The Role of Mid Tropospheric Humidity in Tropical Cyclone Genesis and Intensification

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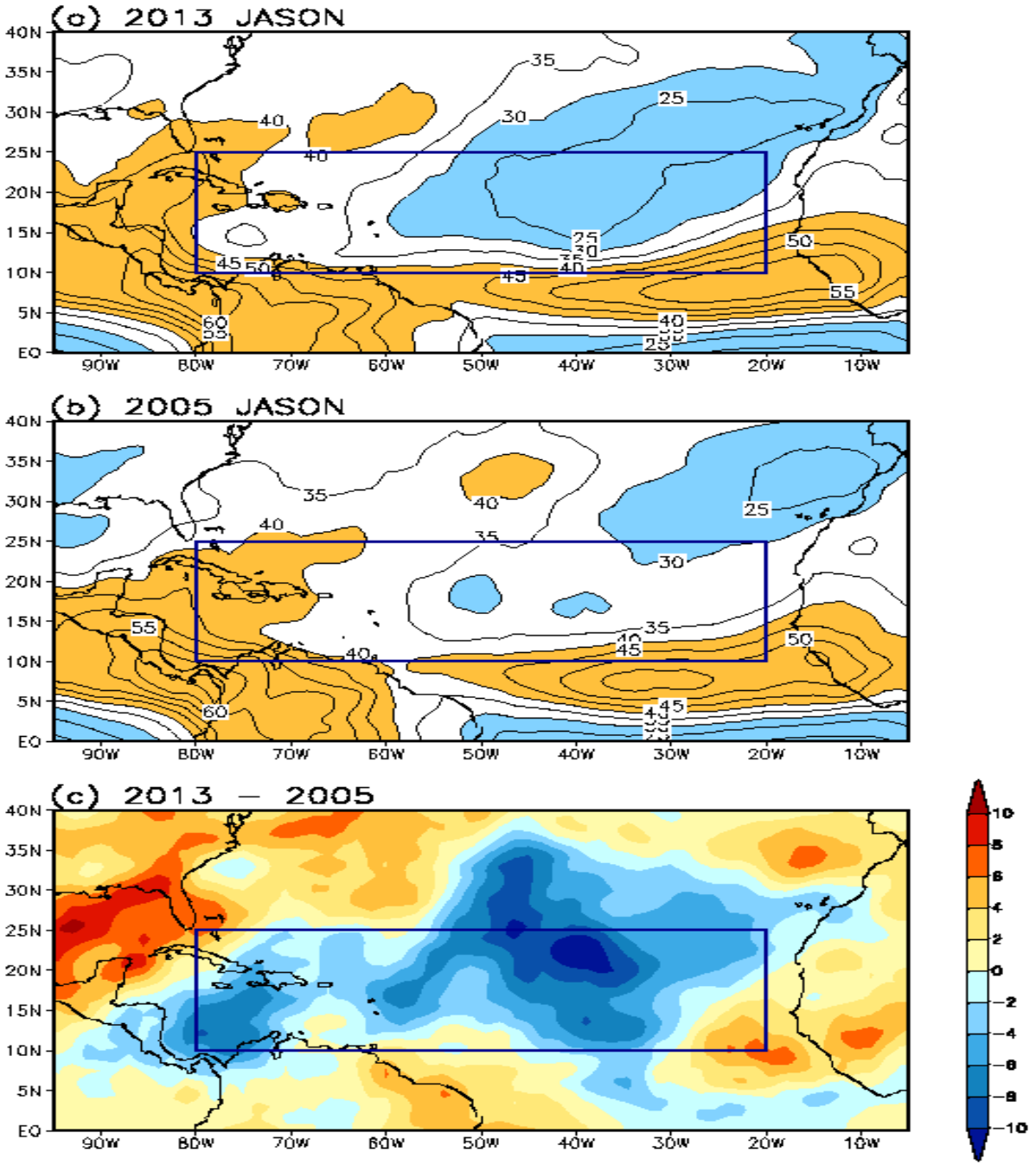
Florida State University

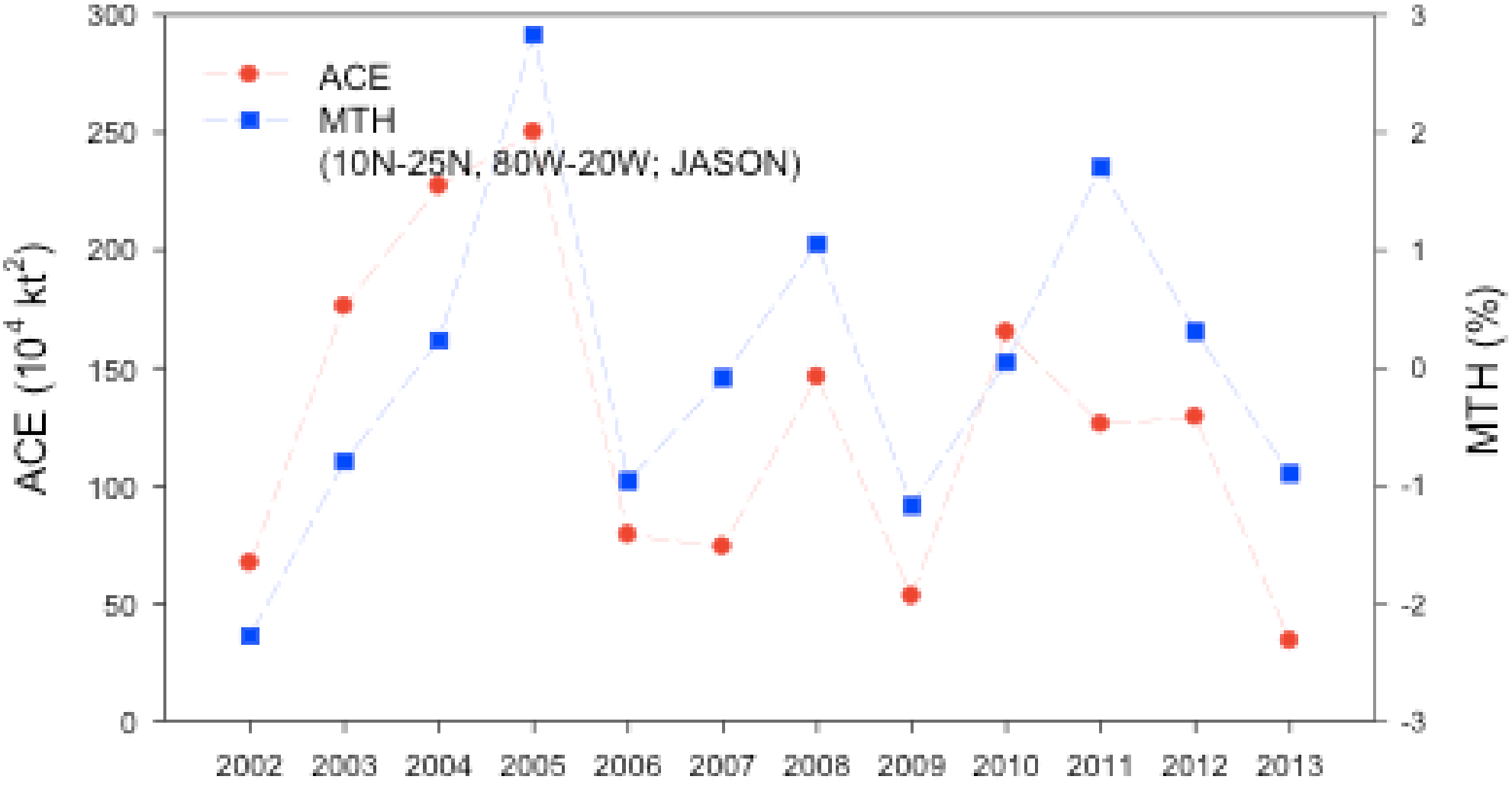
First Lorenz Center Workshop: Water in the Climate System

Atlantic Tropical Cyclone Activity
www.hurricanes.gov
No tropical cyclones
at this time
7:32 AM EDT
Aug 20, 2013
45°N
35°
25°
15°
5°N
85°
75°
65°
55°
45°
35°
25°
15°W

Tropical Atlantic Mid-Tropospheric RH: 2013 vs 2005

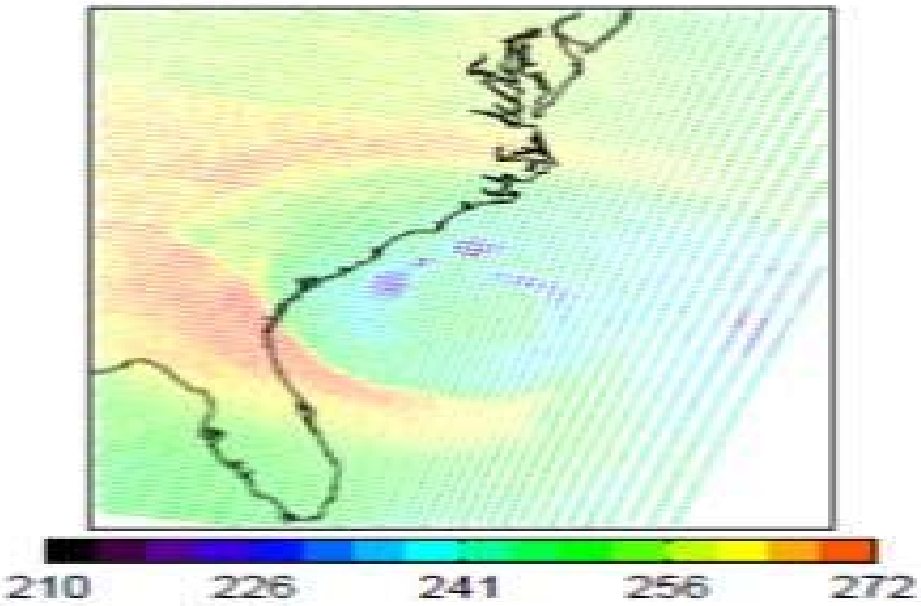


ACE and Mid-Tropospheric RH (2002-2013)

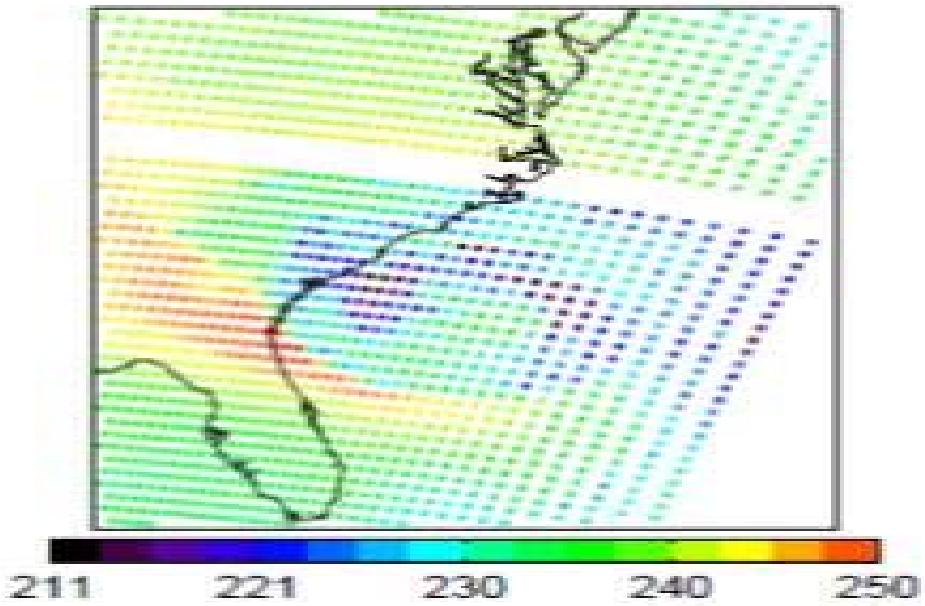


Satellite Measurements of Mid-Tropospheric Relative Humidity

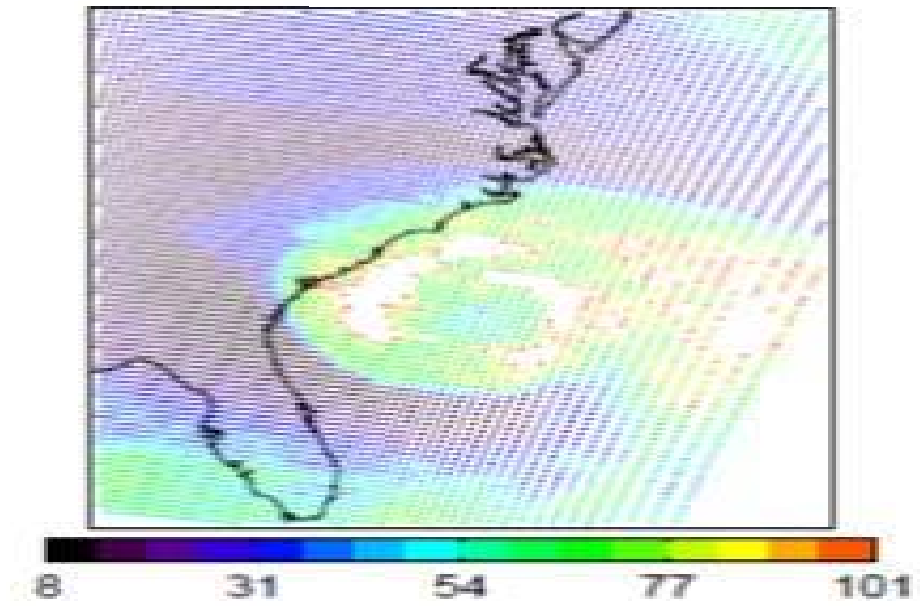
AMSU 183 GHz Tb



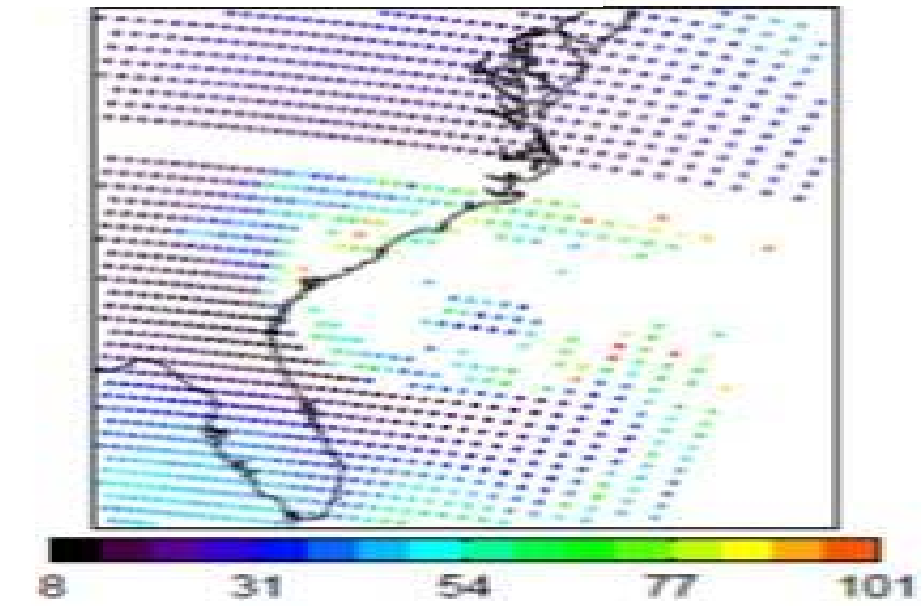
HIRS 7.3 micron Tb



AMSU MTH



HIRS MTH



Microwave

Infrared

Mid Tropospheric Humidity and Tropical Cyclogenesis

Several field campaigns have examined environment before/after genesis:

TEXMEX (Bister and Emanuel 1997)

TCSP (Halverson et al. 2007)

RAINEX (Houze et al. 2006)

PREDICT (Montgomery et al. 2012)

…

-> Theses studies noted the importance of dry air in suppressing development (e.g. Zipser et al. 2009; Dunkerton et al. 2009, Komaromi 2012).

-> Use MW satellite observations and tracks of developing and non-developing Invests/TCs (Cossuth et al. 2013) to examine relation between MTH and TC development/intensification.

