

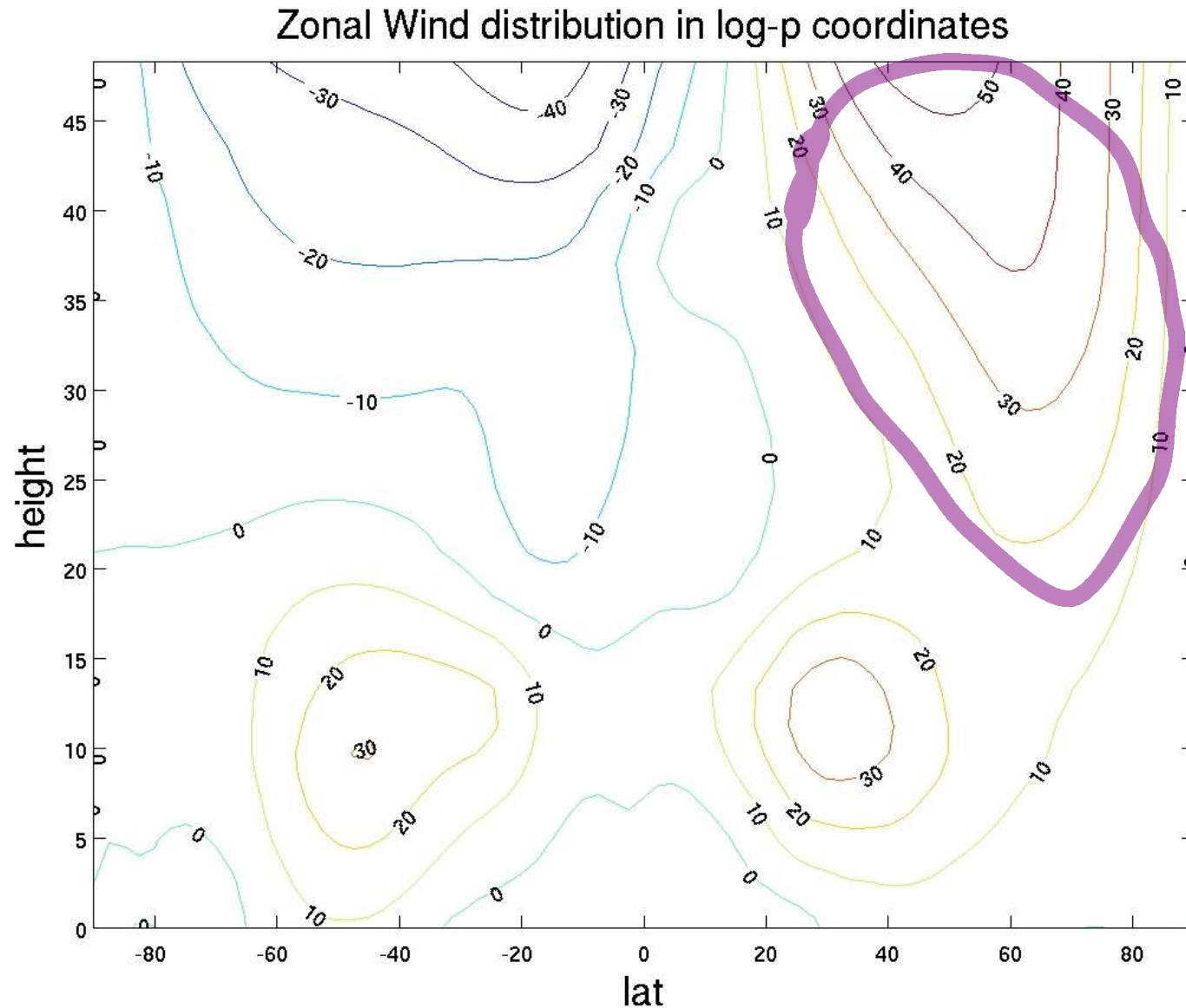
# The Different ENSO Teleconnections and Their Effects on the Stratospheric Polar Vortex

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# Climatological December, 1957-2007



# Preview

- (1) The ENSO modulation of the polar vortex can be separated from the QBO modulation of the polar vortex.
- (2) ENSO typically induces a PNA-like pattern. The PNA is the proximate cause through which ENSO modulates the vortex.
- (3) When WENSO does not generate a PNA, the vortex is not modulated.
- (4) The PNA weakens the vortex by modifying the wave-1 height field in the troposphere.
- (5) The WACCM model realistically simulates the effect of ENSO on the vortex.

# The Influence of ENSO/QBO

## Individually

### ENSO:

- WENSO causes more disturbed polar vortex, warmer polar region
- CENSO causes less disturbed polar vortex, colder polar region

### QBO:

- EQBO causes more disturbed polar vortex, warmer polar region
- WQBO causes less disturbed polar vortex, colder polar region

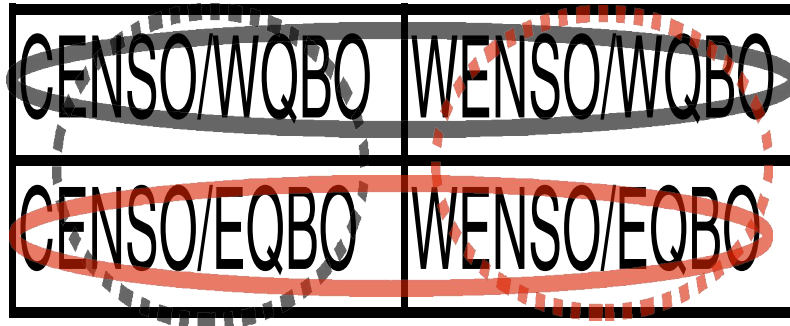
Does the ENSO effect actually exist? How do you distinguish between the effects of ENSO and QBO?

# 1. Separation of QBO and ENSO

2. Physical Mechanism for ENSO
3. Saturation or Masking

# Possible Solutions:

(1) Take the four categories CENSO/WQBO, WENSO/WQBO, WENSO/EQBO, CENSO/EQBO, and compare them to each other.



