Application of Commercial Smallsat Data to Enhance Flood Resilience in Support of Underserved Communities in Puerto Rico

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In Response To NNH22ZDA001N-CSDSA: Commercial Smallsat Data Scientific Analysis

1. Scientific/Technical/Management Plan

1.1 Executive Summary

Tropical Depression Seven of the 2022 Hurricane Season became Hurricane Fiona on September 18, 2022 (NWS, 2022). In Puerto Rico, spatial distribution of Fiona's rainfall was very uneven; with precipitation amount much lower in the north than the south – where storm totals generally ranged from 12-20 inches, and as high as 35 inches. Infrastructure damage was considerable and widespread. Hundreds of thousands were without municipal water, and the power grid (still recovering from Hurricane Maria's impact five years earlier) was again slow to recover.

Most residents of Puerto Rico are considered members of underserved communities, and it is therefore impossible to consider the impacts of a storm like Hurricane Fiona without examining them in the context of environmental justice. The Council on Environmental Quality's Climate and Economic Justice Screening Tool (CEJST) indicates widespread disadvantage and overburden on the island due to climate change, energy, health, housing, legacy pollution, transportation, water and wastewater, and workforce development. Furthermore, a key characteristic of land use in Puerto Rico is the limited spatial extent of many of the properties. For example, the average farm size is about 23 ha, and are mostly family or individual farms.

Compared to most freely-available data, many commercial datasets offer superior spatial resolution, and so it's possible to 1) identify land use type (e.g., agriculture vs. natural vegetation); 2) discriminate vegetation morphology, and 3) even count individual plants (Brandt et al., 2020). These fine-scale observations allow decision-makers access to information that answers questions that cannot be adequately addressed with coarser resolution maps (e.g., 250- or 500-meters with MODIS) because the decisions often concern social and physical dynamics occurring at finer spatial scales. For example, are there differences in resilience status between small-scale farms with tree-free agriculture vs those including forested patches? What amounts and types of vegetation make the difference between flood-resilient and flood-hazardous?

This proposal addresses questions of resilience within a proper context of environmental justice. It is accurate to characterize nearly the entire Commonwealth population as underserved, and no environmental study of Puerto Rico should neglect it. Our plan can be summarized as follows:

1. Research the physical damage from Hurricane Fiona across Puerto Rico, and use the CEJST to identify affected communities that are underserved and those that are not.
2. Work with staff from Puerto Rico Science, Technology & Research Trust (PRSTRT) to engage with decision-makers in a community impacted by flooding due to Hurricane Fiona.
3. Assess what socioeconomic and resilience-relevant metric information exists.
4. Collect available and relevant satellite data provided by Planet as well as public data.
5. Use machine learning techniques to provide annual maps of flooding extent and vegetation characteristics, and model relationships between environmental (satellite-based) metrics and flood resilience.
6. Provide recommendations on land use practices that enhance community resilience to future extreme events as indicated by modeling results.

1.2 Background and Previous Work

In its latest report, the United Nations' Intergovernmental Panel on Climate Change notes that those who contribute least to climate change are generally most vulnerable to its negative impacts. For small island states like the Commonwealth of Puerto Rico, these impacts are disproportionate to their population size, particularly in the contexts of human physical and mental health (IPCC, 2023). Large shares of its population, infrastructure, and economy are vulnerable to sea level rise, more frequent intense rainfall – and with that, coastal flooding, and saltwater intrusion. These risks are compounded by relatively low levels of adaptive capacity as compared to coastal areas within the continental United States. This means extreme climate-related events such as hurricanes can devastate large portions of local economies and cause widespread damage to crops, water supplies, infrastructure, and other critical resources and services (USGCRP, 2018).

In late September of 2022, Puerto Rico sustained a devastating shock from Hurricane Fiona. Although categorized as "just" a Category 1 hurricane, Fiona brought torrential rains and flooding. Coincidentally, this disaster occurred exactly five years after Hurricane Maria made landfall on the main island as a Category 5 storm – leaving many lives lost, and key infrastructure badly damaged, particularly the power grid. Slow recoveries from both events highlighted the underserved status of much of the territory's population.

Absent steps taken to increase its climate resilience, there is little reason to expect improved outcomes for Puerto Rico when the next major hurricane strikes. According to the U.S. General Accountability Office (GAO, 2022), federal recovery programs "lack key information—data and analysis—that would allow them to determine if access barriers and disparate recovery outcomes exist." Furthermore, GAO found several key areas of improvement need to provide meaningful assistance to disaster survivors and local governments, including:

- Better flood mapping: the Federal Emergency Management Agency's (FEMA) flood mapping investments were lower for communities with higher levels of underserved populations than communities with lower levels, other factors being equal.
- Improved support for assistance programs: disaster survivors, including low-income individuals, faced numerous challenges obtaining aid and understanding assistance programs.

This proposal intends to improve flood mapping in Puerto Rico using commercial satellite data, while providing support to community members seeking access to assistance via a community engagement component. Fulfillment of these recommendations would increase climate resilience and speed the progress of recovery from extreme events in Puerto Rico.

This proposal team's relevant published papers and products in this area of remote sensing include land cover classification using machine learning (Borak and Strahler, 1999), vegetation dynamics from temporal metrics (Borak et al., 2000), and gridding global canopy heights from ICESat-2 data (Borak et al., 2020). Team members also have expertise in analysis of hydrologic trends (Jasinski et al., 2019) and the role of vegetation in the water cycle (Kumar et al., 2019).

Project team collaborator Flynn recently led a FEMA-funded effort to directly assist pandemic recovery efforts in the six New England States by working in support of the Region 1 Federal Disaster Recovery Coordinator. This effort involved completing individual Resilience Rapid Needs Assessments for each of the states, involving data collection and interviews with nearly 500 stakeholders in 18 communities, many of them disadvantaged, across New England.

1.3 Goals and Expected Significance

Proposed Deliverables:

- Annual 30-m maps of land cover characteristics (percent cover; tree/no-tree; flooded/not flooded) for the main island of Puerto Rico (2013-2022)
- Map of climate resilience for Comunidad La Margarita (Municipio Salinas)
- Findings on relationship between vegetation characteristics and community resilience to flooding

Objective 1: Research the physical damage from Hurricane Fiona across the main island of Puerto Rico, and use the CEJST to identify affected communities that are underserved, and those that are not. The CEJST operates at the census tract level and illustrates the presence and prevalence of underserved populations in Puerto Rico (Figure 1).

Figure 1: Map of Puerto Rico's advantaged (light grey) disadvantaged communities (dark grey) as labeled by the Climate and Economic Justice Screening Tool (CEJST).

Objective 2: Work with staff from Puerto Rico Science, Technology & Research Trust (PRSTRT) to engage with decision-makers and stakeholders in a community impacted by flooding due to Hurricane Fiona. The primary community of focus here is Comunidad La Margarita in Municipio Salinas, located on the southern coast of the main island of Puerto Rico.

