AWS for Building Regional Climate Capacity in the Caribbean

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Abstract
Climate change and increasing climate variability and their potential impacts have boosted society's demand for tailored climate products and services. The delivery of critical climate services related to climate change and variability in a sustained timely manner requires computational power, model research and know-how. IT expertise, knowledgeable interpretation and national, regional and international collaborations are also essential. To collect data to aliment the aforementioned, it is indispensable to count with a network of dependable and precise instruments positioned in strategic locations over the region of interest. The Caribbean Institute for Meteorology and Hydrology under the Building Regional Climate Capacity in the Caribbean programme funded through the United States Agency for International Development (USAID), installed thirty three automatic stations from St Christopher and Nevis through to Guyana, including Dominica, Saint Lucia, Saint Vincent, and Barbados to provide near real-time weather information to monitor the effects of climate change, and to provide input for hydrological models in the Caribbean region. These stations form part of a network of water level, soil moisture and precipitation stations installed under the BRCCC programme. This paper discusses the installation process of the stations, and highlights the utility of the data that has been provided over the last 24 months to the Caribbean.

Introduction

The CIMH is the technical organ of the Caribbean Meteorological Organization (CMO) which includes sixteen member states: Antigua and Barbuda, Anguilla, Barbados, St. Kitts and Nevis, Montserrat, The British Virgin Islands, Dominica, Saint Lucia, St. Vincent and the Grenadines, Grenada, Trinidad and Tobago, Guyana, Belize, Jamaica, The Cayman Islands and The Turks and Caicos Islands. The objective of the CMO is, as stated in its mandate: "… the promotion and co-ordination of regional activities in the field of Meteorology and allied sciences." As a result, this objective mandates that CIMH, being the technical organ of the CMO, promote and coordinate regional activities in the area of climate sciences. The specific mandate of CIMH is to "assist in improving and developing the meteorological and hydrological services as well as providing the awareness of the benefits of meteorology and hydrology for the economic well-being of the CIMH member states. This is achieved through training, research, investigations, and the provision of related specialized services and advice."

The Programme for Building Regional Climate Capacity in the Caribbean (BRCCC) was established to facilitate the development of the World Meteorological Organization's Regional Climate Centre (RCC) for the Caribbean to be housed at the Caribbean Institute for Meteorology and Hydrology (CIMH) through: (i) infrastructure development, (ii) increasing the range of products and services delivered to stakeholders, (iii) enhancement of human and technical capacities at CIMH and in National Meteorological and Hydrological Services in the Caribbean, and (iv) improvement of service delivery mechanisms to national, regional and international stakeholders.

Under the BRCCC Programme thirty-three automatic stations were purchased to be installed over the three-year duration of the project. These stations comprised of six full automatic weather stations, sixteen non invasive radar water level stations, and eleven soil moisture stations and complimented an existing network of automatic stations providing near real time data to the Caribbean Dewetra platform. The stations under the BRCCC were assigned as follows: four to Antigua, four to Barbados, five to Dominica, two to Grenada, seven to Guyana, three to Saint Lucia, three to Saint Vincent, and five to Saint Kitts. All of the equipment was purchased from Sutron. (www.sutron.com)

1.1 Dataloggers

Three distinct dataloggers were employed in the project; SatLink3 Logger/Transmitter SL3-1, GPRSLink 2-Way Logging Transmitter, XLite 9210B with Satlink2.

1.1.1 SatLink3 Logger/Transmitter SL3-1

SatLink3 provides a cost-effective way to measure, log, calculate and transmit data from remote locations. The unit monitors 32 independent measurements of most hydrological, meteorological, environmental or related sensors. SL3 has built-in support for all CGMS satellites including GOES, EUMETSAT, INSAT and MTSAT for operation anywhere. Most often used directly connected to sensors and transmitting data on a user-set schedule, the Satlink3 additionally has options for cellular and Iridium communications. [1]

1.1.2 GPRSLink 2-Way Logging Transmitter

The GPRSLink provides simple telemetry anywhere. GPRSLink has two purposes: (1) to collect and store data from meteorological and hydrological sensors, and (2) to send that data wirelessly to a central system, phone or other station. GPRSLink includes a quad band GSM cell phone modem that can operate when the unit is within range of a cell phone network. Furthermore, the GPRSLink can be programmed remotely via SMS facilitating rapid configuration updates. [2] In the same way, the station can send out alerts via SMS for predefined scenarios, and also warn the user of certain problems which require attention.

