GEO 5920-003/6920-004 – Seismic Interferometry (3 credits)
Fall 2015

Lecture & Lab:  FASB 388, 10:45 AM-12:05 PM, Monday  
               FASB 206, 10:45 AM-12:05 PM, Wednesday

Instructor:  Fan-Chi Lin (Assistant Professor, Dept. of Geology & Geophysics)

   Office:    FASB 271  
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   Office Hours:  M, W 1:30-2:30 PM. I will be available most other time as well. If you want to make sure I am available, please email me first.

Website:  http://noise.earth.utah.edu/Class_interferometry/

Course Description:  Introduction to seismic interferometry. Extracting Green’s function from a diffusive wavefield. Recent development of seismic ambient noise and coda interferometry. Ambient noise and surface wave tomography. Temporal variation, hazard related topics, and industrial applications. Deeper earth applications. Field experience with the Zland geophone system.

Meet twice a week. One for lecture/paper discussion and one for field experiment/computer lab.

Prerequisite:  Basic Physics, Calculus, PDE, and Seismology knowledge and some programming experiences.

1. Policies

Grades:  Final grades are based on following weights:

   •  Homework (25 %)  
   •  Midterm (25 %)  
   •  Class participation (25 %)  
   •  Project (25 %)

Homework:  About six homeworks will be given through out the semester. Homework is designed to practice the basic concept and train the basic data analysis capability for seismic interferometry. Homework must be turned in to my email/office by 5 pm of the day they are due. 10 % will be marked off for each day they are late.

Midterm:  A written exam will be held on the week after Fall break. The content of the exam includes the theoretic derivation and basic interferometry concepts cover in the first half of the semester.
Class participation: Each student is expected to lead few paper discussions on topics related to seismic interferometry. All students are expected to read the paper ahead of the class and participating in the discussion.

Project: During the semester, every two students will form a group to conduct a research project related to seismic interferometry using Zland geophones. The topic of the research project should be decided before the midterm by discussing with the instructor. At the end of the semester, each group should make a final presentation as well as turn in a GRL style final report on their project.

2. Class Goals

Seismic interferometry has become one of the fastest growing research areas in Seismology in recent years. Primary focus of this class is to introduce basic concept of seismic interferometry and discuss recent development of the technique. In particular, how seismic interferometry can be used to better resolve earth structure will be discussed. At the end of the course, the student is expected to be able to:

• Understand the basic concept of seismic interferometry
• Conduct basic research in seismic interferometry
• Know the recent development and ongoing directions of seismic interferometry
• Deploy and collect seismic data using Zland geophone system

3. Sources of information:

Considering that seismic interferometry is a very active research topic, there isn’t really a good textbook for the exact material will be covered in the class. Most of the material taught in the class will come from recently published papers. An incomplete list of the references can be found below.

Background and Motivation: Theory and Experiment on Diffuse Waves


**Transition to Imaging with Ambient Noise**

Shapiro and Campillo, GRL, 2004. Emergence of broadband Rayleigh waves from correlations of the ambient seismic noise.


Sabra et al., GRL, 2005. Surface wave tomography from microseisms in Southern California.

Bensen et al., GJI, 2007. Processing seismic ambient noise data to obtain reliable broadband surface wave dispersion measurements.

Lin et al., GJI, 2008. Surface wave tomography of the western United States from ambient seismic noise: Rayleigh and Love wave phase velocity maps.

Seats & Lawrence, GRL, 2014, The seismic structure beneath the Yellowstone Volcano Field from ambient seismic noise.

Chen et al., GRL 2014, Low wave speed zones in the crust beneath SE Tibet revealed by ambient noise adjoint tomography.

Huang et al., Science, 2015, Layered deformation in the Taiwan orogeny.

**Directionality of Ambient Noise**

Stehly et al., JGR, 2006. A study of the seismic noise from its long-range correlation properties.

Yang & Ritzwoller, G^3, 2008. The characteristics of ambient seismic noise as a source for surface wave tomography.

Yao & van der Hilst, GJI, 2009. Analysis of ambient noise energy distribution and phase velocity bias in ambient noise tomography, with application to SE Tibet.

Kedar, Compte Rendus Geoscience, 2011, Ocean acoustic noise and passive coherent array processing.
Koper & Burlacu, JGR, 2015, The fine structure of double-frequency microseisms recorded by seismometers in North America.

**Wavefront Tracking & Site Response**

Lin et al., GJI, 2009, Eikonal Tomography: Surface wave tomography by phase-front tracking across a regional broad-band seismic array.

Lin & Ritzwoller, GJI, 2010, Empirically determined finite frequency sensitivity kernels for surface waves.

Lin et al., Nature Geoscience, 2011, Complex and variable crustal and uppermost mantle seismic anisotropy in the western United States.

