GEOS 518
Applied Hydrologic Modeling

Syllabus Table of Contents

Meeting Times and Location

M & W: 12:00 - 1:15 pm ERB 1100

Instructor: Alejandro N. Flores, Ph.D.
Office: ERB 4151
Email: lejoflores@boisestate.edu
Phone: (208) 426-2903
Office hours: by appointment at https://lejoflores.youcanbook.me/index.jsp

Catalog Description: Review, critical analysis, and application of surface hydrology modeling techniques used in hydrology and engineering practice. Covers empirical, statistical, and physics-based approaches. Application of commonly used modeling software to practical problems.

Required Texts:
Title: Time Series Analysis: Forecasting and Control, 5e
Authors: George E. P. Box, Gwilym M. Jenkins, Gregory C. Reinsel, and Greta M. Ljung
Hardcover: 712 pp.
Publisher: Wiley
ISBN-10: 1118675029
ISBN-13: 978-1118675021

Title: Mathematical Modeling of Earth's Dynamical Systems: A Primer
Authors: Rudy Slingerland and Lee Kump
Paperback: 248 pp.
Publisher: Princeton University Press
ISBN-10: 0691145148
ISBN-13: 978-0691145143

Course Goal: The overarching goal of this course is to equip you with the knowledge and skills to use a variety of appropriate models and modeling techniques to solve a broad spectrum of hydrologic problems, interpret output of hydrologic models with a healthy degree of skepticism, and begin to use best practices in scientific computing and programming.

Learning is an active search for meaning by the learner and consists of constructing knowledge rather than passively receiving it. The learner both shapes and is shaped by the experience.

Student Roles and Responsibilities in a learner-centered environment

Learner-Centered Student Roles	*Learner-Centered Student Responsibilities*
Self-teach Work in teams/groups to collaborate with others Take part in inquiry learning Teach others Evaluate own learning Perform/present learning publicly Learn new how-to-learn skills and strategies Solve authentic problems Engage in reflection Demonstrate use of teacher feedback to improve performance Take learning risks Practice more Participate in class Take class notes Listen in class Read the textbook Write papers Take learning celebrations and learning checks Do homework	Make choices about one's own learning Take control of one's own learning Give input to the evaluation/assessment methods of the course Give input to course rules and guidelines Give formative feedback on learning to peers Evaluate one's own learning Spend more time learning outside of class Work with people from outside the university on service projects or other authentic learning activities

Instructor Roles and Responsibilities in a learner-centered environment.

Learner-Centered Instructor Roles	*Learner-Centered Instructor Responsibilities*
Communicate high expectations Effectively manage course time Encourage reciprocity and cooperation among learners Facilitate shared decision-making Give prompt feedback Help learners develop and use effective learning strategies Include peer learning and peer teaching Interact with learners Provide opportunities for active learning	Assess and evaluate learning Be an active teacher Be available to students. Allow learners to be responsible for their learning Know the students Make course relevant to learners Provide learning opportunities Provide structure without being overly directive Recognize and accommodate different

Provide stimulating authentic activities Provide tools and opportunities for critical thinking	learning modalities Respect learners

Course Outcomes, Activities, and Assessment
University Learning Outcomes (ULOs):
The eleven university learning outcomes (ULOs) listed below ensure students are repeatedly exposed to the essential soft skills sought in college graduates as well as the disciplinary outcomes important for breadth of learning. These outcomes were developed by the faculty to provide undergraduates with a common experience aimed at unifying the university's diverse student body and expanding students' awareness of themselves and their world. Every Boise State graduate is expected to have met these ULOs, regardless of major or baccalaureate degree.

<u>Intellectual Foundations:</u>
1. Writing – Write effectively in multiple contexts, for a variety of audiences.
2. Oral Communication – Communicate effectively in speech, both as speaker and listener.
3. Critical Inquiry – Engage in effective critical inquiry by defining problems, gathering and evaluating evidence, and determining the adequacy of argumentative discourse.
4. Innovation and Teamwork – Think creatively about complex problems to produce, evaluate, and implement innovative possible solutions, often as one member of a team.

