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A Recently Revived Production of Global Air-Sea Surface Turbulent Fluxes - the Newly Produced GSSTF2b Dataset Validations & Findings

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UMBC/GEST

NASA/GSFC

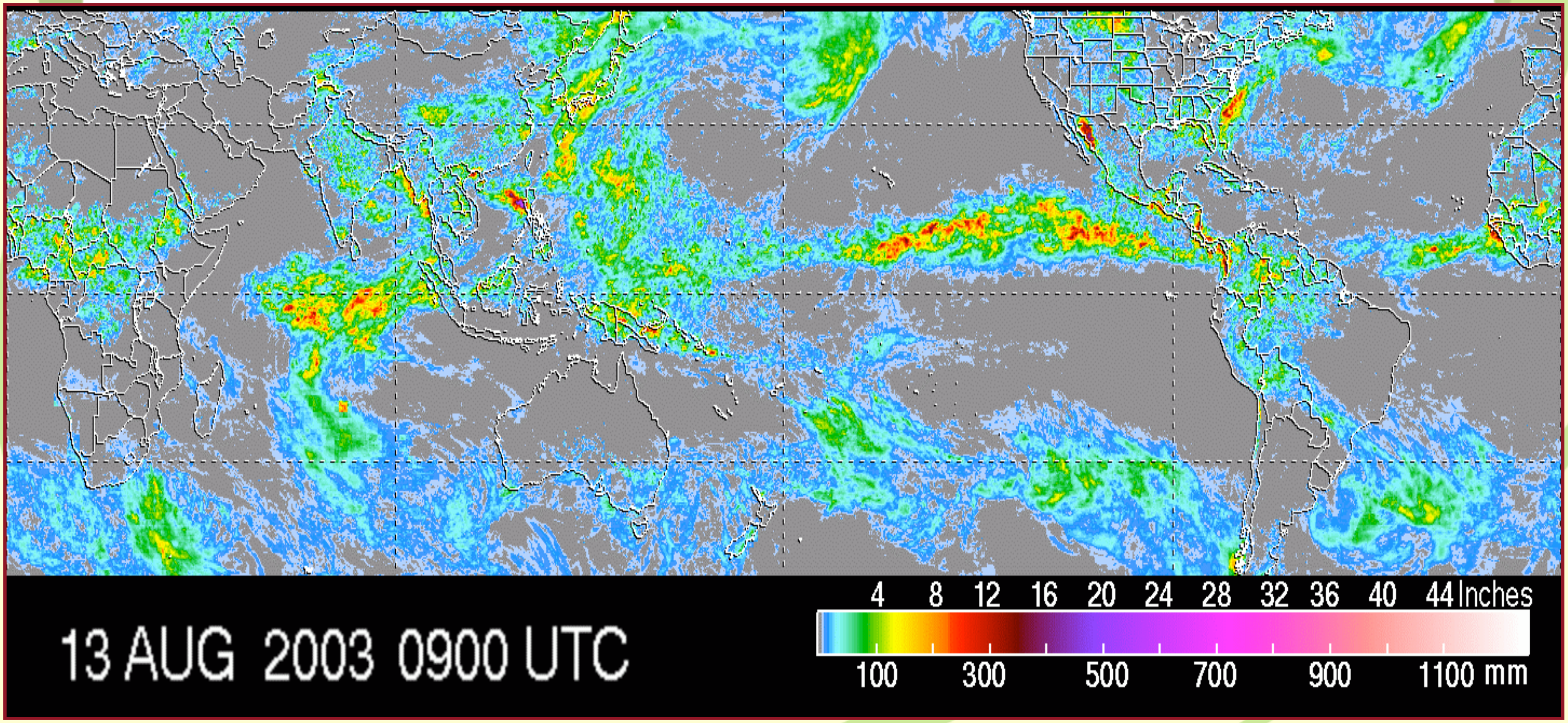
In Memory of
My Mentor

Dr. Shu-Hsien Chou
(aka Sue, 周張淑纖博士)

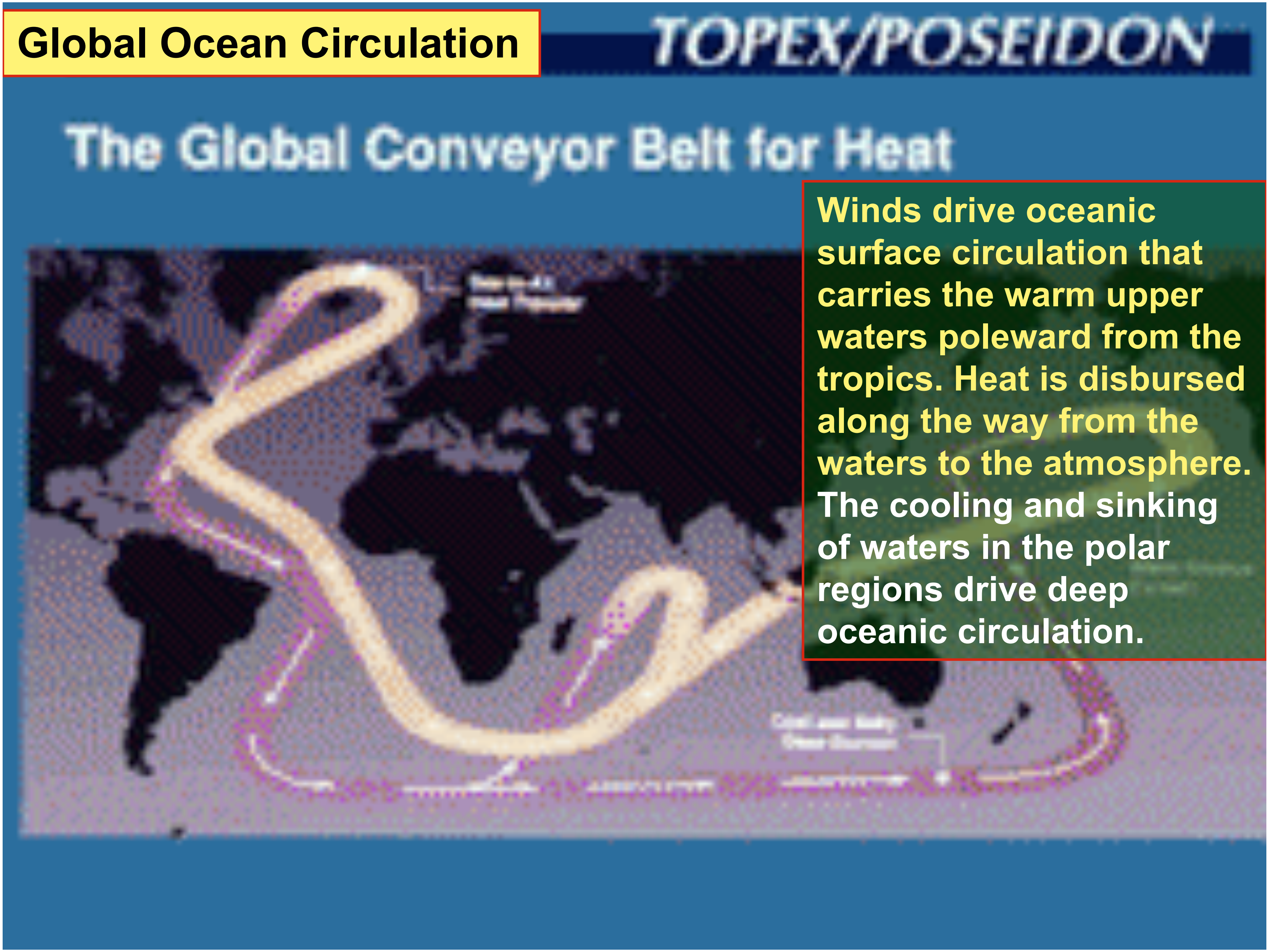
Without her genuine intelligence, intuition,
great vision and perseverance,
the productions of
GSSTF1 (Chou et al. 1997, 2000),
GSSTF2 (Chou et al. 2001, 2003),
& GSSTF2b (Shie et al. 2009, 2010)
would have not been possible.

Background

Two-thirds of global precipitation mainly contributed by air-sea surface fluxes falls in the tropics, providing three-fourths of the energy driving global atmospheric circulation (via Hadley Cell) through latent heating.



Global Ocean Circulation



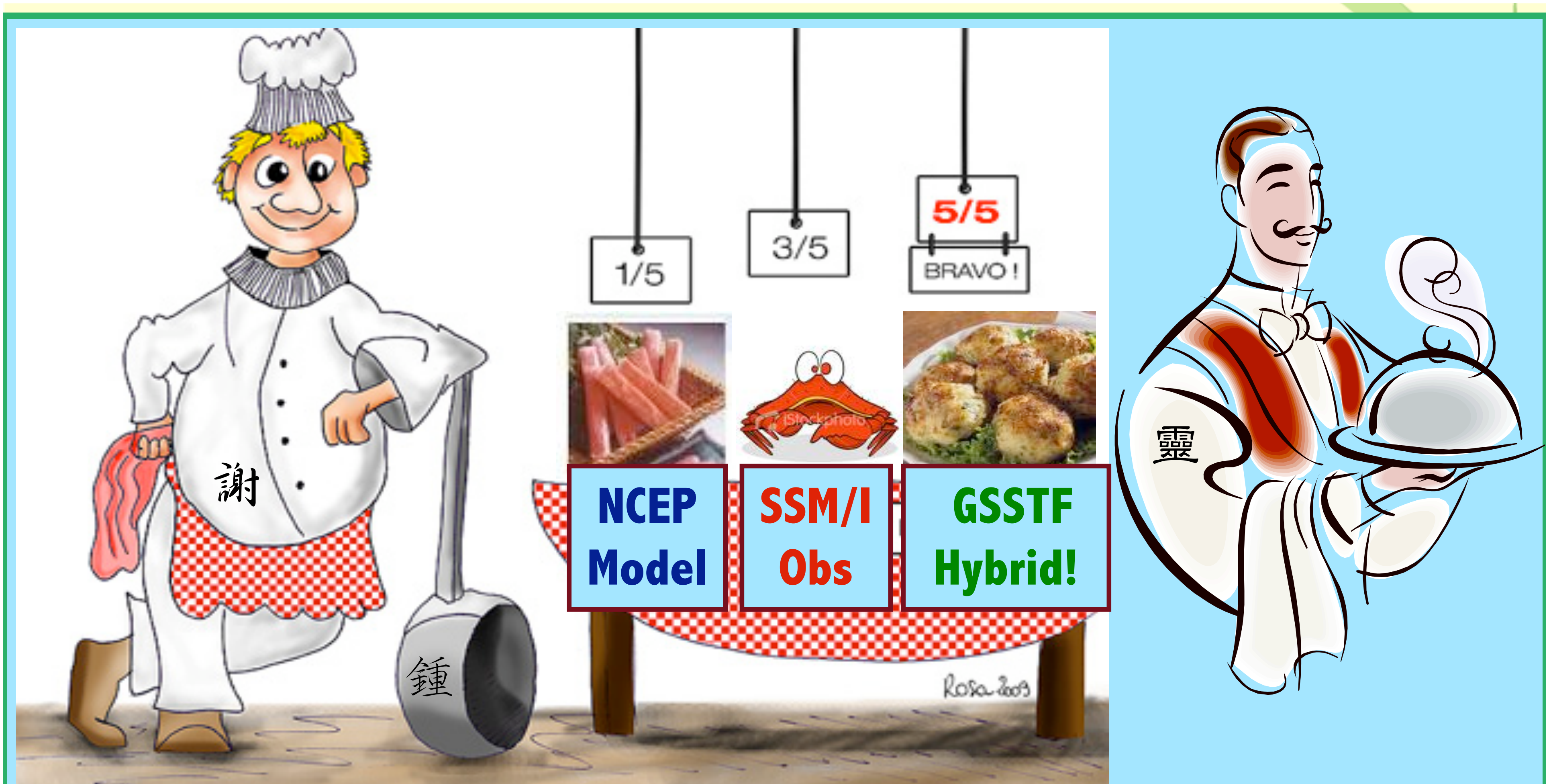
Winds drive oceanic surface circulation that carries the warm upper waters poleward from the tropics. Heat is disbursed along the way from the waters to the atmosphere. The cooling and sinking of waters in the polar regions drive deep oceanic circulation.

