Improving Our Understanding of Gulf Coast Wetland Dynamics with Spaceborne Lidar

In Response To: NNH22ZDA001N-ICESAT2:A.32 Studies with ICESat-2

1. Proposal Summary

This team proposes using ICESat-2 data products to generate new spatiotemporal datasets appropriate for monitoring Gulf Coast Region wetlands from space. The products will incorporate image data from radar and optical sources in order to provide complementary time-series information on surface conditions, and to provide a matrix for generation of two-dimensional data fields from the spatially discontinuous information that is native to the ICESat-2 observatory's along-track products. The gridded datasets will consist of monthly maps of 1) above ground biomass density (AGBD); 2) vegetation canopy height; 3) vegetation canopy base height; 4) fractional vegetation cover; 5) land surface type; and 6) hydrologic status.

The need to improve wetlands monitoring is general, and wetlands in the Gulf Coast Region, covering hundreds of thousands of square kilometers in the immediate coastal zone alone, merit specific attention. These ecosystems provide crucial ecosystem services at the interface between terrestrial and aquatic systems – amounting to unique combinations of the two that vary over space and time. Consequently, their well-being is key to the efficiency with which they provide these services to residents and industries in the Gulf Coast Region.

There is an under-represented, yet valuable spatiotemporal scale of wetlands research: frequent, regional monitoring. This presents an ideal situation to bridge a gap with innovative datasets derived from the unique capabilities of ICESat-2. In the Gulf Coast Region specifically, wetlands cover such a large extent that it would be difficult to assemble appropriate datasets without leveraging spaceborne remotely sensing observations. These efforts will complement existing data and modeling initiatives in novel ways.

2. Scientific/Technical/Management Plan

2.1 Background

Of the seventeen Sustainable Development Goals (SDGs) the United Nations recognizes in its 2030 Agenda [1], there are at least seven that intersect substantively with concerns over wetland status: 1) Life Below Water; 2) Life on Land; 3) Climate Action; 4) Zero Hunger; 5) Clean Water and Sanitation; 6) Sustainable Cites and Communities; and 7) Responsible Consumption and Production. However, it is SDG target 6.6.1 – "Change in the extent of water-related ecosystems over time" – that is considered most relevant to wetland dynamics research [2].

Wetlands provide three major categories of ecosystem services: provisioning, regulating, and cultural. The health of wetlands is clearly key to the efficiency with which they provide these services. Dynamics of physical wetland health link most directly to variability in both land cover and climate. Land cover change affects provisioning (food/water), regulating (water flows), cultural (tourism/recreation and spiritual development) – as well as habitation of both flora and fauna. Yet, consistent information on wetland extent, condition, and their specific ecosystem services is frequently difficult to access or unavailable [3].

Thus, the need to improve wetlands monitoring is general, and wetlands in the Gulf Coast Region (GCR) – covering hundreds of thousands of square kilometers in the immediate coastal zone alone – merit specific attention. These ecosystems provide crucial ecosystem services at the interface between terrestrial (usually forest, agriculture, or urban) and aquatic systems – amounting to unique combinations of the two that vary over space and time. Consequently, their well-being is key to the efficiency with which they provide these services to residents and industries in the GCR.

This proposal team considers wetland ecosystems in the context of both physical and socioecological function – that is, whether the system functions as it should – relative to its natural physical state – and whether it is capable of sustainably providing the services that society derives from the system.

In the Gulf Coast Region, the need to improve monitoring of wetland ecosystem services is clear. Key areas where gaps in needs could be filled by improved monitoring tools include [4]:

1. Detailed wetland mapping
2. Land use planning
3. Trends at the watershed scale

The U.S. Department of the Interior (DOI) conducts and coordinates mapping of wetlands at the national level through its Fish and Wildlife Service's National Wetlands Inventory (NWI) [5]. The NWI is tasked with providing data on extent, status, and change of wetland ecosystems throughout the United States. Although its mapping mission is relatively narrow in scope, dataset updates tend to be infrequent given such a large spatial domain.

Conversely, the U.S. Geological Survey's Wetland and Aquatic Research Center (WARC) takes a more interdisciplinary "applied ecology" approach [6]. With less emphasis on mapping, and a tighter geographic focus – mainly the Southeastern region of the United States – WARC's interdisciplinary research portfolio tends to concern study domains of limited spatial and/or temporal extent.

