EUMETSAT Satellite Application Facility on Climate Monitoring

The EUMETSAT Network of Satellite Application Facilities

CM SAF Climate Monitoring

Product User Manual SSM/I data set products

HOAPS release 3.2

Near Surface Specific Humidity	**CM-141 (NSH_HOAPS)**
Near Surface Wind Speed	**CM-142 (SWS_HOAPS)**
Latent Heat Flux	**CM-143 (LHF_HOAPS)**
Precipitation	**CM-144 (PRE_HOAPS)**
Evaporation	**CM-145 (EVA_HOAPS)**
Freshwater Flux	**CM-146 (EMP_HOAPS)**

Reference Number:	**SAF/CM/DWD/PUM/HOAPS**
Issue/Revision Index:	**1.1**
Date:	**25.03.2011**

Document Signature Table

	Name	Function	Signature	Date
Author	Axel Andersson	HOAPS Team scientist		12/11/2010
Author	Karsten Fennig Marc Schröder	CM SAF scientist		25/03/2011
Editor	Rainer Hollmann	Science Coordinator		25/03/2011
Approval	Rainer Hollmann	Science Coordinator		25/03/2011
Release	Martin Werscheck	Project Manager		

Distribution List

Internal Distribution	
Name	**No. Copies**
DWD Archive	1
CM SAF Team	1

External Distribution		
Company	**Name**	**No. Copies**
PUBLIC		1

Document Change Record

Issue/ Revision	Date	DCN No.	Changed Pages/Paragraphs
1.0	12/11/2010	SAF/CM/DWD/PUM/HOAPS	First official version.
1.1	25/03/2011	SAF/CM/DWD/PUM/HOAPS	Changes from DRI-4

Table of Contents

List of Tables

1 Introduction

This CM SAF Product User Manual provides information on the CM SAF HOAPS data set derived from Special Sensor Microwave/Imager (SSM/I) observations onboard Defense Meteorological Satellite Program (DMSP) platforms F08, F10, F11, F13, F14 and F15. Additionally sea surface temperature (SST) data derived from Advanced Very High Resolution Radiometer (AVHRR) measurements is used. The latent heat flux retrieval utilizes the COARE aerodynamic bulk flux algorithm and depends on satellite derived input parameters from the Hamburg Ocean-Atmosphere Parameters and Fluxes from Satellite (HOAPS) data set.

This manual briefly describes the historical development of CM SAF, the HOAPS data set and the current and upcoming versioning for HOAPS products. A technical description of the data sets including information on the file format as well as on the data access is provided. Furthermore details on the implementation of the retrieval processing chain, and individual algorithm descriptions are available in the Algorithm Theoretical Basis Document [RD 2]. Basic accuracy requirements are defined in the product requirements document [AD 2]. A detailed validation of the HOAPS based parameters is available in the Validation report [RD 1].

The description of the integrated water vapour product from SSM/I (CM-127, HTW_SSMI_global_DS) can be found in the corresponding Product user Manual [RD 3].

1.1 The EUMETSAT SAF on Climate Monitoring (CM SAF)

The importance of climate monitoring with satellites was recognized in 1999 by EUMETSAT Member States when they amended the EUMETSAT Convention to affirm that the EUMETSAT mandate is also to contribute to the operational monitoring of climate and the detection of global climatic changes". Following this, EUMETSAT established within its Satellite Application Facility (SAF) network a dedicated centre, the SAF on Climate Monitoring (CM SAF, http://www.cmsaf.eu). Since the start of the CM SAF in 1999 the project went through three phases, i.e., the Development Phase lasting from 1999 to 2004, the Initial Operations Phase (IOP) and the Continued Development and Operations Phase (CDOP). The consortium of CM SAF currently comprises the Deutscher Wetterdienst (DWD) as host institute, and the partners from the Royal Meteorological Institute of Belgium (RMIB), the Finnish Meteorological Institute (FMI), the Royal Meteorological Institute of the Netherlands (KNMI), the Swedish Meteorological and Hydrological Institute (SMHI) and the Meteorological Service of Switzerland (MeteoSwiss).

