**Idaho Water Resources**

*Estimating Soil Moisture in Semi-arid Sagebrush Steppe Utilizing NASA Earth Observations*

**VPS Title:** RADAR Love: A Symphony of Sensors

**Project Team**

***Project Team*:**

Ian Lauer (Project Lead), laueian@isu.edu

Dane Coats

Leah Kucera

Zach Sforzo

Madi Broddle

***Advisors & Mentors*:**

Keith Weber (Idaho State University, GIS TReC)

**Project Overview**

***Project Synopsis*:**

NASA DEVELOP aims to investigate soil moisture across the sagebrush steppe ecosystem of the Intermountain West to determine if critical indicators of landscape health can be approximated using NASA Earth observing satellites. Using spaceborne data collected from SMAP, GPM, Terra MODIS, and LiDAR, this project will evaluate methods for monitoring soil moisture in semi-arid ecosystems. Integrating vegetation productivity, soil moisture observations, precipitation measurements, and fusion products from land-surface models will provide land managers with a more robust picture of ecosystem health and water budgets in these specialized regions.

***Abstract*:**

Soil moisture is a critical component of ecosystem health, particularly in semi-arid landscapes where seasonal and infrequent precipitation is one of the primary controls on vegetative health. Current land management practices of soil moisture data collection rely on costly and time-consuming field sampling or on extensive modeling. Introduction of remotely sensed soil moisture from NASA Earth observations (EOs) will provide low-effort, high spatio-temporal coverage datasets for management agencies such as our primary partners at the US Fish and Wildlife Service (USFWS). Validating remotely-sensed data with field observations from Reynolds Critical Experimental Watershed (RCEW) in Idaho will increase the confidence in remotely sensed soil moisture data. This project evaluated methods for monitoring soil moisture in semi-arid ecosystems using data from NASA Soil Moisture Active Passive (SMAP) sharpened with European Space Agency (ESA) Sentinel-1 C-Band Synthetic Aperture Radar (C-SAR) backscatter, Global Precipitation Measurement (GPM), Moderate Resolution Imaging Spectroradiometer (MODIS) derived Normalized Differential Vegetation Index (NDVI), and modeled soil moisture from TopoFire and Gridded Surface Meteorologic Dataset (GRIDMET) for the period between December 2016 to July 2018. The Idaho NASA DEVELOP team created useful maps and established a workflow to allow land managers to easily access and visualize soil moisture in their area of interest. Linear regression analysis was used to quantify correlations between soil moisture, precipitation, and vegetation health. Preliminary correlation values show low negative correlation between SMAP and *in situ* soil moisture, which may be explained by differences in measurement depth and rapid dessication in upper soil layers.

**Keywords:** SMAP, MODIS, Soil moisture, NDVI, GPM, , Sentinel-1 C-SAR, Google Earth Engine API

***National Application Area Addressed:*** Water Resources

***Study Location:*** Idaho

***Study Period:*** December 2016 – Present

***Community Concern:***

* Soil moisture is one of the primary determinants of ecosystem health in semi-arid Idaho landscapes; therefore, accurate estimates of soil water content are vital.
* It is difficult to track infreqequent, seasonal precipitation inputs and resulting storage as soil moisture, particularly across large rangelands and hetergenous terrain
* Land managers need this information to better understand grazing impacts, determine fire susceptibility, and target native plant recovery strategies following a disturbance.
* Accurate prediction of timing and extent of soil saturation in Idaho can better constrain “green-up” timing and improve fire hazard assessments.

***Project Objectives:***

* Assess the potential of SMAP in mapping soil moisture across semi-arid environments and potential enhancement by other available sensors
* Validate soil moisture from SMAP by correlating with related variables (i.e. vegetative health and precipitation) to create Soil Moisture Maps
* Produce Google Earth Engine API application that showcases Soil Moisture Maps and allows land managers to easily visualize applicable NASA Earth observations data

