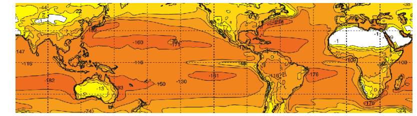
OHF



Towards improved estimate of turbulent heat flux over Global Oceans

OHF Project

Evaluating and Improving the Turbulent Components of the Net Heat Flux

Collaboration CLIVAR / WCRP

Main Scientific Objectives

WP1 (7 tasks / 27 sub tasks): Consolidation of Ocean Heat Flux Products

- Completed: 1
- 75% - 90%
- 50% - 75%

- Consolidation of flux product requirements related to sampling, accuracy, input data, ancillary data, error characteristics (**WP1.1**)

- Consolidation of flux method and algorithms (**WP1.3**)

- Identification of the product algorithm strengths and limitations (**WP1.4**)

- Consolidation of the flux product evaluation and validation strategy (**WP1.5**)

- Consolidation of the method aiming at the generation of a suitable ensemble of realization of turbulent fluxes (**WP1.6**)

Main Scientific Objectives

WP2 (<u>4 tasks / 23 sub tasks</u>): Collection and homogenization of a collection of inputs, turbulent and radiative fluxes and validation data for later product generation and Intercomparison.

- **Completed: 1**
- **75% - 90%**
- **50% - 75%**

- **Reprocessing Bulk inputs (Wind, Humidity, …) (WP2.1)**
- **Generate regional heat constraints for the cage study (WP2.3)**

Main Scientific Objectives

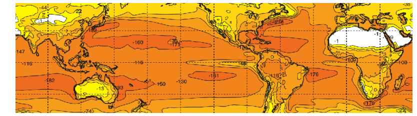
WP3 (<u>4 tasks / 26 sub-tasks</u>): Product Generation, Inter-Comparison and Uncertainty Characterizations

- **Completed: 1**
- **75% - 90%**
- **50% - 75%**

- **Sensitivity studies and algorithm improvement (WP3.1)**
- **Generation of an ensemble of realizations through “smart perturbations” (WP3.2)**
- **Evaluation of datasets and error characterization (WP3.3)**
- **Produce user handbook (WP3.4)**

Error Characterization Procedure

OHF



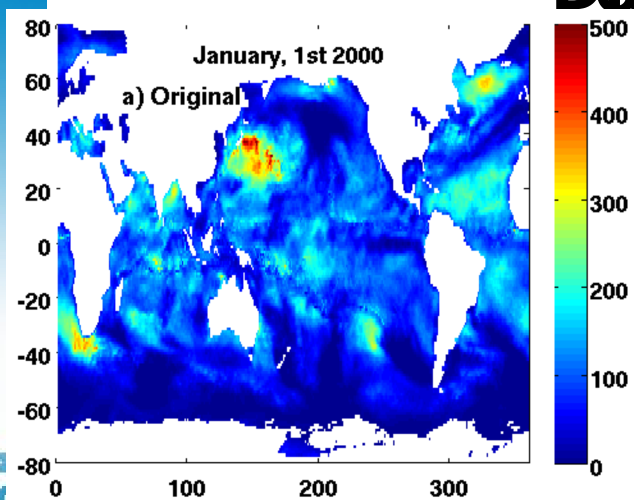
Standardization of Products: OHF Reference Products

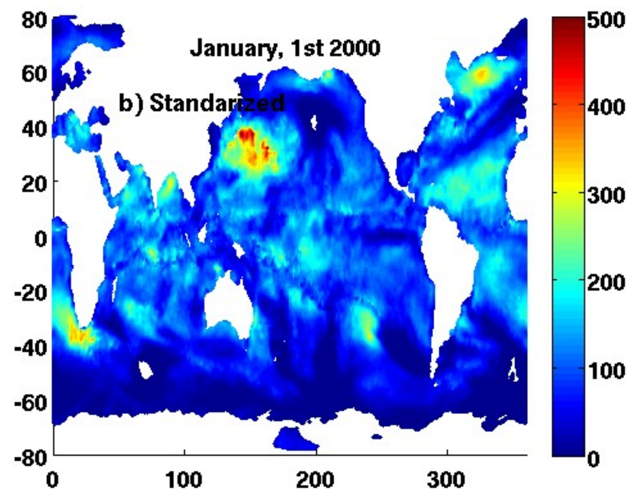
➢ **Estimation of each product data on same grid map over global oceans.**

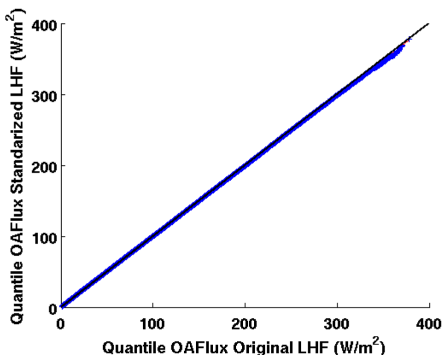
- **Daily / • 0.25° in longitude and latitude / • Global Oceans / • Land/Ice mask / • Format**

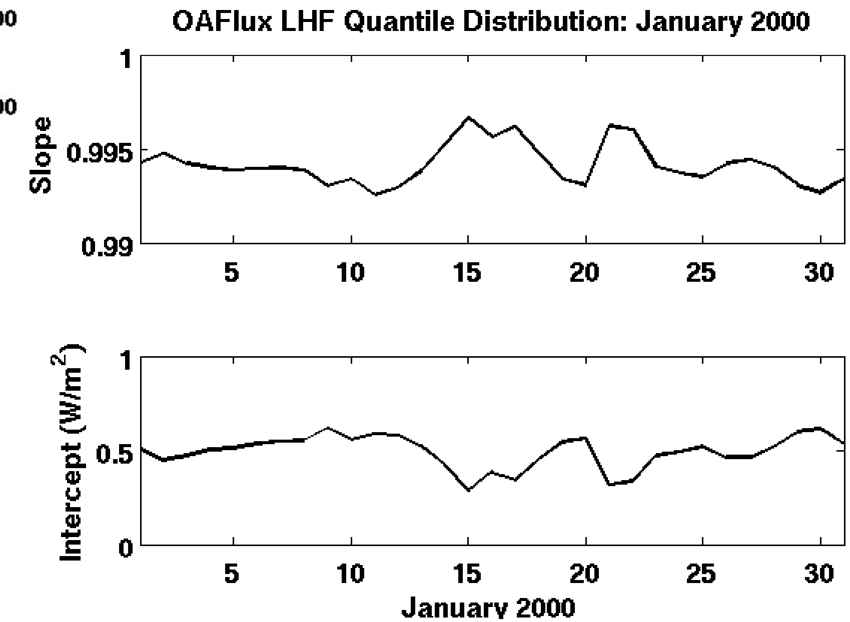
Standardized Vs. Original Flux Distributions

