QUICK REFERENCE: Section 8 contains the calendar of topics and deadlines.

Last compiled: February 21, 2015

1. **Course information.**

GEOS 626	**Applied Seismology**, 4 credits (3+3), Spring 2016
Lecture times:	Tuesday and Thursday, 9:45–11:15
Lab time	Tuesday, 11:30–14:30
Meeting location:	TBA
Prerequisites:	MATH 314 (Linear Algebra) and MATH 202 (Calculus III) GEOS 604 (Seismology) is a recommended prerequisite

2. **Instructor information.**

Instructor:	**Carl Tape**
Office:	413D Elvey (Geophysical Institute)
Email:	`carltape@gi.alaska.edu`
Phone:	(907) 474-5456
Office hours:	Wednesday, 10:00–11:00, or by appointment

3. **Course materials.**

   (a) **Textbooks.** The required (R) and supplemental (S) textbooks are listed in the following table; bibliographic details are listed at the end of this syllabus. The Geophysical Institute's Mather library is located in the IARC/Akasofu building.

Textbook	R	S	Availability			
			UAF bookstore	Mather reserve	PDF	UAF e-book
[1] Stein and Wysession	X			X		X
[2] Shearer	X			X		
[3, 4, 5, 6, 7, 8, 9]		X		X		

   (b) Journal articles assigned as reading will be available as PDFs through the course website on UAF Blackboard.

   (c) Students will need computers for their homework. General-use computers in UAF labs will be made available to students if needed.

   (d) Matlab will be the primary computational program for the course. Matlab is available via a UAF-wide license.

4. **Course description.**

Seismology combines observational data (seismograms) with numerical modeling methods to obtain powerful inferences about earthquake sources and the three-dimensional structure of Earth's interior. *Applied Seismology* will provide essential training for students' interested in academic, industrial, or governmental careers in seismology.

Catalog description: Presentation of modeling techniques for earthquakes and Earth structure using wave propagation algorithms and real seismic data. Covers several essential theories and algorithms for applications in seismology, as well as the basic tools needed for processing and using recorded seismograms. Topics include the seismic wavefield (body waves and surface waves), earthquake moment tensors, earthquake location, and seismic tomography. Assignments require familiarity with linear algebra and computational tools such as Matlab.

5. **Course goals.**

   We will explore the study of earthquakes and Earth's interior structure using seismological theories and algorithms. The underlying physical phenomenon we will examine is the seismic wavefield: the time-dependent, space-dependent elastic waves that originate at an earthquake source (for example, a fault slips) and propagate though the heterogeneous Earth structure, then are finally recorded as time series at seismometers on Earth's surface. Students will examine real seismic data and use computational models to estimate properties about earthquake source and Earth structure. Students will acquire practical, advanced seismological training that will prepare them for seismological investigations in the future, whether in academic, industry, or government jobs.

6. **Student learning outcomes.**

   Upon completion of this course, students should be able to:

   (a) Understand the relevant temporal, spatial, and magnitude scales in the field of seismology.

   (b) Describe the physical quantities that govern seismic wave propagation.

   (c) Describe the seismic phases that arise in a regional or global layered Earth model.

   (d) Describe the seismic moment tensor, the fundamental model of an earthquake source.

   (e) Understand the basic framework of inverse problems within the context of seismology.

   (f) Describe several different seismological tools that can be used to investigate an individual earthquake.

   (g) Understand the connection between earthquakes, continental deformation, and plate tectonics.

   (h) Understand the distinction between one-dimensional and three-dimensional Earth structure, and how this affects theory and algorithms in seismology.

   (i) Read seismological journal articles and summarize the content efficiently.

   (j) Write, improve, and run simple computational algorithms in Matlab.

   (k) Plot and manipulate recorded seismograms.

7. **Instructional methods.**

   (a) Assignments and grades (along with general course information and handouts) will be posted on Blackboard: `classes.uaf.edu`.

   (b) Lectures: 3 hours per week.

   (c) Labs: Computational laboratory sessions (3 hours per week) include dedicated exercises that provide technical training for homework problems.

