

A dataset of 10-year regional-scale soil moisture and soil temperature measurements at multiple depths on the Tibetan Plateau

1. Overview

Tibet-Obs is the first long-term soil moisture and soil temperature (SMST) observatory in the Tibetan Plateau (TP) covering different representative climatic and land surface conditions, which includes the Maqu, Naqu, and Ngari (including Ali and Shiquanhe) networks (Fig. 1). The released long-term (~10 years) SMST profile dataset includes original in-situ measurements at a 15-min interval collected between 2008 and 2019 for all the three networks and a spatially upscaled data for the Maqu and Shiquanhe networks. Summary of main applications of the Tibet-Obs SMST data with focus on simultaneous usage of soil moisture (SM) and soil temperature (ST) measurements or usage of SM/ST measurements at multiple depths are listed in Table1.

This document briefly describes the monitoring networks and contents of the dataset. A publication based on the dataset is submitted to the journal of Earth Systems Science Data in June 2022:

Pei Zhang, Donghai Zheng, Rogier van der Velde, Jun Wen, Yaoming Ma, Yijian Zeng, Xin Wang, Zuoliang Wang, Jiali Chen, and Zhongbo Su, “A dataset of 10-year regional-scale soil moisture and soil temperature measurements at multiple depths on the Tibetan Plateau”

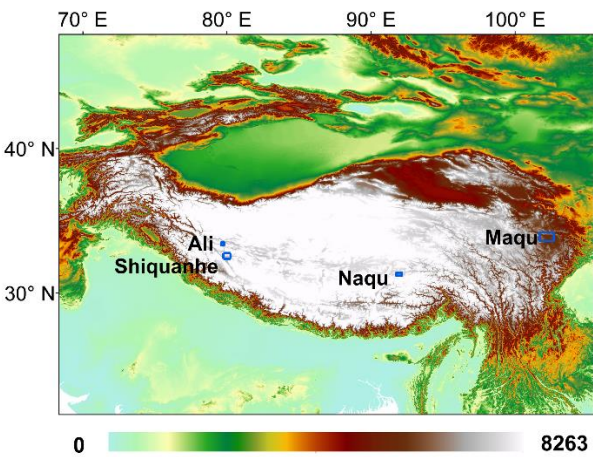


Figure 1. Locations of the Tibet-Obs including Maqu, Naqu, and Ngari (including Ali and Shiquanhe) SMST networks.

Table 1. Summary of the applications of Tibet-Obs SMST data and corresponding findings

Literature	In-situ data	Satellite- and/or model-based products/simulations	Key findings
Simultaneous usage of SM and ST			
Zheng et al. (2016)	SMST at 5, 10, 20, 40, and 80 cm depths from the Maqu network, period between 2009 and 2010.	SMST simulations by the Noah model including three sets of augmentations.	The augmentations for the turbulent and soil heat transport improved the ST profile simulations, while the augmentations for the soil water flow mitigated deficiencies of SM profile simulations by Noah model.
Deng et al. (2020)	SMST at 5, 10, 20, and 40 cm depths from the Maqu network, period between 2010 and 2011.	SMST simulations by two versions of the Community Land Model (CLM), i.e., versions 4.5 and 5.0.	The ST simulations from both CLM model versions coincided with the in-situ measurements, while the SM simulations showed large biases.
Deng et al. (2021)	SMST at 5 cm depth from the Maqu network during period of 2011 and from the Ngari network during period between 2013 and 2014.	SMST simulations by the CLM5.0 that include nine experiments evaluating soil water and heat transfer parameterizations.	(i) At the Ngari network, ST simulations in all experiments generally coincided with the observations yielding RMSE within 3°C, while SM simulations in Experiment 6 (i.e., replaced soil property data, adopted virtual temperature scheme and dry surface scheme) showed the best performance. (ii) At the Maqu network, ST simulations in Experiment 5 (i.e., replaced soil property data, adopted Balland and Arp scheme and dry surface scheme) showed the best performance, while SM simulations in Experiment 1 (i.e., replaced soil property data) showed the best performance.
Usage of SM at multiple depths			
Su et al. (2013)	SM at 5, 10, 20, 40, and 80 cm depths from the Maqu network, period between 2008 and 2009; SM around 5, 10, 20, 40, and 60 cm depths from the Naqu network, period of 2008.	SM simulations by the European Centre for Medium-Range Weather Forecasts (ECMWF) based on optimum interpolation scheme and point-wise extended Kalman filter scheme, respectively.	(i) At the Naqu network, both ECMWF's SM products showed significant overestimations in the monsoon season, indicating the ECMWF model and soil texture parameter need to be improved for the cold-semiarid area on the TP. (ii) At the Maqu network, both ECMWF's SM products generally showed good and comparable performance in the humid monsoon period.
Bhatti et al. (2013)	SM at 5, 10, 20, 40, and 80 cm depths from the Maqu network, period of 2009.	Advanced Microwave Scanning Radiometer-Earth Observing System (AMSR-E) SM product generated by the Vrije University Amsterdam and NASA.	The in-situ SM measurements at 10 cm are more suitable to validate the AMSR-E SM product.
Bi et al. (2016)	SM at 5, 10, 20, 40, and 80 cm depths from the Maqu network, period between 2008 and 2010.	SM products generated by CLM, Noah, Mosaic, and VIC models implemented in Global Land Data Assimilation System V1 (GLDAS-1) and Noah model adopted in GLDAS-2.	(i) The GLDAS-2 SM product did not show better performance than the GLDAS-1 products. (ii) All four models can capture well the temporal variations of in-situ SM measurements but underestimated the SM values, and the Mosaic model yielded the largest bias.
Ju et al. (2020)	SM at 5 and 40 cm depths from the Maqu network, period between 2011 and 2012.	SM simulations by Variable Infiltration Capacity (VIC) model with assimilation of brightness temperature (T_B) data	Assimilation of SMOS T_B data improved the performance of VIC SM product indicated by reducing the root mean square difference (RMSD) for the SM at 5 cm from 0.126 to