OAFlux



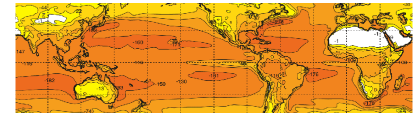


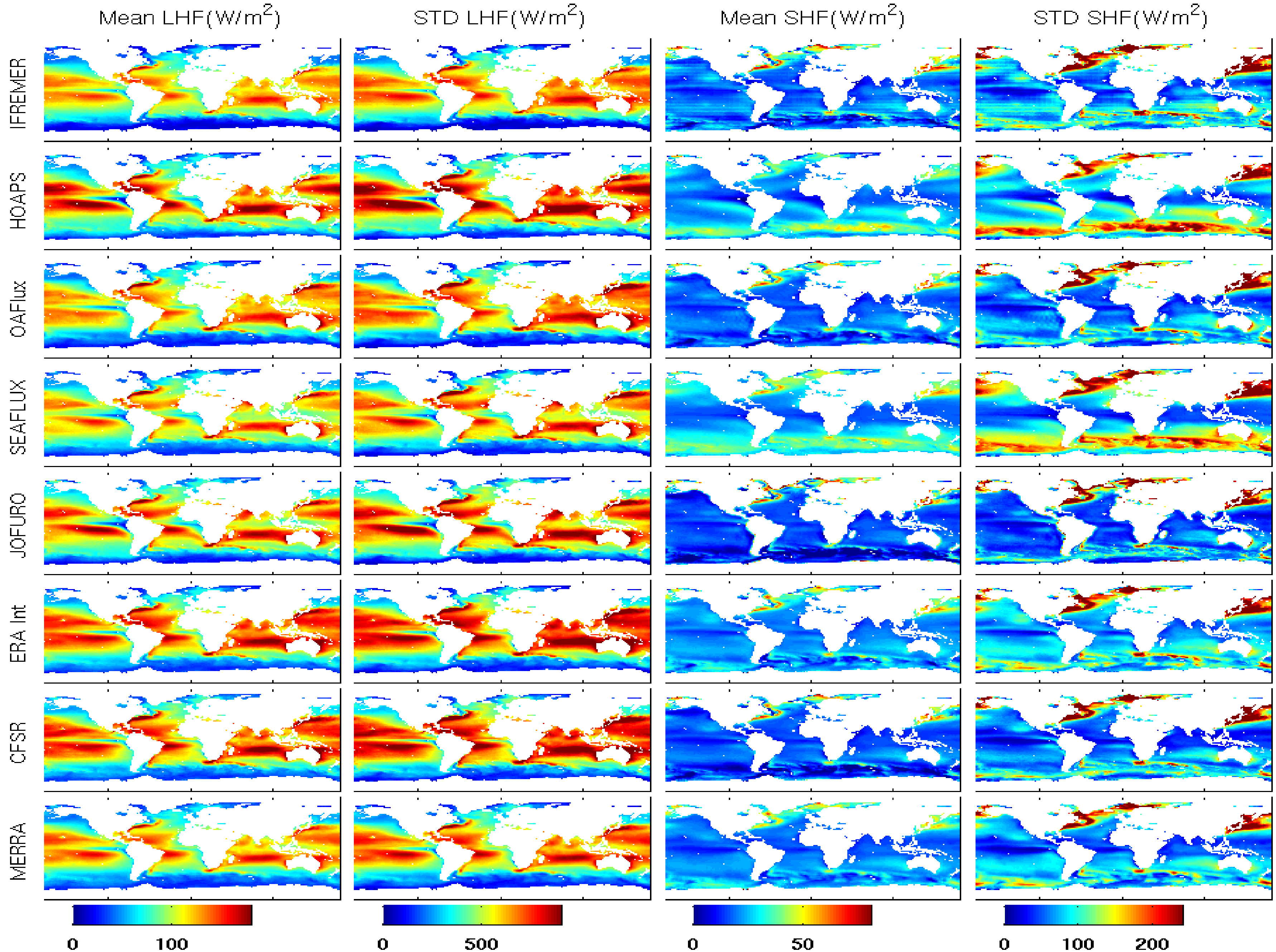




Annual Mean of OHF LHF and SHF

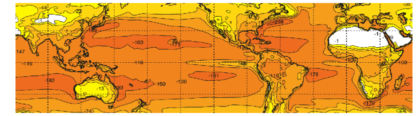
OHF



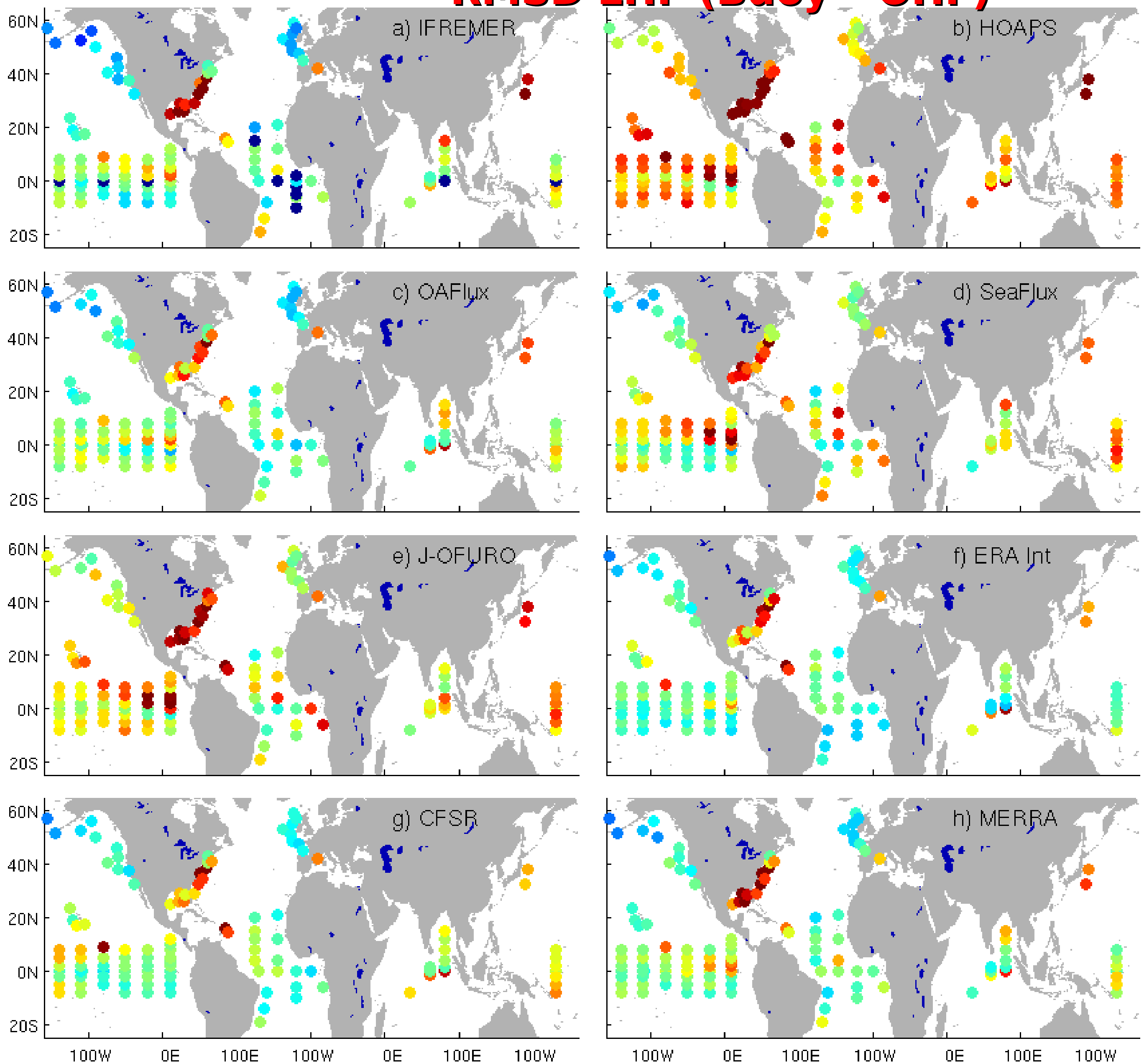


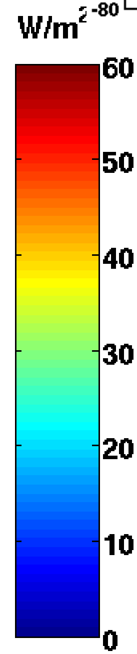
OHF LHF Product Accuracy

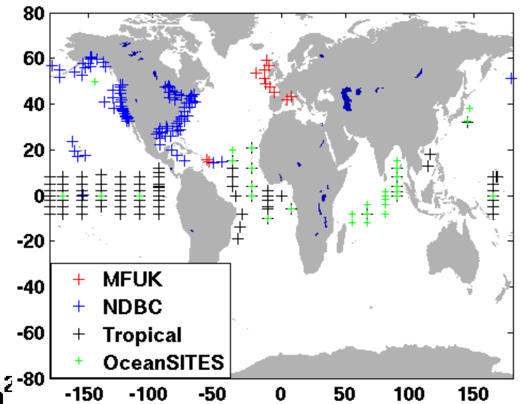
OHF



RMSD LHF (Buoy – OHF)

