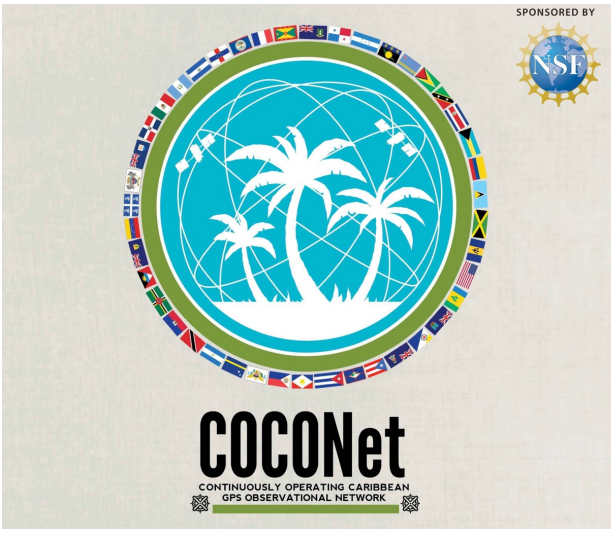
Community Workshop: COCONet - Results, Sustainability, and Capacity Building

Convened in Punta Cana, Dominican Republic
May 3-5, 2016



Final Workshop Report to the National Science Foundation

EAR-1634055

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Executive Summary

This report summarizes the activities and recommendations that arose from the fourth and final COCONet workshop, entitled "Community Workshop: COCONet - Results, Sustainability, and Capacity Building," which focused on science highlights to date that have been funded, facilitated, or based on data from COCONet, data availability and access, network sustainability, and development of a plan for additional capacity-building in the region. The workshop was held in Punta Cana, Dominican Republic over a three-day period from May 3rd to 5th in coordination with a half-day workshop on the last afternoon on UNAVCO *Dataworks* software. There were 78 participants, representing US and international academic and governmental institutions. ***There was overwhelming consensus by the participants that COCONet has provided an excellent basis for Caribbean regional cooperation, coordination, and capacity building that support geoscience investigations, particularly those related to natural hazards, and that the initial investment by the NSF in the COCONet GPS-Met sensor network should be continued to allow station time-series to mature over the next decade to address key science questions in atmospheric, solid Earth, and ocean science.***

The 4th COCONet Community Workshop was designed to provide participants with an update of the current status of the COCONet project, to highlight the science facilitated to date by the COCONet network, to illuminate participants on data accessibility, and to discuss sustainability of the network moving forward. Participation by COCONet regional partners was maximized through formal reports, science presentations from researchers within the COCONet footprint, presentations from COCONet Graduate Fellows, and breakout sessions to solicit additional feedback and interaction. Plenary sessions included network status reports, science highlights, COCONet data and products, updates from COCONet Regional Data Centers, and presentations from COCONet Fellows. Much of the remainder of the workshop focused on breakout sessions. An optional half-day short course on GNSS Dataworks software was held on the final day after the conclusion of the COCONet workshop.

Since the 3rd COCONet workshop (24-26 October 2012 in Tulum, Mexico), the COCONet management team in cooperation and coordination with the COCONet community, implemented many, but not all, of the recommendations from the previous community workshops along with other guidance. Many of these recommendations were highlighted during the breakout session discussions at the 4th COCONet Community Workshop. Progress on recommendations developed during the previous COCONet workshops is also outlined in this report.

Feedback obtained from the breakout sessions combined with additional email input from workshop participants were the source of 38 specific recommendations within eight major themes. We list the eight major themes with two key recommendations from each below.

Theme 1: Broadening the COCONet user base

Recommendation: Develop a unified geodetic reference frame in the Caribbean and update the frame as more data is collected by incorporating at least one station per country within the IGS cGNSS network to ensure that proper network densification is achieved.

Recommendation: Encourage the addition of multiple geophysical instruments at existing COCONet cGPS-Met stations to strengthen collaborations with other user communities.

Theme 2: Post-construction Regional Governance

Recommendation: Approach GGIM (Global Geodetic Information Management) and inform this organization that financial support is needed, currently provided by UNAVCO as a result of its funding from NSF, to continue the societal benefits of COCONet to the Caribbean region.

Recommendation: Develop a COCONet governance structure that will ensure a credible and audible voice within national and international communities, within the Caribbean, and globally. Examine options for COCONet governance through existing CARICOM and UN structures.

Theme 3: Acknowledging and Enhancing Partnerships

Recommendation: Demonstrate the current level of engagement provided by local COCONet partners through an audit, which would document the level of support that each partner institution provides. Make these contributions visible through the COCONet and RDC websites.

Recommendation: Encourage local COCONet station operators to take responsibility for small maintenance issues, while continuing to provide financial support from NSF through UNAVCO for larger issues, such as equipment replacement and repair.

Theme 4: Student and Other Training Opportunities

Recommendation: Develop appropriate and continuous training for regional field and software engineers within the COCONet footprint. Offer technical training via webinars with follow-up Q&A, similar distance-learning courses now routinely available at most US universities.

Recommendation: If possible, continue the COCONet Graduate Fellowship program and expand it to include students from non-U.S. institutions (i.e. students at Caribbean institutions).

Theme 5: Human Resource Development

Recommendation: Inventory the capacities and resources available in the COCONet region through a survey to document and advertise what every country or agency could provide in terms of human resources to aid others in the region.

Recommendation: Increase involvement of local scientists. Encourage projects and collaborations of scientists in a given region, with a specific research focus for that region. Take full advantage of existing NSF programs that provide funding to support these exchanges.

Theme 6: Outreach and Communications

Recommendation: Produce COCONet-specific materials, especially for youth, leveraging existing partner resources. Ideas include digital, downloadable media, such as videos, presentations for teachers, simple games, and ideas for science fair projects.

Recommendation: Offer hands-on experiences for stakeholders by including media participants in workshops and offering field trips for media and policy makers as well as training for K-12 science and geoscience teachers. Offer training for COCONet partners on how to communicate effectively with policy makers as well as the media.

Theme 7: Data Access

Recommendation: Provide more recognition of the support and resources provided by local institutions. For example, raw data files should be more clearly tagged to the country/institution hosting the station using DOIs. This recognition should promote enhanced data sharing.

Recommendation: Simplify meteorological data access. Develop or modify existing tools.

Theme 8: Non-traditional and Other Funding Opportunities

Recommendation: Identify and contact potential sponsor and partner agencies such as the Office of U.S. Foreign Disaster Assistance (OFDA), the Pan American Institute of Geography and History (IPGH), and the Sistema de Referencia Geocéntrico para las Américas (SIRGAS).

Recommendation: Develop a comprehensive funding and long-term operations plan for COCONet to ensure that its assets are included in a larger observation network, like the nascent Subduction Zone Observatory (SZO) and/or a Network of the Americas (NOTA).

1. Introduction

A. Introduction and Overview

Since 2011, UNAVCO has built and operated the Continuously Operating Caribbean GPS Observational Network (COCONet) for the National Science Foundation (NSF) (EAR-1042906/9) in partnership with 28 sovereign nation's 41 distinct administrative entities in the circum-Caribbean region. In addition to ongoing oversight provided by the COCONet Working Group appointed by the UNAVCO Board of Directors, there have been three previous COCONet workshops, which have helped guide the project to date. Participants in the previous workshops have included US and international academic and government researchers, graduate students from US and foreign institutions, local and regional geodetic, meteorological, and seismic network operators, and other interested stakeholders. Previous workshop and other reports submitted to NSF during the course of the project are published on the COCONet website http://coconet.unavco.org/publications/publications.html). The first two meetings, held in Puerto Rico (February 2011) and Trinidad (June 2011), focused on the development and refinement of a COCONet instrumentation siting plan. The third meeting, held in Cancún, Mexico (October 2012), focused on longer-term network operations and maintenance, GPS data processing, generation of higher-level data products, and real-time GPS data distribution.

We requested and were granted funding from the NSF (EAR-1634055) to support a fourth and final COCONet workshop, entitled "Community Workshop: COCONet - Results, Sustainability, and Capacity Building," which focused on science highlights to date that have been funded, facilitated, or based on data from COCONet, data availability and access, network sustainability, and development of a plan for additional capacity-building in the region. The workshop was held in Punta Cana, Dominican Republic over a three-day period from May 3rd to 5th in coordination with a half-day workshop on the last afternoon on UNAVCO *Dataworks* software. There were 78 participants, representing US and international academic and governmental institutions, including one NSF Program Director, and 10 UNAVCO staff, all of whom provided some level of support for COCONet construction, operations and maintenance, outreach, or communications (see Appendix E for participant list). In addition, the PI and Co-PI of the 4th workshop award (EAR-1634055), both of whom are Co-PIs on the COCONet award (EAR-1042906), along with two UNAVCO support staff that were instrumental in facilitating the workshop, also participated. Also 31 of the 78 workshop participants, primarily from the Caribbean region, participated in the *Dataworks* training on the afternoon of the 3rd day.

This workshop proposal and this final report were developed and compiled by the workshop organizing committee shown below (*Co-PIs on the COCONet awards, EAR-1042906/9):

Mr. Karl Feaux*, Plate Boundary Observatory/GPS Operations Manager, UNAVCO, Chair
Ms. Beth Bartel, ECE Specialist, UNAVCO
Dr. John Braun*, University Corporation for Atmospheric Research
Dr. Enrique Cabral-Cano, Instituto de Geofísica, UNAM
Dr. Alexander Holsteinson, Universidad Nacional Pedro Henríquez Ureña (UNPHU)
Dr. Alberto López Venegas, Research Coordinator, PRSN, Department of Geology, UPRM
Ms. Jaime Magliocca, Event Manager, UNAVCO
Dr. Glen Mattioli*, Director of Geodetic Infrastructure, UNAVCO, *Ex Officio*
Dr. Héctor Mora, Director, GEORED Network, Servicio Geológico Colombiano
Dr. Linda Rowan, Director of External Affairs, UNAVCO
Dr. Andrea Sealy, Caribbean Institute for Meteorology and Hydrology
Dr. Yolande Serra, Senior Research Scientist, Joint Inst. for the Study of the Atmosphere and Ocean, University of Washington

This report includes written sections from the 4th workshop proposal to the NSF, additional input by UNAVCO staff, written contributions by members of the organizing committee, reports from the regional data centers/mirrors, written summaries from the breakout sessions, and additional feedback from workshop participants via email. Additional material was provided by the Co-PI Feaux, who compiled and reviewed all the materials, and PI Mattioli, who edited this final report.

Background, Motivation, and Science Objectives of COCONet

The capacity to understand, prepare for, adapt to, and in some cases predict the variety of natural hazards impacting the Caribbean requires observations on large and small scales. While university-based researchers are ideally situated to investigate individual research topics and can operate focused networks addressing targeted problems, they do not typically have the resources to install and maintain regional observation systems, nor to service the broader community who will use the resulting data. Large integrated instrument networks play a crucial role in providing a regional context for regional studies, but also require a different approach to project and data management. The COCONet project was funded by NSF to support these goals in the Caribbean shortly after the devastating Mw7.1 earthquake that struck Léogâne and the capital city of Port-au-Prince, Haiti on January 12, 2010.

COCONet is a fiducial network of continuously operating Global Positioning System and co-located meteorological instrument (cGPS-Met) stations that: 1) provides constraints on the tectonics of the entire Caribbean region; 2) enhances atmospheric observations that can be used to test and extend climate and weather models; 3) improves the analysis of local geodetic measurements by providing access to an integrated backbone of reference stations; and 4) increases our ability to model and predict the natural hazards, which pose such a significant threat to the region. COCONet has been installed and maintained by UNAVCO on behalf of the academic science and other user communities throughout the Americas and the Caribbean region, thus leveraging UNAVCO's proven record of efficient and effective network management (*e.g.* the EarthScope Plate Boundary Observatory (PBO)), its longstanding commitment to collaborative science, and well-established free and open data access tools with long-term data and metadata management. Accordingly, COCONet forms a backbone to support a broad range of geoscience investigations in the Caribbean and thus enables research on process-oriented science questions, most with direct relevance to geohazards.

B. COCONet Construction Status

Since 2010, NSF has provided $6.04M, including Supplemental Funding, to UNAVCO to support the development of the COCONet network, which inlcudes site reconnaissance, permitting, construction, station operation, and maintenance; data archiving and processing; and outreach activities such as science and operational workshops, graduate student fellowships, and the development and maintenance of the COCONet website (http://coconet.unavco.org/coconet.html). The 4th COCONet Community Workshop provided an opportunity for participants to learn about the construction and operational status of the network, that now includes cGPS, meteorological, and tide gauge networks as well as the regional data center and regional mirrors. UNAVCO PBO GPS operations manager, Mr. Karl Feaux, presented a talk and a poster, both of which outlined the current construction status of the network as well as highlighting important engineering milestones.

Sensor Networks

COCONet construction began in 2011 and is scheduled for completion by the final quarter of 2016. The current Collaborative Research awards (EAR-1042906/9) are in Grantee-approved *No Cost Extensions* through August 31, 2016 and a request for a second NSF-approved NCE was submitted and approved in July 2016, which extends the end date to August 31, 2017. The total number of new, refurbished, or co-located stations installed to date is 82, which is a substantially larger number than planned in the proposal. There are 4 stations remaining to be installed as part of the revised COCONet siting plan. As of June 15, 2016, 96% of the core GPS-Met stations are operating as designed and delivering data to the UNAVCO archive.

The COCONet core stations are comprised of GNSS-capable instruments (Trimble NetR9 with Dorn Margolin choke ring antennae elements) coupled with surface meteorological sensors (Vaisala WXT-520) and telecommunications infrastructure, designed to deliver daily, hourly, and in some cases high-rate (1 Hz), real-time, low-latency data streams to support solid earth, atmospheric, oceanic (long- and short-term sea level), and regional spatial reference control applications (Figure 1). In principle, these instruments could also support other missions, for example Earthquake and Tsunami Early Warning systems, but these objectives were not explicitly designated as part of the COCONet proposal to NSF or the revised science plan. Together with the NSF-funded TLALOCNet Major Research Infrastructure (EAR-1338091) project in Mexico, this new suite of cGPS-Met instrumentation is now available to support diverse science objectives in Mexico, Central America, and the Caribbean (Figure 1).

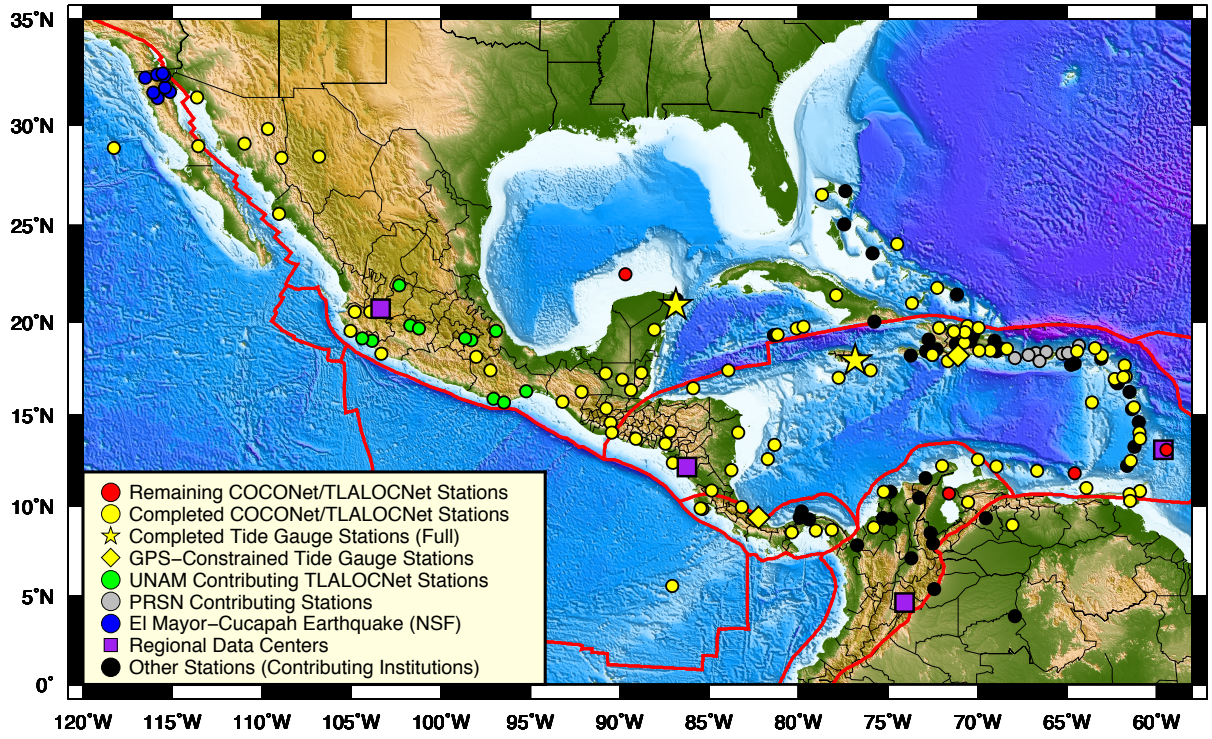


Figure 1. Network construction status, including the cGPS, meteorological, and tide gauge networks, as well as the location of the regional data mirrors and the data center.

