

Combined InSAR-geophysical-seismological data for high-resolution site-effect modeling and ShakeMap generation, case study of Grenoble, France

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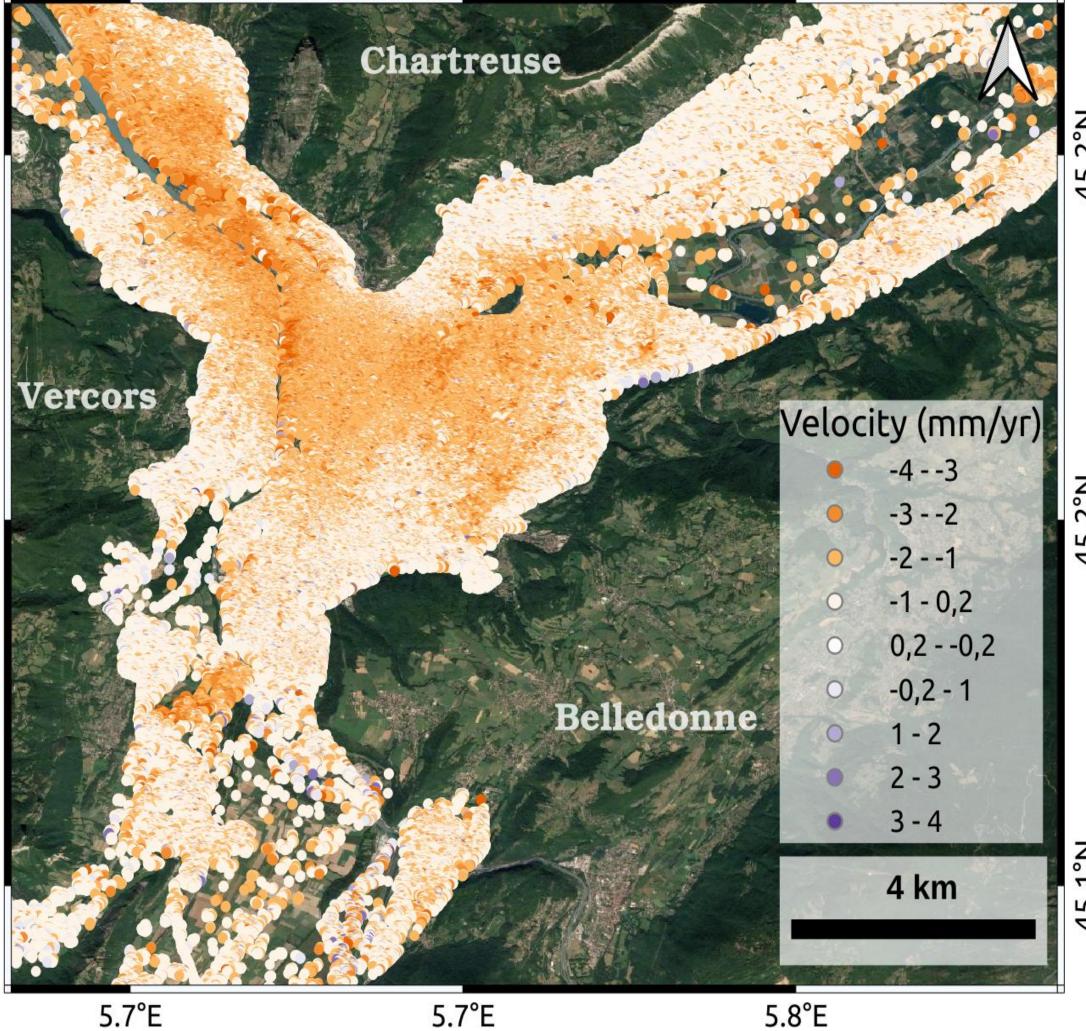
Combined InSAR-geophysical-seismological data for high-resolution siteeffect modeling and ShakeMap generation, case study of Grenoble, France

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Abstract: In the urbanized valley of Grenoble, a well-known sedimentary basin prone to complex 3D site amplifications of seismic waves, multiple geophysical and seismological data from previous temporary campaigns and from permanent networks are gathered to characterize the basin response to earthquakes. Our goal is to find physical correlations between the parameters available at the highest spatial resolutions and the seismic response that is recorded by seismological stations only at a few sparse points in the basin. If such correlations exist, it would allow us to map the seismic response at a finer spatial scale [1]. We process InSAR data to retrieve the subsidence rate of the sediments at millimetric precision and at 354291 points in the basin. We then test multiple correlations between the subsidence rates and all the available siteeffect parameters (as for example the depth of the bedrock below the sediments and the fundamental resonance period), in order to determine a model of aggravation of the ground motion based on the subsidence rates. The obtained model can be applied at a fine spatial scale to predict the Grenoble basin response to earthquakes in high resolution. The modeled response can in turn be used as an input to the ShakeMaps, or to predict earthquake-damage potential at building scale.