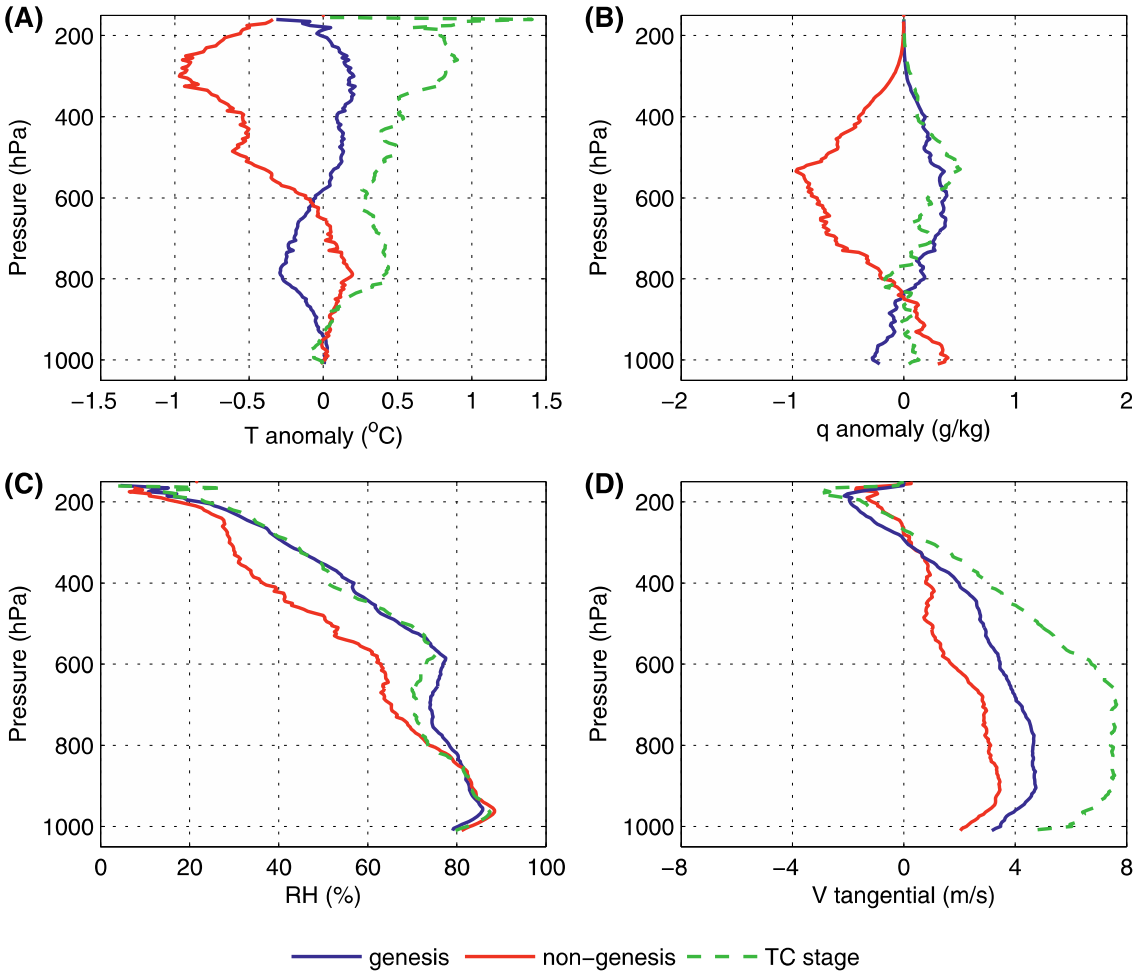
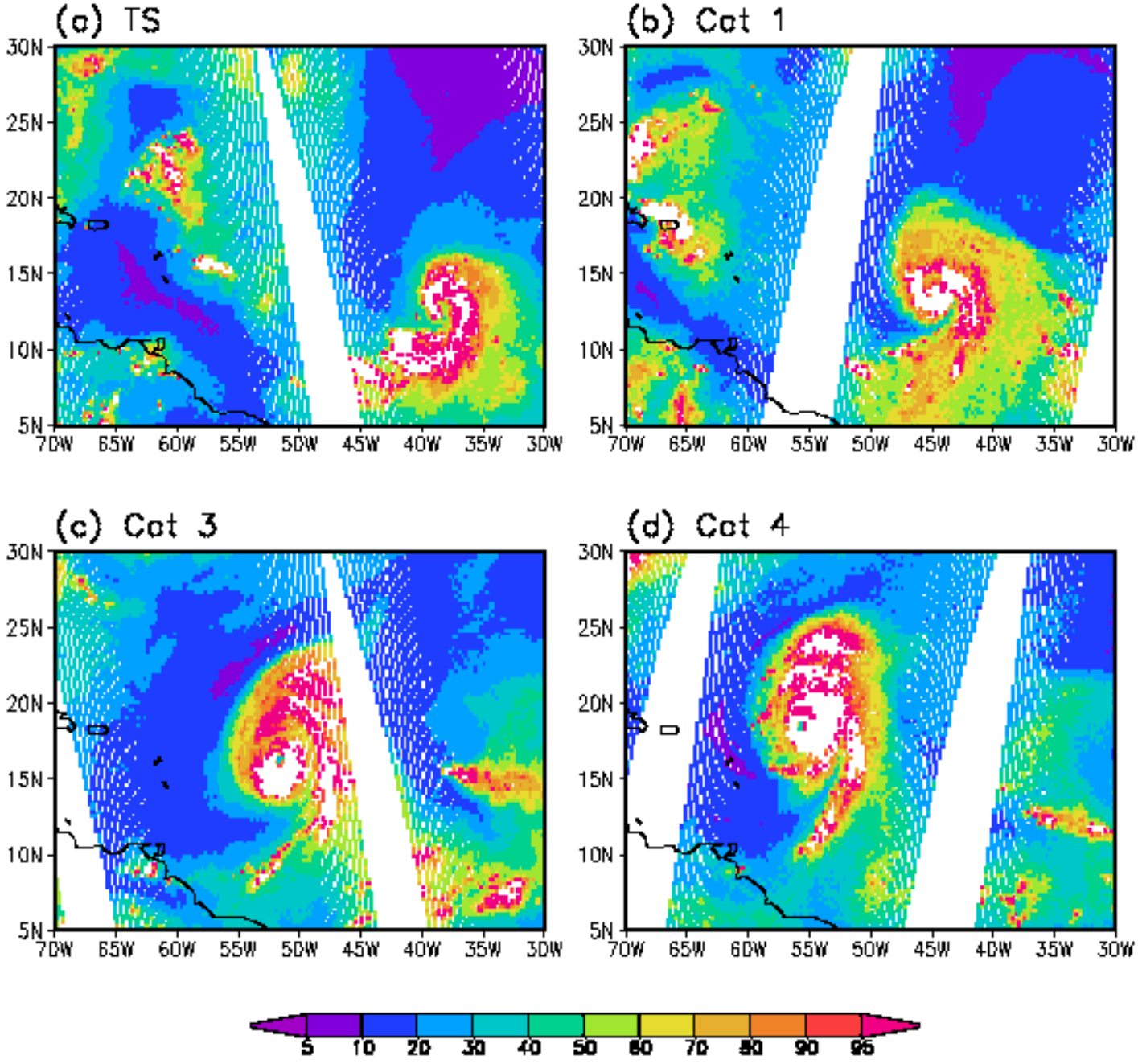


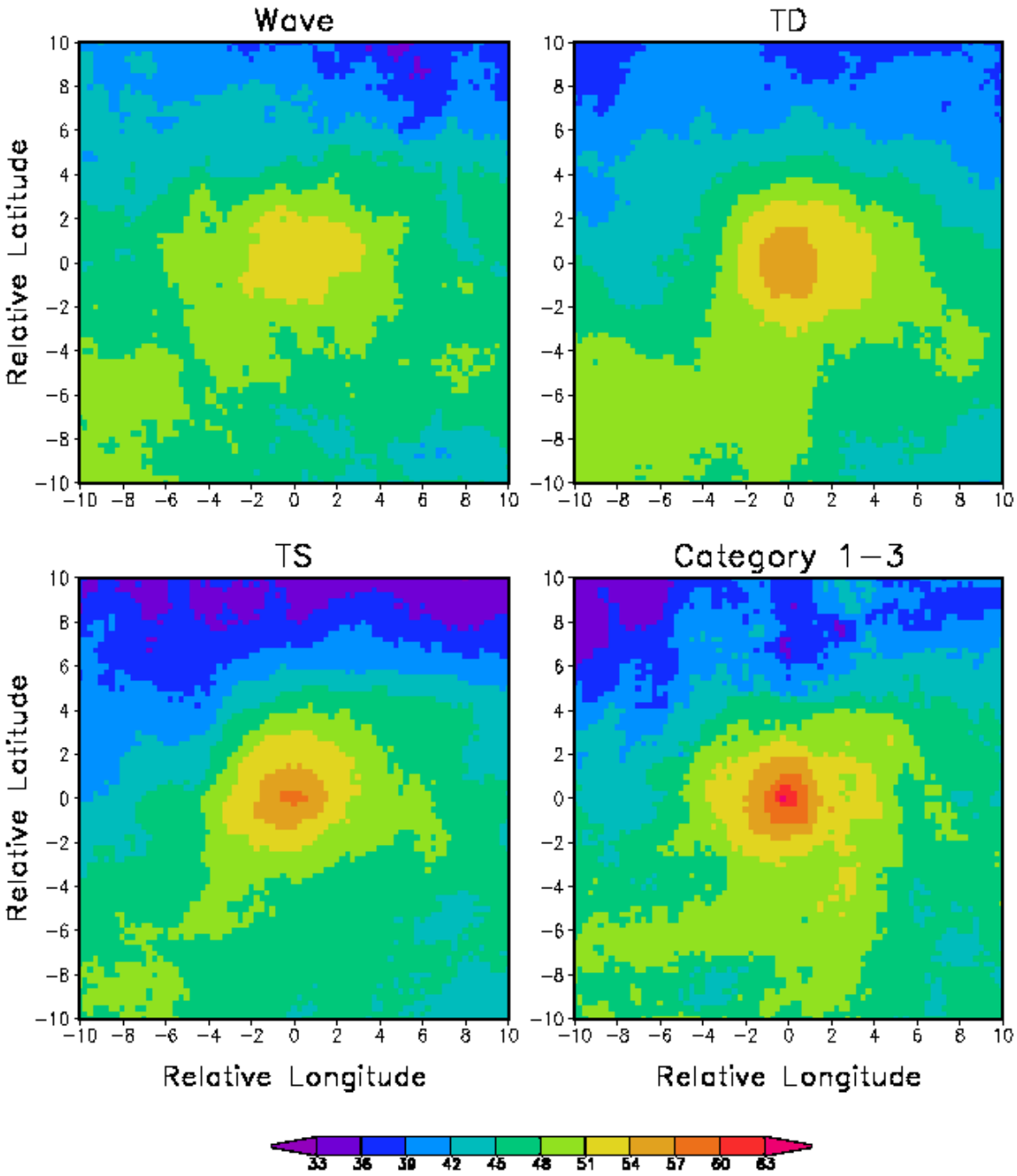
FIG. 3. Composite vertical profiles of anomalies relative to the PREDICT mean of (a) temperature, (b) mixing ratio, (c) relative humidity, and (d) tangential component of wind for genesis, nongenesis, and TC stage categories.

PREDICT (Komaromi 2012)

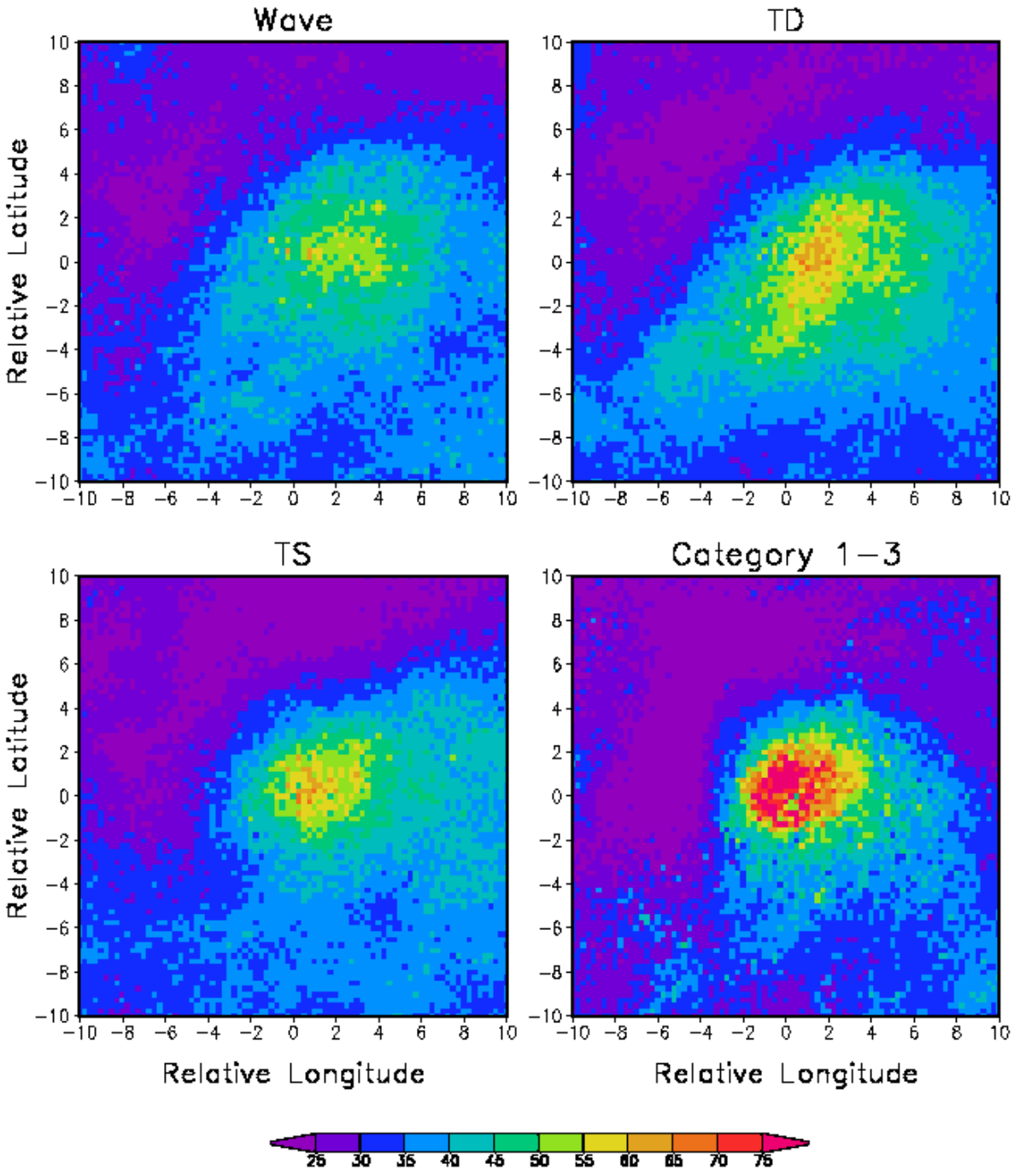
Hurricane Bill (2009)