In 2012, an NSF supplement to COCONet provided funding for two dual-frequency cGPS stations proximal to newly constructed tide gauges: one cGPS in bedrock or stable ground within five kilometers of the tide gauge and the second on the tide gauge platform itself with a

geodetic baseline tie between them to best constrain any tidal sensor vertical displacements from their original installation positions. The supplement also provided funds for the addition of two cGPS stations (one on the pier and one on nearby bedrock) at two existing, functioning tide gauges in the Caribbean. This component of COCONet is now completed, with recently installed GPS-constrained tide-gauge systems in Mexico and Jamaica. Two existing tide-gauge stations in the Dominican Republic and Panama were augmented with cGPS installations to provide an absolute sea-level control for the Caribbean as well as to determine geoid-ellipsoidal offsets at each site. Achieving a unified vertical datum for all the Caribbean countries would be an important geospatial achievement, providing an excellent basis for regional monitoring and research, including integration with the *GPS Tide Gauge Benchmark Monitoring Working Group* (TIGA). All tide-gauge data are freely available and flow seamlessly into the UNESCO/IOC archive. GPS and surface met data flow into the UNAVCO archive (see discussion below).

An example of data from an upgraded COCONet tide gauge at Minches, Dominican Republic may be found in Appendix H.

COCONet Regional Data Centers

One Regional Data Center (RDC) and two Data Mirrors (DM) were established in 2015 in Colombia, Barbados, and Nicaragua, respectively. COCONet along with other regional cGPS-Met data and metadata are mirrored and managed at these regional centers under contract with UNAVCO and with COCONet support. For example, the RDC in Colombia is fully operational and mirrors UNAVCO data holdings for COCONet and also provides local data from Servicio Geológico Colombiano (http://www2.sgc.gov.co).

UCAR also received additional funding for COCONet data analysis, which results in cGPS-derived precipitable water vapor estimates as an extension to the SuomiNet and COSMIC data products (http://www.suominet.ucar.edu). COCONet surface meteorological observations flow directly to the WMO through the GTS system (https://www.wmo.int/pages/index_en.html).

2. COCONet accomplishments relative to previous community recommendations

Since the 3rd COCONet Community Workshop (24-26 October 2012 in Tulum, Mexico), the COCONet management team and the COCONet community implemented many, but not all, of the recommendations from the previous community workshops and other guidance. Many of these recommendations, summarized below as bullets, were again highlighted during discussions at the 4th COCONet Community Workshop. The progress to date is shown below each previously recommended action.

- *Create a working group to promote the science goals of COCONet and how countries in the region are united to learn more about potential geologic and atmospheric hazards.*

COCONet created a working group for community engagement and outreach. The members of the working group include Franck Audemard, Venezuelan Foundation for Seismological Research, Carlos Fuller, Caribbean Community Climate Change Centre, Leslie Hodge, Department of Land and Surveys, Anguilla, Peter Dare, University of New Brunswick, Daniel Davila, Oklahoma State University, and Linda Rowan, UNAVCO. Although work remains to implement fully the strategies pertaining to education and outreach, the working group has focused on the COCONet Fellowship program by evaluating COCONet Fellowship candidate applications and progress reports, discussing strategies for outreach and communication, including supporting the writing of a Letter to the Editor of *Science Magazine* regarding research

collaborations in Cuba, jointly with the Grupo de Óptica Atmosférica de Camagüey (GOAC) from INSMET, Cuba. A quarterly newsletter and more frequent updates to the COCONet webpage also were established.

- *Work towards the establishment of a media library featuring online video tutorials ranging from instrument set-up to data processing and webinars of distinguished lecturers in a variety of UNAVCO-backed science topics.*

Tutorials, webinars, and other instructional media have been made available, primarily through UNAVCO's website, and training available via visits with UNAVCO staff at UNAVCO headquarters. Presentations (either slides or video) from two PASI short courses, one on magma-tectonic interactions and the other on atmospheric processes, were made available online. A distinct COCONet library was not deemed to be essential as the project advanced and therefore this recommendation was not explicitly implemented.

Figure 2. From left to right: Ken Austin (UNAVCO), Julio Marquez (Simon Bolivar University), Chad Pyatt (UNAVCO), and Ricardo Lopez (FUNVISIS) finish the construction of a single-mast monument that will be used as part of a monument comparison investigation funded by NSF-EarthScope through the PBO multi-monument change order.

- *Establish a listserver, a monthly newsletter, and either a forum or a blog for the COCONet community to exchange ideas and post questions as well as answers related to various aspects of the project.*

A COCONet list server and quarterly newsletter were established to enhance and broaden communication and information exchange. The COCONet project also provided frequent updates to the COCONet webpage and Facebook page. All reports to NSF are available on the COCONet website along with archives of COCONet science and engineering highlights published throughout the project award period.

- *Explore the feasibility of having a visiting, rotating expert to address technical and scientific problems in the region. Issues can range from installation of software to the development and implementation of a targeted science research project.*

Visits by experts to support the installation of software as well as computer hardware, sensor infrastructure, and data management have occurred in the COCONet footprint. UNAVCO field engineers regularly provided training to local partners during station installations, including in Nicaragua, Honduras, Venezuela, and Cuba. In August 2013, two students from Venezuela, Ricardo Lopez (La Fundación Venezolana de Investigaciones Sismológicas) and Julio Marquez (Simon Bolivar University) worked with PBO engineers in the Pacific Northwest to learn how to install PBO-style GNSS stations (Figure 2). Students and engineers from the region were invited to participate in the UNAVCO Annual Science Meeting in 2015.

Finally, a short course providing training in *Dataworks* software was held in December 2014 at the UNAVCO facility in Boulder, CO, for staff from the regional data centers in Colombia, Barbados, and Mexico (for COCONet and TLALOCNet) (Figure 3). In addition, on several occasions, COCONet participants from other countries have traveled to UCAR for help with technical and scientific concerns.

- *Frequently update the COCONet website to feature newly installed sites, data availability, research highlights, and recent publications, photos, tutorials, and webinars.*

The COCONet website has updates on station installations, data, research highlights, photos and publications. Tutorials and/or webinars are available on UNAVCO's and UCAR's websites. The website is updated quarterly and more frequently, if needed.

- *Develop and implement a protocol/mechanism to credit and acknowledge COCONet community contributions (for example, data center work or effort, contributed data sets, data products, and publications, etc.), and further to advertise how to acknowledge the use of COCONet data.*

The community encourages appropriate credit and acknowledgement of COCONet data used for publications and the development of other value-added products. A formal mechanism has not yet been developed specifically to assure COCONet data and data product attribution; however, UNAVCO has developed a **Digital Object Identifier (DOI)** system for crediting all data sets in the UNAVCO archive. Additional information about data DOIs may be found here: http://www.unavco.org/data/doi/doi.html.

- *Explore the feasibility of streaming 15-second sample rate data for all stations capable of handling this data rate. This strategy may prove simpler and more cost-efficient than the downloading 1 Hz observations in 30 or 60-minute data files, may reduce latency, and further could allow a larger number of COCONet stations with higher rate real-time streams.*

Implementation of this recommendation has not been feasible within current resource constraints. Increasing the number of streaming stations, whether at 1 Hz or 15 s, is beyond what was planned in the original proposal, which called for 10 COCONet stations to provide high-rate data streams. We note that COCONet has well exceeded this goal.

- *Provide the necessary tools to the COCONet community for the wide range of activities. These include to keep providing short-courses on data processing such as those previously sponsored for GAMIT/GLOBK, Track/TrackRT, and (T)DEFNODE.*

- *Provide training sessions or workshops for the installation and usage of important software (data transmission, processing and products).*

Figure 3. Dataworks training for COCONet and TLALOCNet Regional Data Center (RDC) operators in December 2014 at the UNAVCO Boulder facility. UNAVCO staff S. Weir (standing center) and F. Boler (standing right) provided the training. Photo credit: Beth Bartel, UNAVCO.

PASI short courses and several other training courses have been held at UNAVCO headquarters and in other COCONet-related communities for training on software installation, data access, data processing, and analysis. These courses are delineated in Appendix A.

- *Encourage UNAVCO Associate Membership for countries hosting COCONet stations. The high cost of one-time membership fee may be a limitation for some countries, hence explore a reduced or waived membership fee for eligible countries.*

UNAVCO has encouraged our regional partners in COCONet to become Associate Members in the UNAVCO Consortium, but no new associate members from within the COCONet footprint have joined since the Third workshop though several additional stations have been installed. One likely deterrent is that affiliation with UNAVCO did not guarantee that international members (i.e. Associate Members) will be eligible for reduced GNSS instrument prices from manufacturers. Since the Third COCONet workshop, however, UNAVCO has a new agreement with Belgian GNSS manufacturer Septentrio (http://www.septentrio.com) for GPS/GNSS receiver discounts, and these discounts are available to all UNAVCO Members and Associate Members through the close of the GAGE Facility Cooperative Agreement in September 2018.

3. Workshop Summary

The Fourth COCONet Community Workshop was designed to provide workshop participants with an update of the current status of the COCONet project, to highlight the science facilitated to date by the COCONet network, to illuminate COCONet data accessibility, and to discuss

sustainability of the network moving forward. Participation by COCONet regional partners was maximized through written reports, science presentations from researchers within the COCONet footprint, presentations from COCONet Graduate Fellows, and numerous breakout sessions to solicit additional community feedback and interaction. Brief biographical sketches of the workshop speakers are found in Appendix F. Plenary sessions included network status reports, science highlights, talks outlining COCONet data and products, updates from COCONet Regional Data Centers, and presentations from COCONet Fellows. Much of the remainder of the workshop focused on breakout sessions that were conducted in English and Spanish to facilitate the exchange of ideas. An optional half-day short course on GNSS Dataworks software was held on the final day after the conclusion of the workshop, and this was attended by the vast majority of the participants from the COCOnet footprint. A press release was written by L. Rowan and provided to the local media in English and Spanish at the close of the workshop and posted to the COCONet website. The full English text is in Appendix I.

There was overwhelming consensus by the participants at the workshop that COCONet has provided an excellent basis for Caribbean regional cooperation, coordination, and capacity building that support geoscience investigations, particularly those related to natural hazards, and that the initial investment by the NSF in the COCONet GPS-Met sensor network should be continued to allow station time-series to mature over the next decade to address key science questions in atmospheric, solid Earth, and ocean science.

The final agenda for the workshop is included in Appendix B.

A. Science Highlight Summaries

Plenary sessions dedicated to science highlights were broken into three different sessions, with each focused on a separate scientific discipline with relevance to COCONet: 1) Solid Earth Processes; 2) Atmospheric Processes; and 3) Oceanic Sciences.

Summary of Solid Earth Presentations

The Solid Earth processes session included up-to-date reports on advances made possible by the development of COCONet and other regional networks, such as TLALOCNet in Mexico and the Nicoya Peninsula network in Costa Rica.

In the first presentation in the session, Dr. Marino Protti from OVSICORI, Costa Rica, detailed the recent investigation from Cocos Island to the Caribbean plate across the Panama block and how COCONet data are providing key constraints to the geodynamics in southern Central America. Despite the progress to date, several open questions remain. For example, the characterization of the seismic coupling offshore Central America could still be better defined. In addition, the geodetic community is still lacking a dense enough network to observe motion along the Hess escarpment, thus making any assessment of its potential for a major earthquake are not fully substantiated. These arguments make the current COCONet stations in the region a key asset, with a clear community consensus that they need to continue to operate for a number of years, such that remaining scientific issues are fully addressed. Other key questions still pending full resolution are: better definition of forearc sliver motion during a megathrust earthquake cycle in the Gulf of Fonseca; and definition of rupture zone length as a function of the megathrust width.

In the second presentation of the session, Dr. Enrique Cabral-Cano from UNAM, Mexico, detailed the latest effort for modeling the slow slip events in the Mexican portion of the Middle

American Subduction Zone. Using data from the past 15 years, including recent additional observations from TLALOCNet, the distribution and role of slow slip events in the process of strain accommodation at this subduction zones was examined.

Slow slip events along the Mexican Subduction Zone have been documented for the Guerrero and Oaxaca segments. The densification of GPS sites in southern Mexico over the last few years has allowed a substantial improvement of the available geodetic data inversion efforts. This improved observational data set allows to differentiate between those slow slip events generated in Guerrero from those generated in the Oaxaca area and better determine whether slow slip migrates across the several-hundred km-wide gap between the Guerrero and Oaxaca regions, or whether slow slip in the two regions is spatially and temporally independent. The geodetic data provide evidence that most slow-slip events in fact migrate, similar to that observed for the Guerrero 2014 event, which is the largest amplitude slow slip event recorded so far in the world. Other relevant conclusions are that larger earthquakes, such as the 2012 Ometepec (M7.4) events, seem to have been triggered by an ongoing slow slip event in Oaxaca, similarly to the Guerrero slow slip event and the Tecpan 2014 (M7.2) earthquake.

An important observation is the time dependent coupling of the subduction interface over different time scales. On the short term (inter-SSE periods), the slow slip region is highly coupled, whereas on the long-term, most of the slip deficit is released. This implies that the slow slip events release most of the accumulated strain and behave almost as a regular earthquake (albeit at much slower rupture propagation rates) and may be the reason for the existence of the Guerrero Gap, a segment of the Mexican Subduction Zone that has experienced no rupture over the past 100 years of instrumental observation and which strongly affects hazard assessments for the region.

In the final presentation in this session, Dr. Eric Calais at the Ecole Normale Supérieure in France, presented a thorough review and advances in the study of the plate boundary tectonics and seismic hazard in the northeastern Caribbean using COCONet and other campaign GPS data. Great advances have been made in the past few years in the definition of the Caribbean plate specially on its northern segment. Current consensus of the community considers a well-resolved Caribbean frame with a distinct creeping boundary subduction segment in the Lesser Antilles-Puerto Rico that transitions to an oblique collision in the Bahamas segment (Figure 4). The transition to the presently coupled plate interface coincides with a large upper plate deformation and is consistent with the current topography and exposed geology of the region in Hispaniola. This may indicate that this has been a persistent feature throughout the evolution of this plate margin.

The COCONet stations throughout the region allow a new tectonic interpretation of southern Hispaniola, with implications for seismic hazard. Nevertheless, there are several key questions still to be fully resolved such as the process that controls the coupled/uncoupled behavior and stress transfer within the boundary zone. The extensive geodetic data set collected so far makes the region an excellent target for a detailed geodynamic modeling and calls for a continuous and sustained network and the collaboration efforts throughout the whole region.

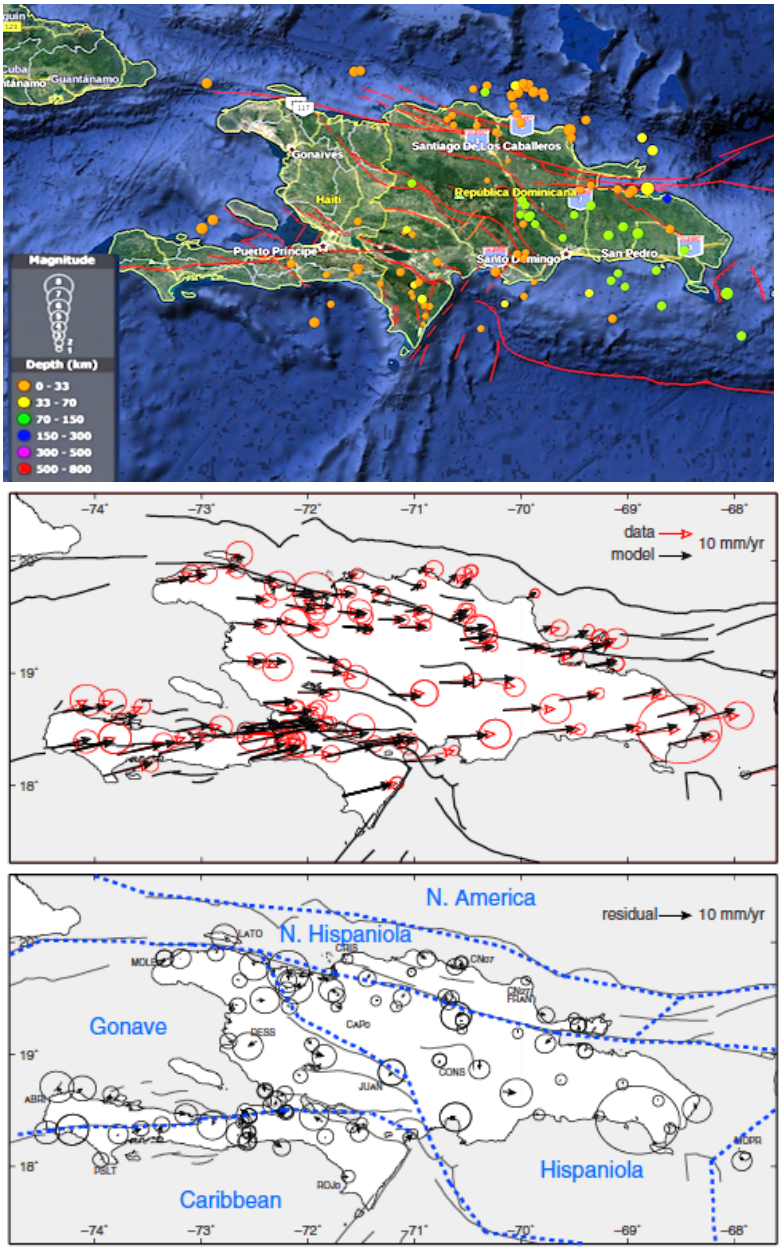


Figure 4. (top plate) Hispaniola Island is the most seismically active region with numerous mapped faults (shown as red lines) in the northern Caribbean. Recent seismic events are shown as colored dots, whose color corresponds to depth and whose diameter corresponds to magnitude. (middle plate) Observed and modeled GPS velocities in Hispaniola shown with respect to the North American plate (assumed fixed). Red vectors are the GPS data and the black vectors are the best-fitting model. (bottom plate) Dashed blue lines show the block boundaries, with block names labeled in the blue. Error ellipses in middle and bottom plates represent 95% confidence. Modified from Symithe et al., 2015, JGR Solid Earth. S. Symithe was a COCONet Science Fellow and recently was awarded his Ph.D. from Purdue University in West Lafayette, IN under the direction of A. Freed and E. Calais.

