AAEC/FREC/GEOG 5544 – Remote Sensing in the Social Sciences

Virginia Tech
Fall 2026

Instructor: Dr. Elinor Benami (Office: 540-231-1147)
Teaching Assistant: Muna Khatiwada (munak@vt.edu)
Course Meeting Time: Mon. & Wed. 2.30 - 3.45PM in Undergraduate Science Laboratory Building 310
Labs: Wed. 4.00 - 5.15pm in Undergraduate Science Laboratory Building 210
Student Advice (Office) Hours with Muna: Wed. 10am - 11am, Thurs. 4 - 5pm, and by appt
Student Advice (Office) Hours with Elinor: Tues. 2 - 3pm, Thurs. 9 - 10am, and by appt
Credits: 4

1 Course Summary and Objectives

The increasing accessibility of frequently updated geospatial information from remote sensors is enabling novel ways to detect changes in environmental conditions, communities, and even cash flows. This geospatial data revolution has in turn been opening up new ways of enhancing environmental compliance, supporting sustainable development efforts, and even managing crisis relief logistics. Yet, the increasing accessibility also comes with the peril of potential misuse, however, and the possibility to bamboozle instead of enlighten. This graduate level course examines how remotely sensed data have and can be used in social science research, with a focus on the practical deployment of publicly available remote sensing data for applications in environment, agriculture, and economic development. By the successful completion of this course, you should be able to:

1. Distinguish the meaning and importance of core remote sensing principles relating to the electromagnetic spectrum, sensor resolution, data types, and processing techniques.
2. Apply basic spatial data wrangling (i.e., extracting, cleaning, visualization, and communication) skills to evaluate social science research questions.
3. Assess the fundamental challenges that spatial data can present for social science research as applied to important social issues such as deforestation, pollution, and economic development.
4. Evaluate the research designs and analytic methods used in recent publications across fields, including scholarship from engineering, as well as the natural and social sciences.
5. Integrate findings and approaches from seminal as well as current scholarship into a well-justified and empirically grounded research project using remotely sensed data.

2 Readings and Course Materials

Course Readings: This course will draw upon portions of three primary textbooks:

- Jeffrey A Cardille et al. (2023). *Cloud-based remote sensing with google earth engine: fundamentals and applications*. Springer Nature.
- J.B. Campbell, R.H. Wynne, and V.A. Thomas (2023). *Introduction to Remote Sensing*. 6th ed. Guilford Press
- J.A. Richards (2022). *Remote sensing digital image analysis*. 6th ed. Springer

These texts (abbreviated EEFA, CWT, and JR in the Detailed Readings) cover many foundational concepts of remote sensing and digital image analysis. As a graduate course, we will also draw upon a variety of recent academic articles that apply remote sensing in the pursuit of assessing the extent and impact of issues such as deforestation, pollution, agriculture, and economic development. A preview of these readings can be found in the Detailed Readings section.

Gradescope
We will use Gradescope for several assignments and labs due to additional features it offers, including easily-updatable rubrics and anonymous grading that allow for faster, more consistent, and fairer evaluations. You should automatically be enrolled in gradescope through integration with the course roseter, though if you need to self-register for gradescope for our class for any reason, use the entry code "**4DNVKB**".

Student Appointments (Open Question Hours) I'm happy to meet with my students and encourage you to come by *at least* once in the semester. You can meet with me in groups or individually to discuss a number of things, such as clarifying a reading or topic, asking for feedback on a project, discussing accommodations you might need if you're having challenges outside of this class, discussing future plans, seeking out research opportunities related to the class or work I do, etc. I have time dedicated for students in this class, which can be either via zoom or in person You can also reserve twenty minutes at a time here: `https://tinyurl.com/5544officehours`, and if none of these times work for you, feel free to contact me with 2-3 alternative times that do.

Prerequisites: We will be dissecting several empirical economics papers in this course. Although not required, a background with microeconomic theory and econometrics will help make this content more easily and quickly understood. Come speak with me at the beginning of the semester if you have concerns about this content so we can develop a strategy for you to keep up.

3 Software

Google Earth Engine As soon as possible, you should sign up for an account with google earth engine (https://earthengine.google.com/signup/). **You should use a non-VT email address to sign-up**, and it may take up to 1-2 days for approval. Google Earth Engine (GEE) is a cloud-based computing platform hosted by Google and is important resource that we will use in our course labs. GEE provides direct access to a multi-petabyte catalog of satellite imagery and geospatial datasets, including the entire EROS (USGS/NASA) Landsat catalog, MODIS, NAIP, and Sentinel-1 imagery, and precipitation, elevation, sea surface temperature, and CHIRPS climate data, among others. However, beyond simply being an image archive, GEE also provides APIs for JavaScript and Python to enable researchers to perform planetary-scale analysis of the Earth's surface. GEE is free for research, education, and nonprofit use.

