WMO Commission for Agricultural Meteorology

Progress Report from Task Team on Soil Moisture Measurements (TT 2.2)

1. Soil moisture needs and applications

Soil moisture is a key factor in climate risk management. Reliable soil moisture information can be used effectively for early warning of drought and flood potential, irrigation management and scheduling, crop yield forecasting, and as input into climate forecasts. Despite the importance of soil moisture, global soil moisture observations are still extremely limited. The lack of more systematic datasets hampers efforts to understand the interactions between land surface changes and the water cycle, and limits advances in the prediction capability on the regional scale.

There is an urgent need to develop an integrated and comprehensive soil moisture data approach to strengthen integrated and participatory early warning and risk management systems for sustainable agriculture, water resource management and renewable energy security in Africa and worldwide. This data observation system can be achieved by the integration of in-situ observations and satellite remote sensing measurements into a more comprehensive dataset that can be used with data assimilation and modeling techniques to enhance an effective soil moisture monitoring system. Satellite remote sensing measurements have been used to monitor surface soil moisture for several decades, and, while in situ measurements provide necessary ground-truth data, these networks are sparse and limited. The Soil Moisture Demonstration Project (SMDP) has already demonstrated its feasibility in a pilot project for improving soil moisture observations in South Africa. Core validation sites, an enhanced network of calibrated in-situ national observations, and satellite products are all integrated into a national application test bed for operational implementation.

The Task Team on Soil moisture measurements was established during WMO CAgM 16th Congress during April 10-15, 2014 at Antalya, Turkey. The major goals are: 1) to facilitate and develop the international standards and guidelines for global in situ soil moisture measurements; 2) to establish soil probe calibration and validation procedures, and, 3) to develop integrated soil moisture data with remote sensing measurements and in situ observations.

2. Members and Contributors Soil Moisture Task Team

2.1 Members

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3. Soil Moisture Task Team activities and status

3.1 WMO CAgM Soil Moisture Task Team Meeting, 2016

The first WMO CAgM Soil Moisture Task Team Meeting was held on Sept. 23, 2016, in New York City, USA immediately after the 3rd Satellite Soil Moisture Validation and Application Workshop.

The meeting agenda is shown in Table 1. The application, distribution, challenges and issues of global soil moisture measurements were discussed. The meeting redefined the tasks of the Soil Moisture Task Team to include soil probe calibration and validation in USA and South Africa, to develop integrated soil moisture data with remote sensing measurements and in situ observations, and to demonstrate soil moisture applications in South Africa. Funding proposal efforts (WMO GFCS and CREWS) were also discussed during the team meeting. A major outcome of the meeting was the agreement that the top 5 cm should be defined as standard surface level for surface soil moisture measurements.

Table 1. Final agenda of the first Soil Moisture Task Team, 2016

John Qu: Status of Global Soil Moisture Demonstration Project
Tom Jackson: Overview of SMAP and In-Situ issues
Wolfgang Wagner: Overview of International Soil Moisture Network
Michael Cosh: Status and Advances of In-situ Soil Moisture Measurements
Johann Malherbe: Overview of South African Soil Moisture Network
Denise Fontana Status of Agrometeorology in Brazil
Xianjun Hao: Challenges and Issues of Integrated Satellite and In-situ Soil Moisture Products
Robert Stefanski: Overview of WMO Commission for Agricultural Meteorology Activities

3.2 In Situ Soil Moisture Cal/Val Efforts

In situ measurements are critical in the assessment and improvement of satellite soil moisture data products. The cross-sensor calibrations can provide error estimates and a basis for modifying algorithms and/or parameters. Reliable and timely observations are of very critical in validating satellite soil moisture products.

This WMO soil moisture task team included partners from USDA and USGS, and, the South African ARC. With these partners, a total of six Cal/Val sites were established to support WMO soil moisture measurement efforts. They include: 1) THREE Cal/Val sites in Stillwater, Oklahoma (supported by USDA ARS); 2) TWO Cal/Val sites in South Africa (supported by ARC, South Africa); and 3) ONE Cal/Val site in Fairbank, Alaska, USA (supported by USGS).

