WEB SERVICE-BASED SMAP SOIL MOISTURE DATA VISUALIZATION, DISSEMINATION AND ANALYTICS BASED ON VEGSCAPE FRAMWORK

Zhengwei Yang[†]*, Lei Hu*[‡]*, Genong (Eugene) Yu*[‡]*, Ranjay Shrestha*[‡]*, Liping Di*[‡]*, Claire Boryan*[†]*, Rick Mueller*[†]

[†]National Agricultural Statistics Service, USDA, Washington DC, 20250, USA
[‡]Center for Spatial Information Science & Systems, George Mason University, Fairfax, VA 22032, USA

ABSTRACT

Timely, frequent, crop vegetation condition information, with complete geospatial coverage acquired throughout the growing season is critical for public and private sector decision making that concerns agricultural policy, production, food security, and food prices. The NASA Soil Moisture Active and Passive (SMAP) mission provides such a reliable data source for cropland soil moisture assessment. This paper presents a prototype of an interactive Web service based SMAP soil moisture visualization, dissemination and analytics system for US soil moisture monitoring based on the VegScape framework. This system automatically retrieves and preprocesses SMAP soil moisture data for US cropland soil moisture condition monitoring and assessment. The prototype takes advantage of the VegScape's service oriented architecture and adds a new component for SMAP soil moisture. It reuses existing VegScape visualization, dissemination and analytical functionalities and tools. The prototype inherits the capabilities of interactive map operations, data dissemination, statistical tabulating and charting, comparison analysis, and various Web services.

Index Terms— SMAP, soil moisture, VegScape, Web service, online visualization, dissemination, analytics

1. INTRODUCTION

Crop condition information is critical to decision making in both the public and private sectors that concern agricultural policy, production, food security, and food prices. Crop conditions change quickly due to changes in temperature, soil moisture, fertilization, or disease, etc. Therefore, timely, frequent, and sufficiently high resolution observation data, that provide full geospatial coverage, which are collected throughout the growing season, are necessary to monitor crop conditions. Therefore, National Agriculture Statistics Services (NASS) of the United States Department of Agricultural (USDA developed and put into operation a Web service based online vegetation condition monitoring system, known as VegScape, based on NASA MODIS data [1]. VegScape has proved to be very helpful in identifying and quantifying some major events in US crop production such as massive flood, drought and hail storm damage. However, one major component, soil moisture, is still missing in the system. NASS currently monitors US crop soil moisture condition using weekly field observations for counties in 45 states. State-level estimates reported are based on subjective and qualitative field observations rather than objective measurements. The surveyed topsoil and subsoil moisture information are published weekly during the growing season. Field observations are conducted by volunteers. The observations are not precise, and they are often inconsistent, unreliable, inefficient, and do not provide full geospatial coverage. Operational costs are high. The NASA Soil Moisture Active Passive (SMAP) mission [2] provides another potential option for improving NASS cropland soil moisture monitoring operations. The remote sensed SMAP soil moisture data are quantitative, objective and inexpensive (the data are free), have full geospatial coverage and a sufficiently high temporal frequency for US national cropland soil moisture monitoring. Therefore, Yang, et al. proposed as an early adaptor, to explore the potential of using SMAP data for NASS soil moisture monitoring [3]. This paper presents a prototype of interactive Web-based, SMAP-based soil moisture monitoring system, which is implemented using the VegScape framework. This system will automatically retrieve and process the SMAP soil moisture data product from the NASA data archive and publish the processed soil moisture data for mapping, visualization, dissemination, and online analytics geospatially through standard geospatial Web services in a publicly accessible online environment.

2. SMAP DATA AND PROCESSING

The SMAP mission (launched on 31 January 2015) measures land surface microwave emission (or brightness temperature at 1.41GHz) and radar backscatter (at 1.26 GHz and 1.29 GHz). It is designed to measure surface soil moisture (the amount of water in the top 5 cm (2 inches) of soil everywhere on Earth's surface). It repeatedly measures soil moisture every 2-3 days. The mission has both active and passive sensors. However, the active L-band Radar sensor failed on July 7, 2015. For improved crop condition assessment, the soil moisture data resolution should be as high as possible. The SMAP soil moisture monitoring system to be prototyped is based on soil moisture data NASA released: SMAP Level 4 Surface and Root Zone Soil Moisture (SPL4SMGP) data product. This data product provides, based on SMAP observations, estimates of both top soil moisture and root zone soil moisture, which are required for NASS operational reports. The root zone soil moisture is defined here nominally as soil moisture in the top 1 meter of the soil column. This selection of the SMAP data product also anticipates the possible future downscaling data product derived from fusion of Sentinel 1 radar and SMAP microwave data. The implementation is also applicable to the other SMAP data products. For a cropland-specific assessment, a crop mask derived from NASS Cropland Data Layer [4] is also used. Therefore the study areas cover all conterminous states in the U.S. In this implementation, the administrative boundaries, MODIS data products and the derived vegetation condition indices remain un-touched. The data processing tasks, such as data retrieving, clipping, reformatting, re-projection, and map generation are implemented following the interfaces of Web Processing Service (WPS) for interoperation. The major data processing flow is given as Fig. 1.