There is an under-represented area of research between these two approaches: frequent, regional monitoring of wetlands. This is frequently the spatiotemporal scale used in land surface models [7] and fire risk mapping [8,9], and thus presents an ideal situation to bridge a gap with innovative datasets derived from the unique capabilities of ICESat-2. In the GCR specifically, wetlands cover such a large extent that it would be difficult to provide appropriate datasets without leveraging spaceborne remotely sensing observations. Such datasets would complement existing data initiatives such as LANDFIRE and various land surface/data assimilation modeling efforts [10].

This team proposes using ICESat-2 data products to generate new spatiotemporal datasets appropriate for monitoring GCR wetlands from space. The products will incorporate image data from radar and optical sources in order to provide complementary time-series information on surface conditions, and to provide a matrix for generation of two-dimensional data fields from the spatially discontinuous information that is native to the ICESat-2 observatory's along-track products. The gridded datasets will consist of monthly maps of 1) above ground biomass density (AGBD); 2) vegetation canopy height; 3) vegetation canopy base height; 4) fractional vegetation cover; 5) land surface type – i.e. what type(s) of vegetation are present (woody/herbaceous/both/neither); and 6) hydrologic status.

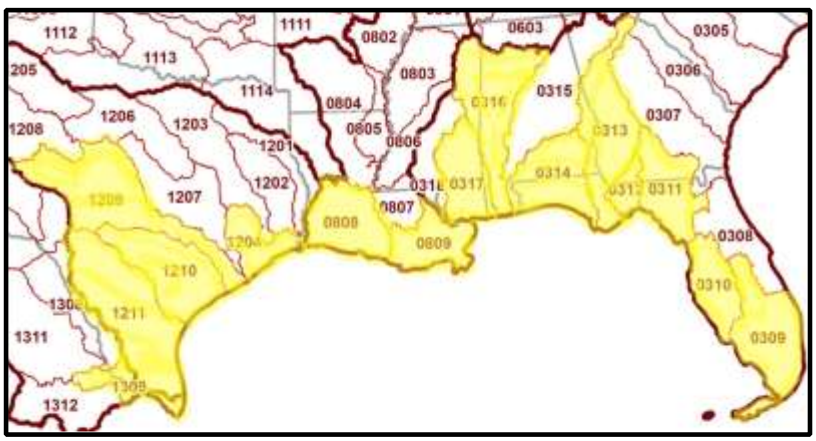

Figure 1: Proposed domain for Gulf Coast Region study; areas of analysis highlighted.

All six datasets will be produced over the entire GCR domain. Here, the proposal team defines the Gulf Coast Region as the set of USGS Hydrologic Unit Code (HUC) 4-digit subregions that empties directly into the Gulf of Mexico (Figure 1). The datasets will be mapped to a common 500-meter grid – a resolution that serves as a practical compromise between spatial and temporal resolutions. Monthly resolution will be realized as a rolling 3-month database that concludes with the month of interest. These tradeoffs in spatiotemporal resolution allow for sufficient ICESat-2 observations to accumulate over the domain to produce the gridded output data. Although the goal of this investigation is to create GCR-specific datasets, the methodology is readily adapted to monitoring wetlands in other regions. Table 1 lists the watersheds of interest identified in Figure 1, and includes their spatial extents.

Table 1: Summary details of the proposed domain, defined as the set of HUC subregions that empty into the Gulf of Mexico. Approximate total area of the domain: 58 million ha.

HUC Region	Subregion(s)	Area (1000s ha)	U.S. State(s)
Rio Grande (13)	Lower Rio Grande (1309)	326	Texas
Texas-Gulf (12)	Nueces-S.W. Texas Coastal (1211)	7511	Texas; Louisiana
	Central Texas Coastal (1210)	4713	
	Lower CO-San Bernard Coastal (1209)	7356	
	Galveston Bay-San Jacinto (1204)	2067	
Lower Mississippi (08)	Louisiana Coastal (0808)	3626	Louisiana
	Lower Mississippi (0809)	2450	
South Atlantic-Gulf (03)	Pascagoula (0317)	3134	Mississippi; Alabama; Georgia; Florida
	Mobile - Tombigbee (0316)	5672	
	Choctawhatchee - Escambia (0314)	3885	
	Apalachicola (0313)	5309	
	Ochlockonee (0312)	945	
	Suwannee (0311)	3574	
	Peace-Tampa Bay (0310)	2590	
	Southern Florida (0309)	4843	

For purposes of this study, a wetland mask will be generated by a spatial union of the most-recent releases of the National Wetlands Inventory and Global Surface Water Extent [11]. Wetland ecosystems within the GCR will receive additional attention, and the team will report statistics and trends for all six datasets on a monthly basis for all wetlands.

