The Response of the Tropical Precipitation to the Extratropical Thermal Forcing

Sarah Kang
Princeton University
Advisor: Isaac Held

Introduction

- Tropical precipitation is assumed to be controlled by tropical mechanisms.
- Extratropical forcing is not considered as a source of tropical climate variability.
- However, recent modeling studies show extratropical influence of the tropical precipitation.
  - High latitude ice cover (Chiang and Bitz, 2005)
  - Atlantic thermohaline circulation (Zhang and Delworth, 2005)

Roadmap

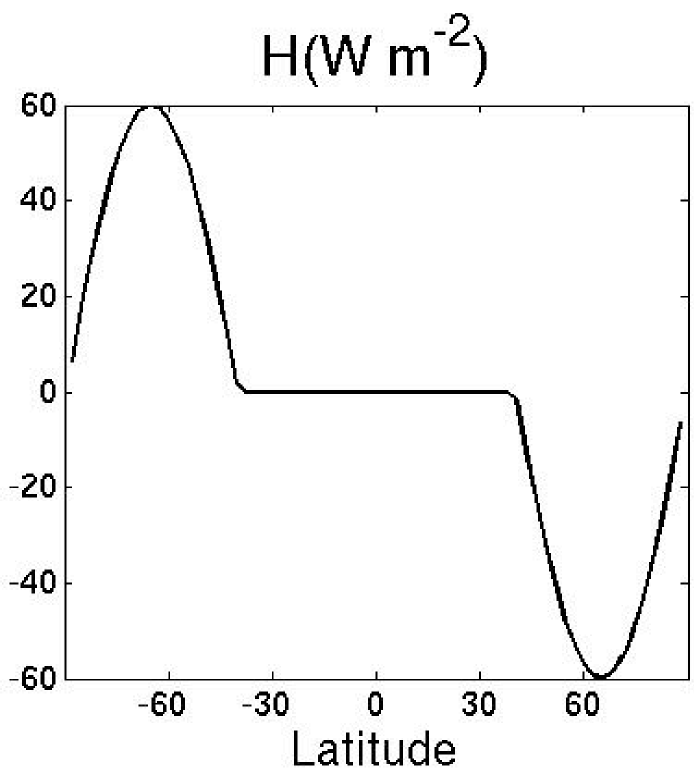
- Model description
  - The simplified moist GCM
- Experiment design
- Results
  - Sensitivity to the convection scheme parameter
  - The response of atmospheric energy transports
- Summary

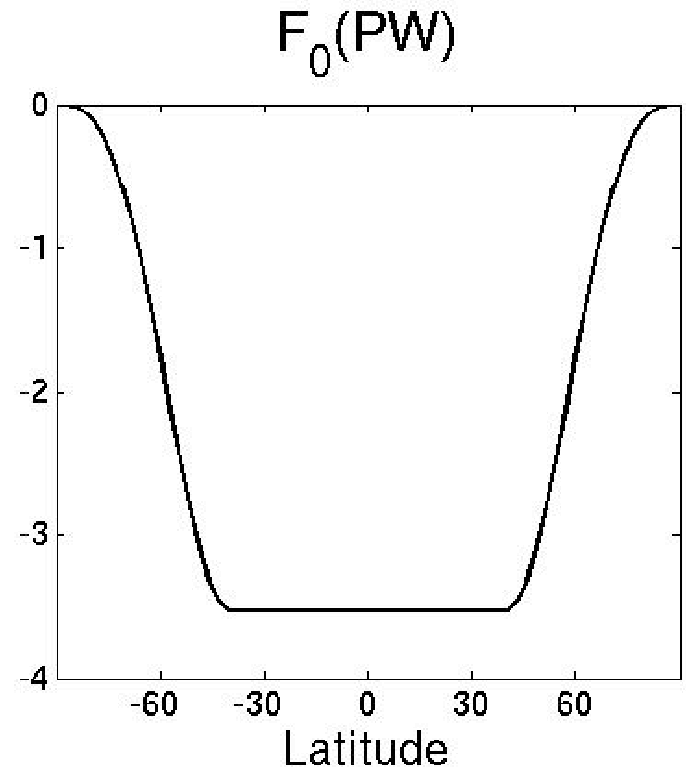
Model Description

Simplified Moist GCM by Frierson et al.

- Primitive equations: T42 resolution, 25 levels
- Aquaplanet slab mixed layer ocean
- Gray radiative transfer
  - No water vapor feedback
  - No clouds
- Simplified Betts-Miller convection scheme
  - T_{ref}: moist adiabat from a surface parcel
  - q_{ref}: specify a fixed RH_{SBM} relative to the T_{ref}
  - Larger RH_{SBM} increases the inhibition of moist convection.

