Recent developments in operational use of seismic and volcanic hazards assessment

Warner Marzocchi,
Istituto Nazionale di Geofisica e Vulcanologia

Outline

- The definition of hazard (and risk)
- Role and responsibilities of scientists and decision makers
- Seismic hazard: state of the art and perspectives
- Volcanic hazard: state of the art and perspectives

The definition of hazard

Hazard is the **probability** of occurrence of a specific threat in a **space-time window**

Risk = **Hazard** x **Exposed Value** x **Vulnerability**

Both definitions have a strong probabilistic nature.

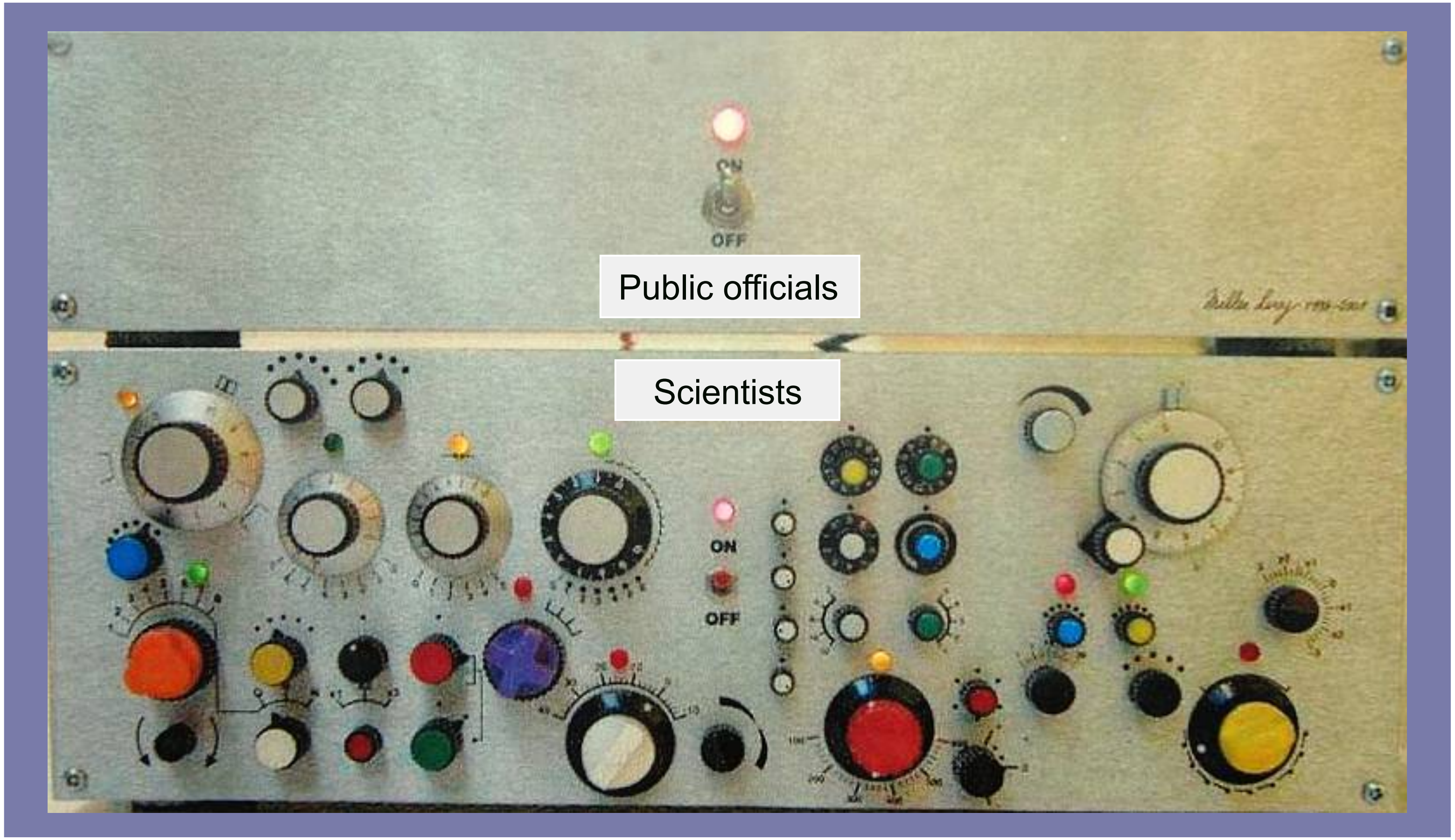
In this view, a scenario is not hazard, but at best a conditional hazard (conditional to the occurrence of that specific scenario).
Hazard is an integration of different scenarios each one with its probability of occurrence

Why probabilities?

- Natural systems usually yield an intrinsic unpredictability (due to nonlinear systems, high number of degrees of freedom, limited knowledge)

- Probabilities can be used to set up a rationale decision making system

Role of scientists and decision makers



The link between science and decision making requires to map a continuous number (the probability) into a Boolean logic (go – not go) of the decision makers

Quantitative Risk assessment is particularly important in some situations

Number of evacuees ↓ / Likelihood of false alarm →	LOW	HIGH
HIGH	Hurricane Remote large tsunami	Explosive eruption in high risk volcanoes
LOW	Tornado Lava flow	Bomb alert (Small) flank collapse at Stromboli

Cost-benefit analysis

C is the cost of a mitigation action
P * L is the probable loss if the mitigation action is not taken

If P * L > C, the probable loss overcomes the costs of the mitigation action. So, a mitigation action becomes worthwhile when

Role of decision makers

Role of scientists

$$P > C / L$$

Basic rule for the DECISION-MAKING UNDER UNCERTAINTY

C/L is a probability threshold, whose value does not have any scientific motivation (it is related to the acceptable risk)

Recommendations on the Immediate Use of Nuclear Weapons, June 16, 1945

Recommendations on the Immediate Use of Nuclear Weapons, by the Scientific Panel of the Interim Committee on Nuclear Power, June 16, 1945.

Source: U. S. National Archives, Record Group 77, Records of the Office of the Chief of Engineers, Manhattan Engineer District, Harrison-Bundy File, Folder #76.

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RECOMMENDATIONS ON THE IMMEDIATE USE OF NUCLEAR WEAPONS

A. H. Compton
E. O. Lawrence
J. R. Oppenheimer
E. Fermi

[signature]
J. R. Oppenheimer
For the Panel

(3) With regard to these general aspects of the use of atomic energy, it is clear that we, as scientific men, have no proprietary rights. It is true that we are among the few citizens who have had occasion to give thoughtful consideration to these problems during the past few years. We have, however, no claim to special competence in solving the political, social, and military problems which are presented by the advent of atomic power.

Volcanic hazard (different time scales for different uses)

- **Long-term** (decades) used for **land use planning**
- **Scenarios** used for evacuation plans
- **Short-term forecasts** used to manage **volcanic unrest** (when an evacuation should be called?)

Hazard/risk assessment for calling an evacuation

GEOPHYSICAL RESEARCH LETTERS, VOL. 34, L22310, doi:10.1029/2007GL031922, 2007

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Probabilistic eruption forecasting and the call for an evacuation

Warner Marzocchi[1] and Gordon Woo[2]

