WATER RESOURCES RESEARCH, VOL. 37, NO. 11, PAGES 2843–2846, NOVEMBER 2001

Long-term soil temperature database, Reynolds Creek Experimental Watershed, Idaho, United States

M. S. Seyfried, G. N. Flerchinger, M. D. Murdock, C. L. Hanson,
and S. Van Vactor

Northwest Watershed Research Center, Agricultural Research Service, U.S. Department of Agriculture
Boise, Idaho, USA

Abstract. We describe long-term soil temperature data collected at the Reynolds Creek Experimental Watershed (RCEW). These data were collected for over 15 years at five locations representing different climatic regimes and soils in the RCEW. Measurements were made at several depths at each site to a depth of 180 cm in most cases. Each site is located in close proximity to a climate station. Descriptive soil profile information is also available for each site. We illustrate two aspects of the data set, the impact of snow depth on soil temperature and the interannual variability of soil temperature at a site. These data are available to the public via the U.S. Department of Agriculture, Agricultural Research Service, Northwest Watershed Research Center anonymous ftp site ftp.nwrc.ars.usda.gov.

1. Introduction

Soil temperature exerts a strong and often overlooked role in a number of critical processes. The mineralization of plant nutrients, such as nitrogen, along with the consequent liberation of carbon dioxide, is strongly temperature-dependent [*Sommers et al*., 1981]. Other biological processes, such as plant root growth and seed germination, are also dependent on soil temperature. Surface energy balance, which supplies an important and often poorly described feedback to atmospheric forcings, is also directly related to soil temperature. Soil temperature has added significance in the Reynolds Creek Experimental Watershed (RCEW) and many relatively high-latitude or high-elevation locations because of the impact of soil freezing on hydrologic processes. In this report we describe how the long-term soil temperature data at the RCEW were collected and illustrate some aspects of soil temperature dynamics they portray.

2. Data Collection

Long-term soil temperature data were collected at multiple depths at five locations that range in elevation from 1190 to 2101 m (see Plate 3c of *Slaughter et al*. [this issue] for locations). Each soil temperature depth profile is located near at least one neutron access tube and a precipitation gauge, and complete climate station information was collected either at the site or in reasonably proximity [*Slaughter et al*., this issue]. All profiles are located on nearly level slopes. Soil profile descriptions corresponding to neutron access tubes are also available [*Seyfried et al*., this issue (b)].

The vegetation at all five sites is dominated by different subspecies of sagebrush. Plant community distributions are described by *Seyfried et al*. [this issue (a)]. A more detailed description of the plant communities is given by *Seyfried et al*. [2000b] (also available from ftp.nwrc.ars.usda.gov). At the Flats, Quonset, and Nancy Gulch sites the dominant plant community is Wyoming big sagebrush, which grows to a height of 0.30–0.60 m. Plant cover, including understory grasses and forbs, is generally <50% of the soil surface. At Lower Sheep Creek the dominant plant community is low sagebrush, which usually grows to a height of ~0.30 m. Ground cover of plants is a little greater than at the lower-elevation sites, ~50% of the soil surface. At Reynolds Mountain the dominant plant community is vaseyana (or mountain) big sagebrush, which typically grows to a height of 0.45–0.60 m. Plant ground cover is greatest at this site, ~60%.

Regular data collection started in 1981 or 1982, depending on the site (Table 1). The temperature sensors used were YSI (Yellow Springs Instruments, Yellow Springs, Ohio) two-thermistor composite thermolinear components accurate to ±0.15°C. Data were originally collected in 1981 by connecting a hand-held voltmeter to the sensor leads. Individual sensors at different depths were read using a manual switch. These data were collected once each week, and the time was recorded. At some sites the switches were bypassed and hooked up to data loggers of various design resulting in more frequent (either 1 or 4 hour) recording intervals (Table 1).

Prior to 1990, soil temperature sensors were installed by attaching the sensors to a 0.05 m diameter wooden pole at the desired depth intervals, drilling a hole a with a drill rig (the soils in the RCEW are very rocky), inserting the pole in the drilled hole, and backfilling. In most sites, there were six or seven measurement depths ranging from 2.5 to 240 cm. In many cases the performance of sensors was observed to deteriorate slowly over time. Apparently, water gradually entered the sensors as the potting compound used to seal the sensors slowly deteriorated, thus altering the circuit resistance of the sensors.

In 1990, new sensors were installed at all sites at depths of 5, 10, 20, 30, 40, 50, 60, 90, 120, and 180 cm. These sensors were of the same design, but a few changes were made. First, the potting compounds used were changed based on considerable experience gained since the previous installation. Second, all sensors were read with Campbell data loggers and recorded

Paper number 2001WR000418.

