Remote Sensing of Environment 184 (2016) 86–100

Contents lists available at ScienceDirect

Remote Sensing of Environment

journal homepage: www.elsevier.com/locate/rse

Retrieving soil moisture for non-forested areas using PALS radiometer measurements in SMAPVEX12 field campaign

Andreas Colliander [a,*], Eni G. Njoku [a], Thomas J. Jackson [b], Seth Chazanoff [a], Heather McNairn [c], Jarrett Powers [c], Michael H. Cosh [b]

[a] Jet Propulsion Laboratory, California Institute of Technology, 4800 Oak Grove Drive, Pasadena, CA, USA
[b] USDA-Agriculture Research Service, Hydrology and Remote Sensing Laboratory, Beltsville, MD, USA
[c] Agriculture and Agri-Food Canada, Canada

ARTICLE INFO

Article history:
Received 30 September 2015
Received in revised form 13 May 2016
Accepted 1 June 2016
Available online xxxx

Keywords:
SMAPVEX12
PALS
SMAP
Soil moisture

ABSTRACT

In this paper, soil moisture retrievals of surface soil moisture was investigated using L-band brightness temperature under diverse conditions and land cover types. The study focused on the PALS (Passive Active L-band System) radiometer data collected during the SMAPVEX12 (Soil Moisture Active Passive Validation Experiment 2012) field experiment which took place in southern Manitoba, Canada in 2012. The experiment domain covers croplands with high clay content as well as croplands and grasslands with sandy soils. A retrieval algorithm was parameterized for these specific land types. The formulation of the retrieval algorithm is based on a traditional surface scattering assumption. Based on this data set we found that for the clayey croplands the surface scattering assumption is inadequate, and that the algorithm needed significant tuning for the sandy soils. Empirically-based parameters for retrieving soil moisture under these conditions were developed. We also applied the parameterized algorithm to the retrieval of soil moisture for the entire experiment domain. We found that the use of sub-grid modeling improves the retrieval performance to a satisfactory level despite the challenging land types encountered.

1. Introduction

Retrieving global soil moisture from satellite measurements has been one of the high priorities of the geoscience community for hydrological and meteorological applications for decades (e.g., Beljaars, Viterbo, Miller, & Betts, 1996; Entekhabi, Rodriguez-Iturbide, & Castelli, 1996; Koster et al., 2004). The development of the measurement approach began in the 1970s (Schmugge, Gloersen, Wilheit, & Geiger, 1974) and different techniques have been used in retrieving global soil moisture ever since (e.g., Njoku. & Li., 1999; Wagner, Lemoine, & Rott, 1999). However, even though it was identified very early that measurements at lower frequencies such as L-band are the most promising approach (Schmugge, O'Neill, & Wang, 1986) it took over three decades for the technology to mature to a level that would enable L-band measurements from space at an adequate spatial resolution. The ESA's SMOS (Soil Moisture Ocean Salinity) satellite launched in 2009 (Mecklenburg et al., 2012) was followed in 2015 by NASA's SMAP (Soil Moisture Active Passive) satellite (Entekhabi et al., 2010). Both satellites have radiometers that allow mapping of global soil moisture at a resolution of about 40 km every 2–3 days. The spatial resolution is dictated by the radiometer footprint size but can also be improved with resampling schemes and auxiliary data, see for example, Merlin, Al Bitar, Walker, and Kerr (2010) and Das et al. (2014).

Aircraft-based field experiments have played a key role in the development of microwave radiometer-based soil moisture retrieval algorithms (e.g., Schmugge, Jackson, Kustas, & Wang, 1992; Jackson et al., 1994, 2005; Panciera et al., 2008; Magagi et al., 2013). Field experiment campaigns have included instrumentation at various frequencies and have been conducted over various geographic domains. Typically, each campaign has its own objectives, and the success of a campaign depends in part on the weather conditions during the experiment. A field experiment was conducted in 2012 for developing and testing SMAP soil moisture algorithms before the launch of the mission, which collected L-band airborne radiometer and radar measurements together with ground truth. The objective of the campaign was to obtain a data set with a long time-series under varying soil moisture, soil type, and land cover conditions over a relatively large spatial domain. The experiment, named the SMAP Validation Experiment 2012 (SMAPVEX12), ran for six weeks and encompassed a wide range of soil moisture and vegetation conditions resulting in a data set that is a very valuable tool for soil moisture retrieval algorithm development and testing (McNairn et al.,

* Corresponding author.
E-mail address: andreas.colliander@jpl.nasa.gov (A. Colliander).