3. ARCHITECTURE AND SYSTEM DESIGN

The SMAP soil moisture data products need to be published, visualized, accessed, analyzed, and disseminated to end users via the online application. VegScape adopts a 3-layer service oriented architecture (SOA) to process, share and disseminate geospatial remote sensing data. The SOA provides maximum system scalability for system augmentation, which enables the expansion of the VegScape system to easily include a new component to perform SMAP soil moisture data interactive mapping, visualization, online analytics, and dissemination as shown in Fig. 1. Open Web standards and OGC geospatial data and processing standards adopted in the extendable VegScape framework make it more accessible, interoperable, and reusable [5].

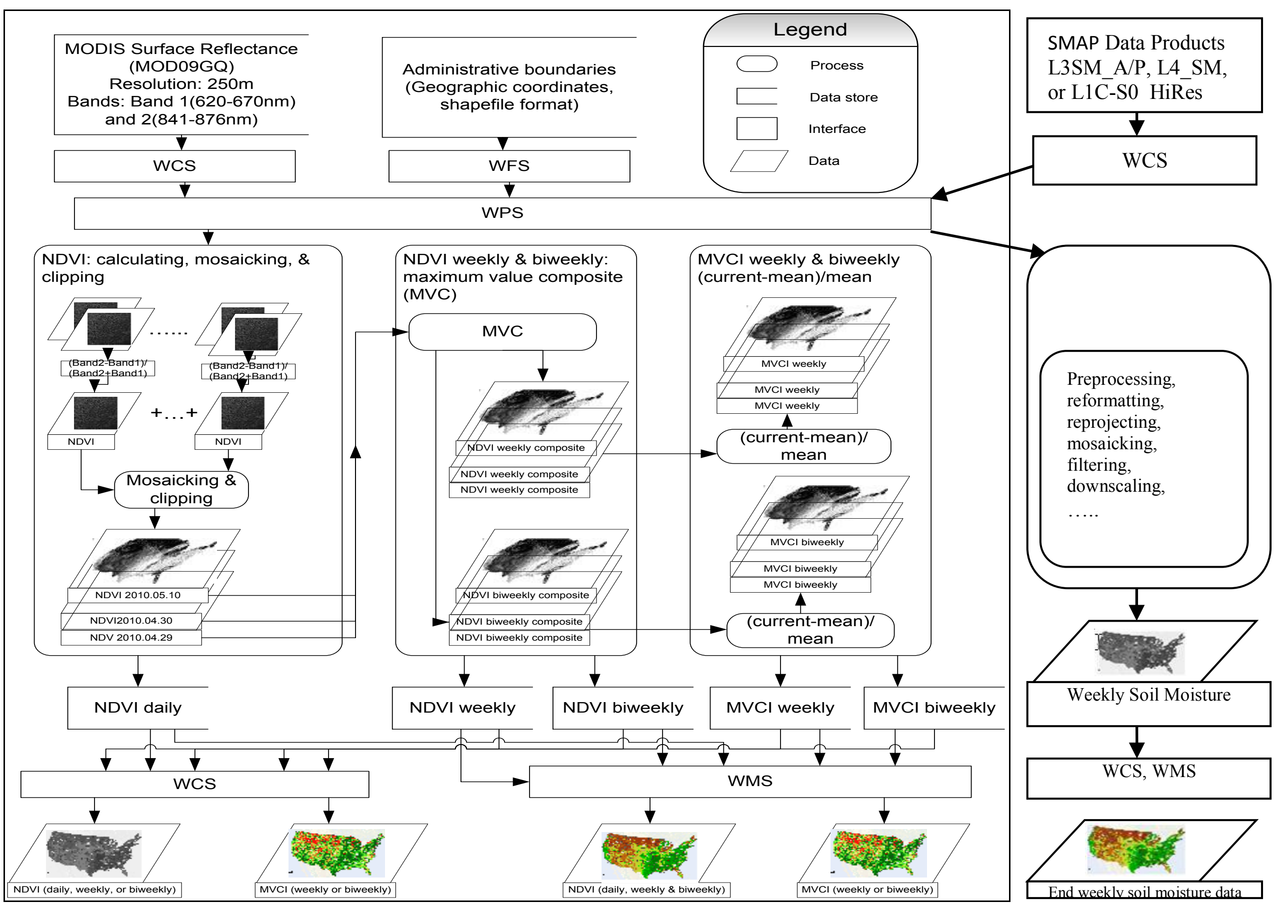

Figure. 1 Data processing flow chart - SMAP data processing component added to scalable VegScape framework

