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► To cite this version:

Maud Devès, Robin Lacassin, Hugues Pécout, Geoffrey Robert. Risk communication successes and limits during sismo-volcanic crisis: the example of Mayotte, France. 2021. insu-03373158

HAL Id: insu-03373158

<https://insu.hal.science/insu-03373158v1>

Preprint submitted on 22 Nov 2021

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1 Risk communication successes and 2 limits during sismo-volcanic crisis: the 3 example of Mayotte, France

4
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15 Abstract

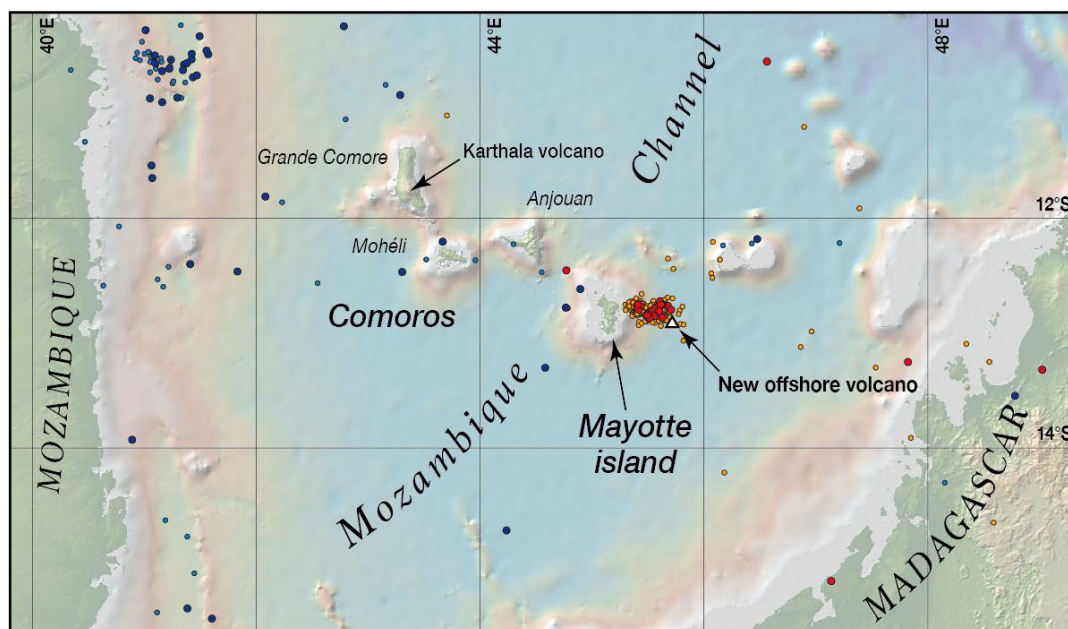
16 On 10 May 2018, an active seismic crisis began on French island of Mayotte, which a year
17 later will be shown to be related to offshore volcanic activity. It affects a vulnerable territory
18 exposed to risks of many kinds (poverty, violence, lack of basic resources). In the absence of
19 known events in human memory, the population is naive with regard to seismic and volcanic
20 hazards. The concern is therefore very strong. In spite of a large number of publications, the
21 communication set up by the main actors of the risk chain does not answer the population's
22 concern. To understand why, we analyse a large corpus of the textual communications (press
23 releases, web pages, scientific bulletins, reports, etc.) issued by the authorities and scientists
24 from May 2018 to April 2021. We draw lessons on the communication strategy put in place in the
25 first three years of the crisis; and we issue recommendations for improvement in the future, in
26 Mayotte, but also elsewhere in contexts where comparable geo-crises may happen. We notably
27 stress the importance of ensuring that communication is not overly technical, that it aims to inform
28 rather than reassure, that it focuses on risk and not only on hazard and that it provides clues to
29 possible risk scenarios.

30 1. Introduction

31 On 10 May 2018 begins on the island of Mayotte, a very active seismic crisis whose
32 intensity and duration surprises the population, scientists and authorities. Scientists in charge of
33 seismic monitoring in the region describe the situation as "*exceptional beyond anything recorded*
34 *in Mayotte*" (Director of BRGM in Mayotte, 16 May 2018 AFP dispatch picked up by many media,
35 e.g. Le Point (2018)). Prior to May 2018, regional instrumental seismicity near the islands (blue



36 dots in Figure 1) was indeed moderate, with the largest magnitudes recorded between Mb 5 and
37 5.5. At the beginning of the 2018 crisis, the island is poorly instrumented, which complicates the
38 monitoring of the seismic crisis, the understanding of its origin, the determination of possible risk
39 scenarios and of preventive measures. Mayotte belongs to the Comoros archipelago, composed
40 of four main islands, which formed as a result of Cenozoic volcanism in a poorly understood
41 geodynamic context (Figure 1). Several hypotheses are put forward: hot-spot volcanism versus
42 rifting volcanism, or a mixture of the two (e.g., Michon, 2016). Karthala, on the westernmost island
43 of Grande Comore (Figure 1), is an active volcano studied by a monitoring network managed by
44 the Karthala Observatory of the CNDRS (Centre National de Documentation et de Recherche
45 Scientifique, in Moroni) in collaboration with the Institut de Physique du Globe in Paris and the
46 University of La Réunion.
47



48 **Earthquakes prior to 2018 seismo-volcanic crisis** **Earthquakes from start of seismo-volcanic crisis**
49 M4.5-5 M \geq 5 (1 Jan 1950 to 9 May 2018, NEIC-USGS) M4-5 M \geq 5 (May 2018 to April 2020, Lemoine et al. 2020, Saurel et al. 2021)

50 Figure 1. Location of Mayotte, easternmost island of the Comoros archipelago. Blue dots:
51 epicenters of seismic events prior to seismic crisis that started on 10 May 2018 (Magnitude
52 \geq 4.5, Jan. 1950 to 9 May 2018, USGS catalog); Red (magnitude \geq 5) and orange ($4 \leq$
53 magnitude $<$ 5) dots show earthquake epicenters with well-constrained hypocentral depth
54 from 10 May 2018 to April 2020 - locations from Lemoine et al. (2020) between May 2018
55 and March 2019 and Revosima catalog between April 2019 and April 2020 (Saurel et al.,
56 2021). Most earthquakes of the ongoing seismic crisis as well as the new offshore volcano
57 discovered in May 2019 (Feuillet et al., 2019, 2021) are located 10-50km east of Mayotte
58 island. To avoid problems with mislocated events on this map we excluded epicenters with
59 10km fixed depth, and only plotted the ones with well-determined hypocentral depths.
60 Topographic and bathymetric visualisation is from GeoMapApp (www.geomapapp.org -
61 CC-BY).



62
63 The seismic crisis is affecting a particularly vulnerable territory, already exposed to risks
64 of many kinds. Mayotte is a French overseas territory and has the status of a regular French
65 department, but is marked by great poverty and strong social inequalities (Roinsard, 2014).
66 Among a population of 256 000 people, 77% live below the poverty line and more than 30% are
67 unemployed, 48% is foreign (and often illegal), 30% have no access to drinking water, and 4 out
68 of 10 people live in informal settlements (2017 Data - INSEE, 2021). Criminality is high, episodes
69 of social unrest follow one another and the population's distrust of the authorities is strong.
70 Mayotte's multiculturalism is a richness that proves difficult for the authorities to manage when
71 the situation requires informing the widest possible audience. 95% of the inhabitants are Muslim
72 (Ministère des Outre-Mer, 2016), 45% are of Comorian origin (INSEE, 2021) and although French
73 remains the official language of communication, ~37% are not speaking French (2007 data -
74 INSEE, 2017). Even when understanding French, a large part of the population speaks Shimaore
75 or Kibushi on a daily basis. One can refer to e.g. Roinsard (2014) or Walker (2019) for more
76 analyses of the economic, political and cultural situations in Mayotte. What is important to keep
77 in mind here is that the absence of seismic and volcanic events known to human memory means
78 that the population is relatively naive with regard to these hazards. A survey conducted by the
79 agency TIFAKI HAZI in 2012 reveals that 75% of the people surveyed consider themselves to be
80 poorly informed and badly sensitized to natural hazards in general (DIRMOM, pers. com.).

81

82 • **High public anxiety and a recurring complaint about a lack of information**

83 Nearly a year elapses between the beginning of the seismic crisis and the announcement,
84 in an inter ministerial press release on 16 May 2019 (e.g., Ministère de la Transition écologique
85 et solidaire, Ministère de l'Enseignement supérieur de la recherche et de l'Innovation, Ministère
86 des Outre-Mer, Ministère de l'Intérieur, 2019) of the discovery of active volcanism off the island
87 of Mayotte (Figure 1). During that first year, the population is shaken by numerous felt
88 earthquakes, some of which slightly damage houses and public buildings such as schools (Sira
89 et al., 2018). Anxiety is very strong, as evidenced by the testimonies of the inhabitants in
90 newspapers and on social networks: *"It's starting to shake strongly, it's frightening"* (Le Figaro,
91 2018a, 14 May). Thousands of people sleep in the street at night (10 to 20% of the population
92 according to official sources, pers. com.). In the days after the beginning of the crisis, a group of
93 Mayotte inhabitants creates a Facebook group called STTM (for "Signalement Tremblement de
94 Terre de Mayotte") that quickly become very active in the public discussion of earthquake-related
95 issues. People complain of a lack of communication from scientists and authorities about the
96 possible origin of these earthquakes, as well as the dangers and risks associated with them.
97 *"Whether or not we know what's going on at more than 3,000 meters deep, there are facts that
98 are there. Earthquakes that sometimes exceed magnitude 5, cracks in buildings, fires, landslides,
99 etc.... and no real reaction from the State apart from information on the magnitude of the tremors
100 already felt."* (excerpt from STTM Facebook group, 26 May 2018). On 5 June 2018, the deputy of
101 Mayotte, Ms. Ramlati Ali, warn the ministries against a confusing communication and alert on the
102 existence of *"false information fueled by fantasies that have the effect of increasing the anxiety of
103 the Mahoran population, generating a state of panic and even psychosis"* (Ali, 2018). On 27
104 August 2018, the local newspaper *Le journal de Mayotte* highlight the inability of experts to
105 document the earthquakes felt and headline: *"Earthquakes: It trembles in Mayotte in silence"*, and



106 again: *"On the phones, the applications of international sites, downloaded with frenzy last May,*
107 *have given nothing, just like the BRGM [the local expert body in charge of seismic monitoring],*
108 *while the earth began to shake again this Sunday in Mayotte"* (Perzo, 2018c). The feeling of being
109 left out reinforces an already existing distrust of state services (it should be recalled that at the
110 time of the first earthquakes, Mayotte is just emerging from a hard social crisis that had lasted for
111 many months). On the STTM feed, one can read: *"How much do you want to bet that in a year*
112 *nothing will have been done? As soon as the crisis passes we play the watch hoping that the next*
113 *one will come when we leave the island. That's how the administration has managed Mayotte for*
114 *decades."* (excerpt from STTM Facebook group, 27 May 2018).

115 A year later, in may 2019, the discovery of the underwater volcanic activity is described
116 by official sources as exceptional. The unexpected *"birth of a new volcano"* (BBC - Science in
117 Action, 2019) causes enthusiasm in the national and international scientific community, and in the
118 media (e.g., Andrews, 2019; Minassian, 2019; Wei-Haas, 2019). Indeed, the large volumes of
119 lava involved are only comparable to those emitted during the Laki eruption in 1783-1784 (Cesca
120 et al., 2020; Feuillet et al., 2021; Thordarson & Self, 1993) and the underwater nature of the
121 eruption requires innovation in terms of observation, research and monitoring. It marks the
122 beginning of an exciting scientific adventure. If the inhabitants are delighted by the sudden interest
123 of the scientific world for their island, they are also worried about the risks linked to this new
124 activity and they continue asking for more information: *"Say nothing, explain nothing... Can only*
125 *create confusion... Questions that go around in circles because we don't have the answers! When*
126 *there is neither answer nor explanation ... One can only wonder ... Why this? What interest or*
127 *motivation do they have in not giving the information ... They would like the population to worry:*
128 *they couldn't do better! The sickly inability of administrations to communicate ..."* (excerpt from
129 Facebook group STTM, 20 June 2019). The announcement of the birth of the volcanological and
130 seismological observation network of Mayotte (REVOSIMA) in June 2019 only partially meets
131 expectations.

132

133 During the first year of the crisis, external observers also point to a lack of scientific
134 information and communication from the authorities and the scientists (Fallou et al., 2020; Fallou
135 & Bossu, 2019). For Fallou et al. (2020), it is this *"information vacuum"* that leads inhabitants to
136 take advantage of social media to develop, by themselves, the *"seismology citizen group"* STTM.
137 The need for information is indeed testified by the very success of the group which soon gathers
138 more than 10,000 members. And, although the sociology of the group is not representative of the
139 entire population of Mayotte (discussions are held mainly in French), it will become a key
140 interlocutor for the local authorities who, a year later, will invite some of its most visible members
141 to the discussion table: *"Earthquakes: the Facebook group STTM received in the Préfecture"*
142 (Journal de Mayotte, 9 August, YD, 2019).

