The HOAPS Climatology: Evaluation of Latent Heat Flux

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Introduction

Big advances in the investigation of the global ocean water cycle have been made by combined use of intercalibrated infrared and microwave satellite data in the last two decades. This largely broadens our knowledge of the detailed ocean atmosphere interaction by deriving high resolution products of precipitation, evaporation, and hence the resulting freshwater and energy fluxes. Such data also serve as a basic requirement for modelling of the global climate system by constraining the heat and freshwater transports at the ocean atmosphere interface (e.g. Flux News 4, Stammer) and the evaluation of the surface fluxes in coupled ocean atmosphere models. For the latent heat component of the water cycle at least five international groups exist that provide frequently updated remote sensing and in-situ data sets that can be compared to our HOAPS product. Intercomparisons of climatological means between these satellite-based data sets on global scale are presented in the following along with the corresponding zonal means. Also important is the temporal development of the latent heat parameter during the last 18 years between 1988 and 2005.

Data Products

HOAPS (Hamburg Ocean Atmosphere Parameters and fluxes from Satellite data) is a purely satellite based climatology of 15 global ocean water cycle parameters covering a time period from July 1987 to December 2005 (Andersson et al., 2007). HOAPS is based on brightness temperatures of the Special Sensor Microwave / Imager (SSM/I) and additionally uses NODC/RSMAS Pathfinder version 5 SST data. Inter-sensor calibration provides a homogeneous and reliable spatial and temporal coverage. The recent version HOAPS-3 is available in half degree gridded data of pentad and monthly means (HOAPS-G), twice daily data on a one degree grid (HOAPS-C) and SSM/I pixel-level resolution for each individual satellite (HOAPS-S). The results presented in this study are based on monthly mean HOAPS-G data. The latent heat product in units of W/m^2 is estimated using the bulk aerodynamic approach after Fairall (1996 and 2003).

