



# COLIMA VOLCANO EXERCISE PLAN

17<sup>th</sup> – 24<sup>th</sup>  
November 2012



*Volcanic Unrest in Europe  
and Latin America:  
phenomenology, eruption  
precursors, hazard  
forecast, and risk  
mitigation*

**WP 9:** Decision-making  
and unrest management

**Task 9.6:** Simulation of  
unrest and decision making



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# 1. INTRODUCTION

## 1.1 The VUELCO project

The VUELCO-COLIMA EXERCISE takes place in the framework of the activities that are being carried- out by the European Union funded project named “VUELCO- Volcanic Unrest in Europe and Latin America: phenomenology, eruption precursors, hazard forecast, and risk mitigation”.

The project, started on 1<sup>st</sup> October 2011, aims at significantly improve the general understanding of the processes behind volcanic unrests and the ability to forecast their outcomes, aiding decision-making and management in an unrest situation.

Today the knowledge of the causative links between subsurface processes, resulting unrest signals and imminent eruption, is actually inadequate to effectively deal with crises of volcanic unrest.

Volcanic unrest is in fact a complex multi-hazard phenomenon of volcanism. There are many uncertainties in identifying the causative processes of unrest and imminent eruption. The various phenomena that can occur during an unrest, even when not leading to a volcanic eruption, are able to cause heavy disease and damages: only consider the possible earthquakes, variation in temperature or level of groundwater in the wells, possible drying up of springs and clouding of springwater, increase in degassing from soil, etc.

The VUELCO project intends to face up to this matter through an international multi-disciplinary consortium, composed by 10 partners from Europe and Latin-America, combining fundamental research into causes and effects of volcanic unrest with uncertainty assessment and probabilistic forecasting, to improve: communication, decision-making and management during volcanic unrest.

The objectives of the project include:

- (i) improving the mechanistic understanding of subsurface processes triggering volcanic unrest;
- (ii) identifying reliable precursors associated with specific subsurface processes;
- (iii) improving the forecasting capacity of the outcome of volcanic unrest in the presence of scientific uncertainty;
- (iv) improving the capacity for early-warning and management of evolving volcanic crises beginning with monitoring capacity through hazard assessment and threat analysis to decision-making;
- (v) improving the preparedness to cope with consequences and potentially adverse outcomes of volcanic unrest.

The project focuses mainly on seven target volcanoes:

1. Colima (Mexico),
2. Campi Flegrei (Italy),
3. Cotopaxi (Ecuador),
4. Morne aux Diabes (Dominica),
5. Soufrier Hills (Monserrat),
6. Teide (Spain),
7. Popocatepetl (Mexico)

The first four of which are going to be interested (in the next years) by a simulation exercise.

## **1.2 The Work Package 9: Decision making and unrest management**

When a volcano develops from dormancy through a phase of unrest, civil authorities in charge of managing volcanic emergencies, have to make hard decisions (e.g. the evacuation of people living around the volcano).

Decision-making is subject to constraints such as availability of data, uncertainty or compliance.

The 9<sup>th</sup> Work Package of VUELCO project aims at identifying effectively measures and providing useful tools to deal with volcanic unrest.

It is expected to identify the decision makers' needs during unrest crises, the network of social trust within the at-risk communities, the ways for determining the best practices of securitization, to provide methods for cost-benefit analysis, and to run simulation of unrest crises, in order to test models, protocols, procedures and any other product developed within the project in a true operational chain.

## **1.3 The Task 9.6: Simulation of unrest and decision making**

In this task the project explore the applicability of methods, models and paradigms, developed within the project, to both real and hypothetical unrest crises.

Probabilistic models and communication protocols developed in other work-packages of the project, will be employed in a number of simulations of volcanic unrest at the target volcanoes: Colima, Campi Flegrei, Cotopaxi and Morne aux Diabes.

The simulations will consider both real unrest crises in the past and hypothetical future unrest crises, according to the reconstructions developed in another work package.

Strengths and weaknesses in the developed models and in the communication chain (scientists-civil protection-public) will be identified, and the whole procedures will be improved through an iteration process whereby unrest simulations will be repeated in the course of the project with progressively improved models, practices and paradigms.