143 As highlighted by Fallou et al. (2020), among the group itself, discussions revolve a lot
144 around scientific knowledge and uncertainties and around the lack of sufficient information for the
145 population to be able to adapt to the associated risks. The questions asked are relevant with
146 respect to risk management, e.g. *"The schools for example, which accommodate some 80,000*
147 *students, have been checked by experts (I hope everywhere in Mayotte) but there has not yet*
148 *been any feedback to the general public. [...] I would like, for example, in the general interest, that*
149 *according to such and such a structure, we could say to what extent it will resist to such and such*



150 *a magnitude (including site effects and other local variables) and also how it will resist to the*
151 *succession of moderate tremors (in swarm, which is obviously our case)"* (excerpt from STTM
152 Facebook group, 27 May 2018). Discussions are informed by publicly available scientific
153 knowledge, in the form of official releases from local authorities, scientific reports from scientific
154 organizations involved in monitoring, and more generally anything that can be found on the
155 Internet. Fallou et al. (2020) point to the absence of a professional scientist who can help the
156 group to translate and contextualize such information.

157

158 **• The difficulty of answering populations' need for information**

159 Informing the population is a fundamental issue at all stages of the risk reduction cycle.
160 Faced with the risk of a disaster, populations are not the passive recipient and executors of
161 decisions taken in a top-down manner by the authorities under the advice of wise scientists.
162 People likely to be affected are the first actors of their own safety and, often, of the safety of their
163 relatives and neighbors (e.g. this principle is included in the French civil protection law since
164 2004). The recent COVID-19 crisis reminded us of the importance of public understanding and
165 acceptance of protective measures and brought the issue of public information back into focus. It
166 also reminded us how enhanced media interest can complicate risk communication. This
167 complexity stems from the fact that public information about risks emerges as an end product of
168 a complex process at the interface between science, policy and society. And, as shown by science
169 studies, the knowledge governing public decision in the domain of environmental as well as
170 natural risks is determined as much by the scientific method and the social context of scientific
171 knowledge production as by the institutional and wider social and political context (e.g. Jasanoff,
172 2004; Oreskes, 2004; Brown, 2009; Oreskes, 2015). This observation has motivated the
173 development of a field of research entitled "social volcanology", with counts some important
174 contributions about information dissemination (e.g. Fearnley, 2013; Fearnley & Beaven, 2018;
175 Donovan, Oppenheimer and Bravo, 2012; Donovan, 2019). The present paper follows this line of
176 thought while also borrowing to the literature dedicated to risk communication in the wider field of
177 the *disaster studies* (e.g. Mileti, 1993; Lindell et al., 2006).

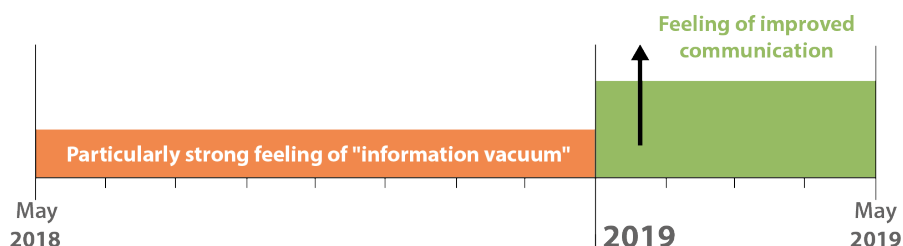
178

179 With regard to sismo-volcanic risks, Mayotte is currently in a phase that, in the language
180 of risk managers, must combine prevention and preparedness. The information transmitted by
181 the actors of the "risk chain" (from hazard monitoring to risk management) should allow people to
182 understand the risks they face, to implement preventive measures and to prepare for a possible
183 rise in the alert level. The recurrent complaint of a lack of information from part of the population
184 suggests that the communication currently in place is not up to the challenges of this period.
185 According to Lindell et al. (2006), populations' need for information can be broken down into a
186 few key questions: What is the risk? Where is it going to happen? When is it going to happen?
187 What will be the effects? To those, one could also add: How do I prepare my family to face that
188 risk? Mileti (1993) also identified four key steps in the process of efficient risk communication: 1)
189 people need to *receive* the information, 2) people need to *consider* the information available, 3)
190 people need to *understand* the information and 4) the sources of that information must be
191 perceived as credible and legitimate - perceptions that can be strongly altered by poor
192 communication.

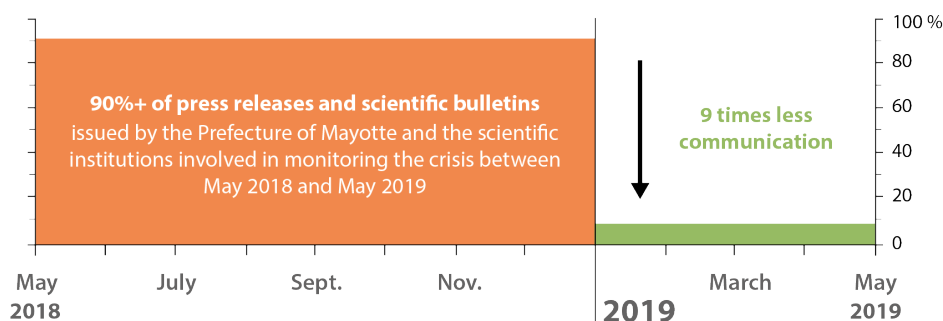


193 In the case of Mayotte, one can wonder whether the communication of the authorities in
194 charge of risk management - but also of the scientists in charge of monitoring - enabled people
195 to *receive, consider* and *comprehend* the information and if it helped them to adapt their response
196 to the seismic crisis and to prepare their potential response to threats associated with the new
197 volcanic activity. Unfortunately, this does not seem to have been the case, as evidenced by the
198 disconnect between the very large number of communications issued by official risk management
199 actors during the first year of the crisis and the sense of lack of information reported by the
200 population on social media (Figure 2).
201

● **Feelings of the population according to Fallou et al. (2020)**



● **Share of communication volume from actors**



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Figure 2. Evolution of the number of communications from the authorities and scientists on the sismo-volcanic crisis of Mayotte in regard to the feeling of “information vacuum” of the population as reported by Fallou et al. (2020). This figure does not cover our whole study period. It illustrates the gap between the perception of the population and the communication efforts made by the actors at the beginning of the crisis, less than a year after the beginning of the seismic crisis and before volcanic activity was discovered. The evolution of this offset throughout the three first years of the crisis is discussed at length in the following sections of the paper.

● **Our study**

The present paper contributes to the effort made by social sciences to identify ways of overcoming the difficulty of answering at risk populations’ information need. Our approach is to



215 factually analyze the way the scientists and the authorities communicated during the first three
216 years of the crisis, in order to understand what has failed in their strategy of communication. We
217 believe that the lessons learned from the case of Mayotte, in a relatively unprecedented context
218 (risks are perceived indirectly, the underwater volcano remaining invisible, and in a poorly
219 instrumented area), can usefully nourish the reflection carried out in the existing literature
220 (Fearnley, 2013; Fearnley & Beaven, 2018; Donovan, Oppenheimer and Bravo, 2012; Donovan,
221 2019).

222 To prevent possible ambiguities, it might be important to specify from the outset that
223 scientists and authorities are not expected to play the same role with respect to risk
224 communication but that their roles are complementary (e.g. Newhall, 1999; Fernley and Beaven,
225 2018). It is the authorities who are officially in charge of communicating information about risks
226 and decisions taken to protect people (notably prevention, preparedness, alert and protection
227 measures). But, as shown by the analysis of social networks and the press (Devès et al., 2021;
228 Fallou et al., 2020) and by earlier studies, scientists have a role to play in helping the population
229 to comprehend scientific information as the latter is often far too technical for non-specialists.
230 Such a role is essential to maintain the legitimacy and credibility of the information on which public
231 decisions are based (Jasanoff, 2005). In Mayotte, as far as telluric risk is concerned, a disaster
232 has not yet occurred - the seismic crisis, although very worrying for the population, has not caused
233 major damage. But many questions remain unanswered concerning the potential effects of the
234 current activity in the short or medium term: are the earthquakes and/or the deformation
235 associated with volcanic activity likely to generate major tsunamis? Can volcanic activity migrate
236 to the island of Mayotte? The challenges of the current phase are therefore those of scientific
237 research to understand, monitoring to alert, and preparedness to reduce potential impacts,
238 improve emergency management, and foster individual and collective resilience. Each of these
239 relies heavily on scientific knowledge and expertise. It is therefore important to analyze not only
240 the communication strategy adopted by local and national authorities, but also by the scientific
241 institutions involved in monitoring. In the case of Mayotte, was it the content, format or modalities
242 to convey the information that failed to meet the needs of the population and to answer their
243 concerns? How does the science/public risk management interface work in practice and how have
244 actors managed to explain what is not yet known, what is uncertain? How people's information
245 needs, and their feelings about seismicity and hazards, evolve in time? What role played the new
246 information resulting from the offshore observation campaigns that started one year after the
247 beginning of the crisis?

248 To address these questions, we have built up a large corpus made up of all the
249 communications (press releases, web pages, scientific bulletins, reports, etc...) issued by the
250 authorities and scientists during the first three years of the crisis (section 2). We analyze this
251 corpus by combining qualitative and quantitative approaches. Section 3 proposes a chronological
252 reading of the main stages of monitoring and crisis management. We distinguish 4 main phases
253 (1, 2, 3, 4) which correspond to the different moments of the structuring of the scientific and state
254 response to the crisis. Section 4 focuses more specifically on the communication aspects of risk
255 management. There the analysis leads us to distinguish not four, but three major phases of
256 communication (A, B, C), because of a certain gap between the structuring of the response and
257 communication to the public. Such analysis allows drawing lessons on the communication
258 strategy put in place in the first three years of the crisis and to issue recommendations for



259 improvement in the future, in Mayotte, but also elsewhere in contexts where comparable geo-
260 crises may happen (section 5).

261 2. Material and methods

262

263 2.1. A two step-methodology combining quantitative and qualitative approaches

264

265 We focus on the first three years of the Mayotte seismic-volcanic crisis, more precisely from
266 10 May 2018 to 1 April 2021. We build our analysis on the following methodology and datasets.

267

268 We searched the archives and in particular the web archives of the scientific and state
269 institutions involved in the monitoring and management of the crisis. We collected and analyzed
270 all the documents made public by the authorities and scientists during these first three years such
271 as press releases, scientific bulletins, news on websites and public notes (table 1). Hereafter, we
272 are citing scientific bulletins and websites as references (including their URL when existing) while
273 authorities' press releases are given in the supplementary dataset (ministerial press releases as
274 well as those from the Préfecture of Mayotte). We also included the academic papers published
275 during our 3 years period of study (Cesca et al., 2020; Famin et al., 2020; Feuillet et al., 2021;
276 Lemoine et al., 2020; Tzevahirtzian et al., 2021). We coded this dataset by date of publication
277 and by publishing institution/author, and quantitatively analysed it to show the time evolution of
278 the publication rate by the different actors of the risk management (see Figure 4). Using the
279 catalog of the felt seismicity provided by EMSC for the period from May 2018 to April 2021 (EMSC-
280 CSEM, 2021), we compare this publication rate to the number of earthquakes felt by Mayotte
281 citizens and its evolution in time (Figure 3, 4). This analysis was made using the R software
282 package. This allows us to quantitatively put the scientist's and authorities' communication effort
283 in perspective with the evolution of the geophysical signal that directly affected the population.

284

285 However, to understand people's feeling of a lack of communication and how the
286 communication has been managed by the scientists and authorities as the crisis developed, we
287 also needed more qualitative approaches: i.e. qualitative analysis of the content of the different
288 documents. We thus studied the content of all the documents in the above dataset and the way it
289 has evolved in time. We also aimed to identify the main stages of scientific monitoring and to
290 understand how the circulation and transfer of knowledge has been managed by the different
291 actors. With this objective, we conducted semi-structured interviews with scientists from the main
292 institutions in charge of the geophysical monitoring of the crisis (7 interviews lasting from 1 to 3
293 hours within BRGM, IPGP, CNRS and REVOSIMA) and with local and national risk managers (6
294 interviews lasting from 40 minutes to 2 hours within the Préfecture of Mayotte, the DIRMOM, the
295 Ministries of Research, Environment and Interior). We asked questions about the actors involved
296 in the monitoring and their role, about the procedures, contents and formats used to exchange
297 between them, with the media and the public. We also asked what were the most important
298 moments for them in terms of knowledge transfer and to give their view on the effectiveness of
299 hazard and risk communication toward the exposed population. We anonymised the citations
300 taken from these interviews to respect interviewee's confidentiality, and provide here our own



301 english translation. We also explored Facebook publication feeds when they existed (i.e. for
302 OVPF-IPGP, REVOSIMA, Préfecture of Mayotte, as well as the STTM citizen group) but without
303 aiming for exhaustiveness as it is difficult to achieve without adequate tools. In particular, we use
304 selected citations extracted from STTM facebook posts to illustrate citizens' feelings about the
305 management of the crisis by the scientists and authorities. Hereafter, we anonymised these
306 facebook excerpts, and provide our own english translation (anonymised French original versions
307 of the facebook posts are given in the supplementary dataset). If this Facebook group gathers
308 more than 10 000 members and has been identified as a key interlocutor by local authorities, it is
309 not representative of the sociology of the whole population of Mayotte. Nevertheless, these
310 excerpts allow us to identify misunderstandings and grasp ways in which communication could
311 be improved.