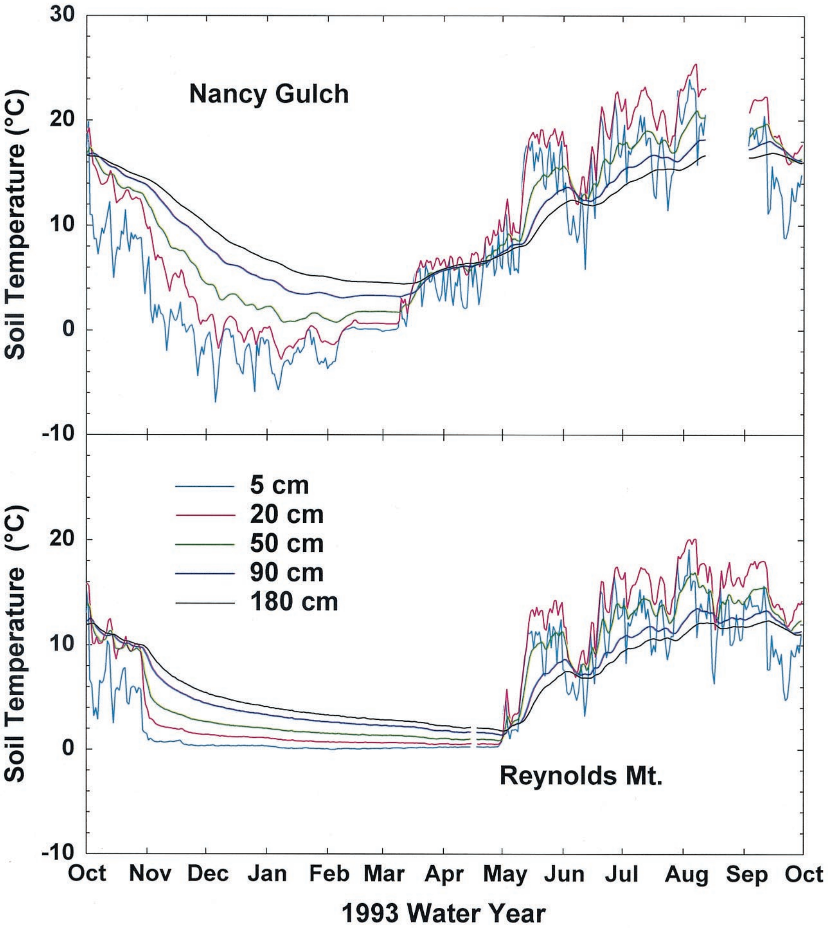

Plate 1. Soil temperature recorded each day at 12:00 A.M. at Nancy Gulch and Reynolds Mountain during water year 1993. Soil temperatures at the higher-elevation, cooler site (Reynolds Mountain) are higher during the winter because of the insulating effects of snow cover.

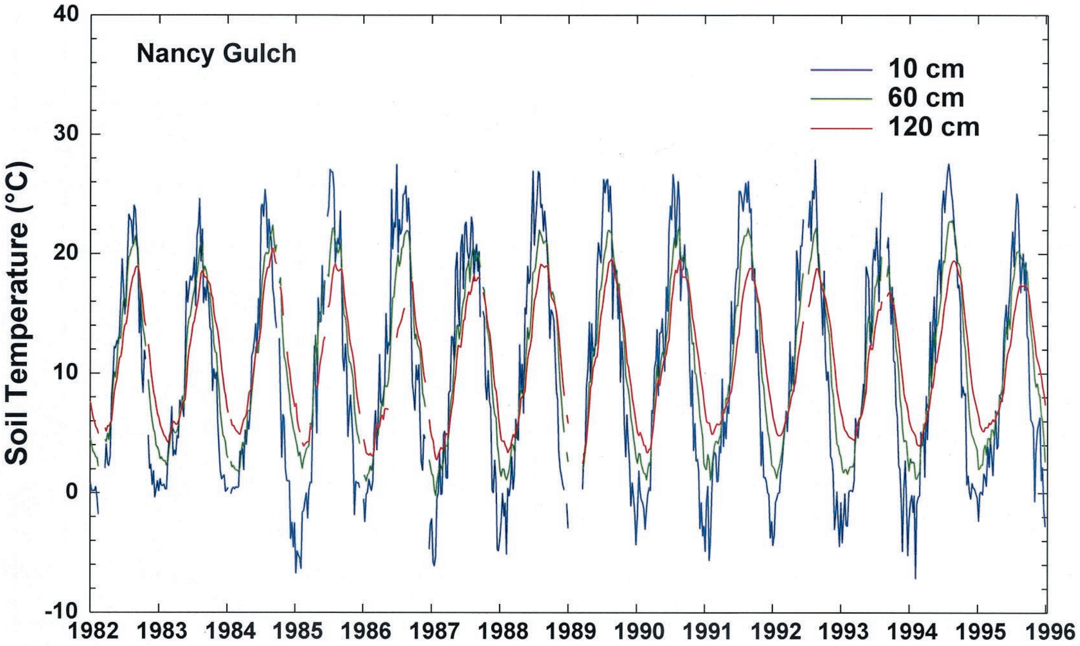

Plate 2. Soil temperature at three depths, 10, 60, and 120 cm, as recorded at noon every 7 days for more than 14 years at Nancy Gulch. These data illustrate the interannual variation and damping of soil temperature with depth.

