**NASA DEVELOP National Program**

**ID**

*Project Summary – Spring 2018*

**Navajo National Monument Water Resources**

*Monitoring and Forecasting Precipitation Patterns and Erosion Potential to Enhance Archaeological Preservation and Decision Making*

**VPS Title:** Gauge Against the Machine: Tracking Precipitation in Navajo National Monument­­­­­­

**Project Team**

***Project Team*:**

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**Project Overview**

***Project Synopsis*:** Yearly monsoonal precipitation patterns in Navajo National Monument (NAVA) are the leading cause of channeled incision, erosion, and downslope deposition, limiting access to three of the most well-preserved 13th century cliff dwellings in the southwestern United States. Recent increases in precipitation intensity are further exacerbating erosional processes. Overland runoff characteristics at NAVA are not yet well understood due to sparse *in situ* rain data collection networks. In order to more effectively allocate resources for restoration efforts and mitigate erosional processes, a regional methodology utilizing NASA Earth observations to estimate how water behaves at broad and fine scales.

***Abstract*:**

Increasing yearly monsoonal precipitation severity in Navajo National Monument (NAVA) is exacerbating erosion and arroyo cutting, affecting culturally significant archaeological sites in the area. In order to better understand and mitigate erosional processes, land managers at the park would benefit from comprehensive rainfall data and information on areas where erosion hazards are more likely to occur. The Idaho NASA DEVELOP team developed virtual rain gauges and erosion hazard maps that utilize NASA Earth observations to provide a more complete picture of rainfall measurements at the monument. Virtual rain gauges were developed in Google Earth Engine API from Global Precipitation Measurement (GPM) Microwave Imager (GMI) and Tropical Rainfall Measuring Mission (TRMM) Precipitation Radar (PR) satellite data. Values derived from these Earth observations were synthetically validated against each other, PRISM data, and were also compared to ground stations near the monument. The data displayed a weak statistical correlation between satellite derived data and ground based weather stations for the study area. Peaks within the data showed temporal similarities suggesting that the differences within the data were representative of regional variability. In future work, rainfall data from these virtual gauges can be used as temporal and intensity parameters, which combined with Shuttle Radar Topography Mission (SRTM)-derived hazard maps can inform land managers performing erosion mitigation.

**Keywords:**

Navajo National Monument, virtual rain gauge, Global Precipitation Measurement, Microwave Imager, Google Earth Engine API, archaeological preservation, alluvial erosion

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

***Study Location:*** Navajo National Monument, AZ

***Study Period:*** 2000 – 2017 (June – September)

***Community Concern:***

* The intensity and duration of seasonal monsoon events are a main driver of erosion in NAVA.
* NAVA is host to culturally-significant cave dwellings built in the 13th century that are under threat of large-scale erosion.
* Access to cave dwelling sites is impacted by erosion and destabilization of service and park roads, creating concerns for management and restoration efforts.
* Due to a sparse network of rainfall monitoring in the area, land managers at NAVA would benefit from the ability to monitor precipitation patterns to assess potential erosional hazards.

***Project Objectives:***

* Leverage Google Earth Engine API to create virtual rain gauges for NAVA
* Integrate virtual rain gauge data with geospatial analyses to map overland flow, flood routes, and fluvial erosion
* Produce maps of areas most at risk of erosion from fluvial channel incision
* Document methodology to allow straightforward reproducibility

**Partner Overview**

***Partner Organizations:***

|  |  |  |  |
| --- | --- | --- | --- |
| **Organization** | **POC (Name, Position/Title)** | **Partner Type** | **Boundary Org?** |
| **National Parks Service, Navajo National Monument** | Dr. Gregory Luna Golya, Field Archaeologist | End User | No |
| **Colorado State University** | Dr. Jeremy Shaw, Research Scientist | Collaborator | Yes |

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

NAVA staff have collaborated with researchers to better understand erosional processes in the canyon hydrologic system comprising the monument. Aerial photography and ground-based field observations have been the primary methods for documenting erosional patterns in and around the park, but spatial and temporal gaps in the coverage necessitate an improved monitoring structure. Additionally, rainfall data from *in situ* rain gauges for the monument are extremely sparse.

