions of significance) are obtained in late winter.
- Note the positive (and always significant) anomaly in troposphere.

# Thermodynamic Effects



- The tropospheric signature of the PNA pattern stands out and is largely statistically significant.
- The zonal structure shows wave 1&2 anomalies that are significant at all levels in stratosphere.



rotation of the anomalies  
at they are associated with  
the propagation.

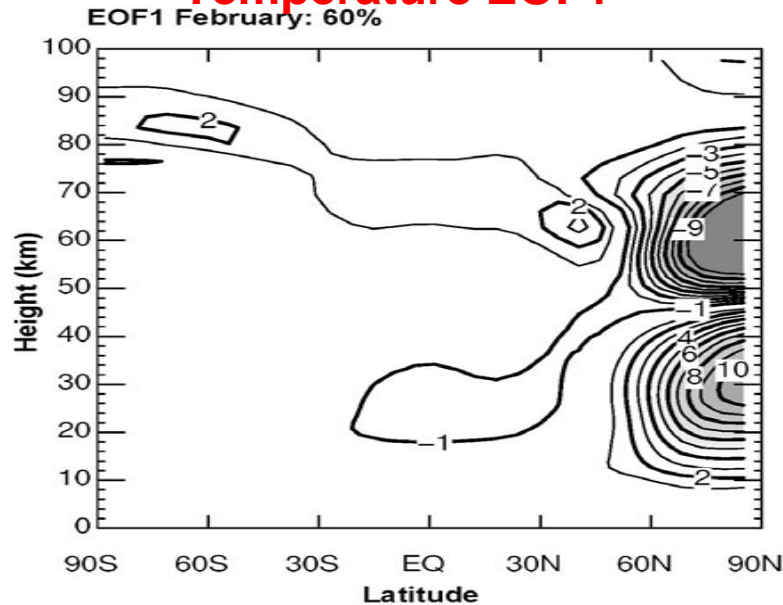
anomalies (and pattern of  
significance) are similar to  
(1995).