8. **Course calendar (tentative).**

	Day	Date	Topic	Reading Due†	Homework Due	Homework Assigned
1	Thurs		Seismology in 1916, 2016, and 2116	SW1, S1	—	HW-1
2	Tues		introduction to seismology	SW1, S1		
	Tues		LAB: Linux and Matlab			
3	Thurs		linear algebra and vectors	SW-A, S-B	HW-1	HW-2
4	Tues		linear algebra and vectors	`matrix_fun.pdf`		
	Tues		LAB: linear algebra			
5	Thurs		seismic moment tensor	SW4.4, S9	HW-2	HW-3
6	Tues		seismic moment tensor	notes		
	Tues		LAB: seismic moment tensors (`lab_mt.pdf`)			
7	Thurs		Fourier transform	SW6, S-E	HW-3	HW-4
8	Tues		Fourier transform	notes		
	Tues		LAB: Fourier transform, seismic spectra (`lab_fft.pdf`)			
9	Thurs		the 2004 Sumatra earthquake	[10, 11, 12, 13]		
10	Tues		processing seismic data	SW6, [14]		
	Tues		LAB: instrument response (`lab_response.pdf`)			
11	Thurs		waves on a string	SW2	HW-4	HW-5
12	Tues		normal modes: theory and observations	SW2.9, S8.6		
	Tues		LAB: spherical harmonics; toroidal modes			
13	Thurs		normal modes: theory and observations	DT10.5	HW-5	
14	Tues		review HW4 and HW5			HW-6
	Tues		LAB: analyzing seismic data (`lab_seismo_rs.pdf`)			
15	Thurs		seismic data analysis			
16	Tues		the 2004 Sumatra earthquake	[10, 11, 12, 13]		
	Tues		LAB: Sumatra earthqquake			
17	Thurs		great earthquakes since 2000		HW-6	HW-7
	Tues		SPRING BREAK			
	Thurs		SPRING BREAK			
18	Tues		surface waves: theory and observations	SW2.7-2.8, S8		
	Tues		LAB: Love waves layer-over-halfspace model			
19	Thurs		surface waves: theory and observations	SW2.7-2.8, S8	HW-7	HW-8
20	Tues		introduction to inverse problems	SW7		
	Tues		LAB: least squares (`lab_linefit.pdf`)			
21	Thurs		introduction to least squares	SW7, notes	HW-8	HW-9
22	Tues		seismic tomography: global	S5, SW7.3		
	Tues		LAB: seismic tomography			
23	Thurs		seismic tomography: crustal	SW3.2-3.3	HW-9	HW-10
24	Tues		least-squares inverse theory	T3		
	Tues		LAB: Newton method (`lab_newton.pdf`)			
25	Thurs		iterative methods	T6.22		
26	Tues		adjoint methods in seismology	[15, 16]	HW-10	
	Tues		LAB: surface wave dispersion (`lab_dispersion.pdf`)			
27	Thurs		finite source models	S9.8, WS4.5		
28	Tues		seismology in the oil industry	S7, WS3.3		
	Tues		LAB: TBD			
29	Thurs		seismic monitoring for nuclear activity	[17]		

†SW = Ref. [1]; S = Ref. [2]; DT = Ref. [5]; T = Ref. [18]

For example, "SW2.9" means Section 2.9 of Stein and Wysession (Ref. [1])

Some Important Dates:

First class:	Thursday	January XX
Last day to add class:	Friday	January XX
Last day to drop class:	Friday	January XX
Last day for student- or faculty-initiated withdraw:	Friday	March XX
Last class:	Thursday	May XX

9. **Course policies.**

   (a) **Attendance**: All students are expected to attend and participate in all classes and labs.

   (b) **Participation and preparation**: Students are expected to come to classes and labs with assigned reading and other assignments completed as noted in the syllabus.

   (c) **Homework assignments**:

   i. All assignments are due **at the start of class** on the due date.

   ii. Late assignments will be accepted with a 10% penalty per day late, up to five days late; an assignment that is ≥ 5 days late will receive a zero. (An assignment that is "one day late" would be handed in less than 24 hours after the start time of class on the due date.)

   iii. No digital submission of assigments will be accepted.