Zhuang et al. (2020)	SM at 5, 10, 20, 40, and 60/80 cm depths from the Maqu, Naqu, and Ngari networks, period between 2013 and 2016.	from the Soil Moisture and Ocean Salinity (SMOS) mission. Surface SM (SSM) data generated by using the blend method, and then rootzone SM (RZSM) data generated by Cumulative Distribution Function (CDF) matching approach and Soil Moisture Analytical Relationship (SMAR) model based on the blended SSM data.	0.087 m ³ m ⁻³ , which however, had a slight positive impact for the SM at 40 cm. (i) The blended SSM product constrained by in-situ SM measurements can eliminate the influence of different LSM simulations. (ii) Both SMAR model and CDF matching approach can give reliable RZSM estimates, but the performances varied from different regions, e.g., the SMAR model provided better estimates in the semi-arid area while the CDF matching approach performed slightly better in the arid area.
Liu et al. (2021)	SM at 5, 10, 20, and 40 cm depths from the Maqu and Ngari networks, period between 2013 and 2015.	China Meteorological Administrational Land Data Assimilation System (CLDAS) and GLDAS SM products	The CLDAS and GLDAS SM data can capture the temporal dynamics with favorable performances, expect for the GLDAS SM data at the layer of 10-40 cm
Usage of ST			
Wang et al. (2016)	ST at 5 cm depth from the Maqu network, period between 2008 and 2009.	ST simulations by Noah and CLM models from GLDAS-1, and by Noah model from GLDAS-2	GLDAS-1 CLM product overestimated the ST, while both GLDAS-1 and GLDAS-2 Noah products showed underestimations although they can replicate the daily variability of in-situ ST measurements.
Li et al. (2019)	ST at 5 m depth from the Maqu and Ngari networks, period between 2010 and 2011.	ST simulations by Common Land Model (CoLM) implementing three different fractional vegetation cover (FVC) schemes.	(i) At the Ngari network dominated by sparse grassland or desert, ST simulations were not sensitive to FVC scheme. (ii) At the Maqu network dominated by grass, ST simulations were improved by implementing a new FVC scheme.
Cao et al. (2020)	ST at 5, 10, 20, and 40 cm depths from the Maqu network, period between 2008 and 2016	ERA5-land ST product.	ERA5-land ST data showed a negative bias in the TP, and it matched better to in-situ ST measurements in permafrost regions than in non-permafrost regions.

2. Content of the Dataset

Folder	File	Sheet
\Original data\	Information.xlsx	<p>-Maqu: The information of monitoring sites in the Maqu network, including location coordinate, elevation, topography, land cover, soil texture, and organic matter content.</p> <p>-Naqu: Same as the “Maqu” sheet but for the Naqu network.</p> <p>-Ngari: Same as the “Maqu ” sheet but for the Ngari network.</p>
\Original data\Maqu\	Site ID.xlsx	-Year (YYYY): All valid SMST data at multiple depths in the year of “YYYY”.
\Original data\Naqu\	Site ID.xlsx	-Year (YYYY): All valid SMST data at multiple depths in the year of “YYYY”.
\Original data\Ngari\	Site ID.xlsx	-Year (YYYY): All valid SMST data at multiple depths in the year of “YYYY”.
\Long-term upscaled data\	Maqu.xlsx	<p>-15-min: Spatial upscaled SMST at depths* of 5, 20, 40, and 80 cm with the input of original in-situ measurements between May 2009 and May 2019</p> <p>-Daily: Spatial upscaled SMST at depths* of 5, 20, 40, and 80 cm with the input of daily average measurements between May 2009 and May 2019</p>
	Shiquanhe.xlsx	<p>-15-min: Spatial upscaled SMST at depths of 5, 10, 20, and 40 cm with the input of original in-situ measurements between August 2010 and September 2019</p> <p>-Daily: Spatial upscaled SMST at depths of 5, 10, 20, and 40 cm with the input of daily average measurements between between August 2010 and September 2019</p>
\Supplementary data\	Validation data\.xlsx	-Maqu: Spatial upscaled SMST at depths of 5, 20, and 40 cm with input of original in-situ measurements collected from the maximum number of available sites between May 2010 and May 2011
		-Shiquanhe: Spatial upscaled SMST at depths of 5, 20, and 40 cm with input of original in-situ measurements collected from the maximum number of available sites between September 2017 and August 2018
\Supplementary data\	Meteorological data.xlsx	-Maqu: Monthly air temperature and precipitation collected from the Maqu weather station (Fig. 3) between January 2010 and December 2018.
		-Shiquanhe: Monthly air temperature and precipitation collected from the Shiquanhe weather station (Fig. 5) January 2011 and December 2018.
\Supplementary data\ Model-based products\	ERA5.xlsx	-Maqu: Daily regional mean SMST at depths of 5, 20, and 40 cm in the Maqu network area from the ERA5 product between January 2010 and December 2018.

	-Shiquanhe: Daily regional mean SMST at depths of 5, 20, and 40 cm in the Shiquanhe network area from the ERA5 product between January 2011 and December 2018.
GLDAS CLSM.xlsx	-Maqu: Daily regional mean SMST at depths of 5, 20, and 40 cm in the Maqu network area from the GLDAS CLSM product between January 2010 and December 2018. -Shiquanhe: Daily regional mean SMST at depths of 5, 20, and 40 cm in the Shiquanhe network area from the GLDAS CLSM product between January 2011 and December 2018.
GLDAS Noah.xlsx	-Maqu: Daily regional mean SMST at depths of 5, 20, and 40 cm in the Maqu network area from the GLDAS Noah product between January 2010 and December 2018. -Shiquanhe: Daily regional mean SMST at depths of 5, 20, and 40 cm in the Shiquanhe network area from the GLDAS Noah product between January 2011 and December 2018.
GLDAS VIC.xlsx	-Maqu: Daily regional mean SMST at depths of 5, 20, and 40 cm in the Maqu network area from the GLDAS VIC product between January 2010 and December 2018. -Shiquanhe: Daily regional mean SMST at depths of 5, 20, and 40 cm in the Shiquanhe network area from the GLDAS VIC product between January 2011 and December 2018.
MERRA2.xlsx	-Maqu: Daily regional mean SMST at depths of 5, 20, and 40 cm in the Maqu network area from the MERRA2 product between January 2010 and December 2018. -Shiquanhe: Daily regional mean SMST at depths of 5, 20, and 40 cm in the Shiquanhe network area from the MERRA2 product between January 2011 and December 2018.