Air-Sea Turbulent Fluxes

- Include:
  - *Latent Heat Flux (LHF)*
  - *Sensible Heat Flux (SHF)*
  - *Momentum Flux (Wind Stress WST)*
- *Exchange of heat, moisture (fresh water), and momentum between atmosphere and ocean*
- *Important in air-sea interaction, climate variations and oceanic circulations of multiple temporal / spatial scales*

Observations of Oceanic Fluxes

- **Direct 'measurements' over ocean**
  - **In-situ observations of u', v', w', T', q'… at very high frequency using specific instruments (Supersonic et al)**
- **Estimation from mean oceanic and atmospheric state variables (temperature, wind speed, humidity)**
  through
  BULK FLUX ALGORITHMS
  - **In-situ observation (ship, buoys..)**
  - **Satellite observation**
  - **Model simulations**



1/5
3/5
5/5
BRAVO !
NCEP
Model
SSM/I
Obs
GSSTF
Hybrid!
謝
鍾
靈

Bulk Aerodynamic Algorithm

LHF (潛熱通量) = $\rho_a L_v C_E (U-U_s)(q_s - q_a)$

SHF (可感熱通量) = $\rho_a c_p C_H (U-U_s)(\theta_s - \theta_a)$

WST (風應力) = $\rho_a C_D (U-U_s)^2$

- ***Physical constants*** $[L_v, c_p]$
- ***State Variable*** $[\rho_a, U, q_s, q_a, \theta_s, \theta_a]$
- ***Bulk Transfer/Turbulent Exchange Coefficients*** $[C_E, C_H, C_D]$

An Improved GSSTF2b

Input

SSM/I V4(GSSTF2); V6(GSSTF2b):

1. Surface Air (~10-m) Specific Humidity
2. Lowest 500-m Precipitable Water
3. 10-m Wind Speed
4. Sea-Air Humidity Difference
5. Total Precipitable Water

NCEP-NCAR R1 (GSSTF2);
NCEP/DOE R2 (GSSTF2b):

6. Sea Surface Temperature
7. Sea Level Pressure
8. 2-m Air Temperature
9. Sea Surface Saturation Specific Humidity

Output

1. Latent Heat Flux
2. Zonal Wind Stress*
3. Meridional Wind Stress*
4. Sensible Heat Flux

*partitioned by surface wind vectors: variational analysis method (VAM) by Atlas et al. 1996); an upgraded version of CCMP/VAM L3 was applied for GSSTF2b

EOF method for Qa Retrieval

(Chou et al., 1995 & 1997)

$$q(t, r, \sigma) = \overline{q}(\sigma) + \sum_{i=1}^{n} C_i(t,r)F_i(\sigma) \quad (1)$$

$\sigma = (p - p_t)(p_s - p_t)^{-1}$, p is pressure, p_s is the surface pressure, p_t is the top pressure (200mb), t is time, r is location, $\overline{q}$ is the spatial and temporal average of q for a climatic regime, F_i is the ith EOF of the covariance matrix of q, and C_i is the corresponding principle component. The profile of $\overline{q}$ and F_i are derived from a sample population of q in a climatic regime. **(23,177 First Global Atmospheric Research Program (GARP) Global Experiment (FGGE) IIb humidity soundings, 64 stations, 12/78-11/79)**

$$Q(t, r) = \overline{Q} + C_1(t, r)\, Q_1 + C_2(t, r)\, Q_2 \quad (2)$$

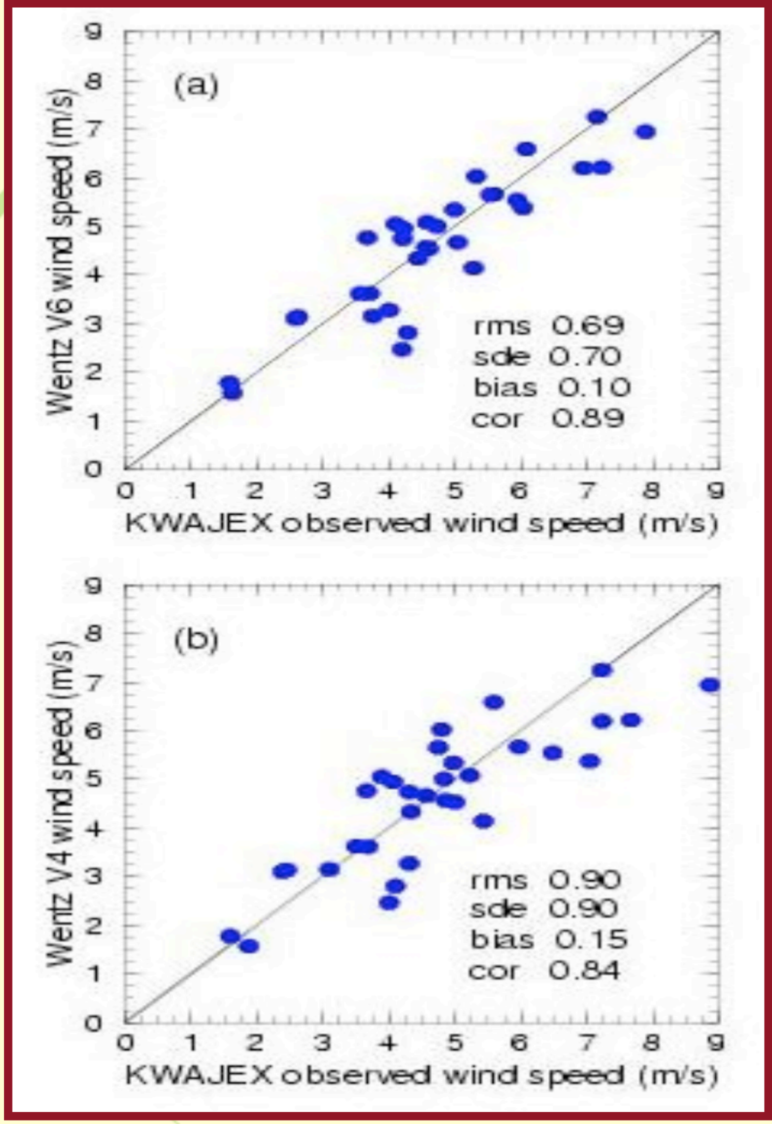
$$W(t, r) = \overline{W} + C_1(t, r)\, W_1 + C_2(t, r)\, W_2 \quad (3)$$

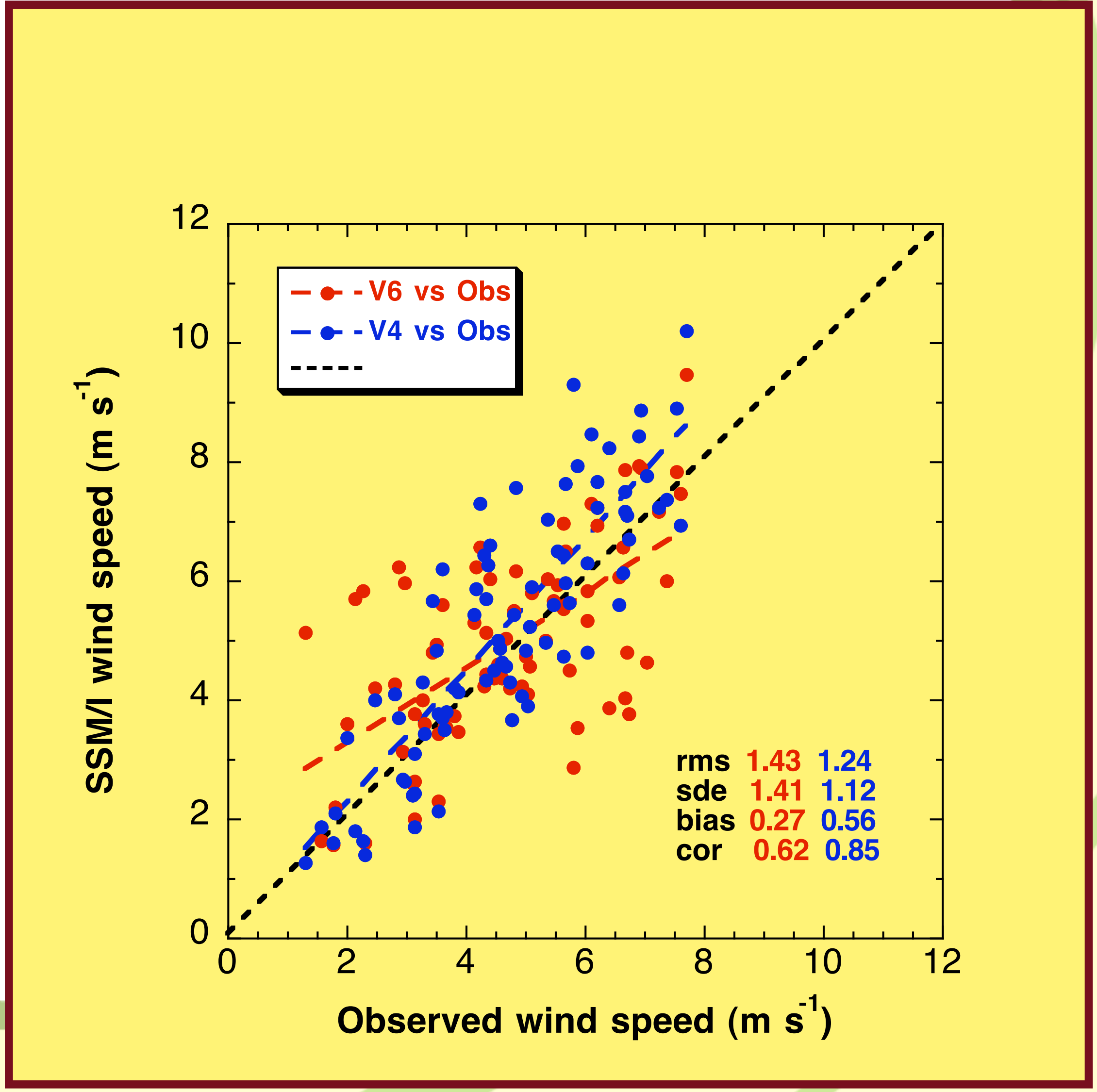
$$W_B(t, r) = \overline{W_B} + C_1(t, r)\, W_{B1} + C_2(t, r)\, W_{B2} \quad (4)$$

Solve C_1 and C_2 based on (3) & (4)
Obtain $Q(t, r)$ using (2)

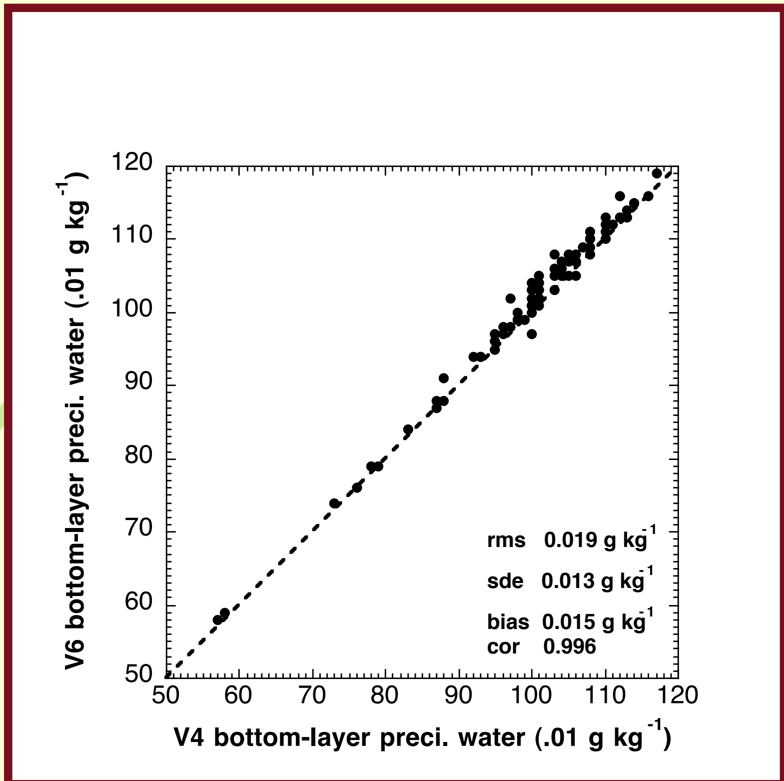
$\overline{Q}$, Q_1, and Q_2 are the values of $\overline{q}$, F_1, and F_2 at $\sigma = 1$; $\overline{W}$, W_1, W_2 and , $\overline{W_B}$, W_{B1}, W_{B2} are the total and bottom-layer precipitable water corresponding to the profiles of $\overline{q}$, F_1, and F_2,
C_1 and C_2 are the principal components for the **first** and **second** EOFs.