After focusing on the development of retrieval schemes to derive a subset of Essential Climate Variables (ECVs) in the development phase, CM SAF delivered to its users products based on Meteosat and polar orbiter data for Europe and Northern Africa supporting NMHSs in their provision of climate services in the IOP from 2004 to 2007. During CDOP, lasting from 2007 to 2012, the product validation continued, the time series were expanded and algorithms were further improved, while the study domain was extended from the baseline area to the MSG disk for the geostationary products and to include global and Arctic coverage for the polar orbiter products. In addition, long term climate datasets from polar orbiting and geostationary satellites are being generated for climate monitoring (i.e. HOAPS, METEOSAT and AVHRR-GAC based products).

A catalogue of available CM SAF products is available via the CM SAF webpage, http://www.cmsaf.eu/. Here, detailed information about product ordering, add-on tools, sample programs and documentation are provided.

1.2 Applicable documents

Reference	Title	Code
AD 1	Memorandum of Understanding between CM SAF and the Max-Planck Institute for Meteorology and Meteorological Institute, University of Hamburg	
AD 2	CM SAF Product Requirements Document	SAF/CM/DWD/PRD/1.6
AD 3	Cooperation Agreement	

1.3 Reference Documents

Reference	Title	Code
RD 1	Validation Report SSM/I Products HOAPS release 3.2	SAF/CM/VAL/HOAPS/1.1
RD 2	Algorithm Theoretical Basis Document SSM/I Products	SAF/CM/ATBD/HOAPS/1.1
RD 3	Product User Manual Vertically Integrated Water Vapour from SSM/I	SAF/CM/PUM/ HTW_SSMI_GLOBAL_DS/1.1

2 Historical overview of the HOAPS data set

Starting in 1987, several groups at the Max-Planck Institute for Meteorology (MPI-M) and the University of Hamburg (UniHH) have been developing retrievals based on microwave observations. The spectral characteristics (resolution and polarization) of the SSM/I instrument channels (Hollinger et al., 1987) allow the derivation of a number of atmospheric and near-surface parameters. The SSM/I instrument is carried among others on the polar orbiting DMSP satellites. The independently developed retrievals were incorporated in a data set, which was named the "**H**amburg **O**cean-**A**tmosphere **P**arameters and Fluxes from **S**atellite Data" (HOAPS). This project was part of the special research initiative on Cyclones and the North Atlantic Climate System (SFB512) funded by Deutsche Forschungsgemeinschaft (DFG).

The version 1 of the HOAPS data set was released in 1998 (Schulz et al., 1998; Jost et al., 2002) and contained the HOAPS parameters, which were derived from a non-homogenized radiance time series from the first SSM/I instruments. Comparisons with other ocean surface turbulent flux data sets within the SEAFLUX project (Kubota et al., 2003; Chou et al., 2004; Curry et al., 2004) indicated that the evaporation in the first HOAPS version was substantially low biased in the tropics. The second version, HOAPS II (Fennig et al., 2006a,b), was available since mid 2004. It included major improvements, such as the concurrent use of all available SSM/I instruments up to December 2002 including inter-calibration and improved algorithms to derive sea surface flux parameters. Further comparisons revealed however, that the global mean precipitation in HOAPS II was significantly lower compared to other climatologies, resulting in an implausibly large global net ocean surface freshwater flux into the atmosphere on the climatological scale. This and a few other issues led to the development of the version 3 of HOAPS (Andersson et al., 2007a,b,c, 2010). The key features and major changes of each version of HOAPS are listed in Table 1.

In 2007, a memorandum of understanding was signed between MPI-M, UniHH and CM SAF to ensure the continuous production, prolongation and development of the HOAPS data set within CM SAF's CDOP [AD 1]. The first parameter from the HOAPS data set released from

Table 1: Overview over HOAPS versioning and availability.

Version	Year	Publisher	Comment	Available at
1	1998	MPI-M / UniHH	First release	http://cera-www.dkrz.de/CERA/ http://www.hoaps.org/
2	2006	MPI-M / UniHH	New retrievals, including homogenisation, Major software re-design	http://cera-www.dkrz.de/CERA/ http://www.hoaps.org/
3	2007	MPI-M / UniHH	Precipitation retrieval update, new SST data set	http://cera-www.dkrz.de/CERA/ http://www.hoaps.org/
3.1	2009	CM SAF	WVPA only, including error estimates	http://www.cmsaf.eu/
3.2	2010	CM SAF	HOAPS parameters as marked in Table 1-2, continuation beyond 2006	http://www.cmsaf.eu/
4		CM SAF	Planned	http://www.cmsaf.eu/

CM SAF was the total column water vapour data set (CM-127, [RD 3]). This release is referred to as HOAPS version 3.1.

