Ocean-atmosphere coupling over mid-latitde oceans

W. Timothy Liu and Xiaosu Xie
Jet Propulsion Laboratory
California Institute of Technology

SST has been viewed as the surface signature of ocean's response to atmospheric forcing or the oceanic driver of atmospheric circulation. Local and remote connections with atmosphere have long been studied

- Local infiuence
- Teleconection

Limited Extra-tropical Coupling

- **Ocean has slow and small-scale, but atmosphere has fast and large-scale processes.**

  Coupling in mid-latitudes at long time period is controversial.

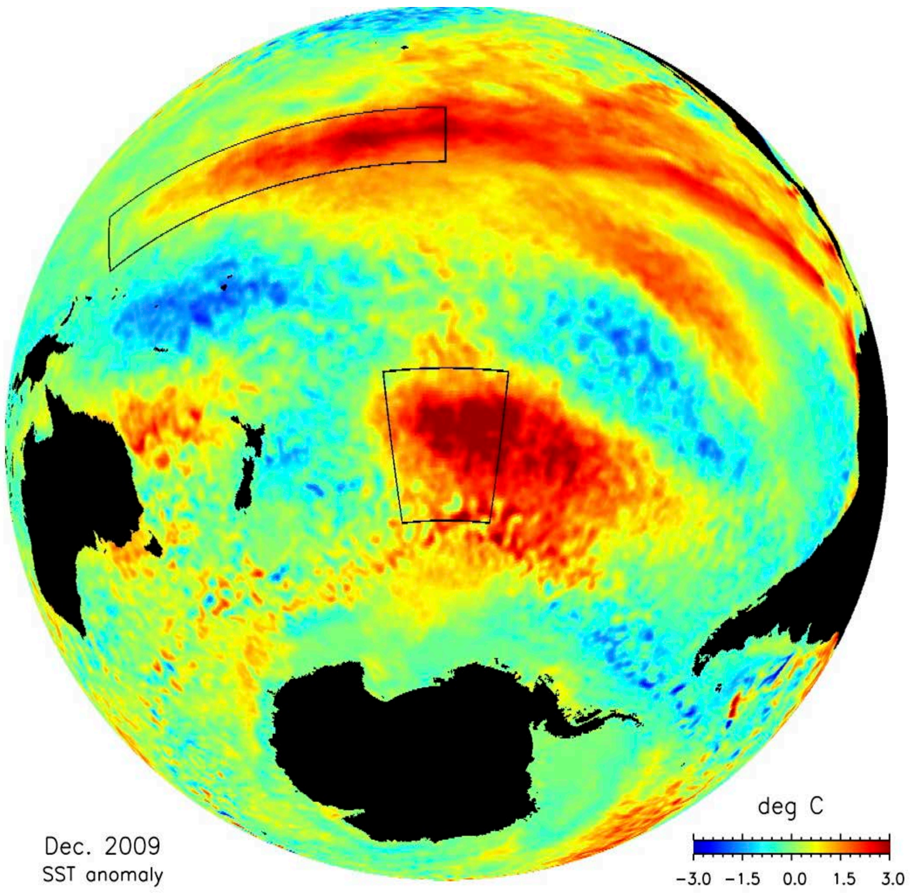
GCM fails to generate systematic response to prescribed midlatitude SST anomalies above boundary layer

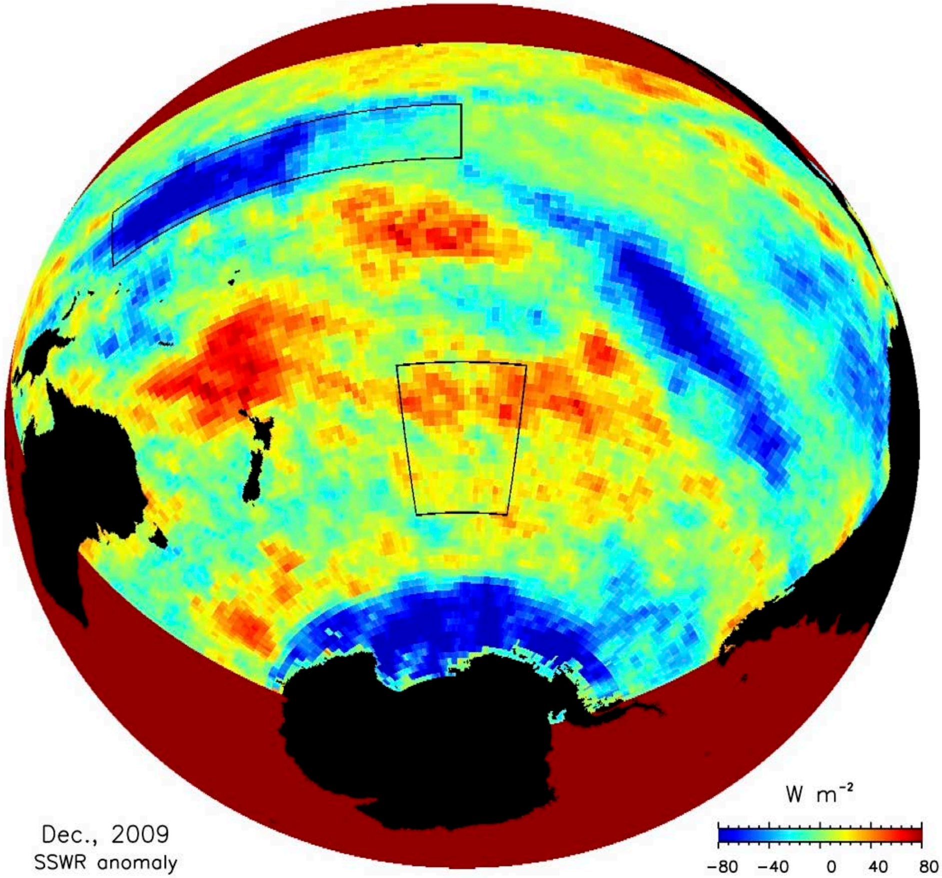
Lapse rate is believe to be too weak to generate deep convection, as over the tropical oceans.

