2009 AGU Fall Meeting
Making Earth Science Data Records II: IN42A
San Francisco, California, 14-18 December, 2009

The Recently Revived and Produced Goddard Satellite-based Surface Turbulent Fluxes Version-2b (GSSTF2b) Dateset

Validation & Findings

Chung-Lin Shie

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Special Thanks: *S. Braun, L. Wu, M. Maiden, J. Entin, H. K. Ramapriyan, W. Olson, A. Hou, A. Chu, M. Grecu, R. Atlas, R. Wu & K. Hilburn*

UMBC/GEST

NASA/GSFC

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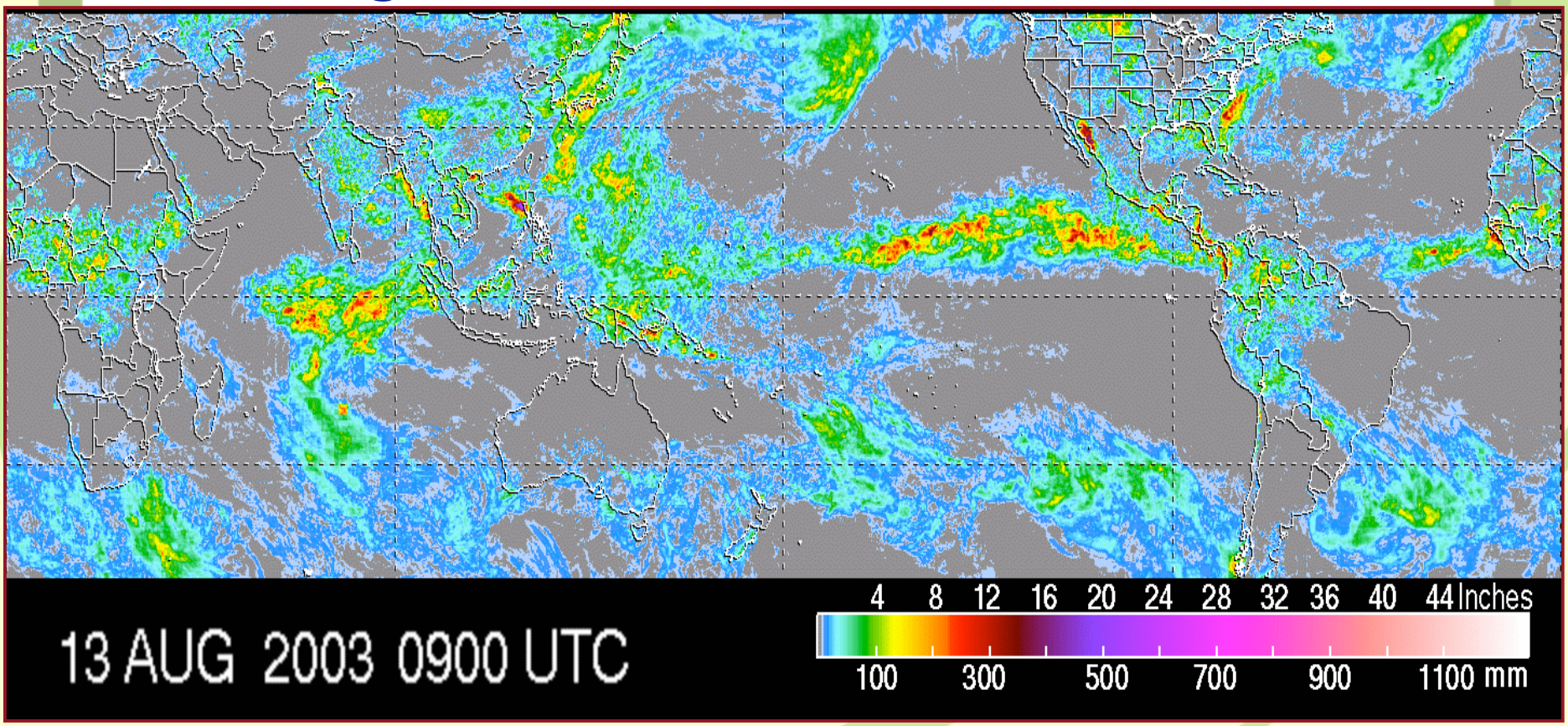
In Memory of
My Mentor

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. 2009a, 2009b)
would have not been possible.

Background

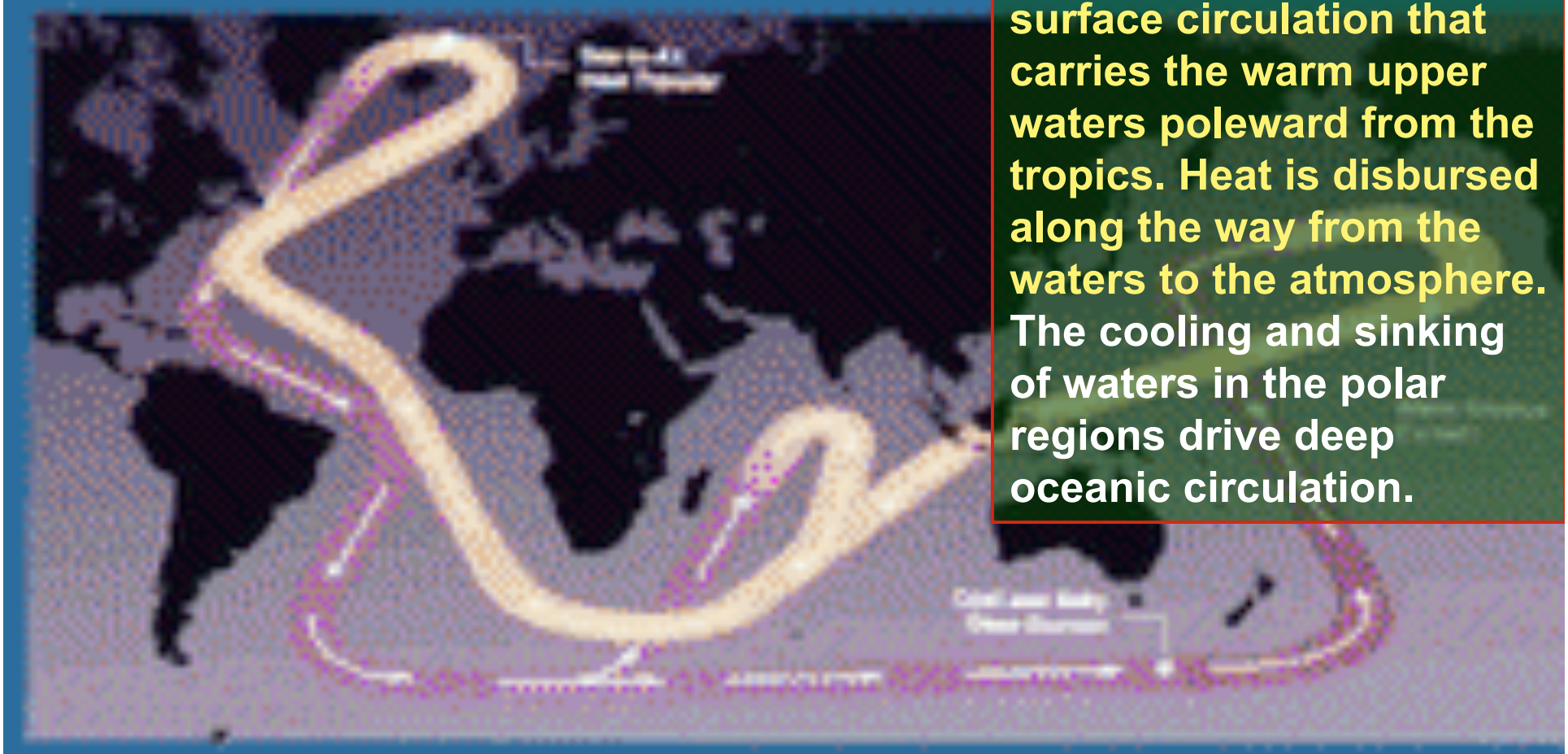
Two-thirds of global precipitation mainly contributed by air-sea surface fluxes falls in the tropics, providing three-fourths of the energy driving global atmospheric circulation (via Hadley Cell) through latent heating.



Global Ocean Circulation

TOPEX/POSEIDON

The Global Conveyor Belt for Heat



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.

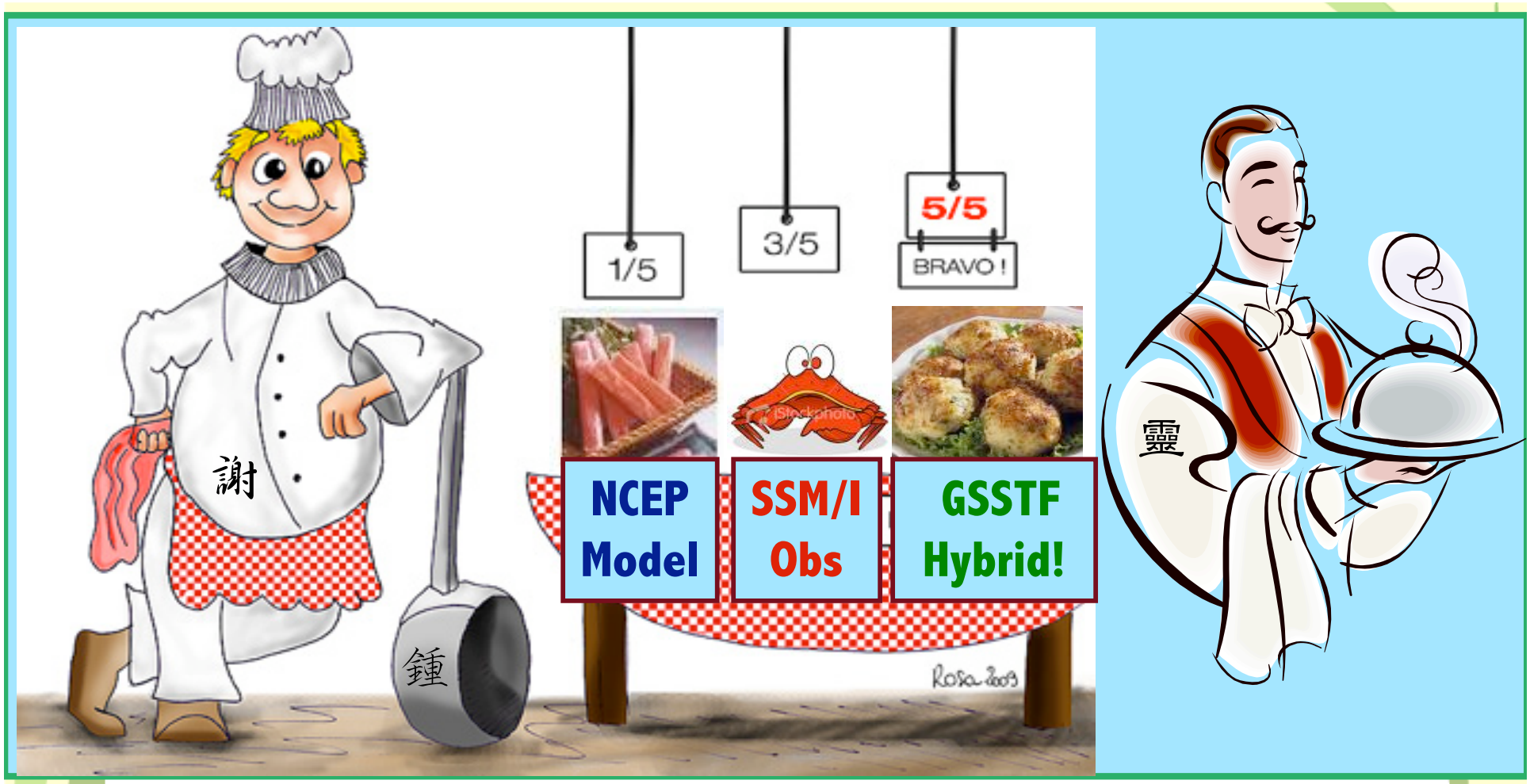
Air-Sea Turbulent Fluxes

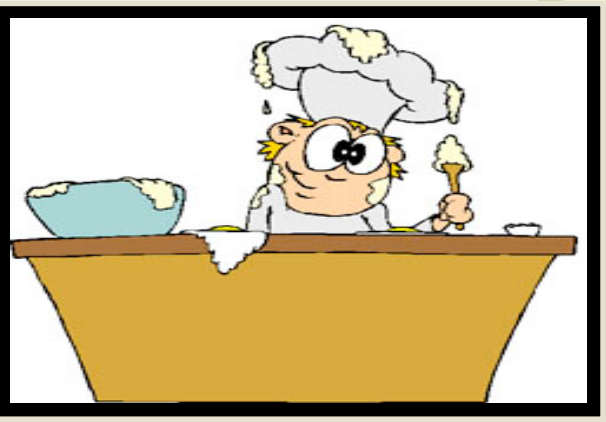
- **Include:**
  - ***Latent Heat Flux (LHF)***
  - ***Sensible Heat Flux (SHF)***
  - ***Momentum Flux (Wind Stress WST)***
- ***Exchange of heat, moisture (fresh water), and momentum between atmosphere and ocean***
- ***Important in air-sea interaction, climate variations and oceanic circulations of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


謝
鍾
1/5
3/5
5/5
BRAVO!
NCEP Model
SSM/I Obs
GSSTF Hybrid!
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 [ρ_a, U, q_s, q_a, θ_s, θ_a]*
- *Bulk Transfer/Turbulent Exchange Coefficients [C_E, C_H, C_D]*

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)

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.

