Authors reply to the comments by Anonymous Referee of the manuscript essd-2020-106

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

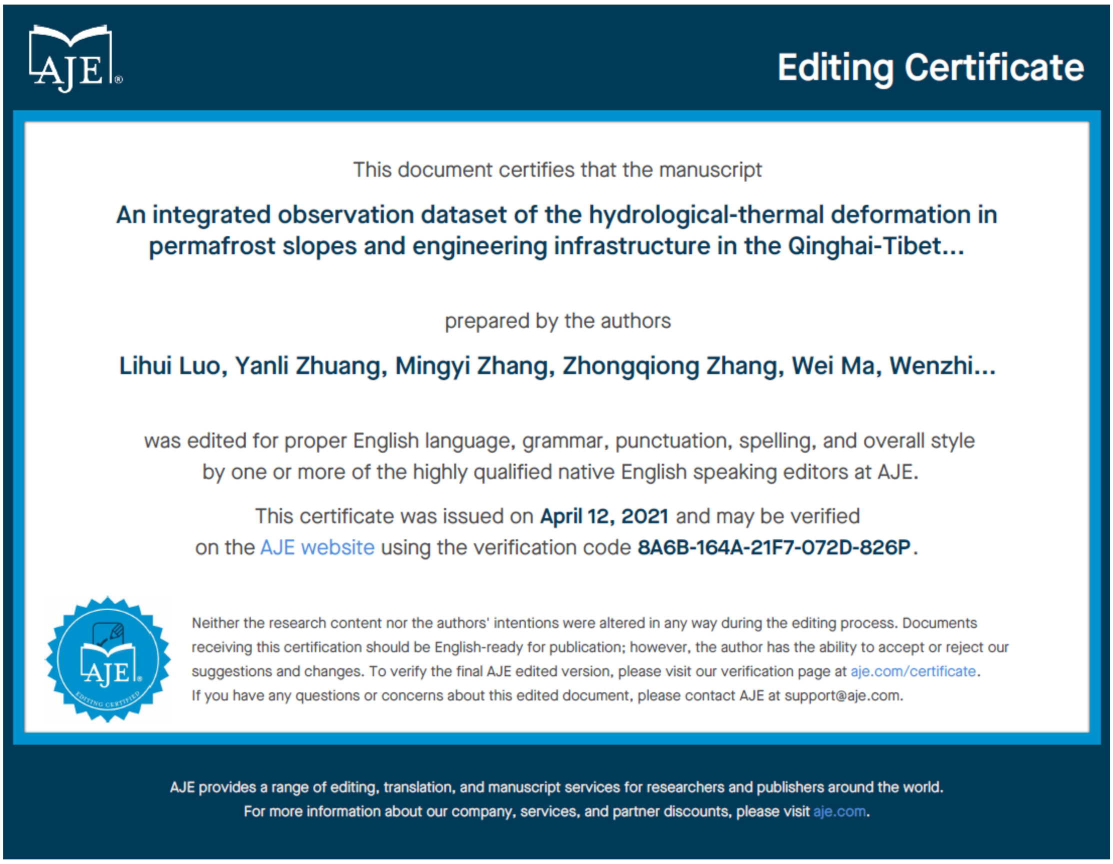
by Lihui Luo et al.

We thank Anonymous Referee #2 for valuable feedback, which helped us improve our manuscript. Please find below the Reviewer comments in black, Author responses in green, and Changes to the manuscript in blue.

Response to referee comment 2:

The manuscript by Luo et al. described multiple observation data sets in the Qinghai-Tibet Engineering Corridor (QTEC). I agree with the previous reviewer's comments about the hard-won data in this manuscript. What is particularly commendable is that the author chose a study area where railway, highway and electrical towers are all distributed on a frozen soil slope. Temperature, air and ground temperature, is the most important indicator of changes in frozen soil. The author uses drones equipped with thermal infrared sensors to monitor spatial changes in surface ground temperature. This data should be relatively rare. This set of data is of great significance for studying the interaction between frozen soil engineering and slopes. Overall, this is a well-prepared manuscript with useful data. The study area is very typical and distinctive.