1.1.3 XLite 9210B

Designed for maximum value and functionality, the XLite 9210B is a high performance data recorder and communications device ideal for remote real-time data acquisition, control, and communications. The 9210B with Satlink2 is used for more applied applications and calculations typically necessary in a full AWS. The XLite 9210B datalogger has the ability to simultaneously take measurements and transmit information for a wide range of applications. [3]

Figure 1 SATLINK3, GPRSLink, 9210B dataloggers

1.2 Site Selection

The first phase of the installation was the documentation and verification of the equipment assigned to each country followed by an analysis of existing networks. Gap analysis was carried out, as was an evaluation of historic stations, some of which may have fallen into disrepair and abandonment. Though this project involved seven countries, this paper will reflect on the installations carried out in the Republic of Guyana as these were the most varied with regard to equipment and also the most challenging of the whole BRCCC project, requiring detailed planning to guarantee a successful outcome.

1.3 Guyanese Installations

Guyana has an area of 216,000 square kilometres and a multi-ethnic population of approximately 765,000. The country has five natural geographic regions: The Coastal Plain, the Hilly Sand and Clay Region, the Highland Region, the Forested Region and the Rupununi Savannahs. The country is well endowed with natural resources including fertile agricultural lands, diversified mineral deposits, and an abundance of tropical rain forests. Guyana’s climate has traditionally been uniform and characterized by high temperatures, humidity and heavy rainfall with temperatures along the coast on an average high of 32 Celsius and a low of 24 Celsius, humidity around 70% year round and rainfall averaging 2500 mm annually with two rainy seasons on the coast (May-June and December-January) and one in the interior (April - September).

Unlike its Caribbean neighbours, Guyana's threats from natural disasters do not come from volcanoes, hurricanes or earthquakes. The principal threat stems from the low-lying nature of its populated seacoast and anthropogenic pressures which makes it vulnerable to flooding from sea level rise and from intense precipitation. [4]

Georgetown, the capital city, has a climate which is considered to be Af (Tropical rainforest climate) according to the Köppen-Geiger climate classification. The average annual temperature in Georgetown is 26.8 °C with an annual precipitation of 2400 mm. Infrastructure, including the drainage and sewage systems, is inadequately maintained; however, recent initiatives are underway to improve this situation.

Over the course of the field reconnaissance, several potential installation sites were visited with a view to evaluating their suitability as future stations under the BRCCC project. One of the main problems encountered was the general lack of GPRS coverage in the interior of the country. This point affected the initial selection of sites, as six of the seven stations funded under this project were equipped with GPRS modems for data transmission.

Another issue, common in many countries and also in the Republic of Guyana, is the theft and vandalism of stations. Certain locations have been identified as too insecure to install costly equipment. Photovoltaic panels, batteries and data loggers have shown to be highly sought after components in previous installations. Although dissuasive measures can be employed to render the installations as unattractive a proposition as possible to would-be thieves, several interesting sites were unfortunately ruled out of this project as there was no way of ensuring the integrity of the equipment. This is especially the case at in one inner city site at East Ruimveldt Market, Georgetown, which would benefit from real-time or near real-time water level data to mitigate flood damage and optimise excess runoff evacuation; nonetheless, the probability of the instrumentation remaining in the location is highly questionable.

The Sutron equipment assigned to the BRCCC project in Guyana is listed below:

- One (1) Radio/ Goes Satellite Full AWS
- Two (2) GPRS Soil Moisture Stations
- Four (4) SatLink-3 Water Level Stations, no boom, no tripod, radar sensor type

Guyana Hydromet additionally provided Six (6) Sutron 0.2 mm tipping bucket rain gages to be added to the stations.

The preliminary field reconnaissance was carried out in December of 2015 and involved far-reaching discussions with the Guyanese Hydromet Office.

The sites for the soil moisture stations and the full AWS were finalised following several days of field visits, however, the sites for the radar water level stations were to prove more challenging. The main issue for this latter equipment was the lack of GPRS coverage in the areas of maximum interest according to the focus of the BRCCC project. With this information in hand, it was agreed to divide the installation phase into two separate missions, covering a combined total of thirty-five days. The first mission took place in February 2017 and consisted of the commissioning of two soil moisture stations, one at Uitvlugt sugar refinery and the second at Kairuni agricultural station. The masts for both stations were fabricated locally from 1.5-inch galvanised piping. All bolts and screw threads were welded to reduce the possibility of theft, and all elements etched with Hydromet details.