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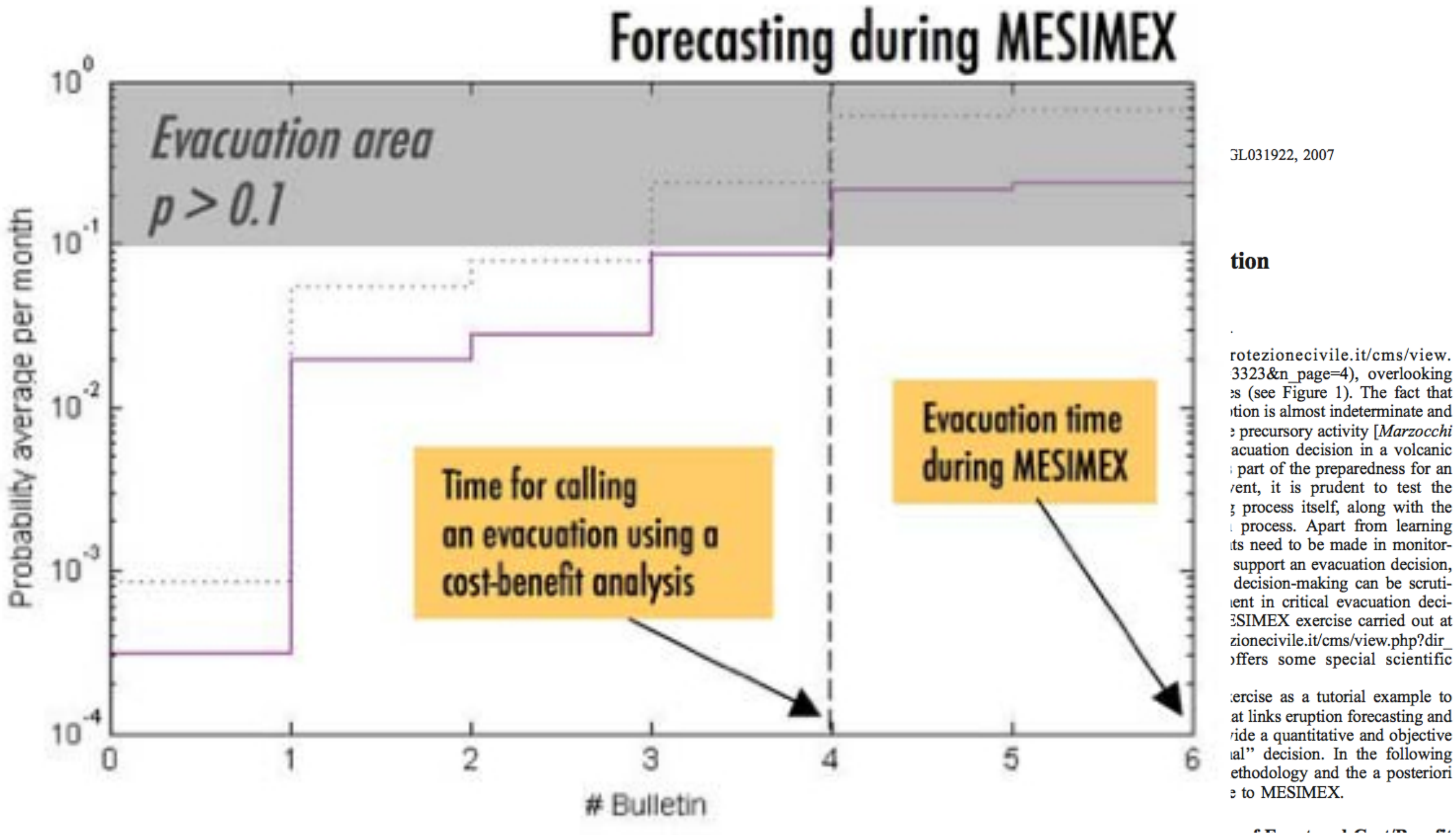
[1] One of the most critical practical actions to reduce volcanic risk is the evacuation of people from threatened areas during volcanic unrest. Despite its importance, this decision is usually arrived at subjectively by a few individuals, with little quantitative decision support. Here, we propose a possible strategy to integrate a probabilistic scheme for eruption forecasting and cost-benefit analysis, with an application to the call for an evacuation of one of the highest risk volcanoes: Vesuvius. This approach has the following merits. First, it incorporates a decision-analysis framework, expressed in terms of event probability, accounting for all modes of available hazard knowledge. Secondly, it is a scientific tool, based on quantitative and transparent rules that can be tested. Finally, since the quantitative rules are defined during a period of quiescence, it allows prior scrutiny of any scientific input into the model, so minimizing the external stress on scientists during an actual emergency phase. Whilst we specifically report the case of Vesuvius during the MESIMEX exercise, the approach can be generalized to other types of natural catastrophe. **Citation:** Marzocchi, W., and G. Woo (2007), Probabilistic eruption forecasting and the call for an evacuation, *Geophys. Res. Lett.*, *34*, L22310, doi:10.1029/2007GL031922.

1. Introduction

vius (see http://www.protezionecivile.it/cms/view.php?dir_pk=395&cms_pk=3323&n_page=4), overlooking the populous Bay of Naples (see Figure 1). The fact that the size of an imminent eruption is almost indeterminate and it cannot be predicted by the precursory activity [*Marzocchi et al.*, 2004] makes any evacuation decision in a volcanic crisis especially fraught. As part of the preparedness for an extreme natural hazard event, it is prudent to test the evacuation decision-making process itself, along with the logistics of the evacuation process. Apart from learning what technical improvements need to be made in monitoring and communications to support an evacuation decision, the actual criteria used for decision-making can be scrutinized. As a major experiment in critical evacuation decision-making, the recent MESIMEX exercise carried out at Vesuvius (http://www.protezionecivile.it/cms/view.php?dir_pk=395&cms_pk=3323) offers some special scientific insights.

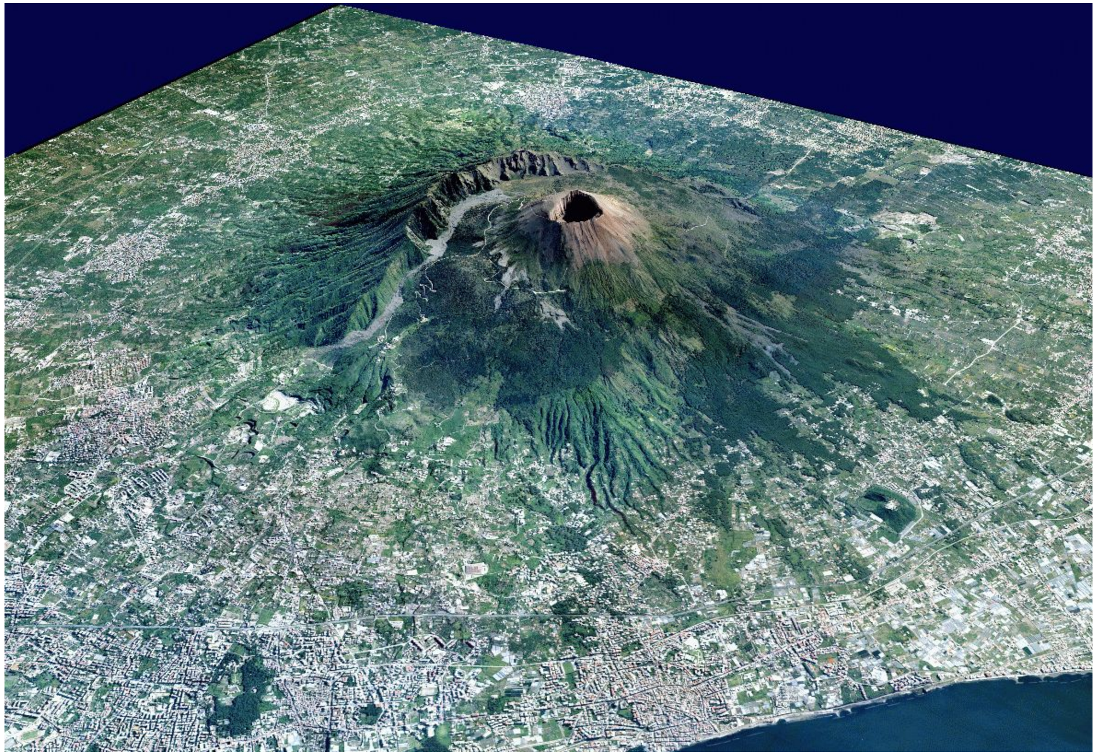
[4] Here, we use this exercise as a tutorial example to describe a new procedure that links eruption forecasting and cost/benefit analysis to provide a quantitative and objective rule for taking the "optimal" decision. In the following sections we describe the methodology and the a posteriori application of the procedure to MESIMEX.

Hazard/risk assessment for calling an evacuation



How to define an evacuation area?

