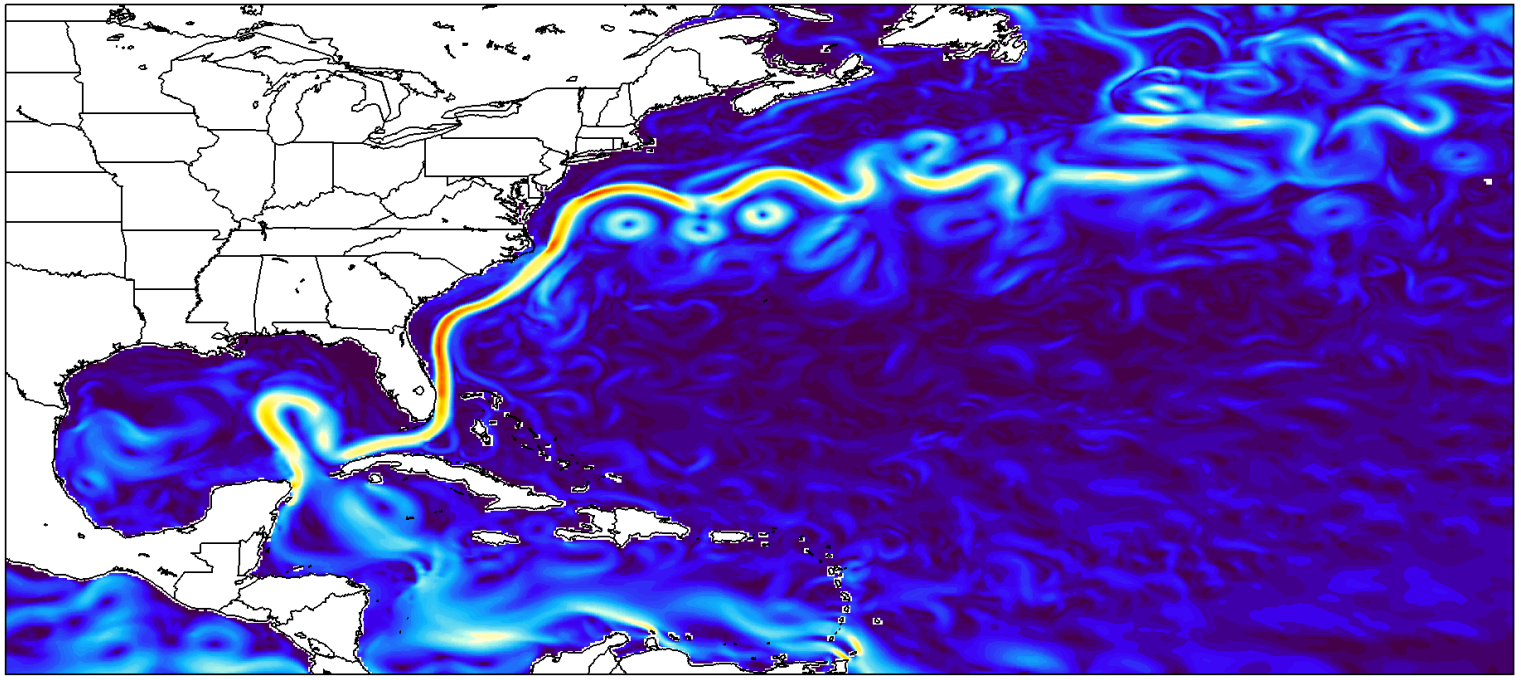
UNIVERSITY
OF MIAMI
ROSENSTIEL
SCHOOL of MARINE &
ATMOSPHERIC SCIENCE

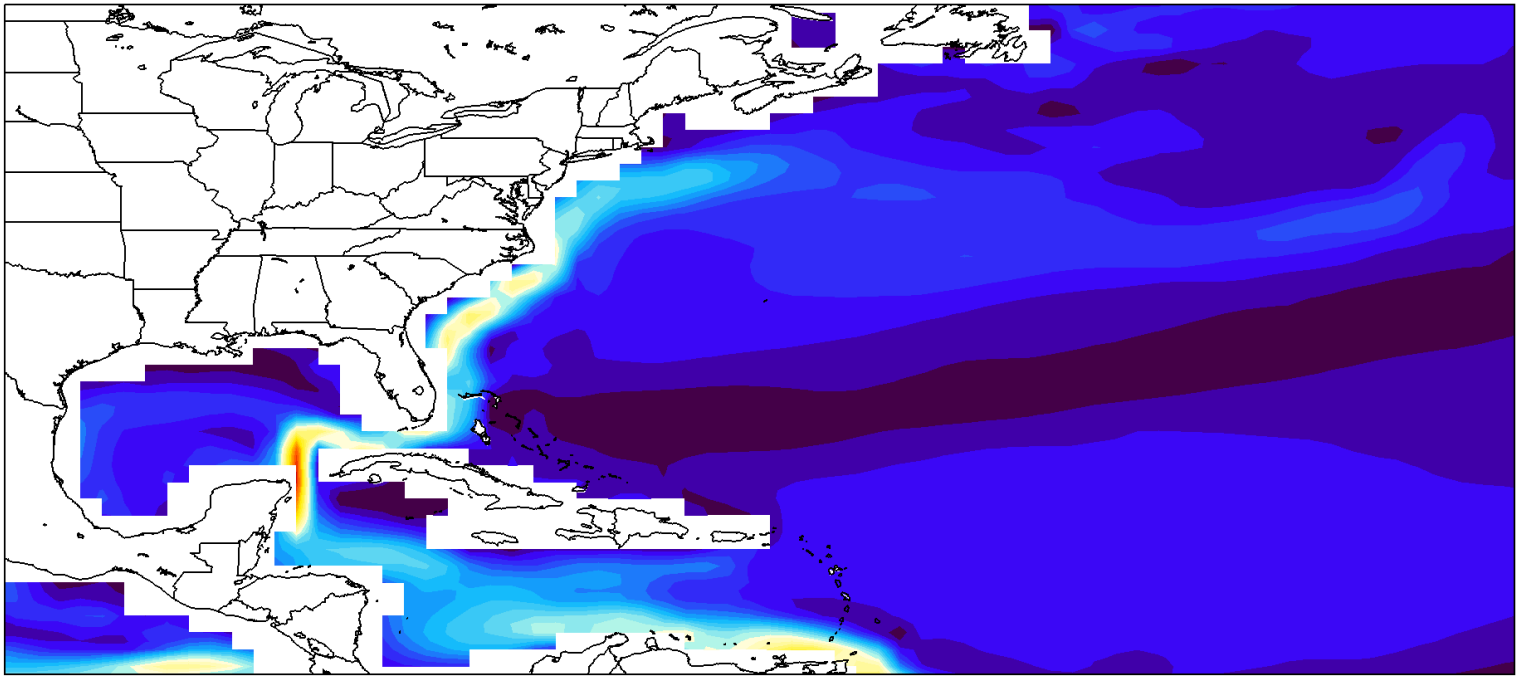
CCS | CENTER FOR COMPUTATIONAL SCIENCE
UNIVERSITY OF MIAMI

Impact of Ocean Model Resolution on CCSM4 Simulations



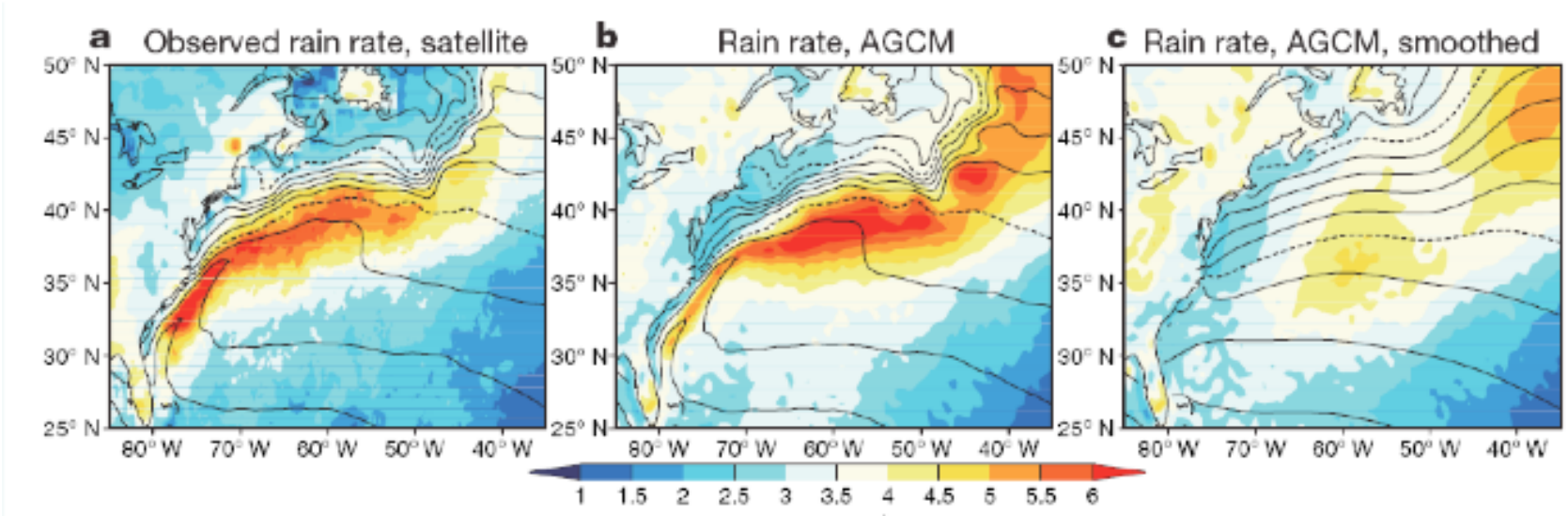
“Peta-Apps”-Team

Ben P. Kirtman, Cecilia Bitz, Frank Bryan, William Collins, John Dennis, Nathan Hearn, James L. Kinter III, Richard Loft, Clem Rousset, Ben Shaw, Leo Siqueira, Cristiana Stan, Robert Tomas and Mariana Vertenstein



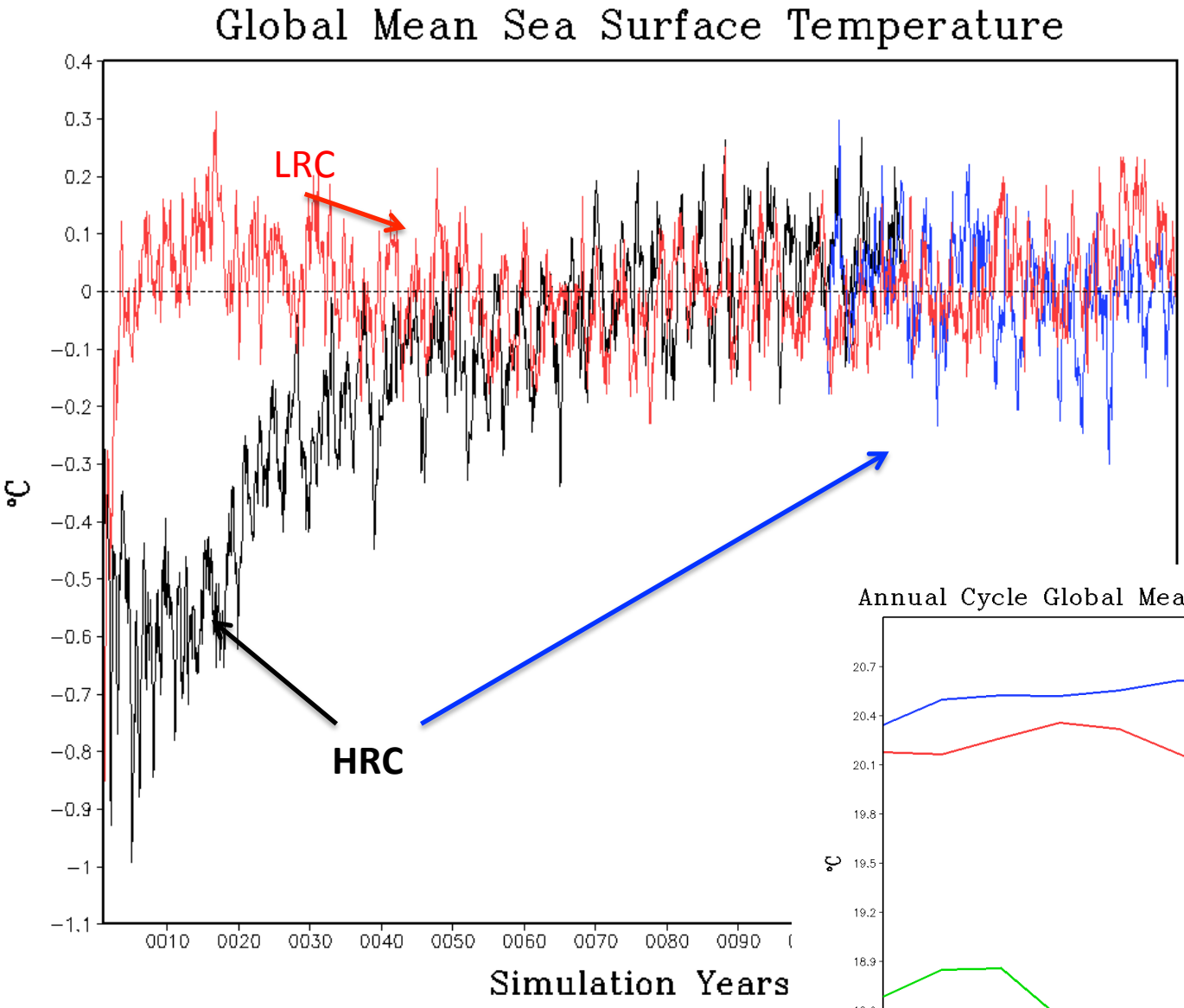
Outline

- **Motivation:**
  - **Scale Interactions – How Do Ocean Eddies Impact the Large Scale Climate?**
  - **Minobe et al. (2008) - Nature**
  - **Number of Previous Studies Focused on Atmospheric Resolution**
  - **Recent focus on the Importance of Ocean Eddies**
    - **Toniazzo et al. (2009); Zheng et al (2009); McWilliams and Colas (2010)**
  - **McClean et al. (2011); Bryan et al. (2010)**
    - **Order 10-20 Year Simulations**

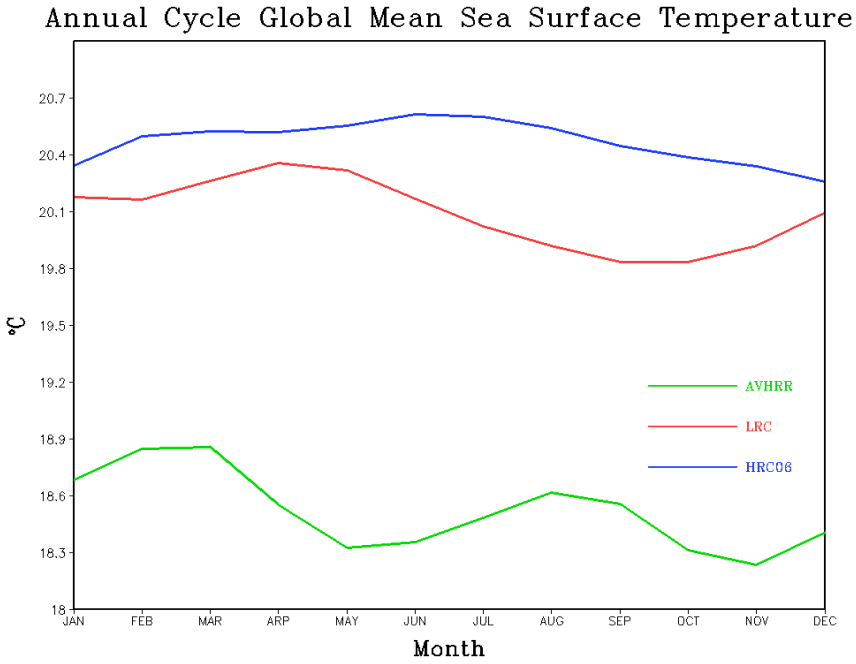


Outline

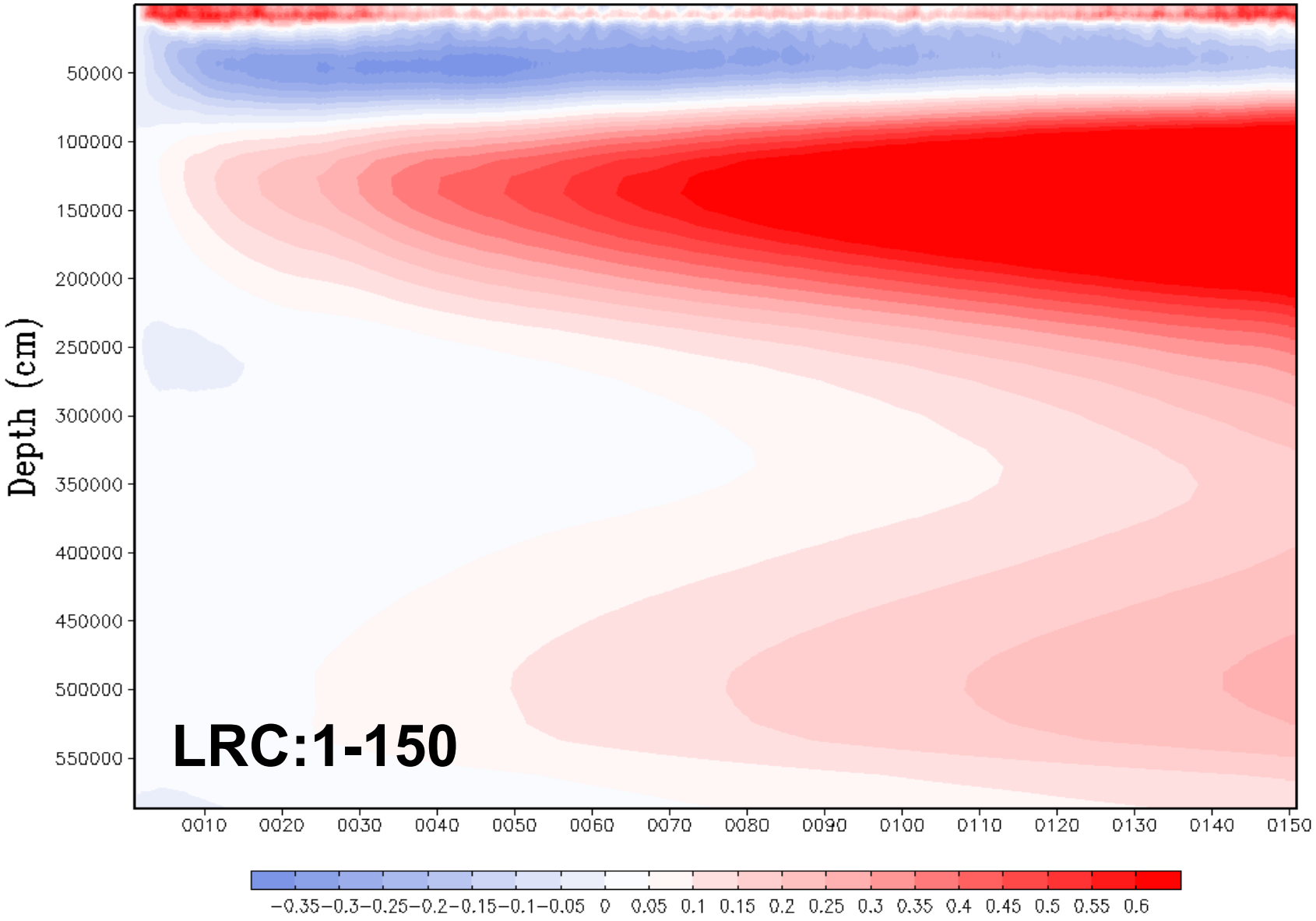
- **CCSM3.5***
  - **Atmosphere: 0.5x0.5**
  - **Two Versions: 1x1 [LRC] and 0.1x0.1 [HRC*]**
- **Spin-Up Issues/Polar Filter**
- **Ubiquitous Warm Signal**
  - **Ocean Heat Transport, Ice Albedo Feedback, Water Vapor Feedback, Cloud Partitioning**
- **Survey of Large Scale Climatic Features**
  - **North Atlantic: Gulf Stream, Air-Sea Feedbacks**
  - **North Pacific: Kuroshio**
  - **Equatorial Pacific: ENSO, TWIs, ENSO-symmetry**

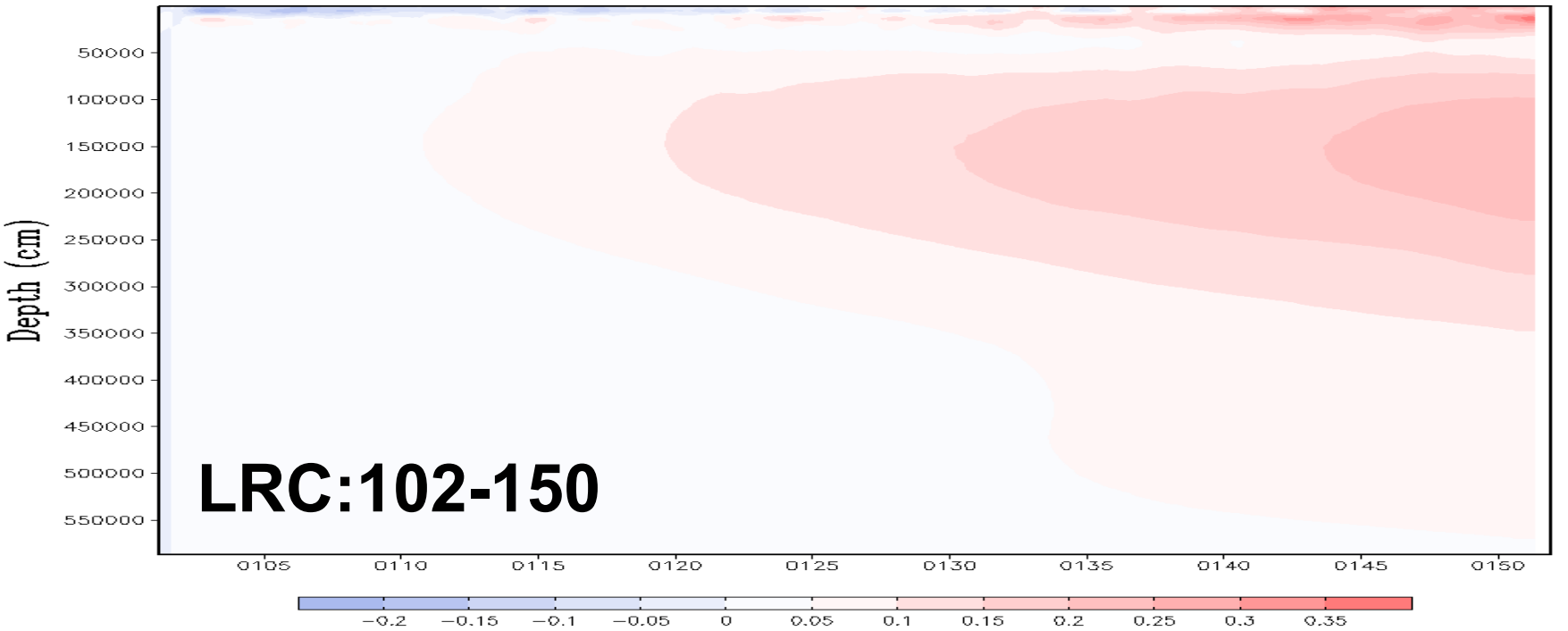

Global Mean Sea Surface Temperature
LRC
HRC
°C
Simulation Years
0.4
0.3
0.2
0.1
0
−0.1
−0.2
−0.3
−0.4
−0.5
−0.6
−0.7
−0.8
−0.9
−1
−1.1
0010
0020
0030
0040
0050
0060
0070
0080
0090

