Analysis of Stratospheric and Tropospheric Impacts from the Mount Pinatubo Eruption in the GFDL R30 and GISS GCMs

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Outline

- Introduction
- GFDL and GISS GCMs
- Volcanic Aerosol Data Sets
- NCEP Reanalysis
- Results for GFDL
- Results for GISS
- Conclusions and Future Work

Introduction

- Can the GFDL R30 model with its low stratospheric resolution simulate the positive AO response following a large tropical eruption?

- Can the new GISS modelE GCM produce a positive AO response to a large tropical eruption?

  Strong sudden perturbation to the climate system

  2-5 year runs – many ensemble members

  We have observations

Introduction (cont.)

- Testing the water vapor feedback

In this paper they examined the results from a global perspective. Here we look at the spatial results.

Soden, B. J., R. T. Wetherald, G. L. Stenchikov, and A. Robock, 2002: Global cooling after the eruption of Mount Pinatubo: A test of the climate feedback by water vapor, *Science*, **296**, 727-730.

GFDL R30 GCM

- Spectral transform method with zonal truncation at wavenumber 30 (Rhomboidal 30 truncation)
- Equivalent to ~ 2.25° x 3.75°
- 14 vertical levels (only 3 in the stratosphere)
- Mixed layer ocean
- Volcanic aerosols (Stenchikov et al. 1998)
- Fixed clouds
- 3 ensemble members (Jan. 1991 to Dec. 1996)

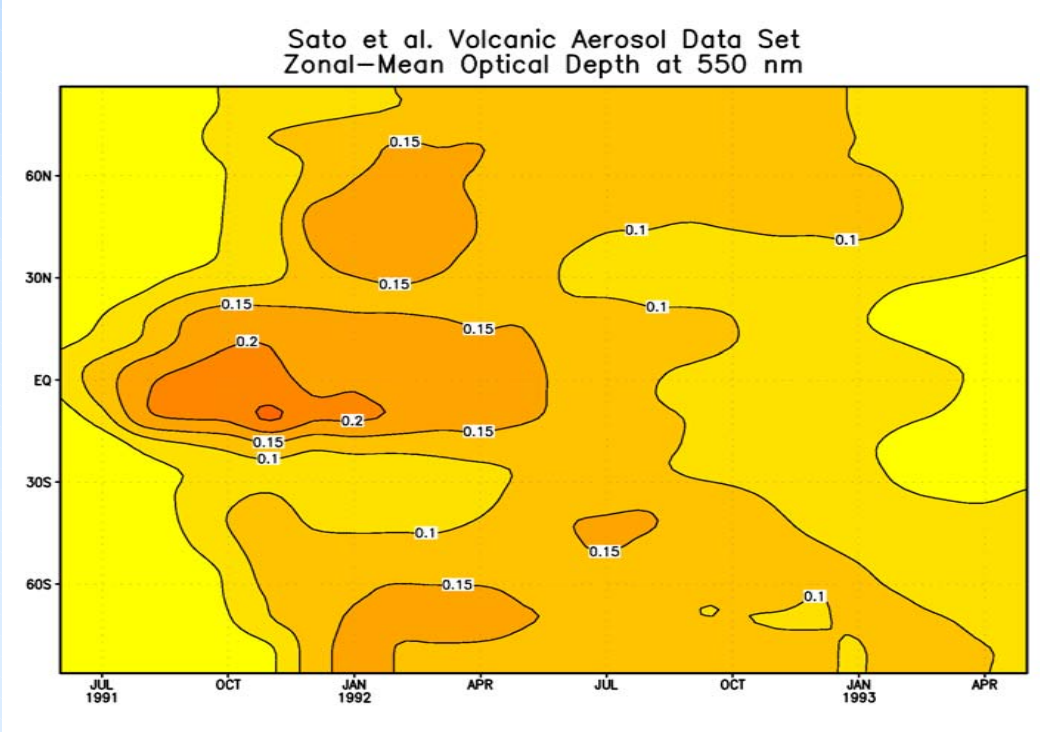
GISS modelE GCM

- Horizontal resolution 4° x 5°
- 18 vertical levels (9 in the stratosphere)
- Fixed climatological SSTs and Sea Ice Conc. (1990-1999)
- Volcanic Aerosols (Sato et al. 1993, updated through 1999)
- 5 ensemble members (Dec. 1990 – Feb. 1994)

Volcanic Aerosol Data Sets

Sato et al. (1993, updated through 1999)

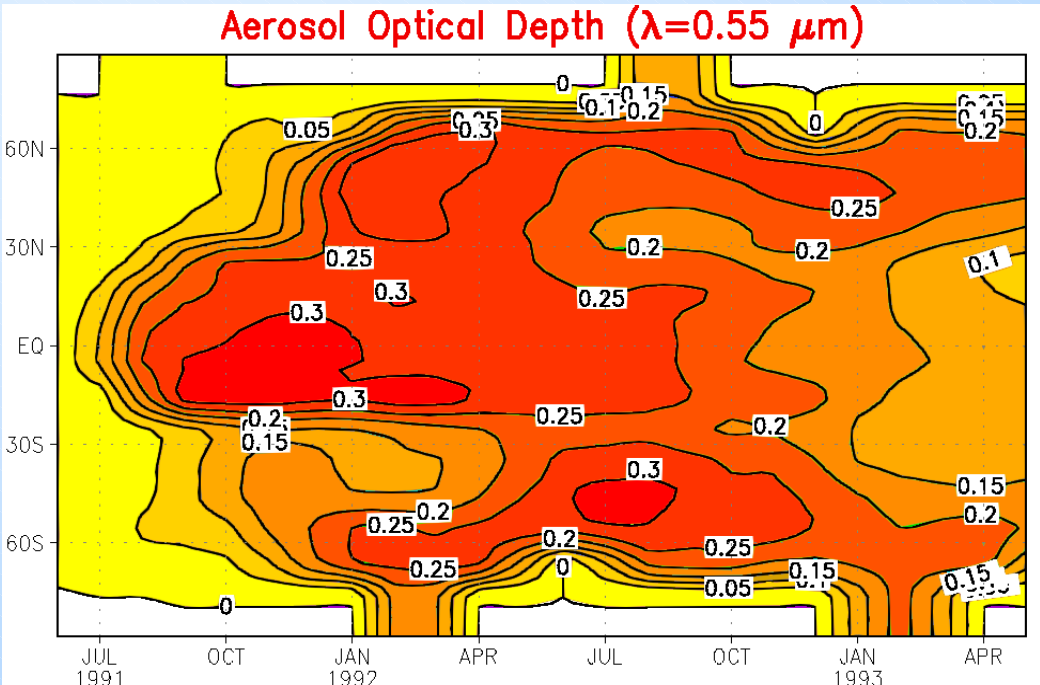
GISS GCM



Ramachandran et al. (2000)

GFDL SKYHI GCM

Calculated from Stenchikov et al. (1998)