No room for **maximum credible events**
The decision makers **choose a scenario** that fits many requirements (similar to a cost-benefit analysis)

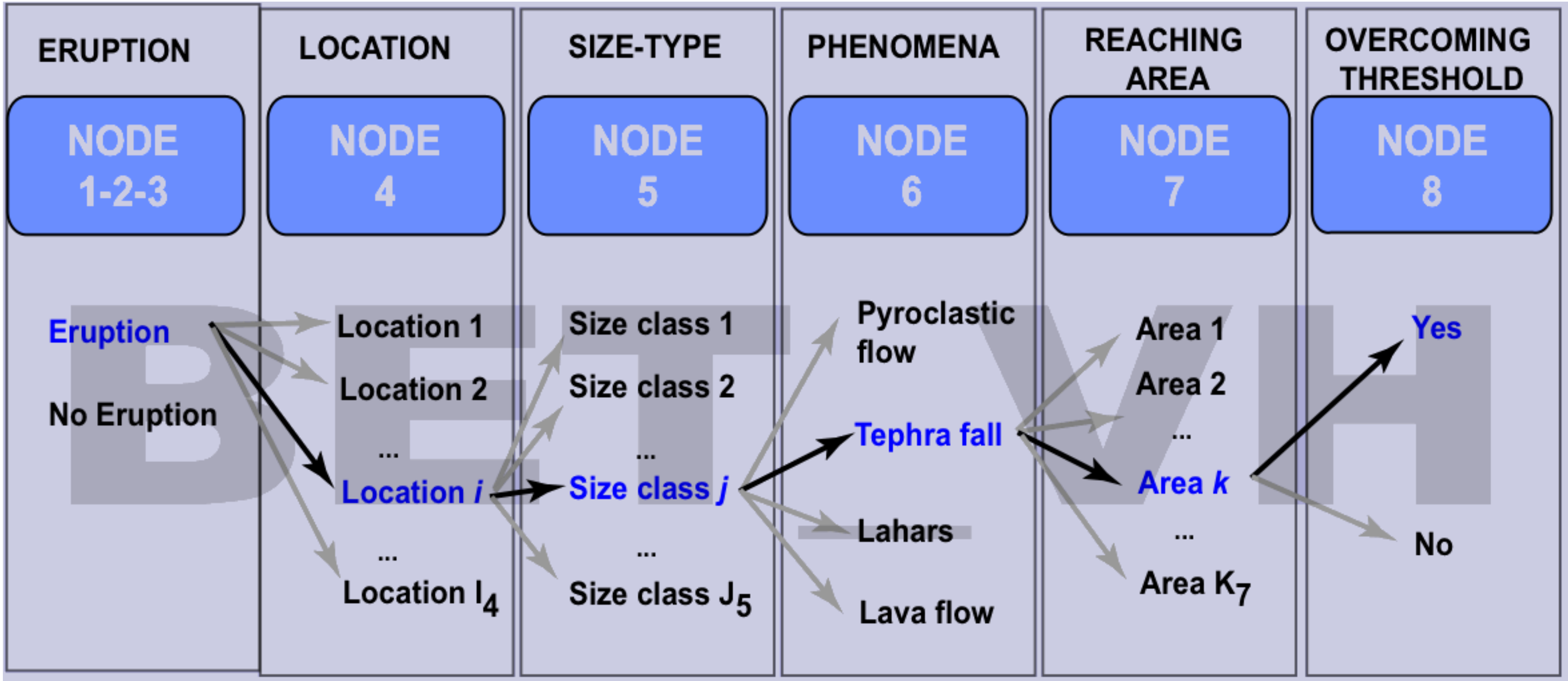


Vesuvius last awoke with a small blast in 1944. A large eruption could unleash incendiary avalanches and ash that would threaten millions of people.

EUROPE'S TICKING TIME BOMB

Vesuvius is one of the most dangerous volcanoes in the world — but scientists and the civil authorities can't agree on how to prepare for a future eruption.

Volcanic hazard



BET_VH assesses the long-term Volcanic Hazard
*from a **generic phenomenon***
*in **selected areas around the volcano**…*

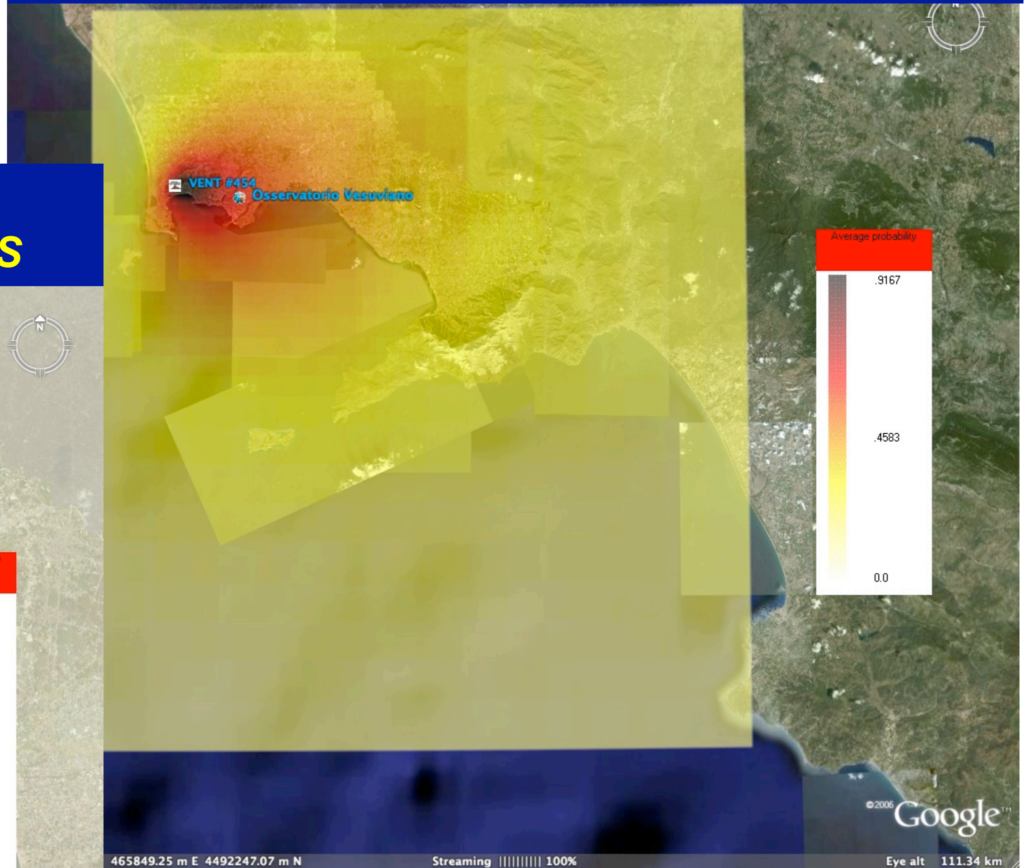
Volcanic hazard

ES: M.Nuovo eruption

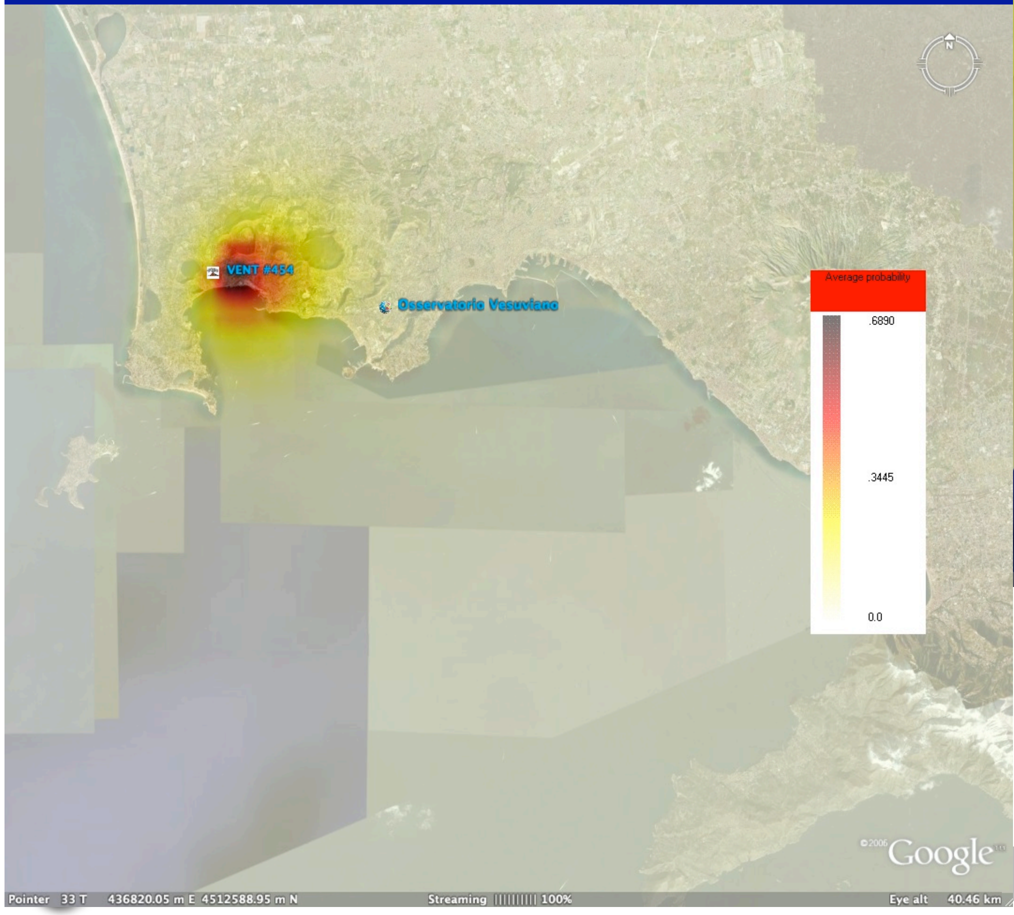
vent: #454

size: Small exlposive

NODE 7: probability that an area is reached GIVEN an eruption with this ES



NODE 8: probability that 300 kg m^{-2} is overcome GIVEN an eruption with this ES



