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## **Building a Natural-Hazard-Resilient High-Quality Seismic Network: How WI Network Sustained Hurricanes Maria and Irma**

Jean-Marie Saurel, Jordane Corbeau, Sébastien Deroussi, Tristan Didier, Arnaud Lemarchand, Séverine Moune, Lloyd Lynch, Anne-Marie Lejeune, Roberto Moretti, Jean-Christophe Komorowski

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## Building a natural-hazard resilient high-quality seismic network: how WI network sustained hurricanes Maria and Irma --Manuscript Draft--

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<b>Corresponding Author:</b>	Jean-Marie SAUREL Institut de Physique du Globe de Paris Paris, Île-de-France FRANCE
<b>Corresponding Author Secondary Information:</b>	
<b>Corresponding Author's Institution:</b>	Institut de Physique du Globe de Paris
<b>Corresponding Author's Secondary Institution:</b>	
<b>First Author:</b>	Jean-Marie SAUREL
<b>First Author Secondary Information:</b>	
<b>Order of Authors:</b>	Jean-Marie SAUREL Jordane Corbeau Sébastien Deroussi Tristan Didier Arnaud Lemarchand Séverine Moune Lloyd Lynch Anne-Marie Lejeune Roberto Moretti Jean-Christophe Komorowski
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1 **Building a natural-hazard resilient**  
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5 JM. Saurel<sup>1</sup>, J. Corbeau<sup>1,3</sup>, S. Deroussi<sup>1,2</sup>, T. Didier<sup>1,2</sup>, A. Lemarchand<sup>1</sup>, S. Moune<sup>1,2</sup>, L. Lynch<sup>4</sup>,

6 AM. Lejeune<sup>1,3</sup>, R. Moretti<sup>1,2</sup>, JC. Komorowski<sup>1</sup>

7

8 1. Université de Paris, Institut de physique du globe de Paris, CNRS, 75238 Paris, France

9 2. Observatoire volcanologique et sismologique de Guadeloupe, Institut de physique du globe de Paris,  
10 97113, Gourbeyre, Guadeloupe, France

11 3. Observatoire volcanologique et sismologique de Martinique, Institut de physique du globe de Paris,  
12 97250, Saint-Pierre, Martinique, France

13 4. Seismic Research Center, The University of the West Indies, Gordon Street, St Augustine, Trinidad,  
14 Trinidad and Tobago

15 Corresponding author : Jean-Marie Saurel, [saurel@ipgp.fr](mailto:saurel@ipgp.fr) .

## 16 **Abstract**

17 Between 2008 and 2014, IPGP (Institut de Physique du Globe de Paris) and UWI-SRC (University of  
18 the West Indies, Seismic Research Centre) designed and built a regional seismic network across the  
19 Lesser Antilles. One of the goals of the network is to provide real-time seismic data to the tsunami  
20 warning centers in the framework of the ICG-CARIBE-EWS (Intergovernmental Coordination Group  
21 working toward the establishment of a tsunami and other coastal hazards Early Warning System for the  
22 Caribbean and adjacent regions, McNamara et al, 2016). In an area prone to hurricanes, earthquakes,  
23 tsunamis and volcanic eruptions, we choose different techniques and technologies to ensure our co-  
24 operated network could survive and keep providing data in case of major natural hazards. The  
25 Nanometrics VSAT technology is at the heart of the system. It allows duplicated data collection at the  
26 three observatories (Trinidad, Martinique and Guadeloupe, Anglade et al, 2015).

27 In 2017, the network design and implementation were put to test with Saffir-Simpson category 5  
28 hurricanes Irma and Maria that went, respectively, through the North and Central portion of the Lesser  
29 Antilles, mainly impacting the sites operated by volcanological and seismological observatories of  
30 IPGP in Martinique (OVSM) and in Guadeloupe (OVSG). Our concepts proved to be valid with a  
31 major data shortage of less than 12h and only two stations having sustained heavy damages.

32 In this paper, we review the strength and weaknesses of the initial design and discuss various step  
33 forward that can be taken in order to enhance even more the ability of our co-operated network to  
34 provide timely real-time seismic data to tsunami warning center under any circumstances.

35

## 36 **Geographic context**

37 The Lesser Antilles active subduction zone spreads across 1000km from Trinidad in the South to Virgin  
38 Islands in the North (figure 1). The American plate moves toward Caribbean plate at a relative slow  
39 rate around 2cm/year (Symithe et al, 2017) . This slow converging movement has still generated two  
40 major thrust earthquakes that killed several hundred people and destroyed two main cities in the  
41 nineteenth century. The 1839 M 8.0 and the 1843 M 8.5 earthquakes (e.g., Bernard and Lambert, 1988;  
42 Feuillet et al., 2011; Hough, 2013) respectively destroyed Fort Royal (now Fort de France) and Pointe à  
43 Pitre, economic centers of Martinique and Guadeloupe at the time. The 1843 event also triggered a  
44 small tsunami with evidence found in Antigua (Bernard and Lambert, 1988). The 850 km long Lesser  
45 Antilles is a chain of volcanic islands formed as the result of this subduction below the Caribbean plate  
46 since at least about 40 Millions years. Since 1600 C.E. and European settlement, the region has  
47 produced at least 34 eruptions from its 21 active volcanoes located on 11 islands, from the Grenadines  
48 (South) to Saba (North) (Lyndsay et al., 2005). The Lesser Antilles region is known for the most deadly  
49 volcanic eruption in the world since 1600 C.E. when Montagne Pelée killed directly about 29 000  
50 persons in 1902 (Witham, 2005), totally destroying the towns of Saint-Pierre and Morne Rouge in  
51 Martinique. Between July 1976 and March 1977, the non-magmatic and phreatic eruptions of La  
52 Soufrière de Guadeloupe forced the evacuation of about 74 000 people of out of the southern part of  
53 Basse-Terre island for as much as 4 to 6 months (Feuillard et al., 1983; Komorowski et al., 2005:  
54 Hincks et al., 2014). More recently, the ongoing eruption of Soufriere Hills that began in 1995 has  
55 severely impacted the island of Montserrat, killing 19 people in 1997 (Wadge et al., 2014) and sent ash  
56 plumes in the region that brought to a complete stop of the airline traffic in February 2010 (Cadelis et  
57 al., 2013). Brown et al. (2015) have shown that the Lesser Antilles is the region in the world that is the  
58 most exposed to volcanic hazards if we rank by the proportion of its total population that live within