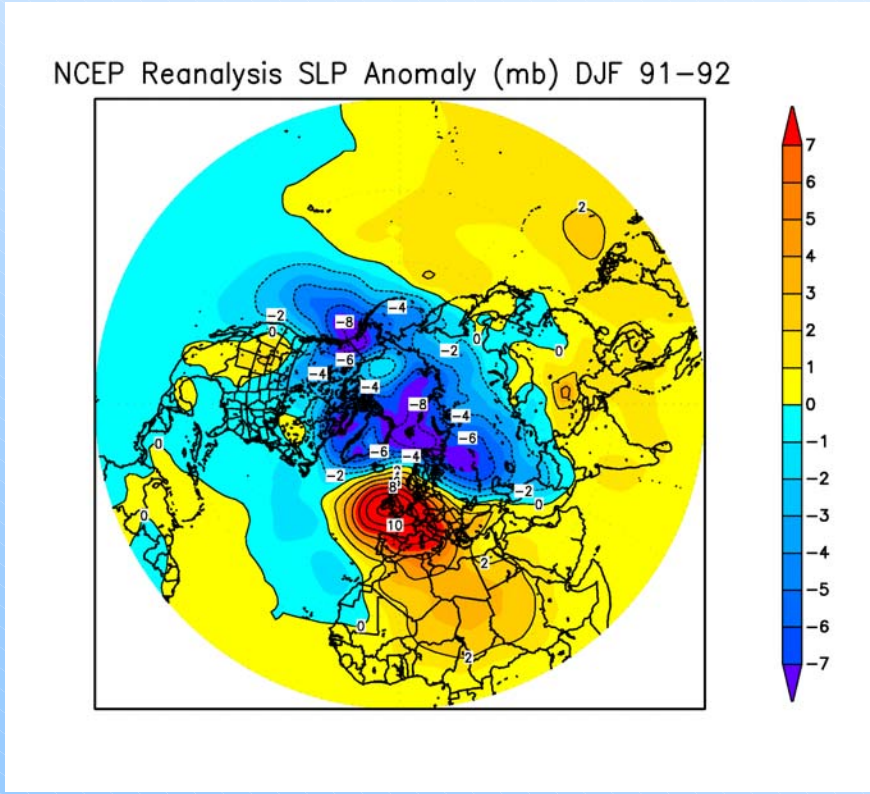


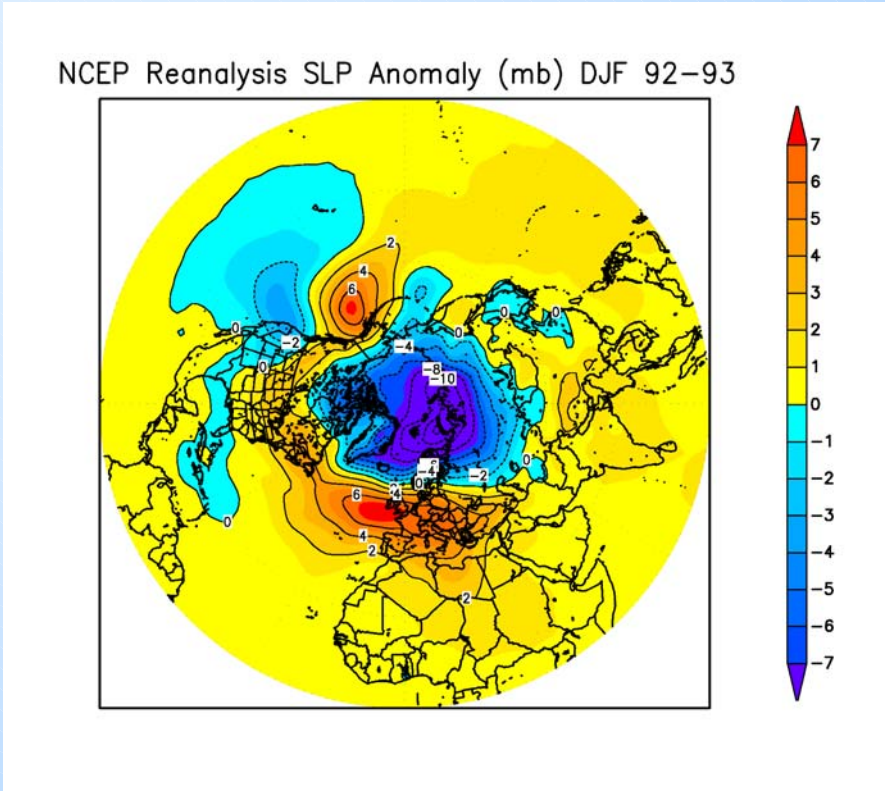
NCEP Reanalysis

Sea Level Pressure (SLP) Anomaly

Positive phase of the AO (El Niño in 1st Winter)

Decreased pressure over the Arctic and some increased pressure over the midlatitude Atlantic



