**SMOS Freeze and Thaw Processing and Dissemination Service**

# ReadMe-first Technical Note

## Deliverable

| | |
|---|---|
| **ESRIN Contract Nro:** | **4000124500/18/I-EF** |
| **Issue / Revision:** | 1 / 3 |
| **Date:** | 10 July 2019 |


**Prepared by**

Kimmo Rautiainen, Tuomo Smolander

Finnish Meteorological Institute (FMI)


FINNISH METEOROLOGICAL INSTITUTE

GAMMA REMOTE SENSING

*This page is intentionally left blank.*

## Document change log

| Issue/ Revision | Date | Observations |
|---|---|---|
| 0.1 | 26-Jun-2018 | Draft issue for Kick-Off meeting |
| 1.0 | 28-Nov-2018 | Updated version |
| 1.1 | 28-Feb-2019 | Updated based on ESA comments |
| 1.2 | 5-Mar-2019 | Minor modification in Section 1.1 Data access; and in table 2, FT values corrected |
| 1.3 | 10-Jul-2019 | Processor version updated to 2.01, text updated accordingly |

*This page is intentionally left blank.*

## Table of Contents

*This page is intentionally left blank.*

# 1 Information on the current data product

| | |
|---|---|
| **Processor version** | v2.01 (Level 3 F/T product – L3FT) |
| **Release date** | Data has been available since March 2019 |
| **Authors** | Kimmo Rautiainen, Timo Ryyppö, Finnish Meteorological Institute |
| **Further information** | Details on the product content can be found in the Product Description Document (PDD) available http://nsdc.fmi.fi/services/SMOSService/docs/FTS-PDD.pdf<br><br>Details on the processing algorithm can be found in the Algorithm Theoretical Baseline Document (ATBD) available http://nsdc.fmi.fi/services/SMOSService/docs/FTS-ATBD.pdf<br><br>Data access from FMI dissemination service: http://nsdc.fmi.fi/services/SMOSService/<br><br>Data access from ESA dissemination service: https://smos-diss.eo.esa.int/oads/access/ |
| **Contact for help** | Issues related to data access at FMI servers, please contact smos.dissemination.support@nsdc.fmi.fi<br><br>Issued related to data access at ESA servers, please contact smos.dissemination.support@esa.int |
| **Feedback comments to** | The FT Service webpage in FMI has a user feedback channel: http://nsdc.fmi.fi/services/SMOSService/<br><br>Additionally, feedback related to science can be sent by email to: kimmo.rautiainen(at)fmi.fi |

This Read-me-first technical note introduces the Level 3 SMOS soil Freeze and Thaw (F/T) status product (SMOS L3FT). The SMOS L3FT product is daily generated based on SMOS observations and associated ancillary data, with corresponding quality information. The soil Freeze and Thaw status detection algorithm uses SMOS CATDS (Centre Aval de Traitement des Données SMOS) daily gridded level 3 brightness temperatures products as input data.

The daily operational generation of the SMOS L3FT products is based on the earlier work performed within the frame of SMOS + Innovation Permafrost and SMOS + Frost2 Study. Within the frame of earlier studies, several demonstrator datasets have been published earlier. The operational F/T product versions and the two main demonstrator versions prior the release of the operational product, with their corresponding CATDS and DPGS versions are collected in Table 1.

The first version of the operational SMOS L3FT product (v 2.0) was released in March 2019 (official announcement in April 2019). The current product version is 2.01

**Table 1. SMOS L3FT product versions and their correspondence to CATDS and DPGS products versions.**

| L3FT FMI | L3 CATDS | L1 DPGS | Release date | Notes |
|---|---|---|---|---|
| v 0.1 | 2.5 | v500 | March 2013 | First official global F/T product, outcome of SMOS+ Innovation Permafrost project. |
| v 1.0 | 2.7 | v600 | July 2015 | Updated algorithm based on outcome of Frost2Study. Results published in (Rautiainen et al. 2016) |
| v 2.0 | 3.1 | v620 | March 2019 | First version of the operational F/T product |
| v 2.01 | 3.1 | v620 | 23-May-2019 | Minor bug related to the orientation of the data matrix fixed. No effect to scientific data. |

### 1.1 Data access

The SMOS L3FT products are accessible through FMI and ESA ftp/http dissemination services; both have the identical datasets. Links to FMI SMOS L3FT dissemination service:

http://nsdc.fmi.fi/services/SMOSService/

Direct link to FMI ftp server is:

ftp://litdb.fmi.fi/outgoing/SMOS-FTService/

For ftp client users (e.g. FileZilla) and command line ftp users, use Logon Type/username: anonymous and Password: your email address.