Figure 1 shows the three soil moisture cal/val sites at OSU Range Station, Stillwater, OK, USA (photo by Dr. Xianjun Hao), which are the long-term soil moisture cal/val sites operated by USDA, ARS. Figure 2 shows the sample soil moisture, temperature and precipitation measurements in South Africa. Other sample soil moisture and temperature data can be obtained from the website of WMO South Africa Soil Moisture Project (http://wamis.gmu.edu/Africa/).

Figure 3 shows the comparison results between two soil moisture sensors (DFM and Hydro soil moisture instruments). The measured soil moisture values are different from the figure 3 because the two sensors measured different levels (Hydro: 5 cm vs. DFM 10 cm).   DEM soil moisture data can be calibrated to standard surface (5 cm) level in the future.

Cal/Val sites at OSU Range Station, Stillwater, OK

Fig 1 Soil moisture cal/val sites at OSU Range Station, Stillwater, OK, USA

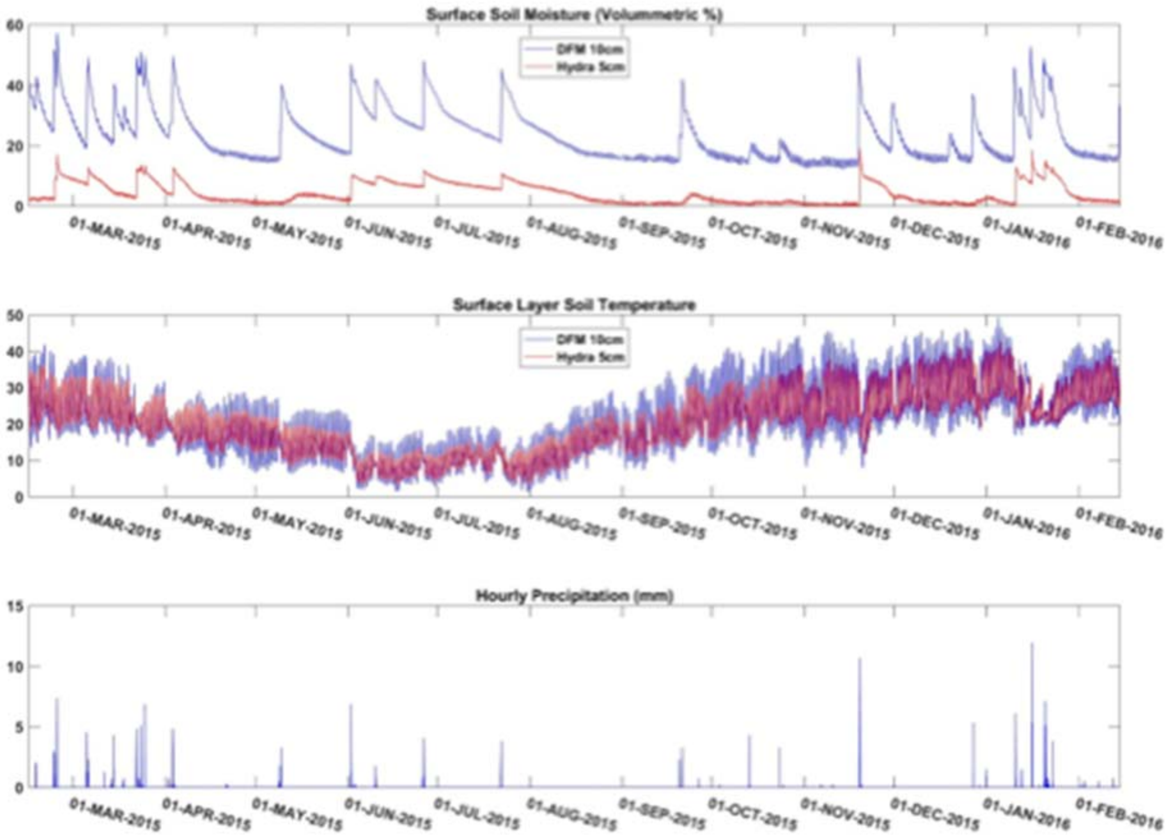

Fig 2 Soil moisture and temperature and precipitation measurements in South Africa

