Product documentation: Hot Spot Regions of Permafrost Change (“Hot Spot Product”)

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Consortium:

Signatures

	Name	**Organisation**	**Signature**
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Distribution

Version	People and/or Organisation	Publicly available on website
1.0	Users	

Change Log

Version	Date	Details	Editor
1.1	11 December 2017	Adapted to changed tiling	Ingmar Nitze

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1. Product Overview

The GlobPermafrost project develops, validates and implements Earth Observation (EO) products to support research communities and international organisations in their work on better understanding permafrost.

We here provide robust trend products of different multi-spectral indices: Tasseled Cap Brightness, Greenness, and Wetness; Normalized Difference Vegetation Index; Normalized Difference Moisture Index; and Normalized Difference Water Index. These indices represent specific surface properties, such as albedo, vegetation or moisture/water on the Earth's surface. Changes of specific surface properties over time can be linked to particular processes in permafrost regions, such as permafrost degradation from thermokarst or erosion (Nitze & Grosse, 2016).

The robust Theil-Sen regression algorithm was used to calculate trend parameters (slope and intercept) on the USGS Landsat time-series stacks. The entire Landsat archive, pre-processed to surface reflectance, for the peak summer season (July, August) between the years 1999 and 2014, was processed for the trend calculation for Landsat Tasseled Cap, NDVI, NDWI, NDMI.

The trend products are available for four large North-South transects: T1 Western Siberia, T2 Eastern Siberia, T3 Alaska, and T4 Eastern Canada. The transects cover a wide range of permafrost types and geo-ecological zones (Figure 1). They have the Landsat-specific spatial resolution of 30m and the geometric accuracy of the Landsat Surface Reflectance product.

