

Operational Earthquake (and Loss) Forecasting in Italy: The CSEP Legacy and Future Perspectives

Warner Marzocchi

Seismic Hazard Center (CPS)

Istituto Nazionale di Geofisica e Vulcanologia

In collaboration with many CPS colleagues and RELUIS (an Italian consortium of seismic engineering departments).

SCEC meeting, Palm Springs, Sept. 12-16, 2005

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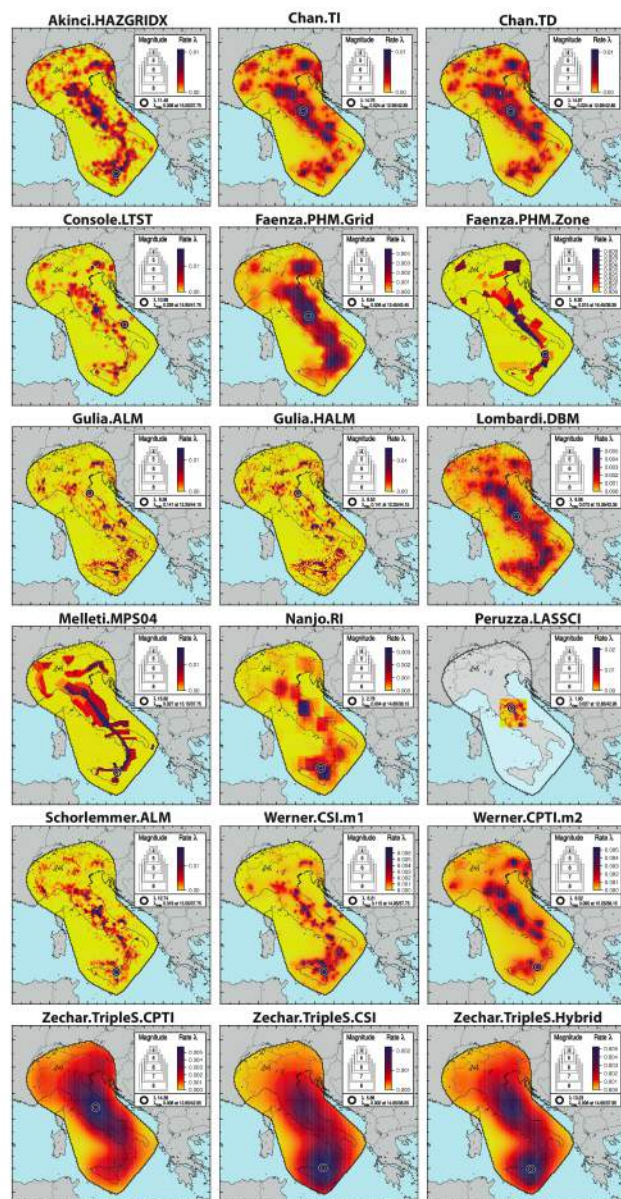


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Outline of the talk

- ❑ CSEP in Italy: where we are now.
- ❑ The current OEF implementation in Italy
- ❑ From OEF to OELF
- ❑ Future planned CSEP/OEF developments and challenges

CSEP in Italy



- August 1, 2009, a CSEP experiment in Italy started (ended July 31, 2014)
- EU testing center is at ETH Zurich
- First testing region in EU is Italy
- **18** *five-ten years* forecasting models have been submitted (M 5+)
- **5** *three-months* models (M 4+)
- **5** *one-day* models (M 4+)