Atmospheric Bridges Hypothesis (e.g.,Kushnir et al. 2002; Alexander et al. 2002)

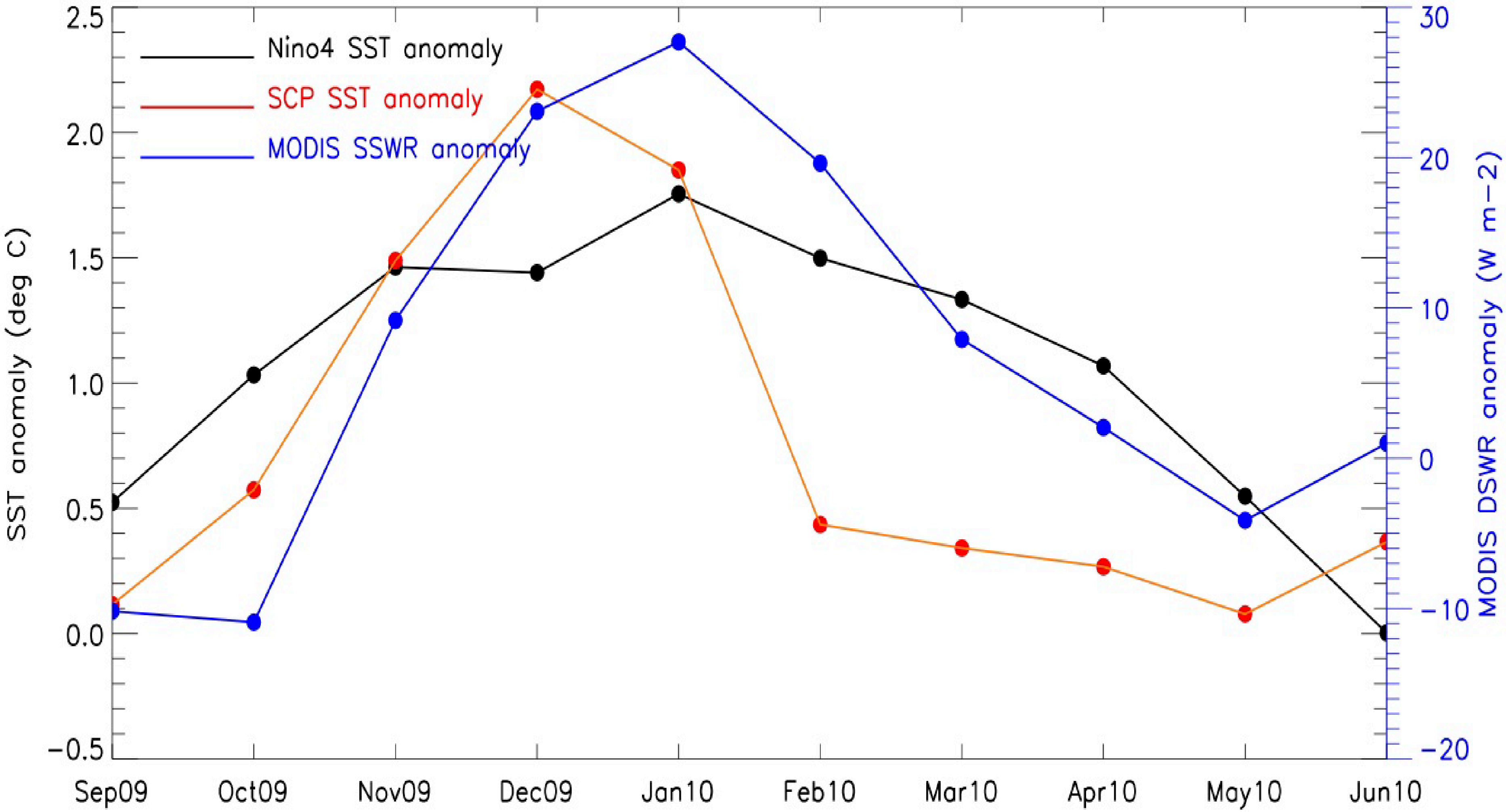
- In the tropical Pacific, SST anomalies during El Nino cause deep convection that affect large scale atmospheric circulation, that alters the near-surface air temperature, humidity and wind far from the equatorial Pacific.
- The resulting variation in heat, water, and momentum flux drive local SST anomalies at extra-tropical oceans.

- A record warming-event occurred in the south-central Pacific, starting in September and peaking in December of 2009.
- Lee et al. [2010] attribute the warming to reduced evaporative cooling and Ekman advection caused by persistent anticyclone.
- Boening et al. [2011] attributed to mass convergence in the ocean resulted from wind stress curl associated with the anticyclone.
- Solar heating was deemed unimportant because NCEP reanalysis show reduced solar heating.