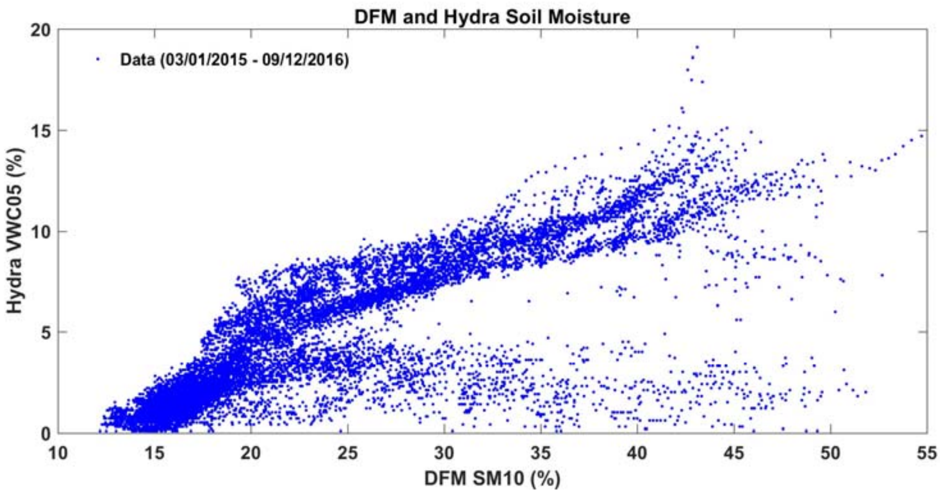

Fig 3 Soil moisture measurements between DFM and Hydra sensors

3.3 Integrated Satellite and In Situ Soil Moisture Products

There are satellite soil moisture measurements at different spectral, spatial and temporal scales. Most microwave remote sensing instruments such as SMOS, have the 10km to 150km spatial scales while most optical/thermal sensors with < 2 km scales such MODIS, AVHRR and Landsat (Chauhan, N.S., 2003 and Wang, L. and J.J Qu 2009). In situ soil moisture measurements are point-source data. There have been many remote sensing methods for soil moisture retrieval based on microwave or optical thermal infrared (TIR) measurements. TIR remote sensing has been popular for surface soil moisture retrieval due to its fine spatial and temporal resolutions. However, because of limitations in the penetration of optical TIR radiation and cloud cover, TIR methods can only be used under clear sky conditions. Microwave surface soil moisture retrieval is based on solid physical principles, and has advantages in cases of cloud cover, but it has low spatial resolution Recent study has done for "Downscaling of Surface Soil Moisture Retrieval by Combining MODIS/Landsat and In Situ Measurements" (Xu, C et al. 2018). Integrated satellite remote sensing and in situ soil moisture products become important not only for validating satellite remote sensing soil moisture products but also for fitting different level requirements of stack-holders and ender users.

The integrated soil moisture maps are generated through calibration and validation of soil moisture estimation models with in situ observations. A database is established and maintained by spatial and temporal matchup of daily satellite remote sensing measurements and in-situ observations, and the database is used for model calibration and validation to control the quality of soil moisture estimation. Daily satellite remote sensing measurements are processed to generate soil moisture estimates at 1km resolution, and 10-day soil moisture data and maps are generated based on spatial and temporal composition of daily soil moisture data. The quality of these soil moisture estimates at 1km resolution depends on the availability and accuracy of in-situ measurements, as well as ancillary information such as soil type and vegetation type. The following diagram shows details of the technical approach. Figure 4 shows the flowchart of integrated satellite soil moisture products. The demonstrating 10-day soil moisture data and maps can be obtained from WMO South Africa Soil Moisture Project website (http://wamis.gmu.edu/Africa/).

