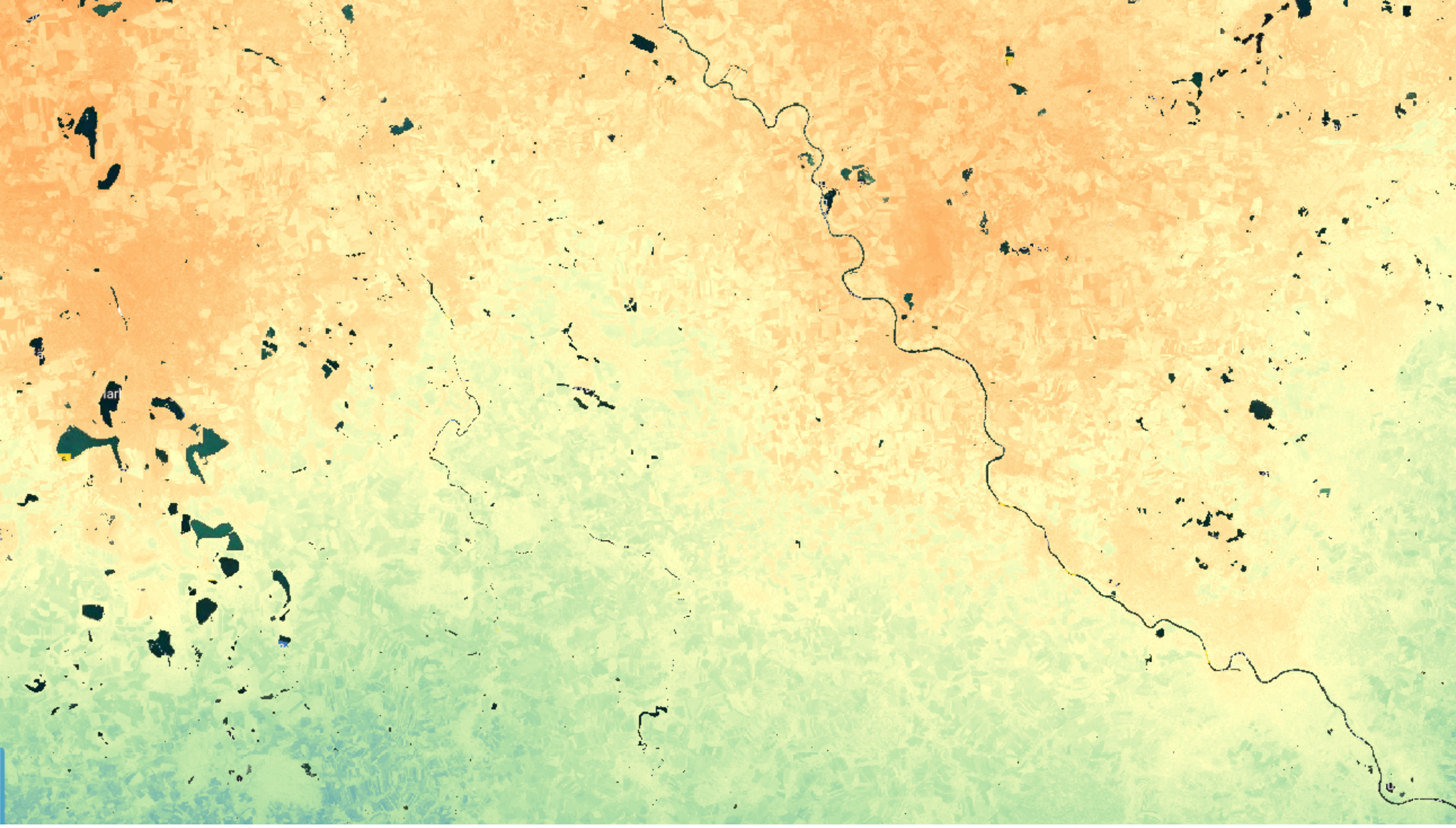

PLANET SOIL WATER CONTENT
TECHNICAL SPECIFICATION

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TABLE OF CONTENTS

1. SOIL WATER CONTENT OVERVIEW

Soil water content is an essential component of the hydrologic cycle, significantly influencing evaporation, precipitation, infiltration, and runoff. By its nature, at the boundary between the atmosphere and the solid earth, the soil water content plays a very important role in the partitioning of energy and water. The amount of fresh water stored in the unsaturated zone is crucial for providing water and nutrients to the biosphere. Water in the unsaturated zone is expressed as the soil water content, soil moisture or soil wetness, most often defined as the volume of water per bulk volume of the soil. For example, a value of 0.3 m^3/m^3 refers to a soil in which 30% of the total volume consists of water. Soil water content has a strong spatio-temporal variability, and to approximate such a variability, the use of ground measurements is often not adequate to support many applications. Instead, remote sensing techniques have a strong potential to provide consistent and reliable observations at multiple scales globally.

