What can we learn from the January 2012 Northern Italy earthquakes?

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This note focuses on the ground motion recorded during the recent moderate earthquakes occurred in the central part of Northern Italy (panel 1), a region characterized by low seismicity.
For this area the Italian seismic hazard map (Stucchi et al., 2011) assigns a maximum horizontal acceleration (rock site) up to 0.2 g (10% probability of exceedance in 50 yrs). In the last 4 years, the region was struck by 9 earthquakes in the magnitude range $4 \leq M_w \leq 5.0$, with the three largest located in the Northern Apennines (M_w 4.9 and 5.0 Parma events, December 2008 and January 2012) and in the Po plain (M_w 4.9 Reggio Emila event of January 2012). We analyze the strong-motion data (distance < 300 km) from these events recorded by stations belonging to the INGV (RAIS, http://rais.mi.ingv.it; RSNC http://iside.rm.ingv.it) and DPC (RAN, www.protezionecivile.it; http://itaca.mi.ingv.it).
The 2008 and 2012 Parma events, both characterized by reverse focal mechanisms (http://cnt.rm.ingv.it/), have depths of 27 and 60 km respectively. The deep event produced a maximum peak ground acceleration (PGA) of 97 cm/s^2 at Novellara (NVL, EC8 C class) station (70 km from the epicenter). The 25th January 2012 event (depth of 34 km) produced a maximum PGA of 114 cm/s^2 at Sorbolo (SRP) station (7 km from the epicenter).
Preliminary analyses show:
1) a peculiar ground-motion attenuation of the deep Parma event with respect to the shallow one. In panel 2, the PGAs for the two Parma events are plotted as a function of hypocentral distance and compared to the global ground motion prediction equation (GMPE) calibrated by Cauzzi and Faccioli (2008) using events with depth < 30 km. The different distance-decay of PGA for the deep event (blue for A class of EC8 and red for B and C classes, CEN 2003) is evident, in particular for distance up to 100 km. On the other hand, the PGAs of the 2008 Parma crustal event (grey) are well explained by this GMPE.
In panel 3, the PGAs for the deep 2012 event, grouped for EC8 classes, are compared to the national GMPE calibrated by Bindi et al. (2011) using crustal events and epicentral distance. Also in this case, the GMPE underestimates the PGAs up to 200 km. Although most of the class C sites (red) show the largest PGAs, the underestimation cannot be completely ascribed to site effects.
The large PGAs from the Parma deep event, with respect to the shallow one, could be explained in terms of source effects (e.g. large stress drop values enhancing the high-frequency radiation). In addition, as explained by Castro et al. (2008), the different attenuation in the lower and upper crust could explain the large PGAs recorded for the 2012 deep event.
2) seismic amplification at Po Plain sites:

In panel 4, the PGAs of the January 25th, M_w 4.9, Reggio Emilia event are plotted as a function of the epicentral distance, together with the Bindi et al. (2011) GMPE. In general, the largest amplitudes occur at the Po plain sites (red), suggesting possible peculiar site response. An overall increase of the PGAs is observed around 100km, in agreement with the results of Bragato et al. (2011) that studied the regional influence of Moho S-wave reflections in the area.

An example of site response is shown in panel 5, considering TREG (class C) and ZEN8 (class A) stations (panel 5a), located at 88 km from the Reggio Emila epicentre. The rotational standard spectral ratio (panel 5b) for 10 s of S wave shows polarized amplifications around 2 Hz, detected also at others Po plain sites (not reported), as well as amplification on the vertical component.

The points discussed above should to be interpreted as a warning for future applications dealing with ground motion estimation in the aftermath of an earthquake in this area (e.g. ShakeMap calculation): currently used GMPEs, based on different events and sites characteristics could lead to significant bias in the final results.