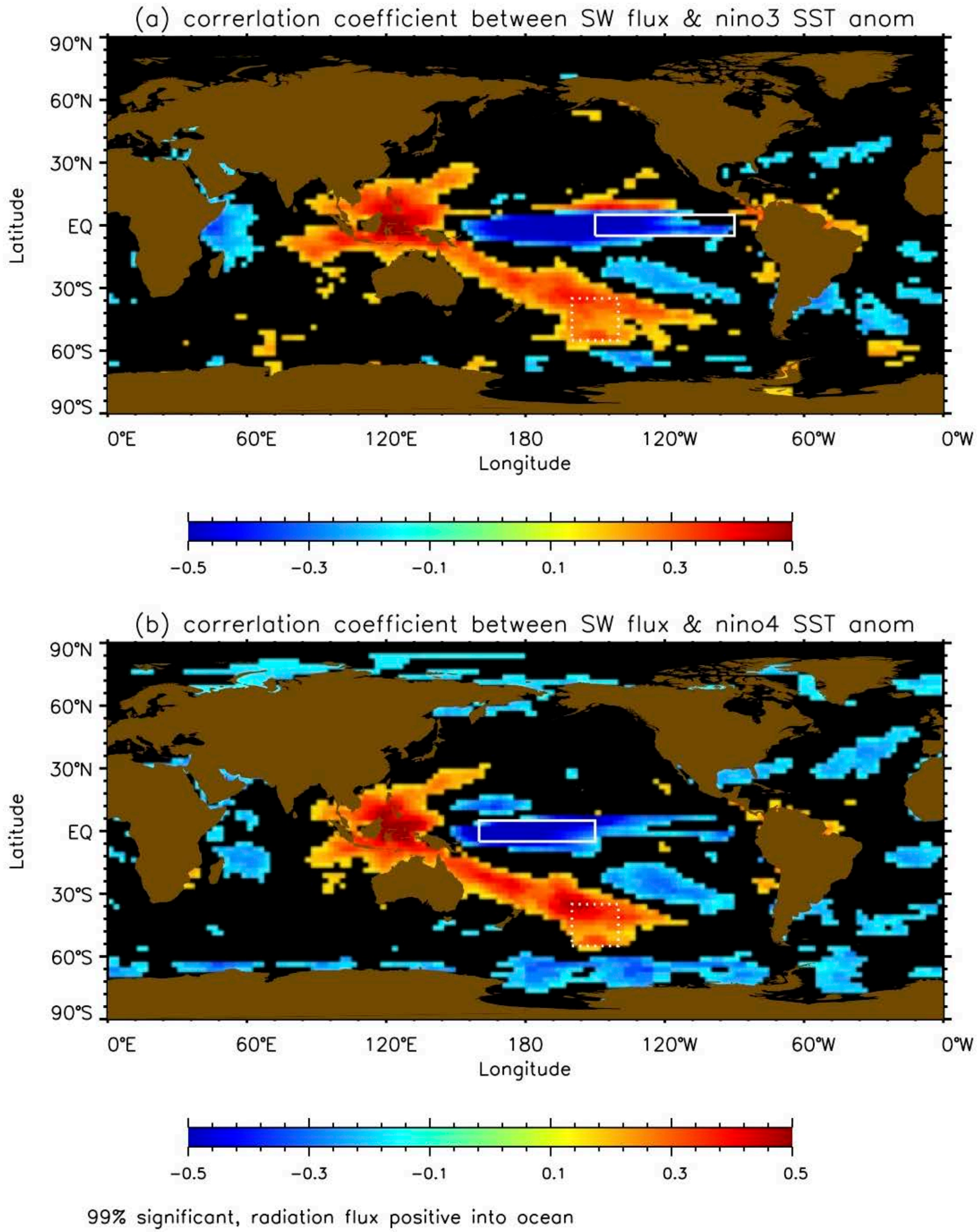
Liu et al., 2013, IJRS, I npress

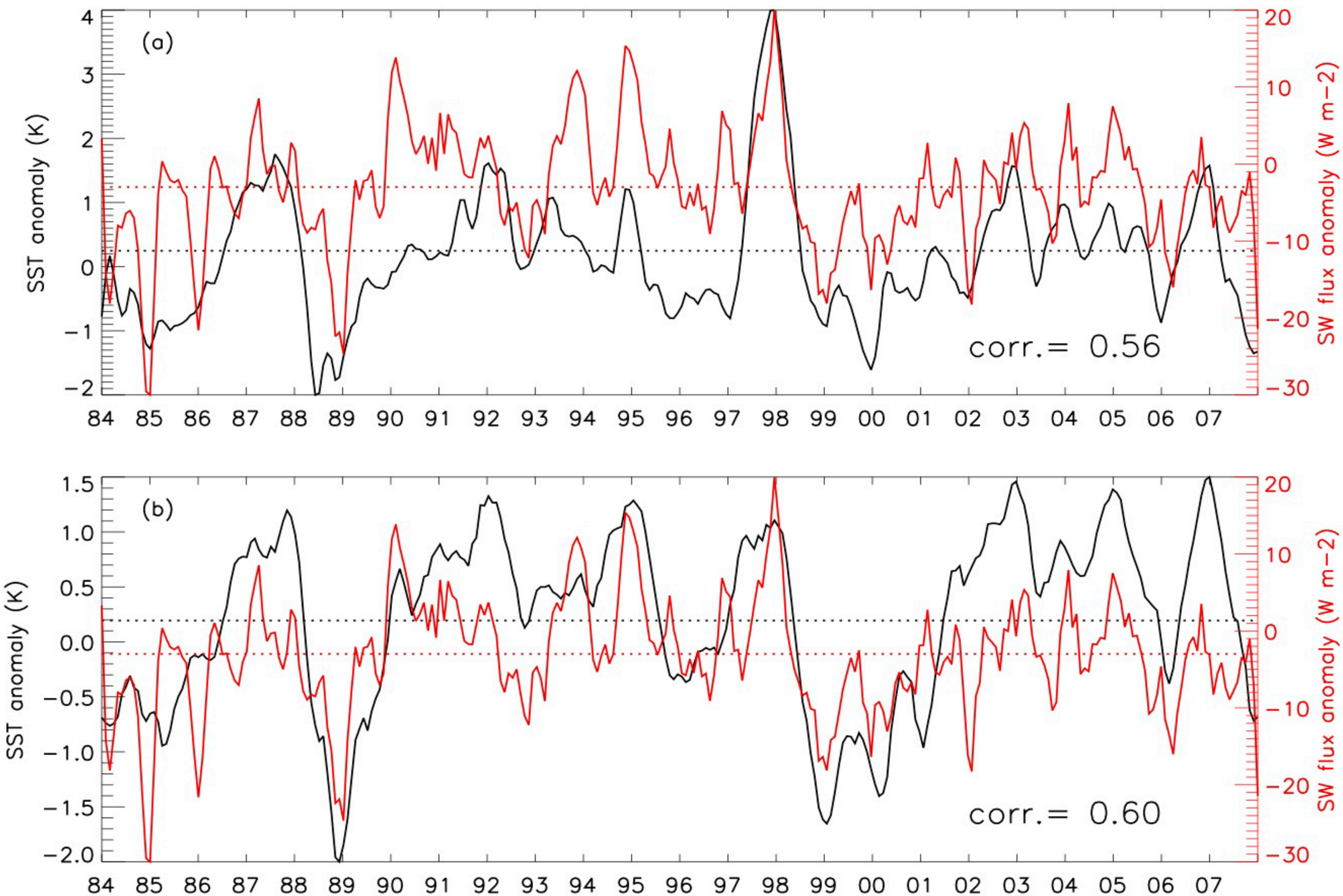


Nino4 SST anomaly
SCP SST anomaly
MODIS SSWR anomaly
SST anomaly (deg C)
MODIS DSWR anomaly (W m−2)
2.5
2.0
1.5
1.0
0.5
0.0
−0.5
30
20
10
0
−10
−20
Sep09
Oct09
Nov09
Dec09
Jan10
Feb10
Mar10
Apr10
May10
Jun10