p_{ES} **= 2.03 10^{-3}**

probability of the selected ES, given that an eruption occurs

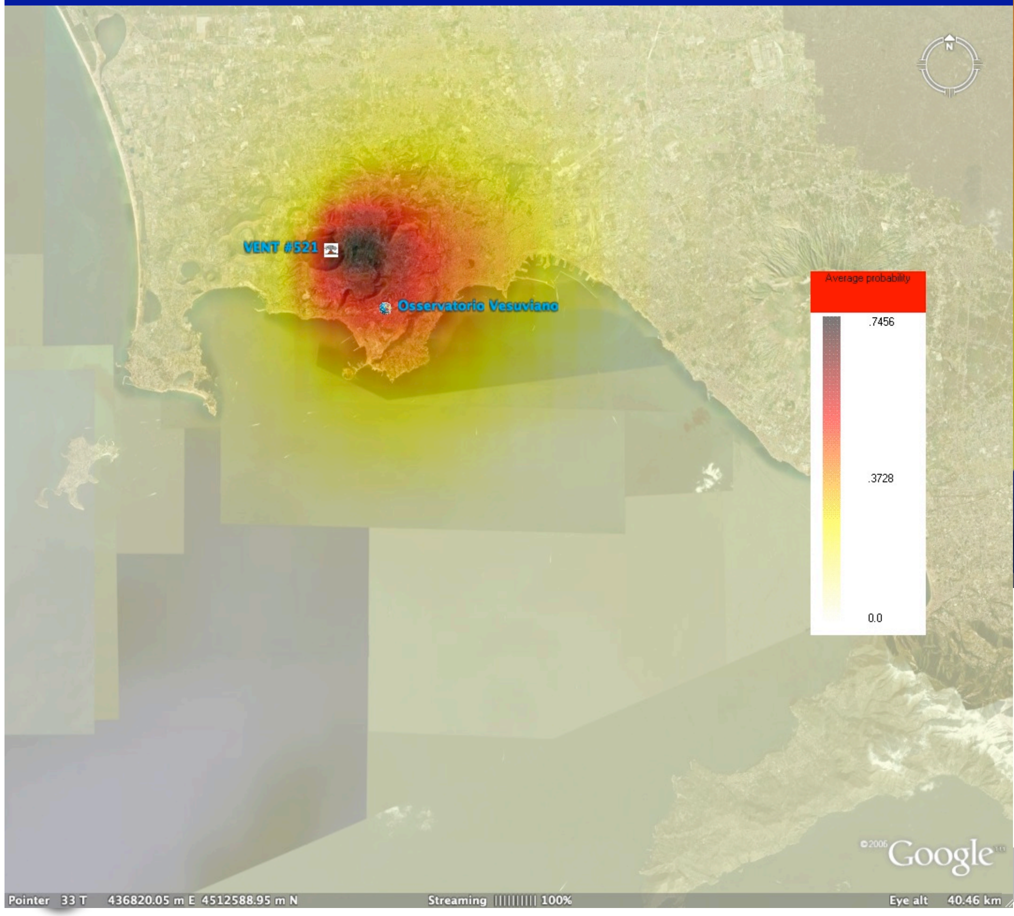
Volcanic hazard

ES: Astroni 6 eruption

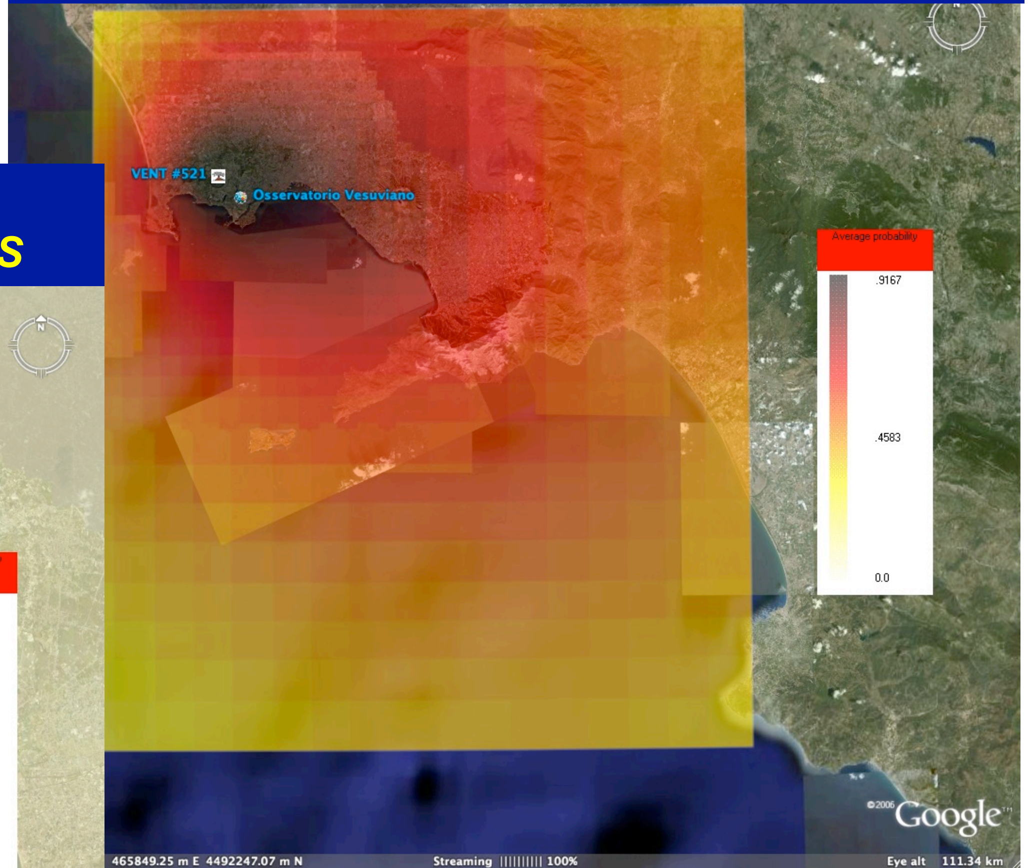
vent: #521

size: Medium Explosive

NODE 8: probability that 300 kg m^{-2} is overcome GIVEN an eruption with this ES