Microwave remote sensing provides a unique capability for direct observation of the water in the top centimeters of the soil. These measurements from space allow consistent, frequent, and global sampling. Planet is able to retrieve data regarding the soil water content at 1 km and 100 m from satellite passive microwave measurements. An essential property of microwave data is that it is not sensitive to cloud cover, and therefore Planet can deliver a global near-daily data coverage. Planet developed a proprietary method to improve the spatial resolution of the passive microwave observations, which initially have a spatial representation of several kilometers. Optical imagery from Sentinel-2 is included to further improve the spatial resolution.

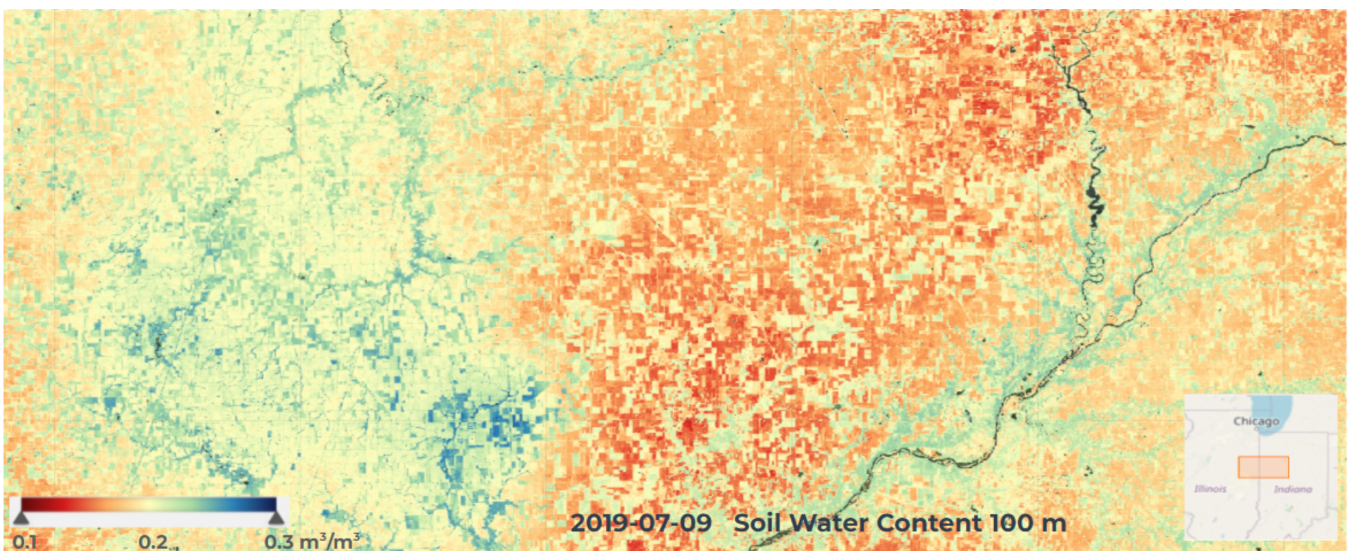
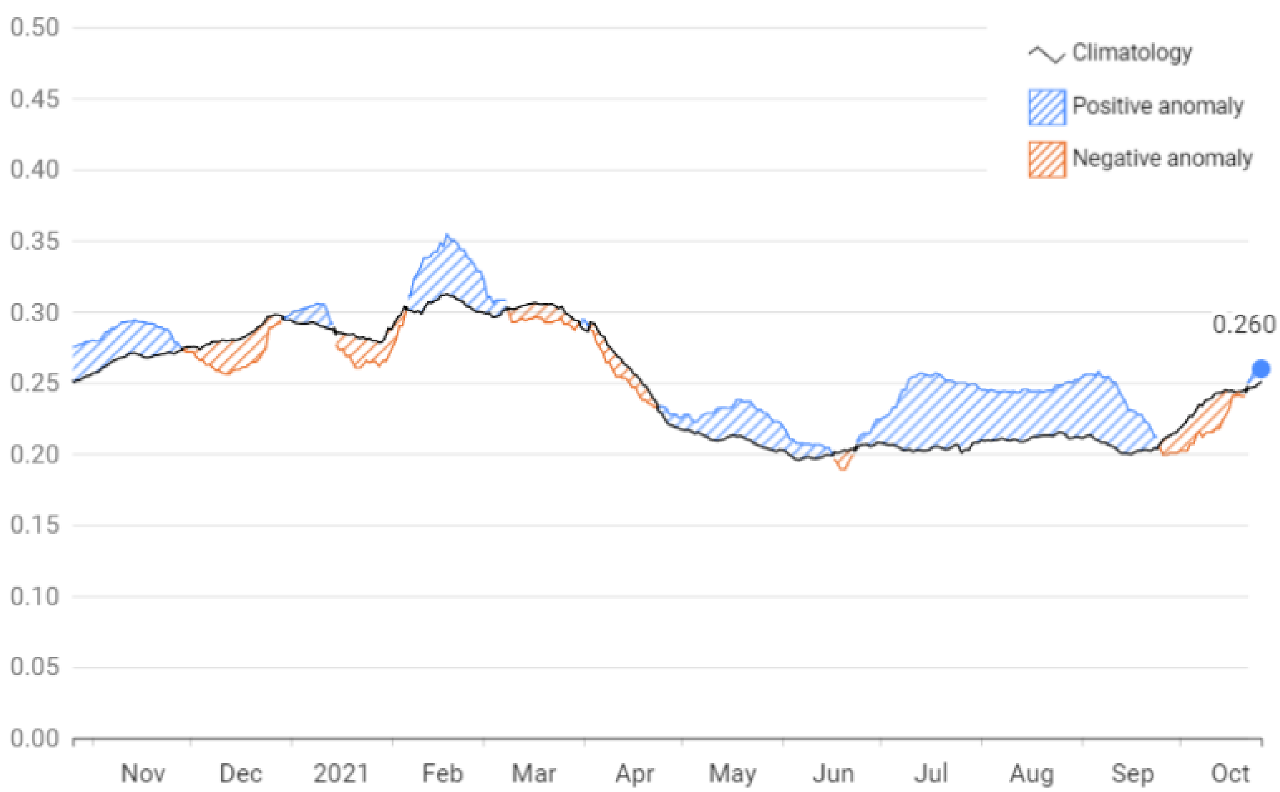


