Seismic signal of avalanches

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Fig. 1

The characterization of avalanches with seismic signals is an important task. For risk mitigation, estimating remotely avalanche activity by means of seismic signals is a good alternative to direct observations that are often limited by visual conditions and observer's availability. In seismology, the main challenge is to discriminate avalanche signals within the natural earth seismic activity and background noise. Some anthropogenic low frequency (infra-sound) sources like helicopters also generate seismic signals. In order to characterize an avalanche seismic signal, a 3-axis broad band seismometer (Guralp 3T) has been set-up on a real scale avalanche test site in Lautaret (France) [Fig. 1, Fig. 2]. The sensor is located in proximity of 2 avalanche paths where avalanches can be artificially released.
Preliminary results of seismic records are presented, correlated with avalanche physical parameters (volume released, velocity, energy).

Fig. 2

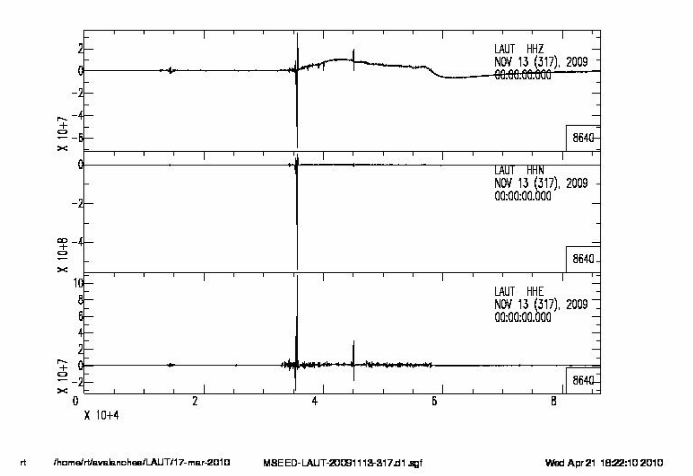

Fig. 3

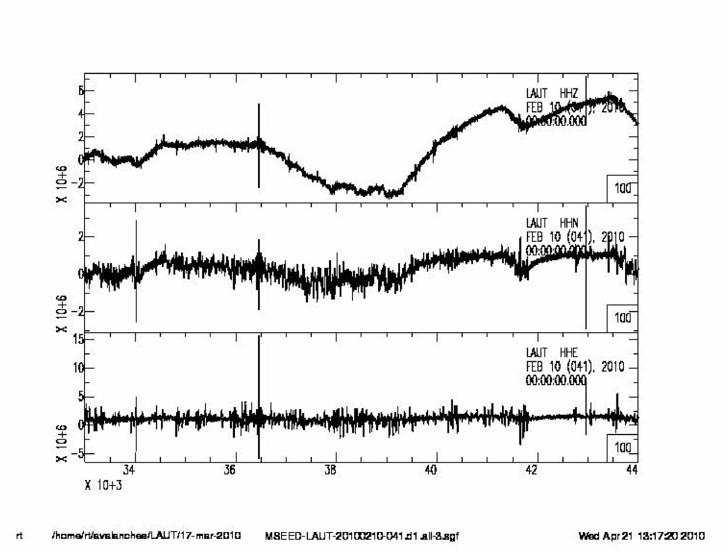

Fig. 4

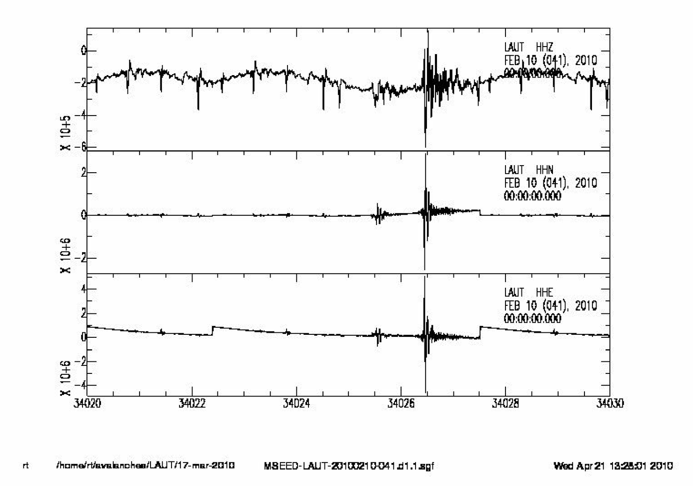

Fig. 5

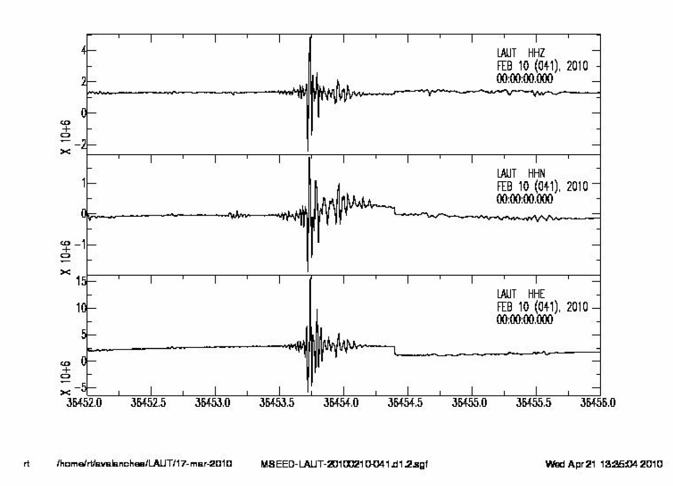

Fig. 6

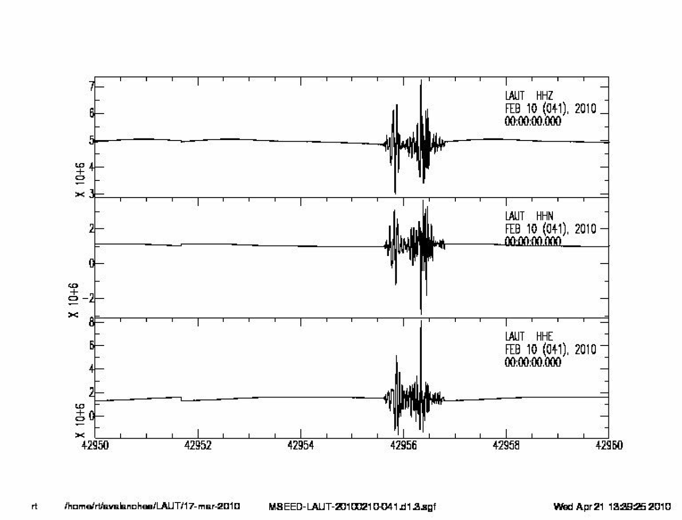

Figure 7

Figure 3 shows the recordings of a 3m^3 Gazex explosion occurred on 13/11/2009 at 12:29 GMT. Such a mass provides between 60 and 125 Mjoule of energy released a few meters about the snow cover, cover which at that time was very reduced and therefore its attenuation factor in the energy transmissions to the ground could be neglected. The maximum peak-to-peak values recorded by the seismic station for this explosion is between 100 and 600 x 10^6 counts.
For comparison, a M_L=2.7 earthquake occurred about 100km away [Figure 10-11] produced maximum peak-to-peak values between 1.0 and 1.3 x 10^6 counts.
Figure 4 shows 3 events recorded on February 10 2010. The large variation on the vertical component of the seismometer is due to the human perturbation caused inside the shelter where the seismometer is installed, mainly trough temperature variations.

