

How Permanent is Permafrost?

This classroom activity helps to explore the relationship between surface air temperature and permafrost (soil) temperature. Permafrost, or permanently frozen ground, is soil, sediment, or rock that remains at or below 32° F (0°C) for at least two years and generally occurs in the higher latitudes of the Earth.

Permafrost is thawing as climate warms. One way to look at this is to examine the relationship between soil temperature below the ground and surface air temperature above the ground. This is easiest to do in the great northern expanse of Russia, where buildings were often erected on frozen ground but are now collapsing due to the thawing of the ground (See Figure 1). Records of soil temperature in Russia from boreholes (narrow holes drilled into the ground to take scientific measurements) go back many decades. Scientists and engineers have compiled these soil temperature records over the years. NSIDC has assembled a selection of these borehole data and surface air temperature data, where available, for five boreholes in Russia: Churapcha, Isit', Pokrovsk, Verkhoyansk, and Yakutsk. A description of the data files is provided in section **4 About the Permafrost Data Files** of this document.



Figure 1. A building that has buckled due to thawing permafrost. —*Credit: Vladimir Romanovsky, UAF*

Soil temperature at depth reflects changes in air temperature at the surface but with a lag in time. For example, the temperature of the soil at 0.8 m depth responds to changes at the surface with about a 2-week lag time, while the temperature at 3.2 m depth has about a 6-month lag time. However, rapid fluctuations of air temperature do not affect the soil temperature except very near the surface: day-to-day or high frequency temperature changes are not seen in the soil at depth. Ups and downs in air surface temperature must have taken place steadily over a long time to register at depth.

To say that soil temperature is rising in response to rising surface air temperature is a valid generalization. However, on a case-by-case basis, it is not so simple. At Yakutsk, for example, the presence or absence of snow cover and the depth of the snow plays a large role. In winter, snow insulates the ground from getting cold. In summer, the snow that fell in winter increases the soil moisture. As the moisture in the soil evaporates, it cools the soil. Topography, land cover, and weather influence soil temperature on a local scale.

1 GETTING STARTED

To start the activity, do the following:

1. Read the [Earth Exploration Toolbook \(EET\): How Permanent is Permafrost](#) guide for classroom use. The EET guide offers detailed instructions on how to make the most of these data in a classroom setting.
2. Students and teachers download permafrost borehole data files by clicking on the links below. There is an easy-to-use version that will be easier for students to use right away (the EET guide references these) and a complete version that is suitable for a more advanced exploration of the topic.

Permafrost data, easy-to-use version

[HPIP_Churapcha_subset.xls](#)

[HPIP_Isit_subset.xls](#)

[HPIP_Pokrovsk_subset.xls](#)

[HPIP_Verkhoyansk_subset.xls](#)

[HPIP_Yakutsk_subset.xls](#)

Permafrost data, complete version

[HPIP_Churapcha_full.xls](#)

[HPIP_Isit_full.xls](#)

[HPIP_Pokrovsk_full.xls](#)

[HPIP_Verkhoyansk_full.xls](#)

[HPIP_Yakutsk_full.xls](#)

2 HAVE A LOOK IN GOOGLE EARTH

Students and teachers can also explore permafrost with Google Earth. With Google Earth, the location of the boreholes can be seen on a globe, temperature trends and a permafrost map can be overlaid on the globe, and students can get a sense of where permafrost is on the Earth.

It is easy to get started with Google Earth. Go to [Google Earth - Getting Started for Educators](#) to learn how to install it.

After Google Earth is installed, download [permafrost_eet.kmz](#). To open the file, either double click on it to automatically launch Google Earth; or open Google Earth first; then open the file using the drop-down menu (File --> Open...).

The layers in the *Temporary Places* section of Google Earth shows the borehole locations, permafrost extent, and trends in surface air temperature. If you cannot see the boreholes, permafrost map, or surface temperature map on the globe, click on the check boxes next to *Borehole Locations*, *Permafrost Map*, and *Surface Temperature Trend Maps*, respectively, to make them visible.

