

# Methodology for hazards map construction

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# Basic principles for the elaboration of hazards maps

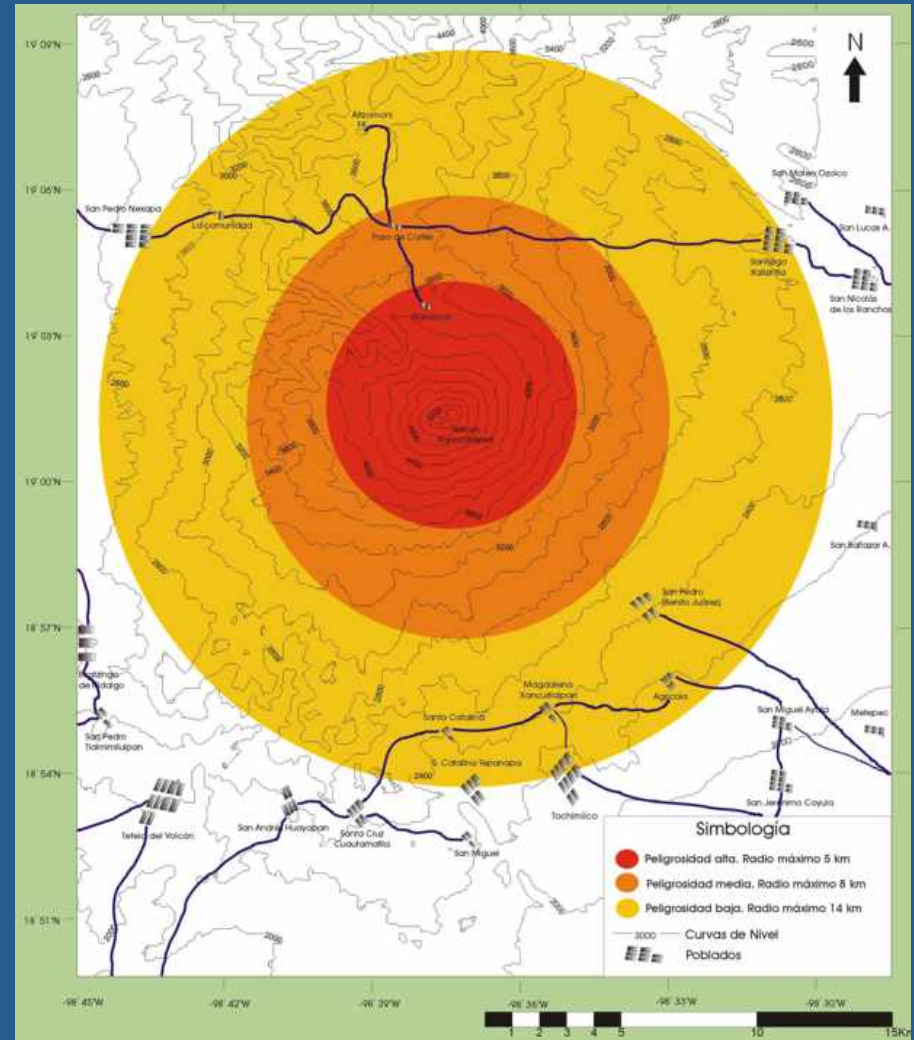
- Hazards maps should be based on sound scientific studies, as much geological and physical data as possible, modeling and simulations
- Even though the elaboration process implies scientific methodologies and data, hazards maps are not a product for scientists
- Hazards maps are tools designed for being used by non-specialists (authorities, people, media)
- Then, the maps should be simple and accessible
- An accessible and unified or basic methodology is needed for those who make hazards maps

# Hazard maps are...

- probability maps:
  - tools depicting the probable/likely distribution, in space or time, of products related to the occurrence of certain volcanic process
  - tools that depict probable/likely magnitude scenarios of volcanic processes' occurrence in accordance to actual events documented for a particular site, or to events occurred at a similar site for which detailed data is available
- forecast maps
  - simulation of calibrated events, at different magnitude scenarios establish volcanic process forecasts
  - however, forecasts are limited

# Hazards Maps should be:

- Consistent
- Objective
- Simple
- Reproducible
- Sound
- Relevant
- Long-standing



# however landscape changes...

- *Very active geologic systems may strongly change the morphology of a region after an event*
- *Some phenomena should be followed as they occur in order to make real-time decisions*

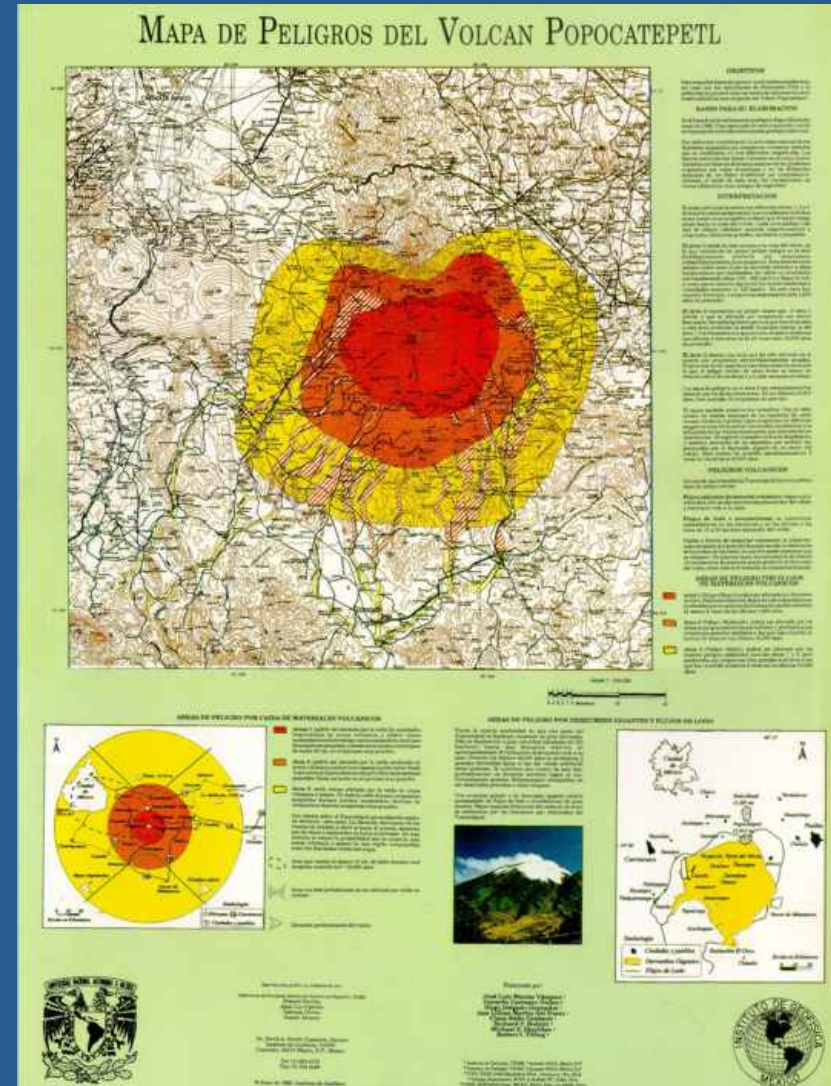
Therefore, **two types** of hazards maps are envisaged according to purposes, scope and use:

- *Hazards Static Maps*
- *Hazards Dynamic Maps*



# Hazards Static Maps are designed...

- to be printed or accessible through the internet
- to be widely distributed for everyone to know them, learn about the surrounding processes, how to protect against those processes, and how to use the maps
- to stand for a long time without large modifications, changes may provoke...
  - Confusions
  - Credibility loss



# Hazards Dynamic Maps are designed...

- to be used by specialists and /or trained civil defense technicians
- to be changed at any time by authorized people
- to be used on a GIS framework
- to summarize and monitor geologic events and deploy them near real-time
- initially made from the static map, but as events come, it can be modified for emergency attendance



# Methodology: examples

Decision for the making of a ballistics hazard map

Data compilation

Field data

Data processing

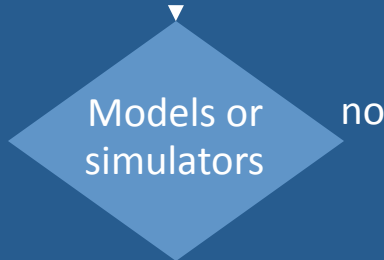
Parameter identification

Can not be defined



yes

Scenario determination



no

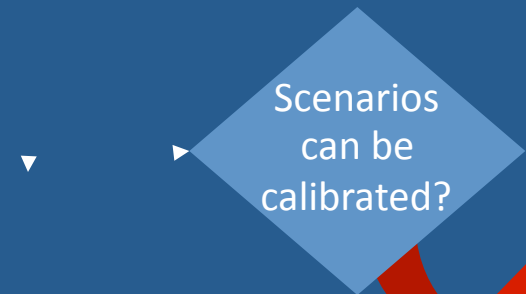
yes

Choose models and simulators

Research

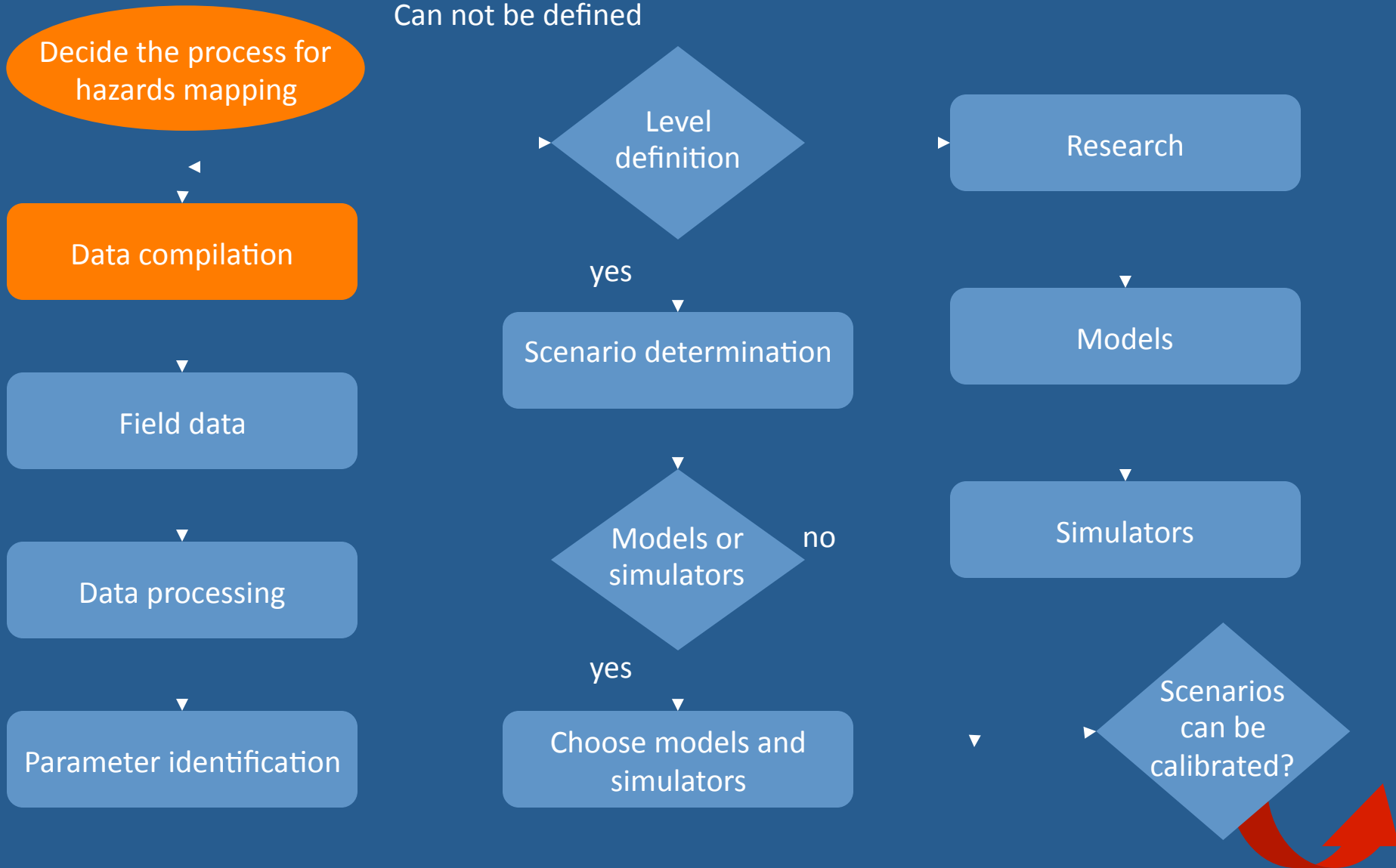
Models

Simulators



Scenarios can be calibrated?

# Methodology: examples



**Experimental determination of drag coefficient for volcanic materials: Calibration and application of a model to Popocatepetl volcano (Mexico) ballistic projectiles**

Miguel A. Alatorre-Ibarra and Hugo Delgado-Grisales<sup>1</sup>

Received 12 March 2006; revised 1 June 2006; accepted 11 April 2006; published 13 June 2006.

[1] This study shows the results of experiments performed in a subsonic wind tunnel to measure drag coefficients ( $C_d$ ) for volcanic particles emitted by Popocatepetl volcano (Mexico). The results indicate that volcanic projectiles move in a range of Reynolds number ( $Re$ ) values where  $C_d$  is independent of  $Re$ . Drag coefficients of volcanic fragments were found between the values of spheres and cubes with low values. In this study, initial conditions of the ballistic equations were calibrated with the "launching" kinetic energy from ballistic experiments conducted by Popocatepetl volcano during the eruptive event of December 17, 1994. The maximum range of the projectiles calculated with the experimentally measured drag coefficient is in better agreement with the field and observational data reported here than using the values of geometrical bodies as in previous studies. Our study can be useful for definition of safety areas around volcanoes to protect people and infrastructure adequately. **Citation:** Alatorre-Ibarra, M. A., and H. Delgado-Grisales (2006), Experimental determination of drag coefficient for volcanic materials: Calibration and application of a model to Popocatepetl volcano (Mexico) ballistic projectiles, *Geophys. Res. Lett.*, 33, L11302, doi:10.1029/2006GL023095.

**1. Introduction**

[2] Volcanic projectiles represent Earth's natural energy source. In areas with high population density, volcanic projectiles represent a serious threat to the population.

**Hazard zoning for ballistic impact during volcanic explosions at Volcán de Fuego de Colima (México)**

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Instituto de Geología, Universidad Nacional Autónoma de México, Ciudad de México, México

**ABSTRACT**

Volcanic explosions emit fragments following ballistic trajectories. The volcanic ballistic projectiles represent a hazard due to their high velocities and temperatures. They may affect people, ecology, infrastructure, and aircraft. In order to avoid volcanic ballistic projectile-related hazards, a map can be constructed. A volcanic ballistic projectile hazard map depicts the likely distribution and maximum range of ballistic projectiles under given explosive scenarios. Different level hazard zones show on the map allow local inhabitants and concerned authorities to make development, protection, and mitigation plans, and to define restricted areas.

In order to determine the potential areas where the ballistics may fall, it is necessary to estimate their maximum range under different explosive scenarios. Explosive magnitude scenarios are defined by their characteristic kinetic energy. Therefore, the ballistic projectiles reach maximum distance from the source according to the maximum energy for each scenario. The trajectories described for the ballistic projectiles are determined by gravity and drag forces. Drag force depends, among other factors, on the drag coefficient as a function of the geometry of the ballistics. The maximum range of the projectiles depends also on the initial kinetic energy, the "launching" angle, the ballistic diameter, and the wind velocity. Another relevant aspect is that drag force is proportional to the air density which decreases with altitude.

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Journal of Volcanology and Geothermal Research

Journal of Volcanology and Geothermal Research

**Scientific and public responses to the ongoing volcanic crisis at Popocatepetl Volcano, Mexico: Importance of an effective hazards-warning system**

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**Abstract**

Volcanic eruptions and other potentially hazardous natural phenomena occur independently of any human actions. However, such phenomena can cause disasters when a society fails to foresee the hazardous manifestations and adopt adequate measures to reduce its vulnerability. One of the reasons of such a failure is the lack of a consistent perception of the changing hazards posed by an ongoing eruption, i.e., with members of the scientific community, the Civil Protection authorities and the general public having diverging notions about what is occurring and what may happen. The problem of attaining a perception of risk as consistent as possible in a population measured in millions during an ongoing eruption requires reaching the consensus both that can describe, as simply as possible, the relations between the level of threat posed by the volcano, and the level of response of the authorities and the public. The hazards-warning system adopted at Popocatepetl Volcano, called the Volcano Traffic Light (VTLAS), is a basic communication protocol that translates volcanic threat into seven levels of preparation for the emergency management authorities, but only three levels of alert for the public (code color green-yellow-red). The changing state of the volcano threat is represented on the map by a color sensitive according to the consensus of an official scientific committee analyzing all available data. The implementation of the VTLAS was intended to reduce the possibility of ambiguous interpretations of interaction levels by the endangered population. Although the VTLAS is superior and has not solved all problems involved in mass communication and decision-making during a volcanic crisis, it makes a significant advance in the management of volcanic crises in Mexico.

Keywords: Popocatepetl volcano hazard, volcano monitoring, warning system, volcano-emergency management, risk perception

**1. Introduction**

Popocatepetl Volcano is located in the central Mexican Volcanic Belt (Fig. 1) within a densely populated region, with over 20 million people vulnerable to direct hazards associated with a major explosive eruption. Situated about 70 km southeast of downtown Mexico City, Popocatepetl is arguably the most dangerous volcano in the country. This 5424-m-high volcano's ongoing past clearly indicates that it is capable of producing catastrophic eruptions: three Plinian events have occurred within the past 3500 years B.P., well within the period

of human settlement in central Mexico (Schieb et al., 1996; Sotelo and Macías, 2004). Fortunately, to date the current eruptive episode—beginning in December 1994 after being dormant for nearly six decades—has consisted of relatively minor activity, which has characterized Popocatepetl's activity since the 14th century (De la Cruz-Reyna et al., 1991). Nevertheless, given the huge population proximity at risk, together with concerns about possible escalation of eruptive activity, the management of the ongoing "volcanic crisis" at Popocatepetl (CONAPREVOLCAN, 1995) has proved, and continues to pose, a major challenge for volcanologists, national and local-level authorities, and the affected public.

The effective management of a volcanic crisis usually involves several integral components, which in most cases, may be

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Year	VEI
1512	2
1519	3
1539-1540	2
1548	2
1571	2
1592	2
1642	2
1663	2
1664	3
1665	2
1697	2
1720	1
1804	1
1919-1920	2
1921	2
1925-1927	2
1994-1997	2
2000	3
2001-present	1-2

Binomial probabilities of at least one eruption in the corresponding VEI class at Popocatepetl volcano within any 20-year interval

VEI Pr<sub>vei</sub>(20)

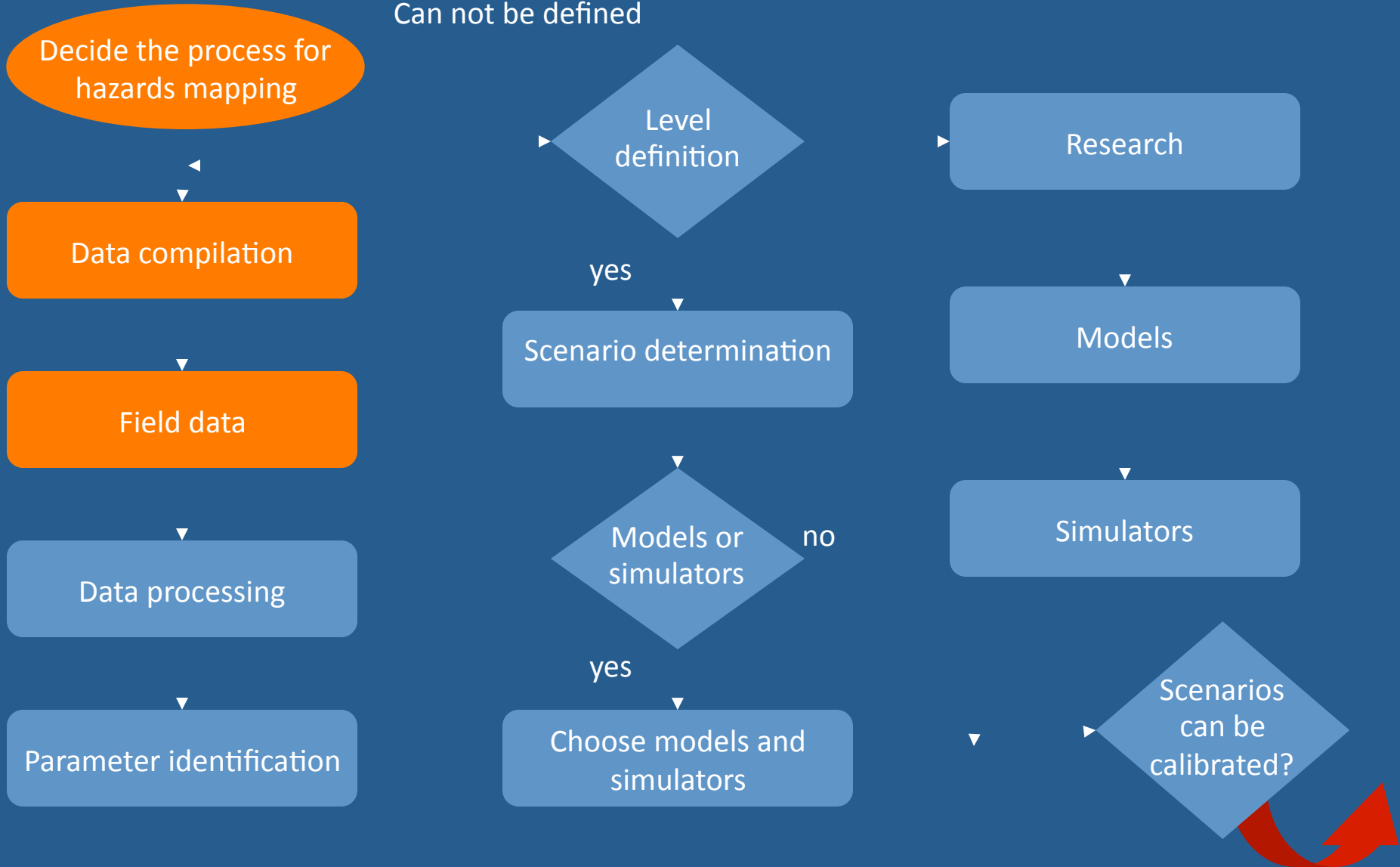
2	0.410
3	0.113
4	0.039
5	0.013
6	0.005

De la Cruz-Reyna and Tilling, 2008

De la Cruz-Reyna et al., 1995

# Methodology: examples

Can not be defined





14 Feb 2003 05:39, (14 Feb 2003, 11:39 GMT)

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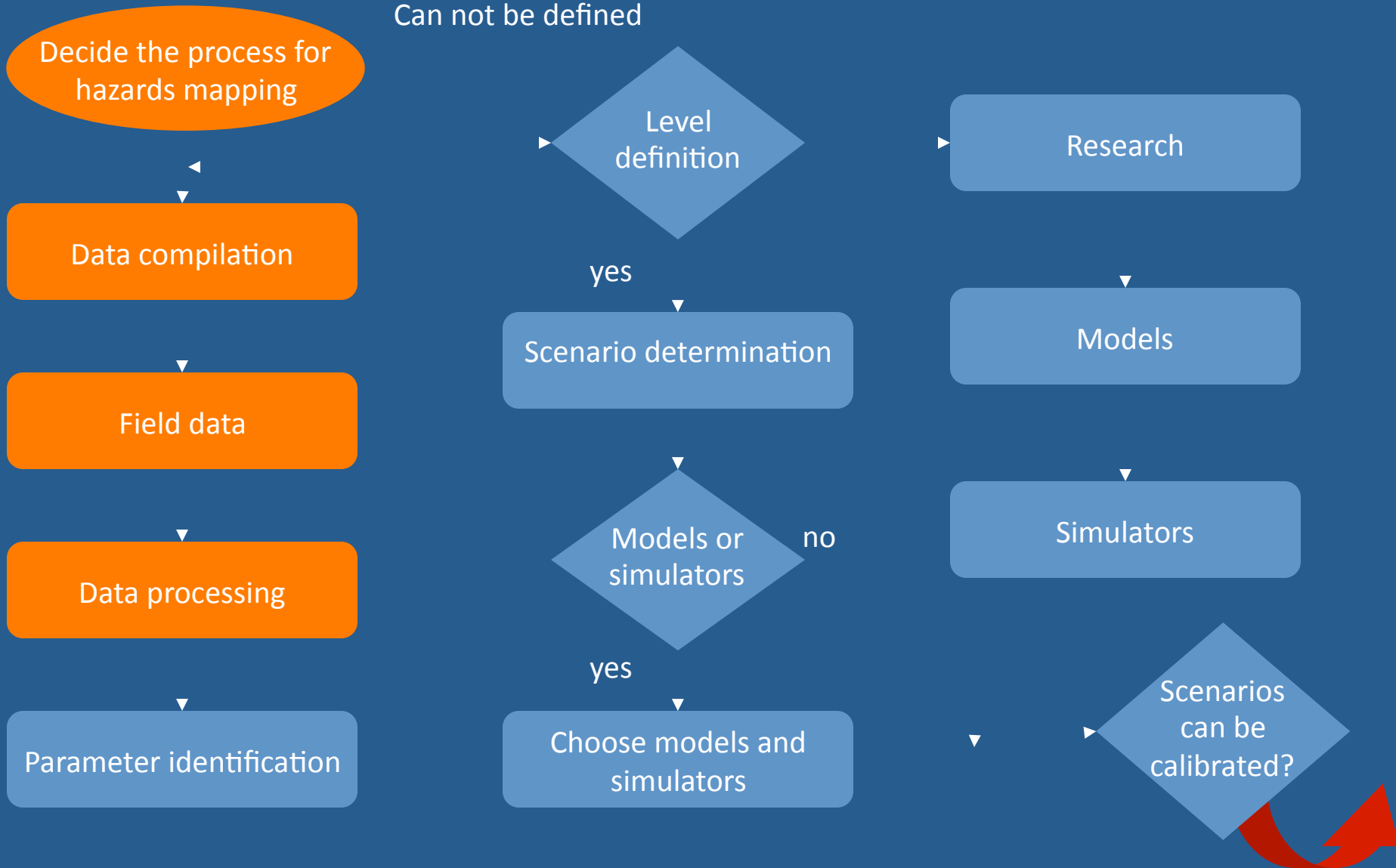