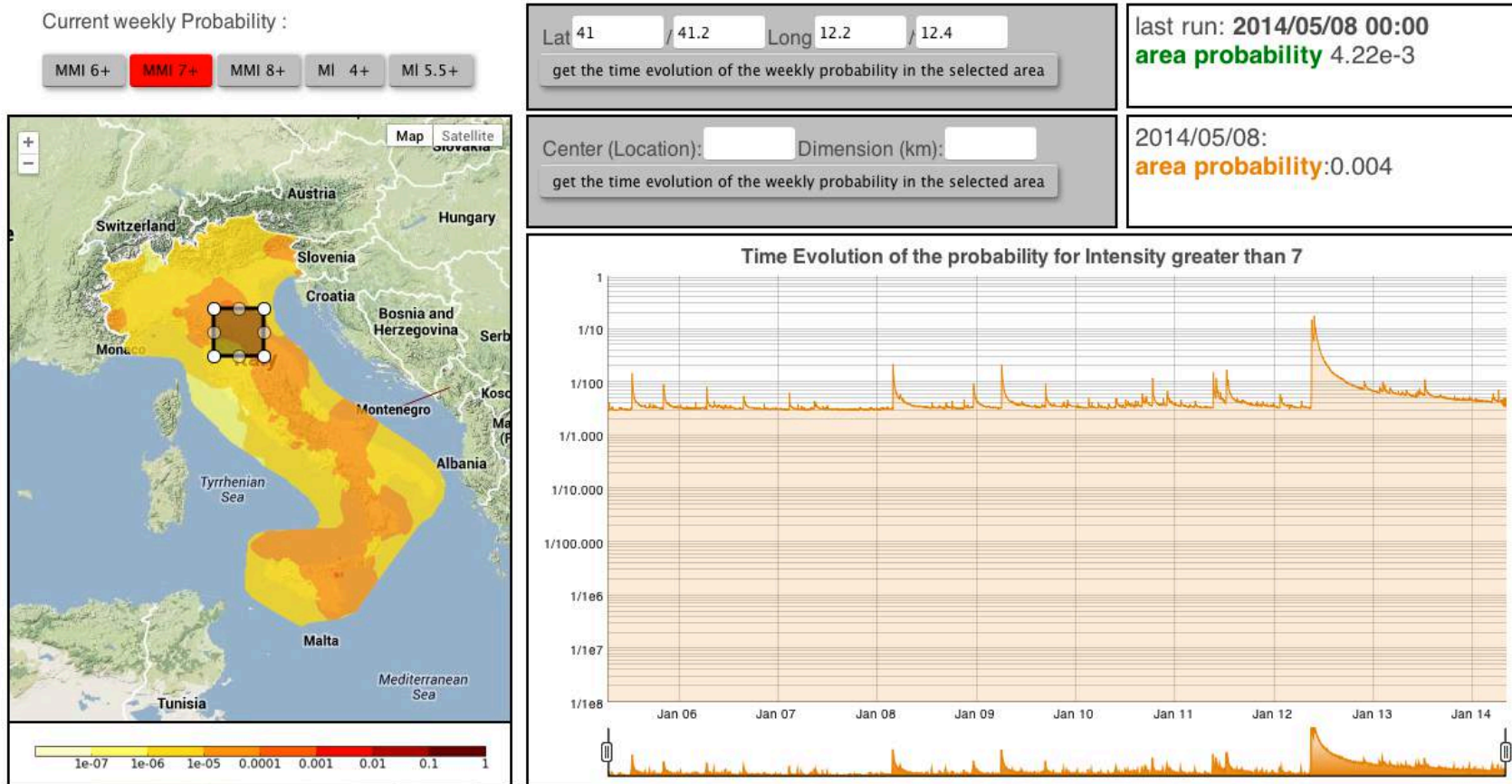
CSEP in Italy: where we are now?

- ❑ The experiment started on August 1, 2009, and it is ended on **July 31, 2014**.
- ❑ The official catalog is available until **Dec 31, 2012** (Emilia earthquakes & legal issues)
- ❑ The testing center at ETH in Zurich **are running the forecasts until Dec. 31, 2012** in order to get some preliminary results.
- ❑ The interest about the experiment was initially biased **towards long-term models (RELM-like)**, but due to the need to test **OEF models**, the interest shifted towards the **shorter forecasting time intervals**.
- ❑ We plan to work on the testing phase since this fall (some results for the next SCEC meeting!)