<u>Civic and Ethical Foundations:</u>
5. Ethics – Analyze ethical issues in personal, professional, and civic life and produce reasoned evaluations of competing value systems and ethical claims.
6. Diversity and Internationalization – Apply knowledge of cultural differences to matters of local, regional, national, and international importance, including political, economic, and environmental issues.

<u>Distribution Requirements/Disciplinary Lens Clusters:</u>
7. Mathematics (DLM) – Apply knowledge and the methods of reasoning characteristic of mathematics, statistics, and other formal systems to solve complex problems.
8. Natural, Physical, and Applied Sciences (DLN) – Apply knowledge and the methods characteristic of scientific inquiry to think critically about and solve theoretical and practical problems about physical structures and processes.
9. Visual and Performing Arts (DLV) – Apply knowledge and methods characteristic of the visual and performing arts to explain and appreciate the significance of aesthetic products and creative activities.
10. Literature and Humanities (DLL) – Apply knowledge and the methods of inquiry characteristic of literature and other humanities disciplines to interpret and produce texts expressive of the human condition.
11. Social Sciences (DLS) – Apply knowledge and the methods of inquiry characteristic of the social sciences to explain and evaluate human behavior and institutions.

<u>Draft</u> Geoscience Graduate Program Learning Outcomes (PLOs):
At the completion of the **any graduate degree** in Geoscience, graduates will be able to:

1. Assimilate discipline-appropriate theory and methods of practice, including knowledge content, skills, and habits of mind,
2. Navigate the interrelationships and integration of geosciences with other scientific and engineering disciplines,
3. Formulate novel geoscientific research questions, hypotheses, and experimental designs informed by the scientific literature,
4. Collect, process, analyze, and interpret diverse geoscientific data, including the quantification of error, resolution, probability, and risk,
5. Master the skills of oral and written communication to diverse audiences,
6. Articulate scientific contributions to their field, other disciplines, and society,
7. Practice effective leadership, project management, and teamwork,
8. Develop competencies and credentials defined by their professional goals, and
9. Establish a professional identity that engages the geoscience community.

Draft MS Hydrologic Science Program Learning Outcomes (PLOs):

At the completion of the Master of Science in Hydrologic Sciences degree, the graduate will be able to:

1. Identify knowledge gaps in hydrologic science related to the fluxes of water in the environment that constitute the water cycle as well as the mass and energy transport function of the water cycle, and its interactions with the lithosphere, biosphere, and society,
2. Based on review of extant hydrologic science literature, select and use appropriate field and laboratory methods to collect data to characterize key parameters characterizing storages and fluxes of water, energy, and biogeochemical products within and across the boundaries of a given hydrologic systems,
3. Choose and apply appropriate data analysis and/or modeling techniques, through a critical assessment of applicable literature, to analyze, interpret, and draw inference from data that directly and indirectly characterize hydrologic systems,
4. Organize and document data and other research products to meet standards commonly used within the hydrologic and Earth science community (where available) for scientific reproducibility and reusability,
5. Design and carry out a research project that addresses an identified knowledge gap in the hydrologic sciences and involves a coordinated process of data collection, analysis, and interpretation of data, and
6. Create products to effectively communicate outcomes of research in the hydrologic sciences that are tailored to audiences that include the general public, key stakeholders, and the scientific community.

