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CONTINUOUSLY OPERATING CARIBBEAN GPS OBSERVATIONAL NETWORK

2011 NETWORK OPERATORS MEETING REPORT

Installation at Curacao Department of Meteorology, with the radiosonde launch facility in the background.

The COCONet workshop was supported by NSF-EAR Instrumentation and Facilities Award #1042906. Supplemental contributions were made by NSF-EAR Education & Human Resources, and the Tectonics program; NSF-AGS Atmospheric and Space Sciences; and NSF-OISE, the Office of International Science and Engineering.

The COCONet project was awarded by the National Science Foundation to UNAVCO and UCAR with formal participation by Purdue University and University of Puerto Rico. Its success hinges on engagement and participation by an international community of scientists with interests in the Caribbean region and geodesy.

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CONTINUOUSLY OPERATING CARIBBEAN GPS OBSERVATIONAL NETWORK

2011 COCONet Network Operators Meeting Report

Introduction

COCONet (the Continuously Operating Caribbean GPS Observational Network) was funded by the National Science Foundation to help develop a regional infrastructure for the identification and mitigation of natural hazards in the Caribbean, with a particular focus on the threats posed by earthquakes, tsunamis, and hurricanes. This project was intended to strengthen and complement existing geodetic and meteorological infrastructure in the Caribbean to provide an observational backbone for a broad range of Earth and atmospheric science investigations.

In February 2011, a COCONet community workshop was held in Puerto Rico to refine the overarching science goals for the network, provide input on an initial GPS station siting plan, identify existing stations in the Caribbean for possible inclusion in COCONet archiving and processing, and to define and prioritize additional science experiments that could capitalize on this investment in a pan-Caribbean infrastructure.

A follow-on meeting was held in Port-of-Spain, Trinidad on June 28-29, 2011 to solicit input from regional scientists and geodetic network operators into the operational planning for COCONet. Fifty-one participants representing 39 institutions in 18 countries took part in discussions on the project's progress to date, finalizing the location of new and existing stations in support of COCONet science goals, and capacity building in the Caribbean in the areas of data collection, processing and archiving.

This report details the activities and outcomes of the Port-of-Spain meeting. Appendix A lists the station locations jointly agreed to by COCONet PIs and workshop participants, Appendix B is the text of an article submitted to EOS by the COCONet PIs, Appendix C is the workshop agenda, and Appendix D the list of workshop participants.

COCONet Overview

COCONet is a five-year project funded by an NSF grant for a Caribbean-wide regional GNSS and meteorological network including at least 50 new continuous GNSS stations and incorporating data from additional GNSS stations already operating in the region. COCONet is meant to provide a pan-Caribbean backbone of high-quality geodetic instrumentation along with freely available data and data products to serve as a backbone for solid Earth and atmospheric science studies around the entirety of the Caribbean plate and its complex boundaries.

Critical to the COCONet vision is the free and open availability of data and data products will to all users in all nations. The COCONet data model is based on the precedent and processes set by the EarthScope Plate Boundary Observatory (PBO), and includes the distribution of all raw GNSS and meteorological observations (some in real time), along with the production of higher-level data products such as the time series of daily positions, and a crustal velocity field.

