WHOI Analysis of Daily Air-Sea Heat Fluxes for the Atlantic Ocean

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1. Introduction

High-quality, time-dependent, and basin-to-global-scale air-sea heat fluxes are of great interest to climate research community for modeling and understanding coupled variability of the atmosphere-ocean system. Surface heat fluxes can be computed from bulk algorithms using surface meteorological variables obtained from three sources: marine surface weather reports from Voluntary Observing Ships (VOS), satellite remote sensing, and outputs of numerical weather predication (NWP) models such as those at NCEP (National Centers for Environmental Prediction) and ECMWF (European Centre for Medium-Range Weather Forecasts). However, different sources have different spatial coverages and different sampling rates, and those differences influence both temporal and spatial representativeness of resulting flux estimates. The present study is to demonstrate that we can produce daily gridded heat flux fields with improved quality by using advanced objective analysis to combine the advantages of the three data sources.

2. Methodology

The WHOI analysis of air-sea heat fluxes for the Atlantic Ocean covers the period from 1988 to 1999 with daily and 1° × 1° resolution. The latent and sensible heat fluxes are created from a synthesis of several data sources by a weighted objective analysis and from the use of the COARE bulk flux algorithm 2.6a. The development procedure is shown in the flow-chart in Fig.1. The net shortwave and longwave radiations are derived from the International Satellite Cloud Climatology Project (called ISCCP-FD dataset, kindly provide by Dr. William B. Rorrow). The ISCCP-FD data are available every three hours over the whole globe on 2.5° × 2.5° grid covering the time period July 1983 through June 2001. To derive a radiation dataset for the Atlantic Ocean that has the same spatial and temporal resolution as the latent and sensible heat fluxes, daily average and linear interpolation in space were applied to the ISCCP-FD data.

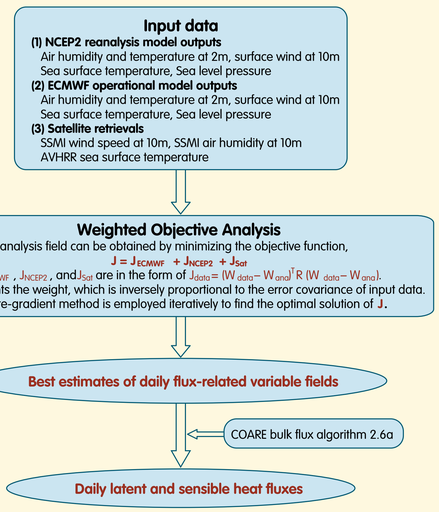

Fig.1 Flow chart of the development procedure for WHOI latent and sensible heat fluxes

3. FTP site for downloading WHOI flux data

WHOI air-sea heat fluxes and related meteorological variables for the Atlantic Ocean (65°S - 65°N) with daily and 1°×1° resolution for the period from 1988 to 1999 can be downloaded from the WHOI ftp site: ftp://ftp.whoi.edu/pub/users/lyu/flux. There are two subdirectories.

Subdirectory of turbulent contains:	Subdirectory of radiation contains
Latent heat flux	Net shortwave radiation
Sensible heat flux	Upward shortwave radiation
Wind speed at 10 m	Downward shortwave radiation
Sea surface temperature	Net longwave radiation
Air temperature at 2 m	Upward longwave radiation
Air humidity at 2 m	Downward longwave radiation

4. Comparison with ECMWF, NCEP1, NCEP2 at in situ flux buoy/ship locations

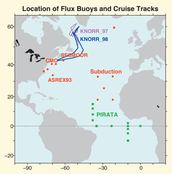

Fig. 2 Location of flux buoys and cruise tracks used in the validation analysis. The WHOI surface mooring sites are denoted by red dots.

