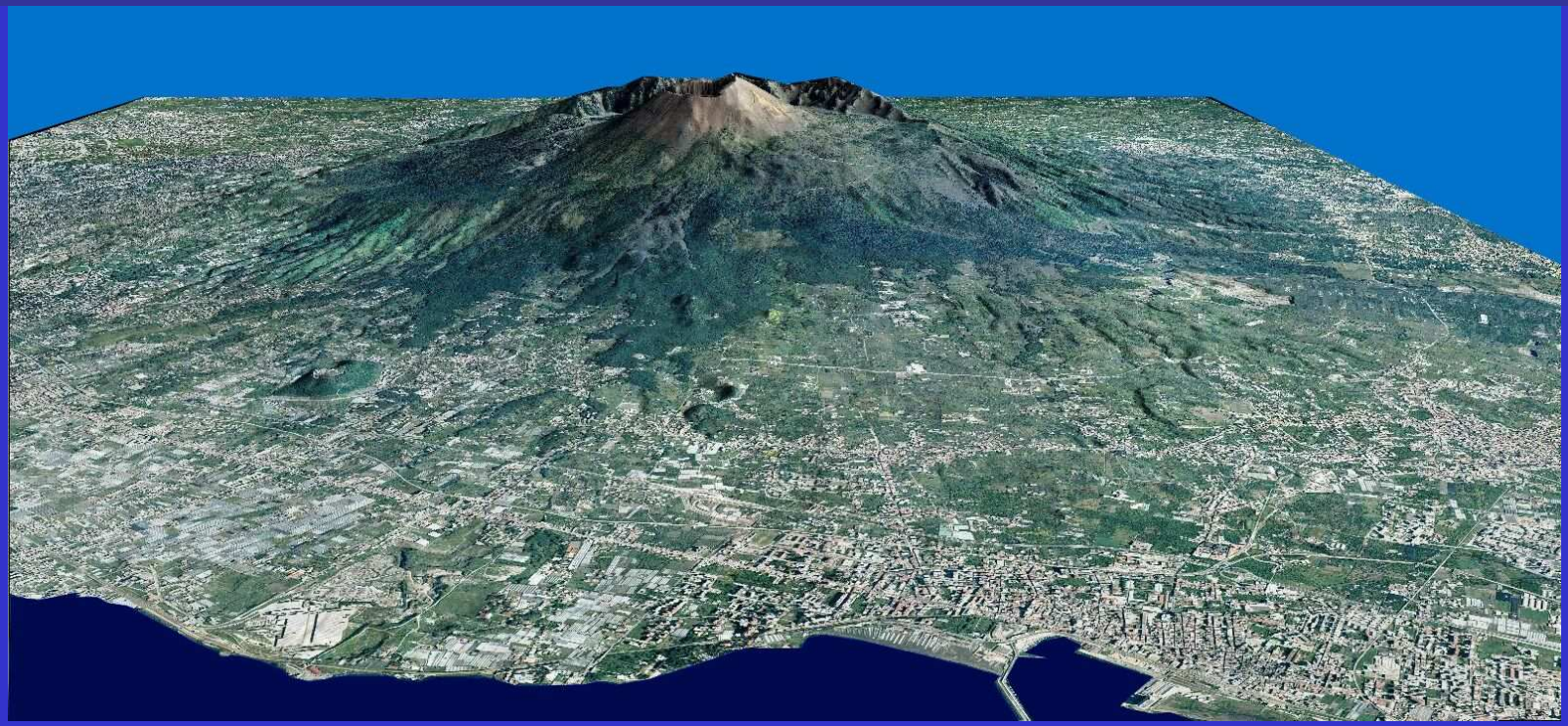
CERG – C WORKSHOP "Risk Management"

Some crucial problems in Vesuvius emergency management



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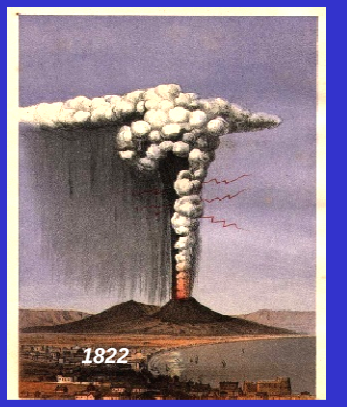
Geneva 4 November 2011

The reference eruption for the Vesuvius emergency plan

In 1944, after nearly 3 centuries of almost continuous activity, Vesuvius entered a new quiescence stage whose duration cannot be assessed.



The choice of the next eruption (type, energy, related hazards) is of fundamental importance for the preparation of an adequate plan for the protection of the exposed people.

This is not an easy task because of the difference recorded in the Vesuvius eruptions along time. Recent studies addressed the evaluation of the probability of occurrence at short or mid-term for the three main types of Vesuvius explosive eruptions.

Probability of occurrence (repose time 60 to 200 years)		
Violent Strombolian	Sub-Plinian I	Plinian
(VEI = 3)	(VEI = 4)	(VEI = 5)
72%	27%	1%
Modified after Marzocchi et al., 2004		

A Sub-Plinian eruption, similar to that occurred in 1631, though less probable than a "violent Strombolian", was selected as the reference event for the Vesuvius emergency preparedness plan

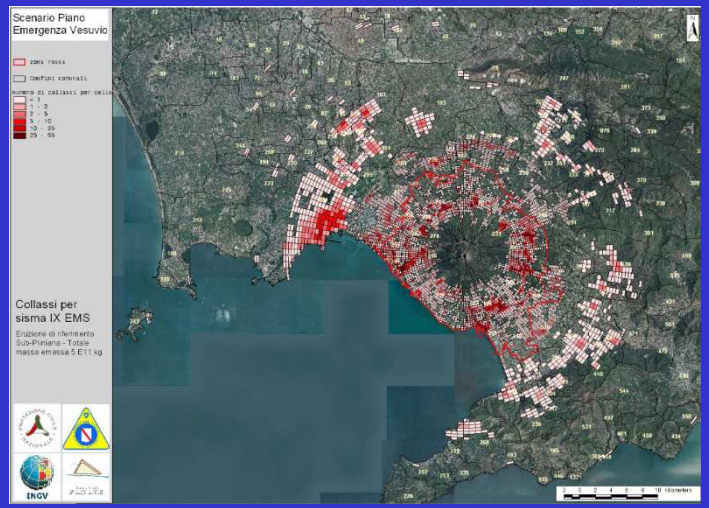
Main hazards related to a Sub-Plinian eruption

- **Pre-eruption earthquakes**

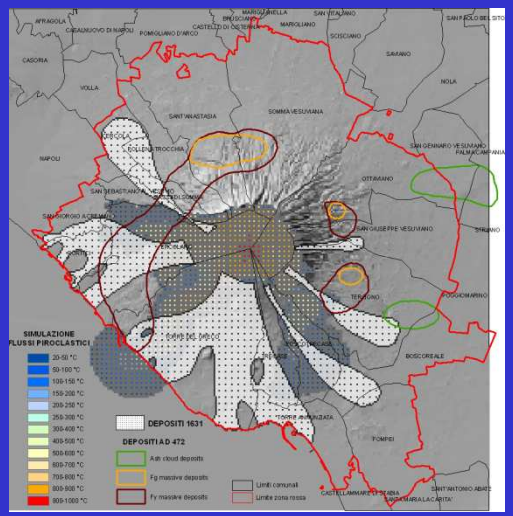
- **Eruption ongoing:**
  - **ash fallout from wind dispersed pyroclastic column**
  - **pyroclastic flows from column collapse**

- **Sin-and-post eruption: lahar by rain mobilization of loose tephra on the volcanic edifice and downwind steep reliefs**

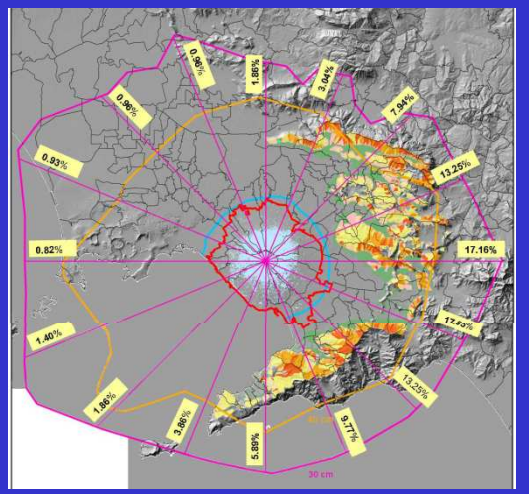
Earthquakes



Pyroclastic Flows



Lahar



All these phenomena are being studied in detail in order to provide the hazard or risk scenarios for the emergency planning

