Climate Monitoring from Space: The EUMETSAT Satellite Application Facility on Climate Monitoring

GCOS Science Conference
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Martin Werscheck
Deutscher Wetterdienst
CM SAF: Content

- Motivation & Mandate
- EUMETSAT Satellite Application Facility (SAF) network
- Products & Services
- Users
- Downstream application (examples)
- Planning 2017 – 2022
- Summary

www.cmsaf.eu
“Life can only be understood backwards; but it must be lived forwards.”
CM SAF: In a nutshell

The Satellite Application Facility on Climate Monitoring

develops
generates
archives
distributes

high quality satellite data derived products of the

energy and water cycle

in support to

monitor, understand and adapt to

climate variability and climate change.
CM SAF: The EUMETSAT SAF Network

- **CM SAF**: Climate Monitoring
- **H SAF**: Support to Operational Hydrology and Water Management
- **O3M SAF**: Ozone and Atmospheric Chemistry Monitoring
- **LSA SAF**: Land Surface Analysis
- **NWC SAF**: Support to Nowcasting and Very Short Range Forecasting
- **OSI SAF**: Ocean and Sea Ice
- **NWP SAF**: Numerical Weather Prediction
- **ROM SAF**: Radio Occultation Meteorology SAF

- EUMETSAT Member States
- EUMETSAT Cooperating States
CM SAF: Partners

Swedish Meteorological and Hydrological Institute

Koninklijk Nederlands Meteorologisch Instituut
Ministerie van Verkeer en Waterstaat

Royal Meteorological Institute of Belgium

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra
Swiss Confederation

Federal Department of Home Affairs FDHA

Federal Office of Meteorology and Climatology

MeteoSwiss

Finnish Meteorological Institute

Met Office, United Kingdom

Centre National de la recherche scientifique
Global Energy- and Water Cycle

The product portfolio of the CM SAF comprises long times series of Essential Climate Variables (ECVs) related to the energy and water cycle as defined by the Global Climate Observing System (GCOS); eg.:

- Global cloud parameters
- Global precipitation (planned)
- Global radiation at surface
- Global water vapour
- Regional (Europe & Africa) radiation top of the atmosphere
- Regional Land Fluxes (planned)
Re-calibration and inter-calibration Coefficients

Satellite Raw Data

FCDR
Fundamental Climate Data Records

Multi-satellite corrected and inter-calibrated physical observations, e.g. radiances

TCDR
Thematic Climate Data Records

Multi-satellite geophysical parameter records derived from FCDRs

Geophysical Parameters/
Essential Climate Variables
# CM SAF: Climate Data Records

<table>
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<th>Climate Data Record</th>
<th>Parameters</th>
<th>Coverage</th>
<th>Time period</th>
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<td>CM SAF Surface Radiation MVIRI Data Set 1.0</td>
<td>Cloud albedo, solar surface irradiance, direct irradiance</td>
<td>Meteosat disc</td>
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<td>CM SAF ToA Radiation „GERB” dataset - Edition 1</td>
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<td>Hamburg Ocean Atmosphere Parameters and Fluxes from Satellite Data HOAPS 3.2</td>
<td>Wind speed, specific humidity, latent heat flux, evaporation, precipitation</td>
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<td>1987 - 2008</td>
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<td>Vertically Integrated Water Vapour from SSM/I</td>
<td>Water vapour</td>
<td>Global ice-free ocean</td>
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<tr>
<td>CM SAF Surface Daylight Radiation Data Set</td>
<td>Daylight</td>
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<td>Brightness temperatures</td>
<td>Global</td>
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<td>Vertically integrated water vapour, humidity and temperature at pressures levels and layers from ATOVS</td>
<td>Water vapour, specific humidity</td>
<td>Global</td>
<td>1999 - 2011</td>
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<td>CM SAF Cloud property data set using SEVIRI (CLAAS), edition 1</td>
<td>Cloud properties, surface radiation &amp; albedo, cloud forcing</td>
<td>Meteosat disk</td>
<td>2004 - 2011</td>
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<tr>
<td>SEVIRI 15min cloud mask dataset</td>
<td>Cloud mask</td>
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<td>MVIRI+SEVIRI free tropospheric humidity (FTH) dataset</td>
<td>Humidity</td>
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</table>
CM SAF: Quality Control and product life cycle

The definition, generation and the release of a CM SAF Climate Data Record undergoes a three-step, rigorous peer review process:

Requirement Review (RR) ← GCOS requirements as primary input
• Assess the adequateness and feasibility of the product requirements

Product Consolidation Review (PCR)
• Assess the maturity of the algorithm selected / developed for product generation
• Assess the infrastructure capability to generate the data set

Delivery Readiness Review (DRR)
• Assess the validation results against the defined product requirements
• Assess the readiness to deliver the data record

Operations Review (OR) (annual review)
• Assess the level of compliance of the delivered products & services against the Service Specifications
GCOS Steering Committee recommends that data producers pay particular attention to the following 12 needs:

1. Full description of all steps taken in the generation of FCDRs and ECV products, including algorithms used, specific FCDRs used, and characteristics and outcomes of validation activities
2. Application of appropriate calibration/validation activities
3. Statement of expected accuracy, stability and resolution (time, space) of the product, including, where possible, a comparison with the GCOS requirements
4. Assessment of long-term stability and homogeneity of the product
5. Information on the scientific review process related to FCDR/product construction (including algorithm selection), FCDR/product quality and applications
6. Global coverage of FCDRs and products where possible
7. Version management of FCDRs and products, particularly in connection with improved algorithms and reprocessing
8. Arrangements for access to the FCDRs, products and all documentation
9. Timeliness of data release to the user community to enable monitoring activities
10. Facility for user feedback
11. Application of a quantitative maturity index if possible
12. Publication of a summary (a webpage or a peer-reviewed article) documenting point-by-point the extent to which this guideline has been followed

Guideline for the Generation of Datasets and Products Meeting GCOS Requirements*

*An update of the “Guideline for the Generation of Satellite-based Datasets and Products meeting GCOS Requirements” (GCOS-128, WMO/TD-No. 1488), including in situ datasets and amendments

May 2010

GCOS-143 (WMO/TD No. 1530)
## CM SAF: GCOS recommendations

<table>
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<tr>
<th>#</th>
<th>Climate Data Record</th>
<th>01</th>
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**CM SAF: Maturity Matrix**

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<th>User documentation</th>
<th>Uncertainty characterization</th>
<th>Public access, feedback and update</th>
<th>usage</th>
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Scores range from 1 (lowest) to 6 (highest)

*Assessment of #1 thru #5 according to:*

“CORE-CLIMAX European ECV CDR capacity assessment report”;
DocNo.: CC/EUM/REP/14/004 EUMETSAT, December 2014

*#6 thru 10: self-assessment by SAF on Climate Monitoring*

*See also:*

“CORE-CLIMAX System Maturity Matrix Instruction Manual”
DocNo.: CC/EUM/MAN/13/002 EUMETSAT, May 2014
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#6 thru 10: self-assessment by SAF on Climate Monitoring

See also:
“ CORE-CLIMAX System Maturity Matrix Instruction Manual”
DocNo.: CC/EUM/MAN/13/002 EUMETSAT, May 2014
Overview

The CLARA-A1 dataset is a global dataset of cloud, surface albedo and surface radiation products derived from measurements of the Advanced Very High Resolution Radiometer (AVHRR) onboard the polar orbiting NOAA and Metop satellites. Monthly and daily mean products have been compiled over a time period of 29 years starting in 1982 and ending in 2010. Results are available for individual satellites as well as aggregated for all satellites. The data are provided on two types of grids: a global regular latitude-longitude grid with 0.25 degrees resolution and two equal-area grids covering the polar regions with 25 km resolution (products on the polar grids are restricted to cloud amount and surface albedo). Further extensions, e.g. single- and multi-parameter histograms, and subsets, e.g. daytime-only and night-time-only results, are also available.

Available documentation:

- Product User Manual
- Algorithm Theoretical Basis Document
- Validation Report


Temporal coverage of used AVHRR instruments aboard NOAA and Metop satellites.

Products

- Fractional Cloud Cover:
  - CFC
  - Surface Albedo: SAL
- Joint Cloud Property Histograms:
  - JCH
  - Surface Net Shortwave Radiation: SNS
- Cloud Top Height, Temperature, Pressure:
  - CTO
  - Surface Outgoing Longwave Rad.: SOL
- Cloud Optical Thickness:
  - COT
  - Downward Longwave Rad.: SDL
- Cloud Phase:
  - CPH
  - Surface Net Longwave Rad.: SNL
- Liquid Water Path:
  - LWP
  - Radiation Budget: SRB
- Ice Water Path:
  - IWP
  - Cloud Radiative Effect short wave: CPS
- Surface Incoming Shortwave Radiation:
  - SIS
  - Cloud Radiative Effect long wave: CFL