Thank you for the insightful comments. In revising the paper, we have carefully considered your comments and suggestions. We agree with your comments regarding the metadata, code execution, and data description, among others. To address these concerns, we have made the following modifications to the manuscript: (1) we have added README.md files for the entire dataset of the manuscript and for each data set, such as meteorological and ground observations, TLS measurements, UAV RGB and TIR images, and R code of permafrost indices and visualization, and generated the corresponding README pdf and html files; (2) we have checked the integrity of the data file and added the missing data, including InSAR data and the study area boundary shapefile data in the TLS measurement dataset; (3) we have added vector and raster data of the boundary, DSM (digital surface model), and mosaic of the study area processed by UAV monitoring data; (4) we have renamed some data files because it was difficult for data users to obtain certain data due to naming reasons, and reorganized the file directory, (5) we have modified many inappropriate expressions, including the title; (6) we have updated the data DOI; (7) we have deleted some references with little relevance and added some related references; and (8) we have improved the flow of the language throughout the manuscript (Figure R1). We have tried our best to address each of your points in detail. We feel the revision represents an improvement, and we hope that you agree. For more details, please see our replies below.



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

prepared by the authors

Lihui Luo, Yanli Zhuang, Mingyi Zhang, Zhongqiong Zhang, Wei Ma, Wenzhi...

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Figure R1. Editorial Certificate.

Therefore, I don't have any major suggestions on how to improve the manuscript. Please see some minor comments below.

Minor comments:

1. Please provide a more detailed metadata description of the data set.

We have added metadata files README.md for all datasets and generated the corresponding html and pdf format files. The study area embeds Google Maps in the README.md file. Meteorological and ground observations, as well as the R code of permafrost indices and visualization, include the period from 1955 to 2019. TLS measurements and UAV RGB and TIR images are from 2014 to 2017. We have added a description of the time period in the main text and README.md.

2. It is recommended to add the running notes in the code, and increase the readability of the code, so that users can not only execute, but also modify and improve.

Thank you for the insightful comments. We have reorganized the code, added the required comments and instructions to the code, added a new instruction document on how to use the code, and added the README.md markdown file for operation of the code, including the corresponding html and pdf files. We have also recorded an operation video and provided it in README.md and README.html.

3. Please delete Figure B3. If possible, just describe it in the text.

We have deleted Figure B3.

4. The latest references need to be cited, and some references need to be added. As in the following article:

Wu, Q., Sheng, Y., Yu, Q., Chen, J., and Ma, W.: Engineering in the rugged permafrost terrain on the roof of the world under a warming climate, Permafrost and Periglacial Processes, 31, 417-428, https://doi.org/10.1002/ppp.2059, 2020.

We have added the indicated reference and updated some references in the manuscript.

5. This manuscript focuses on ground and drone monitoring data, so it is recommended to delete InSAR data.

As a supplement to the TLS point cloud data, we have prepared Sentinel-1 deformation data for the freeze-thaw stage in the study area from 2014 to 2020 using interferometric synthetic aperture radar (InSAR) technology. These are the InSAR data for the entire study area. These data are a good supplement and comparison to the TLS point cloud data. We still retain these data in the TLS measurement dataset.

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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 1955-2018.

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

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Data details

> **Scale:** UAV RGB: ~5 cm; UAV TIR: ~ 20 cm; TLS measurements: 0.009°
> **Coordinate Reference System:** EPSG: 4326 - WGS 84
> **Filesize:**~ 5 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	1955-2018	National Reference Station
Meteorological observations	Xidatan station	2014-2018	National General Station
Meteorological observations	Wudaoliang station	1956-2018	National Reference Station
Ground observations	Study Area	2014-2019	Field test site
Ground observations	Golmud station	1955-2018	National Reference Station

Data Type	Location	Period	Remark
Ground observations	Xidatan station	2014-2018	National General Station
Ground observations	Wudaoliang station	1956-2018	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	1955-2018	Plot Fig. 2 & F1; Computing MAAT & MAGST

Meteorological and Ground observations

> **Table 2.** Observations period of datasets.

Data Type	Location	Period	File Names
Meteorological observations	Golmud station	1955-2018	Meteo_52818_Golmud_1955-2010.dat;Meteo_52818_Golmud_2010-2018.xlsx
Meteorological observations	Xidatan station	2014-2018	Meteo_00000_Golmud_2014-2019.xlsx
Meteorological observations	Wudaoliang station	1956-2018	Meteo_52908_Wudaoliang_1956-2010.dat;Meteo_52908_Wudaoliang_2010-2018.xlsx
Ground observations	Study Area	2014-2019	GT00000_Slopes_2014-2019.xlsx

Data Type	Location	Period	File Names
Ground observations	Golmud station	1955-2018	GT52818_Golmud.txt
Ground observations	Xidatan station	2014-2018	Meteo_00000_Xidatan_2014-2019.xlsx
Ground observations	Wudaoliang station	1956-2018	GT52908_Wudaoliang.txt

> **Table 3.** Ground data Metadata of meteorological stations data. The file name with **'GT'** is ground observation data.