Map 1 Guyana [5]

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Figure 2 Soil Moisture Stations at Uitvlugt and Kairuni, Guyana

The full AWS was destined to the Amerindian village of Santa Rosa situated on the Moruka River, 29 km from its mouth, in the Barima-Waini region of northern Guyana. Selecting an appropriate site for a weather station is critical for the procurement of accurate meteorological data. Once the site had been defined, the exact location for the AWS was marked out and a foundation 1 m square with a depth of 1.20 m excavated and appropriate form work and rebar structure installed. The base plate of the tower was affixed to the rebar meshwork and a mixture of 1:2:3 concrete added to the foundation. Likewise, a concrete base was laid for the rain gage at the requisite distance from the tower. Characteristically, the site should be representative of the area of interest, and be at a sufficient distance from obstructions such as buildings and trees; nevertheless, there is always a compromise between climatological and practical requirements, and in this particular case, several nearby trees had to be felled to accommodate the station under optimum conditions. Forty-eight hours later the assembly of the tower was initiated. The tower was an equilateral triangle welded truss design, made of aircraft-grade 6063- T832 aluminium tubes and 6061-T6 bracing rods. 10-foot lengths were supplied for ease of transportation, including one top section, a tapered section, a straight section, and an appropriate base. The guyed tower provides extra strength and stability by adding three 150 cm anchor rods, braided steel guy wires and associated hardware. Once mounted, the tower was fixed to the base plate atop the armoured foundation, and elevated to vertical and anchored with the appropriate braided steel guy wires.

Figure 3 Construction of the AWS foundation at Santa Rosa, Guyana

The stainless steel instrument enclosure was affixed to the north side of the tower, the ultrasonic wind sensor to the eastern flank to intercept the prevailing winds, with the temperature and relative humidity sensors housed in a ventilated radiation shield on the south side of the tower. The antenna was orientated towards 75W GOES 13 satellite using the Dishpointer Software : http://www.dishpointer.com/

Address: Santa Rosa Guyana	Elevation: 69.0°
Latitude: 7.6690°	Azimuth (true): 245.3°
Longitude: -58.7820°	Azimuth (magn.): 261.4°

The station was programmed to transmit data to the NOAA 75W GOES 13 satellite using Pseudobinary B format. Data is measured at five minute intervals, archived to a buffer and sent hourly in a ten second time slot allocated to the station by NOAA. All programming was carried out via the front panel of the 9210B and using Sutron's XTerm software communications program. The data captured by the station includes rainfall, wind speed, temperature, leaf wetness, soil moisture, soil temperature etc. A sample message from the station is illustrated in table 2. As is customary when livestock are present, the installation was professionally fenced using locally sourced materials.

Figure 4 Santa Rosa AWS

UTC: Mon Oct 02 20:24:11 2017

140593AE ()

DCP Address:	140593AE
First transmission time:	00:06:30
Self-timed channel:	69
Transmission interval:	01:00:00
Transmission window:	10
Preamble:	S
Baud rate:	300

GOES channel	Date	Transmit start	Transmit end	Window start	Window end	Failure code	Signal strength	Message length	Frequency offset	Modulation index	DRGS code	Bat
69	10/02/2017	--:--:--	--:--:--	20:06:30	20:06:40	M	0	0	N/A	N/A	--	
69	10/02/2017	--:--:--	--:--:--	19:06:30	19:06:40	M	0	0	N/A	N/A	--	
69	10/02/2017	--:--:--	--:--:--	18:06:30	18:06:40	M	0	0	N/A	N/A	--	
69	10/02/2017	--:--:--	--:--:--	17:06:30	17:06:40	M	0	0	N/A	N/A	--	
69	10/02/2017	--:--:--	--:--:--	16:06:30	16:06:40	M	0	0	N/A	N/A	--	
69	10/02/2017	--:--:--	--:--:--	15:06:30	15:06:40	M	0	0	N/A	N/A	--	
69	10/02/2017	14:06:30.3	14:06:39.6	14:06:30	14:06:40	G	36	321	0	N	UP	
69	10/02/2017	13:06:30.3	13:06:39.6	13:06:30	13:06:40	G	38	321	0	N	UB	
69	10/02/2017	12:06:30.3	12:06:39.6	12:06:30	12:06:40	G	38	321	0	N	UP	
69	10/02/2017	11:06:30.3	11:06:39.6	11:06:30	11:06:40	G	38	321	0	N	UP	
69	10/02/2017	10:06:30.3	10:06:39.6	10:06:30	10:06:40	G	38	321	0	N	UP	
69	10/02/2017	09:06:30.3	09:06:39.6	09:06:30	09:06:40	G	38	321	0	N	UB	
69	10/02/2017	08:06:30.3	08:06:39.6	08:06:30	08:06:40	G	38	321	0	N	UP	
69	10/02/2017	07:06:30.3	07:06:39.6	07:06:30	07:06:40	G	38	321	0	N	UP	
69	10/02/2017	06:06:30.3	06:06:39.6	06:06:30	06:06:40	G	38	321	0	N	UB	
69	10/02/2017	05:06:30.3	05:06:39.6	05:06:30	05:06:40	G	38	321	0	N	UB	
69	10/02/2017	04:06:30.3	04:06:39.6	04:06:30	04:06:40	G	37	321	0	N	UB	
69	10/02/2017	03:06:30.3	03:06:39.6	03:06:30	03:06:40	G	38	321	0	N	UP	
69	10/02/2017	02:06:30.3	02:06:39.6	02:06:30	02:06:40	G	38	321	0	N	UP	
69	10/02/2017	01:06:30.3	01:06:39.6	01:06:30	01:06:40	G	38	321	0	N	UP	
69	10/02/2017	00:06:30.3	00:06:39.6	00:06:30	00:06:40	G	38	321	0	N	UP	

