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A Recently Revived Dataset of Satellite-based Global Air-sea Surface Turbulent Fluxes (GSSTF2b) – Features & Application

Chung-Lin Shie

Collaborators: *L. Chiu, R.F. Adler, S. Gao, R. Chokngamwong, I-I Lin, E.J. Nelkin, J.V. Ardizzone, P.P. Xie, and F.-C. Wang*

Special Thanks: *R. Atlas, M. Bosilovich, S. Braun, A. Chu, J. Entin, M. Grecu, G. Gu, K. Hilburn, A. Hou, M. Maiden, W. Olson, H. K. Ramapriyan, A. Savtchenko, L. Wu, R. Wu, and P.P. Xie*

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.

Outlines

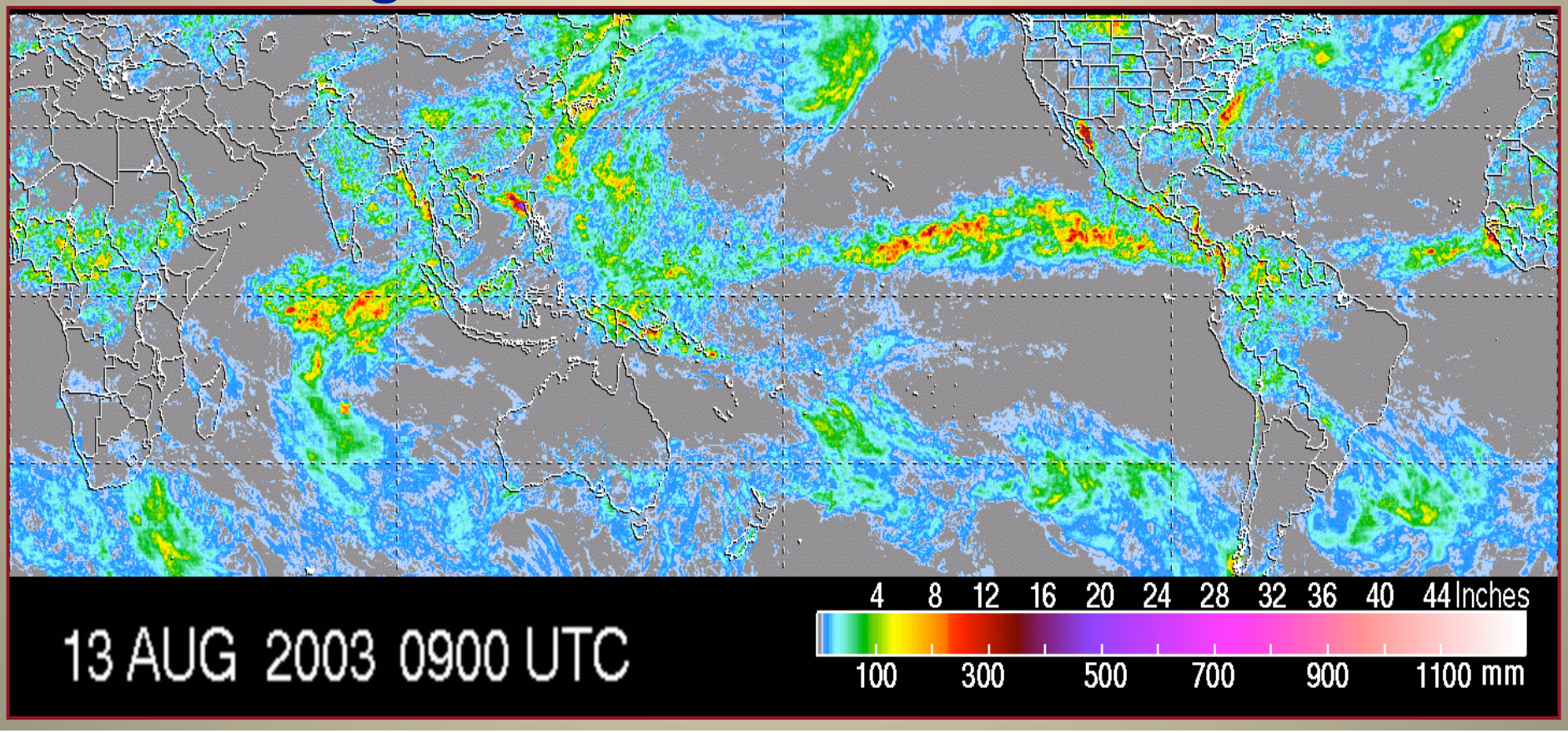
1. Introduction of Air-Sea Turbulent Fluxes

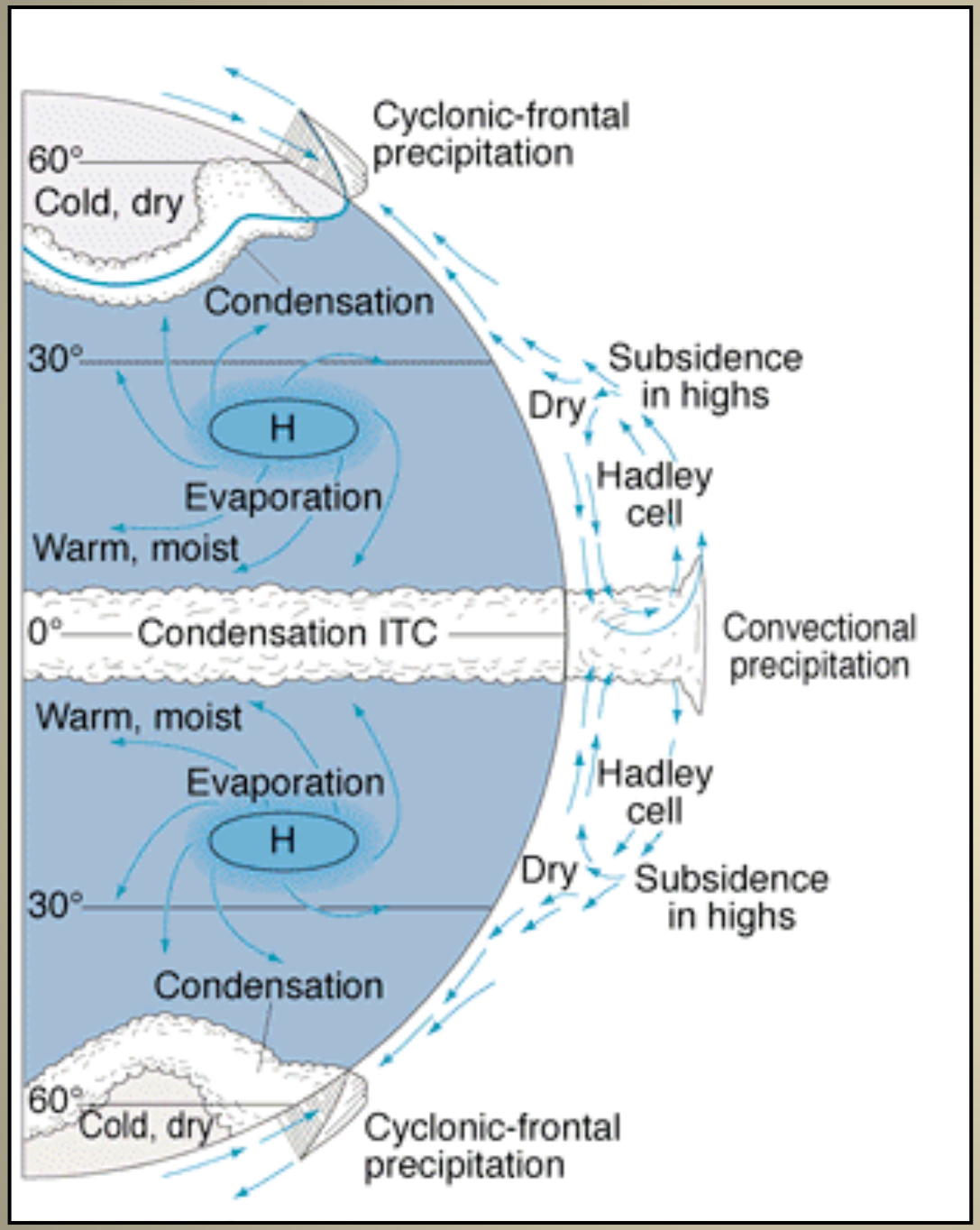
2. GSSTF2b Features & Applications

1. Introduction of Air-Sea Turbulent Fluxes

Background

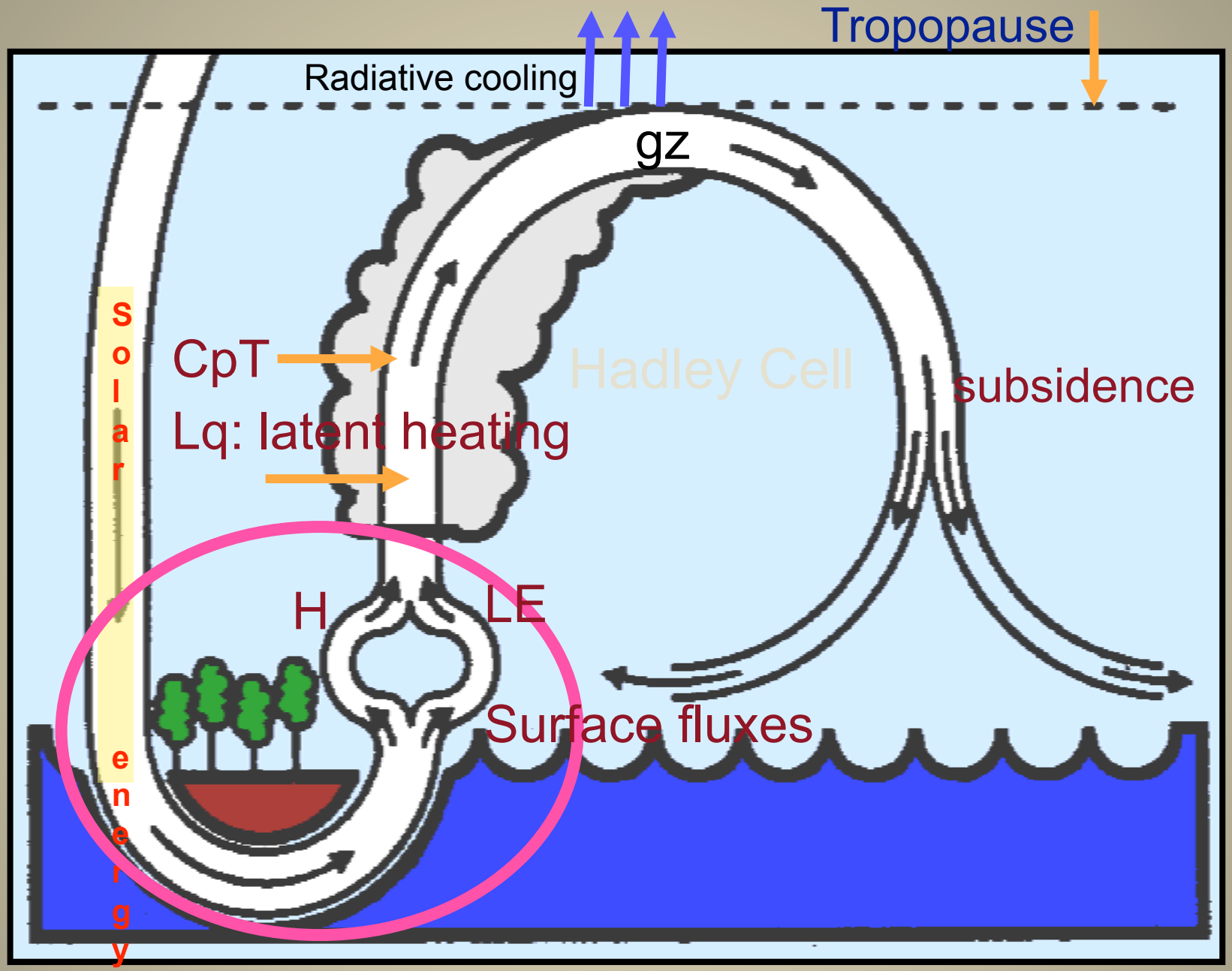
Two-thirds of global precipitation mainly contributed by air-sea surface fluxes falls in the tropics, providing three-fourths of the energy driving global atmospheric circulation (via Hadley Cell) through latent heating.





The **release of latent heat** in precipitating tropical clouds promotes vertical motion and the formation of the **Hadley cell**.

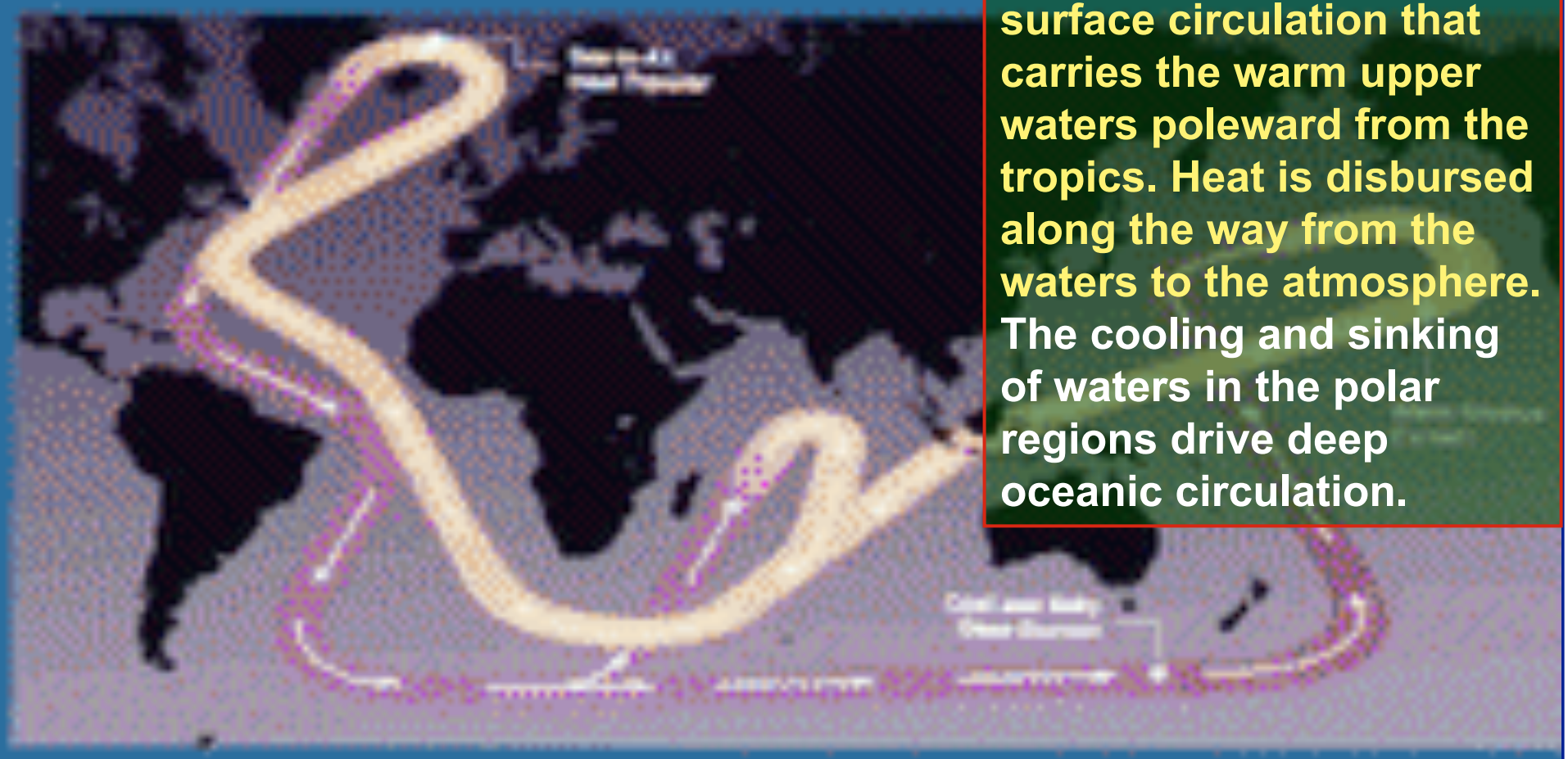
The Hadley cell transports **energy** towards higher latitudes, strongly influencing **global circulation** and **weather patterns**.