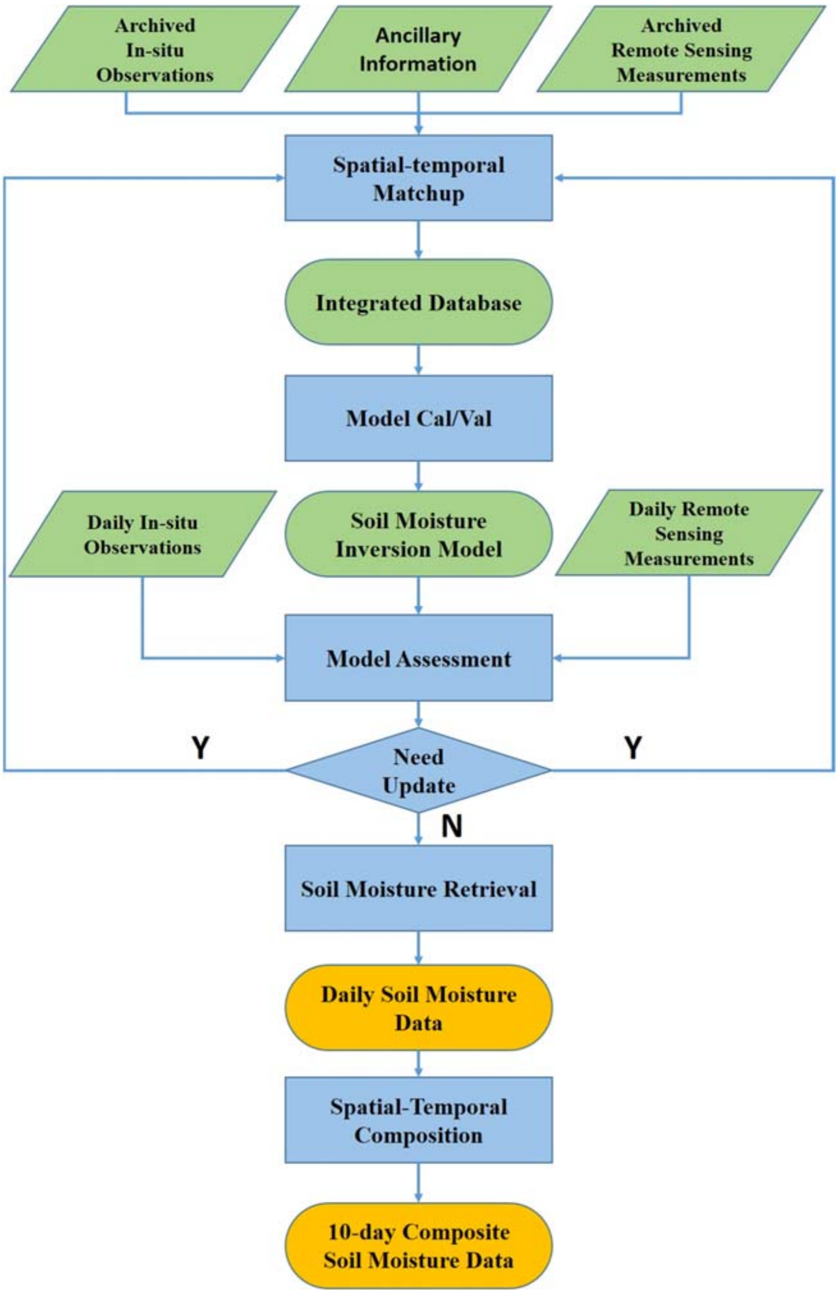

Fig 4 Integrated soil moisture product flowchart

4 Summary and future works

During last four years, the WMO Soil Moisture Task Team has reviewed the international in situ soil moisture standards and guidelines for global ground-truth soil moisture measurements. The top 5 cm was defined as standard surface level for surface soil moisture measurements. Cross-sensor calibration and validation of different soil probes have been performed. For demonstration purposes, the integrated soil moisture data combining remote sensing measurements and in situ observations have been generated and are available. Downscaling of surface soil moisture retrieval by combining satellite and in situ measurements also has been developed.

Future work includes: 1) to review and provide the standards and guidelines for international soil moisture measurements; 2) to enhance soil moisture cal/val efforts; 3) to write proposals for further development and expanded national coverage of the WMO Soil Moisture Demonstration Project (SMDP); and, 4) to study soil moisture applications impacting agriculture, natural hazards and the Water-Energy-Food Nexus.

5 References

Chenyang Xu, John J. Qu, Xianjun Hao, Michael H. Cosh, John H. Prueger, Zhiliang Zhu and Laurel Gutenberg, 2018, Downscaling of Surface Soil Moisture Retrieval by Combining MODIS/Landsat and In Situ Measurements, Remote Sensing 2018, 10(2), 210; doi:10.3390/rs10020210.

Wang, L.; Qu, J.J. Satellite remote sensing applications for surface soil moisture monitoring: A review, Front. Earth Sci. China 2009, 3, 237–247.

Chauhan, N.S.; Miller, S.; Ardanuy, P. Spaceborne soil moisture estimation at high resolution, A microwave-optical/IR synergistic approach. Int. J. Remote Sens. 2003, 24, 4599–4622.

Appendix A: WMO Task Team on Soil Moisture Measurements

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