Simulated sensitivity of the tropical climate on extratropical thermal forcing

Stefanie Talento - Marcelo Barreiro

Universidad de la República
Uruguay

UNIVERSIDAD
DE LA REPUBLICA
URUGUAY

Motivation

- Tropics driving extratropics:
- Extratropics driving tropics:

Motivation

- Tropics driving extratropics:

  Well known
  Example: El Niño Southern Oscillation

- Extratropics driving tropics:

Motivation

- Tropics driving extratropics:

  Well known
  Example: El Niño Southern Oscillation

- Extratropics driving tropics:

  Not so well understood
  Evidence:

Motivation

- Tropics driving extratropics:

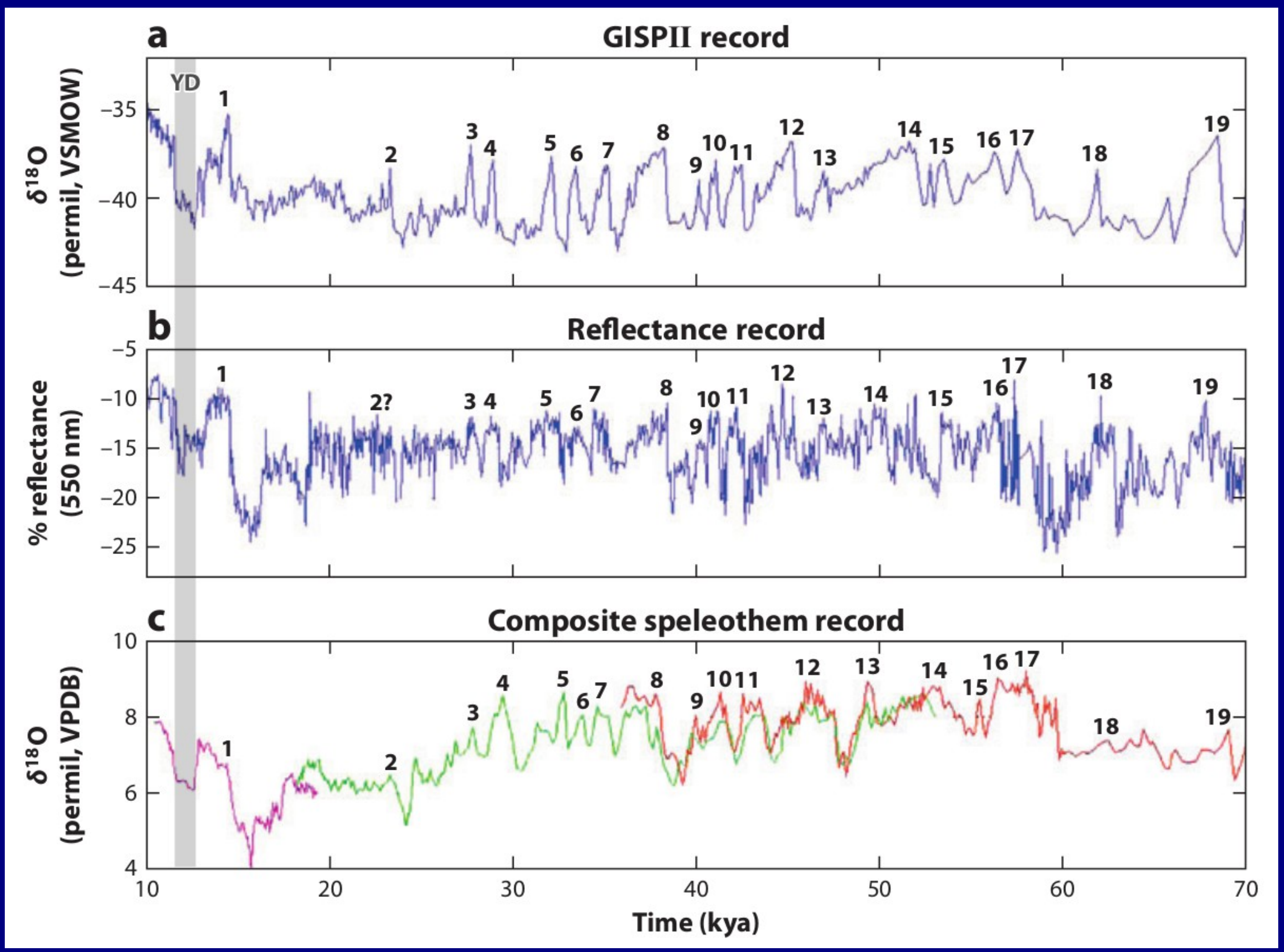
  Well known
  Example: El Niño Southern Oscillation

- Extratropics driving tropics:

  Not so well understood
  Evidence:
  Paleoclimatic studies

Extra-tropical driving of the tropics: Paleoclimatic evidence

Close relationship between Greenland temperatures and rainfall in tropical Atlantic and China during the last glacial period.



Greenland temperature

Hydrological changes in Cariaco Basin (Venezuela)

Hydrological changes in China

Chiang and Friedman, 2012.

Motivation

- Tropics driving extratropics:

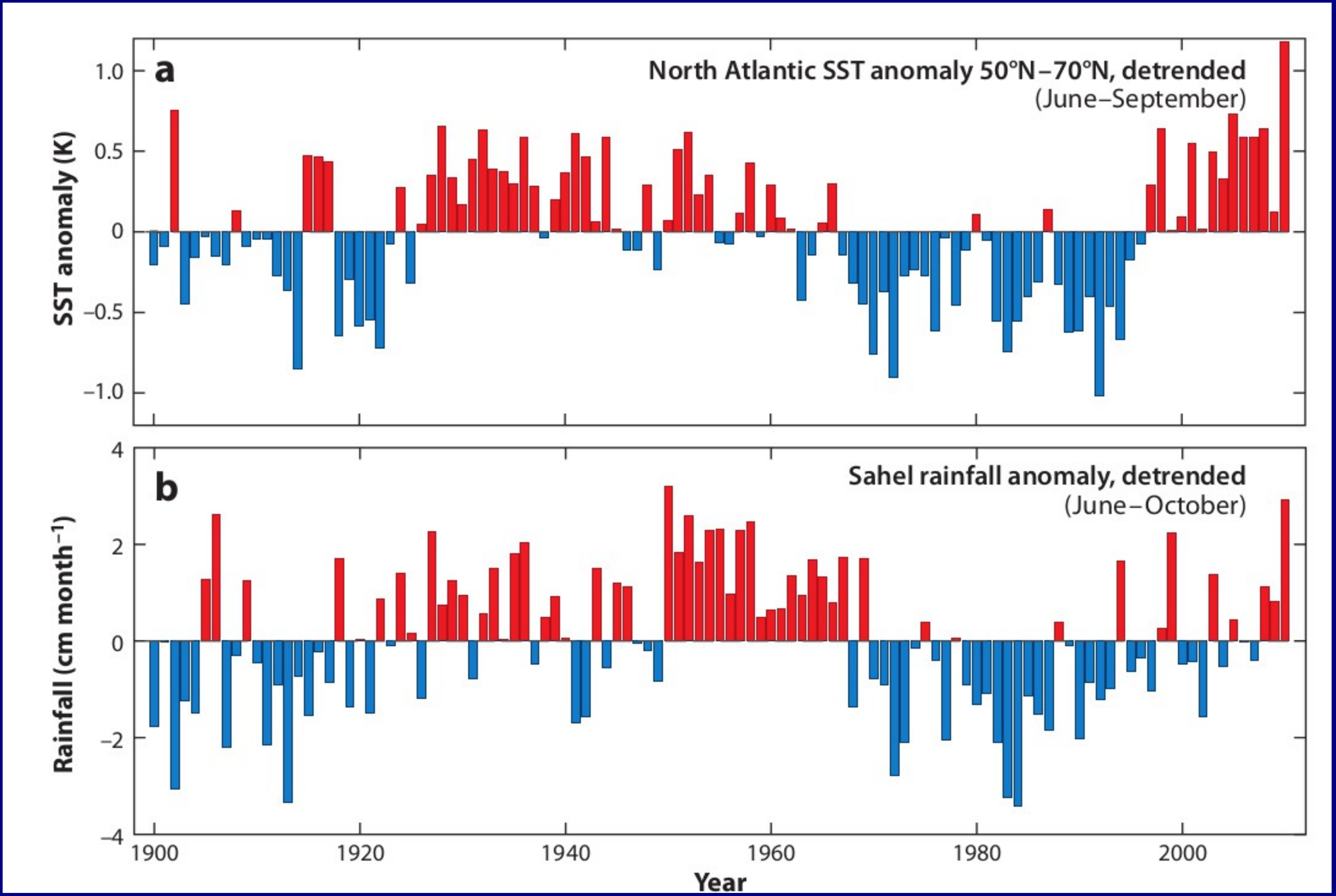
  Well known
  Example: El Niño Southern Oscillation

- Extratropics driving tropics:

  Not so well understood
  Evidence:
  - Paleoclimatic studies
  - 20th century observations

Extra-tropical driving of the tropics: 20th century observations

Influence of the high-latitude North Atlantic on Sahel rainfall.



