Data description for essd-2020-106

An integrated observation dataset of the hydrological-thermal deformation in the permafrost slopes and engineering infrastructure in the Qinghai-Tibet Engineering Corridor

Description

- **Meteorological observations**
  Observation of meteorological factors was conducted at two permanent meteorological stations (Golmud and Wudaoliang) and one field meteorological station (Xidatan) with daily meteorological records. All three meteorological stations contain ground observations.

- **Ground observations**
  The ground temperature and moisture data from the near-surface to within 270 cm in the active layer were recorded. In situ ground observations were deployed starting in July 2013 using thermocouple probes (105T, Campbell Scientific) to measure the soil temperature and using 11 time-domain reflectometer (TDR) probes (model CS615-L, Campbell Scientific) to measure the soil volumetric water content.

- **TLS measurements**
  A FARO Focus3D X130 3D laser scanner and six Trimble 5700 GNSS systems were deployed around permafrost slopes between May 2014 and October 2015. As a supplement to the TLS point cloud data, we used Interferometric Synthetic Aperture Radar (InSAR) technology to prepare Sentinel-1 deformation data for the study area from 2014 to 2020.

- **UAV RGB and TIR images**
  Two permafrost slopes were conducted four flight experiments with UAV-mounted RGB and TIR sensors in 2016 and 2017.

- **R code of permafrost indices and visualization**
  R Script for plotting meteorological observation data and permafrost indices (MAAT and MAGST) during 1955-2020.

Keywords

– **Theme:** Permafrost slope; Permafrost engineering; Freeze-thaw; hydrological-thermal-Deformation; Qinghai-Tibet plateau
– **Discipline:** cryosphere; In-situ monitoring data; Remote sensing data using TLS and UAV
– **Places:** Qinghai-Tibet Engineering Corridor; Kunlun Mountain Pass close to Hoh Xil Nature Reserve

Data details

– **Scale:** UAV RGB: ~5 cm; UAV TIR: ~ 20 cm; TLS measurements: 0.009°
– **Coordinate Reference System:** EPSG: 4326 - WGS 84
– **Filesize:**~ 13 G
– **Data format:** GeoTiff, CSV, EXCEL XLSX, TXT, WRP, Tif, JPG

Space scope

North: 35°39′ 10″
West: 90°3′ 30″ - East: 90°3′ 55″
South: 35°38′ 35″

Time period

Table 1. Observations period of all datasets.

Data Type	Location	Period	Remark
Meteorological observations	Golmud station	1955-2020	National Reference Station
Meteorological observations	Xidatan station	2014-2018	National General Station
Meteorological observations	Wudaoliang station	1956-2020	National Reference Station
Ground observations	Study Area	2014-2019	Field test site
Ground observations	Golmud station	1955-2020	National Reference Station

Data Type	Location	Period	Remark
Ground observations	Xidatan station	2014-2018	National General Station
Ground observations	Wudaoliang station	1956-2020	National Reference Station
TLS measurements	Study Area	2014-2015	Contains measurement and comparative analysis data
InSAR	Study Area	2014-2020	Contains thawing and freezing period data
UAV RGB and TIR images	Study Area	2016-2017	tif & jpg can be processed by Pix4Dmapper & FLIR
R code of permafrost indices and visualization	Stations	1955-2020	Plot Fig. 2 & H1; Computing MAAT & MAGST

Meteorological and Ground observations

Table 2. Observations period of datasets.

Data Type	Location	Period	File Names
Meteorological observations	Golmud station	1955-2020	Meteo_52818_Golmud_1955-2020.csv
Meteorological observations	Xidatan station	2014-2018	Meteo_XDTMS_Xidatan_2014-2018.csv
Meteorological observations	Wudaoliang station	1956-2020	Meteo_52908_Wudaoliang_1956_2020.csv
Ground observations	Study Area	2014-2019	GT_00000_Slopes_2014-2019.csv
Ground observations	Golmud station	1955-2020	GT_52818_Golmud_1955-2020.csv
Ground observations	Wudaoliang station	1956-2020	GT_52908_Wudaoliang_1956-2020.csv

Table 3. Ground data Metadata of meteorological stations data. The file name with **'GT'** is ground observation data. Field Name is a data variable customized by the China Meteorological Administration.

