Soil Temperatures in Liechtenstein

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1. Introduction

Soil temperatures are significant in agriculture, meteorology, biology, civil engineering (building) and heating systems. They have only been accessible on-line in Liechtenstein since May 2008. The objective of the present work is to summarize the most important results of a study of observations made over a four-year period and to highlight examples of recurring patterns of long, middle and short-term trends.

2. Method

Temperatures have been measured in Liechtenstein at various soil depths since May 18, 2008 as part of the GLOBE Project (http://globe.gov). Four calibrated temperature gauges of the type Campbell Scientific 105T were buried at depths of 5, 10, 50 and 100 cm for this purpose. The measurements were located at the coordinates N 47°09'20'', E 09°30'10'' which was at an elevation of 453 m above sea level. This is an enclosed area of rough pasture located to the west of, and bordering on, the school building of the Liechtenstein Gymnasium, and is moved two to three times annually. The mantel comprised gravel and sand. The cables for the temperature measurements run directly to the recording point in the service facility. The measurements were taken at 10 minute intervals and can be called up from the website http://meteovaduz.schulen.li.

3. Results

3.1. Long term observations over many years

Soil temperatures follow a rhythmic cycle (**Fig.1**) varying between -4 °C and +30 °C. The lowest temperatures were reached in the winter months of January and February, the highest in the summer months from July to September. The coldest value of -4 °C was measured on February 13, 2012 at 06:50 at a depth of 5 cm (**Fig. 2**), the warmest value of +30 °C was also measured at a depth of 5 cm on July 3, 2010 at 17:15 (**Fig. 3**). The soil in the Liechtenstein valley seldom freezes to a depth greater than 30 cm.

3.2. Middle term observations over the seasons

Typical seasonally conditioned profiles are shown in **Fig. 4**. The Spring and Fall months show a near isothermal characteristic. In the summer months the temperatures of the soil are maximum at the surface and maximum in the winter months at the greatest soil depths. The amplitude at the surface of up to 35 °C is thus significantly greater than the some 10 °C at the depth of one meter. The greatest temperature variation occurs in summer, the least in winter.

3.3. Short term observations

3.3.1. Variations in weekly behavior

Weekly observations give information of day/night cycles and show that short-term fluctuations are only evident in the uppermost layers of the soil (**Fig. 5-7**). As the depth is increased the soil reacts more weakly and with a time delay to changes in air temperature. Only long-term changes in the average air temperatures are able to affect the temperature of the deeper layers of soil (**Fig. 1**). During the winter months the upper layers react imperceptibly to changes in the air temperature (**Fig. 6**).

3.3.2. Variations in daily routine

A closer examination of the hourly variation shows clearly that the upper soil levels react faster and more strongly to variations in air temperature than do those at greater depths (**Fig. 7**). The temperatures of the upper levels respond in their form like a whip-lash to the warm summer days (**Fig. 8**). It is clear that in the summer the soil reaches its maximum temperature at only around 17:00 and cools down during the night and continues on into the following morning.