These datasets comprise physical properties that can be quantified with models and measurements, and that indicate whether the ecosystem is in a physical state that is conducive to functioning as it would in a purely natural state. The wetland aspects being monitored here – vegetation and hydrology – are by no means exhaustive. A comprehensive wetland monitoring system would also incorporate water quality, soil, and buffer characteristics [12], but those are outside the scope of this study.

Ecosystem services depend not just on the objective ecosystem physical properties; they are defined by the extent to which humans are able to derive value from the ecosystem. Thus it is very possible for an ecosystem to be physically healthy, but if its societal value is perceived to be low, its ecosystem service value will be correspondingly low. Homeowners commonly encounter this situation when they apply for a permit to build on a property they already own, only to learn that this parcel of land includes protected wetland that they cannot build on, and so the property becomes “worthless” to them. The ecosystem may be pristine, and have great value for regulating (by controlling for flooding of the rest of the property or filtering out chemical pollutants before they enter the water supply), but that is not how the property owner sees it.

Of particular significance is the Harmonized Landsat Sentinel (HLS) dataset, which provides spectrally and spatially consistent 30-m atmospherically-corrected imagery from Landsat and Sentinel-2 going back to 2013.

2.2 Goals and Expected Significance

When the Global Ecosystem Dynamics Investigation (GEDI) instrument is de-installed from the International Space Station (scheduled for early 2023), ICESat-2 will be the only lidar mission on orbit. This team's main goal is to use ICESat-2 data products to create new datasets that will leverage the unique characteristics of the ATLAS instrument aboard ICESat-2 in order to improve wetland monitoring.

It is expected that the information about vegetation structure dynamics will be useful to wetland ecologists as they study impacts due to natural stressors (e.g., hurricanes), climate change (e.g., sea-level rise and warming), and anthropogenic influences such as conversion. Policymakers may be interested as well, particularly in the context of development.

Fire researchers will also want to work with the vegetation data. Biomass and canopy height information are both used as fuel parameters in fire likelihood and propagation models. Seasonally-inundated wetlands in particular are sensitive to short-term meteorological stresses such as droughts and excessive heat, and can burn out of control – especially those with peaty soils.

It is also anticipated that trends in hydrologic status will be of high interest to ecologists. Wetlands that are changing quickly in size or moisture character, or if exhibiting anomalously high interannual variability would merit additional research and possibly action on the part of stakeholders.

Ultimately, people in the Gulf Coast Region whose livelihoods depend on healthy wetlands for ecosystem services such as fishing and farming may be the group that is most concerned about dynamics of GCR wetlands. Few of them will make use of the datasets, but they will certainly benefit from their existence.

2.3 Technical Approach and Methodology

The proposal team will use a multisensor approach to characterize and monitor the wetland ecosystems. In addition to ICESat-2 products, the team will acquire visible and radar data, which will complement the information value of the lidar-based products. The optical remote sensing analysis will be based on the Harmonized Landsat and Sentinel-2 (HLS) surface spectral reflectance dataset with nominal 30-meter spatial resolution. Although the HLS data acquisition plan promises frequent overpasses of the Sentinel-2 and Landsat sensors, the area of interest experiences frequent cloud cover, and so having a second imagery option is likely to be a necessity. Hence, the inclusion of Sentinel-1 C-Band SAR imagery.

The general strategy is to use the optical and radar image data along with in-situ (or airborne) data to extrapolate the ICESat-2 along-track information across the entire domain. This is generally achieved in two stages:

1. Use ground observations of the intended outputs – e.g., AGBD, canopy height, etc. – to build mathematical models that relate the ICESat-2 observations (canopy height metrics or water heights) to the ground data and predict the outcome for new instances [13]:

$$\textit{ICESat-2 data} = \text{f(ground data)} \quad (1)$$

Initial candidate models would be ordinary least-squares regression or Random Forest if relationships were non-linear. More-complicated models would only be employed if neither of these approaches produced acceptable results.

2. After selecting a usable model, the radar and optical image data can be used to extrapolate the sparsely-distributed estimates based on ICESat-2 across the terrestrial portion of the domain [14, 15]:

$$\textit{distributed estimate} = \text{f(image data)} \quad (2)$$

As above, initial candidate models would use regression or Random Forest at first.

For ground data, the team will acquire field observations collected by the National Ecological Observatory Network (NEON) project [16], which includes several field sites within the GCR domain, both terrestrial and aquatic.