The architecture of the new soil moisture component includes the same three layers: application, service and data. The application layer implements various geospatial applied functionalities that support standard Web and OGC services and can invoke Web processing services in their own environment. The service layer contains OGC standard compliant Web Feature Service (WFS), Web Map Service (WMS), Web Coverage Service (WCS) and Web geoprocessing services to provide geospatial data and processing services. The Data Layer includes original VegScape data sets and new SMAP soil moisture data products, as well as geospatial feature data. Similarly, the soil moisture data in Data Layer are processed and or served by Web services of the Service Layer. The processed results or data retrieved from the Data Layer are sent back to the clients in the Application Layer.

4. PROTOTYPE IMPLEMENTATION

4.1. Prototype Implementation Description

VegScape has a front-end thin client for users to interact with the back-end server and different web services. The system was implemented based on open geospatial specifications, i.e. those specifications from the Open Geospatial Consortium [7]. Those specifications include WCS for raster data storage and service, WPS for processing algorithms and their managements, WFS for storing and serving vector geographical features, and WMS for web-based geospatial presentation.

In prototype implementation, open source JavaScript libraries, ExtJS and OpenLayers [8], used to develop an Ajax-powered rich Internet application VegScape, which can be accessed through most common browsers such as Internet Explorer, Firefox, Safari, Opera, and Chrome, are used for development.

Similar to VegScape implementation, the Service Layer contains open Web geospatial data services and specially developed Web geo-processing services. The MapServer [8] deployed in Apache's Common Gateway Interface (CGI) is configured as the server of WCS, WFS, and WMS to support retrieval and rendering of soil moisture data. The W3C Web service is adopted in implementing the Web geoprocessing service and Web processing services for SMAP data reformatting and reprojection while web map services are implemented for data visualization, publishing and dissemination [3]. In the prototype, the application sends a WMS GetMap request to render map layers, a WMS GetFeatureInfo request to query the detailed information of specified features, and a WFS GetFeature request to retrieve boundary features in GML. Other services defined in OGC standards can be accessed by users in their applications to interoperate with geospatial data deployed in VegScape.

In the prototype, the vector data layers remain the same as the original VegScape. The raster data layers have been changed. The SMAP soil moisture data products have been included. The soil moisture data files are served by WMS to provide images for the VegScape client and other geospatial applications, and by WCS and WFS to retrieve soil moisture defined by an AOI. The rest of the data services remain unchanged.

Moreover, the prototype for SMAP soil moisture reuses the existing functionalities and tools of the VegScape system. The new soil moisture data layers and associated legends, and product selection interface are to be added to include SMAP data products.

4.2. VegScape Based Prototype Interface

The VegScape based SMAP soil moisture application prototype user interface (client) is shown in Fig. 2. The interface components are the same as the original VegScape interface, including data layers, legends, product selection, overview window, map window, and a toolbar. The only difference is a new addition of SMAP soil moisture data products. The new soil moisture legends are added to the Legends panel. The product selection panel is slightly changed as the new SMAP data products are added to the selection list. The users can access the functional tools to interactively perform map operation, information queries, area of interest selections (importing and exporting), online vegetation condition quantitative analysis and statistics, change analysis, data profiling, automatic PDF format vegetation condition map creation, and data dissemination (downloading and exporting) for the added SMAP soil moisture data layers. Fig. 2 illustrates the SMAP soil moisture data in the map window of the prototyped application. The implementation enables SMAP soil moisture data easy access, visualization, interactive mapping, dissemination and online analytics, which will greatly facilitate the use of SMAP soil moisture data products for decision support.

5. CONCLUSION

This paper presents a prototype of an interactive Web based SMAP soil moisture visualization, dissemination and analytics system for US soil moisture monitoring based on the VegScape framework. The implementation adds a new component for SMAP soil moisture to the existing VegScape by utilizing the VegScape service oriented architecture. This prototype inherits VegScape's capabilities of interactive map operations, data access, visualization, online analytics and charting and graphing, and comparison analysis, data dissemination, comparison analysis, and on-the-fly soil moisture map generation, as well as Web geoprocessing services. The prototype system automatically retrieves and processes SMAP soil moisture data for US soil moisture condition monitoring and assessment. The Web service implementation provides the capability of machine to machine data communication, which enables users' application systems to retrieve soil moisture data served on the VegScape platform automatically. The prototype has proven that the existing VegScape is an appropriate framework for geospatial remote sensed data accessing, processing, querying, visualization, dissemination, and online analytics, and will greatly enhance the user experience for using SMAP soil moisture for US crop condition monitoring.

