Observing the Water Cycle from Space – Hamburg's Unique Satellite Climatology

The global water cycle is a key component of the global climate system as it describes and links many important processes such as evaporation, convection, cloud formation and precipitation. Through latent heat release, it is also closely connected to the global energy cycle and its changes. The difference between precipitation and evaporation yields the freshwater flux, which indicates if a particular region of the earth receives more water through precipitation than it loses through evaporation or vice versa. On global scale and long time periods, however, the amounts of evaporation and precipitation are balanced. A profound understanding of the water cycle is therefore a key prerequisite for successful climate modeling.

However, measuring the relevant water cycle quantities in an accurate manner is a notoriously difficult task. This applies in particular to measurements over the global ocean with generally insufficient spatial and temporal coverage by ships or buoys. Satellite data are of great value is this respect, as they allow for studying the main elements of the hydrological cycle almost all over the globe with high data quality.

Compiling a global data set of the ocean surface freshwater flux from suitable satellite data has been the aim of a long-term cooperation between scientific working groups at the Max Planck Institute for Meteorology (MPI-M) and the Meteorological Institute at the University of Hamburg. Scientists around Dr. Stephan Bakan and Dr. Axel Andersson from the department "The Land in the Earth System" at MPI-M and Dr. Christian Klepp from the University of Hamburg have now published the global satellite climatology "HOAPS" that contains 15 essential parameters of the global water and energy cycle.

The HOAPS (Hamburg Ocean Atmosphere Parameters and Fluxes from Satellite Data) climatology covers the years 1987 to 2005 and includes the parameters evaporation, precipitation and freshwater flux (evaporation minus precipitation) as well as 12 other parameters which provide all basic state variables that are necessary to determine the evaporation. The parameters are derived from measurements of the SSM/I microwave radiometers (Special Sensor Microwave Imager) that are flying onboard polar orbiting satellites of the US Defense Meteorological Satellites Program (DMSP). With up to three coexisting satellites sampling the earth's surface, a nearly complete global coverage over the oceans is achieved twice a day for all parameters. Although all sensors on to the different DMSP satellites are nominally identical, a thorough calibration among them is required for HOAPS to be a homogenized climatological data set.

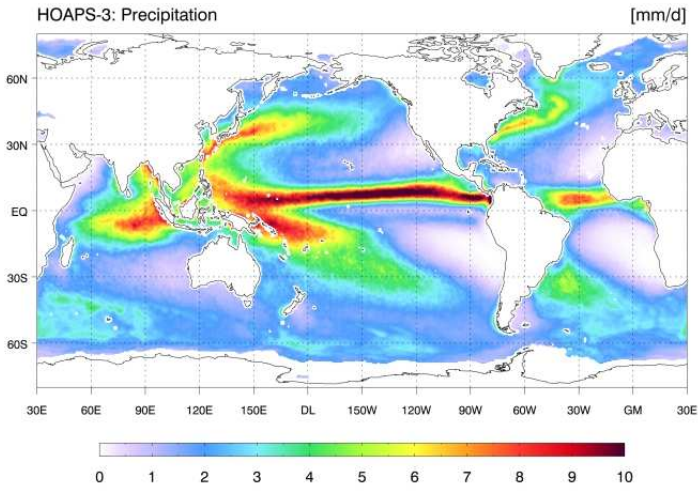

Fig. 1: Climatological mean of HOAPS-3 precipitation, years *1988 – 2005, source: www.hoaps.org*

Up to now HOAPS is the only data set available which comprises both precipitation and evaporation records derived from globally available satellite data in order to estimate the freshwater flux over the ocean. The parameters are solely derived from satellite data; no other data (e. g. re-analysis data) is used in the retrieval procedures. This fact makes HOAPS an independent and ideal reference data set for the evaluation of model data.

HOAPS data allow to determine turbulent fluxes at the ocean surface along with the precipitation rate. Climate modelers are particularly interested in the freshwater flux at the ocean surface as it plays an important role in the global water cycle and thus in the earth's energy budget.