Chiang and Friedman, 2012.

Motivation

- Tropics driving extratropics:

  Well known
  Example: El Niño Southern Oscillation

- Extratropics driving tropics:

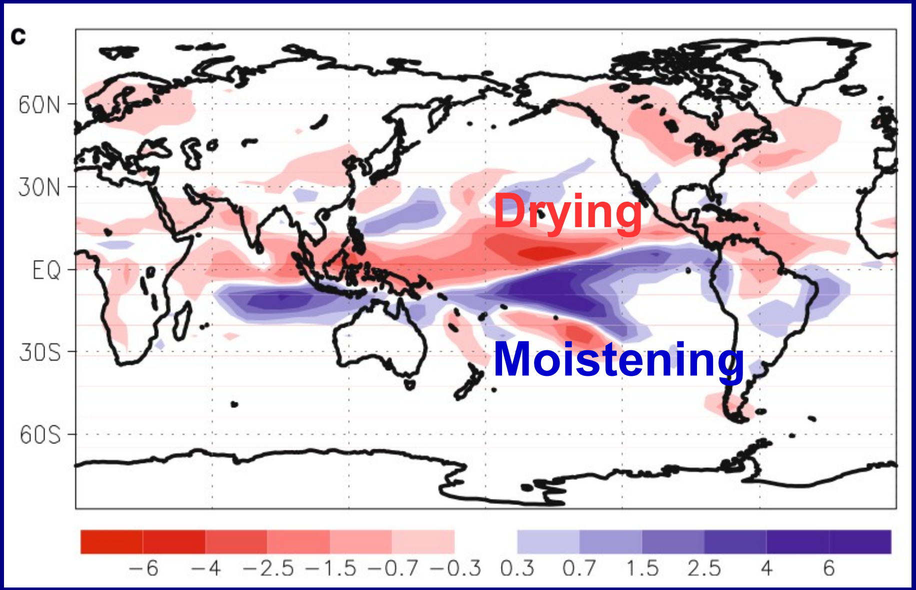
  Not so well understood
  Evidence:
  - Paleoclimatic studies
  - 20th century observations
  - Numerical Simulations

Extra-tropical driving of the tropics: Numerical Simulations

Increase in NH high-latitude ice →

Southward displacement of Intertropical convergence zone (ITCZ)

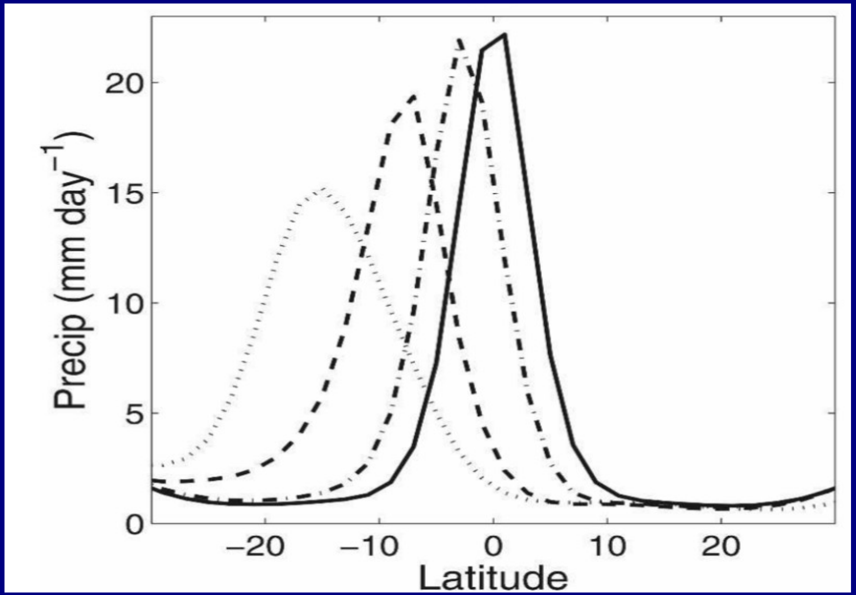
Precipitation anomalies



Chiang and Bitz, 2005.

Aquaplanet simulations,
AGCM + slab ocean

Imposed inter-hemispheric gradient →
ITCZ shifts to the wamer Hemisphere



Kang et al, 2008.

Motivation

- Tropics driving extratropics:

  Well known
  Example: El Niño Southern Oscillation

- Extratropics driving tropics:

  Not so well understood
  Evidence:
  Paleoclimatic studies
  20^{th} century observations
  Numerical Simulations

Objective:
Investigate the ITCZ response to extratropical thermal forcing, using realistic boundary surface conditions.

Methodology

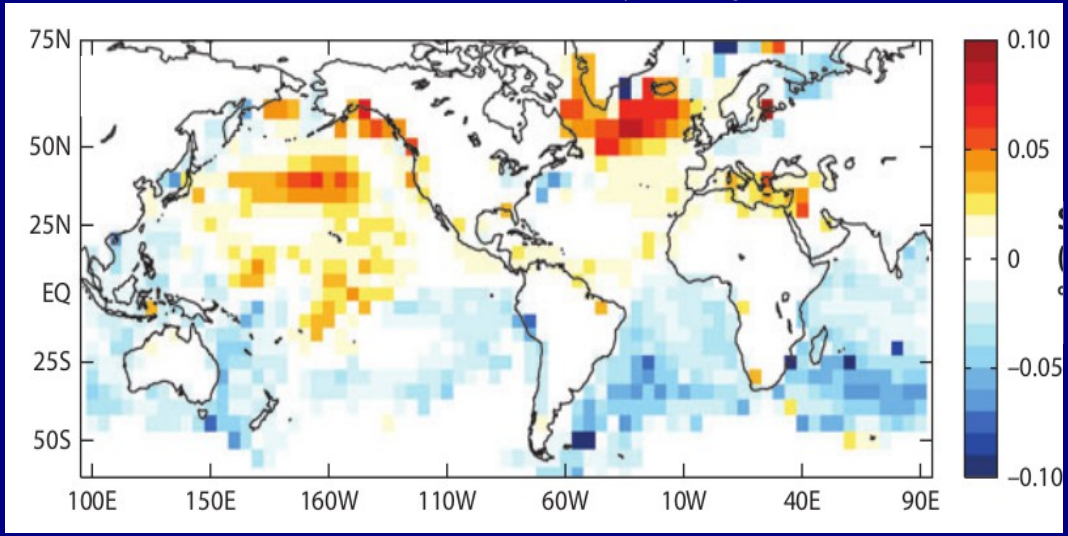
- Objective:

  Investigate the ITCZ response to extratropical thermal forcing, using realistic boundary surface conditions.