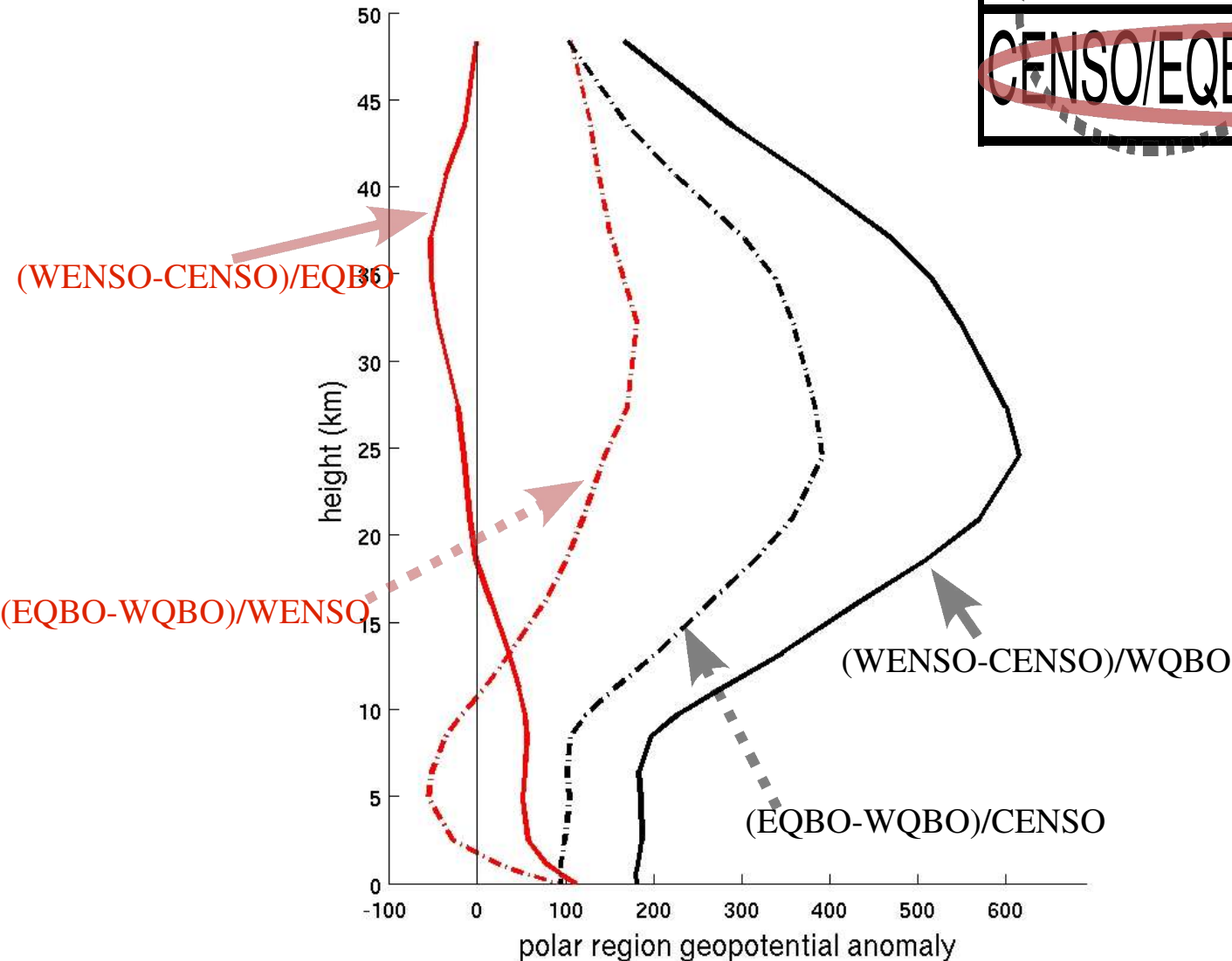
(2) Take QBO(ENSO) when ENSO(QBO) is in its neutral phase. (see Garfinkel, C. I., and D. L. Hartmann, 2007)

# The Data Used

- ♦ The ERA-40 dataset (Sep. 1957-Aug. 2002) plus ECMWF TOGA Data (Sep. 2002-Feb. 2007).
- ♦ Monthly average of 12UTC  $\Phi$ , minus current month's climatology.
- ♦ Nino3 index for ENSO, and 50mb QBO from ECMWF data.

# QBO Signal $\approx$ ENSO Signal

<del>CENSO/WQBO</del>	<del>WENSO/WQBO</del>
<del>CENSO/EQBO</del>	<del>WENSO/EQBO</del>



both black curves significant at 95% confidence level, even removing volcanic months and pre-satellite data, in the stratosphere; one month after Nov, Dec, Jan, Feb event.



# Why is the response to ENSO weaker under EQBO than WQBO? (Why is the response to QBO weaker under WENSO than CENSO?)

## 2 Possible Hypotheses:

- The Polar Vortex can only be weakened so much (the warming of the pole “saturates”)
- There is fundamentally something different about the wave sources in WENSO/EQBO (or CENSO/EQBO) such that the WENSO/EQBO-CENSO/EQBO polar vortex anomaly is small.

To answer this, we need to understand how ENSO modulates the vortex.

