

FORMAT 1

Submit original with signatures + 1 copy + electronic copy to Faculty Senate (Box 7500).
See <http://www.uaf.edu/uafgov/faculty-senate/curriculum/course-degree-procedures/> for a complete description of the rules governing curriculum & course changes.

TRIAL COURSE OR NEW COURSE PROPOSAL

SUBMITTED BY:

Department	Geology and Geophysics	College/School	CNSM
Prepared by	Carl Tape	Phone	907-474-5456
Email Contact	carltape@gi.alaska.edu	Faculty Contact	Carl Tape, x5456

1. ACTION DESIRED

(CHECK ONE):

Trial Course ☐

New Course ☒

2. COURSE IDENTIFICATION:

Dept

GEOS

Course #

F627

~~F609~~

No. of Credits

3

Justify upper/lower division status & number of credits:

This is a graduate-level science class with MATH F202X (Calculus III) and MATH F314 (Linear Algebra) as prerequisites.

3. PROPOSED COURSE TITLE:

Inverse Problems and Parameter Estimation

4. To be CROSS LISTED?

YES/NO

NO

If yes, Dept:

Course #

(Requires approval of both departments and deans involved. Add lines at end of form for such signatures.)

5. To be STACKED?

YES/NO

NO

If yes, Dept:

Course #

6. FREQUENCY OF OFFERING:

Spring, Odd-numbered Years

Fall, Spring, Summer (Every, or Even-numbered Years, or Odd-numbered Years) — or As Demand Warrants

7. SEMESTER & YEAR OF FIRST OFFERING (AY2011-12 if approved by 3/1/2012; otherwise AY2012-13)

Spring AY2012-13

RECEIVED

SEP 28 2011

8. COURSE FORMAT:

NOTE: Course hours may not be compressed into fewer than three days per credit. Any course must be approved by the college or school's curriculum council. Furthermore, any core course compressed to less than six weeks must be approved by the core review committee.

COURSE FORMAT:

(check all that apply)

☐ 1

☐ 2

☐ 3

☐ 4

☐ 5

☒ X

6 weeks to full semester

OTHER FORMAT (specify)

Mode of delivery (specify lecture, field trips, labs, etc)

9. CONTACT HOURS PER WEEK:

3

LECTURE hours/weeks

0

LAB hours/week

0

PRACTICUM hours/week

Note: # of credits are based on contact hours. 800 minutes of lecture=1 credit. 2400 minutes of lab in a science course=1 credit. 1600 minutes in non-science lab=1 credit. 2400-4800 minutes of practicum=1 credit. 2400-8000 minutes of internship=1 credit. This must match with the syllabus. See <http://www.uaf.edu/uafgov/faculty-senate/curriculum/course-degree-procedures-/guidelines-for-computing-/> for more information on number of credits.

OTHER HOURS (specify type)

10. COMPLETE CATALOG DESCRIPTION including dept., number, title, credits, credit distribution, cross-listings and/or stacking (50 words or less if possible):

GEOS 609 Inverse Problems and Parameter Estimation

3 Credits Offered Spring Odd-numbered Years

A forward problem uses a model to make predictions; an inverse problem uses observations to infer properties of an unknown physical model. One example of an inverse problem is how to use seismometer recordings to infer the location of an earthquake. This course covers inverse theory and methods for solving inverse problems, including numerous examples arising in the natural sciences. Topics include linear regression, method of least squares, discrete ill-posed inverse problems, estimation of uncertainties, iterative optimization, and probabilistic (Bayesian) and sampling approaches. Assignments require familiarity with linear algebra and computational tools such as Matlab.

Prerequisites: MATH F202X and MATH F314; or permission of instructor. (3+0)

- 11. COURSE CLASSIFICATIONS:** Undergraduate courses only. Consult with CLA Curriculum Council to apply S or H classification appropriately; otherwise leave fields blank.

H = Humanities

S = Social Sciences

Will this course be used to fulfill a requirement for the baccalaureate core? If YES, attach form.