Objective 3: Assess what socioeconomic and resilience-relevant metric information exists. Several candidate metrics and tools exist; we intend to investigate the Flood Resilience Measurement for Communities (FRMC, Keating et al., 2017) and the scalable Flood Resilience Index presented by Leandro et al. (2020), but will work cooperatively with PRSTRT and the community engagement consultant to identify what is the best metric to use based on available information and participation from the community. Ultimately, we will evaluate their appropriateness based primarily on availability of necessary physical and socioeconomic input data at the local level; however it is crucial that the contextual definition of “resilience” to include community perspectives on needs.

Objective 4: Collect available and relevant commercial satellite data provided by Planet and Maxar, as well as public data (see Table 1). Our primary commercial data source will consist of PlanetScope acquisitions, as the frequency of overpasses increases the likelihood of obtaining cloud-free looks over the location of interest. A limited number of high-quality Maxar scenes will serve to evaluate results produced from spatially coarser input datasets.

Objective 5: Use machine learning techniques to provide annual maps of flooding extent and vegetation characteristics, and to model relationships between environmental (satellite-based) metrics and flood resilience. The primary interests here are discrimination of water and vegetation from other surface elements, and splitting vegetated surfaces into tree vs. non-tree categories. These categories all translate into explainable land use categories and practices.

We will leverage the Maxar acquisitions for building machine learning models – i.e., for provision of training, tuning, and validation data. A random forest model – whether using the traditional (Breiman, 2001) algorithm or a boosted approach (e.g, Hastie et al., 2009) is appropriate for classification of the vegetation characteristics of interest (USFS, 2020), and generally provides classification rules and results that are more easily interpretable than deep learning. Random forest is also appropriate for flood mapping in this context, as it is intended to be retrospective rather than real-time (Leach et al., 2022). Ideally, a single random forest model would map both vegetation and flooding; however if this is unsuitable – e.g., the vegetation classification works, but discrimination between water/not-water is unclear – we will apply a separate random forest model to map surface water from PlanetScope data and train/tune/test with data from the Maxar scenes.

Objective 6: Provide recommendations on land use practices that enhance community resilience to future extreme events as indicated by modeling results. Our intent is to co-produce these recommendations along with community members in Salinas. This will involve the joint efforts of the entire team, but it is a key element of the environmental justice component of this investigation and is the primary motivation for including a community engagement consultant on our team. This cooperative approach is far more likely to yield results that will of actionable value to community members than a simplistic, top-down methodology.

1.4 Technical Approach and Methodology

Objectives 1-3 consist primarily of working with PRSTRT and the consultant to acquire data and reports on Fiona’s local impacts. This will not provide an unbiased or exhaustive inventory of affected areas, but it will provide direction about where to look and whom to contact. Flooding damage from Fiona was widespread, especially in southern coastal areas of the main island, and one example of a profoundly affected location in that region is Communidad La Margarita (Figure 2); collaborators on this proposal team are currently funded by NASA’s Equity and

Environmental Justice program to investigate how NASA Earth observations can assist members of this community (PI: Dr. Flynn).

Our team will identify other communities in Puerto Rico – underserved or not – impacted to varying degrees by Fiona. Likely candidates include populations located in the Jacaguas, Coamo, and Bucaná river floodplains. As with La Margarita, we will investigate relationships between satellite data products and resilience, although active engagement with community members in these other locations is likely beyond the scope of this project.

(a) (b)

Figure 2: True-color composites of La Margarita and beach, acquired by Maxar's Worldview-3 in January 2022, before Hurricane Fiona (a) and in September 2022, immediately afterward (b). Note collapsed bridge over storm-breached inlet in upper left of scene, and missing piers along shoreline.

We will employ a multisensor approach to characterize the vegetation of the study area, and how it relates to flood resilience. PlanetScope provides the frequent looks required in Puerto Rico's tropical location, but is inadequate on its own for supplying the combination of extensive spatial and temporal coverage of a source such as Landsat. Therefore, much of our analysis will be based on Planet's multispectral datasets at 3-4 meter resolution to characterize sub-pixel variability of Harmonized Landsat and Sentinel-2 (HLS) imagery, which has a 30-meter nominal spatial resolution (Claverie et al., 2018). For example, 3-meter PlanetScope data, when geolocated with the coarser HLS observations, can provide accurate estimates of percent vegetation cover at the HLS (30-m) scale. In addition, the team will utilize data products from other sensors to provide collateral information such as vegetation seasonality and height (see Table 1 for summary list).

The static datasets listed in Table 1 will be acquired first, followed by the time-varying datasets. Of the latter, the HLS dataset is limited in terms of period of record; it begins in 2013. Thus, for each time-varying indicator, we will acquire all publicly-available input data products (i.e., excluding commercial) for 2013 onward for the main island of Puerto Rico. Since the vast majority of census tracts in Puerto Rico are considered "underserved" we will effectively use the Climate and Economic Justice Tool to identify areas that are *not* underserved; these will be identified as candidates for experimental controls. We select Comunidad La Margarita in Salinas – the same community of interest in Dr. Flynn's EEJ project – as the main experimental test case. Areas around Salinas experienced substantial flooding impacts due to Hurricane Fiona's heavy rainfall.

Next, we will acquire all PlanetScope data available for the La Margarita area, and perform simple data classifications that discern: 1) vegetated/unvegetated; 2) tree/no-tree; and 3) flooded/dry. These labels, confirmed with higher-resolution Maxar acquisitions, will be used to map the underlying areal proportions from PlanetScope (~3-m) to the HLS (30-m) scale. We will

Table 1: Remote sensing products to be used by this project for monitoring vegetation.

Vegetation Indicator Type	Source(s) (index names)	Reference(s)	Spatial Resolution	Temporal Resolution
Phenology	MODIS/VIIRS	Zhang *et al.* (2018)	500-m	Annual
Land Use	MODIS/VIIRS	Friedl *et al.* (2010)	500-m	Annual
Aquatic Indices	Maxar, PlanetScope, HLS[1] (NDWI[2])	McFeeters (1996); Xu et al. (2006)	sub-meter, 3-m, 30-m	1, 2-3 Days
Vegetation Indices	Maxar, PlanetScope, HLS (NDVI[3]; EVI[4])	Huete *et al.* (2002)	sub-meter, 3-m, 30-m	1, 2-3 Days
Vertical structure	GEDI Gridded Canopy Height & Ground Elevation	Dubayah *et al.* (2021)	1000-m	Static
Biomass Density	GEDI Gridded Biomass	Dubayah *et al.* (2022)	1000-m	Static

[1]HLS = Harmonized Landsat Sentinel; [2]NDWI = Normalized Difference Water Index; [3]NDVI = Normalized Difference Vegetation Index; [4]EVI = Enhanced Vegetation Index

do the same for 2-3 "control" (advantaged) locations that experienced extensive flooding, 2-3 control locations that did not experience extensive flooding, and 2-3 underserved locations that did not experience extensive flooding. The intent is to create an exhaustive comparison of flood/no-flood and underserved/advantaged cases (although the Salinas area will receive the most attention as it will be our most data-rich).

