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	PUM-Product User Manual Time-Series Product	Date:	14/01/2017
			SCIRoCCo
L'a		Proj:	Scatterometer Instrument
			Competence Centre



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#### Change register

Version/Rev.	Date	Reason for Change	Changes
v0.1	07/08/2016	first draft	-
v0.2	06/11/2016	first project delivery	references

### **Document Approval**

$\mathbf{Role}/\mathbf{Title}$	Name	Signature	Date



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- 2.1 Instrument configuration and resulting orbit grid representation (swath) of ERS ESCAT  $\dots 8$

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## 1 Introduction

The Product User Manual (PUM) summarizes the product lineage and format of the ERS ESCAT surface soil moisture time series product. A general introduction of the purpose of the document followed by an overview of the surface soil moisture products concerned by this document are describe. An extensive description of the ESCAT instrument and Level 1 product processing is outlined in Section 2. The product lineage and description are discussed in section 3 and section 4, followed by information about product validation (section 5) and product availability in Section 6). References to technical reports and journal articles are summarized at the end of the document in Section 7.

In the framework of the SCIRoCCo project several soil moisture products, with different spatial resolution, format (e.g. time series, swath orbit geometry) are generated and distributed to users. A list of available soil moisture products, as well as other SCIRoCCo products (such as wind vector fields) can be looked up on the SCIRoCCo website [http://scirocco.sp.serco.eu/]. The following Table 1.1 gives an overview of the instances of soil moisture products related to this PUM.

ID	Product Name
ERS2-ASPS-N-SSM-Ts	ERS-2 ESCAT nominal resolution SSM time series (12.5 km sampling)
ERS2-ASPS-H-SSM-Ts	ERS-2 ESCAT high resolution SSM time series $(12.5 \text{ km sampling})$

Table 1.1: List of soil moisture products related to this PUM.

### 1.1 Scope

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

The 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 characteristics: Spatial resolution and sampling, observing cycle and time sampling
- 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 PUM's rely on other documents for further details [RD-1, RD-2].

#### **Targeted audience**

This document mainly targets:

- 1. Remote sensing experts interested in soil moisture from active microwave data sets.
- 2. Users of the remotely sensed soil moisture data sets.



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### **1.2 Applicable and Reference Documents**

#### **Applicable Documents**

The following documents are related to this document:

ID	Reference	Document Title	Issue	Date
AD-1				
AD-2				
AD-3				

#### **Reference Documents**

The following documents provide further reference information:

ID	Reference	Document Title	Issue	Date
RD-1	SCI-TNO-16-0044-v02	Algorithm Theoretical Baseline Document (ATBD)	v0.2	-
RD-2	SCI-RPT-16-0046-v02	Product Validation Report (PVR)	v0.2	-
RD-3	SCI-TNO-16-0045-v02	WARP 5 grid	v0.2	-



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	$\operatorname{unit}$	ERS-1	ERS-2
		43	
	[orbits]	501	501
Popost quala		2411	
Repeat cycle		3	
	[days]	35	35
		168	
		14.333	
Orbits/day	-	14.314	14.314
		14.351	
Ground velocity	$[\rm km/s]$	7	
LMT at ascending node	-	22:15	22:30
Spacecraft mass	[kg]	2384	2516
SCAT payload mass	[kg]	11	00

Table 2.1: ERS-1/2 mission parameter overview.

## 2 ESCAT on-board the European Remote Sensing Satellites

On 17 July 1991, ESA launched the first European Remote Sensing (ERS) satellite from the Kourou launch site in French Guiana [Vass et al., 1992]. ERS-1 was the major forerunner of the present European satellites for environmental monitoring, with development and predecessor studies dating back to the early seventies [ESA, 2013]. The ERS-1 payload carried an array of instruments for environmental monitoring of land, water, ice and atmosphere. The centrepiece of the ERS-1 payload was the Active Microwave Instrument (AMI), combining the functionality of a Synthetic Aperture Radar (SAR) and a wind scatterometer (ESCAT). Other instruments on-board were a Radar Altimeter, an Along-Track Scanning Radiometer, a Precise Range and Range-Rate equipment and a Laser Retro-Reflector. The system was designed for a nominal lifetime of 3 years, but it was not until March 2000, that ERS-1 mission ended after 9 years of excellent service due to a failure in the on-board attitude control system. Already on 21 April 1995 the follow-on mission ERS-2 was launched, equipped with an almost identical payload as ERS-1, but with an additional sensor on-board for atmospheric ozone research. In July 2011, after 16 years in space, ERS-2 was decommissioned and removed from its operational orbit, comprising, together with ERS-1, a scatterometer data archive of 20 years of Earth backscatter measurements. Both satellites were brought into an elliptical sun-synchronous orbit at approximately 785 km altitude and  $98.5^{\circ}$  inclination. Consequently, the nominal orbit period was approximately 100 minutes, with an ascending node (crossing of the Equator northwards) time of 22:15 local mean time (LMT) for ERS-1 and of 22:30 LMT for ERS-2 respectively. A standard orbit repeat cycle of 35 days was appointed for both satellites, supplemented with two additional repeat cycles of 3 and 168 days specifically dedicated to ERS-1. An overview of mission relevant parameters is given in Table 2.1.