ID	Variable	Type	Field Name	Unit	Description
1	Station ID	Number(5)	V01000		
5	Year	Number(4)	V04001	Year	
6	Month	Number(2)	V04002	Month	
7	Day	Number(2)	V04003	Day	

ID	Variable	Type	Field Name	Unit	Description
32	Evaporation	Number(6)	V13241	mm	evaporation
53	average ground temperature at 0 cm	Number(6)	V12240	℃	GT_0_AVG
54	daily maximum ground temperature at 0 cm	Number(6)	V12213	℃	GT_0_MAX
56	daily minimum ground temperature at 0 cm	Number(6)	V12214	℃	GT_0_MIN
58	average ground temperature at 5 cm	Number(6)	V12240_005	℃	GT_5_AVG
59	average ground temperature at 10 cm	Number(6)	V12240_010	℃	GT_10_AVG
60	average ground temperature at 15 cm	Number(6)	V12240_015	℃	GT_15_AVG
61	average ground temperature at 20 cm	Number(6)	V12240_020	℃	GT_20_AVG
62	average ground temperature at 40 cm	Number(6)	V12240_040	℃	GT_40_AVG
63	average ground temperature at 50 cm	Number(6)	V12240_050	℃	GT_50_AVG
64	average ground temperature at 80 cm	Number(6)	V12240_080	℃	GT_80_AVG
65	average ground temperature at 160 cm	Number(6)	V12240_160	℃	GT_160_AVG
66	average ground temperature at 320 cm	Number(6)	V12240_320	℃	GT_320_AVG

Table 4. Meteorological Metadata of meteorological stations data. The file name with **'Meteo'** is Meteorological observation data. The suffixes _MIN, _MAX, _AVG, and _QC indicate the minimum, maximum, and average values and quality control code of the variable, respectively, while 32766, NA, and NAN indicate null values. The suffix of TotalPrecip with "20_8", "8_20", and "20_20" are the total precipitation from 20 to 8 o'clock the next day, 8 to 20 o'clock, and 20 to 20 o'clock the next day, respectively. The suffixes of Evaporation with "SmallEvaporators" and "LargeEvaporators" are the data monitored by the small and large evaporator respectively. The suffix of GT with a number indicates the ground temperature in centimeters.

Variable Name	Description	Unit
Temperature	Air temperature	°C
Wind	Wind speed	m/s
WindDirection	Wind direction	16 directions
Extreme_Wind	Extreme wind speed	m/s
WindDirection_Extreme_Wind	Wind direction with extreme wind speed	16 directions
TotalPrecip	Precipitation	mm
Corrected_P	Corrected precipitation	mm
Evaporation	Evaporation	mm
Humidity	Air humidity	%
Press	Atmospheric pressure	hPa

Variable Name	Description	Unit
Sunshine	Sunshine duration	h
GT	Ground temperature	°C

Table 5. Metadata of Xidatan field station. Underlay type: Alpine meadow.

Observations	Probe Model	Erection Height	Variable Name	Unit
Air temperature	HMP45C	2m	Ta_2m	°C
Air humidity	HMP45C	2m	RH_2m	%
Precipitation	T-200B	1.5m	Precipitation	mm
Wind speed	05103_L/RM	2m	WS_2m	m/s
Total radiation	CM3	2m	DSR	w/㎡

Table 6. Metadata of ground data of Slope. Underlay type: Bare land. The suffixes "_" , number and "cm" indicate the underground observe depth of the variable.