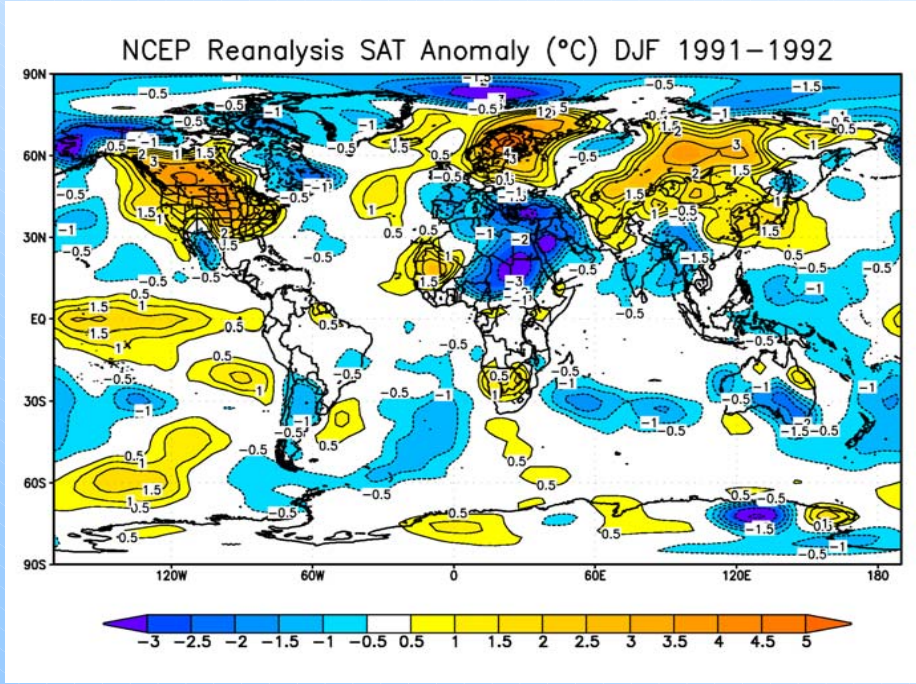


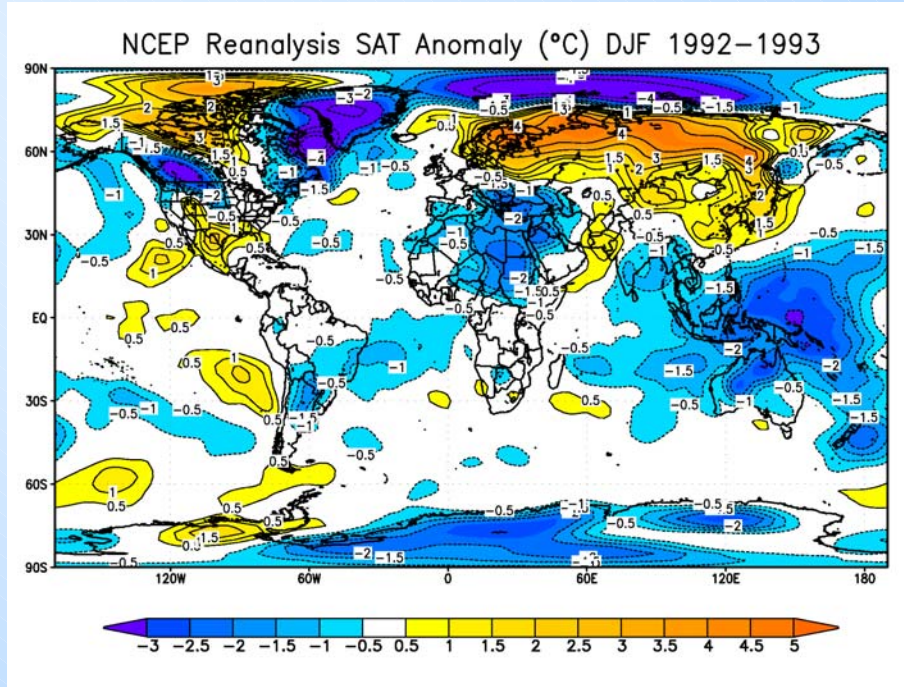
Surface Air Temperature (SAT) Anomaly

Warming over continental regions in the midlatitude NH

Cooling over the Mediterranean region and Greenland

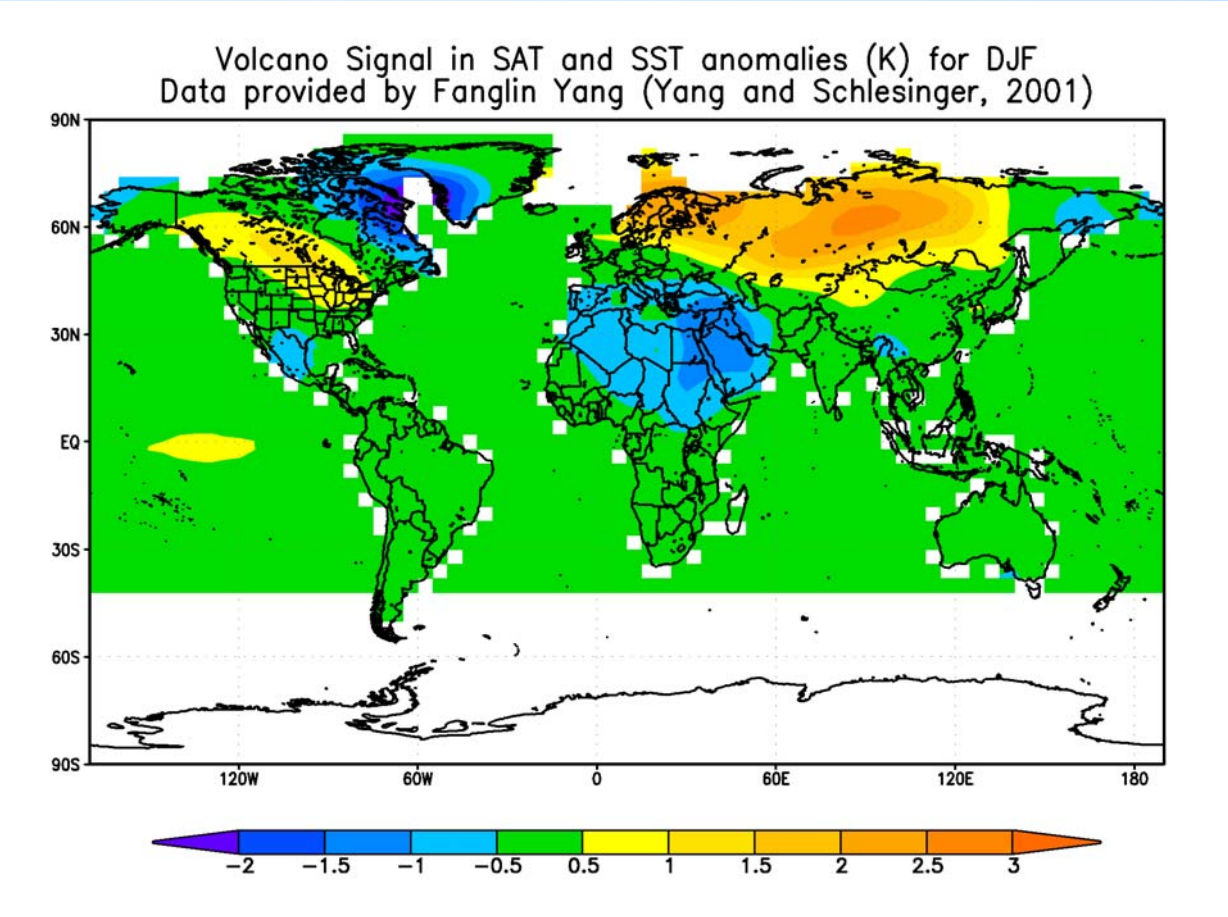
El Niño visible in DJF 1991-1992





Volcanic Composite from Yang and Schlesinger (2001)

Composite of the 2 years following the last 3 major eruptions with the ENSO signal removed