* The measurements at the 10 cm are not used for the upscaling because the sensor at the 10 cm of CST05 site was changed one time in the mid of May 2011 which leads to a discontinuity in the collected time series.

3. Brief description of the monitoring network and data record

The Tibet-Obs was originally established in 2008 and includes three regional-scale SMST monitoring networks (Fig. 1). Each network includes various numbers of in situ SMST monitoring sites, and each monitoring site is configured with one Decagon EM50 data logger and several Decagon SMST probes (i.e., EC-TM and 5TM) to monitor SMST profile dynamics every 15-minute. The SMST probes were installed with the pins inserted in horizontal direction at multiple depths up to 80 cm (see Fig. 2). The measured range of the ST sensor is from -40 to 60 °C at 0.1 °C resolution with ± 1 °C accuracy. The SM sensor measures liquid water content at a 0.0008 m³ m⁻³ resolution with ± 0.03 m³ m⁻³ accuracy. Brief descriptions of SMST profile data records at each monitoring network are further provided in the following subsections, and additional information about the Tibet-Obs can be found in Zhang et al. (2021) and Su et al. (2011).



Figure 2. An example of instruments configured for each SMST monitoring site.

3.1 Maqu network

The Maqu network is located in the north-eastern edge of the TP (33°30'-34°15'N, 101°38'-102°45'E) at the first major bend of the Yellow River (Fig. 3). The landscape is dominated by the short grass at elevations varying from 3400 to 3800 m. The climate type is characterized as cold-humid with cold dry winters and rainy summers. The mean annual air temperature is about 1.2 °C, with -10 °C for the coldest month (January) and 11.7 °C for the warmest month (July). The annual precipitation is about 600 mm that falls mainly in the warm season (May-October). The Maqu network totally includes 26 SMST monitoring sites and covers an area of approximately 40 km by 80 km. There are 13 sites collect the SMST measurements at depths of 5, 10, 20, 40 and 80 cm, 4 sites at 5, 10, 20, and 40 cm, one site at 5, 10, and 20 cm, and 8 sites at 5 and 10 cm. The corresponding data length for every depth of each site is presented in Fig. 4 for every year from May 2008 to May 2019. The basic information of each monitoring site is summarized in Table 2.

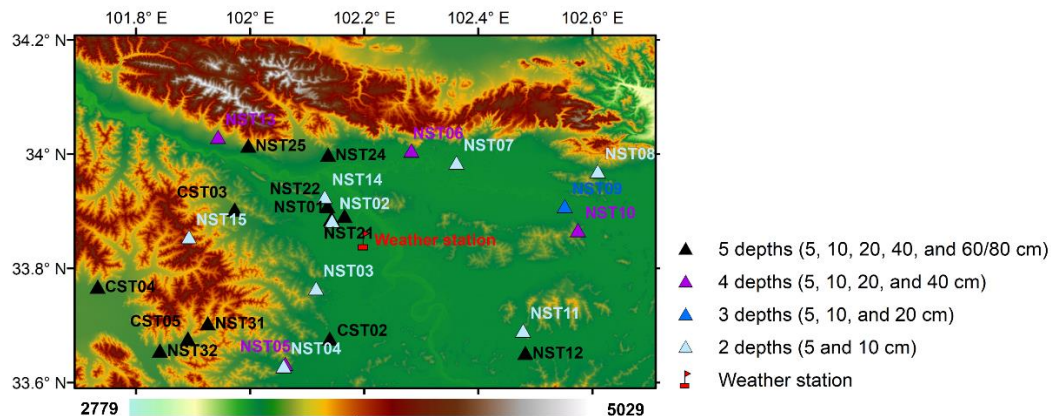


Figure 3. Spatial distributions of SMST monitoring sites and weather station within the Maqu network.