Summary of Atmospheric Science Presentations

The atmospheric session provided an update on and overview of how COCONet data are being used to support atmospheric science research as well as operational activities in the Caribbean.

Dr. John Braun, a project scientist in the COSMIC program and the University Corporation for Atmospheric Research (UCAR), summarized the progress that has been made in addressing some of the fundamental science questions initially proposed for the COCONet project. This includes the use of COCONet data to understand strength of ocean-atmosphere coupling in the Caribbean and their use to improve the initialization of atmospheric analysis fields for numerical weather prediction. COCONet data have been used to identify significant systematic biases in the Global Forecast System (GFS) analysis fields. The GFS is the primary global forecasting model used by the National Center for Environmental Prediction (NCEP). GFS analysis fields

appear to be systematically moist across the COCONet region when atmospheric conditions are relatively dry (Precipitable Water Vapor (PWV) less than 40 mm). This moist bias changes to a dry bias as the atmosphere becomes wetter (PWV greater than 40 mm). This result indicates that COCONet PWV data may play a significant role in improving initial conditions within the primary numerical weather model used by NCEP. Dr. Braun also summarized how data assimilation scientists within the UCAR COSMIC program have modified the Gridpoint Statistical Interpolation (GSI) data assimilation system to properly ingest GPS PWV data. The GSI system is the core data assimilation package to the GFS numerical weather model. This activity has allowed COCONet data to be assimilated within a case study of Hurricane Isaac (2012). In this ongoing research, COCONet data have shown an initial positive impact on the track forecast of Isaac as it moved across the Caribbean into the Gulf of Mexico (Figure 5).

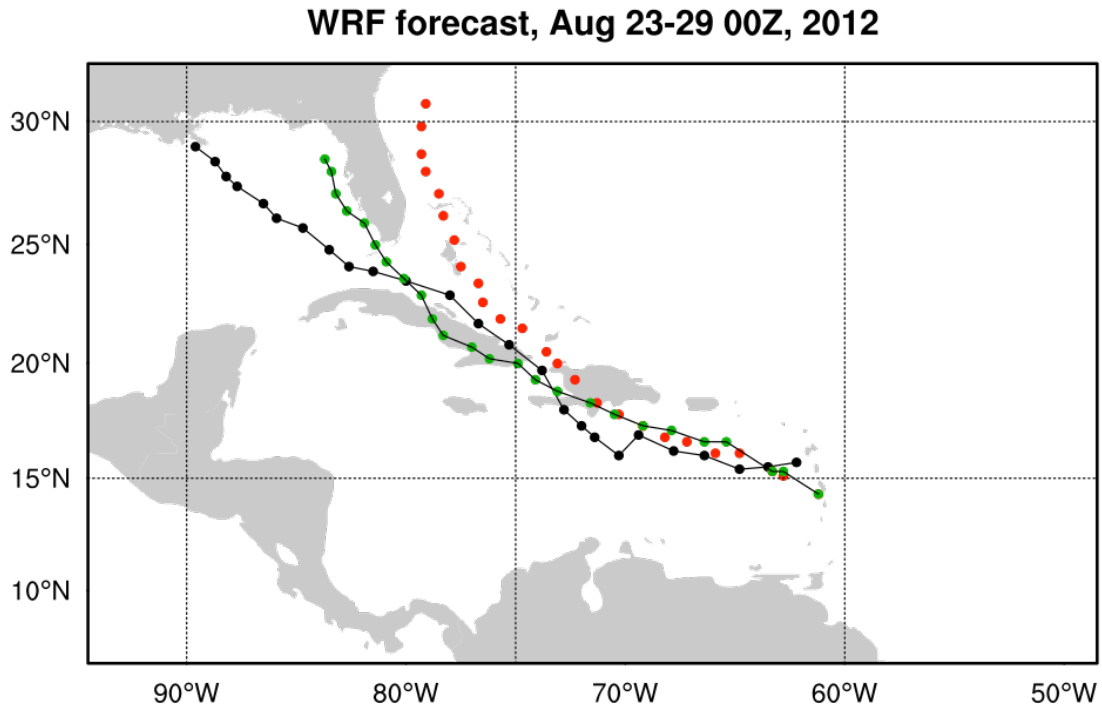


Figure 5. Assimilation of COCONet data have shown a positive impact on the track forecast of Hurricane Isaac (2012). The red dots show the track forecast of the storm from August 23-29, 2012 when all conventional data, except COCONet PWV data, are assimilated into the analysis field. The green dots show the forecast track after COCONet PWV data have been assimilated into the analysis over a 24 hr time period (August 22). The black dots are the best track estimates for this event from the National Hurricane Center (NHC).

Dr. Andrea Sealy, a scientist and lecturer from the Caribbean Institute of Meteorology and Hydrology (CIMH), gave a presentation describing how their institution has utilized COCONet data for research and operational applications. COCONet data are being included into the DEWETRA decision support system. DEWETRA is a real-time data and information integration system for hydro-meteorological risk monitoring and forecasting. The CIMH have incorporated COCONet data, both PWV and surface meteorology, into this system, and were able to apply the data products to verify a June 3, 2015 flooding event. The DEWETRA application has highlighted a number of challenges and opportunities for the project. The COCONet GPS-Met sensors, their configuration, and station locations, are different from most World Meteorological

Organization (WMO) approved stations. This implies that training and validation are required for these data to be used effectively within a disaster management application. This includes the need for improved metadata for each station to define instrument accuracy, reporting standards, and local environmental conditions of each site. The DEWTRA platform has also highlighted the need to ensure robust installation of the stations (including power and communication infrastructure) if the network is to be relied upon for an operational hazard monitoring application. The DEWETRA project has also highlighted the difficulty in incorporating data into a system as it is being built. A number of COCONet stations were not available when the system was initially integrated into DEWETRA, resulting in delays in its use within the risk monitoring and forecasting system.

CIMH has also used COCONet data within their own research and training efforts. COCONet data were used by a student working with Dr. Sealy to investigate errors in GFS analysis fields for the initial life cycle of Hurricane Sandy. This study revealed differences between GFS analysis and GPS derived PWV of up to 20%. These differences are significant. They indicate a need to verify the accuracy of both the GPS analysis and GPS PWV estimates as well as identify a potential data assimilation case study within a high resolution numerical weather forecast model such as the Weather Research and Forecasting (WRF) model.

Dr. David Adams, a professor at the Universidad Nacional Autónoma de México (UNAM), described a number of ways in which COCONet data may be used to support some basic atmospheric research questions on the initiation of convection and water vapor transport in the tropics, its diurnal variability, and easterly atmospheric wave structure in the region. Dr. Adams noted that COCONet is complementary to previous projects in the Amazon and North American Monsoon area. He also highlighted how COCONet provides a backbone for potential future field programs, such as the Organization of Tropical Eastern Pacific Convection (OTREC) field campaign planned for 2018. COCONet is also complementary to the TLALOCNet project in Mexico that is looking to refine research objectives related to the North American Monsoon.

In addition to the atmospheric session, there were a number of other talks within the other portions of the workshop that highlighted the application of COCONet data for atmospheric applications. Dr. Teddy Allen, a COCONet science fellow, gave a presentation summarizing the Caribbean rain belt pattern, with an emphasis of how COCONet PWV and surface meteorology data could be used to verify both the large scale synoptic conditions of the Panama Low to enhance water vapor transport and produce significant rainfall events prior to hurricane season. He also highlighted a number of opportunities that COCONet data can be used to support and train local meteorological agencies and farmers.

Summary of Oceanic Science Presentations

Three presentations in a plenary session focused on oceanic science research, with specific emphasis on tides and long-term sea level trends, using COCONet data.

In the first presentation of the session, Dr. Jorge Zavala of the Universidad Nacional Autónoma de México (UNAM) presented an overview of modern sea level stations and the importance of GNSS observations for sea level monitoring. Mexico monitors sea level changes, especially sea level rise related to climate change along the Pacific, the Gulf of California, and Gulf of Mexico coasts and continues to upgrade existing stations and install new stations. Across Mexico, 40% of the tide gauge stations currently have collocated GPS. Mexico has consolidated several organizations that monitor sea-level into a National Tsunami Warning System; this consolidation

included additional funds to upgrade and expand existing sea level networks. COCONet installed a new tide gauge with two GPS systems to measure absolute sea level change at Puerto Morelos. The arrival of tsunami waves from the 2011 Tohoku, 2014 Iquique, 2014 Guerrero and 2015 Maule earthquakes were recorded and analyzed to help Mexico prepare for future tsunamis and better understand tsunami features.

In the second presentation of the session, Dr. Marcelino Hernandez Gonzalez of the Instituto de Oceanología, Cuba gave an introduction to sea level and oceanography research in Cuba. Cuba monitors sea level changes related to sea surface temperatures, severe weather, major oceanic patterns, such as El Nino Southern Oscillation (ENSO) events and climate change. Over the past several decades, Cuba has upgraded and installed new tide gauges to improve the spatial and temporal resolution of sea level measurements. The largest monthly sea level anomalies occur during ENSO years and forecasting sea level heights during severe storms or hurricanes remains challenging. Coastal flooding and erosion are significant concerns for Cuba. Dr. Hernandez reported that Cuba is interested in installing additional GNSS stations with current or planned tide gauge sites to determine absolute sea level variation, improve forecasts of sea level changes, and to better understand oceanic and coastal processes.

In the third and final plenary presentation, Dr. John LaBrecque formerly a Program Director in the Earth Science Enterprise of NASA and now representing the Global Geodetic Observing System (GGOS), outlined the need and importance of integrating GPS/GNSS data into hemispheric and global tsunami early warning systems. Research shows that GNSS ground-based networks record the motion of the solid earth related to a large magnitude earthquake and these observations can provide a rapid and more accurate assessment of the size, origin and direction of a subsequent tsunami. Other research shows that GNSS networks sense the atmosphere and can track ionospheric disturbances created by the tsunami waves. These ionospheric waves can be used to track tsunami waves with greater accuracy and over large ocean basins where other observations are limited and the waves are of low amplitude. The Global Geodetic Observing System has issued a call for participation for the implementation of GNSS augmentation to tsunami early warning (http://www.ggos.org). LaBrecque encouraged members of the COCONet community to participate in GGOS and thus to work to integrate geodetic data into tsunami early warning systems in the Caribbean and elsewhere.

B. Interoperability / Data Access

In addition to the Plenary sessions focusing on the three science themes, additional Plenary sessions focused on COCONet data accessibility and data products, with presentations on geodetic and atmospheric data types. A summary of the presentations is below.

Geodetic Data

Data and metadata from 145 COCONet stations are archived by UNAVCO and available through the Archive's DAI and GSAC web services data and metadata distribution systems (see Figure 6); real time data are available for a subset of the COCONet stations through UNAVCO's real time system, which is available to registered users. The GSAC web services provided by UNAVCO are interoperable with other data centers using GSAC, including the COCONet Regional Data Centers, the TLALOCnet Data Center, the GSAC at SIO-UCSD, and several operating in Europe. UNAVCO uses GSAC internally for numerous applications including delivery of SINEX and XML formatted metadata and for spatial searches delivered by UNAVCO's RESTful web services.

Figure 6. Map of current COCONet stations with data available in the UNAVCO archive. Map shows all COCONet stations, including COCONetCore, COCONetRefurb, and COCONetPartner (total stations, n=145). On July 13, 2016, 51 of 57 or 89.5% of COCONetCore and 16/25 or 64.0% of COCONetRefurb stations had delivered data to the archive within 24 hrs. This corresponds to 81.7% for all COCONet stations that have received any NSF resources for construction, upgrades, and/or ongoing O&M.

COCONet stations fall into three categories according to the support received from UNAVCO through NSF. Core COCONet stations (57 stations) include all the sites that UNAVCO has installed and currently maintains. Refurbished COCONet stations (25 stations) include all the existing sites operated by collaborating institutions where UNAVCO has provided upgrades to equipment and now provides operations and maintenance. Partner COCONet stations (63 stations) include stations that UNAVCO does not operate, but whose data have been contributed by various regional partners for free and open data access by the entire global geodetic community. These designations are searchable in UNAVCO's data access systems and indicated in results using the grouping (or network) designations COCONetCore, COCONetRefurb, and COCONetPartner.

All COCONet station data (Core, Refurbished, and Partner) are analyzed by the GAGE Analysis Centers and combinations provided by the GAGE Analysis Center Coordinator as part of the expanded GAGE analysis. Products including position time series, solutions, and velocities, and all products are available through the DAI, GSAC web services, and UNAVCO web services.

COCONet data and products are regularly accessed by users through UNAVCO's ftp service. For calendar year 2015, 5.6 million files totaling close to 1 TB were accessed via ftp. RINEX files comprise 96% of file downloads. The US educational domain (.edu) is the largest top level domain using COCONet data by file count and volume downloaded (Figure 7 and Appendix C).

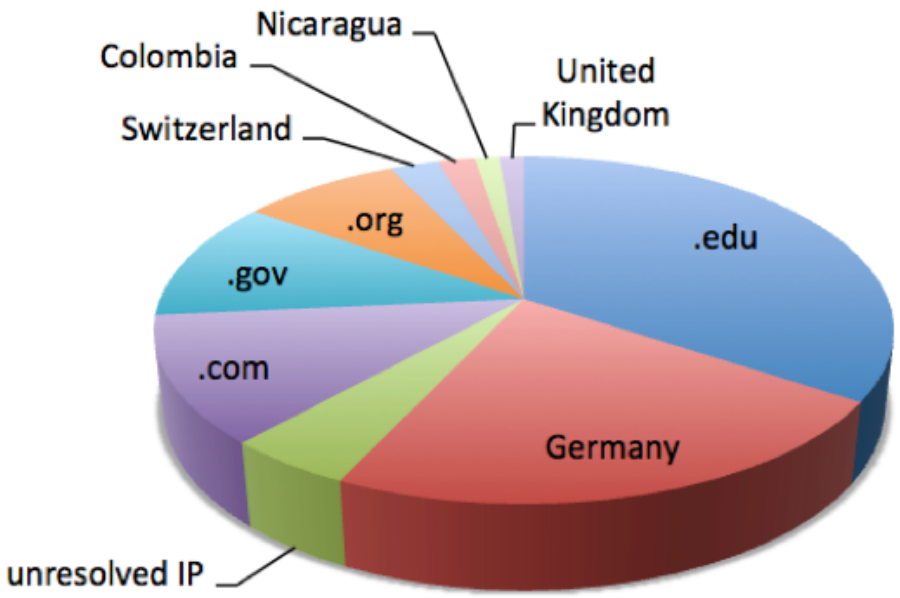


Figure 7. Top ten, top-level domains/countries by file count that have accessed COCONet data and products from UNAVCO archive in 2015.

Atmospheric Data

As discussed above, COCONet provides raw GPS and surface meteorological data and metadata for every station through the UNVACO archive. In addition, these data metadata along with other local observations are provided through the COCONet Regional Data Centers and Mirrors (see below). Atmospheric data products include the raw surface met observations of temperature, pressure, relative humidity, wind speed and direction, and rain intensity (basically the amount of liquid precipitation).

GPS-derived estimates of the tropospheric water vapor, in the form of zenith wet delay (ZWD), are produced by the GAGE Facility Analysis Centers during their routine processing of the GPS observations to estimate topocentric positions. These data are also available to the COCONet community as ASCII text files for all COCONet stations, with estimates every 300 s (ftp://data-out.unavco.org/pub/products/troposphere) from the GIPSY-OASISII software (CWU solution) and every 2 hours from the GAMIT software (NMT solutions). We note that these estimates are derived from processing system configurations that are not necessary optimized for further production of precipitable water vapor estimates.

In addition to these standard met data products, COSMIC/SuomiNet provide validated, synoptic PWV estimates for North America and the Caribbean in NETCDF as well as ASCII format files (http://www.suominet.ucar.edu/data.html). In contrast to the ZWD estimates from the GAGE ACs, PWV estimates are derived from the BERNESE software using a system configuration that is optimized to yield ZWD and to convert to PWV.

Sea Level and Tide Gauge Data

As part of the COCONet project, UNAVCO constructed sea level and tide monitoring instrumentation at two locations in the Caribbean Basin. The locations for these stations (Port Royal, Jamaica and Puerto Morelos, Mexico) enhance the coverage of tide gauge instrumentation in the Caribbean region. Each station consists of tide gauge instrumentation (including radar ranging sensor and a pressure gauge) on a marine pier co-located with a cGPS-Met system to provide near real-time positions of relative sea-level measurements. A second cGPS system was installed a short distance away (<5 km). Two other existing tide-gauge stations in the Dominican Republic and Panama were augmented with co-located GPS to provide absolute sea- level measurements. All tide-gauge data are freely available via the UNESCO/IOC archive, which provides either raw GTS messages or tab delimited ASCII files of sea-level measurements (http://www.ioc-sealevelmonitoring.org/index.php), while all GPS and meteorological data are archived at UNAVCO (see discussion above). An example data set from the upgraded station at Miches, Dominican Republic is shown in Appendix G.

C. COCONet Regional Data Center Summaries

There were two presentations and a written report in a plenary session addressing the COCONet Data Centers. As part of the NSF funded COCONet project, UNAVCO provided startup funding for three Caribbean host institutions to operate Regional Data Centers or Regional Mirrors. Two institutions were selected to host a Regional Mirror Centers and one institution was selected to host the Regional Data Center, which has more advanced functionality. Each institution was eligible for up to two years of funding and received all required hardware and software from UNAVCO. Onsite installation and training were provided by UNAVCO during the first year of funding with ongoing operations support provided during the second year via phone and email. The local host institutions provide information technology infrastructure (e.g. power, cooling, internet, networking) as an in-kind contribution to the Data Centers they host.

