**Midwest Water Resources**

*Developing an Evapotranspiration Climatology to Analyze Spatiotemporal Water Budget Patterns for Agriculture and Natural Resources Managers in the Midwest*

**Project Team**

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**Project Overview**

***Project Synopsis:***

The Midwest is one of the most agriculturally intensive regions in the United States and seasonal shifts in climatic variables, such as evapotranspiration, can have a major impact on resource availability and economic productivity. This project examined spatiotemporal patterns of evapotranspiration and precipitation from 2001 to 2020 in the Midwest using Earth observations. Partners for this work included the United States Department of Agriculture (USDA) Midwest Climate Hub, the National Oceanic Atmospheric Administration’s National Integrated Drought Information System’s (NIDIS) Midwest Drought Early Warning System, the Minnesota Department of Agriculture, Michigan State University, and the USDA Foreign Agricultural Service.

***Abstract:***

Evapotranspiration (ET) is a climatic variable critical to the hydrologic cycle and is used to evaluate spatiotemporal trends in drought conditions. Although *in-situ* observations provide accurate ET information, these records are spatially sparse. The United States Department of Agriculture (USDA) Midwest Climate Hub, National Integrated Drought Information System, Minnesota Department of Agriculture, Michigan State University, and the USDA Foreign Agricultural Service have partnered with DEVELOP to gain new insights on spatiotemporal patterns of ET with NASA satellite data. This project evaluates the feasibility of using remotely sensed ET data products to understand trends from 2001 through 2020. Actual ET (aET) data were sourced from NASA’s Terra Moderate Resolution Imaging Spectroradiometer (MODIS), and reference ET (refET) and precipitation data were sourced from the Gridded Surface Meteorological Dataset (gridMET). Spatial and temporal differences in the MODIS and gridMET data sets were resolved such that gridded data could be compared. These data sets were then used to produce monthly Normals maps of mm/8-day of precipitation, aET, and refET. Using precipitation and ET Normals maps, hydrologic state maps were produced by subtracting either refET or aET from precipitation. These hydrologic state maps provide a proxy water balance by summarizing the difference between water entering and leaving the ground surface. Additionally, the ET products were compared in timeseries plots. The ET products from this project provided partners with comparable datasets to assess potential drought and flooding conditions to support Midwest agricultural and natural resource managers in decision-making.

***Key Terms:***

Terra MODIS, gridMET, timeseries, climatology, evapotranspiration, precipitation, Midwest, water balance

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

***Study Location:*** MI, MN, OH, WI, IA, IL, MO, IN, KY

***Study Period:*** January 2001 – December 2020

***Community Concerns:***

* Evapotranspiration (ET) variability impacts the Midwest’s production of corn and soybean crops, irrigation schedules, growing seasons, and ecosystem health monitoring.
* Current scarcity and expense of *in-situ* measurements limits the holistic understanding of ET variability through space and time.
* Additional ET information is needed to help managers mitigate impacts from extreme weather events and the adverse effects of climate change on agricultural productivity.
* Understanding ET’s role within the Midwest’s seasonal hydrologic cycle and its spatiotemporal patterns will allow water resource managers to enhance their drought monitoring practices and provide a more complete timeline of historical trends.

***Project Objectives:***

* Calculate actual ET (aET), reference ET (refET), and precipitation averages over the full study period
* Create aET and refET monthly Normals maps to provide a holistic view of ET over time
* Plot timeseries of aET and refET throughout the study period
* Produce hydrologic state maps by subtracting aET and refET Normals from precipitation Normals

**Partner Overview**

***Partner Organizations:***

|  |  |  |  |
| --- | --- | --- | --- |
| **Organization** | **POC (Name, Position/Title)** | **Partner Type** | **Boundary Org?** |
| **USDA Midwest Climate Hub** | Dr. Dennis Todey, Director | End User | Yes |
| **NOAA, National Integrated Drought Information System (NIDIS), Midwest Drought Early Warning System** | Molly Woloszyn, Regional Drought Information Coordinator | End User | Yes |
| **Minnesota Department of Agriculture, Pesticide and Fertilizer Management Division** | Dr. Jeppe Kjaersgaard, Research Scientist | Collaborator | Yes |
| **Michigan State University, Department of Geography, Environment, and Spatial Sciences** | Dr. Jeffery Andresen, Professor and Michigan State Climatologist | Collaborator | Yes |
| **USDA Foreign Agriculture Service** | Dr. Sunita Yadav-Pauletti | Collaborator | Yes |