The simulations will also take into account real monitoring capacities at specific volcanoes, so to evaluate the kind of information available, the effective capability to detect signals and feed models on the appropriate time-scale at the required accuracy, and the specific needs for monitoring capacity improvements.



Fig. 1: VUELCO target volcanoes – in green the volcanoes where an exercise is planned to take place, in red the other volcanoes included in the project

## 2. THE COLIMA VOLCANO

### 2.1 Overview

<b>Country</b>	México
<b>States</b>	Colima, Jalisco
<b>Municipalities</b>	Comala, Cuauhtémoc, Tuxpan, Zapotitlán, Tonila
<b>Volcano Type</b>	Stratovolcano
<b>Last Known Eruption</b>	2011
<b>Summit Elevation</b>	3860 m a.s.l.
<b>Latitude</b>	19°30'44"N
<b>Longitude</b>	103°37'02"W

The Colima volcanic complex is the most prominent volcanic centre of the western Mexican Volcanic Belt. It consists of two volcanoes: *Nevado de Colima* (4330 m, the highest point of the complex) on the north and the 3860-m-high historically active *Volcán de Colima* at the south.

A group of cinder cones of late-Pleistocene age is located on the floor of the Colima graben west and east of the Colima complex.

Volcán de Colima (also known as Volcán de Fuego) is a youthful andesitic stratovolcano constructed within a 5-km-wide caldera, breached to the south, that has been the source of large debris avalanches.

Major slope failures have occurred repeatedly from both the Nevado and Colima cones, and have produced a thick apron of debris-avalanche deposits on three sides of the complex. Frequent historical eruptions date back to the 16<sup>th</sup> century. Occasional major explosive eruptions (most recently in 1913) have destroyed the summit and left a deep, steep-sided crater that was slowly refilled and then overtopped by lava dome growth.

### 2.2 Eruptive history outlines

During the past 500 years, the Volcán de Fuego of Colima has reported over 40 eruptive events of the explosive and effusive kind, which include those occurred in 1585, 1606, 1622, 1690, 1818, 1869, 1872, 1890, 1903, 1913, 1975-76, 1998-99, 2001-2003 and 2005. In addition, minor activity must be taken into account. All of the above shows that this volcano has increased its eruptive process over the course of the past five centuries.

Clear manifestations of the Volcán de Fuego, shown during its periods of activity, are the eruptions of magmatic material thrown out in different ways.

One of the latest, reported in 1913, left a crater measuring approximately 500 meters in depth. This crater began to fill with lava over time and lava eventually flowed

beyond the edges of the crater, thus forming a dome that blocked the main chimney of the volcano.

In 1991, an episode of lava dome growth in blocks resulted in the partial collapse of the body itself, thus producing slides of incandescent material and eventual lahars.

The effusive eruption (1998) showed that the internal activity of the volcano displays the patterns of the behaviour of past centuries during which the eruptive cycle ends with a change in the style of the volcano's activity and a subplinian to plinian eruption, with an eruptive column higher than 10 kilometres and an ash rain that covered a radius no larger than 30 kilometres.

In addition, this eruption produced pyroclastic flows down the slopes covering a radius of 15 kilometres, just as it happened in 1818 and 1913.

The latest explosions of the Volcán de Fuego include those of 1987 and 21<sup>st</sup> July 1994, which produced a crater on the surface of the dome that was formed in 1991 and reached a diameter of 130 m by 50 m in depth, and also produced a light ash rain on the west. On 10<sup>th</sup> February 1999, a new explosive event was reported at the summit of the volcano. Smaller eruptions were also reported on 18<sup>th</sup> February and 10<sup>th</sup> May 1999. A new and violent explosion occurred on 17<sup>th</sup> July 1999, which threw out a large amount of incandescent material that ran down the slopes of the volcano, and produced an ash column higher than 8 kilometres. During the months of May (16, 24 and 30) and June (2 and 5) five of the most important explosive events recorded by the monitoring systems of the University of Colima occurred.

