Assessing the vulnerability of the evacuation emergency plan: the case of the El Hierro, Canary Islands, Spain

J.M. Marrero (1), A. Garcia (1), A. Llinares (2), P. Lopez (3), and R. Ortiz (1)

(1) Institute of Geosciences (IGEO) CSIC-UCM, Madrid. Spain (josemarllin@gmail.com), (2) Department of Soils Science and Geology. University of La Laguna. Tenerife, Canary Islands. Spain, (3) YAPAMIRI, S.L

ABSTRACT

On July 17, 2011, an unrest was detected in the El Hierro Island. A serretian submarine eruption started on October 10th in the southern area of the island, two miles away from La Restinga village. The analysis and interpretation of seismic and deformation data shows a large volume of intruded magma. These data also show a high probability of a new vent opening.

One of the most complex volcanic hazard scenarios is a new open vent in the El Golfo Valley, in the north slope of the island, where more than 5,000 people live. In this area there are only two possible terrestrial evacuation routes: 1) HI-1 road NE direction, the fastest but most vulnerable one, close to a 1,000 meters height cliff, through a 2 km tunnel. The tunnel has a structural deficiency, having to be closed during high energy periods of seismic activity; and 2) HI-1 road SW direction, a mountain road with many curves, frequent small landslides and fog.

The Emergency Plan of the island takes into account the entire evacuation of El Golfo Valley in case of eruption. This process will be carried out by means of an assisted evacuation. The evacuees will be transported to a temporally regrouping shelter outside the valley to organize the transport to Tenerife Island. Only those people who have a second residence or relatives outside the affected area will be able to remain in the island.

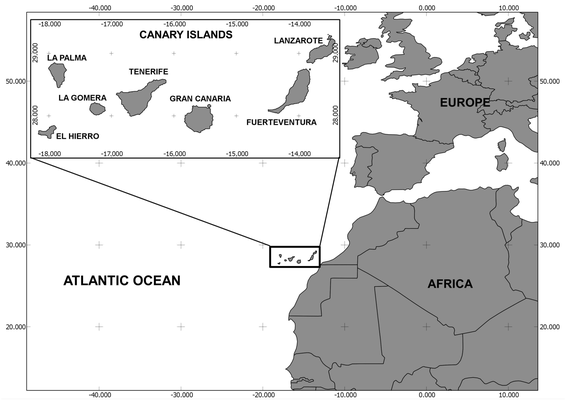
The evacuation time estimated by authorities for the entire evacuation of El Golfo Valley is of about 4 hours. This time is extremely low considering: the complexity of the area; the number of evacuees; the lack of preparedness by the population; and adverse weather conditions.

To evaluate the Evacuation Plan vulnerability, a series of evacuation scenarios have been simulated: self-evacuation; assisted evacuation; both terrestrial evacuation routes. The warning time, the response time by the population and the evacuation time have been taken into account.

EI HIERRO ISLAND

The El Hierro island is located further west of the Canary archipelago. It is the smallest one with 268.71 km^2 and 10995 inhabitants distributed in three municipalities:

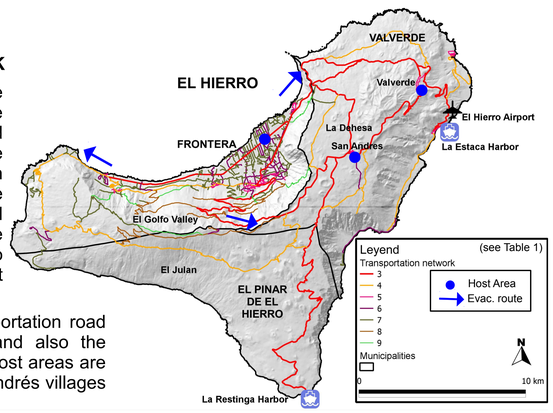
Valverde (5048), Frontera (4143) and El Pinar de el Hierro (1804). From the geographical point of view, three areas can be distinguished: the El Golfo Valley, in the north, is a 1500 m high steep wall; El Julan, in the south-west; and La Dehesa, a smooth slope area in the central-east.