Hypothesis: PNA

1. Separation of QBO and ENSO

## 2. Physical Mechanism for ENSO

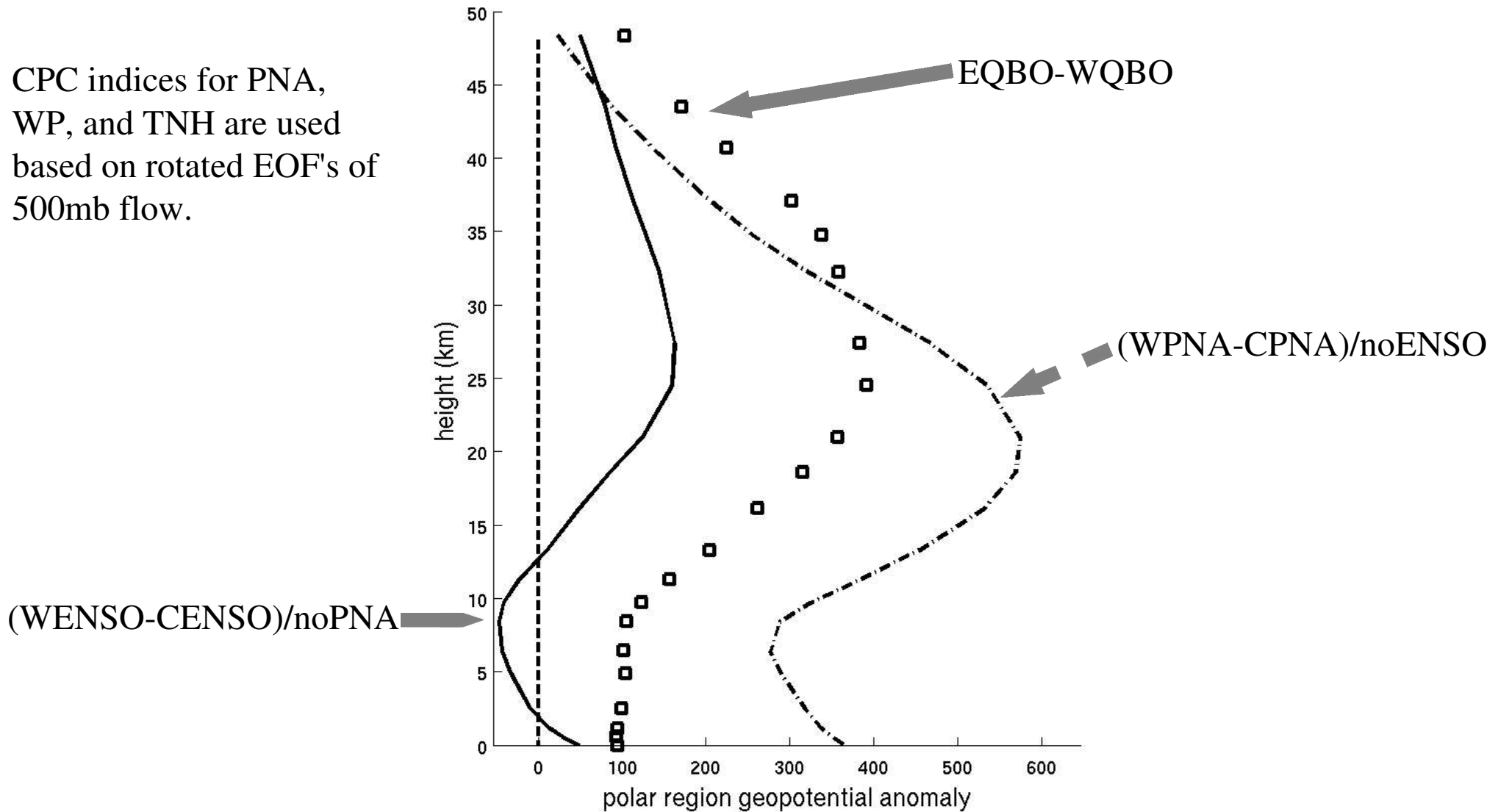
### I. The PNA-Observations

II. The PNA-Model Results

3. Saturation or Masking

# The PNA effect on the vortex is greater than the ENSO effect on the vortex

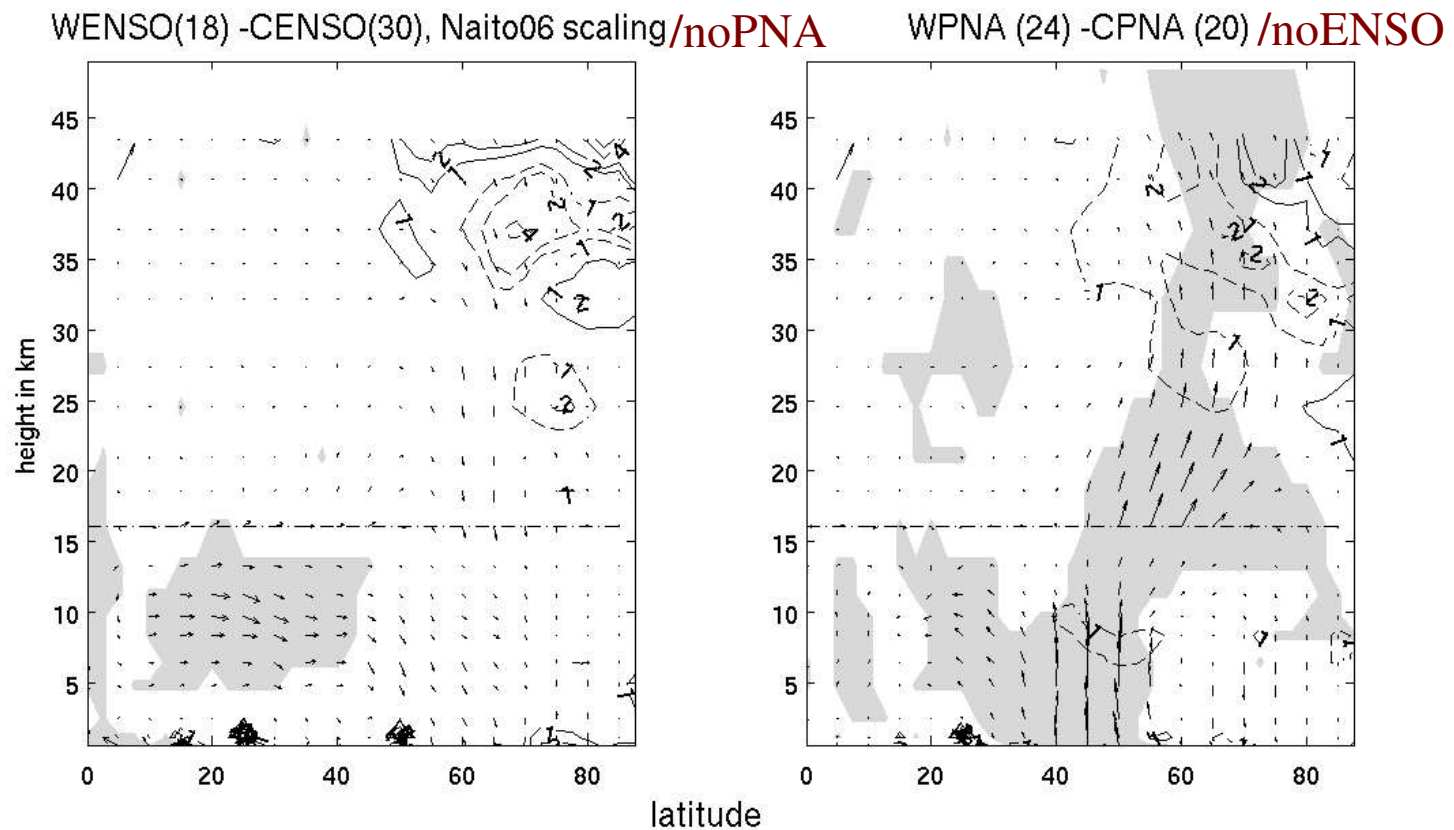
CPC indices for PNA, WP, and TNH are used based on rotated EOF's of 500mb flow.