Table 1 List of messages transmitted from the station at Santa Rosa

140593AE - 10/02/2017 14:06:31 UTC
No Matching TransportMedium for Channel 69

Message Parameters:

DCP Address: 140593AE	Message Quality: Good
Signal Strength: 36 dBM	Frequency Offset: 0 (0 Hz)
GOES Channel: 69E	Message Length: 321
DRGS code: UP	DRGS Description:
Carrier Start (UTC): 14:06:30.288	Carrier Stop (UTC): 14:06:39.646
Additional Flags: (none)	

Raw Data:


```
        140593AE17275140631G36+0NN069EUP00321bB1F@DC@DD@DE@DH@DG@DI@DC@DD@DF@DG@DH@DI@D
D@DE@DI@DH@DJ@DL@A_@A_@A^@A]@A\@A\@C{//////@C{/////////////////////////////
////////////////////////////////////////////////////////////////////////////
////////B^GB^FB^IB^GB^EB^F@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@a@@a@@a@@a@@
_@@_@@^@@^@@^@@^@@]@@]@@v@AV@AG@@o@@g@@Z:BL 12.17
```


Table 2 Content of a standard Pseudobinary B message transmitted by the AWS at Santa Rosa

In July of 2017, a second mission to Guyana was launched to complete the installation of the four remaining water level stations. This mission was to prove to be drastically more challenging than phase one. Through field tests carried out in situ, the originally purchased GPRSlink data loggers were found to be unsuitable for the available communications in country. Although basic network coverage was obtainable in some areas, the telecommunications network at the time of inspection did not provide reliable 3G coverage. As a solution, the original loggers were substituted for the latest Satlink3 data loggers. These loggers provided an extremely flexible platform with the added advantage of Linkcomm intuitive programming and GOES satellite transmission. As the selected sites were not in areas affected by flash floods, the fact that the data would be sent on an hourly basis was not an issue. It should be stated that in other locations in the Caribbean such as Saint Vincent and the Grenadines, it has become apparent that under adverse conditions, sensor poling and data transmission can be required every sixty seconds especially in flashy catchments. Satlink3 is equipped to use the emergency channel to warn of imminent flooding however, the frequency of messages and the message size is limited by constraints of NOAA, per se, an alternative backup communication would need to be sought for near-real time data transmission.

The selected river gaging sites were allocated around the country according to the needs expressed by the Hydromet department and the project stakeholders. These locations were Malawi, Pirara, Karawab and Portage Falls.

Pirara, near Lethem is located in the Upper Takutu-Upper Essequibo Region is accessed by air or as was the case for the installation via over 400 km of dirt tracks snaking through the tropical rain forest. As this was July of 2017, the rainy season was advanced, rendering the expedition treacherous in places. Lamentably, on arrival the selected site was inaccessible due to exceptionally high precipitation in the preceding days causing localised flooding, as such, the installation was deferred until September 2017.

The second station to be installed was at the Amerindian Reservation of Malali, situated on the Demerara River, approximately 80 kilometres up river from the prosperous town of Linden. To obtain permission for the installation of equipment in a reservation necessitates an involved and often drawn-out process of negotiation with community leaders prior to the initiation of any civil works. On the positive side, this negotiation habitually guarantees that the station is considered to be an indispensable element within the community, affording local protection and consequently a higher degree of security than many stations. Subsequent to approval, the supporting structure for the station was installed on the left bank of the river, within visual distance of the main settlement for security reasons. The station was also specified with a 0.2 mm tipping bucket rain gage to compliment the radar water level. The SATLINK3 was programmed to send the data in Standard Hydrometeorological Exchange Format (SHEF). This format was selected as it provides the local agencies and stakeholders with easily decipherable online access to data for spot consultations. The site offers ample warning of imminent flooding for Linden and Georgetown beyond.

