EUMETSAT Satellite Application Facility on
Support to Operational Hydrology and Water Management
http://hsaf.meteoam.it/

SUPPORT TO OPERATIONAL
HYDROLOGY AND WATER
MANAGEMENT

Product User Manual
(PUM)
H26

Soil Wetness Index in the roots region
by ASCAT soil moisture assimilation

Revision History

Revision	Date	Author(s)	Description
0.1	2021/05/07	David Fairbairn and Patricia de Rosnay	First draft.
0.2	2021/07/14	David Fairbairn and Patricia de Rosnay	Revised version after H26 ORR.

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List of Acronyms

ASAR Advanced Synthetic Aperture Radar (on Envisat)

ASAR GM ASAR Global Monitoring

ASCAT Advanced Scatterometer

ATBD Algorithm Theoretical Baseline Document

BUFR Binary Universal Form for the Representation of meteorological data

DORIS Doppler Orbitography and Radiopositioning Integrated by Satellite (on Envisat)

ECMWF European Centre for Medium-range Weather Forecasts

ERS European Remote-sensing Satellite (1 and 2)

ESA European Space Agency

EUMETCast EUMETSAT's Broadcast System for Environment Data

EUMETSAT European Organisation for the Exploitation of Meteorological Satellites

FTP File Transfer Protocol

H SAF SAF on Support to Operational Hydrology and Water Management

HTESSEL Hydrology Tiled ECMWF Scheme of Surface Exchanges over Land

LDAS Land Data Assimilation System

Météo France National Meteorological Service of France

Metop Meteorological Operational Platform

NRT Near Real-Time

NWP Numerical Weather Prediction

PRD Product Requirements Document

PUM Product User Manual

PVR Product Validation Report

SAF Satellite Application Facility

SEKF Simplified Extended Kalman Filter

SSM Surface soil moisture

SWI Soil Wetness Index

TU Wien Technische Universität Wien (Vienna University of Technology)

WARP Soil Water Retrieval Package

WARP H WARP Hydrology

WARP NRT WARP Near Real-Time

ZAMG Zentralanstalt für Meteorologie und Geodynamic (National Meteorological Service of Austria)

1. Executive summary

The Product User Manual (PUM) summarizes the product lineage and format of the near-real-time (NRT) H SAF scatterometer root zone soil moisture product (RZSM-ASCAT-NRT-10km/H26). The 10 km resolution H26 product is generated by assimilating ASCAT-derived surface soil moisture observations into the dedicated H SAF land data assimilation system. The output files are provided daily in two different file types with different formats: a cubic octahedral reduced Gaussian grid in GRIB format and a regular lat/lon grid in netCDF format.

A general introduction of the purpose of the document (section 2) is followed by a description of the H26 product (section 3). The product characteristics, production chain and structure/-format of the product are discussed in sections 4, 5 and 6 respectively. This is followed by brief information about product validation (section 7) and product availability (section 8). A conclusion is given in section 9. More information about the organisational structure of H SAF can be found in the Appendix.

2. Introduction

2.1. Purpose of the document

The Product User Manual (PUM) is intended to provide a detailed description of the main Product characteristics, format, validation activities and availability. Each PUM contains:

- Product introduction: principle of sensing, satellites utilized, instrument(s) description, highlights of the algorithm, architecture of the products generation chain, product coverage and appearance;
- Main product operational characteristics: Spatial resolution and sampling, observing cycle and time sampling, timeliness;
- Overview of the product validation activity: validation strategy, global statistics, product characterization;
- Basic information on product availability: access modes, description of the code, description of the file structure.

Although reasonably self-standing, the PUMs rely on other documents for further details. Specifically:

- Algorithm Theoretical Baseline Document (ATBD) for extensive details on the algorithms [1];
- Product Validation Report (PVR), for a full recount of the validation activity, both the evolution and the latest results [2].

2.2. Targeted audience

This document mainly targets:

- Hydrology and water management experts

- Operational hydrology and Numerical Weather Prediction communities
- Users of remotely sensed soil moisture for a range of applications (e.g. climate modelling validation, trend analysis)

2.3. H SAF soil moisture products

In the framework of the H SAF project several soil moisture products, with different timeliness (e.g. near real time products and data records), spatial resolution, format (e.g. time series, swath orbit geometry, global image) or the representation of the water content in various soil layers (e.g. surface, root-zone), are generated on a regular basis and distributed to users. A list of all available soil moisture products, as well as other H SAF products (such as precipitation or snow) can be looked up on the H SAF website (hsaf.meteoam.it). More general information about H SAF can be found in the Appendix.

3. Description of the root-zone soil wetness index product H26

3.1. Principal of the product

The H26 production chain uses an offline sequential Land Data Assimilation System (LDAS) based on an Simplified Extended Kalman Filter (SEKF) method, as in [3]. The SEKF constitutes the central component of the H26 production chain. The HTESSEL Land Surface Model is used to propagate in time and space the soil moisture information through the root zone, accounting for physiographic information (soil texture, orography), meteorological conditions and land surface processes such as soil evaporation and vegetation transpiration [4–6]. H26 is a root zone soil moisture product derived from Metop ASCAT-A/B/C surface soil moisture (SSM) observations. The retrieval approach relies on an sequential Land Data Assimilation System (LDAS) using the stand-alone surface analysis (SSA) configuration of [7]. The atmospheric analysis is forced from the archived operational 9 km ECMWF analysis, but the LDAS and coupled first guess are performed independently. Figure 3.1 illustrates the H26 LDAS production suite.

