QUICK REFERENCE: The calendar of topics is listed on the final page.
Last revision: January 13, 2026

1. Course information.

GEOS 626/426	**Applied Seismology**, 4 credits (3+3), Spring 2026
Lecture:	Elvey Auditorium, 8:30–11:30
Lab:	Elvey Auditorium, 8:30–11:30
Prerequisites:	MATH 314 (Linear Algebra) and MATH 252 (Calculus 3)

2. Course type. In person.

3. Instructor information.

Instructor:	Carl Tape
Office:	413D Elvey (Geophysical Institute)
Email:	ctape[a]alaska.edu
Phone:	907-474-5456
Office hours:	Friday 9-10am or by appointment

4. Course materials.

a. **Textbooks**. The recommended (R) and supplemental (S) textbooks are listed in the following table; bibliographic details are listed at the end of this syllabus.

	R	S
[1] Stein and Wysession	X	
[2] Shearer	X	
[3,4,5,6,7,8,9,10,11]		X

b. For an excellent overview of the field of seismology, consider reading [13,14].
c. Journal articles assigned as reading will be available as PDFs via the class google drive.
d. Notes will be posted to the class google drive.
e. Students will need computers and internet connections for their homework and labs. They will need to have administrative access in order to install software needed for the class (e.g., a conda environment).
f. Python will be the primary computational program for the course. It is open-source (i.e., free to use).
g. A Slack workspace will be available for efficient communication among students and faculty. The channel discussions will be visible only to members of the class.

5. 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.

The course presents modeling techniques for analyzing earthquakes and Earth structure using wave propagation algorithms and real seismic data. It 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 Python.

Catalog description: Presentation of modeling techniques for analyzing earthquakes and Earth structure using wave propagation algorithms and real seismic data. Topics include the seismic wavefield (body waves and surface waves), earthquake moment tensors, earthquake location, and seismic tomography.

6. **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 through 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.

7. **Student learning outcomes.** Upon completion of this course, students in 426 and 626 should be able to:
    a. Understand the relevant temporal, spatial, and magnitude scales in the field of seismology.
    b. Describe the seismic phases that arise in a regional or global layered Earth model.
    c. Describe the seismic moment tensor, the fundamental model of an earthquake source.
    d. Describe several different seismological tools that can be used to investigate an individual earthquake.
    e. Understand the connection between earthquakes, continental deformation, and plate tectonics.
    f. Understand the distinction between one-dimensional and three-dimensional Earth structure, and how this affects theory and algorithms in seismology.
    g. Write, improve, and run simple computational algorithms in Python.

In addition, students in 626 should be able to:
    h. Understand the technical details needed to make publication-quality plots and figures.
    i. Describe the physical quantities that govern seismic wave propagation.
    j. Understand the basic framework of inverse problems within the context of seismology.
    k. Plot and manipulate recorded seismograms.
    l. Explain how numerical solutions can contain artifacts that depend on tolerance levels.

8. **Instructional methods.** See also "Course type" above.
    a. General course information, assignments, and handouts will be posted on the class website or in the class google drive.
    b. Lectures (3 hours per week) will be the primary mode of instruction.
    c. Computational laboratory sessions (3 hours per week) include dedicated exercises that provide technical training for homework problems.
    d. There are 10 homework assignments and 11 lab assignments (see class website).

9. **Course calendar.** ***The tentative calendar is listed on the final page of the syllabus.***

First day of UAF classes	Monday	Jan 12
First class meeting	Tuesday	Jan 13
Last day for student- and faculty-initiated drops with refund (course does not appear on academic record)	Friday	Jan 23
Spring Break	March 9–13	
Last day for student- and faculty-initiated withdrawals (W grade appears on academic transcript)	Friday	March 27
Last class meeting:	Thursday	April 23
Last day of UAF classes:	Monday	April 27
UAF final exams week (there is no final exam in this course)	Tues–Sat	April 28 to May 2
Research project report and presentation	TBD	TBD

10. Course policies.

a. **Attendance**: All students are expected to attend and participate in all classes and labs. Students who anticipate being absent for 1-2 weeks—due to academic commitments—should contact me at the start of the class to consider accommodations. Students who anticipate being absent for more than 2 weeks should contact me prior to registering for the class.

