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The legacy of MPS19, the "useless" Italian hazard model

Carlo **Meletti – INGV** Pisa

carlo.meletti@ingv.it

Perciò il Governo commette un errore gravissimo quando, dopo avvenuto un disastro sismico, impone dei regolamenti di edilizia sismica, limitandoli alla regione colpita. La sismologia non sa dire quando, ma sa dire dove avverranno i terremoti rovinosi, e sa graduare la sismicità delle diverse parti della regione calabro-lucana, poiché anche in essa ci sono zone relativamente tranquille.

In altre parole, la sismologia saprebbe indicare al Governo dove sono necessari regolamenti edilizi più o meno rigorosi, senza aspettare, come s'è fatto finora, che prima il terremoto distrugga quei paesi che si vogliono salvare.

Giuseppe Mercalli
1850-1914

Therefore, the Government commits a very serious error when, after an earthquake disaster, it imposes seismic building regulations, limiting them to the affected region. Seismology cannot say *when*, but it can tell *where* the destructive earthquakes will occur, and it knows how to graduate the *seismicity* of the different parts of the Calabria-Lucania region, since there are relatively quiet areas in it too.

Seismic hazard

In other words, seismology would be able to indicate to the Government where more or less stringent building regulations are needed, without waiting, as has been done so far, for the earthquake to first destroy those villages that need to be saved.

Building code

Mercalli, I danni prodotti dai terremoti nella Basilicata e nelle Calabrie, 1910

Costs of the largest earthquakes in Italy since 1968

Earthquake	Mw	M€ (current value)	Period	Casualties	Homeless
Belice 1968	6.4	9179	1968-2018	296	57000
Friuli 1976	6.5	18540	1976-2006	965	189000
Irpinia 1980	6.8	52026	1980-2023	2735	280000
Umbria-Marche 1997	6.0	13463	1997-2024	11	22600
S. Giuliano 2002	5.5	1427	2002-2023	30	10600
Abruzzo 2009	6.1	17500*	2009-2029	309	65000
Emilia 2012	5.9	13300*	2012-2047*	27	15000
Centro Italia 2016	6.5	23000*	2016-2047*	303	65000

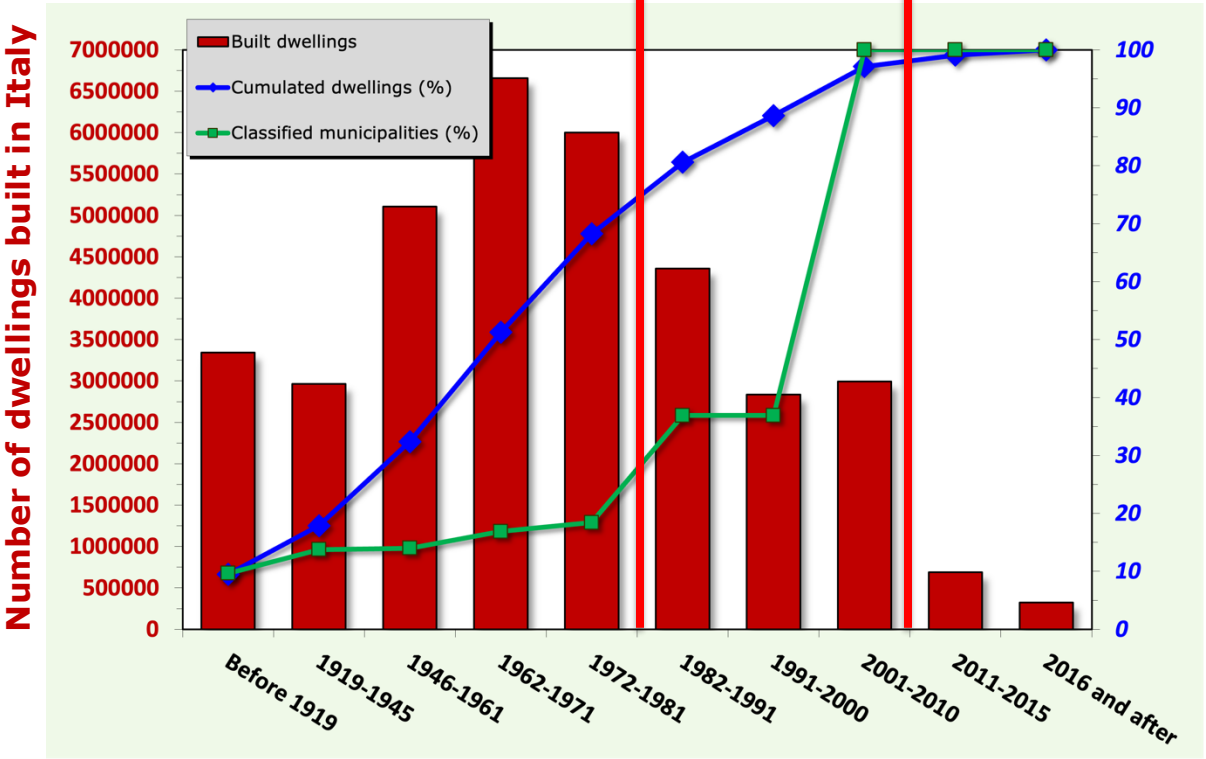
Sum for all the earthquakes from 1968 to 2021:
200 billions of euros

*estimated

http://documenti.camera.it/leg16/dossier/Testi/Am0065.htm

First zoning for the whole National territory (1984)

Adoption of building code inspired by EC8 (2009)

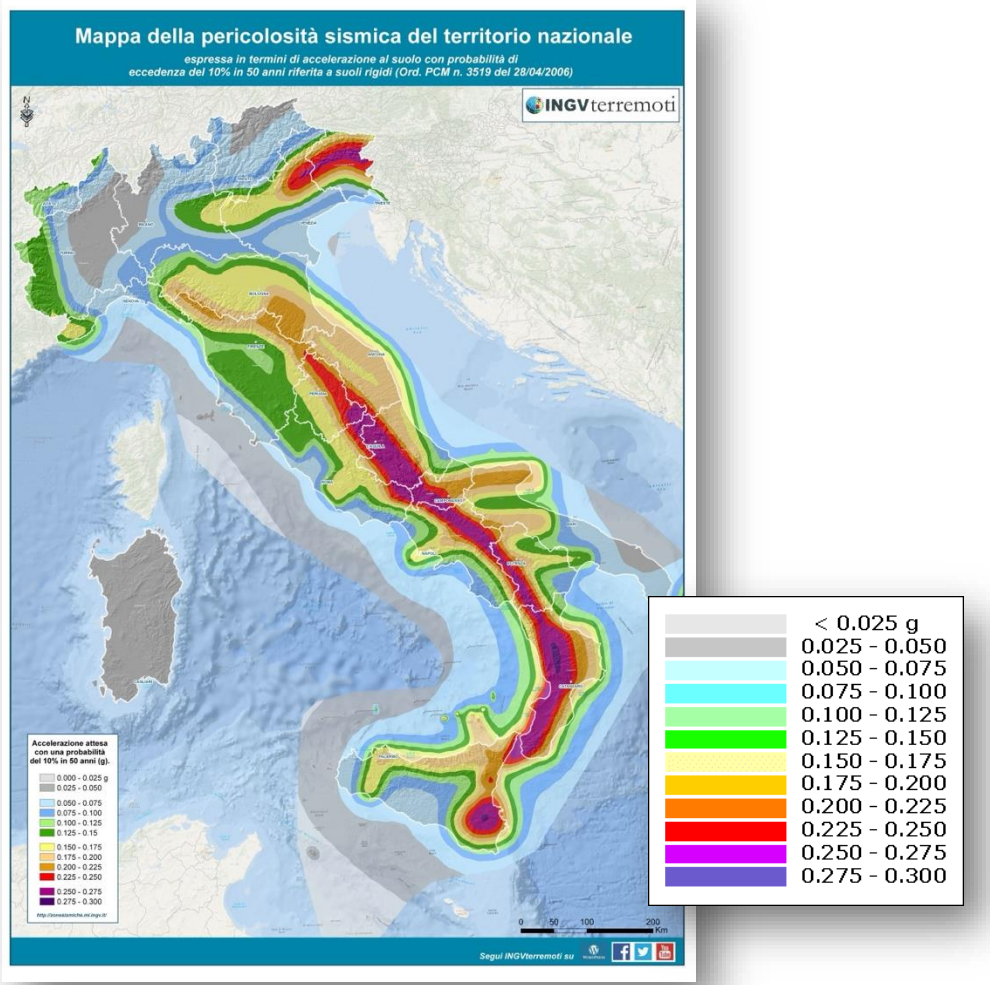


MPS04

Reference seismic hazard map of Italy (OPCM 3519/2006)