NODE 7: probability that an area is reached GIVEN an eruption with this ES



p_{ES} = 1.44 10^{-3}

probability of the selected ES, given that an eruption occurs

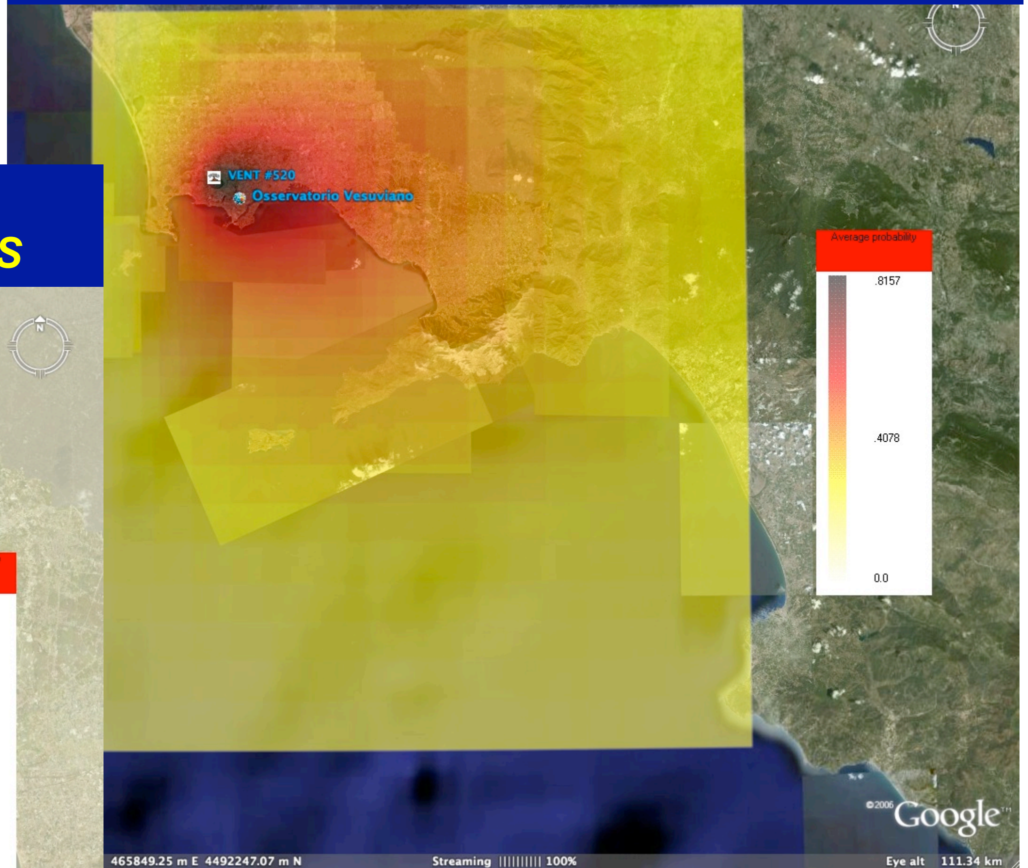
Volcanic hazard

ES: COMBO 1 (standard for central volcano)

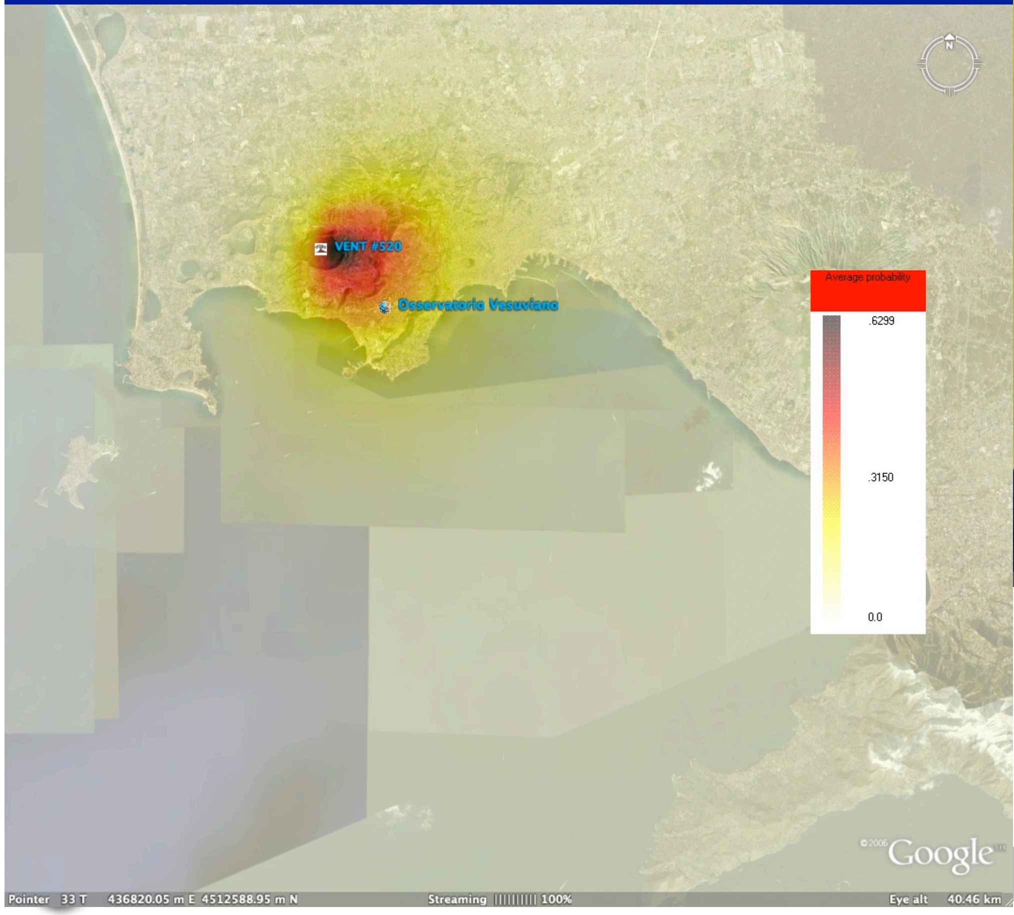
vent: #520 (most likely)

size: **all possible sizes**

NODE 7: probability that an area is reached *GIVEN an eruption with this ES*



NODE 8: probability that 300 kg m^{-2} is overcome *GIVEN an eruption with this ES*



$\boldsymbol{p_{ES} = 5.83\ 10^{-3}}$

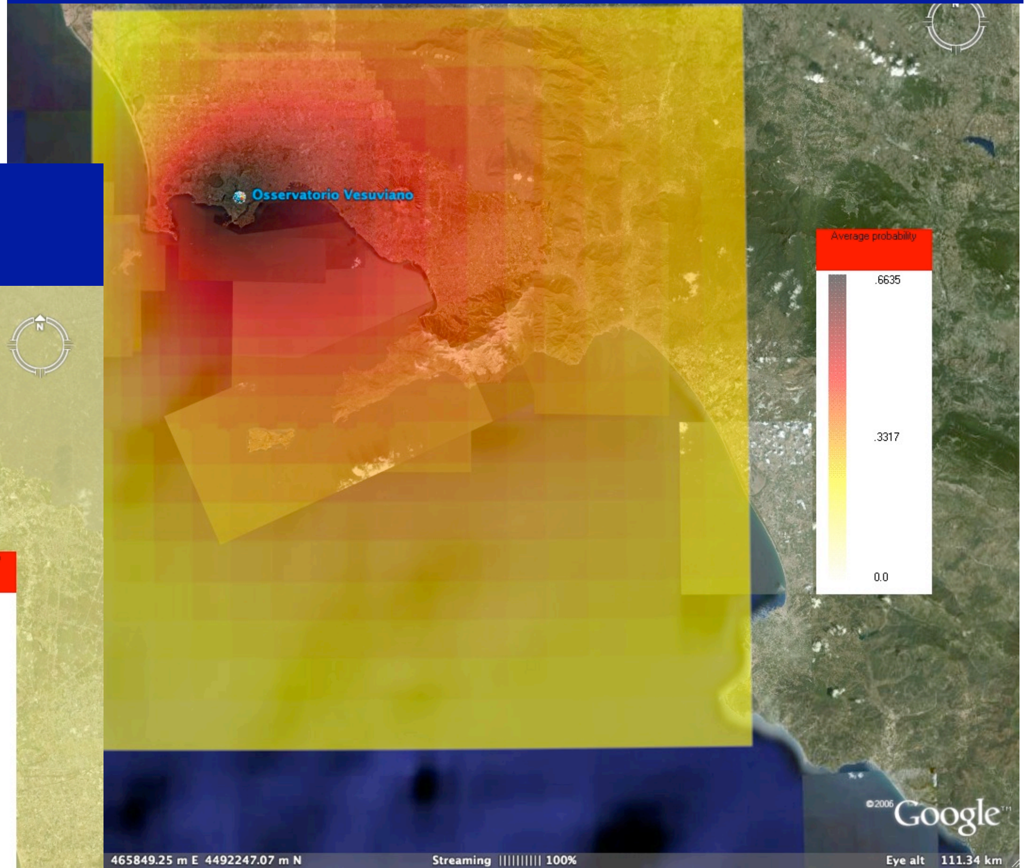
probability of the selected ES, given that an eruption occurs