Technical Specifications

- Time period: 1982-2009 (Clouds & Surface Albedo); 1989-2009 (Radiation)
- Temporal resolution: daily mean, pentad mean, monthly mean, monthly histograms (depending on product)
- Spatial coverage: global on a regular latitude/longitude grid (polar areas: equal area)
- Spatial resolution: 0.25° x 0.25° (JCH: 1° x 1°, polar areas: 25° x 25 km²)
- Data Format: NetCDF 3, Climate and Forecast (CF) Metadata Convention v1.5
- Note: On request, data are also available reformatted using the CIMOR (http://www.cimor.org/cimor/obs4mips/) file format standard.

Free Data Access & Contact

www.cmsaf.eu/wui
User help desk: contact.cmsaf@dwd.de
Sustained, Coordinated Processing of Environmental Satellite Data for Climate Monitoring

SCOPE-CM is a

- network of agencies and operators of environmental satellite systems and
- interfaces with WMO, WCRP, GCOS, CGMS, CEOS and GEO.
- It offers its support to coordinate and facilitate international activities to generate Climate Data Records (CDR) from multi-agency satellite data.
Sustained, Coordinated Processing of Environmental Satellite Data for Climate Monitoring

10 SCOPE-CM phase 2 projects (6 with CM SAF):

**SCM-01**: Sustained generations of upper tropospheric humidity Climate Data Records from multiple sensors with multi-agency cooperation.

**SCM-02**: Multiplatform surface albedo demonstrator from polar-orbiting satellites.

**SCM-03**: Land surface albedo from geostationary satellites (LAGS).

**SCM-04**: Utility of Satellite derived winds for Monsoon and Cyclone studies over Indian region.

**SCM-05**: Advancing the status of the AVHRR FCDR.

**SCM-06**: Inter-calibration of passive imager observations from time-series of geo stationary satellites (IOGEO).

**SCM-07**: Liquid Water Path and Rain Water Path Climatologies in the GPM era.

**SCM-08**: Radio occultation based gridded climate data sets (RO-CLIM).

**SCM-09**: Sustained production of the International Satellite Cloud Climatology Project (ISCCP) cloud products.

**SCM-10**: Atmospheric Motion Vectors and Clear/All Sky Radiances from historical satellites in geostationary and polar orbit.
CM SAF: Next Phase (2017 – 2022)

Currently drafting the proposal for 2017 – 2022:

- Continue with successful product & service portfolio

- Extend to
  - Global Precipitation Climate Data Record
  - Include regional Evapotranspiration Climata Data Record

- Focus on Thematic Climate Data Records (long time series of ECVs)

- New partner CNRS/LEGOS (France)
CM SAF: Data Access

Free and easy access via

https://wui.cmsaf.eu/

Web User Interface allows:

• Easy selection and online ordering of Data Records (DOI-referenced)
• Standing orders
• Postprocessing, i.a.
  • Reformating of data
  • Area selection (also CORDEX areas)
  • On request some data are available compliant with Ops4MIPs

Offline tools:

• Graphical User Interface (cloud & radiation products)
• R tools
• Climate Data Operators (CDO)
CM SAF: R Toolbox

- CM SAF provides CM SAF R Toolbox
- ‘cmsaf’ R-package collection of functions for basic analysis and manipulation of CM SAF netcdf formatted data (see cran.r-project.org)
- Functions of ‘cmsaf’ R-package provides are inspired by the Climate Data Operators (cdo)
- R-scripts to analyze and plot CM SAF data
- R-scripts, which help unexperienced R-users to apply easily the functions of the ‘cmsaf’ R-package (starting from .tar file ordered at wui.cmsaf.eu)
- R Toolbox is freely available via www.cmsaf.eu/tools
CM SAF: Users

- Research Institute: 46%
- Meteorological Service: 34%
- Private Company: 12%
- Government Service: 8%
- Others: 0%

Number of registered users over time:

- 2009: 1762
- 2008: 1501
- 2007: 1301
- 2006: 1115
- 2005: 860
- 2004: 687
- 2003: 477
- 2002: 382
- 2001: 227
- 2000: 193
- 1999: 94

Countries with no CM SAF users:
- Countries with 1 to 5 users:
- Countries with 11 to 100 users:
- Countries with more than 100 users:
- New countries added in reporting period:
CM SAF: User support