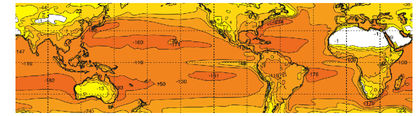


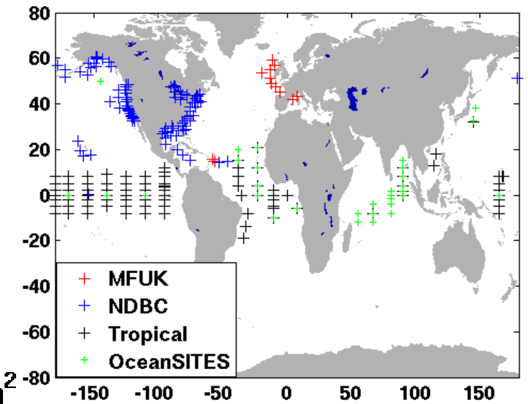




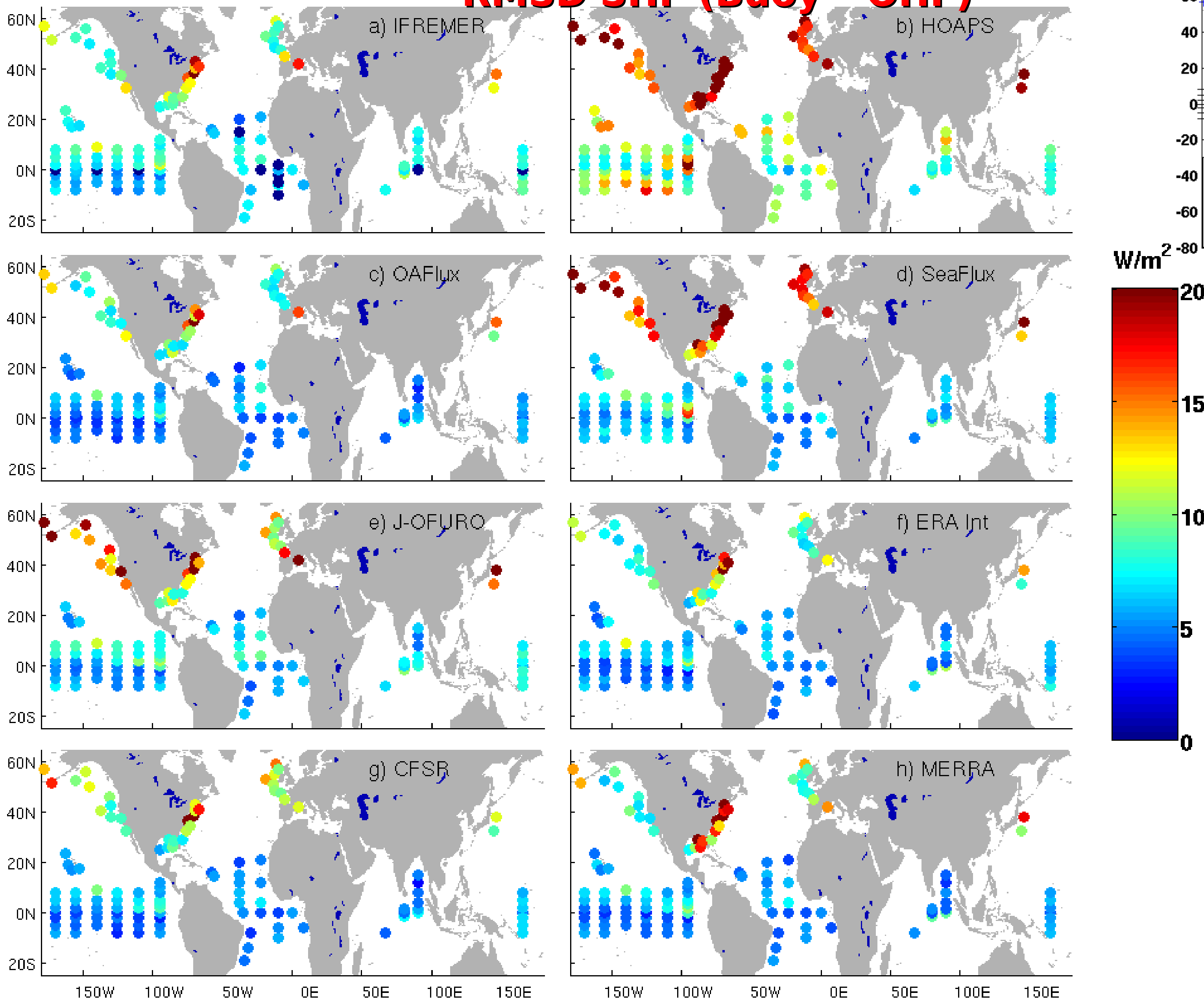
OHF SHF Product Accuracy

OHF

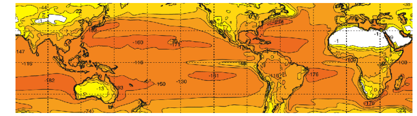




RMSD SHF (Buoy – OHF)



OHF



OHF Ensemble Determination

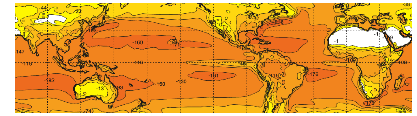
Error characteristics determined from in-situ and products comparison results

OHF MultiProduct Ensemble (OHF/MPE)

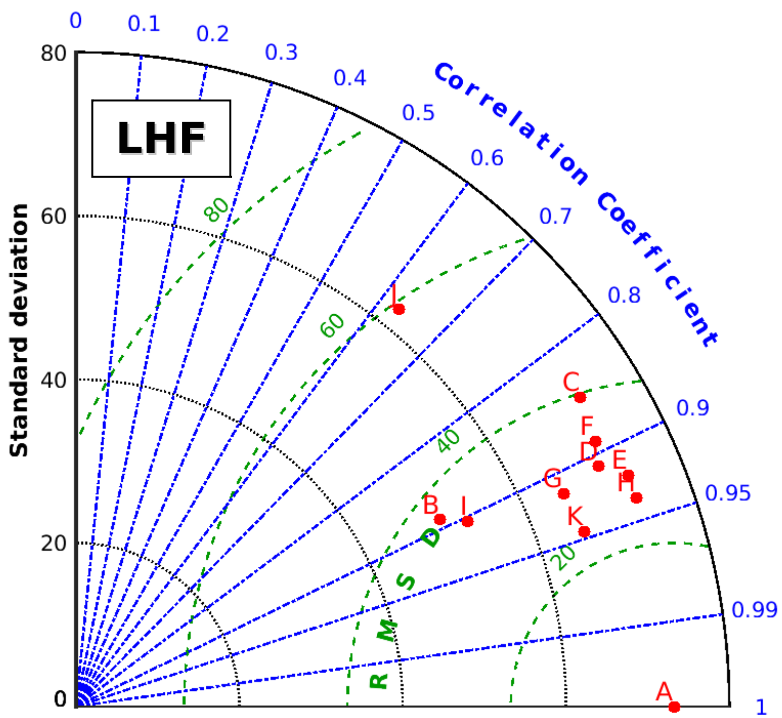
- **OHF/MPE is estimated based on the use of the standardized IFREMER, HOAPS, OAFlux, SeaFlux, J-OFURO, ERA Interim, and CFSR daily fluxes. It is calculated on a daily basis over the standardized OHF product grid map (0.25°×0.25°) over global free ice oceans.**
- **MERRA data is not used for OHF/MPE calculation. It is kept for further inter-comparison issues.**