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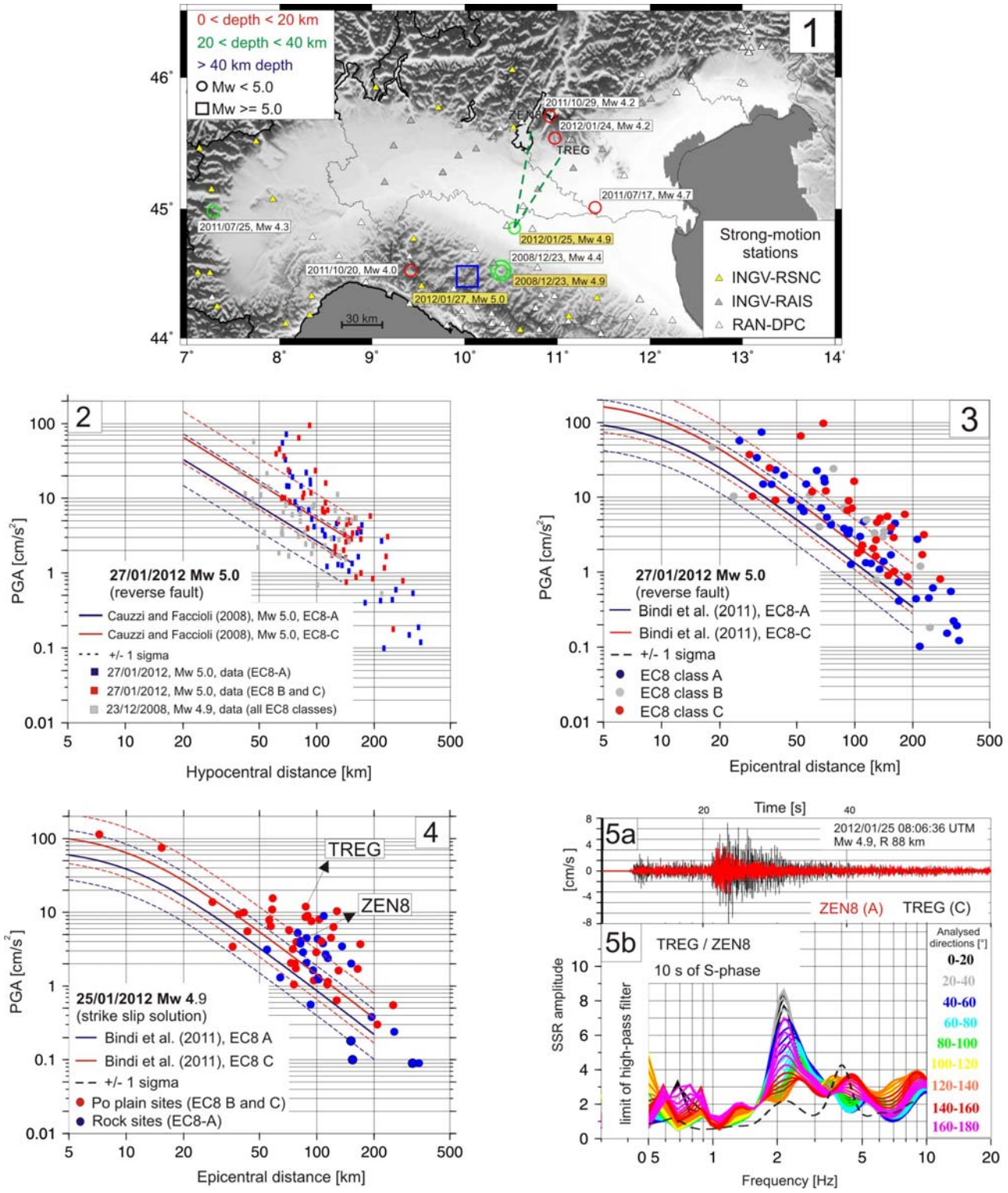

Panels

1: 2008-2012 instrumental seismicity of the area ($M_w \geq 4$, http://cnt.rm.ingv.it/tdmt.html). Yellow insets indicate the analysed events. **2**: comparison between PGAs recorded for the 27th January, M_w 5.0, event and Cauzzi and Faccioli (2008) GMPEs. Grey symbols indicate PGAs recorded for the 2008 Parma M_w 4.9 event. **3**: comparison between PGAs recorded for the 27th January, M_w 5.0, event and Bindi et al. (2011) GMPE. **4**: comparison between PGAs recorded for the 25th January, M_w 4.9, event and Bindi et al. (2011) GMPE. **5a**: NS component of 25th January 2012 event (M_w 4.9) as recorded at TREG (C class) and ZEN8 (A class) RAIS stations. **5b**: rotational Standard Spectral Ratio (SSR) calculated on 10 s of S-phase for the 25th January M_w 4.9 at TREG station (ZEN8 is the reference). Dashed black line indicates the vertical SSR.