Tropopause
Radiative cooling
gz
solar energy
CpT
Lq: latent heating
Hadley Cell
subsidence
H
LE
Surface fluxes

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 (LH)
  - Sensible Heat Flux (SH)
  - Momentum Flux (Wind Stress WS)
- 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

Oceanic Flux Products [a]

- **GSSTF-2** (Chou et al. 2001, 2003)
  - Goddard Satellite-based Surface Turbulent Flux Version 2
  - Monthly / Daily time series (July 1987-December 2000)
  - Satellite observations (SSM/I)
  - Global / 1° lat/lon
- **HOAPS** (Grabl et al. 2000)
  - Hamburg Ocean Atmosphere Parameters and Fluxes from Satellite
  - Daily, Monthly / Pentad time series (July 1987-Dec 1998, -2002 newly)
  - Satellite observations (SSM/I)
  - Global (80N-80S)/ 0.5^{o} lat/lon
- **J-OFURO** (Kubota et al. 2002)
  - Japanese Ocean Flux Data Sets with Use of Remote Sensing Observations
  - Monthly time series (1991-1995); Three-day (1992-2000)
  - Satellite observations (SSM/I)
  - Global / 1° lat/lon

Oceanic Flux Products [b]

- **FSU**
  - Florida State University Flux (wind stress+) data set
  - Monthly time series (1978/1990-2006)
  - In situ + Satellite observations
  - Basins➔global / 1° lat/lon
- **OAFlux**
  - Objectively Analyzed Air-sea Flux of WHOI
  - Daily time series of LH/SH (1981-2002)
  - In situ + Satellite observations + Reanalysis
  - Global / 1° (?) lat/lon
- **IFREMER**
  - French Research Institute for Exploitation of the Sea
  - Weekly time series of latent heat .. (Nov.1995 – Dec.2000)
  - Satellite observations
  - Global / 1° lat/lon

Oceanic Flux Products [c]

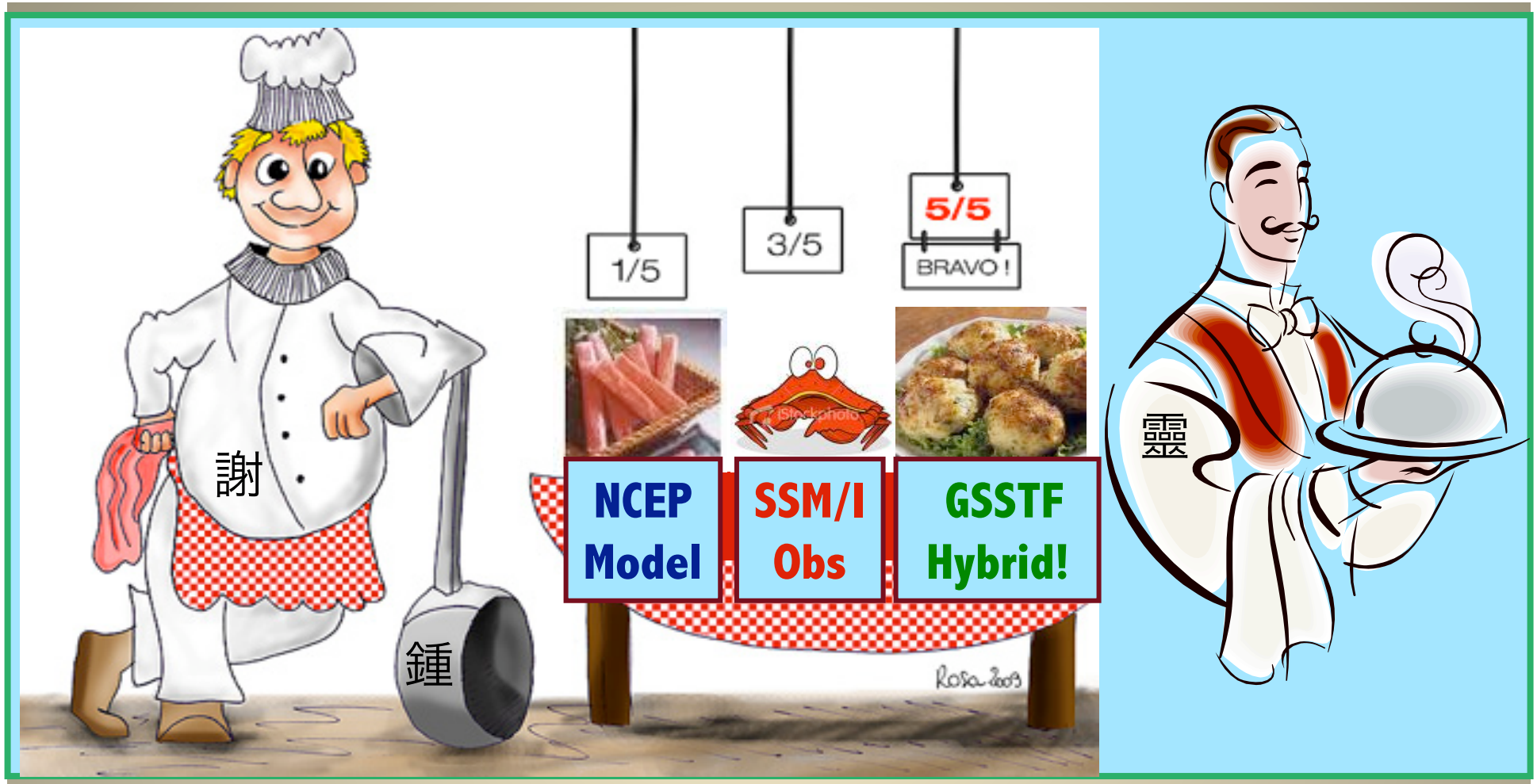
- **COADS**
  - COADS / NODC / da Silva (1994)
  - Monthly time series (? – 1993)
  - COADS 1a ship observations
  - Global / 1° lat/lon
- **SOC**
  - Southampton Oceanography Centre
  - Monthly Climatology
  - COADS 1a ship observations (1980-1993)
  - Global / 1° lat/lon
- **SEAFLUX**
  - An international project under GEWEX (Coordinators: J. Curry and C. A. Clayson)
  - Inter-comparison and assessment of oceanic fluxes

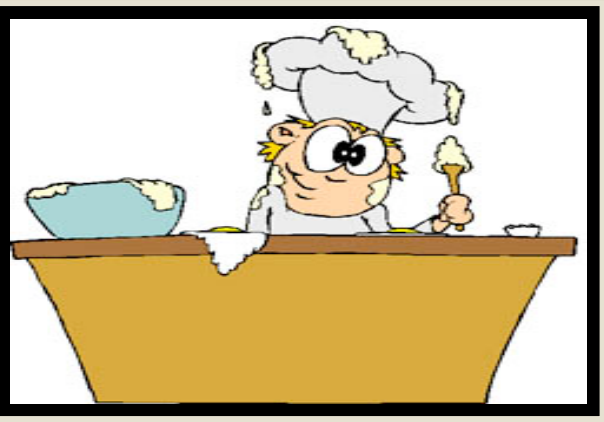
2. GSSTF2b
Features & Applications

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**

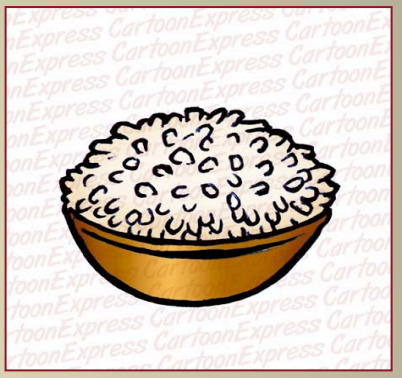
  BULK FLUX ALGORITHMS
  - In-situ observation (ship, buoys..)
  - Satellite observation
  - Model simulations

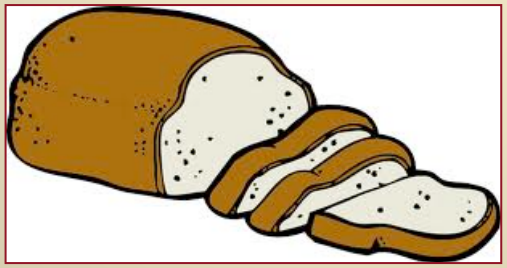

謝
鍾
1/5
3/5
5/5
BRAVO !
NCEP
Model
SSM/I
Obs
GSSTF
Hybrid!
靈

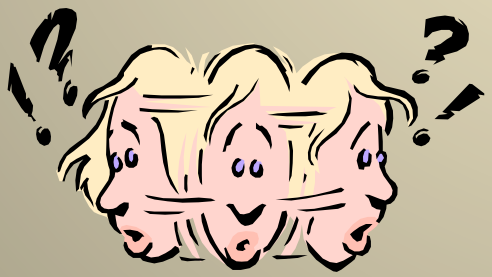


"Rice Cooker Theory"

Models/Algorithms







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)

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

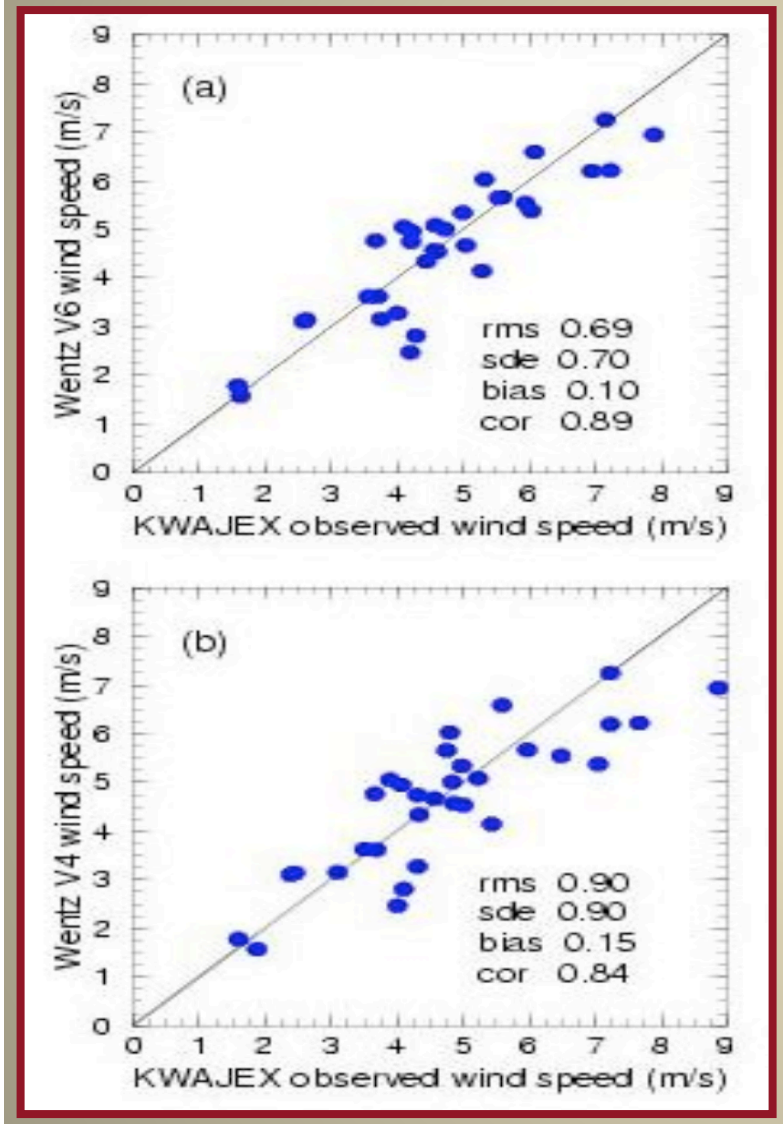
$\sigma = (p - p_t)(p_s - p_t)^{-1}$, p is pressure, p_s is the surface pressure, p_t is the top pressure (200mb), t is time, r is location, $\bar{q}$ is the spatial and temporal average of q for a climatic regime, F_i is the ith EOF of the covariance matrix of q, and C_i is the corresponding principle component. The profile of $\bar{q}$ 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)**

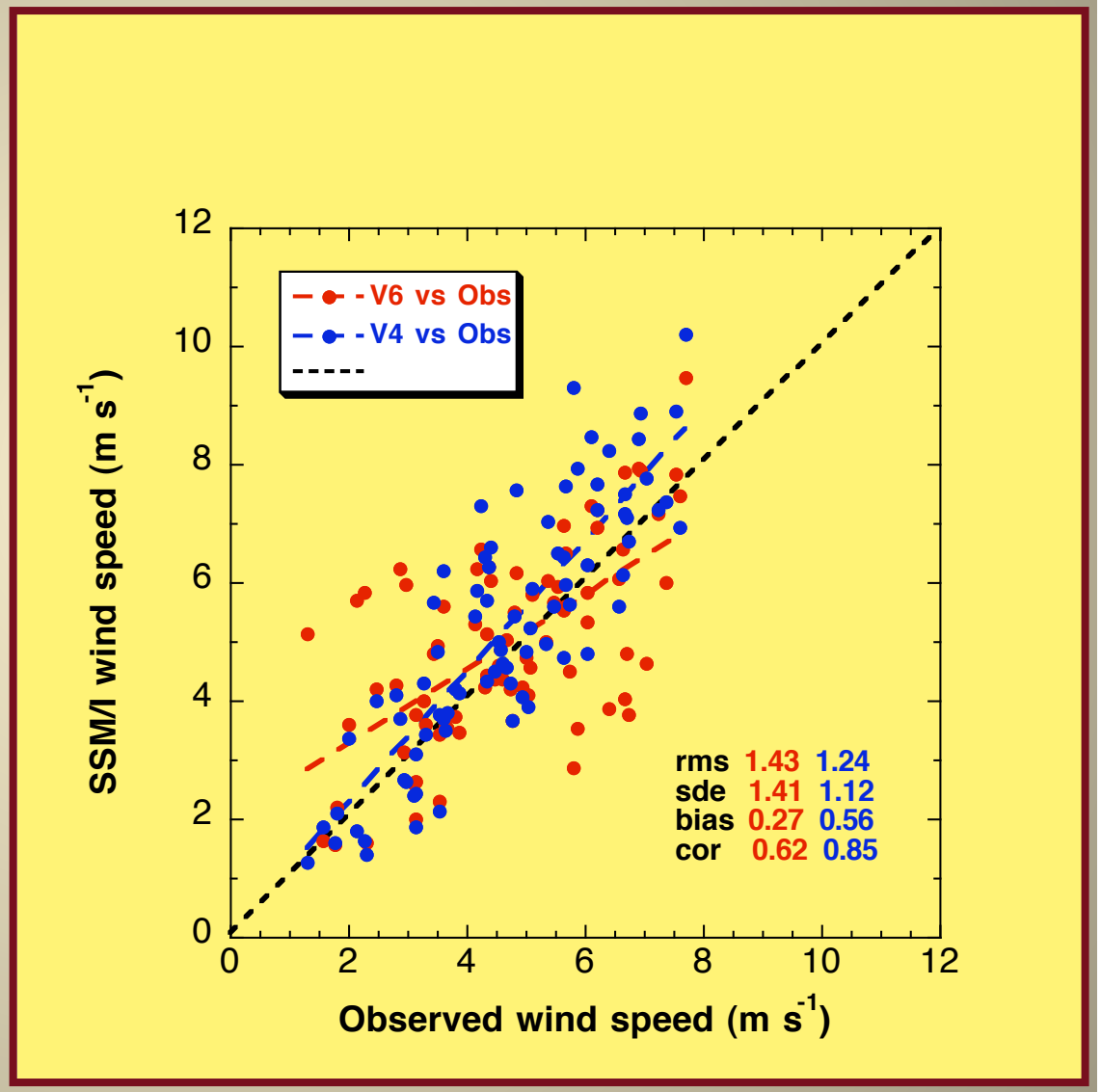
$$Q(t, r) = \bar{Q} + C_1(t, r)\, Q_1 + C_2(t, r)\, Q_2 \quad (2)$$
$$W(t, r) = \bar{W} + C_1(t, r)\, W_1 + C_2(t, r)\, W_2 \quad (3)$$
$$W_B(t, r) = \bar{W}_B + C_1(t, r)\, W_{B1} + C_2(t, r)\, W_{B2} \quad (4)$$