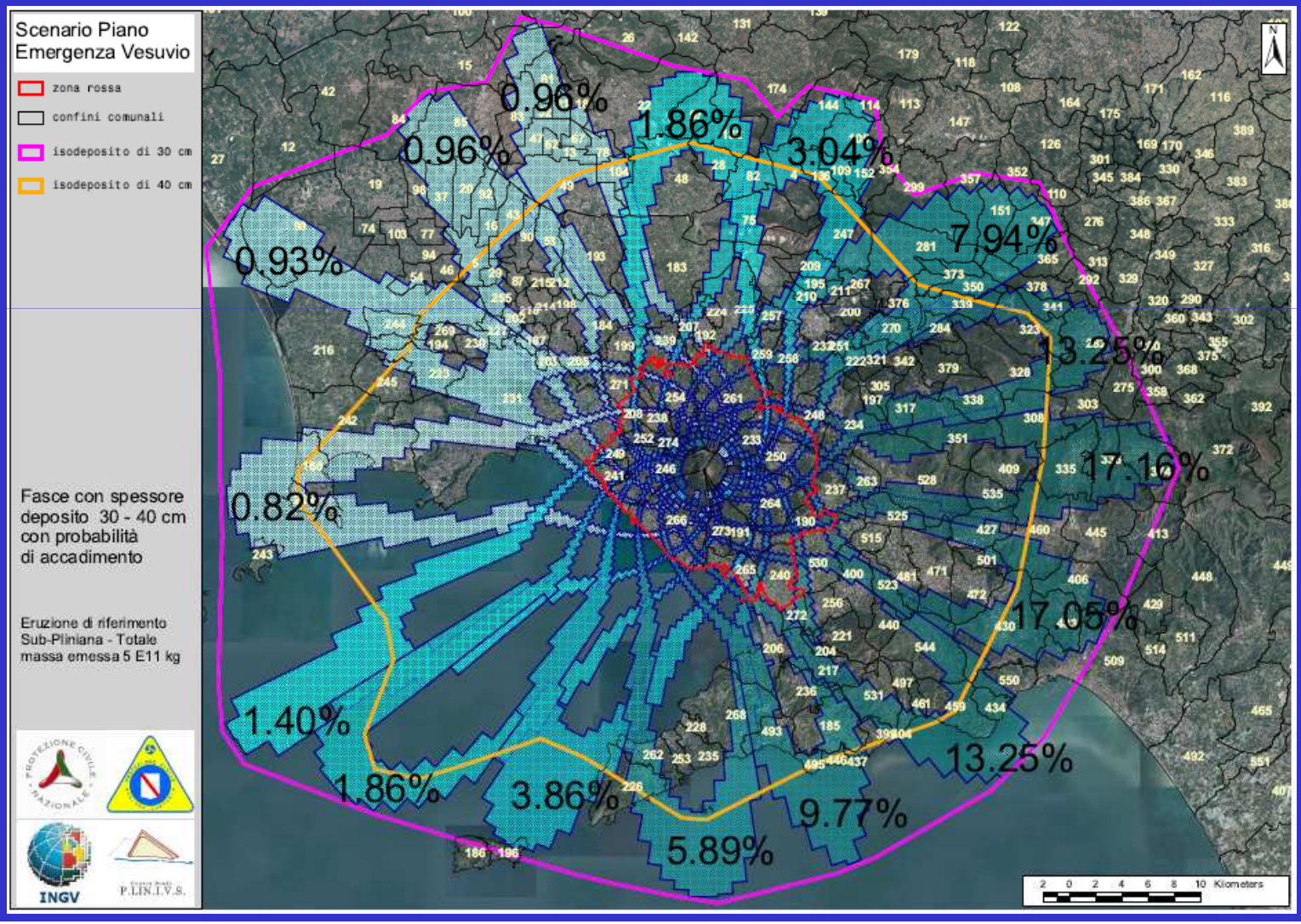
Hazard assessment for pyroclastic fallout

Reference eruption: Sub-Plinian (VEI=4)

Column height: 18 km

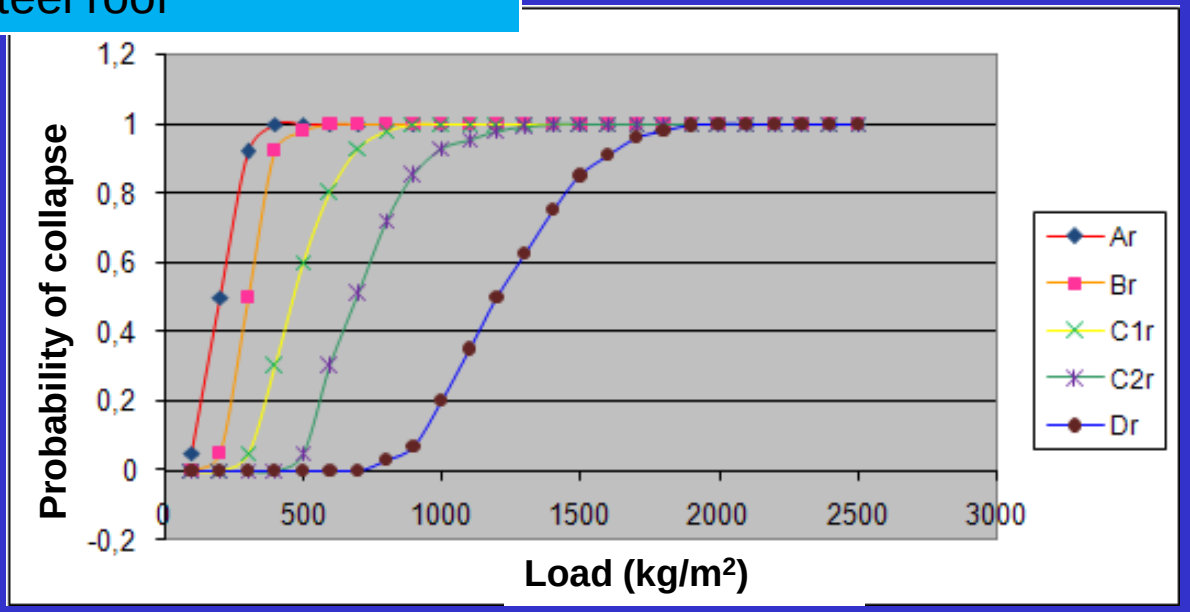
Total discharged mass: 5×10^{11} kg

Wind data: 1991-2010 (from NOAA)



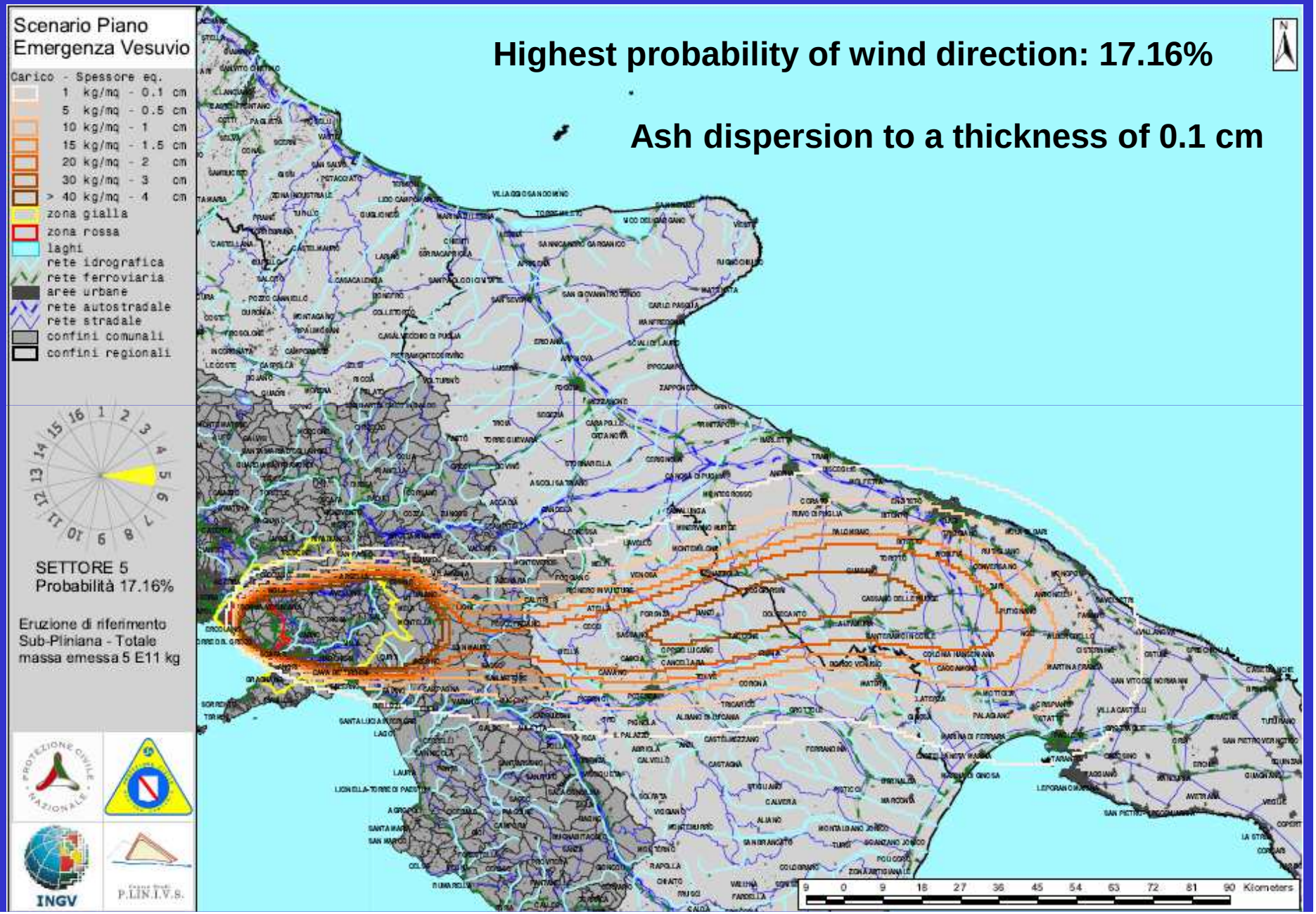
Roof vulnerability to ash load

Type	Description
Ar	Weak pitched wooden roof
Br	Flat standard wooden roof Reinforced concrete flat roof – SAP type Weak steel and little vaults flat roof
C1r	Flat r.c. roof older than 20 years
C2r	Flat r.c. roof younger than 20 years
Dr	Recent pitched r.c. roof Recent pitched steel roof

