Numerical Modeling in the Geosciences
GEO 325M/398M, Spring 2025

Class details

Class time:	Tu/Th 9:30-11:00pm
Class room:	JGB 3.120
Canvas:	[click for link]
Class webpage:	https://mhesse.github.io/numerical_modeling/
Unique:	(27460/27875 - 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. Course topics alternate between subsurface flow (odd years) and geodynamics (even years). 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/

Grading policy

Grading: The class will be graded based on weekly homeworks - no exams.
Collaboration: Students can discuss homeworks, but must code up solutions individually.
Late policy: Ten percent of the maximum score is subtracted from late assignements.
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

Class Attendance:

I expect that all students will attend every class meeting. Students who attend and are prepared for each class perform better than those who miss class.

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.

Syllabus

week	dates	lecture	modeling	homework
1	14, 16 Jan	1, 2	Introduction, Conservation laws	
2	21, 23 Jan	3, 4	Finite differences, Discrete operators 1D	HW 1
3	28, 30 Jan	5, 6	Boundary conditions	HW 2
4	4, 6 Feb	7, 8	Fluxes, Heterogeneity	HW 3
5	11, 13 Feb	9, 10	Time integrationn	HW 4
6	18, 20 Feb	11, 12	Advection 1D	
7	25, 27 Feb	13, 14	Discrete operators 2D	HW 5
8	4, 6 Mar	15, 16	Advection 2D	HW 6
9	11, 13 Mar	17, 18	Stokes equation	
10	18, 20 Mar		Spring break	
11	25, 27 Mar	19, 20	Stokes discretization	HW 7
12	1, 3 Apr	21, 22	Streamfunction	TBD
13	8, 10 Apr	23, 24	Variable viscosity	TBD
14	15, 17 Apr	25, 26	Rayleigh-Bernard Convection	TBD
15	22, 24 Apr	27, 28	Convection in high-pressure ice	TBD

Course project

In spring 2025 we will develop a model for the convection in high-pressure ice in icy ocean worlds that may controll the transfer of nutrients from the rocky interior into the ocean sandwiched between the layers of high and low pressure ice.

Previous course projects:

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: Preferential infiltration

Useful books:

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