### 2.1 Functional Description

As already mentioned, the Active Microwave Instrument (AMI) was the center-piece of the ERS payload. It was designed as a multi-mode RADAR, operating at a frequency of 5.3 GHz (C-band), by combining the functionality of a high resolution SAR and a low resolution wind scatterometer (ESCAT) [Attema, 1991]. AMI SAR operations were performed in two distinct modes: image and wave. In wind mode, AMI was configured as a wind scatterometer to provide backscatter measurements of the Earth's surface. The

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image and wind mode were mutually exclusive due to the high power consumption and data rate required for high resolution SAR image acquisition. Nevertheless, AMI could operate in a wind/wave mode, in which wind and wave mode were operated sequentially, enabling simultaneous characterization of the wind and wave fields over the oceans. Measurements in wind mode were acquired with three sideways looking, vertically polarized (VV) fan-beam antennas, one looking perpendicular to the right with respect to the satellite track (mid-beam), one looking forward at 45° angle (fore-beam) and one looking backward at  $135^{\circ}$  angle (aft-beam) illuminating a 500 km wide swath (see Figure 2.1). The transmitter unit of the scatterometer generated a rectangular radio frequency pulse with a duration of 130  $\mu s$  for the fore- and aft-beam and of 70  $\mu s$  for the mid-beam antenna. The three antennas were operated in sequences of 32 radio frequency pulses each, starting with the Fore-beam antenna. The pulse repetition frequency was chosen to be 98 Hz for the side antennas and 115 Hz for the mid antenna, resulting in a total repeat cycle length of 940.84 ms referred to as FMA sequence. Four FMA sequences last 3.763 s, which correspond to approximately 25 km along the ground track of the satellite. During each beam sequence of 32 pulses, 4 internal calibration pulses and 28 noise signals were measured [Lecomte, 1998]. The internal calibration pulse was a replica of the transmitted pulse fed into the receiver chain. The aim was to monitor the power of the transmitted pulse and the receiver gain to guarantee instrument stability during the mission, hence the term internal calibration. Noise measurements were necessary to account for thermal radiation superimposing the received echo signal to improve the signal-to-noise ratio. An analogue to digital converter (ADC) was used to sample the echo signal, the internal calibration pulses and the noise measurements at 30 kHz. A sampling of the received echo signal at 30 kHz corresponds to a across track resolution of approximately 32.4 km at  $18^{\circ}$  and 14 km at  $45.5^{\circ}$  incidence angle for the mid-beam.

	$\operatorname{unit}$	ESCAT
Frequency	[GHz]	5.3
Wavelength	[cm]	5.66
Chirp rate	[kHz/ms]	-
Polarisation	-	VV
Peak Power Pulse	[W]	4800
Pulse Duration	[]	70 (mid)
r uise Duration	$[\mu s]$	$130 \; (fore/aft)$
DDE	[11_]	115 (mid)
1 101	[IIZ]	$98~(\mathrm{fore}/\mathrm{aft})$
Ingidongo Anglo	[dog]	18-47 (mid)
Incluence Angle	[deg]	25-59 (fore/aft)
		45  (fore)
Antenna Angle	[deg]	$0 \pmod{1}$
		-45 (aft)
Swath width	[km]	500
Swath offset	[km]	200
Radiometric Res.	[%]	6.5 - 7.0

Table 2.2: Overview of ESCAT technical parameters.

### 2.2 Ground Processing

On-board tape recorders were used to store the sampled echo signals, the internal calibration pulses and the noise measurements after various on-board processing steps. These data packages were down-linked to



