

# **Earth Sciences 4420a/Geophysics 9505a**

## **Geophysical Forward and Inverse Modelling**

### **Course Outline – Fall 2023**

## **1. Course Information**

### **ES4420a/GP9505a – Geophysical Forward and Inverse Modelling**

**List of Prerequisites:** Calculus 2302 or Calculus 2502 or permission of the instructor.

Unless you have either the requisites for this course or written special permission from your Dean to enroll in it, you may be removed from this course and it will be deleted from your record. This decision may not be appealed. You will receive no adjustment to your fees in the event that you are dropped from a course for failing to have the necessary prerequisites.

## **2. Instructor Information**

| <b>Instructors</b>                            | <b>Email</b>       | <b>Office</b> | <b>Phone</b> | <b>Office Hours</b> |
|---|--------------------|---------------|--------------|---------------------|
| Dr. Robert Shcherbakov<br>(Course Instructor) | rshcherb[at]uwo.ca | B&GS 1080     | x84212       | By appointment      |
| TA: N/A                                       |                    |               |              |                     |

## **3. Course Syllabus, Schedule, Delivery Mode**

This course will provide an introduction into parameter estimation and data inversion for several geophysical problems. During the course, the students will be given an overview of fundamental concepts related to the construction of forward models, design of optimization methods and algorithms, and inversion of data for the underlying geophysical processes. Topics will include discrete linear inverse problems, maximum likelihood methods, singular value decomposition, uniqueness and accuracy, data and model weighting, Bayesian formulation of the inverse problems, and non-linear inverse problems.

### **Course Objectives and Learning Outcomes:**

Upon successful completion of this course, students will be able to:

- Explain the basic principles of forward and inverse modelling and their applications;
- Apply the methods of the theory of inverse modelling to the problems in geophysics;
- Implement the numerical algorithms of forward and inverse modelling in Matlab;
- Identify and use different methods of inverse data analysis applied to geophysical measurements;
- Apply the basic principles of Bayesian analysis to model fitting and inversion.

## Summary of Lecture Topics (*approximate and subject to change!*):

- Introduction into forward and inverse modelling.
- Review of linear algebra and probability and statistics.
- Linear regression.
- Discretizing continuous inverse problems.
- Ill-conditioning and regularization.
- Ill-posed problems and Tikhonov regularization.
- Iterative methods.
- Nonlinear regression.
- Nonlinear inverse problems.
- Bayesian methods.

## Course Work

Assignments/Labs will consist of examination-style answer questions and/or Matlab scripts, and require no formal writeup. Late submissions will be accepted with a **5% per day penalty**. Under exceptional circumstances, late submissions will be accepted with no penalty, provided that adequate documentation is given. With a few exceptions, only SI units should be used to report any physical quantities.

For **ES4420a** only: The midterm exam will be held during the class period on Friday, October 27. The final exam will be **two hours** in length and will take place during the December examination period. For both exams, a **single-sided hand-written crib sheet** and a non-programmable calculator may be used.

The project will involve a written report (~10 pages + figures). The topic will be chosen by the student and approved by the instructor. Research topics must be in any area of the forward and inverse modelling covered during the course. The project must include references to the scientific literature. Projects are due December 8 and oral presentations will be given during the last week of the term.

**Plagiarism:** *Students must write their essays and assignments in their own words. Whenever students take an idea, or a passage from another author, they must acknowledge their debt both by using quotation marks where appropriate and by proper referencing such as footnotes or citations. Plagiarism is a major academic offence (see Scholastic Offence Policy in the Western Academic Calendar).*

## The relevant Key Sessional Dates:

|                |                               |
|----------------|-------------------------------|
| Classes begin: | September 7, 2023             |
| Reading Week:  | October 30 – November 5, 2023 |
| Classes end:   | December 8, 2023              |
| Exam period:   | December 10 – 22.             |

## Contingency plan:

Although the intent is for this course to be delivered in person, should any university-declared emergency require some or all of the course to be delivered online, either synchronously or asynchronously, the course will adapt accordingly. The grading scheme will not change. Any assessments affected will be conducted online as determined by the course instructor.

