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Database for ground temperature and freezing depth in Japan

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Abstract: Ground temperature data in Japan, obtained from as early as 1888 to date, were collected, digitized in the comma-separated-value format, and quality-controlled with respect to physical and meteorological contexts. Hourly station data on ground temperatures from 34 Japan Meteorological Agency sites and 7 sites of the Agricultural Research Department of the Hokkaido Research Organization were included, along with the accompanying meteorological observation data. The dataset was published by the Arctic Data archive System and made available for non-commercial use.

1. Background & Summary

Information on subsurface thermal states (ground temperature and frozen or thawed ground) is important for indexing the climatic situation of the environment[1], as well as for socioeconomic activities such as agriculture[2] and civil engineering[3]. The relevant areas in Japan span from the sub-tropics to the sub-arctic. Thermal and hydrological subsurface conditions determine the ecological environment of a location[4], including the local climate, and are affected by climate change[1]. Past records of ground temperatures can provide basic information and understanding on how domestic above-surface and subsurface thermal states have changed[5,6], and they form the basis for current assessments as well as initial or boundary conditions for future projection simulations of the environment.

Since the Meiji era (late 1800s), various Japanese institutions and groups, both governmental and private, have measured subsurface thermal states, such as the ground temperature at various depths including freezing or thawing depths. Regarding air temperature and precipitation data, the Japan Meteorological Agency (JMA) has played a central role in determining measurement protocols and standards, conducting continuous long-term measurements throughout the country, managing the data, and publishing them in electronic formats. As for the subsurface thermal variables, however, limited efforts[7] have been invested to collect, compile, or digitize such data for several reasons: 1) The JMA and Ministry of Agriculture, Forestry and Fisheries are the two major governmental bodies that have managed the systematic and organizational measurement of subsurface temperature conditions, but their methods are not uniform, and they employ different standards and routines in terms of continuity, equipment, measurement frequency, depth, and conditions of the measured surface. 2) The measured values are generally site-specific, and representability is limited because of the high heterogeneity of the physical and chemical ground conditions. 3) Standard measurement protocols have not been prepared, since the measurement methods and frequencies depend largely on the measurement objectives, which differed widely among different practitioners. If efforts are not made to mine, collect, digitize, quality-control, and publish data on subsurface thermal variables, a large portion of these data could be lost. Therefore, we promoted such efforts[8] and compiled the “Database for ground temperature and freezing depth in Japan (version 1.1)” with the data collected and digitized to date.

2. Location

The locations of 41 stations, of which the measurement data were entered into the database, are shown in Figure 1, and the geographic and descriptive information are summarized in Table 1. These stations included JMA offices and weather stations as well as experiment stations and research centers of the Hokkaido Research Organization, Agricultural Research Department (HRO). The items listed in the table are the number (#), name (Site), latitude (Lat.), longitude (Lon.), altitude

from the mean sea level in meters (Alt.), the starting year of the ground temperature observations (OY1), the ending year of the ground temperature observations (OYN), the first year of the digitized records (DY1), the last year of the digitized records (DYN), number of the digitized ground temperature records and for HRO, that of all records including meteorological observations in parenthesis (#Rec), and the organization (Org.) of each station.

3. Methods

Ground and surface temperature measurements made by the JMA were adherent to the official routine protocol, which was established by the agency since they made their earliest observations (for example, Meteorological Observation Guideline[9] published in 1943) as summarized in Table 2a. Covered and curved-tube thermometers were used as measurement equipment for the shallower ground layers, such as the surface, 5 cm, 10 cm, 20 cm, and 30 cm; and cased thermometers were used for layers deeper than 50 cm. Operational practices, however, in terms of measurement frequencies, depths, types of surface condition (bare ground, sand, or grass), and recording formats varied from station to station and time to time. At the end of 1970, the routine measurement of surface and subsurface temperatures was officially terminated. The original JMA ledger data, archived as microfiche images, were digitized. In most cases, the JMA ledger data included 10-day and monthly averages for quality checks.

In contrast to the JMA practices that followed the common routine, the measurements and data storage protocols were different at each HRO site. Table 2b summarizes the measurement periods, methods, and available archives of the HRO-measured data. The ledger data were photocopied and digitized. The electronic data files were reformatted in accordance with the style described in Section 4. Meteorological data collected at the HRO sites were also included when available. After digitization, the ground temperature data of both institutes were subjected to the quality control procedures described in Section 5.

