

Supplementary Materials

In Year 2009, 2012, 2013 and 2014, the correlation coefficient between soil temperature and Average detrended SNR is 0.0235, 0.1929, -0.1988 and 0.0740, and they are presented in Fig.1.1- Fig.1.4, the elevation angle used in the analysis is among 45° and 50° . At these large angles, multipath is negligible, and they show no relation with temperature variations.

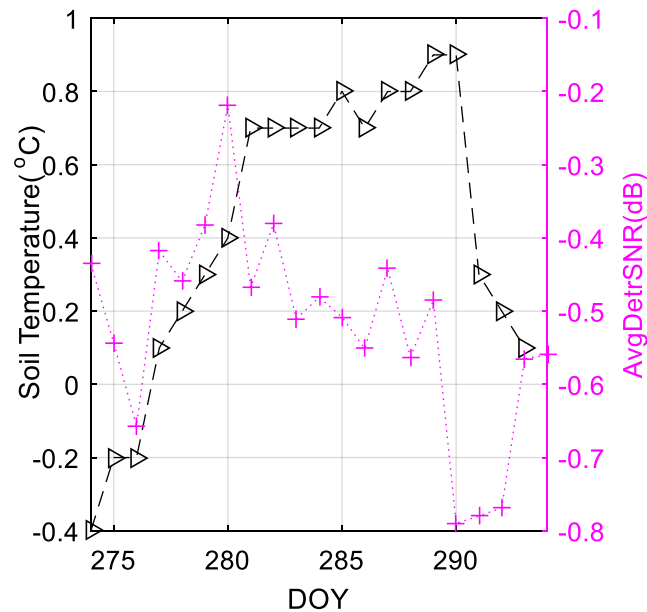


Figure S1.1. Comparisons between GPS site (AB33) and SNOTEL site (ID 958) from DOY 270 (2009) to DOY 295 (2009). The elevation angle is between 45° and 50° . Comparisons of soil temperature (black Δ) and average SNR (pink +) are presented. Low-order polynomial is used to remove the direct signals.

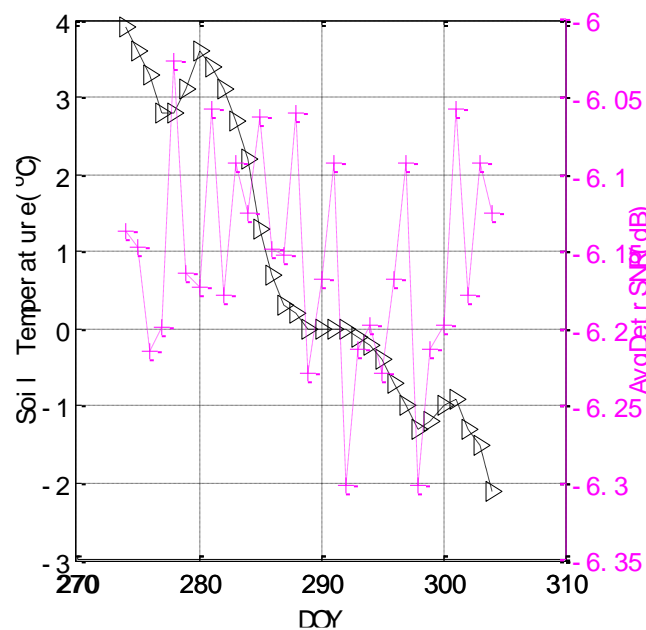


Figure S1.2. Comparisons between GPS site (AB33) and SNOTEL site (ID 958) from DOY 270 (2009) to DOY 310 (2012). The elevation angle is between 45° and 50°. Comparisons of soil temperature (black Δ) and average SNR (pink +) are presented. Low-order polynomial is used to remove the direct signals.