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

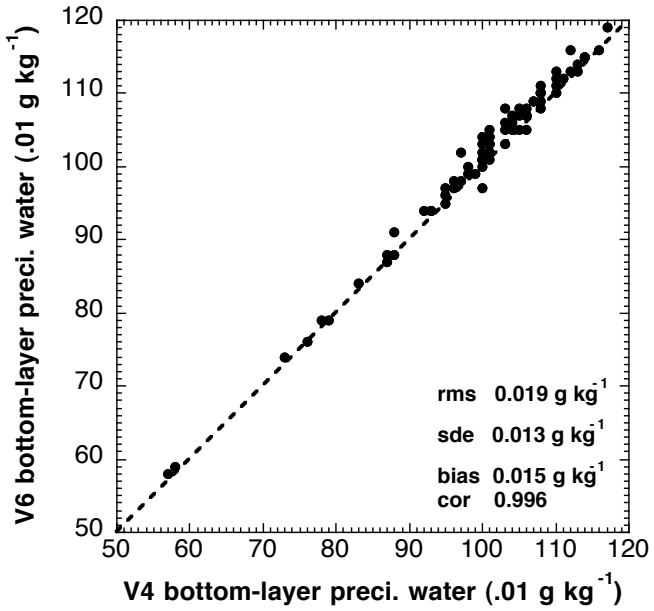
$\bar{Q}$, Q_1, and Q_2 are the values of $\bar{q}$, F_1, and F_2 at $\sigma = 1$; $\bar{W}$, W_1, W_2 and , $\bar{W}_B$, W_{B1}, W_{B2} are the total and bottom-layer precipitable water corresponding to the profiles of $\bar{q}$, F_1, and F_2,
C_1 and C_2 are the principal components for the **first**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

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



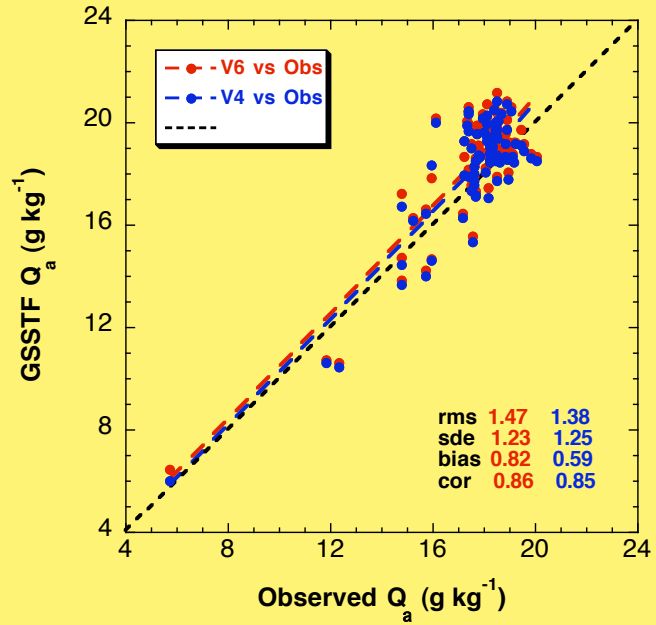


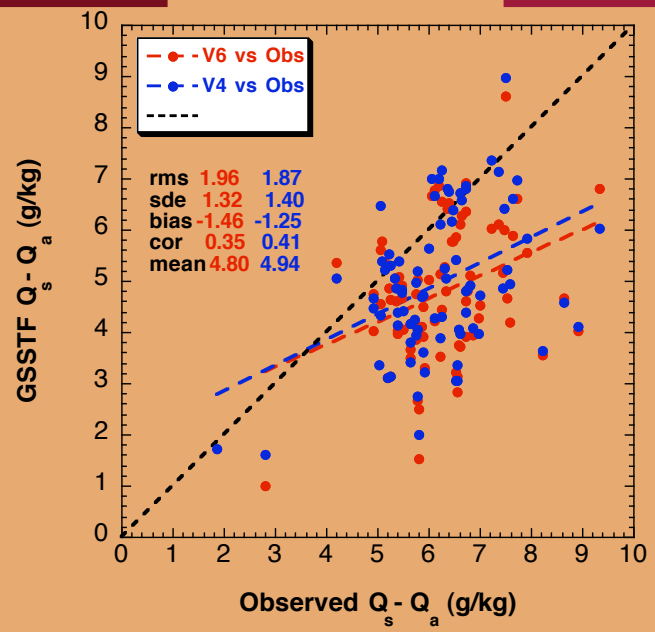
(Labels of x/y axis need to be swapped)



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

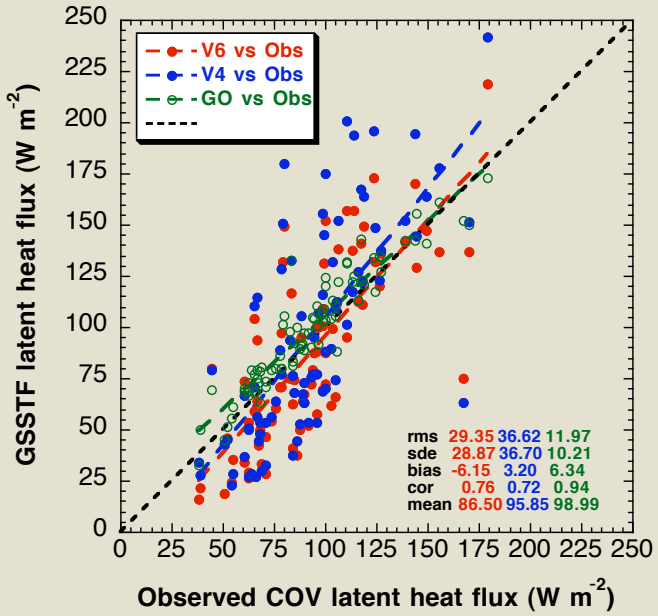
Qsea-Qair (g kg^{-1}) *V6/V4* vs. *Obs (82)*



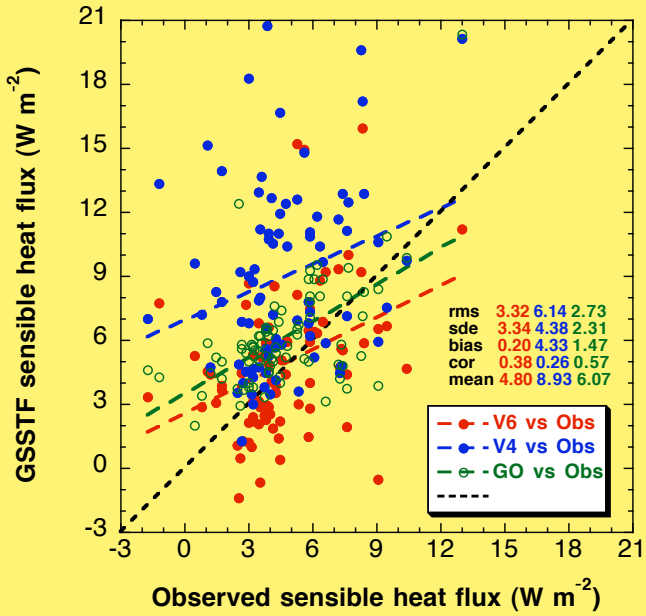


Qair (g kg^{-1}) *V6/V4* vs. *Obs (82)*

V6/V4/GO vs. Obs (82)

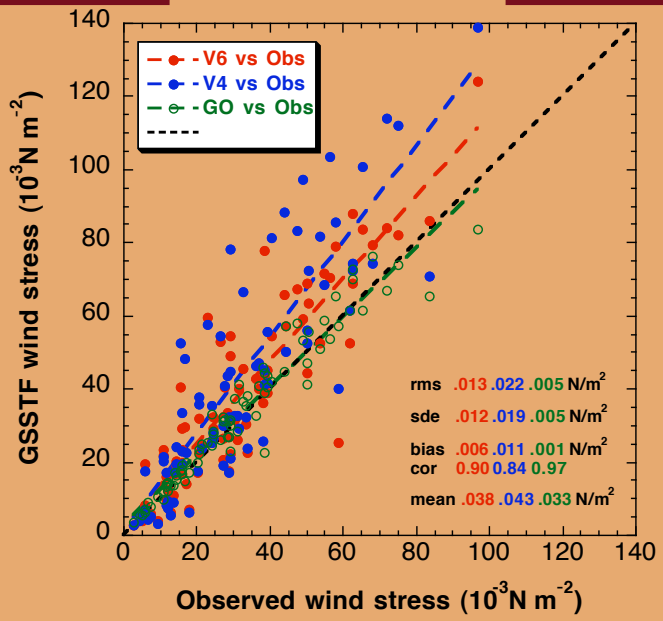


LHF (Wm^{-2})



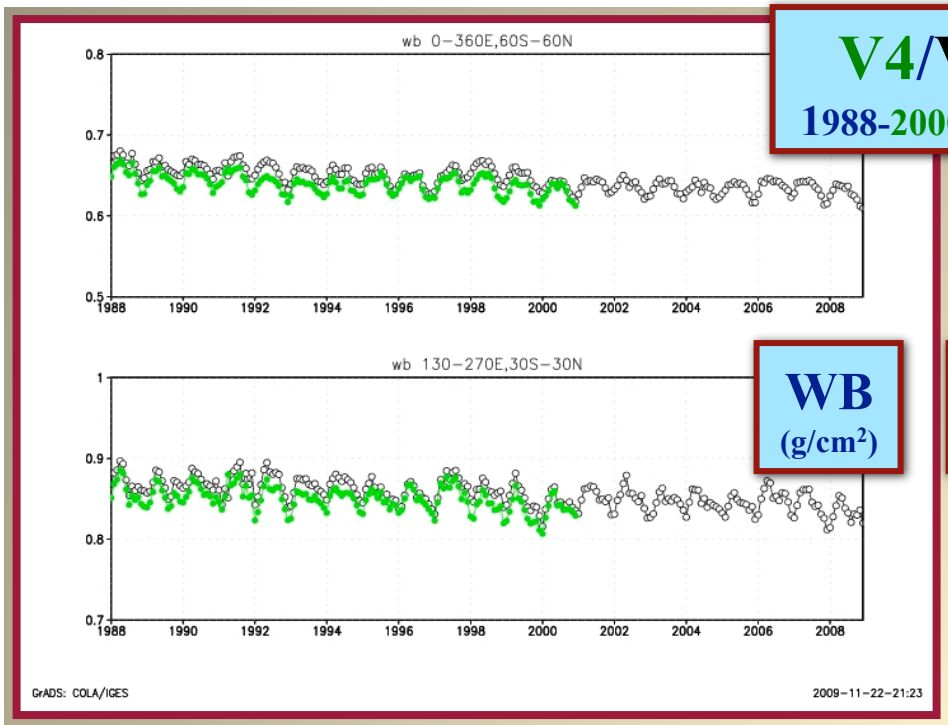
SHF (Wm^{-2})

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



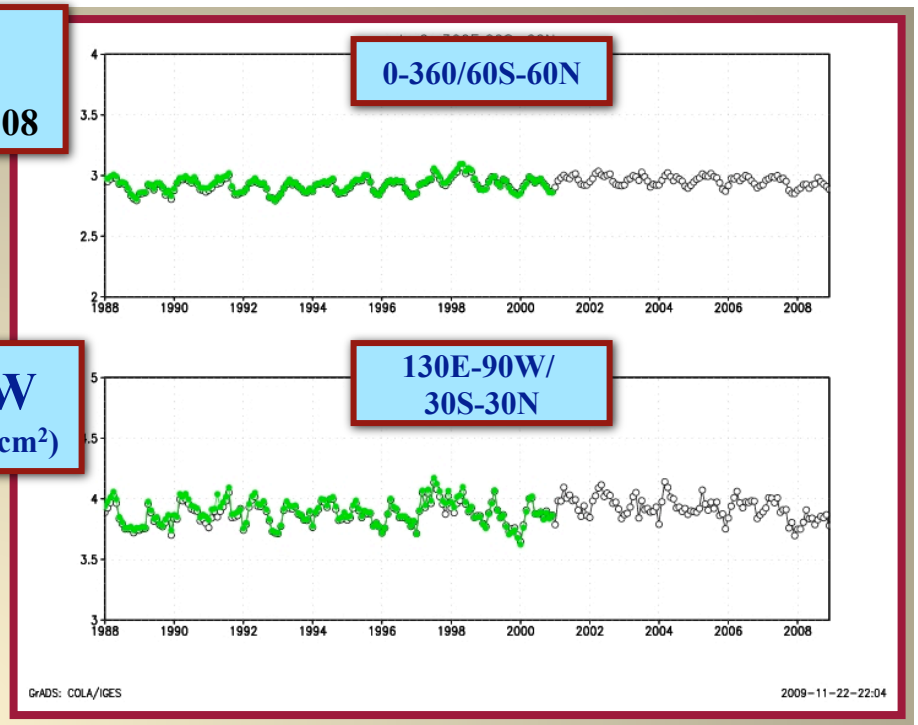
V4/V6

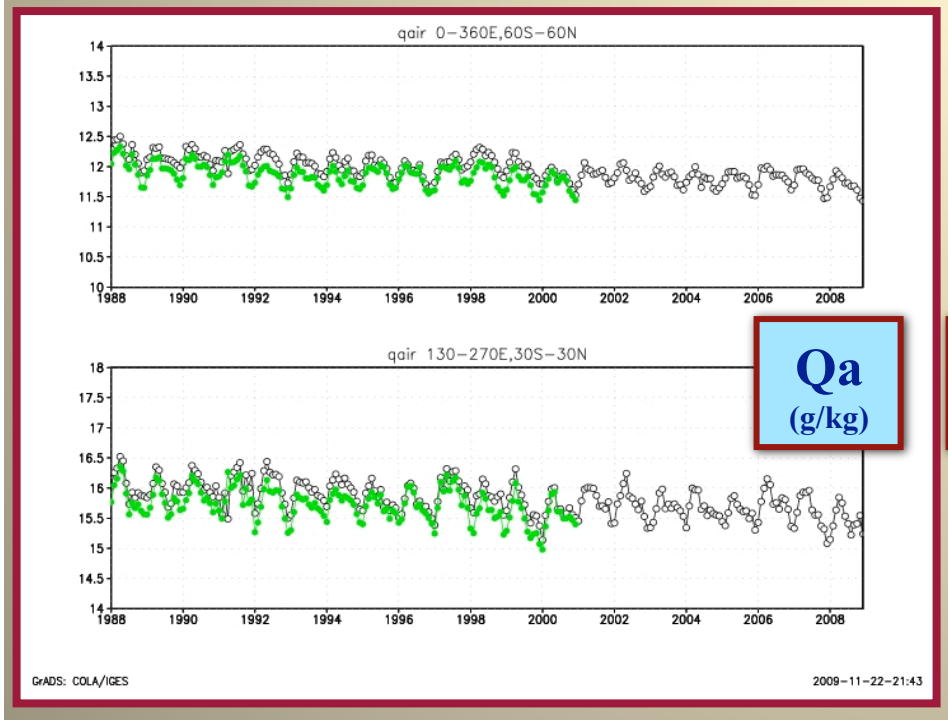
1988-2000/2008



WB (g/cm²)

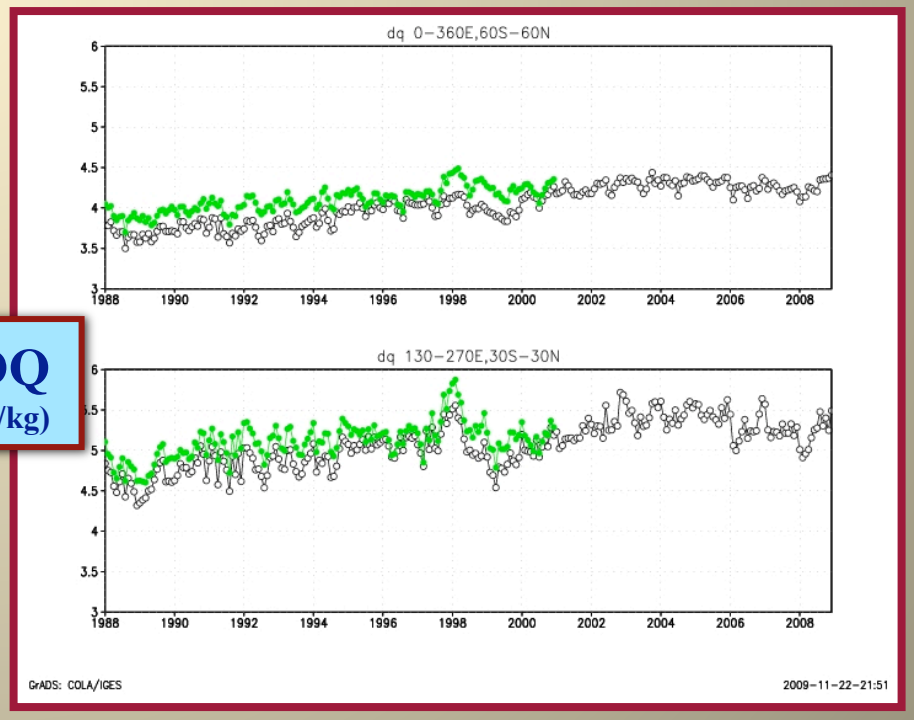
W (g/cm²)