4. Data Records

In the database, one line constitutes one data entry corresponding to one measurement. One data entry comprises 18 elements in a comma-separated-value format, namely Station Name, City Name, Latitude, Longitude, Altitude, Year, Month, Day, Hour, Minute, Variable Name (abbreviated), Unit, Measurement Method, Depth, Measurement Value, Flag, Institute, and Remarks. Details of these elements are summarized in Table 3, and full variable names are summarized in Table 4.

One comma-separated-value-formatted file was prepared for each station and labeled “GTset_XXX_YYY.csv” where XXX and YYY denoted the name of the organization (JMA or HRO in this dataset) and the station, respectively. The JMA files only contain ground temperature

data, while the HRO files contain ground temperature data and the accompanying meteorological observation data when and where available.

Two additional files were included in the dataset; one (GTmonthly_JMA.csv) contained monthly mean ground temperature data at the JMA stations compiled by the Ministry of Agriculture, Forestry and Fisheries and the JMA (1982)[7]. The other file (airTdaily_JMA.csv) contained daily near-surface air temperature data at selected JMA stations, taken from the JMA's past meteorological data archive (http://www.data.jma.go.jp/obd/stats/etrn/index.php).

5. Technical Validation

The JMA ledger data were provided as microfiche image files. The HRO ledger data were photocopied to image files from the original books by the authors. Both image files on ground temperatures were digitized manually and their description checked visually in the original form that had the criteria (corresponding to flags N0–A2 in Table 5). After digitization, the ground temperature data were screened in accordance with contextual criteria (1)-(4), and closely examined both physically and meteorologically to determine the most reliable values. The contextual criteria were set in relatively broad terms to detect possible errors or controversial values. "Best estimate in context" for flags R5 and A1-A4 in Table 5 include, but are not limited to, retainment of the original values, removal of non-number symbols, conversion of the special "negative-value" convention (addition of 100 to a negative value. *Cf.* flag R1) to the natural negative value, correction of hand-written errors or adjustment of outliers to the most likely value in the physical and/or temporal context with adjacent data, depending on the types of flag R5, A1–A4 (e.g., assuming the same depths and time for observations in the previous/next month for R5).

(1). Temperature lower than -25 °C (values possibly too low).

(2). Temperature between 45 and 85 °C or higher than 100 °C (values possibly too high, and conversion error of "negative-value" convention not suspected).

(3). Temperature between 70 and 100 °C (conversion error of "negative-value" convention suspected).

(4). The absolute value of the gradient of temperature increase (or decrease) from the closest previous measurement is larger than 20 °C/h.

6. Competing interests

Not Applicable.