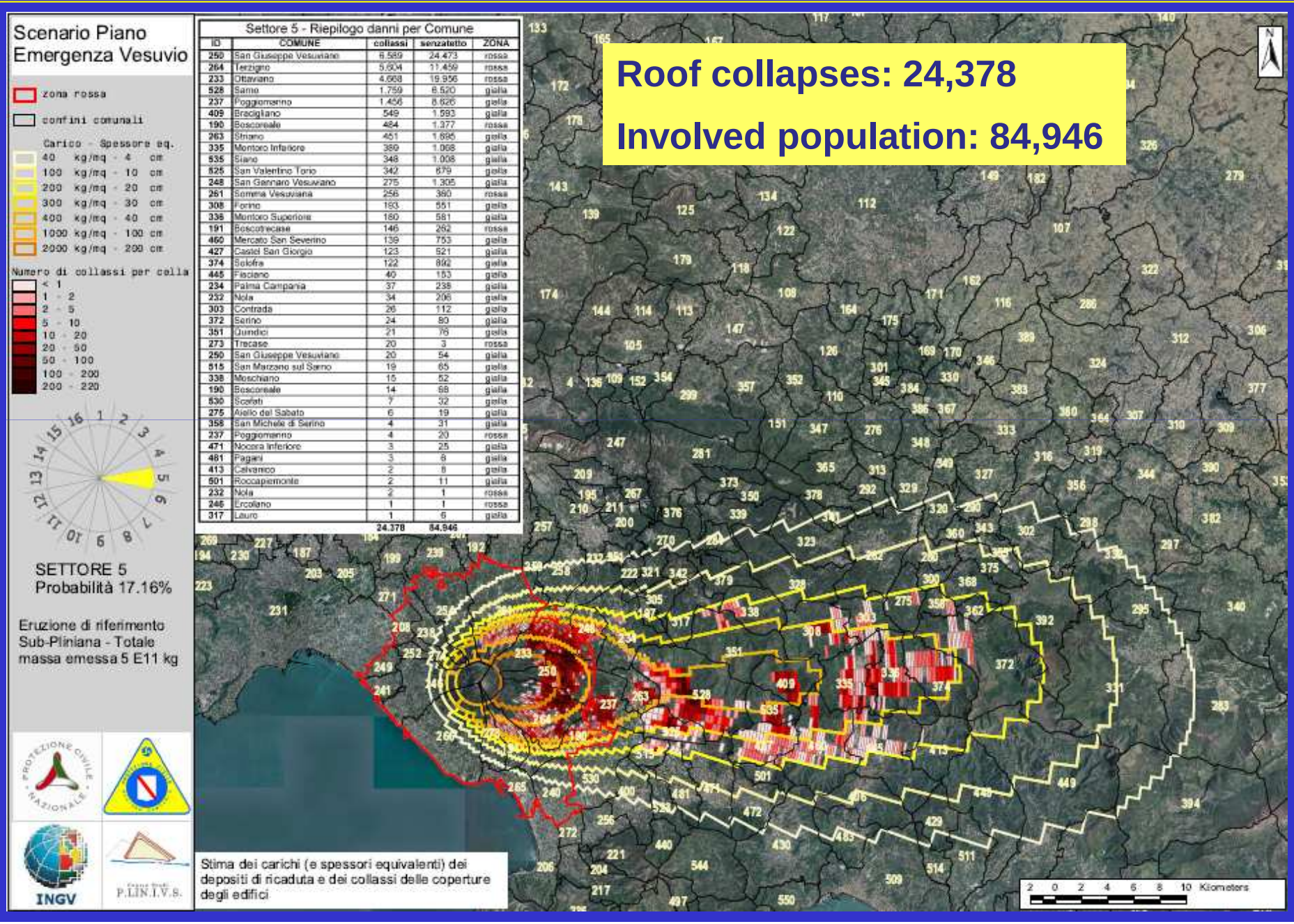


After Zuccaro et al., 2008

Hazard assessment for pyroclastic fallout



Risk assessment for pyroclastic fallout



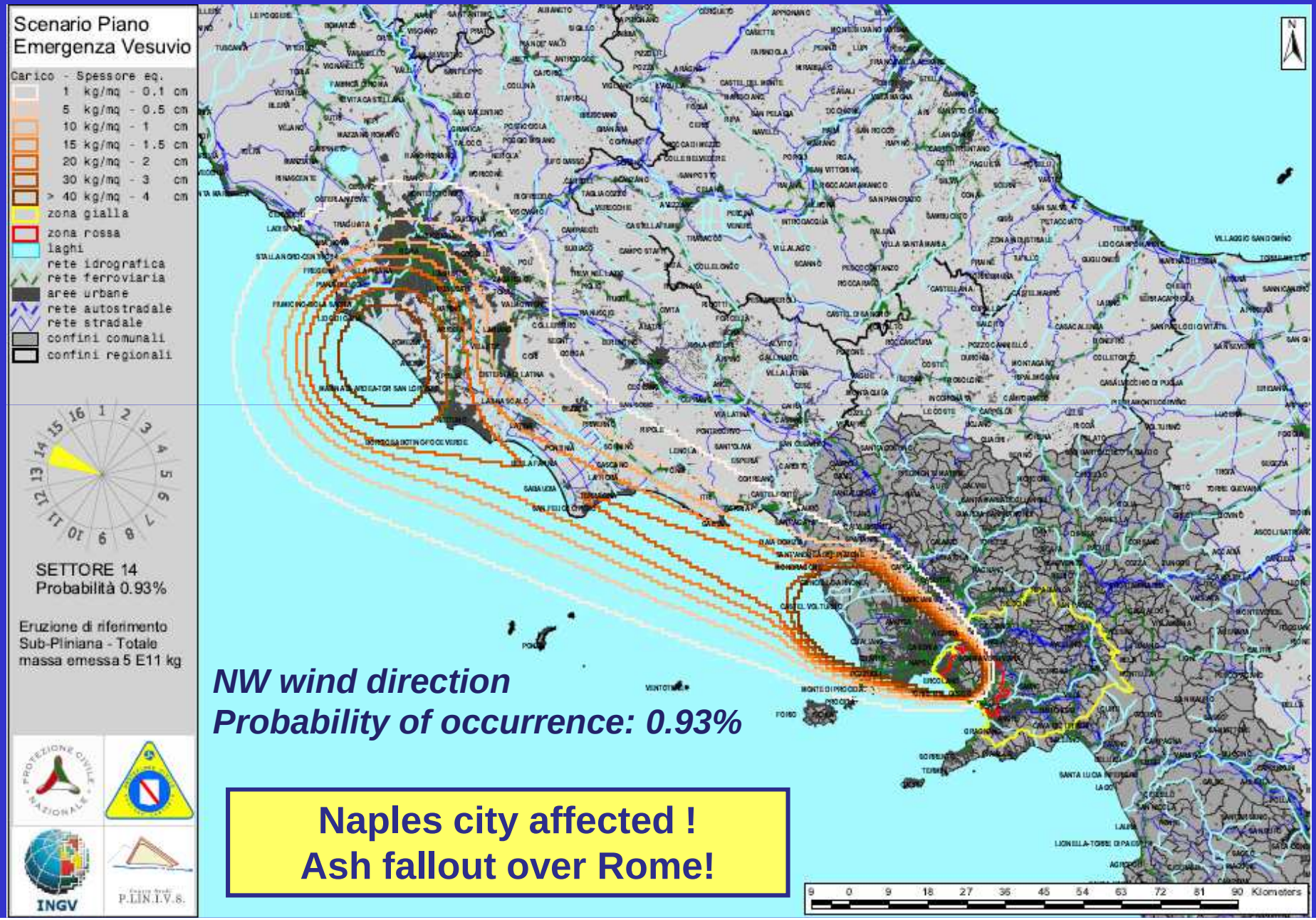
Settore 5 - Riepilogo danni per Comune

ID	COMUNE	collassi	senzatetto	ZONA
250	San Giuseppe Vesuviano	6.589	24.473	rossa
264	Terzigno	5.604	17.459	rossa
233	Ottaviano	4.668	19.956	rossa
528	Sarno	1.759	6.520	gialla
237	Poggiomarino	1.456	6.626	gialla
409	Bracigliano	549	1.593	gialla
190	Boscoreale	484	1.377	rossa
263	Striano	451	1.695	gialla
335	Mercato Inferiore	389	1.068	gialla
535	Siano	348	1.008	gialla
525	San Valentino Torio	342	879	gialla
248	San Gennaro Vesuviano	275	1.305	gialla
261	Somma Vesuviana	256	390	rossa
308	Forino	193	551	gialla
336	Mercato Superiore	180	581	gialla
191	Boscotrecase	146	262	rossa
460	Mercato San Severino	139	753	gialla
427	Castel San Giorgio	123	521	gialla
374	Solofra	122	892	gialla
445	Fisciano	40	153	gialla
234	Palma Campania	37	238	gialla
232	Nola	34	206	gialla
303	Contrada	26	112	gialla
372	Serino	24	80	gialla
351	Quindici	21	76	gialla
273	Trecase	20	3	rossa
250	San Giuseppe Vesuviano	20	54	gialla
515	San Marzano sul Sarno	19	65	gialla
338	Moschiano	15	52	gialla
190	Boscoreale	14	68	gialla
530	Scafati	7	32	gialla
275	Avella del Sabato	6	19	gialla
358	San Michele di Serino	4	31	gialla
237	Poggiomarino	4	20	rossa
471	Nocera Inferiore	3	25	gialla
481	Pagani	3	8	gialla
413	Calvanico	2	6	gialla
501	Roccapiemonte	2	11	gialla
232	Nola	2	1	rossa
246	Ercolano	1	1	rossa
317	Lauro	1	6	gialla
		24.378	84.946	