ground stations for further on-ground processing, along with external data (orbit and attitude information) and characteristics of the instrument, in order to achieve the required system performance. In a first step, the signal is processed to improve the signal-to-noise ratio and to correct for transmitter and receiver chain fluctuations (internal calibration). Subsequently, the power echo samples were converted to the normalized radar cross section,  $\sigma^0$ , by utilizing predetermined normalization factors. The normalization factors were defined as the power at the input equal to a uniform reference backscatter coefficient of unity on the Earth's surface. These normalisation factors are a function of changing geometry along the orbit for a given antenna provided as Look-Up-Tables. In a further processing step, a spatial filter was applied to the  $\sigma^0$  samples to increase the radiometric resolution and achieve the desired point target response along a grid of nodes, representing the entire swath. Calculation of the position of each node in the swath was based on the Mid-beam antenna. The central node position of the swath was determined at the intersection of the Mid-beam bore-sight direction with the Earth's surface. From this central node, more nodes are computed at every 25 km arc distance towards the near and far edge of the swath, along a perpendicular oriented line with respect to the satellite ground track. This is repeated after 4 FMA sequences, corresponding to an along track node interval of 25 km. Once the node positions within the swath were determined, the  $\sigma^0$  samples located within a certain area around a node were averaged in along and across-track direction using a so-called Hamming function for each antenna beam. The aim of this function is to apply weights to various  $\sigma^0$  samples, according to their distance to the regarded node. Ultimately, each node in the swath holds a  $\sigma^0$  value of each antenna beam referred to as  $\sigma^0$ -triplet. This processing step is of major importance, due to the fact that it impacts the characteristic of the  $\sigma^0$  values and particularly the final spatial resolution of the product. A detailed discussion about the on-ground processing steps of ERS-1/2ESCAT data packages can be found in Lecomte [1998] and Neyt et al. [2002].



Figure 2.1: Instrument configuration and resulting orbit grid representation (swath) of ERS ESCAT adopted from Bartalis [2009].

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Release Date	WARP Version	Level 1 Input Data	Temporal Coverage	Spatial Coverage
2002	WARP 4.0	ERS-1/2 ESCAT Wind Fields	1991-2000	global
2007	WARP 5.0	ERS- $1/2$ ESCAT Wind Fields and	1001 2007	global,
2007	WAILI 5.0	ERS-2 ESCAT fast delivery UWI	1991-2007	regional from 2001 onwards
2015	WARP 5.6	ERS-2 ESCAT	1006 2011	$\operatorname{global},$
2015	WAITI 5.0	ASPS nominal resolution	1990-2011	regional from 2003 onwards
2015 WADD 5.6		ERS-2 ESCAT	1006 2011	global,
2015	WARF 5.0	ASPS high resolution	1990-2011	regional from 2003 onwards

Table 3.1: Overview of ERS-1/2 ESCAT soil moisture products produced by TU Wien. Products highlighted in red have been produced in the framework of the SCIRoCCo project.

## 3 Product lineage

Surface soil moisture records are derived from the backscatter coefficient  $\sigma^{\circ}$  measured by the scatterometer (ESCAT) on-board the European Remote Sensing (ERS) satellites using the TU Wien soil moisture retrieval algorithm Naeimi et al. [2009]; Wagner et al. [1999]. In the TU Wien algorithm, long-term records of backscatter measurements are used to model the incidence angle dependency of backscatter, which allows a normalization to a common reference incidence angle ( $\theta_r = 40$ ). The relative surface soil moisture estimates range between 0% and 100% and are derived by scaling the normalized backscatter between the lowest/highest backscatter values corresponding to the driest/wettest soil conditions. Soil moisture is represented in degree of saturation  $S_d$ , but can be translated from relative (%) to absolute volumetric units  $(m^3m^{-3})$  using porosity information (see Eq. 4-1).

The soil moisture retrieval algorithm is implemented in a software called the WAter Retrieval Package (WARP). ERS ESCAT Level 1b data sets with a spatial sampling of 12.5 km, high resolution, and 25 km, nominal resolution, are used to retrieve relative surface soil moisture information. Except surface temperature data, used for training a freeze-thaw detection algorithm, and a static climate classification map (used for the determination of the wet correction) no external data is required for the retrieval. A detailed description of the TU Wien soil moisture retrieval algorithm together with a description of the derivation of the model parameters can be found in the Algorithm Theoretical Baseline Document (ATBD) [RD-1]. Three distinct ERS ESCAT soil moisture products have been released since the launch of ERS-1 in 1991 and ERS-2 in 1995, created by TU Wien, Department of Geodesy and Geoinformation, Research Group Remote Sensing (see Table 3.1). The released datasets are classical research products funded through several ESA projects with irregular release dates.

## 4 Product description

### 4.1 Product parameters

The Level 2 soil moisture product is composed of several parameters (geophysical parameters, flags, geolocation information, etc.). The following subsections will give an overview of all relevant Level 2 parameters and flags.

#### Level 2 Soil Moisture parameters

The Level 2 parameters represent new variables which have been derived from the respective Level 1b product. The following table summarizes these parameters.



Name	Scaling factor	Units	Type	Byte size	NaN
SM	-	%	int8	1	127
SM_NOISE	-	%	int8	1	127
SSF	-	-	int8	1	127

Table 4.1: Overview of Level 2 parameters included in the ERS ESCAT soil moisture time series product.

