**Illinois Disasters**

*Utilizing NASA Earth Observations to Enhance Drought Monitoring in Illinois*

**Project Team**

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**Project Overview**

***Project Synopsis:***

In recent decades, Illinois experienced historic drought conditions, resulting in economic loss and decreased agricultural yield. Evaluating soil moisture response to drought events is an important component to analyzing the environmental and societal implications of drought. This project assessed the suitability of integrating modeled, satellite, and *in-situ* data for drought monitoring. Analyzed datasets included remotely sensed products from NASA Earth observations and *in-situ* data provided by the state of Illinois. This research evaluated the short-term and seasonal soil moisture variability and accuracy of remotely sensed measurements compared to *in-situ* data.

***Abstract:***

 Drought and flooding in Illinois have severe impacts on the communities and ecosystems of the state. Soil moisture is a valuable indicator of drought and flood vulnerability but can be difficult to measure since in situ monitoring is limited to discrete stations throughout the state. The team created a framework to compare in situ, modeled, and NASA satellite soil moisture measurements to increase the spatial coverage of soil moisture monitoring. The team partnered with the Illinois State Weather Survey, USDA Midwest Climate Hub, NOAA Regional Climate Services of the Central Region, NOAA National Integrated Drought Information System’s Midwest Drought Early Warning System, and the NOAA North Central River Forecast Center. The team standardized and compared soil moisture data from NASA’s Soil Moisture Active Passive (SMAP) mission, modeled soil moisture outputs from NASA’s SPoRT Land Information System (SPoRT-LIS), and in situ measurements from the Illinois State Weather Survey’s Water and Atmospheric Resources Monitoring (WARM) program. Compared to the WARM data, the satellite and modeled data showed seasonally variable differences and bias. The difference was highest in the winter months and lowest in the late summer and early fall months for the SMAP and SPoRT-LIS data products. SPoRT-LIS produced lower seasonal variability and SMAP demonstrated higher correlation values and lower differences. These analyses suggest that both SMAP and SPoRT-LIS products offer unique strengths and limitations when used for soil moisture monitoring.

***Key Terms:***

drought monitoring, Illinois,SMAP, soil moisture, SPoRT-LIS

***National Application Area Addressed:*** Disasters

***Study Location:*** IL

***Study Period:*** January 2003 to May 2021

***Community Concerns:***

* Illinois’ productive agricultural industry is a leading producer of corn, soybeans and swine for the nation. Illinois is located in the Midwest, a region that is sensitive to precipitation extremes. Drought can occur rapidly and cause significant agricultural and ecological damage resulting in high mitigation and compensation costs.
* Drought events affect large areas of the state and result in severe economic damage. In 2020, more than 20% of Illinois experienced moderate to severe drought conditions. In 2012, a fast-moving drought struck Illinois in the midst of its growing season resulting in $3.5 billion in crop insurance payouts.
* Soil moisture can be used as a primary drought indicator and can provide insight into forthcoming drought before other environmental indicators are prompted. *In-situ* data provides necessary soil moisture observations, but is spatially limited. A spatially comprehensive assessment is needed to make climate informed decisions.

***Project Objectives:***

* Compare standardized soil moisture measurements, anomalies, and percentiles from satellite, modeled, and *in-situ* data through time series analyses
* Evaluate the data bias and variability between satellite products and *in-situ* data through statistical indicators such as correlation, root mean square error, and mean bias error
* Create maps that provide a spatial overview of the data bias and variability found between datasets at each of the WARM network stations
* Publish an Esri ArcGIS StoryMap that provides an engaging narrative related to the importance of drought monitoring in specific locations of Illinois: Springfield, Decatur, and St. Charles

**Partner Overview**

***Partner Organizations:***

|  |  |  |  |
| --- | --- | --- | --- |
| **Organization** | **POC (Name, Position/Title)** | **Partner Type** | **Boundary Org?** |
| **Illinois State Water Survey** | Dr. Trent Ford, Illinois State Climatologist; Jennie Atkins, Water and Atmospheric Resources Monitoring Program Manager | End User | No |
| **USDA Midwest Climate Hub** | Dr. Dennis Todey, Director | End User | No |
| **NOAA, Regional Climate Services, Central Region** | Doug Kluck, Regional Climate Services Director | Collaborator | No |
| **NOAA, National Integrated Drought Information System, Midwest Drought Early Warning System** | Molly Woloszyn, Regional Drought Information Coordinator | Collaborator | No |
| **NOAA, North Central River Forecast Center** | Mike Welvaert, Senior Hydrologist; Steve Buan, Hydrologist | Collaborator | No |

***Decision-Making Practices & Policies***

The Illinois State Water Survey (ISWS) distributes local climate and weather data, basic and applied research, and maps to Illinois farmers, government agencies, policymakers, and local stakeholders. The Illinois State Climatologist, housed in the ISWS, expands on these products to investigate past climate events, monitor current conditions, and understand the future of climate change. The ISWS produces reports on developing drought conditions based on measurements of precipitation, humidity, land surface temperature, and soil moisture content from remotely sensed, modeled, and *in-situ* datasets. They use these datasets to inform practices such as agricultural planning and water resource allocation. The ISWS's current *in-situ* data collection infrastructure, the Illinois Climate Network, comprises of 19 sites that measure soil moisture across the state. Similarly, the USDA Midwest Climate Hub delivers region-specific information and technologies to agriculture and natural resource managers that enable climate-informed decision-making. The Hub hosts monthly climate and drought outlook webinars to inform local stakeholders of potential and ongoing impacts from climate phenomena across sectors.

