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Research papers

Temporal transferability of soil moisture calibration equations

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ABSTRACT

Several large-scale field campaigns have been conducted over the last 20 years that require accurate measurements of soil moisture conditions. These measurements are manually conducted using soil moisture probes which require calibration. The calibration process involves the collection of hundreds of soil moisture cores, which is extremely labor intensive. In 2012, a field campaign was conducted in southern Manitoba in which 55 fields were sampled and calibration equations were derived for each field. The Soil Moisture Active Passive Experiment 2016 (SMAPVEX16) was conducted in this same region, and 21 of the same fields were resampled. This study examines the temporal transferability of calibration equations between these two field campaigns. It was found that the larger range in soil moisture over which samples were collected in 2012 (average range 0.11–0.41 $m^3\ m^{-3}$) generally resulted in lower errors when used in 2016 (average range 0.24–0.44 $m^3\ m^{-3}$) than the equations derived in 2016 when used with data collected in 2012. Combining the data collected in 2012 and 2016 did not improve the errors, overall. These results suggest that the transfer of calibration equations from one year to the next is not recommended.

1. Introduction

Knowledge of soil moisture variability, both spatially and temporally, at different scales is important for the validation of applications such as land surface models and remote sensing products (Crow et al., 2012; Famiglietti et al., 2008; Western et al., 2002). Although gravimetric sampling provides the most accurate estimation of soil moisture, it is labor intensive and time consuming. Electromagnetic sensors have been investigated extensively as an alternative for measuring soil moisture. Numerous studies have been conducted which investigate calibration strategies for soil moisture sensors that relate the measured soil dielectric permittivity to soil water content through (e.g. Bogena et al., 2017; Ojo et al., 2015; Rosenbaum et al., 2010; Rowlandson et al., 2013; Seyfried et al., 2005). Studies have also examined the variability between different commercially available soil moisture sensors. A study by Walker et al. (2004) found that sensors requiring soil disturbance for installation presented the highest errors in soil moistures retrieval despite calibration efforts. Cosh et al. (2016), using data from a soil moisture sensor testbed, found that electromagnetic sensors installed at a depth of 5 cm, when scaled to the field, had similar root mean square errors, all of which were <0.04 $m^3\ m^{-3}$. More specifically, studies have noted that lower frequency sensors exhibit sensitivity in the measurements of the soil dielectric permittivity resulting from the soil electrical conductivity (Seyfried et al., 2005; Seyfried and Murdock, 2004) and changes in soil temperature (Merlin et al., 2007; Wraith and Or, 1999). Inter-sensor variability is an issue that has been noted in several studies (e.g. (Bogena et al., 2017; Cosh et al., 2016; Rosenbaum et al., 2010; Seyfried and Murdock, 2004)); however, it has been noted that sensor-specific calibrations, which prior deriving a relationship between the soil water content and the soil dielectric permittivity, measurements are first made in media of known dielectric permittivity to determine inter-sensor variability (Rosenbaum et al., 2010).

Large-scale field campaigns (~50^2 km^2) have been held where surface soil moisture measurements have been collected across a defined domain in an effort to capture the intra and inter-field soil moisture variability, particularly as it relates to remote sensing applications. Some of these field campaigns include: the Southern

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Great Plains 1997 (SGP97) Hydrology Experiment (Mohanty et al., 2002), the Soil Moisture Experiments (SMEX) in 2002 (Bindlish et al., 2006), 2003 (Bosch et al., 2006; Cosh et al., 2005), 2004 (Bindlish et al., 2008), and 2005 (Cosh et al., 2005); National Airborne Field Experiment 2006 (NAFE'06, Australia) (Merlin et al., 2008); Australian Airborne Cal/Val Experiments for SMOS (AACES) (Peischl et al., 2012); Canadian Experiment for Soil Moisture in 2010 (CanEX-SM10) (Magagi et al., 2013), Soil Moisture Active Passive (SMAP) Validation Experiment in 2012 (SMAPVEX12) (McNairn et al., 2015); and most recently, the SMAPVEX16 field experiment, which was conducted in the same general region as the SMAPVEX12 campaign.

In each of the aforementioned field campaigns, transects or grids of soil moisture were manually sampled at varying spatial scales. For each field campaign, large quantities of soil cores were collected to derive calibration equations (Cosh et al. 2005; Rowlandson et al. 2013). In SMAPVEX12 for example, over 700 cores were collected over the duration of the six week field campaign (Rowlandson et al., 2013). These cores provide the volumetric water content estimates upon which calibration equations are developed for dielectric soil moisture probes. Efficiency and accuracy are critical, because the SMAP mission requirement is to estimate surface soil moisture with an unbiased root mean square error (RMSE) of 0.04 $m^3\,m^{-3}$ relative to ground measurements (Chan et al., 2016). Dielectric probes are an efficient method for estimating soil moisture in the field. However, careful calibration of the ground sampled soil moisture is essential to ensure that the error in ground sampling measurements is less than this threshold.