- Model Simulations:
  - AGCM (ICTP-SPEEDY) coupled to slab ocean model (just thermodynamic coupling).
  - Boundary surface conditions: Realistic
  - 40 years of simulation
  - 2 sets of simulations:
    - Set 1: Slab ocean applied globally
    - Set 2: Fixed SST in the tropics, slab ocean elsewhere

Extratropical forcing

Regression of NH – SH SST difference
time series for the 20th century on global SST field

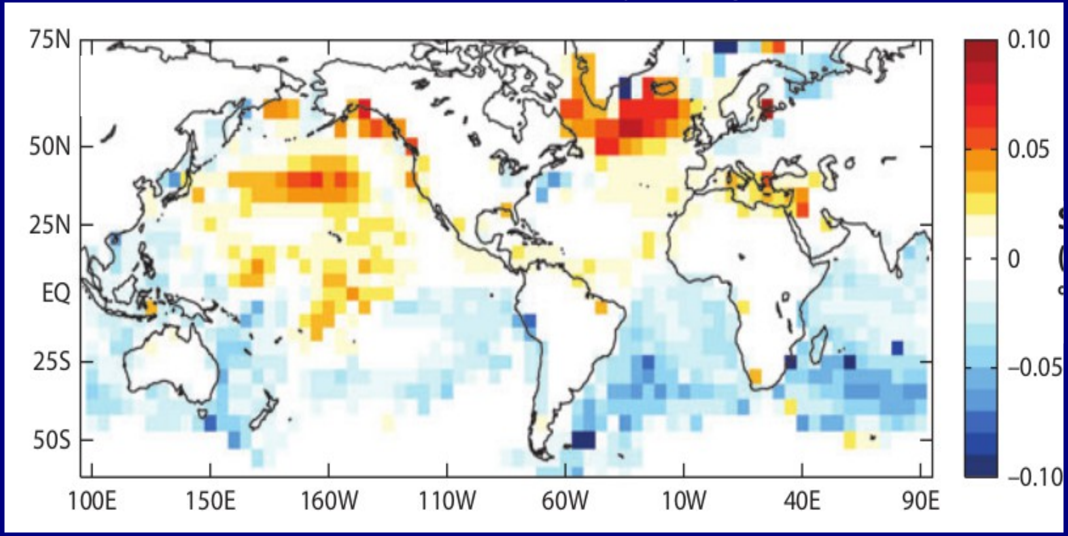


Inter-Hemispheric SST gradient in the 20th century.

Thompson et al., 2010.

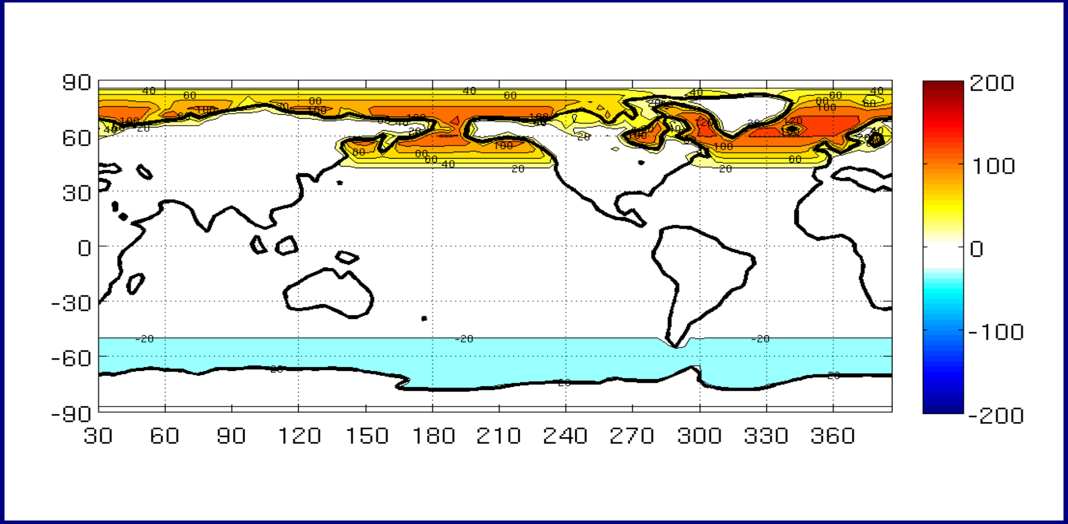
Extratropical forcing

Regression of NH – SH SST difference
time series for the 20th century on global SST field



Inter-Hemispheric SST gradient in the 20th century.

Thompson et al., 2010.



Forcing: Heat flux (W/m^2) out of sea, A=35.

Warming in NH / Cooling in SH

Poleward of 40º

Global average: zero

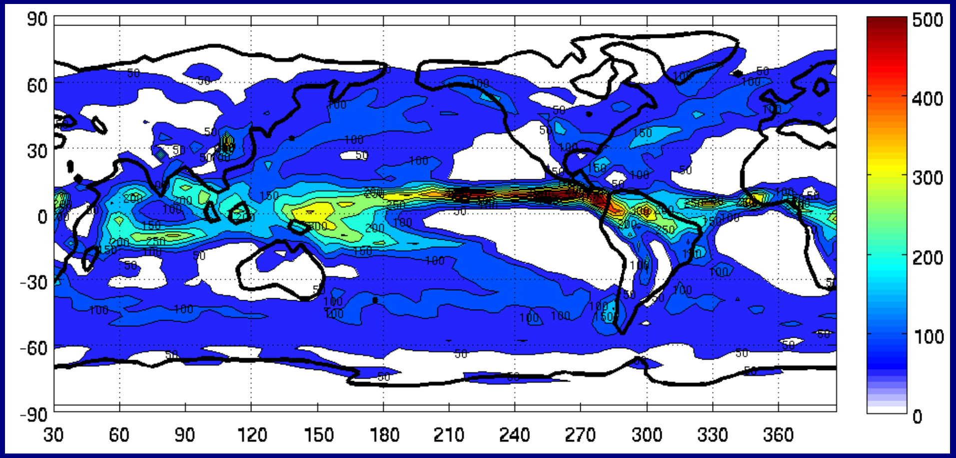
Increasing amplitude,
factor A = 5, 10,..., **35**

Results

Experiments with global slab ocean

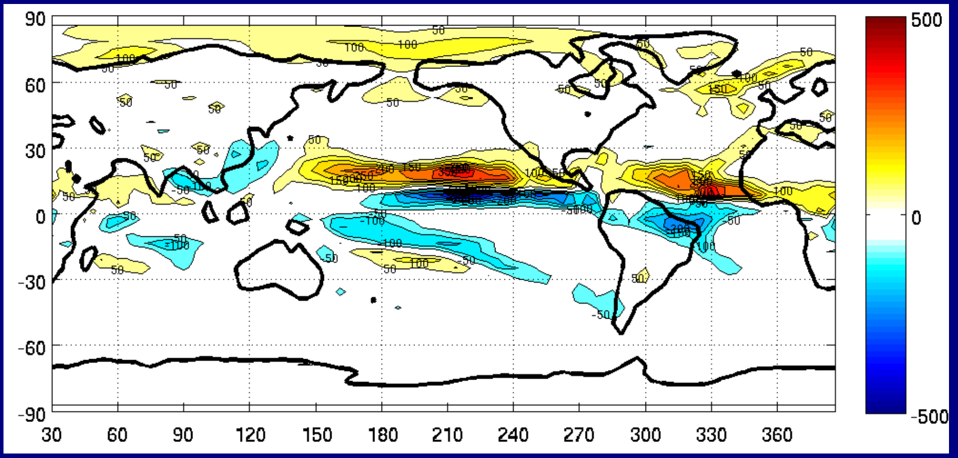
Precipitation
Annual means

Control



Contour interval: 50 mm/month.

Departures from control, A=35

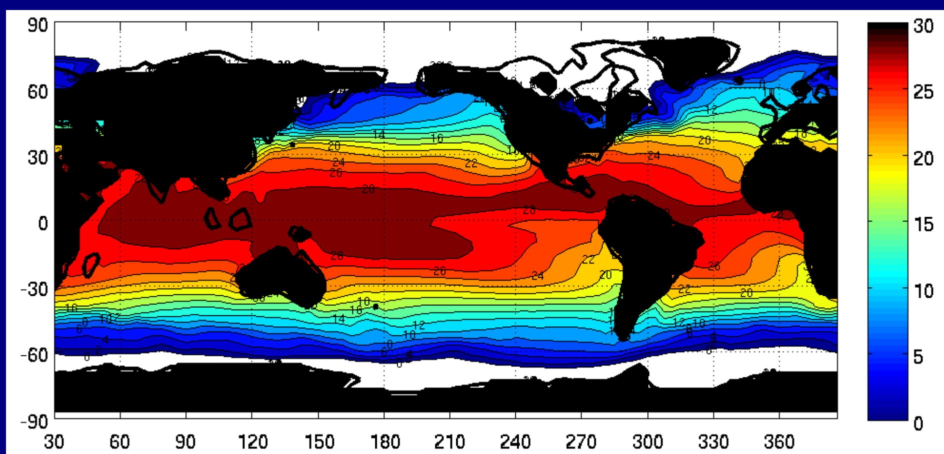


Contour interval: 50 mm/month.