The current OEF implementation in Italy

Current OEF implementation in Italy

OPERATIONAL EARTHQUAKE FORECAST 4 - Italy



Evolution of the **weekly probability** with time for the selected area: updated every **day** or after a M3.5+
Presently available at the Department of Civil Protection for internal evaluation

Philosophy of OEF_Italy system (a.k.a. Cassandra): **transparency, reproducibility and testability.**

This philosophy fits well the **ICEF requirements** because it guarantees that the scientific information delivered is **authoritative, timely** and in a **proper format**

- ❑ **Authoritativeness** is given by the stakeholders (we need to convince them)
- ❑ **Timely** means **continuously** (sporadic forecasts imply that the hazard/risk do not change when the forecasts is not delivered; overlapping with the decision-making)
- ❑ **Proper format** means **quantitative**. Only quantitative forecasts can be used for a rational decision making and allow citizens to compare the occurrence of different events.

It respects the hazard/risk separation principle and it facilitates the definition of justifiable protocols for the decision making

Current OEF implementation in Italy

ANNALS OF GEOPHYSICS, 53, 3, 2010; doi: 10.4401/ag-4848

The ETAS model for daily forecasting of Italian seismicity in the CSEP experiment

Anna Maria Lombardi^{1,*} and Warner Marzocchi¹

¹ Istituto Nazionale di Geofisica e Vulcanologia, sezione di Roma, Italy

Article history

Received October 30, 2009; accepted August 10, 2010.

Subject classification:

Earthquake probability, Forecasting, Italian seismicity, Hypothesis test, Aftershocks.

ABSTRACT

This study investigates the basic properties of the recent shallow seismicity in Italy, through stochastic modeling and statistical methods. Assuming that earthquakes are the realization of a stochastic point process, we have modeled the occurrence rate density in space, time and magnitude using an epidemic type aftershock sequence model. By applying the maximum likelihood procedure, we estimated the parameters of the model that best fit the Italian instrumental catalog, as recorded by the Istituto Nazionale di Geofisica e Vulcanologia (INGV) from April 16, 2005, to June 1, 2009. Then we applied the estimated model to a second independent dataset (June 1, 2009, to September 1, 2009). We show that the model performed well on this second database, through the relevant statistical tests. The model proposed

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ANNALS OF GEOPHYSICS, 53, 3, 2010; doi: 10.4401/ag-4812

Building self-consistent, short-term earthquake probability (STEP) models: improved strategies and calibration procedures

Jochen Woessner^{1,*}, Annemarie Christophersen^{1,3}, J. Douglas Zechar^{1,2}, Damiano Monelli¹

¹ ETH Zurich, Swiss Seismological Service, Zurich, Switzerland

² Lamont-Doherty Earth Observatory, Columbia University, Palisades, NY, USA

³ GNS Science, Auckland, Lower Hutt, New Zealand

Article history

Received October 23, 2009; accepted April 13, 2010.

Subject classification:

Earthquake statistics, Earthquake forecasting, Likelihood testing, Aftershock model, Seismicity analysis.

ABSTRACT

We present two self-consistent implementations of a short-term earthquake probability (STEP) model that produces daily seismicity forecasts for the area of the Italian national seismic network. Both implementations combine a time-varying and a time-invariant contribution, for which we

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frameworks such as epidemic type aftershock sequence (ETAS) models and short-term earthquake probability (STEP) models are used for automated, near-real-time applications [e.g., Console et al. 2003, Gerstenberger et al. 2005, Helmstetter et al. 2006, Marzocchi and Lombardi 2008]. Both of these frameworks can adapt to ongoing earthquake sequences by re-estimating model parameter values and automatically generating forecasts that account for the most recent seismicity. Physics-based models that combine calculations of stress changes with a rate-and-state friction

ANNALS OF GEOPHYSICS, 53, 3, 2010; doi: 10.4401/ag-4760

Short-term and long-term earthquake occurrence models for Italy: ETES, ERS and LTST

Giuseppe Falcone^{1,*}, Rodolfo Console¹, Maura Murru¹

¹ Istituto Nazionale di Geofisica e Vulcanologia, sezione di Roma, Italy

Article history

Received October 1, 2009; accepted April 22, 2010.

