INSTITUTE FOR GEOPHYSICS
JACKSON SCHOOL OF GEOSCIENCES
THE UNIVERSITY OF TEXAS AT AUSTIN

Linking Ocean Circulation to Abrupt Climate Change*

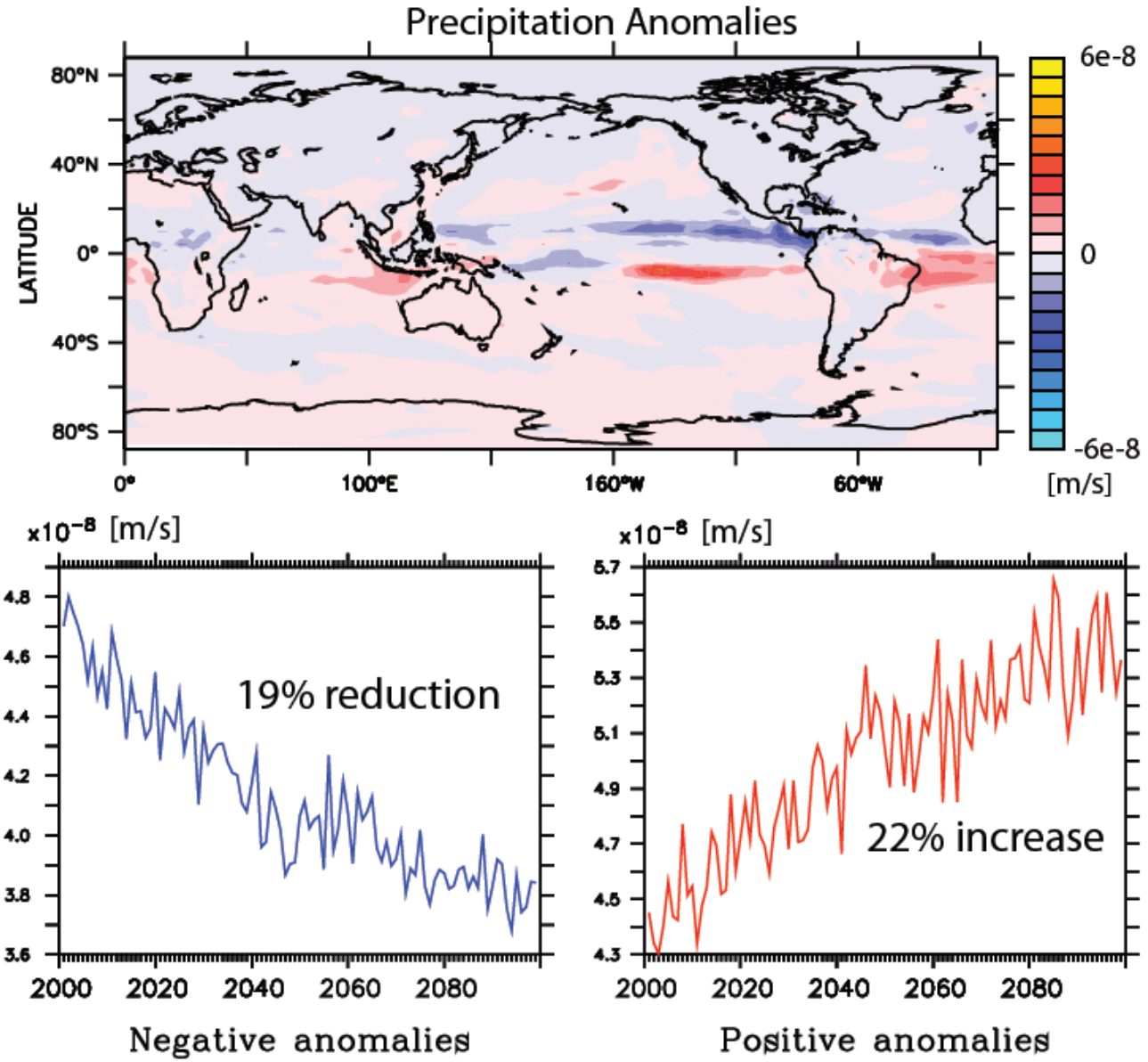
Charles Jackson, University of Texas
Ping Chang, Texas A&M University
Link Ji, Texas A&M University

Climate and Earth System Modeling PI Meeting
September 19 – 22, 2011

*supported by DOE grants DEFG02-08ER64619 and DEFG02-08ER64620

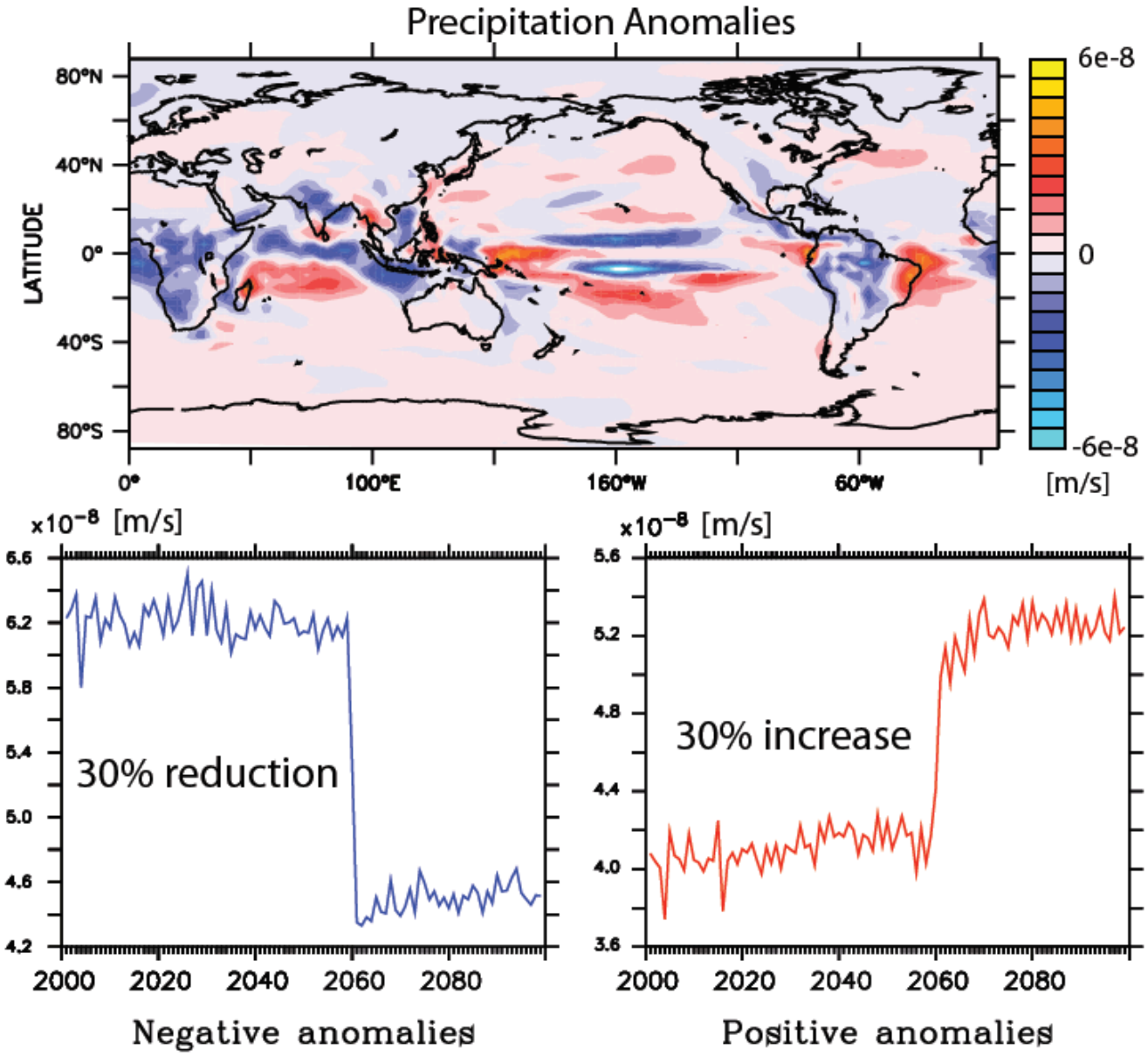
100 year response of CCSM3 to freshening of North Atlantic Ocean