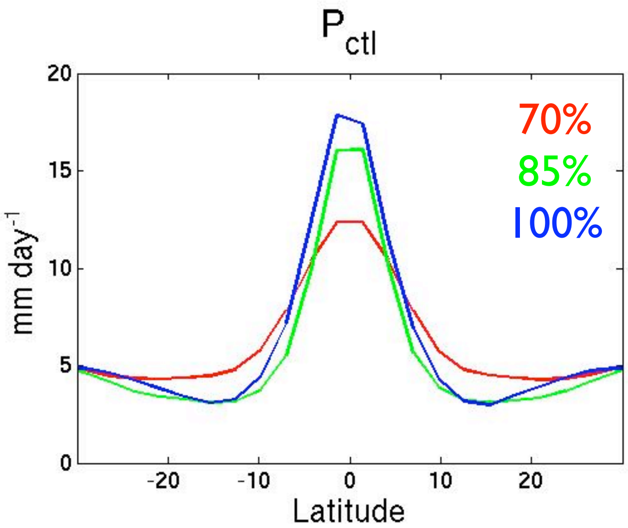
Experiment Design



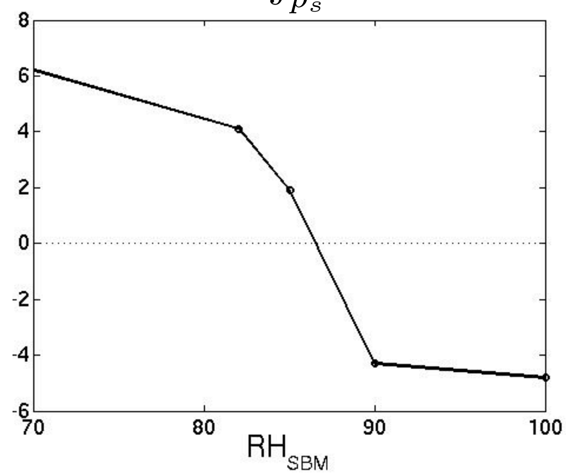


$$H = -\nabla \cdot F_0$$

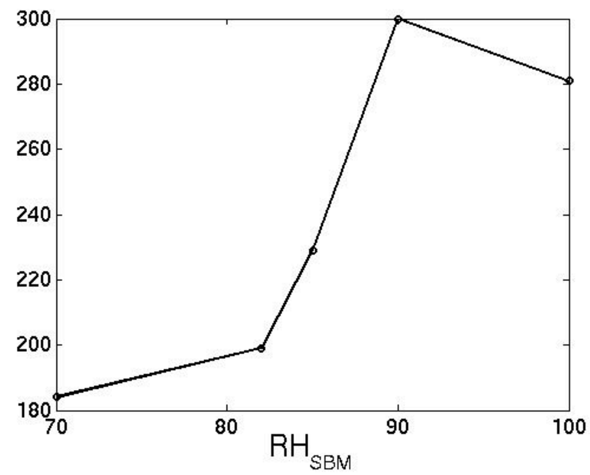
Sensitivity to RH_{SBM}



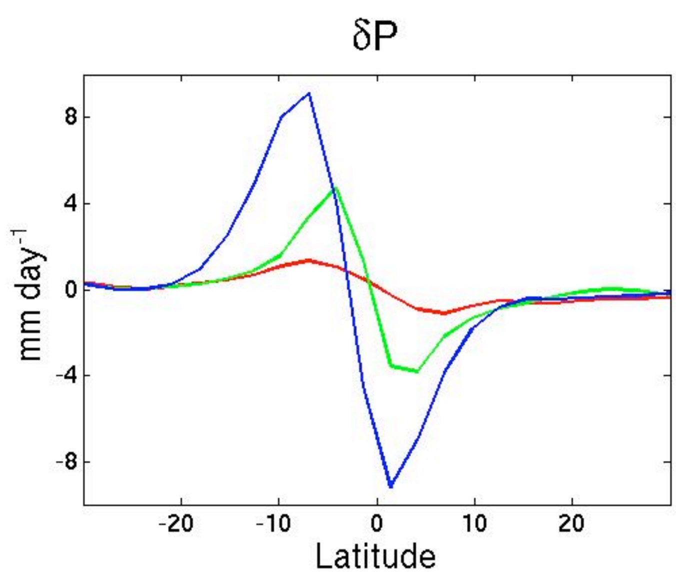
$$GMS \equiv \frac{\int_{p_s}^{0} \overline{v}\,\overline{m}\,dp}{\int_{p_s}^{p_m} \overline{v}\,dp}$$

