Responses of Atmospheric General Circulation to Groundwater Dynamics

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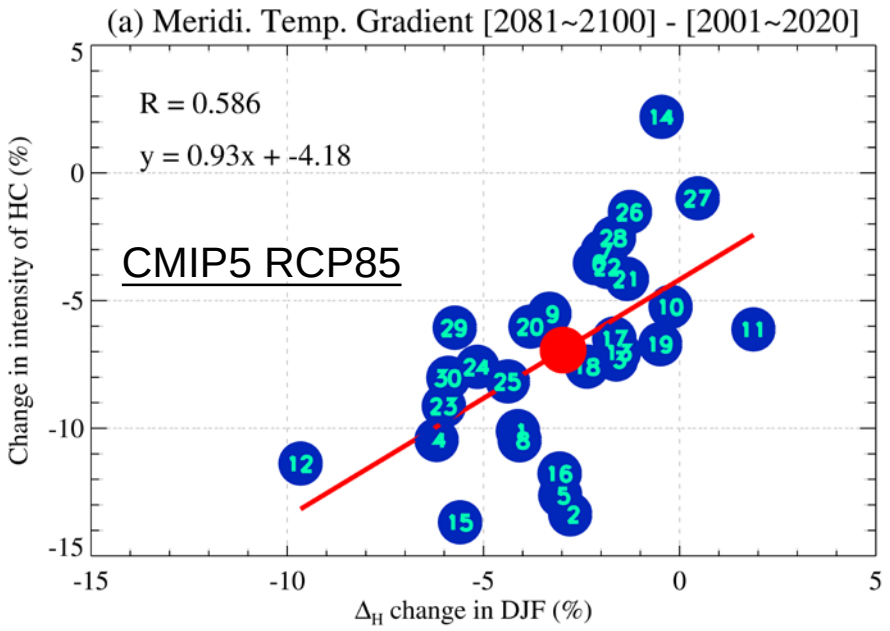
I-GEM 1st Workshop Oct 3th-5th, 2016

Introduction

- **The strength of the Hadley Circulation**
  - The meridional potential temperature gradient
  - Gross static stability
  - Tropopause height



[Seo et al., 2014]

- **HC widening from 1997 to 2012 is associated with increased mid-latitude temperatures and hence reduced temperature gradients.**

[Adam et al., 2014]

- An intermediate-complexity atmospheric model coupled with a simple land-surface model and a mixed layer ocean model is used to investigate the processes involved in an idealized monsoon occurring on a single rectangular continent.

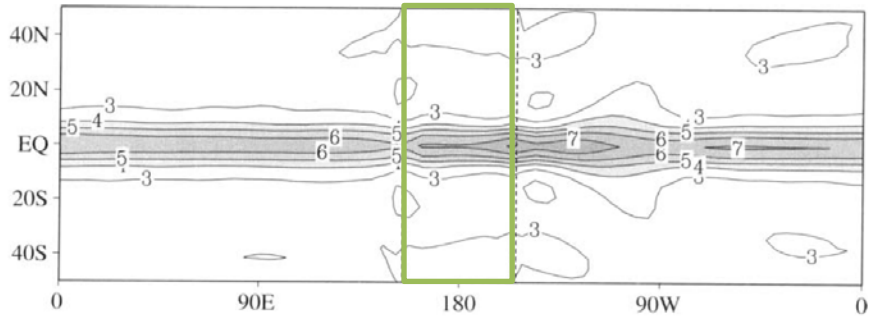


Figure 1. Precipitation (mm day^{-1}) for an experiment with zero Q-flux, equinox conditions, and saturated soil moisture. Only part of the model latitudinal domain (60°S–60°N) is shown. The continent is indicated by dashed lines.

- Soil Moisture is saturated (Wet)

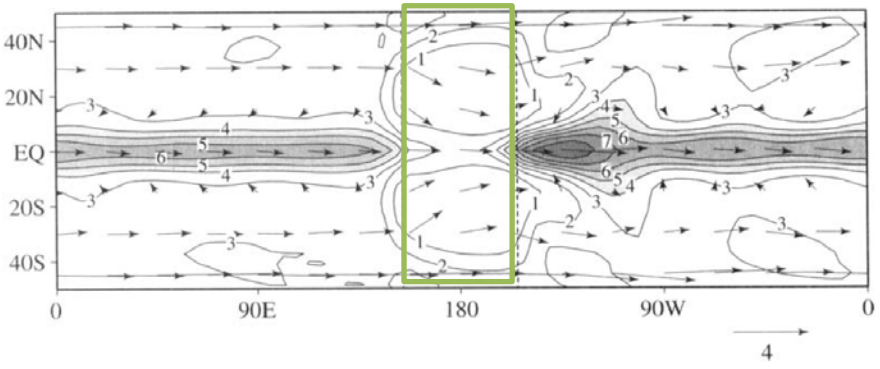


Figure 2. As in Fig. 1, except for interactive soil moisture. The vectors are 850 mb winds (m s^{-1}, shown at 1/4 of the grid points).