Tables 2-3 contain lists of satellite-based indicators for characterizing the vegetation and hydrology GCR wetland ecosystems. The team will generate temporal indicators and analyze their trends [10, 25]. Also for each indicator, the team will construct a baseline reference from multiyear timeseries leading up to Project Year 1. The cadence and period of record will vary for different sensors, but the conservative goal is for each to include at least 5 years of previous observations. Once the team has a representative satellite-based history of the wetland sites, it can begin looking at new data – from the start of the project onward.

For vegetation (Table 2), the team plans to assess the vertical structure of the forest canopy using ICESat-2 Land and Vegetation Height (ATL08), as well as monitor the seasonality of the wetland ecosystems. The team also includes indices designed specifically to monitor both aquatic and terrestrial vegetation formations. It is probably unrealistic to commit to identifying different species of aquatic vegetation, but it may be possible to discriminate broadleaved floating vegetation like hyacinth from herbaceous types.

Table 2: Remote sensing inputs to be used for characterizing wetland vegetation status. The ICESat-2 canopy metrics will be distributed over the GCR domain using the HLS and Sentinel-1 image data.

Vegetation Indicator Type	Source(s) (index names)	Reference(s)	Spatial Resolution	Temporal Resolution
Vertical structure	ICESat-2 Land & Veg. Height (ATL08)	[17]	20-m 100-m	Variable
Aquatic Vegetation Indices	HLS[1] (NDAVI[2]; WAVI[3]; EAVI[4])	[18, 19, 20]	30-m	2-3 Days
Terrestrial Vegetation Indices	HLS (NDVI[5]; EVI[6])	[21]	30-m	2-3 Days
Canopy Backscatter	Sentinel-1 Interferometry	[22]	~5x20-m	Variable

[1]HLS = Harmonized Landsat Sentinel; [2]NDAVI = Normalized Difference Aquatic Vegetation Index; [3]WAVI = Water Adjusted Vegetation Index; [4]EAVI = Enhanced Aquatic Vegetation Index; [5]NDVI = Normalized Difference Vegetation Index; [6]EVI = Enhanced Vegetation Index

Table 3 presents the proposed hydrology indicators; these are mostly designed to capture variability in water cycle components, but they also track flooding and other changes in surface water volume. These indicators also reflect the broad, multisensor nature of this team's approach. As with the vegetation data, the ICESat-2 Inland Surface Water Data product will be modeled and distributed over the aquatic parts of the domain.

Table 3: Remote sensing inputs for monitoring wetland hydrology. Vertical surface water information from ICESat-2 will be distributed over the GCR domain using the HLS and Sentinel-1 image data.

Hydrology Indicator Type	Source(s)	Reference(s)	Spatial Resolution	Temporal Resolution
Surface Water Storage	ICESat-2 Inland Surface Water Data (ATL13)	[23]	Variable	Variable
Global Surface Water Extent	Landsat	[11]	30-m	Static
Inundation	HLS (MNDWI[1])	[24]	30-m	2-3 Days
Surface Moisture Content	Sentinel-1 Interferometry	[22]	~5x20-m	Variable

[1]MNDVI = Modified Normalized Difference Water Index

Finally, the proposal team plans to incorporate into this project new remote sensing sources as they become available. These include satellite sensors like NISAR [26] and its L-Band SAR scheduled to launch in 2023, and the hyperspectral OCI (Ocean Color Instrument) – scheduled for launch in the same year aboard the PACE (Plankton, Aerosol, Cloud, ocean Ecosystem) platform [27]. The OCI will provide hyperspectral information at moderate spatial resolution on a near-daily basis, which affords our team opportunities to develop and apply novel spectral indices with frequent looks.

2.3.1 Sources of error and uncertainty

Potential quantifiable sources of error consist mainly of satellite and other GIS data products, which are never perfect, and satellite data collected over the Gulf Coast Region often exhibit persistent atmospheric effects. This is a primary reason for including radar data.

Another source of error is insufficient resolution – spatial or temporal – for resolving a phenomenon of interest. As mentioned above, it is not realistic to claim that this study will capable of describing wetland vegetation in terms of species composition; however the proposal team does expect to be able to discriminate between broadly distinct physiognomies (e.g., broadleaf versus graminoid).

One other source of uncertainty is the in-situ data collected at the NEON sites. For a given data type, the error on field data collection is almost certain to be smaller than satellite-based estimates.