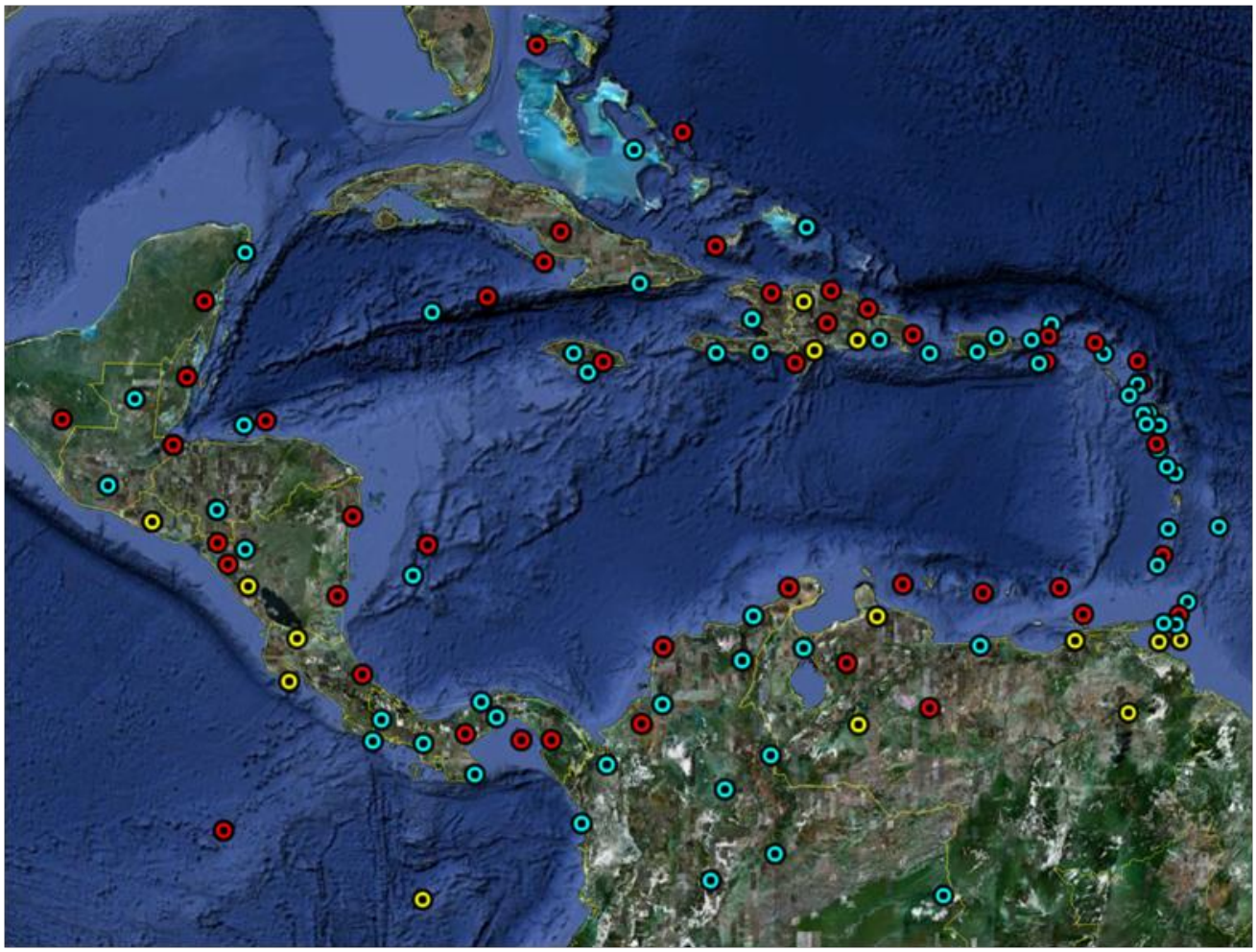

Figure 1. COCONet station network, as decided at the Port-of-Spain meeting. Red indicates new GNSS/meteorological station installations to be built by the COCONet project, light blue indicates existing GNSS stations that will contribute data to the project, and yellow indicates inoperable GNSS stations that will be refurbished in exchange for station data contribution to the network.

COCONet will also provide precise estimates of column integrated tropospheric water vapor to enable better forecasting of the dynamics of airborne moisture associated with the yearly Caribbean hurricane cycle and will provide a regional framework for other atmospheric science objectives. Because of its open data design, COCONet is expected to have broad impact on the research, education and private sectors, with unanticipated science applications and commensurate societal benefits.

COCONet Siting Plan

The original COCONet proposal was based on information available to NSF-funded PIs who maintain existing regional cGNSS sites as well as a review of open data archives for available data of appropriate quality and utility for the overarching science goals. This process produced a preliminary siting plan for COCONet, which identified 50 possible locations for new station installations along with 50 existing sites that could provide raw GNSS data with appropriate characteristics (e.g. a geodetic quality antenna, receiver, and monument, good data reliability, and low transmission latency).

The February 2011 COCONet Workshop in Puerto Rico provided an opportunity for local investigators and regional network operators to help modify siting decisions with the benefit of detailed local knowledge and full consideration of regional logistics, political feasibility, and other factors. The outcome of these discussions was a list of 32 stations that UNAVCO could use for operations planning, with separate categories for entirely new installations, existing stations that needed refurbishment to become operational, and existing stations that could contribute data to COCONet with little or no effort.

The goal of the Port-of-Spain meeting was to modify and complete the initial station list based on UNAVCO's permitting and installation experiences in the 5 months elapsed from the Puerto Rico workshop and the further input of Caribbean investigators, many of whom had attended the Puerto Rico meeting and came prepared with considerably more information about the location and operational status of stations in their countries. Five sessions over two days were reserved to review station siting for each region of the Caribbean, and the result was a list of 50 new, 15 refurbished, and 61 existing stations that represent the consensus opinion of the workshop participants about the distribution of the COCONet network (Figure 1, Appendix A).

COCONet Siting Committee

The need for a siting committee was identified during the workshop as a means for providing rapid feedback to UNAVCO in response to anticipated modifications to the adopted siting plan. If an acceptable station location cannot be found during reconnaissance or if permitting of a selected site is not possible, UNAVCO will seek guidance from the siting committee. The committee will meet via regularly scheduled telecon or by email if appropriate. UNAVCO's Karl Feaux will serve as the project liaison to the committee and bring in other field operations staff if needed.

Charge: The COCONet Siting Committee reviews technical issues related to site installation including relocation when a suitable station cannot be cannot be identified to meet the intended purpose, when unanticipated costs or benefits are identified, or when there are changes in the planned site configuration such as data sampling rate or the ability to support meteorological observations.

Siting Committee Members: John Braun (UCAR)
Eric Calais (Purdue University)
Lloyd Lynch (University of the West Indies)
Glen Mattioli (University of Texas, Arlington)
Chuck Meertens (UNAVCO)
Hector Mora-Paez (INGEOMINAS)
Omar Perez (Simon Bolivar University)
Alberto Venegas (University of Puerto Rico)
Guoquan Wang (University of Puerto Rico)
Karl Feaux (UNAVCO, project liaison)

IT Resource Considerations for Regional Data Management and Archiving

Data management for COCONet was originally proposed to include components both at UNAVCO and at regional partner institutions. The requirements for data management of a broad distributed network like COCONet were outlined in a presentation by UNAVCO Facility Director Chuck Meertens, who described the following competencies that are required for a complete end-to-end data management structure: (1) network operations, including instrument configuration and data communications, (2) data downloading and initial quality control, (3) metadata management, (4) data processing and analysis, (5) archiving and distribution of data and metadata products, and (6) maintaining a web presence for data users and education and outreach.

The strategic questions that need to be addressed in this area are:

- What are the goals for regional network stakeholders and how can COCONet be aligned to help meet these objectives?
- What software IT tools would be most useful to develop for regional network operations, processing, and analysis? How might we collaborate to develop these tools?
- What types of training and capacity building activities would COCONet participants like to receive and/or contribute to?
- How can we mobilize and piggyback on regional resources to meet our broader goals?

The discussion centering on these and other questions related to community/capacity building is summarized in the next section of this report.

COCONet Community Building, International Partnerships, and Mutual Capacity Building

The last session of the Port-of-Spain meeting focused on developing partnerships and capacity building to support realization of the COCONet science goals and broader impact. The discussion was framed by forward-looking recommendations to cement the scientific community. Activities to develop the emerging community of international science stakeholders focused on

training, development of tools, and translation of the results for societal benefit. "Mutual capacity building" was used to define the need for all partners to expand technical, scientific, and authentic collaboration capabilities through international interactions, with a long-term goal of developing capacity and partnerships that flourish long beyond the COCONet project.