Cortesía: Martha Navarro



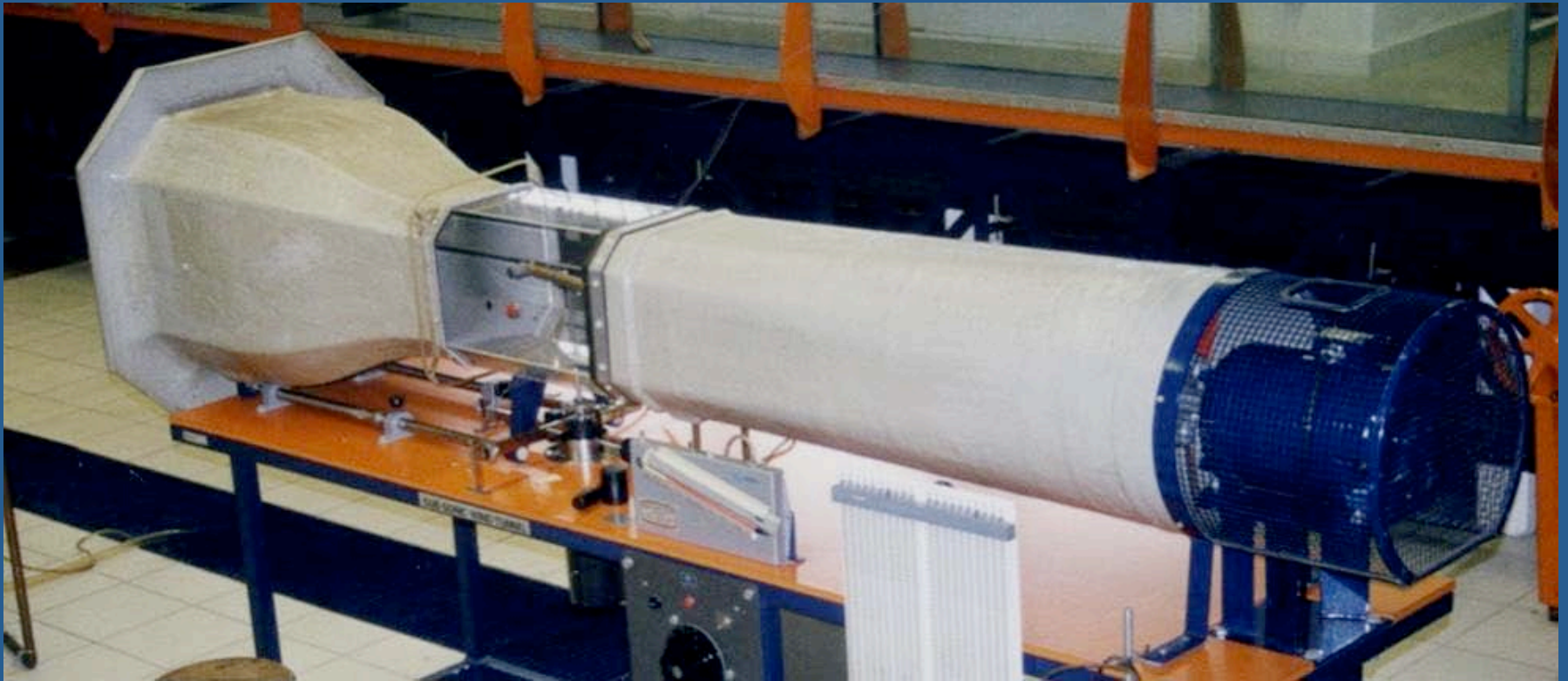


# Methodology: examples



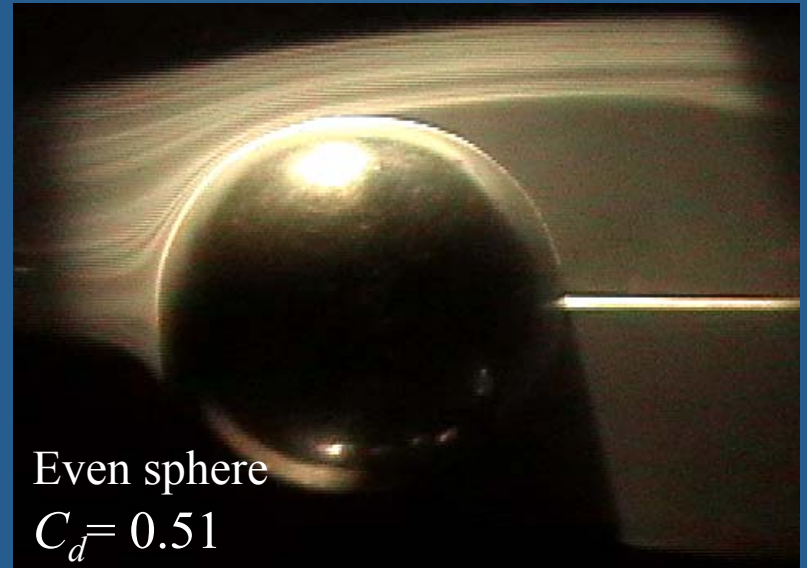


# Subsonic wind tunnel



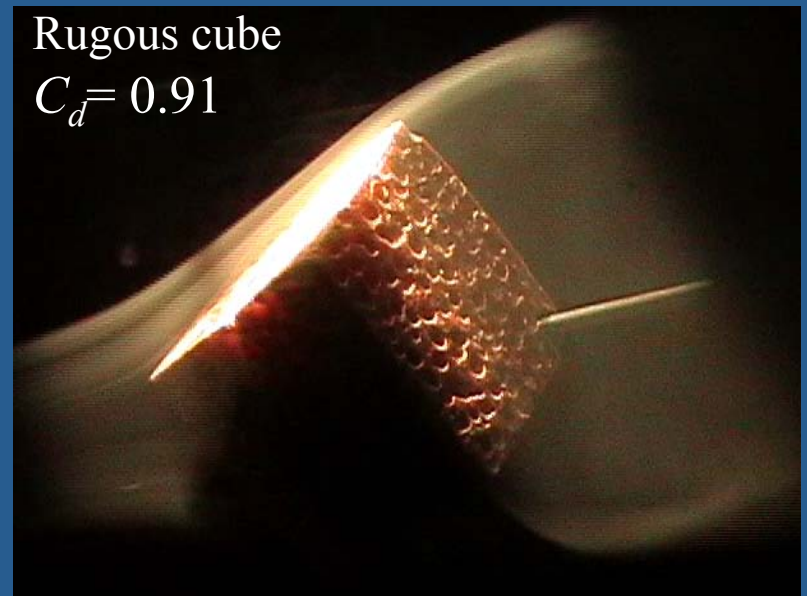
Volcanic sample VI

$C_d = 0.62$



Even sphere

$C_d = 0.51$



Rugous cube

$C_d = 0.91$

The relative size of the stele with the object is proportional to drag coefficient ( $C_d$ ).

# Experimental results

<b>Sample</b>	<b>Area (cm<sup>2</sup>)</b>	<b>Equivalent diameter (cm)</b>	<b>Drag coefficient</b>
<i>I</i>	11.62	3.85	0.71
<i>II</i>	12.37	3.97	0.66
<i>III</i>	16.21	4.54	0.98
<i>IV</i>	16.29	4.55	1.01
<i>V</i>	28.72	6.05	0.74
<i>VI</i>	38.14	6.97	0.62

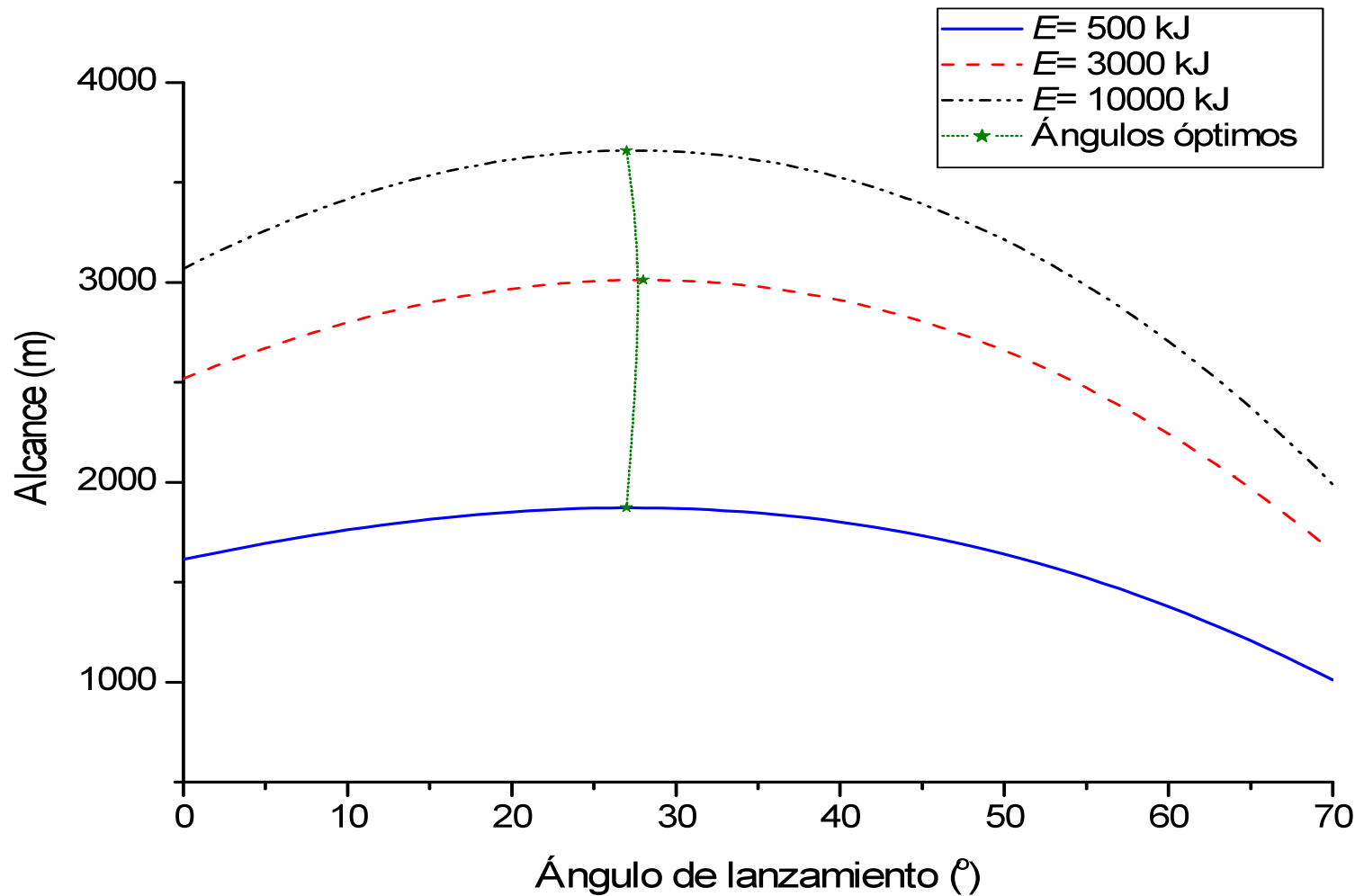
# Calibration using an explosion from Popocatépetl



Time = 33 seg

	Maximum range (m)	kinetic energy(x10 <sup>6</sup> J)
Measured	3700	-
This model	3650	2.2
$C_d = 1.0$	3000	2.5
<i>Eject!</i> Sphere	4750	1.1
<i>Eject!</i> Low cube	3430	2.6

# Range as a function of launching angle

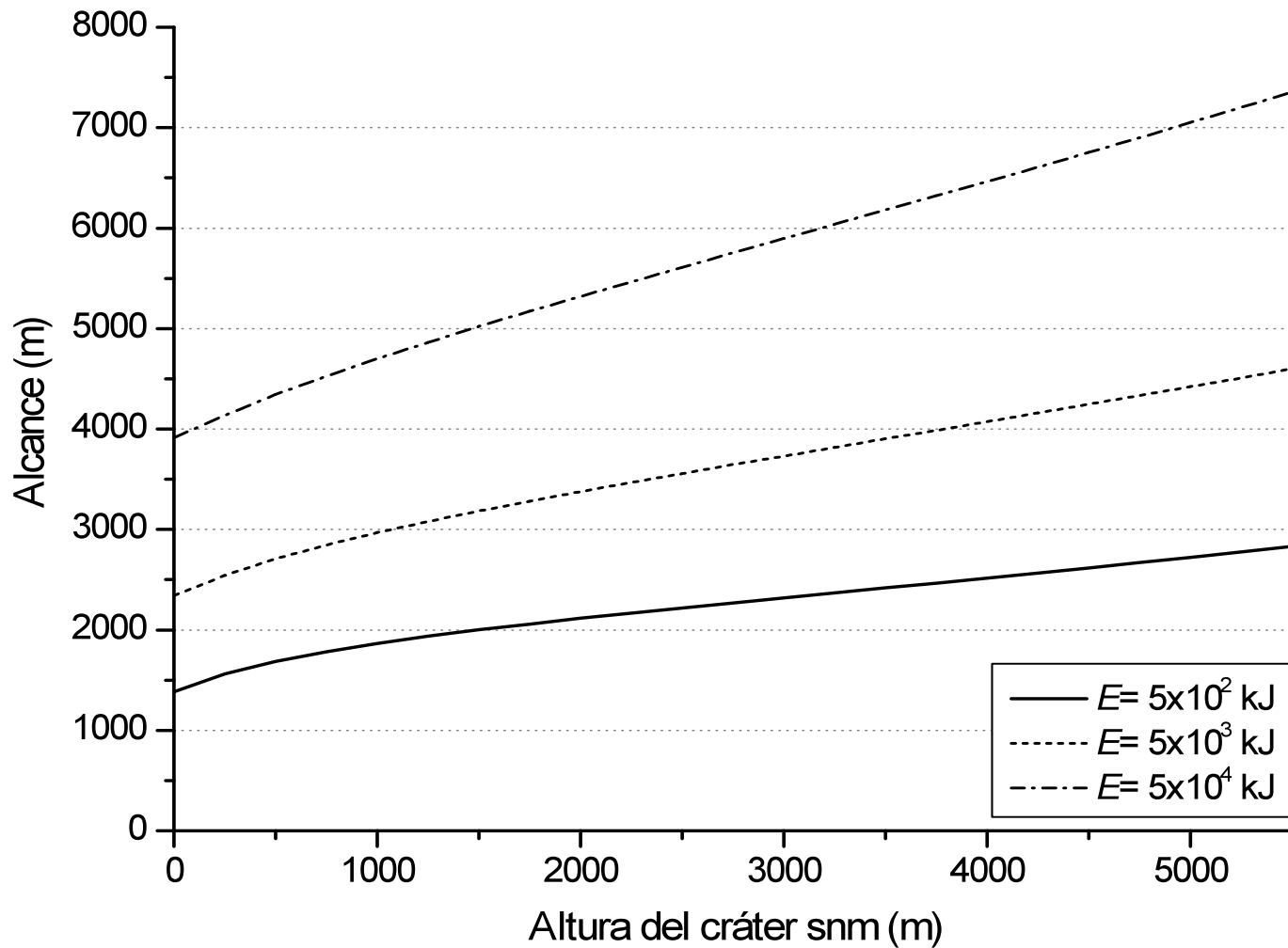




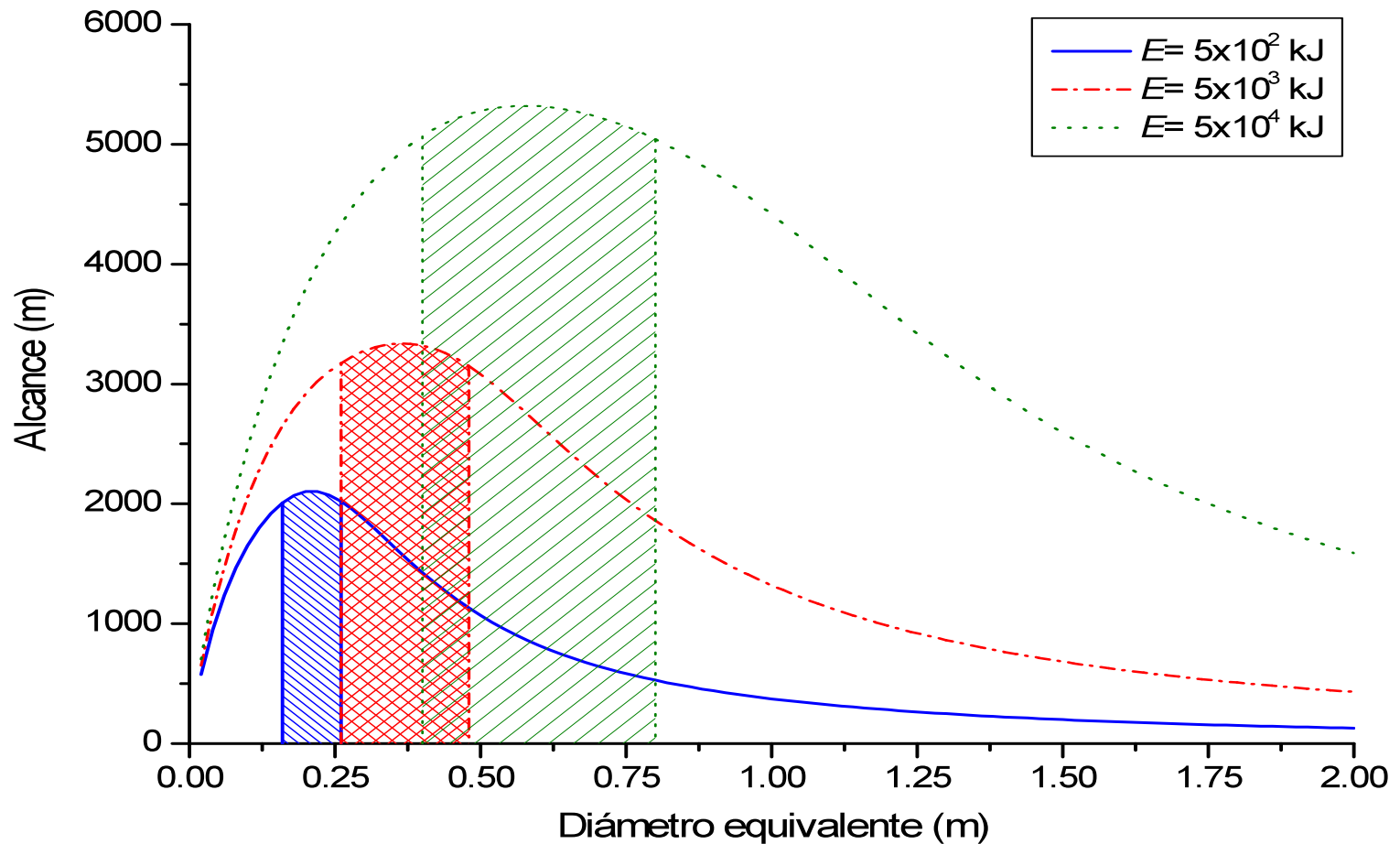




# Maximum range as a function of volcano's altitude

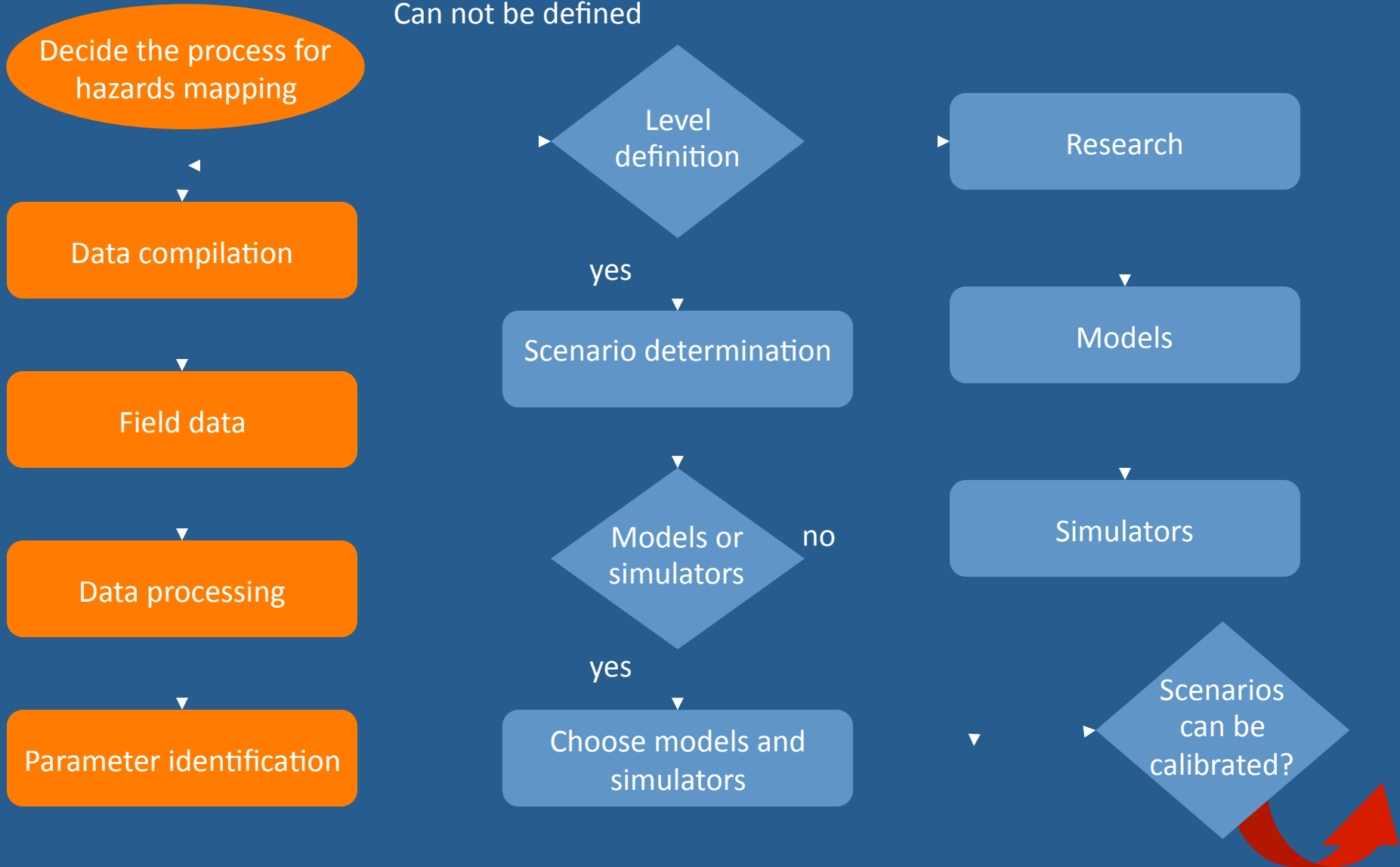


# Maximum range as a function of the average diameter for different launching energies



# Methodology: examples

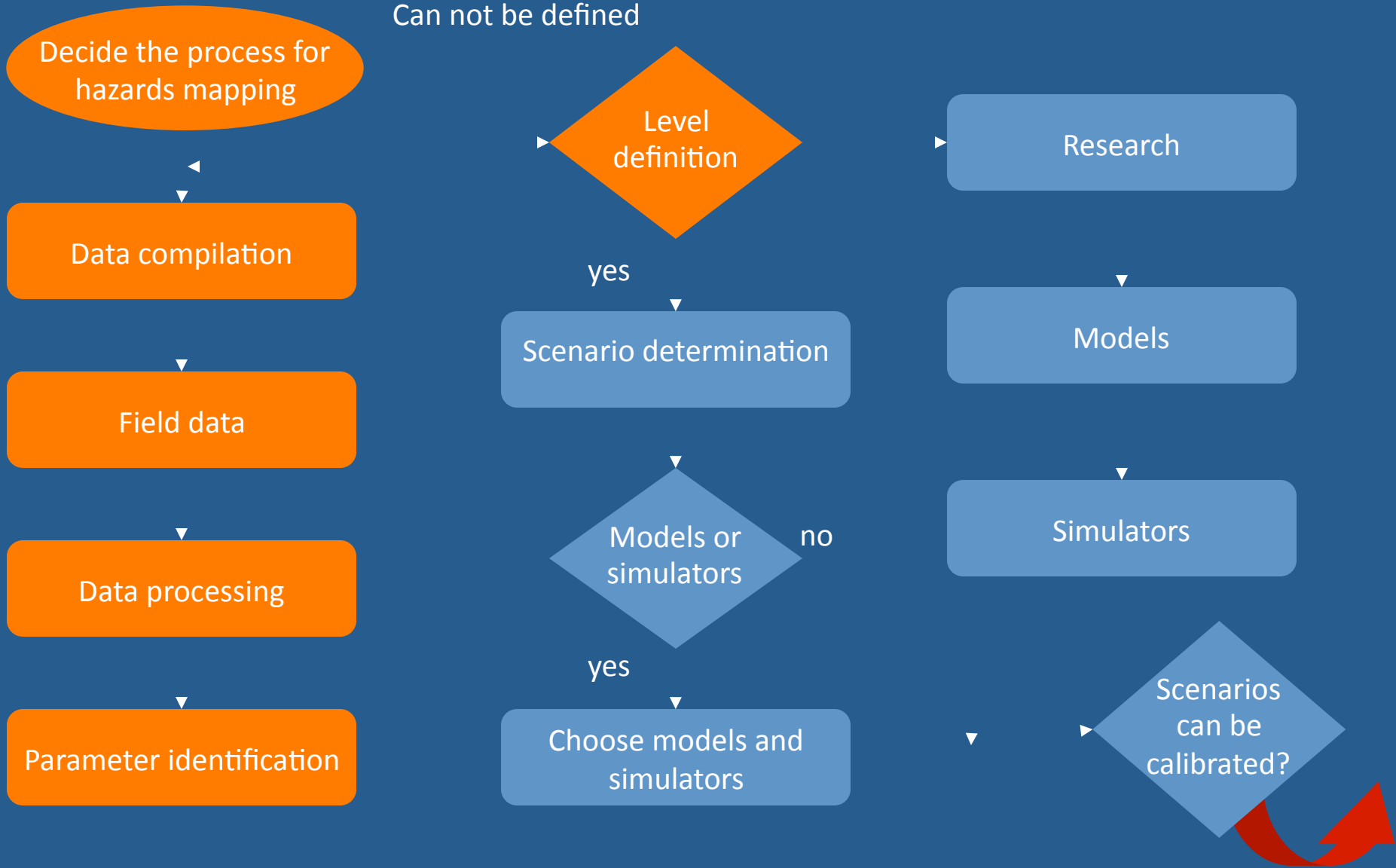
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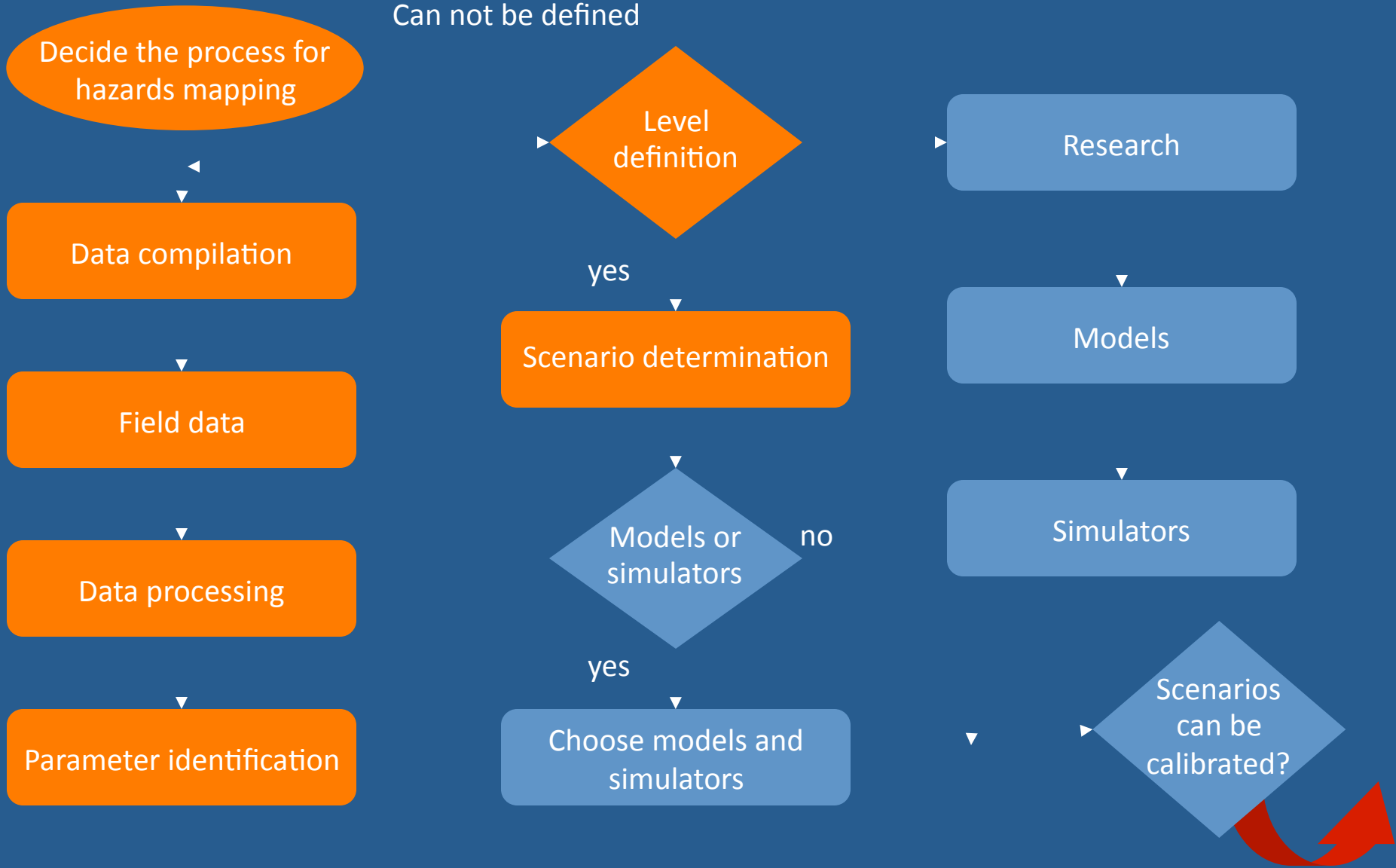
TLAMACAS



