



Syllabus

Course Information

Course Subject, Number and Title: AI for Sustainability Science ENVIR ST 403

Credits: 3

Credit Hour Explanation: 6 python-based labs, Presentation-leading part of a class, AI proposal, two writing reflection assignments

Course Description: People and the planet are changing at unprecedented speeds- from transgressing planetary boundaries, to increased extreme weather events, to the continued loss of ecosystems and biodiversity, and ever high levels of ocean heat and atmospheric warming. The time to make change and secure a sustainable future for all, is now. Technology is moving just as fast- AI, sensors, and compute power is fundamentally changing society and economies- with accompanying profound ethical and even existential challenges. This course will examine the role of AI in advancing sustainability science, as well as the ethical concerns the methods and energy required to enable it poses for people and the planet. We will begin with foundations of machine learning for those with no prior experience, including classical machine learning (e.g. random forest), classical deep learning such as neural networks, convolutional neural networks (CNN) and long short-term memory networks (LSTMs), and newer AI approaches such as transformers, foundation models, and LLMs (Large Language models). We will review applications of these models in 7 domains of sustainability science, including global risks, earth systems, water management, ocean challenges, biodiversity, urbanization, and collective decision making. The course will include several light programming exercises and labs or homework assignments in Python, but do not require prior programming experience. Homework labs may draw on common dataset types in sustainability science including satellite imagery, geospatial data, temporal climate data, photography, and large bodies of text such as news media and sustainability reports. Tutorials will be provided to those without prior Python experience to ensure it is accessible. Students will be supported to work on a final project alone or in groups or pairs, to propose an application of AI in a sustainability domain or problem of their choice. Ambitious students or groups with programming experience or interest will be supported to pilot an AI model or application with instructor and TA support. Students will leave the course understanding the main modalities of AI used in modern sustainability sciences, and how to review or assess the validity or usefulness of an AI application in the sustainability sciences to solve real problems for people and our planet.

Requisites: none

Course Designations/Attributes: 50% Graduate Coursework Requirement for graduate students

Learning Outcomes

By the end of the semester students will:

- 1) Understand how the dominant AI architectures used in sustainability science work and how to evaluate their effectiveness
- 2) Design an AI “intervention” for a sustainability science problem that is appropriately scoped, with known ethical issues, bias, and risks mitigated
- 3) Be able to engage in relevant debates regarding if AI will ultimately or degrade planetary sustainability, and how to evaluate these questions

Meeting and Instructor Information

Meeting Time and Location: 2:30-3:45pm Mondays and Wednesdays Room 1280 Mechanical Engineering

Instructional Modality: In-person

Instructor Title and Name: Beth Tellman with support from Saurabh Kaushik (postdoctoral scientist who is an AI expert and is supporting labs)

Instructor Contact Information: beth.tellman@wisc.edu, and skaushik8@wisc.edu

Day/Time/Location of Office Hours: Directly after class Mondays and Wednesdays, or Tuesdays 3-5pm in the Enzyme Building 144 (Saurabh and Beth available for live python or lab debugging)

Overview

Materials

Link to Canvas Site: <https://canvas.wisc.edu/courses/501615>

FYI NO CLASS Jan 28, March 18, or April 27

Coursework and Grading

The course is set up mainly to teach an algorithm on Mondays, and demonstrate an application in Sustainability Science on Wednesdays

Assignments/Exams/Other Graded Work:

Labs: There are 6 labs assigned throughout the semester, assigned on a Monday, and due the following Wednesday (e.g. 10 days between lab assignment/lecture regarding the algorithm and

due date). I encourage you to come to office hours or ask questions after class if you get stuck on the labs. You have 10 days to finish each to give you ample time- DO NOT WAIT to start the lab until the night before it is due in case you need programming/debugging help. I encourage you to use LLMs for coding/debugging support, but if you use them to complete the lab you may miss out on the learning opportunity. In order to ensure students understand material, I will be asking students to answer/explain labs after they are due, and these responses will be part of your discussion/participation grade.

Presentation of AI in the world: Each student will sign up to lead a ~10-15 minute presentation with some discussion and Q and A of an example of AI being used to apply to a sustainability concern in the world, or an ethical issue related to an application of AI. Students will sign up for one presentation, and are required to submit either the article, report, website, or example of the AI solution they wish to discuss to the instructor one week before their assigned discussion lead. This is to give both the instructor and students time to prepare for the discussion. Ideally, the example should be related to the relevant chapter of the AI for a Planet Under Pressure report or the algorithm being taught that week, but not a requirement. You may source examples from the AI for a Planet Under Pressure report, but also not a requirement. Choose something that is of interest to you.