Roof collapses: 24,378

Involved population: 84,946

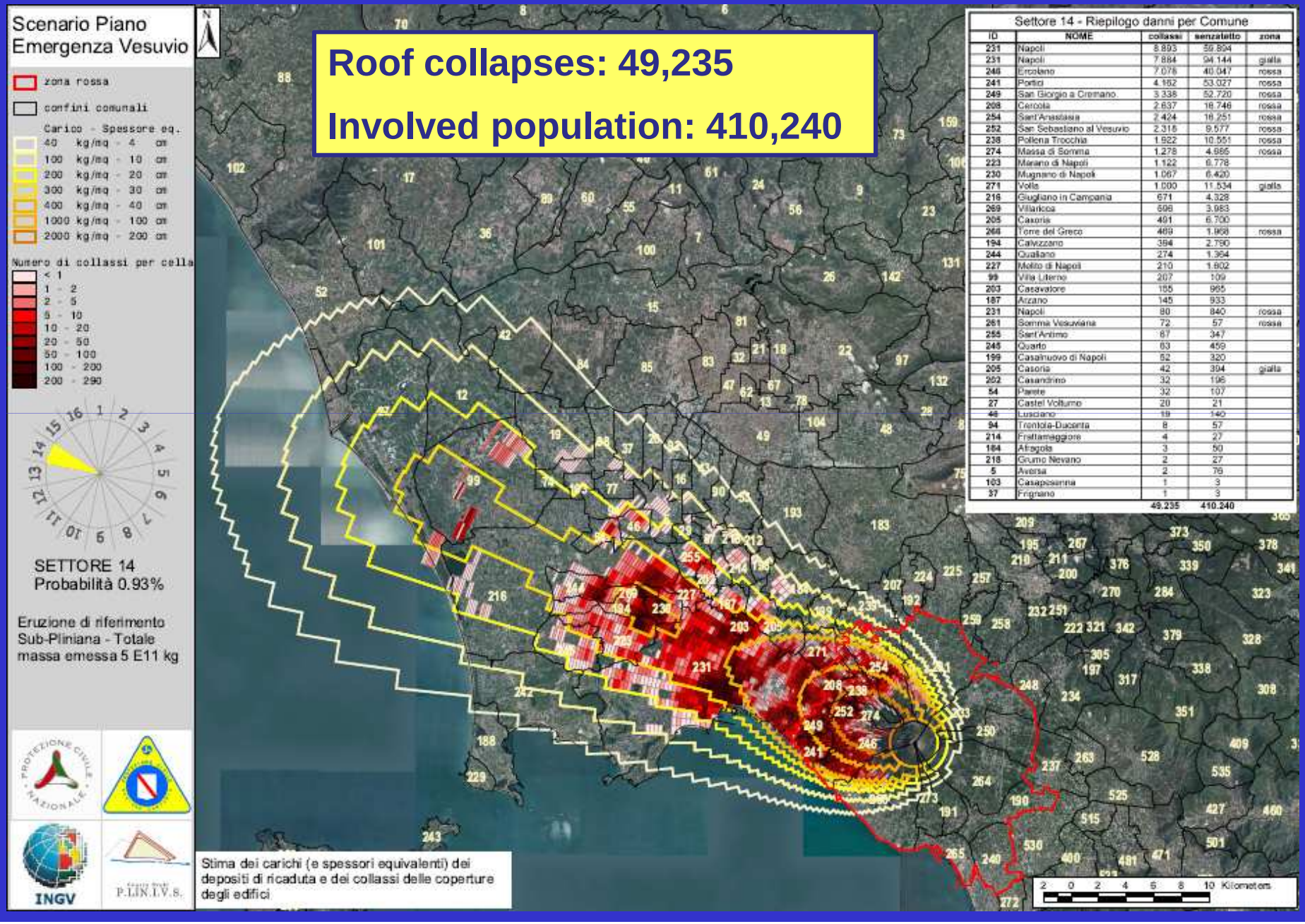
Hazard assessment for pyroclastic fallout



NW wind direction
Probability of occurrence: 0.93%

Naples city affected !
Ash fallout over Rome!

Risk assessment for pyroclastic fallout



Criticalities from pyroclastic fallout

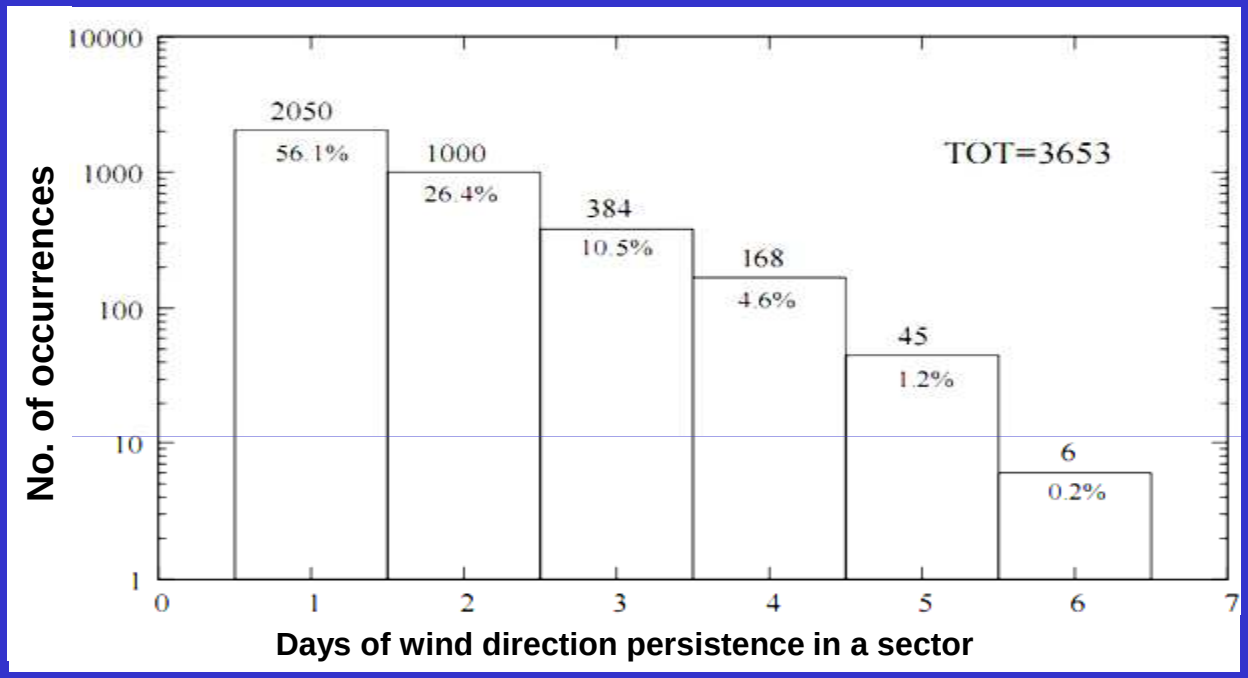
Many persons live in zones that could be severely affected by tephra fallout in the first phase of the eruption. The highest damages would be produced by a WNW wind, toward the city of Naples, which fortunately has a very low occurrence probability (<1%).

The zones to the East of the Vesuvius are the most exposed to pyroclastic fallout, as there is a probability of about 60 % that wind will blow toward ENE to SE. Depending on the specific wind direction and the dimensions of invested villages 22,960 to 32,415 roof collapses involving from 84,946 to 158,842 people are expected.

Most of these collapses would obviously occur within the Red Zone which should have been evacuated. However, also villages outside that zone will be severely affected. As they are not exposed to pyroclastic flow hazard, their pre-eruption evacuation is not foreseen in the plan.

Criticalities from pyroclastic fallout

It is almost impossible to identify in advance the sector that will be effectively affected by pyroclastic fallout, as wind direction changes too rapidly (probability of persistence only 10% after 3 days).

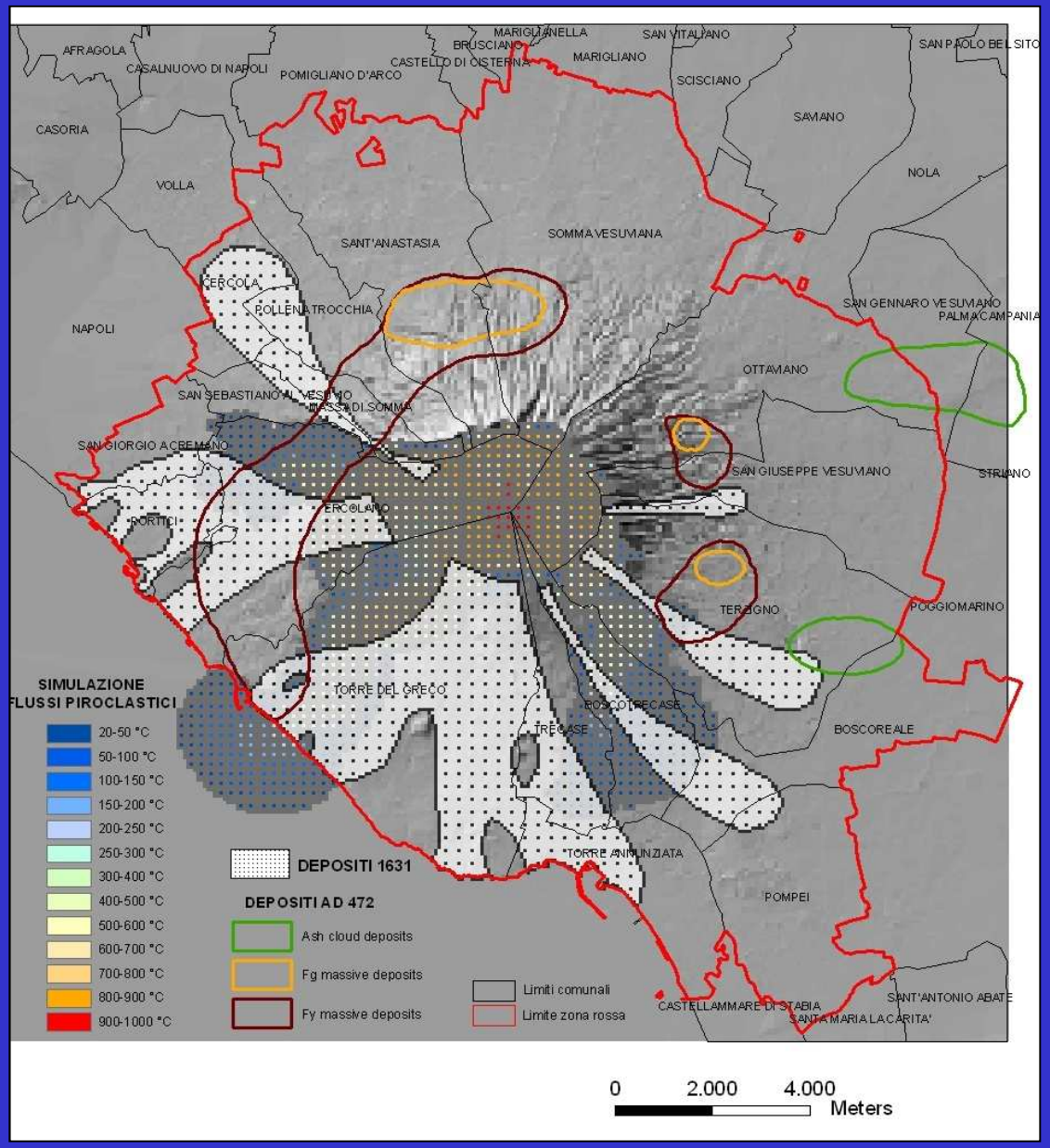


<u>Two prevention actions can be envisaged to mitigate the roof collapses risk:</u>

1) at the moment of the eruption onset, when the exposed sectors will be known, people should be moved from the buildings more vulnerable to ash load, to pre-identified safe near structures

2) a long-term program of intervention to reduce roof vulnerability in the vesuvian area has to be undertaken.