http://dx.doi.org/10.1016/j.rse.2016.06.001

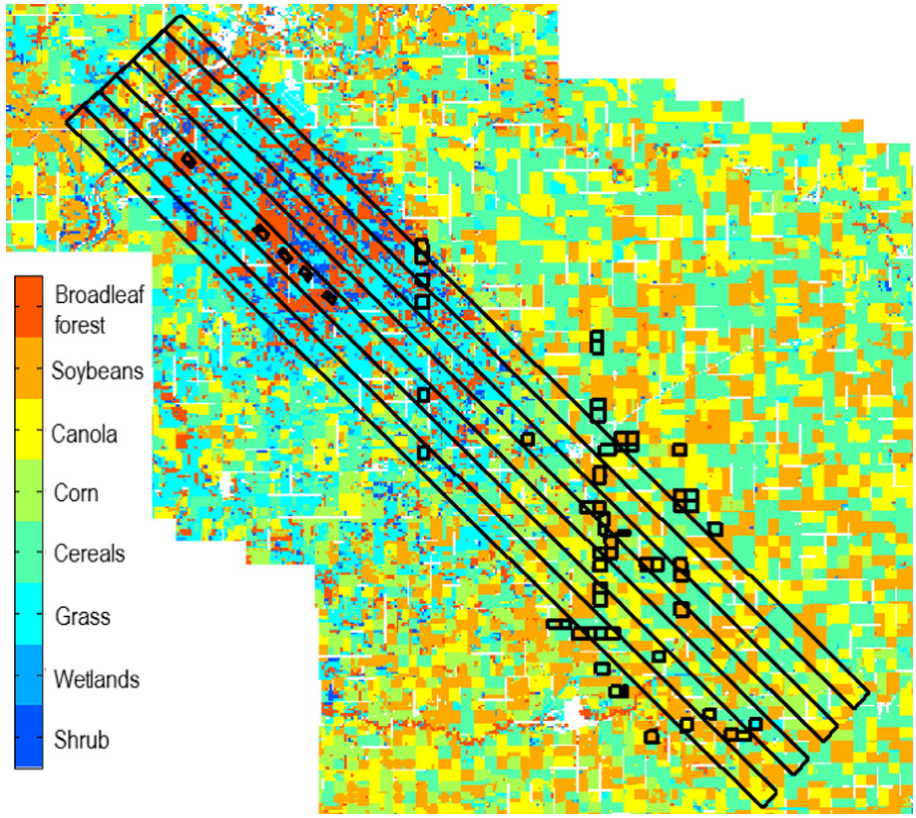

Fig. 1. SMAPVEX12 domain showing PALS high-altitude flight lines and fields with in situ soil moisture sampling, superimposed on a land cover map based on (McNairn, Powers, & Wiseman, 2014a).

2015). The experiment added to a series of field campaigns conducted in the context of SMAP pre-launch activities. These campaigns include SMAPVEX08 in Maryland, USA (Colliander et al., 2012), SMAPEx 1–3 in New South Wales, Australia (Panciera et al., 2014), and also CanExSM-10, Saskatchewan, Canada (Magagi et al., 2013), which was primarily focused on SMOS validation objectives, but included SMAP contributions.

In this study we use the SMAPVEX12 field experiment data to investigate microwave radiometer based soil moisture retrieval over a wide range of soil texture types. The soil types include heavy clay and sandy croplands and sandy grasslands. The airborne measurements of SMAPVEX12 included low-altitude high-resolution flights over sampling fields. For optimal soil moisture retrieval performance we use these flights to parameterize the forward model for the different soil and vegetation types. The retrieval algorithm accounts also for soil moisture level and, as a novel feature, the proximity of the last rain event. Optimizing parameters has been done in many experiments in the past (see Section 3.3) but not for such a wide range of soil types in a single experiment as presented in this study. The measurements also included high-altitude mapping flights over the entire experiment domain; we applied the parameterized algorithm to this data set to retrieve the soil moisture distribution over the domain on a regular grid. One of the objectives of the paper is to present a well-characterized surface soil moisture product for the SMAPVEX12 domain which will also be distributed through NSIDC DAAC. To this end we apply the ground measurements collected in the experiment to validate the aerial retrieval. Particular attention is paid to the criteria to select which in situ measurements are matched up with the airborne retrievals and how. We also comparatively use two different methods (dominant land cover and sub-grid modeling methods) to handle the spatial heterogeneity in the grid pixels.

2. SMAPVEX12

2.1. Experiment overview

SMAPVEX12 was located south west of Winnipeg, Canada and took place between June 7 and July 19, 2012 (McNairn et al., 2015). The study area (12.8 km wide by 70 km long) is characterized by changes

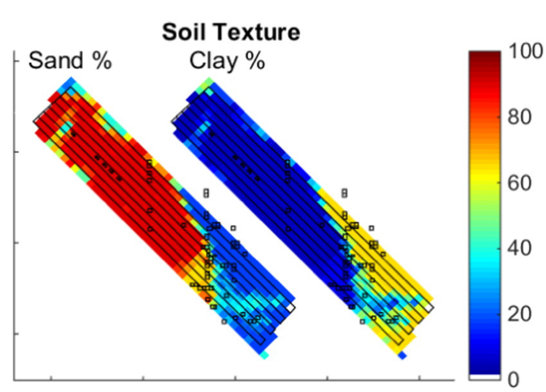

Fig. 2. Sand fraction (left) and clay fraction (right) maps of the entire domain based on (McNairn, Powers, & Wiseman, 2014b).