Figure 3 illustrates the overall flow of the proposed research. Once we bring the earth observation datasets together – commercial and public – we will use machine learning to map percent tree cover and flooded/dry for the entire main island from the HLS data on an annual basis. We will then analyze how differences in flood resilience correlate with physical vegetation characteristics at the 30-m level. Next, we will incorporate socioeconomic data and knowledge from Salinas to understand how vegetation characteristics and resilience relate with socioeconomic condition and cultural practices. The intent is to work with Salinas-area decision-makers on actionable suggestions for improving flood resilience through vegetation management practices, and to uncover patterns in the data that point to wider-scope actions that would benefit other underserved communities in Puerto Rico with enhanced flood resilience.

1.4.1 __Sources of error and uncertainty__

Chief source of error and uncertainty in the satellite data include inadequate screening of low-quality data, poor radiometric characterization, incorrect co-location of datasets, and misclassifications. Our use of compositing promotes, but does not ensure, moderation of atmospheric contamination.

1.4.2 __Resilience of the approach and methodology__

By selecting PlanetScope as a primary input, versus Maxar, we trade away better spatial resolution in favor of increased frequency of quality looks. This is a key consideration in a tropical environment such as Puerto Rico, where frequent cloud cover is a perennial issue.

1.5 Impact of the Proposed Work on the State of Knowledge in the Field

A science-backed approach to vegetation characteristics serves as the evidence-based foundation for user engagement – leading to more informed decision-making for flood resilience. An open science approach and co-creation of monitoring tools – facilitated by efforts of the Puerto Rico Science, Technology & Research Trust – will advance understanding of both the threats to, and positive drivers of, flood resilience to a range of audiences from small-scale farmers to senior decision-makers. An assessment of users and user needs is underway as part of Dr. Flynn's EEJ project in Salinas, which is anticipated to provide NASA with specific environmental justice concerns with which its data can be applied, identify barriers to the use of that data, and list ways in which NASA could equitably aid communities in overcoming these barriers. It will also have articulated a pathway for community engagement that ensures federal resources will be appropriately suited and leveraged by communities facing environmental injustices.

Although it is a U.S. territory, the Commonwealth of Puerto Rico is typically understudied in U.S.-based Earth science. Many datasets and programs exclude Puerto Rico from their domains because of political reasons (it's not a state) or practical considerations (it's inconvenient to include it and CONUS in the same data fields). By producing annual 30-meter vegetation maps of Puerto Rico, we are filling data gaps that have existed for years. For example, the Multi-Resolution Land Cover program (MRLC) releases 30-m tree cover data for the conterminous U.S. every five years, but to date they've only produced maps for Puerto Rico in 2011 and 2016 (MRLC, 2019), which completely miss effects of Hurricanes Maria.

1.6 Relevance to the Program Element and to NASA Programs and Interests

This research is relevant according to the National Academy's latest Decadal Survey (NASEM, 2018), as it seeks to address Question H-4: "How does the water cycle interact with other Earth system processes to change the predictability and impacts of hazardous events and hazard-chains (e.g., floods, wildfires, landslides, coastal loss, subsidence, droughts, human health, and ecosystem health), and how do we improve preparedness and mitigation of water-related extreme events?" It comports with Earth Science/Applications Objective H-4d – to "[u]nderstand linkages between anthropogenic modifications of the land, including…land use…on response to hazards.'

The proposed research is also relevant to several of NASA's Strategic Goals and Objectives (NASA, 2022). It responds directly to Strategic Objective 1.1, "Understand the Earth system and its climate" by mapping floods and vegetation in Puerto Rico. It also responds to Strategic Objective 1.3, "Ensure NASA's science data are accessible to all and produce practical benefits to society." This project's results are intended to provide actionable recommendations regarding land use in Puerto Rico, and all science and derived data products are explicitly proposed as "open."

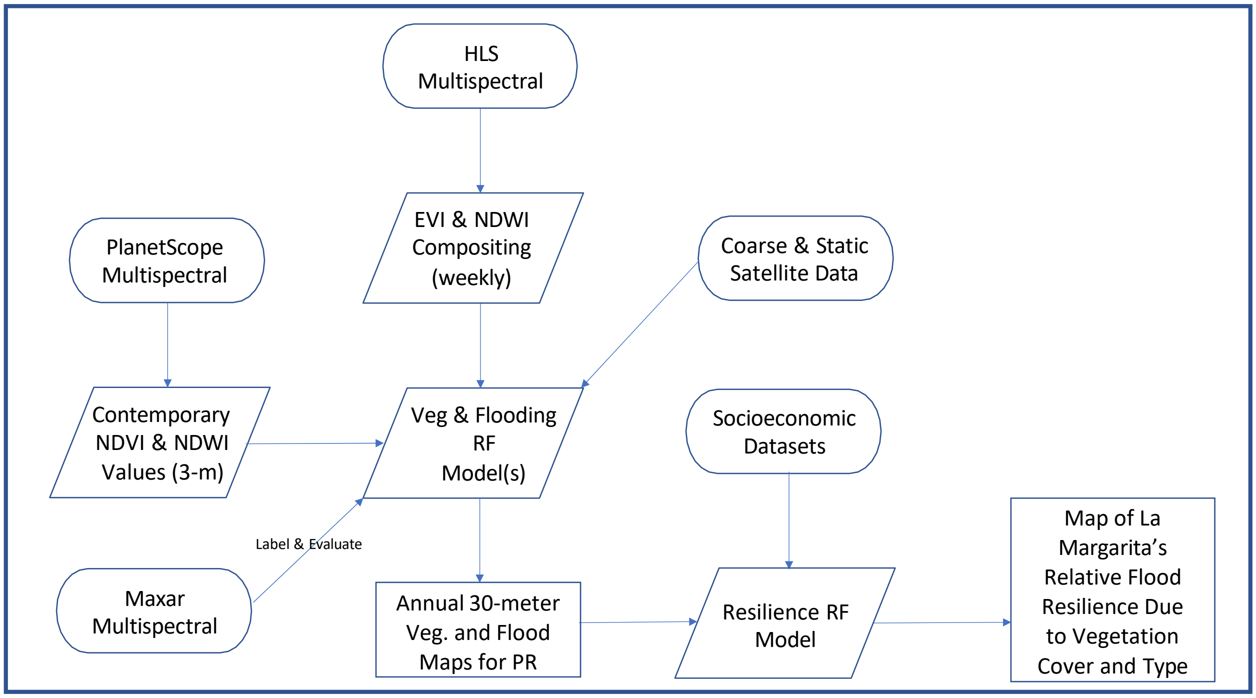

Figure 3: Synopsis of project flow and methodology. Inputs are represented by ovals, with outputs represented by rectangular boxes.