# Methodology: examples



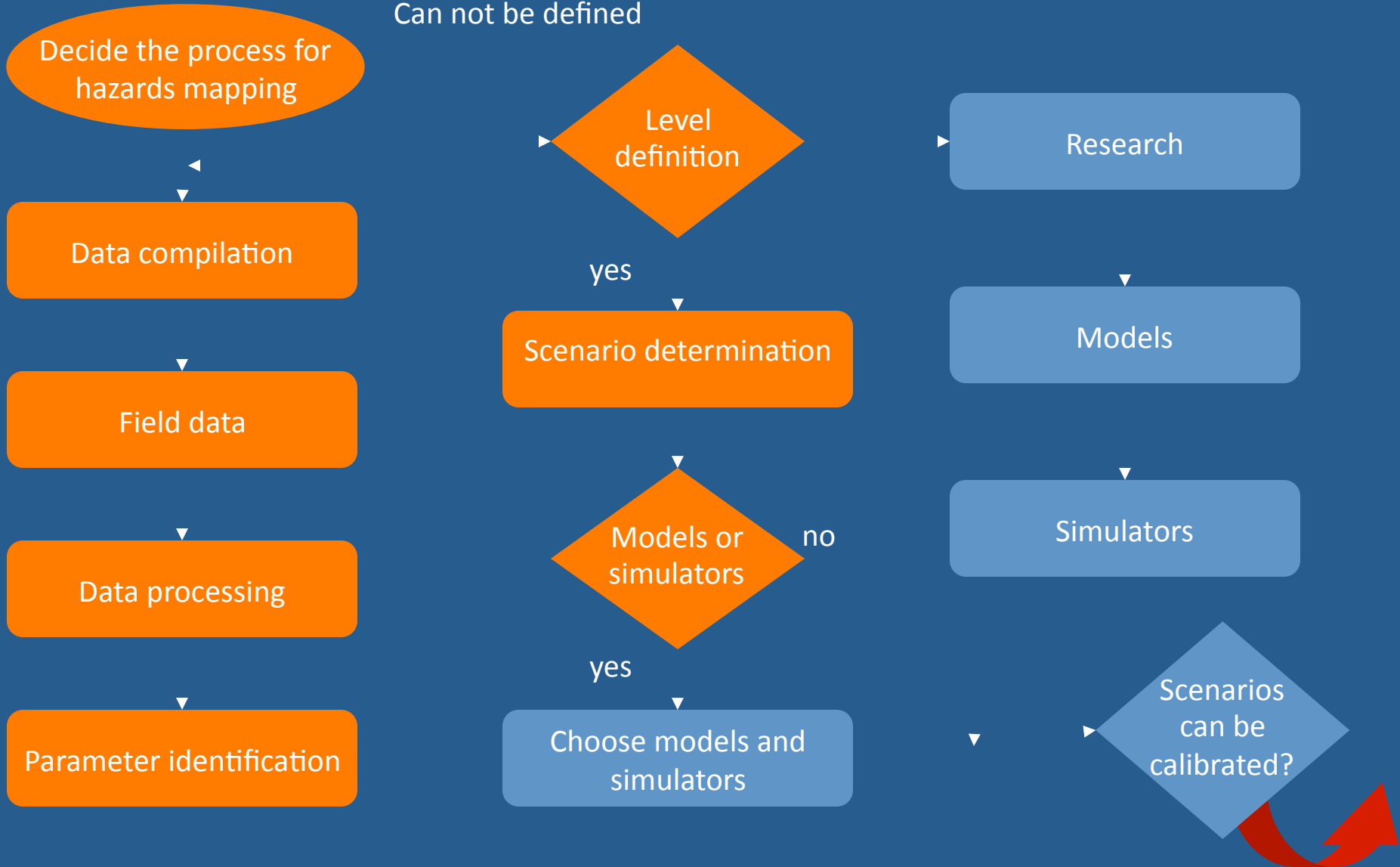
# Methodology: examples





# Methodology: examples

Can not be defined



# Movement Equation

$$\frac{d^2 \vec{r}}{dt^2} = \vec{g} + \frac{C_d \left( \left| \vec{v} - \vec{u} \right| \right) \rho_a(z) A \left[ \vec{v} - \vec{u} \right]^2}{2m} \hat{F}_a$$

$\vec{g}$  = aceleración de la gravedad

$C_d$  = coeficiente de arrastre

$\vec{v}$  = velocidad del balístico

$\vec{u}$  = velocidad del viento

$\rho_a$  = densidad del aire

$A$  = Área transversal

$m$  = masa

$\hat{F}_a$  = Vector unitario F. de arrastre

$$\frac{A}{m} = \frac{1}{\rho_b k D}$$

$D$  = diámetro característico

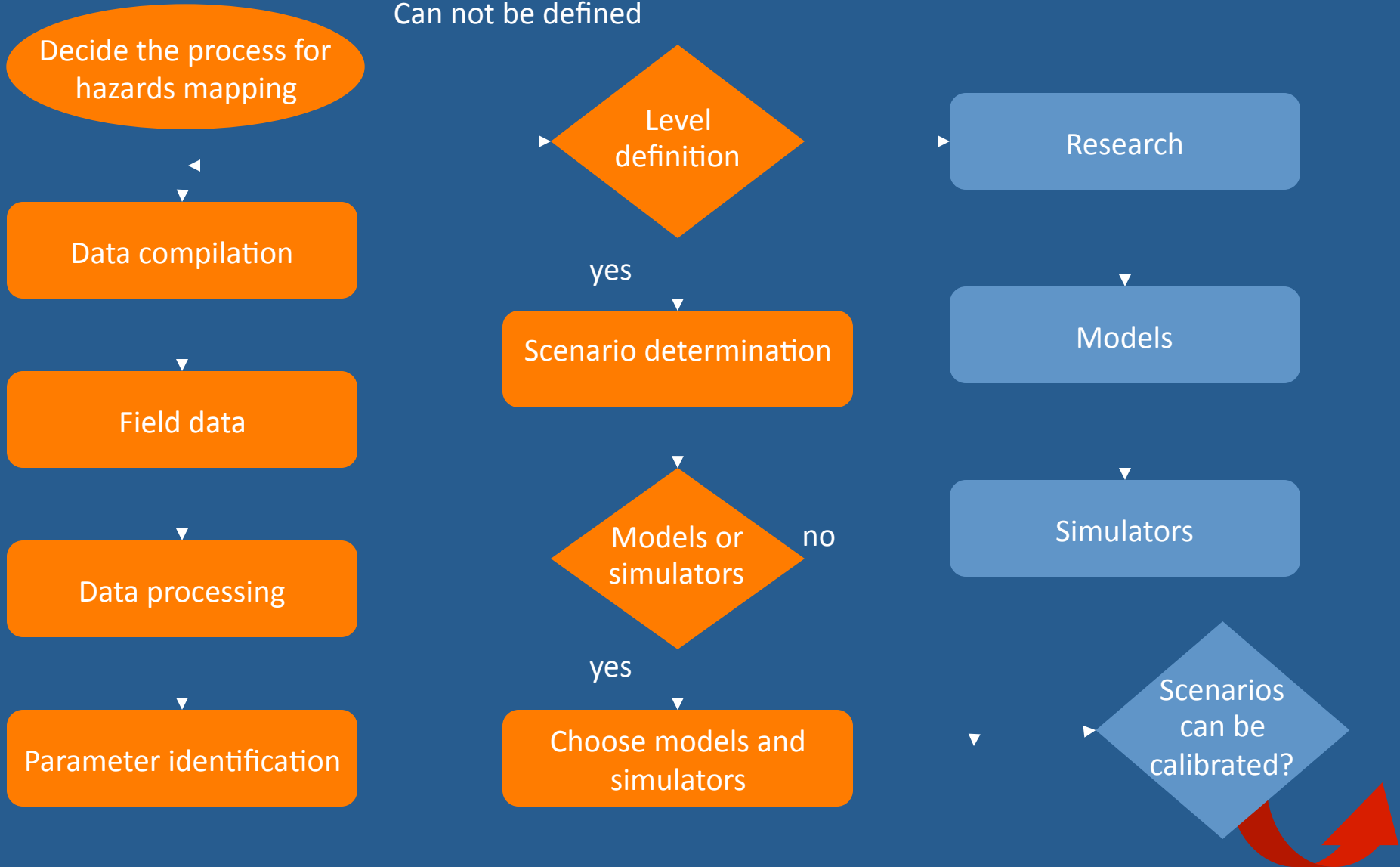
$\rho_b$  = densidad del balístico

$k$  = constante de forma

<i>Hazard</i>	<i>Associated kinetic energy (kJ)</i>	<i>Maximum range (km)</i>	<i>Corresponding diameter (cm)</i>	<i>Maximum altitude (km asl)</i>
High	$4.2 \times 10^3$	4.8	33	7.4
Intermediate	$5.5 \times 10^4$	7.6	57	9.6
Low	$7.0 \times 10^5$	13.8	95	14.7

# Methodology: examples

Can not be defined

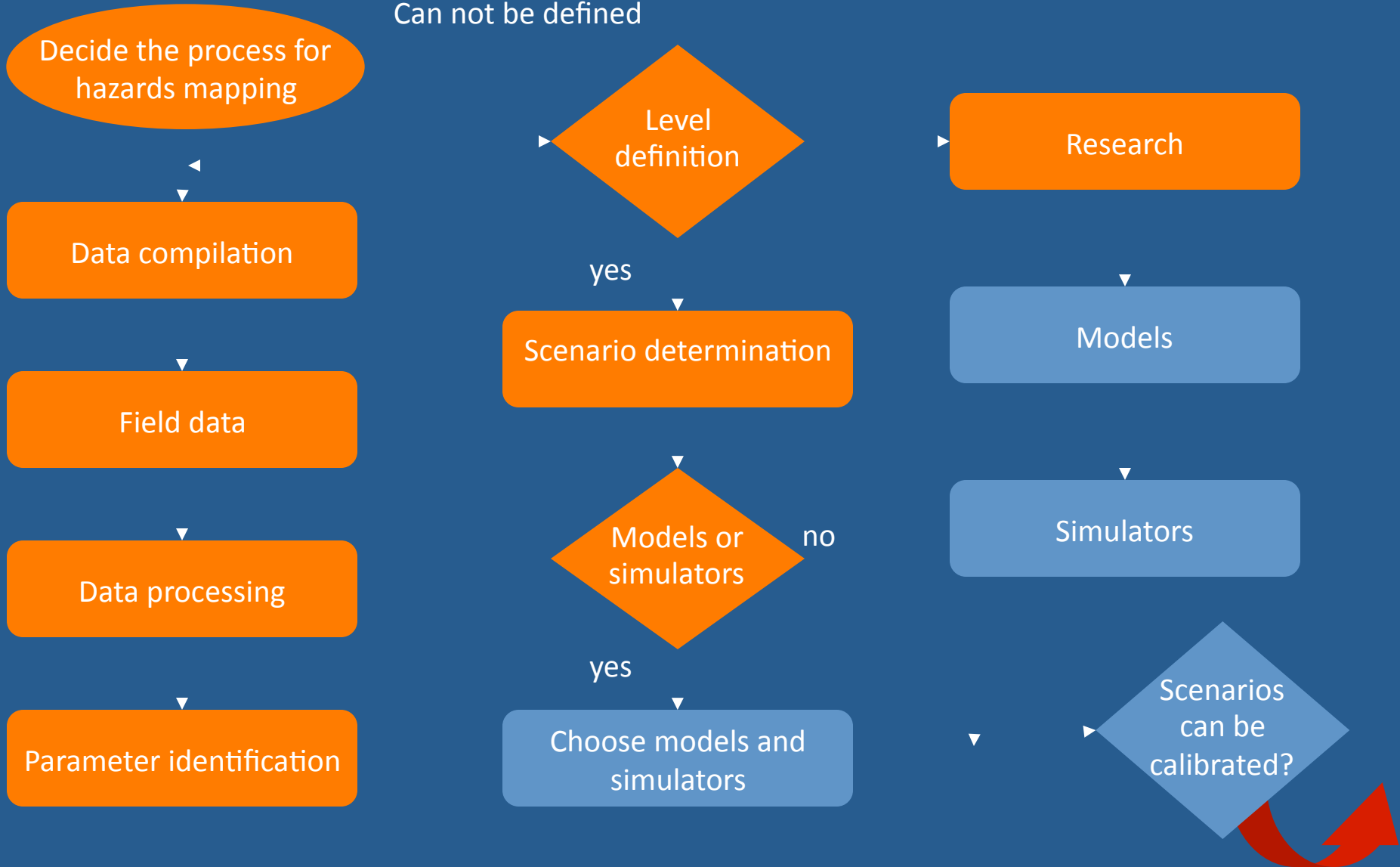


# Tools: depend on the process

- Ballistic projectiles
  - *Eject!*
  - *Ballistic*
- Ash fall
  - *ASHFALL*
  - *Fall3D*
- Pyroclastic flows
  - *Flow3D*
  - *Titan2D*
- Lahars
  - *LAHARZ*
  - *Flow3D*
  - *VOLCFLOW*
  - *DAN3D*
  - *MSF*
- Collapse
  - *Flow3D*
  - *Titan2D*

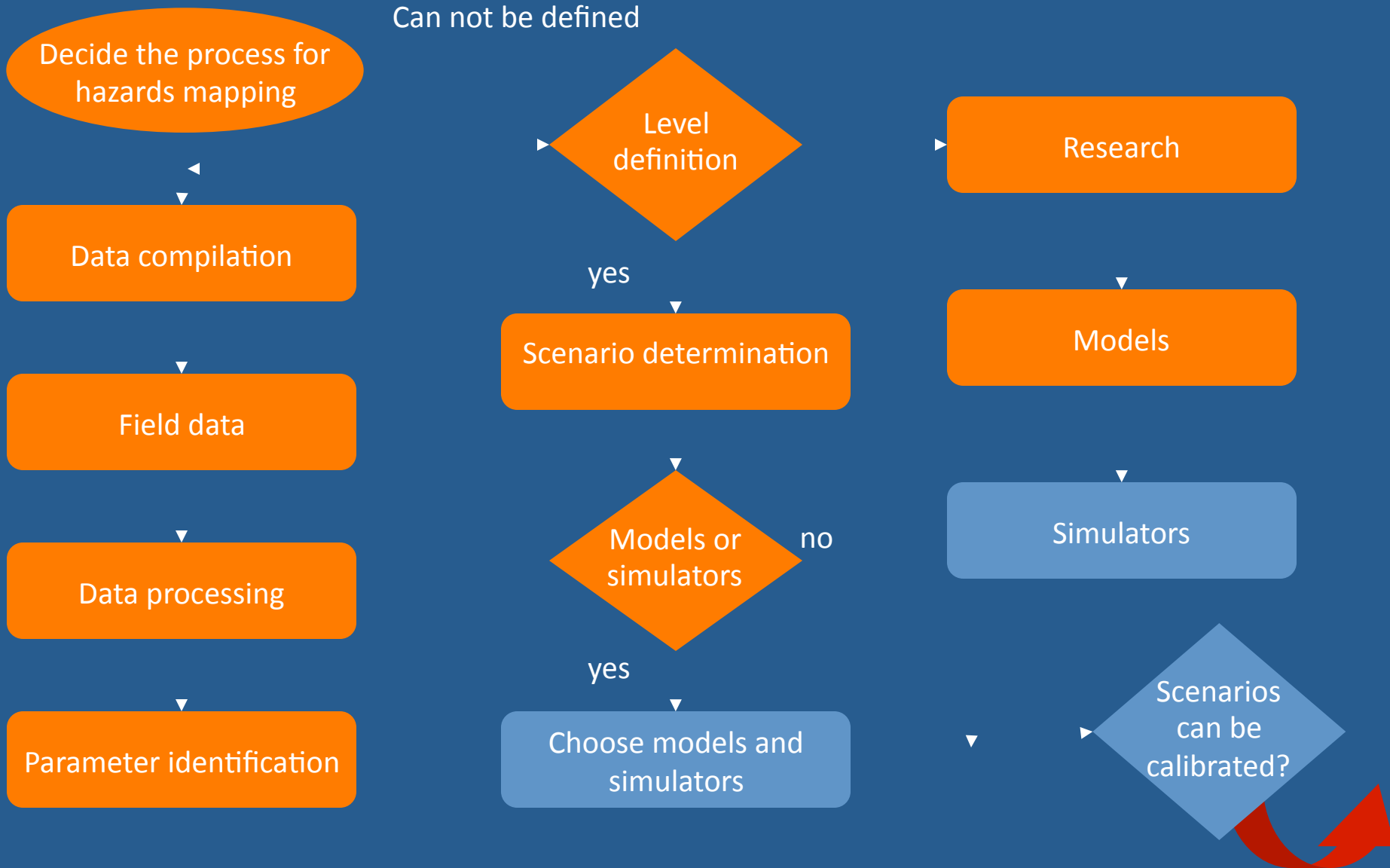
# Methodology: examples

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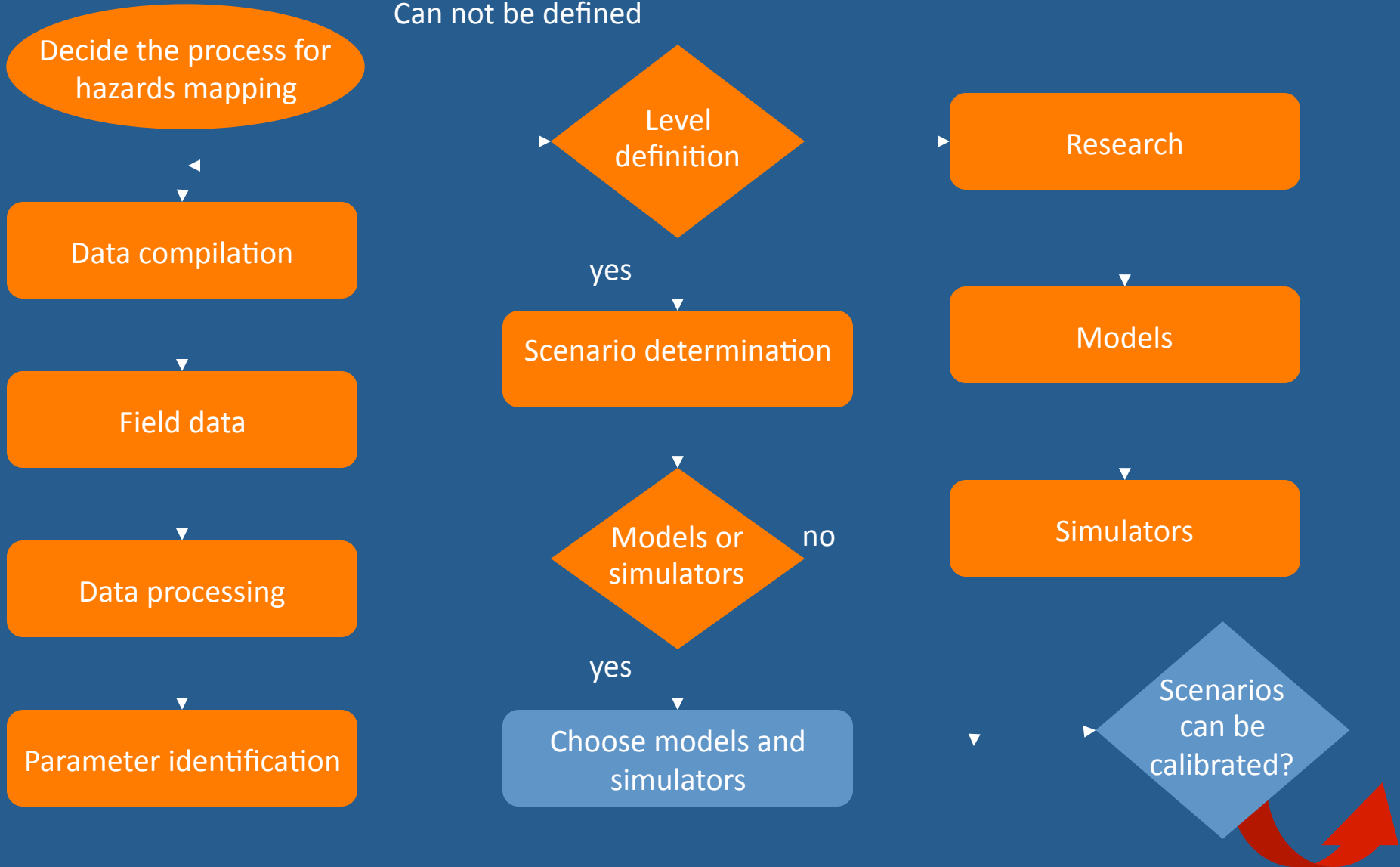