3.2. Main characteristics

H26 is a daily NRT product valid at 00UTC and with a timeliness of 12 hours i.e. the 00 UTC output should arrive on the H SAF ftp no later than 12 UTC. H26 is a daily NRT product valid at 00UTC and with a timeliness of 12 hours i.e. the 00 UTC output should arrive on the H SAF ftp no later than 12 UTC. H26 is produced at a horizontal resolution of about 10km on four vertical layers in the soil: surface to 7 cm (layer 1), 7 cm to 28 cm (layer 2), 28 cm to 100 cm (layer 3), and 100 cm to 289 cm (layer 4). Whilst the 4th layer is provided it is not listed in the product requirements as there are no in situ reference observations available to validate soil moisture at this depth. H26 relies on a data assimilation approach that propagates the information in time and space (on the vertical dimension in the root zone). Therefore, it allows a global update of the root zone soil moisture states using SSM derived from the aforementioned ASCAT products. H26 is a daily product valid at 00UTC. The soil moisture in the model and in the data assimilation process is in volumetric units. Prior to data assimilation, the SSM scatterometer derived observations are rescaled to match the model soil moisture climatology (described in the Algorithm Theoretical Baseline Document, ATBD, [1]) and in the process they are effectively

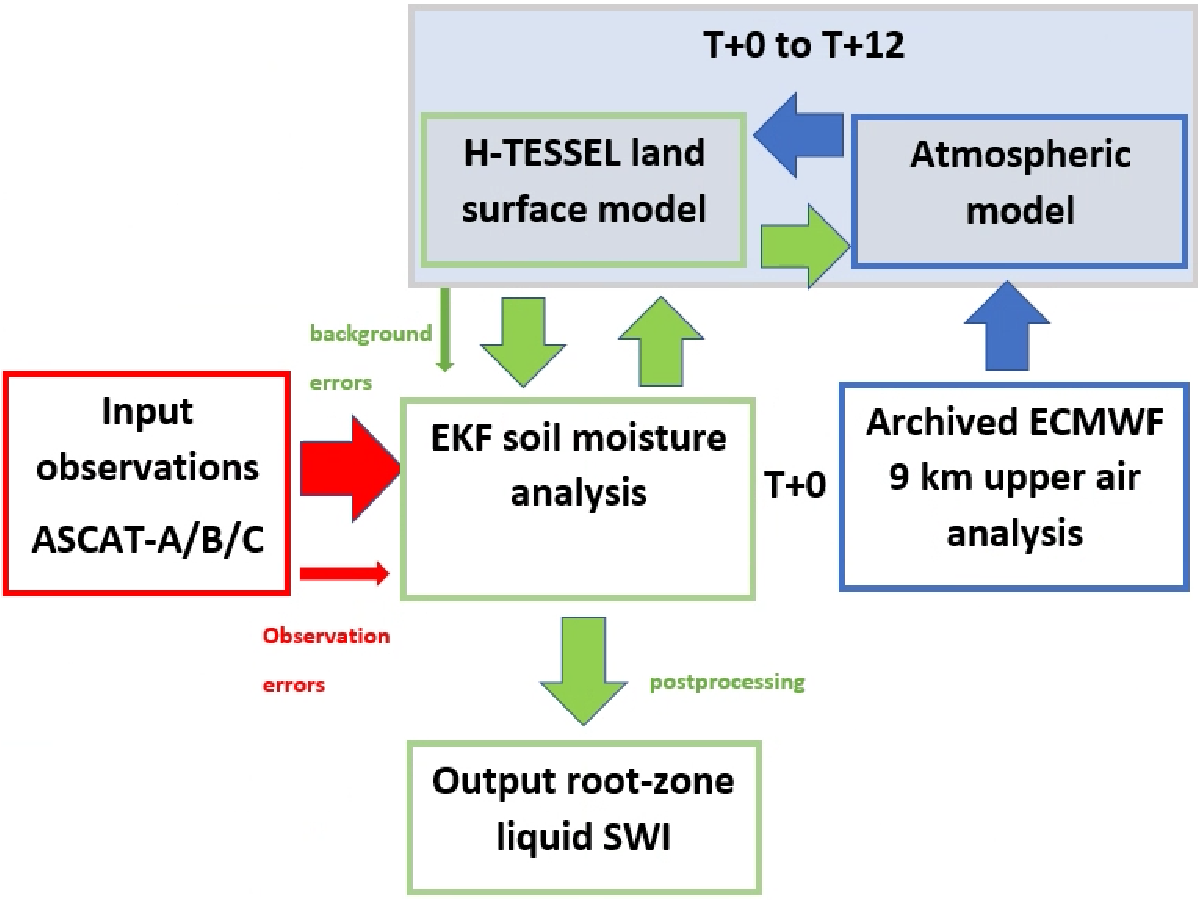

Figure 3.1: Illustration of the H26 root zone soil moisture production chain based on ASCAT-A/B/C satellite derived surface soil moisture data assimilation in the SSA configuration. The highlighted box encompasses the coupled land-atmosphere 12-hour first guess.

converted to volumetric units. However, the H26 root-zone soil moisture product is expressed as a liquid SWI, with units between 0 (zero soil moisture) and 1 (saturation), representing the lower and upper soil moisture limits. After data assimilation, a post-processing step is required to convert the volumetric soil moisture analysis into the SWI. It is computed using the soil texture (as defined by the FAO/United Nations Educational, Scientific and Cultural Organization (UNESCO) Digital Soil Map of the world [8]), the saturated soil moisture, and the fraction of liquid water content (the fraction of water that is not frozen) on each grid point and each soil layer. Having the units of H26 as a liquid SWI is consistent with all the other ASCAT soil moisture products that are available for the surface (e.g. H14 and H101). Furthermore, It is relevant to various applications and can be combined with different hydrological models (e.g. [9]).