59 30km of an active dangerous volcano. As a tropical area, the Lesser Antilles also face a yearly  
60 hurricane season which exposes the islands to heavy rains, winds, waves and storm surges. Between  
61 1965 and 2019, 77 named tropical cyclones made their way in the Lesser Antilles. Statistically, a  
62 tropical cyclone has then approached the islands at less than 100km every 5 years for the northern  
63 islands of Saint-Martin/Sint-Maarten and Saint-Barthélemy, 8 years for Guadeloupe and 10 years for  
64 Martinique (MétéoFrance, personal communication). There is however a lot of year to year variation in  
65 the number of tropical cyclones and just a few of them have had some severe impact on the islands.  
66 During the same time-period, 13 major hurricanes (category 3 and above) happened. Since the  
67 beginning of hurricanes records in the region in 1851, several hurricanes have marked memories in the  
68 French West Indies. In 1963, Edith went over Dominica, heavily impacting the island and both  
69 Martinique and Guadeloupe. In Guadeloupe, Cleo in 1964 and Hugo in 1989 remain in the inhabitants  
70 memory for the devastation and death they spread over the archipelago, but Luis and Marilyn in 1995  
71 and Lenny in 1999 also caused considerable damages. In Martinique, the heavy rains of Dorothy in  
72 1970 spread devastation on the island and more recently, Dean in 2007, the closest hurricane from  
73 Martinique ever recorded, damaged most of the Martinique IPGP observatory seismic network. Finally,  
74 2017 hurricane season was one of the most actives with two category 5 hurricanes crossing the islands  
75 3 weeks apart.

76 The Lesser Antilles regional and volcanic activity is monitored by the Seismic Research Center of the  
77 University of the West Indies (UWI-SRC) established in Trinidad and by Institut de Physique du Globe  
78 de Paris (IPGP) through its two observatories in the France's overseas departments of Martinique and  
79 Guadeloupe (OVSM and OVSG). Netherland Antilles islands of Saba and Sint-Eustatius volcanic  
80 activity is monitored by Koninklijk Nederlands Meteorologisch Instituut (KNMI). UWI-SRC is in  
81 charge of the volcano monitoring in Montserrat (through the Montserrat Volcano Observatory - MVO)

82 and in all the independent English speaking islands from Trinidad up to Barbuda and also monitor the  
83 area regional seismicity since the 1953 (Dondin et al, 2019). OVSM-IPGP and OVSG-IPGP are  
84 respectively in charge of Montagne Pelée (since 1902) and Soufrière de Guadeloupe (since 1950)  
85 volcanoes monitoring and, since the 1980's, of the regional seismicity monitoring in the central portion  
86 of the Lesser Antilles.

87

## 88 **Station, network and data distribution designs**

89 Beginning with analog telemetry network of short-period stations around the volcanoes, the 3  
90 Caribbean observatories (OVSM-IPGP, OVSG-IPGP and UWI-SRC) followed the evolving  
91 technologies, with digital telemetry starting to be deployed in the 2000's. In 2004, in the aftermath of  
92 the December 26th Sumatra/Andaman earthquake and tsunami, UNESCO orchestrated activities in  
93 identified tsunami threatened basins to establish Early Warning Tsunami Warning Systems (EW-TWS).  
94 In the Caribbean, it fostered collaboration between existing seismic monitoring network under the  
95 umbrella of the International Coordination Group for a Caribbean Tsunami and other coastal hazard  
96 Early Warning System (ICG-CARIBE EWS) to share real-time high quality broadband seismic data to  
97 the Tsunami Service Providers (TSP) in charge of the area (McNamara 2015). In 2008, following the  
98 first 5 stations (TR FDSN network code) installed two years earlier by UWI-SRC (Dondin et al, 2019),  
99 UWI-SRC and IPGP partnered to install and co-operate an extended seismic network (WI FDSN  
100 network code) at the scale of the Lesser Antilles subduction zone (figure 1).  
101 To deal with the various natural hazards, the WI network uses redundant systems at several levels  
102 (transmission, station power, instruments). In an area prone to earthquakes, tsunamis, volcanic  
103 eruptions and hurricanes, land telecommunication networks cannot be considered reliable. To securely

104 cover the full 1000km span of the Antilles, Very Small Aperture Terminal (VSAT) satellite technology  
105 was chosen. Each one of the 3 observatories is equipped with a satellite hub to receive directly from the  
106 satellite link data from all the stations of the network (figure 2a). On each one of the 6 satellite  
107 frequencies used, the master hub operation is secured by the two other hubs configured in slave and  
108 backup mode which can take over the scheduling of the stations transmissions, should the master hub  
109 fail.

