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The change of the realtime intensity and early warning estimated from the strong motion records of the earthquake at 01:36, 24th August 2016 (UTC) causing severe damage around Amatrice

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This report overviews the characteristics of the earthquake motion at some sites from the realtime seismic intensity (a patent technology of SDR) using the strong motion record of the represented earthquake (M6.0, depth 4.2km by INGV) released by the strong motion observation network in Italy ITACA (http://itaca.mi.ingv.it/ItacaNet/).

The observation stations around the epicenter are pointed on Google Earth as Figure 1. Figure 2 shows the change of the realtime intensity with detection time for each site. This figure also shows that of the L'Aquila earthquake in 2009 at AGV station suburban of L'Aquila for the reference. The additional figure is enlarged for ten seconds after the earthquake detection to confirm precisely the change after the earthquake arrival. Please see addendum for the definition of realtime intensity and other information. Also note that although the realtime intensity is defined newly and opened as papers by us in 1998 and 2003, another organization creates confusion with adding same name for the other definition.

Figure 2 also shows the estimation of the alarm timing of FREQL. And it shows the time margin of EEW against intensity 4 assigned as the beginning level for the damage, considering that the damage is caused by the earthquake motion more than intensity 5 in Japan. The right axis of this figure indicates MMI for reference.

It is possible to save only two to five seconds in epicentral area for this earthquake from this result. And it seems that it is difficult to survive from vulnerable buildings except for some extraordinary preparation because of such extremely short time margin. It makes us confirm again that the fundamental of the earthquake disaster prevention is keeping the earthquake-proof characteristics.

The change of the realtime intensity is divided for some small severe rise, not similar to that of the ordinary epicentral earthquake as AQV station at the time of the L'Aquila earthquake, increasing in one stroke just after the earthquake arrival. As a result, the alarm requires astonishingly long time after P wave detection, and the limited time margin becomes shorter. This figure includes two safety stations not exceeding the seismic intensity 4, and the P wave alarm is seems to be not issued for these two sites. And it seems that the P wave alarm should be issued for the other sites at the time between two pink arrows.

The strong motion record at AMT close to Amatrice with serious damage indicates the maximum realtime intensity 5.1, corresponding to the instrumental seismic intensity, and this earthquake motion should cause no damage in Japan. However the maximum realtime intensity 5.3 was observed at NRC station at northern side of the epicentral area, there is almost no damage without any death in Norcia. Yomiuri newspaper on 30th August 2016 says this area has been reinforced, and it seems effective.

So the degree of the reinforcement may differ for each area. The amplitude characteristics of the surface layer is usually noticed as the local characteristics, and the earthquake motion seems to be amplified larger at NRT station from the realtime intensity at AMT and NRT. In spite of this situation, severer damage was suffered around AMT station. Of course it is important to grasp the ground characteristics, however this fact shows that it is rather important to grasp the vulnerability and take proper countermeasure for individual structure, especially for the area with ancient traditional structures as Italy. There is an urgent need to progress seismic diagnosis with microtremor and establish the way to proper reinforcement.

The seismic wave required about 2.8 seconds to propagate for the first five strong motion stations, and the location of epicenter can be estimated as Figure 3 from the P wave arrival time of these five stations with least-square method. This result says rather east against that of INGV and it was the northern side of Amatrice with depth of 9.6km. Because UrEDAS procedure of AMT data also indicates the epicenter at northern Amatrice, it is considered reasonable as an initial estimation of epicenter location. FREQL alarm was issued about 1.3 seconds after P wave detection, and if these strong motion sites work together, it is estimated that the location of the epicenter was grasped about 1.5 seconds after that and then the magnitude might be decided. However it is

little late alarm for the damaged area, it will be useful trigger information for quick response of the local relevant departments for the disaster prevention.

Figure 4 shows the distribution of the aftershocks till 29th August 2016 by INGV.