4 Evaluation

Grades will be determined based on the following activities:

1. *Reading Responses (15%)*: An important part of this course—and scholarly work more broadly—involves becoming comfortable engaging with scientific research. A portion of your grade will come from weekly reading responses to papers related to course content. You are expected to demonstrate in both written and oral forms that you can concisely capture the key contributions of the paper and start generating critiques or extensions. Each week, you will submit a short write-up on at least one paper, and we will rotate through class participants for presentations (sign-ups will occur at the beginning of the semester).

2. *Quizzes (15%)*: To encourage synthesis of course materials and enable course adjustment as needed, we will have two quizzes throughout the course of the semester. The first (listed as the *Midterm on Remote Sensing Fundamentals* in the Course Outline) will come at the end of the 'remote sensing basics' section of the course, in Week 5 (week of Sep. 21; exact day to be announced in class), to shore up the foundational concepts we cover. The second will occur in person in Week 13 (week of Nov. 16; exact day to be announced in class) to wrap up the course content, and will emphasize the synthesis of principles for the application of remotely sensed data in social science research, based primarily on the labs, course readings, and discussions. There is no exam during the final exam period; instead, the final project report serves as the course capstone and is due by the end of our scheduled final exam slot (Sat, Dec. 12, 5:25PM).

3. *Labs (30%)*: We have six graded labs – see the Lab Outline for more details on the goals for each. The remaining lab meetings will be dedicated to support you in completing your projects.

4. *Term Project (30%)*: Each student in the course will complete a term project in which you propose and begin executing an original analysis using remotely sensed data. This is not a proposal on paper alone: you will conduct real empirical work with the data you propose to use, and the final report should read like the first draft of a research paper – one that could grow into a thesis chapter, a conference paper, or part of a future dissertation proposal. In your final project report, you are expected to (1) explain and motivate the question you're interested in (2) outline the structure of the argument or approach you take that draws upon remotely sensed data – including the variables you use and any assumptions required (3) demonstrate familiarity with some of the core problems or literature you expect to confront (4) present preliminary empirical results from executing the approach you lay out, along with the critical summary and results graphics you would intend to develop further. The 30% will be cumulative, generated from the following milestones:

Milestone	**Value**	**Week**	**Due**
Topic ideas/"pitch"	0%	3	Wed, Sep. 9
Project outline due & in-class discussion	5%	8	Wed, Oct. 14
Preliminary results and rescoping	5%	12	Wed, Nov. 11
Presentation	10%	14	Mon, Nov. 30 & Wed, Dec. 2
Final project report	10%	15	Sat, Dec. 12 by 5:25PM (in lieu of a final exam)

For applied examples in this genre, think of a first draft of a research paper: an extended conference paper, a write-up for an advisor demonstrating a paper topic is worth pursuing, the pilot analysis behind a dissertation chapter, etc.

5. *Engagement & Advancing the Conversation (5%)*: Throughout the course I expect you to engage in the course content and share your learning with your classmates. This engagement may manifest in several ways, including (1) posting relevant topics from ongoing news on our course discussion board (2) asking questions in class or on our course discussion board, and/or responding constructively to others' questions in those fora (3) being responsive and active participants in class activities.

6. *Syllabus Reflection (5%)*: To help the teaching team get to know you better and gauge where the class is starting from, in the first week of class you will be asked to complete a survey in which you will share a bit more of your academic background as well as reflect on some of the highlights of this syllabus as it pertains to your research and semester plans. The beginning of the course survey is linked here.

7. *Course Evaluations (Bonus 2%)*: Course evaluations are important for assessing student perceptions of the course and improving course quality, yet nonrandom response bias can dilute the value of them. We'll have a near-end-of term evaluation (SPOT evaluations) and a more customized evaluation after all the course assignments (including the final) are completed. While the content of these surveys will be anonymized, I can see the submission rate. To help overcome non-sampling errors, if the submission rate exceeds 80% of the enrolled course participants, everyone will receive a bonus 2% to their final grades.

Grading

I assume everyone is here because you anticipate it will be useful for your research and professional development, and in graduate school, as long as you continue to meet the general requirements of your program, your research and publications typically matter far more than your grades anyway. That said, the university still requires grades, which will follow the below standard grading schema used by Virginia Tech:

$\geq$ 93 A	90–92 A−	87–89 B+	83–86 B	80–82 B−	77–79 C+
73–76 C	70–72 C−	67–69 D+	63–66 D	60–62 D−	$<$ 60 F

Pass-Fail is also certainly for an option for this course, too. Fundamentally, I believe that with some effort and planning, everyone can master the essential components of this class. Reach out to the instructional team and your classmates to overcome stumbling blocks you perceive in your pursuit of content mastery. The earlier you connect, the more options are available to address your questions.