Volcanic hazard

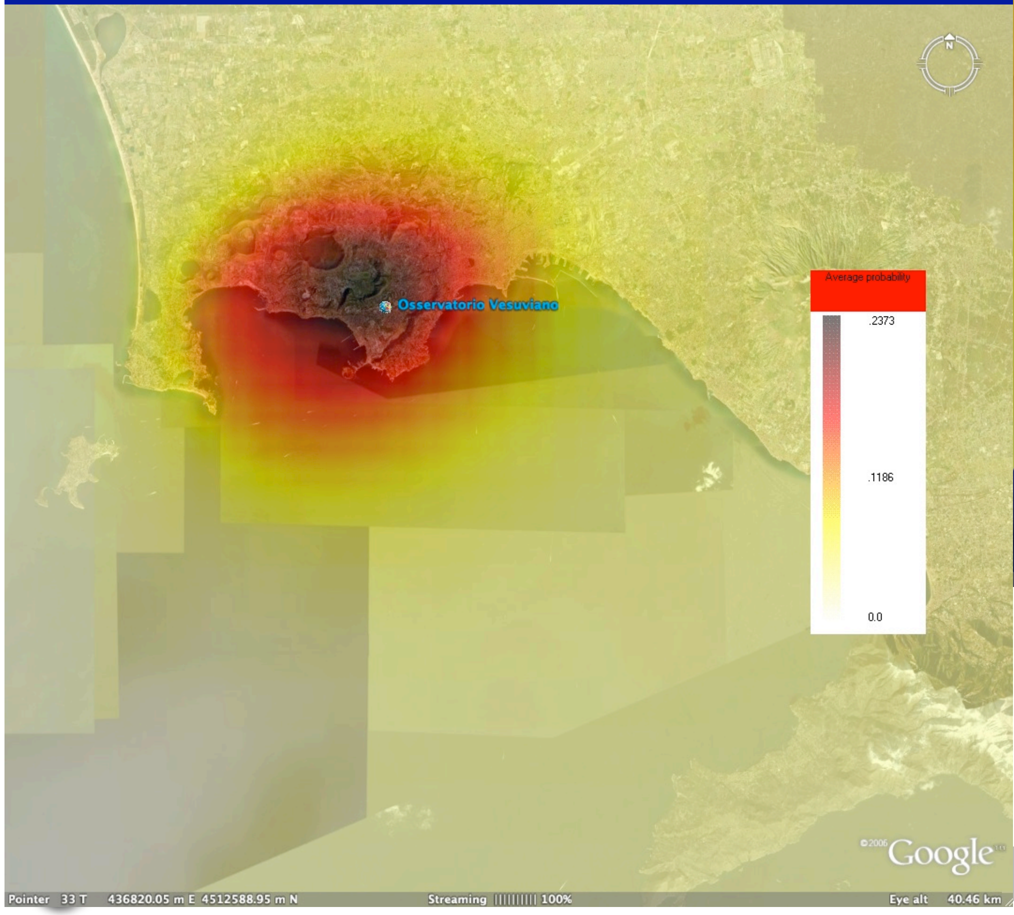
ES: COMBO 2

vent: **all possible vents**
size: **all possible sizes**

NODE 7: probability that an area is reached GIVEN an eruption



NODE 8: probability that 300 kg m^{-2} is overcome GIVEN an eruption



p_{ES} = 1

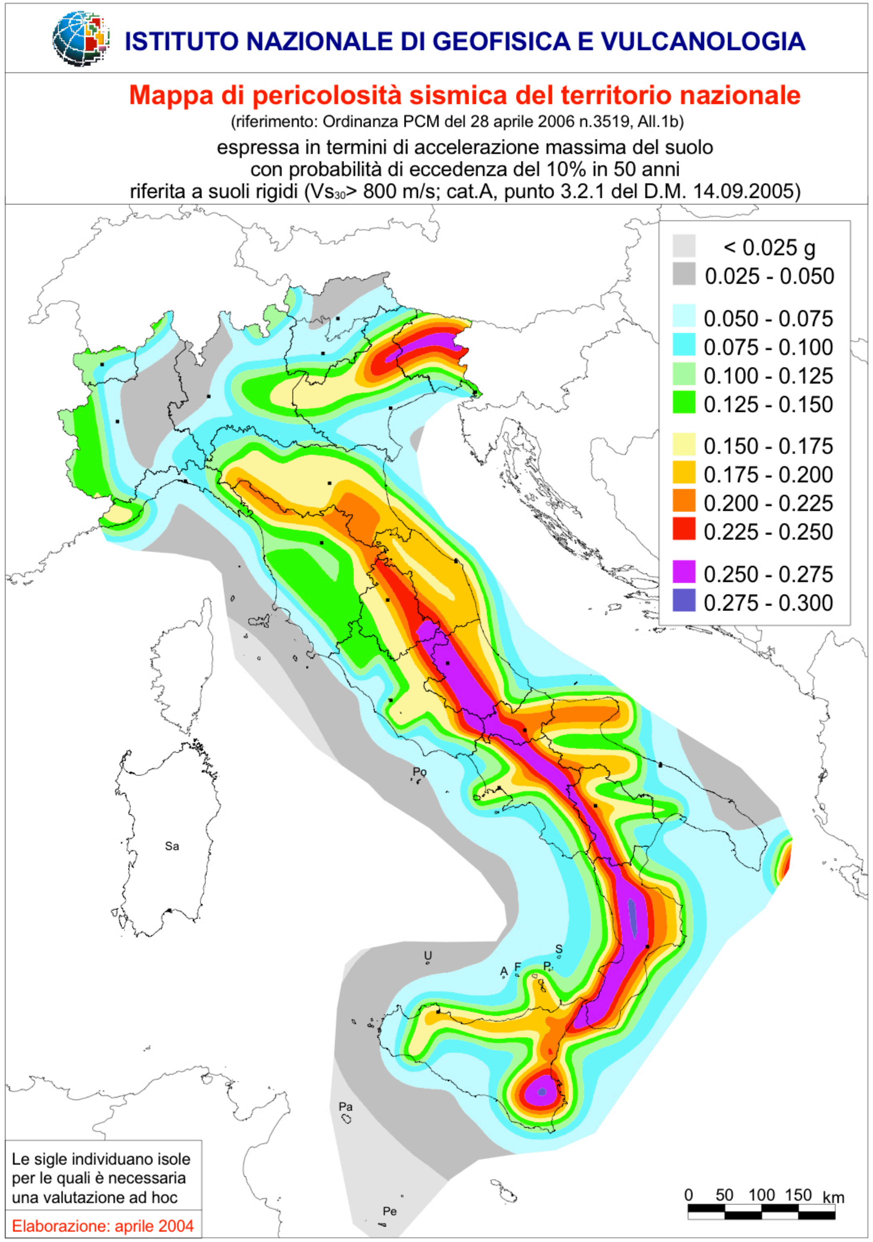
probability of the selected ES, given that an eruption occurs

Seismic hazard (different time scales for different uses)

- **Long-term** (decades) is used for **the building code**

- **Medium term** (years) is used for prioritizing areas for retrofitting

- **Short-term** (days to weeks) is used to manage seismic sequences (before and after a mainshock) – presently under study...



Long-Term

The map shows ground motion values that have 10% of probability to be overcome in the next 50 years

Main purpose: Defining the building code for Italy (by law)

International Commission on Earthquake Forecasting (ICEF)

- Charged on 11 May 2009 by Dipartimento della Protezione Civile (DPC) to:
  1. Report on the current state of knowledge of short-term prediction and forecasting of tectonic earthquakes
  2. Indicate guidelines for utilization of possible forerunners of large earthquakes to drive civil protection actions
- ICEF report: ***"Operational Earthquake Forecasting: State of Knowledge and Guidelines for Utilization"***
  - Findings & recommendations released by DPC (Oct 2009) and endorsed by IASPEI (July 2011)
  - Final report published in *Annals of Geophysics* (Aug 2011)