4. Product uniqueness and heritage

The ECMWF H SAF dedicated LDAS has been operational since the First Continuous Development phase (starting in 2012) for the NRT H14 product. It is run independently of the ECMWF operational system. The validations of H SAF products have demonstrated that the LDAS is robust, reliable and that it provides high quality root zone soil wetness index fields.

H26 supersedes the original NRT product (H14), which was the first global product of consistent surface and root zone soil moisture available NRT for the NWP, climate and hydrological communities. H26 improves on H14 through increased resolution (25 to 10 km) and improved timeliness (12 hours instead of 36 hours). The H26 product employs a more recent version of the SEKF soil moisture analysis that was introduced in cycle 46r1 of the ECMWF/H SAF LDAS, which benefits from an ensemble of data assimilations (EDA) approach to provide flow-dependent uncertainty information. Also, it is the first operational product to employ the efficient SSA configuration (illustrated in Figure 3.1) and benefits from an update to the ASCAT soil moisture bias correction parameters. More details on these modifications are provided in the ATBD [1].

5. Production chain

The input observations for H26 consist of the ASCAT-A/B/C SSM products, as in Table 6.2 below. Note that the ASCAT-A satellite is planned to be decommissioned in November 2021. A quality control is applied to filter ASCAT SSM observations so that only observations with a noise level lower than 15% are used for H26. The quality control also rejects ASCAT SSM observations for pixels with a water fraction larger than 15% and with a topographic complexity larger than 20%, as well as observations in frozen soil and/or snow covered surface conditions. A processing flag filters out ASCAT observations that are considered to be corrupted.

The input ASCAT SSM products are assimilated in the H26 LDAS, which propagates the ASCAT SSM information in space on the soil vertical profile and in time at a daily time scale. The main components of the production chain are (i) the pre-processing of the ASCAT data (ii) the assimilation using the SEKF, and (iii) post-processing to convert the volumetric soil moisture analysis to a liquid soil wetness index (SWI). A detailed description of the H26 LDAS production chain can be found in the ATBD [1].

Table 5.1: Scaterrometer SSM products used in the NRT H26 product. N.A. stands for "not applicable".

Sensor	Producer	Reference
ASCAT-A (until Nov 2021), ASCAT-B and ASCAT-C 25 km sampling	EUMETSAT CAF	ASCSMO02: ASCAT-A/B/C 25 km swath grid product distributed by CAF. (https://vnavigator.eumetsat.int/product/EO:EUM:DAT:METOP:SOMO25). Equivalent to H SAF level 2 surface soil moisture products H102 (Metop-A 25 km sampling), H103 (Metop-B 25 km sampling) and H105 (Metop-C 25 km sampling).

6. Product structure and format

6.1. Introduction

The H26 output has 5 variables (i) soil wetness index analysis for each of the 4 layers; (ii) a quality control flag, which identifies gridpoints with soil wetness index values outside the nominal range (i.e. less than 0 or greater than 1), or where any layer has a soil temperature below 4°C i.e. there is a risk of frozen conditions. The quality control flag has one of 3 values for each gridpoint:

- 1 = normal
- 2 = risk of frozen conditions (one of the layers has a soil temperature less than 4°C)
- 3 = outside nominal range.

By design the SWI should always be in the nominal range (0-1), but a check is performed in case of corrupted data. However, many mountainous and high latitude regions are frozen, especially in winter. This can be useful to link very low liquid SWI values with frozen conditions. Note that a value outside the nominal range (labelled 3) would always override a frozen value (2).

The H26 output data is provided at approximately 10 km resolution in two different formats in order to cater for the needs of different users. The model and data assimilation are performed on a cubic octahedral reduced Gaussian grid ($T_{CO}1279$), which has approximately equidistant grid points between the equator and the poles i.e. the number of latitude points reduces closer to the poles. Daily files in GRIB edition 1 format are provided for the soil moisture analysis (valid at 00 UTC) on the original $T_{CO}1279$ grid, giving four fields of global SWI (one for each soil layer). Additionally, the same fields are provided as a single netCDF file on a 0.1 degree regular lat/lon grid (created by interpolating the $T_{CO}1279$ grid points onto a regular lat/lon grid). The $T_{CO}1279$ GRIB files are cheaper to store than the regular lat/lon netCDF files, partly because they have fewer latitude points near the poles and partly because missing values (e.g. over the oceans) are not stored explicitly. While many standard software packages are still better adapted to read in and plot data from regular lat/lon grids in netCDF format than irregular grids in GRIB format, increasingly software providers such as Python are developing tools to read in and plot the native reduced Gaussian grids directly. Thus it was decided to

Table 6.1: H26 grid information

H SAF attribute name	Type	Size	Value
latitudeOfFirstGridPointInDegrees	Real	6	89.947
longitudeOfFirstGridPointInDegrees	Real	1	0
laitutudeOfLastGridPointInDegrees	Real	7	-89.947
longitudeOfFirstGridPointInDegrees	Real	6	359.93
"dataDate"	String	8	"yyyymmdd"
"dataTime"	String	1	"hh"
"dataTime"	String	1	"hh"

provide the data in both formats for the benefit of different users. The output data formats are described and demonstrated in the following section.

6.2. Output data formats

6.2.1. Global map grid

The T_{CO}1279 grid (also referred to as O1280) has a quasi-regular grid spacing in distance at each latitude. The grid is symmetrical at the equator with no latitude row at either the pole or at the Equator. The centred first pixel is at longitude 0 and latitude 89.947 and the points are equally spaced along each line of latitude. The precise location of each latitude row and the number of reduced Gaussian grid longitude points are given on the ECMWF website [1]. The total number of T_{CO}1279 grid points for a global map of H26 is 6,599680. Information about the T_{CO}1279 grid is given in Table 6.1. One grib file has a size of about 31 mb.

