**NASA DEVELOP National Program**

**2021 Fall Project Proposal**

**North Carolina – NCEI**

**Midwest Water Resources**

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

**Project Overview**

***Project Synopsis*:** The Midwest is one of the most agriculturally intensive regions in the country and seasonal shifts in climatic variables, such as evapotranspiration, can have a major impact on resource availability and economic productivity. This project will partner with the USDA Midwest Climate Hub, NOAA’s Midwest Drought Early Warning System (DEWS), Minnesota Department of Agriculture, and Michigan State University to analyze spatiotemporal patterns of hydrologic conditions from evapotranspiration and precipitation climatologies in the Midwest. Using Terra MODIS, gridMET, and NClimGrid observations, the team will create regional evapotranspiration, precipitation, and hydrologic condition climatology maps to historically evaluate seasonal variability and trends in the Midwest’s hydrologic cycle. A climatological perspective of these variables will provide project partners with a holistic assessment of seasonal shifts and patterns in the regional water balance and can be used to proactively communicate drought risk to agricultural and water resource managers.

***Community Concern:*** The Midwest encompasses the world's most expansive region of corn and soybean production, with over 70 million ha of land used for cultivation. Understanding seasonal water variability is of vital importance to this region — affecting irrigation schedules, growing seasons, and ecosystem health monitoring. Evapotranspiration plays an integral role in land surface and water balance processes, returning approximately two-thirds of precipitation to the atmosphere in the Midwest. This is a critical component of the seasonal hydrologic cycle and can be used to monitor the temporal evolution of drought conditions, however, *in situ* observations are sparse and short periods of record limit the historical perspective of evapotranspiration. There is insufficient research about the spatiotemporal patterns of evapotranspiration and its role in the hydrologic cycle in the Midwest. Placing evapotranspiration into a climatological perspective will allow water resource managers to enhance their drought monitoring practices and communicate how current evapotranspiration conditions compare to the past.

***Source of Project Idea:*** NOAA NIDIS connected DEVELOP North Carolina leadership with the USDA Midwest Climate Hub. NIDIS and the USDA Midwest Climate Hub expressed interest in exploring evapotranspiration in the Midwest from a historical context.

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

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

***Study Period:*** January 2001 – September 2021

***Advisors:*** Dr. Olivier Prat (NOAA National Centers for Environmental Information, North Carolina Institute for Climate Studies); Dr. Brian Nelson (NOAA National Centers for Environmental Information)

**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, 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 |

***End User Overview***

***End User’s Current Decision-Making Process:*** The USDA Midwest Climate Hub provides science-based, region-specific information and technologies to agricultural and natural resource managers to enable climate informed decision making. The Hub assembles research information surrounding water resources in the Midwest to determine the natural resource response to weather and climate variation. In partnership with NOAA, the Hub hosts monthly climate and drought outlook webinars to inform the regions stakeholders of potential and ongoing impacts from climate phenomena, such as evapotranspiration, across sectors. Similarly, NOAA NIDIS, Midwest Drought Early Warning System’s (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.

***End User’s Capacity to Use NASA Earth Observations:***

*USDA Midwest Climate Hub* – The USDA Midwest Climate Hub produces monthly Midwest agriculture focused outlooks that provide a summary of past and current conditions of many climate variables and places them in context for agriculture in the Midwest. Currently, the climate outlooks incorporate remotely sensed data products, such as the Standardized Precipitation Index (SPI), and *in situ* observations from regional mesonet stations. The Hub is interested in evaluating remotely sensed evapotranspiration data products to incorporate in their climate outlook webinars.

*NOAA, National Integrated Drought Information System, Midwest Drought Early Warning System* – The Midwest DEWS prepares drought status update reports that incorporate U.S. Drought Monitor Status and often use remotely sensed soil moisture data products, such as GRACE and SMAP, for drought monitoring. The Midwest DEWS is interested in evaluating how remotely sensed evapotranspiration products may be incorporated in Midwest drought monitoring practices and communication.