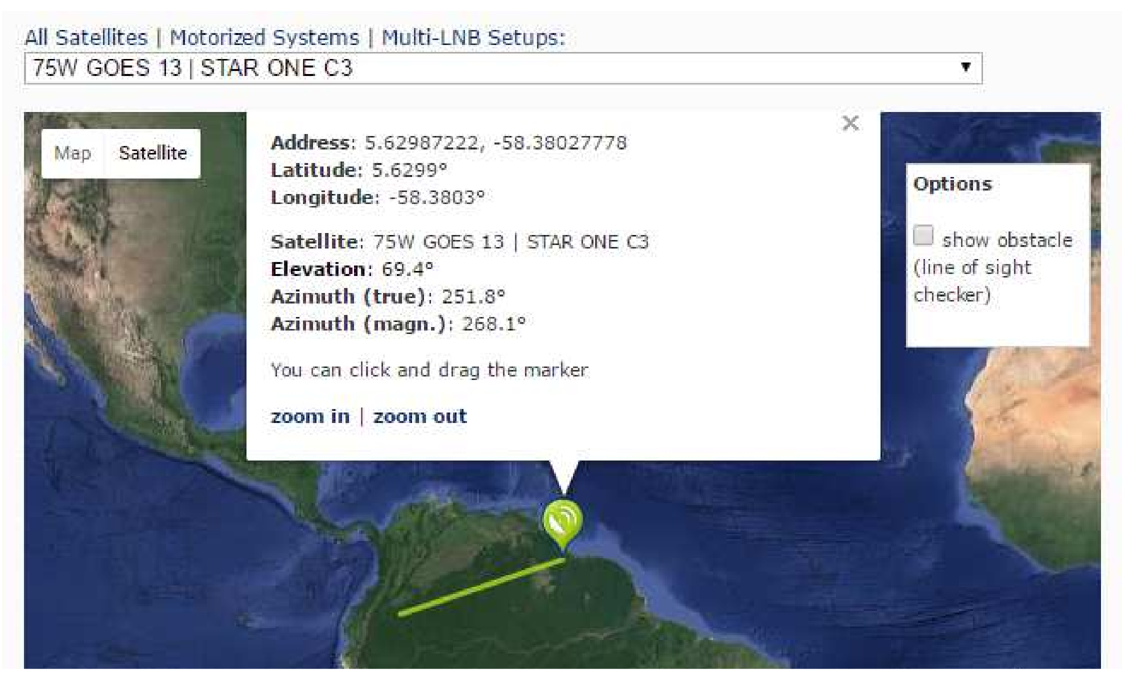

Figure 5 Antennae data associated with Malali river gaging station.

Figure 6 Malali river gaging station, Guyana

14004206 - 10/02/2017 22:43:31 UTC
No Matching TransportMedium for Channel 79

Message Parameters:

DCP Address: 14004206	Message Quality: Good
Signal Strength: 41 dBM	Frequency Offset: 0 (0 Hz)
GOES Channel: 79E	Message Length: 219
DRGS code: UB	DRGS Description:
Carrier Start (UTC): 22:43:30.289	Carrier Stop (UTC): 22:43:36.922
Additional Flags: (none)	

Raw Data:

14004206172752243316G41+0NN079EUB00219":WL 3 #5 4.54 4.54 4.54 4.54 4.54 4.54 4.54 4.54 4.54 4.54 4.54 4.54 :RainRt 3 #5 0.00 0.00 0.00 0.00 0.00 0.00 0.00

Table 3 Sample data transmission from Malali station. (SHEF format)

The third site at Karawab located on the eastern bank of the Upper Pomeroon River, 70 km upriver from Charity on the Essequibo Coast. This site as with that at Malali can only be accessed via river.

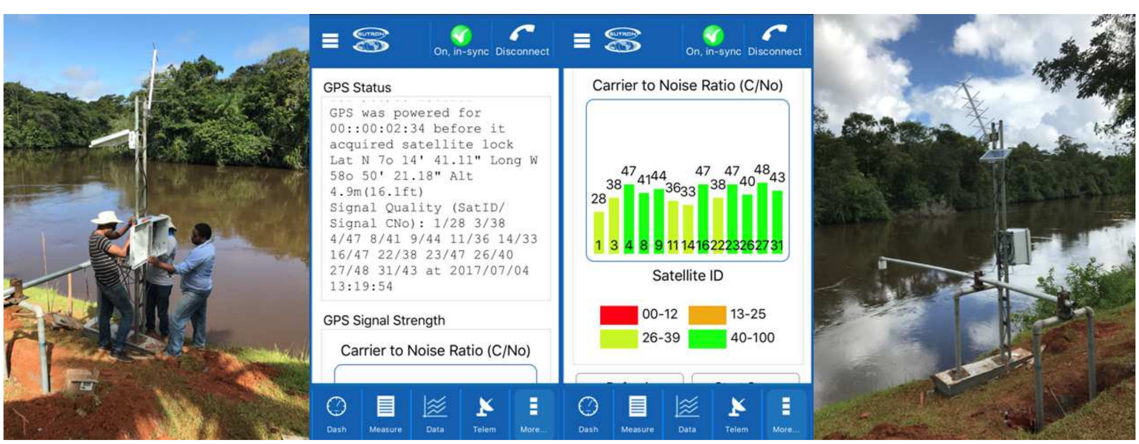

Figure 7 Karawab river gauging station, illustrating details of the Linkcomm software on IOS