# ENSO Influences:

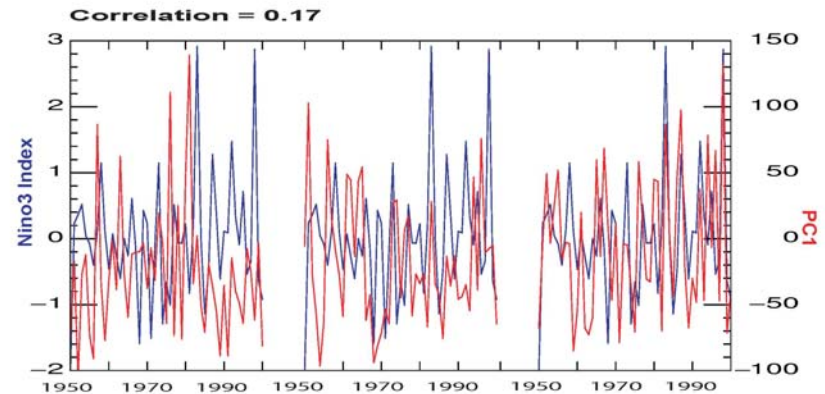
## Statistical Significance

# Statistical Significance

## Temperature EOF1



## Correlation between NINO3 and PC1 = 0.17



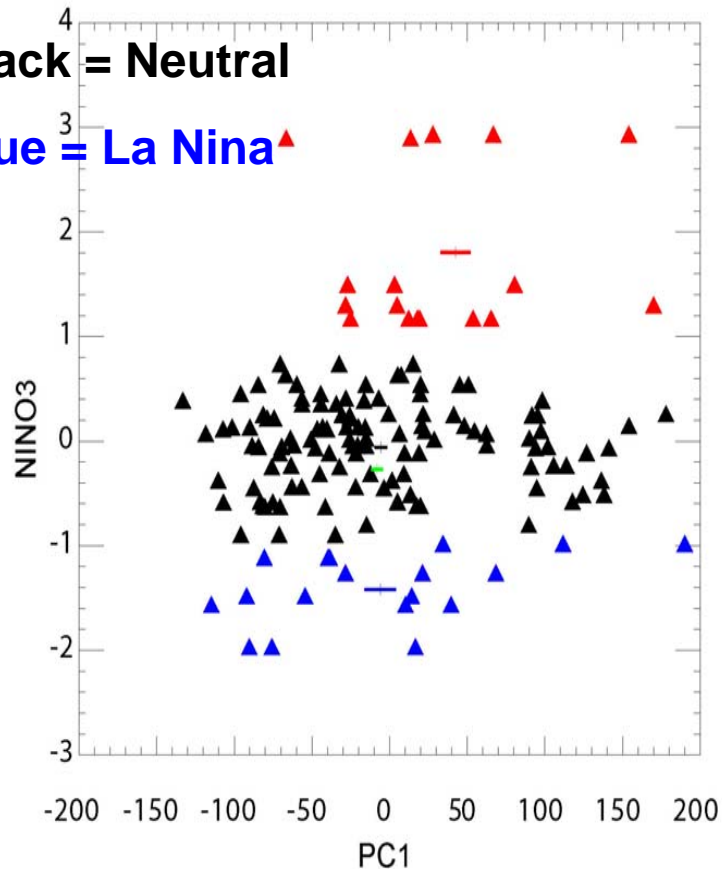
Less than 2% of the total variance of temperature is explained by contemporaneous variations of the NINO3 index.

