Enhancement of the oceanic turbulent fluxes estimated from remotely sensed data

A. Bentamy	IFREMER. France
S. Grodsky	Univ. of Maryland. USA
R. Pinker	Univ. of Maryland. USA
K. Katsaros	NOAA. USA.
A. Mestas-Nuñez	Univ Corpus Christi. USA.
J. Hanafin	Univ de Bretagne Ouest (LPO/UBO). France.
B. Blanke.	Univ de Bretagne Ouest (LPO/UBO). France.
F. Desbiolles	Univ de Bretagne Ouest (LPO/UBO). France.

Surface Flux Determination : Bulk Aerodynamic Method

- **Most common and easy method used for estimating the surface fluxes since they can be parameterized in terms of mean surface quantities :**

Wind stress

$$\tau = (\tau_x, \tau_y) = \rho C_D \overline{U}(u,v)$$

Latent heat flux

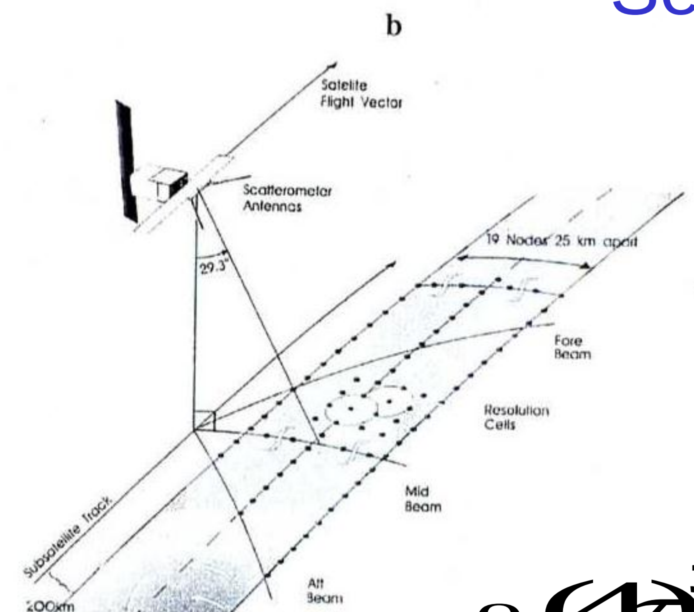
$$Q_{latent} = -l \rho C_E \overline{U}(q_a - q_s)$$

Sensible heat flux

$$Q_{sens} = -\rho C_p C_h \overline{U}(T_a - T_s)$$

- **Thus to calculate evaporation correctly we need: U(*u,v*), q_a, q_s, T_s, T_a and an appropriate model of C_D, C_E and C_H**
- **NOTE: Over the ocean we assume that our estimated fluxes should identically equal the eddy covariance fluxes**

Sea Surface Winds



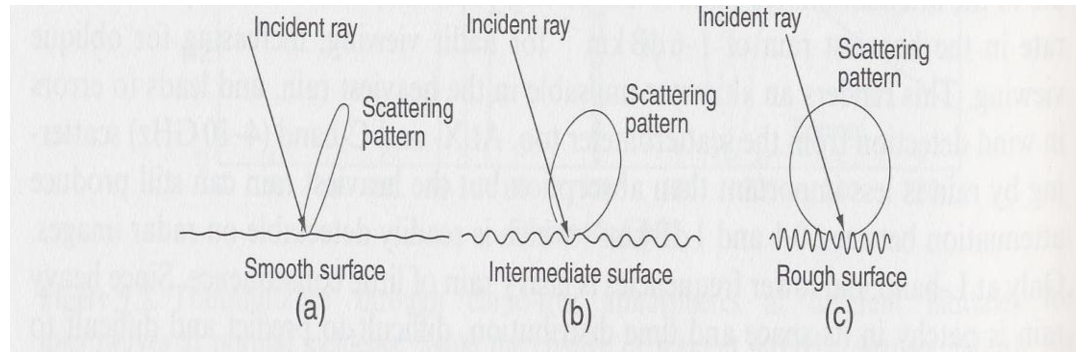


Figure 9.8. The directional envelope of microwave scattering from (a) a perfectly calm sea surface, (b) a slightly roughened surface, and (c) a rough surface.

$$\sigma^o = \frac{(4\pi)^3 R^4 P_r}{\lambda^2 G^2 A_e}$$

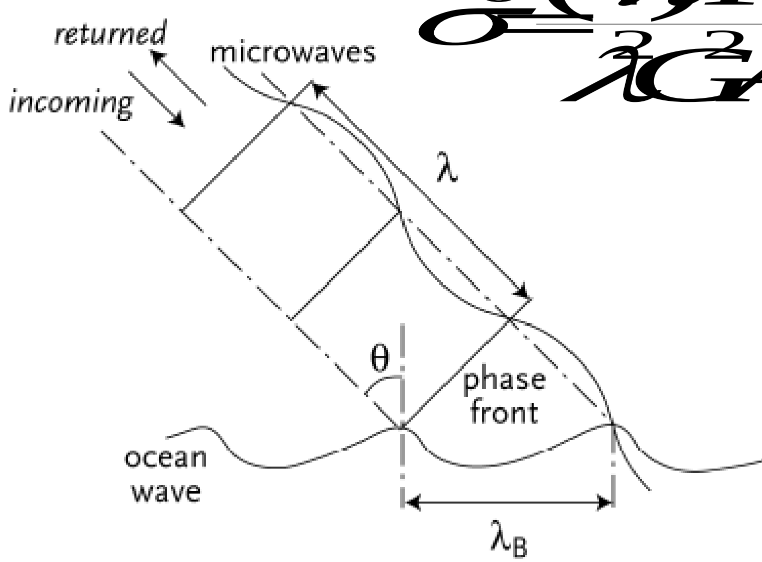


Figure 11. Bragg scattering: A plan-parallel radar beam with wavelength λ hits the rough ocean surface at incidence angle θ, where capillary gravity waves with Bragg wavelength λ_B will cause microwave resonance.