0.4 Sv
Run 2

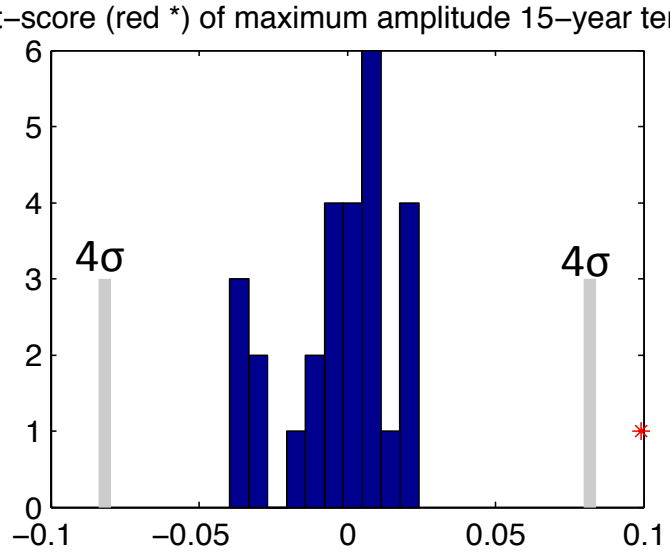


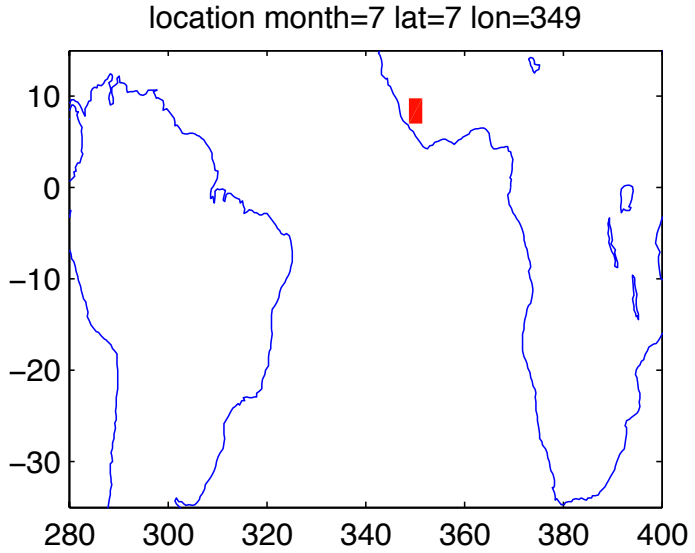
Same experiment, different initial conditions