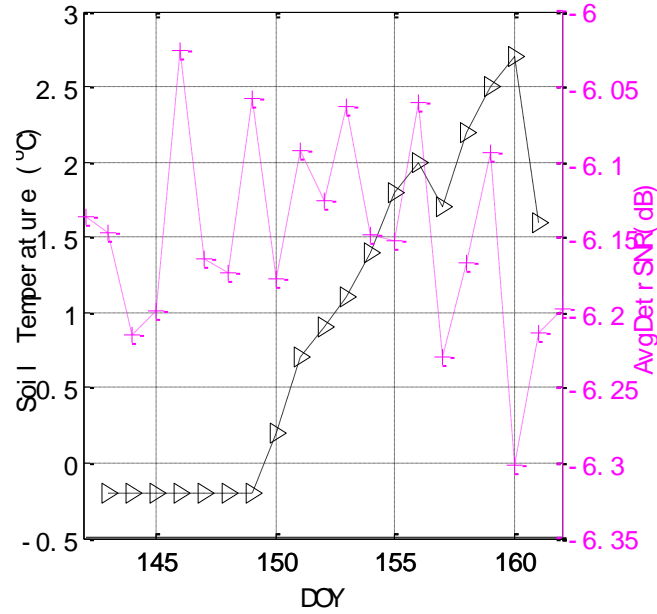


Figure S1.3. Comparisons between GPS site (AB33) and SNOTEL site (ID 958) from DOY 140 (2009) to DOY 165 (2013). The elevation angle is between 45° and 50°. Comparisons of soil temperature (black Δ) and average SNR (pink +) are presented. Low-order polynomial is used to remove the direct signals.

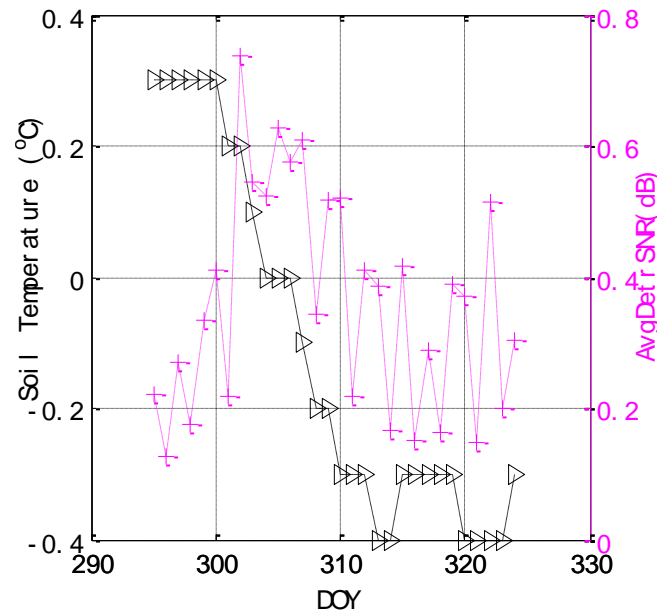


Figure S1.4. Comparisons between GPS site (AB33) and SNOTEL site (ID 958) from DOY 290 (2014) to DOY 330 (2014). The elevation angle is between 45° and 50°. Comparisons of soil temperature (black Δ) and average SNR (pink +) are presented. Low-order polynomial is used to remove the direct signals.

Figure S 2.1-2.8 are provided to illustrate why we have skipped Year 2010 and 2011 and discarded the freezing or thawing event for years 2009, 2012, 2013, and 2014. As can be seen from Fig.2-9, when the thawing or freezing event has occurred, there is sudden change of soil moisture and snow depth, which do not satisfy the data analysis requirements.