**Partner Overview**

***Partner Organization(s):***

|  |  |  |  |
| --- | --- | --- | --- |
| **Organization** | **POC (Name, Position/Title)** | **Partner Type** | **Boundary Org?** |
| **US Fish and Wildlife Service, Eastern Idaho Field Office** | Evan Ohr, Biologist;Lisa Dlugolecki, Biologist;Matt Bringhurst, Soil Conservation Tech | End User | Yes |
| **Idaho Department of Fish and Game, Southeast Regional Office** | Scott Bergen, Sr. Wildlife Research Biologist | End User | No |
| **USDA, Natural Resources Conservation Service, Pocatello Field Office** | Nate Matlack, Soil Conservationist; Trudy Pink, Resource Soil Scientist | Collaborator | No |
| **Idaho National Laboratory** | Tammie Borders, Research Scientist;Trent Armstrong, Research Scientist | Collaborator | No |
| **USDA, Agricultural Research Service, Northwest Watershed Research Center** | Dr. Patrick E. Clark, Range Scientist | Collaborator | No |

***Decision Making Practices & Policies***:

In the Intermountain West, the health of viable grazing lands is primarily controlled by precipitation in tandem with soil water content. Specific areas of concern for threatened species are noted as priority conservation areas. These areas are currently identified via field observations, and information is shared between a variety of state and federal agencies. Currently, the Eastern Idaho Field Office uses remote sensing and GIS tools for map creation and decision support. The Idaho Department of Fish and Game (IDFG) conducts research and manages groups that currently use satellite-derived imagery primarily from MODIS and Landsat for natural resource management throughout the state of Idaho. For example, IDFG utilizes Landsat OLI, ETM+, and TM to measure annual vegetation production, invasive species detection, and fire recovery estimation (dNBR). Senior Wildlife Research Biologist, Scott Bergen, assists in developing methodological protocols and interpreting the resulting information.

***Project Benefit to End User***:

This project will familiarize the USFWS with additional remote sensing resources and the opportunity to expand their usage of NASA Earth observations. Current soil moisture data collected for IDFG is done in the field, which is time-consuming and costly. Access to remotely-sensed or modelled data will decrease costs of land management and offer greater coverage of managed areas. Validation of soil moisture data for this region will increase confidence in applying these observations for land management. End-products will provide partners with better data and visualizations of soil moisture for various management practices. For example, in the case of livestock grazing, the gathered data will allow for better estimates of vegetation health and enable more sustainable use of semi-arid landscapes. For fire applications, remotely-sensed pre-fire estimates of soil moisture will complement limited existing field monitoring sites and fuel moisture calculations. This work will provide a robust baseline for understanding the regional water budget, which will serve as a foundation to provide partners with a more holistic picture of water resources during a continuation project in the fall 2018 term.

**Earth Observations & End Products Overview**

***Earth Observations:***

|  |  |  |
| --- | --- | --- |
| **Platform & Sensor** | **Parameter(s)** | **Use** |
| **SMAP**  | Soil moisture | SMAP was used to determine soil moisture content.  |
| **SMAP/Sentinel-1 enhanced** | Soil moisture, enhanced by Sentinel-1 C-SAR backscatter | SMAP/Sentinel-1 enhanced L2 products were used to determine soil moisture content at 1km. |
| **GPM GMI** | Precipitation | GPM GMI products was used to approximate near-real time precipitation intensity. |
| **Terra MODIS** | NDVI | Terra MODIS was used to monitor vegetation health. NDVI maps will provide estimates for vegetation health, which will support soil moisture data validation. |

***Ancillary Datasets:***

Reynolds Creek Experimental Watershed soil moisture data – Ground-based soil moisture data from multiple locations distributed across the watershed (1970-present)

Gridded Surface Meteorologic Dataset (GRIDMET) – Combined gridded datasets PRISM and NLDAS. Provides time-series temperature and precipitation data and land cover type (1979-2018).

TOPOFIRE - A topographically-resolved drought and wildfire danger monitoring system for the conterminous US; provides interpolated soil moisture and vegetative moisture estimates.

Idaho LiDAR Consortium, Reynolds Creek LiDAR – provided the elevation data necessary to create aspect and slope, which will be important parameters for hydrologic transport.