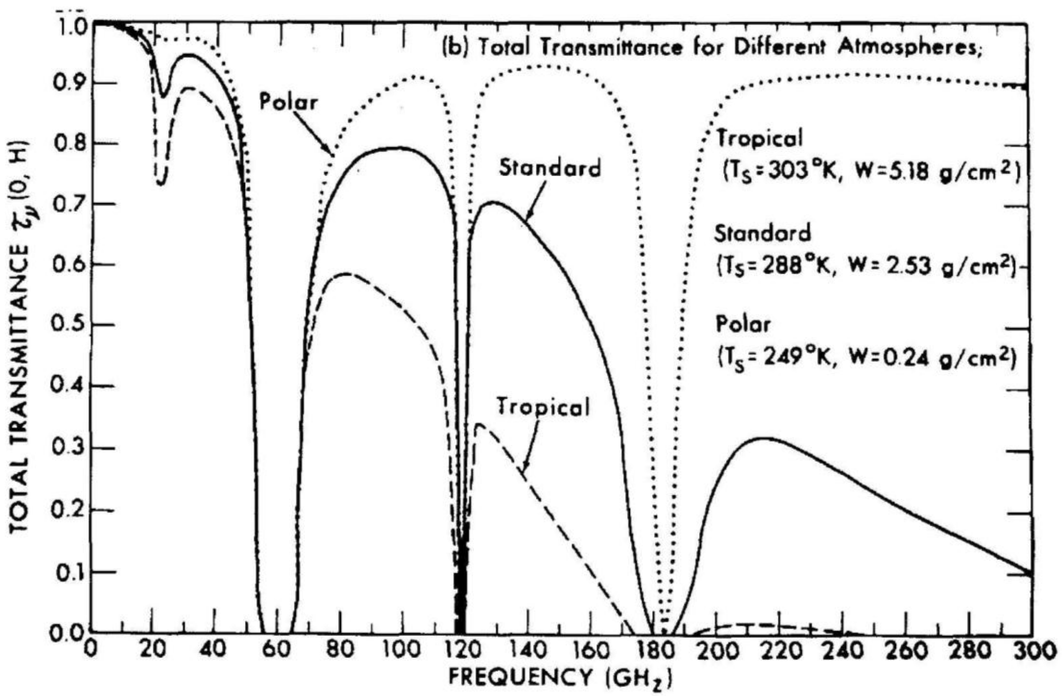
- **Retrieving Surface Winds from Backscatter Coefficient Measurements**

- **Calibration Procedure: Determination of Geophysical Model Function (GMF):**

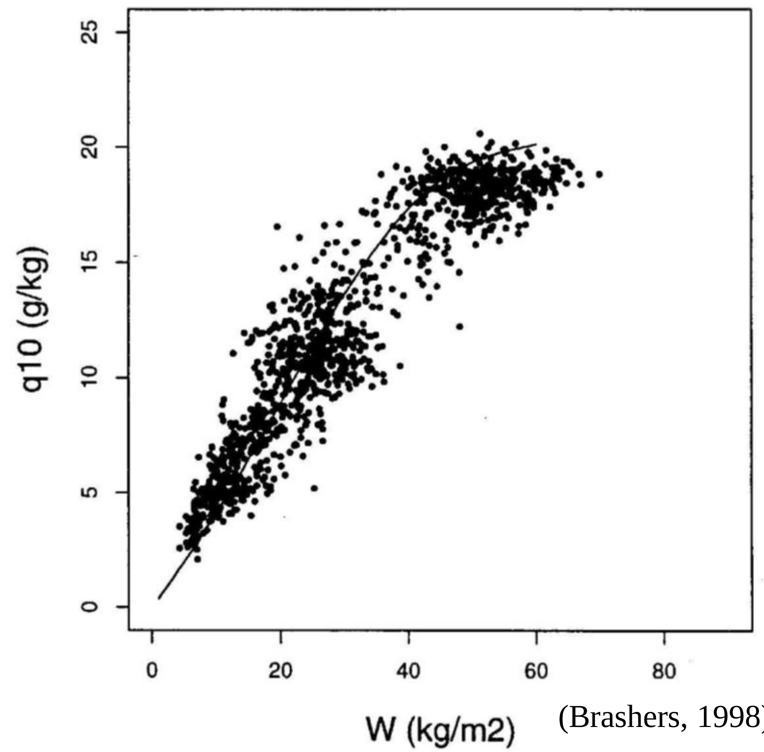
$$\sigma^o = f(U, \theta, \chi, P, fc, \ldots.)$$

Specific Air Humidity

- SSM/I : 19GHz,22GHz, 37GHz, 85GH



gure 1.1 Vertical atmospheric transmittance vs. frequency for different atmospheric conditions (from Grody, 1976)

