Ocean's Role in Water/Energy/ Carbon Cycles

W. Timothy Liu and Xiaosu Xie

- Evaporation
- Moisture Transport
- Carbon Dioxide Fugacity
- Wind Power
- Anomalous Warming
- Ocean Front

Accomplishments

Using AMSR data, we developed and validated retrieval methods for
(1) Ocean surface evaporation (E) through bulk parameterization
(2) E directly from brightness temperatures measured by AMSR-E
(3) Integrated water transport. The divergence of the transport is E-P
(4) Wind power distribution for deployment of floating wind farms
(5) Ocean surface carbon dioxide fugacity
Produced and provided accessibility to 9 years (6/2002-9/2011) data of (1)-(5)
http://airsea.jpl.nasa.gov/seaflux/seaflux.html

Application of all-weather Sea Surface Temperature
(1) Understanding air-sea coupling over ocean fronts
(2) Study south central Pacific anomalous warming

Water

HYDROLOGIC BALANCE

$$\frac{\partial W}{\partial t} + \nabla \bullet \Theta = E - P$$

$$\Theta = \frac{1}{g}\int_0^{p0} qU\mathbf{d}p$$

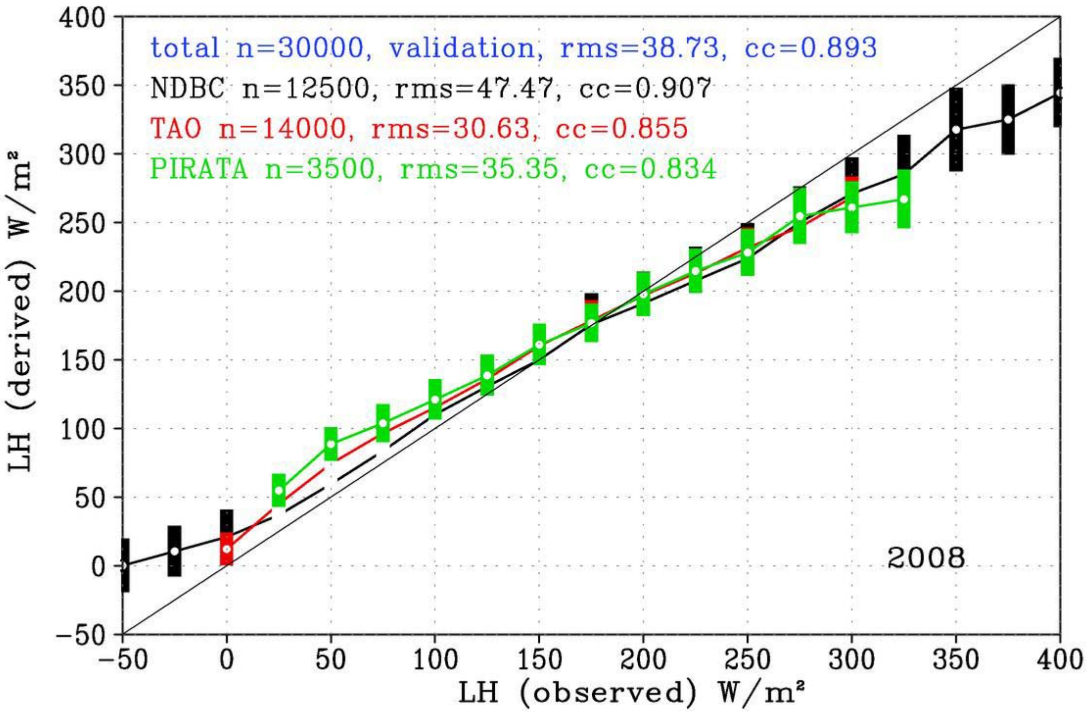
$$W = \frac{1}{g}\int_0^{p0} q\mathbf{dp}$$

Bulk parameterization

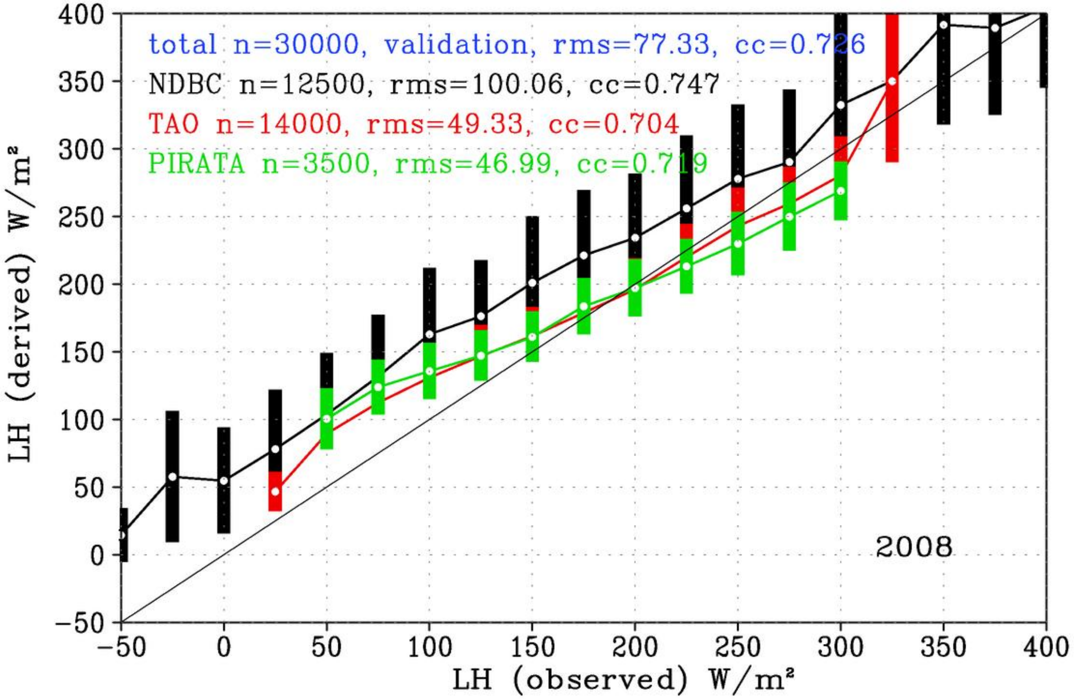
- Bulk parameterization was first used as a zero order approximation of what we wanted from what we had: bulk measurements. We hided our ignorance or incapability in the coefficient and we need to understand its limit.

$$E = \rho C_E (u - u_s)(q_s - q)$$

- AMSR measures u, T_s (q_s), but we could not measure q. Liu first demonstrated getting q from W in 1982.
- u, q_s, and q are derived from brightness temperatures of microwave radiometes, and we should be able to retrieve E from brightness temperatures.