WPNA-> phase of PNA typically associated with WENSO  
CPNA-> phase of PNA typically associated with CENSO

# Wave-1 EP Flux during ENSO(PNA) under neutral PNA(ENSO)

ENSO, in the absence of PNA, does not have a strong effect on the vortex



1. Separation of QBO and ENSO

## 2. Physical Mechanism for ENSO

I. The PNA-Observations

## II. The PNA-Model Results

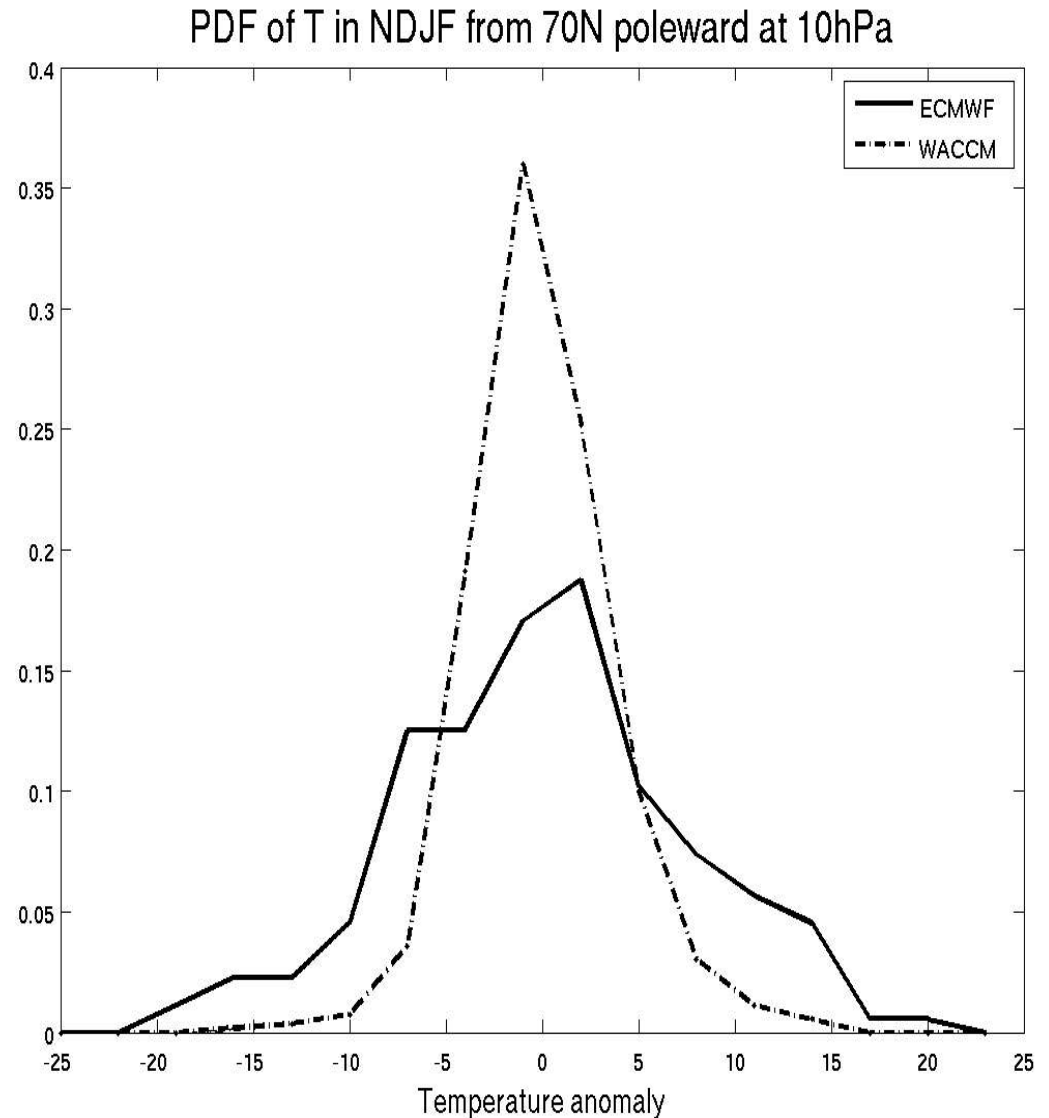
3. Saturation or Masking

# The Data Used

- ♦ 3 ensembles of WACCM used in CCMVal (Garcia, et al. 2007)
- ♦ Period 1960-2003 used, giving 132 years of model data
- ♦ WACCM lacks a QBO

