CROP-CASMA - A WEB GIS TOOL FOR CROPLAND SOIL MOISTURE MONITORING AND ASSESSMENT BASED ON SMAP DATA

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ABSTRACT

Timely, frequent, and complete cropland soil moisture information acquired throughout the growing season is critical for agricultural policy, production, food security, and food prices. The NASA Soil Moisture Active and Passive (SMAP) mission provides a reliable data source for cropland soil moisture assessment. This paper presents Crop-CASMA - a web GIS application tool for cropland soil moisture monitoring and assessment based on SMAP data. This interactive Web service-based GIS application tool enables CONUS SMAP derived soil moisture data visualization, dissemination, and analytics. In this paper, we describe the Crop-CASMA application system architecture, the application implementation, and the data it serves. In addition, we also present a few snapshots of the Crop-CASMA data for cropland soil moisture monitoring. The release of Crop-CASMA greatly enhances the user experience and facilitates using soil moisture data products for crop condition monitoring and decision support.

Index Terms **—** SMAP, soil moisture assessment, Crop-CASMA, cropland

1. INTRODUCTION

Crop condition information is critical for decision makers in both public and private sectors. It affects agricultural policy, crop production management, 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 collection throughout the growing season with full geospatial coverage, are much needed for monitoring crop conditions. Soil moisture condition, a key crop growth parameter, is part of the weekly state Crop Weather Report of National Agricultural Statistics Services (NASS), the United States Department of Agriculture (USDA). The NASS state-level report are based on subjective and qualitative field observations, which are conducted by approximately 4000 respondents. The observations do not provide geospatial coverage information and the respondent burden is very high. However, the NASA Soil Moisture Active Passive (SMAP) mission [1] provides another option for improving NASS cropland soil moisture monitoring operations. It was proposed to use SMAP data for NASS soil moisture monitoring and an interactive web-based, SMAP-based soil moisture monitoring system was further prototyped, based on the VegScape platform [2][3]. The remotely sensed SMAP soil moisture data provide free, quantitative, and objective measurements, and have full geospatial coverage and a sufficiently high temporal frequency for US national cropland soil moisture monitoring. To facilitate using the remotely sensed soil moisture data by users, an effective and user-friendly tool was developed and made freely available to the public.

This paper presents Crop-CASMA (Crop Condition and Soil Moisture Analytics), a web-based interactive geospatial application. It is designed to help users effectively utilize the remotely sensed geospatial soil moisture and vegetation index data derived from NASA SMAP and MODIS missions to assess conterminous U.S. crop vegetation and soil moisture conditions. This application tool automatically retrieves and processes the SMAP soil moisture data product and publishes the processed soil moisture data for mapping, visualization, dissemination, and online analytics through standard geospatial Web services in a publicly accessible online environment.

2. SMAP SOIL MOISTURE DATA

The SMAP mission, launched on 31 January 2015, was designed to measure surface soil moisture, defined here as the amount of water in the top 5 cm (2 inches) of soil everywhere on Earth's surface. SMAP repeatedly measures soil moisture every 1-3 days. For cropland soil moisture condition assessment, Crop-CASMA serves the SMAP 9km resolution level 4 soil moisture data product (SPL4SMGP), and also 1km disaggregated high resolution soil moisture data.

The Level 4 data product provides estimates of both surface soil moisture (top 5cm) and root-zone soil moisture (defined nominally as soil moisture in the top 1 meter of the soil column) [4]. The 1 km resolution surface soil moisture data, developed from SMAP data and MODIS land surface temperature data, enable near field size assessment [5].

Crop-CASMA also offers derivative data products including weekly soil moisture and crop soil moisture condition data calculated to match the NASS Crop Progress Report [6] soil moisture condition categories. Additionally, Crop-CASMA provides NASA Moderate Resolution Imaging Spectroradiometer (MODIS) based vegetation condition index data products in the United States.

For a cropland-specific assessment, a crop mask [7] is used in the Crop-CASMA to help users visualize volatile weather events affecting cropland in the United States.