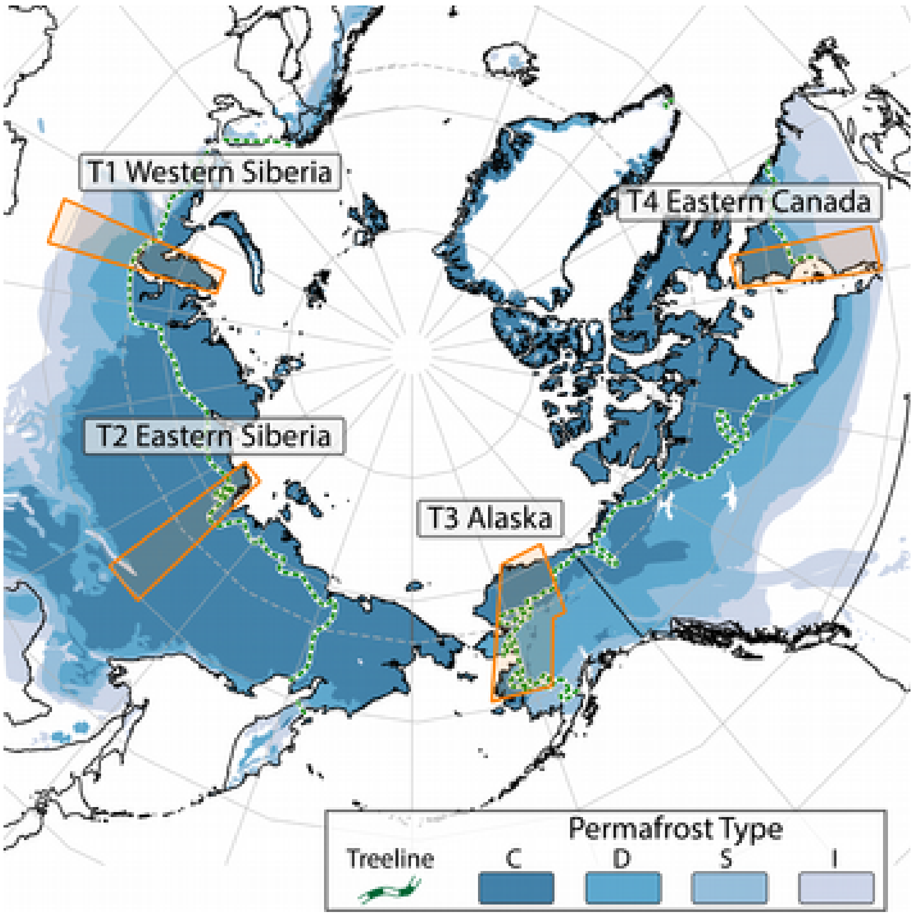

Figure 1: Overview of location of all transects for the Hot Spot product. Permafrost regions based on IPA Permafrost map (Brown et al., 1997), treeline after Walker et al. (2005)

2. Product Specification

Table 1: Specifications of the File Naming Nomenclature for the Hot Spot Product.

Subject	*Code*	*Specification*
Organization	AWI	Alfred Wegener Institute
Product	HOT	Hot Spot Regions of Permafrost Change
Algorithm	TCBR TCGG TCWE NDVI NDMI NDWI	Tasseled Cap Brightness Tasseled Cap Greenness Tasseled Cap Wetness Normalized Difference Vegetation Index Normalized Difference Moisture Index Normalized Difference Water Index
Satellite sensor and mode used to create product *	LASAT	Landsat-5 TM, Landsat-7 ETM+, Landsat-8 OLI
Product version	V01	
Start date and time	19990701	
End date and time	20140831	
Region of interest**	T1 T2 T3 T4	Western Siberia Eastern Siberia Alaska Eastern Canada
Zone Identifier	Z0XX	e.g. Z052, UTM Zone
Tile	XXtoXX	e.g. 64to66, degrees latitude
File Extension	TIF	GeoTIFF

* The identifier will be renamed accordingly depending on satellite sensor and mode.

** The value of the “Region of Interest” field is defined according to the Observation Strategy document.

Table 2: Specifications of the Hot Spot Product.

Variable	*Specification*
Units	Decadal change of index value
Coverage	Hot Spot Transects T1-T4
Time period	1999 through 2014
Temporal frequency	1 (trend from 1999 to 2014)
Seasonal observation window	01 July to 31 August
Coordinate system	UTM, WGS84
Spatial resolution (grid spacing)	30 m
Geometric accuracy	Landsat L1T/Surface Reflectance
Data (file) format	GeoTIFF

3. Detailed Data Product Information

3.1. Product Types

The Hot Spot Product consists of three different product types (Table 3).

1. Trend Product
   Six different Trend Products with n=4 Bands each for Tasseled Cap Brightness, Tasseled Cap Greenness, and Tasseled Cap Wetness, Normalized Difference Vegetation Index, Normalized Difference Moisture Index; and Normalized Difference Water Index.
   The trend product provides robust trend information with its linear function parameters in the form of slope and intercept as well as the confidence intervals of slope.

   - B1: Slope (linear change of index value) per decade
   - B2: Intercept (interpolated value on July 1st 2014)
   - B3: Lower confidence interval of Slope (alpha = 5%)
   - B4: Upper confidence interval of Slope (alpha = 5%)

2. Visual Product
   The Visual Product combines the slope value of the TC components Brightness, Greenness, Wetness to an RGB composite image with three bands, where different colors represent typical land cover changes. For examples see below or (Fraser et al., 2014; Brooker et al., 2014; Nitze and Grosse, 2016; Nitze et al., 2017).

   - B1 on RED: Scaled Slope Tasseled Cap Brightness
   - B2 on GREEN: Scaled Slope of Tasseled Cap Greenness.
   - B3 on BLUE: Scaled Slope of Tasseled Cap Wetness.

   For correct visualization, any visual stretch should be disabled in the used display software. ArcGIS for example applies a stretch per default.
   In addition to the full resolution visual product, we added a georeferenced preview image in GeoPNG data format with a reduced resolution.

3. Metadata
   The metadata currently contains information on the number of used images (valid observations) for the calculation of trends and a kml file for visualizing the data extent in GoogleEarth.