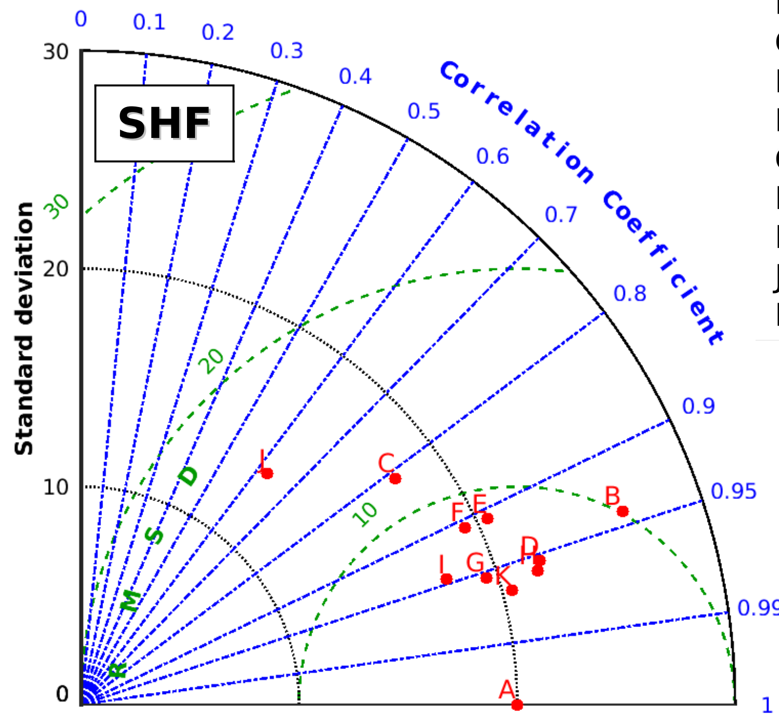
Ensemble (OHF/MPE) and Standardized Product Evaluation

OHF



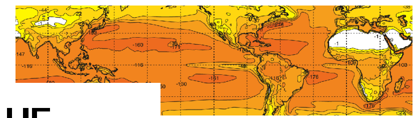
Taylor diagram summarizing the intercomparison results between daily <u>OceanSites</u> buoys and OHF a) LHF and b)SHF products calculated for the period 2000 - 2007

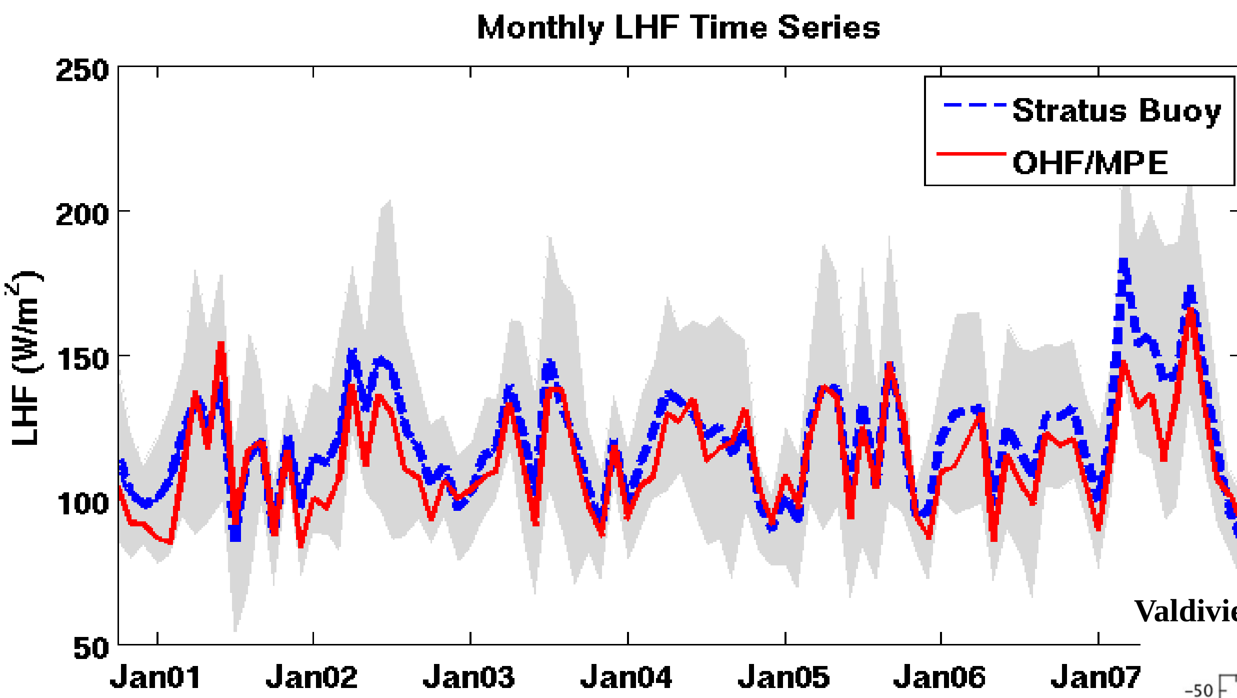


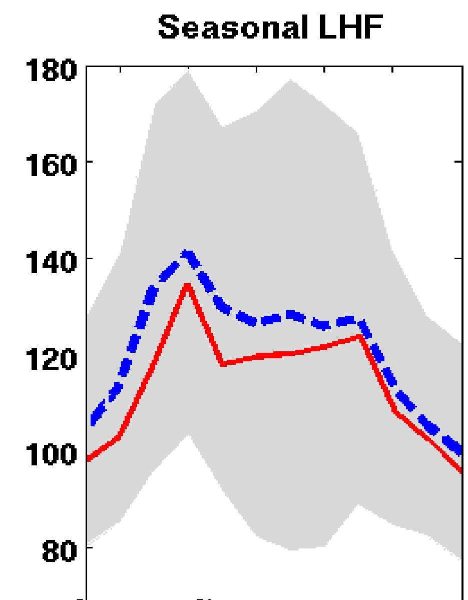


A : OceanSite buoy
B : Ifremer
C : Hoaps
D : OAFlux
E: SeaFlux
G: J-Ofuro
H: Era Interim
I: Cfsr
J: Nocs2
K: Ensemble(OHF/MPE)