312

313 **2.2. Presentation of the key actors of risk communication**

314 Before describing the course of the crisis, it is important to present the actors involved in
315 the monitoring and management of seismic, volcanic and tsunami risks in Mayotte (Table 1). Two
316 main categories of actors can be distinguished according to their function: risk management or
317 scientific monitoring. On the risk management side, our analysis is based on communication from
318 1) the Préfecture of Mayotte, which is the body representing and implementing government policy
319 at the local level, and 2) the ministries concerned with risk prevention, civil protection, research,
320 and overseas administration, whose actions have been coordinated by an Inter-ministerial
321 Delegation for Major Overseas Risks (DIRMOM) since 24 April 2019. We do not consider the
322 communication put in place by the Mayors of the communes because, in the case of the seismo-
323 volcanic crisis in Mayotte, the communication was mainly orchestrated by the state authorities.
324 On the scientific monitoring side, we consider the institutions that have played a central role in
325 the collection and analysis of data on the hazard and/or associated risks. We also take into
326 account individual researchers who issued key analyses at crucial times during the crisis (Briole,
327 2018). One must note that not all scientific actors play a similar role and that the number of actors
328 involved in monitoring the crisis has increased over time¹. To sum up, the *Institut de Physique du*

-
- ¹ The *Bureau de Recherche Géologique et Minière* (BRGM) and the *Institut Français de Recherche pour l'Exploitation de la Mer* (IFREMER) are public industrial and commercial institutions dedicated to, respectively, geosources and marine resources placed under the joint authority of the Ministries in charge of ecology, research and, respectively, economy or agronomy. The *National Institute of Geographic and Forest Information* (IGN) is a public administrative establishment placed under the joint authority of the Ministries in charge of ecology and forestry.
 - The *Institut de Physique du Globe de Paris* (IPGP) is an institution for higher education and research in geosciences which is in charge of certified observation services in volcanology, and seismology through its permanent volcanological and seismological observatories like the one in La Réunion island (OVPF for Observatoire Volcanologique du Piton de la Fournaise). It operates the Volcanological and Seismological Monitoring Network of Mayotte (REVOSIMA).
 - The *School and Observatory of Earth Sciences* (EOST) is an institution under the supervisory authority of the University of Strasbourg and the CNRS (French National Center for Scientific Research) in charge of education, research, and observation in Earth Science. The IPGP and EOST equip and maintain global geophysics networks that monitor seismic activity (GEOSCOPE network) around the globe. EOST is sometimes referred to as the Institut de physique du Globe de Strasbourg (IPGS), the two bodies having intimate links. The EOST pilots the BCSF-RéNass, *Bureau central sismologique français - Réseau national de surveillance sismique*, which is in charge of centralising, archiving and distributing national seismic data. The BCSF-RéNass issues a bulletin after each event and collects public testimonies of felt earthquakes (www.franceseisme.fr). It also provides assistance to the public authorities by sending a task force of seismologists (GIM for Groupe d'intervention macrosismique) to estimate impacts after significant earthquakes in French territories.



329 *Globe de Paris* (IPGP), the *School and Observatory of Earth Sciences* in relation with the *École*
330 *et observatoire des sciences de la terre / Institut de Physique du Globe de Strasbourg* (hereafter
331 referred as EOST), the *Bureau de Recherche Géologique et Minière* (BRGM) and the *Institut*
332 *Français de Recherche pour l'Exploitation de la Mer* (IFREMER) are the scientific actors directly
333 involved in monitoring the sismo-volcanic activity of Mayotte. The REVOSIMA brings together
334 these different scientific actors. It is operated by the IPGP from its closest observatory of the
335 Indian Ocean region, i.e. the *Observatoire volcanologique du Piton de la Fournaise* (OVPF) in
336 Reunion Island, and with the support of the antenna of BRGM in Mayotte. The *Bureau central*
337 *sismologique français - Réseau national de surveillance sismique* (BCSF-RéNass), the
338 *European-Mediterranean Seismological Centre* (EMSC) and the *National Institute of Geographic*
339 *and Forest Information* (IGN) centralise, distribute or provide data. Table 1 lists the preferred
340 publication format and volume of communication of each actor during our period of study. We do
341 not count the numerous automatic bulletins emitted by REVOSIMA (daily automatic bulletin are
342 emitted since march 2020), BCSF-RéNass and EMSC but we count the report published by the
343 BCSF-RéNass's Groupe d'intervention macrosismique (GIM) and a web article from the EMSC
344 that aims at providing a global view of the seismic crisis. We include in our database the five
345 academic papers (one is a preprint version of a submitted paper) dedicated to the crisis that were
346 published during our period of study (Cesca et al., 2020; Famin et al., 2020; Feuillet et al., 2021;
347 Lemoine et al., 2020; Tzevahirtzian et al., 2021) and commented by the press and/or the members
348 of STTM facebook group.

349 3. Description of the phases of the crisis from a 350 monitoring and risk management perspective

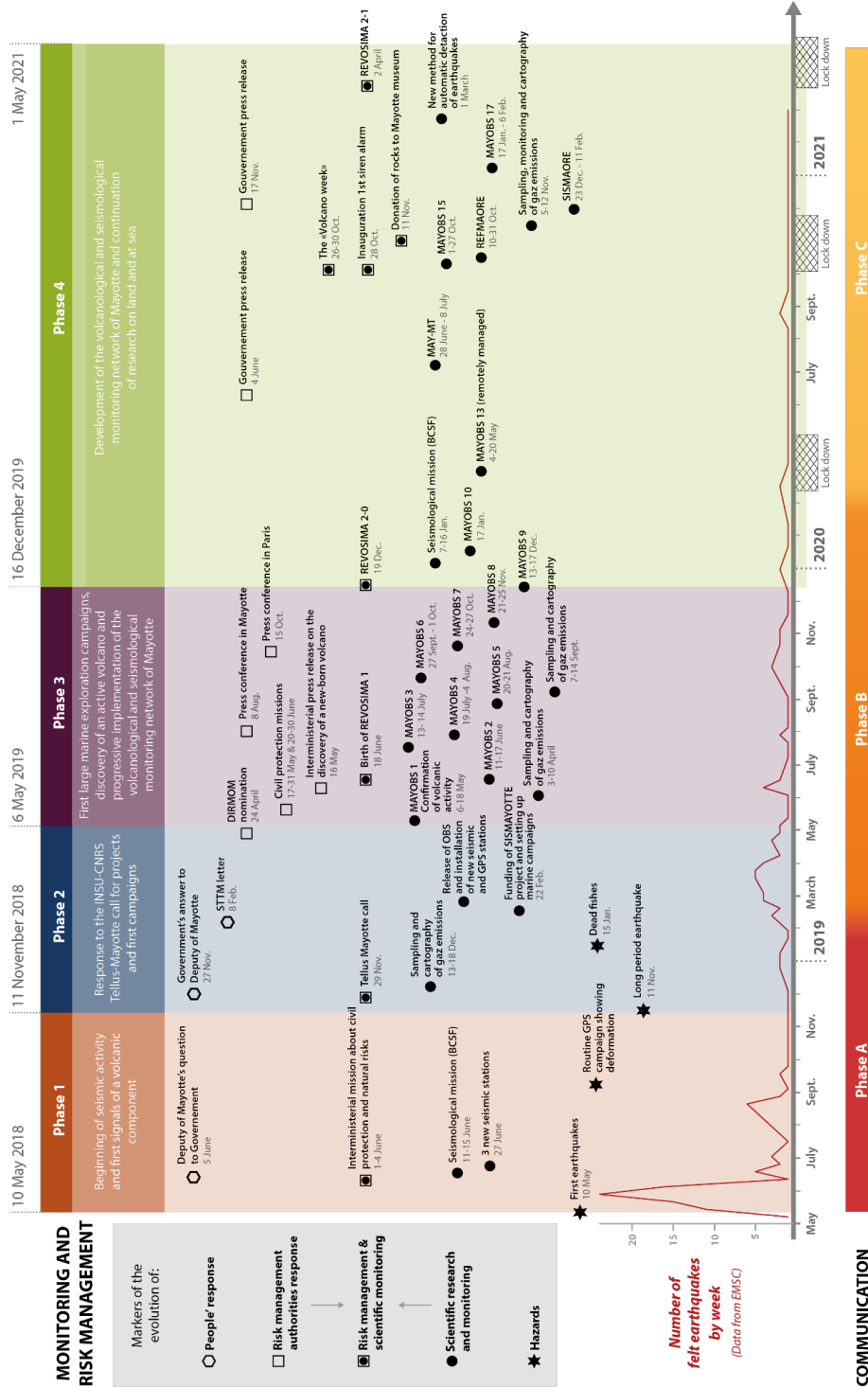
351
352 The seismic crisis starts on the night of 10 to 11 May 2018 with an earthquake of
353 magnitude M_L 4.3 being felt by the population. It intensifies on 15 May 2018 with several
354 earthquakes of magnitude M_L greater than 4 and an earthquake of M_L 5.8 (M_W 5.9) that slightly
355 damages buildings (Lemoine et al., 2020). One month after the beginning of the crisis, 140
356 earthquakes with magnitudes $M_L > 4$ have been recorded (Lemoine et al., 2020). For weeks, the
357 people of Mayotte feel several earthquakes a day. During the first month of the crisis, the EMSC
358 catalog (EMSC-CSEM, 2021) reports ~10 to 20 felt earthquakes per week (i.e. seismic events
359 with at least 4 online citizen testimonies, which EMSC call "felt reports"). Mayotte citizens testify
360 largely after earthquakes of the largest magnitudes: EMSC catalog lists ~200 to more than 500

-
- The *French National Centre for Scientific Research* (CNRS) is an interdisciplinary public research organisation under the administrative supervision of the French Ministry of Higher Education and Research. A significant part of French researchers belong to CNRS and work within laboratories which are placed under the joint authorities of the CNRS and the local university. The *National Institute for Universe Sciences* from CNRS (INSU) has the mission to develop and coordinate French research in astronomy and Earth sciences, as well as ocean, atmospheric, and space sciences.
 - The *European-Mediterranean Seismological Centre* (EMSC) runs an Earthquake Alert System for potentially damaging earthquakes in the Euro-Mediterranean region. As BCSF-RéNass, EMSC collects testimonies through its Lastquake application (e.g., Bossu et al., 2019). Within the hour following the occurrence of an earthquake, EMSC publishes a web page with its epicentre and magnitude, and the collected testimonies.



361 felt reports for each $M_L > 5$ events that occurred in May and June 2018. Between May 2018 and
362 May 2019, the seismic networks record about 1900 events with $M_L \geq 3.5$ (Cesca et al., 2020;
363 Lemoine et al., 2020). However, there is a sharp decrease in the number of felt earthquakes after
364 June 2018 (Figure 3), with only ~4 felt events per month until the end of 2018, and then a
365 moderate recovery in the number of felt events between February and June 2019 (~9 felt events
366 per month on the average). The seismic crisis is still ongoing at the time of writing, 3 years after
367 its start.

368 The interviews conducted with monitoring and risk management actors led us to
369 distinguish four main phases in the course of the crisis. The first phase goes from the recording
370 of the first earthquakes to the recording of the first unambiguous signals of a volcanic component.
371 The second phase corresponds to the mobilization of scientists, and funding agencies in relation
372 to ministries, to get the financial means to instrument the area. The third phase runs from the first
373 measurement campaigns to the proof of the volcanic activity which signed the official setting up
374 of the seismo-volcanic monitoring network of REVOSIMA. The fourth phase begins with the
375 official creation of REVOSIMA and ends with our windows of study. Figure 3 summarizes the key
376 events that marked each of these four phases. In addition to the events linked to monitoring, we
377 show some key events in the response of scientists, authorities and inhabitants of Mayotte. The
378 following description illustrates the role of these different actors and the timing and context of their
379 involvement phase by phase.
380





382 **Figure 3:** Major phases and markers of the management of the seismic-volcanic crisis in Mayotte from
383 10 May 2018 to 1 April 2021, end of our period of study.