For the current release, the time series of HOAPS-3 has been continued to make use of all available SSM/I data until the end of 2008. The retrieval schemes have not been changed, but the homogenisation of the radiance time series has been improved. It is the implementation of the HOAPS parameters at CM SAF. The release is thus called version 3.2 to indicate that it is not a major new version. A list of all HOAPS parameter and those released by CM SAF is available in Table 2. Future planned extensions of the HOAPS data set may include an updated input data base or changes in the retrieval schemes and will thus be major new releases, carrying version number 4 and onwards. The release of version 4 is planned within the CM SAF's CDOP-2 (see again Table 1 for an overview over the HOAPS data set versions)

Due to the fading of SSM/I instruments in the years 2007 and later, the data source for the HOAPS version 4 release will be extended using measurements of the SSMIS instrument. CM SAF also aims at providing advanced error and stability estimates for that release.

3 Product definitions

The CM SAF HOAPS data set from SSM/I provides quasi-global coverage over the ice-free ocean surface, i.e., within ±180° longitude and ±80° latitude. Instantaneous SSM/I retrievals at original swath level are used to derive the spatio-temporal averaged data sets. The products are available as 6-hourly composites and monthly averages on a regular latitude/longitude grid with a spatial resolution of 0.5° × 0.5° degrees. The temporal coverage of the data sets ranges from 9^{th} of July 1987 to 31^{st} of December 2008.

The products covered by this document are:

- Near surface wind speed (CM-142, see ATBD [RD 2])
- Near surface specific humidity (CM-141, see ATBD [RD 2])
- Latent heat flux at sea surface (CM-143, see ATBD [RD 2])
- Evaporation (CM-145, see ATBD [RD 2])
- Precipitation (CM-144, see ATBD [RD 2])
- Freshwater flux (CM-146, see ATBD [RD 2])

3.1 Parameter Retrievals

3.1.1 Near surface wind speed

Following a neural network approach after Krasnopolsky et al. (1995), the wind speed is estimated using a fully connected 3-layer feed forward neural network, composed of one input layer utilizing TB19v/h, TB22v, and TB37v/h, a hidden layer with three neurons and an output layer with one neuron, the wind speed. All three neurons in the hidden layer are non-linear with the sigmoid function *tanh* as the unit's activation function. The output neuron is linear in order to maximize the networks extrapolation capabilities. Two different data sets serve as input for the training data set, one derived from radiosonde profiles and radiative transfer simulations and a second one from collocated SSM/I and buoy observations. This approach ensures the representativeness of the input and output data of the neural network.

More details on the retrieval and the specific limitations are given in ATBD on HOAPS wind speed retrieval [RD 2]. Information on the accuracy of the product is contained in the HOAPS validation report [RD 1].

3.1.2 Near surface specific humidity

Since a significant signal of the water vapour in the lower boundary layer is contained in the SSM/I measurements it is possible to retrieve q_{air} from the brightness temperatures. A linear relationship from Bentamy (2003) is used here that is based on the two-step retrieval of Schulz (1993) and the refinement of Schlüssel (1995). It derives q_{air} directly from SSM/I brightness temperatures using the 19 GHz, 22 GHz, nd 37 GHz channels. An additional advantage of this multi-channel approach is the possibility of a better separation of wind induced surface signals from the water vapour signal through the 19 and 37 GHz channels, which reduces the errors in the retrieval.

More details on the retrieval and the specific limitations are given in ATBD on the HOAPS near surface specific humidity [RD 2]. Information on the accuracy of the product is contained in the HOAPS validation report [RD 1].

3.1.3 Latent heat flux / Evaporation

The latent heat flux is not directly derived from SSM/I radiances. The retrieval is based on the parameterization of the latent heat transfer coefficients from the Coupled Ocean–Atmosphere Response Experiment (COARE) bulk aerodynamic approach of Fairall (1996, 2003).