Red Zone exposed to Pyroclastic Flows

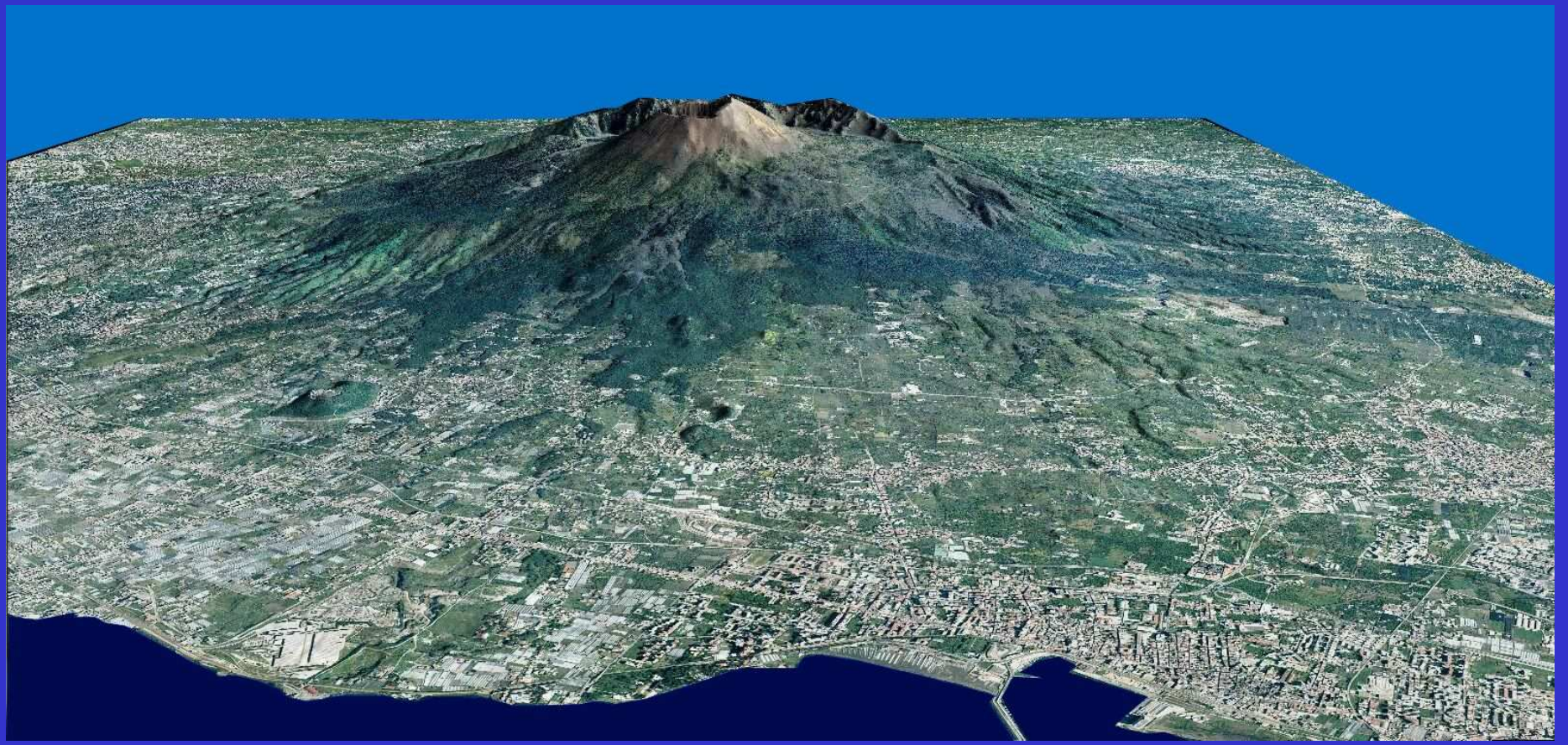


- **Run out boundaries of pyroclastic flows of the 1631 and 472 subplinian I eruptions;**
- **3D simulations of pyroclastic flows from a subplinian I eruption.**
- **Propagation time of the pyroclastic flows from the crater to the urbanized areas is of only few minutes.**

The red zone has to be evacuated before the eruption onset

Red zone exposed to pyroclastic flow risk:

18 municipalities with 550,000 residents



Main eruption precursory phenomena expected in the Vesuvius unrest phase:

- **Anomalous seismicity**
- **Ground deformation (uplift)**
- **T increase, chemical changes in fumaroles**

They are used to define the state of the volcano in a process with increasing probability of eruption (alert level)

Level	Main actions
Attention	Monitoring increase
Pre-alarm	Civil Protection preparation to the emergency
Alarm	Evacuation of the red zone (550,000 people)

Expected earthquakes in the Vesuvius unrest phase (before alarm is declared)

- Epicenter in the crater area
- Focal depth 3-4 km
- Magnitude: 4.5-5.5 max
- Intensity at epicentre VIII-IX

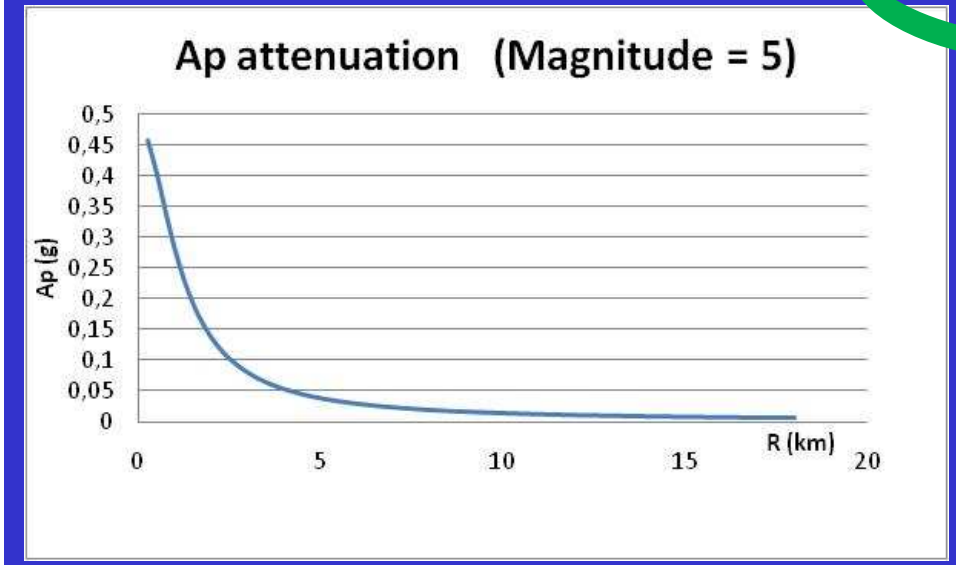
(Intensity in the settlements of the red zone: VII-VIII)