# Fidelity of WACCM's Polar Vortex

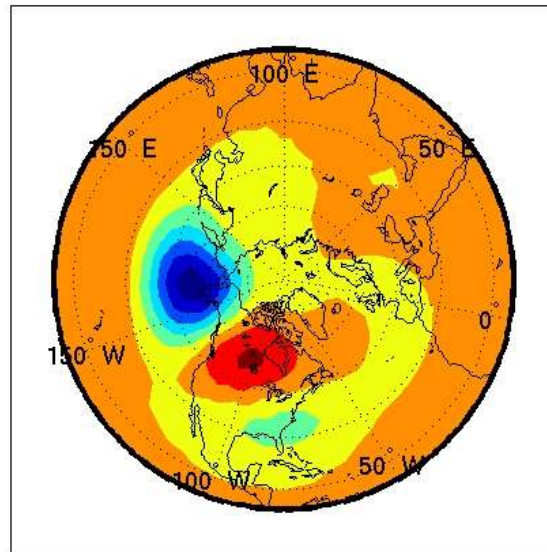
- Polar Vortex Temperature from 70N and poleward is a few degrees warmer than ECMWF, but ECMWF has a slight cold bias (Randel, 2004)
- Variability of the polar vortex is less in WACCM than in ECMWF



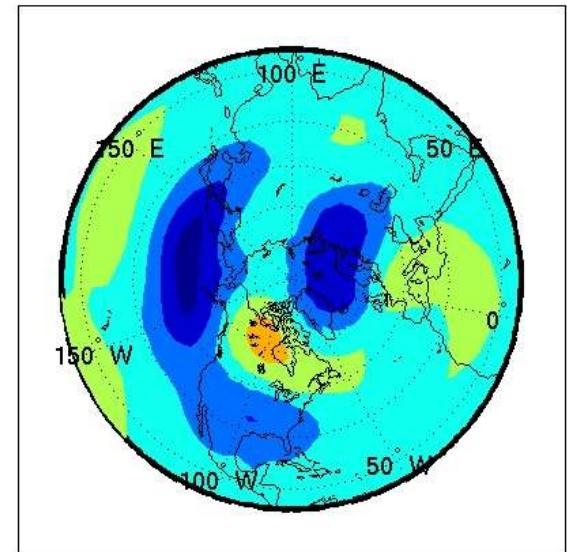
# PNA index for WACCM

Random extratropical variability differs in model from observed atmosphere

1<sup>st</sup> PC of 500mb height from 22N poleward over the Central and East Pacific.