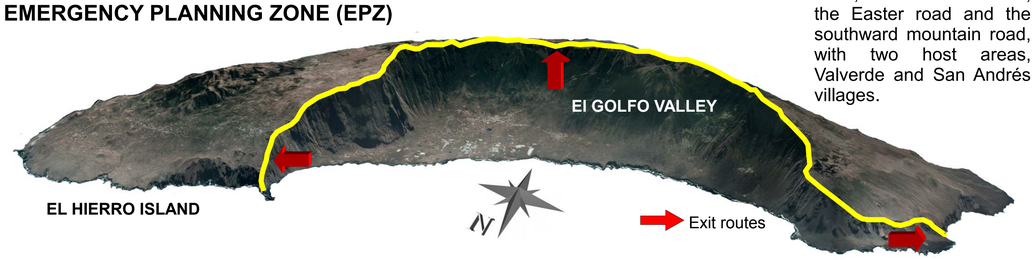
TRANSPORTATION NETWORK

The El Golfo Valley is one of the highest volcanic risk areas due to the transportation road network vulnerability and the difficulties in carrying out an evacuation. To evaluate the emergency planning, several evacuation scenarios have been designed taking into account all the available exit routes.

All the El Golfo Valley's transportation road network has been digitized and also the main roads of the island. The host areas are situated in Valverde and San Andrés villages (see the figure).



EMERGENCY PLANNING ZONE (EPZ)



There are only three possible terrestrial evacuation routes in the El Golfo Valley. The Eastern route has a road tunnel that was closed during the volcanic crisis due to the possibility of a roof collapse. The Western route is very vulnerable due to the land-slides frequent occurrence. The souther route is a mountain road with frequent fogs in the upper part. Sea evacuation are really dangerous because the rugged coastline.

TABLE 1

Nº	Type	Lanes	Speed 1 km/h (dry)	Speed 2 km/h (rain)	Characteristic
1	Highway	>2	120	108	There is not a highway in the El Hierro island
2	Motorway	2	120	108	There is not a motorway in the El Hierro island
3	Road 1	1	80	72	Road with a shoulder. Best quality pavement and rectilinear layout
4	Road 2	1	70	63	Road without a shoulder. Old road with curve path or renewed older path.
5	Street	1	40	36	On urban areas with a short-haul.
6	Path 1	1	60	54	Paved long-haul road. Old unpaved path converted into a no-shoulder narrow road with or wihtout one defined lane.
7	Path 2	-	50	45	Unpaved, dirt or cement, without defined lanes
8	Track	-	40	36	Unpaved, dirt, on mountains areas without defined lanes
9	Footpath	-	3	3	No entry vehicles

TABLE 2

Evacuation Scenario type	Response type	Warning Time (hours)	Response Time (hours)	Total Time (hours)	Incorporation Medium time (hours)	Incorporation Dispersion (hours)	Characteristic
Self-evacuation	Day – Fast	1	1	2	1.5	0.2	Volcanic activity felt
Self-evacuation	Day – Slow	1	3	4	2	0.35	Non volcanic activity felt
Self-evacuation	Night – Fast	3	2	5	2.5	0.45	Volcanic activity felt
Self-evacuation	Night - Slow	3	4	7	3.5	0.55	Non Volcanic activity felt

MAIN PARAMETERS

To obtain the evacuation time the **Variable Scale Evacuation Model (VSEM)** has been used (Marrero et al., 2010). The main parameters are the maximum road speed and the incorporation time function.

EVACUATION SCENARIOS CHARACTERISTICS

Six main evacuation scenarios have been designed. The differences between them are the diverse combination of the terrestrial evacuation routes used and the destiny points.

In the **CCP evacuation scenario**, the host area is situated inside the EPZ area, close to an agricultural cooperative.

In the **11 evacuation scenario,** only the Easter terrestrial rout is used with one host area, Valverde village.

In the **21 evacuation scenario**, two terrestrial evacuation routes are used, the Easter road and the southward mountain road, with one host area, Valverde village.

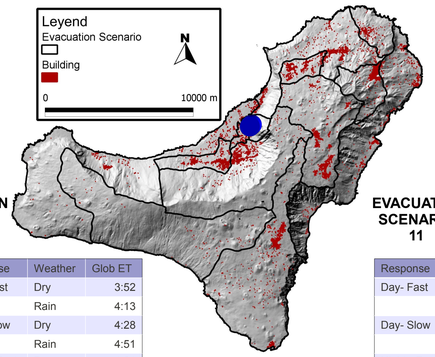
In the **22 evacuation scenario**, two terrestrial evacuation routes are used, the Easter road and the southward mountain road, with two host areas, Valverde and San Andrés villages.

