**NASA DEVELOP National Program**

NOAA National Centers for Environmental Information

*Summer 2017*

**Short Title: US Pacific Islands Oceans**

**Subtitle:** Utilizing the NASA and NOAA Joint Ocean Surface Topography Mission and Modeled Wave Data to Assess Patterns and Trends in Sea-surface Height in the US Affiliated Pacific Islands

**VPS Title:** Coexisting with Oceanic Oscillations: Forecasting Coastal Inundation for the US Affiliated Pacific Islands (USAPI)

**Project Team**

**Project Team:**

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**Advisors & Mentors:**

Michael Kruk (Earth Resources Technology, Inc., NOAA NCEI)

**Project Overview**

**80-100 Word Objectives Overview:**

The project team will produce a set of tools including a significant wave height climatology, a wave direction climatology, to incorporate alongside seasonal tidal data and a weekly sea level anomaly forecast in order to create a sub-monthly or monthly outlook for coastal inundation in the USAPI. Inundation risk was assigned a categorical value in terms of percent severity above average sea surface height. The risk metric was applied to the Republic of the Marshall Islands (RMI) as a study site with the goal of testing applicability for all of the USAPI.

**Abstract:**

The project team will partner with the Regional Climate Services Director (RCSD) for the Pacific Region, Dr. John J. Marra, under NOAA National Centers for Environmental Information (NCEI) to analyze near-real time (i.e., weekly) spatial and temporal patterns and trends in sea-surface height (SSH) around the U.S. Affiliated Pacific Islands (USAPI). Ocean Surface Topography Mission data and current tidal data from in-situ measurements will be used. *In situ* and satellite data from buoys, tide gauges, NASA’s Sea Surface Height (SSH) climate record derived from the TOPEX/Poseidon mission and Ocean Surface Topography Mission data from Jason-2 and Jason-3 satellites, and a blend of satellites for NOAA’s CoastWatch and OceanWatch will be utilized. The team will produce a significant wave height climatology, wave direction climatology, a 1 week to 3 week outlook, and a categorical inundation risk metric to assess island inundation risk. End users Dr. John Marra and Dr. Matthew Widlansky will use the risk metric tool set climatologies and distribute this information to coastal hazard and climate adaptation decision-makers in the USAPI.

**Keywords:**

Wave model, climatology, US Affiliated Pacific Islands, coastal flooding, risk metric, sea level anomaly, sea surface height, tides

**Partner Organizations:**

|  |  |  |  |
| --- | --- | --- | --- |
| **Organization** | **POC (Name, Position/Title)** | **Partner Type** | **Boundary Org?** |
| NOAA Regional Climate Services, Pacific Region | Dr. John Marra, Director | End User | Yes |
| University of Hawaii, SeaLevel Center & International Pacific Research Center | Dr. Matthew Widlansky | End User | Yes |
| NOAA Center for Satellite Applications and Research (STAR), Satellite Oceanography & Climatology Division | Dr. Eric Leuliette | Collaborator | No |

**Community Concerns:**

* The vast majority of the USAPI are low lying islands and are highly vulnerable to coastal hazards influenced by changes in sea level. Sea surface height in the USAPI follows seasonal changes and can be influenced by El Niño Southern Oscillation (ENSO) events.
* The majority of Pacific Island populations, urban centers, and infrastructure are located near the coast, compounding their vulnerability to coastal hazards such as erosion, storm surges, and inundation.
* The Pacific Islands are also subject to some of the most extreme changes in climate. Between 1993 and 2009 the tropical Pacific experienced rates of sea level rise four times the global average, approximately 12 mm per year and 3.3 mm per year respectively.
* In March 2014, the Marshall Islands experienced a flooding event that displaced many island inhabitants. A combination of unusually high tides and large swells led to inundation in Majuro. Elevated sea surface height is projected in the Marshall Islands as early as August 2017.
* Tide gauges, currently used to monitor sea level changes, offer an expansive temporal record but fail to provide continuous spatial coverage. *In situ* measurements are sparse when compared to the number of and broad distribution of the USAPI.

**Current Decision-Making Practices & Policies**:

Dr. John J. Marra and local organizations throughout the USAPI currently use tide gauges and ocean buoys to measure sea level and monitor anomalies. The Pacific Islands Ocean Observing System (PacIOOS), housed within the University of Hawaii at Mānoa’s School of Ocean and Earth Science and Technology, provides near real-time wave, tide, and sea-level measurements and forecasts for islands with available data. Decision makers rely on this information to prepare for potential coastal hazards like flooding and erosion. The University of Hawaii’s Sea Level Center (UHSLC) also produces monthly sea-level anomaly (SLA) forecasts. Relatively sparse stations in comparison to island area and distribution, cause *in situ* sea level measurements to show a limited view of actual sea-surface height. Therefore, coastal managers are in need of more accurate forecasting with a greater temporal resolution and more spatial coverage.