2.1 Go to Yakutsk and the Kolyma River Region of Russia with College Students

Chersky, Siberia, is north of the Arctic Circle on the Kolyma River. It is the home of the Northeast Science Station and is home base for many scientists studying the region, including Russian and U.S. undergraduates in the [Polaris Project](#) field course. You can see where Chersky is in Google Earth by selecting the check box *Chersky, Russia* under the *Temporary Places* layer.

The Kolyma River is completely underlain by permafrost. Permafrost plays a role in the transport and transformations of carbon and nutrients as they move with water from terrestrial uplands to the Arctic Ocean. The Polaris Project student science team studies this aspect of the Arctic system and shares the experience of doing science in this part of Siberia with a blog, stories, and photos.

Figure 2 shows a barge that transports the students to the sampling sites. The Polaris project started in 2008 and continues at least through 2011.



Figure 2. A barge transported the student science team to sampling sites on the Kolyma River upstream and downstream of Chersky. —Credit: *Courtesy of EOS.*

3 SCIENTISTS IN THE FIELD

“[What Science Takes](#)” is another story about collecting data in the Russian Arctic published in the Winter 2009/10 ESRL Quarterly Newsletter. To help understand the details of the methane cycle, scientists from NOAA’s Earth System Research Laboratory (ESRL) and collaborators are measuring methane, a potent greenhouse gas that is tied up in frozen organic matter in the soil and released when permafrost thaws.

4 ABOUT THE PERMAFROST DATA FILES

The permafrost data files in this classroom activity come from the NSIDC [Soil Temperature Station Data from Permafrost Regions of Russia \(Selection of Five Stations\), 1915 – 2000](#) data set.

This data set includes soil temperature data from boreholes located at five stations in Russia: Yakutsk, Verkhoyansk, Pokrovsk, Isit', and Churapcha. The data have been compiled into five Microsoft Excel files, one for each station. Each Excel file contains three worksheets:

- **G02189info worksheet:** Contains the same content in each Excel file - latitude and longitude information and notes on the stations. Refer to Figure 3.
- **Jan soil & surface temp worksheet:** Contains winter (January) soil temperature and air temperature. Note: The Churapcha file only contains soil temperature because air temperature was not available for that region.
- **Jul soil & surface temp worksheet:** Contains summer (July) soil temperature and air temperature. Note: The Churapcha file only contains soil temperature because air temperature was not available for that region.

This spreadsheet file is a component of NOAA@NSIDC dataset G02189, and of an educational activity from the Earth Exploration toolkit "How Permanent Is Permafrost" chapter.					
WMO Station Number	WMO Station Name	Latitude (decimal degrees N)	Longitude (decimal degrees E)	Approximate Elevation (meters)	Notes
24959	Yakutsk	62.0	129.7	98	Surface air temperature data available from NCARds570 and GHCN, use from ds570
24266	Verkhoyansk	67.6	133.4	136	Surface air temperature data available from NCARds570 and GHCN, use from ds570
24856	Pokrovsk	61.5	129.2	117	No surface air temperature data available in ds570 or GHCN
24951	Isit'	60.8	125.3	117	Surface air temperature data available from GHCN only
24768	Churapcha	62.0	132.6	181	No surface air temperature data available in ds570 or GHCN
Reference links:					
NSIDC 'How Permanent Is Permafrost': http://nsidc.org/frozenground/classroom/permanent_permafrost.html					
NCAR data set 570: http://dss.ucar.edu/datasets/ds570.0/					
NOAA GHCN data set: http://www.ncdc.noaa.gov/oa/climate/ghcn-monthly/index.php					

Figure 3. An example of the G02189info worksheet that is in each data file.