OHF LHF and SHF Time Series

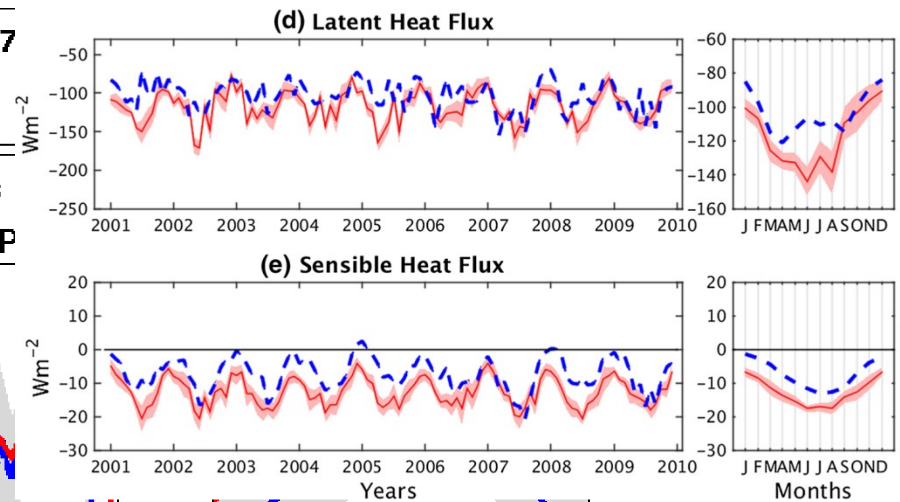


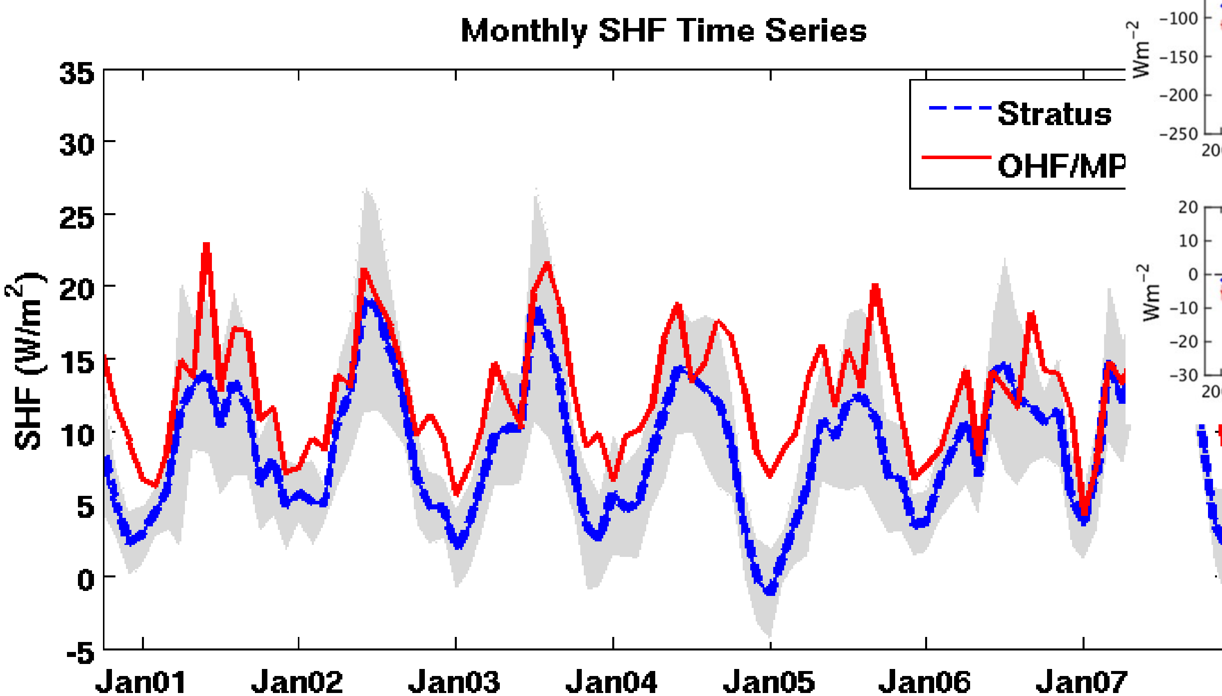


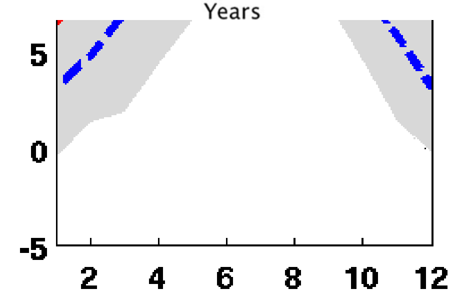


Stratus Buoy 19.9°S, 85.3°W ((WHOI), Weller *et al*, 2014)

Valdivieso *et al*, 2015 Clim. Dyn. *DOI 10.1007/s00382-015-2843-3*



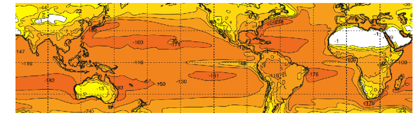


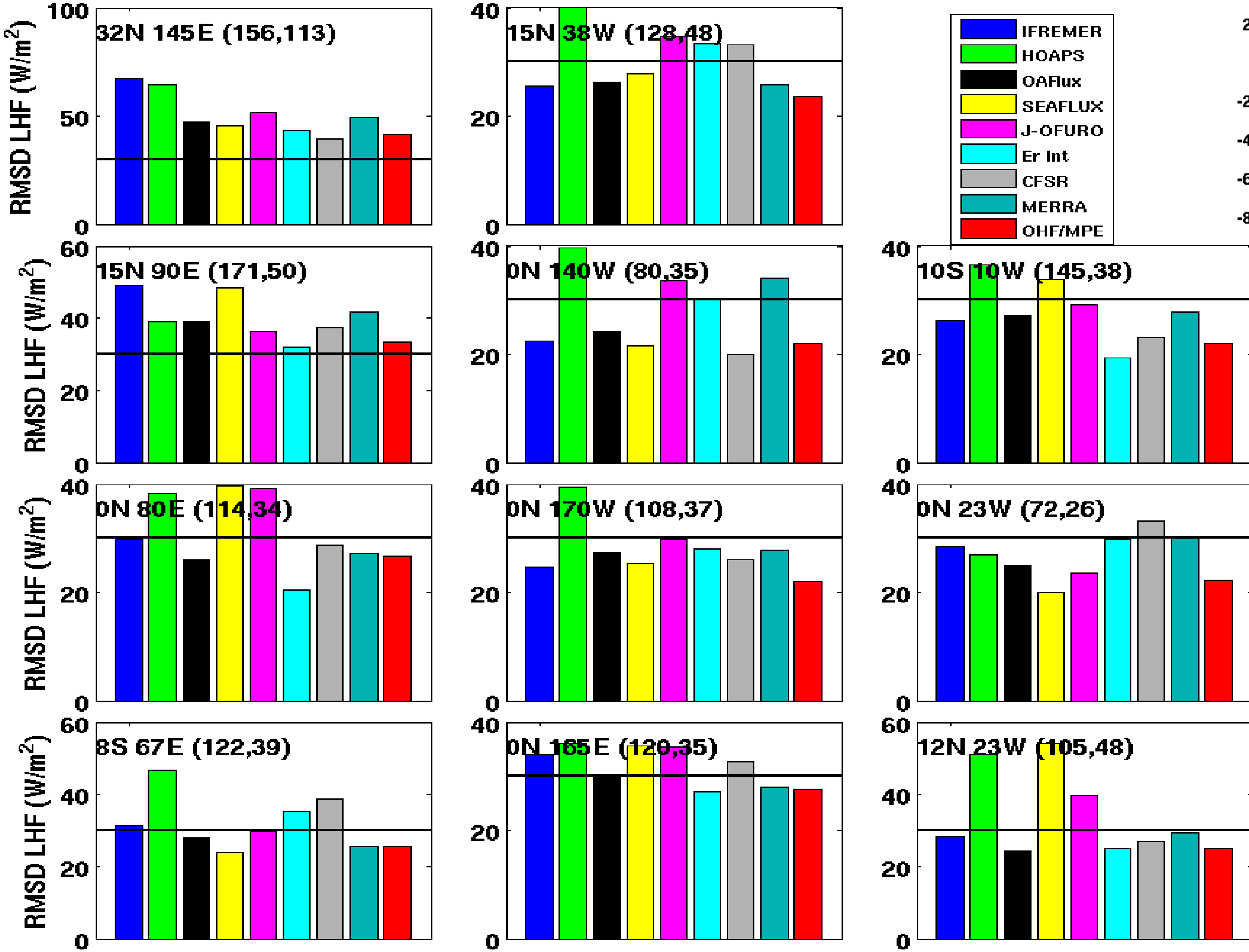


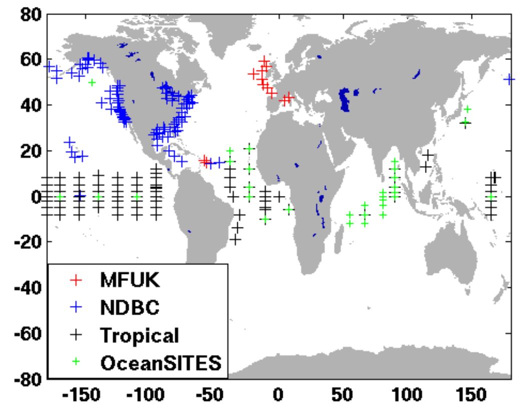
:aleza B razil

LHF RMSD at individual selected OceanSites buoy and each OHF product.