Total Column Water Vapor Composites

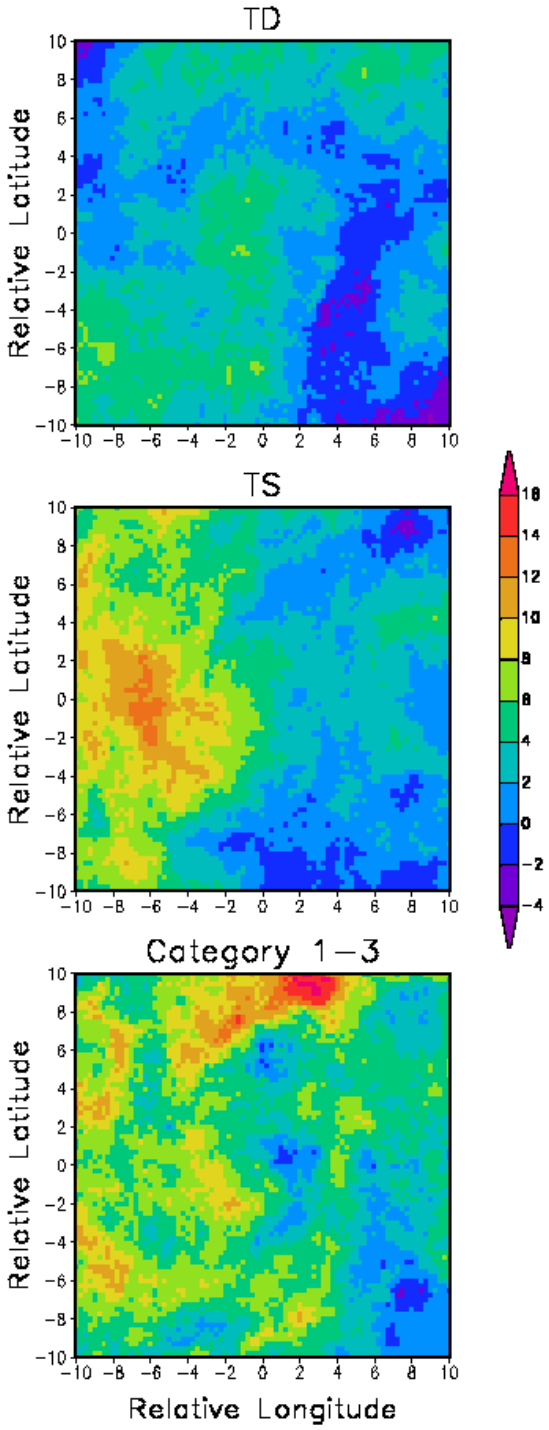


Mid-Tropospheric Relative Humidity Composites

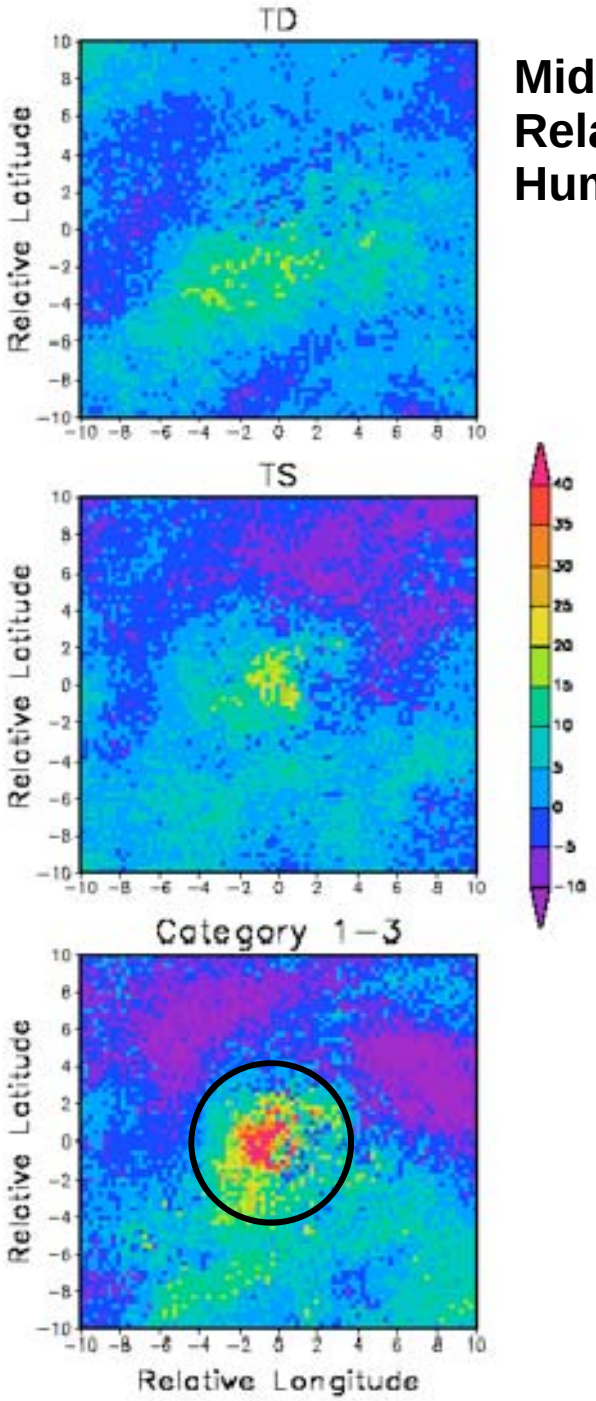


Water Vapor Composites (6 hours prior): Strengthening - Weakening

Total Column Water Vapor

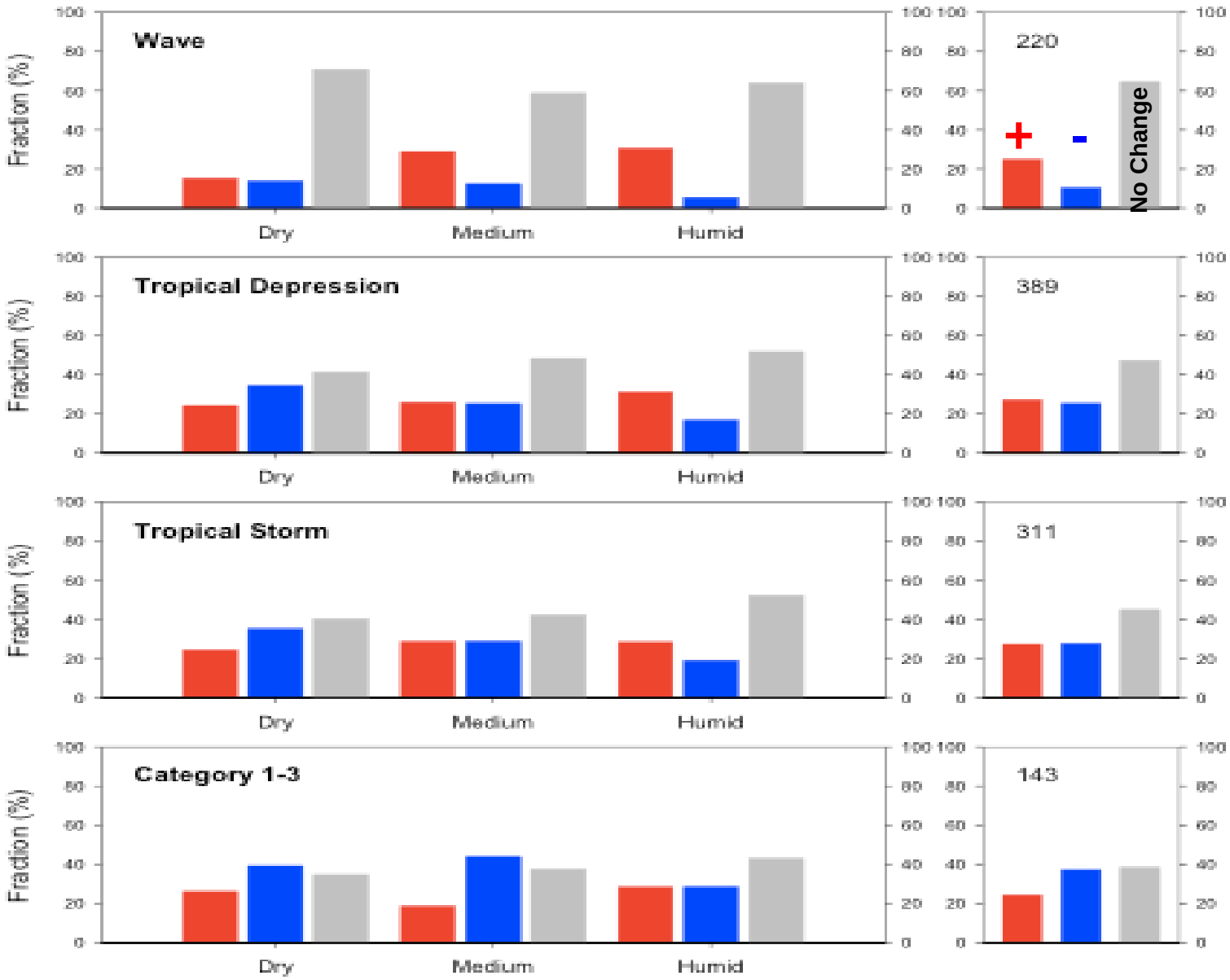


Mid-Tropospheric Relative Humidity

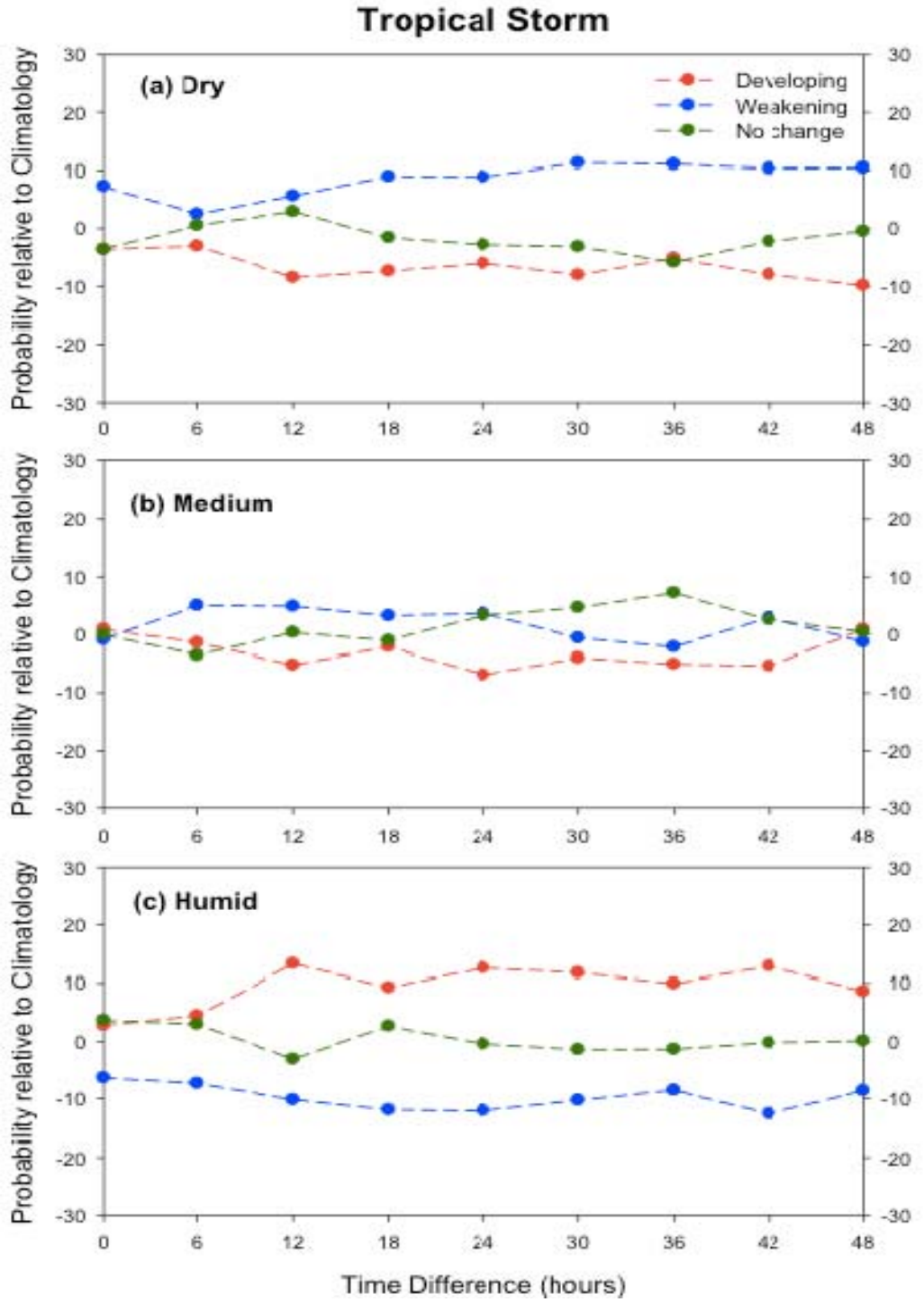


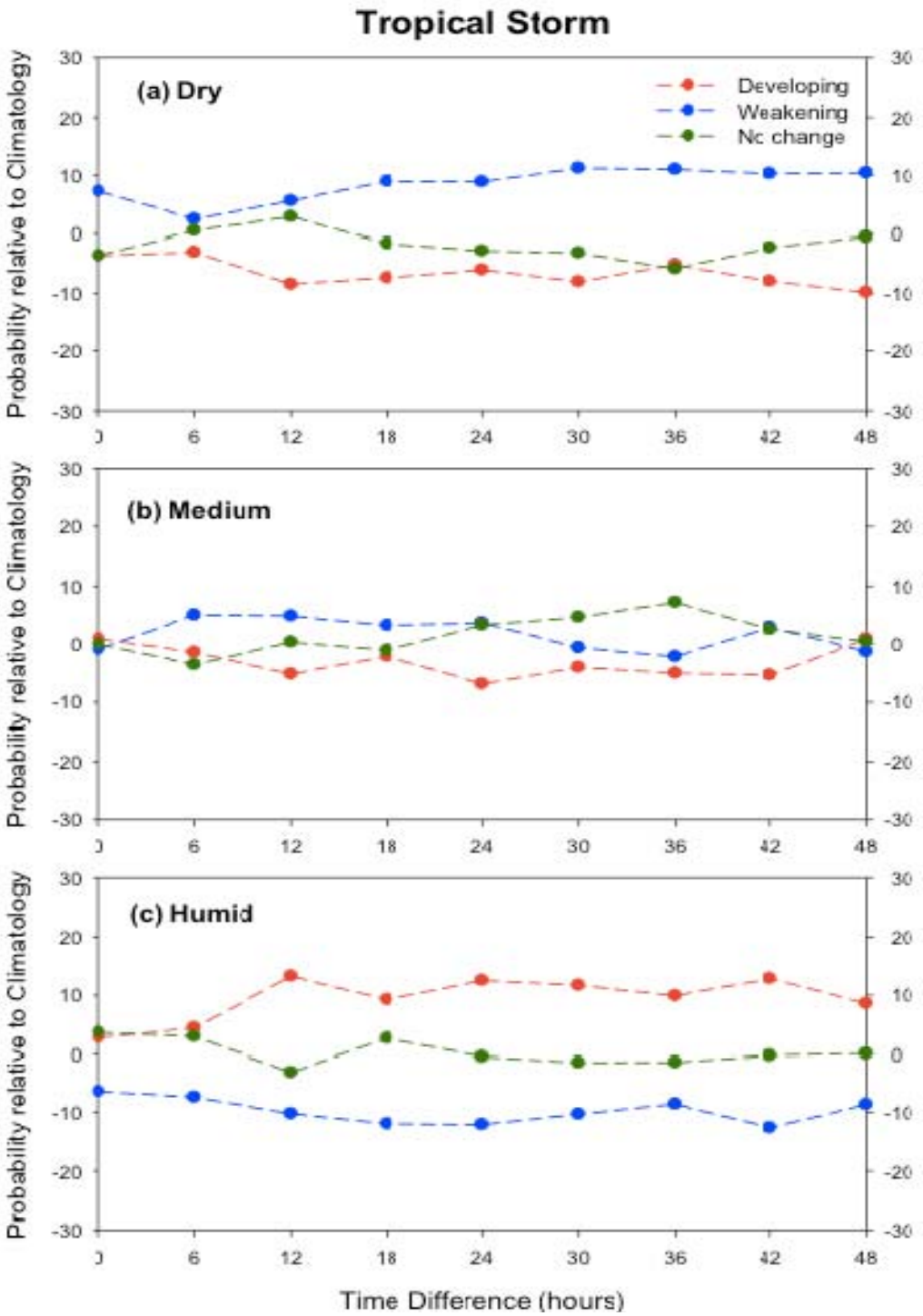
Storm Development and Mid Tropospheric Relative Humidity

Frequency of intensity change (strengthening/weakening/no change)
for MTH terciles: Dry, Neutral, Humid