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. Each assignment contains clearly-marked problems that are required for GEOS 626 students only. GEOS 426 students can choose to do these problems for extra credit. These problems are generally related to Student Learning Outcomes that are specific to GEOS 626 and go beyond a basic understanding of the concepts (see above).

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

  iii. Submit assignments into your dedicated google drive folder.

  iv. The only acceptable file format is PDF. If you prefer, you can also submit other files, such as Python notebooks, but this is not required. Ideally, the solution set is a single PDF, but it is also acceptable to submit two PDFs: one containing computer-based responses (such as an executed notebook) and the other containing scanned hand-written responses.

  v. 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.)

  vi. The submission day/time for the assignment will be visible in the google drive, so do not update/replace the submission after the due date; otherwise it will be counted as a late submission. If you need to make a minor update, please first ask the instructor for permission.

  vii. The contents within each assignment need to be correctly and clearly ordered. See "Homework Tips" below.

viii. The assignments are written in Latex. If students wish to learn Latex, please see the Overleaf project here: https://www.overleaf.com/read/mdbkczrhncms#e19e0a To use this, you will need to have a (free) Overleaf account. For each new assignment, upload the corresponding latex template to your overleaf project; the templates are found in GEOS626_seis/latex/
Ask Carl or others for help with Latex (there is a learning curve).

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.
Labs will be graded on a scale from 0 to 2:

0	student does not participate in lab
1	student participates in lab and demonstrates partial completion of work, as identified by **a subset of lab questions** identified by the instructor
2	student demonstrates completion of work, as identified by **a subset of lab questions** identified by the instructor

It is the student's responsibility to demonstrate the work that they have completed for each lab. This should be done during lab time or during office hour.
A missed lab can be made up during the instructor's office hour and only within the 2-week time period following the in-class lab session. After 2 weeks, the lab grade will remain 0.

e. **Reporting grades**: All student grades, transcripts, and tuition information are available online at www.uaonline.alaska.edu .
f. **Consulting fellow students**. Students are welcome to work with each other, especially within any lab sessions and also in order to overcome technical hurdles (e.g., how to change the tick marks on a plot). Students are encouraged 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. **Cheating:** "attempting to give or use materials, information, notes, study aids, or other devices not authorized by the course instructor." Any occurrence of cheating will result in forfeiture of all points for the particular homework assignment. Further action may be taken by the instructor, in accordance with UAF policies.
h. **Plagiarism**: "presenting the work of another as one's own." 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. Further action may be taken by the instructor, in accordance with UAF policies.
i. All UA student academics and regulations are adhered to in this course. You may find these in the UAF catalog (section "Academics and Regulations").

11. Homework tips.

a. Start early, ideally as soon as an assignment is assigned.
b. Read the instructions carefully. For example, if it says "use a computer to row-reduce any matrices," then you do not want to get bogged down doing this by hand.
c. Look at how much each question is worth. This should give you an idea of how much effort is expected for the problem. It may also help you decide what to skip, if time is short.
d. Run all the template codes. Make sure you are using what has been provided.
e. Ask for help. From the instructor: during lab or office hours. From classmates: as needed.

f. Work on scratch paper, then write up your final work. This catches mistakes, reinforces solutions, and provides a better presentation.
g. Find an efficient mechanism for compiling your solutions. This might involve exporting a single Python Notebook containing text answers, code, and figures. Or it might involve copy-pasting output and figures into a separate file.

