**NASA DEVELOP National Program**

**Fall 2016 Project Proposal**

**NASA Ames Research Center**

**Navajo Nation Climate III**

Utilizing NASA Earth Observations data and the Drought Severity Assessment Tool to assess inter-annual and seasonal drought trends and changes in snow pack in the Navajo Nation

**Project Overview**

***Objective:***

To incorporate CHIRPS and in-situ rain gauge data in the Drought Severity Assessment Tool to analyze long-term drought and compare against snow water equivalent trends in the Navajo Nation

***Community Concern:***

Water is one of the most important resources for the Navajo Nation (NN), and has wide environmental, social, and political implications. Over 70,000 Navajo residents (roughly one-third of the Reservation population) do not have access to running water due to water rights and infrastructural issues. Climate change impacts in the Southwestern US are predicted to disproportionately affect the NN, with substantial issues in regard to water resource availability. The projected climate change impacts on water resources include: declines in snowpack, more persistent and long-term droughts, decreases in late spring and summer streamflow due to changes in snowmelt timing, and decreases in water quality. In the western US, where snowmelt contributes 50-80% of the annual runoff (Pagano and Garen, 2006), the relationship between snow cover and drought is critical to gaining a comprehensive understanding of the climate regime. This project aims to assess the impacts on water resource availability on the NN using NASA Earth Observing (EO) satellite data and the Drought Severity Assessment Tool (DSAT).

***National Application Areas Addressed:*** Water Resources, Agriculture, Climate

***Study Location:*** Navajo Nation

***Study Period:*** June 1981 to current

***Advisors:*** Ms. Vickie Ly (Bay Area Environmental Research Institute) NASA Ames Research Center, Dr. Juan Torres-Pérez (Bay Area Environmental Research Institute) NASA Ames Research Center, Dr. Venkat Lakshmi (University of South Carolina), Dr. Cindy Schmidt (Bay Area Environmental Research Institute) NASA Ames Research Center

***Source of Project Idea:***

The previous DEVELOP science advisor at Ames Research Center, Dr. Cindy Schmidt, has been working with students from the United Tribes Technical College (UTTC) for many years on an internship with tribal students using remote sensing for issues related to native lands. Dr. Schmidt originally forged a relationship with the Navajo Technical University and the Navajo Nation Department of Water Resources (NNDWR). From there, there have been 2+ terms dedicated to developing a drought monitoring tool and growing a partnership between the NNDWR and NASA DEVELOP.

**Partner Overview**

***Partner Organizations:***

|  |  |  |  |
| --- | --- | --- | --- |
| **Organization** | **POC (Name, Position/Title)** | **Partner Type** | **Boundary Org?** |
| Navajo Nation Department of Water Resources, Water Management Branch | Carl McClellan, Senior Hydrologist; Teresa Showa, Principal Hydrologist; Robert Kirk, Principal Hydrologist; Maurice Upshaw, tech support; Jason John, Branch Manager | End-User | Yes |
| USDA Natural Resource Conservation Services (NRCS) | Brian Domonkos, Colorado Snow Survey Supervisor | Collaborator | No |

***End-User Overview***

***End-User’s Current Decision Making Process:***

The Navajo Nation Department of Water Resources (NNDWR) currently monitors water conditions using a network of 88 rain gauges, 8 stream gages, and 9 climate stations (NNDWR, 2003). However, limited government funding, as well as staff and infrastructural constraints have made it difficult to consistently collect these data and maintain an accurate record of rainfall.

Quantifying drought intensity is necessary to monitoring water resources. To determine the Nation’s drought status, the NNDWR uses the Standardized Precipitation Index (SPI), an internationally used probability-based indicator of abnormally wet or dry time periods. The NN currently relies on SPI values that are calculated by the Western Regional Climate Center (WRCC). However, these SPI values represent the region in three large footprints, lacking the spatial detail needed to provide a consistent understanding of the drought regime within the Nation’s regional boundaries. The NN does not currently calculate the SPI for its specific region, and does not collect or process any remotely sensed data for management purposes (personal communication, Feb. 11, 2015). The use of NASA Earth Observation data can provide coverage and spatial resolution to calculate SPI for the reservation to better monitor drought conditions in the NN.

During the first two phases of this project, the Drought Severity Assessment Tool (DSAT) was created to address the challenges in the NNDWR’s current decision making process. DSAT is a decision support tool created for the Navajo Nation to allow water managers to use satellite data to calculate and visualize Standardized Precipitation Index (SPI) values specific to chosen boundaries within the Nation. The tool was created by the NASA DEVELOP Climate Team at the Ames Research Center in Mountain View, CA.

