National Oceanographic Partnership Program (NOPP) – Hurricane Coastal Impacts (NHCI)

https://nopphurricane.sofarocean.com/

8 March 2023

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National Oceanographic Partnership Program

What is the NOPP?
www.nopp.org

- The National Oceanographic Partnership Program (NOPP) is a collaboration of Federal agencies which facilitates partnerships between Federal agencies, academia, industry, and others in the ocean scientific community to advance ocean science research and education
- Through this collaboration, Federal agencies can leverage resources to invest in priorities that fall between agency missions or that are too large for any single agency to support
- The program was established by the 1997* National Defense Authorization Act to:
  - Promote national goals of assuring national security, advancing economic development, protecting quality of life, and strengthening science education and communication through improved knowledge of the ocean; and
  - Coordinate and strengthen oceanographic efforts in support of those goals by identifying and carrying out partnerships among Federal agencies, academia, industry, and other members of the oceanographic scientific community in the areas of data, resources, education, and communication; and reporting annually to Congress

What defines a NOPP project?

- The project addresses important research objectives or operational goals
- The project has, or is designed to have, appropriate participation within the oceanographic community of public, academic, commercial, private participation or support
- The partners have a long-term commitment to the objectives of the project
- The resources supporting the project are shared among the partners
- The project has been subjected to adequate review
- The project is brought forward to the NOPP-IWG for interagency consideration of support
- At least 2 partners, Federal or non-Federal, invest in the project
  - Note that a partner is not limited to direct financial participation, but may also contribute ship time, loan instruments, or personnel time, among other possibilities
- Is related to ocean science or ocean-related technology
  - "Ocean" includes the open ocean, coasts, estuaries, coastal watersheds, and Great Lakes

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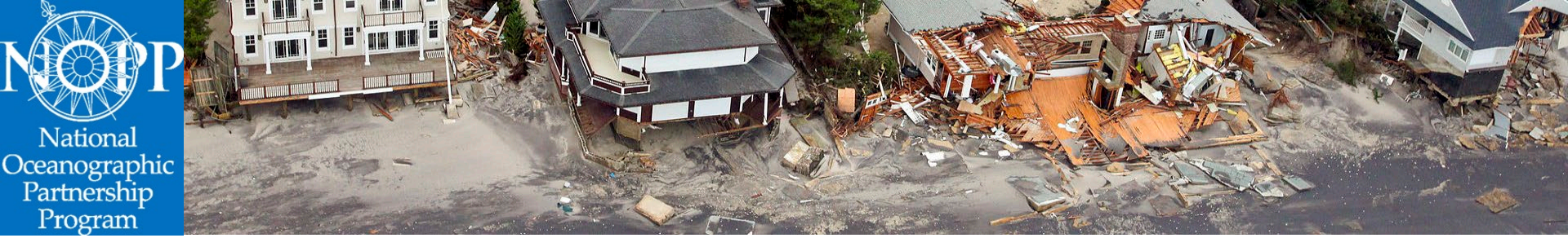
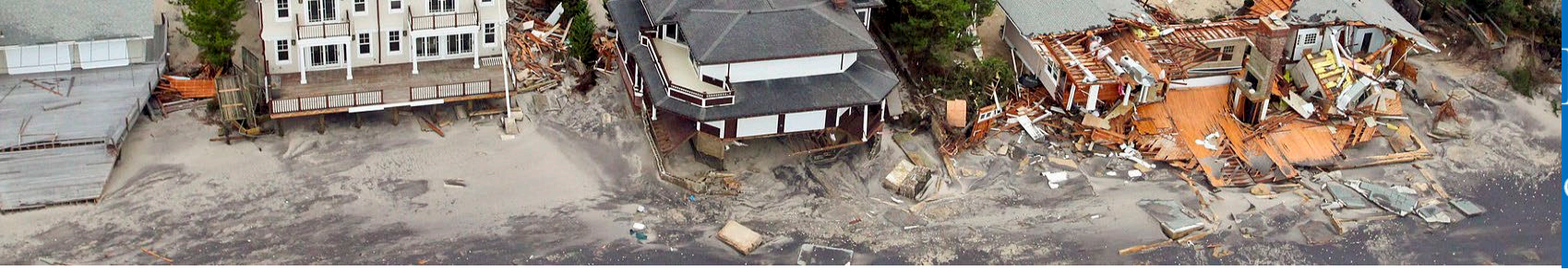