Figure 1: Example of soil water content 100 m for a region in Illinois - USA

The downscaled high resolution microwave observations are converted to soil water content using the physical based Land Parameter Retrieval Model (LPRM, Owe et al. 2001; Owe et al. 2008; Van der Schalie et al., 2018). The core of the LPRM was developed in the early 2000s in a collaboration between the VU University Amsterdam and the National Aeronautics and Space Administration (NASA) and has been further refined and evaluated by numerous researchers (*e.g.* De Jeu et al., 2014; Van der Schalie, et al., 2021) and is currently the baseline algorithm for the ESA CCI soil moisture products (Scanlon et al., 2021).

Figure 2: Example of 20 day rolling average soil water content (m^3/m^3) time series and its anomaly for a region in Illinois USA.



The unique features of Planet Soil Water Content data can be summarized as:

- Proprietary method to provide near-daily soil water content at 100m and 1km resolution
- Soil water content signal retrieved from satellite passive microwave observations
- Inclusion of Sentinel-2 data to obtain a better spatial representation (only for 100m product)
- Typically available within 12 hours of satellite overpass
- Not hindered by clouds
- Soil water content signal performs well over the majority of vegetation covers, with the exception of tropical rainforests
- Available near-daily since 2002 at 1km resolution, and since 2017 at 100m resolution

2. PLANET SOIL WATER CONTENT INPUTS

The soil water content algorithm is based on a set of observations provided by three passive-microwave radiometers, Sentinel-2 multispectral reflectances, and a set of ancillary data including a digital elevation model, a custom global land classification and soil property maps. The brightness temperatures, derived from the following passive-microwave radiometers, are a core input for the soil water content algorithm at 100m and 1 km resolution:

- The NASA-operated Soil Moisture Active Passive (SMAP) satellite includes a passive-microwave radiometer and a synthetic aperture radar (SAR) operating at L-band. However, the radar instrument ceased operation in 2015 due to a failure of its power supply.[1] SMAP's radiometer is a very sensitive receiver that accurately measures the naturally occurring radio frequency energy at 1.41 GHz. The SMAP spacecraft operates on an 685-km, near-polar, sun-synchronous orbit, with equator crossings at 6 a.m. and 6 p.m. local time. The full operation of SMAP started in April 2015.

- The Advanced Microwave Scanning Radiometer for EOS (AMSR-E) onboard NASA's Aqua satellite is a twelve-channel, six-frequency, total power passive-microwave radiometer system. It measures brightness temperatures of microwave emissions at multiple frequencies from 6.9 to 89.0 GHz. Vertically and horizontally polarized measurements are taken at all channels. The Aqua satellite was launched on May 4, 2002 and orbits earth sun-synchronous with an altitude of 705 km. The ascending path crosses the equator at around 1:30 p.m. local mean solar time, while the descending path crosses the equator at around 1:30 a.m. The AMSR-E sensor was retired in October 2011.

- Advanced Microwave Scanning Radiometer 2 (AMSR2) is the follow-on mission of AMSR-E supported by the Japanese space agency JAXA. The multi-frequency microwave radiometer is onboard the GCOM-W1 satellite and has an additional C-band channel (7.3 GHz) to mitigate Radio Frequency Interference (De Nijs et al., 2015). The satellite was launched on May 17, 2012 into an sun-synchronous orbit with an altitude of 699.6-km.