**Surface soil moisture and its noise** The surface soil moisture estimate (SM) represents the topmost soil layer (< 5 cm) and is given in degree of saturation  $S_d$ , ranging from 0% (dry) to 100% (wet).  $S_d$  can be converted into (absolute) volumetric units  $m^3m^{-3}$  with the help of soil porosity information.

$$\Theta = p \cdot \frac{S_d}{100}$$
 Eq. 4-1

where  $\Theta$  is absolute soil moisture in  $m^3m^{-3}$ , p is porosity in  $m^3m^{-3}$ . As it can be seen in Eq. 4-1, the accuracy of soil porosity is as much as important as the relative soil moisture content. An estimate of the uncertainty of soil moisture is given in the parameter soil moisture noise (SM\_NOISE) and its unit is degree of saturation in %. Surface soil moisture and its noise have been rounded to full integer values (e.g. original value of 2.3% or 6.7% is rounded to 2% or 7% final value).

**Surface state flag** The surface state flag (SSF) indicates the surface conditions: unknown, unfrozen, frozen, temporary melting/water on the surface or permanent ice. The flag is intended to help filtering soil moisture values derived under frozen soil conditions.

#### **Geo-location and satellite parameters**

The geo-location and satellite parameters

Table 4.2: Overview of geo-location and satellite parameters.				
Name	Scaling factor	Units	Type	Byte size
LOCATION_ID	-	-	int64	8
ROW_SIZE	-	-	int64	8
LATITUDE	-	Degrees North	float32	4
LONGITUDE	-	Degrees East	float32	4
TIME	-	Days since 1900-01-01 00:00:00 UTC	float64	8
ORBIT_DIR	-	-	$\operatorname{char}(1)$	1
SAT_ID	-	-	$\operatorname{char}(1)$	1

**Location ID** The location id (LOCATION\_ID) is a unique identifier for a single grid point (GP) of the WARP5 grid [RD-3]. It is also often called Grid Point Index (GPI).

**Row size** The number of observations per GP is indicated by the row size (ROW\_SIZE) or in other words the length of the time series per GP. This parameter is needed to extract the time series of a certain GP.

**Latitude** The latitude (LATITUDE) position of the GP in degrees north.

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**Longitude** The longitude (LONGITUDE) position of the GP in degrees east.

**Time** The time parameter (TIME) represents the time stamp for the measurements. It is defined as the days since 1900-01-01 00:00:00 UTC (e.g. 1900-01-01 00:00:00 UTC + 39081.2494791667 = 2007-01-01 05:59:15 UTC).

**Orbit direction** The orbit direction  $(ORBIT_DIR)$  indicates the movement of the spacecraft through the plane of reference. The ascending direction (A) represents a movement north through the plane of reference, and the descending (D) south through the plane of reference.

**Satellite id** The satellite id (SAT\_ID) represents the sensor's platform identification (ERS-1=1, ERS-2=2).

#### Processing flags

These flags indicate several conditions of interest if a certain bit has been set. A bit is set when it has value 1 and not set when it has value 0.

Table 4.3: Processing and correction field.				
Name	Scaling factor	Units	Type	Byte size
PROC_FLAG	-	-	uint8	1

Processing flags (PROC\_FLAG) are set to flag the reason for a soil moisture value not being provided in the product and/or that the soil moisture value has been modified after the retrieval for a different reason.

- *Bit 1 set:* Original soil moisture larger than or equal to -50% but less than 0%, value set to 0% artificially.
- *Bit 2 set:* Original soil moisture larger than or equal to 100% but less than 150%, value set to 100% artificially.
- Bit 3 set: Original soil moisture lower than -50%, value set to NaN.
- Bit 4 set: Original soil moisture larger than 150%, value set to NaN.
- *Bit 5 set:* Normalized backscatter is out of limits or dry/wet reference is NaN. Soil moisture set to NaN.
- Bit 6-8 set: Reserved for future use.

#### 4.2 Product limitations and caveats

Product limitations and caveats are discussed in detail in the ATBD [RD-1].

#### 4.3 Spatial resolution and sampling

The spatial resolution of the products is about 25 km  $\times$  25 km (high resolution) or 50 km  $\times$  50 km (nominal resolution) geo-referenced on the WARP5 grid [RD-3]. The WARP5 grid represents a discrete global grid

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(DGG) with a grid spacing of 12.5 km. The location of the points can be viewed interactively with the tool DGG Point Locator [http://rs.geo.tuwien.ac.at/dv/dgg].