The ultimate success of COCONet will be the international science and collaborations seeded by the network in the three identified areas: *training*, *tools*, and *translation*. Some of the needed activities will be regional and international in scope; others will address local needs or circumstances. Many of these activities will require new resource streams to be established.

1. Training and sustaining an international science community

COCONet stakeholders bring a strong collective record of geodesy expertise. Nonetheless, the potential for synergies from better coordination and professional interactions was evident, and could be realized by relatively modest investments in a series of training short courses and science workshops or topical sessions at regional meetings. International visits among the partners could further opportunities for technology transfer. Because these synergies rely on long-term collaborations, finding international and in-country support for regular meetings is paramount.

An opportunity for knowledge transfer also exists through the engineering and data processing effort that will be required to build and operate COCONet. Three general areas of need for technical training for COCONet partners were identified: (1) station instrumentation, monumentation, power & communications, and maintenance; (2) data acquisition and archiving; and (3) data post-processing, analysis, modeling, and interpretation.

Other themes were also developed under this umbrella: (1) partner training to strengthen protocols for research and civic networks, (2) establishing stakeholder-informed best practices for tropical station deployment and hazards hardening, (3) data archiving and sharing capabilities, (4) regional atmospheric data assimilation, and (5) a clearing house for COCONet results that can be used with a variety of audiences, including students. Interest arose in developing an open data commitment, an Access Committee to support PIs in developing data sharing mechanisms, and a process to identify and remove obstacles to data sharing. The web and other electronic media will be essential to coordination of a dispersed community.

Recommendation: Develop a four-year plan for a series of short courses and international exchanges focused on GPS infrastructure and data management, applications across the geosciences, and topics that will support return on COCONet infrastructure and data sets. The plan should explicitly include a role for international students and post-docs, including training exchanges. This will require identification of funding for collaborative exchange among researchers.

Recommendation: Build a community web portal so that institutions and countries can effectively share information about priorities, capabilities, and needs in the areas of communication facilities, locations, management/contact information, data availability, educational resources, partnerships, and other topics of mutual interest. Web portal functionality as ranked by responses from the workshop survey includes:

Information about data availability (9)
General information sharing (7)
Site information and status (7)
Links to disaster risk reduction information and organizations (7)
Remote on-line training (7)
Linkages to partner organizations (6)
A repository of regionally-focused educational materials (6)
Technical information about networks and communication systems (5)
Community calendar (4)
Sharing of stories and pictures (4)
Specialized data information access for teachers, surveyors or planners (4)

Recommendation: Identify an operator in each country hosting COCONet infrastructure to be a local leader and point of coordination between COCONet and in-country geodesy stakeholders (including existing networks, survey organizations, universities, earthquake agencies emergency planners, etc.).

2. Tools for Geodesy

A second focus – to further develop, adapt, and disseminate geodetic and modeling tools for the COCONet community – also emerged. These tools are particularly needed in several key areas, including (1) the definition of Caribbean plate reference frames for horizontal and vertical deformation – the latter to integrate with sea level, ocean tide, and local coastal uplift and subsidence observations, (2) metadata management and coordination, (3) extensible tactics for data archiving, management, and regional mirroring of data holdings, and (4) the modeling software required to interpret results. Technical issues related to station resilience during heavy ground shaking or high winds from seasonal hurricanes were another area of focus. The value of additional observational instrumentation that would be complementary to COCONet was also noted: co-location with tide-gauges; campaign pool GPS equipment; augmentation of COCONet with a small number broadband seismometers. Lastly, the need for disseminating technical advances in the rapidly-evolving area of realtime GPS was also identified.

Recommendation: Secure funding to establish disseminated regional data archives and processing centers for COCONet solutions, located within the circum-Caribbean region and providing access, products, and instrument pools for regional campaign studies. This initiative should build on UNAVCO's seamless archive capabilities and on established pathways for data

processing of large networks. This initiative could also be used to advance strategic partnerships among Caribbean nations.

Recommendation: Establish a working group to define the Caribbean reference frame and to coordinate with SIRGAS and SNARF.

Recommendation: Develop stakeholder-informed best practices for COCONet construction, management, and dataflow. Identify resources for local operators to access technical support to solve relatively minor technical issues.

Investigator-driven initiatives should incorporate graduate students from the Caribbean and North America, funded through NSF and NSF-USAID programs and national aid programs of other countries, in investigations that build upon COCONet infrastructure. Individual initiatives should contribute to a coordinated effort to enhance regional strengths in secondary and professional education.

3. Translation of Observations and Discoveries for the Benefit of Society

The third major theme was translation: identifying the scientific gains and capacity building from COCONet data sets and rendering useful products for hazards management. While this is a long-term goal, it will rely on early investments in the relationships that connect scientific and technical communities with planning and disaster response organizations. Immediate steps include cultivating formal connections to the GEM (Global Earthquake Model) project, the Caribbean Tsunami Warning Center, and investigators whose work focuses on neotectonics and paleoseismology, strain mapping, weather modeling, tsunami generation, and earthquake occurrence probabilities. Suggested mechanisms included development of COCONet working groups, or formal liaisons to working groups from related initiatives (GEM continued to be a salient example; significant synergies could be realized with ALMAS), and augmenting the web resources identified above with scientific sessions and meetings. Mining existing list serves to seed working groups was also suggested. Whatever structure is adopted, clear goals and timelines should be identified for COCONet working groups.

Recommendation: Establish vibrant and visible intellectual and professional connections that supersede political barriers, and focus on common science and societal impact goals (e.g., regionally coordinated plans for tsunami warning) shared among the international participants. This is tightly coupled to recommendation 1a under Training.