5 Course Policies

Class Attendance

Regular attendance is expected as well as beneficial to course discussion. Although we will not formally be taking attendance in every class, notable lack of participation can affect your 'engagement' grade. If you think you may be unwell, however, please do not come to class and reach out to the instructor as soon as is feasible.

Late Submissions

Prompt submission of assignments allows the instructional team to provide timely feedback and adjust the course content as appropriate. Due dates for each assignment are noted on the course calendar. Work turned in by the due date, as evidenced by the date stamp on submission, will be considered on time and will receive full credit. Any assignments submitted after the due date will receive 20% grade deduction per day past the due date. No late assignments will be accepted 48 hours after the deadline. In lieu of penalty, you may also apply a slip day to the assignment. All students have four "**slip**" days that can be used for any assignment in the course with the exception of exams and project deadlines. Your slip days will be automatically applied in the way most favorable to you at the end of the course – you do not need to ask for them.

Honor Code

While I strongly encourage you to work in groups and help tutor each other on concepts and examples, all work submitted in this course must be of your own production, and all sources must be properly acknowledged and documented. Failure to acknowledge your sources, whether deliberate or not, constitutes plagiarism. If you have questions about this policy, please reach out. I will appreciate your efforts to behave with integrity and will be happy to help.

The tenets of the Virginia Tech Graduate Honor Code apply in this course, and all assignments shall be subject to the stipulations of the Graduate Honor Code. For more information on the Graduate Honor Code, please refer to the GHS Constitution located at https://graduateschool.vt.edu/academics/expectations/graduate-honor-system.html

Policy on ChatGPT, Copilot, Claude, Gemini, and other AI assistants

I anticipate that understanding the capabilities of AI assistants and their limitations/drawbacks will be an important part of your lives and careers. Thus, you are permitted to use AI assistant tools, though you will be responsible for flagging that you used them in your materials, indicating what prompts you used in your final submissions, and more broadly take responsibility for all the outputs generated.

Furthermore, while you are permitted to use such tools to address conceptual questions on assignments, you are discouraged from doing so, especially as it will get some of these questions right and some of them wrong. These questions are meant to deepen your understanding of the course content, and relying on AI assistants for your answers will negatively impact your learning and using your own logic and skills developed in this class to address questions presented to you. In summary:

- You may use AI assistants to help you edit text **based on your own ideas**.
- You must document that you used an AI Assistant and the prompts you used.
- You are responsible for all content generated.
- You are discouraged from using AI assistants for questions relating to interpretation.

Accessibility
Virginia Tech welcomes students with disabilities into the University's educational programs. The University promotes efforts to provide equal access and a culture of inclusion without altering the essential elements of coursework. If you anticipate or experience academic barriers that may be due to disability, including but not limited to ADHD, chronic or temporary medical conditions, deafness or hearing impairment, learning disabilities, mental health, or vision impairment, please contact the Services for Students with Disabilities (SSD) office (540-231-3788, ssd@vt.edu, or visit www.ssd.vt.edu). If you have an SSD accommodation letter, please meet with me privately during office hours as early in the semester as possible to deliver your letter and discuss your accommodations. You must give me reasonable notice to implement your accommodations, which is 5 business days generally and 10 business days for final exams or projects.

Emergency Well-Being Resources (Lauren's Promise)
I will listen and believe you if someone is threatening you. Any form of harassment or violence will not be excused or tolerated at VT. If you are in immediate danger, call 911. If you are experiencing harassment, relationship violence, or stalking, you can report it to me, and I will (and am obligated to) connect you to resources such as VT's Office of Equity and Accessibility, which has established procedures and resources for Sexual Misconduct Response and Prevention, detailed here: https://oea.vt.edu/title-ix-vawa.html. You may also contact a 24-7 emergency evaluation and crisis intervention team from the NRVCS (New River Valley Community Services) Emergency Services line at 540-961-8400.

Other University Resources
Virginia Tech has an array of resources available to students at low or no additional cost, including writing support, mental health services, or career counseling. I've included some of these resources below, and I ask that you please help share others in our class discussion page that you've found helpful and that your classmates might, too.

- Geospatial Data Services at VT https://guides.lib.vt.edu/geospatialdata
- Writing Center: https://lib.vt.edu/study-learn/writing-center.html
- Cook Counseling Center: https://ucc.vt.edu/
- Career and Professional Development Advising: https://career.vt.edu/advising.html

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Many thanks to Robert Heilmayr, Sam Heft-Neal, Ani Ghosh, Andrew Hobbs, Matthieu Stigler, Yohtaro Kobayashi, and Randy Wynne for providing feedback on the reading lists for this syllabus in ways that helped improve its coverage.