1.7 Implementation Plan

1.7.1 Project Schedule

PY1: Acquire all earth observation datasets and process as described; discuss community requirements and status with representatives of Puerto Rico Science, Technology & Research Trust; acquire socioeconomic data and information as appropriate and available.

PY2: Build statistical and machine learning models; run and interpret results with feedback from Puerto Rico Science, Technology & Research Trust; deliver maps to OpenData site as described in Data Management Plan; provide vegetation management recommendations to Puerto Rico Science, Technology & Research Trust and to community.

1.7.2 Management Structure

Key Personnel

Dr. Jordan Borak of the University of Maryland and NASA's Goddard Space Flight Center will serve as Principal Investigator (PI) for this uniquely qualified proposal team. Dr. Borak possesses considerable expertise as a remote sensing and data scientist, including two-plus decades of participation in NASA-funded research projects as both a Co-I and PI, and is currently a member of the ICESat-2 Science Team. His background includes the design, assessment, and analysis of a wide variety of both passive and active remote sensing data products, with particular focus on land use/cover, land surface hydrology, and their variability. His current activities of relevance to this proposed investigation include: 1) Co-I on NASA's "National Climate Assessment Land Data Assimilation System" (NCA-LDAS); 2) PI on "Enhanced Vegetation Roughness Length Estimates from ICESat-2 Vegetation Products"; and 3) research associate on "Remote Sensing of Vegetation in Puerto Rico for NIST's Hurricane Maria Infrastructure Project," funded under a cooperative agreement between UMD and the National Institute of Standards and Technology.

Dr. Nathan Morrow of Tulane University will serve as Co-Investigator. Dr. Morrow has led efforts for resilience decision support in more than 20-countries. He has designed, implemented, and evaluated decision support systems for many international organizations and completed a technical review of SDG target indicator 2.1.2 for Zero Hunger. He has supported the Food and Agriculture Organization's global resilience capacity development efforts and supported action research and citizen science on Gulf Coast disasters. With World Food Program's Resilience Analysis and Mapping function, he worked on digital strategies for more inclusive engagement with communities through mobile surveys and big data/social media.

Collaborators
Dr. Stephen E. Flynn of Northeastern University will serve as a collaborator on the project. Dr. Flynn is the founding director of the Global Resilience Institute, and is a Principal Investigator on a NASA-funded investigation entitled, "Leveraging Earth Observation Data to Support Environmental Justice: A Puerto Rico Coastal Community Case Study." From that project, he brings community-based data and engagement in partnership with the Puerto Rico Science, Technology & Research Trust to the current project. Flynn is a Professor of Political Science and Professor of Civil and Environmental Engineering and as director of GRI, leads a major university-wide research initiative to inform and advance societal resilience in the face of growing human-made and naturally-occurring turbulence. He serves as a Guest Scientist at Los Alamos National Laboratory and has led teams in conducting post-disaster community and infrastructure resilience assessments, initially with support from the Alfred P. Sloan Foundation, the U.S. Department of Homeland Security S&T Directorate, and FEMA. With support from the U.S. Economic Development Administration, he has been leading projects that inform how economic development can be undertaken to advance community resilience, sustainability, and equity.

Fernando E. Pabón Rico, director of the Caribbean Center for Rising Seas (CCRS) at the Puerto Rico Science, Technology & Research Trust (PRSTRT) will serve as the project's second collaborator. Representing PRSTRT, Mr. Pabón's role is to discuss with other project team members the possible avenues of collaboration to ensure the successful completion of the project. In particular, the CCRS team will be available as an ad hoc sounding board and liaison with stakeholders, and will provide input on identifying an appropriate consultant for the project's community engagement consultant.

Consultant
The consultant will work to facilitate engagement of project personnel with community members (e.g., leaders, stakeholders, and other residents) in order to a) identify and evaluate for use/quality the available secondary data – including damage and loss information within the

scope of project objectives and deliverables; and b) arrive in a participatory way at recommendations on land use practices that enhance community resilience to future extreme events.

1.7.3 Work Flow

PI Borak will manage the project and direct the members of the project team. He will also be responsible for the open data and open science requirements. Dr. Borak's research responsibilities will focus on acquiring data and generating satellite-based data using requested NASA/GSFC computing resources. He will also work as needed with Collaborator Flynn and Collaborator Pabón on community outreach and understanding how to tailor satellite-derived products for optimal use by decision-makers and stakeholders. Dr. Borak's annual trips to Puerto Rico are meant to strengthen these connections.

Co-I Morrow will be the project team's lead on socioeconomic concerns, including social justice, and ensuring proper consideration for all underrepresented groups. He will be responsible guiding socio-economic data integration and community engagement aspects of the proposed research. At island scale, Dr. Morrow will support Dr. Borak with Geographic Information System-based spatial and visual analysis including overlay analysis of CJEST indicators as necessary. Dr. Morrow will review socio-economic assessments and data beyond CJEST indicators are available/useful. At local level, Dr. Morrow will advise the PRSTST-affiliated consultant to identify and evaluate for use/quality the available secondary data including damage and loss information. Dr. Morrow will evaluate existing data for construction of a resilience index that can be further parameterized by CSDSA and other remotely sensed data in collaboration with Dr. Borak. Dr. Morrow will help to frame and document overall local government and community engagement efforts of PRSTST and affiliated consultant within the scope of project objectives and deliverables through supporting work planning and regular update reporting. Participatory evaluation with multiple stakeholders of the proposed resilience metrics will be supported by Dr. Morrow. He will also attend all team meetings and contribute to data management, publishing and reporting requirements.

Collaborator Flynn and the PI will work together to understand how best to use these Earth observation datasets to improve La Margarita's resilience to flooding, and they will exchange insights from their respective projects. Collaborator Pabón will also work with the PI on how best to use the Earth observations in La Margarita, and will also assist the PI in identifying an appropriate community engagement consultant.

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3. Data Management Plan

In general, this project will follow an open data and science policy, where the databases, algorithms, and code used for the development of the project will be made freely and openly available, as well as sample Jupyter notebooks that contain basic code for programmatic access to the outputs. The team will post product versions to NASA's Open Data Portal and provide metadata as required. The team will post project output data there, and evaluate the feasibility to have that hosted at a DAAC if data volume becomes too large for the Portal.

Data types, volume, formats, and (where relevant) standards:
There are two main groups of data the team will need to distribute: 1) Vegetation parameter data fields; and 2) flooding fields, which will likely be distributed as netCDF files at an anticipated data volume of roughly 1TB per project year (as also indicated in HEC request).

Note that because the input datasets used by this project are all freely available via open data sites on the Internet, there is no requirement for the team to manage those data.

Intended repositories for archived data, including mechanisms for public access & distribution:
As described above, in deference to open data and science policies, the output data will be transferred from NASA/GSFC to the NASA Open Data Portal.

How the plan enables long-term preservation of data:
If the Open Data Portal is capable of maintaining the outputs long term, that would comply with open data protocols. Otherwise, the team's preference would be to use Zenodo owing to its commitment to FAIR compliance.