**Decision Support Tools & Benefits:**

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| --- | --- | --- | --- |
| **End Product** | **Earth Observations Used** | **Partner Benefit & Use** | **Software**  **Release** |
| Near-Real Time Island Inundation Risk Tool | Topex/Poseidon, Jason-1, OTSM/Jason-2, Jason-3, Sentinel-3 | The tool will download near real-time OSTM/Jason-2 and Jason3 SSH data and combine tidal predictions (harmonic), island-centered altimetry averages (AVISO or NASA-JPL) and wave analyses/forecasts (Wavewatch III) to develop an inundation risk metric. The end user will be able to monitor weekly SLAs and assess coastal management risks. | N/A |
| Significant Wave Height Climatology | None | This dataset will allow scientists to measure the degree to which significant wave height contributes to anomalously high sea level events. | N/A |
| Wave Direction Climatology | None | This dataset enables scientists to see if a hazardous significant wave height will actually affect an island or if it will only affect open ocean areas. | N/A |

**Project Benefit to End User**:

A regional wave model by Hoeke et al. (2013) was created for the USAPI; however, this model fails to include the influence of both SS (sea and swell waves) and IG (infragravity) waves. With the Merrifield et al. (2014) model there is an improvement as it estimates extreme water levels, but this model lacks the significant wave height and wave direction inputs. Long-term observations of significant wave height are based on current buoy data, of which there are only two in the Marshall Islands. The limited spatial resolution of buoy data cannot be solely relied upon to create an accurate inundation risk metric. Therefore, project end users, Dr. John Marra and Dr. Matthew Widlansky are seeking an interactive inundation metric which includes the influence of significant wave height, wave direction, and tides so that the USAPI nations may be better equipped in terms of disaster preparedness.

**Project Details**

**Applied Sciences National Applications Addressed:** Climate, Oceans, Disasters

**Study Area:** US Affiliated Pacific Islands- Federated States of Micronesia (FM),

Guam (GU), Republic of the Marshall Islands (MH), Commonwealth of the Northern Mariana Islands (MP), Republic of Palau (PW)

**Study Period:** 1979-2017; Forecasting to 2 to 3 weeks in the future from present day.

**Earth Observations & Parameters:**

|  |  |  |
| --- | --- | --- |
| **Platform & Sensor** | **Parameter(s)** | **Use** |
| OSTM/Jason-2  Jason-3  Sentinel-3  CryoSat-2  SARAL | Sea level anomaly | This is a blended product from NOAA CoastWatch and OceanWatch and will be used as an input into our inundation risk metric. This is an excellent dataset to drive our model because it is near-real time data, with a 3-5 hour latency. |
| Topex/Poseidon Poseidon Altimeter  Topex/Poseidon TMR  Jason-1 Poseidon -2  Jason-1 JMR  OSTM/Jason-2 Poseidon-3  OSTM/Jason-2 AMR  Jason-3  Sentinel-3 | Sea Surface height | This dataset is a blended product from NASA Jet Propulsion Lab, which will be used to validate the accuracy of our near real-time, as provided by NOAA CoastWatch and OceanWatch. |

**Ancillary Datasets Utilized:**

* NASA PODAAC – Integrated Multi-Mission Ocean Altimeter Data for Climate Research v1.0 sea surface height (MEaSUREs)
* PacIOOS Tide Gauge SSH – *in situ* will be used to validate satellite derived SSH and project results
* NOAA CoastWatch and OceanWatch – Optimal Interpolation SLAs from Multiple Altimeter Missions – near-real time SLAs
* University of Hawaii – monthly SLA forecasts
* UHSLC Tidal Predictions – tidal data
* NOAA WAM – significant wave height and wave direction climatology
* GOW2 – significant wave height and wave direction climatology
* NOAA WaveWatch III – significant wave height and wave direction climatology
* National Buoy Data Center – *in situ* buoy data to validate wave models

**Models Utilized:**

* NOAA WaveWatch III

**Software Utilized:**

* Esri ArcGIS – raster manipulation and analysis, map creation
* Python – data processing and analysis
* R Studio – data processing

**Project Handoff Package**

**Transition Plan:**

The project team will immediately share the final products with the end users so they can implement them in August 2017. The final products and tutorials will be presented to the end users over videoconference on Thursday, August 10th, 2017. The forecasting model, significant wave height and wave direction climatologies, and user tutorials will then be transferred to the end users either through email or in a shared drive.

**Team POC:** India Young, indiajyoung@gmail.com

**Partner POC**: John Marra, john.marra@NOAA.gov

**Handoff Package:**

* Marshall Islands Significant Wave Height Climatology (1979 - 2009): GIS raster layers with statistical calculations and Excel sheets with coordinates and climatology outputs over gridded economic region of Marshall Islands
* Marshall Islands Wave Direction Climatology (1979 - 2009): GIS raster layers with statistical calculations and Excel sheets with coordinates and climatology outputs over gridded economic region of Marshall Islands
* Inundation risk metric forecast GIS model builder tool and accompanying tutorial

**References:**

Hoeke, R. K., McInnes, K. L., Kruger, J. C., McNaught, R. J., Hunter, J. R., & Smithers, S. G. (2013). Widespread inundation of Pacific islands triggered by distant-source wind-waves. *Global and Planetary Change*, *108*, 128-138.

Merrifield, M. A., Becker, J. M., Ford, M., & Yao, Y. (2014). Observations and estimates of wave‐driven water level extremes at the Marshall Islands. *Geophysical Research Letters*, *41*(20), 7245-7253.