**Earth Observations & End Products Overview**

***Earth Observations:***

|  |  |  |
| --- | --- | --- |
| **Platform & Sensor** | **Parameters** | **Use** |
| **SMAP L-band** | L4 - Surface and Rootzone Soil Moisture  | Instantaneous daily surface soil moisture values at a 9 km resolution acquired from the CROP-CASMA (Crop Condition and Soil Moisture Analytics) web-based application were compared to SPoRT-LIS and WARM soil moisture data and used to compute daily soil moisture percentiles and anomalies for comparison. |

***Ancillary Datasets:***

* Illinois Climate Network, Water and Atmospheric Resources Monitoring Program (WARM)– Daily *in-situ* soil moisture data were used to compute soil moisture percentiles, anomalies, and volumetric water content time series for comparison across datasets from 2003 to 2021
* NASA Short-term Prediction Research and Transition-Land Information System (SPoRT-LIS) –Instantaneous daily volumetric soil moisture data were used to compute anomalies and percentiles from 2003 to 2021 for comparison across datasets

***Software & Scripting:***

* Esri ArcGIS Pro 2.6.2 – StoryMap generation, data analysis, and visualization
* Python 3.9.2 – Data analysis and visualization
* QGIS 3.16 – Data analysis and visualization

***End Products:***

|  |  |  |  |
| --- | --- | --- | --- |
| **End Product** | **Earth Observations Used**  | **Partner Benefit & Use** | **Software Release Category** |
| **Soil Moisture Variability Analysis Maps & Graphs** | SMAP L-band | Soil moisture variability analysis maps and graphs enhance partners understanding of the suitability of soil moisture data products. This is beneficial to ensure accuracy in future drought monitoring maps.  | N/A |
| **Soil Moisture Case Study**  | SMAP L-band | A soil moisture case study provides an example of how soil moisture variability changes during dry and wet periods. The case study is a concrete way for partners to connect with the data and analysis. | N/A |
| **Soil Moisture Drought Analysis Tool (SMDAT)** | SMAP L-band | This software enables users to spatially and temporally standardize satellite, modelled, and in-situ soil moisture data, and generate analytical products including drought anomaly and percentile timeseries as well as cross-dataset correlation and error scatterplots. | III |
| **ArcGIS StoryMap** | SMAP L-band | Through creative visualization, an ArcGIS StoryMap conveys an accessible and engaging narrative of the project to partners and the public. | N/A |

***Product Benefit to End User:***

Satellite products provide spatially comprehensive coverage of soil moisture, which is more useful in drought monitoring than the limited coverage of *in-situ* data. Statistical analysis of soil moisture variability between modeled, remotely sensed, and *in-situ* data sets will inform the Illinois State Water Survey, USDA Midwest Climate Hub, and other project collaborators of data product suitability for drought monitoring. Quantifying the uncertainty between and within soil moisture data products is critical to enhancing the interpretation of drought forecasts products by key stakeholders, including natural resource managers, agricultural communities, and at-risk populations.

**References**

Cook, B. I., Mankin, J. S., & Anchukaitis, K. J. (2018). Climate Change and Drought: From Past to Future. *Current Climate Change Reports*, *4*(2), 164–179. <https://doi.org/10.1007/s40641-018-0093-2>

Ford, W. T. & Quiring M. S. (2019). Comparison of contemporary in situ, model, and satellite remote sensing soil moisture with a focus on drought monitoring. *Water Resources Research, 55(2)*, 1565-1582. <https://doi.org/10.1029/2018WR024039>

Leeper, R., Bell J.E., & Palecki M. (2019). A description and evaluation of U.S. Climate Reference Network standardized soil moisture dataset. *Journal of Applied Meteorology and Climatology, 58(7)*, 1417-1428. <https://doi.org/10.1175/JAMC-D-18-0269.1>

McDonough, K., Hutchinson S., Hutchinson J.M., Case J., & Rahmani V. (2018). Validation and assessment of SPoRT-LIS surface soil moisture estimates for water resources management applications. *Journal of Hydrology, 566,* 43-54. <https://doi.org/10.1016/j.jhydrol.2018.09.007>

Tavakol, A., Rahmani V., Quiring S., & Kumar S. (2019). Evaluation analysis of NASA SMAP L3 and L4 and SPoRT-LIS soil moisture data in the United States. *Remote Sensing of Environment, 299*, 234-246. <https://doi.org/10.1016/j.rse.2019.05.006>