Roles and responsibilities of team members in accomplishing the DMP:
The project PI will have responsibility for managing any code or output data products.

Licensing Considerations:
End User License agreements for PlanetScope and Maxar Worldview describe how commercial data can be used by NASA researchers for Scientific Use research purposes as outlined in the research award agreement. Public Release or Commercial Use of the CSDA data is prohibited. Any raw imagery must be securely handled. Only derivative products with clearly defined research purposes are to be shared with the general public, used in publications or shared with our community-based stakeholders.

Every effort will be made to limit the access to original or raw PlanetScope and Maxar Worldview data. The PI works in a secure NASA affiliated research center with a nasa.gov email. The raw data will almost exclusively be processed in the HEC computing environment by Dr. Borak following the strict security protocols of his center. On occasions when Co-I Morrow is required to use imagery, it will be processed in HEC environment or on a secured workstation. No raw data will be present on laptops during travel.

4. Biographical Sketches

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Education

- Graduate Certificate, Data Science: University of Maryland, College Park, 2019.
- Ph.D. in Geography: Boston University, 2000.
- Master of Arts in Geography: Boston University, 1996.
- Bachelor of Science in Geography (Math minor): University of Illinois, Urbana-Champaign, 1992.

Areas of Research Specialization

- Inter-annual and seasonal variability of vegetation and water cycle components.
- Earth science data processing and analysis: particular focus on long-term time series data at regional and continental scales.
- Land-cover characterization from satellite observations.
- Quality assessment of remotely sensed data.

Current Research Projects

- Principal Investigator/ICESat-2 Science Team Member: "Enhanced Roughness Length Estimates from ICESat-2 Vegetation Products" (NASA Cryospheric Sciences Program).
- Co-Investigator: "National Climate Assessment Land Data Assimilation System, NCA-LDAS" (NASA National Climate Assessment Program).
- Co-Investigator: "Shallow Water Bathymetry Products and Analysis for Near-Shore Coastal and Inland Waters" (NASA Earth Science Research and Analysis Program).
- PREP Research Associate: "Remote Sensing of Vegetation in Puerto Rico for NIST's Hurricane Maria Infrastructure Project" (NIST Community Resilience Program).
- PACE Early Adopter: "Mapping Wetland Vegetation Parameters with PACE's OCI."

Computing Skills

- Programming and scripting: 25+ years of C programming and shell scripting in Unix-type environments; 4+ years with Python and Java.
- Machine learning software: scikit-learn and Keras.
- Statistics and visualization packages: R, Tableau, and SAS.
- GIS and image processing packages: extensive work with ENVI, ID, and ArcGIS.

Employment

- Associate Research Scientist, Earth System Science Interdisciplinary Center, University of Maryland and Hydrological Sciences Laboratory, NASA/Goddard Space Flight Center (June 2011 – present).
- Senior Support Scientist, Science Systems and Applications, Inc., then Wyle Information Systems, LLC, and Hydrological Sciences Branch, NASA/GSFC (July 2002 – June 2011).
- Support Scientist, Science Systems and Applications, Inc., MODIS Land Data Operational Product Evaluation Facility, NASA/GSFC (November 2000 – June 2002).
- Research Associate, Department of Geography and Laboratory for Global Remote Sensing Studies, University of Maryland (July 1999 – November 2000).
- Research Fellow, Department of Geography and Center for Remote Sensing, Boston University (September 1993 – June 1999).

Publications (selected)

Borak, J.S., M.F. Jasinski, and N. Tangdamrongsub, 2022: Effects of ICESat-2 Vegetation Product Spatial Sampling Rate on Satellite-Derived Momentum Aerodynamic Roughness Fields [Poster presentation C35D-0915]. AGU 2022 Fall Meeting, 12-16 Dec.

Borak, J.S., M.F. Jasinski, and N. Tangdamrongsub, 2021: Fusing ICESat-2 and MODIS Vegetation Data Products to Enhance Momentum Aerodynamic Roughness Fields with Spatially-Explicit Scaling for Improved Land Surface Modeling [Poster presentation G15B-0350]. AGU 2021 Fall Meeting, 13-17 Dec.

Tangdamrongsub, N., C. Hwang, **J.S. Borak**, S. Prabnakorn, and J. Han, 2021: Optimizing GRACE/GRACE-FO data and *a priori* hydrological knowledge for improved global Terrestrial Water Storage component estimates. *J. Hydrol.*, **598**, 126463.

Borak, J.S., M.F. Jasinski, and N. Tangdamrongsub, 2020: Enhanced vegetation aerodynamic roughness for momentum with ICESat-2 data products: early results [Poster presentation H194-0005]. AGU 2020 Fall Meeting, 1-17 Dec.

Jasinski, M.F., **J.S. Borak**, S.V. Kumar, D.M. Mocko, C.D. Peters-Lidard, M. Rodell, H. Rui, H.K. Beaudoing, B.E. Vollmer, K.R. Aresenault, B. Li, J.D. Bolten, and N. Tangdamrongsub, 2019: NCA-LDAS: Overview and Analysis of Hydrologic Trends for the National Climate Assessment. *J. Hydrometeorol.*, **20**, 1595-1617.

Kumar, S.V., M. Jasinski, D. Mocko, M. Rodell, **J. Borak**, B. Li, H. Kato Beaudoing, and C. D. Peters-Lidard, 2019a: NCA-LDAS land analysis: Development and performance of a multisensor, multivariate land data assimilation system for the National Climate Assessment. *J. Hydrometeorol.*, **20**, 1571-1593.

Kumar, S.V., D.M. Mocko, S. Wang, C.D. Peters-Lidard, and **J. Borak**, 2019b: Assimilation of remotely sensed Leaf Area Index into the Noah-MP land surface model: Impacts on water and carbon fluxes and states over the Continental U.S. *J. Hydrometeorol.*, **20**, 1359-1377.

Borak, J.S., and M.F. Jasinski, 2009: Effective interpolation of incomplete satellite-derived leaf-area index time series for the continental United States. *Agr. Forest Meteorol.*, **149**, 320-332.

Borak, J.S., M.F. Jasinski, and R.D. Crago, 2005: Time series vegetation aerodynamic roughness fields estimated from MODIS observations. *Agr. Forest Meteorol.*, **135**, 252-268.

Roy, D.P., **J.S. Borak**, M. Zheng, and J. Descloitres, 2002: The MODIS Land product quality assessment approach. *Remote Sens. Environ.*, **83**, 62-76.

Borak, J.S., E.F. Lambin, and A.H. Strahler, 2000: The use of temporal metrics for land-cover change detection at coarse spatial scales. *Int. J. Remote Sens.*, **21**, 1415-1432.

Borak, J.S., and A.H. Strahler, 1999: Feature selection and land cover classification of a MODIS-like data set for a semiarid environment. *Int. J. Remote Sens.*, **20**, 919-938.

Co-I/Institutional PI: Nathan Morrow, PhD.