2.3.2 Resilience of the approach and methodology

As mentioned previously, the proposal team has identified multiple options for image data sources so that success never depends on degree of cloud cover or is prevented by a single point of failure with one of the satellite sensors. Thus, several of the entries in Tables 2-3 list multiple data sources. Additionally, the proposal team considers risk factors due to mission length and life cycle to be low at this time, as several new sensors have, or will come online during the course of the proposed project. For example, Landsat 9 launched in September 2021, and is now providing science data for the HLS product, and Sentinel-1C is scheduled for a 2023 launch.

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

The most direct impact of the proposed work is for land surface and fire modelers who use time series canopy structure data to drive their models. Improvement in those datasets will lead to more realistic LSM outputs and greater understanding of fire risk and likelihood. Given their very large areal extent and crucial role as an ecosystem, it is particularly important in the Gulf Coast Region to model wetland processes well.

Indirectly, the residents of the GCR stand to benefit from improved understanding of the dynamics of wetlands in the region. Citizens who depend on provisioning services of these wetlands have the most critical stakes in their preservation. Food and water security are particular concerns for low-income residents; especially women, and underrepresented groups such as indigenous people – who often have severe health outcomes due to remoteness of location and lack of adequate health services.

Also of great concern are the regulating services; air quality, local climate regulation, and hurricane/flood protection. Perhaps of less importance to locals, but of great interest to policymakers is preserving these assets in support of aesthetic and touristic ventures.

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

This proposed investigation is clearly relevant to the program element. As indicated in the text of the call, it is clearly of an exploratory nature. Although the technical aspects build on previously published research, the crux of the project is quite novel to the best of the team's knowledge. Literature searches turned up no peer-reviewed articles that tested the applicability of ICESat-2 to map fire likelihood or fuel parameters. Similarly, there seems to be little work being done with ICESat-2 that focuses specifically on wetland ecosystems – even in some of the existing boreal land work, where wetlands are ubiquitous. Finally, there seem to be no active efforts to conduct research specific to the Gulf Coast Region. This is somewhat surprising given the region's high vulnerability to natural hazards.

Regarding NASA's interests [28], the proposed research is relevant to Strategic Goal 1, to "Expand Human Knowledge through New Scientific Discoveries" and Strategic Objective 1.1, which is to "Understand the Earth system and its climate." Novel data on vegetation and hydrology in will help scientists and modelers better understand the dynamics of a vast ecosystem that (when functioning correctly) promotes resilience in an area that is both ecologically and economically fragile.

Furthermore, the work comports with Strategic Objective 1.3, which is to "Ensure NASA's science data are accessible to all and produce practical benefits to society." Regarding accessibility, the Data Management Plan clearly explains how the datasets produced by this project are to be made available and accessible through NASA's own Open Data Portal. In terms of yielding societal benefit, it is difficult to name an area of the U.S. that is in greater ecological peril than the Gulf Coast, and so providing datasets designed to improve environmental models of that region shows obvious benefit.

Finally, the PI understands that they will serve as a member of the ICESat-2 Science Team, with responsibilities to:

- represent ICESat-2 at meetings and conferences, and provide the liaison with the broader discipline science and applications communities
- report to NASA Headquarters on the impacts to ICESat-2 science resulting from any changes with mission operations
- and provide guidance to the ICESat-2 Project Office for mission planning, as requested.

2.6 Implementation Plan

2.6.1 Project Schedule

Project Year 1:

1. The project PI hires and onboards a Postdoctoral Associate to support data processing efforts
2. The PI works with the Postdoctoral Associate to establish data acquisition and processing pipelines for:
    a. ICESat-2 products
    b. Optical remote sensing datasets
    c. SAR data
    d. NEON site data

3. The PI and the Postdoc begin to build models that relate ICESat-2 Vegetation products to NEON site data.
4. The PI and the Co-I begin to build models that relate ICESat-2 Inland Water product data to NEON site data.
5. The team writes up the results from PY1; publishes data on Open Data Portal.
6. PI provides annual report to HQ.

Project Year 2:

1. The project team continues to acquire new data as they become available; look into incorporating NISAR data upon their release.
2. The team works on distributing the along-track model datasets (derived from ICESat-2) over the full GCR domain using the image data.
3. As in PY1, the team will write up modeling results and post data to Open Data Portal.
4. PI provides annual report to HQ.

Project Year 3:

1. Project team updates input dataset with latest versions of all inputs.
2. The team generates final models and final outputs.
3. The team also generates temporal trends over the domain
4. Project team writes up trend results and posts final datasets to Open Data Portal.
5. PI provides final annual report to HQ.