The retrieval algorithm of the 100m resolution product uses additional information from optical data:

- Sentinel-2 is a European wide-swath, high-resolution, multi-spectral imaging mission. The mission supports Copernicus Land Monitoring studies, including the monitoring of vegetation, soil and water cover, as well as observation of inland waterways and coastal areas. The full mission consists of twin satellites flying in the same sun-synchronous orbit at 786 km but phased at 180°, giving a revisit frequency of 5 days at the Equator in cloud-free conditions. Each satellite carries an optical instrument payload (the MultiSpectral Instrument) that samples 13 spectral bands from 492 nm to 2202 nm: four bands at 10 m, six bands at 20 m and three bands at 60 m spatial resolution. The orbital swath width is 290 km. The Sentinel-2A satellite was launched on June 23, 2015 and the SentineL-2B satellite on April 25, 2016. More information can be found here.

[1] See https://llis.nasa.gov/lesson/27701.

Table 1: List of inputs currently used in Soil Water Content production.

Product	Description
Brightness Temperature L-band	Soil Moisture Active Passive (SMAP) Level-1B Radiometer Half-Orbit Time-Ordered L-band Brightness Temperatures, Version 5 (downloaded from n5eil01u.ecs.nsidc.org in HDF5 format). This Level-1B product provides calibrated estimates of time-ordered geolocated brightness temperatures at 1.41 GHz with a footprint size of 39x47km. SMAP L-band brightness temperatures are referenced to the Earth's surface with undesired and erroneous radiometric sources removed. Data has been available since April 2015 with a latency of 12 hours. Detailed information is available in the link.
Brightness Temperature X-band	Advanced Microwave Scanning Radiometer for EOS (AMSR-E) and Advanced Microwave Scanning Radiometer 2 (AMSR-2) Level-1B Radiometer X-band Brightness Temperatures (downloaded from ftp.gportal.jaxa.jp in HDF5 format). This Level-1B product provides calibrated estimates of geolocated brightness temperatures at 10.7 GHz with a footprint size of 24x42 km. Data has been available from June 2002 to October 2011 (AMSR-E) and from June 2012 (AMSR-2) up to now with a latency of 12 hours. Detailed information is available in the link.
Brightness Temperature C-band	AMSR-E and AMSR-2 Level-1B Radiometer C-band Brightness Temperatures (downloaded from ftp.gportal.jaxa.jp in HDF5 format). This Level-1B product provides calibrated estimates of geolocated brightness temperatures at 6.9 GHz with a footprint size of 35x62 km. Data has been available from June 2002 to October 2011 (AMSR-E) and from June 2012 (AMSR-2) up to now with a latency of 12 hours. Detailed information is available in the link.
Brightness Temperature Ka-band	AMSR-E and AMSR-2 Level-1B Radiometer C-band Brightness Temperatures (downloaded from ftp.gportal.jaxa.jp in HDF5 format). This Level-1B product provides calibrated estimates of geolocated brightness temperatures at 36.5 GHz with a footprint size of 7x12 km. Data has been available from June 2002 to October 2011 (AMSR-E) and from June 2012 (AMSR-2) up to now with a latency of 12 hours. Detailed information is available in the link.
Brightness Temperature W-band	AMSR-E and AMSR-2 Level-1B Radiometer W-band Brightness Temperatures (downloaded from ftp.gportal.jaxa.jp in HDF5 format). This Level-1B product provides calibrated estimates of geolocated brightness temperatures at 89 GHz with a footprint size of 3x5 km. Data has been available from June 2002 to October 2011 (AMSR-E) and from June 2012 (AMSR-2) up to now with a latency of 12 hours. Detailed information is available in the link.
Reflectances SWIR and NIR (for 100m only)	SENTINEL-2 Level-1C reflectances (downloaded from Google Cloud or the Earth Observation Data Center based on availability) for the two bands: SWIR (shortwave-infrared around 1610 nm) and NIR (near-infrared around 842 nm). This product provides orthorectified (geometric ortho-correction taking into account a DEM) Top Of Atmosphere reflectance (more details here). The processing to retrieve level-2 (bottom of atmosphere) and cloud masking is performed in-house using Sen2Cor, fmask and S2Cloudless. Detailed information is available in the link.
Digital elevation model	Digital elevation model (DEM) static map resampled at 100m based on the Copernicus DEM GLO-90 product covering the full global landmass of the time frame of data acquisition (2011-2015). Detailed information is available in the link.
Land Cover map	Custom global land classification including permanent water bodies based on the Copernicus Global Surface Water Bodies product from PROBA-V. Detailed information is available in the link.
Soil map	Soil property maps resampled at 100 m based on the SoilGrids product. SoilGrids was funded by the core funding of ISRIC with additional support from the EUH2020 CIRCASA project. Detailed information is available in the link

3. PLANET SOIL WATER CONTENT PRODUCTS

The current Planet soil water content product line is outlined in Table 2. The Planet soil water content products are not hindered by clouds, resulting in a consistent number of observations per year. They are available on fixed grids with a 1 km (since 2002) and a 100 m resolution (since July 2017).