- User (requirements) workshops
- User training workshops (next November 2016 @ ECMWF)
- CM SAF community site (http://training.eumetsat.int/enrol/index.php?id=147)
- User help desk
- User information & documentation, including i.a.
  - Newsletter
  - Service Messages
  - Change logs
  - FAQs
  - Product User Manuals (PUM)
  - Algorithm Theoretical Baseline Documents (ATBD)
  - Validation Reports (ValReps & Annual Quality Assessment; AQA)
  - Operations Reports

Upcoming

- Commentary Metadata
- Maturity Matrix (System & Application)
- Web Mapping Services (WxS)
CM SAF: Downstream Application; Example 1 PVGIS @ JRC

New: PVGIS expanded to cover Asia. Click here to read about it.

Performance of Grid-connected PV

Radiation database: [What Is this?]
PV technology: Crystalline silicon
Installed peak PV power: 1 kWP
Estimated system losses [0;100] 14 %
Fixed mounting options:
Mounting position: Free-standing
Slope [0;90] 0 °
Azimuth [-180;180] 0 °
Optimize slope
Also optimize azimuth
(Azimuth angle from -180 to 180. East=0, South=0)

Tracking options:
- Vertical axis Slope [0;90] 0 °
- Inclined axis Slope [0;90] 0 °
- 2-axis tracking

Output options
- Show graphs
- Show horizon
- Web page
- Text file
- PDF

Re-calibration and inter-calibration Coefficients

Satellite Raw Data

1st order calibration

FCDR Fundamental Climate Data Records
Multi-satellite corrected and inter-calibrated physical observations, e.g. radiances

TCDR Thematic Climate Data Records
Multi-satellite geophysical parameter records derived from FCDRs

ICDR Interim Climate Data Records
Multi-satellite geophysical parameter records
CM SAF: Climate Monitoring and Services

- Climatic Assessment
- Maps & films
- Statistics
- Indices &
- Indicators

Climatological Background Information:
Thematic Climate Data Records (TCDR)

TCDR
Thematic Climate Data Records
Multi-satellite geophysical parameter records derived from FCDRs

Climatological Up-to-date Information:
Intermediate Climate Data Records (ICDR)

ICDR
Interim Climate Data Records
Multi-satellite geophysical parameter records
CM SAF: Downstream Application; Example 2 WMO Regional Climate Centre RA VI

Absolute anomaly Global Radiation

http://www.dwd.de/rcc-cm

TCDR
Thematic Climate Data Records
Multi-satellite geophysical parameter records derived from FCDRs

ICDR
Interim Climate Data Records
Multi-satellite geophysical parameter records
CM SAF: Summary

Products & services related to the global energy & water cycle

Thorough quality assurance & control mechanisms

Comprehensive user interaction and support

Free data access

www.cmsaf.eu
CEOS Essential Climate Variable (ECV) Inventory

- CNES
- EC
- ESA
- Eumetsat
- Jaxa
- JMA
- NASA
- NOAA
- USGS
- Multiple or not selected

90% from CM SAF

Courtesy A. Ratier; 2014
CM SAF: From data to information

CDS ➔ CIS ➔ O&D

Climatological Background Information:
- Thematic Climate Data Records (TCDR)

Climatological Up-to-date Information:
- Intermediate Climate Data Records (ICDR)

CIS:
- Maps & films
- Statistics
- Indices & Indicators
- ....

O&D:
- Interactive
- User-taylored
- Post-processing
- Web-Mapping services
- others
# CM SAF: FCDR -> TCDR -> ICDR

<table>
<thead>
<tr>
<th></th>
<th>FCDR</th>
<th>TCDR</th>
<th>ICDR</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CDR type</strong></td>
<td>Fundamental Climate Data Record</td>
<td>Thematic Climate Data Record</td>
<td>Intermediate Climate Data Record</td>
</tr>
<tr>
<td><strong>CDR description</strong></td>
<td>Calibrated / Intercalibrated Sensor data</td>
<td>Long time series of Essential Climate Variables</td>
<td>Regular &amp; consistent updates of TCDRs</td>
</tr>
<tr>
<td><strong>Provider</strong></td>
<td>Satellite operators</td>
<td>e.g. CM SAF</td>
<td>GCFS?, RCC?, C3S?</td>
</tr>
</tbody>
</table>

---

**Climate Monitoring & Services**
CM SAF: FCDR -> TCDR -> ICDR

- Peer-reviewed dataset and method
- Continuous development and scientific updates of algorithms
- Clear traceability of user requirements
- High quality
- Well documented
- User support & training