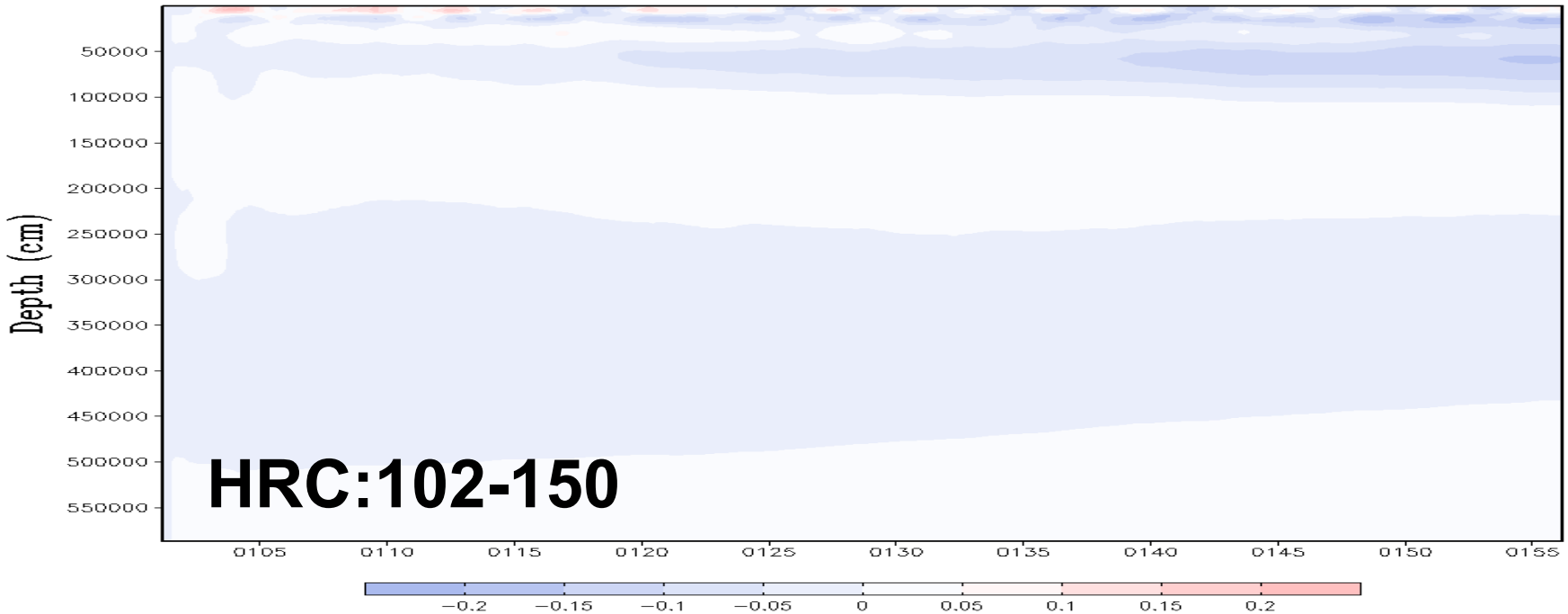
AGCM Grid


Annual Cycle Global Mean Sea Surface Temperature
°C
Month
AVHRR
LRC
HRC06
20.7
20.4
20.1
19.8
19.5
19.2
18.9
18.6
18.3
18
JAN
FEB
MAR
ARP
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC

Global Ocean Temperature Drift




LRC:102-150
Depth (cm)
50000
100000
150000
200000
250000
300000
350000
400000
450000
500000
550000
0105
0110
0115
0120
0125
0130
0135
0140
0145
0150
−0.2
−0.15
−0.1
−0.05
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35


HRC:102-150
Depth (cm)
50000
100000
150000
200000
250000
300000
350000
400000
450000
500000
550000
0105
0110
0115
0120
0125
0130
0135
0140
0145
0150
0155
−0.2
−0.15
−0.1
−0.05
0
0.05
0.1
0.15
0.2

Outline

- **CCSM3.5***
  - **Atmosphere: 0.5x0.5**
  - **Two Versions: 1x1 [LRC] and 0.1x0.1 [HRC*]**
- **Spin-Up Issues/Polar Filter**
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  - **Ocean Heat Transport, Ice Albedo Feedback, Water Vapor Feedback, Cloud Partitioning**
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  - **North Atlantic: Gulf Stream, Air-Sea Feedbacks**
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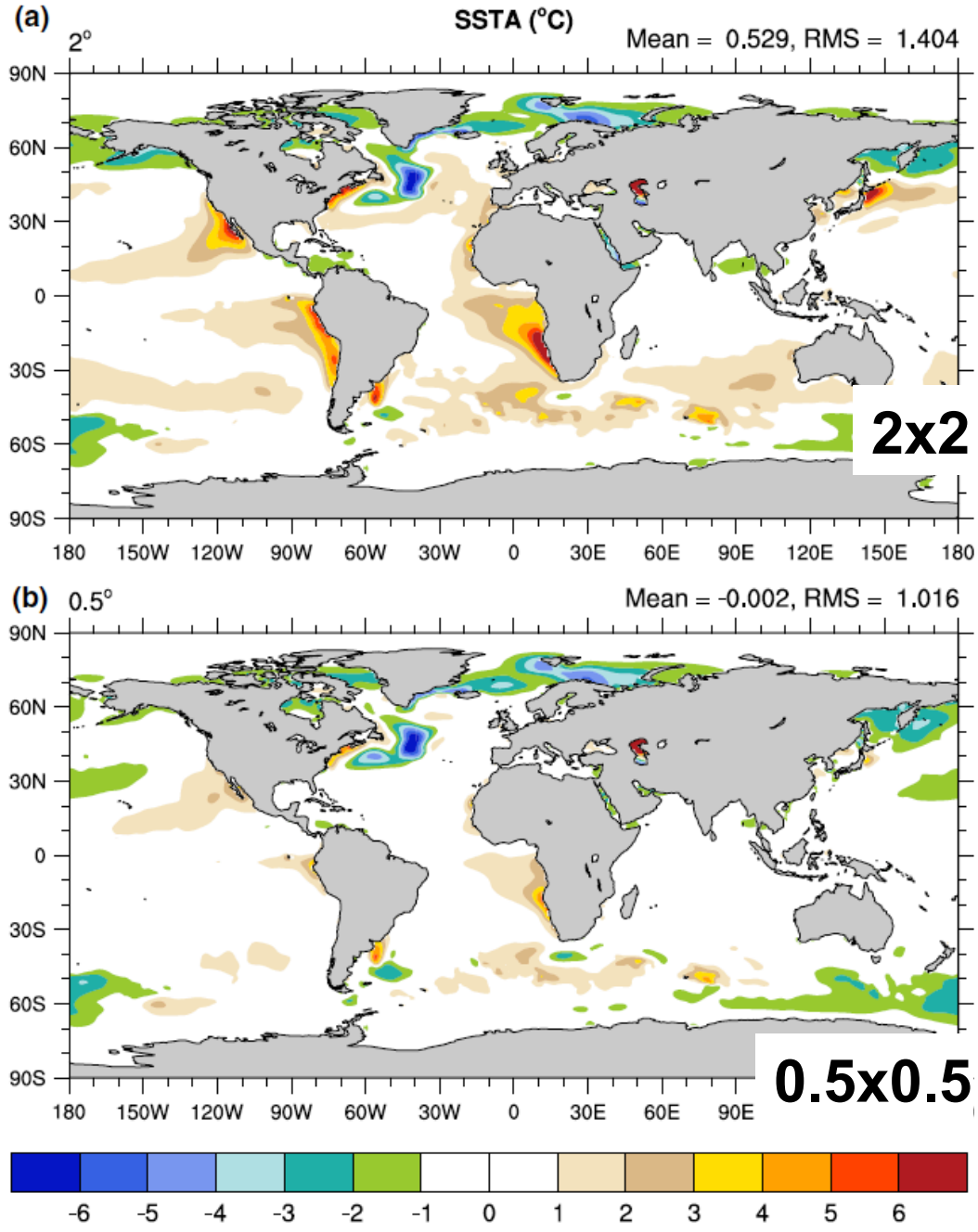
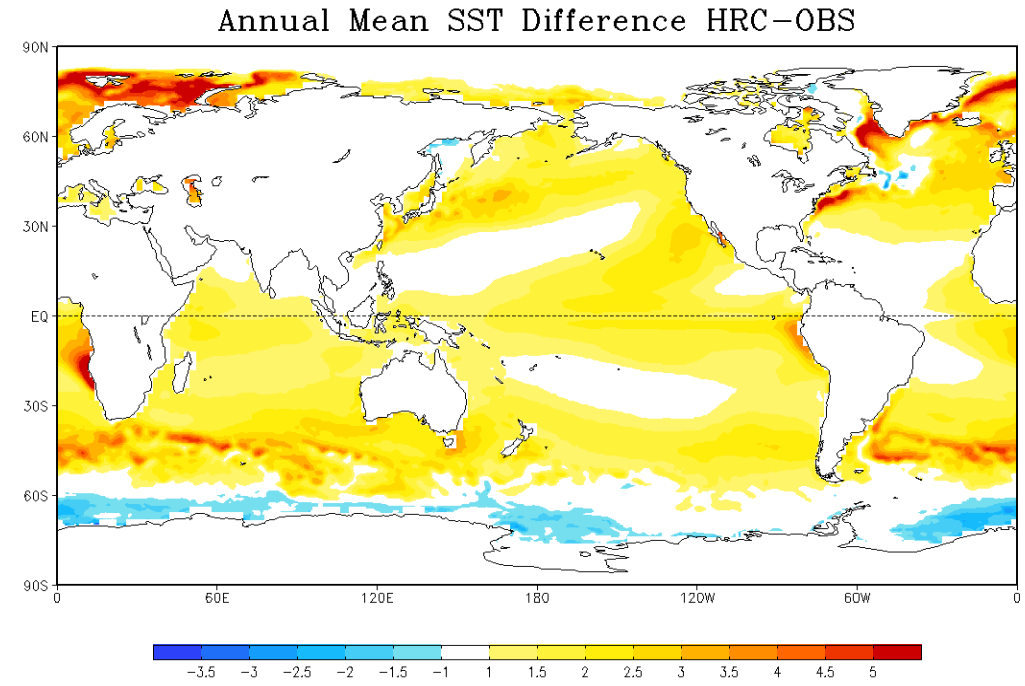
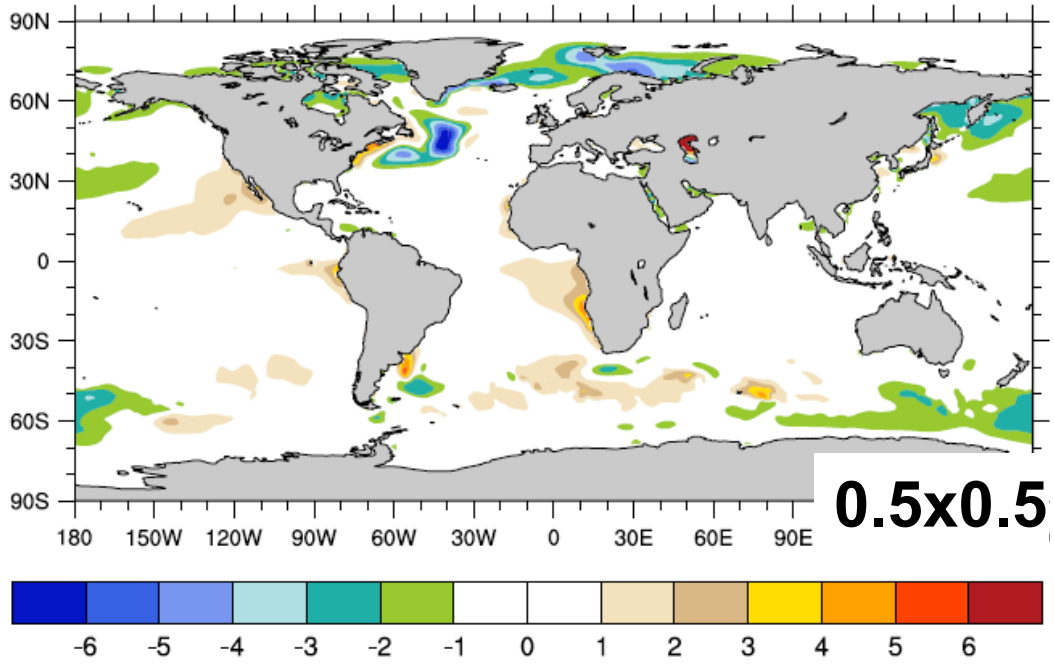


Increasing OGCM Resolution: Eddy Permitting vs. Resolving

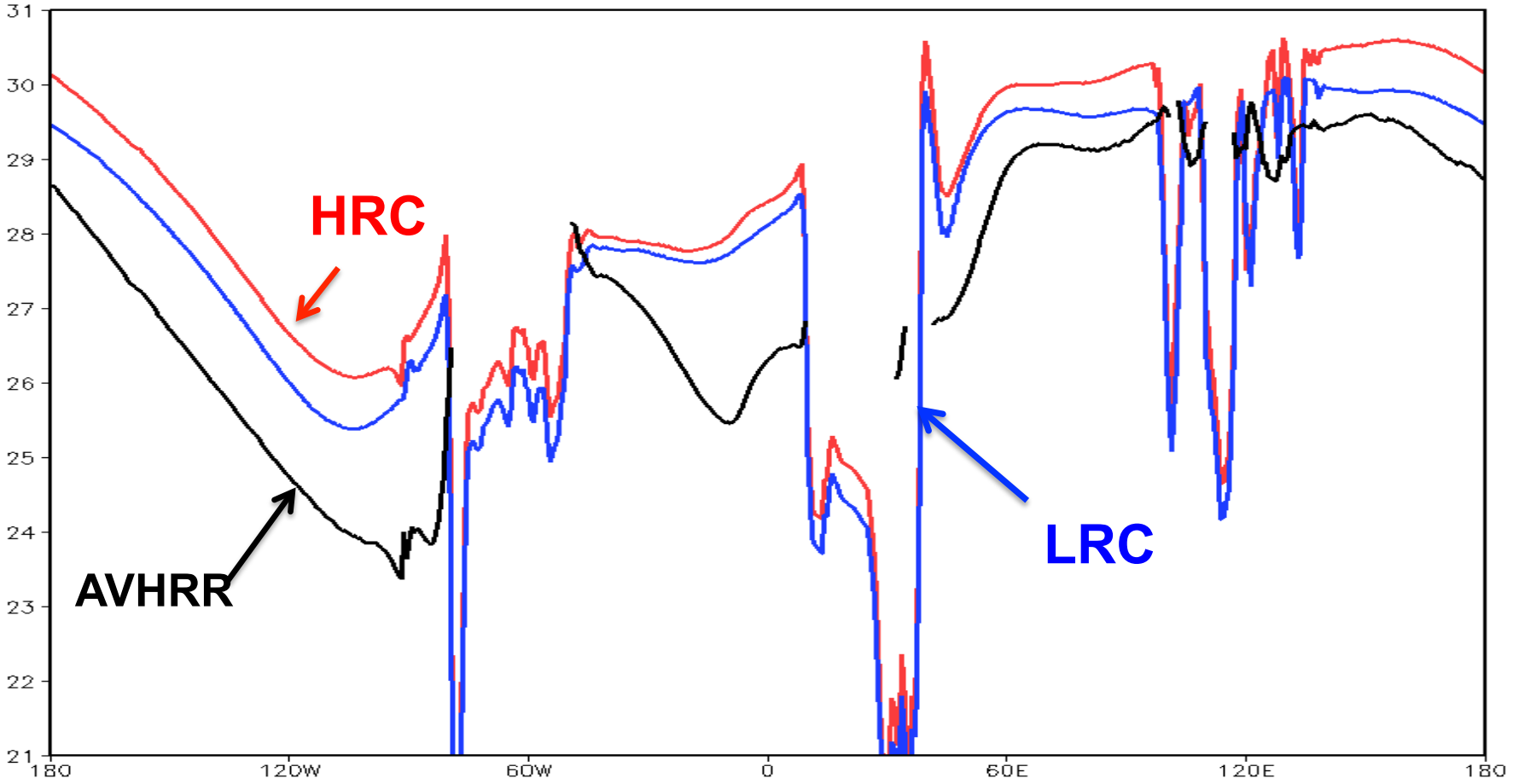




Increasing OGCM Resolution: Eddy Permitting vs. Resolving

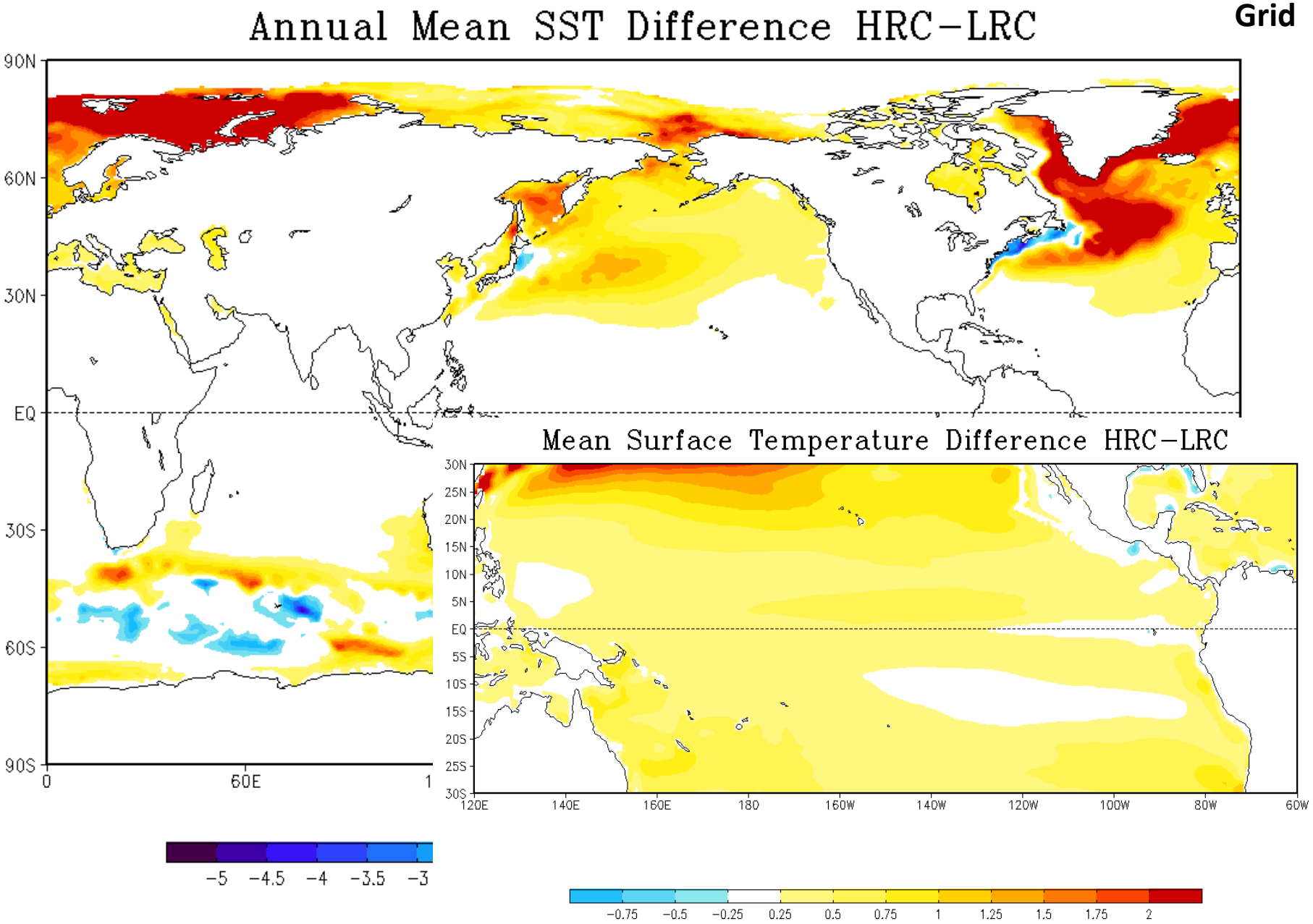
Affect of Resolved Ocean Eddies

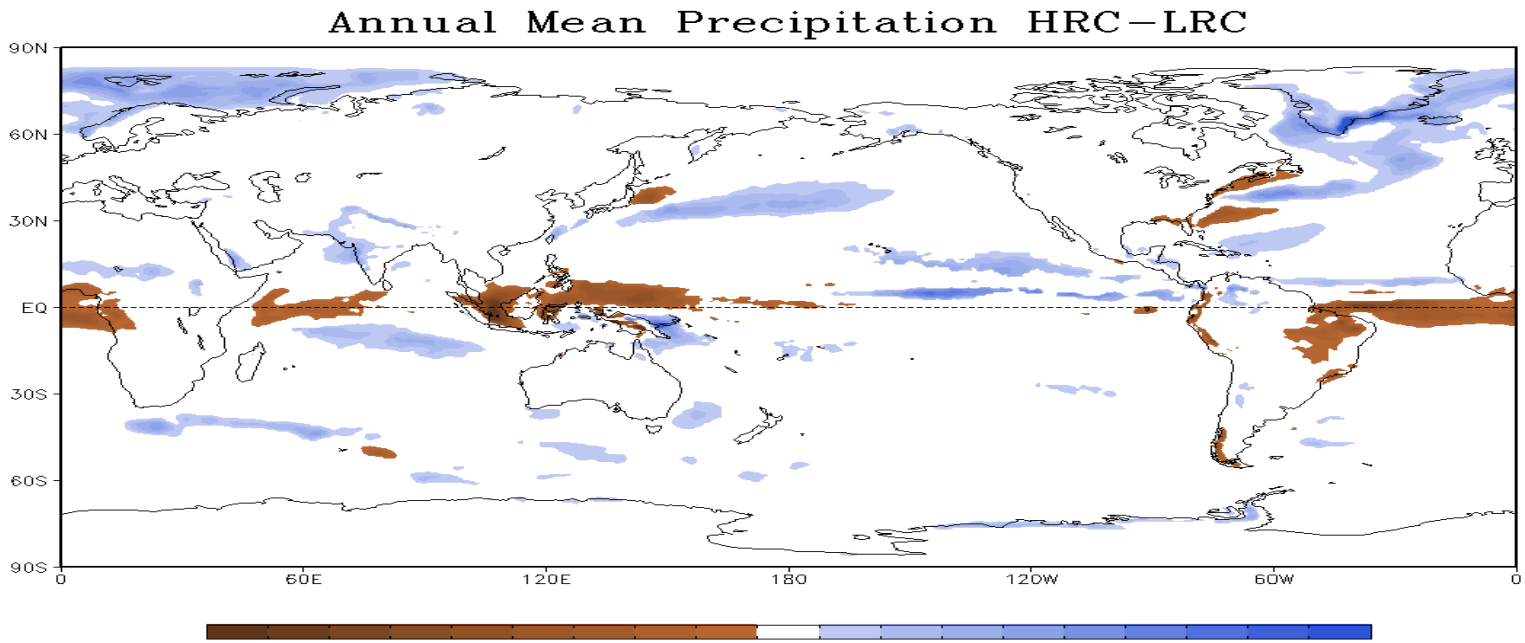
- **CCSM4**
  - **Atmosphere: 0.5x0.5**
  - **Two Versions: 1x1 [LRC] and 0.1x0.1 [HRC]**