Link to ESA dissemination service:

https://smos-diss.eo.esa.int/oads/access/

Please refer to the Product Description Document (PDD) for the contents of the data files (http://nsdc.fmi.fi/services/SMOSService/docs/FTS-PDD.pdf).

### 1.2 Main improvements from the previous version

The operational processor was updated to version 2.01 on May 22$^{nd}$, 2019. Re-processing of the data was finished on May 23$^{rd}$. This update has no effect to the scientific F/T data. The previous processor version (2.0) had problems with some GIS software related to the orientation of the data matrix. The problem has been fixed in version 2.01.

## 2 Product validation

This section presents the comparison results between the SMOS L3FT product estimates and in situ measurements. The point scale in situ data consists of soil temperature and soil moisture/permittivity measurements from various locations in Alaska, Canada, Finland and Siberia. SNOTEL and SCAN networks in Alaska form the major part of the in-situ observations; both acquired from International Soil Moisture Network data portal (https://ismn.geo.tuwien.ac.at/en/). Additionally, in situ dataset includes data from Berms and Kenaston stations in Saskatchewan, Canada, FMI stations from Finland and Tiksi, Russia and from Kolyma, Chreskii, Russia.

The comparisons between SMOS L3FT products and in situ observations (separately for soil temperature and soil moisture) are performed using day of freezing (*DoF*) information defined from these datasets. A threshold soil temperature value of 0°C was selected for in situ observations when defining *DoF*. The *DoF* was defined as the first day the soil temperature was below 0°C and would stay below 0°C for the following seven days. Sensor depth of 5 cm was used.

To determine *DoF* from in situ soil moisture a 14-day-moving-average was calculated from each day *n* to day *n+13.* Then daily change was calculated as the difference between soil moisture measurements from each day and the day before. The daily change was scaled using standard deviation of the time series. The *DoF* was defined as the first day to fulfill the following requirements: (1) in situ soil temperature is below 0°C, (2) there has been a relatively large drop in the soil moisture during previous 14 days, (3) there are no large changes in the soil moisture for the following 14 days. Sensor depth of 5 cm was used.

The *DoF* was defined from the SMOS L3FT product as the first day when (1) partial freezing occurred (F/T value equals to 2) and (2) freezing occurred (F/T value equals to 3). In situ stations on the coastal zone and in F/T grid cells having higher open water bodies percentage than 20% were screened out.

Comparison results between the SMOS L3FT product and in situ observations at 5 cm depth are shown in Figure 1 (soil temperature) and in Figure 2 (soil moisture). The results are collected in Table 2.

**Table 2. Comparison results of Day of Freezing (*DoF*) between in situ observations and F/T estimations.**

| Comparison | Number of points | Bias (days) | Correlation |
|---|---|---|---|
| Partial frozen (FT = 2) vs soil temperature (ST) | 134 | -2 | 0.62 |
| Frozen (FT = 3) vs soil temperature (ST) | 134 | 9 | 0.60 |
| Partial frozen (FT = 2) vs soil moisture (SM) | 86 | -8 | 0.65 |
| Frozen (FT = 3) vs soil moisture (SM) | 86 | 2 | 0.65 |

The first day of freezing is estimated to be earlier when defined using the soil temperature observations compared to soil moisture observations. This was expected since the soil temperature observations were needed when detecting the soil freezing from the soil moisture observations. The F/T algorithm using SMOS measurements is based on detecting the permittivity change due to freezing of the free liquid water within the soil. The soil moisture observations are likewise based on detecting the soil permittivity. Soil temperature information alone is not necessary enough to define whether the soil is frozen, for moisture soils the freezing process may take some time during which the free liquid water remains in the freezing temperature. On the other hand, for dry areas, the annual dynamics of the soil moisture observations may be very low and for such areas it is very challenging to define whether the soil is frozen or not based on the soil moisture observations alone. The very different spatial scales between in situ observations (point scale) and satellite observations (large pixels) provide further challenges for the validation of the product. The results shown here show good consistency between the product estimates and the in-situ observations considering all the challenges. The comparison and validation work will be continued, and new results will be published when ready.