LH (Direct)
N=30,000
RMS=38.73
CC=0.893



LH (Bulk)
N=30,000
RMS=77.33
CC=0.726

HYDROLOGIC BALANCE

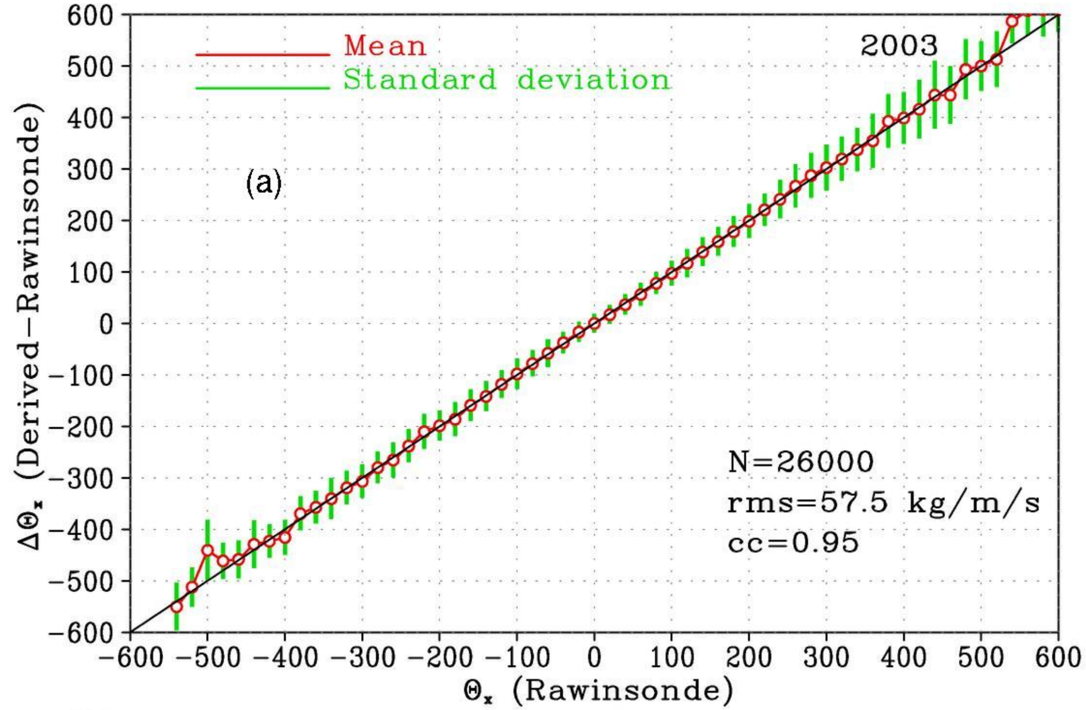
$$\frac{\partial W}{\partial t} + \nabla \bullet \Theta = E - P$$

$$\Theta = \frac{1}{g}\int_0^{p0} qU\mathbf{d}p$$

$$W = \frac{1}{g}\int_0^{p0} q\mathbf{dp}$$

$$\Theta = \mathbf{Ue}\ \mathbf{W}$$

Θ is equivalent to column water vapor W advected by Ue.
Ue is the depth-averaged wind weighted by humidity
We use SVR to relate Ue to wind at two levels:
1. U_N: scatterometer surface wind stress
2. U_{850mb}: cloud drift wind (free-stream wind)

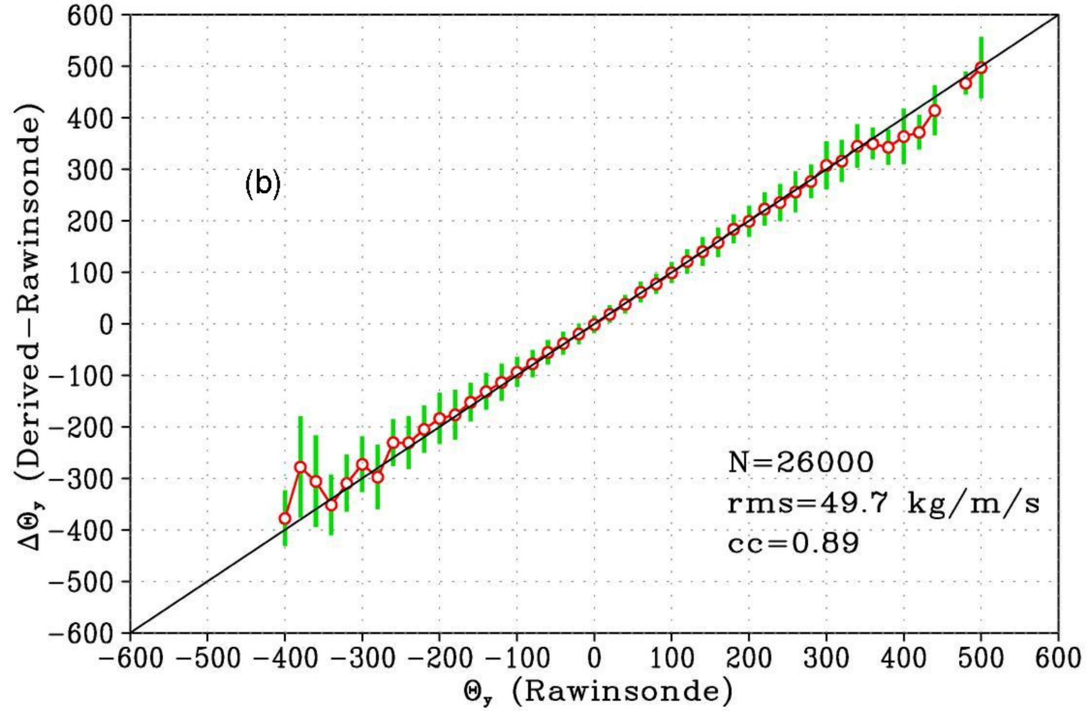


Θx

N=26,000

rms=57.5 kg/m/s

CC=0.95

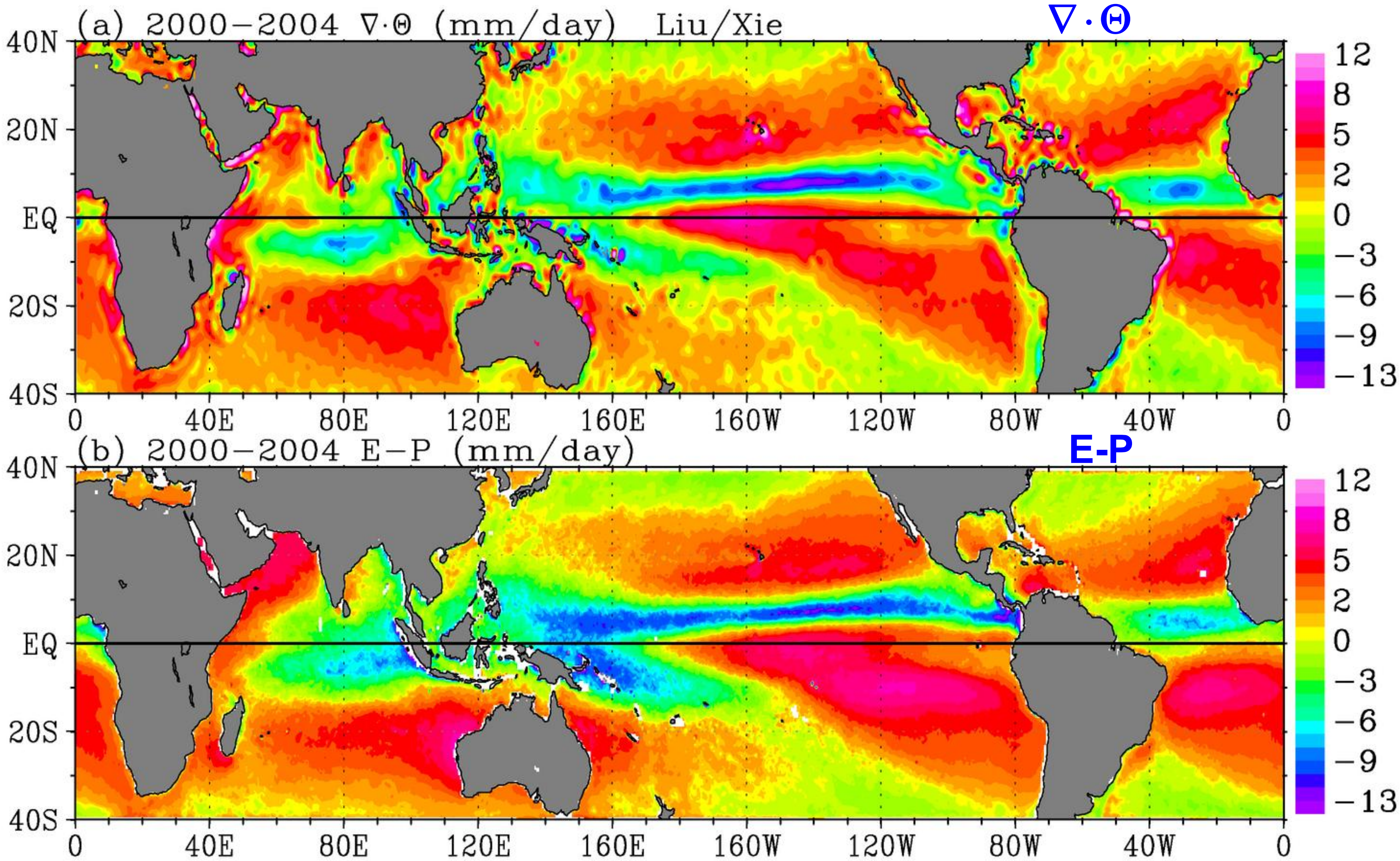


Θy

N=26,000

rms=49.7 kg/m/s

CC=0.89



(a) 2000–2004 ∇·Θ (mm/day) Liu/Xie
∇·Θ
40N
20N
EQ
20S
40S
0
40E
80E
120E
160E
160W
120W
80W
40W
0
12
8
5
2
0
−3
−6
−9
−13
(b) 2000–2004 E–P (mm/day)
E-P
40N
20N
EQ
20S
40S
0
40E
80E
120E
160E
160W
120W
80W
40W
0
12
8
5
2
0
−3
−6
−9
−13