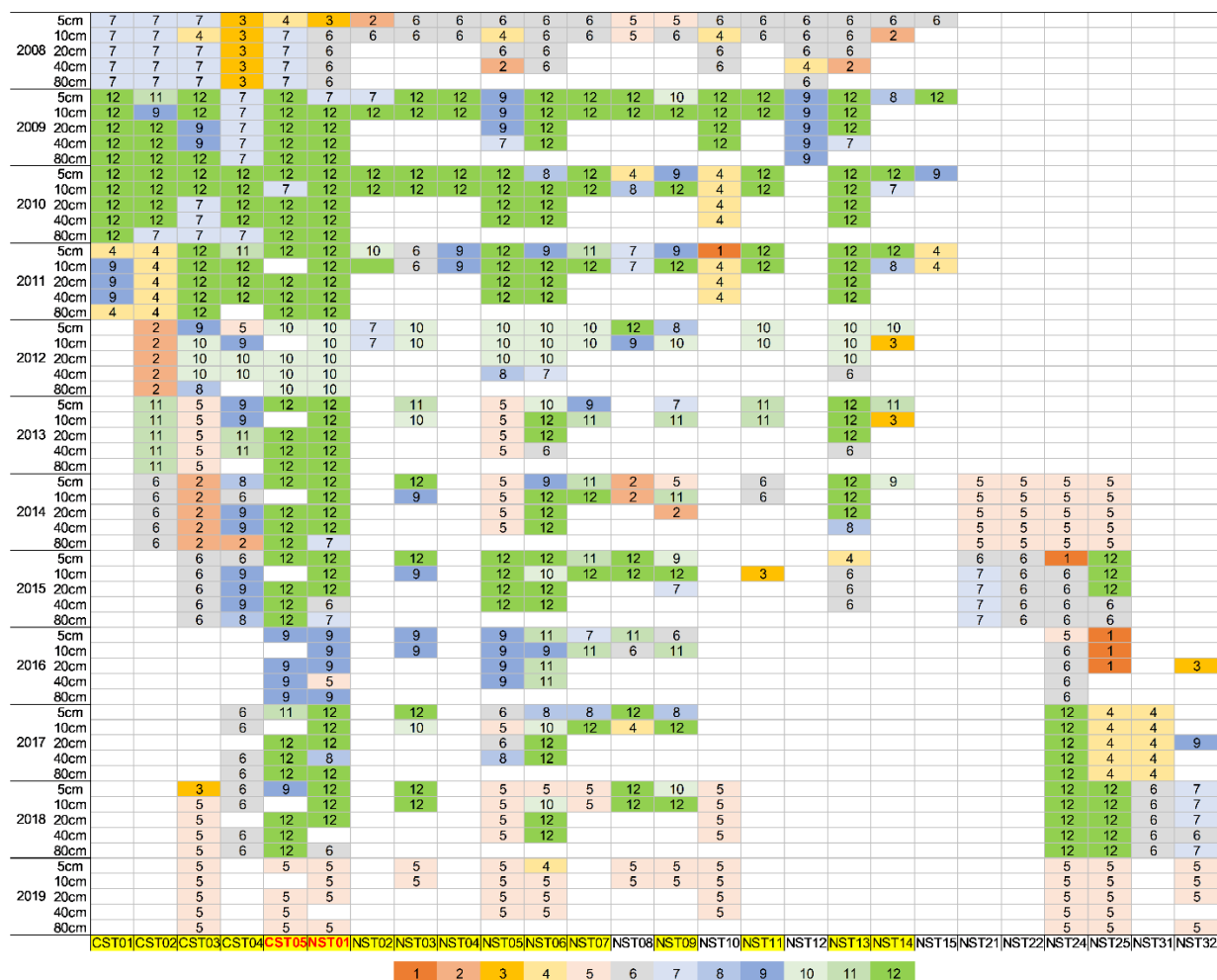


Figure 4. Data records of the SMST measured at different depths with temporal persistence from May 2008 to May 2019 (Y-axis) for all the monitoring sites in the Maqu network (X-axis). Cells with different colours and digits represent different number of

months that contain valid SMST data in each year. Blank cells indicate that there are no measurements performed. Site names with highlight and red font represent the sites used for producing the long-term (May 2009 ~ May 2019) upscaled SMST dataset, and site names only with highlight represent the sites used for generating “ground truth” for a selected year (May 2010 ~ May 2011).

Table 2. Site information of the Maqu network (site name, elevation, topography (TPG), land cover (LC), soil texture at 5-15 cm depth (STX), soil bulk density at 5cm depth (BD), soil organic matter content at 5-15cm depth (OMC), Not Available (NA), BD and OMC values are measured in the laboratory).

Site name	Elevation (m)	TPG	LC	STX	BD (kg m ⁻³)	OMC (g/kg)
CST01	3431	River valley	Grass	NA	NA	NA
CST02	3449	River valley	Grass	NA	NA	NA
CST03	3507	Hill valley	Grass	NA	NA	NA
CST04	3504	Hill valley	Grass	NA	NA	NA
CST05	3542	Hill valley	Grass	NA	NA	NA
NST01	3431	River valley	Grass	Silt loam	0.96	18
NST02	3434	River valley	Grass	Silt loam	0.81	18
NST03	3513	Hill slope	Grass	Silt loam	0.63	49
NST04	3448	River valley	Wetland	Silt loam	0.26	229
NST05	3476	Hill slope	Grass	Silt loam	0.75	22
NST06	3428	River valley	Grass	Silt loam	0.81	23
NST07	3430	River valley	Grass	Silt loam	0.58	23
NST08	3473	Valley	Grass	Silt loam	1.06	34
NST09	3434	River valley	Grass	Sandy loam	0.91	17
NST10	3512	Hill slope	Grass	Loam-silt loam	1.05	24
NST11	3442	River valley	Wetland	Organic soil	0.24	136
NST12	3441	River valley	Grass	Silt loam	1.02	39
NST13	3519	Valley	Grass	Silt loam	0.67	29
NST14	3432	River valley	Grass	Silt loam	0.68	30
NST15	3752	Hill slope	Grass	Silt loam	0.78	56
NST21	3428	River valley	Grass	Silt loam	NA	NA
NST22	3440	River valley	Grass	Silt loam	NA	NA
NST24	3446	River valley	Grass	Silt loam	NA	NA
NST25	3600	Hill slope	Grass	Silt loam	NA	NA
NST31	3490	NA	NA	NA	NA	NA

NST32	3490	Hill valley	Grass	NA	NA	NA
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75 **3.2 Ngari network**

The Ngari network is located in the western part of the TP at the headwater of the Indus River. It consists of two SMST networks established around the cities of Ali and Shiquanhe, respectively. The landscape is dominated by a desert ecosystem at elevations varying from 4200 to 4700 m. The climate type is characterized as cold-arid with a mean annual air temperature of 7.0 °C. The annual precipitation is less than 100 mm that falls mainly in the monsoon season (July-August). The Shiquanhe network situated in vicinity of the Shiquanhe county (32.36°-32.76°N, 79.75°-80.25°E) totally includes 20 monitoring sites and covers an area of approximately 30 km by 40 km (Fig. 5b). There are 9 sites collect the SMST measurements at depths of 5, 10, 20, 40, and 60 cm, 9 sites at 5, 10, 20, and 40 cm, and 2 sites at 5, 10, and 20 cm. The Ali network is located near the Ngari station for the Desert Environment Observation and Research of the Chinese Academy of Science (NASDE/CAS) (33.30°-33.50°N, 79.60°-79.80°E). It consists of 4 monitoring sites (Fig. 5a) that all collect the SMST measurements at depths of 5, 10, 20, 40, and 60 cm. The corresponding data length for every depth and each site are presented in Fig. 6 for every year from August 2010 to August 2019. The basic information of each monitoring site is summarized in Table 3.