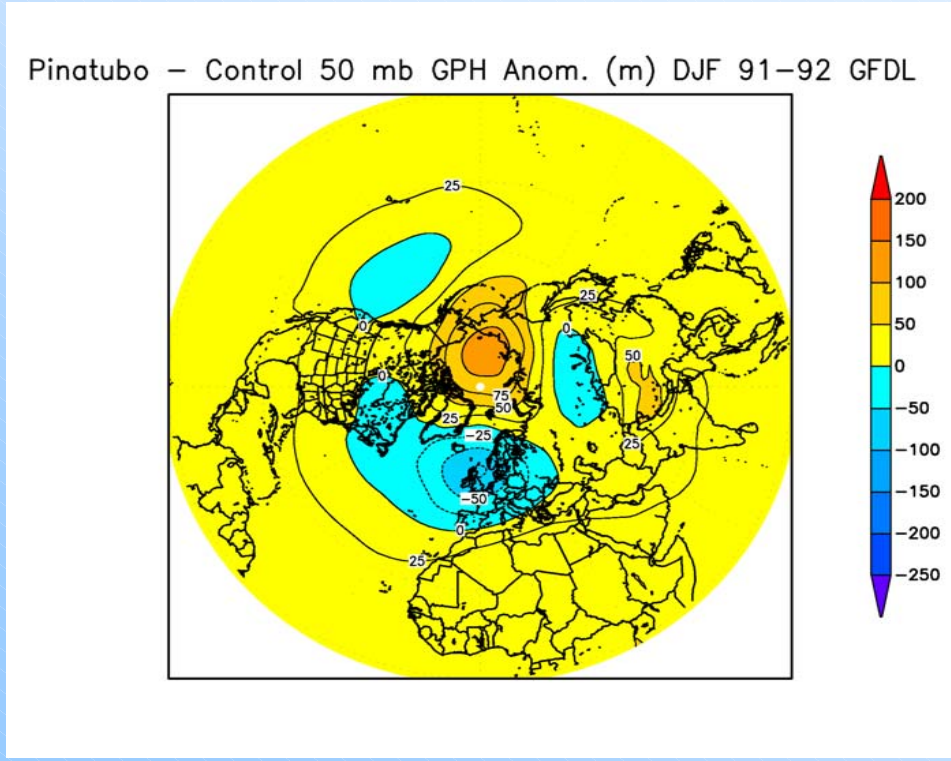


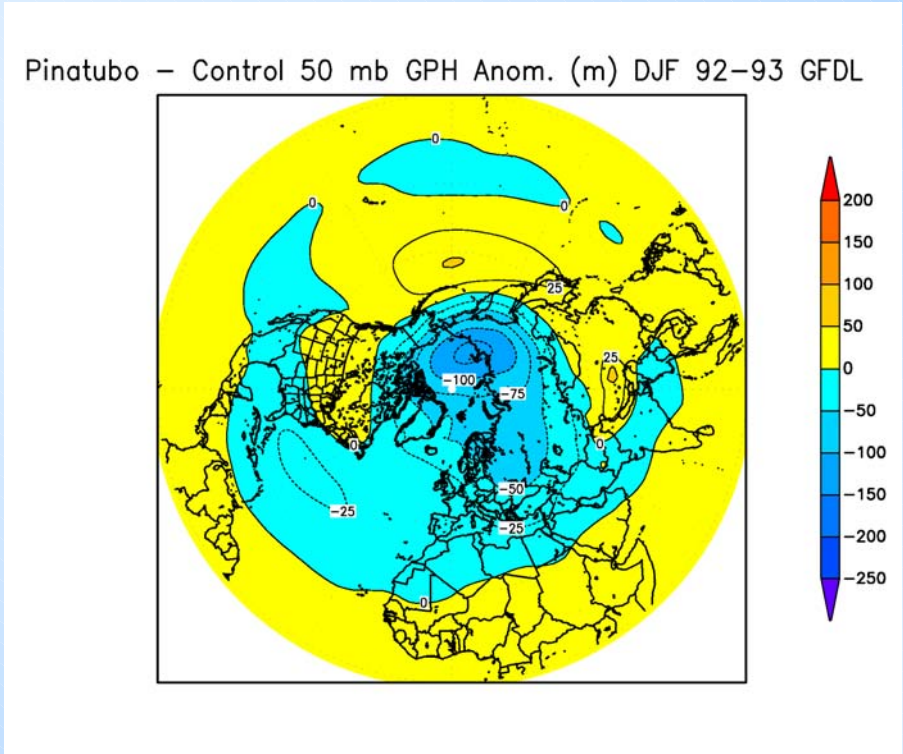
GFDL R30 GCM Results

50 mb GPH Anomaly

Did not produce a stronger polar vortex in first winter

The second winter had a stronger polar vortex with a deepening of ~125 m

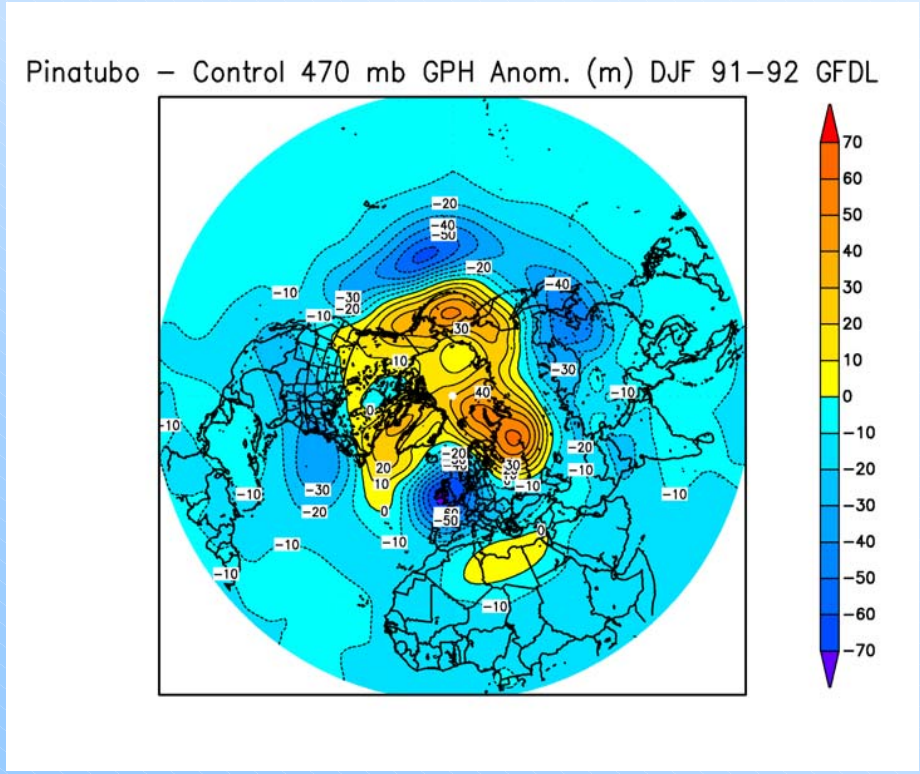


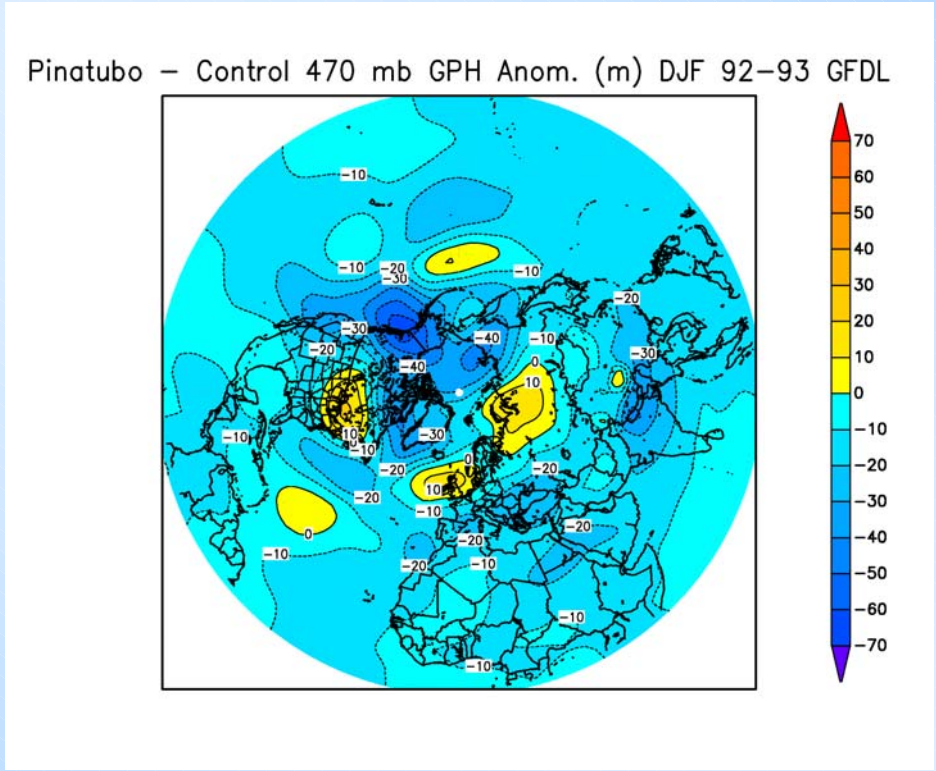