***Boundary Organization Overview***

***Dissemination by Boundary Organizations*:**

*USDA Midwest Climate Hub* – The USDA Midwest Climate Hub works in close coordination with other USDA groups and federal agencies along with university and NGO partners to transfer management practices, decision tools, and information to land management stakeholders. The Hub may disseminate project findings with this network of organizations as well as incorporate findings in the monthly climate outlook webinars.

*NOAA, National Integrated Drought Information System, Midwest Drought Early Warning System* – The Midwest DEWS has a network of federal, state, local, tribal, and academic partners that work collaboratively to address regional drought needs. The Midwest DEWS may disseminate the findings of this project with the Midwest DEWS network and share results on the NIDIS website at www.drought.gov.

***Project Communication & Transition Overview***

***In-Term Communication Plan*:** Biweekly partner meetings will occur via Google Meet to discuss project objectives, methodology, results, and feedback. The DEVELOP Fellow will initiate the first partner meeting and the Project Lead will serve as the main points of contact throughout the term. Email exchanges will occur as needed.

***Transition Plan*:** The DEVELOP team will plan to hold a virtual handoff via Google Meet in Week 10 of the term. In this handoff, the team will showcase project methodology, results, and end products to partners. Project deliverables and end products will be sent to the partners electronically after clearing export control.

**Earth Observations Overview**

***Earth Observations:***

|  |  |  |
| --- | --- | --- |
| **Platform & Sensor** | **Parameter** | **Use** |
| **Terra MODIS** | Evapotranspiration | The MODIS evapotranspiration latent heat flux product (MOD16A2, version 6) evapotranspiration data from 2001 to 2021 will be used to quantify actual evapotranspiration, compute an actual evapotranspiration climatology, and generate actual evapotranspiration climatology maps. |

***Ancillary Datasets:***

* University of Idaho Gridded Surface Meteorological Dataset (gridMET) – Derived potential evapotranspiration measurements from 2001 to 2021 will be used to quantify potential evapotranspiration, compute a potential evapotranspiration climatology, and generate potential evapotranspiration climatology maps.
* NOAA Monthly U.S. Climate Gridded Dataset (NClimGrid) – Monthly precipitation values from 2001 to 2021 will be used to quantify precipitation, compute a precipitation climatology, and generate precipitation climatology maps.

***Software & Scripting:***

* Google Earth Engine Python API – Data acquisition, preprocessing, and analyses
* Climate Engine API – Used to submit Climate Engine API calls to Google Earth Engine to standardize climatology and time series operations
* ESRI ArcGIS Pro version 2.6.2 – Data visualization and map generation

**Decision Support Tool & End Product Overview**

***End Products:***

|  |  |  |  |
| --- | --- | --- | --- |
| **End Product** | **Partner Use** | **Datasets & Analyses** | **Software Release Category** |
| **Actual Evapotranspiration Climatology Maps** | This product will analyze actual evapotranspiration in the Midwest over the study period. This will provide partners with a holistic spatiotemporal assessment of large-scale actual evapotranspiration over time. | Actual evapotranspiration observations from MODIS will be used to generate monthly average actual evapotranspiration climatology maps. | II |
| **Potential Evapotranspiration Climatology Maps** | This product will analyze potential evapotranspiration in the Midwest over the study period. This will provide partners with a holistic spatiotemporal assessment of large-scale potential evapotranspiration over time. | Potential evapotranspiration will be calculated from gridMET variables using the Penman-Monteith equation and used to generate monthly average potential evapotranspiration climatology maps. | II |
| **Precipitation Climatology Maps** | This product will analyze precipitation in the Midwest over the study period. This will provide partners with a holistic assessment of large-scale precipitation over time. | Precipitation observations from NClimGrid will be used to generate monthly average precipitation climatology maps. | II |
| **Potential Hydrologic State Maps** | This product will identity regions historically at risk of water surplus or deficits from precipitation and evapotranspiration. Project partners can use these maps to pin point flood and drought susceptible landscapes. | Potential evapotranspiration climatology maps created from gridMET will be subtracted from precipitation climatology maps created from NClimGrid to identify flood or drought susceptible landscapes. | II |
| **Actual Hydrologic State Maps** | This product will be used to assess the historical hydrologic state of the landscape. Project partners can use these maps to assess regional water stress and will provide a holistic assessment of water balance trends. | Actual evapotranspiration climatology maps created from MODIS will be subtracted from precipitation climatology maps created from NClimGrid to assess the hydrologic state of the region. | II |
| **Actual Evapotranspiration Timeseries Analysis** | Project partners will use this product to quantify actual evapotranspiration temporal trends over the study period. | A timeseries analysis of actual evapotranspiration derived from MODIS. | II |
| **Potential Evapotranspiration Timeseries Analysis** | Project partners will use this product to quantify potential evapotranspiration temporal trends over the study period. | A timeseries analysis of potential evapotranspiration derived from gridMET. | II |