***Software & Scripting:***

Esri ArcGIS and Esri ArcPro – Raster manipulation and analysis, map creation

Google Earth Engine API – Scripting and raster analysis, tool creation

Python – Scripting and raster analysis

Excel -– Statistical analysis

MATLAB – Statistical analysis

Adobe Creative Suite – Graphic creation and map manipulation

***End Products:***

|  |  |  |  |
| --- | --- | --- | --- |
| **End Products** | **Earth Observations Used**  | **Partner Benefit & Use** | **Software Release Category** |
| **Soil Moisture Maps – Vegetation/Soil Moisture** | SMAP and Sentinel-1 C-SAR, Terra MODIS | These maps will provide partners with information about the timing of peak NDVI vs soil moisture availability. Historic data will allow us to show spatial and temporal relationships between these variables. | N/A |
| **Soil Moisture Maps – Precipitation/Soil Moisture**  | SMAP and Sentinel-1 C-SAR, GPM GMI | These maps will provide end users with information about soils and their relationship to regional precipitation trends. This can help partners identify locations with hydrophobic soils.  | N/A |

**Project Handoff Package**

**Transition Plan:**

End users will be granted access to the data, technical paper, and project video directly through NASA Large File Transfer (LFT) or via physical electronic transfer devices. Final imagery will be disseminated electronically following the project closeout. Software release will take place, if necessary, via the proper channels.

*Project Continuation Plan*: This project is proposed for a second term, which will continue building on the SMAP and modelled data used in the first term to investigate a more holistic exploration of water balance measurements in the system. This future project will incorporate MODIS (MOD16A2) 8-day composite evapotranspiration (ET) products, NLDAS-2 Mosaic LSM, MERRA-2, and other evapotranspiration-focused datasets.

**Team POC:** Ian Lauer, laueian@isu.edu

**Software Release POC**: Zachary Sforzo, zachsforzo@gmail.com

**Partner POC**: Matt Bringhurst, matthew\_bringhurst@fws.gov

**Handoff Package:**

* Technical paper
* Project video
* Project presentation
* Project poster
* Correlation Statistics for soil moisture, vegetation, precipitation
* Soil Moisture Maps – Precipitation/Soil Moisture and Vegetation/Soil Moisture

**References:**

Abatzoglou J. T. (2012). GRIDMET netCDF file. Google Earth Engine, retrieved 5 July 2018. doi: http://dx.doi.org/10.1002/joc.3413

Didan, K. (2015). MOD13Q1 MODIS/Terra Vegetation Indices 16-Day L3 Global 250m SIN Grid, Version 6. NASA EOSDIS LP DAAC. doi: 10.5067/MODIS/MOD13Q1.006

Das, N., D. Entekhabi, R. S. Dunbar, S. Kim, S. Yueh, A. Colliander, P. E. O'Neill, and T. Jackson. 2018. SMAP/Sentinel-1 L2 Radiometer/Radar 30-Second Scene 3 km EASE-Grid Soil Moisture, Version 2. Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center, accessed 5 July 2018. doi: https://doi.org/10.5067/KE1CSVXMI95Y.

Glenn, N., Boise Aerospace Center Laboratory(2007). "CZO Dataset: Reynolds Creek - Digital Elevation Model (DEM), Land Cover, LiDAR (2007)." Retrieved 28 Jun 2018, from http://criticalzone.org/reynolds/data/dataset/3932/

Holden, Z. A., Jolly, M., Warren, A., Landguth, E., Abatzoglou, J., Parsons, R., Luce, C. TOPOFIRE: A web mapping server for monitoring insect, climate and terrain-induced impacts on fire danger in complex terrain, acsessed 6 July 2108. https://topofire.dbs.umt.edu/

NASA, Precipitation Measurement Missions. (2014). Global Precipitation Measurement (GPM), v5. Google Earth Engine, 10 July 2018. doi: 10.5067/GPM/IMERG/3B-HH/05

O'Neill, P. E., S. Chan, E. G. Njoku, T. Jackson, and R. Bindlish. 2018. SMAP L3 Radiometer Global Daily 36 km EASE-Grid Soil Moisture, Version 5. Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center, 5 July 2018. doi: https://doi.org/10.5067/ZX7YX2Y2LHEB.

USDA-ARS. Idaho State University. Boise State University. (2014). "CZO Dataset: Reynolds Creek - GIS/Map Data (2014)," retrieved 28 Jun 2018. http://criticalzone.org/reynolds/data/dataset/3934/