The purpose of the large field campaigns described above is in the estimation of large-scale soil moisture estimates for the purpose of remote sensing calibration and validation. Therefore, the basis of the design is to collect statistically accurate soil moisture values for contributing land surfaces within the domain of the study in question. Efficient sampling is a key factor in this type of sampling, as time is of the essence in conducting the sampling over large spatial scales. Many of these campaigns are held within the same domain, separated by several years or months (e.g. SMAPVEX12 and SMAPVEX16 in Manitoba, SMAPEx-1 through SMAPEx-3 (Panciera et al., 2014), July 2010, December 2010, September 2011, respectively in Australia's Murrumbidgee catchment). Understanding if it is possible for transferring calibration equations over the same domain from one year to the next would enable future experimental design to be improved.

This study evaluates the temporal transferability of calibration equations, in an effort to minimize the labor intensity associated with core collection during these types of large field campaigns while retaining low calibration RMSEs. The manufacturer of the

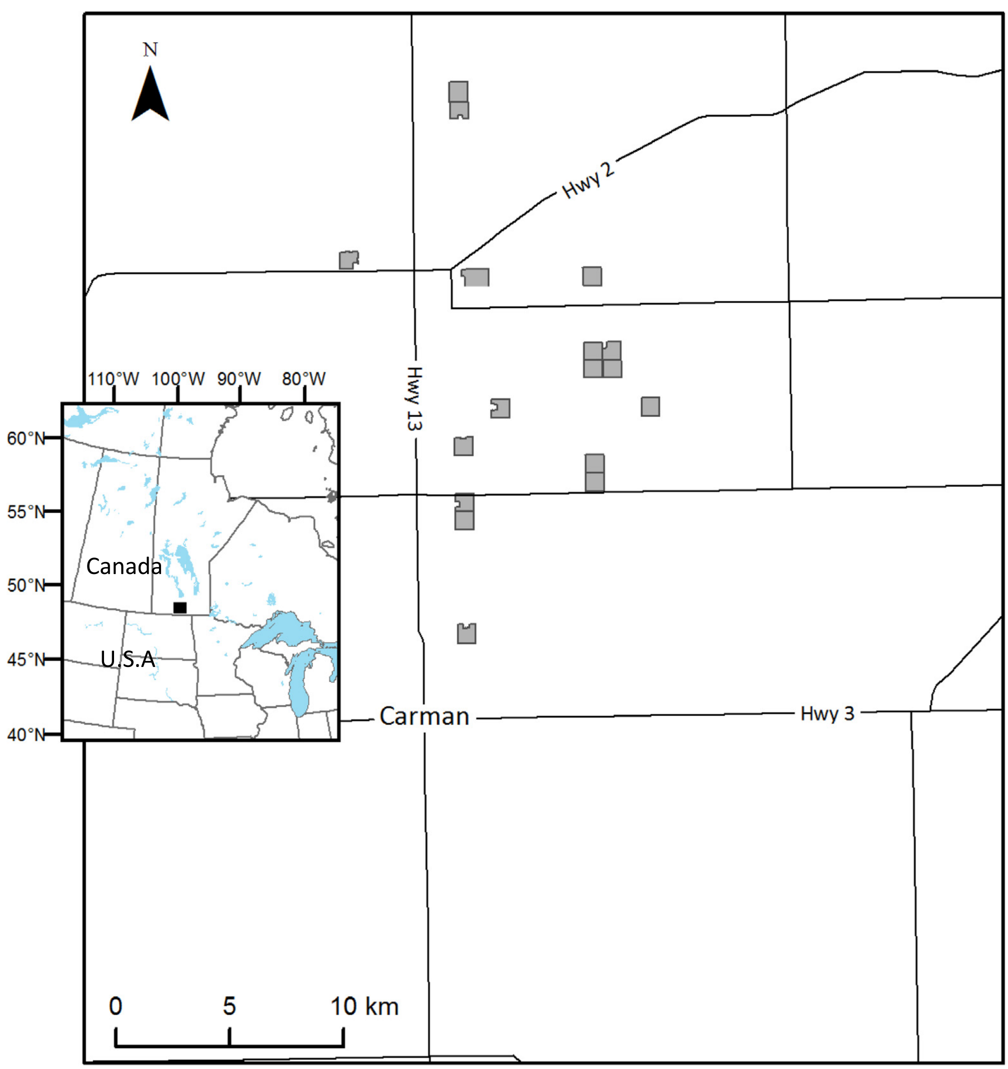

Fig. 1. Map of the SMAPVEX16 Manitoba study region. The fields that are light gray are fields that were sampled in both 2012 and 2016 (17 fields used in this study). Note the location of the study region in the insert.