384

385 • **Phase 1: 10 May 2018 to 10 November 2018**

386 During the **first phase of the crisis**, the French Geological Bureau (BRGM) plays a
387 central role. It is the only geo-scientific institution with a permanent office in Mayotte and, at the
388 beginning of the seismic crisis, it is in charge of maintaining the only 3 accelerometric seismic
389 stations installed on the island (which was not known to be particularly active seismically). In this
390 context, at the beginning of the crisis, BRGM Mayotte is the authorities' natural interlocutor for
391 decision support. It should however be noted that, for BRGM, as for the other scientific
392 organizations involved in monitoring before the creation of REVOSIMA, real-time data processing
393 is organized thanks to scientists' voluntary commitment. But the situation is difficult as crucial data
394 are missing. Only the largest magnitude earthquakes ($M > 5$) are reported by global seismic
395 networks while the existing local network – the few accelerometric stations in Mayotte completed
396 by few regional stations in Comoros and in Madagascar – does not allow a good record of the
397 surge of moderate magnitude earthquakes felt by the population. Because of this inadequate
398 network the BRGM operators initially encountered difficulties in accurately locating the
399 earthquakes and assessing their epicentral depths.

400 In June 2018, the persistence of the seismic crisis leads other actors to become involved.
401 Ministries in charge of civil protection and disaster risk prevention send an interministerial mission.
402 Mid-June 2018, a team of seismologists from BCSF-RéNass is sent to "*estimate the levels of*
403 *damage induced by this seismic swarm according to the vulnerability of the buildings at the date*
404 *of the field analysis*" (Sira et al., 2018). 3 more seismic stations are installed (two short-period
405 RaspberryShake velocimeters by the BCSF, one broad-band velocimeter in the frame of the
406 'Sismo à l'École' network). During the summer, scientists from IPGP and EOST help the BRGM
407 team to monitor the activity as its intensity decreases.

408 In September 2018, seismic activity intensifies again. The French scientific community
409 starts organising to seek funding to instrument the area, notably at sea. A note is sent to the
410 French National Centre for Scientific Research (CNRS) to attract funding agencies' attention to
411 Mayotte's issues. As surveys have to be done mostly offshore using research vessels and heavy
412 human and technical logistics, the funding to be mobilized is typically of the order of several million
413 euros per year. In parallel, one also have to deal with vessel's availability for their work programs
414 are often planned years in advance. At the same moment, routine GNSS measurements led by
415 the IGN reveal strong displacement anomalies affecting stations on the Mayotte island.
416 Researchers from the Ecole Normale Supérieure (ENS) Geoscience Lab. analyze the GNSS
417 data, tracing the onset of surface deformation back to July 2018. They explain it by the deflation
418 of a huge magmatic chamber located off the coast of Mayotte. These results are published in the
419 form of notes on the public website of the laboratory in October 2018 (Briole, 2018). The lack of
420 geological observations offshore Mayotte still prevents a good understanding of the phenomenon
421 but the scientific community urges public authorities to fund geophysical instrumentation and
422 surveys in the region.

423



424 • **Phase 2: 11 November 2018 to 5 May 2019**

425 The **second phase of the crisis** starts on 11 November 2018 with a long period
426 earthquake with peculiar characteristics (a very long trend of monochromatic seismic waves). The
427 event, not felt by the population because of its long period character, is recorded by global seismic
428 networks. It is much discussed on social networks and appears to be mentioned in the
429 international and soon national and local press (see discussion in Lacassin et al., 2020). It
430 supports the volcanic hypothesis (Cesca et al., 2020; Lemoine et al., 2020). Mid-november, a
431 meeting is organised with representatives of the four ministries, scientists and institutional
432 stakeholders like CNRS-INSU. On 29 November, public authorities set up a call for projects to
433 fund observation and research in the area. The call, named “*Tellus-Mayotte*”, is coordinated by
434 the CNRS-INSU and co-financed by the Ministry in charge of disaster risk prevention (MTES).

435 In January 2019, fishermen report dead deep sea fishes at the surface of the ocean east
436 of Mayotte (Perzo, 2019a). On 22 January, three projects are eventually selected on the Tellus
437 Mayotte call, involving 11 laboratories and 44 scientists from CNRS, IPGP, EOST, BRGM, Ifremer
438 and IGN. On 22 February, CNRS, IPGP, BRGM and EOST announce the launch of the first major
439 monitoring missions. Between February and March 2019, 6 OBS are deployed at sea in the frame
440 of these Tellus-Mayotte projects, and new seismic and GNSS stations are installed on land (by
441 OVPF-IPGP, BRGM, EOST). A team from the University of Réunion associated with OVPF-IPGP
442 carry out field missions to consolidate knowledge of the tectonic and volcanic history of Mayotte.

443

444 • **Phase 3: 3 May 2019 to 5 December 2019**

445 The **third phase of the crisis** starts with the first MAYOBS marine campaigns on the
446 scientific ship *Marion Dufresne* (MAYOBS 1 on 6-18 May 2019 and MAYOBS 2 on 11-17 June).
447 The campaigns are led under the auspices of the CNRS and involves scientists from BRGM,
448 IPGP, EOST, IFREMER, the University Clermont Auvergne, the University of La Rochelle with
449 the support of IGN, the Centre nationale d'études spatiales (CNES) and the Service Hydrographic
450 and Oceanographic Marine Observations (SHOM). The OBSs deployed in February are retrieved
451 and new ones are released. The data allow relocating the earthquakes and specifying the location
452 of the seismic swarms (Deplus et al., 2019; Feuillet et al., 2019, 2021; Jacques et al., 2019; Saurel
453 et al., 2019). Scientists are also acquiring high-resolution marine geophysical data, studying the
454 water column and carrying out rock dredging operations on the seafloor. An ongoing deep sea
455 volcanic activity is discovered with a new ~800m high underwater volcano, confirming the already
456 suspected volcanic hypothesis. The discovery is announced by an official press release signed
457 by four ministries (e.g., Ministère de la Transition écologique et solidaire, Ministère de
458 l'Enseignement supérieur de la recherche et de l'Innovation, Ministère des Outre-Mer, Ministère
459 de l'Intérieur, 2019) and relayed by the scientific institutions involved in the campaign on their
460 websites. The Préfecture and vice-rectorate of Mayotte launch a competition among primary and
461 secondary schools to name the new-born volcano.

462 Numerous other marine campaigns will follow that will allow refining the understanding of
463 the phenomenon (see Feuillet et al. (2019) to access the MAYOBS campaigns' reports). On 18
464 June 2019, an inter-ministerial meeting sets up a scientific and technical committee of crisis
465 monitoring and officializes the creation of the Volcanological and Seismological Monitoring
466 Network of Mayotte (REVOSIMA) with the implementation of “*a monitoring of volcanological and
467 seismological activity in real time and continuously*” (IPGP, 2019b, published on 27 August 2019,



468 translation by the authors). Several phases are envisaged for the implementation of this network.
469 In a first phase, the REVOSIMA (called REVOSIMA 1 by the actors) is supported by a 2.5 million
470 euros fund in order to establish a monitoring network and to guarantee a scientific follow-up of
471 the phenomenon with the implementation of new oceanic campaigns aiming at deploying and
472 recovering OBS. The monitoring mission is entrusted to the IPGP, already in charge of the other
473 French volcanological and seismic observatories. IPGP operates this network through the
474 Observatoire volcanologique du Piton de la Fournaise (OVFP-IPGP) in co-responsibility with the
475 BRGM and its regional direction in Mayotte. The REVOSIMA is expected to set up specific
476 scientific actions in order to : "i) monitor the seismo-eruptive dynamics on land and at sea, in
477 particular in connection with offshore campaigns and underwater instrumentation to monitor the
478 possible migration of seismicity and volcanism, ii) monitor marine deformation and submersion,
479 iii) characterize and monitor gravitational instabilities and tsunami hazard, iv) improve knowledge
480 of the tectonics and geodynamic context of Mayotte, v) monitor the geochemistry of volcanic
481 fluids." (IPGP, 2019b, published on 27 August 2019, translation by the authors). In October 2019,
482 a "pickathon" is organised by the geoscientists of REVOSIMA in order to speed up the process of
483 relocation of the seismicity.

484

485 ● **Phase 4: 16 December 2019 to 1 April 2021**

486 **The fourth phase of the crisis** corresponds to the perpetuation of the volcanological and
487 seismological monitoring network of Mayotte which allows the development of new research on
488 land and at sea (there has been more than 8 research and monitoring campaigns since december
489 2019). In December 2019, a new interministerial meeting ratifies the perpetuation of the
490 surveillance network and the release of 4.5 million Euros funding. REVOSIMA 2 is launched at
491 the beginning of 2020. In January 2020, seismologists of BCSF-RéNass come back to Mayotte
492 to trace the evolution of damages due to the earthquakes from June 2018 and a second pickathon
493 is organised to relocate seismicity. From March 2020 onwards, the actors have to deal with
494 disruptions due to the international pandemic of COVID-19. A double maritime campaign
495 (MAYOBS 13-1, MAYOBS 13-2) is nevertheless organized in May with the support of the French
496 Navy. The second mission is remotely operated by scientists from IFREMER, IPGP, BRGM and
497 CNRS located in metropolitan France. It is followed, in June, by a magnetotelluric campaign
498 (MAY-MT) and, in October, by a seismic-refraction campaign (REFMAORE), both coordinated by
499 BRGM. The oceanographic campaigns have continued at a steady pace since then, despite the
500 second and third COVID-19 lock down. The only notable change, at the end of our study period,
501 is the improvement of the automatic earthquake location method announced by REVOSIMA in
502 March 2021.

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507 **4. Analysis of the scientific and official**
 508 **communication**

509 **Table 1.** Format and volume of the documents made public by the main actors involved in the scientific
 510 monitoring and risk management of the sismo-volcanic crisis in Mayotte during our period of study. As
 511 discussed in the text, we only count a report and a web article for, respectively, the BCSF-RéNass and the
 512 EMSC, and not their automatic reports. We do not count the daily automatic bulletin from REVOSIMA. We
 513 include the five academic articles dedicated to the understanding of the phenomena occurring in Mayotte
 514 that were published during our study period.
 515

	Scientific bulletins	Press releases	News on website	Public notes	Academic papers	TOTAL
<u>Scientific monitoring</u>						
BRGM	104		22			126
REVOSIMA	40	1				41
IPGP		1	15			16
IFREMER			10			10
Researchers				4	5	9
EOST			8			8
CNRS/CNRS-INSU		2	1			3
IGN			1			1
EMSC			1			1
BCSF-RéNaSS	1					1
<u>Risk management</u>						
Préfecture of Mayotte		100				100
Ministries/Gouvernement		4				4
TOTAL	145	108	58	4	5	320

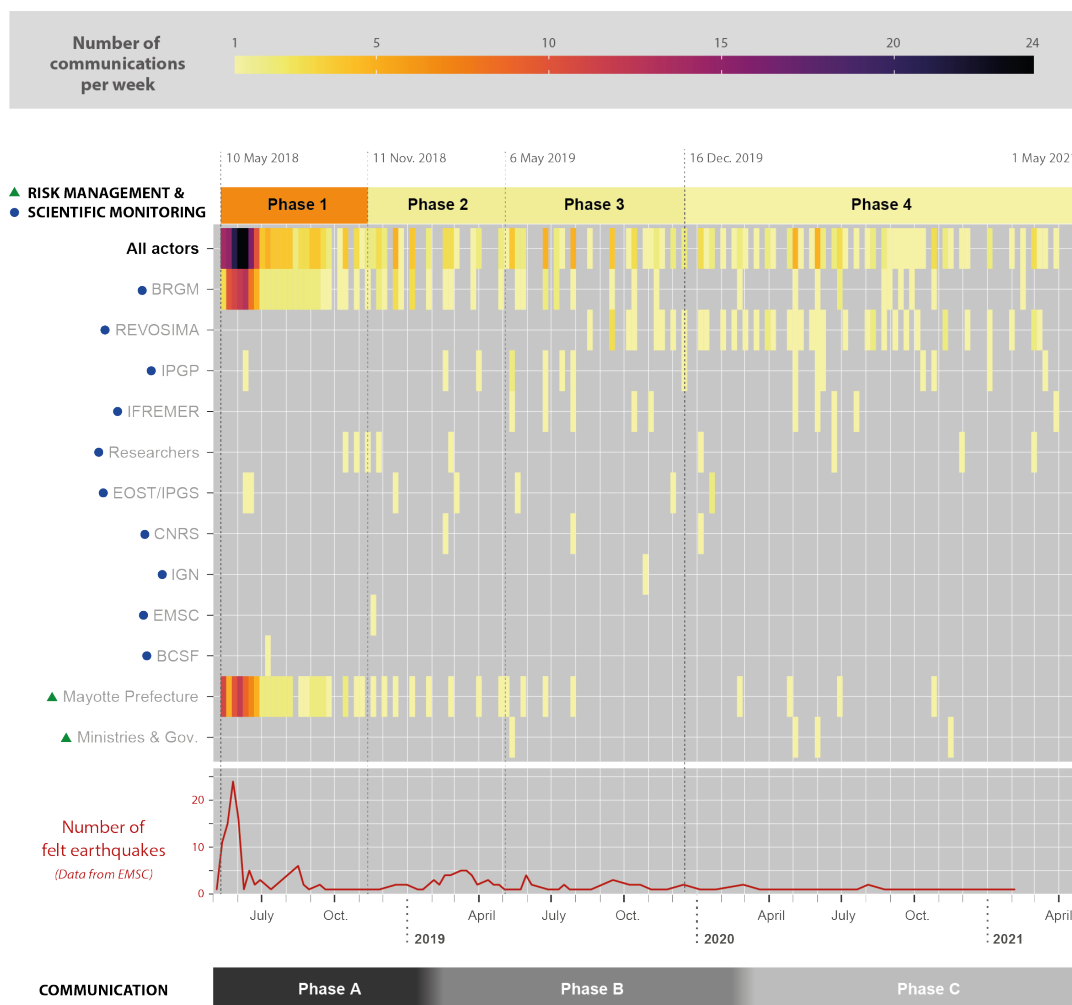
516 The number and frequency of publications vary greatly over time and among actors
 517 (Figure 4). Communication is particularly intense during the first six weeks of the crisis and
 518 continues with some regularity throughout 2018. The average number of communications per day
 519 is 6,8 during the first phase of the crisis (phase 1), compared to 1,3 (phase 2), 1,2 (phase 3) and
 520 1,0 (phase 4) during subsequent phases (Figure 4). As mentioned in the introduction, Fallou et
 521 al. (2020) show that, during phase 1, at the same time communication rate was very high, the
 522 population perceived a lack of information on the part of authorities and scientists. This finding
 523 deserves an in-depth analysis to understand the discrepancy between the initial high
 524



525 communication rate and the “*information vacuum*” felt by local people. Hence, hereafter, we
526 analyze in some detail not only the frequency but also the content and modalities of the
527 information circulation during the different phases of the sismo-volcanic crisis.