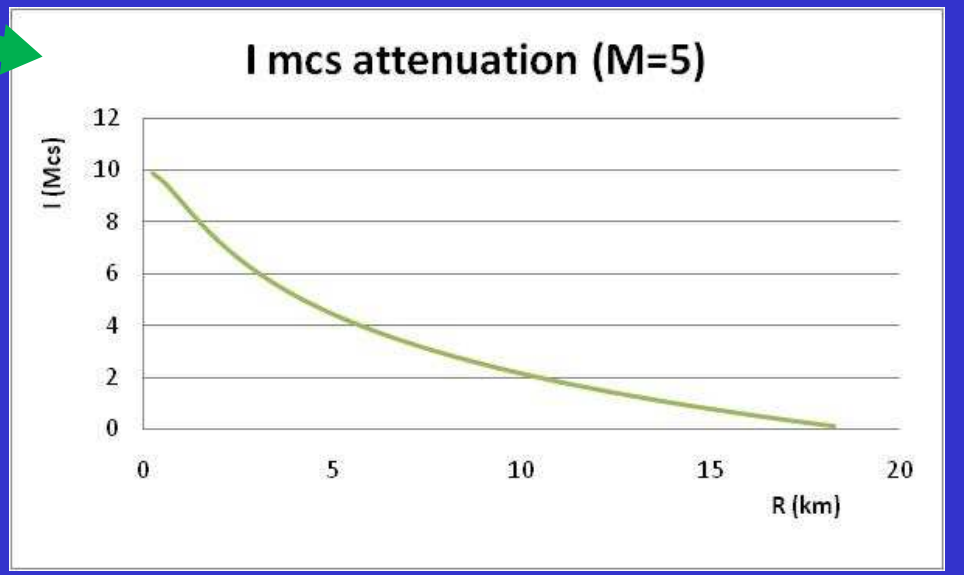
Seismic attenuation at Vesuvius

Attenuation laws in PGA and MCS Intensity

$$Log_{10}(PGA) = a + bM + c\ log_{10}(R^2+h^2)^{½} \pm \sigma$$

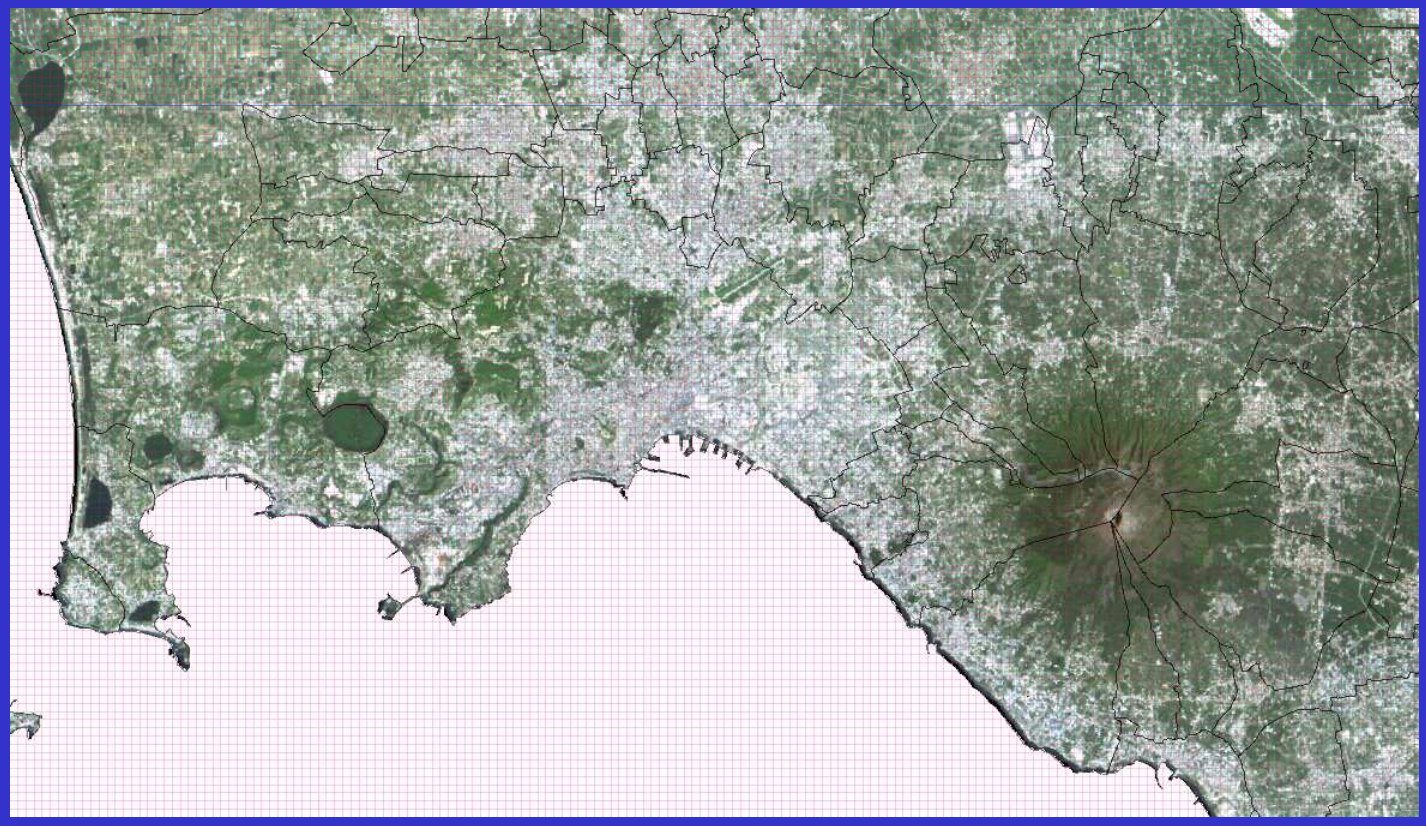
$$I_{MCS} = (1.33 - log_{10}(PGA))*5$$





Seismic vulnerability of Vesuvius buildings

The inventory of the building vulnerability class distribution has been evaluated on about the 50 % of the all buildings of the red zone; the residual 50% has been evaluated by aerial photogrammetry and statistic calibration of the census data ISTAT 2001.