   - B1: Number of valid observations

Table 3: Overview of Product Types

Product Type	*Product Name*	*# of Bands*	*Data-type*	*Short Description*
Type 1	Trend Product	4	Float	Slope, Intercept, lower slope CI and upper slope CI of trends
Type 2	Visual Product	3	Byte	RGB representation of Tasseled Cap Trends
Type 3	Metadata	1	Byte	Number of Observations

3.2. Spatial structure of data

All products are available in a hierarchical order of three different levels in descending order: Transects, Zones and Blocks. An example for the division of data is shown in Figure 2.

1. **Transects:**

T1 Western Siberia, T2 Eastern Siberia, T3 Alaska, T4 Eastern Canada. The location of all Transects is shown in Figure 1.

2. **Zones:**

Each transect is subdivided into zones, which correspond to their respective UTM Zones[1] e.g. zones Z051 and Z052 for T2 Eastern Siberia.

3. **Blocks/Tiles:**

Due to the large data size and for better usability, the zones are subdivided into smaller tiles of 2° latitude (e.g. 64°N to 66°N) and the full width of the UTM zone within the respective transect. Therefore, the longitudinal extent (west to east) and file sizes may vary.

[1] Single Transect data may be implemented in later versions

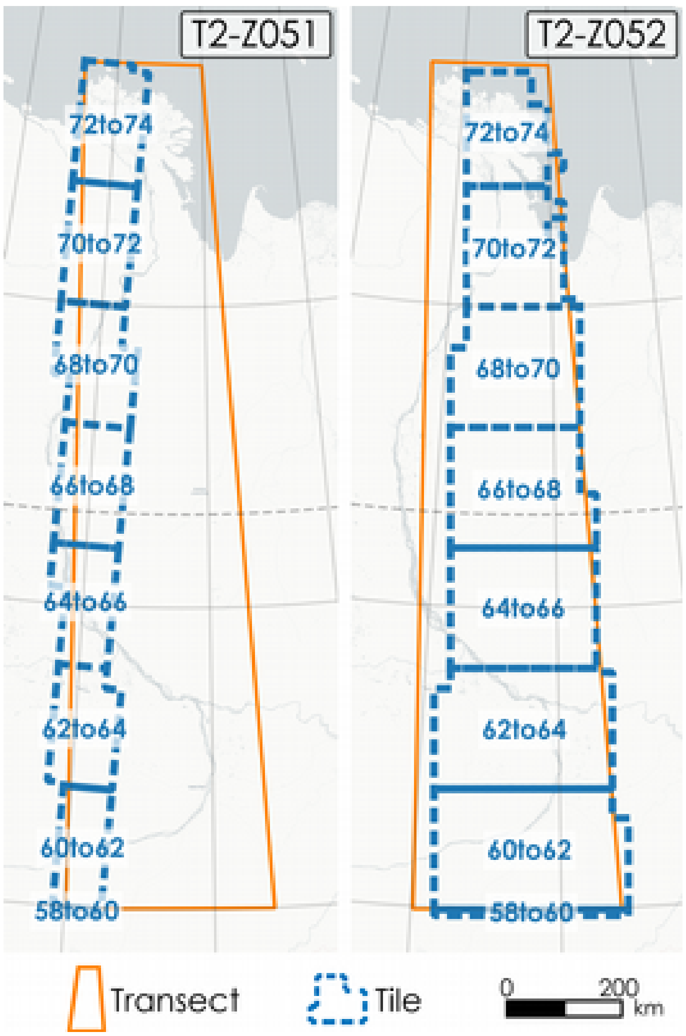

Figure 2: Subsetting structure of data products with example of Transect T2 (Eastern Siberia) including UTM Zones 51N (T2-Z051) and 52N (T2-Z052).

3.3. Projections

Each file is projected in UTM-WGS84, according to the named zone within each transect. For a detailed overview see Table 4.