ITCZ shifts to the warmer Hemisphere

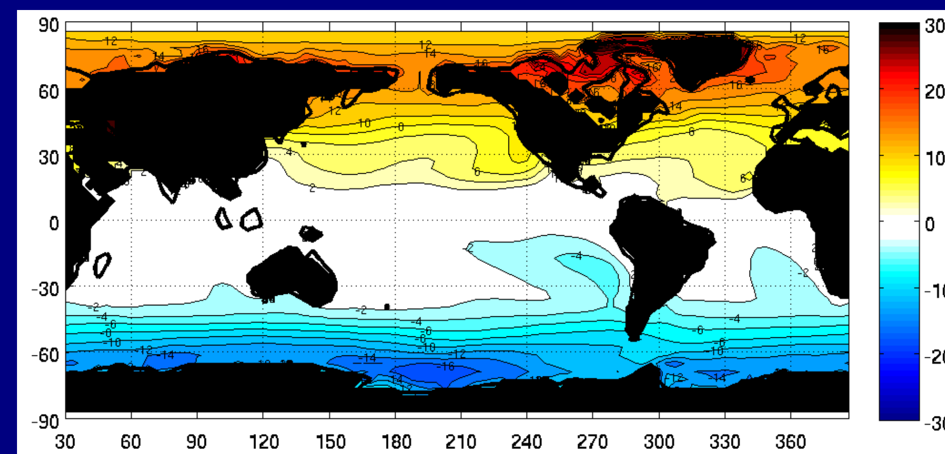
Sea Surface Temperature
Annual means

Control



Contour interval: 2ºC

Departures from control, A=35

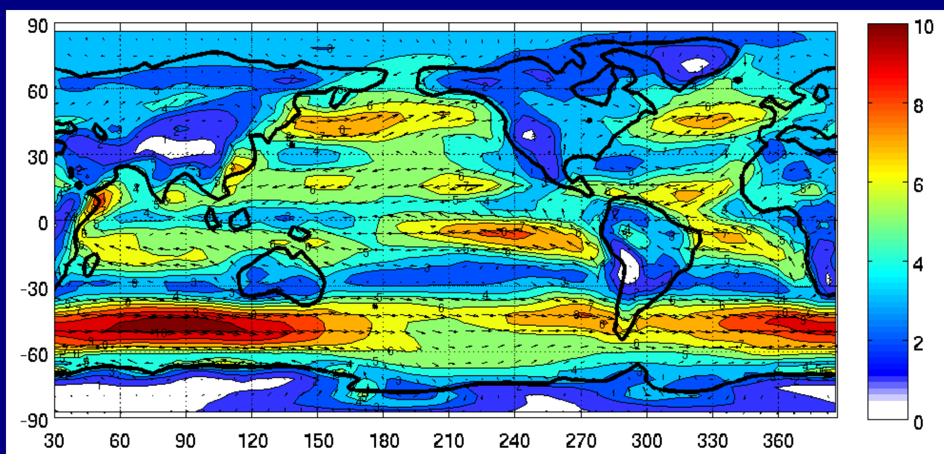


Contour interval: 2ºC

Warming in NH
Cooling in SH

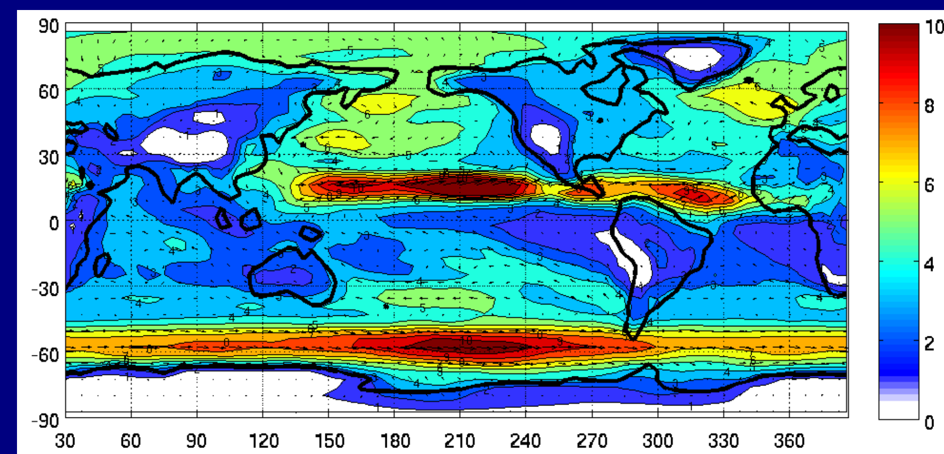
Surface Wind
Annual means

Control



Contour interval: 1 m/s
Colour scale denotes magnitude of vector wind.

Departures from control, A=35



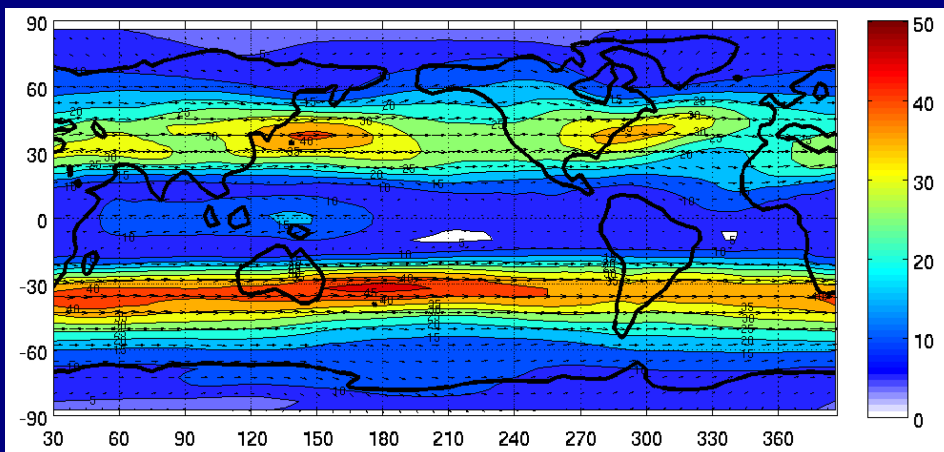
Contour interval: 1 m/s
Colour scale denotes magnitude of vector wind.

The response is not only important at the tropics, but also in the SH.

Wind at 200 hPa

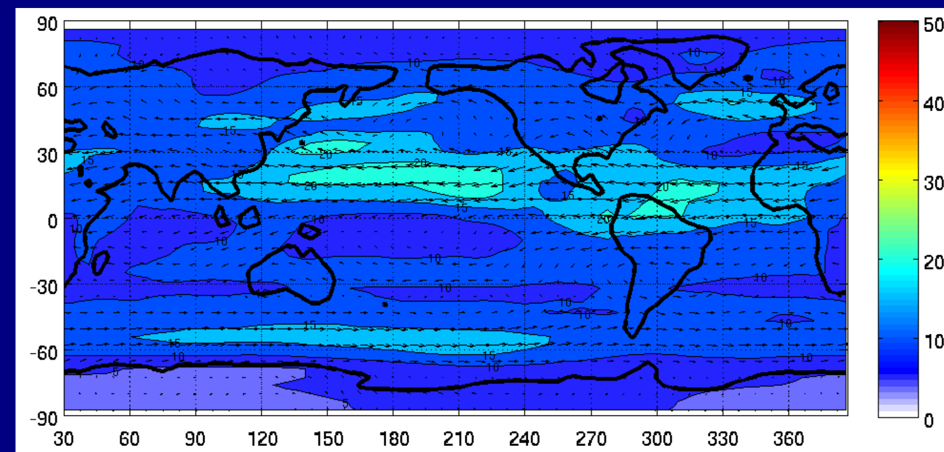
Annual means

Control



Contour interval: 5 m/s
Colour scale denotes magnitude of vector wind.