The explosive event that took place on 5 June 2005, at 14:20 (local time), produced pyroclastic flows throughout the entire volcanic building, and produced a column higher than 4 kilometres from the summit, which was blown by the winds to the south-east of the volcano at a speed of 25 km/hr approximately.

## **2.3 Monitoring system**

The monitoring of the Volcán de Fuego is the responsibility of the staff of the Volcano Observatory of the University of Colima, with the assistance of the Civil Protection System of the states of Colima and Jalisco.

It consists of the following monitoring networks: seismometric, ground deformations, visual and thermal cameras, geochemical, rain-gauges.

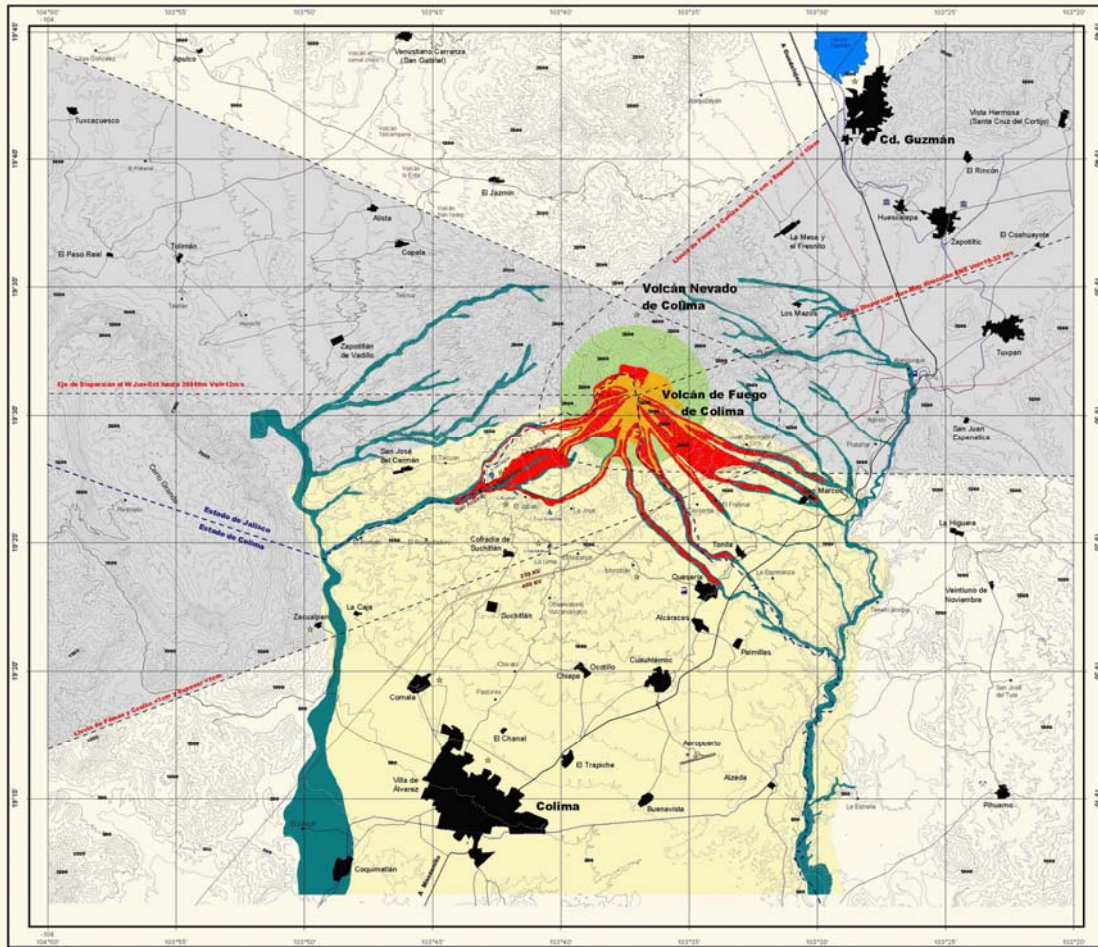
## **2.4 Volcanic hazard and risk**

The hazard map of the Volcán de Colima (fig. 2) defines the areas potentially involved in different phenomena: pyroclastic flows, ash fallout, lahars, lava flows, pyroclastic ballistic fallout, debris avalanche due to flank collapse.