Using the bulk aerodynamic formula the latent heat flux is estimated from wind speed and sea-air humidity differences as follows:

$$Q_l = \rho L_E C_E u(q_s - q_a)$$

where ρ is air density, u is the wind speed at 10 meters height, L_E is the latent heat of evaporation, C_E is the Dalton number (transfer coefficient), q_s is the saturation specific humidity at the sea surface, and, q_a is the specific humidity at the 10 m atmospheric measurement level. Nearly all of these geophysical parameters needed to derive the fluxes can be retrieved directly or indirectly from satellite observations.

The physical parameters used to derive the latent heat flux / evaporation are available as individual products through CM SAF. Sea surface temperature and sea surface specific humidity are available as auxiliary products.

More details on the latent heat flux retrieval and the specific limitations are given in ATBD on the HOAPS turbulent flux retrieval [RD 2]. Information on the accuracy of the product is contained in the HOAPS validation report [RD 1].

3.1.4 Precipitation

A neural network based statistical retrieval is used to derive the precipitation from SSM/I brightness temperatures. The neural network was trained with precipitation rates retrieved from assimilated brightness temperatures in a 1D-Var scheme from the ECMWF. The resulting HOAPS precipitation retrieval algorithm only depends on SSM/I brightness temperatures as input an does not need first guess or other ancillary data.

More details on the retrieval and the specific limitations are given in ATBD on HOAPS precipitation retrieval [RD 2]. Information on the accuracy of the product is contained in the HOAPS validation report [RD 1].

3.1.5 Freshwater flux

The gridded freshwater flux products are not computed directly from the SSM/I swath data, since the concurrent retrieval of precipitation and evaporation is not possible for the most cases with precipitation.

In order to retrieve the freshwater flux, the input parameters precipitation and evaporation are averaged separately. Then the freshwater flux is computed the gridded data products for each grid box as the difference between the spatial and temporal means of evaporation and precipitation.

More details on the retrieval and the specific limitations are given in ATBD on the freshwater flux [RD 2]. Information on the accuracy of the product is contained in the HOAPS validation report [RD 1].

3.2 General limitations of the HOAPS data set

The HOAPS retrievals are not valid over land surfaces and ice covered regions. Thus all HOAPS products are restricted to ice-free oceanic conditions. This results in temporally varying sampling density in the polar regions, where the retrieval is only possible during ice-free summer months.

The number of DMSP satellite platforms available throughout the years covered by the data set varies between 1 and 3. The first months of the data set are derived from only on one satellite, which leads to a greater uncertainty in the mean fields due to the insufficient sampling.

The sun synchronous orbit of the DMSP satellites does not allow to resolve a detailed diurnal cycle of a parameter. Hence, systematic biases may occur in regions where a parameter exhibits a strong, non-sinusoidal, diurnal cycle dependency.

3.3 Gridding Procedures and Data Products

Two gridded data subsets of the HOAPS data set are supplied: a composite product (HOAPS-C) and a monthly averaged product (HOAPS-G). This allows HOAPS to be used for a wide range of applications. Moreover, both data sets are available in NetCDF format including extensive metadata.

3.3.1 HOAPS-S

The HOAPS-S data subset contains all parameters in the native SSM/I scan-oriented pixel-level resolution for each individual satellite, providing the basis for the gridded data products HOAPS-G and HOAPS-C. The HOAPS-S products are not disseminated as formal CM SAF products. However, they are available from CM SAF by request to the User Help Desk.

3.3.2 HOAPS-G

HOAPS-G climatological data sets contain monthly mean globally gridded data with a spatial resolution of 0.5°. The mean fields are computed from the HOAPS-S data by aggregating all SSM/I pixels that have their centre of the FOV falling in the respective grid box and averaging over the specific time period. The resulting data sets consist of multi-satellite averages that include all SSM/I instruments available at the same time. The data fields are supplemented by basic statistical information about standard deviation and number of observations per grid cell as well as the satellites used for each grid cell.

