COCONet EAR 1042906/9 Quarterly Report

December 2013 - February 2014 (FY2014-Q2)

SUMMARY

This quarterly report covers COCONet project (EAR-1042906/EAR-1042909) activities for the time period from December 1, 2013 to February 28, 2014. COCONet is a Collaborative Research project between UNAVCO (EAR-1042906) and University Corporation for Atmospheric Research (UCAR) (EAR-1042909) awarded on September 14, 2010. The project is under the direction of M. Meghan Miller, as PI, with Co-PIs, Karl Feaux, Glen Mattioli, and Guoquan Wang. Dr. Glen Mattioli is acting as Project Director in his role as Director of Geodetic Infrastructure at UNAVCO and Dr. John Braun is the UCAR PI.

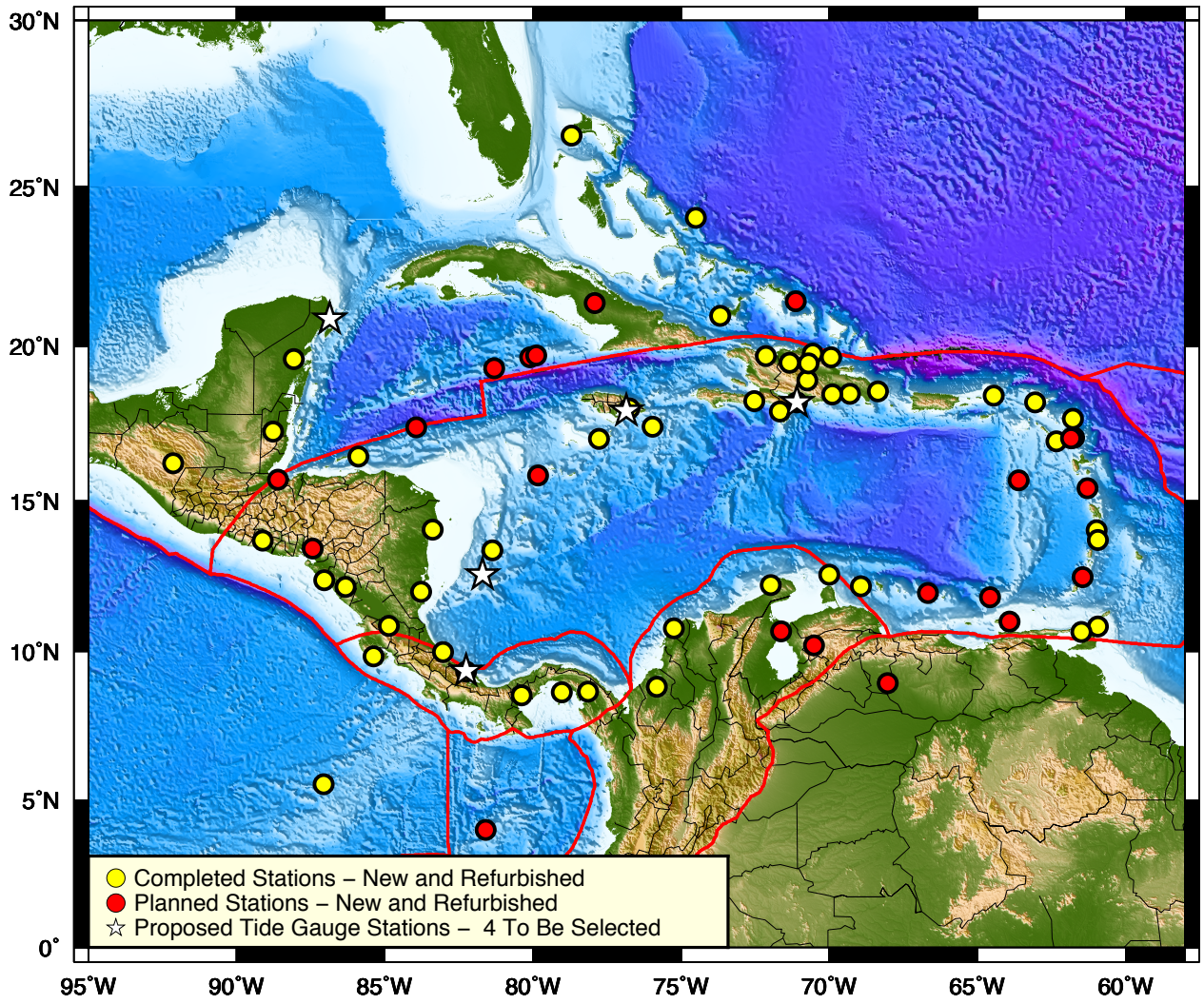

Figure 1. The current COCONet siting plan. Yellow dots represent the 49 completed COCONet stations (new and refurbished) and red dots represent the 21 planned stations (new and refurbished). The white stars represent the proposed tide gauge locations (with 2 additional GPS sites per location). The existing GPS stations (61+), which either already or are soon to be delivering data to the COCONet archive, are not shown in this map.

To date, UNAVCO engineering personnel have performed site reconnaissance at 70 locations in 26 countries, submitted land use permits for 70 sites, received permits for 67 sites, and currently have 49 stations installed (Figure 1, yellow dots). Reconnaissance at the tide gauge locations will begin in April 2014.

Two significant issues remain unresolved for COCONet at the time of this quarterly report. The first is the continuing political unrest in Venezuela and its impact on the planned installations there for both the COCONet sites (n=4) and the temporary sites (n=6) for the associated CU project (EAR-1215782 "Strain Partitioning in Northwest Venezuela: Potential for a Great Quake," PI R. Bilham). The materials for these two projects are being shipped together through Department of State diplomatic pouch to the US Embassy in Caracas; the combined weight for this shipment is close to 7,000 lbs. In order to assure that the materials will be available for the UNAVCO engineers to install upon their arrival in Venezuela, additional packaging care, shipping consolidation, and negotiations with embassy staff had to be undertaken, which has delayed the shipment. In addition, our local partners at Simon Bolivar University and FUNVISIS, were concerned about potential problems in the field for both US and Venezuelan technical staff and thus urged UNAVCO to delay shipment as well as travel plans to deploy to Venezuela. The situation on the ground has improved somewhat and we now believe that the installations will occur in the upcoming quarter. The second significant unresolved issue is the ongoing problems with cellular communications