Course Learning Objectives (CLOs):

Assumed Prior Knowledge:

1. Write the water budget equation for a given system, label and describe all relevant components, and state any assumptions made

2. Defend any assumptions made in writing a water budget equation for a given system in light of temporal or spatial scales, or other relevant information given to you about a hydrologic problem
3. Explain which components of the water budget equation can be constrained with data and describe the methods and/or instrumentation required to collect that data
4. Define and interpret the meaning of statistical properties of a dataset such as the mean, median, mode, standard deviation, and autocorrelation

Course Learning Objectives: At the end of this class, students will be able to:

1. Explain the principle of stationarity as it pertains to hydrologic data, describe how to assess whether hydrologic time series are stationary, and explain some potential ramifications of assuming stationarity in analysis when it does not hold,
2. Apply principles of stochastic processes to characterize hydrologic time series data, including two time series that may be related,
3. Analyze hydrologic time series data in both the time and frequency domains, explain the duality between the two approaches, and describe the merits of each approach,
4. Construct forecasting models of hydrologic processes using characterizations of hydrologic time series as stochastic processes,
5. Articulate the steps in quantitative problem solving in the hydrologic sciences,
6. Draw a conceptual diagram illustrating how finite difference methods can be applied to solve differential differential equations, how the accuracy of the approximation is affected by the discretization interval, and use finite difference methods to create a numerical solution to a second order, linear partial differential equation,
7. Apply numerical methods using a scientific programming language to solve scientific problems dominated by diffusion, advection, and transport (advection-diffusion) problems,
8. Use modern scientific programming languages, tools, and workflows to acquire, analyze, and visualize hydrologic data from a number of credible sources.

The Course Environment

Format: This format of class time in this course can best be characterized as **"New Old Stuff."**
What is the "New" in "New Old Stuff?" Virtually every class period will include an active learning component with work being done in pairs or small groups. Active learning provides an opportunity for all students to be involved and it keeps the majority from finding something else to attend to. A bonus is that the class is more energetic and fun. Considerable research in cognitive science and the scholarship of teaching and learning have established that you will learn far more through active learning than from simply watching and listening to lectures. Thus, I will spend little time telling you what you need to know. Rather you will spend time discovering what you need to know through activities that will require you to read, think, solve, move, interpret, and do more than simply watch, listen, and take notes.
What is "Old" in "New Old Stuff?" To the extent that lectures, derivations, and examples are done in this course, I will rely almost exclusively on the whiteboard. Don't get me wrong, I love technology (no one loves technology more than me). I spend most of each working day at a

computer and most of my research involves complex mathematical models that are frequently run on supercomputers. Nevertheless, when I compare and contrast the classes from my own educational experience where lectures were done either on the chalk/whiteboard or via PowerPoint slides, there is absolutely no comparison: I retain far more of the subject material and problem-solving skills from those classes where lecture was conducted via chalk/whiteboard. I believe there are several underlying reasons for this. Here are a few of the more prescient ones:

1. Writing on the board by hand slows down the presentation of the subject matter, which in this case (and often in STEM fields) involves a significant amount of math, physics, chemistry, and geology
2. Taking notes by hand forces you to watch and listen, process, transcribe, and record the material as you understand it. It also creates a record of your understanding at the time, which can be compared with your peers and my notes. If need be it can be reconciled, allowing you to correct your own misperceptions and misunderstandings and help your peers do the same
3. I, the instructor, will inevitably make mistakes. Evidence shows that it's good for you, the learner, to see me make mistakes and struggle to correct them. It is also far easier for me and more helpful for your notes to correct a mistake on the board rather than let it fester and go uncorrected in a PowerPoint presentation. This also presents an opportunity for us to solve problems as a class.
4. It will force us to keep the lights on in class, which will hopefully make everyone have an easy time staying awake in an afternoon class.

That's not to say that the projector will never be used in class. But I will restrict my use of PowerPoint to situations where it is necessary to show photographs or complex graphics that cannot be economically drawn in a short period of time. When needing to use PowerPoint, I will bring handouts to allow you to take notes on top of the graphics, photographs, etc. All that said, me lecturing for 75 wall-to-wall minutes is not a desirable nor effective way to educate you. As such, it's my promise to you that lectures will:

1. Be no more than 20 minutes in duration,
2. Have a well defined beginning, middle, and end, and
3. Be associated with clear learning outcomes that will be communicated at the beginning of each of these 20 minute lecturettes.