GSSTF2 Current Flux Products

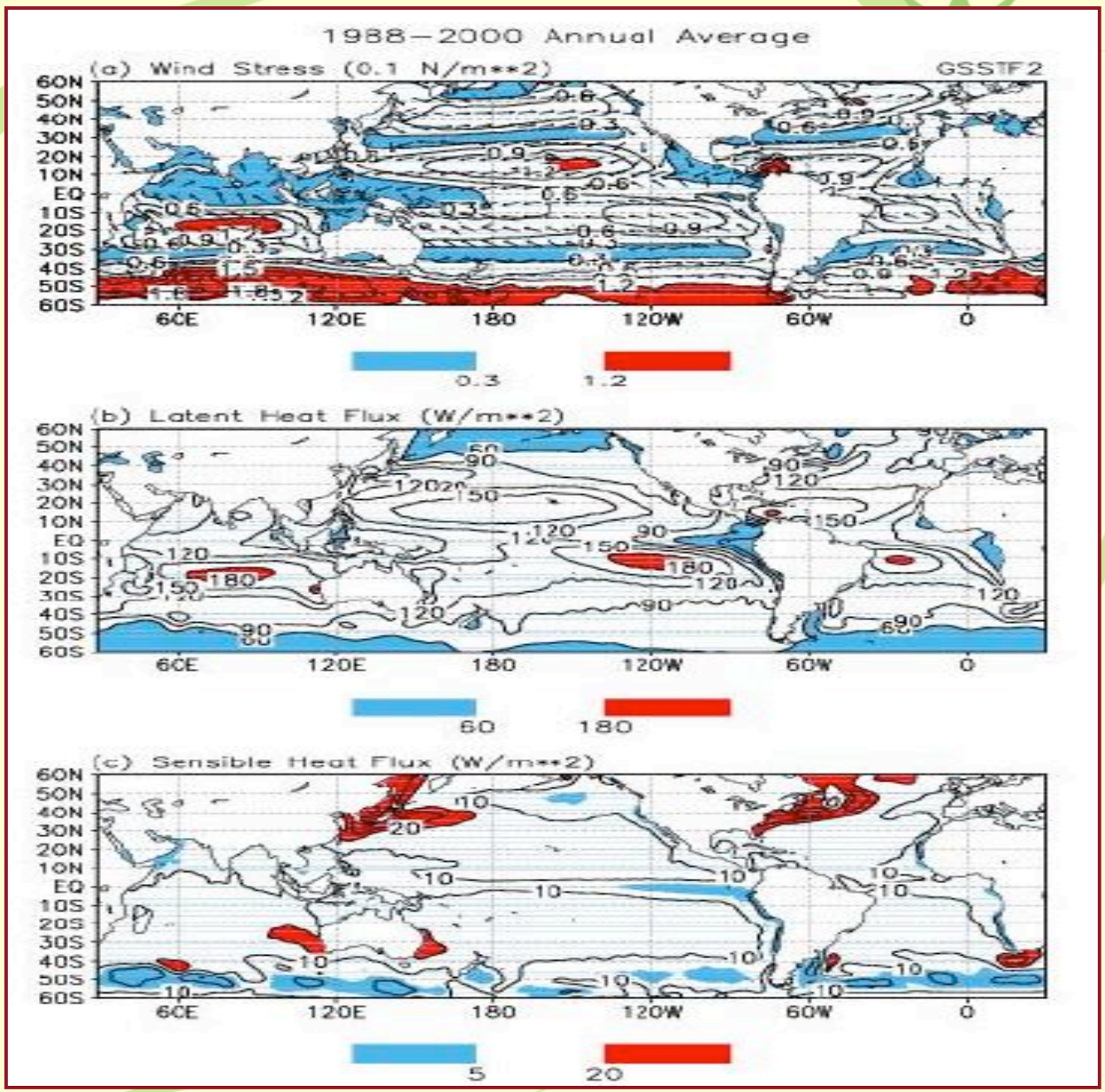
GSSTF2 Annual-mean (1988-2000)

(a) Wind stress,

(b) Latent heat flux,

(c) Sensible heat flux

Arrows indicate wind stress direction.



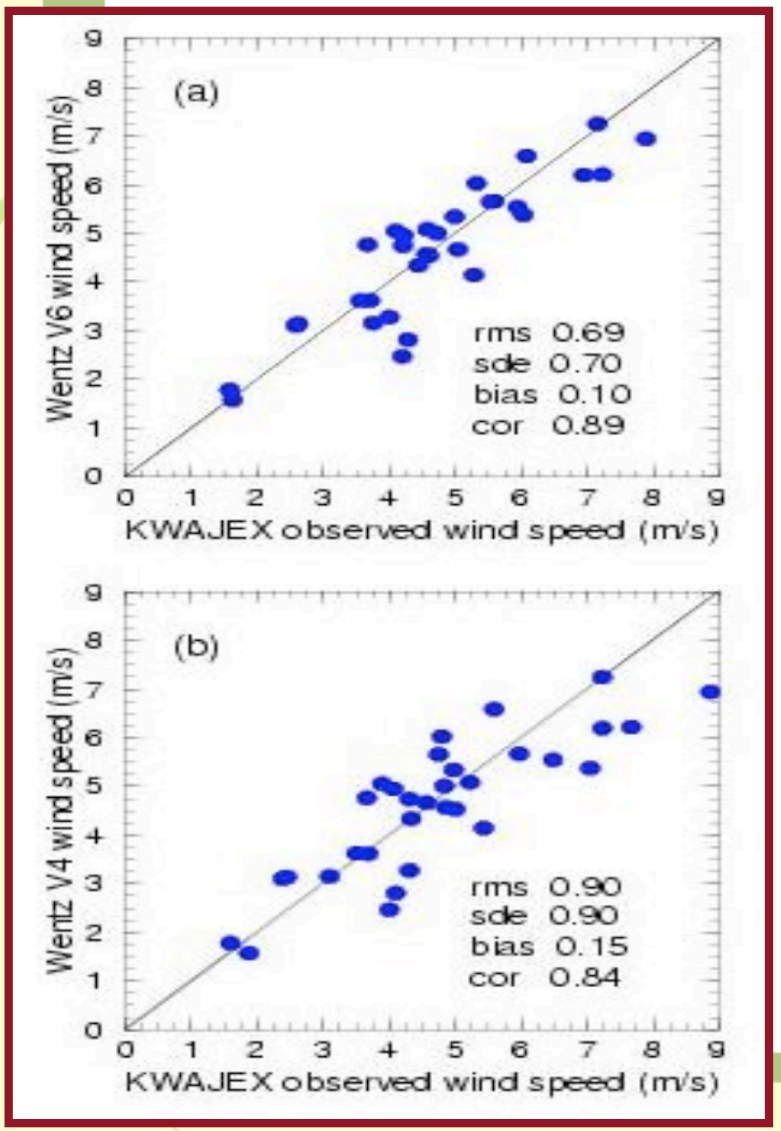
How To Improve GSSTF

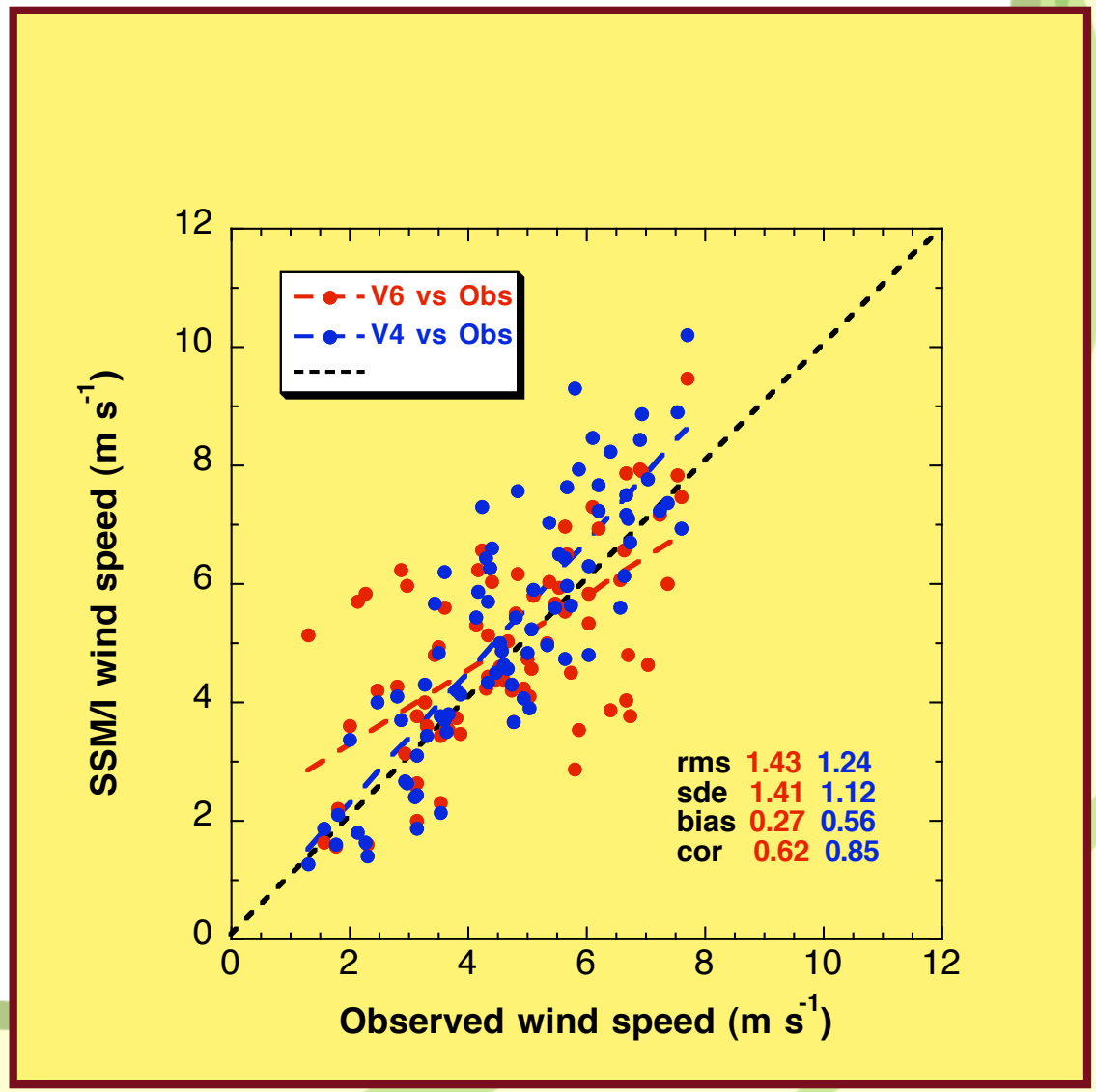
Reprocess and improve GSSTF dataset to cover the entire SSM/I observation period of 1987 – present, using Improved input datasets: i.e., RSS SSM/I V6, NCEP/DOE R2, CCMP/VAM L3, and upgraded spatial and temporal resolutions