### 4.4 File format

#### File naming

The product is provided as time series stored in NetCDF-4. All files follow the NetCDF Climate and Forecast (CF) Metadata Conventions version 1.6 [Eaton et al., 2011]. The grid points are organized in cells, in order to reduce the number of files. The cell size is defined as  $5^{\circ} \times 5^{\circ}$  and does contain up to 2000 grid points, mainly depending on latitude. The cell number and the number of grid points per cell are shown in Figure 4.1. A look-up containing GPI cell number, longitude and latitude can be found in this file: TUW\_WARP5\_grid\_info\_<version>.nc available on the SCIRoCCo FTP site. The file naming of these soil moisture time series products is: <cell>.nc

#### Time series storage format

The time series are stored in the contiguous ragged array representation defined by the NetCDF Climate and Forecast (CF) Metadata Conventions [Eaton et al., 2011]. The time series parameters (like soil moisture, soil moisture noise) are associated with the coordinate values time(obs), lat(i) and lon(i), where i indicates which time series. The time series i comprises the following data elements:

```
row_start(i) to row_start(i) + row_size(i)-1
```

where

 $row_start(i) = 0$  if i = 0

row\_start(i) = row\_start(i-1) + row\_size(i-1) if i > 0

The variable row\_size is the count variable containing the length of each time series feature. It is identified by having an attribute with name sample\_dimension whose value is name of the sample dimension (obs in this case). The auxiliary location parameters lat and lon are GPI variables.

#### Example

An example of the NetCDF variables is shown in the Listing 1. The NetCDF files can also be easily read using the open source python package Pytesmo<sup>1</sup> (Toolbox for the Evaluation of Soil Moisture Observations). For more information (installation instructions, documentation, examples and links to the source code) please consult the Pytesmo website<sup>2</sup>).

 $^{1} https://github.com/TUW\text{-}GEO/pytesmo$ 

 $<sup>^{2}</sup> http://rs.geo.tuwien.ac.at/validation\_tool/pytesmo/docs/index.html$ 