110 We took care to install the WI stations outside of the main volcanic risk area on each island. Since  
111 Lesser Antilles volcanoes are mostly andesitic ones, characterized by the likely emission of ash clouds  
112 over large area (Michaud-Dubuy et al, 2019), the stations are equipped with independent double solar  
113 power systems and each one is rated to withstand station operation during at least 10 days without sun.  
114 This allows the operator to clean the solar panels in case of ash fallout. Moreover, special care was  
115 taken to install high-end broadband and accelerometer sensors in insulated underground vaults to  
116 provide high quality data (Anglade et al, 2015) for any earthquake in the Caribbean region.

117 Hurricane being the most frequent hazard for the network, one of the VSAT reception hub and 4  
118 stations were equipped with hurricane-resistant radome to form a reinforced minimal core-network that  
119 can still operate under hurricane winds up to 120kt (Anglade et al, 2015).

120 Because the local observatories Internet bandwidth are limited, WI network data is made available to  
121 TSP only by IPGP data center in Paris which can handle virtually unlimited connections. Centralized  
122 WI data comes preferably from Martinique or Guadeloupe observatories, depending on the stations (the  
123 other observatory acting as a back-up). Trinidad observatory is considered as a last resort solution  
124 should Martinique and Guadeloupe observatories be out of service at the same time. WI stations,  
125 operated by IPGP or UWI-SRC are openly distributed in real-time from IPGP datacenter. TR stations  
126 operated by UWI-SRC are distributed in real-time to warning centers from UWI-SRC facilities in



127 Trinidad. TR and WI real-time data are also shared among the 3 observatories and locally used by each  
128 one for the routine earthquake processing. Archived WI data are made available to the scientific  
129 community after validation through IPGP, RESIF and IRIS data centers.

## 130 **Network resilience through the 2017 hurricane season**

131 In 2017, an exceptionally active hurricane season impacted the Lesser Antilles (on September 8<sup>th</sup>, three  
132 hurricanes were visible on a single Caribbean satellite image : Katia, Irma and Jose). Irma was the first-  
133 ever Saffir-Simpson category 5 hurricane to cross the Antilles since the beginning of the records in the  
134 region in 1851, followed 3 days after by Jose that avoided the islands, turning Northward at the last  
135 moment. 3 weeks later, the Antilles were struck in the middle by Maria, which grew explosively in less  
136 than 24h from a category 1 to a category 5 when it crossed the arc in Dominica (figure 1).

137 On September 1<sup>st</sup>, hurricane Irma was already a Major Hurricane and we knew it would cross the  
138 northern tip of the Lesser Antilles. On September 4<sup>th</sup>, the NOAA NHC (National Oceanic and  
139 Atmospheric Administration, National Hurricane Center) raised the alert level to a warning with  
140 sustained winds expected up to 150kt (Cangialosi et al, 2018). Two of the WI network stations were on  
141 its predicted path : ANBD in Antigua and SBLM in Saint-Barthélemy (figure 1). On September 5<sup>th</sup>,  
142 around 20:00 UTC, Irma heavy rains struck Guadeloupe and blurred the Guadeloupe stations  
143 transmission during a few hours (figure 3c). The 6<sup>th</sup> of September, between 00:00 and 05:00 UTC, Irma  
144 center passed 70km away of Antigua stations, at the time of its intensity peak (lowest pressure) with  
145 sustained winds estimated above 50kt on Antigua, generating a noise peak at the station above the swell  
146 induced rising noise (figure 3a). This station was equipped with a radome and did not suffer any  
147 damage and only minor real-time data flow outages during the heavy rains. A few hours later, at 08:07  
148 UTC, 130kt wind gusts were recorded on Saint-Barthélemy weather station (173kt unofficial

149 observation of wind gusts were reported, Cangialosi et al, 2018), Irma eye wall made landfall on the  
150 island just before 09:00 UTC. SBLM station stopped responding and recording data just minutes  
151 earlier, at 08:04 UTC. Later onsite examination showed that all the surface equipments (VSAT antenna,  
152 solar panels, batteries) were thrown away by the winds (figure 1). The vaults and instrument stayed  
153 safe without any damage. None of the other installations (stations, hubs, servers) of the WI network  
154 were impacted by Irma.

155 3 weeks later, on September 17<sup>th</sup>, hurricane Maria, still a tropical storm the day before, rapidly grew up  
156 to category 4 as it approached the islands of Martinique, Dominica and Guadeloupe (figure 1). Several  
157 stations of the WI network and two of the reception hubs were threatened by its winds and rains.

158 Northern Martinique was the first impacted land. As the heavy rains screened out any VSAT  
159 transmission from the island and started infiltrating the 1936 observatory building, forcing the  
160 shutdown of its servers for 24 hours, Martinique stations data collection was quickly manually re-  
161 routed to the Guadeloupe reception hub on September 18<sup>th</sup> at 16:00 UTC (figure 3d). The hurricane  
162 then quickly turned North while reinforcing to a category 5 and crossed Dominica from South-East to  
163 North-West (Pasch et al, 2019), destroying the DSLB station surface equipments (the station  
164 transmission was already down for a few months after a modem failure). In the night of September 19<sup>th</sup>,  
165 the eye of Maria was at the closest of Guadeloupe archipelago (10km away from Les Saintes islands,  
166 TDBA station, figure 1). All data transmissions stopped at 02:20 UTC, when the observatory and the  
167 reception hub suffered heavy damages that rendered all its facilities non-operational for 3 days. Data  
168 collection of all the network was routed back to Martinique hub after the restart of their servers on  
169 September 19<sup>th</sup>, at 14:00 UTC (figure 3d). While an initial goal of the WI network was to ensure  
170 possible WI data collection from Trinidad in case of Martinique and Guadeloupe observatories failure,  
171 this was unfortunately not yet operational at the time it was needed during Maria hurricane. Several