Observations	Probe Model	Variable Name	Unit
Ground Temperature	105T	Soil_Temp	°C
Ground Moisture	CS615-L	Soil_Water	%

TLS measurements

TLS measurements

There are a total of 4 monitorings between May 2014 and October 2015 within two thawing periods and a freezing period. The three freeze-thaw phases are referred to as "first thawing" (May 2014 to October 2014, called here "period 2-1"), "first freezing" (October 2014 to May 2015, called here "period 3-2"), "second thawing" (May 2015 to October 2015, called here "period 4-3"), "one thawing and one freezing stage" (May 2014 to May 2015, called here "period 3-1"), and "two thawing and one freezing stage" (May 2014 to October 2015, called here "period 4-1") in the following. The file directories for each monitoring are: first, second, third, and fourth. And the file also contains comparative analysis data of different periods.

Table 7 Freeze-thaw stages of TLS scanner data. The folder name is from number to number, such as "3-1", which represents the fusion data of the first and third monitoring. The suffix of TLS measurement data is wrp. The folder name is a or b, representing permafrost slope A or B.

Status	Condition	Date Span	Days	Slope	Data points
Period 2-1	Thawing	05/02/2014–10/10/2014	161	Slope A	1251706
Period 2-1	Thawing	05/02/2014–10/10/2014	161	Slope B	1367438
Period 3-2	Freezing	10/10/2014–05/03/2015	205	Slope A	1291356

Status	Condition	Date Span	Days	Slope	Data points
Period 3-2	Freezing	10/10/2014–05/03/2015	205	Slope B	1366141
Period 4-3	Thawing	05/03/2015–10/04/2015	154	Slope A	1248325
Period 4-3	Thawing	05/03/2015–10/04/2015	154	Slope B	1382768
Period 3-1	one thawing and one freezing	05/02/2014–05/03/2015	366	Slope A	1278448
Period 3-1	one thawing and one freezing	05/02/2014–05/03/2015	366	Slope B	1279204
Period 4-1	two thawing and one freezing	05/02/2014–10/04/2015	520	Slope A	1279706
Period 4-1	two thawing and one freezing	05/02/2014–10/04/2015	520	Slope B	1207493

- **InSAR data**

  The Sentinel-1 mission provides data from a dual-polarization C-band Synthetic Aperture Radar (SAR) instrument. This collection includes the S1 Ground Range Detected (GRD) scenes, processed using the Sentinel-1 Toolbox to generate a calibrated, ortho-corrected product. File directory is InSAR.

> **Table 8.** InSAR data for Permafrost slope A & B, including the study area vector shapefile file(SlopeAB). Direction of the orbit ('ASCENDING' or 'DESCENDING') for the oldest image data in the product (the start of the product). The spatial resolution is 10 meters.

Data Type	Period	Condition	Remark
asc	2014-2016	Tawing	ASCENDING
asc	2014-2017	Freezing	ASCENDING
asc	2017-2019	Tawing	ASCENDING
asc	2017-2020	Freezing	ASCENDING
desc	2014-2016	Tawing	DESCENDING
desc	2014-2017	Freezing	DESCENDING
desc	2017-2019	Tawing	DESCENDING
desc	2017-2020	Freezing	DESCENDING
Study Area boundary			SlopeAB:Shapefile

- **Photogrammetry data**

  In addition, during the first TLS experiment, we also used a Nikon D-series digital camera to take pictures of slope A without interruption while moving in a straight line along the Qinghai-Tibet Highway. The finally generated point cloud data was also placed in the data set, and the file name was **"Photogrammetry dense point cloud.txt".**

UAV RGB and TIR images

> For these two slopes, we conducted four flight experiments with UAV-mounted RGB and TIR sensors. The directory of flight images for RGB and thermal infrared sensors is RGB and TIR. The TIR data formats selected for 2016 and 2017 were TIF and JPG, respectively.

> There are three directories under the RGB directory: **20160417, 20160830 and 20170822**, the format is yyyyymmdd, which represent the UAV photos taken by the RGB camera that day. Please use **exiftool** to view the metadata information of pictures such as timestamp and location.