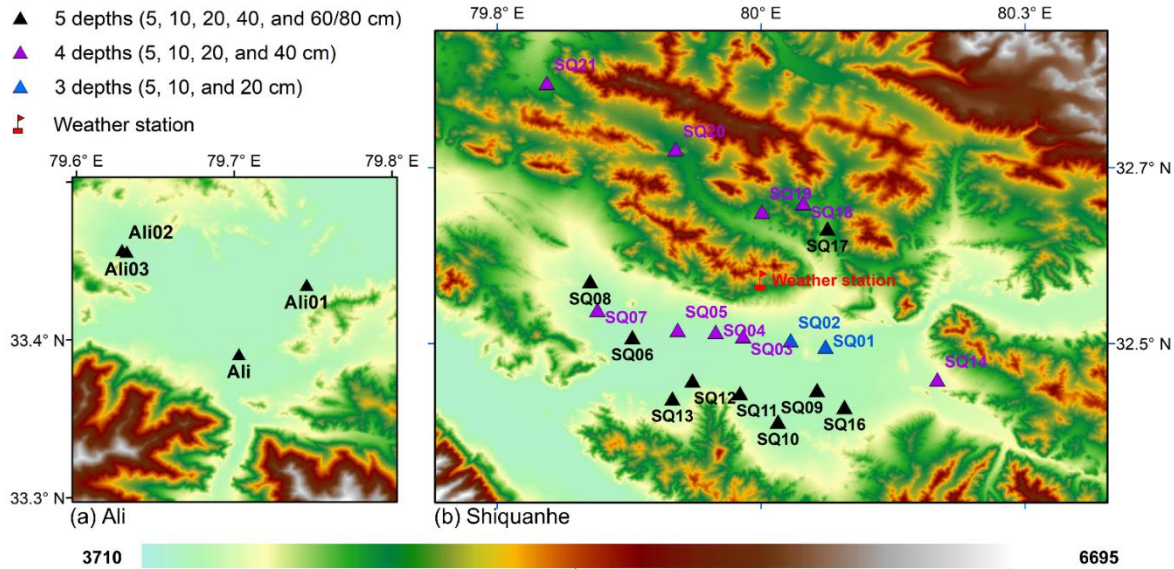
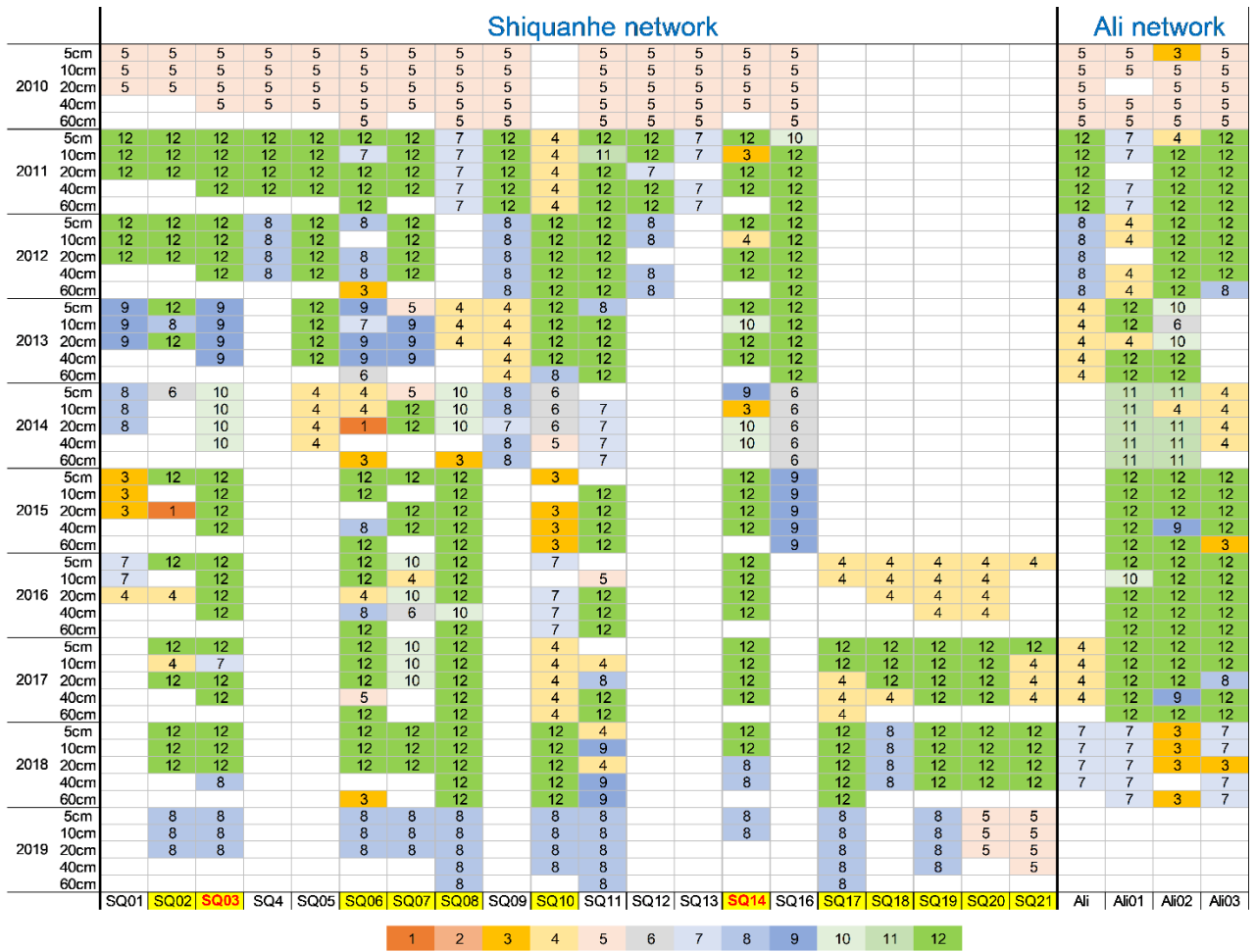


Figure 5. Spatial distributions of SMST monitoring sites and weather station within the (a) Ali and (b) Shiquanhe networks.