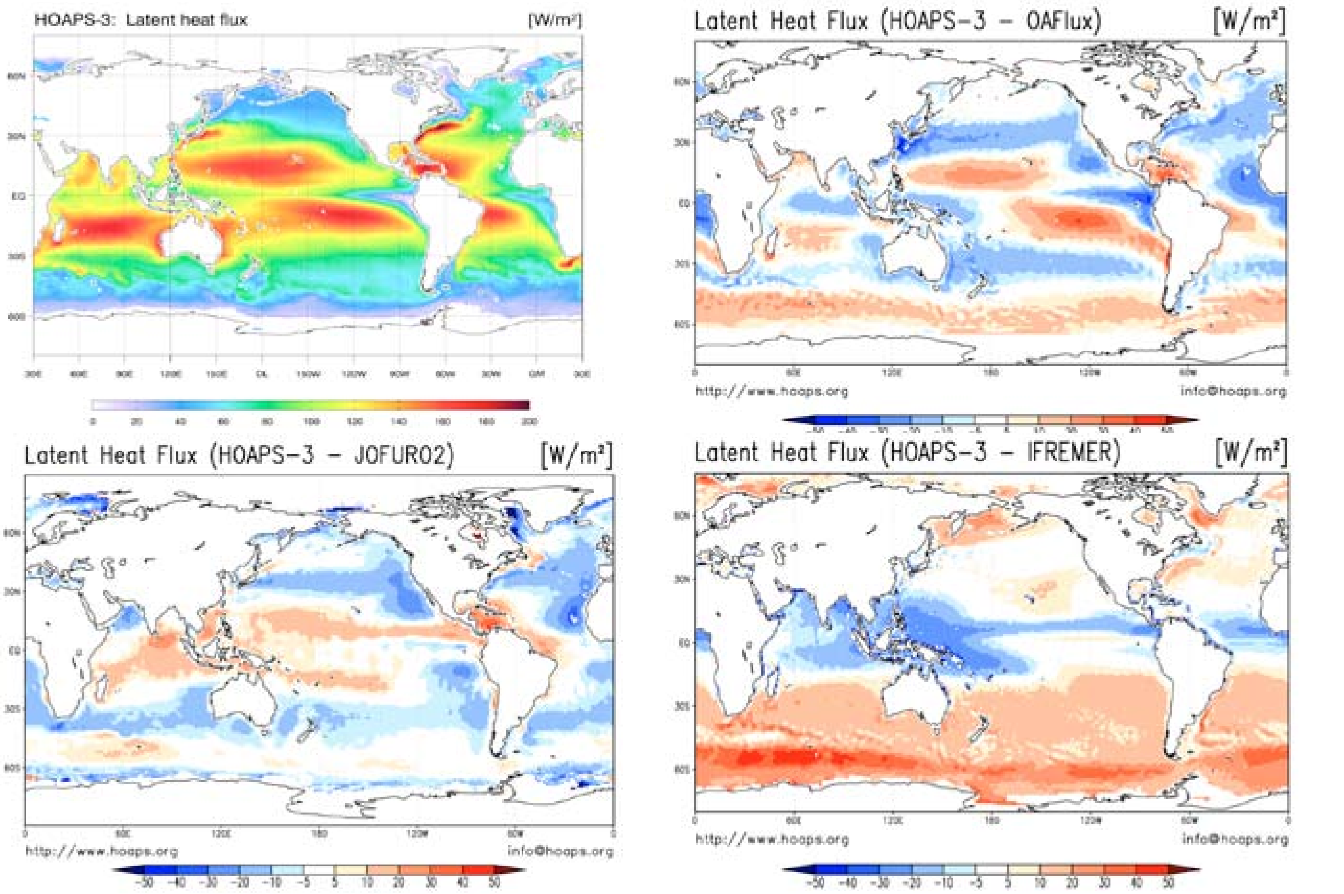

Figure 1: Climatological latent heat flux of HOAPS-3 between 1988 to 2005 (upper left panel) and difference plots for OAFlux (upper right), J-OFURO2 (lower left) and IFREMER (lower right) in W/m^2.

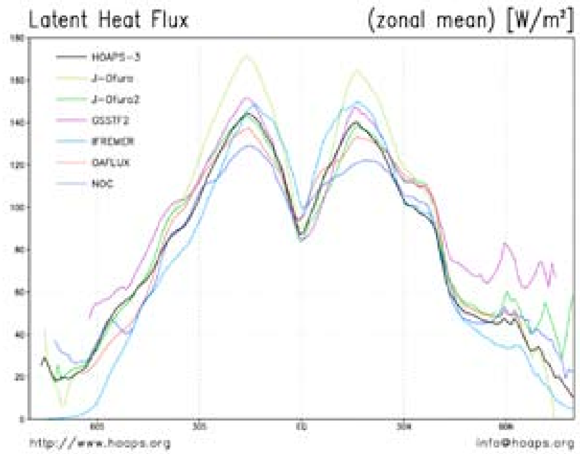

FIGURE 2: ZONAL MEAN OF THE LATENT HEAT FLUX FOR VARIOUS DATA SETS COMPARED TO HOAPS-3 (THICK BLACK CURVE).

More detailed information on the HOAPS database and retrieval techniques have been presented in Flux Newsletter 4 and in Klepp et al. (2005). The data is freely available via www.hoaps.org.

HOAPS latent heat data is compared to four mainly satellite based climatologies and an in-situ data base. The Goddard Satellite based Surface Turbulent Fluxes data set (GSSTF2, Chou et al., 2003) provides turbulent flux products until 2001. The Objectively Analyzed air-sea FLUX climatology of WHOI (OAFLUX, Yu and Weller, 2007) synthesizes satellite data, in-situ and NWP products until 2003. The Japanese Ocean Flux data set with the Use of Remote sensing Observations (J-OFURO; Kubota et al., 2002) derives turbulent heat fluxes from SSM/I and NWP data until 2006 in version 2. Bentamy et al. (2003) developed a remotely sensed data set of latent heat flux, named IFREMER in the following for the time period until 2006.

The National Oceanographic Centre (NOC) provides the Comprehensive Ocean Atmosphere Data Set (COADS, Josey et al., 1998) based on in-situ buoy and voluntary observing ship measurements. It is widely used as a reference for the evaluation of model and satellite based data sets until 1994.

Latent Heat Flux Evaluation

Figure 1 shows the HOAPS-3 climatological mean of the latent heat flux from 1988 to 2005 in W/m^2 compared to OAFlux, J-OFURO2 and IFREMER (1992 to 2005)

