The Dirt on Soil Temperature: 3 Studies

Soil temperature is important for many reasons. Warmer temperatures accelerate chemical weathering on mountains. Soil temperatures determine what vegetation will grow and therefore what animals will be able to live on a mountain. And on a scale not even visible to the naked eye, soil temperature impacts microorganisms that live in the soil. Soil temperature can be very different from the temperatures measured by a weather station, so scientists who want to understand what temperatures nature really feels, often have to look below ground.

We are going to look at three studies in soil temperature.

The first is remarkable for its global scale and is called **SoilTemp**. This global database of soil and near-surface temperature data is gathering its information from 7,538 temperature sensors in more than 70 countries around the world. Since organisms living close to the ground are so strongly influenced by soil temperatures, such so-called 'microclimate' data can help us to understand how species are experiencing climate change. As Jonas Lembrechts, scientist at the University of Antwerp in Belgium explains:

> "This is of immense importance to organisms… If we think about nature from our own 'human' perspective, we miss a lot of the details. Tiny organisms don't see or feel the world like we do. Think about a lizard on a cold and sunny day. You might be freezing cold and putting on a warm jacket, but the lizard could be basking on a stone in the sun and feeling very happy and warm indeed. As a scientist, we try to look at the world from the perspective of the organism, which is why it is so important to measure the temperatures (and other things) there where they are."

SoilTemp is an initiative from Jonas Lembrechts and Ivan Nijs at the University of Antwerp, and Jonathan Lenoir at the Université de Picardie Jules Verne, and is developed in partnership with GEO Mountains. The database is used to provide scientists across the globe with the necessary soil temperature data to understand and study nature and how it is reacting to climate change and other stressors. For more information about this study, see https://www.geomountains.org/projects-impact-stories/affiliated-projects/2869-soiltemp or www.soiltempproject.com.

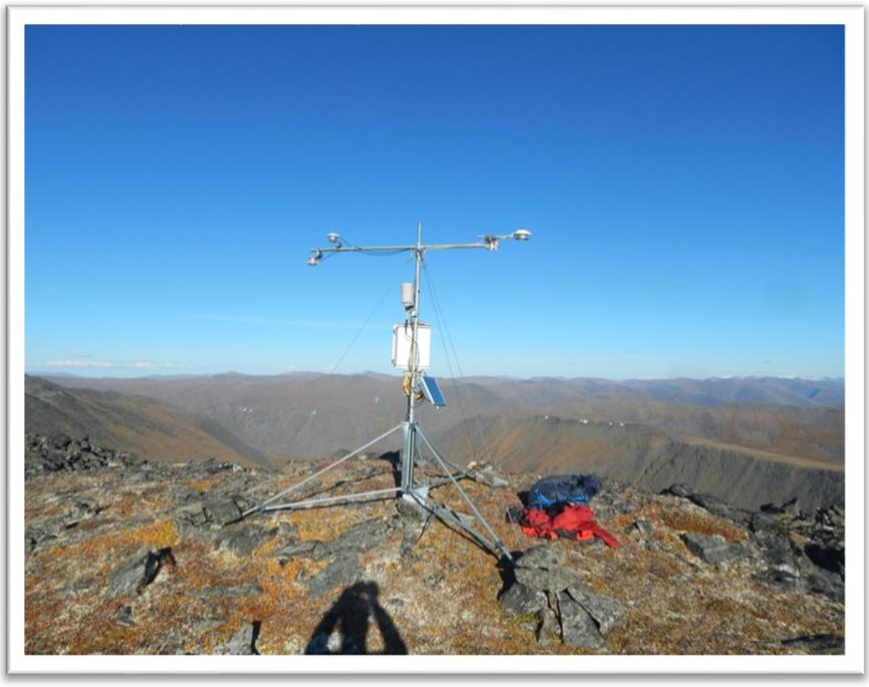
The second study is an excellent example of citizens' science in action and nature-based solutions to climate change and sustainability. The **"Curious Noses"** project in Belgium asked 5,000 citizens to install a microclimate sensor – a 'mini weather station'

sometimes called a “lawn dagger”– in their gardens. Thanks to the help of all these citizens, the researchers could learn more about protecting garden ecosystems – and people – from the impact of extreme weather events such as heatwaves, droughts or heavy rainfall. The smart sensors measure soil temperature and drought in various locations including gardens, school playgrounds, parks, and fields. Each sensor shared its data via link to the internet, so the citizens (and the whole community) could follow the impact of extreme events on their gardens. See https://curieuzeneuzen.be/home-en/.