7. Figures

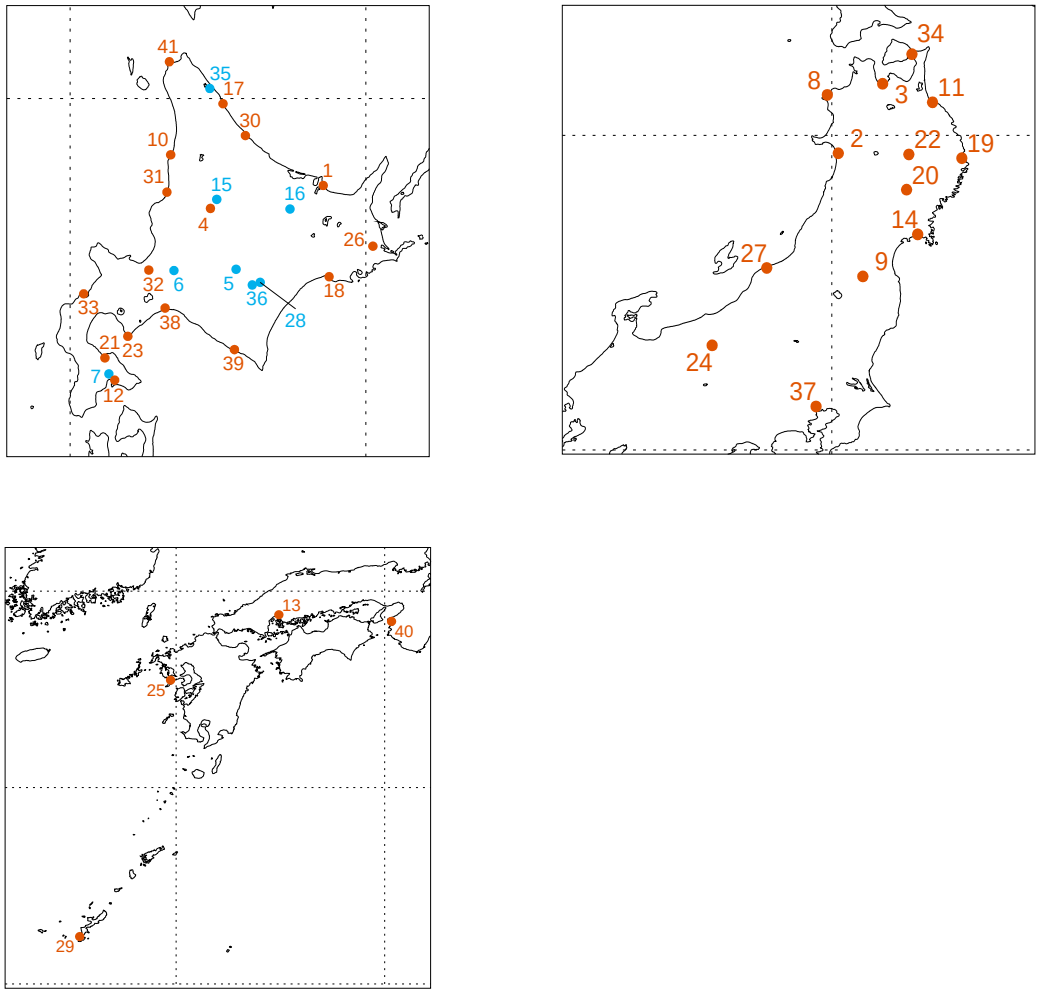

Figure 1. Locations of stations for ground temperature measurements. Sites of Japan Meteorology Agency are shown in red, and those of Hokkaido Research Organization, Agricultural Research Department are shown in blue. Scales vary among maps.

8. Tables

Table 1. Geographic and descriptive information on stations where data were gathered and archived.

#	Site	Lat.	Lon.	Alt.	OY1	OYN	DY1	DYN	#Rec	Org.
1	Abashiri	44.0167	144.278	37.6	1896	1970	1896	1970	1169320	JMA
2	Akita	39.7167	140.098	9.2	1893	1970	1893	1970	1056168	JMA
3	Aomori	40.8217	140.768	3.6	1893	1990	1893	1990	1353150	JMA
4	Asahikawa	43.7567	142.372	111.3	1895	1970	1895	1970	2136494	JMA
5	Chikusan	43.0686	142.805	245	1999	in op.*	1999	2013	124327 (124327)	HRO
6	Chuuou	43.0547	141.755	31	1966	in op.	1966	1995	25864 (96396)	HRO
7	Donan	41.8865	140.654	27	1912	1995	1926	1993	45788 (139459)	HRO
8	Fukaura	40.645	139.932	67.7	1940	1970	1940	1970	336660	JMA
9	Fukushima	37.7583	140.47	67.3	1901	1970	1901	1970	1705248	JMA
10	Haboro	44.3633	141.7	19.2	1921	1970	1921	1970	935580	JMA
11	Hachinohe	40.5267	141.522	27.4	1936	1970	1936	1970	513075	JMA
12	Hakodate	41.8167	140.753	2.6	1898	1970	1898	1970	1594633	JMA
13	Hiroshima	34.3983	132.462	29.3	1888	1970	1956	1970	72540	JMA
14	Ishinomaki	38.4267	141.298	43	1894	1970	1894	1970	1567794	JMA
15	Kamikawa	43.8593	142.479	158	1910	1975	1910	1975	65216 (97058)	HRO
16	Kitami	43.75	143.717	190	1969	1995	1969	1995	899 (899)	HRO
17	Kitamiesashi	44.94	142.585	6.1	1942	1970	1942	1970	299460	JMA
18	Kushiro	42.985	144.377	32.7	1903	1970	1903	1970	1040240	JMA
19	Miyako	39.6383	141.965	42.7	1897	1970	1897	1970	1448940	JMA
20	Mizusawa	39.1367	141.13	50	1904	1963	1904	1963	1898316	JMA
21	Mori	42.0667	140.588	125	1962	1970	1962	1970	43524	JMA
22	Morioka	39.6983	141.165	155.2	1923	1970	1923	1970	1632769	JMA
23	Muroran	42.3117	140.975	18.8	1923	1970	1923	1970	663024	JMA
24	Nagano	36.6617	138.192	418.2	1889	1970	1889	1970	1379934	JMA
25	Nagasaki	32.7333	129.867	131.5	1891	1970	1891	1970	399125	JMA
26	Nemuro	43.33	145.118	25.7	1890	1970	1890	1970	1491229	JMA
27	Niigata	37.8933	139.018	2	1891	1970	1956	1970	72540	JMA
28	Obihiro	42.9217	143.212	38.9	1897	1970	1897	1970	1093745	JMA
29	Okinawa	26.2067	127.687	34.9	1900	1970	1900	1970	974578	JMA
30	Oumu	44.58	142.963	13.7	1942	1970	1942	1970	322896	JMA
31	Rumoi	43.941	141.637	22.3	1943	1970	1943	1970	292020	JMA