Datasets	GSSTF2	GSSTF2b	GSSTF3
C_E (transfer coeffi.)	Chou (1993)	PDB[1] (high wind)	PDB (high wind)
U (speed)	Wentz V4 (1997)	Wentz V6 (2006)	Wentz V6 (2006)
U (vector)	Atlas et al. (1996)	Atlas et al. (1996) or QuikSCAT	QuikSCAT and ADEOS2-SeaWinds
W/WB	Wentz V4 (1997)	Wentz V6 (2006)	Wentz V6 (2006)
SST	NCEP Reanalysis (V1) Reynolds and Smith (1994)	NCEP Reanalysis (V2) Reynolds et al. (2002)	AMSR-E & TMI
Q_a	Chou et al. (1995, 1997)	Chou et al. (1995, 1997)	Chou et al. (1995, 1997)
$Tair/SLP$	NCEP	NCEP	NCEP
Spatial resolution	1° by 1°	1° by 1°	0.25° by 0.25°
Spatial coverage	Global Oceans	Global Oceans	"Global Oceans"[2]
Temporal resolution	Daily and monthly	Daily and monthly	12-hr and monthly
Temporal coverage	Jul. 1987 – Dec. 2000	Jul. 1987 – Dec. 2010	July 1999 – Dec. 2010

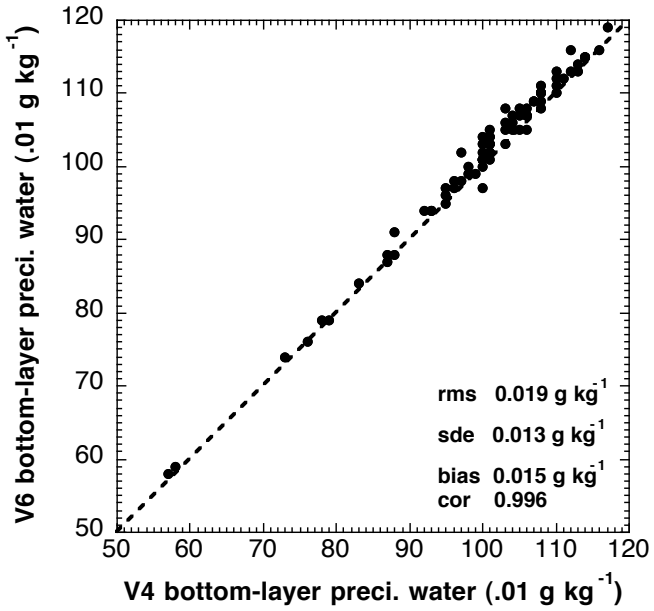
[1]Stands for Powell et al., 2003; Donelan et al., 2004; Black et al., 2006. [2]Likely a smaller domain than 90Nx90S

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



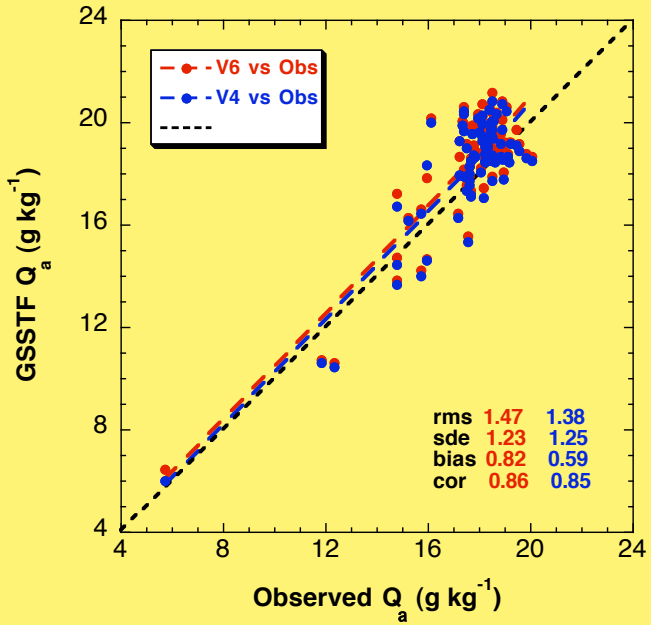


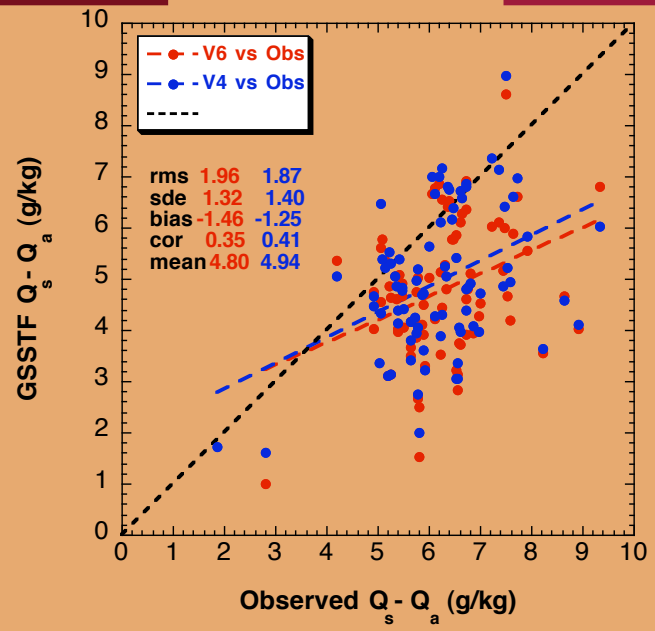
(Labels of x/y axis need to be swapped)



WB (.01 g cm^{-2}) (*V6 vs. V4*)

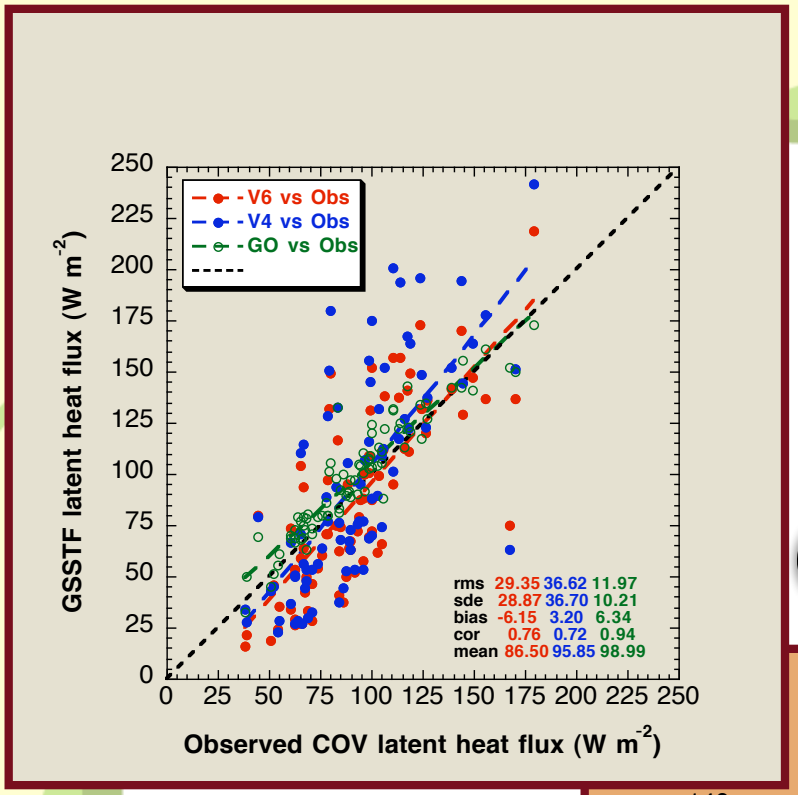
Qsea-Qair (g kg^{-1}) *V6/V4* vs. *Obs (82)*





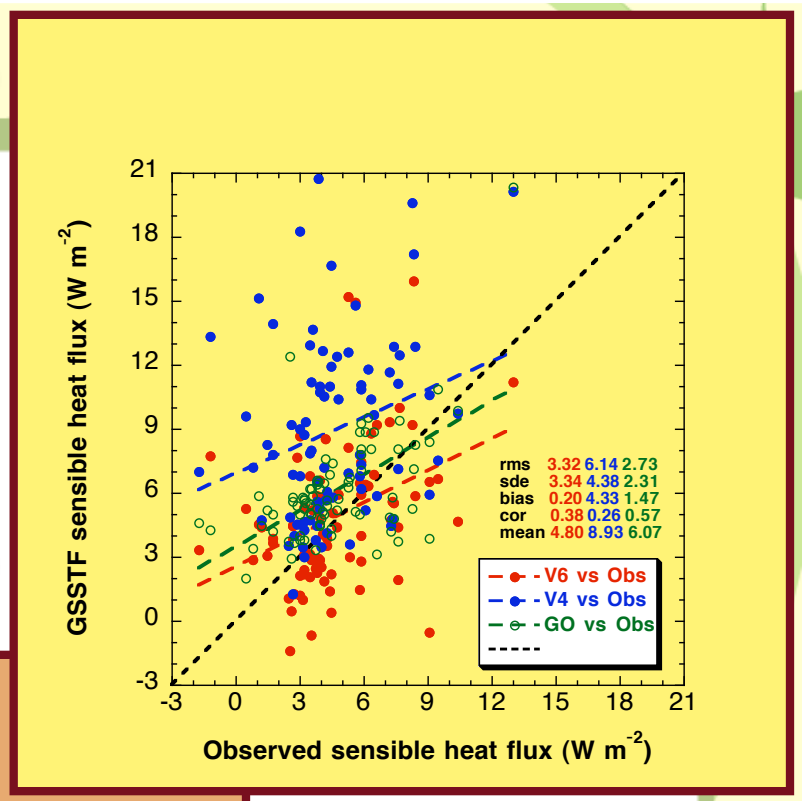
Qair (g kg^{-1}) *V6/V4* vs. *Obs (82)*

V6/V4/GO vs. Obs (82)

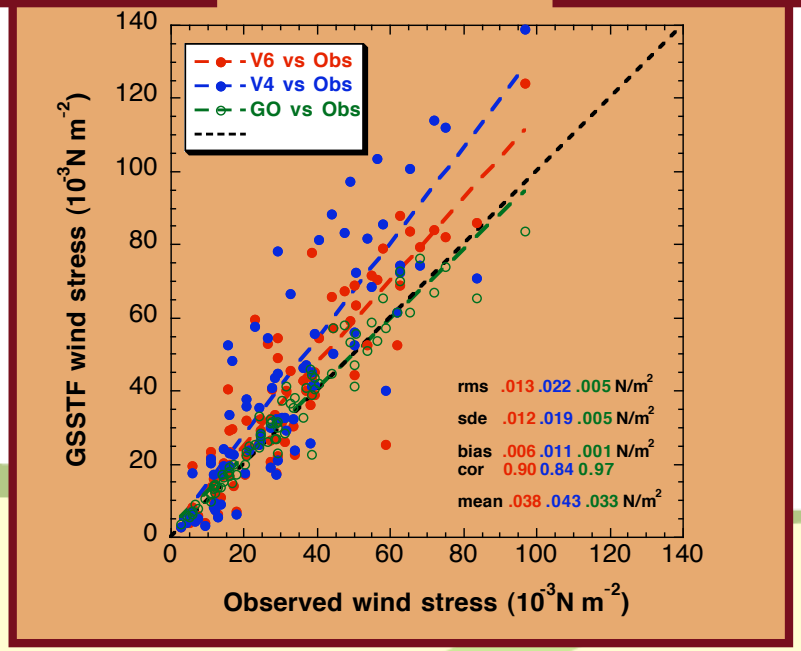


LHF (Wm^{-2})