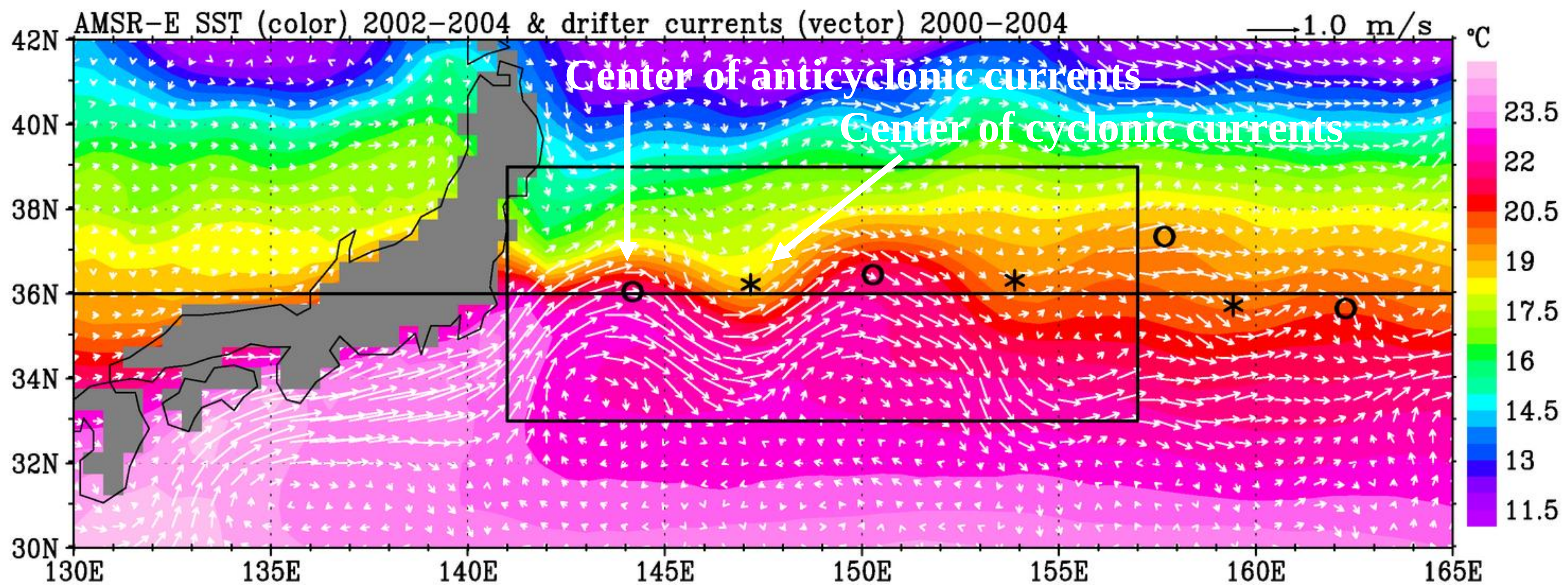
Solar contribution to SCP warming

	(a) SSWR anomalies (W/m^2)	(b) Ta (°C)	(c) SSTa (°C)	(d) Ta / SSTa (%)
Sept. 2009	-10.17	-0.1280	0.1153	-
Oct. 2009	-10.92	-0.1373	0.5736	-
Nov. 2009	9.17	0.1154	1.4890	7.75
Dec. 2009	23.07	0.2903	2.1725	13.36
Jan. 2010	27.70	0.3485	1.8502	18.84
Feb. 2010	19.62	0.2469	0.4350	56.76
Mar. 2010	7.91	0.0995	0.3415	29.14
Apr. 2010	2.04	0.0257	0.2666	9.64
May 2010	-4.14	-0.0521	0.0780	-
Jun. 2010	1.00	-0.0126	0.3661	-