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

The project will provide the National Park Service team at NAVA with two tools: (1) virtual rain gauges enabling ongoing measurements of precipitation within NAVA, and (2) erosion hazard maps delineating areas that may be most affected by erosion. These tools will help NAVA target their management efforts.

**Earth Observations & End Products Overview**

***Earth Observations:***

|  |  |  |
| --- | --- | --- |
| **Platform & Sensor** | **Parameter** | **Use** |
| **GPM GMI** | Precipitation | GPM products were used to generate virtual rain gauges and approximate near real time precipitation intensity. |
| **SRTM** | Elevation | SRTM elevation data were used to create slope and aspect maps which will be used to generate flood models and erosion risk zones. |
| **TRMM PR** | Precipitation | TRMM Precipitation Radar (PR) and Microwave Imager (TMI) provided precipitation data for 2000-2015. |

***Ancillary Datasets:***

Parameter-elevation Relationships on Independent Slopes Model (PRISM) – Time-Series Temperature and

Precipitation data (1979-2018)

NOAA Global Historical Climatology Network – Ground weather station based precipitation values (1999-

 2017)

***Software & Scripting:***

Esri ArcGIS – Raster manipulation and analysis, map creation

Google Earth Engine API – Scripting a Virtual Rain Gauge tailored to the study area

Land Serf 2.3 – Elevation processing and feature parameter classification

Python – Scripting and raster analysis

Excel – Statistical analysis

Adobe Creative Suite – Graphic creation and map manipulation

***End Products:***

|  |  |  |  |
| --- | --- | --- | --- |
| **End Product** | **Earth Observations Used**  | **Partner Benefit & Use** | **Software Release Category** |
| **Virtual Rain Gauges** | GPM GMI, TRMM PR | The virtual rain gauges will enable ongoing measurements of precipitation and other climatic effects within the park. | III |
| **Erosion Hazard Maps** | SRTM | These maps will denote high to low flooding probabilities. | N/A |

**Project Handoff Package**

**Transition Plan:**

End users will be granted access to all data and project deliverables, including the technical paper, project video, and other media generated by the project directly through NASA Large File Transfer. End users will also be given a workflow document enabling replication of our methodology. Final imagery will be distributed electronically after closeout. All code is going through NASA’s software release process.

*Software Release Plan*: The virtual rain gauge code falls under NASA’s software release category III. The Navajo National Monument water resources team has made sure the partner understands that code release will take time and that after the NASA’s software release process is finished our DEVELOP team will help the end user to implement the script.

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**Partner POC**: Gregory Luna Golya, gregory\_lunagolya@nps.gov

**Handoff Package:**

* Technical paper
* Project video
* Project presentation
* Project poster
* Virtual Rain Gauges and associated documentation
* Erosion Hazard Maps

**References:**

Aleotti, P. (2004). A warning system for rainfall-induced shallow failures. *Engineering Geology*, *73*(3-4), 247-265.

 Caraballo-Arias, N. A., Conoscenti, C., Di Stefano, C., Ferro, V., & Gómez-Gutiérrez, A. (2016).

Morphometric and hydraulic geometry assessment of a gully in SW Spain. *Geomorphology*, *274*, 143-151.

Corominas, J., & Moya, J. (1999). Reconstructing recent landslide activity in relation to rainfall in the

Llobregat River basin, Eastern Pyrenees, Spain. *Geomorphology*, *30*(1-2), 79-93.

Crosta, G. B., & Frattini, P. (2003). Distributed modelling of shallow landslides triggered by intense

rainfall. *Natural Hazards and Earth System Science*, *3*(1/2), 81-93.

De Smedt, F., Yongbo, L., & Gebremeskel, S. (2000). Hydrologic modelling on a catchment scale using GIS

and remote sensed land use information. *WIT Transactions on Ecology and the Environment,* 45*.*

Douglass, J., Dorn, R. I., & Gootee, B. (2005). A large landslide on the urban fringe of metropolitan Phoenix,

Arizona. *Geomorphology*, *65*(3-4), 321-336.

Finlay, P. J., Fell, R., & Maguire, P. K. (1997). The relationship between the probability of landslide

occurrence and rainfall. *Canadian Geotechnical Journal*, *34*(6), 811-824.