Table 2: Planet soil water content product line

Product key	Description
SM- 100 m - L band	100 m resolution volumetric soil water content derived from L band brightness temperature and Sentinel-2 reflectance.
SM- 100 m - X band	100 m resolution volumetric soil water content derived from X band brightness temperature and Sentinel-2 reflectance.
SM - 100 m - C band	100 m resolution volumetric soil water content derived from C band brightness temperature and SENTINEL-2 reflectance.
QF-100 m	Quality flag layer for the three 100m resolution soil water content products.
SM-1 km - L band	1 km resolution volumetric soil water content derived from L band brightness temperature.
SM-1 km - X band	1 km resolution volumetric soil water content derived from X band brightness temperature.
SM- 1km - C band	1 km resolution volumetric soil water content derived from C band brightness temperature.
QF 1 km	Quality flag layer for the three 1km resolution soil water content products

3.1. L band, C band and X band products specifications

Satellite observed volumetric soil water content derived from L, C and X bands microwave data is based on the latest version of the Land Parameter Retrieval Model (Owe et al., 2008; Van der Schalie et al., 2021) in combination with a proprietary disaggregation method to increase the spatial resolution. It provides the soil water content of the top layer of the soil, varying from 1 to 5 cm depending on soil moisture conditions and the microwave band used. The 100 m and 1 km specifications for all bands are described in the tables below.

Table 3: 100 m data format specifications

Layer	L band	C band	X band
Name	Soil water content (L band)	Soil water content (C band)	Soil water content (X band)
Version	1.0	1.0	1.0
Unit	m^3/m^3	m^3/m^3	m^3/m^3
Sensing depth[2]	±5 cm	±2 cm	±1 cm
Pixel size	100x100 m (0.00089 degree)	100x100 m (0.00089 degree)	100x100 m (0.00089 degree)
Temporal resolution	±230 observations[3] per year at 52 degree latitude	320 observations per year at 52 degree latitude	320 observations per year at 52 degree latitude
Overpass time	6:00 AM Local Solar Time	01:30 AM Local Solar Time	01:30 AM Local Solar Time
Coverage	Global	Global	Global
Data availability	July 2017 - Present	July 2017 - Present	July 2017 - Present
Satellites used	AMSR-2, SMAP, Sentinel 2	AMSR-2, Sentinel 2	AMSR-2, Sentinel 2
Available to user (latency)	+/- 12 hours after overpass of the satellites	+/- 12 hours after overpass of the satellites	+/- 12 hours after overpass of the satellites

[2] The sensing depth described in the table is an estimation of the average condition. Several studies (e.g. Schmugge et al., 1986; Wang et al., 1987; Owe et al., 1998) have shown that microwave-based soil water content penetration depth depends on the soil water content conditions and frequency. At 1.41 GHz the penetration depth varies from approximately 10 cm to 1 m for soil conditions ranging from saturated to dry, whereas at 10.7 GHz the penetration depth varies from less than a few mm to a little over 2 cm for similar conditions. Thus, the drier the soil, the deeper the sampling depth.

[3] The number of observations per year of the L-band product varies from 46 (at equator) to 320 (at 60 degree latitude). The L-band revisit time is limited by the overlapping swaths of AMSR2 and SMAP gradually shifted over an 8 days period. L-band revisit time map is provided in the appendices.

Table 4: 1 km data format specifications

Layer	L band	C band	X band
Name	Soil water content (L band)	Soil water content (C band)	Soil water content (X band)
Version	4	4	4
Unit	m^3/m^3	m^3/m^3	m^3/m^3
Sensing depth[4]	±5 cm	±2 cm	±1 cm*
Pixel size	1000x1000 m (0.0089 degree)	1000x1000 m (0.0089 degree)	1000 x 1000 m (0.0089 degree)
Temporal resolution	±230 observations[5] per year at 52 degree latitude	320 observations per year at 52 degree latitude	320 observations per year at 52 degree latitude
Overpass time	6:00 AM Local Solar Time	01:30 AM Local Solar Time	01:30 AM Local Solar Time
Coverage	Global	Global	Global
Data availability	July 2017 - Present	July 2017 - Present	July 2017 - Present
Satellites used	AMSR-2, SMAP	AMSR-E (June 2002 - October 2011), AMSR-2 (June 2012 - now), TMI (on request <+-40 degree lat), GPM-GMI (used as backup only)	AMSR-E (June 2002 - October 2011), AMSR-2 (June 2012 - now), TMI (on request <+-40 degree lat), GPM-GMI (used as backup only)
Available to user (latency)	+/- 12 hours after overpass of the satellites	+/- 12 hours after overpass of the satellites	+/- 12 hours after overpass of the satellites

[4] See footnote 2 above.