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

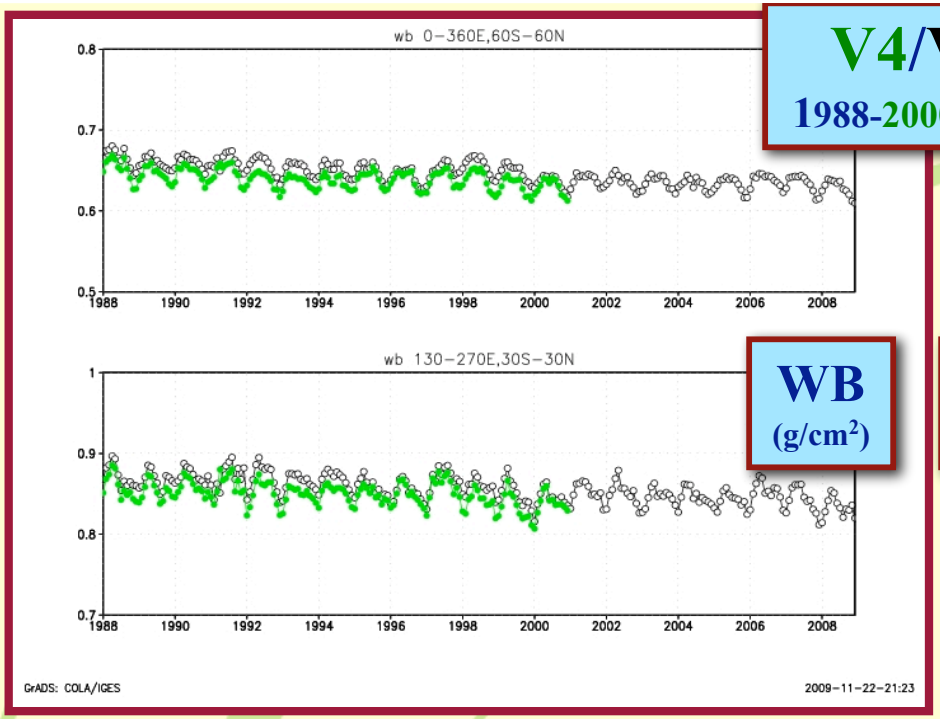


SHF (Wm^{-2})



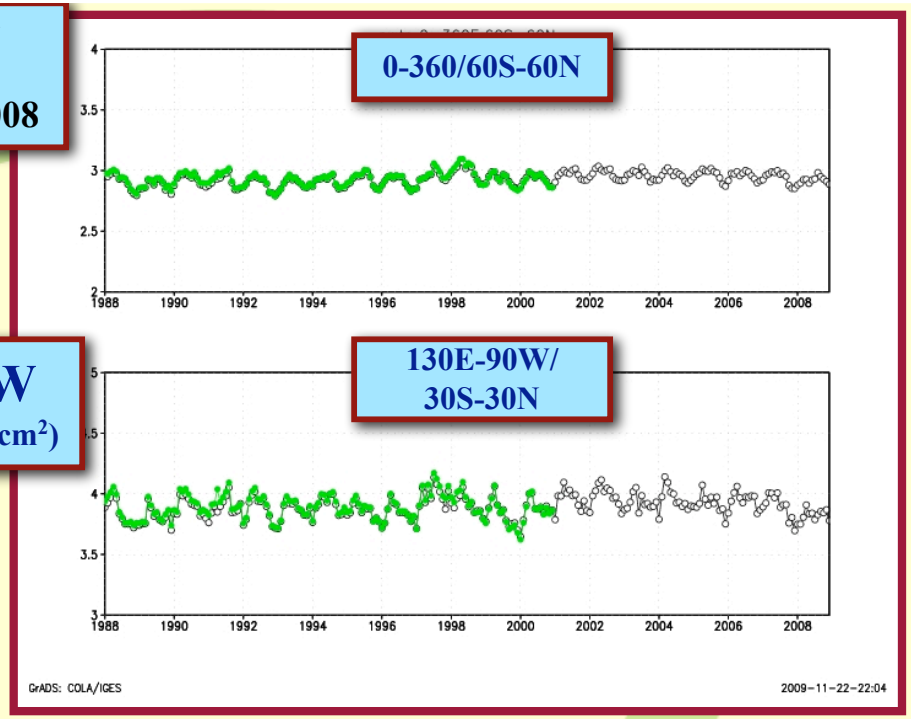
V4/V6

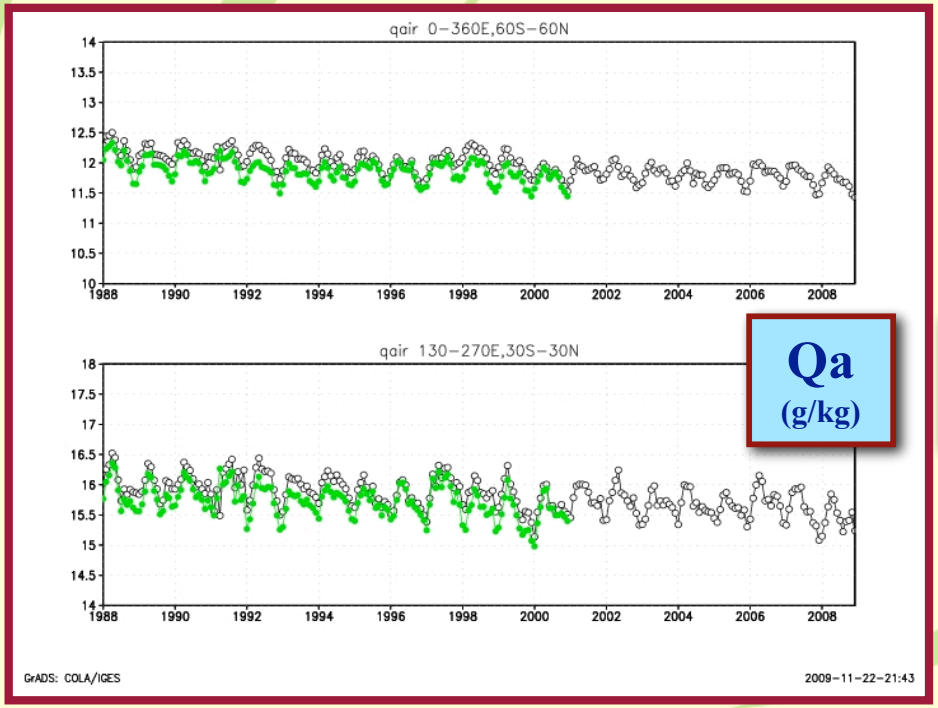
1988-2000/2008



WB (g/cm^2)

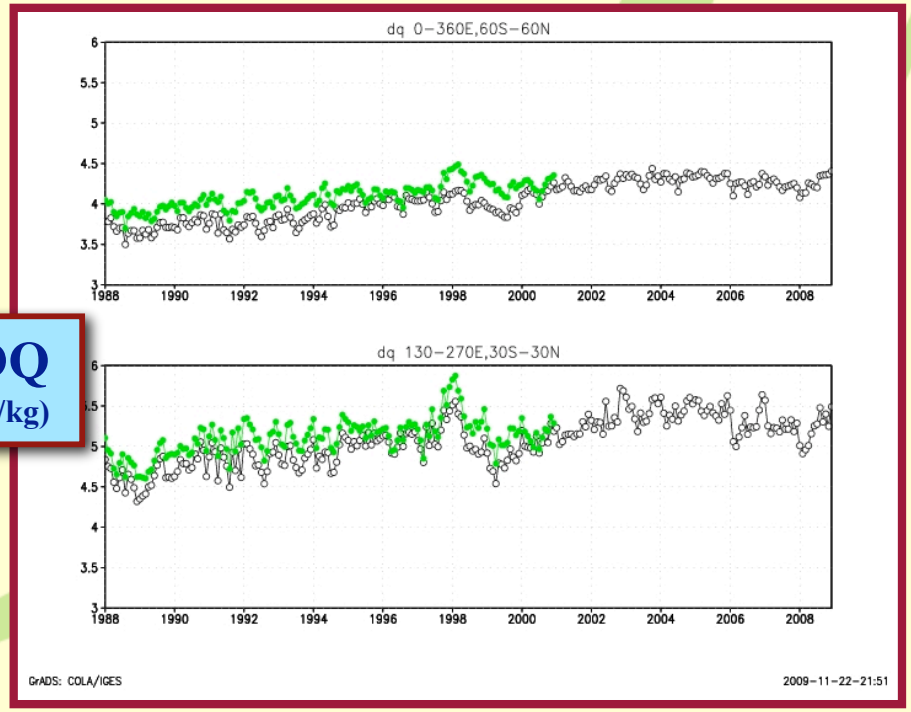
W (g/cm^2)

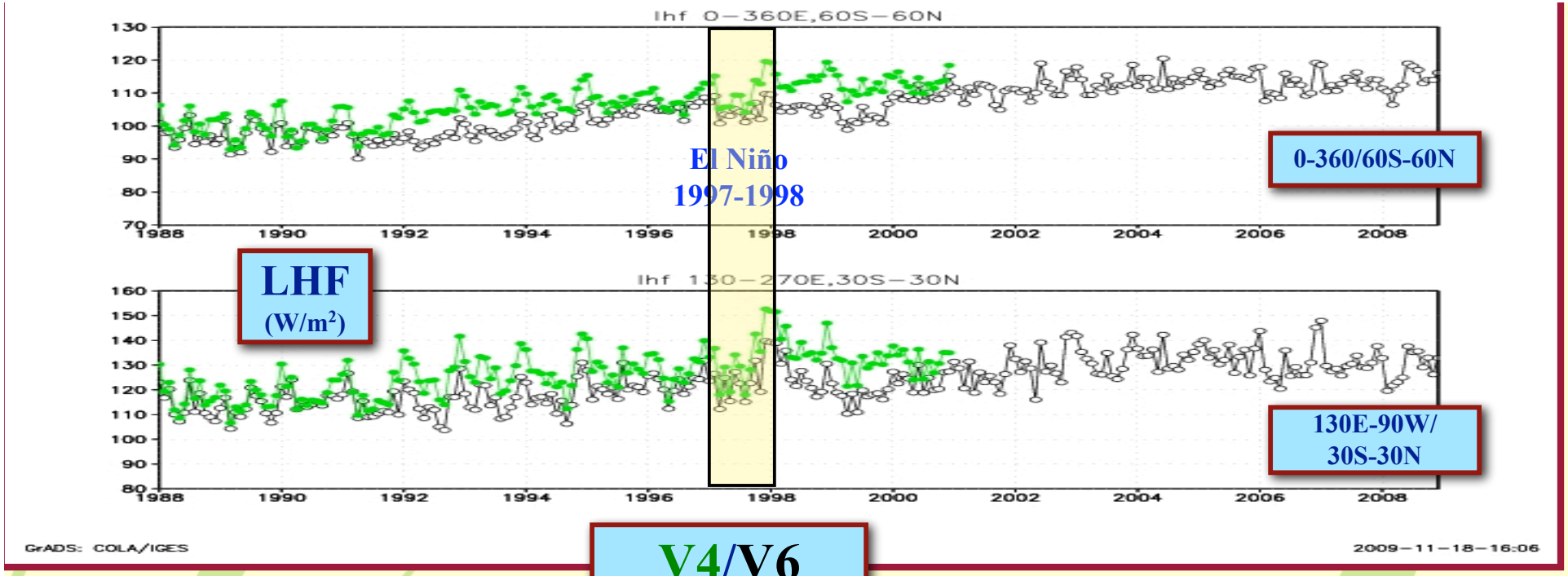




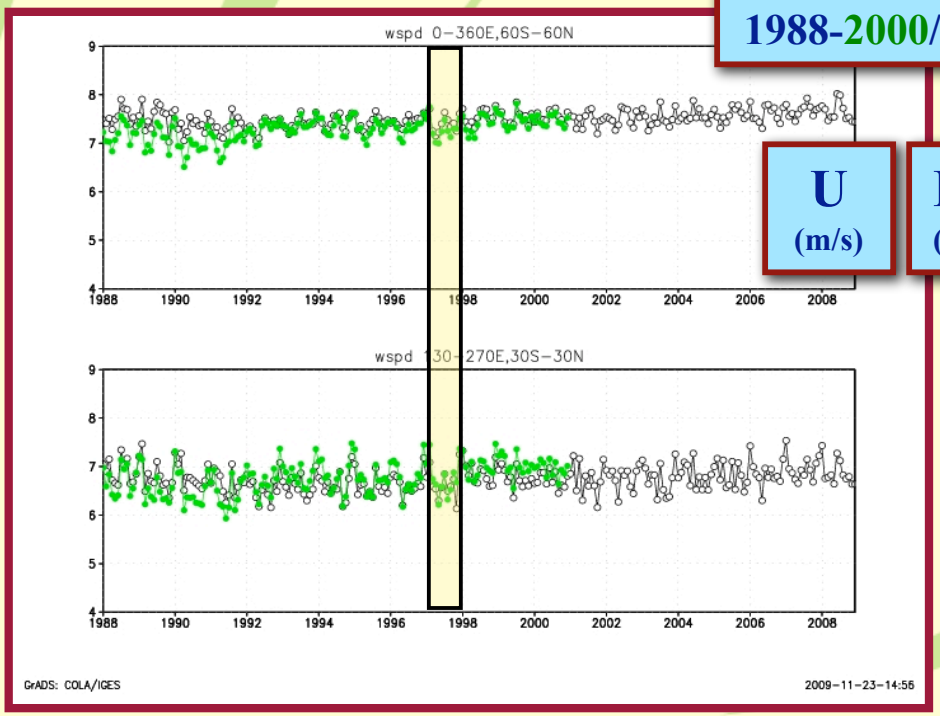
Qa (g/kg)