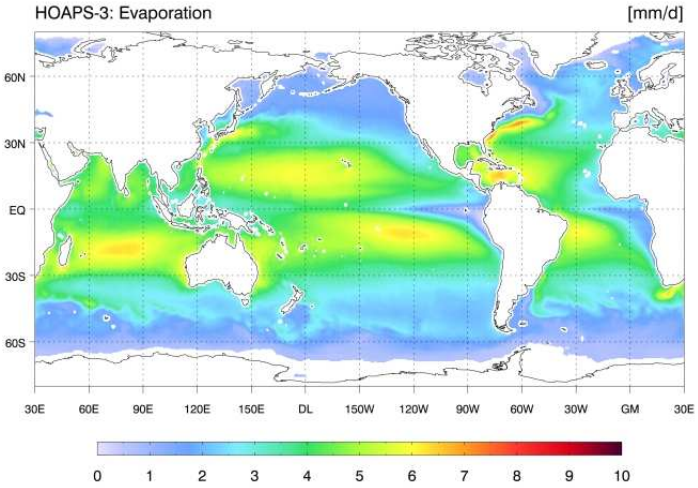

Fig. 2: Climatological mean of HOAPS-3 evaporation, years *1988 – 2005, source: www.hoaps.org*

Moreover, the freshwater flux specifies a freshwater loss or gain of the ocean surface as the difference between evaporation and precipitation. Knowing this quantity is crucial for coupling ocean and atmosphere models because the resulting changes in the salinity of the upper ocean layers are important for driving the global ocean circulation.

The figures 1 to 3 represent the climatological means of precipitation, evaporation and the resulting freshwater flux. Regions with predominant precipitation, e. g. over the Gulf Stream, Kuroshio and the Intertropical Convergence Zone, are clearly recognizable. Here, freshwater input from the atmosphere into the ocean is prevailing whereas in large parts of the subtropics, evaporation is the dominating parameter. Here, the atmosphere gains freshwater from the ocean.

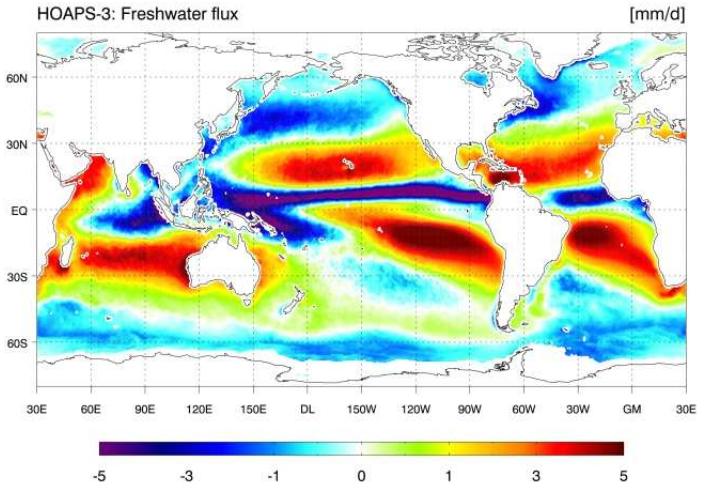

Fig. 3: Climatological mean of HOAPS-3 freshwater flux, years *1988 – 2005, source: www.hoaps.org*

The HOAPS data set can be currently downloaded freely for scientific purposes from the CERA database located at the German Climate Computing Centre (DKRZ). Detailed information can be found at the project site www.hoaps.org. Future versions of the data set will be made available through the CM SAF (Satellite Application Facility on Climate Monitoring of EUMETSAT and the German Weather Service). In close cooperation with the working group from Hamburg, the data set will be extended to the year 2008 for the parameters precipitation, evaporation, freshwater flux as well as the near-surface wind speed and specific humidity in the near future.

As a next step, climate modelers will be given the opportunity to evaluate their model results by applying the HOAPS climatology. For this purpose a simulator is under development that provides an interface between the spatio-temporally unevenly sampled satellite observations with the model data.

Despite the success of HOAPS, validation of the satellite data – particularly for precipitation measurements over the ocean – still remains an important task. To accomplish this task, Dr. Christian Klepp from KlimaCampus Hamburg, sponsored by the company Mabanaft GmbH & Co. KG, and with the involvement of MPI-M, has recently mounted optical rain sensors on several research vessels (e. g. R/V Polarstern) for the measurement of precipitation and snowfall data especially at high latitudes. These data will be used as a unique validation source to verify satellite data and model results.

Over land surfaces the satellite data and retrieval procedures used in HOAPS are less suited to derive the freshwater flux parameters. Here the signal received by the satellite is strongly impaired by the inhomogeneous land surface background. To derive the relevant quantities, much more complex methods and data synthesis from different sources have to be applied. Hence, a working group around Dr. Alexander Loew (MPI-M) is particularly focusing on retrieving essential parameters of the water cycle derived from satellite data over land surfaces.

The working group's long-term goal is to extend HOAPS by a land component. This combined data set will then allow for studies of the global water cycle encompassing exchange processes over the ocean as well as over land surfaces.

Further information: www.hoaps.org

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