Today, both in Colima and Jalisco, there are a number of towns that would be in danger should a volcanic eruption take place.



# MAPA DE PELIGROS VOLCÁN DE FUEGO DE COLIMA



0 5 10 KM  
Escala Gráfica

## OBSERVACIONES SOBRE RANGO DE PELIGROSIDAD VOLCÁNICA

- 1) FLUJOS PIROCLÁSTICOS:** Son una mezcla fluida y densa de rocas, ceniza y gases que bajan a velocidades mayores a 100 km/h, por las laderas de un volcán con altas temperaturas (> a los 800°C). En un radio de 15 a 20 km al sur del volcán es el principal peligro volcánico. Históricamente presentes en las erupciones de 1919, 1983 y 1913.
- 2) LLUVIA O CAÍDA DE CENIZA Y PÓMEZ:** Son lluvias de material fragmentado en erupciones explosivas, siendo controladas por la dirección y velocidad del viento, cubriendo como un manto grandes extensiones de terreno. Históricamente con alcances de 30 a 50 km en dirección del viento. Se han encontrado espesores de 10 m en un radio de 7 km. Se incluye en esta, la lluvia o caída de productos por trayectoria balística (fragmentos de roca hasta 50 cm de diámetro) con alcances máximos de 5 km.
- 3) FLUJOS DE LODO O LAHARES:** Son avenidas repentinas de lodo, rocas y agua que escurren por las cañadas del volcán con velocidades cercanas a 50 km/h. Tienen la consistencia del concreto mojado y son disparados por lluvias torrenciales. Es el segundo depósito más abundante en un radio de 15 a 20 km. En erupciones mayores, aguas abajo puede afectar por inundación grandes extensiones.
- 4) FLUJOS DE LAVA EN BLOQUES:** Son flujos de lava densa que descienden lentamente por las laderas del volcán, con velocidades menores a 100 m/día. En los últimos 40 años los alcances máximos son de 3.5 km, mientras que los flujos prehistóricos presentan alcances de hasta 8 km a partir de la cima.
- 5) AVALANCHA DE ESCOMBROS VOLCÁNICOS:** Es el escenario más catastrófico que puede ocurrir en el volcán de Colima, consiste en un derrumbe parcial o total del volcán, cuyos depósitos de escombros cubren el valle norte de Colima con espesores mayores a 50 m. Se han reconocido al menos 3 depósitos de este tipo, con una recurrencia de miles de años, fechándose la última con el método de C14 en 7,500 años antes del presente.

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Este mapa se basa en trabajo de campo geológico  
durante 3 años con 525 puntos de verificación  
Cartografía Base: INEGI, E13B-24, E13B-25,  
E13B-34, E13B-35, E13B-44, E13B-45  
Escala Base 1:50,000

ELIPSOIDE: GRS 80  
PROYECCIÓN: TRANSVERSA DE MERCATOR  
CUADRICULA: LATITUD - LONGITUD  
AUTORIDAD: UNIVERSIDAD DE COLIMA  
FUENTE: INEGI - OBSERVATORIO VULCANOLÓGICO  
IMPRESIÓN: ABRIL 2002

## LEYENDA

Peligros con Índice de Explosividad Volcánica (VEI) 0 a 6

Nota: Se asume que la erupción tendrá lugar en o cerca del cráter activo actual

- Flujos Piroclásticos (Alcance Max. 12 Km)
- Avalancha de Escombros Volcánicos (>30 km)
- Flujos de Lava (hasta 8 km)
- Lahares y Zonas de Inundación (>12 Km)
- Bombas o Projectiles Balísticos (hasta 5 Km)
- Lluvia o Caída de Ceniza
- Asentamientos Humanos
- Lagunas
- Límite Estatal
- Via Ferrea
- ✕ Aeropuerto Nacional
- ✕ Aeropistas
- Carreteras de Cuota
- Carreteras
- Terracería
- 400 KV
- Líneas de Alta Tensión
- 500
- Curvas de Nivel C/100m
- Minas de Hierro
- Industria Maderera
- Industria Azucarera
- Industria Cementera y Calera
- Zona Turística