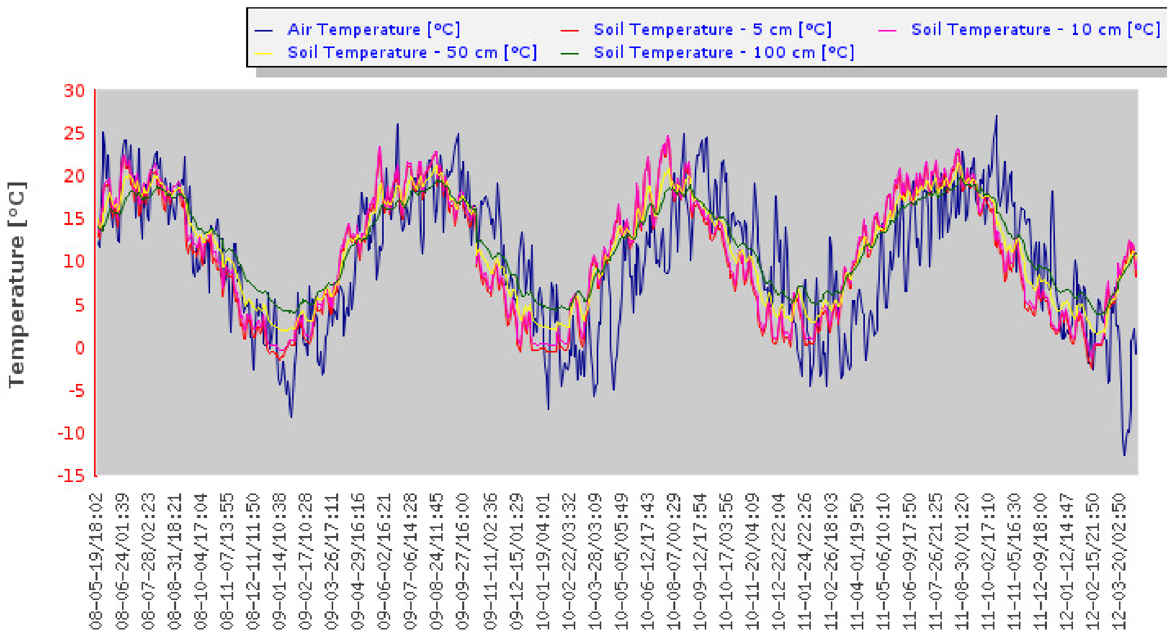

Fig. 1 Profiles of the soil temperatures in Liechtenstein from May 2008 to April 2012

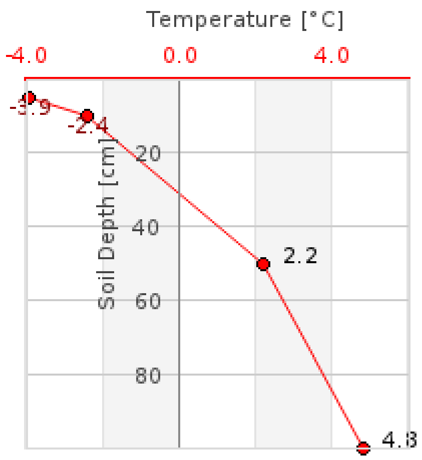

Fig. 2. At 06.50 on February 13, 2012 the soil at a depth of 30 cm was deeply frozen.

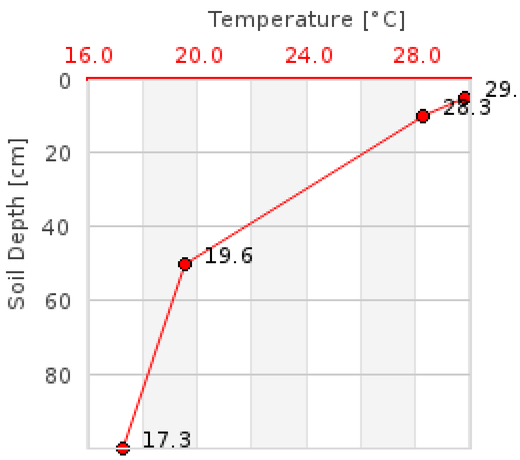

Fig. 3 The warmest soil temperatures were measured at the surface at 17.15 on July 3, 2010.