from COCONet sites around the Caribbean, which in turn impacts GPS-Met data return and latency. UNAVCO staff are continuing to investigate new technologies, and working together with our local contacts and partners, are now making significant improvements in COCONet station data communications. As part of this effort, we are developing processes to track these important metrics and provide these to the NSF and users of COCONet observations. We intend to have these metrics available for FY2014Q3.

COCONET HIGHLIGHT: ST. LUCIA INSTALLATIONS

UNAVCO engineers in collaboration with the University of the West Indies (Trinidad) and St. Lucia's Ministry of Physical Development, Housing and Urban Renewal installed GPS/Met stations at CN04 and CN47 on the island of St. Lucia. CN47 is located near the center of the Lesser Antilles arc. Since there is only one COCONet site (contributing) located immediately to the north on Martinique (LMMF) and none to the south on St Vincent, CN47 will provide important data for this eastern region of the Caribbean plate.

CN47 is located near the Vieux Fort lighthouse, which is the southernmost point of St. Lucia. Surrounded on three sides by a 200-foot cliff, CN47 experiences 30 mph winds on a daily basis. Exposed basaltic bedrock, 24-hour security, and clear sky view make CN47 an ideal location for a COCONet station. The data communications telemetry consists of a radio shot to the local cable company office located in the town of Vieux Fort.

St. Lucia's Ministry of Physical Development (Housing and Urban Renewal) has expressed interest in using the GPS data for surveying purposes. Because this COCONet partner was instrumental in getting COCONet equipment through customs, UNAVCO engineers will upgrade this site to enable RTK early next quarter to support local surveyors. Similar to other COCONet installations, CN47 will provide raw GPS data, GPS-PWV, surface meteorology measurements, and standard GPS (position and velocity) data products generated by the PBO Analysis Centers (NMT and CWU) and combined and QCed by the ACC at MIT.

During the same trip, CN04 was installed at St. Lucia's National Emergency Management Office (NEMO) in Castries. CN04 is another superior location for a COCONet station, with excellent security, good sky view, and an engaged site contact. NEMO will benefit from the data collected from the surface met observations, a real plus for this COCONet partner because St. Lucia can experience hurricanes and other severe tropical storms. CN04 is connected directly to a router inside the NEMO building; accordingly, data flow should be consistent and also have very low latency, both of which are requirements to support local weather prediction, hazard mitigation, and numerical weather modeling at the regional scale.