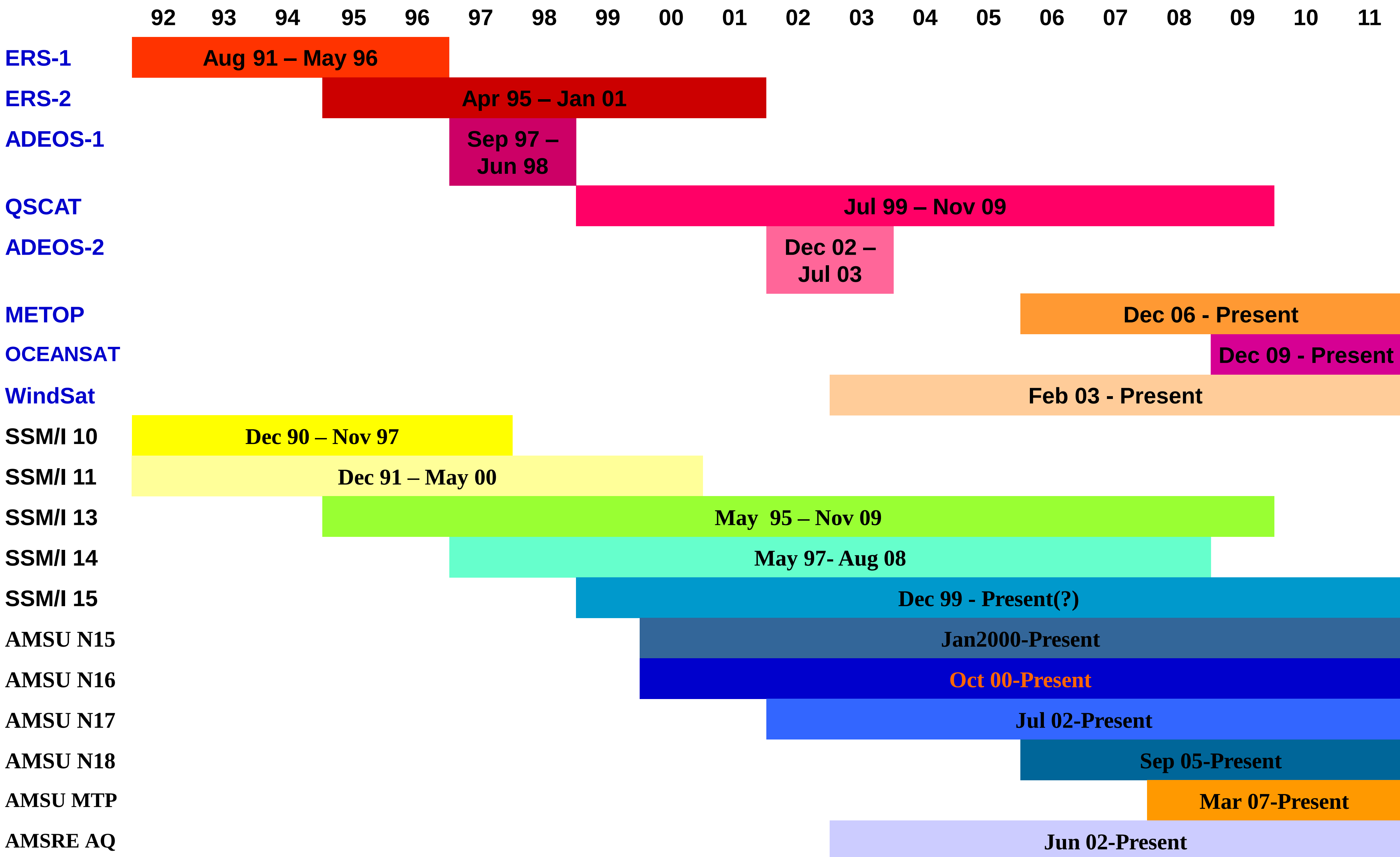


(Brashers, 1998)

- Specific Air Humidity : $q_a = f(T_{B19V}, T_{B19H}, T_{B22V}, T_{B37V})$

(Bentamy *et al*, 2003)

Useful Satellite Measurements for Turbulent Flux Estimations



New Release of Turbulent Fluxes (Bentamy *et al*, 2013)
Main Changes

- **Wind :**
  - QuikScat retrievals (V3 (Fore *et al*, 2011)) including (Bentamy *et al*, 2012) results
- **Specific Air Humidity :**

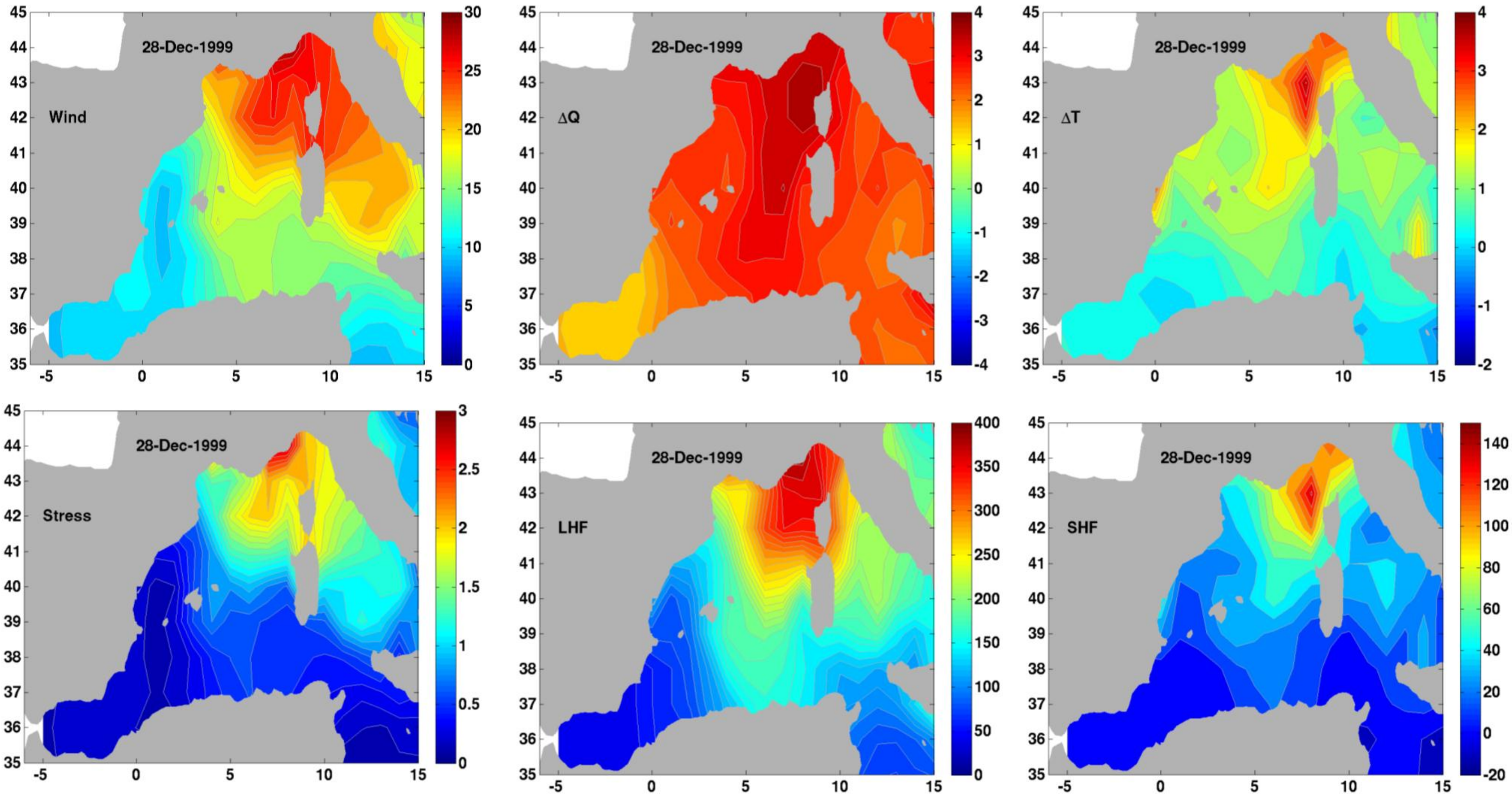
$$qa_{10} = f_1(Tb_{19V}) + f_2(Tb_{19H}) + f_3(Tb_{22V}) + f_4(Tb_{37V}) + g(SST) + h(\Delta T)$$