Savage et al., GRL, 2013, Ambient noise cross-correlation observations of fundamental and higher-mode Rayleigh wave propagation governed by basement resonance.

Lin et al., GJI, 2014, 3-D crustal structure of the western United States: application of Rayleigh-wave ellipticity extracted from noise cross-correlations.


**Industrial and Hazard Applications**

Lin et al., Geophysics, 2013. High-resolution 3D shallow crustal structure in Long Beach, California: Application of ambient noise tomography on a dense seismic array.

Mordret et al., GRL, 2013. Azimuthal anisotropy at Valhall: The Helmholtz equation approach.

Mordret et al., Geophysics, 2013. Helmholtz tomography of ambient noise surface wave data to estimate Scholte wave phase velocity at Valhall Life of the Field.


Denolle et al., Science 2014, Strong ground motion prediction using virtual earthquakes.

**Body Waves in Ambient Noise**

Gerstoft et al., GRL, 2008. Global P, PP, and PKP wave microseisms observed from distant storms.

Zhan et al., GJI, 2010. Retrieval of Moho-reflected shear wave arrivals from ambient seismic noise.

Lin et al., GRL, 2013. Extracting Seismic Core Phases with Array Interferometry.

Lin & Tsai, GRL, 2013. Seismic Interferometry with Antipodal Station Pairs.

Wang et al., Natural Geoscience, 2015. Equatorial anisotropy in the inner part of Earth’s inner core from autocorrelation of earthquake coda.

**Temporal Variation**

Zhan et al., GJI, 2013. Spurious velocity changes caused by temporal variations in ambient noise frequency content.

Brenguier et al., Science, 2008. Postseismic relaxation along the San Andreas fault at Parkfield from continuous seismological observations.


Brenguier et al., Compte Rendus Geoscience, 2011, Monitoring volcanoes using seismic noise correlations.

Brenguier et al., Science, 2014, Mapping pressurized volcanic fluids from induced crustal seismic velocity drops.

Starr et al., GRL, 2015, Ambient resonance of Mesa Arch, Canyonlands National Park, Utah.

**Attenuation**

Prieto et al., JGR, 2009. Anelastic Earth structure from the coherency of the ambient seismic field.

Lawrence et al., JGR, 2011. Attenuation tomography of the western United States from ambient seismic noise.

Lin et al., GRL, 2011. On the reliability of attenuation measurements from ambient noise crosscorrelations.

Tsai, JGR, 2011. Understanding the Amplitudes of Noise Correlation Measurements.

German et al., Compte Rendus Geoscience, 2011, On amplitude information carried by the ambient seismic field.
5. Seismic Interferometry – Fall 2015 Schedule (preliminary)

Week 1 (8/24; 8/26): Introduction of seismic interferometry
Week 2 (8/31-9/2): Green’s function
Week 3 (9/7 Labor Day; 9/9): Green’s function
Week 4 (9/14; 9/16): Surface waves
Week 5 (9/21; 9/23): Surface waves
Week 6 (9/28; 9/30): Theory on seismic interferometry
Week 7 (10/5; 10/7): Theory on seismic interferometry
Week 8 (10/12; 10/14): Fall Break
Week 9 (10/19; 10/21): Tomography
Week 10 (10/26-10/28): Midterm
Week 11 (11/2-11/4): Noise source
Week 12 (11/9-11/11): Temporal variation
Week 13 (11/16-11/18): Core phases
Week 15 (11/30-12/2): Seismic hazard
Week 16 (12/7-12/9): Final presentation and final report.

6. Additional Notes

Statement Concerning Disabilities: “The University of Utah seeks to provide equal access to its programs, services and activities for people with disabilities. If you will need accommodations in the class, reasonable prior notice needs to be given to the Center for Disability Services, 162 Union Building, 581-5020 (V/TDD). CDS will work with you and the instructor to make arrangements for accommodations.” (www.hr.utah.edu/oeo/ada/guide/faculty).

Faculty and Student Responsibilities: “All students are expected to maintain professional behavior in the classroom setting, according to the Student Code, spelled out in the Student Handbook. Students have specific rights in the classroom as detailed in Article III of the code. The Code also specifies proscribed conduct (Article XI) that involves cheating on tests, plagiarism, and/or collusion, as well as fraud, theft, etc. Students should read the Code carefully and know they are responsible for the content. According to Faculty Rules and Regulations, it is the faculty responsibility to enforce responsible classroom behaviors, beginning with verbal warnings and progressing to dismissal from class and a failing grade. Students have the right to appeal such action to the Student Behavior Committee.”

“Faculty… must strive in the classroom to maintain a climate conducive to thinking and learning.” PPM 8-12.3, B.

“Students have a right to support and assistance from the University in maintaining a climate conducive to thinking and learning.” PPM 8-10, II. A.