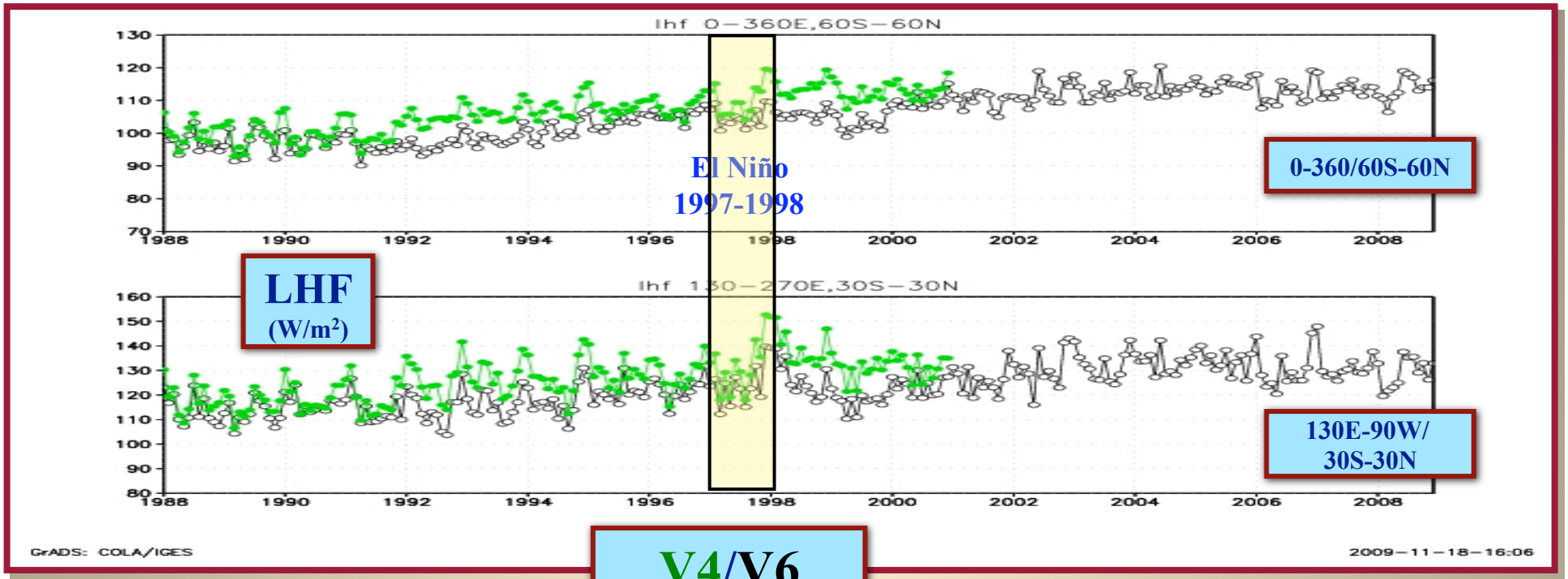




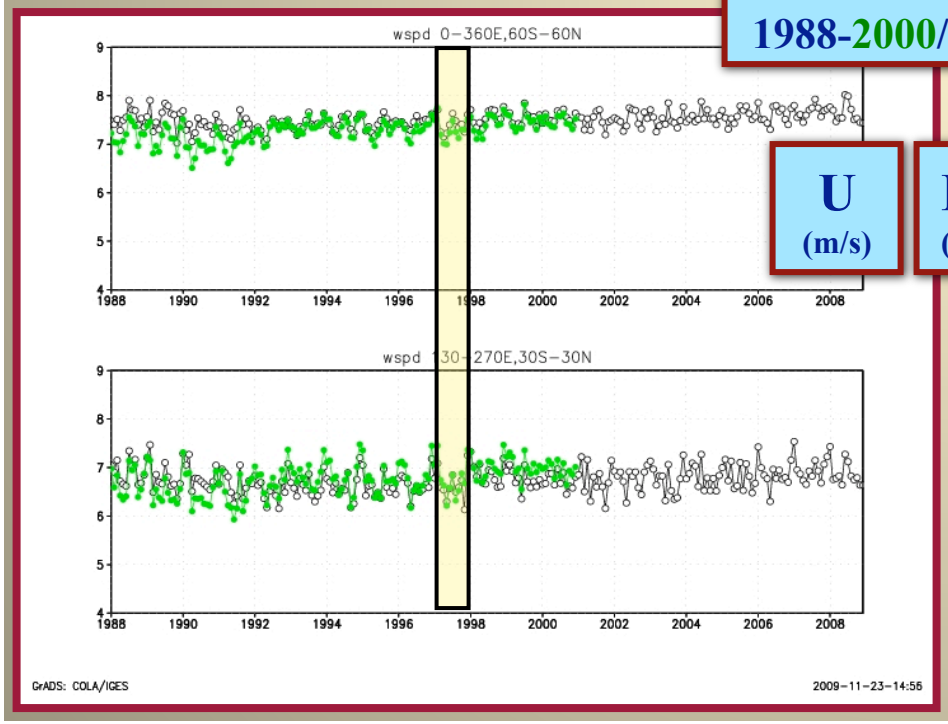
Qa (g/kg)

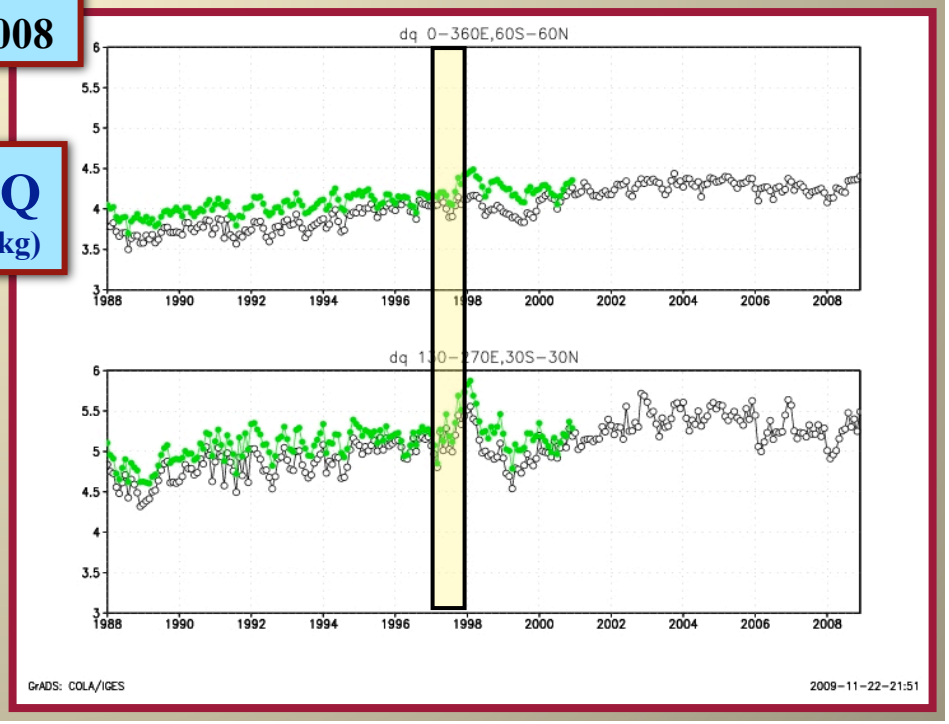
DQ (g/kg)



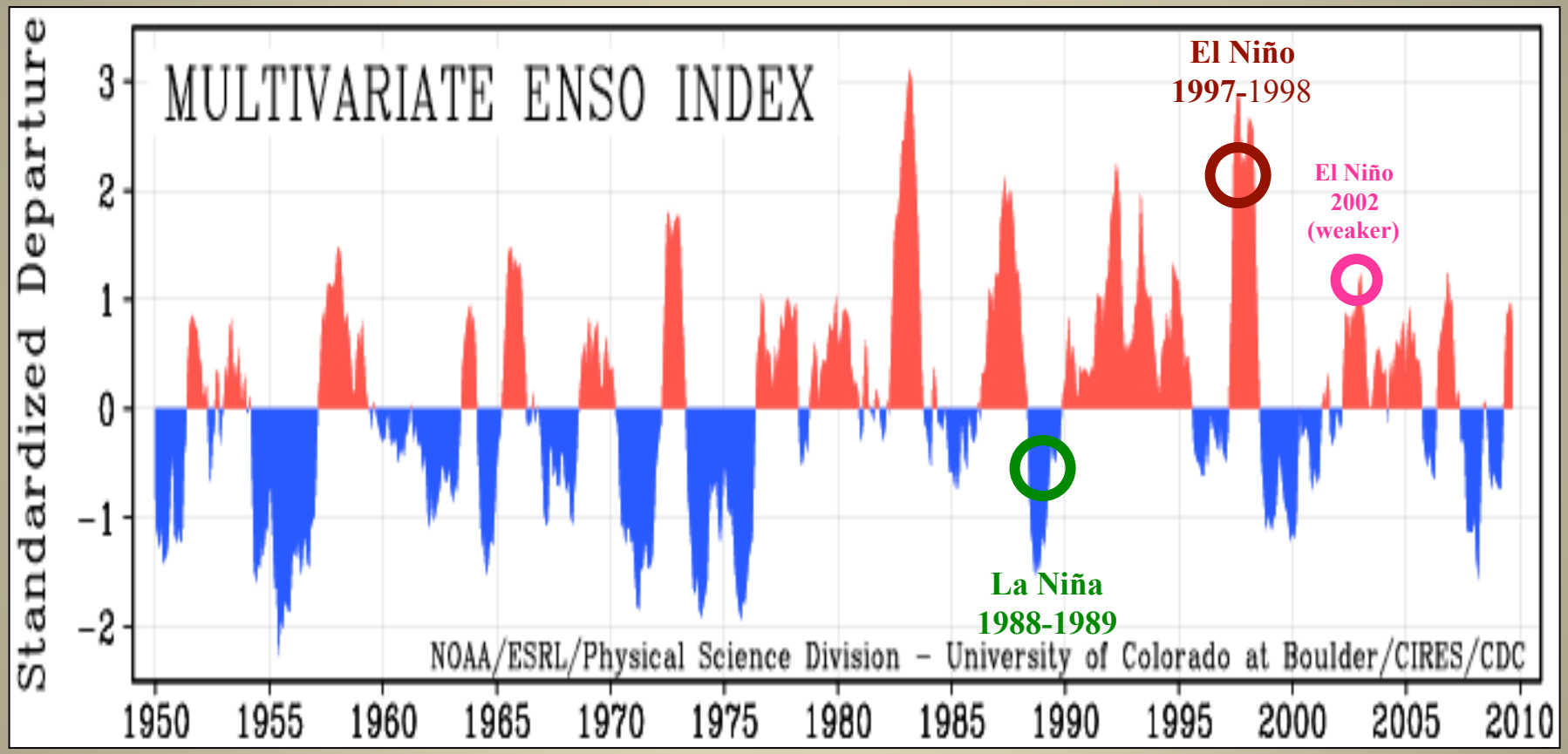


V4/V6
1988-2000/2008





Multivariate ENSO Index (MEI)



Courtesy of NOAA/Earth System Research Laboratory/Physical Sciences Division

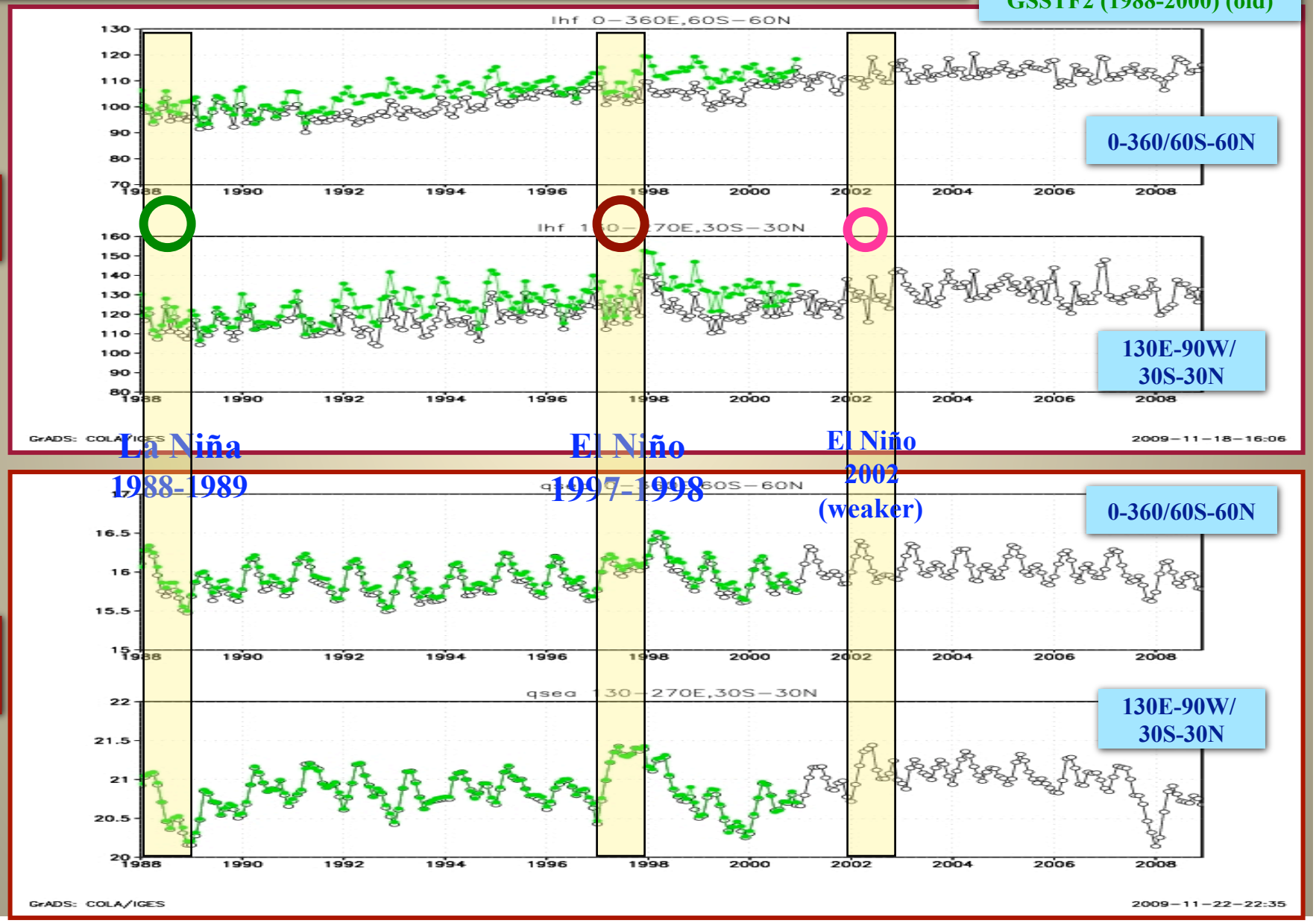
http://www.esrl.noaa.gov/psd//people/klaus.wolter/MEI/#ref_wt1