YES:

NO:

X

If YES, check which core requirements it could be used to fulfill:

O = Oral Intensive, Format 6

W = Writing Intensive, Format 7

Natural Science, Format 8

- 12. COURSE REPEATABILITY:**

Is this course repeatable for credit?

YES

NO

X

Justification: Indicate why the course can be repeated (for example, the course follows a different theme each time).

How many times may the course be repeated for credit?

TIMES

If the course can be repeated for credit, what is the maximum number of credit hours that may be earned for this course?

CREDITS

If the course can be repeated with variable credit, what is the maximum number of credit hours that may be earned for this course?

CREDITS

- 13. GRADING SYSTEM:** Specify only one. Note: Later changing the grading system for a course constitutes a Major Course Change.

LETTER:

X

PASS/FAIL:

RESTRICTIONS ON ENROLLMENT (if any)

- 14. PREREQUISITES**

MATH F202X and MATH F314; or permission of instructor

These will be required before the student is allowed to enroll in the course.

- 15. SPECIAL RESTRICTIONS, CONDITIONS**

- 16. PROPOSED COURSE FEES**

none

Has a memo been submitted through your dean to the Provost for fee approval?

Yes/No

- 17. PREVIOUS HISTORY**

Has the course been offered as special topics or trial course previously?

Yes/No

No

If yes, give semester, year, course #, etc.:

- 18. ESTIMATED IMPACT**

WHAT IMPACT, IF ANY, WILL THIS HAVE ON BUDGET, FACILITIES/SPACE, FACULTY, ETC.

This graduate-level will fulfill part of the teaching workload for new Geology & Geophysics faculty member Tape. Anticipated enrollment is 10-15 students; a small classroom in Elvey or Reichardt will be required.

- 19. LIBRARY COLLECTIONS**

Have you contacted the library collection development officer (kljensen@alaska.edu, 474-6695) with regard to the adequacy of library/media collections, equipment, and services available for the proposed course? If so, give date of contact and resolution. If not, explain why not.

No

Yes

X

TEXT HERE

20. IMPACTS ON PROGRAMS/DEPTS

What programs/departments will be affected by this proposed action?

Include information on the Programs/Departments contacted (e.g., email, memo)

The Department of Geology and Geophysics will be affected by this proposal action in the sense that Inverse Problems and Parameter Estimation will fulfill credit requirements for M.S. or Ph.D. geophysics students. In the revised geophysics curriculum, this course fulfills the "advanced skills" category of "Statistics and Parameter Estimation" toward the Ph.D. in geophysics. It is an elective course within the M.S. geophysics program.

21. POSITIVE AND NEGATIVE IMPACTS

Please specify positive and negative impacts on other courses, programs and departments resulting from the proposed action.

The course will have a positive impact on the M.S./Ph.D. geophysics program (see "Justification" below).

The applied nature of the proposed course will provide valuable research training for students. The computational training would allow students to excel in several other courses with computational applications, such as the STAT 4XX and MATH 6XX courses listed in the proposed revisions to the geophysics curriculum.

The addition of a new graduate-level geophysics course could potentially diminish enrollment in other geophysics courses; however, students tend to take several more courses than the minimum requirements in geophysics M.S./Ph.D.

JUSTIFICATION FOR ACTION REQUESTED

The purpose of the department and campus-wide curriculum committees is to scrutinize course change and new course applications to make sure that the quality of UAF education is not lowered as a result of the proposed change. Please address this in your response. This section needs to be self-explanatory. Use as much space as needed to fully justify the proposed course.

Inverse Problems (aka "Inverse theory" or "Inverse methods") is a fundamental course for many geophysics programs throughout the country. It is also one of the few courses within geophysics programs that has the potential (and relevance) to attract students from across all natural sciences and mathematics. There is currently no such course at UAF, and therefore there is arguably a void in the UAF-wide curriculum. The closest courses at UAF, in terms of topic covered, are: ATM 693 (Analysis Methods in Meteorology and Climate), MATH 661 (Optimization), STAT 401 (Regression and Analysis of Variance), and STAT 461 (Applied Multivariate Statistics). I have emailed or spoken with the professors who teach these courses (U. Bhatt, E. Bueler, J. McIntyre, R. Barry) to ensure that Inverse Problems is sufficiently distinct from their courses.