172 early modem failures on Trinidad hub and some loose coordination with IPGP after the end of the  
173 funding projects made the emergency software setup prepared in Paris to collect the data from UWI-  
174 SRC servers just before Maria arrival (figure 2a) useless. On September 19<sup>th</sup>, at 18:14 UTC, 12 out of  
175 the 15 WI stations recorded in real-time the 7.1 earthquake that occurred in Puebla, Mexico. Despite  
176 the still rough sea and subsequent high micro-seismic pick noise level (figure 3b), the signal to noise  
177 ratios (SNR) at 10s, on horizontal or vertical channels, ranged from 3 to 30 depending on the station  
178 (minimum SNR was 10 at 20s and 30s), which is still a decent level for real-time data processing. In  
179 comparison, the SNR at 10s was 5 times higher in June 22, for the 6.8 earthquake offshore Puerto San  
180 José, Guatemala (SNR at 10s from 15 to 200). In the end, while being directly impacted, the WI  
181 seismic network only had a maximum of 12 hours of real-time data shortage due to the passage of the  
182 most devastating hurricanes that hit the area since 1989.

183 The radome protected core network proved efficient as, even ANBD station and Martinique hub  
184 exposed to >50kt Irma and Maria winds did not suffer any damage. The ability to receive the data in  
185 different hubs spanning the whole subduction zone also proved very efficient in limiting the real-time  
186 data flow shortage for early warning services. Unfortunately, some delays in securing funding to repair  
187 modems hub in Trinidad prevented to take full advantage of the resilient network design. After those  
188 two major hurricanes, only 3 stations were damaged, requiring moderate to heavy maintenance: SBLM  
189 and DSLB stations whose surface equipment were destroyed by the direct hit of the hurricanes, and  
190 DHS whose seismic vault was drowned by Maria heavy rains and the seismometer damaged.

## 191 **Discussion**

192 The Irma and Maria hurricanes showed us two main weaknesses in our system : the need for manual  
193 reconfiguration to take full benefit of the redundant Nanometrics Libra II system and the critical role of  
194 SBLM station to constrain Northern Antilles seismicity.

195 During the year it took to secure funding, order and install the replacement equipment in SBLM, this  
196 station proved to be a key point for the monitoring of the Northern part of the Lesser Antilles, where  
197 the small number of islands only allows a sparse network (figure 1). As the radome in Antigua and on  
198 Martinique stations and hub proved its effectiveness, SBLM station, given its importance for the  
199 Northern Lesser Antilles coverage, was re-installed with a radome that should withstand strong  
200 hurricanes that are expected to be more frequent with global warming (Knutson et al, 2019).

201 Even if Paris is obviously a safe place to collect and globally distribute the real-time data of the  
202 network, the data routing still needs some manual actions. Furthermore, there is no people on duty in  
203 IPGP Paris. This could be overcome by installing automatic re-routing solutions based on keepalived  
204 automatic IP fail-over software solution (figure 2b). Data would be preferentially routed from  
205 Martinique or Guadeloupe observatories. If both IPGP hubs fail, the second keepalived stage then falls  
206 back to Trinidad hub. To keep the system flexible and avoid putting all the bandwidth stress on a single  
207 observatory, the routing is made on a station by station basis. This automated system is still pending  
208 implementation on IPGP servers, which are currently being moved on a new cluster infrastructure.

209 The hurricanes heavy rains flooded DHS vault and damaged the broadband seismometer despite the  
210 drainage system included during the construction and the CASIS shielding (Anglade et al, 2015).

211 Today, this could be solved by using a 5 to 10m deep post-hole installation with watertight specific  
212 sensor, which is also proved to have huge benefits on the station noise level (Vergne et al, 2019).

## 213 **Conclusions**

214 Designing and running a monitoring network in a natural hazard rich area always lead to compromises  
215 and choices between initial investment, station sitting, station performance, maintenance cost and the  
216 probability of impacting hazards. Although worst-case scenarios were considered when we decided to  
217 install a monitoring network that has to last for the next 25 years, their very small probability of  
218 occurrence suggested a very small likelihood that we would never confront design concepts with the  
219 harsh reality. In 2017, Irma and Maria category 5 hurricanes, while throwing devastation on the Lesser  
220 Antilles, also provided us a unique opportunity to learn from exposing our design and networks to a  
221 real-life test by identifying and overcoming their weaknesses. The WI network, co-operated between  
222 three observatories and 2 research institutions from 2 different countries, proved the benefits of the key  
223 initial concepts with less than 12 hours of total real-time data shutdown. Except for one station wiped  
224 out by Irma winds, all continuous data were recovered and less than 24 hours after Maria, 80% of the  
225 network recorded good signals during the 2017 Mw7.1 Puebla (Mexico) earthquake. With SBLM  
226 station upgrade and the future automatic data routing implementation, the ability of the network to  
227 transmit high quality, timely, real-time data for early warning, monitoring and research and risk  
228 reduction in the region has been reinforced.

229 The next important step to improve the Lesser Antilles seismic monitoring and tsunami early warning  
230 will be the installation of permanent sea-bottom cabled observatories, something that we have begun to  
231 work on in the Mayotte volcano-seismic crisis context in 2020.