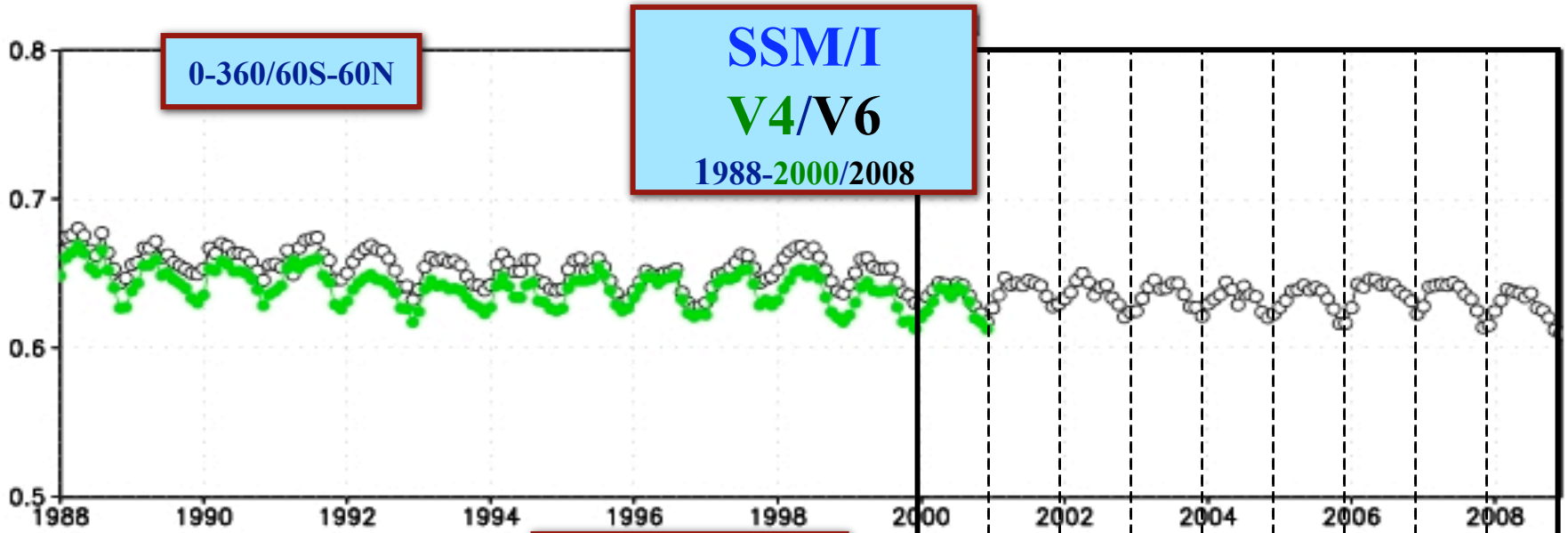
Last update: 5 October 2009. ***The views expressed are those of the author and do not necessarily represent those of NOAA.***

NASA/Goddard Recently Revived and Produced Global Air-Sea Surface Turbulent Fluxes Dataset: GSSTF2b

(Shie et al. 2010)

GSSTF2b (1988-2008) (new)
GSSTF2 (1988-2000) (old)



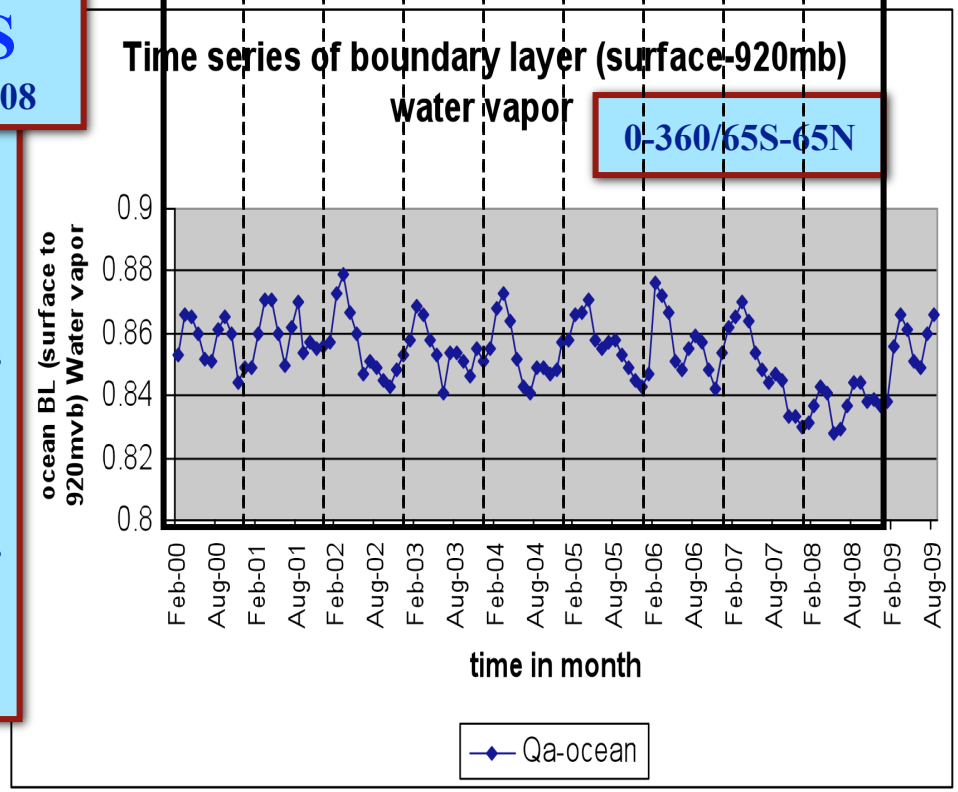


WB
(g/cm²)

MODIS
2000/02-2009/08

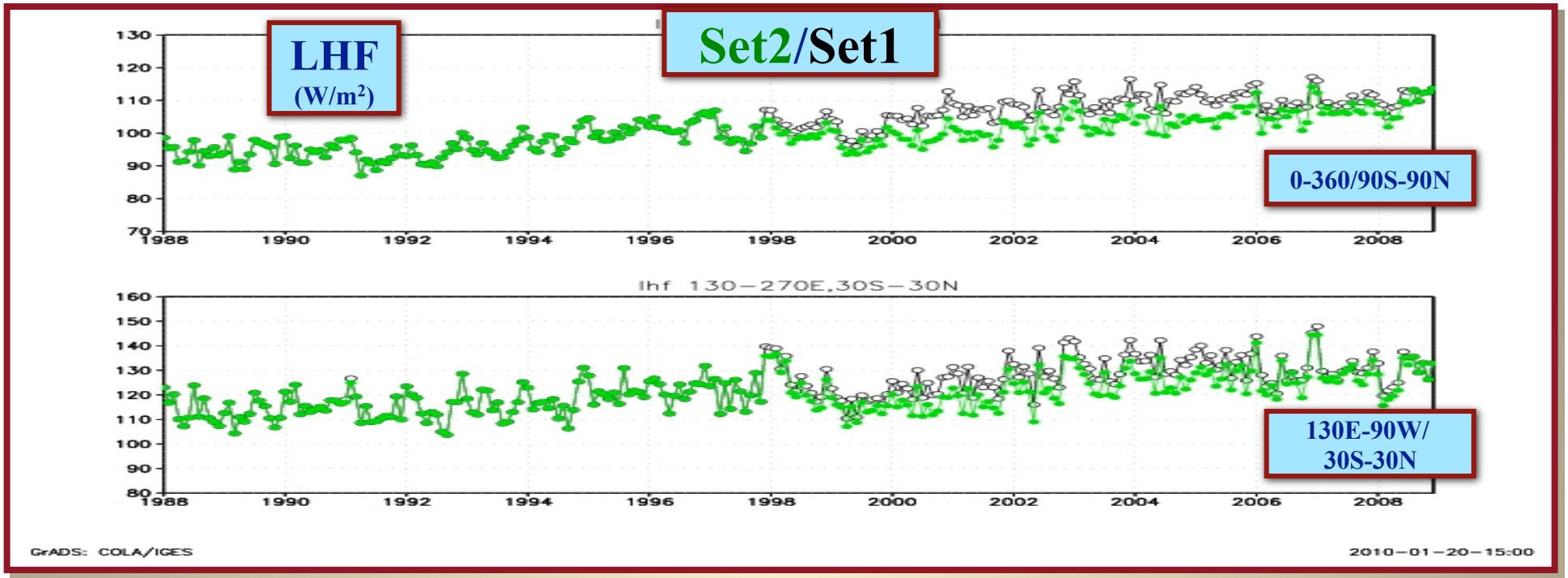
Bottom Layer (500m from surface) Precipitable Water based on

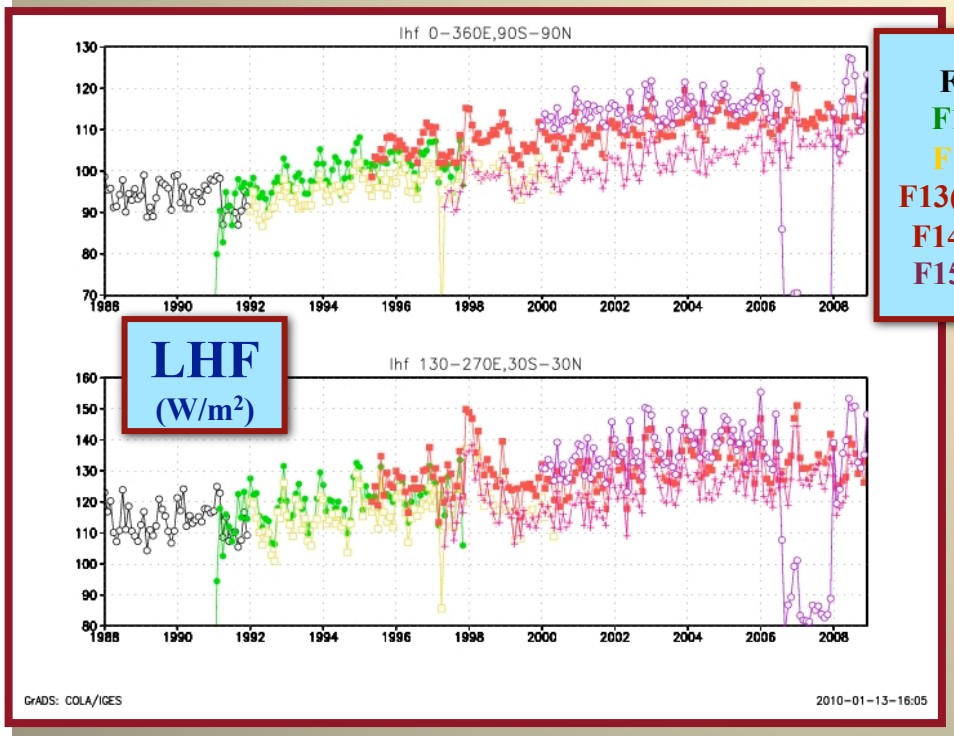
(a)Retrievals from SSM/I (upper panel) using interpolated data. 1988-2000 (V4) / 1988-2008 (V6)
(b)Estimates from MODIS (lower panel). 2000/02-2009/08



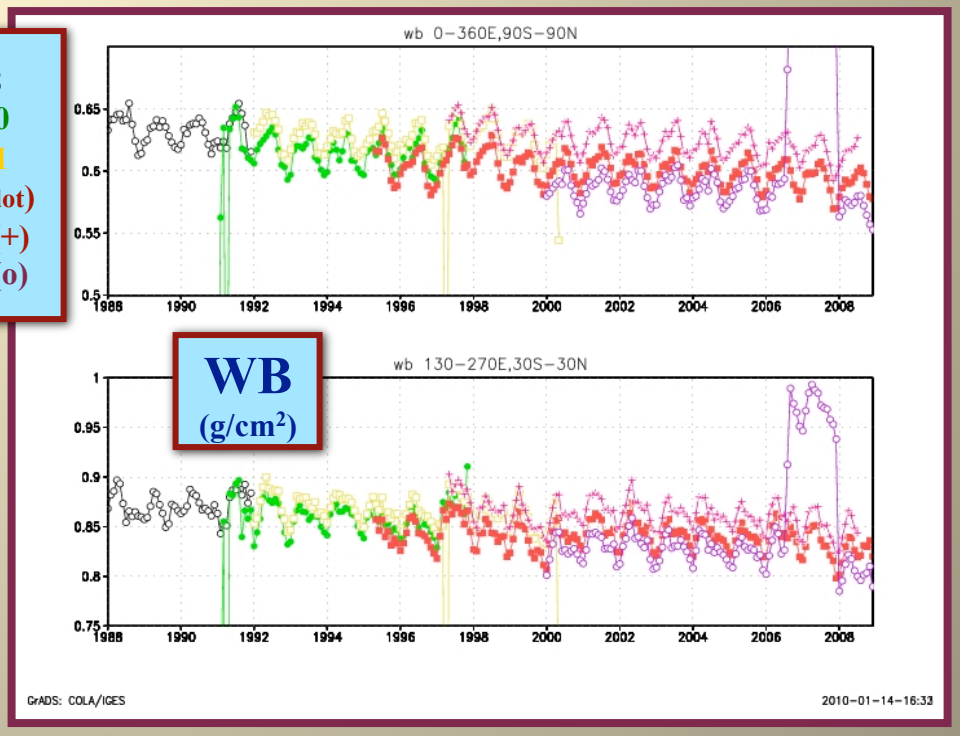
GrADS: COLA/IGES

21:23

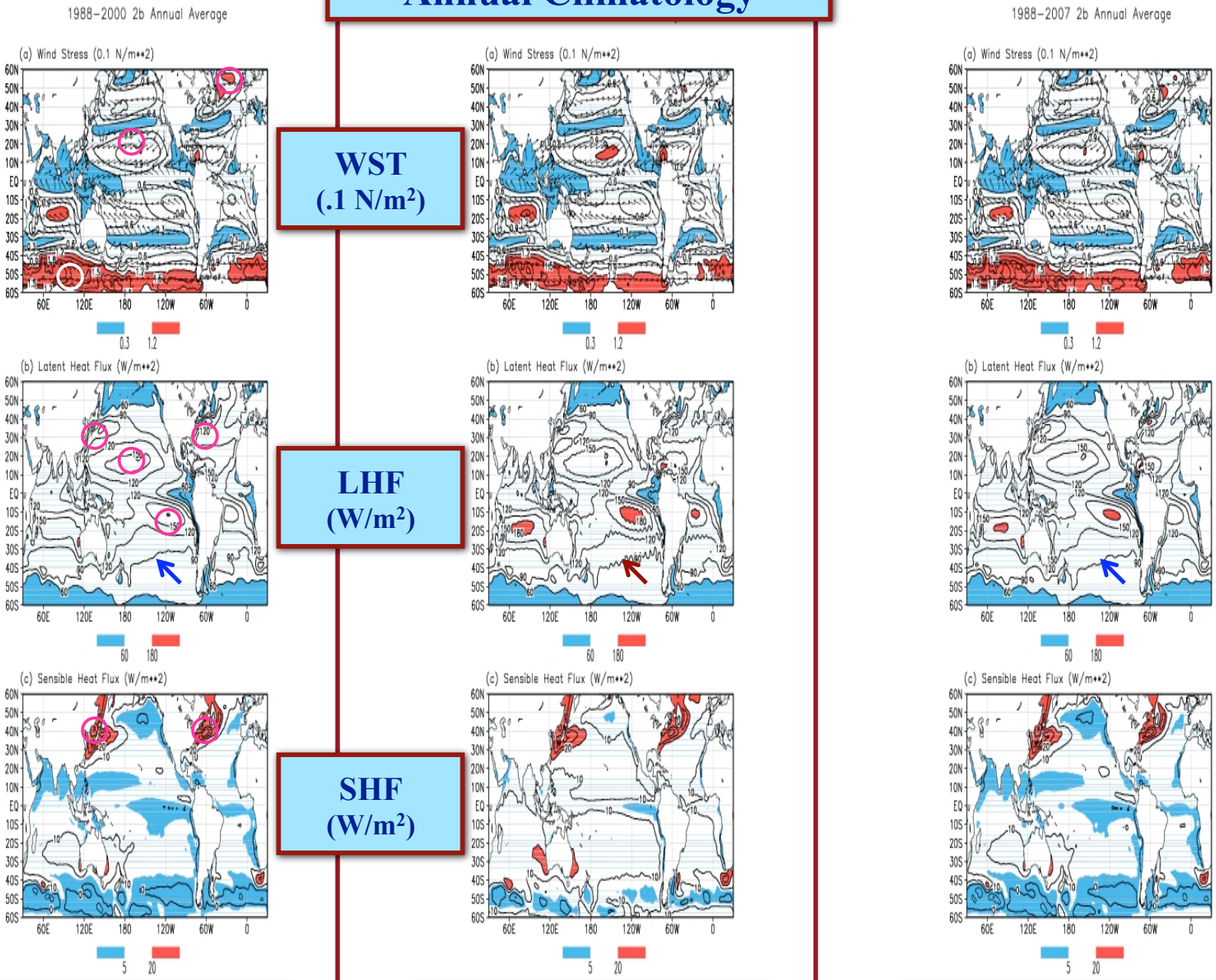




F8
F10
F11
F13(dot)
F14(+)
F15(o)