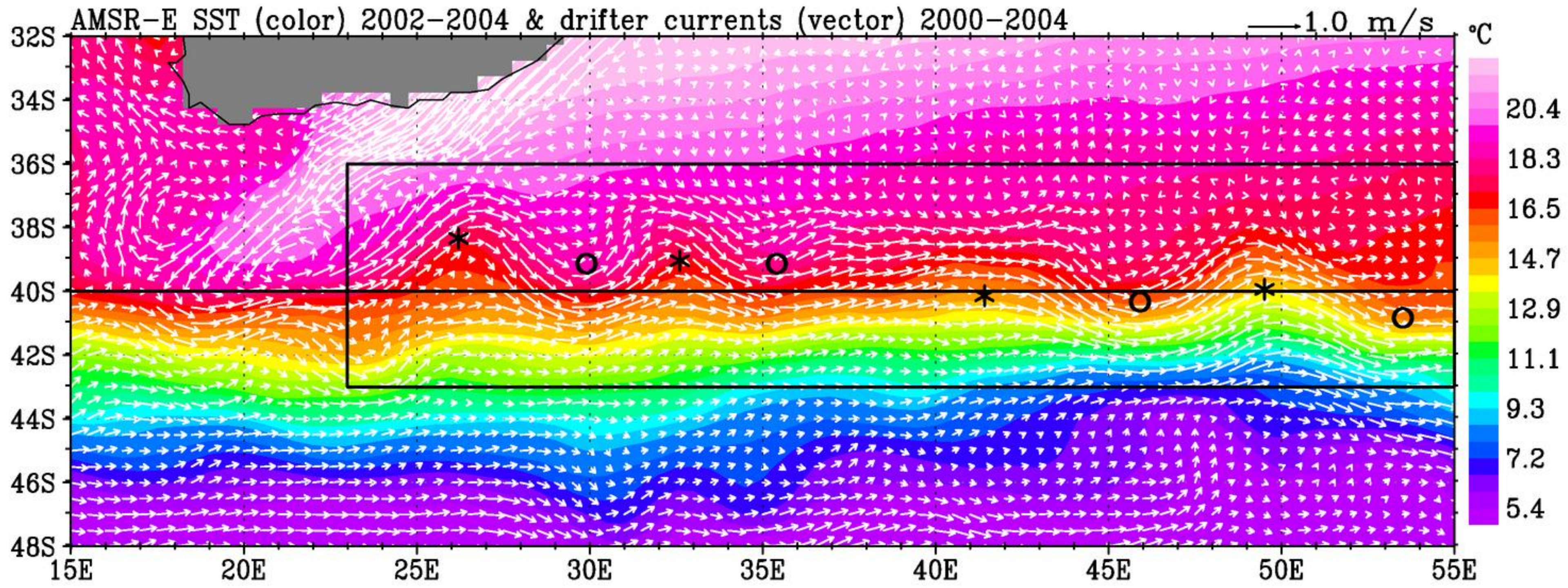

(a) correrlation coefficient between SW flux & nino3 SST anom
90°N
60°N
30°N
EQ
30°S
60°S
90°S
Latitude
0°E
60°E
120°E
180
120°W
60°W
0°W
Longitude
-0.5
-0.3
-0.1
0.1
0.3
0.5
(b) correrlation coefficient between SW flux & nino4 SST anom
90°N
60°N
30°N
EQ
30°S
60°S
90°S
Latitude
0°E
60°E
120°E
180
120°W
60°W
0°W
Longitude
-0.5
-0.3
-0.1
0.1
0.3
0.5
99% significant, radiation flux positive into ocean



(a)
SST anomaly (K)
SW flux anomaly (W m−2)
corr.= 0.56
84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 00 01 02 03 04 05 06 07
(b)
SST anomaly (K)
SW flux anomaly (W m−2)
corr.= 0.60
84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 00 01 02 03 04 05 06 07



AMSR-E SST (color) 2002-2004 & drifter currents (vector) 2000-2004
1.0 m/s
Center of anticyclonic currents
Center of cyclonic currents
°C
23.5
22
20.5
19
17.5
16
14.5
13
11.5
42N
40N
38N
36N
34N
32N
30N
130E
135E
140E
145E
150E
155E
160E
165E

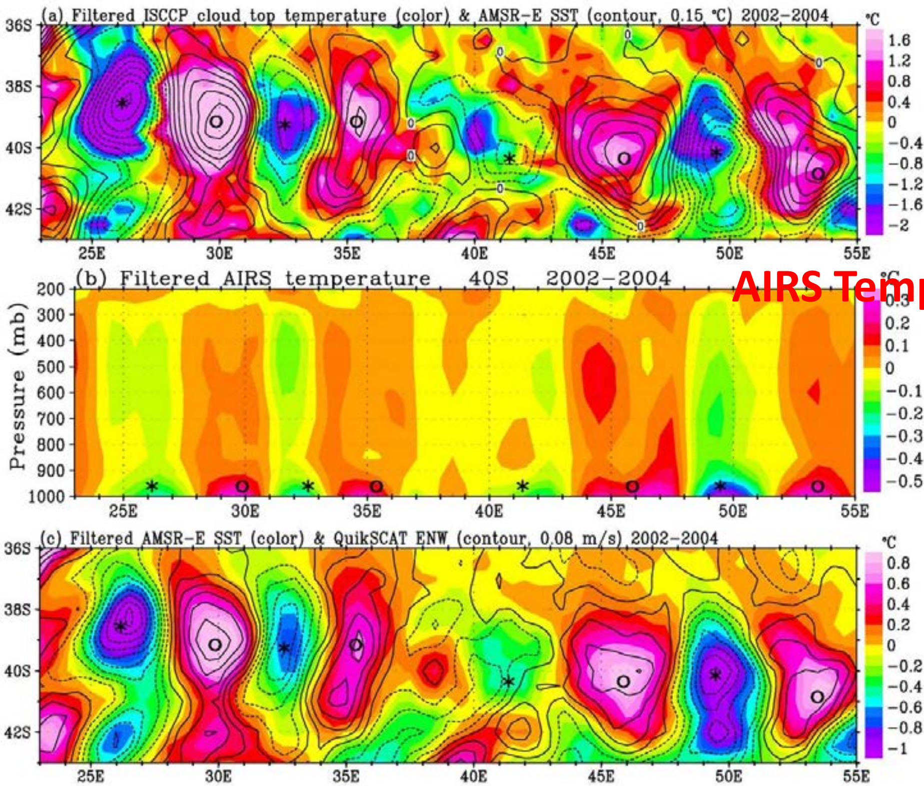


AMSR-E SST (color) 2002-2004 & drifter currents (vector) 2000-2004
1.0 m/s
°C
20.4
18.3
16.5
14.7
12.9
11.1
9.3
7.2
5.4
32S
34S
36S
38S
40S
42S
44S
46S
48S
15E
20E
25E
30E
35E
40E
45E
50E
55E