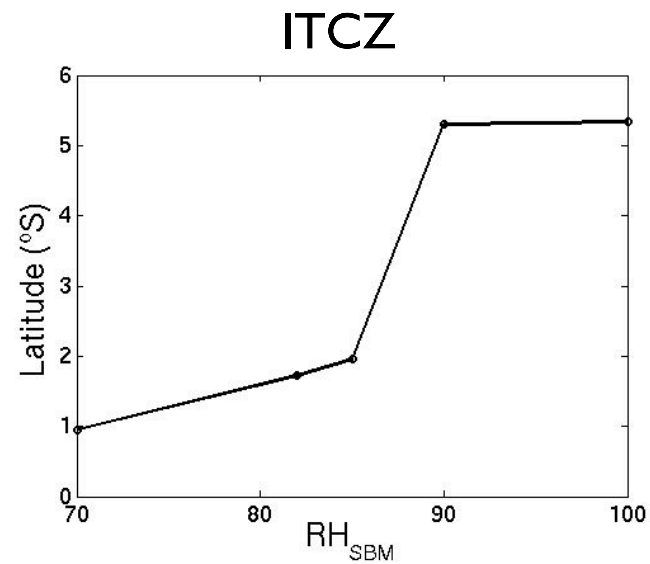


$$\psi(10^9\ kg\ s^{-1})$$



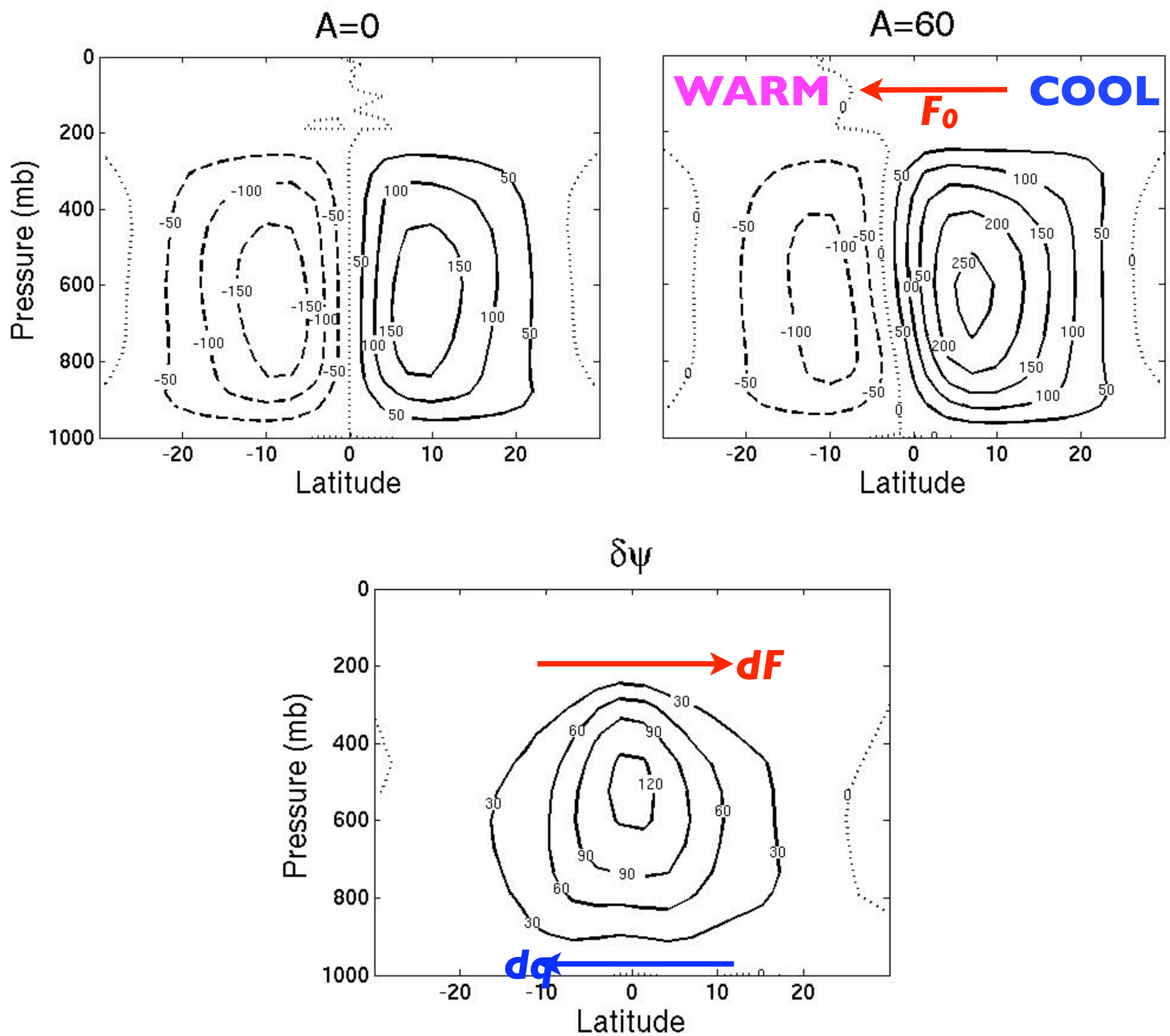
Precipitation Response





- Larger tropical precipitation with RH_{SBM}.

Hadley Circulation



Energy Balance

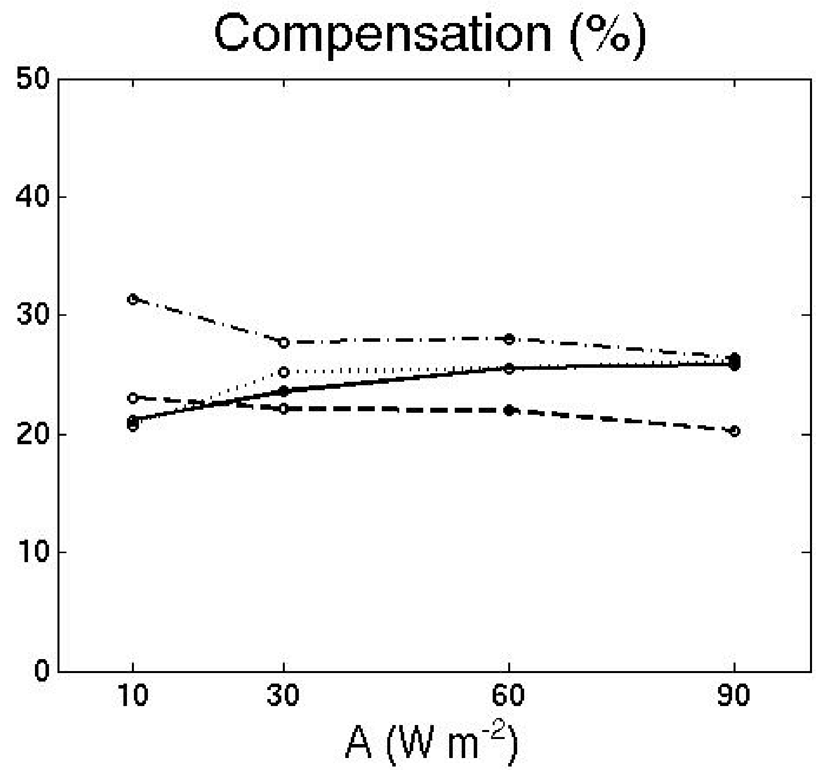
$$SW - OLR_{ctl} = \nabla \cdot \overline{vm}_{ctl}$$
$$SW - OLR = \nabla \cdot \overline{vm} + \nabla \cdot F_0$$

$$[OLR - OLR_{ctl}] + [\nabla \cdot \overline{vm} - \nabla \cdot \overline{vm}_{ctl}] = -\nabla \cdot F_0$$

- Define the degree of compensation *C*,

$$C \equiv \left|\frac{\delta \overline{vm}}{F_0}\right| \times 100$$

Compensation



- This idealized model produces a low level of compensation of about 25% regardless of the convection scheme parameter RH_{SBM}.

Simple Theory

- From the compensation, predict the mass transport.

