EUROPEAN COMMISSION
JOINT RESEARCH CENTRE
Space Security & Migration (SSM) Directorate
Disaster Risk Management Unit

15 Aug 2021

Mw 7.2 Earthquake and Tsunami in Haiti

GDACS Red Alert for Earthquake

GDACS Orange alert for Tropical Cyclone GRACE

14 Aug 2021

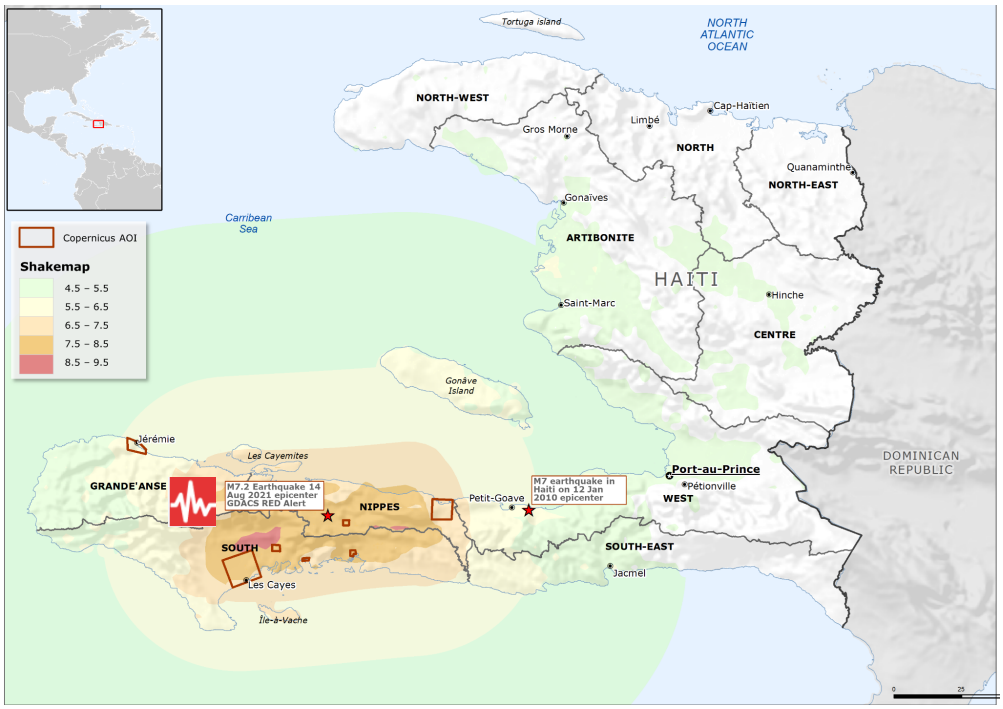


Fig. 1 - Area of the Earthquake with indication of the maximum ground acceleration

1 Executive Summary

- On August 14th 2021, 12:29 UTC (08:29 local time), a **M 7.2** earthquake occurred in the Hispaniola island with an epicentre approximately 125 kilometres west of Port-au-Prince,

13 km south east of Petit Trou de Nippes (Nippes Department). Several aftershocks are occurring, worsening the situation. The population of the three most affected departments (Nippes, Grand'Anse and Sud) represents around 16% of the country's total population, estimated at 11.4 million.

- On **12 Jan 2010**, Haiti was hit by a similar Mw. 7.0 earthquake that **caused 200 thousands fatalities**. The epicenter was approximately 25 kilometres west of Port-au-Prince (about 100 km far from the current EQ).
- A precise indication of the damages is not yet known; as of today, 6:40 CET **the number of fatalities is 304** (160 in Sud department, 42 in Nippes, 100 in Grand'Anse, 2 in Nord-Ouest), ad reported by the Haitian Civil Protection, but this number is constantly increasing. Hundreds of buildings collapsed and **major damages to critical infrastructures** have been declared by the national authorities (hospitals and schools severely damaged and collapsed). Early social media images showed severe damage to emblematic buildings such as the cathedral in Jeremie (Grand'Anse).
- Humanitarian operations could be affected by the persistent insecurity, exacerbating social vulnerabilities as a consequence of the assassination of the Haiti's President **Jovenel Moïse**, killed on the 7th July 2021. On 20 July, Ariel Henry was formally taking over as Prime Minister.
- **GDACS** issued a **Red alert** for the earthquake event and a Green alert for Tsunami (0.5m estimated wave height), 15 minutes after the event. The **Copernicus Emergency Rapid Mapping** service has been activated by the ERCC few hours after the event. The first High Resolution optical images will be acquired on August 15th at 3pm CET, given good weather conditions. The first maps should be available on the early morning of the 16th.

2 Situation Overview

2.1 Situation

On August 14th 2021, 12:29 UTC (08:29 local time), a **M 7.2 earthquake occurred in the Hispaniola island** with an epicentre approximately 125 kilometres west of Port-au-Prince, 13 km south-east of Petit Trou de Nippes (Nippes Department) and mostly impacted the Haiti southern peninsula and in particular the Grand Anse and Sud provinces. Several aftershocks occurred, worsening the situation (as of 15 August, 9:40 CET, 17 aftershocks have been recorded, of which 6 with M>5).

The earthquake appears to have been generated by the Enriquillo fault system (also known as the Enriquillo-Plantain-Garden system), which is responsible for some of the most important earthquakes in the region, including the 2010 Port-au-Prince event.

Haiti was hit by a similar Mw. 7.0 earthquake on 12 Jan 2010 that caused 200 thousands fatalities. The epicenter was near the town of Léogâne, Ouest department, approximately 25

kilometres west of Port-au-Prince. The large number of victims in that case was determined by the large soil liquefaction that caused entire buildings to collapse.