6 Course Outline

The below is subject to change at the discretion of the instructional team.

Week of	#	Lecture Topic	Labs and Assignments
Aug-24	1	Intro to the Course. Basics of Earth Observation, the electromagnetic spectrum, & RS data	Lab 1: Remote Sensing Basics and Intro to GEE
Aug-31	2	Spatial Data Formats & Types; Geocomputation; Ethics	Lab 2: Digital Imagery and Image Processing
Sep-7	3	Spectral Indices & Transformations; Classification; Accuracy Assessment; Smoothing & Edge Detection **(no class Mon 9/7, Labor Day)**	Lab 3: Spectral Indices and Transformations and *Project Topics Due*
Sep-14	4	Change Detection and Applications: Forests and Land Cover Change	Lab 4: Classification & Regression
Sep-21	5	Nonclassical Measurement Error, Censoring, and Scale within the context of Land Use Classification and Change Detection	*Midterm on Remote Sensing Fundamentals*
Sep-28	6	Time Series Analysis and crop phenology, with applications to agriculture	Lab 5: Time Series
Oct-5	7	***No Class – work on project outlines. Fall Break: Fri, Oct 9***	
Oct-12	8	Weather Data, with an emphasis on uses and mis-uses of (interpolated) and gridded data on temperature, precipitation, and soil moisture for agricultural applications	*Project Outline Due*
Oct-19	9	Economic Development: Night Lights, Daylights, Conflict	Lab 6: Applications
Oct-26	10	Aerosol optical depth and its uses for varying kinds of smog, haze, desert dust	
Nov-2	11	Seeing Beyond the Visible: Thermal & IR analysis, with applications to fire and air pollution	
Nov-9	12	Seeing Beyond the Visible: Gravimetric modeling (e.g., water availability) & the physics of active sensing (RADAR, LiDAR, SAR)	*Project Prelim Results Due*
Nov-16	13	Active sensing applications: (1) flood & sea-level risk (2) oil spills (3) building height/population (4) soil moisture & groundwater	*Quiz 2: Course Content Wrap-Up*
Nov-23		**Thanksgiving Break (Nov 21–29)**	
Nov-30	14	Student Presentations on Term Projects, Open Topics	
Dec-7	15	Work on Final Project Reports – (*AGU week; last class Wed 12/9*)	
Dec-12		**Sat: Final Project Reports Due by 5:25PM (in lieu of a final exam)**	*Final Project Reports Due*

7 Lab Outline

Title	Description
1: Remote Sensing Basics & Intro to GEE	Overview of remote sensing, its underlying theory, and how it can be accessed through/used in Google Earth Engine for research. On completion, you'll know the basics of remote sensing, GEE, and the JavaScript syntax. **GEE data structures:** Strings, Numbers, Lists, Arrays, Objects, Functions **EEFA Section**: F1.0
2: Digital Imagery & Image Processing	Search, find, and visualize remotely sensed imagery in GEE and visualize remote sensing concepts introduced in prior lab. By completion, you should be able to distinguish between radiance and reflectance, load imagery, make true color and false color composites, and visually identify land cover types based on spectral characteristics. **GEE skills:** Importing, Exporting, Assets, Sorting, Expressions **EEFA Section**: F1.1, F1.2, F1.3
3: Spectral Indices & Transformations	Extract, visualize, combine, and transform spectral data in GEE to highlight and indicate the relative abundance of particular features of interest from an image. At completion, you should be able to describe the difference between wavelengths, load visualizations displaying relevant indices, discuss the use of spectral transformations, and compute and examine image texture. **GEE Skills:** Clipping, Masking, Reducing **Resources:** David Moaza's Spectral Index Table **EEFA Section**: F2.0
4: Classification & Regression	Introduction to classification, including exploring the processes of (a) training data collection (b) classifier selection and training (c) image classification and (d) accuracy assessment. At completion, you should be able to apply these skills to assess change in a given area. **GEE Skills:** Band Math, Hyperparameter tuning, Change Detection **EEFA Section**: F2.1, F2.2, F3.0
5: Time Series	Establish a foundation for analyzing time series of remotely sensed data, usually in the form of a temporally ordered stack of images. You will be introduced to concepts of smoothing, interpolation, linear modeling, and phenology. By completion, you should be able to perform analysis of multi-temporal data for evaluating trends and seasonality. **GEE Skills:** Map/Reduce II to Calculate Statistics, Time Series Charts **EEFA Section**: F4
6: Applications of Remote Sensing	This lab will highlight cases of applied remote sensing analyses. **EEFA Section**: A1, A2, A3 (Part II)