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

With the partnership and development of DSAT 2.0 during the first 2 terms of the Navajo Nation Climate project (see “Multi-Term Objectives” for more detailed information on the accomplishments), the NNDWR has gained some exposure to NASA Earth Observation data (TRMM, GPM, CHIRPS) from the first 2 terms. This term, the goal is to introduce other types of datasets (AMSR-E, AMSR2) that complement existing products and facilitate a more comprehensive use of the tool to the NNDWR.

***Collaborator & Boundary Organization Overview***

***Collaborator Support:***

USDA NRCS - Brian Domonkos will provide support in acquiring and manipulating snow survey data. The NNDWR conducts monthly snow surveys from January to April each year. These snow surveys, along with snow surveys conducted by the NRCS, are compiled for the greater Southwest.

***Project Communication & Transition Overview***

***In-Term Communication Plan:***

The team will communicate biweekly with the NNDWR through telecons or video conferences at throughout the term. The main POCs for this communication will be Brittany Zajic, the current Center Lead, Jenna Williams, the Assistant Center Lead, as well as the project’s Team Lead.

***Transition Approach:***

During the first week, the team will hold a telecon or video conference with the NNDWR to review the project’s objectives, past terms accomplishments and available datasets. Communication will remain robust throughout the term via email and telecons. Results and manuals produced from this project will be presented to the NNDWR at the end of the term in an in-depth discussion of findings, accompanied by a question and answer period. All results will be disseminated to NNDWR via email. DSAT passed NASA Export Control

**Letter of Support:**

**Earth Observations Overview**

***Earth Observations:***

|  |  |  |
| --- | --- | --- |
| **Platform & Sensor** | **Parameter(s)** | **Use** |
| **Climate Hazards Group InfraRed Precipitation with Station data (CHIRPS)** | Precipitation rate | CHIRPS data will be used to calculate SPI rasters for the Navajo Nation and minimum bounding rectangle of HUC-8 watersheds encompassing the NN.  |
| **Aqua, Advanced Microwave Scanning Radiometer** **(AMSR-E)** | Snow Water Equivalent | AMSR-E data will be used to create a time series of Snow Water Equivalent. SWE will be used to compare against SPI calculated rasters to gain a better understanding of drought regimes.  |
| **GCOM-W, Advanced Microwave Scanning Radiometer 2 (AMSR2)** | Snow depth, Snow Water Equivalent | AMSR2 data will be used to create a time series of Snow Water Equivalent. SWE will be used to compare against SPI calculated rasters to gain a better understanding of drought regimes. |
| **ESA GlobSnow**  | Snow Water Equivalent | If time permits/there is interest, ESA GlobSnow data can be used to gain a long-term understanding of changes in SWE *for a particular region.* Temporal coverage: 1979 to present. \*Note: the extent of the data just skims the bottom of the NN territory.  |

***Ancillary Datasets:***

* NNDWR shapefiles - Infrastructure (roads, irrigation areas, dams, political boundaries), lakes, rivers, wells, springs, dams, snowpack, precipitation, streamflow
* NNDWR snow survey and USDA Natural Resource Conservation Service snow survey data
* NNDWR rain gauge data
* Environmental Protection Agency (EPA) Ecoregions Level III & IV shapefiles
* Snow Data Assimilation System (SNODAS), Snow water equivalent (2004-2014)
* NRCS Snow Survey data (2002-2011)

**Other possibly relevant datasets:**

* Digital Elevation Model (DEM), National Elevation Dataset
* Hydrological Sub-Regions, National Hydrology Dataset (NHD), USGS
* Land Cover (1990, 2001, 2006), National Land Cover Data (NLCD) products
* Forecasted Precipitation, Forecasted Maximum Temperature, Forecasted Minimum Temperature (2010-2100), Coupled Model Intercomparison Project Phase 5 (CMIP5), NASA Earth Exchange (NEX) Downscaled Climate Projections (NEX\_DCP30)
* Soil Moisture and Soil Temperature, NASA’s North American Land Assimilation System (NLDAS-2) data

***Modeling:***

n/a

***Software & Scripting:***

* Esri ArcGIS Desktop 10.3.1 - Spatial Analysis Toolbox, CHIRPS raster processing and analysis using ModelBuilder
* Python – Data processing
* R 3.3.0 Statistical Package - Calculation of SPI values with SPI package utilizing CHIRPS data, webapp development using R Shiny