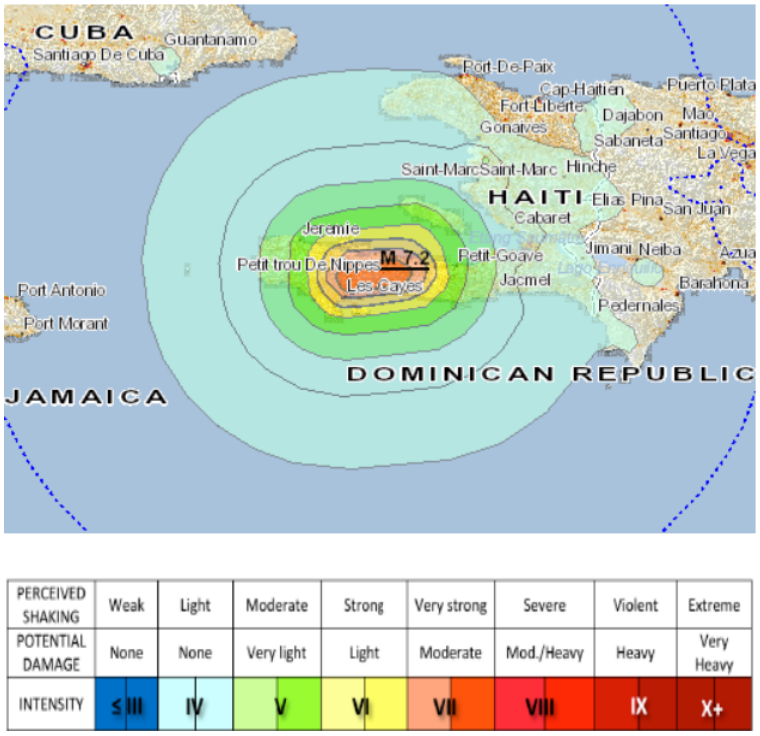


Fig. 2 - Shake map indicating the areas mostly affected

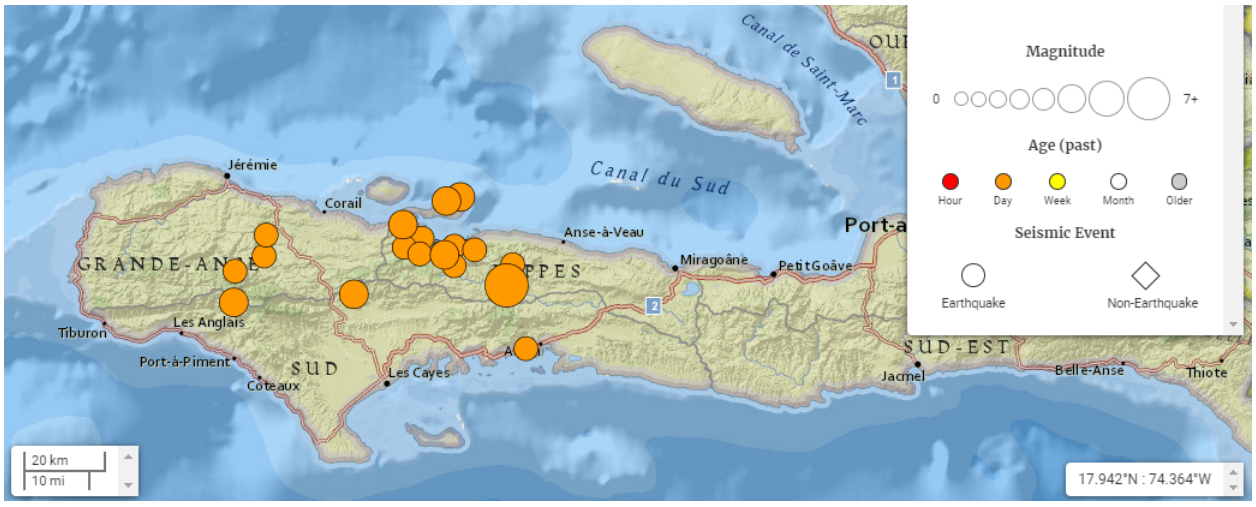


Fig. 3 - Main earthquake and aftershocks (source: USGS).

A precise indication of the damages is not yet known; as of today, 6:40 CET **the number of fatalities is 304** (160 in Sud department, 42 in Nippes, 100 in Grand'Anse, 2 in Nord-Ouest)[1] but this number is constantly increasing. Hundreds of buildings collapsed and major damages to

[1] Source: https://twitter.com/Pwoteksyonsivil

critical infrastructures have been declared by the national authorities (hospitals and schools severely damaged and collapsed). More information on the impact are provided in the "Humanitarian situation" session.

According to the estimated shake map, indicating the expected damage, 360K people have been exposed to an intensity **VIII** of the Modified Mercalli scale (i.e. moderate/heavy damage). The mostly affected provinces are indicated below (please note that in Fig. 4 Grand'Anse includes also the Nippes department).

Intensity	Region Province	Country	Population
VIII	Grand Anse	Haiti	140000 people
VIII	Sud	Haiti	220000 people
VII	Grand Anse	Haiti	230000 people
VII	Sud	Haiti	260000 people
VII	Ouest	Haiti	1100 people
VII	Sud-Est	Haiti	<1000 people
VI	Grand Anse	Haiti	140000 people
VI	Sud	Haiti	190000 people
VI	Ouest	Haiti	160000 people
VI	Sud-Est	Haiti	110000 people
V	Grand Anse	Haiti	220000 people
V	Sud	Haiti	36000 people
V	Ouest	Haiti	2.8 million people
V	Sud-Est	Haiti	350000 people
V	Artibonite	Haiti	670000 people

Fig. 4 - List of regions estimated mostly affected[2]

The principally affected regions are the Nippes, Sud and Grand'Anse departments, all of which have experienced intensity VIII shaking.

A seismic microzonation of **Les Cayes** (Sud) was carried out in 2015 by the University of Sherbrooke, Canada, predicting moderate to high seismic amplification in the plains that compose the south-western urban area, meaning intensity values (and therefore damage) in this area might be higher than currently estimated.

Civil protection reports documented about 950 destroyed dwellings, mostly in the **Nippes** department, and a further 800 damaged dwellings[3]. Early social media images showed severe damage to emblematic buildings such as the cathedral in **Jeremie** (Grand'Anse) among several

[2] It should be noted that the GDACS database is still using Grand'Anse as unique region while since 2003 it was split in two with the creation of Nippes Region

[3] Source: Centre d'opérations d'urgence national (Haïti). Tremblement de terre - Samedi 14 août 2021 - Rapport de situation #2

damaged centres of worship, as well as important infrastructure such as the hospital at **L'Asile** (Nippes) and 3 health centers in Grand'Anse, as well as several schools and law-enforcement buildings. However, according to civil protection reports, ports, airports and telecommunication infrastructure are not reporting damage, although press reports indicate that phone lines were cut off in **Petit-Trou-de-Nippes** (Nippes). More detail concerning the humanitarian impacts can be found in paragraph 2.2 of this report.

The earthquake has also generated several landslides, with the Massif de La Hotte mountain range being prone to ground instabilities. Several rockfalls and landslides are reported in **Etang Rey**, **Petit-Trou-de-Nippes** and **Brody**. Furthermore, there has been widespread damage to the road infrastructure due to ground instabilities, most notably National Route 7, which connects the departmental capitals of **Les Cayes** (Sud) and **Jeremie** (Grand'Anse) being cut off due to a landslide at Riviere Glace. There are also reports of landsliding in the south-west coast, near **Port-a-Piment** (Grand'Anse), meaning landslides can also be expected outside of the areas with highest probability indicated in the USGS map. The USGS is rating the landslide risk as "orange" (significant area affected and significant population exposed)[4].

