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

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In Memory of my Mentor

Dr. Shu-Hsien Chou
(aka Sue, 周張淑織博士)

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
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.
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
  - Satellite observations (SSM/I)
  - Global / 1° lat/ion

- **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° lat/ion

- **J-OFURO** (Kubota et al. 2002)
  - Japanese Ocean Flux Data Sets with Use of Remote Sensing Observations
  - Satellite observations (SSM/I)
  - Global / 1° lat/ion
Oceanic Flux Products [b]

- **FSU**
  - Florida State University Flux (wind stress+) data set
  - In situ + Satellite observations
  - Basins: global / 1° lat/lon

- **OAFlux**
  - Objectively Analyzed Air-sea Flux of WHOI
  - In situ + Satellite observations + Reanalysis
  - Global / 1° (?) lat/lon

- **IFREMER**
  - French Research Institute for Exploitation of the Sea
  - Satellite observations
  - Global / 1° lat/lon
Oceanic Flux Products [c]

- **COADS**
  - COADS / NODC / da Silva (1994)
  - 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
NCEP Model  SSM/I Obs  GSSTF Hybrid!
“Rice Cooker Theory”

Models/Algorithms
Bulk Aerodynamic Algorithm

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

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 \( i \)th 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)

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

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

\[ W_B(t, r) = \overline{W^+_B} + C_1(t, r) W_{B1} + C_2(t, r) W_{B2} \quad (4) \]

\( \overline{Q}, Q_1, \) 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.

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

LHF (W/m²)


U (m/s)

DQ (g/kg)
The Multivariate ENSO Index (MEI) is a measure of the strength and phase of the El Niño-Southern Oscillation (ENSO). The index is based on a multivariate analysis of a variety of climate variables, including sea surface temperature, sea level pressure, and wind stress. The MEI is calculated as a standardized departure from the long-term mean of these variables. High positive values indicate strong El Niño conditions, while negative values indicate strong La Niña conditions. The graph shows significant El Niño episodes in 1982-1983, 1997-1998, and 2002, as well as a notable La Niña event in 1988-1989. The MEI is available at the NOAA/Earth System Research Laboratory website: [http://www.esrl.noaa.gov/psd/people/klaus.wolter/MEI/#ref_wt1](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)

LHF (W/m²)

Qsea (g/kg)

La Niña 1988-1989


El Niño 2002 (weaker)
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
Annual Climatology

Qa (g/kg)

Qsea (g/kg)

SST (°C)

GSSTF2b 1988-2000

GSSTF2 1988-2000

GSSTF2b 1988-2007
TMI Rain Rate Anomaly (mm/day)
(Courtesy of Olson 2010)

El Niño 1998

GSSTF2b Monthly Anom: LHF (W/m²)
(Shie et al. 2010)
**GPCP vs MERRA**
Rain Rate Climatology (mm/day)
1998-2004  (Courtesy of Gu 2010)

**GSSTF2b Monthly Clim.: LHF (W/m²)**
1988-2008  (Shie et al. 2010)

- **S. Asian Monsoon**
  - (60E-110E)
- **E. Asian Monsoon**
  - (110E-160E)

- **S. Asian Monsoon**
  - (60E-110E)
- **E. Asian Monsoon**
  - (110E-160E)
Linear Trend of Global LHF
GSSTF2 1988–2000: 0.109 (W/m²/mon)
GSSTF2b 1988–2000: 0.086 (W/m²/mon)
GSSTF2b 1988–2008: 0.090 (W/m²/mon)

GSSTF2 (1988-2000)

GSSTF2b (1988-2000)

GSSTF2 - GSSTF2b (1988-2000)
LHF (W/m²)

Set2/Set1

0-360/90S-90N

130E-90W/30S-30N

E (mm/day)

Ocean Evaporation (mm day⁻¹)

(Courtesy of Mike Bosilovich)

* GSSTF2b-S2 (Appro. by Shie)
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.
Improved estimated LHF at the Kuroshio region with higher spatial resolution

(Lin & Wang, 2006)
Monthly Climatology (1988-2008)

LHF (W/m²)

SHF (W/m²)

SST (°C)

January

Latent Heat Flux (W m⁻²)

Sensible Heat Flux (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!