470 mb GPH Anomaly

Negative AO response in first winter

Negative anomalies over northern Canada during second winter but not very strong



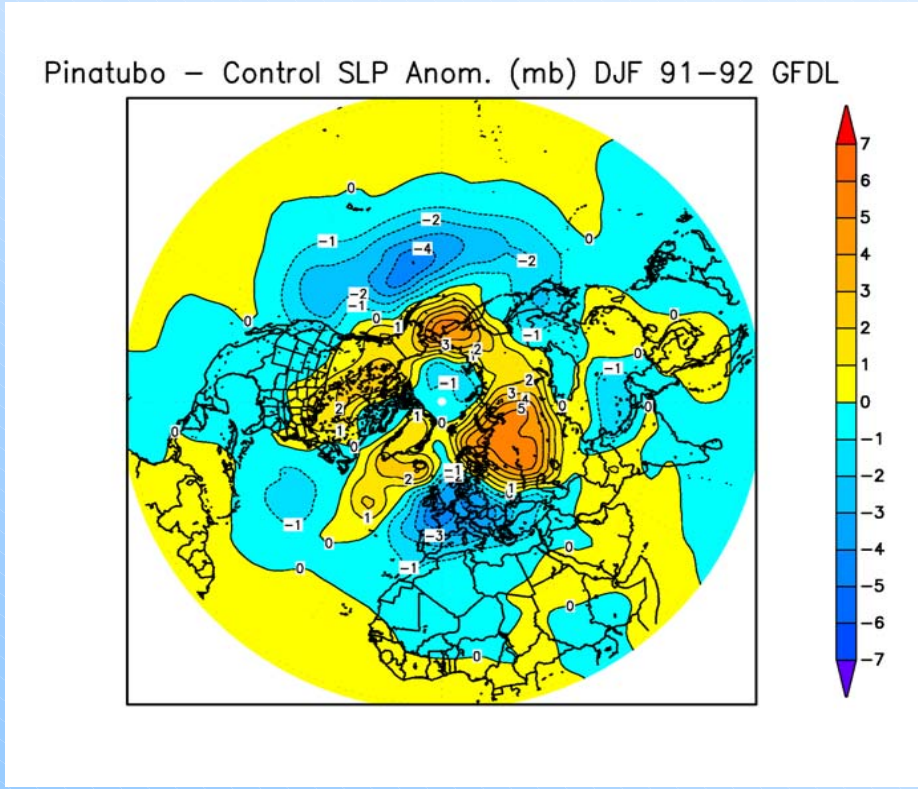


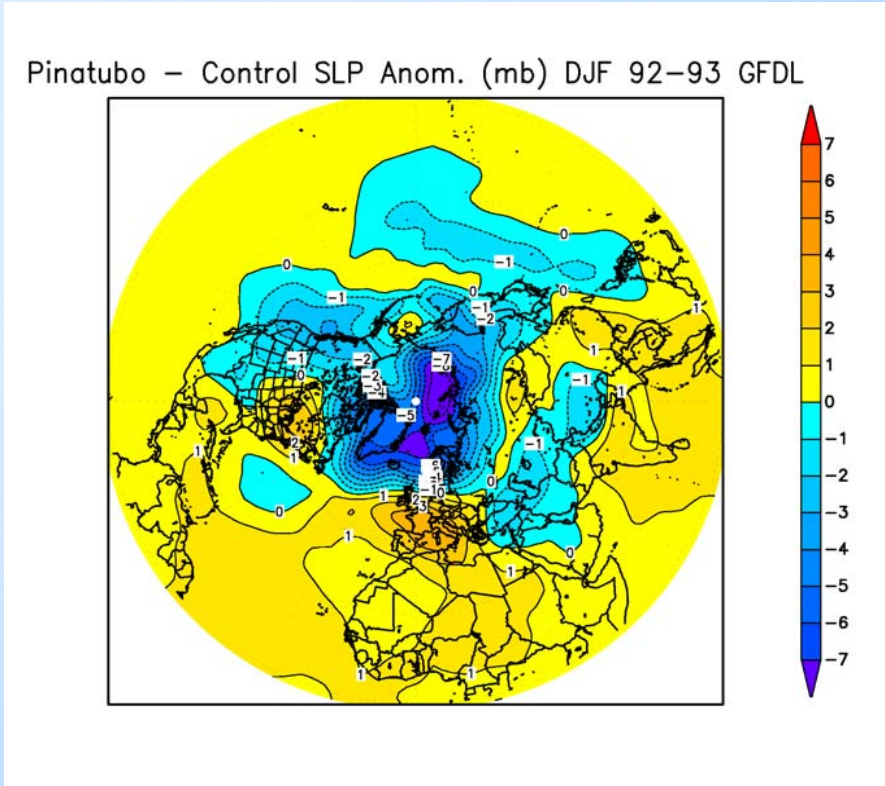
Sea Level Pressure (SLP) Anomaly

Positive NAO response in second winter?