3.3.3 HOAPS-C

HOAPS-C contains 6-hourly globally gridded multi-satellite composite fields of each parameter at a spatial resolution of 0.5°. HOAPS-C was introduced to fulfil the need for a globally gridded data product with at least daily temporal resolution. Each grid cell contains the spatial average of data from the specific satellite that passed this grid box closest to 06:00, 12:00, 18:00, and 24:00 UTC respectively. Hence, each grid cell contains data from only one satellite pass (spatially averaged) and there is no average from two or more satellite passes. This method provides higher spatial consistency on the sub-daily time scale than just averaging all available data to daily mean fields, e.g. the appearance of back and forth moving fronts of fast moving weather systems is minimized. The fields are archived for 00:00 to 06:00 UTC, 06:00 to 12:00 UTC, 12:00 to 18:00 UTC and 18:00 to 24:00 UTC. Time steps in the data files are 00:00 UTC, 06:00 UTC, 12:00 UTC and 18:00 UTC respectively.

4 Outlook

Future tasks will involve the investigation of retrieval uncertainties and hence the specification of error estimates. This task will be a new development within CDOP-2 and shared between CM SAF and the University of Hamburg. As this CM SAF HOAPS release v3.2 is a HOAPS v3 heritage release, the product designs are only slightly modified. The retrieval uncertainties will be either estimated from collocation matchup data base for the statistical retrievals or by implementing new 1D-Var retrieval schemes. Error estimates for the derived products will be gained with error propagation.

Moreover, a comprehensive assessment of the long-term stability of satellite-based climatologies is still a not fully resolved issue, which is important for applications regarding local and global trend analyses. As no new SSM/I instruments will be launched into space, a continuation of HOAPS will require the inclusion of new sensors, preferably the Special Sensor Microwave Imager/ Sounder (SSMIS). This work is also planned for the next CDOP.

A study is underway at University of Hamburg to assess different SST products in order to solve the indentified problems with the currently used Pathfinder SST which includes the ARC SST (ATSR reprocessing for Climate) and the OSTIA (Operational Sea Surface Temperature and Sea Ice Analysis).

5 Data format description

CM SAF‘s climate monitoring HOAPS products are provided as NetCDF (Network Common Data Format) files (http://www.unidata.ucar.edu/software/netcdf/). The data files are created following NetCDF Climate and Forecast (CF) Metadata Convention version 1.5 (http://cf-pcmdi.llnl.gov/) and NetCDF Attribute Convention for Dataset Discovery version 1.0.

For data processing and conversion to various graphical packages input format, CM SAF recommends the usage of the climate data operators (CDO), available under GNU Public License (GPL) from MPI-M (http://www.mpimet.mpg.de/~cdo).

5.1 Data file contents

A common NetCDF file consists of dimensions, variables, and attributes. These components can be used together to capture the meaning of data and relations among data. All HOAPS products files are built following the same design principles.

Each data file contains the following coordinate variables:

time
: start of averaging/composite time period
[days counted from 1987-01-01]

time_bnds
: two-dimensional array defining the averaging/composite time period
[days counted from 1987-01-01]

latitude
: geographical latitude of grid-box centre [degree_north]

longitude
: geographical longitude of grid-box centre [degree_east]

Each data file contains a subset of the following 3-dimensional variables:

hair, wind, evap, late, rain, budg
: parameter grid box mean value, the name depends on the parameter,
(see also Table 2 in Appendix A for HOAPS parameter names)

numo
: total number of observations counted during the average/composite period
(not available for monthly mean freshwater flux product)

satm
: the satellite instruments used, encoded in a bit mask

numd
: total number of days with at least one observation counted during the average period (not available for freshwater flux product)
{HOAPS-G only}

stdv
: root mean squared variance (not available for freshwater flux product)
{HOAPS-G only}

dtime
: time elapsed since start of composite period [seconds]
(HOAPS-C only)

Each file extracted from the CM SAF database has one record of the dimension (time, lat, lon) with the time dimension as the record dimension. This allows it to concatenate the individual records into an aggregated file. Global attributes are summarized in Table 3 and possible variable attributes in Table 4 (Appendix A).

6 Data ordering via the Web User Interface (WUI)

User services are provided through the CM SAF homepage www.cmsaf.eu. The user service includes information and documentation about the CM SAF and the CM SAF products, information on how to contact the user help desk and allows to search the product catalogue and to order products.

On the main webpage, a detailed description how to use the web interface for product search and ordering is given. We refer the user to this description since it is the central and most up to date documentation. However, some of the key features and services are briefly described in the following sections.

