On observations of barometric pressure inside tunnels

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It is of primary importance to precise observations by means of gravimeters or extensometers how the effects of atmosphere are corrected. Such instruments are often installed inside a tunnel so that they are not affected seriously by environmental changes. At the Matsushiro Seismological Observatory in Nagano prefecture and the Kamioka Mine in Gifu prefecture, both a superconducting gravimeter and an extensometer are installed inside horizontal tunnels. The effects of atmosphere on gravity consist mainly of loading, whereas quartz-tube extensometers are also affected by adiabatic changes of the air inside the tunnel caused by pressure changes. Although correction for these effects requires barometric pressure recorded in situ, several problems arise when we make observations of barometric pressure inside a tunnel.

First, if there are multiple entrances of a tunnel, distribution of barometric pressure inside the tunnel will be very similar to a spatial average provided by the boundary values at the entrances. Spatial averaging implies temporal averaging following the correlation distance of pressure distribution, thus providing a natural low-pass filter. However, if one of the entrances faces a south-side hill, an upward wind along the hill is caused by sunshine in the daytime, resulting in a decrease in pressure near the entrance. At Matsushiro, the difference in barometric pressure between the gravimeter room (near the south entrance) and the extensometer room (innermost) indicates daily changes, especially on sunny days. Such a local circulation of air must have some effect also on adiabatic changes of the inside air.

Second, if the tunnel has vertical branches out to the surface as in Kamioka, the tunnel functions like a wind-cave, and there are steady winds inside it whose direction changes seasonally. This causes seasonal biases in the barometric pressure recorded inside the tunnel. Gravity correction using the pressure data acquired inside the tunnel may be thus biased. This effect is not evidently seen at Matsushiro.

Third, elastic properties of the air inside the observation room with a narrow entrance and a finite volume cause a phase delay in the transmission of barometric pressure changes. Partitions inside the tunnel also function as resistors for pressure changes. In fact, barometric pressure in the gravimeter room of Kamioka indicates a time delay as large as several tens of second compared with that at the entrance. In addition, this amount of time delay changes seasonally. A similar phenomenon is observed also at Matsushiro, but much less evidently. This effect can be modeled with an aid of the analogy to electrical circuits, using acoustic resistors and compliances.

In addition to these effects, barometric pressure inside a tunnel is often seriously disturbed by artificial operations or constructions, especially at Kamioka. This indicates a negative aspect of the tunnel as a site for precise geophysical observations.

Keeping these in mind, we will discuss how to distribute barometers and how to process the records so that we can obtain pressure data which are representative spatially for corrections of gravimeters and extensometers inside a tunnel.