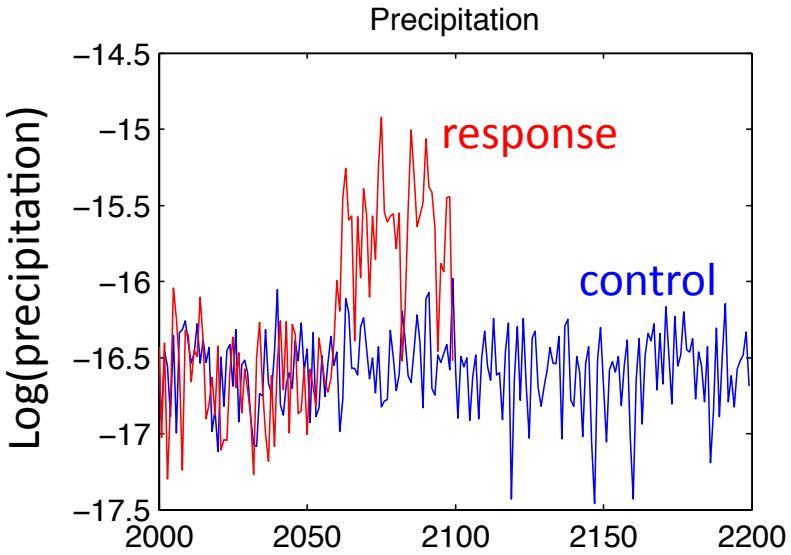
0.4 Sv
Run 1

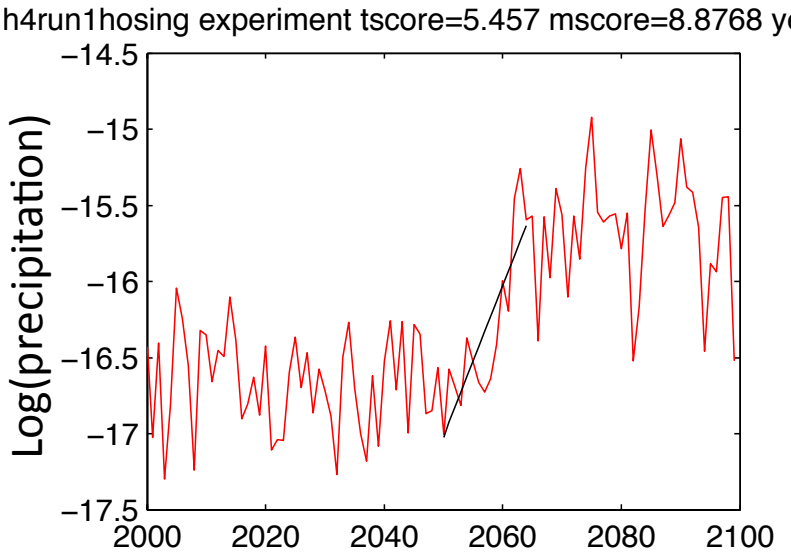


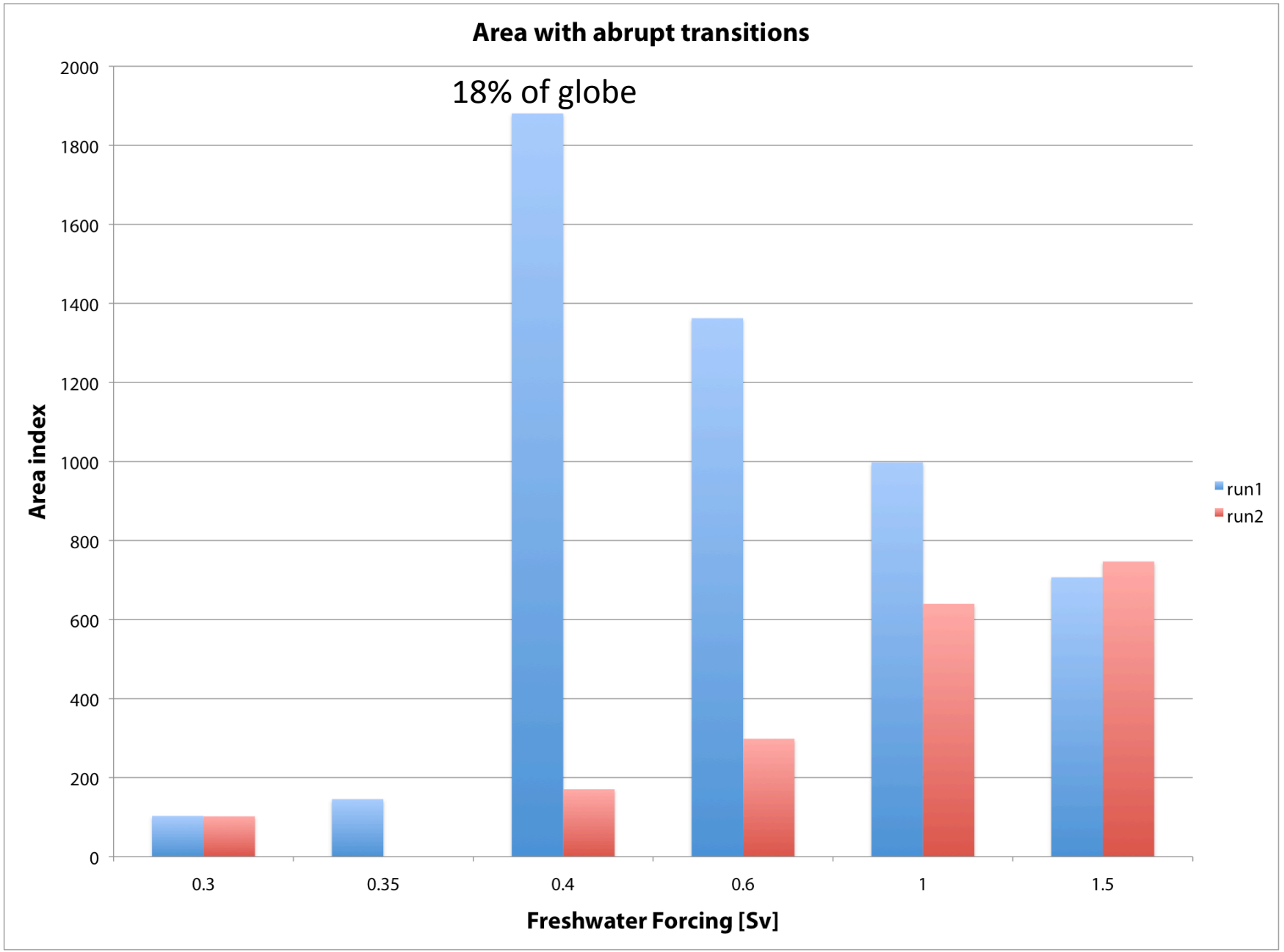
T-test for abrupt transitions

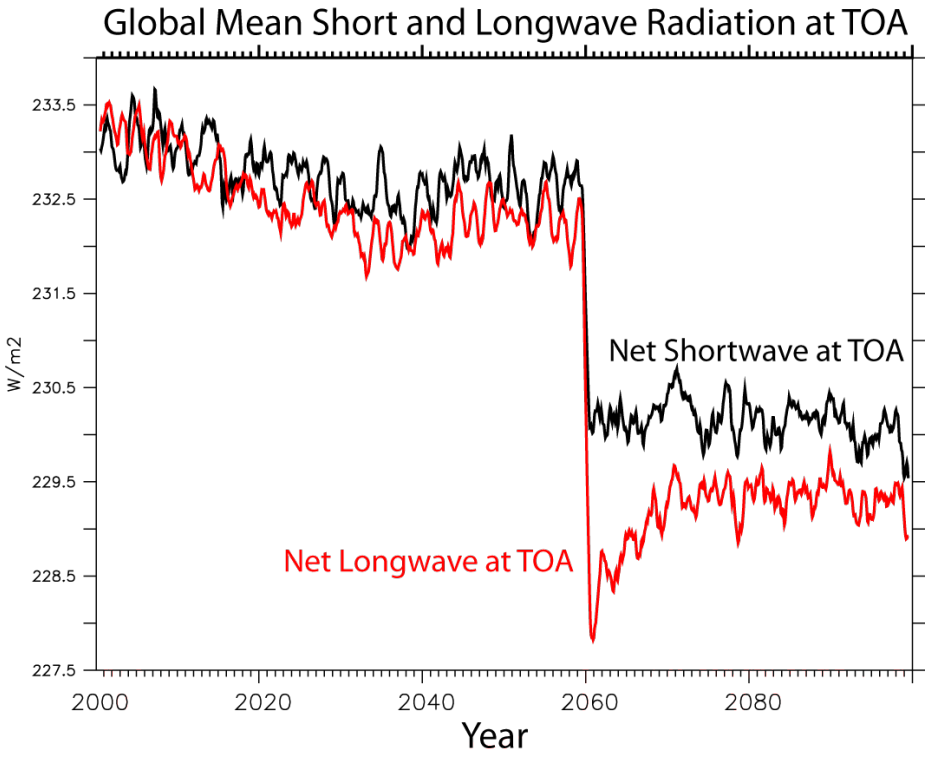


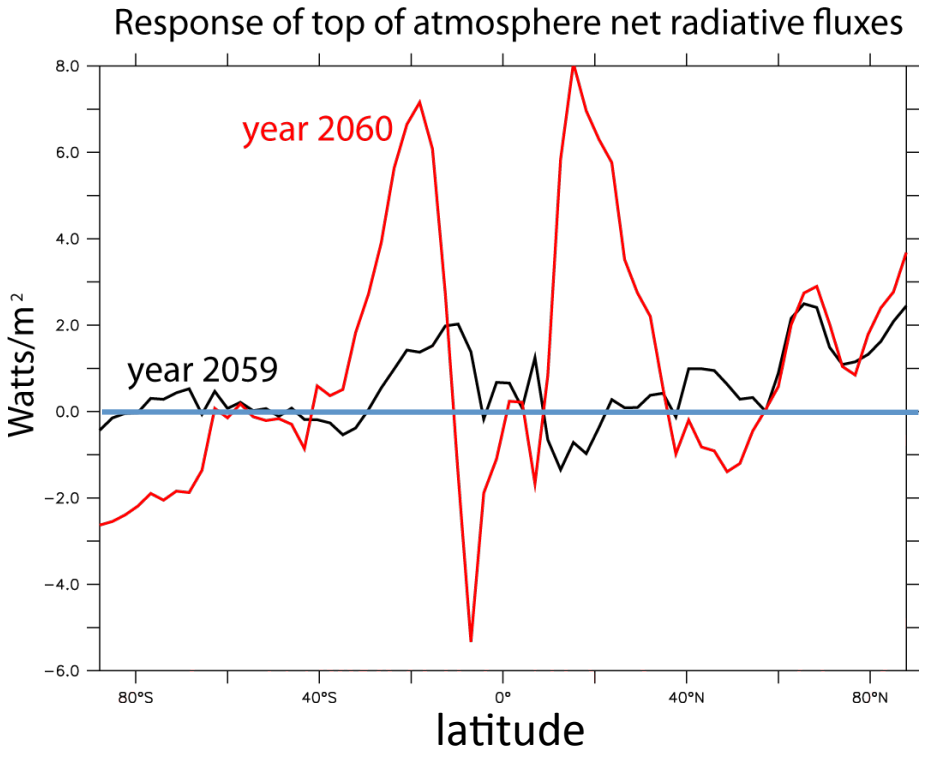







Area with abrupt transitions
18% of globe
2000
1800
1600
1400
1200
1000
800
600
400
200
0
Area index
0.3
0.35
0.4
0.6
1
1.5
Freshwater Forcing [Sv]
run1
run2