Figure 2. CN47 above the town of Vieux Fort, St Lucia.

OPERATIONS SUMMARY

A number of planning, operational, and logistical tasks were completed during the last quarter that position the UNAVCO engineering team to bring the construction phase of COCONet to completion, including:

- In February 2014, Andre Basset visited two COCONet stations (CN09 and JME2) in Haiti. The purpose of this trip was to upgrade the cellular modems in order to bring these two stations online. The stations are currently operational and are delivering data to the UNAVCO archive.
- Five new COCONet stations were installed, including Punta Cana (CN05) in the Dominican Republic, the Bahamas (CN13 and CN14), and St. Lucia (CN04 and CN47).
- Station materials and equipment were recently shipped to Grenada enroute to Carriacou. This site installation will be completed sometime in March 2014 with collaboration and coordination with the University of the West Indies - Seismic Research Center.
- Equipment was prepared and tested for shipment to Venezuela. UNAVCO personnel are currently preparing all the required documents to use the DoS diplomatic pouch for shipment into the country. Efforts to complete the COCONet installations have been delayed because of political unrest over the past several months in Venezuela. The safety of UNAVCO staff during installations and the collaboration with our partners in Venezuela are paramount in evaluating the timing of this large shipment and final schedule for installation of the sites. We now are confident that the new COCONet stations and the temporary stations for R. Bilham's CU project (EAR-1215782) will occur during the next quarter.
- A memorandum of understanding and permit were completed with the Government of St. Lucia for CN47.
- A memorandum of understanding was drafted and sent to the Grand Turk authorities for GTK0.
- The new COCONet site in Punta Cana, Dominican Republic (CN05) was permitted in February 2014 with the Punta Cana Corporation.

Work planned for FY2014-Q3 includes:

- PBO AK Region Field Engineer Ellie Boyce will install meteorological instruments at six existing sites in Guatemala. This will provide access to GPS-Met data from the IGN network in Guatemala to the entire COCONet community.
- Three meteorological instruments will be installed at existing CORS stations in the Cayman Islands. GPS-Met data will be absorbed into the COCONet processing and archive systems (see above).
- John Braun (UCAR PI) and Jim Normandeau (COCONet Project Manager) plan to install CN16 in Camaguey (Cuba) in April 2014; this will complete a key project milestone and be the first such installation of a scientific instrument in Cuba with open data access.
- COCONet engineers will install CN46 on Carriacou in Grenada in late March or early April 2014. Materials and instruments have been shipped from Boulder and should

arrive and clear customs within two weeks.

- Reconnaissance trips to evaluate potential tide gauge installation locations in Mexico and Jamaica have been scheduled for April 2014. In addition, evaluation and testing of tide gauge instrumentation and associated data logging systems will be completed in Boulder prior to the deployment of the first tide gauges.

Additional details related to COCONet field activities this quarter may be found in Table 1 below.

	Cumulative	**Since Previous Quarter**	**Details From Current Quarter**
Station Recons	70	7	
Permits Submitted	70	9	
Permits Accepted	67	9	CN46 (Carriacou), CN26 (Guatemala), CN05 (Punta Cana), and remaining refurbished
Stations Installed New / Refurbished	37 new 12 refurbished	5 new 0 refurbished	CN47, CN04 (St. Lucia), CN13, CN14 (Bahamas), CN05 (Dominican Republic)
Maintenance Visits	24	4	Cellular upgrades at 2 stations in Haiti and CN10 and CN11 (Jamaica)

Table 1. COCONet Status: Tasks completed to date and in FY2014-Q2.

TIDE GAUGE NETWORK

The tide gauge components have been ordered from Sutron, Inc., with expected delivery to UNAVCO HQ in March 2014. Once the instruments and associated components are received, UNAVCO engineers will begin testing and configuration. A standard tsunami warning "setup" was ordered consisting of primary acoustic radar sensor, pressure sensor backup, and a tide gauge data logger with GOES telemetry as well as an IP interface for co-location with COCONet GPS instrumentation and data flow. This instrument configuration was recommended by several experts in the tide gauge community, including Christa G. von Hillebrandt (NOAA and the Puerto Rican Seismic Network), Mark Merrifield (U of HI), and Doug Wilson (Caribbean Wind LLC).