1. Professional Preparation

Boston University, Geography, Bachelor of Arts with Honors 1997
Boston University, Geography, Master of Arts 1998
University of Maryland, Geography, Doctor of Philosophy (M. Hansen advisor) 2021

2. Professional Experience and Positions

Current Sponsored Research:

- PI, Assessment of the Gulf Coast Environmental Justice Landscape for Equity (AGEJL-4-Equity), NASA-funded, 10/22-4/23
- PI, Open Science Outlook for Environmental Justice and Resilience of the Louisiana Gulf Coast (O8O-LoGiC), NASA-EPSCoR-funded, 5/22-4/23

Appointments at Tulane University:

- Ass. Research Prof, Public Health & Tropical Medicine, 2022-/Ass. Research Prof, Law School, 2014-2018, Adjunct 2007-2012/Ass. Clinical Prof, School of Social Work, 2012-2014/Ass. Clinical Prof, Public Health & Tropical Medicine, 2011-2014, Adjunct 2007-2022

3. Selected Bibliography

***Morrow, N.,** Mock, N. B., Gatto, A., LeMense, J., & Hudson, M. (2022). Protective Pathways: Connecting Environmental and Human Security at Local and Landscape Level with NLP and Geospatial Analysis of a Novel Database of 1500 Project Evaluations. *Land,* 11(1), 123. https://doi.org/10.3390/land11010123

***Morrow, N.** (2022). *People-centered design in Open Sourced Science for enhanced use of Earth observation in equitable engagement, empowerment for collective action, and meaningful measurable impact.* Open Sourced Science (OSS) for Earth System Observatory (ESQ) Mission Science Data Processing Study. **https://doi.org/10.5281/zenodo.5932699**

***Morrow, N.,** & Friedl, M. (1998). Modeling biophysical controls on land surface temperature and reflectance in grasslands. *Agricultural and Forest Meteorology,* 92(3), 147-161. https://doi.org/10.1016/80168-1923(98)00098-7

4. Research Experience: Scientific, Technical, Management

Dr. Morrow has acquired a wide range of skills and expertise with 25 years of experience not only as a professor but also leading implementation, developing capacity and ensuring research-based evidence for interdisciplinary/multi-sectoral food security, humanitarian response, and child wellbeing policy implementation projects. He has served as Chief of Party for a multi-organizational consortium for multi-country developmental relief and humanitarian aid response valued at over 400 million USO responding to an El Nino drought food security crisis in southern Africa As co-chair of the Emergency and Disaster Evaluation thematic group at the American Evaluation Association, Dr. Morrow has promoted inclusive engagement and more rigorous measurement models in resilience research and intervention planning. The Global Environment Facility (GEF-7) replenishment strategy was informed, in part, by a geospatial analysis of environmental security led by Dr. Morrow. Dr. Morrow is PI for two projects that intend to strengthen capacity for open source science to address challenges in CJ & EJ research in collaboration with Gulf Coast EJ community networks and organizations. Dr. Morrow continues to actively use remote sensing and geospatial analysis in his applied research following on early contributions to the MODIS, NPOESS, and Land-Use and Land-Cover Change science mission.

5. Table of Personnel and Work Effort

Name	Role	Commitment (months per year)								
		Year 1			*Year 2*			*Sum*		
		This Project		*Other Funded Projects*	*This Project*		*Other Funded Projects*	*This Project*		*Other Funded Projects*
		NASA Support	*Total*		*NASA Support*	*Total*		*NASA Support*	*Total*	
Jordan Borak	PI	2.4	2.4	3.0	2.4	2.4	0	4.8	4.8	3.0
Nathan Morrow	Co-I/ Institutional PI	2.4	2.4	0	2.4	2.4	0	4.8	4.8	0.0
Stephen Flynn	Collaborator (unfunded)	de minimis	de minimis	de minimis	de minimis	de minimis	de minimis	de minimis	de minimis	de minimis
Fernando Pabón	Collaborator (unfunded)	de minimis	de minimis	de minimis	de minimis	de minimis	de minimis	de minimis	de minimis	de minimis
Sum of work effort:		**4.8**	**4.8**	**3.0**	**4.8**	**4.8**	**0**	**9.6**	**9.6**	**3.0**

Comments:
Additional effort to be provided on hourly basis by TBD community engagement consultant (see Budget)

6. Current and Pending Support

Current and Pending: Dr. Jordan Borak

The following information should be provided for each investigator and other senior personnel. Failure to provide this information may delay consideration of this proposal.

Investigator: Dr. Jordan S. Borak	Other agencies (including NASA) to which this proposal has been/will be submitted.

Support: ☒ Current ☐ Pending
Project/Proposal Title: Enhanced Roughness Length Estimates from ICESat-2 Vegetation Products
Role: PI
Source of Support: NASA Cryospheric Program/Studies with ICESat-2
Total Award Period Covered: 05/20-04/23
Person-Months Per Year Committed to the Project: 3.0

Support: ☒ Current ☐ Pending
Project/Proposal Title: National Climate Assessment Land Data Assimilation System, NCA-LDAS
Role: Co-I
Source of Support: NASA National Climate Assessment Program
Total Award Period Covered: FY16-FY23
Person-Months Per Year Committed to the Project: 3.6

Support: ☒ Current ☐ Pending
Project/Proposal Title: Shallow Water Bathymetry Products and Analysis for Near-Shore Coastal and Inland Waters
Role: Co-I
Source of Support: NASA The Science of Terra, Aqua, and Suomi-NPP
Total Award Period Covered: FY22-FY24
Person-Months Per Year Committed to the Project:3.0

Support: ☒ Current ☐ Pending
Project/Proposal Title: Remote Sensing of Vegetation in Puerto Rico for NIST's Hurricane Maria Infrastructure Project
Role: PREP Research Associate
Source of Support: NIST Community Resilience Program
Total Award Period Covered: 07/22-06/23
Person-Months Per Year Committed to the Project: 3.0

Support: ☐ Current ☒ Pending
Project/Proposal Title: Improving Our Understanding of Gulf Coast Wetland Dynamics with Spaceborne Lidar
Role: Co-I
Source of Support: NASA Cryospheric Program/Studies with ICESat-2
Total Award Period Covered: 05/23-04/26
Person-Months Per Year Committed to the Project: 3.0

Support: ☐ Current ☒ Pending
Project/Proposal Title: Spatio-Temporal Connections of Integrated Energy, Water and Biogeochemical Processes Across Alaska's Land and Ocean Ecosystems
Role: Co-I
Source of Support: NASA Interdisciplinary Research in Earth Science
Total Award Period Covered: 6/23-05/26

Person-Months Per Year Committed to the Project: 1.2

Support: ☐ Current ☒ Pending

Project/Proposal Title: High-resolution Extreme Event and Localized Temperature for Health Forecasting in Underserved Lowlands of the Gulf Coast (HEELTHFUL-GC)

Source of Support: NASA Interdisciplinary Research in Earth Science

Total Award Period Covered: 07/23-06/26

Person-Months Per Year Committed to the Project: 3.6/2.4/1.8

Support: ☐ Current ☒ Pending

Project/Proposal Title: Ancient Climate Change Resilient but Understudied Enset agrifood system Diversity Mapping for Food Security and Sustainability (ACCRUED-MFSS)

Role: Co-I

Source of Support: NASA Commercial Smallsat Data Scientific Analysis

Total Award Period Covered: 09/23-08/25

Person-Months Per Year Committed to the Project: 3.6

Support: ☐ Current ☒ Pending

Project/Proposal Title: Analysis of Locally Flooded Areas with Environmental Justice Communities (ALFA-EJC)

Role: Co-I

Source of Support: NASA Commercial Smallsat Data Scientific Analysis

Total Award Period Covered: 09/23-08/25

Person-Months Per Year Committed to the Project: 2.4

Current and Pending: Dr. Nathan Morrow

The following information should be provided for each investigator and other senior personnel. Failure to provide this information may delay consideration of this proposal.