The final station to be installed was planned to be down river of Amaila Falls located on the Kuribrong River (Potaro-Siparuni Region), a tributary of the Potaro River in west central Guyana. The river drops from the escarpment over Amaila Falls vertically approximately 60 m, and continues in a series of rapids and falls for almost four kilometres before reaching placid water at an elevation of 54 metres. The waterfall is approximately 45 m wide, and the estimated mean discharge is 64 m^3/s. [6] The hydrology for Amaila Falls is not very well established since continuous series of direct flow measurements in Kuribrong River do not exist. Flow records from the gauging station at Kaieteur Falls in the neighbouring Potaro River catchment provided the basis for a feasibility study for hydropower suitability in 2001. Simultaneous flow measurements were carried out on the Kuribrong River near to Amaila Falls and at Kaieteur Falls in June-July 1975 and in June-August 2001. These measurements were used for selecting the transposing factor of 0.3. The records during these brief periods of measurement showed great variation in the ratio between the simultaneous flows in Kuribrong River at Amaila Falls and in Potaro River at Kaieteur Falls. [7] In order to reduce hydrological uncertainty, which is especially desirable in the low flow season, longer periods of direct measurements in Kuribrong River were necessary. Bearing the aforementioned information in mind, the brief of the project was to encounter a suitable site on the Kuribrong river to estimate the discharge. The initial site proposed by the Hydromet department was situated at approximately 5 km below Amaila falls, in the vicinity of a mining hamlet. The site was proposed as in previous years a consulting team working for the hydroelectric project had commissioned a station to evaluate the hydroelectric generating potential of the river. Over the last five years it transpired that said station had been vandalised with components being appropriated. On inspection, the location was overgrown and also considered to be a security risk for the project, consequently a new site was identified some 115 km downstream of the suggested site and 1 km upriver of Portage Falls. As this site was positioned at a permanently manned crossing point of the river Kuribrong, subsequent to consultation with land owners it was deemed to be a suitable secure site for the installation to go ahead. Over a period of two extremely wet tropical days the station was mounted.

Figure 8 Portage Falls river gauging station, Guyana

1.4 Station Configuration

The configuration and testing of the stations was carried out in the offices of HYDROMET in Georgetown. This was considered essential to eliminate possible problems in remote field locations. As can be seen from figure 9, the programming of the data logger is via Linkcomm software with pull down menus and text boxes. This software can be run on IOS, Android and windows, as such is an exceedingly flexible tool in the field.

