Numerical Modeling in the Geosciences
GEO 325M/398M, Spring 2026

Class details

Class time:	Tu/Th 9:30-11:00pm
Class room:	JGB 3.120
Canvas:	https://utexas.instructure.com/courses/1436793
Class webpage:	https://mhesse.github.io/numerical_modeling/
Unique:	(27915/28310 - undergrad/grad)
Prerequisites:	MATH 427J (ode's & matrices), MATH 427 L (∇, $\nabla\cdot$, $\nabla\times$) GEO 325G (Matlab) or equivalent
Description:	The course introduces geoscientists to numerical solution of dynamical problems arising in the Earth and Planetary Sciences. The students will develop their own codes in Matlab and apply it to solve an actual research problem that changes each year, see below. Familiarity with Matlab is assumed, for an introduction to Matlab please attend GEO 325G or an equivalent course.

Instructor

Instructor:	Dr. Marc Hesse
Office:	JGB 4.216G
Office hours:	TBD
Email:	mhesse@jsg.utexas.edu
website:	https://www.jsg.utexas.edu/hesse/

Assessment

Undergraduates: 50% Homework + 30% Exams + 20% Attendance
Graduate students: 50% Homework + 30% Exams + 20% Project

Grading scheme: Below are the grade cut offs in percent on the total points in the course.

A	A-	B+	B	B-	C+	C	C-	D+	D	D-	F
>94	90	87	84	80	77	74	70	67	64	60	<60

Late policy: Ten percent of the maximum score is subtracted from late assignments.
Collaboration: Students can discuss homework, but must code up solutions individually.
AI use: You cannot use AI to complete your homework. If AI use is detected the HW score is 0.

Class Attendance:

For undergraduates attendance is mandatory and part of your grade. Students who attend and are prepared for each class perform better than those who miss class.

Graduate projects:

Opportunity for graduate students to apply the numerical methods from this course to a project of their interest. Graduate students give short presentation on project results on last day of class (Apr 23).

Syllabus

week	dates	lecture	modeling	homework
1	13, 15 Jan	1, 2	Introduction, porous media, conservation laws	
2	20, 22 Jan	3, 4	Finite differences, Discrete operators 1D	HW 1
3	27, 29 Jan	5, 6	Flow in Elastic and Ductile Rocks,	HW 2
4	3, 5 Feb	7, 8	Boundary conditions	HW 3
5	10, 12 Feb	9, 10	Fluxes, Heterogeneity	HW 4
6	17, 19 Feb	11, 12	Time integration	
7	24, 26 Feb	13, 14	Advection 1D	HW 5
8	3, 5 Mar	15, 16	Tracer transport	HW 6
9	10, 12 Mar	17, 18	Radioactive tracers, Midterm	
10	17, 19 Mar		Spring break	
11	24, 26 Mar	19, 20	Discrete operators 2D	HW 7
12	31 Mar, 2 Apr	21, 22	Advection 2D	TBD
13	7, 9 Apr	23, 24	Heterogeneous melt migration	TBD
14	14, 16 Apr	25, 26	Non-Newtonian rheology	TBD
15	21, 23 Apr	27, 28	Newton-Raphson Method, Grad Projects	
	30 Apr		Final Exam	

Course theme 2026

In spring 2026 we will develop a models for melt migration and planetary differentiation.

Previous course themes:

Spring 2018: Post-impact thermal evolution of Occator crater on Ceres. (paper 1, paper 2)
Spring 2019: Oxidant transport by brine drainage through Europa's ice shell. (paper 1)
Spring 2020: Ice shell convection in icy ocean worlds (paper 1, paper 2)
Spring 2021: Mars groundwater response to impact cratering (paper 1)
Spring 2022: Two-phase convection in Europa's ice shell
Spring 2023: Post-impact hydrothermal convection
Spring 2024: Melt infiltration into firn (paper 1)

Useful books:

Computational Methods for Geodynamics, Ismail-Zadeh A. and Tackley P.
An Introduction to Reservoir Simulation Using MATLAB/GNU Octave, Lie K.-A.

Academic accommodations from Disability and Access (D&A)

Please let me know if you are a student with a disability and deliver your Accommodation Letter to me as early as possible in the semester. See here for the UT standard statement.

For general University Policies and Resources follow this link.

Learning Outcomes

1. Students will be able to apply fundamental numerical methods to geoscientific problems by discretizing and solving differential equations using finite difference techniques.
2. Students will be able to develop numerical models in MATLAB by writing, testing, and documenting code that simulates geophysical processes.
3. Students will be able to analyze physical processes in the geosciences by interpreting numerical solutions for heat transfer, advection–diffusion, and wave propagation problems.
4. Students will be able to implement realistic boundary conditions and spatial heterogeneity by incorporating variable coefficients and constraints into numerical simulations.
5. Students will be able to solve advanced fluid and transport problems by constructing and evaluating numerical models of Stokes flow and coupled processes.
6. Students will be able to evaluate the accuracy and stability of numerical schemes by assessing numerical error, convergence, and model limitations.
7. Students will be able to conduct an independent computational research project by designing, implementing, and presenting a semester-long numerical modeling study.