By measuring, observing, and recording, “Curious Noses” studied whether vegetation in effect acts as an air conditioner. The results indicate that tree canopies, shade, late-afternoon sun, paved areas and asphalt, fencing and open garden borders that allow air circulation, light-coloured walls, the planting shrubs or vines next to walls – all influence this. Vegetation can also serve as a cushion to extreme precipitation, slowing the infiltration of water.

The third study illustrates what raw data from **meteorological stations** look like, and how the data can be transformed into meaningful information.

Below is a meteorological station in the southwest Yukon at ~2200 metres above sea level.



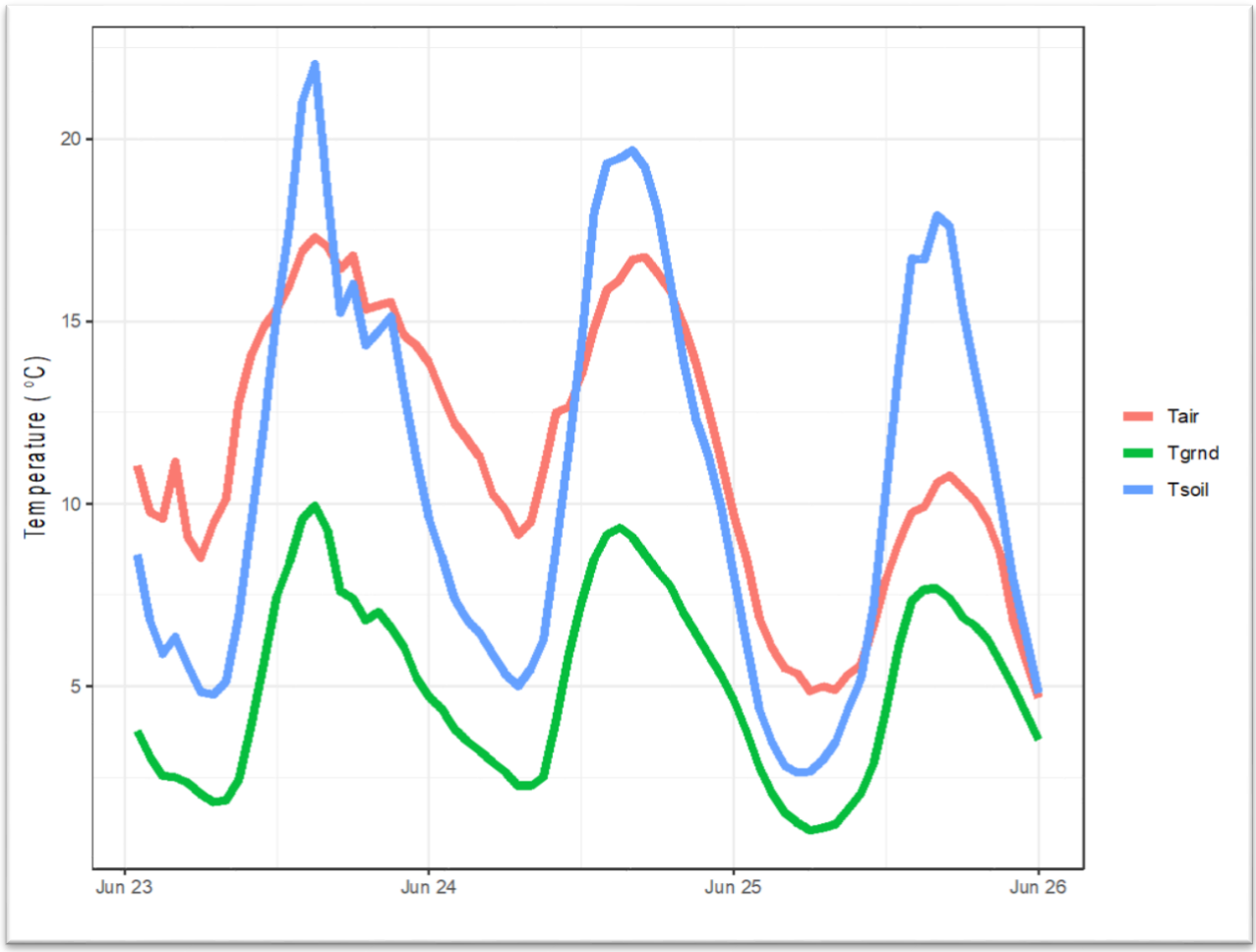
Meteorological station in the southwest Yukon at ~2200 m asl from June 2012. Photo by Scott Williamson.