6.1 Product ordering process

You need to be registered and logged in to order products. A login is provided upon registration, all products are delivered free of charge. After the selction of the product, the desired way of data transfer can be choosen. This is either via a temporary ftp account (the default setting), or by CD/DVD or email. Each order will be confirmed via email, and the user will get another email once the data have been prepared. If the ftp data transfer was selected, this second email will provide the information on how to access the ftp server.

6.2 Contact User Help Desk staff

In case of questions the contact information of the User Help Desk (e-mail address contact.cmsaf@dwd.de, telephone and fax number) are available via the CM SAF main webpage (www.cmsaf.eu) or the main page of the Web User Interface.

6.3 Feedback/User Problem Report

Users of CM SAF products and services are encouraged to provide feedback on the CM SAF product and services to the CM SAF team. Users can either contact the User Help Desk (see chapter 6.2) or use the “User Problem Report” page. A link to the “User Problem Report” is available either from the CM SAF main page (www.cmsaf.eu) or the Web User Interface main page.

6.4 Service Messages / log of changes

Service messages and a log of changes are also accessible from the CM SAF main webpage (www.cmsaf.eu) and provide useful information on product status, versioning and known deficiencies.

7 References

Andersson, Axel; Bakan, Stephan; Fennig, Karsten; Grassl, Hartmut; Klepp, Christian-Phillip; Schulz, Joerg: Hamburg Ocean Atmosphere Parameters and Fluxes from Satellite Data - HOAPS-3 - monthly mean., electronic publication, World Data Center for Climate, doi:10.1594/WDCC/HOAPS3_MONTHLY, 2007a.

Andersson, Axel; Bakan, Stephan; Fennig, Karsten; Grassl, Hartmut; Klepp, Christian-Phillip; Schulz, Joerg: Hamburg Ocean Atmosphere Parameters and Fluxes from Satellite Data - HOAPS-3 - 5-days mean., electronic publication, World Data Center for Climate, doi:10.1594/WDCC/HOAPS3_PENTAD, 2007b.

Andersson, Axel; Bakan, Stephan; Fennig, Karsten; Grassl, Hartmut; Klepp, Christian-Phillip; Schulz, Joerg: Hamburg Ocean Atmosphere Parameters and Fluxes from Satellite Data - HOAPS-3 - twice daily composite., electronic publication, World Data Center for Climate, doi:10.1594/WDCC/HOAPS3_DAILY, 2007c.

Andersson, A., Fennig, K., Klepp, C., Bakan, S., Graßl, H., and Schulz, J.: The Hamburg Ocean Atmosphere Parameters and Fluxes from Satellite Data – HOAPS-3, Earth Syst. Sci. Data, 2, 215-234, doi:10.5194/essd-2-215-2010, 2010.

Bentamy, A., Katsaros, K. B., Mestas-Nunez, A. M., Drennan, W. M., Forde, E. B., and Roquet, H.: Satellite Estimates of Wind Speed and Latent Heat Flux Over the Global Oceans, J. Climate, 16, 637–656, 2003.

Chou, S. H., Nelkin, E., Ardizzone, J., and Atlas, R. M.: A Comparison of Latent Heat Fluxes Over Global Oceans for Four Flux Products, J. Climate, 17, 3973–3989, 2004.

Curry, J. A., Bentamy, A., Bourassa, M. A., Bourras, D., Bradley, E. F., Brunke, M., Castro, S., Chou, S. H., Clayson, C. A., Emery, W. J., Eymard, L., Fairall, C. W., Kubota, M., Lin, B., Perrie, W., Reeder, R. A., Renfrew, I. A., Rossow, W. B., Schulz, J., Smith, S. R., Webster, P. J., Wick, G. A., and Zeng, X.: SEAFLUX, B. Am. Meteorol. Soc., 85, 409–424, 2004.

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

Fairall, C. W., Bradley, E. F., Hare, J. E., Grachev, A. A., and Edson, J. B.: Bulk parameterization of Air-sea Fluxes: Updates and Verification for the COARE Algorithm, J. Climate, 16, 571–591, 2003.

Fennig, K., Bakan, S., Graßl, H., Klepp, C., and Schulz, J.: Hamburg Ocean Atmosphere Parameters and Fluxes from Satellite Data – HOAPS II – monthly mean, World Data Center for Climate, doi:10.1594/WDCC/HOAPS2 MONTHLY, electronic publication, 2006a.