Pressure decrease of ~ 5 to 7 mb over the Arctic

Weak positive anomaly over Europe



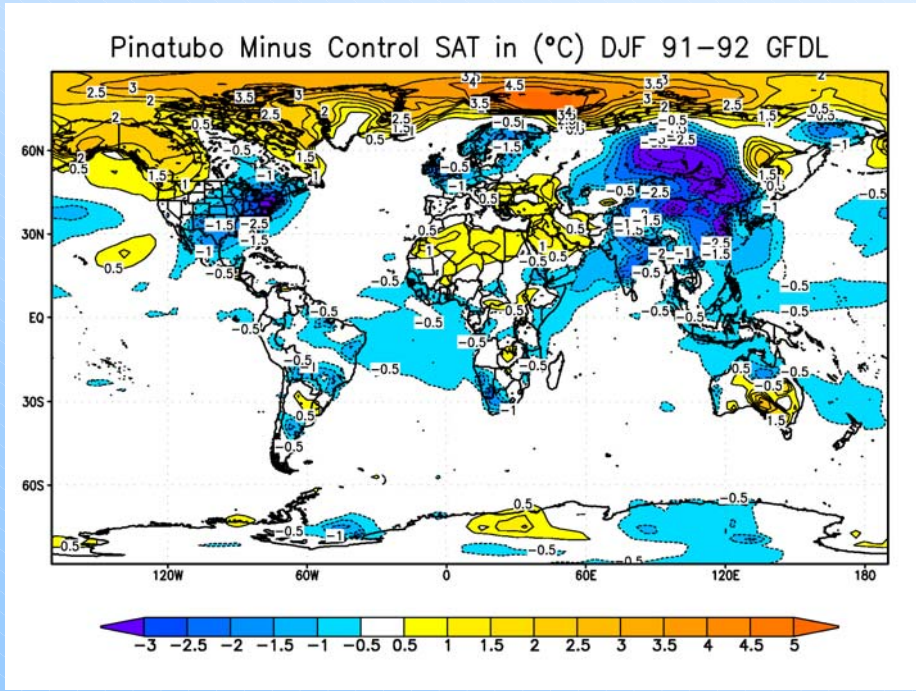


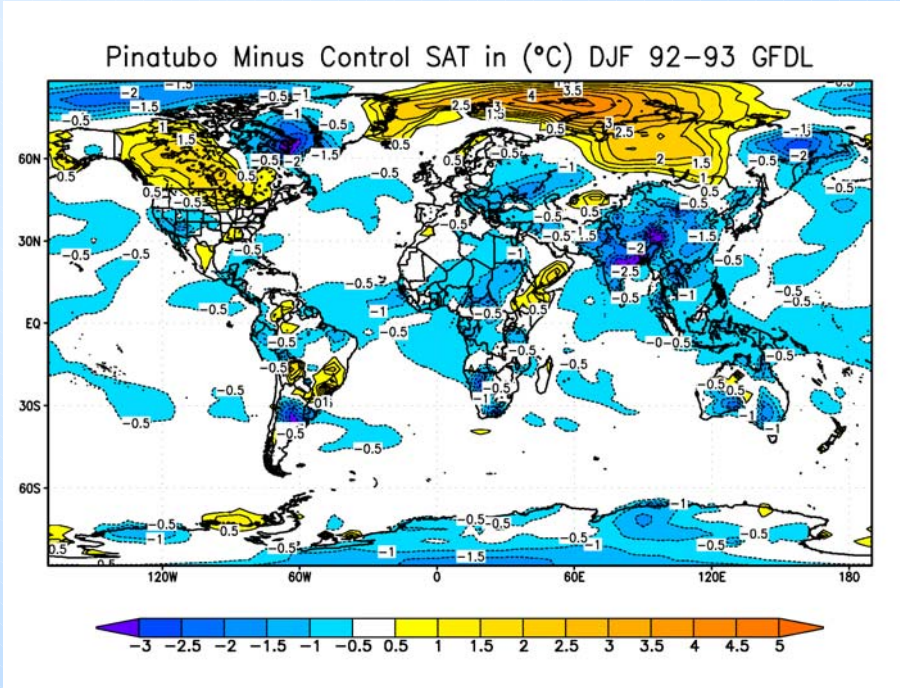
Surface Air Temperature (SAT) Anomaly

Most of the warming is shifted north

In the second winter the pattern over North America is reasonable

Negative AO response in first winter



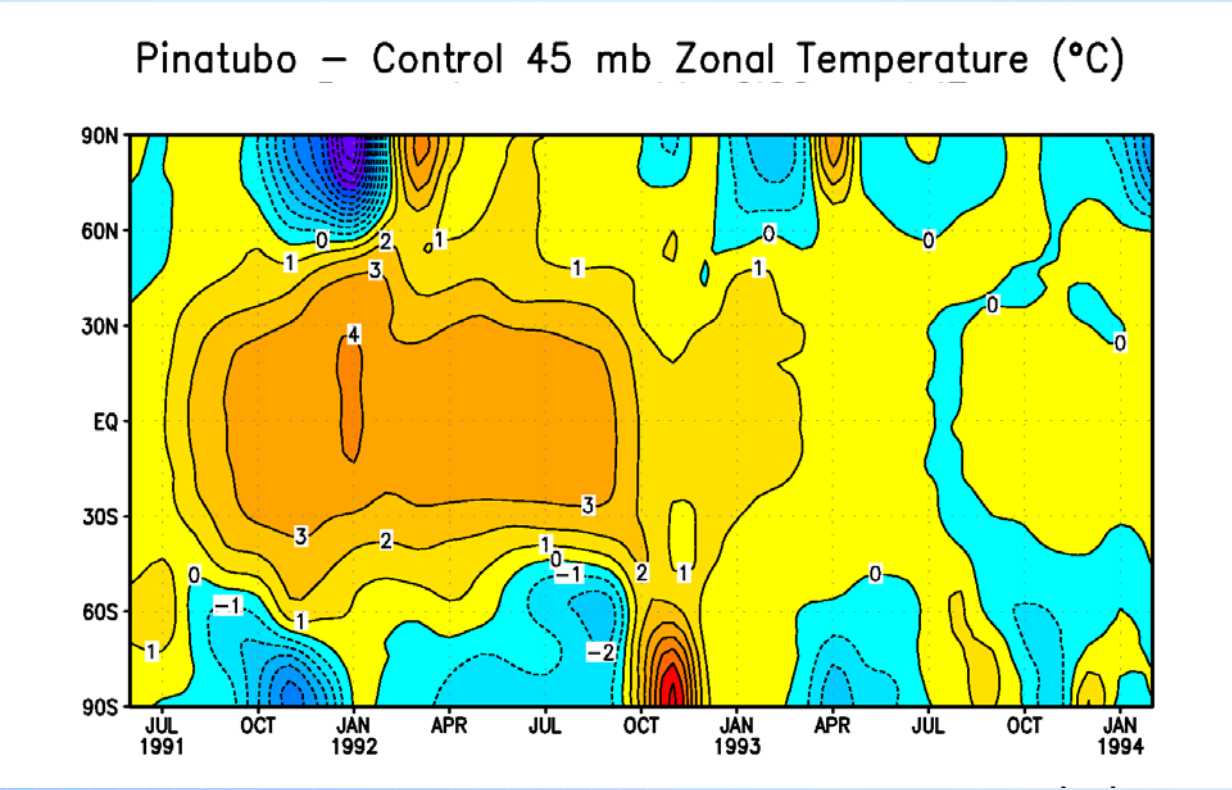


GISS modelE GCM Results

45 mb Zonal Temp. Anomaly

Warming of 3 to 4°C is higher then observations but is reasonable compared to other studies (Kirchner et al. 1999)

Strong cooling during the first winter and less cooling during second winter

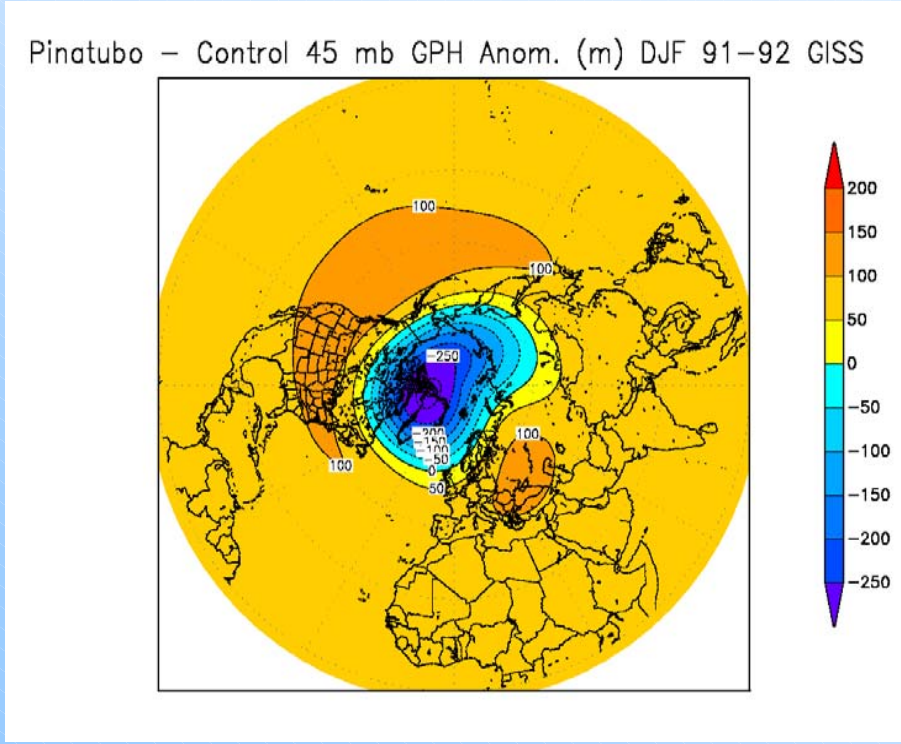


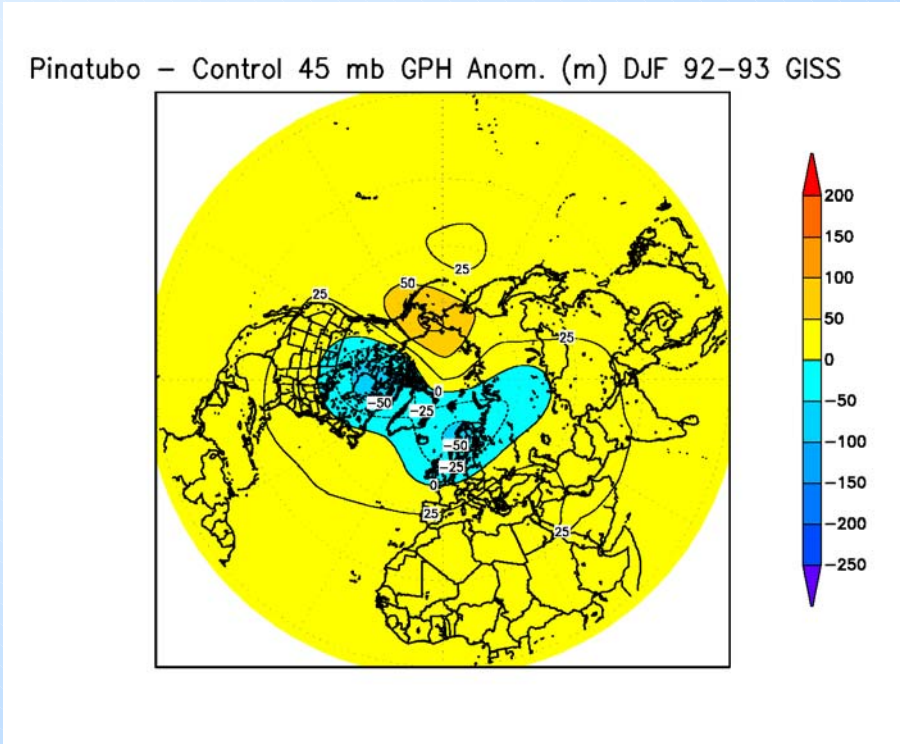
45 mb GPH Anomaly

Much stronger vortex in first winter (-300 m)