The COCONet project provided support for Dataworks development and for three Regional Data Centers that were selected via a competitive proposal process. The purpose of the RDCS is to provide new or expanded capabilities within the region. A focus on regional data sharing is a benefit of the COCONet RDCs.

The COCONet Regional Data Centers and Mirrors were established in the following institutions:

- The Colombian Geological Survey (SGC), Colombia –
  Regional Data Center
- Caribbean Institute for Meteorology and Hydrology (CIMH), Barbados -
  Regional Mirror Data Center
- Instituto Nicaraguense de Estudios Territoriales (INETER), Nicaragua -
  Regional Mirror Data Center

The Colombian Geological Survey has been serving as host of the Regional Data Center (RDC) of COCONet Project since April, 2015. The purpose of the RDC is to build capacity to manage, archive and distribute GNSS data within the Caribbean region.

The CIMH and INETER have been serving as Regional Mirror Data Centers (RMDC) since March 2015. The RMDC functions as a mirror for COCONet data and metadata holdings from the COCONet primary archive at UNAVCO; metadata and data are also served by the RMDC.

The value of a COCONet Regional Data Center at the SGC includes: 1) a strong background in the use of GNSS technologies as part of the CASA, Pre-GeoRED, GeoRED and now the COCONet projects; 2) experience in densification of continuous geodetic networks as well as the execution of field campaigns; experience in GPS data processing; and 3) the central location of Colombia in the Caribbean region. The benefits of hosting a RDC for the SGC were outlined as follows: 1) geodetic application management for different purposes in Colombia; and 2) continuity in the support and generation of new projects and core support in the temporal and spatial processes of expansion the network of permanent stations and field campaigns.

The benefits to the CIMH of hosting the mirror data center are the strengthening of the Caribbean climate data archive hosted at CIMH, reaffirmation of the commitment of the CIMH to support climate science and climate product development in the region and supporting the role of CIMH as a World Meteorological Organization (WMO) Regional Climate Center (RCC). The outlined future plans and sustainability with regards to the ability of the host institution to sustain the data center hosting beyond the first two years of funding are mainly that the COCONet data will be incorporated into the existing weather and climate data streams of the CIMH and the automated data transmissions can be supported as part of the data capture and collection process of the institution.

Last, INETER is planning on taking advantage of the architecture of the RMDC's data archiving and query system to integrate GPS data from local networks and to allow other users access to these data for a variety of scientific purposes. Unfortunately, no representative from INETER came to the COCONet Fourth Workshop to update the participants about the current status of RMDC at the INETER facility in Managua, Nicaragua.

D. COCONet Graduate Fellow Presentations

COCONet has supported nine graduate research fellows completing research using COCONet and other data within the COCONet footprint over the past three years (Figure 8). Of the nine fellows, four have completed their doctoral degrees and moved to postdoctoral or faculty positions at other research institutions. Five are pursuing their doctoral degrees at U.S. universities and have received their last year (2015 - 2016) of funding through the COCONet Graduate Fellowship program. The COCONet Graduate Fellows have been very successful in advancing research, outreach and capacity building, and community engagement within the COCONet footprint. Short biographical sketches are below and in Appendix G.

Four COCONet Fellows were able to attend the Fourth COCONet Community Workshop in Punta Cana to present their research findings. Below is a summary of their presentations at the workshop. All of the fellows have been using observations collected from COCONet.

Teddy Allen, who graduated from the University of Miami with a Ph.D. in Meteorology in 2015, is now a post-doctoral researcher at the International Research Institute for Climate and Society, Columbia University. He continues to work in the Caribbean region and currently spends much of his time at the Caribbean Institute for Meteorology and Hydrology (CIMH) in Barbados. He presented his latest research on extreme rainfall during the Caribbean early rain season. Extreme rainfall occurs more frequently during periods when the Caribbean rain-belt pattern is observed. High amounts of total precipitable water from the tropics advected by the cyclonic circulation associated with the Panama Low help to fuel intense rainfall along the Caribbean rain-belt.

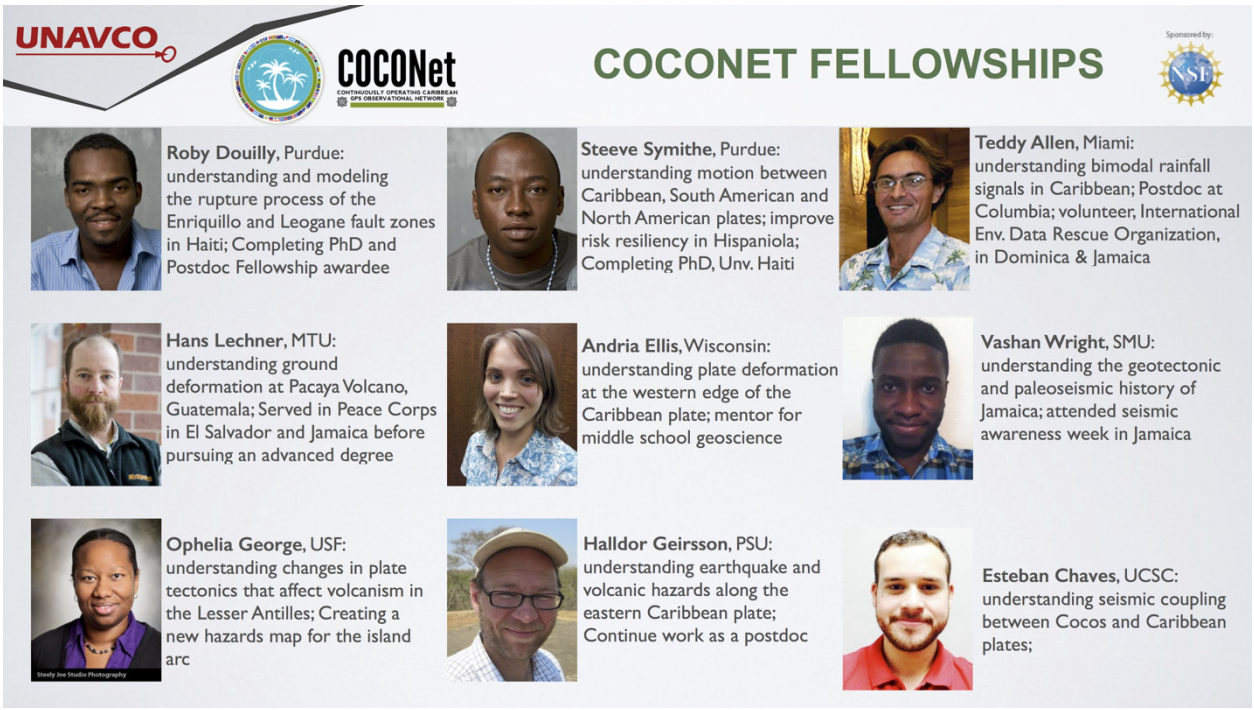


Figure 8. Photos and brief bios of the nine COCONet Graduate Fellows.

Ophelia George, who is at the University of South Florida, plans to complete her doctoral degree in Geology in 2016. She presented her latest research at the workshop. She has been analyzing seismic, geodetic and InSAR imagery from Dominica to create a volcanic hazard map for the island. The clustered nature of seismicity and volcanism on Dominica makes the island a suitable target for developing a geophysics-based weighting method that bridges the gap between traditional long and short-term volcanic hazard assessment methods.

Steeve Symithe graduated from Purdue University with a Ph.D. in Geophysics and Seismology in April 2016. He will return to Haiti as a new faculty member at the University of Haiti. He presented his latest research on utilizing updated GPS data to show that seismogenic strain accumulation in southern Haiti involves an overlooked component of shortening on a reverse fault, in addition to the known motion on the long-recognized strike slip fault.

Vanshan Wright, who is at Southern Methodist University working on a doctoral degree in Geophysics, is studying fault dynamics in Jamaica. He presented his latest results regarding the neotectonics of Jamaica and its implications for potentially hazardous earthquakes in the future. In particular, there are previously unrecognized faults in Kingston, the largest city on the island, that may represent significant seismic hazards.

E. Workshop Breakout Session Summaries

During the workshop, four breakout sessions covered the following themes: 1) Transitioning from network construction to operations and maintenance; 2) capacity building; 3) outreach and communications; and 4) long-term financial and operational sustainability. Each breakout session was held in both English and Spanish, with participants welcome to attend either

session. This format encouraged input from workshop attendees who may have been more comfortable speaking in their native language. Breakout sessions were assigned a facilitator to encourage and stimulate discussion, and student participants were assigned note-taking responsibilities. These notes were then transcribed, reviewed, and summarized by the workshop organizing committee. The principal themes emerging from each breakout session are described below.

Breakout Session 1: Sustainability of COCONet - Transitioning from Construction to Operations and Maintenance

In the first breakout session of the workshop, led by Enrique Cabral-Cano (Spanish) and Eric Calais (English), there was overwhelming agreement among the participants that continued operation of the network is essential to achieve the science goals established for COCONet. The COCONet data will serve future generations of scientists and the value of the data increases over time. Some of the initial science objectives have been completed, but continued operation of the network is necessary for all of the objectives to be realized. With limited future funding available from the NSF after the close of the COCONet award, the discussions in this breakout session focused on developing new or enhancing existing, established training opportunities, identifying new users of COCONet data, developing a post-construction COCONet governance structure, and determining how local partnerships can continue to collaborate with UNAVCO to sustain COCONet in the long-term.

Breakout Session 2: Capacity Building

The capacity building breakout session was led by Marino Protti (Spanish) and Lloyd Lynch (English). There was clearly some overlap with themes developed in the previous session, such as a need for a post-construction COCONet governance structure, need for continued project accountability, and training opportunities in the future. One important idea that emerged is the need for a regional COCONet governance body that is independent of the UNAVCO Board of Directors-appointed Working Group. This newly established body would have UNAVCO representation, but would primarily be accountable to the regional stakeholders rather than UNAVCO management or the NSF. This session also focused on research opportunities for COCONet-host country students, post-doc opportunities, the development of distance learning opportunities with semester-long courses to build intellectual capacity, and the development of educational materials for non-scientific communities in the Caribbean region. Forums which promote input from COCONet stakeholders was also a topic of discussion in this session.

Breakout Session 3: Outreach and Communication

The third breakout session, led by Beth Bartel (Spanish) and Linda Rowan (English) focused on outreach and communication needs related to network sustainability. Goals for communication included broadening the user base, raising awareness among decision-makers, and informing and inspiring the next generation of scientists, business owners, and policy makers. Participants agreed that effective outreach and communications can be used to support network sustainability by addressing the following key issues: increase the COCONet user base; gain monetary, in-kind, and policy support for the network; decrease station vandalism; and invest in the future by informing and inspiring the next generation of policymakers, scientists, and educators. Participants identified key audiences and messages (see Appendix H) for COCONet. Participants also expressed interest in sharing existing resources and forming a working group tasked with developing new resources, and leveraging the many existing communications resources at partner institutions.

Breakout Session 4: Funding Opportunities for Partnerships for Sustainability

In the fourth session of the workshop, led by Alexander Holsteinson (Spanish) and Linda Rowan (English), many participants suggested several potential funding agencies, additional instrumentation and new data centers, as well as regional joint scientific research funding opportunities. Sustainability after NSF funding ends in August 2017 (COCONet is in an NSF-approved No Cost Extension and modest Supplemental Funding has been provided to the GAGE Facility Cooperative Agreement to maintain data flow, archiving, and processing) was the main concern among the workshop participants. Because all data and products are free and openly available to the public, it is difficult to generate funds to sustain the project. Some ideas were suggested in this session, however, related to obtaining funding for COCONet from non-traditional sources. Furthermore, participants felt that COCONet sustainability is at a high risk, given the low priority of public funding assigned to geosciences and geophysical network infrastructure by many local policy makers in the region. Discussions focused on how COCONet can become a long-term presence in the Caribbean and promote its goals and achievements by providing raw data, data products, and tools which should encourage sharing of data and resources moving forward.

Breakout Sessions: Major Themes and Specific Recommendations

Many of the major themes discussed during the breakout sessions were relevant to more than one breakout session. Below is a summary of these eight major themes, with recommendations made from the various breakout sessions. A total of 38 specific recommendations were developed by the workshop participants. Two key recommendations from each theme were outlined in the *Executive Summary* of this workshop report.

Theme 1: Resources and broadening the COCONet user base

Recommendation 1-1: Establish regional caches of spare parts for station maintenance, as part of a COCONet Regional Technical Center to reduce the burden of shipping and importation of equipment, and provide faster response time in case of station malfunction.

Recommendation 1-2: Establish a set of standards for hardware, software, data, and metadata that are shared across COCONet, taking into consideration existing local, regional, and international standards, such as WMO for surface met data.

Recommendation 1-3: Develop a unified geodetic reference frame in the Caribbean and update the frame as more data is collected by incorporating at least one station per country be included in International GNSS Service (IGS) network to ensure that proper network densification is achieved.

Recommendation 1-4: Develop station position time-series solutions computed based on a regional geodetic reference frame and disseminate within the region.

Recommendation 1-5: Develop a hierarchy of COCONet-specific data products with an easy, one-stop access for GPS-Met data and data products. This could be based on the GAGE Facility products for North America, but recast into a Caribbean-fixed frame.

Recommendation 1-6: Clearly display raw GPS-Met data and broadcast that it is open and publicly available. Use COCONet data as part of a toolbox to build capacity when working with Met stations in the Caribbean. Encourage the use of the IRI climate or data library to help with GPS-Met data distribution.

Recommendation 1-7: Process COCONet data using well-established software and methods at Regional Data Centers and provide solutions and COCONet-specific data products (*e.g.* position time series or differential positioning - baselines).

Recommendation 1-8: Encourage the addition of multiple instruments at COCONet cGPS-Met stations to strengthen the collaborations with other user communities.

Theme 2: Post-construction Regional Governance

Recommendation 2-1: Approach the GGIM (Global Geodetic Information Management) and inform this organization that financial support is needed to continue the societal benefits to the Caribbean region currently provided by COCONet through its initial funding by the NSF.

Recommendation 2-2: Develop a COCONet governance structure that will ensure a credible and audible voice within individual partner nations, the Caribbean region, and international community. This would, in particular, help create and maintain ties with organizations such as ICG, GGIM, and CDEMA as well as attract other potential sponsors, such as WB, IDB, and CRIF. Care must be taken that the governance structure actually serves the purpose of sustaining the program by informing policymakers at all levels about the need for their support. Any governance system for COCONet would require a Board of Directors or Steering Committee on which members and the chair rotate, with the intention of an annual face-to-face meeting. In additional, this governance system would also potentially include a wider governance group that represents the broader interests of stakeholders.

Recommendation 2-3: Identify country champions, who would advocate for COCONet and serve as points of contact for their local institution, country, and region.

Recommendation 2-4: Customize the Intergovernmental Coordinating Group (ICG) governance structure to suit the needs of COCONet; information on the bylaws is available on the UNESCO website.

Theme 3: Partnerships

Recommendation 3-1: Identify current COCONet users and their needs; determine what support they might provide and how COCONet and UNAVCO might partner with regional users to more effectively meet their needs.

Recommendation 3-2: Demonstrate the current level of support provided by each local COCONet partner, through an audit, which would document the level of support that each partner institution is currently providing. Make the contributions visible through the COCONet website and the Regional Data Centers. Also, identify current partnerships that each country has with external entities (e.g. bilateral agreements, international organizations, and MOUs).

Recommendation 3-3: Encourage local COCONet station operators to take responsibility for small maintenance issues, while continuing to provide financial support from NSF through UNAVCO for larger issues, such as equipment replacement and repair.

Theme 4: Students and Other Training Opportunities

Recommendation 4-1: Develop appropriate and continuous training for regional field engineers and software engineers who install and maintain the hardware and software within COCONet. For example, establish regional engineering centers with field staff who can maintain stations

throughout a given region, similar to the regional data centers. Develop a program for formal training at UNAVCO, with assistance from local partners.

Recommendation 4-2: Develop detailed manuals and checklists to assist with station maintenance. Make these available as PDF files on the UNAVCO Knowledgebase with links to the COCONet website, Regional Data Centers, and other partners.

Recommendation 4-3: Provide enhanced training and documentation on data formats, interoperability, and accessibility. If these are already available, highlight existing resources on the COCONet and Regional Data Center websites.

Recommendation 4-4: Continue building and nurturing a strong base of local geoscientists in countries within the COCONet footprint including Central America, South America and the Caribbean regions who are making use of the data and are serving as local advocates for the COCONet initiative. If possible, continue the COCONet Fellowship program and expand it to include undergraduate and graduate students from non-U.S. institutions (*i.e.* students at Caribbean and other institutions in the rest of the Americas).

Recommendation 4-5: Encourage faculty at US and COCONet regional institutions to accept Caribbean and Central American students for internships and advanced degrees with an emphasis on analysis and modeling of COCONet observations.

Recommendation 4-6: Promote the use of regularly scheduled virtual meetings (via WebEx or similar technology) and teleconferences for group work.

Recommendation 4-7: Promote mobility of students between universities/institutions as a mechanism for generating products disseminated by the data centers.

Recommendation 4-8: Offer training and hands-on workshops in GPS-Met data processing and modeling. This could be achieved through distance learning technologies, e.g. WebEx.

Recommendation 4-9: Offer technical training via webinars with follow-up Q&A, similar to on-line and distance-learning courses now routinely available at most US universities. See recommendation 8 above.

Theme 5: Human Resource Development

Recommendation 5-1: Inventory the capacities and resources available in the region through a survey, and organize them into a database to advertise what every country or agency can provide in terms of human resources to aid others in the region (*e.g.* computer programming, field tools and capabilities, electronics repair, computer software installation, and data processing).