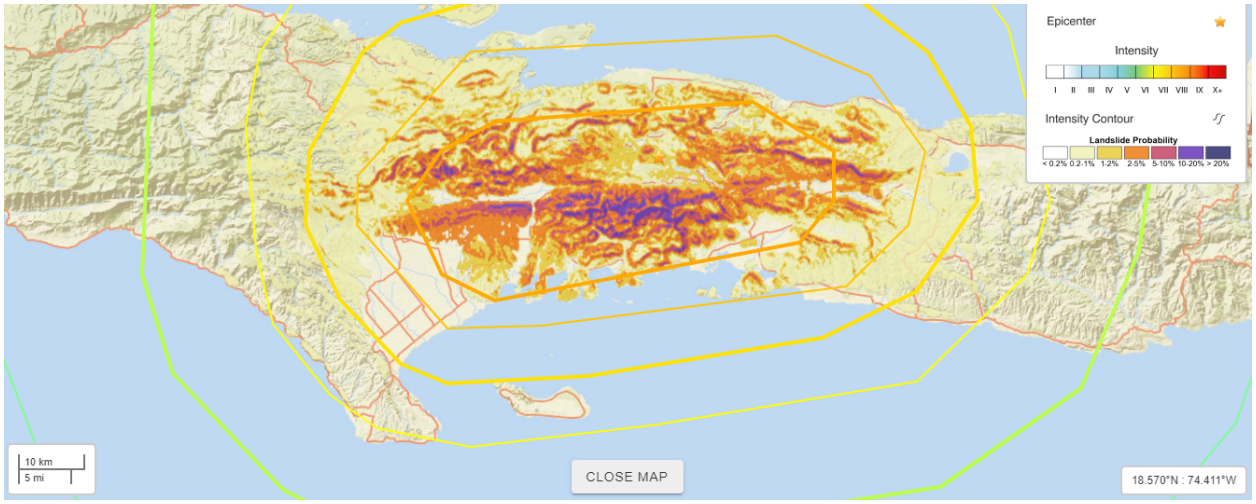


Fig. 5 - Induced landslide probability map (source: USGS).

No reports of earthquake-induced liquefaction have been detected so far, although this was a major source of damage in the Port-au-Prince event in 2010. However, it is likely that this is due to underreporting at this stage. The USGS identifies several high-probability areas for liquefaction, including several beaches and riverbeds, but most notably the totality of the urban area of **Les Cayes** (Sud). The USGS is rating the liquefaction risk as "orange" (significant area affected and significant population exposed).

[4] Source: https://earthquake.usgs.gov/earthquakes/eventpage/us6000f65h/executive

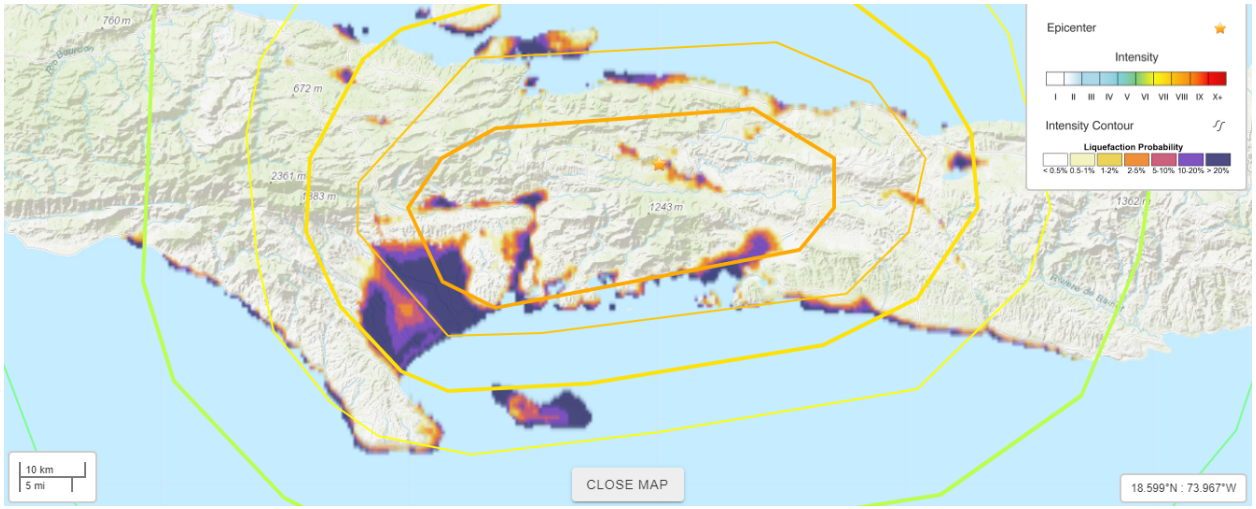
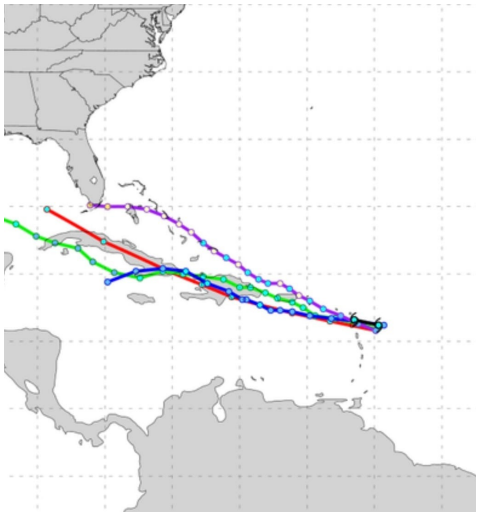


Fig. 6 - Liquefaction probability map (source: USGS).

2.3 Meteorological situation

The most relevant point is the Tropical Storm GRACE that is approaching the area between Sunday 15 and Monday 16. These are the key messages from the NOAA Hurricane Center:



*1. Tropical storm conditions are expected over the Virgin Islands and Puerto Rico on Sunday. **Tropical storm conditions** are possible over eastern parts of the Dominican Republic Sunday night and Monday.*

*2. Heavy rainfall could lead to flash and urban flooding over the Leeward and Virgin Islands, **Haiti** and the Dominican Republic. Across Puerto Rico, heavy rainfall may lead to flash, urban and small stream flooding, along with the potential for mudslides.*

*3. There is a risk of wind and rainfall impacts across the rest of the Dominican Republic, Haiti, the Turks and Caicos Islands, the Bahamas, Cuba, and Florida next week, but forecast uncertainty remains higher than usual. Interests in those areas should monitor the progress of **GRACE** and updates to the forecast.*

Fig. 7 - Key messages from the NOAA Hurricane Center regarding Tropical Storm GRACE (source: NOAA).

At the moment the cyclone eye track appears passing in the north, but heavy rain (up to 200-250 mm) could affect on 16 and 17 August parts of Haiti and Dominican Republic but uncertainty still exists on the real track and therefore the situation could still change.

GDACS identified this as an Orange alert, due to the high population possibly involved in the Dominican Republic (https://www.gdacs.org/report.aspx?eventid=1000814&episodeid=7&eventtype=TC).

Fig. 8 - GRACE track and expected rainfall in the area

2.3 Tsunami

The event caused a small Tsunami that was even shown in some social media posts. The Tsunami was probably generated on both sides of the peninsula but mostly on the southern coast. The maximum estimated height is about 20 cm and therefore should not have created any damage, considering also the low tide at the moment of the event and the overall size of the tide in the area (about 1.6 m). Details about the Tsunami calculations are present in Appendix B.