## 4. Course Materials

### Recommended Textbooks:

- Aster, R., Borchers, B., and Thurber, C., *Parameter Estimation and Inverse Problems*, 3rd edition, Elsevier, 2018.
- Menke, W., *Geophysical Data Analysis*, 4th edition, Academic Press, 2018.
- Gubbins, D. *Time Series Analysis and Inverse Theory for Geophysicists*, Cambridge University Press, 2004.
- Tarantola A. *Inverse Problem Theory and Methods for Model Parameter Estimation*, SIAM, 2005.
- Stein S., Wyssession M., *An Introduction to Seismology, Earthquakes, and Earth Structure*, Blackwell, 2003.

Matlab software package is going to be used for Labs. It can be installed on your personal computer using Western site license or it can be accessed through MyVlab. The instructions will be provided.

Students are responsible for checking the course OWL site (<http://owl.uwo.ca>) on a regular basis for news and updates. This is the primary method by which information will be disseminated to all students in the class.

All course material will be posted to OWL: <http://owl.uwo.ca>.

If students need assistance with the course OWL site, they can seek support on the OWL Help page. Alternatively, they can contact the Western Technology Services Helpdesk. They can be contacted by phone at 519-661-3800 or ext. 83800.

## 5. Methods of Evaluation

The overall course grade will be calculated as listed below:

For **ES4420a**

| Assignments/<br>Labs | Midterm Exam | Final Exam | Participation | Project/<br>Presentation |
|----------------------|--------------|------------|---------------|--------------------------|
| 20%                  | 20%          | 20%        | 10%           | 30%                      |

For **GP9505a**

| Assignments/<br>Labs | Participation | Presentation | Project |
|----------------------|---------------|--------------|---------|
| 35%                  | 10%           | 15%          | 40%     |

## 6. Student Absences

### Academic Consideration for Student Absences

Students who experience an extenuating circumstance (illness, injury or other extenuating circumstance) sufficiently significant to temporarily render them unable to meet academic requirements may submit a request for academic consideration. Note that in all cases, students are required to contact their instructors within 24 hours of the end of the period covered, unless otherwise instructed in the course outline.

For work totalling 10% or more of the final course grade, you must provide valid medical or supporting documentation to the Academic Counselling Office of your Faculty of Registration as soon as possible. For further information, please consult the University's medical illness policy at

[https://www.uwo.ca/univsec/pdf/academic\\_policies/appeals/accommodation\\_medical.pdf](https://www.uwo.ca/univsec/pdf/academic_policies/appeals/accommodation_medical.pdf).

The Student Medical Certificate is available at

[https://www.uwo.ca/univsec/pdf/academic\\_policies/appeals/medicalform.pdf](https://www.uwo.ca/univsec/pdf/academic_policies/appeals/medicalform.pdf).

Students should also note that individual instructors are not permitted to receive documentation directly from a student, whether in support of an application for consideration on medical grounds, or for other reasons. **All documentation required for absences that are not covered by the Self-Reported Absence Policy must be submitted to the Academic Counselling office of a student's Home Faculty.**

### Absences from Final Examinations

If you miss the Final Exam, please contact the Academic Counselling office of your Faculty of Registration as soon as you are able to do so. They will assess your eligibility to write the Special Examination (the name given by the University to a makeup Final Exam).

You may also be eligible to write the Special Exam if you are in a "Multiple Exam Situation" (e.g., more than 2 exams in 23-hour period, more than 3 exams in a 47-hour period).

If a student fails to write a scheduled Special Examination, the date of the next Special Examination (if granted) normally will be the scheduled date for the final exam the next time this course is offered. The maximum course load for that term will be reduced by the credit of the course(s) for which the final examination has been deferred. See the Academic Calendar for details (under Special Examinations).

## 7. Accommodation and Accessibility

### Religious Accommodation

When a course requirement conflicts with a religious holiday that requires an absence from the University or prohibits certain activities, students should request accommodation for their absence in writing at least two weeks prior to the holiday to the course instructor and/or the Academic Counselling office of their Faculty of Registration. Please consult University's list of recognized religious holidays (updated annually) at

<https://multiculturalcalendar.com/ecal/index.php?s=c-univwo>.