## 232 **Data and Resources**

233 Real-time data statistics were taken from IRIS-DMC data archive and all WI  
234 (<https://doi.org/10.18715/antilles.WI>) stations validated and real-time data are available from IPGP  
235 Data Center (<http://volobsis.ipgp.fr>) and RESIF national Data Center (<http://seismology.resif.fr>).  
236 Seismic noise amplitudes were computed with Thomas Lecocq's SeismoRMS code  
237 (<https://github.com/ThomasLecocq/SeismoRMS>).  
238 DEM used for the map is a compilation of GEBCO 2020 Grid, Shom 2018 Homonym Project and  
239 NASA STRM.  
240 Hurricanes statistics for French Islands were collected by MétéoFrance Antilles/Guyane and discussed  
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256

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300

## 301 **Author mailing list**

302 JM. Saurel : [saurel@ipgp.fr](mailto:saurel@ipgp.fr), Université de Paris, Institut de physique du globe de Paris, CNRS, 75238

303 Paris, France

304 J. Corbeau : [corbeau@ipgp.fr](mailto:corbeau@ipgp.fr), Observatoire volcanologique et sismologique de Martinique, Institut de

305 physique du globe de Paris, 97250, Saint-Pierre, Martinique, France

306 S. Deroussi : [deroussi@ipgp.fr](mailto:deroussi@ipgp.fr), Observatoire volcanologique et sismologique de Guadeloupe, Institut

307 de physique du globe de Paris, 97113, Gourbeyre, Guadeloupe, France

308 T. Didier : [didier@ipgp.fr](mailto:didier@ipgp.fr), Observatoire volcanologique et sismologique de Guadeloupe, Institut de

309 physique du globe de Paris, 97113, Gourbeyre, Guadeloupe, France

310 A. Lemarchand : [arnaudl@ipgp.fr](mailto:arnaudl@ipgp.fr), Université de Paris, Institut de physique du globe de Paris, CNRS,

311 75238 Paris, France

312 S. Moune : [moune@ipgp.fr](mailto:moune@ipgp.fr), Observatoire volcanologique et sismologique de Guadeloupe, Institut de  
313 physique du globe de Paris, 97113, Gourbeyre, Guadeloupe, France

314 L. Lynch : [lloyd.lynch@sta.uwi.edu](mailto:lloyd.lynch@sta.uwi.edu), Seismic Research Center, The University of the West Indies,  
315 Gordon Street, St Augustine, Trinidad, Trinidad and Tobago

316 AM. Lejeune : [anne-marie.lejeune@sorbonne-universite.fr](mailto:anne-marie.lejeune@sorbonne-universite.fr), Observatoire volcanologique et  
317 sismologique de Martinique, Institut de physique du globe de Paris, 97250, Saint-Pierre, Martinique,  
318 France

319 R. Moretti : [moretti@ipgp.fr](mailto:moretti@ipgp.fr), Observatoire volcanologique et sismologique de Guadeloupe, Institut de  
320 physique du globe de Paris, 97113, Gourbeyre, Guadeloupe, France

321 JC. Komorowski : [komorow@ipgp.fr](mailto:komorow@ipgp.fr), Université de Paris, Institut de physique du globe de Paris,  
322 CNRS, 75238 Paris, France

## 323 **Figure captions**

### 324 **Figure 1**

325 Irma and Maria hurricane tracks across the WI network. Irma eye track passed right over SBLM  
326 station. Maria grew explosively in less than 12h from a category 3 to a category 5 as it passed  
327 Martinique. Hurricane tracks from NOAA reports. Lesser Antilles bathymetry from GEBCO 2020 Grid  
328 and Shom 2018 Homonim project. Land DEM from NASA SRTM. The photo inset show SBLM  
329 station as it was before and after Irma hurricane passage. Fences, solar panels and VSAT antenna have  
330 been thrown away by the winds.