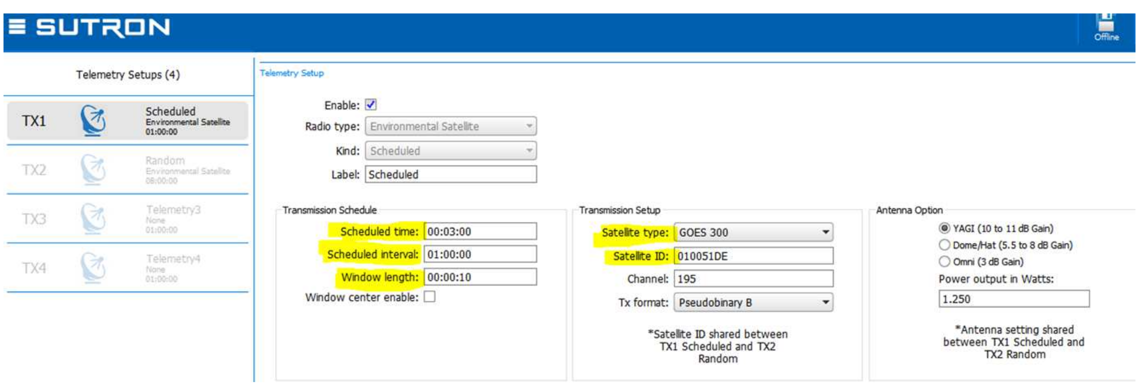

Figure 9 Example of the Linkcomm interface

1.5 Data Analysis

Data transmitted from the stations is presented on the Caribbean Dewetra platform. The Dewetra Platform is a web-based Geographic Information System Tool created through an Italian Disaster Risk Reduction Civil Defense project in the Caribbean from 2009 to 2011 and managed by the Caribbean Institute for Meteorology and Hydrology (CIMH). It was created to enhance ongoing efforts for the collection, analysis and application of data to improve early warning systems, to enhance hazard mitigation, and, to provide National Disaster Management Agencies with additional technical support to strengthen their planning and operations. The platform currently provides users with near real-time data from over one hundred stations in the Eastern Caribbean. In the very near future it is proposed to increase the potential of the platform through the incorporation of data received from more than forty GOES Automatic Weather Stations in the CIMH network. The following screen captures provide an overview of one of the many utilities of the platform to represent data captured from multiple automatic stations over the Caribbean region. Dewetra access can be obtained from the following link and credentials.

http://bb02.cimafoundation.org:8080/dewetra/

User: ICAWS   Password: ICAWS

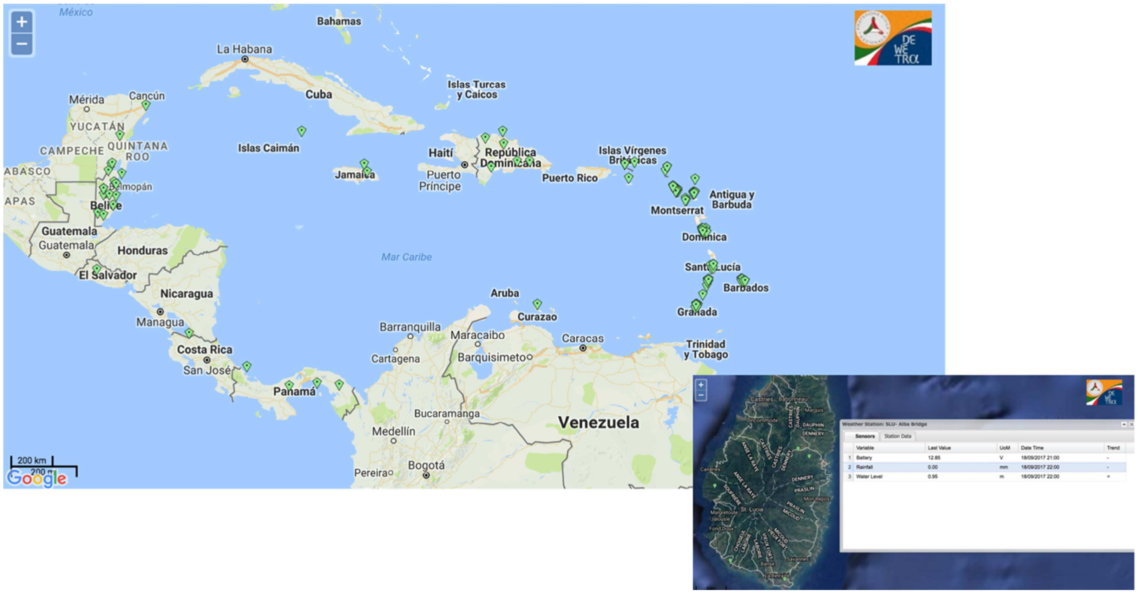

Figure 10 Stations in Caribbean Dewetra

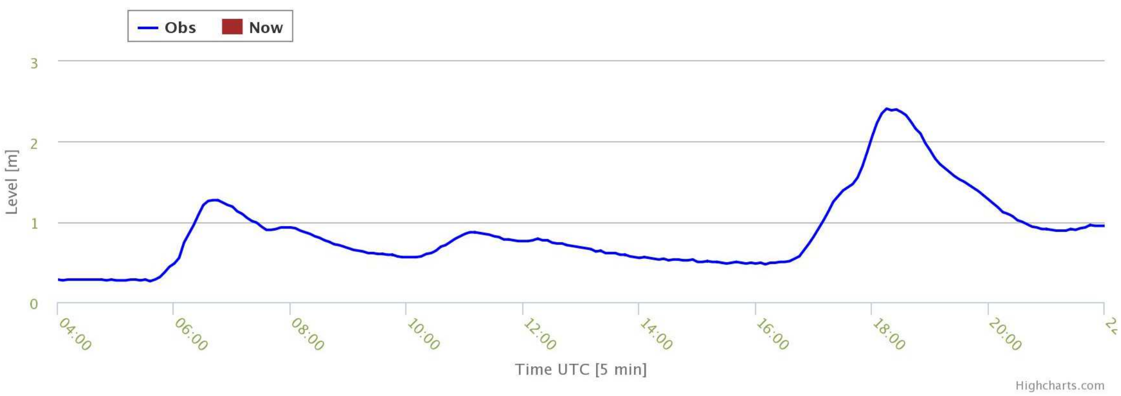

Figure 11 Water level registered at Alba Bridge St Lucia.