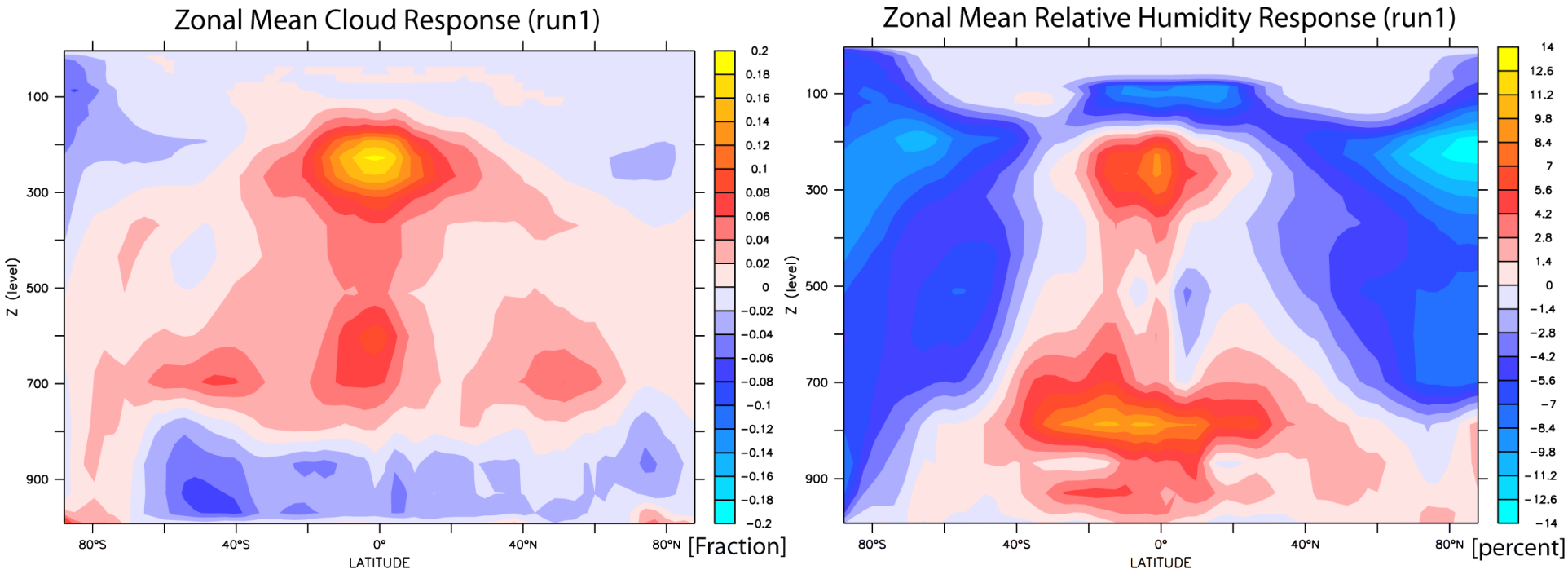


At transition:

-2.5 Watt increase (i.e. cooling) in shortwave cloud forcing

3.5 Watt increase (i.e. warming) in longwave cloud forcing

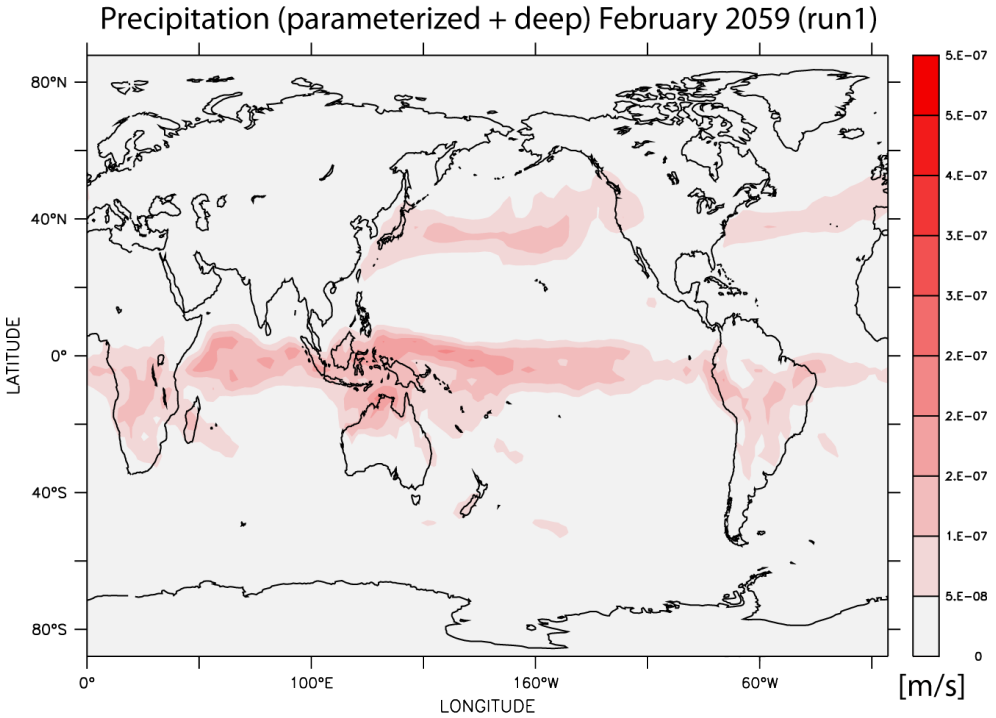
0.7 degree increase in global mean temperature



Structural changes occur because of a large increase in deep convection.