Input Subsidence rates from InSAR (354291 points)



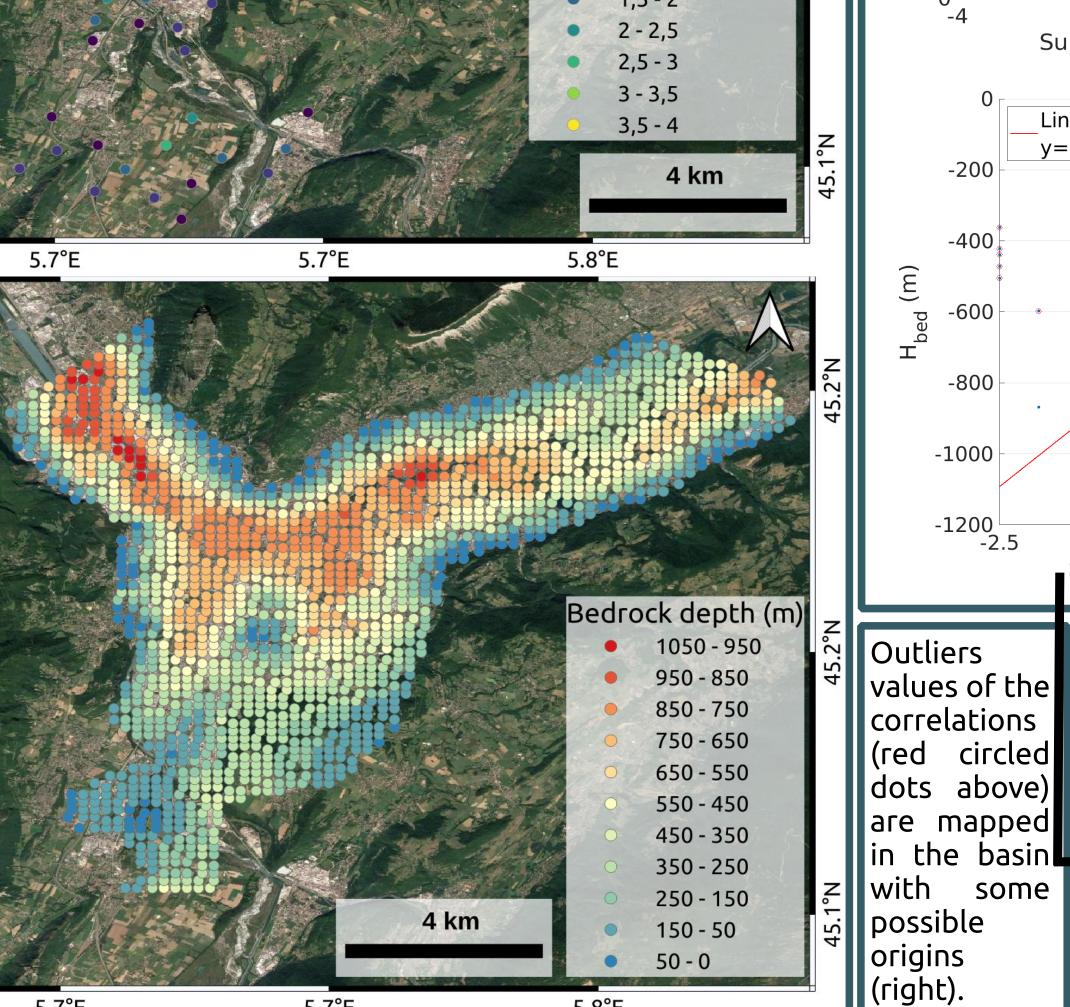
We investigate the correlation between the **subsidence rates** of the sediments and **5 parameters** of the site response: V_{S10} , f_0 , To, $\log_{10}(f_0)$ and H_{bed} [2, 3, 4]. The best linear fits are obtained with the bedrock depth ($R^2=0.67$) and the resonance period $(R^2=0.53)$ (shown below).