[5] The number of observations per year of the L-band product varies from 46 (at equator) to 320 (at 60 degree latitude). The L-band revisit time is limited by the overlapping swaths of AMSR2 and SMAP gradually shifted over an 8 days period. L-band revisit time map is provided in the appendices.

3.2. QUALITY FLAGS

The quality product consists of a combination of critical flags and non-critical flags. Critical and non-critical flags are combined into one file for each product and provided each time a product is made. The critical and non-critical flags are described in Table 5 and Table 6.

Critical flags indicate that data is of unusable quality for most applications. As such, for pixels covered by a critical flag, we replace the soil water content value with a no data value. However, when retrieving our data, users can access the original data by looking at Band 2 in GeoTIFF files. All values in the flag file > 127 are critical. Non-critical flags mean that the data can be used with caution, taking into account the information given in the flag description. All values in the flag file <= 127 are non-critical.

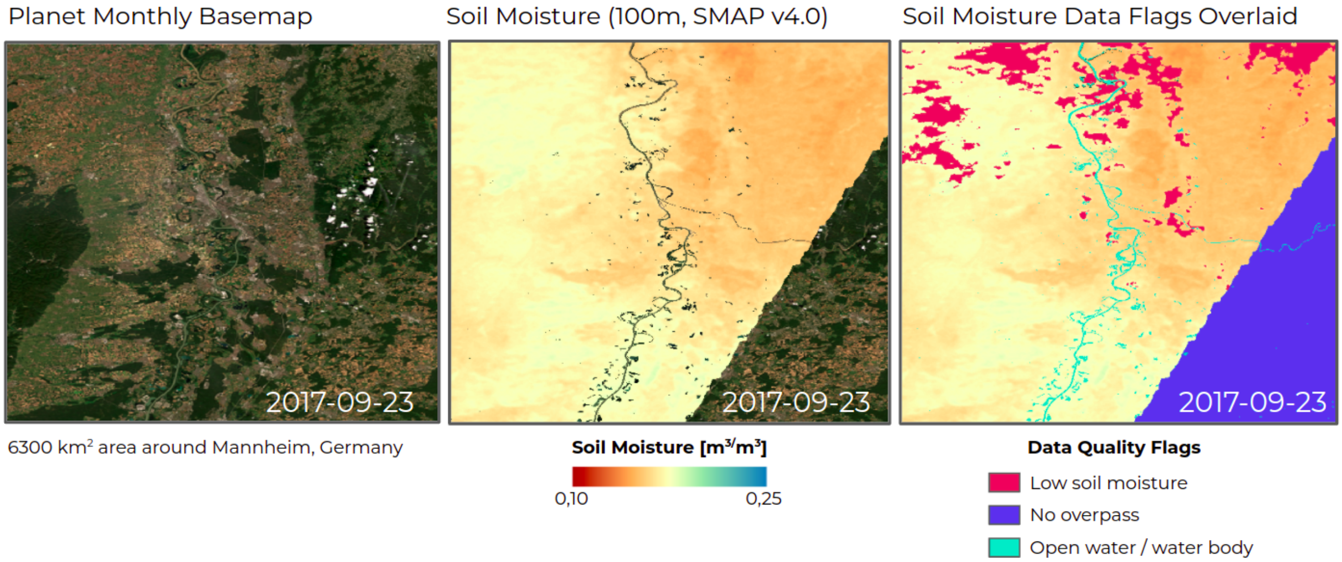
Table 5: Non-critical data flag layers in binary system

Bit -	Flag layer	Description	Notes
1.	Dense vegetation	This flag indicates high vegetation cover, where soil water content retrieval is less reliable. Depending on the frequency, the flag value for vegetation-corrected soil water content and Microwave Vegetation Optical Depth (VOD) is applied.	- C/X band: medium Vegetation Optical Depth threshold = 0.45 and high Vegetation Optical Depth threshold = 0.6 - L band: medium VOD threshold = 0.3 and high VOD threshold = 0.4
2.	Low soil water content	The retrieved soil water content is lower than the estimated wilting point.	
3.	High soil water content	The retrieved soil water content is higher than the estimated porosity.	
4.	Possibly influenced by snow or severe rainfall	Part of the footprints touch an area flagged as severe rainfall or snow.	The critical flag snow or severe rainfall is described in table 6.
5.	Possibly influenced by RFI	Radio Frequency Interference (RFI) occurs when unwanted radio frequency signals disrupt the microwave signal. Part of the footprints touch an area flagged as RFI.	See tabel 5. RFI detected
6.	Not used		
7.	Possible frozen soil	This flag indicates areas where frozen soil may occur	Soil temperature < 273.15 K.