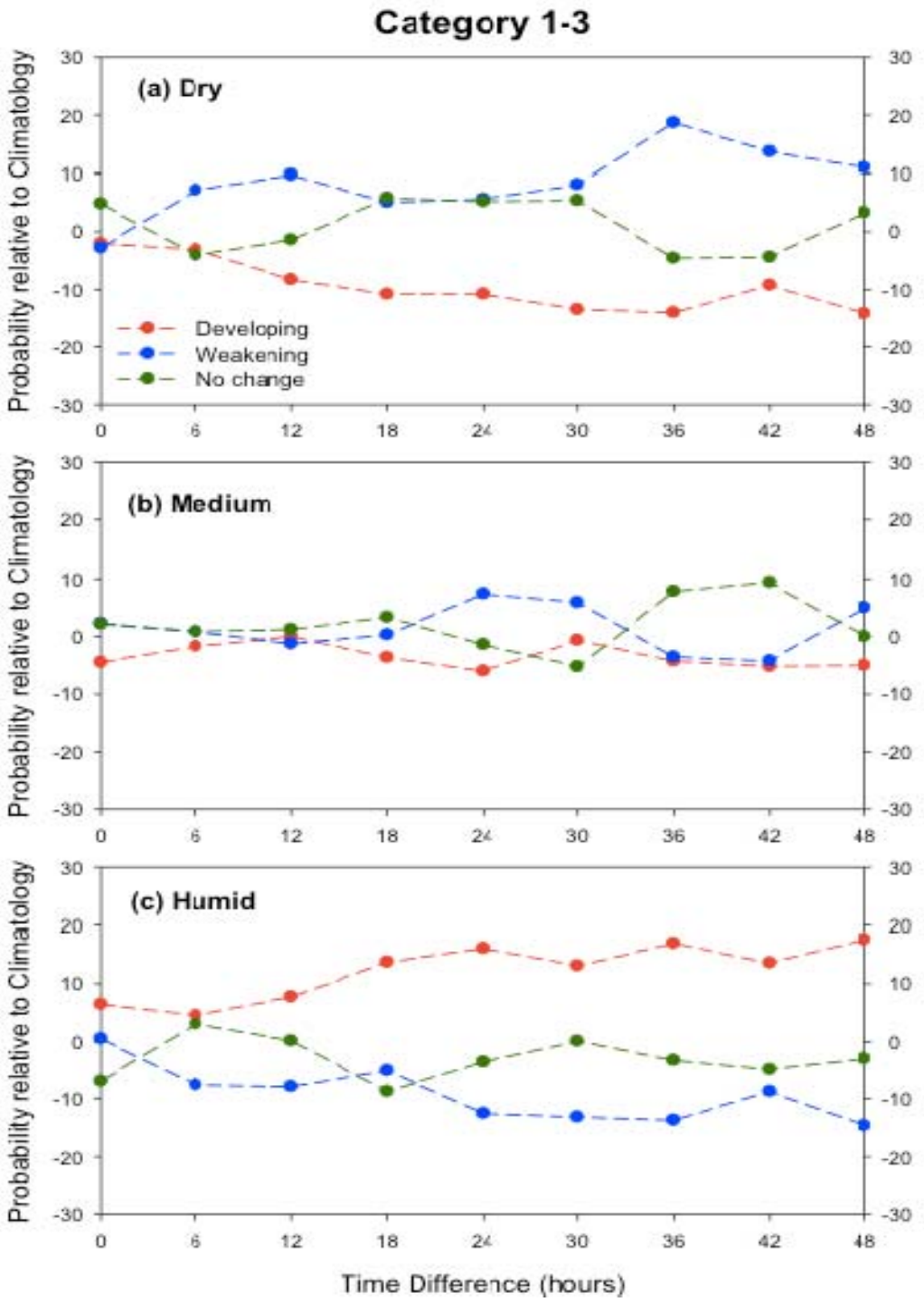


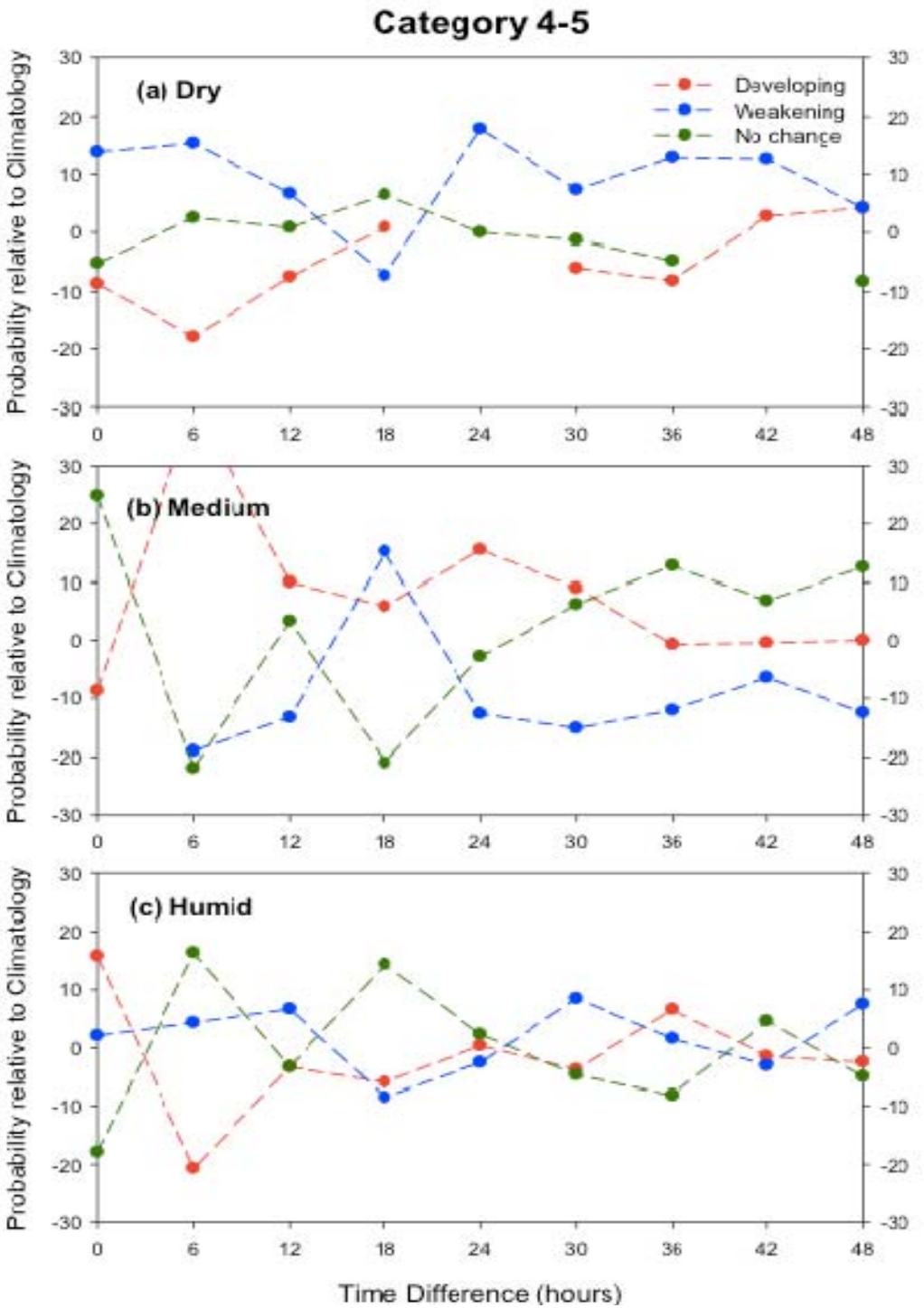
Intensity Change and MTH





Intensity Change and MTH



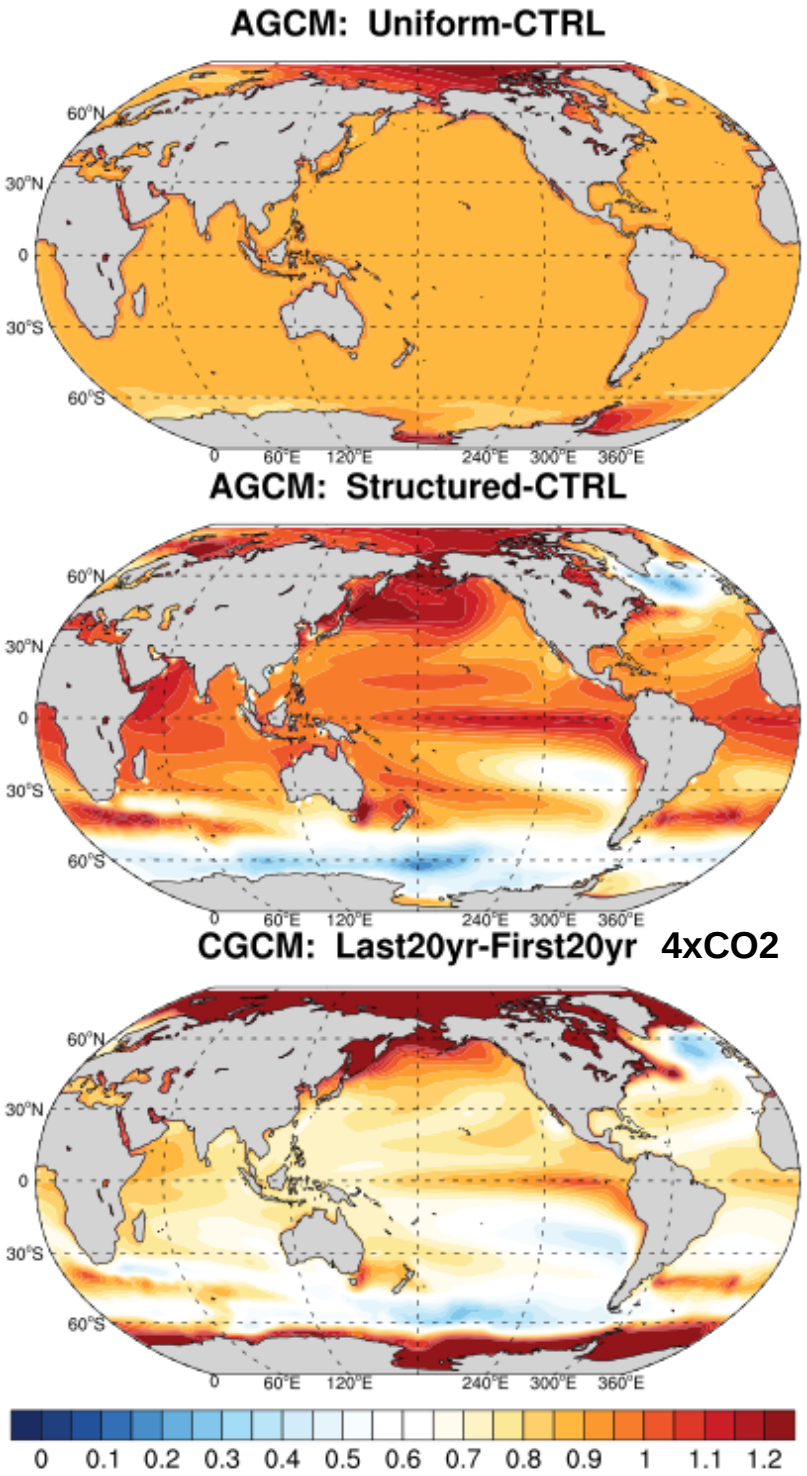


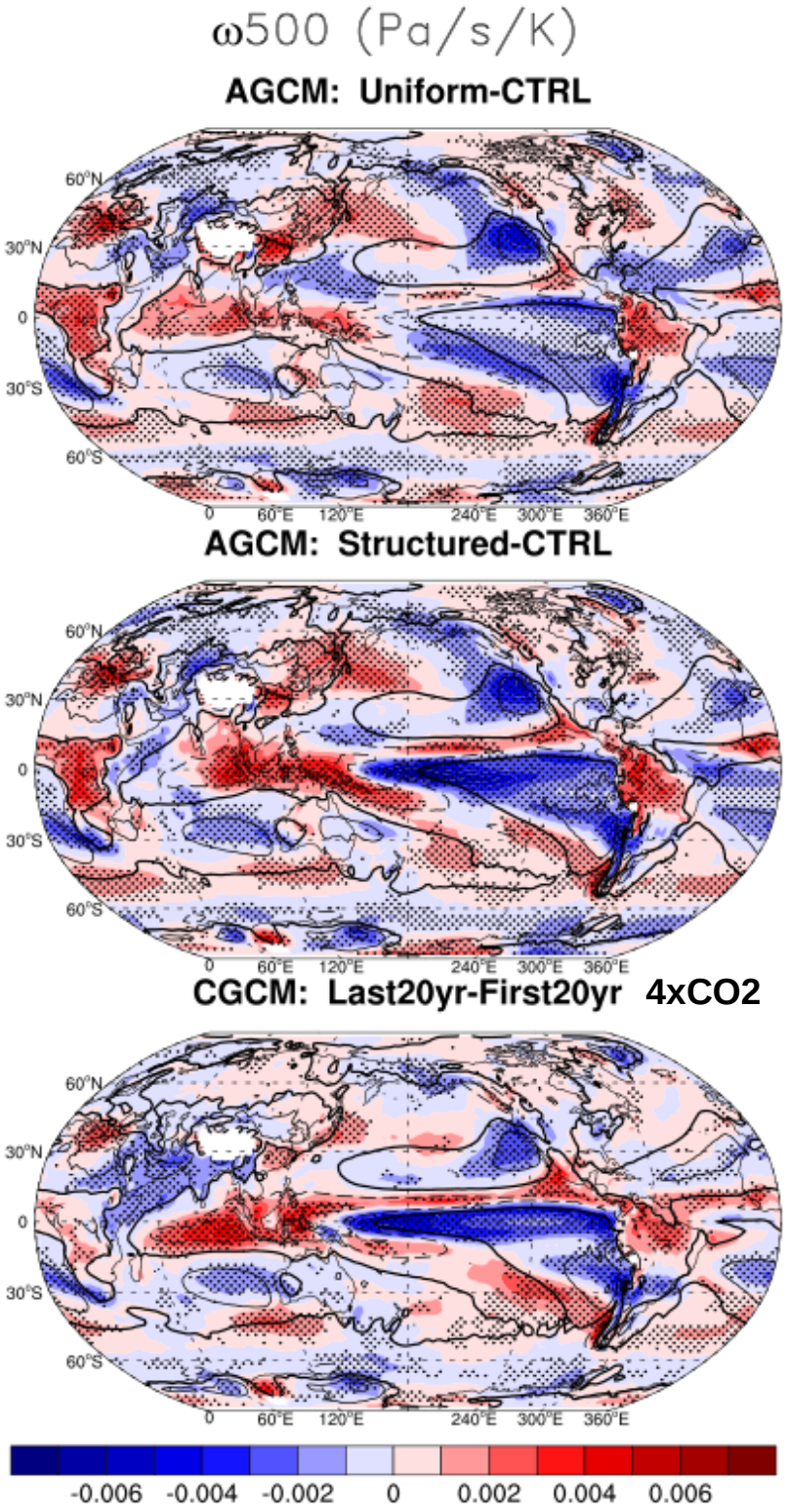
<INSERT MODELING STUDY HERE>

What determines regional patterns of circulation (precipitation) change?

A) Mean surface warming
B) Spatial pattern of warming
C) Ocean coupling
D) Radiative heating from increased CO_2

Normalized Surface Warming: 8 member multi-model ensemble (CMIP5)

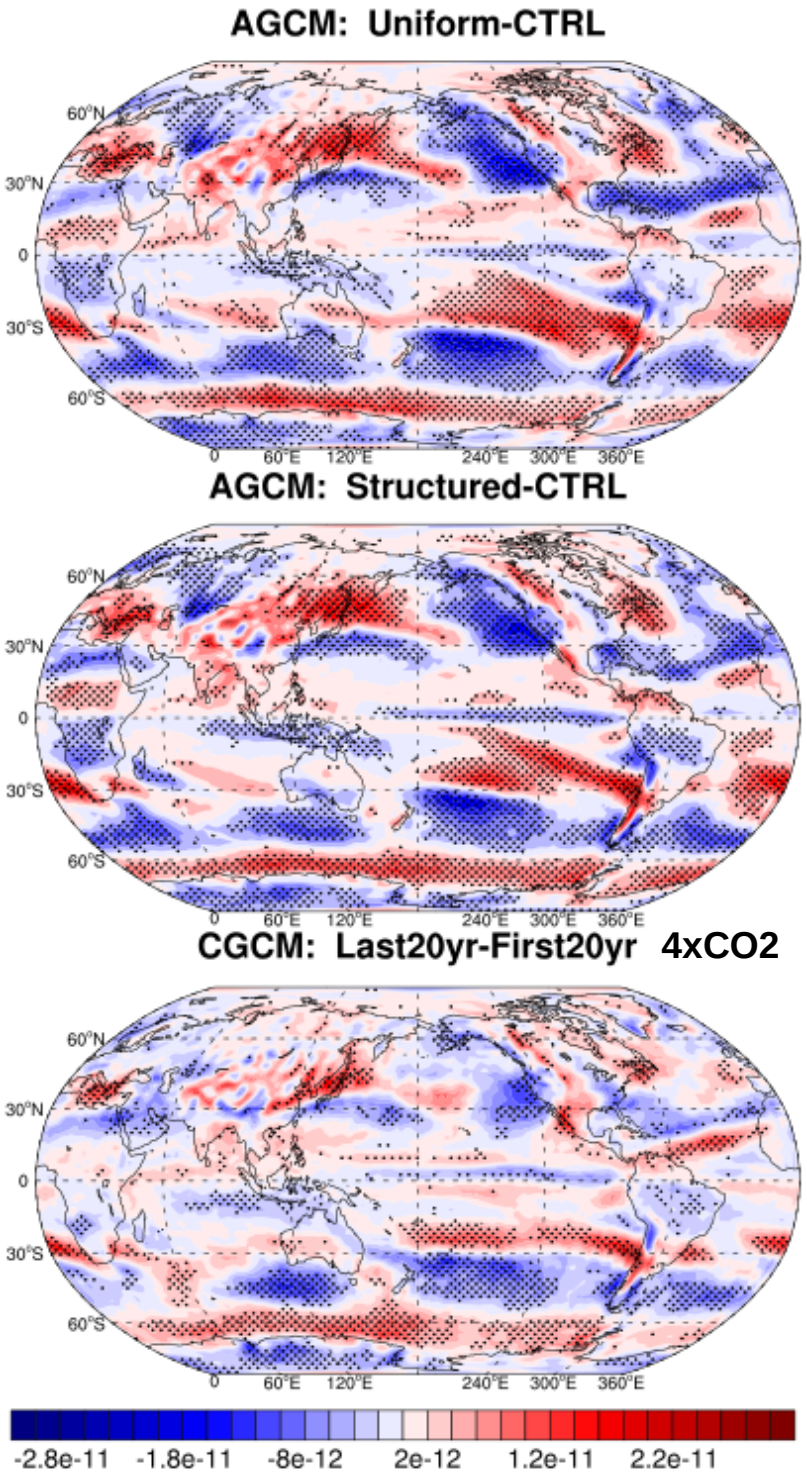




Tropics:
Weakening of Circulation
→ Change opposes mean circulation
(Ma and Xie 2013)

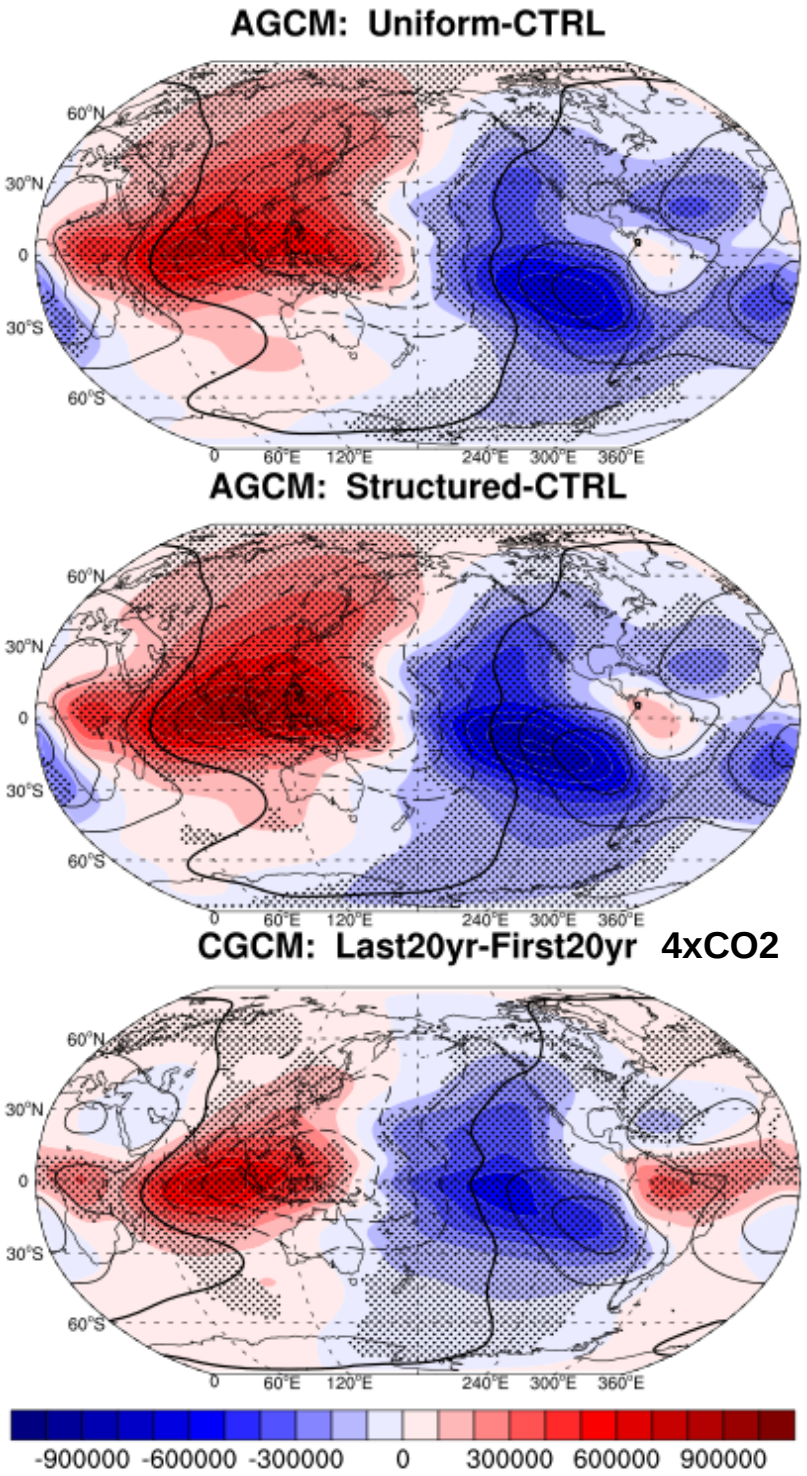
Extratropical response due to dispersion of Rossby waves from tropics?

Rossby Wave Source (1/s2/K)



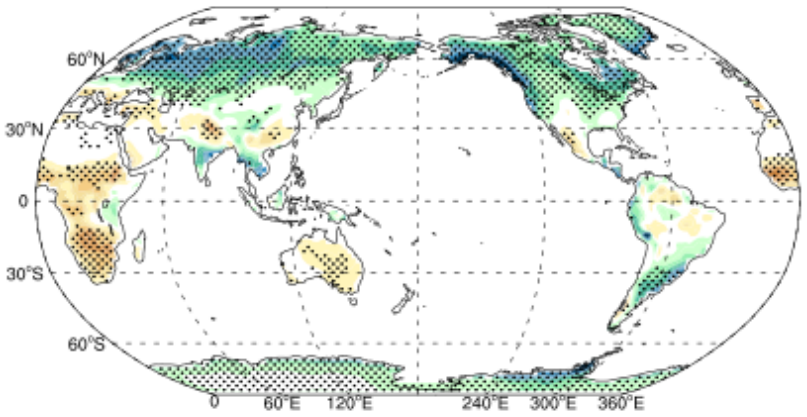
Extratropical response due to dispersion of Rossby waves from tropics

Velocity Potential (m2/s/K)



Precip (mm/day/K)

AGCM: Uniform-CTRL



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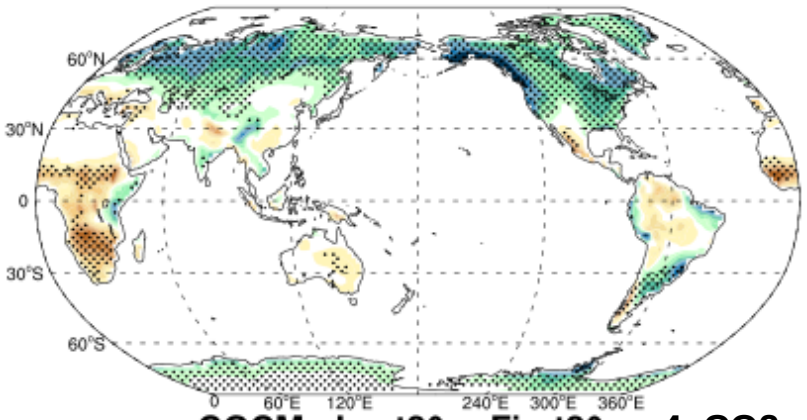
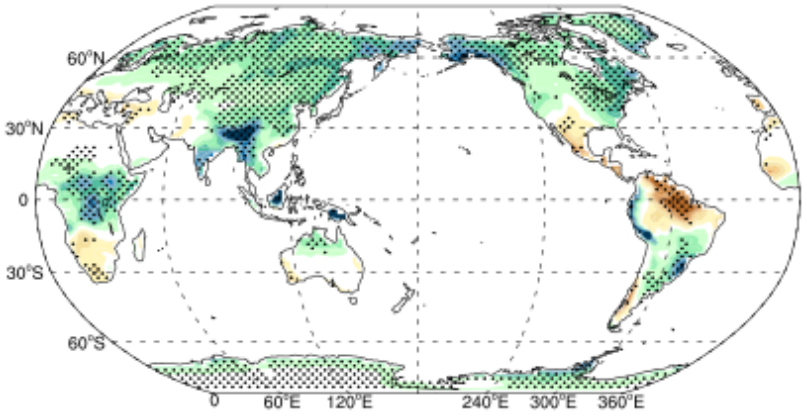
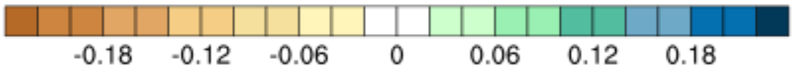


CGCM: Last20yr-First20yr 4xCO2



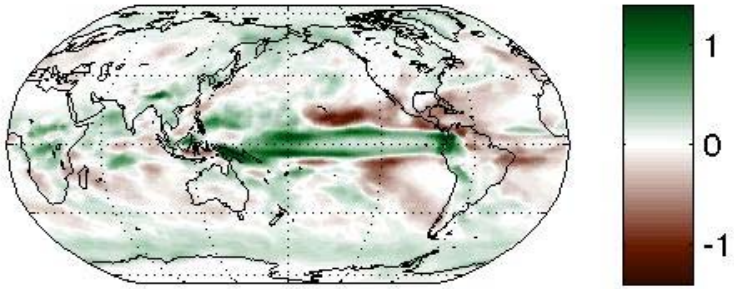


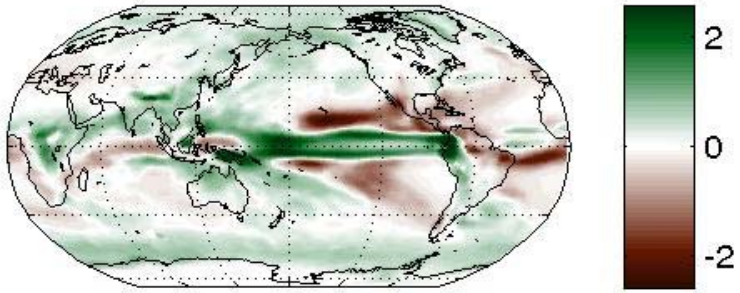
Is Coupling Important?