# Methodology: examples



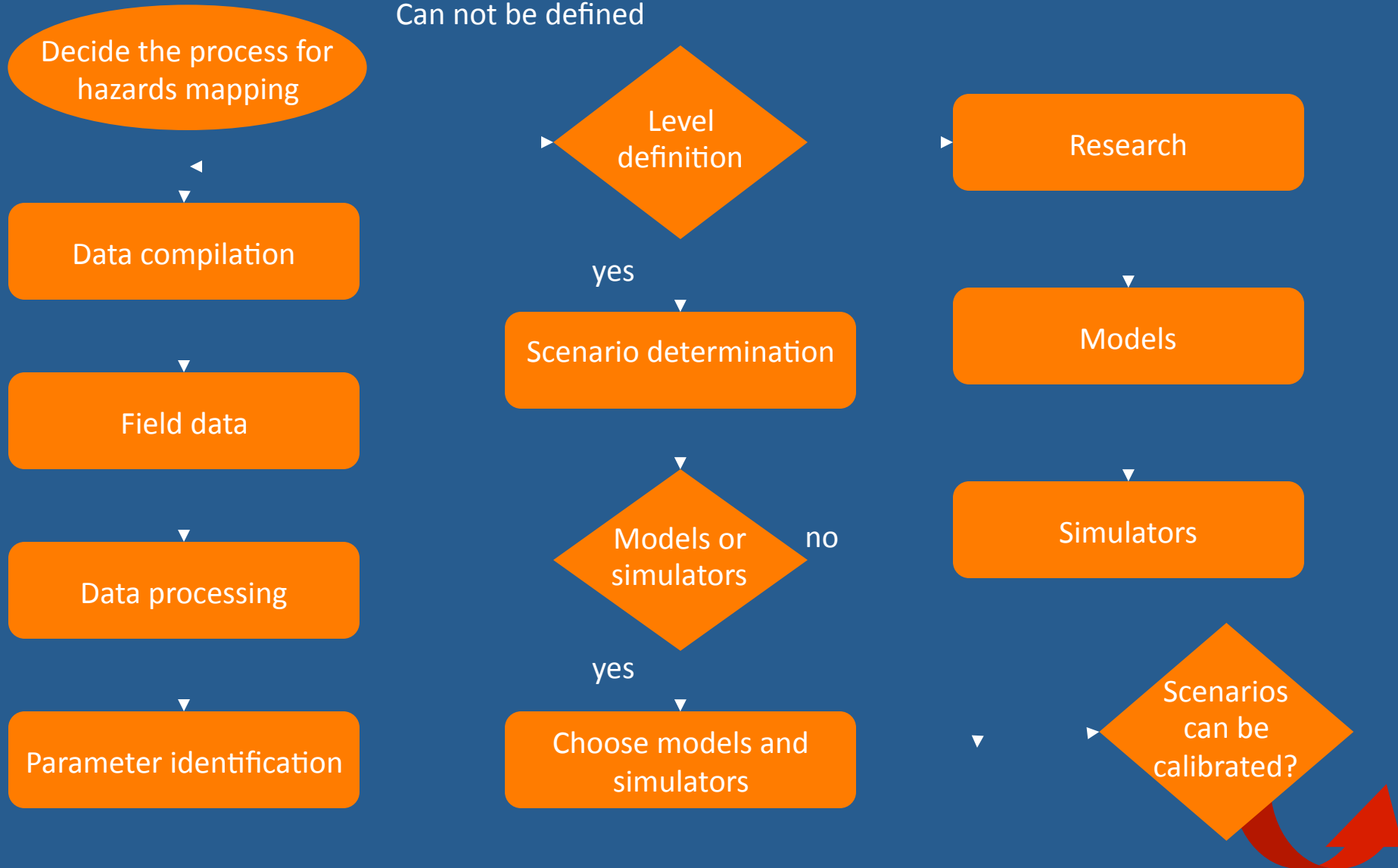
# Methodology: examples

Can not be defined



# Methodology: examples

Can not be defined



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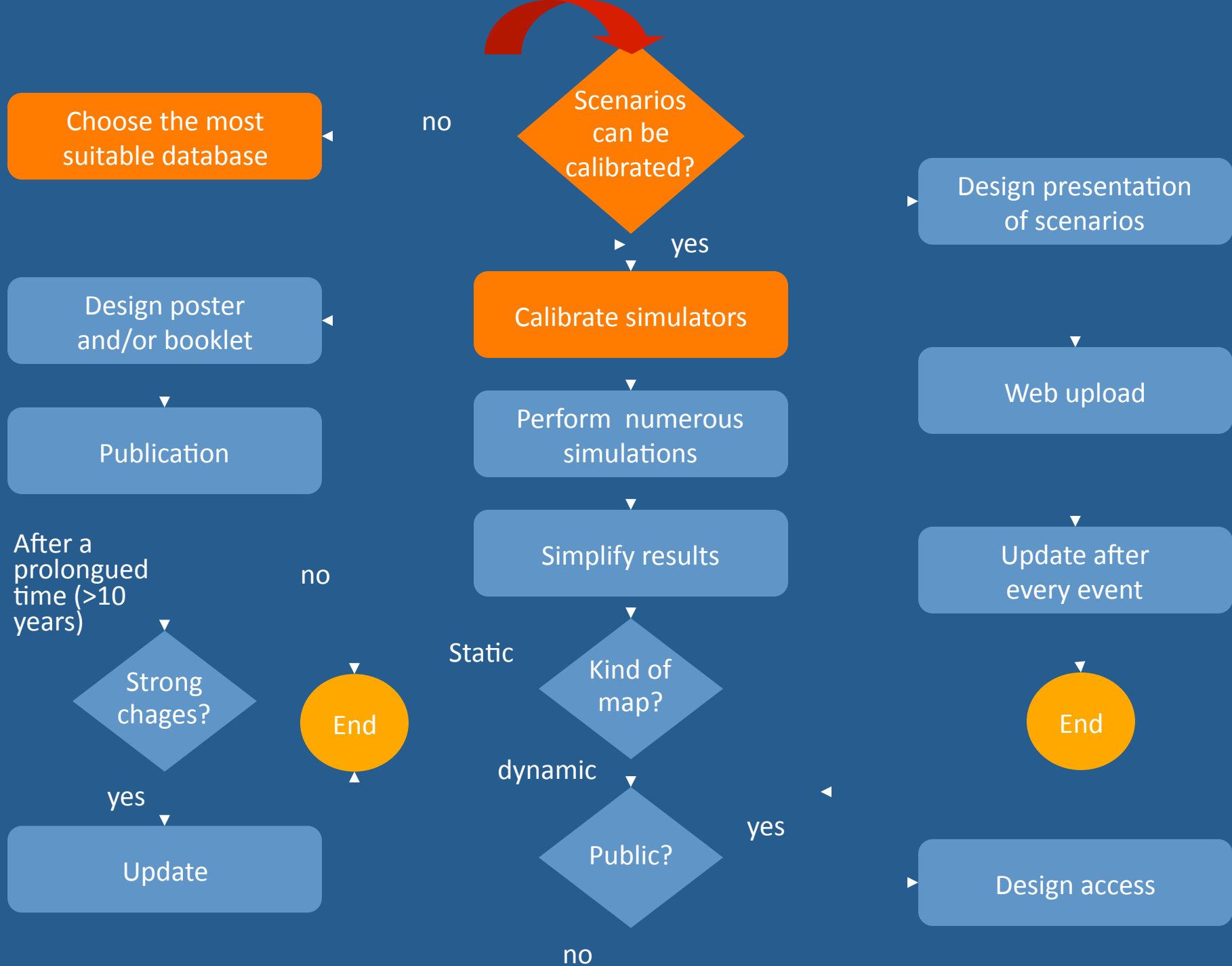
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## BALLISTIC

Programa para calcular la trayectoria y alcance  
de proyectiles balísticos volcánicos

Por: Miguel Angel Alatorre Ibarguengoitia  
Dr. Hugo Delgado Granados

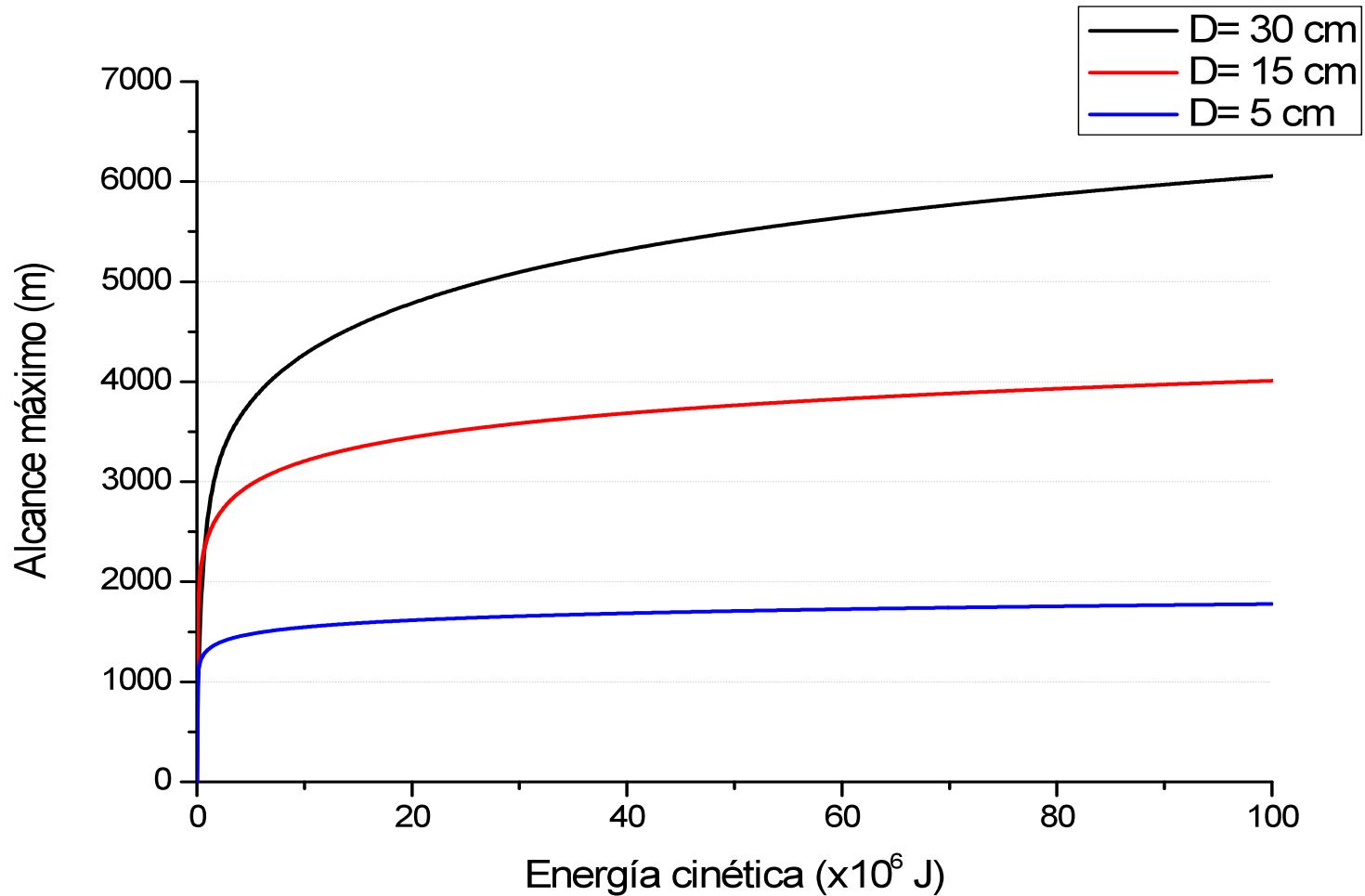




```
C:\ F:\curso\balis14\Debug\balis14.exe
Que es lo que quieres hacer?
(1) Calcular la energia inicial de una balistico
(2) Calcular el alcance maximo para una energia dada
(3) Calcular las zonas aereas de peligro
1
Condiciones iniciales
Utilizar en todos los casos punto decimal
Dime la energia inicial en kJ
-
```

Launching angle	Wind velocity	Crater's altitude	Altitude fall	Diameter	Density	Range
40.	0	5000. m	2882. m	.54 x .32 x .23 average: 0.32 m	2500. kg/m3	

# Maximum range as a function of the energy for different diameters





# Ballistics used to define the hazard scenarios for the Popocatépetl hazards map

High probability scenario (Vulcanian)

Launching angle	Wind velocity	Crater's altitude	Fall altitude	Diameter	Density	Range
45.	10	5000. m	2820. m	0.50 m	2500. kg/m <sup>3</sup>	11000

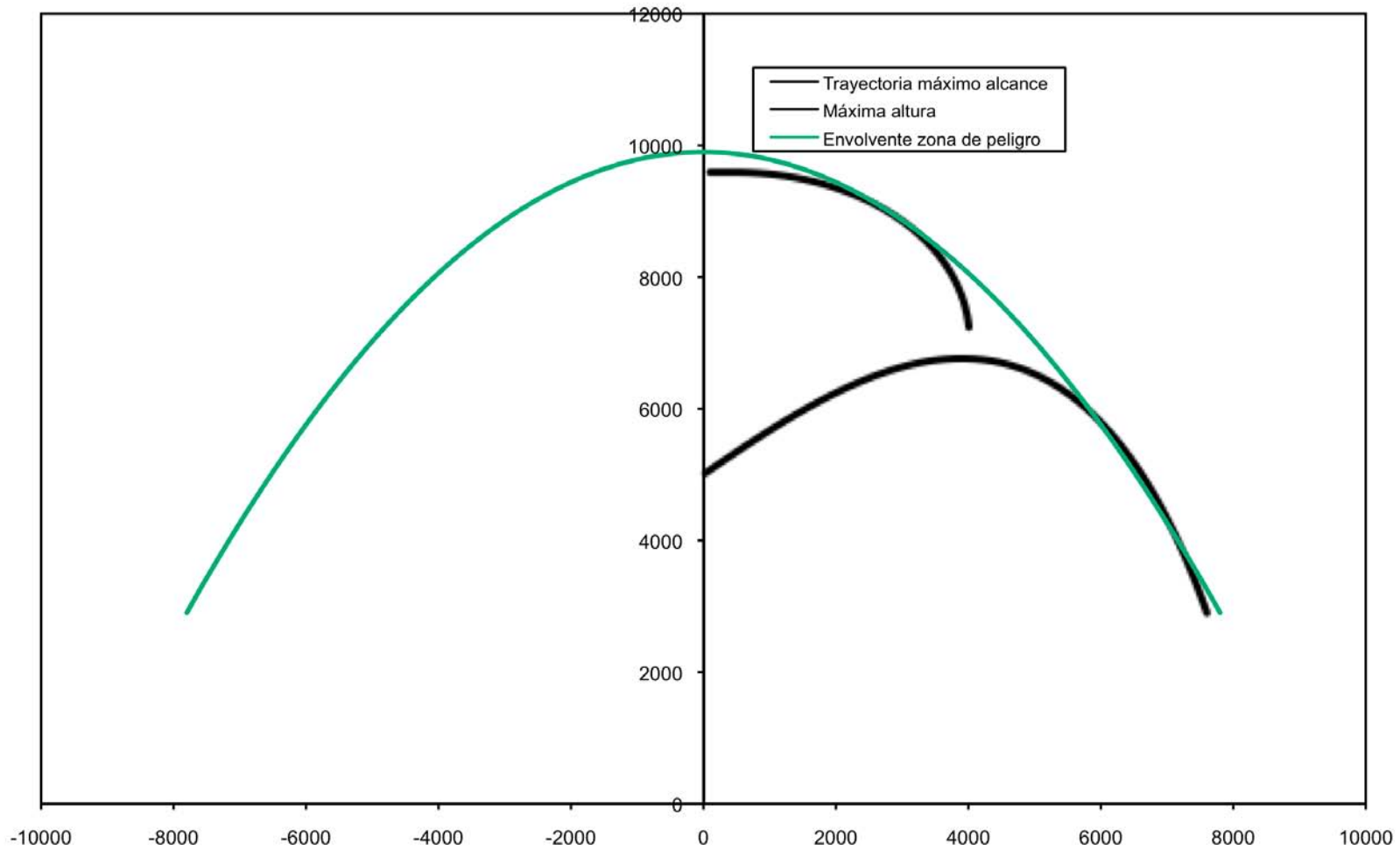
Maximum range

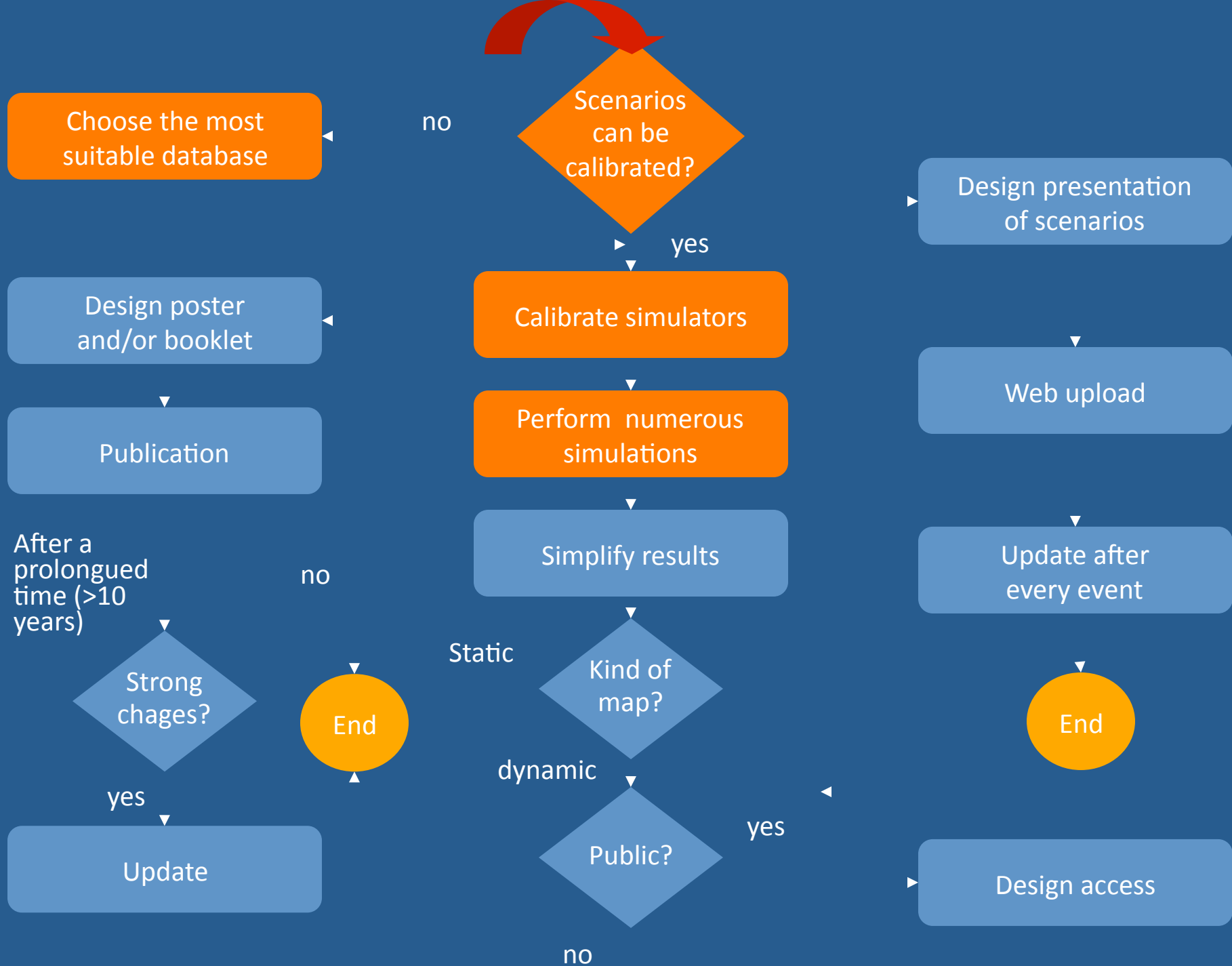
Launching angle	Wind velocity	Crater's altitude	Fall altitude	Diameter	Density	Range
35-50.	20	5000. m	15000. m	0.90- 1.3 m	2500. kg/m <sup>3</sup>	

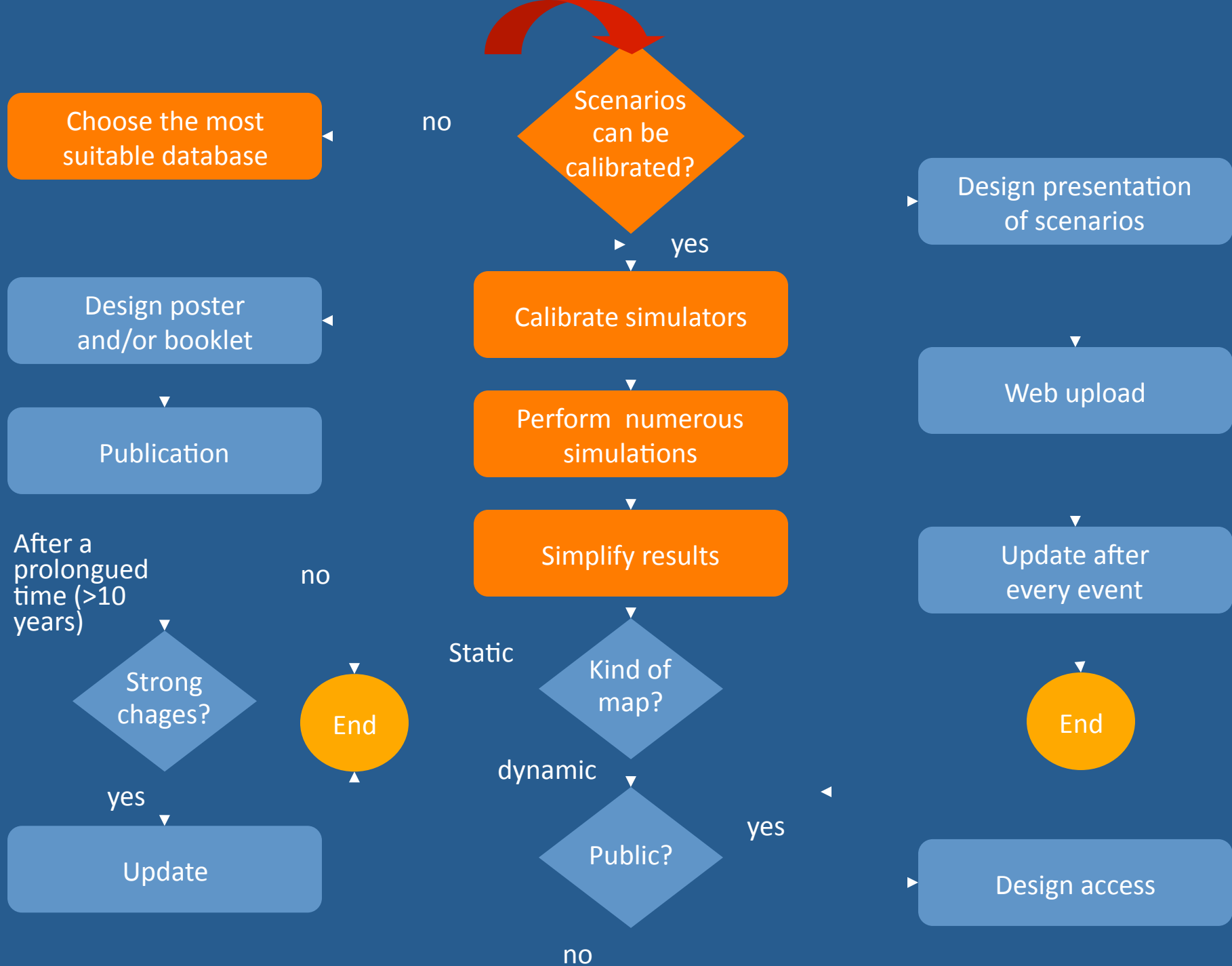
# Parameters of the hazards map by ballistic projectile impact

## Popocatépetl volcano

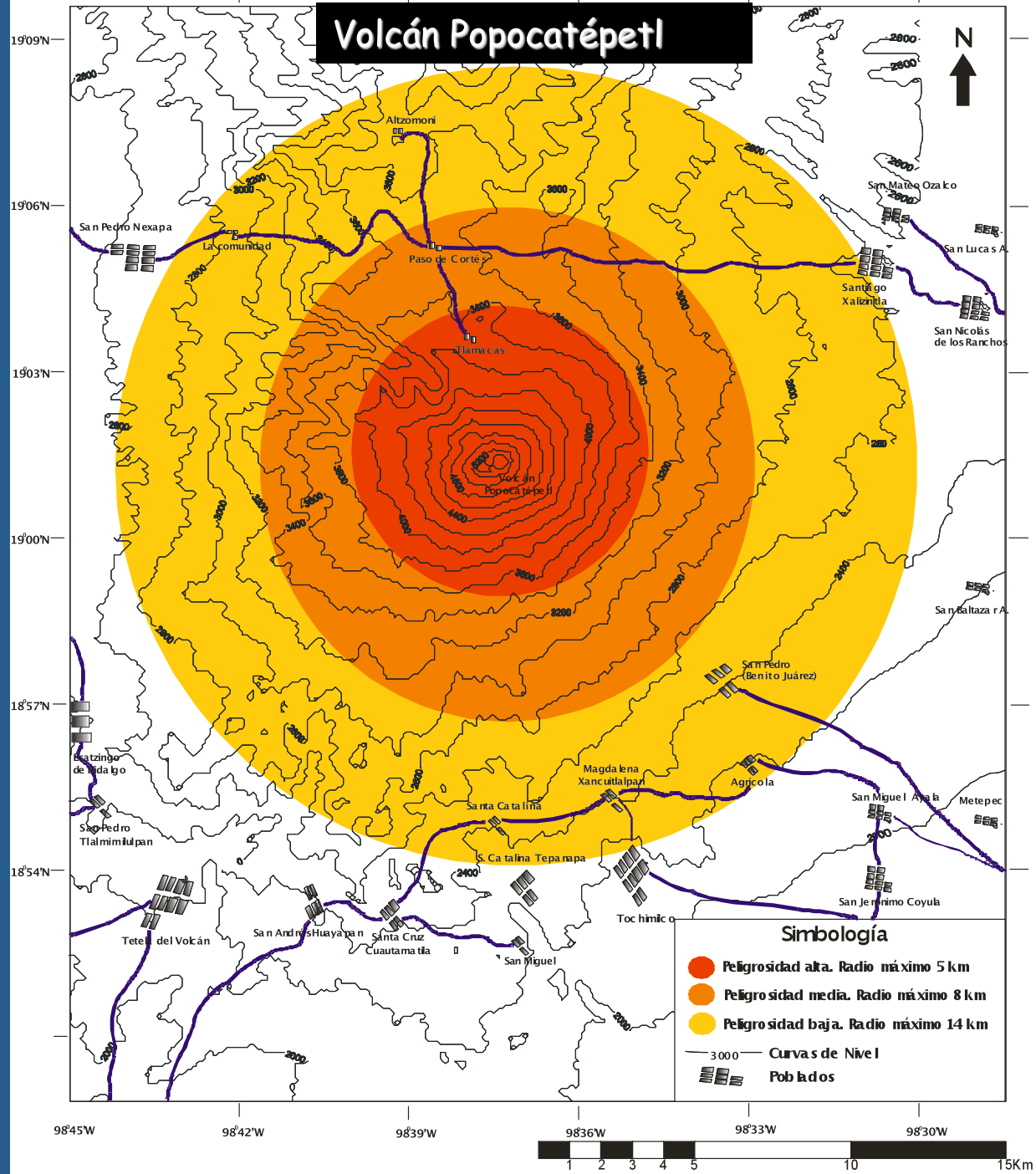
<i>Hazard</i>	<i>Associated kinetic energy (kJ)</i>	<i>Maximum range (km)</i>	<i>Corresponding diameter (cm)</i>	<i>Maximum altitude (km asl)</i>
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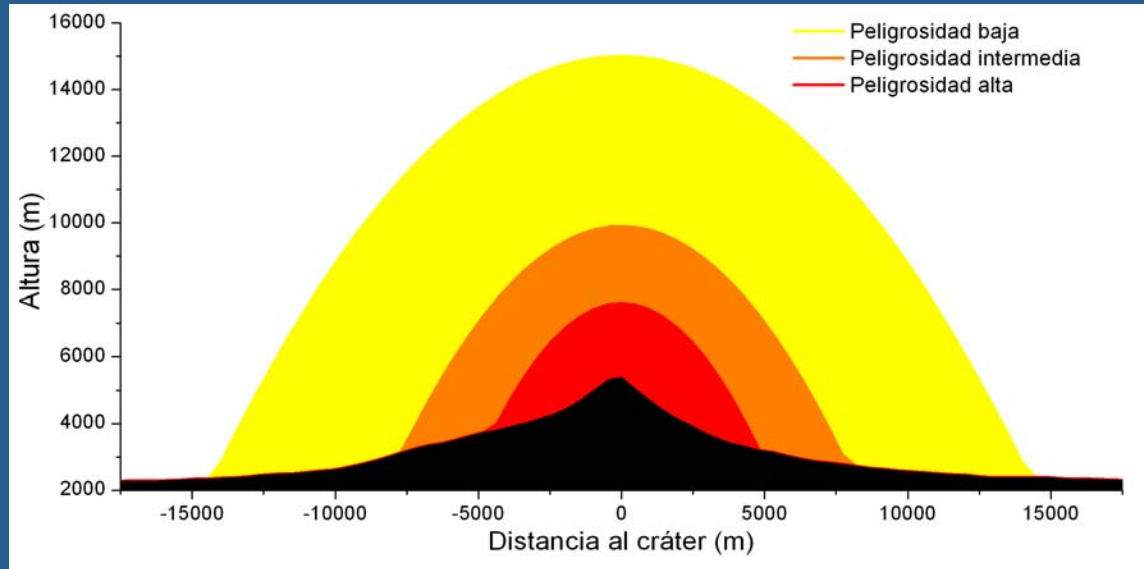