90 **Figure 6.** Same as Figure 4 but for the Ngari network with temporal persistence from August 2010 to August 2019. Site names with highlight and red font represent the sites used for producing the long-term (August 2010 ~ August 2019) upscaled SMST dataset, and site names only with highlight represent the sites used for generating “ground truth” for a selected year (August 2017 ~ August 2018) in the Shiquanhe network.

Table 3. Same as the Table 2 but for the Ngari network (BD and OMC data are not available).

Site name	Elevation (m)	TPG	LC	STX
Shiquanhe network				
SQ01	4306	Flat	Desert	Loamy sand
SQ02	4304	Gentle slope	Desert	Sand
SQ03	4278	Gentle slope	Desert (with sparse bushes)	Sand
SQ04	4269	Edge of a wetland	Sparse grass	Loamy sand
SQ05	4261	Edge of a marsh	Sparse grass	Sand

SQ06	4257	Flat	Sparse grass	Loamy Sand
SQ07	4280	Flat	Desert (with sparse bushes)	Sand
SQ08	4306	Flat	Desert	Sand
SQ09	4275	Flat	Desert/river bed	Sand
SQ10	4275	Flat	Grassland	Fine sand with some thick roots
SQ11	4274	Flat	Grassland with bushes	Loamy sand
SQ12	4264	Flat	Edge of riverbed	Sandy loam
SQ13	4292	Flat	Valley bottom	Sand
SQ14	4368	Slope	Desert	Sandy loam
SQ16	4288	Flat	Desert/river bed	Loam
SQ17	4563	NA	NA	NA
SQ18	4634	NA	NA	NA
SQ19	4647	NA	NA	NA
SQ20	4695	NA	NA	NA
SQ21	4606	NA	NA	NA
Ali network				
Ali	4288	Flat	Grass	Loamy sand
Ali01	4262	Flat	Sparse grass	Sand
Ali02	4266	Flat	Sparse grass	Sand
Ali03	4261	Edge of a wetland	Grass	Sand

3.3 Naqu network

The Naqu network is located in the Naqu river basin (31.20°-31.40°N, 91.75°-92.15°E) with an average elevation of 4500 m (Fig. 7). The climate type is characterized as cold-semiarid with cold dry winters and rainy summers. Over three-quarters of total annual precipitation (400 mm) falls between June and August. The landscape is dominated by the short grass. The Naqu network totally includes 11 SMST monitoring sites that all collect the SMST measurements at around 5, 10, 20, 40, and 60 cm depths. The corresponding data length for every depth of each site is presented in Fig. 8 for every year from June 2010 to August 2019. The basic information of each monitoring site is summarized in Table 4.

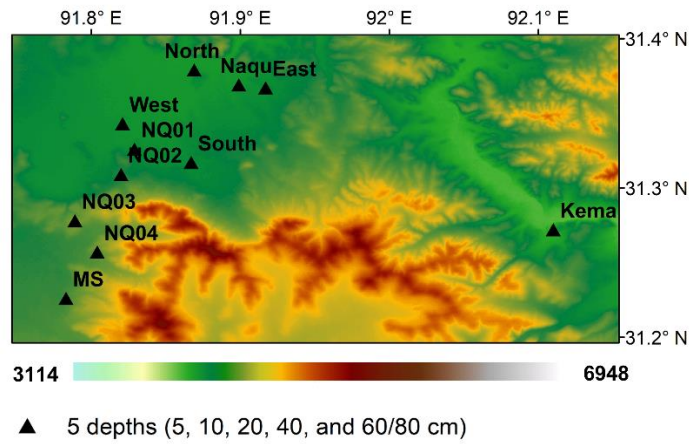


Figure 7. Spatial distributions of SMST monitoring sites and weather station within the Naqu network.

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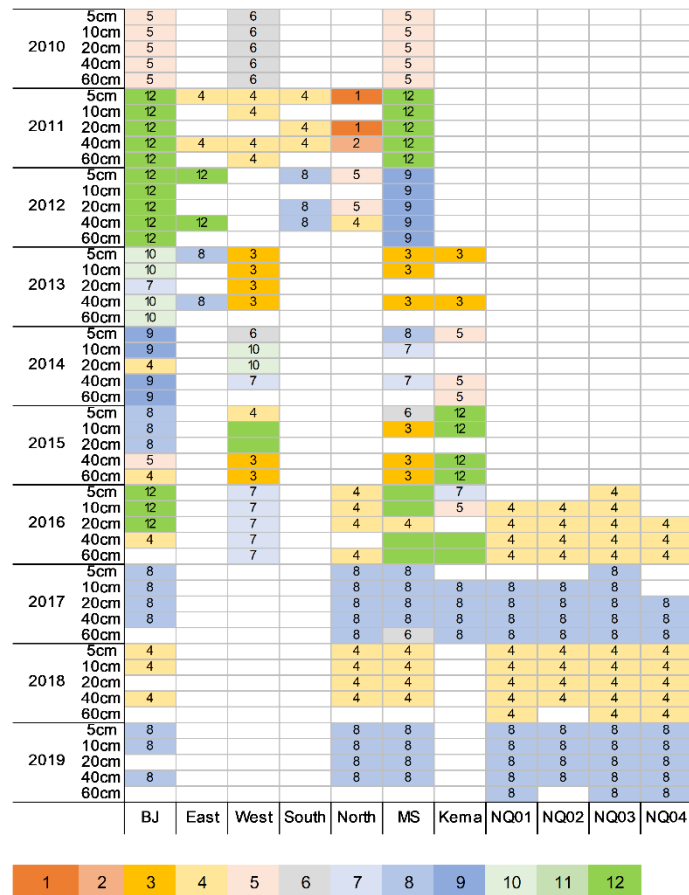


Figure 8. Same as Figure 4 but for the Naqu network with temporal persistence from June 2010 to August 2019.