Tb are from SSM/I F11 – F15

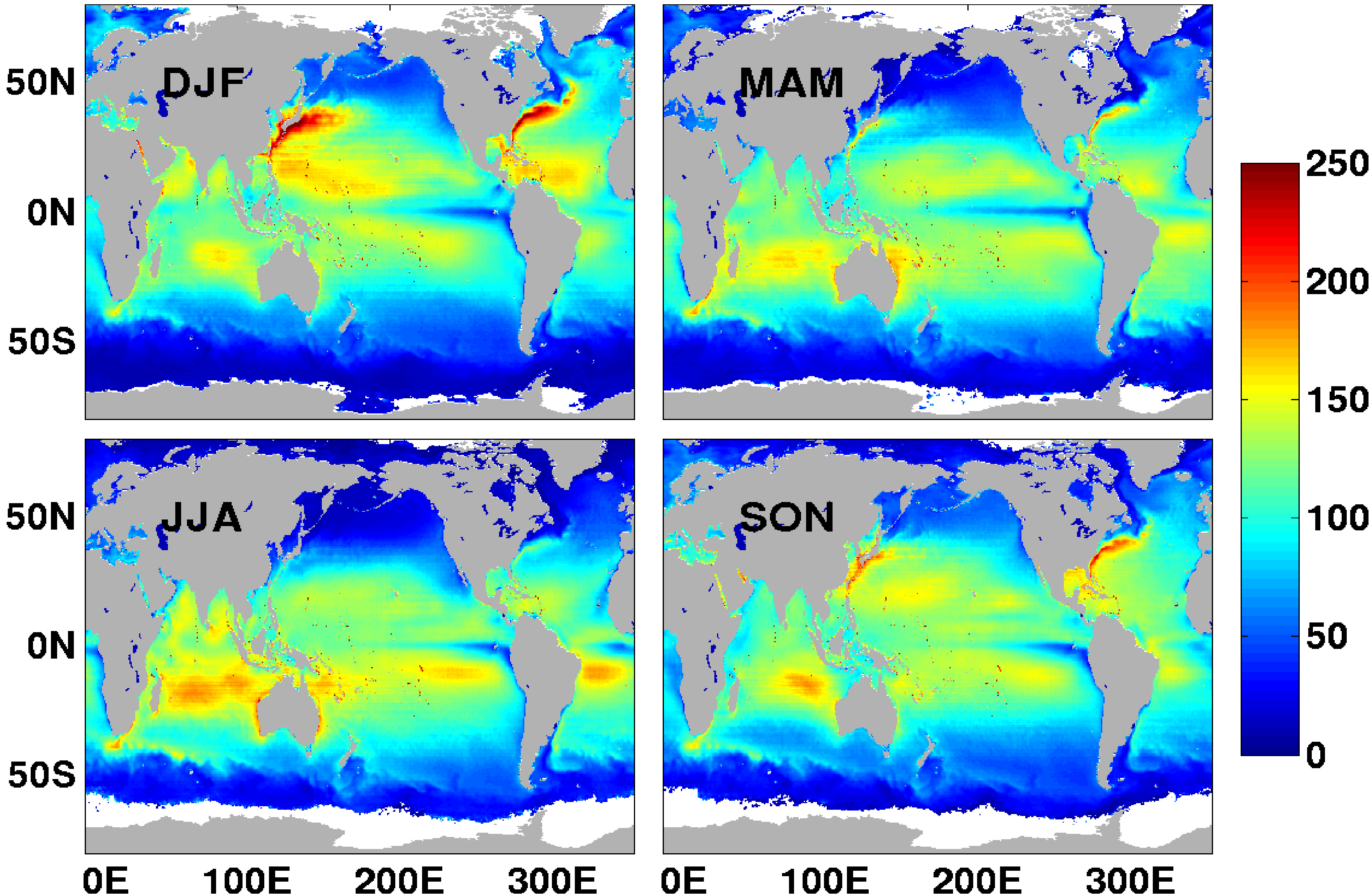
- **Air Temperature:**
  - Corrected Era Interim
- **Sea Surface Temperature**
  - HR SST V2 (Reynolds et al, 2007)

Objective Method (Bentamy *et al* , 2011)
Calculations of Global Daily and Monthly 0.25°x0.25° Flux Analyses.