32	Sapporo	43.06	141.33	0	1889	1970	1889	1970	1178076	JMA
33	Suttsu	42.791	140.229	15.7	1900	1970	1900	1970	1093370	JMA
34	Tanabu	41.2923	141.21	3.1	1935	1969	1935	1969	300638	JMA
35	Tenpoku	45.1125	142.361	20	1953	in op.	1953	2013	2196 (14112)	HRO
36	Tokachi	42.8914	143.078	92	1960	in op.	1960	2000	27495 (73509)	HRO
37	Tokyo	35.69	139.762	4.1	1890	1970	1952	1970	109244	JMA
38	Tomakomai	42.631	141.606	5.9	1942	1970	1942	1970	299460	JMA
39	Urakawa	42.1617	142.777	33.5	1930	1970	1930	1970	565006	JMA
40	Wakayama	34.2283	135.163	13.6	1888	1970	1888	1970	715387	JMA
41	Wakkanai	45.415	141.678	1.8	1938	1970	1938	1970	373860	JMA

*: currently in operation.

Table 2. Summary of ground temperature measurements and data storage at a) Japan Meteorological Agency, and b) Hokkaido Research Organization, Agricultural Research Department.

a) Japan Meteorological Agency

Periods	Shallow layers	Deep layers	Form of records	Notes
Start dates vary (See Table 1). The official routine measurement ended in 1970.	Covered and curved-tube thermometers. Typical measurement depths are on the surface (0 cm), 5 cm, 10 cm, 20 cm, and 30 cm.	Cased thermometers Depth at 50 cm and more.	Archived as microfiche images.	Operational practices, such as measurement frequencies, depths, types of surface condition (bare ground, sand, or grass), varied from station to station, and time to time.

b) Hokkaido Research Organization, Agricultural Research Department

Stations	Periods	Availability of data in Ledger books	Availability of electronic data	Methods (probes, depths, frequency)
Chikusan	1999 to present.	―	17:00, October 26, 1999 to present (occasional missing due to lightning or other reasons)	Platinum resistance thermometers. Hourly at a depth of 10 cm.
Chuuou	1966 to present.	1966–1995	November 1995 to October 1997, and 1999 to the present. MAMEDAS* system after 1999.	Prior to the MAMEDAS system: Probes unknown. Daily at a depth of 5 cm (1966–1976), and at 10 and 20 cm (1966–1995). MAMEDAS system#: Platinum resistance thermometers. Hourly at depths of 10 and 20 cm until 2011, then at 10-min intervals.
Donan	1912–1999.	1912–1995 (data occasionally missing for earlier and later periods).	―	Until 1943: Daily at a depth of 30 cm. After 1944: Daily at depths of 10, 20, and 30 cm (April to November).
Kamikawa	Until 1992.	1902–1992 (with occasional interruptions)	―	Ground temperature records for 1910–1975 only. Probes unknown. Daily at depths of 10, 20, and 30 cm.
Kitami	1969–1995.	1969–1995. Data available only for 10-day averages.	―	Probes unknown, 10-day mean, measured at 9:00 at a depth of 10 cm. Type of thermometer unknown.
Tenpoku	From 1953 to present.	―	1953 to present	Until 2009: likely thermocouples. After 2010: “Ondotori” (T&A Inc.). 10-day mean at a depth of 10 cm. May to October (April to November, in recent years)
Tokachi	1960 to present.	1960–1991. ① 1960–1980. ② Ledger books lost for 1981–1991.	April 1992 to present ③ Microsoft Excel files for April 1992 to March 2000. ④ MAMEDAS system after June 2000.	① 1960–1980: Probes unknown, Hourly at depths of 10 cm (1960–1980) and 20 cm. (1962–1978) [April to October]. ③ April 1992 to March 2000: Thermocouples. (for April 1992 to March 2000). Daily at surface and depths of, 5, 10, 20, 30, and 40 cm. ④ After June 2000, MAMEDAS system#: Platinum resistance thermometers. Hourly at a depth of 10 cm.