Table 5. Same as the Table 3 but for the Naqu network (BD and OMC data are not available).

Site name	Elevation (m)	TPG	LC	STX
Naqu	4509	Plain	Grassland	Loamy sand
East	4527	Flat hill top	Grassland	Loamy sand
West	4506	Plain	Grassland	Loamy sand
North	4507	Slope on riverbank	Grassland	Loamy sand
South	4510	Slope of wetland	Wetland	Loamy sand
Kema	4465	River valley	Grass	Silt loam
MS	4583	NA	NA	NA
NQ01	4517	NA	NA	NA
NQ02	4552	NA	NA	NA
NQ03	4638	NA	NA	NA
NQ04	4632	NA	NA	NA

110 4. Online datasets

4.1 ERA5 product

The ERA5 is a reanalysis product obtained through the assimilation of as many observations as possible in the upper air and near surface. The SMST data are available from 1979 till present, with a grid spacing of $0.25^{\circ} \times 0.25^{\circ}$ and a temporal resolution of hourly.

115 Downloading online ERA5 data through Climate Data Store (CDS):

1. Register a Copernicus account.
2. Go to the link <https://cds.climate.copernicus.eu/cdsapp#!/dataset/reanalysis-era5-single-levels?tab=form>
3. The dataset catalogue entries include the following tabs:
 - **Overview:** It gives a description of the dataset and metadata information (e.g. data description and main variables).
 - **Download data:** It is a download web form.
 - **Quality assessment:** It is a new feature, work in progress (The CDS datasets are assessed by the Evaluation and Quality Control (EQC) function of C3S independently of the data supplier).
 - **Documentation:** It provides links to details documentation about the dataset.
4. Go to the download data tab to select the required data.
 - Variable: Soil
 - Volumetric soil water layer 1
 - Volumetric soil water layer 2
 - Volumetric soil water layer 3
 - Soil temperature level layer 1
 - Soil temperature level layer 2
 - Soil temperature level layer 3
 - Year: Select 2010-2018
 - Month: Select all
 - Day: Select all
 - Time: Select all
 - Geographical area: Select sub-region extraction, Maqu (33.6° - 34.2° N, 101.7° - 102.7° E), Shiquanhe (32.36° - 32.76° N, 79.75° - 80.25° E)
 - Format: NetCDF
5. Click the **Submit Form** and wait for the request processing (about several hours), until the green button **download** appears, you can click it and download the data.

4.2 GLDAS CLSM product

The GLDAS-2.1 CLSM product (Global Land Data Assimilation System Version 2 Catchment Land Surface Model) is based on simulations by the Catchment-F2.5 land surface model (LSM) performed with the Land Information System (LIS) Version

145 7. The SMST data are available from 2000 till present, with a grid resolution of $1.0^{\circ} \times 1.0^{\circ}$ and at a time interval of 3-hour.

Downloading online GLDAS CLSM data through Goddard Earth Sciences Data and Information Service Center (GES DISC):

1. Register an EARTHDATA account.
2. Go to the link https://disc.gsfc.nasa.gov/datasets/GLDAS_CLSM10_3H_2.1/summary
3. The dataset catalogue entries include the following tabs:
 - 150 • **Product Summary:** It gives a description of the dataset and metadata information (e.g. temporal spatial, file format, etc.).
 - **Data citation:** To cite the data in publications.
 - **Documentation:** It provides links to details documentation about the dataset.
 - **Reference:** It is data collection reference.
- 155 4. Click the button of **Subset/ Get data** on the right of the interface to select the required data.
 - **Download Method:** Select the Get File Subsets using the GES DISC Subsetter
 - **Date Range:** 2010-01-01 to 2018-12-31
 - **Region:** Maqu (101.7, 33.6, 102.7, 34.2), Shiquanhe (79.75, 32.36, 80.25, 32.76)
 - **Variables:**
 - 160 SoilTMP0_10cm_inst = Soil temperature (0-10 cm underground) (K)
 - SoilTMP10_29cm_inst = Soil temperature (10-29 cm underground) (K)
 - SoilTMP29_68cm_inst = Soil temperature (29-68 cm underground) (K)
 - SoilMoist_S_inst = Surface soil moisture (0-2 cm underground) (kg m^{-2})
 - SoilMoist_RZ_inst = Root zone soil moisture (0-100 cm underground) (kg m^{-2})
- 165 • **Format:** netCDF
5. Click the **Get Data** and **Down load links list**, and then the tool like **Chrono Download Manager** can be used to download the data via the links list.

4.3 GLDAS Noah product

The GLDAS-2.1 Noah product is based on the Noah LSM version 3.6 simulations performed with the LIS Version 7. The SMST data are available from 2000 to present, with a grid resolution of $0.25^{\circ} \times 0.25^{\circ}$ and with a 3-hour interval.

Downloading online GLDAS Noah data through GES DISC:

1. Register an EARTHDATA account.
2. Go to the link https://disc.gsfc.nasa.gov/datasets/GLDAS_NOAH025_3H_2.1/summary
3. The dataset catalogue entries include the following tabs:

- **Product Summary:** It gives a description of the dataset and metadata information (e.g. temporal spatial, file format, etc.).
- **Data citation:** To cite the data in publications.
- **Documentation:** It provides links to details documentation about the dataset.
- **Reference:** It is data collection reference.