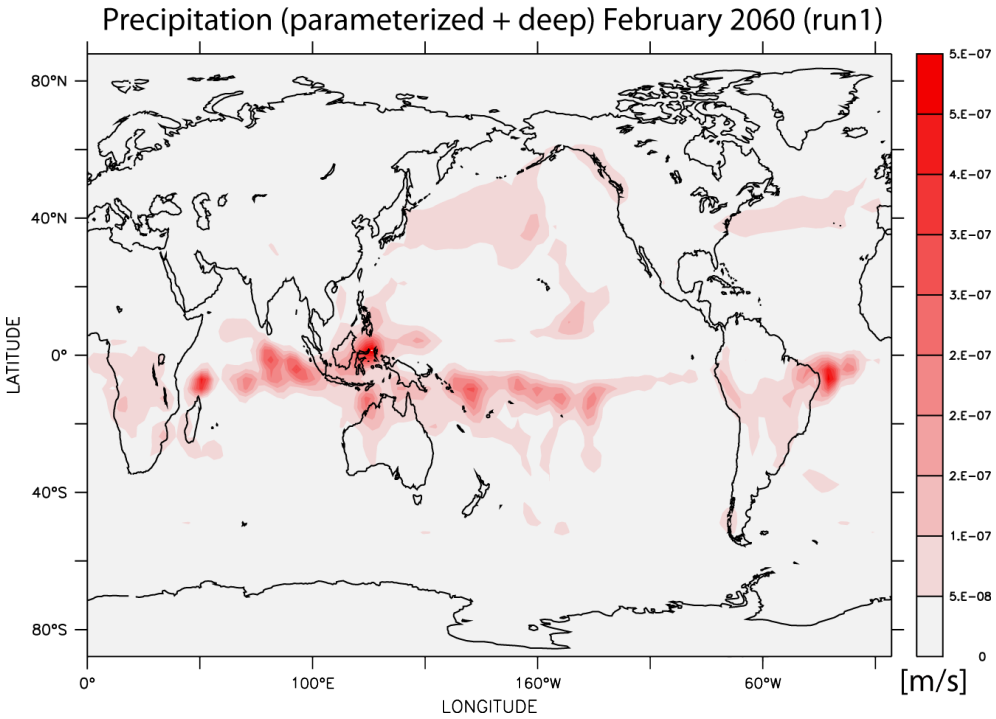
February 2059 and before:

4.5% of tropical precipitation is large-scale.



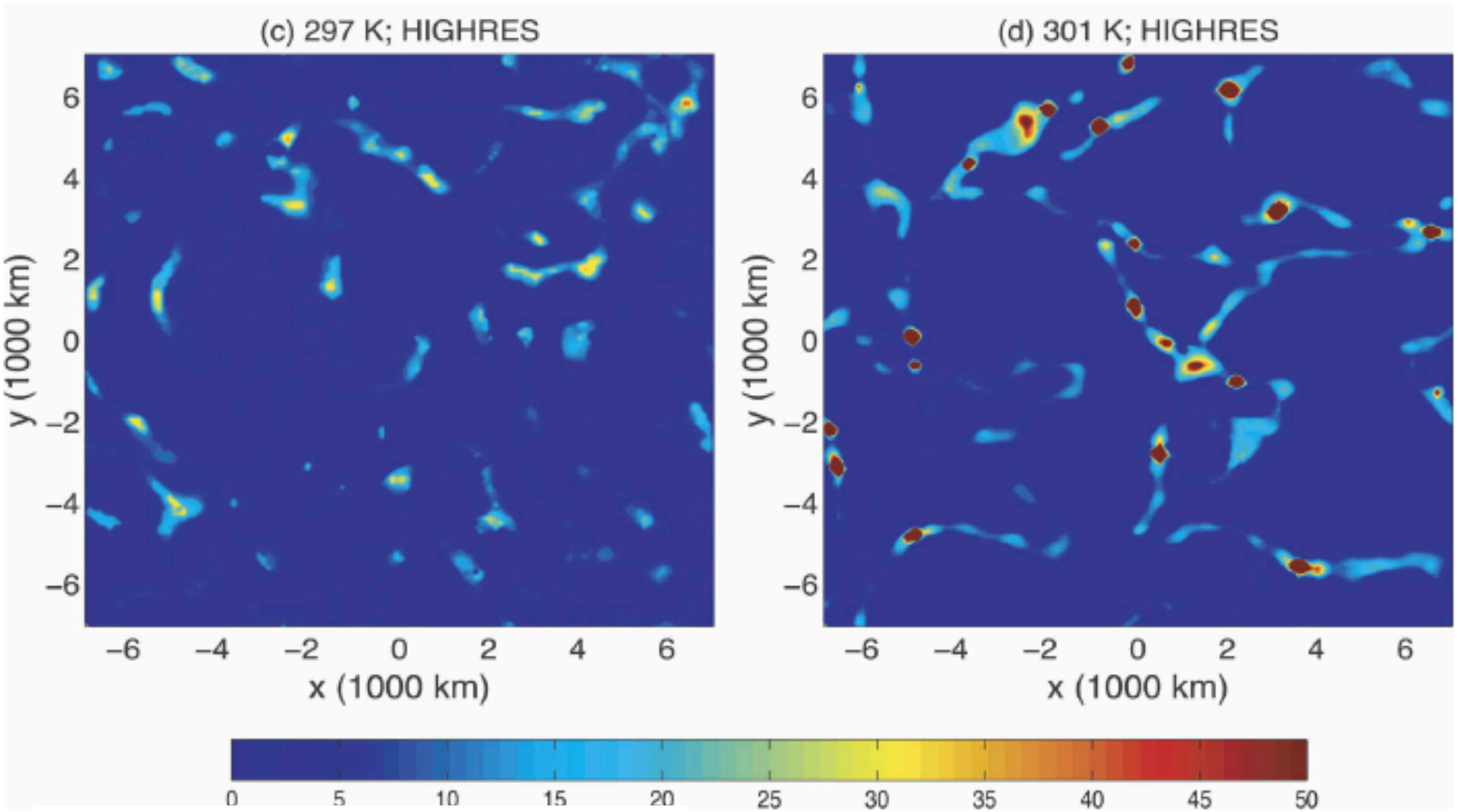
February 2060 and after:

12.5% of tropical precipitation is large-scale.

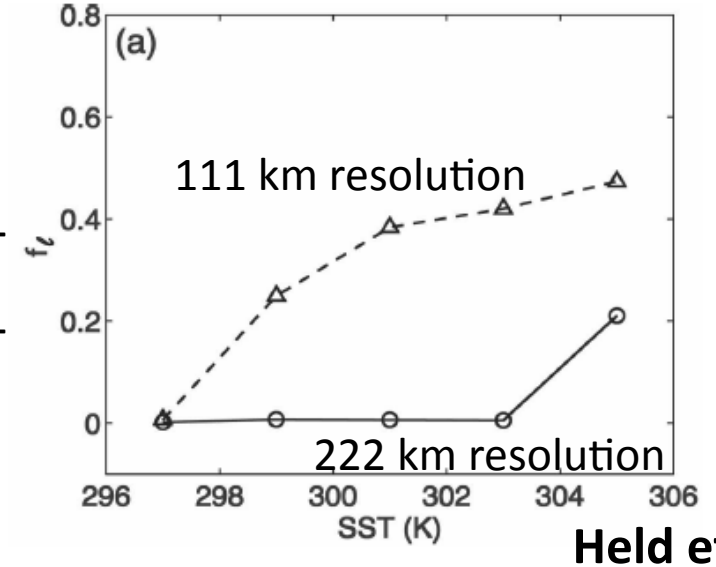


Convection multiple equilibria

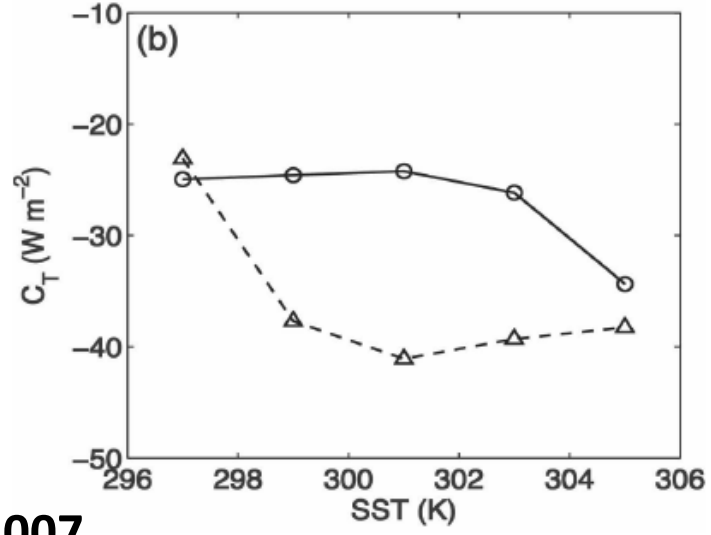
- Held et al. 2007 “Dynamic Radiative-Convective Equilibria Using GCM Column Physics” J. Atmos. Sci.
- Sobel et al., 2007 “Multiple equilibria in a single-column model of the tropical atmosphere” GRL
- Sessions et al., 2010 “Multiple equilibria in a cloud-resolving model using the weak temperature gradient approximation” JGR