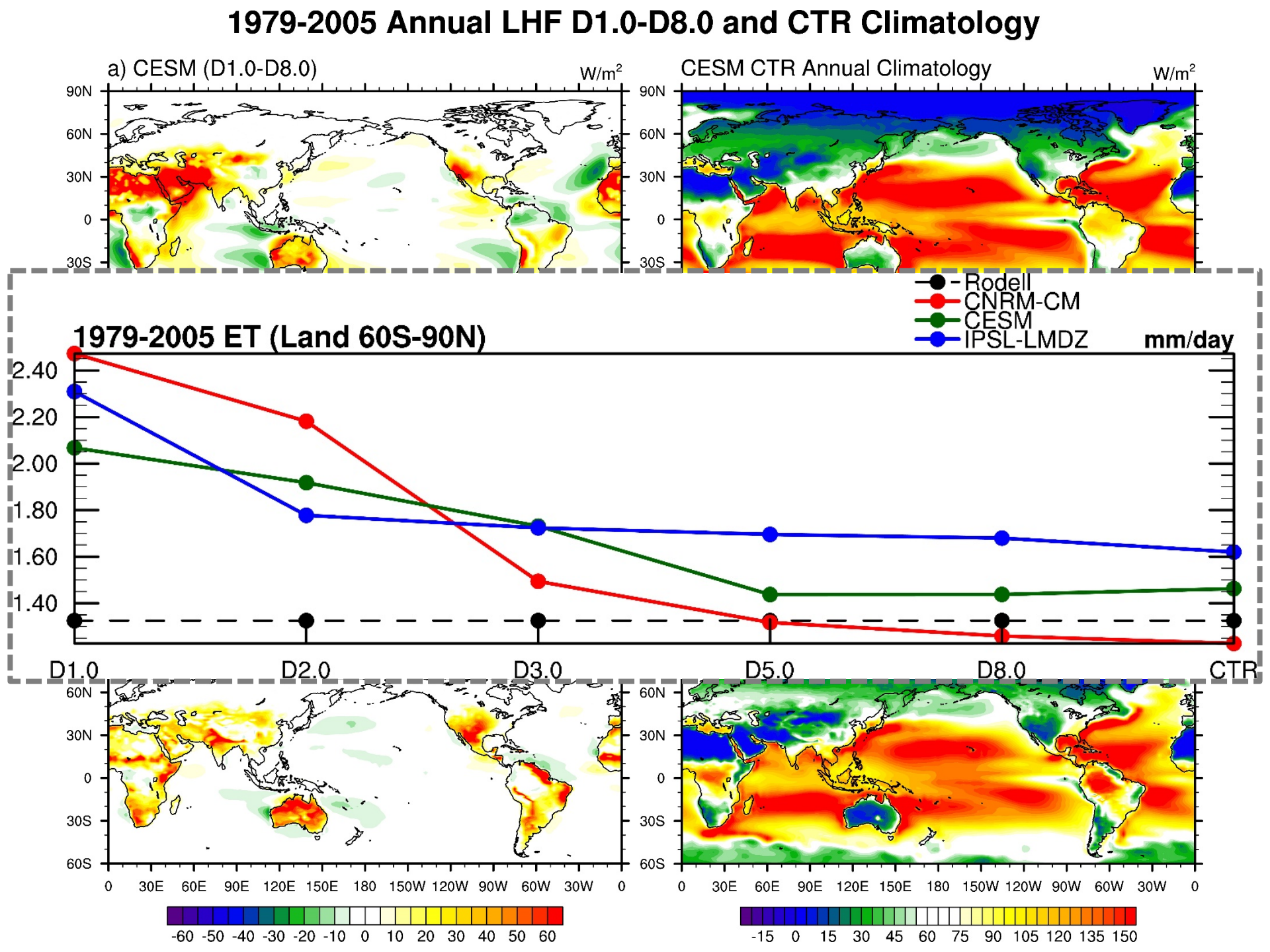
- Soil Moisture is interactive (Dry)

[Chou et al., 2001]

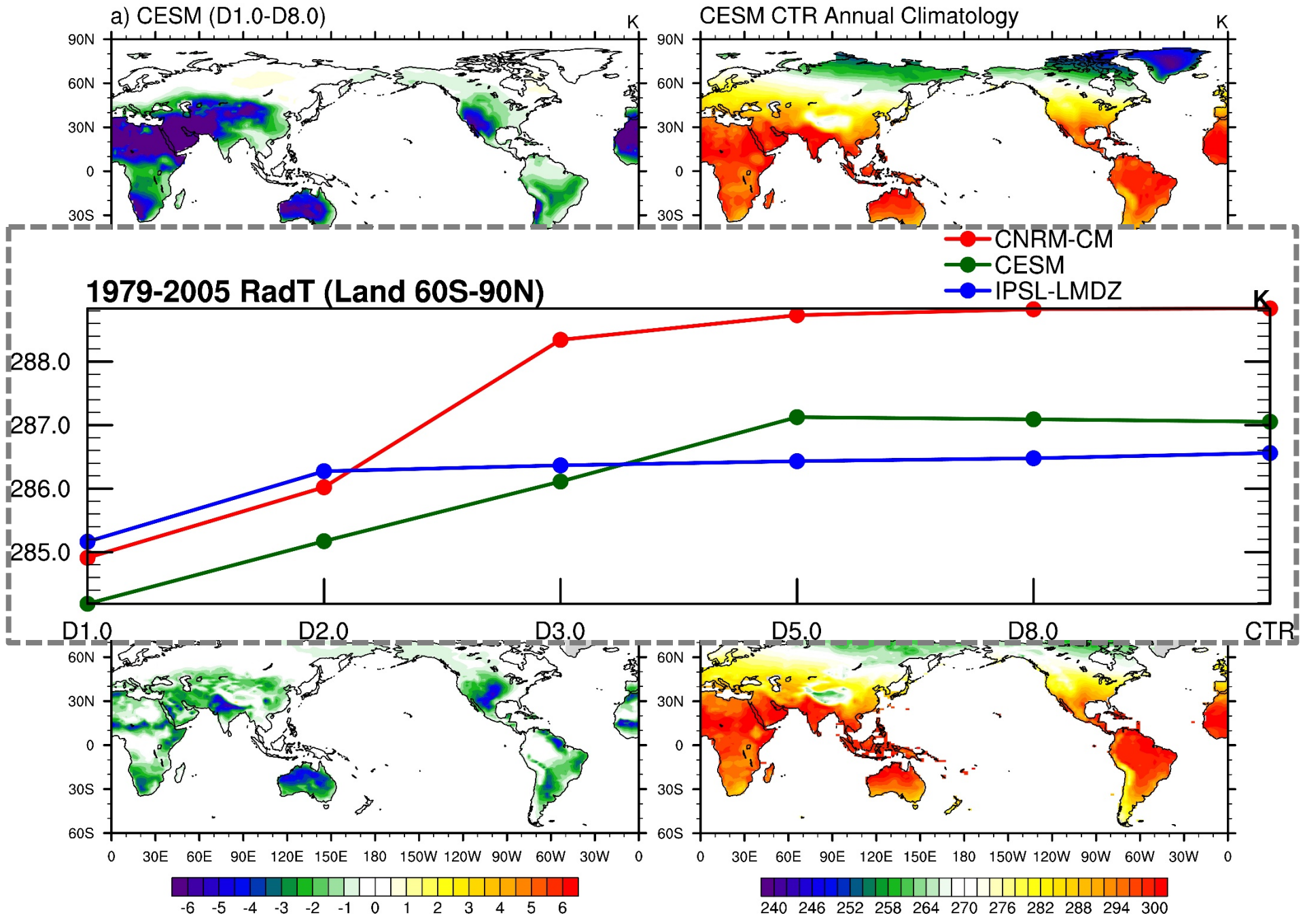
Methodology

- **On-line Simulation**
  - CNRM-CM
  - CESM
  - IPSL-LMDZ
- **From D01 (shallower) to D08 (deeper)**
- **Prescribed SST**

- **Showing differences between D01 (wettest) and D08 (driest)**


1979-2005 Annual LHF D1.0-D8.0 and CTR Climatology
a) CESM (D1.0-D8.0)
W/m2
CESM CTR Annual Climatology
W/m2
90N
60N
30N
0
30S
Rodell
CNRM-CM
CESM
IPSL-LMDZ
1979-2005 ET (Land 60S-90N)
mm/day
2.40
2.20
2.00
1.80
1.60
1.40
D1.0
D2.0
D3.0
D5.0
D8.0
CTR
60N
30N
0
30S
60S
0 30E 60E 90E 120E 150E 180 150W 120W 90W 60W 30W 0
-60 -50 -40 -30 -20 -10 0 10 20 30 40 50 60
-15 0 15 30 45 60 75 90 105 120 135 150