Your presentation should

- 1) Describe the algorithm being implemented. If you need, help, ask the instructor.
- 2) What training and evaluation data is used for the algorithm?
- 3) Describe how the algorithm is deployed or why. What problem is it solving? Does it solve a problem more effectively or in a novel way that previous solutions could not provide?
- 4) Describe what you think of the application and its evaluation (give it a critique)
- 5) Go over any ethical concerns regarding bias, cost, carbon emissions, or anything else.

Final Project:

For your final project you will design an AI intervention to address a sustainability concern.

Your written project and presentation should address

1. Why your problem is important
2. Why AI can uniquely address the problem of concern
3. What algorithm you propose to use and how it works
4. The data you plan to use to train and evaluate the algorithm
5. How the AI solution will be deployed
6. What ethical issues or concerns you have and how they will be mitigated
7. The project team and design required to implement the solution in an 18 month time frame.

Your project will be written as a pitch/grant to a funder. I will provide the call for proposals from the Klarna/Milkywire AI for Climate Resilience program (<https://www.milkywire.com/ai-for-climate-resilience-program>) and the criteria we used to select projects (I was an advisor for the program). The criteria will be made available and I will use it as a rubric for grading. Check out the 6 projects on their website as good examples. You may also choose to structure your final project around the Climate Change AI Innovation Grants

(https://www.climatechange.ai/innovation_grants?) check out their 22 project and grant calls from 2022, 2023 , and 2024. I was awarded a grant through this program and will make my proposal available as an example on canvas. Final project would be about 5 pages of single spaced 12 point font text.

If you do not want to design an AI intervention but rather write a paper of equivalent length about AI ethics/bias or data centers on a relevant sustainability issue, I am also open to that option.

Outlines of your project (one page or ~500 words) are due April 8

Final presentations are in class April 29

Written project reports are due Tuesday May 5

Course Feedback:

In addition to the course evaluation at the end of the semester, I will elicit feedback at two points during the semester to improve the pace of the course, the labs, my teaching, and take feedback on suggestions to improve the classroom experience. I welcome at any time articles you think would be important in topics we will cover that are not currently on the reading list- just let me know after class or in an email!

Grades:

40% labs (6 total)

10% reflection papers (one on ethics/data centers, and another on AI and water from the Symposium)

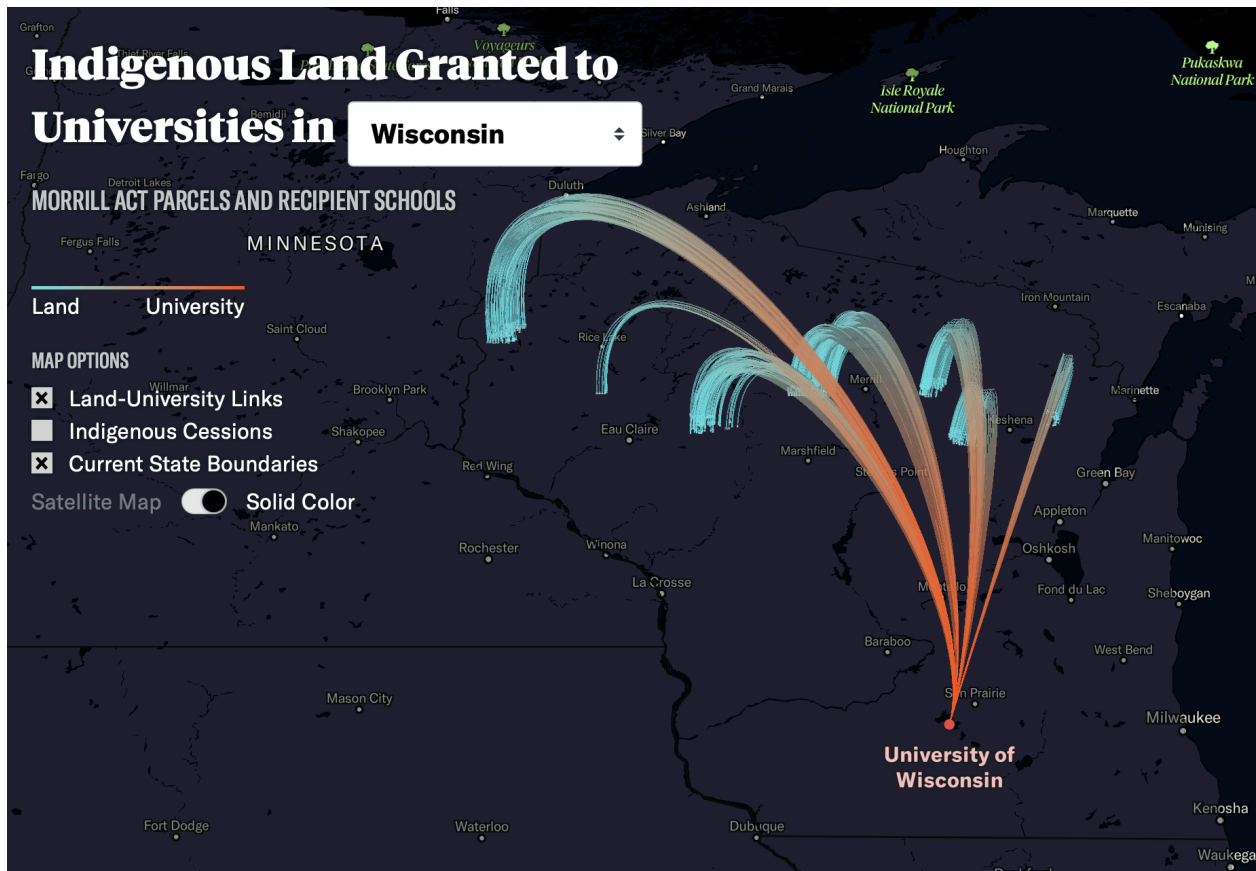
25% participation (leading discussion for AI in the world, attending class, answer lab questions/discussion)