So, what can I expect every day when I show up to class? Each class period will begin with a 5 minute introduction to the learning objectives addressed in the class period. The remaining 70 minutes will be broken up into three 20 minute blocks, with 5 minute breaks in between. Each class period will typically contain a mixture of these 20 minute "lecturettes" and learning activities. As an example, below contains an example of how class periods might be blocked out into periods of lecture and activities. These range from lecture intensive to activity intensive formats. During the introduction to each class period, I will clearly communicate how these three class blocks will be allocated.

Block A: Lecture intensive	
Activity	**Time (minutes)**
Introduction	5
Lecturette	20
Break	5
Lecturette	20
Break	5
Lecturette	20
Total	***75***

Block B: Balanced	
Activity	**Time (minutes)**
Introduction	5
Lecturette	20
Break	5
Activity	20
Break	5
Lecturette	20
Total	***75***

Block C: Activity intensive	
Activity	**Time (minutes)**
Introduction	5
Lecturette	20
Break	5
Activity	20
Break	5
Activity	20
Total	***75***

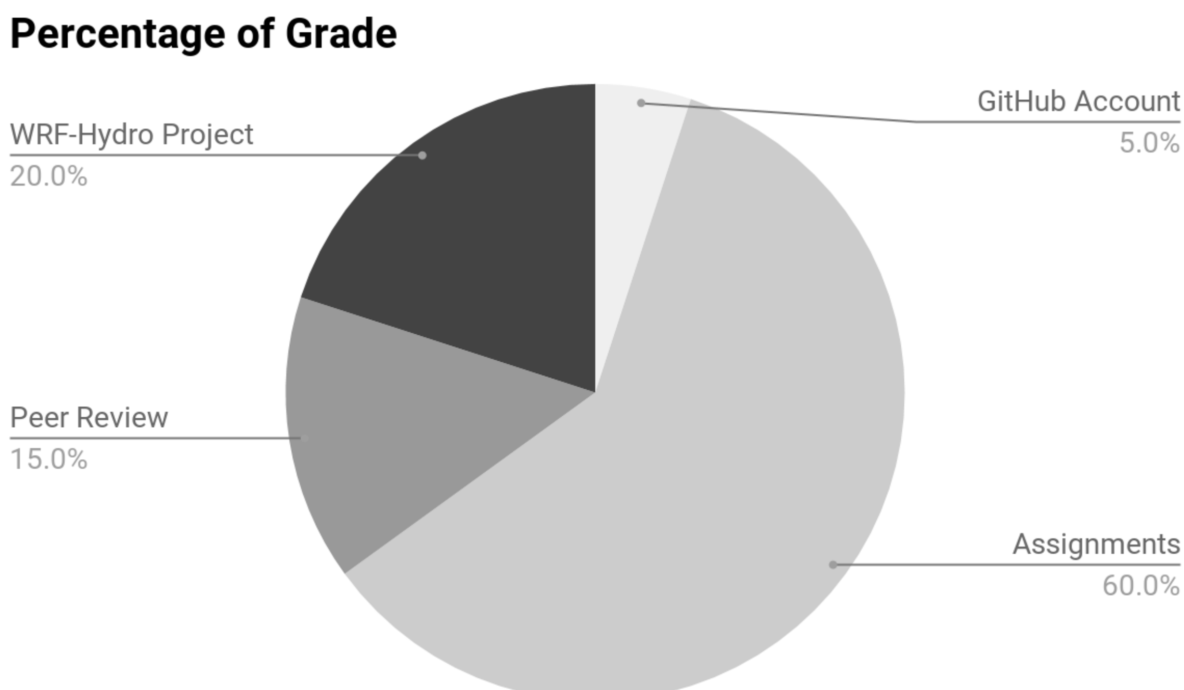
Optimizing the Environment:

1. Please refrain from using the following in class: cell phones, other personal electronic devices not used for notetaking, and social media and other distracting websites on laptops/tablets. You may record class audio if that helps you.
2. Please review the University Attendance Policy. Please attend all classes and arrive on time. You have the responsibility for contacting the instructor prior to missing grading opportunities. An acceptable written verification of the nature of the absence may be requested by the instructor prior to scheduling a make-up. Make-ups must be scheduled within one week of the absence.
3. Any academic dishonesty, including cheating and plagiarism, will result in a failing grade for the course. It is your responsibility to understand the Boise State University Student Code of Conduct.
4. Any student who feels s/he may need accommodations based on the impact of a disability should contact me privately to discuss your specific needs. You will also need to contact the Education Access Center at 208-426-1583 (eacinfo@boisestate.edu) located on the first floor of the Lincoln Parking Garage.

Measuring Success

<u>Create a GitHub account and create a GEOS 518 repository:</u> You will submit programming assignments (see below) throughout the semester via GitHub. GitHub is a webpage for code version control and a repository. It encourages open source and freely available code and provides many additional functions that allow you to document, backup, and share your code. It has become exceptionally widespread in terms of use in the scientific computing community and many employers now ask prospective employees for a link to their GitHub profile.
Reading Quiz percentage weight: 5%
<u>Programming Assignments:</u> These are approximately seven programming assignments to be submitted as Jupyter notebooks on your own GitHub account. These will be hands-on problems using real data. Although you are strongly encouraged to work in small groups, Jupyter

notebooks should be submitted to reflect your individual work. The code you will write and publish on GitHub is meant to represent an online professional presence that indicates some of your professional skills.
Problem Set percentage weight: 60%
<u>Peer Review:</u> An important process in creating scientific code that functions correctly, efficiently, and is reusable is peer review. In this class, we will review our colleagues code according to guidelines established by the National Weather Service Office of Hydrologic Development. Although not all elements of review will apply, these guidelines provide a good overview of how to review a colleague's code to ensure that it both functions and adheres to best practices
Peer Review percentage weight: 15%
<u>Final Modeling Project:</u> Instead of a final exam, the final summative assessment in the class will be a modeling exercise using the WRF-Hydro model, the model that serves as the backbone of the National Water Model. Learning outcomes, instructions, and write-up requirements will be provided later in the class. The modeling project is to be performed individually.
Total percentage weight: 20%



Documenting Success

Letter grades will be assigned as follows

A+	≥ 96.67%
A	93.33 – 96.66
A-	90.00 – 93.32
B+	86.67 – 89.99
B	83.33 – 86.66
B-	80.00 – 83.32
C+	76.67 – 79.99
C	73.33 – 76.66
C-	70.00 – 73.32
D+	66.67 – 69.99
D	63.33 – 66.66
D-	60.00 – 63.32
F	≤ 59.99

PRogramming assignments will generally be returned within two weeks after their completion, although grades may be posted earlier.

Strategies for Success

I want you to succeed in this class and I truly hope that it becomes an important part of your educational experience at Boise State. Here are a few tips that I have that I hope will help you succeed as a student in this course:

- <u>Attend and be present:</u> you are far more likely to succeed if you come to class, prepared (i.e., having done required reading), ready to take well-organized notes, and free of distractions from technological devices
- <u>Draw pictures:</u> when taking notes and solving problems in problem sets, draw large, labelled, and colorful pictures. This will help you ensure that you understand what is being presented in the problem at hand and will help me (and the grader) an additional opportunity to identify gaps in conceptual understanding or misperceptions
- <u>Keep your notes organized:</u> Keep a three ring binder of your notes, returned problem sets, mid-term exams and any handouts. Include dates and page numbers on your lecture notes, put dates on any handouts and integrate
- <u>Take pride in your programming assignments:</u> Use the Markdown cells effectively and frequently in order to provide adequate context and description of your programming. Use Markdown cells to break programming steps into smaller, more self-contained pieces of code/analyses. Label all axes on figures and make sure they are plotted large enough that they can be read by external users and use color effectively.