new PNA index

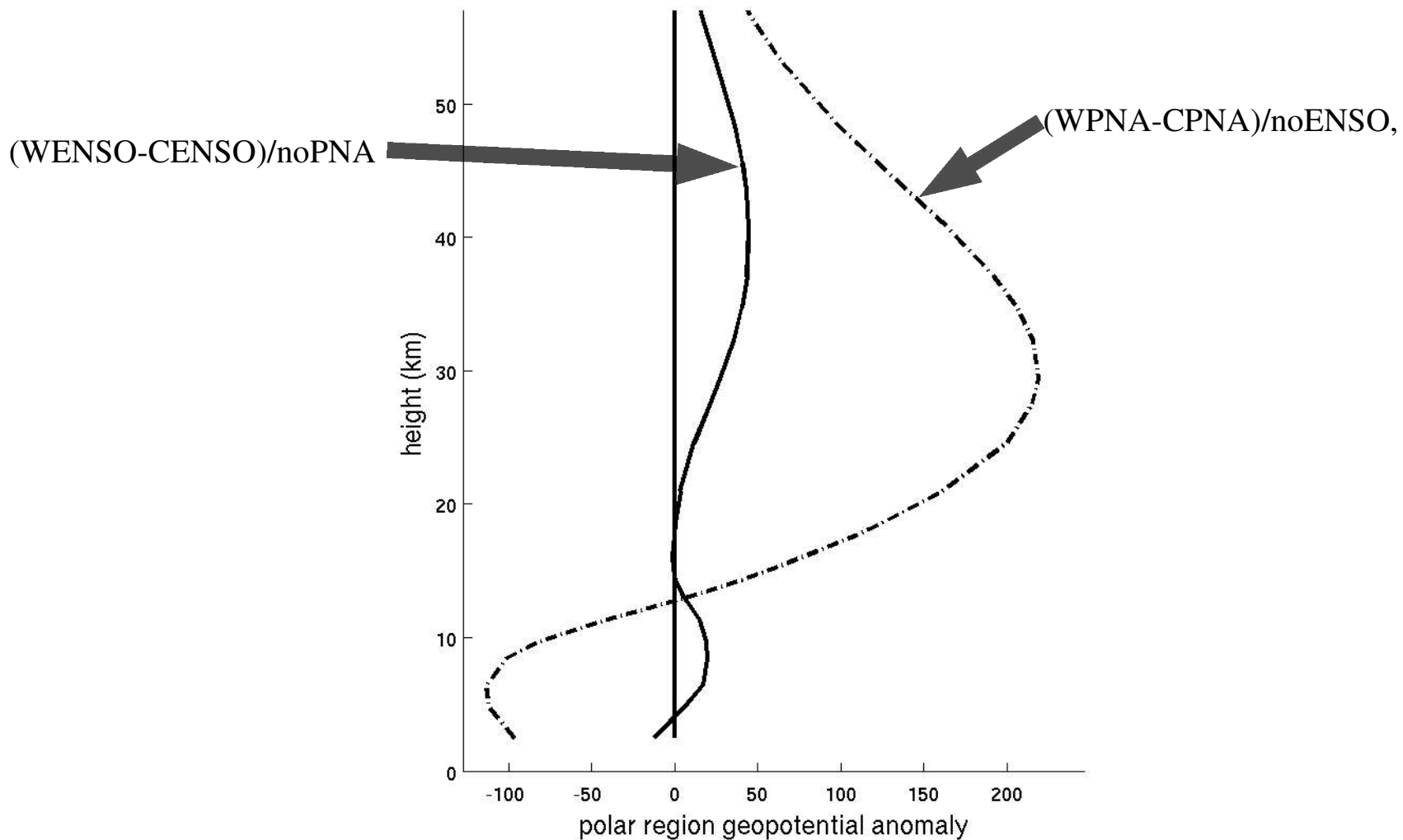


observed PNA index



# PNA's effect on vortex in WACCM

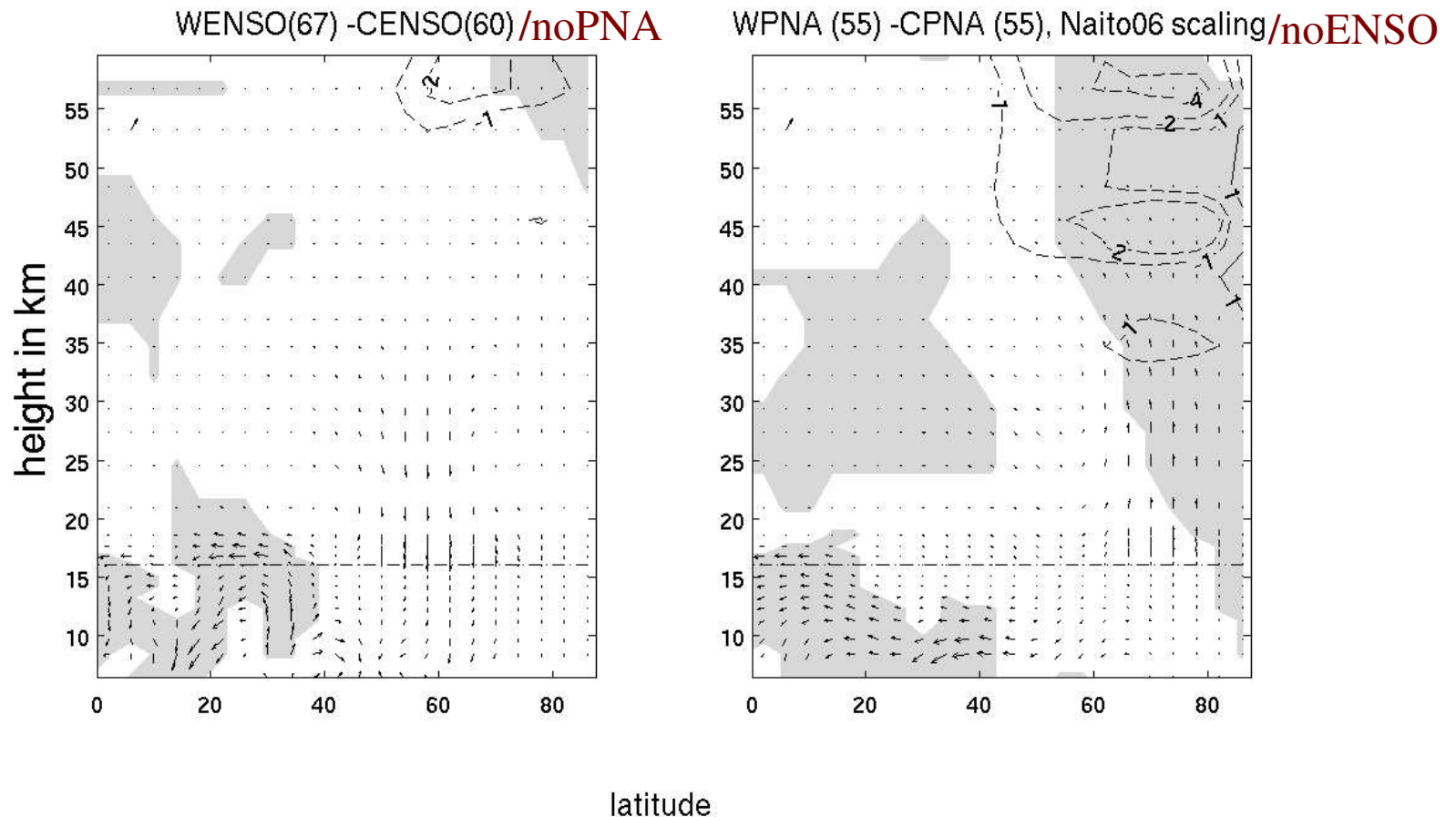
- WPNA/noENSO, CPNA/noENSO, CENSO/noPNA and WENSO/noPNA composites created (Nino4 region)
- PNA/noENSO modulation significant at 95% level throughout stratosphere