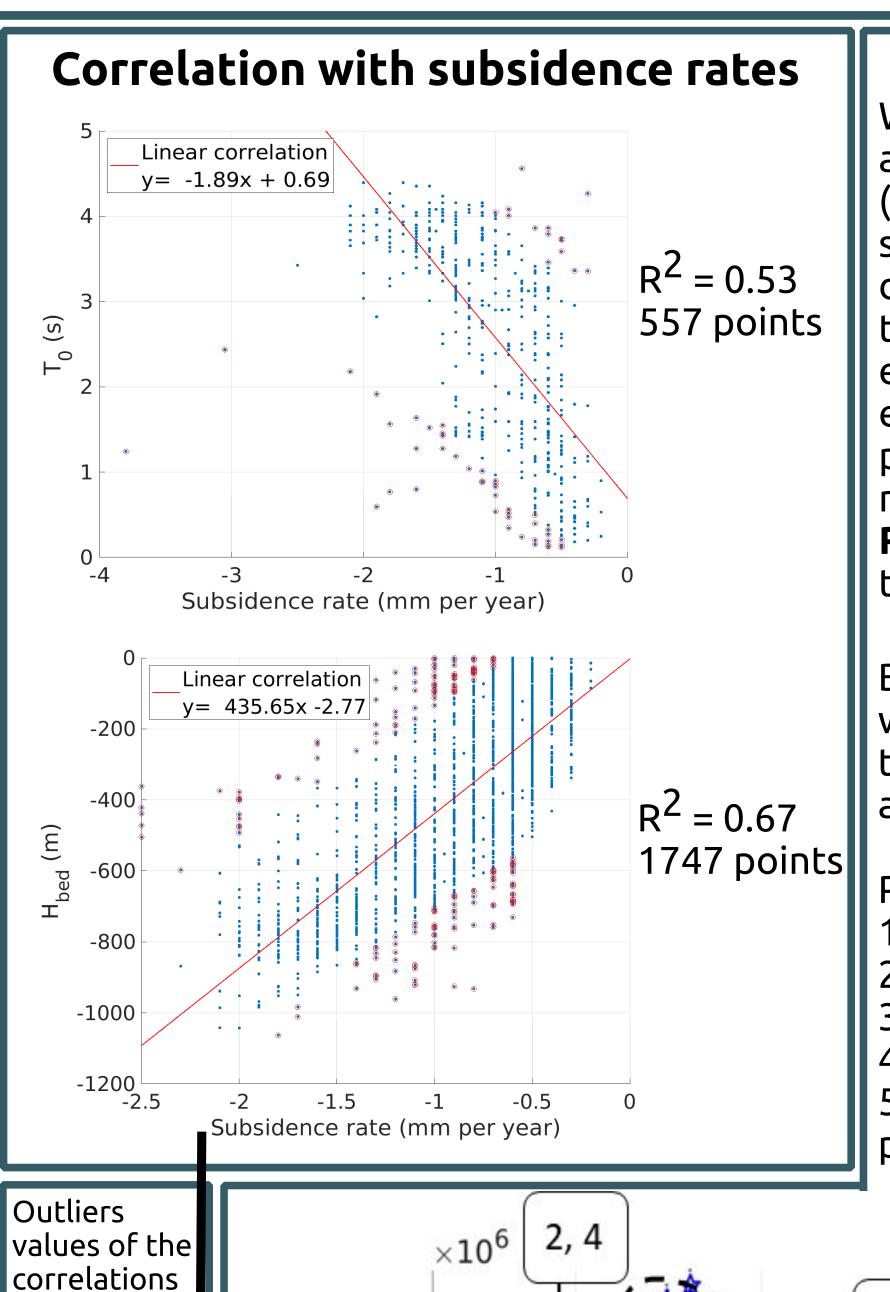
The amplification factors are available **only** at 7 RAP stations (black triangles on the right), using the standard spectral ratios (SSR) from an earthquake and ground-motion catalog [5]. To estimate the amplification in all of the Grenoble basin, we use the link between observed the amplifications at low frequency and the bedrock depths at the stations to extrapolate these values. The subsidence rate is used to retrieve the bedrock depth at a fine spatial scale, using the correlation found, hence we finaly map at high resolution the amplification factor (see right).

The misfits between the amplification factors obtained with this method and from the bedrock depth model are shown on the right. The largest misfits are located on the edges of the basin, where the depth of the basin is less well constrained.