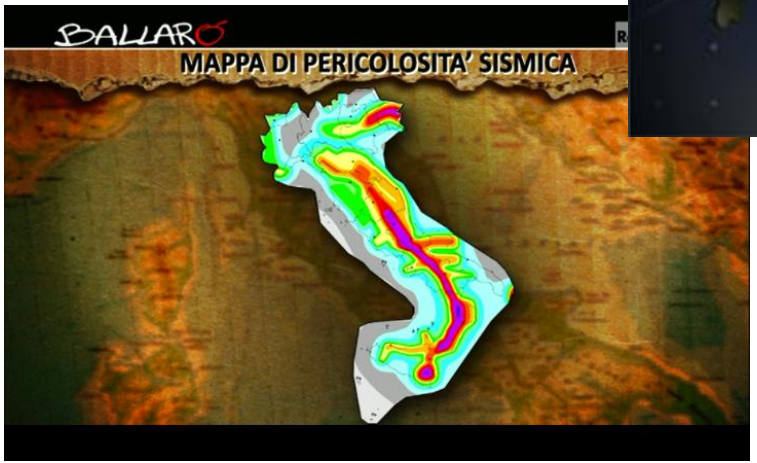
PGA, 10% exceedance prob. in 50 years very stiff soil (cat. A: Vs30>800 m/sec)

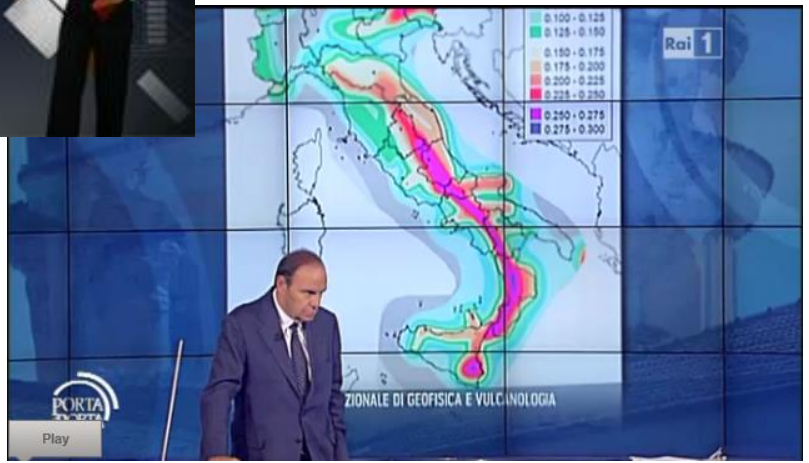
http://zonesismiche.mi.ingv.it




Perché la pericolosità ci dice
soltanto quando un evento avverr


MANTOVA
FERRARA
MODENA
BOLOGNA
Rai 1
PRIMASER


BALLARÒ
MAPPA DI PERICOLOSITA' SISMICA


0.100 - 0.125
0.125 - 0.150
0.150 - 0.175
0.175 - 0.200
0.200 - 0.225
0.225 - 0.250
0.250 - 0.275
0.275 - 0.300
Rai 1
PORTA
ZIONALE DI GEOFISICA E VULCANOLOGIA
Play

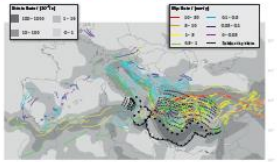
European Seismic Hazard Map

edited by D. Giardini, J. Woessner, and L. Danciu, Swiss Seismological Service, ETH Zurich, August 2013

European Commission

2013

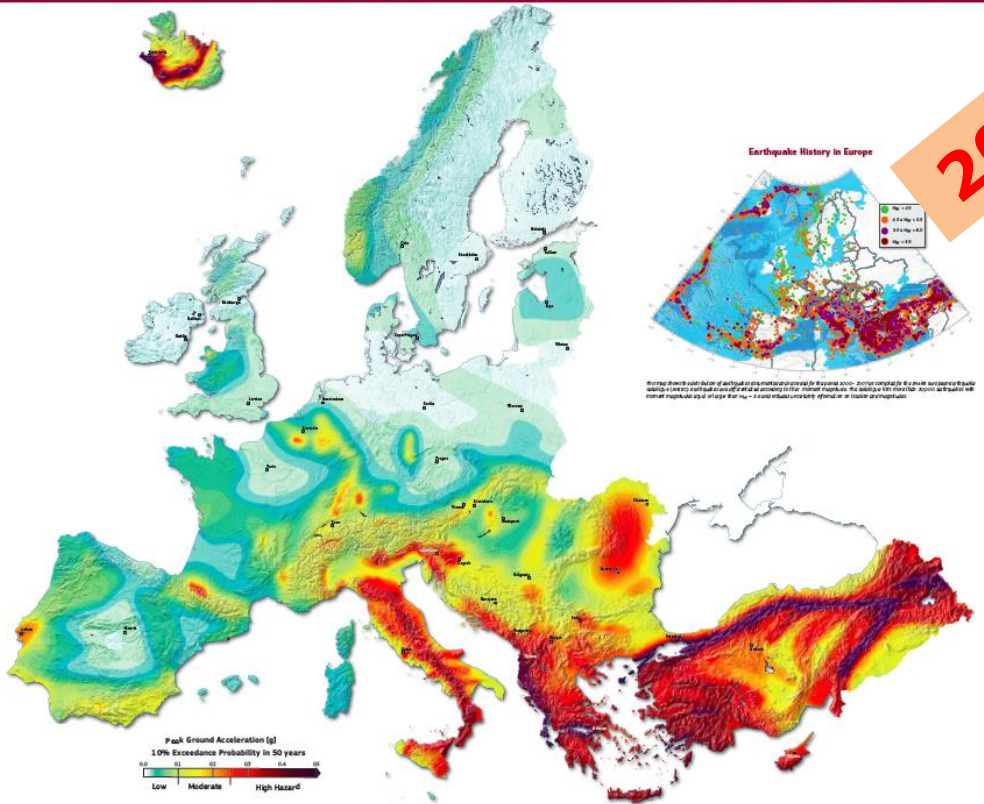
Active Faults in Euro-Mediterranean Region