# Statistical Significance

Red = El Nino

Black = Neutral

Blue = La Nina

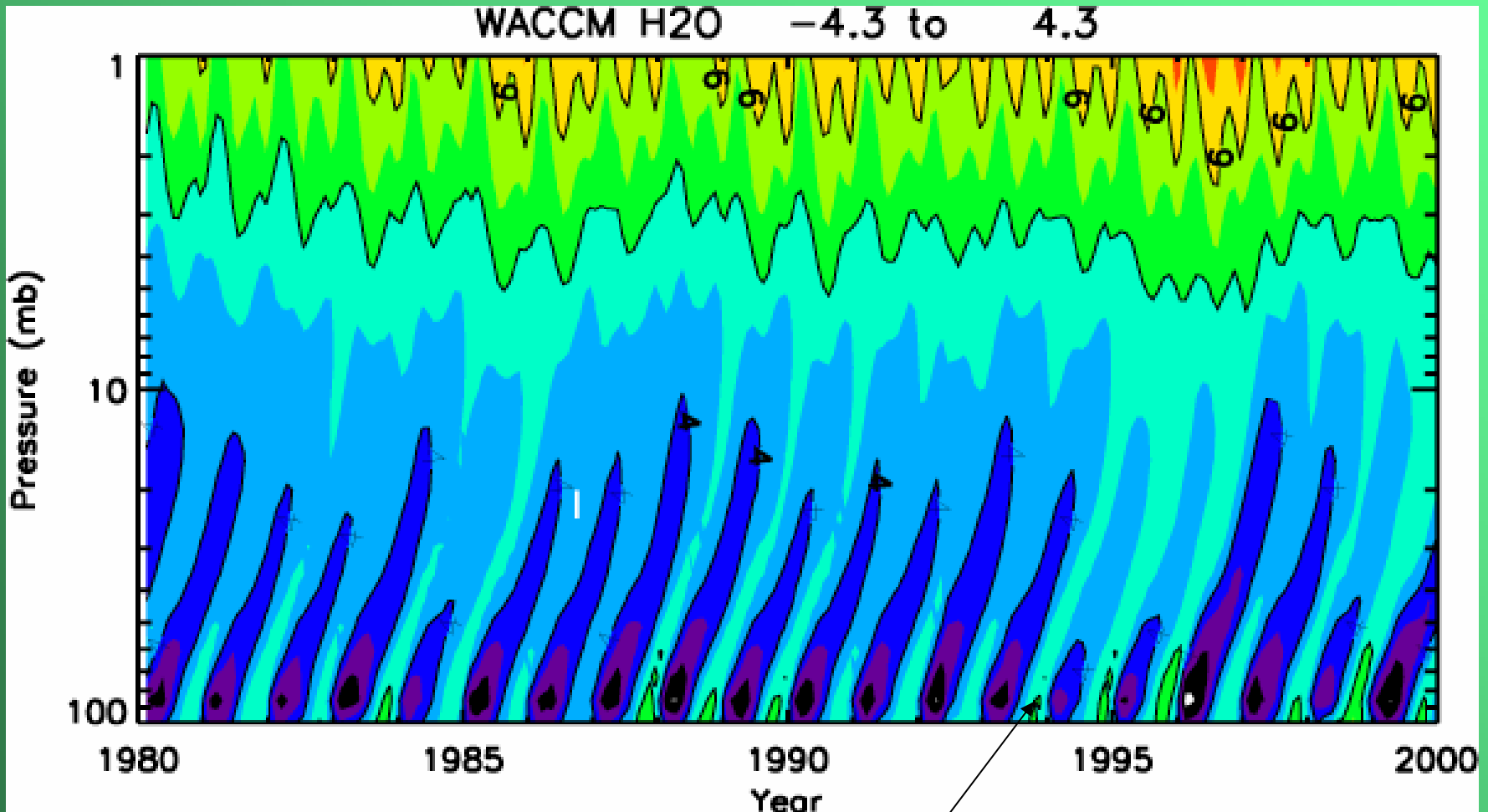


- Overall, little correlation is found.
- When only the extreme events are selected, some correlation emerges.
- The population averages show that El Niño events are distinguishable from both La Niña and Neutral events. La Niña events, however, are not distinguishable from the Neutral ones.
- *The emerging correlation is solely due to positive excursions of the NINO3 index.*