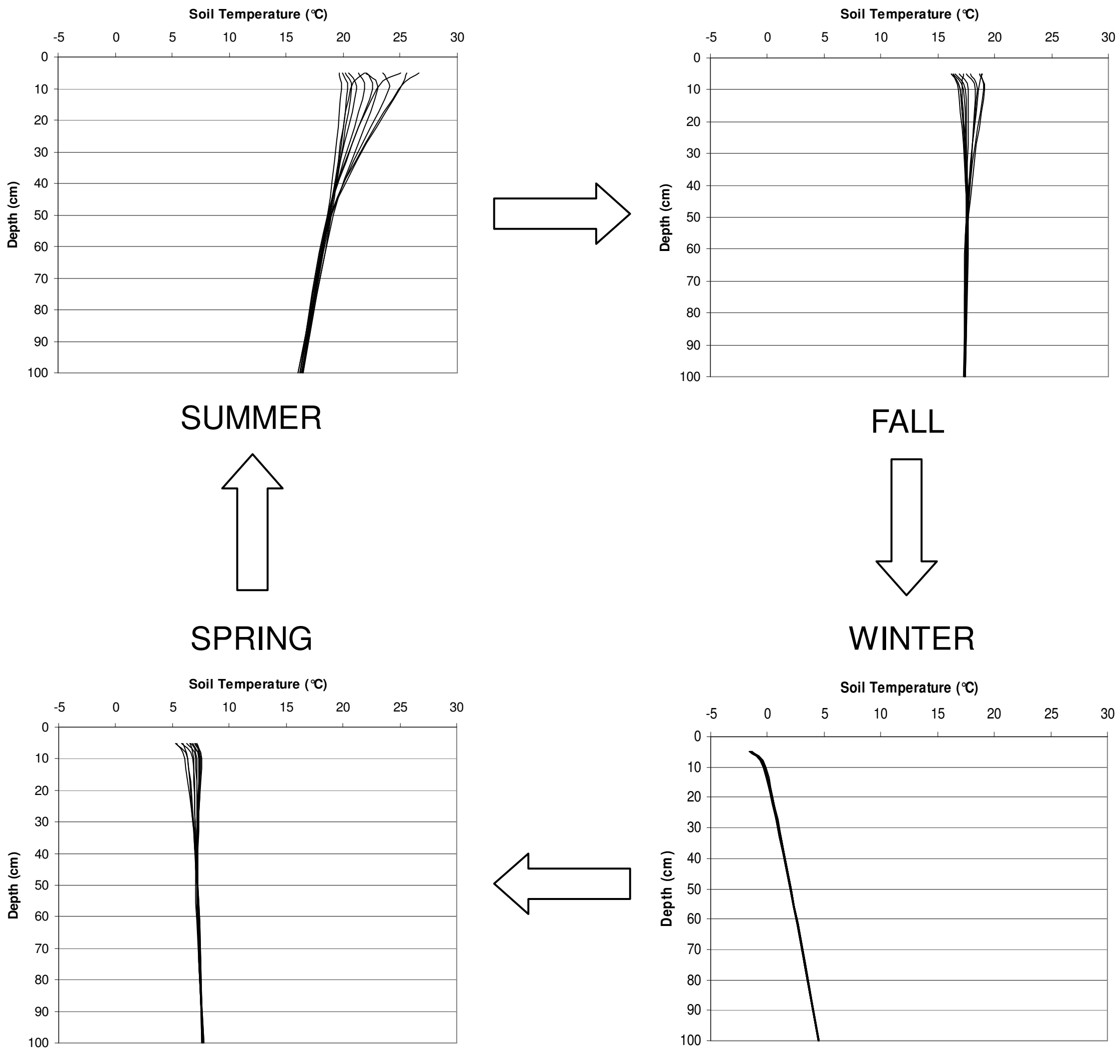

Fig. 4 Examples of typical temperature profiles at various seasons:
Summer (June 23, 2008), Fall (September 11, 2008), Winter (January 12, 2009), Spring (March 31, 2009).