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Focussing on the communication of scientists and authorities, three main phases can be distinguished (A, B, C) that can be discussed in regard to the major phases 1, 2, 3, 4 of hazard monitoring and risk management (Figures 3, 4).



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Figure 4. Number of documents made public per week by the main actors in charge of monitoring and risk management. The average number of documents published per day is indicated for each of the phases identified in Figure 3.



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- **Phase A: from the beginning of the crisis to February 2019**

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Between the beginning of the seismic crisis and February 2019, the modalities of communication do not vary much. The local stakeholders in charge of monitoring and risk management, BRGM and the Préfecture of Mayotte, are the main contributors. Other scientific actors, such as the IGP and the EOST who are gradually getting involved in monitoring from the first months of the crisis, are only communicating punctually to report on the geodynamic context of the activity and/or on their involvement in the collect and treatment of data: e.g., on 11 June 2018, EOST announces the dispatch of the macroseismic response mission (GIM) to Mayotte (EOST, 2018a); on 12 June, IGP publishes an information brief on the ongoing crisis in Mayotte (IPGP, 2018).

The first communication to the public is a press release from the Préfecture of Mayotte on 14 May 2018. Referring to the monitoring undertaken by the BRGM since 10 May 2018, it mentions a *"swarm of earthquakes"*, distinguishes it from seismic aftershocks and recalls the safety instructions to be followed in case of earthquakes. Three press releases are published on 15 May that list the time and magnitude of felt earthquakes and specify that *"all the earthquakes take place in the same sector (around 50km off Mayotte) and, although located at sea, are too weak to generate a tsunami"*. The experts appear as puzzled by this unusual seismic activity as the people of Mayotte and the authorities. In an interview given to the French national press, the director of BRGM Mayotte declares: *"Unfortunately, we are in the unknown"* (15 June, Le Figaro, 2018b). Confronted with the repetition of felt earthquakes, the Préfet of Mayotte activates a crisis unit on 16 May 2018. From then on, the Préfecture publishes press releases on a daily basis (sometimes more) while the BRGM, which switched to "crisis monitoring", publishes daily reports. As testified by several interviewees, during that first phase of the crisis, the local branch of BRGM is put under strong pressure *"to be able to inform, almost 'day and night', the authorities on the magnitude, on the location of the earthquakes, a more precise location than the one announced by the international networks which were not reliable because of their distance"* (anonymous, interview May 2020). It is important to outline again that, before the creation of REVOSIMA, real-time data processing is organized through the voluntary commitment of scientists.

During the first weeks of the crisis, the scientific reports and official press releases follow one another within a few hours. BRGM publishes its bulletins on the BRGM website², while the Préfecture sends press releases to the press and publishes them on Facebook. These official press releases generally reproduce the elements communicated by the expert body. They remain often very technical, recalling the number of earthquakes recorded per day, their magnitude, the time at which they were detected and their distance from the island (the reports mention uncertainties of the order of 10-15 km). The Préfecture's press releases can contain additional elements about impacts (injuries, building damage) and often recall safety instructions. They also provide information about the decisions taken by the Préfecture to support the inhabitants of the island (e.g. with the setting up of a toll-free phone number and the opening of a psychological

² <https://www.brgm.fr/fr/actualite/dossier-thematique/volcan-seismes-mayotte-brgm-fortement-implicite>



582 support unit ; the demand for (and arrival of) a support mission of civil protection and natural risks
583 in June 2018).

584

585 But, despite significant effort from all parties, a careful read shows that the communication
586 of the first weeks is overall marked by a sense of surprise, uncertainty and even sometimes
587 inaccuracy. Two anecdotes have been quite commented upon within the scientific community.
588 The first public scientific bulletin, published on 16 May 2018, indicates that *"in all rigor and given
589 the limited knowledge in the region, a tremor of magnitude greater than those already observed
590 cannot be excluded"* and outlines again that *"these earthquakes do not produce damage and,
591 although at sea, are too weak to generate tsunamis"* (bulletin of 16 May, BRGM, 2018a). This is
592 taken up word for word by the officials and the Minister of Outremers declares the same day that
593 *"there is no risk of damage on land, nor a tsunami at sea"* (quote from the Minister of Outremers
594 in *L'express de Madagascar*, 16 May 2018). Retrospectively, such statements seem
595 inappropriate, especially because the tsunami risk is the focus of recent monitoring and warning
596 systems developments. Another unfortunate example occurs on 1 June 2018. After a public press
597 briefing with civil protection experts and seismologists (Perzo, 2018b), the Préfecture posts on
598 Facebook and Twitter that *"there will be no earthquake of a higher magnitude than what we have
599 already known"*, a seismologically inexact prediction, which has been commented as an
600 inappropriate attempt to reassure the population. Beyond these missteps, it can be noted that the
601 technicalist and minimalist tone adopted in official communications is at odd with the statements
602 that are made by scientists and officials who insist on the unprecedented and *de facto* very
603 uncertain nature of the activity (e.g. the press release of 3 June 2018, which states that *"seismic
604 activity remains abnormal and continues"*).

605

606 The arrival of the interministerial mission composed of civil protection experts and
607 seismologists in early June 2018 is an opportunity to take a step back from the situation (e.g.,
608 Mayotte la 1ère, 2018; Perzo, 2018b). The experts conclude that i) the impact of the earthquakes
609 mainly resulted in an aggravation of disorders on buildings that were already vulnerable
610 (widening, elongation of cracks) and that ii) about thirty people got minor injuries, often linked to
611 misbehaviour in stressful situations during the earthquakes (e.g. falling down stairs). They also
612 outline that the repetition of shaking causes a feeling of anxiety and fear among the population,
613 all the more marked as this seismic swarm phenomenon was unknown in Mayotte until then.
614 Despite several attempts to address the problem of anxiety (notably with the opening of a toll-free
615 phone number and of a psychological support unit at the local hospital), the dialogue between the
616 authorities and the people remains difficult. Mid-June 2018, the BRGM publishes a Frequently
617 Asked Questions (FAQ) on its website explaining in a more educational way the state of
618 knowledge and the main uncertainties. The attempt is virtuous but not sufficient. As written a few
619 months later by the Ministry of Interior in its answer to the deputy of Mayotte, *"the most inventive
620 explanations have found an echo in part of the population (conspiracy, actions of evil spirits, etc.)
621 and communication is proving difficult. The State has obviously been concerned about this
622 situation since the beginning of the event, and everything possible is being done to inform the
623 population in a reliable manner"* (Question à l'assemblée nationale n°8992, 27 November 2018,
624 Ali, 2018). Among the explanations that have emerged, a popular one is that the earthquakes are
625 caused by oil exploration off the coast of Mayotte (Fallou et al., 2020). The hypothesis of a



626 volcanic cause has also surfaced: it is discussed on the websites of national scientific laboratories
627 (EOST, 2018b; IPGP, 2018) and in the local press (e.g., YD, 2018) as early as May-June 2018.

628

629 From the end of June 2018, the number of communications decreases with the decrease
630 in seismic activity (2 BRGM bulletins per week from 29 June 2018). In September 2018, BRGM
631 announces that *"the swarm is still running [but that] the lull observed since the end of June justifies*
632 *the change from "crisis" monitoring to "routine" monitoring"* (bulletin of 17 Sept, BRGM, 2018a).
633 From then on, BRGM publishes bulletins twice a month, with exceptional bulletins in case of felt
634 earthquakes. In October 2018, analysing the routine GNSS measurements led by the IGN, a
635 geophysicist from the Ecole Normale Supérieure suggests that the seismicity could be related to
636 the deflation of a deep magma chamber. He publishes two notes explaining his results on his
637 laboratory blog (Briole, 2018); two more notes are published in November and December. In the
638 opinion of several scientists we interviewed, the *"wild"* publication of his results played an
639 important role in raising awareness of the importance of this seismic crisis among scientists and
640 authorities in charge of risk management. On 7 November 2018, a press release from the
641 Préfecture of Mayotte mentions that the IGN measured a shift of the island eastward as well as a
642 *"slight downward shift"*. The risk implications are not specified but it is the first time the
643 volcanological component is officially mentioned, 6 months after the hypothesis circulated among
644 experts and in the press. The infrasound signal of November 11, 2018, which occurrence supports
645 the volcanic hypothesis, give rise to intense discussions among the international scientific
646 community (Lacassin et al., 2020). It is mentioned by the BRGM in a news item summarizing
647 current knowledge on the understanding of the ongoing activity published on its web site on 17
648 December 2018 (BRGM, 2018b).

649 From January 2019, the frequency of BRGM bulletins continues to decrease to reach a
650 frequency of one bulletin every 20-30 days.

651

652 • **Phase B: from February 2019 to February 2020**

653 On 8 February 2019, following the initiative of the STTM group of Mayotte, 140 inhabitants
654 of Mayotte sign an open letter addressed to the Préfet of Mayotte, the local administration, the
655 BRGM and the local media. Pressing them for more information (Picard, 2019, on change.org),
656 they write: *"You are not unaware that, for almost 9 months, a large majority of "your" population*
657 *has been living in anxiety, incomprehension ... Even anguish! The most "basic" questions in terms*
658 *of security of people, conduct to hold and even projection in the near future ... Are found without*
659 *any answer! You are certainly convinced that you are doing the maximum so that the panic does*
660 *not reach your "constituents"? BUT this is not the reality on the ground."* Expectations are
661 particularly high toward scientists, who are expected to provide explanations and guidance with
662 respect to risk scenarios. But, in the absence of offshore observations, the scientific advances
663 are still poor.

664 February 2019 is an important tipping point, however, as the scientific community finally
665 receives the funding to work in the area. On 22 February 2019, CNRS issues a press release with
666 the laureates of the Tellus-Mayotte call for tenders (CNRS, 2019). With the launch of the Tellus
667 Mayotte program, communication opens up to new scientific actors. IPGP and EOST announce
668 their involvement in the up-coming missions on their website. BRGM scientists publish the first



669 public catalog of the seismic data collected since the beginning of the crisis (Bertil et al., 2018;
670 Lemoine et al., 2019).

671 BRGM continues to publish a monthly bulletin dedicated to the monitoring of the seismicity
672 but communication from the Préfecture of Mayotte becomes more episodic. It focuses on relaying
673 BRGM's situation points (with the list of events - among which the felt ones - in the past months)
674 and on announcing the arrival of Tellus Mayotte scientific campaigns. It is worth pointing out that
675 the press release of 3 April 2019 mentions a *"scientific volcanological mission"* which aims at
676 *"consolidating knowledge of the tectonic and volcanic history of Mayotte and at highlighting the*
677 *tectonic structures of the island by means of dating of magmatic rocks, or analyses of the*
678 *composition of soil gases"*.