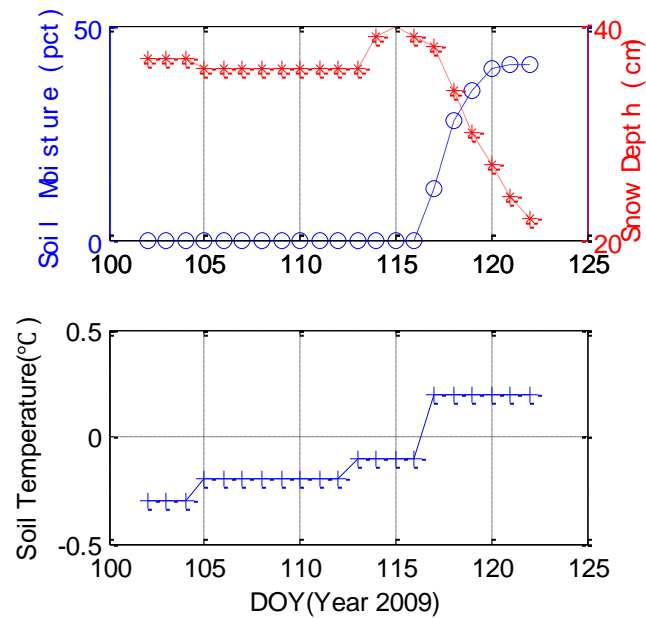


Figure S2.1. Variations of soil moisture, snow depth and soil temperature in the thawing even of Year 2009.

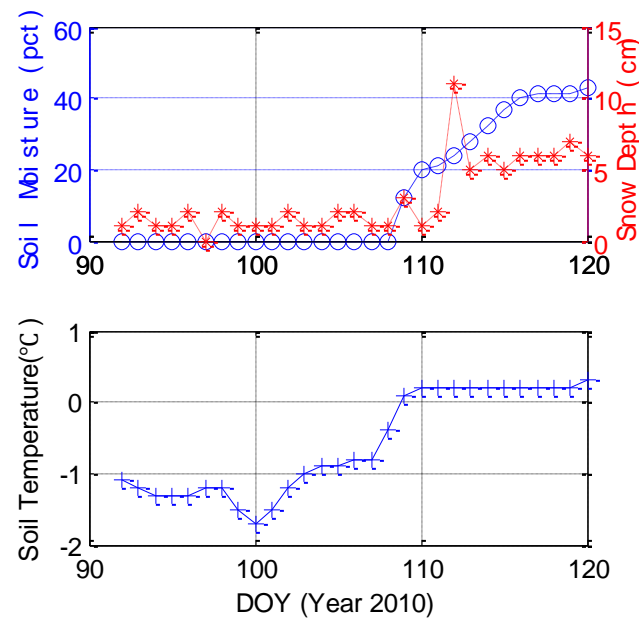


Figure S2.2. Variations of soil moisture, snow depth and soil temperature in the thawing even of Year 2010.

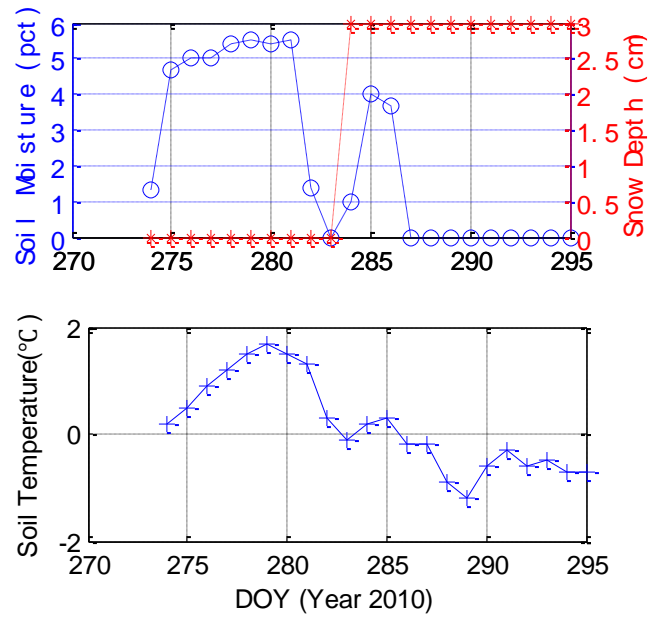


Figure S2.3. Variations of soil moisture, snow depth and soil temperature in the freezing even of Year 2010.