# Volcán Popocatepetl

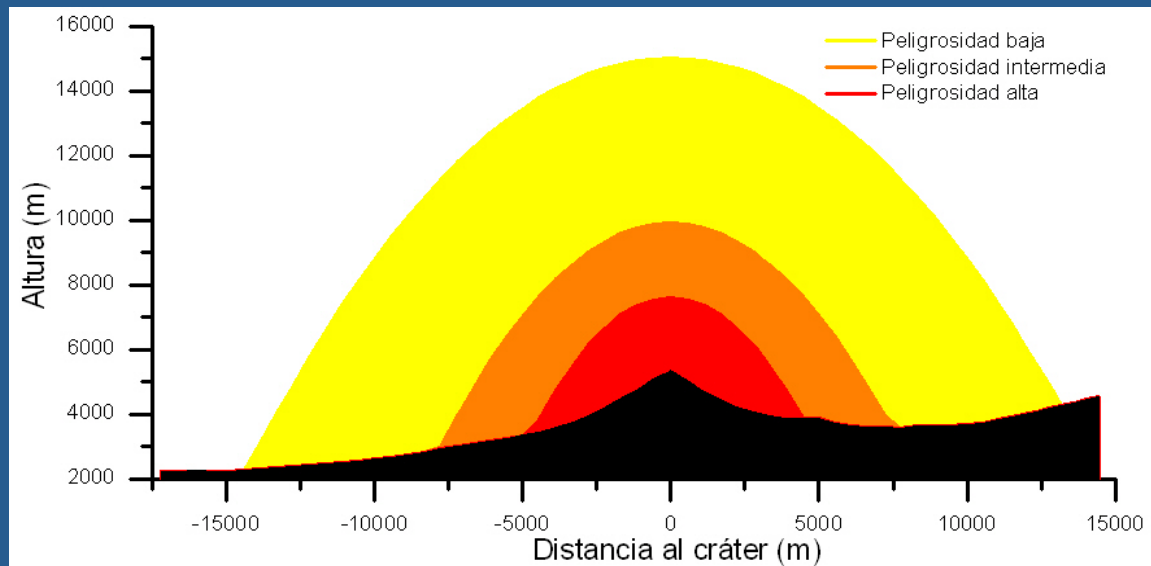


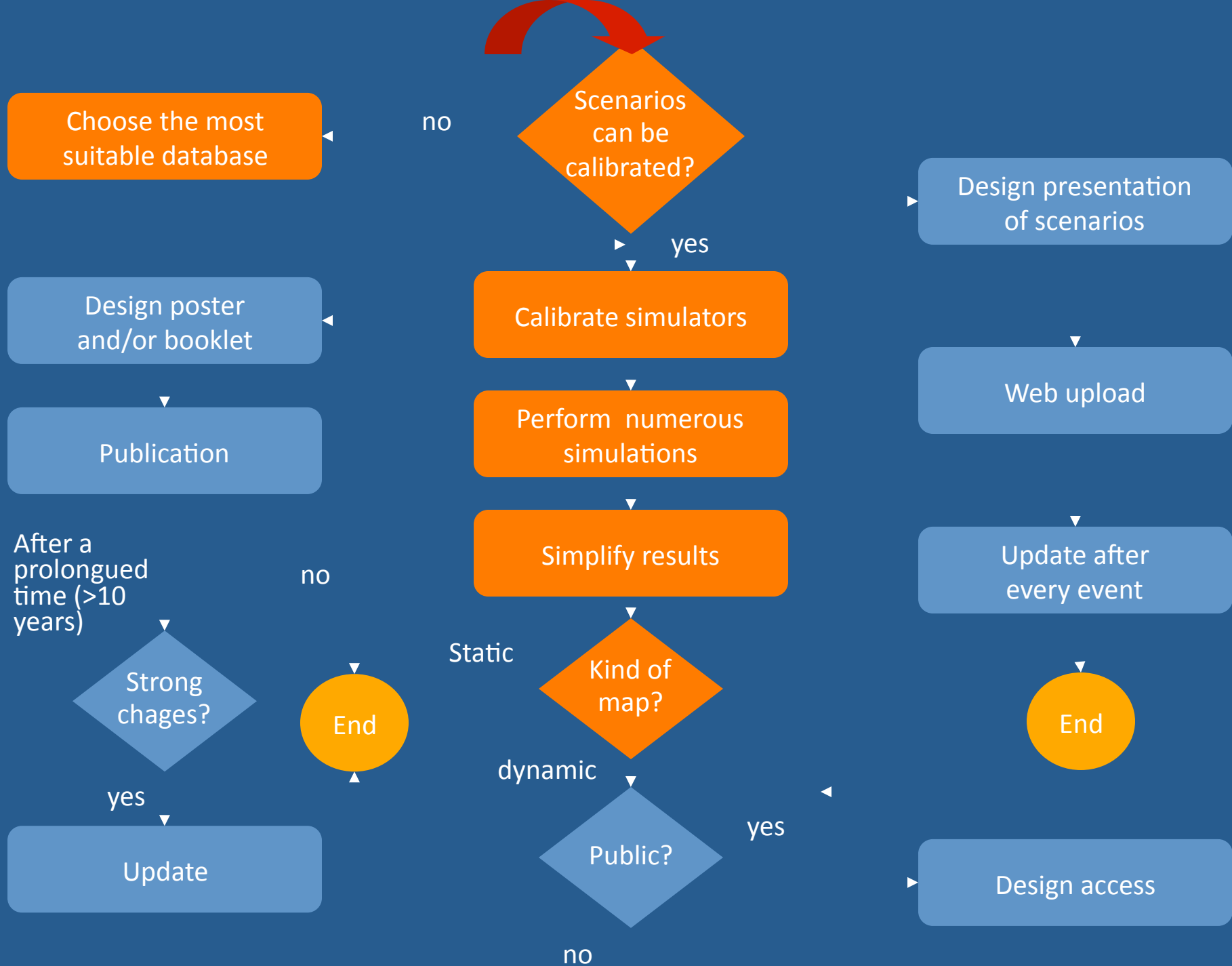
# Volcán Popocatepetl

Perfil Oeste-  
Este

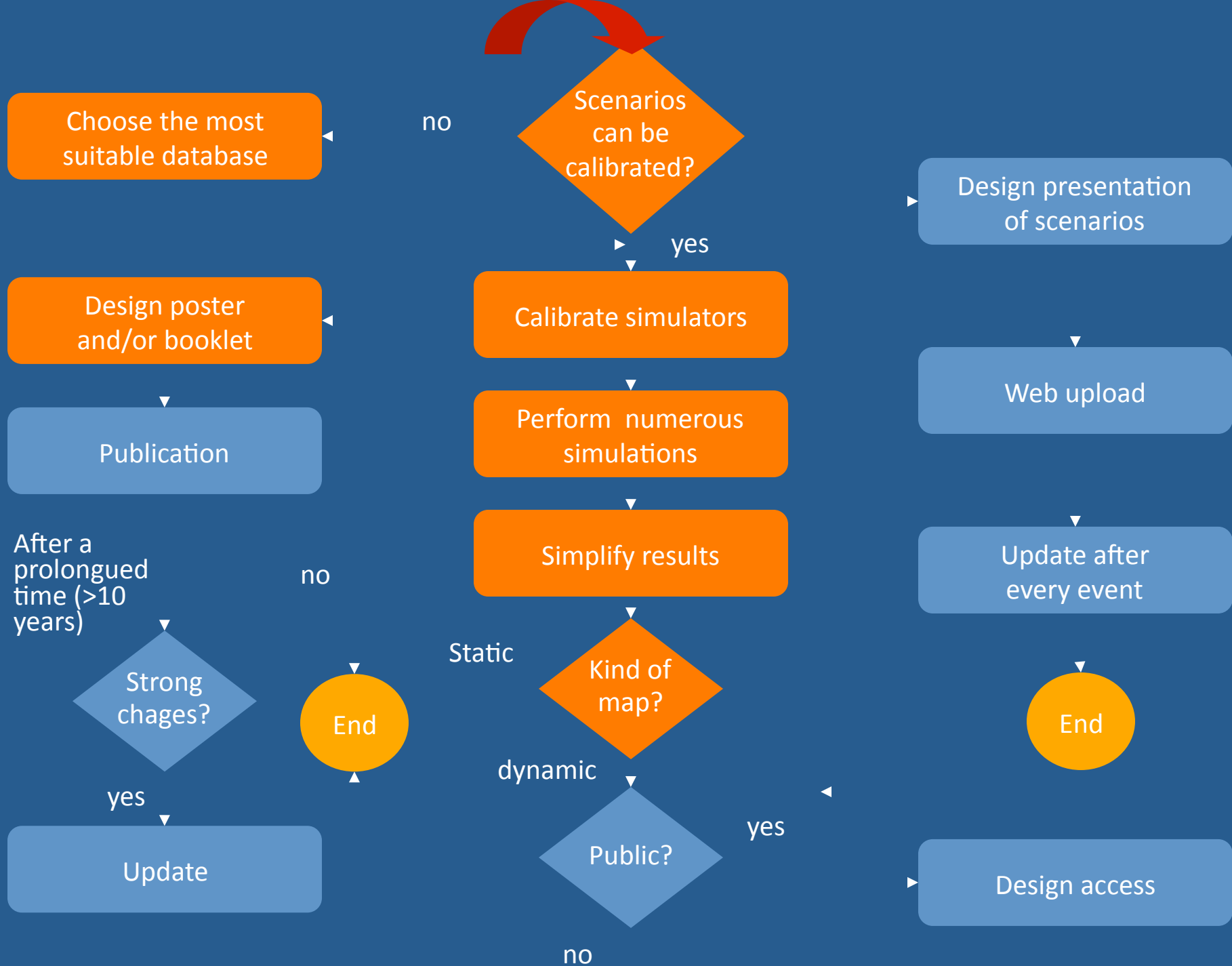


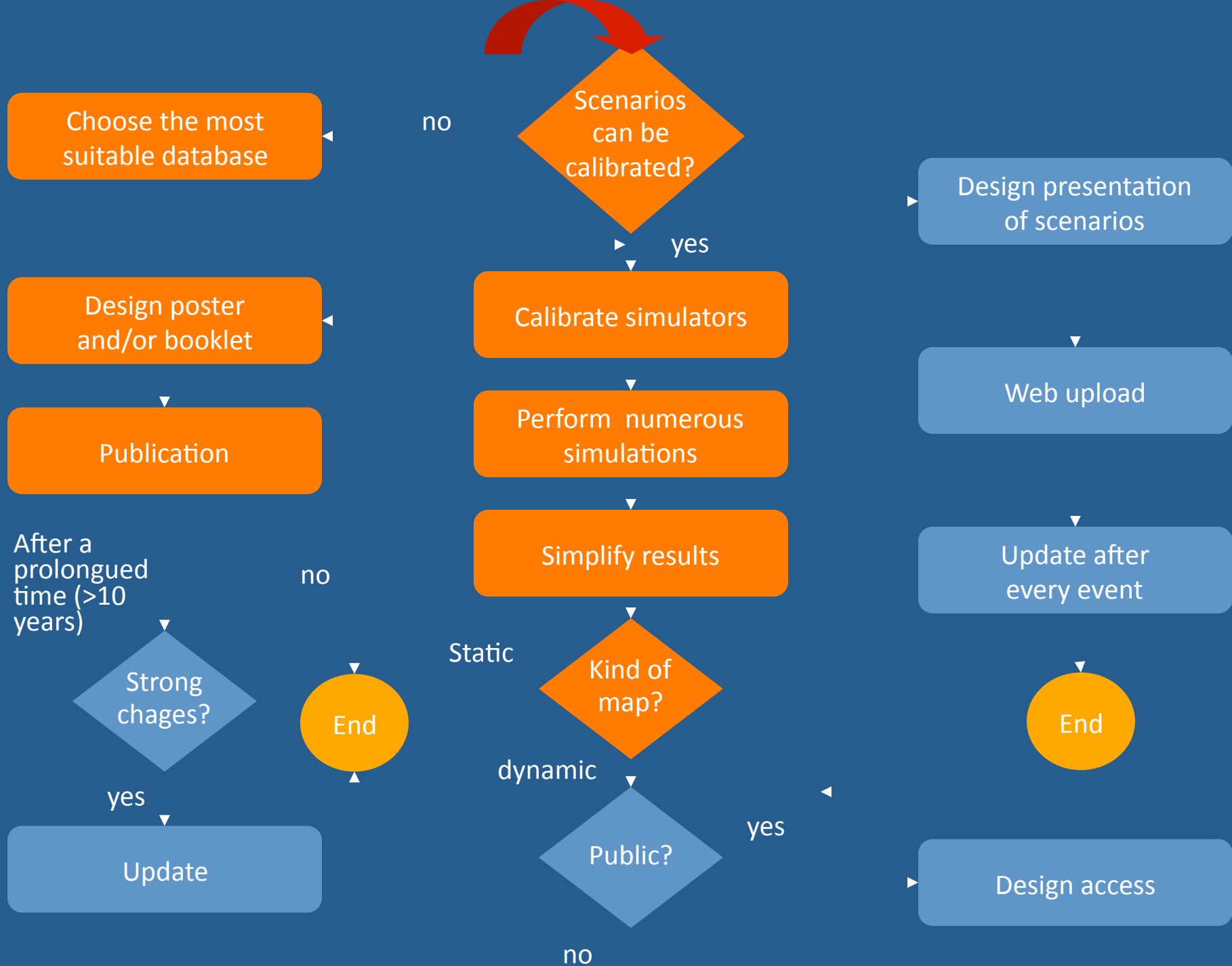
Perfil Sur-  
Norte





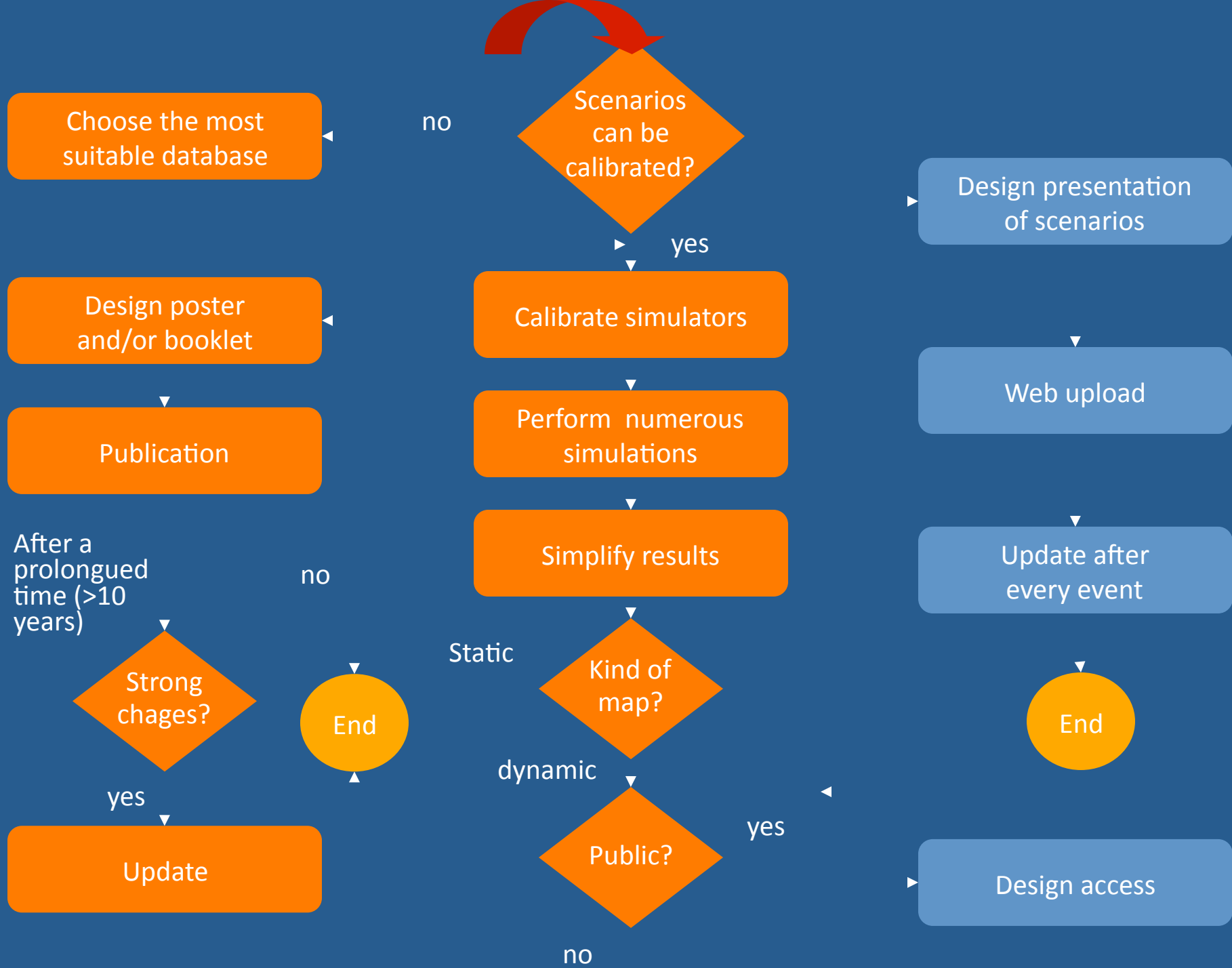


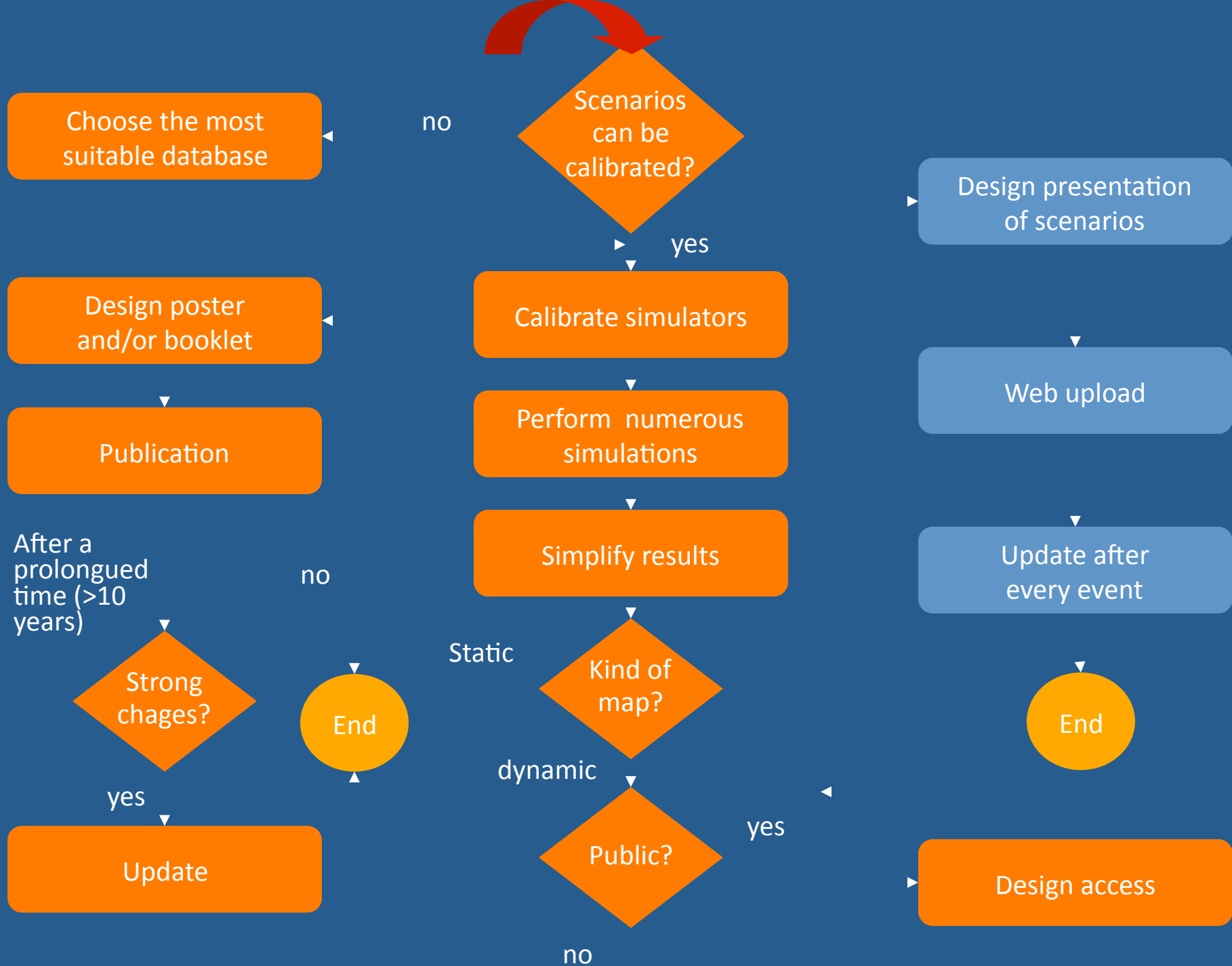


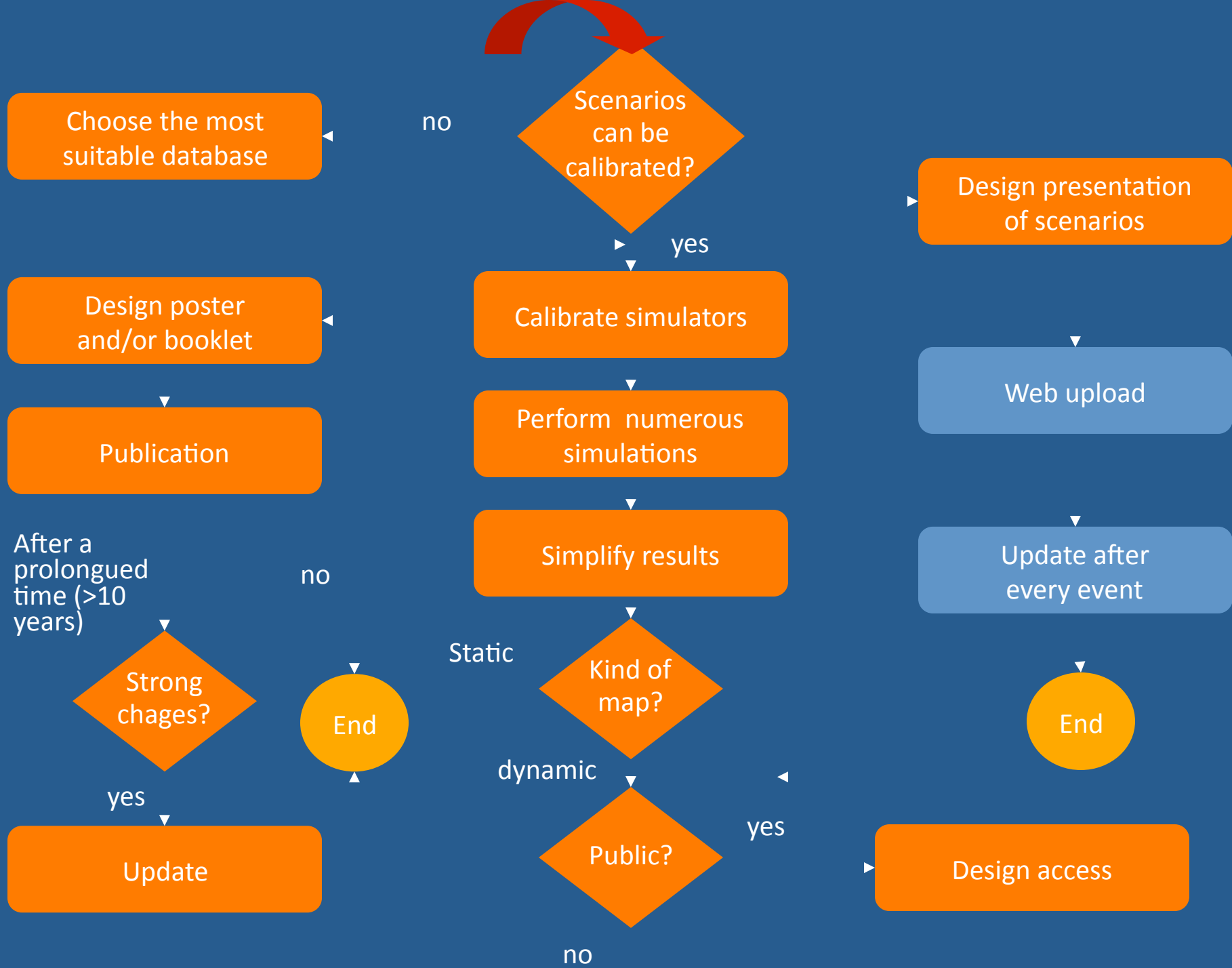


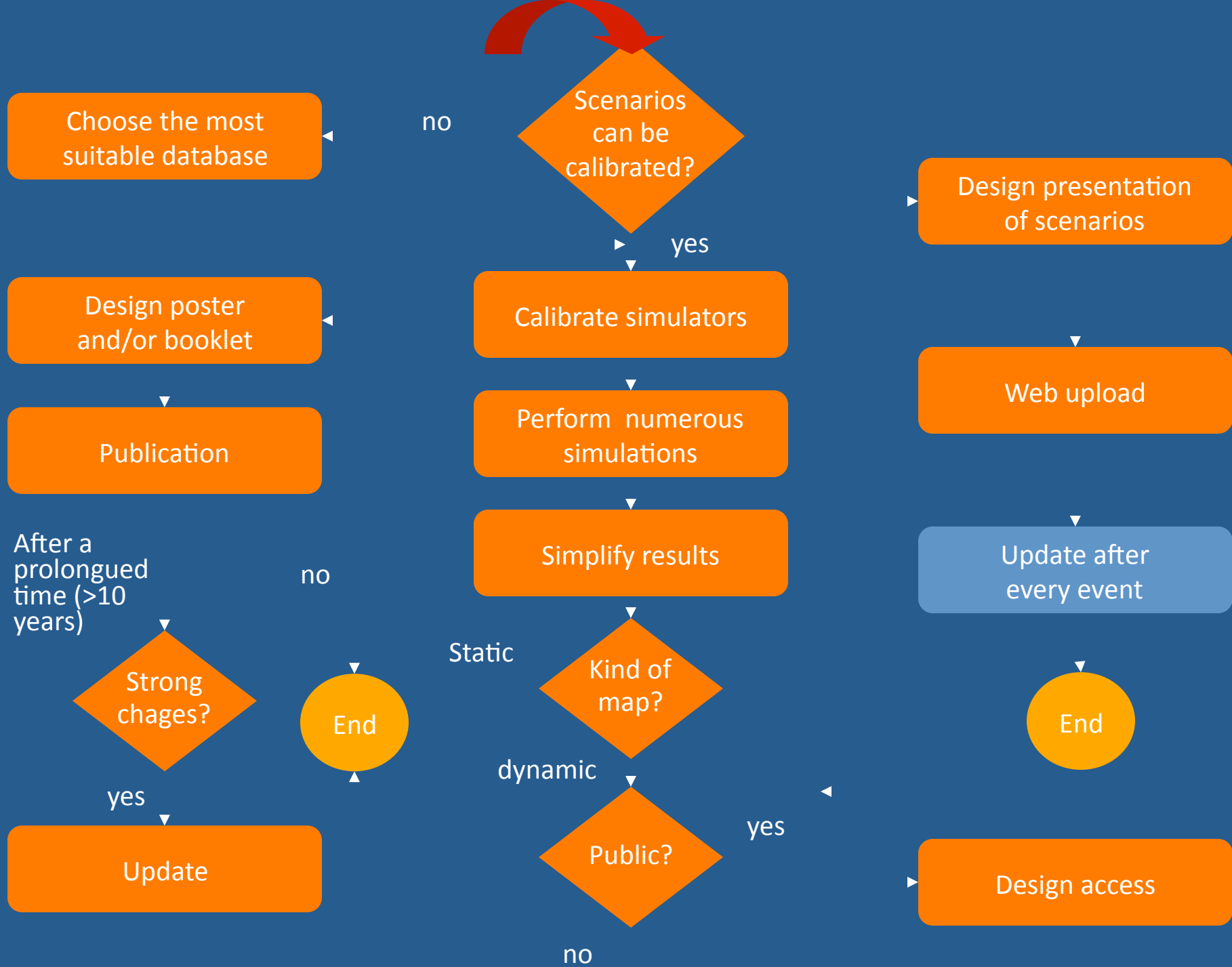



























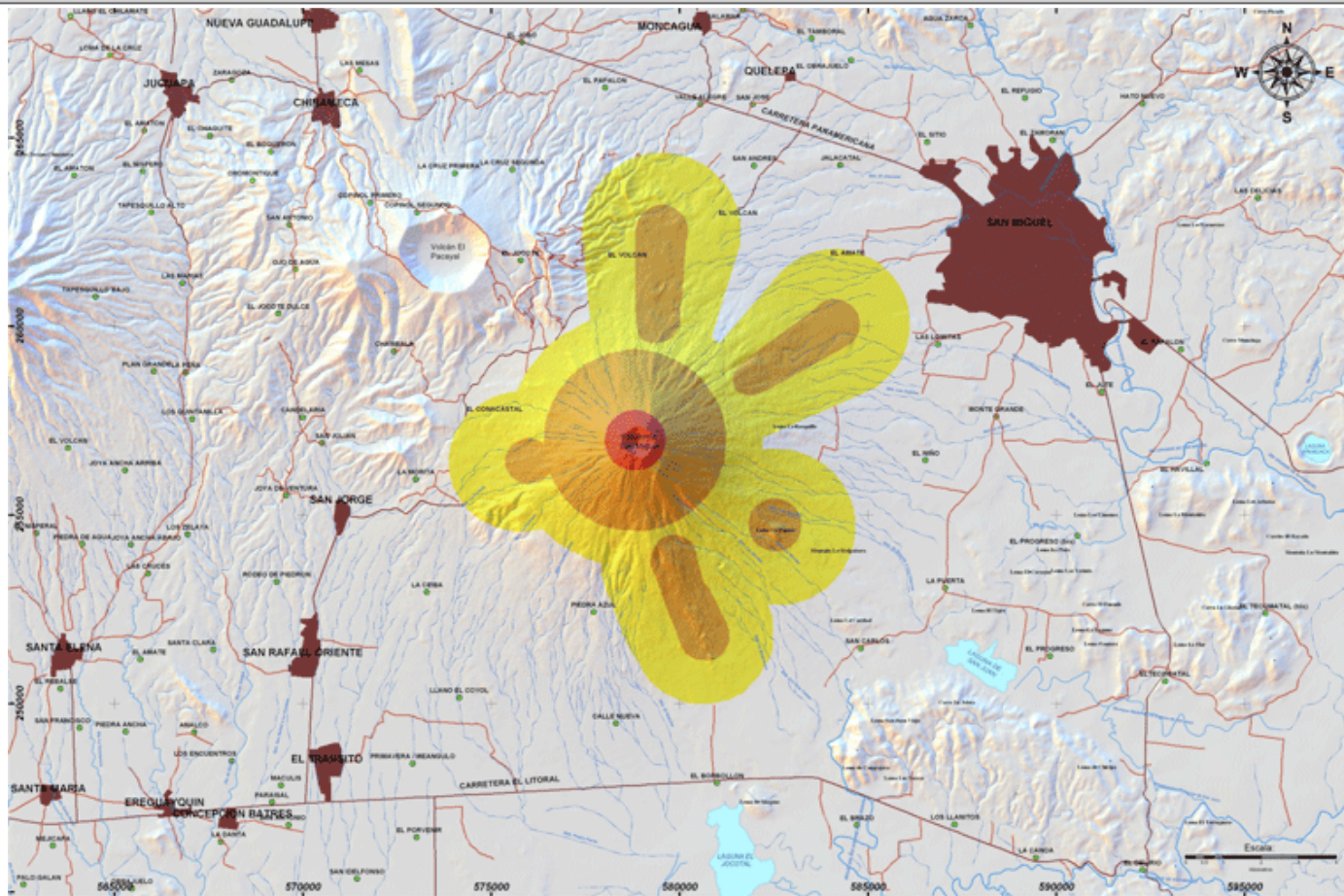






Mapa de Amenaza Volcánica Complejo volcánico de San Miguel

- Referencia
-  Sitios Poblados
  -  Etiquetas
  -  Red Mal
  -  Asentamientos
  -  Escuelas
- Lahares
-  Escenario 1
  -  Escenario 2
  -  Escenario 3
- Caida de Balísticos
-  Escenario 1
  -  Escenario 2
  -  Escenario 3
- Caida de Cenizas
-  Escenario 1
  -  Escenario 1
  -  Escenario 2
  -  Escenario 2
  -  Escenario 3
  -  Escenario 3
- Flujos de Lava
-  Escenario 1
  -  Escenario 2
- Actualizar



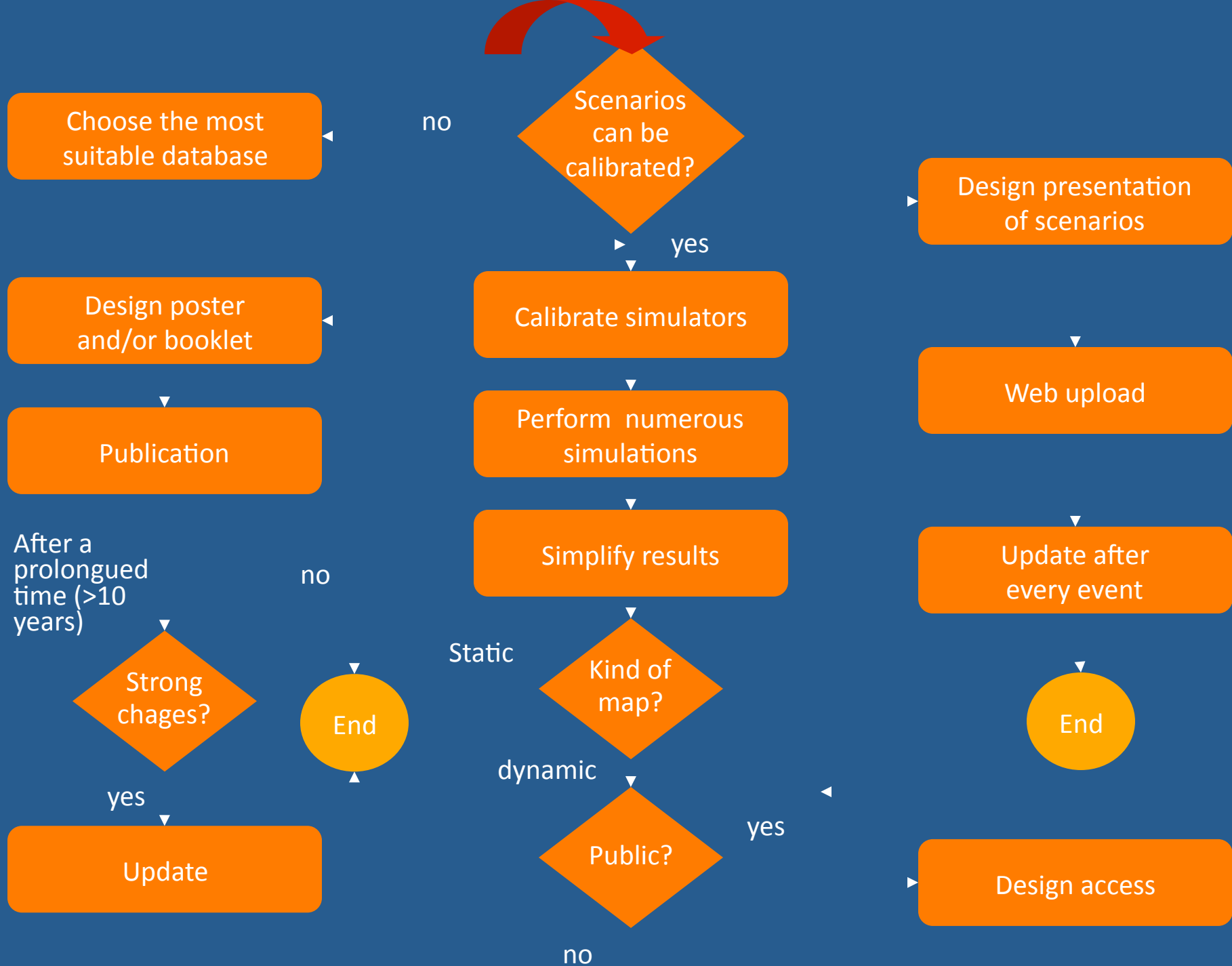
Nota Aclaratoria

El propósito de este mapa es ser una herramienta útil para orientar las acciones de prevención y mitigación necesarias para reducir la posibilidad de pérdidas y daños dentro de la zona de influencia del volcán. Las áreas representadas en el mapa son el resultado de la aplicación de modelos numéricos y portando una aproximación a la realidad del fenómeno. Los límites de las áreas delimitadas deben tomarse con precaución, considerándolos como referencias y no como absolutos.