NOPP Hurricane Coastal Impacts (NHCI)

- Nearly every year during hurricane season US Gulf and Atlantic coastal communities are threatened by large storms, which can inflict flooding, erosion, coastal breaching and destruction of property and infrastructure. While forecasts of hurricane intensity and track have improved considerably over the last decade, uncertainty remains as to what will actually happen above mean sea level on land as a result
- Studies of past hurricanes, using accurate winds, track, and groundtruth, indicate coastal wave-current, surge and sediment transport models have skill in predicting impacts
- The greatest uncertainties are not in the numerical models, but on land, in terms of boundary conditions for elevation, sediment type, vegetation, infrastructure and buildings
- NHCI will begin to forecast/predict hurricane coastal impacts during the hurricane seasons of 2022-2024. These will be “research-grade” forecasts and are not to be confused with operational ones from the National Hurricane Center.
- To tackle this monumental challenge, NHCI is comprised of 10 teams, each of which is critical to success and must work cohesively to produce the forecasts and quantitative evaluation of performance
- The ultimate goals are: skillful forecasts of hurricane coastal impacts; the ability to initialize models, data bases and ground truth solely from satellite remote sensing to allow worldwide application; AND to identify topics which need additional research investment



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Five NHCI Tasks/Thrusts

Task 0) Year 1, COAMPS-TC[1] provide a hindcast of Hurricane Michael; Years 2-4, provision of hurricane track and intensity predictions for 3 CONUS landing hurricanes; Winter – reanalysis of the 3 hurricanes following best-track and intensity. Provides Apples:Apples forcing for Task 4;

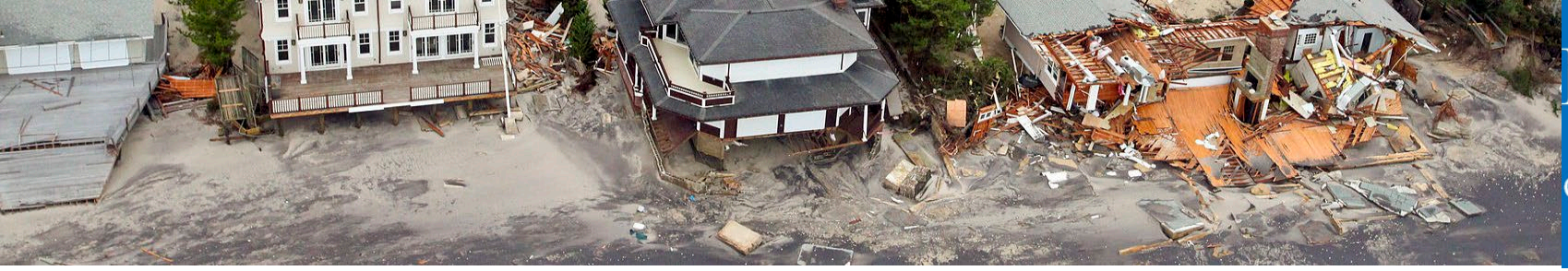
Task 1) Year 1, the building of a Digital Elevation Model (DEM) and in Years 2-4 regular updates and quantitative post-hurricane impact summaries; Provides Apples:Apples boundary conditions and ground truth for Task 4;

Task 2) New quantitative capabilities in satellite remote sensing for both building a ground-truth DEM and quantitative geophysical measurements during the storms, for comparison to and possible assimilation into model forecasts;

Task 3) In situ measurements to include offshore waves, and both offshore and inland water levels, for assimilation prior to landfall and ground truth evaluations afterward; Provides Apples:Apples observations for Task 4 assimilation and ground truth; and

Task 4) Forecasting of wave, surge, sediment transport (erosion and accretion above and below mean sea level), structure interaction and damage