SSM/I V6/V4 surface wind speed vs. the observed of KWAJEX (left: 32 samples) & JKMNP (right: 82 samples)





(Labels of x/y axis need to be swapped)



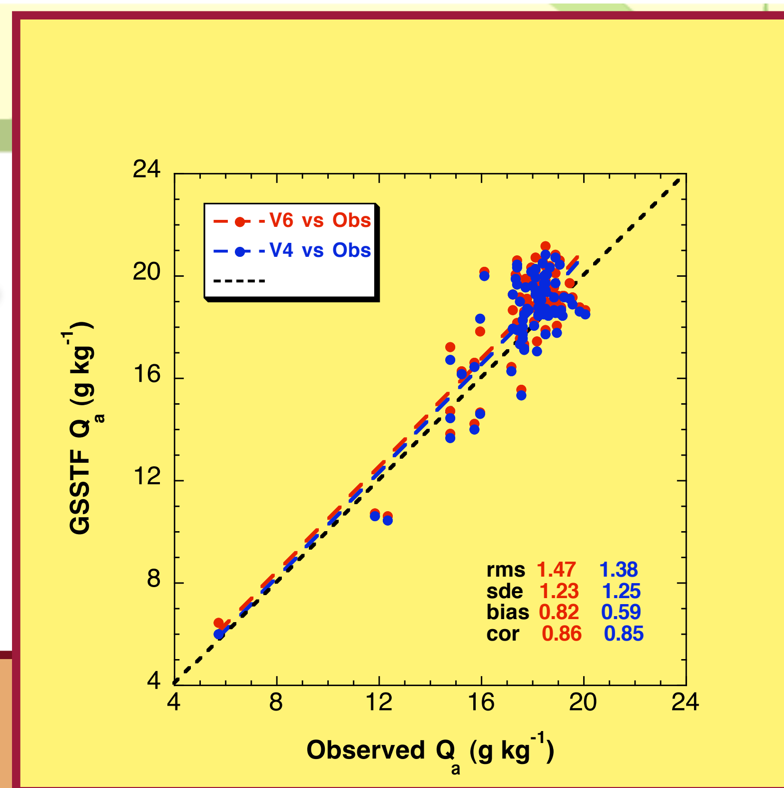
Qsea-Qair

(g kg^{-1})

V6/V4

vs.

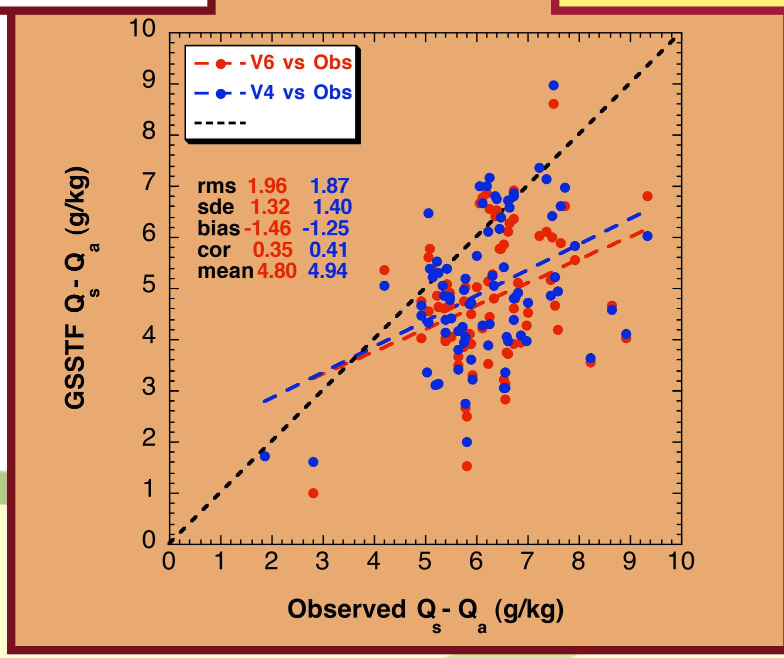
Obs (82)



WB

(.01 g cm^{-2})

(V6 vs. V4)



Qair

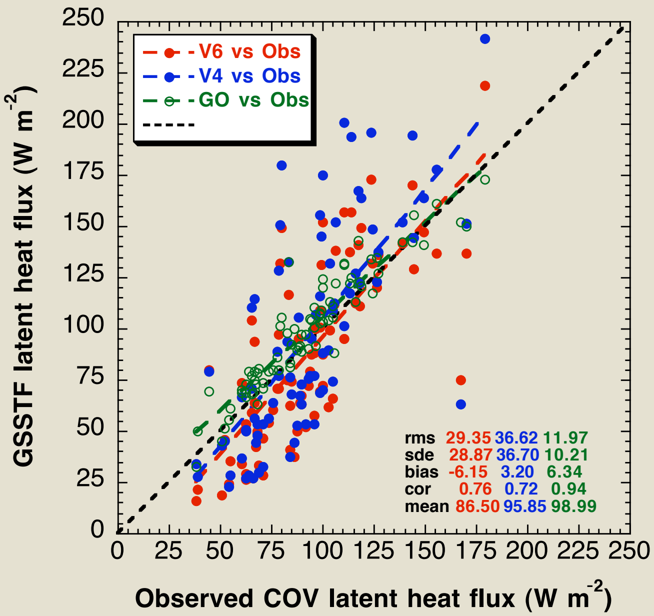
(g kg^{-1})

V6/V4

vs.

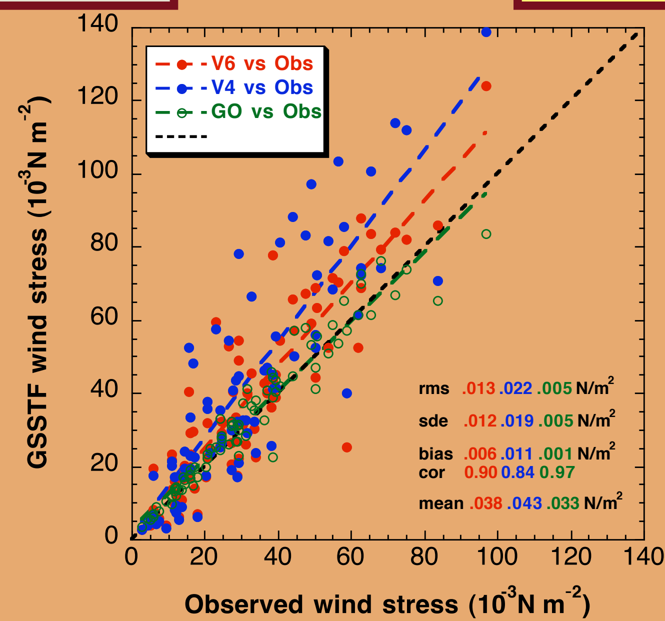
Obs (82)

V6/V4/GO vs. Obs (82)

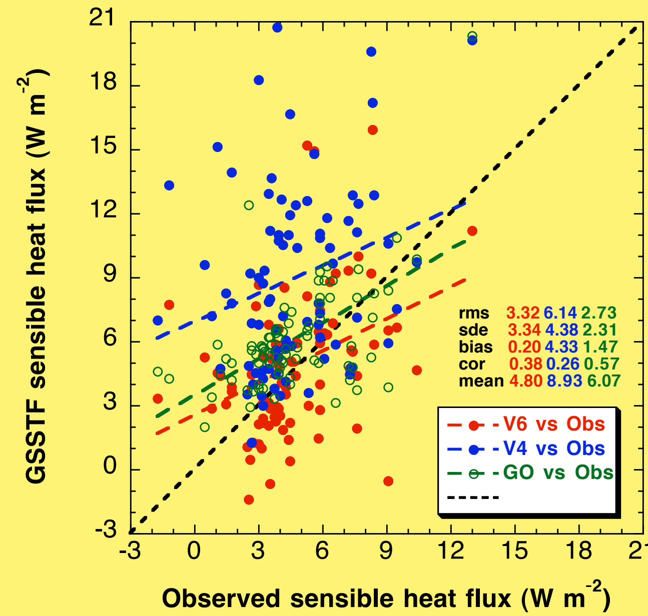


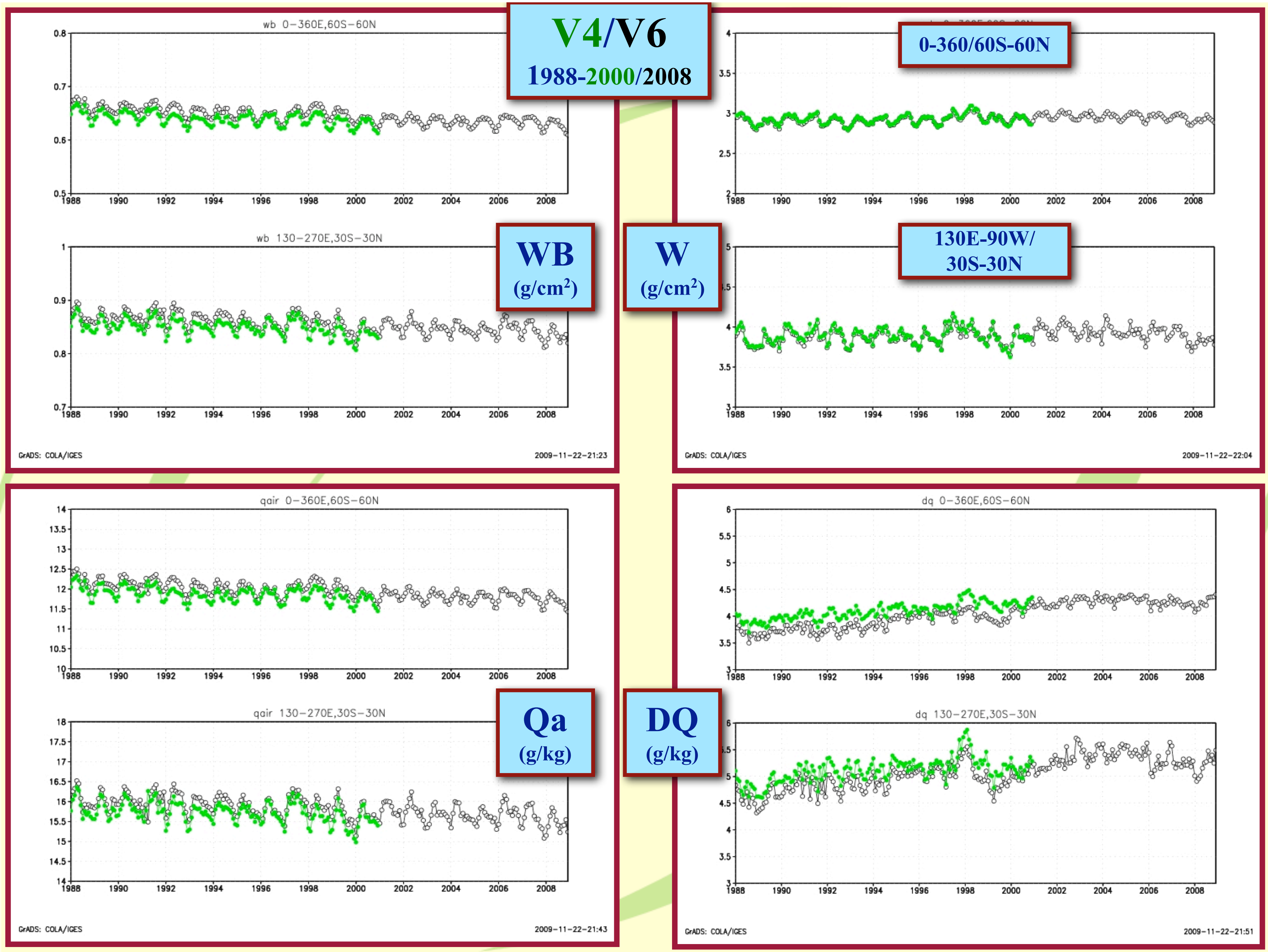
LHF (Wm^{-2})

