

Assessing and projecting surface air temperature conditions required to sustain permafrost in Japan

Tokuta Yokohata^{a,*}, Go Iwahana^{b,a}, Kazuyuki Saito^c, Noriko N. Ishizaki^a, Taiga Matsushita^d, Tetsuo Sueyoshi^e

^a *National Institute for Environmental Studies, Tsukuba, Japan*

^b *University of Alaska Fairbanks, Alaska, USA*

^c *Japan Agency for Marine-Earth Science and Technology, Yokohama, Japan*

^d *Tsukuba University, Tsukuba, Japan*

^e *National Institute for Polar Research, Tokyo, Japan*

Table S1 Locations of permafrost occurrence based on ground temperature measurements or estimated from the basal temperature of snow (BTS). Locations No. 1 to 7 are in the Daisetsu Mountains, No. 8 is in the Northern Japan Alps, and No. 9 to 15 are on Mt. Fuji.

No	Name	Altitudes	Reference
1	Mt. Hakuundake	2170 m	Iwahana et al. 2011
2	Mt. Koizumidake	2150 m	Iwahana et al. 2011
3	Hokkaidaira	2075 m	Fukuda and Sone 1992
4	Mt. Goshikidake	2035 m	Iwahana et al. 2011
5	Mt. Chubetsudake	1850 m	Ishikawa and Hirakawa 2000 (BTS)
6	Mt. Takanegahara	1755 m	Sone and Watanabe 2018
7	Mt. Hiragatake	1720 m	Sone 2020
8	Tateyama	2720 m	Fukui and Iwata 2004
9	Mt. Fuji, Hakusan	3740 m	Ikeda et al. 2012
10	Mt. Fuji, Osawa	3700 m	Ikeda et al. 2012
11	Mt. Fuji, N37	3700 m	Ikeda et al. 2012
12	Mt. Fuji, N36	3600 m	Ikeda et al. 2012
13	Mt. Fuji, N35	3500 m	Ikeda et al. 2012
14	Mt. Fuji, N33	3300 m	Ikeda et al. 2012
15	Mt. Fuji, S36	3600 m	Ikeda et al. 2012

Table S2. Locations of observational sites used in Figure S2. Data are provided by the Ministry of the Environment Monitoring Sites 1000 project (downloaded from <http://www.biodic.go.jp/moni1000/findings/data/index.html>).

ID	Site name	Altitude	Latitude (°N)	Longitude (°E)
1Ca	Daisetsu Mountains	1840 m	43.6766	142.9423
2Ba	Northern Japan Alps	2705 m	36.5	137.6
2Ca	Northern Japan Alps	2830 m	36.566325	137.605928
3Aa	Northern Japan Alps	2450 m	36.3333	137.726806
4Aa	Northern Japan Alps	2448 m	36.148852	136.768152
5Aa	Southern Japan Alps	2880 m	35.665111	138.233333
6Ba1	Mt. Fuji	2350 m	35.335490	138.745840
6Ba2	Mt. Fuji	2350 m	35.335620	138.745930