1979-2005 Annual RadT D1.0-D8.0 and CTR Climatology



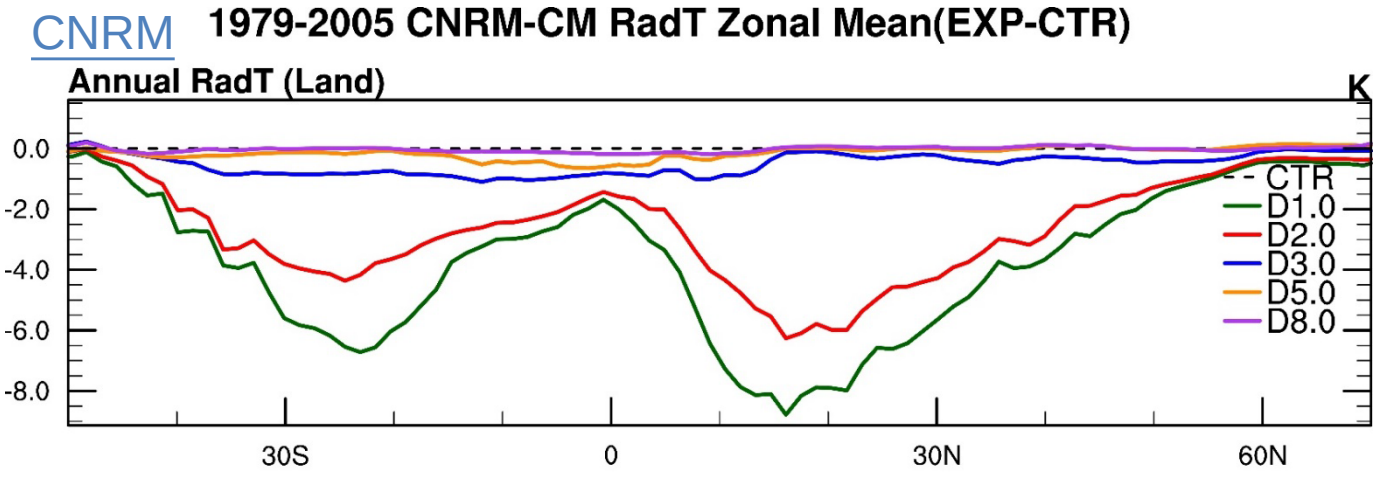
Increased latent heat in mid-latitude

Decreased surface temperature in mid-latitude

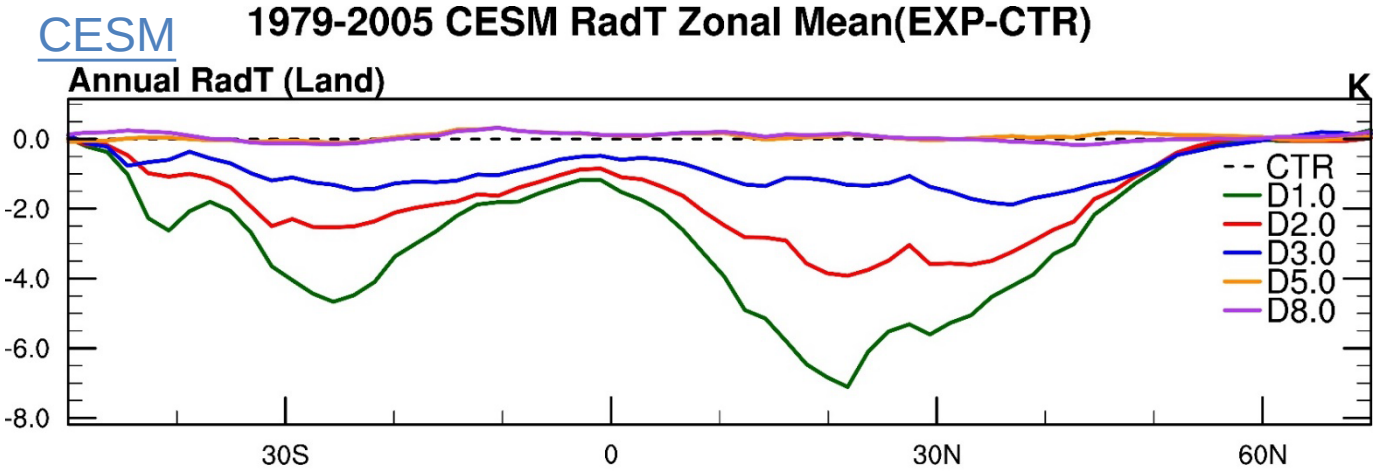
Increased meridional temperature gradient