 Deshabilitar Java

Powered by...



# Optimizando el proceso de elaboración de mapas de amenaza volcánica: la suite VOLCWORKS

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**Hugo Delgado Granados<sup>2</sup>**

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# Elaboración de mapas de amenazas en la última década

- Se han utilizado paquetes de cómputo que permiten simular diferentes procesos volcánicos:
  - Caída de cenizas
  - Caída de proyectiles balísticos
  - Flujos piroclásticos
  - Flujos de lava
  - Flujos laháricos
- Los paquetes utilizados son por ejemplo:
  - ASHFALL
  - FALL3D
  - BALLISTICS
  - FLOW3D
  - TITAN2D
  - LAHARZ

# Problemas a los que se enfrenta quien elabora un mapa de amenazas

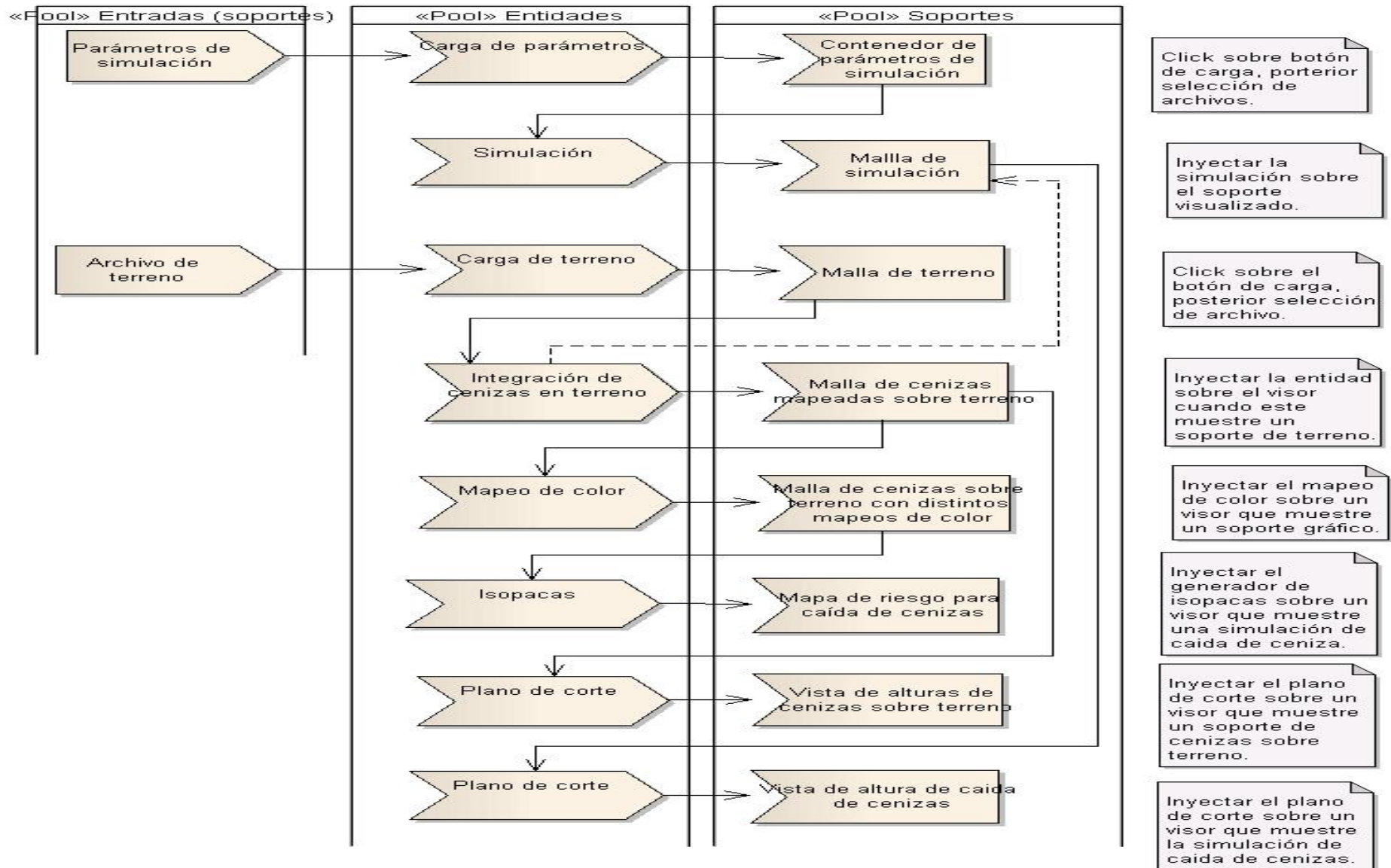
- Paquetes/software poco amigables (elaborados por geólogos/vulcanólogos)
- Incompatibilidad
- Recursos de cómputo
- Portabilidad
- Consumo de tiempo excesivo
  - Aprendizaje
  - Bugs
  - Salida del software
  - Formatos de salida
- Estos paquetes han sido escritos en diferentes lenguajes:
  - ASHFALL
  - FALL3D
  - BALLISTICS
  - FLOW3D
  - TITAN2D
  - LAHARZ

**The suite VOLCWORKS**

# Modelo soporte -Entidad caída de cenizas

analysis Flujos

## Modelo soporte-entidad de simulación de caída de cenizas.

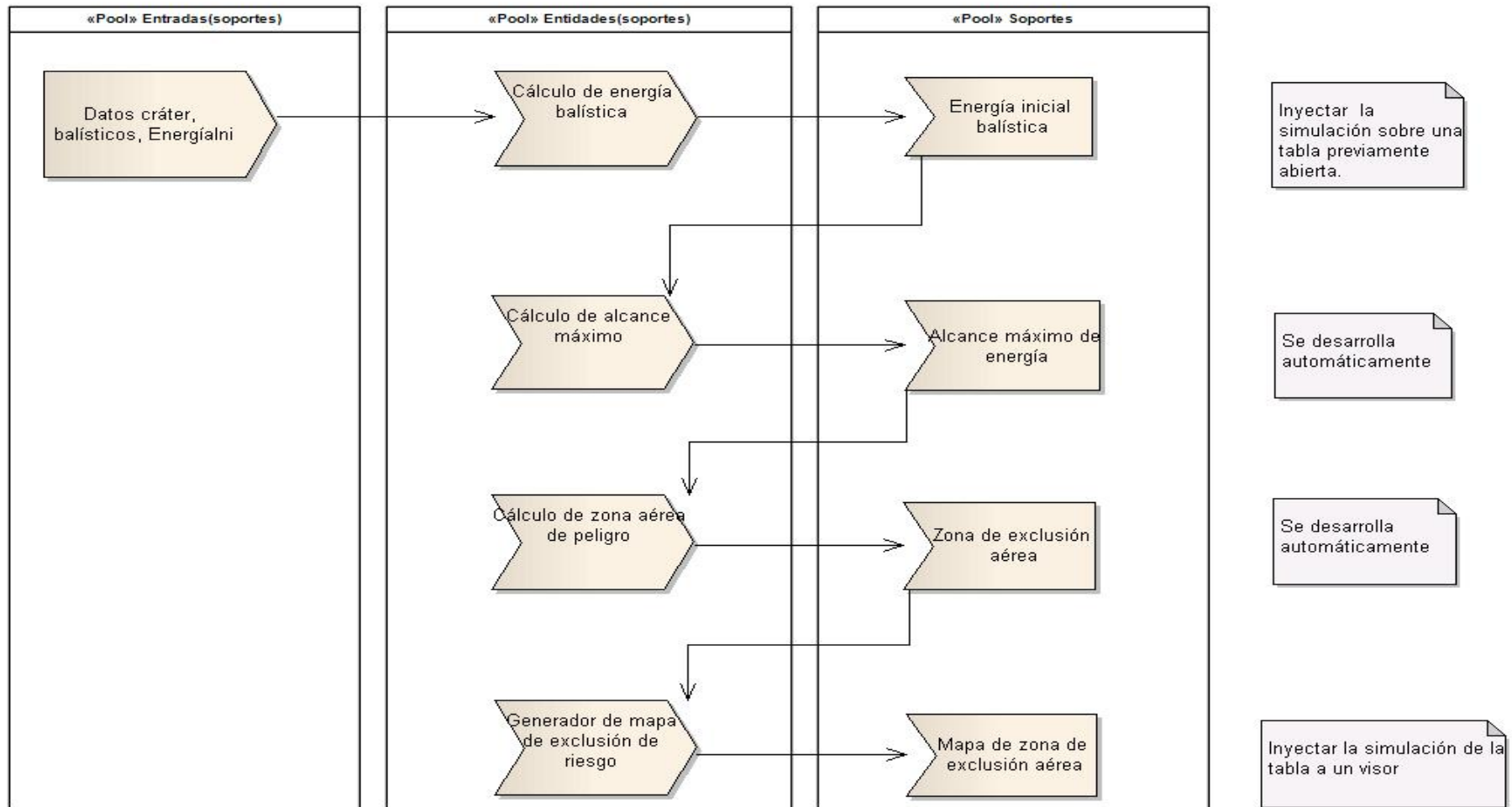




# Modelo soporte-entidad balísticos

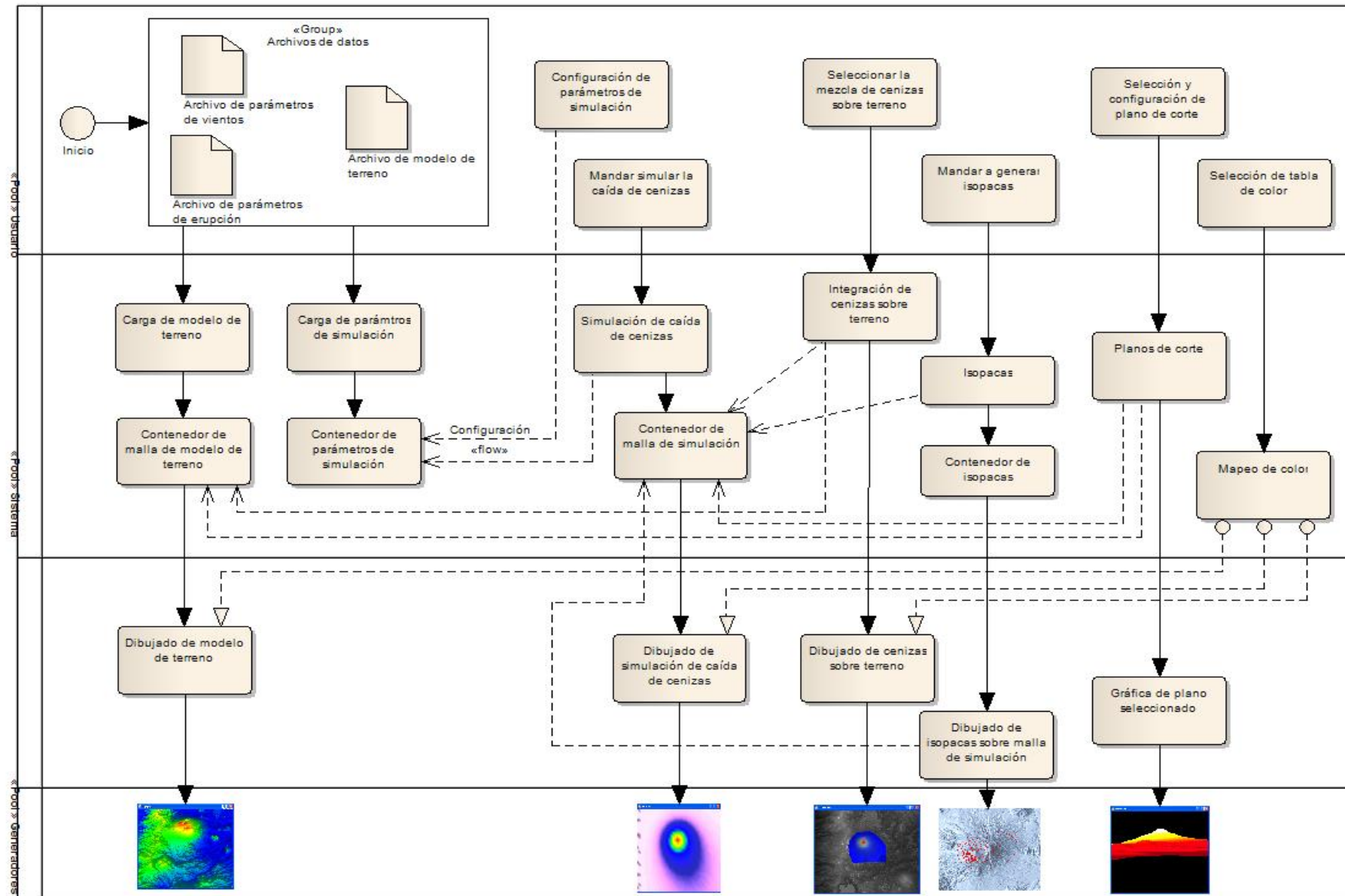
analysis Diagrama proceso de visualizaci...