Recommendation 5-2: Follow up with PASI students to evaluate the effectiveness of the courses and how COCONet can improve workshops to ensure continued use of new skills.

Recommendation 5-3: Increase involvement of local scientists. Encourage research projects and collaborations of scientists throughout a given region, with a specific research focus generated within that region.

Theme 6: Outreach and Communications

Recommendation 6-1: Establish centers of coordination and dissemination of information.

Recommendation 6-2: Determine what materials already exist from partners within the COCONet footprint and provide a means to share these materials among all network partners. This may be facilitated through the COCONet website, for example.

Recommendation 6-3: Refurbish or repurpose existing educational and outreach materials relevant to but not specific to COCONet with a tropical or Caribbean focus, and translate these to English, Spanish, and/or French.

Recommendation 6-4: Produce COCONet-specific materials, especially for youth, leveraging existing partner resources such as agency design departments. Ideas include digital, downloadable media, such as videos, infographics, presentations for teachers, simple digital games, and instructions for science fair projects. Additional paper materials including brochures, newsletters, pamphlets, maps, annual reports, information packages for newly elected officials, and equipment signage were suggested for distribution. UNAVCO staff brought a draft of a COCONet poster to the workshop to solicit feedback from all participants, which will be incorporated into the final version. Participants also suggested advertisements in public spaces, such as on busses and in airports, and proposed increased use of social media.

Recommendation 6-5: Offer hands-on experiences for stakeholders by including media participants in workshops and offering field trips for media and/or policy makers and training for K-12 science and geography teachers. Offer training for COCONet partners on communicating with policy makers and/or the media. Many, but not all active COCONet partners, have support to communicate with policymakers and media through their institutions.

Recommendation 6-6: Encourage partner institutions and regional scientists to participate in established events like the USGS ShakeOut and other regional workshops related to seismic, volcanic, and tsunami hazards.

Recommendation 6-7: Promote COCONet by developing links from websites of partner institutions, ensuring that the data from the three regional data centers are clearly labeled as COCONet data, and through self-promotion by private sector partners that benefit from their service to help mitigate hazards and support local commerce.

Theme 7: Data Access

Recommendation 7-1: Provide more recognition of support and resources provided by local institutions. For example, raw data files should be more clearly tagged to the country/institution hosting the station. DOIs could be associated with COCONet data. This would promote more data sharing.

Recommendation 7-2: Simplify meteorological data access. Develop appropriate and intuitive tools for data discovery.

Theme 8: Non-traditional and Other Funding Opportunities

Recommendation 8-1: Look for potential applications, such as providing information for insurance underwriting, which can be offered to the private sector to generate additional funding for long-term sustainability.

Recommendation 8-2: Identify the primary sponsor of stations in each COCONet partner country. Establish or enhance public-private partnerships for the multiple uses of COCONet locally, nationally, regionally, and/or internationally.

Recommendation 8-3: Identify and contact potential funding and partnering agencies such as the Office of U.S. Foreign Disaster Assistance (OFDA), the Pan American Institute of Geography and History (IPGH), and the Sistema de Referencia Geocéntrico para las Américas (SIRGAS).

Recommendation 8-4: Evaluate potential new partners to obtain usage fees for access to COCONet data. Suggestions include the aeronautical and maritime port administrators in the region because GNSS and surface meteorological data are very useful for the current as well as the future of these operations.

Recommendation 8-5: Develop a comprehensive funding and operations plan for COCONet to be included in a larger observation network, like the Subduction Zone Observatory (SZO) and/or the Network of the Americas (NOTA).

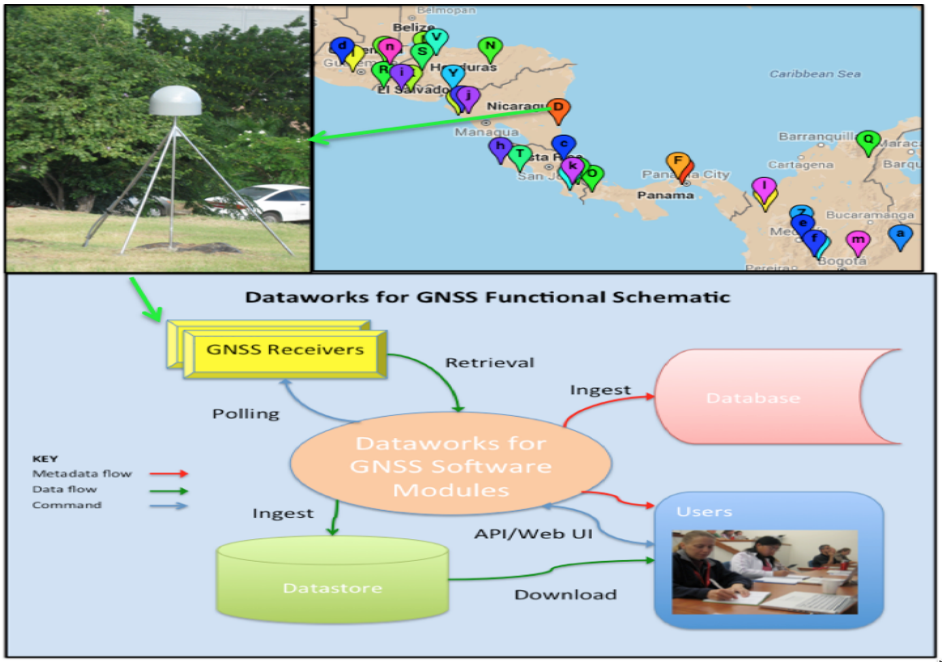


Figure 9. Functional schematic showing Dataworks for GNSS software modules with data and metadata flow.

F. Dataworks for GNSS – Report on Demonstration and Training at COCONet workshop

An optional training session on Dataworks for GNSS was held in the afternoon on day three of the Fourth COCONet workshop. Dataworks for GNSS is the UNAVCO-developed software system consisting of open-source software modules that can be employed by regional GNSS managers for small networks for data and metadata management (Figure 9).

Figure 10. UNAVCO software engineer S. Wier conducting Dataworks training on the 3rd afternoon of the COCONet workshop.

Thirty-one people attended the Dataworks software training (Figure 10). The major components of Dataworks, including the database, GSAC, receiver download, metadata management, and mirroring scripts were presented at an introductory level with more detailed presentation of selected topics. Systems level topics including preparing a Linux server, software installation, metrics, and security were presented, as was starting up an Amazon Elastic Compute instance and installing the Dataworks Amazon Machine Image. Dataworks software, server, and installation manuals were provided as PDF files on a thumb drive to each participant.

G. Summary of Posters

All student attendees to the COCONet Fourth workshop were required to submit an abstract and present a poster. In addition, all COCONet Graduate Fellows in attendance at the workshop were asked to present a brief talk, and three gave independent oral presentations and S. Symithie's Ph.D. work was summarized in part by Dr. E. Calais' plenary talk. A total of 11 posters were presented, with the content of the posters briefly summarized in Appendix D. The participants at the workshop were able to view the posters after the close of Thursday afternoon session. Refreshments were made available and significant and positive interactions occurred during the poster session.

4. Key Challenges and Summary Recommendations

The key challenges that face COCONet include: 1) the need to build upon and expand the use of COCONet cGPS-Met sensor data and to continue to expand the COCONet community to additional stakeholders; 2) the sun setting of COCONet construction and O&M award, with no clear long-term commitment of continued funding from NSF; 3) a US Federal as well as COCONet-partner institutional budgetary environment that remains flat (and thus declining in terms of real dollars) for the foreseeable future; and 4) a continuing need to improve training and human resource development in the Caribbean region to take full advantage of the initial NSF investment in COCONet and allied networks like PBO and TLALOCNet. Despite these challenges, however, there was overwhelming consensus by the participants at the Fourth Workshop that COCONet has provided an excellent basis for Caribbean regional cooperation, coordination, and capacity building that support geoscience investigations, particularly those related to natural hazards. Unlike the previous three COCONet Community workshops, there was a palpable sense that many participants from the Caribbean region view efforts to grow the geoscience community centered on COCONet has been an overwhelming success and that the initial investment by the NSF in the COCONet GPS-Met sensor network should be continued to allow station time-series to mature over the next decade to address key science questions in atmospheric, solid Earth, and ocean science.

Appendix A: List of COCONet Training and Short Courses

Training or Short Course	Date	Location
PASI Short Course on Atmospheric Processes in Latin America/Caribbean	May 27 - June 3, 2013	Cartagena, Colombia
PASI Course on Magma-Tectonic Interactions in the Americas	May 5 - 18, 2013	León, Nicaragua
Finite Element Modeling of Deformation at Volcanoes	May 21 - 23, 2013	UNAVCO, Boulder, CO, USA
InSAR Processing and Theory with GMTSAR	June 26 - 28, 2013	UNAVCO, Boulder, CO, USA
GPS Data Processing and Analysis with GAMIT/GLOBK/TRACK	July 8 -12, 2013	UNAVCO, Boulder, CO, USA
InSAR: An Introduction to Processing and Applications using ROIpac and GIAnT	July 29 - 31, 2013	UNAVCO, Boulder, CO, USA
Introduction to Terrestrial Laser Scanning (Ground Based LiDAR) for Earth Science Research	October 25, 2013	UNAVCO, Boulder, CO, USA
Imaging and Analyzing Southern California's Active Faults with LiDAR.	November 4 - 6, 2013	Scripps, La Jolla, CA, USA
Working with Strainmeter Data	March 3, 2014	Broomfield, CO, USA
2014 UNAVCO Science Workshop	March 4 - 6, 2014	Broomfield, CO, USA
Hydrogeology Short Course	March 5, 2014	Broomfield, CO, USA
The Next Generation of LiDAR Analysis for Critical Zone Research	May 12 - 14, 2014	University of Colorado, Boulder, CO, USA
Using Real Geodesy Data in Undergraduate Structural Geology and Geophysics	June 19, 2014	CO School of Mines, Golden, CO, USA

Introduction to Terrestrial Laser Scanning (Ground-based LiDAR) for Earth Science Research	June 20, 2014	UNAVCO, Boulder, CO, USA
Introduction to GPS Geodesy and High Precision Observations	July 14 - 18, 2014	OIGA, University of Antananarivo, Madagascar
InSAR Processing and Theory with GMTSAR	July 21 - 23, 2014	UNAVCO, Boulder, CO, USA
An Introduction to Processing and Applications using ISCE and GIAnT	August 4 - 6, 2014	UNAVCO, Boulder, CO, USA
Field Education and Support by the UNAVCO GAGE Facility	November 17 - 19, 2014	UNAVCO, Boulder, CO, USA
Dataworks for GNSS Training for Regional Data Center Operators	December 2014	UNAVCO, Boulder, CO, USA
Geophysical Information for Teachers (GIFT) Workshops	December 15 - 16, 2016	Westin Hotel, San Francisco, CA, USA
GPS Data Processing and Analysis with GAMIT/GLOBK/TRACK	August 10 - 14, 2015	UNAVCO, Boulder, CO, USA
How to Talk to Strangers: Selling Yourself and Your Science, for Students	October 31, 2015	Baltimore, MD, USA
Advanced InSAR Processing	June 29 - July 2, 2015	UNAVCO, Boulder, CO, USA
InSAR Processing and Theory with GMTSAR	August 10 - 12, 2015	Scripps, La Jolla, CA, USA
Working with Strainmeter Data	June 14, 2015	Stowe, VT, CA
Imaging and Analyzing Southern California's Active Faults with High Resolution Topography	January 25 - 26, 2016	Arizona State University, Tempe, AZ, USA
Scientific Drivers and the Future of Mount Erebus Volcano Observatory Workshop	February 22 - 24, 2016	UNAVCO, Boulder, CO, USA
2016 UNAVCO Science Workshop	March 29 - 31, 2016	Broomfield, CO, USA
Geodesy Data Teaching Modules, GETSI Short Course	March 30, 2016	Broomfield, CO, USA

Working with Strainmeter Data	March 28, 2016	Broomfield, CO, USA
Imaging and Analyzing Active Faults with High Resolution Topography	April 18 - 19, 2016	UNAVCO, Boulder, CO, USA
2016 Community Workshop: COCONet - Results, Sustainability, and Capacity Building	May 3 - 5, 2016	Punta Cana, Dominican Republic

Appendix B: Final Workshop Agenda

2016 COCONet Workshop
Results, Sustainability, & Capacity Building
Barcelo Bavaro Beach Resort • Punta Cana, Dominican Republic • May 3-5, 2016

Arrival Day - Mallorca 1 & Ibiza 3

Scheduled Activities:	4:00pm - 7:30pm	Registration and Poster Set up Reg in Mallorca 1
	7:30pm - 8:30pm	Welcome meet and greet (In Lobby - Spa Lounge)

WORKSHOP MASTER OF CEREMONIES: DR. ALBERTO LOPEZ (UPRM)

DAY 1 - Tuesday - May 3 - Ibiza 1 & 2

8:00 - 9:00	Breakfast	Main Buffet (First Floor)
9:00 - 9:15	Introductions and charge to workshop participants	*G. Mattioli, UNAVCO*
9:15 - 9:25	Welcome (slide from Russ Kelz, NSF)	*G. Mattioli, UNAVCO*
9:25 - 9:45	Status of the network	*K. Feaux, UNAVCO*
9:45 - 10:45	**Reports from local operators - Network Status, Maintenance Issues, Future Plans, Sustainability** Divide into 4 regions: North, South, East, West (15 minutes each)	
	• Western Caribbean	*E. Cabral, UNAM*
	• Northern Caribbean	*A. Lopez, PRSN/A. Holsteinson, UNPHU*
	• Southern Caribbean, including COLOVEN update	*H. Mora-Paez, SGC*
	• Eastern Caribbean	*A. Sealy, CIMH*
10:45 - 11:00	Break (out side of meeting room)	
11:00 - 12:00	**Science Highlights - SOLID EARTH PROCESSES** (20 minutes each)	
	• From Cocos to Caribbean plate across the Panama block: how COCONet is helping constrain the motions in southern Central America	*M. Protti, OVSICORI*
	• Slow slip events modeling in the Mexican Subduction Zone	*E. Cabral-Cano, UNAM*
	• Plate boundary tectonics and seismic hazard in the northeastern Caribbean from COCONet and other GPS data: what's new	*E. Calais, ENS*
12:00 - 1:30	Lunch/Group Photo (photo at 1:20)	
1:30 - 2:30	**Science Highlights - ATMOSPHERIC PROCESSES** (20 minutes each)	
	• Assessing the Impact of COCONet PWV Data in the Initialization of Numerical Weather Models	*J. Braun, UCAR*
	• Using COCONet Data for Disaster Risk Management	*A. Sealy, CIMH*
	• COCONet as a backbone network for the study of Central American land-based convective processes and large-scale water vapor transport for the North American Monsoon	*D. Adams, UNAM*

2:30 - 3:30	**Science Highlights - OCEANIC SCIENCES** (20 minutes each)	
	• Description of modern sea level stations and the importance of GNSS for Sea Level Monitoring	*J. Zavala, UNAM*
	• Sea-level and oceanography in Cuba	*M. Hernandez Gonzalez, INF*
	• Implementation of a Global Navigation Satellite System (GNSS) Augmentation to Tsunami Early Warning Systems	*J. LaBrecque, GGOS*
3:30 - 3:45	Break	
3:45 - 4:00	**Sustainability of COCONet: An Overview and introduction** • How can the network be sustained? • Who can be partners for sustainability?	*A. Lopez, UPRN*
4:00 - 4:15	**Sustainability & Lessons learned related to the Chilean GNSS Network**	*J. Baez, CSN*
4:15 - 5:30	**BREAK OUT SESSION I - Sustainability of COCONet (Spanish/English)** ***Chairs:*** *E. Cabral-Cano (Spanish)/E. Calais (English)* ***Students:*** *Registered Students will serve as note takers in breakout sessions.* • Is there a fundamental need to continue to operate the network? • What are the science and non-science drivers for continued operation? • Who can be partners for sustainability? • How do we transition COCONet from a construction project to an operational, sustainable network? • What resources do local partners intend to provide to ensure the continued operation of the network? • How can our regional partners feel ownership of the network?	
5:30 - 6:00	**Summary of Discussion on Sustainability of COCONet**	
7:00 - 8:30	Dinner	

DAY 2 - Wednesday, May 4 - Ibiza 1 & 2

8:00 - 9:00	Breakfast	Main Buffet (First Floor)
9:00 - 10:00	**COCONet DATA SERVICES, DATA TOOLS, PRODUCTS -** (15 minutes each)	
	• Overview of the PBO, COCONet, and TLALOCNet Data Products	*C. Meertens, UNAVCO*
	• Atmospheric data flow, processing	*J. Braun, UCAR*
	• UNAVCO Data Tools, COCONet data usage	*F. Boler, UNAVCO*
	• Real-time data usage	*C. Meertens, UNAVCO*
10:00 - 10:40	**UPDATES FROM COCONet REGIONAL DATA CENTER DIRECTORS** *LESSONS LEARNED FUTURE PLANS* (10 minutes each)	
	• Colombia	*H. Mora-Paez, SGC*
	• Barbados	*A. Sealy, CMIH*
	• Nicaragua	*TBD*
	• Mexico	*E. Cabral-Cano, UNAM*