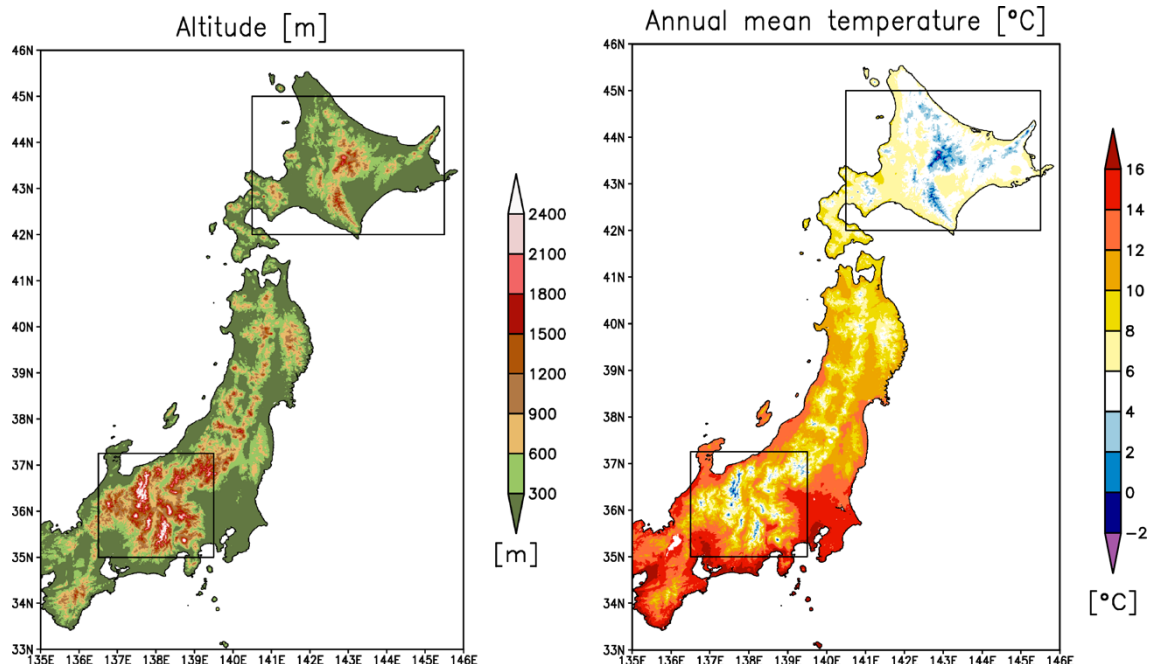


Figure S1. Left) The altitude distribution [m], and right) the distribution of the annual mean surface air temperature [°C] of the eastern Japan region. The annual mean temperature is averaged over 1999–2018 and the outputs of nine bias-corrected and downscaled climate models. The Grid Analysis and Display System (GrADS, <http://cola.gmu.edu/grads/>) is used to plot this figure.

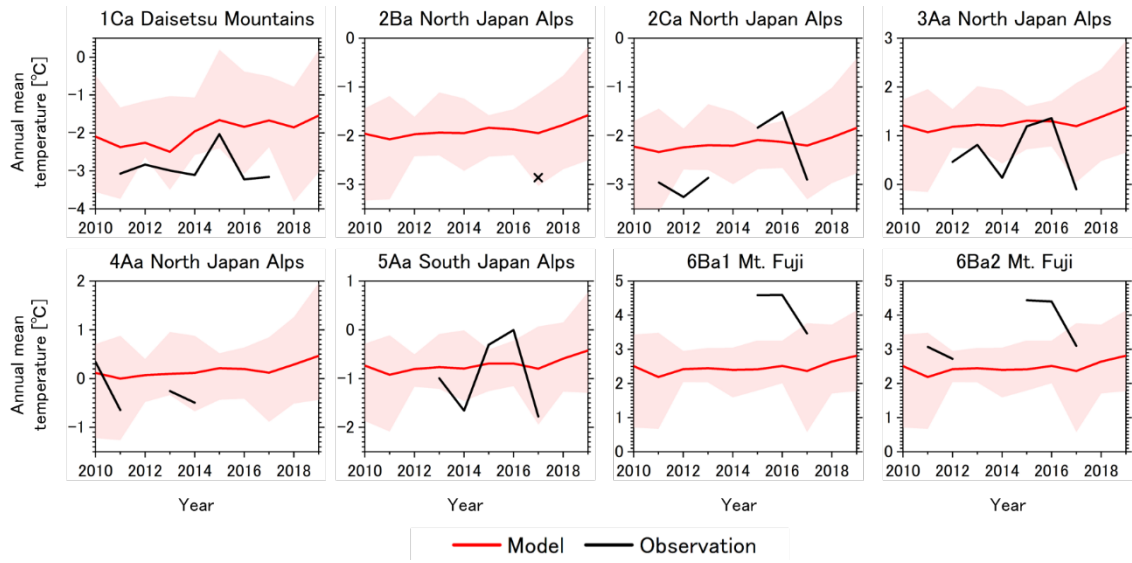


Figure S2. Time series of annual mean surface air temperature at the locations where we detected ECP regions (Daisetsu Mountains, Northern Japan Alps, Southern Japan Alps, and Mt. Fuji). The red lines show the averages of nine bias-corrected global climate models (GCMs), and the shading indicates their spread. The black lines show the field observational data provided by the Ministry of the Environment Monitoring Sites 1000 project (downloaded from <http://www.biodic.go.jp/moni1000/findings/data/index.html>). The locations of the observational sites are shown in Table S2. For the calculation of bias-corrected GCMs, we choose the nearest grid points of the observational site and corrected for altitude ($0.65^{\circ}\text{C}/100\text{ m}$) by using the difference in altitudes between the GCM grid point and the observational site.