### Accommodation Policies

Students with disabilities are encouraged to contact Accessible Education, which provides recommendations for accommodation based on medical documentation or psychological and cognitive testing. The policy on Academic Accommodation for Students with Disabilities can be found at:

[https://www.uwo.ca/univsec/pdf/academic\\_policies/appeals/Academic\\_Accommodation\\_disabilities.pdf](https://www.uwo.ca/univsec/pdf/academic_policies/appeals/Academic_Accommodation_disabilities.pdf).

## 8. Academic Policies

The website for Registrarial Services is <http://www.registrar.uwo.ca>.

In accordance with policy,

[https://www.uwo.ca/univsec/pdf/policies\\_procedures/section1/mapp113.pdf](https://www.uwo.ca/univsec/pdf/policies_procedures/section1/mapp113.pdf),

the centrally administered e-mail account provided to students will be considered the individual's official university e-mail address. It is the responsibility of the account holder to ensure that e-mail received from the University at their official university address is attended to in a timely manner.

For both mid-term and final exams, a single-sided hand-written crib sheet and a non-programmable calculator may be used.

**Scholastic offences** are taken seriously and students are directed to read the appropriate policy, specifically, the definition of what constitutes a Scholastic Offence, at the following Web site:

[http://www.uwo.ca/univsec/pdf/academic\\_policies/appeals/scholastic\\_discipline\\_undergrad.pdf](http://www.uwo.ca/univsec/pdf/academic_policies/appeals/scholastic_discipline_undergrad.pdf).

All required papers may be subject to submission for textual similarity review to the commercial plagiarism detection software under license to the University for the detection of plagiarism. All papers submitted for such checking will be included as source documents in the reference database for the purpose of detecting plagiarism of papers subsequently submitted to the system. Use of the service is subject to the licensing agreement, currently between The University of Western Ontario and Turnitin.com (<http://www.turnitin.com>).

Tests and examinations in this course will be conducted using a remote proctoring service. By taking this course, you are consenting to the use of this software and acknowledge that you will be required to provide **personal information** (including some biometric data) and the session will be **recorded**. Completion of this course will require you to have a reliable internet connection and a device that meets the technical requirements for this service. More information about this remote proctoring service, including technical requirements, is available on Western's Remote Proctoring website at:

<https://remoteproctoring.uwo.ca>.

## 9. Support Services

Please visit the Science & Basic Medical Sciences Academic Counselling webpage for information on adding/dropping courses, academic considerations for absences, appeals, exam conflicts, and many other academic related matters: <https://www.uwo.ca/sci/counselling/>.

Students who are in emotional/mental distress should refer to Mental Health@Western (<https://uwo.ca/health/>) for a complete list of options about how to obtain help.

Western is committed to reducing incidents of gender-based and sexual violence and providing compassionate support to anyone who has gone through these traumatic events. If you have experienced sexual or gender-based violence (either recently or in the past), you will find information about support services for survivors, including emergency contacts at

[https://www.uwo.ca/health/student\\_support/survivor\\_support/get-help.html](https://www.uwo.ca/health/student_support/survivor_support/get-help.html).

To connect with a case manager or set up an appointment, please contact [support@uwo.ca](mailto:support@uwo.ca).

Please contact the course instructor if you require lecture or printed material in an alternate format or if any other arrangements can make this course more accessible to you. You may also wish to contact Accessible Education at

[http://academicsupport.uwo.ca/accessible\\_education/index.html](http://academicsupport.uwo.ca/accessible_education/index.html)

if you have any questions regarding accommodations.

Learning-skills counsellors at the Student Development Centre (<https://learning.uwo.ca>) are ready to help you improve your learning skills. They offer presentations on strategies for improving time management, multiple-choice exam preparation/writing, textbook reading, and more. Individual support is offered throughout the Fall/Winter terms in the drop-in Learning Help Centre, and year-round through individual counselling.

Western University is committed to a thriving campus as we deliver our courses in the mixed model of both virtual and face-to-face formats. We encourage you to check out the Digital Student Experience website to manage your academics and well-being: <https://www.uwo.ca/se/digital/>.

Additional student-run support services are offered by the USC, <https://westernusc.ca/services/>.