Source/sink of CO_2

The air-sea exchange in CO_2 (F) is

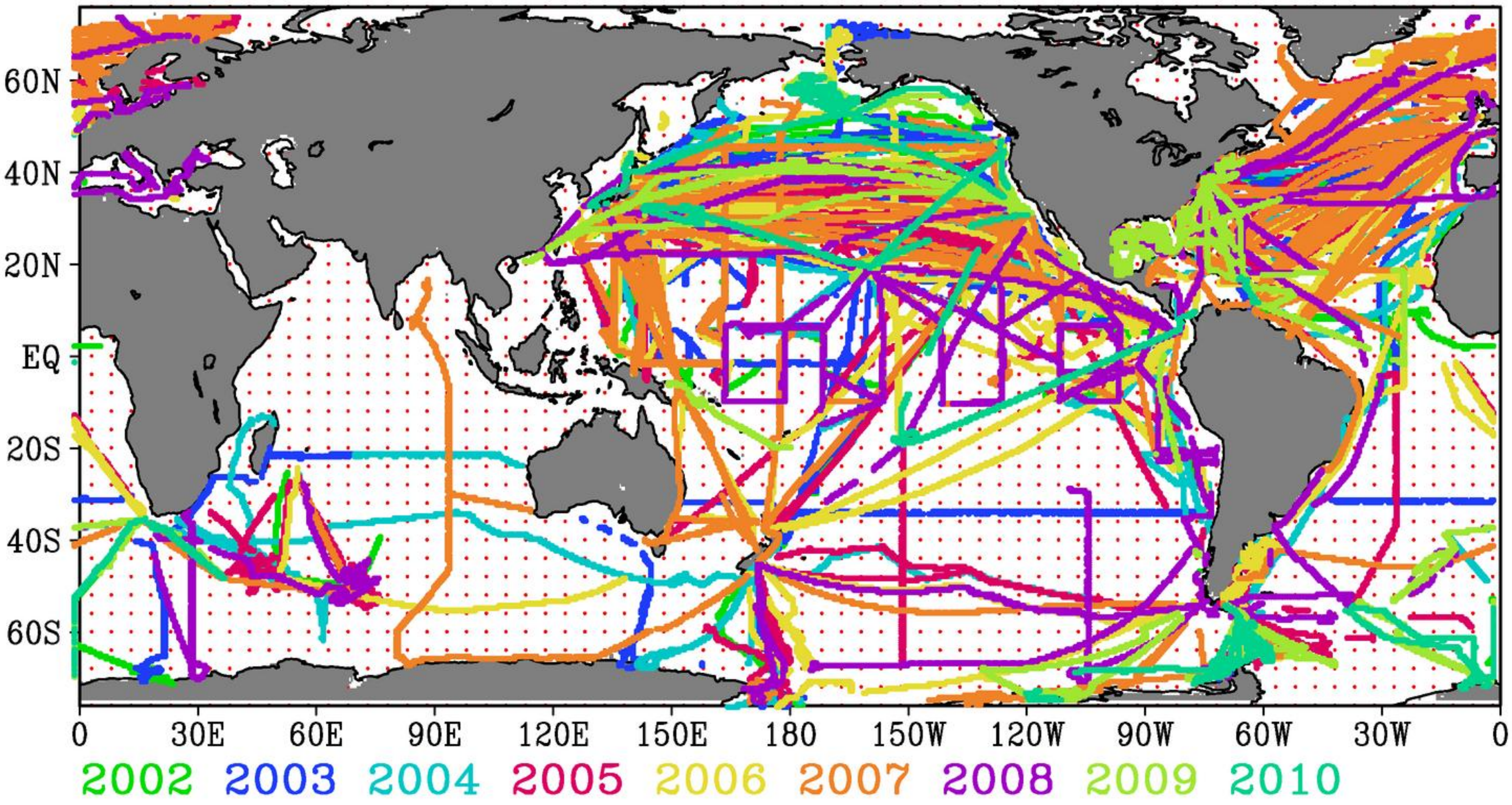
$$F = k\alpha(\Delta pCO_2)$$

k: CO_2 gas transfer (piston) velocity

α: solubility of CO_2 in seawater

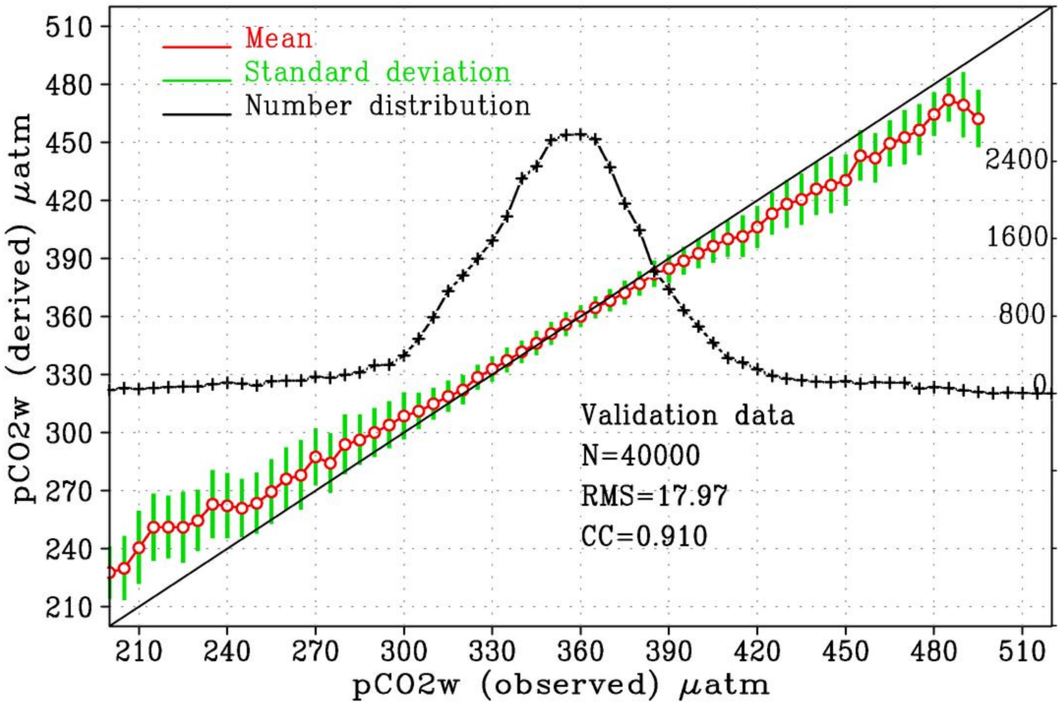
$(\Delta pCO_2) = pCO_{2,sea} - pCO_{2,air}$