Seismic Hazard Assessment

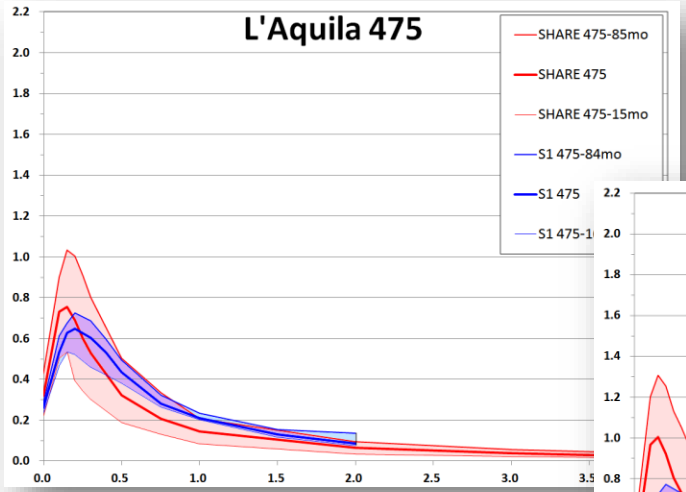
Map Content

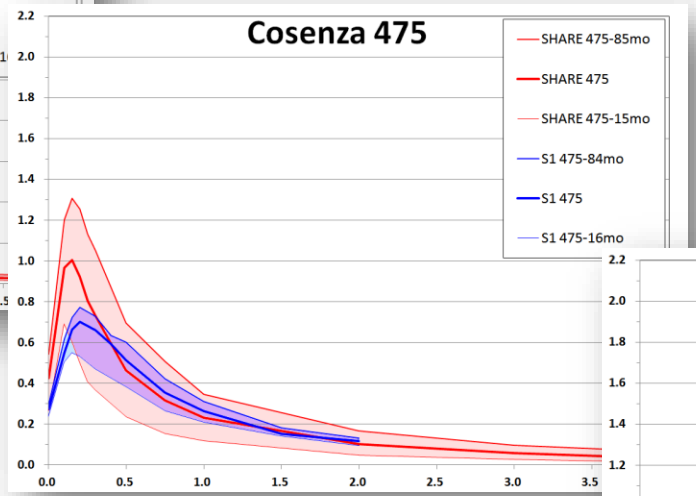
Acknowledgements

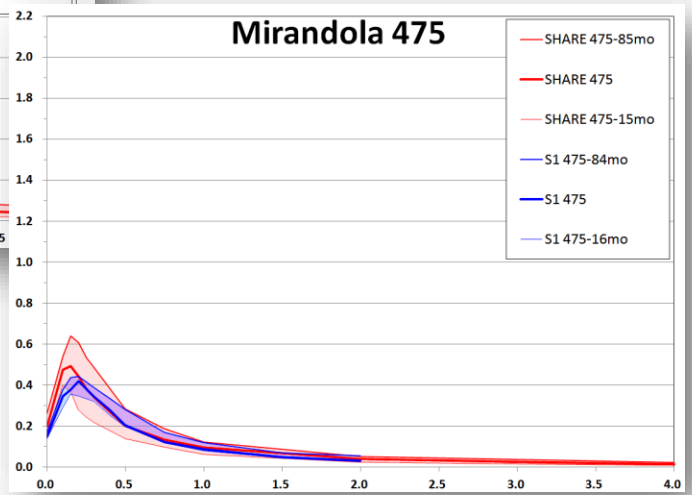


Earthquake History in Europe

MPS04 vs SHARE







Meletti et al., 2014 - doi: 10.7414/PS.5.1.15-25

CPS: the Center for Seismic Hazard

In January 2013, INGV established a Seismic Hazard Center (Centro di Pericolosità Sismica, CPS). Coordinators: W. Marzocchi, C. Meletti

CPS promoted a coordination between the many teams at INGV focused on research on seismic hazard.
From 2013 to 2021 CPS was funded by Civil Protection with annual agreement.

CPS had three main goals:

1. to promote innovative researches for seismic hazard assessment

2. to implement procedures for testing and evaluating seismic hazard output and their components (strong link with CSEP activities)

3. to provide authoritative seismic hazard assessment at different time scales: **long-term** (50 years), **mid-term** (5-10 years), **short-term** (days-weeks; the so-called Operational Earthquake Forecasting, OEF)

CPS strategies for defining the new seismic hazard model for Italy (2015-2019)

- ✓ **The adoption of the best international standards** according to the state-of-the-art (e.g., SSHAC, 1997; SHARE model, 2013), as confirmed in Gerstenberger et al. (2020)
- ✓ **Open and transparent procedures**, with the participation of the national and international scientific community: **more than 100 researchers were involved in the project after a public call**
- ✓ **Release of fully reproducible data** and transfer to decision makers
- ✓ **The new seismic hazard model is not the combination of closed and released models**, but the selection of the best available data in order to combine them in a model to obtain the largest agreement
- ✓ **The final model is determined after the testing of each single input element and of resulting model** with respect to the observables and through agreed approaches. Models not in agreement with tests, **were rejected**.
- ✓ **The model accounts for information** of different nature on earthquake occurrence (past seismicity, geological features, fault distribution, and ground deformation) **that were not included in previous analysis**

The requirements of the model

In meetings with **DPC (Italian Civil Protection Department)**, **REluis** and **Eucentre** (reference institutions on earthquake engineering for DPC) the requirements of the new model were discussed and defined.

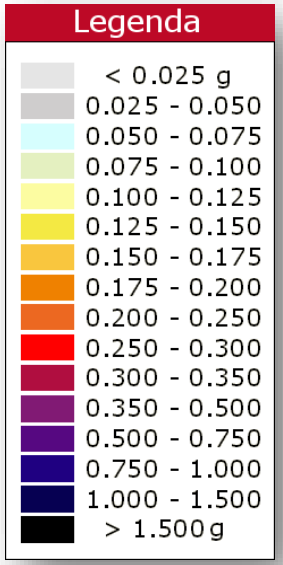
1. **Time independent model based on a probabilistic approach**
2. National coverage with uniform level of reliability
3. Hard rock soil (Class A according EuroCode 8)
4. Spectral acceleration, velocity, displacement, macroseismic intensity
5. Return period 30-5000 years
6. Spectral ordinates 0.05-4 seconds
7. **The "best available science"**

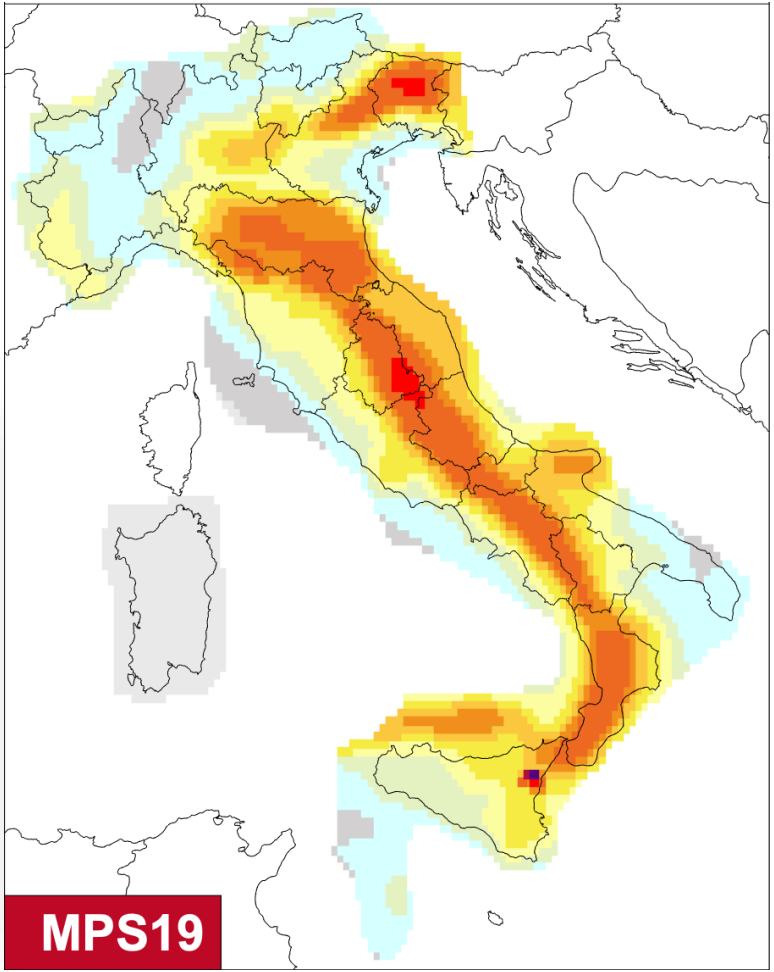
Francesco Visini yesterday presented some key point of the MPS19 model.