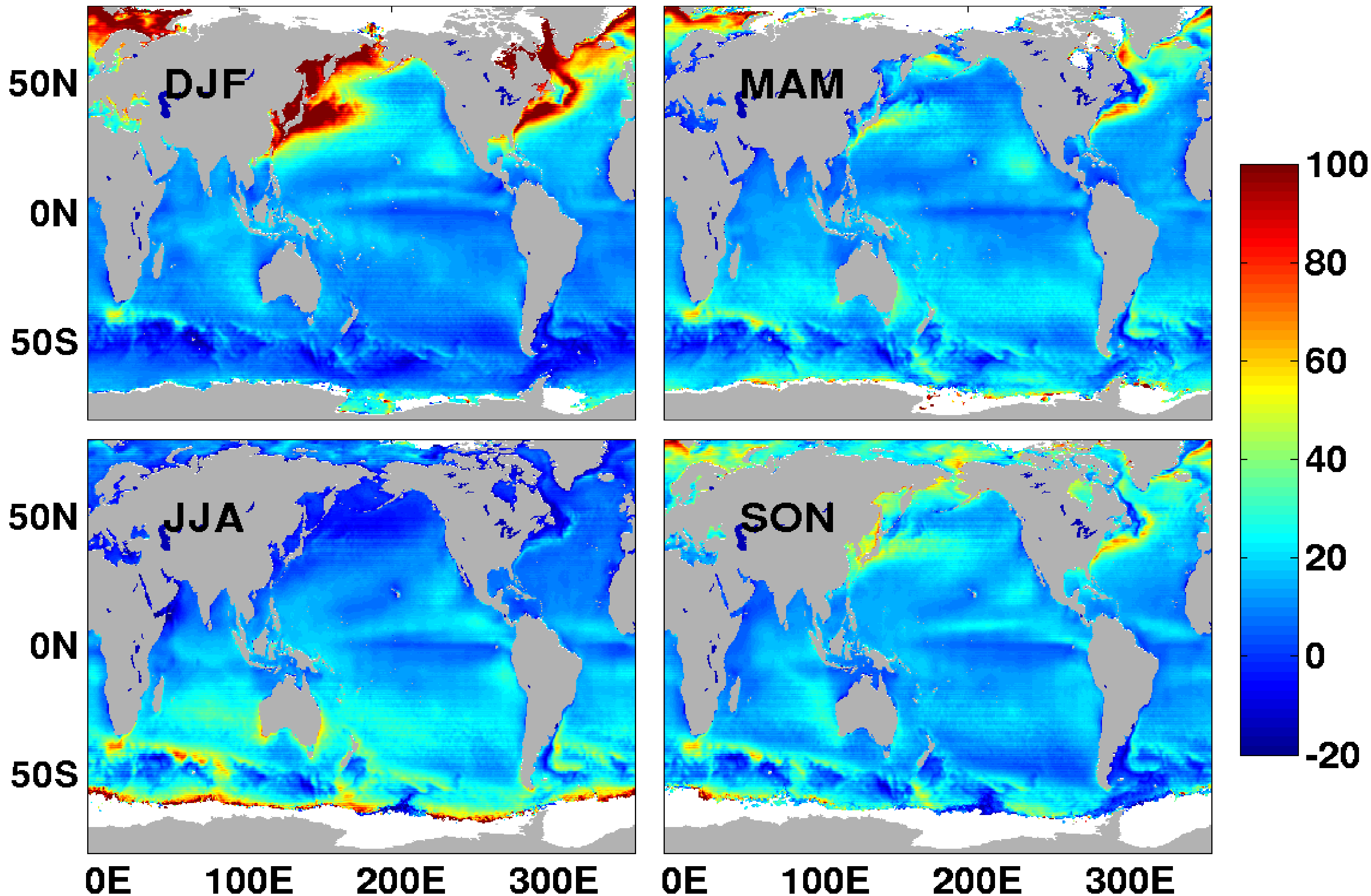
Daily Fluxes from Remotely Sensed Data



LHF Seasonal Patterns



SHF Seasonal Patterns



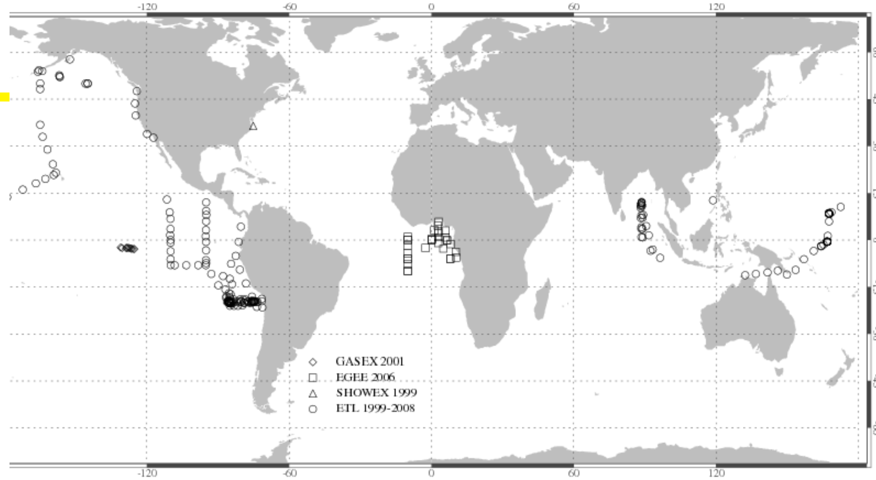
ifremer

Validation Procedure

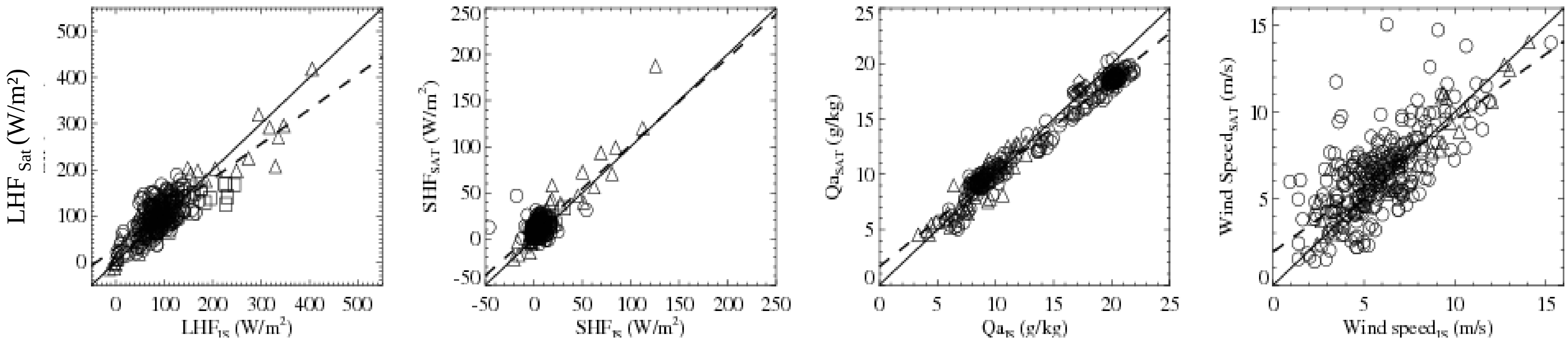
- Local/Regional Validations
  - ➢Experiment data : ETL; EGEE; GASEX; SHOWEX
  - ➢Buoy Estimates: TAO; PIRATA; RAMA; NDBC; MFUK
- Global Comparisons
  - ➢ In-situ: ICOADS (NOCS)
  - ➢ Re-analyses: ERA Interim (ECMWF); CFSR (NCEP/NCAR)
  - ➢ Satellite: SeaFlux V1 (WHOI)