[1] Coupled Ocean Atmosphere Model Prediction System-Tropical Cyclone



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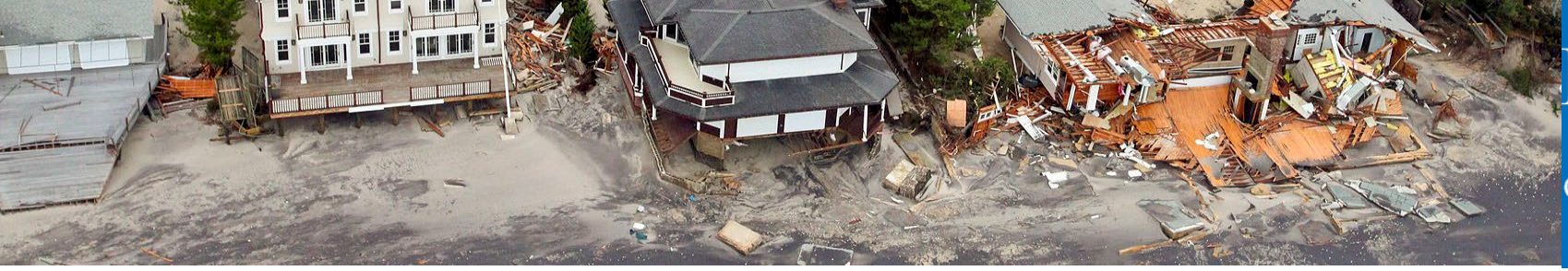
4 Years of Activities

The CY21 (first 1.5 year) developed the supporting DEM's; began development of quantitative DEM satellite remote sensing techniques for use before, during and after storms; developed methods to rapidly deploy wave (airborne) and water level sensors (moving to airborne); and set up model's with sufficient nesting capabilities to forecast the above properties, from Mexico to Maine, during the following three hurricane seasons (CY 2022, 2023 and 2024). The DEM's will be continually updated, with the most frequent updates to include bathymetry and topography, before landfall and quantitative summaries of the damage to infrastructure and buildings post landing.

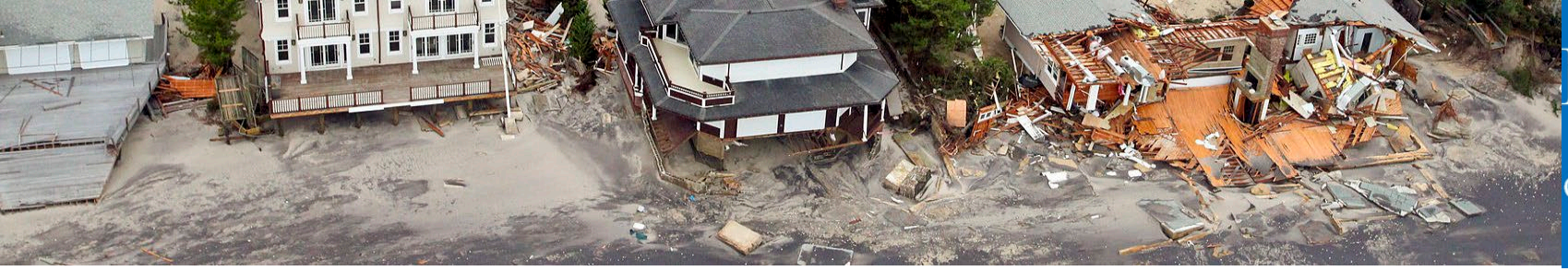
Goal: During each of the CY 2022-2024 hurricane seasons, provide a single daily forecast of hurricane coastal impacts (see below), beginning five days prior to landfall, for three named hurricanes per season. Data collected after the event (bathymetry/topography, inundation, erosion, accretion, infrastructure & structure damage) will quantify the abilities of the model to forecast the coastal response. A number of teams, across all tasks will funded and will work collectively together to meet the overall challenge. Forecasting teams must provide documented computational capability, priority run-time and storage ability (either dedicated institutional computational assets or those from cloud services), to be eligible. Prior experience indicates that it is roughly 5000 CPU hours, per forecast, using 400 cores and at least 3 dedicated Terabytes of storage.

CY2022 – Hurricane Ian was forecast, with ground and air deployments for verification.



Winter Analysis

In CY22-24, outside of hurricane season, a hind-cast of COAMPS-TC which follows the agreed upon “best-track” will be provided to investigators for use in forcing the storm impact prediction models. These hindcasts will be used to determine strengths and weaknesses of the different models and whether they stem from too few observations, physics-based understanding, numerical implementation, or boundary conditions, etc. These analyses will help to improve the effort for the following season and guide future research investments.