The figures below are a three-day record from an adjoining station in June 2012. The weather was clear with some intermittent cloudy periods, but no rain. The air temperature was recorded at 2 m above ground, the soil temperature at 1 cm below surface in soil, and the ground temperature at 10 cm below surface.

Date	Time	Temp	Variable
2012-06-23	1:00:00	11.05	Tair
2012-06-23	2:00:00	9.77	Tair
2012-06-23	3:00:00	9.59	Tair
2012-06-23	4:00:00	11.15	Tair
2012-06-23	5:00:00	9.07	Tair
2012-06-23	6:00:00	8.52	Tair
2012-06-23	7:00:00	9.46	Tair
2012-06-23	8:00:00	10.13	Tair
2012-06-23	9:00:00	12.78	Tair

Sample data from a three-day meteorological station record from the southwest Yukon at ~2200 m asl from June 2012, measuring air, soil and ground temperature. Provided by Scott Williamson.

The station measured air, soil, and ground temperatures. See pages 7-12 for the full three-day meteorological record. When the raw data are graphed as below, the differences in temperature and their diurnal fluctuations are clear.



Air, ground and soil temperature fluctuations over a 3 day period June 2012. Data frame by Scott Williamson.

The temperature curves show that air temperature is warmer than soil temperature at night, but the opposite during the day. This is because sunlight warms the soil more than the air during the day, while at night the soil radiates more energy than the air and cools to below air temperature. Because the ground is insulated, the range between maximum and minimum temperature is much less than for soil temperature. There is no shade above the tree line where the station is located, but small variations in afternoon temperatures are caused by clouds reducing incoming sunlight. This is most noticeable on the first day.

Your study:

Mountains provide a great living laboratory. How to measure soil temperature yourself? Use a soil thermometer. Measure 5 cm below ground. Measure the surface temperature right on top of the soil. Then measure the air temperature 2 metres directly above. Take these readings in a shaded area and then in an open area.

If you are using the soil tester thermometer rather than an air temperature thermometer to measure the air temperature two metres above the soil, put a white tissue on top of the sensor. Hold the sensor so the probe that normally goes into the soil is pointed straight up and drape the tissue over it. This will prevent it from absorbing solar radiation and elevating the temperature reading above what it should be.

Doing this regularly over a period of time, one would see diurnal, seasonal, and long-term climate change temperature patterns.

Photo by Martha Warren

1. As mountains grow warmer, what changes in microbial life do you think we will see?

2. Draw a school garden that would help keep the playground cool. What does your design include to benefit from transpiration, shade, colour, and airflow?

3. If you were creating a citizen's science initiative like the "Curious Noses," what weather or climate change indicators would you want to measure and why?

Three-day meteorological station record from the southwest Yukon at ~2200 m asl from June 2012, measuring air, soil and ground temperature.