Recommendation: Web site resource that would address this topic includes (1) links to disaster risk reduction information and organizations; (2) specialized data information access or teachers, surveyors or planners; and (3) a repository of regionally focused educational material. The latter two would require specific proposals or new resources for implementation.

Recommendation: Develop pathways for data and science to inform governments and agencies on natural hazards.

Recommendation: Identify resources to develop real-time data streams and data access customized for users in surveying, planning, hazards, primary education and other specialties identified in conversations with regional and local stakeholders.

Recommendation: Develop pathways for data and science to inform governments and agencies on natural hazards.

Implementation – First Steps

Sustaining and developing this emerging international community through professional interactions will secure the scientific merit and broader impact of COCONet. As a result of the discussions in Port of Spain, we intend to advance a plan that focuses on providing optimized tools, technical training, and science interactions for this emerging community, through proposals for a series of short courses, workshops, and multilateral international exchanges or visits by researchers, faculty, and students, with an emphasis on early career scientists.

Tier I recommendations – those that are both foundational and most urgently require resources, include:

- Develop a four-year plan for a series of short courses and, if possible, international exchange focused on GPS infrastructure and data management, applications across the geosciences, and topics that will support return on COCONet infrastructure and data sets. The plan should explicitly include a role for international students and post-docs, including training exchanges. Identify and secure funding for collaborative exchange among researchers. This will further the goal of vibrant and visible intellectual and professional connections that supersede political barriers, and focus on shared science goals and societal impact goals (e.g., regionally coordinated plans for tsunami warning) shared among the international participants.

- Build a community web portal so that institutions and countries can effectively share information about priorities, capabilities, and needs in the areas of communication facilities, locations, management/contact information, data availability, educational resources, partnerships, and other topics of mutual interest.

- Develop a plan and secure funding to establish approximately four disseminated regional data archives and processing centers for COCONet solutions, located within the circum-Caribbean region, building on UNAVCO's seamless archive capabilities, and on established pathways for data processing of large networks.

There are other recommendations above that can be advanced in parallel or very soon within the scope of existing project scope or other established collaborations.

Potential sponsors for some of these activities include USAID (PEER program through NAS), NSF, World Bank, UNESCO and the International Centre for Theoretical Physics (ICTP), the U.S. Department of State, as well as governments, agencies, national networks, observatories and universities of the 43 nations of the Caribbean region.

Appendix A. Station Tables: New, Refurbished, Existing

COCONet New Stations Table (50 total)

#	Name	Type	Country	Locale	Latitude	Longitude
1	CN01	New	Anguilla	Wallblake Airport	18.21	-63.05
2	Barbuda/CN00	New	Antigua and Barbuda	Barbuda	17.67	-61.79
3	Antigua	New	Antigua and Barbuda	Antigua	17.06	-61.71
4	Redonda	New	Antigua and Barbuda	Redonda	16.94	-62.34
5	CN14	New	Bahamas	Great Inagua Isl.	20.97	-73.68
6	San Salvadar	New	Bahamas	San Salvador	24.04	-74.50
7	CN15	New	Bahamas	Grand Bahama	26.56	-78.69
8	CN23	New	Belize	Belize City	17.54	-88.31
9	CN03	New	British Virgin Islands	Virgin Gorda	18.42	-64.45
10	CN16	New	Cayman Islands	Cayman Brac	19.69	-79.88
11	CN35	New	Colombia	Monteria	8.83	-75.83
12	Galerazamba/CN37	New	Colombia	Galerazamba	10.79	-75.25
13	Puerto Bolivar	New	Colombia	Puerto Bolivar	12.22	-71.98
14	ISCO	New	Colombia	Cocos Island	5.54	-87.06
15	CN34	New	Columbia	Isla de Providencia	13.36	-81.36
16	CN31	New	Costa Rica	Moin	9.99	-83.09
17	Camaguey	New	Cuba	Cameguey	21.38	-77.90
18	Cuba TBD	New	Cuba	TBD	20.60	-78.35
19	CN40	New	Curacao	Willemstad	12.19	-68.96
20	Dominica/CN48	New	Dominca	Dominca	15.44	-61.43
21	CN05	New	Domincan Rep.	Punta Cana	18.56	-68.37
22	CN07	New	Domincan Rep.	Puerto Plata	19.76	-70.56
23	CN06	New	Domincan Rep.	Constanza	18.91	-70.72
24	Cabo Rojo	New	Domincan Republic	Cabo Rojo	17.91	-71.64
25	Samana	New	Domincan Republic	Samana	19.32	-69.50
26	Carriacou	New	Grenada	Carriacou	12.47	-61.45
27	CN26	New	Guatemala	Puerto Barrios	15.74	-88.59
28	CN09	New	Haiti	Cap Haitien	19.74	-72.19
29	CN21	New	Honduras	San Lorenzo	13.24	-87.15
30	CN19	New	Honduras	Isla de Guanaja	16.44	-85.90
31	Swan Island/CN18	New	Honduras	Swan Islands	17.40	-83.94
32	CN12	New	Jamaica	UWI Mona	18.00	-76.75
33	Pedro Cay	New	Jamaica	Pedro Cay	17.02	-77.78
34	Morant Cay	New	Jamaica	Mona Cay	17.42	-75.98
35	COMI	New	Mexico	Comitan	16.28	-92.14
36	Mexico TBD	New	Mexico	TBD	19.56	-87.98
37	CN30	New	Nicaragua	Bluefields	12.00	-83.77
38	CN29	New	Nicaragua	Puerto Cabezas	14.05	-83.38
39	Leon	New	Nicaragua	Leon	12.69	-86.84
40	CN33	New	Panama	Penenome	8.53	-80.37
41	La Palma	New	Panama	La Palma	8.41	-78.14
42	Panama TBD	New	Panama	TBD	8.40	-78.92
43	St. Lucia/CN45	New	Saint Lucia	TBD	13.71	-60.95
44	CN42	New	Trinidad & Tobago	TBD	10.59	-61.35
45	St. Croix/CN04	New	U.S. Virgin Islands	St. Croix	17.76	-64.58
46	El Baul	New	Venezuela	El Baul	8.95	-68.30
47	CN52	New	Venezuela	Isla la Blanquilla	11.85	-64.60
48	Los Roques	New	Venezuela	Los Roques	11.86	-66.79
49	Marguerita	New	Venezuela	Isla de Margarita	11.10	-63.94
50	Quebrada Arriba	New	Venezuela	Quebrada Arriba	10.24	-70.50