**ENSO effects:**

**WACCM water vapor**

# WACCM water vapor

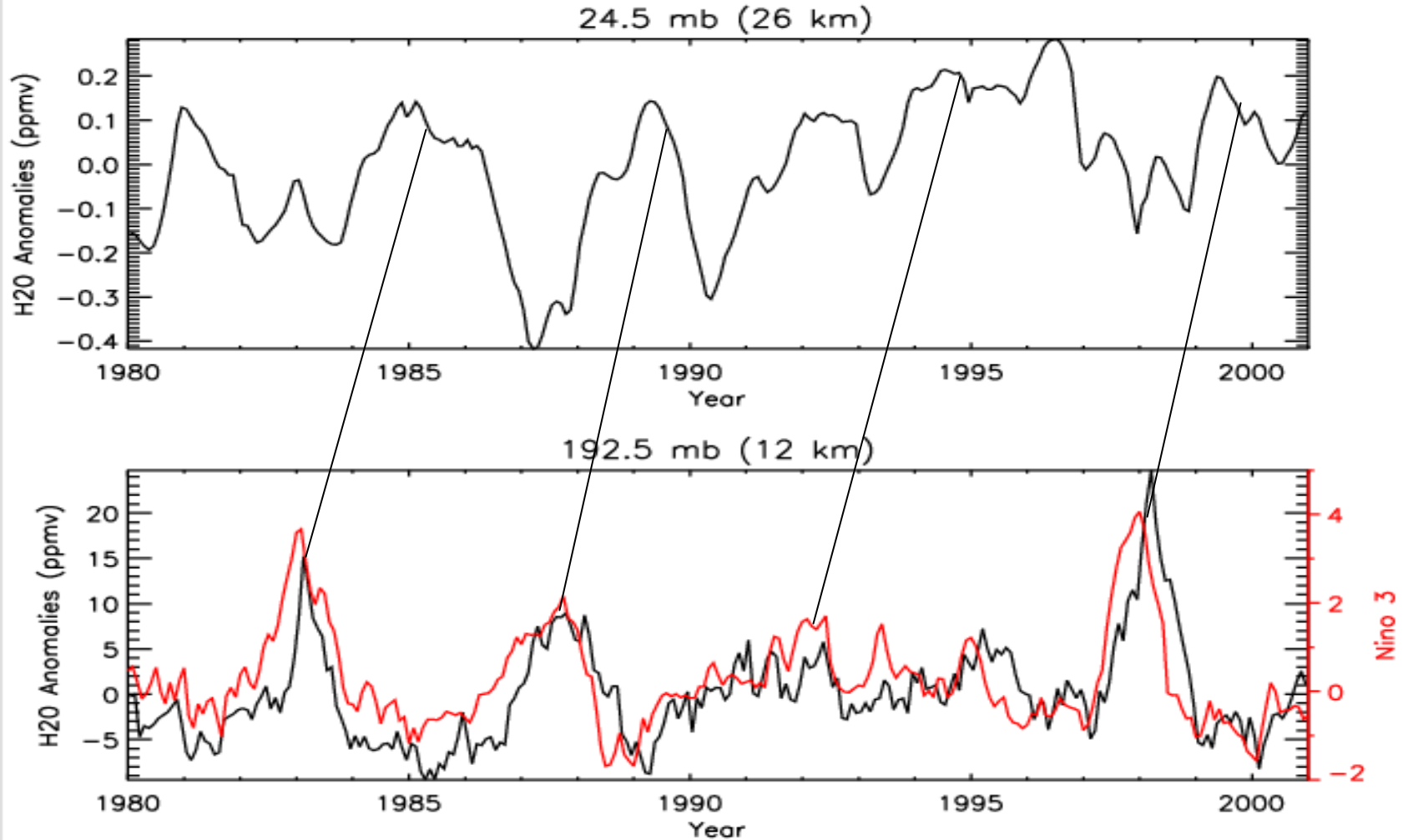


tape recorder + low-frequency variability (+ trend?)

# WACCM water vapor

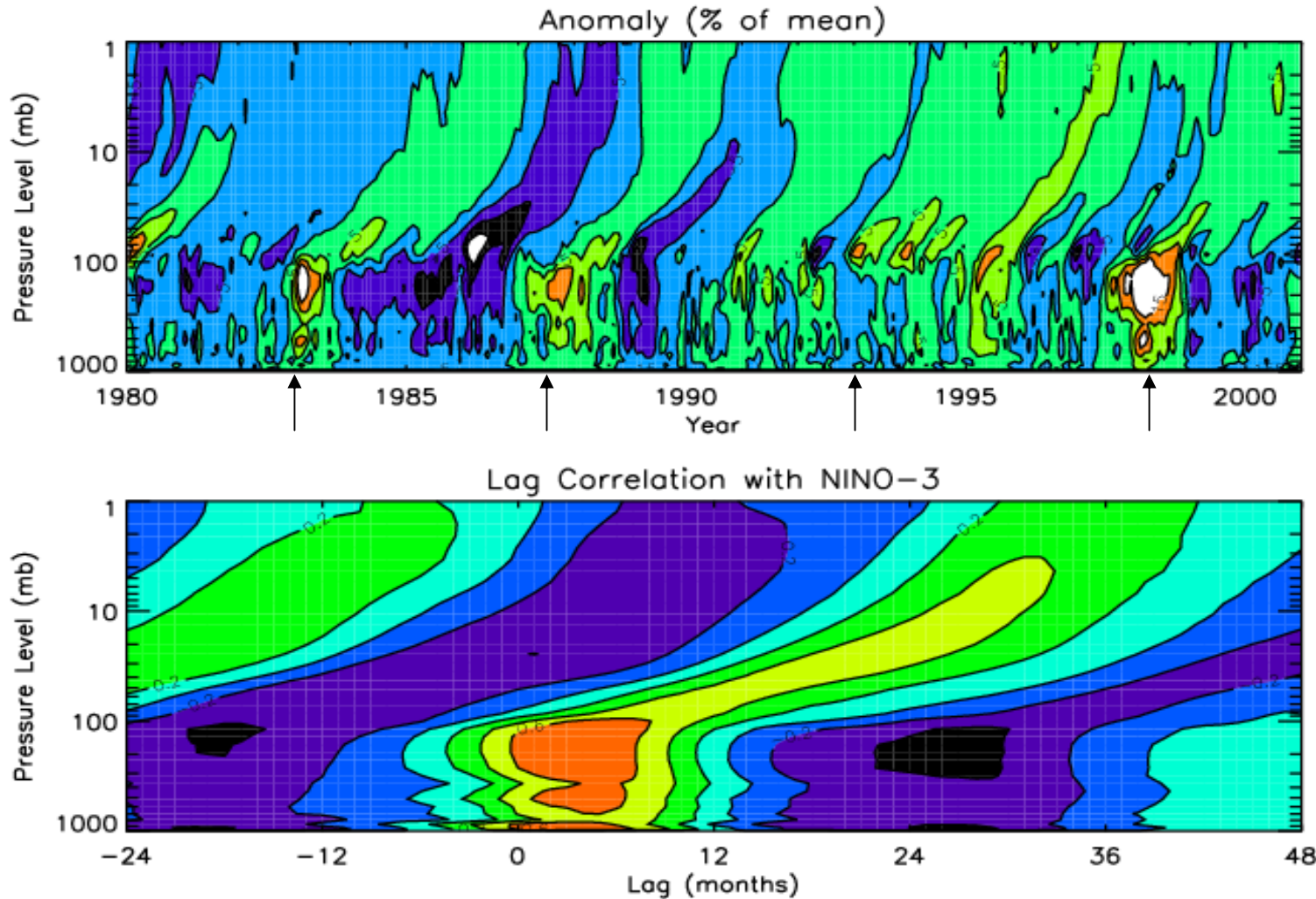


NCAR



- In WACCM, **low-frequency variability** in lower stratosphere is linked to ENSO <sup>20</sup>