The only closer working tide gauge is in the Dominican Republic (Barahona) and does not show any level disturbance.

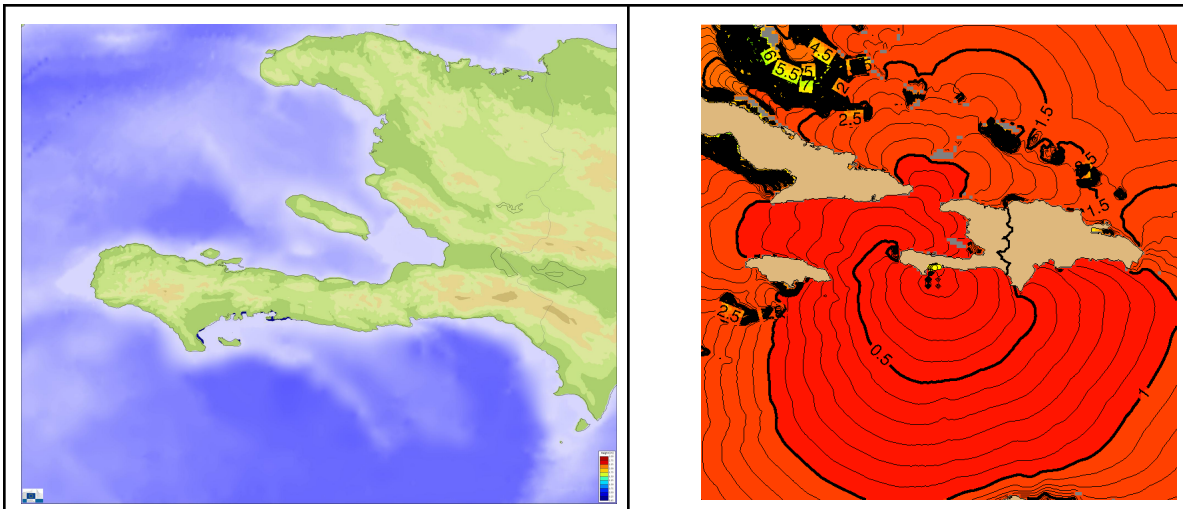


Fig. 9 - Estimated height from the Tsunami (left), Travel time (right)

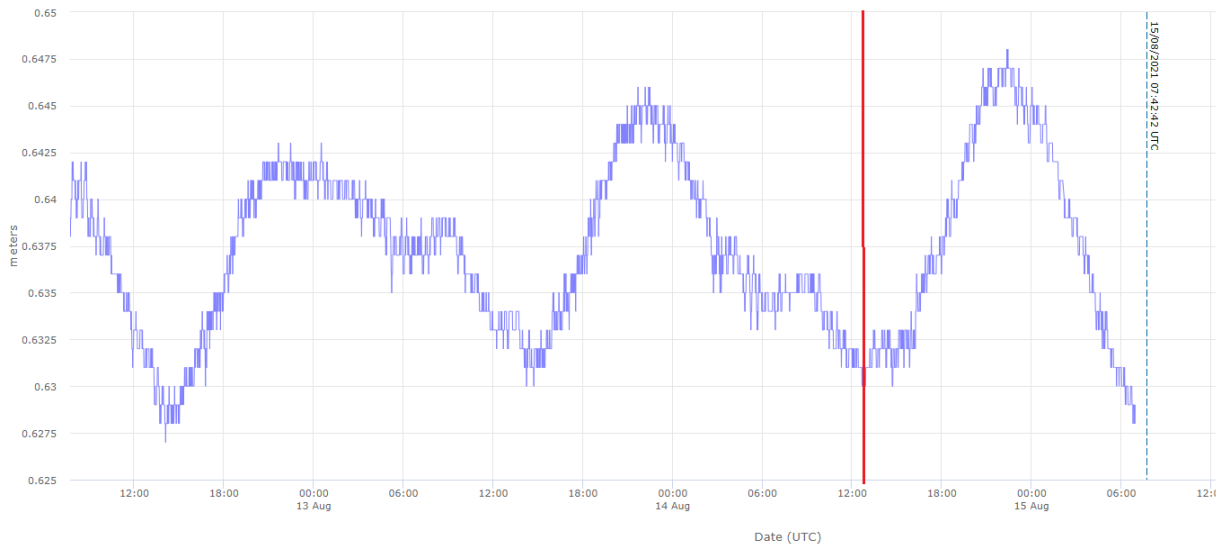


Fig. 10 - Sea Level in Barahona, Dominican Republic

2.2 Humanitarian impact

It is worth mentioning that the earthquake has struck Haiti while the political situation in the country remains highly complex and unpredictable, and the humanitarian operations could be affected by the persistent insecurity, exacerbating already alarming social vulnerabilities, as reported by UN OCHA[5], as a consequence of the **assassination of the Haiti's President Jovenel Moïse**, killed on the 7th July. On 20 July, Ariel Henry was formally installed as Prime Minister.

The Centre d'opérations d'urgence national - National emergency operations center (Department of Haitian Civil Protection - National system of Disaster management) reported the information below (translated from Situation Report #2 in French):

At the moment 304 deaths (160 in the South, 42 in Nippes, 100 in Grand'Anse and 2 in the North-West department) are reported . Hundreds of injured people, among around 1,800 listed (at least 1,500 in the South, 35 in Grand'Anse and 281 injured in Nippes) were received and treated in several hospitals.

Several buildings are destroyed or damaged, many houses have cracked walls. The departments most concerned are the South, Nippes and Grand'Anse.

The first evaluations of the building, show:

At least 899 houses were destroyed and 783 damaged (50 in the department of Grand'Anse and 723 in the department of Nippes), according to initial assessments. Many public buildings (hospitals, schools, hotels, churches, etc.) were damaged or collapsed in the departments of Sud and Grand'Anse as well.Major damage has been reported on road, health and educational infrastructures in the most affected departments. However, with regard to port, airport, sports and telecommunications infrastructure, so far no major damage has been reported.

Department of Grand'Anse

• 3 health centers are damaged.

• 3 schools are destroyed.

• 1 church is damaged.

Department of Nippes

• 1 prison and 1 police station were damaged, while the sub-police station in Changeux in Baradères was destroyed. The Changeux peace court is damaged.

5 https://reliefweb.int/report/haiti/haiti-insecurity-and-humanitarian-access-situation-report-no-6-8-august-2021

• At least 5 churches were damaged and another collapsed in Baradères. Asylum's downtown rectory is damaged.
• At least seven school buildings were damaged, including a damaged national school in Baradères and the Asile Basic School of Application and Professional Support Center (EFACAP). A school is destroyed in Baradères.
• The administrative block of the Asylum Hospital is damaged.
• Two lighthouses were overturned in the sea at Grand Boucan.
• All the water points are no longer usable at the Asylum.
• The old customs building in Miragoâne was damaged
• A municipal road is damaged near Saint-Marc in Petite-Rivière de Nippes.
• Several landslides are reported, at Rey pond (Paillant), Petit-Trou-de-Nippes and the sand quarry in Brody, Plaisance.
• 1 damaged hotel.

