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A New International Network for in Situ Soil Moisture Data

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The International Soil Moisture Network (ISMN) is a new data-hosting center where globally available ground-based soil moisture measurements are collected, harmonized, and made available to users through a Web interface (http://www.ipf.tuwien.ac.at/insitu). As the first international initiative of its kind, the ISMN will play a crucial role in globally assessing the quality of soil moisture estimates from spaceborne microwave sensors and land surface models; in uncovering how the hydrological cycle integrates with land, the atmosphere, and the ocean; and in studying climate change. The ISMN is fully operational and currently hosts soil moisture data from more than 500 stations spanning 18 different networks. For scientific use, access to the data is free of charge.

Overcoming Obstacles Through ISMN

Soil moisture observations provide the link between terrestrial water, energy, and carbon cycles. Further, soil moisture determines how precipitation is partitioned into infiltration and runoff [*Dirmeyer et al.*, 2006]. Hence, it is fundamental in streamflow forecasting [*Koster et al.*, 2010] and in determining water and energy budgets. The importance of soil moisture in the global climate system has recently been underlined by the Global Climate Observing System (a joint undertaking of the World Meteorological Organization, the United Nations, and the International Council for Science), which in 2010 endorsed soil moisture as an "essential climate variable."

Although several local and regional meteorological and hydrological networks routinely measure soil moisture, globally the number of long-term ground-based monitoring networks is still small and largely restricted to midlatitude regions. Moreover, the lack of standard measurement techniques and protocols complicates the use of network data. As a result, there are many differences between measurement depths, units of soil moisture, sampling interval, and precision. Also, the fact that the various data sets are managed by a large number of organizations means that global studies incorporating ground-based soil moisture measurements are tedious to perform.

To overcome these issues, the Global Energy and Water Cycle Experiment (GEWEX) of the World Climate Research Programme (WCRP), with the continued support of the Group on Earth Observations (GEO) and Committee on Earth Observation Satellites (CEOS), envisioned and began developing an integrative platform for ground-based soil moisture measurements in 2006. The launch of the Soil Moisture and Ocean Salinity (SMOS) mission (http://www.esa.int/esaLP/LPsmos.html) in November 2009 by the European Space Agency (ESA) provided decisive impetus for this platform—in support of calibration and validation of SMOS products, an integrative system was needed to host quality-controlled and harmonized soil moisture measurements emerging from various ground validation campaigns and operational networks. Consequently, ESA provided the financial support for the development of this platform, which became ISMN.

The network itself is managed at the Vienna University of Technology. The first phase of ISMN has been completed—it involved designing and implementing the system and ingesting the first data sets. The second phase, which began in January 2011, entails the implementation of an improved quality control system, inclusion of additional networks, and the development of a plan that works toward full automation and near–real time ingestion of data sets. Subsequent phases will likely involve transferring the whole system to a fully operational organization.

Data Management

Input to ISMN is provided on a voluntary basis by locally and regionally operating networks—any network is encouraged to join. Currently, data from 18 historical and operational networks in North America, Europe, Asia, and Australia are hosted by ISMN (Figure 1), while several other networks have announced plans to participate in the near future. The Global Soil Moisture Data Bank [see *Robock et al.*, 2000], which until the launch of the ISMN was the only significant effort to centralize soil moisture measurements from various ground-based networks, has merged its data collection with the ISMN and has now closed.

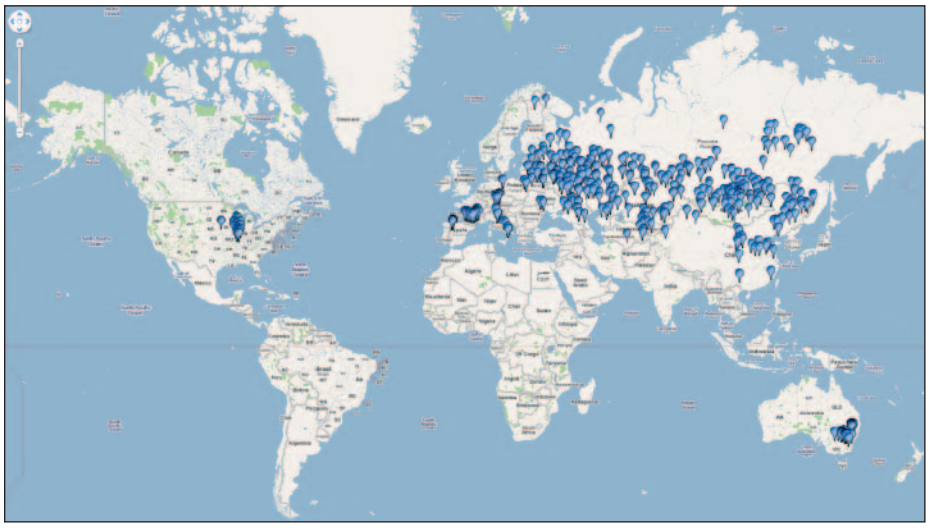

Fig. 1. Locations of stations currently in the International Soil Moisture Network (blue droplets). Map courtesy of Google Earth imagery © Google Inc., Europa Technologies, Geocentre Consulting, Instituto Nacional de Estadística y Geografía (INEGI), Map Link, Tele Atlas, WhereiS®, and Sensis Pty Ltd. Used with permission.

Data streams in on various time scales: Some networks post data in near real time, while others share them only after they are published in a peer-reviewed journal. Incoming soil moisture measurements are checked for consistency and quality and converted into a common volumetric unit of measurement.

A graphical user interface allows the user to search, for example, by geographical extent or time period and visualize the selected data. After selection of specific records, the data sets are prepared for download according to prevailing standards for data and metadata, as established by WCRP/GEWEX.

Although initially set up to support the SMOS mission, other current and upcoming satellite soil moisture missions will be supported by the established network because more harmonized data will be available globally for calibration and validation. Already, several satellite product validation studies have benefited from the network [e.g., *Brocca et al.*, 2010; *Liu et al.*, 2011; *Loew and Schlenz*, 2011]. However, the scope of the ISMN is to go beyond the role of a satellite validation resource and serve other communities such as hydrologists, meteorologists, climate modelers, and water managers. To help find comprehensive answers to fundamental science questions related to soil moisture and its role in the integrated water cycle, the ISMN stores soil moisture measurements not only of the surface layer but also of deeper layers, along with relevant auxiliary variables such as precipitation, temperature of air and soil, soil porosity, and soil texture.

Next Steps

The establishment of the ISMN marks a first important step toward the fully integrated soil moisture observing system envisaged by GEO. Nevertheless, it will be necessary to establish, expand, and improve current soil moisture observations by, for example, developing a coordinated plan for networks through standardizing measurement techniques, data formatting, and selecting sites to improve global spatial coverage; designing a "supersite" program with high-density measurements over a small spatial area; and enhancing consistency and standardization of measurements, data, and metadata. Existing networks should be encouraged to share their data with the community and continue their measurements to obtain long-term records.

The success of these efforts will depend upon long-term financial commitment. Fortunately, the positive contributions from international organizations such as WCRP/GEWEX, the support of space agencies, and voluntary contributions from numerous individual networks are widespread, raising confidence in the scientific community's willingness to realize an integrated soil moisture observing system.

For more information about the ISMN and to share or download data, visit http://www.ipf.tuwien.ac.at/insitu or contact Wouter Dorigo (ismn@ipf.tuwien.ac.at).

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