2.6.2 Work Flow

The Principal Investigator will manage the project, direct the members of the project team, and be responsible for fulfilling all reporting requirements. The PI's research responsibilities will focus on acquiring data and working with the Postdoctoral Associate to create workflows to process input data. The PI will travel to all Science Team meetings and will also attend one conference each year to discuss/exchange results with colleagues.

The Co-I will work with the PI to ensure the assembly of an optimal wetland hydrology dataset as defined above, and will be the point person on the utilization of lidar hydrology data products.

An unfunded collaborator will join the proposal team as its advisor on socioeconomic concerns, including social justice, and ensuring proper consideration for all underrepresented groups. They will also provide advice on potential partnerships between the team and social scientists interested in working in the Gulf Coast Region.

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4. 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) hydrology data fields, which will likely be distributed as netCDF files at an anticipated data volume of roughly 15TB 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.

5. Table of Personnel and Work Effort

Name	Role	Commitment (months per year)											
		Year 1			***Year 2***			***Year 3***			***Sum***		
		This Project		*Other Funded Projects*	*This Project*		*Other Funded Projects*	*This Project*		*Other Funded Projects*	*This Project*		*Other Funded Projects*
		NASA Support	*Total*		*NASA Support*	*Total*		*NASA Support*	*Total*		*NASA Support*	*Total*	
PI	PI	3.0	3.0	6.6	3.0	3.0	3.0	3.0	3.0	0.0	9.0	9.0	9.6
Co-I	Co-I	1.2	1.2	13.0	1.2	1.2	7.6	1.2	1.2	3.6	3.6	3.6	24.2
TBD	Postdoctoral Associate	8.2	8.2	0.0	7.8	7.8	0.0	7.2	7.2	0.0	23.2	23.2	0.0
Collaborator	Collaborator (unfunded)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sum of work effort:		**12.4**	**12.4**	**19.6**	**12.0**	**12.0**	**10.6**	**11.4**	**11.4**	**3.6**	**35.8**	**35.8**	**33.8**

REDACTED BUDGET

Sponsor: NASA

Proposal Title: Improving Our Understanding of Gulf Coast Wetland Dynamics with Spaceborne Lidar

Due Date: 10/12/2022

Period of Performance: May 1, 2023 - April 30, 2026

			YEAR 1	YEAR 2	YEAR 3	**TOTAL**
I. PERSONNEL		***FTE Months***				
	Principal Investigator	*(3.0 / 3.0 / 3.0 Months)*	$ -	$ -	$ -	$ -
	Post Doc	*(8.2 / 7.8 / 7.2 Months)*	$ -	$ -	$ -	$ -
	TOTAL SALARY AND WAGES		$ -	$ -	$ -	**$ -**
II. FRINGE BENEFITS		***Fringe Rate***				
	Principal Investigator	*[REDACTED]*	$ -	$ -	$ -	$ -
	Post Doc		$ -	$ -	$ -	$ -
	TOTAL FRINGE BENEFITS		$ -	$ -	$ -	**$ -**
III. TRAVEL						
	DOMESTIC		$ 6,000	$ 6,000	$ 6,000	$ 18,000
	FOREIGN		$ -	$ -	$ -	$ -
	TOTAL TRAVEL		$ 6,000	$ 6,000	$ 6,000	$ 18,000
IV. EQUIPMENT						
			$ -	$ -	$ -	$ -
	TOTAL EQUIPMENT		$ -	$ -	$ -	$ -
V. SUBCONTRACTS						
	TOTAL SUBCONTRACTS		$ -	$ -	$ -	$ -
VI. OTHER DIRECT COSTS						
	PUBLICATIONS		$ 2,900	$ 2,900	$ 2,900	$ 8,700
	TOTAL OTHER DIRECT COSTS		$ 2,900	$ 2,900	$ 2,900	$ 8,700
TOTAL DIRECT COSTS			$ 8,900	$ 8,900	$ 8,900	**$ 26,700**
VII. INDIRECT COSTS *[REDACTED]*			$ -	$ -	$ -	**$ -**

	YEAR 1	YEAR 2	YEAR 3	TOTAL
CO-I INSTITUTION REQUESTED SUPPORT	$ 19,872	$ 16,312	$ 18,804	$ 54,988
TOTAL REQUESTED SUPPORT	$ 28,772	$ 25,212	$ 27,704	$ 81,688

Redacted Budget Justification

Proposal Title: Improving Our Understanding of Gulf Coast Wetland Dynamics with Spaceborne Lidar