- Ask questions: I will provide multiple opportunities and modalities for asking me questions, identifying my mistakes, and identifying misunderstandings you might have. At the beginning of every class period I will provide a note card for you to identify the “Muddiest Point” that you encounter during the class period. This will be your “exit ticket” from every class.

Important Dates

Date	Significance
01-08 (Mo)	Classes begin
01-14 (Su)	Drop Fee Begins
01-22 (Mo)	Last date for refund & drop without a W
02-07 (W)	Lejo travel date (guest lecturer)
02-12 (M)	Lejo travel date (guest lecturer)
02-14 (W)	Lejo travel date (guest lecturer)
03-16 (Fr)	Last date to drop with a W
03-26 (M)	No class: Spring Break
03-28 (W)	No class: Spring Break
04-11 (W)	Lejo travel date (guest lecturer)
04-25 (W)	Final day of classes
04-30 (M)	Final exam period (modeling write-up due)

Tentative Class Schedule

Unit	Week	LOs	Reading Chapters	Topics	Assessments
1	1 (1/8)	5	Handouts, BJRL Ch 1	Review learning outcomes; introductions; introduction to Jupyter notebooks; Python	GitHub account
	2 (1/15)	1	BJRL Ch 1	Introduction to time series, forecasting, analysis and estimation	
	3 (1/22)	1, 2, 8	BJRL Ch 2.1	Simple operators; linear filter model; intro to autoregressive processes; hydrologic time series in Python	
	4 (1/29)	2, 3, 8	BJRL Ch 2.2	Stationary stochastic processes; stationarity of linear functions; autocorrelation	Jupyter NB 1 due
	5 (2/5)	3, 4, 8	BJRL Ch 3.1-3.3	Periodogram; spectrum and spectral density function; estimating SDF with data	
	6 (2/12)	4, 8	BJRL Ch 4.1, Ch 4 Appendix	General linear processes, autoregressive processes, moving average processes, developing AR models from data	Jupyter NB 2 due
	7 (2/19)	4, 8	SK Ch 1	ARIMA processes; IMA processes; developing ARIMA models from data	Jupyter NB 3 due
2	8 (2/26)	5, 6	SK Ch 2	Introduction to dynamical models; linear algebra review; linear algebra with numpy	Jupyter NB 4 due
	9 (3/5)	6, 7	SK Ch 3	Introduction to finite difference techniques; accuracy and stability; solving 1D spring and mass problem with FD	
	10 (3/12)	6, 7, 8	SK Ch 4	Introduction to box models and IVPs; finite difference solutions to IVPs; Boise State bucket model as a box model	Jupyter NB 5 due
	11 (3/19)	6, 7	SK Ch 5	One dimensional diffusion problems; FD applications to 1D diffusion problems; solving 1D flow in a homogenous, unconfined aquifer	
	12 (3/26)	SPRING BREAK			
	13 (4/2)	6, 7	SK: Ch 6,7	Multidimensional diffusion problems; FD solutions to multidimensional diffusion problems; advection dominated systems	Jupyter NB 6 due
	14 (4/9)	6, 7	SK: Ch 7	Advection diffusion/dispersion problems; QUICK scheme for solving the transport equation	
3	15 (4/16)	5, 8	Handouts	WRF-Hydro model introduction and practicum; Linux intro; compiling WRF-Hydro	Jupyter NB 7 due
	16 (4/23)	5, 8	Handouts	WRF introduction; WRF-Hydro test case; visualizing WRF-Hydro output	
	17 (4/30)	FINALS WEEK			WRF-Hydro writeup