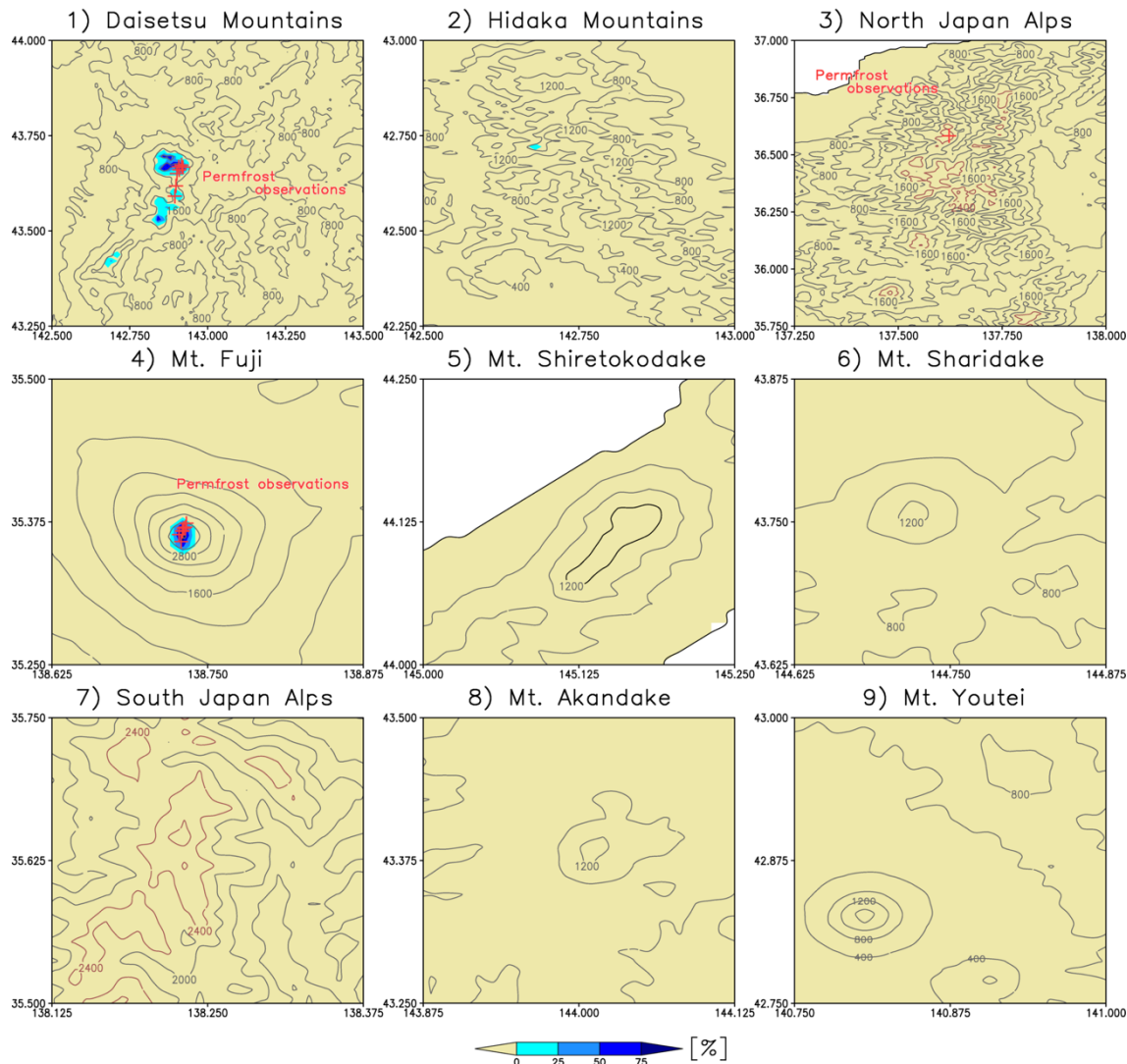


Figure S3. Same as Figure 2 but for the future projection of the surface air temperature environment that maintains permafrost in the mountainous regions of Japan (2100 in the RCP2.6 scenario). 1) Daisetsu Mountains, 2) Hidaka Mountains, 3) Northern Japan Alps, 4) Mt. Fuji, 5) Mt. Shiretokedake, 6) Mt. Shari, 7) Southern Japan Alps, 8) Mt. Akandake, and 9) Mt. Yotei.