OHF





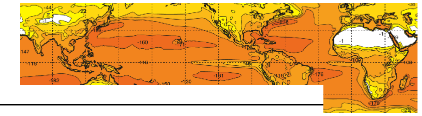


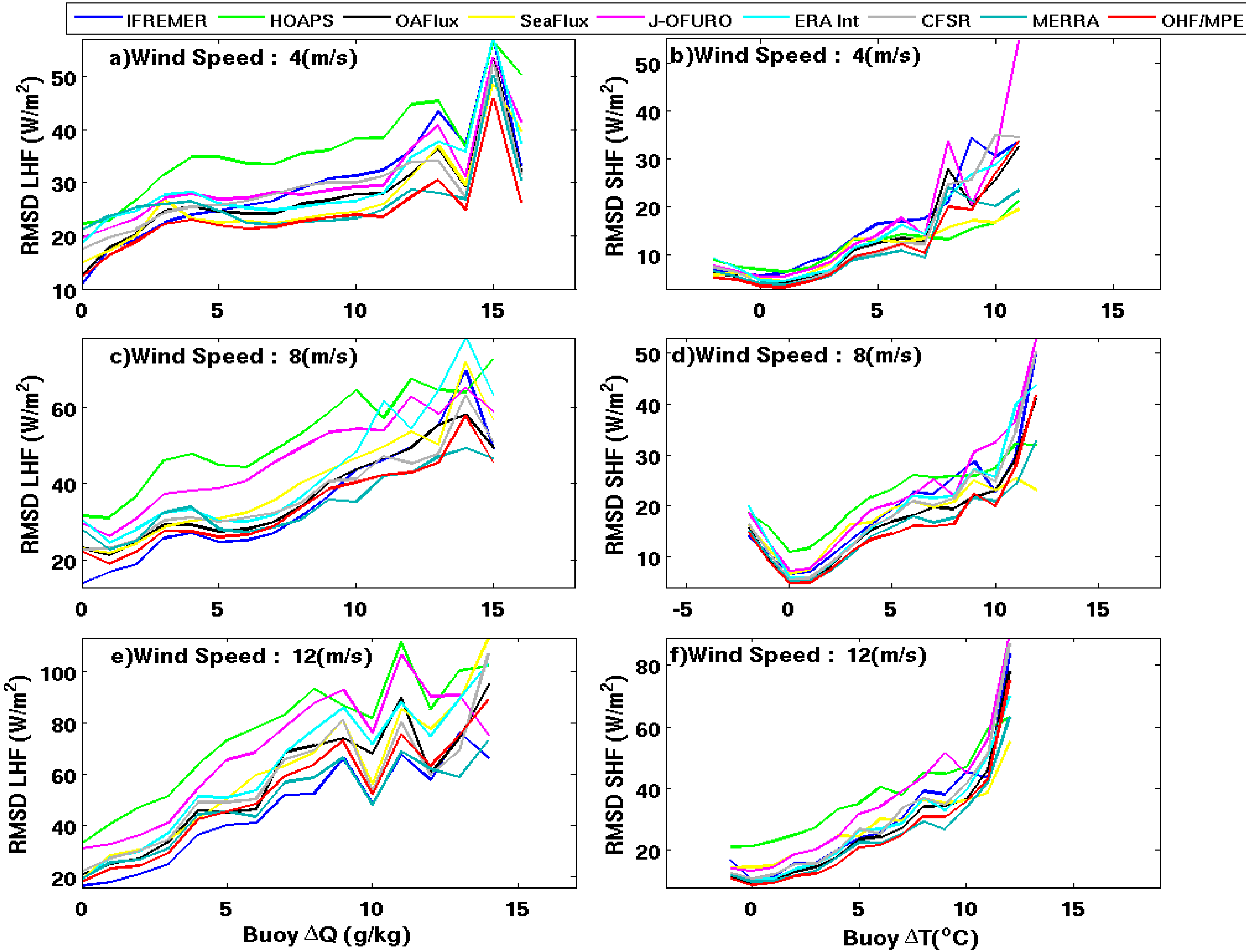
Error sources:

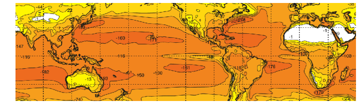
- Wind Speed
- Specific air humidity
- Air temperature
- ΔQ
- ΔT

LHF Accuracy as a Function of Bulk Variables

OHF







OHF WP3

Product Generation, Inter-Comparison and Uncertainty Characterizations

Evaluation of datasets and error characterization

- **Estimation of flux uncertainties (Clayson *et al*, 2013)**

$$\sigma_F=\sqrt{\left(\frac{\partial F}{\partial x}\right)^2\sigma_x^2+\left(\frac{\partial F}{\partial y}\right)^2\sigma_y^2+2r_{xy}\left(\frac{\partial F}{\partial x}\frac{\partial F}{\partial y}\right)\sigma_x\sigma_y}$$

$$\left(\frac{\partial F}{\partial x}\right)^2\sigma_x^2\Rightarrow\left(\frac{\partial F}{\partial x}\right)^2\sigma_{x,sys}^2+\left(\frac{\partial F}{\partial x}\right)^2\sigma_{x,ran}^2\left(N^{-1/2}\right)^2$$

F **== LHF or SHF Flux**

***x*, *y* are:**

- **bulk variable (Wind speed, specific humidity, SST, Ta,…) or**
- **Drag coefficients**

r_{xy} correlation coefficient

- ***Sys and ran*** **refer to the systematic and random components, respectively**
- ***N is the*** **sampling length of data collection.**

- **Total uncertainty for SHF as a function of *U*, (*Ts – Ta*), and C_H**

$\sigma_{SHF} = [(\rho a Cpa U(Ts - Ta)\sigma_{CH,sys})^2 + (\rho a Cpa C_H(Ts - Ta)\sigma_{U,sys})^2 + (\rho a Cpa C_H U\sigma_{(Ts-Ta),sys})^2 + 2r_{(Ts-Ta),U}((\rho a Cpa C_H)^2 (Ts - Ta)U\sigma_{(Ts-Ta),sys}\sigma_{U,sys}) + (\rho a Cpa U(Ts - Ta)\sigma_{CH,ran})^2 + (\rho a Cpa CH (Ts - Ta)\sigma U,ran)^2 + (\rho a Cpa C_H U\sigma_{(Ts-Ta),ran})^2 + 2r_{(Ts-Ta),U}((\rho a Cpa C_H)(Ts - Ta)U\sigma_{(Ts-Ta),ran}\sigma_{U,ran})]^{(1/2)}$

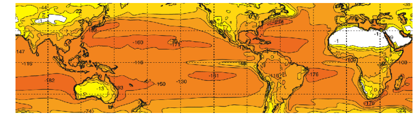
- **Total uncertainty for LHF as a function of *U*, (*Qs – Qa*), and C_E**