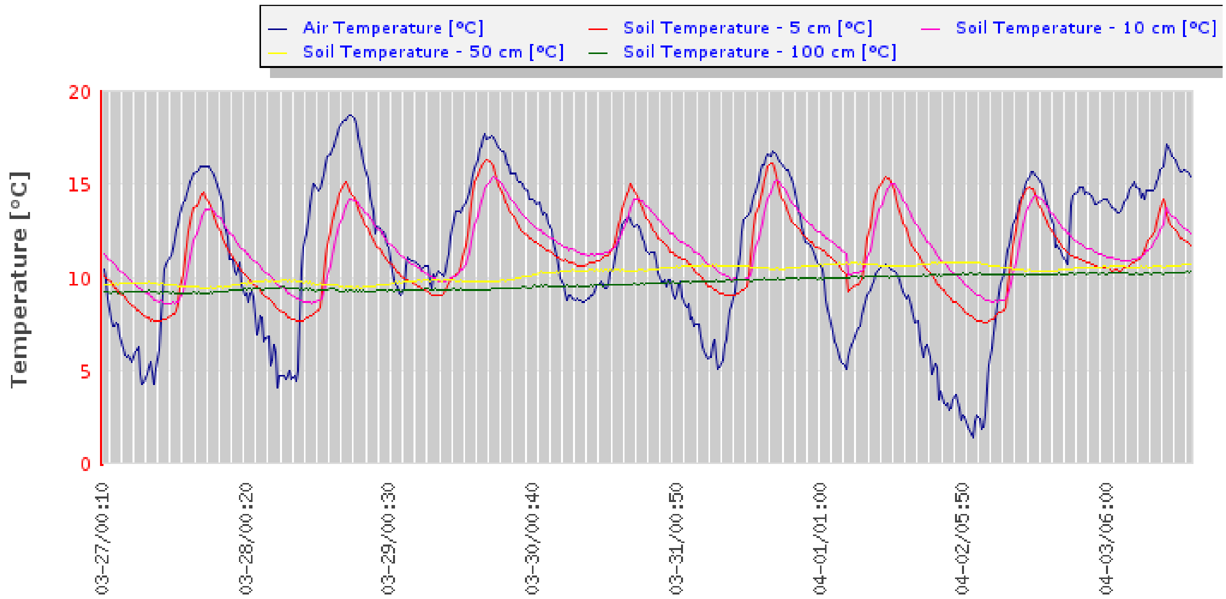

Fig. 5 Example of a typical temperature profile during a week in springtime (March 27, 2012 to April 3, 2012)

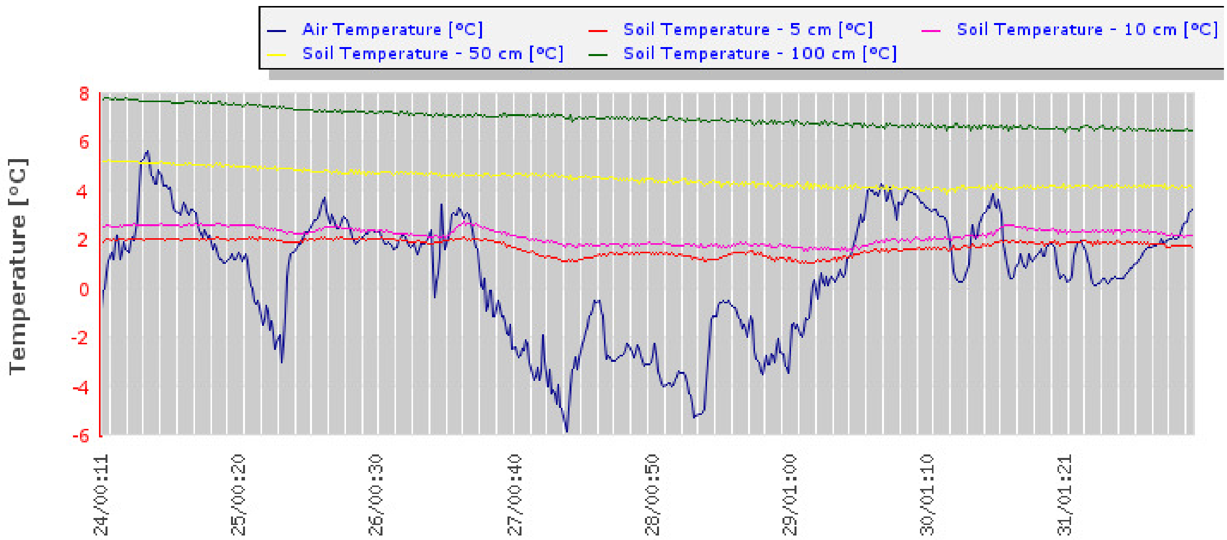

Fig. 6 Example of a typical temperature profile during a week in winter (December 24, 2011 to December 31, 2011)