Detailed tips:

h. Keep the solutions in the order the problems are assigned. (An exception is if there are two portions: computer output and hand-written scanned; within each subset, make sure that the problems are in order.)
i. Type or write neatly.
j. Include only relevant computer output in your solutions. In cases where things do not seem to be working, include all the code.
k. Highlight important numbers in the output and label them with the question number, if needed.
l. 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.

12. Evaluation.

a. Grading is based on:

10%	Lab assignments (14 total)
90%	Homework assignments (10 total)

b. Overall course grades are based on the following:

A	x ≥ 93	excellent performance: student demonstrates deep understanding of the subject
A–	90 ≤ x < 93	
B+	87 ≤ x < 90	strong performance: student demonstrates strong understanding of the subject, but the work lacks the depth and quality needed for an ‘A’
B	83 ≤ x < 87	
B–	80 ≤ x < 83	
C+	77 ≤ x < 80	mediocre performance: student demonstrates comprehension of some essential concepts only
C	73 ≤ x < 77	
C–	70 ≤ x < 73	
D	60 ≤ 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 substituting a research project for any 2 homework assignments except for sumatraB (which everyone must complete). In order to have this option, students must commit to

pursuing the project by Tuesday 2/16, the start of the sixth week of the semester. At that time, a tentative title and abstract are due.

- The title and abstract are due on Tuesday 3/16. Following this date, one-on-one weekly meetings with the instructor are required for students pursuing the project option.
- The project is due in the form of a report on Thursday 4/27.
- The theme of the project is Exploration of the Seismic Wavefield.
- The project should contain three components:
  - a review of essential literature on the topic
  - a detailed explanation of what facet of the seismic wavefield is represented by the project
  - 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 6 pages of single-spaced text (not including references) 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 examples:

- 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: MTUQ.
- Eigenfunctions and eigenfrequencies for radial and spheroidal modes. Code: Python.
- Implementation and application of some semi-standard seismological software packages.
- 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.

The scoring of the final project is as follows:

Background, including references	3
Relevance to theme (Exploration of the Seismic Wavefield)	3
Connection with concepts covered in the course	3
Implementation (coding and analysis)	2
Exposition (writing, figures)	2
Presentation (5-10 slides in 5-10 minutes)	2
TOTAL	**15**

13. Required syllabus addendum. Go here.

14. 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. H. Igel, Computational Seismology: A Practical Introduction. Oxford U. Press, 2016.
4. J. Tromp, Theoretical and Computational Seismology, Princeton U. Press, 2025.
5. B. L. N. Kennett, The Seismic Wavefield: Introduction and Theoretical Development, vol. 1. Cambridge, UK: Cambridge U. Press, 2001.
6. B. L. N. Kennett, The Seismic Wavefield: Interpretation of Seismograms on Regional and Global Scales, vol. 2. Cambridge, UK: Cambridge U. Press, 2002.
7. F. A. Dahlen and J. Tromp, Theoretical Global Seismology. Princeton, New Jersey, USA: Princeton U. Press, 1998.
8. T. Lay and T. C. Wallace, Modern Global Seismology. San Diego, Calif., USA: Academic Press, 1995.
9. K. Aki and P. G. Richards, Quantitative Seismology. San Francisco, Calif., USA: University Science Books, 2 ed., 2002. 2009 corrected printing.
10. L. E. Malvern, Introduction to the Mechanics of a Continuous Medium. Upper Saddle River, New Jersey, USA: Prentice-Hall, 1969.
11. R. C. Aster, B. Borchers, and C. H. Thurber, Parameter Estimation and Inverse Problems. Amsterdam: Elsevier, 3 ed., 2019.
12. A. Fichtner, Full Seismic Waveform Modelling and Inversion. Heidelberg, Germany: Springer Verlag, 2010.

13. W. H. K. Lee, H. Kanamori, P. C. Jennings, and C. Kisslinger, eds., International Handbook of Earthquake and Engineering Seismology, vol. 81A of International Geophysics Series. London: Academic Press, 2003.
14. W. H. K. Lee, H. Kanamori, P. C. Jennings, and C. Kisslinger, eds., International Handbook of Earthquake and Engineering Seismology, vol. 81B of International Geophysics Series. London: Academic Press, 2003.