From Ocean Surface to Tropopause

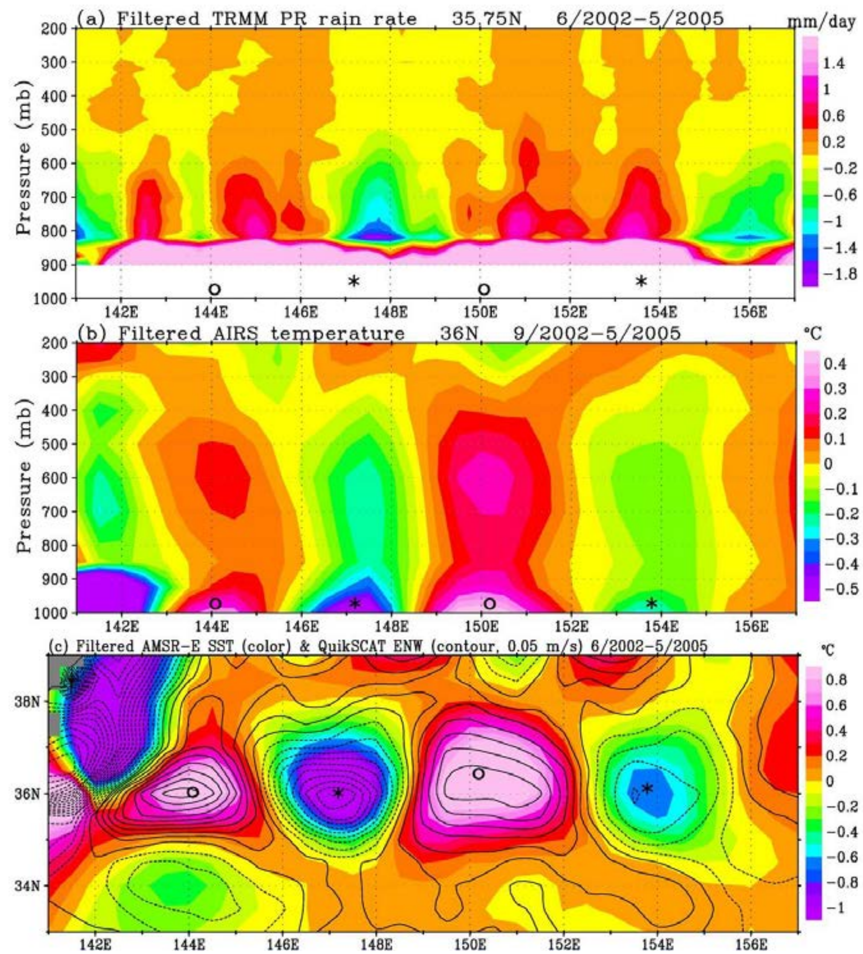
Over mid-latitude ocean, lapse rate is too weak to generate deep convection and transfer ocean effects beyond boundary layer?

