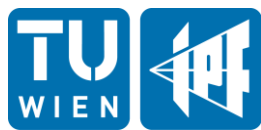


SAR Freeze/Thaw v2 product guide



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1 Product overview

The Synthetic Aperture Radar (SAR) Freeze/Thaw (F/T) product is derived from data acquired by the ENVISAT ASAR sensor operating in Global Monitoring (GM) mode (Park et al. 2010).

The SAR F/T product represents timing (day of year) of ground surface freeze-up and thawing at a resolution of 1 km. The version 2 release of the data covers the years 2005 through 2010 for the regional sites Ob Estuary, Alaska, Mackenzie, Laptev Sea Coast and Central Yakutia. Product quality and geographical coverage is strongly dependent on the availability of ASAR GM data.

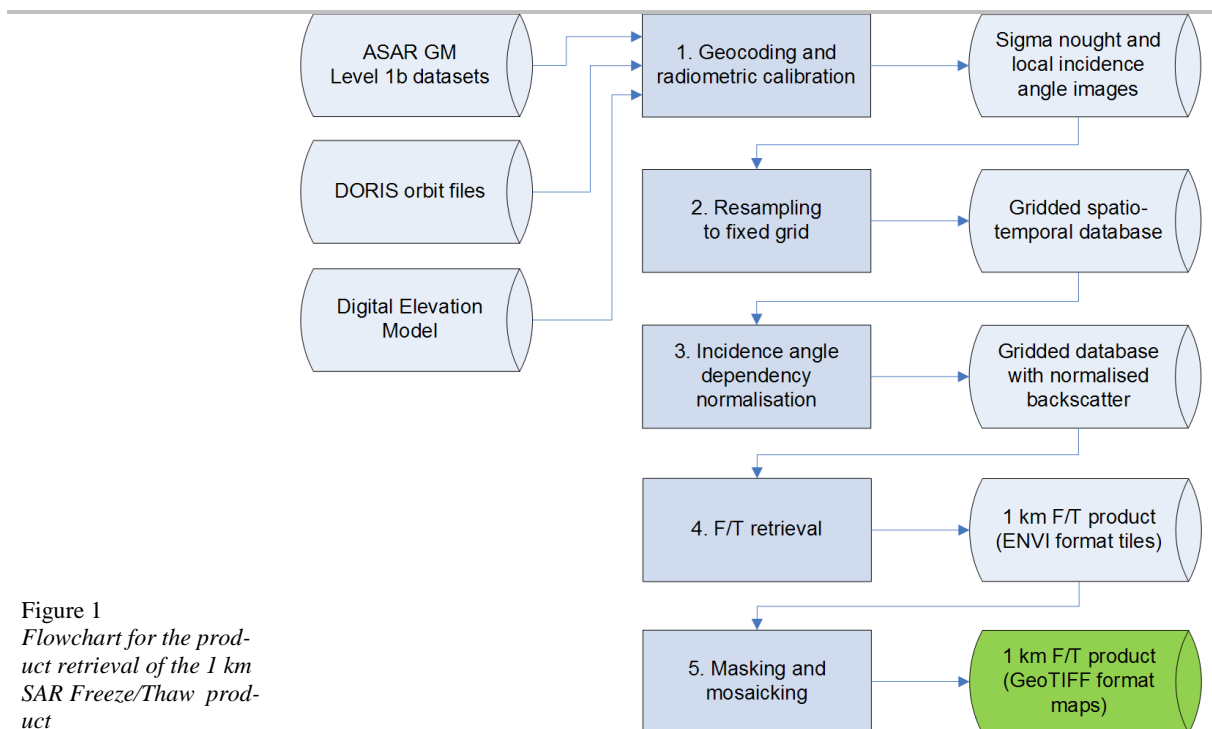


Figure 1
Flowchart for the product retrieval of the 1 km SAR Freeze/Thaw product

An overview of the product retrieval process is given in Figure 1. The processing steps (1 to 5) are explained below:

1. ASAR GM level 1b datasets are radiometrically calibrated and geocoded with a terrain-correction approach (Pathe et al. 2009). The SRTM30 Digital Elevation Model was used. DORIS orbit files were used in order to improve on the state vectors included in the ASAR GM data.