10:40 - 11:00	Break	
11:00 - 12:00	**COCONet FELLOWS - PRESENTATION OF RESEARCH** • Combining Geophysical and geological data to create dynamic volcanic hazard maps on the island of Dominica, Lesser Antilles — *O. George, COCONet Fellow, USF* • Building the weather to climate bridge: The late spring Caribbean rain-belt and its mid-summer cessation — *T. Allen, Former COCONet Fellow* • Neotectonics of Kingston and its Implications for Earthquake Hazards in Jamaica — *V. Wright, COCONet Fellow, SMU*	
12:00 - 1:30	Lunch	Main Buffet (First Floor)
1:30 - 3:00	**INTRODUCTION TO CAPACITY BUILDING**	*L. Lynch, UWI/M. Protti, OVSICORI*
	COCONet Capacity Building Highlights	*J. Braun, UCAR*
	BREAKOUT SESSION II: Ideas for Future Capacity Building in the Caribbean (Spanish/English) ***Chairs:*** *M. Protti (Spanish)/L. Lynch (English)* ***Students:*** *Registered Students will serve as note takers in breakout sessions.* • What more can be done to build capacity in the region? • How are the PASI graduates using the data in their research? • How do we transition COCONet from a construction project to an operational, sustainable network? What capacity is needed? • What specific services and training are needed by the COCONet Community to enhance the usability of the network?	
3:00 - 3:30	**Summary of Discussion on Capacity Building of COCONet**	
3:30 - 4:00	Break	
4:00 - 5:00	**BREAKOUT SESSION III: Outreach and Communication (Spanish/English)** **Chairs:** *B. Bartel (Spanish)/L. Rowan (English)* ***Students:*** *Registered Students will serve as note takers in breakout sessions.* • Who are the key stakeholders we want to reach? • What are our key messages? • What are some possible means for delivering our messages? • What training, if any, would help with outreach and communication? • What resources are needed to allow COCONet partners to deliver their messages? • What are the other goals of outreach and communication and who are the audiences for these broader goals?	
5:00 - 5:30	**Summary from Breakout Session**	
5:30 - 7:00	**Poster Session** **Optional Session:** Dataworks for GNSS Intro (30 min)	Ibiza 3 *F. Boler, UNAVCO*
7:30	Dinner	

DAY 3 - Thursday, May 5 - Ibiza 1 & 2

8:00 - 9:00	Breakfast	Main Buffet (First Floor)
9:00 - 10:30	**FUNDING OPPORTUNITIES FOR PARTNERSHIPS FOR SUSTAINABILITY: Overview and Introduction**	*A. Holsteinson, UNPHU*
	International Scientific Networks, Policy and Capacity Building at the US National Science Foundation	*C. Estabrook, NSF*
	BREAK OUT SESSIONS IV- Sustainability of COCONet (Spanish/English) **Chairs:** A. Holsteinson (Spanish)/ L. Rowan (English) ***Students:*** *Registered Students will serve as note takers in breakout sessions.* • Discussion of opportunities related to inter-agency and international cooperation and collaboration. • How can the network be sustained and who are the partners for sustainability? • Who and what can support the network going forward? • What national or international organizations should be approached for support? • How can the network be integrated into larger earth observation platform such as subduction zone observatory?	
10:45 - 11:30	**Summary of discussion about partnerships**	
10:30 - 10:45	Break	
11:30 - 12:30	**Wrap up, review of findings, recommendations, and prioritization plan**	*E. Cabral Cano, UNAM/H. Mora-Paez, CGS*
12:00 - 1:00	Lunch	Main Buffet (First Floor)
1:00 - 5:00	***[For Workshop Planning Committee]*** Drafting on initial report - assembly of written summaries and development of key milestones	

2016 COCONet Workshop
Results, Sustainability, & Capacity Building
Barcelo Bavaro Beach Resort • Punta Cana, Dominican Republic • May 3-5, 2016

1pm - 5pm Introduction to GNSS Dataworks Short Course

1:00 - 1:15	GNSS Data and Metadata Management Fundamentals and Dataworks Overview	*F. Boler, UNAVCO*
1:15 - 2:00	Dataworks Datase: Dataworks Schema and Working with the Database	*S. Wier, UNAVCO*
2:00 - 2:45	GSAC	*S. Wier, UNAVCO*
2:45 - 3:00	Break	
3:00 - 3:45	GNSS Receiver Download Module and File Management	*M. Rost, UNAVCO*
3:45 - 4:15	GSAC Mirroring and GSAC Federation	*S. Wier, UNAVCO*
4:15 - 4:30	Tracking Metrics, Backing Up Your Dataworks System, Data and Metadata	*S. Wier, UNAVCO*
4:30 - 5:00	Server Requirements for Dataworks Accessing Dataworks Software Implementing Dataworks in the Amazon Cloud	*M. Rost, UNAVCO* *S. Wier, UNAVCO* *S. Wier, UNAVCO*

Appendix C: COCONet Data Access Statistics

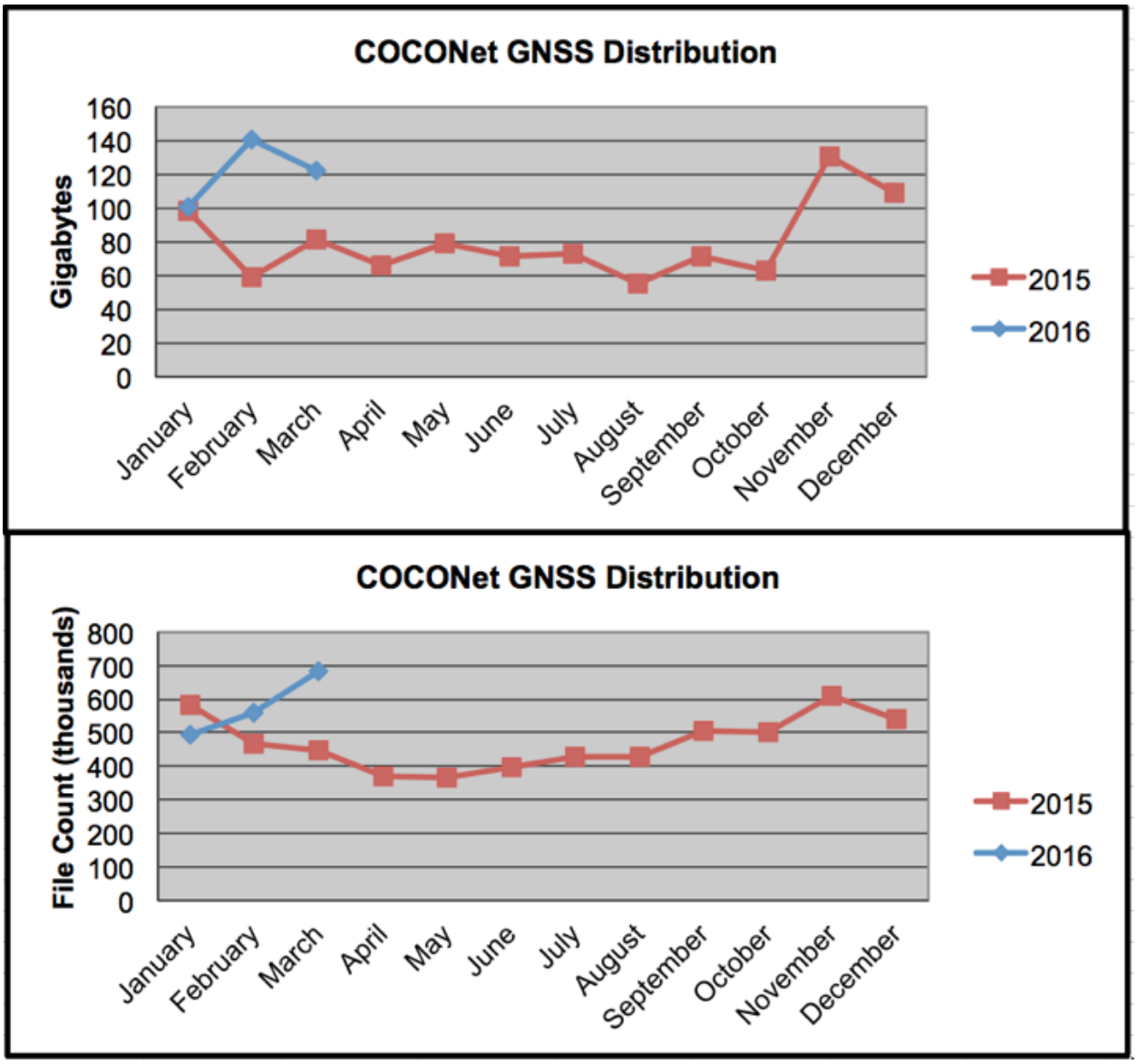
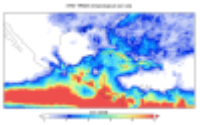
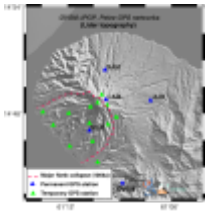
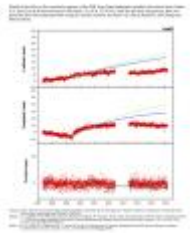
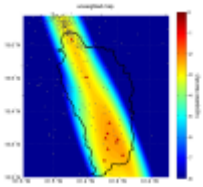


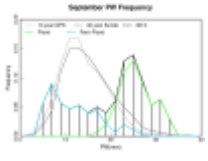
Figure C1. COCONet data and product distribution from UNAVCO from January 2015-March 2016. Top: Monthly file volume delivered. Bottom: Monthly file counts delivered.

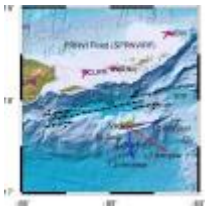
Appendix D: Workshop Poster Abstracts

Registrant	Title	Author(s)	Abstract	Image
Teddy Allen The International Research Institute for Climate and Society	Building the weather to climate bridge: The Caribbean Rain-Belt	Teddy Allen	An annual bimodal rainfall cycle with peaks during the late spring and late summer is observed throughout the Caribbean. A rainfall minimum occurs after the early rainfall season (ERS) and is known as the “mid-summer drought” (MSD). Despite the interest in the well-studied MSD, there is a lack of research describing the onset and variability of the ERS. Rainfall during the ERS is important for farmers as it moistens the soil after the dry season and can provide a catalyst for significant agricultural success. Contrary to the acceptance of long term anecdotal evidence, heavy rainfall during the ERS is not simply the result of mid-latitude fronts. Instead, heavy rainfall during the ERS arises through a series of storms or “weather events” that result from the simultaneous occurrence of two primary ingredients over the region: upper tropospheric uplift dynamics and lower tropospheric tropical moisture advection steered by the “Panama Low”. A rainfall pattern emerges during the late spring in the western Caribbean, known as the Caribbean rain-belt, from the accumulated rainfall of each weather event during the ERS. During some years the Caribbean rain-belt is weak or absent, however, it remains a climatological rainfall feature that is shaped by the consistency of late spring weather events. Sub-daily rainfall time series from the COCONet rain gauge network are used to construct the pattern of daily weather events that are then used to decompose the climatological Caribbean rain-belt. Farmers depend on the succession of ERS weather events that shape the Caribbean rain-belt, but deadly flooding and landslides have also been recorded along the its path.	 The Caribbean Early Rain Season rain-belt precipitation climatology

Juan Carlos Antuña Sánchez Grupo de Óptica Atmosférica de Camagüey (GOAC)	Website for meteorological data on COCONet Camaguey station.	J. C. Antuña-Sánchez, A. Rodríguez, R. Estevan and J. C. Antuña-Marrero.	A byproduct of the measurements conducted by the automatic meteorological station coupled to the COCONET GPS installed in Camaguey, Cuba, It a presented. It consisted in a new real time informative service of the meteorological variables measured by the meteorological station. The behavior of all the measured meteorological variables in the last 24 hours is displayed in an interactive graphic, where the numerical value is displayed upon clicking in the point and variable of interest. Additional information is provided regarding the local forecasts for the rest of the day, together with the maximum and minimum values of the whole period registered by the station beginning in March 2014. Also the most recent weather map for Cuba and the local radar and satellite images are available. This is the first service if this type already in operation in the Meteorological Institute network	 Web page in real-time.
Valerie Clouard Obs. Volc. Sismo. Martinique (OVSM/IPGP)	GPS networks in the French Caribbean islands: Application to tectonic and volcanic monitoring	V. Clouard, J.-B. de Chabalier, F. Beauducel, S. Deroussi, J.-M. Saurel, A. Lemarchand	French West Indies observatories from the Institut de Physique du Globe de Paris (IPGP) are in charge of monitoring the French volcanoes of Soufrière in Guadeloupe and Mount Pelée in Martinique and of monitoring of the Eastern Caribbean seismicity. In this framework, we operate and maintain permanent GPS networks at volcano and regional scale. Two type of data are recorded: 34h/30s daily transmitted to the observatories and 1h/1s, which can be downloaded on-site in case of a particular event. Data are automatically processed either with Gamit and/or Gipsy. In addition, repetitive GPS field surveys are carried out to monitor volcano flank instabilities. We present here our volcanic and regional networks, the monument characteristics, the daily synchronization with IPGP Data Center, the data availability and our data processing.	 GPS networks on Mount Pelée volcano.

Ana Beatriz Cosenza Muralles UW-Madison	Modeling of the viscoelastic response for the 2009 Swan Islands earthquake	Beatriz Cosenza and Charles DeMets	When an earthquake occurs, transients related to different processes such as coseismic slip, viscous flow, afterslip and poroelastic rebound contribute to the deformation that is recorded at nearby and far-field GPS stations. The often-similar deformation patterns of these processes in both space and time can make them difficult to separate from each other in GPS position time series, yet doing so is critical for efforts to estimate and model interseismic deformation and crustal rotations. After the 2009 Swan Islands (Mw = 7.3) earthquake, the motions of some continuous GPS stations in northern Central America were perturbed measurably relative to their previous steady motion. As part of a broader effort to calibrate the transients of effects of this earthquake, three subsequent M=7+ subduction zone earthquakes in Costa Rica, El Salvador, and Guatemala in 2012, and the 1976 M=7.6 Motagua Fault earthquake, we forward-modeled the viscoelastic response to the 2009 Swan Islands earthquake using different assumed rheologies for the crust and mantle and a published earthquake slip solution. Initial results, limited to a linear viscoelastic rheology, indicate that a plausible range of lower crust/upper mantle viscosities cannot fully explain the observed motions. By implication, earthquake after slip is required or non-linear lower crust/upper mantle rheologies must be considered.	 Viscoelastic response to the 2009 Swan Islands earthquake on ROA0 GPS site.
Ophelia George University of South Florida	Combining Geological and Geophysical Data in Volcanic Hazard Estimation for Dominica, Lesser Antilles	Ophelia George (1), Joan L. Latchman (2), Charles Connor (1), Rocco Malservisi (1), Laura Connor (1)	Risk posed by volcanic eruptions are generally quantified in a few ways; in the short term geophysical data such as seismic activity or ground deformation are used to assess the state of volcanic unrest while statistical approaches such as spatial density estimates are used for long term hazard assessment. Spatial density estimates have been used in a number of monogenetic volcanic fields for hazard map generation and utilize the age, location and volumes	 Unweighted Spatial intensity map for Dominica showing the catalog location

		1 School of Geosciences, University of South Florida, Tampa, Florida, 33620 2 Seismic Research Center, University of the West Indies, Port of Spain, Trinidad, West Indies	of previous eruptions to calculate the probability of a new event occurring at a given location within this field. In a previously unpublished study, spatial density estimates of the Lesser Antilles volcanic arc showed the island of Dominica to have the highest likelihood of future vent formation. In this current study, this technique was used in combination with the SRC catalog of seismic events occurring beneath Dominica within the last ~ 20 years to generate a hazard map which not only takes into consideration the past events but also the current state of unrest. Here, geophysical data serve as a weighting factor in the estimates with those centers showing more vigorous activity receiving stronger favorability in the assessment for future activity. In addition to this weighting, the bandwidth utilized in the 2D-elliptical kernel density function was optimized using the SAMSE method so as to find the value which best minimizes the error in the estimate. The end results of this study are dynamic volcanic hazards maps which will be readily updatable as changes in the geophysical data occur.	of earthquakes during 2010-2013 that will be used as a weighting factor in the volcanic hazard map
Alexander Holsteinson Universidad Nacional Pedro Henriquez Ureña (UNPHU)	Larger Antilles Operator Report Status	Alexander Holsteinson	Provide an update status on operating COCOnet and non COCOnet CORS sites in Puerto Rico, Cuba, Jamaica, Haiti, and Dominican Republic. Ongoing local sustaining efforts Discuss where new stations should be added either for seismic or weather, or both. View integration with existing tide gauges and discuss where new ones are needed.	
Hannah Huelsing University at Albany	Examination of Water Vapor Characteristics during the 2013 Colorado Flood	Hannah K. Huelsing Junhong Wang	During September 9-16, 2013, the Front Range region of Colorado experienced heavy rainfall which resulted in severe flooding. Precipitation totals during the event exceeded 450mm in Boulder, Colorado, 9 lives were lost, and damages to public and private properties were estimated to be over $2 billion. This study analyzes the characteristics of water vapor surrounding the event, including the	 Statistical frequency distributions for the month of September, including the

			abnormality of total column water vapor, the sources of moisture, and the relationship between water vapor and precipitation characteristics. It was found that the atmosphere was very near saturation during the duration of the event and monthly-averaged precipitable water (PW) was 30% higher than climatology for September of 2013. The frequency distribution for the first half of September of 2013 was reverse-lognormal, which confirmed that the atmosphere was near saturation during the event. Moisture fluxed into the Front Range region from both the eastern Tropical Pacific and the Gulf of Mexico and the intensity of the flux was controlled by the strength of a cutoff low over the southwestern United States and a subtropical anticyclone over the southeastern United States. Precipitation began when PW rose between 2 and 3 standard deviations above the long-term mean. However, PW did not appear to contribute to precipitation intensity throughout the event.	division of September into two halves, with 2013 GPS PW data over Boulder, 40 years of climatologically-averaged radiosonde PW data over Denver, and 10 years of climatologically-averaged GPS PW data over Boulder.
Hanlin Liu University of Houston	Relative motion between St. Croix and the Puerto Rico-Northern Virgin Islands (PRNVI) block derived from continuous GPS observations (1995-2014)	Hanlin Liu (hliu30@uh.edu), Guoquan (Bob) Wang	St. Croix is located inside the sweep of the Lesser Antilles arc and near the southeastern edge of the Greater Antillean ridge. It is separated from the Puerto Rico and the northern Virgin Islands (PRNVI) block by the Virgin Islands basin. This study illustrates out a detailed way of deriving relative motion between St. Croix and the PRNVI block using current GPS geodesy infrastructure in the PRVI region. The local geodesy infrastructure includes over 20 continuous GPS stations and a Stable PRNVI Reference Frame (SPRNVIRF). Twenty-year continuous GPS observations (1995-2014) on St. Croix indicate that the island is presently moving away from the PRNVI block toward the southeast (S55° E) at a steady rate of 1.7 mm/year. Quantitative results indicate that the Virgin Islands basin presently experiences left-lateral motion in a nearly east-west direction and it is opening in a nearly north-south	 StCroix_vs_PRVI_Vector