*MAMEDAS[10]: A meteorological observation using an Automatic Weather Observation System, developed by the Hokkaido Regional Office of Japan Weather Association (JWA).

#: MAMEDAS data will be included in the prospective next version.

Table 3. Format of data entry in database.

#	Item	Explanation
1	Station name	Name of station as shown in Table 1.
2	City name	Name of city where station is/was located.
3	Latitude	Northern latitude of station, presented as decimal number.
4	Longitude	Eastern latitude of station, presented as decimal number.
5	Altitude	Representative altitude of station relative to sea level.
6	Year	Year in which data were measured.
7	Month	Month in which data were measured.
8	Day	Day on which data were measured.
9	Hour	Hour (in 24-hour system) at which data were measured.
10	Minute	Minute at which data were measured.
11	Variable name	Name of variable; details are shown in Table 4.
12	Unit	Unit of entry value.
13	Measurement method	Method used to measure data.
14	Depth	Depth (m) at which data were measured, with 0 m indicating surface.
15	Measurement value	Numerical value of data.
16	Flag	Flag for quality control purpose; details are shown in Table 5.
17	Institute	Name of institute from which the data originate.
18	Remarks	Remarks to data entry.

Table 4. Variable names used for measured data.

Variable name	Description
AirTemp	Air temperature (°C)
GroundTemp	Ground temperature, covered (°C)
GroundTempCas	Ground temperature, casing (°C)
GroundTempUnc	Ground temperature, uncovered (°C)
MaxAirTemp	Daily maximum air temperature (°C)
MaxWind	Daily maximum wind speed (m s^{-1})
MinAirTemp	Daily minimum air temperature (°C)
NetRadiation	Net radiation (MJ m^{-2})
Precip	Precipitation (mm)
PrecipDays	Precipitating days (days)
RHumid	Relative humidity (%)
SnowDepth	Snow depth (cm)
SunshineDur	Sunshine duration (hours)
SurfacePress	Surface pressure (hPa)
SurfaceTemp	Surface temperature (°C)
SurfaceTempGrass	Surface temperature on grass (°C)
SurfaceTempLoam	Surface temperature on loam (°C)
SurfaceTempSand	Surface temperature on sand (°C)
SurfaceTempUnc	Surface temperature, uncovered (°C)
Wind	Wind speed (m s^{-1})
minTempSurface	Minimum surface air temperature (°C)

Table 5. Flag summary.

Types	How it appears originally	How it is transcribed in data	Flag
Normal value	--	--	N0
Remarks	Negative values (below freezing point) *x* is described as 100+*x* Ex. -0.1 °C is 99.9	Converted to real temperature value in centigrade.	R1
	Variable name is “Surface temperature on snow”	--	R2
	Variable name is “Surface temperature on bare ground”	--	R3
	Variable name is “Ground temperature of sand”	--	R4
	Failure to fill in (e.g., time, depth, or method), hard to read, or possible hand-written errors	Best estimate in context	R5
	Denoted as “guess value”	Original value	R6
	Strikethrough	Original value	R7
	Questionable value	Original value	R8
Warnings	Blank	Blank	W1
	Missing notes	-999	W2
	Illegible, unclear writing	-888	W3
Abnormal values	Inclusion of non-numerical values	Best estimate in context	A1
	Inconsistencies with statistics (e.g., 10-day mean; JMA only)	Best estimate in context	A2
	Outliers (below or above thresholds)	Best estimate in context	A3
	Abnormality in temporal changes	Best estimate in context	A4
	Meteorologically inconsistent values (not checked in this version)	Best estimate in context (not applicable in this version)	A5

Author contributions

K. Saito initiated and designed the entire project, collected observational data from Hokkaido Agriculture laboratories, and led the digitizing and archiving of the data. K. Watanabe and T. Sueyoshi assisted in designing the project and collecting unpublished data. S. Haginoya and H. Hosaka provided JMA data and related information. T. Hirota provided information on ground temperature data measurement at the National Agriculture and Food Research Organization K. Takeda and M. Kimura provided information on ground temperature data measurement at Obihiro University of Agriculture and Veterinary Medicine. M. Mizoguchi provided the monthly ground temperature data from JMA/MRI compiled in his previous project. K. Harada provided data on frost depth in Hokkaido. H. Yabuki managed the data archive in the Arctic Data archive System.

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Data Citations

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