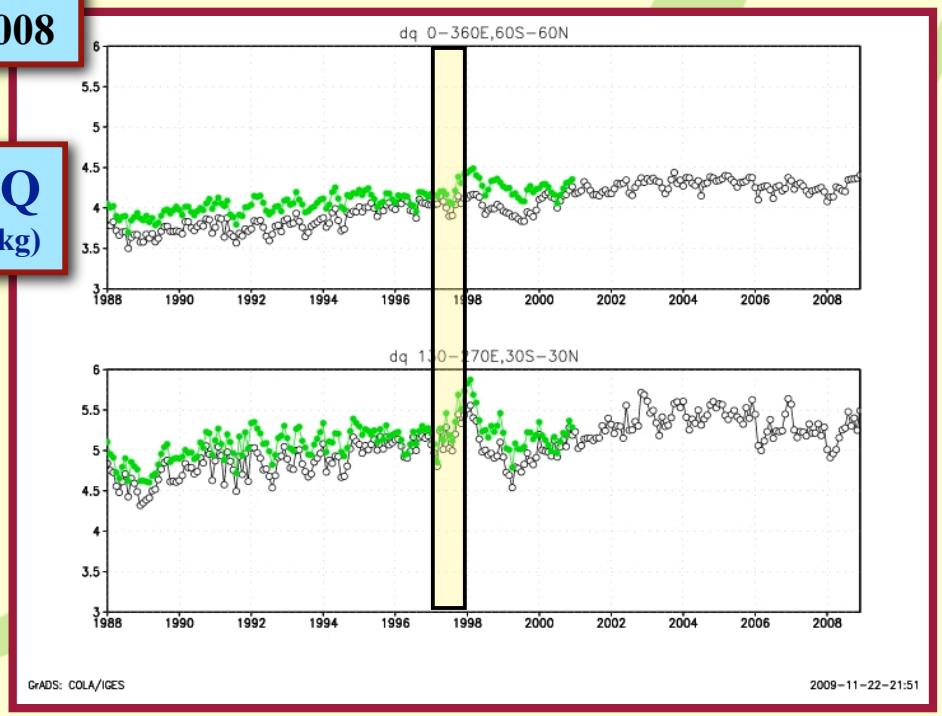
DQ (g/kg)

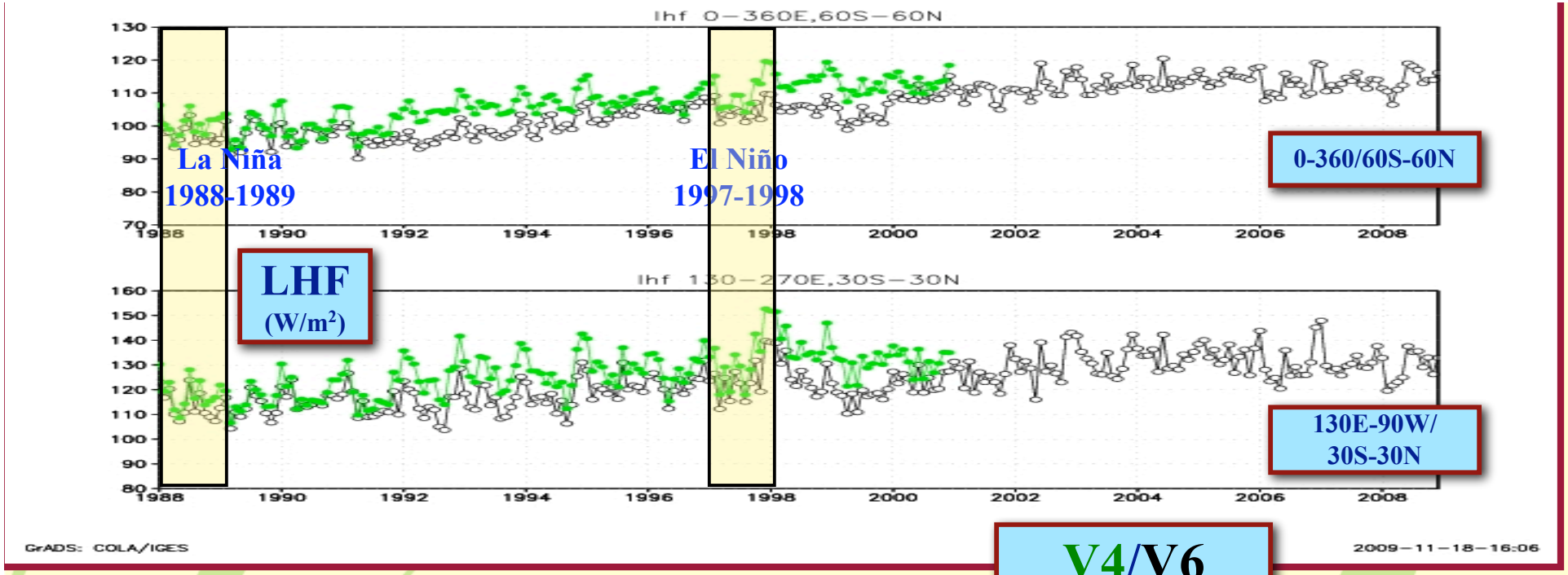




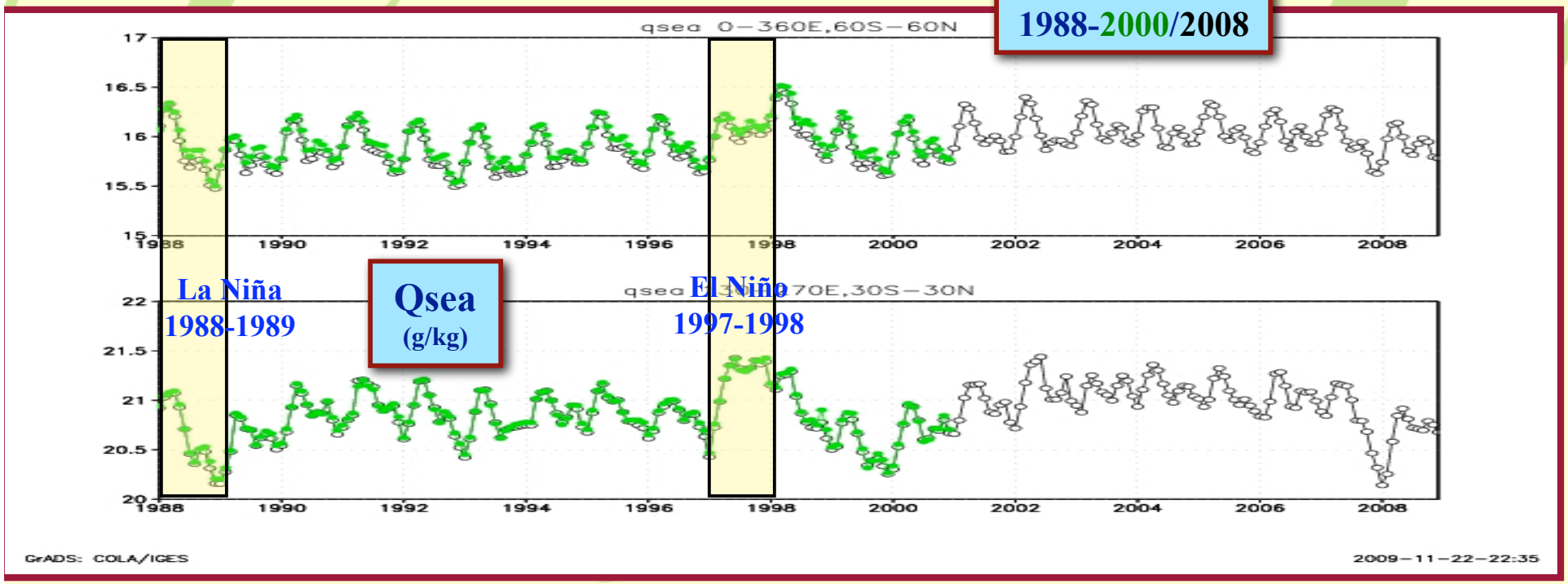
V4/V6
1988-2000/2008

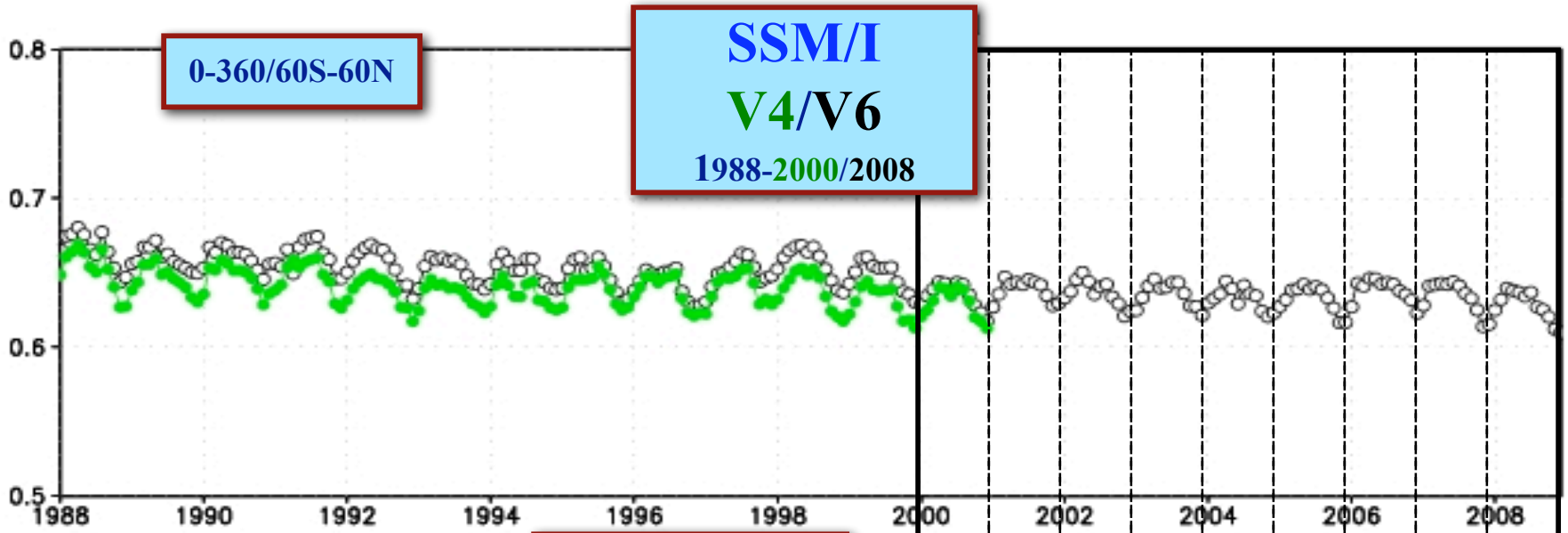






V4/V6
1988-2000/2008



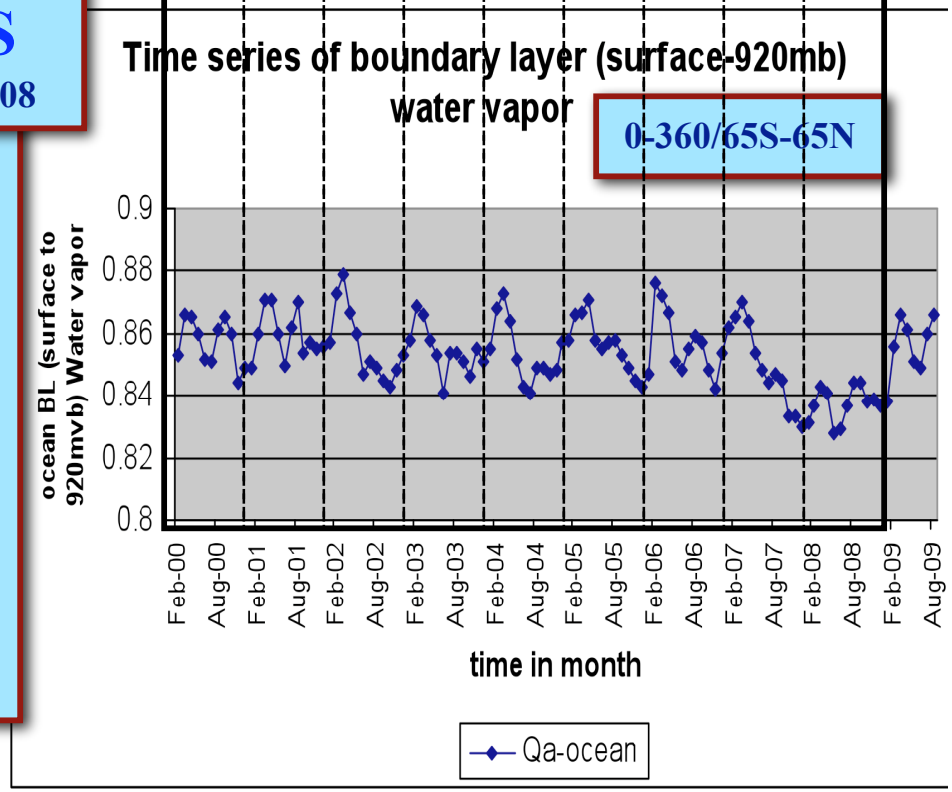


WB
(g/cm^2)