Department of South

• 2 hotels and 3 churches were destroyed.
• A section of the road going to Port-à-Piment is damaged.
• The Damassin bridge is damaged.
• National road # 7, connecting Les Cayes and Jérémie, is cut off near the Glace River due to a landslide caused by the earthquake

The following pictures were provided by Mimose Jusmond (private courtesy):

Fig. 11 - Damage to the Cathedral in Jeremie (source: J-COM news site).

Fig. 12 - Damage due to the earthquake (source: private communication).

Fig. 13 - Damage due to the earthquake (source: private communication).

2.3 COVID-19 situation

One of the risks connected with large events like this, during the ongoing pandemic situation. At the moment the COVID-19 situation is not as severe as it was few months ago; nevertheless the vaccination campaign in the country is not proceeding fast and only a small portion of the population has been vaccinated and therefore an increase of the cases could be possible within 7-10 days, due to the large assembly of people in shelters

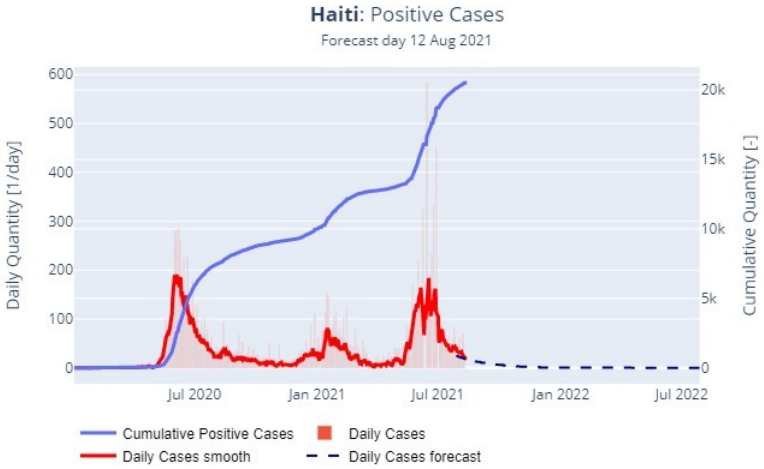


Fig. 14 - COVID situation in Haiti

3 JRC involvement

3.1 GDACS alert

The Global Disasters Alerts and Coordination System identified the event 12 minutes after the event and classified the event as **Red** alert for earthquake and Green alert for Tsunami, as the wave height estimation was lower than 1 m (i.e. 0.5 m). The alert has been sent to all the 30,000 users registered to receive the GDACS alert.

Episode Timeline

ID	Alert	Score	Date	Mag, Depth	MMI*	Population**	Tsunami risk***	Delay (hh:mm)	Source
1391565		0.2	14 Aug 2021 12:29	6.7M, 10km	N/A	No people affected (in 100km)	**0.3m (at 00:11)**	00:39	GEOFON
1391571		3.9	14 Aug 2021 12:29	7M, 10km	N/A	2.2 million (in 100km)	**0.5m (at 00:08)**	00:15	PTWC
1391575		3.8	14 Aug 2021 12:29	7M, 10km	N/A	2.3 million (in 100km)	**0.5m (at 00:07)**	00:18	NTWC
1391580		4.3	14 Aug 2021 12:29	7.2M, 10km	8.71	950 thousand (in MMI>=VII)	**0.5m (at 00:00)**	00:26	NEIC
1391652		4.3	14 Aug 2021 12:29	7.2M, 10km	8.89	880 thousand (in MMI>=VII)	**0.2m (at 00:27)**	03:37	NEIC

The episode that generated the alert; the next major evaluations beyond 12 hours will not trigger additional alerts.
The episode that has the last updated information.
* The max MMI detected for sources having shakemaps;
** The population detected in MMI>=7 for episode with shakemap or in a 100km radius;
*** The tsunami max height.

Fig. 15 - GDACS episode timeline

GDACS also provides the analysis of Twitter messages in real time. The analysis shows that almost immediately there was a sudden increase of the tweets reporting Earthquake and Haiti and about 30 min after also the word Tsunami was extensively mentioned, with tweets reporting the inundation, and around 3 hours later the number of tweets decreased as the alert was canceled.

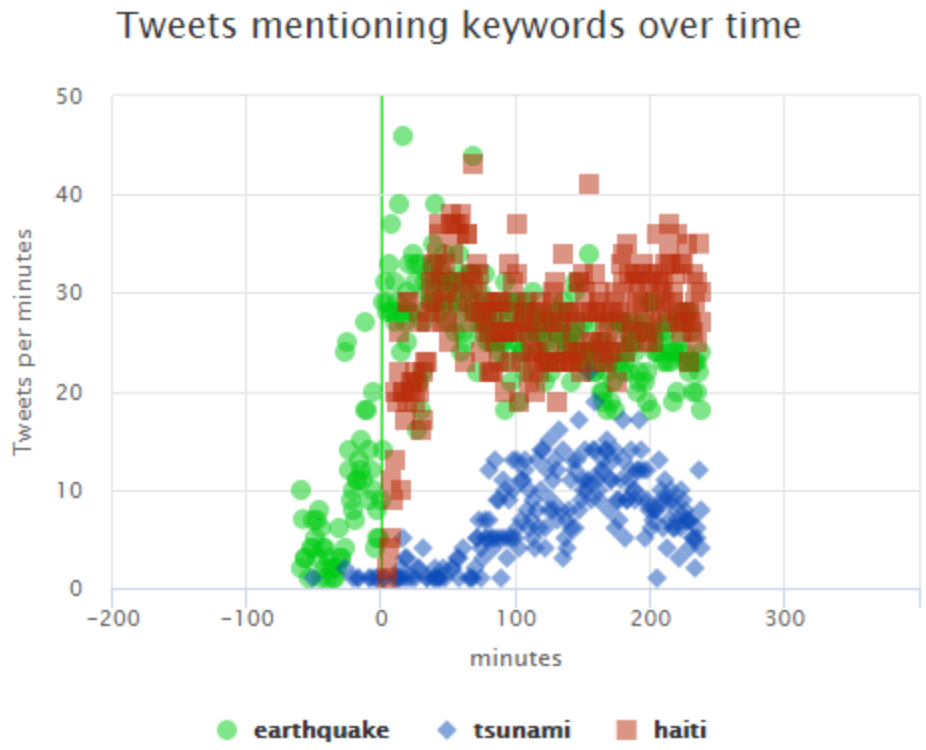


Fig. 16 - Twitter monitoring in GDACS; see Appendix C for a list of relevant links

GDACS automatically detects the potential Area of Interest for satellite acquisitions, based on the most exposed area to ground shaking. The areas in the image below have been automatically detected and suggested for the Copernicus Emergency Management Service - Mapping.