Subject classification:

Earthquake interactions and probability, Statistical analysis, Stress, Historical seismology, Earthquake faults.

ABSTRACT

This study describes three earthquake occurrence models as applied to the whole Italian territory, to assess the occurrence probabilities of future ($M \geq 5.0$) earthquakes: two as short-term (24 hour) models, and one as long-term (1 and 10 years). The first model for short-term forecasts is a purely stochastic epidemic type earthquake sequence (ETES) model. The second short-term model is an epidemic rate-state (ERS) forecast based on a model that is physically constrained by the application to the earthquake clustering of the Dieterich rate-state constitutive law. The third forecast is based on a long-term stress transfer (LTST) model that considers the perturbations of earthquake probability for interacting faults by static Coulomb stress changes. These models have been submitted to the Collaborative for the Study of Earthquake Predictability (CSEP) for forecast testing for Italy (ETH Zurich), and they were locked down to test their validity on real data in a future setting starting from August 1, 2009.

Helmstetter et al. 2006]. These models were proposed to answer the most common questions of the general public and the media that arise in particular after sizable events, such as, «What will happen next?» and, «What is the chance that another large earthquake will occur?».

Stochastic short-term models describe seismicity as a random point process, for which a continuous space-time density distribution of the earthquake occurrence can be defined. A best-fit procedure based on the maximum likelihood criterion has been used for statistical analysis of random processes. In particular, Kagan and Knopoff [1976, 1987], Kagan [1991], Ogata [1999], Kagan and Jackson [2000], Console and Murru [2001], Imoto [2004], Rhoades and Evison [2006], and Helmstetter et al. [2006] have applied the

- To date, only **earthquake clustering models** are used.
- We consider only models that are submitted to at least one **CSEP experiment (CSEP liaison)**

ENSEMBLE forecasting model.