Stronger global Hadley circulation

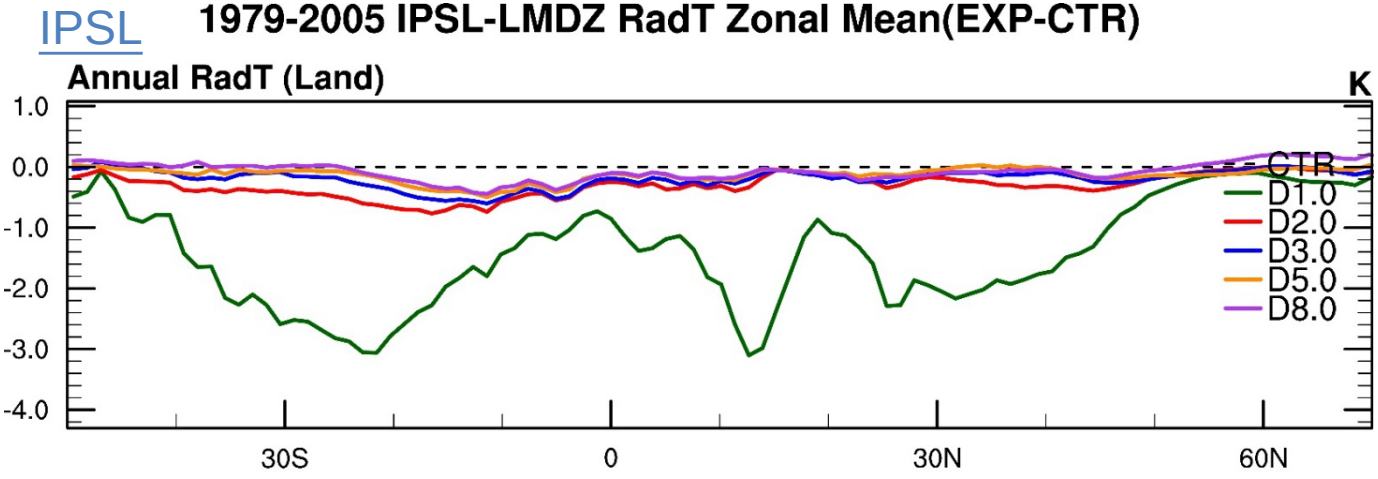
CNRM



CESM

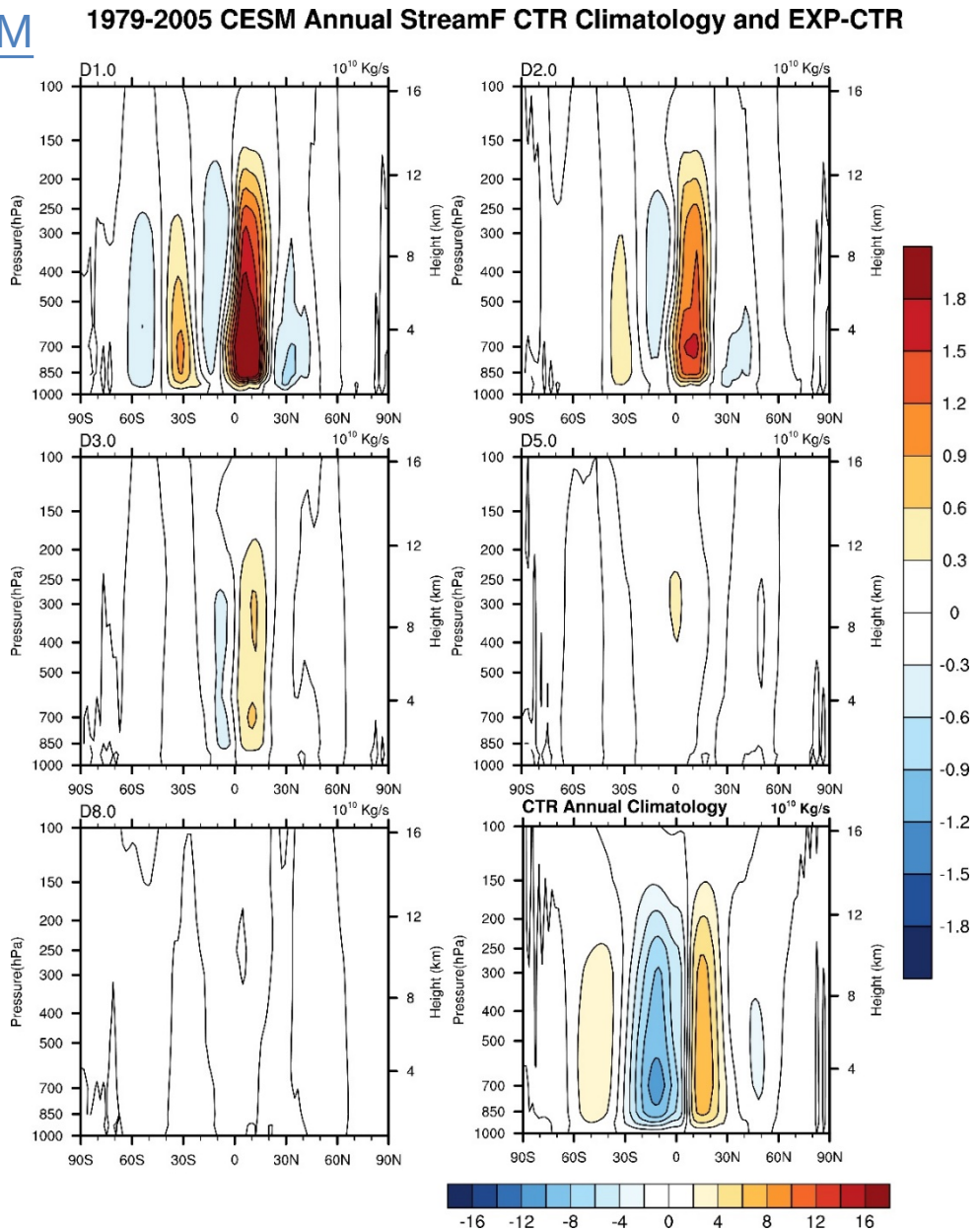


IPSL

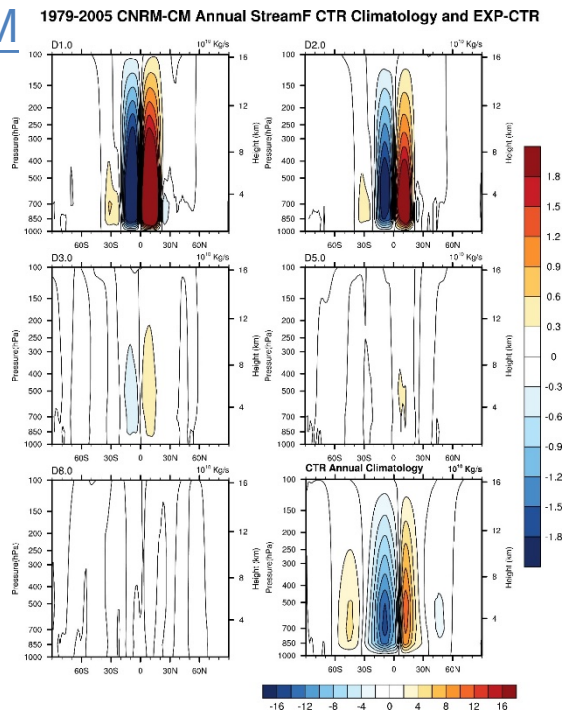


General Circulation Strength

