HOAPS-3:
IMPROVED CLIMATOLOGY OF THE GLOBAL OCEAN WATER CYCLE PARAMETERS DERIVED FROM SSM/I SATELLITE DATA

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Abstract

HOAPS-3, the third version of the "Hamburg Ocean Atmosphere Parameters and Fluxes from Satellite Data" climatology of precipitation and evaporation over the global ice-free ocean between 1987 and 2005, has recently been released and is freely available from www.hoaps.org.

The climatology is entirely satellite-based. All variables are derived from SSM/I passive microwave radiometers, except for the SST, which is included from the completely reprocessed AVHRR based NODC/RSMAS Pathfinder SST V5 data set. Multi-satellite averages, inter-sensor calibration, and an efficient sea ice detection procedure lead to a homogeneous time series of now more than 18 years. A newly derived neural network based precipitation algorithm together with the evaporation leads to an improved global freshwater balance, which now is in much better agreement with GRDS runoff-data results than previous versions.

This paper will give an introduction to the HOAPS climatology, will cover validation evidence from other surface and satellite based data products and NWP data, and discuss the use of an alternative SST dataset.

INTRODUCTION

Proper knowledge of global water cycle parameters and turbulent heat fluxes is an indispensable prerequisite for the successful modeling and understanding of the global climate system. High resolution global data sets of such information are required for various applications. These are constraining the heat and freshwater transports in the global ocean, diagnosing regional and time variations, evaluating the surface fluxes in coupled atmosphere-ocean models, and providing surface forcing for ocean models. Schlosser and Houser (2006) stressed the need for global climatological freshwater flux data sets. The compilation of the relevant quantities is however a challenging task, especially over the global ocean with its generally insufficient spatial and temporal data coverage provided by ships or buoys.

Satellite based measurements became in recent years a reliable source of surface meteorological data, providing high accuracy and sufficient sampling density over sea and over land. The advent of the passive microwave detectors in space with their all weather observing capability allowed the derivation of some essential water cycle and energy flux components over the global ocean.

The Hamburg Ocean Atmosphere Parameters and Fluxes from Satellite Data (HOAPS) climatology uses the Special Sensor Microwave Imager (SSM/I) operating on the polar orbiting Defense Meteorological Satellites Program (DMSP) satellites to derive such fields over the ice-free global oceans. It consists of the individual flux-related variables as well as derived fluxes such as turbulent heat flux, evaporation, precipitation, freshwater flux and all basic state variables needed to derive these fluxes. One intention during the development of HOAPS was to derive the global ocean freshwater flux consistently from one satellite based data set. Consequently, great care was put into inter-sensor calibration for homogeneous and reliable spatial and temporal coverage. Except for the

SST, all HOAPS variables are therefore derived from brightness temperatures of the SSM/I radiometers. Additionally, an efficient sea ice detection procedure based on the NASA Team algorithm has been implemented.

The initial version of HOAPS was developed in 1995 mainly based on the algorithms of Bauer and Schluessel (1993). An improved second version of HOAPS became available in the middle of 2004 featuring the concurrent use of all available SSM/I instruments up to December 2002, radiometer intercalibration and improved algorithms to derive sea surface flux parameters (Klepp et al., 2005).
The most recent version, HOAPS-3 covers the period from July 1987 to December 2005 and includes a new neural network algorithm for precipitation. This algorithm substantially improves the accuracy of precipitation estimates and, therefore, the freshwater balance in the HOAPS climatology. In addition, this version utilizes the newest NODC/RSMAS Pathfinder version 5 SST data and a new algorithm to synthesize the defective 85GHz channel on the F08 instrument. The sea surface flux algorithms were not changed from the previous version.

Besides our own quality checks, first global evaluations of the performance of global ocean water cycle parameters revealed the high quality of the HOAPS evaporation products (Bourras, 2007).