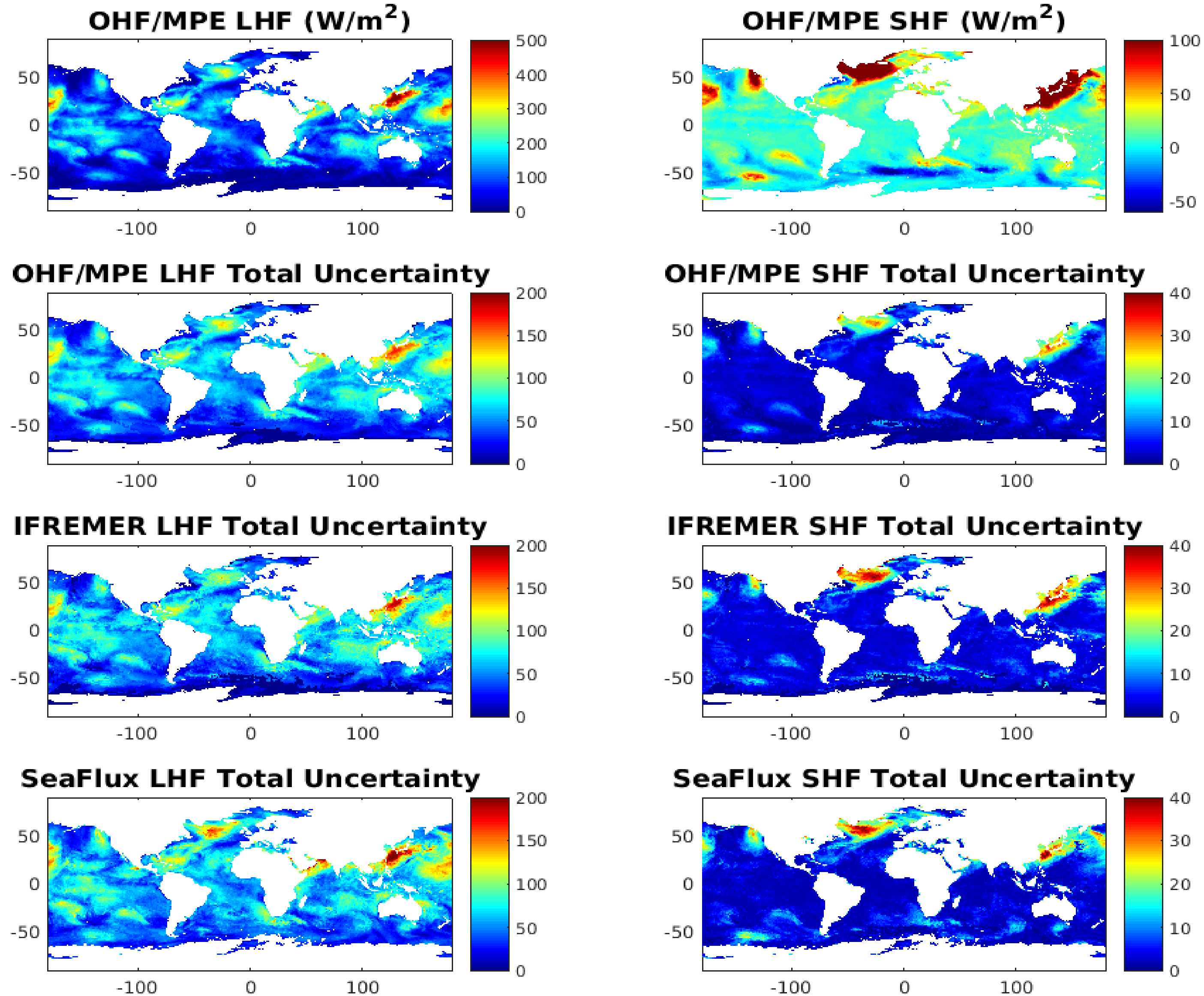
$\sigma_{LHF} = [(\rho a LvU(Qs - Qa)\sigma_{CE,sys})^2 + (\rho a LvC_E(Qs - Qa)\sigma_{U,sys})^2 + (\rho a LvC_E U\sigma_{(Qs-Qa),sys})^2 + 2r_{(Qs-Qa),U}((\rho a LvC_E)^2(Qs - Qa)U\sigma_{(Qs-Qa),sys}\sigma_{U,sys}) + (\rho a LvU(Qs - Qa)\sigma_{CE,,ran})^2 + (\rho a LvCE(Qs - Qa)\sigma_{U,ran})^2 + (\rho a LvCEU\sigma_{(Qs-Qa),ran})^2 + 2r_{(Qs-Qa),U}((\rho a LvCE)(Qs - Qa)U\sigma_{(Qs-Qa),ran}\sigma_{U,ran})]^{(1/2)}$

