Virginia Tech
Department of Civil and Environmental Engineering

CEE 5984 Modeling of Environmental Flows (Fall 2018)

Description: The purpose of this course is to introduce students to different ways in which flow and transport processes can be modeled in natural environments and to give students an opportunity to gain hands-on experience with coding and use of software such as HEC-RAS and Delft3D. The course is designed to give students a basic understanding of numerical approaches to modeling rivers and estuaries, and to expose students to different levels of model resolution and capabilities. The first half of the course covers basic finite difference theory applied to simple ODE and PDE settings with an emphasis on hands-on coding of simple flow and transport situations. The second half of the course focuses on modeling more complex environments with open-source or freely available computational resources. There are no graduate-level prerequisites for the course. *However the course material will assume that students are familiar with the differential forms of the equations of motion and transport.*

Prerequisites: C- or better in CEE 3314

Instructor: Kyle Strom, Associate Professor
office: Patton Hall 221D
office hours: Tuesday/Thursdays 2:30-4:30pm
phone: 540.231.0979
email: strom@vt.edu

Course Material:

1. Required material will be distributed through Canvas or in class.

Reference Material:

Below are a few recommended books and other resources.

1. Text Books
   (a) *A First Course in Computational Fluid Dynamics*[*], by Aref and Balachandar (2018), Cambridge.

[*]electronic access through the VT library

(b) *Computational River Dynamics**, by Weiming Wu (2007)
(c) *Open-Channel Flow**, H. Chaudhry (2008), Springer
(d) *Computational fluid dynamics: applications in environmental hydraulics**, editors Bates, P. D; Lane, S. N.; Ferguson, R. I.
(e) *1D Morphodynamics of Rivers and Turbidity Currents*, by Gary Parker (e-book)
(f) *Fluid Mechanics*, by Kundu and Cohen (2008), Elsevier
(g) *MIXING in Inland and Coastal Waters*, Fischer et al. (1979), Academic Press
(h) *An Introduction to Turbulent Flow*, Mathieu and Scott (2000), Cambridge Press.

2. Movies
   (a) NSF Sponsored series on fluid mechanics (playlist can be found here).
   (b) University of Iowa Hunter Rouse video series (playlist can be found here).
   (c) Other fluid mechanics playlist on the same YouTube channel.
   (d) The APS Division of Fluid Dynamics's Gallery of Fluid Motion.

3. Other resources
   (a) A few links and examples to help you get going with Python
   (b) Introductory lectures on computing with python by Robert Johansson

Course Topics:

1. Introductory concepts
   (a) Introductory ideas and terms
   (b) Python and Jupyter notebooks
   (c) Governing equations and different levels of averaging
   (d) Overview of terminology, different types of numerical approaches, and levels of modeling
2. Building understanding and skill with simplified systems
   (a) Introduction to Finite Difference (FD) methods
   (b) ODEs: concepts, methods, and examples (including: Poiseuille-Couette flow, Blasius boundary layer flow, gradually varied river hydraulics, jets and river mouth discharges, and 1D density currents)
   (c) PDEs: concepts, methods, and examples (including: pure advection, pure diffusion, and advection-diffusion transport as well as examples in morphodynamics such as adjustment of a river bed to changes in sediment supply, bed dynamics under the influence of base-level change, prediction of the bedrock to alluvial cover transition in steep rivers).
   (d) 1D Hydraulics: modeling with Saint Venant equations
   (e) Discretization of domain and equations, boundary conditions, and closure
   (f) Development of Saint Venant equation solver
   (g) Introduction to 1D HEC-RAS (with project)
3. 2D Hydraulics: modeling with the Shallow Water equations
   (a) Shallow water eqs and depth-averaged advection-diffusion equation
   (b) Closure and model calibration

    (c) Introduction to horizontal grid types
    (d) Introduction to HEC-RAS 2D (with project)
4. 3D Hydraulics: modeling with Multilayer Shallow Water equations standard RANS equations
    (a) Multi-layer shallow water equations and vertical grid types
    (b) Delft3D Project
    (c) 3D RANS
    (d) Introduction to turbulence modeling and closure
    (e) Introduction to OpenFoam (if time allows)

Student Assessment:

Student assessment in the course will be based on (1) homework, (2) class participation, and (3) a final project.

Homework:

Homework in this class will revolve around mini-projects. Collaboration is acceptable when working through all assignments. For assignments given to individuals, each student must turn in a full set of their own completed work. For assignments given to teams, only one item (write up and/or presentation) will be required. Specific dates for homework will be given along with the handout. There will be approximately 6 assignments.

Homework Requirements:

1. Discussion of homework and collaboration with peers is encouraged. However, each student must submit their own **unique** work for credit if the homework is given out to individuals. Anything deemed of "suspicious origins" will not be graded, and Honor Code violations will be addressed.
2. All homework submissions must be **legible** and **well organized**. Any illegible homework will not be graded. Homework solutions should be handwritten or printed on the front side of each piece of paper only (i.e., do not write on the front and back of a page). Please give an overview of the problem statement before presenting your work and solution. All final solutions should be boxed.

Class Participation:

At times students will be asked to complete in-class assignments or give a demonstration or overview of a concept to help enforce material being discussed.

Project & Presentation:

The final assignment of the course will be a two-person project and presentation. The purpose of the project will be to setup and use a model to test a hypothesis or answer a specific research question. That is, the purpose is to "use" the model to answer a question (not just setup the model). You can model and idealized setting or a specific river or estuary, and any level of detail is okay (1D, 2D, or 3D). The key is to pick the model type and dimensionality that is suited to answering the question you want to ask. I will assign the teams by mid October. By the first week of November I would like each team to stop by my office hours to discuss their research question, hypothesis, and modeling approach for their project. The last two days of class will be devoted to final project presentations. There is no written report associated with the final project.

Grading

Contributions Towards Final Grade	
Homework	70%
Class participation	10%
Project & Presentation	20%
Total	100%

Letter Grade	Overall Avg.	Letter Grade	Overall Avg.
A	94-100%	C	73-76%
A-	90-93%	C-	70-72%
B+	87-89%	D+	67-69%
B	83-86%	D	63-66%
B-	80-82%	D-	60-62%
C+	77-79%	F	<60%

Honor Code:

The Undergraduate Honor Code pledge that each member of the university community agrees to abide by states: **"As a Hokie, I will conduct myself with honor and integrity at all times. I will not lie, cheat, or steal, nor will I accept the actions of those who do."**

Students enrolled in this course are responsible for abiding by the Honor Code. A student who has doubts about how the Honor Code applies to any assignment is responsible for obtaining specific guidance from the course instructor before submitting the assignment for evaluation. Ignorance of the rules does not exclude any member of the University community from the requirements and expectations of the Honor Code. For additional information about the Honor Code, please visit: www.honorsystem.vt.edu.

The Virginia Tech Honor Code applies to all work in this class, including homework, laboratory reports, and examinations. When written work is submitted for grading, it is implied that the work is the sole effort of the person, or persons, whose name(s) appears on the paper. You may seek help on the principles and applications involved in the major assignments, and you may talk to each other about these principles and applications, but you are not to simply copy the work of another person or allow another person to work a problem for you.

Special Accommodations Statement:

If you need adaptations or accommodations because of a disability, if you have emergency medical information to share with me, or if you need special arrangements in case the building must be evacuated, please make an appointment with me within the first two weeks of classes.