In situ flux buoy/ship measurements at limited locations provide valuable benchmark time series for quantifying the accuracy of flux products. Over the 12-year synthesis period from 1988 to 1999, there exist a dozen flux buoy deployments plus the Pilot Research Moored Array in the Tropical Atlantic (PIRATA) and a few cruises in the Atlantic basin north of 15°S (Fig.2). The comparisons between measurements and the WHOI analysis are shown in Figs 3-4. To facilitate the assessment of the improvement over the NWP outputs, the plots include also ECMWF and NCEP1&2 outputs. At all sites, the WHOI flux estimates not only have a mean closest to the measurement value but also have standard deviation smallest among all products. In general, ECMWF and NCEP1&2 overestimate the latent and sensible heat losses everywhere by about 10–35 %.

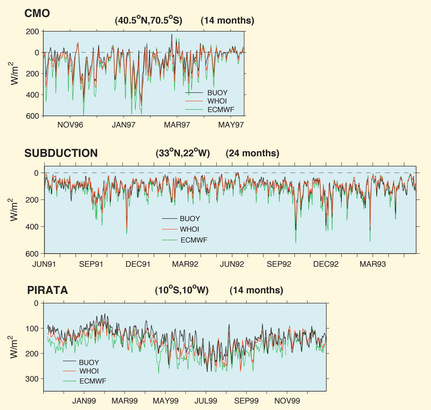

Fig.3 (a) Time series comparison of latent and sensible fluxes with buoy measurements

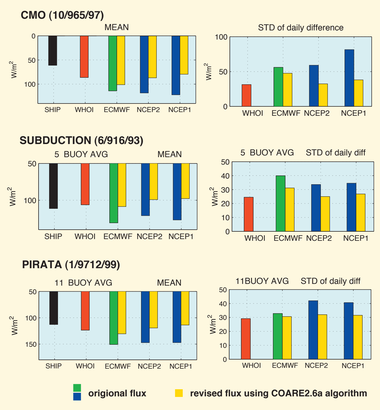

Fig. 3 (b) bar plots of mean flux averaged over the measurement periods and standard deviation of daily differences between flux analysis and buoys.

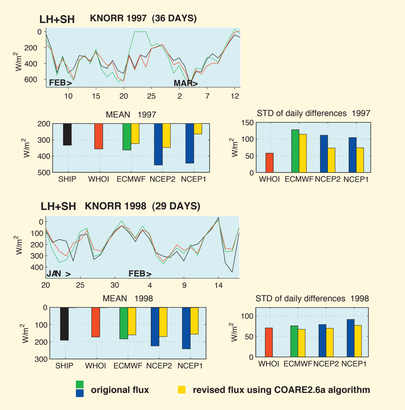

Fig.4 (a) Time series comparison of latent and sensible fluxes with Knorr measurements; (b) bar plots of mean flux averaged over the measurement periods and standard deviation of daily differences between flux analysis and ship measurements.

5. Comparison with SOC, NCEP1, NCEP2 flux products

The flux climatology analysis of the Southampton Oceanographic Centre (SOC) was composed from marine surface weather reports from Voluntary Observing Ships. This dataset provides an independent reference for the basin-scale long-term mean field structure (Fig.5). The WHOI analysis agrees considerably well with the SOC climatological analysis – despite the major differences in data source, approach, and temporal resolution used in making these two data sets. The mean net heat flux pattern from WHOI analysis differs greatly from NCEP1&2 in the tropical and subtropical regions.

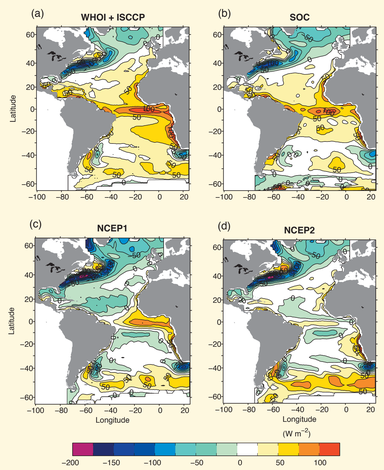

Fig.5 Net surface heat flux averaged over the period of 1988-1997 from (a) WHOI analysis, (b) SOC climatological analysis, (c) NCEP1 reanalysis, and (d) NCEP2 reanalysis.