Reconnaissance trips are scheduled for March 2014 to Puerto Morelos, Mexico and Kingston, Jamaica. In-country organizations have agreed to provide installation assistance and long-term support at both locations. Additional discussions are ongoing regarding the final location of the two additional upgrade stations.

DATA SUMMARY

The Port-of-Spain, Trinidad planning meeting resulted in 50 target locations for new stations, 15 targets for refurbished stations, and at least 61 existing stations for integration into the COCONet network. After a number of changes approved by the COCONet Siting Committee and COCONet Working Group (see http://coconet.unavco.org/project-management/project-management.html), the current siting plan calls for 50 new stations, 20 refurbished stations and at least 61 existing stations to be incorporated into the COCONet data archive. The COCONet data plan also calls for at least 10 stations to provide high-rate, low-latency (1 Hz, <1 ms) or real-time GPS data streams.

UNAVCO currently provides a suite of geodetic data products from the COCONet GPS stations. COCONet stations are mostly configured for 15-second hourly downloads, with some exceptions for sites that have BGAN satellite data communications infrastructure in place. Level 1 GPS data products include quality-checked RINEX files. At the time of this report, Level 1 GPS data are available from 94 COCONet stations (includes new, refurbished, and existing stations). Level 2 GPS data products include station position solutions, station position time series, station position velocity estimates, and tropospheric delay parameters. Level 2 products are produced by the Plate Boundary Observatory (PBO) Analysis Centers (ACs) in collaboration with the Analysis Center Coordinator (ACC), and are identical in format to corresponding PBO data products. At the time of this report, Level 2 GPS products are available from 90 COCONet stations (includes new, refurbished, and existing stations). Note: data products may not be available from all stations installed at the time of this report due to unresolved communication issues or other reasons, such as the station being recently built and the data not yet being available for archiving or analysis.

Currently, 39 COCONet stations are configured to deliver high-rate, low-latency (1 Hz, < 2 s) data streams in real-time via the Networked Transport of RTCM via Internet Protocol (NTRIP). This exceeds a project goal outlined in the project proposal, which called for at least 10 stations to deliver high-rate, low-latency data in real-time.

BUDGET AND SCHEDULE

The current schedule includes at least 50 new station installations, 20 refurbished stations, and contribution of data from at least 61 existing stations. The installation schedule was extended to four years, given the delay in starting the field component of the project, the development of the Trinidad siting plan, and other approved changes.

While the project has been running slightly behind the schedule for station installations (according to the August 2012 rebaseline), the original installation goals of COCONet (50 new stations) have mostly been met (Figure 3). In FY2014-Q2, significant progress was made in station installations, with 5 new installations completed as well as progress in tide gauge station logistics and planning. The projection for the next quarter is to install or upgrade at least 6 new/refurbished stations. The current construction estimate for the end of FY2014 will be 60 new/refurbished stations, including 1 tide gauge station in Cancun, Mexico.

COCONet expenditures are over $4.034M through the end of February 2014, giving the project a slight budget under run to date. The cost variance (10%) is consistent with the schedule variance. Tuition for the COCONet Fellowships was paid in the last quarter, which helped to reduce the cost variance. With most of the site permits obtained, the riskiest part of the construction project is now coming to an end. Remaining station installations are expected to continue into FY2015, but by then, COCONet management will be able to focus on Venezuela, including Aves Island, along with the tide gauge installations.