Total Uncertainty Estimated for OHF/MPE, IFREMER, and SeaFlux

for January, 1st 2005

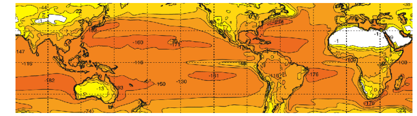
OHF

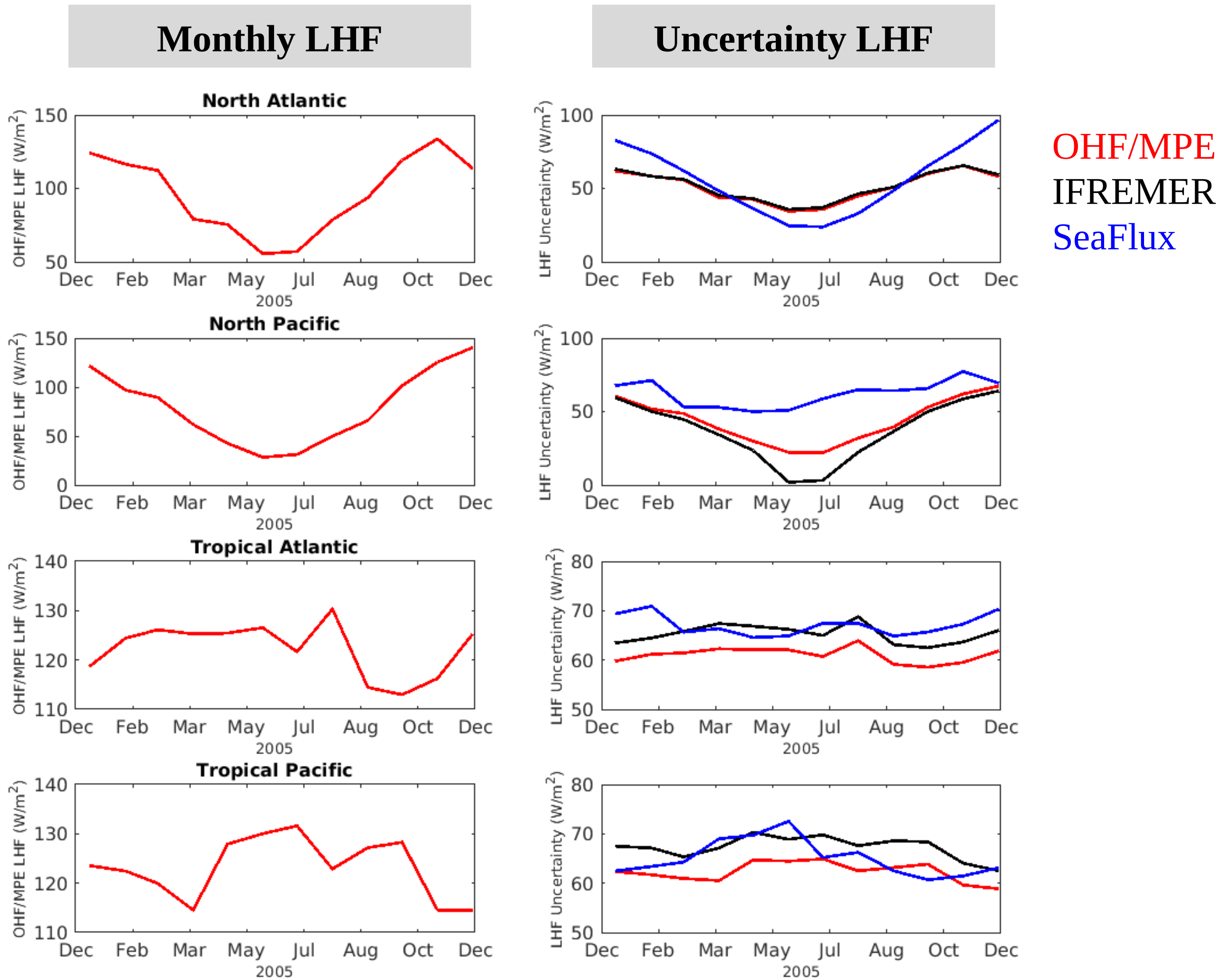




Monthly Total Uncertainty Estimated for OHF/MPE, IFREMER, and SeaFlux 2005

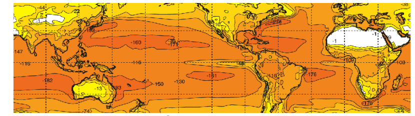
OHF





Uncertainties of OHF LHF and SHF Products

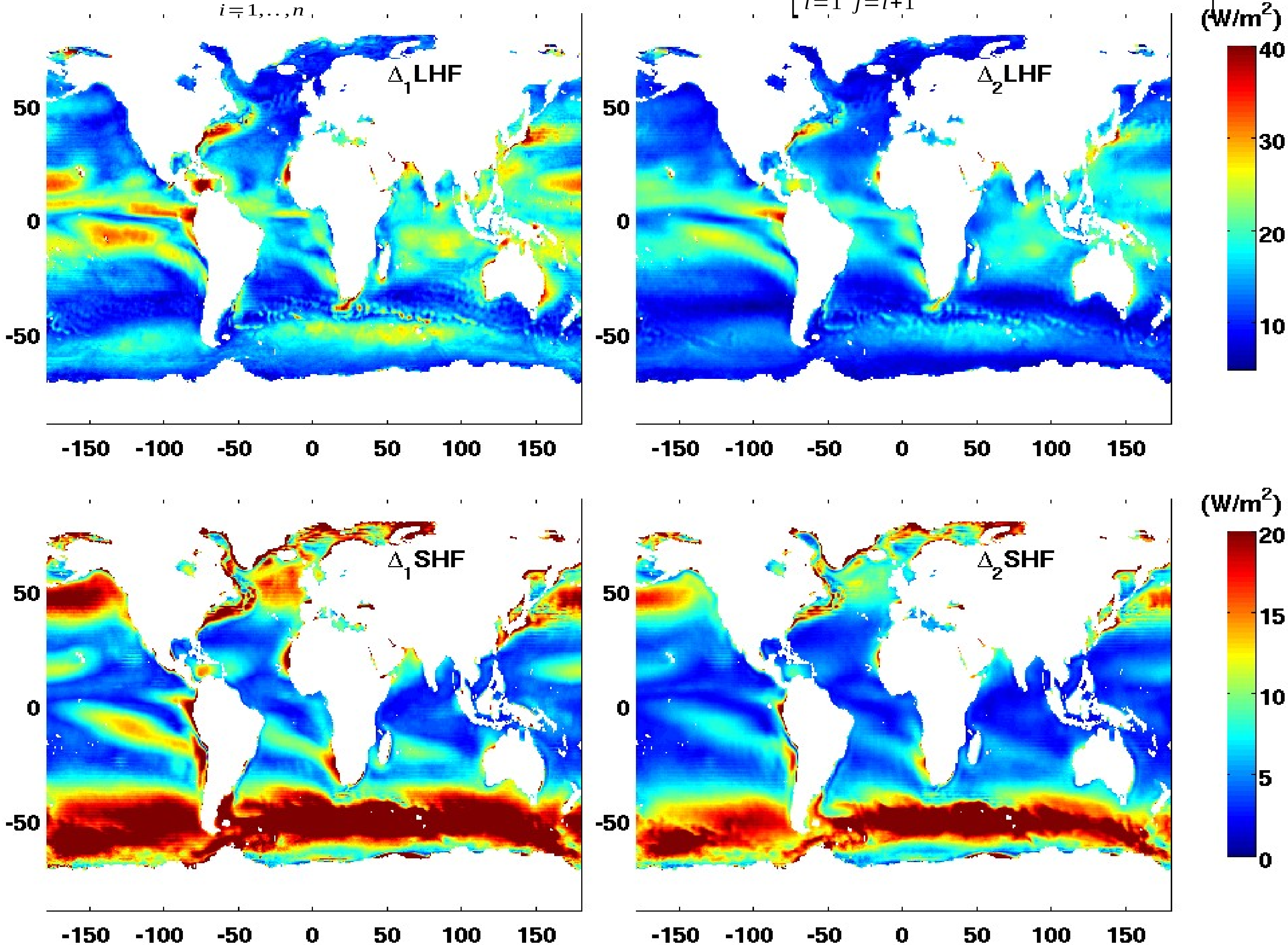
OHF



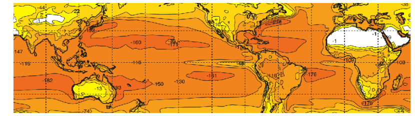
Găinuşă-Bogdan *et al*, 2015 (JGR)

$$\Delta_1 OHF = \max_{i=1,..,n} (|OHF_i - MPE|)$$

$$\Delta_2 OHF = \left[\sum_{i=1}^{n-1} \sum_{j=i+1}^{n} (OHF_i - OHF_j)^2 / C_2^n \right]^{1/2}$$



OHF



Summary

Results meet the main OHF requirements (WCRP, CLIVAR,…):

✓ **Determination of accuracy of existing satellite and NWP fluxes through direct pointwise comparisons with selected high accurate flux measurements such as derived from OCEANSITE and from dedicated experiments.**

✓ **Characterization of flux accuracy depending on atmospheric and oceanic conditions.**

✓ **Investigation of the impact of uncertainties of input variables and bulk parameterizations on the flux accuracy.**

✓ **Determination of the effect of spatial and temporal sampling on the resulting flux quality at global and regional scales.**

✓ **Development of an innovative *ensemble* approach to generate multiple realizations of EO based flux products. It should combine the existing data sets, the latest improvements in bulk formulations and associated input data, and the most recent efforts in the climate quality (e.g. CCI) re-processing of EO data.**

✓ **Assessment of the new flux quality based on the comparison with in-situ data.**

✓ **Development of Web-based interfaces to facilitate access to daily averaged and higher resolution heat fluxes and meteorological state variables from mooring sites and satellites.**

OHF Related Publications

- Desbiolles Fabien, Blanke Bruno, Bentamy Abderrahim, Roy C. (2016). Response of the Southern Benguela upwelling system to fine-scale modifications of the coastal wind . *Journal Of Marine Systems* , 156, 46-55 . Publisher's official version : http://doi.org/10.1016/j.jmarsys.2015.12.002
- Bentamy Abderrahim, Grodsky Semyon A., Elyouncha Anis, Chapron Bertrand, Desbiolles Fabien (2017). Homogenization of scatterometer wind retrievals . *International Journal Of Climatology* , 37(2), 870-889 . Publisher's official version : http://doi.org/10.1002/joc.4746
- Desbiolles Fabien, Bentamy Abderrahim, Blanke Bruno, Roy Claude, Mestas-Nunez Alberto M., Grodsky Semyon A., Herbette Steven, Cambon Gildas, Maes Christophe (2017). Two Decades [1992-2012] of Surface Wind Analyses based on Satellite Scatterometer Observations . *Journal Of Marine Systems* , 168, 38-56 . http://doi.org/10.1016/j.jmarsys.2017.01.003
- Bentamy Abderrahim, Piolle Jean-François, Grouazel AntoinePiolle , Danielson R., Gulev S., Paul Frederic, Azelmat Hamza, Mathieu P. P., Von Schuckmann Karina, Sathyendranath S., Evers-King H., Esau I., Johannessen J. A., Clayson C. A., Pinker R. T., Grodsky S. A., Bourassa M., Smith S. R., Haines K., Valdivieso M., Merchant C. J., Chapron Bertrand, Anderson A., Hollmann R., Josey S. A. (2017). Review and assessment of latent and sensible heat flux accuracy over the global oceans . *Remote Sensing Of Environment* , 201, 196-218 . http://doi.org/10.1016/j.rse.2017.08.016
- Pinker Rachel T., Bentamy Abderrahim, Zhang Banglin, Chen Wen, Ma Yingtao (2017). The net energy budget at the ocean-atmosphere interface of the "Cold Tongue" region . *Journal Of Geophysical Research-oceans* , 122(7), 5502-5521 . http://doi.org/10.1002/2016JC012581

Improvement Requirements : Considered Methods

- Using the new reprocessed ICOADS (Freeman *et al*, 2017)
  - Calibration and validation of model relating brightness temperature and Qa
- Using the new reporcessed surface wind field analyses (Desbiolles *et al*, 2017)
  - Homogenization of satellite retrievals
- Assessment of Air Temperature accuracy
  - Comparison to remotely sensed Ta estimates (e.g. Jackson and Wick, 2010)
- Assessment of SST and Air Temperature consistency
- ……..

Improvement Requirements : Considered Methods

Regarding Bulk approach for Estimating OHF at Global scale:

Reprocessing Qa

Reprocessing Satellite Wind Retrievals

Long Time Series of OHF over Global Ocean 1992 - 2012

Accuracy investigation at various spatial and temporal scales

Accuracy Issue