



Seismo-acoustic signals of the Baumgarten (Austria) gas explosion detected by the AlpArray seismic network

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ABSTRACT

On December 12, 2017 a devastating release and combustion of gas occurred at the Baumgarten gas hub in Eastern Austria, which is a major European distribution node for natural gas. We have detected the resulting seismo-acoustic signal on permanent and temporary broadband seismic stations at distances between 30 and 175 km from the gas hub, most prominently in the 2–4 Hz range. Two distinct phase arrivals correspond to acoustic waves traveling through the troposphere and stratosphere. The passing of a cold front shortly before the explosion led to several temperature inversions at low altitude, and acoustic waveguides within the troposphere that facilitated our infrasound detections at distances as close as 50 km from the source, in addition to the commonly observed stratospheric reflections. 3D acoustic raytracing using temperature and wind velocities from the HRES (high-resolution) forecast model of the European Center for Medium Range Weather Forecast (ECMWF) has allowed to precisely relate the spatial distribution of our detections with calculated surface bounce points of infrasound rays. This has provided a precise and independent estimate of the time of the accident, to be used in forensic investigations. In addition to the acoustic signal we find evidence for weak seismic phases on the stations closest to the gas hub, yet the sudden release of gas above the surface generated acoustic waves more effectively than seismic waves. After the first explosion signal, we also detect a prolonged coda of elevated noise, which is probably due to ongoing gas release and/or the fire from the escaping gas. Systematic analyses like the one conducted here are of great value to detect, locate, and characterize anthropogenic sources at a regional scale.

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1. Introduction

Seismic monitoring has proven very useful not only for detecting earthquakes, but also to observe other types of seismic sources, from different natural causes to human activity. Within that wide range of applications the study of both deliberate and accidental explosions has a particular role, due to the need to investigate such incidents using all available information. Case studies where seismology provided unique insight have included accidental explosions of pipelines (Koper et al., 2003; Evers et al., 2007), of

industrial plants (Ceranna et al., 2009; Ottemöller and Evers, 2008), of ammunition depots/factories and of war remnants (Kristekova et al., 2008; Green et al., 2011; Hinzen, 2014) as well as the sinking of submarines or ships (Koper and Wallace, 2001; Hong, 2011), and military and/or terrorist activity (Aleqabi et al., 2015; Koper et al., 1999, 2002).

Seismological measurements are particularly useful, if they are not only available from single seismometers, but from distributed networks, as demonstrated using the USArray (Walker et al., 2011; Nippress et al., 2014; Chunchuzov et al., 2014; Hedlin and Drob, 2014). The recently installed AlpArray network across the European Alps (Hetényi et al., 2018) is so far the largest dense deployment of that kind in Europe. It consists of 628 broadband seismic 3-component stations, and has an average station spacing of around 40 km. The primary purpose of the network is the study of the subsurface under the Alpine region; yet the dense station spacing makes it attractive also for investigating other geophysical phenomena.

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³ www.alparray.ethz.ch.