MODIS
2000/02-2009/08

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

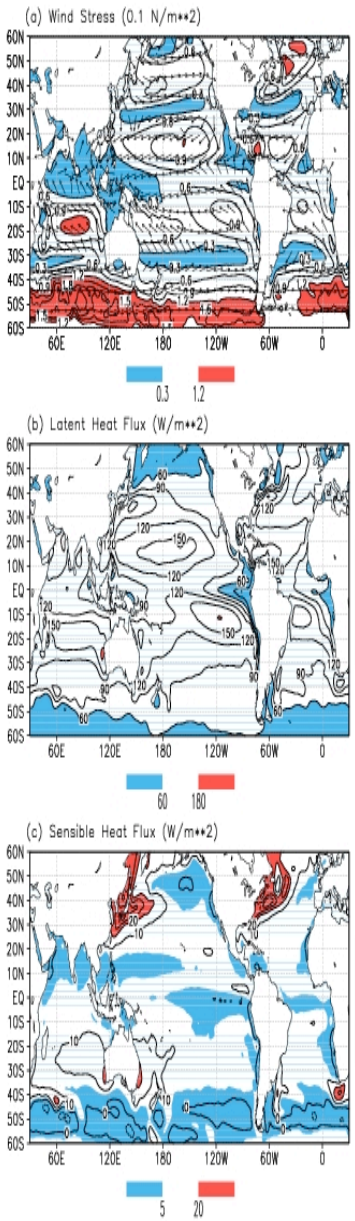
(a)Retrievals from SSM/I (upper panel) using interpolated data. 1988-2000 (V4) / 1988-2008 (V6)
(b)Estimates from MODIS (lower panel). 2000/02-2009/08



GrADS: COLA/IGES

Annual Climatology

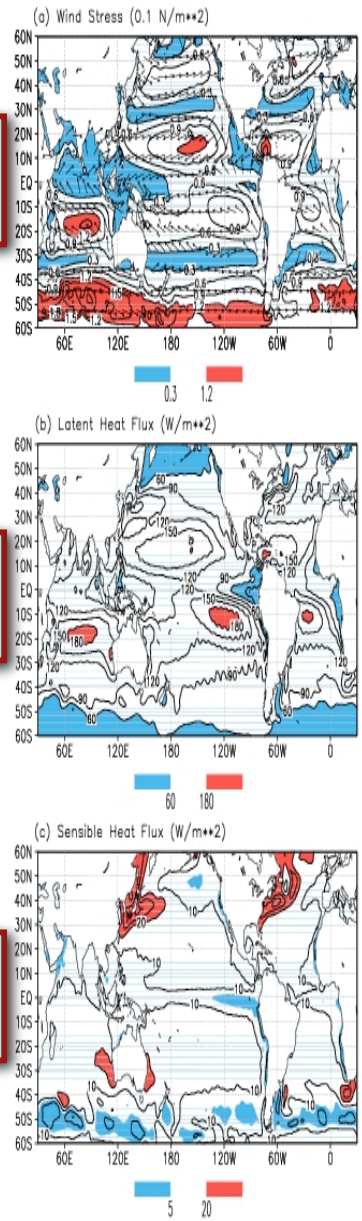
1988–2000 2b Annual Average



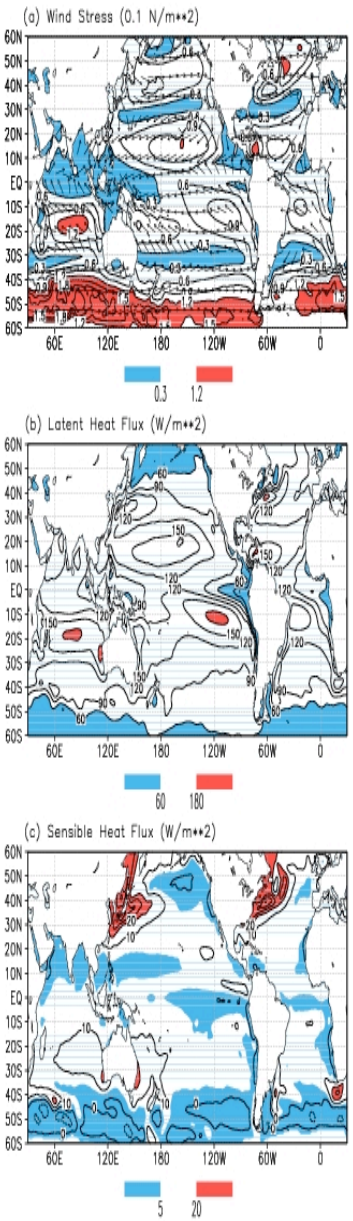
WST (.1 N/m²)

LHF (W/m²)

SHF (W/m²)



1988–2007 2b Annual Average



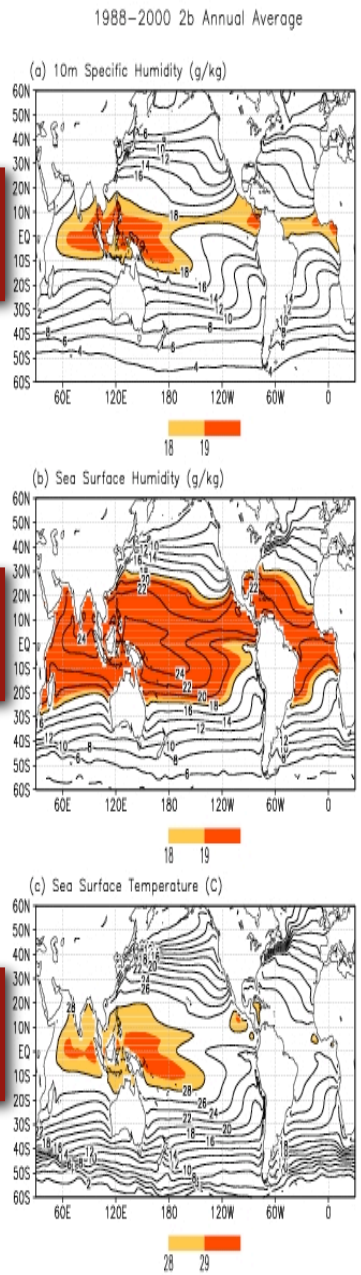
GSSTF2b 1988-2000 | **GSSTF2 1988-2000** | **GSSTF2b 1988-2007**

Annual Climatology

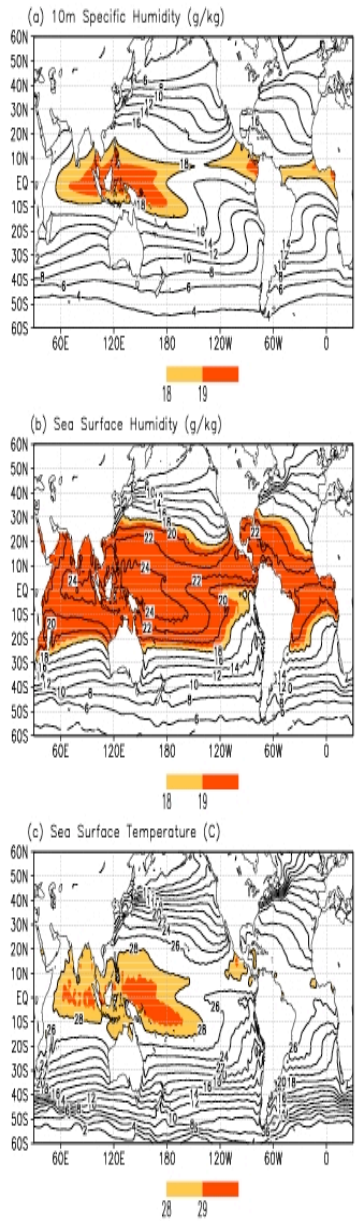
Qa (g/kg)

Qsea (g/kg)

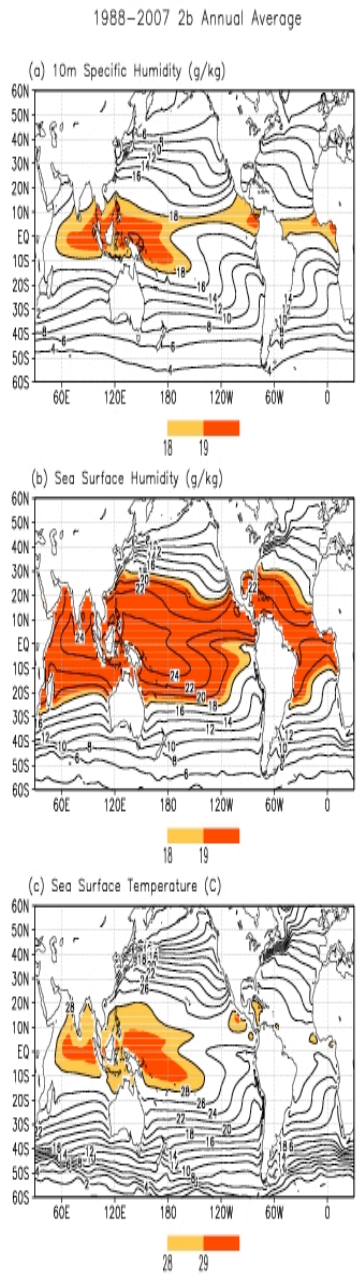
SST (ºC)