679 One year after the beginning of the seismic crisis, it's time to take stock of the situation. In
680 a press release published on 10 May 2019, the Préfecture of Mayotte reviews the actions
681 undertaken, both from a scientific and risk management point of view, during the past year, and
682 concludes that *"the latest data collected by the experts and the modeling of the phenomenon*
683 *[now] suggest a volcanic origin, possibly linked to a large-scale underwater eruption, or even to*
684 *an origin combining both tectonic and volcanic phenomena"*. When the scientists of the MAYOBS
685 campaign arrive at the dock on 16 May 2019, they are accompanied with an inter-ministerial press
686 release (e.g., Ministère de la Transition écologique et solidaire, Ministère de l'Enseignement
687 supérieur de la recherche et de l'Innovation, Ministère des Outre-Mer, Ministère de l'Intérieur,
688 2019) announcing the discovery of a newborn volcano at the origin of the abnormal seismicity
689 endured by the Mahorais for the past year. The government, through the voice of 4 of its
690 ministries, commits to reinforce monitoring and prevention measures. IPGP relays the press
691 release on its web site on the very same day (IPGP, 2019a), IFREMER, EOST and BRGM follow
692 soon after. The announcement is relayed on Twitter, with a spectacular picture of the underwater
693 volcanic edifice and of the rising plume above it (Lacassin, 2019), which raises the interest of
694 international scientists and of media such as National Geographic, Science, or the BBC (BBC -
695 Science in Action, 2019; Pease, 2019; Wei-Haas, 2019). There are similar surges of
696 communication after the return of the next marine campaigns MAYOBS 2 to 4 in June and July
697 2019, but much less communication afterwards³. The effort of communication will resume again
698 in May 2020 after the MAYOBS13 campaign.

699
700 From the discovery of the underwater volcanic activity, the Préfecture of Mayotte and the
701 BRGM are no longer the only two central actors regarding risk communication. On 28 May, 2019,
702 BRGM publishes its latest seismic bulletin on its own and the Préfecture of Mayotte publishes its
703 latest press release only dedicated to the seismic crisis. Monitoring falls in the hand of the newly
704 born REVOSIMA. Communication is now discussed at a more centralised level by the DIRMOM
705 who reports directly to the prime minister cabinet. The Préfecture works closely with the DIRMOM
706 to elaborate new communicational tools such as information leaflets. Early August, the Préfet
707 organizes a press conference during which scientists present the results of the last campaigns to
708 elected officials and local dignitaries.

³ Reports and press releases following MAYOBS campaigns are listed on this dedicated IPGP web page:
<https://www.ipgp.fr/fr/revosima/rapports-communiqués-de-presse-missions-mayobs>



709 On 27 August 2019, the first web news concerning the creation of REVOSIMA is published
710 on the IPGP website (IPGP, 2019b). Entitled "*Volcanological and Seismological Monitoring*
711 *Network of Mayotte*", it presents the mandate of the IPGP and its partners in monitoring the
712 seismic-volcanic crisis in Mayotte. REVOSIMA issues its first scientific bulletin at the end of
713 August 2019. It corresponds to the bulletin of July 2019, the two bulletins for August follow in
714 September creating an apparent surge of communication on Figure 4. From now on, two scientific
715 monitoring bulletins are published every month (it will be reduced to one per month in March
716 2020)⁴.

717

718 A scientific conference is organized at IPGP in Paris on 15 October 2019. It aims to
719 present the obtained scientific results on the ongoing seismic-volcanic crisis, and to discuss the
720 challenges of its future monitoring. It is followed by a public conference and a question-and-
721 answer session in the presence of state representatives and of the media. It is covered by national
722 media, which are stoned by the unprecedented nature of the activity (e.g., Vey, 2019), and the
723 local press, which is proud to see a local scientist, Said Said Hachim, invited (Perzo, 2019b). In
724 October 2019, the Préfecture set up a "*stakeholder committee*" that brings together "*all the*
725 *notables, heads of department, politicians, around a table*" and to whom scientists should present,
726 about every six months, "*the assessment of the crisis and the scientific findings*" (anonymous,
727 interview May 2020). In November 2019, the Préfecture organises public meetings in several
728 communes of Mayotte but with a sparse audience (a few tens of people, anonymous, interview
729 May 2020).

730

731 In December 2019, the American Geophysical Union fall meeting hosts a special session
732 dedicated to the Mayotte new volcano discovery where the scientific results from the first
733 MAYOBS campaigns are presented (e.g., Deplus et al., 2019; Feuillet et al., 2019; Jacques et al.,
734 2019; Saurel et al., 2019). From our interviews, we understand that some tensions emerge
735 between the authorities and the scientists about one of the communications (Poulain et al., 2019),
736 which mentions a delay of a few minutes between a triggering event due to the volcanic activity
737 and the arrival of a tsunami on land. The authorities do not want such information to be
738 communicated without having thought beforehand about the protection measures to be put in
739 place. Scientists defend their academic freedom. But the case is quickly closed.

740

741 At the end of 2019, EOST also announces the arrival of the second mission of the BCSF-
742 RéNaSS macro-seismic intervention group in Mayotte. The continuation of REVOSIMA decided
743 at the December 2019 interministerial meeting is not really announced, at least publicly.

744

745 In January 2020, a team of French and German researchers, not members of REVOSIMA,
746 publishes in *Nature Geoscience* the first academic paper analysing the time evolution and the
747 dynamics of the ongoing volcanic activity (Cesca et al., 2020). This paper, mostly based on
748 seismic data acquired by worldwide seismic networks, mentions the discovery of the new volcano
749 before its publication by the scientists directly involved in the survey campaigns and the close
748 monitoring of the crisis. The CNRS and the University of Toulouse, which hosts the second author
749 of this paper, publishes a press release in French (CNRS & Université de Toulouse III, 2020)

⁴ All REVOSIMA bulletins and reports are listed and accessible from the following IPGP web page:
<https://www.ipgp.fr/fr/revosima/actualites-reseau>



750 bearing a sketch section of the proposed magmatic plumbing system, which is largely commented
751 by the STTM group: *"So much questions !!! In particular on the position of the magma chamber*
752 *[...] One or Two? 1 or 2 chambers? The island is moving east, towards the supposed chamber*
753 *near the volcano??? And there's another one just below under the doormat on our front door",*
754 *"Silly question, but does that portend a big disaster for us?"* (excerpts from STTM Facebook group,
755 8 Jan 2020)

756 In January, EOST also announces the results of the GIM mission and of a pickathon
757 organized by the REVOSIMA to get help in relocating earthquakes. In February, the BRGM and
758 the Préfecture of Mayotte announce the future launch of seismic-refraction and magnetotelluric
759 surveys (MAY-MT and REFMAROE).

760

761 • **Phase C: From March 2020 to April 2021**

762 From the beginning of 2020, with the perpetuation of REVOSIMA, the number of actors
763 communicating diminishes. REVOSIMA refocuses the communication effort. From March 2020,
764 the frequency of its scientific bulletins becomes monthly and automatic bulletins are released
765 every day. The monthly bulletins, consisting of about ten to twenty pages, are particularly
766 appreciated by the scientific community because they contain details on scientific hypotheses,
767 instruments, methods and results as well as the related uncertainties. Despite a first summary
768 page aimed at popularizing the contents of the bulletin, the monthly bulletin remains nevertheless
769 difficult for the lay public to access as it is testified of by discussions within the STTM group:
770 *"Gee.... a REVOSIMA bulletin of 21 pages, we didn't expect so much.....I don't understand*
771 *everything, so I count on THE scientists to tell me if there is something new..."*, and in response,
772 *"Sorry but I can't stand these bulletins anymore! I force myself to read them ? Why : 89 % of*
773 *repetitions and reminders of the facts ... I haven't read this one yet (the 25th) ! I think that the*
774 *objective is reached ! To make the "average" readers like us run away ! Impossible a short, sharp*
775 *and clear bulletin ??? Saying : "since the last time..."* (excerpts from STTM Facebook group, 5
776 Jan 2021). Shorter exceptional bulletins are issued in case of felt earthquakes. REVOSIMA
777 monthly and daily bulletins and exceptional press releases (in case of felt earthquake) are the
778 main supports for information. They are made accessible to the public on a dedicated facebook
779 feed and are regularly commented on, in the STTM facebook group as well as in the local press.
780 The Préfecture continues to inform the population about new scientific campaigns.

781 The COVID 19 pandemics, the related lockdowns and travel restrictions complicate the
782 scientific survey of the crisis. A part of it has to be remotely managed, including the MayOBS13-
783 2 bathymetric survey in May 2020, operated by a commercial survey vessel while the scientific
784 team worked on it from their homes. The objectives of these missions are announced by a press
785 release from the Préfecture of Mayotte (2 May 2020) relayed on the websites of REVOSIMA
786 partner institutions (IPGP, IFREMER, BRGM). The information is backed up by a government
787 press release (6 May 2020) which recalls *"the State's permanent commitment to protecting the*
788 *population of Mayotte"* and states that, as such, REVOSIMA *"continues to carry out its land and*
789 *sea monitoring missions, including in the current health context, with all due precautions"*. Two
790 information leaflets are also issued that describe the release and recovery of OBS (MAYOBS 13-
791 1) and the acquisition of underwater acoustic data (MAYOBS 13-2). While surprisingly, no press
792 release followed the MayOBS 5 to 12 missions, REVOSIMA issues in May 2020 a detailed report
793 about MayOBS13 results (REVOSIMA, 2020), which is relayed on the websites of partner



794 institutions (IPGP, BRGM, IFREMER) on 4 June 2020. The same day, the government publishes
795 a press release that summarizes the main scientific results and thanks all the staff for their
796 commitment in these missions.

797 Two more scientific papers are published in June 2020, one on the volcanological and
798 seismotectonic context of the seismo-volcanic crisis (Famin et al., 2020), the other one, led by
799 BRGM scientists, analyses the seismic and GNSS data from the first year (2018-2019) of the
800 seismo-volcanic episode (Lemoine et al., 2020). It should be noted that a preprint preliminary
801 version of the latter was publicly available in February 2019 (Lemoine et al., 2019).

802

803 The following months are marked by more scattered communications from the
804 REVOSIMA partner institutions (in addition to the monthly REVOSIMA bulletin), aiming to
805 summarize the knowledge acquired since the beginning of the crisis (e.g. "two years of seismic
806 crisis and the birth of an underwater volcano in Mayotte", August 25th, Paquet, 2020). There is a
807 new surge of communication in October 2020 with the preparation of the MAYOBS-15 campaign.
808 IPGP presents the campaign's objectives on its website on 13 October, 2020 and publishes a
809 preliminary assessment of the mission on 29 October (IPGP, 2020). The Préfecture of Mayotte
810 issues a press release presenting MAYOBS-15 results on 28 October. Some of the scientists of
811 the campaign remain in Mayotte to participate in the "volcano week". Organized by the Préfecture
812 of Mayotte, in close collaboration with the DIRMOM and REVOSIMA, this "volcano week" aims to
813 raise awareness of the volcano among the inhabitants of Mayotte. Local personalities and
814 scientists take turns talking about the ongoing telluric crisis. The scientists present their
815 understanding of the ongoing volcanic activity without dwelling on the possible scenarios. Only
816 the tsunami risk is presented in some detail. Alternative scenarios are shared to the public
817 recalling that a working group is already working to identify possible evacuation routes and that a
818 program has been launched to work on a network of sirens and, in the longer term, a mass alert
819 system by telephone operators. But the information shared during that week remains quite light
820 on the overall topic of risks and the reactions posted live on the facebook feed of the Préfecture
821 during the presentations are pretty skeptical. The tsunami risk will be commented in the local
822 press as being eventually "quite limited" (Journal de Mayotte, 2 November, YD, 2020). Two
823 presentations by scientists from REVOSIMA are also organized by the education authority for
824 high school students and 160 science teachers in Mayotte. During the same week, the Préfet of
825 Mayotte inaugurates the first tsunami warning siren in Dembeni and scientists symbolically hand
826 over volcanic rocks to the Museum of Mayotte. The government issues a press release on 17
827 November 2020 that reviews the results of the MAYOBS-15 campaign and the outputs of the
828 "Volcano Week."

829

830 In January 2021, IPGP announces to be laureate of a major instrumentation project in
831 Mayotte (Programme Investissement d'Avenir 3, MARMOR project). Led by IFREMER, the
832 project brings together the core partners of REVOSIMA and prefigures a restructuring of the
833 governance of research and observation in the region. This change in governance will be all the
834 more important in the months to come as the DIRMOM's mission ends at the beginning of May
835 2021, leaving room for a reorganization within the State services themselves. This reorganization
836 is underway at the time of writing and is therefore beyond the scope of this paper. However, it is



837 interesting to note that our study period, which covers the first three years of the crisis,
838 corresponds to the first major stage of volcanic risk management in Mayotte.

839

840 In March 2021, the researchers involved in the first MAYOBS campaigns and in
841 REVOSIMA publicly release a preprint of their paper submitted to Nature Geoscience (Feuillet et
842 al., 2021). This paper was initially submitted to Nature in September 2019, then transferred to
843 Nature Geoscience in June 2020, but remained confidential until March 2021. It is still under
844 review after revision at the time of writing. The preprint describes the new offshore volcano and
845 its activity, the evolution of the crisis from the initial deep fracturation processes to the upward
846 migration of magma across the lithosphere, and discusses the geodynamic context, but does not
847 discuss future scenarios of evolution and related hazards. Local press summarizes its main
848 results using a lithospheric-scale cross-section from the preprint that illustrates the processes at
849 work and the location of the seismicity and of magma chambers (YD, 2021). On 15 March 2021,
850 the online media from the Cité des Sciences et de l'Industrie (a science museum in Paris)
851 publishes a webdoc summarizing in a popularized way all main results obtained so far on the
852 Mayotte seismo-volcanic crisis (Minassian, 2021).