Annual Climatology



WST (.1 N/m²)

LHF (W/m²)

SHF (W/m²)

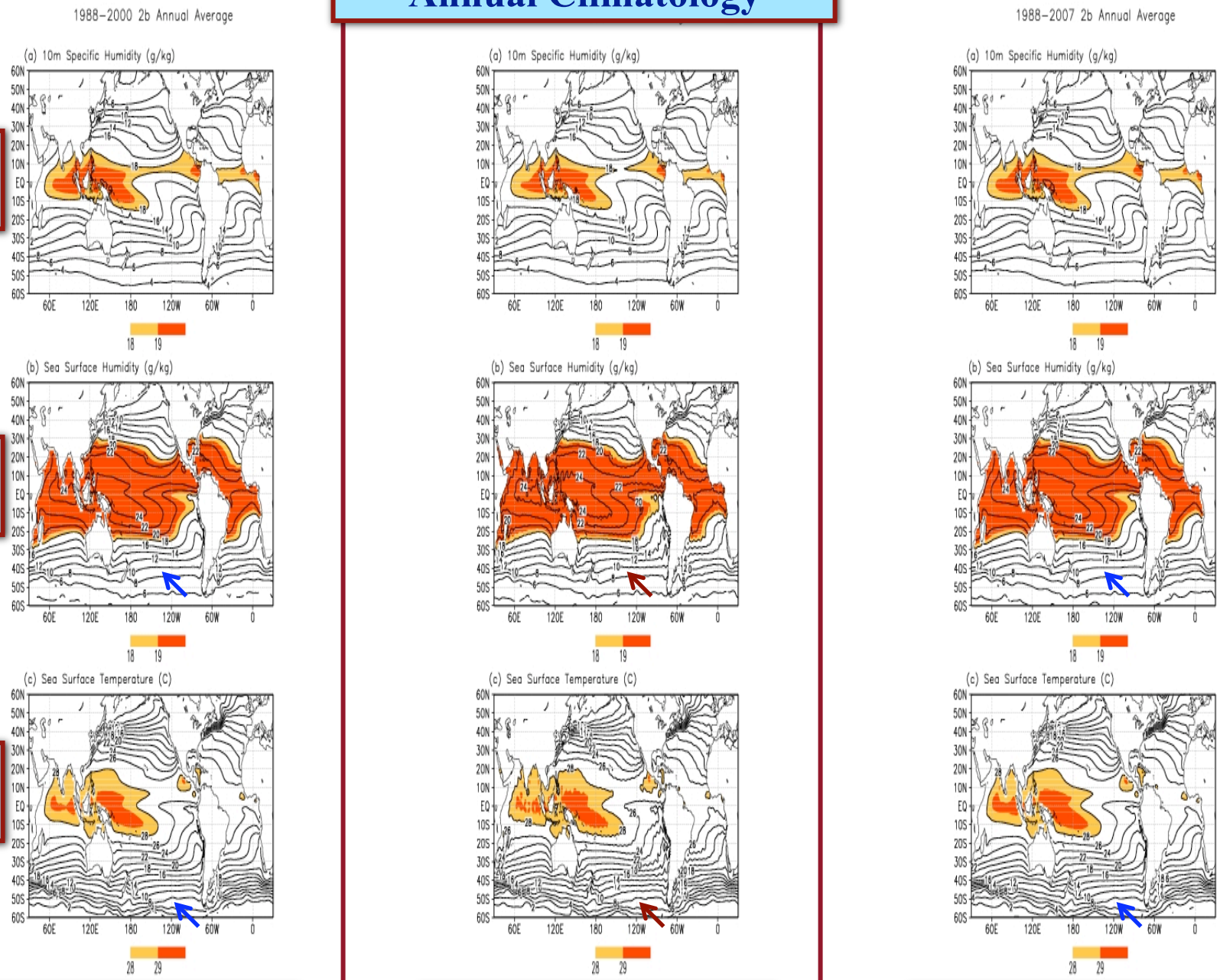
GSSTF2b 1988-2000 | **GSSTF2 1988-2000** | **GSSTF2b 1988-2007**

Annual Climatology

Qa (g/kg)

Qsea (g/kg)

SST (°C)

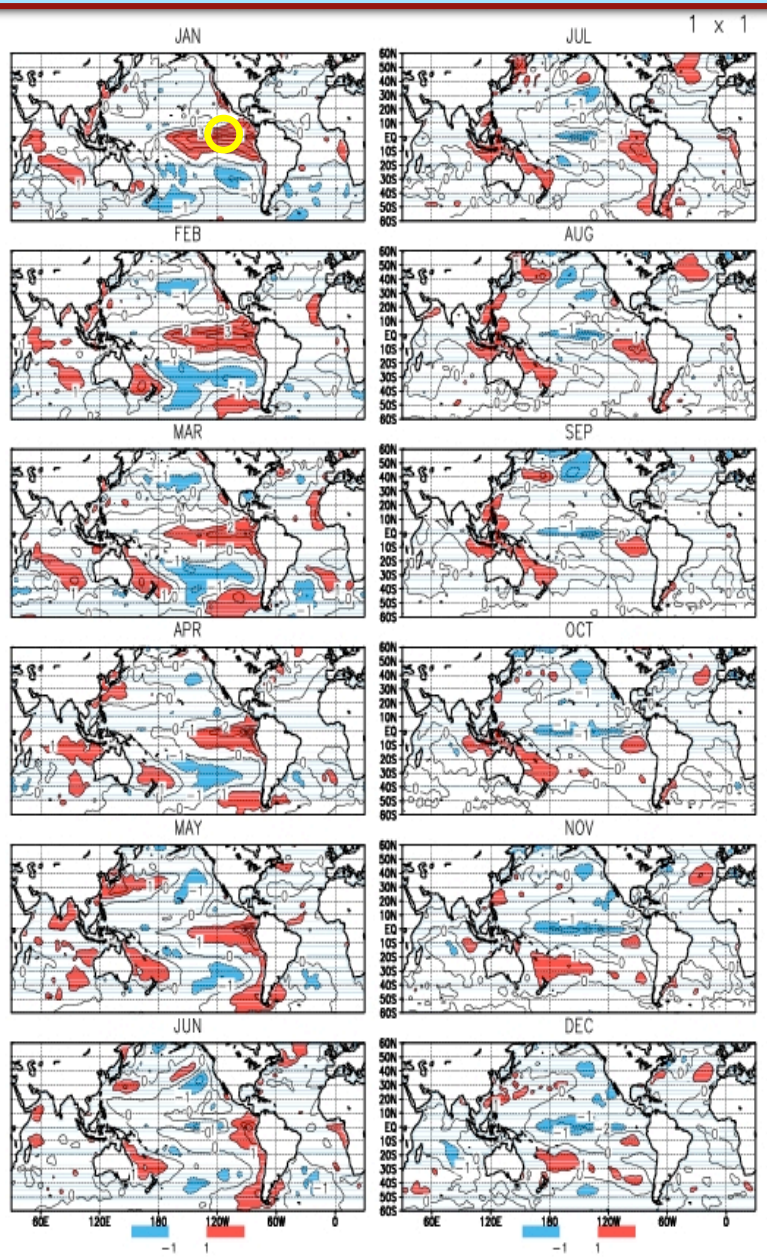


GSSTF2b 1988-2000

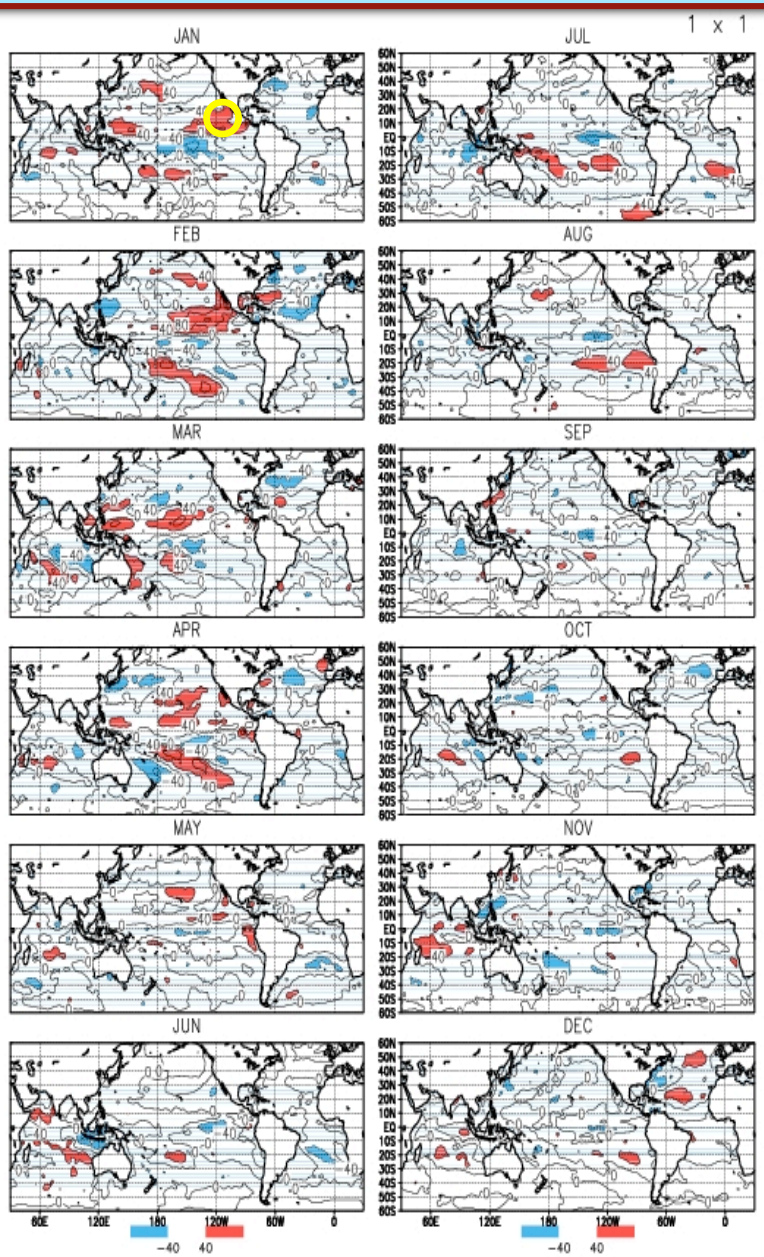
GSSTF2 1988-2000

GSSTF2b 1988-2007

NCEP/DOE R2 Monthly Anom: SST (°C)



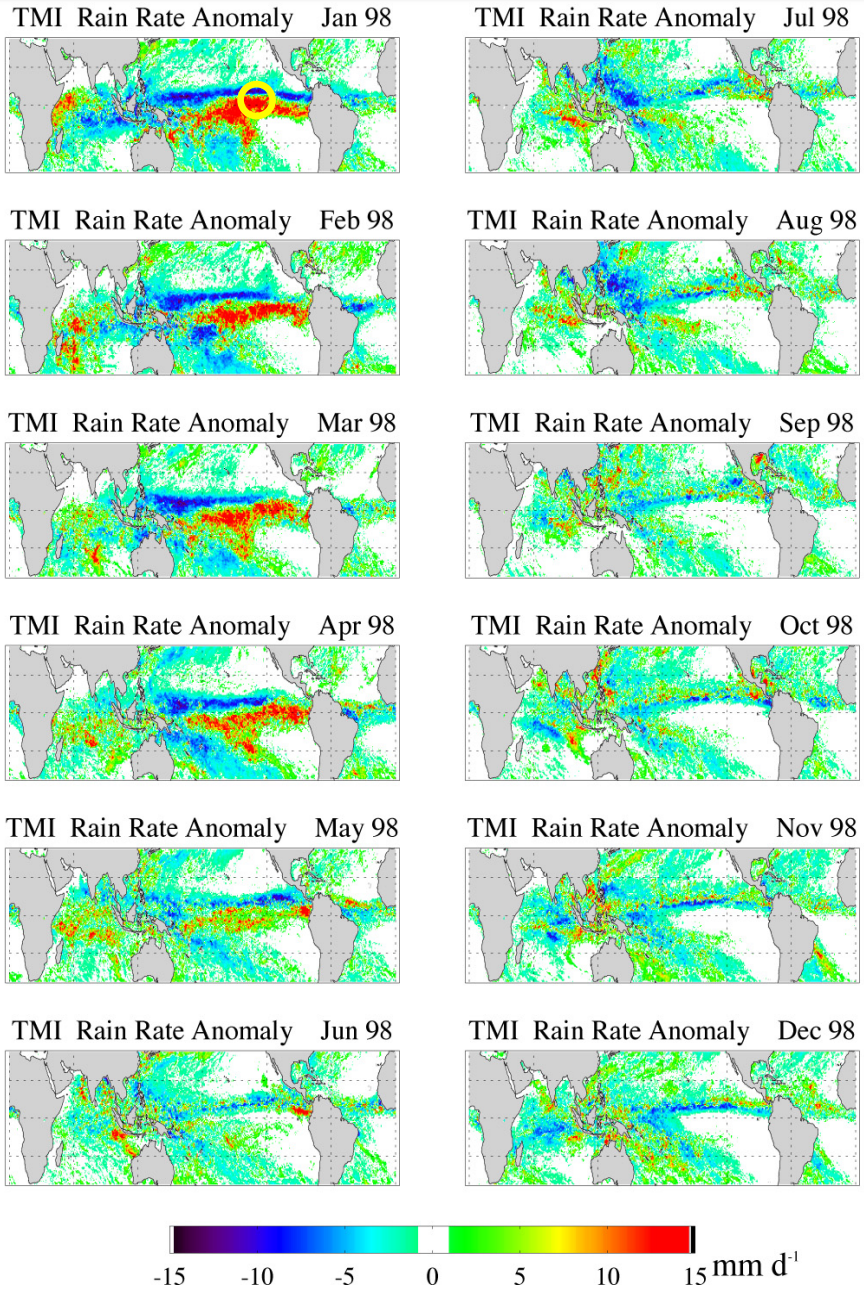
GSSTF2b Monthly Anom: LHF (W/m²)