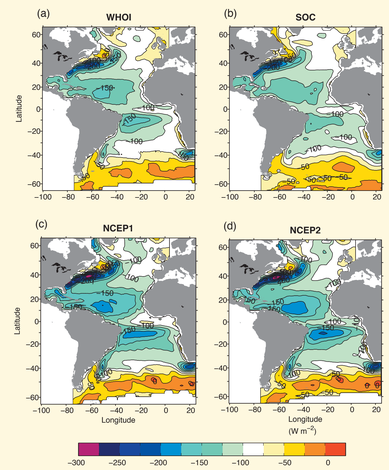

Fig.6 Turbulent latent and sensible heat flux averaged over the period of 1988-1997 from (a) WHOI analysis, (b) SOC climatological analysis, (c) NCEP1 reanalysis, and (d) NCEP2 reanalysis.

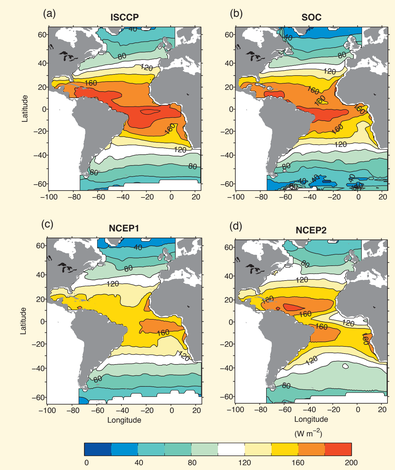

Fig.7 Net radiation flux averaged over the period of 1988-1997 from (a) WHOI analysis, (b) SOC climatological analysis, (c) NCEP1 reanalysis, and (d) NCEP2 reanalysis.

6. Summary

We present in this study the WHOI analysis of daily heat fluxes with 1° by 1° resolution for the Atlantic Ocean (65°S - 65°N) for the period from 1988 to 1999. The latent and sensible heat fluxes are developed through a synthesis of several data sources using a weighted objective analysis and the state-of-the-art COARE bulk flux algorithm. The net shortwave and longwave radiations are derived from International Satellite Cloud Climatology Project (called ISCCP-FD dataset, kindly provide by Dr. William B. Rorrow) that is available every three hours on 280-km equal-area global grid. The presentation shows the validation of WHOI latent and sensible heat flux analysis with in situ flux buoy/ship measurements and the comparison of the WHOI net heat flux with SOC climatology and NCEP1 and NCEP2 reanalysis flux products. Major results are summarized as follows.

- The validation study indicates that the WHOI flux analysis represents an improvement over the NWP fluxes. The NWP fluxes systematically overestimate the turbulent heat losses everywhere by 10–35 %.
- The good consistence in mean net heat flux field between WHOI analysis and independent SOC climatological analysis justifies the long-term mean aspect of WHOI analysis.
- The mean net heat flux field from WHOI analysis differs from those from NCEP1&2 reanlaysis products, and the differences are particularly pronounced in the tropical and subtropical regions.
- The WHOI analysis of daily surface heat flux for the Atlantic is available from the ftp site: ftp://ftp.whoi.edu/pub/users/lyu/flux.

8. Acknowledgments

This work is support by the NOAA CLIVAR-Atlantic program under Grant NA06GP0453.

9. For further information

Project website
http://www.whoi.edu/science/PO/people/lyu/

Publications

Sun, B., L. Yu, and R. A. Weller, 2003: Comparisons of surface meteorology and turbulent heat fluxes over the Atlantic: NWP model analyses versus moored buoy observations. J. Clim., 16, 679-695.

Yu, L., R. A. Weller, and B. Sun, 2004: Improving latent and sensible heat flux estimates for the Atlantic Ocean (1988-1999) by a synthesis approach. J. Clim. 17, 373-393.

Yu, L., R. A. Weller, and B. Sun, 2004: Mean and variability of the WHOI daily latent and sensible heat fluxes at in situ flux measurement sites in the Atlantic Ocean. J. Clim. In Press.