Date	Time	Temp	Variable
2012-06-23	1:00:00	11.05	Tair
2012-06-23	2:00:00	9.77	Tair
2012-06-23	3:00:00	9.59	Tair
2012-06-23	4:00:00	11.15	Tair
2012-06-23	5:00:00	9.07	Tair
2012-06-23	6:00:00	8.52	Tair
2012-06-23	7:00:00	9.46	Tair
2012-06-23	8:00:00	10.13	Tair
2012-06-23	9:00:00	12.78	Tair
2012-06-23	10:00:00	14.09	Tair
2012-06-23	11:00:00	14.86	Tair
2012-06-23	12:00:00	15.32	Tair
2012-06-23	13:00:00	15.99	Tair
2012-06-23	14:00:00	16.92	Tair
2012-06-23	15:00:00	17.3	Tair
2012-06-23	16:00:00	17.03	Tair
2012-06-23	17:00:00	16.43	Tair
2012-06-23	18:00:00	16.8	Tair
2012-06-23	19:00:00	15.32	Tair
2012-06-23	20:00:00	15.43	Tair
2012-06-23	21:00:00	15.53	Tair
2012-06-23	22:00:00	14.62	Tair
2012-06-23	23:00:00	14.33	Tair
2012-06-24	0:00:00	13.85	Tair
2012-06-24	1:00:00	13	Tair
2012-06-24	2:00:00	12.21	Tair
2012-06-24	3:00:00	11.75	Tair
2012-06-24	4:00:00	11.27	Tair
2012-06-24	5:00:00	10.26	Tair
2012-06-24	6:00:00	9.84	Tair
2012-06-24	7:00:00	9.15	Tair
2012-06-24	8:00:00	9.5	Tair
2012-06-24	9:00:00	10.91	Tair
2012-06-24	10:00:00	12.5	Tair
2012-06-24	11:00:00	12.65	Tair
2012-06-24	12:00:00	13.53	Tair

2012-06-24	13:00:00	14.82	Tair
2012-06-24	14:00:00	15.86	Tair
2012-06-24	15:00:00	16.14	Tair
2012-06-24	16:00:00	16.69	Tair
2012-06-24	17:00:00	16.76	Tair
2012-06-24	18:00:00	16.32	Tair
2012-06-24	19:00:00	15.82	Tair
2012-06-24	20:00:00	14.95	Tair
2012-06-24	21:00:00	13.86	Tair
2012-06-24	22:00:00	12.57	Tair
2012-06-24	23:00:00	11.17	Tair
2012-06-25	0:00:00	9.67	Tair
2012-06-25	1:00:00	8.49	Tair
2012-06-25	2:00:00	6.864	Tair
2012-06-25	3:00:00	6.052	Tair
2012-06-25	4:00:00	5.488	Tair
2012-06-25	5:00:00	5.349	Tair
2012-06-25	6:00:00	4.864	Tair
2012-06-25	7:00:00	4.99	Tair
2012-06-25	8:00:00	4.903	Tair
2012-06-25	9:00:00	5.333	Tair
2012-06-25	10:00:00	5.584	Tair
2012-06-25	11:00:00	6.667	Tair
2012-06-25	12:00:00	7.95	Tair
2012-06-25	13:00:00	8.95	Tair
2012-06-25	14:00:00	9.76	Tair
2012-06-25	15:00:00	9.92	Tair
2012-06-25	16:00:00	10.58	Tair
2012-06-25	17:00:00	10.77	Tair
2012-06-25	18:00:00	10.42	Tair
2012-06-25	19:00:00	10.07	Tair
2012-06-25	20:00:00	9.51	Tair
2012-06-25	21:00:00	8.6	Tair
2012-06-25	22:00:00	6.821	Tair
2012-06-25	23:00:00	5.726	Tair
2012-06-26	0:00:00	4.682	Tair
2012-06-23	1:00:00	8.61	Tsoil
2012-06-23	2:00:00	6.797	Tsoil
2012-06-23	3:00:00	5.885	Tsoil
2012-06-23	4:00:00	6.351	Tsoil