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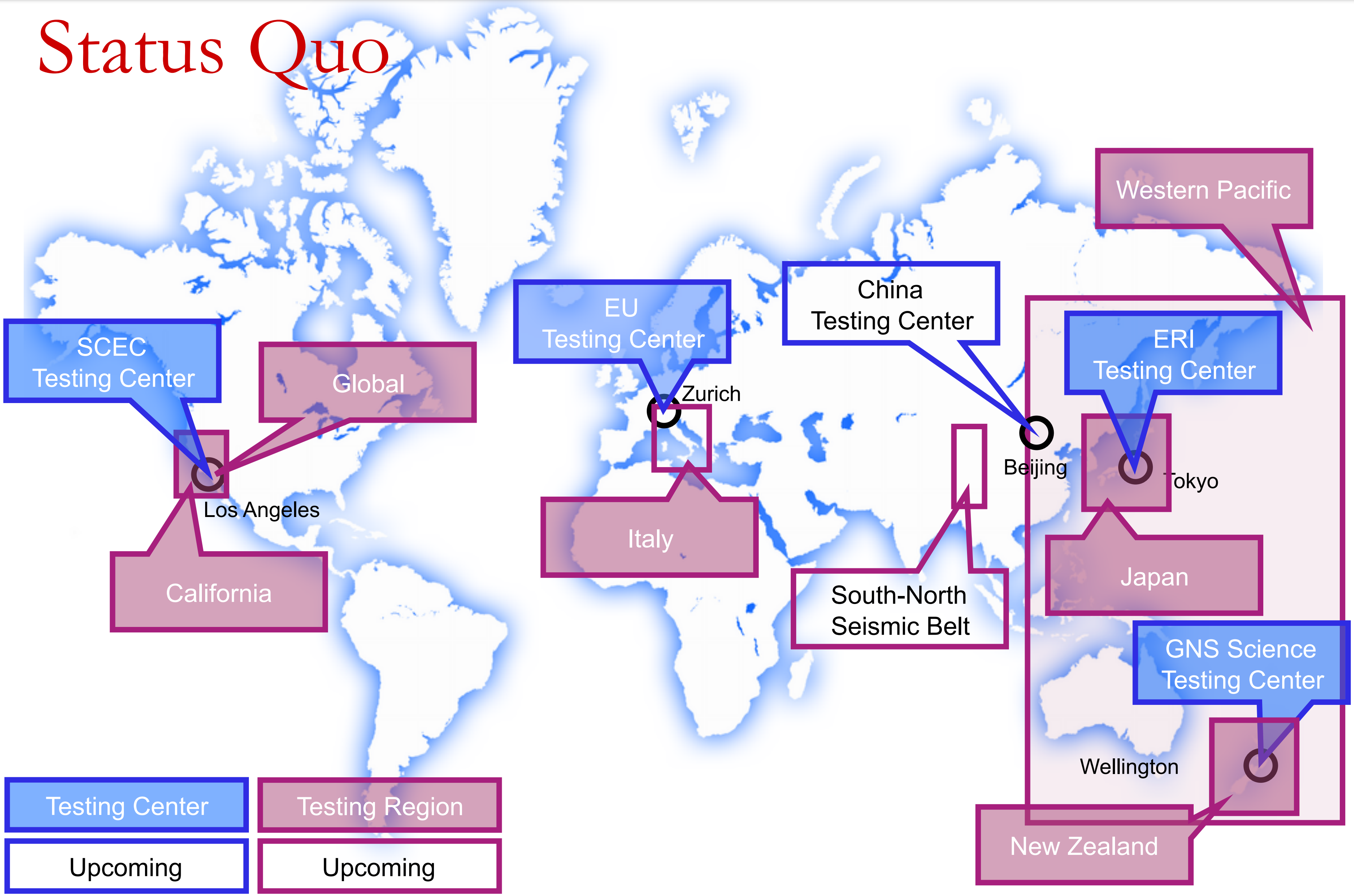
Some issues on OEF...

- Seismic (and risk) hazard **varies with time** (in particular in the short-term)
- During a seismic sequence the weekly probability of a destructive earthquake can **increase 100-1000 times** with respect to the reference level (derived from the long-term hazard), but this **probability rarely reaches 1%**.
- Some of the available earthquake forecasting models are able to provide **accurate estimations of such probabilities** (verified through **CSEP** experiment)
- Despite the usual belief, such models are verified empirically **much better** than long-term hazard models.

Status Quo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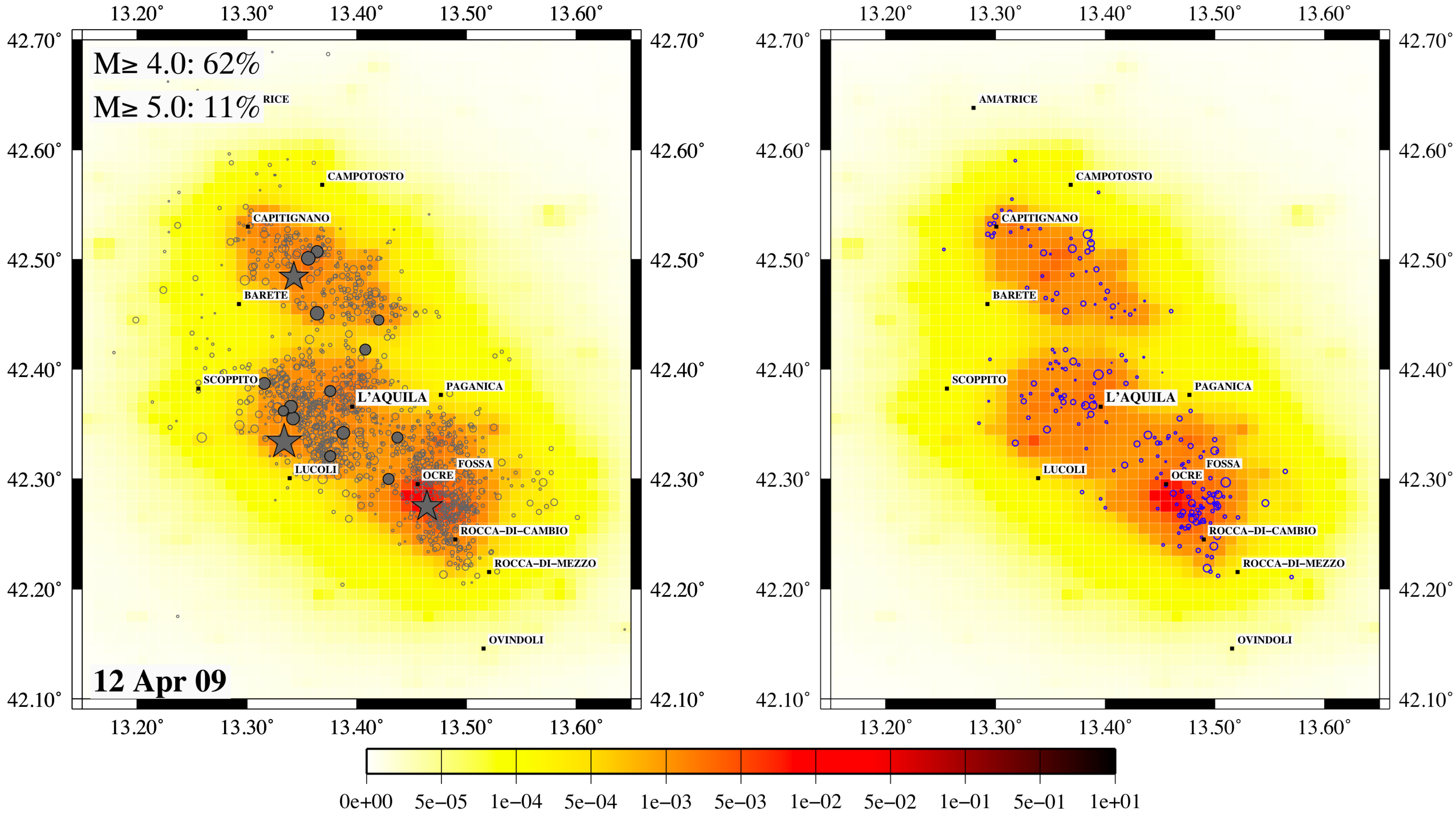
Japan
GNS Science
Testing Center
Wellington
New Zealand
Testing Center
Testing Region
Upcoming
Upcoming