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	0 0	2553 2589 ° 0	2552 2588	2551 2587	768 770	619 758 619 758	2549 2585	2548 2584	112 212	2547 2583	2546 2582	2545 2581	•	0 0	2543 2579	2542 2578	2541 2577	•	0 0	2539 2575 0 0	2538 2574	0 0 3537 3573	0 11	2536 2572	2535 2571	2534 2570	2533 2569	0 0 1532 2568	•	2531 2567 145 0	2530 2566 622 840	2529 2565	2528 2564	2527 2563	2526 2562	2525 2561	•	2524 2560	2523 2559	2522 2558	2521 2557	0 0	2520 2556 e d	0 175
	0 0 0 0 0	481 2517	480 2516	479 2515	111 769	646 JOS	477 2513	476 2512	200 200	475 2511	474 2510	473 2509	•	4/2 2508	471 2507	470 2506	469 2505	•	468 2504	467 2503	466 2502	0 0	10C7 CO-	464 2500 270 0	463 2499	462 2498	461 2497	281 639 460 2496	•	459 2495	458 2494	457 2493	456 2492	455 2491	454 2490	6 0 0 453 2489	•	452 2488	451 2487	450 2486	449 2485	0	448 2454 0 0	1 22
	2 0 0	9 2445 2	8 2444 2	7 2443 2	692 QL	7 7th7 0	5 2441 2	M 2440 2	2012 W	2 2439 2	2438 2	1 2437 2	•	0 2436 2	9 2435 2	18 2434 2	7 2433 2	•	0 2452 2	15 2431 2 15 142	M 2430 2	0 0175 52		2 2428 2	1 2427 2	0 2426 2	9 2425 2	0 0 8 2424 2	•	57 2423 2 70 0	5 2422 2	5 2421 2	4 2420 2	3 2419 2	2 2418 2	1 2417 2	•	0 2416 2	9 2415 2	8 2414 2	7 2413 2	0	6 2412 2 0 0	155 160
	*7 */C7	2373 240	2372 240	2371 240	191	6 06	2369 240	2368 240	~	2367 240	2366 240	2365 240	•	2364 24(	2363 239	2362 235	2361 235	22	141	2359 235	2358 235	0	20 Per	2356 235	2355 235	2354 235	2353 238	2352 238	1736 14	2351 235	2350 238	2349 238	2348 238	2347 238	2346 238	° 2345 238	٩	2344 238	2343 237	2342 237	2341 23	0	2340 23	29 21
	9 0 0 0 0	105 2337	1300 2336	2335	111 091	906 906	297 2333	2332	1191	1565 2931 1300 1300	2294 2330	293 2329	105.4 213	5 1673	2327	230 2326	2289 2325	•	2288 Z324	146 2323	2286 2322	0 0	17C7 C07	2284 2320 926 2320	283 2319	282 2318	281 2317	1851 1844 2280 2316	1111 1241	1021 2315	278 2314 ett 216	277 2313	276 2312	275 2311	274 2310	° °	•	272 2308 ° °	271 2307	270 2306	269 2305	0	0 0	1 071
	0077 0	29 2265	28 2264	27 2263	712 769	7077 07	25 2261	24 2260	191 194	23 2259 IN 114	22 2258	21 2257	27 SR	0077 PB	19 2255 2	18 2254	17 2253	•	0 7577 QI	15 2251 2	14 2250	101 100	NCI IN	12 2248 1	11 2247 2	10 2246	09 2245	851 1853 DS 2244 2	212 275	07 2243	06 2242 3	05 2241	04 2240	03 2239	02 2238	01 2237	•	00 2236	99 2235 2	98 2234	97 2233 2	0	96 2232 9	120 130
	0 12 CT2	2193 22	2192 22	5 2191 22	191 0	606 (	2189 22	2188 22	1166	1 2187 22	2186 22	9 2185 22	2 1090	27 27 19	2183 22	5 2182 22	5 2181 22	110	1001	3 2179 22	2178 22	2 JTL 1	1000	2176 22	9 2175 22	3 2174 22	2173 22	3 1851 1 5 2172 22	1 21/1 0	2171 22	1 2170 22	3 2169 22	2 2168 22	2167 22	2166 22	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	•	8 2164 22 0 0	2163 21	2162 21	5 2161 21	0	2160 21	81 81
		2121 2157	2120 2156	2119 215	u u	9617 2117	2117 2153	2116 2152	1100	2115 2115 1151 1151	2114 2150	2113 2149	1503 157	1665 165	2111 2147 1741 174	2110 2146	2109 214	219 11	1108 2144	2107 2143	2106 2142	301 1121	1001	2104 2140	2103 2139	2102 2138	2101 2137	2100 2136	811	2099 2135 167 185	2098 2134	2097 213	2096 2132	2095 2131	2094 2130	2093 2125	•	2092 2128	212 002	2090 2126	2089 212	0	2088 212	1 211 0
	9977 PC	449 2085	M8 2084	M7 2083	101 101	506 006 7007 0te	M5 2081	M4 2080	1100	N43 2079	M2 2078	M1 2077	1621 662	010 2076	339 2075 311	38 2074	37 2073	101 101	2/07 950	35 2071	34 2070	111 111	100 100	332 2068 115 1154	031 2067 °	30 2066	29 2065	° °	•	27 2063 ° °	26 2062	25 2061	24 2060	23 2059	22 2058	° °	•	020 2056	019 2055	018 2054	17 2053	0	016 2052	12
	0 0 0	7 2013 2	6 2012 2	5 2011 21	92 93	005 90	12 2009 2	2 2008 21	1105	1 2007 2	0 2006 21	9 2005 2	1580	8 2004 2 3 1657	7 2003 21	6 2002 21	5 2001 21	1001	2 2000 2	12 1999 21	12 1998 21	1001	011 0	0 1996 2	9 1995 21	8 1994 21	7 1993 21	6 1992 21	•	5 1991 21 0 0	4 1990 2I	3 1989 2	2 1988 2	1 1987 21	0 1986 21	9 1985 21	•	8 1984 21 0 0	0 0	1982 21	1981 21	0	4 1980 Z	82 100
		1941 197 1 1941	1940 197	1939 197	L LL	6 906 T	1937 197	1936 197	11 2011	1915 2691 11 BATI	1934 197 1411 14	1933 196	1507 15	1932 199	1931 196 1740 17	1930 196	1929 196	19	1928 192	1927 196 0 2	1926 196	0	0	1924 196	1923 195	1922 195	1921 19	0 1920 192	•	0 0	1918 191	1917 195	1916 195	1915 191	1914 195	° 1913 194	•	1912 194	0 1161	1910 194	1909 194	0	0	8