15. 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. Ekstr¨om, K. Satake, and S. Sipkin, “The great Sumatra-Andaman earthquake of 26 December 2004,” Science, vol. 308, pp. 1127–1133, 2005.
16. 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.
17. 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. Van 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.
18. S. Ni, D. Helmberger, and H. Kanamori, “Energy radiation from the Sumatra earthquake,” Nature, vol. 434, p. 582, 2005.

19. C. G. Reyes and M. E. West, “The Waveform Suite: A robust platform for manipulating waveforms in MATLAB,” Seismol. Res. Lett., vol. 82, pp. 104–110, 2011.
20. Q. Liu and J. Tromp, “Finite-frequency kernels based on adjoint methods,” Bull. Seis mol. Soc. Am., vol. 96, no. 6, pp. 2383–2397, 2006.
21. 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.
22. A. Tarantola, Inverse Problem Theory and Methods for Model Parameter Estimation. Philadelphia, Penn., USA: SIAM, 2005.

COURSE SCHEDULE

	Date	Topic	Reading Due	HW due	HW assigned
1	1/13	Seismology: past, present, future linear algebra and vectors	SW1, S1		1/gr
2	1/15	LAB: JupyterLab, Python notebooks LAB: hw_gr	notes_linalg.pdf notes_matrix.pdf SW-A, S-B		
3	1/20	seismic moment tensors	SW4.4, S9		
4	1/22	LAB (mt): seismic moment tensors, part 1 LAB (beachball): seismic moment tensors, part 2 [start]	notes_mt_626.pdf	1/gr	2/math
5	1/27	seismic moment tensor			
6	1/29	LAB (beachball): seismic moment tensors, part 2 [finish] LAB: hw_mt (rotation)		2/math	3/mt
7	2/3	Fourier transform	notes_fft.pdf SW6, S-E		
8	2/5	LAB (fft): Fourier transform, seismic spectra LAB (response): instrument response		3/mt	4/sumatraA
9	2/10	Processing seismic data LAB (waves): Waves on a string LAB (spherical_harmonics): Spherical harmonic functions	SW6, [19] SW2 notes_sw.pdf		
10	2/12	LAB: Sumatra earthquake		4/sumatraA	5/modesA
11	2/17	The 2004 Sumatra-Andaman earthquake	[15,16,17,18]		
12	2/19	LAB: modes of a spherical shell			
13	2/24	Normal modes: theory and observation	SW2.9, S8.6, DT10.5	5/modesA	6/sumatraB
14	2/26	LAB (record_section): analyzing seismic data			
15	3/3	review hw_sumatraA and hw_modesA			
16	3/5	LAB (sumatraB): modes of Sumatra		6/sumatraB	7/modesB
SPRING BREAK MARCH 9–13					
17	3/17	LAB: hw_modesB			
18	3/19	LAB: Love waves for a layer-over-halfspace			
19	3/24	surface waves: theory and observations	SW2.7-2.8, S8	7/modesB	8/inv

20	3/26	LAB (linefit): least squares			
21	3/31	introduction to inverse problem introduction to least squares			
22	4/2	LAB (tomo): seismic tomography		8/inv	9/tomo
23	4/7	seismic tomography			
24	4/9	LAB (newton): Newton method			
25	4/14	least squares inverse theory iterative methods		9/tomo	10/genlsq
26	4/16	LAB (dispersion): surface wave dispersion			
27	4/21	adjoint methods in seismology finite source models		10/genlsq	
28	4/23	LAB			

SW = Ref. [1]; S = Ref. [2]; DT = Ref. [7]; T = Ref. [22]
For example, "SW2.9" means Section 2.9 of Stein and Wysession (Ref. [1]); "S-E" means Appendix E of Shearer (Ref. [2])