Assessment of the Turbulent Flux Accuracy

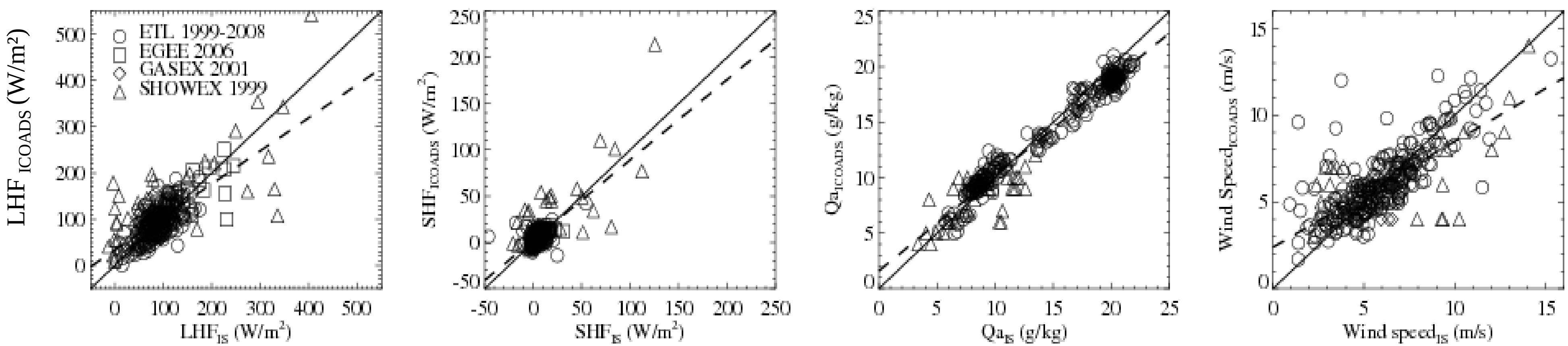
- Spatial and temporal Collocation of Daily Estimates



In-Situ / Satellite

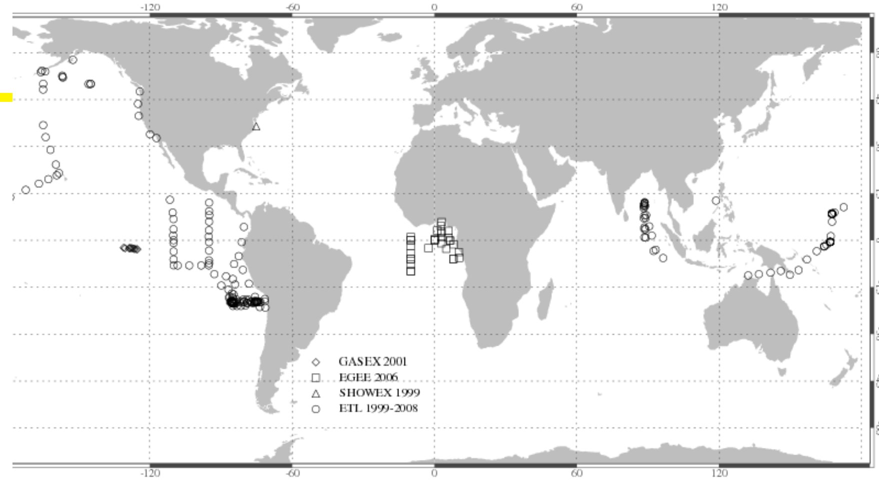


In-Situ / ICOADS(Berry et al, 2011)



ifremer

Assessment of the Turbulent Flux Accuracy



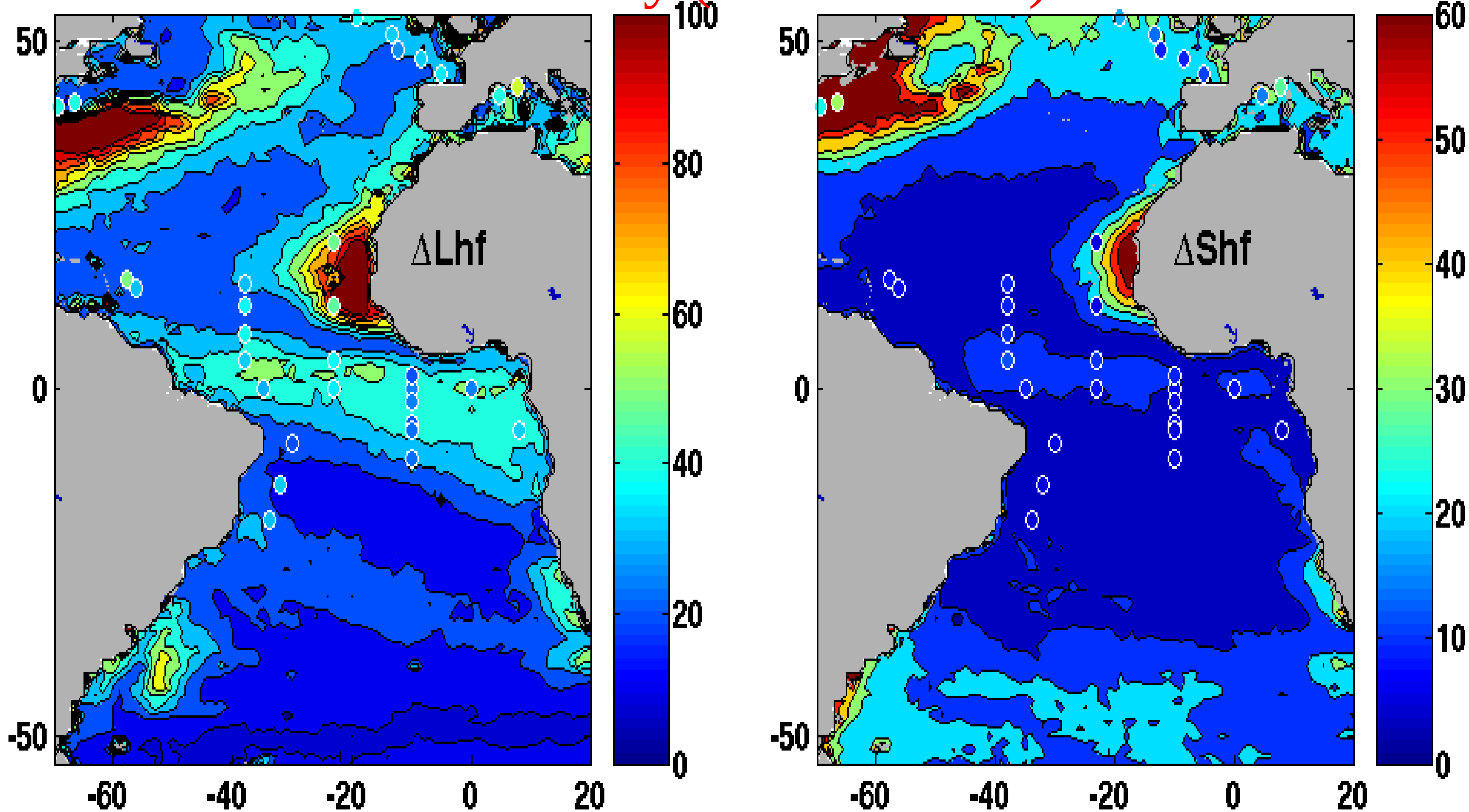
- Spatial and temporal Collocation of Daily Estimates
- Outliers are excluded