## Proceso de visualización de balísticos



# Sistema de simulación de caída de cenizas.

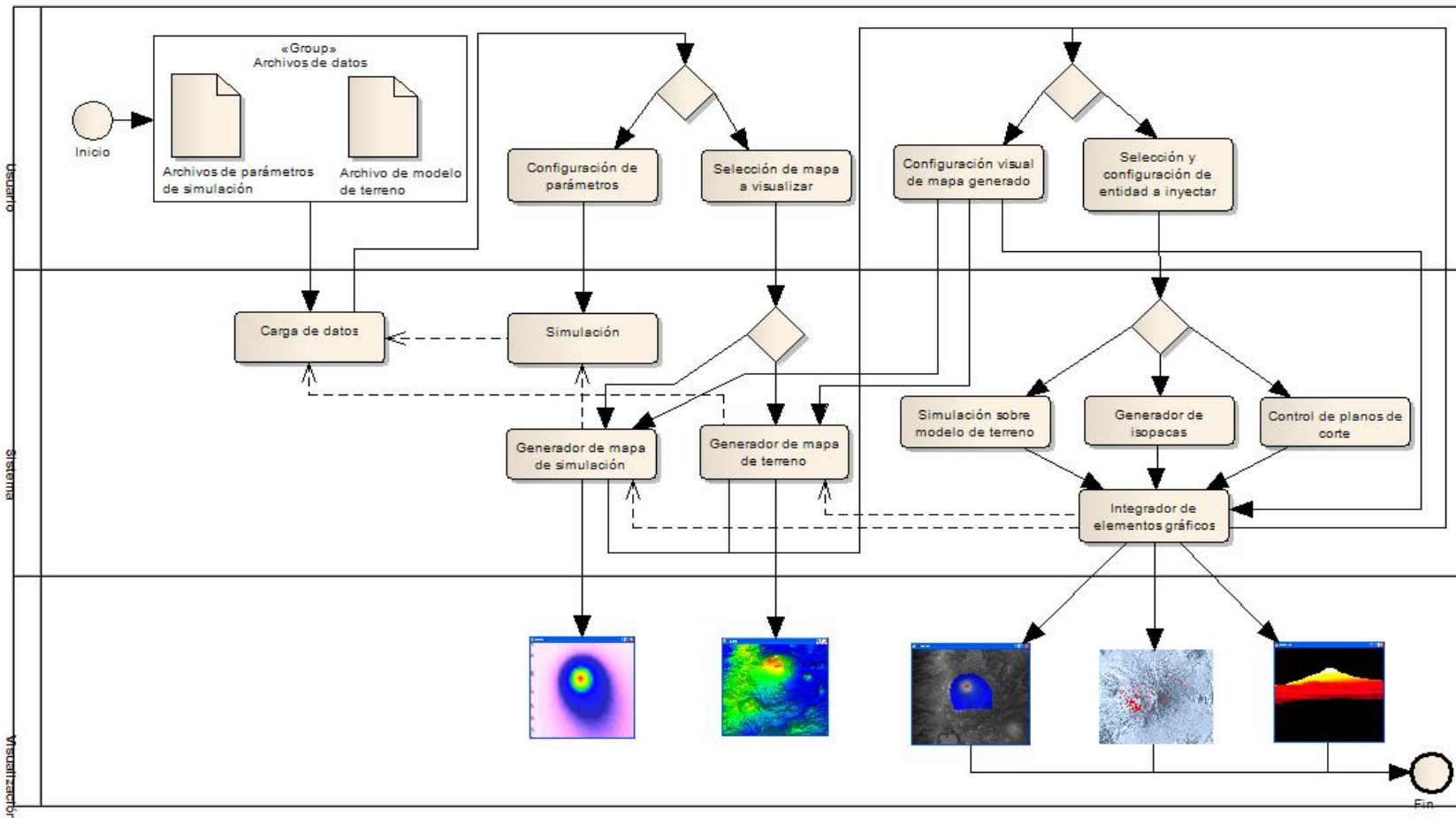
BPMN Procesos del sistema



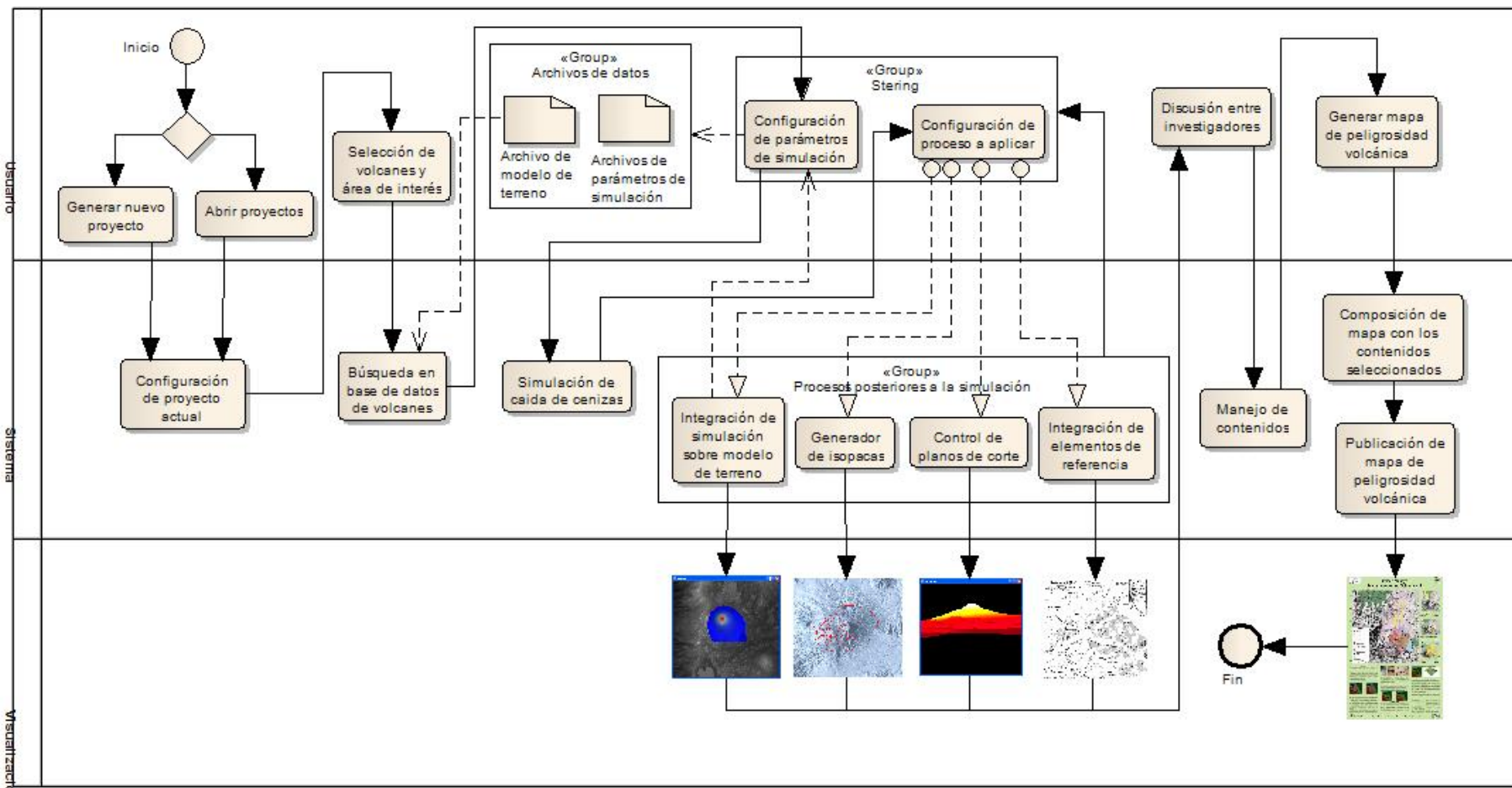
# Diagrama de vista particular del proceso de caída de cenizas

BPMN Proceso de negocio

## Proceso de tarea para la simulación de caída de ceniza.



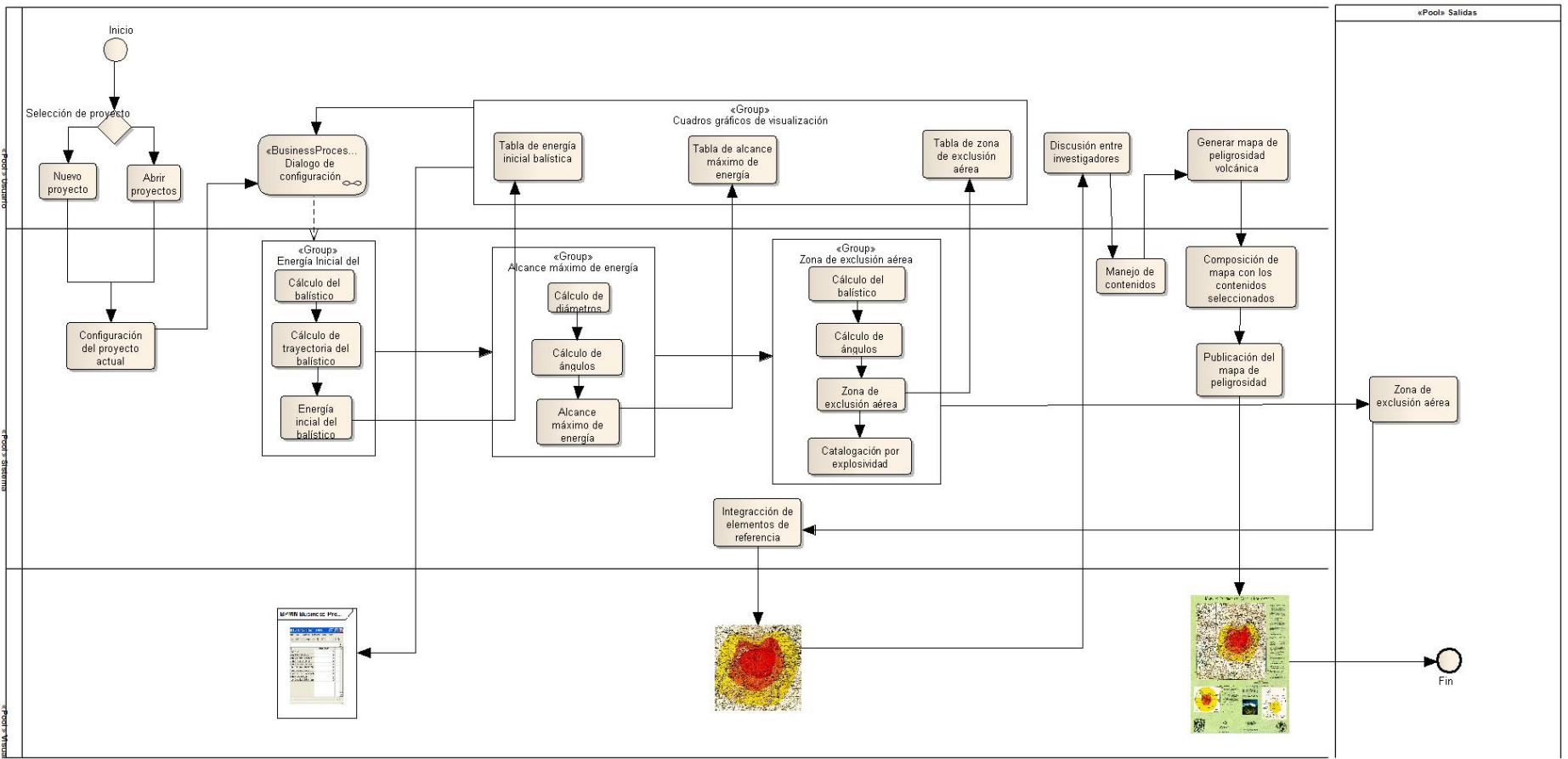
# Proceso de tarea para la simulación de caída de ceniza.



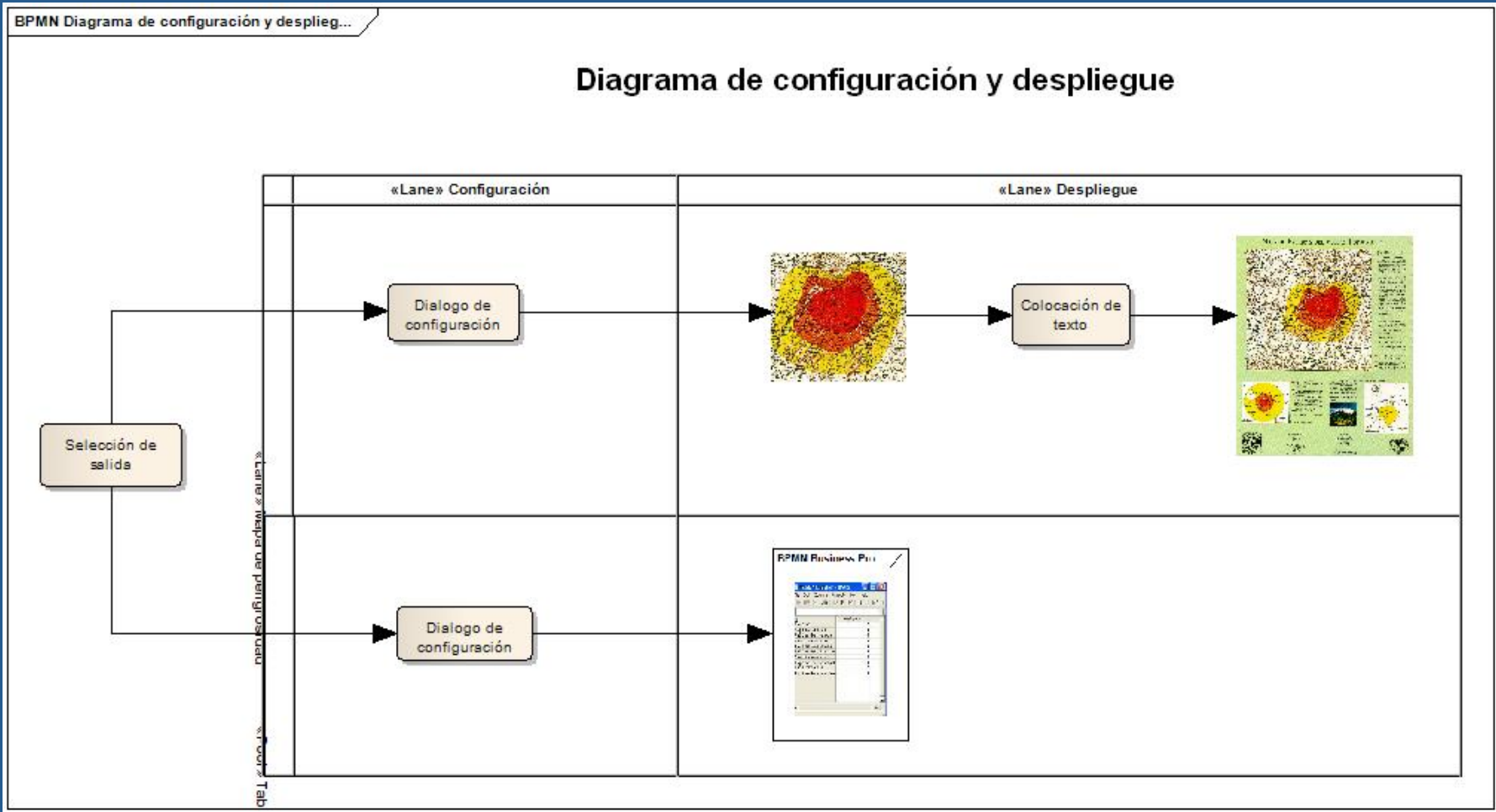
# Diagrama de vista general del flujo de balísticos

BPMN Diagrama de flujo de balísticos BPMN

## Diagrama BPMN de balísticos

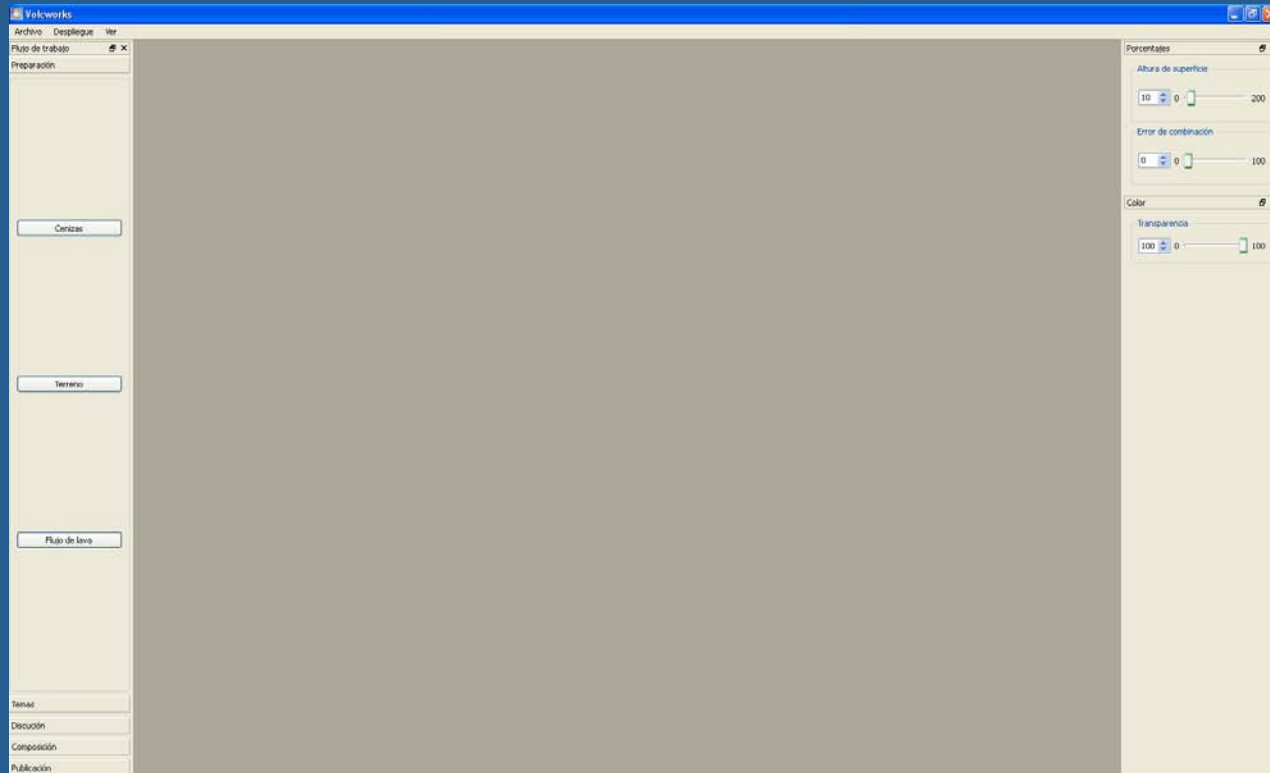


# Diagrama del flujo de visualización.



# Secuencia del uso de volcworks

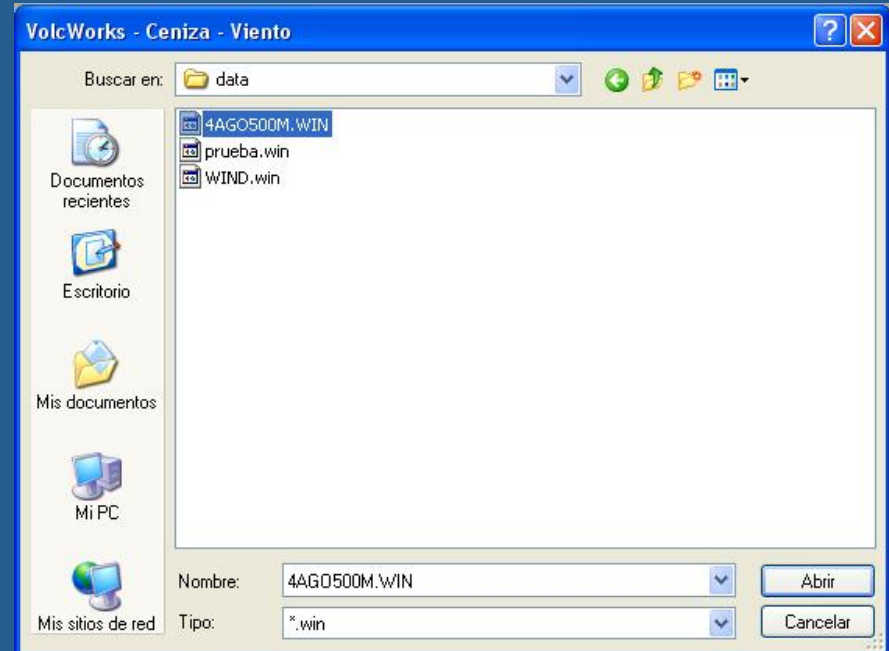
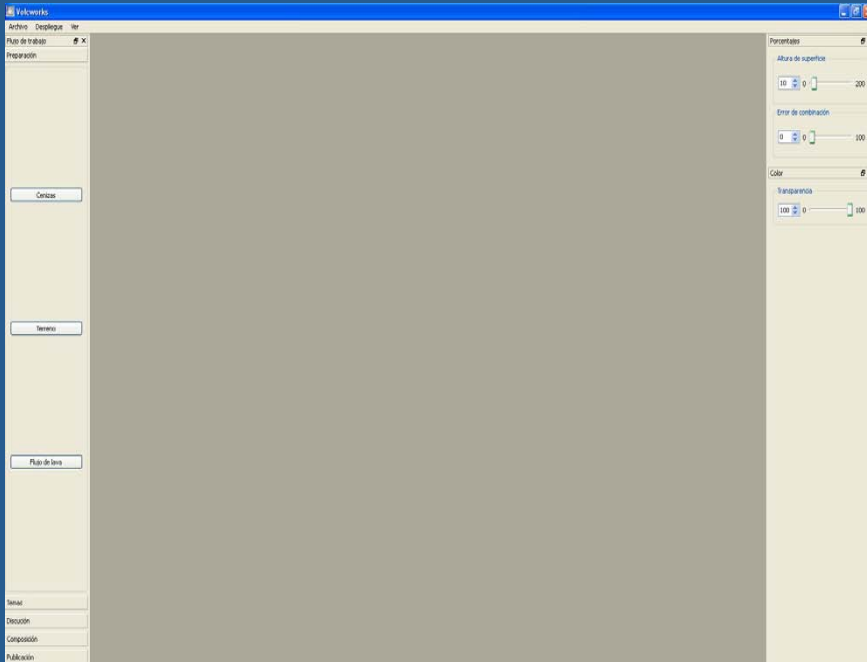
# Paso 1



Abrir programa VOLCWORKS, esta es la pantalla principal

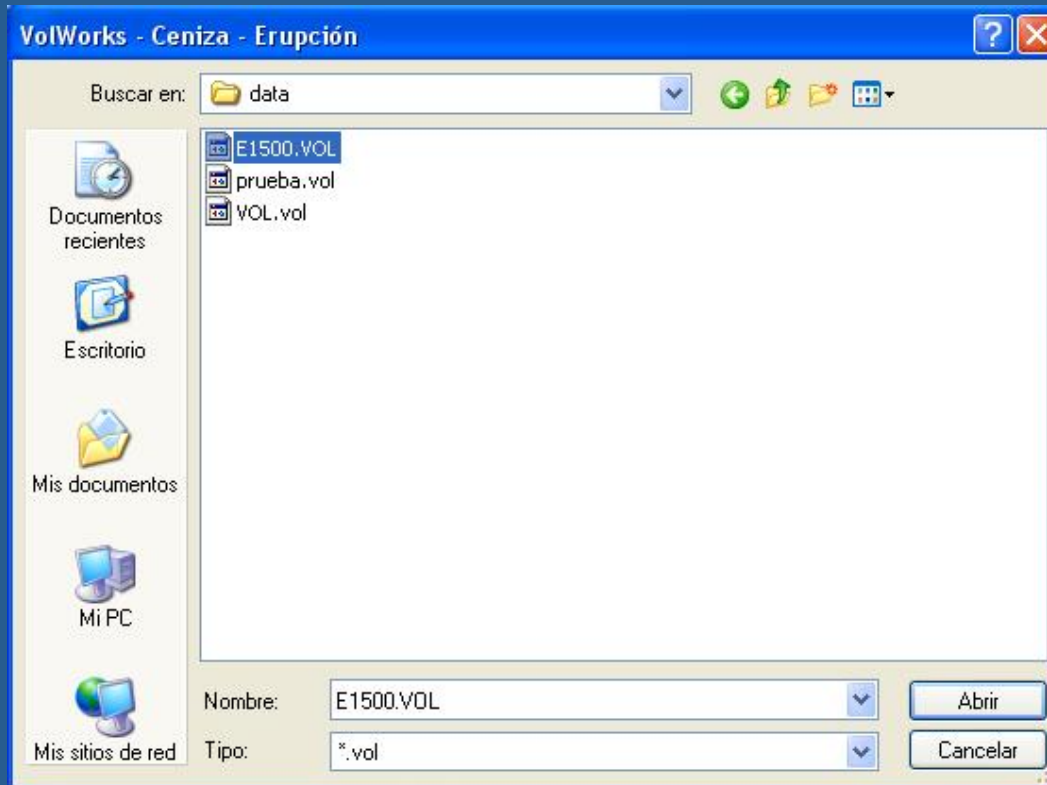


# Paso 2



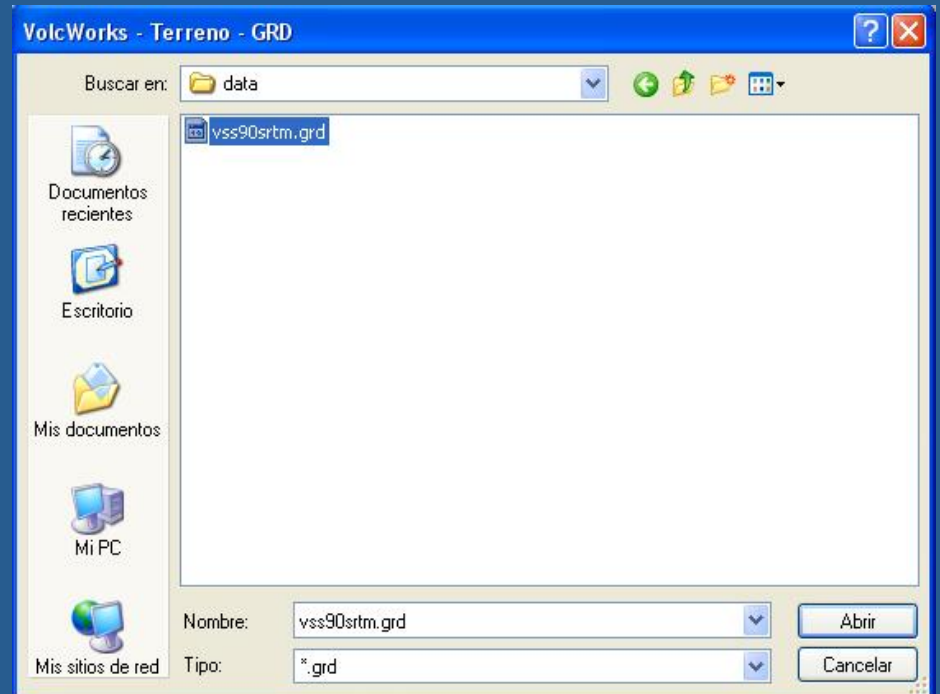
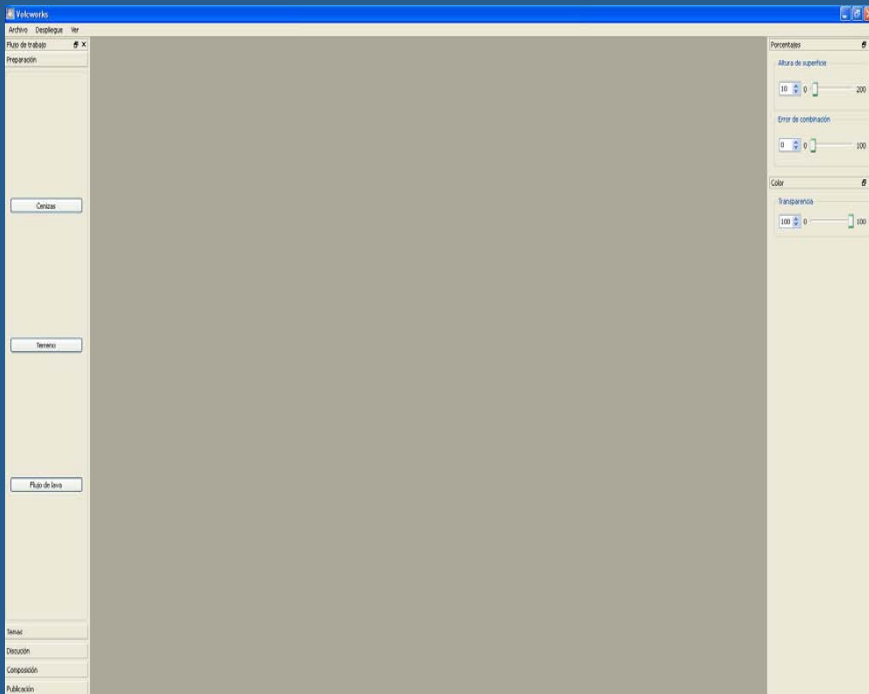
Seleccionar el botón cenizas y a continuación nos muestra una ventana para seleccionar el archivo de cenizas

# Paso 3



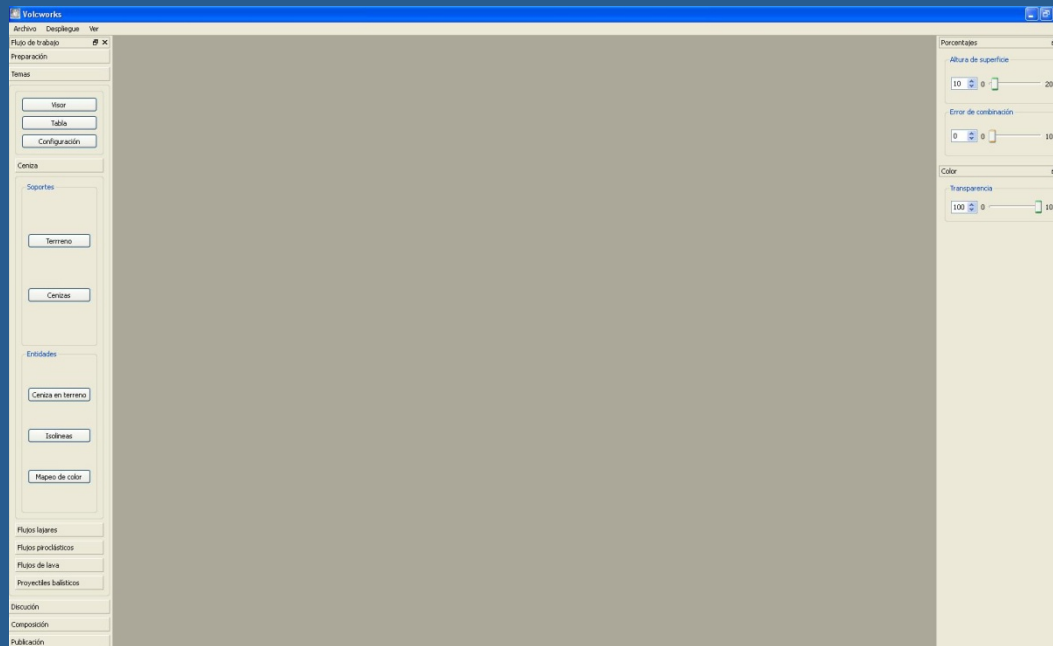
Una vez que damos clic en aceptar nos aparece una ventana en donde debemos seleccionar el archivo de erupciones ubicados estos archivos en la carpeta data, seleccionamos el archivo y damos clic en abrir.