Agulhas, 40S, ISCCP CTT & AMSR-E SST



AMSR-E SST & QuikSCAT U_N

Kuroshio, 36N, TRMM PR rain

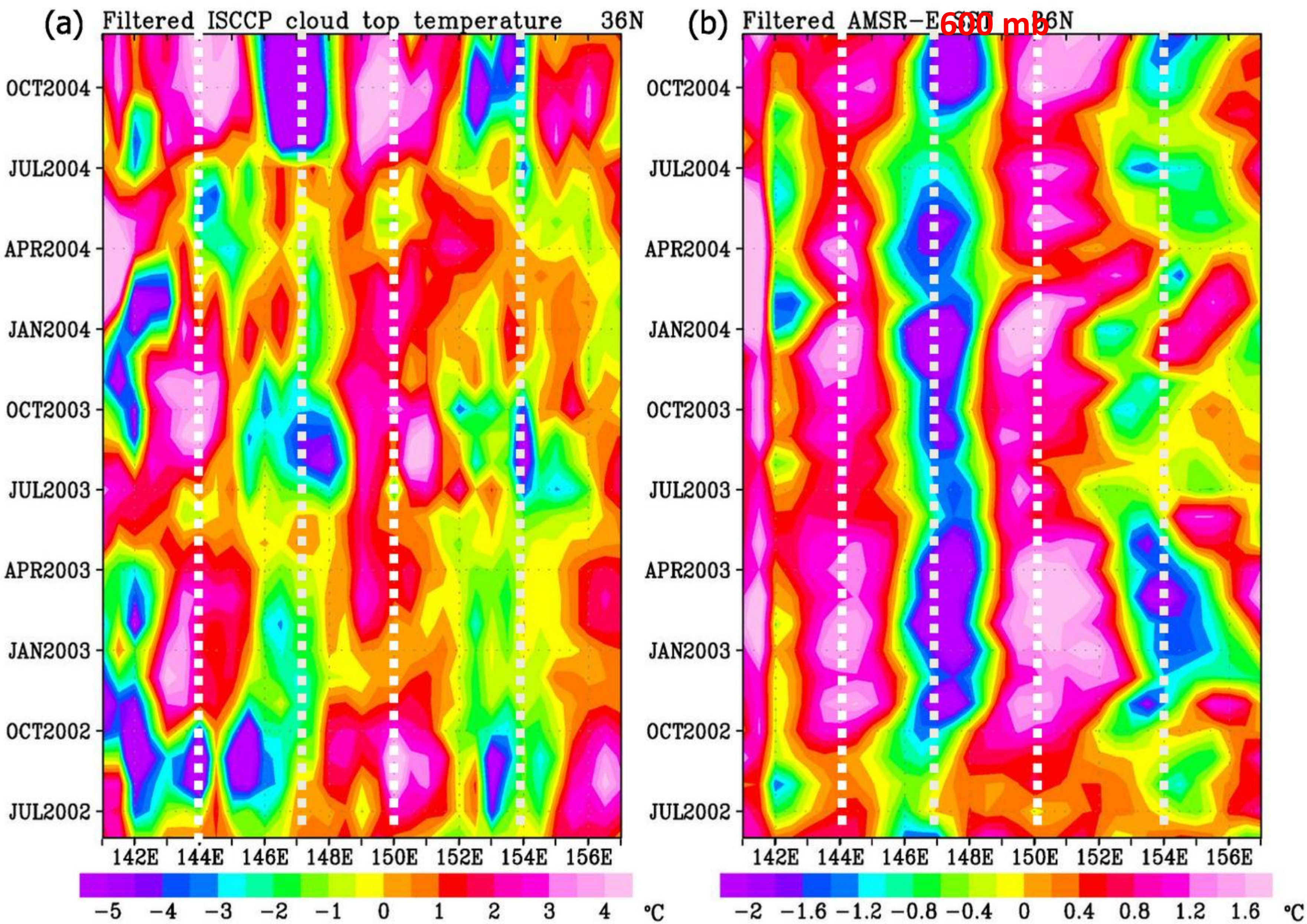


From tropical to mid-latitude oceans,

GPM is needed to monitor western boundary currents

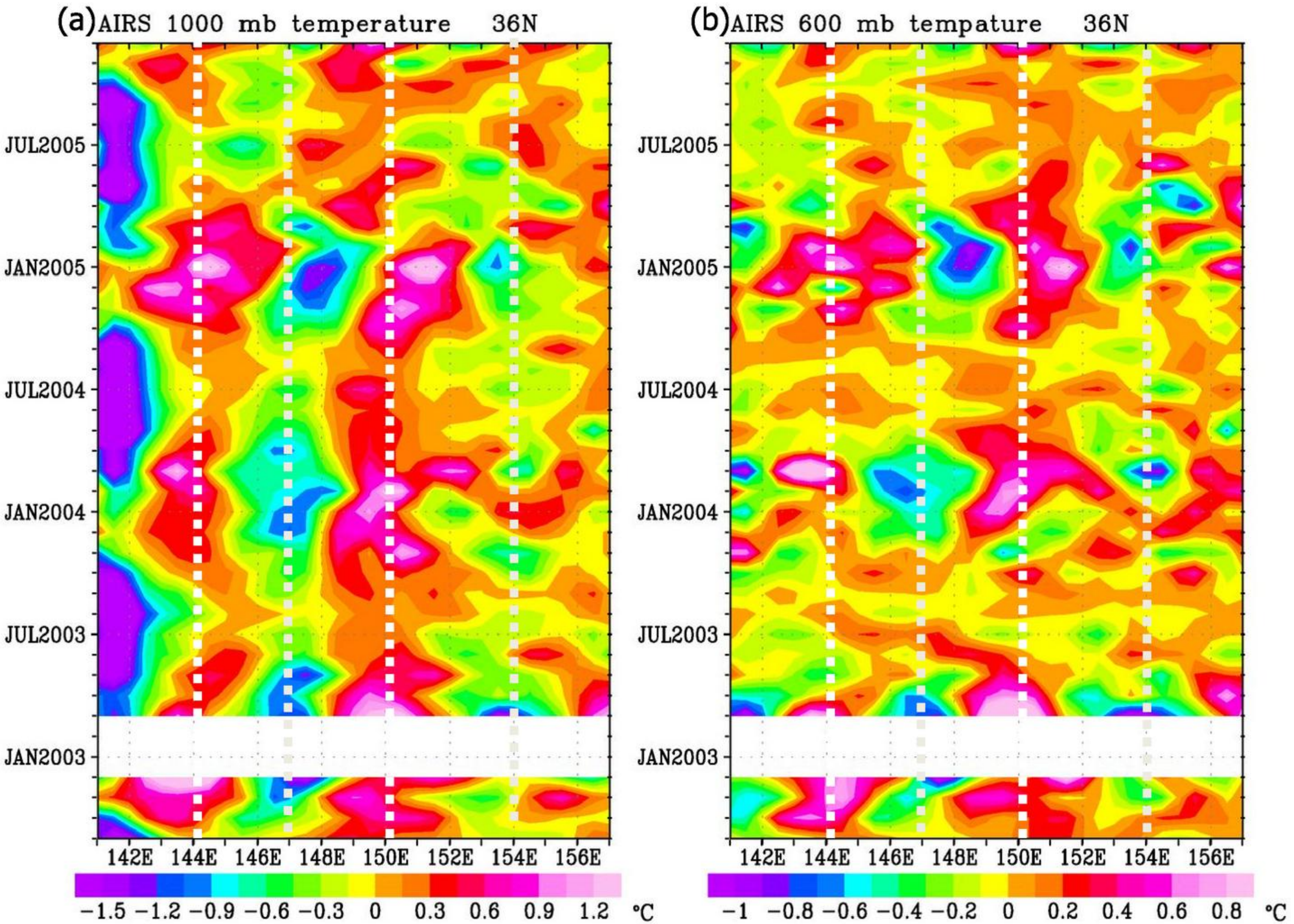
ISCCP cloud top temperature   AMSR sea surface temperature