Within the geophysics program there is need for a single course on inverse methods and problems. Faculty in all three geophysics concentrations have expressed a need for such a course, notably Freymueller in solid earth, Meyer in remote sensing, and Truffer in snow-ice-permafrost; this support has made it easier for me to pursue teaching a topic I feel is critical for observational scientists. Geophysics research at UAF is extremely strong in observational techniques; thus an inverse problems course would play a valuable role in providing a framework for translating observations into physical inferences using mathematical methods. Inverse Problems would be one of four courses within the "advanced skills courses" category of "Statistics and Parameter Estimation" within the revised M.S./Ph.D. geophysics curriculum. Given that the topic spans all sub-disciplines of geophysics, we expect a greater enrollment (10-15) in Inverse Problems than in other, concentration-specific geophysics courses (e.g., Tectonic Geodesy, Applied Seismology, Sea Ice).

APPROVALS: Add additional signature lines as needed.

	Date	
Signature, Chair, Program/Department of:		
	Date	9/30/11
Signature, Chair, College/School Curriculum Council for: CNSM		
	Date	Oct 3, 2011
Signature, Dean, College/School of: CNSM		
	Date	
Signature of Provost (if applicable)		
Offerings above the level of approved programs must be approved in advance by the Provost.		

ALL SIGNATURES MUST BE OBTAINED PRIOR TO SUBMISSION TO THE GOVERNANCE OFFICE

	Date	
Signature, Chair		
Faculty Senate Review Committee: <input type="checkbox"/> Curriculum Review <input type="checkbox"/> GAAC		
<input type="checkbox"/> Core Review <input type="checkbox"/> SADAC		

ADDITIONAL SIGNATURES: (As needed for cross-listing and/or stacking)

	Date	9/27/11
Signature, Chair, Program/Department of: Geology + Geophysics		
	Date	
Signature, Chair, College/School Curriculum Council for:		
	Date	
Signature, Dean, College/School of:		



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

1. Course information. Course number is F627 (as of 2/21/2012, JH).

GEOS F627 Inverse Problems and Parameter Estimation, 3 credits, Spring 2013
 Meeting times: Tuesday and Thursday, 9:45–11:15
 Meeting location: TBD
 Prerequisites: MATH 202 (Calculus III) and MATH 314 (Linear Algebra); or permission of instructor

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 (see “References” at the end of this syllabus) listed in the following table. “Software” lists the software (if any) used in examples within each book.

Textbook	R	S	Software	Availability			
				UAF bookstore	Mather reserve	PDF	UAF e-book
[1] Aster	X		Matlab		X		X
[2] Tarantola	X		none		X	X	
[3] Weisberg		X	R		X		X
[4] Menke		X	none		X		
[5] Parker		X	none		X		

- (b) Journal articles (and PDF books) 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.

An inverse problem is a procedure by which observations or measurements are used with quantitative models to gain inferences about some underlying physical quantity or system. Inverse problems occur in all fields of natural sciences — even something as simple as fitting a line to scattered data is an inverse problem. This course will provide a general framework, as well as general computational algorithms, for approaching inverse problems. The training should benefit all students in natural sciences who are seeking inferences from data.

Catalog description: A forward problem uses a model to make predictions; an inverse problem uses observations to infer properties of an unknown physical model. One example of an inverse problem is how to use seismometer recordings to infer the location of an earthquake. This course covers inverse theory and methods for solving inverse problems, including numerous examples arising in the natural sciences. Topics include linear regression, method of least squares, discrete ill-posed inverse problems, estimation of uncertainties, iterative optimization, and probabilistic (Bayesian)

and sampling approaches. Assignments require familiarity with linear algebra and computational tools such as Matlab.

5. Course goals.

We will explore the ubiquitous realm of inverse problems in Earth sciences: how to use observations to make inferences about underlying physical quantities or processes. Our ultimate goal is to be able to recognize the fundamental components of an inverse problem — measurements, model parameters, misfit function, forward model — then to pose an approach to solving the problem, then solve the problem with computational algorithms. Concepts of inverse theory and parameter estimation are fundamental to all observational scientists, which includes most students in the natural sciences. During this course students should acquire both a philosophical and scientific appreciation for inverse methods and problems.