3. SYSTEM ARCHITECTURE

The architecture of the Crop-CASMA web service system is illustrated in Figure 1. It adopts a three-layer service-oriented architecture (SOA) to process, share, and disseminate geospatial remote sensing data similar to CropScape [8]. This architecture consists of an application layer, a data layer, and a service layer on top of an infrastructure layer. The infrastructure layer supports the architecture and manages the fundamental computing resources for the entire system. The data layer harvests and stores all geospatial soil moisture data and vegetation index data as well as ancillary data for the web service. The service layer includes all geospatial web services of the system including geoprocessing services and map services. Both data layer and service layer are deployed as the instance of virtual machine (VM) of the infrastructure layer. This SOA architecture maximizes system's scalability and transferability of web services. The system can be automatically scaled up and quickly duplicated with the increased load. Moreover, the instance can be disseminated through general VM formats which are compatible with most of the cloud platforms such as Amazon Web Services. The system scalability enables the future expansion of the Crop-CASMA system to easily include a new data or services for interactive mapping, visualization, online analytics, and dissemination.

4. CROP-CASMA IMPLEMENTATION

4.1. Implementation Description

Crop-CASMA adopts a browser-based application front-end for users to interact with the back-end server for web services and various data. The system web services and map services were implemented based on Open Geospatial Consortium (OGC) specifications [9]. OpenLayers was adopted for client-side geospatial map rendering, map navigation and manipulation implementation. The Graphic user interface of the Crop-CASMA web client was implemented based on React. All data processing tasks, such as data retrieval, clipping, reformatting, re-projection, and map generation, and all application functions including statistical analysis, pdf map generation, downloading, etc. were implemented in web geoprocessing services on the server end and accessible from the Crop-CASMA application client and third-party applications via OGC standard compliant web services specifications.

In the implementation, the MapServer was used to create map files from the processed raster data for client rendering and operation. The MapServer was deployed in Apache's Common Gateway Interface (CGI) and configured as the server of Web Coverage Service (WCS), Web Feature Service (WFS), and Web Map Service (WMS) to support the retrieval and rendering of soil moisture data. The W3C Web service was adopted in implementing the Web geoprocessing service and Web processing services for data processing, such as reformatting and reprojection while Web Map services were implemented for data visualization, publication, and dissemination.