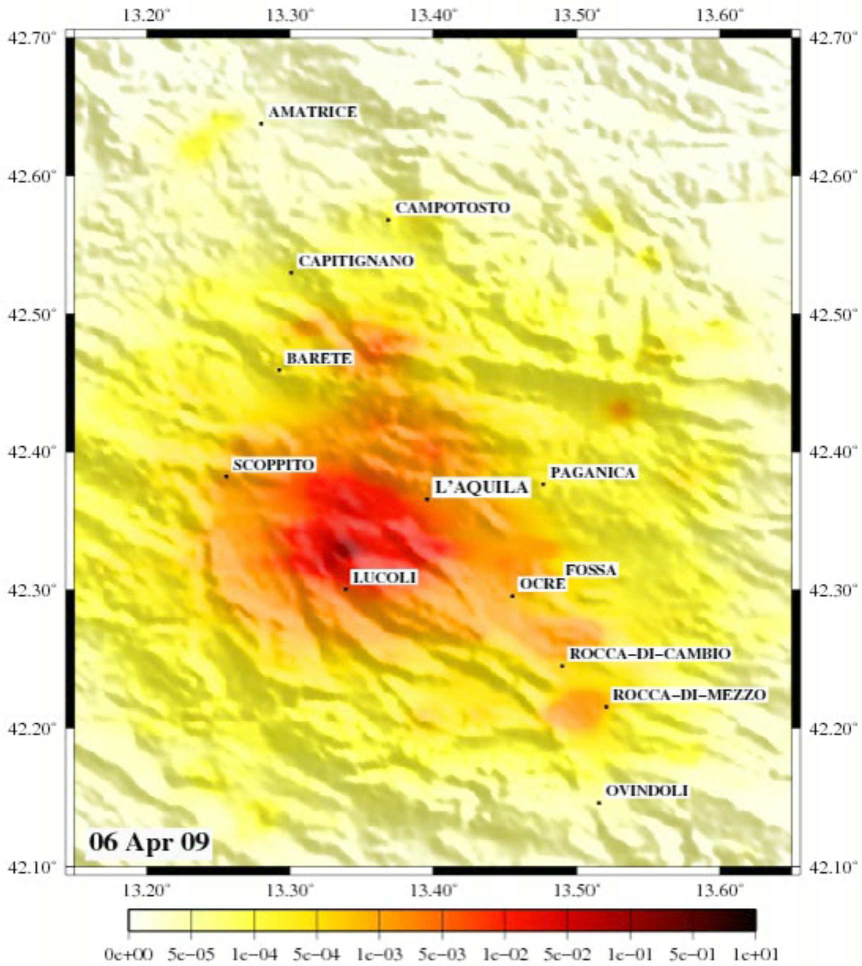
Short-term seismic hazard: The L'Aquila earthquake legacy

The 1-day forecasts *(the palette represents the rate of M 4+)*

Daily forecasts released at 8:00 AM (no overlaps)



The 1-day forecast
since Apr 6 – May 10



The 1-day forecast since May 19

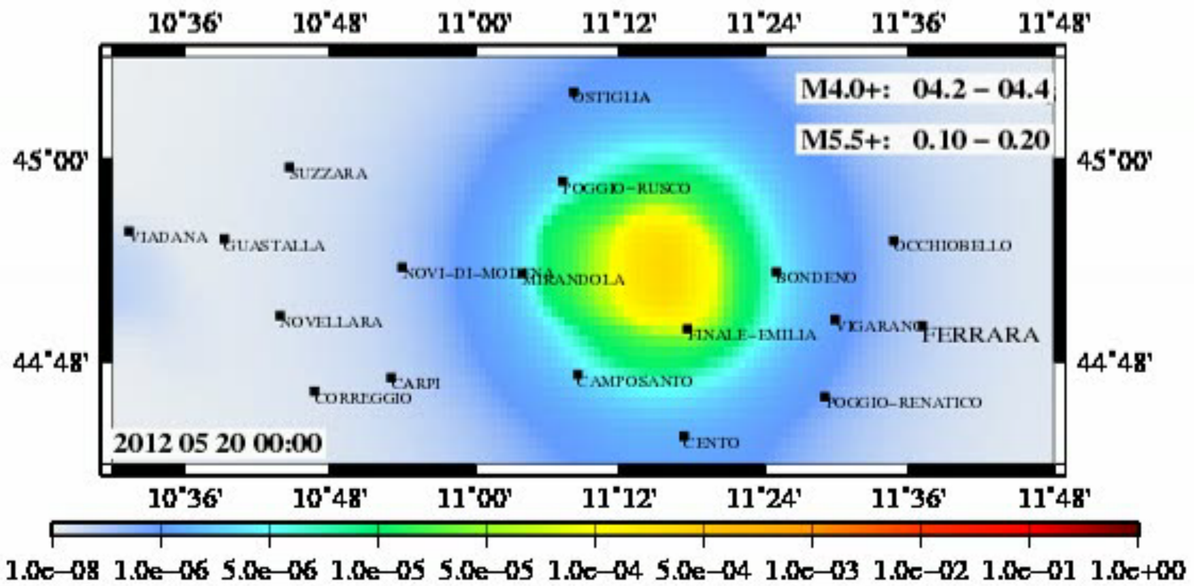
(2 independent models: **Lombardi-Marzocchi** & **Murru-Console-Falcone**)

Background probability for M4+= 0.007%

Probability gain on May 19= about 500

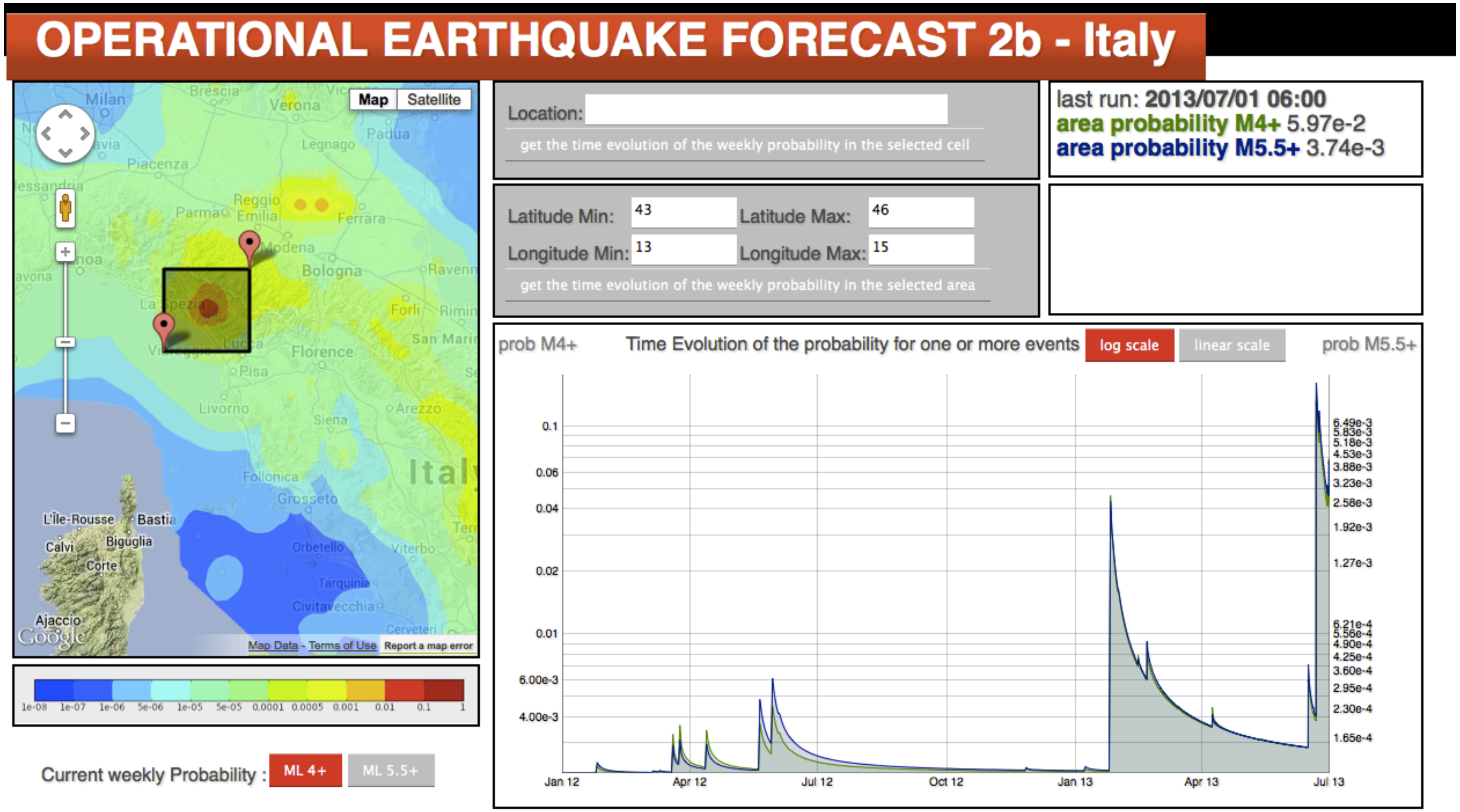
Probability gain on May 28= about 5000

Spatial density of the expected number of earthquakes with M4+ per km²



Short-term seismic hazard: The L'Aquila earthquake legacy

CASSANDRA v01: the example of the recent seismic sequence @ Garfagnana



Evolution of the **weekly probability** with time for the selected area: updated every **three hours**

Thanks!

warner.marzocchi@ingv.it