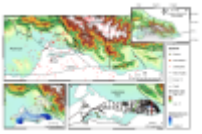
			direction. The GPS observations presented in this study also suggest the Lesser Antilles outer forearc is not moving with respect to the PRNVI block.	
Margarita Solares University of Puerto Rico Mayagüez	New GPS Constraints on Crustal Deformation within the Puerto Rico-Virgin Islands Microplate	M. Solares, A. López, P.E. Jansma, and G.S. Mattioli	GPS data from continuous and campaign stations along the Northern Caribbean Plate Boundary Zone (NCPBZ) have been used in the past to evaluate crustal deformation that has been occurring in the Puerto Rico and Virgin Islands (PRVI) microplate for the past two decades. Continuous collection of time series from GPS sites in the Caribbean are critical to characterize the rate and orientation of the deformation to infer fault locations and their potential. This research build upon previous studies in the PRVI region by employing new GPS sites installed as part of the COCONet project and augmenting time series associated to both continuous and campaign observations. The updated GPS time series allows us to redefine and set additional constraints on the existing plate kinematics model for the PRVI microplate. Of particular interest for this study is processing data from GPS campaign sites in Mona and Desecheo Islands to quantify the kinematics of the Mona Passage, the western boundary of PRVI located between Hispaniola and Puerto Rico. The occurrence of a significant M7.3 earthquake in 1918, and a geodetically-derived extension rate of 5±3 mm/yr across the numerous N-S, NE-SW oriented normal faults indicate the Mona Passage is an active feature that elevates the seismic risk of the Island. A selection of COCONet sites, including partner and core sites will be used in this study to estimate baseline length changes across the Mona Passage. All GPS data will be processed with GIPSY/OASIS II (v.6.2) using an absolute point positioning strategy with final, precise orbits and clocks from JPL. Here we present preliminary results of sites velocities in both the North America and Caribbean reference frames in	 PRVI GPS Network

			IGS08. COCONet sites in this region are reaching the appropriate maturity to be incorporated for further kinematic analysis of the PRVI boundaries and are critical to advance in our understanding of the PRVI-Caribbean tectonic configuration.	
Steeve Symithe Purdue University	Present-day Plate Deformation on Active Faults in the Caribbean and Crustal Deformation in Southern Haiti	Steeve Symithe, Eric Calais	The Caribbean plate and its boundaries with North and South America, marked by subductions and large intra-arc strike-slip faults, are a natural laboratory for the study of strain partitioning and interseismic plate coupling in relation to large earthquakes. Here we use most of the available campaign and continuous GPS measurements in the Caribbean to derive a regional velocity field expressed in a consistent reference frame. We use this velocity field as input to a kinematic model where surface velocities results from the rotation of rigid blocks bounded by locked faults accumulating interseismic strain, while allowing for partial locking along the Lesser Antilles, Puerto Rico, and Hispaniola subductions. We test various block geometries, guided by previous regional kinematic models and geological information on active faults. We also use this GPS data set to show that seismogenic strain accumulation in southern Haiti involves an overlooked component of shortening on a south-dipping reverse fault along the southern edge of the Cul-de-Sac basin, in addition to the well-known component of left- lateral strike-slip motion.	

Kevin Tankoo University of the West Indies, Mona	Tectonic Controls, Seismicity & Structural Geology of the North Coast Belt, Jamaica-	Kevin R. Tankoo & Simon F. Mitchell	Reconstructing the geotectonic evolution of the North Coast Belt is imperative for understanding the structural relationships as well as the tectonic controls for northern Jamaica and the Upper Nicaraguan Rise. A combination of geological mapping, geophysical and seismic data has been incorporated for interpretations	 Field Photograph Showing Outcrop Section In Study Area

	Contributions to Nicaraguan Rise Geology		on fault orientation and activity within the field area of north-central Jamaica. Stress orientation, fault kinematic solutions and focal plane solutions for faults have also been produced and supplements tectonic interpretations. New geological mapping has identified Pliocene Coastal Limestones and elevated reefs, Eocene-Middle Miocene White Limestone Group, Eocene Yellow Limestone as well as Upper Cretaceous conglomerates/undifferentiated volcaniclastics of the fault bounded Sunderland Inlier. Focal mechanism solutions have been derived for multiple earthquake events within the field area and concentrated on the 2 predominant fault trends: NW-SE and E-W faults. A combination of field and seismicity data highlights strike-slip, normal and reverse faults with differential slip rates and near vertical plunges across western sections of the study area. Structural interpretations have identified signatures of a Late Miocene transpressional event within Eocene-Miocene successions. Strike-slip faulted-folded successions, E-W and NE-SW trending anticlines, well defined systematic joint arrays, NW-SE and N-S striking normal faults, reverse faults and a series of E-W and NE-SW striking normal faults defines the structure of the North Coast Belt. Fault kinematic solutions yield a compressional E-W stress direction and an extensional regime propagated along NW-SE and N-S faults. The relative structures in surface geology do not display significant E-W offsets along the previously interpreted left-lateral strike-slip Duanvale Fault Zone. This research emphasizes that structural signatures of the Late Miocene transpressional event of the Northern Caribbean Plate Boundary are expressed onshore (North Coast Belt) within the White Limestone Group of Jamaica as a series of sheared anticlines and synclines. This study contributes to a new understanding on	

			faults and fault inter-connectivity in north-central Jamaica and by extension the Upper Nicaraguan Rise. Future studies will incorporate additional focal plane solutions from earthquake data, slip transfer rates and GPS data on plate motion for the Nicaraguan Rise to better understand the seismotectonics of the region. Keywords- Duanvale Fault Zone, Jamaica, Miocene transpression, North Coast Belt, seismicity, tectonics, Upper Nicaraguan Rise	
Guoquan Wang University of Houston	GPS Geodetic Infrastructure for Natural Hazards Study in the Puerto Rico and Virgin Islands Region	Linqiang Yang(1), Guoquan Wang(1), Victor Huerfano(2), Christa G. von Hillebrandt-Andrade(3), Jose A Martínez-Cruzado (4), Hanlin Liu(1)	The Puerto Rico and Virgin Islands (PRVI) are located within the complex plate boundary zone between the North American and Caribbean plates. This region faces multiple natural hazards, such as earthquakes, tsunamis, landslides, hurricanes, and flooding. The islands are part of the Greater Antilles island chain, which is one of the earliest places that employed Global Positioning System (GPS) technology in plate tectonics and natural hazards studies. A dense Continuously Operating Reference Stations (CORS) network with 24 permanent GPS stations is currently operated by a joint effort of academic, government, and local land surveying communities. This region has been regarded as one of the densest CORS coverage regions worldwide. This article summarized the current GPS geodetic infrastructure in the PRVI region, which includes three components: a dense CORS network that is open to the public, a stable local reference frame that is updated in time, and sophisticated software packages for GPS data processing that are freely available to the academic and research community. This article focused on establishing a local reference frame, the stable Puerto Rico and Virgin Islands reference frame of 2014 (PRVI14), which is essential for precisely delineating local ground deformation over space and time. Applications of the geodetic infrastructure for precise faulting, landslide, and sea-level	 1 Map showing the locations of current GPS, tide gauge and seismic stations in the Puerto Rico and Virgin Islands region.

			monitoring were illustrated in this study. According to this study, the St. Croix Island is moving away from the Puerto Rico and Northern Virgin Islands toward southeast with a steady velocity of 1.7 mm/year; the Lajas Valley in southwestern of Puerto Rico may be experiencing a north-south direction extension (1.5 mm/year) and a minor right-lateral strike slip (0.4 mm/year) with respect to the PRVI14 reference frame; the current absolute sea-level rise rate in the PRVI coastal region is about 1.6 to 2.0 mm/year. ***This article has been accepted by the journal Natural Hazards. (1) Department of Earth and Atmospheric Sciences, National Center for Airborne Laser Mapping (NCALM), University of Houston, Houston, Texas 77004, USA (2) Puerto Rico Seismic Network, Department of Geology, University of Puerto Rico at Mayaguez, Mayaguez, Puerto Rico 00680, USA (3) US National Weather Service Caribbean Tsunami Warning Program, National Oceanic and Atmospheric Administration (NOAA), Puerto Rico 00680, USA (4) Puerto Rico Strong Motion Program, Department of Civil Engineering, University of Puerto Rico at Mayaguez, Mayaguez, Puerto Rico 00680, USA	
Vanshan Wright Southern Methodist University	Neotectonics of Kingston and its Implications for Earthquake Hazards in Jamaica	Vanshan Wright, Matthew Hornbach, Lyndon Brown and Cecilia McHugh	The Enriquillo-Plaintain Garden Fault Zone (EPGFZ) has generated large (>Mw 6) but infrequent earthquakes in Jamaica (e.g. the = Mw 6.9 1692 and Mw 6.5 1907 events). The damages from these earthquakes have been focused within Kingston -- i.e. the capital city where ~1 million people live. To date, the geometric and deformational relationship between the EPGFZ and other major faults in the Kingston remain largely unconstrained. Herein we integrate seismic, coring, GPS, focal mechanism and field mapping data to identify and characterize a previously unrecognized segmented fault system within the closest depositional environment (the Kingston Harbour) to Kingston. The fault system is likely	 (a) Map shows that regional topography, geology and seismicity of Kingston and the EPGFZ. (b) Map shows the locations of the GPS and the zones within which we assume that

			a blind extension of two major faults (the Long Mountain and Cavaliers fault) that receives slip from the EPGFZ or the South Coastal Fault Zone. The faults were last active ~5000-1500 ka. During this time, the faults were accommodating strain via a complex mix of compression (structural folds) and extension (a pull-apart and fault wedge basin). The horizontal rate of motion along the hanging wall (0.7-1.4 mm/yr) is lower than the current horizontal rates of motion (5-15 mm/yr) within Kingston. Based on the length and throw of the fault, we estimate that the 2 segments of the fault are individually capable of generating a Mw 4-6.6 earthquake. Ongoing studies suggest that a Mw 4-6.6 event is likely to cause liquefaction, slope failure and tsunamigenesis along the coastline of the Harbour. In light of the new data, we conclude that Kingston remains one of the most seismically at risk locations in Jamaica and the Caribbean.	deformation is homogeneous. (c) Map shows seismic and core data collection locations.

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Appendix F: Workshop Speaker Bios

Dr. David Adams, Universidade do Estado do Amazonas
I work in atmospheric convection and thermodynamics, particularly in the Tropics, and utilize GNSS/GPS data for calculating precipitable water vapor. My Ph.D. is in atmospheric sciences from the U of Arizona. I have lived and worked in Latin America; Northeast Brazil, the Brazilian Amazon and Mexico City during the last 10 years. We created Dense GPS meteorological networks and transects in the Amazon (Manaus 2011-2012), northern Brazil (Belem 2011) and the Sierra Madre Occidental in NW Mexico (2013) to study aspects of deep convection and water vapor interactions. I am currently research faculty at the UNAM, Mexico City and an Affiliate of the Dept. of Atmospheric Sciences at the University of Arizona.

Dr. Teddy Allen, Int. Res. Inst. for Climate and Society, COCONet Science Fellow
Teddy mixes geography (BS and MA) and meteorology (PhD) to co-produce interdisciplinary human applied climate services. He recently finished his PhD from The University of Miami where his research focused on the diagnostics of Caribbean rain season onset dynamics. Allen aims to improve our understanding of the timing of the Caribbean rain season onset and the intra to interannual rainfall variability during the Caribbean early rain season and the mid-summer drought. He is also interested in studying Caribbean rainfall dynamics in the context of other regional subtropical convergence zone analogs like the Meiyu-Baiu rainfall pattern of the west Pacific. Allen is part of the International Research Applications Program team at the IRI working on the Jamaican Coffee Leaf Rust project. He is responsible for integrating information from farmer field surveys into research and applications efforts that will ultimately reduce Jamaican coffee farmer's vulnerability to coffee leaf rust outbreaks. Much of his work will also be adapted throughout the greater Caribbean. Allen also enthusiastically explores ways to visualize environmental data through web based analysis and plotting tools like the IRI Climate Data Library and the Unidata IDV. In addition, Teddy serves as the Director of Scientific Applications for the International Environmental Data Rescue Organization where he supports data rescue projects.

Dr. Juan Baez, Centro Sismológico Nacional, Chile
I have worked at the University of Concepción in Chile from 1991 in geodetic department, estimating plate tectonics with GNSS from 1992, with Bevis et al, installing, operating and processing GNSS observations. During the Maule 2010, I worked with a UNAVCO group deploying several GNSS rx (Blume et al). I did the same kind of work with GFZ in Potsdam and DGFI in Munich, Germany. Currently, I work at the Chilean National Seismological Center, at University of Chile, as a header of geodetic group. Today we have a large GNSS network installed, with some of the stations streaming observations in RTCM 3.x and other have RTX capabilities. All observations are published in a public ftp sites, due to our open data policy.

Dr. Fran Boler, UNAVCO, Inc.
GNSS Archive Manager and Project Manager at UNAVCO. Dr. Boler received her Ph.D. on Geophysics from the University of Colorado, Boulder. She has been instrumental in developing and deploying the Dataworks software package for the COCONet and other GNSS data centers. She was one of the instructors in the Dataworks workshop held on the afternoon of the 3rd day of the Fourth COCONet workshop.

Dr. John Braun, UCAR/COSMIC
Dr. Braun is a Project Scientist II in the COSMIC Program at UCAR. His research interests are focused on using GNSS signals to remotely sense atmospheric and land properties. He is the

UCAR PI for the Continuously Operating Caribbean Observational Network (COCONet). Currently he is a member of the WMO Global Reference Upper Air Network (GRUAN) GNSS PW Task Team, the International GNSS Service (IGS) Real-time Working Group, Tropospheric Working Group, and serves as a UNAVCO member representative. In 2013, Dr. Braun was the PI and co-organizer of the Pan American Advanced Studies Institute (PASI) on Atmospheric Processes in Latin America and the Caribbean: Observations, Analysis, and Impacts held in Cartagena, Colombia.

Dr. Enrique Cabral-Cano, Universidad Nacional Autónoma de México
Dr. Enrique Cabral-Cano specializes on applications of remote sensing techniques at the Universidad Nacional Autónoma de México. His research in recent years has focused on the application of remote sensing and satellite geodesy techniques for natural hazards, in particular the use of InSAR and GPS in detecting and characterizing the subsidence process and associated surface faulting in urban areas as a result of groundwater extraction. His managing experience includes the development and operation of TLALOCNet, a binational Mexico-US funded cGPS network in Mexico for solid earth and atmospheric applications.

Dr. Eric Calais, Ecole Normale Supérieure, Paris
Dr. Calais' research focuses on the kinematics and dynamics of active tectonic processes which he studies by combining observations from space geodesy and mechanical models of lithospheric deformation. He initiated and led field experiments in the Caribbean, central Asia, and east Africa to study active deformation processes at spatial and temporal scales ranging from individual earthquakes or volcanic events to the deformation of plate margins. His is also involved in research on large earthquakes in intraplate regions such as the Central Eastern U.S. and western Europe. He was science advisor for the United Nations in 2010-2012 in the aftermath of the Haiti earthquake and is currently professor and Head of the Geosciences Department at the Ecole Normale Suprieure in Paris, France.

Dr. Charles Estabrook, National Science Foundation
Dr. Estabrook is the Program Manager for the Americas Program in the Office of International Science and Engineering (OD/OISE) at the U.S. National Science Foundation. Previously, Dr. Estabrook was a Program Manager in the Earth Sciences Division EarthScope Science Program. Dr. Estabrook's program at NSF has provided partial support for the COCONet project and the COCONet Fourth Workshop awards.

Mr. Karl Feaux, UNAVCO, Inc.
GPS Operations Manager for the Plate Boundary Observatory (2003-present) and project manager at UNAVCO. Karl received his B.S. in Aerospace Engineering from Auburn University and his M.S. in Aerospace Engineering from the University of Colorado, Boulder. He Karl is a Co-PI for the COCONet project and Co-PI on the COCONet 4th Workshop awards from NSF.

Dr. Alexander Holsteinson, Univ. Nacional Pedro Henriquez Ureña (UNPHU)
Universidad Autonoma de Santo Domingo professor, Trimble Geospatial Dominican distributor for Trimble CORS products specialist, Trimble GNSS RTK products specialist, Trimble Business Center specialist, Civil Engineer with postgraduate in ports and coastal engineering/construction management Host, and I manage and operate RDSD, RDMI, RDHI, RDSF, RDSJ, RDBO, RDF2, RDMA COCONet-cooperative GNSS sites.