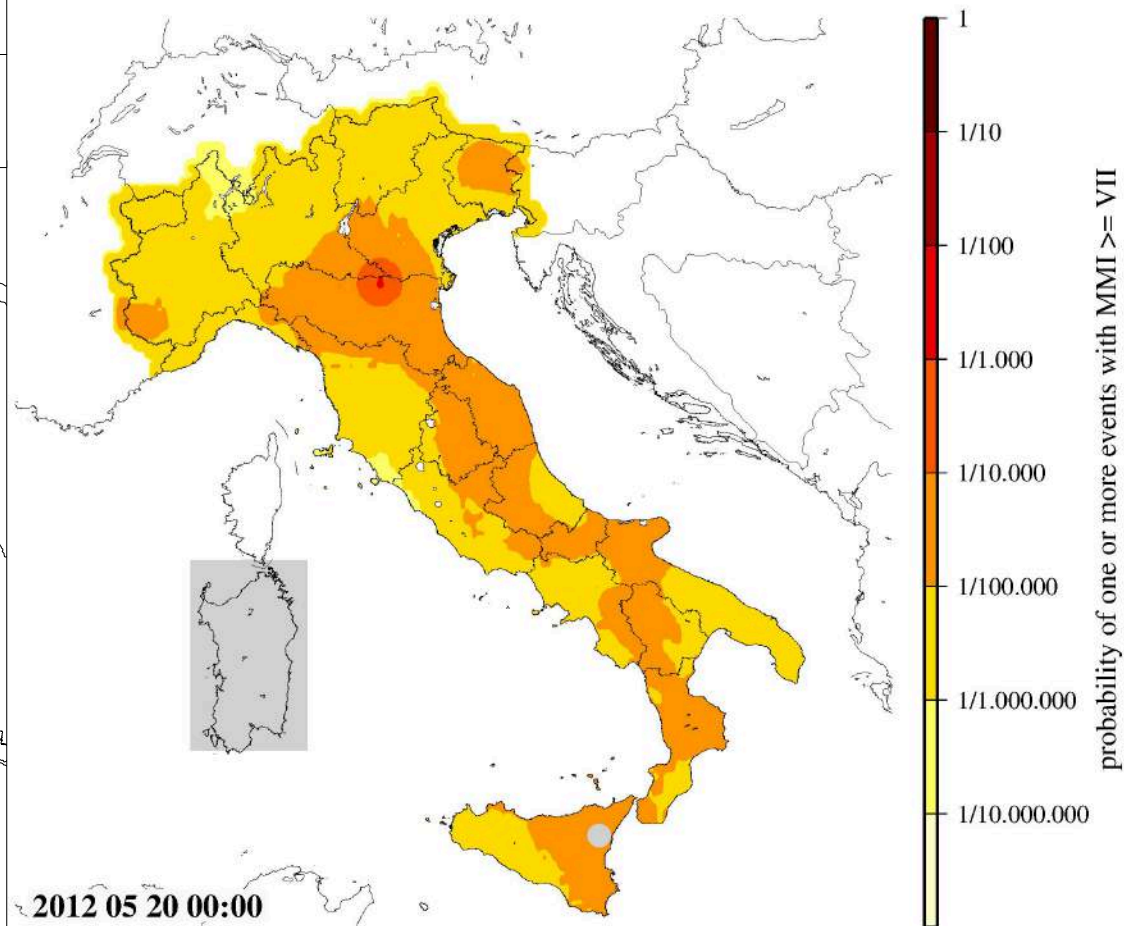
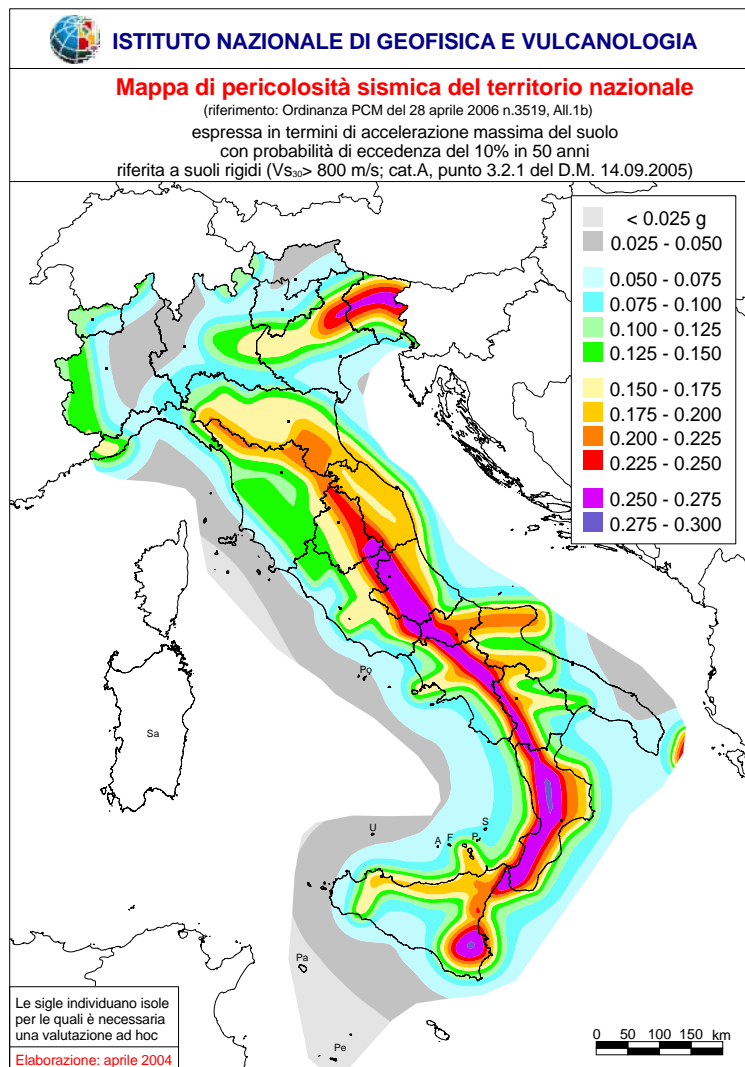
Each model is **weighted** according to its **forecasting performances** (it is also possible to estimate the epistemic uncertainties)