Table 1. Soil Temperature Measurement Depths and Temporal Intervals[a]

Station Identification	Period	Interval	Depths, cm
Flats 057x96	March 1981 to July 1990	weekly	10, 30, 60, 90, 120, 180
	August 1990 to October 1992	weekly	5, 20, 30, 50, 120
	November 1992 to September 1996	1 hour	5, 10, 20, 30, 50, 60, 90, 120, 180
Quonset 076x59	January 1981 to July 1985	4 hour	2.5, 5, 10, 15, 20, 30, 40, 55, 70
	August 1985 to June 1994	1 hour	2.5, 5, 10, 15, 20, 30, 40, 60, 90
	June 1994 to September 1996	1 hour	5, 10, 20, 30, 40, 50, 60, 90, 120, 180
Nancy Gulch 098x97	November 1981 to June 1985	1 hour	10, 30, 60, 90, 120
	June 1985 to September 1990	1 hour	5, 10, 30, 60, 90, 120, 180, 240
	September 1990 to September 1996	1 hour	5, 10, 20, 30, 40, 50, 60, 90, 120, 180
Lower Sheep Creek 127x07	January 1982 to December 1984	weekly	10, 30, 60, 90, 120, 180, 240
	December 1984 to September 1990	1 hour	10, 30, 120
	September 1990 to September 1996	1 hour	5, 10, 20, 30, 40, 50, 60, 90, 120, 180
Reynolds Mountain 176x14	December 1981 to August 1990	weekly	10, 30, 60, 90, 120, 180, 240
	August 1990 to May 1992	weekly	5, 10, 20, 30, 40, 50, 60, 90, 120, 180
	June 1992 to September 1996	1 hour	5, 10, 20, 30, 40, 50, 60, 90, 120, 180

[a] In some cases, especially prior to 1990, there are significant data gaps due to sensor failure.

hourly. (Each hourly recorded value is the average of six 10 min readings such that the 12:00 P.M. recorded value is the average of the 11:10, 11:20, 11:30, 11:40, 11:50 A.M. and 12:00 P.M. readings). Third, the sensors were installed horizontally into the face of an exposed backhoe pit face much as suggested by *Livingston* [1993]. The sensors have generally performed very well since the latest installation.

The soil temperature data are listed by site identification (using six-digit nomenclature related to the site location) and measurement frequency (hourly or daily). For each measurement the date, time (mountain standard time), and temperature in degrees Centigrade are provided. We made a concerted effort to detect gradual deterioration of sensors and eliminate those from the data set. Some such errors, in subtle form, may still exist. We made less of an attempt to eliminate localized "spikes," which should be obvious to the user. We made no effort to interpolate between dates of missing data, which are denoted with a dot.

3. Data Availability

Data from the soil temperature sites described in this report and an electronic copy of a more detailed description of the RCEW soil climate data [*Seyfried et al*., 2000a] are available from the anonymous ftp site ftp.nwrc.ars.usda.gov maintained by the U.S. Department of Agriculture, Agricultural Research Service, Northwest Watershed Research Center in Boise, Idaho, United States. A detailed description of data formats, access information, licensing, and disclaimers is presented by *Slaughter et al*. [this issue].

4. Examples of Data Use

These data allow a variety of analyses of processes related to soil temperature over time in different environments. Of particular interest in this environment is soil freezing because of implications for hydrology. For example, *Flerchinger and Hanson* [1989] found that the soil heat and water (SHAW) model accurately simulated frost depth at three elevations in the RCEW and found that the cooler, higher-elevation site had the least soil frost. In a subsequent paper, *Flerchinger* [1991] showed that SHAW simulations of soil temperature are particularly sensitive to the depth of snow cover, which can effectively insulate the soil. This is illustrated in Plate 1 which shows the effects of snow and ice formation on soil temperature dynamics at two sites in the RCEW.