There are two different versions of the Excel files: a complete version and a subsetted version. The complete version is suitable for a more advanced exploration of the topic, and the subsetted version is easier to use and understand quickly. Both versions exist for each of the five stations for a total of 10 files. The complete versions of the files have the word full in their filename. These files contain borehole temperature data at all available standard depths: 0.2 m, 0.4 m, 0.6 m, 0.8 m, 1.2 m, 1.6 m, 2.0 m, 2.4 m, and 3.2 m. The subsetted versions of the files have subset in their filename. These files contain data from the 0.8 m and 3.2 m depths only. Missing data are indicated by the value -999.0.

NSIDC has included air temperature measured at the five stations when it is available. There are two sources for the surface air temperature data:

- [NCAR World Monthly Surface Station Climatology, 1738-cont](#)
- [NOAA Global Historical Climatology Network \(GHCN\) Monthly data set](#)

These two sources both draw on the same single original source: data from the World Meteorological Organization (WMO) station network. The full files have data from one or both sources, while the subset files only include data from the source with the most complete record.

One of the ways to learn about this data is to visualize it in a graph. An example of a graph that could be created from the summer Verkhoyansk data is shown in Figure 4. The [EET Guide](#) explains how to create these graphs.

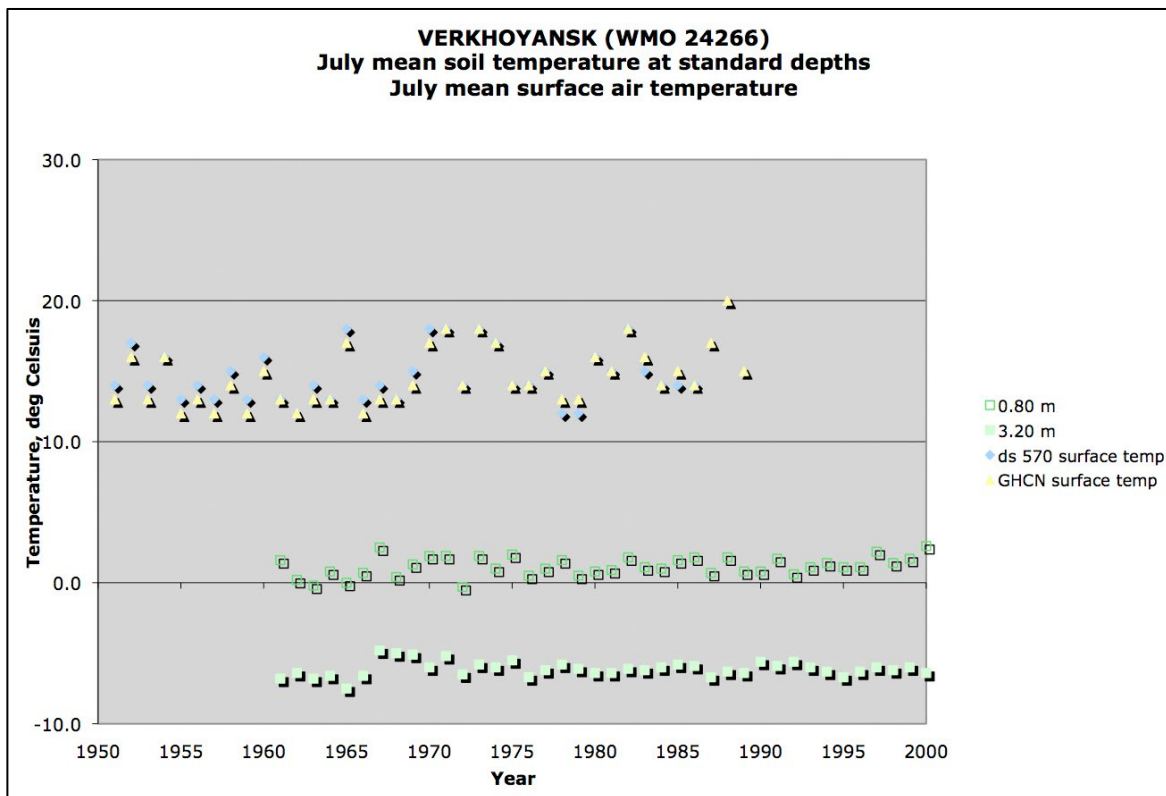


Figure 4. An example of a graph of summer data that could be created from the HPIP_Verkhoyansk_full.xls file.