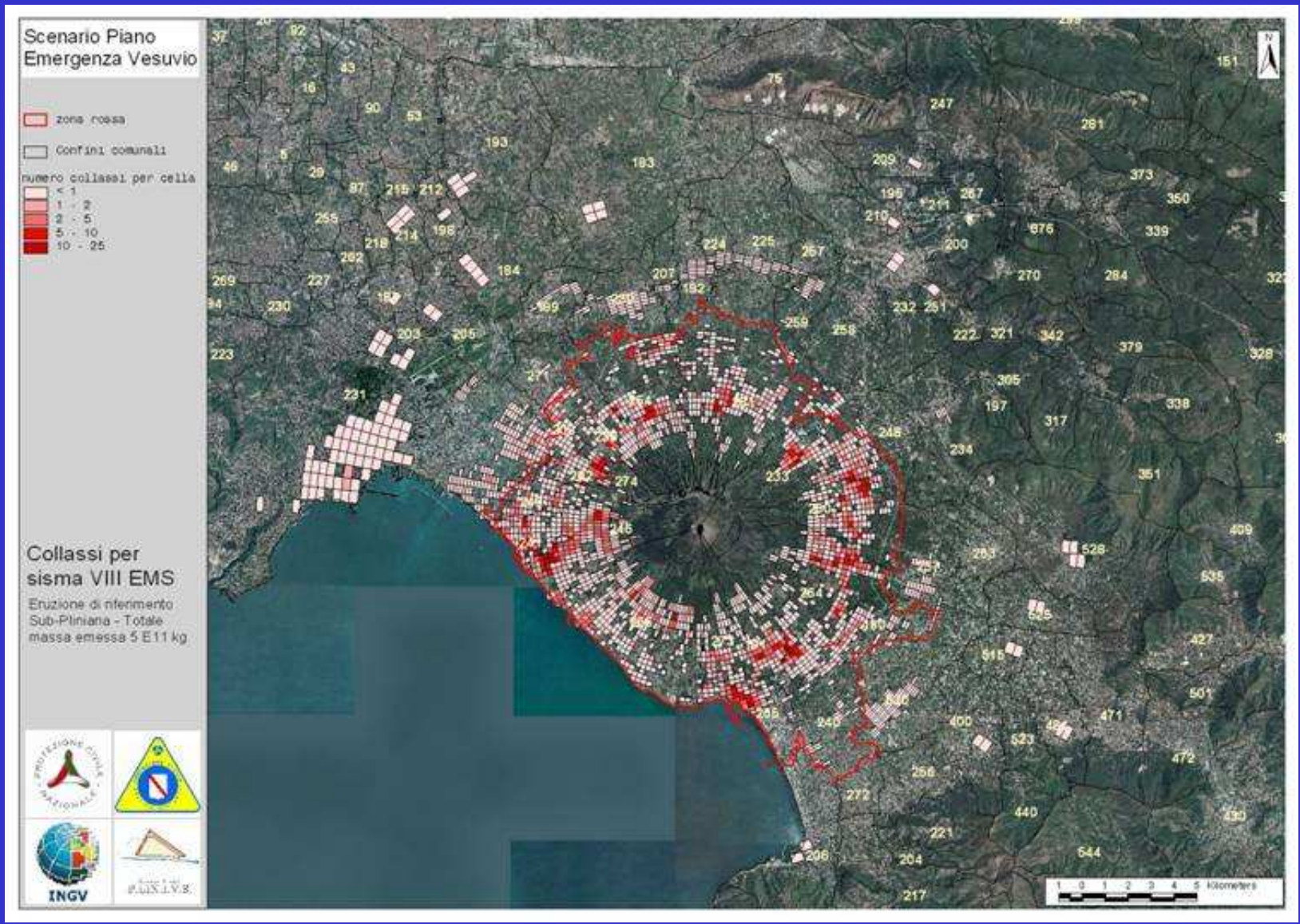


Seismic Building Structures Classification

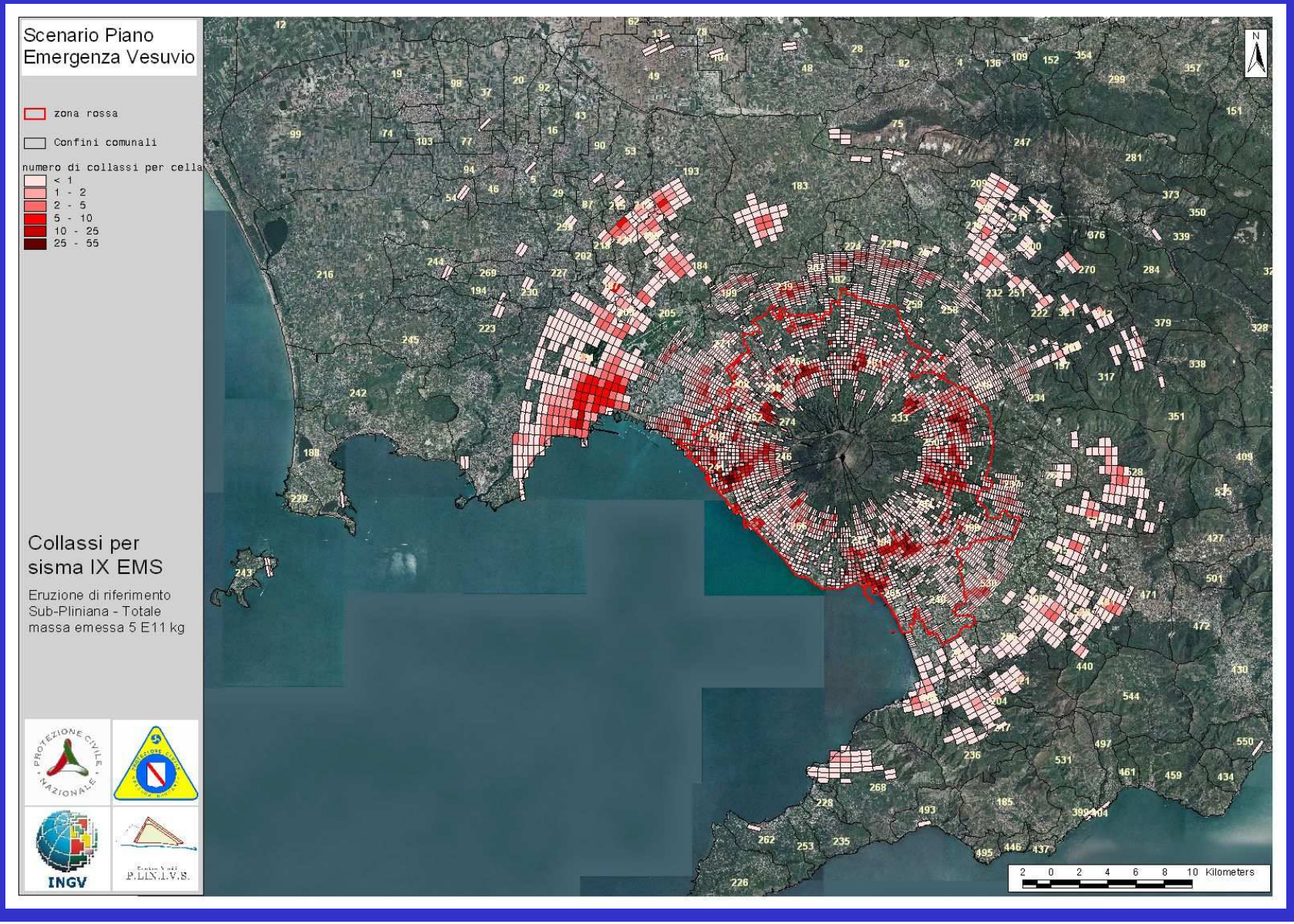
Horizontal Structures / Vertical Structures	POOR RIGIDITY Vaults and/or wooden floor (without ties)	POOR TECHNO-LOGY "SAP" Floor	MEDIUM RIGIDITY Vaults and/or wooden floor (with ties)	MEDIUM HIGH RIGIDITY Iron beam floor	HIGH RIGIDITY Reinforced Concrete floor.
WEAK MASONRY Rubble masonry neglected (lavic stone, not squared tuff, etc.)	A	A	A	A	A
MEDIUM QUALITY Rubble masonry maintained (lavic stone, not squared tuff, etc.)	A	A	B	B	B
GOOD MASONRY Squared masonry (Lavic stone, tuff etc.)	A	A	B	B	C
FRAMED STRUCTURES (R.C. or steel)	–	B	–	–	C

Example: Seismic vulnerability of Torre Annunziata

Expected damage scenario for a single earthquake of intensity VIII



Expected damage scenario for a single earthquake of intensity IX



Expected damages for I = VIII

Tabella B. Perdite attese nell'area circumvesuviana per evento sismico del VIII grado di intensità EMS con epicentro nel cratere del Vesuvio

NUM	CIPC	NOME	collassi totali	morti	feriti	senzatetto	inagibili	ZONA
246	63064	Ercolano	381	32	117	4221	843	ROSSA
264	63082	Terzigno	253	6	22	841	591	ROSSA
233	63051	Ottaviano	192	10	37	1366	446	ROSSA
266	63084	Torre del Greco	189	17	59	2751	452	ROSSA
250	63068	San Giuseppe Vesuviano	181	7	25	1023	448	ROSSA
261	63079	Somma Vesuviana	176	9	33	1253	423	ROSSA
254	63072	Sant'Anastasia	155	11	39	1382	351	ROSSA
190	63008	Boscoreale	142	10	35	1288	345	ROSSA
265	63083	Torre Annunziata	138	33	118	4142	324	ROSSA
241	63059	Portici	137	17	61	2453	337	ROSSA
191	63009	Boscotrecase	134	9	34	1161	299	ROSSA
231	63049	Napoli	117	18	64	5682	540	GIALLA
238	63056	Pollena Trocchia	56	3	11	419	132	ROSSA
273	63091	Trecase	55	4	13	478	127	ROSSA
252	63070	San Sebastiano al Vesuvio	54	2	7	291	128	ROSSA
208	63026	Cercola	53	3	12	488	134	ROSSA
249	63067	San Giorgio a Cremano	52	8	28	1391	147	ROSSA
274	63092	Massa di Somma	38	2	7	279	95	ROSSA
239	63057	Pomigliano d'Arco	23	1	5	399	96	GIALLA
530	65137	Scafati	23	1	5	396	100	GIALLA
240	63058	Pompei	19	1	2	205	79	ROSSA
232	63050	Nola	15	1	4	215	52	GIALLA
225	63043	Marigliano	14	1	3	294	63	GIALLA
237	63055	Poggiomarino	13	1	3	227	54	GIALLA
271	63089	Volla	9	1	3	152	29	GIALLA
192	63010	Brusciano	9	1	2	174	38	GIALLA
199	63017	Casalnuovo di Napoli	9	1	2	205	39	GIALLA
259	63077	Scisciano	8	1	2	113	29	GIALLA
248	63066	San Gennaro Vesuviano	8	0	1	87	30	GIALLA
258	63076	Saviano	5	0	1	98	20	GIALLA
234	63052	Palma Campania	4	0	1	75	20	GIALLA
224	63042	Mariglianella	4	0	1	61	18	GIALLA
207	63025	Castello di Cisterna	4	0	1	41	15	GIALLA
205	63023	Casoria	3	0	1	157	18	GIALLA
528	65135	Sarno	3	0	1	99	23	GIALLA
206	63024	Castellammare di Stabia	3	0	1	149	17	GIALLA
183	63001	Acerra	2	0	1	90	19	GIALLA
184	63002	Afragola	2	0	1	119	15	GIALLA
214	63032	Frattamaggiore	2	0	0	70	14	GIALLA
193	63011	Caivano	2	0	0	74	14	GIALLA
400	65007	Angri	2	0	0	60	13	GIALLA
257	63075	San Vitaliano	1	0	0	32	7	GIALLA
481	65088	Pagani	1	0	0	63	11	GIALLA
268	63086	Vico Equense	1	0	0	44	10	GIALLA

Tabella B. Perdite attese nell'area circumvesuviana per evento sismico del VIII grado di intensità EMS con epicentro nel cratere del Vesuvio

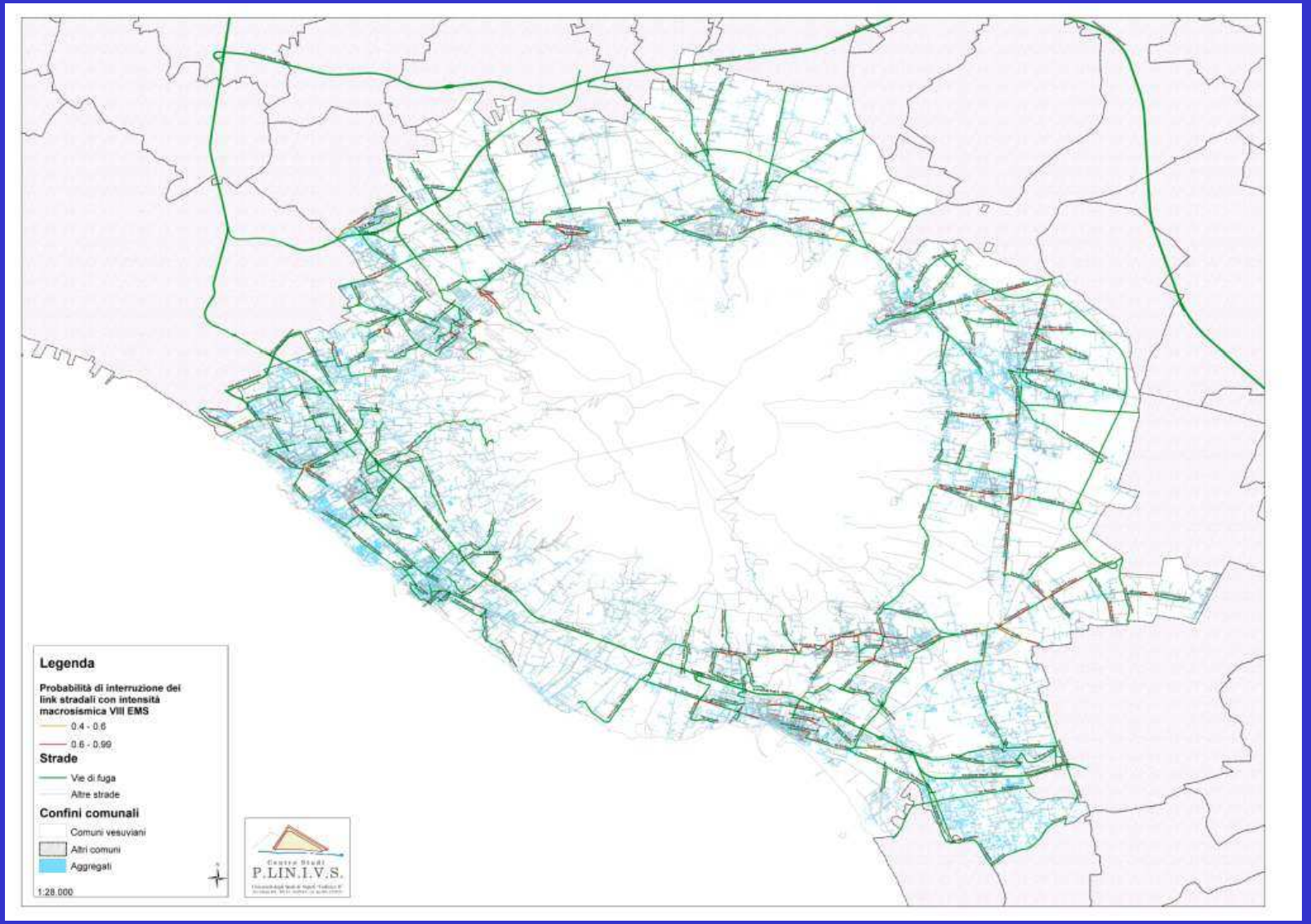
NUM	CIPC	NOME	collassi totali	morti	feriti	senzatetto	inagibili	ZONA
525	65132	San Valentino T	1	0	0	18	8	GIALLA
187	63005	Arzano	1	0	0	43	8	GIALLA
217	63035	Gragnano	1	0	0	42	8	GIALLA
198	63016	Cardito	1	0	0	41	8	GIALLA
515	65122	San Marzano s	1	0	0	18	6	GIALLA
523	65130	Sant'Egidio del	1	0	0	16	6	GIALLA
210	63028	Cimitile	1	0	0	12	5	GIALLA
209	63027	Cicciano	1	0	0	22	5	GIALLA
256	63074	Sant'Antonio A	1	0	0	24	5	GIALLA
263	63081	Striano	1	0	0	8	4	GIALLA
203	63021	Casavatore	1	0	0	24	4	GIALLA
251	63069	San Paolo Bel S	0	0	0	14	3	GIALLA
221	63039	Lettere	0	0	0	9	3	GIALLA
212	63030	Crispano	0	0	0	19	3	GIALLA
317	64043	Lauro	0	0	0	12	3	GIALLA
270	63088	Visciano	0	0	0	12	3	GIALLA
195	63013	Camposano	0	0	0	9	3	GIALLA
236	63054	Pimonte	0	0	0	9	2	GIALLA
204	63022	Casola di Napo	0	0	0	11	2	GIALLA
272	63090	Santa Maria la	0	0	0	12	2	GIALLA
321	64047	Marzano di No	0	0	0	8	2	GIALLA
342	64068	Pago del Vallo	0	0	0	8	2	GIALLA
200	63018	Casamarciano	0	0	0	8	2	GIALLA
197	63015	Carbonara di N	0	0	0	7	2	GIALLA
222	63040	Liveri	0	0	0	7	2	GIALLA
440	65047	Corbara	0	0	0	9	2	GIALLA
218	63036	Grumo Nevano	0	0	0	8	2	GIALLA
211	63029	Comiziano	0	0	0	4	1	GIALLA
75	61075	San Felice a Ca	0	0	0	6	1	GIALLA
471	65078	Nocera Inferior	0	0	0	4	1	GIALLA
267	63085	Tufino	0	0	0	4	1	GIALLA
305	64031	Domicella	0	0	0	4	1	GIALLA
379	64106	Taurano	0	0	0	3	1	GIALLA