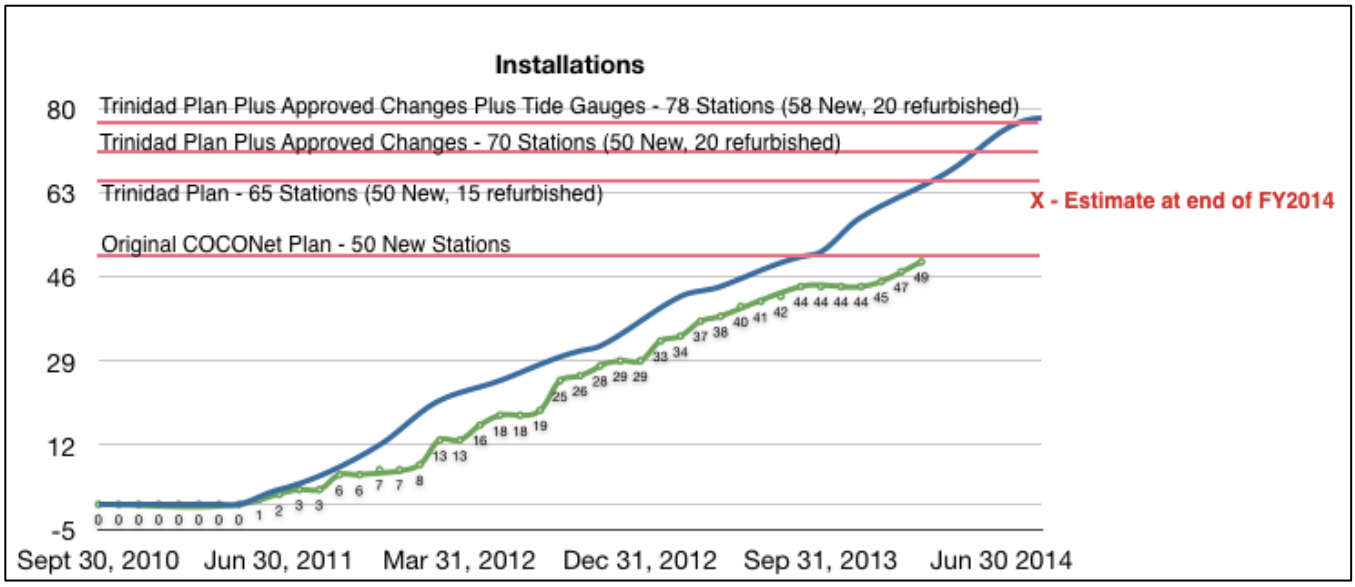

Figure 3. COCONet Installations: Plan (blue line) vs. Actual (green line).

EDUCATION, OUTREACH, AND COMMUNITY ENGAGEMENT

The COCONet project continues to expand and advance outreach activities to achieve the objectives of the project and ensure the broader impacts to science and society.

Regional Data Centers

UNAVCO staff met with representatives of the Caribbean Institute for Meteorology and Hydrology (CIMH) who will host a one of the two COCONet regional mirrors (RM), the Nicaraguan Institute for Terrestrial Studies (Instituto Nicaraguense De Estudios Territoriales, INETER) who will host the other regional mirror and the Colombian Geological Survey, Center for Processing and Analysis of Geodetic Data who will host a regional data center (RDC), to discuss final requirements and roll-out plans. These plans are now under review at the host institutions. We anticipate that the RMs and the RDC will be operational in the upcoming quarter.

COCONet in the News and Related Publications

COCONet-related work was highlighted in many news stories in late 2013 and early 2014. Below is a summary of a few media highlights.

There were several stories about using geodetic measurements to anticipate the 5 September 2012, M7.6 Nicoya earthquake (two stories are linked below). These stories were related to a December 2013 publication, Protti, M., V. González, A.V. Newman, T.H. Dixon, S.Y. Schwartz, J.S. Marshall, L. Feng, J.I. Walter, R. Malservisi, and S.E. Owen (2013), Nicoya earthquake rupture anticipated by geodetic measurement of the locked plate interface, Nature Geoscience, DOI: 10.1038/NGEO2038. UNAVCO prepared a Science Snapshot about these results and it is available on the UNAVCO website.

Scientists Anticipated Size and Location of 2012 Costa Rica Earthquake, 22 December 2013, Brett Israel, *Science News.*

GPS Helped Forecast 2012 Earthquake, 26 December 2013, Becky Oskin, *LiveScience.*

An article in EOS, Transactions of the American Geophysical Union entitled “Mexican GPS Tracks Convection From North American Monsoon,” (Adams et al., 18 February 2014, *Eos Transactions, American Geophysical Union)* described efforts to track the North American Monsoon with 10 new GPS/meteorological stations and 7 existing SuomiNet GPS sites in the southwestern border of the United States and the northwestern edge of Mexico. The work will help to understand atmospheric processes and track climate and weather precipitated by the North American Monsoon. COCONet supports and enhances such studies while leveraging partnerships and limited resources.

Geographers studying the interaction of science and policy in relation to the hazards of the Soufriere Hills Volcano on the Caribbean island of Montserrat published a paper on their findings in November 2013 (Donovan, A. and C. Oppenheimer, 2013, Science, policy and place in volcanic disasters: Insights from Montserrat, Environmental Science & Policy, DOI: 10.1016/j/envsci.2013.08.009). Although this study ended in 2010 before COCONet was fully established, it is relevant to current and future interactions between science and policy related

to the existing CALIPSO GPS network in Montserrat (Mattioli et al., 2004) and elsewhere in the Caribbean. A link to the related news story is below.