CESM



CNRM



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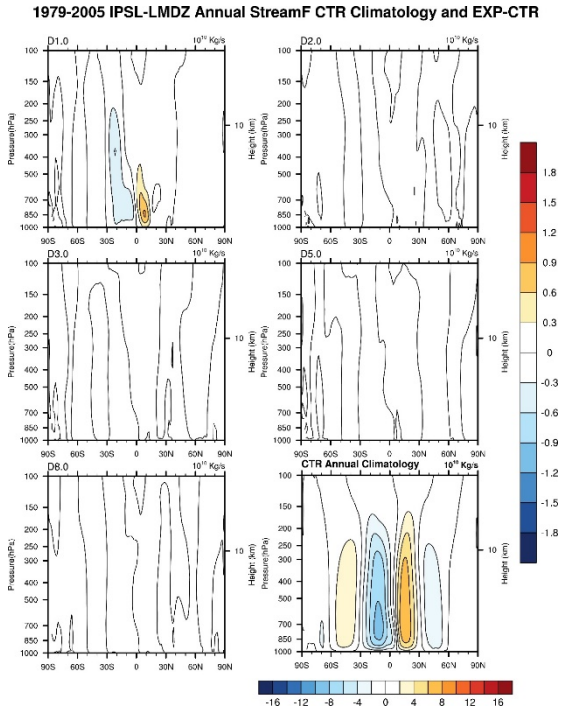
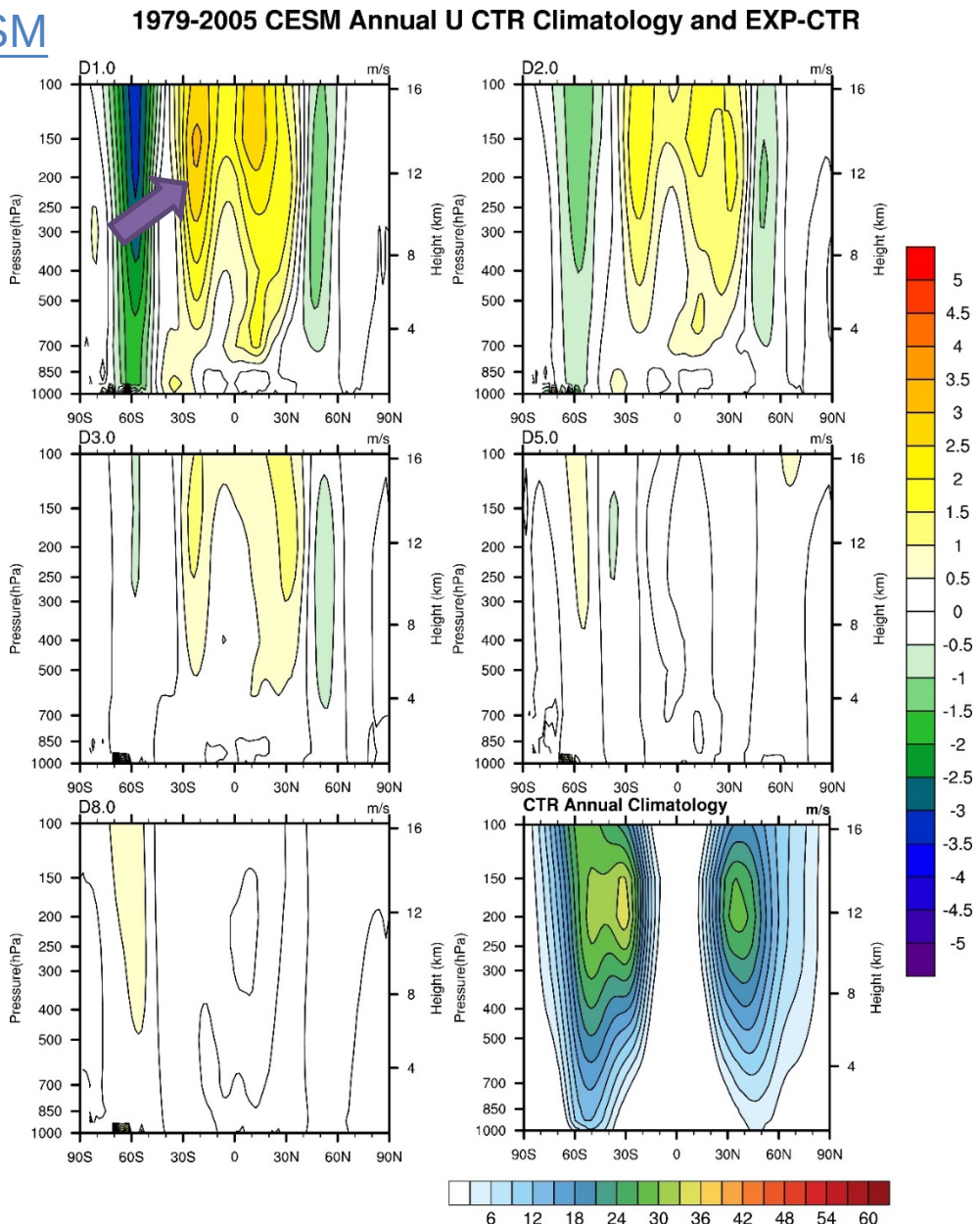
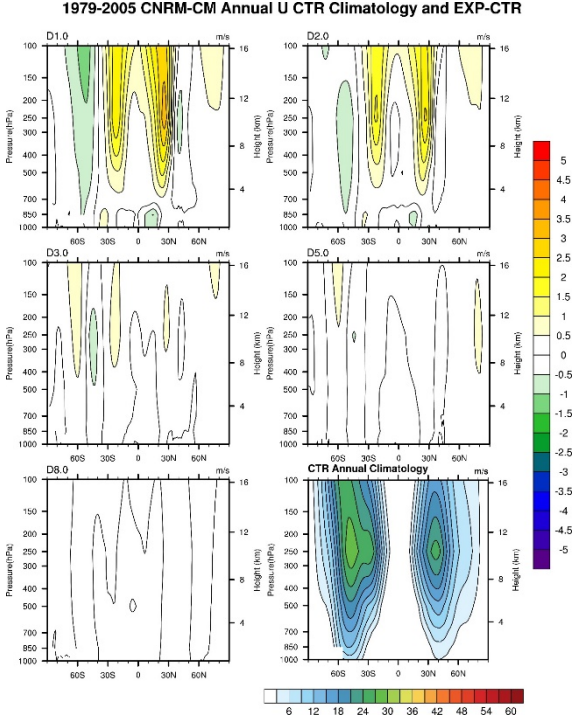