Departures from control, A=35

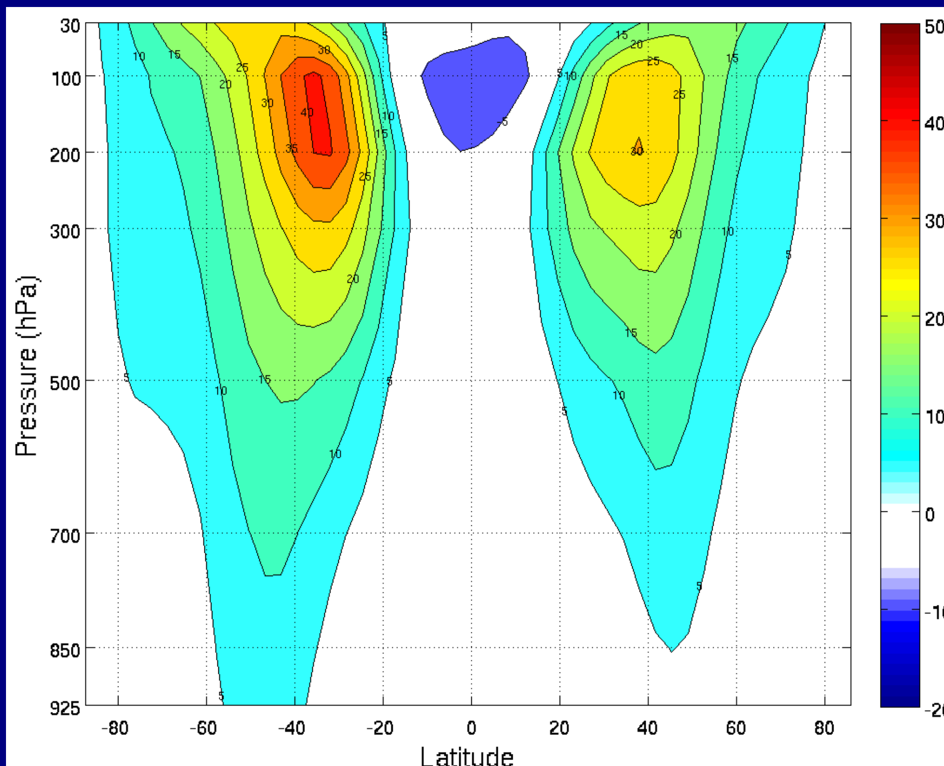


Contour interval: 5 m/s
Colour scale denotes magnitude of vector wind.

Anomalies in northern tropics as well as in the southern subtropical jet.

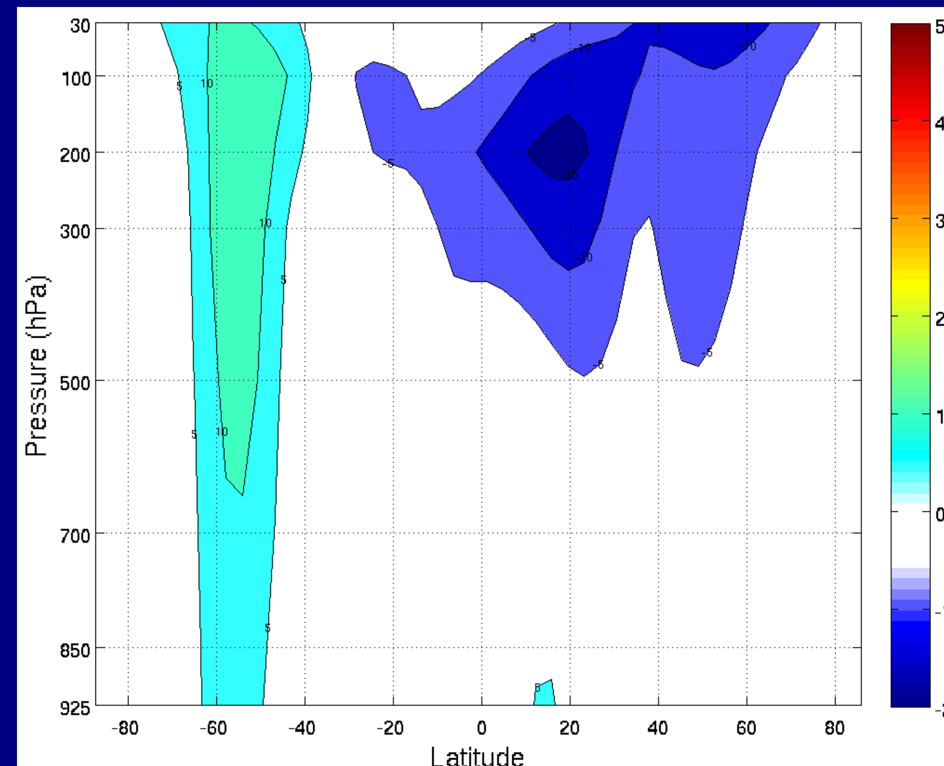
Zonal wind with height
Annual means

Control



Contour interval: 5 m/s

Departures from control, A=35



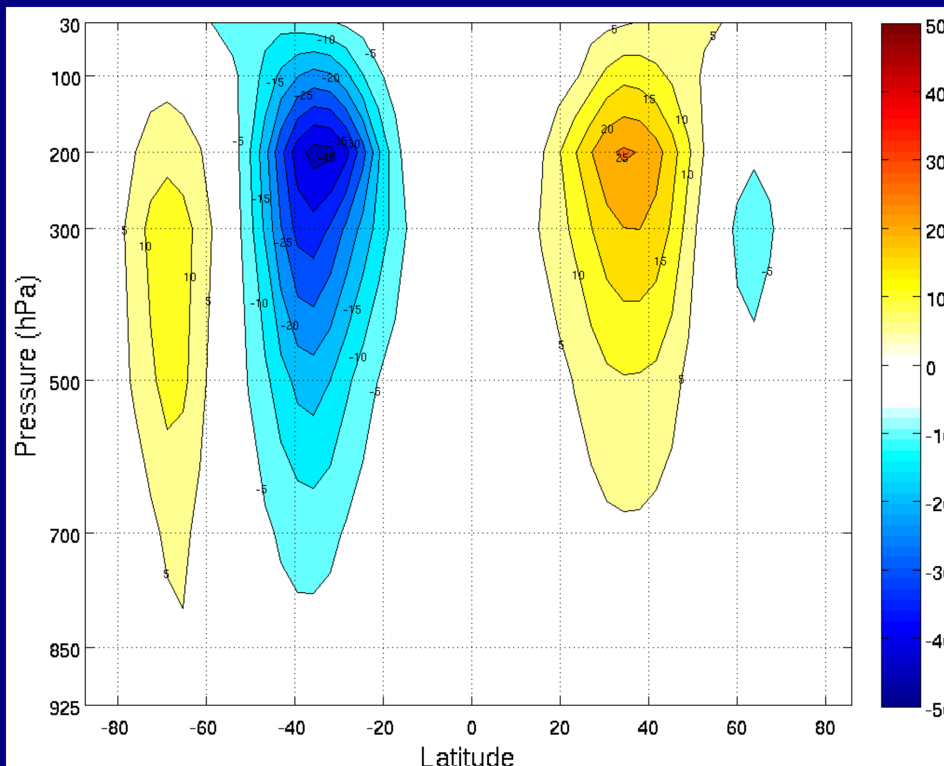
Contour interval: 5 m/s

Barotropic structure in SH (around 50°S)

NH response only evident in height.