Investigator: Dr. Nathan Morrow	Other agencies (including NASA) to which this proposal has been/will be submitted.

Support: ☒ Current ☐ Pending

Project/Proposal Title: Assessment of the Gulf Coast Environmental Justice Landscape for Equity (AGEJL-4-Equity)

Source of Support: NASA A.49 Earth Science Applications: Equity and Environmental Justice

Total Award Period Covered: 10/22-06/23

Person-Months Per Year Committed to the Project: 2.0

Support: ☒ Current ☐ Pending

Project/Proposal Title: Open Science Outlook for Environmental Justice and Resilience of the Louisiana Gulf

Role: PI

Source of Support: NASA EPSCoR Louisiana BoR RID Project

Total Award Period Covered: 3/22-05/23

Person-Months Per Year Committed to the Project: 2.0

Support: ☐ Current ☒ Pending

Project/Proposal Title: High-resolution Extreme Event and Localized Temperature for Health Forecasting

Role: PI

Source of Support: NASA A.28 Interdisciplinary Science

Total Award Period Covered: FY24-FY26

Person-Months Per Year Committed to the Project: 5.4

Support: ☐ Current ☒ Pending

Project/Proposal Title: EJ Core GC; Engaging diverse researchers and EJ communities in inclusive

Role: PI

Source of Support: NASA Science Mission Directorate –F.14- Transform to Open Science Training

Total Award Period Covered: 07/23-06/25

Person-Months Per Year Committed to the Project: 3.6

7. Letters of Support

To the ROSES Proposal Review Panel

Re: Letter in support of Dr. Jordan Borak's Initiative towards building community resilience against the impacts of flooding disasters in Puerto Rico

Dear Members of the Review Panel,

I am pleased to write this letter of support for Dr. Borak's proposed investigation regarding the role of vegetation in building community resilience to flooding impacts in Puerto Rico. At the time of writing this letter it stands as "*Application of Commercial Smallsat Data to Enhance Flood Resilience in Support of Underserved Communities in Puerto Rico*." Understanding the relationship of land use to flood resilience has never been more important here, with increasing frequency and severity of tropical cyclone activity. Hurricane Fiona unleashed torrential rains and flooding on Puerto Rico in September 2022, almost five years to the day that Hurricane Maria made landfall and brought devastation to the island. In both cases we saw the disproportionate impact of climate change on underserved and vulnerable communities.

The Puerto Rico Science, Technology & Research Trust (PRSTRT) is a 501(c)(3) non-profit organization based in Puerto Rico and created in 2004 to encourage and promote innovation, transfer and commercialization of technology, and creation of jobs in the technology sector. The PRSTRT's mission is to invest, facilitate and build capacity to continually advance Puerto Rico's economy and its citizens' well-being through innovation-driven enterprises, science and technology, and its industrial base. The vision is that Puerto Rico is a globally recognized innovation hub. The PRSTRT contributes to the creation and implementation of the Puerto Rico Government's public policy for the advancement of science, technology, research and development, and public health.

Dr. Borak's project will integrate high-resolution commercial satellite observations with publicly available remote sensing products in a novel way to produce maps of vegetation type and density. It will also identify flood-affected areas. These maps will then be associated with socio- economic and infrastructure information to improve our understanding of 1) how vegetation distribution correlates with flooding impacts on underserved communities; 2) how residents and other stakeholders in the community can use this information to increase resilience; and 3) how this policy-relevant information can be conveyed to decisionmakers such that federal resources will be appropriately allocated to, and applied by, communities experiencing environmental injustices.

This project is very relevant especially to the Caribbean Center for Rising Seas' (CCRS), one of the PRSTRT's newest programs. CCRS's mission is to prepare Puerto Rico and the Caribbean to adapt and thrive in the new era of increasing flood risk from storms, tides, and sea level rise. The CCRS is tasked with further establishing Puerto Rico's leadership and stature as a center of excellence and innovation. Flooding is worsening in communities all over the world since 100-year storms and extreme rain events are happening more frequently, often every couple of years. Sea level rise continues to accelerate, with estimates ranging from a foot higher by midcentury, to 7 feet higher by the end of the century. During hurricanes and severe storms, a few inches of higher sea level may result in flood waters entering buildings and causing major damage to infrastructure. Coastal communities are in jeopardy while facing billions of dollars of assets going underwater. The CCRS' focus on resiliency and adaptation – promoting guidelines and best practices for the built environment to better prepare communities for increased flooding would benefit greatly from the results of this study. Specifically, it will inform one of the primary areas of focus: promoting 100-year flood safe communities.

In keeping with the mission of facilitating the researchers' primary tasks, the PRSTRT stands ready to discuss any possible avenues of collaboration to ensure the successful completion of the project. While the CCRS team remains available as an ad hoc sounding board and liaison with stakeholders, other components of the PRSTRT are available to provide local technical and/or administrative support for a fee be it in Information Technology subfields such as data management and web-page development or Strategic Outreach and Communications to make available and publicize research progress and findings.

The PRSTRT commends Dr. Borak for his initiative. It will provide useful knowledge to develop initiatives that will reduce or eliminate risk and damage from future natural hazards, increase resiliency, and promote a culture of preparedness. We hope the proposal is considered favorably and we look forward to its implementation and the initiatives that will arise from it.

If you have any questions, please feel free to contact Mr. Fernando Pabón at fpabon@prsciencetrust.org.