GSSTF2b 1988-2000

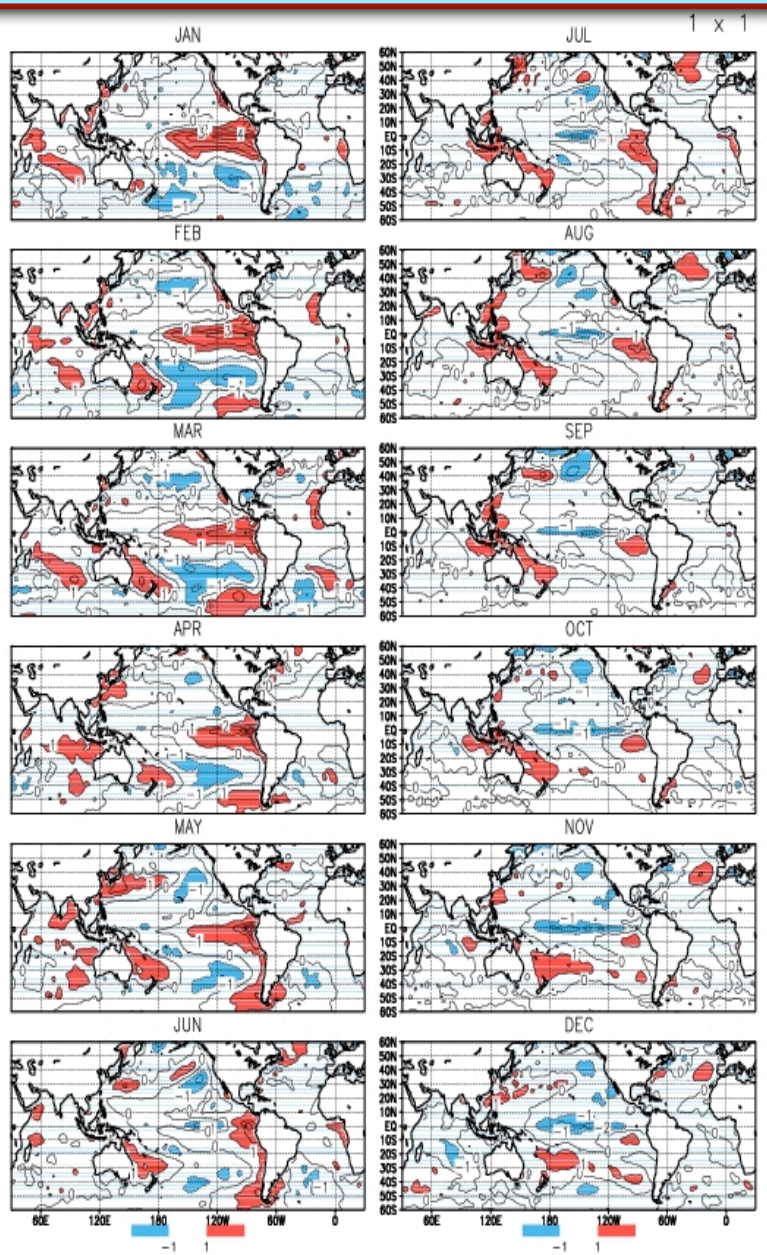


GSSTF2 1988-2000

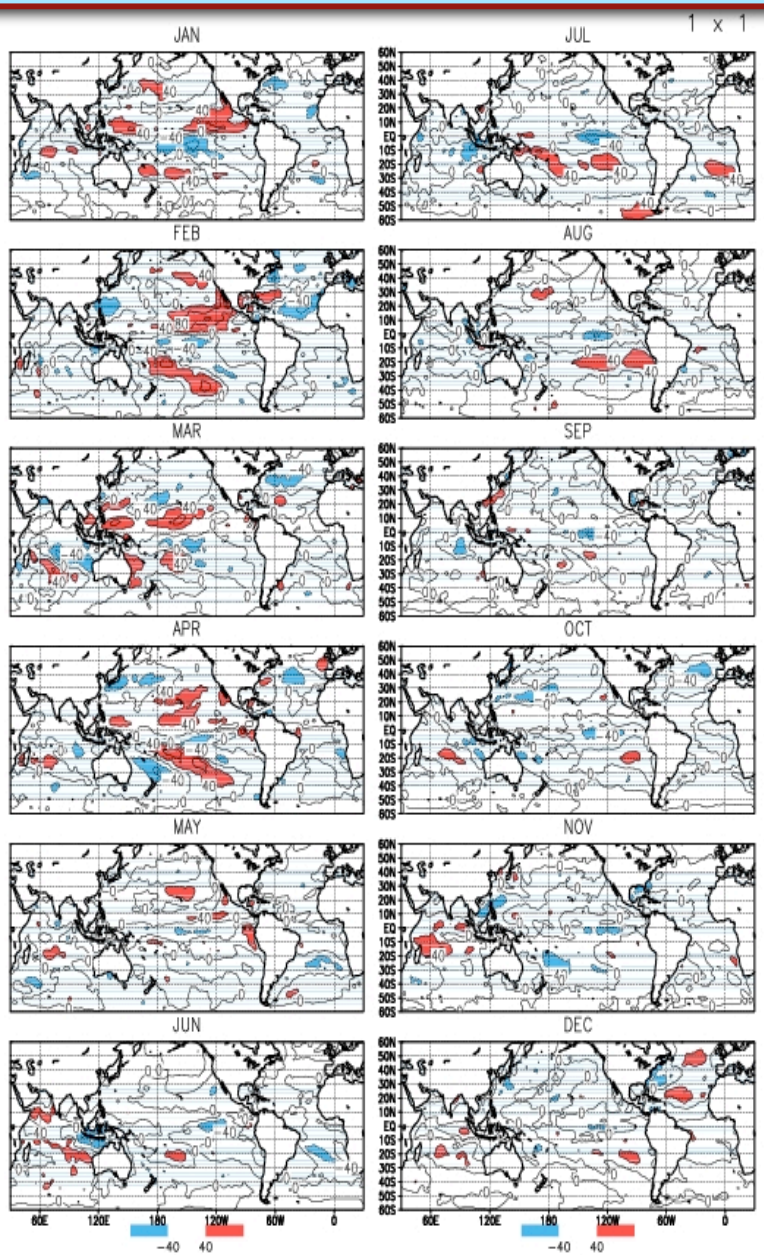


GSSTF2b 1988-2007

NCEP/DOE R2 Monthly Anom: SST (°C)



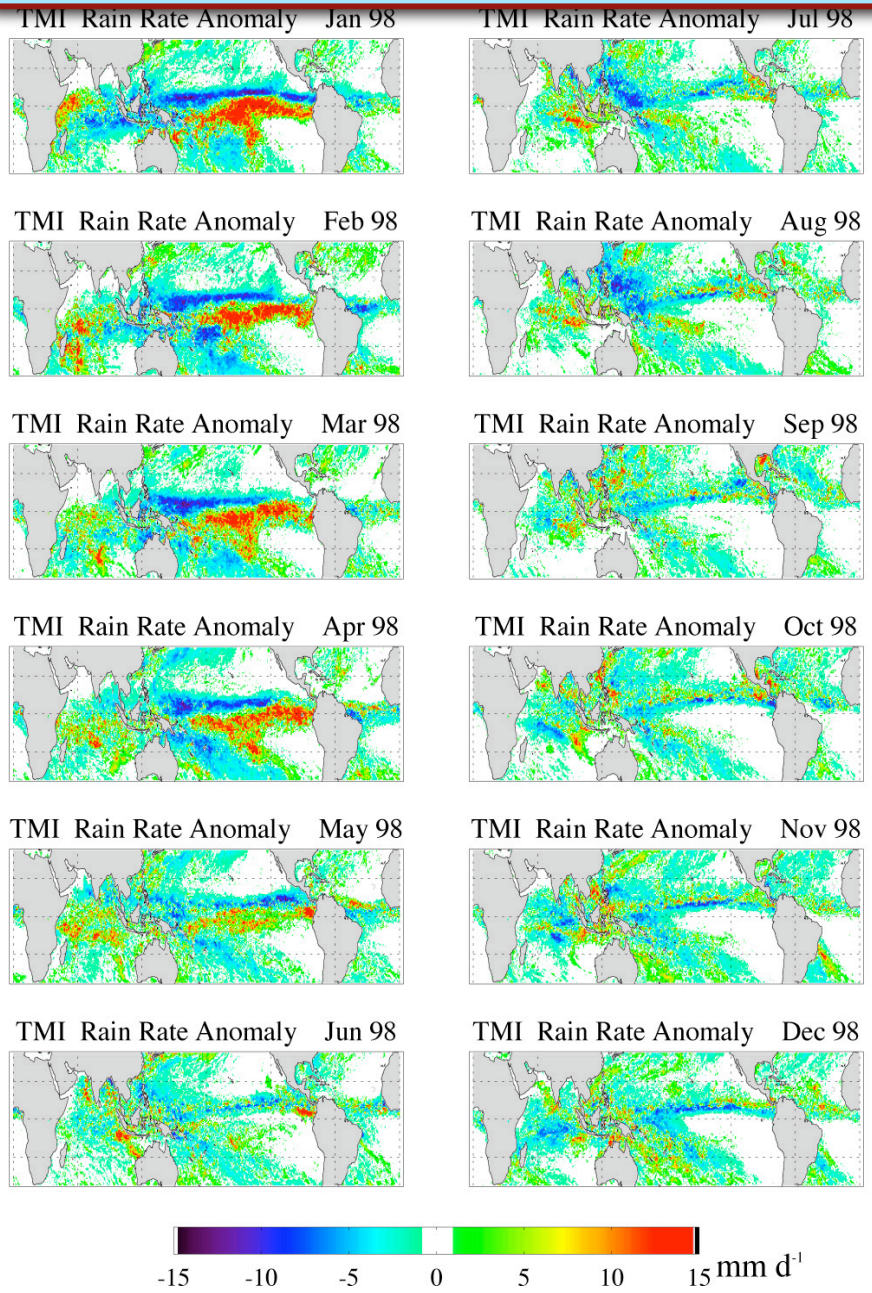
GSSTF2b Monthly Anom: LHF (W/m²)



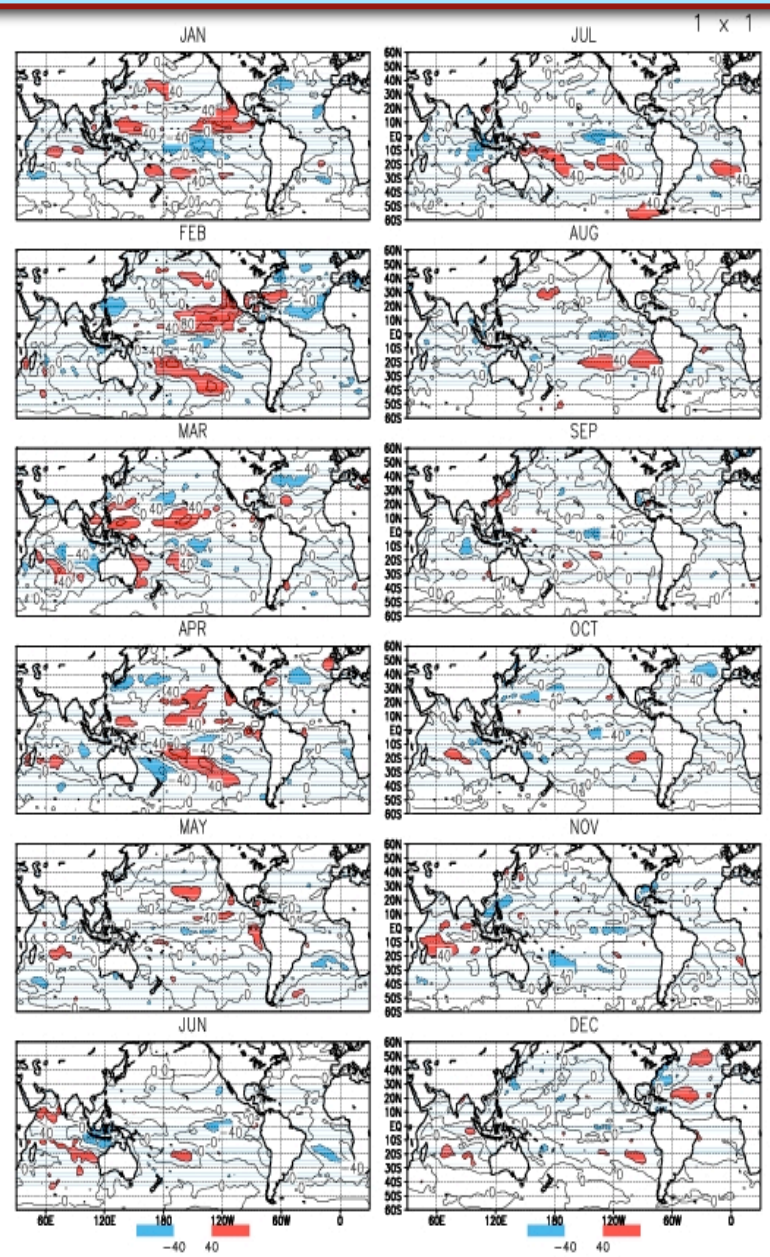
El Niño 1998

TMI Rain Rate Anomaly (mm/day)

Courtesy of W. Olson (UMBC/JCET)



GSSTF2b Monthly Anom: LHF (W/m²)