The first event illustrated in Figure 5 it's due to a Gazex explosion occurred at 11:51 GMT that caused an avalanche that reached the road close to the shelter. Volume of the avalanche was 140 m^3 with density 0.3 which gives 42,000 kg of snow. Altitude loss was -160 m which gives a total energy of 66 Mjoules. The maximum peak-to-peak values recorded with the seismic station for this event was between 0.7 and 9.6 x 10^6 counts.
Path n°1 was released 8 minutes later with Sofranex explosive, successfully also with an avalanche the reached the road also. CEMAGREF use typically 2.2 kg cartridge directly lying on the snow cover to destabilize. Such an explosion can provide 10,4 MJoules directly into the snow: we can consider that half of it gets into the snow cover. Volume of the avalanche was 71 m^3 which gives 21,000 kg (at density d=0.3) and with an altitude loss of -115 m which results in 24 Mjoules. Its seismic recordings are illustrated in Figure 6, with a maximum peak-to-peak values ranging from 3.7 to 21.4 x 10^6 counts.
The North East shot at 12:30 was not successful so in Figure7 we just record the Avalhex explosion but no avalanche signal here. The Avalhex system uses hydrogen whose energy is similar to Gazex, around 100 MJoules released in the atmosphere. Max peak-to-peak values for this event ranged between 4.2 and 9.7 x 10^6 counts.
We didn't estimated the fraction of energy transmitted from an explosion a few meters above the ground level into the ground. Nevertheless we could roughly estimate the energy reduction factor of a few meters snow cover in the order of 10, comparing max peak-to-peak values of the first event illustrated in Figure 3 and the 3 events illustrated in Figure 4.
Signals of avalanches recorded at CEMAGREF Col du lautaret test site are shorter in time compared to those previously studied [Valt, Pesaresi & Cagnati, 2009; Valt & Pesaresi, 2009], which correspond to avalanches with smaller run outs.