Table 4: Overview of Available Projections for Each Transect and Zone

Tran-sect	*Zone*	*EPSG*
T1	Z042	32642
T1	Z043	32643
T2	Z051	32651
T2	Z052	32652
T3	Z003	32603
T3	Z004	32604
T3	Z005	32605
T4	Z017	32617
T4	Z018	32618

3.4. Data Formats

All files are currently provided as GeoTIFF. Datatypes are variable among products. Trend products (Type 1) are delivered in Float. Visual (Type 2) and Metadata Products (Type 3) are delivered in Byte/8-bit Unsigned Integer datatype.

3.5. Product Examples

Retrogressive Thaw Slumps

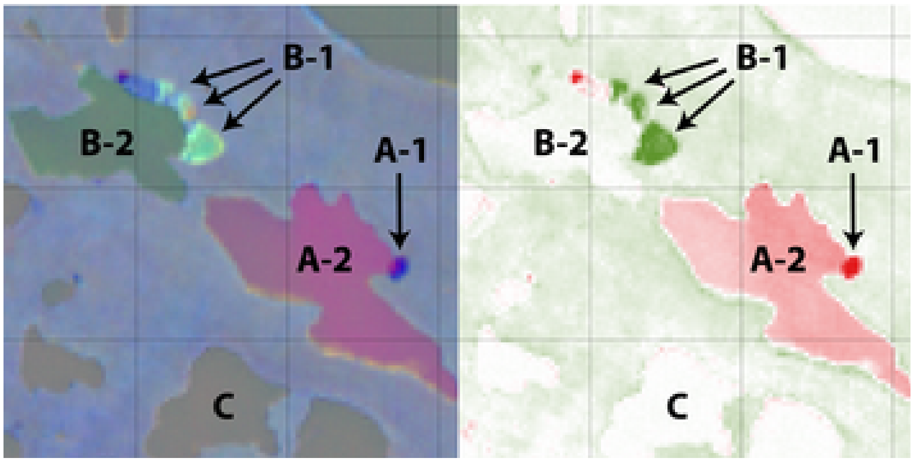

Figure 3: Product Example of thaw slump affected landscape in Eastern Siberia (T2). Left: Visual Product (Type 2). Right: Slope of the Tasseled Cap Greenness index. Grid Size = 1 km. Coordinates: 68.827°N, 124.268°E. Tile: T2-Z051-68to70

In Figure 3, we can see an active retrogressive thaw slump (A-1) as well as a lake affected by an increase in suspended sediments (A-2), which causes the purple color (higher brightness, lower greenness and wetness). The decrease in Greenness can be seen on the right.

At the edge of the adjacent lake, there are several inactive retrogressive thaw slumps, which are characterized by an increase in surface vegetation (B-1). The lake (B-2) shows a slight decrease (greenish shade) in suspended sediment load. C shows a lake, which is unaffected by thaw slumping.

Wildfires

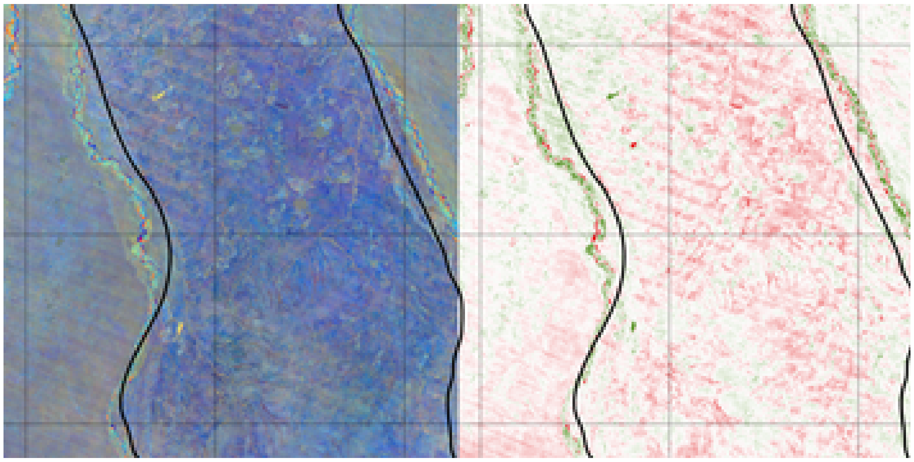

Figure 4: Product example of the large Anaktuvuk tundra Fire in northern Alaska (T3). Left: Visual Product, Right: NDVI slope. Grid Size = 10 km. Location: 69.127°N, 150.635°W. Tile: T3-Z005-68to70.