Nancy Gulch is at a lower elevation (1417 m) than Reynolds Mountain (2100 m) and hence the mean annual air temperature is considerably warmer. Soil temperatures plotted (Plate 1) were recorded at 12:00 A.M. as opposed to hourly, to eliminate diurnal fluctuations which obscure the longer-term patterns. On October 1 the 0.90 and 1.80 m depth temperatures were ~17°C at Nancy Gulch and 12°C at Reynolds Mountain. It is apparent that the two sites experience the same general weather frontal patterns, as evidenced by the soil temperature dip at both sites on June 1. Precipitation immediately prior to November 1 arrived as rain at Nancy Gulch and as snow at Reynolds Mountain. The 5 cm temperature at Nancy Gulch quickly dropped below freezing and was followed at 20 cm in early December. Day-to-day fluctuations were effectively damped while the soil was frozen. The soil surface was essentially snow-free until February 15 when snow covered the site and soil temperatures stabilized with a slightly positive gradient.

By contrast, the 5 cm temperature at Reynolds Mountain rapidly descended to near 0°C but never froze as snow provided a 0°C surface boundary condition. Snow accumulated throughout the winter, effectively insulating the soil and damping temperature fluctuations. During the winter, temperatures at all depths gradually approached 0°C until snow melt, when the temperature at 180 cm was 2°C. Significant day-to-day variation in temperature is evident immediately after the snow cover disappeared on about May 3.

These data also can be used to examine interannual soil temperature variations at a site. Temperatures at Nancy Gulch recorded at noon every seventh day are plotted in Plate 2. The expected seasonal fluctuations are obvious, with minima near the beginning of each year at 10 cm. The temperature range of each annual cycle decreases with depth in an approximately exponential fashion [*Jury et al*., 1991] from ~29°C at 10 cm to ~15°C at 120 cm. Peaks are delayed with depth and appear over 1 month later at 120 cm than at 10 cm. Perhaps a little less widely appreciated is the high degree of interannual stability in the timing and magnitude of soil temperature. Note also the missing data periods, which are typical.

References

Flerchinger, G. N., Sensitivity of soil freezing simulated by the SHAW model, *Trans. ASAE*, *34*, 2381–2389, 1991.

Flerchinger, G. N., and C. L. Hanson, Modeling soil freezing and thawing on a rangeland watershed, *Trans. ASAE*, *32*, 1551–1554, 1989.

Jury, W. A., W. R. Gardner, and W. H. Gardner, *Soil Physics*, 328 pp., John Wiley, New York, 1991.

Livingston, N. J., Soil temperature, in *Soil Sampling and Methods of Analysis*, edited by M. R. Carter, pp. 673–682, Lewis, Boca Raton, Fla., 1993.

Seyfried, M. S., G. N. Flerchinger, C. L. Hanson, M. Murdock, and S. Van Vactor, Long-term microclimate database, Reynolds Creek Experimental Watershed, Idaho, USA, *Tech. Bull. NWRC 2000-7*, 29 pp., Northwest Watershed Res. Cent., Agric. Res. Serv., U.S. Dep. of Agric., Boise, Idaho, 2000a.

Seyfried, M. S., R. C. Harris, D. Marks, and B. Jacob, A geographic database for watershed research, Reynolds Creek Experimental Watershed, Idaho, USA, *Tech. Bull. NWRC 2000-3*, 26 pp., Northwest Watershed Res. Cent., Agric. Res. Serv., U.S. Dep. of Agric., Boise, Idaho, 2000b.

Seyfried, M. S., R. C. Harris, D. Marks, and B. Jacob, Geographic database, Reynolds Creek Experimental Watershed, Idaho, United States, *Water Resour. Res*., this issue (a).

Seyfried, M. S., M. Murdock, C. L. Hanson, G. N. Flerchinger, and S. S. Van Vactor, Long-term soil water content database, Reynolds Creek Experimental Watershed, Idaho, United States, *Water Resour. Res*., this issue (b).

Slaughter, C. W., D. Marks, G. N. Flerchinger, S. S. Van Vactor, and M. Burgess, Thirty-five years of research data collection at the Reynolds Creek Experimental Watershed, Idaho, United States, *Water Resour. Res*., this issue.

Sommers, L. E., C. M. Gilmour, R. E. Wildung, and S. M. Beck, The effect of water potential on decomposition processes in soils, in *Water Potential Relations in Soil Microbiology*, edited by J. E. Parr, W. R. Gardner, and W. R. Elliot, *SSSA Spec. Publ*., *9*, 97–117, 1981.

G. N. Flerchinger, C. L. Hanson, M. D. Murdock, M. S. Seyfried, and S. Van Vactor, Northwest Watershed Research Center, Agricultural Research Service, U.S. Department of Agriculture, 800 Park Blvd., Suite 105, Boise, ID 83712, USA. (gflerchi@nwrc.ars.pnb.usbr.gov; chanson@nwrc.ars.usda.gov; mmurdock@nwrc.ars.usda.gov; mseyfrie@nwrc.ars.usda.gov; ssvanvact@nwrc.ars.usda.gov)

(Received September 6, 2000; revised March 7, 2001;
accepted April 16, 2001.)