Large-scale Fraction of precipitation



Cloud radiative forcing

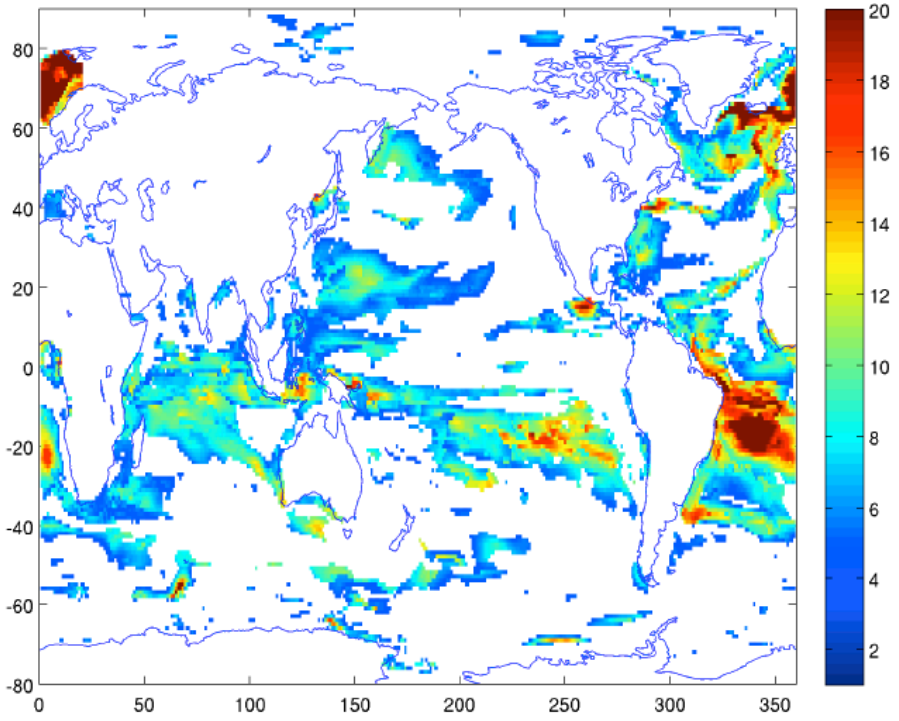


Held et al, JAS, 2007

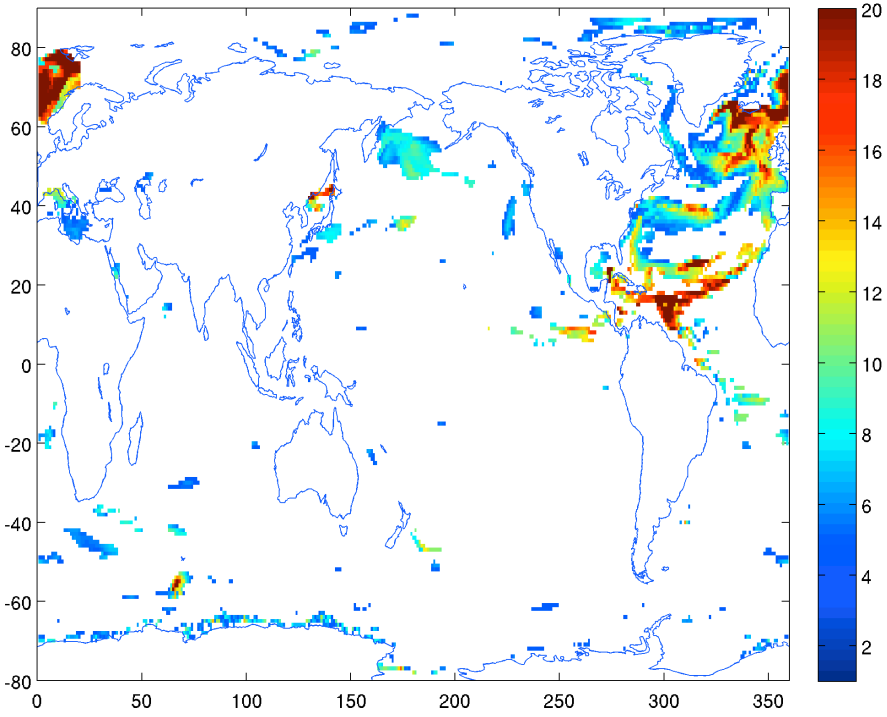
Evidence supporting tropical Atlantic trigger/memory

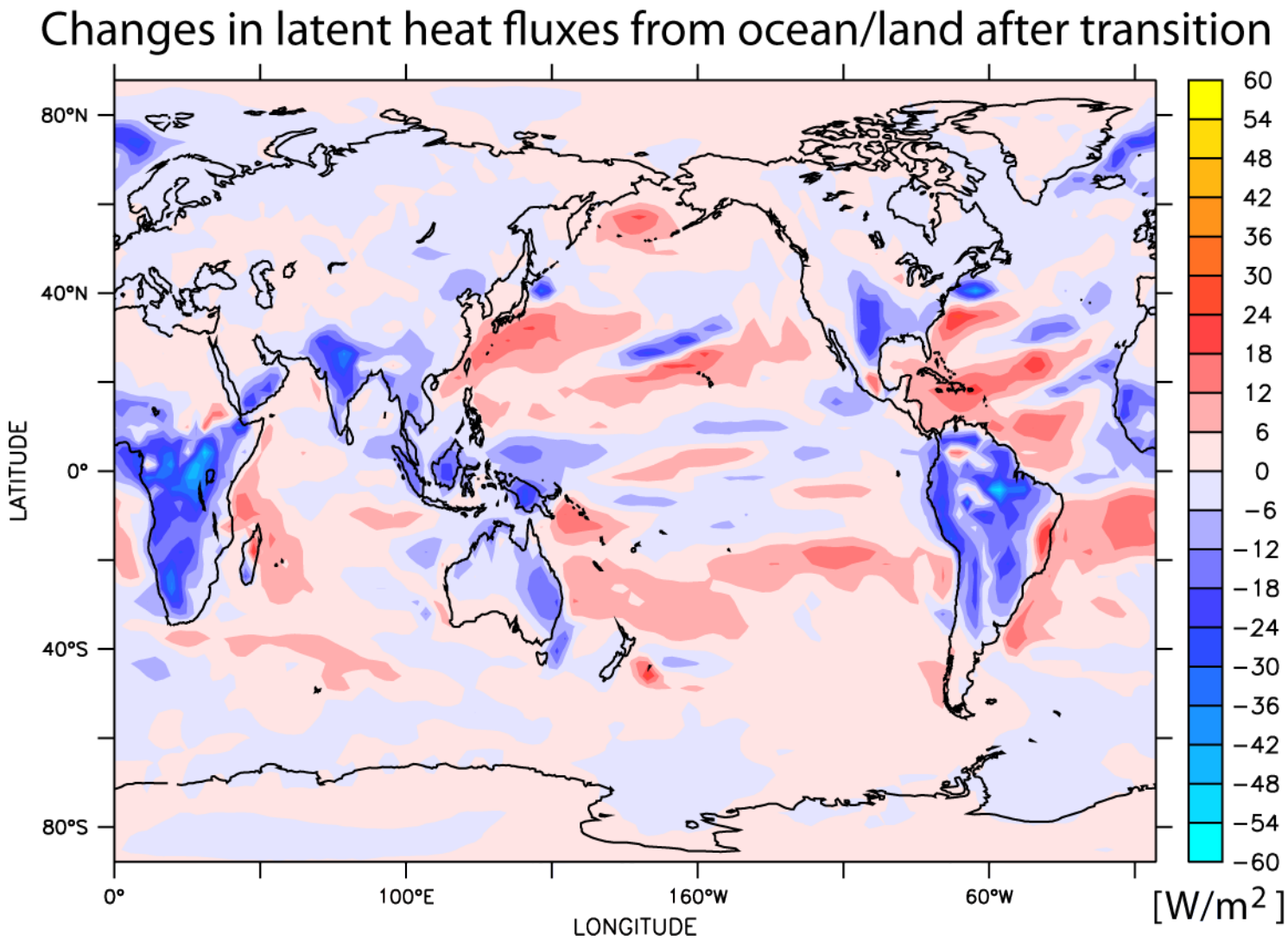
Significance test for changes in ocean surface temperature
[units: standard deviation of the control SST]