2. The geocoded data were then transferred from image format to a database format in order to allow efficient time series analysis of the data. This was done in the resampling step by means of bilinear interpolation of the sigma nought values in the linear domain. Also the co-located local incidence angle images were resampled to the database.
3. Due to the side-looking geometry of SAR sensors, the recorded backscatter is in general dependent on the incidence angle, with a decrease in backscatter with increasing incidence angle. This dependency is normalised before comparing backscatter measurements acquired over the same area but under different incidence angles. The normalisation is carried out by fitting the time series of sigma nought and local incidence angles to a linear model and then reverting the backscatter to a reference local incidence angle of 30 degrees.
4. The retrieval of the yearly F/T estimates was carried out by fitting a piecewise step function to the time series of normalised backscatter measurements for each year (Park et al. 2010). The output of this step consisted of image tiles of estimates of timing of ground freeze-up and thawing.
5. A masking was then applied to product pixels believed to contain unreliable estimates. Product pixels for which less than 52 ASAR GM acquisitions per annum were available for product retrieval were masked out as less than weekly SAR measurements are believed to render a poor product quality. In addition, pixels fulfilling the following product component specific criteria were masked out:
 - Thawing maps: $DOY < 90$ (~Apr. 1) or $DOY > 180$ (~Jun. 30)
 - Freeze-up maps: $DOY < 227$ (~Aug. 15) or $DOY > 287$ (~Oct. 15)Finally, the masked product tiles were mosaicked to full-extent maps and converted to the GeoTIFF format.

2 Improvements relative version 1

The improvements of the F/T product version 2 relative version 1 are:

- Extending coverage to include the Laptev Sea Coast and Central Yakutia regional sites.
- Including year 2010.
- Some artifacts, resulting from SAR processing or ASAR level 1b product issues, could be eliminated through manual inspection followed by removal and re-processing.
- Applied masking (see Product overview section) to remove estimates expected to be unreliable.

3 Product specification

The SAR Freeze/Thaw (F/T) parameters represent timing (in units of day of year, DOY) of ground surface freeze-up and thawing. Due mainly to the limited availability of ASAR data and its relatively high radiometric noise, the exact interpretation of the timing parameters is not straightforward. Roughly, “freeze-up” refers to the beginning of soil surface freeze-up and “thawing” refers to end of spring snow thaw.

The v2 product consists of yearly freeze-up and thaw maps for the years 2005 through 2010 for the regional sites of Alaska, Mackenzie and Ob Estuary, Laptev Sea Coast and Central Yakutia (the Permafrost project regional sites, see Table 3–3). The product specification is given in Table 3–1.

Subject	Specification
Variables	Timing of thawing (day of year, files named *tha.tif). Timing of freezing (day of year, files named *fre.tif). Number of measurements used in parameter retrieval (files named *num.tif).
Units	Day of year (DOY)
Coverage	Regional sites: Ob Estuary, Mackenzie, Alaska, Laptev Sea Coast and Central Yakutia.
Time period	2005-2010
Temporal frequency	Yearly
Coordinate system	Plate Carée map projection, WGS84 datum
Spatial resolution	1 km
Spatial sampling	15 arc-seconds
Geometric accuracy	<500 m
Thematic accuracy	Thawing ¹ : ±2 weeks (with 80% probability) ±1 week (with 60% probability) Freezing: to be determined (higher accuracy than thawing)
Data format	GeoTIFF
Other data codes	-1 for missing or masked data

Table 3-1
Product specification.

¹ Preliminary estimate over the Ob Estuary site for the year 2009, with on average weekly ASAR observations. The estimation was generated through a comparison with a coarse spatial but high temporal resolution snowmelt product from QuikScat (Bartsch et al. 2007).

For each region and year, the product consists of three maps (GeoTIFF format), namely the freeze-up and thawing maps and a quality indicator map containing the number of ASAR GM measurements that were used in the retrieval of the F/T parameters for each product pixel. Note that pixels for which less than 52 ASAR measurements per annum were available for product retrieval have been masked out (i.e. set to the default no-data value).

The product files are named according to the following pattern:

OOO_SSSSS_PPP_VVV_vvv_yyyymmdd_hhmmss-
YYYYMMDD_HHMMSS_RRR_DDD.EEE

The filename syntax is specified in Table 3–2.

Product filename field	Field description	F/T v2 value
OOO	Organisation	"TUW"
SSSSS	Sensor and Mode	"ASAGM"
PPP	Product	"FTH"
VVV	Product/software version	"002"
vvv	Processing index	"001"
YYYYMMDD_HHMMSS	Start Date/Time	Always Jan. 1 at 00:00:00, e.g. "20100101_000000"
yyymmdd_hhmmss	End Date/Time	Always Dec. 31 at 23:59:59, e.g., "20101231_235959"
RRR	Region of Interest	E.g. "001" (see Table 3–3)
DDD	Parameter	"fre" (freeze-up data), "tha" (thawing data) and "num" (quality parameter)
EEE	Extension	"tif"

Table 3–2
Product filename syntax specification.

The value of the “Region of Interest” field, specified in Table 3–3 follows the definition in the Permafrost Observation Strategy document (“Service Case Areas”).

Permafrost Regional site	“Region of Interest” field
Alaska	001
Mackenzie	002
Laptev Sea Coast	003
Central Yakutia	004
Ob Estuary	005

Table 3–3
Definitions for the “Region of Interest” field in the product file name, following the Permafrost project Service Case Areas.