Vertical Zonal Mean of U Wind

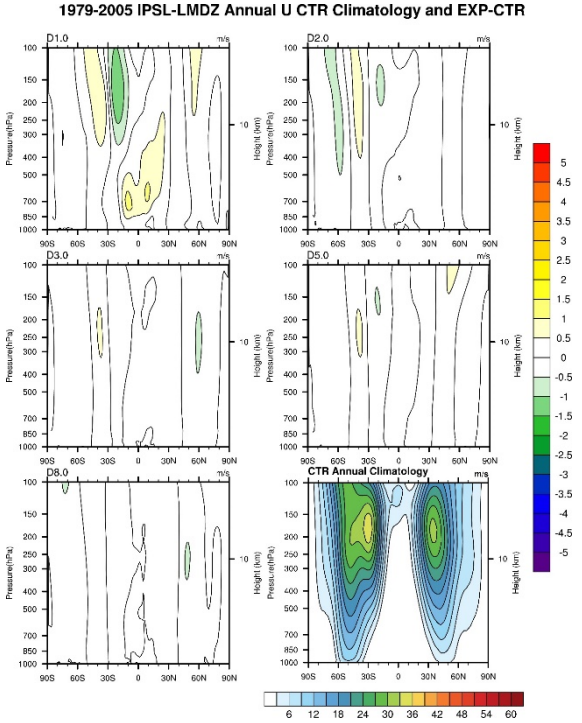
CESM



CNRM



IPSL



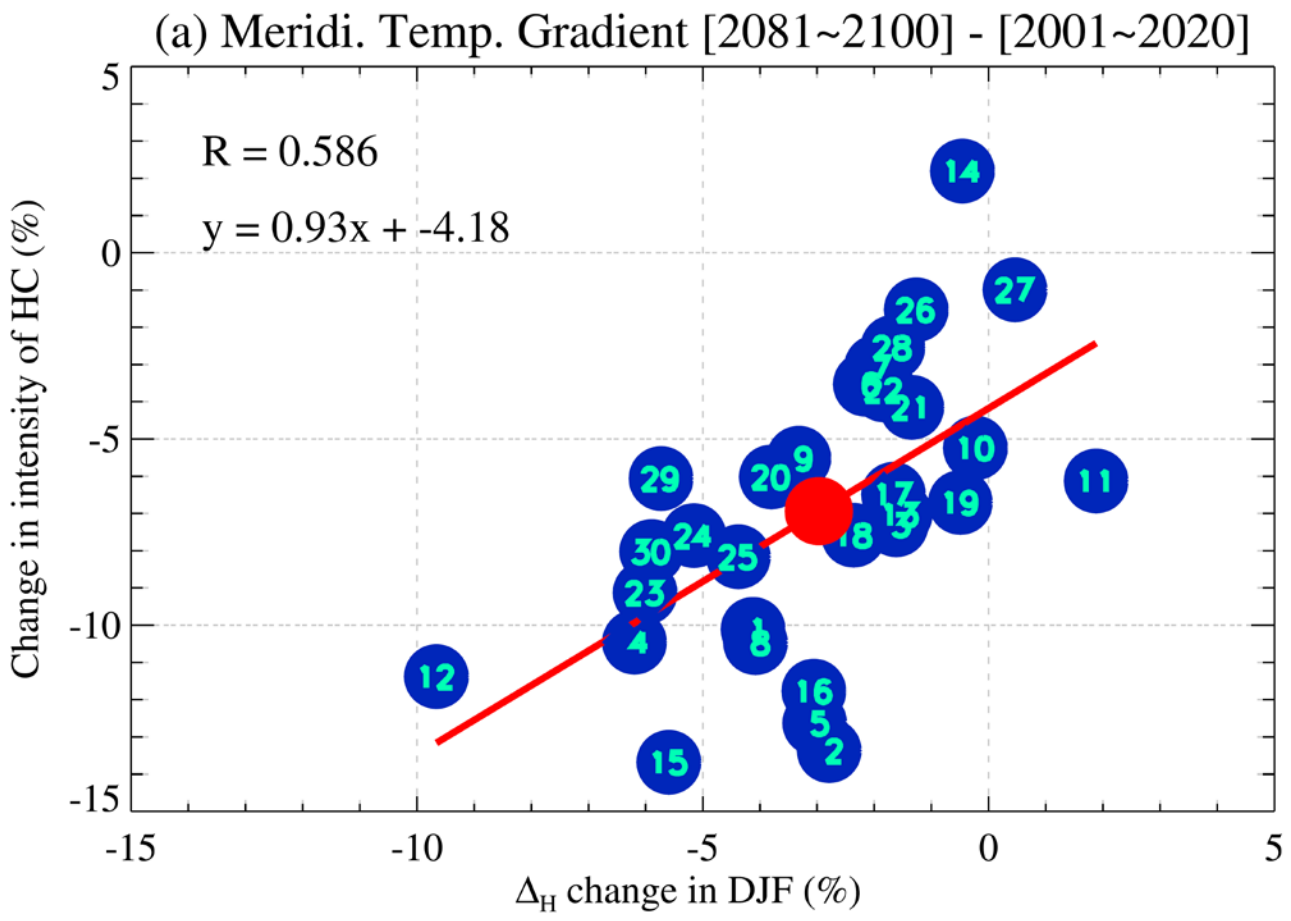
CMIP5 RCP85

Increased latent heat in mid-latitude

Decreased surface temperature in mid-latitude

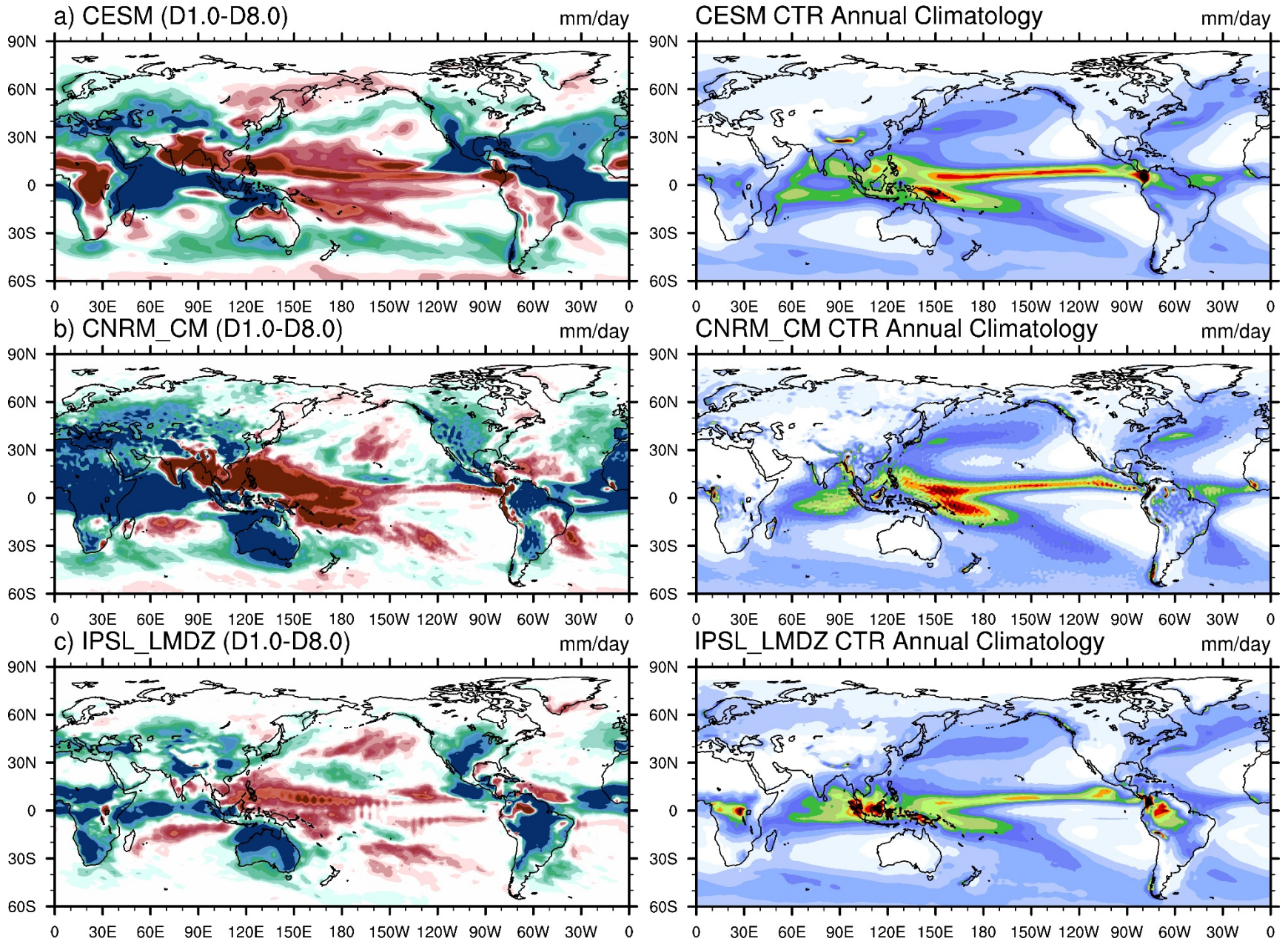
Increased meridional temperature gradient