Total damages from earthquakes

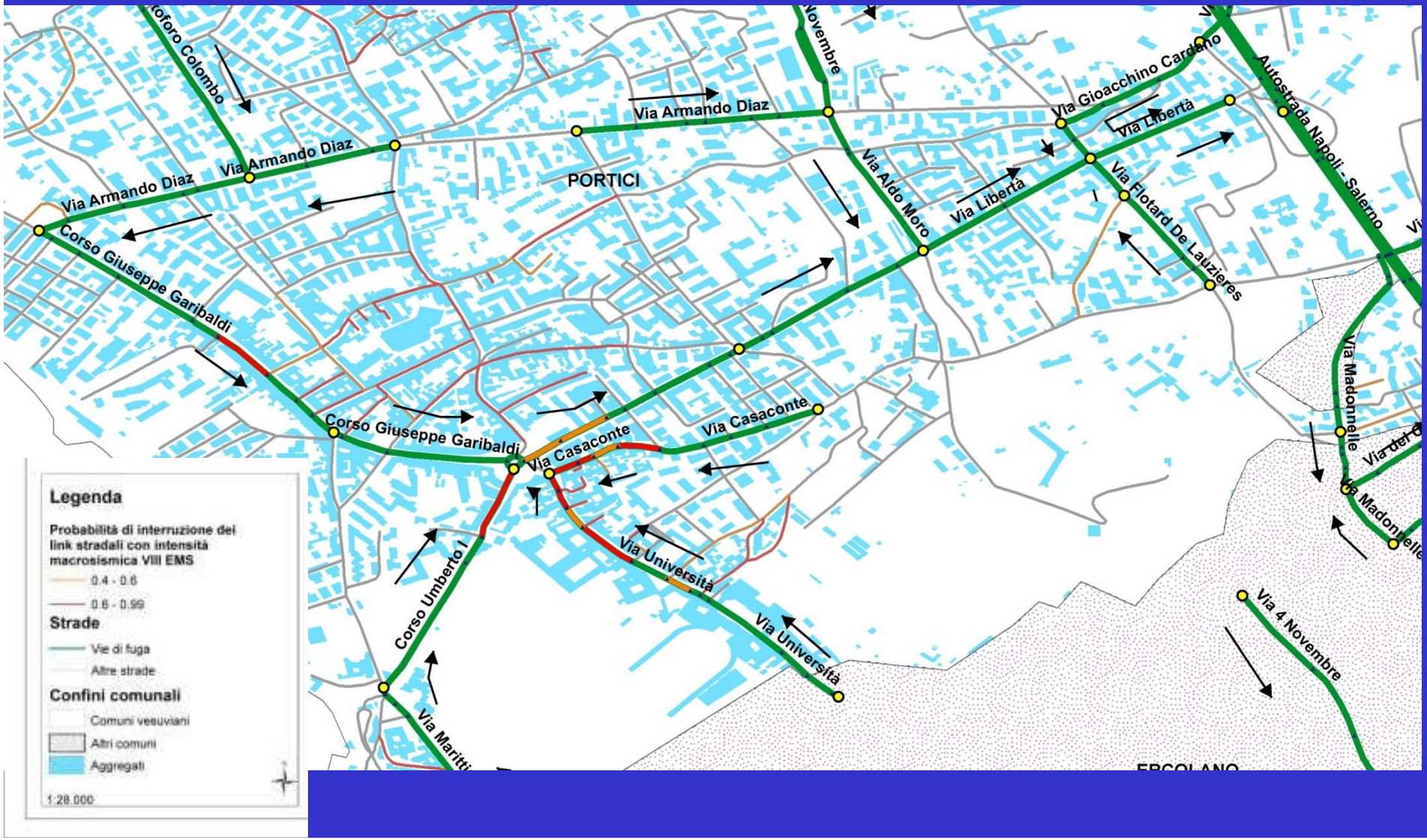
	Event of Intensity VIII at the epicentre				
Zone	**tot. Collapse**	**Blds. Unusable**	**Deaths**	**Injuried**	**Homeless**
red	301	1418	31	107	9631
other	2406	5700	184	662	25430
Total	**2707**	**7118**	**215**	**769**	**35061**

	Event of Intensity IX at the epicentre				
Zone	**tot. Collapse**	**Blds. Unusable**	**Deaths**	**Injuried**	**Homeless**
red	2012	6316	237	842	44334
other	5261	9754	463	1697	42996
Total	**7273**	**16070**	**700**	**2539**	**87330**

Red zone: impact of the earthquakes of the unrest phase on the evacuation road practicability



Red zone: impact of the earthquakes of the unrest phase on the evacuation road practicability (Portici)



Red zone: impact of the earthquakes of the unrest phase on the evacuation road practicability

PROB. Pi OF INTERRUPTION FOR INTENSITY VIII (NUMBER OF ROAD LINK INTERRUPTED)			
municipality	Pi ≥60%	40%≤Pi≤60%	Pi< 40%
Boscoreale	20	41	275
Boscotrecase	16	42	217
Cercola	2	8	78
Ercolano	22	36	184
Massa di Somma	2	10	59
Ottaviano	21	43	196
Pollena Trocchia	2	6	50
Pompei	0	3	52
Portici	25	23	103
San Giorgio a Cremano	1	10	51
San Giuseppe Vesuviano	12	38	158
San sebastiano al Vesuvio	1	14	77
Sant'Anastasia	16	34	139
Somma Vesuviana	17	35	220
Terzigno	22	39	164
Torre Annunziata	9	42	364
Torre del Greco	4	19	240
Trecase	0	12	130
TOTALI	**192**	**443**	**2757**

PROB. Pi OF INTERRUPTION FOR INTENSITY IX (NUMBER OF ROAD LINK INTERRUPTED)			
municipality	Pi ≥60%	40%≤Pi≤60%	Pi< 40%
Boscoreale	92	60	184
Boscotrecase	73	50	152
Cercola	15	20	53
Ercolano	80	49	113
Massa di Somma	20	18	33
Ottaviano	90	39	131
Pollena Trocchia	12	5	41
Pompei	4	9	42
Portici	55	33	63
San Giorgio a Cremano	15	15	32
San Giuseppe Vesuviano	64	54	90
San sebastiano al Vesuvio	23	16	53
Sant'Anastasia	60	27	102
Somma Vesuviana	69	52	151
Terzigno	74	44	107
Torre Annunziata	89	72	254
Torre del Greco	33	50	180
Trecase	25	23	94
TOTALI	**893**	**636**	**1875**

Criticalities from precursory earthquakes

The evaluation of expected damage due to earthquakes occurring during the unrest phase of a possible eruption at Vesuvius is very relevant to assess the criticality of the evacuation plan for the red zone.

Many buildings in the red zone have an high level of seismic vulnerability, therefore vast damages caused by pre-eruption earthquakes have to be expected.

This could lead to:

- face up a severe seismic emergency, before the official warning of imminent eruption;
- the ruins of the buildings deriving from total or partial collapses could compromise the practicability of some crucial escape paths and hamper the rescue activities of the trapped victims.

A Mitigation Plan to reduce the vulnerability of the buildings along the evacuation paths is urgently needed.

Some suggestions on key strategies for volcanic risk reduction

- Precursory phenomena are fundamental for understanding when a volcano is near to erupt
- However, they do not give information on the characteristics of the impending eruption, which have to be derived from previous activity of each specific volcano

This is the main frontier of volcanology research

Risk assessment requires a very close cooperation between volcanologists (hazard assessment) and engineers (vulnerability assessment)

They must work together in volcanic emergency planning and management