Some small strengthening in second winter (-50 m)

Aerosol forcing is much weaker during second winter



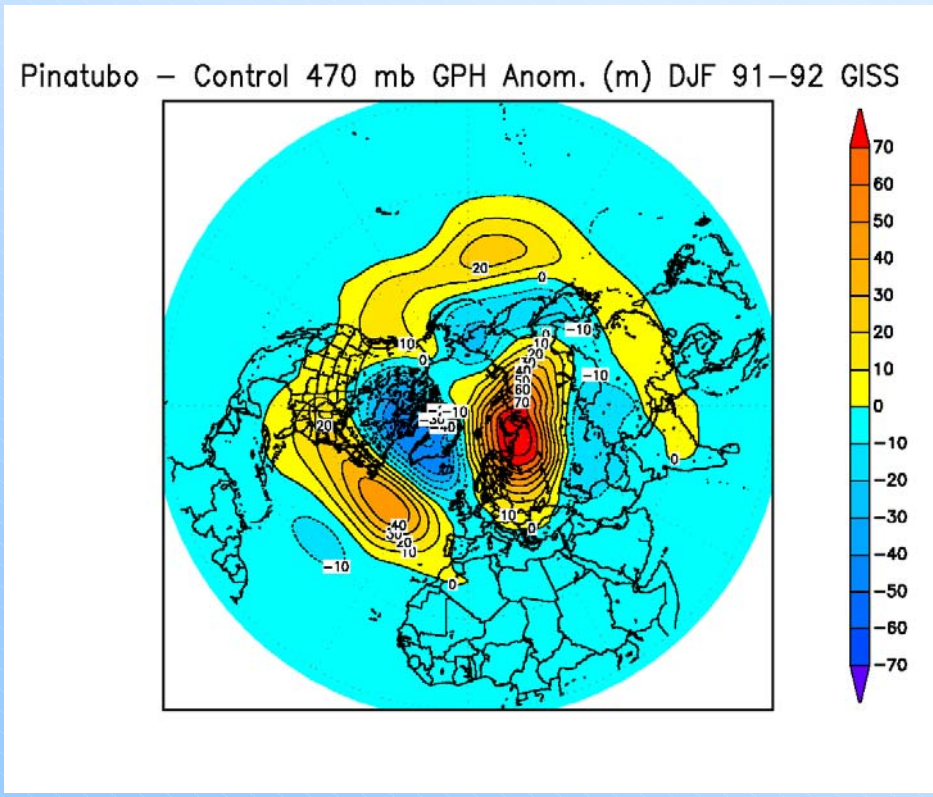


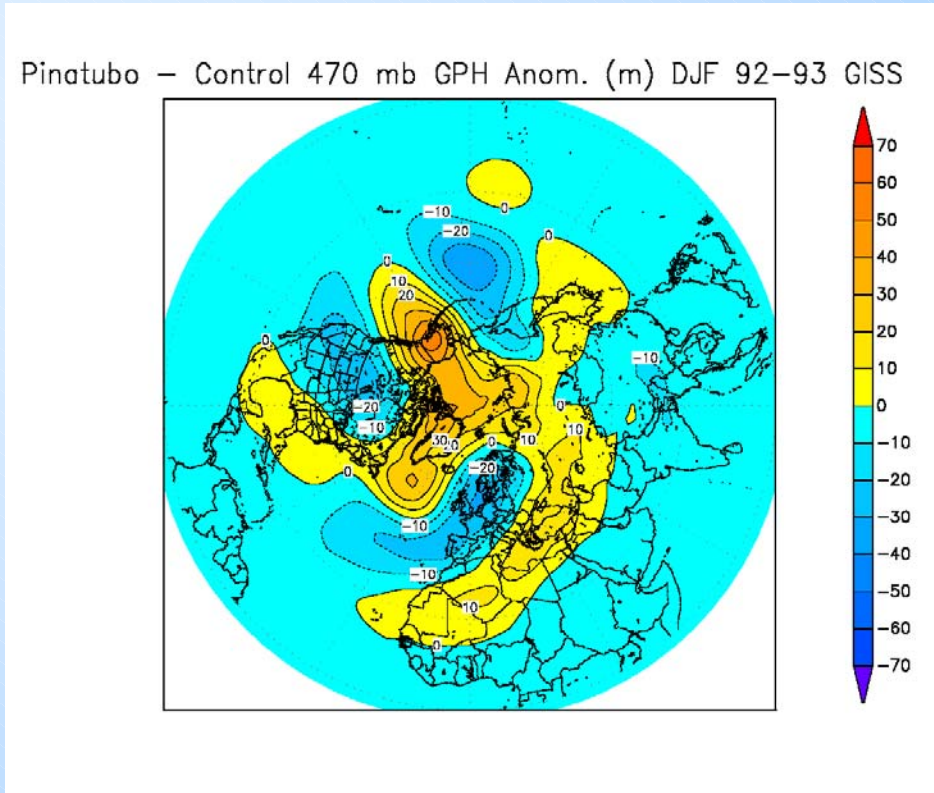
470 mb GPH Anomaly

GPH deepens by 50 m over Greenland – Labrador Sea

Height rises over North Atlantic (40 m) and northern Eurasia (80 m)