The netCDF files are provided on a 0.1 degree regular lat/lon grid. They use the same grid information as in Table 6.1. Without compressing the data, the netCDF files would be expensive to store (about 100 mb per file). Therefore, they are stored as compressed netCDF4 files with a size of only about 18 mb. The data can be read directly from the compressed netCDF4 files using software that is compatible with netCDF4 e.g. Python, Matlab.

6.2.2. File naming

For H26 on T_{CO}1279, the file naming convention is: h26_YYYYMMDDHH_TCO1279.grib with YYYY the year, MM the month, DD the day of month, HH valid time UTC (Coordinated Universal Time). The product is available daily at 00UTC. Similarly for the H26 netCDF files, the naming convention is h26_YYYYMMDDHH_R01.nc, where "R01" stands for "0.1 degree regular lat/lon".

6.2.3. Product parameters

For H26 T_{CO}1279 GRIB files each contain five messages. The first four messages are for each soil layer, using the GRIB parameters 40, 41, 42, and 43 of the table version 228. These parameters describe the SWI in the soil layer 1 (0-7cm), layer 2 (7-28cm), layer 3 (28-100 cm) and layer 4 (100-289 cm), respectively. They are exclusively used for the H SAF root zone products (as

[1] https://confluence.ecmwf.int/display/FCST/Introducing+the+octahedral+reduced+Gaussian+grid

Table 6.2: H26 GRIB and netCDF file parameters

H SAF attribute name	Type	Size	Value
table2Version	Real	3	228
Variables	Real	2	40, 41, 42, 43, 200
MissingValue	Real	4	9999
bitsPerValue	Real	2	24
"dataTime"	String	1	“hh”
numberOfValues	Real	7	“Number of values”

originally defined in the Second Continuous Development and Operations Phase, CDOP-2). The fifth message contains the GRIB parameter 200, which corresponds to the quality control flag described in Section 6.1. The same variables and table versions are included in the netCDF files. Table 6.2 shows the parameters of the H26 product.

6.3. Examples

An example of the GRIB data for the first layer is shown below for 07 May 2021. The GRIB files can be easily opened using the GRIB API package [2].

GRIB listing

```
#==============   MESSAGE 1 ( length=6417534 )              ==============
GRIB {
  editionNumber = 1;
  table2Version = 228;
  # European Centre for Medium-Range Weather Forecasts (common/c-1.table)
  centre = 98;
  generatingProcessIdentifier = 255;
  # SWI1 Soil wetness index in layer 1  (dimensionless)  (grib1/2.98.228.table)
  indicatorOfParameter = 40;
  # Surface  (of the Earth, which includes sea surface)  (grib1/local/ecmf/3.table , grib1/3.ta
  indicatorOfTypeOfLevel = 1;
  level = 0;
  # Forecast product valid at reference time + P1  (P1>0)  (grib1/local/ecmf/5.table , grib1/5.
  timeRangeIndicator = 0;
  # Unknown code table entry (grib1/0.ecmf.table)
  subCentre = 0;
  paramId = 228040;
  #-READ ONLY- cfNameECMF = unknown;
  #-READ ONLY- cfName = unknown;
  #-READ ONLY- cfVarNameECMF = swi1;
  #-READ ONLY- cfVarName = swi1;
  #-READ ONLY- units = dimensionless;
  #-READ ONLY- nameECMF = Soil wetness index in layer 1;
  #-READ ONLY- name = Soil wetness index in layer 1;
  decimalScaleFactor = 0;
  dataDate = 20210507;
  dataTime = 0;
```