An example of the 2010 F/T product for the Mackenzie site is shown in Figure 2 (thaw map), Figure 3 (freeze-up map) and Figure 4 (quality indica-

tor). Please note that the color scheme and map/legend layout is not included in the product.

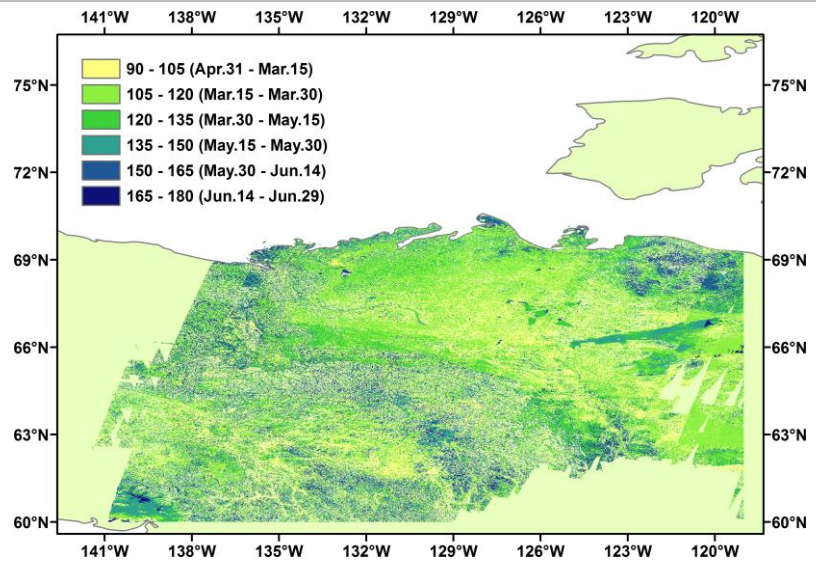


Figure 2
2010 thaw map for the Mackenzie site. Units in day of year (DOY).

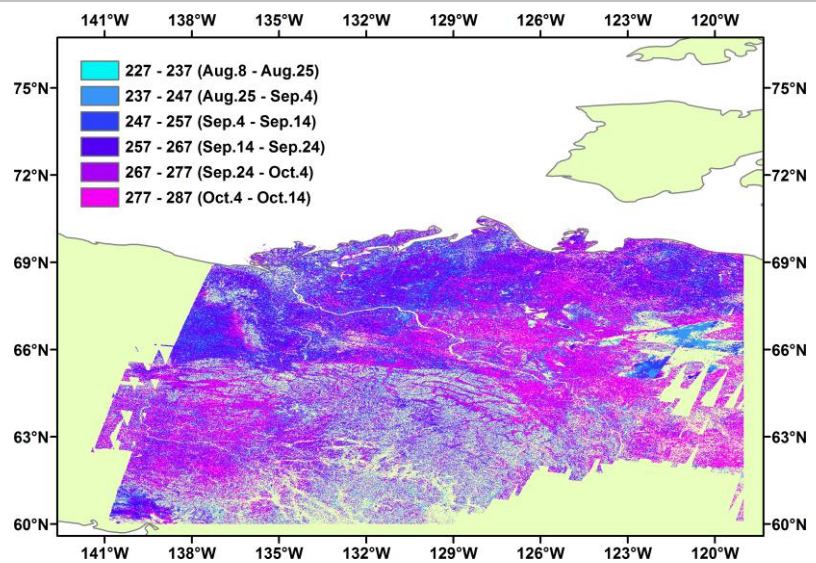


Figure 3
2010 freeze-up map for the Mackenzie site. Units in day of year (DOY).

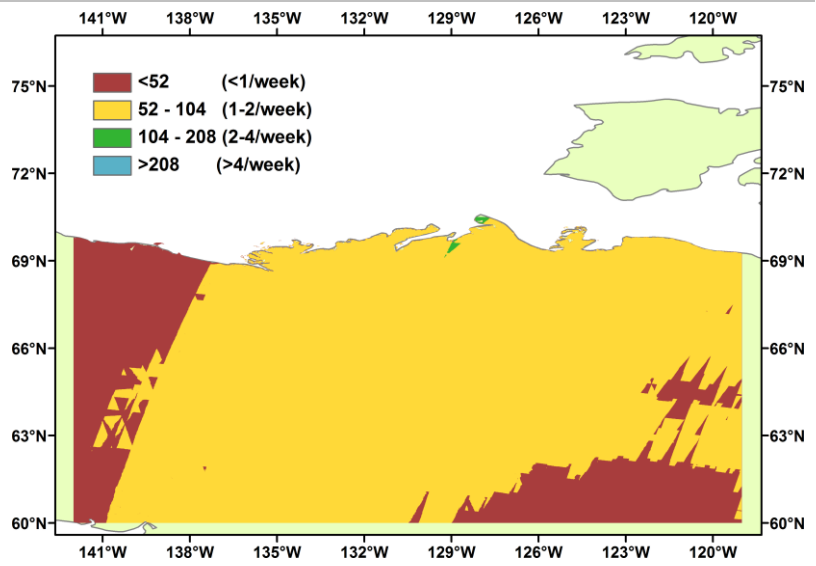


Figure 4
2010 F/T quality indicator map for the Mackenzie site containing number of ASAR GM measurements used for product retrieval.