2012-06-23	5:00:00	5.562	Tsoil
2012-06-23	6:00:00	4.836	Tsoil
2012-06-23	7:00:00	4.77	Tsoil
2012-06-23	8:00:00	5.126	Tsoil
2012-06-23	9:00:00	6.938	Tsoil
2012-06-23	10:00:00	9.53	Tsoil
2012-06-23	11:00:00	12.18	Tsoil
2012-06-23	12:00:00	15.24	Tsoil
2012-06-23	13:00:00	17.64	Tsoil
2012-06-23	14:00:00	21.01	Tsoil
2012-06-23	15:00:00	22.04	Tsoil
2012-06-23	16:00:00	18.46	Tsoil
2012-06-23	17:00:00	15.23	Tsoil
2012-06-23	18:00:00	16.02	Tsoil
2012-06-23	19:00:00	14.34	Tsoil
2012-06-23	20:00:00	14.72	Tsoil
2012-06-23	21:00:00	15.13	Tsoil
2012-06-23	22:00:00	13.09	Tsoil
2012-06-23	23:00:00	11.21	Tsoil
2012-06-24	0:00:00	9.57	Tsoil
2012-06-24	1:00:00	8.54	Tsoil
2012-06-24	2:00:00	7.39	Tsoil
2012-06-24	3:00:00	6.803	Tsoil
2012-06-24	4:00:00	6.445	Tsoil
2012-06-24	5:00:00	5.876	Tsoil
2012-06-24	6:00:00	5.326	Tsoil
2012-06-24	7:00:00	5.005	Tsoil
2012-06-24	8:00:00	5.476	Tsoil
2012-06-24	9:00:00	6.258	Tsoil
2012-06-24	10:00:00	8.82	Tsoil
2012-06-24	11:00:00	11.5	Tsoil
2012-06-24	12:00:00	14.42	Tsoil
2012-06-24	13:00:00	17.99	Tsoil
2012-06-24	14:00:00	19.33	Tsoil
2012-06-24	15:00:00	19.46	Tsoil
2012-06-24	16:00:00	19.68	Tsoil
2012-06-24	17:00:00	19.21	Tsoil
2012-06-24	18:00:00	18.03	Tsoil
2012-06-24	19:00:00	16.06	Tsoil
2012-06-24	20:00:00	13.97	Tsoil

2012-06-24	21:00:00	12.33	Tsoil
2012-06-24	22:00:00	11.29	Tsoil
2012-06-24	23:00:00	9.9	Tsoil
2012-06-25	0:00:00	8.01	Tsoil
2012-06-25	1:00:00	6.163	Tsoil
2012-06-25	2:00:00	4.364	Tsoil
2012-06-25	3:00:00	3.462	Tsoil
2012-06-25	4:00:00	2.816	Tsoil
2012-06-25	5:00:00	2.631	Tsoil
2012-06-25	6:00:00	2.661	Tsoil
2012-06-25	7:00:00	2.982	Tsoil
2012-06-25	8:00:00	3.457	Tsoil
2012-06-25	9:00:00	4.386	Tsoil
2012-06-25	10:00:00	5.191	Tsoil
2012-06-25	11:00:00	7.19	Tsoil
2012-06-25	12:00:00	10.42	Tsoil
2012-06-25	13:00:00	13.81	Tsoil
2012-06-25	14:00:00	16.72	Tsoil
2012-06-25	15:00:00	16.69	Tsoil
2012-06-25	16:00:00	17.9	Tsoil
2012-06-25	17:00:00	17.59	Tsoil
2012-06-25	18:00:00	15.36	Tsoil
2012-06-25	19:00:00	13.6	Tsoil
2012-06-25	20:00:00	11.91	Tsoil
2012-06-25	21:00:00	10.02	Tsoil
2012-06-25	22:00:00	7.91	Tsoil
2012-06-25	23:00:00	6.361	Tsoil
2012-06-26	0:00:00	4.805	Tsoil
2012-06-23	1:00:00	3.781	Tgrnd
2012-06-23	2:00:00	3.071	Tgrnd
2012-06-23	3:00:00	2.549	Tgrnd
2012-06-23	4:00:00	2.502	Tgrnd
2012-06-23	5:00:00	2.355	Tgrnd
2012-06-23	6:00:00	2.04	Tgrnd
2012-06-23	7:00:00	1.827	Tgrnd
2012-06-23	8:00:00	1.874	Tgrnd
2012-06-23	9:00:00	2.443	Tgrnd
2012-06-23	10:00:00	3.963	Tgrnd
2012-06-23	11:00:00	5.691	Tgrnd
2012-06-23	12:00:00	7.47	Tgrnd