> There are three directories under the TIR directory: **20160830, 20170722 and 20170823**, the format is yyyyySlope, which represent UAV photos taken by the TIR sensor of the year. Please use exiftool to view the metadata information of pictures such as timestamp, location, and center point temperature.

> To obtain temperatures, a sensor that is able to provide absolute temperature is needed (instead of relative temperature). The FLIR Vue Pro and the Zenmuse XT do not provide absolute temperature. However, the FLIR Vue Pro and the Zenmuse XT both have a radiometric version that does record absolute temperature. It is recommended to do the processing with the uncompressed Tiff images and create the following index to view absolute temperature.

```
0.04*thermal_ir - 273.15
```

- This also applies (with the same formula) to the newer Wiris camera.
- The Thermomap camera from senseFly also records absolute temperature. The corresponding index is

```
0.01*thermal_ir - 100
```

- This index is already present in the software and is loaded automatically for Thermomap projects.

> **How to get the coefficient of Tiff format? or is the coefficient variable?**

> A **new method** to build the function.

- **1.** Use exiftool software (Ubuntu) to get the meta of TIFF or JPG data.

```
exiftool DJI_0777.tif
```

- **2.** Find “Central Temperature”.

```
exiftool DJI_0777.tif|grep "Central Temperature"
```

- **3.** Get the Min/Max Digital Values of TIFF or JPG data from ARCGIS or QGIS.
- **4.** Central temperature is the min temperature in my data through the analysis of FLIR Tools, PLEASE NOTICE, this may be different.
- **5.** Build a linear equation between Digital Values and Central Temperature.
- **6.** Get temperature from TIFF or JPG format data through the equation.
- **7.** And then, we can do anything, such as simple operation and modeling using Matlab, R, Python and so on.