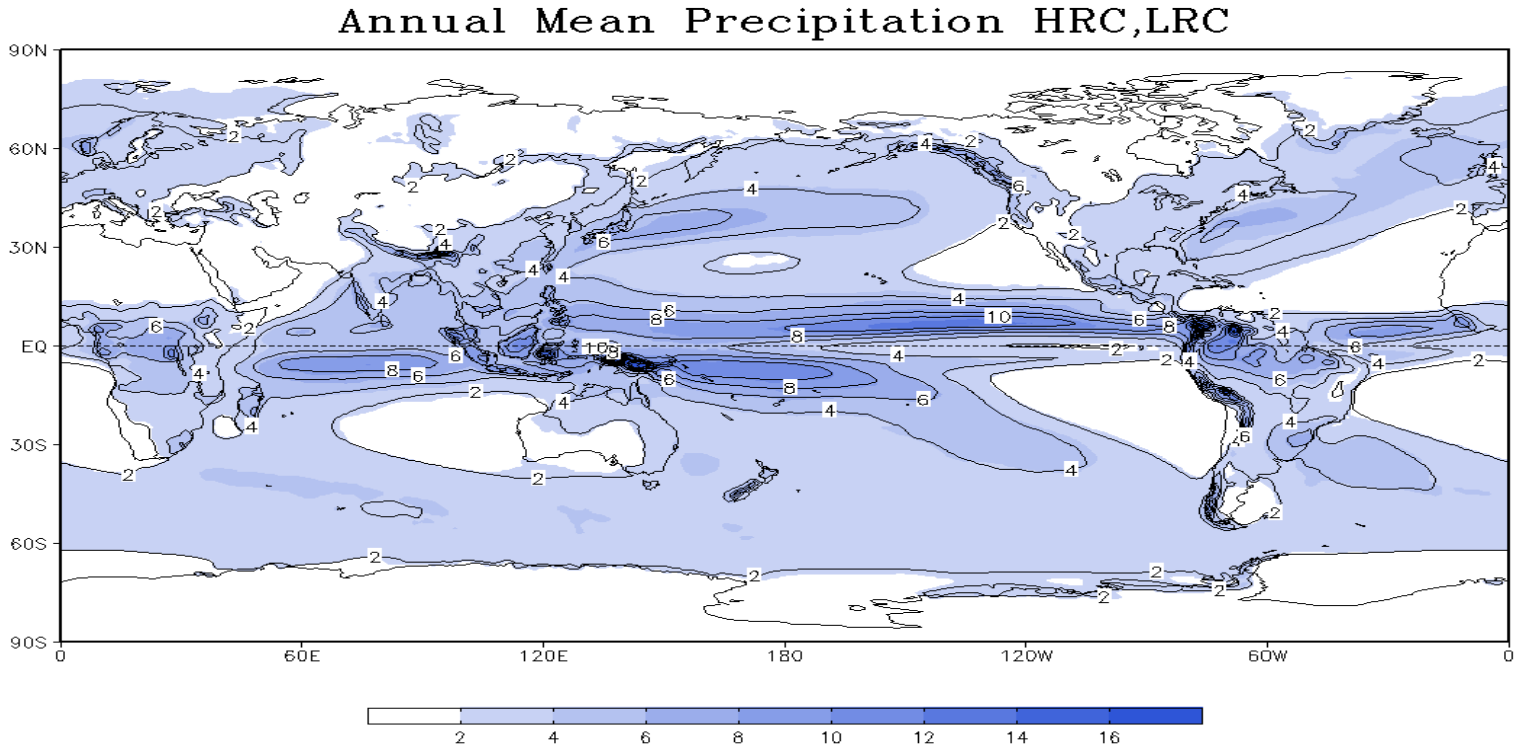


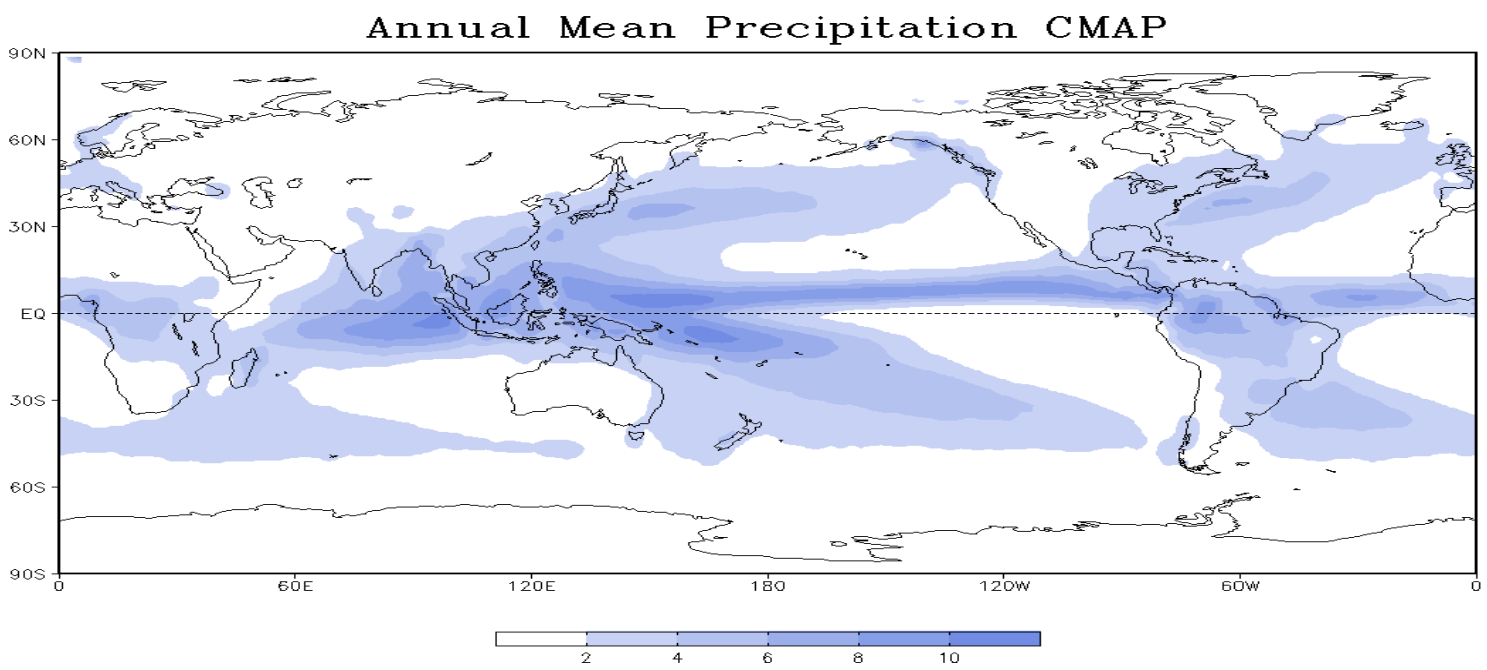
Climatological Equatorial SST

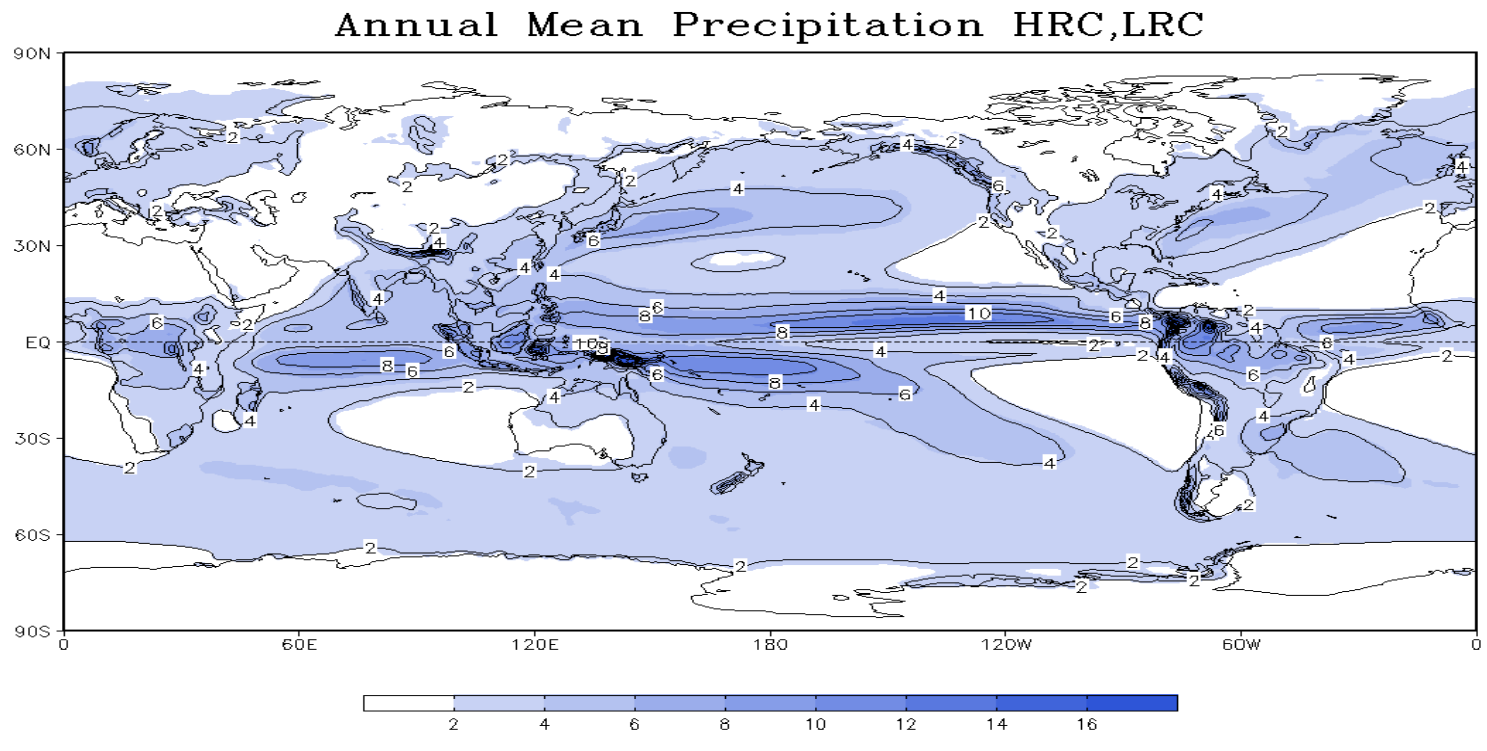
AGCM Grid


Annual Mean SST Difference HRC−LRC
90N
60N
30N
EQ
30S
60S
90S
0
60E
1
Mean Surface Temperature Difference HRC−LRC
30N
25N
20N
15N
10N
5N
EQ
5S
10S
15S
20S
25S
30S
120E
140E
160E
180
160W
140W
120W
100W
80W
60W
−5
−4.5
−4
−3.5
−3
−0.75
−0.5
−0.25
0.25
0.5
0.75
1
1.25
1.5
1.75
2

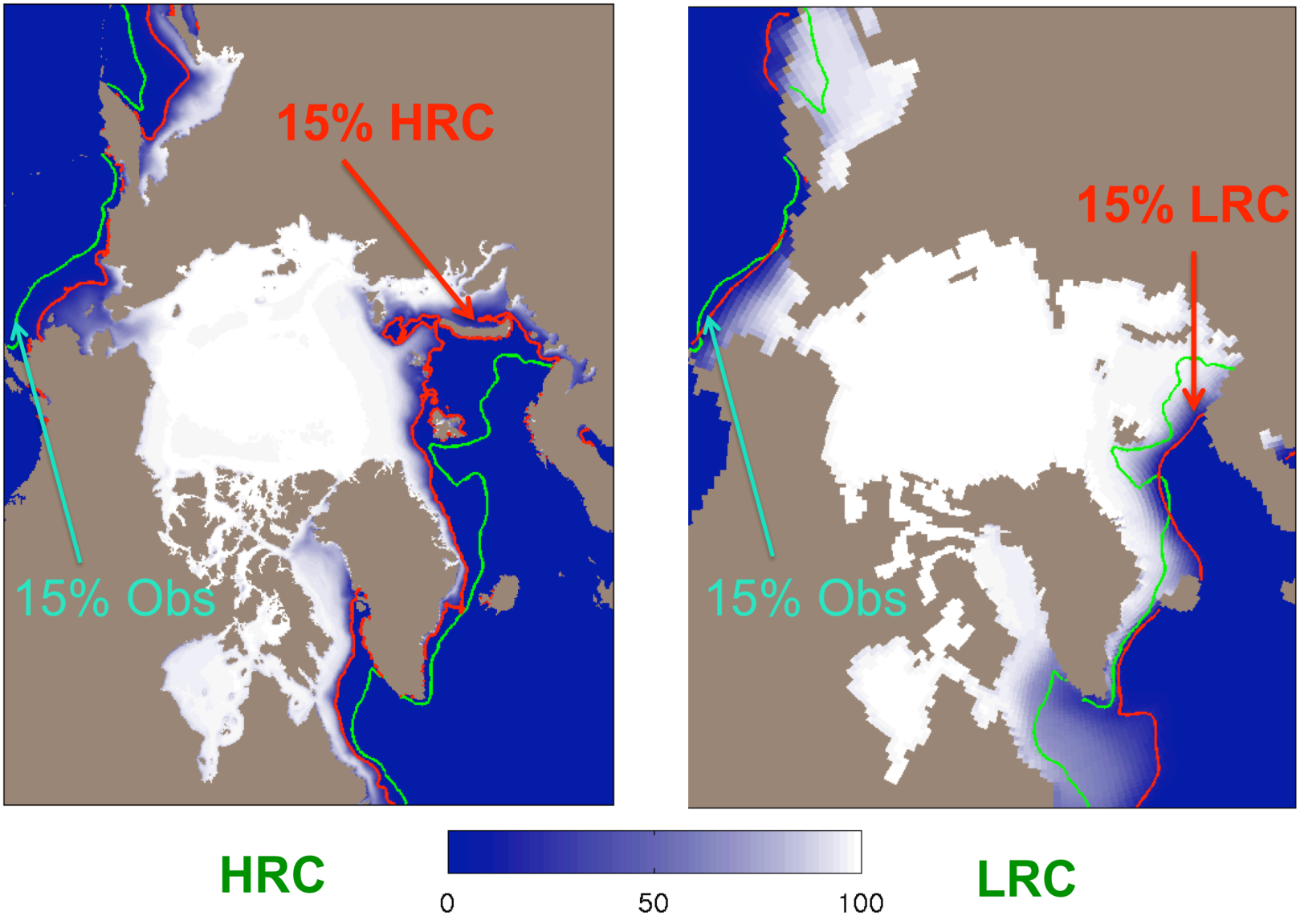

Annual Mean Precipitation HRC−LRC
90N
60N
30N
EQ
30S
60S
90S
0
60E
120E
180
120W
60W
0


Annual Mean Precipitation HRC,LRC
90N
60N
30N
EQ
30S
60S
90S
0
60E
120E
180
120W
60W
0
2
4
6
8
10
12
14
16

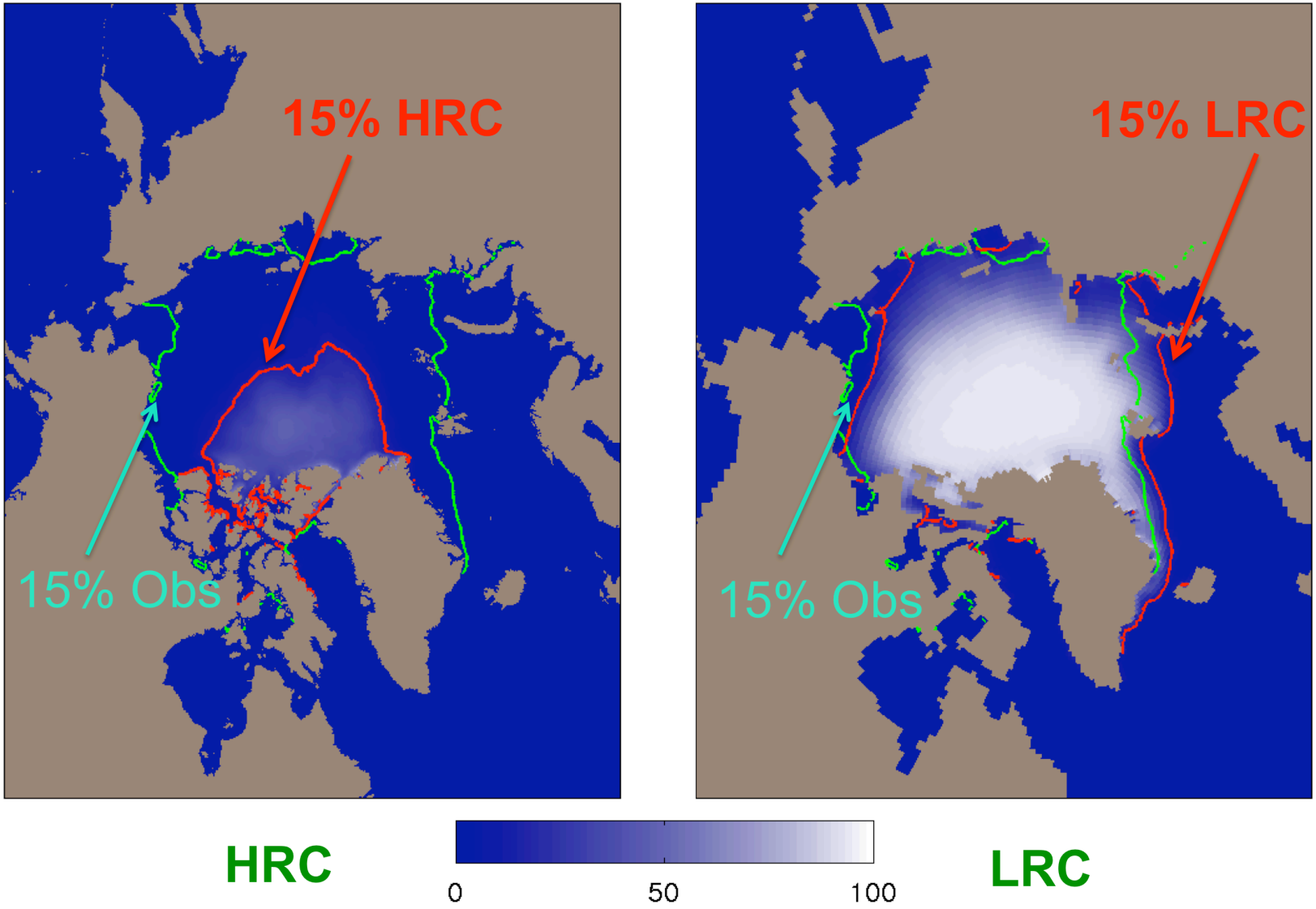

Annual Mean Precipitation CMAP
90N
60N
30N
EQ
30S
60S
90S
0
60E
120E
180
120W
60W
0
2
4
6
8
10