2012-06-23	13:00:00	8.39	Tgrnd
2012-06-23	14:00:00	9.58	Tgrnd
2012-06-23	15:00:00	9.95	Tgrnd
2012-06-23	16:00:00	9.26	Tgrnd
2012-06-23	17:00:00	7.61	Tgrnd
2012-06-23	18:00:00	7.4	Tgrnd
2012-06-23	19:00:00	6.809	Tgrnd
2012-06-23	20:00:00	7.03	Tgrnd
2012-06-23	21:00:00	6.592	Tgrnd
2012-06-23	22:00:00	6.079	Tgrnd
2012-06-23	23:00:00	5.231	Tgrnd
2012-06-24	0:00:00	4.709	Tgrnd
2012-06-24	1:00:00	4.368	Tgrnd
2012-06-24	2:00:00	3.83	Tgrnd
2012-06-24	3:00:00	3.488	Tgrnd
2012-06-24	4:00:00	3.232	Tgrnd
2012-06-24	5:00:00	2.915	Tgrnd
2012-06-24	6:00:00	2.639	Tgrnd
2012-06-24	7:00:00	2.267	Tgrnd
2012-06-24	8:00:00	2.268	Tgrnd
2012-06-24	9:00:00	2.515	Tgrnd
2012-06-24	10:00:00	4.086	Tgrnd
2012-06-24	11:00:00	5.872	Tgrnd
2012-06-24	12:00:00	7.31	Tgrnd
2012-06-24	13:00:00	8.49	Tgrnd
2012-06-24	14:00:00	9.16	Tgrnd
2012-06-24	15:00:00	9.34	Tgrnd
2012-06-24	16:00:00	9.08	Tgrnd
2012-06-24	17:00:00	8.61	Tgrnd
2012-06-24	18:00:00	8.15	Tgrnd
2012-06-24	19:00:00	7.74	Tgrnd
2012-06-24	20:00:00	7.03	Tgrnd
2012-06-24	21:00:00	6.446	Tgrnd
2012-06-24	22:00:00	5.856	Tgrnd
2012-06-24	23:00:00	5.289	Tgrnd
2012-06-25	0:00:00	4.607	Tgrnd
2012-06-25	1:00:00	3.751	Tgrnd
2012-06-25	2:00:00	2.778	Tgrnd
2012-06-25	3:00:00	2.07	Tgrnd
2012-06-25	4:00:00	1.55	Tgrnd

2012-06-25	5:00:00	1.26	Tgrnd
2012-06-25	6:00:00	1.057	Tgrnd
2012-06-25	7:00:00	1.125	Tgrnd
2012-06-25	8:00:00	1.218	Tgrnd
2012-06-25	9:00:00	1.637	Tgrnd
2012-06-25	10:00:00	2.056	Tgrnd
2012-06-25	11:00:00	2.877	Tgrnd
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2012-06-25	13:00:00	6.115	Tgrnd
2012-06-25	14:00:00	7.34	Tgrnd
2012-06-25	15:00:00	7.66	Tgrnd
2012-06-25	16:00:00	7.67	Tgrnd
2012-06-25	17:00:00	7.41	Tgrnd
2012-06-25	18:00:00	6.89	Tgrnd
2012-06-25	19:00:00	6.652	Tgrnd
2012-06-25	20:00:00	6.278	Tgrnd
2012-06-25	21:00:00	5.645	Tgrnd
2012-06-25	22:00:00	4.99	Tgrnd
2012-06-25	23:00:00	4.258	Tgrnd
2012-06-26	0:00:00	3.533	Tgrnd

Meteorological station record provided by Scott Williamson.