NH SPACE GRANT FELLOWSHIP: SUMMARY REPORT

Project Title: Satellite Remote Sensing for Attribution of Winter and Spring Peak Streamflow Events

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Research Summary

My proposed research seeks to understand the causes of historic winter and spring flooding events in the CONUS using NASA satellite remote sensing datasets and identify current data gaps and potential needs for future observing systems to monitor cold-season flood risks at the basin scale.

Summary of Progress

Objective 1: Select multiple basins having a peak flow event whose attribution is "All True" and identify additional data sources for these basins.

Status: *In Progress (Modified)*

Basins used for the first objective were to be selected based on the preliminary flood attribution study which was completed before the start of the fellowship. The preliminary study identified the causes of flooding associated with the largest winter/spring peak instantaneous streamflow event at a set of U.S. Geological Survey (USGS) streamflow gages in the Contiguous United States (CONUS). However, discussion with the project advisor, NASA point of contact, and PhD proposal committee determined that the preliminary flood attribution study required modifications before it could be used for basin selection. The three primary modifications were:

i. **New approach to identify antecedent conditions within the basin *(status – in progress, awaiting completion of objective two)*:** Conditions at each basin were identified from satellite and modeled data which overlapped the basin area. The original methodology extracted the values from the pixels in and around the basin and determined if at least one pixel value met the threshold condition (e.g., freezing ground indicated by soil temperature ≤ 273.15 K) that the entire basin met the specified condition. Committee feedback suggested that only pixels that fall fully or mostly within the basin polygon should be included. They also proposed using a less binary approach that considered the proportion of the basin meeting the condition (e.g., 50% of the basin pixels affected by frozen ground) to determine flood attribution.
ii. **Include more than just the largest peak flow event at each basin (status – nearly complete):** Initial attribution only considered the largest peak flow event recorded at each basin and did not account for typical streamflow conditions at each gage and year-to-year

variation. Alternative approaches for distinguishing peak flows (e.g., annual maximum series, peaks-over-threshold) were suggested.

iii. **Consider seasonal/annual trends** ***(status – in progress, awaiting completion of objective two):*** The time period (i.e., "event") used to for identification of antecedent conditions was selected based on the travel time calculated for each basin (approximately 1 – 3 days). However, the impact of antecedent conditions on flooding requires an understanding of the seasonal, and in some cases annual, trends preceding them. The committee suggested that conditions during the event should be compared to historical and seasonal averages to provide context on their severity and relevance to event conditions.

Despite the adjustments required for basin selection, additional data sources were explored. Sources that will be considered for the continuation of this task are listed in **Appendix A**.

Objective 2: Create a multidecadal record of winter and spring conditions at the selected basins (e.g., land cover type, slope, winter/spring precipitation patterns, average daily streamflow) to determine how flood characteristics deviated from typical site conditions.

Status: *In Progress*

The second objective included compiling basin characteristics (e.g., land cover type, slope), antecedent conditions (e.g., liquid precipitation, air temperature, snow cover), and average daily streamflows. The summary of basin characteristics and average daily streamflows are nearly complete. The summary of antecedent conditions is still in progress as this step required the most significant updates to the R code written for the previous analysis. Daily antecedent conditions will be extracted only for the basins selected in the first objective. Due to the size of the geospatial data from modeled and satellite resources and the number of daily data records required, many updates were required to make the code to extract the antecedent conditions run more efficiently. These improvements and updates to the analysis are planned to continue into the fall semester and the code and associated data resources will be uploaded to GitHub once complete. Once data on antecedent conditions has been compiled along with the basin characteristics and streamflow data, event conditions will be compared to average daily site conditions to determine how they deviated from typical conditions. Further analysis will also compare the conditions during the largest peak flow event to those which occurred during the peak annual flow events over a 20-year period of record.

Objective 3: Repeat flood attribution for the new data and compare to the results of the preliminary attribution. Identify current data gaps and potential needs of future observing systems for observation of cold-season flood risks at the basin-scale.

Status: *Postponed*

Due to the required modifications to the preliminary attribution and the extensive code updates needed to compile the daily antecedent conditions at each basin, the third objective was postponed to fall 2024.

Updated Project Timeline

- Modifications to the first objective will be completed by mid-September 2024.
- Objective two code updates and sharing via GitHub repository will continue through October 2024.
- Completion of objective three is planned for late November/early December 2024.
- Results will be presented at the 2024 American Geophysical Union (AGU) Annual Meeting held on December 9 – 13, 2024 in Washington, D.C. (abstract included in **Appendix B**).

I am very grateful to the NH Space Grant for funding this work, and I sincerely appreciate this opportunity to improve upon my preliminary analysis and expand the scope of my research.

Appendix

Appendix A*: Summary of potential data sources identified as part of Objective 1*

The USGS GAGES-II metadata will be used to identify basin characteristics such as the drainage area, elevation, and slope. Additional characteristics relevant to flood generation such as land cover and soil types will be identified from the sources mentioned in Table 1. Conditions related to flood risk, such as population density and socioeconomic characteristics, will also be considered for this analysis.