COCONet Refurbished Stations Table (15 total)

#	Name	Type	Country	Locale	Latitude	Longitude
51	CAYS	Refurb	Colombia	Isla Seranilla	15.83	-79.83
52	MALO	Refurb	Colombia	Isla Malo	4.0032	-80.3939
53	GRZA	Refurb	Costa Rica	Garza	9.9155	-85.6356
54	VERA	Refurb	Costa Rica	Veracruz	10.8539	-84.8685
55	BARA	Refurb	Domincan Republic	Bara	18.22	-71.10
56	RDSD	Refurb	Domincan Republic	Santo Domingo	18.4610	-69.9110
57	SROD	Refurb	Domincan Republic	Sabaneta	19.4753	-71.3412
58	SSIA	Refurb	El Salvador	San Salvador	13.6971	-89.1166
59	MANA	Refurb	Nicaragua	Managua	12.1489	-86.2490
60	FORT	Refurb	Trinidad & Tobago	Trinidad SW	10.18	-61.68
61	GALE	Refurb	Trinidad & Tobago	Trinidad SE	10.15	-61.00
62	Barinas	Refurb	Venezuela	Barinas	8.63	-70.21
63	Coro	Refurb	Venezuela	Coro	11.40	-69.68
64	Ciudad Guayana	Refurb	Venezuela	Ciudad Guayana	8.35	-62.63
65	Cumana	Refurb	Venezuela	Cumana	10.43	-64.20

COCONet Existing Stations Table (61 total)

#	Name	Type	Country	Locale	Latitude	Longitude
66	ABMF	Existing	Guadeloupe	Les Abymes	16.27	-61.49
67	ABVI	Existing	British Virgin Islands	Anegada	18.73	-64.33
68	ACHO	Existing	Panama	Los Santos	7.41	-80.17
69	ACP1	Existing	Panama	Colon	9.3713	-79.9499
70	ACP5	Existing	Panama	Panama City	8.9828	-79.5546
71	ALBN	Existing	Trinidad & Tobago	Port of Spain	10.66	-61.52
72	ALPA	Existing	Colombia	Guajira	11.5280	-71.0822
73	BASO	Existing	Colombia	Bahía Solano	6.2030	-76.6068
74	BDOS	Existing	Barbados	Bridgetown	13.0879	-59.6091
75	BGGY	Existing	Antigua and Barbuda	Antigua	17.0450	-61.8611
76	BOGT	Existing	Colombia	Bogotá	4.6401	-73.9191
77	CALD	Existing	Trinidad & Tobago	Tobago	11.16	-60.75
78	CANA	Existing	Panama	Veraguas	8.20	-81.52
79	CAPI	Existing	Colombia	Yopal	5.3514	-71.5722
80	CAYE	Existing	Haiti	Les Cayes	18.2009	-73.7446
81	CDPR	Existing	Colombia	Valledupar	10.4358	-72.7522
82	CNC0	Existing	Mexico	Cancun	20.87	-86.87
83	CORO	Existing	Colombia	Corozal	9.3281	-74.7121
84	CRCS	Existing	Venezuela	Caracas	10.52	-66.91
85	CUC1	Existing	Colombia	Cucúta	7.9323	-71.4872
86	DHS0	Existing	Guadeloupe	Deshaies	16.25	-61.73
87	Dominica TBD	Existing	Dominica	Roseau	15.31	-61.39
88	ELEN	Existing	Guatemala	Santa Elena	16.9161	-89.8676
89	ESTI	Existing	Nicaragua	Esteli	13.0995	-86.3621
90	EXU0	Existing	Bahamas	Exuma	23.5640	-75.8730
91	GCGT	Existing	Grand Cayman	George Town	19.2899	-81.3800
92	GRAN	Existing	Trinidad & Tobago	Sangre Grande	10.59	-61.13
93	GRE0	Existing	Grenada	Sauters	12.2217	-61.6404
94	GTK0	Existing	Turks & Caicos	Grand Turk	21.4328	-71.1446
95	Guadeloupe TBD	Existing	Guadeloupe	Beausejour	16.29	-61.10
96	Guadeloupe TBD	Existing	Guadeloupe	Marie Galante	15.92	-61.26
97	GUAT	Existing	Guatemala	Guatemala City	14.5904	-90.5202
98	HOUE	Existing	Guadeloupe	Soufriere de Guadeloupe	15.98	-61.70
99	JACM	Existing	Haiti	Jacmel	18.1947	-72.5691
100	LAM0	Existing	Martinique	Mount Pelee	14.81	-61.16
101	MARA	Existing	Venezuela	Maracaibo	10.67	-71.62
102	MARC	Existing	Haiti	St. Marc	19.0521	-72.7578
103	Martinique TBD	Existing	Martinique	TBD	14.62	-60.84
104	MECE	Existing	Colombia	Barrancabermeja	7.1072	-72.2880
105	MOPR	Existing	Puerto Rico	Mona Island	18.0769	-67.9312
106	P780	Existing	Puerto Rico	Cerillos	18.0750	-66.5791
107	PIKE	Existing	Jamaica	Pike	18.2262	-77.5348
108	PLND	Existing	Jamaica	Portland	17.7421	-77.1571
109	PTPP	Existing	Panama	Burica	8.20	-82.88
110	PUIN	Existing	Colombia	Puerto Inírida	3.8512	-66.0967
111	ROA0	Existing	Honduras	Roatan Island	16.3181	-86.5266
112	SABA	Existing	Saint Kitts and Nevis	Saba Island	17.63	-63.22
113	SAN0	Existing	Colombia	San Andrés	12.5805	-80.2843
114	SCUB	Existing	Cuba	Santiago de Cuba	20.0121	-75.7623
115	SMRT	Existing	Sint Maarten	Simpson Bay	18.0423	-63.1089
116	SPED	Existing	Domincan Republic	Cerillos	18.46	-69.31
117	St Barts TBD	Existing	Saint Barthelemy	TBD	17.90	-62.82
118	STEU	Existing	Saint Kitts and Nevis	Saint Eustatius	17.47	-62.94
119	SVGK	Existing	San Vincent	Kingstown	13.1620	-61.2500
120	TEGU	Existing	Honduras	Tegucigalpa	14.0904	-87.2056
121	TRNT	Existing	Montserrat	Trants Bay	16.7643	-62.1633
122	VIKH	Existing	Virgin Islands	Saint Croix	17.7199	-64.8000
123	VITH	Existing	Virgin Islands	Saint Thomas	18.3399	-64.9700
124	VOLC	Existing	Panama	Volcan	8.78	-82.67
125	VORA	Existing	Colombia	Apartadó	7.8184	-75.2782
126	ZSU1	Existing	Puerto Rico	San Pedro de Macoris	18.4299	-65.9900