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GOBIERNO DEL ESTADO DE COLIMA



PROTECCIÓN CIVIL COLIMA

Fig. 2: Colima volcano hazard map



The deposit of pyroclastic flows, pumice and ash rain, as well as mudflows and lahars could affect, firstly, the towns of La Yerbabuena, La Becerrera, Barranca de Agua, Rancho El Jabalí, Suchitlán, San Antonio and Rancho La Joya, in the state of Colima, in addition to Juan Barragán, Agostadero, Los Machos, El Borobollón, Durazno, San Marcos, Tonila, Cofradía de Tonila, Causentla, El Fresnal, Atenguillo, Saucillo, El Embudo and El Chayán, in the state of Jalisco.

Other towns from the two states that are further afield may also be affected, such as Quesería, Ciudad Guzmán, Tuxpan, the city of Colima, Villa de Álvarez, Comala and Cuauhtémoc, to name a few.

The figure n. 3 on the left, shows the evacuation route for the villages located south of Colima volcano, designed by the Colima State Civil Protection System.



Fig. 3: Colima volcano emergency plan - evacuation route

## 3. THE EXERCISE

### 3.1 Involved institutions

The VUELCO COLIMA EXERCISE involves local, national and international institutions.

Mexican involved institutions and committees:

- Mexican National System of Civil Protection (MNSCP).
- State of Colima Civil Protection System (SCCPS).
- State of Jalisco Civil Protection (JCV)
- National Center for Disaster Prevention (CENAPRED)
- Universidad Nacional Autónoma de México, Mexico (UNAM)
- University of Colima (UC)
- Colima Volcanic Observatory (CVO)
- Scientific Committee for Colima Volcano (SCCV)

International involved institutions:

- University of Bristol (UNIVBRIS)
- University of Leeds (UNIVLEEDS)
- Agencia Estatal Consejo Superior de Investigaciones Científicas, Spain (CSIC)
- Istituto Nazionale di Geofisica e Vulcanologia, Italy (INGV)
- Dipartimento della Protezione Civile, Italy (DPC)
- Ludwig-Maximilian University of Munich, Germany (LMU)
- Centre National de la Recherche Scientifique, France (CNRS)
- Seismic Research Centre- University of West Indies, Trinidad and Tobago (SRC-UWI)
- Instituto Geofísico de Escuela Politécnica Nacional, Ecuador (IGEPN)

### 3.2 Exercise goals

The main goals of the VUELCO-COLIMA exercise are:

- Analysis of the situation, hazard evaluation, risk perception and management of the European and the Latin-American participants;
- Explore the applicability of products (methods, models, procedures, protocols) developed within the project to the decisional-operational chain in an unrest crisis;
- Test the applicability of probabilistic models developed at WP7 (in turn fed by knowledge and models developed in WPs3-5);
- Test the applicability of communication protocols developed at WP8;
- Test their usability and helpfulness, also in respect to the already existing ones in use at Colima.
- Assess and scrutinize the communication between scientists and civil protection and between civil protection, media and population;

- Scrutinize the process to analyze precursory signals, the process to define the possible scenarios, the process to identify the most likely scenario, the process to make a decision;
- Carefully observe and audit the development of Colima exercise in each step and take note of strength points and weakness points;
- Identify the users' needs in different phases in order to find how to improve the system;
- Identify the critical points, pointing out what didn't work at its best, defining what is improvable and how.
- Civil protection operational goals (verifying procedures, means, timing, functionality of emergency areas, evacuation routes, operational centres, radio communication, displaying of forces, relief organization, etc.)

Since this is the first simulation exercise to take place, after just one year of project, it is possible that not every WP has already developed its own products to be tested (methods, models, procedures, protocols). It is therefore possible that some previously collected or developed products will be tested in the exercise, together with the local ones.

### 3.3 Exercise development

The VUELCO COLIMA exercise will take place along with the 7<sup>th</sup> *Cities on Volcanoes* international congress.

The exercise will develop through 8 days, with the purpose of simulating a possible real evolution of an unrest crisis, from the appearance of the first anomalies to an ever increasing occurrence of potential eruption precursors.