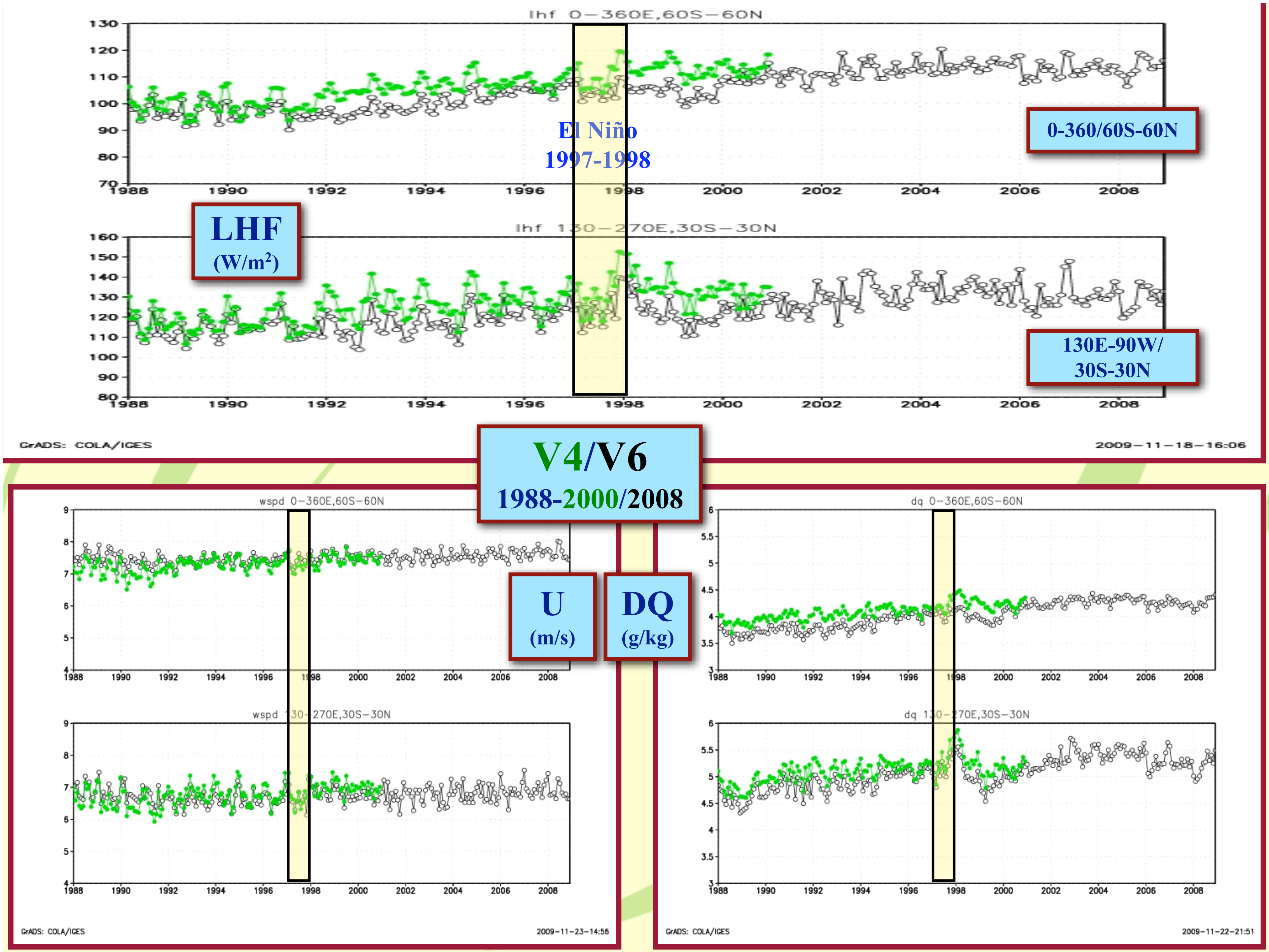
WST (10^{-3} Nm^{-2})



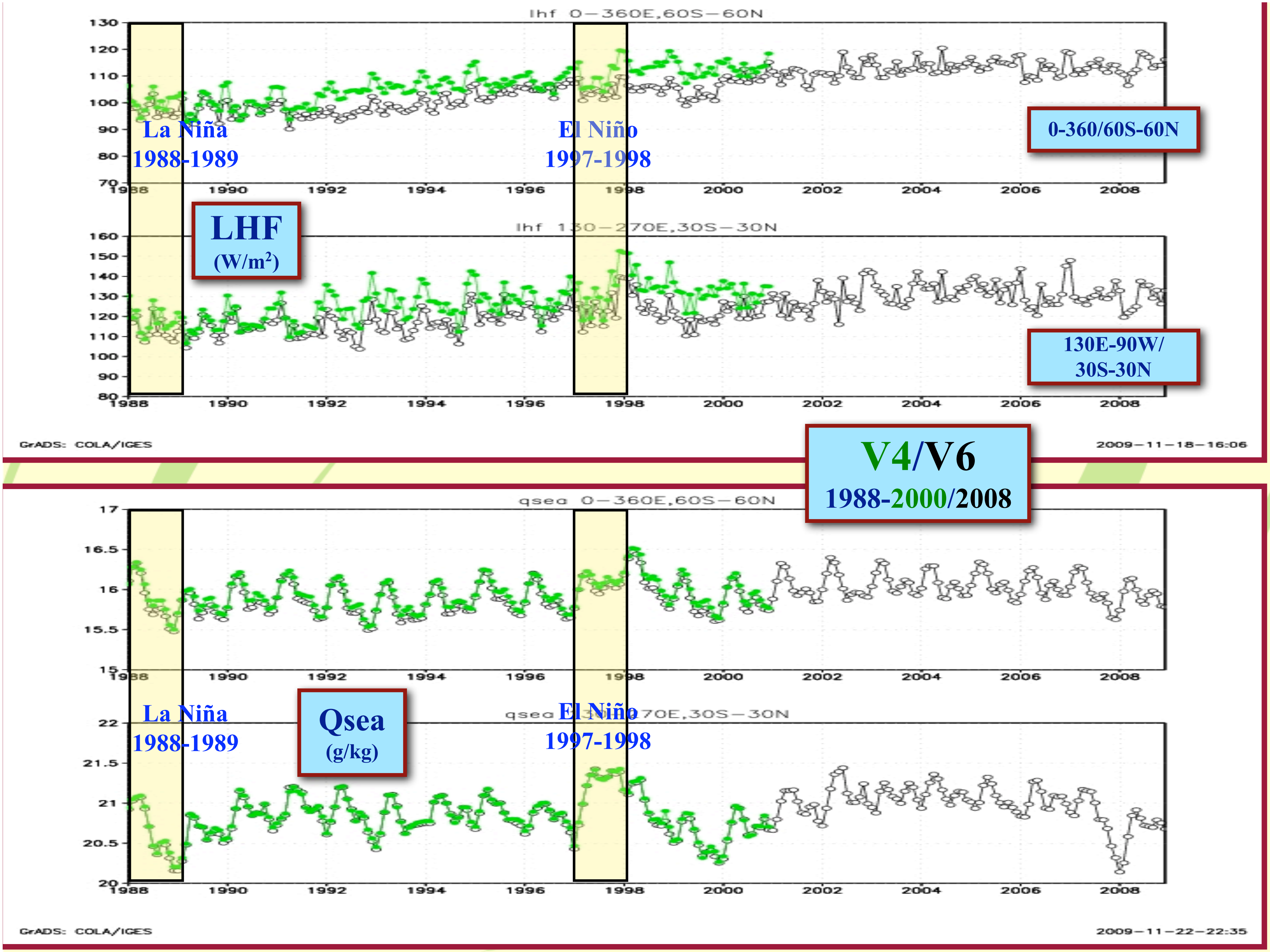
SHF (Wm^{-2})

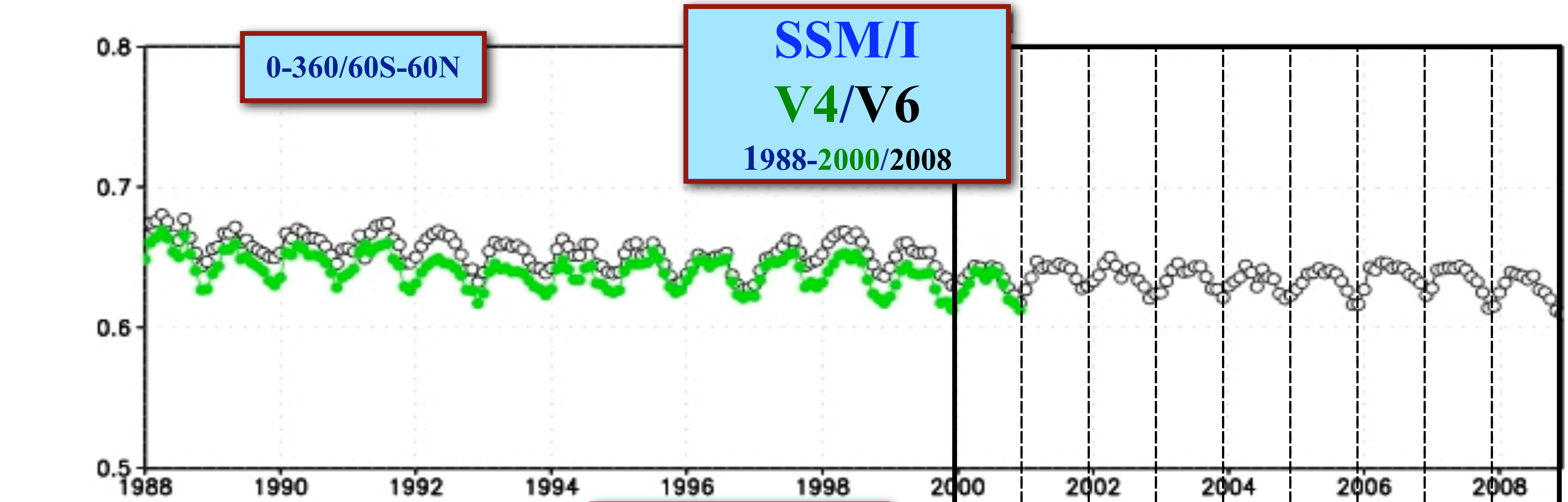



V4/V6
1988-2000/2008
0-360/60S-60N
130E-90W/
30S-30N
wb 0–360E,60S–60N
wb 130–270E,30S–30N
WB
(g/cm2)
W
(g/cm2)
qair 0–360E,60S–60N
qair 130–270E,30S–30N
Qa
(g/kg)
dq 0–360E,60S–60N
dq 130–270E,30S–30N
DQ
(g/kg)
GrADS: COLA/IGES
2009–11–22–21:23
2009–11–22–22:04
2009–11–22–21:43
2009–11–22–21:51



lhf 0-360E,60S-60N
0-360/60S-60N
El Niño
1997-1998
LHF
(W/m2)
lhf 130-270E,30S-30N
130E-90W/
30S-30N
GrADS: COLA/IGES
2009-11-18-16:06
V4/V6
1988-2000/2008
wspd 0-360E,60S-60N
wspd 130-270E,30S-30N
U
(m/s)
DQ
(g/kg)
dq 0-360E,60S-60N
dq 130-270E,30S-30N
GrADS: COLA/IGES
2009-11-23-14:56
GrADS: COLA/IGES
2009-11-22-21:51


lhf 0–360E,60S–60N
La Niña
1988-1989
El Niño
1997-1998
0-360/60S-60N
LHF
(W/m2)
lhf 130–270E,30S–30N
130E-90W/
30S-30N
GrADS: COLA/IGES
2009–11–18–16:06
V4/V6
1988-2000/2008
qsea 0–360E,60S–60N
Qsea
(g/kg)
qsea 130–270E,30S–30N
GrADS: COLA/IGES
2009–11–22–22:35