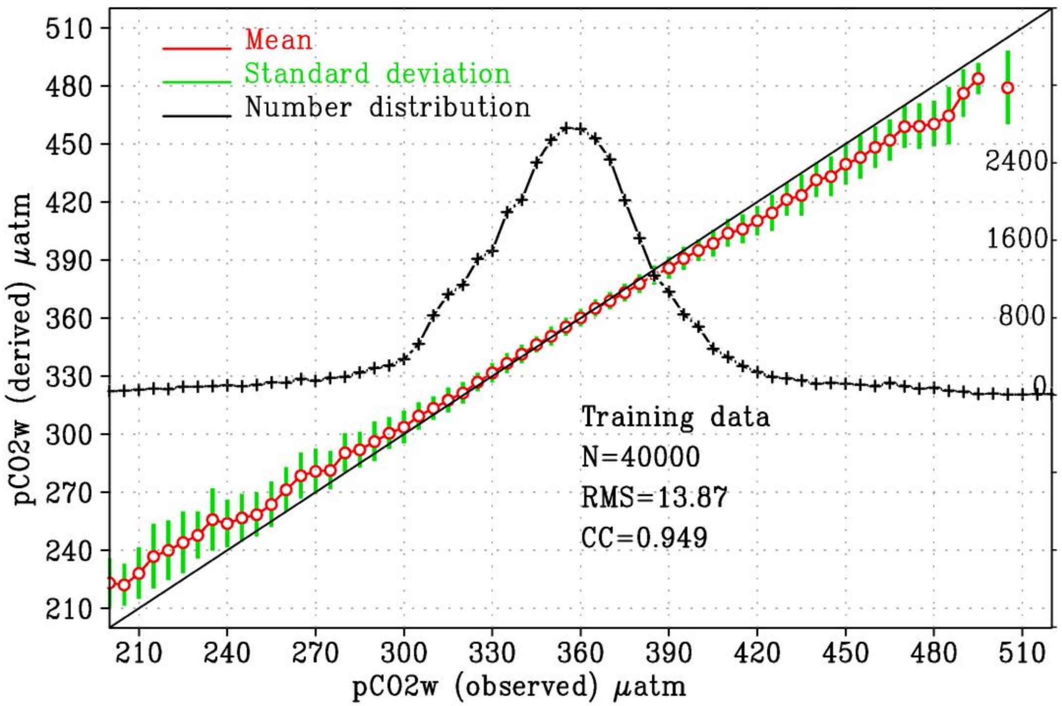
We do not distinguish fugacity (f) from partial pressure (p)

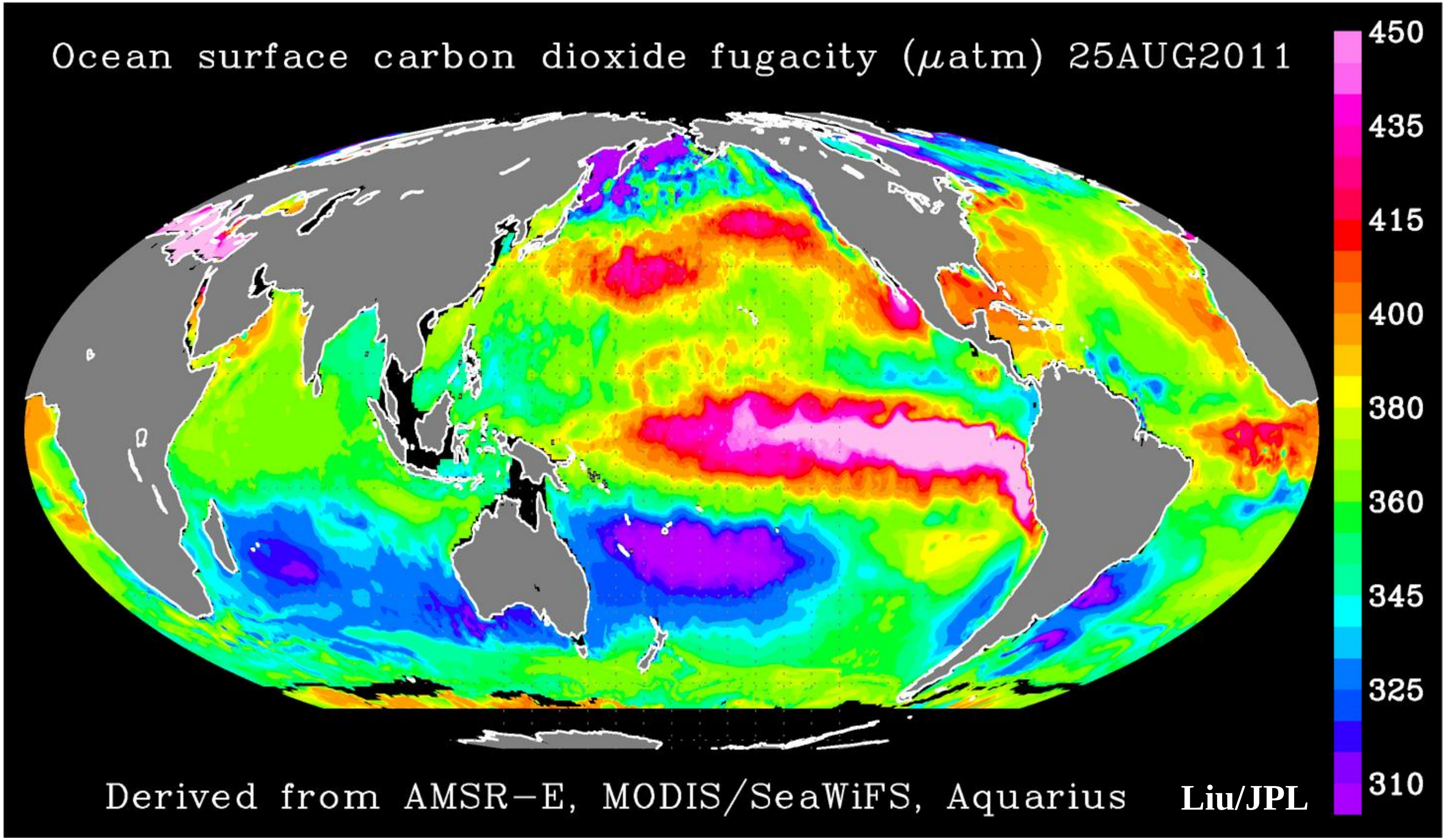


Compiled from SOCAT+all other sources through CDIAC
206,265 colocated daily data points

- Statistical model was developed using support vector regression
- Input (3-day): sin(day), cos(day), lat, sin(lon), cos(lon), AMSR-E SST, AVISO SLHA, SeaWiFS+MODIS TERRA+MODIS Aqua Chl-a, Argo SSS
- 206265 data groups found 2002-2010 40,000 randomly selected for training and 40,000 for validation
- Output: 9 year $pCO2_{sea}$ at 0.5°, daily resolution

