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Understanding the dynamics of a geyser using seismic ambient noise

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Old Faithful Geyser in Yellowstone National Park, Wyoming, is one of the most studied geysers in the world. The predictability, the repeatability and the short time lag, $\sim$1.5 hour, between 2 eruptions make the study convenient. The surface expression of the geyser is a 4m high, 60m wide mound with an approximately 2m x 1m opening at the top, which permits to deploy a dense network of sensors closed to the orifice. In 1992, Sharon Kedar deployed 96 vertical geophones in a tight grid over the geyser's dome. The geophones recorded the ambient seismic noise during an entire eruptive cycle, including a short period of quiet seismic activity. The survey was completed by seven shots carried out with a sledge hammer. The signal consists in a series of impulsive events, most likely due to bubble collapse in boiling water areas inside the geyser's plumbing system. The aim of this study is to locate the sources of these events.

We revisited a 10 minutes-long data set from S. Kedar's records and processed the signal using a Matched Field Processing (MFP) algorithm derived from ocean acoustics. The cross-correlation of the signals recorded by the 96 geophones showed a great level of coherency between the sensors, which is a pre-requisite to use MFP. This method introduced in geophysics by Capon is based on comparing forward modelling solutions of the wave equation in a grid search with acquired data, measured on an array of motion sensors. The process consists in placing a test source at each point of the grid search, computing the acoustic field corresponding at all the elements of the array and then correlating this modelled field with the data. The correlation is maximum when the candidate point source is co-located with the true point source. We used both linear (Bartlett) and non linear (MVDR : Minimum Variance Distorsionless) processors. The MFP processor was performed either incoherently from the raw ambient noise data or coherently from the cross-correlated traces between all pairs of seismic stations. The processing of the 10 minutes-long record using a velocity model adapted from S. Kedar's results gave a very stable source at 12 m below the orifice. This location is consistent with in-situ observations using a remote camera made by Hutchinson et al. on 1992 and 1993. The MFP output is well focused, with an accuracy of about 2m. The processing of the seismic signals recorded during an eruptive cycle should lead us to monitor the rise of the boiling region and thus to better understand the geyser's dynamics.