Fennig, K., Bakan, S., Graßl, H., Klepp, C., and Schulz, J.: Hamburg Ocean Atmosphere Parameters and Fluxes from Satellite Data – HOAPS II – pentad mean, World Data Center for Climate, doi:10.1594/WDCC/HOAPS2 PENTAD, electronic publication, 2006b.

Hollinger, J.P., Lo, R., Poe, G., Savage, R. and Peirce, J.: Special Sensor Microwave/Imager User’s Guide (Washington D.C., Naval Research Laboratory), 1987.

Jost, V., S. Bakan and K. Fennig: HOAPS – A new satellite-derived freshwater flux climatology. Meteorol. Zeitschrift, 11, 61-70, 2002.

Kubota, M., Kano, A., Muramatsu, H., and Tomita, H.: Intercomparison of Various Surface Latent Heat Flux Fields, J. Climate, 16, 670–678, 2003.

Schlüssel, P.: Passive Fernerkundung der unteren Atmosphäre und der Meeresoberfläche aus dem Weltraum, Vol. 20, Berichte aus dem Zentrum für Meeres- und Klimaforschung, Reihe A: Meteorologie, Max Planck Institute for Meteorology, Bundesstr. 55, 20146 Hamburg, Germany, ISSN 0947-7128, 1995.

Schulz, J., Schlüssel, P., and Graßl, H.: Water-vapor in the Atmospheric Boundary Layer over Oceans from SSM/I Measurements, Int. J. Remote Sens., 14, 2773–2789, 1993.

Schulz, J., V. Jost and S. Bakan: A new satellite-derived freshwater flux climatology (Hamburg Ocean Atmosphere Parameters and Fluxes from Satellite). International WOCE Newsletter, 32, 20-26, 1998.

8 Appendix A

Table 2: HOAPS code table with mapping to CM SAF product ID's.

Acronym	Description	Unit	Par. ID	CM SAF ID	CM SAF CODE
WIND	Wind speed at 10m height	m/s	0	CM-142	NSW_HOAPS
HAIR	Near surface specific humidity	g/kg	1	CM-141	NSH_HOAPS
RAIN	Precipitation	mm/d	2	CM-144	PRE_HOAPS
WVPA	Vertically integrated water vapour	kg/m**2	3	–	–
TWPA	Vertically integrated total (ice+liquid) water	kg/m**2	4	–	–
LWPA	Vertically integrated liquid water	kg/m**2	6	–	–
ASST	Sea surface temperature	deg C	30	–	–
HSEA	Sea surface saturation specific humidity	g/kg	31	–	–
FNET	Longwave net flux at sea surface	W/m**2	60	–	–
DHUM	Difference in humidity	g/kg	61	–	–
TRCE	Latent heat transfer coefficient (Dalton number)	-	64	–	–
LATE	Latent heat flux at sea surface	W/m**2	65	CM-143	LHF_HOAPS
HEAT	Sensible heat flux at sea surface	W/m**2	66	–	–
EVAP	Evaporation	mm/d	67	CM-145	EVA_HOAPS
BUDG	Freshwater flux	mm/d	68	CM-146	EMP_HOAPS

Table 3: Global NetCDF attributes.