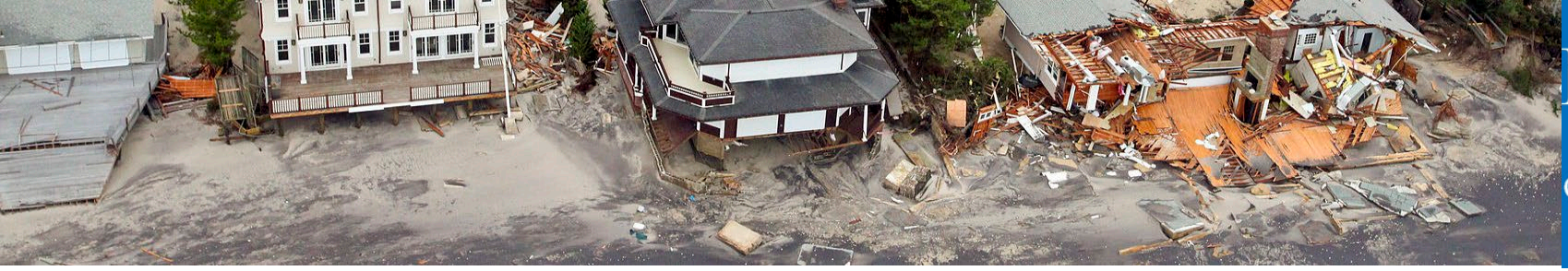


Task 0: COAMPS-TC Supplied Variables, at 4km resolution, hourly, beginning 5 days from projected landfall

COAMPS-TC [1], which is coupled to the Navy Coastal Ocean Model (NCOM), will provide the following variables to each team, updated once daily, beginning 5 days (T-5) from projected landfall.

10-m Winds	Surface Relative Humidity
Surface Pressure	Surface Wind Stresses
2-m Air Temperature	Long Wave and Short Wave Radiation at the Surface
Surface Latent and Sensible Heat Fluxes	Surface Net Radiation
Hourly Precipitation	

[1] Coupled Ocean Atmosphere Model Prediction System-Tropical Cyclone



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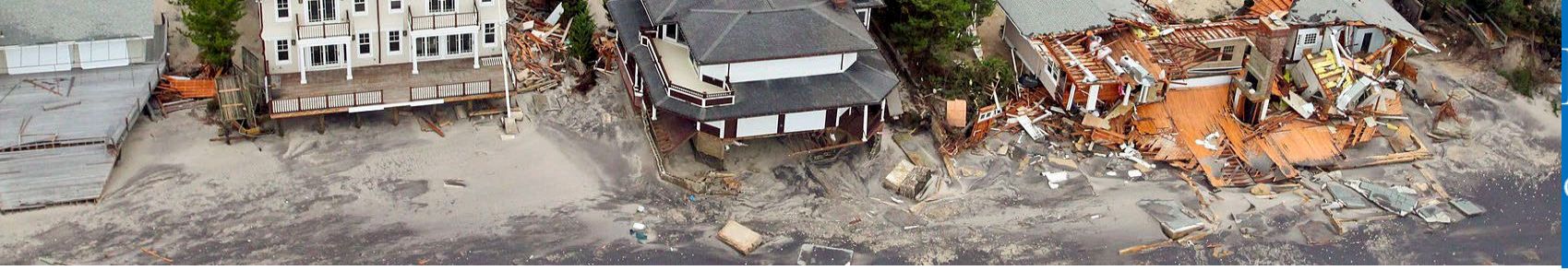
Task 1: Digital Elevation Models (DEM), to include topography and bathymetry

Develop, at the scale of 1-5m, digital elevation models (DEM) of the US coastline subject to land-falling hurricanes that includes; the US Gulf of Mexico coast, the Florida Keys, mainland Florida, and the Eastern Atlantic Seaboard. From the shoreline, these high resolutions need to extend inland 2km and seaward to close out depths (depths of minimal sediment movement). Inland, they can then blend with coarser DEM's suitable for inundation only, i.e., possible > than 1-5m, and seaward of closeout depths to resolutions sufficient to support wave and current modeling. Where large inland bays are located, focus should start with characterizing the main stems, leaving branches to be added in the later years of the project.

Variables should include:

1. Elevation (10 cm) and sediment type
2. Vegetation type including root depth
3. Structures (construction type/materials) and number of stories/elevation
4. Inland water bodies and waterways, lakes, marshes, inlets
5. Roads, bridges, boardwalks, and any other man-made alterations, jetties, piers, etc.