4 Known issues

4.1 Limited ENVISAT ASAR GM data coverage

The quality of the derived timings for freezing and thawing is dependent on the revisit time between ASAR observations. In general, to reach a reasonable thematic accuracy, at least weekly ASAR acquisitions for the entire year are required (pixels with lower data coverage have been masked out). ASAR data coverage varies both spatially and temporally. Ob Estuary is the most problematic region in this aspect, with up to about 50% of the area masked out due to low data coverage (with exception for 2010 for which the product has very little area masked out). The Alaska site exhibited sufficient ASAR coverage for all years except for 2005, for which only retrievals for the coastal region could be provided. For the Mackenzie site, up to about 20% of region was masked due to low coverage during 2005, 2006 and 2010. The Laptev Sea Coast and Central Yakutia sites exhibited sufficient ASAR data coverage at all times.

4.2 Influence of sub-pixel water bodies

The occurrence of lakes in arctic environments may have an impact on the product as (1) lake ice can last longer than the snow cover and (2) the opposite backscatter behavior occurs (if ice does not freeze to ground): lower backscatter in summer than in winter. This issue has not been explicitly accounted for. However, the masking of pixels expected to contain unreliable results mitigates its influence on the product quality.

4.3 Map artifacts

There are artifacts in the form of sudden (unnatural) jumps in the estimations of the freeze-up and thawing timing. Through manual data inspection and testing of the processing software, it was concluded that these artifacts did not arise from any particular erroneous ASAR datasets or through software issues. Rather, they arise from a combination of the temporal sampling of the ASAR acquisitions in combinations with thaw/re-freeze

events to which the retrieval algorithm is sensitive. This has been chiefly observed in some of the thaw maps.

There are also artifacts in the shape of lines transecting the maps along the azimuthal directions of some ASAR swaths. These artifacts stem from a SAR processing issue with the NEST software.

5 Data access and contact information

The SAR Freeze/Thaw (F/T) product version 2 can be accessed via PANGAEA (<http://doi.pangaea.de/10.1594/PANGAEA.780111>) and should be cited as:

Sabel, Daniel; Park, Sang-Eun; Bartsch, Annett; Schlaffer, Stefan; Klein, Jean-Pierre; Wagner, Wolfgang (2012): Regional surface soil moisture and freeze/thaw timing remote sensing products with links to geotiff images, Institute of Photogrammetry and Remote Sensing, TU Vienna, doi:10.1594/PANGAEA.779658

In: DUE Permafrost Project Consortium (2012): ESA Data User Element (DUE) Permafrost: Circumpolar Remote Sensing Service for Permafrost (Full Product Set) with links to datasets. doi:10.1594/PANGAEA.780111

The product is alternatively stored on the Institute of Photogrammetry and Remote Sensing (TU Wien) FTP server which can be accessed via the DUE Permafrost data portal (www.ipf.tuwien.ac.at/permafrost). The dataportal includes a WebGIS for visualization. Login information is available on request.

For login access to the dataportal, contact Annett.Bartsch@tuwien.ac.at.

For questions about the product, contact Daniel.Sabel@tuwien.ac.at or Annett.Bartsch@tuwien.ac.at.

For ESA's technical officer, contact Frank.Martin.Seifert@esa.int.

Additional information on the ESA DUE Permafrost project can be found at the web - site: <http://www.ipf.tuwien.ac.at/permafrost>

6 References

Sabel, Daniel; Bartalis, Zoltan; Wagner, Wolfgang; Doubkova, Marcela; Klein, Jean-Pierre (2012): Development of a Global Backscatter Model in support to the Sentinel-1 mission design. *Remote Sensing of Environment*, 120, 102-112.

Park, Sang-Eun; Bartsch, Annett; Sabel, Daniel; Wagner, Wolfgang; Naeimi, Vahid; Yamaguchi, Yoshio (2011): Monitoring freeze/thaw cycles using ENVISAT ASAR Global Mode. *Remote Sensing of Environment*, 115(12).

Park, S.-E., Bartsch, A., Sabel, D. and Wagner, W. (2010, 25-30 July 2010). Monitoring of thawing process using ENVISAT ASAR global mode data. Paper presented at the Geoscience and Remote Sensing Symposium (IGARSS), 2010 IEEE International.