- 14 new or updated databases about seismological data as shared basis for all participating modellers
- 11 seismicity model based on area source zones, grid, faults, each of them subjected to elicitation and testing
- Rigorous selection of GMPEs and their elicitation and testing
- Test of consistency of the outputs against available observations

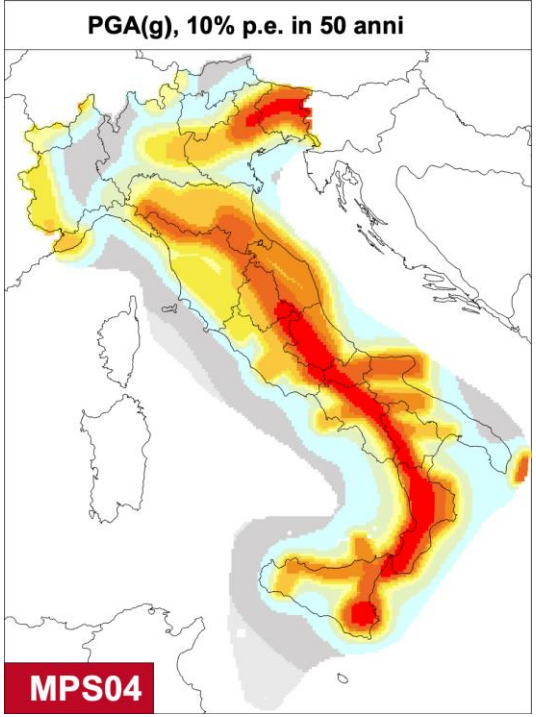
MPS19

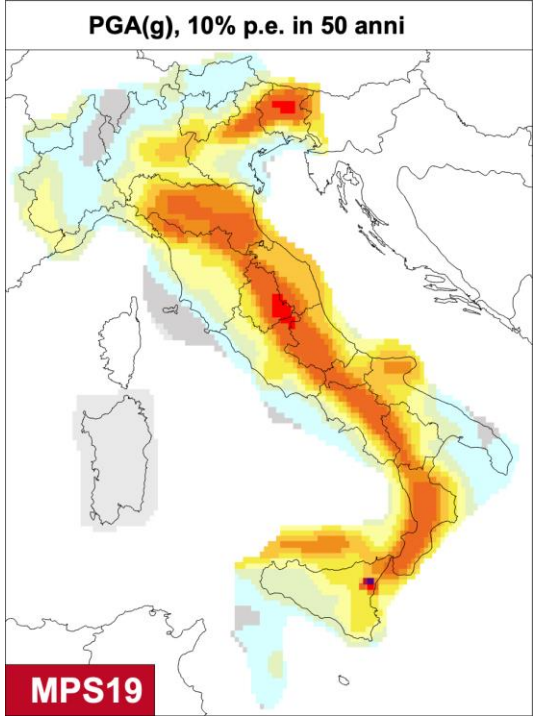
PGA with 10% of probability of exceedance in 50 years