Precipitation Change 2xCO2-1xCO2

Precipitation Change 4xCO2-1xCO2

Coupled

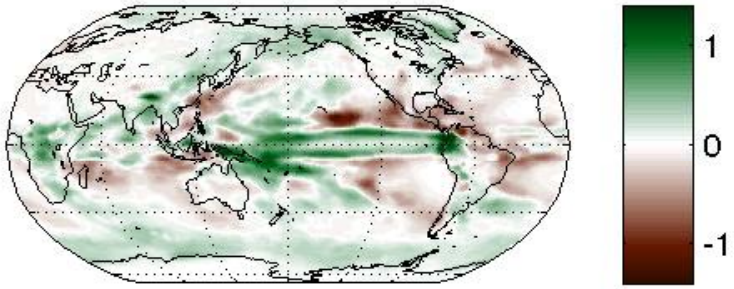


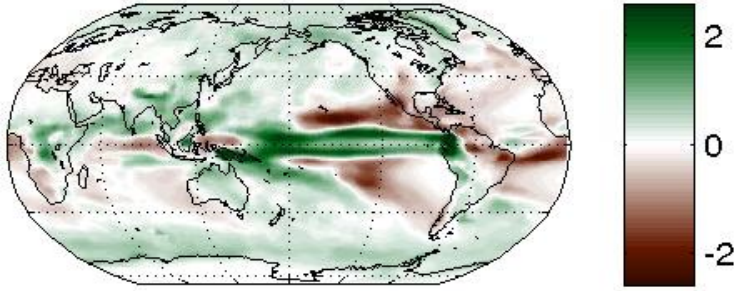


Precipitation Change 2xCO2-1xCO2

Precipitation Change 4xCO2-1xCO2

AMIP (w/ ΔCO2)

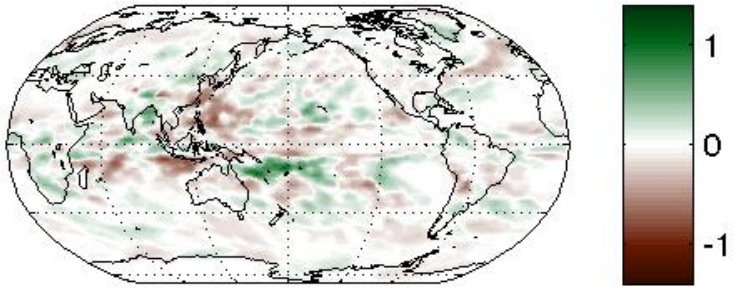


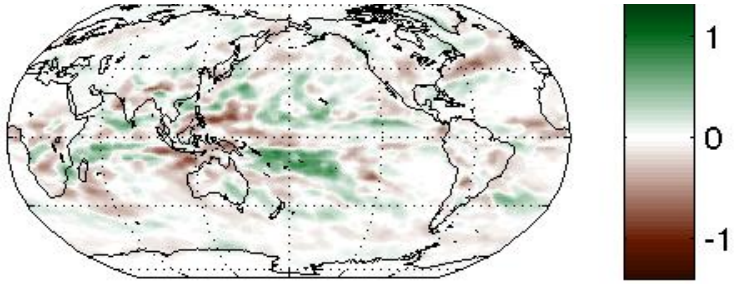


Precipitation Error (AMIP-Coupled)

Precipitation Error (AMIP-Coupled)

Error

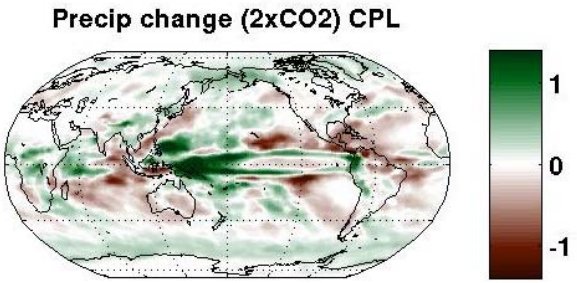




Is Coupling Important?

2xCO2

coupled

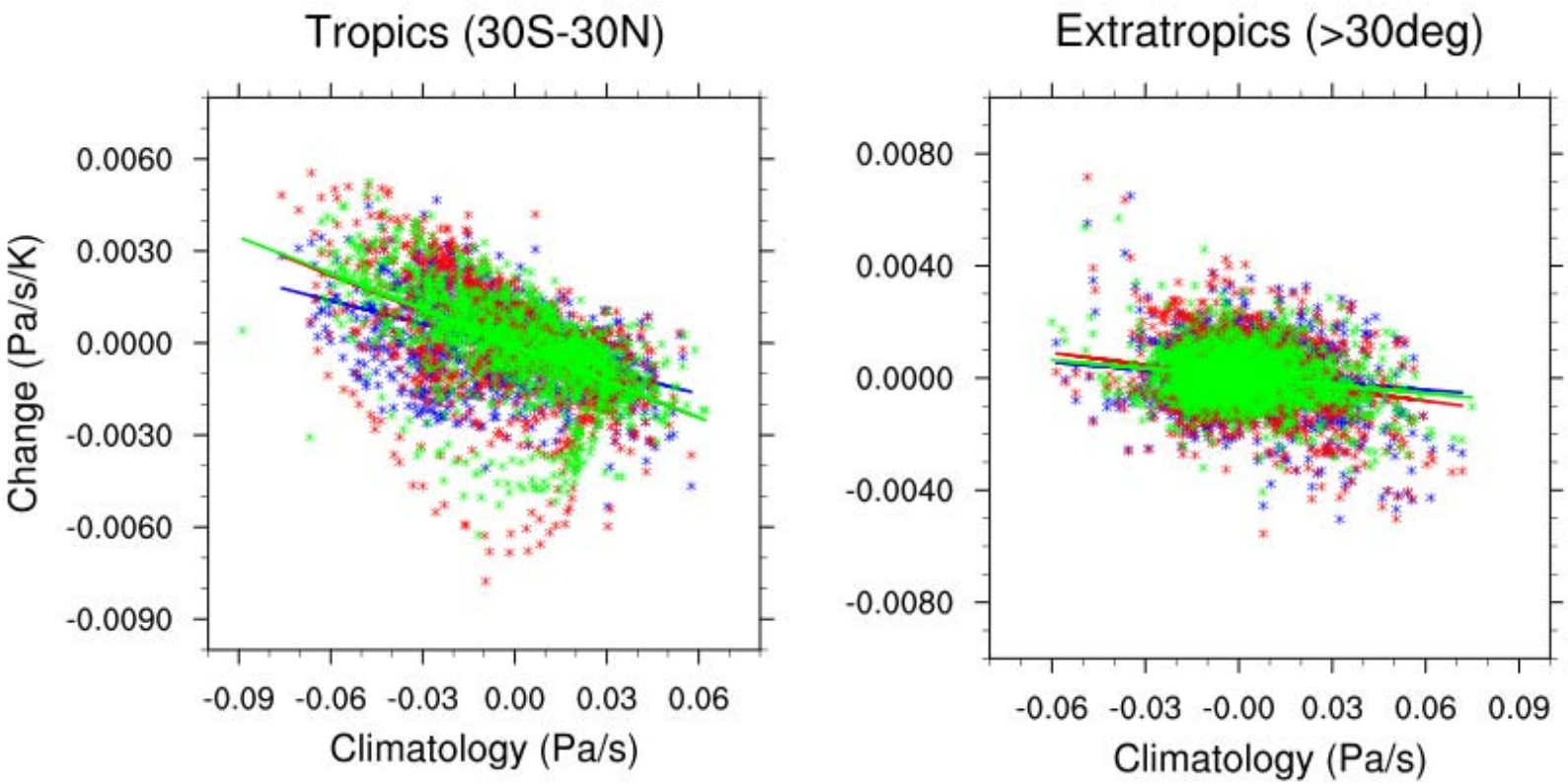


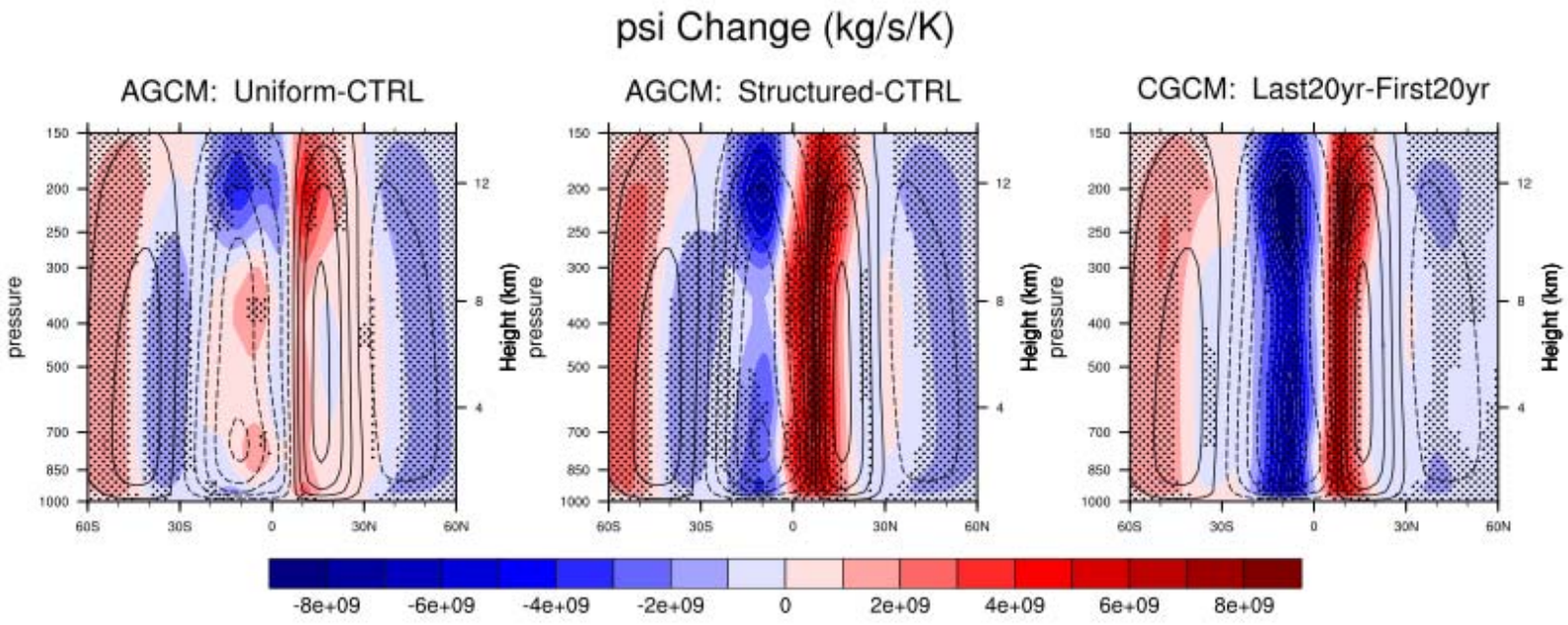
AMIP

Error (AMIP-coupled)

GRL paper figures

Annual mean

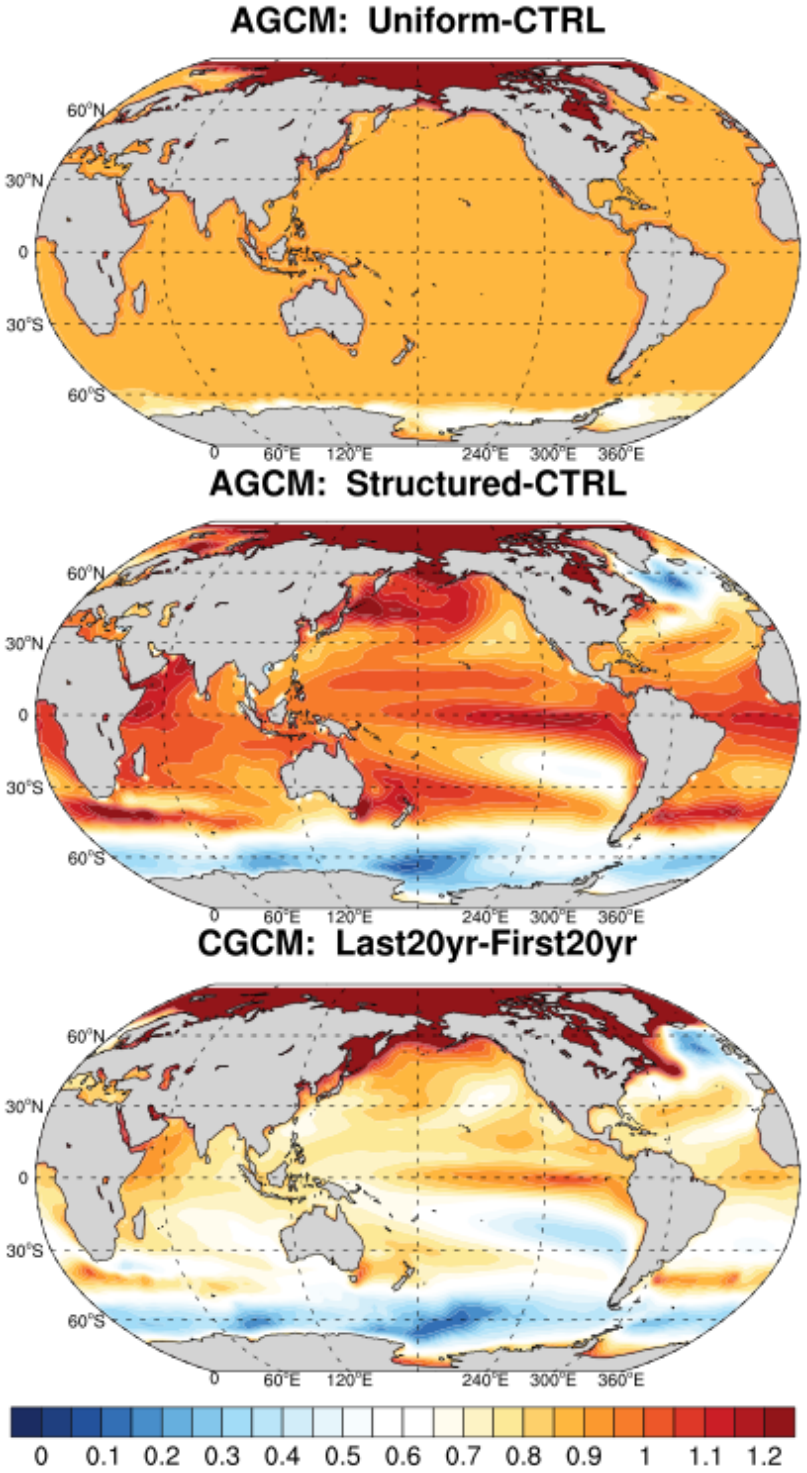

Tropics (30S-30N)
Change (Pa/s/K)
0.0060
0.0030
0.0000
-0.0030
-0.0060
-0.0090
-0.09 -0.06 -0.03 0.00 0.03 0.06
Climatology (Pa/s)
Extratropics (>30deg)
0.0080
0.0040
0.0000
-0.0040
-0.0080
-0.06 -0.03 -0.00 0.03 0.06 0.09
Climatology (Pa/s)


psi Change (kg/s/K)
AGCM: Uniform-CTRL
AGCM: Structured-CTRL
CGCM: Last20yr-First20yr
pressure
Height (km)
150
200
250
300
400
500
700
850
1000
12
8
4
60S
30S
0
30N
60N
-8e+09
-6e+09
-4e+09
-2e+09
0
2e+09
4e+09
6e+09
8e+09