(End of Text)

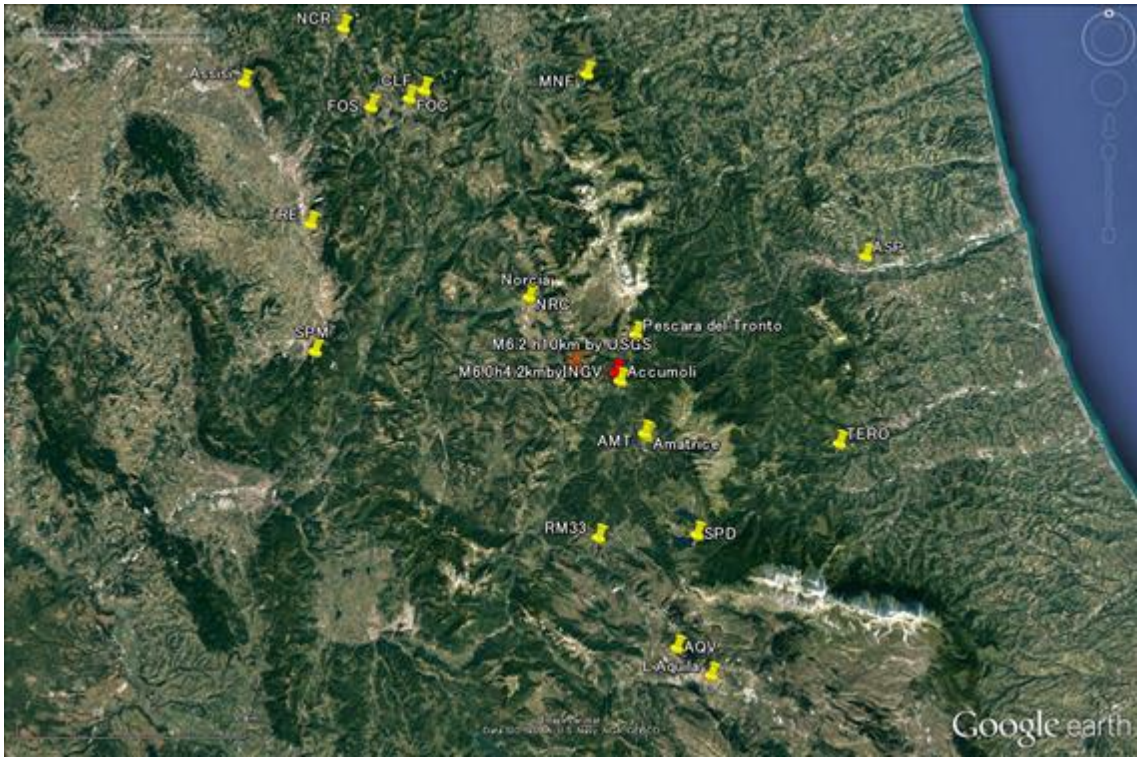

Figure 1

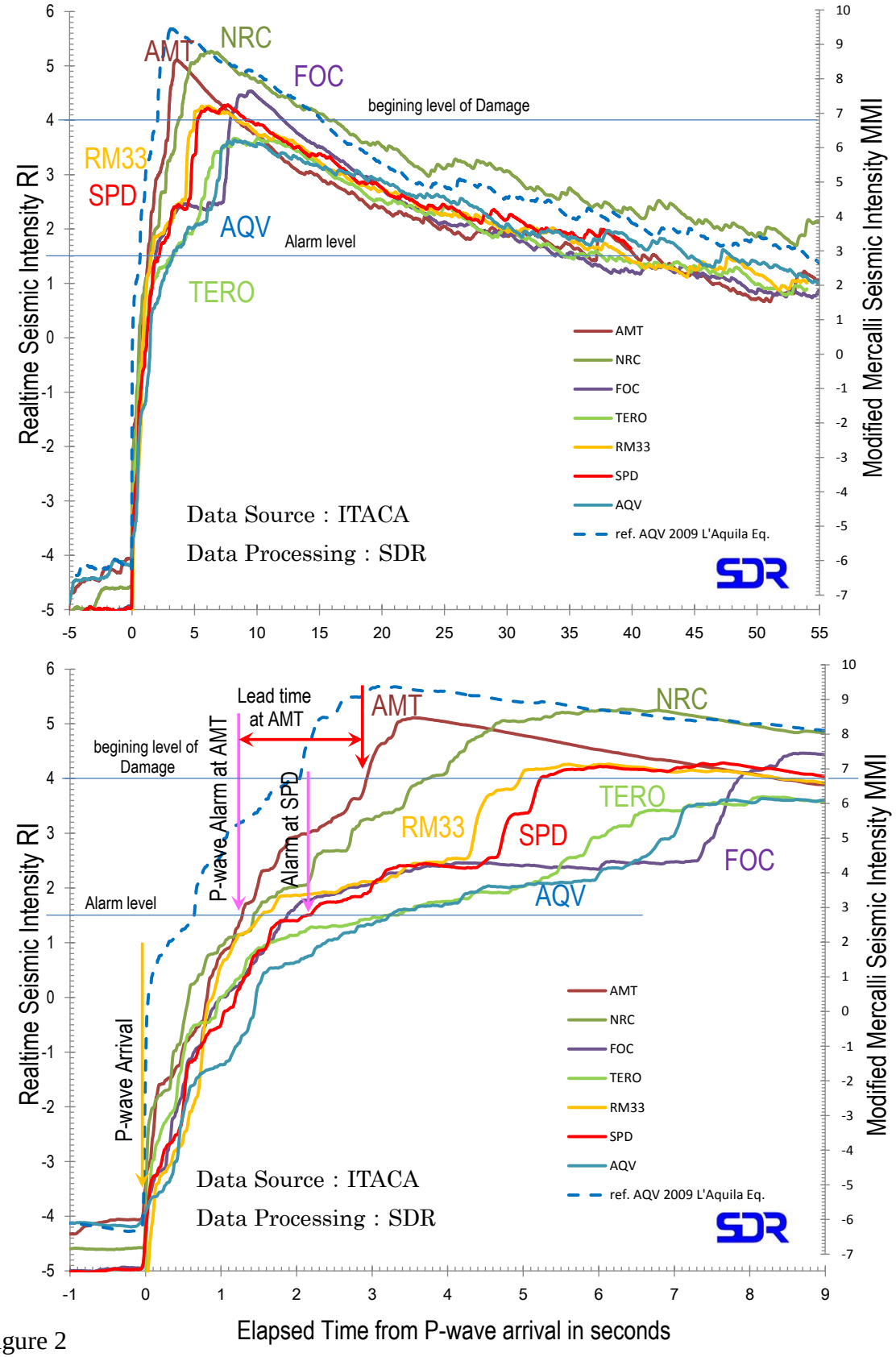
Realtime Seismic Intensity RI
Modified Mercalli Seismic Intensity MMI
AMT
NRC
FOC
RM33
SPD
AQV
TERO
begining level of Damage
Alarm level
Data Source : ITACA
Data Processing : SDR
ref. AQV 2009 L'Aquila Eq.
Lead time at AMT
P-wave Alarm at AMT
Alarm at SPD
P-wave Arrival
Elapsed Time from P-wave arrival in seconds