DATA PRODUCTS

HOAPS-3 consists of the three main data subsets that originate from one common data source. The scan based HOAPS-S supplies global ocean fields of all parameters in SSM/I pixel level resolution for every individual satellite and the entire time period. These can be used for case study applications and validation purposes. The gridded HOAPS-G data product contains pentade, monthly and climatological means of all 15 parameters for climate variability studies with a spatial resolution of 0.5 degrees. The HOAPS-C product is a gridded dataset with high temporal resolution. It contains twice daily multi-satellite composites of 1 degrees resolution.
The HOAPS data sets are publicly available from www.hoaps.org. This address provides also a detailed overview of all 15 parameters and their specifications, as well as a general list of references on the product and a convenient data browsing interface.

SEA SURFACE FLUX RETRIEVAL SCHEMES AND PARAMETERIZATIONS

Latent and sensible heat fluxes are based on the bulk aerodynamic COARE 2.6a algorithm of Fairall et al. (1996 and 2003). This algorithm utilizes wind speed, SST and near surface atmospheric specific humidity. All these variables are derived directly from the available satellite measurements. The air temperature for the derivation of the sensible heat flux is computed as the mean of two bulk estimates; from the near surface specific humidity assuming a relative humidity of 80 % at any time and from the SST assuming a constant air-sea temperature difference of 1 K. Together with the new neural network-based precipitation retrieval, the freshwater flux E-P is calculated in units of mm/day.

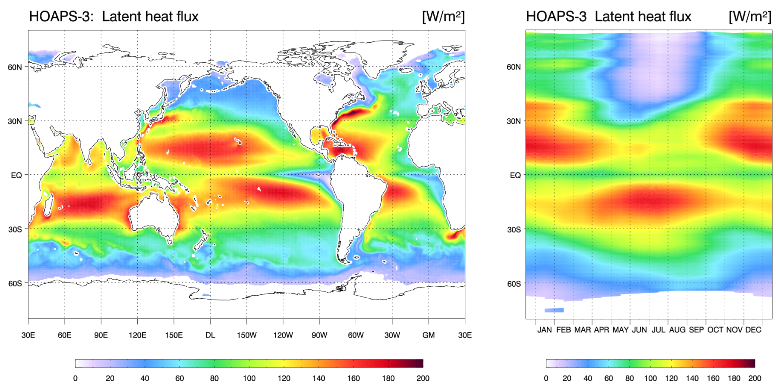

Figure 1: **HOAPS-3 latent heat flux climatological mean 1988-2005 and climatological zonal mean annual cycle.**

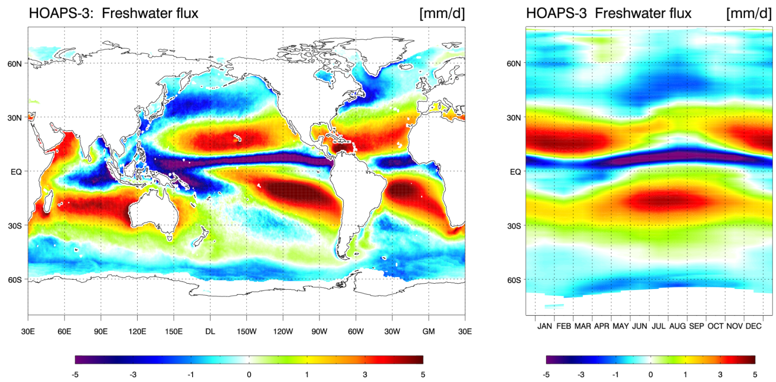

Figure 2: **HOAPS-3 freshwater flux (evaporation-precipitation) climatological mean 1988-2005 and climatological zonal mean annual cycle.**

The net longwave flux at the sea surface is computed after Schluessel et al. (1995) from the atmospheric back radiation and the SST. The atmospheric back radiation is estimated directly from SSM/I measurements under clear or cloudy conditions using 22, 37 and 85 GHz channels.

Figures 1 to 4 show climatological means and zonal mean annual cycles of latent and sensible heat fluxes, net longwave flux, and net freshwater flux at the sea surface. All commonly known spatial patterns and their temporal variability are resolved. Extreme values over the Gulf Stream and Kuroshio currents as well as the mid to high latitude storm tracks are dominant features and are clearly visible in all parameters. Subtropical regions are dominated by dry zones where evaporation exceeds the precipitation. The inner tropics are characterized by low values of net longwave flux and a negative freshwater flux. The annual cycles show the seasonal dependence of the variables. Especially the energy release in mid and high latitudes during the cold season is evident.

