Data Manual V1.1: Helicopter-borne thermal infrared surface temperature during the MOSAiC expedition

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01.02.2022

1 Introduction

The sea ice surface temperatures were measured with helicopter-borne thermal infrared imaging while the surface temperature is derived from the measured brightness temperature with a constant emissivity of 0.996. The measurements were part of the MOSAiC expedition within the period from Sep 2019 until Sep 2020 and taken along the transpolar drift of the MOSAiC ice floe from the northern Laptev Sea towards the Fram Strait. The current data set includes the data from the Arctic winter 2019/2020, i.e. from 02.10.2019 (Leg 1) until 23.04.2020 (Leg3). The images are recorded with the Infrared VarioCAM HD head 680 from InfraTec. The device and its actions are registered in the AWI Sensor web (https://sensor.awi.de/) under the Device URN 'aircraft:heli-ps:ir_variocam_02'. This data set consists of two data types: (1) images, and (2) maps. As an advanced data set, we developed maps that include the data from all images of each flight. The usual flight duration was 90 minutes at an altitude of about 300 m. All data are ice drift corrected and georeferenced and provided with longitude and latitude coordinates as well as relative coordinates with the RV Polarstern as reference points. We provide high-resolution surface temperature data which are important for the validation of coarser satellite products. The sea ice surface temperature is an important parameter for a better understanding of the heat exchange in the Arctic, especially, in a warming climate. More information can be found in our associated data paper.

2 Data Description

All temperature (and corresponding) data are provided in the NetCDF format. The raw data were recorded in the binary format IRB. There is one file for every flight and we have two types of data:

1. images
   (a) 640 x 480 pixel
   (b) 1 Hz images frequency (reduced from originally 4 Hz due to large overlap)
   (c) Image size is about a few hundreds of meters in each direction (depends on flight altitude)
2. maps
   (a) Combines all images of one flight
   (b) 1 m horizontal resolution as the standard product

(c) 5 m horizontal resolution as a low resolution product with smaller file size

(d) Extent depends on the flight pattern

3 Published data sets

a) Images (NetCDF-format, 35 files, 1 per flight)

b) Maps (NetCDF-format, 35 files, 1 per flight)

c) Plotted maps of gridded surface temperatures + time-fixed surface temperatures (png-format, 35 files, 1 per flight)

3.1 File Naming

The flights can be identified by the Flight-ID, which includes the recording date or the Device Operation which was registered during the expedition. The resolution is only for the mapping in the naming scheme included. The naming of the files are according the following scheme: *main-variable*_*device*_*data-type*_*resolution*_*device-operation*_*fid*.nc.

4 Helicopter-borne flights

Following flights were performed during the MOSAiC expedition:

- Processed flights (35): Table 1
- Unprocessed flights (9): Table 2

The unprocessed flights are not included in the current data set, but will be processed later.
The flights were performed with different flight pattern:

- Central Observatory (CO): local (5 km scale)over the MOSAiC ice floe
- L-site: regional (20 km scale) including the outer observation sites
- L-site grids: local at outer sites
- Event-Grids: focusing on a specific event, like a crack opening

5 Processing steps

The data sets are based on several processing steps to correct artificial effects and make them easy usable:

1. Image correction
2. Radial gradient (center - edge)
3. Corner exclusion (shielding effect)
4. NUC filtering (internal calibration)
5. Ice-drift correction (Reference time: middle of the flight)
6. Georeferencing (stereographic projection)
7. Gridding (value closest to reference time taken)
8. Temperature-drift correction (maps only)

For the maps, also relative coordinates are included with RV Polarstern as reference. Thus the maps are inter-comparable in the same coordinate system over the whole measurement period.

5.1 Variables and Dimensions

The available variables are listed with their units and dimensions in Table 3 for the images and in Table 4 for the maps. The data sets for the images includes temperature arrays with the dimension of x=640 pixel, y=480 pixel, and t=number of images. The number of images varies per flight whereas not usable images from the start or end of the flight, for example, due to low flight altitude or due to the NUC are already excluded. Thus, the time indices for the excluded images are not included in the data at all.

The mapped data include the surface temperature on a 1 m grid for the whole flight whereas the extent and therefore the dimension varies for every flight. Additionally, the corrected gridded surface temperature for a fixed time, helicopter position data, and the time are included. Every gridded data set includes the relative distances to the center point according to the ship position of RV Polarstern.

The parameter latitude, longitude, heading, roll, and pitch are measured by an embedded GNSS inertial system and registered in the AWI Sensor web with the Device URN 'aircraft:heli-ps:applanix-ap60av-9873'. The mean sea surface height data [1] are located under https://ftp.space.dtu.dk/pub/DTU21/1_MIN/.

6 Uncertainties

In the following, the main uncertainties are listed. Further uncertainties of the measurements and processing are discussed in the associated data paper.