# WACCM water vapor



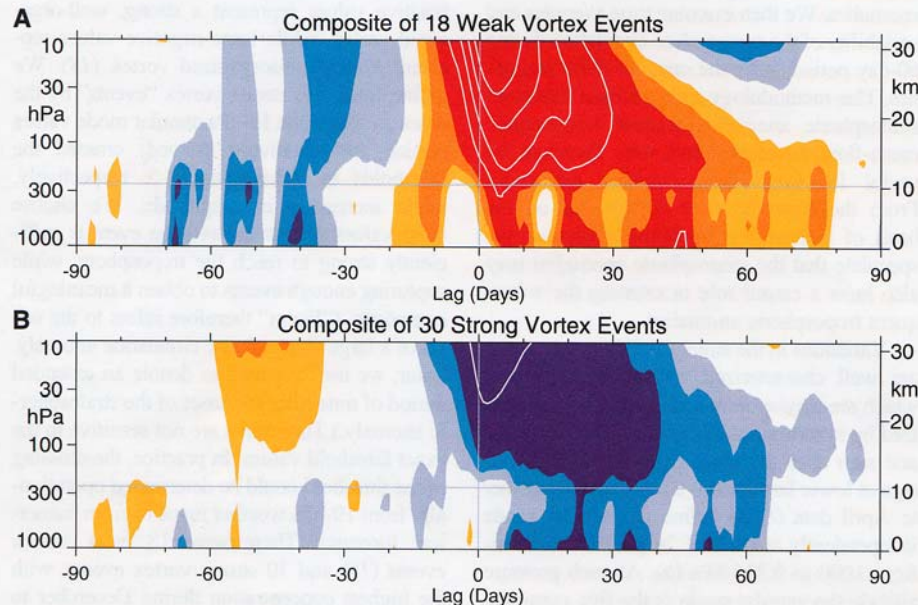
# ENSO effects:

## Annular modes

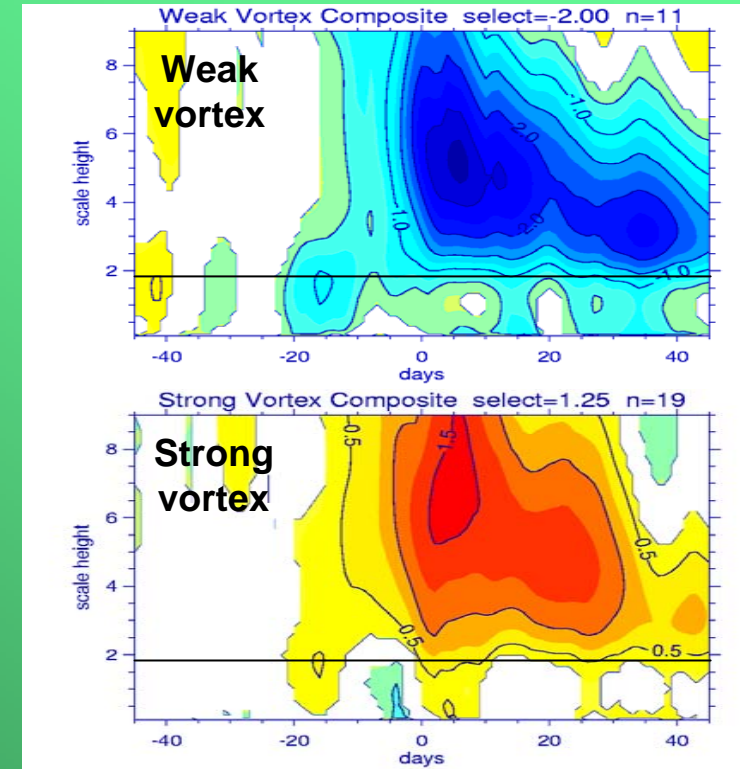
# Annular Mode

Baldwin and Dunkerton, *Science*, 2001

Model



**Fig. 2.** Composites of time-height development of the northern annular mode for (A) 18 weak vortex events and (B) 30 strong vortex events. The events are determined by the dates on which the 10-hPa annular mode values cross  $-3.0$  and  $+1.5$ , respectively. The indices are nondimensional; the contour interval for the color shading is 0.25, and 0.5 for the white contours. Values between  $-0.25$  and  $0.25$  are unshaded. The thin horizontal lines indicate the approximate boundary between the troposphere and the stratosphere.

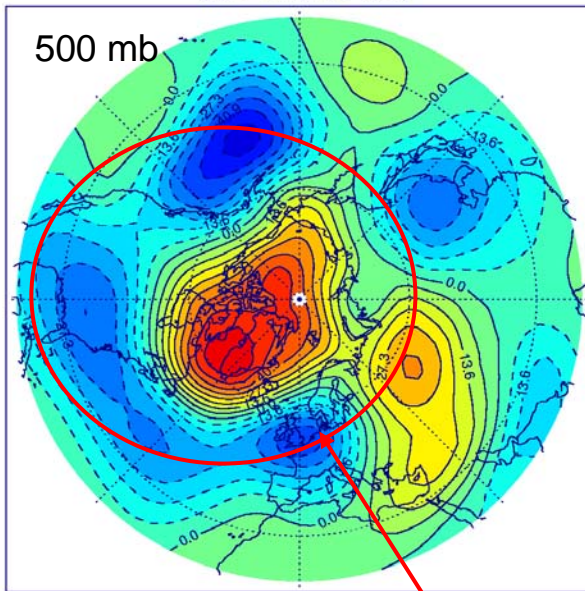


Note similarity to observations (and reversed color contours!)  
The salient features of the observations can be reproduced by the model.

# Annular Mode

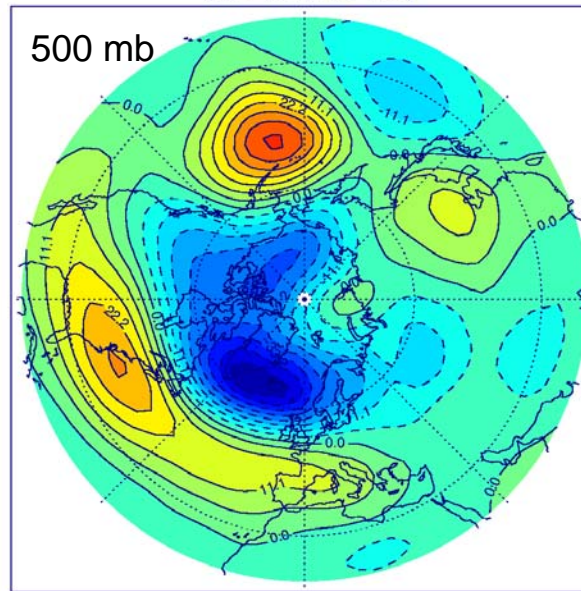
## Weak vortex composite

Average of 11 Weak Vortex Events at 4.339e+02 mb  
(max=61.4, min=-50.8)



## Strong vortex composite

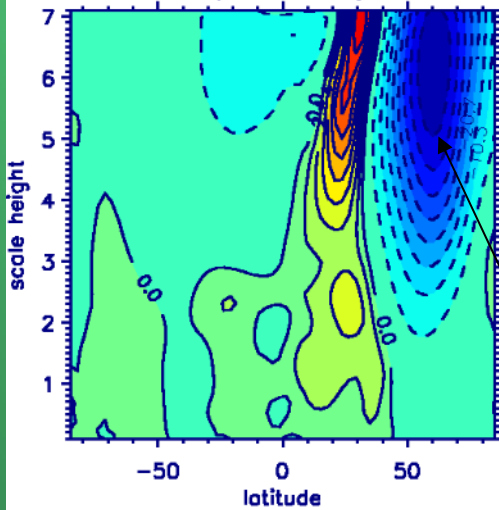
Average of 19 Strong Vortex Events at 4.339e+02 mb  
(max=39.4, min=-49.9)