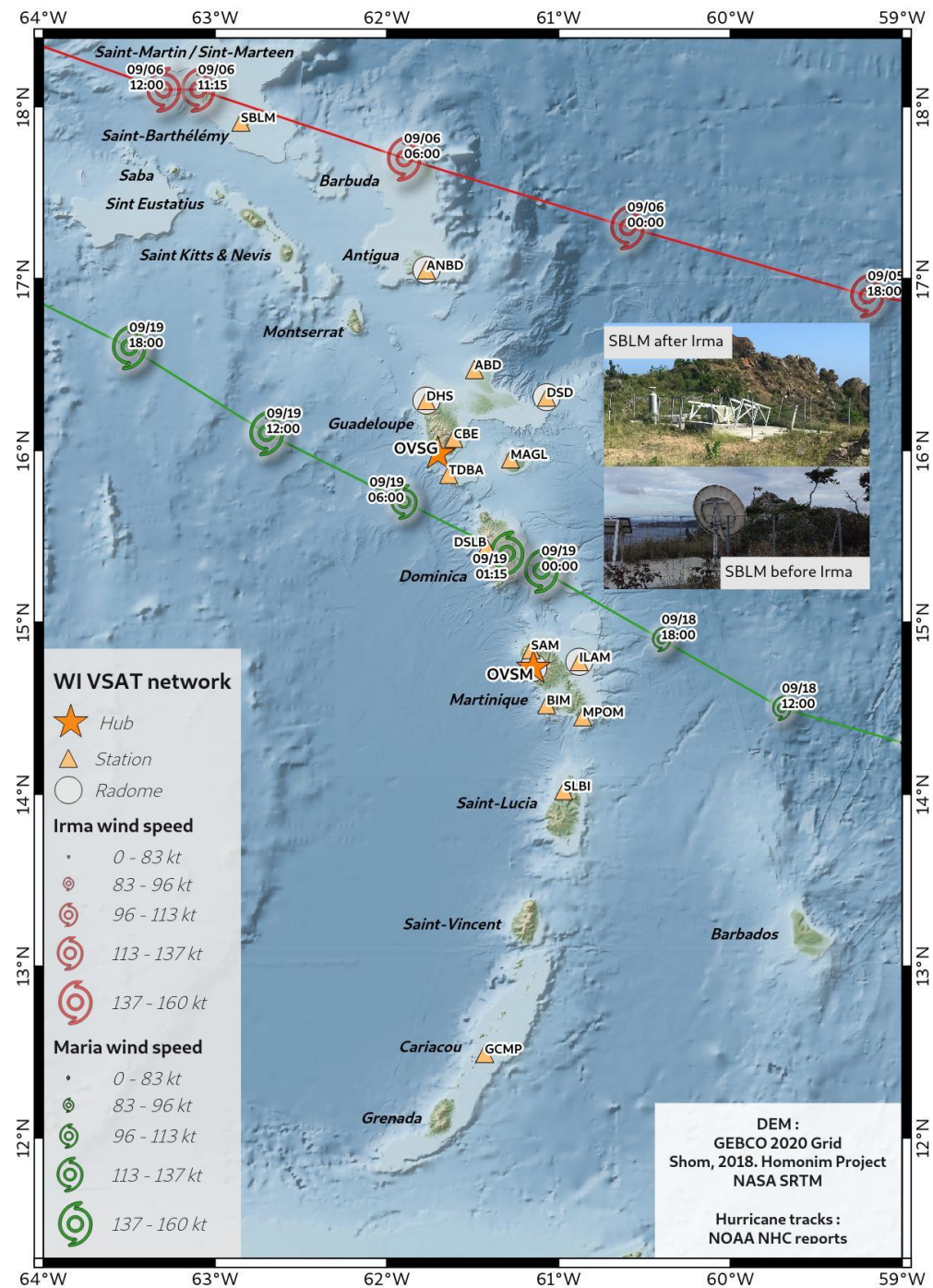
### 331 **Figure 2**

332 Real-time data flow from one station up to the early warning centers. Depending on the station, the  
333 default route comes either from OVSM or OVSG. OVS-1 is the default IPGP hub reception point,  
334 OVS-2 is the backup one. Data flow in 2017 in (a) which required manual re-configuration of the data  
335 collection in IPGP. The data collection is switched from OVS-1 to OVS-2 and ultimately to SRC.  
336 Proposition of an improved data flow with automatic re-routing mechanisms in (b) : we propose to use  
337 keepalived code in failover mode in a two stages configuration. Default route from OVS-1 simply pass  
338 through a single keepalived instance. Backup route of the first stage comes from the second stage,  
339 preferably from the backup IPGP hub (OVS-2) or from the SRC. As soon as the default IPGP hub  
340 OVS-1 becomes live again, the data are automatically switched to it by the first stage.

341 **Figure 3**

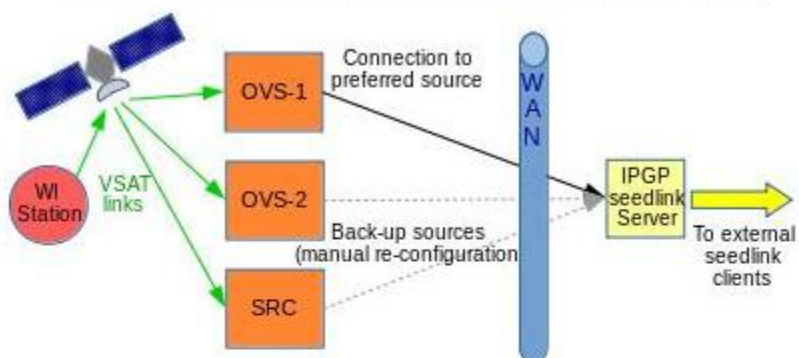
342 Seismic noise amplitude in the 0.1 – 1.0Hz range during Irma (a) and Maria (b) hurricanes. TDBA  
343 (Terre de Bas, south of Guadeloupe) show the highest noise level during both hurricanes as it sits in the  
344 middle of Les Saintes channel, sensitive to swell. In (a), ANBD (Antigua) peaks during Irma eye  
345 passage close to the station, the second high noise period is caused by José hurricane 3 days after Irma.  
346 In (b), all the stations are impacted almost equally as Maria hurricane cross all the islands. The real-  
347 time data availability during the hurricane passage is shown in (c) and (d), corresponding to the yellow  
348 frames in (a) and (b). In (c), the red square highlights the real-time data dropout during the heavy rain  
349 associated with Irma in Guadeloupe. In (d), the red square shows the 1 hour time necessary to switch  
350 from Martinique to Guadeloupe hub data collection. The grey frame in (b) and the corresponding blank  
351 space correspond to the time needed to switch back to Martinique hub after Guadeloupe observatory  
352 damages by Maria.

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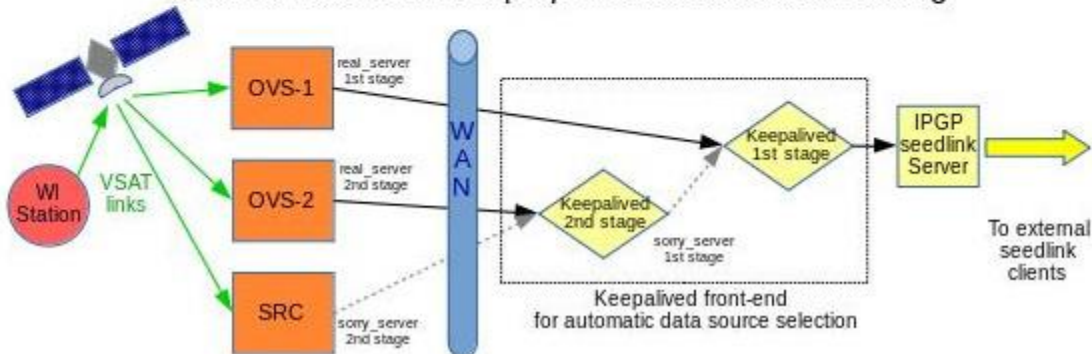


**Figure 1** : Irma and Maria hurricane tracks across the WI network. Irma eye track passed right over SBLM station. Maria grew explosively in less than 12h from a category 3 to a category 5 as it passed Martinique. Hurricane tracks from NOAA reports. Lesser Antilles bathymetry from GEBCO 2020 Grid and Shom 2018 Homonym project. Land DEM from NASA SRTM. The photo inset show SBLM station as it was before and after Irma hurricane passage. Fences, solar panels and VSAT antenna have been thrown away by the winds.