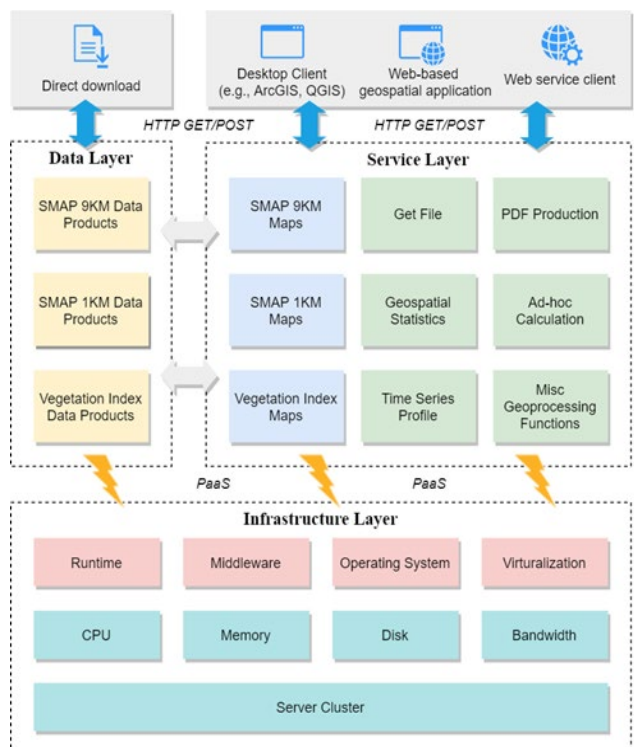

Figure 1. System architecture of Crop-CASMA

4.2. Crop-CASMA Graphic User Interface

The Crop-CASMA web client graphical user interface (GUI) interface includes the data layer catalog, product selection, map window, legend, overview window, area of interest (AOI) tool bar, operational function toolbar, and ancillary toolbar, as shown in Figure 2. The operational function toolbar allows users to select a specific tool to interactively perform map operations, such as selecting a specific data layer from the data catalog, generating a PDF map of the selected data layer, performing simple zonal statistical analysis, creating ad-hoc composite of the available data layers, performing change analysis using Swipe functionality, profiling a data time series of a specific location, or animating the soil moisture change dynamics for a given period. The AOI tool bar enables users to set, import, and export analysis areas of interest. The Ancillary toolbar provides tools for pixel information queries, boundary data selection, crop mask overlay, Cropland Data Layer overlay, and legend toggling. The Crop-CASMA web client enables SMAP soil moisture data to be easily accessed, visualized, interactively mapped, analyzed and disseminated.

4.3. Crop-CASMA Tools

The implemented Crop-CASMA tools are designed to help users navigate, visualize, monitor, analyze, present, and disseminate data and results in map, tabular, and chart format. They include three major categories: 1) data management and analysis tools; 2) area of interest tools; and 3) auxiliary tools.

The Data Management tools include Catalog and Layers. The Catalog tool allows user to browse and select data available on Crop-CASMA while the Layers tool enables users to control which data layer is the active working layer (for display or analysis).

The Analysis tools include Statistics, PDF Map, Profile, Composite, Swipe, Animation, and Download. The Statistics, PDF Map, and Download tools allow users to calculate statistics, generate PDF maps, and download area of interest soil moisture or vegetation condition data. The Profile, Swipe, and Animation tools provide users the capability of viewing, comparing, and illustrating change dynamics of soil moisture or vegetation condition data. The Composite tool enables users to create ad-hoc composite layers from existing layers by either averaging or maximizing the selected data layers of the same type. The AOI tool allows users to select an existing administrative area, such as a county, state, an agricultural statistics district, or region, to draw a polygon or free-hand shape of area of interest for analysis. In addition, the tool set also include the ability to import a user provided AOI boundary file and to export a user drawn AOI for future use.

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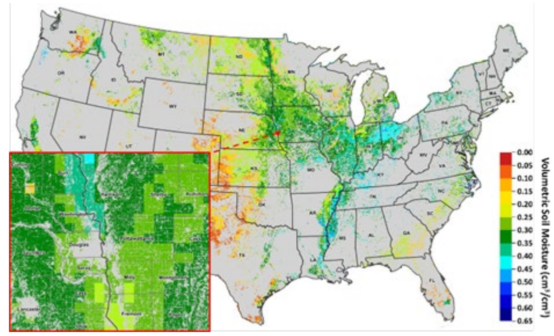
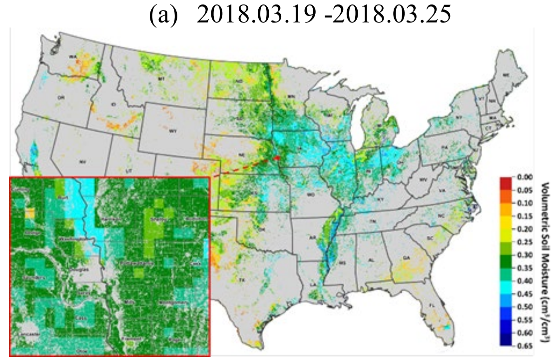
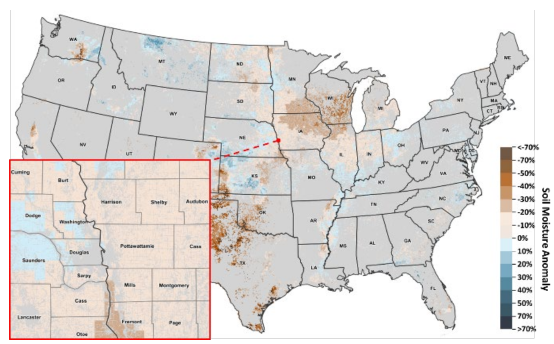