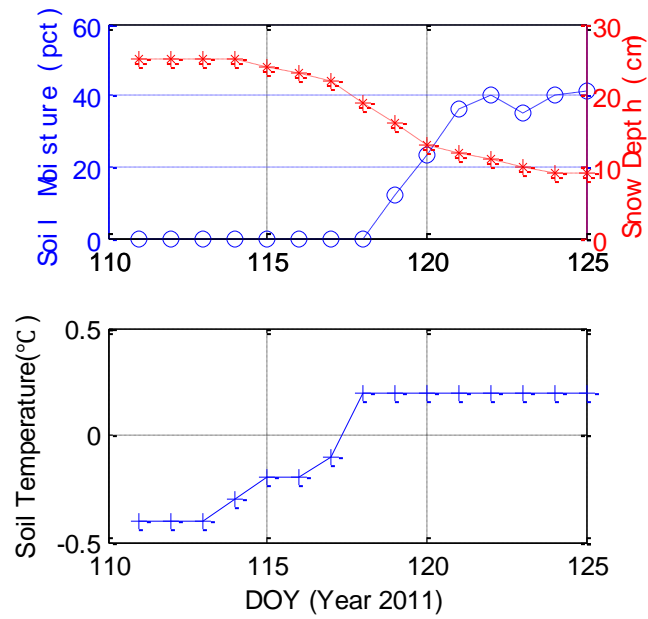


Figure S2.4. Variations of soil moisture, snow depth and soil temperature in the thawing even of Year 2011.

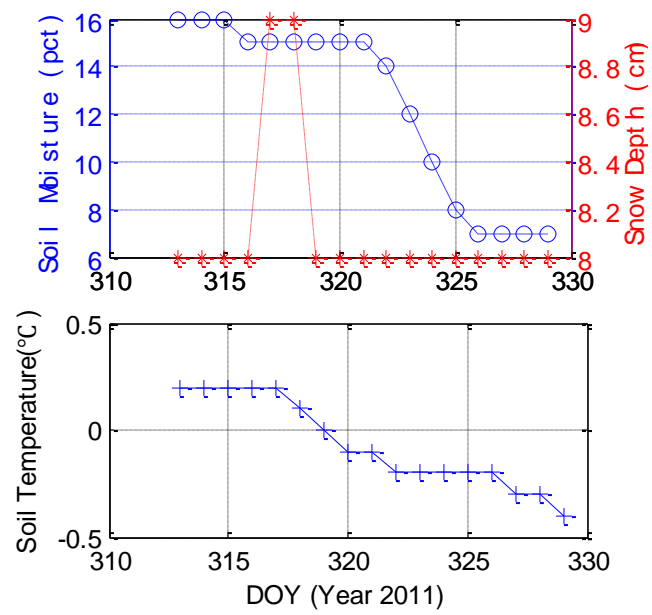


Figure S2.5. Variations of soil moisture, snow depth and soil temperature in the freezing even of Year 2011.

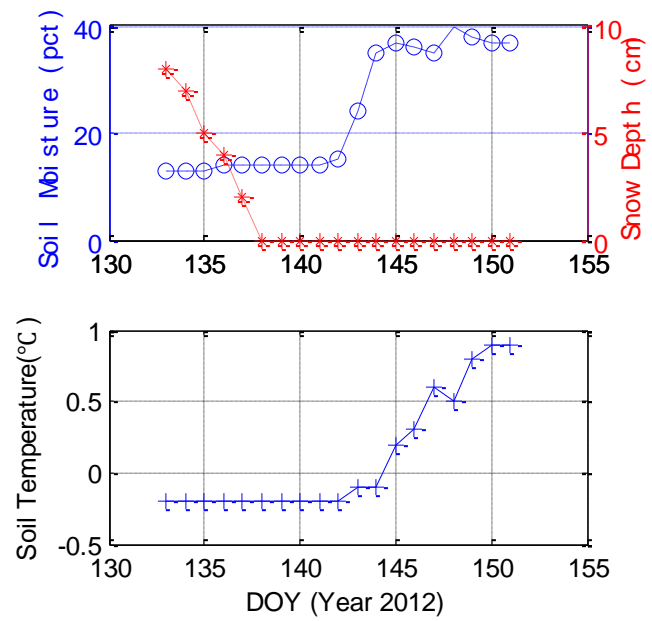


Figure S2.6. Variations of soil moisture, snow depth and soil temperature in the thawing even of Year 2012.