6. REFERENCES

[1] Yang, Z., Yu, G., Di, L., Zhang, B., Han, W., Mueller R., "Web Service-Based Vegetation Condition Monitoring System – Vegscape," Proc. of IEEE IGARSS 2013, Melbourne, Australia, July 2013.

[2] Entekhabi, D. et al. "The Soil Moisture Active Passive (SMAP) Mission." Proceedings of the IEEE 98.5: pp.704-716, 2010.

[3] Yang, Z., Mueller, R., and Crow, W., "Us National Cropland Soil Moisture Monitoring Using SMAP," Proc. of IEEE IGARSS 2013, Melbourne, Australia, July 2013.

[4] Claire Boryan, Zhengwei Yang, Liping Di, "Deriving 2011 cultivated land cover data sets using usda National Agricultural Statistics Service historic Cropland Data Layers," 2012 IEEE International Geoscience and Remote Sensing Symposium, pp. 6297 - 6300.

[5] Granell, C., Díaz, D., Gould, M., "Service-oriented applications for environmental models: Reusable geospatial services," *Environmental Modelling and Software*, 25(2), pp.182-198, February, 2010.

[6] Iosifescu-Enescu, I., Hugentobler, M., L. Hurni, "Web cartography with open standards - A solution to cartographic challenges of environmental management," *Environmental Modelling and Software*, 25(9), pp.988–999, September, 2010.

[7] OGC: Open Geospatial Consortium Standards. http://www.opengeospatial.org/standards, [accessed 4 January, 2016].

[8] OpenLayers: Free maps for the Web, OpenLayers. *http://www.openlayers.org/, [accessed 12 May, 2013]*.

[9] Kropla, B., *Beginning MapServer: Open Source GIS Development*. Apress, Berkley, CA, 448pp, 2005.

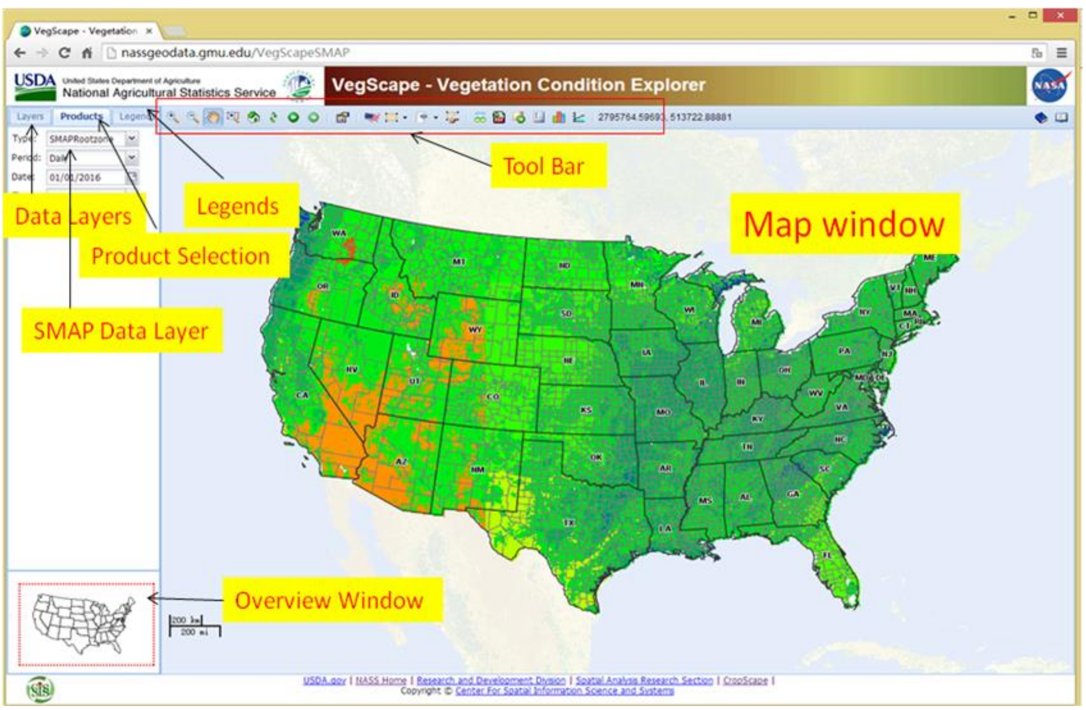

Figure 2. VegScape based Prototype client (browser) user interface