Name	Description
title	dataset title, "HOAPS-G" for all files containing averages, “HOAPS-C” for all composite products
Conventions	conventions followed, "CF-1.5" for all files
Metadata_Convention	conventions followed, "Unidata Dataset Discovery v1.0" for all files
institution	institution where the data was produced
creator_url	URL contact information for the creator of the data
creator_email	email contact information for the creator of the data
references	references that describe the data or methods used to produce it
source	original data source, “HOAPS-S” for gridded products
cdm_data_type	data type, “grid” for gridded products
filename	original filename
time_coverage_start	temporal coverage start of the data [ISO8601 date]
time_coverage_end	temporal coverage end of the data [ISO8601 date]
time_coverage_duration	temporal coverage duration of the data [ISO8601 duration]
geospatial_lat_units	latitude attributes unit
geospatial_lat_resolution	latitude grid resolution
geospatial_lat_min	latitude bounding box minimum
geospatial_lat_max	latitude bounding box maximum
geospatial_lon_units	longitude attributes unit
geospatial_lon_resolution	longitude grid resolution
geospatial_lon_min	longitude bounding box minimum
geospatial_lon_max	longitude bounding box maximum
hoaps_major_version_number	HOAPS major release version
hoaps_minor_version_number	HOAPS minor release version
hoaps_parameter_name	HOAPS parameter name (see Table 2 for the code table)
hoaps_parameter_id	HOAPS parameter ID (see Table 2 for the code table)
processed_satellite_id	satellites id’s processed for this mean
processed_orbit_node	satellite orbit nodes processed for this mean "ascending, descending" for all files
cmsaf_parameter_id	CM SAF product identifier (see Table 2 for the code table)
cmsaf_parameter_code	CM SAF product name (see Table 2 for the code table)
intercalibration	intercalibration version applied
date_created	date on which the data was created [ISO8601 date]
date_modified	date on which the data was modified [ISO8601 date]
history	provides an audit trail for modifications to the original data

Table 4: Attributes assigned to variables.

Name	Description
long_name	long descriptive name
standard_name	standard name that references a description of a variable's content in the CF standard name table
units	physical unit [udunits standards]
C_format	format string that should be used for C applications to print values for this variable, applies to the scaled (internal) type and value
FORTRAN_format	format string that should be used for FORTRAN applications to print values for this variable, applies to the scaled (internal) type and value
valid_min	smallest valid value of a variable
valid_max	largest valid value of a variable
scale_factor	The data are to be multiplied by this factor after it is read.
add_offset	This number is to be added to the data after it is read. If scale_factor is present, the data are first scaled before the offset is added.
_FillValue	This number represent missing or undefined data. Missing values are to be filtered before scaling.
cell_methods	method used to derive data that represents cell values
flag_masks	list of bit fields expressing Boolean or enumerated flags
flag_meanings	descriptive words for each flag value

9 Glossary

AFGWC	Air Force Global Weather Center
ARC	ATSR Reprocessing for Climate
ATBD	Algorithm Theoretical Baseline Document
ATSR	Along Track Scanning Radiometer
AVHRR	Advanced Very High Resolution Radiometer
CDO	Climate Data Operators
CDOP	Continuous Development and Operations Phase
CERA	Climate and Environmental Climate and Archive
CM SAF	Satellite Application Facility on Climate Monitoring
COARE	Coupled Ocean Atmosphere Response Experiment
DFG	Deutsche Forschungsgemeinschaft
DMSP	Defense Meteorological Satellite Program
DRI	Delivery Readiness Inspection
DWD	Deutscher Wetterdienst (German MetService)
ECMWF	European Centre for Medium Range Forecast
ECV	Essential Climate Variable
EPS	European Polar System
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
FMI	Finnish Meteorological Institute
FNMOC	Fleet Numerical Meteorology and Oceanography Center
FOV	Field of view
GCOS	Global Climate Observing System
HOAPS-C	HOAPS Composite product
HOAPS-G	HOAPS Gridded product
HOAPS-S	HOAPS Scan product
HOAPS	The Hamburg Ocean Atmosphere Fluxes and Parameters from Satellite data
IOP	Initial Operations Phase
KNMI	Koninklijk Nederlands Meteorologisch Institut
MPI	Max-Planck Institute for Meteorology
MSG	Meteosat Second Generation
NASA	National Aeronautics and Space Administration
NetCDF	Network Common Data Format
NOAA	National Oceanic & Atmospheric Administration
NWP	Numerical Weather Prediction
OSTIA	Operational Sea Surface Temperature and Sea Ice Analysis
PRD	Product Requirement Document
PUM	Product User Manual

RMIB	Royal Meteorological Institute of Belgium
RSMAS	Rosenstiel School of Marine and Atmospheric Science
SAF	Satellite Application Facility
SEAFLUX	Ocean Surface Turbulent Flux Project
SFB	Sonderforschungs Bereich
SMHI	Swedish Meteorological and Hydrological Institute
SSM/I	Special Sensor Microwave Imager
SSMIS	Special Sensor Microwave Imager Sounder
SST	Sea Surface Temperature
WDCC	World Data Center for Climate
WOCE	World Ocean Circulation Experiment