5 CITING THESE DATA

If you use these data in a publication, please cite them as you would a publication:

Zhang, T. Z. and O. W. Frauenfeld. 2011. *Soil Temperature Station Data from Permafrost Regions of Russia (Selection of Five Stations), 1880s - 2000, Version 1*. [Indicate subset used]. Boulder, Colorado USA. NSIDC: National Snow and Ice Data Center. doi: <https://doi.org/10.7265/N5C24TC5>. [Date Accessed].

6 ACKNOWLEDGEMENT

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The Google Earth file was constructed by Lisa Ballagh at NSIDC using the following data sources:

- The trends in surface air temperature layer was acquired from the [NASA Goddard Institute for Space Studies \(GISS\) Surface Temperature Analysis \(GISTEMP\)](#) Web site. The GISS site was used to generate pictures of temperature trends, and these were then converted to display as kml file layers.
- The permafrost map layer came from the NSIDC [Circum-Arctic Map of Permafrost and Ground-Ice Conditions](#) data set.

The text on this Web page was written by Florence Fetterer, June 2010, based on information provided by Dr. Tingjun Zhang and Dr. Oliver Frauenfeld in May 2009. Ann Windnagel of NSIDC edited the content and created the Web page.

7 RELATED PUBLICATIONS

Chudinova, S. M., O. W. Frauenfeld, R. G. Barry, T. Zhang, and V. A. Sorokovikov. 2006. Relationship Between Air and Soil Temperature Trends and Periodicities in the Permafrost Regions of Russia. *Journal of Geophysical Research* 111, F02008. doi:10.1029/2005JF000342.

Frauenfeld, O. W., T. Zhang, R. G. Barry, and D. Gilichinsky. 2004. Interdecadal Changes in Seasonal Freeze and Thaw Depths in Russia. *Journal of Geophysical Research* 109, D05101. doi:10.1029/2003JD004245.

Gilichinsky, D. A., S. S. Bykhovets, V. A. Sorokovikov, D. G. Fedorov-Davydov, R. G. Barry, T. Zhang, M. K. Gavrilova, O. I. Alexeeva. 2000. Use of the Data of Hydrometeorological Survey for Century History of Soil Temperature Trends in the Seasonally Frozen and Permafrost Areas of Russia, Kriosfera Zemli. *The Earth Cryosphere* 4(3): 59-66.

Gilichinsky, D. A., R. G. Barry, S. S. Bykhovets, V. A. Sorokovikov, T. Zhang, S. L. Zudin, and D. G. Fedorov-Davydov. 1998. A Century of Temperature Observations of Soil Climate: Methods of Analysis and Long-term Trends. Proceedings of the 7th International Conference on Permafrost, Yellowknife, Canada, June 22-27, 1998, p. 313-317.

Zhang, T., O. W. Frauenfeld, M. C. Serreze, A. Etringer, C. Oelke, J. McCreight, R. G. Barry, D. Gilichinsky, D. Yang, H. Ye, F. Ling, and S. Chudinova. 2005. Spatial and Temporal Variability of Active Layer Thickness over the Russian Arctic Drainage Basin. *Journal of Geophysical Research* 110, D16101. doi:10.1029/2004JD005642.

Zhang, T., Roger G. Barry, D. Gilichinsky, S. S. Bykhovets, V. A. Sorokovikov, and Jingping Ye. 2001. An Amplified Signal of Climatic Change in Soil Temperatures During the Last Century at Irkutsk, Russia. *Climatic Change* 49(1-2): 41-76.

8 RELATED DATA SET

Zhang, T., et al. 2009. [Russian Historical Soil Temperature Data](https://doi.org/10.5065/D66971QC). Version 1.0. UCAR/NCAR - Earth Observing Laboratory. <https://doi.org/10.5065/D66971QC>. Accessed 14 Nov 2017.