## a. Real-time data flow with manual route switching

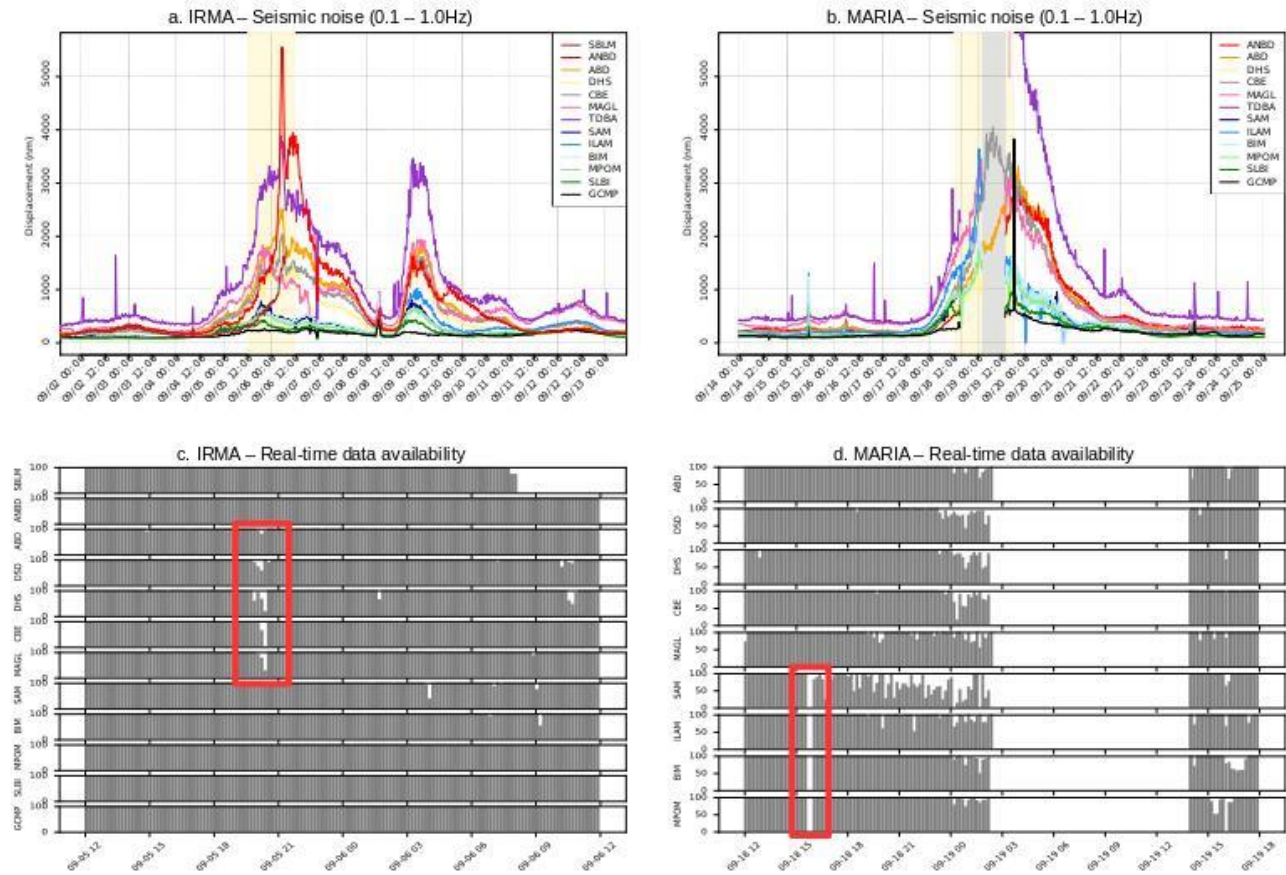


## b. Real-time data flow proposal with automatic routing



**Figure 2:** Real-time data flow from one station up to the early warning centers. Depending on the station, the default route comes either from OVSM or OVSG. OVS-1 is the default IPGP hub reception point, OVS-2 is the backup one. Data flow in 2017 in (a) which required manual re-configuration of the data collection in IPGP. The data collection is switched from OVS-1 to OVS-2 and ultimately to SRC. Proposition of an improved data flow with automatic re-routing mechanisms in (b) : we propose to use keepalived code in failover mode in a two stages configuration. Default route from OVS-1 simply pass through a single keepalived instance. Backup route of the first stage comes from the second stage, preferably from the backup IPGP hub (OVS-2) or from the SRC. As soon as the default IPGP hub OVS-1 becomes live again, the data are automatically switched to it by the first stage.