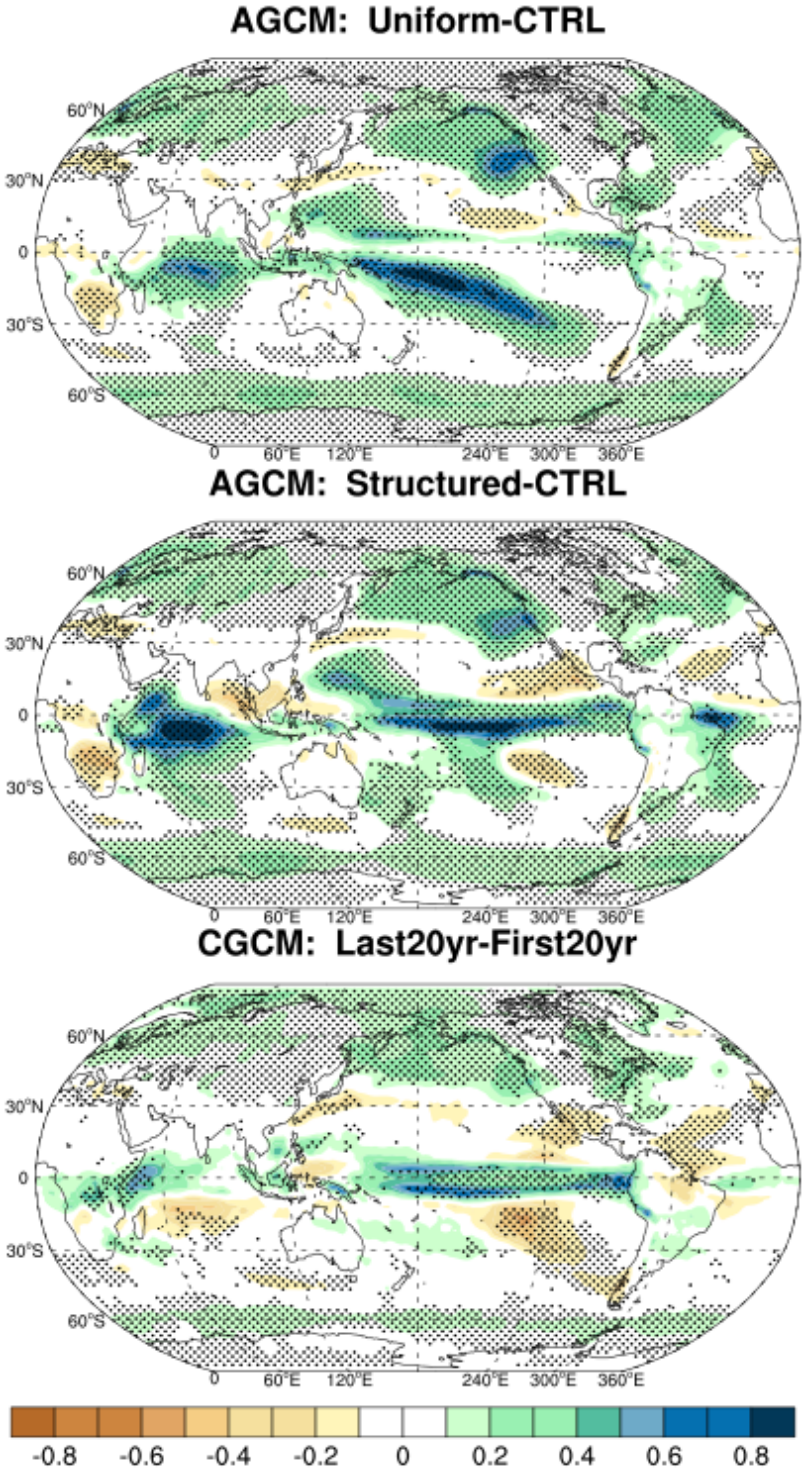
GRL paper figures

DJF

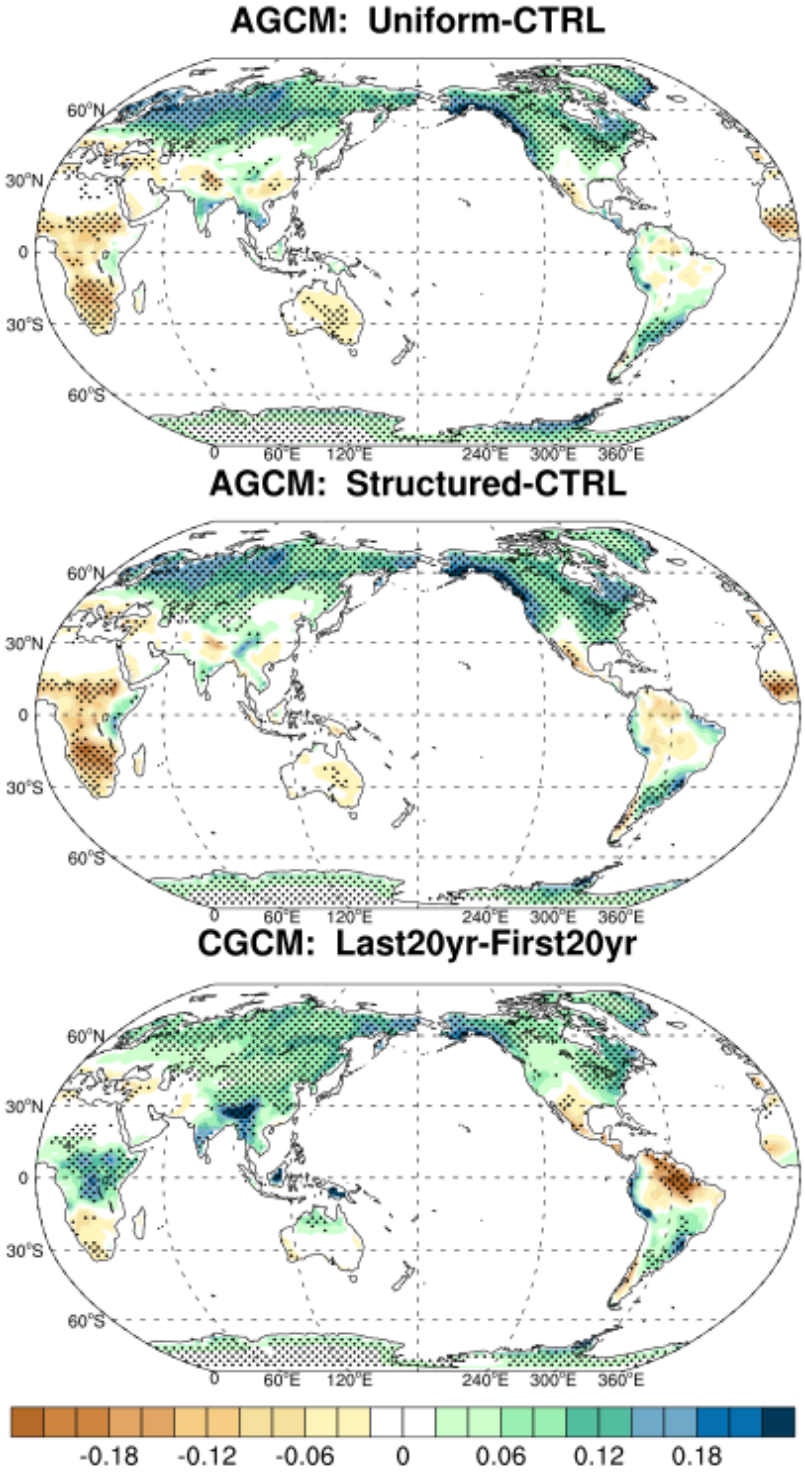
TS (K/K)


AGCM: Uniform-CTRL
AGCM: Structured-CTRL
CGCM: Last20yr-First20yr
60°N
30°N
0
30°S
60°S
0
60°E
120°E
240°E
300°E
360°E
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1 1.1 1.2

Precip (mm/day/K)

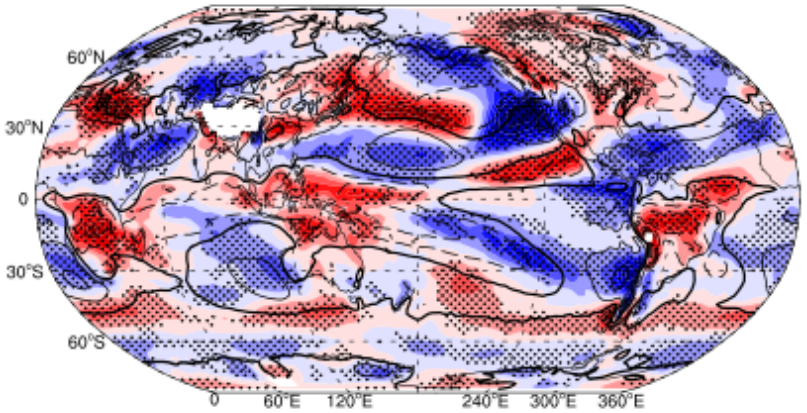


Precip (mm/day/K)



ω500 (Pa/s/K)

AGCM: Uniform-CTRL



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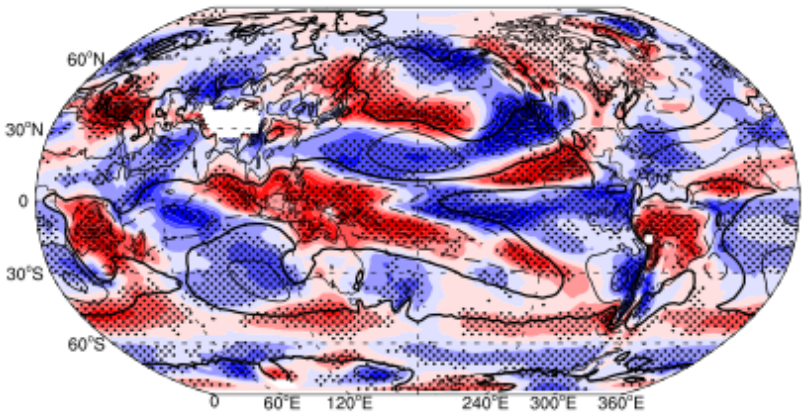
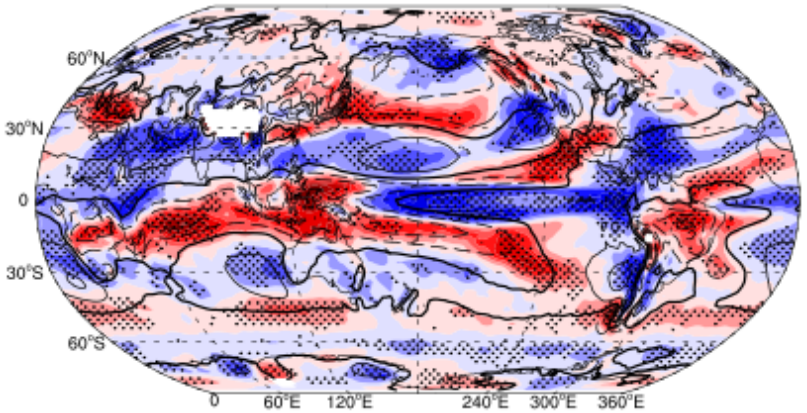
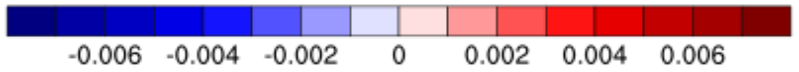


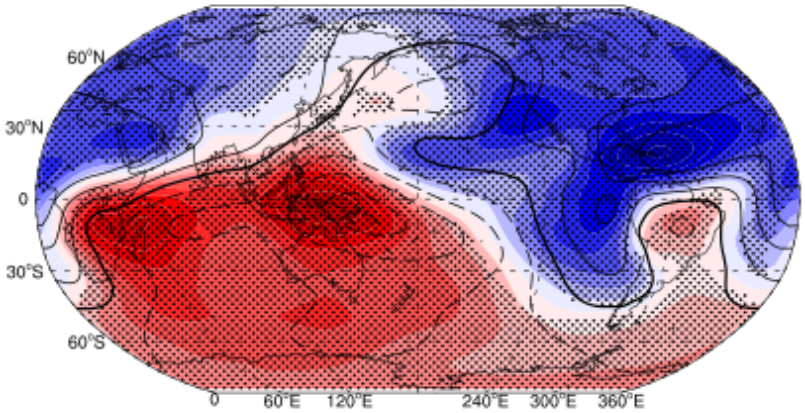
CGCM: Last20yr-First20yr



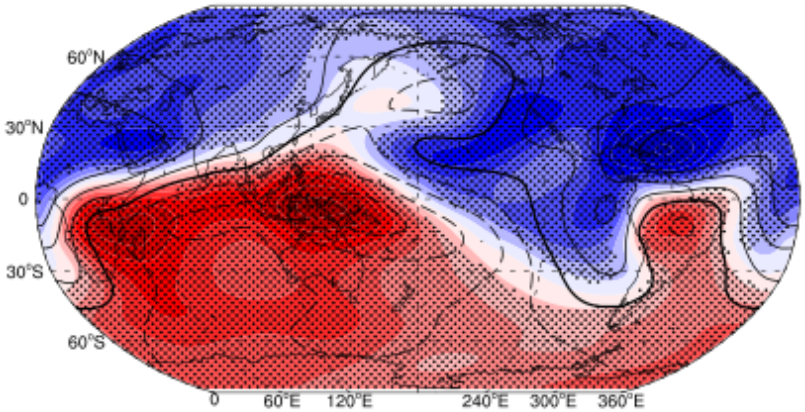


VP250 (m2/s/K)