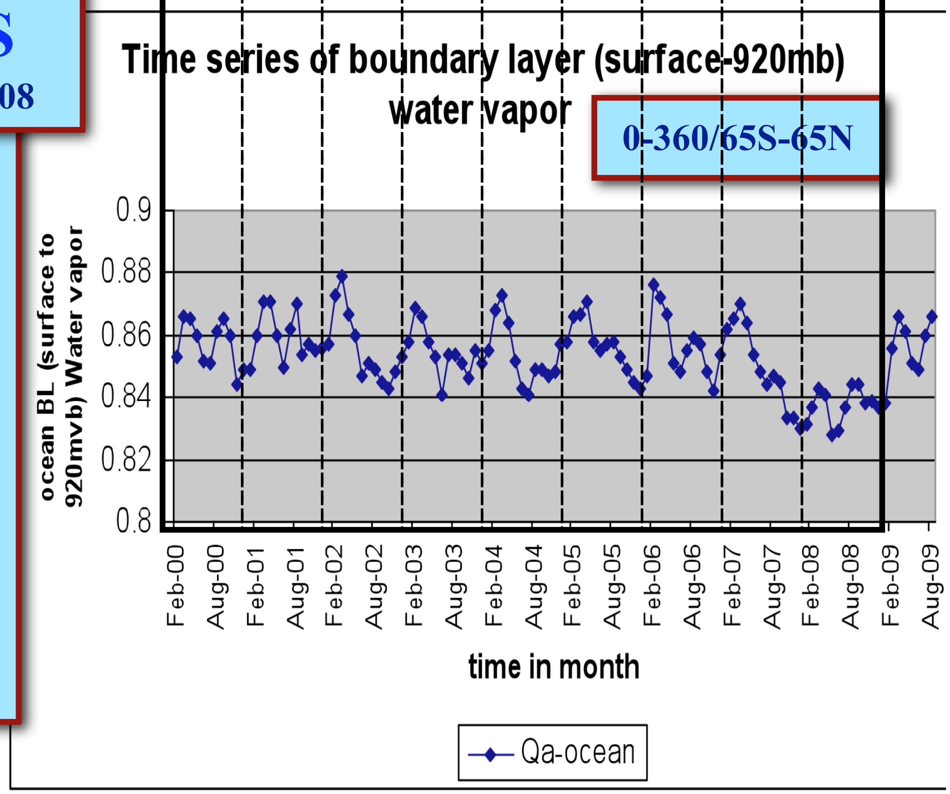


WB
(g/cm²)

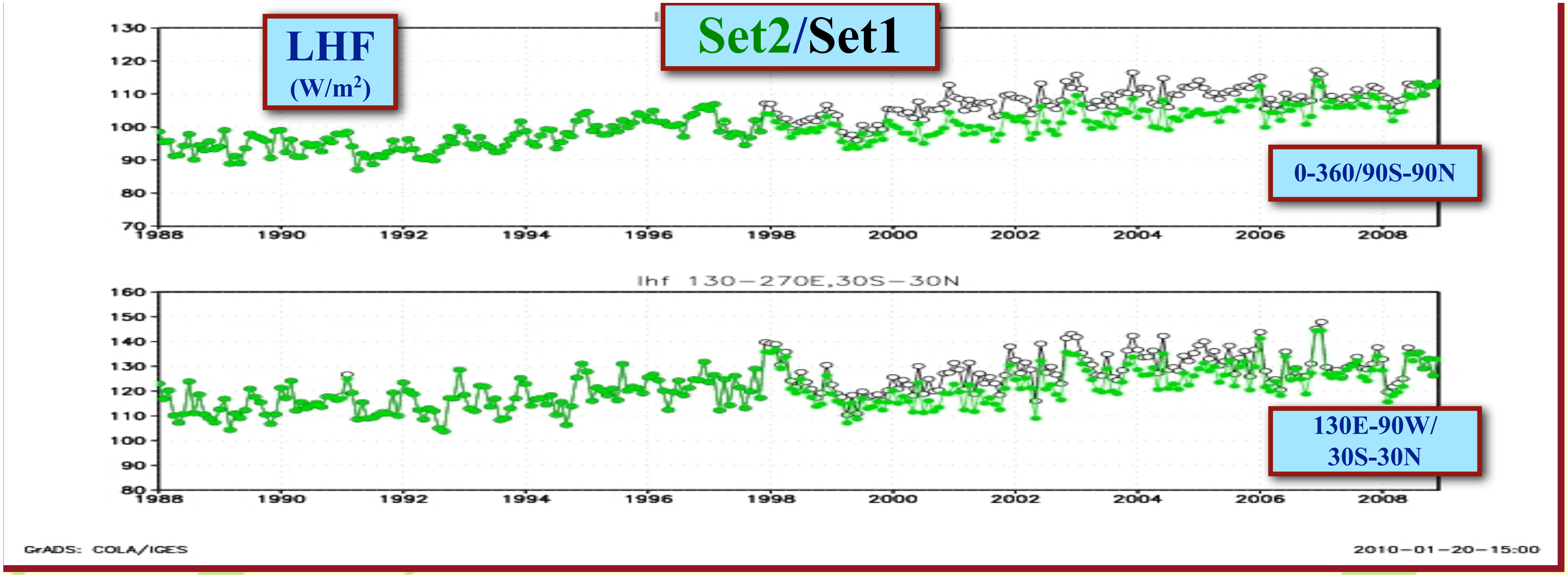
MODIS
2000/02-2009/08

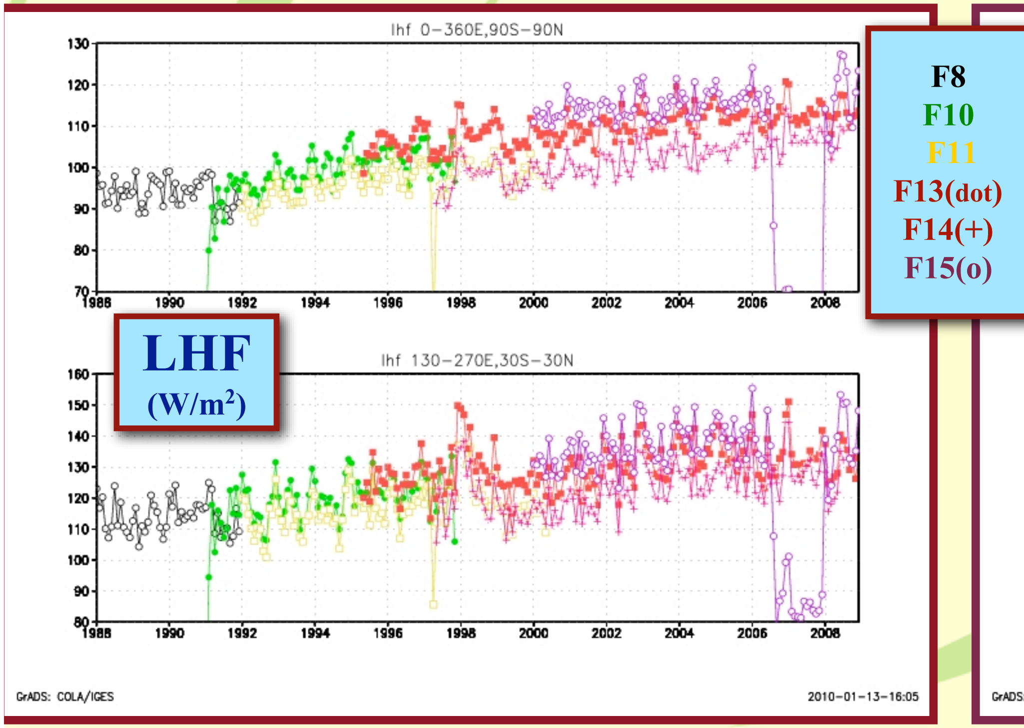
Bottom Layer (500m from surface) Precipitable Water based on

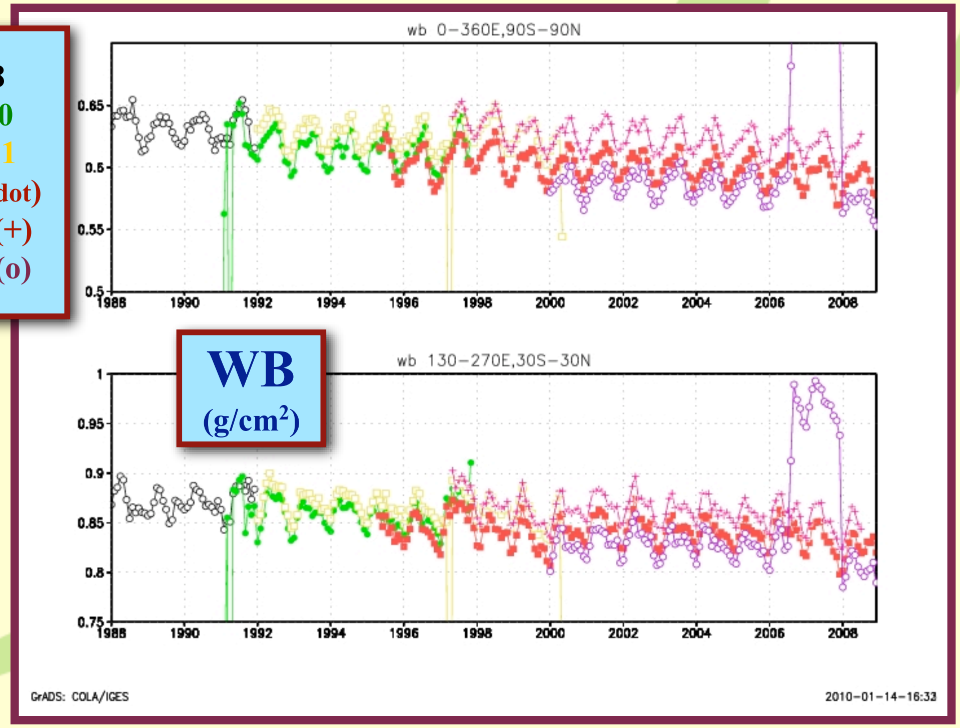
(a)Retrievals from SSM/I (upper panel) using interpolated data. 1988-2000 (V4) / 1988-2008 (V6)
(b)Estimates from MODIS (lower panel). 2000/02-2009/08