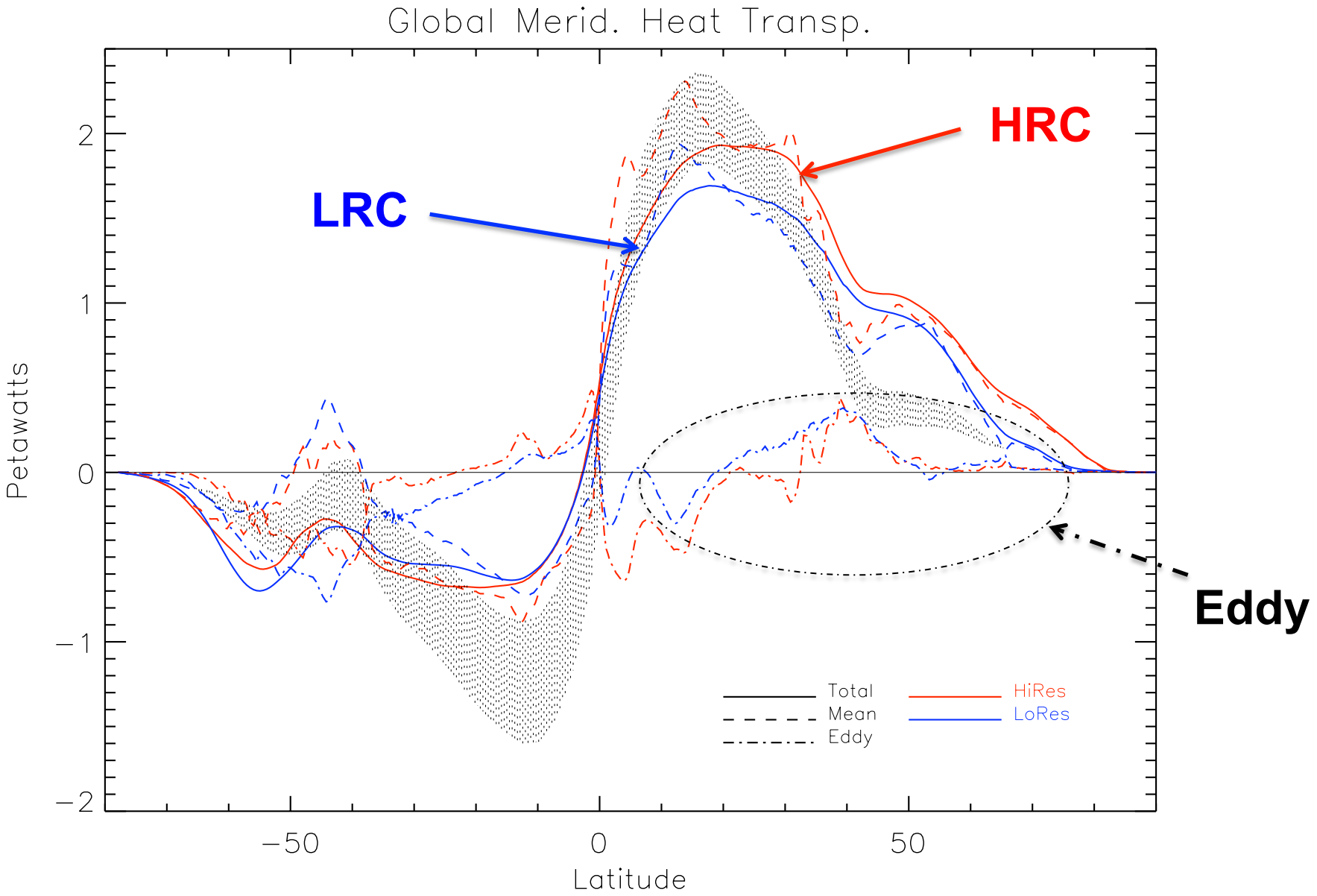

Annual Mean Precipitation HRC,LRC
90N
60N
30N
EQ
30S
60S
90S
0
60E
120E
180
120W
60W
0
2
4
6
8
10
12
14
16

March Sea Ice Concentrations



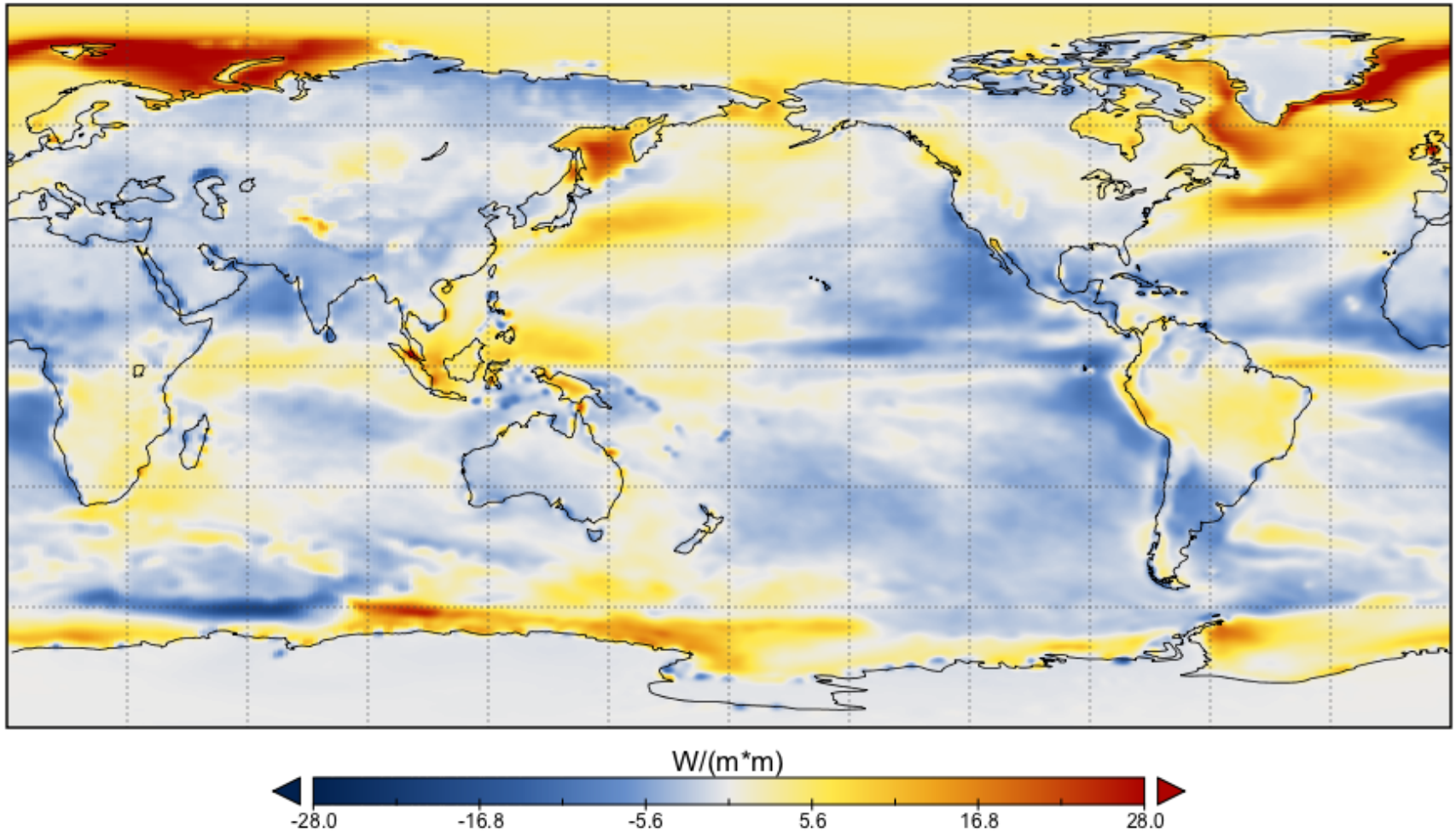
September Sea Ice Concentrations





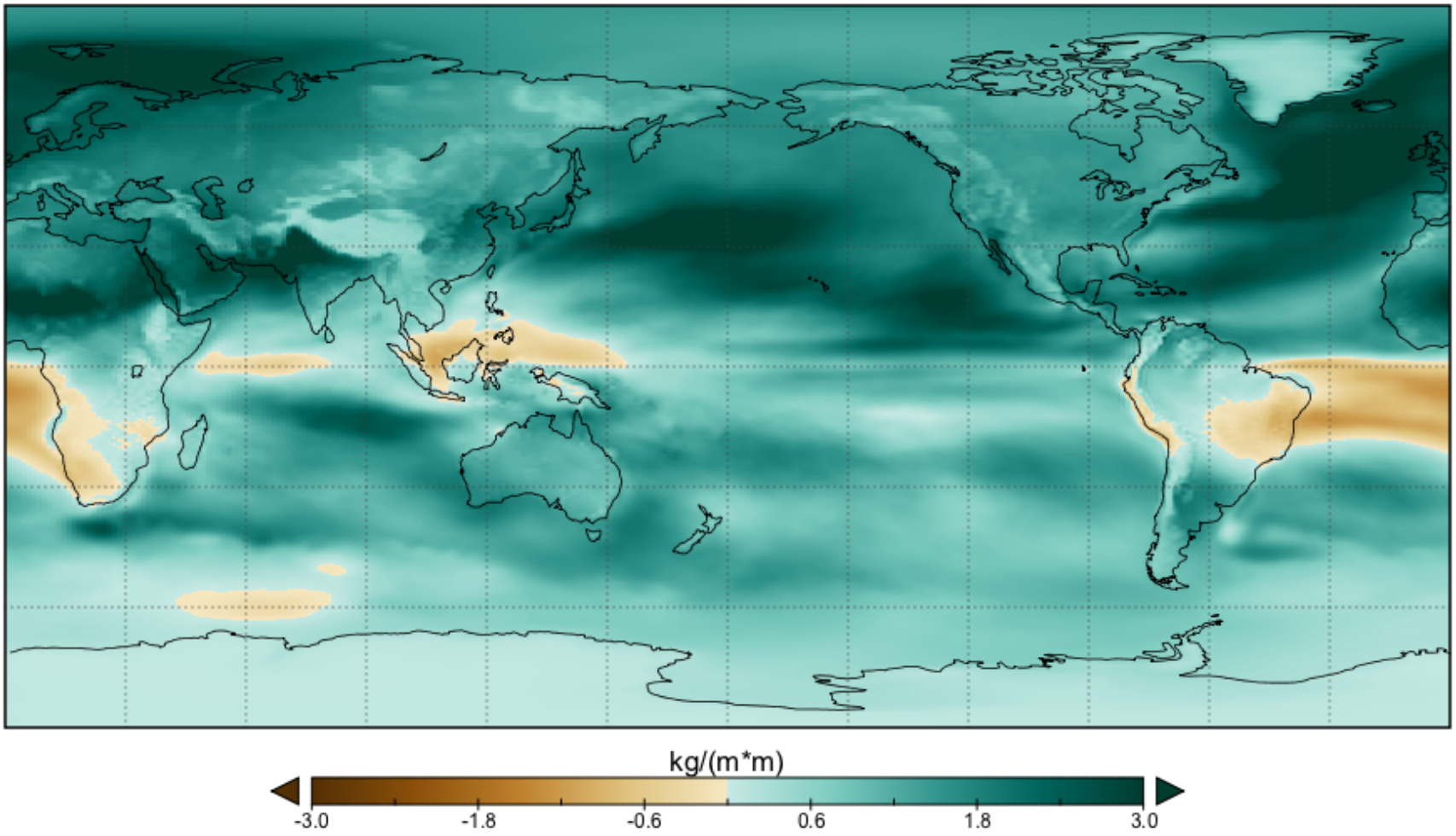
Northward Ocean Heat Transport Dominated by Changes in Mean Transport

Short Wave Absorbed at the Surface: HRC-LRC



- North Pole: Ice-Albedo Feedback
- Western Boundary Current Region: Repartitioning of Clouds
- Decrease Short Wave Absorbed in Tropics and Sub-Tropics

Vertically Integrated Water Vapor: HRC-LRC



- **Water Vapor Feedback – Long Wave Radiation Warming**

Outline

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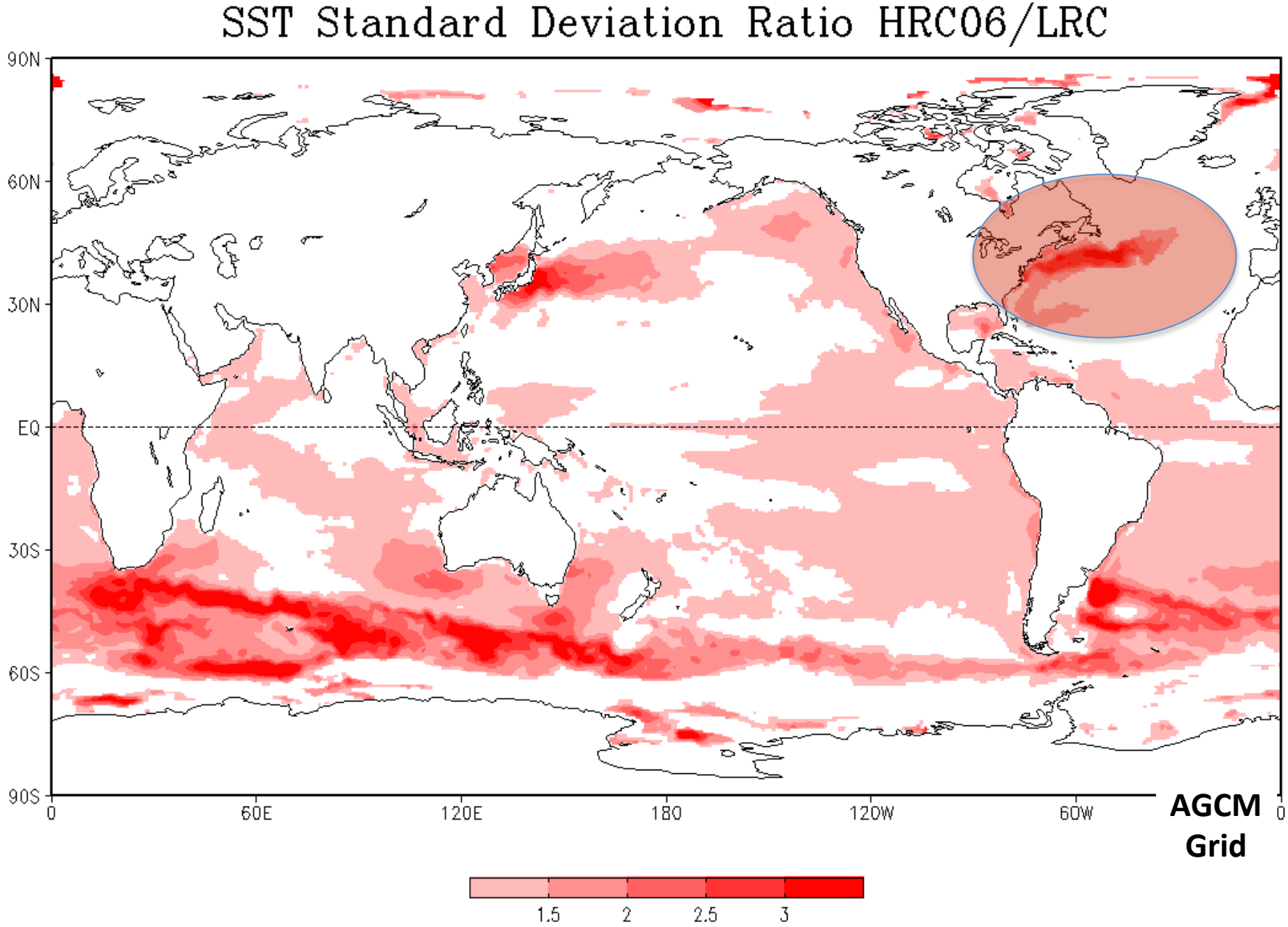
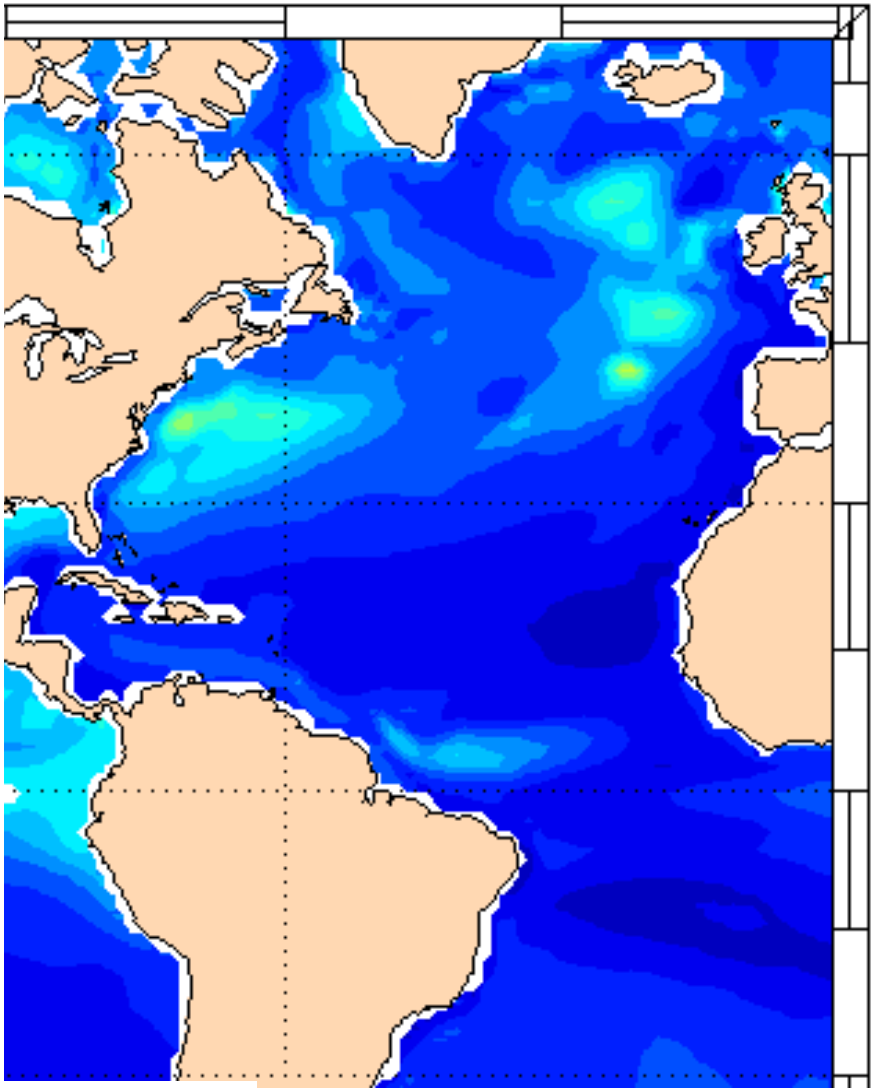
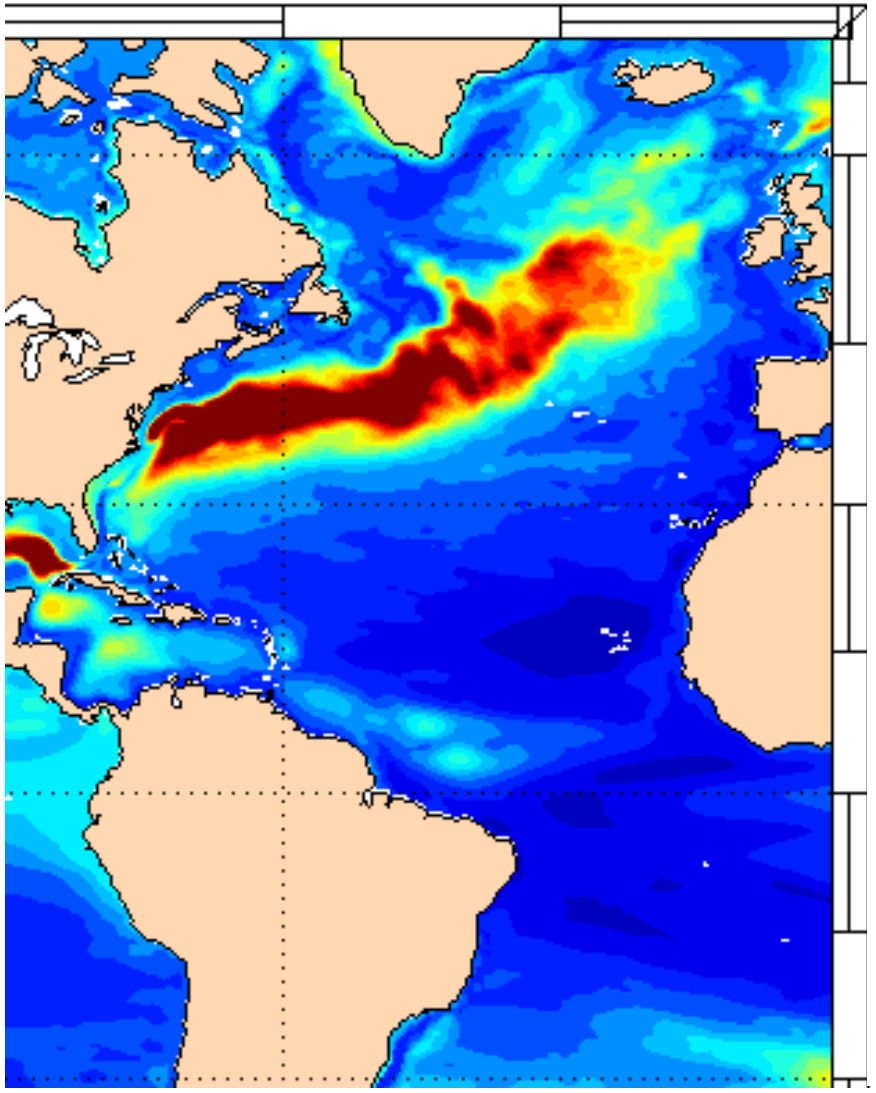

SST Standard Deviation Ratio HRC06/LRC
90N
60N
30N
EQ
30S
60S
90S
0
60E
120E
180
120W
60W
0
AGCM Grid
1.5
2
2.5
3