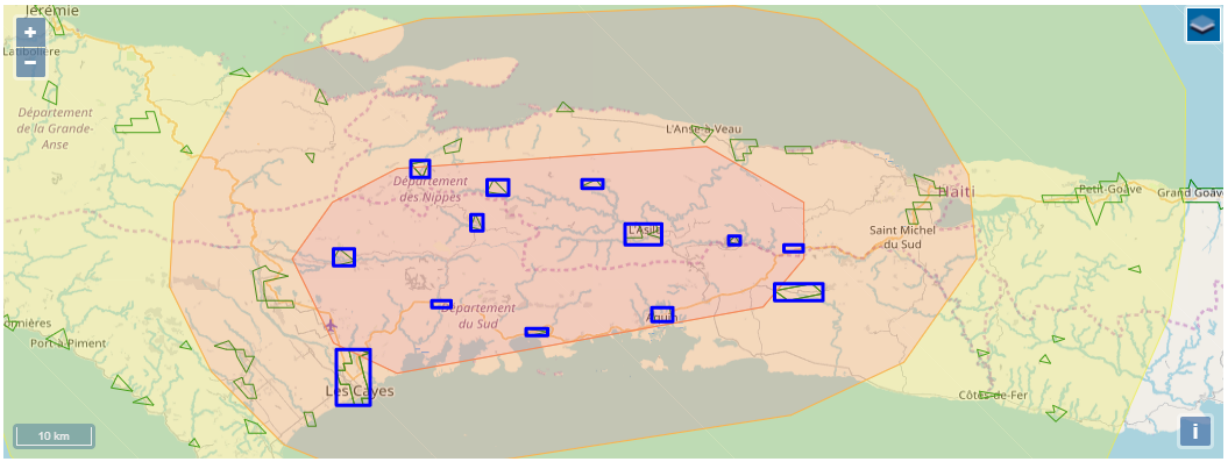


Fig. 17 - GDACS - Automatic detection of the potential Area of Interest for satellite acquisitions (https://gdacs.org/aoi.aspx?eventtype=EQ&eventid=1281677).

3.2 Copernicus activation

The Copernicus EMS Rapid Mapping was activated (Activation ID: EMSR536) on the 14th of August at 5pm to produce Damage Assessment over seven Areas of Interest:

- Jeremie
- Les Cayes
- Cavaillon
- Saint Louis
- Aquin
- Lasile
- Miragoane

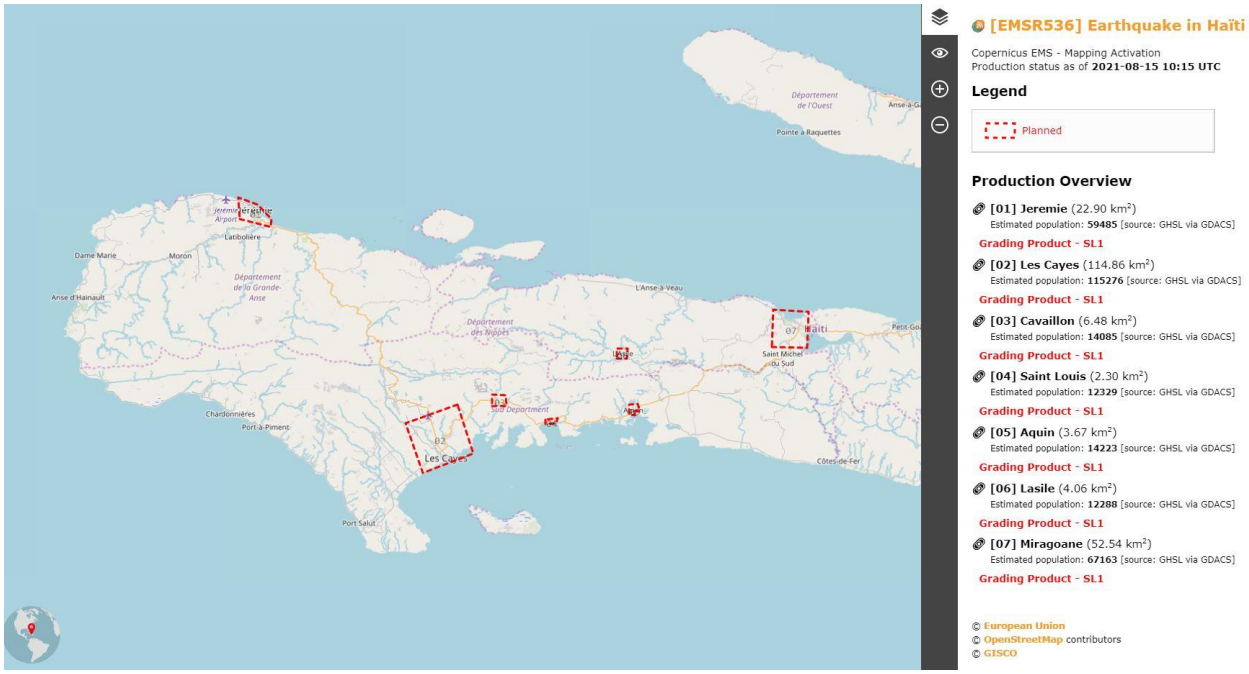


Fig. 18 - EMSR536 Activation Extent Map

The first High Resolution optical images will be acquired on the 15th at 3pm, given good weather conditions. The first maps should be available on the early morning of the 16th.

The production plan and the products will be available at https://emergency.copernicus.eu/mapping/list-of-components/EMSR536.

In parallel the International Disaster Charter was activated and Rapid Mapping requested access to the collaboration platform in order to maximise the availability of data.

The JRC is providing technical management and support for the activation.

4 Involvement with other services of the European Commission, the EEAS or other institutional stakeholders

4.1 ERCC Emergency

ERCC is following the events in close collaboration with the local ECHO offices. ERCC activated the ARISTOTLE analysis system that produced a quick report 3h after the event. The report indicated the high risk of humanitarian disaster from the event. At that time the precise number of fatalities was not yet known.

JRC sent an information email to ERCC to raise alert on the event and provided a first estimate of the possible AOIs useful for the Copernicus activation

4.2 EUCPM activation

N/A

4.3 VOSOCC Activation

The GDACS coordination tool managed by UN OCHA (the Virtual On Site Coordination Centre - VOSOCC) has been activated a few minutes after the GDACS alert has been issued and several messages have been exchanged among the humanitarian stakeholders.. Currently it is reported that the following UN Rosters have been alerted:

- Environmental Emergencies Roster, Alerted (14-Aug-2021 23:33)
- OCHA Operational Support PartnersAlertStatusHaiti: Info message sent
- UNDAC Team Alert, Alerted (14-Aug-2021 23:23)

5 Expected Updates

An updated version of the report will be developed if important changes to the situation will be shown.