6. Student learning outcomes.

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

- (a) Articulate the basic features of forward problems and inverse problems.
- (b) Describe numerous examples of inverse problems and the basic components of each problem.
- (c) Set up and solve an inverse problem using the least squares approach.
- (d) Obtain a linear model from a set of data using multiple linear regression.
- (e) Understand and use data covariances and model covariances within an inverse problem.
- (f) Describe singular value decomposition and its relevance to inverse methods.
- (g) Explain and implement a regularization technique.
- (h) Explain the importance of sampling algorithms for estimating uncertainties of model parameters.
- (i) Pose and answer statistical questions from a particular set of model samples.
- (j) Describe probabilistic approaches to inverse problems.
- (k) Write, improve, and run simple computational algorithms in Matlab.

7. Instructional methods.

- (a) Assignments and grades (along with general course information and handouts) will be posted on Blackboard: `classes.uaf.edu`.
- (b) Lectures will be the primary mode of instruction. Some lectures will be supplemented with computational examples to prepare students for homework problems.
- (c) Each student is expected to lead one extended discussion of a case study of an inverse problem.

8. Course calendar (tentative).

	Day	Date	Topic	Reading Due [†]	Homework Due	Assigned
1	Thurs	Jan-17	Overview of inverse problems	A1	.	PS-1
2	Tues	Jan-22	Review of linear algebra	AA		
3	Thurs	Jan-24	Review of vector calculus	AC	PS-1	PS-2
4	Tues	Jan-29	Method of least squares, Part I	T1,T3		
5	Thurs	Jan-31	Method of least squares, Part II	T1,T3	PS-2	PS-3
6	Tues	Feb-05	Simple linear regression	A2,W2		
7	Thurs	Feb-07	Multiple linear regression	A2,W3	PS-3	PS-4
8	Tues	Feb-12	Data visualization	W1		
9	Thurs	Feb-14	Model selection	W10	PS-4	PS-5
10	Tues	Feb-19	Discretization	A3		
11	Thurs	Feb-21	Collinearity and rank deficiency	A4	PS-5	PS-6
12	Tues	Feb-26	Singular value decomposition	A4		
13	Thurs	Feb-28	Regularization	A5,A7	PS-6	PS-7
14	Tues	Mar-05	Principal component analysis	handout		final project
15	Thurs	Mar-07	Linear discriminant analysis	handout	PS-7	PS-8
	Tues	Mar-12	SPRING BREAK			
	Thurs	Mar-14	SPRING BREAK			
16	Tues	Mar-19	Sampling algorithms	T2		
17	Thurs	Mar-21	Bayesian approach to inverse problems	T1,A11	PS-8	PS-9
18	Tues	Mar-26	Iterative and nonlinear methods	T6.22		
19	Thurs	Mar-28	Iterative and nonlinear methods	T6.22	PS-9	PS-10
20	Tues	Apr-02	Iterative and nonlinear methods	A6,A9		
21	Thurs	Apr-04	Iterative and nonlinear methods	A6,A9	PS-10	PS-11
22	Tues	Apr-09	Resolution analysis	A5.3		
23	Thurs	Apr-11	Resolution analysis	handout	PS-11	final project
24	Tues	Apr-16	Case study and discussion, 1	TBD		final project
25	Thurs	Apr-18	Case study and discussion, 2	TBD		final project
26	Tues	Apr-23	Case study and discussion, 3	TBD		final project
27	Thurs	Apr-25	Case study and discussion, 4	TBD		final project
28	Tues	Apr-30	Case study and discussion, 5	TBD		final project
29	Thurs	May-02	Case study and discussion, 6	TBD	REPORT	
	May-XX		FINAL PROJECT PRESENTATION			

[†]A = Ref. [1], T = Ref. [2], W = Ref. [3]

Some Important Dates:

First class:	Thursday	January 17
Last day to add class:	Friday	January 25
Last day to drop class:	Friday	Feb XX
Last day for student- or faculty-initiated withdraw:	Friday	March XX
Last class:	Thursday	May 2
Final project report:	Thursday	May 2
Final project presentation:		TBD (May 7–10)

9. Course policies.

- (a) **Attendance:** All students are expected to attend and participate in all classes.
- (b) **Tardiness:** Students are expected to arrive in class prior to the start of each class. If a student does arrive late, they are expected to do so quietly and inform the instructor without disturbing the class.
- (c) **Participation and Preparation:** Students are expected to come to class with assigned reading and other assignments completed as noted in the syllabus.
- (d) **Assignments:**
 - i. All assignments are due at the start of class on the due date noted in the Syllabus.
 - ii. Late assignments will be accepted with a 20% penalty per day late; an assignment that is ≥ 5 days late will receive a zero.
 - iii. The lowest homework assignment will be dropped when computing the course grade.

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). Also clearly circle or highlight important numbers in the output, and label them with the question number. I also suggest that you to include your Matlab code in your answers, both so that you can refer back to it for future assignments and so that I can identify where a mistake may have occurred. 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. I encourage you to discuss homework problems with other students, however the work you turn in must be your own.

- (e) **Graded Assignments:** Assignments will be graded for students within seven days of their receipt and returned at the end of the next class.
- (f) **Reporting Grades:** All student grades, transcripts and tuition information are available online at www.uaonline.alaska.edu.
- (g) **Consulting fellow students:** Students are welcome 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.
- (h) **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 a maximal penalty of forfeiture of all points for the particular homework assignment. If the plagiarism is between two students, then both students will potentially receive the penalty. Furthermore, the UAF catalog states: “The university may initiate disciplinary action and impose disciplinary sanctions against any student or student organization found responsible for committing, attempting to commit or intentionally assisting in the commission of . . . cheating, plagiarism, or other forms of academic dishonesty . . .”
- (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”).

10. Evaluation.

- (a) For students in the M.S. or Ph.D. program, you must receive a C or higher for this course for it to count toward your degree requirements.
- (b) Grading is based on:

10%	Attendance and participation (including case study discussions)
60%	Homework Assignments
30%	Individual Final Project

(c) Overall course grades are based on the following criteria:

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+	$77 \leq x < 80$	average performance:
C	$73 \leq x < 77$	student comprehends the essential material
C-	$70 \leq x < 73$	as reflected by the average quality of assignments
D	$60 \leq x < 70$	below average performance:
		student demonstrates comprehension of some concepts
F	$x < 60$	Failure to complete work with 60% quality

- (d) **Final Project.** The final project will constitute 30% of the course grade. The project will involve independent research into one aspect of seismology. It will require some computation and will be presented in the form of a written report, due on the last lecture class of the semester, and a short in-class presentation during the scheduled final exam. The report will be written in manuscript-submission style and format, using the guidelines for *Geophysical Research Letters*. Additional details, including project suggestions, will be provided by the instructor midway through the course.
- (e) **Case study discussions.** Each student will lead a discussion of a case study in a particular inverse problem. I will provide a list of suggested questions for discussion, as well as a list of potential topics to choose from. Each student must choose a topic that is different from his or her final project topic. Leading discussion will count toward half of the "Attendance and participation" category of the course grade.

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 (203 WHIT, 474-7043) to provide reasonable accommodation to students with disabilities.

13. References listed in syllabus.

- [1] R. C. Aster, B. Borchers, and C. H. Thurber, *Parameter Estimation and Inverse Problems*. Burlington, Mass., USA: Elsevier, 2005.
- [2] A. Tarantola, *Inverse Problem Theory and Methods for Model Parameter Estimation*. Philadelphia, Penn., USA: SIAM, 2005.
- [3] S. Weisberg, *Applied Linear Regression*. Hoboken, New Jersey: Wiley, 5 ed., 2005.
- [4] W. Menke, *Geophysical Data Analysis: Discrete Inverse Theory*. San Diego, Calif., USA: Academic Press, 1989.
- [5] R. L. Parker, *Geophysical Inverse Theory*. Princeton, New Jersey, USA: Princeton U. Press, 1994.