Table 1: Potential data sources on basin characteristics.

Characteristic	**Source**	**Coverage**	**Description**
Basin Characteristics	USGS GAGES-II	U.S. & territories	Geospatial data & classifications for 9,322 USGS stream gages
Land Cover	EROS Center's National Land Cover Database (NLCD)	30 m 2001 – 2019	Land cover derived from Landsat Data
Soil Type	Digital General Soil Map of the United States (STATSGO2)	1:250,000 scale most of U.S. & territories (1:1M for AK)	Based on generalized detailed soil survey maps with soil classification & extent estimated from topography, geology, vegetation, & climate data
	USDA NRCS Web Soil Survey	Polygons, >95% of U.S. & territories	SSURGO database of observations & samples from National Cooperative Soil Survey
Population density & socioeconomic characteristics	Gridded Population of the World v4	Global 30 arc-second	Estimates of human population density
	EPA EJScreen	County-scale Updated annually since 2015	7 socioeconomic indicators from the 5-year American Community Survey (ACS)
	CDC/ATSDR Social Vulnerability Index	County-scale 2000 – 2022	16 variables from the 5-year ACS
	U.S. Climate Vulnerability Index	County-scale or census tract 2017 – 2019	Baseline vulnerabilities & climate change risks from 184 indicators

Satellite remote sensing sources will be used to identify antecedent basin conditions which contribute to flood generation (e.g., soil moisture, SWE). Potential datasets from satellite remote sensing platforms are listed in Table 2.

Table 2: Proposed satellite remote sensing sources for identification of flood-generating conditions.

Observation Type	Satellite Platform	Sensor	Spatial Resolution	Temporal Coverage
Soil Moisture	SMAP	Passive microwave radiometer	9 km to 40 km	2015 – Present
	GCOM-W1	AMSR2	25 km	2012 – Present
Soil Frost	SMAP	Passive microwave radiometer	9 km to 40 km	2015 – Present
Precipitation	GCOM-W1	AMSR2	15 km	2012 – Present
	Aqua	AIRS	25 km	2002 – Present
Snow Cover/SWE	Terra & Aqua	MODIS	500 m, 1 km, 0.05 degrees	2000 – Present
Change in freshwater storage & river discharge	SWOT	KaRIn, Jason-class Altimeter, microwave radiometer	128 x 128 km^2 swaths	2022 – Present

When available, climate characteristics (e.g., precipitation) will also be derived from in-situ data sources (Table 3) to fill data gaps and validate satellite retrievals. In some cases, modeled data may be used where no other data are available.

Table 3: Potential in-situ data sources for identification of flood-generating mechanisms and basin antecedent conditions.

Observation Type	Observing System	# of Sites	Temporal Coverage
Precipitation, snowfall, snow depth, maximum & minimum temperature	NOAA Global Historical Climatology Network (GHCN)	> 100,000 globally	Variable
Temperature, precipitation, wind speed, soil conditions, etc.	USCRN	114 in CONUS	Variable
Soil moisture	Soil Climate Analysis Network (SCAN)	212	1991 – Present
SWE	Northern Hemisphere Historical in-situ Snow Water Equivalent Dataset	9,113	1979 – 2021
Snow depth & SWE	SNOTEL	900	Variable
Climate normals (daily & monthly)	Oregon State PRISM	Modeled data based on observations from ~13,000 precipitation stations & 10,000 temperature stations	1895 – Present

***Appendix B**: Abstract Submitted to the 2024 American Geophysical Union (AGU) Annual Meeting*

Abstract Title: Satellite Remote Sensing for Attribution of Routine and Extreme Winter and Spring Flood Events

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Previous studies have reviewed major flood events in large basins to document conditions, determine the main cause, and identify appropriate mitigation factors. Adequate documentation of relevant flood conditions for prediction and monitoring still poses challenges, especially during the winter and spring. In many cases, models and satellite remote sensing may be the only available resources to estimate cold-season flood risk factors over an entire basin. This investigation identifies the differences between normal and extreme winter and spring conditions and provides context for conditions that are linked to flood severity and extent. This work compiled a multi-decadal record of peak streamflow events, atmospheric conditions (e.g., precipitation, air temperature), and antecedent conditions (e.g., snowpack snow water equivalent, soil moisture, soil temperature) during the winter and spring for a subset of United States Geological Survey (USGS) Hydro-Climatic Data Network (HCDN) gaged basins in the CONUS. Data on basin conditions was derived from satellite remote sensing sources and supplemented by in situ and modeled data when necessary. The timing of large flow events was compared to atmospheric and antecedent conditions during the winter and spring to differentiate the mechanisms which contribute to routine versus extreme flood hazards. Data for establishing flood exposure and vulnerability, including basin characteristics (e.g., slope, land cover) and population data (e.g., demographics, social vulnerability, infrastructure), were used to identify locations where flood potential presents the greatest risk. Based on current data gaps, guidance is provided for future observing systems to monitor cold-season flood risks at the basin scale. Methods for addressing these data gaps using low cost in situ and uncrewed aerial system (UAS) remote sensing will be discussed.

Presentation format request: Assigned by program committee