El Niño 1998

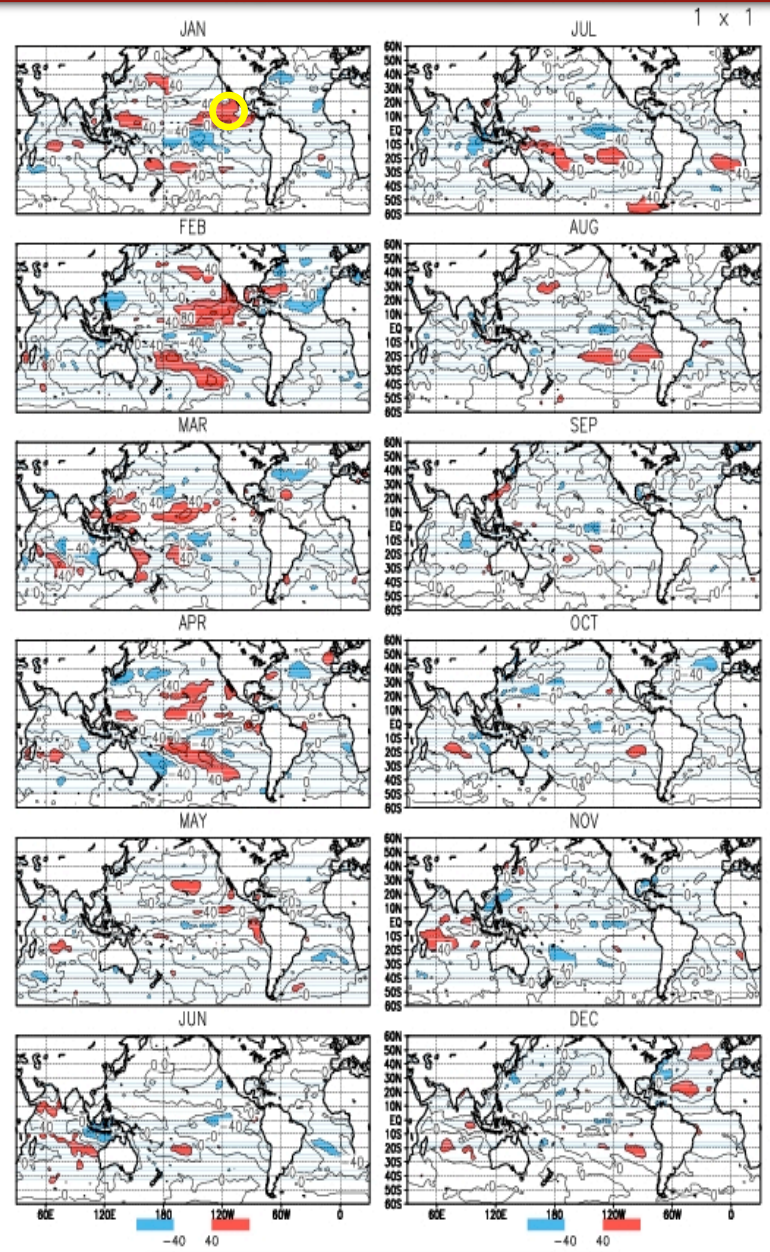
TMI Rain Rate Anomaly (mm/day)

(Courtesy of Olson 2010)



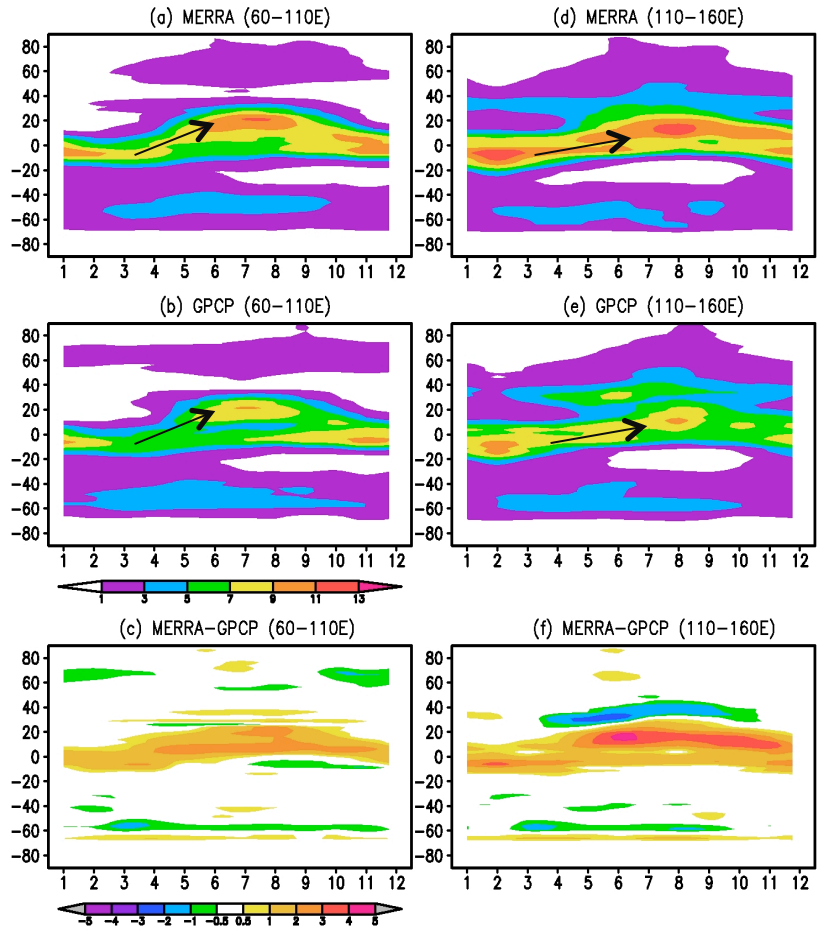
GSSTF2b Monthly Anom: LHF (W/m^2)

(Shie et al. 2010)



El Niño 1998

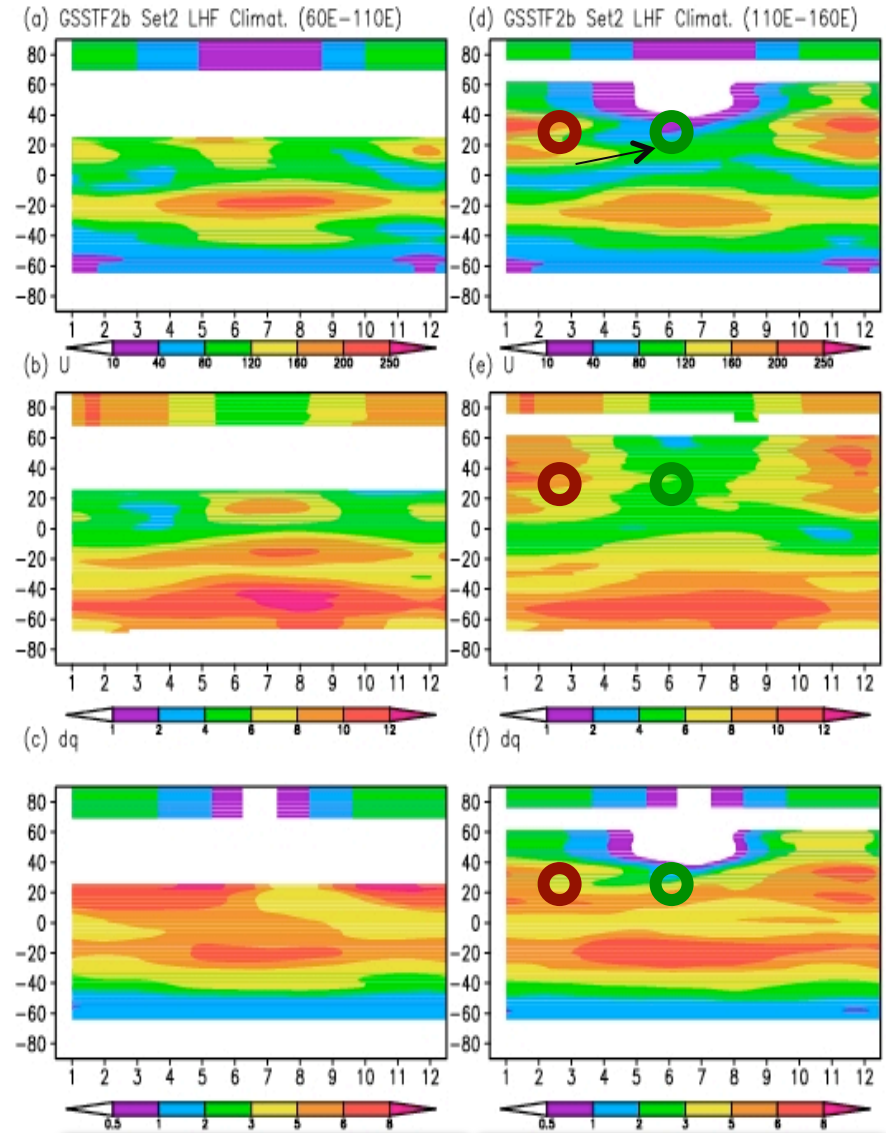
GPCP vs MERRA
Rain Rate Climatology (mm/day)
1998-2004 (Courtesy of Gu 2010)



S. Asian Monsoon (60E-110E)

E. Asian Monsoon (110E-160E)

GSSTF2b Monthly Clim.: LHF (W/m^2)
1988-2008 (Shie et al. 2010)



S. Asian Monsoon (60E-110E)

E. Asian Monsoon (110E-160E)

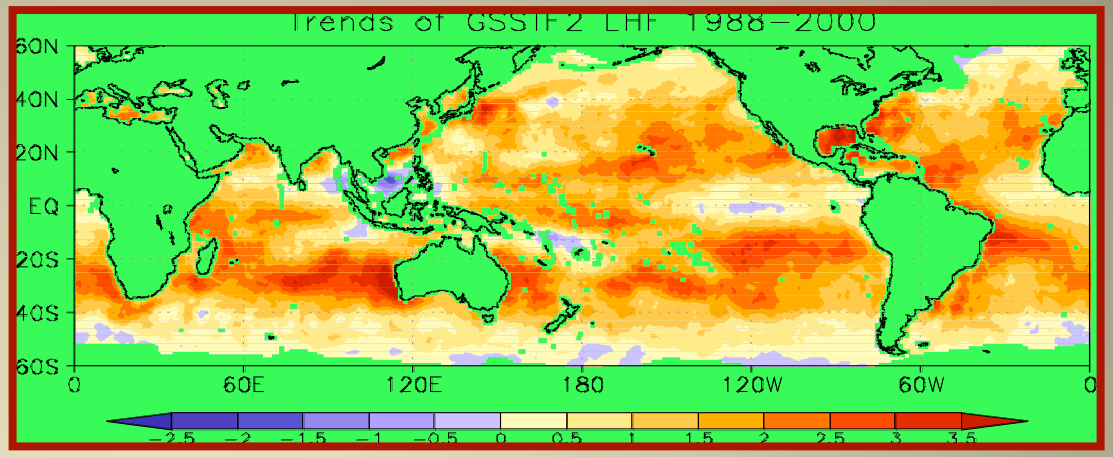
Linear Trend of Global LHF

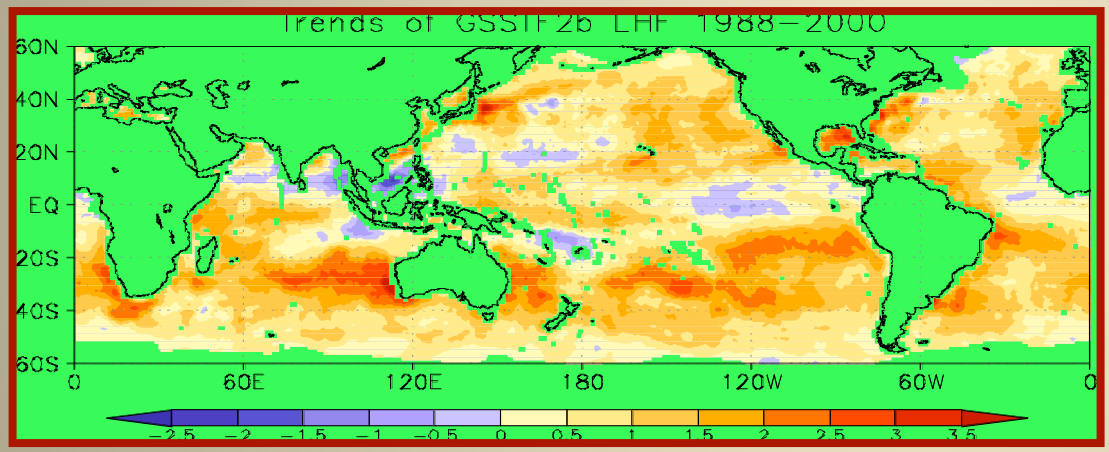
GSSTF2 1988–2000: 0.109 (W/m^2 /mon)

GSSTF2b 1988–2000: 0.086 (W/m^2 /mon)

GSSTF2b 1988–2008: 0.090 (W/m^2 /mon)

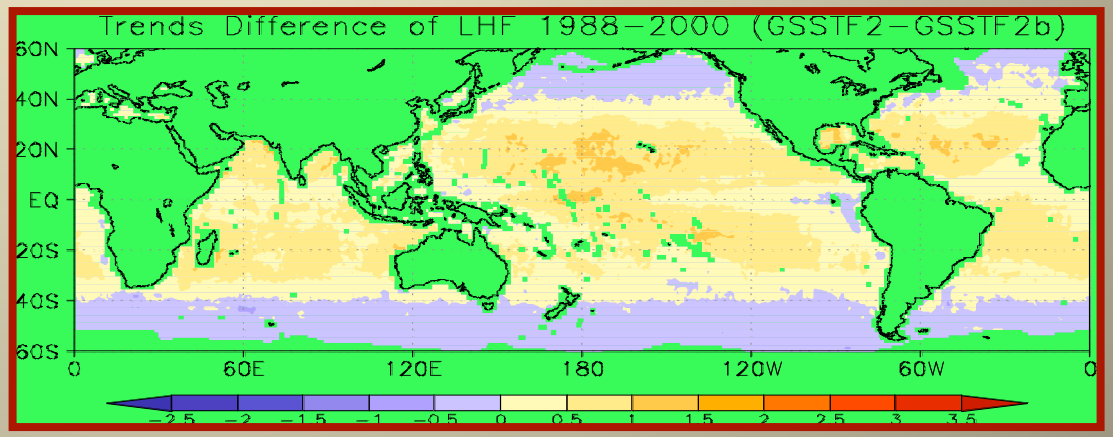
GSSTF2 (1988-2000)