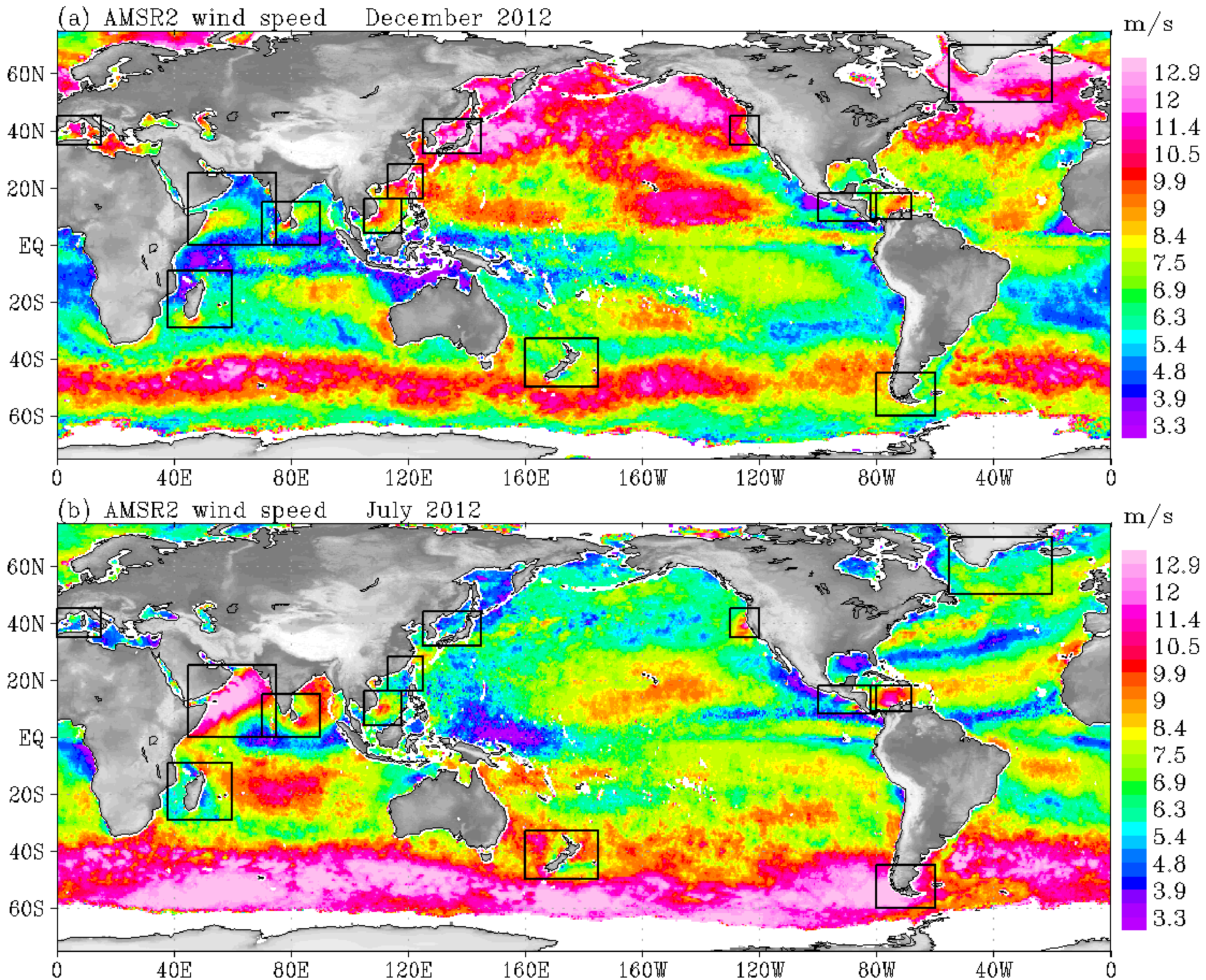

Mean
Standard deviation
Number distribution
Validation data
N=40000
RMS=17.97
CC=0.910
pCO2w (derived) μatm
pCO2w (observed) μatm
510
480
450
420
390
360
330
300
270
240
210
2400
1600
800
0

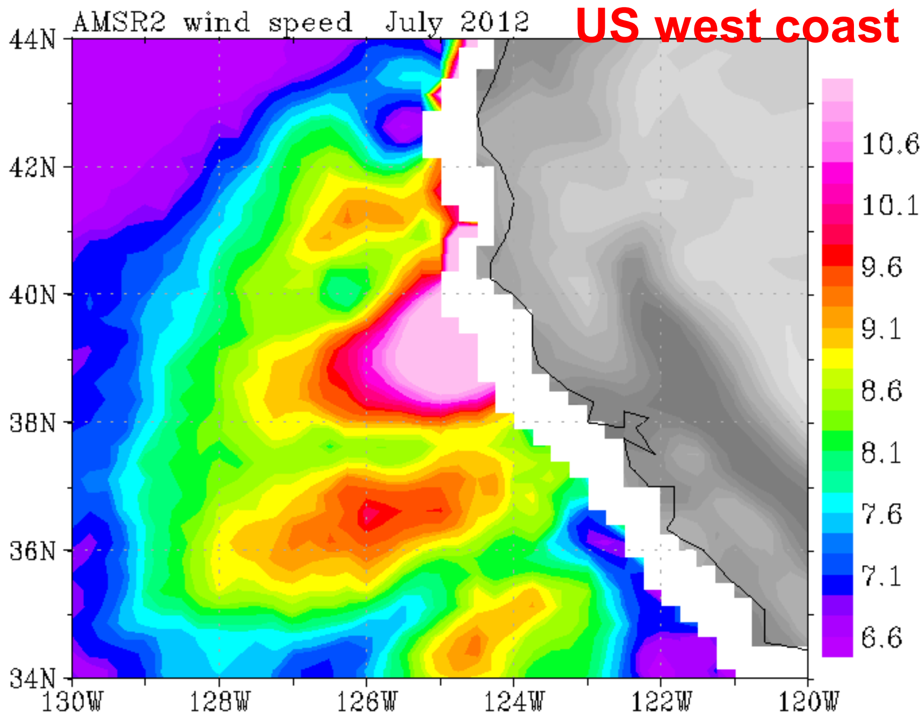

Mean
Standard deviation
Number distribution
Training data
N=40000
RMS=13.87
CC=0.949
pCO2w (derived) μatm
pCO2w (observed) μatm
510
480
450
420
390
360
330
300
270
240
210
2400
1600
800
0

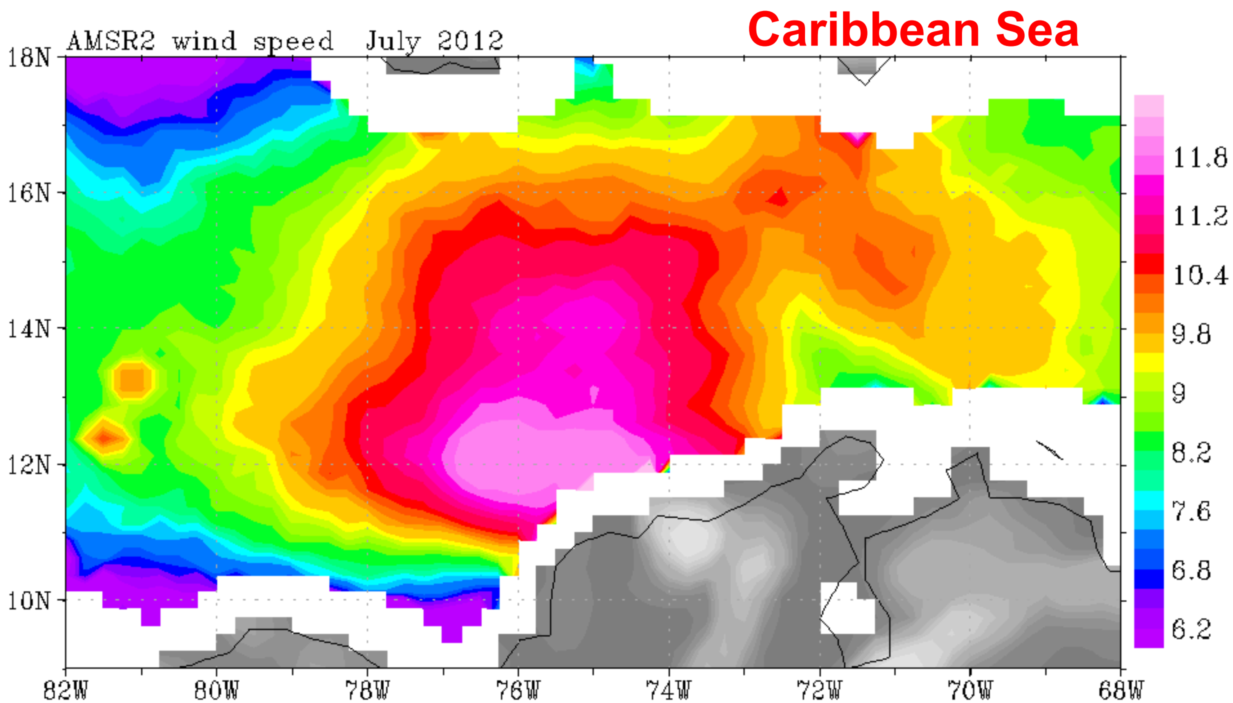


Ocean surface carbon dioxide fugacity (μatm) 25AUG2011
450
435
415
400
380
360
345
325
310
Derived from AMSR-E, MODIS/SeaWiFS, Aquarius
Liu/JPL