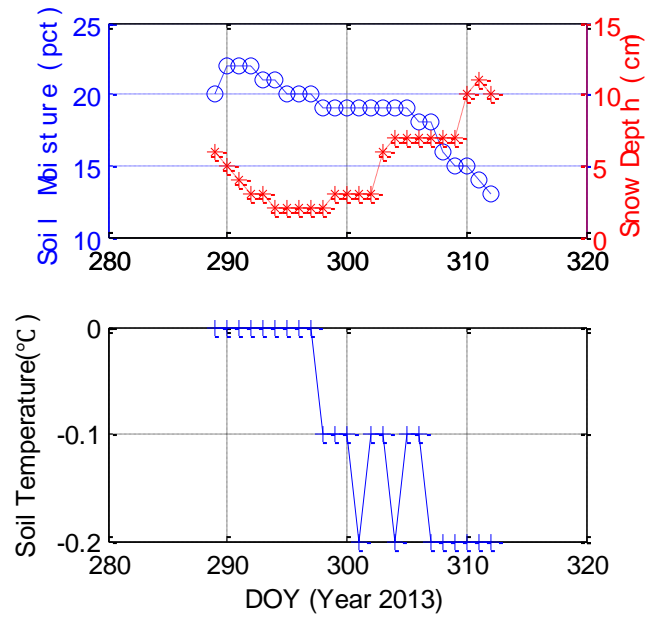


Figure S2.7. Variations of soil moisture, snow depth and soil temperature in the freezing even of Year 2013.

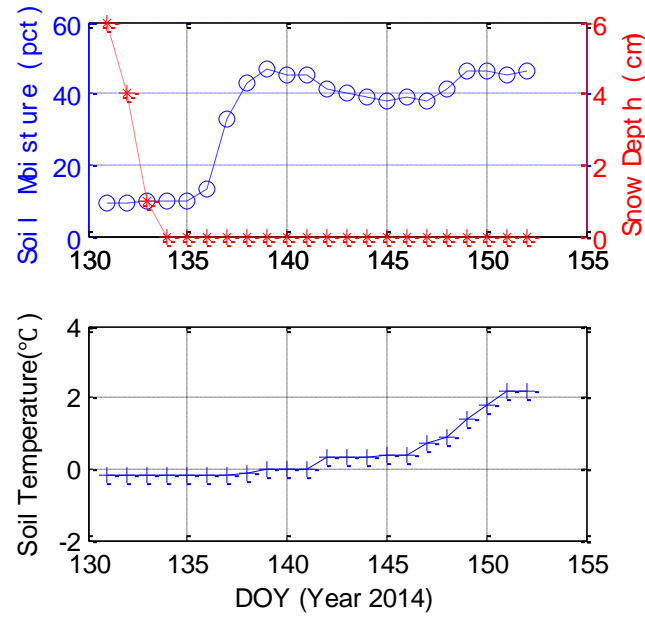


Figure S2.8. Variations of soil moisture, snow depth and soil temperature in the thawing even of Year 2014.

We provide the comparisons of soil temperature and ADSNR for the elevation angles between 10° and 30° , and they indicate that there is a good correlation between these two variables.

As for Year 2009, the absolute correlation coefficient between soil temperature and ADSNR from DOY 270 (2009) to DOY 295 (2009) is 0.8302.

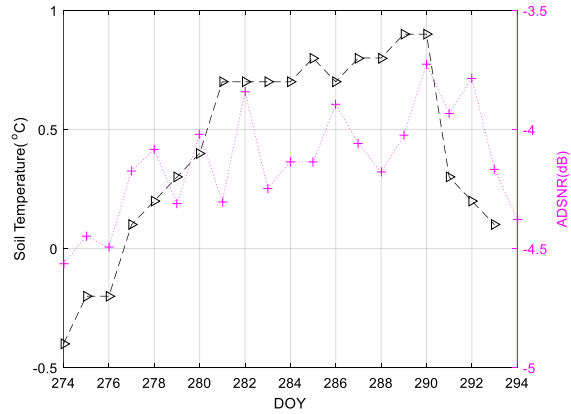


Figure S3.1. Comparison of soil temperature (black \triangle) and ADSNR (pink +) between GPS site (AB33) and SNOTEL site (ID 958) from DOY 270 (2009) to DOY 295 (2009). The elevation angle is 10° - 30° .