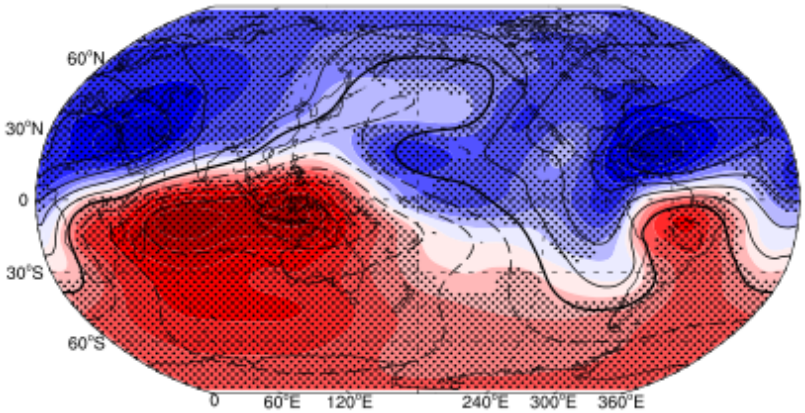
AGCM: Uniform-CTRL

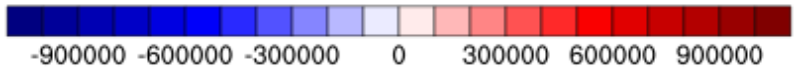


AGCM: Structured-CTRL

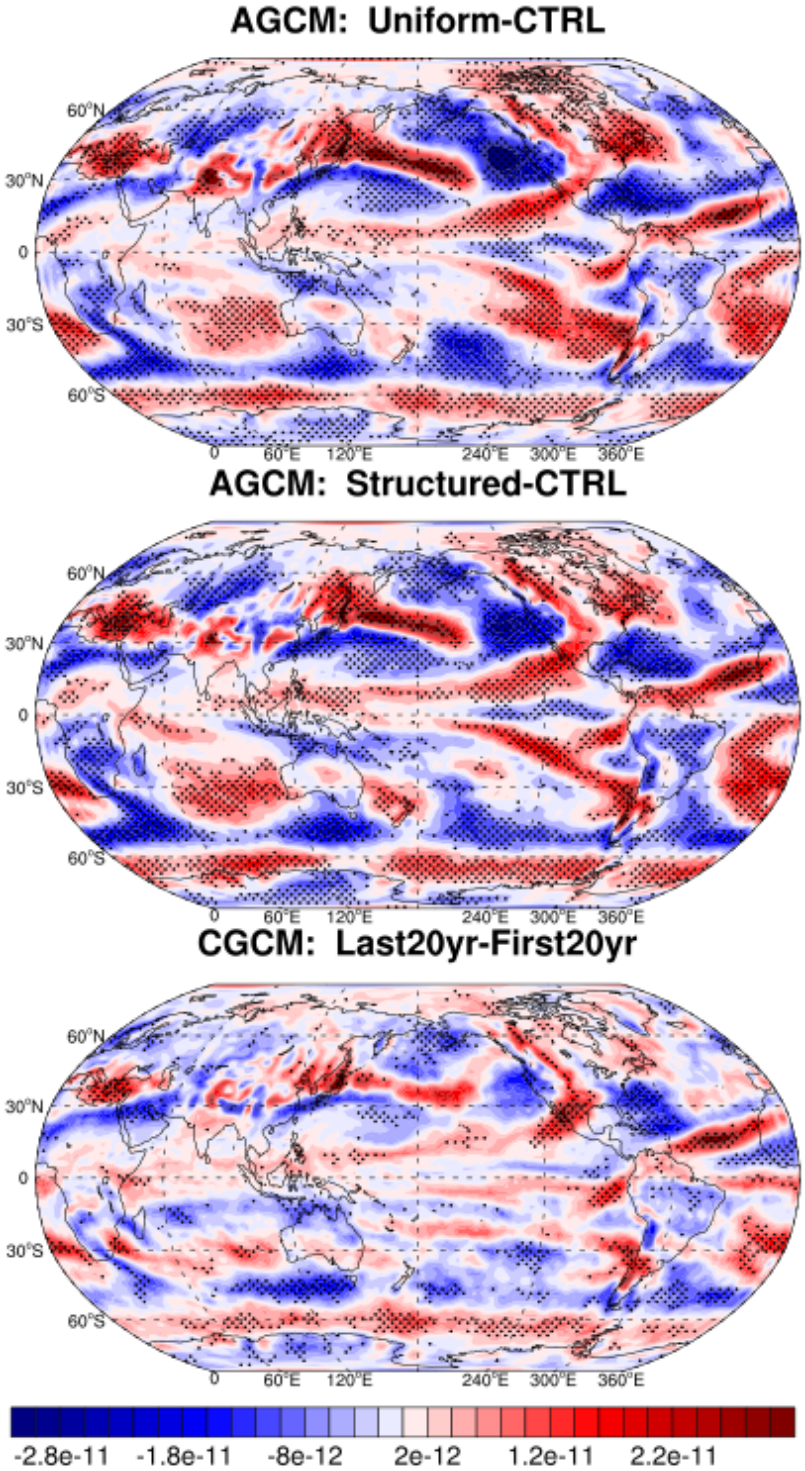


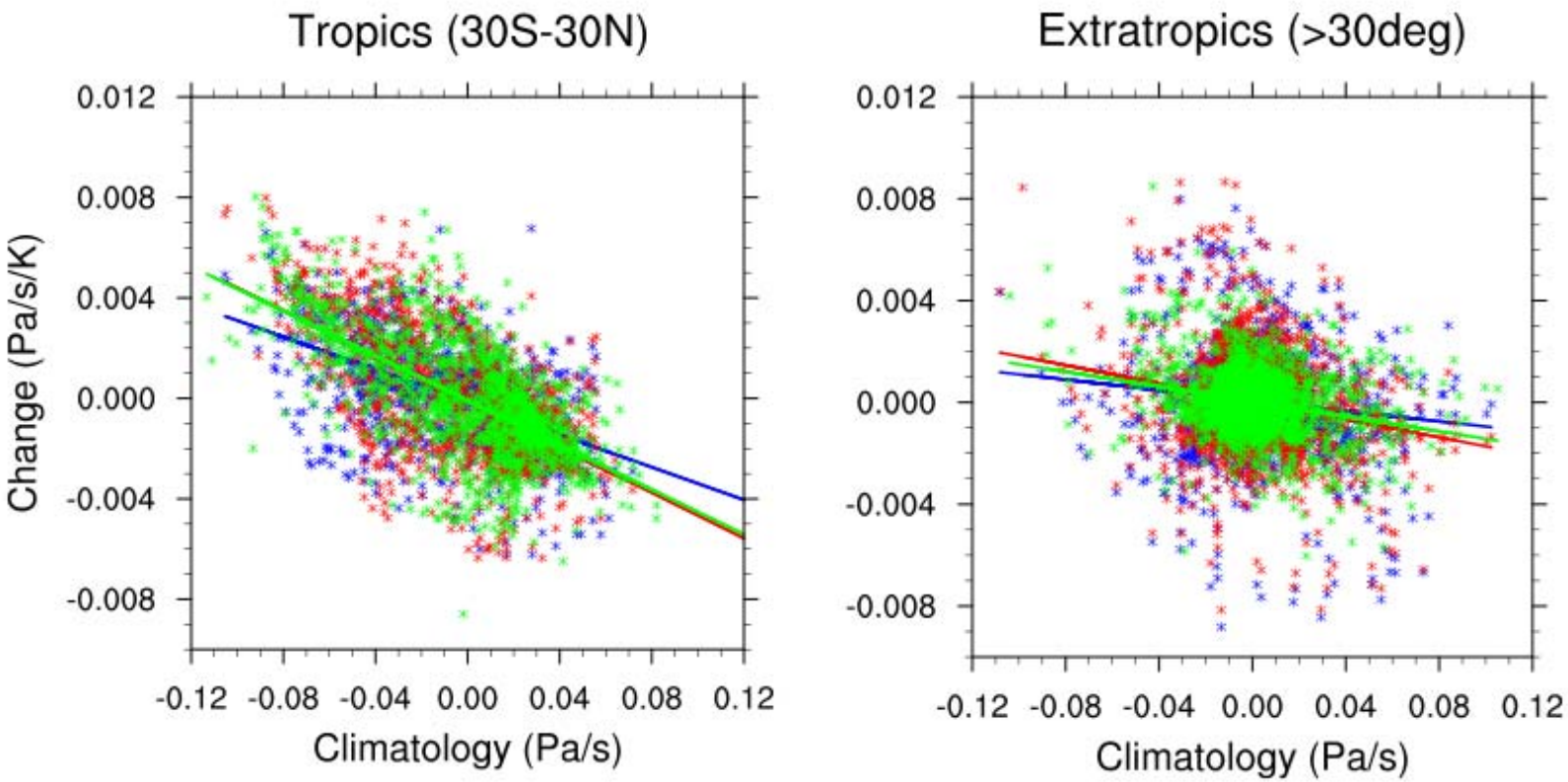
CGCM: Last20yr-First20yr

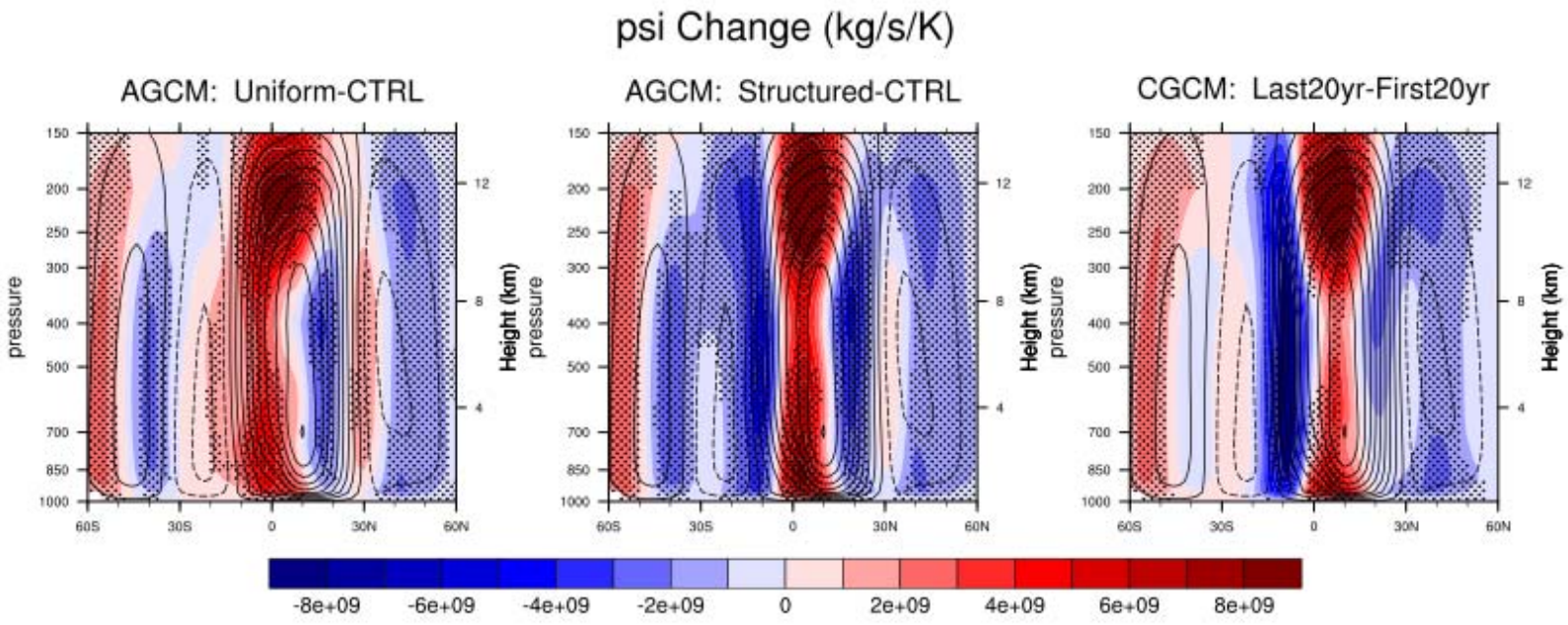




RWS (1/s2/K)


AGCM: Uniform-CTRL
60°N
30°N
0
30°S
60°S
0
60°E
120°E
240°E
300°E
360°E
AGCM: Structured-CTRL
60°N
30°N
0
30°S
60°S
0
60°E
120°E
240°E
300°E
360°E
CGCM: Last20yr-First20yr
60°N
30°N
0
30°S
60°S
0
60°E
120°E
240°E
300°E
360°E
-2.8e-11
-1.8e-11
-8e-12
2e-12
1.2e-11
2.2e-11

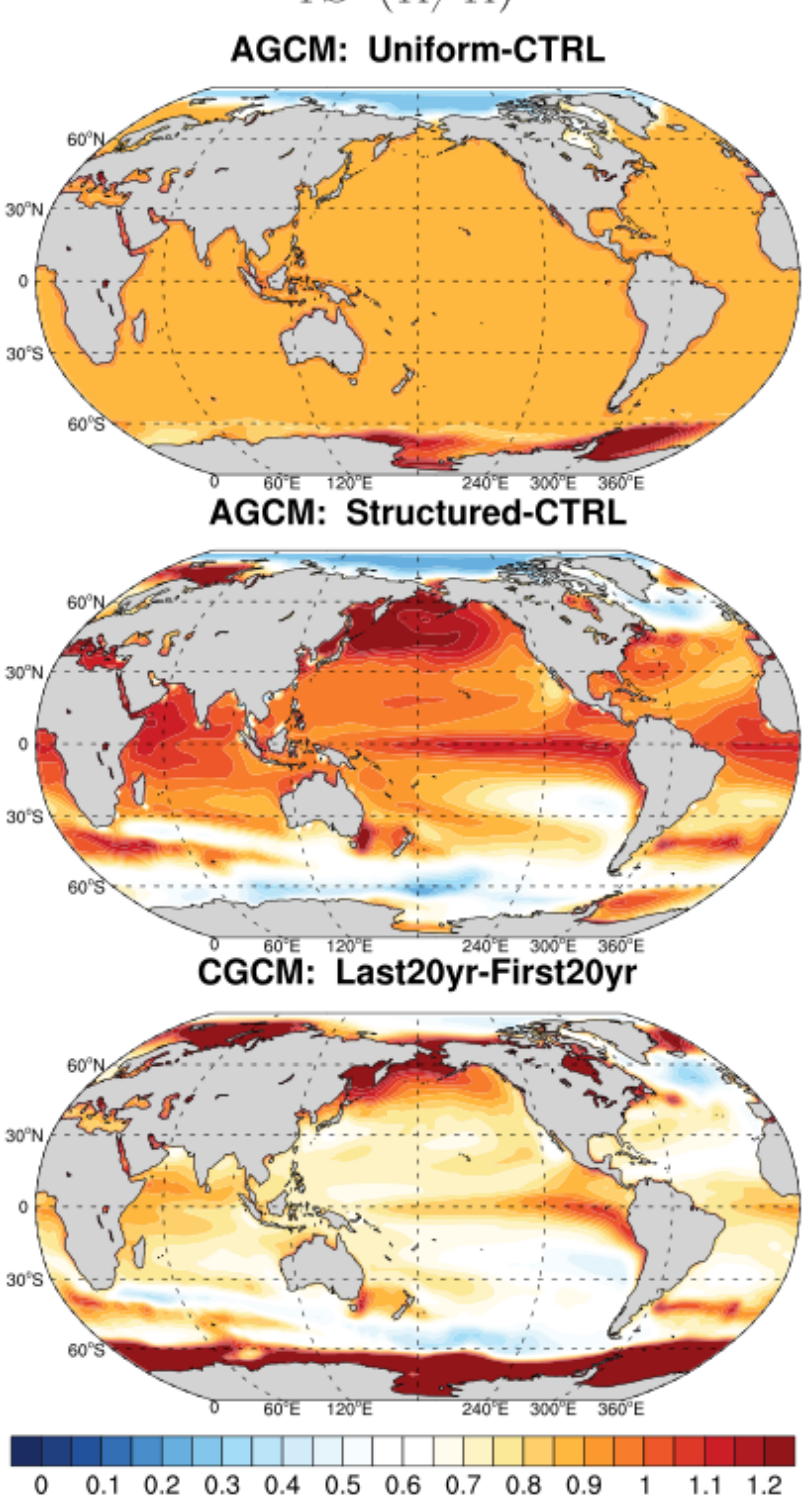

Tropics (30S-30N)
Extratropics (>30deg)
Change (Pa/s/K)
Climatology (Pa/s)
Climatology (Pa/s)
0.012
0.008
0.004
0.000
-0.004
-0.008
-0.12
-0.08
-0.04
0.00
0.04
0.08
0.12


psi Change (kg/s/K)
AGCM: Uniform-CTRL
AGCM: Structured-CTRL
CGCM: Last20yr-First20yr
pressure
Height (km)
150
200
250
300
400
500
700
850
1000
12
8
4
60S
30S
0
30N
60N
-8e+09
-6e+09
-4e+09
-2e+09
0
2e+09
4e+09
6e+09
8e+09

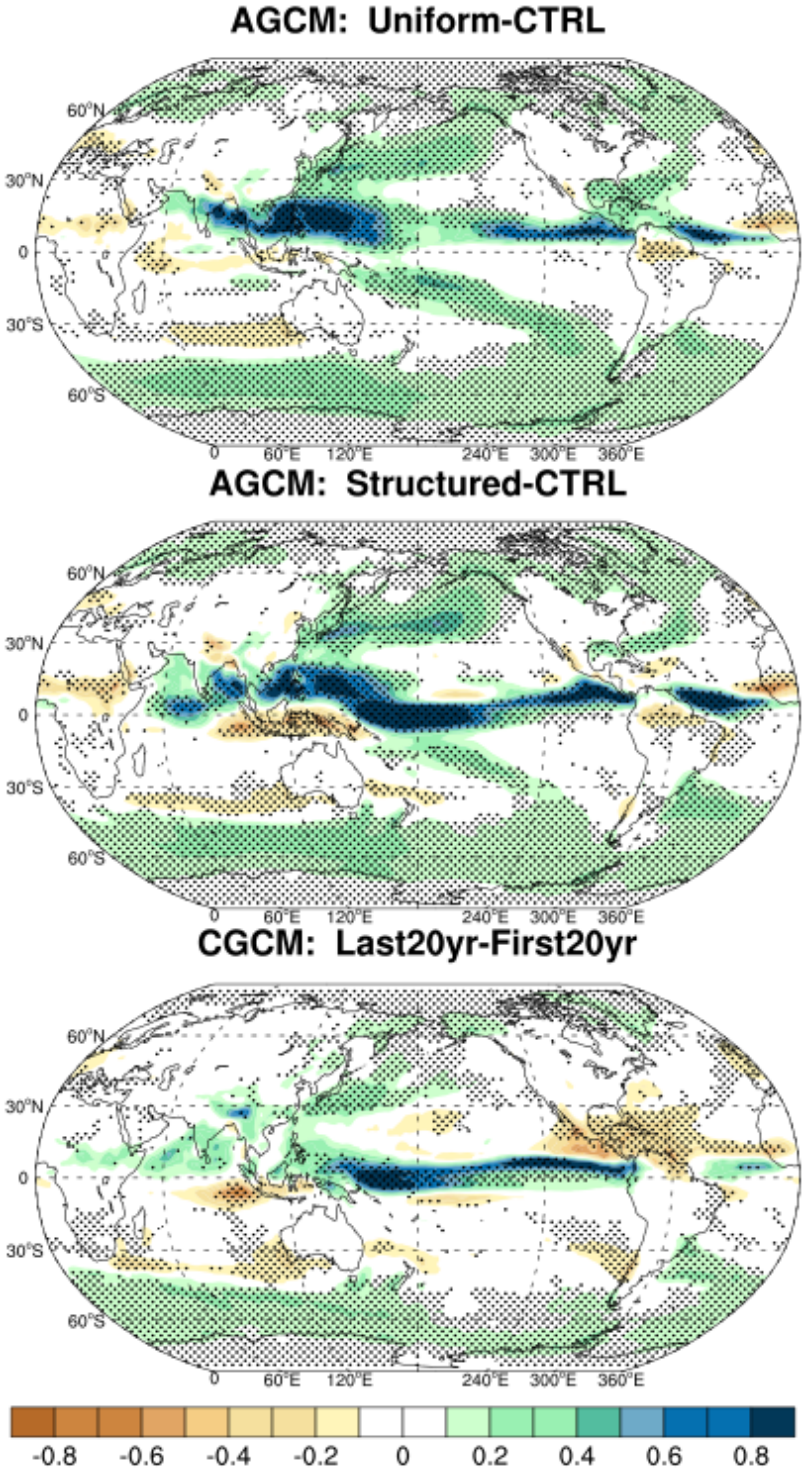
GRL paper figures

JJA

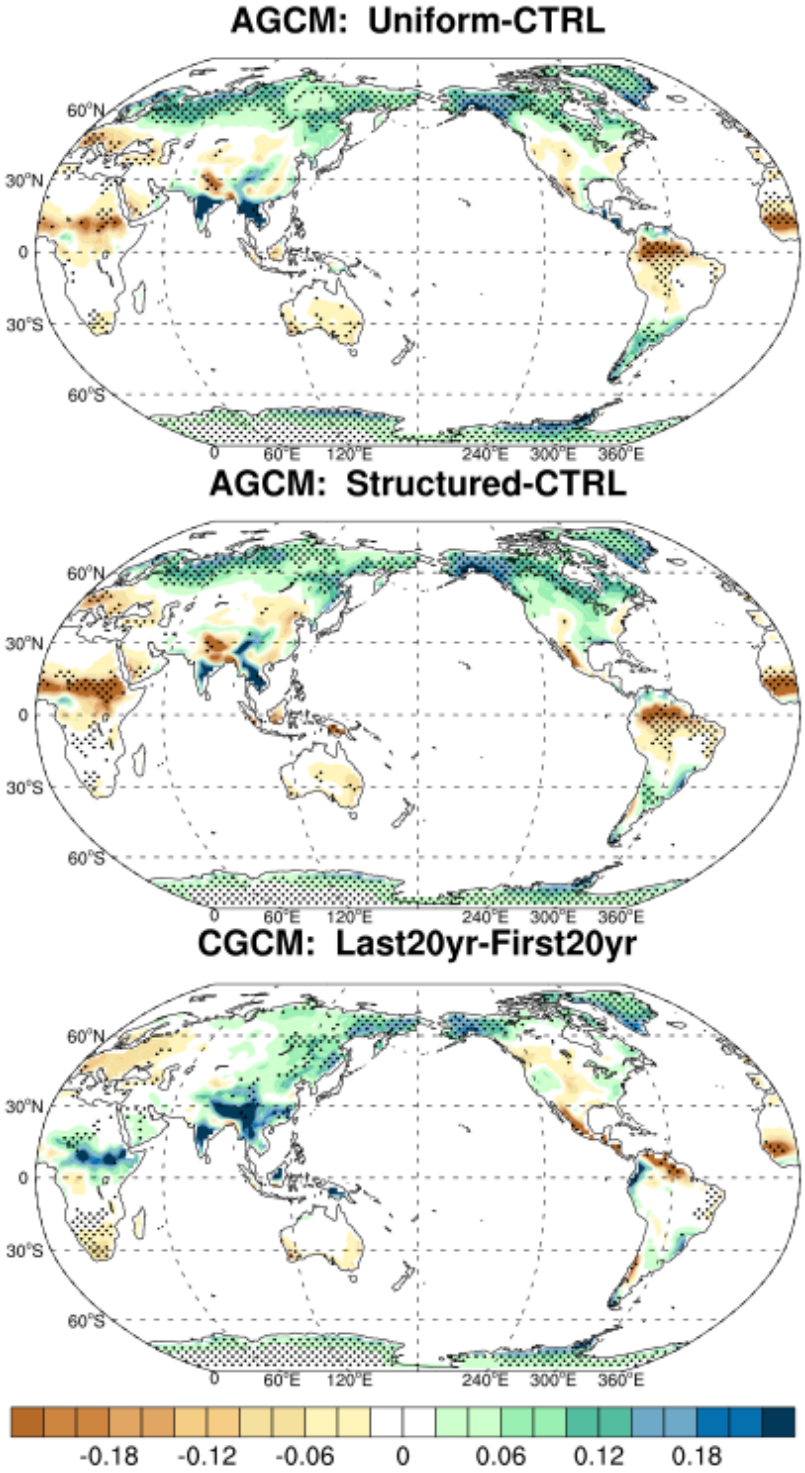
TS (K/K)


AGCM: Uniform-CTRL
AGCM: Structured-CTRL
CGCM: Last20yr-First20yr
60°N
30°N
0
30°S
60°S
0
60°E
120°E
240°E
300°E
360°E
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1 1.1 1.2

Precip (mm/day/K)