4. Click the button of **Subset/ Get data** on the right of the interface to select the required data.

- **Download Method:** Select the Get File Subsets using the GES DISC Subsetter
- **Date Range:** 2010-01-01 to 2018-12-31
- **Region:** Maqu (101.7, 33.6, 102.7, 34.2), Shiquanhe (79.75, 32.36, 80.25, 32.76)
- **Variables:**

SoilMoi0_10cm_inst = Soil moisture content (0-10 cm underground) (kg m^{-2})

SoilMoi10_40cm_inst = Soil moisture content (10-40 cm underground) (kg m^{-2})

SoilMoi40_100cm_inst = Soil moisture content (40-100 cm underground) (kg m^{-2})

SoilTMP0_10cm_inst = Soil temperature (0-10 cm underground) (K)

SoilTMP10_40cm_inst = Soil temperature (10-40 cm underground) (K)

SoilTMP40_100cm_inst = Soil temperature (40-100 cm underground) (K)

- **Grid:** bilinear interpolation on GLDAS-2_0.25 grid
- **Format:** netCDF

5. Click the **Get Data** and **Down load links list**, and then the tool like **Chrono Download Manager** can be used to download the data via the links list.

195 4.4 GLDAS VIC product

The GLDAS-2.1 VIC (Variable Infiltration Capacity) product is based on the VIC 4.1.2 LSM simulations performed with the LIS Version 7. The coverage period, grid spacing and time interval of the SMST data are the same as the GLDAS-2.1 CLSM product. The depth of second layer varies with region that can be found at <https://ldas.gsfc.nasa.gov/gldas/specifications> (click “VIC soil depth data : 1 degree”)

200 Downloading online GLDAS Noah data through GES DISC:

1. Register an EARTHDATA account.
2. Go to the link https://disc.gsfc.nasa.gov/datasets/GLDAS_VIC10_3H_2.1/summary?keywords=GLDAS%20VIC
3. The dataset catalogue entries include the following tabs:
 - **Product Summary:** It gives a description of the dataset and metadata information (e.g. temporal spatial, file format, etc.).
 - **Data citation:** To cite the data in publications.
 - **Documentation:** It provides links to details documentation about the dataset.
 - **Reference:** It is data collection reference.
4. Click the button of **Subset/ Get data** on the right of the interface to select the required data.

- 210
- **Download Method:** Select the Get File Subsets using the GES DISC Subsetter
 - **Date Range:** 2010-01-01 to 2018-12-31
 - **Region:** Maqu (101.7, 33.6, 102.7, 34.2), Shiquanhe (79.75, 32.36, 80.25, 32.76)
 - **Variables:**

SoilMoi0_30cm_inst = Soil moisture content of surface layer (kg m⁻²)

215 SoilMoi_depth2_inst = Soil moisture content of second layer (kg m⁻²)

SoilTMP0_30cm_inst = Soil temperature of surface layer (K)

SoilTMP_depth2_inst = Soil temperature of second layer (K)

- **Grid:** bilinear interpolation on GLDAS-2_0.25 grid

- **Format:** netCDF

220 5. Click the **Get Data** and **Down load links list**, and then the tool like **Chrono Download Manager** can be used to download the data via the links list.

4.5 MERRA2 product

225 The MERRA2 (Modern-Era Retrospective analysis for Research and Applications version 2) is the latest version of global atmospheric reanalysis product, which uses the Goddard Earth Observing System Model (GEOS) version 5.12.4. The SMST data are available from 1980 to present, with a grid size of $0.5^{\circ} \times 0.625^{\circ}$ and hourly interval. The layer thicknesses of model layers for the ST data varies with region can be found at https://disc.gsfc.nasa.gov/datasets/M2C0NXLND_5.12.4/summary

Downloading online MERRA2 data through GES DISC:

1. Register an EARTHDATA account.
2. Go to the link https://disc.gsfc.nasa.gov/datasets/M2T1NXLND_5.12.4/summary
- 230 3. The dataset catalogue entries include the following tabs:
 - **Product Summary:** It gives a description of the dataset and metadata information (e.g. temporal spatial, file format, etc.).
 - **Data citation:** To cite the data in publications.
 - **Documentation:** It provides links to details documentation about the dataset.
 - 235 • **Reference:** It is data collection reference.
4. Click the button of **Subset/ Get data** on the right of the interface to select the required data.
 - **Download Method:** Select the Get File Subsets using the GES DISC Subsetter
 - **Date Range:** 2010-01-01 to 2018-12-31
 - **Region:** Maqu (101.7, 33.6, 102.7, 34.2), Shiquanhe (79.75, 32.36, 80.25, 32.76)
 - 240 • **Variables:**

SFMC = water surface layer (0-5 cm)

RZMC = water root zone (0-100 cm)

TSOIL1 = soil temperatures layer 1

TSOIL2 = soil temperatures layer 2

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TSOIL3 = soil temperatures layer 3

- **Grid:** bilinear interpolation on GLDAS-2_0.25 grid
- **Format:** netCDF

5. Click the **Get Data** and **Down load links list**, and then the tool like **Chrono Download Manager** can be used to download the data via the links list.

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4.6 Meteorological datasets

The precipitation (mm) and air temperature (°C) data is from the Maqu (34.00°N, 102.08°E) and Shiquanhe (32.50°N, 80.08°E) weather stations operated from the China Meteorological Administration (CMA). The daily precipitation is the cumulative value for the period between 20h of the previous day and 20h of the current day in Beijing time, while the daily air temperature is the mean value. The monthly precipitation was calculated by summing up daily precipitation, while the monthly air temperature is average of daily air temperature for each month. The monthly precipitation and air temperature data for Maqu and Shiquanhe network are contained in the “Supplementary data/Meteorological data” folder.

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