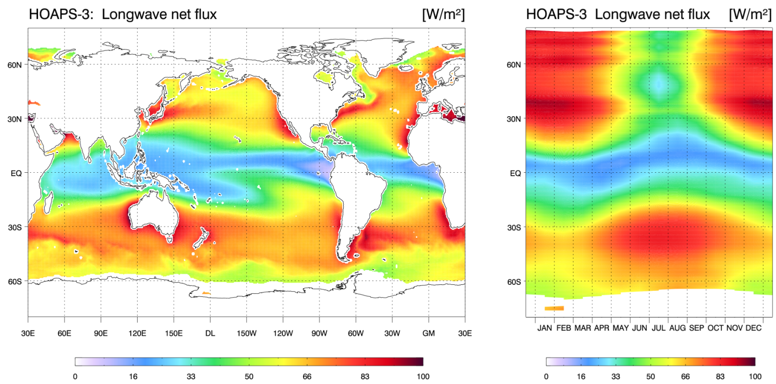

Figure 3: **HOAPS-3 longwave net flux climatological mean 1988-2005 and climatological zonal mean annual cycle.**

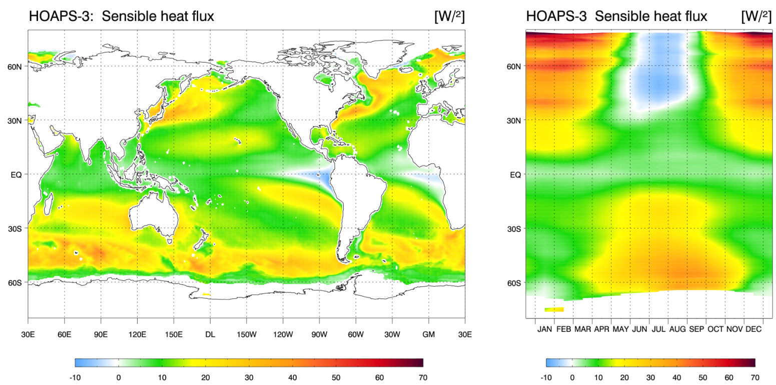

Figure 4: **HOAPS-3 sensible heat flux climatological mean 1988-2005 and climatological zonal mean annual cycle.**

EVALUATION OF GLOBAL EVAPORATION

For a quantitative evaluation of HOAPS the evaporation estimates are compared to different datasets. These data are satellite and ship based measurements J-Ofuro (Kubota et al., 2002), GSSTF2 (Chou et al., 2003) and NOC (Josey et al., 1996) as well as reanalysis and climate model data NCEP-1, NCEP-2 and ECHAM control runs. The OAFlux data set is a mixed satellite and NWP product (Yu et al., 2007). If necessary, datasets containing latent heat flux were converted to evaporation values in mm/d.

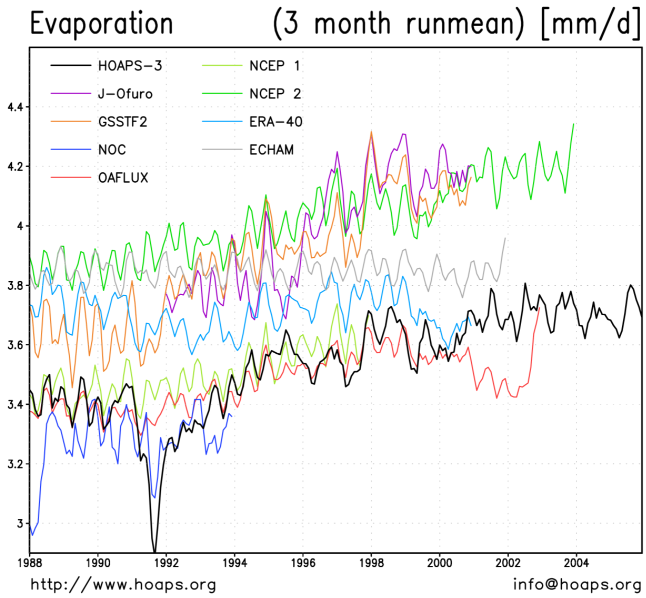

Figure 5: **Comparison of satellite and NWP based evaporation estimates from different sources.**

