**NASA DEVELOP National Program**

**2018 Summer Project Proposal**

**Georgia – Athens**

**Puerto Rico Disasters**

*Assessing Changes in Cloud Dynamics in a Tropical Montane Cloud Forest Using Remotely Sensed and In Situ Observations Following Catastrophic Defoliation from Hurricane Maria*

**Project Overview**

***Project Synopsis*:** This project will determine changes in orographic cloud dynamics in Puerto Rico’s Luquillo cloud-immersed rainforest, following catastrophic defoliation experienced during Hurricane Maria in September 2017. This project will be a collaboration with the US Forest Service International Institute for Tropical Forestry (IITF) and the U.S. Geological Survey. NASA’s CALIPSO satellite will provide observations of cloud altitudes (2006-present), which will be calibrated against theoretical cloud base heights (CBH) from nearby radiosonde observations, IITF ceilometer observations, and USGS cloud monitoring cameras. MODIS-based NDVI and evapotranspiration (ET) products will also be compared against CBH to assess the contribution of forest-based moisture to orographic clouds. The end-products will be a cartographic forecasting tool depicting areas that will encounter ecological vulnerability due to CBH increase and a statistical tool that will diagnose CBH from the daily radiosonde launches in San Juan, PR. These end products will aid IITF foresters to develop appropriate management strategies during the reforestation process.

***Community Concern:*** The Luquillo Mountains, contained within the IITF-managed El Yunque National Forest, is home to a well-studied tropical montane cloud forest – one of only two such ecosystem sites in the United States. El Yunque and the Luquillo Mountains are an endemically-diverse ecosystem and vibrant tourist attraction. Organisms in this environment are regularly immersed in thick, orographically driven clouds that provide water through direct deposition, in addition to light orographic rainfall occurring every 8 hours on average. Any systematic CBH increase resulting from the defoliation caused by Hurricane Maria (Sept 2017) poses significant ecological challenges toward the recolonization of the cloud forest. Further, CBH increases may locally reduce precipitation and ET rates altering the current water budget in an ecosystem that requires very high rainfall to survive.

***Source of Project Idea:*** The Luquillo Mountains underwent a devastating interaction with Hurricane Hugo in 1989, a category 3 storm upon landfall in PR. In a 1991 paper describing the physical impacts of Hugo on the Luquillo Mountains ecosystem, an IITF ecologist reported visual observations that cloud bases had risen from 500-600 m to 900-1000 m in wake of Hugo, however, no measurements were made. Additionally, rainfall was suppressed in the months following Hugo, possibly due to defoliation in the Luquillo Mountains. Because Hugo pre-dated CALIPSO, Hurricane Maria’s impact offers the best opportunity for reaffirming this report.

This project was initiated by Dr. Thomas Mote and began to take shape after a meeting with the Georgia node leadership. Dr. Mote, his post-doc, and two of his students who are familiar with the community concerns and research objectives for this project assisted with the proposal writing. After responding to initial questions and comments from NPO, the proposal was completed and submitted for the summer 2018 term.

***National Application Area Addressed:*** Disasters

***Study Location:*** El Yunque National Forest, PR, USA

***Study Period:*** January 2006 – January 2018

***Advisor:*** Dr. Thomas Mote, University of Georgia

**Partner Overview**

***Partner Organizations:***

|  |  |  |  |
| --- | --- | --- | --- |
| **Organization** | **POC (Name, Position/Title)** | **Partner Type** | **Boundary Org?** |
| **USDA, US Forest Service, International Institute of Tropical Forestry** | Dr. Grizelle González, Research scientist | End User | No |
| **USGS, National Research Program**  | Martha Scholl, Research hydrologist | Collaborator | No |

***End-User Overview***

***End User’s Current Decision-Making Process:***The current IITF forest management decision-making process relies largely upon anecdotal observations to assess cloud base patterns. This project will allow the community to better focus their post-disaster forest management practices to reflect the highest ecological priorities. For example, should management practices be modified to account for potential hydrological (i.e., cloud base lifting) changes that occur in concert with ecological changes (i.e., defoliation)? Or, should the community focus their efforts and resources solely on ecological restoration?

***End-User’s Capacity to Use NASA Earth Observations:***

*USDA, US Forest Service, International Institute of Tropical Forestry* – The IITF regularly incorporates MODIS imagery into its planning strategies. As mentioned above, the IITF has employed CALIPSO data to study the cloud base in a limited fashion. The IITF is overall very comfortable drawing reliable conclusions from Earth observations, but this effort will build their ability to synthesize Earth observations with *in situ* records. The IITF research scientists will provide additional *in situ* data for comparison to the CALIPSO cloud detections. A Vaisala CL31 ceilometer has been operated by the IITF in the Luquillo Mountains since April 2013. These observations will be shared with the NASA DEVELOP team as an additional means of calibrating the CALIPSO and radiosonde records.

***Collaborator & Boundary Organization Overview***

***Collaborator Support:***

*USGS, National Research Program*  – The USGS will contribute a 25-year record of rain event amount, duration, and intensity from the Rio Icacos gage at 640 m in the Luquillo Mountains to assess changes in orographic precipitation patterns resulting from CBH changes. Records from cloud-monitoring cameras and temperature/relative humidity sensors installed at different elevations in the Luquillo Mountains will be used to further calibrate the cloud altitudes from the CALIPSO satellite, the IITF ceilometer, and the radiosonde-calculated values.