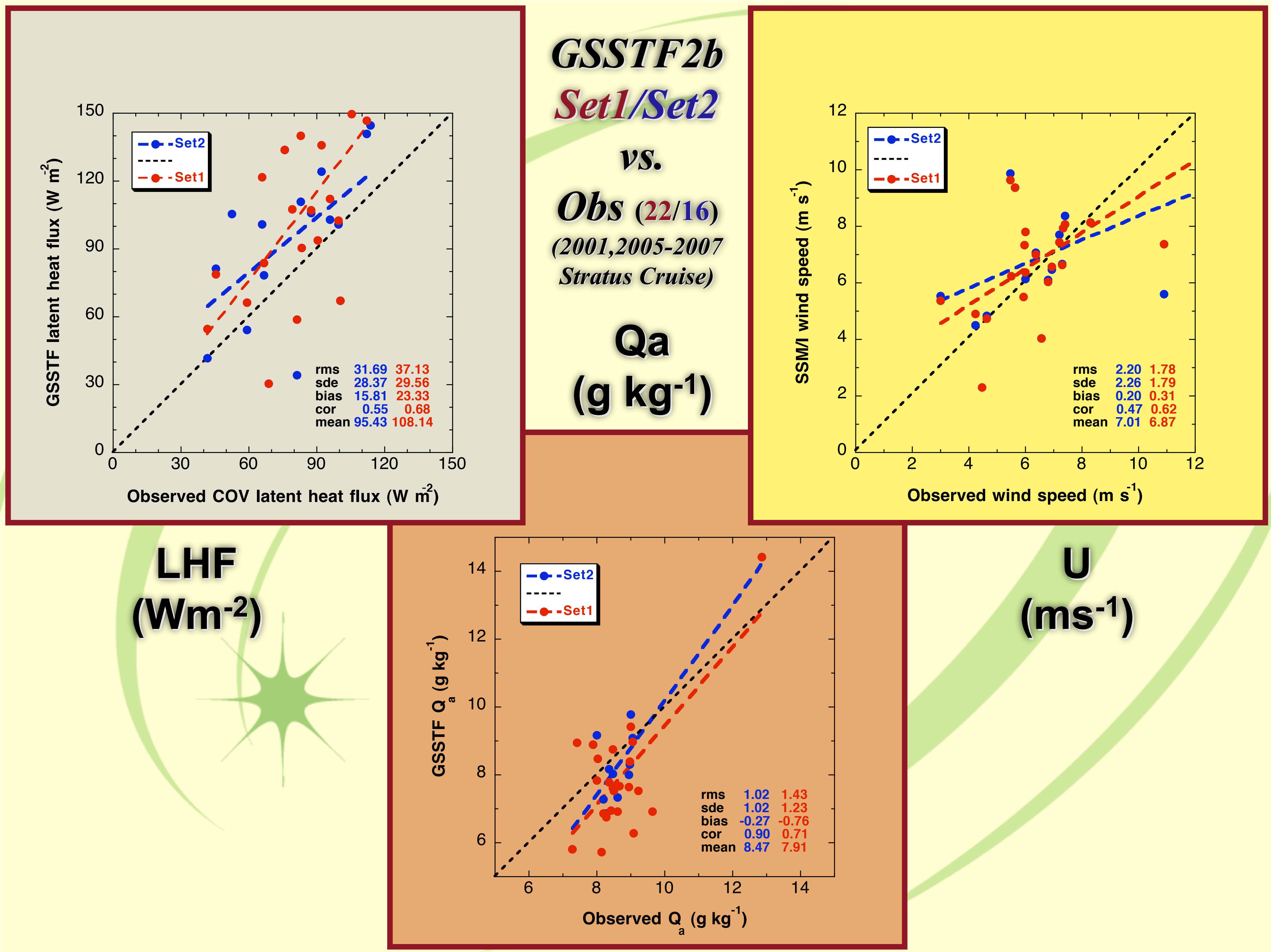


GrADS: COLA/IGES


LHF
(W/m²)
Set2/Set1
0-360/90S-90N
lhf 130–270E,30S–30N
130E-90W/
30S-30N
GrADS: COLA/IGES
2010–01–20–15:00


lhf 0–360E,90S–90N
LHF
(W/m²)
lhf 130–270E,30S–30N
F8
F10
F11
F13(dot)
F14(+)
F15(o)
GrADS: COLA/IGES
2010–01–13–16:05


wb 0–360E,90S–90N
WB
(g/cm²)
wb 130–270E,30S–30N
GrADS: COLA/IGES
2010–01–14–16:33



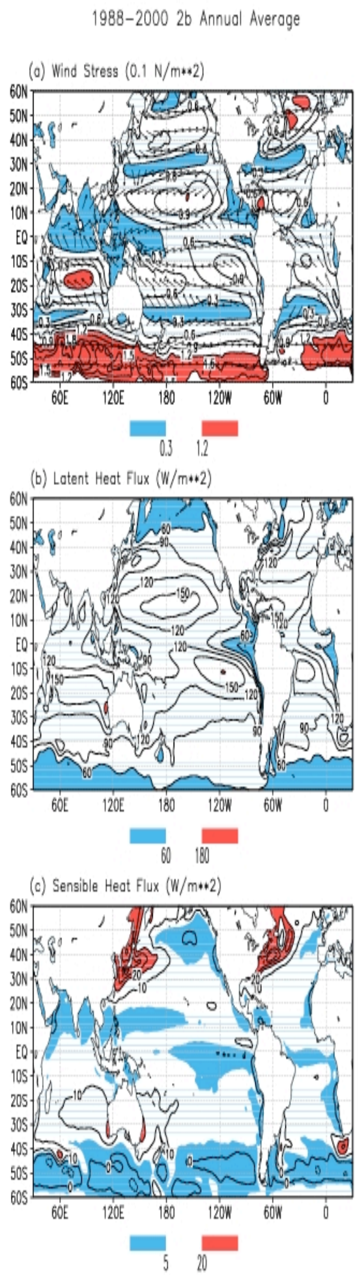
GSSTF2b
Set1/Set2
vs.
Obs (22/16)
(2001,2005-2007
Stratus Cruise)
Qa
(g kg-1)
LHF
(Wm-2)
U
(ms-1)
Set2
Set1
GSSTF latent heat flux (W m-2)
Observed COV latent heat flux (W m-2)
rms 31.69 37.13
sde 28.37 29.56
bias 15.81 23.33
cor 0.55 0.68
mean 95.43 108.14
SSM/I wind speed (m s-1)
Observed wind speed (m s-1)
rms 2.20 1.78
sde 2.26 1.79
bias 0.20 0.31
cor 0.47 0.62
mean 7.01 6.87
GSSTF Qa (g kg-1)
Observed Qa (g kg-1)
rms 1.02 1.43
sde 1.02 1.23
bias -0.27 -0.76
cor 0.90 0.71
mean 8.47 7.91

Annual Climatology

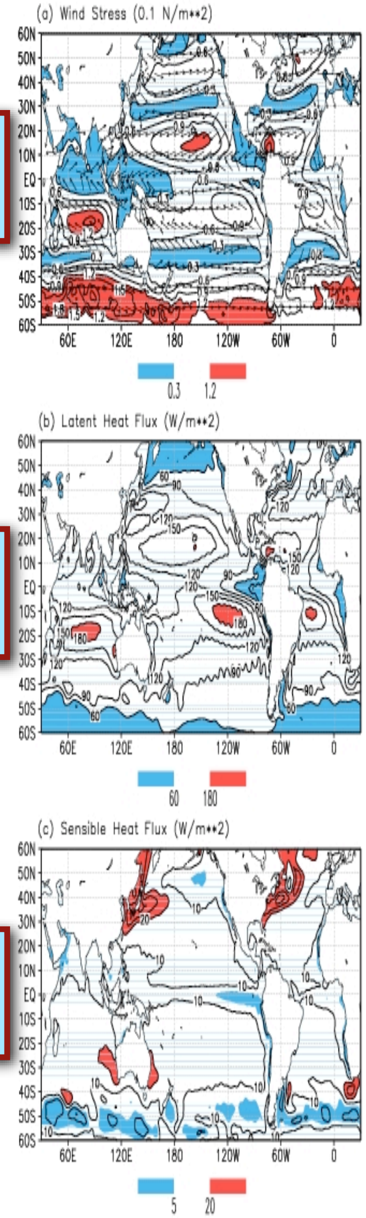
WST (.1 N/m²)

LHF (W/m²)

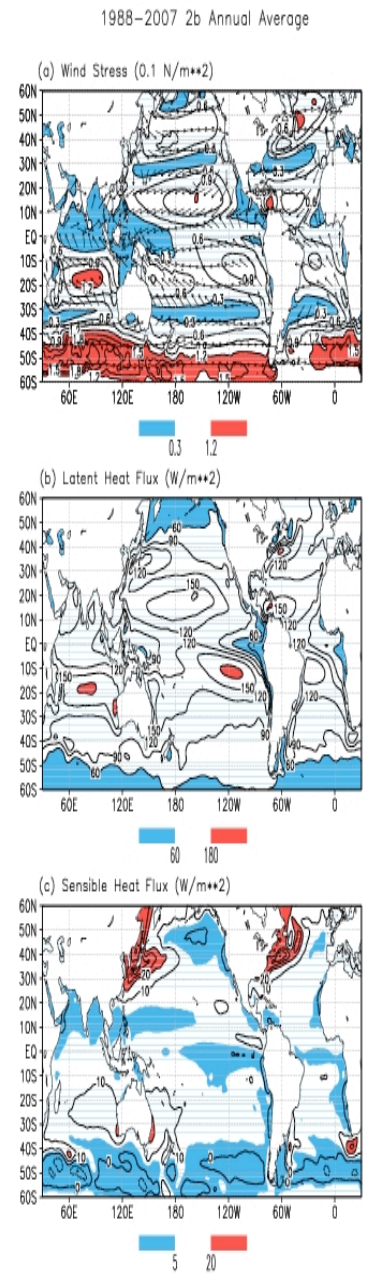
SHF (W/m²)



GSSTF2b 1988-2000

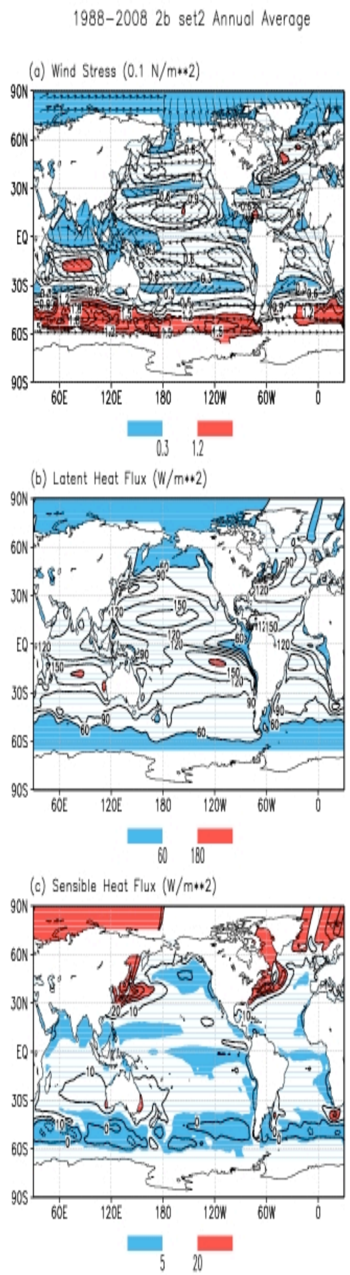


GSSTF2 1988-2000



GSSTF2b 1988-2007

Annual Climatology

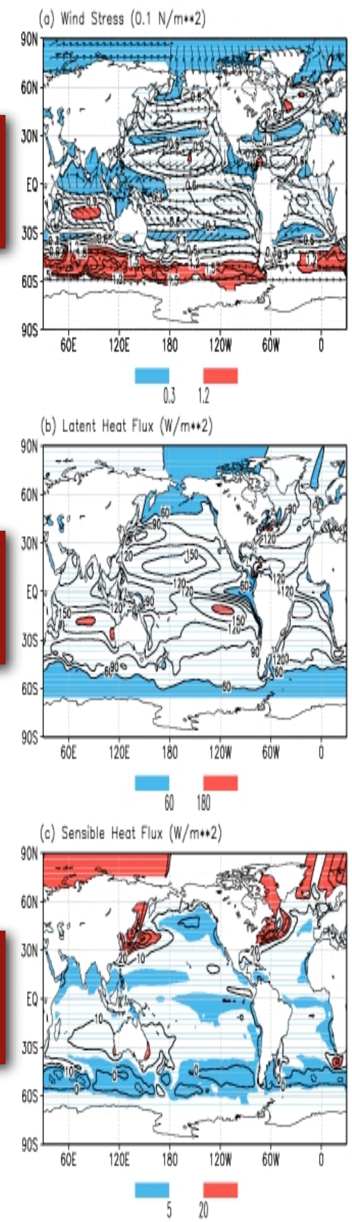


GSSTF2b-S2 1988-2008

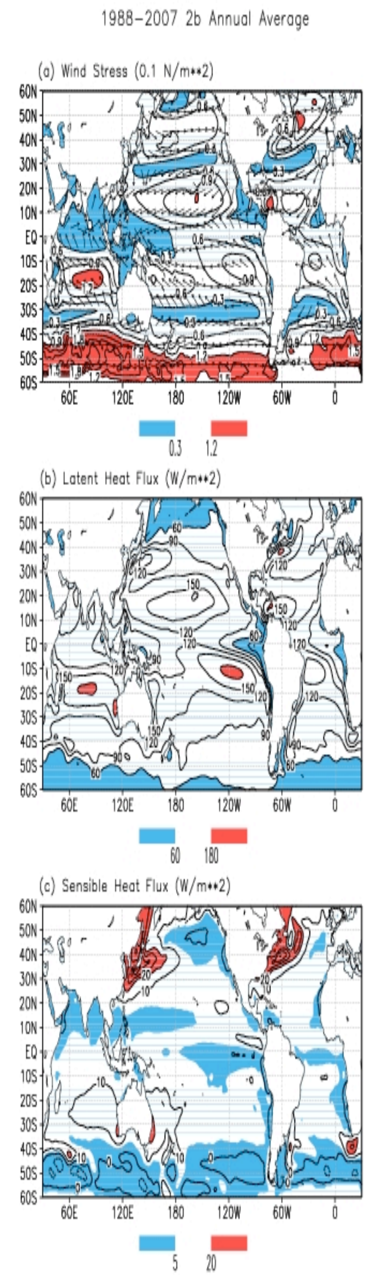
WST (.1 N/m²)