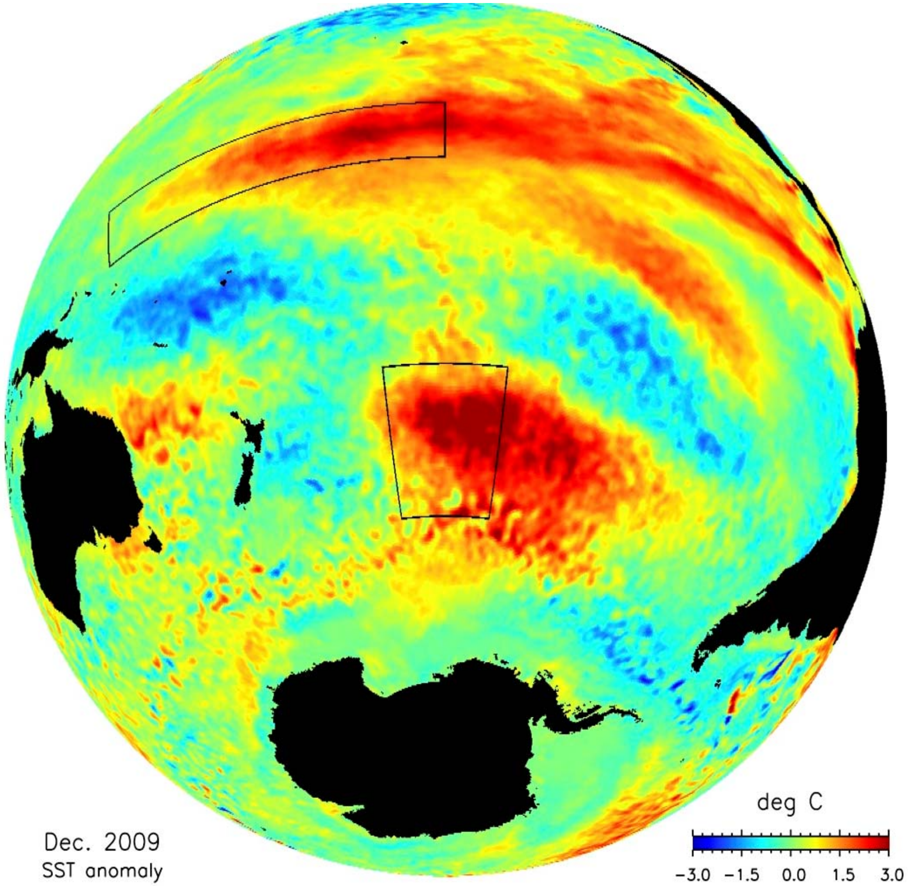
Wind Farm Distribution

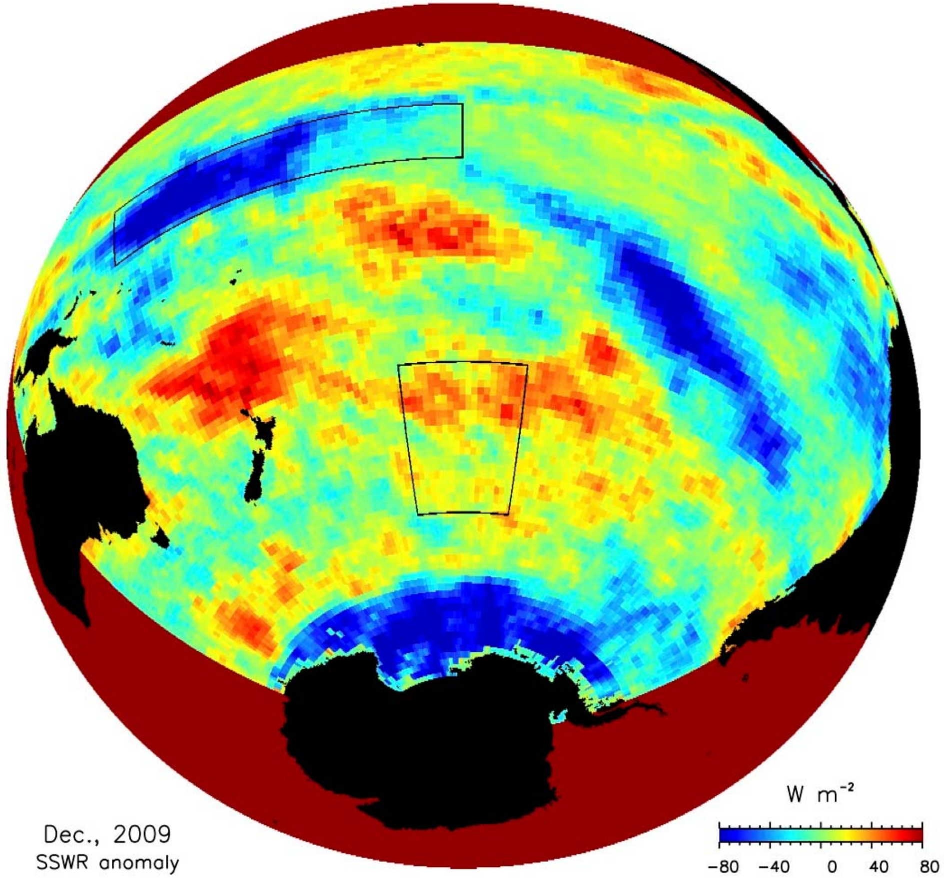

(a) AMSR2 wind speed December 2012
m/s
12.9
12
11.4
10.5
9.9
9
8.4
7.5
6.9
6.3
5.4
4.8
3.9
3.3
60N
40N
20N
EQ
20S
40S
60S
0
40E
80E
120E
160E
160W
120W
80W
40W
0
(b) AMSR2 wind speed July 2012
m/s
12.9
12
11.4
10.5
9.9
9
8.4
7.5
6.9
6.3
5.4
4.8
3.9
3.3
60N
40N
20N
EQ
20S
40S
60S
0
40E
80E
120E
160E
160W
120W
80W
40W
0