Ms. Ophelia George, University of South Florida, COCONet Science Fellow
I am an aspiring volcanologist in the final year of my PhD at the University of South Florida. My research is primarily focused on the long-term evolution of magmatic systems and the generation of probabilistic volcanic hazard maps. This research uses a variety of geophysical data streams and techniques including seismology, geodesy, numerical and statistical modeling and potential fields analysis (gravity and magnetics). I have been working on combining geophysical data with statistical models of future volcanism in Dominica.

Dr. M. Hernandez Gonzalez, Instituto de Oceanología, Cuba
Dr. Hernandez Gonzalez is responsible for the sea-level monitoring network in Cuba.

Dr. John Labrecque, Global Geodetic Observing System, Univ. of Texas at Austin
John LaBrecque is the Lead, Geohazards Monitoring Focus Area Global Geodetic Observing System. John L. LaBrecque is vice chair of the IUGG GeoRisk Commission and leads the Geohazards Monitoring Focus Area of the Global Geodetic Observing System. John LaBrecque is a 1977 graduate of Columbia University and a former senior research scientist of Columbia's Lamont-Doherty Earth Observatory where he conducted geophysical research in global tectonic evolution and geopotential fields using ocean surveying and drilling ships, aircraft, and satellites including the early evaluation of GPS for geophysical research. In 1993, Dr. LaBrecque joined NASA's Solid Earth Program where he encouraged the development of ground and spaceborne GNSS applications for environmental and geohazards measurement. Dr. LaBrecque served as program scientist for several NASA missions including the Shuttle Radar Topography Mission, the GRACE gravity missions, and numerous international GPS occultation missions including SAC-C, CHAMP, Oersted, and COSMIC. Dr. LaBrecque is the 2009 recipient of the Golden Medal of Merit from the Institute of Applied Astronomy of the Russian Academy of Sciences, and the 2013 recipient of the American Geophysical Union Edward A. Flinn III Award. Dr. LaBrecque retired from NASA in May, 2014. In July, 2015 John assumed leadership of the Global Geodetic Observing Systems (GGOS) Geohazards Monitoring Focus Area. The application of GNSS unique capabilities to Tsunami Early Warning.

Dr. Alberto Lopez, University of Puerto Rico, Mayagüez
Born and raised in Puerto Rico. BS ('97) and MS (2000) from the University of Puerto Rico at Mayaguez. PhD ('06) from Northwestern University and USGS Mendenhall Postdoctoral Fellow from 2006-08. Moved back to Puerto Rico on October 2008. Became Assistant Professor at University of Puerto Rico - Mayaguez Campus from February 2009 until June 2011. Associate Professor since July 2011, and Researcher at the Puerto Rico Seismic Network. Currently working on crustal deformation and seismicity of the Northeastern Caribbean and tsunami modeling of the Caribbean region.

Mr. Lloyd Lynch, Seismic Research Centre, University of the West Indies
Lloyd Lynch is the instrumentation engineer at the Seismic Research Centre, UWI. As a trained electronics engineer, his core responsibility at the SRC-UWI is to design and maintain a network of over eighty monitoring instruments that span the anglophone territories of the Eastern Caribbean. Linked by satellite and Internet communications to the Centre at St. Augustine, the network provides surveillance of earthquake and volcanic activities as well as tsunamis. He has played the leading role in the development of this monitoring infrastructure, including a sub-regional monitoring network for the Kick' em Jenny volcano and also in the fashioning of an emerging Caribbean Tsunami Warning System. He holds a B.Sc in Electronics and Computer Science from the UWI. He is a professional member of the American Geophysical Union. He is the author of numerous publications and conference presentations with the theme of Disaster Risk Reduction.

Dr. Glen Mattioli, UNAVCO, Inc.
Glen S. Mattioli is the Director of Geodetic Infrastructure (GI) at UNAVCO, Inc., which operates the Geodesy Advancing Geosciences and EarthScope (GAGE) Facility for the NSF, with additional core support from NASA. Mattioli also is an adjunct professor of Earth & Environmental Sciences at the University of Texas at Arlington having transitioned to a full-time position at UNAVCO in 2015. The GI program at UNAVCO is responsible for the planning, construction, operation and maintenance, and data flow of geodetic networks, including the EarthScope Plate Boundary Observatory, which spans the North American continent, COCONet throughout the Caribbean region, the recently funded TLALOCNet in Mexico, and POLENet in Greenland and Antarctica. In addition, the GI program supports NSF, NASA, and community PIs with planning, logistics, engineering, and GPS and TLS imaging instrumentation, as requested. Mattioli received his B.A. from the University of Rochester in geology, and his M.S. and Ph.D. from Northwestern University, in geological sciences, before completing post-doctoral fellowships at Caltech and UC Berkeley. Mattioli has been doing tectonic and volcanic geodesy across the Caribbean since 1994. He has over 275 total publications, including 64 peer-reviewed articles. He is the Project Director and a Co-PI for the COCONet project and PI on the COCONet 4th Workshop awards from NSF.

Dr. Chuck Meertens, UNAVCO, Inc.
Chuck Meertens is Director of Geodetic Data Service Group at UNAVCO that supports COCONet and other projects around the world. Meertens manages the GDS team of software and data engineers, data technicians, and other IT staff who provide data services (operations, data and metadata management, distribution, products, and archiving) for an extensive global network of thousands of GPS/GNSS and borehole geophysics sensors (strainmeter, seismometer, tiltmeter, pore pressure) as well as data archiving of terrestrial laser scanner surveys and acquisition of data from satellite Synthetic Aperture Radar sources. He is also a member of the Executive Committee of the International GNSS Service. Dr. Meertens received his B.A. in Geology and Physics from UC Santa Barbara, and his M.S. and Ph.D. from the University of Colorado, Boulder. He his published widely in geophysics and applications of GPS geodesy and was recently awarded the 2015 Ivan I. Mueller Award for Distinguished Service and Leadership from the American Geophysical Union.

Dr. Hector Mora-Paez, Colombian Geological Survey
Researcher at the Colombian Geological Survey. Chief of the GNSS GeoRED Project, research project focused in geodynamics studies in Colombia. Dr. Mora-Paez is a member of the Fourth COCONet Workshop organizing committee and the COCONet Working Group.

Dr. Marino Protti, OVSICORI-UNA
Marino Protti (a) Professional Preparation Nov. 2015: Completed the coursework for a Masters Program on International Relations and Diplomacy (working on thesis). Universidad Nacional, Costa Rica. June 1994: Ph.D. in Earth Sciences (Geophysics). University of California, Santa Cruz. USA. June 1991: M.Sc. in Earth Sciences University of California, Santa Cruz. USA. August 1984: Post-degree in Seismology International Institute of Seismology and Earthquake Engineering Tsukuba, Japan. August 1983: BS. in Geology Universidad de Costa Rica Costa Rica (b) Appointments Sept.., 1984-present Researcher at the Costa Rica Volcanological and Seismological Observatory, Universidad Nacional, Costa Rica. Dec., 1986-Apr., 1988 Elected Director of the Costa Rica Volcanological and Seismological Observatory, Universidad Nacional, Costa Rica. Jun. 1997-May 2002 Re-elected Director of the Costa Rica Volcanological and Seismological Observatory, Universidad Nacional, Costa Rica. (c) Membership in academies and societies Secretary of the Costa Rica Academy of Sciences

Member of the American Geophysical Union Member of the International Network of Academies of Sciences for Human Rights President of the Costa Rica Local Committee of International Union of Geodesy and Geophysics Costa Rica National Correspondent of IASPEI President of the Latin American and Caribbean Seismological Commission (LACSC) of IASPEI. (d) Synergistic Activities.

Dr. Mike Rost, UNAVCO, Inc.
Developer of the Dataworks Downloader for use in COCONet Support. He was one of the instructors in the Dataworks workshop held on the afternoon of the 3rd day of the Fourth COCONet workshop.

Dr. Andrea Sealy, Caribbean Institute for Meteorology and Hydrology
Andrea Sealy is a Meteorologist/Lecturer at the Caribbean Institute for Meteorology and Hydrology (CIMH) and a Lecturer in Meteorology at the University of the West Indies, Cave Hill Campus, Barbados. She obtained a B.S. in Meteorology from Jackson State University, a M.S. in Meteorology from The Pennsylvania State University and a Ph.D. in Atmospheric Science from Howard University. She then went on to the National Center for Atmospheric Research (NCAR) in Boulder, Colorado as an Advanced Study Program Postdoctoral Fellow in the Terrestrial Sciences Section of the Climate and Global Dynamics Division. Her Ph.D. work examined the impact of soil moisture initialization on West African rainfall using the Regional Spectral Model. For her postdoctoral work at NCAR, she worked closely with Dr. Natalie Mahowald in studying the interaction of dynamic vegetation with Saharan dust and Sahel rainfall in the Community Atmosphere Model (CAM). Currently she is facilitating the CIMH's involvement in the World Meteorological Organization (WMO) Sand and Dust Storm Warning Advisory and Assessment System (SDS-WAS) and the Caribbean Aerosol-Health Network as well as coordinating the CIMH Dust and Air Quality Forecasting Centre which uses WRF/Chem model to run dust and air quality forecasts for the Caribbean region. She has also worked on analysis of data from the Japanese super high resolution GCM during a visit to the Meteorological Research Training Institute (MRI) in Tsukuba, Japan.

Dr. Stuart Wier, UNAVCO, Inc.
Dr. Wier is a software engineer in the UNAVCO GDS group. He is the principal GSAC developer and instrumental in the development of Dataworks. He was one of the instructors in the Dataworks workshop held on the afternoon of the 3rd day of the 4th COCONet workshop.

Mr. Vashan Wright, Southern Methodist University, COCONet Science Fellow
A doctoral student in Geophysics at Southern Methodist University, Dallas. I have a Bachelor's degree in Geology from Calvin College. In my research, I use a combination of GPS data, seismic reflection profiles and gravity cores to understand the neotectonic and paleoseismic history of Jamaica. As a native of Jamaica, I am familiar with the environment and my work will help prepare residents for future earthquakes in Jamaica.

Dr. Jorge Zavala, Universidad Nacional Autónoma de México
Scientist at the Centro de Ciencias de la Atmosfera at UNAM, Mexico. Research in the areas of Ocean-Atmosphere Interaction, Gulf of Mexico Dynamics and Numerical Modeling of the atmosphere and the oceans. He has been responsible for the UNAM sea-level network since late 2006.

Appendix G: Tide Gauge Data Highlight

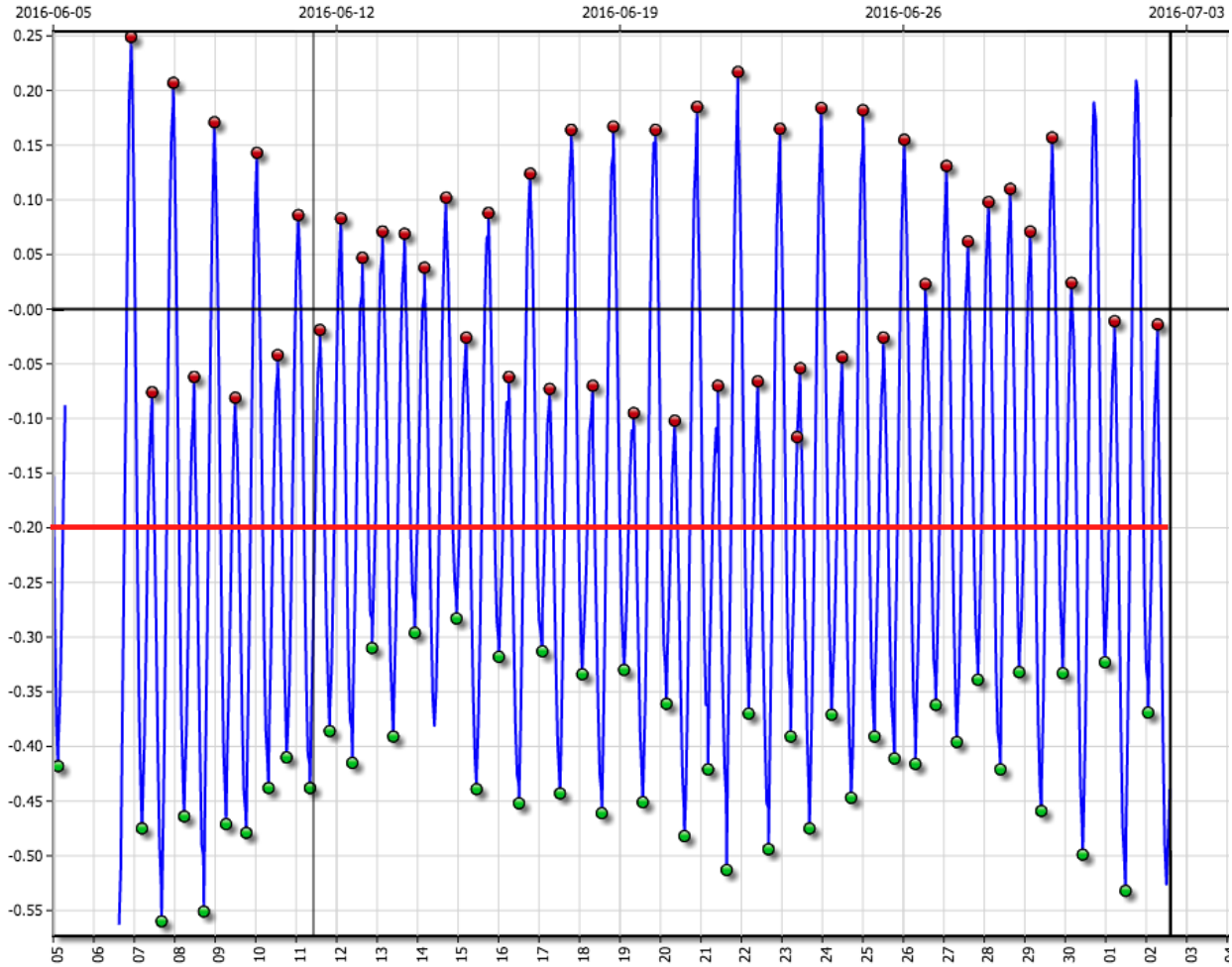

Figure G1. Tide gauge chart from Miches, Dominican Republic showing the black line Mean Sea Level is equal to ±0.000m elevation derived from a GNSS static session with EGM2008 global geoid model and the MSL red line computed from a tide gauge sensor, where this vertical discrepancy along the coast of each Caribbean country must be determined to calibrate the geoid model. Vertical geoid model delta for this station is -0.20 m.

Appendix H: COCONet Messaging for Effective Outreach

Effective outreach and communications can be used to support network sustainability by addressing the following key issues:

- Increase user base
- Gain monetary, in-kind, and policy support for the network
- Decrease station vandalism
- Invest in the future by informing and inspiring the next generation of policymakers, scientists, and educators

The key audiences for these objectives include scientists from multiple disciplines, emergency response personnel, the private sector including agriculture, surveyors, large resort companies, and industry, the weather forecasting community, media, policymakers and government agencies, other potential partner agencies, international organizations such as the IOC, United Nations, and World Bank, specialty groups such as Rotary International and Geoscientists without Borders, civil defense, the general public, and youth.

While messaging customized for each of these groups is important, common messaging related to COCONet also includes:

- COCONet addresses complex hazards, as well as solid earth and atmospheric processes; societal resilience is based on knowledge of hazards and risks
- COCONet provides tools and opportunities for economic advancement and education, facilitates development, and helps mitigate losses due to natural hazards
- The cost of maintenance is a fraction of the cost of establishing the network; the built network exists and there is already a build community in place
- Careers in the geosciences are accessible and offer benefits to society as well as to the individual
- The applications of the data produced by COCONet are becoming more diverse and essential
- The COCONet network functions on multiple scales, providing important information locally, regionally, and globally
- COCONet data are open access, free, and standardized
- Additional messaging should align with the priorities of elected officials

Appendix I: Workshop Press Release (English version)

COCONet Press Release, 5 May 2016

An international organization of scientists, engineers, and educators met at the Barceló Bávaro Beach Resort in Punta Cana, Dominican Republic to discuss an earth observation network in the Circum-Caribbean. The network is called the Continuously Operating Caribbean GPS Observational Network or COCONet. COCONet consists of more than 100 sites throughout the Circum-Caribbean. These sites provide geodetic (precise positions of the earth surface and changes in the earth surface), meteorological and sea level measurements. These measurements are utilized for research, risk resiliency, communication, navigation, natural resource management and security.

COCONet is critical for earthquake early warning, tsunami early warning, hurricane tracking, monitoring volcanic unrest and many other hazards. It was noted that there have been 75 tsunamis in the Caribbean over the past 500 years and COCONet can help with preparedness, warning and response to earthquake- or volcano- generated tsunamis.

Research using COCONet data helps to define plate motions throughout the Caribbean region and determine earthquake hazards. For example, data and models of the fault that caused the 2010 Haiti earthquake, defines the potential for future earthquakes in Hispaniola and Jamaica.

COCONet is valuable for other stakeholders beyond research. For example, surveyors, farmers, engineers, emergency responders and many others use the data from COCONet for their daily work. Alexander Holsteinson from UNPHU in the DR and a COCONet partner works with many members of the private sector in the DR to share the data from the network. Alex said, "It was a very successful conference thanks to the generous support of the United States National Science Foundation (NSF) and the Dominican Republic was honored and delighted to host this COCONet Workshop".

79 people from 28 countries and 40 institutions participated in the three-day conference from 3-5 May 2016. The conference was a great success for international collaboration, advancing research, and advancing resiliency, security and economic development. The participants enjoyed the wonderful hospitality of the Barceló Bávaro Beach Resort and the beautiful environment of the Dominican Republic.