8 Detailed Readings

**** Indicates Required.** All other references are provided as further background in the topic.

Week 1: Aug 24

Introductions, Basics of Earth Observation, the Electromagnetic Spectrum, Orbits, and Resolution four ways (spatial, temporal, spectral, radiometric)

- CWT Ch 1-2 **
- JR Ch 1
- Mark Monmonier (2018). *How to lie with maps*. *Third Edition. Note: Humorous yet critical view of how the conscious and unconscious decisions of map-makers present but one of many stories about the place depicted.* University of Chicago Press. [Focus on the Intro and Chapter 12 "Image Maps: Picture That"] **
- Morgan A. Crowley et al. (2023). "Pillars of Cloud-Based Earth Observation Science Education". *AGU Advances* 4.4, e2023AV000894. DOI: 10.1029/2023AV000894 [Short read that outlines some of the principles relating to our course design and objectives] **
- Josh Gray (Apr. 2021). *What Economists Should Know About Remote Sensing*. Excellent video of about 1 hour 15 minutes for the NC State Center for Geospatial Analytics. URL: https://youtu.be/DMbUtFSznvo **
- Mia M. Bennett et al. (2024). "Bringing Satellites Down to Earth: Six Steps to More Ethical Remote Sensing". *Global Environmental Change Advances* 2, p. 100003. DOI: 10.1016/j.gecadv.2023.100003
- Michael A Wulder et al. (2022). "Fifty years of Landsat science and impacts". *Remote Sensing of Environment* 280, p. 113195

Week 2: Aug 31

Spatial Data Literacy: Data Formats & Types; Geocomputation; Ethics

- CWT Ch 5, 6 **
- JR Ch 2-4
- Noel Gorelick et al. (2017). "Google Earth Engine: Planetary-scale geospatial analysis for everyone". *Remote Sensing of Environment* 202, pp. 18–27 **

Week 3: Sep 7

Labor Day Holiday Monday, Sept. 7 – no class

Spectral Indices and Transformations; Classification; Accuracy Assessment; Smoothing and Edge Detection

- JR Chapter 5.1-5.5 **
- CWT Ch 13, 15
- Pontus Olofsson et al. (2014). "Good practices for estimating area and assessing accuracy of land change". *Remote Sensing of Environment* 148, pp. 42–57 **
- Pontus Olofsson (2021). "Updates to good practices for estimating area and assessing accuracy of land cover and land cover change products". *2021 IEEE International Geoscience and Remote Sensing Symposium IGARSS*. IEEE, pp. 1982–1985 **

- A Bannari et al. (1995). "A review of vegetation indices". *Remote Sensing Reviews* 13.1-2, pp. 95–120
- Gregory P Asner, David E Knapp, et al. (2005). "Selective logging in the Brazilian Amazon". *Science* 310.5747, pp. 480–482
- Lyndon Estes et al. (2018). "A Large-Area, Spatially Continuous Assessment of Land Cover Map Error and Its Impact on Downstream Analyses". *Global Change Biology* 24.1, pp. 322–337

Week 4: Sep 14
Change Detection and Applications: Forests and Land Cover Change

- CWT Ch 21 *
- JR Ch 8, 9 (can skim), 11
- Zhe Zhu and Curtis E Woodcock (2014). "Continuous change detection and classification of land cover using all available Landsat data". *Remote Sensing of Environment* 144, pp. 152–171 **
- Matthew C Hansen et al. (2013). "High-resolution global maps of 21st-century forest cover change". *Science* 342.6160, pp. 850–853 **
- Seema Jayachandran et al. (2017). "Cash for carbon: A randomized trial of payments for ecosystem services to reduce deforestation". *Science* 357.6348, pp. 267–273
- Christian Baehr, Ariel BenYishay, and Bradley Parks (2021). "Linking Local Infrastructure Development and Deforestation: Evidence from Satellite and Administrative Data". *Journal of the Association of Environmental and Resource Economists* 8.2, pp. 375–409
- Tyler J. Lark, Richard M. Mueller, et al. (2017). "Measuring Land-Use and Land-Cover Change Using the US Department of Agriculture's Cropland Data Layer: Cautions and Recommendations". *International Journal of Applied Earth Observation and Geoinformation* 62, pp. 224–235
- Tyler J. Lark, Ian H. Schelly, and Holly K. Gibbs (2021). "Accuracy, Bias, and Improvements in Mapping Crops and Cropland Across the United States Using the USDA Cropland Data Layer". *Remote Sensing* 13.5, p. 968

Week 5: Sep 21
Nonclassical Measurement Error, Censoring, and Scale within the context of Land use Classification and Change Detection