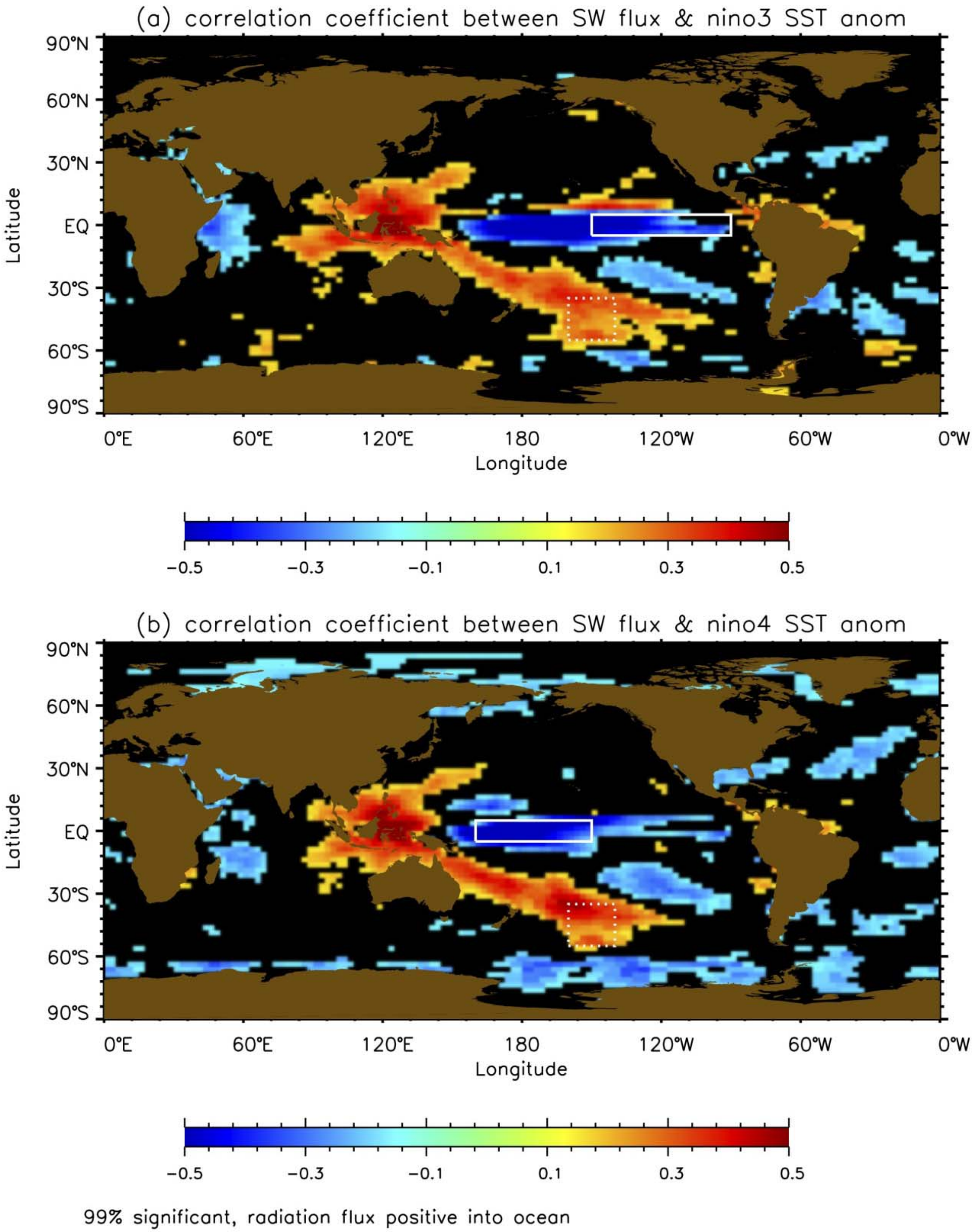

AMSR2 wind speed July 2012
US west coast
44N
42N
40N
38N
36N
34N
130W
128W
126W
124W
122W
120W
10.6
10.1
9.6
9.1
8.6
8.1
7.6
7.1
6.6


AMSR2 wind speed July 2012
Caribbean Sea
18N
16N
14N
12N
10N
82W
80W
78W
76W
74W
72W
70W
68W
11.8
11.2
10.4
9.8
9
8.2
7.6
6.8
6.2

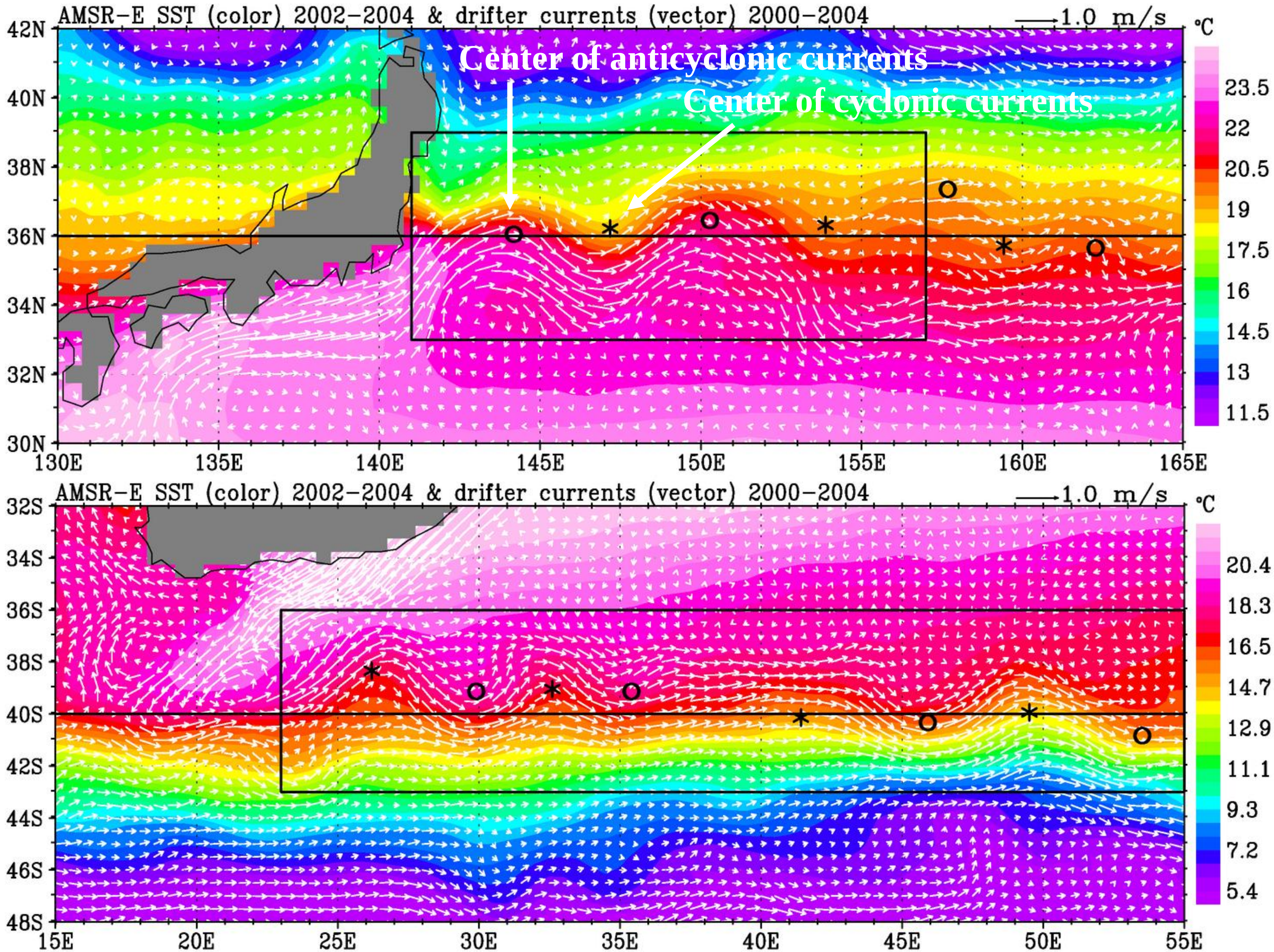
Warming Anomalies


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


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


(a) correlation 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) correlation coefficient between SW flux & nino4 SST anom
99% significant, radiation flux positive into ocean

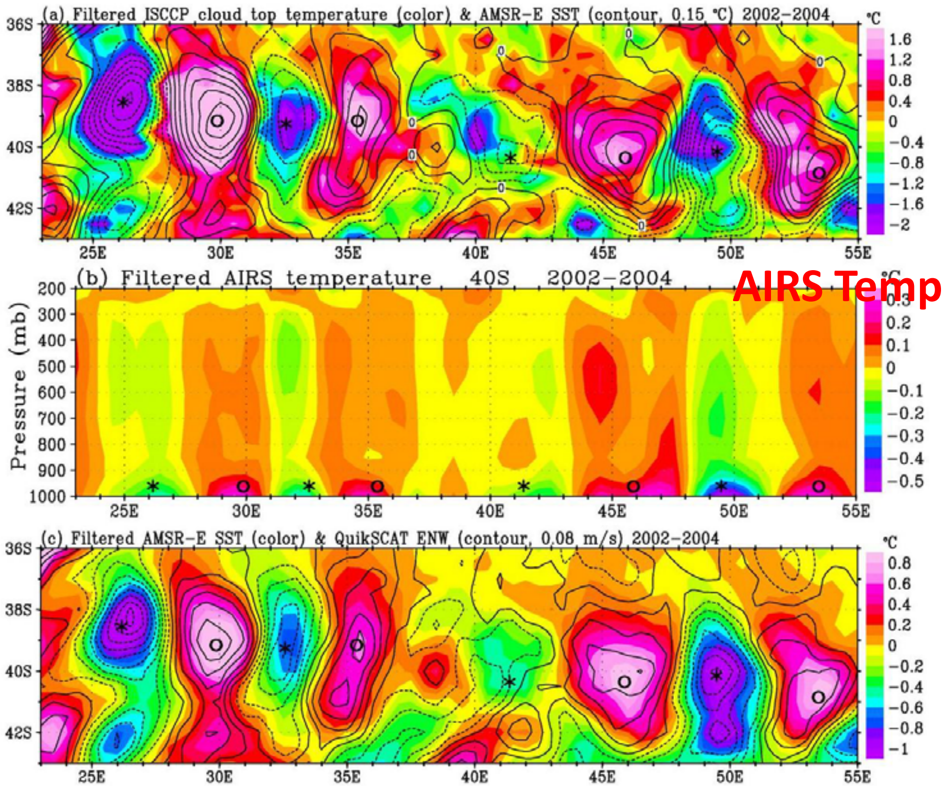
Ocean Fronts


AMSR-E SST (color) 2002-2004 & drifter currents (vector) 2000-2004
1.0 m/s
°C
Center of anticyclonic currents
Center of cyclonic currents
42N
40N
38N
36N
34N
32N
30N
130E
135E
140E
145E
150E
155E
160E
165E
23.5
22
20.5
19
17.5
16
14.5
13
11.5
AMSR-E SST (color) 2002-2004 & drifter currents (vector) 2000-2004
1.0 m/s
°C
32S
34S
36S
38S
40S
42S
44S
46S
48S
15E
20E
25E
30E
35E
40E
45E
50E
55E
20.4
18.3
16.5
14.7
12.9
11.1
9.3
7.2
5.4