25% Final project

Grading: A, AB, B, BC, C, or S

Land Acknowledgement

The University of Wisconsin has financially benefited from at least 235,530 acres of expropriated Indigenous land which was not paid for and resulted in raising over 4.9 M USD for its endowment in 1862. The university campus in Madison sits on ancestral Ho-Chunk land. The Morrill Act of 1862 granted the University of Wisconsin 235,530 acres of land taken through the 1837 Treaty with the Chippewa (Ojibwe), the 1842 Treaty with the Chippewa of the Mississippi and Lake Superior (Ojibwe), and 1831, 1836, and 1848 Treaties with the Menomini (Menominee). - see: <https://www.hcn.org/issues/52.4/indigenous-affairs-education-land-grab-universities> for more and download the university land grab data here: <https://github.com/HCN-Digital-Projects/landgrabu-data>. Kasey Keeler and others at UW received an NEH grant in 2023 to document this more extensively and are generating teaching modules on the topic: <https://news.wisc.edu/teaching-indigenous-land-dispossession-in-wisconsin-and-beyond/>



From: <https://www.landgrabu.org>, High Country News

Class Anti-Discrimination Policy

“As a classroom community, our capacity to generate excitement is deeply affected by our interest in one another, in hearing one another’s voices, in recognizing one another’s presence.”
 — bell hooks, [Teaching To Transgress: Education as the Practice of Freedom](#)

I encourage you to bring your whole self to the classroom, and to actively make the classroom a respectful place so that others can bring their whole selves if they desire to do so. We will learn more by welcoming a diversity of perspectives and life experiences. Creating a respectful space and being anti-racist is an intentional act. Racism, discrimination, and microaggressions will not be tolerated. If you feel another student, or the instructor has done or said something disrespectful to you or others please let me know to address the issue. You may also say “oops” or “ouch” if something says something you feel is disrespectful during class to let them know. If you unintentionally make a comment that may feel like a microaggression, racist, or disrespectful, and someone points it out, I invite you to gratefully accept the learning experience.

Draft Course Schedule

Jan 21 **Going over the Syllabus and What is AI?**

Jan 26 **Taxonomy of AI for the Sustainability Sciences**

Read: pages 2-34 and pages 65-70 of AI for a Planet Under Pressure

Jan 28 **NO CLASS- Beth at American Meteorological Association Conference**

Feb 2 **Introduction to Python, Pytorch, and Scikit Learn**

Lab 1 assigned- due Feb 11

Feb 4 **AI model evaluation**

AI in the world Presentation with Matyas Toulec:
<https://www.youtube.com/watch?v=rzjgFoW98kc>

Simon Prince Understanding Deep Learning Chapters 1 (1.1-1.3), 2, and 8 (8.2.1; 8.3; 8.6) pages 1-11; 17-22; 122-127; 133-136)

Watch AssemblyAI's review of How to Evaluate ML Models:
<https://www.youtube.com/watch?v=LbX4X71-TFI>

Rolf, E. Evaluation Challenges for Geospatial ML. Preprint at
<https://doi.org/10.48550/arXiv.2303.18087> (2023).