- Jeffrey D. Michler et al. (2026). *Treatment geometry and causal identification with Earth observation data*. arXiv preprint. Forthcoming in *Geospatial Impact Evaluation in Practice*, eds. Ben-Yishay & Singh. arXiv: 2607.19908 [econ.GN] † **
- Anthony Louis D'Agostino, Faraz Usmani, and Elinor Benami (2026). "Causal inference and counterfactuals in Earth observation research". *Geospatial Impact Evaluation in Practice*. Ed. by Ariel Ben-Yishay and Kunwar Singh. Forthcoming. Chap. 14 † ** **[Required for students who have not taken a causal inference/impact evaluation course; recommended for all others]**
- Jennifer Alix-Garcia and Daniel L Millimet (2021). *Remotely Incorrect? Accounting for Nonclassical Measurement in Satellite Data on Deforestation*. Working Paper. **
- Alberto Garcia and Robert Heilmayr (2024). "Impact evaluation with nonrepeatable outcomes: The case of forest conservation". *Journal of Environmental Economics and Management* 125, p. 102971

- Matthew Gordon et al. (2026). “Debiasing Estimates of Global Forest Cover Loss”. *AEA Papers and Proceedings* 116, pp. 81–86
- Robert Heilmayr et al. (2020). “Brazil’s Amazon Soy Moratorium reduced deforestation”. *Nature Food* 1.12, pp. 801–810
- Jonathan Proctor, Tamma Carleton, and Sandy Sum (2026). “Parameter Recovery Using Remotely Sensed Variables”. *Journal of the Association of Environmental and Resource Economists*. DOI: 10.1086/742595
- Peter Richards et al. (2017). “Are Brazil’s deforesters avoiding detection?” *Conservation Letters* 10.4, pp. 470–476
- Meha Jain (2020). “The benefits and pitfalls of using satellite data for causal inference”. *Review of Environmental Economics and Policy* 14.1, pp. 157–169 ******
- Andre Fernandes Tomon Avelino, Kathy Baylis, and Jordi Honey-Rosés (2016). “Goldilocks and the raster grid: selecting scale when evaluating conservation programs”. *PloS one* 11.12, e0167945 ******

Week 6: Sep 28
Time Series Analysis and crop phenology, with applications to agriculture

- CWT Ch 17
- Geospatial Data and the Farm Service Agency: https://usdaonline.maps.arcgis.com/apps/Cascade/index.html?appid=d5312c64f0534f88a8b3de8f5e9a96b2
- Marie Weiss, Frédéric Jacob, and G Duveiller (2020). “Remote sensing for agricultural applications: A meta-review”. *Remote Sensing of Environment* 236, p. 111402 ******
- David B Lobell, George Azzari, et al. (2020). “Eyes in the Sky, Boots on the Ground: Assessing Satellite-and Ground-Based Approaches to Crop Yield Measurement and Analysis”. *American Journal of Agricultural Economics* 102.1, pp. 202–219 ******
- David B Lobell, Stefania Di Tommaso, et al. (2020). “Sight for sorghums: Comparisons of satellite-and ground-based sorghum yield estimates in mali”. *Remote Sensing* 12.1, p. 100
- Meha Jain et al. (2019). “The impact of agricultural interventions can be doubled by using satellite data”. *Nature Sustainability* 2.10, pp. 931–934
- Eric Strobl and Robert O Strobl (2011). “The distributional impact of large dams: Evidence from cropland productivity in Africa”. *Journal of Development Economics* 96.2, pp. 432–450 – *Note: incorporates satellite derived measures of ag. productivity into econometric framework to estimate impacts of dams on agriculture*
- Alyssa K Whitcraft, Eric F Vermote, et al. (2015). “Cloud cover throughout the agricultural growing season: Impacts on passive optical earth observations”. *Remote Sensing of Environment* 156, pp. 438–447
- Alyssa K Whitcraft, Inbal Becker-Reshef, and Christopher O Justice (2015). “A framework for defining spatially explicit earth observation requirements for a global agricultural monitoring initiative (GEOGLAM)”. *Remote Sensing* 7.2, pp. 1461–1481
- Yuchi Ma et al. (2024). “Subfield-level crop yield mapping without ground truth data: A scale transfer framework”. *Remote sensing of environment* 315, p. 114427

Week 7: Oct 5
No Class (Oct 5–9) – Work on Project Outlines

Week 8: Oct 12
Weather Data, with an emphasis on uses and misuses of (interpolated) and gridded data on temperature, precipitation, and soil moisture for agricultural applications (e.g., Growing/Killing Degree Days)