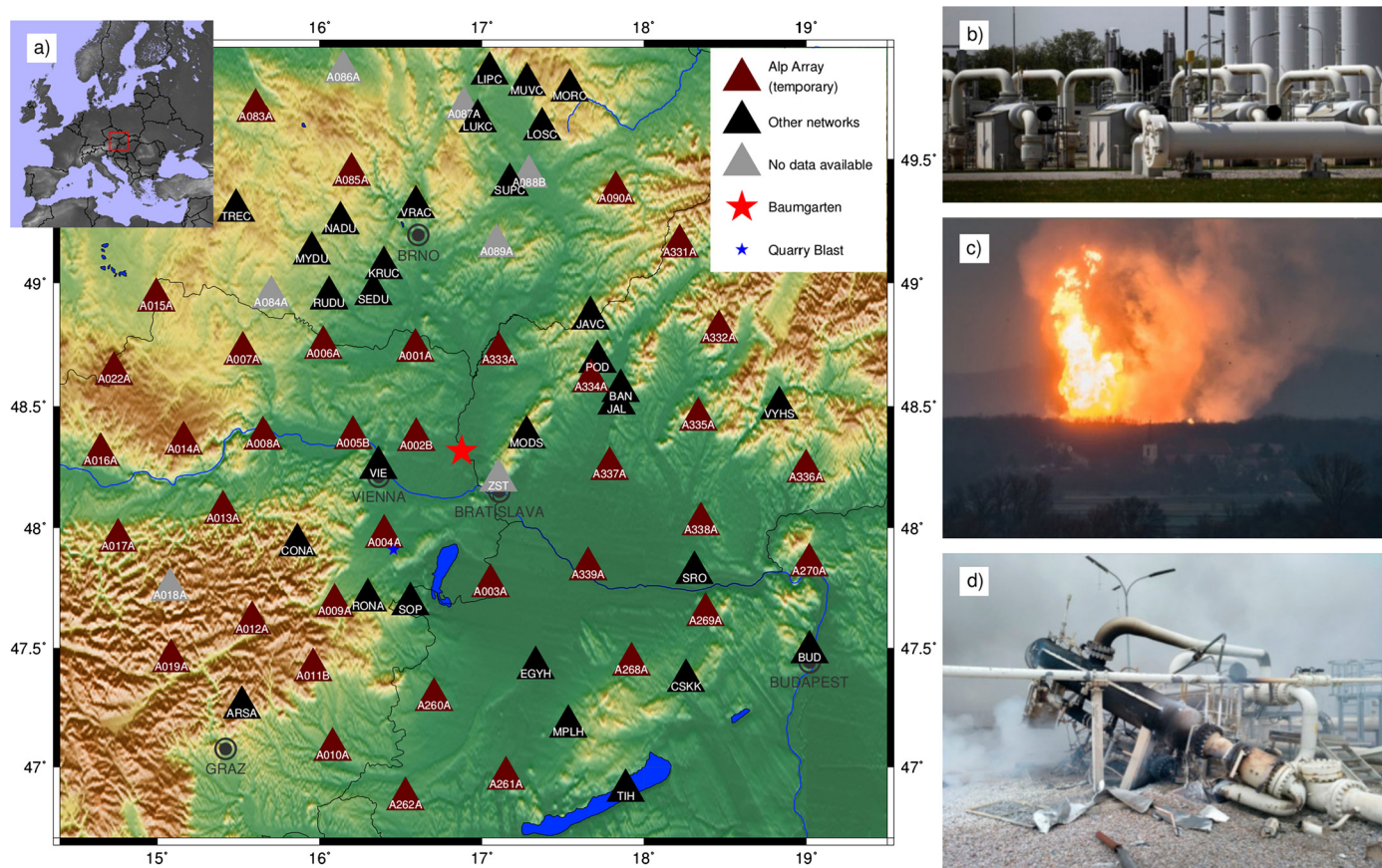


Fig. 1. a) Map of the seismic stations (triangles) in the wider Vienna region used for this study from AlpArray and other networks. The location of the Baumgarten gas explosion is marked by the red star. The inset shows the position of the study area within Europe. All stations are marked with names. Station names following the scheme AxxxA, with xxx being digits only, denote temporary AlpArray stations (network code Z3), while all other stations are associated with various permanent networks (for network codes see Acknowledgments). b) Intact gas filtering devices at the Baumgarten gas hub before the explosion.⁵ c) The fire during the explosion as seen from larger distance.⁶ d) Destroyed gas filter device after the explosion.⁷

We report here about a study of infrasound and seismic waves from Eastern Austria, which has shown the capability of the AlpArray network to detect seismo-acoustic waves, and to contribute to investigations of human accidents. On December 12, 2017 a devastating release and combustion of gas occurred at the Baumgarten gas hub in Eastern Austria. The Baumgarten gas hub is located 35 kilometers to the North-East of Vienna, near the Austria–Slovakia border (see Fig. 1); it is one of the major distribution hubs for natural gas in Europe. With an annual transported volume of 40 billion cubic meters (equivalent to 10% of Europe's gas demand) it is Austria's main reception point for natural gas imports, especially from Russia and Norway.² The majority of the gas is transported to other European countries, in particular Germany, Italy and Hungary.

In this paper, we begin with a ground truth description of the incident; then we focus on the characteristics of the seismic data. We introduce the raypath modeling we performed, and the meteorological data that were used, and compare the observations with the predicted arrivals. We will show how the origin time can be determined best by using the entire timefield of the acoustic waves. A supplementary section shows all analyzed data and briefly discusses additional information, e.g. comparison of the meteorological forecast model with measured balloon data, and more details on the determination of the origin time.

2. Ground truth

On December 12, 2017 around 07:45 UTC (time of the first emergency call) a devastating release and combustion of gas occurred at the Baumgarten gas hub (see Fig. 1). The incident caused one fatality and left over 20 people injured.³ As news about the incident spread, the price for natural gas temporarily increased by more than 80% on several gas exchange markets in Europe.⁴ While commonly termed “The Baumgarten explosion” the incident was technically not an explosion. Rather, according to forensic on-site investigations, highly pressurized gas was released very suddenly and forcefully blown out of a gas filtering device located above ground and was subsequently set on fire. A missing safety bolt at one of the closing lids resulted in failure of the lid at a pressure of few tens of bars, and gas got suddenly released. The lid forcefully crashed into a second filter device located opposite at several meters distance. Highly pressurized gas was released from the second device as well. Likely, the impact of the first metallic lid onto the second created sparks which ignited the gas. However, since

³ <https://www.nytimes.com/2017/12/12/world/europe/austria-gas-explosion.html>.

⁴ <https://www.theguardian.com/world/2017/dec/12/italy-declares-state-emergency-gas-explosion-austria>.

⁵ <http://www.heute.at/welt/news/story/Italien-erklart-Notstand-nach-Gasexplosion-bei-OMV-49525073>.

⁶ <https://diepresse.com/home/panorama/oesterreich/5336872/Explosion-in-Gasstation-Baumgarten-fordert-ein-Todesopfer>.

⁷ <http://www.noen.at/gaenserndorf/verheerende-explosion-opfer-mehrheitlich-gas-connect-mitarbeiter/70.752.356>.

² https://www.gasconnect.at/fileadmin/Broschueren-Folder/GCA_2016-04-Baumgarten_EN_web.pdf.

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