Watch Andrew Ng's review of Linear Regression:
[youtube.com/watch?v=fusSss43jD8&list=PL2qEL_7r0QITYMa5FcJMB8Pw0sEggqO-M&index=1](https://www.youtube.com/watch?v=fusSss43jD8&list=PL2qEL_7r0QITYMa5FcJMB8Pw0sEggqO-M&index=1)

Feb 9 **Random Forest**

Goodfellow 2015. Chapter 5, Machine Learning Basics pages 137-142 (section 5.7)

Watch Andrew Ng's review of Linear Algebra:
https://www.youtube.com/playlist?list=PL2qEL_7r0QISg3wu4D_j9xRJodZsfjBEu

Random Forest Classification with Scikit-Learn (blog):
<https://www.datacamp.com/tutorial/random-forests-classifier-python>

Lab 2 assigned, due Feb 18

Feb 11 **Preparing for a Future of Interconnected Shocks, guest speaker Hannah Friedrich**

Chapter 1, AI for a Planet Under Pressure, p 27-29.

Friedrich, H. K., B. Tellman, J. A. Sullivan, et al. “Earth Observation to Address Inequities in Post-Flood Recovery.” *Earth’s Future* 12, no. 2 (2024): e2023EF003606. <https://doi.org/10.1029/2023EF003606>.

Friedrich, H.K., September 8 2023. **Mapping tarps and stories to spotlight inequitable disaster recovery.** CLIMAS blog. <https://legacy.climas.arizona.edu/blog/mapping-tarps-and-stories-spotlight-inequitable-disaster-recovery.html>

Ahvo, Aino, Matias Heino, Vilma Sandström, Daniel Chrisendo, Mika Jalava, and Matti Kummu. “Agricultural Input Shocks Affect Crop Yields More in the High-Yielding Areas of the World.” *Nature Food* 4, no. 12 (2023): 1037–46. <https://doi.org/10.1038/s43016-023-00873-z>.

Feb 16 DBSCAN and clustering

Soni, Sachin. Dev 26 2023. Clustering Like a Pro: A Beginner’s Guide to DBSCAN <https://medium.com/@sachinsoni600517/clustering-like-a-pro-a-beginners-guide-to-dbscan-6c8274c362c4>

Feb 18 Understanding a Complex Earth System

AI in the world presentation with MJ Diaz:

Barreto, Joan Sebastian, and Dolors Armenteras. “Open Data and Machine Learning to Model the Occurrence of Fire in the Ecoregion of ‘Llanos Colombo–Venezolanos.’” *Remote Sensing* 12, no. 23 (2020): 3921. <https://doi.org/10.3390/rs12233921>.

Chapter 2, AI for a Planet Under Pressure, p 32-36.

Harteg, Jakob, Lukas Röhrich, Kobe De Maeyer, et al. “TOAD v1.0: A Python Framework for Detecting Abrupt Shifts and Coherent Spatial Domains in Earth-System Data.” Preprint, Climate and Earth system modeling, January 29, 2026. <https://doi.org/10.5194/egusphere-2026-356>.

TOAD package Github: <https://github.com/tipmip-methods/toad?tab=readme-ov-file>

Feb 23 Neural Nets

- Free range statistics: Extrapolation is tough for trees (blog)
- Neural Networks Vs. Random Forests (Peter Robbach (blog)

Prince 2025. Understanding Deep Learning Chapters 3 and 4 (pages 25-52- skim and focus more on network graphs like 4.6 and less on the equations themselves).

Videos

- 3Blue1Brown: But what is a neural network? (~18 mins)

Optional Videos for more!

- 3Blue1Brown: Gradient Descent, how neural networks learn (~20 mins)
- 3Blue1Brown: Backpropagation, step-by-step (~12 mins)

- 3Blue1Brown: Backpropagation calculus (~10 mins)

Lab 3 assigned, due March 4

Feb 25 Enhancing Nature's Contributions to People

Chapter 5, AI for a Planet Under Pressure, p 45-49.