Target Predicted amplification factor in the Grenoble basin at 0.33 Hz 6.462 6.46 6.458 6.454 Misfit 100 6.452 6.45 6.448 9.15 9.2 Easting (m) $\times 10^5$

Site response parameters Resonance period (s) 0,5 - 1 1 - 1.5 1.5 - 2 2 - 2,5 2,5 - 3 3 - 3,5 3,5 - 4





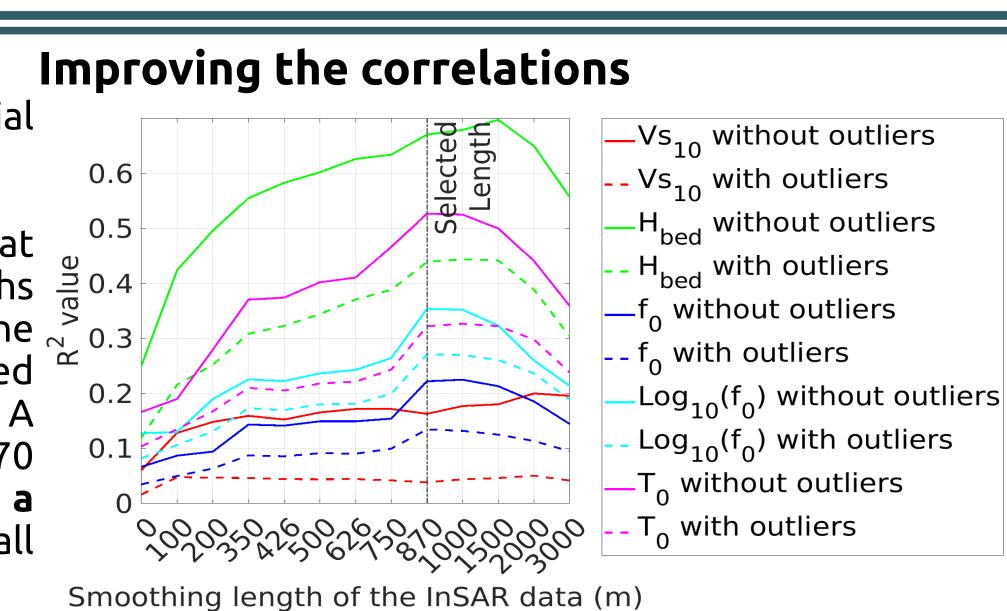
6.448

9.1

9.12

9.14

We apply a spatial averaging (**smoothing**) of the subsidence rates at different wavelengths $\frac{2}{5}$ 0.4 mitigate effects of isolated extreme values. A particular length (870 m) allows to reach **a maximum** in all tested correlations.



By excluding extreme values from the correlations with Hhed and To that we interpret as outliers, we **improve** the R² value. We explore the origins of those potential outliers. Their location in the Grenoble basin is not aleatory and they tend to group into clusters.

Possible origins for the outliers (labels on the map below):

- 1. Location close to the **edges of the basin**.
- 2. Area with **heavy buildings** [6].
- 3. Irregular or **complex bedrock geometry** at depth.
- 4. Area corresponding to strong and variable gravimetric anomalies [4].
- 5. The **distance** between the site-effect parameter and the closest InSAR point is **too large** (> 200 m).

 \star T₀ outliers

9.2

9.22

9.24

 $\times 10^5$

5.7°E 5.7°E 5.8°E The ANR project **SASHA** relies on the strong collaboration between **three** SNOs: RAP (strong-motion data), ISDeform (processing of space radar imagery for ground deformation measurements) and BCSF-Rénass (seismicity, macroseismic intensities and ShakeMaps in France).

- [1] Albano, M. et al. (2016) 'An innovative procedure for monitoring the change in soil seismic response by InSAR data: application to the Mexico City subsidence'. International Journal of Applied Earth Observation and Geoinformation.
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- la cuvette grenobloise par inversion des anomalies gravimétriques'. [5] - Buscetti et al. 'RESIF RAP and RLBP Database of earthquake ground

[6] - Base de données nationale des bâtiments (BDNB) - data.gouv.fr (2023).

[3] - Guéguen, P. et al. (2007) 'On the limitation of the H/V spectral ratio using seismic noise as an exploration tool: application to the Grenoble valley motion in mainland France: Updated and improved version covering the 1996-2021 period'. In preparation.

2, 4 6.462 6.458 6.456 1, 4 6.454 Interpreted map of the outliers Heavy buildings 6.452 Distance H_{bed} to closest InSAR point > 200 m Distance T₀ to closest InSAR point > 200 m 2, 3, 4 6.45 Strongest gravimetric anomalies ★ H_{bed} outliers

9.16

Easting (m)

9.18