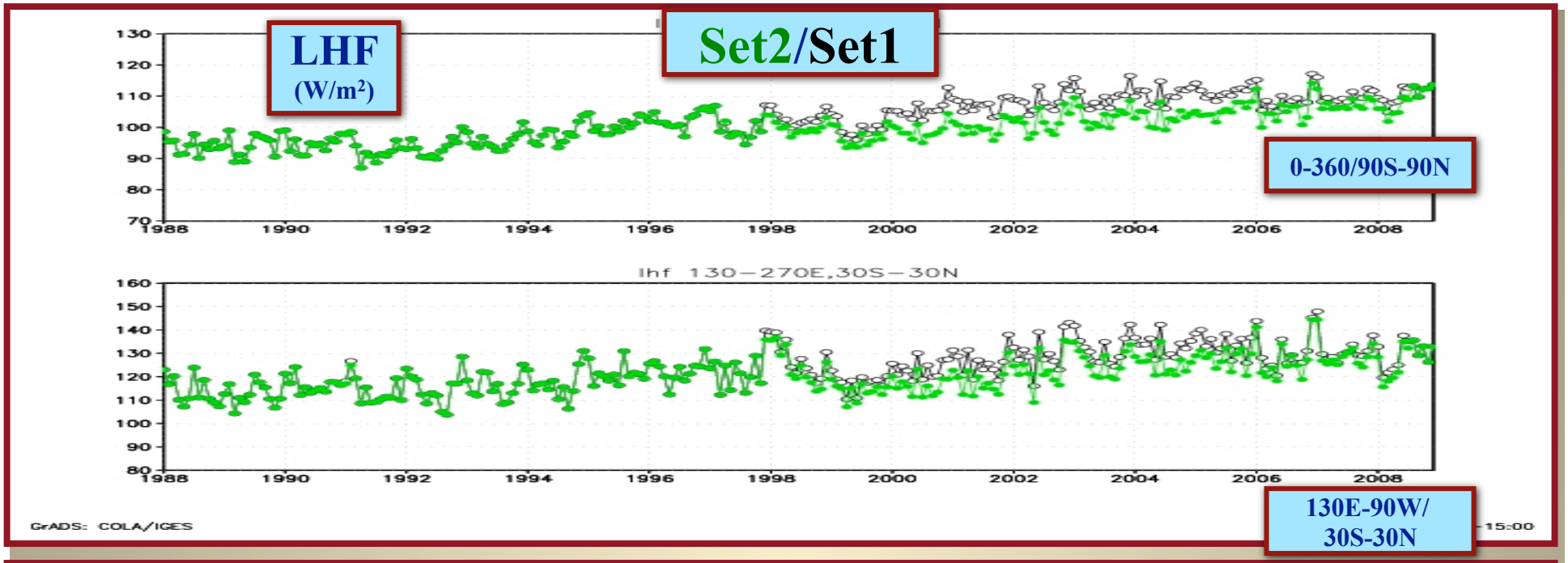


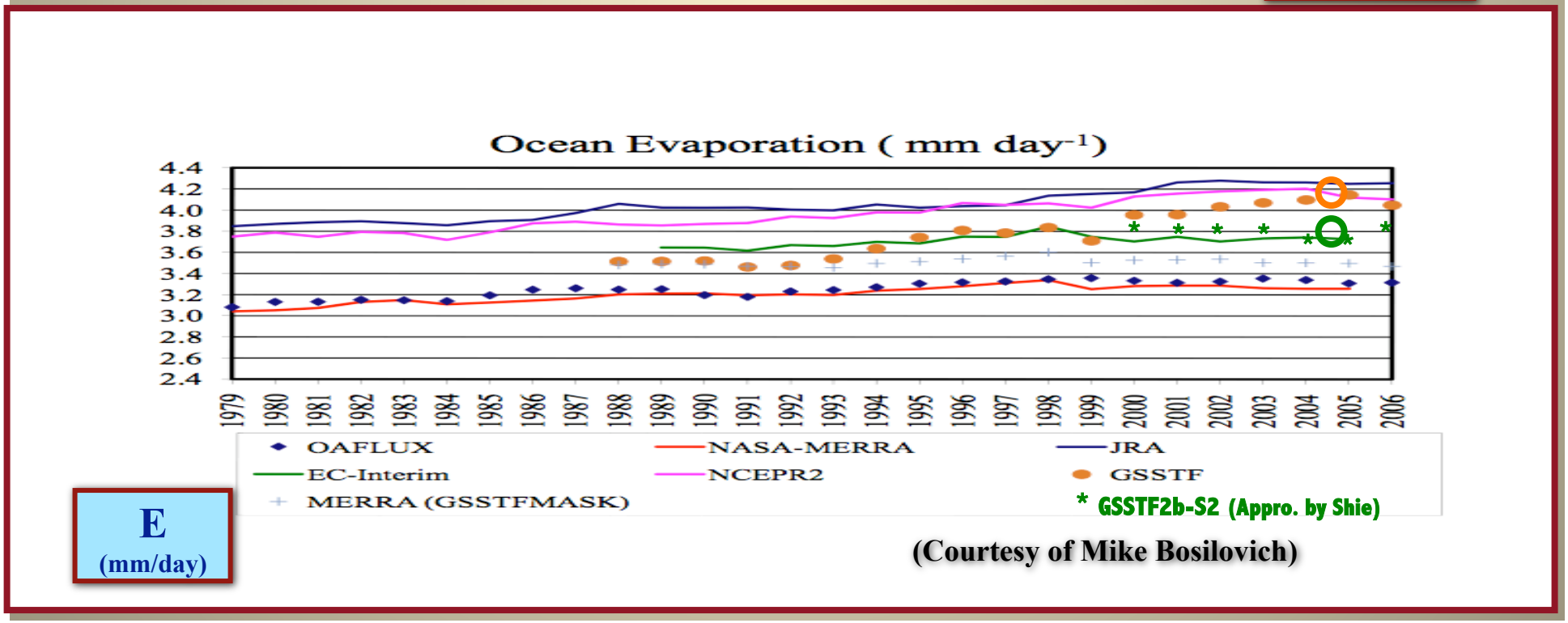


GSSTF2b (1988-2000)

GSSTF2 - GSSFT2b (1988-2000)





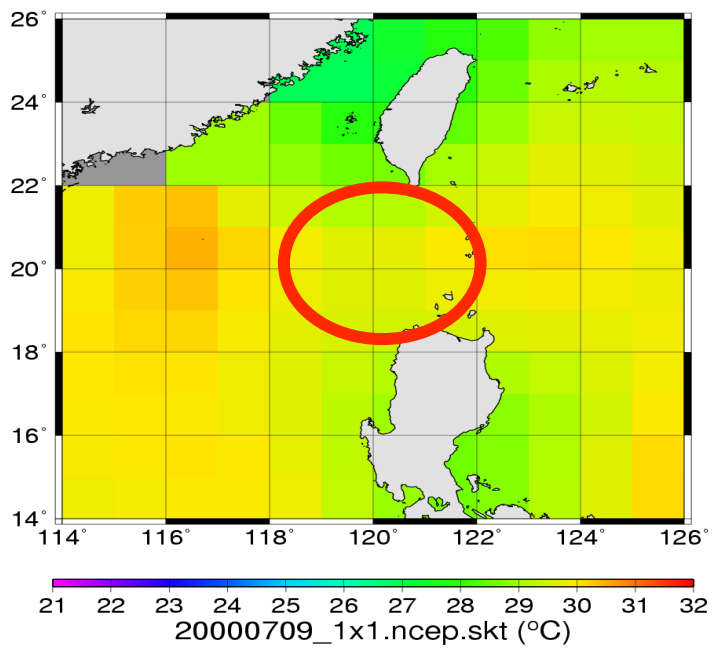


(Courtesy of Mike Bosilovich)

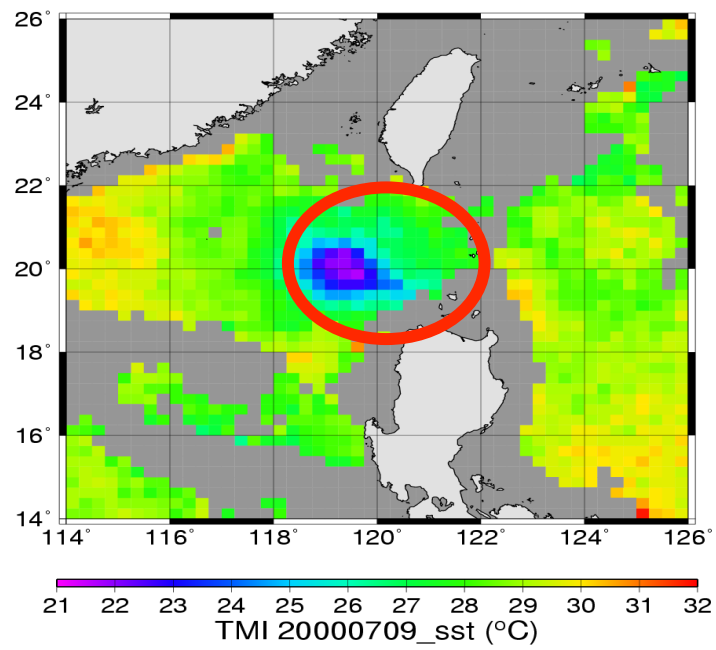
Improvement on SST using Cloud-penetrating TRMM/TMI and AMSR-E

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°



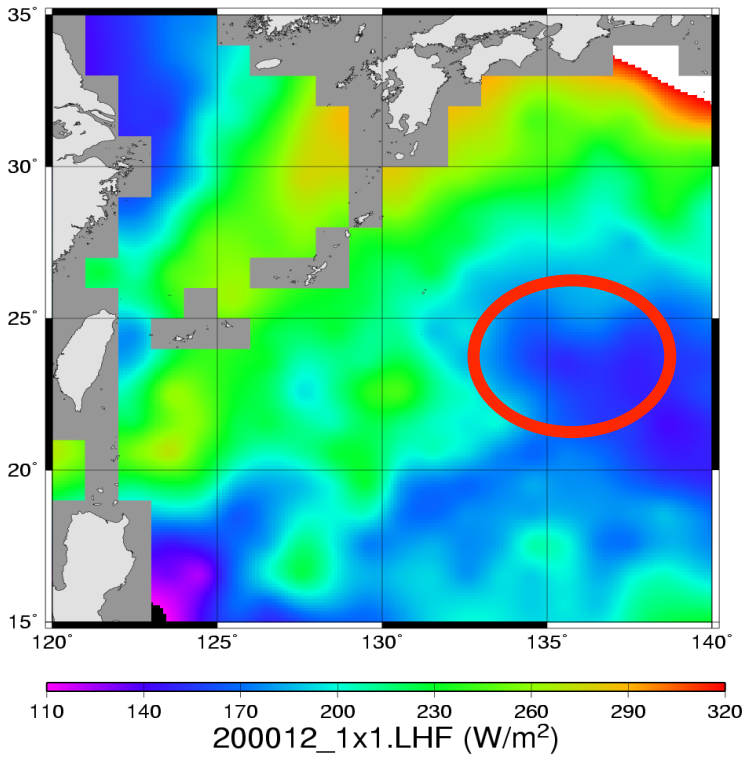
0.25°×0.25°



(Lin & Wang, 2006)

Improved estimated LHF at the Kuroshio region with higher spatial resolution

1°×1°



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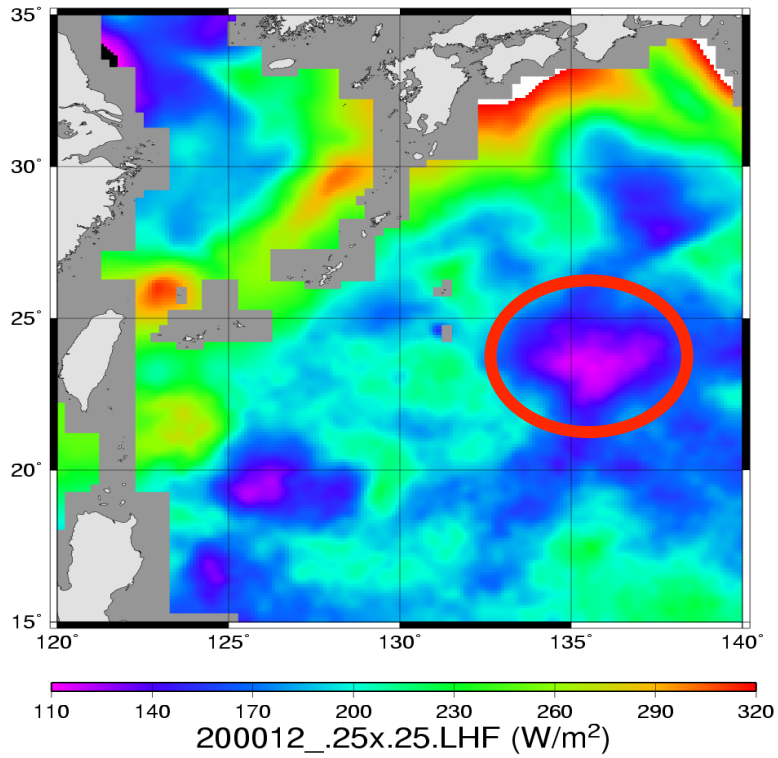
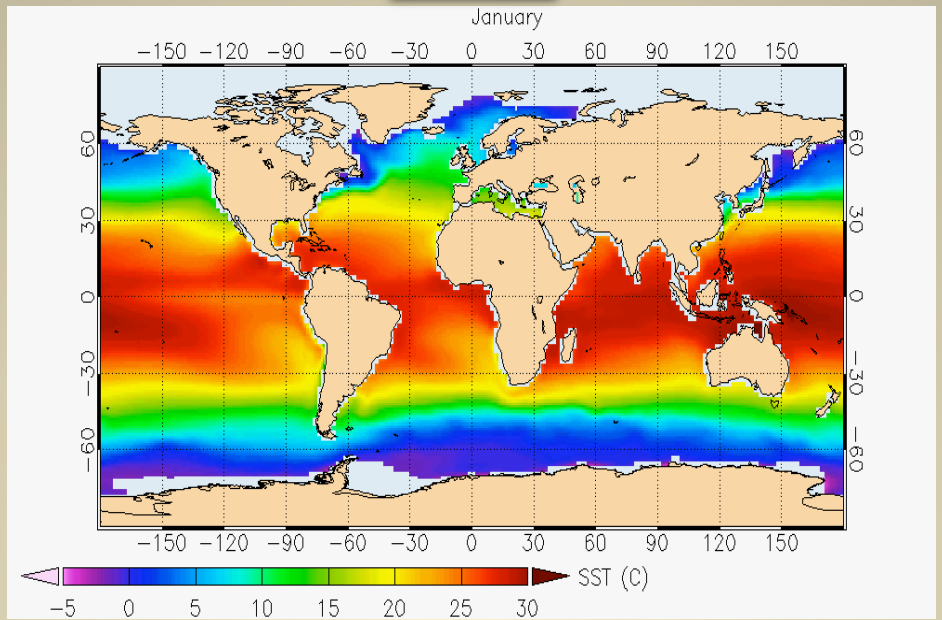


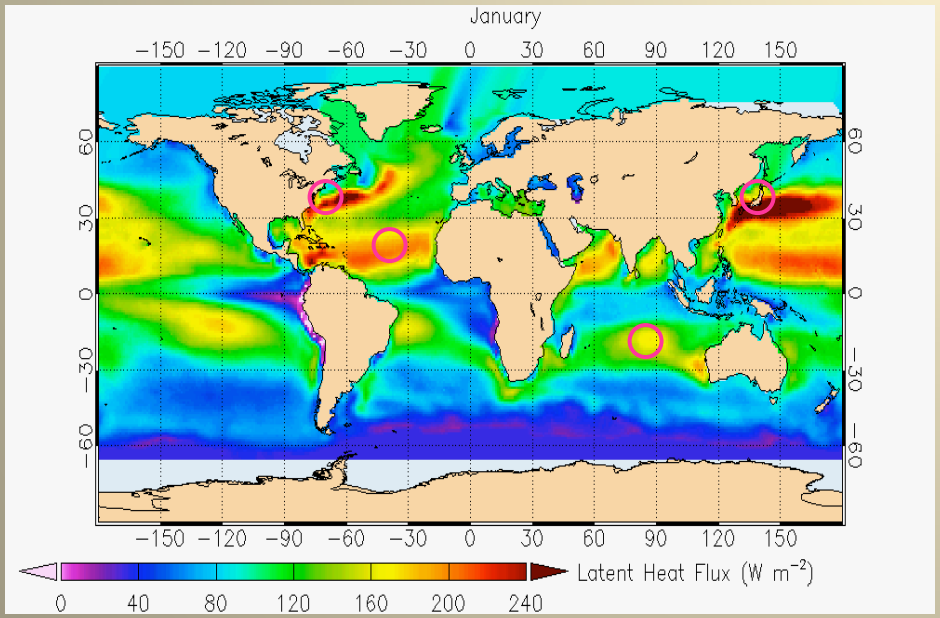
(Lin & Wang, 2006)

Monthly Climatology (1988-2008)

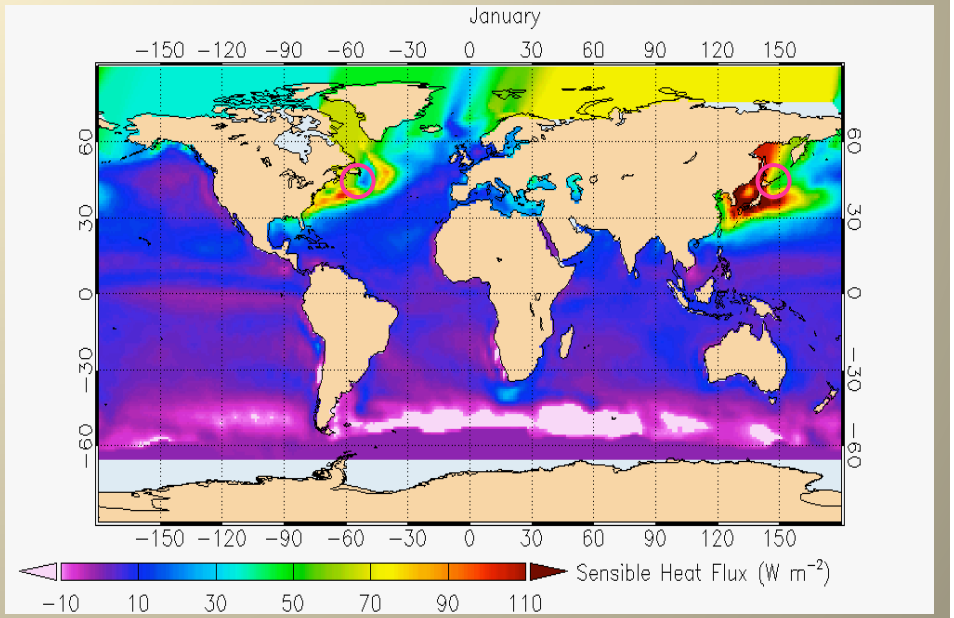
SST (C)



LHF (W/m^2)



SHF (W/m^2)



The GSSTF2b Dataset will VERY SOON be officially released by NASA GES-DISC with a converted format of HDF-EOS5!

Stay tuned!

Please contact "Chung-Lin.Shie-1@nasa.gov" Should You be interested.

Thanks!