   Homework tips: Please type or write neatly, keep the solutions in the order assigned and staple pages together. Include only relevant computer output in your solutions (a good approach is to cut and paste the relevant output for each problem into an editor such as MS Word or Latex). Clearly circle or highlight important numbers in the output, and label them with the question number. Staple your assigments.

   I also suggest that you to include the most relevant portions of your Matlab code in your answers, especially in cases when you think your code is not working. Display numerical answers with a reasonable number of significant figures and with *units* if the quantity is not dimensionless.

   Homework scores are based on clarity of work, logical progression toward the solution, completeness of interpretation and summaries, and whether a correct solution was obtained.

   (d) **Labs**: Computational labs are designed to provide technical training relevant for topics in the course and within the homework problems. Students are welcome to work in pairs on the lab exercises. The students' completed lab exercises will be evaluated as pass or fail.

   (e) **Reporting grades**: All student grades, transcripts, and tuition information are available on line at `www.uaonline.alaska.edu`.

   (f) **Consulting fellow students**: Students are permitted to discuss with each other general strategies for particular homework problems. However, the write-up that is handed in—including any computer codes—must be individual work.

   (g) **Plagiarism:** Students must acknowledge any sources of information—including fellow students—that influenced their homework assignments or final project. Any occurrence of plagiarism will result in forfeiture of all points for the particular homework assignment. If the plagiarism is between two students, then both students will potentially receive the penalty.

   (h) All UA student academics and regulations are adhered to in this course. You may find these in the UAF catalog (section "Academics and Regulations").

10. **Evaluation.**

(a) Grading is based on:

10%	Attendance and participation in lectures and labs
90%	Homework assignments

(b) Overall course grades are based on the following:

A	$x \geq 93$	excellent performance:
A–	$90 \leq x < 93$	student demonstrates deep understanding of the subject
B+	$87 \leq x < 90$	strong performance:
B	$83 \leq x < 87$	student demonstrates strong understanding of the subject,
B–	$80 \leq x < 83$	but the work lacks the depth and quality needed for an 'A'
C+	$77 \leq x < 80$	mediocre performance:
C	$73 \leq x < 77$	student demonstrates comprehension of some
C–	$70 \leq x < 73$	essential concepts only
D	$60 \leq x < 70$	poor performance:
		student demonstrates poor comprehension of concepts
F	$x < 60$	Failure to complete work with 60% quality

(c) **Research Project.**

Students have the option of of substituting a research project for any 2 homework assignments.

- It is due in the form of a report on Monday, April 28.
- The theme of the project is **Exploration of the Seismic Wavefield**.
- The project should contain three components:
  i. a review of essential literature on the topic
  ii. a detailed explanation of what facet of the seismic wavefield is represented by the project
  iii. a moderate level of applied analysis, either through modeling or examination of data

  The instructor will base his evaluation of the project on these three components, weighted equally.
- The report should contain no more than 4 pages of single-spaced text and 4 pages of figures. The report will be written in manuscript-submission style and format, using the guidelines for *Geophysical Research Letters*.

Students are welcome to propose topics to the instructor. Here are some possibilities:

- Exploration of air-solid-topography coupling of wave propagation. Code: SPECFEM2D
- Generation of 1D synthetic seismograms using normal modes or axisymmetric spectral-element method. Code: MINEOS, AXISEM.
- Seismic moment tensor inversion of regional earthquakes. Code: FK, CAP.
- Eigenfunctions and eigenfrequencies for radial and spheroidal modes. Code: Matlab.
- Implementation and application of some semi-standard seismological software package: `http://www.orfeus-eu.org/Software/softwarelib.html`
- Investigation of variability of finite source models: `http://www.seismo.ethz.ch/static/srcmod/`
- Resolvability of the isotropic component of source mechanisms using 2D synthetic experiments. Code: SPECFEM2D.

11. **Support Services.**

The instructor is available by appointment for additional assistance outside session hours. UAF has many student support programs, including the Math Hotline (1-866-UAF-MATH; 1-866-6284) and the Math and Stat Lab in Chapman building (see `www.uaf.edu/dms/mathlab/` for hours and details).