Fig. 8

Fig. 9

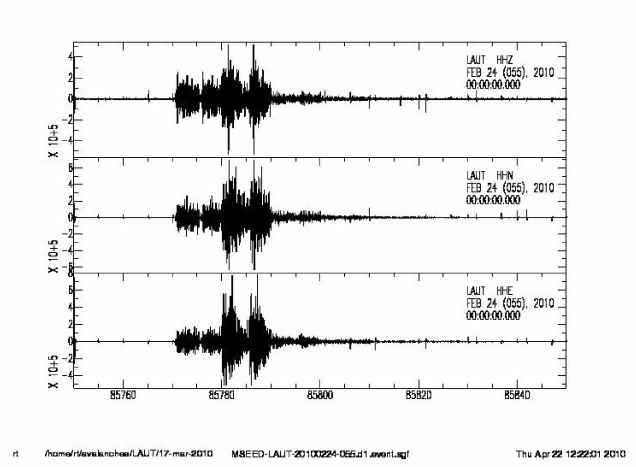

Fig. 10

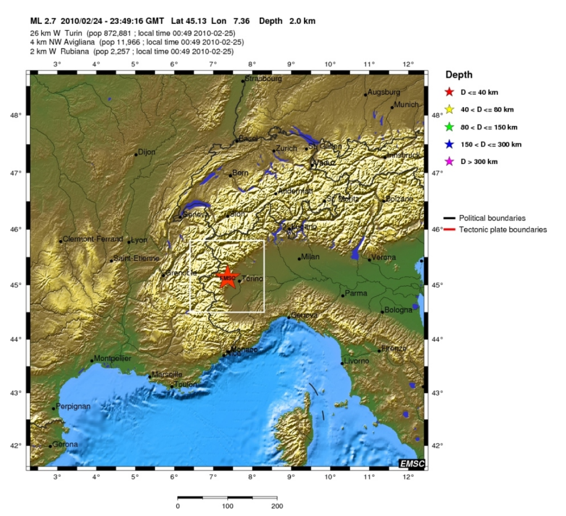

Fig. 11

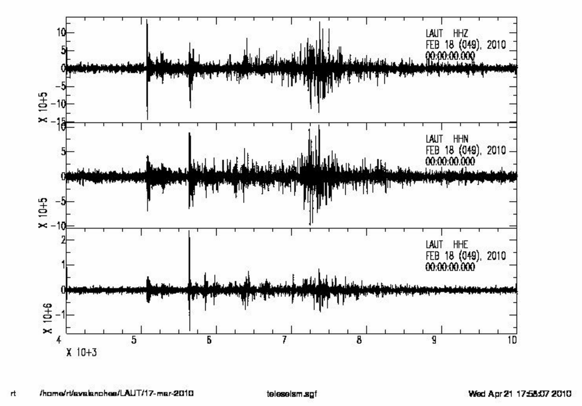

Fig. 12

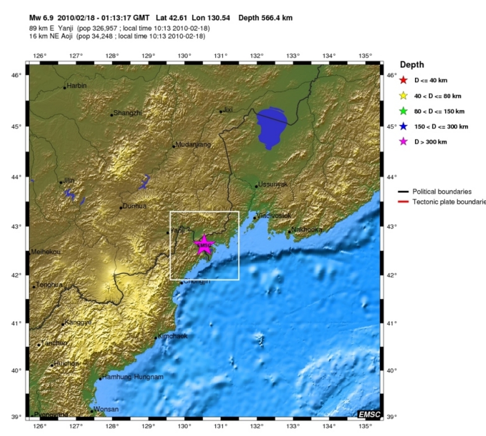

Fig. 13

Figure 8 and Figure 9 show respectively the Lennartz M24 seismic data-logger and the Guralp CMG40T 3-axial broad-band seismometer installed in the shelter in CEMAGREF avalanches test site at Col du Lautaret outside Grenoble (France). The Guralp CMG40T seismometer response curve is flat between 30 sec and 100Hz. The Lennartz data-logger sensitivity was fixed at 2.5 V full scale. The seismometer has been oriented normally with the North-South component aligned toward the geographic North. Its Est-West component is then almost aligned with the avalanches path directions of the test site.
Figure 10 shows a local earthquake as recorded by the seismic stations installed in Col du Lautaret. As illustrated in Figure 11, it is a M_L=2.7 earthquake located in the Maritime Alps 26 km West of Torino, about 100km from the seismic station in Col du Lautaret test site. The earthquake parameters are taken from European Seismological Center (EMSC) web site. In this work we evaluate the the maximum peak-to-peak values for each event. In classic seismology this is directly correlated with the local magnitude M_L of the event itself: it is then directly correlated to the energy of the avalanches.
Figure 12 shows the recordings of a teleseismic event. Checking from EMSC web site it is a M_W=6.9 earthquake occurred at the China-Russia-North Korea border region at about 570 km depth on 2010/02/18 at 01:13:17 GMT time [Figure 13].
Both the regional and teleseismic earthquakes recordings testify the good funcionality of the seismic stations installed at Col du Lautaret test site, both at high frequencies (local event) and long periods (teleseismic event). The maximum signal amplitudes are correctly recorded on the radial North-Est component of the seismometer.
Nevertheless we experienced a serious problem in decoding the internal Standard for the Exchange of Earthquake Data (SEED) format of the Lennartz data logger, which doesn't correspond to the SEED standard. We had to fix a workaround to overcome the problem.

References

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Guralp CMG40-T broad band seismometer, http://www.guralp.com/products/40T/

Standard for the Exchange of Earthquake Data (SEED), http://www.iris.edu/manuals/SEED_chpt1.htm

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