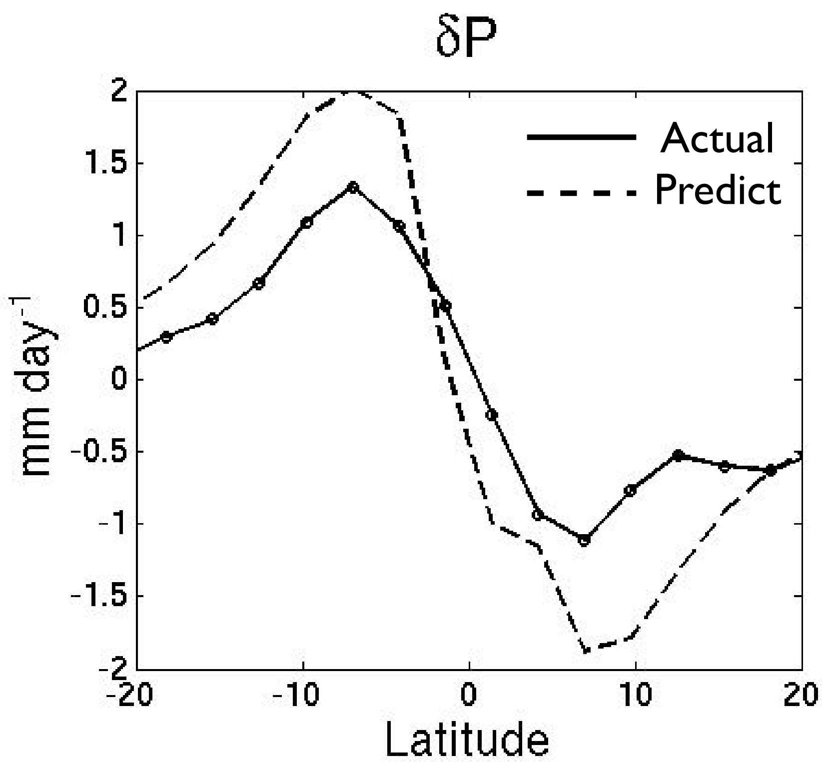
$$\Delta m = \frac{\overline{vm}}{v_2} \quad \Longrightarrow \quad \delta v_2 \simeq \frac{\delta\overline{vm}}{\Delta m_{ctl}} \simeq \frac{C \cdot F_0}{\Delta m_{ctl}}$$

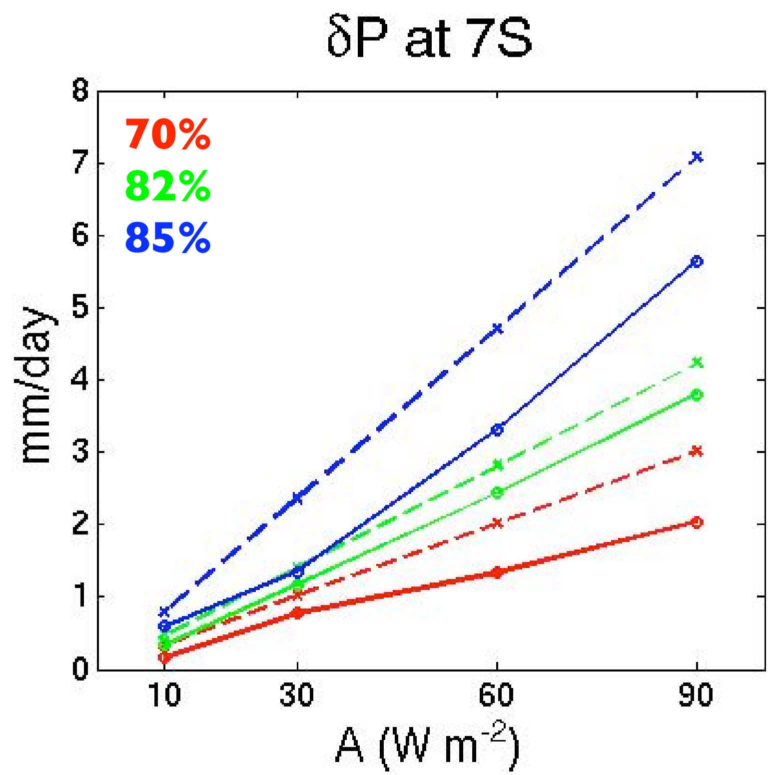
- Define $\Delta q = -\frac{\overline{vq}}{v_2}$ to approximate the precipitation.

$$\begin{aligned} \delta P &\simeq -\delta \nabla \cdot \overline{vq} \\ &\simeq \nabla \cdot (\Delta q_{ctl}\, \delta v_2) \\ &\simeq \nabla \cdot \left(C F_0 \cdot \frac{\Delta q_{ctl}}{\Delta m_{ctl}} \right) \end{aligned}$$

- Larger RH_{SBM} $\rightarrow$ Smaller GMS $\rightarrow$ Stronger Hadley cells $\rightarrow$ Greater precipitation response

Prediction


δP
Actual
Predict
mm day^{-1}
Latitude
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-20
-10
0
10
20


δP at 7S
70%
82%
85%
mm/day
A (W m^{-2})
8
7
6
5
4
3
2
1
0
10
30
60
90

Summary

- The extratropical thermal forcing can influence the tropical precipitation.
- The magnitude of the tropical precipitation response is closely related to the degree of compensation between the imposed oceanic flux and the resulting response in the atmospheric energy transport in the tropics.
- The sensitivity to the convection scheme in the idealized model results from different values of gross moist stability.