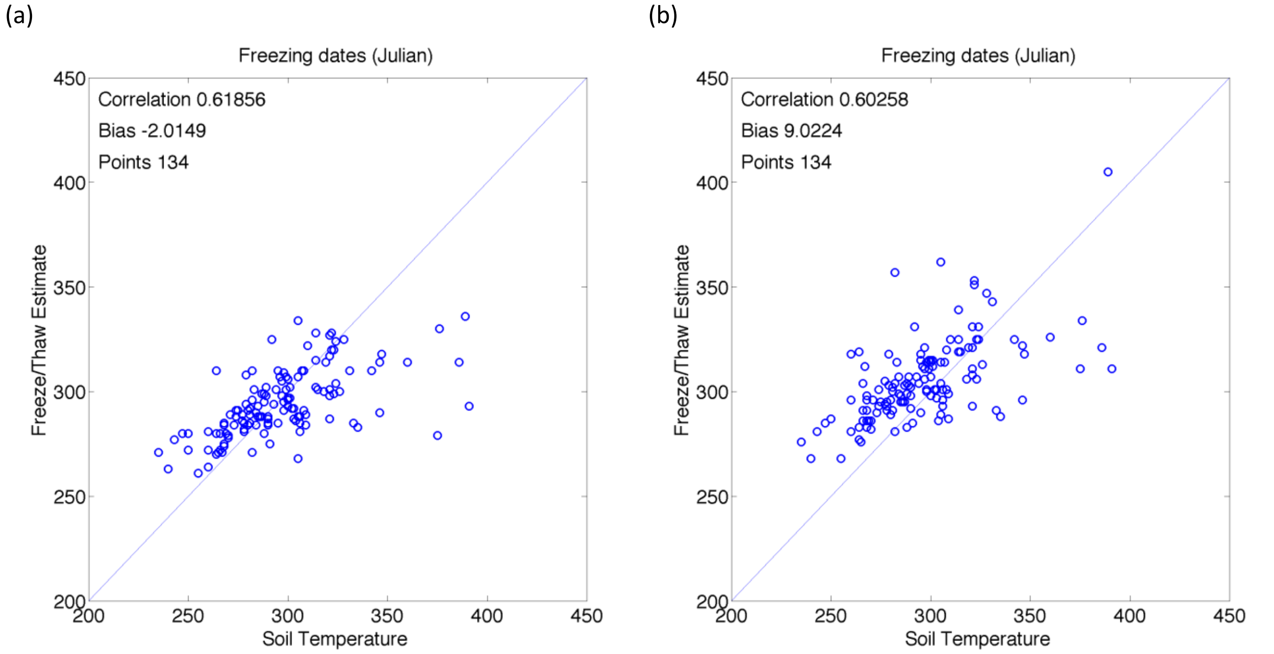


**Figure 1. Comparsion of the first day of freezing (*DoF*) between soil temperature observations at 5 cm depth and (a) F/T estimation of partial soil freezing and (b) F/T estimation of frozen pixel.**