[2] https://software.ecmwf.int/wiki/display/GRIB/Documentation

```
# Hour (stepUnits.table)
stepUnits = 1;
stepRange = 0;
startStep = 0;
endStep = 0;
#-READ ONLY- marsParam = 40.228;
# MARS labelling or ensemble forecast data (grib1/localDefinitionNumber.98.table)
localDefinitionNumber = 1;
# Research department (mars/class.table)
marsClass = 2;
# Analysis (mars/type.table)
marsType = 2;
# Atmospheric model (mars/stream.table)
marsStream = 1025;
experimentVersionNumber = h26o;
perturbationNumber = 0;
numberOfForecastsInEnsemble = 0;
shortName = swi1;
GDSPresent = 1;
bitmapPresent = 1;
numberOfVerticalCoordinateValues = 0;
Ni = MISSING;
Nj = 2560;
latitudeOfFirstGridPointInDegrees = 89.946;
longitudeOfFirstGridPointInDegrees = 0;
earthIsOblate = 0;
uvRelativeToGrid = 0;
latitudeOfLastGridPointInDegrees = -89.946;
longitudeOfLastGridPointInDegrees = 359.93;
iDirectionIncrement = MISSING;
iDirectionIncrementInDegrees = MISSING;
N = 1280;
iScansNegatively = 0;
jScansPositively = 0;
jPointsAreConsecutive = 0;
#-READ ONLY- alternativeRowScanning = 0;
global = 1;
#-READ ONLY- numberOfDataPoints = 6599680;
#-READ ONLY- numberOfDataPointsExpected = 6599680;
#-READ ONLY- numberOfValues = 1862447;
isOctahedral = 1;
pl(2560) = {
20, 24, 28, 32, 36,
40, 44, 48, 52, 56,
60, 64, 68, 72, 76,
80, 84, 88, 92, 96,
100, 104, 108, 112, 116,
120, 124, 128, 132, 136,
140, 144, 148, 152, 156,
160, 164, 168, 172, 176,
180, 184, 188, 192, 196,
200, 204, 208, 212, 216,
220, 224, 228, 232, 236,
240, 244, 248, 252, 256,
260, 264, 268, 272, 276,
280, 284, 288, 292, 296,
300, 304, 308, 312, 316,
```

```
  320, 324, 328, 332, 336,
  340, 344, 348, 352, 356,
  360, 364, 368, 372, 376,
  380, 384, 388, 392, 396,
  400, 404, 408, 412, 416
  ... 2460 more values
  }
  missingValue = 9999;
  tableReference = 0;
  #-READ ONLY- binaryScaleFactor = -23;
  #-READ ONLY- referenceValue = 0;
  sphericalHarmonics = 0;
  complexPacking = 0;
  integerPointValues = 0;
  additionalFlagPresent = 0;
  packingType = grid_simple;
  bitsPerValue = 24;
  values(6599680) = {
  9999, 9999, 9999, 9999, 9999,
  9999, 9999, 9999, 9999, 9999,
  9999, 9999, 9999, 9999, 9999,
  9999, 9999, 9999, 9999, 9999,
  9999, 9999, 9999, 9999, 9999,
  9999, 9999, 9999, 9999, 9999,
  9999, 9999, 9999, 9999, 9999,
  9999, 9999, 9999, 9999, 9999,
  9999, 9999, 9999, 9999, 9999,
  9999, 9999, 9999, 9999, 9999,
  9999, 9999, 9999, 9999, 9999,
  9999, 9999, 9999, 9999, 9999,
  9999, 9999, 9999, 9999, 9999,
  9999, 9999, 9999, 9999, 9999,
  9999, 9999, 9999, 9999, 9999,
  9999, 9999, 9999, 9999, 9999,
  9999, 9999, 9999, 9999, 9999,
  9999, 9999, 9999, 9999, 9999,
  9999, 9999, 9999, 9999, 9999,
  9999, 9999, 9999, 9999, 9999
  ... 6599580 more values
  }
  #-READ ONLY- numberOfCodedValues = 1862447;
  #-READ ONLY- maximum = 1;
  #-READ ONLY- minimum = 0;
  #-READ ONLY- average = 0.452681;
  #-READ ONLY- numberOfMissing = 4737233;
  #-READ ONLY- standardDeviation = 0.348227;
  #-READ ONLY- skewness = 0.0474485;
  #-READ ONLY- kurtosis = -1.46413;
  #-READ ONLY- isConstant = 0;
  gridType = reduced_gg;
  #-READ ONLY- getNumberOfValues = 6599680;
}
```

An example of the netCDF file header data is shown below using the standard netCDF software package from UCAR [3].

[3] https://www.unidata.ucar.edu/software/netcdf/netcdf-4/newdocs/netcdf/NetCDF-Utilities.html

netCDF headers

```
netcdf h26_2021050700_R01 {
dimensions:
        time = UNLIMITED ; // (1 currently)
        lon = 3600 ;
        lat = 1801 ;
        depth = 1 ;
        bnds = 2 ;
variables:
        double time(time) ;
                time:standard_name = "time" ;
                time:units = "hours since 2021-5-7 00:00:00" ;
                time:calendar = "proleptic_gregorian" ;
                time:axis = "T" ;
        double lon(lon) ;
                lon:standard_name = "longitude" ;
                lon:long_name = "longitude" ;
                lon:units = "degrees_east" ;
                lon:axis = "X" ;
        double lat(lat) ;
                lat:standard_name = "latitude" ;
                lat:long_name = "latitude" ;
                lat:units = "degrees_north" ;
                lat:axis = "Y" ;
        double depth(depth) ;
                depth:long_name = "depth_below_land" ;
                depth:units = "cm" ;
                depth:positive = "down" ;
                depth:axis = "Z" ;
                depth:bounds = "depth_bnds" ;
        double depth_bnds(depth, bnds) ;
        float var40(time, lat, lon) ;
                var40:table = 228 ;
                var40:missing_value = -9.e+33f ;
        float var41(time, lat, lon) ;
                var41:table = 228 ;
                var41:missing_value = -9.e+33f ;
        float var42(time, lat, lon) ;
                var42:table = 228 ;
                var42:missing_value = -9.e+33f ;
        float var43(time, lat, lon) ;
                var43:table = 228 ;
                var43:missing_value = -9.e+33f ;
        float var200(time, depth, lat, lon) ;
                var200:table = 228 ;
                var200:missing_value = -9.e+33f ;
}
```

The GRIB files can be read in and plotted directly using the new metview-python package developed by ECMWF. Download instructions, documentation and examples can be found on GitHub [4]. A metview-python script below plots the root-zone SWI over Europe on 07/05/2021. The corresponding output plot is shown in Figure 6.1. The regular lat/lon netCDF files can be

[4] https://github.com/ecmwf/metview-python

plotted using most standard graphics packages (e.g. Python, Matlab). Various examples of how to read in and plot root-zone SWI maps and time series from regular lat/lon netCDF files using Python are demonstrated on the ECMWF H SAF website [5].