853 5. Overcoming the gap between risk actors and 854 populations: the role of scientific explanation and 855 risk scenarios

856 The previous analysis, based on a quasi exhaustive documentation, shows that the
857 communication strategy of the authorities and scientists has become more structured and more
858 centralised from the summer 2019, with the establishment of a dedicated monitoring body
859 (REVOSIMA) and with a support of a inter ministerial mission dedicated to risk reduction in the
860 overseas (DIRMOM). Before and after that, our analysis also shows a constant commitment of
861 scientific and state actors to understand and monitor the crisis and a care to communicate their
862 progress publicly. But despite this, there is a persistent discontent among the population. Our
863 study of how information circulates from its place of production to its communication in public
864 scientific or official documents allows drawing a few lessons, which could help to improve future
865 communication strategies. The question that arises is: why does the population of Mayotte
866 complain about a lack of information when, objectively, the volume of documents made public by
867 the main risk actors is significant, corresponding to a real effort to communicate on their part? We
868 will attempt to answer that question by taking into account the specific issues at stake in each of
869 the four scientific monitoring phases 1, 2, 3 and 4, the adaptation of the communication strategies
870 between phases A, B and C and the evolution of the population's information needs.

871

872 **5.1. Two factors determining the evolution of population's need for information**

873

874 In the case of Mayotte, the evolution of the population's need for information seems to be
875 a modulation of two main factors: 1) a need for "basic" information that is typical of all populations
876 at risk and well known to disaster studies (see for instance Lindell et al., 2006; Mileti, 1993), and



877 2) a need for information that adapts to the level of perceived danger, i.e. to the evolution of the
878 hazard.

879 Regarding the first factor, Lindell et al. (2006) report 8 typical questions people ask
880 themselves before making any decision when they receive a warning message from the
881 authorities: Is there a real threat that requires my attention? Do I need to take protective action?
882 What can I do to achieve protection? What is the best method of protection? Do I need to take
883 protection action now? What information do I need to answer my questions? Where and how can
884 I obtain this information? Do I need the information now? In the case of Mayotte, we are not strictly
885 in the case of receiving a warning message, but feeling earthquakes warns people in a very
886 efficient manner and one can suppose that similar questions arise. Mileti (1993) points out that it
887 is important for risk actors to answer four main questions people face: What is the risk? Where
888 will it happen? When will it happen? What will be the effects?

889 Regarding the second factor, it is important to recall that the inhabitants of Mayotte
890 perceive the existence of offshore volcanic activity only indirectly, mainly through felt earthquakes
891 and, secondarily, through stories told on social media and in the press or reported, for instance,
892 by fishermen who observe dead fishes coming up from deep seas. Numerous studies have shown
893 that experiencing the effects of a hazard increases the attention paid to information about that
894 hazard (e.g., Sorensen, 2000). From this point of view, it seems reasonable to consider that the
895 thirst for information of the inhabitants of Mayotte has evolved during the crisis, in response to the
896 evolution of the seismicity (Figure 3). The beginning of the crisis was marked by repeated and
897 strongly felt earthquakes, which goes hand in hand with a strong demand for information (Fallou
898 et al., 2020). This interest in the topic of earthquakes is further evidenced by a peak in the number
899 of articles published in the local press at the beginning of the crisis (Devès et al., 2021). The
900 number of felt earthquakes decreased thereafter and so did interest in earthquake-related news.
901 This is shown by a significant drop in the number of articles in the local press. Inhabitants of
902 Mayotte report that, today, the risks associated with the seismic or volcanic activity are barely
903 mentioned in everyday discussions (anonymous, interview). Indeed, people are exposed to a
904 variety of risks, some of which are more immediate than those associated with the seismic-
905 volcanic crisis: financial insecurity, energy insecurity, risk of being expelled from the country, daily
906 struggle for access to water, food, and among the natural hazards, flooding, which is far more
907 frequent.

908

909 **5.2. The role of the evolving available information content**

910

911 The need for information also changes according to the content of the information that is
912 disseminated. Regarding this issue, we have identified three main phases of communication (A,
913 B, C).

914 *5.2.1. The technicalist biais*

915 From the beginning of the seismic crisis in May 2018 to the launch of the first scientific
916 campaigns in February/March 2019 (phase A), the communication is overall characterized by a
917 frequent but minimalist and technicalist discourse (i.e. many lists of earthquakes with magnitude
918 and location). The effect of surprise, and the lack of proper instrumentation to monitor and
919 understand the seismic crisis, creates a context of strong uncertainties that leads to some



920 confusion. We already illustrated that point earlier. A final example can be given about the
921 uncertainties linked to the initial setup of the seismic network. As reported by Fallou et al. (2020),
922 the fact that some of the felt earthquakes are not reported in the scientific bulletins fuels a sense
923 of distrust among the population. Scientists in charge of monitoring take care to publish a note
924 explaining the limitations of the seismic network and the difference with international networks (22
925 May, BRGM, 2018a). But the efforts made to explain these uncertainties are challenged by the
926 publication of real-time data, albeit of lower quality, by web applications accessible to all. The
927 Préfecture tries to bridge the gap by communicating immediately after earthquakes of magnitude
928 greater than 5 using the data issued by international networks while recalling that *"the estimates*
929 *of international measurement centers are relayed [...] [waiting for] the BRGM to refine its results"*
930 *that will be "more accurate because the sensors [are] located in Mayotte and in the area"* (Press
931 release, 5 June 2018). Unfortunately, this strategy, which is legitimate from a scientific point of
932 view, tends to make it even more difficult to understand data uncertainties. It seems paradoxical
933 to say that the data is of poor quality when they are de facto used in official communication without
934 waiting to be improved.

935 5.2.2. *The reassuring bias*

936 Beyond the fact that it remains essentially focussed on the seismic hazard, the first phase
937 of communication is marked by the propensity of the various actors of the risk chain (the
938 authorities, but also the scientists and the local press) to try "reassuring" the population in order
939 to "avoid panic". The local Journal de Mayotte reports that "the mayor of Mamoudzou is calling
940 people to calm down and not to give in to any form of panic" (Journal of Mayotte, 23 May, Perzo,
941 2018a). Coming back onto that stage of the crisis, a scientist explains: "At the beginning, we
942 talked a lot about the seismic risk to minimize it in the sense that these were only moderate
943 earthquakes, 5.8 was the larger and afterwards we stayed on moderate earthquakes, we
944 communicated quite a lot saying that to have a lot of damage it was necessary to have high
945 enough magnitudes, that it was, maybe, not in the functioning of the system that we knew"
946 (anonymous scientist, interview). And thus, in the local press, one could read that "Mayotte [was]
947 indeed in a seismic zone, but the tremors [were] not of a nature to worry the scientists" (Journal
948 de Mayotte, 2 June, Perzo, 2018b). This desire to reassure the population in order to avoid
949 disturbances of public order is not specific to the case of Mayotte. It has been observed in other
950 crises – like industrial accidents (e.g., Borraz, 2019) or other earthquake sequences (e.g.,
951 L'Aquila, see discussion in Cocco et al., 2015; Jordan, 2013) – even though mass panic is a rare
952 phenomenon, considered highly unlikely by disaster specialists who have shown that it only
953 occurs in very specific settings - such as crowds trapped in a confined and restricted space
954 (Quarantelli, 2008).

955 On the contrary, communities facing disaster risks tend to react by reinforcing social
956 control mechanisms (Solnit, 2010). In Mayotte, people like the members of the STTM facebook
957 group cope pretty well with the stressful nature of the situation. By sharing experiences, emotions
958 and information, they collectively increase their capacity for resilience. But coping also means, for
959 them, understanding what causes seismicity. In order to achieve that goal, they then work at
960 describing the phenomenon as accurately as possible (following the group, you could know
961 whenever an earthquake was felt, with which intensity and what impact from place to place). To
962 that respect, the expectations are very high toward scientists who are seen as the ones who can



963 understand and explain. Among the scientists we interviewed, most argue that "it's not worth
964 worrying people about things that are still hypothetical so [given the uncertainties] we chose to
965 remain very factual" (anonymous, interview). But has this "factual" communication only dedicated
966 to seismic hazards, and taking the form of lists of events, enabled people to understand "the big
967 picture", i.e. what was happening and what could happen next? Has the great caution adopted by
968 the scientists and the authorities to communicate on certainties rather than on hypotheses and
969 means answered the basic information needs of the exposed population? We tend to believe that
970 it adds confusion by delaying the sharing of robust information. The fact that the Préfecture
971 mentioned the volcanic hypothesis 6 months after the local press undoubtedly contributed to the
972 population's feeling of a lack of information, and also facilitated the emergence of complotism. It
973 is true that, given the uncertainties, some questions could not be answered but, as suggested by
974 Lindell et al. (2006), one might have explained earlier what was known and not known, and what
975 will be done to address that lack of knowledge. As noted by Sharma & Patt (2012), recent
976 empirical studies tend to show that *"lay people do understand uncertainty and, under conditions
977 of good communication, even understand probabilistic forecasts. Therefore, there may be value
978 in communicating uncertainty from the point of view of improving the credibility of the message.
979 This is particularly important as the experience about the credibility of the message in the current
980 hazard event would most likely affect the response to warning in the next future event."*

981 5.2.3. The hazard bias and the lack of risk scenarios

982 From the launch of the first scientific campaigns in February/March 2019 to the creation
983 and perpetuation of the REVOSIMA (phase B), the format and the nature of communication
984 changes. At first, it is distributed among much more actors and then changes scale with a
985 resumption of communication by national actors (major scientific institutions, CNRS, ministries
986 and government through the DIRMOM). But it remains relatively coherent as each of these actors
987 refers to the joint Tellus Mayotte work program. The discoveries made during the MAYOBS1-2
988 and MAYOBS 3-4 missions constitute an important turning point in the information that is shared.
989 From May 2019, communications no longer focus only on seismic hazard but start drawing a more
990 general explanatory framework attributing earthquakes to an offshore, and unexpected, volcanic
991 activity. But despite this important change, the communication remains centered on hazards
992 rather than on risks, which still does not allow answering the population information needs.
993 Reading the press and the STTM facebook feed, one realizes that people are very excited by the
994 unprecedented scientific mobilisation around their island and expect to learn a lot from scientists.
995 But after the first campaigns, given the extent of the discovery that makes fear of potentially high
996 associated risks, the authorities become very cautious about communication. They ask the
997 scientists to refine their scenarios before sharing openly information about risks with the
998 population (we mentioned earlier some tensions in AGU). A scientist reports that *"today [a year
999 after the discovery of the volcano] we are starting to talk about all the risks. But we are talking
1000 about it with frilosity. But it is not the scientists who talk about it with frilosity, I think that the
1001 authorities have locked up this subject a little."* (anonymous, interview in May 2020). Some of the
1002 scientists actually share the frilosity of the risk managers pointing out that *"I prefer to publish, and
1003 to get a peer-to-peer validation of my hypotheses, before sharing them publicly [...] I don't want
1004 to panic people"* (anonymous, interview in July 2020). Hence, the scientific as well as the official
1005 communication settles for highlighting the unprecedented nature of volcanic activity and the



1006 prowess scientists must deploy to study it. Little is said about the possible evolution of the hazard
1007 although, as recalled by another scientist, “*we identified [coarsely] the possible scenarios*
1008 *probably from May-June 2019*” (anonymous, interview in May 2020). The population feels
1009 abandoned. “[...] *The State gives up a lot of money and resources... But no respect for the*
1010 *population! No info (the same for 2 years! True!) No listening to people and their requests! No*
1011 *explanation in the villages [...] And when they give a conference (scientific or press) it is to repeat*
1012 *the same information over and over!*” (excerpt from STTM Facebook group, 5 Jan 2021). The
1013 feeling prevails that communication does not answer the important questions, which are intimately
1014 linked to the issue of risk scenarios.

1015 So far, i.e. three years after the beginning of the seismic crisis, scenarios have only been
1016 communicated orally, in the form of a listing of potential hazards, indicating that scientists are still
1017 working to refine their assessment of the associated risks. But this strategy is debated among
1018 scientists. Some argue that “*these are still scenarios, so we must be very careful [in*
1019 *communicating] [...] I understand that some scientists are a little confused because a lot of work*
1020 *has been done and not all the information has been passed on to the general public, but I think*
1021 *that the general public does not need to know certain information either, because it is all just*
1022 *hypotheses and then you take a sentence out of context and it's panic. I understand that*”
1023 (anonymous, interview in May 2020). Others respond: “*I think it's better [...] that people are aware*
1024 *that one day there could be a mudslide in their garden or a tsunami than not to know. I know that*
1025 *Mayotte is maybe more complicated because, I don't know, they have other problems but it's not*
1026 *a reason to hide it from [people]...*” (anonymous, interview in June 2020). Between the supporters
1027 of a communication based on certainties and quantitative assessment, which is structurally close
1028 to the strategy adopted by the authorities, and the supporters of a certain level of academic
1029 freedom in communicating hypotheses at work and not just confirmed results, the debate is still
1030 open.