	ID	Variable	Type	Field Name	Unit	Description
1	1	Station ID	Number(5)	V01000		
2	5	Year	Number(4)	V04001	Year	
3	6	Month	Number(2)	V04002	Month	
4	7	Day	Number(2)	V04003	Day	
5	32	Evaporation	Number(6)	V13241	0.1mm	evaporation
6	53	average ground temperature at 0 cm	Number(6)	V12240	0.1℃	GT_0_AVG
7	54	daily maximum ground temperature at 0 cm	Number(6)	V12213	0.1℃	GT_0_MAX
8	56	daily minimum ground temperature at 0 cm	Number(6)	V12214	0.1℃	GT_0_MIN

	ID	Variable	Type	Field Name	Unit	Description
9	58	average ground temperature at 5 cm	Number(6)	V12240_005	0.1℃	GT_5_AVG
10	59	average ground temperature at 10 cm	Number(6)	V12240_010	0.1℃	GT_10_AVG
11	60	average ground temperature at 15 cm	Number(6)	V12240_015	0.1℃	GT_15_AVG
12	61	average ground temperature at 20 cm	Number(6)	V12240_020	0.1℃	GT_20_AVG
13	62	average ground temperature at 40 cm	Number(6)	V12240_040	0.1℃	GT_40_AVG
14	63	average ground temperature at 50 cm	Number(6)	V12240_050	0.1℃	GT_50_AVG
15	64	average ground temperature at 80 cm	Number(6)	V12240_080	0.1℃	GT_80_AVG
16	65	average ground temperature at 160 cm	Number(6)	V12240_160	0.1℃	GT_160_AVG
17	66	average ground temperature at 320 cm	Number(6)	V12240_320	0.1℃	GT_320_AVG

	ID	Variable	Type	Field Name	Unit	Description

> **Table 4.** Meteorological Metadata of meteorological stations data. The file name with **'Meteo'** is Meteorological observation data.

	ID	Variable	Type	Unit	Description
1	1	Station ID	Number(5)		
2	5	Year	Number(4)	Year	Year
3	6	Month	Number(2)	Month	Mon
4	7	Day	Number(2)	Day	Day
5	32	daily mean air temperature at 2 m	Number(6)	0.1℃	Temperate
6	53	maximum air temperature at 2 m	Number(6)	0.1℃	Tmax
7	54	minimum air temperature at 2 m	Number(6)	0.1℃	Tmin
8	56	average wind speed	Number(6)	0.1℃	Wind
9	58	average precipitation	Number(6)	0.1mm	Precip
10	59	Corrected average precipitation	Number(6)	0.1℃	Corrected_P
11	60	Evaporation	Number(6)	0.1mm	Evaporation
12	61	Air humidity	Number(6)	%	Humidity
13	62	Air pressure	Number(6)	0.1Pa	Press
14	63	sunshine time	Number(6)	0.1h	Sunshine
15	64	average ground temperature at 0 cm	Number(6)	0.1℃	GT

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 5 Freeze-thaw stages of TLS scanner data.

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
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 6. 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

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.

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: **2016SlopeA and 2017SlopeAB**, 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 ...