Example metview-python plotting script (from GRIB file) of root-zone SWI (07/05/2021):

```
import metview as mv
import numpy as np

fs =mv.read('h26_2021050700_TCO1279.grib')

cmin=0.0
cmax=1.0

contouring=np.linspace(cmin,cmax,9).tolist()

legend_vals=np.around(np.linspace(cmin,cmax,7),2).tolist()

#Setup a contour plot with min/max values
cont_pc = mv.mcont(contour = "off",
                legend = "on",
                contour_shade = "on",
                contour_level_selection_type = "level_list",
                contour_level_list = contouring,
                contour_label_format = "(F4.1)",
                contour_label = "off",
                contour_label_height = 0.40,
                contour_label_colour = "charcoal",
                contour_label_frequency = 10,
                contour_highlight              = "off",
                contour_level_count           = 10,
                contour_shade_technique = "cell_shading",
                contour_shade_cell_resolution = "50",
                contour_shade_colour_method = "gradients",
                contour_gradients_colour_list = ['burgundy','red','orange','yellow','green','cyan
                contour_gradients_step_list = [20,20,20,20,20,20,20,20,20])

#Create legend:
my_legend = mv.mlegend(legend_display_type = "continuous",
                  legend_entry_border='off',
                  legend_text_colour = "charcoal",
                  legend_values_list= legend_vals,
                  legend_text_composition = 'user_text_only',
                  legend_text_font_size = 1,
                  legend_user_maximum = "off",
)


# shaded land to make the points stand out more
grey_land_shading = mv.mcoast(
    map_coastline_land_shade         = "on",
    map_coastline_land_shade_colour = "grey",
    map_grid_latitude_increment      = 4,
    map_grid_longitude_increment     = 4,
```

[5] https://confluence.ecmwf.int/display/LDAS/H+SAF

```
    map_grid_colour                    = "charcoal",
    map_label_height = 0.80,
    map_grid = "off",
    map_label = "off")

#Extraxt European domain
area_view = mv.geoview(
    map_area_definition = 'corners',
    area = [30,-20.0,65,20],
    coastlines = grey_land_shading
)

#Extract root-zone SWI values by depth-integrating the first 3 layers:
RZSM = fs[0]
RZSM = RZSM.set_values(fs.values()[0]*0.07 + fs.values()[1]*0.21\
                        + fs.values()[2]*0.72)

#Save plot output
mv.setoutput(mv.png_output(output_name = 'RZSM_plot_Europe.png'))


title_name="H26 Root-zone SWI over Europe on 07/05/2021"
#Create title
title = mv.mtext(text_lines = ["<font size='0.8'>"+title_name+"</font>",""],
          text_justification = "centre",
          text_font_size = 0.5,
          text_colour = "charcoal")

dw = mv.plot_superpage(pages = mv.mvl_regular_layout(area_view,1,1,1,1))

#Make plot
mv.plot(dw[0], RZSM, cont_pc, my_legend, title)
```

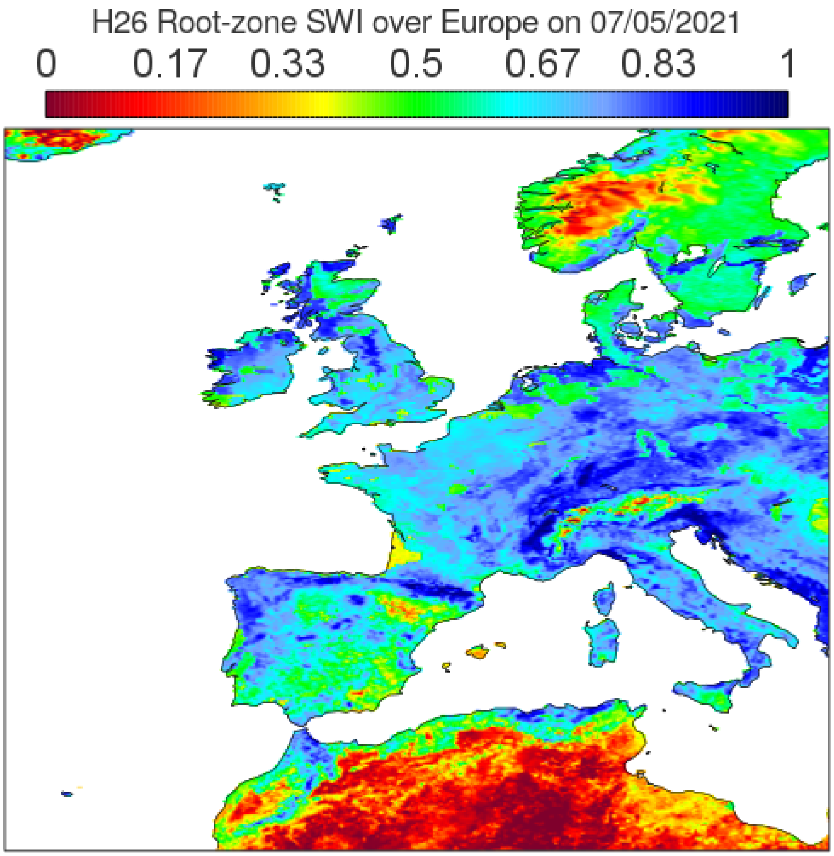

Figure 6.1: Plot of the H26 root-zone SWI over Europe for 07 May 2021

Table 7.1: Performance requirements for H26 [CC]

Unit	Threshold	Target	Optimal
Dimensionless	0.5	0.65	0.8

It is important to consider that the ASCAT SSM products are swath-based, whereas H26 is a daily gridded product with a global coverage. The root zone soil wetness generation relies on land data assimilation, which ensures the ASCAT information is propagated in space and time, even when there are gaps in ASCAT observations. So, the land surface model component ensures the soil wetness evolution until the next ASCAT observations are available. In some areas the ASCAT SSM observations are seasonally or permanently not available. It is the case over tropical forests, mountainous areas, in frozen or in snow covered conditions. In these conditions the production of the root zone soil moisture entirely relies on the land surface model which ensures physically-based soil moisture evolution in the absence of ASCAT observations.