Andermann, Tobias, Alexandre Antonelli, Russell L. Barrett, and Daniele Silvestro. "Estimating Alpha, Beta, and Gamma Diversity Through Deep Learning." *Frontiers in Plant Science* 13 (April 2022): 839407. <https://doi.org/10.3389/fpls.2022.839407>.

Student AI in the world presentation:

Leorna, Scott, and Todd Brinkman. "Human vs. Machine: Detecting Wildlife in Camera Trap Images." *Ecological Informatics* 72 (December 2022): 101876. <https://doi.org/10.1016/j.ecoinf.2022.101876>.

March 2 Convolutional Neural Networks

Prince 2025. Understanding Deep Learning Chapter 10 pp 161-179 (note we are skipping 5, 6, 7, and 9 which you can go back to if a term comes up you don't understand, Ill summarize key points in lecture however).

FastAI Book. Ch 13 – Convolutional Neural Networks
<https://fastai.github.io/fastbook2e/convolutions.html>
-focus on questions 1-11 which we will discuss in class

Water: The U-Net (actually) explained in 10 minutes by Rupert AI (~ 10 mins)
<https://www.youtube.com/watch?v=NhdzGfB1q74>

Lab 4 assigned, due March 11

March 4 Stewarding our Blue Planet

Chapter 3, AI for a Planet Under Pressure, p 37-40.

Kroodsma, David A., Juan Mayorga, Timothy Hochberg, et al. "Tracking the Global Footprint of Fisheries." *Science* 359, no. 6378 (2018): 904–8. <https://doi.org/10.1126/science.aao5646>.

March 9 and 11 Long Short-Term Memory Networks

Lab 5 assigned, due March 18

Olah, Christopher, 2017. Understanding LSTM networks. <https://colah.github.io/posts/2015-08-Understanding-LSTMs/>

Prince 2025. Understanding Deep Learning Chapter 11 pp 186-199

Goodfellow 2010. Chapter 10 (Sections 10.1, 10.2, 10.7, 10.10), pp 367-387; 396-407

Student AI in the world presentation:

Guo, Qingchun, Zhenfang He, and Zhaosheng Wang. “Monthly Climate Prediction Using Deep Convolutional Neural Network and Long Short-Term Memory.” *Scientific Reports* 14, no. 1 (2024): 17748. <https://doi.org/10.1038/s41598-024-68906-6>.

March 16 Ethics, Bias, and Emissions, Guest Speaker Jennifer Jones- Data Centers and American Indian Land, Energy, and Policy

Galaz, Victor. “Algorithmic resistance for people and planet.” Chapter 9 in *Dark Machines: How Artificial Intelligence, Digitalization and Automation is Changing Our Living Planet*. Taylor & Francis, 2024.

Podcast: Agents of Change “*What would a just energy transition look like for US tribes?*” <https://www.ehn.org/tribal-energy-justice> ([Spotify link](#))

Washington Post: “*In the Shadows of Arizona’s data center boom, thousands live without power*” <https://www.washingtonpost.com/technology/2024/12/23/arizona-data-centers-navajo-power-aps-srp/>

Assignment, Due March 23- one page reflection/op-ed on what you think the biggest issues are with AI in terms of Ethics, Bias and/or Emissions for Sustainability.

Optional:

Federal officials are encouraging Tribes to partner with Data Centers <https://www.kjzz.org/indigenous-affairs/2026-02-17/federal-officials-are-encouraging-tribes-to-partner-with-data-centers>

Op-Ed: Wisconsin’s unfolding energy crisis <https://wisconsinexaminer.com/2026/02/19/wisconsins-unfolding-energy-crisis/>

March 18 no class Beth at American Association of Geographers Conference

March 23 Securing Freshwater for All

Chapter 4, AI for a Planet Under Pressure, p 41-44.

Nearing, Grey, Deborah Cohen, Vusumuzi Dube, et al. “Global Prediction of Extreme Floods in Ungauged Watersheds.” *Nature* 627, no. 8004 (2024): 559–63. <https://doi.org/10.1038/s41586-024-07145-1>.