Sea Surface Height Standard Deviation

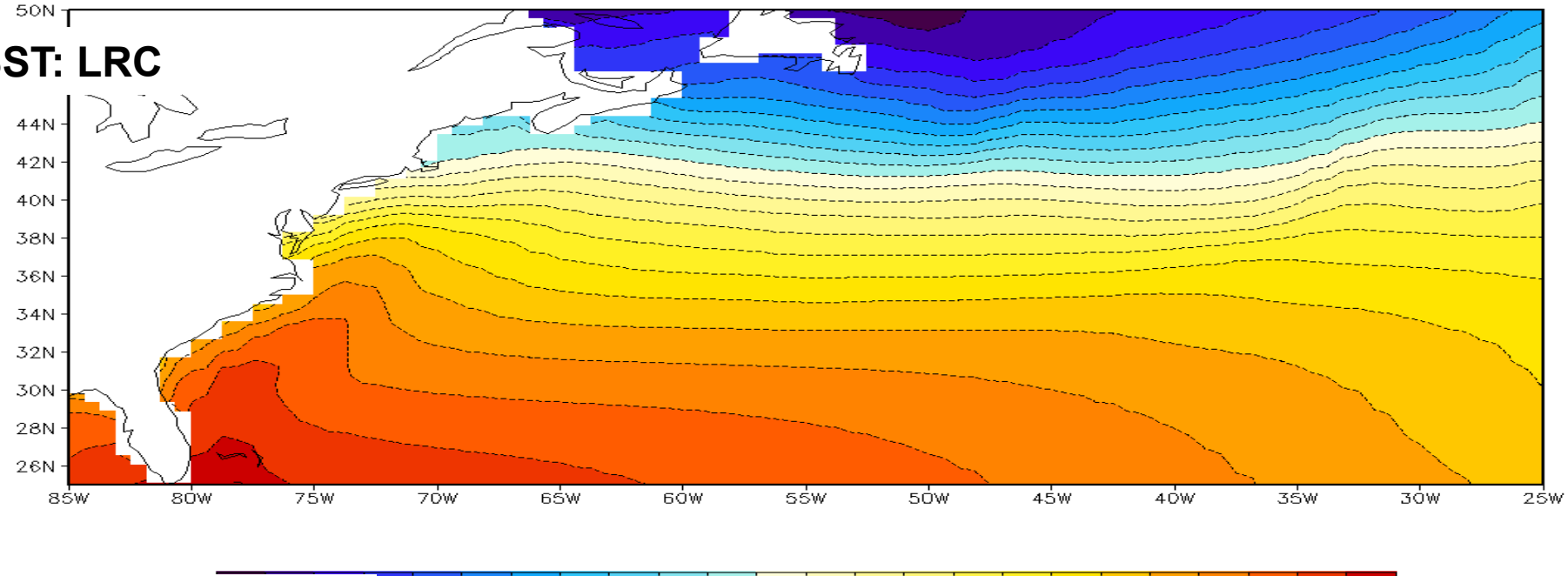


LRC SSH

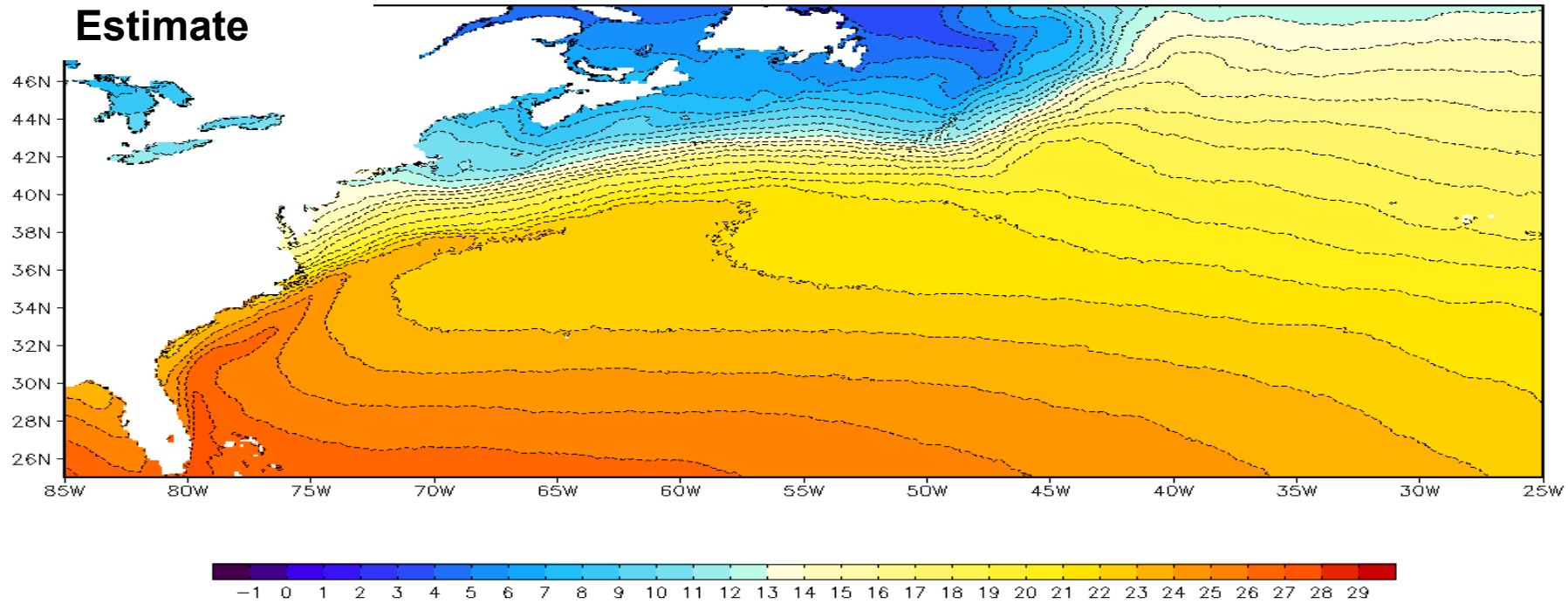


HRC SSH

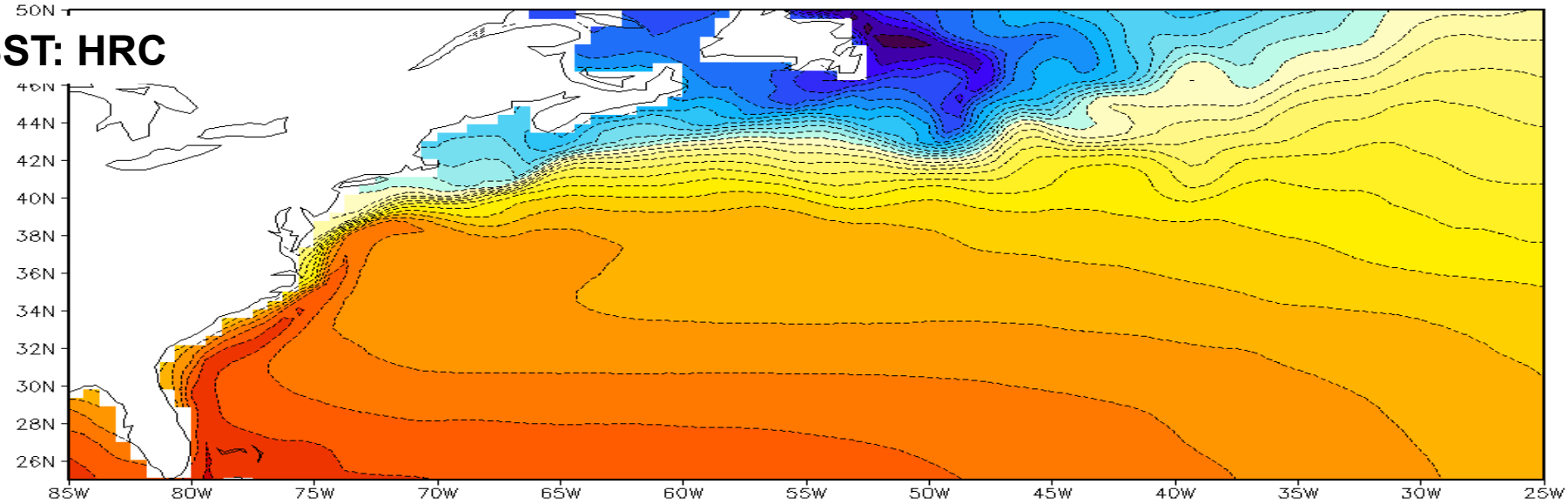
SST: LRC



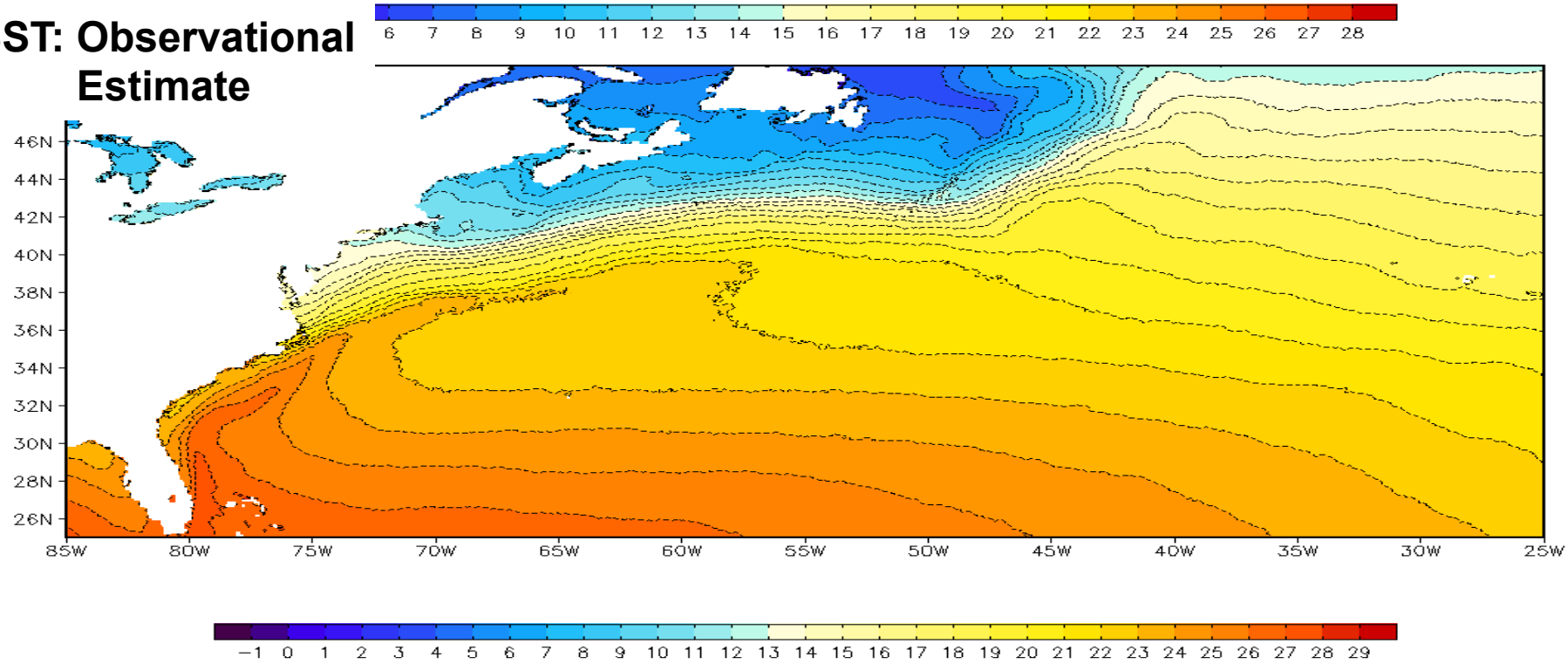
SST: Observational Estimate



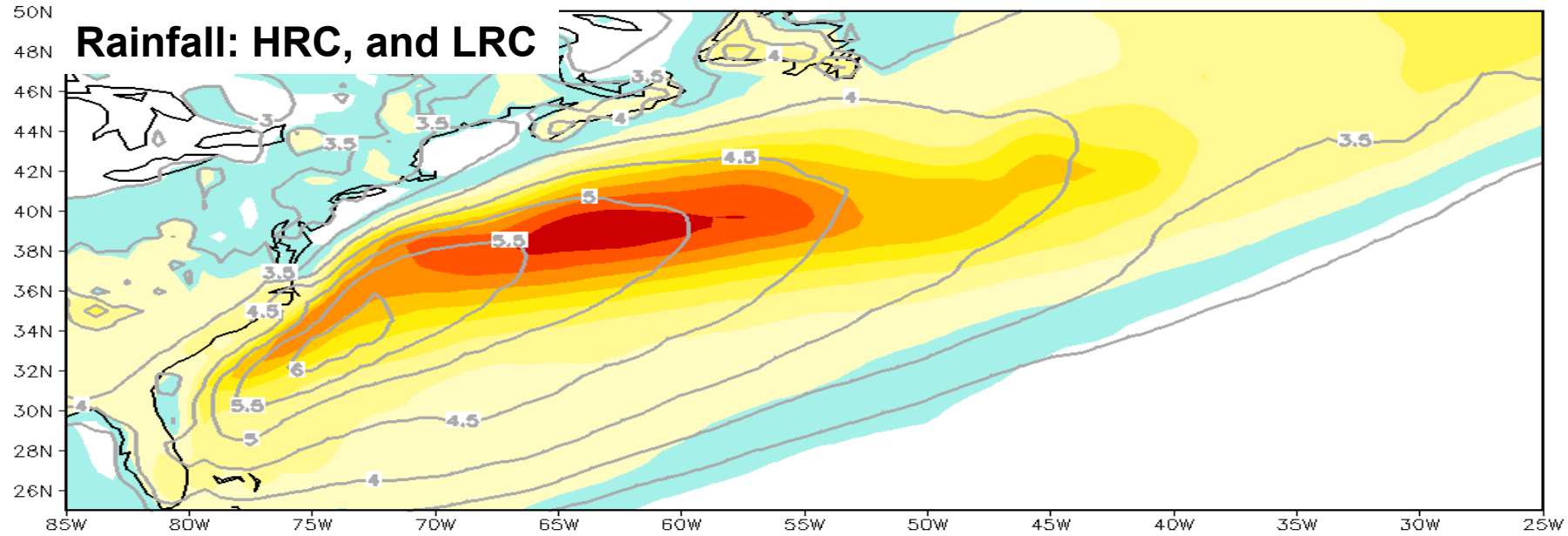
SST: HRC



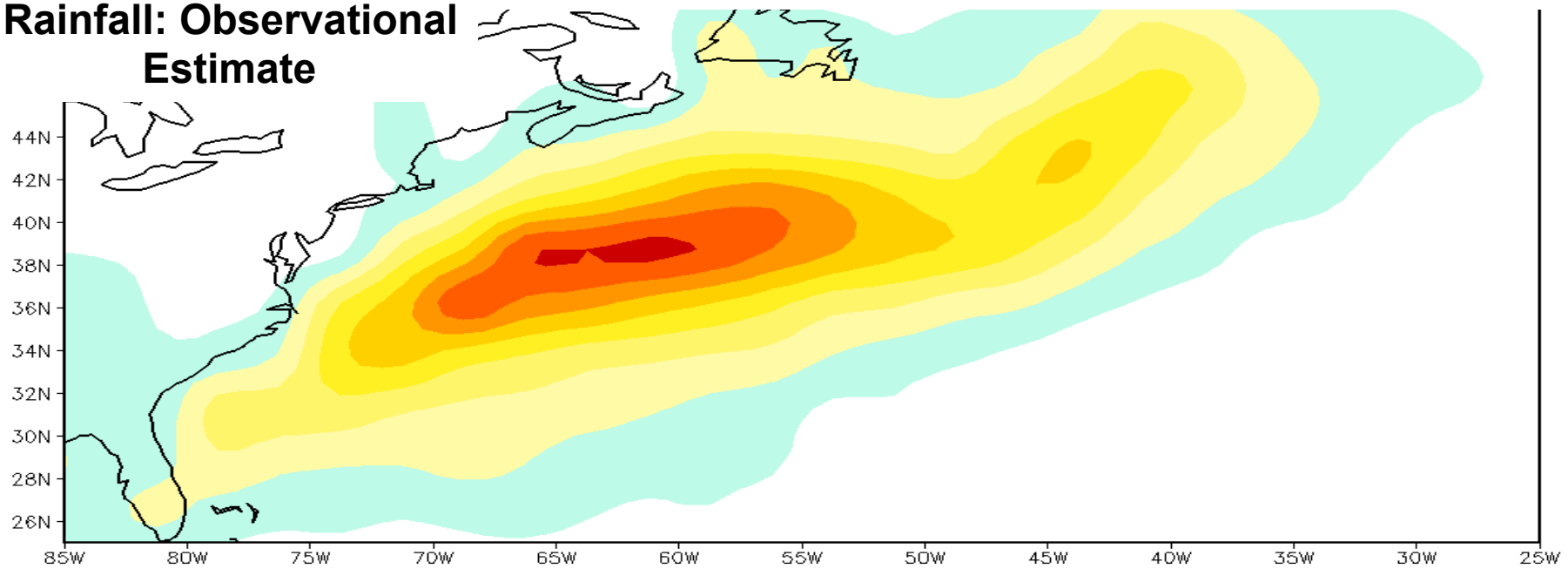
SST: Observational Estimate



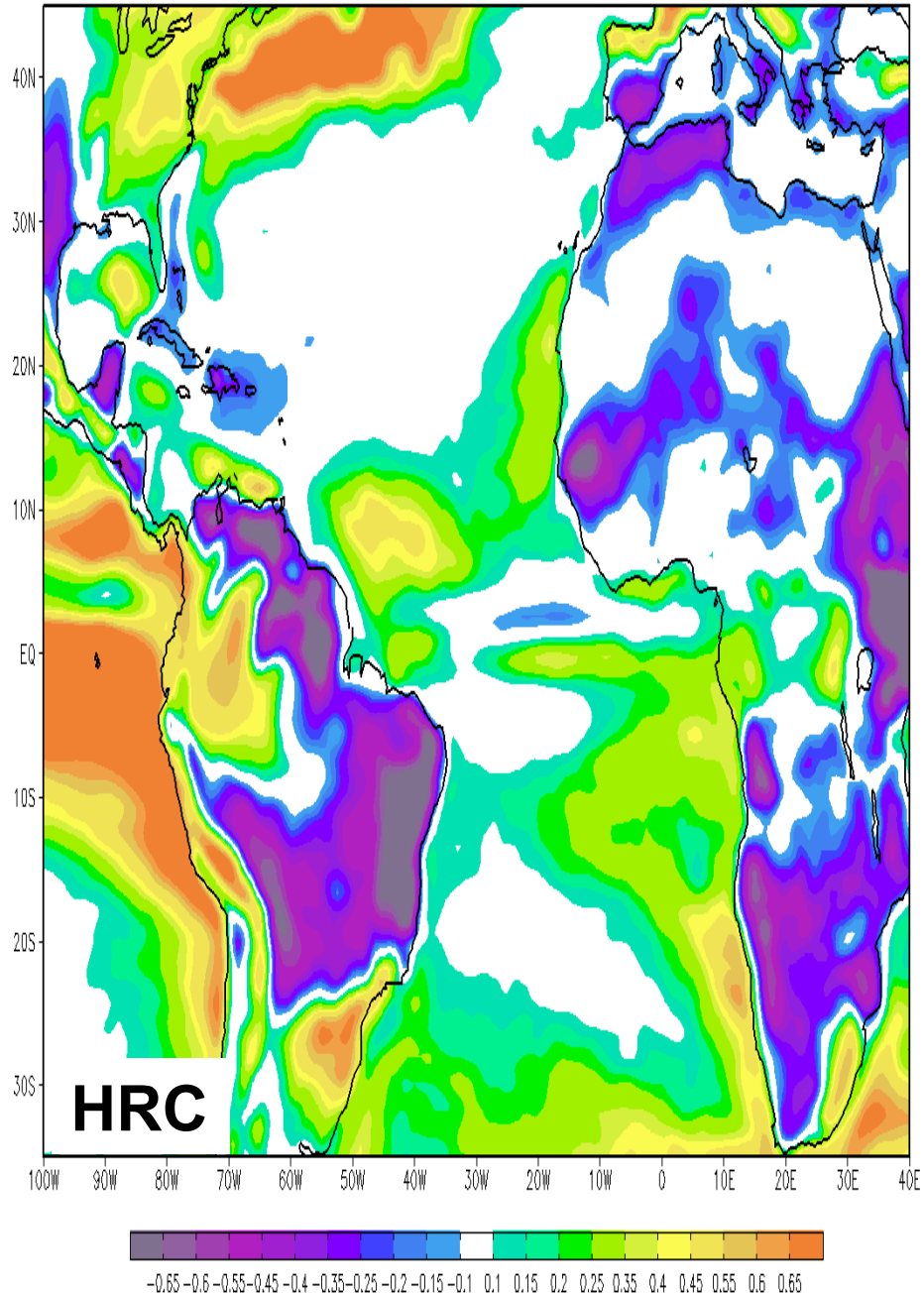
Rainfall: HRC, and LRC

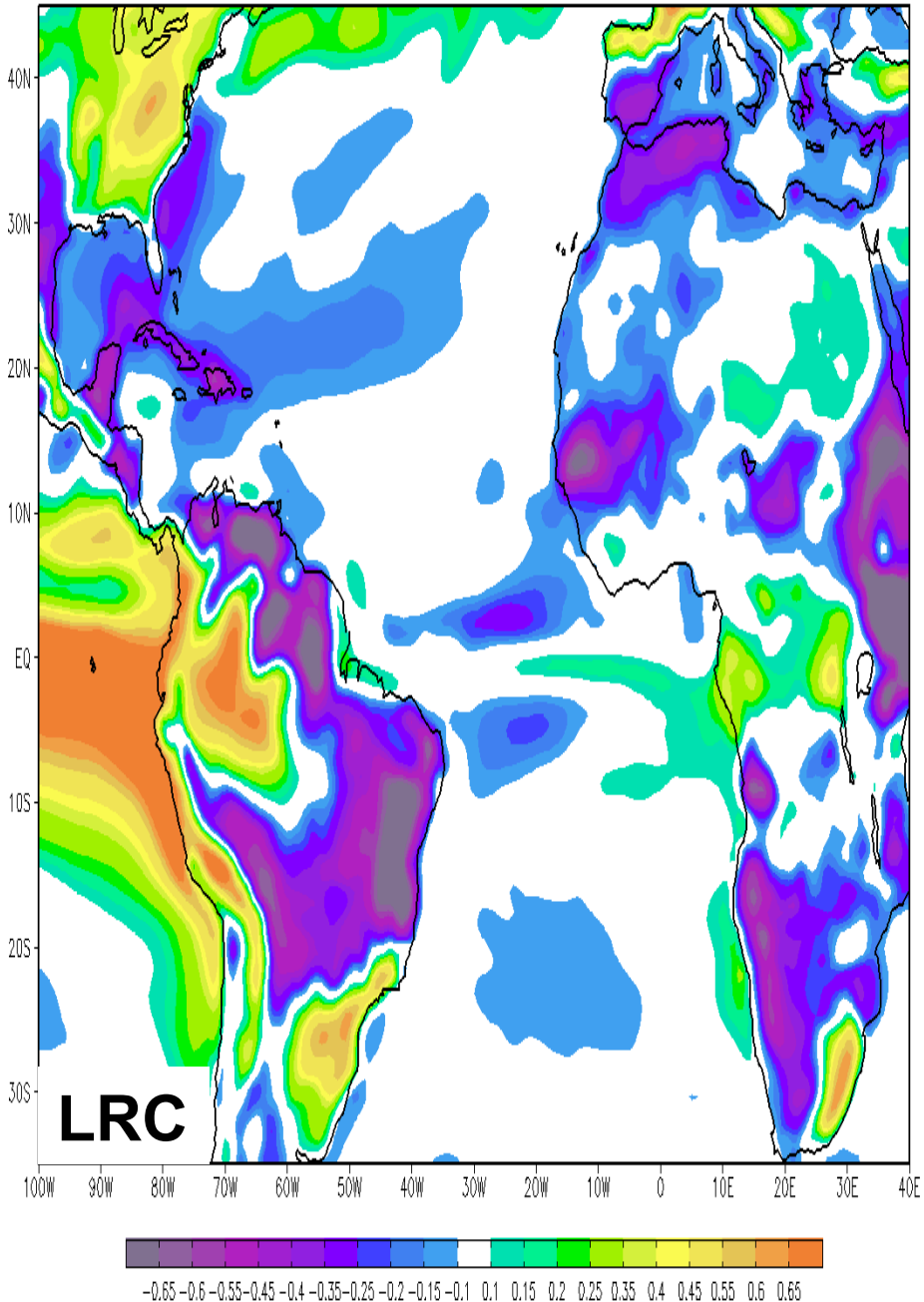


Rainfall: Observational Estimate

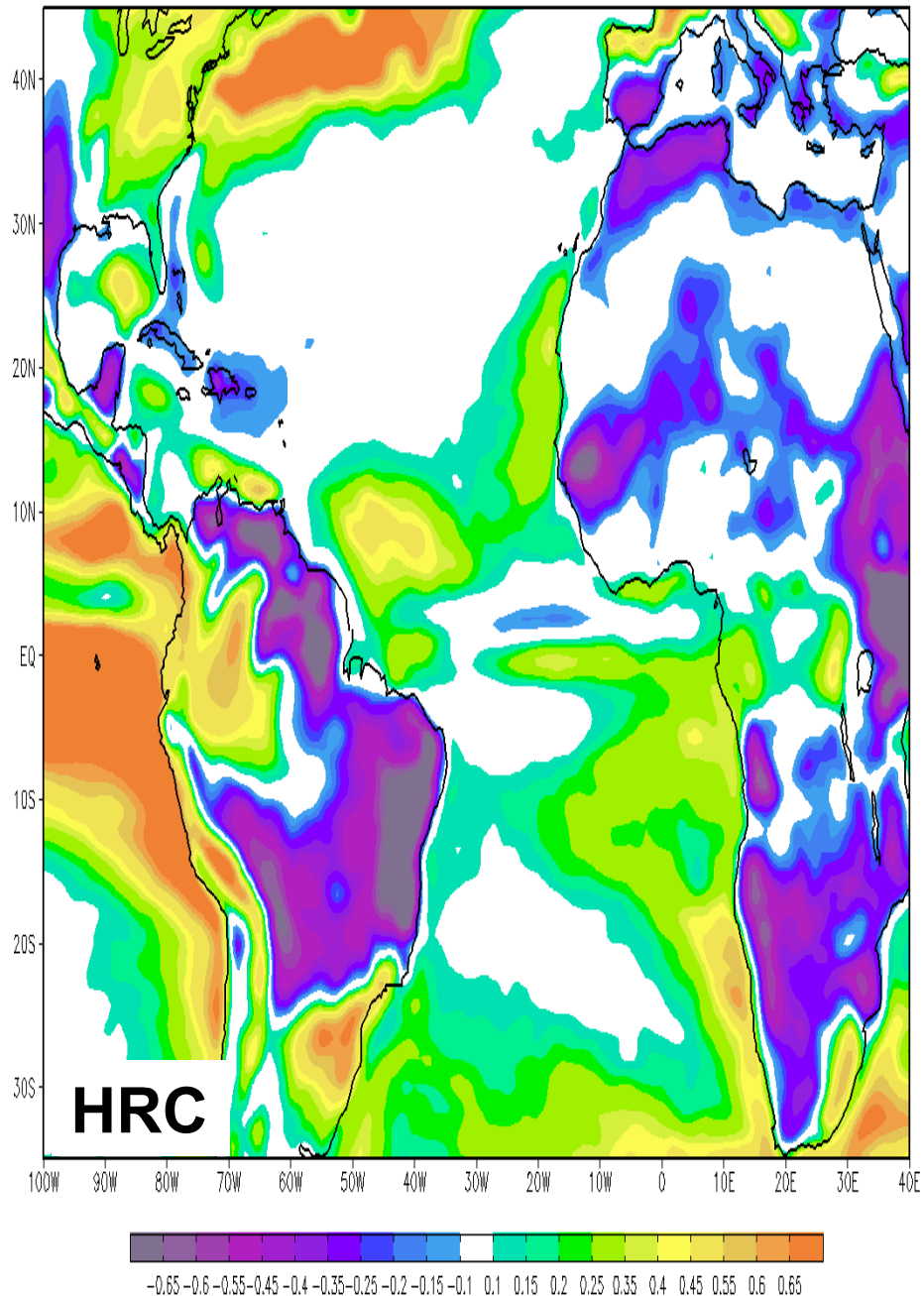