LHF (W/m²)

SHF (W/m²)



GSSTF2b-S1 1988-2008



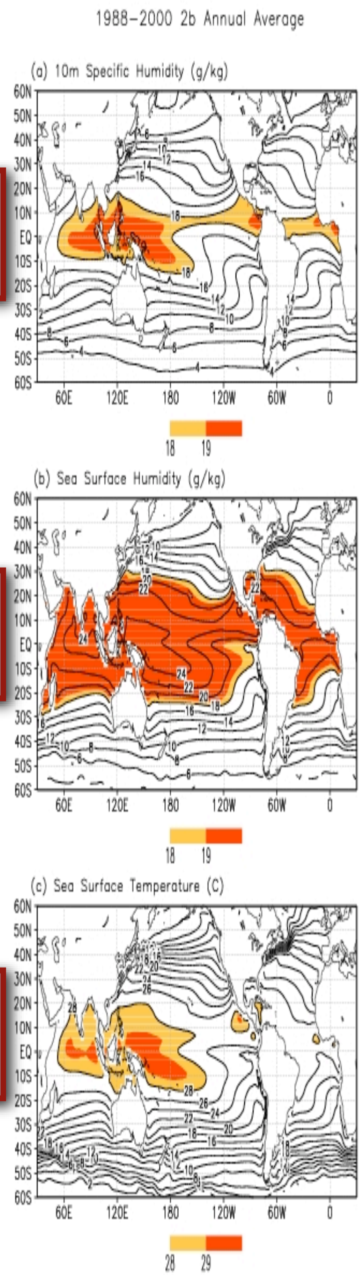
GSSTF2b-S1 1988-2007

Annual Climatology

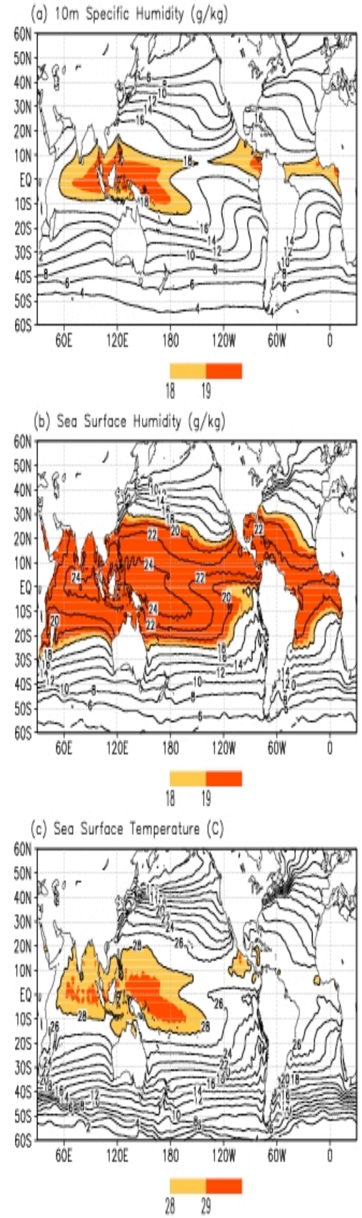
Qa (g/kg)

Qsea (g/kg)

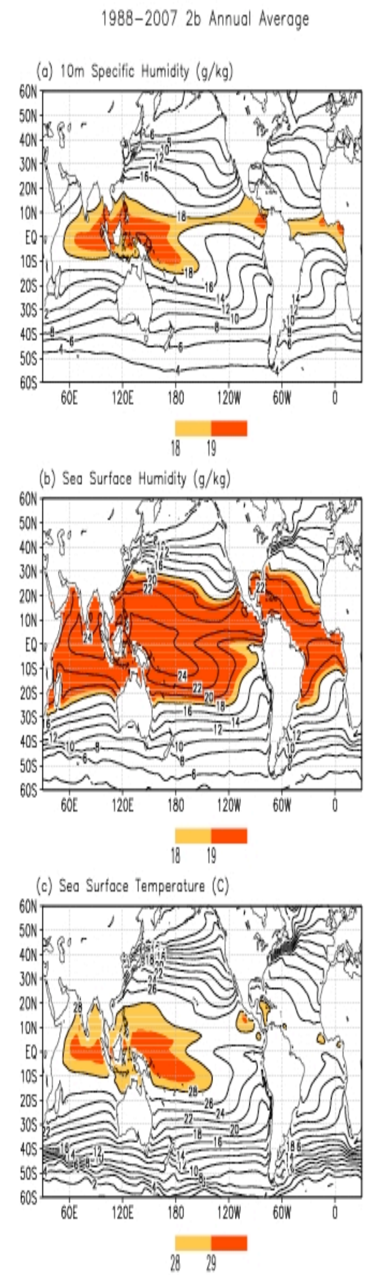
SST (^oC)



GSSTF2b 1988-2000

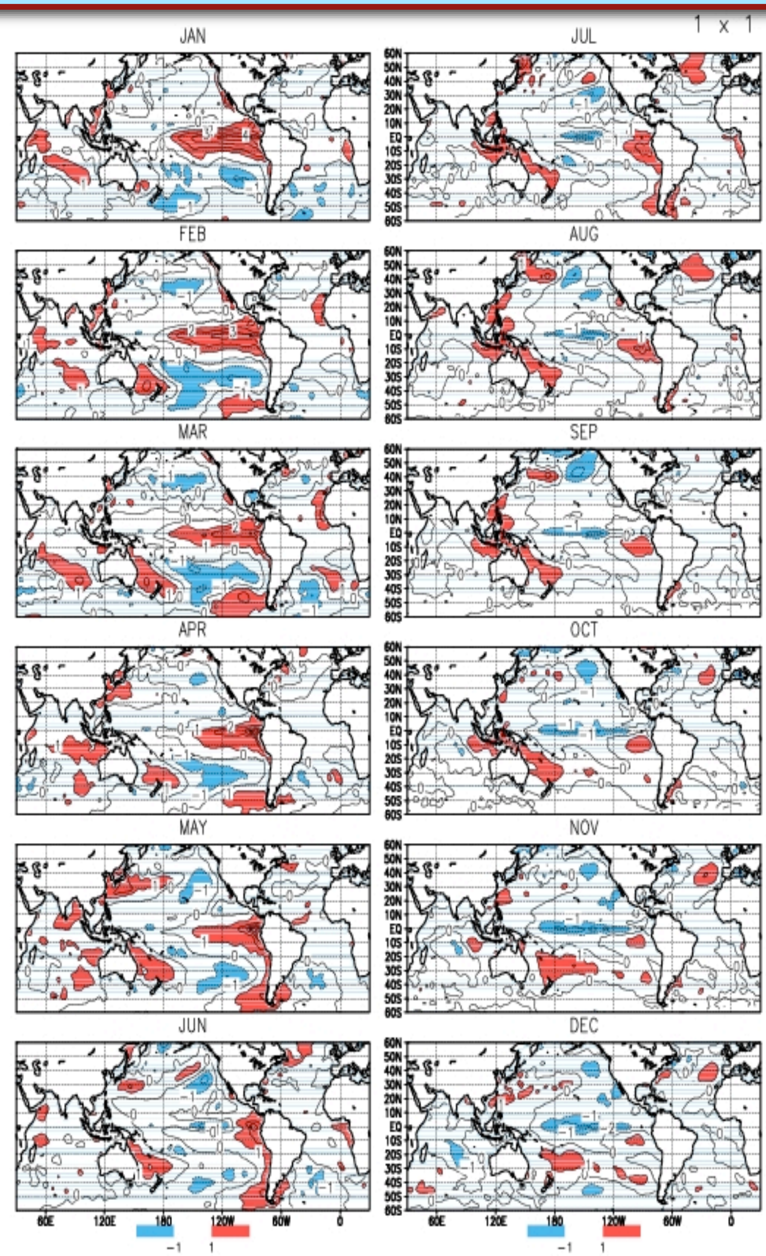


GSSTF2 1988-2000

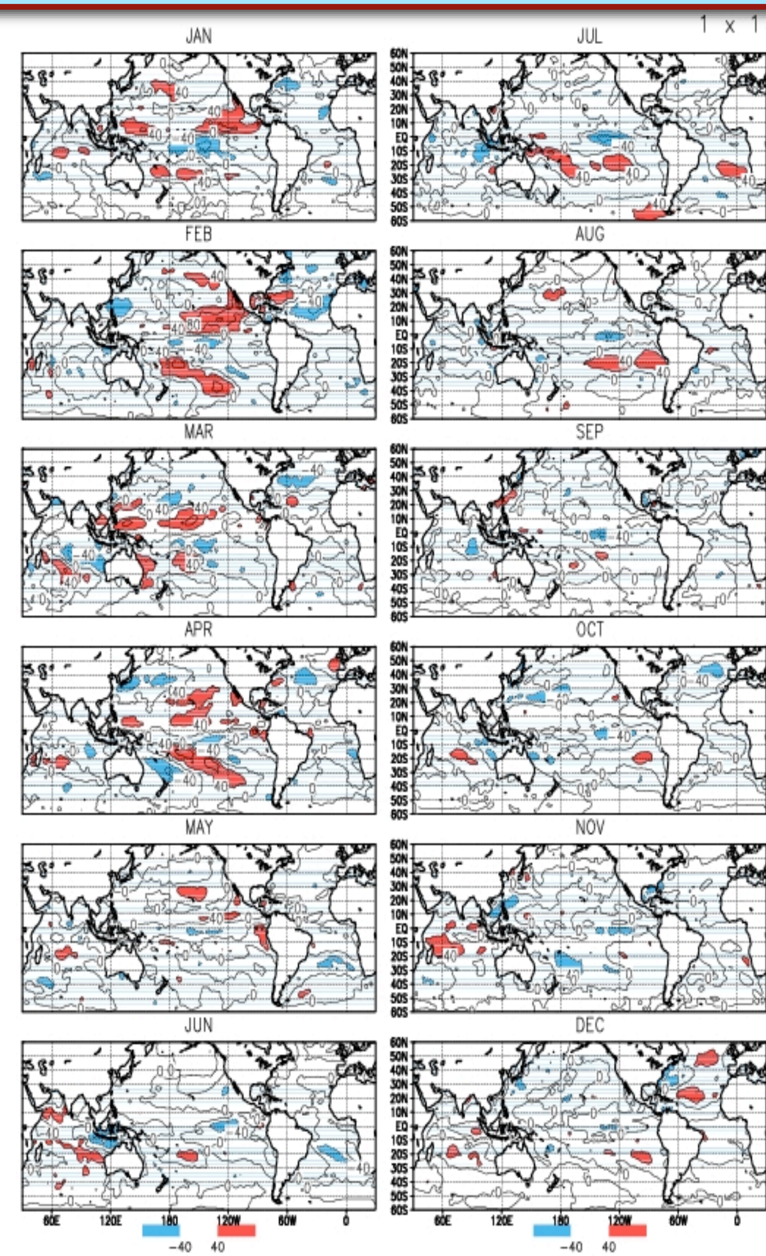


GSSTF2b 1988-2007

NCEP/DOE R2 Monthly Anom: SST (^oC)