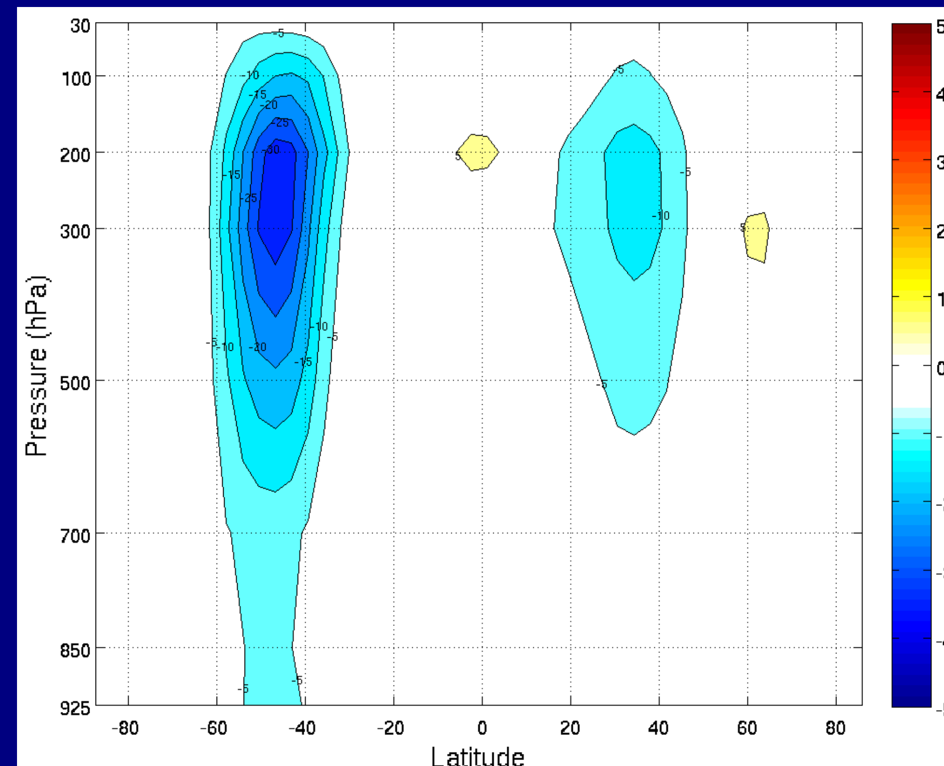
Meridional momentum transport
Annual means

Control



Contour interval: 5 m^2/s^2

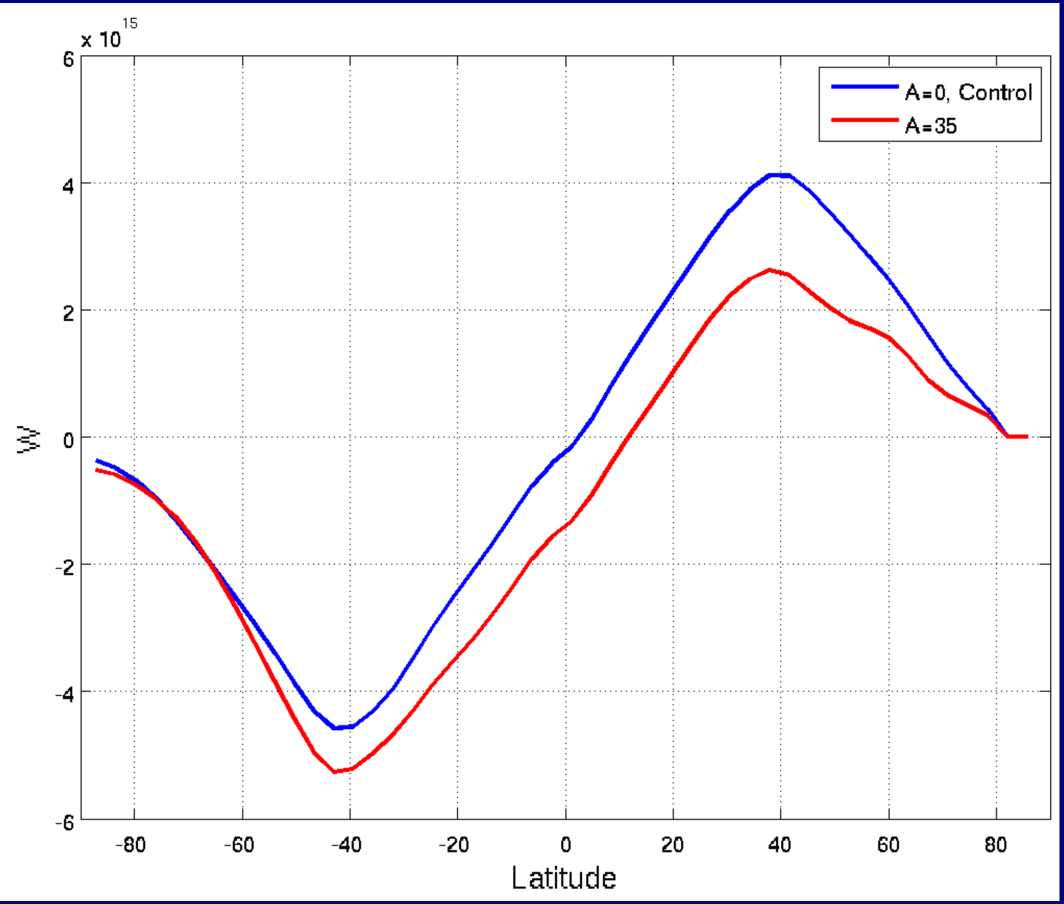
Departures from control, A=35



Contour interval: 5 m^2/s^2

Increased transport → strengthening of the jet

Northward atmospheric transport
Annual means

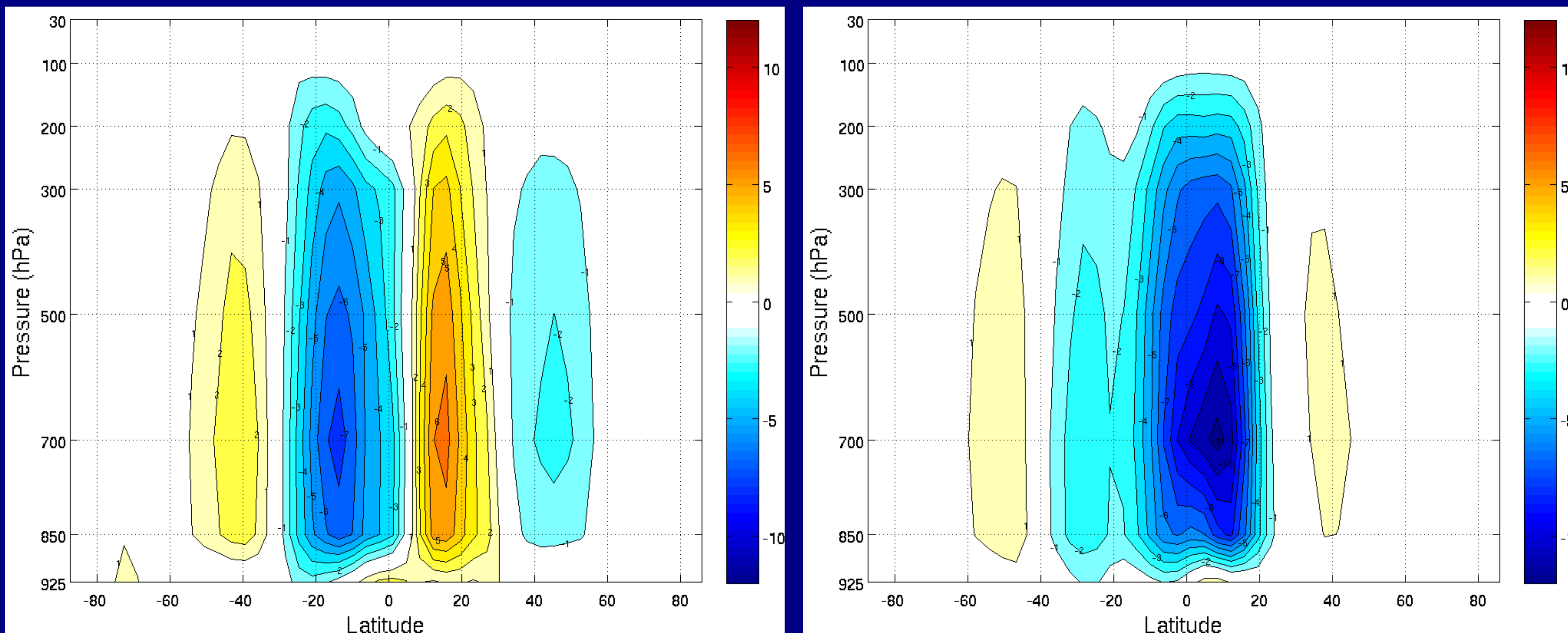


Transport from the tropics to the North Pole weakens.
Transport from the tropics to the South Pole intensifies.

