**NASA DEVELOP National Program**

**Virginia – Wise**

*Project Summary – Summer 2018*

**Fremont River Basin Water Resources II**

*Water Availability Assessment from Annual Snow Cover in the Fremont River Basin Based on NASA Earth Observations and In Situ Data*

**VPS Title:** Winter is Coming: Forecasting Streamflow in the Fremont River Basin

**Project Team**

***Project Team*:**

Jessica Li (Project Lead), jessica.li9530@gmail.com

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***Advisors & Mentors*:**

Joseph Spruce (Science Systems & Applications, Inc., Consultant) – Lead Science Advisor

Dr. L. DeWayne Cecil (NOAA National Centers for Environmental Information, Global Science & Technology, Inc.) – Advisor

Bob VanGundy (The University of Virginia’s College at Wise) – Mentor/Advisor

***Past or Other Contributors*:**

Margaret Mulhern

Manda Au

Nolan Barrette

Austin Counts

**Project Overview**

***Project Synopsis*:** As a largely snowmelt fed watershed, Utah’s Fremont River flows through Capitol Reef National Park (CARE) providing year-round irrigation for approximately 16,000 acres of agricultural areas in Rabbit Valley, including historic orchards and pastures. In recent years, estimates of water availability in the area have become increasingly unpredictable, thus raising concerns over future water allotment plans. Therefore, the Fremont River Basin Water Resources team sought to assess patterns in water availability upstream of CARE using NASA Earth observation data in addition to creating a streamflow forecasting tool to help predict and assess streamflow for a given year.

***Abstract*:**

As a largely snowmelt-fed watershed, Utah’s Fremont River Basin provides year-round irrigation for approximately 16,000 acres of agricultural areas, including historic orchards and pastures maintained by Capitol Reef National Park (CARE). However, forecasts for seasonal water availability within the basin based on *in situ* snowpack data have been unreliable compared to water use allocations in the past. For this reason, a more robust method was required to provide accurate water availability assessments that help CARE plan future water allocations more effectively. Multiple NASA Earth observations and *in situ* data were employed to derive key trends and data insights for snowmelt and relevant climate variables across the watershed.

Furthermore, a forecasting tool that predicts seasonal streamflow in the Fremont River Basin was created using machine learning models. The results of the snowmelt and climate analyses along with the forecasting tool will inform water resource management and enhance future irrigation allocation plans at CARE.

**Keywords:**

Snowmelt, streamflow, forecasting, machine learning, Capitol Reef National Park, NDSI, Terra MODIS, PERSIANN - CDR

***National Application Areas Addressed:*** Water Resources, Agriculture & Food Security

***Study Location:*** Fremont River Basin, Utah

***Study Period:*** October 2000 – September 2017

***Community Concern:***

* Forecasted Fremont River streamflow from *in situ* snowpack data versusstreamflow data do not agree, but sufficient observational data are lacking to explain causes of these disagreements.
* The Utah Division of Water Resources is requesting reductions in irrigation water allotment in the Fremont River. There is a need for better streamflow forecasts to help officials at the CARE reallocate irrigation water under these new conditions.
* The 16,000 acres of irrigated agricultural lands within the Fremont River Basin, including historic orchards and pastures managed by CARE, are dependent on irrigation water allocations that are based on sparsely distributed *in situ* based streamflow estimates.
* Currently, the National Resources Conservation Service (NRCS) creates forecasts for the Dirty Devil River downstream of CARE, but does not predict outflows for the Fremont River upstream.

***Project Objectives:***

* Predict streamflow for the Fremont River Basin at the upstream Bicknell stream gauge using machine learning models
* Create a user-friendly Graphic User Interface (GUI) for partners to easily interact with the forecasting tool
* Conduct an Exploratory Data Analysis (EDA) report that reveals key trends and insights between snowmelt and climate variables in the Fremont River Basin
* Detect and visualize time series of snow cover changes in the Fremont River Basin

***Previous Term:*** 2018 Spring (VA) – Fremont River Basin Water Resources

**Partner Overview**

***Partner Organizations:***

|  |  |  |  |
| --- | --- | --- | --- |
| **Organization** | **POC (Name, Position/Title)** | **Partner Type** | **Boundary Org?** |
| **National Park Service, Capitol Reef National Park** | Terry Fisk, Chief of Resource Stewardship & Science | End User | No |
| **National Park Service, Northern Colorado Plateau Network** | Rebecca Weissinger, Ecologist | End User | No |

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

Currently, remote sensing is not incorporated into the National Park Service’s decision-making process in assessing their water use retrieval from the Fremont River Basin, which is allocated by the state of Utah. The existing management practices are provided via state and federal agencies, such as the Utah Division of Water Rights and the United States Department of Agriculture (USDA). Irrigation reduction is currently the only decision made to help conserve water. More specifically, The Utah Division of Water Resources has directed a reduction in water use for irrigation despite existing data that suggests positive trends in snowpack accumulation in recent years.

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

A streamflow forecasting tool and a complementary exploratory data analysis report deriving data insights for the Fremont River Basin will help CARE understand seasonal water availability better and subsequently devise more efficient water allocation plans. Advanced planning for future irrigation water use and better anticipation of calls for voluntary reductions in irrigation are some of the decisions that may be enhanced by the results of this project.