Caribbean case study reveals how to manage volcano risk, 23 December 2013, Maria Elena Hurtado, *SciDev.Net.*

UCAR UPDATE

The UCAR/COSMIC program is participating in COCONet under support from NSF grant (EAR-1042909). UCAR/COSMIC produces continuous estimates of atmospheric precipitable water vapor (PW) using a heterogeneous network of GNSS stations, including those stations that are part of COCONet. These data are produced and distributed through the Suominet (www.suominet.ucar.edu) web portal as well as with the local data management (LDM) system. In an effort to make COCONet met data more widely available to the global atmospheric science and numerical weather modeling communities, COCONet data and derived data products are now being incorporated into the World Meteorological Organization's (WMO) Global Telecommunications System (GTS). The COSMIC group at UCAR has the ability to create 'BUFR' files, which would include PI Braun's estimates of PWV and temporally averaged surface met data (over the same epoch as the PWV), for delivery to the WMO GTS. Braun is currently in negotiations with appropriate NOAA staff to provide PWV products for all COCONet sites.

An abstract from the Fall AGU Annual Meeting in San Francisco entitled "The Assessment and Validation of Global Analysis and Reanalysis Products within the Broader Caribbean from the Continuously Operating Caribbean Observational Network (COCONet)," by Braun, J and T. Van Hove, Abstract A53B-0167 presented at 2013 Fall Meeting, AGU, San Francisco, Calif., 9-13 Dec. is reproduced below.

> The Continuously Operating Caribbean Observational Network (COCONet) is a collaborative project to create an international network of Global Navigation Satellite System (GNSS) stations in the Caribbean for natural hazards research. Atmospheric data products generated from COCONet include estimates of column integrated tropospheric water vapor, precipitation, as well as measurements of surface temperature, relative humidity, pressure, and horizontal winds. Observations from this project are expected to be useful in studying water vapor variability in the related to ocean-atmosphere coupling, transport of moisture, and precipitation. Global analysis and reanalysis activities require validation with independent observations to properly identify errors and biases within their data products. The distribution of COCONet stations across the Caribbean basin allows for a robust evaluation of existing atmospheric reanalysis products. Stations along the boundary of the Caribbean Sea are important for regional moisture studies; North-South transects, on both the eastern and western edges, can measure differences in moisture transport from low level jets into the mid-latitudes; and data collected from small and large islands reveal the interaction between the

ocean, land, and atmosphere. This presentation will focus on the comparison of COCONet derived atmospheric observations with GFS final, ERA-Interim, and MERRA analysis products. Specific emphasis will be given to the water cycle in the Caribbean.

PROJECT CONCERNS

Venezuela Installations – Political unrest in Venezuela is making the installation of COCONet stations difficult and causing shipping and scheduling delays. Concerns include safety for UNAVCO engineers as well as the ability to use the Diplomatic Pouch Service through the US State Department for the large volume and weight of the shipment. **Risk mitigation**: *Shipping* - UNAVCO will continue to work closely with the US State Department to determine the best way to ship materials and equipment into Venezuela. *Safety* – COCONet Project Manager J. Normandeau has been carefully monitoring developments on the ground and is in close contact with our local partners and staff at the US Embassy in Caracas. The COCONet PI team will continue to develop our relationships with partners at FUNVISIS and Simon Bolivar University. One option currently being considered is to provide training to engineers and technicians from these institutions on UNAVCO best practices for station installation techniques. Once trained, these engineers could install the stations in Venezuela without the need for UNAVCO personnel to be onsite. This training began in 2013 when engineers from FUNVISIS and SBV assisted PBO personnel in the installation of GPS monuments as part of multi-monument change order for the PBO. In March 2014, an engineer from FUNVISIS and a student from SBV came to Broomfield, CO and participated in the UNAVCO Science Workshop.

Project control: Much of the remaining work, especially in the West Indies, Venezuela, and Cuba relies heavily on local collaborators. **Risk mitigation**: COCONet management will make these stations a priority in the next quarter. Collaborations will be developed and strengthened in order to continue to make progress in the installation of these stations and close out the installation phase of the COCONet project.