Appendix B. COCONet article submitted to EOS

Multi-Disciplinary Natural Hazards Research Initiative Begins Across the Caribbean Basin

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The Caribbean is a region of lush vegetation, beaches, active volcanoes, and significant mountain ranges. As frequently is the case with natural beauty, this environment was created through geological, oceanic, and atmospheric processes that from the human perspective are also natural hazards. Natural hazards can be particularly devastating to developing countries in the Caribbean that have seen a significant rise in population density, the migration to coastal areas, and substandard building practices. These demographic and social changes are taking place against a backdrop of threats that also increase from an evolving climate which produces a more vigorous hurricane environment and rising mean sea-level (Peterson et al., 2002). Recent examples include the January 12, 2010 earthquake in Haiti and Hurricane Ike (2008) that passed through the multiple countries in the region causing widespread destruction and loss of life. Both events illustrate the need for a scientific focus on the processes underlying natural hazards of the Caribbean. We outline here a new National Science Foundation funded initiative termed COCONet (Continuously Operating Caribbean Observation Network), which commits approximately $7M over five years, of which $3.6M has already been awarded to a collaborative research team including UNAVCO, Purdue University, University of Puerto Rico, Mayagüez (UPRM), and the University Corporation for Atmospheric Research (UCAR).

COCONet is a project aimed at infusing large-scale, state of the art geodetic infrastructure into the Caribbean, forming the backbone for a broad range of geoscience investigations and enabling research on process-oriented science questions with direct relevance to geohazards. The observational infrastructure will serve as a regional platform for more focused topical geophysics studies by members of an international community of scientists. COCONet will also serve as a focal point for leveraging regional infrastructure for international partnerships, broader impact applications, and capacity building.

COCONet will install 50 new continuous GNSS (cGNSS) and meteorology stations in the Caribbean and Central America, refurbish an additional 15 stations, and archive data from 58 cGNSS stations that are already or will soon be in operation (Figure 1) by various institutions who are committed to free and open data access. Products will include raw data, estimates of column integrated tropospheric water vapor, time series of daily positions, a velocity field to support geoscience investigations, and high-rate low-latency data from a subset of stations. These data and derived products will be provided to the broader community through a common

archival center such as UNAVCO or in collaboration with a regional data and analysis center. Because of its open data design, COCONet also promises broad impact with unanticipated science applications and commensurate societal benefits.

The COCONet regional framework will facilitate additional experiments of higher spatial density that address specific science problems. Some of the science questions and objectives that motivated this investment are briefly outlined below.

The large oceanic extent of the Caribbean and the presence of many offshore active faults make the region both a source and a recipient of tsunamis. The Central America and Lesser Antilles subduction zones are associated with explosive volcanoes that pose a direct threat to large population centers. Much of the region's tectonic context is still relatively poorly constrained, however, and the risk level is not yet quantified. For instance, only a few of the active plate boundary faults have well-determined geodetic slip rates. In fact, some key plate boundary structures are not even considered in current hazard assessments (Frankel et al., 2010). One obvious example is Haiti (Calais et al., 2010).

The diverse tectonic context of the Caribbean region is an asset for process-oriented studies where major science questions can be addressed. This has long been recognized by the U.S. tectonics and geophysics community, which has invested in geodetic studies along several segments of the Caribbean plate boundary since the early 1990's. To date, no concerted, multilateral effort has taken place to equip the Caribbean region with a consistent geodetic infrastructure that would support both plate-wide research efforts and regional densifications.

Some key tectonic questions that COCONet should be able to address include: What are the kinematics of the Caribbean domain? How rigid is the Caribbean plate? What Caribbean reference frame is appropriate for tectonic studies? More targeted questions related to the earthquake cycle include: How is stress released at convergent plate boundaries? What controls interplate coupling? How does interseismic plate coupling change along strike at the leading edge of the Caribbean plate where the North and South American plates are subducted and along the trailing edge where the Cocos plate is subducted? In addition, COCONet will also help place tectonic and earthquake cycle processes in the global context and examine questions that include: What controls strain partitioning at convergent margins in general? How is stress transferred across plate boundaries? COCONet will provide critical geodetic constraints to evaluate the role of descending slab morphology, the location of local asperities, and how this modulates episodic slip and tremor as well as the nucleation of large earthquakes.

From an atmospheric perspective, COCONet will help constrain key processes in the Caribbean region tied to ocean-atmosphere coupling, transport of moisture and convergence, and precipitation. It will also better enable hazard prediction and preparation related to heavy precipitation, storm surge, winds and hurricanes.