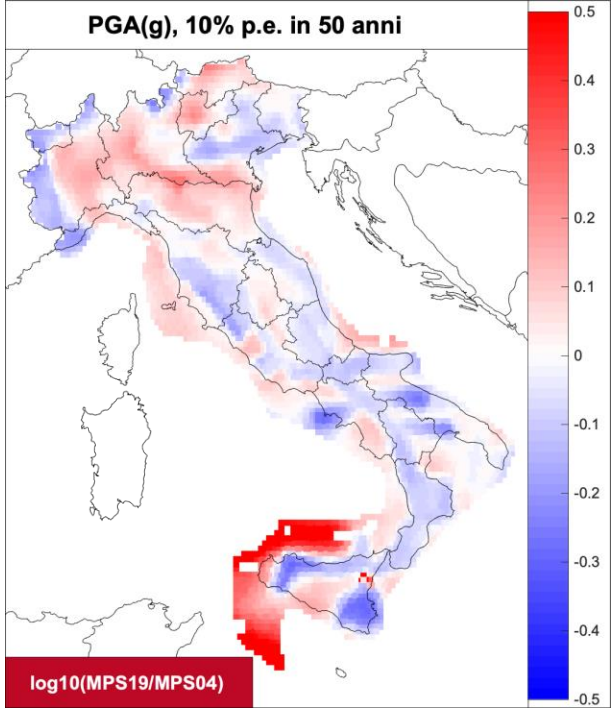




Meletti et al., 2021 - https://doi.org/10.4401/ag-8579

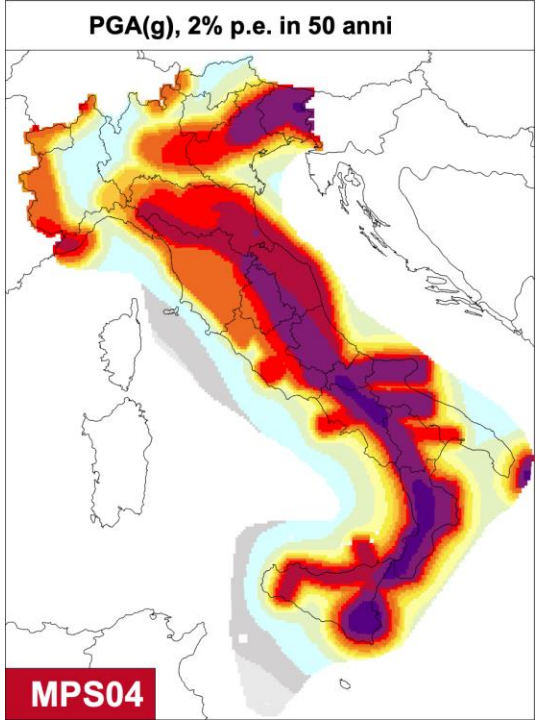


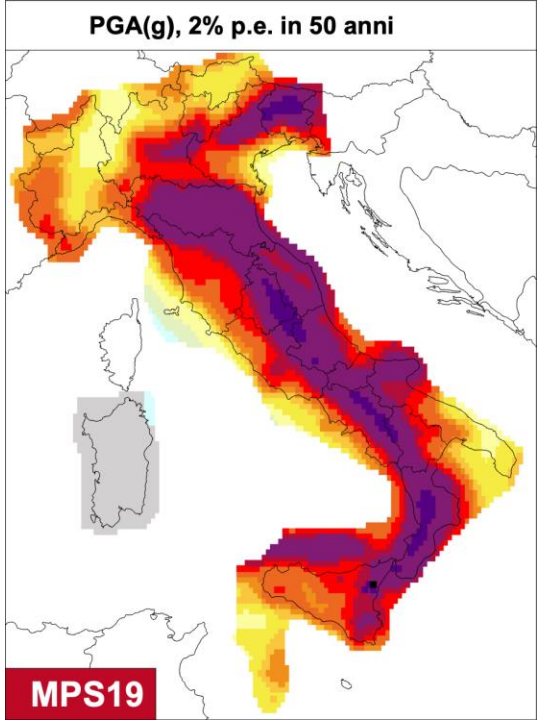


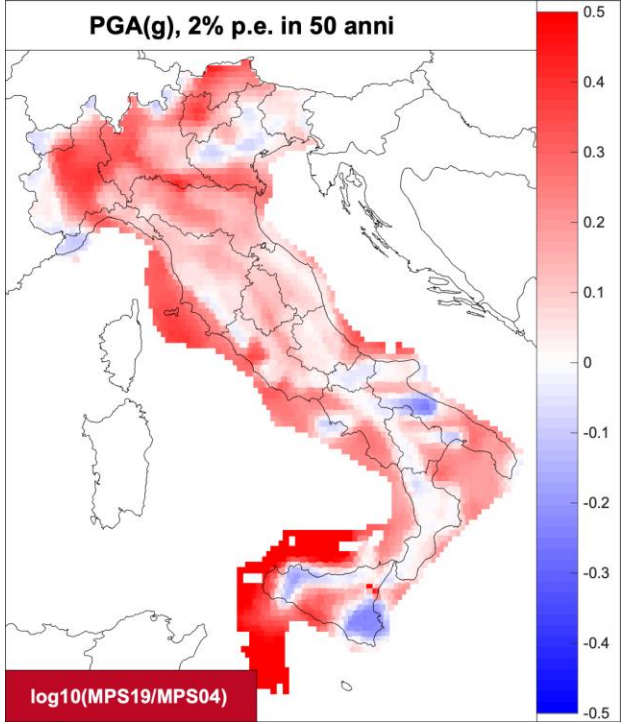


MPS04
PGA 10% p.e. in 50 years

MPS19
PGA 10% p.e. in 50 years







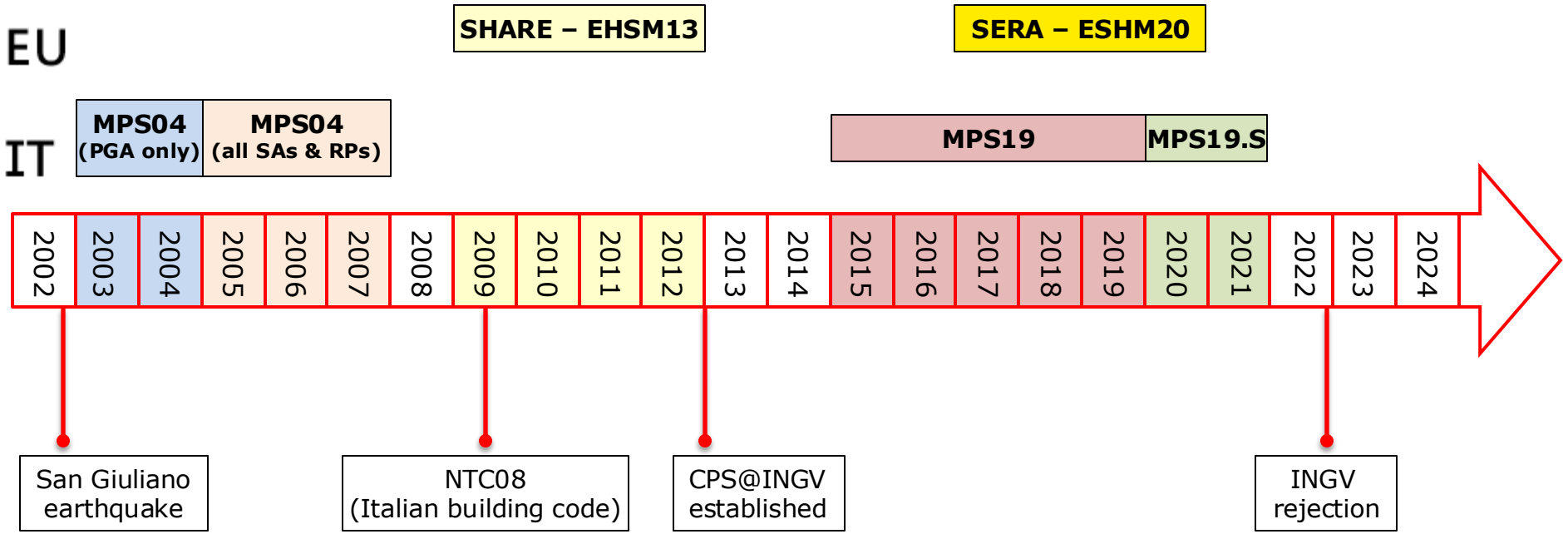
MPS04
PGA 2% p.e. in 50 years

MPS19
PGA 2% p.e. in 50 years

Main features of MPS19

- ✓ The new seismic hazard model of Italy was completed in May 2019.
- ✓ The model widely describe the epistemic uncertainty and the aleatory variability. This makes the model testable, keeping seismic hazard into a scientific domain.
- ✓ The model is fully transparent and reproducible.
- ✓ We created an ensemble, merging different "views" about the earthquake occurrence, which hopefully describes different features of the earthquake occurrence process.
- ✓ Each model has been weighed according to its testing performances and experts' opinion.
- ✓ It is important for us the respect of the criteria defined at the beginning, with very few expert judgements adopted on the fly. This makes the model modular, simply emendable.
- ✓ **If and how to transfer MPS19 into the building code is a "political" decision, not up to scientists**.

The roadmap to update national building code: a chronology



The roadmap to update national building code: a chronology

- In **2015** DPC asked and funded INGV for a new seismic hazard model of Italy
- CPS-INGV opened a call for contribution to several tasks
- The project started with more than 100 researchers from 24 teams
- The initiative was subject to a participatory review by DPC experts
- In **2019** CPS-INGV released MPS19 model and submitted it to DPC

The reviewers' panel evaluation

The test operation […], strictly speaking, cannot be defined as "validation" - which is a wellcoded statistical procedure - since the learning data set and the voting data set are not independent. This comparison, however, provides an important sanity check: if the results of a model disagree with historical seismicity, can they credibly agree with the future one?

From this point of view, MPS19 represents an undoubted progress not only compared to MPS04 but also, to the knowledge of the GDL (the reviewers' panel), to all the PSHA procedures that have been adopted to derive the national hazard maps currently existing in the world.

[…]

Finally, satisfaction is expressed for the intellectual honesty brought by the researchers in the interaction with the GDL and the transparency with which MPS19 was developed, characteristics that constitute the best guarantee for further progress. Future updates of MPS19-derived hazard maps will find robust foundations to build upon.

The roadmap to update national building code: a chronology

- DPC asked to Major Risks Commission (CGR)* the evaluation of the model in terms of application to building code
- CGR suggested some modifications during many technical meetings
- In **2021** CPS-INGV applied the requests and released a new, simplified version (MPS19.S), tailored for the application to building code

* *CGR is the link between the Civil Protection and the scientific community with the main function of providing the Head of Department with technical-scientific opinions.*

The CGR (DPC) evaluation in 2019

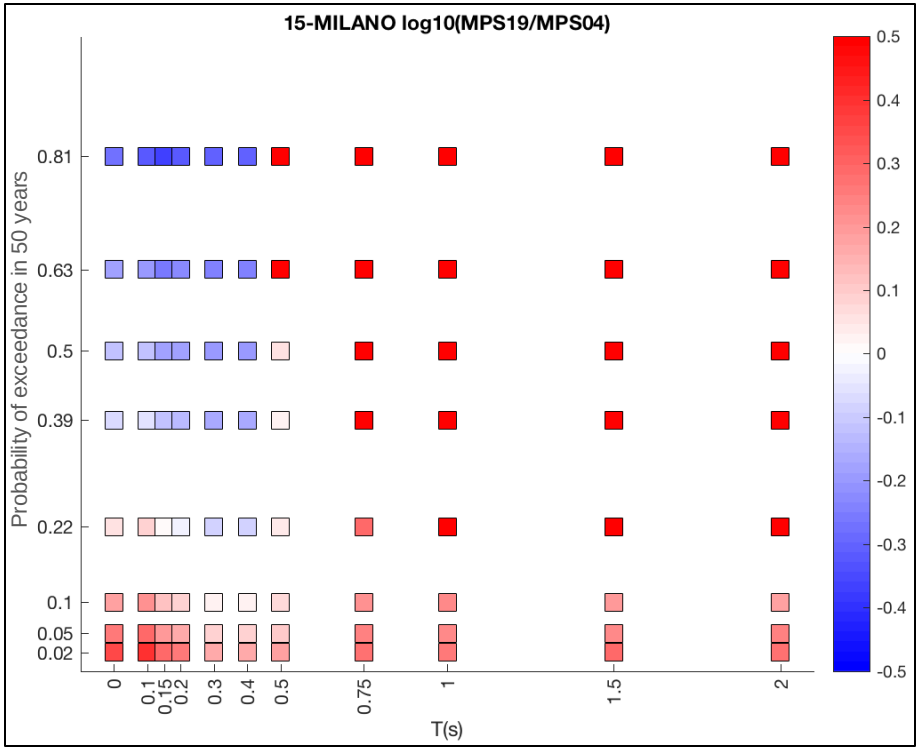
The Commission reiterates its appreciation of the work carried out to draft the MPS19 model, based on its breadth and scientific quality, the undoubted improvement of the input data, the involvement and coordination of numerous research groups from very different cultural areas;