Stream function ($/10^{10}$)
Annual means

Control

Departures from control, A=35



Contour interval: 1 Kg/s

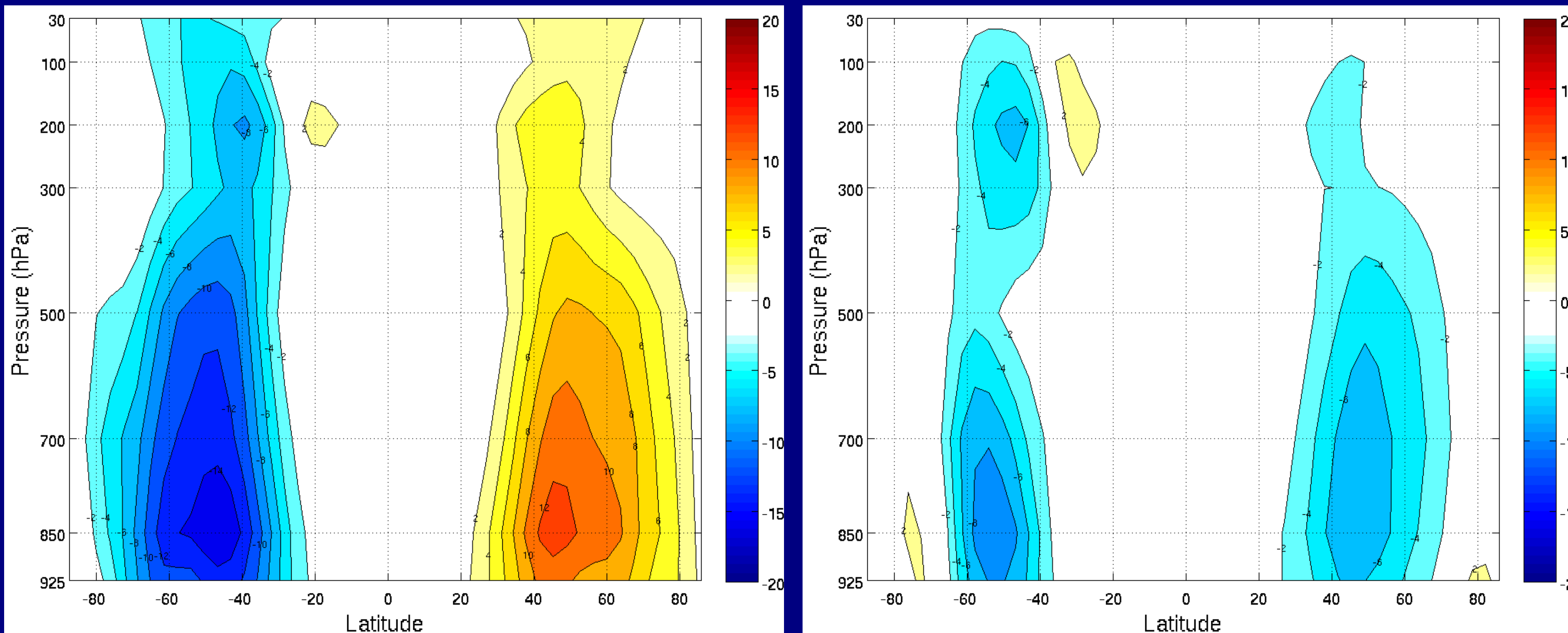
Contour interval: 1 Kg/s

ITCZ shift to the north.
Southern Cell is intensified.

Meridional heat transport
Annual means

Control

Departures from control, A=35



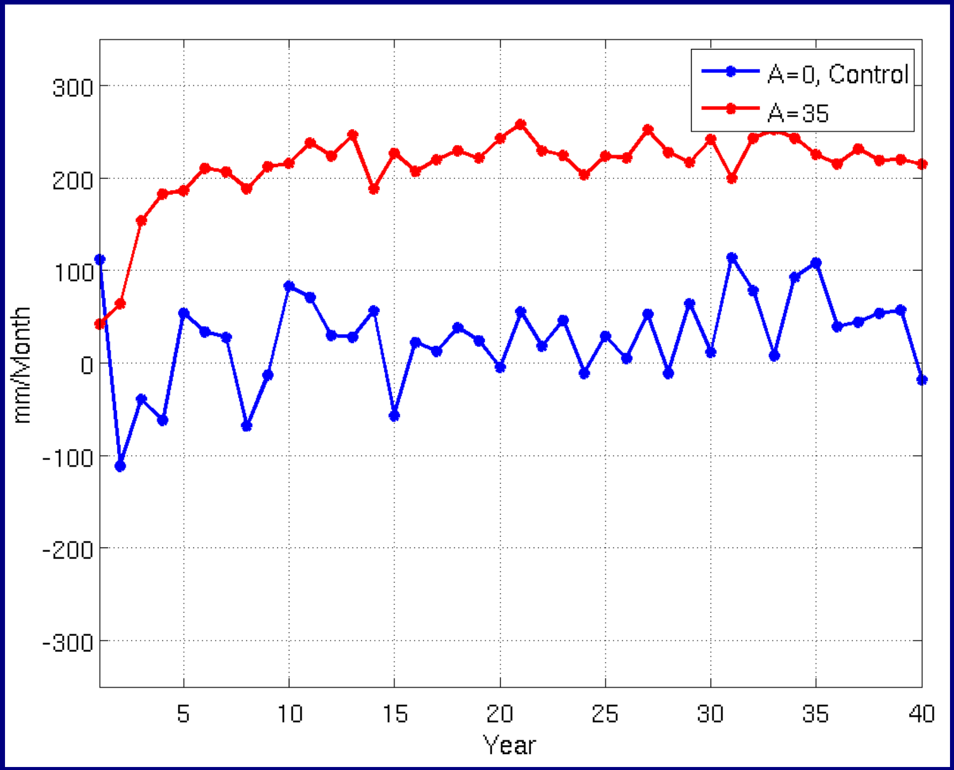
Contour interval: 2 mK/s

Contour interval: 2 mK/s

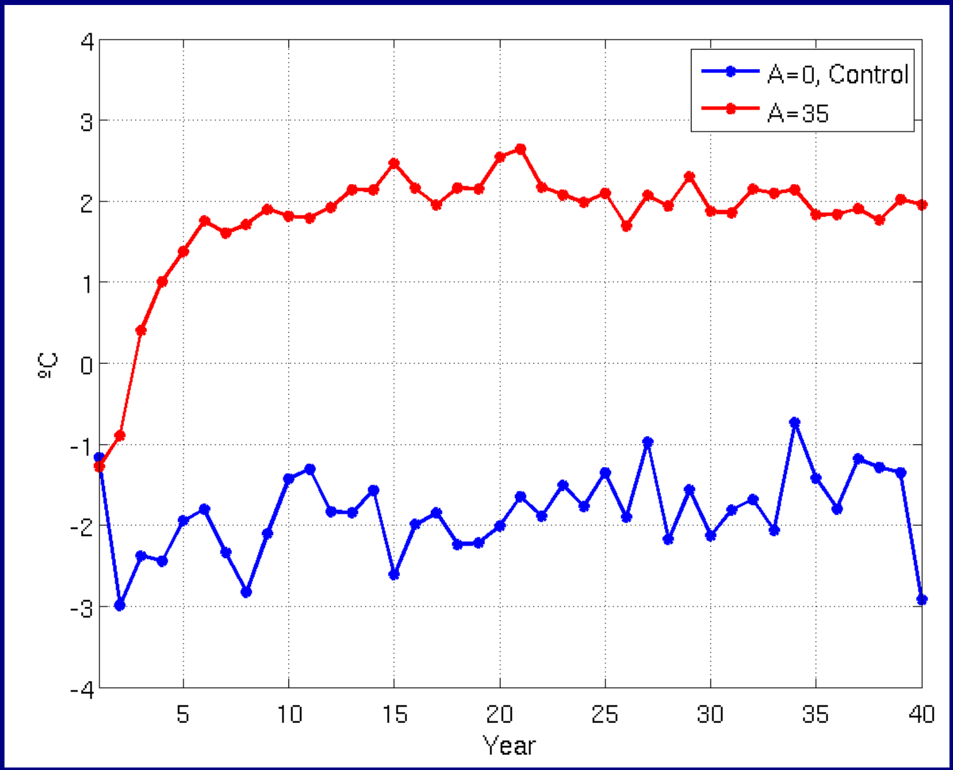
Increase in the southern trasnport in SH.
Decrease in northern transport in NH.