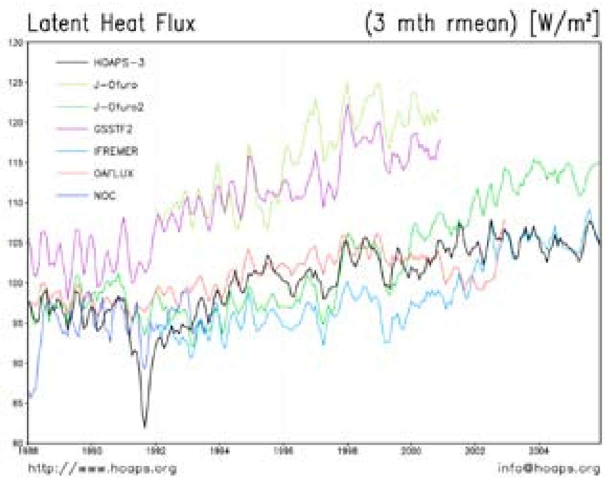

FIGURE 3: TEMPORAL DEVELOPMENT OF THE LATENT HEAT FLUX GIVEN AS A THREE MONTH RUNNING MEAN BETWEEN 1988 AND 2005 FOR VARIOUS DATA SETS COMPARED TO HOAPS-3 (THICK BLACK CURVE).

as difference plots. High values (up to 180 W/m^2) occur in the 30°N to 30°S subtropic latitudinal band outside of the ITC. Largest values (up to 200 W/m^2) exist over the warm ocean currents of the Kuroshio and the Gulf Stream with a pronounced maximum during the cold season. Overall HOAPS-3 compares well against the data sets shown. The largest regional differences are in the order of 20%.Compared to OAFlux the HOAPS-3 maximum latent heat fluxes are higher in the subtropics while they are remarkably lower over the Gulf Stream and the Kuroshio current. Compared to J-OFURO2, HOAPS-3 shows higher latent heat flux values in the convective tropical regions and lower values in the extra-tropics. Compared to these findings IFREMER, however, exhibits an inverse latent heat flux pattern. Here, HOAPS-3 shows lower values in the tropics and higher values in the extra-tropics. Especially IFREMER has a systematic low bias in the Southern Oceans. The HOAPS-3 zonal mean of the climatological latent heat flux is shown in Figure 2 compared to both versions of J-OFURO, GSSTF2, IFREMER, OAFLUX and NOC. Here, each data set is used over its entire duration as can be seen in Figure 3. While most of the data sets are similar in the mid latitudes the differences become larger in the maxima of the subtropics. The temporal development of the latent heat flux for all data sets is given in Figure 3. The three month running mean is shown for the time period from 1988 to 2006. All satellite based data sets show a systematic increase in latent heat flux during the last 18 years. However, GSSTF2 and J-OFURO exhibit a positive bias that is no longer evident in J-OFURO2. As a refrerence, the in-situ based NOC data set is available between 1988 and 1994 and compares well to HOAPS-3 in terms of magnitude. The spike in the HOAPS-3 latent heat flux in mid 1991 is caused by a cool bias in the daily fields of the NODC/RSMAS Pathfinder SST due to undetected aerosol contamination during night-time measurements after the Mt. Pinatubo eruption (Reynolds, 1993).

Conclusions

The HOAPS-3 climatology contains 15 parameters for global ocean water cycle and energy flux analysis for 18 complete years from 1987 to 2005. The data is freely available through www.hoaps.org.

Here, the evaluation of the latent heat flux shows that the HOAPS-3 climatology compares well against most of the state of the art satellite based data sets. Furthermore there is an overall agreement among these data sets that the latent heat flux has increased over the past two decades. The largest regional differences between the data sets usually stay below 20%.

Hence, the HOAPS-3 monthly and pentad means along with the scan based twice daily products are beneficial to assess the atmosphere ocean interface from space.

Acknowledgements

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References

Andersson, A., S. Bakan, K. Fennig, H. Grassl, C. Klepp, and J. Schulz, 2007: Hamburg Ocean Atmosphere Parameters and fluxes from Satellite data – HOAPS3 – monthly mean. DOI: 10.1594/ WDCC/ HOAPS3 MONTHLY.

Bentamy, A., K. B. Katsaros, M. Alberto, W. M. Drennan, E.B. Forde and H Roquet, 2003: Satellite Estimates of wind speed and latent heat flux over the global oceans. J. Climate, 16, 637 – 656.

Chou, S. H., E. Nelkin, J. Ardizzone, R. Atlas, and C. L. Shie, 2003: Surface turbulent heat and momentum fluxes over global oceans based on the Goddard satellite retrievals, version 2 (GSSTF2). J. Climate, 16, 3256-3273.

Fairall, C. W., E. F. Bradley, D. P. Rogers, J. B. Edson, and G. S. Young, 1996: Bulk parameterization of air-sea fluxes for Tropical Ocean-Global Atmosphere Coupled-Ocean Atmosphere Response Experiment. J. Geophys. Res., 101, 3747-3764.