Period of Performance: May 01, 2023 – April 30, 2026

Section I. PERSONNEL
Principal Investigator FTE:
Year 1 – 3.0 person months
Year 2 – 3.0 person months
Year 3 – 3.0 person months

Post Doc FTE:
Year 1 – 8.2 person months
Year 2 – 7.8 person months
Year 3 – 7.2 person months

Section II. FRINGE BENEFITS
[REDACTED AND ANONYMIZED]

Section III. TRAVEL
Funds are requested in the amount of $18,000 ($6,000 per year) for the PI to attend one domestic conference, the American Geophysical Union (AGU) Annual Meeting, and two trips to attend the ICESat-2 Team Meetings 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 AGU in the previous fiscal year. Please note that this travel is contingent upon COVID-19 regulations imposed at the state and federal level.

Year 1: AGU Annual Meeting, Destination TBD ($3000/person x 1 trip): $3,000
ICESat-2 Science Team Meeting ($1,500/person x 2 trips): $3,000
Year 2: AGU Annual Meeting, Destination TBD ($3000/person x 1 trip): $3,000
ICESat-2 Science Team Meeting ($1,500/person x 2 trips): $3,000
Year 3: AGU Annual Meeting, Destination TBD ($3000/person x 1 trip): $3,000
ICESat-2 Science Team Meeting ($1,500/person x 2 trips): $3,000

AGU- TBD ***(Projected Cost per trip $3,000)***				
Expense	**Cost**	**Day(s)**	**# of Trips**	**Total**
Airfare	$615	1.00	1.00	$615
Hotel	$185	5.00	1.00	$925
Per-diem	$120	6.00	1.00	$720
Ground transportation	$20	6.00	1.00	$120
Conference registration	$500	1.00	1.00	$500
Abstract fee	$70	1.00	1.00	$70
Other/Baggage Fee	$25	2.00	1.00	$50
Total				**$3,000**

Science Team Meeting - Destination TBD				
Expense	**Cost**	**Day(s)**	**# of Trips**	**Total**
Airfare	$615	1.00	2.00	$1,230
Hotel	$185	2.00	2.00	$740
Per-diem	$120	3.00	2.00	$720
Ground transportation	$35	3.00	2.00	$210
Conference Registration fee	$0	1.00	2.00	$0
Abstract fee	$0	1.00	2.00	$0
Other/Baggage Fee	$25	2.00	2.00	$100
Total				**$3,000**

Section IV. EQUIPMENT

N/A

Section V. SUBCONTRACTS

N/A

Section VI. OTHER DIRECT COSTS

Publications: Funds are requested in the amount of $8,700 ($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).

Co-I Institution Support: Funds are requested in the amount of $54,988 to support the Co-I Institution expenses for this project:

Year 1: $19.872
Year 2: $16,312
Year 3: $18,804

Section VII. INDIRECT COSTS
[REDACTED AND ANONYMIZED]

Below is the total budget for the items described in the Budget Narrative. Also below are any supporting budgets.

Per ROSES solicitation instructions, all labor dollars are redacted from budgets in Proposal Documents.

COMPETITION SENSITIVE - FOR PROPOSAL SUBMISSION & PANEL REVIEW ONLY
Budget by Program Year

Solicitation: NNH22ZDA001N-ICESAT2, Studies with ICESat-2, A.32

Proposal Title: Improving Our Understanding of Gulf Coast Wetland Dynamics with Spaceborne Lidar

Total Excluding Labor Dollars and Indirect Costs: $54,988
Proposal Start Date: 05/01/2023
Proposal End Date: 04/30/2026

Description	PY 1 FTE	PY 1 Cost	PY 2 FTE	PY 2 Cost	PY 3 FTE	PY 3 Cost	Total FTE	Total Cost
A. Personnel	0.10		0.10		0.10		0.30	
B. Personnel								
Subtotal Labor-Redacted Cost	0.10		0.10		0.10		0.30	
Travel Total		3,353						3,353
Other Costs								
Publications						2,200		2,200
ADP/Computer Services		396		408		420		1,224
Other Direct Costs		16,123		15,904		16,184		48,211
Other Assessment		0		0		0		0
Reserves/Contingency		0		0		0		0
Subtotal Other Cost		16,519		16,312		18,804		51,635
Total Labor-Redacted Proposal Costs	0.10	19,872	0.10	16,312	0.10	18,804	0.30	54,988

Title: Improving Our Understanding of Gulf Coast Wetland Dynamics with Spaceborne Lidar
Submitted in response to NNH22ZDA001N-ICESAT2, Studies with ICESat-2, A.32

Summary of Personnel and Work Effort

The following table reflects the level of support required of all personnel necessary to perform the proposed investigation, regardless of whether these individuals require funding from this proposal.