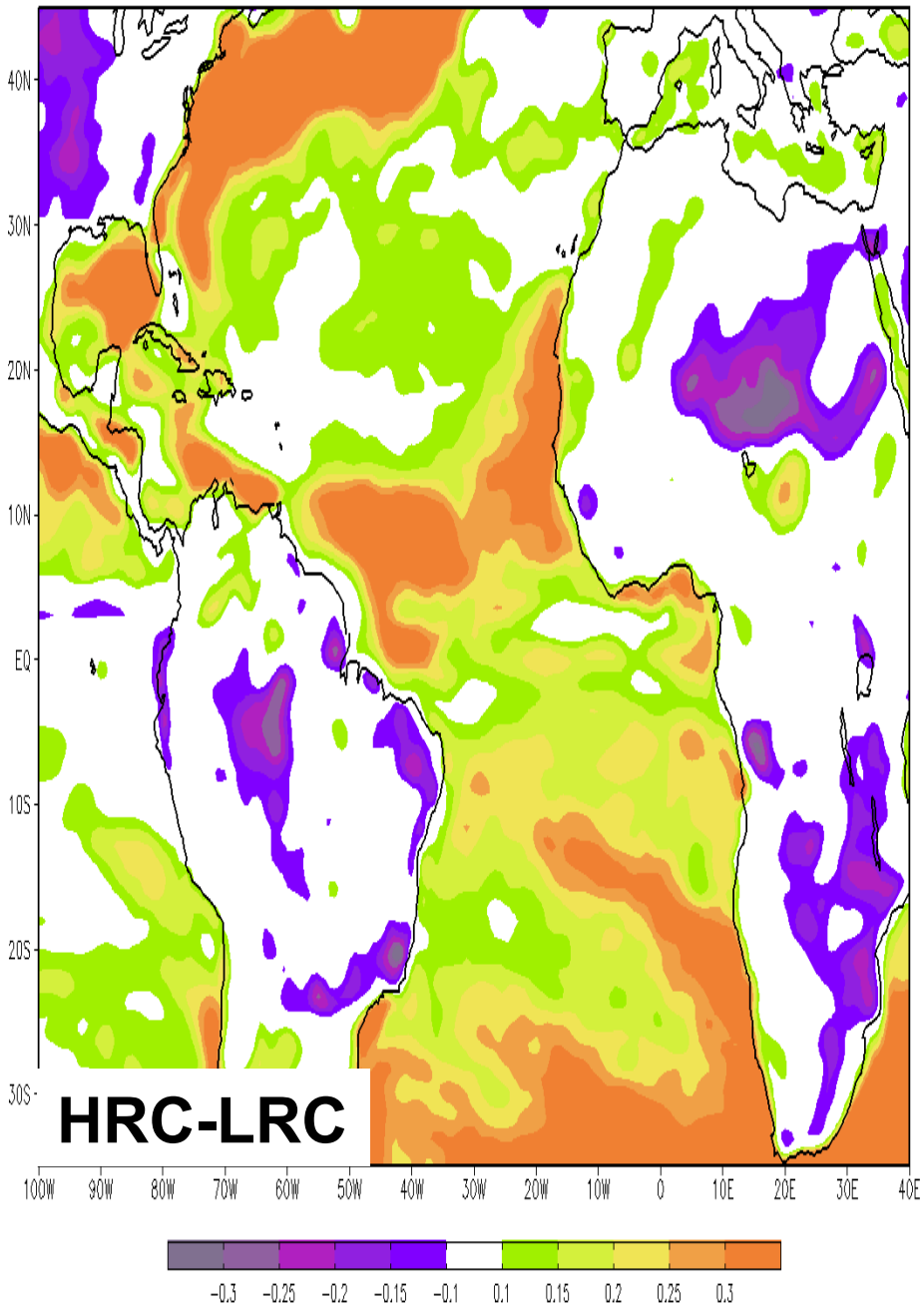
Local SSTA-Latent Heat Flux Correlation



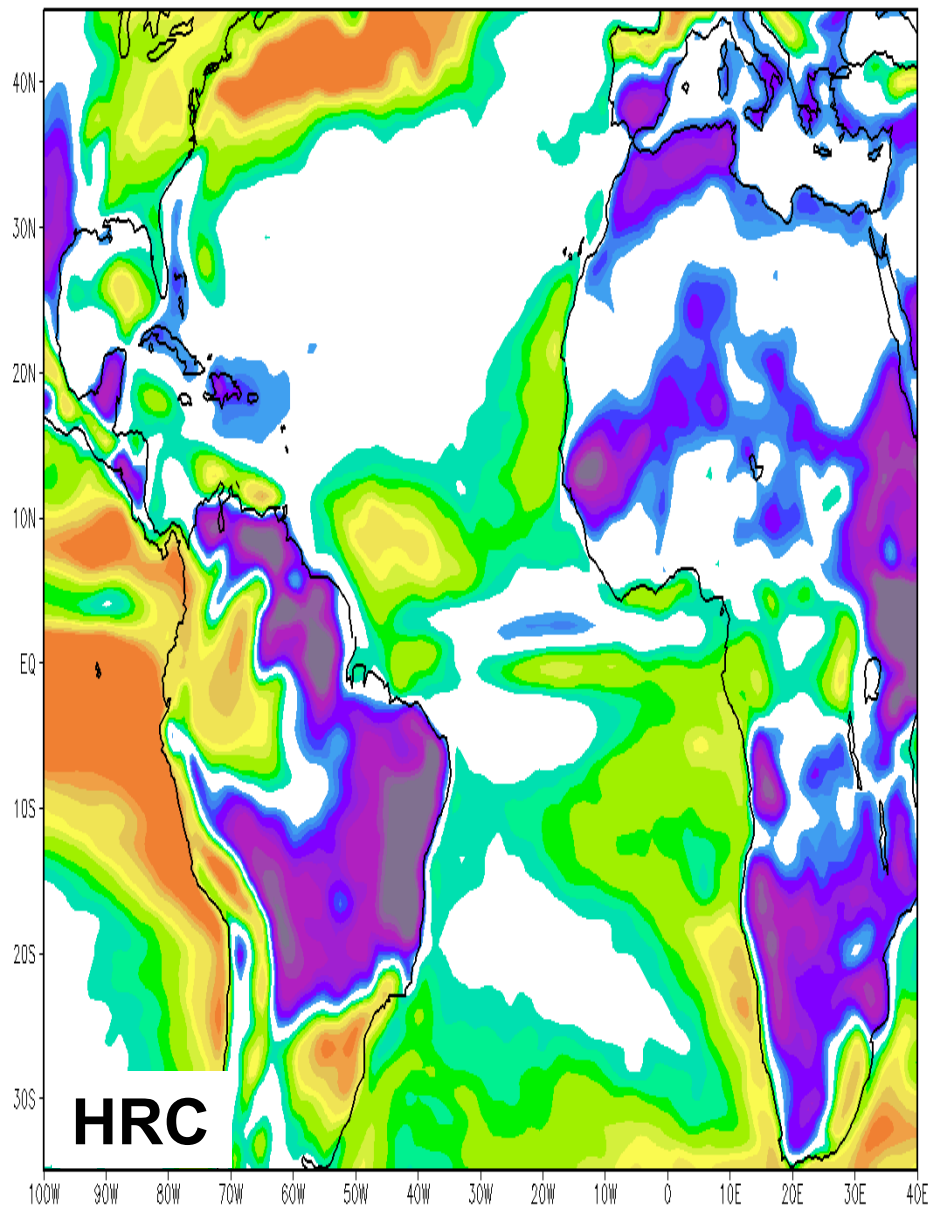


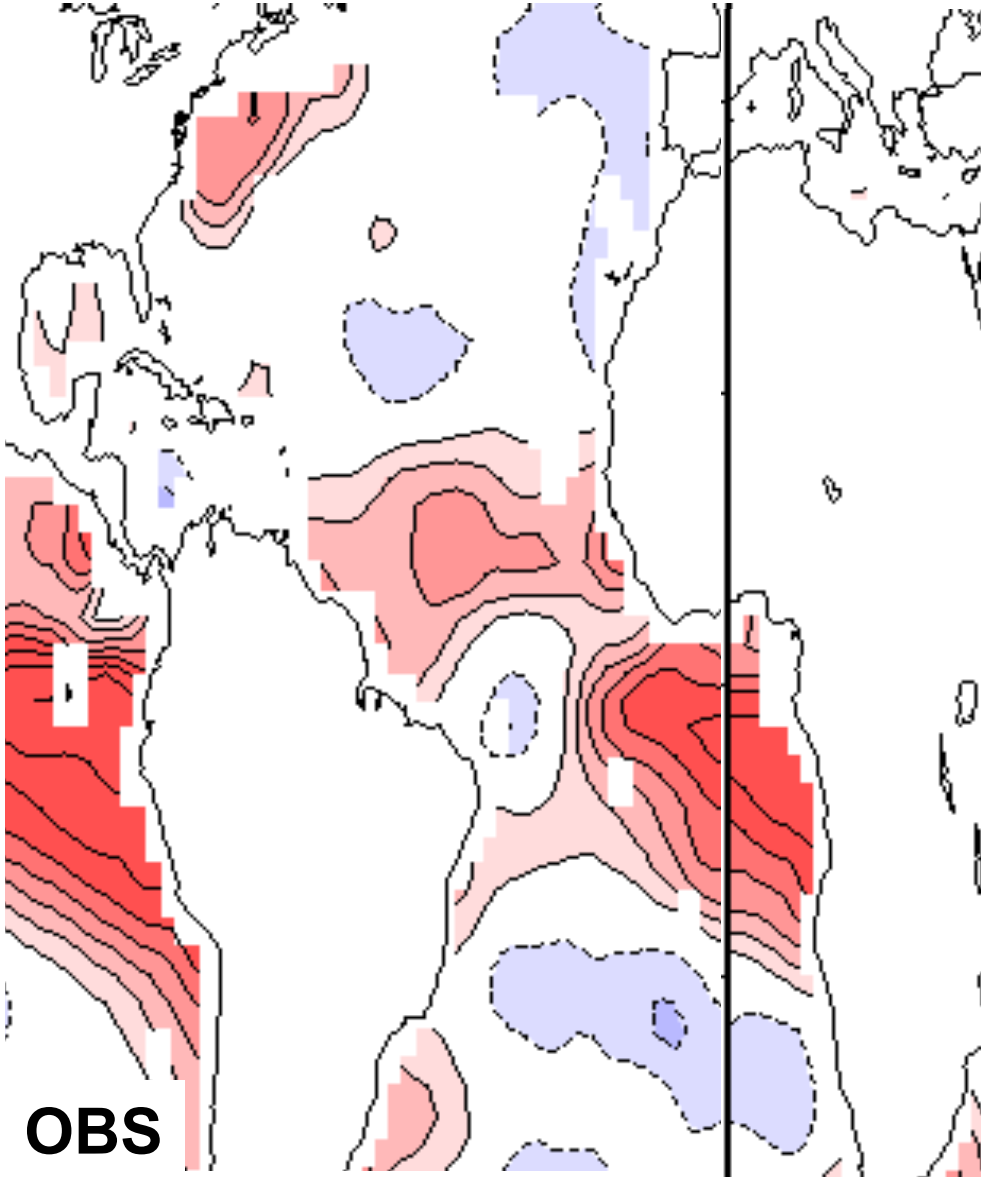
Local SSTA-Latent Heat Flux Correlation

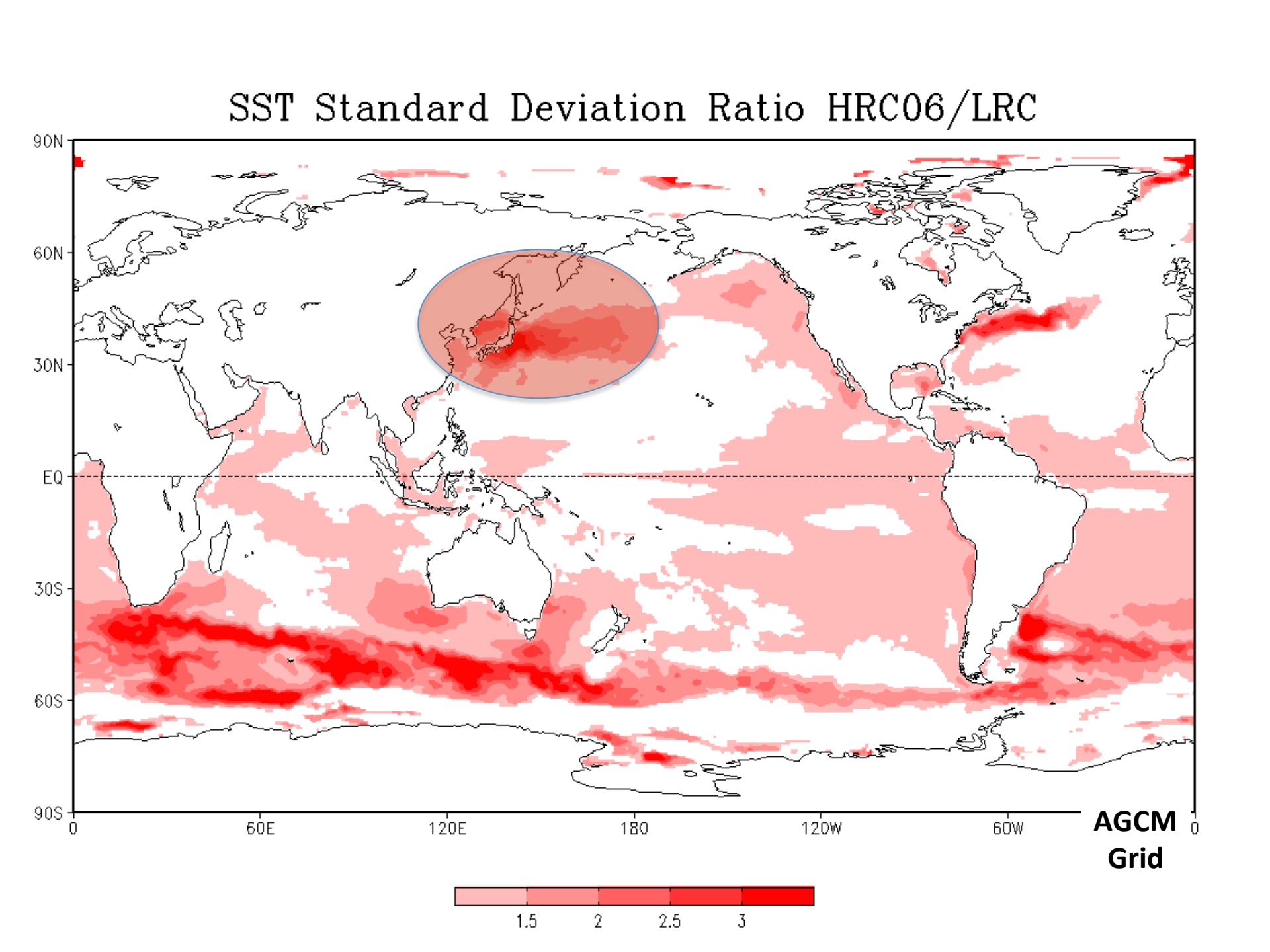


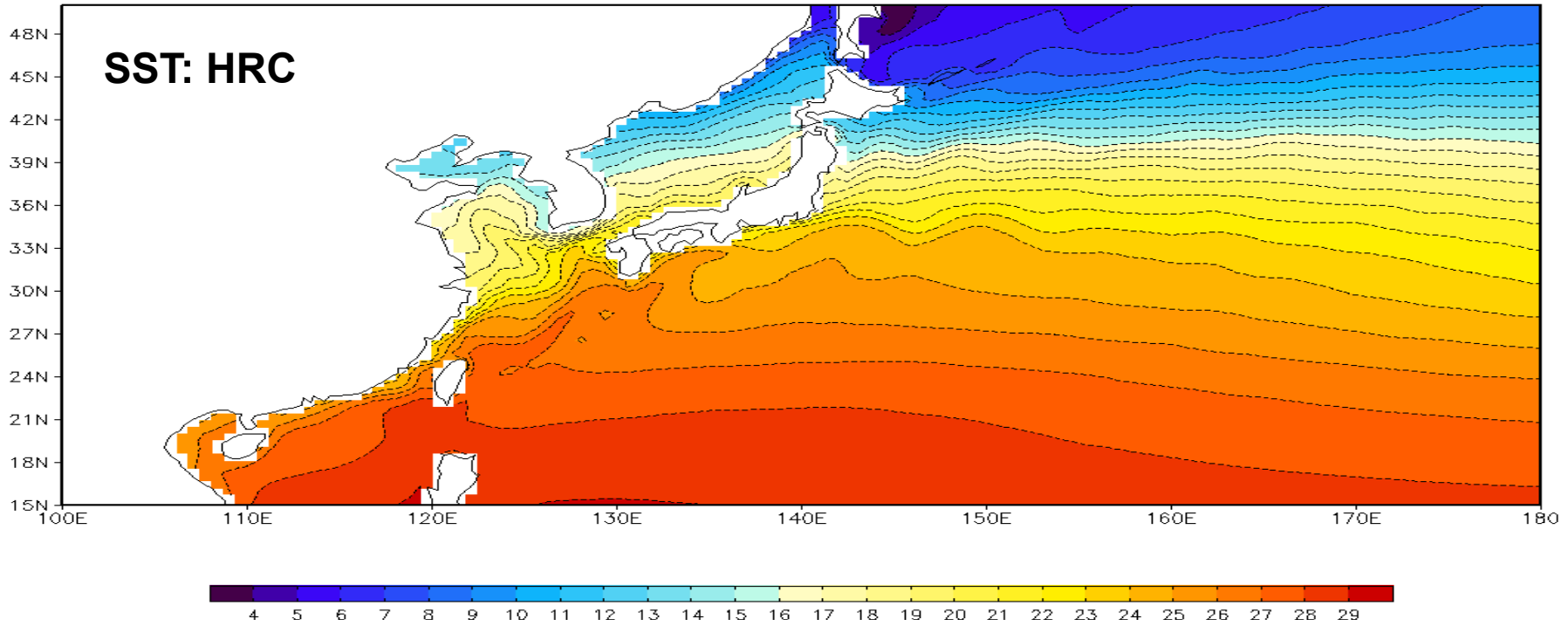


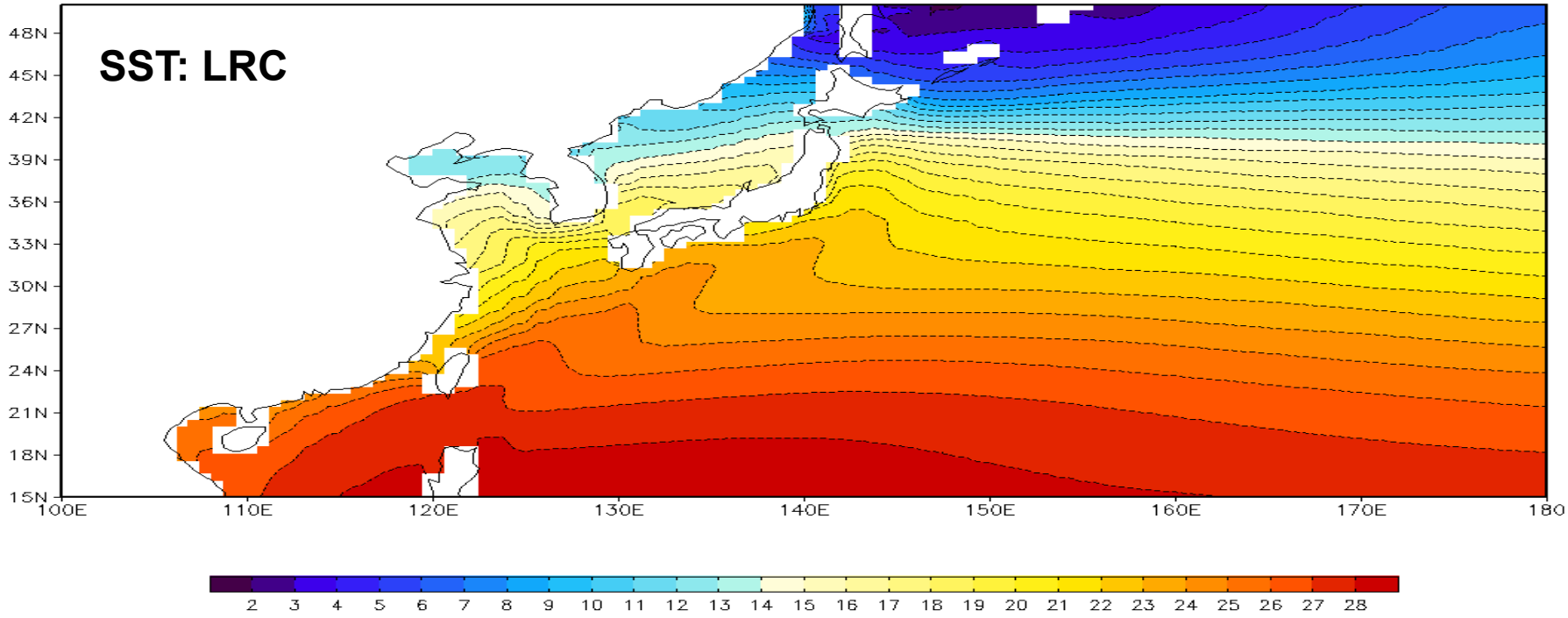
Local SSTA-Latent Heat Flux Correlation

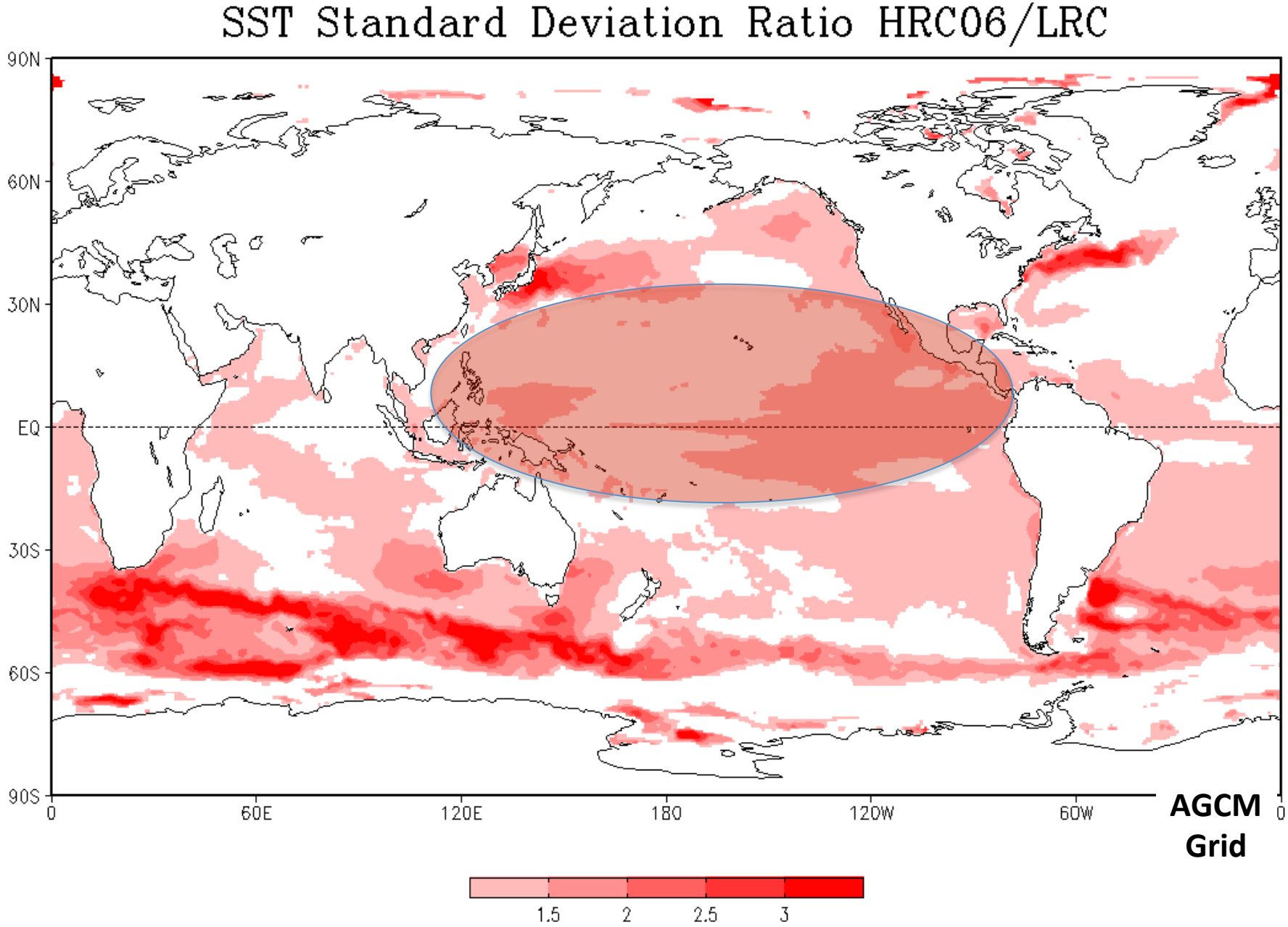




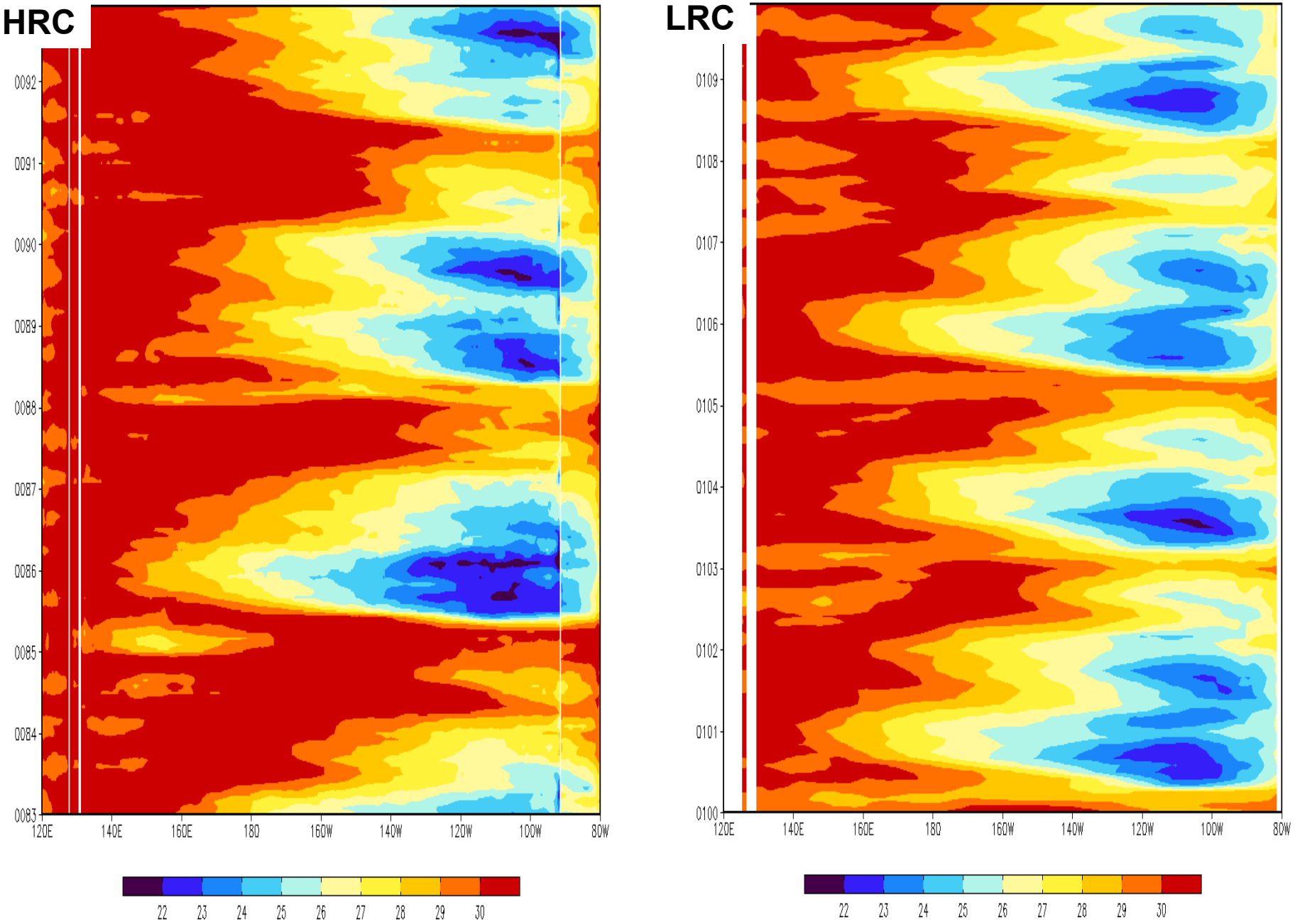

SST Standard Deviation Ratio HRC06/LRC
90N
60N
30N
EQ
30S
60S
90S
0
60E
120E