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Current OEF implementation in Italy



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From OEF to OELF (a joint effort CPS and RELUIS)

Risk reduction is made on risk assessment, not on hazard (except for the building code)

- ❑ We link **OEF output** with the estimation of vulnerability and exposed value to calculate the **expected loss** using **different metrics**, such as the expected number of collapsed buildings, displaced residents, injuries, and fatalities (a joint effort of CPS and RELUIS). **NOTE: we respect the hazard/risk principle** (CPS estimates only the hazard); presently, we estimate the risk, but we are not engaged in managing it.
- ❑ We found that the orders of magnitude **increase in the hazard** reflects in a **comparable increase of the risk**
- ❑ We found that “**small earthquake probabilities**” are sometimes linked to an **intolerable Individual Risk of Death (IRD)**

(Marzocchi, Iervolino, Giorgio, Falcone, 2015, SRL in press)

From OEF to OELF (are the earthquake probabilities too low?)

OPERATIONAL EARTHQUAKE FORECAST 4 - Italy

Current weekly Probability :

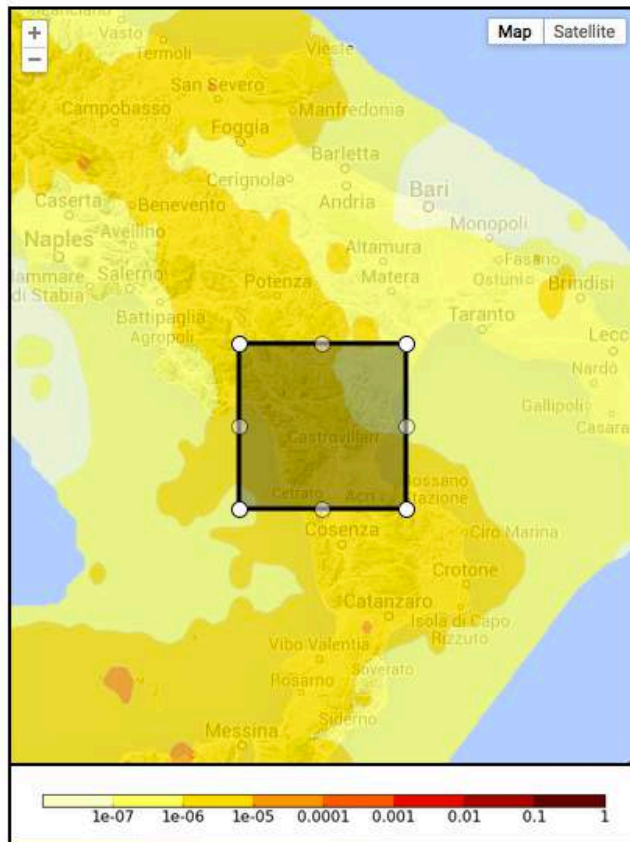
MMI 6+

MMI 7+

MMI 8+

MI 4+

MI 5.5+



Lat / Long /

get the time evolution of the weekly probability in the selected area

Center (Location): 39.85 16.05 Dimension (km): 50

get the time evolution of the weekly probability in the selected area

last run: 2015/05/12 02:30

area probability 1.80e-4

2012/10/26:

area probability: 0.004

Time Evolution of the probability for one or more events with Magnitude greater than 5.5