This pattern is not produced in the second winter

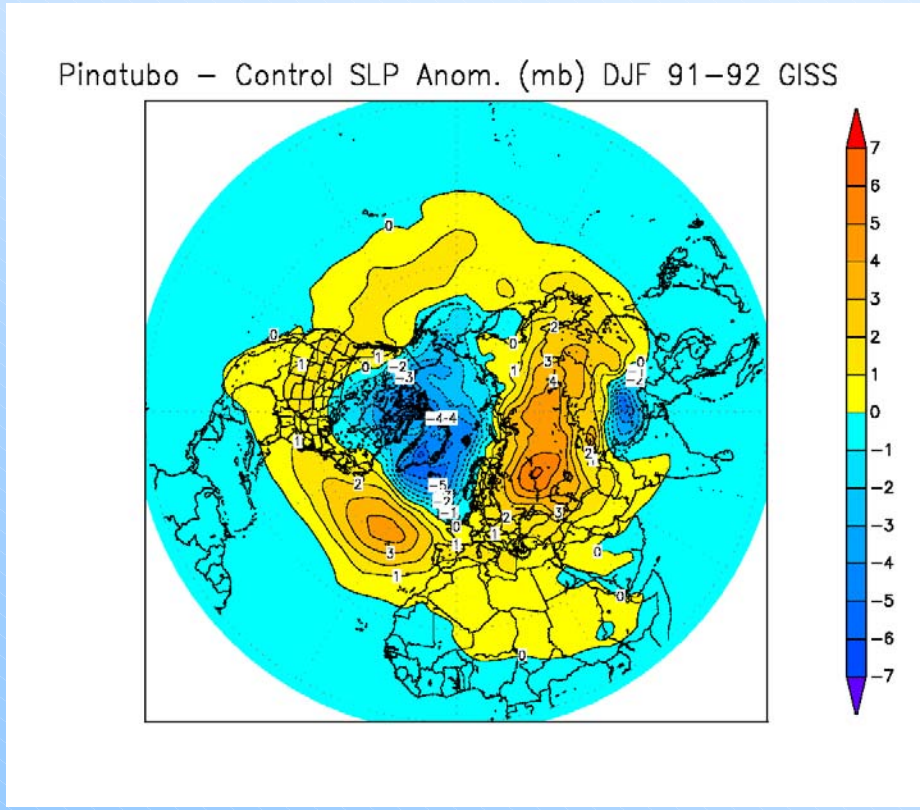


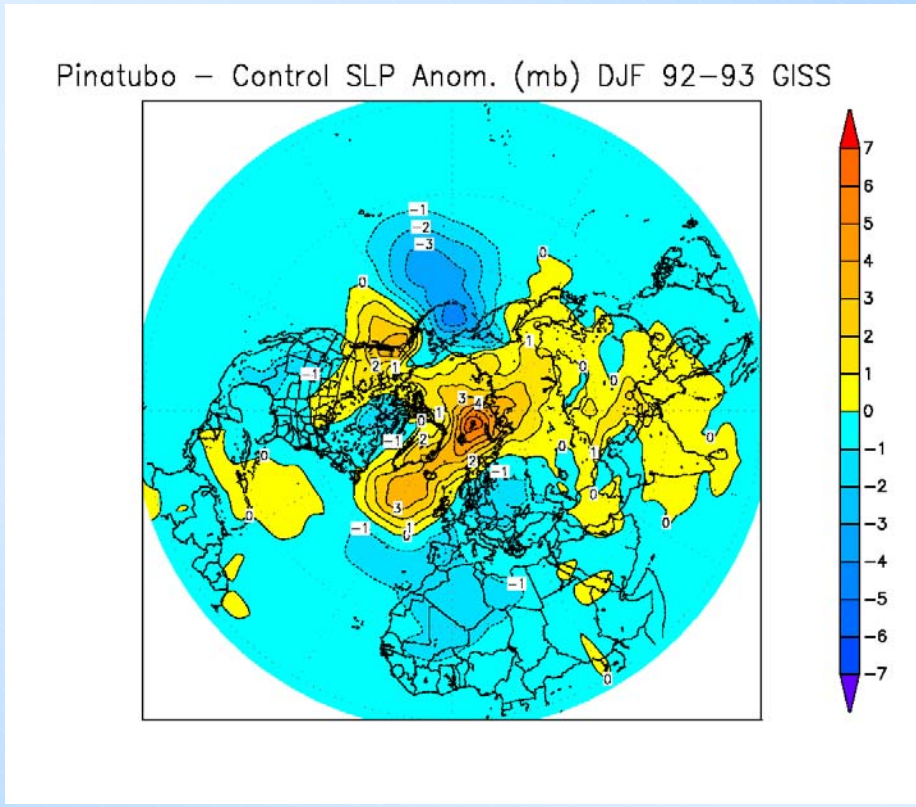


Sea Level Pressure (SLP) Anomaly

Pressure deepening of 4-5 mb over Greenland and northern Canada during first winter

Pressure rises over midlatitude North Atlantic 3-4 mb and over Asia 3-5 mb





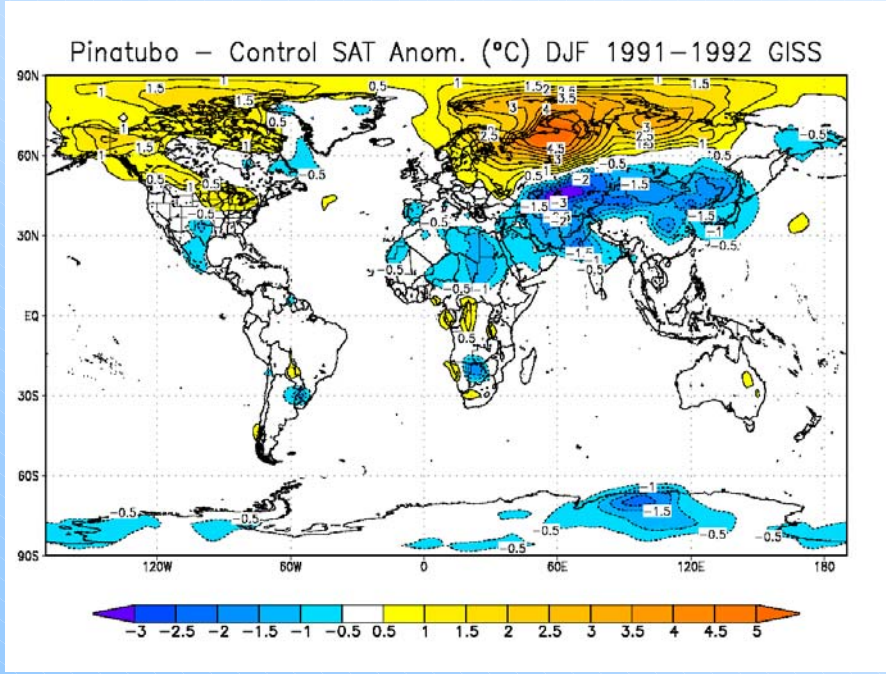
Surface Air Temperature (SAT) Anomaly

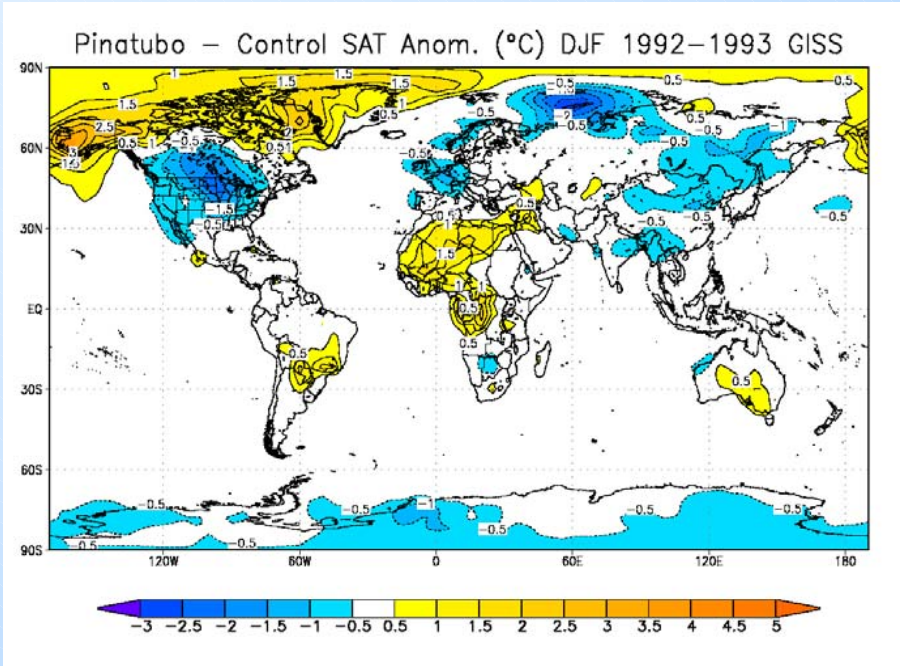
Winter warming over northern Eurasia and central North America during first winter

Cooling over the Middle East and southern Asia

Slight cooling over southern Labrador Sea

More of a negative AO pattern in second winter





Conclusions

- GFDL model did not produce positive AO response in first winter, but did to some extent produce a positive NAO response in second winter
- Could be from its low vertical resolution in the stratosphere
- GISS model produced strong positive AO response especially in the lower stratosphere in first winter, not in second winter
- Sato et al. (1993) aerosol data set has lower optical depths vs. Stenchikov et al. (1998) and could contribute to the weak response seen in second winter in GISS GCM

Future Work

- Force the GISS model using Stenchikov et al. 1998
- Adding a mixed layer ocean to the GISS simulations
- Test volcanic response to different vertical resolutions (or higher model top)
- Use the GISS model to simulate the Laki eruption

The Physics of the Stratosphere (Goody 1958)

"The stratosphere appears to be an inactive region (as regards heat) in which nothing much happens."

(Crossley 1934)