Table 6: Critical data flag layers in binary system

Bit - Flag layer	Description	Notes
8. Frozen soil	This flag indicates areas where frozen soil is detected.	Pixels with Soil Temperature < -10C are flagged as critical, while pixels with TEFF values between 0C and -10C are flagged as non-critical. A conservative value of -10C was chosen to avoid masking valid data. For areas marked as frozen soil, no Soil water content is given. The data is filtered out during the processing in LPRM.
9. Severe rainfall	This flag indicates areas where severe precipitation is detected.	Areas marked as severe precipitation events occurred, no soil water content is given. They are filtered out during the processing of the raw satellite data.
10. High vegetation	This flag indicates if the vegetation cover is too dense for the algorithm to converge to a reliable soil water retrieval.	The data is filtered out during LPRM processing.
11. No overpass	An overpass is when the field of view of a satellite's instrument passes over. This flags if there is an overpass.	If one or more brightness temperature frequencies are missing (due to a combination of different satellite swaths), the no coverage flag is produced during downscaling.
12. RFI detected	Radio Frequency Interference (RFI) occurs when man-made transmitters emit in the same frequencies and thus corrupt the radiometer measurements of the natural microwave emission. Even though the L-band is a protected band, authorized transmitters emit either within the band or in adjacent bands, also causing RFIs.	If a footprint is contaminated for more than 25% with RFI, Footprints with less contamination than 25% are retained but the data is marked as influenced by RFI, see the non-critical flag 'possibly influenced by RFI' .
13. Instrumental flaws	This flag has unrealistic values due to instrumental flaws.	If the brightness temperature at 36.5 GHz V produces values either over 400K or under 0.9 * the water temperature, the data is considered as unrealistic and is removed.
14. Out of valid range	This flag has soil water content values retrieved that are outside of the valid range	If soil water content retrieved is 0 or above 1
15. Waterbody	This flag return no valid data because of a waterbody	This static data layer is retrieved from a land cover map. They are filtered out during the processing of the raw satellite data.

Figure 2: An example of three quality flags for a region around Manheim, Germany. The image shows critical flags (Open water, no overpass, and a non-critical flag (low soil water content).



3.3. PROJECTION, GRIDDING, AND DELIVERY

Soil water content products are delivered as gridded raster data and time series. The data is delivered through a subscription model in GeoTIFF format. The subscription model allows for automatic creation as soon as the source data is available, and getting HTTP webhook notification when processing is complete. Each automatic creation is called a “fulfillment”. Subscriptions allow for specifying the requested geometry.

Table 7: Raster properties of SWC 100 m and SWC 1 km

Raster Property	Description
Format	GeoTIFF
Pixel Size	0.00089 degree (±100 m) or 0.0089 degree (±1000 m)
Data type	uint16
NoData	65535
Offset	0
Scale	0.001
Spatial Reference	EPSG:4326
Number of bands	2
Delivery	Gridded data, time series

4. PLANET SOIL WATER CONTENT METHODOLOGY

4.1 Downscaling method

The downscaling technology[1] aims to improve the resolution of sensor data, in this case the brightness temperatures observed by passive microwave sensors. The technique redefines the exact geolocation and additionally reconstructs the antenna footprints of each observation. It uses the abundance of overlaps between these footprints for downscaling purposes sampled at a target resolution. Based on the footprint center, microwave frequency, incidence angle, azimuth angle, and footprint size for a given intensity, footprints are created and disaggregated in equal interval ellipses using an internal gaussian distribution. Within the ellipse-shaped footprints, the center of the footprint contributes more to the observed values than the edges. Water bodies will have a fixed value and will be considered; thus, the land brightness temperature can be retrieved accurately. This method elucidates the exact source of the signal of each observation point. With this information, we are able to filter out important influences in the signal, such as water bodies and Radio Frequency Interference (RFI). The output of the downscaling method are brightness temperatures for a given frequency and at the target resolution.

[1] Patent US10643098, EP3469516B1 : Method and system for improving the resolution of sensor data

4.2 Inclusion of optical data processing (for the 100m product only)

Soil water content is also highly variable in space, mainly due to soil properties, topography, agricultural practices, and land cover heterogeneity. Space-borne optical/thermal sensors can help retrieve high-resolution surface parameters. Several studies (Lobell & Asner 2002, Fensholt and Sandholt 2003, Sadeghi et al. 2017, Yue et al. 2019) found that soil and plant water content greatly influences the reflection in the shortwave infrared (SWIR) part of the spectrum. The SWIR, combined with the Near-Infrared (NIR) reflectance which is affected by internal leaf structure and leaf dry matter content but not by water content, will enhance the water content retrieval from reflectances (Gao 1996, Ceccato et al. 2001).