**Decision Support Tool & End-Product Overview**

***End Products:***

|  |  |  |  |
| --- | --- | --- | --- |
| **End Product(s)** | **Partner Use** | **Datasets & Analyses** | **Software Release Category** |
| Validation model for satellite: in-situ data comparison | The next stage for the implementation and usability of DSAT relies on validation of CHIRPS and in-situ data. With an understanding of the discrepancy between datasets, the NNDWR will be able to assess the accuracy of the remotely derived SPI values.  | The team will investigate the discrepancy (true error, localized variation, and error with ground-truth data) between CHIRPS and in-situ rain gauge data collected by the NNDWR. The team will investigate methods to determine error through a simple point comparison and interpolations of station data to grid cells, if the station data seems appropriate. The end product will be in the form of graphs (scatter plots, standard error, root mean square error, etc.).  |  |
| Incorporation of in-situ data into DSAT processes | The NNDWR collects rain-gauge data on a monthly basis. After validating the CHIRPS-derived SPI rasters and values, the team will incorporate in-situ data in the DSAT workflow to create a closed-loop system of collecting, downloading, and analyzing SPI values on a month-by-month time scale.  | The team will work with Carl McClellan (NNDWR POC) to incorporate in-situ data measurements into the DSAT processes. This may manifest in changes to DSAT 2.0 (e.g. addition of a layer of rain gauge point data to the Visualization feature), an algorithm living outside of the tool to calculate SPI values from in-situ data and compare it to CHIRPS-derived SPI values.  |  |
| Updated Drought Severity Assessment Tool and user manual(DSAT 2.1 – 3.0)  | Changes and incorporation of in-situ data will be included in an updated DSAT package. An update user manual is essential to keeping relevant documentation for the tool.  | All changes and additions will be included to make an updated DSAT (2.1 – 3.0) package and user manual. A virtual hand-off will take place at the end of the term. The finalized DSAT (2.1 – 3.0) package will be uploaded onto Github.  |  |
| Analysis of inter-annual and seasonal SPI anomalies and major drought events  | The NNDWR will benefit from an analysis of inter-annual and seasonal anomalies in SPI values using CHIRPS data. The NNDWR currently does not calculate SPI values within their own jurisdiction. Identification of major drought events will provide basis for further investigation with Snow Water Equivalent. The NNDWR will be able to use these graphs and visualizations to illustrate the use of DSAT in their drought management decisions, reports, and papers.  | This analysis will use CHIRPS data and DSAT 2.0 to obtain the graph and excel outputs. The team can use DSAT 2.0 to identify drought trends with spatial and temporal significance. This end-product will come in the form of graphs and visualizations that the NNDWR can used in updates and reports.  |  |
| Time series analysis of Snow Water Equivalent (SWE) 2002 -2011 | The NNDWR will be able to visualize spatial and temporal changes of Snow Water Equivalent for the Navajo Nation political boundaries and the minimum bounding rectangle of the HUC-8 watersheds encompassing the NN. This end-product will help the NNDWR better understand and estimate snow pack, summer stream flow, and reservoir.  | This time series will be created from AMSR-E and AMSR2 data. The team will investigate the application of SNODAS and SNOTEL. These images and data will be processed using ArcGIS, Python, and/or ENVI. End-products will come in the form of visualizations and graphs.  |  |
| Comparison of SPI drought trends and SWE trends  | An analysis of SPI and SWE trends will provide the NNDWR with a more comprehensive picture of drought regimes and the impact of drought on water availability in the Navajo Nation.  | The results from the time series analysis will be used to compare against long-term SPI and SWE trends. Statistical analysis of relationship between drought and snow water equivalent. This will come in form of visualizations and graphs.  |  |

***End-User Benefit:***

The NNDWR currently relies on SPI values calculated by the WRCC because the ground station network within the Nation does not provide the coverage of data needed to calculate Nation-specific SPI values. However, the WRCC uses state-based climate divisions which do not take the Navajo Nation’s political boundaries into consideration. The application of remotely-sensed Earth Observation data through the DSAT 2.0 will provide the NNDWR with an avenue to calculate SPI values specific to a user-defined boundary. This phase of the project is building upon 2 terms of previous work to develop the DSAT 1.0 and DSAT 2.0 products to provide a strong basis for application and implementation of this tool. Furthermore, DSAT (2.1-3.0) will provide end-users with the ability to calculate and visualize SPI rasters, and update their database with a click of a mouse, each month. An analysis of drought and SWE trends will provide a broader understanding of the impact of drought in the NN and the application of Earth Observations to ongoing drought-monitoring efforts.

[quote from Carl on benefit of project and tool]

**Project Timeline & Previous Related Work**

***Project Timeline:*** 3 Terms: 2015 Spring, 2015 Summer, 2016 Fall

***Multi-Term Objectives:***

* **Term 1:** 2015 Spring (ARC) – Navajo Nation Climate I

The first phase of this project focused on understanding water resources in the NN and the role of NASA Earth Observation data in water management and drought mitigation. The team focused on data collection and processing, creating a geodatabase of precipitation data. The project examined methodologies of a rasterized SPI calculation and strengthening the partnership to build the framework for the following term.