	0/0	869 1905 11 19	868 1904	867 1903	110 110	306 TOTT	1061 238	864 1900	3911 1911	863 1899 1114 1114	862 1898	861 1897	1621 1621	860 1896 1654 1654	859 1895 ttt att	858 1894	857 1893	101 101	2620 062 162 6881	855 1891	854 1890	0 0	6007 6007	852 1888	851 1887	850 1886	849 1885	e 848 1884	•	847 1883	846 1882	845 1881	844 1880	843 1879	842 1878	° ° 841 1877	•	840 1876	839 1875	838 1874	837 1873	0 000	836 18/2	8
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		1761 17	1760 17	1759 17	22	5 506	1757 17	1756 17	11 2611	1755 177	1754 17	1753 17	1593 15	1/1 26/1	1751 171 U 1021	1750 171	1749 171	•	1/48 1/	1747 17	1746 171	0 1745		1744 17	1743 17	1742 17	1741 17	1740 17	•	1739 17.	1738 177	1737 17	1736 17	1735 17	1734 17	1733 170	•	1732 17	1731 170	1730 170	1729 17	0	1728 17	8
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	o o	517 1653 12 48	516 1652	515 1651	623 724	906 906 NCOT 610	513 1649	512 1648	1011 2011	511 1647 usi uu	510 1646	509 1645	1503 1586	008 1644 1655 1655	507 1643 1711 1025	506 1642	505 1641	1800	004 1040	503 1639 1912 1914	502 1638	101 1C37		500 1636 163 134	599 1635 600 605	598 1634	597 1633	808 184 596 1632	122 197	695 1631 ° °	594 1630 ° °	693 1629 0 0	592 1628	591 1627	590 1626	° °	•	688 1624 0 0	687 1623 0 0	86 1622	585 1621	0	0 0	4 4
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		1509 154	1508 154	1507 154	u 011	36 (05	1505 154	1504 154	1164 11	1503 153	1502 153	1501 153	142 151	241 0041 241 04	1499 153 1716 177	1498 153	1497 153	1860 186	149b 153 1912 191	1495 153	1494 153	1403 157	7CT CG+T	1492 152 1902 194	1491 152	1490 152	1489 152	1682 189 1488 152	1716 121	1487 152	1486 152	1485 152	1484 152	1483 151	1482 151	° 1481 151	۰	1480 151	1479 151	1478 151	1477 151	0	1476 151	8
	0	437 1473	436 1472	435 1471	692 SQL	106 Gr8	433 1469	432 1468	1101 1105	431 1467	430 1466 1404 1446	429 1465	607 1315	713 1144	427 1463	426 1462	425 1461	1870 1860	424 1460 1912 1912	423 1459 1945 1941	422 1458	1002 B001	1301 1301	420 1456 1945 1941	419 1455 1912 1912	418 1454	417 1453	416 1452	1679 1738	415 1451 903 1653	414 1450	413 1449	412 1448	411 1447	410 1446	0 0 409 1445	•	408 1444	407 1443	406 1442	405 1441	0	404 1440	8
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	0	1329 136	1328 136	1327 136	0	2 81 0707	1325 136	1324 136	10	1323 135	1322 135	1321 135	1260 12	1520 13:	1319 135	1318 135	1317 135	1000	1516 15:	1315 135	1314 135	01 21		1312 134	1311 134	1310 134	1309 134	0 1308 134	•	1307 134	1306 134	1305 134	1304 134	1303 133	1302 133	1301 13	۰	1300 13	0 133	1298 133	1297 13	0	0 1236	м о
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	0 0	81 717 36 405	10 716	9 715 L	800 E		713	6 712 1	88 1154	2 110	14 710	3 709 1	1621 16	2091 25	102 17	0 706	502 6	216	80 /04 82 /04	103	6 702	1 74 L		54 700 0 200	669 5	2 698	1 697	0 969 0.	•	569 652 0 0	694 o	57 693 C	6 692	169 1	4 690	• 689 E	•	52 688 0 0	687	0 686	9 685 1	0 0	0 0 0	6 8
	*	645 61 425 6	644 68	643 63	52	9 780 7 70	641 6	640 6	1 1611	639 6.	638 6.	637 63	1592 15	1653 16	4635 6.	634 6	633 66	10 10 10	0 03Z 00	631 6	630 66	8 C 0 C 0		628 6	627 6	626 6t	625 66	624 66	•	623 °	622 6	621 6	620 65	619 65	618 65	617 65	•		a 615 6	614 6	613 64	0	612 6	8- 8
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	4 4 7	213 24	212 24	211 24	81	6 805 6 805	2 209 24	208 24	•	202 °	206 24	205 24	•	204 2	203 2:	202 25	201 23	8	2 00 Z	199 2:	198 23	107 73		196 2:	195 25	194 25	193 22	192 22	•	191 2. 0	190 2. °	189 21	188 22	187 22	186 22	185 22	•	0 2	183 21	182 21	181 21	0	180 Z	155 - 150
		141 177	140 176	139 175	12 N	905 901	137 173	136 172	28	135 IN 0	134 170	133 169	•	132 102	131 167	130 166	129 165	202	128 164	127 163 ° 0	126 162	131 311		124 160	123 159	122 158	121 157	0 6 120 156	•	119 0 0	118 154	117 153	116 152	115 151	114 150	, ° 113 149	•	112 145	111 147	110 146	109 145	0	105 144	- 150 -
	9 °	69 105 ° °	68 104	67 103	40 SS 04	107 00	65 101	64 100		6 °	62 98	61 97	•	6°	59 95 °	58 94	57 93	•	26 92 9	55 91 •	54 90	• •	6°	52 88 °	51 87	50 86	49 85	• 48 • 48	•	47 。 83	46 82 °	45 81	44 80	43 79	42 78	41 77	•	40 76	39 75 • •	38 74	37 73	0	36 72	-170 -16
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```