For the purposes of the simulation, the monitoring signals and the evolution of the situation will be previously decided by a UNAM-CENAPRED-UC restricted team, taking into account the development of signals already occurred in the past during other unrest episodes at Colima or Popocatepetl. To better test the real response of the Scientific Committee, these signals will be kept secrets and not revealed to anyone until the last moment.

At the occurrence of new significant anomalies, the Colima Volcanic Observatory will inform the Colima State Civil Protection System, that will summon the Scientific Committee for Colima Volcano (SCCV).

The SCCV is a sub-committee of the State of Colima Scientific Committee for Disaster Prevention (SCSCDP), which is an advisory committee to coordinate preventive actions against destructive natural phenomena: earthquakes, eruptions, landslides, hurricanes, etc., and it has a member for each type of phenomenon. When precursors or any indications of the possible occurrence of one of those phenomena are detected, the ad-hoc committee is summoned.

This committee has permanent members, including the member of the SCSCDP, the members of the Colima Volcano Observatory and “external members”, which are scientists from Mexico or from abroad that are invited to participate in the SCCV.

For the present exercise, the SCCV will be integrated with scientists belonging to institutions partner of the VUELCO project.

Therefore, during the exercise, an Enlarged Scientific Committee (ESCCV) formed by members of the SCCV and scientists of VUELCO team, will analyze together the precursors and the situation, using the protocol commonly used in Mexico:

First, the available seismic, geodetic, geochemical, and any other available data are presented in that order and with the maximum possible detail.

Secondly, possible interpretations of the sources of such signals are discussed.

Thirdly, possible outcomes of such precursors are discussed, mostly as eruption scenarios until a consensus is reached.

Finally, the most likely scenarios are communicated to the SCCPS.

In this session, the highest rank SCCPS and SJCPD directors may be present during the whole session, or only at the final stage (scenario discussion), and they may ask questions to the ESCCV at any time.

**Each ESCCV meeting will be focused on a different phase:**

- A. The analysis and interpretation of precursory signals;**
- B. The elaboration of risk scenarios (based on those precursors);**
- C. The decision making (based on the previous points)...**
- D. The communication of the decision to the population**
- E. The partial evacuation of a vulnerable town.**
- F. Debriefing**

The programme of the exercise is reported in the following scheme, where other meetings related to the congress are indicated in grey-field.

Saturday 17 <sup>th</sup> November 2012	
h 09.00 – 17.00	Vuelco Steering Committee Meeting
Phase A: “Analysis and interpretation of precursory signals”	
h 12.00	-Colima Volcanic Observatory (CVO) detects the occurrence of some events and/or anomalies and informs State of Colima Civil Protection System (SCCPS)
h 15.00	-SCCPS summons a meeting of the Scientific Committee of Colima Volcano (SCCV) at h 15.45
h 15.45 – 17.45	<b>Phase A1:</b> -Constitution of the Extended Scientific Committee (ESC =Colima SC+VUELCO scientists); -Briefing on the Colima volcano: eruptive history, recent activity, hazards, vulnerabilities, risk; - CVO presents the new activity detected by the monitoring systems. - The ESC adjourns until Tuesday h 06.45;



<b>Sunday 18<sup>th</sup> November 2012</b>	
h 09.00 – 17.00	<b>Vuelco Workshop – Cities on Volcanoes 7</b> "Volcanic unrest: Interfacing science and decision-making".

<b>Monday 19<sup>th</sup> November 2012</b>	
All day	Cities on Volcanoes 7: conference programme

<b>Tuesday 20<sup>th</sup> November 2012</b>	
h 06.45 - 08.45	<b>Phase A2:</b> - Inclusion of VUELCO participants arriving to Colima after Saturday into the ESC; - CVO continues the presentation of the new activity registered, including eventual updates; - Each group presents its own models and interpretation; - ESC Brainstorming; - Conclusion of the meeting with an advice for the SCCPS (e.g. increase monitoring activities, etc.); - SCCPS receives and analyses the advices from the ESC and adjourns the meeting, asking to ESC to remain at disposal; - SCCPS decides whether to change the alert level, inform local authorities or civil protection operational forces, and evaluates the opportunity to inform the population and in which way.
h 09.00-18.00	Cities on Volcanoes 7: conference programme