Stronger global Hadley circulation

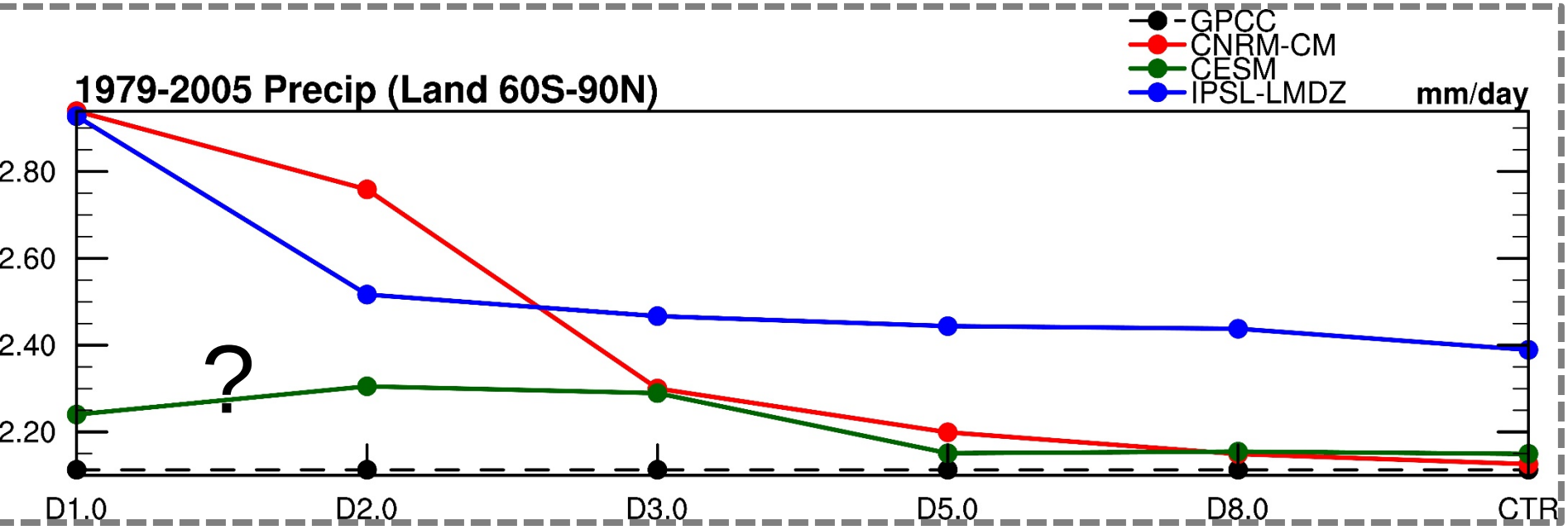


[Seo et al., 2014]

Impacts on the global precipitation?


1979-2005 Annual Precip D1.0-D8.0 and CTR Climatology
a) CESM (D1.0-D8.0)
mm/day
CESM CTR Annual Climatology
mm/day
b) CNRM_CM (D1.0-D8.0)
mm/day
CNRM_CM CTR Annual Climatology
mm/day
c) IPSL_LMDZ (D1.0-D8.0)
mm/day
IPSL_LMDZ CTR Annual Climatology
mm/day
90N
60N
30N
0
30S
60S
0 30E 60E 90E 120E 150E 180 150W 120W 90W 60W 30W 0
-0.8 -0.6 -0.4 -0.2 0 0.2 0.4 0.6 0.8
1 2 3 4 5 6 7 8 9 10 11 12

Precipitation changes over global land



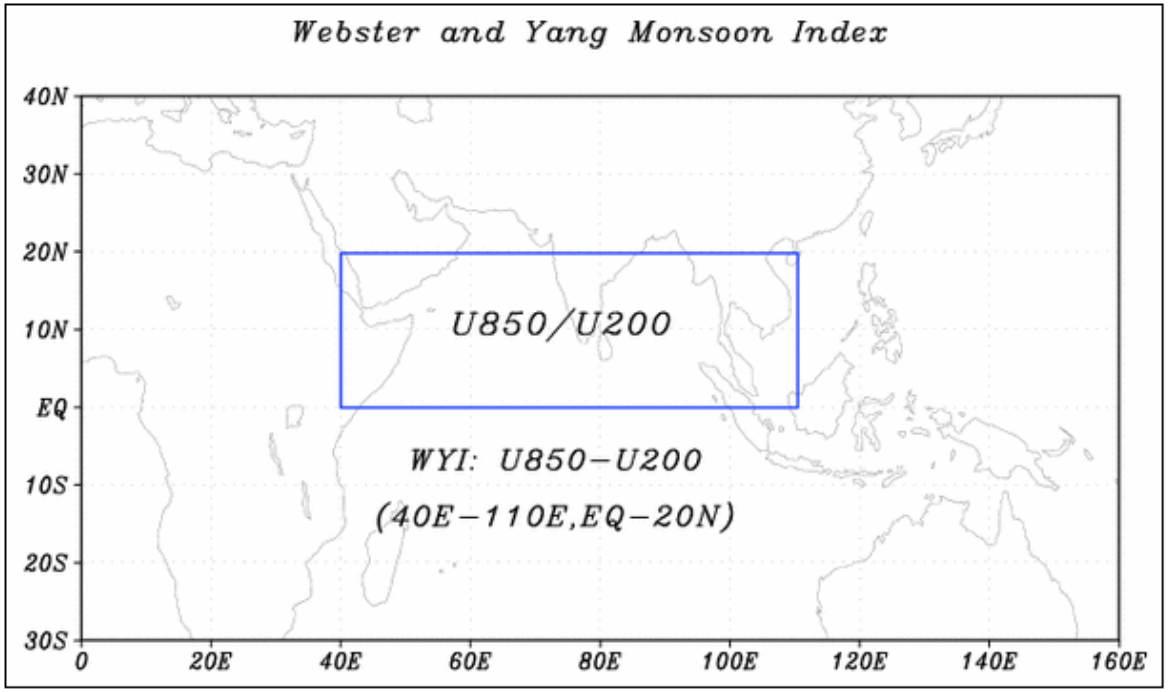
Shallower water table depth → More surface latent heat flux over land → More precipitation over the land when including GW in CLM (Lo and Famiglietti, 2011)

More precipitation move to land from the ocean, consistent results with Chou et al. in 2001

Precipitation changes over the Asia monsoon regions?