180
120W
60W
0
AGCM Grid
1.5
2
2.5
3

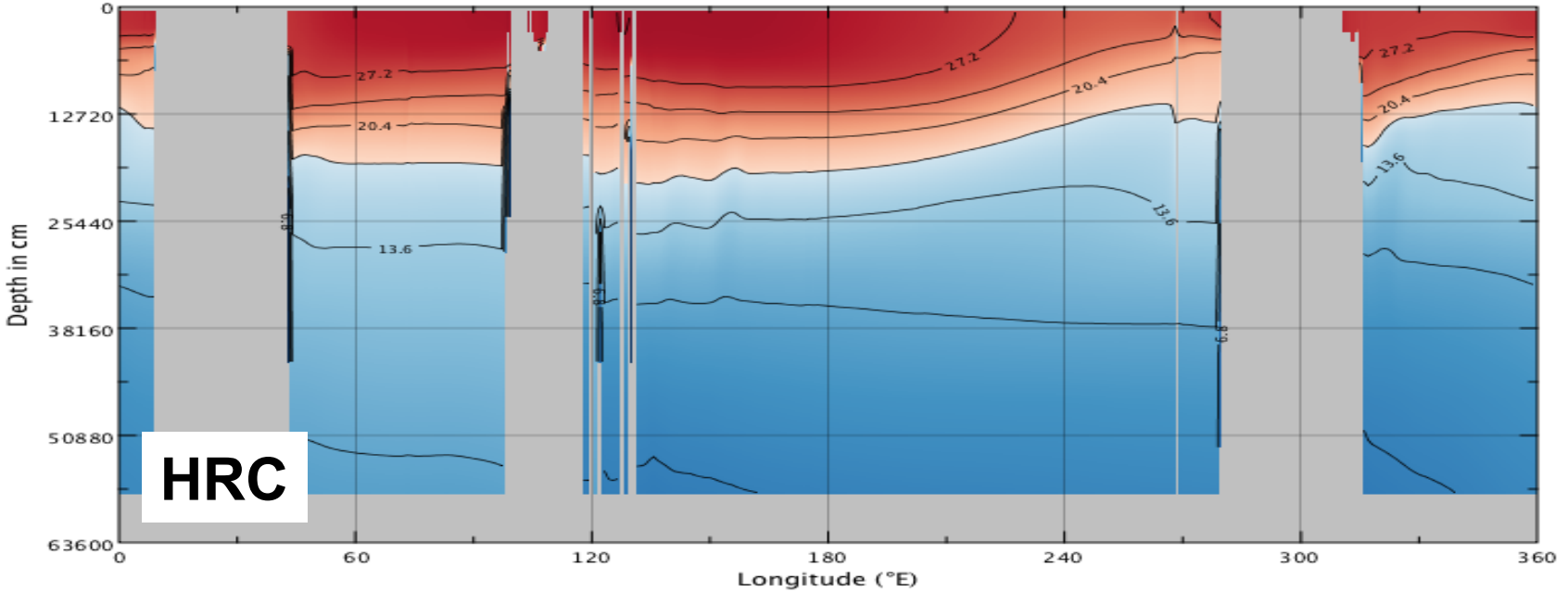

SST: HRC
48N
45N
42N
39N
36N
33N
30N
27N
24N
21N
18N
15N
100E
110E
120E
130E
140E
150E
160E
170E
180
4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29

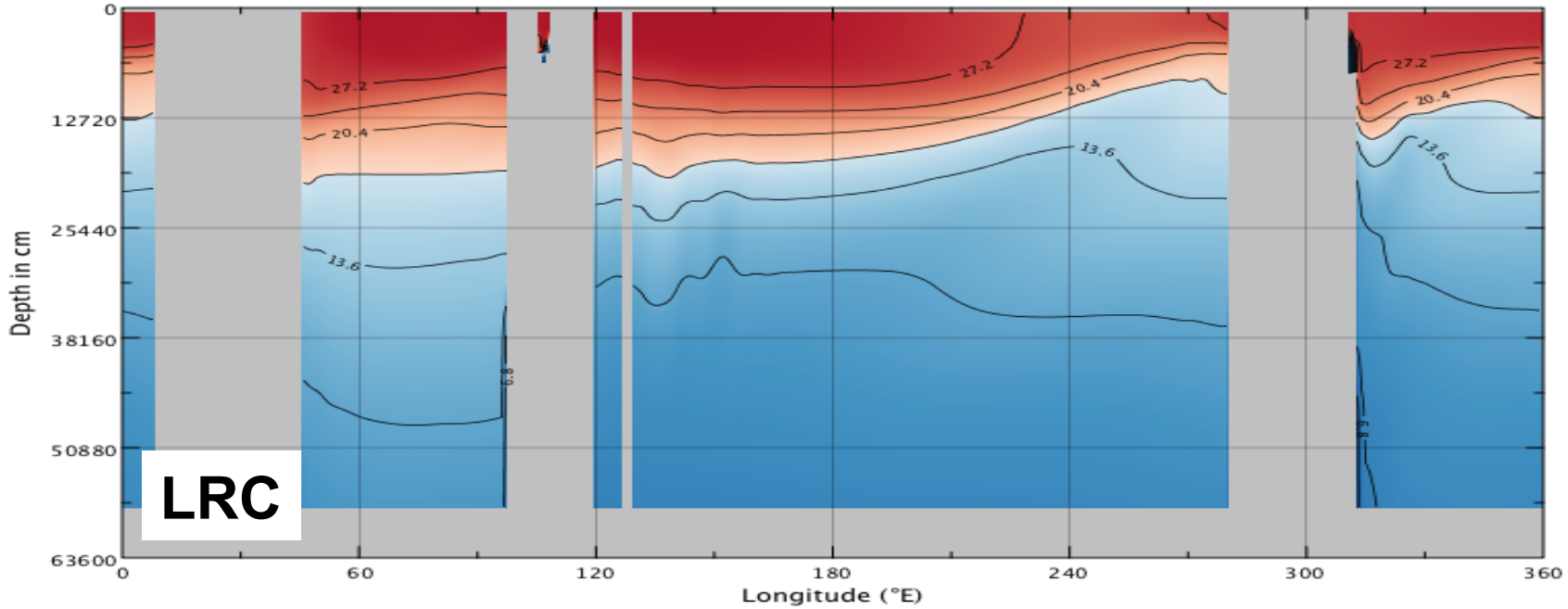

SST: LRC
48N
45N
42N
39N
36N
33N
30N
27N
24N
21N
18N
15N
100E
110E
120E
130E
140E
150E
160E
170E
180
2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28


SST Standard Deviation Ratio HRC06/LRC
90N
60N
30N
EQ
30S
60S
90S
0
60E
120E
180
120W
60W
0
AGCM Grid
1.5
2
2.5
3