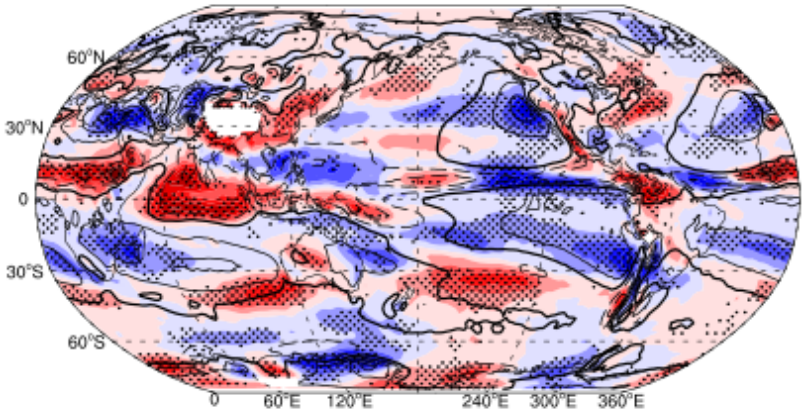


Precip (mm/day/K)

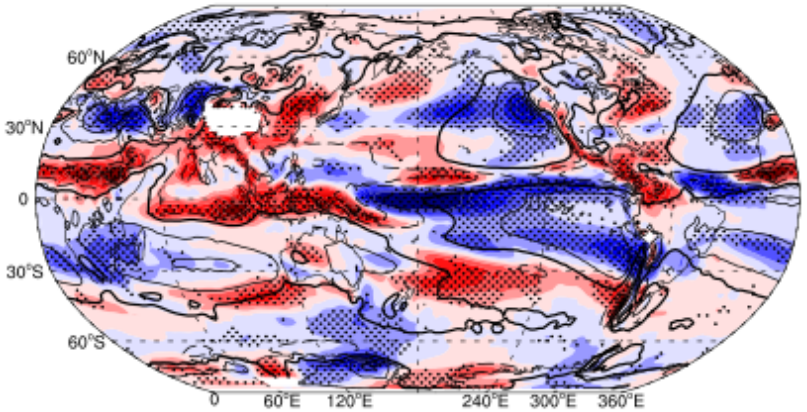


ω500 (Pa/s/K)

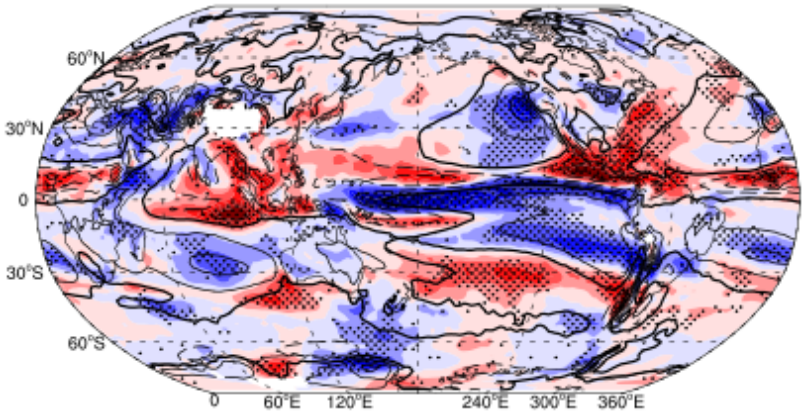
AGCM: Uniform-CTRL

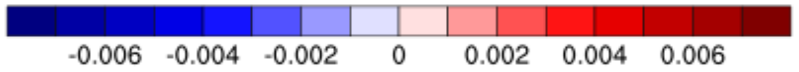


AGCM: Structured-CTRL

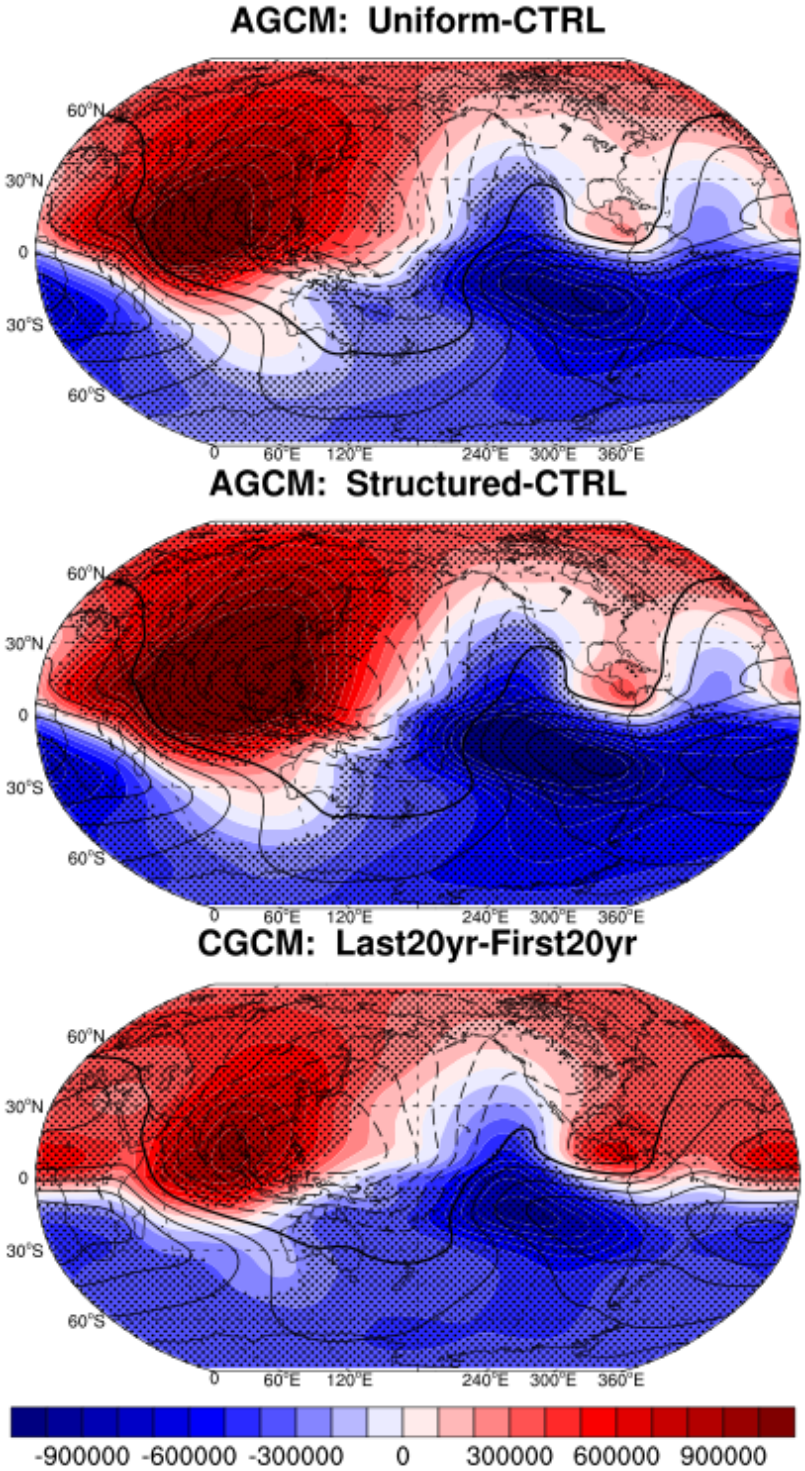


CGCM: Last20yr-First20yr



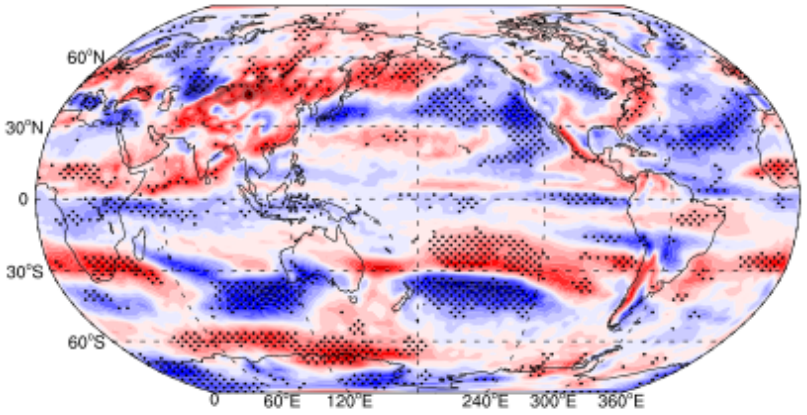


VP250 (m2/s/K)

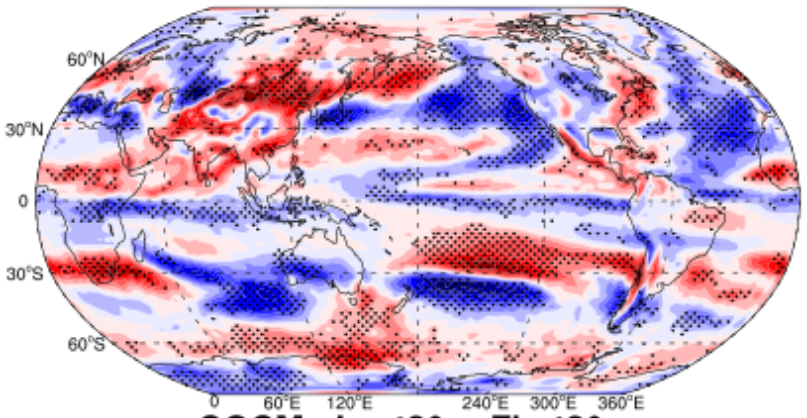

AGCM: Uniform-CTRL
AGCM: Structured-CTRL
CGCM: Last20yr-First20yr
60°N
30°N
0
30°S
60°S
0
60°E
120°E
240°E
300°E
360°E
-900000
-600000
-300000
0
300000
600000
900000

RWS (1/s2/K)

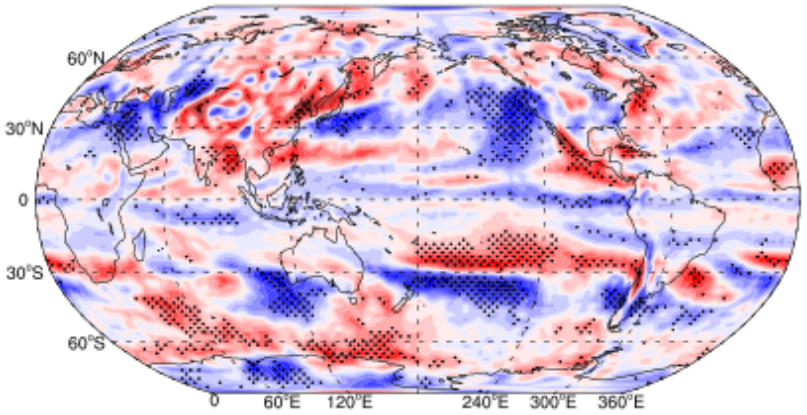
AGCM: Uniform-CTRL

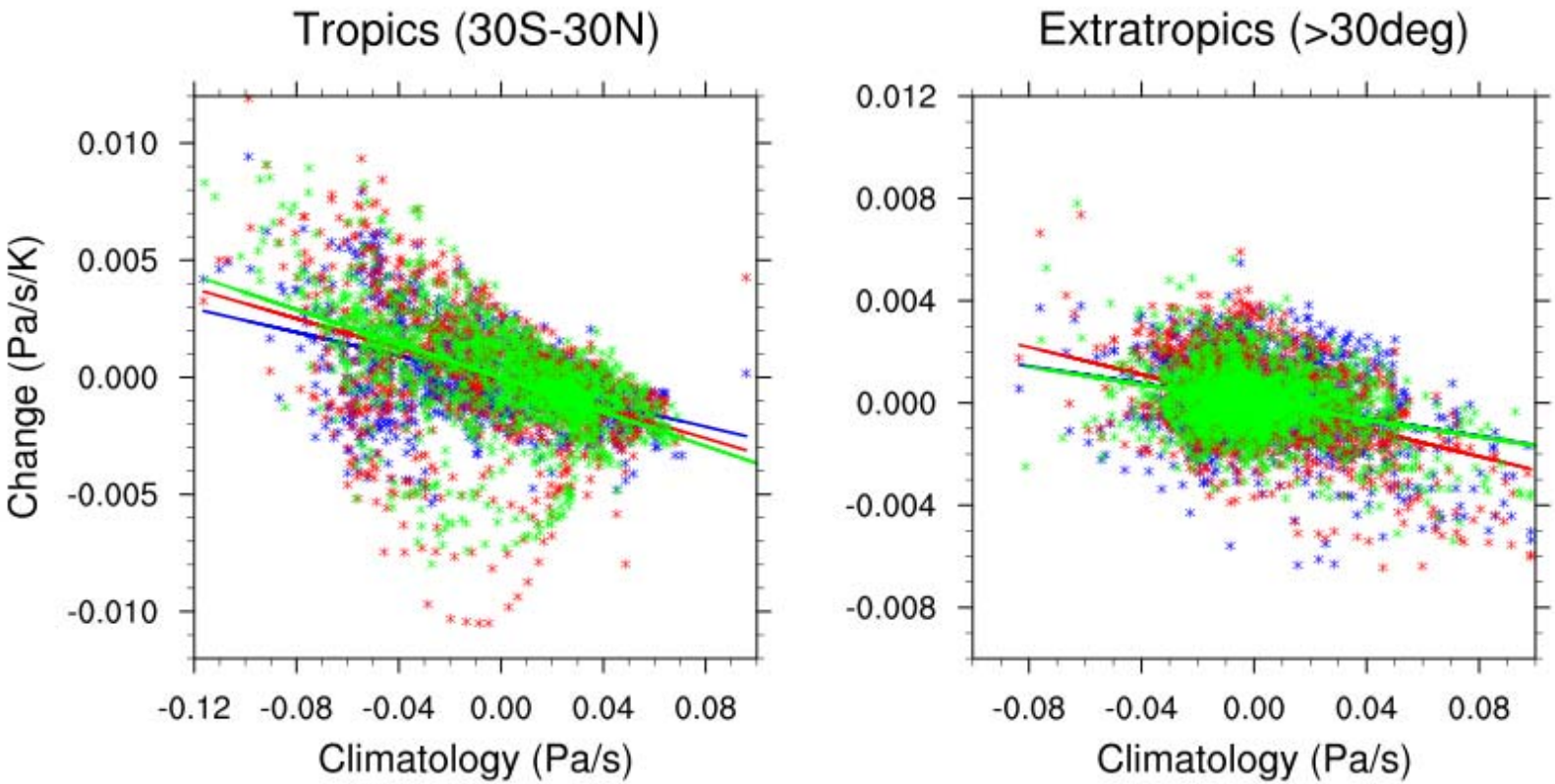


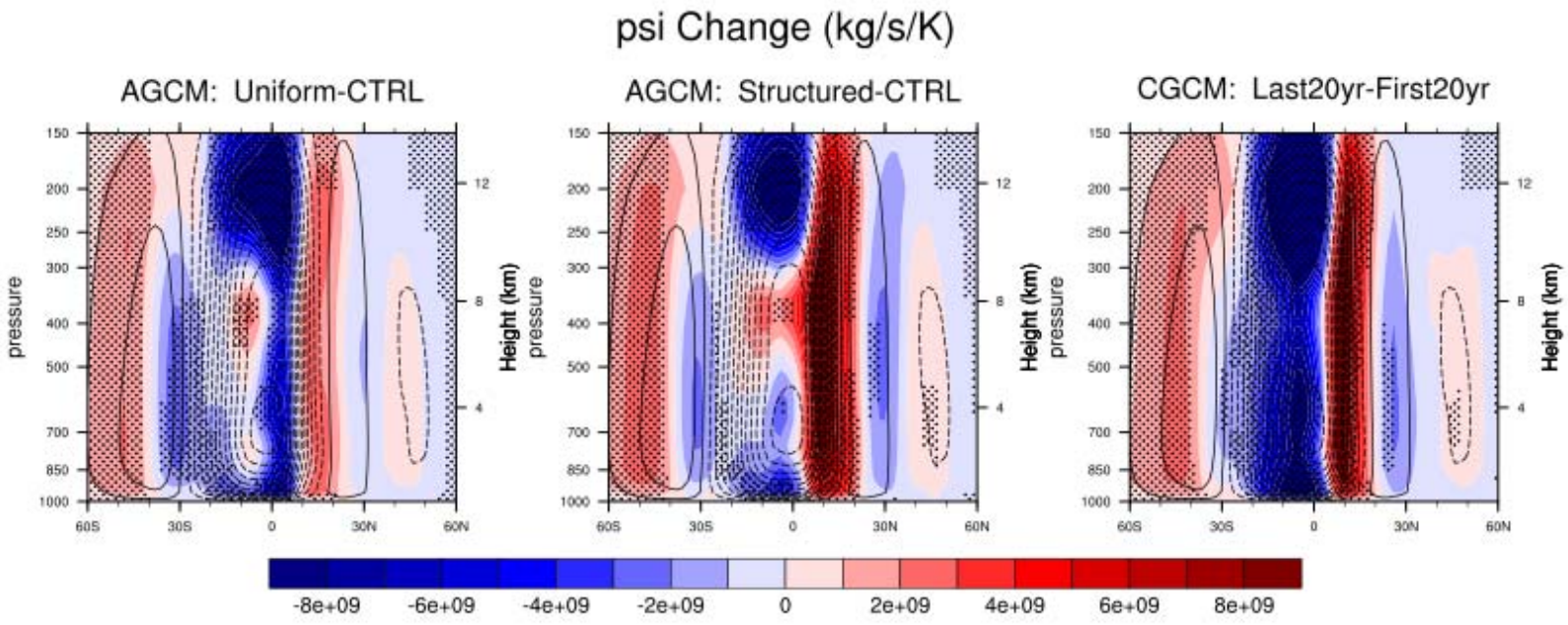
AGCM: Structured-CTRL



CGCM: Last20yr-First20yr




Tropics (30S-30N)
Extratropics (>30deg)
Change (Pa/s/K)
Climatology (Pa/s)
Climatology (Pa/s)
0.010
0.005
0.000
-0.005
-0.010
0.012
0.008
0.004
0.000
-0.004
-0.008
-0.12
-0.08
-0.04
0.00
0.04
0.08
-0.08
-0.04
0.00
0.04
0.08


psi Change (kg/s/K)
AGCM: Uniform-CTRL
AGCM: Structured-CTRL
CGCM: Last20yr-First20yr
pressure
Height (km)
150
200
250
300
400
500
700
850
1000
12
8
4
60S
30S
0
30N
60N
-8e+09
-6e+09
-4e+09
-2e+09
0
2e+09
4e+09
6e+09
8e+09