To the degree possible, leverage existing public and government databases and develop methods, perhaps AI/ML-based, using remotely sensed satellite data to more rapidly turn such data into geophysically useful fields, e.g., Landsat 8 vegetation data to vegetation type, then root depth and drag coefficients. As NOPP is a partnership at both the sponsor and performer level of industry, government and academia, it may be that, under the guise of national emergencies and disaster prevention and response, that arrangements may be made with commercial entities for use of their databases (e.g., Google Earth, Airbus). At the end of the project, said project databases are to be compatible with existing US Gov't provided databases and reside in the public domain.



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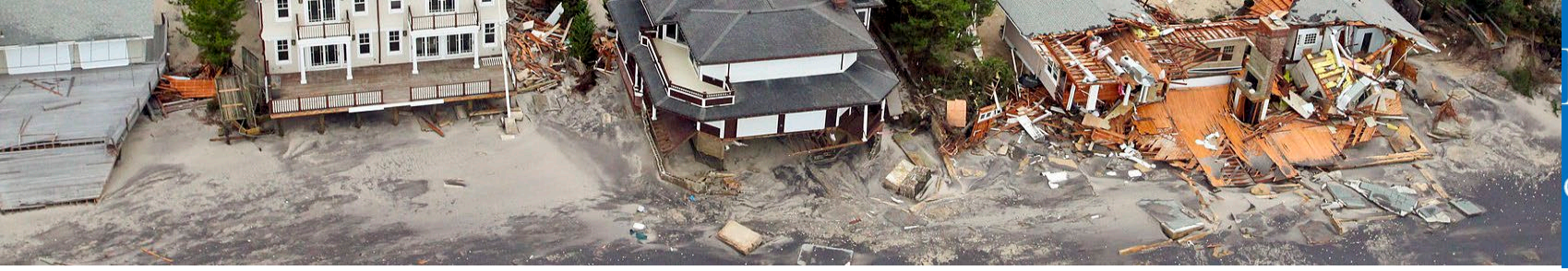
Task 2: Remote Sensing (collect imagery sufficient to image the entirety of the coastline each year, with localized imagery prior to, during and after any landfall for ground truth purposes)

Develop the ability to produce digital elevation models of the beach, foreshore and backshore from Synthetic Aperture Radar (and/or any other modalities), such that data bases can be rapidly built from space, and measurements of the coast made before, during and after a hurricane. The resolution should match the above databases, at horizontal resolutions between 1 and 5m, and 10cm in elevation (relative to the geoid). Quantitative ground truth/comparison of SAR wind and wave products with the deployable, measured wave and wind field during the storm should also take place.

To the degree possible, leverage existing databases and imagery and develop methods, perhaps AI/ML-based, for use on remotely sensed satellite data to more rapidly turn such data into geophysically useful fields, infrastructure, roads, and buildings and building characteristics.

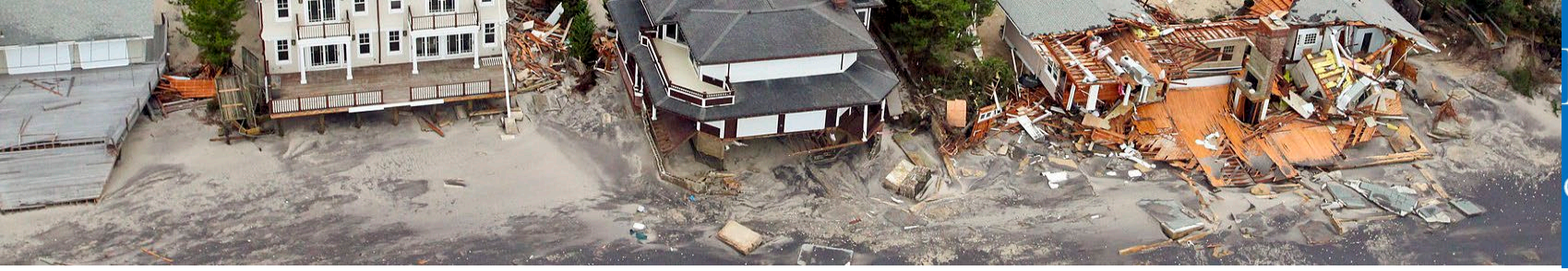


Task 3: In Situ Measurements (up to three teams to be funded, including equipment purchase, deployment, recovery and refurbishment)

Air Deployed Wave Buoys: Airborne deployed, real-time satellite reporting (and internal recording) directional wave-spectra buoys in sufficient numbers to entirely encircle a hurricane, with re-seeding to occur on the landward portion, 48 and 24 hours prior to landfall. The real-time measurements are to be used to predict wave heights, periods and directions on an hourly basis, from the hurricane eye, to 300 km to either side of the predicted landfall location. Airborne deployment flights will be provided and should not be included in costs.