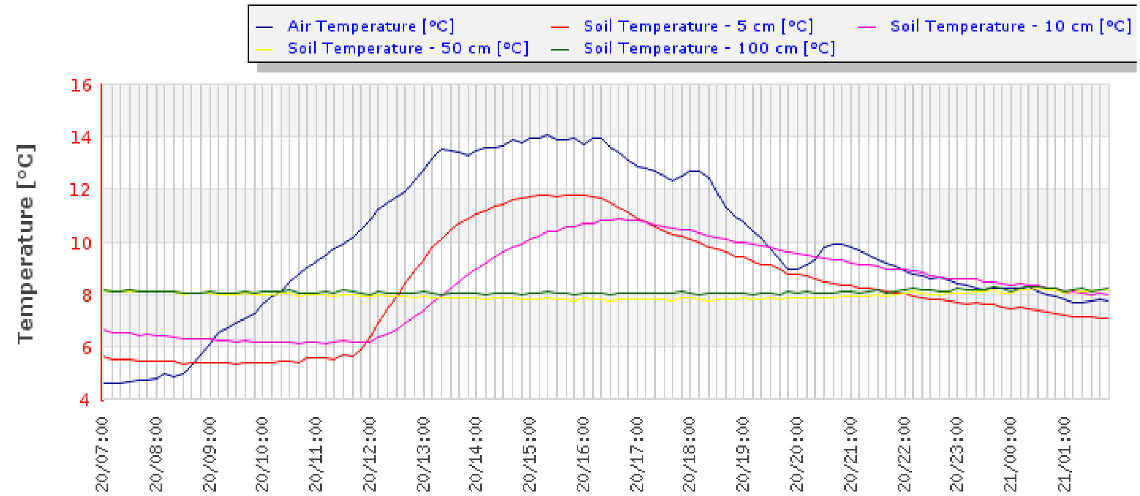

Fig. 7 Example of a typical temperature profile over most of a day (March 20, 2012 to March 21, 2012)

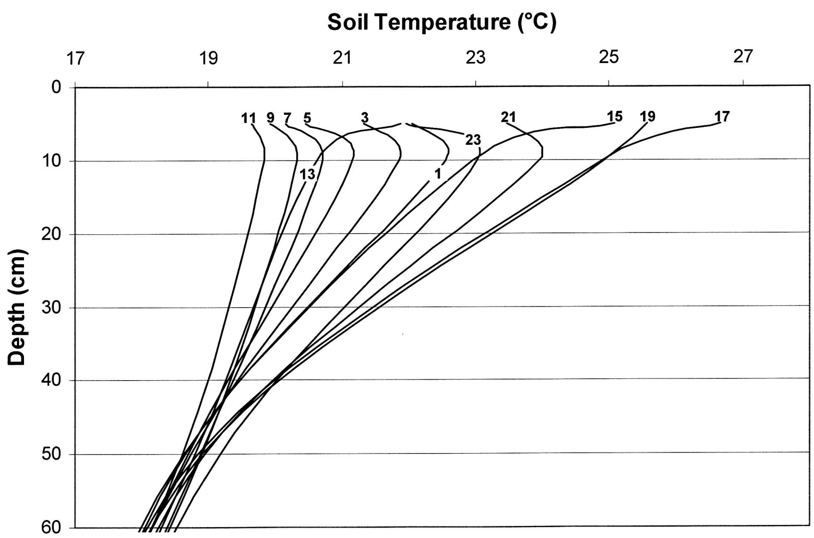

Fig. 8 Temperature values of the uppermost soil layer on a warm summer's day, showing the typical whip-lash profiles (June 23, 2008). The digits 1 to 23 on the curves indicate the hour.

4. Acknowledgements

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