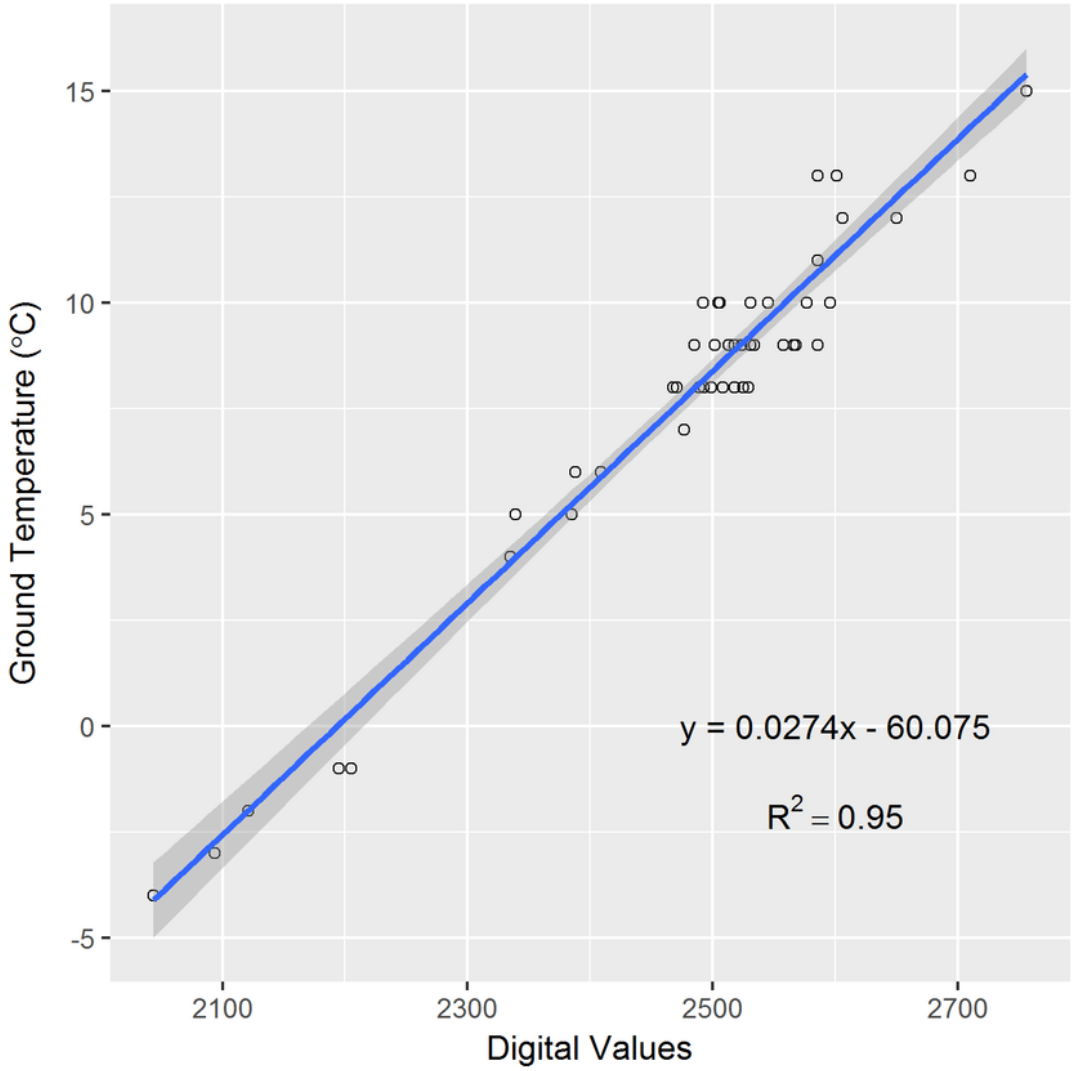

Figure 1. The linear equation between Digital Values and Central Temperature.

Table 9. UAV flight time during the 2016–2017.

Flight Date	Flight Time	Height	Slope	Sensor
yyyymmdd	hh:mm	m		
20160417	13:36-13:56	20-120	Slopes A and B	RGB
20160830	10:18-13:55	120	Slopes A and B	RGB
20170822	11:26-13:46	120	Slopes A and B	RGB
20160830	12:47-12:52	30	Slope A	TIR
20170722	11:00-15:51	150	Slopes A and B	TIR
20170823	10:30-17:25	150	Slopes A and B	TIR

Table 10. Processed UAV data.

Data Type	file name
Boundary	SlopeAB:Shapefile

Data Type	file name
Digital Surface Model(DSM)	DSM_SlopeAB:Raster
Mosaic	Mosaic_SlopeAB:Raster
Classification of frozen soil	QTP_FrozenSoil_Class:Shapefile

R code of permafrost indices and visualization

Script

- [ ] **MAAT.R**

  - Function for computing Mean Annual Air Temperature (MAAT) index

- [ ] **MAGST.R**

  - Function for computing Mean Annual Ground Surface Temperature (MAGST) index

- [ ] **Meteorogical.R**

  - Plot Meteorogical station observation data, MAAT and MAGST indices

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Data

> The **Data directory** "./Data" contains the following data:

> **Table 11.** Data files for computing and drawing. Other files in the data directory are calculated files and can be deleted.

Data file	Description	Figure
Meteo_52818_Golmud_1955-2020.csv	Meteorological observations of Golmud field station	H1
Meteo_52908_Wudaoliang_1956_2020.csv	Meteorological observations of Wudaoliang field station	H1
XDTMS2014-2018.csv	Meteorological observations of Xidatan field station	
XDTMS2014-2018_GT.csv	Xidatan field station, ONLY Ground Temperature in different depth	2
XDTMS2014-2018_PREC.csv	Xidatan field station, ONLY Precipitation	2
MAAT_MAGST_Golmud_Wudaoliang_1956-2020.csv	After running MAAT and MAGST, the data of the two field stations need to be merged together for drawing. This data has been manually merged	H1

> The **output data** is also placed in this directory "./Data".