Fairall, C. W., E. F. Bradley, J. E. Hare, A. A. Grachev, and J. B. Edson, 2003: Bulk parameterization of air-sea fluxes: Update and verification for the COARE algorithm. J. Climate, 16, 571-591.

Josey, S. A., E. C. Kent, and P. K. Taylor, 1998: The Southampton Oceanography Centre (SOC) Ocean - Atmosphere Heat, Momentum and Freshwater Flux Atlas. Southampton Oceanography Centre Report No. 6, 30 pp.

Klepp, C.-P., K. Fennig, S. Bakan, and H. Graßl, 2005: HOAPS-II gobal ocean precipitation data base. Eumetsat Proceedings, P.44, Second International Precipitation Working Group Workshop, ISBN 92-9110-070-6, 169-176.

Kubota, M., N. Iwasaka, S. Kizu, M. Konda, and K. Kutsuwada, 2002: Japanese Ocean Flux data sets with the use of Remote Sensing Observations (J-OFURO). J. Oceanogr. 58, 213-225.

Reynolds, R. W., 1993: Impact of Mt. Pinatubo aerosols on satellite-derived sea surface temperatures. J. Climate, 6, 768-774.

Yu, L., and R. A. Weller, 2007: Objectively Analyzed Air-Sea Heat Fluxes for the Global Ice-Free Oceans (1981-2005). Bull. of the Amer. Met. Soc., 88 (4), DOI: 10.1175/BAMS-88-4-527, 527-539.

MEDITERRANEAN REGIONAL ENERGY BALANCE

Surface Heat and Freshwater fluxes into the Mediterranean Sea for the period 1985-2001

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1 Introduction

The semi-enclosed nature of the Mediterranean Sea makes it an attractive region to close heat and freshwater budgets. The first requirement is accurate measurements of the transports through Gibraltar and exchanges with the Black Sea. The latter have been found to be negligible for heat (Tolmazin, 1985). Estimates of the former are 5.2 ± 1.3 W/m^2 (Macdonald et al. 1994) and7±3 W/m^2 (Bethoux 1979) for heat and about 0.7m/yr (Bethoux and Gentili 1999) for freshwater, where the transports have been divided by the Mediterranean area of $2.5 \cdot 10^{12}$m^2 to give equivalent surface fluxes, Q_G and F_G respectively. Similarly, the frashwater from the Black Sea becomes F_B = 0.08m/yr.

The second requirement is estimates of the surface heat and freshwater fluxes. Bunker et al. (1982) and Garrett et al. (1993) closed the budget using rather ad hoc adjustments for biases in the wind and solar radiation respectively.

Finally, closure of the freshwater budget requires an estimate of the continental runoff R = 0.17 m/yr (Large and Yeager 2004) into the Mediterranean.

Castellari et al. (1998) developed a 'calibrated set' of-bulk formulas using the heat closure problem as a constraint. In this work we propose an alternative approach. Different corrections and adjustments are applied to the basic forcing fields required as inputs for our bulk formulas in order to resolve the 'Mediterranean heat closure problem'. In this way, we have computed the components of the surface heat and freshwater fluxes from 1985 through 2001. The purpose of this note is to describe the flux calculations (section 2), to demonstrate how the basin averaged fluxes, with the mentioned corrections, over the 17 years close theMediterranean heat and freshwater budgets (section 3), and to present the inter-annual variability on the considered period (section 4).

2 Data sets and methodology

The total heat flux, Q_T , and freshwater flux, F_T , are found as sums of components, and over timescales of negligible storage equal to the lateral Gibraltar transports:

$Q_T = Q_S + Q_L + Q_H + Q_E$ □ $-Q_B$ (1)
□ -6 ± 2W/m^2

$F_T = P + E$ □ $-(F_G + F_B + R)$ □ -0.95m/yr
(2)

where all fluxes are considered positive into the Mediterranean. The radiative fluxes are the solar Q_S and long wave Q_L, while the turbulent fluxes are the sensible heat Q_H, the latent heat Q_E and the evaporation E, where Q_E and E are related by the latent heat of vaporization. P is the precipitation for which we used both ERA-40 (Uppala et al. 2005) and the Climate Prediction Center Merged Analysis of Precipitation (CMAP) (Xie and Phillip, 1996) data sets.

Basic fields provided by the ERA-40 reanalysis include