Coastal and Inland Water Levels and Wave Measurements: The ability to rapidly [air/helicopter?] deploy water level measurement capabilities along coasts both to seaward and to inland waterways where such bodies exist and back immediately to the backshore of the beach. Real-time satellite reporting (and internal recording) will enable observation and assimilation into models and used to assess breach potential. Directional wave-spectra buoys (as above), will be as well. Airborne deployment flights will not be provided and should be included in costs, if appropriate.

It is expected that much of the equipment will be retrieved after the storm as possible and re-used, though losses are expected. Iridium Satellite SBD cards can be provided for all sensors as needed.



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Task 4: Wave, Surge, Sediment Transport (moveable bed), Structure Response Forecasting (WSSTSR Forecast); Up to three teams to be funded. Only one team will be funded to utilize any one particular model

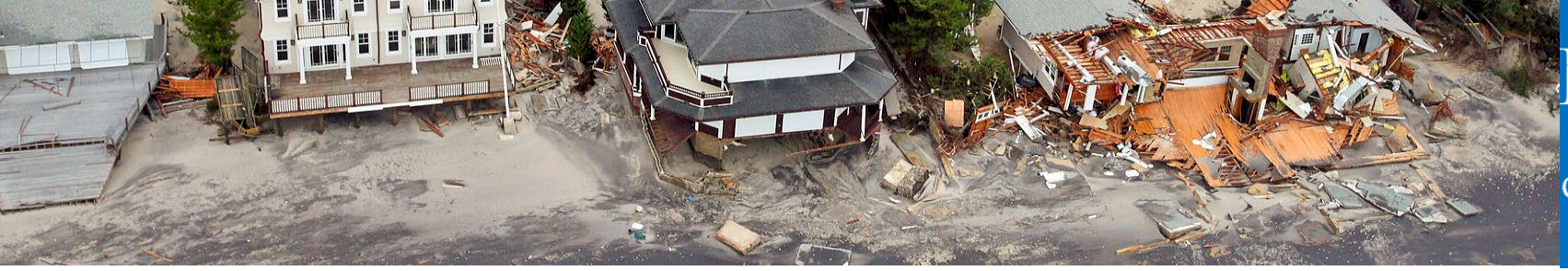
COAMPS-TC [1], which is coupled to the Navy Coastal Ocean Model (NCOM), will provide the following variables to each team, updated once daily, beginning 5 days (T-5) from projected landfall.

Using open source community code [2] and supplied boundary conditions [3] from the other teams, for each daily hurricane forecast supplied by COAMPS-TC, forecast the coastal/shoreline waves, currents, sediment transport, coastal erosion and accretion (above and below MSL), inundation, breaches and structure response at human scale (1-5m along and inland), to a distance inland that encompasses all inundation from the seaward side (not from rainfall). Days T-5 and Day T-4 may be probabilistic, but Day T-3 to landfall must be deterministic. These forecasts will be provided to first responders as a research product, not an operational (certified/verified) one. Structural response in this case means to indicate whether a coastal structure will survive the storm, and/or how it will be damaged or compromised.

[1] Coupled Ocean Atmosphere Model Prediction System-Tropical Cyclone

Nominal Funding By Task and Year

Task	Number of Teams	Year 1 Funding per team	Year 2 Funding per team	Year 3 Funding per team	Year 4 Funding per team	Total Per Task
0. Wind Forcing (COAMPS-TC)	1	$112,000	$208,000	$236,000	$188,000	$744,000
1. Digital Elevation Models (DEM)	2	$500,000	$200,000	$200,000	$200,000	$1,100,000
2. Remote Sensing	1	$455,879	$776,332	$666,365	$669,234	$2,569,000
3. In Situ Measurements	3	$930,000	$887,000	$800,000	$651,000	$3,266,000
4. Forecasting (WSSTSR)	3	$918,000	$1,517,000	$1,524,000	$1,468,000	$5,428,000
Total Project Funding		$2,916,000	$3,588,000	$3,426,000	$3,176,000	~$13,407,000