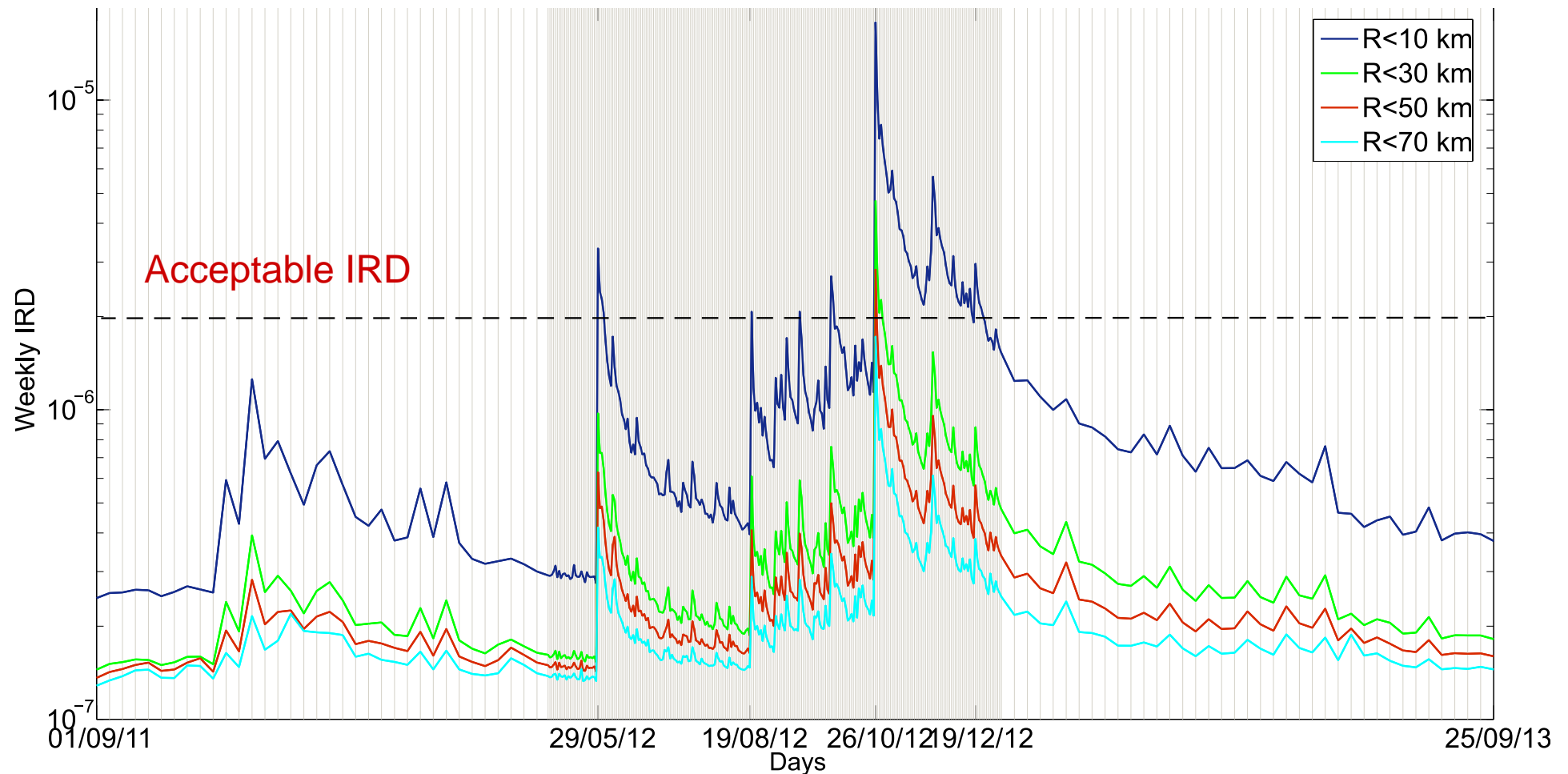


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From OEF to OELF (are the earthquake probabilities too low?)



It may be misleading asking if the probability of large earthquake is **too small**; it is the related risk that can be **acceptable or not**

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Future CSEP/OEF developments in Italy and challenges

Future CSEP/OEF developments and challenges in Italy

- ❑ The CSEP forecasts are for **1-day** and **3-months**. OEF is using **1-week**, and we probably will go for other time windows (**medium-term forecasts**), depending on the **stakeholders requirements**.
- ❑ Comparing CSEP/OEF results using the **official** and the **real-time catalog**.
- ❑ Need to testing **ensemble models**.
- ❑ Need to **strengthen the testing phase** (maybe a major restyling is needed; **panel discussion on epistemic uncertainty**)
- ❑ The CSEP/OEF/OELF **communication issue**

The end