Transient adjustment
Annual means

Precipitation index:
Precipitation in North Tropical Pacific Ocean - South Tropical Pacific Ocean



SST index:
SST in North Tropical Pacific Ocean - South Tropical Pacific Ocean



Time-scale of 7-10 years to reach equilibrium.
Reflected in both precipitation and SST.

Are ITCZ shifts possible without changes in tropical SST?

It has been argued that the role of tropical SST changes was secondary in controlling the ITCZ shifts.

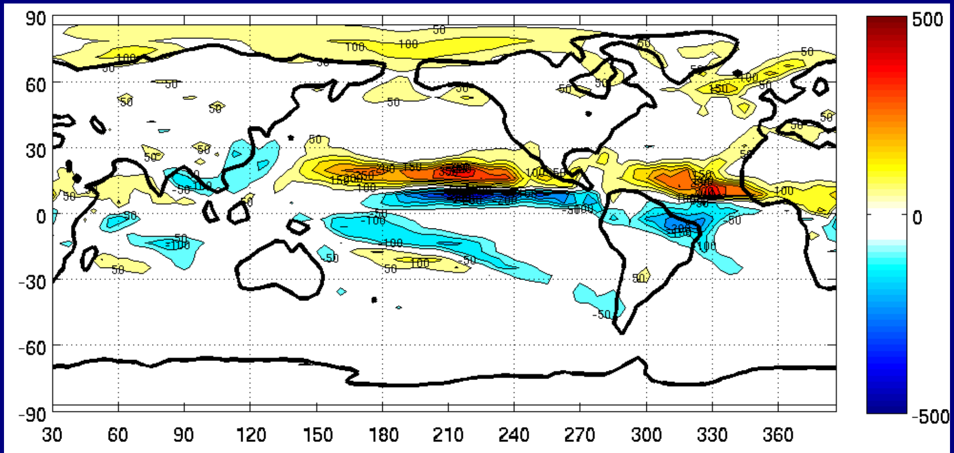
We repeat the experiments keeping the tropical (30ºS-30ºN) SST fixed.

Results

Experiments with tropical SST fixed

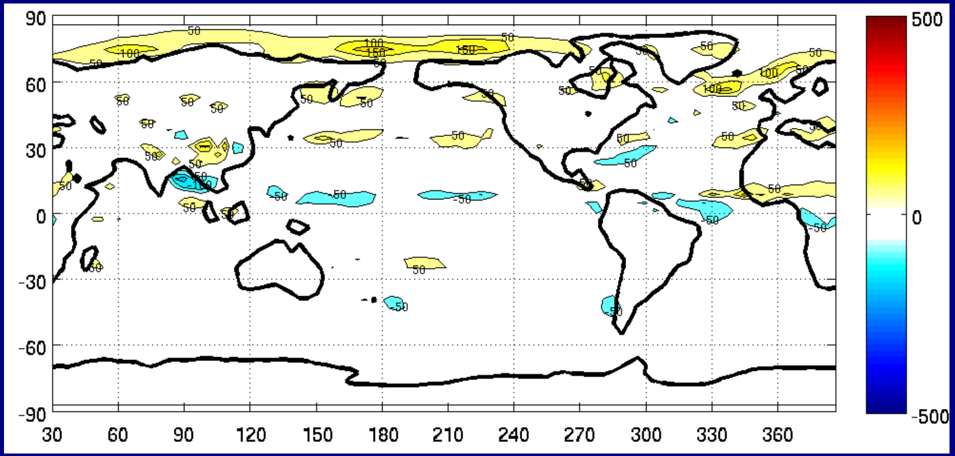
Precipitation
Annual means

Global slab ocean
Departures from control for A=35



Contour interval: 50 mm/month.

Tropical SST fixed
Departures from control for A=35



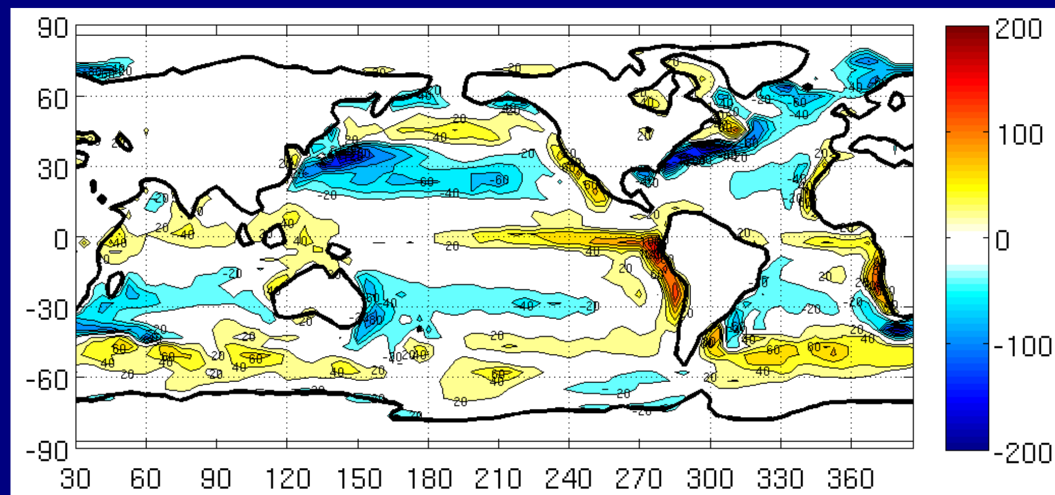
Contour interval: 50 mm/month.

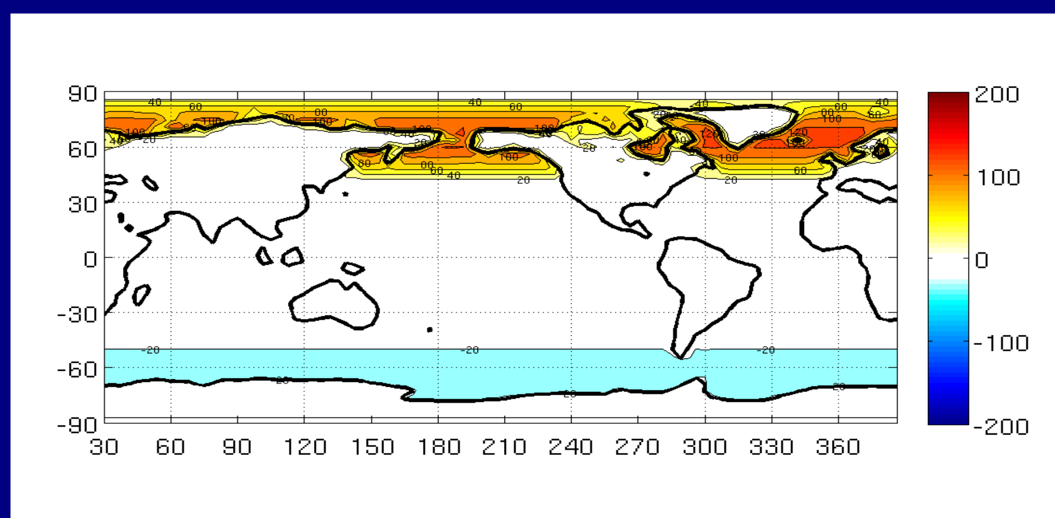
Very weak respose in the tropics.

Summary

- The ITCZ is shifted toward the warmer Hemisphere.
- The stronger the forcing, the larger the shift.
- Time-scale of 7-10 years to reach equilibrium.
- If tropical SST is kept fixed the ITCZ response is very weak.
- Next step:
  Perform the same simulations but coupling the AGCM to a intermediate-complexity model of the tropical oceans.

Thank you.


90
60
30
0
-30
-60
-90
30 60 90 120 150 180 210 240 270 300 330 360
200
100
0
-100
-200


90
60
30
0
-30
-60
-90
30 60 90 120 150 180 210 240 270 300 330 360
200
100
0
-100
-200