# PNA's effect on vortex in WACCM

all-wave EP flux

Consistent with Observations



1. Separation of QBO and ENSO

2. Physical Mechanism for  
ENSO

3. Saturation or Masking

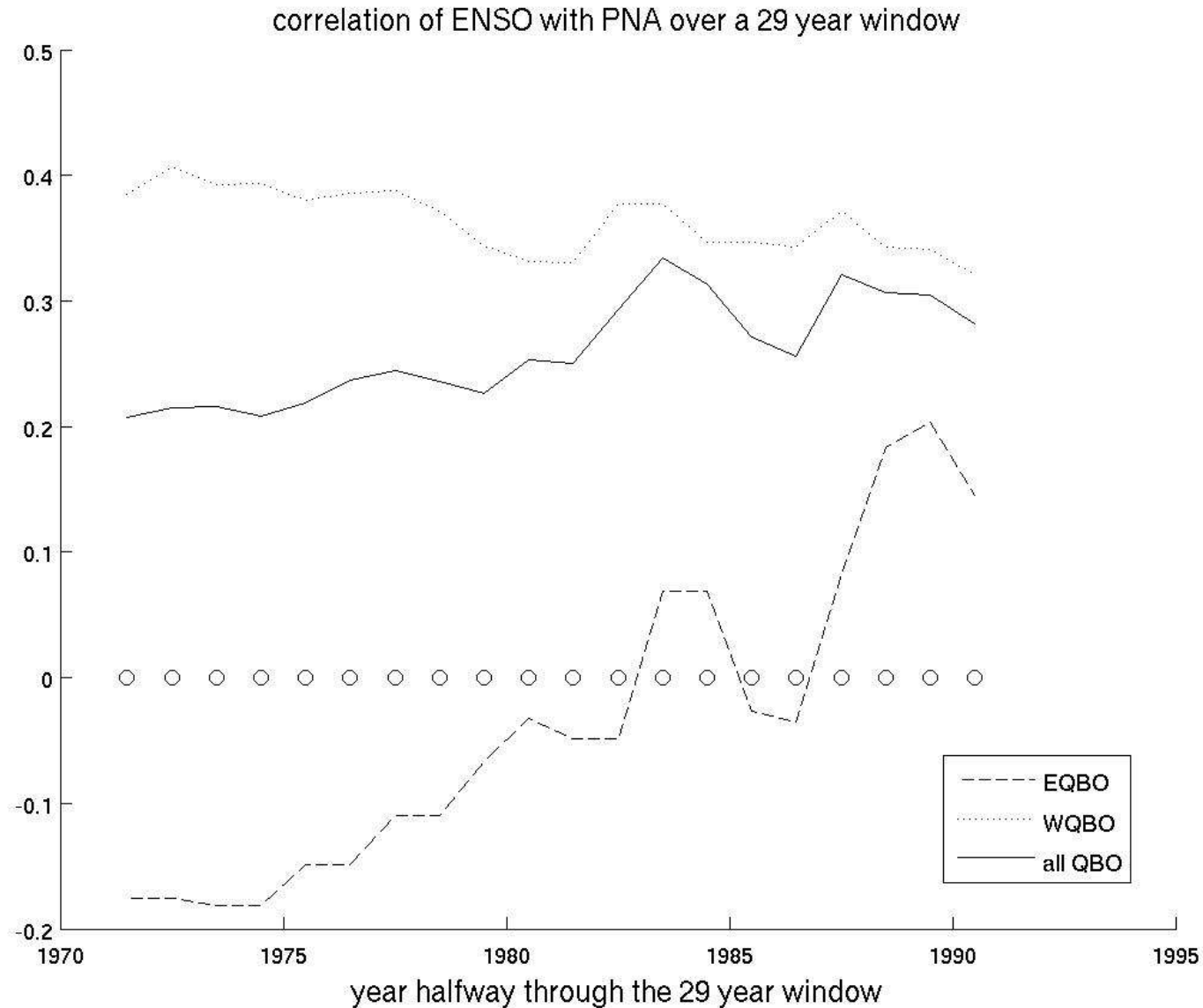
I. ENSO/WQBO vs.  
ENSO/EQBO

Why is the response to ENSO weaker under EQBO than WQBO?

<del>CENSO/WQBO</del>	<del>WENSO/WQBO</del>
<del>CENSO/EQBO</del>	<del>WENSO/EQBO</del>

# When is ENSO correlated with the PNA?

Barnston, Livezey, and Halpert [1991]



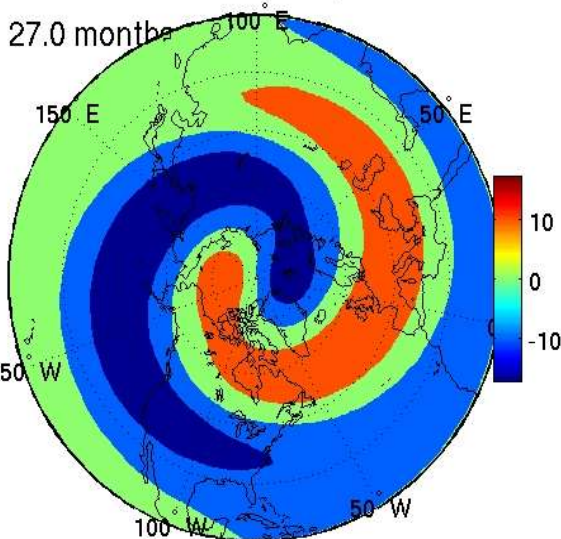
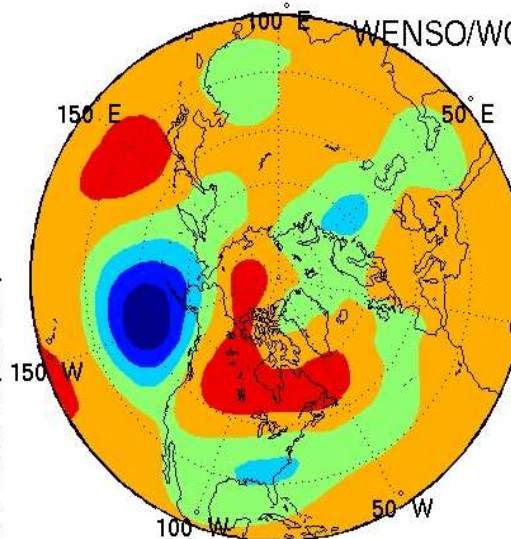
# Height at 500hPa

- PNA like pattern appears in WENSO/WQBO (and WENSO/noQBO) but not in WENSO/EQBO

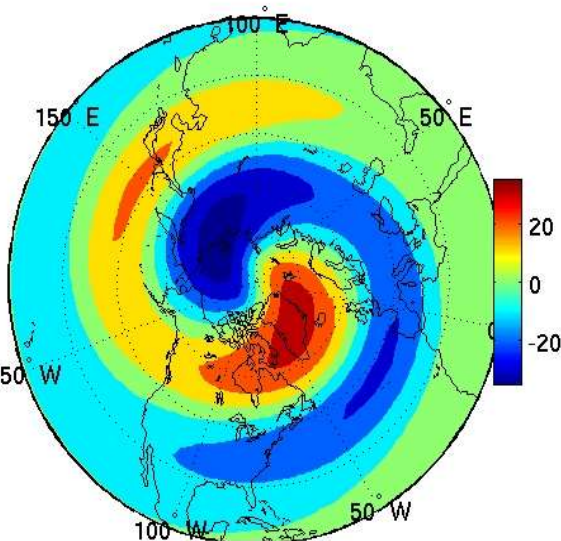
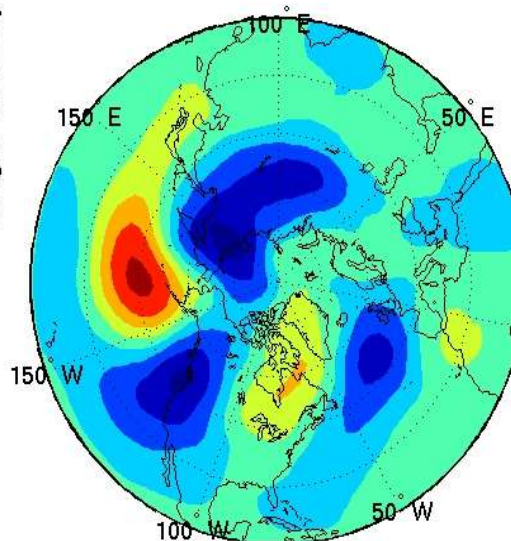
full field