		LHF (W/m²)		SHF(W/m²)		Stress(10^{-3}N/m²)	
		Bias	SDE	Bias	SDE	Bias	SDE
	Ifremer	-6.0	31.5	-1.9	11.9	-7.5	23.3
Brunke *et al*, 2011	ERA-I	17.6	34.7	2.7	14.2	-2.3	43.3
	CFSR	19.3	44.8	-0.3	22.6	4.8	89.1
	HOAPS	1.7	50.3	-1.4	18.1		
	OAFLUX	11.6	41.0	2.2	18.1		

RMS Differences between

Buoy(MFUK; NDBC; Tropical) – Ifremer / Ifremer – Seaflux

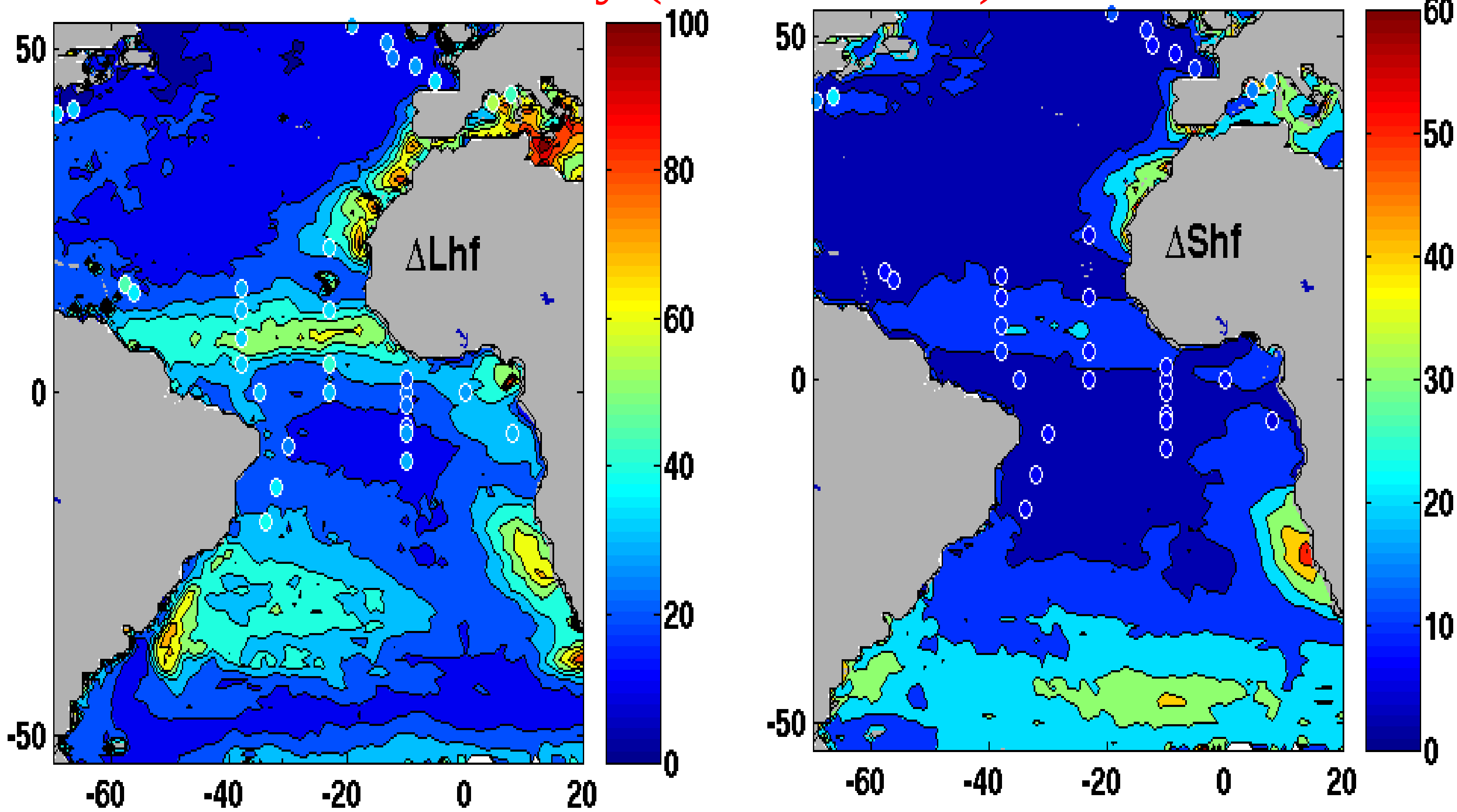
January (2003 – 2005)



RMS Differences between

Buoy(MFUK; NDBC; Tropical) – Ifremer / Ifremer – Seaflux

July (2003 – 2005)