* **Term 2:** 2015 Summer (ARC) – Navajo Nation Climate II

The second phase of the project focused on developing the Drought Severity Assessment Tool (DSAT 1.0) to calculate and visualize SPI rasters using PRISM, TRMM, and GPM data.

DSAT 1.0 was built in the statistical program R and interface utilizing R Shiny. The main features of DSAT 1.0 included Calculate SPI Values, Calculate Summary Statistics, and Visualizations. ArcGIS ModelBuilder models were built to process PRISM, TRMM, and GPM outside of the tool to be plugged into the DSAT afterwards.

After the second phase, work continued on the project throughout the Spring and Summer of 2016. Concentration was put on troubleshooting and fixing issues with the code. During this time, DSAT went through major revisions, including: switching to CHIRPS precipitation data to provide in-house downloading, processing, SPI calculation and visualization within one tool; and added features and changes to the UI, including the workflow of the tool, ability to stack boundaries, see cities as reference points. 5+ virtual workshop sessions to install DSAT onto Carl McCllelan’s computer and instruct/familiarize Carl with the tool. Suggestions from the NNDWR were incorporated to finalize a DSAT 2.0 package. A user-manual was created to details installation and tool workflow, with examples of the output and potential calculations the user could perform. DSAT was passed through NASA software release in April 2016.

* **Term 3 (Proposed Term):** 2016 Fall (ARC) – Navajo Nation Climate III

The third phase of this project will focus on two main objectives: 1) the validation of CHIRPS and in-situ rain gauge data collected by the NNDWR and 2) comparisons of drought and snow water equivalent. The team will investigate the discrepancy (true error, localized variation, and error with ground-truth data) between CHIRPS and in-situ rain gauge data collected by the NNDWR. The team will investigate methods to determine error through a simple point comparison and interpolations of station data to grid cells, if the station data seems appropriate. The team will work intimately with the NNDWR how to incorporate in-situ rain gauge data into DSAT and/or the DSAT workflow, a major step in the application and implementation of DSAT into the NNDWR’s operations. An analysis of seasonal and inter-annual drought trends with CHIRPS-derived SPI values will provide a foundation to understanding drought regimes in the Navajo Nation. Second, a time series of Snow Water Equivalent will be created using AMSR-E data to provide an estimation of snowpack and to compare against SPI raster maps to assess the impact of drought.

The team will hold at least 2 virtual sessions with Carl McClellan and the NNDWR partners to install and run DSAT. At the end of the term, the team will have a virtual hand-off of the analyses, updated DSAT package, and end-products.

***Related DEVELOP Work:***

Spring 2016 (NCEI) – Cascades & Sierra Water Resources: A Comparison of Remotely-Sensed Climate Data Records over the Cascade and Sierra Nevada Mountains for Improved Climate Monitoring

Spring 2015 (ARC) - Navajo Nation Climate I: Monitoring Drought Conditions in the Navajo Nation Using NASA Earth Observations

Summer 2015 (ARC) - Navajo Nation Climate II: Assessing Climate Change Impacts on Ground Water Availability and Drought Vulnerability in the Navajo Nation Using NASA Earth Observations

Summer 2016 (ARC) – Navajo Nation user manual

**Notes & References:**

***Notes:*** Carl McCllelan, the POC and main end-user, has indicated that he would also be interested in soil moisture. There are agricultural groups on the Navajo Nation that would be interested in results related to soil moisture. From the NN DWR stand-point, a better understanding of snow-pack is of interest.

***References:***

Websites:

Navajo Nation Government

<http://www.navajo-nsn.gov/govt.htm>

Navajo Nation Department of Water Resources

<http://www.frontiernet.net/~nndwr_wmb/>

[USDA NRCS – Snow water equivalent](http://www.nrcs.usda.gov/wps/portal/nrcs/detail/or/snow/?cid=nrcs142p2_046155)

Garfin, G. (2013), *Assessment of Climate Change in the Southwest United States: A Report Prepared for the National Climate Assessment*, Island Press.

Nania, J., K. Cozzetto, N. Gillett, S. Duren, A. Tapp, M. Eitner, and B. Baldwin (2014), *Considerations for Climate Change and Variability Adaptation on the Navajo Nation*, University of Colorado, Boulder, Boulder, CO.

Pagano, T.C. and Garen, D.C. (2006) Integration of Climate Information and Forecasts into Western US Water Supply Forecasts

Verdin, J.P. (2012) Remote Sensing of Drought: Innovative Monitoring Approaches