From Ocean Surface to Tropopause

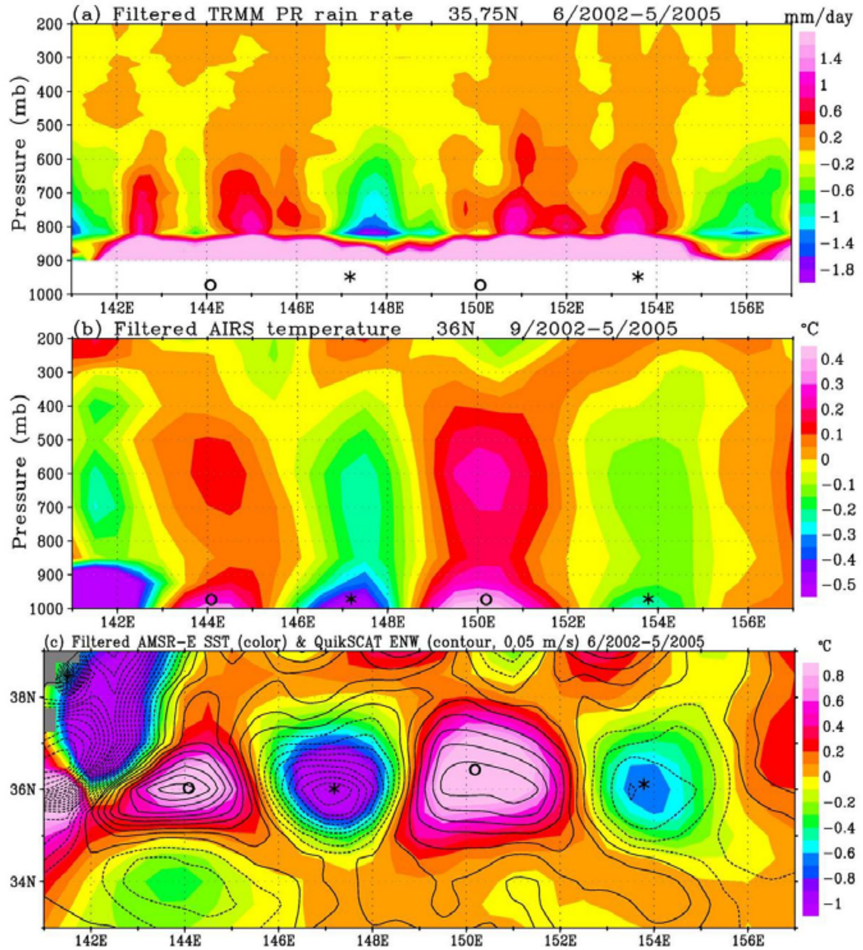
Over mid-latitude ocean, lapse rate is too weak to generate deep convection and transfer ocean effects beyond boundary layer?

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

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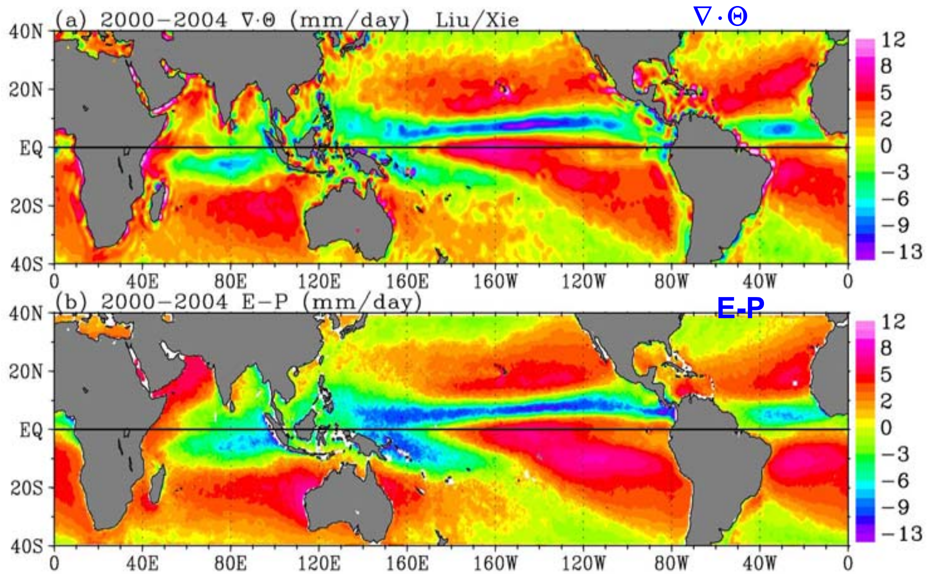
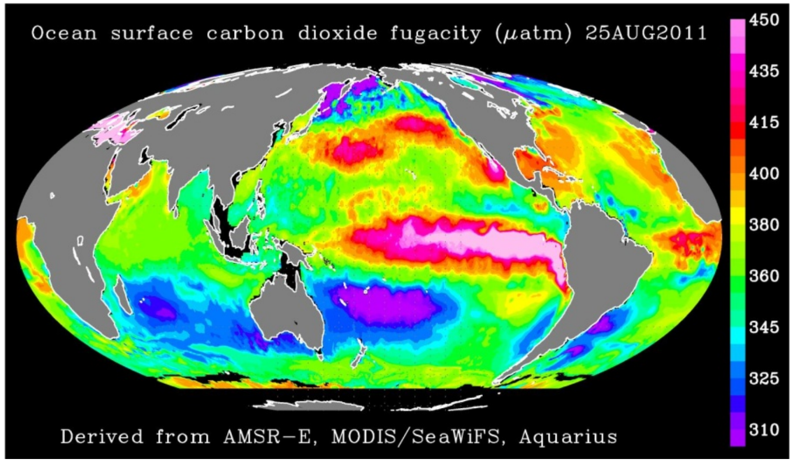
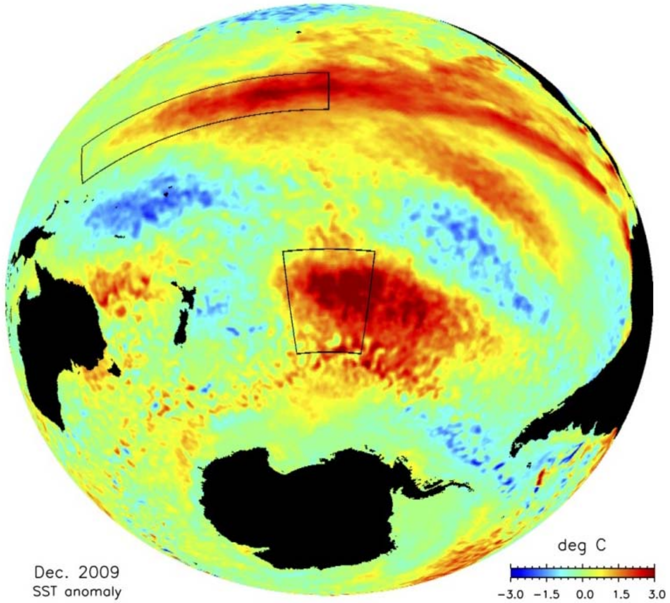
Water Cycle



Carbon Cycle



Temperature Anomalies



Wind Farm Deployment