12. **Disabilities Services.**

The Office of Disability Services implements the Americans with Disabilities Act (ADA), and it ensures that UAF students have equal access to the campus and course materials. The Geophysics Program will work with the Office of Disability Services (208 Whitaker, 474-5655) to provide reasonable accommodation to students with disabilities.

13. **References listed in syllabus.**

[1] S. Stein and M. Wysession, *An Introduction to Seismology, Earthquakes, and Earth Structure.* Malden, Mass., USA: Blackwell, 2003.

[2] P. M. Shearer, *Introduction to Seismology.* Cambridge, UK: Cambridge U. Press, 2 ed., 2009.

[3] B. L. N. Kennett, *The Seismic Wavefield: Introduction and Theoretical Development*, vol. 1. Cambridge, UK: Cambridge U. Press, 2001.

[4] B. L. N. Kennett, *The Seismic Wavefield: Interpretation of Seismograms on Regional and Global Scales*, vol. 2. Cambridge, UK: Cambridge U. Press, 2002.

[5] F. A. Dahlen and J. Tromp, *Theoretical Global Seismology.* Princeton, New Jersey, USA: Princeton U. Press, 1998.

[6] T. Lay and T. C. Wallace, *Modern Global Seismology.* San Diego, Calif., USA: Academic Press, 1995.

[7] K. Aki and P. G. Richards, *Quantitative Seismology.* San Francisco, Calif., USA: University Science Books, 2 ed., 2002. 2009 corrected printing.

[8] L. E. Malvern, *Introduction to the Mechanics of a Continuous Medium.* Upper Saddle River, New Jersey, USA: Prentice-Hall, 1969.

[9] R. C. Aster, B. Borchers, and C. H. Thurber, *Parameter Estimation and Inverse Problems.* Waltham, Mass., USA: Elsevier, 2 ed., 2012.

[10] T. Lay, H. Kanamori, C. J. Ammon, M. Nettles, S. N. Ward, R. C. Aster, S. L. Beck, S. L. Bilek, M. R. Brudzinski, R. Butler, H. R. DeSchon, G. Ekström, K. Satake, and S. Sipkin, "The great Sumatra-Andaman earthquake of 26 December 2004," *Science*, vol. 308, pp. 1127–1133, 2005.

[11] C. J. Ammon, C. Ji, H.-K. Thio, D. Robinson, S. Ni, V. Hjorleifsdottir, H. Kanamori, T. Lay, S. Das, D. Helmberger, G. Ichinose, J. Polet, and D. Wald, "Rupture process of the 2004 Sumatra-Andaman earthquake," *Science*, vol. 308, pp. 1133–1139, 2005.

[12] J. Park, T.-R. A. Song, J. Tromp, E. Okal, S. Stein, G. Roult, E. Clevede, G. Laske, H. Kanamori, P. Davis, J. Berger, C. Braitenberg, M. V. Camp, X. Lei, H. Sun, H. Xu, and S. Rosat, "Earth's free oscillations excited by the 26 December 2004 Sumatra Andaman earthquake," *Science*, vol. 308, pp. 1139–1144, 2005.

[13] S. Ni, D. Helmberger, and H. Kanamori, "Energy radiation from the Sumatra earthquake," *Nature*, vol. 434, p. 582, 2005.

[14] C. G. Reyes and M. E. West, "The Waveform Suite: A robust platform for manipulating waveforms in MATLAB," *Seis. Res. Lett.*, vol. 82, pp. 104–110, 2011.

[15] Q. Liu and J. Tromp, "Finite-frequency kernels based on adjoint methods," *Bull. Seis. Soc. Am.*, vol. 96, no. 6, pp. 2383–2397, 2006.

[16] C. Tape, Q. Liu, and J. Tromp, "Finite-frequency tomography using adjoint methods—Methodology and examples using membrane surface waves," *Geophys. J. Int.*, vol. 168, pp. 1105–1129, 2007.

[17] D. Bowers and N. D. Selby, "Forensic seismology and the Comprehensive Nuclear-Test-Ban Treaty," *Annu. Rev. Earth Planet. Sci.*, vol. 37, pp. 209–236, 2009.

[18] A. Tarantola, *Inverse Problem Theory and Methods for Model Parameter Estimation.* Philadelphia, Penn., USA: SIAM, 2005.