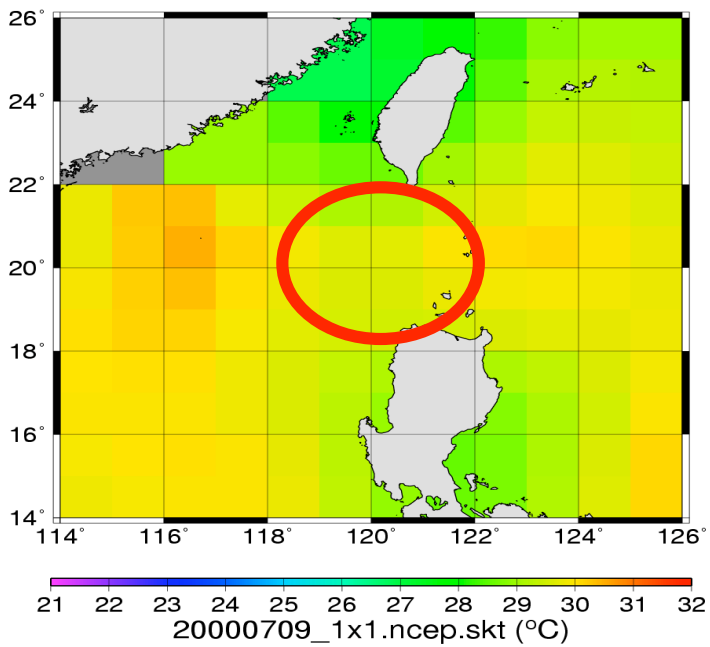


El Niño 1998

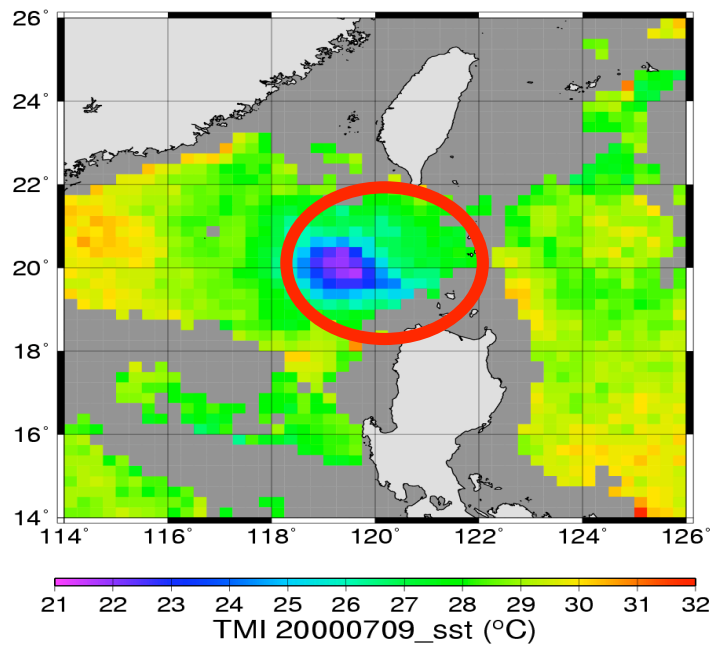
Improvement on SST using Cloud-penetrating TRMM/TMI and AMSR-E

Current SST is based on the NCEP 7-day average SST (composite using cloud-limiting AVHRR), thus many dynamic air-sea processes, e.g. typhoon-induced cooling and associated processes can not be studied using existing scheme.

1°×1°



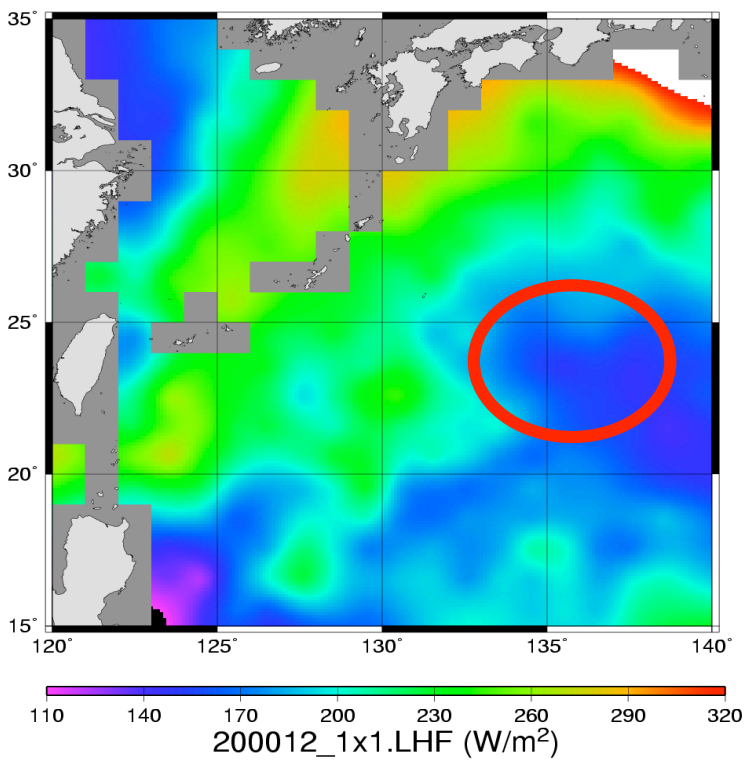
0.25°×0.25°



(Lin & Wang, 2006)

Improved estimated LHF at the Kuroshio region with higher spatial resolution

1°×1°



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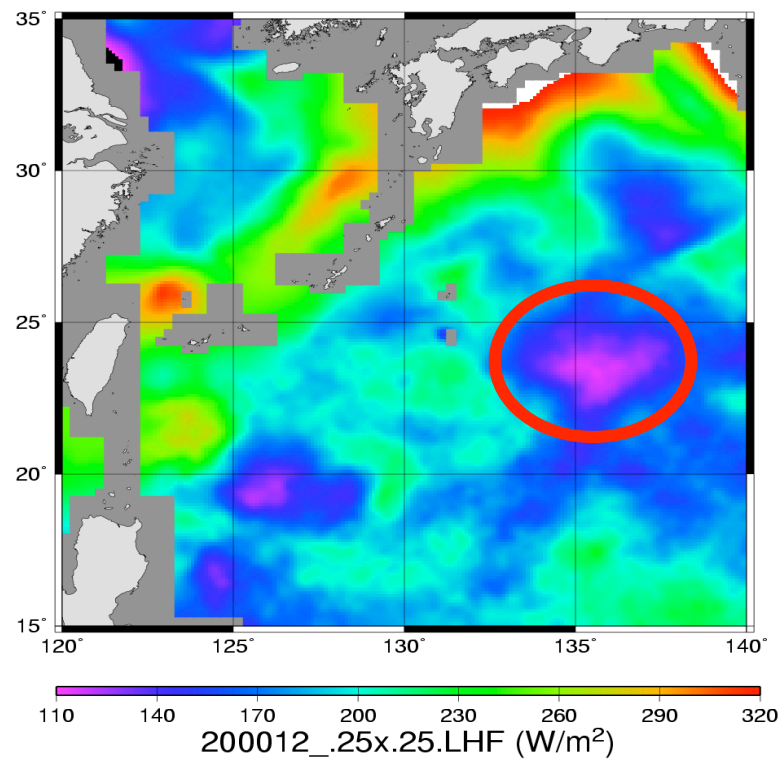
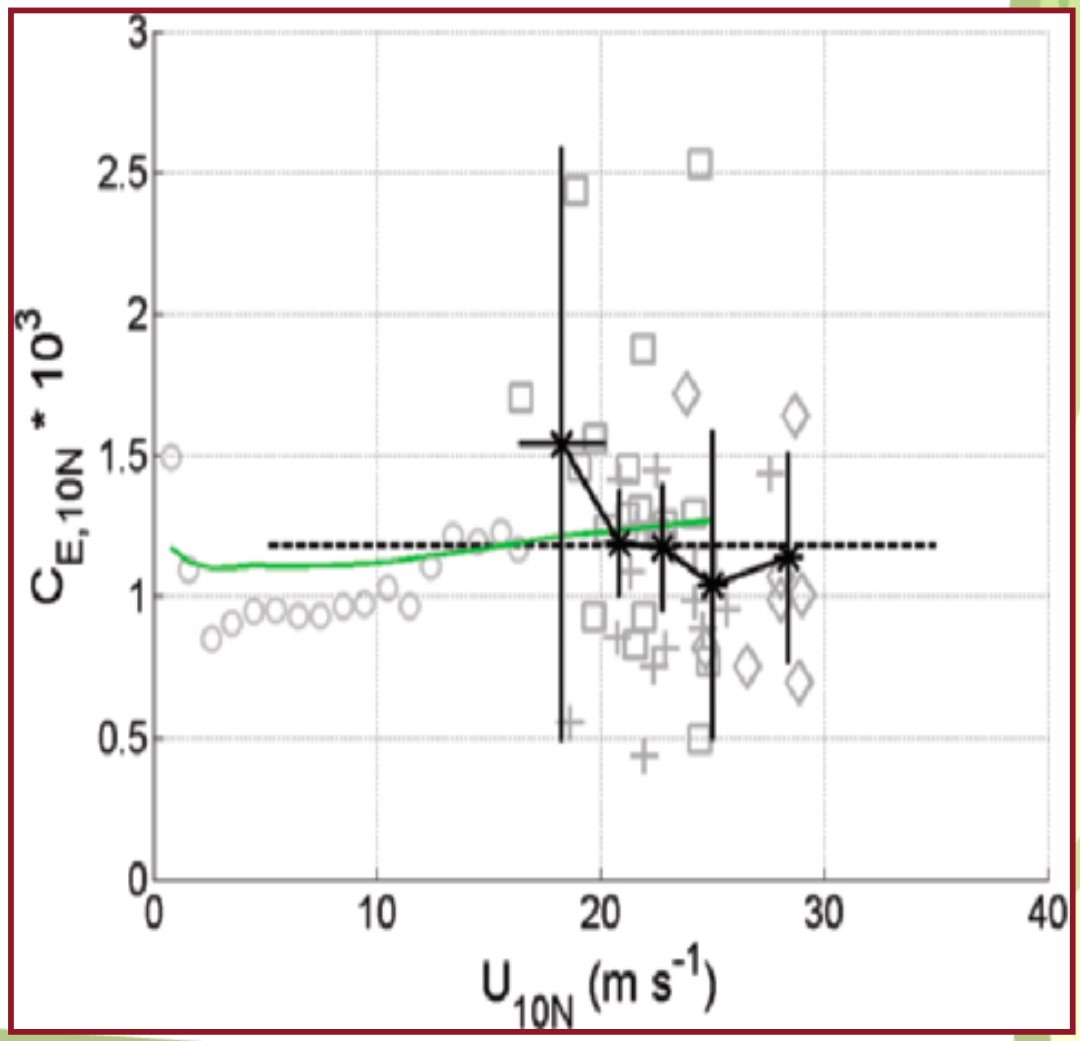


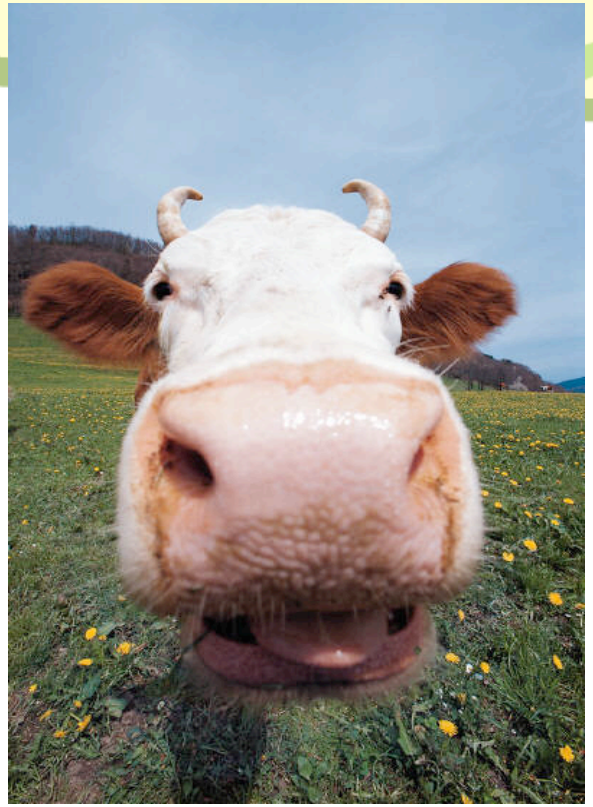
(Lin & Wang, 2006)

Transfer Coefficients for High winds

Moisture exchange coefficient (Dalton number) estimates derived from CBLAST stepped-descent flight legs in Hurricanes Fabian and Isabel (2003). The "asterisks" represent average values in 2.5 m s–1 bins, and the "bars" show 95% confidence limits. The "squares" are from flight legs in the right-front quadrant of the storms, "plus" signs from the right-rear quadrant, and "diamonds" from the left-front quadrant. The black dashed line represents the HEXOS line (DeCosmo et al. 1996), modified as per Fairall et al. (2003) and extended to 36 m s–1. The green solid line is the COARE 3.0 curve (Fairall et al. 2003), and the gray circles are from CBLAST-Low (Edson et al. 2007).



Courtesy of Black et al., 2007 BAMS



Thanks!