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Effect of underground water on gravity at Matsushiro, Japan (part 2)

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The superconducting gravimeter station at Matsushiro, Japan, is housed in a tunnel dug inside Mt. Maizuru (560m). At this station, observed gravity decreases after rainfall due to the effect of underground water. Imanishi et al. (2006) modeled the effect as (i) the gravity decrease is proportional to the amount of rainfall, and (ii) the gravity change due to underground water decays linearly with time to the original level. This model describes the effect of underground water above the tunnel empirically, and works well for the short term effects. However, there has been no theoretical explanation on why the gravity shows such a response, and also it has been unknown what determines the decay rate of gravity.

The inside of the tunnel where the gravimeter is installed is always wet everywhere, and water often drops from the ceiling at particular points. A rain gauge is installed at one of such points (about 90 m below the surface) to measure the amount of water drops. Comparing the water drop data with the rainfall data outside the tunnel, it is found that (i) water begins to drop about 3 hours after the onset of rainfall, (ii) the drop rate is almost constant, and (iii) the amount of water drops is approximately proportional to the rainfall amount.

The rate of the underground water, which is assumed to descend inside the mountain steadily, is about 30 m per hour. On the other hand, the rate of osmosis in the soil was found to be lower than the rate of the underground water by about one order of magnitude from our measurements of soil moisture near the summit of Mt. Maizuru. The thickness of soil may be some tens of centimeters at most near the summit and negligibly small at the base of the mountain. Also, assuming a Hagen-Poiseuille flow in a vertically oriented round tube, the observed rate of underground water flow gives 0.5 mm as the radius of the tube.

Combining these observations, we can conclude that the water supplied by rainfall is first preserved by the thin layer of soil on the surface, and then percolates downward into the rocks at a steady rate. In this picture, the soil and the rocks behave as a tank and capillary, respectively. This gives a theoretical justification to the model of Imanishi et al. (2006), in which the gravity decay rate is determined by the flow rate in the capillary. It is also found that the amount of water drop inside the tunnel is not exactly proportional to the surface rainfall, implying that some part of the water does not percolate into the soil but escape to the sky by evapotranspiration.

Keywords: superconducting gravimeter, underground water