Fig. 5 shows monthly global mean values of the compared datasets. The data is smoothed using a 3 month running mean. The global mean values of all datasets are within a range of 3.4 to 4.2 mm/d, resulting in differences of up to 20% on the global scale

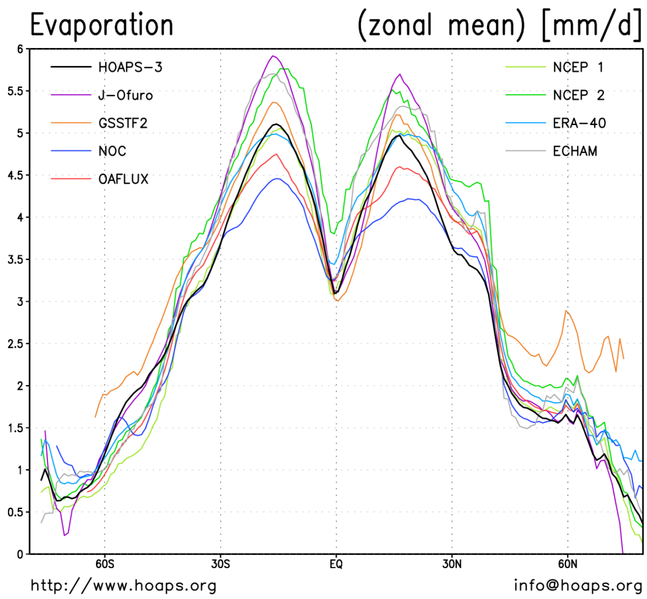

Figure 6: **Comparison of zonal mean evaporation of each dataset shown in figure 5.**

The data sets of HOAPS, OAFlux, NCEP-1, and NOC data agree quite well in magnitude and temporal development. Other satellite based data sets like J-Ofuro and GSSTF2 and NCEP-2 exhibit a similar temporal development with increasing values, but with a positive bias of up to 0.5 mm/d compared to HOAPS. ERA-40 and the ECHAM control-run show a stable time series and do not have any significant trends.

Fig. 6 shows the corresponding zonal mean values for each dataset. While all data sets are in overall good agreement in mid and high latitudes, big differences in the subtropics come evident. This indicates systematic regional differences especially in the regions of maximum evaporation.

SST INPUT DATA

In Fig 5 HOAPS data exhibits a distinct minimum in global evaporation right after the Mt. Pinatubo eruption in 1991. This minimum is induced by low SST values, mainly in the tropics. These infrared satellite based SST measurements were influenced by volcanic aerosol. This leads to a cool bias in daily SST fields due to undetected aerosol contamination during nighttime measurements. (Reynolds, 1993).

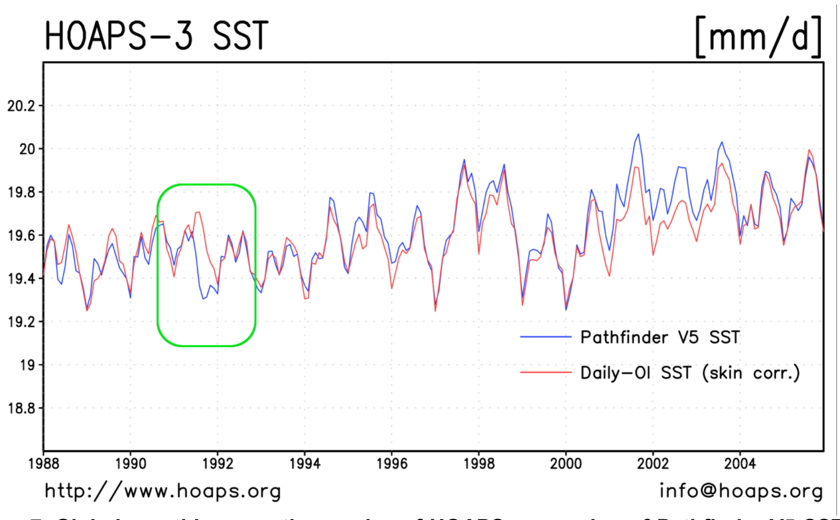

Figure 7: **Global monthly mean time series of HOAPS remapping of Pathfinder V5 SST as it is used in HOAPS-3 (blue line) and the Reynolds Daily-OI SST (red line). After the eruption of Mt. Pinatubo in 1991 both datasets differ substantially (green rectangle).**