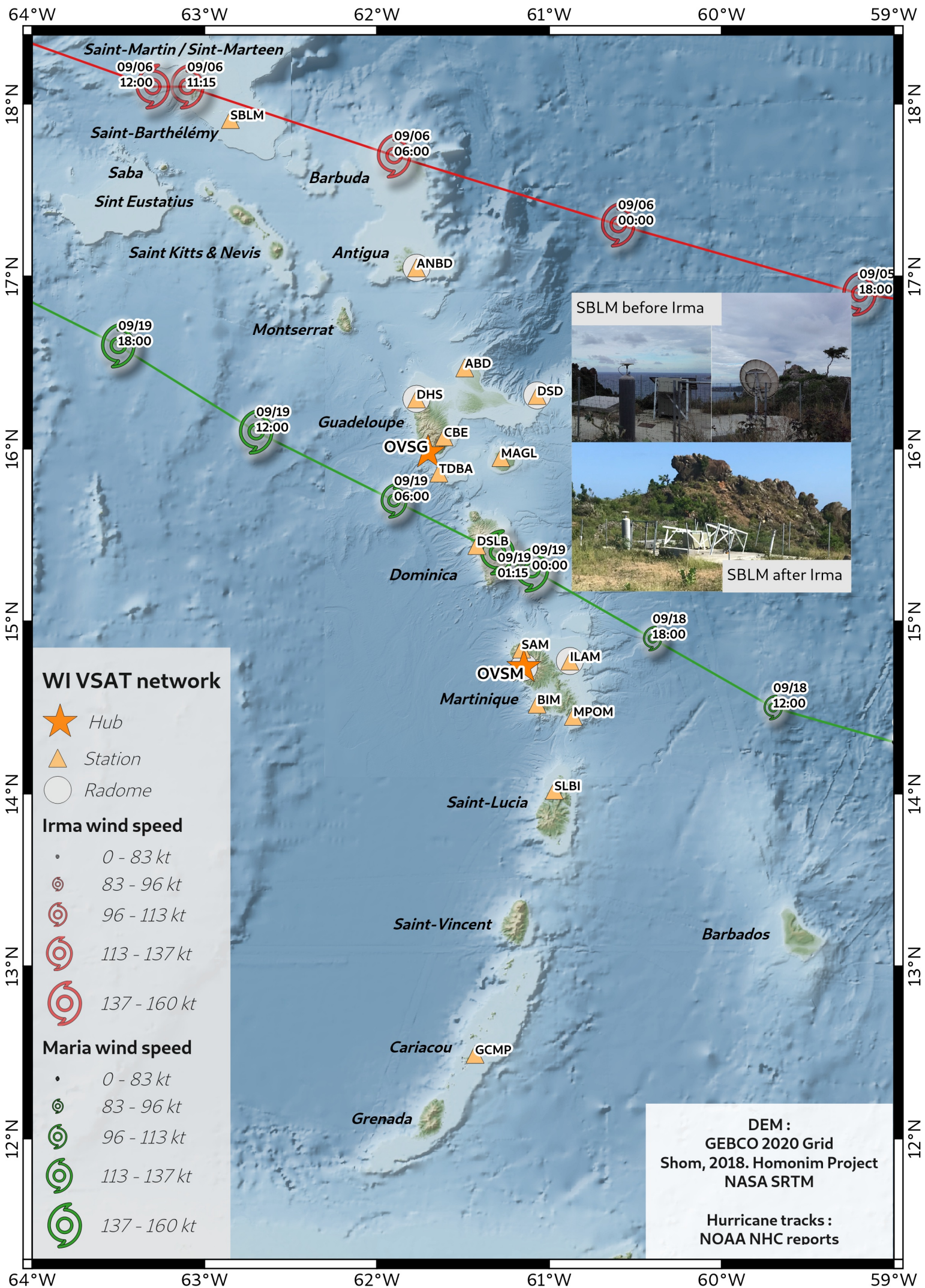




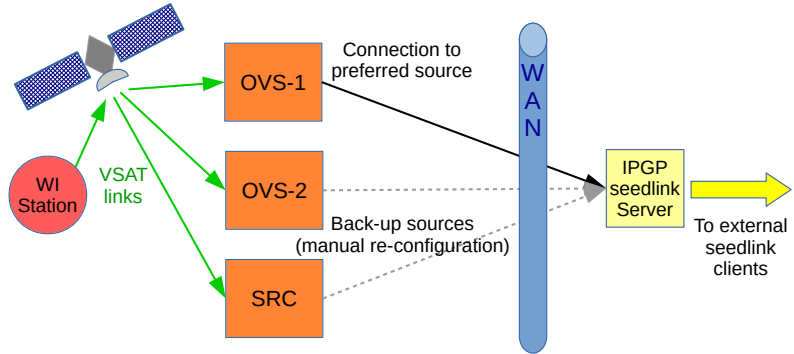
**Figure 3 :** Seismic noise amplitude in the 0.1 – 1.0Hz range during Irma (a) and Maria (b) hurricanes. TDDBA (Terre de Bas, south of Guadeloupe) show the highest noise level during both hurricanes as it sits in the middle of Les Saintes channel, sensitive to swell. In (a), ANBD (Antigua) peaks during Irma eye passage close to the station, the second high noise period is caused by José hurricane 3 days after Irma. In (b), all the stations are impacted almost equally as Maria hurricane cross all the islands. The real-time data availability during the hurricane passage is shown in (c) and (d), corresponding to the yellow frames in (a) and (b). In (c), the red square highlights the real-time data dropout during the heavy rain associated with Irma in Guadeloupe. In (d), the red square shows the 1 hour time necessary to switch from Martinique to Guadeloupe hub data collection. The grey frame in (b) and the corresponding blank space correspond to the time needed to switch back to Martinique hub after Guadeloupe observatory damages by Maria.



High resolution figure 1



### a. Real-time data flow with manual route switching



### b. Real-time data flow proposal with automatic routing