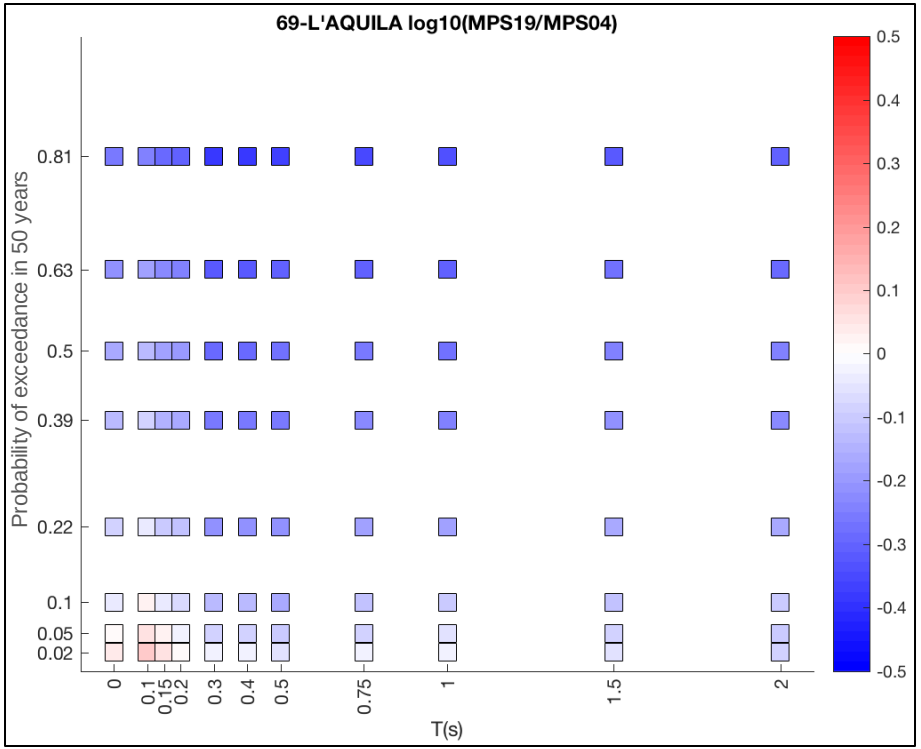
The Commission reiterates, as already reported in the meeting of 16 July 2018, the suitability and centrality of a probabilistic formulation of the seismic hazard analysis to address in a rational and coherent manner both the design and verification of structures with different performance objectives and the optimal allocation of resources for seismic risk mitigation interventions;

The Commission highlights how, even for the most significant return period values for seismic design, **there are significant differences between the hazard estimates provided by MPS19 compared to those of MPS04 in different areas.**

The comparison shows that the results of MPS 19 suggest an increase in hazard values in large areas of Northern Italy and a simultaneous decrease, sometimes very significant, in Central and Southern Italy, even in areas where strong earthquakes have occurred in the past.

Distribution of Log10(MPS19/MPS04) as a function of POE and SA





The impact of the catalog

Distribution of Log10(CPTI15/CPTI04) as a function of POE and SA

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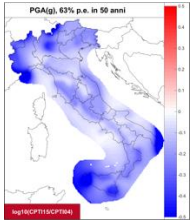
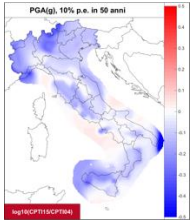
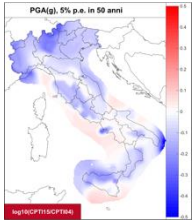
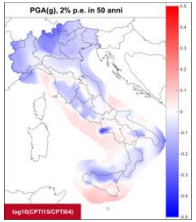
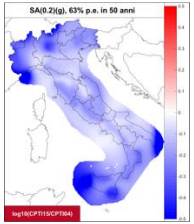
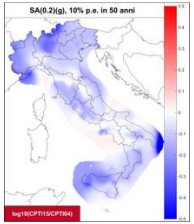
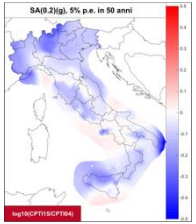
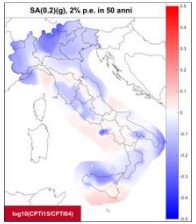
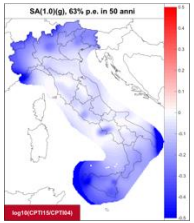
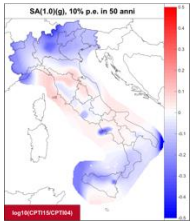
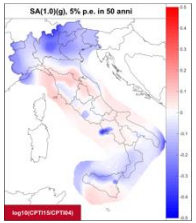
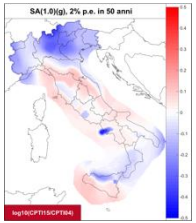
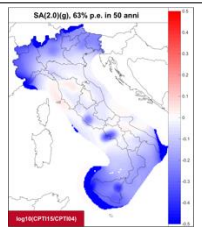
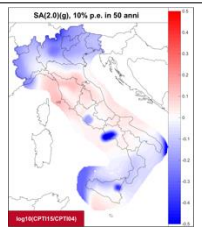
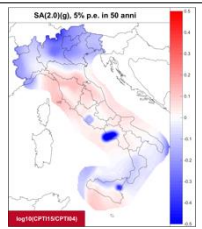
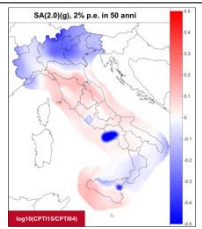
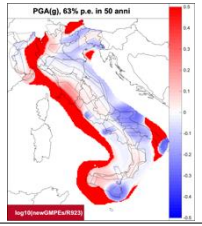
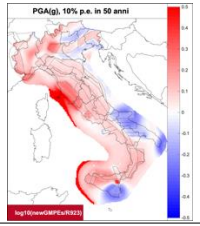
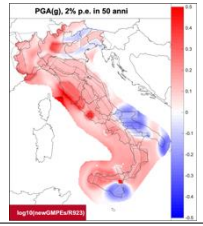
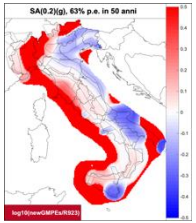
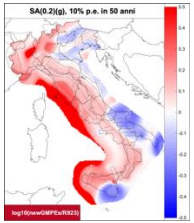
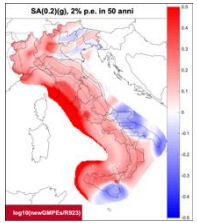
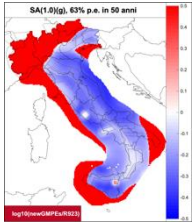
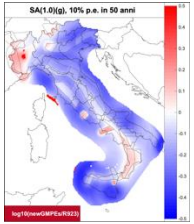
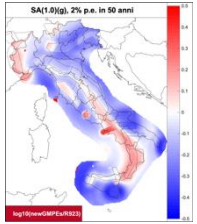
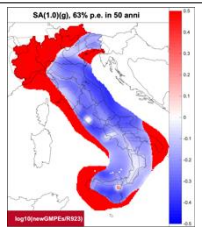
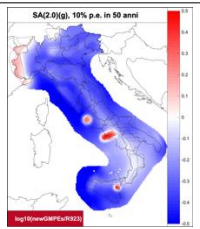
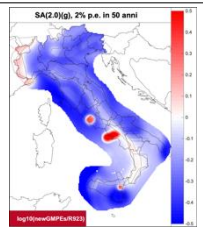
PGA				
0.2s				
1.0s				
2.0s				