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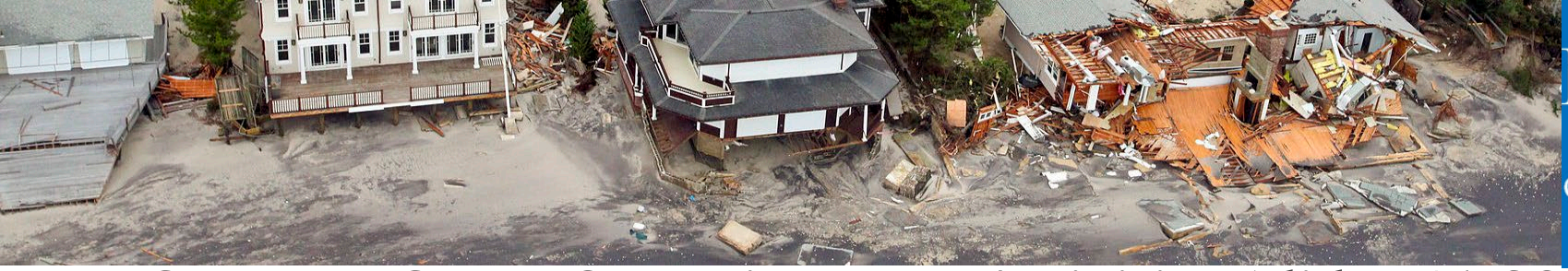
10 NHCI Teams, By Task

Team/Task/E-mail	Lead PI	Title
NHCI_T0_Komaromi	Will Komaromi	COAMPS-TC Deterministic, Ensemble, and Nowcast Model Support of the NOPP Project: Predicting Hurricane Coastal Impacts
NHCI_T1_Gesch	Dean Gesch	Coastal Elevation Models and Land Surface Variables for Predicting Hurricane Impacts
NHCI_T1_Peeri	Shachak Pe'eri	NOPP Predicting Hurricane Coastal Impacts, Task 1
NHCI_T2_Romeiser	Roland Romeiser	Remote Sensing of the U.S. Coastline Impacted by Land-Falling Hurricanes
NHCI_T3A_Centurioni	Luca Centurioni	Lagrangian Drifter Laboratory Ocean Wave In Situ Measurements
NHCI_T3A_Thomson	Jim Thomson	Air-deployed wave buoys
NHCI_T3B_Brown	Jenna Brown	In-situ Measurements of Coastal and Inland Wave and Water Levels
NHCI_T4_Luettich	Rick Luettich	Forecasting Coastal Impacts from Tropical Cyclones along the US East and Gulf Coasts using the ADCIRC Prediction System
NHCI_T4_Nederhoff	Kees Nederhoff	Wave, Surge, Sediment Transport, Structure Response Forecasting.
NHCI_T4_Olabarrieta	Maitane Olabarrieta	Coupled Ocean Atmosphere Waves Sediment Transport Waves, Sediment, Surge and Structure Response

10 Teams, ~90 Participants: 15 Universities, 18 Gov't Labs, 9 Companies



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Summary Status & Hurricane Ian Activities (slides 16-203); This Years Plans

- COAMPS-TC did an excellent job with real-time forecasts, but landfall was north. Working to correct landfall in hindcast to follow NHC Best Track and Intensity.
- DEM's at 1-3m along/cross cross coast were essential to accurately modeling inundation, erosion and breaching. Inland waterway islands needed to be included, and once they were, observed erosion (Sanibel Bridge Island), matched that modeled.
- Remote Sensing with SAR was quite successful at imaged locations. There are issues with targeting locations, which are based on hurricane forecasts 3 days prior, misses occur and given demand, you don't always get your shot(s). SfM and DEM's from SAR are promising.
- *In situ* verification at coastal sites are logistically difficult to instrument, given 100's of miles of uncertainty in 5-3 day track forecast. Working strategies to stash equipment prior, and/or switch to all air-deployed instrumentation from Navy P-3.
- Deepwater buoy deployments were near flawless, but again, biased by early forecast tracks. Working sensor trials with NOAA for additional deployments on other air assets as space available, in addition to Navy P-3. Chris Fairall is NOAA POC.
- All 3 modeling groups, ADCIRC (Luettich), COAWST (Olabarrieta), and Deltares (Kees) matched wave and water levels well. Erosion of inland waterway and beach matched observations. Damage to infrastructure, buildings and roads is ongoing, but promising. Rainfall should be included.
- CY23 – Address up to 3 CONUS Landing Hurricanes; Welcome additional partners/synergy.