Figure

> The output Figures are placed in Figure directory './Figure', and the **operation video** are also placed in this directory.

Usage

> **Please execute the following statement in Rstudio or R software.**

> First, please install **ggplot2** package in Rstudio or R software, and set the environment variables.

```
install.packages('ggplot2')
library('ggplot2')
# Init
# clear the environment
rm(list=ls())
# set workdir
# setwd('./Script')
# Data directory
DataRoot  <- './Data'
# Figure directory
FigRoot  <- './Figure'
```

> and then run Meteorological.R.

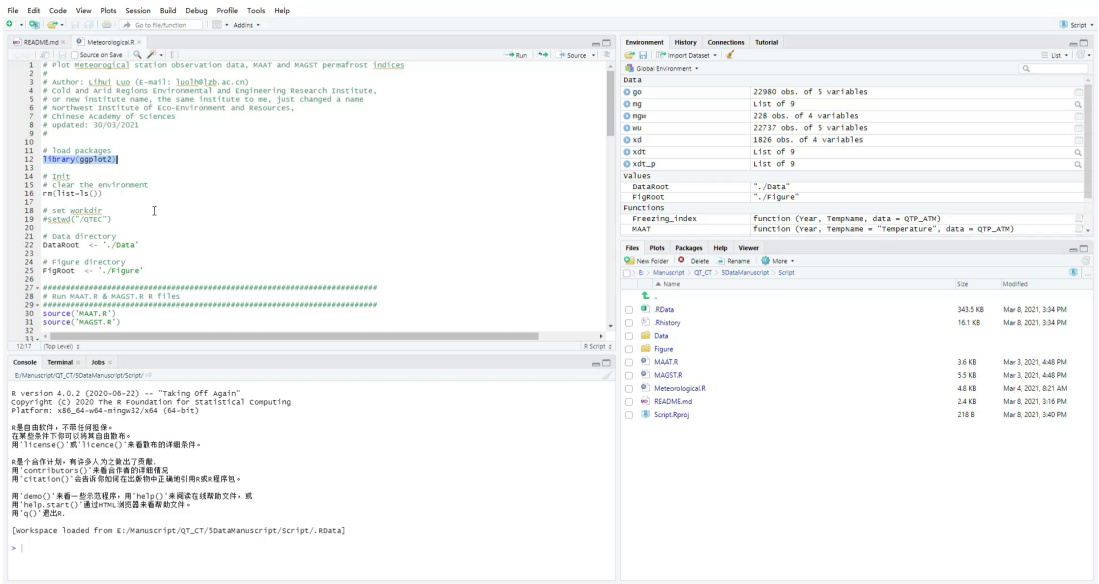
```
source('Meteorological.R')
```

> Or copy the code in Meteorological.R **in turn** and execute it in Rstudio or R software.

> MAAT.R and MAGST.R have been implemented in Meteorological.R, **no additional execution is required.**

```
source('MAAT.R')
source('MAGST.R')
```

Operation video



Requirements

> - RStudio Version 1.3.959 or later
> - R Statistical Computing Software, 4.0.2 or later
> - Package ggplot2 version 3.3.2

Article DOI

> - https://doi.org/10.5194/essd-2020-106
> - This article contains all the data DOI.

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Abbreviation

> **Table 12.** Some abbreviations

Abbreviation	Full name
CGCS	China Geodetic Coordinate System
DSM	Digital surface model
GNSS	Global navigation satellite system
InSAR	Interferometric Synthetic Aperture Radar
KMP	Kunlun Mountain Pass
MAAT	Mean annual air temperature
MAGST	Mean annual ground surface temperature
MAGT	Mean annual ground temperature
NGCN	National Geodetic Control Network
NMIC	National Meteorological Information Center
QTEC	Qinghai-Tibet Engineering Corridor
QTH	Qinghai-Tibet Highway

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