- Consistent with TCDR datasets
- Based on TCDR expertise & team
- Regular updates
- Esp. for climate monitoring and services
- Capitalize on TCDR production & service environment
CM SAF: TCDRs of ECVs

Courtesy: Alain Ratier, EUMETSAT
CM SAF: Processing Centres

- **Satellite Data Reception/Procurement**
  - **DWD, Offenbach**
    - Local Archive
    - Product generation at DWD
    - Product generation at ECMWF
  - **RMIN, Brussels**
    - Local Archive
    - Product generation at RMIN
    - Scientific development and validation at RMIN

- **Central Archive**
  - CM-SAF Database, DWD
  - Interoperability

- **USER**
  - WUI, CM SAF
  - EO Portal, EUMETSAT
  - FTP-ServerError
    - DVD etc.
  - EDR generation at CAF
    - (planned)

2-4 March 2016

GCOS Science Conference; M. Werscheck
## CM SAF: Radiative Products

<table>
<thead>
<tr>
<th>Radiation</th>
<th>Acronym</th>
<th>Coverage</th>
<th>Europe &amp; Africa</th>
<th>global</th>
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<tbody>
<tr>
<td>Surface Radiation Budget</td>
<td>SRB</td>
<td>◊</td>
<td>●</td>
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<tr>
<td>Surface Incoming Shortwave</td>
<td>SIS</td>
<td>●</td>
<td>●</td>
<td>○</td>
</tr>
<tr>
<td>Surface Net Shortwave</td>
<td>SNS</td>
<td>◊</td>
<td>●</td>
<td>-</td>
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<tr>
<td>Direct Irradiance at Surface</td>
<td>SID</td>
<td>●</td>
<td>●</td>
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</tr>
<tr>
<td>Direct Normalized Irradiance at Surface</td>
<td>DNI</td>
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<td>-</td>
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<tr>
<td>Spectrally Resolved Irradiance</td>
<td>SRI</td>
<td>-</td>
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<tr>
<td>Daylight</td>
<td>DAL</td>
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<tr>
<td>Surface Albedo</td>
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<td>◊1</td>
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<tr>
<td>Cloud Albedo</td>
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<tr>
<td>Cloud Radiative Effect SW &amp; LW</td>
<td>CFS/L</td>
<td>-</td>
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<tr>
<td>Surface Net Longwave</td>
<td>SNL</td>
<td>◊</td>
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<tr>
<td>Surface Downward Longwave</td>
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<td>◊</td>
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<tr>
<td>Surface Outgoing Longwave</td>
<td>SOL</td>
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<tr>
<td>Top of Atmosphere Reflected Solar Radiative Flux</td>
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<tr>
<td>Top of Atmosphere Emitted Thermal Radiative Flux</td>
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<tr>
<td>Top of Atmosphere Incoming Solar Radiation</td>
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- Available
- not available

◊ data are only available until March 2012
1 including Arctic
○ planned
## CM SAF: Cloud & Aerosol Products

#### Water Vapour + Temperature, radiances

<table>
<thead>
<tr>
<th>Cloud &amp; Aerosol</th>
<th>Acronym</th>
<th>Coverage</th>
<th>Europe &amp; Africa</th>
<th>global</th>
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<tbody>
<tr>
<td></td>
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<td>EDR</td>
<td>CDR</td>
<td>EDR</td>
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<tr>
<td>Cloud Fractional Cover</td>
<td>CFC</td>
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<tr>
<td>Cloud Optical Thickness</td>
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<tr>
<td>Cloud Phase</td>
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<td>○</td>
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<tr>
<td>Cloud Top Temperature/Height/Pressure</td>
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<td>●</td>
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<tr>
<td>Cloud Water Path (ice &amp; liquid)</td>
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<tr>
<td>Liquid Water Path</td>
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<tr>
<td>Ice Water Path</td>
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<td>High Cirrus Cloud Amount</td>
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<td>Joint Cloud property Histograms</td>
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<td>Cloud Type</td>
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<td>Water Vapour + Temperature, radiances</td>
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<td>Layered Water Vapour and Temperature</td>
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<tr>
<td>Specific Humidity and Temperature at pressure levels</td>
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<tr>
<td>Free Tropospheric Humidity</td>
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2-4 March 2016
### CM SAF: HOAPS Product

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<th>HOAPS</th>
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<td>Near Surface Specific Humidity</td>
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