***Project Communication & Transition Overview***

***In-Term Communication Plan*:** The DEVELOP team will participate in monthly Skype calls with the IITF POC, Grizelle González. Dr. González will also be available as needed to provide updated ceilometer observations in the early spring 2018. Similarly, Martha Scholl will advise on previous and concurrent cloud forest research at Luquillo and provide established USGS datasets relevant to the project.

***Transition Plan*:** The DEVELOP team will present the findings to the IITF partners at the end of the project term. Further, the DEVELOP team will prepare a white paper describing the statistical adjustment tool for future CBH prediction.

***Letters of Support*:** Grizelle González, Research Scientist, IITF & Martha Scholl, Research Hydrologist, USGS

**Earth Observations Overview**

***Earth Observations:***

|  |  |  |
| --- | --- | --- |
| **Platform & Sensor** | **Parameter(s)** | **Use** |
| **CALIPSO CALIOP** | Cloud height, Cloud thickness | Cloud heights and thicknesses will be calibrated against radiosonde and ceilometer observations to determine the change in CBH pre- and post-Maria. |
| **Terra MODIS** | NDVI, ET | MODIS will be used to assess degree of defoliation pre- and post-Maria as well as changes to ET from the forest.  |

***Ancillary Datasets:***

NOAA NCEI Integrated Global Radiosonde Archive (IGRA) – Calculate theoretical CBH using the mixed-layer lifted condensation level (MLLCL) from temperature and moisture trajectories measured by weather balloons from San Juan, PR.

IITF Vaisala CL31 ceilometer – *In situ* laser measurements of CBH to cross validate CALIPSO and MLLCL calculations

USGS cloud monitoring camera – *In situ* images of cloud immersion at multiple altitudes in the Luquillo Mountains

USGS precipitation records – 25-yr record of rainfall in the Luquillo Mountains which will be compared to pre- and post-Maria CBH

USGS National Elevation Dataset (NED) – Topographic data to visualize areas that will experience regular cloud-immersion loss following Hurricane Maria.

***Software & Scripting:***

Python – process radiosonde observations using SHARPpy module

Esri ArcGIS – visualize areas that lost/retained cloud-immersion; process MODIS NDVI and NED

Visualization of CALIPSO (VOCAL) – visualize and process CALIPSO cloud heights

JMP – conduct statistical comparisons of ceilometer, CALIPSO, and MLLCLs

**Decision Support Tool & End Product Overview**

***End Products:***

|  |  |  |  |
| --- | --- | --- | --- |
| **End Product** | **Partner Use** | **Datasets & Analyses** | **Software Release Category** |
| **Cartographic CBH Exposure Tool** | This end product will allow IITF to more accurately develop its forest management strategies in the wake of Maria, specifically, which areas of the Luquillo Mountains as susceptible to species migration in the absence of cloud immersion. | CALIPSO-detected cloud parameters will be calibrated against the MLLCL from the San Juan IGRA data and the ceilometer detected CBH. The change in calibrated CBH pre- and post-Maria will serve as the CBH increase estimate. MODIS-based NDVI and ET products will also be compared against CBH to assess the contribution of forest-based moisture to orographic clouds. | III |
| **Statistical CBH Diagnostic Tool** | This tool will allow IITF to use the MLLCL from the San Juan, PR, radiosonde and adjust it to determine the most likely post-Maria CBH in the forest. | The mathematical relationship between the San Juan MLLCL and the CALIPSO-observed cloud heights will be shared with IITF so they can diagnose CBH in the forest using the twice-daily San Juan radiosonde data. | III |

***End-User Benefit*:** The IITF will benefit from the results of this project by developing more appropriate management strategies that reflect shifts in the CBH and resulting effects on ET in the forest. This will also help them anticipate which areas of the forest are vulnerable to species displacement. For instance, previously cloud-immersed elevations may no longer receive regular cloud cover, and the epiphytes and other cloud-water dependent species in the elfin woodland may experience difficulty re-establishing.

**Project Timeline & Previous Related Work**

***Project Timeline:*** 1 Term: Summer 2018

***Related DEVELOP Work:***

2017 Summer (LaRC) – CALIPSO Cross-Cutting: Enhancements to Visualization of CALIPSO (VOCAL) through Case Studies of Saharan Dust

2017 Summer (ARC) – US Virgin Islands Ecological Forecasting: Using NASA Earth Observations to Monitor Land-use Change and Map At-risk Coastal Habitats in the U.S. Virgin Islands

2017 Spring (UGA) – Southern Appalachia Disasters: Using NASA Earth Observations to Monitor Vulnerability, Wildfire Damage, and Recovery in the Appalachian Forests

2015 Summer (LaRC) – CALIPSO Cross-Cutting II: Interfacing CALIPSO Data through a Graphical User

Interface

**Notes & References:**

***Notes*:** This project leverages the work of previous NASA DEVELOP initiatives. For instance, the VOCAL software for processing CALIPSO data was originally created by a NASA DEVELOP team, and received upgrades as recently as summer 2017.

The functionality of some instruments may be limited in the immediate aftermath of Hurricane Maria. At the time of the proposal submission, we assume that functionality will be restored promptly enough to permit completion of the project. However, even if it is not, the project can still be completed without the inclusion of the IITF ceilometer data.

***References:***

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