# Paso 4



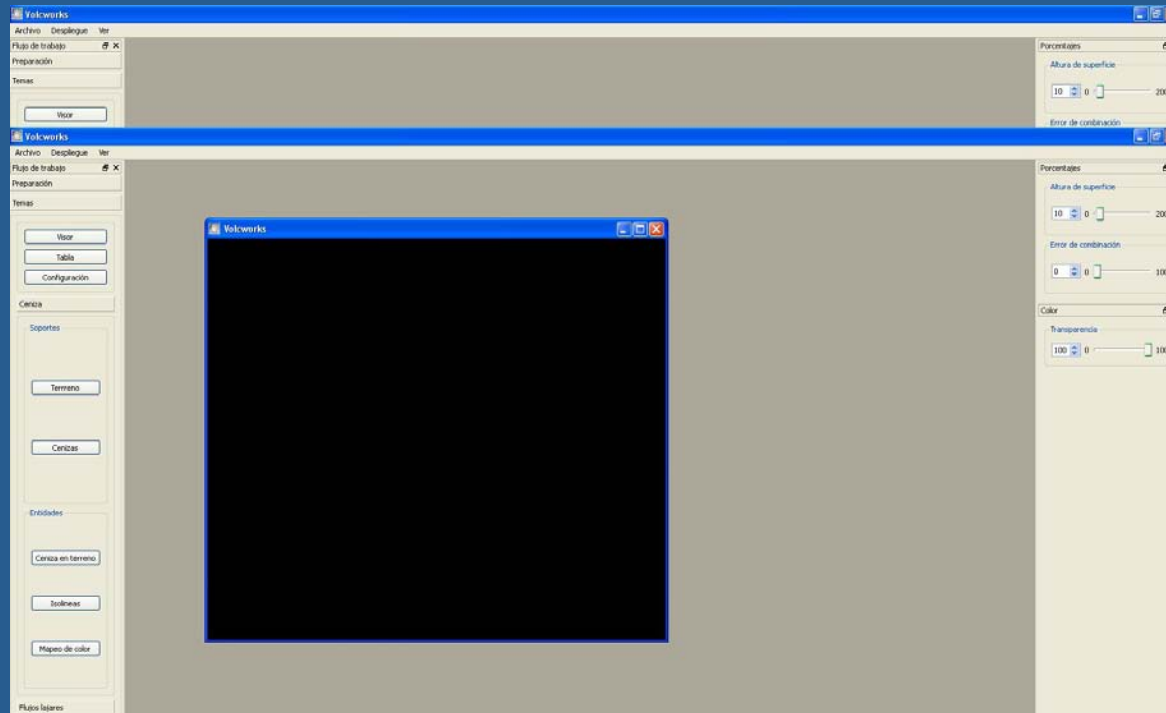
Ahora nos vamos al botón de seleccionar terreno y nos aparece una ventana en donde indicamos el modelo de terreno que utilizaremos, damos clic en abrir

# Paso 5



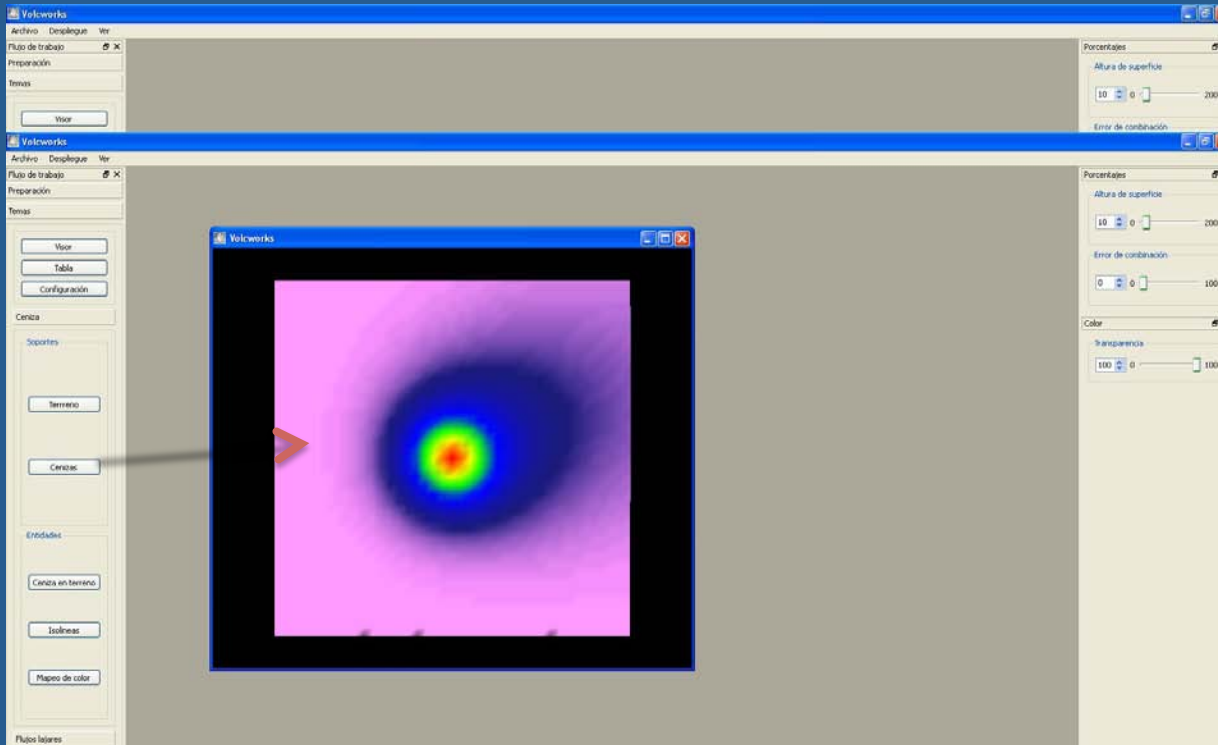
Ahora tenemos todo cargado para poderlo visualizar, ahora nos posicionamos dentro de la pestaña preparación.

# Paso 6



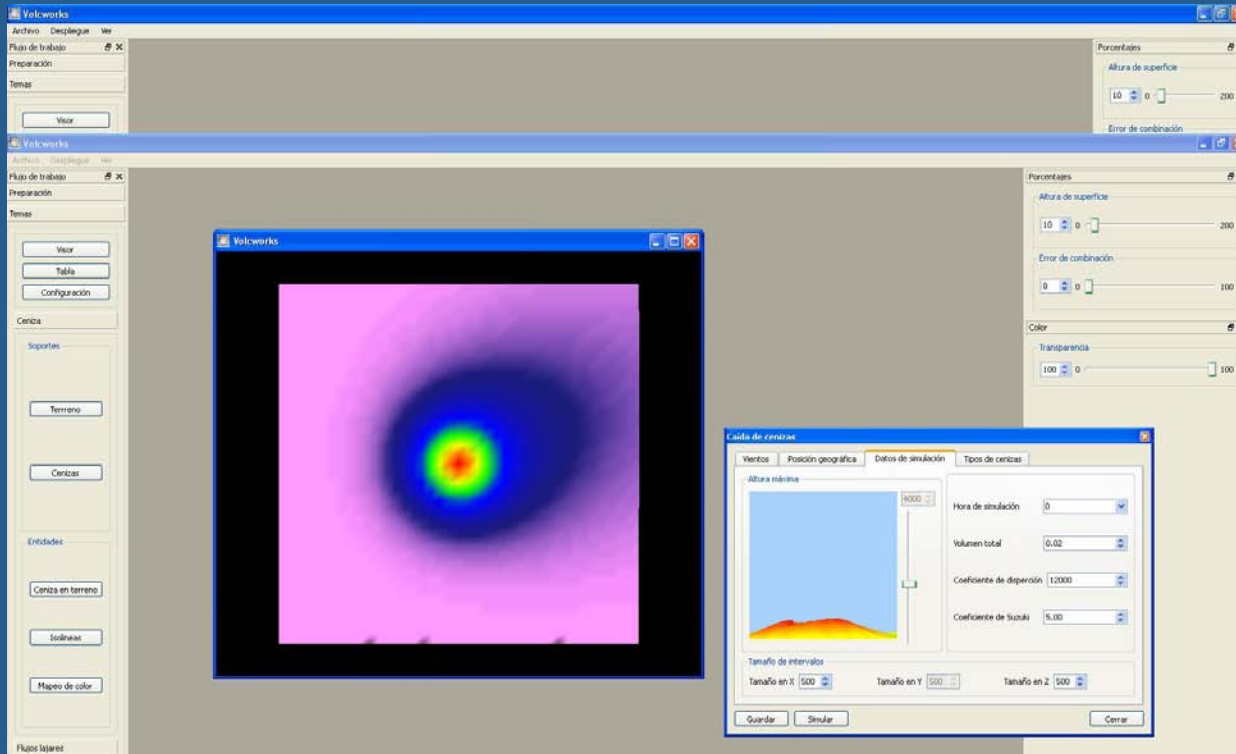
Una vez que seleccionamos esta pestaña nos aparece esta vista para poder ver el terreno seleccionamos la opción de visor y nos aparece la ventana negra, es aquí donde se visualizará el terreno.

# Paso 7



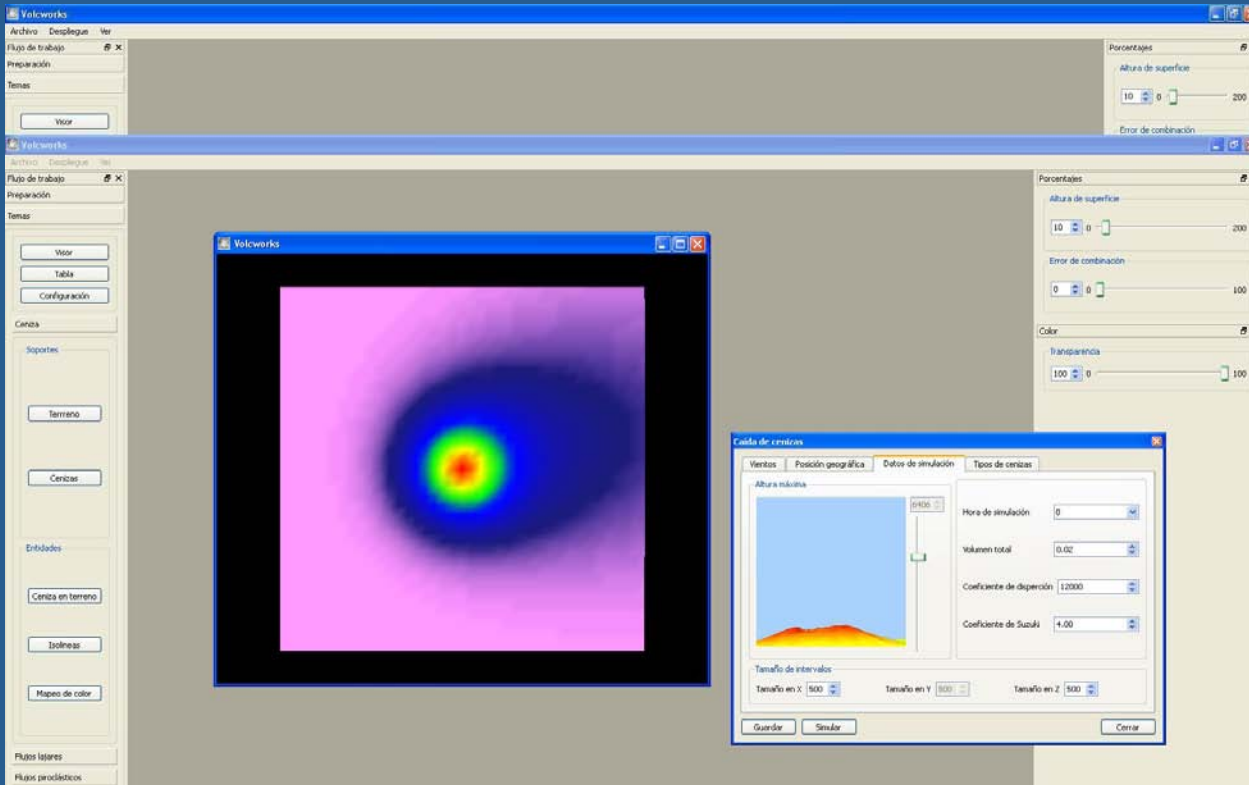
Para poder visualizar la caída de cenizas arrastramos el botón de cenizas directamente al visor.

# Paso 8



Para poder cambiar la configuración de la caída de cenizas lo podemos hacer desde la opción de configuración, una vez que tenemos hecha la configuración deseada, damos clic en simular, para que esta se muestre.

# Paso 9

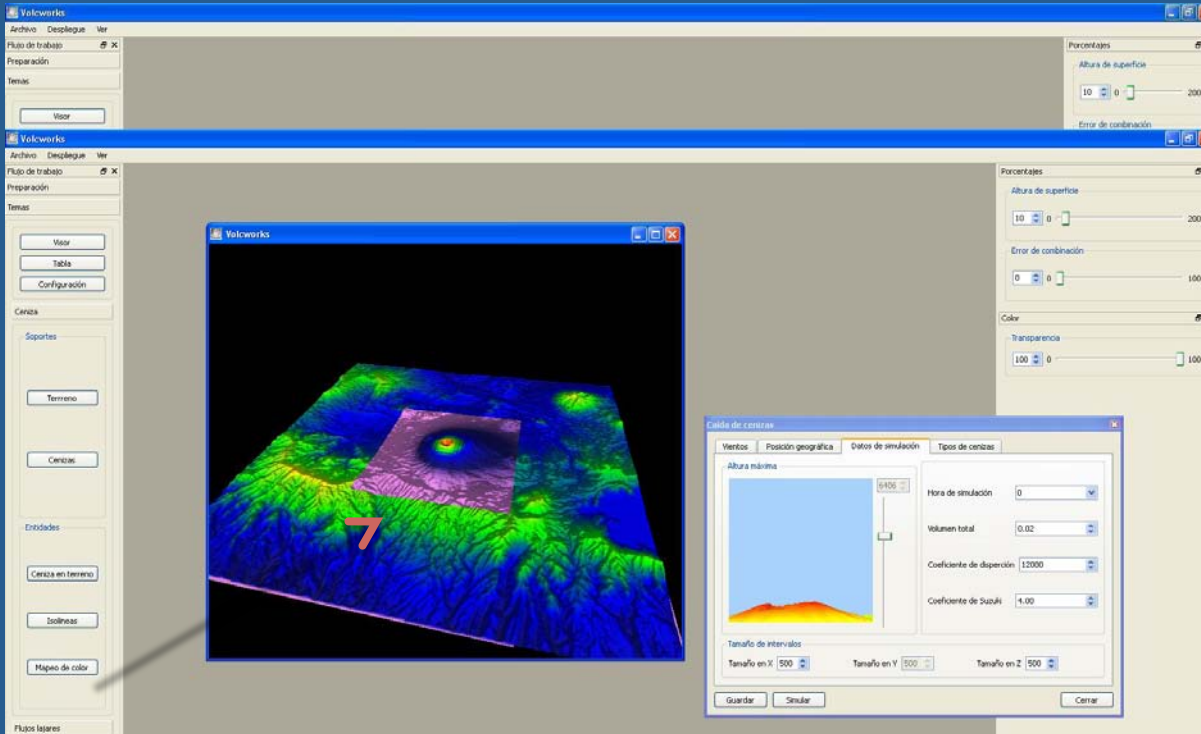


Esta es la nueva vista de la caída de cenizas mostrada.



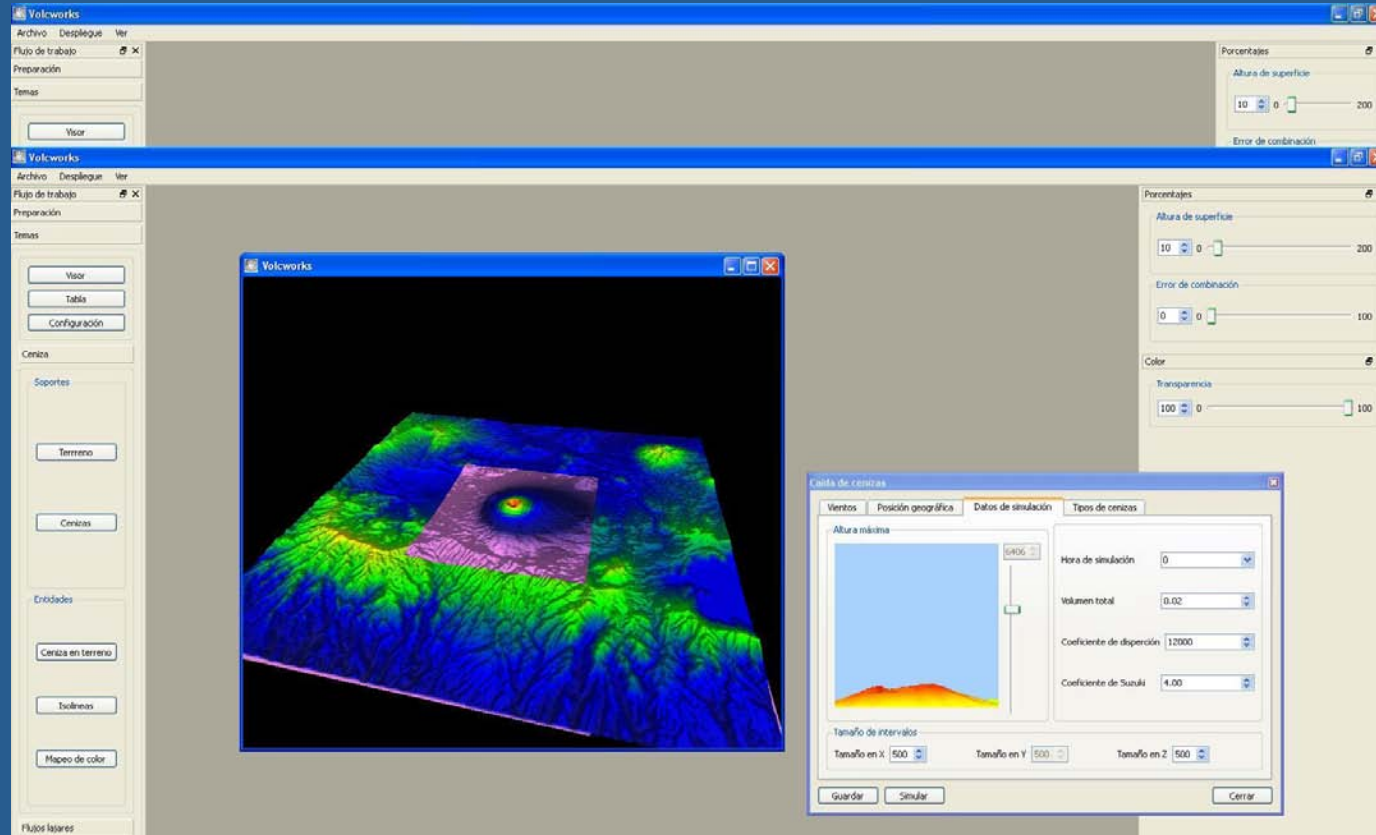


# Paso 11



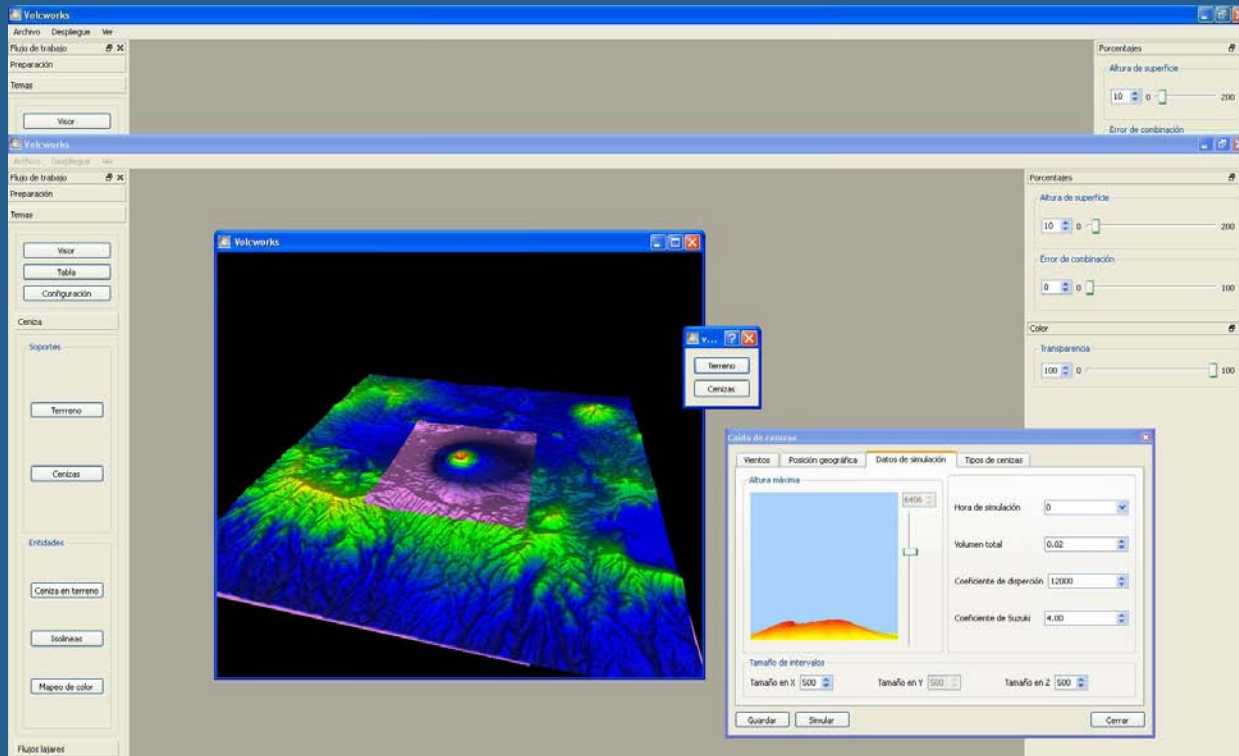
Si queremos ver las cenizas sobre el terreno seleccionamos la opción de terreno en cenizas y arrastramos al visor, esta opción también se puede configurar.

# Paso 12



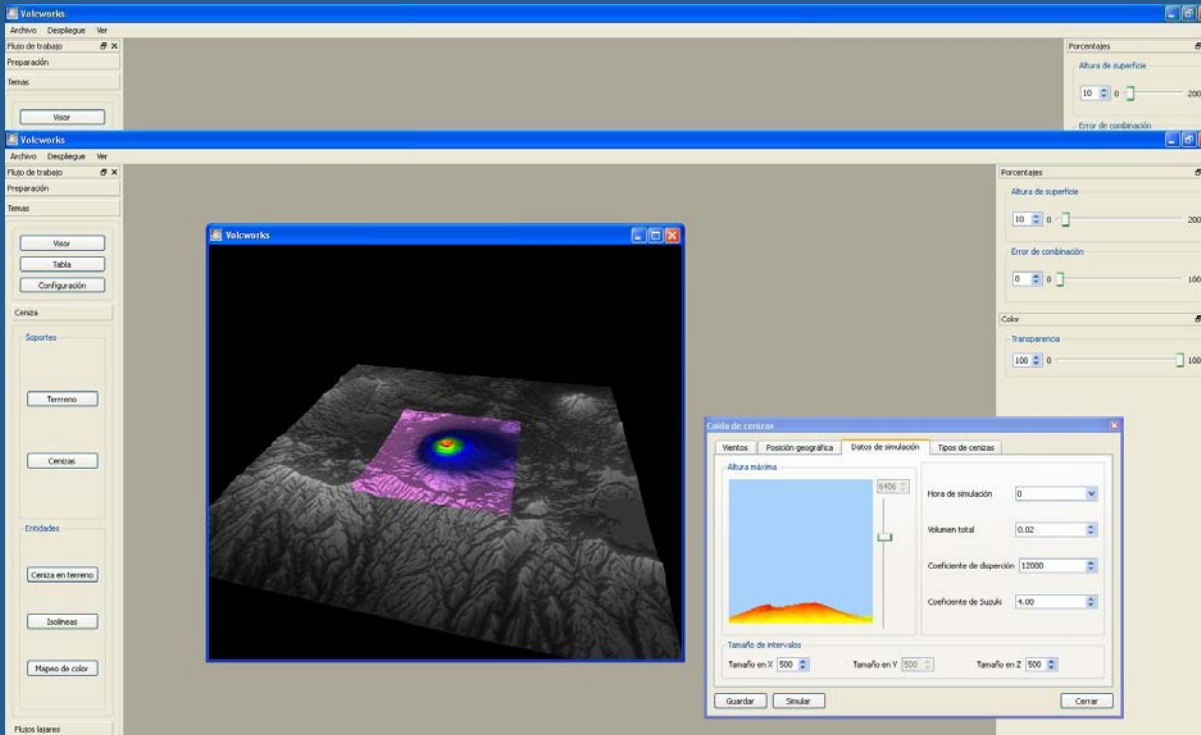
Esta es la vista de los cambios que se realizan en configuración

# Paso 13



Para cambiar el mapeo de color sobre el terreno o las cenizas nos vamos a la opción de mapeo de color y seleccionamos el tipo de mapeo que deseamos, además de seleccionar en donde se realiza si en el terreno o en las cenizas

# Paso 14



Esta es la vista del mapeo de color

# Metas de volcworks

- Generación de mapas de amenaza de una manera más amigable
- Simular diferentes procesos volcánicos con recursos de entrada y salida compatibles
- Realizar simulaciones para tres niveles de usuarios: educativo, operativo e investigación
- VOLCWORKS será multi plataforma (Macintosh, PC, LINUX...)
- La idea es que la suite sea portátil
- Inicialmente el idioma de la suite será en español, para luego, de ser necesario, traducirse a otros idiomas
- Realizar simulaciones para tres niveles de usuarios: educativo, operativo e investigación
- Formación de un catálogo de casos de erupciones con la mayor cantidad de información posible: MDE, parámetros físicos, parámetros de salida, etc.



Thank you

Questions?