(a) 2018.03.19 -2018.03.25

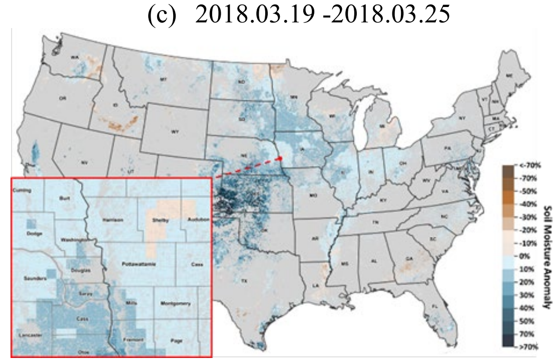


(b) 2019.03.18 -2019.03.24

Figure 3. Snapshots of the weekly average map of SMAP 9km L4 surface soil moisture



(c) 2018.03.19 -2018.03.25



(d) 2019.03.18 -2019.03.24

Figure 4. Snapshots of 9km resolution soil moisture anomaly maps of CONUS Cropland

The Auxiliary tool set includes Pixel Info, Legend Toggle, and Auxiliary Layers. The Pixel Info tool is designed for identifying the data name and value of a selected pixel. The Legend Toggle allows users to toggle the legend on/off.

4.4. Snapshots of Crop-CASMA Data for Cropland Soil Moisture Monitoring

This section presents a few snapshots of Crop-CASMA data for cropland soil moisture monitoring. Fig. 3 (a) and (b) show 9km L4 weekly surface soil moisture maps of CONUS during 2018.03.19 -2018.03.25 and 2019.03.18 -2019.03.24. The maps clearly show that the cropland in late March 2019 is much wetter than the same period of 2018.

Figure 4 illustrates 9km resolution soil moisture anomaly maps of CONUS for the same March weeks for 2018 and 2019. The anomaly map of 2019 shows that the soil moisture in the zoomed-in area (Iowa) is much higher than normal (five-year average), while the anomaly map of 2018 shows that the soil moisture in the same area is clearly lower than normal. This observation is consistent with soil moisture maps shown in Figure 3.

5. CONCLUSION

This paper presents Crop-CASMA, an application for interactive soil moisture and vegetation condition data visualization, dissemination, and analytics. Crop-CASMA is a unique web GIS application for cropland soil moisture monitoring and assessment based on SMAP data. It enables direct use of soil moisture data products for crop condition monitoring and decision support.

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Disclaimer: The findings and conclusions in this publication are those of the authors and should not be construed to represent any official USDA or U.S. Government determination or policy.

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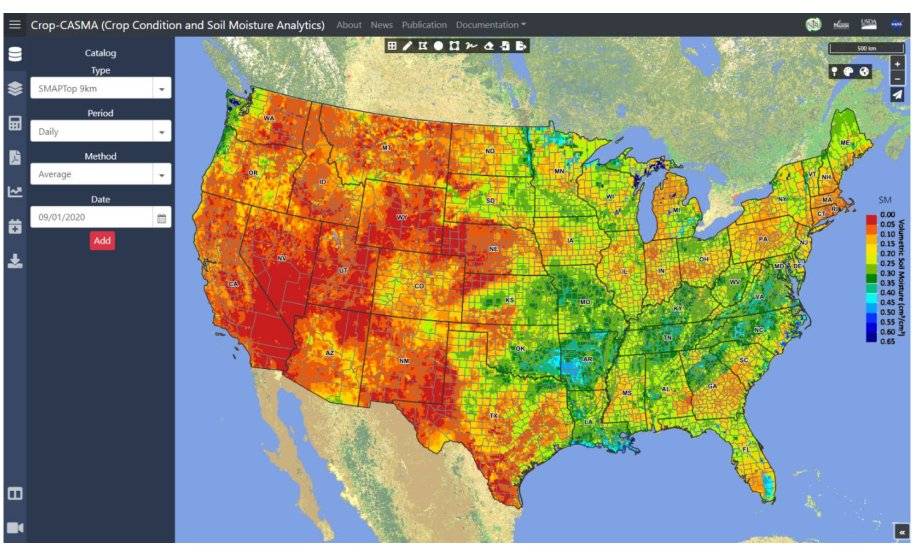

Figure 2. Graphic user interface of Crop-CASMA web client