Better observations are critical for making progress in this data-sparse region, both to improve initial conditions for numerical weather prediction (NWP) forecasts and to provide data to assess and evaluate important model details related to precipitation and latent heat transport. The distribution of stations across the Caribbean basin will allow both large and small-scale processes to be studied: stations along the boundary of the Caribbean sea will be important in evaluating regional transport of moisture; North-South transects on both the eastern and western edges will measure seasonal differences in moisture distribution related to low level jets and transport of water from the tropics to the mid-latitudes; and data from land masses ranging in scale from cays to islands to the continental areas of Central and South America will reveal details of the interaction between the ocean, land, and atmosphere. Errors in analyses of atmospheric moisture and in seasonal forecasts are anomalously high in the Caribbean region, suggesting that current models do not properly capture the essential atmospheric physics of the region and that the low spatial density of data used to condition these models may also be a problem.

COCONet observations will contribute a number of key atmospheric questions including: What are the sources and predictability of climate anomalies in the Caribbean? Are convective parameterizations, originally derived from western Pacific data sets, applicable to a Caribbean atmosphere? How does land heating and small island topography influence moisture transport and precipitation in the region?

The most obvious weather hazard that affects the Caribbean region is hurricanes. A major emphasis of COCONet will be in determining how continuous and reliable estimates of precipitable water vapor, with temporal resolution of 15 minutes or less, can be applied in understanding of latent heat release in convective towers and synoptic scale moisture transport can fuel the evolution of tropical storms. While hurricane track forecasts have steadily increased in accuracy, hurricane genesis and intensity changes have remained difficult to predict.

Three broad themes for capacity development have been identified to help ensure the success of COCONet. The first theme is the need for COCONet to effectively complement, augment and extend regional geodetic infrastructure, and technical capabilities through enhanced data acquisition and analysis methods while simultaneously promoting open data policies. COCONet regional partners will play leading roles in transforming data obtained through the COCONet investment into concrete benefits for hazards mitigation and scientific advancement. The second theme is the need to bridge the gap between scientific understanding and knowledge and the application of that knowledge for public benefit. As COCONet advances science, it should also be used to improve public use of the acquired knowledge. Therefore, primary-school students, teachers, surveyors, emergency managers, policy and decision makers have all been identified as key audiences for COCONet outreach. The third and final theme, closely aligned with the first, is the need for bidirectional scientific partnerships to nurture a new generation of researchers in the region.

Knowledge flow from COCONet activities should work in multiple directions – from and among Caribbean nations as well as between all of the project's international stakeholders. Mechanisms for promoting intellectual exchange include traditional opportunities such as bringing students from the Caribbean to North America for advanced training or graduate school as well as fostering the development of Caribbean training centers, bidirectional science exchanges, and field campaigns, which include partners from across the Americas.

While still in its first year of funding, results from the COCONet project include the successful *COCONet Workshop for Community Science, Station Siting, and Capacity Building,* which was held during early February 2011 in Puerto Rico. More than one hundred scientists representing twenty-five countries attended the *COCONet Workshop*. Outcomes from this workshop included a refined set of science goals and a prioritization of initial site installations. Workshop participants developed ideas for initiatives to strengthen resources and technical capabilities for regional Caribbean geodetic networks and to identify outreach opportunities related to the COCONet project. The complete workshop report and original proposal to NSF-EAR can be found through UNAVCO (http://www.unavco.org/community/meetings-events/2011/coconet).

A second workshop was held in Port-of-Spain, Trinidad in June 2011 and hosted by the Seismic Research Center of the University of the West Indies. This meeting allowed for a further refinement of the site development plan and identification of locations of new, refurbished, and existing cGNSS sites that will comprise the COCONet network (Figure 1).

UNAVCO engineers have worked closely with regional network operators to make progress on the construction of the network. Preliminary reconnaissance for 26 sites has been completed. Ten new site permits have been requested and four have been accepted. Two sites, one on Cocos Island in the Pacific Ocean and one on Grand Bahama Island have already been installed and data are available from the UNAVCO archive.

As COCONet is in its initial implementation and build-out phase, it represents an excellent opportunity for scientists already working in the region and those interested in developing new research portfolios on related topics, to leverage COCONet data and products for their own interests. Investigators are encouraged to contact UNAVCO, UCAR, members of the COCONet organizing committee, or the authors for additional information.