7. Validation

Following the previous NRT product (H14) approach, H26 is assessed using the temporal correlation against ground measurements. Additional metrics, including the anomaly correlation coefficient, the root-mean-square error and the bias are also considered. The previous NRT product H14 is used as a benchmark to validate the performance of H26 over June 2018 to May 2019. Table 7.1 presents the soil wetness index user requirements originally adopted in the H SAF Second Continuous Development and Operations Phase CDOP-2 and also used for the near-real-time (NRT) product (H14) and the H141 data record in the third development phase (CDOP-3). Furthermore, a triple colocation validation is provided for the surface layer of H26. Details and results regarding the validation can be found in the Product Validation Report [2].

8. Product availability

8.1. Download

The NRT H26 product is available via FTP in the "products" directory. Download details are available after registering at the H SAF website[6]. If you need help, please contact the H SAF user helpdesk[7].

8.2. Conditions of use and citations

All H SAF products are owned by EUMETSAT, and the EUMETSAT SAF Data Policy applies. They are available for all users free of charge. Users should recognize the respective roles of EUMETSAT, the H SAF Leading Entity and the H SAF Consortium when publishing results that are based on H SAF products. EUMETSAT's ownership and intellectual property rights into the SAF data and products is best safeguarded by simply displaying the words "© EUMETSAT" under each of the SAF data and products shown in a publication or website. The H26 data record should be cited as [10] (the DOI will be confirmed shortly).

[6] http://hsaf.meteoam.it
[7] us_hsaf@meteoam.it

9. Conclusion

The RZSM-ASCAT-NRT-10km (H26) NRT product consists of a unique global scatterometer derived root zone soil wetness index, which is computed on a daily basis. The product results from data assimilation which enables the propagation of the surface soil moisture information observed by ASCAT-A/B/C to the root zone.

The 10 km resolution H26 product is provided at 00 UTC daily as a soil wetness index across the four root-zone layers with a timeliness of 12 hours. It is provided in two different file formats: 1) An octahedral reduced Gaussian grid ($T_{CO}1279$) in GRIB format, which has approximately equidistant grid points between the equator and the poles, and 2) a regular lat/lon grid in compressed netCDF4 format. Most standard software packages are better suited to reading in netCDF with regular lat/lon grids than GRIB files with irregular grids. Nevertheless, recently ECMWF has developed the metview-python software package that can handle the GRIB files directly. For the benefit of the different users, both file types are provided. Examples of reading and plotting the data are provided or referenced in this document.

More information about the data assimilation theory can be found in the H26 algorithm theoretical baseline document [1]. A comprehensive validation against in situ measurements and a triple colocation analysis can be found in the product validation report [2], which demonstrates that the product fulfills its performance requirements.

10. References

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Appendices

A. Introduction to H SAF

H SAF is part of the distributed application ground segment of the "European Organization for the Exploitation of Meteorological Satellites (EUMETSAT)". The application ground segment consists of a Central Application Facilities located at EUMETSAT Headquarters, and a network of eight "Satellite Application Facilities (SAFs)", located and managed by EUMETSAT Member States and dedicated to development and operational activities to provide satellite-derived data to support specific user communities (see Figure A.1):

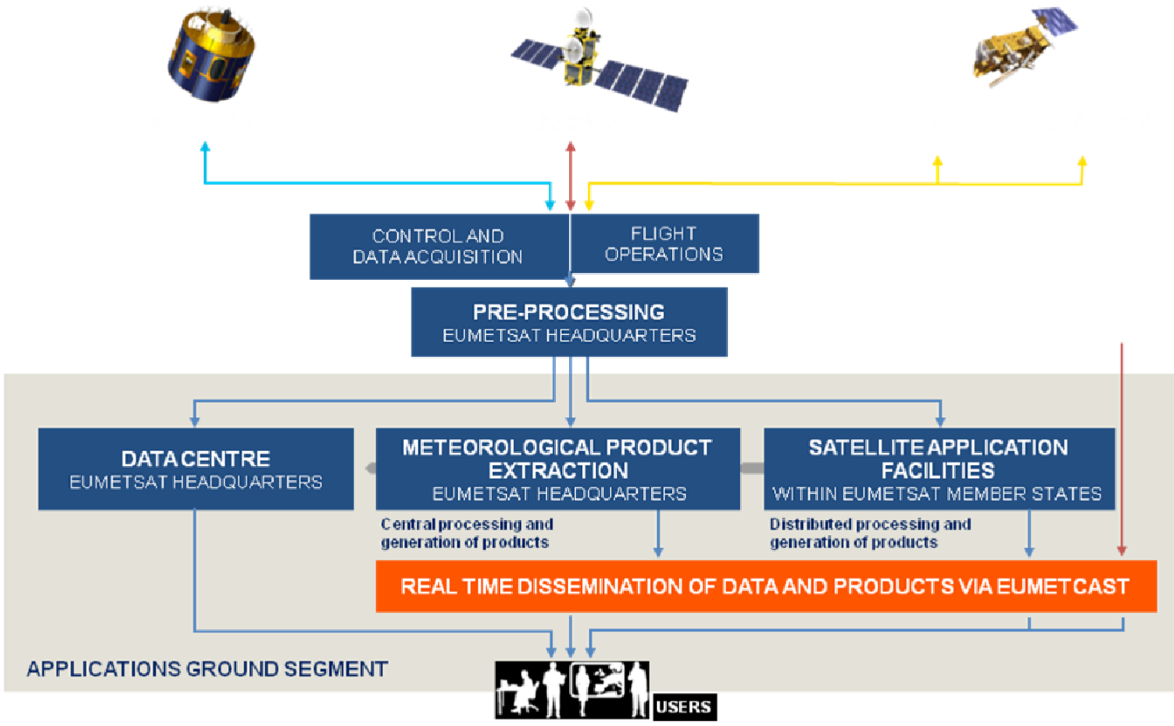

Figure A.1: Conceptual scheme of the EUMETSAT Application Ground Segment.