In the **31 evacuation scenario**, three terrestrial evacuation routes are used, the Western road, the Easter road and the southward mountain road, with one host area, Valverde village.

In the **32 evacuation scenario**, three terrestrial evacuation routes are used, the Western road, the Easter road and the southward mountain road, with two host areas, Valverde and San Andrés villages.

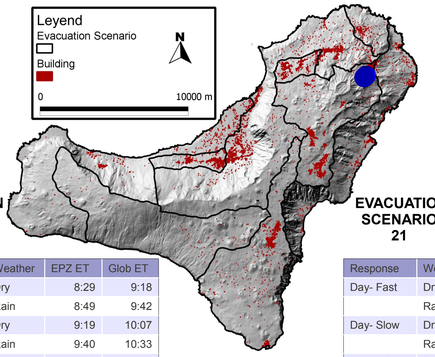
SELF-EVACUATION SCENARIOS, THE EMERGENCY RESPONSE PLANNING AREAS (ERPAs) AND EPZ AND GLOBAL EVACUATION TIME

EVACUATION SCENARIO CCP



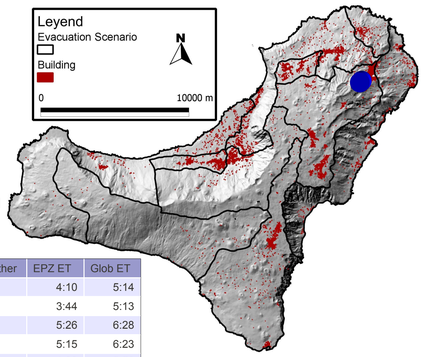
Response	Weather	Glob ET
Day- Fast	Dry	3:52
	Rain	4:13
Day- Slow	Dry	4:28
	Rain	4:51
Night - Fast	Dry	4:24
	Rain	5:37
Night - Slow	Dry	6:13
	Rain	6:13

EVACUATION SCENARIO 11



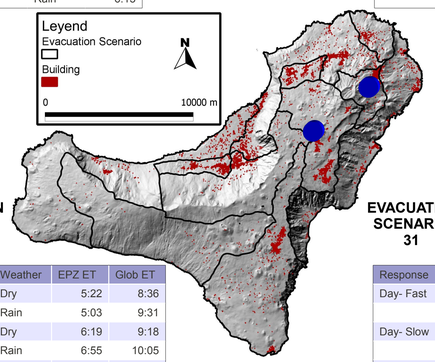
Response	Weather	EPZ ET	Glob ET
Day- Fast	Dry	8:29	9:18
	Rain	8:49	9:42
Day- Slow	Dry	9:19	10:07
	Rain	9:40	10:33
Night - Fast	Dry	9:00	9:49
	Rain	9:36	10:28
Night - Slow	Dry	10:35	11:24
	Rain	10:52	11:46

EVACUATION SCENARIO 21



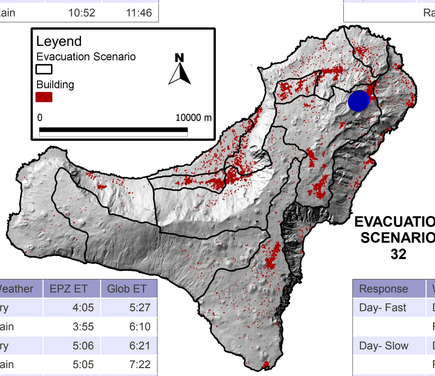
Response	Weather	EPZ ET	Glob ET
Day- Fast	Dry	4:10	5:14
	Rain	3:44	5:13
Day- Slow	Dry	5:26	6:28
	Rain	5:15	6:23
Night - Fast	Dry	4:39	5:52
	Rain	4:23	5:49
Night - Slow	Dry	6:19	7:07
	Rain	7:08	7:58

EVACUATION SCENARIO 22



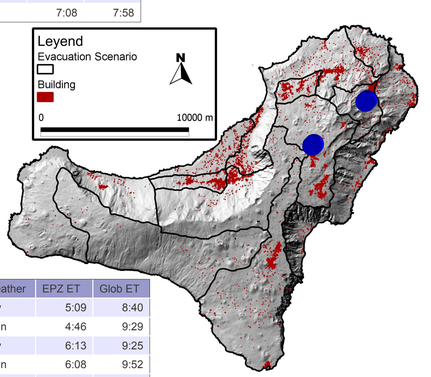
Response	Weather	EPZ ET	Glob ET
Day- Fast	Dry	5:22	8:36
	Rain	5:03	9:31
Day- Slow	Dry	6:19	9:18
	Rain	6:55	10:05
Night - Fast	Dry	5:49	8:38
	Rain	5:43	9:46
Night - Slow	Dry	7:40	10:15
	Rain	8:32	10:57