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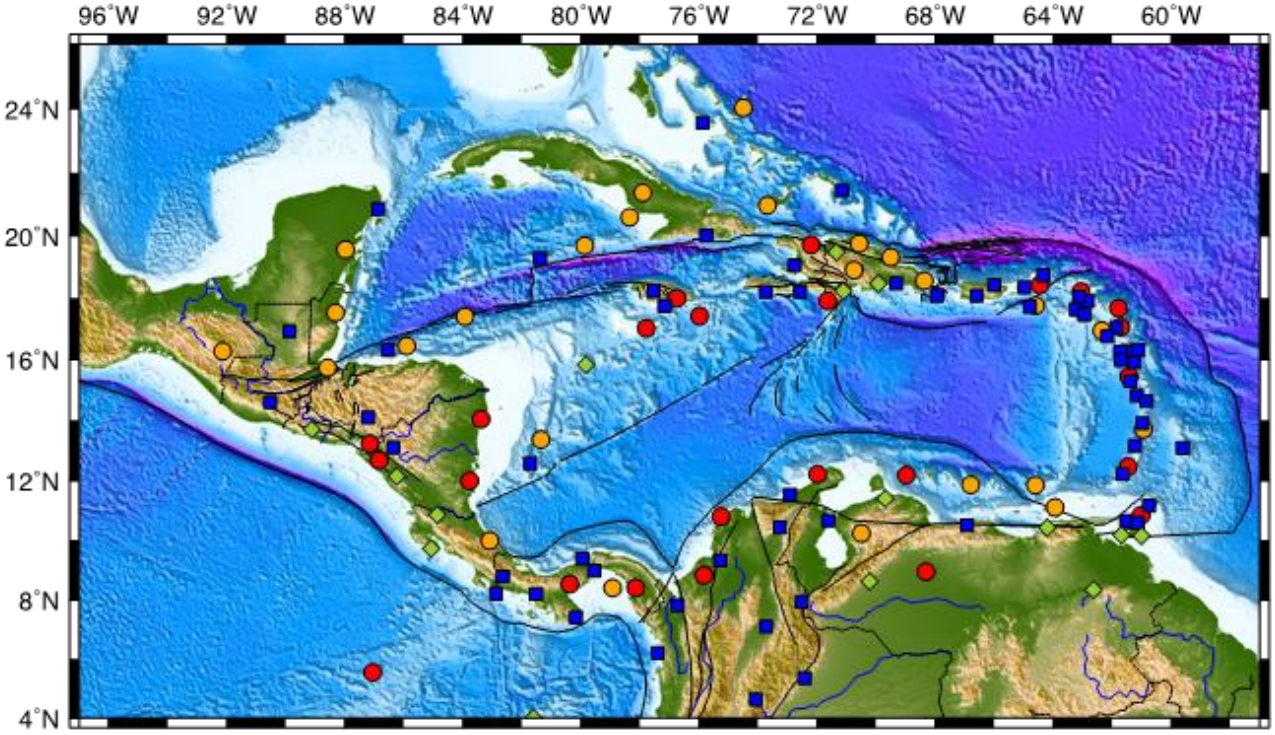

Figure 2: New COCONet sites defined during the February, 2011 meeting are shown as red circles (n=25), COCONet sites defined during the June, 2011 meeting are shown as orange circles (n=25). Existing or planned sites (n=58) to be included in the COCONet archive and data products are shown as blue squares. Existing sites that require modest additional equipment or upgrades (n=15) are shown as yellow-green diamonds. Bathymetry and topography are from ETOPO1. Well-defined structural elements (faults and block boundaries) are shown as black lines.

Appendix C. Workshop Agenda

Session I Objectives: Summary of COCONet project and review of operational accomplishments and planning since Puerto Rico meeting.

8:00 - 8:10	Welcome / Introduction (M. Miller, UNAVCO President)
8:10 - 8:30	Summary of the COCONet Project, Science Goals, and a summary of Puerto Rico Meeting (M. Miller, M. Jackson)
8:30 - 9:00	COCONet Climate Science Rationale (J. Braun)
9:00 - 9:30	COCONet Tectonics/Hazards Science Rationale (E. Calais)
9:30 - 9:45	BREAK
9:45 - 10:00	Accomplishments since the Puerto Rico Meeting, including station design reconnaissance guidelines, schedule/EVM, MOU (K. Feaux)
10:00 - 10:30	Review of Phase 1 siting map of 32 stations, station-by-station review of recons to date (B. Friesen)
10:30 - 10:45	Review of dataflow, data processing, submitting existing station data (A. Borsa)
10:45-11:00	BREAK

Session II Objectives: Station siting for new and existing locations within the smaller sub-region. The core of this session will be devoted to identifying the remaining new station locations and identifying existing stations whose data can be made freely and openly available. This session will be led by representative scientist from the region of interest, with the goal of getting as many sites as possible brought forward for consideration. The goal is to get high quality new site locations and existing high quality stations put forward for consideration. Final station locations will be established based on COCONet science goals in Day 2, Session 3.

11:00 - 12:00	Session II-A: South America - Caribbean Boundary (Chairs: H. Mora, F. Audemard, Cochairs: A. Borsa, K. Feaux)
12:00 - 1:00	LUNCH
1:00 - 2:00	Session II-B: Coco/Nazca - Caribbean Boundary (Chairs: A. Abrego, R. Bennett, Cochairs: A. Borsa, K. Feaux)
2:00 - 3:00	Session II-C: North American - Caribbean boundary -Lesser Antilles Focus (Chairs: L. Lynch, A. Nercessian, Cochairs: A. Borsa, K. Feaux)
3:00 - 3:15	BREAK
3:15 - 4:15	Session II-D: North American-Caribbean boundary - Cayman, Hispanola, Puerto Rico Focus (Chairs E. Calais, G Wang, Cochairs: A. Borsa, K. Feaux)
4:15 - 5:00	Session II-E: Cuba (Chairs: Juan Carlos Añtuna, J. Braun, Cochairs: A. Borsa, K. Feaux)

Session III Objectives: This session will confirm the targets for the final COCONet stations and 50 existing stations. The criteria for final selection of new stations will be based on COCONet science goals, adherence to a regional framework concept, land-use access, data communications, and security. Existing stations will be chosen based on station data quality, longevity, and ease of data flow.

8:00 - 8:15	Review of objectives for Day 2 (M. Jackson).
8:15 - 10:00	Discussion and final selection of existing stations presented in Session II (Chair: G. Mattioli, Cochair: M. Jackson).
10:00 - 10:15	BREAK
10:15 - 12:00	Discussion and final selection of new stations presented in Session II. These stations will be and based on selection of new stations and will be informed by the progress of COCONet operations activities to date. (Chair: G. Mattioli, Cochair: M. Jackson).
12:00 - 1:00	LUNCH
1:00 - 1:30	How do we make changes to the COCONet plan? (M. Jackson)

Session IV Objectives: This session will discuss resources (such as regional data management and archiving hubs) that will help to build international collaborations and on activities (science workshops, short courses, and student exchanges) that will support those collaborations.

1:30 - 3:00	Discussion: Building Future Caribbean Collaborations (Chairs: R. Robertson, E. Calais, Cochair: C. Meertens)
3:00	ADJOURN
3:00 - 5:00	Continuation of discussion or Report writing session for COCONet PI's

Appendix D.
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