The impact of the GMPE

Distribution of Log10(GMPE19/GMPE04) as a function of POE and SA

	63%	10%	2%
PGA			
0.2s			
1.0s			
2.0s			

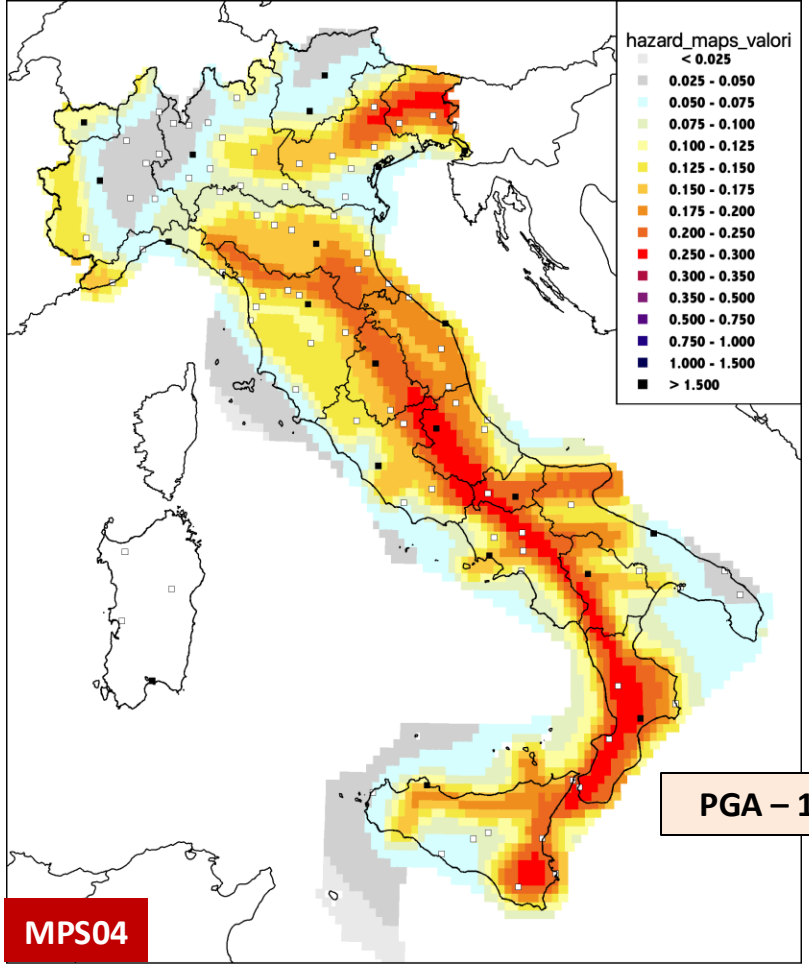
From MSP19 to MPS19.S

In the period 2020-2021, CPS worked for a version of the model that takes into consideration the observation of CGR.
In particular, a simplified structure with very few branches, to be chosen with a new approach for considering the performance of each branch with respect to the macroseismic observation.
The approach was described yesterday by Francesco Visini.

MPS19.S (where S stand for simplified) model is constituted by 4 branches:

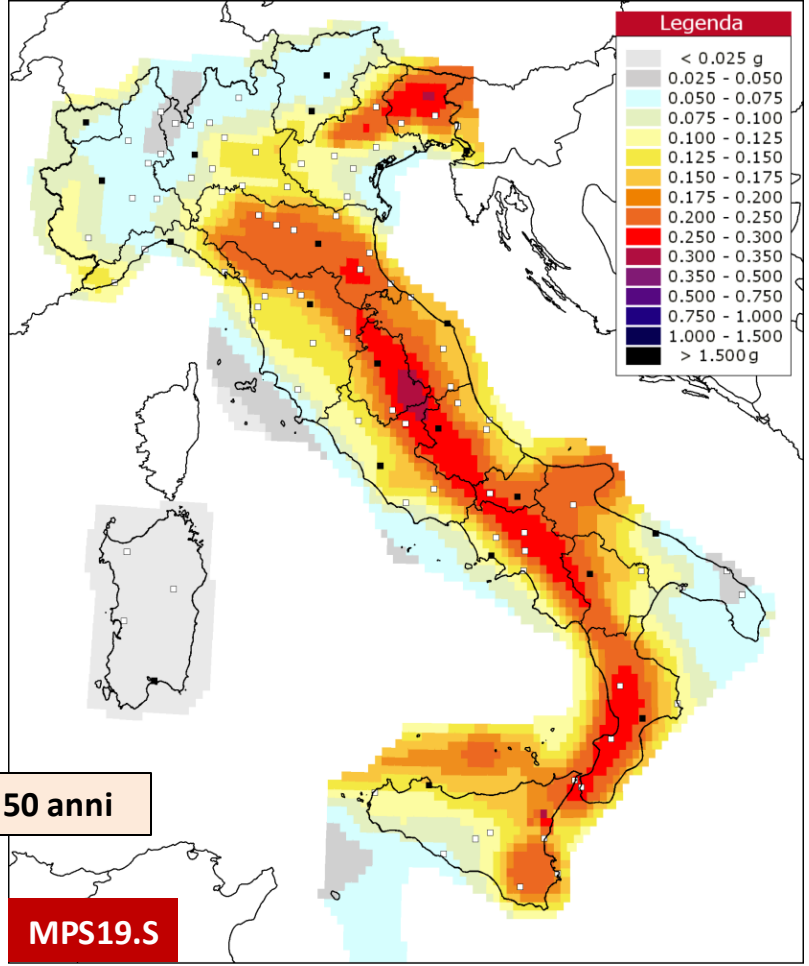
- 3 branches are selected from MPS19
- 1 new branch derives from the same approach adopted in MPS04 in determination of seismicity rates

MPS19.S was released for the same return period and the same SA evaluated for MPS19.
The model is not provided by estimation of the epistemic uncertainty.