The NDSWIR is a satellite-derived index constructed from the NIR and SWIR channels. This index uses a normalized difference formulation index of wavelengths 819/1600 nm, corresponding to bands B08 and B11 for Sentinel-2 as (B11 - B08) / (B11 + B08). The NDSWIR product is dimensionless and varies between -1 to +1. Sentinel-2 based NDSWIR composite is produced daily using a weighted backward gaussian. Consequently, Sentinel-2 based NDSWIR composite is integrated into the downscaling framework when attributing the weight of a brightness temperature per pixel within the footprint (in addition to the 2D gaussian distribution). The output format is similar to the output of the downscaling algorithm without Sentinel-2 input. Applications using NDSWIR include agricultural crop management, forest canopy monitoring, and stress detection. But optical observations are susceptible to clouds, atmospheric effects, and vegetation errors and thus, cannot be directly used as a soil water content value but only as a spatial proxy. Therefore, combining passive microwave signal with Normalized Difference SWIR/NIR (NDSWIR) observation into the downscaling algorithm improves the soil water content's spatial representation while maintaining the microwave information's temporal consistency and accuracy.

The Sentinel-2 preprocessing is performed in-house using Sen2Cor, fmask and S2Cloudless. Sen2Cor applies atmospheric, terrain and cirrus correction to the L1C granule. The processing converts the input (L1C) from Top of the Atmosphere (TOA) to Bottom of the Atmosphere (BOA) reflectances. The preprocessing also produces a scene classification of four different classes for clouds (including cirrus) and six different classes for shadows, cloud shadows, vegetation, soils / deserts, water and snow. Two additional algorithms are also performed in-house: 1) Python FMASK produces a multiclass mask, which includes clouds, cloud shadow, snow (or high reflectance) and water and 2) S2Cloudless produces a binary map which distinguishes between clouds and non clouds.

4.3 Land Parameter Retrieval Model (LPRM)

The downscaled microwave observations are then linked to land surface variables, including soil water content, land surface temperature and vegetation optical depth through a retrieval algorithm, the Land Parameter Retrieval Model (LPRM, Owe et al,. 2001; Owe et al., 2008; De Jeu et al., 2014). The core of the LPRM was developed in the early 2000's in a collaboration between the VU University Amsterdam and the National Aeronautics and Space Administration (NASA) and has been further developed (e.g., Van der Schalie et al., 2021).

LPRM makes use of a radiative transfer model. The propagation of microwaves through the soil, vegetation and atmosphere is described by a set of mathematical equations. The soil emission in the microwave domain is dependent on the soil dielectric constant, which has a strong relationship with soil water content. Microwave technology is a remote sensing method that measures a direct response to the absolute amount of water in the soil, with a sensing depth ranging from millimeters for 37 GHz to tens of cm for 1.4 GHz. Vegetation also contributes to the microwave signal by absorbing, reflecting and emitting radiation. The LPRM solves the radiative transfer equation at different frequencies and polarizations to retrieve soil temperature (Land Surface Temperature (LST, TEFF)), soil water content (Volumetric soil water content (SWC)) and VOD (Vegetation Optical Depth (VOD)). Within the retrieval, water bodies are treated separately, and a flagging system was developed to signal other potential interferences to the microwave signal including RFI, frozen soil, snow, and heavy rain events (see Data Flags).

5. UNCERTAINTY ESTIMATES

The quality of soil water content retrievals from passive microwave observations and in particular the performance of the Land Parameter Retrieval Model have been described widely in the scientific literature. It has been compared to ground stations , hydrological models and other satellite derived products (e.g. Van der Schalie et al., 2021; Gruber et al., 2020; Gevaert et al., 2018). The accuracy of the retrievals are sensitive to the microwave frequency. The soil water content based on L-band observations have the highest quality with an average accuracy of approximately 0.04 m3/m3 which is often equal to the quality of ground sensors (e.g. see Ganjegunte et al., 2012). The accuracy of the C and X band based products is lower and approximately 0.05 m3/m3. In addition the quality of the soil water content is a direct function of the vegetation cover as clearly demonstrated by Van der Schalie et al, 2018. The X and C-band based retrievals are most sensitive to the density of the vegetation cover and provide the most reliable values with short vegetation. L-band retrievals perform well over the majority of land covers, with the exception of dense tropical rainforest.

6. KNOWN LIMITATIONS AND CAVEATS

- **False cloud/shadow detections** may occur in certain cases: 1) if surface conditions change very rapidly, 2) during prolonged cloudiness, or 3) over AOIs with significant terrain and shadowing. Significant effort has gone into developing automated techniques to differentiate between actual change and atmospheric contamination, but in some cases commision errors can still be an issue.

- **Gap-filling artifacts** may occur during periods of 1) prolonged cloudiness for the 100 m resolution product and 2) snow for both resolution products.

- Planet Soil water content is not suited for studies over **snow covered surfaces** or **sloped terrain** (> 20 degrees).

- **RFI (Radio Frequency Interference)** occurs when unwanted radio frequency signals disrupt the microwave signal. Consistent as well as strong dynamic RFI are filtered out during processing. However, subtle (dynamic) RFI sources are more difficult to detect and can have a negative impact on the SWC products.

- **Dynamic water bodies** may cause wrong soil water content estimates. They influence the microwave observations and without proper mitigation they could result in unrealistic retrievals.

APPENDICES

1. Coverage map

Figure 1 Coverage map of SWC 100 m and 1 km L-band