March 25 Transformers and Embeddings and LLMs

The moment we stopped understanding AI [AlexNet] by WelchLabs (~17 mins)

Smith, Emily, 2025. **CNN vs. RNN vs. LSTM vs. Transformer: A Comprehensive Comparison.** <https://medium.com/@smith.emily2584/cnn-vs-rnn-vs-lstm-vs-transformer-a-comprehensive-comparison-b0eb9fdad4ce>

CloudFlare. **What are embeddings in machine learning?**
<https://www.cloudflare.com/learning/ai/what-are-embeddings/>

Jean and Wang. 2019. **Tile2Vec: Unsupervised representation learning for spatially distributed data** <https://ermongroup.github.io/blog/tile2vec/>

RoboFlow. **Comprehensive Guide to Vision Transformers** <https://blog.roboflow.com/vision-transformers/>

Student AI in the world presentation 1:

Conley, Gary, Stephanie Castle Zinn, Taylor Hanson, Krista McDonald, Nicole Beck, and Howard Wen. “Using a Deep Learning Model to Quantify Trash Accumulation for Cleaner Urban Stormwater.” *Computers, Environment and Urban Systems* 93 (April 2022): 101752.
<https://doi.org/10.1016/j.compenvurbsys.2021.101752>.

Spring Break

April 6 Improving Sustainability Science Communication

Student AI in the world presentation:

Utku, Anil. “From Trash to Technology: Ai-Driven Waste Classification with Hybrid CNN-Transformer Approach for Sustainable Recycling.” *Journal of Material Cycles and Waste Management* 28, no. 1 (2026): 253–69. <https://doi.org/10.1007/s10163-025-02411-4>.

Chapter 7, AI for a Planet Under Pressure, p 56-60.

Kuznetsov, Ivan, Antonia Anna Jost, Dmitrii Pantiukhin, Boris Shapkin, Thomas Jung, and Nikolay Koldunov. “Transforming Climate Services with LLMs and Multi-Source Data Integration.” *Npj Climate Action* 4, no. 1 (2025): 97. <https://doi.org/10.1038/s44168-025-00300-y>.

April 8 Agentic and Reinforcement Models+ Collective Decisions for a Planet Under Pressure

Student AI in the world presentation:

Chapter 8, AI for a Planet Under Pressure, p 61-64.

Arroyo, Blum, Bene, and Figueroa. 2022. Building Control with RL using BOPTTEST. Climate Change AI Tutorials. https://github.com/climatechange-ai-tutorials/building-control-boptest/blob/main/Building_Control_with_RL_using_BOPTTEST.ipynb

Salesforce. The AI Economist. 2020. <https://www.salesforce.com/blog/the-ai-economist/>

Zhang, Tianyu, Andrew Williams, Soham Phade, et al. “AI for Global Climate Cooperation: Modeling Global Climate Negotiations, Agreements, and Long-Term Cooperation in RICE-N.” *Proceedings of the 42 Nd International Conference on Machine Learning, Vancouver, Canada*, ahead of print, 2025. <https://doi.org/10.2139/ssrn.4189735>.

Watch a 3 minute video of the RICE-N model here: <https://icml.cc/virtual/2025/poster/45380>

13 min video: What's next for AI agentic workflows ft. Andrew Ng of AI Fund 2025. <https://www.youtube.com/watch?v=sal78ACtGTc>

April 13 Foundation Models

AI for a Planet Under Pressure, p 31-32.

Adeel, Hassan. 2025. Exploring AlphaEarth Embeddings. *Element 84 Blog*. <https://element84.com/machine-learning/exploring-alphaearth-embeddings/>

Walczak, Sebastian, 2025. AI Foundation Models for Geospatial and Earth Observation: A New Era of Earth Understanding. *Geoawesome* <https://geoawesome.com/ai-foundation-models-for-geospatial-and-earth-observation-a-new-era-of-earth-understanding/>

Lab 6 assigned, due April 22

April 15 Prospering on an Urban Planet

Chapter 6, AI for a Planet Under Pressure, p 50-55.

Kaushik, Saurabh, Lalit Maurya, Elizabeth Tellman, and ZhiJie Zhang. “Assessing the Value of Geo-Foundational Models for Flood Inundation Mapping: Benchmarking Models for Sentinel-1, Sentinel-2, and Planetscope for End-Users.” *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing*, ahead of print, 2026. <https://doi.org/10.1109/JSTARS.2026.3656855>.

April 20 Course Summary

April 22 Class at Water@UW Symposium at the Holt Center

<https://water.wisc.edu/event/spring-symposium-2026/>

Assignment- one page reflection on best AI for water solution, or an idea you have based on a problem discussed.

April 27 no class Beth at International Conference on Learning Representations Machine Learning for Remote Sensing Workshop

April 29 Final Project Pitches

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