**Earth Observations & End Products Overview**

***Earth Observations:***

|  |  |  |
| --- | --- | --- |
| **Platform & Sensor** | **Parameter(s)** | **Use** |
| **Terra MODIS** | Snow Indices (NDSI); Snow Cover; Land Surface Temperature | Terra MODIS daily data served as the major predictor variables for the machine learning models. The data included spatio-temporal representation of snow cover, snow indices as a proxy for snow volume, and land surface temperature for capturing snowpack sublimation dynamics. |
| **PERSIANN-CDR** | Precipitation | PERSIANN-CDR daily precipitation data were used as a predictor variable for the models. River water that originates from precipitation is an important consideration in the process of predicting streamflow. |

***Ancillary Datasets:***

LiDAR derived DEM (USGS National Elevation Dataset) – Extracted DEM elevation values to classify the basin into different elevation zones, aiming to capture unique ecosystems within the basin

NWQMC Water Monitoring STOrage and RETrieval (STORET) Data – Water monitoring results covering the study period

PRISM Climate Data – Precipitation at low elevations

USDA Snowpack Telemetry (SNoTEL) Snow Water Equivalent (SWE) – Daily *in situ* data for snow water equivalent, precipitation, and temperature

USGS National Hydrography Datasets – Hydrologic units and water years for watersheds

USGS Stream Gauge Data – Daily *in situ* streamflow data covering the study period

USGS Watershed Boundary Dataset (WBD) – Areal extent of surface water drainage

***Modeling:***

Soil and Water Assessment Tool (SWAT) (Dr. Kenton Ross, NASA Langley Research Center) – Delineation of the Fremont River Basin into unique elevation zones

Snowmelt-Runoff Model (M-SRM) (Dr. Kenton Ross, NASA Langley Research Center) – Base code and structure for the SNOW-M model

SNowmelt Observational Watershed Model (SNOW-M) (Margaret Mulhern, NASA DEVELOP) – Statistical modeling of streamflow from annual snowmelt and projected flow of the Fremont River; update to the original Modified Snowmelt-Runoff Model (M-SRM)

Recurrent Neural Networks (POC: Jessica Li, NASA DEVELOP) – streamflow forecasting tool that served as the model framework for SPAM

ARIMA (POC: Jessica Li, NASA DEVELOP) – streamflow forecasting tool that served as the model framework for SPAM

***Software & Scripting:***

Google Earth Engine – Data acquisition and image classification

ESRI ArcGIS – Data processing and analysis

Python – Data processing

JavaScript – Earth observation data processing

R – Data processing, machine learning models, statistical analysis, graphing, and software development

***End Products:***

|  |  |  |  |
| --- | --- | --- | --- |
| **End Product(s)** | **Earth Observations Used** | **Partner Benefit & Use** | **Software Release Category** |
| **Streamflow Prediction and Assessment Model (SPAM)** | Terra MODIS, LiDAR derived DEM, PERSIANN-CDR | The SPAM, created by machine learning models, will predict streamflow at various points of the basin. Forecasted data will assist our partners in monitoring water availability and plan future irrigation allocations. | IV |
| **SPAM User Manual** | N/A | The SPAM user manual will explain how to interact with the code and maintain current data for SPAM. Partners can understand how to reproduce this model for other basin research in the future. | I |
| **Exploratory Data Analysis (EDA) Report** | Terra MODIS, PERSIANN-CDR | The EDA will reveal key trends and data insights from Earth observation and *in situ* data for the Fremont River Basin. Partners will have a greater understanding of snowmelt and climate variables interactions. | I |
| **Snow Cover Time Series Maps (2000 - 2017)** | Terra MODIS | The time series maps are supplementary information that provides the partners insight into snowpack accumulation patterns in recent years for understanding historical water availability. | I |

**Project Handoff Package**

**Transition Plan:**

The team met with CARE partners in the last week of the term via WebEx to perform a live demonstration of the Streamflow Prediction and Assessment Model (SPAM) and present data findings from the EDA report. A handoff package excluding SPAM was delivered via Google Drive. After code was approved via the Software Release process, SPAM was delivered to the partners via Large File Transfer (LFT). A follow up e-mail was sent introducing package contents. Interim communication occurred via e-mail.

*Software Release Plan*: This project includes code for SPAM as well as intermediate processing code for data acquisition and processing. This falls under software release category IV. The team will stay in active communication with the partners post-term. Partners are aware that this process will result in delayed handoff package delivery. After code is approved, the project lead will deliver SPAM via LFT and subsequently e-mail partners with descriptions on package contents and usage directions. Furthermore, the User Manual will help partners interact with SPAM and understand how they could apply it to other basins in the future.

**Team POC:** Jessica Li, jessica.li9530@gmail.com

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**Partner POC**: Rebecca Weissinger, rebecca\_weissinger@nps.gov; Terry Fisk, terry\_fisk@nps.gov

**Handoff Package:**

This package includes all products that were handed to the partners at the end of the term. This **excludes** SPAM, which will be delivered after approval from the Software Release process.

* Overall project deliverables:
  + Poster
  + Presentation
  + Project video
  + Technical paper
* End Products:
  + Data Analyses Package (containing EDA report and Snow Cover Times Series Maps)
  + User’s Manual

**References:**

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