In HOAPS the NODC/RSMAS SST Pathfinder dataset is used. A comparable data set is the Daily optimum interpolation (OI) SST on a 1/4-degree grid, based on 1971-2000 OI.v2 SST (Reynolds, 2007). This product uses buoy and other ancillary data to correct the satellite measurements and additionally fills data gaps. Therefore it should not contain any artifacts during the period affected by Mt. Pinatubo. Here, we subtracted a globally constant value of 0.2 K from the Daily OI fields to obtain sub-skin SST values comparable to the Pathfinder SST data set.

Fig. 7 shows the HOAPS remapping of the Pathfinder V5 SST and the skin corrected Daily OI SST. The overall agreement of both datasets is very good, which is no surprise as the Daily OI dataset is based on the Pathfinder data set. In contrast, in the second half of 1991 after the Mt. Pinatubo eruption, both data sets differ up to 0.2 K on the global scale. The contaminated AVHRR measurements are corrected in the Daily OI SST. Consequently the distinct minimum in HOAPS-3 disappears, as Fig. 8 shows.

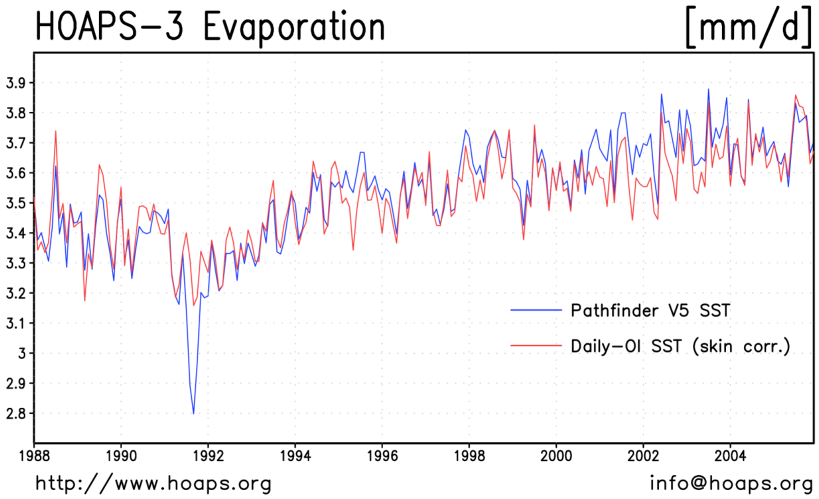

Figure 8: **HOAPS-3 global mean evaporation calculated with Pathfinder V5 SST (blue line) and Reynolds Daily-OI SST (red line).**

CONCLUSION

HOAPS-3 presents various data products of turbulent heat fluxes, evaporation, precipitation, freshwater flux and atmospheric flux-related variables required to derive these fluxes. Freely available monthly and pentade means, twice daily composites and scan-based data make HOAPS-3 a versatile dataset for studying ocean-atmosphere interaction on different temporal and spatial scales.

The use of all available intercalibrated SSM/I instruments provides a dense sampling in HOAPS-3 and hence a detailed information of the underlying weather situations. Evaluation and validation efforts along with the use of the new improved algorithms result in a state-of-the-art global ocean satellite-based climatology.

Comparisons with other satellite based and NWP evaporation estimates show similarities as well as systematic differences between the data sets.

The impact of the eruption of Mt. Pinatubo in 1991 on the evaporation parameter is caused by aerosol contaminated SST measurements. When the corrected Daily OI data set is used, this effect is minimized.

Further information on HOAPS-3 is available on the project web page www.hoaps.org. A publication containing a detailed description of the HOAPS climatology is in preparation.

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