Figure A.2 here following depicts the composition of the EUMETSAT SAF network, with the indication of each SAF's specific theme and Leading Entity.

B. Purpose of the H SAF

The main objectives of H SAF are:

a) to provide new satellite-derived products from existing and future satellites with sufficient time and space resolution to satisfy the needs of operational hydrology, by generating, centralizing, archiving and disseminating the identified products:

- precipitation (liquid, solid, rate, accumulated);
- soil moisture (at large-scale, at local-scale, at surface, in the roots region);

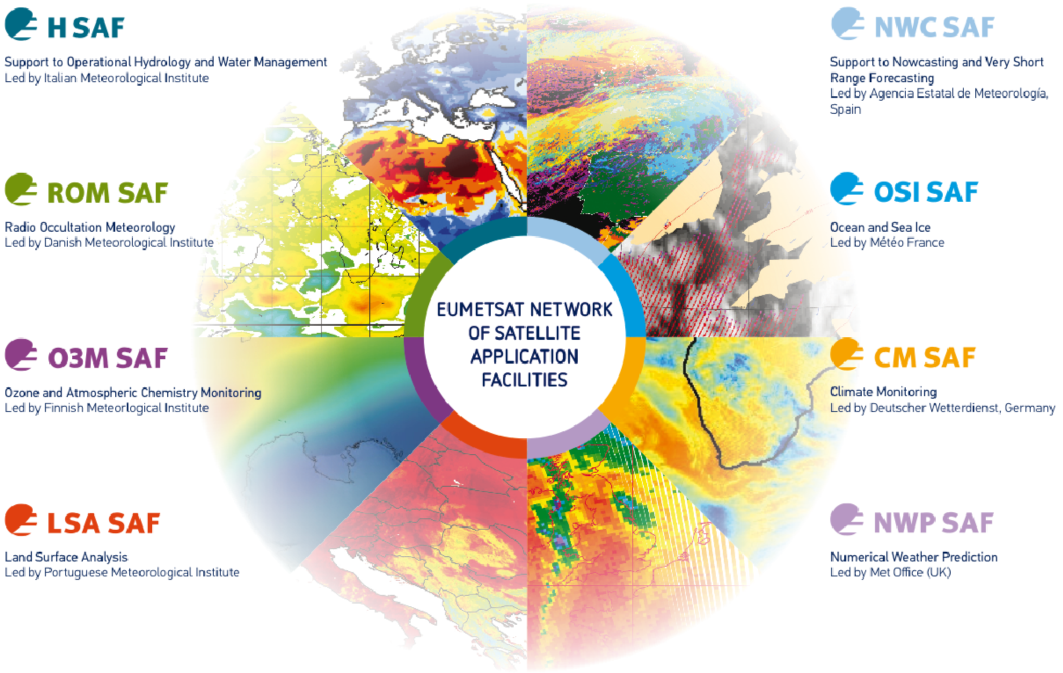

Figure A.2: Current composition of the EUMETSAT SAF Network.

- snow parameters (detection, cover, melting conditions, water equivalent);

b) to perform independent validation of the usefulness of the products for fighting against floods, landslides, avalanches, and evaluating water resources; the activity includes:

- downscaling/upscaling modelling from observed/predicted fields to basin level;
- fusion of satellite-derived measurements with data from radar and raingauge networks;
- assimilation of satellite-derived products in hydrological models;
- assessment of the impact of the new satellite-derived products on hydrological applications.

C. Products / Deliveries of the H SAF

For the full list of the Operational products delivered by H SAF, and for details on their characteristics, please see H SAF website hsaf.meteoam.it. All products are available via EUMETSAT data delivery service (EUMETCast[1]), or via ftp download; they are also published in the H SAF website[2].

All intellectual property rights of the H SAF products belong to EUMETSAT. The use of these products is granted to every interested user, free of charge. If you wish to use these products, EUMETSAT's copyright credit must be shown by displaying the words "copyright (year) EUMETSAT" on each of the products used.

[1] http://www.eumetsat.int/website/home/Data/DataDelivery/EUMETCast/index.html
[2] http://hsaf.meteoam.it

D. System Overview

H SAF is lead by the Italian Air Force Meteorological Service (ITAF MET) and carried on by a consortium of 21 members from 11 countries (see website: hsaf.meteoam.it for details)

Following major areas can be distinguished within the H SAF system context:

- Product generation area
- Central Services area (for data archiving, dissemination, catalogue and any other centralized services)
- Validation services area which includes Quality Monitoring/Assessment and Hydrological Impact Validation.

Products generation area is composed of 5 processing centres physically deployed in 5 different countries; these are:

- for precipitation products: ITAF CNMCA (Italy)
- for soil moisture products: ZAMG (Austria), ECMWF (UK)
- for snow products: TSMS (Turkey), FMI (Finland)

Central area provides systems for archiving and dissemination; located at ITAF CNMCA (Italy), it is interfaced with the production area through a front-end, in charge of product collecting. A central archive is aimed to the maintenance of the H SAF products; it is also located at ITAF CNMCA.

Validation services provided by H SAF consists of:

- Hydrovalidation of the products using models (hydrological impact assessment);
- Product validation (Quality Assessment and Monitoring).

Both services are based on country-specific activities such as impact studies (for hydrological study) or product validation and value assessment. Hydrovalidation service is coordinated by IMWM (Poland), whilst Quality Assessment and Monitoring service is coordinated by DPC (Italy): The Services activities are performed by experts from the national meteorological and hydrological Institutes of Austria, Belgium, Bulgaria, Finland, France, Germany, Hungary, Italy, Poland, Slovakia, Turkey, and from ECMWF.