➢ Using Webster and Yang Monsoon Index (WYM)

– WYM Index = U850(40-110E,EQ-20N)-U200(40-110E,EQ-20N)

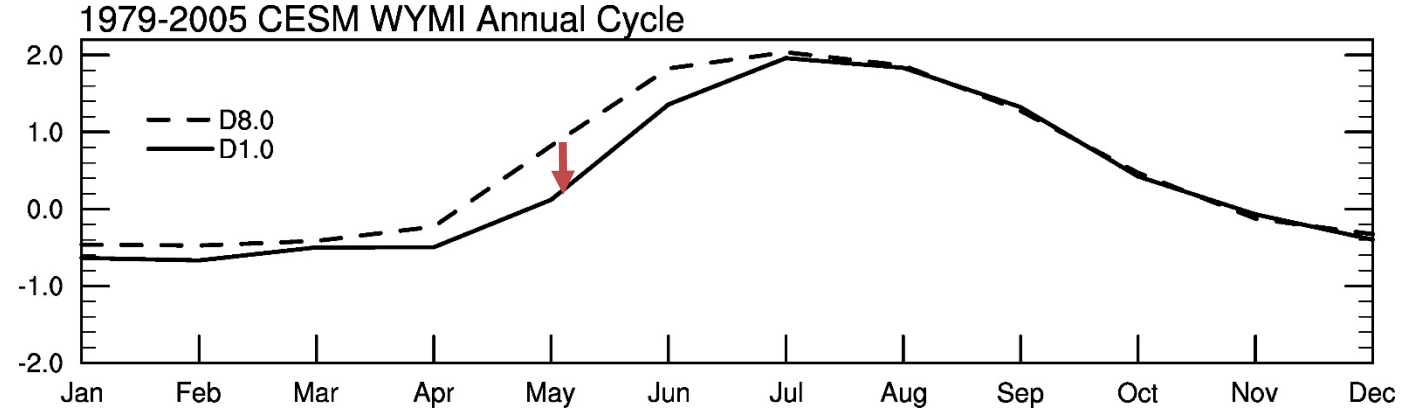


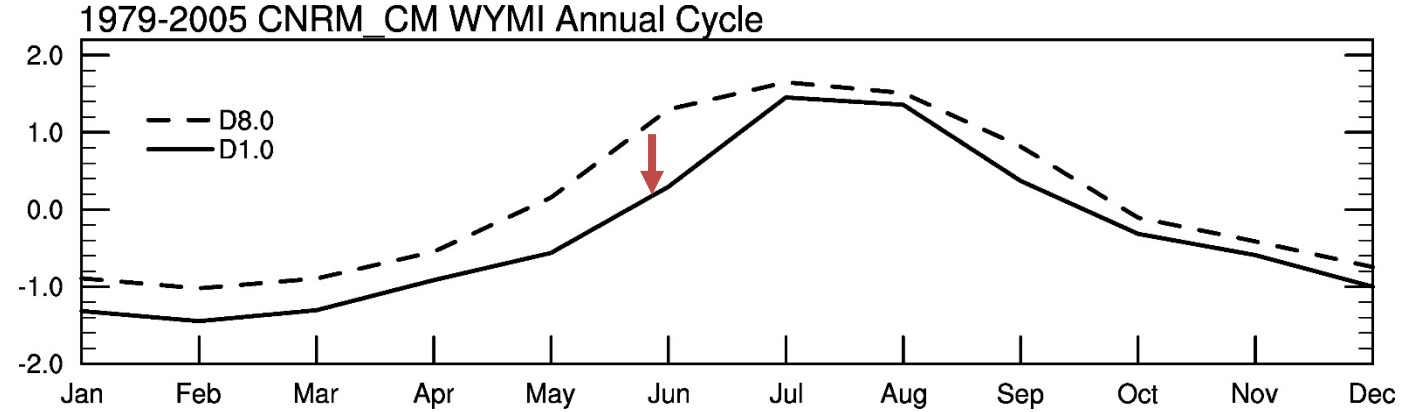
WYM Index = U850(40-110E,EQ-20N)-U200(40-110E,EQ-20N)

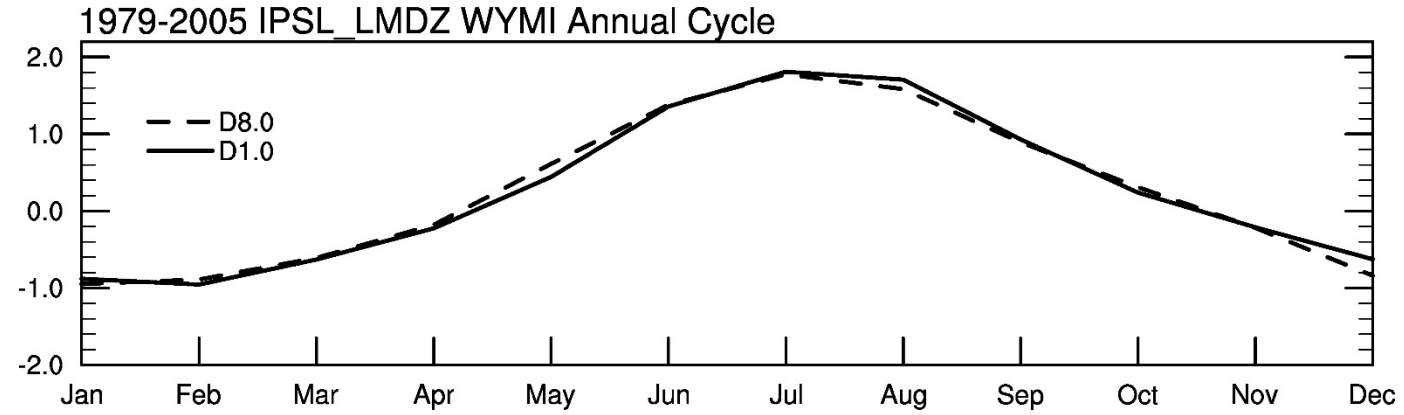
[Webster and Yang, 1992]

http://apdrc.soest.hawaii.edu/projects/monsoon/definition.html

Monsoon Index Annual Cycle (WYMI)







Cooling over land in mid-latitude

Decreased land-sea temperature contrast

Weaker Indian monsoon

Reduce the precipitation over the monsoon regions

Summary

Water Table Depth Sensitivity Experiments

CNRM-CM, CESM, and IPSL-LMDZ

Shallower Water Table Depth

Increased surface latent heat flux
Decreased surface temperature in mid-latitude
Increased meridional low level temperature gradient
Stronger global Hadley circulation

Precipitation over Land

Shallower water table depth has higher precipitation over land due to more latent heat flux over land, consistent results with Chou et al. in 2001; Lo and Famiglietti, 2011

Monsoon Index (WYMI)

Cooling over land reduces the land-sea temperature contrast, and then lead to weaker Indian monsoon. Less precipitation over the monsoon regions.

Any Questions?