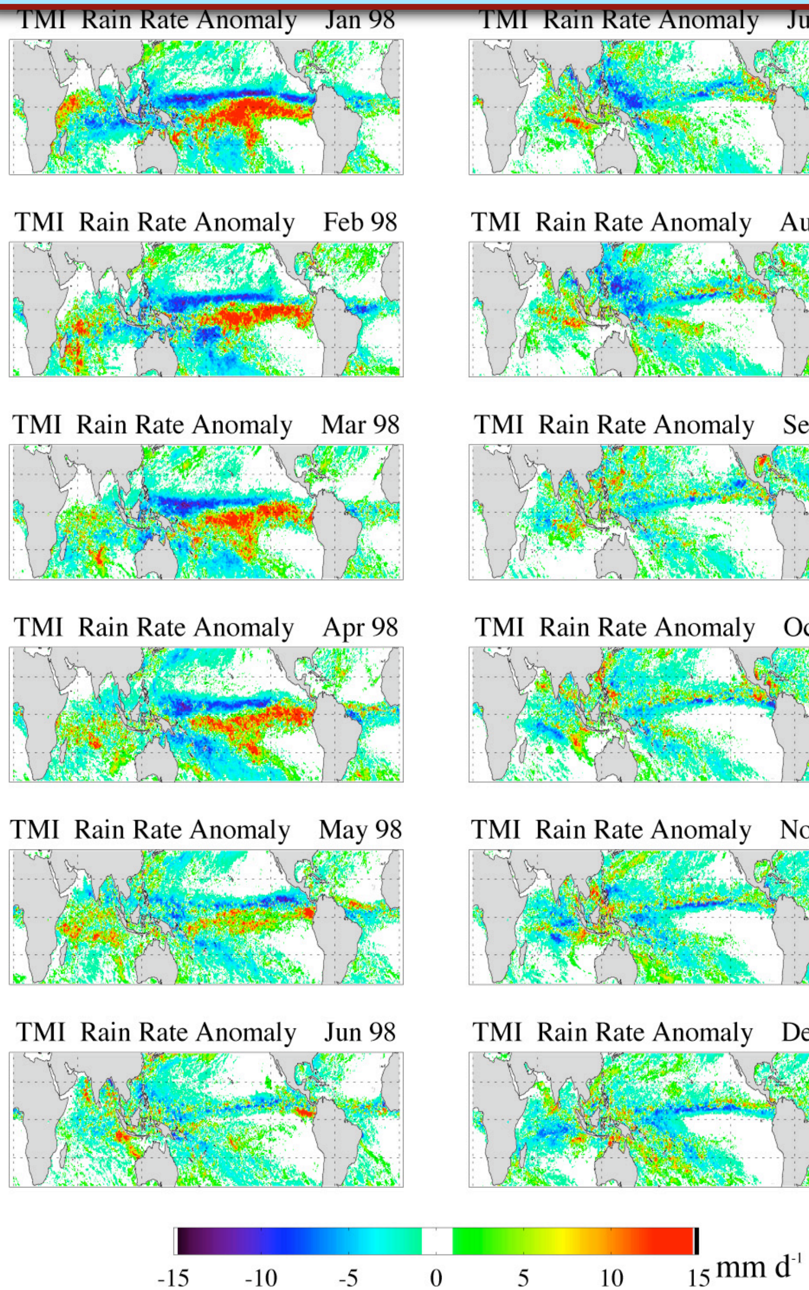
GSSTF2b Monthly Anom: LHF (W/m^2)



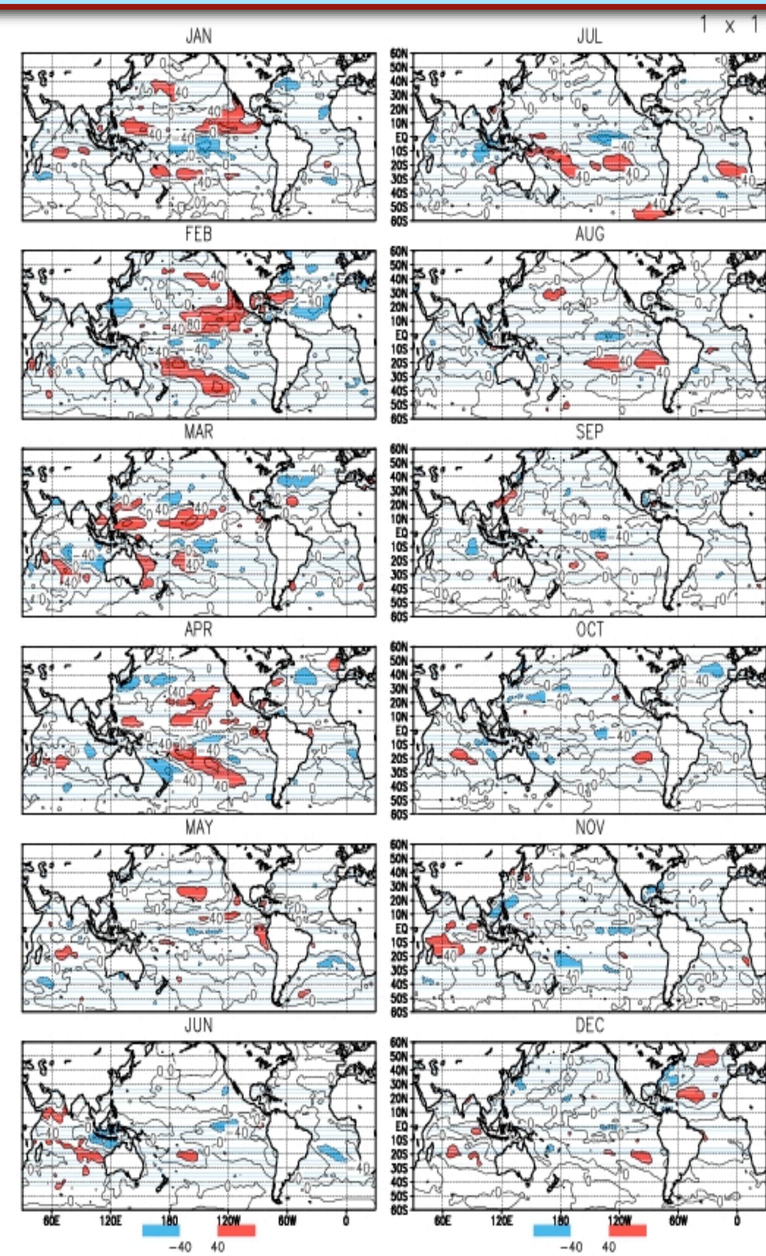
El Niño 1998

TMI Rain Rate Anomaly (mm/day)

Courtesy of W. Olson (UMBC/JCET)

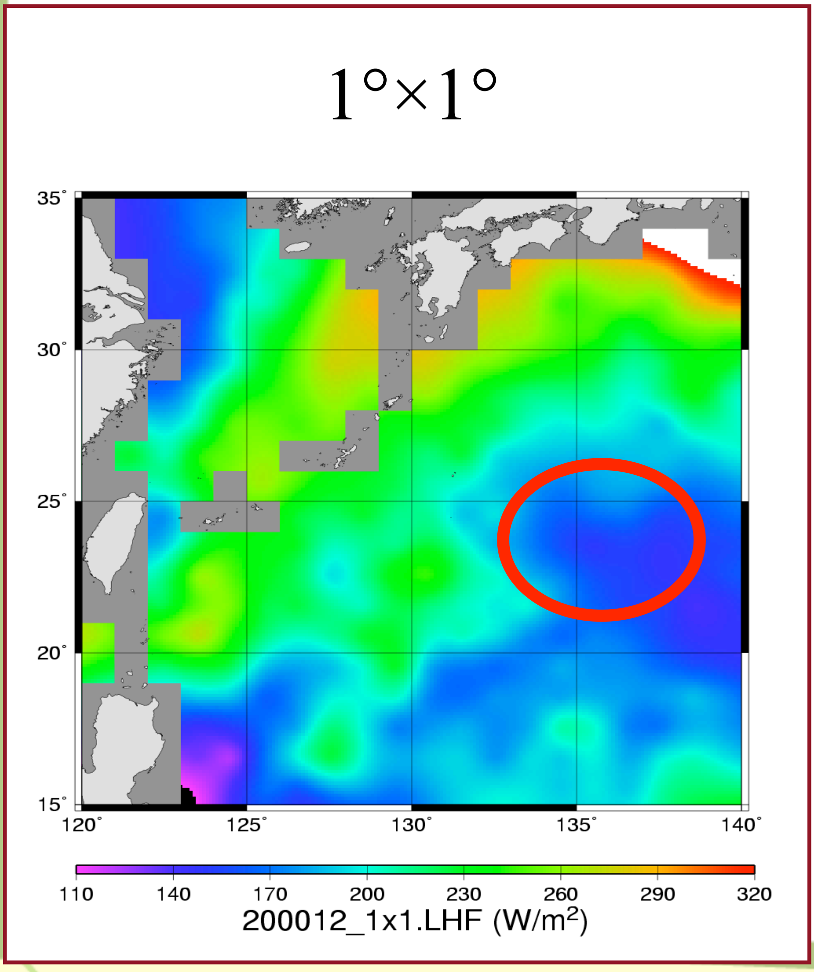


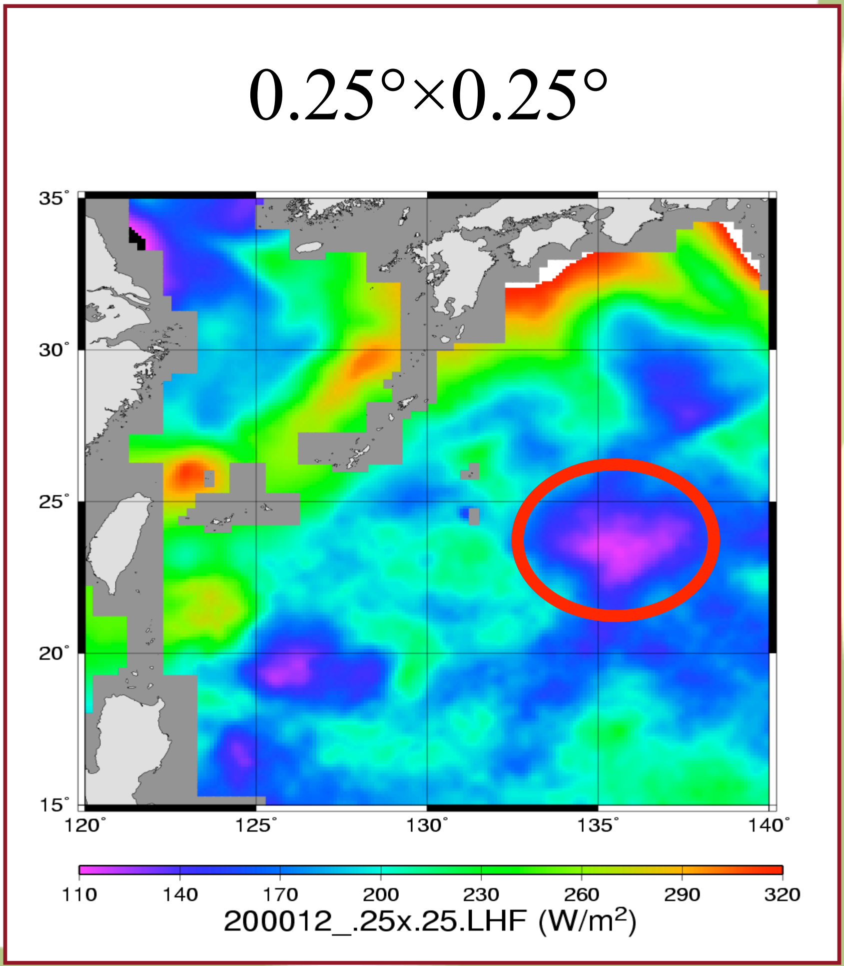
GSSTF2b Monthly Anom: LHF (W/m^2)



El Niño 1998

Improved estimated LHF at the Kuroshio region with higher spatial resolution





(Lin & Wang, 2006)


Thanks!