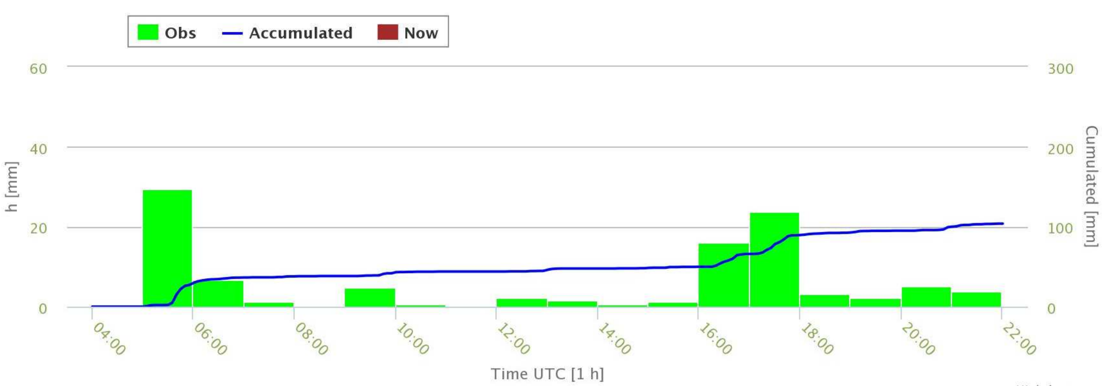

Figure 12 Rainfall at Alba Bridge station, Saint Lucia

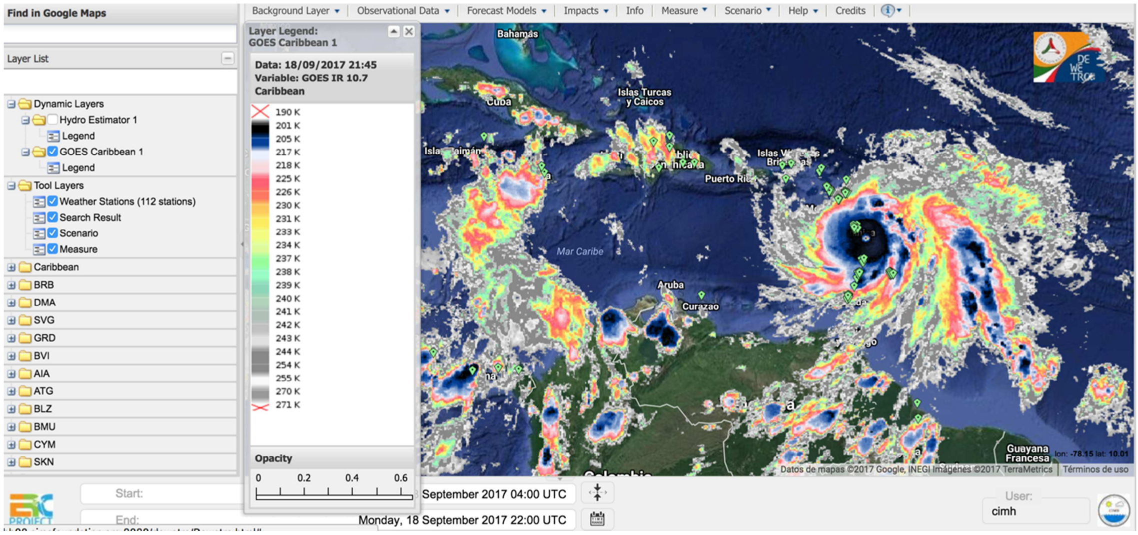

Figure 13 GOES Caribbean Hurricane Maria

1.6 Conclusions

Tailored climate products dedicated to disaster mitigation are a valuable tool in modern hazard management. To achieve quality data, stations must be strategically sited and professionally installed so as to be representative of the region and to withstand natural phenomena such as floods and hurricanes. Preventive and corrective maintenance must be routinely performed to guarantee the quality of the data recorded and transmitted. Local agencies should be tasked with routine maintenance, and when required, seek back up from regional specialised agencies. strategic locations over the region of interest. Projects designed to increase the number of reporting stations in a network should have a sufficient budget to permit maintenance of such installations for a period of at least five years following deployment. Good technical backup and customer service from equipment suppliers is fundamental to ensure optimum up time and swift equipment repair or substitution.

1.7 References

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United Nations Development Programme
Capacity Development and Mainstreaming for Sustainable Land Management
PIMS 3413 – Atlas Project ID 00047476
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