<b>Wednesday 21<sup>st</sup> November 2012</b>	
All day	Cities on Volcanoes 7: intra-congress field trip

<b>Thursday 22<sup>nd</sup> November 2012</b>	
<b>Phase B: "Elaboration of hazard and risk scenarios"</b>	
h 05.00	-CVO detects the occurrence of new increasing events and anomalies and informs SCCPS
h 06.00	-SCCPS summons a new meeting of the ESC at 07.00
h 06.45 - 08.45	- CVO presents the new signals registered; - ESC Brainstorming; - Elaboration of risk scenarios based on the analysis of the monitoring signals; - Release of an advice (including one or more potential scenario) to the SCCPS; - SCCPS receives and analyses the advices and the scenarios, adjourns the meeting, asking to ESC to remain at disposal; - SCCPS decides whether to change the alert level, how to inform local authorities and CP operational forces, and evaluates the opportunity to inform the population and in which way.
h 09.00-18.00	Cities on Volcanoes 7: conference programme

<b>Friday 23<sup>rd</sup> November 2012</b>	
h 09.00-18.00	Cities on Volcanoes 7: conference programme
<b>Phase C: "Decision making"</b>	
h 15.00	-CVO detects the occurrence of further new increasing events and anomalies and informs SCCPS.
h 16.00	-SCCPS summons a new meeting of the ESC at 18.00.
h 17.00 - 19.00	- Analysis of the latest monitoring signals developments; -Brainstorming in order to analyse the events and anomalies occurred and to define the <u>most likely scenario (including time of occurrence of forecasted events)</u> ; -ESC gets to a final advice for the SCCPS (including the most likely scenario); -SCCPS receives and analyses the advices and the scenario and makes the decision whether to change alert level and evacuate people or not.

<b>Saturday 24<sup>th</sup> November 2012</b>	
<b>Phase D: "Communication of the decision to the population"</b>	
h 08.00	Briefing on the decision making process, and the evacuation logistics and procedures
h 08.30	Translation to the sites where buses for the evacuation will be requested
h 08.45	Immediate translation to the endangered town (La Becerrera)
h 09.00	-SCCPS communicates to the population on the site the ongoing situation and the decision to evacuate.
<b>Phase E: "Evacuation of an exposed town"</b>	
h 09.30	- Evacuation begins
h 15.00	- People are transported to Civil Protection shelters- End of exercise

<b>Date: to be decided</b>	
<b>Phase F: "Debriefing"</b>	

If on Friday 23<sup>rd</sup>, during the ESCCV and SCCPS meeting, it will be decided that a preventive evacuation is necessary, SCCPS (with the possible participation of SJCPs and MNSCP) will proceed to evacuate part of the population of a town located in the high risk area of the southern sector of the volcano on the morning of Saturday 24<sup>th</sup> (probably about 100-200 people). This is the town of La Becerrera, which has been affected by lahars recently.

The location of La Becerrera may be seen in the Volcanic Hazards Map of Colima Volcano (fig. 2 and 3) in a red area, just NE of San Antonio.

The times assigned to the meetings in phases A to C will be the same as the times commonly spent in the meetings of the Mexican Scientific Committees.

Each session should end with a consensual conclusion. If consensus is not reached on a given issue, the discussion will concentrate on the other subjects in which there is a meeting of minds. Reasons of disagreement will be clearly declared.

Civil Protection (in any level of government) may be present in all phases, and may ask questions at any time.

The communications to the population in phases C, and D+E will be made after the ESC session ends. Additional time may be dedicated to answer questions of the population representatives.

The process of communicating the risk to the people living around the volcano, has been going on for years at Colima, as a task of the Civil Protection System, and, for the purposes of the present exercise, some meetings have been held with the population in the preceding weeks in order to explain the exercise itself and to refresh the volcanic risks and hazards.

## ACKNOWLEDGEMENTS

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Project web page:  
[www.vuelco.net](http://www.vuelco.net)

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