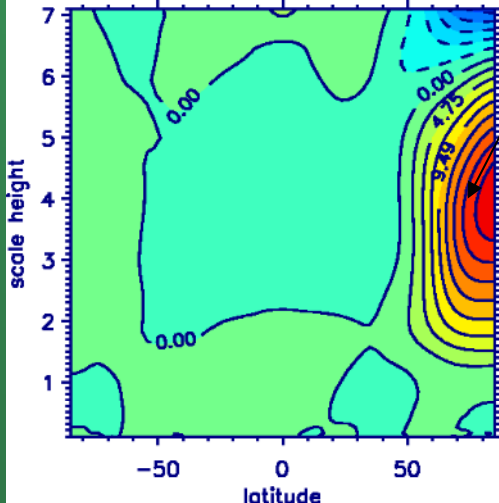
Note PNA-like pattern:  
Several large-amplitude weak  
events occur in ENSO years

# Annular Mode

45-d ave. **following** event onset



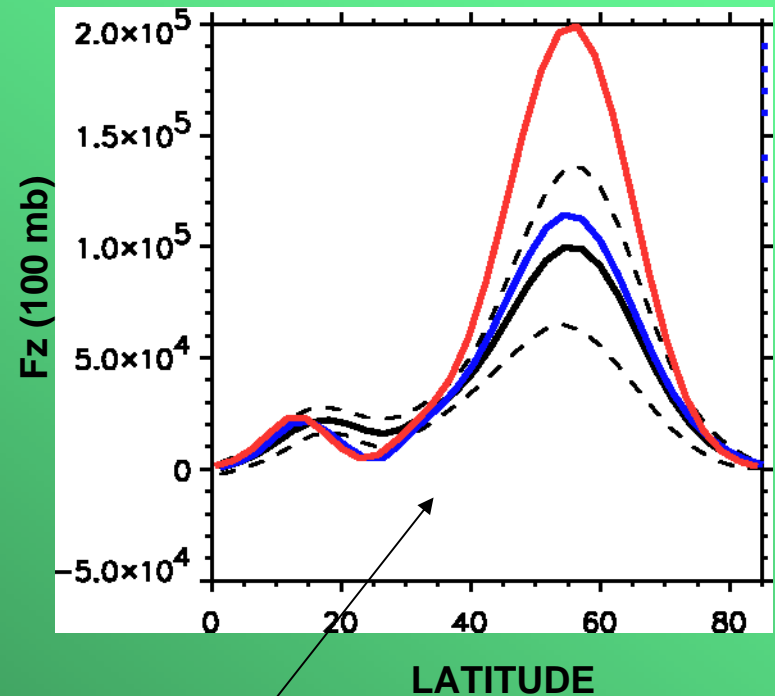
T Weak-Strong Difference  
 (t0, t0+45)



**U** is decelerated and shifted equatorward, consistent with a large **T** anomaly extending into the upper troposphere

45-d ave. **preceding** event onset

**blue:** Fz for 11 strong events  
**red:** Fz for 19 weak events  
**black:** Fz for 50 random events  $\pm 1$  sd



**Fz (100 mb)** averaged over 45 days preceding the events is much larger for weak events

# Summary and Conclusions



- During El Nino events the winter stratosphere is warmer, the mesosphere is colder. This is accompanied by anomalies of the mean meridional circulation that support those thermal anomalies.
- Largest zonal mean temperature anomalies (and their statistical significance) are attained in late winter. Smallest anomalies in mid-winter.
- A statistically significant zonal mean warming of the tropical troposphere is obtained during El Nino events and is present in all months.
- The horizontal structure of the anomalies shows statistically significant planetary wave features throughout the stratosphere.
- Variations of NINO3 explain less than 2% of the contemporaneous total variability of temperature.
- *Only positive excursion of NINO3 (→ El Nino) contribute significantly to variability in the middle atmosphere. Negative excursions (→ La Nina) are equivalent to no-events.*

# Summary and Conclusions



- El Nino events are highly correlated with larger values of water vapor in mid-troposphere.
- The same signal – although mitigated – propagates in stratosphere with a time delay associated with tropical mean upwelling.
- The annular mode in WACCM is very similar to observations: downward progression and tropospheric influences are detected.
- Weak stratospheric vortex events are associated with a strengthening of the tropospheric PNA pattern → El Nino events.