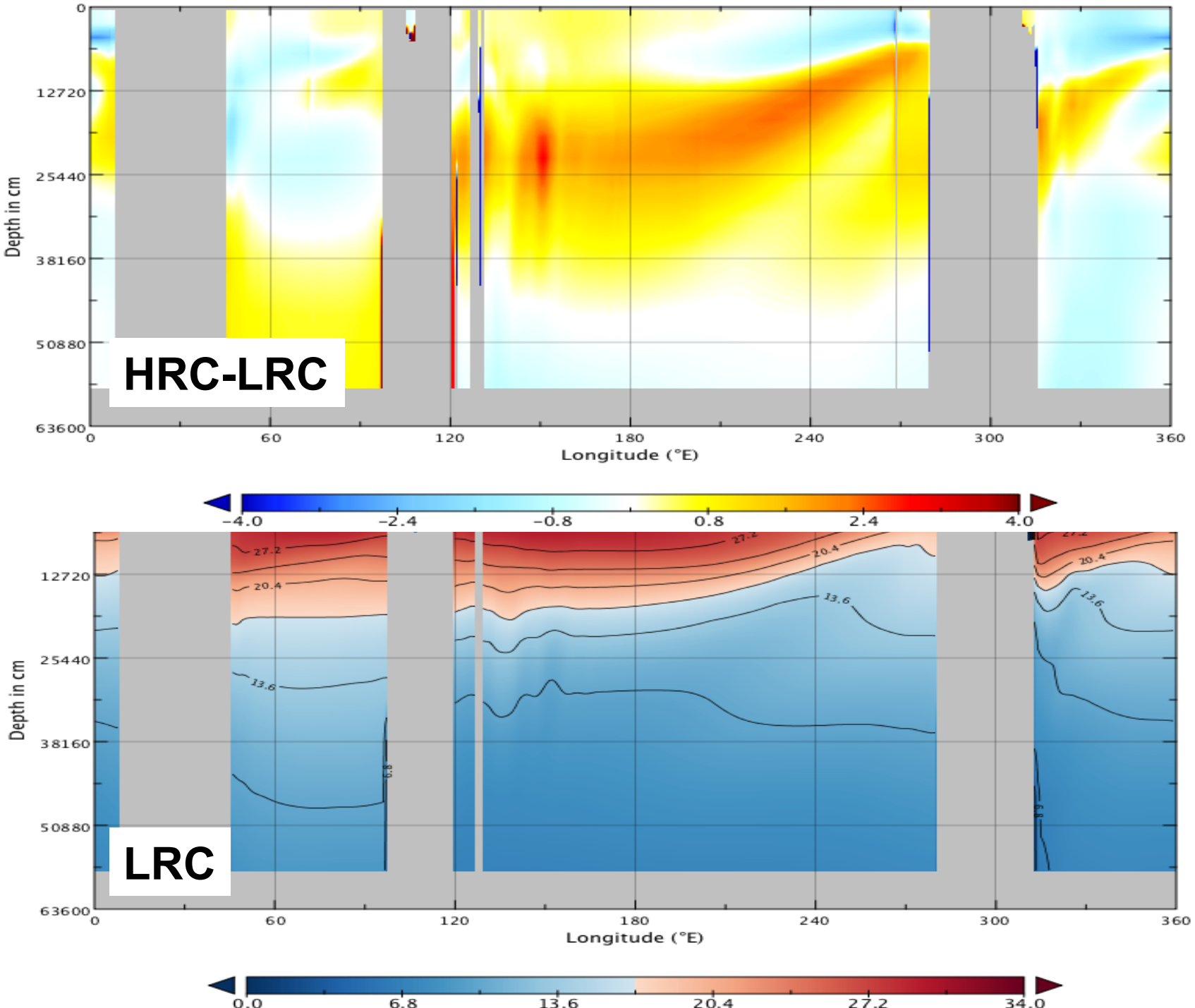
Equatorial SSTs

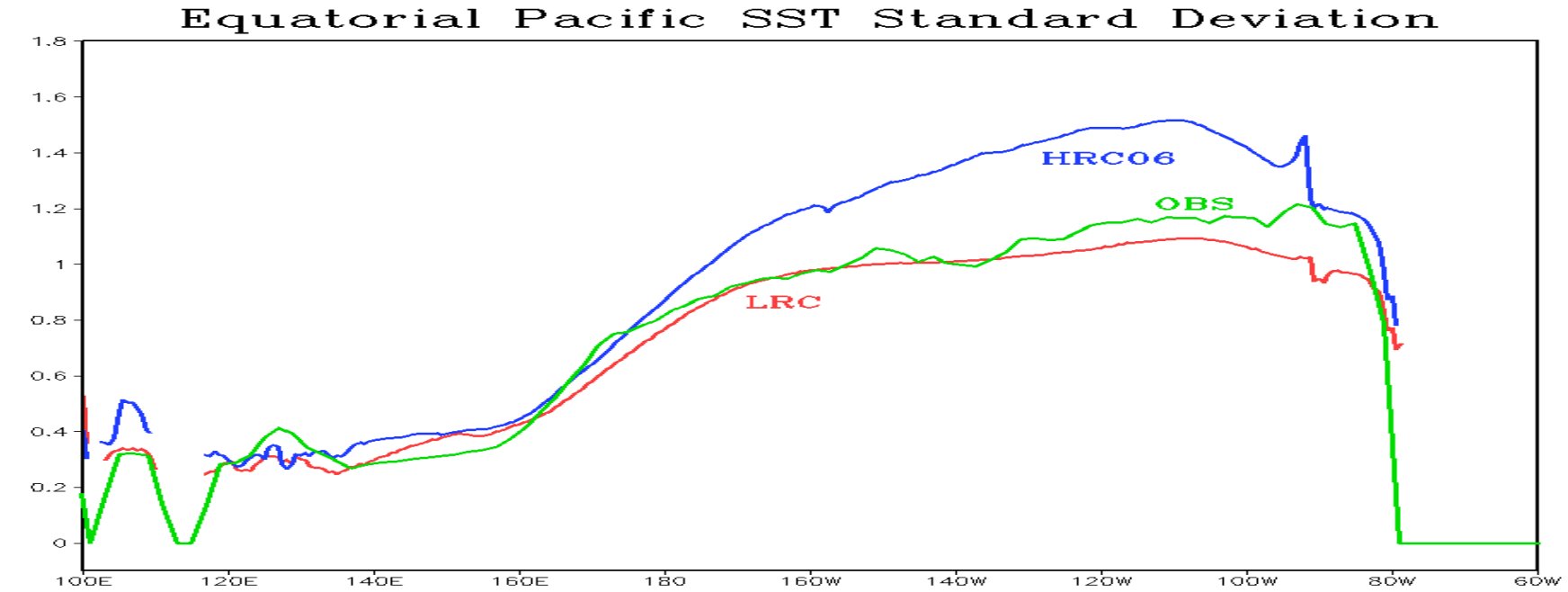


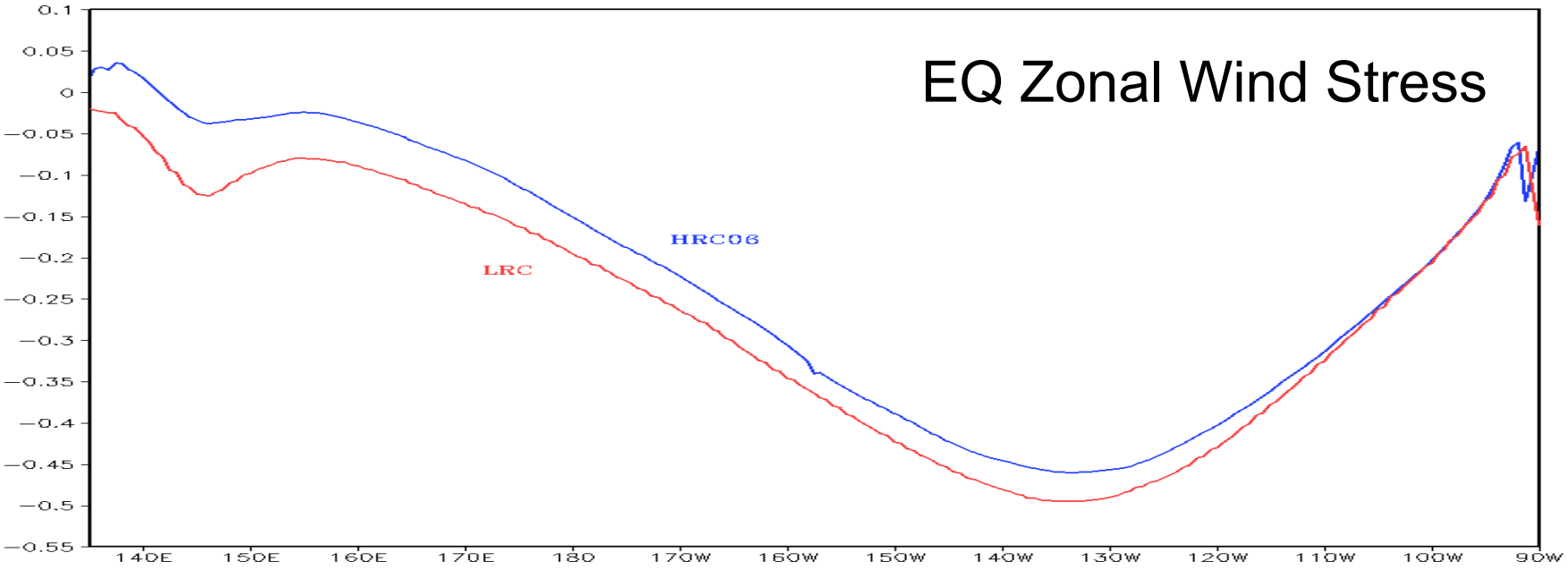

HRC
Depth in cm
0
12720
25440
38160
50880
63600
0
60
120
180
240
300
360
Longitude (°E)
27.2
20.4
13.6
6.8


LRC
Depth in cm
0
12720
25440
38160
50880
63600
0
60
120
180
240
300
360
Longitude (°E)
27.2
20.4
13.6
6.8

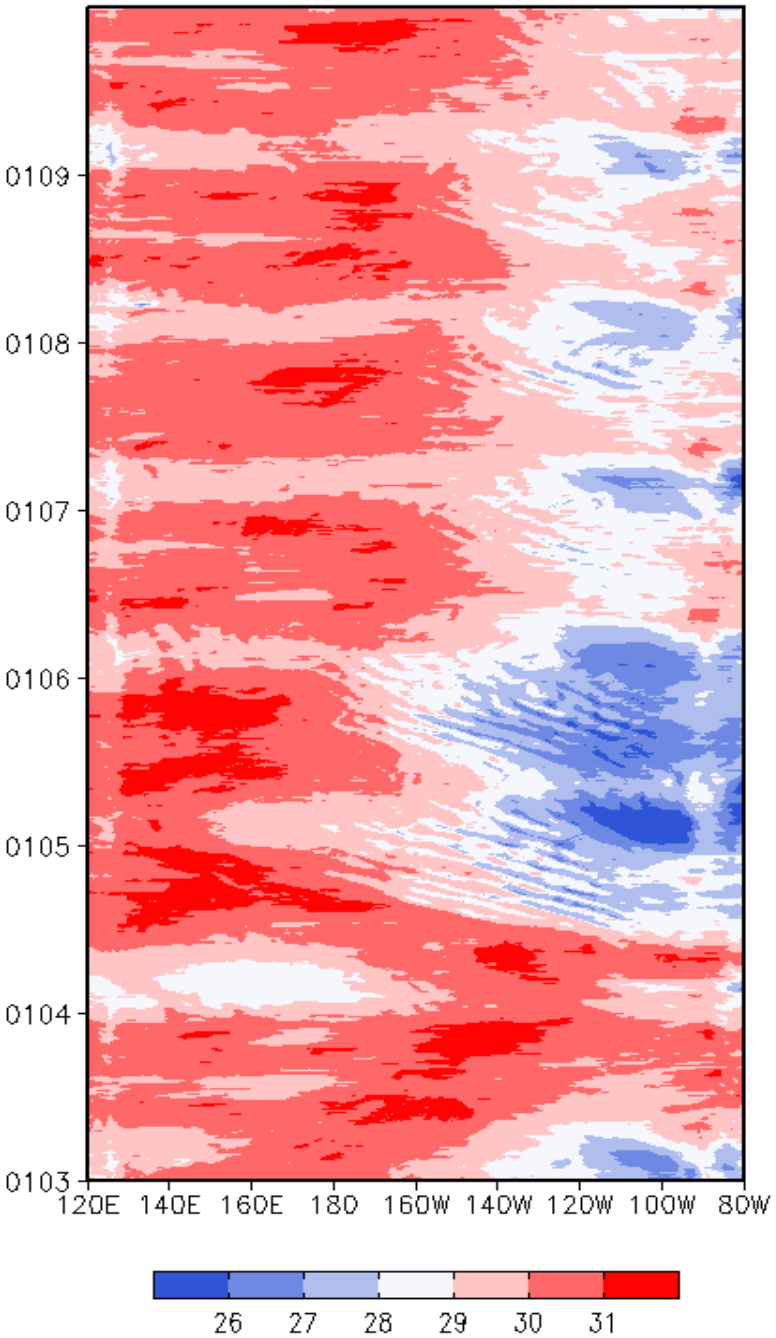

0.0
6.8
13.6
20.4
27.2
34.0

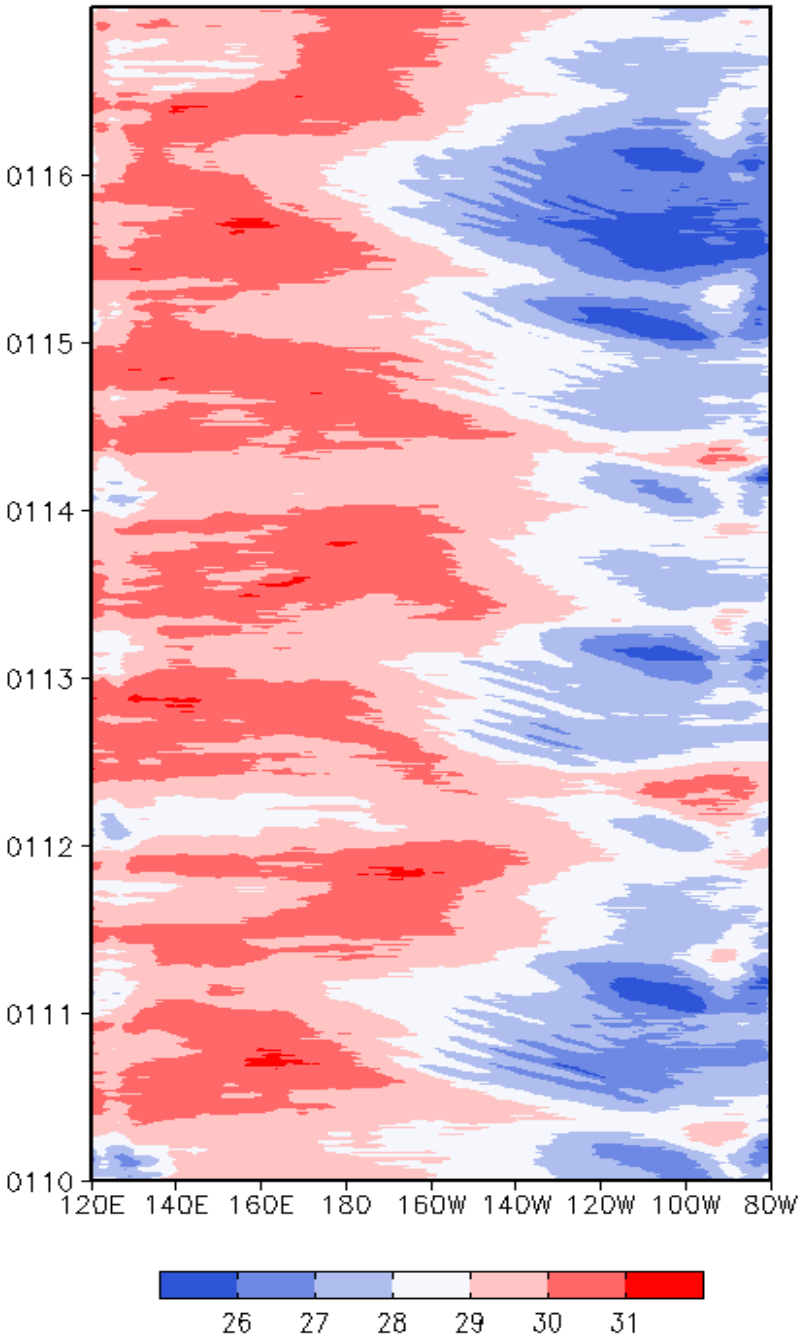

HRC-LRC
Depth in cm
0
12720
25440
38160
50880
63600
0
60
120
180
240
300
360
Longitude (°E)
−4.0
−2.4
−0.8
0.8
2.4
4.0
LRC
27.2
20.4
13.6
6.8
0.0
34.0

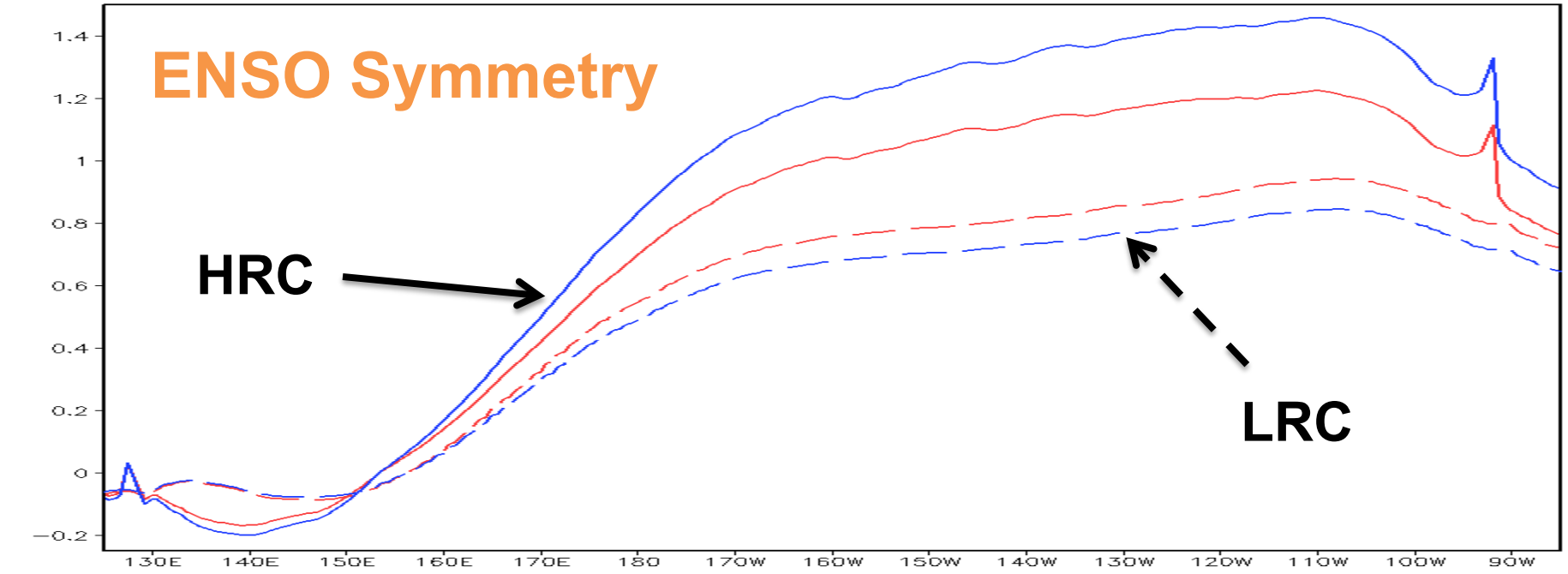

Equatorial Pacific SST Standard Deviation
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
HRC06
OBS
LRC
100E
120E
140E
160E
180
160W
140W
120W
100W
80W
60W

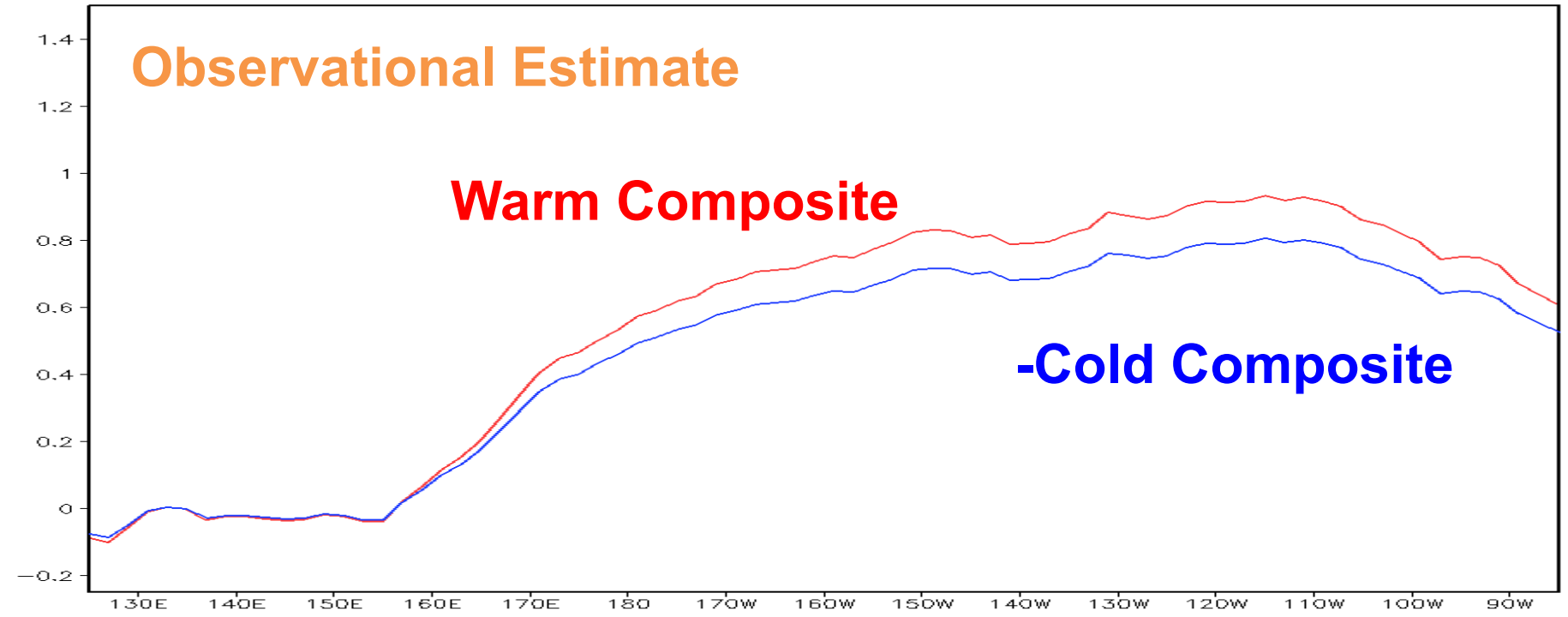

EQ Zonal Wind Stress
0.1
0.05
0
−0.05
−0.1
−0.15
−0.2
−0.25
−0.3
−0.35
−0.4
−0.45
−0.5
−0.55
HRC06
LRC
140E
150E
160E
170E
180
170W
160W
150W
140W
130W
120W
110W
100W
90W

Tropical Instability Waves: SST 3-6N






ENSO Symmetry
HRC
LRC
1.4
1.2
1
0.8
0.6
0.4
0.2
0
−0.2
130E
140E
150E
160E
170E
180
170W
160W
150W
140W
130W
120W
110W
100W
90W


Observational Estimate
Warm Composite
-Cold Composite
1.4
1.2
1
0.8
0.6
0.4
0.2
0
−0.2
130E
140E
150E
160E
170E
180
170W
160W
150W
140W
130W
120W
110W
100W
90W

Outline

- CCSM3.5*
  - Atmosphere: 0.5x0.5
  - Two Versions: 1x1 [LRC] and 0.1x0.1 [HRC*]
- Spin-Up Issues/Polar Filter
- Ubiquitous Warm Signal
  - Ocean Heat Transport, Ice Albedo Feedback, Water Vapor Feedback, Cloud Partitioning
- Survey of Large Scale Climatic Features
  - North Atlantic: Gulf Stream, Air-Sea Feedbacks
  - North Pacific: Kuroshio
  - Equatorial Pacific: ENSO, TWIs, ENSO-symmetry