Solid/Fluid Interactions of the Earth

Shingo Watada,
Earthquake Research Institute, Univ. of Tokyo

1. Global scale solid/fluid interactions

As the technology of measurement of the solid Earth advanced, it is often found that various behaviors of the solid Earth part are controlled by the interaction with the fluid part of the Earth (Figure 1.). The fluid part includes the atmosphere, the ocean and the fluid outer core. The center of the mass and the rotational speed and orientation of the Earth must be precisely monitored to keep the location precision of the Global Positioning System (GPS). Recent centimeter-level monitoring shows clear seasonal change of the position of the center of the mass of the Earth. To conserve the linear momentum of the Earth system, the center of the mass is moved to balance the motion of the fluid in the atmosphere and the ocean. To conserve the total angular momentum of the Earth, the rotational speed and axis of the solid Earth are altered by the currents and flows in the atmosphere, the ocean, and likely the molten outer core. Decadal change of the rotational speed is caused by the angular momentum exchange through the interaction of the solid Earth and the fluid outer core. The change of the mass distribution is associated with the change of the gravity, because of the Newton's law. In the future Precise measurement of the irregular gravity field of the Earth using satellite laser tracking technology will reveal the deep water circulations the surface current flow in the ocean. El Nino, weather irregularity causing flooding and drought, is associated with a large mass re-distribution and is clearly seen as a low rotational speed.

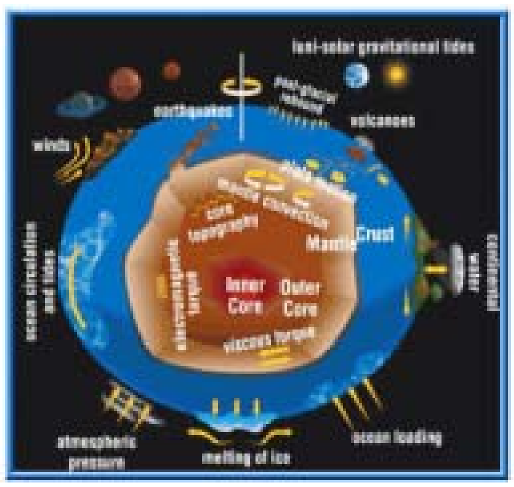

Figure 1. Global scale solid-fluid interactions within the Earth system.

2. Seismology with atmosphere

Seismology is a science to study earthquakes and records of ground motions, i.e., seismograms. Elastic waves generated by earthquakes, i.e., seismic waves are propagated within the Earth. Seismic wave propagation theory has been developed to understand the behavior of the wave reflection and transmission within the solid Earth and the fluid core. In the theory, the existence of the atmosphere has been ignored and the atmosphere is treated as a vacuum. This approximation is good for almost all studies of seismology. Recently we encounter a few cases in which the simple vacuum treatment of the atmosphere is needed abolished.

In 1991 Mt. Pinatubo erupted. The eruption is the third largest in the last century, but the first after deployment broadband seismographs in the world. During the eruption the ground of the entire Earth oscillated harmonically (Figure 2), which is distinct from usual ground motions by large earthquakes.

The harmonic ground motion was caused by the resonance between the solid Earth seismic surface waves and the atmospheric long-period acoustic waves which were excited by the large energy input in the atmosphere supplied by the eruption. The similar resonance was later confirmed in the power spectrum of the continuous oscillations of the Earth. In this first example air motion induced the ground motion.

In September 26, 2003, M8.3 Tokachi-oki earthquakes shocked the northern part of Japan. During the passage of the largest amplitude seismic surface waves, clear pressure changes are recorded. Spectrum analysis shows that the pressure records are proportional to the upward ground velocity at the site. The excess pressure is well expressed by (air density)x(ground velocity)x(sound velocity). We have witnessed that the ground motion causes air pressure change.

At long-period, the acoustic wave length becomes comparable to the thickness of the atmosphere, about 10 km and the response of the pressure change relative to the ground motion becomes frequency dependent.

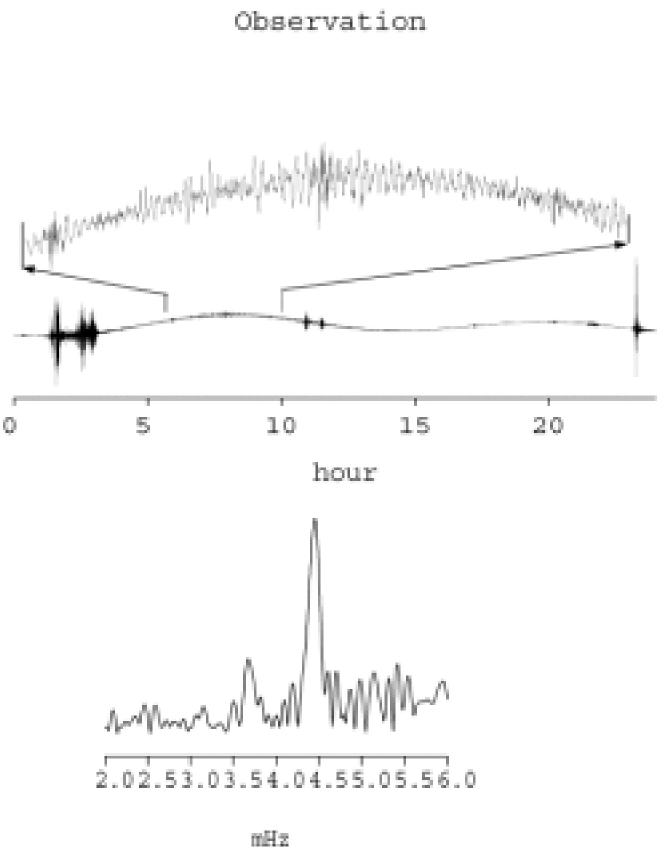

Figure 2. (top) original seismograms recorded in Japan showing harmonic ground motion during Mt. Pinatubo eruption. (bottom) amplitude spectrum of the ground motion.

3. Conclusion

The scope of seismology is expanded and now starts including the atmosphere.

References.

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