EVACUATION SCENARIO 31



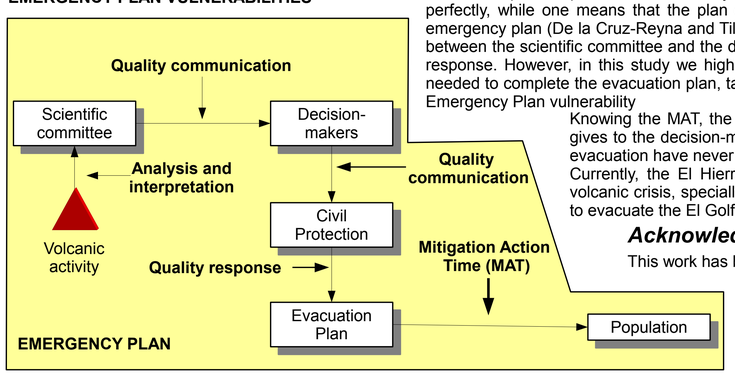
Response	Weather	EPZ ET	Glob ET
Day- Fast	Dry	4:05	5:27
	Rain	3:55	6:10
Day- Slow	Dry	5:06	6:21
	Rain	5:05	7:22
Night - Fast	Dry	4:53	6:00
	Rain	4:21	7:05
Night - Slow	Dry	6:51	8:13
	Rain	6:31	8:46

EVACUATION SCENARIO 32



Response	Weather	EPZ ET	Glob ET
Day- Fast	Dry	5:09	8:40
	Rain	4:46	9:29
Day- Slow	Dry	6:13	9:25
	Rain	6:08	9:52
Night - Fast	Dry	5:32	8:59
	Rain	5:22	9:55
Night - Slow	Dry	7:48	10:07
	Rain	7:41	10:58

EMERGENCY PLAN VULNERABILITIES



From a simple viewpoint, the vulnerability of an emergency plan can be measured from 0 to 1. Zero corresponds to an emergency plan that works perfectly, while one means that the plan does not work which increases the vulnerability of the population. There are many vulnerabilities in an emergency plan (De la Cruz-Reyna and Tilling, 2008). There may be mistakes in the data analysis and interpretation or a poor quality communication between the scientific committee and the decision-makers. In turn, the latter convey erroneous information to Civil Protection which may cause a bad response. However, in this study we highlight the relevance to know ahead of time the Mitigation Action Time (MAT) (Marrero et al., 2012), time needed to complete the evacuation plan, taking into account the warning time, response time and evacuation time, such a methodology to reduce the Emergency Plan vulnerability

Knowing the MAT, the minimum response time window to carry out the evacuation plan could be established. That information gives to the decision-makers and Civil Protection a power tool to improve the emergency management, specially in areas where evacuation have never been carried out.

Currently, the El Hierro Emergency Plan has not been completed, although some lines of action were designed during the volcanic crisis, specially to evacuate the El Golfo Valley. The objective of this study is to know the MAT for all possible strategies to evacuate the El Golfo Valley, reducing the evacuation plan strategies.

Acknowledgments

This work has been supported by 201130E011-CSIC and CGL2011-28682-C02-01-MINECO (Spain) Research Projects.

BIBLIOGRAPHY

De la Cruz-Reyna, S. & Tilling, R.I. 2008. Scientific and public responses to the ongoing volcanic crisis at Popocatepetl Volcano, Mexico: Importance of an effective hazards-warning system. Journal of Volcanology and Geothermal Research, 170: 121–134.

Marrero, J.M.; García, A.; Llinares, A.; Rodríuez-Losada, J.A. & Ortiz R. 2010. The Variable Scale Evacuation Model (VSEM): a new tool for simulating massive evacuation processes during volcanic crises. Natural Hazards and Earth System Sciences, 10: 747–760.

Marrero, J.M.;Garcia, A.; Llinares, A.; De la Cruz-Reyna, S.; Ramos. S. and Ortiz, R. 2012. Virtual Tools for volcanic crisis management, and evacuation decision support: Applications to El Chichón volcano (Chiapas, Mexico). Submitted.