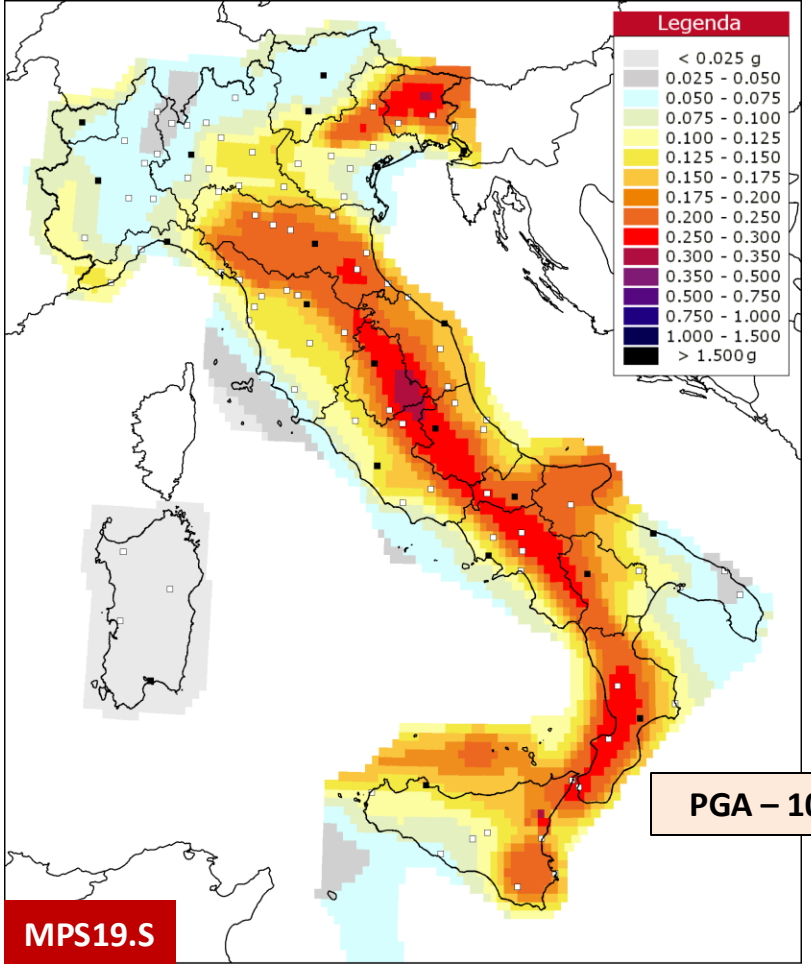


MPS04

PGA – 10% PE in 50 anni

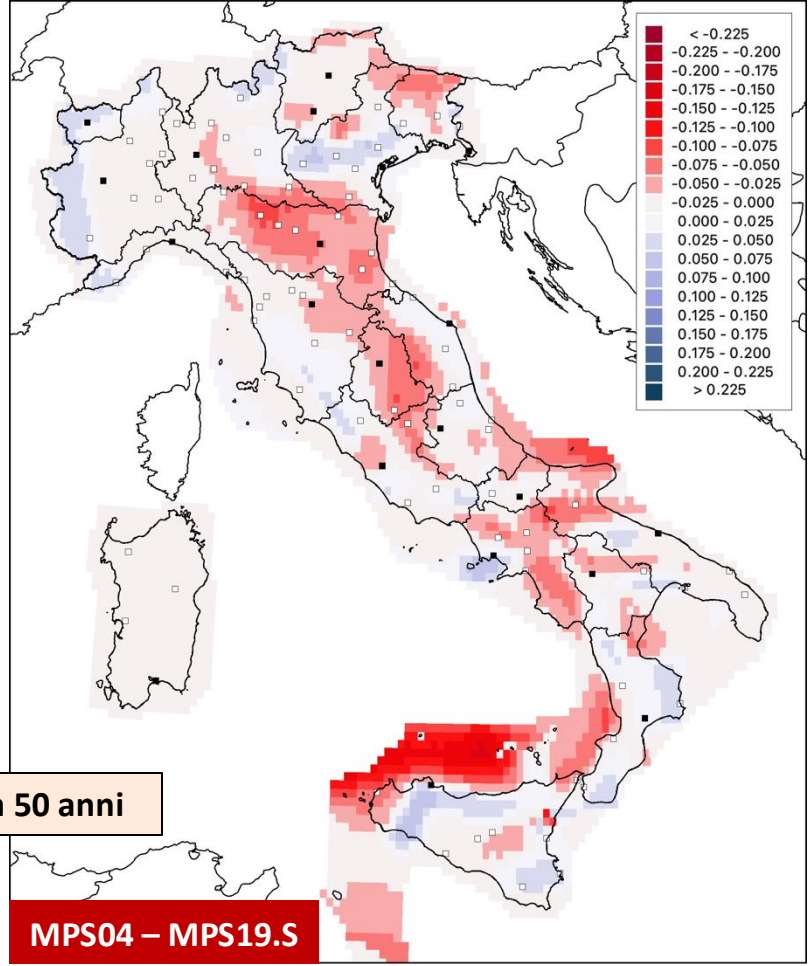


MPS19.S



MPS19.S

PGA – 10% PE in 50 anni



MPS04 – MPS19.S

The roadmap to update national building code: a chronology

- In **2022** CGR approved the new version
- In the meantime, INGV adopted an internal procedure for validating scientific products with regulatory implications.
  Nine anonymous experts gave a unanimous negative evaluation of MPS19 as well as of ***any possible probabilistic model***.

The reviews

Some numbers…

- from **2015 to 2021**, we had **41** meetings with DPC, expert's groups and working groups.

- Starting from **2019** we produced:
  1021 slides,
  722 report pages,
  4237 plots;

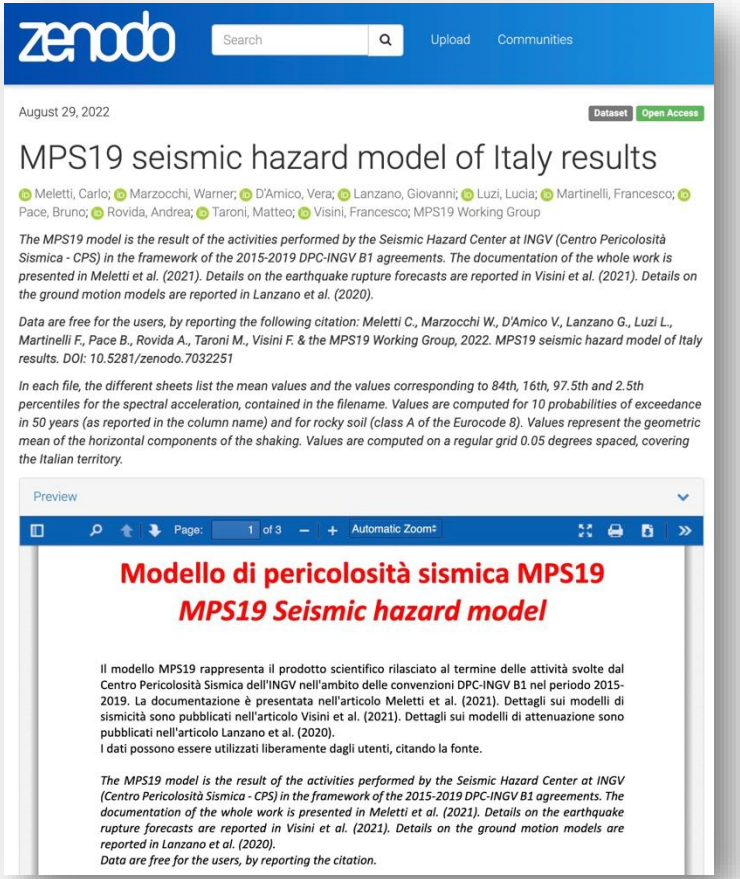
- Several hundred runs have been done with OpenQuake.

The reviewers

We estimated that since 2015 more than **55** researchers expressed their opinion on MPS19 or MPS19.S.

https://www.nature.com/articles/d43978-022-00081-6

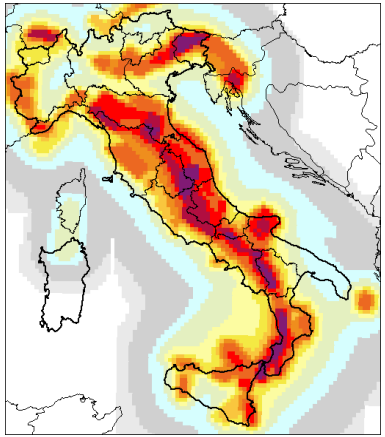
https://www.nature.com/articles/d43978-023-00072-1



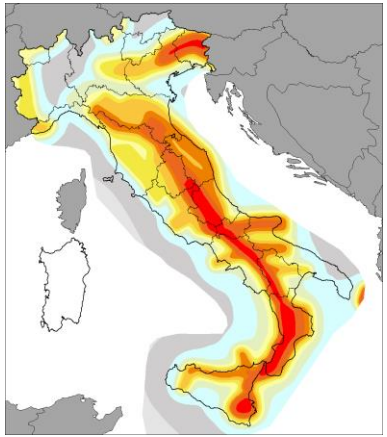
https://zenodo.org/records/7032251

Question:

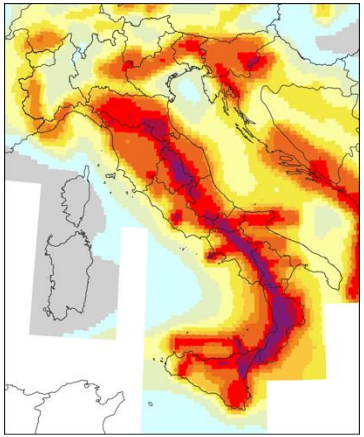
Who decided that new models must always provide higher values of hazard?



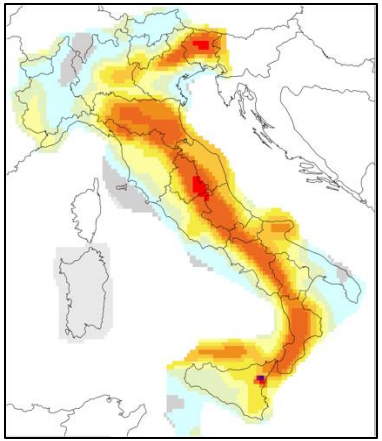
1996
PS4



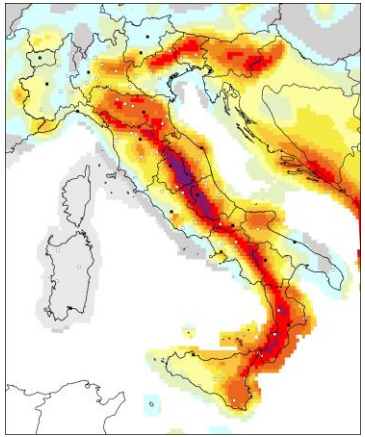
2004
MPS04



2013
EHSM13



2019
MPS19



2020
EHSM20

This is the end of my story!