Figure 2

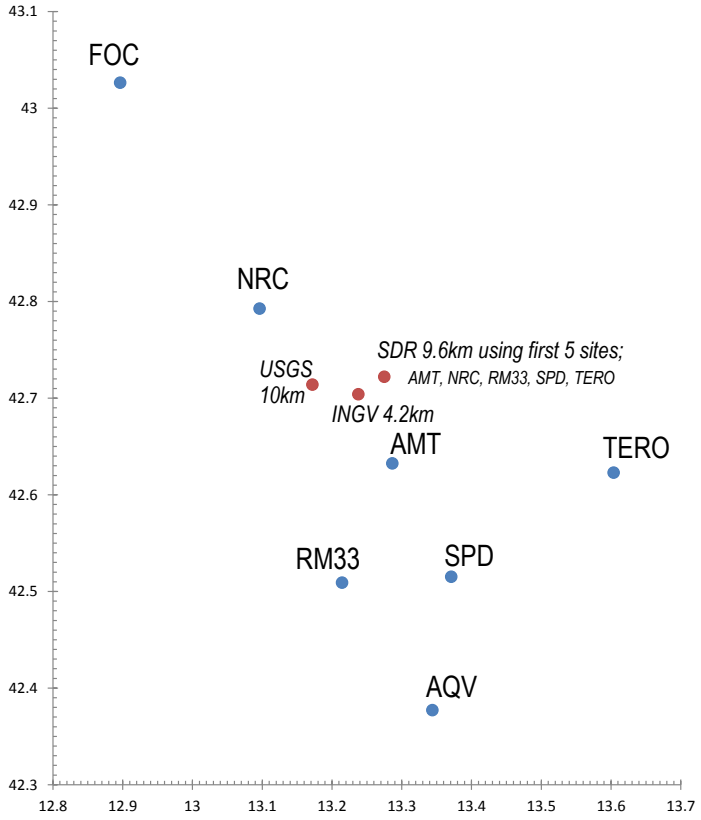

Figure 3

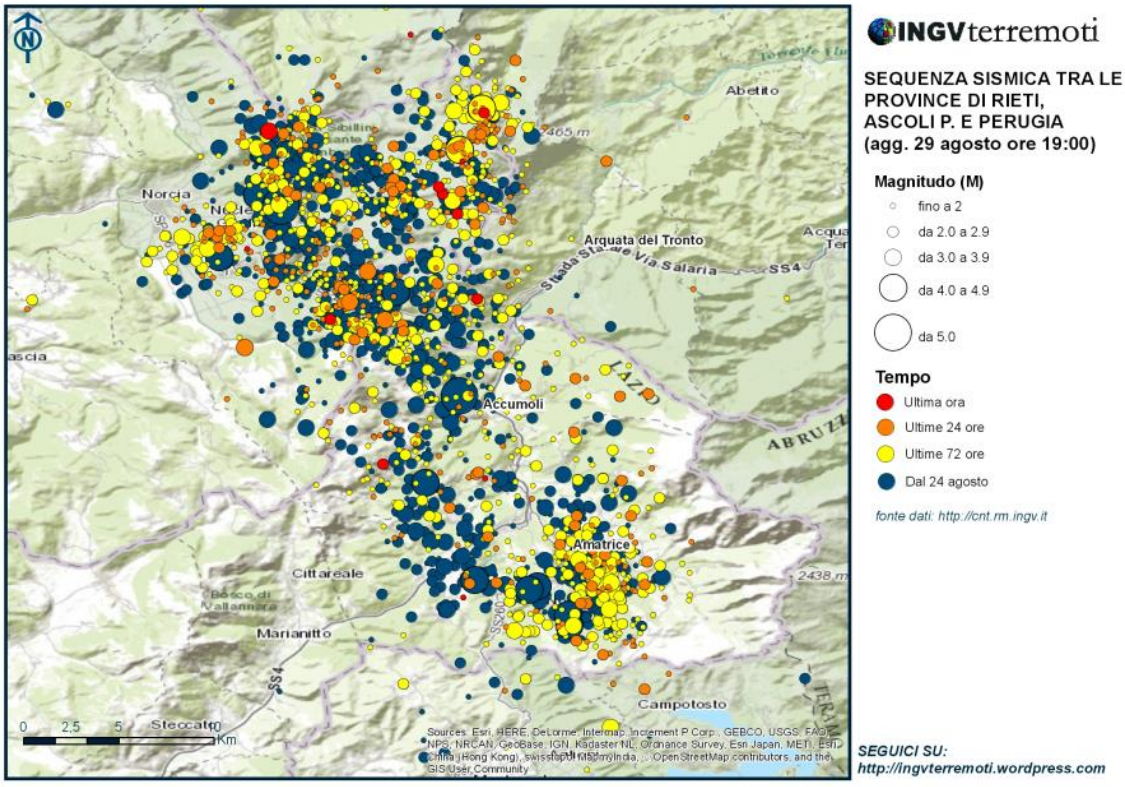

Figure 4

(Addendum)
Definition of realtime intensity and conversion to MMI

Realtime intensity RI is defined as the following formula, the common logarithm of the power of the earthquake motion acting to the mass of 1kg adding a constant (see the reference).

$$RI = \log(PD)+6.4$$
$$PD = \mathbf{a}\cdot\mathbf{v}$$

Here, **a** and **v** are the vector of earthquake acceleration and velocity, respectively. And operator · indicates the inner product. The constant is set the maximum value of RI to fit the JMA instrumental intensity and it will be 6.4 and 2.4 in case of the unit in MKS and in case of Gal (cm/s2) and kine (cm/s), respectively.

MMI is converted by the next formula following to the reference.

$$\mathrm{MMI} = \mathrm{RI} \times (11/7) + 0.5$$

The power for unit mass PD, Power Density in W/kg, can indicate the basal metabolic expenditure of human body as around 1 W/kg. That is, the PD corresponding to the basal metabolic expenditure of human body is about 6.4, converting to the realtime intensity. The power of the earthquake motion seems to be unexpectedly small. However this acts to the entire mass, the heavier thing is effected by larger power of earthquake motion.

References

Yutaka NAKAMURA: EXAMINATION OF A RATIONAL STRONG MOTION INDEX
- Relationship between the DI value and the other strong motion indices -, 22st JSCE Earthquake Engineering Symposium, 2003. (in Japanese with English abstract)

(End of Addendum)