Kuroshio Extension, 36N, 600 mb

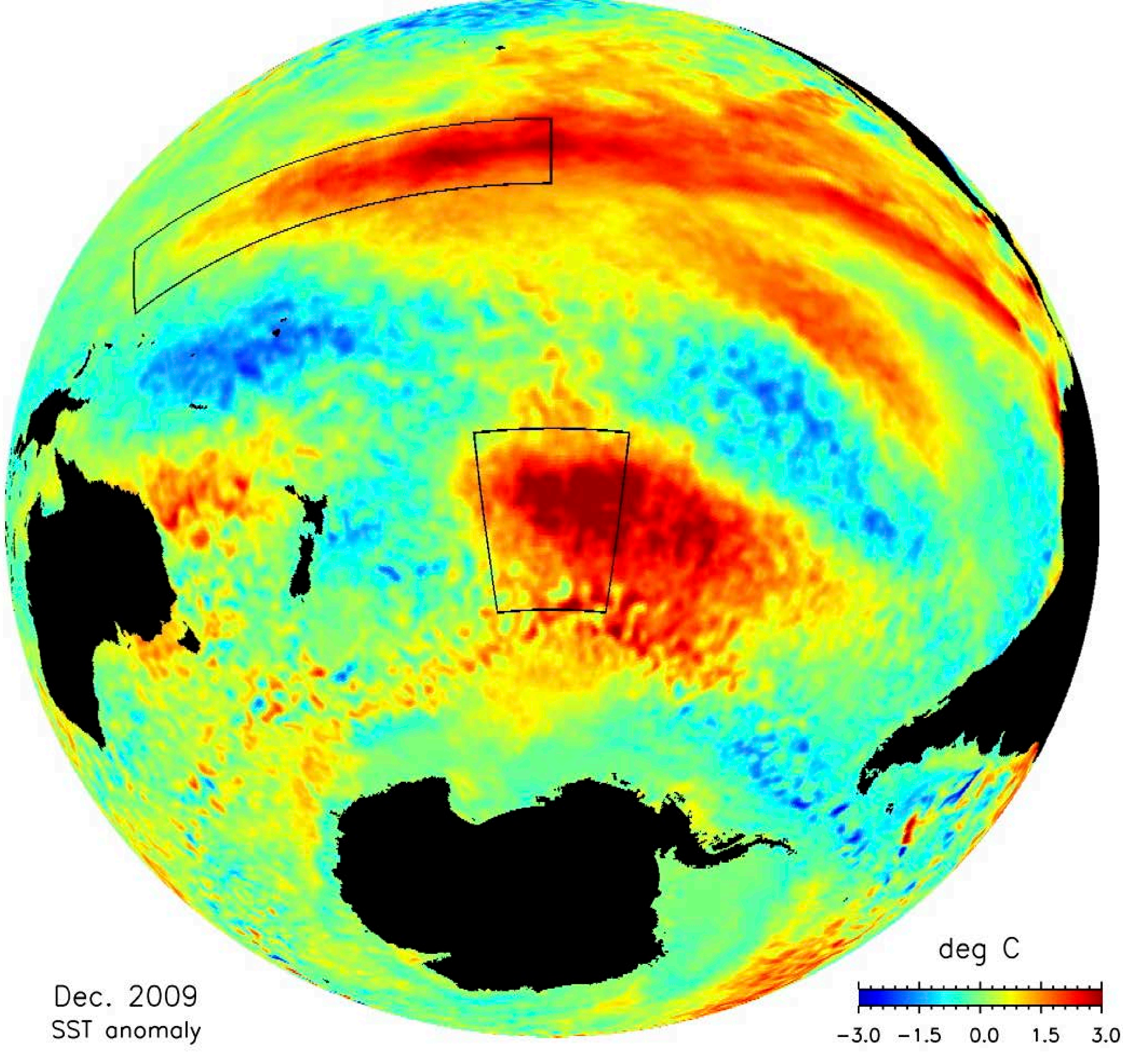


AIRS temperature, Kuroshio Extension, 36N,

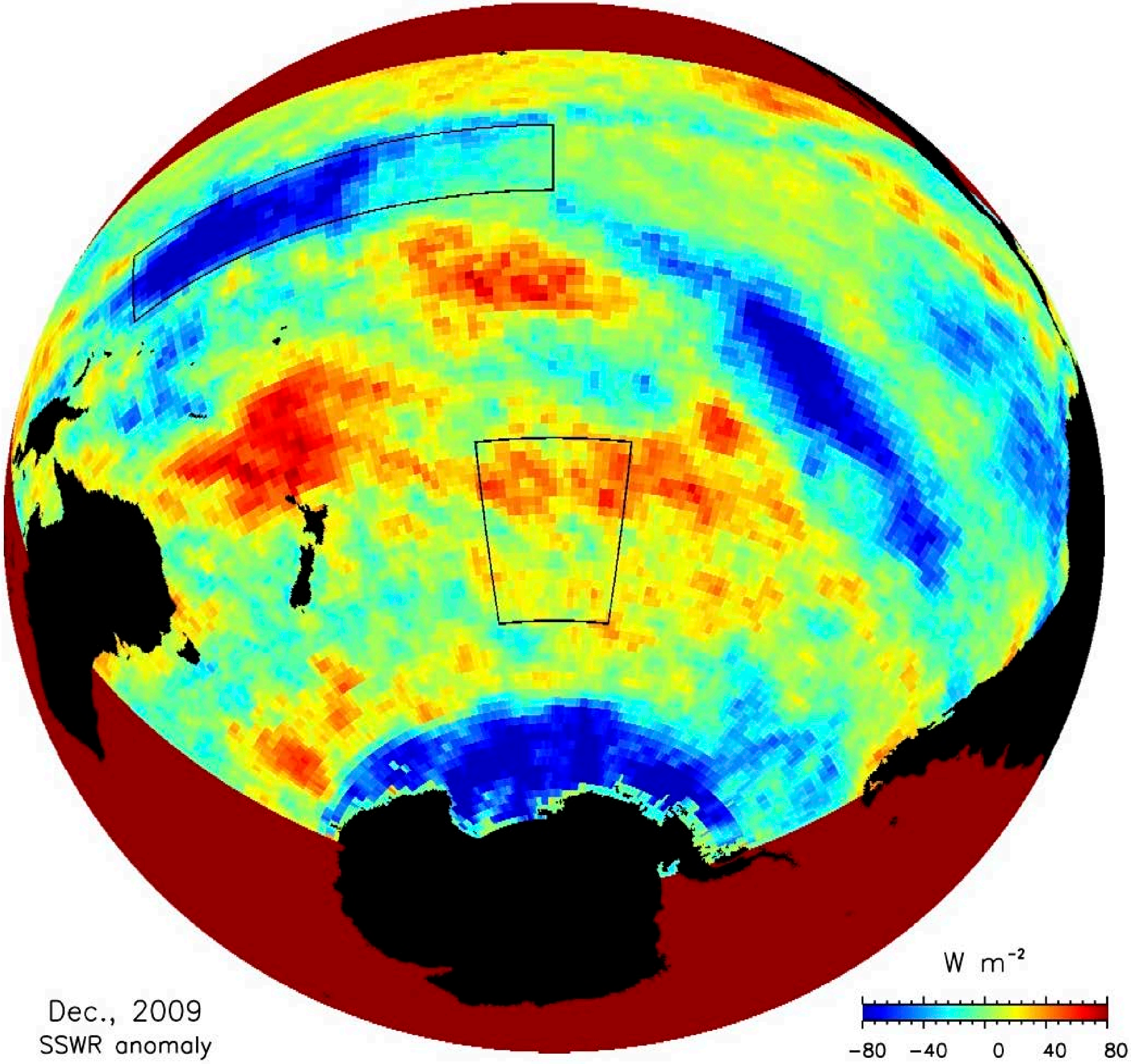
1000 mb **600 mb**



Backup



Dec. 2009
SST anomaly
deg C
−3.0 −1.5 0.0 1.5 3.0


W m^-2
-80 -40 0 40 80
Dec., 2009
SSWR anomaly

- **AIRS, TRMM, and ISCCP reveal signature of SST way above the atmospheric boundary layer at low frequencies.**

- **Present GCM or operational NWP data, do not show vertical propagation of ocean SST effect beyond atmospheric boundary layer.**

- **The observations present a challenge to** understand the transition from random turbulence to organized convection and to improve **spatial versus temporal scales parameterization in GCM**

- The correlation coefficients of the geographic variations (585 pairs of data at a 0.5° grid in the region of 42°–38°S, 23°–55°E) between SST and CTT for 3-yr, 1-yr, and 3-m, 1-m periods are nearly constant, over 0.7