6 References and contact points within JRC

Contact points within JRC: Disaster Risk Management Unit
- Alessandra Zampieri, alessandra.zampieri@ec.europa.eu, HoU
- Tom De Groeve, tom.de-groeve@ec.europa.eu , dHoU

Analysis Team
- Alessandro Annunziato, alessandro.annunziato@jrc.ec.europa.eu
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- Jaime Abad, jaime.abad@ec.europa.eu
- Azzurra Lentini, azzurra.lentini@ext.ec.europa.eu
- Valerio Lorini, valerio.lorini@ec.europa.eu
- Andrea Gerhardinger, andrea.gerhardinger@ext.ec.europa.eu

Copernicus EMS - Mapping Team
- Simone Dalmasso, simone.dalmasso@ec.europa.eu
- Ines Joubert Boitat, ines.joubert-boitat@ext.ec.europa.eu

For updated information on the disaster, please consult the following web sites:

- GDACS: www.gdacs.org
- ERCC portal: http://erccportal.jrc.ec.europa.eu/
- Copernicus: http://emergency.copernicus.eu

Relevant Links

GDACS reports:

Earthquake: http://www.gdacs.org/report.aspx?eventid=1281677&episodeid=1391652&eventtype=EQ

Trop. Cyclone: http://www.gdacs.org/report.aspx?eventid=1000814&episodeid=7&eventtype=TC

Copernicus maps - https://emergency.copernicus.eu/mapping/list-of-components/EMSR536

Appendix A - Seismotectonic details

The island of Hispaniola is located on a tectonic microblock at the convergence between the Caribbean and North-American tectonic plates, the latter of which moves westwards with respect to the Caribbean plate at a rate of about 2 cm per year[6]. The Enriquillo fault system (also known as the Enriquillo-Plantain Garden fault system) is a 600 km long left-lateral strike-slip fault that accommodates part of this deformation, suffering about 7 mm of displacement every year (Terrier et al. 2017)[7].

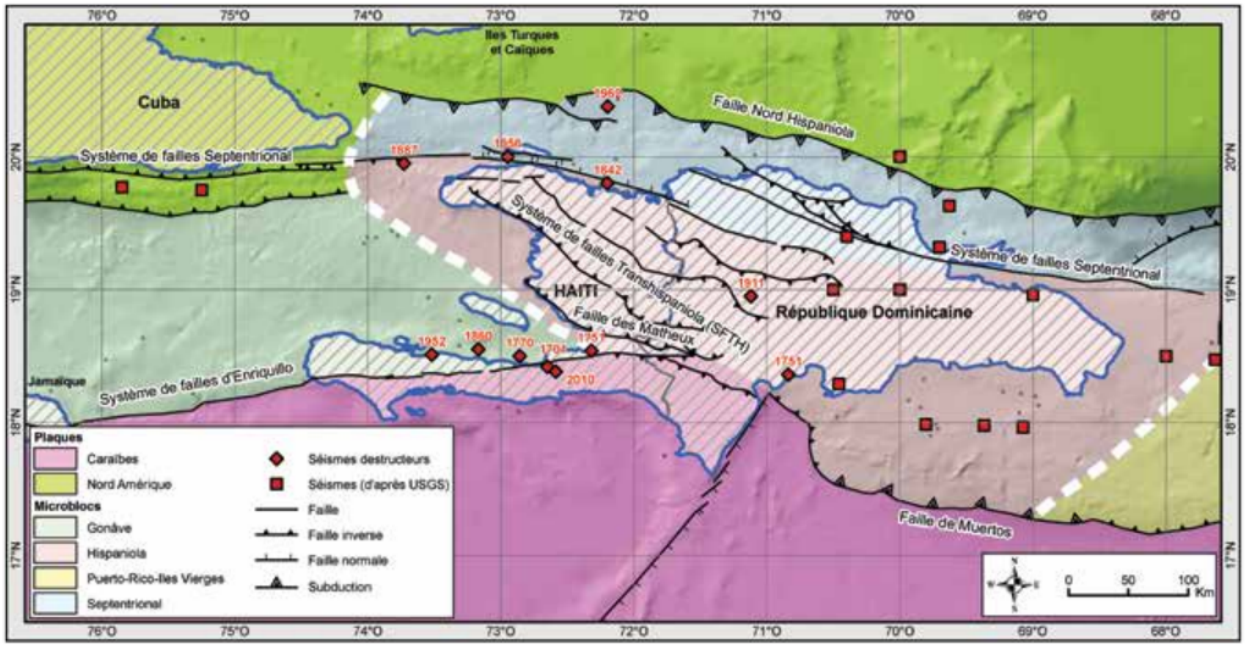

Fig. A.1 - Seismotectonic overview of Hispaniola (source: Terrier et al. 2017).

This fault system has generated some of the worst earthquakes that have struck Haiti. The following table is a translated excerpt from Terrier et al. 2017 and details the impacts of the historical M = 6+ earthquakes in Haiti associated with this fault system.

[6] Source: https://earthquake.usgs.gov/earthquakes/eventpage/us6000f65h/region-info

[7] Source: Terrier, Monique & Rançon, Jean-Philippe & Bertil, Didier & Chêne, Frédéric & Desprats, Jean-François & Lecacheux, Sophie & Le Roy, Sylvestre & Stollsteiner, Philippe & Bouc, Olivier. (2017). Atlas des menaces naturelles en Haïti.

Date	Lat	Long	Depth (km)	Magnitude	Impact
9/11/1701	18.42	-72.65		6.5	Damage in Léogane and in La Plaine du Cul-de-Sac. Some casualties.
21/11/1751	18.54	-72.32		6.6	Several tens of casualties.
3/6/1770	18.50	-72.86		7.5	Destruction of Port-au-Prince, Léogane, Petit-Goave. Several hundreds of casualties..
8/4/1860	18.55	-73.17		6.3	Widespread damage in Anse-à-Veau. No casualties.
28/10/1952	18.51	-73.52	24	6.0	Damage and casualties in Anse-à-Veau (6 deaths ?).
12/1/2010	18.38	-72.59	15	7.0	Main damage in Léogane and Port-au-Prince. According to official estimates, 230 000 deaths, about 100 000 destroyed houses and 200 000 damaged houses.

Appendix B - Details of the Tsunami calculation

The Tsunami calculation presented in the report has been performed using the source provided by USGS as NP2

```
Lat         =18.350000   * degree
Lon         =-73.480003   * degree
Mag         =7.200000   * Richter scale

flenght     =63.000000   * km
fwidth      =17.000000   * km
strike      =266.519989   * degree   (geog North=0)
slip        =1.652000   * m
dip         =62.270000   * degree
rake        =48.750000   * degree
depth       =10.000000   * km (top of the fault)
```