- Elinor Benami et al. (2026). "The uses (and misuses) of Earth observation data for weather and vegetation analysis". *Geospatial Impact Evaluation in Practice*. Ed. by Ariel Ben-Yishay and Kunwar Singh. Forthcoming. Chap. 8 † **
- Maximilian Auffhammer et al. (2013). "Using weather data and climate model output in economic analyses of climate change". *Review of Environmental Economics and Policy* 7.2, pp. 181–198 ** – *Read alongside the chapter above: what changed in the intervening decade, and why?*
- Chris Funk et al. (2015). "The climate hazards infrared precipitation with stations—a new environmental record for monitoring extremes". *Scientific Data* 2.1, pp. 1–21 **
- Amir AghaKouchak et al. (2015). "Remote sensing of drought: Progress, challenges and opportunities". *Reviews of Geophysics* 53.2, pp. 452–480 **
- Zhiyun Li and Ariel Ortiz-Bobea (2022). "On the Timing of Relevant Weather Conditions in Agriculture". *Journal of the Agricultural and Applied Economics Association* 1, pp. 180–195 **
- Richard T. Carson and Chu Yu (2026). "Mismeasured and Misunderstood: Unmasking the Temperature Proxy Problem in Climate Impact Estimates". *Journal of the Association of Environmental and Resource Economists*. DOI: 10.1086/742106
- Morgan C Levy et al. (2019). "Spatiotemporal error in rainfall data: consequences for epidemiologic analysis of waterborne diseases". *American journal of epidemiology* 188.5, pp. 950–959
- Jillian M Deines et al. (2019). "Mapping three decades of annual irrigation across the US High Plains Aquifer using Landsat and Google Earth Engine". *Remote Sensing of Environment* 233, p. 111400
- Wolfram Schlenker and Michael J Roberts (2009). "Nonlinear temperature effects indicate severe damages to US crop yields under climate change". *Proceedings of the National Academy of sciences* 106.37, pp. 15594–15598 *Note: Appendix covers best practices in use of weather data into econometrics, though many also covered and incorporated in the Auffhammer et al. (2013) paper*
- Mauro Di Luzio et al. (2008). "Constructing retrospective gridded daily precipitation and temperature datasets for the conterminous United States". *Journal of Applied Meteorology and Climatology* 47.2, pp. 475–497 – *Methods discussed in previous paper. Data of daily minimum and maximum temperature as well as total precipitation on a 2.5x2.5 mile grid for the contiguous United States linked here: https://prism.oregonstate.edu/recent/, and Schlenker's updated version of this dataset is linked here https://zenodo.org/records/10625288. Schlenker's version corrects many of the issues with stations entering and exiting the PRISM sample.*
- Jun Yang et al. (2013). "The Role of Satellite Remote Sensing in Climate Change Studies". *Nature Climate Change* 3.10, pp. 875–883
- D. Patel (2024). *Floods*. *Working Paper/Job Market Paper Example – Links use of sat data and surveys with economic models to provide insights on adaptation to floods and economic development outcomes*

Week 9: Oct 19
Economic Development: Night Lights, Daylights, Value of Public Info, Conflict

- Xi Chen and William D Nordhaus (2011). “Using luminosity data as a proxy for economic statistics”. *Proceedings of the National Academy of Sciences* 108.21, pp. 8589–8594 **

- J Vernon Henderson, Adam Storeygard, and David N Weil (2012). “Measuring economic growth from outer space”. *American Economic Review* 102.2, pp. 994–1028 **

- John Gibson et al. (2021). “Which night lights data should we use in economics, and where?” *Journal of Development Economics* 149, p. 102602 **

- Neal Jean et al. (2016). “Combining satellite imagery and machine learning to predict poverty”. *Science* 353.6301, pp. 790–794 **

- Daniel Ayalew Ali, Klaus Deininger, and Michael Wild (2018). “Using satellite imagery to revolutionize creation of tax maps and local revenue collection”. *World Bank Policy Research Working Paper* 8437

- Mariaflavia Harari (2020). “Cities in Bad Shape: Urban Geometry in India”. *American Economic Review* 100.8, pp. 2377–2421

- Marshall Burke et al. (2021). “Using satellite imagery to understand and promote sustainable development”. *Science* 371.6535

- Benjamin Marx, Thomas M Stoker, and Tavneet Suri (2019). “There is no free house: Ethnic patronage in a Kenyan slum”. *American Economic Journal: Applied Economics* 11.4, pp. 36–70 *Uses daytime satellite imagery to assess housing quality in Kibera*

- Ran Goldblatt, Kilian Heilmann, and Yonatan Vaizman (2020). “Can medium-resolution satellite imagery measure economic activity at small geographies? Evidence from Landsat in Vietnam”. *The World Bank Economic Review* 34.3, pp. 635–653