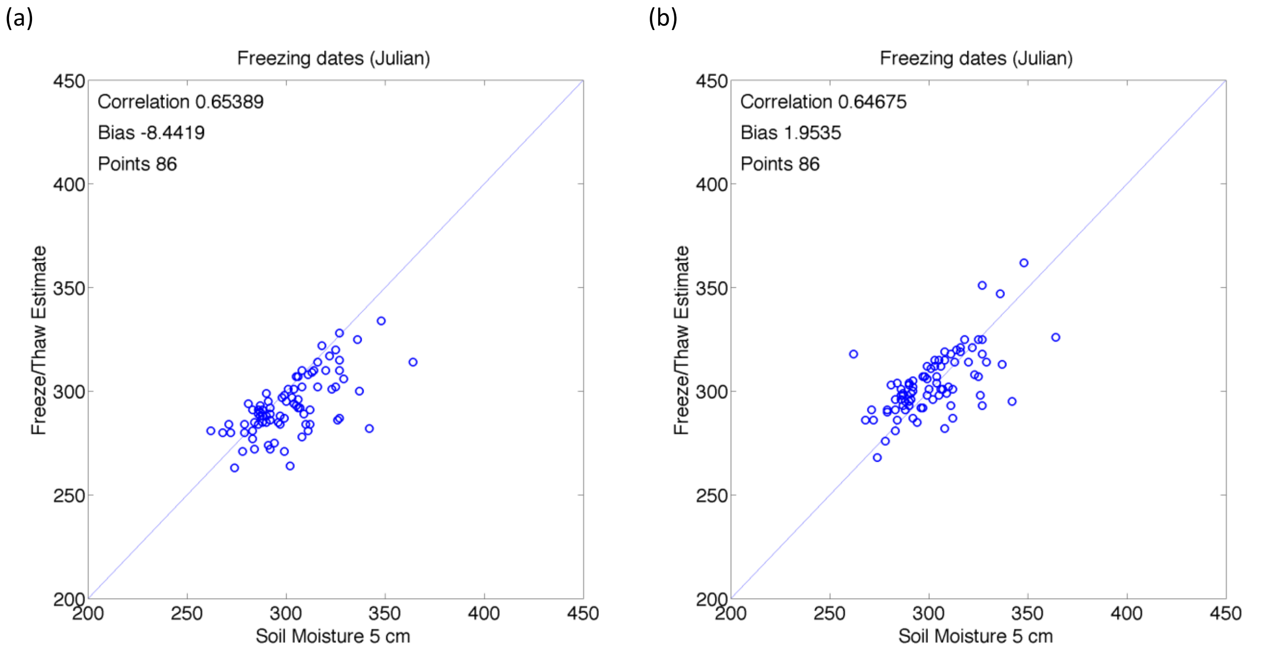


**Figure 2. Comparsion of the first day of freezing (*DoF*) between soil moisture observations at 5 cm depth and (a) F/T estimation of partial soil freezing and (b) F/T estimation of frozen pixel.**

# 3 Known challenges and caveats

The algorithm has the best performance at high latitudes (above 60 degrees) due to many reasons: (1) the seasonal changes are typically very evident, (2) vegetation cover if existing, is typically sparser compared to vegetation cover at lower latitudes, and (3) due to orbit configuration the SMOS instrument is observing the high latitudes more frequently (sun synchronous orbit).

Areas that are typically dry are challenging for reliable detection of soil freezing, since the permittivity change due to soil freezing is very small. E.g. on many rocky areas and mountains, the estimation of the algorithm is mostly defined by the processing mask (PM) determined by the ancillary input data. PM is used to omit the obvious omission and commission errors, more detailed description provided in ATBD.

The quality flag provides pixel-wise information on (1) how much PM has affected the estimation of the soil F/T state, and (2) the number of observation days included in each 20-day moving average. Details on how to interpret the quality flag information are provided in product description document (PDD).

The user should also be aware that large open water bodies provide a very large dynamic range between summer and winter conditions: there is a high difference in observed signal between an open water target and a thick ice target. For areas with high open water percentage, the estimation of the soil freezing may be dominated by the freezing of the open water rather than the freezing of soil. It is recommended to use land cover data (e.g GlobCover 2009, Global Land Cover 2000 and Land Cover CCI) and be critical to results on such pixels that have an open water coverage higher than 20 %.

# 4 Citations

Data users, please refer to:

Rautiainen, K., Parkkinen, T., Lemmetyinen, J., Schwank, M., Wiesmann, A., Ikonen, J., Derksen, C., Davydov, S., Davydova, A., Boike, J., Langer, M., Drusch, M., Pulliainen, J., (2016) SMOS prototype algorithm for detecting autumn soil freezing Remote Sensing of Environment, SMOS 5 Years Special Issue 180:346-360