Role	PY 1 FTEs	PY 2 FTEs	PY 3 FTEs	Total
Co-I - 1	0.10	0.10	0.10	0.30
Total:	0.10	0.10	0.10	0.30

Role	Commitment (months per year)											
	Year 1			Year 2			Year 3			Sum		
	This Project		Other Funded Projects	This Project		Other Funded Projects	This Project		Other Funded Projects	This Project		Other Funded Projects
	NASA Support	Total		NASA Support	Total		NASA Support	Total		NASA Support	Total	
Co-I	1.20	1.20	10.2	1.20	1.20	7.8	1.20	1.20	7.8	3.60	3.60	25.8
Sum of work effort:	1.20	1.20	10.2	1.20	1.20	7.8	1.20	1.20	7.8	3.60	3.60	25.8

The proposed work level is appropriate for the Co-I to perform the investigation.

Budget Justification: Narrative and Details

Budget Justification: Narrative

Labor Redacted Costs Only

Per ROSES solicitation instructions, all labor dollars are redacted from budgets in Proposal Documents.

Funding By Program Year

	PY 1 Cost	PY 2 Cost	PY 3 Cost	Total Cost
Total:	19,872	16,312	18,804	54,988

Roles and Cost Basis:

The Co-I will advise the PI and provide supporting input on ICESat-2 ATL13 surface water products that include mixed vegetation and open water signals including inland and coastal wetlands. The Co-I will assist in the interpretation of ICESat-2 photon clouds in the presence of vegetation and surface water.

<u>Other Direct Costs</u>

Travel

The budget includes travel as shown below based on the following cost assumptions:

- Estimated airfare and auto rental costs were obtained from either customary source or from other airfare estimating search engines (ie, Travelocity, etc.)
- Inflation of 3% per year is applied for annual occurrences.

Cost Details
Trip 1

	Lodging	MI&E or Per Diem	Airfare	Ground Trans	Auto Rental	Conf Fee	Fuel	Parking	Tolls	Other	Total	
Rate	232	79	2,100	50	75	0	45	0	0	0		
Nbr of People	1	1	1	1								
Nbr of Days	3	3			3							
Total	696	237	2,100	50	225	0	45	0	0	0	3,353	PY 1
											0	PY 2
											0	PY 3
											3,353	Total

Purpose of Trip: Science Team Meeting
Depart from: Origin
Arrive To: San Francisco

Summary of Travel Budget Requirements

Domestic/Foreign; Purpose	PY 1	PY 2	PY 3	Total
Domestic; Science Team Meeting	3,353	0	0	3,353
Total:	3,353	0	0	3,353

Other

Computer Support - Computer Support is required for the Co-I's laptop and two servers that will be used for this project.

Item	PY 1	PY 2	PY 3	Total
IT support	396	408	420	1,224
Total:	396	408	420	1,224

Publications - Cost estimates are based on recent similar publication costs.

Item	PY 1	PY 2	PY 3	Total
Journal publication	0	0	2,200	2,200
Total:	0	0	2,200	2,200

Other Direct Costs - 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.

Cost Sharing/Leveraging/Contributions

The project will leverage off the ICESat-2 data products currently produced at the Snow and Ice Data Center (NSIDC). The specific products will include the ATL13, ATL22 and ATL03 Georeferenced Photon Products

Budget Justification: Details

Title: Improving Our Understanding of Gulf Coast Wetland Dynamics with Spaceborne Lidar
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Co-I - 1	0.10	0.10	0.10	0.30
Total:	0.10	0.10	0.10	0.30

Role	Commitment (months per year)											
	Year 1			Year 2			Year 3			Sum		
	This Project		Other Funded Projects	This Project		Other Funded Projects	This Project		Other Funded Projects	This Project		Other Funded Projects
	NASA Support	Total		NASA Support	Total		NASA Support	Total		NASA Support	Total	
Co-I	1.20	1.20	10.2	1.20	1.20	7.8	1.20	1.20	7.8	3.60	3.60	25.8
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The proposed work level is appropriate for the Co-I to perform the investigation.

Budget Justification: Narrative and Details

Budget Justification: Narrative

Labor Redacted Costs Only

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Funding By Program Year

	PY 1 Cost	**PY 2 Cost**	**PY 3 Cost**	**Total Cost**
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Depart from: Origin
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