***End User Benefit*:** End products created by the team will provide project partners a more holistic view of evapotranspiration trends and regional water budgets. These products can be used to inform water resource allocation, land management practices, and drought mitigation strategies in the Midwest. A climatological perspective of evapotranspiration will provide project partners with a communication tool to compare current climate conditions to historical averages and identify spatiotemporal shifts of evapotranspiration in the Midwest.

**Project Timeline & Previous Related Work**

***Project Timeline:*** 2 Terms: 2021 Fall to 2022 Spring

***Multi-Term Objectives:***

* **Term 1 (Proposed Term):** 2021 Fall (NC) – Midwest Water Resources
  + The fall term project will focus on satellite-derived evapotranspiration and precipitation climatological analysis. These data will be used to compute time series analyses and generate regional climatological hydrologic state maps to understand spatiotemporal patterns and trends in the Midwest. The products and workflow will set the stage for a more comprehensive analysis of evapotranspiration products.
* **Term 2:** 2022 Spring (NC) – Midwest Water Resources II
  + This proposed second term will expand upon the climatological analysis completed by the first term and incorporate an additional evapotranspiration product from OpenET. Evapotranspiration products will be validated at select *in situ* locations to provide a holistic exploration of product suitability in the Midwest. From these findings, the proposed second term may refine climatological evapotranspiration maps produced by the first term and calculate anomaly, trend, and generic ranking statistics of evapotranspiration. Results from both projects will be handed off following the spring term.

***Related DEVELOP Work:***

2018 Fall (ID) – Idaho Water Resources II: Approximating Evapotranspiration in Semi-Arid Sagebrush Steppe to Improve Water Balance Calculations in Southeast Idaho

2019 Spring (ID) – Argentina Water Resources: Measuring Soil Moisture and Evapotranspiration in Semi-arid Climates with NASA Earth Observations to Understand Water Balance in the Patagonian Steppe of Argentina

2020 Spring (ARC) – Eastern Washington Disasters: Integrating NASA Earth Observations to Analyze Spatiotemporal Distributions of Lightning-Caused Wildfires in Eastern Washington

2020 Spring (NC) – Ohio River Basin Water Resources: Monitoring Flash Drought Potential and Quantifying the Hydrologic Impacts in the Ohio River Basin Utilizing NASA Earth Observations

**Notes & References:**

***Notes*:** A platform providing easily accessible satellite-based estimates of evapotranspiration, OpenET (<https://openetdata.org/>), is scheduled to launch in 2021. OpenET will provide data from multiple models and provide a single ET value from the average of all models. Pending the portals launch, data provided from this platform may be incorporated in the second term of this project.

***References:***

Hussain Z. M., Hamilton S. K., Bhardwaj A. K., Basso B., Thelen K. D., Robertson G. P. (2019). Evapotranspiration and water use efficiency of continuous maize and maize and soybean in rotation in the upper Midwest U.S. *Agricultural Water Management, 221,* 92-98. <https://doi.org/10.1016/j.agwat.2019.02.049>.

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>