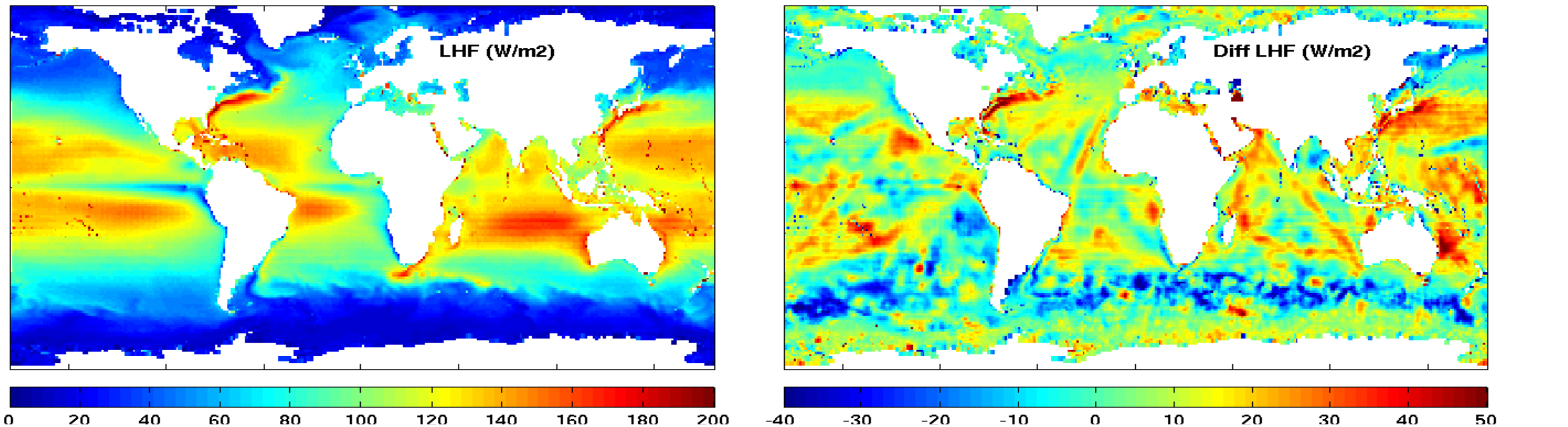
ICOADS / Satellite Comparisons
Impact of Basic Variables

$$dLhf = (\partial Lhf/\partial U)dU + (\partial Lhf/\partial Ce)dCE + (\partial Lhf/\partial Qa)dQa + (\partial Lhf/\partial Qs)dQs$$

$$= dLHF_U + dLHF_{Ce} + dLHF_{Qa} + dLHF_{Qs}$$

$$Lhf = \rho \times Lv \times U \times (Qs - Qa)$$

$dU = U_{nocs} - U_{satellite}$; $dCe = Ce_{nocs} - Ce_{satellite}$; $dQa = Qa_{nocs} - Qa_{satellite}$; $dQs = Qs_{nocs} - Qs_{satellite}$



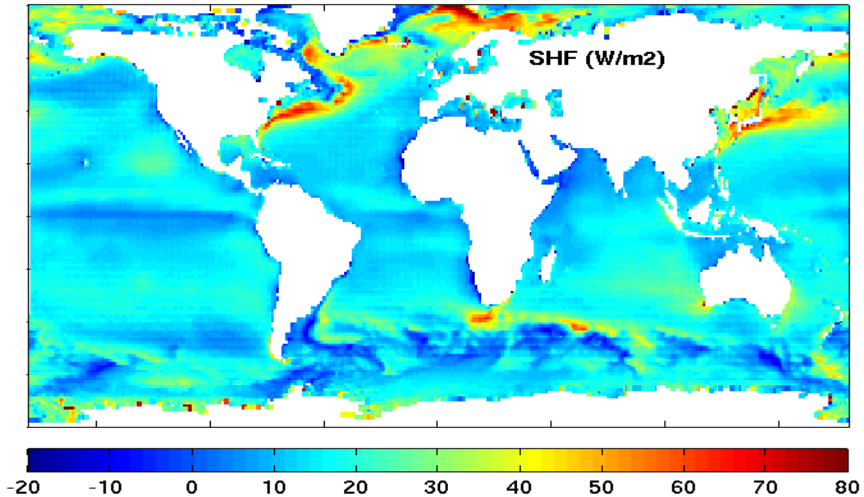
ICOADS / Satellite Comparisons
Impact of Basic Variables

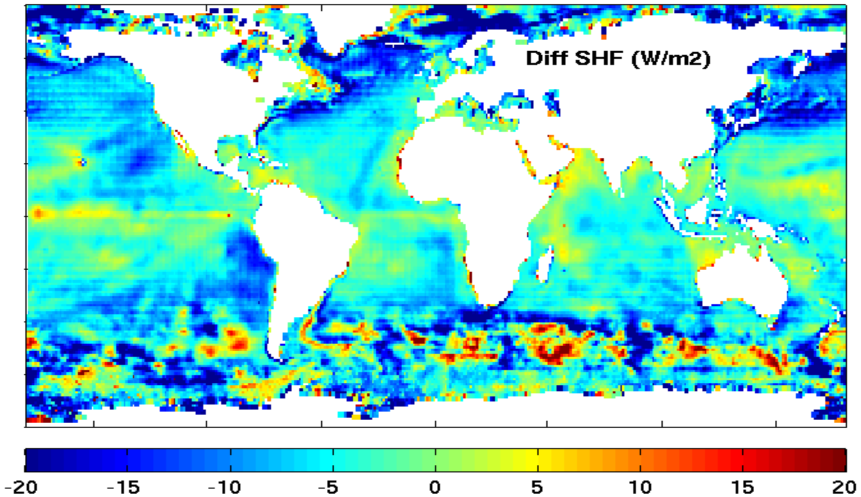
$$\mathbf{dShf = (\partial Lhf/\,\partial U)dU + (\partial Lhf/\,\partial Ch)dCH + (\partial Lhf/\,\partial Ta)dTa + (\partial Lhf/\,\partial Sst)dSst}$$

$$\mathbf{= dLHF_{U} \quad + \; dLHF_{Ch} \quad + \; dLHF_{Ta} \quad + \; dLHF_{Sst}}$$

$$Shf = \rho \times CP \times U \times (Sst - Ta)$$

$$dU = U_{buoy} - U_{satellite;}\; dCh = Ch_{buoy} - Ch_{satellite};\; dTa = Ta_{buoy} - Ta_{satellite};\; dSst = Qsst_{buoy} - Qsst_{satellite}$$





Summary / Perspectives

- **Flux Improvements are achieved**
- **Better Results at global scale**
- **Good Agreement with In-situ Estimates**
- **Long Time Series: 1999 - 2009**
- **Further Validations**
- **Spatial and Temporal Resolutions Issues**
- **Forcing Impact : exp. Upwelling systems**
- **Extended Time Period: 1992 - 2012**

ifremer

Ocean Surface Momentum and Heat Fluxes from remotely Sensed Observations.

$Q_{net} = Q_{sensible} + Q_{latent} + Q_{SWnet} + Q_{LW}$

Freshwater = Evaporation – Precipitation

Wind stress = (downward momentum flux)

- **Determination, improvement , and analysis of turbulent fluxes estimated from multi-satellite observations at high spatio-temporal resolutions over global ocean**