wave-1 component

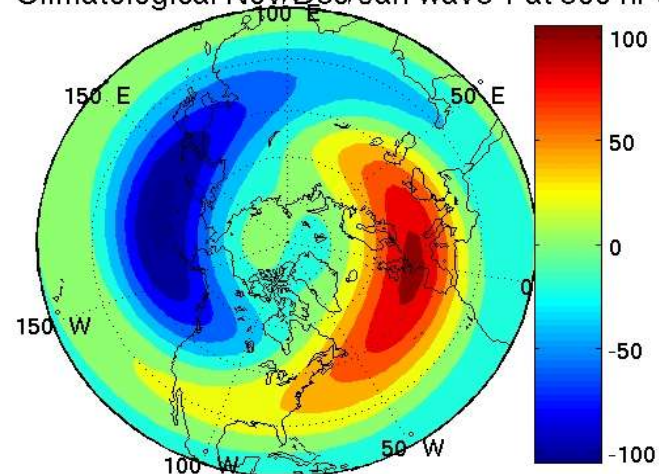
WENSO/WQBO; 27.0 months



WENSO/EQBO; 12.0 months



Climatological Nov/Dec/Jan wave 1 at 500 hPa

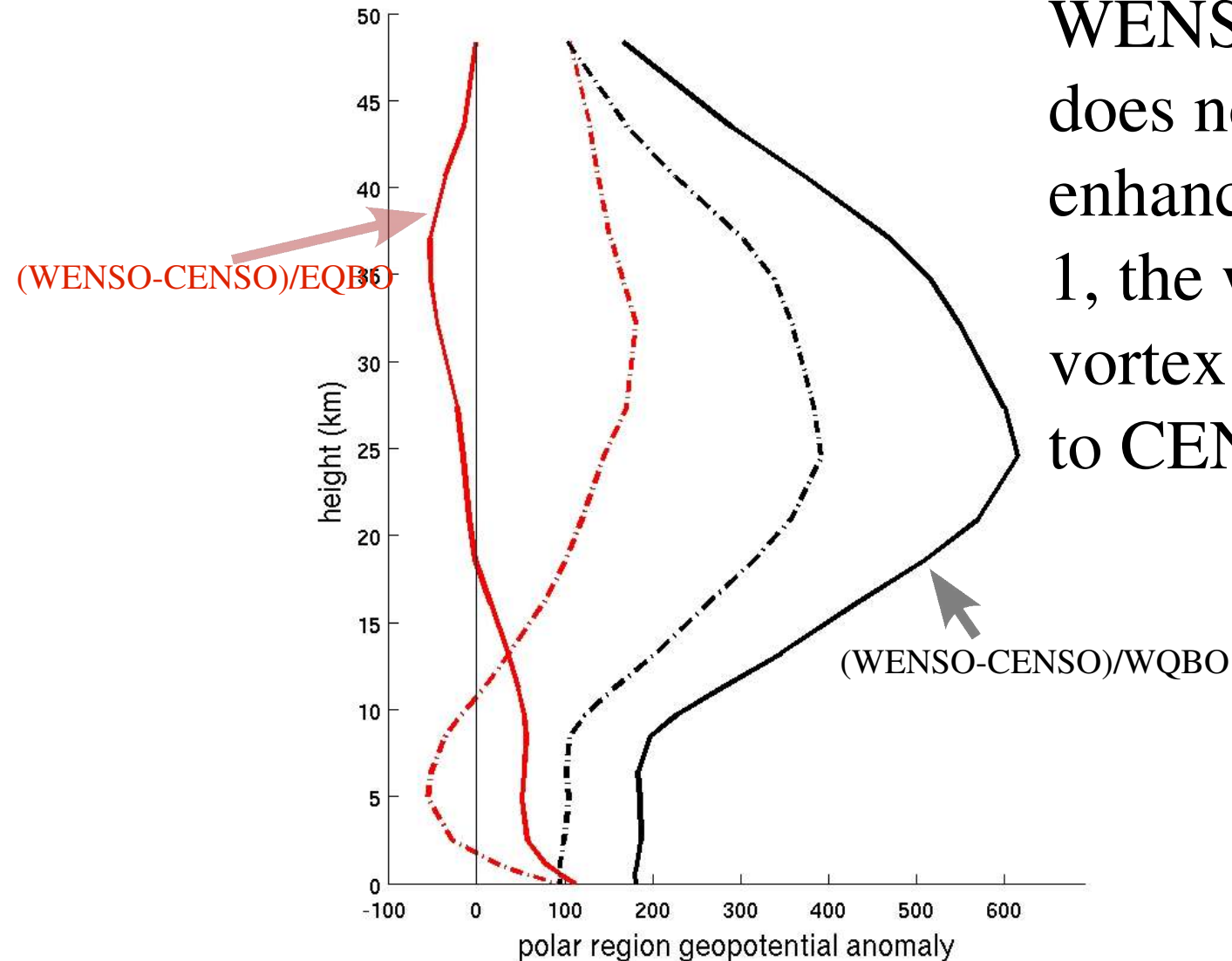


height anomaly at lev: 500 hPa (4.9 km)



# Cause of Little Vortex Modulation by ENSO under EQBO

Because the WENSO/EQBO composite does not have a PNA and enhanced tropospheric wave 1, the weakening of the vortex in WENSO relative to CENSO is small



# Conclusions

(1) When ENSO induces a PNA-like pattern, it modifies the wavenumber-1 field in the troposphere.

This modification in wave-1 propagates to the stratosphere, modulating the vortex.

(2) An exception to WENSO causing enhanced wave-1 is the WENSO/EQBO case. WENSO does not generate a WPNA under EQBO in the observational record.

(3) WACCM realistically simulates the stratospheric response to ENSO and the PNA. The inclusion of a QBO would enhance WACCM's utility.

Garfinkel, C. I., and D. L. Hartmann (under review), The Different ENSO Teleconnections and Their Effects on the Stratospheric Polar Vortex, *J. Geophys. Res.*



THANKS FOR LISTENING!!