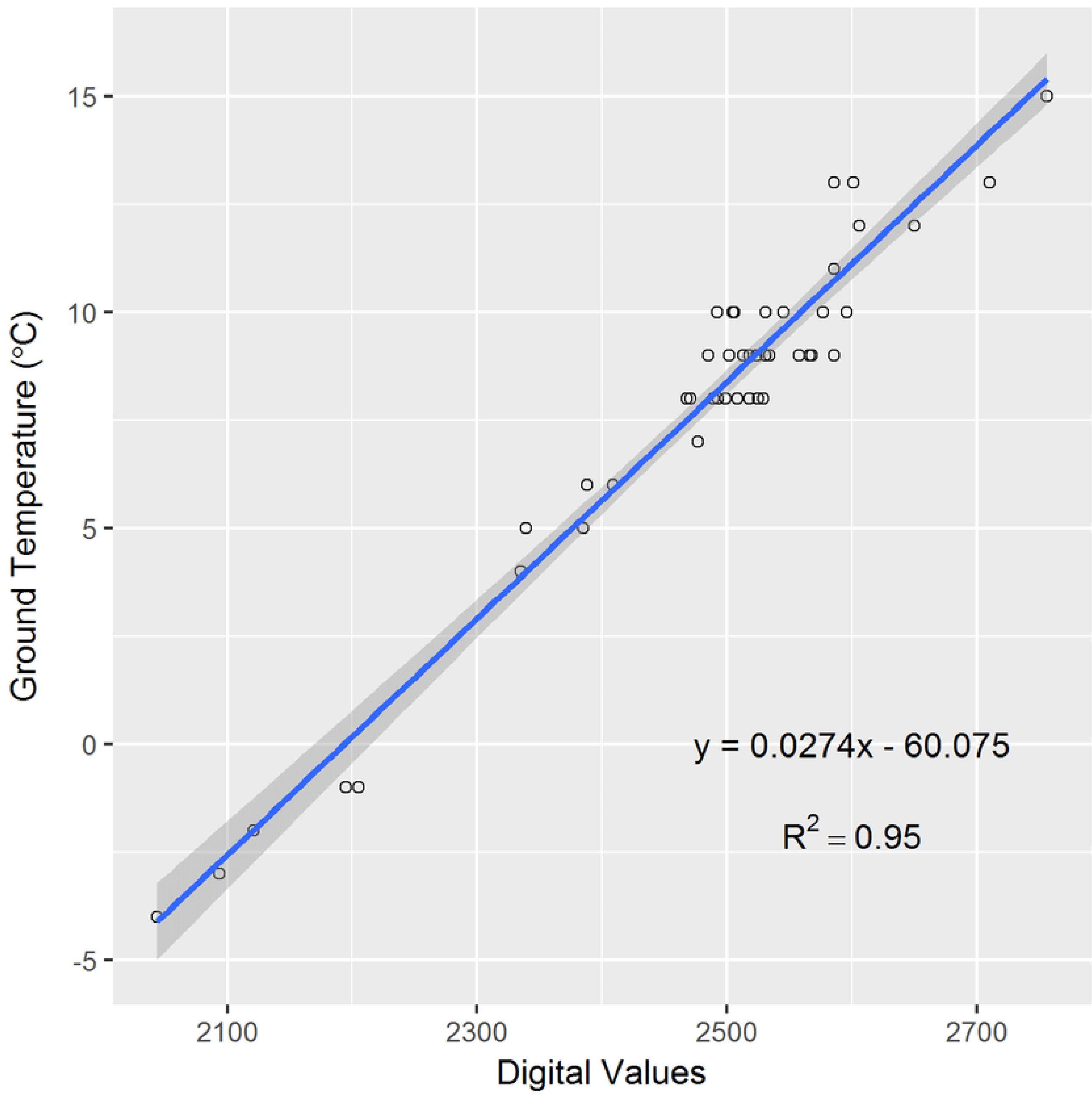

Figure 1. The linear equation between Digital Values and Central Temperature.

Table 7. 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

Flight Date	Flight Time	Height	Slope	Sensor
20170722	11:00-15:51	150	Slopes A and B	TIR
20170823	10:30-17:25	150	Slopes A and B	TIR

> **Table 8.** Processed UAV data.

Data Type	Remark
Boundary	SlopeAB:Shapefile
DSM	SM_SlopeAB:Raster
Mosaic	Mosaic_SlopeAB:Raster

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 9.** Data files.

Data file	Description
Golmud1955-2018.csv	Meteorological observations of Golmud field station
Wudaoliang1956-2018.csv	Meteorological observations of Wudaoliang field station
XDTMS2014-2018.csv	Meteorological observations of Xidatan field station
XDTMS2014-2018_GT.csv	Xidatan field station, ONLY Ground Temperature in different layers
XDTMS2014-2018_PREC.csv	Xidatan field station, ONLY Precipitation
MAAT_MAGST_Golmud_Wudaoliang_1956-2018.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.

> 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.

