Numerical Modeling in the Geosciences
GEO 325M/398M, Spring 2022

Class details

Class time:	Tu/Th 9:30-11:00pm
Class room:	JGB 2.312
Zoom room:	[click for link] (password on Canvas)
Canvas:	[link]
Class webpage:	https://mhesse.github.io/numerical_modeling/
Unique:	(27425/27765 - 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.

Course project

In spring 2022 we will develop a model for two-phase convection in Europa's ice shell. Europa is one of the Galilean moons of Jupiter. Tidal heating due to Jupiter's gravity leads to melting and the persistence of an internal ocean that might harbor life (NASA video). This year we will explore the effect of tidal heating on Europa's ice shell, where it leads to partial melting and the formation of a dense brine. This leads to complex two-phase (Darcy-Stokes) convection where warm buoyant ice rises and dense brine percolates downwards. To date these dynamics are largely unexplored but have the potential to dramatically thin the ice shell and hence our ability to probe the internal ocean.

Previous course projects:

Spring 2018:	Post-impact thermal evolution of Occator crater on asteroid 1 Ceres. (Hesse and Castillo-Rogez 2019, Raymond et al. 2020)
Spring 2019:	Oxidant transport by brine drainage through Europa's ice shell. (Hesse et al. 2020)
Spring 2020:	Ice shell convection in icy ocean worlds (Carnahan et al. 2021, Wolfenbarger et al. 2021)
Spring 2021:	Mars groundwater response to impact cratering

Instructor

Instructor:	Dr. Marc Hesse
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Useful books:

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

Syllabus

week	dates	lecture	modeling	homework
1	18, 20 Jan	1, 2	Introduction to class project & Darcy-Stokes	
2	25 27 Jan	3, 4	Conservation laws	HW 1
3	1, 3 Feb	5, 6	Discrete operators 1D, BC's	HW 2
4	8, 10 Feb	7, 8	Darcy flow/Poisson equation	HW 3
5	15, 17 Feb	9, 10	2D discrete operators	HW 4
6	22, 24 Feb	11, 12	Momentum balance/Stokes equation	
7	1, 3 Mar	13, 14	Stokes grid and operators	HW 5
8	8, 10 Mar	15, 16	Linear Stokes flow	HW 6
9	15, 17 Mar	Spring break		
10	22, 24 Mar	17, 18	Two-phase Darcy-Stokes equations	
11	29, 31 Mar	19, 20	Darcy-Stokes operators	HW 7
12	5, 7 Apr	21, 22	Instantaneous Darcy-Stokes solution	HW 8
13	12, 14 Apr	21, 22	Porosity evolution, advection equation	
14	19, 21 Apr	23, 24	Advection, upwind method	HW 9
15	26, 28 Apr	25, 26	Thermal convection	-
16	3, 5 May	27, 28	Advection-diffusion equation	-