Run 1

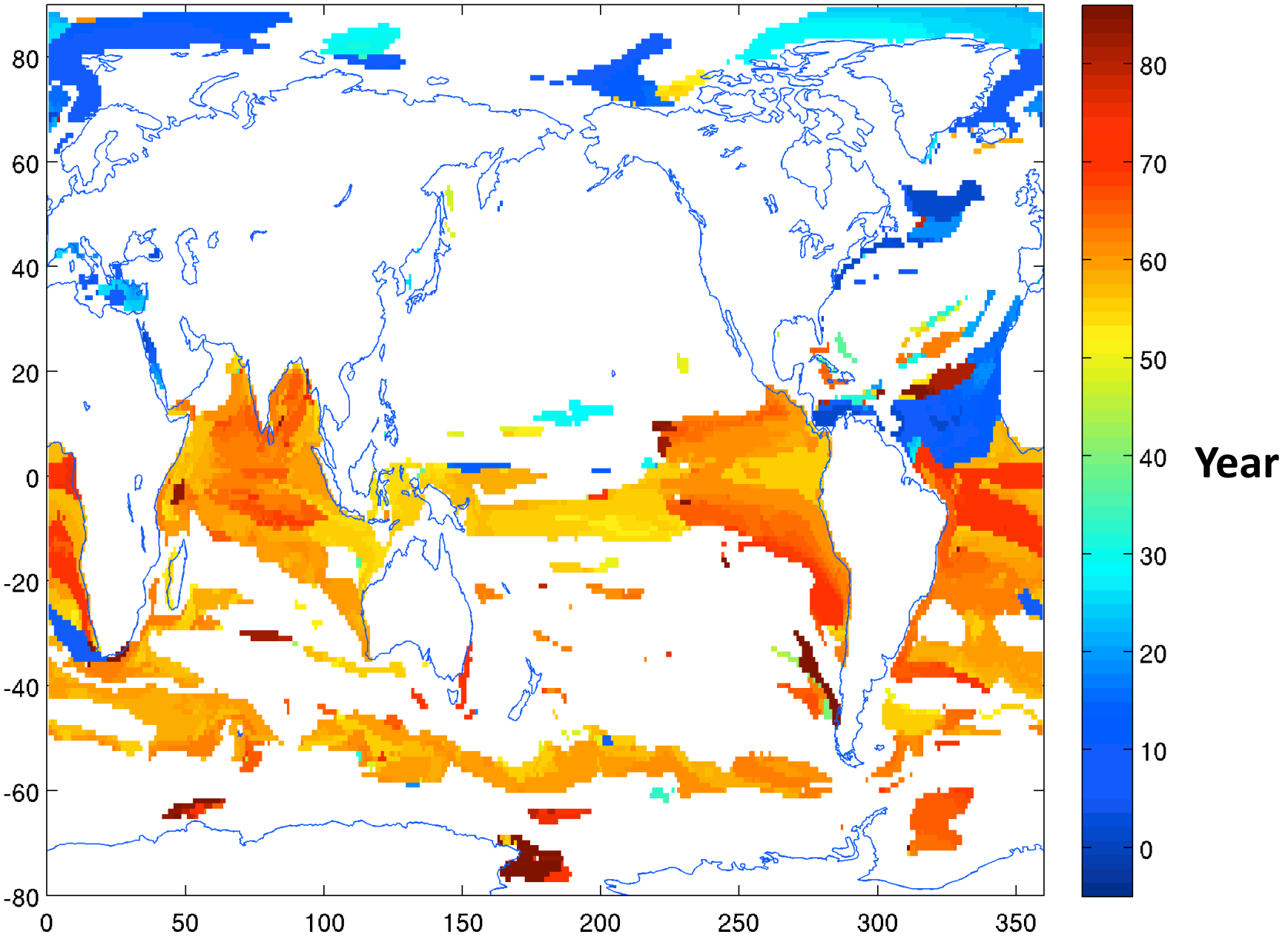


Run 2

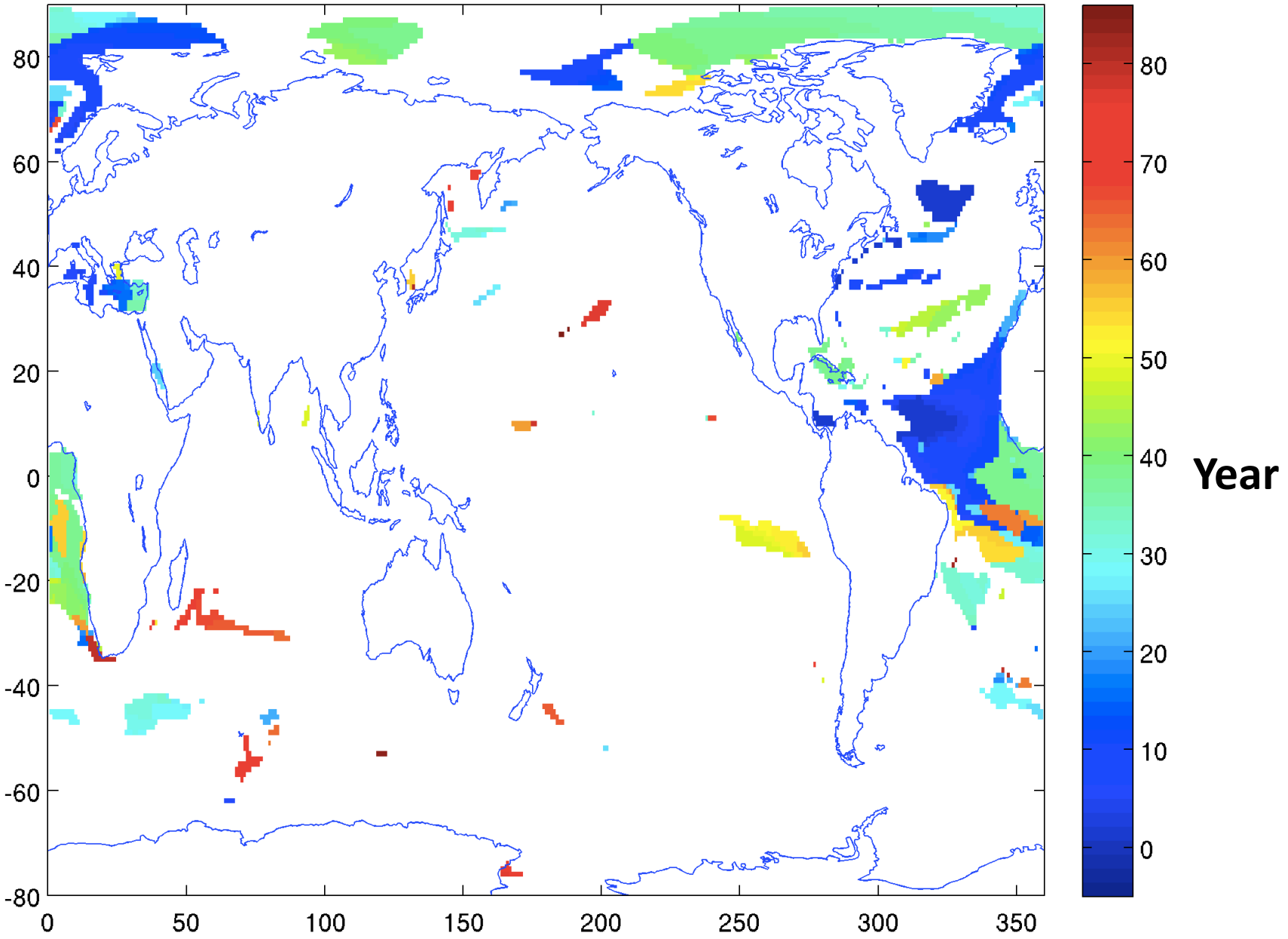


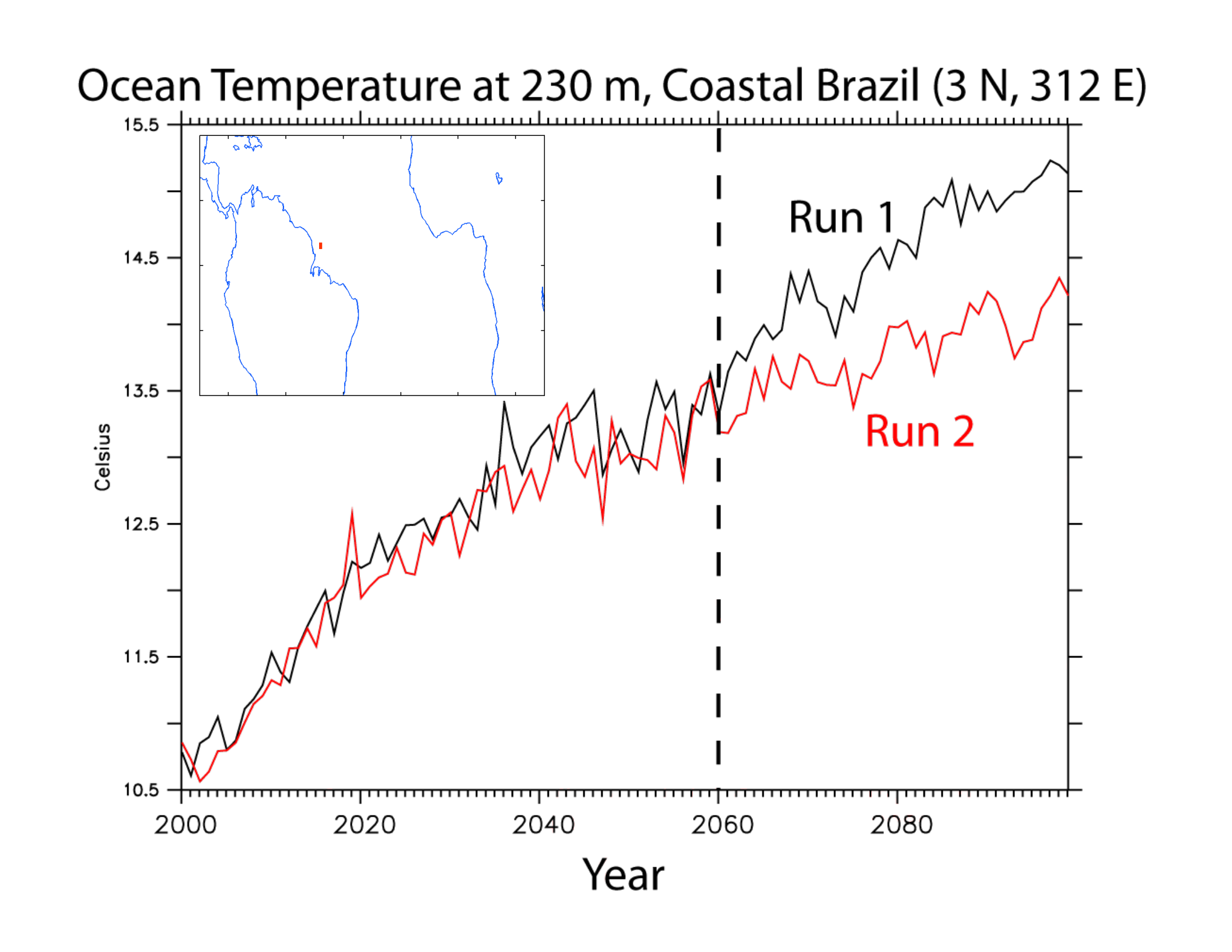

Changes in latent heat fluxes from ocean/land after transition
80°N
40°N
0°
40°S
80°S
LATITUDE
0°
100°E
160°W
60°W
LONGITUDE
60
54
48
42
36
30
24
18
12
6
0
−6
−12
−18
−24
−30
−36
−42
−48
−54
−60
[W/m2]

Run 1 year of abrupt transition in ocean heating/cooling rates at 230 m depth



Run 2 year of abrupt transition in ocean heating/cooling rates at 230 m depth




Ocean Temperature at 230 m, Coastal Brazil (3 N, 312 E)
15.5
14.5
13.5
12.5
11.5
10.5
Celsius
Run 1
Run 2
2000
2020
2040
2060
2080
Year

Summary

- Rapid transition to a new global climate state is identified when North Atlantic freshening reaches a certain threshold (0.4 Sv).
- Transition is sensitive to initial state of the ocean.
- Transition is very rapid (< 1 month), suggesting that main transitional dynamics is in the atmosphere.
- Precise trigger has not been identified, but preliminary analysis suggests that substantial warming in the tropical Atlantic is likely to be the major player.