Figure 4 shows a burn scar in blue (approximate fire boundary indicated) that can be distinguished from the surrounding undisturbed surface in the visual trend product (Fig. 4 left). The NDVI trend (Fig. 4 right) shows a decline in vegetation within the fire scar, but also outside.

Thermokarst Lake Change and Infrastructure Development

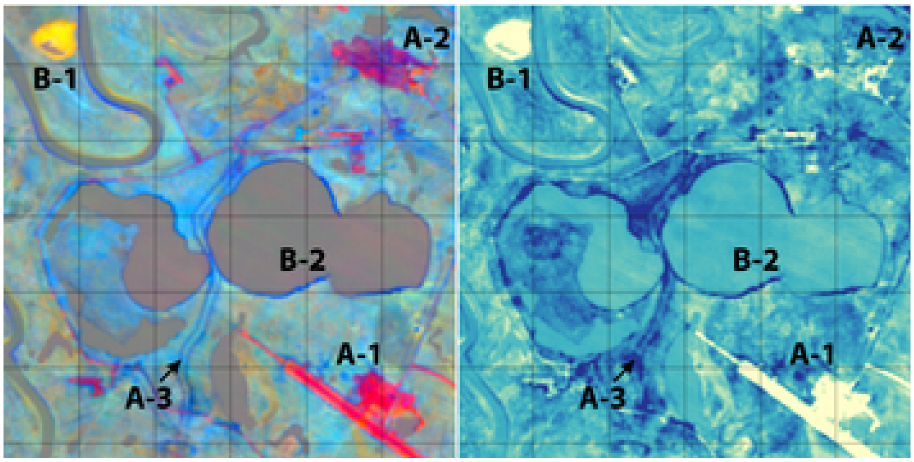

Figure 5: Product example of the Bovanenkovo Gas Field area on the Yamal Peninsula, north-western Siberia (T1). Left: Visual Product. Right: Tasseled Cap Brightness Slope. Grid Size = 1 km.Coordinates: 70.338°N, 68.304°E. Tile: T1-Z042-70to72

The subset shown in Figure 5 contains a highly dynamic environment, which is affected by economic development and thermokarst processes. In this region, strong infrastructure development took place in the form of construction of a new airport (A-1), industrial buildings and open pit mining for gravel (A-2) as well as construction of pipelines (A-3). At the same time, lakes drained (B-1) or expanded rapidly (B-2).