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

Partner organizations seek more accessible and comprehensive ET climatologies. While NOAA’s NIDIS utilizes all types of atmospheric and land surface data relating to drought such as NASA’s SMAP and NASA-Sport soil moisture products in their climate outlook webinars, they are seeking a spatially comprehensive ET climatology product. In partnership with NOAA, the USDA Midwest Climate Hub hosts monthly climate and drought outlook webinars to inform the region’s stakeholders of potential and ongoing impacts from climate phenomena, such as ET. Similarly, the NOAA NIDIS Midwest Drought Early Warning System (DEWS) uses a network of federal, tribal, state, local, and academic partners to make climate and drought science accessible and useable for decision makers in the Midwest. The Midwest DEWS prepares drought status update reports and disseminates region-specific information surrounding drought monitoring, prediction, planning, outreach, and research applications. The Minnesota Department of Agriculture uses satellite data from NASA to support informed decisions on policy. The USDA Midwest Climate Hub is responsible for advising agricultural stakeholders on climate issues and primarily uses surface-based and radar data with occasional usage of satellite data.

**Earth Observations & End Products Overview**

***Earth Observation:***

|  |  |  |
| --- | --- | --- |
| **Platform & Sensor** | **Parameter** | **Use** |
| **Terra MODIS** | Evapotranspiration | The ET product was used to generate twelve aET Normals maps, one for each month across all years. |

***Ancillary Datasets:***

* University of Idaho Gridded Surface Meteorological (gridMET) Dataset – Reference ET and precipitation data from 2001 to 2020 for generation of refET Normals and precipitation Normals maps

***Software & Scripting:***

* Google Earth Engine Python API – Data acquisition, preprocessing, and analysis
* Google Colab Notebook – Scripting and coding collaboration
* ESRI ArcGIS Pro 2.6.2 – Shapefile creation, data processing check, and map formatting
* Adobe Illustrator – Map formatting

***End Products:***

|  |  |  |  |
| --- | --- | --- | --- |
| **End Product** | **Earth Observations Used**  | **Partner Benefit & Use** | **Software Release Category** |
| **Actual Evapotranspiration Climatology Maps** | Terra MODIS | Actual evapotranspiration climatology maps, derived from MODIS data products, provide partners with a spatiotemporal assessment of estimated actual evapotranspiration over the study period. | II |
| **Reference Evapotranspiration Climatology Maps** | N/A | Reference evapotranspiration climatology maps, based on reference (alfalfa) ET data from gridMET, provide partners with a spatiotemporal assessment of reference evapotranspiration over the study period.  | II |
| **Precipitation Climatology Maps** | N/A | Precipitation climatology maps were generated using gridMET data to provide partners with a high-level view of precipitation over the study area. | II |
| **Reference Hydrologic State Maps** | N/A | Potential hydrologic state maps were created by subtracting refET from precipitation to identify regions particularly susceptible to drought or flooding. | II |
| **Actual Hydrologic State Maps** | Terra MODIS | Actual hydrologic state maps were created by subtracting aET from precipitation to provide a proxy for trends in water balance by region. | II |
| **Actual Evapotranspiration Timeseries Analysis** | Terra MODIS | An aET timeseries was extracted and plotted for nine points within the study area to show trends across time. | II |
| **Reference Evapotranspiration Timeseries Analysis** | N/A | A refET timeseries was extracted and plotted for nine points within the study area to show trends across time. | II |

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

These end products will provide the project partners with a more comprehensive understanding of evapotranspiration trends, and how they compare with precipitation, in the Midwest. These products can be used as a resource to guide decision-making in water resources, land management, and drought mitigation strategies. These maps and time series will also allow partners to compare current and historical ET to identify anomalies and changes over time.

***Project Continuation Plan:***

The first term focused on satellite-derived ET and precipitation climatological analysis. Handoff materials produced served as a foundation for ET analysis in this agriculturally significant region. The proposed second term will expand upon this work by incorporating additional evapotranspiration data from the Landsat Provisional Actual Evapotranspiration product and comparing product performance across geographic space. The team will validate ET with *in-situ* measurements to evaluate product suitability in the Midwest. For the second term, refined ET maps, anomalies, and statistical analyses will be included in handoff materials.

**References**

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Niyogi, D., Jamshidi, S., Smith D., & Kellner O. (2020). Evapotranspiration climatology of Indiana using in situ and remotely sensed products. *Journal of Applied Meteorology and Climatology*, *59*(12), 2093–2111*.* https://doi.org/10.1175/JAMC-D-20-0024.1