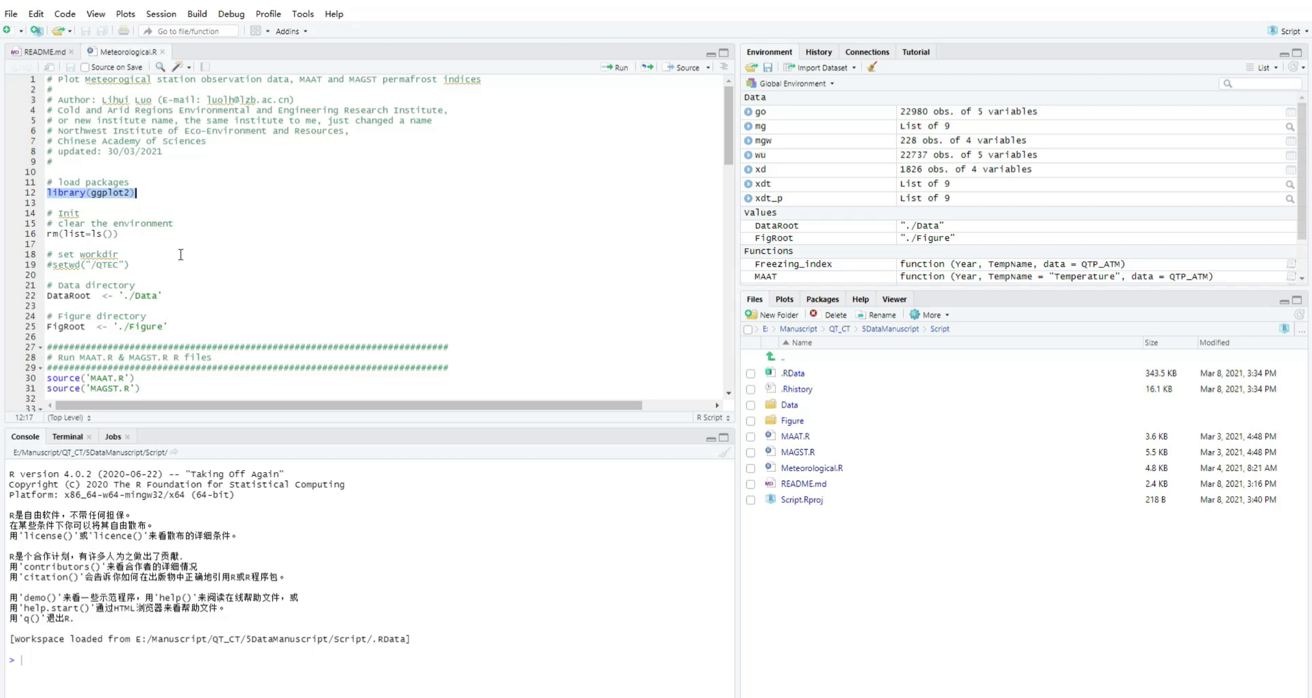
```
source('Meteorological.R')
```

> 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.

Citation

> Luo, L., Zhuang, Y., Zhang, M., Zhang, Z., Ma, W., Zhao, W., Zhao, L., Wang, L., Shi, Y., Zhang, Z., Duan, Q., Tian, D., and Zhou, Q.: An integrated observation dataset of the hydrological-thermal-deformation dynamics in the permafrost slopes and engineering infrastructure in the Qinghai-Tibet Engineering Corridor, Earth Syst. Sci. Data Discuss. [preprint], https://doi.org/10.5194/essd-2020-106, in review, 2020.

Abbreviation

> - **TDR:** Time-domain Reflectometer
> - **TLS:** Terrestrial Laser Scanning
> - **UAV:** Unmanned Aerial Vehicle
> - **RGB:** Red-Green-Blue
> - **TIR:** Thermal Infrared
> - **InSAR:** Interferometric Synthetic Aperture Radar
> - **MAAT:** Mean Annual Air Temperature
> - **MAGST:** Mean Annual Ground Surface Temperature

Data resource provider

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Data Sources and Terms of Use

The use of data is conditional on citing the original data sources. Full details on how to cite the data are given at the bottom of each page. For research projects, if the data are essential to the work, or if an important result or conclusion depends on the data, co-authorship may need to be considered. Permafrost engineering and slope monitoring facilitate the acquisition of data to encourage its use and promote understanding of the potential impact of freeze-thaw cycles on Permafrost engineering. Respecting original data sources is key to help secure the support of data providers to enhance, maintain and update valuable data.

Acknowledgements

Funded by the National Natural Science Foundation of China (41871065), the National Science Fund for Distinguished Young Scholars (41825015), the Key Research Project of Frontier Science of Chinese Academy of Sciences (QYZDJ-SSW-DQC040), and the Strategic Priority Research Program of the Chinese Academy of Sciences (XDA19090122).

License

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updated: 2021/04/14