Sincerely,

Luz A. Crespo Valentín

Luz A. Crespo Valentín

Chief Executive Officer

8. Budget

		YEAR 1	YEAR 2	TOTAL
TRAVEL				
	FOREIGN	$ 4,000	$ 4,000	$ 8,000
	TOTAL TRAVEL	$ 4,000	$ 4,000	$ 8,000
EQUIPMENT				
	TOTAL EQUIPMENT	$ -	$ -	$ -
SUBCONTRACTS				
Tulane University		$ 2,610	$ 2,610	$ 5,220
	TOTAL SUBCONTRACTS	$ 2,610	$ 2,610	$ 5,220
OTHER DIRECT COSTS				
	Community Engagement Consultant (TBD)	$ 20,000	$ 20,000	$ 40,000
	Publications	$ 2,900	$ 2,900	$ 5,800
	TOTAL OTHER DIRECT COSTS	$ 22,900	$ 22,900	$ 45,800
TOTAL DIRECT COSTS		$ 29,510	$ 29,510	**$ 59,020**

NASA GSFC 20% Assessment	$ 5,902	$ 5,902	**$ 11,804**
TOTAL REQUESTED SUPPORT	$ 35,412	$ 35,412	**$ 70,824**

University of Maryland, College Park (UMD) – Budget Justification

TRAVEL

International Travel: Funds are requested in the amount of $8,000 ($4,000 per year) for the PI to attend a Team / Community Engagement meeting in Puerto Rico, in each year of this project for the purpose of collaborating with colleagues and disseminating research findings. The standard travel cost estimates below are based on the average expenses reported by department faculty for attending meetings and conferences in the previous fiscal year. All travel costs are budgeted in accordance with UMD, state, and federal policies and are estimated based on historical averages, UMD per diem rates (domestic travel, only) and current gsa.gov rates. Please note that this travel is contingent upon COVID-19 regulations imposed at the state and federal level.

Year 1: NASA Team / Community Engagement Meeting, Puerto Rico: $4,000
Year 2: NASA Team / Community Engagement Meeting, Puerto Rico: $4,000

Team / Community Engagement Meeting, Peurto Rico				
Expense	**Cost**	**Day(s)**	**# of Trips**	**Total**
Airfare	$1,300	1.00	2.00	$2,600
Hotel	$280	5.00	2.00	$2,800
Per-diem	$150	6.00	2.00	$1,800
Ground transportation	$50	6.00	2.00	$600
Other/Baggage Fee	$50	2.00	2.00	$200
Total				**$8,000**

EQUIPMENT

N/A

SUBCONTRACTS

Funds are requested in the amount of $5,220 to support one (1) subcontract with the Tulane University.

Year 1: $2,610
Year 2: $2,610

OTHER DIRECT COSTS

Community Engagement Consultant (TBD): Funds are requested in the amount of $40,000 ($20,000 in each year of this project). The consultant will facilitate the engagement of the project personnel with community members (e.g., leaders, stakeholders, and other residents). The purpose: a) identifying and evaluating for use/quality the available secondary data – including damage and loss information within the scope of project objectives and deliverables; and b) arriving in a participatory way at recommendations on land use practices that enhance community resilience to future extreme events.

Publications: Funds are requested in the amount of $5,800 ($2,900 per year) to support the publication of one peer-reviewed journal article of approximately 20 pages in length in each year of this project. This standard estimate is based on current rates for publishing in the Journal of Geophysical Research (JGR), American Geophysical Union (AGU).

NASA GSFC Assessment Fee: Funds are requested in the amount of $11,804 to support the NASA Goddard Space Flight Center expenses for this project. These costs, as discussed in NASA financial regulations, are for services to support the research effort that go beyond the standard costs considered under Center Management and Operations (Center Overhead), and are not incurred elsewhere within GSFC. Within the Sciences and Exploration Directorate these costs cover system administration for the complex information technology services required to support the proposed research activities, administrative and resource analysis support, and supplies to support the research effort. The assessment rate is 20% of the total direct costs of the project:

Year1:$5902
Year2:$5902

REDACTED BUDGET
NASA - Puerto Rico
Prime: Univ. Maryland

Tulane		**Year 1**	**Year 2**	**Total**
	Personnel			
	Faculty - Morrow - .15 LOE	-	-	-
		-	-	-
		-	-	-
	Travel - Puerto Rico (6 days)			
	Airfare	750.00	750.00	1,500.00
	Hotel (DoD rate)	1,170.00	1,170.00	2,340.00
	Ground and meals (DoD rate)	690.00	690.00	1,380.00
Total Direct Costs - Tulane		2,610.00	2,610.00	5,220.00
		-	-	-
Total Project Cost		**2,610.00**	**2,610.00**	**5,220.00**

Redacted Budget Narrative : Dr. Nathan Morrow, Tulane Univeristy

Application of Commercial Smallsat Data to Enhance Flood Resilience in Support of Underserved Communities in Puerto Rico
(expected September 2023-August 2025)
University of Maryland, prime

Nathan Morrow as Co-I Institutional PI will provide 0.15 FTE to Application of Commercial Smallsat Data to Enhance Flood Resilience in Support of Underserved Communities in Puerto Rico project activities

A site visit in project years will allow Dr. Morrow to work with the PRSTST-affiliated consultant to ground truth the use/quality the available secondary data including damage and loss information. A site visit in the second project year will allow Dr. Morrow to support the participatory evaluation with multiple stakeholders of the proposed resilience metrics.

Travel - Puerto Rico (6 days)			
Airfare	750.00	750.00	1,500.00
Hotel (DoD rate)	1,170.00	1,170.00	2,340.00
Ground and meals (DoD rate)	690.00	690.00	1,380.00
sts - Tulane	2,610.00	2,610.00	5,220.00

9. Facilities and Equipment

The technical management and infrastructure to facilitate and support grant-based research computing is available to Earth System Science Interdisciplinary Center (ESSIC) scientists at the University of Maryland (UMD) Discovery District location.

The Center provides a modern data center with 10-Gigabit network capability, including dedicated HVAC, electrical, and fire-suppression systems, as well as raised flooring, cipher-controlled access, and both public and private-facing networks.

ESSIC technical staff manage an array of physical and virtual compute servers associated with existing research grants, including high-performance computing clusters with total storage resources of nearly three Petabytes. Server operating systems include both Windows Server and Red Hat Linux.

ESSIC scientists rely on the main UMD campus for additional technical resources that include software licensing, network support, email, authentication, specialized vendor contracts, and both no-cost (google) and fee-based storage. Deep Thought, the UMD high-performance computing facility with over 1000 compute nodes and several Petabytes of storage, is available to ESSIC scientists for approved projects.

The Center staffs a local helpdesk office offering researchers an array of services including desktop and personal computing deployment and support, technical procurement consultation and order assistance, IT security, connectivity, backups, asset management, and system diagnostics and troubleshooting.

The Center also offers network-accessible color printers, scanners/copiers, as well as meeting and conference spaces equipped with integrated projectors, conference phones, and room PCs. A rooftop platform, which currently hosts a NOAAPORT satellite-receiving dish and other sensors, is also available for instrumentation hosting.

Additionally, the UMD PI will work on-site at the NASA's Goddard Space Flight Center (GSFC), through a co-operative agreement between GSFC and UMD. GSFC facilities offer high-speed internet access, printing services (including a plotter for poster printing), office space, and conference rooms. The UMD PI will have access to High Efficiency Computing resources at the NASA Center for Climate Simulation to perform the proposed data analysis and to process the observations data sets.