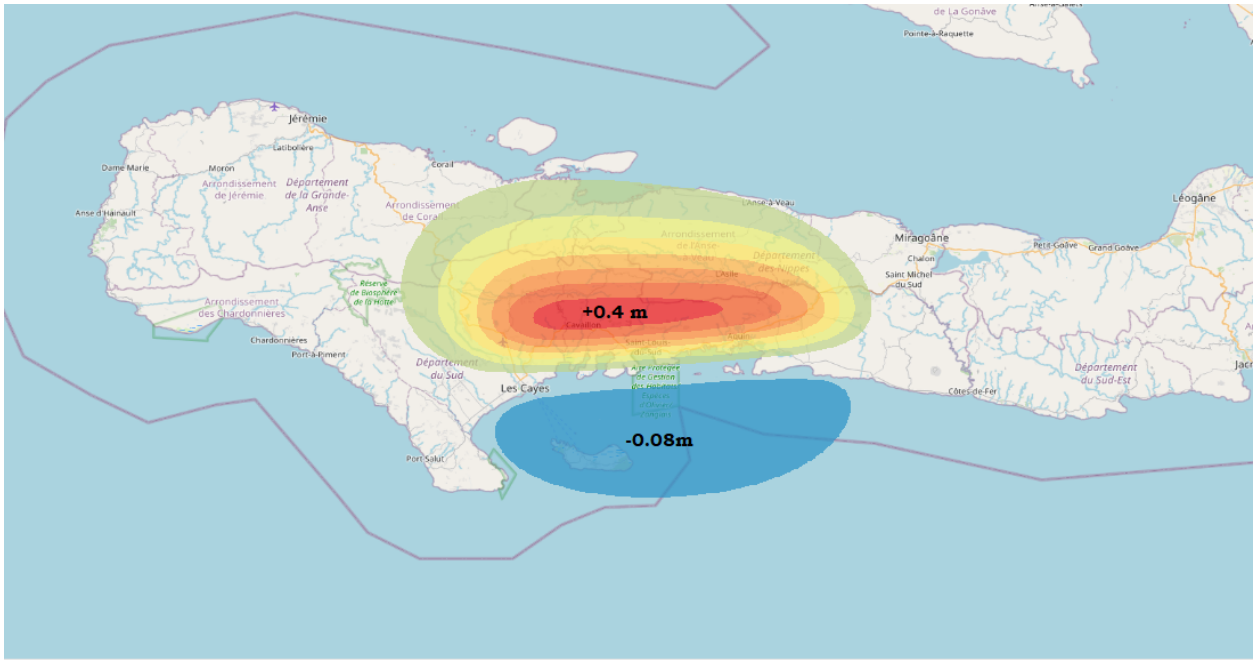

Fig. B.1 - Depression and uplift estimated by the tsunami model.

The image above represents the initial condition of this calculations and shows a depression in the southern part of the peninsula in the order of 8 cm. The largest uplift occurred in the area on land with about 39 cm.

USGS provided also a Finite Fault Model for this event and the situation is rather concentrated deformation in the central part of the fault plane, very close to the epicentre.

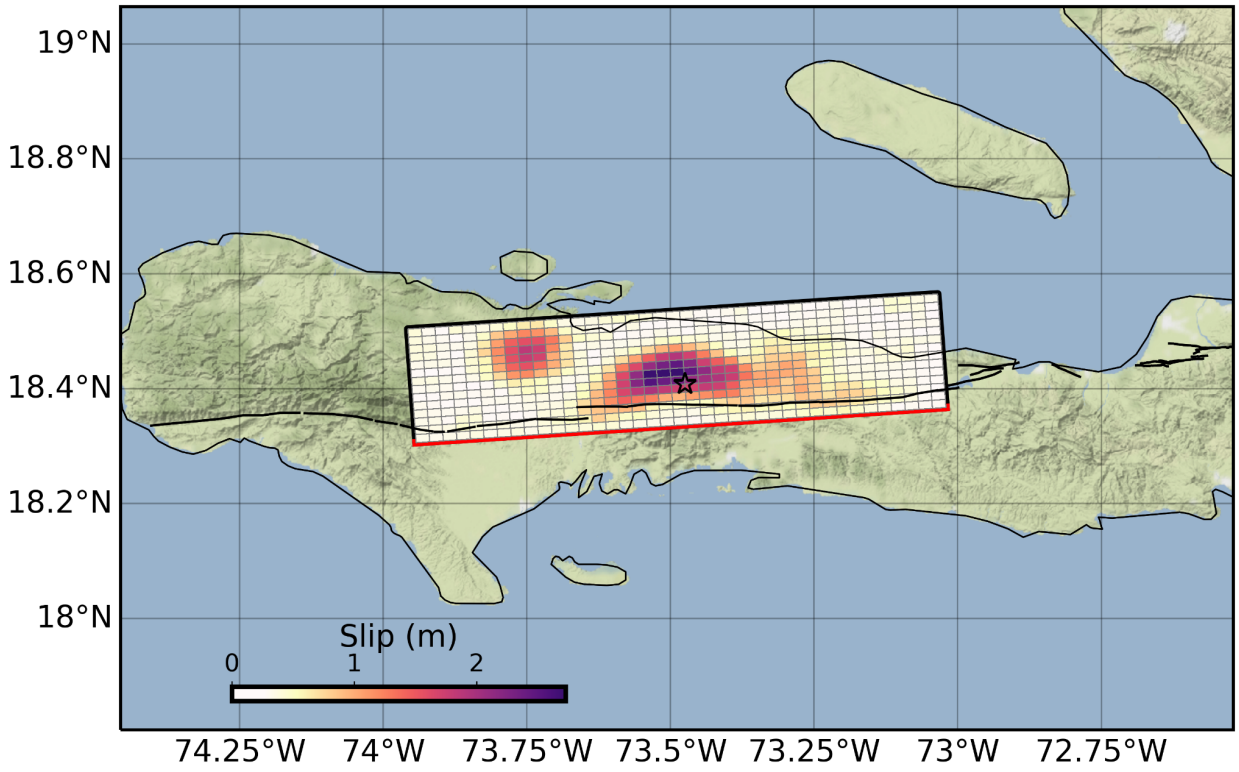

Fig. B.2 - USGS finite fault model.

Appendix C - Relevant Tweets detected by the system

12:57

Diego Renaldo DESULME on Twitter: "Not again 😔😔😔😔#Haiti #earthquake https://t.co/JjGDyDLvkb " / Twitter

13:05

https://twitter.com/erickjura/status/1426530408490049537

13:24

https://twitter.com/Boomdotnews/status/1426535190852116487

13:48

Dr_Greg_Newman on Twitter: "RT @Frantzduval: L'hôpital général aux Cayes est débordé. Beaucoup de blessés. Beaucoup de maisons se sont effondrées aux Cayes. Dont un hô…" / Twitter

13:48

Ander🥶 on Twitter: "RT @Frantzduval: L'hôpital général aux Cayes est débordé. Beaucoup de blessés. Beaucoup de maisons se sont effondrées aux Cayes. Dont un hô…" / Twitter

13:49 Video

SewAlways on Twitter: "RT @Micheal_Wick: Several buildings destroyed in Haiti after massive #earthquake #sismo #tsunami https://t.co/6bo77eUs5g" / Twitter

13:49 video

ZakPug on Twitter: "RT @JamaicaGleaner: Footage from Haiti showing extensive #earthquake damage to buildings and other infrastructure. There are also fears tha…" / Twitter

14:14 video

Seli on Twitter: "RT @LeoFeldmanNEWS: #NEW: Images reveal mass destruction following the 7.2 earthquake in #Haiti. Similar in strength to the catastrophic ea…" / Twitter