1. The measured temperature has an accuracy of 1% for temperatures lower than 0°C with a thermal resolution of up to 0.02 K.
2. The used emissivity is constant for simplicity whereas there is a dependence on the surface type and incidence angle
3. The accuracy of the ice-drift correction is affected by the variability of ice drift in the covered area, while the correction is based on the RV Polarstern position only
4. High incidence angles cause uncertainty in geolocation
5. The estimated maximum error is 10 m

References

[1] Ole B Andersen and Per Knudsen. The DNSC08 mean sea surface and mean dynamic topography. *J. Geophys. Res.*, (114):C11, 2009.

Tables

Table 1: Chronological list of the helicopter flights including Device Operation, Flight ID, date as well the type of the flight pattern.

Device Operation	**Flight ID**	**Date**	**Flight Type**
PS122-1_2-57	20191002_01	2019-10-02	CO
PS122-1_2-167	20191020_01	2019-10-20	CO
PS122-1_5-9	20191029_01	2019-10-29	L-Site
PS122-1_6-11	20191105_01	2019-11-05	CO
PS122-1_7-24	20191112_01	2019-11-12	L-site
PS122-1_7-25	20191112_02	2019-11-12	CO
PS122-1_8-23	20191119_01	2019-11-19	CO
PS122-1_9-98	20191130_01	2019-11-30	CO
PS122-1_10-78	20191206_01	2019-12-06	L-Site
PS122-2_17-98	20191224_01	2019-12-24	CO
PS122-2_17-99	20191225_01	2019-12-25	CO
PS122-2_17-101	20191228_01	2019-12-28	CO
PS122-2_18-7	20191230_01	2019-12-30	L-Site
PS122-2_19-44	20200107_01	2020-01-07	CO
PS122-2_19-45	20200107_02	2020-01-07	L-Site
PS122-2_19-46	20200108_01	2020-01-08	L-Site 2 Grid
PS122-2_19-52	20200108_03	2020-01-08	L-Site 1 Grid
PS122-2_19-53	20200108_04	2020-01-08	L-Site 3 Grid
PS122-2_20-52	20200116_01	2020-01-16	CO
PS122-2_20-53	20200116_02	2020-01-16	L-Site
PS122-2_21-41	20200121_01	2020-01-21	CO
PS122-2_21-77	20200123_01	2020-01-23	L-Site
PS122-2_21-78	20200123_02	2020-01-23	Event-Grid
PS122-2_21-122	20200125_01	2020-01-25	Event-Grid
PS122-2_22-16	20200128_01	2020-01-28	CO
PS122-2_22-97	20200202_01	2020-02-02	L-Site (partial)
PS122-2_23-14	20200204_01	2020-02-04	CO
PS122-2_23-109	20200209_01	2020-02-09	L-Site
PS122-2_24-31	20200212_01	2020-02-12	CO
PS122-2_25-7	20200217_01	2020-02-17	L-site (partial)
PS122-2_25-8	20200217_02	2020-02-17	CO
PS122-3_29-49	20200227_01	2020-02-27	CO
PS122-3_32-70	20200321_01	2020-03-21	CO
PS122-3_32-71	20200321_02	2020-03-21	L-site
PS122-3_37-63	20200423_01	2020-04-23	CO

Table 2: Not yet published, but available flights including Device Operation, Flight ID, date as well the type of the flight pattern. When the Device Operation is in brackets the flight does not have its own but is a second flight.

Device Operation	**Flight ID**	**Date**	**Survey Type**
PS122-1_2-45	20190928_01	2019-09-28	Small scale (loop)
PS122-2_19-51	20200108_02	2020-01-08	Regional
(PS122-2_21-41)	20200121_01	2020-01-21	Small scale (loop)
(PS122-2_21-122)	20200125_01	2020-01-25	Lead event
(PS122-3_29-49)	20200227_01	2020-02-27	Transit
PS122-3_37-66	20200423_02	2020-04-23	L-site
PS122-3_39-109	20200510_01	2020-05-10	CO
PS122-5_63-3	20200921_02	2020-09-21	Regional
PS122-5_63-118	20200928_01	2020-09-28	Regional, thin ice

Table 3: List of variables in the images data set with name, unit and dimensions.

Name	**Unit**	**Dimensions**
surface temperature	K	(x,y,t)
x-coordinate	m	(x,y,t)
y-coordinate	m	(x,y,t)
time	seconds since daystart	(t)
longitude	degree north	(t)
latitude	degree east	(t)
heading	decimal degree	(t)
altitude	m	(t)
mean sea surface height	m	(t)
roll angle	decimal degree	(t)
pitch angle	decimal degree	(t)
image index	1	(t)
corner mask	1	(x,y)
correction array	1	(x,y)

Table 4: List of variables in the grid data set with name, unit and dimensions.

Name	**Unit**	**Dimensions**
relative x-coordinate (ref: RV Polarstern)	m	(x)
relative y-coordinate (ref: RV Polarstern)	m	(y)
rotated x-coordinate (ref: RV Polarstern)	m	(x)
rotated y-coordinate (ref: RV Polarstern)	m	(y)
longitude	degree north	(x,y)
latitude	degree east	(x,y)
surface temperature	K	(x,y)
time-fixed surface temperature	K	(x,y)
time	seconds since daystart	(x,t)
roll angle	decimal degree	(x,y)
pitch angle	decimal degree	(x,y)