Foster, G. R., Toy, T. E., & Renard, K. G. (2003). Comparison of the USLE, RUSLE1. 06c, and

RUSLE2 for application to highly disturbed lands. In *First Interagency Conference on Research in Watersheds* (Vol. 27, No. 30, pp. 154-160).

Gires, A., Tchiguirinskaia, I., Schertzer, D., Schellart, A., Berne, A., & Lovejoy, S. (2014). Influence of small

scale rainfall variability on standard comparison tools between radar and rain gauge data. *Atmospheric Research*, *138*, 125-138.

Guzzetti, F., Peruccacci, S., Rossi, M., & Stark, C. P. (2008). The rainfall intensity–duration control of shallow

landslides and debris flows: an update. *Landslides*, *5*(1), 3-17.

Holm, A. M., Cridland, S. W., & Roderick, M. L. (2003). The use of time-integrated NOAA NDVI data and

rainfall to assess landscape degradation in the arid shrubland of Western Australia. *Remote Sensing of Environment*, *85*(2), 145-158.

Hong, Y., Adler, R. F., Negri, A., & Huffman, G. J. (2007). Flood and landslide applications of near real-time

satellite rainfall products. *Natural Hazards*, *43*(2), 285-294.

Hong, Y., Adler, R., & Huffman, G. (2006). Evaluation of the potential of NASA multi‐satellite precipitation

analysis in global landslide hazard assessment. *Geophysical Research Letters*, *33*(22).

Johnson, J. P., Whipple, K. X., & Sklar, L. S. (2010). Contrasting bedrock incision rates from snowmelt and

flash floods in the Henry Mountains, Utah. *Bulletin*, *122*(9-10), 1600-1615.

Kunkel, K. E., Andsager, K., & Easterling, D. R. (1999). Long-term trends in extreme precipitation events

over the conterminous United States and Canada. *Journal of Climate*, *12*(8), 2515-2527.

Nikolopoulos, E. I., Borga, M., Creutin, J. D., & Marra, F. (2015). Estimation of debris flow triggering

rainfall: Influence of rain gauge density and interpolation methods. *Geomorphology*, *243*, 40-50.

Papaioannou, G., Vasiliades, L., & Loukas, A. (2015). Multi-criteria analysis framework for potential flood prone areas mapping. *Water resources management*, *29*(2), 399-418.

Rahardjo, H., Li, X. W., Toll, D. G., & Leong, E. C. (2001). The effect of antecedent rainfall on slope

stability. In *Unsaturated Soil Concepts and Their Application in Geotechnical Practice* (pp. 371-399). Springer,

Dordrecht.

Shaw, J. R., & Cooper, D. J. (2008). Linkages among watersheds, stream reaches, and riparian vegetation in

dryland ephemeral stream networks. *Journal of Hydrology*, *350*(1-2), 68-82.

Sideris, I. V., Gabella, M., Erdin, R., & Germann, U. (2014). Real‐time radar–rain‐gauge merging using spatio‐

temporal co‐kriging with external drift in the alpine terrain of Switzerland. *Quarterly Journal of the Royal Meteorological Society*, *140*(680), 1097-1111.

Souchere, V., Cerdan, O., Ludwig, B., Le Bissonnais, Y., Couturier, A., & Papy, F. (2003). Modelling

ephemeral gully erosion in small cultivated catchments. *Catena*, *50*(2-4), 489-505.

Stromberg, J. C., Setaro, D. L., Gallo, E. L., Lohse, K. A., & Meixner, T. (2017). Riparian vegetation of

ephemeral streams. *Journal of Arid Environments*, *138*, 27-37.

Sutfin, N. A., Shaw, J. R., Wohl, E. E., & Cooper, D. J. (2014). A geomorphic classification of ephemeral

channels in a mountainous, arid region, southwestern Arizona, USA. *Geomorphology*, *221*, 164-175.

Ziadat, F. M., & Taimeh, A. Y. (2013). Effect of rainfall intensity, slope, land use and antecedent soil moisture on soil erosion in an arid environment. *Land Degradation & Development*, *24*(6), 582-590.