（別紙様式５）

変革を駆動する先端物理・数学プログラム（FoPM）

国外連携機関長期研修　報告書

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I visited John Vidale's group at the University of Southern California (USC) to conduct research on analyzing short-period (high-frequency) seismic data. Since I use long-period data in my research at the University of Tokyo, this served as an opportunity for me to cover a wider range of methods and techniques used in the field of seismic waveform analysis.



The Zumberge Hall of Science in the University of Southern California, where I visited for a month to conduct collaborative research with John Vidale's group.

Research at John Vidale's group

John Vidale's group, along with their collaborators at the University of California San Diego, deployed five dense seismic arrays near the San Jacinto fault in southern California from November 2024 to February 2025. Each array has a 100 m aperture and contains 81 seismic stations. I worked with the members of John Vidale's group to search for any interesting features that may exist in the seismic data, such as signals from seismic scatterers and seismic tremors.

Taking a look at the observed seismograms, we first noticed that some of the stations had time shifts; signals from earthquakes appeared to arrive significantly (up to 12 s) earlier at specific stations compared to others. To correct the time of the seismograms with time shifts, we shifted the waveforms so that the cross correlations of waveforms among stations were maximized. Although we would be using a high frequency band (4-40 Hz) in our investigations, it was impossible to correctly align high-frequency waveforms with time shifts of up to 12 s, so we carried out the aligning procedure in two steps: we first roughly aligned the waveforms in a low-frequency band (0.05-0.4 Hz), then we aligned the waveforms more precisely in the high-frequency band. Inspecting the values of the determined time shifts, we found that the values increased linearly throughout the deployment period. Thus, the times shifts seemed to arise from slow internal clocks in some of the stations.

We then created record sections of the observed seismograms, where we plot seismic waveforms from different earthquakes, offset by the distance from the epicenter. Observed data from all stations in an array are stacked to eliminate the noise. If we are able to select earthquakes with similar depths and focal mechanisms when creating this record section, we would be able to spot reflections off seismic discontinuities and signals from seismic scatterers as pulses aligned across the multiple waveforms. However, even earthquakes clustered within a small area did not seem to have depths and focal mechanisms close enough to each other to produce a detectable alignment of signals, so we were not able to identify any seismic scatterers using this method from this set of data.

We also utilized various techniques to search for and analyze any interesting signals that may be contained in the seismograms, such as seismic tremors. We created spectrograms, which visualize the intensity of signals at each frequency over time, to look through the whole duration of the data and find various signals. We compared those signals with the catalog of known earthquakes in the region and picked out any signals that were unexpected. The seismograms recorded some buzzy energy that continued in a wide frequency band for several minutes. To investigate those signals further, we conducted beamforming, which can determine the direction from which seismic waves are arriving from. The buzzy energy turned out to be coming from somewhere below the arrays, though we have not yet figured out what they may really be.

Other activities

Besides working on the research, I was able to attend various seminars that were held at USC. The Earthquake Seminar, held every Tuesday, invited speakers from other institutions to give talks related to seismology. From these talks, I was able to learn about the tectonic setting and seismicity in and around California and about hot topics that are investigated in the region. The Lithospheric Dynamics Seminar was held every Wednesday and provided talks about studies on near-surface phenomena, such as volcanos, landslides, and the isotopic signature of rocks. In the Department Seminar, held every Monday, and the P/E Seminar, held every Friday, I was able to hear about various types of research in different fields of Earth and planetary science. In addition, I was able to attend doctoral defense presentations that were held during my stay and found that they were carried out in a more friendly and casual atmosphere than in Japan.

I also got a chance to visit the California Institute of Technology (Caltech) to attend a seminar that was held there. The talk was about seismic structure analysis of Mars, and while I got to know about the hot topics that are being studied about Mars, I could also feel the frustration of the researchers concerning the cost cuts that the institutions, including NASA, are currently facing.

I was also invited to play frisbee with the members of the department at USC. I was surprised to hear that they played frisbee one hour in the afternoon three times a week. I was only able to join two times during my stay, but it was very fun.

On weekends, I went around visiting sightseeing spots in the city. I appreciate my new friends who drove me to the Hollywood sign. Overall, I had a very good time, and I feel the experiences I had were very meaningful.