1031 Both strategies have advantages and caveats. Davies et al. (2015) argue that “*quantitative*
1032 *risk assessment and risk management processes*” are “*of value at regional or larger scales by*
1033 *governments and insurance companies*” but do not provide “*a rational basis for reducing the*
1034 *impacts at the local (community) level because in any given locality disaster events occur too*
1035 *infrequently for their future occurrence in a realistic timeframe to be accurately predicted by*
1036 *statistics*”. They suggest, instead, that “*communities, local government officials, civil society*
1037 *organisations and scientists could form teams to co-develop local hazard event and effects*
1038 *scenarios, around which the teams can then develop realistic long-term plans for building local*
1039 *resilience*”. As outlined by earlier studies, as providers of the primary information about the
1040 hazards, scientists are - whether they like it or not - at the heart of the risk reduction process (e.g.
1041 Donovan, Oppenheimer & Bravo, 2012; Fearnley and Beaven, 2018; Donovan, 2021). They
1042 cannot wait for the very last quantitative results to share their knowledge, i.e. their hypothesis,
1043 their methods and their results (that can be negative ones proving that an hypothesis does not
1044 hold). They have a moral, if not legal, responsibility to respond to the demand for information from
1045 different audiences (authorities, people likely to be affected, journalists, etc.) and at all times
1046 (times of larger or smaller uncertainties). Jasanoff (2005) speaks about “*civic epistemology*” as
1047 “*the institutionalized practices by which members of a given society test knowledge claims used*
1048 *as a basis for making collective choices*”. Scientists’ role is indeed all the more central as their
1049 opinions not only inform, but also legitimize the decisions taken by the authorities in charge of



1050 civil protection. Of course, such a posture is not easy to adopt, notably because there is a bounded
1051 understanding of the scientific approach in our societies (e.g., Bromme & Goldman, 2014). During
1052 our interviews, we were said that the comments posted on STTM hurted some scientists.
1053 Referring to the criticisms read on the Facebook of the STTM group, one of them says: *"What*
1054 *they did not understand is that we did not understand what was happening either [...] Because*
1055 *there is no analog [...] We started from an area considered as [inactive]. We find ourselves in an*
1056 *unknown zone to manage a phenomenon without analogue while having to organize missions*
1057 *involving unprecedented means [i.e. large scientific boats that should be booked months in*
1058 *advance] [...] Our role is to make scientific reports [but] I think these have a limited impact*
1059 *[because] there is no one on the ground [who can translate what we do]."* (anonymous, Interview
1060 in July 2020). That such knowledge "translation" has to be done by concerned scientists actively
1061 engaged in science communication and in answering people's concerns, or by professional
1062 "knowledge brokers" (Hering, 2016), is an open question.

1063 The publication of an article by REVOSIMA researchers on EarthArxiv (Feuillet et al.,
1064 2021) in march 2021 gives rise to mixed feelings in the STTM feed. The fact that the publication
1065 is not associated with a document in French and addressed to the lay public is not much
1066 appreciated: *"they are seriously starting to get on my nerves! A choice to address only peers! And*
1067 *damn for a minimum of popularization and "simple" explanations. Afterwards, they are surprised*
1068 *that some and others tell everything, anything! or blame them for their "Height!"*" (excerpt from
1069 STTM Facebook group, 17 March 2021). The intuitive interpretations they make of the article,
1070 from the point of view of risks, are rather accurate: *"I learn from this cross-section that the*
1071 *volcano's chimney is 15km from Mamoudzou and not 50, where the underwater volcano is*
1072 *formed. Not reassuring. Moreover, the last activities mentioned are in the main volcano, so very*
1073 *close to us."* (excerpt from STTM Facebook group, 17 March 2021). People have clearly
1074 understood that it is not the new volcano that poses a significant risk to them. They are very
1075 concerned about the seismicity located closer to the island, especially since the publication of the
1076 cross-sectional diagrams of Cesca et al. (2020) and Feuillet et al. (2021). They ask themselves
1077 questions about a future eruption very close, and/or collapse on the outer-reef slope generating
1078 tsunamis, which corresponds more or less to the scenarios considered by scientists. To this
1079 respect, it seems rather vain not to communicate on scenarios, at least towards the part of the
1080 population who is able to understand, with only a little help, how science works and what are the
1081 hypotheses and uncertainties.

1082 5.2.4. The complexity of multiculturalism

1083 To conclude this discussion, it is important to come back to an essential fact about risk
1084 reduction in Mayotte in its communication aspect. Lindell et al. (2006) emphasize that for
1085 individuals to effectively adapt their response to a risky situation, they must not only receive
1086 information, but also consider and understand it. It is clear that individuals comprehend
1087 information only if it is provided in a language they understand, at a time and in a format they are
1088 accustomed to use. The above discussion shows that even if information is shared publicly, it is
1089 not properly formatted to be understood even by the educated part of the population. The fact that
1090 written communication to date has been primarily in French, an official language but one that is
1091 far from being well understood by the majority of the population, is a major problem. Efforts have
1092 been made to translate some of the communication materials, including the seismic safety



1093 guidelines, into Shimaoré in May 2020, but this is far from sufficient. Identifying the various habits
1094 of the population with respect to communication (not only language but also practices, who listens
1095 to who?) would also be important to adapt both format and contents. As pointed out by the Senator
1096 of Mayotte, Thani Mohamed Soilihi, orality plays an important role in Mayotte and written formats
1097 would gain to be accompanied orally (radio, animated movies but also neighborhood meetings
1098 and informal discussions with prominent members of the various social groups composing
1099 Mayotte (associations, cadis), etc.) (interview excerpt in the Report of activity of the DIRMOM,
1100 May 2019 - July 2020).

1101 6. Conclusions

1102 As pointed out by Stewart and Lewis (2017), *"scientists' attention to technical accuracy*
1103 *and their emphasis on professional consensus may do little to influence multiple publics whose*
1104 *worries instead root into their sense of place, trust and governance, as well as equity and ethics."*
1105 The work done on the circulation of information from its place of production (the laboratory, the
1106 boat, the field) to different publics (authorities, media, population) during the first three years of
1107 the Mayotte seismo-volcanic crisis supports this observation. There is a real gap between the
1108 culture of the scientists and authorities in charge of monitoring and risk management, and that of
1109 the local populations. The efforts made by the risk chain actors to share information are
1110 undeniable, as well as the knowledge built up over time at the cost of a high level of commitment
1111 (from the Prime Minister's office to ship technicians). This is reflected in a significant volume of
1112 publications that take various forms, from press releases to scientific bulletins, web news or
1113 communication events. But the effort is insufficient insofar as it does not allow to cross *"the last*
1114 *mile"* (e.g., Shah, 2006) towards the populations. Many factors come into play here, some of
1115 which are well known to the social sciences, and some of which have to do with the complicated
1116 relations between metropolitan France and the overseas territories.

1117 In terms of communication there are several levers that could be pulled to gain efficiency.
1118 The first lever consists in establishing a real strategy of research and expertise dedicated not only
1119 to hazards monitoring but more broadly to the reduction of risks, the latter being considered in
1120 their technical dimension but also in their human and social aspects. The second lever is to work
1121 on the content and formats of information sharing. As emphasized by Oreskes (2015) about
1122 seismic risk, *"earthquake safety has never been simply a matter of geophysics, but most*
1123 *earthquake scientists, acting qua scientists, have traditionally understood their job to be to study*
1124 *how, when, and why earthquakes happen, and only to a lesser extent (if at all) how to*
1125 *communicate that knowledge to engineers and officials responsible for mitigation, or to the*
1126 *general public [...] But in the contemporary world, the inter-relationship between knowledge and*
1127 *safety is not easily disentangled. Seismology is no longer simply a matter of geophysics, if it ever*
1128 *was. It involves consideration of ethics, values, and monetary and social costs. [The trial of]*
1129 *L'Aquila shows that scientists can no longer ignore the social factors that affect and even control*
1130 *how damaging a particular earthquake may be. Earthquake prediction is a social science."* The
1131 reasoning applies to the assessment of other *"natural"* risks. If scientists' main job is not to
1132 communicate, they are nevertheless the only ones able to appreciate the robustness of the
1133 science-based information. As such, they are expected to take the time to present it in a way that
1134 can help risk managers, elected officials, but also journalists and the wider population to act



1135 effectively. From this point of view, it seems important to work at clarifying the frontier between
1136 the communication of scientific advances on hazard understanding, and the communication of
1137 operational risk management measures. That frontier seems particularly blurry in the case of
1138 Mayotte. The advantage of this clarification would be twofold. Allowing scientists to explain their
1139 hypotheses, results and uncertainties would lead to an improvement of the population's scientific
1140 culture while reinforcing the credibility of the scientific expertise. The latter is a pillar of any
1141 science-based risk governance process, as one may adhere to decisions made by authorities
1142 only if he/she believes their scientific basis to be credible. The adhesion to the scientific approach
1143 is thus a prerequisite to the adhesion to the risk reduction approach carried out by the other actors
1144 of the chain. The third lever is the association of local personalities, elected officials, local NGOs,
1145 to the reflection on the risk scenarios and adaptation strategies. The international Sendai
1146 Framework for Disaster Risk Reduction calls for a more integrated practice. The signatory
1147 countries reckon that, in order to reduce efficiently the risk of disasters, *“there is a need for the
1148 public and private sectors and civil society organizations, as well as academia and scientific and
1149 research institutions, to work more closely together and to create opportunities for collaboration
1150 [...]”* (Sendai framework page 7 - UNISDR, 2015). Following Ismail-Zadeh et al. (2017), Stewart,
1151 Ickert and Lacassin (2018) emphasize that the willingness for greater integration defines a *“new
1152 social contract between hazard scientists and the wider public [...] that encourages the scientific
1153 community to endeavour, alongside their existing technical expertise, to ‘... support action by local
1154 communities and authorities; and support the interface between policy and science for decision-
1155 making’ (Sendai framework page 22 - UNISDR, 2015)”*. As shown in this paper, this change of
1156 expectations creates new challenges for scientists, notably on the issue of communication. We
1157 hope that this work will contribute to open new avenues for transdisciplinary research drawing on
1158 geosciences, social sciences and humanities that can improve the effectiveness of the science-
1159 society nexus for disaster risk reduction.

1160 Data availability

1161 EMSC data on the felt seismicity are available from <https://doi.org/10.5281/zenodo.4734032>.
1162 Instrumental seismicity plotted on Figure 1 is from Lemoine et al. (2020) dataset, and from
1163 REVOSIMA catalog (not yet available for distribution, these data will be included in Saurel et al.,
1164 2021). Press releases from the Préfecture de Mayotte and French ministries are given in
1165 supplementary dataset. French version of STTM post excerpts are also given in supplementary
1166 dataset. Full verbatim of interviews from which we extracted cited excerpts are not public for
1167 confidentiality. All other data used in this paper are available from cited references.

1168 Author contribution

1169 MHD was responsible for the conceptualization of the study, project administration, methodology
1170 and writing the original draft of the paper. MHD and RL undertook the revision and editing of the
1171 final paper in concert with all co-authors. MHD and GR were responsible for data curation and
1172 investigation. RL curated the STTM Facebook threads and selected relevant excerpts. MHD and



1173 GR conducted and transcribed the interviews. MHD, RL and GR undertook the formal analysis.
1174 MHD and RL carried out the validation. HP, RL and MHD were responsible for the figures.

1175 Acknowledgements

1176 This work benefited from the data of felt seismicity collected by the EMSC
1177 (<https://doi.org/10.5281/zenodo.4734032>) whose activities is supported by the *Fondation SCOR*
1178 *pour la Science*. The authors would also like to thank Rémy Bossu, Laure Fallou and Matthieu
1179 Landès from EMSC who provided very useful comments at different stages of the work. People
1180 interviewed during these three years are also to be thanked for their invaluable contribution to our
1181 thinking process. The authors also want to thank scientists and officials from the DIRMOM, the
1182 Préfecture of Mayotte and the REVOSIMA for their help in setting up exhaustive records on the
1183 communication elements put in place by the scientists and the authorities during the course of
1184 the crisis. Many thanks also to Aline Peltier, scientific director of the REVOSIMA, who kindly
1185 agreed to read and comment on the paper before its submission. And finally, thanks to Louise Le
1186 Vagueresse and Hugo Pierrot, whose work helped us to check the completeness of our
1187 communication database.

1188
1189 This research has been supported by the IdEx Université de Paris, Centre des Politiques de la
1190 Terre, ANR-18-IDEX-0001.
1191

1192 Competing interests

1193 The authors declare that they have no conflict of interest.
1194



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