Fluvial Processes and Thermo-erosion of Shores

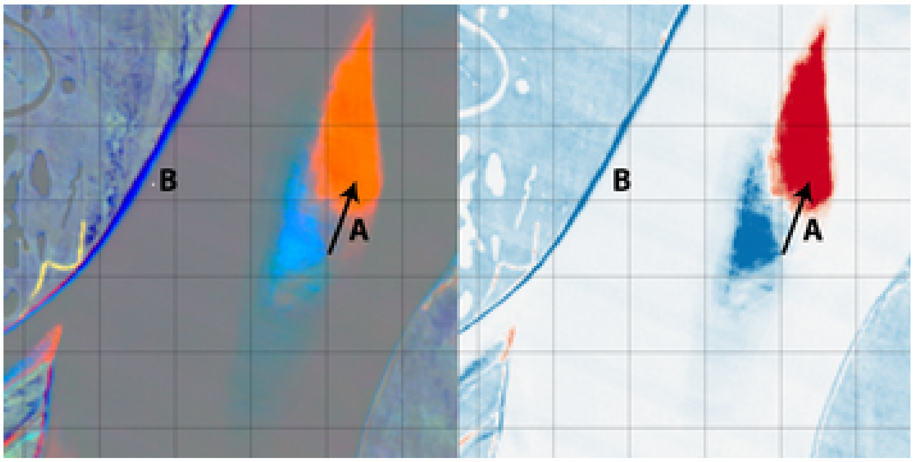

Figure 6: Product example of fluvial processes and thermo-erosion within the Lena River in Eastern Siberia (T2). Grid Size = 1km.Coordinates: 69.644°N, 124.969°E. Tile: T2-Z051-68to70

The example in Figure 6 shows fluvial processes within the Lena River. Here we see the downstream migration of sand banks over the observation period from 1999 through 2014 (A). With a transition of the surface from sand to water, the wetness signal at the former sand bank location increased (Fig. 6), whereas the brightness signal decreased. Along the western banks of the Lena River, strong thermo-erosion along the shore can be observed (B).

Similar processes of erosion or sediment accumulation and the migration of barrier islands and sand spits can be observed along coasts.

4. Data Access, Contact Information and Citation

Data Access

Data are available for download via the PANGAEA archive:

https://doi.pangaea.de/10.1594/PANGAEA.884137

Single Transects can be found here:
T1 - Western Siberia: https://doi.pangaea.de/10.1594/PANGAEA.884134
T2 - Eastern Siberia: https://doi.pangaea.de/10.1594/PANGAEA.884136
T3 - Alaska: https://doi.pangaea.de/10.1594/PANGAEA.884274
T4 - Eastern Canada: https://doi.pangaea.de/10.1594/PANGAEA.884276

They follow the structure described in section 3.

The visual product (Type 2) is also available on the PerSys-WebGIS for visualization and browsing.

WebGIS-Link: http://maps.awi.de/map/map.html?cu=Globpermafrost_Overview#layers

Contact Information

For further information or feedback, please feel free to contact Ingmar Nitze (ingmar.nitze@awi.de).

Citation

In case you used the data or methodology, please refer to:

Nitze, I., & Grosse, G. (2016). Detection of landscape dynamics in the Arctic Lena Delta with temporally dense Landsat time-series stacks. *Remote Sensing of Environment*, *181*, 27-41.

5. References

Brooker, A., Fraser, R. H., Olthof, I., Kokelj, S. V., & Lacelle, D. (2014). Mapping the activity and evolution of retrogressive thaw slumps by tasselled cap trend analysis of a Landsat satellite image stack. *Permafrost and Periglacial Processes, 25*(4), 243-256.

Brown, J., Ferrians Jr, O. J., Heginbottom, J. A., & Melnikov, E. S. (1997). *Circum-Arctic map of permafrost and ground-ice conditions*. Reston, VA: US Geological Survey.

Fraser, R. H., Olthof, I., Kokelj, S. V., Lantz, T. C., Lacelle, D., Brooker, A., Wolfe, S. & Schwarz, S. (2014). Detecting Landscape Changes in High Latitude Environments Using Landsat Trend Analysis: 1. Visualization. *Remote Sensing, 6*(11), 11533-11557.

Nitze, I., & Grosse, G. (2016). Detection of landscape dynamics in the Arctic Lena Delta with temporally dense Landsat time-series stacks. *Remote Sensing of Environment*, *181*, 27-41.

Nitze, I., Grosse, G., Jones, B.M., Arp, C.D., Ulrich, M., Fedorov, A., & Veremeeva, A. (2017): Landsat-based trend analysis of lake dynamics across northern permafrost regions. *Remote Sensing, 9(7)*, 640.

Walker, D. A., Raynolds, M. K., Daniëls, F. J., Einarsson, E., Elvebakk, A., Gould, W. A., ... & Moskalenko, N. G. (2005). The circumpolar Arctic vegetation map. *Journal of Vegetation Science*, *16*(3), 267-282.