As for Year 2009, the absolute correlation coefficient between soil temperature and ADSNR from DOY 270 (2012) to DOY 295 (2012) is -0.8042.

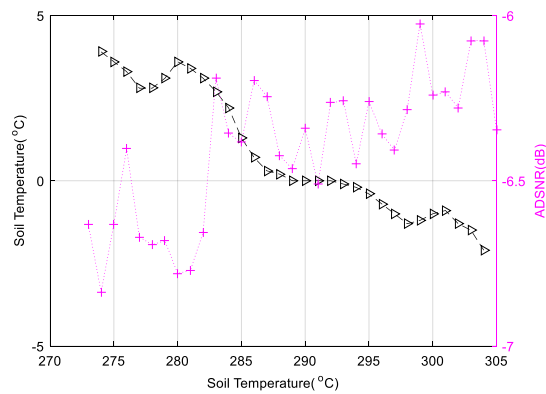


Figure S3.2. Comparison of soil temperature (black \triangle) and ADSNR (pink +) between GPS site (AB33) and SNOTEL site (ID 958) from DOY 270 (2012) to DOY 305 (2012). The elevation angle is 10° - 30° .

From DOY 142 (2013) to DOY 162 in Year 2013, the absolute correlation coefficient between soil temperature and ADSNR is 0.7878.

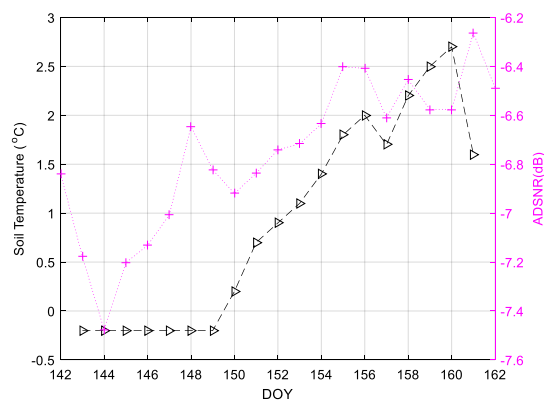


Figure S3.3. Comparison of soil temperature (black \triangle) and ADSNR (pink +) between GPS site (AB33) and SNOTEL site (ID 958) from DOY 142 (2013) to DOY 162 (2013). The elevation angle is 10° - 30° .

From DOY 295 (2014) to DOY 325 (2014) in Year 2014, the absolute correlation coefficient between soil temperature and ADSNR is -0.8302.

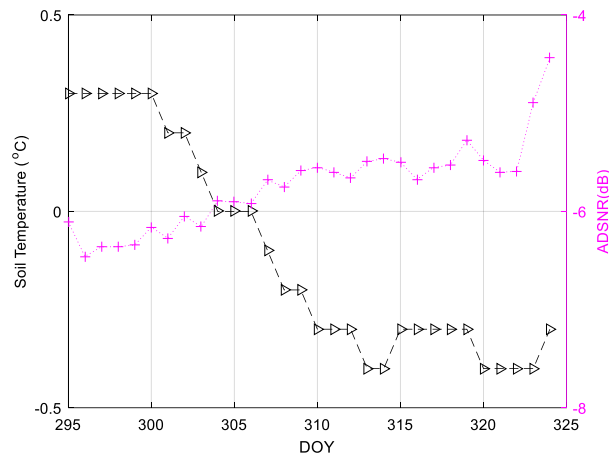


Figure S3.4. Comparison of soil temperature (black \triangle) and ADSNR (pink +) between GPS site (AB33) and SNOTEL site (ID 958) from DOY 295 (2014) to DOY 325 (2014). The elevation angle is 10° - 30° .