dimensions:
 locations = 4;
 obs = UNLIMITED; // (21827 currently)
variables:
 int64 row size(locations) ;
   row_size:long_name = "number of observations at this location" ;
   row size: sample dimension = "obs";
 float lon(locations) ;
   lon:units = "degrees east";
   lon:long name = "location longitude" ;
   lon:standard name = "longitude" ;
   lon:valid range = -180., 180.;
 float lat(locations) ;
   lat:units = "degrees north";
   lat:long name = "location latitude" ;
   lat:standard name = "latitude" ;
   lat:valid range = -90., 90.;
 float alt(locations) ;
   alt:units = "m";
   alt:long name = "vertical distance above the surface";
   alt:standard name = "height";
   alt:axis = "Z";
   alt:positive = "up";
 int64 location id (locations);
 string location description(locations) ;
 double time(obs) ;
   time:units = "days since 1900-01-01 00:00:00";
   time:long name = "time of measurement";
   time: standard name = "time";
 byte proc flag(obs) ;
   proc flag:long name = "processing flag";
   proc flag:name = "proc_flag" ;
   proc flag: flag meanings = "sensitivity to soil moisture below 1dB
     soil moisture noise above 50";
   proc_flag:flag_masks = 1b, 2b;
   proc flag: coordinates = "time lat lon alt";
   proc flag:valid range = 0b, 3b;
 byte corr flag(obs) ;
   corr_flag:long_name = "correction flag";
   corr flag:name = "corr_flag" ;
   corr flag: flag meanings = "soil moisture set to 0 it was between 0 and -25
     soil moisture set to 100 it was between 100 and 125
```



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```
soil moisture set to nan it was below -25
   soil_moisture_set_to_nan_it_was_above_125 wet_correction_applied
   soil moisture set to nan backscatter not usable";
  corr flag:flag masks = 1b, 2b, 4b, 8b, 16b, 32b;
  corr flag:coordinates = "time lat lon alt";
  corr flag:valid range = 0b, 63b;
byte sm(obs) ;
 sm:long name = "soil moisture";
 sm:name = "sm";
 sm:units = "\%";
 sm:missing value = 127b;
 sm:coordinates = "time lat lon alt";
 sm:valid range = 0b, 100b;
ubyte sat id(obs);
  sat id:long name = "satellite id";
  sat id:flag values = 1b, 2b, 3b, 4b, 5b;
  sat id:name = "sat id";
  sat id:flag meanings = "ers -1, ers -2, metop-a, metop-b, metop-c";
  sat id:missing value = 127b;
  sat id:coordinates = "time lat lon alt";
 sat id:valid range = 1b, 5b;
byte ssf(obs) ;
  ssf:name = "ssf";
  ssf:flag meanings = "unknown unfrozen frozen temporary
    melting_water_on_the_surface permanent_ice" ;
  ssf:coordinates = "time lat lon" ;
  ssf:valid range = 0b, 4b;
  ssf:long name = "surface state flag" ;
  ssf: flag values = 0b, 1b, 2b, 3b, 4b;
  ssf:missing value = 127b;
byte dir(obs);
  dir:name = "dir";
  dir:flag meanings = "ascending descending";
  dir:coordinates = "time lat lon";
  dir:valid range = 0b, 1b;
  dir:long name = "orbit direction";
  dir:flag values = 0b, 1b;
  dir:missing_value = 127b;
byte sm noise(obs);
 sm noise:long name = "soil moisture noise";
 sm noise:name = "sm noise";
 sm noise: units = "\%";
 sm_noise:missing_value = 127b;
 sm noise:coordinates = "time lat lon alt" ;
 sm noise:valid range = 0b, 100b;
```



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Date: 14/01/2017
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Competence Centre

## **5 Product validation**

Information about product verification and validation can be found in the PVR (Product Validation Report) [RD-2].

## 6 Product availability

### 6.1 Download

The soil moisture data records are available via FTP. Download details are available after registering at ESA data portal website [https://earth.esa.int]. If you need help with respect to data access please contact the ESA EO portal helpdesk [https://earth.esa.int/web/guest/contact-us] and for questions about the product itself please contact the TU Wien support [remote.sensing@geo.tuwien.ac.at].

### 6.2 Conditions of use

ERS ESCAT soil moisture products have been produced in the framework of the ESA funded project SCIRoCCo and are disseminated under ESA Data Policy. They are available for all users free of charge after registration.

## 7 References

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