- Lukas Kondmann and Xiao Xiang Zhu (2021). “Under the Radar–Auditing Fairness in ML for Humanitarian Mapping”. *arXiv preprint arXiv:2108.02137 – A review of some of the daytime poverty prediction lit.*

- Abhishek Nagaraj (2022). “The Private Impact of Public Data: Landsat Satellite Maps Increased Gold Discoveries and Encouraged Entry”. *Management Science* 68.1, pp. 564–582

- Tillmann von Carnap et al. (2026). “Using satellite imagery to map rural marketplaces and monitor their activity at high frequency”. *Nature Communications*

- Hannah Kerner et al. (2024). “Satellite Data Shows Resilience of Tigrayan Farmers in Crop Cultivation During Civil War”. *Science of Remote Sensing* 10, p. 100140

- Josias Láng-Ritter, Marko Keskinen, and Henrikki Tenkanen (2025). “Global gridded population datasets systematically underrepresent rural population”. *Nature Communications* 16.1, p. 2170

Week 10: Oct 26
Aerosol optical depth and its uses for varying kinds of smog, haze, desert dust

- Bryan N Duncan et al. (2014). “Satellite data of atmospheric pollution for US air quality applications: Examples of applications, summary of data end-user resources, answers to FAQs, and common mistakes to avoid”. *Atmospheric environment* 94, pp. 647–662 **

- Meredith Fowlie, Edward Rubin, and Reed Walker (2019). “Bringing satellite-based air quality estimates down to earth”. *AEA Papers and Proceedings*. Vol. 109, pp. 283–88 **

- Daniel M Sullivan and Alan Krupnick (2019). “Using satellite data to fill the gaps in the US air pollution monitoring network”. *Resources for the Future Working Paper*. **

- Roland Stirnberg, Jan Cermak, and Hendrik Andersen (2018). "An analysis of factors influencing the relationship between satellite-derived aod and ground-level PM10". *Environment international* 9, p. 1353
- Hai Zhang and Shobha Kondragunta (2021). "Daily and hourly surface PM2. 5 estimation from satellite AOD". *Earth and Space Science* 8.3, e2020EA001599
- Qian Di et al. (2019). "An ensemble-based model of PM2. 5 concentration across the contiguous United States with high spatiotemporal resolution". *Environment International* 130, p. 104909
- Colleen E Reid et al. (2021). "Daily PM 2.5 concentration estimates by county, ZIP code, and census tract in 11 western states 2008–2018". *Scientific data* 8.1, pp. 1–15 – *Similar to Di et al. (2019) but purportedly outperforms their model in the Western US, where wildfire smoke is prevalent*
- Sam Heft-Neal et al. (2020). "Dust pollution from the Sahara and African infant mortality". *Nature Sustainability* 3.10, pp. 863–871

Week 11: Nov 2
Seeing Beyond the Visible: Thermal and IR analysis, with applications to estimating impacts of fire and air pollution

- CWT Ch 10 **
- Tianjia Liu et al. (2020). "Diagnosing spatial biases and uncertainties in global fire emissions inventories: Indonesia as regional case study". *Remote Sensing of Environment* 237, p. 111557 **
- Leigh B Lentile et al. (2006). "Remote sensing techniques to assess active fire characteristics and post-fire effects". *International Journal of Wildland Fire* 15.3, pp. 319–345 **
- Gregory P Asner and Ane Alencar (2010). "Drought impacts on the Amazon forest: the remote sensing perspective". *New Phytologist* 187.3, pp. 569–578 – compares findings from field and satellite studies
- Patrick Baylis and Judson Boomhower (2019). *Moral hazard, wildfires, and the economic incidence of natural disasters*. Tech. rep. *Note: doesn't use remote sensing, but does consider spatial elements associated with estimating wildfire losses.* National Bureau of Economic Research
- Wesley A Campanharo et al. (2019). "Translating fire impacts in southwestern amazonia into economic costs". *Remote Sensing* 11.7, p. 764
- M Sowden and D Blake (2021). "Using infrared geostationary remote sensing to determine particulate matter ground-level composition and concentration". *Air Quality, Atmosphere & Health*, pp. 1–10
- B Kelsey Jack et al. (2025). "Money (not) to burn: payments for ecosystem services to reduce crop residue burning". *American Economic Review: Insights* 7.1, pp. 39–55

Week 12: Nov 9
Seeing Beyond the Visible: Gravimetric modeling (e.g., water resource availability) and an introduction to the physics of active sensing (RADAR, LiDAR, SAR)

- Byron D Tapley et al. (2004). "GRACE measurements of mass variability in the Earth system". *Science* 305.5683, pp. 503–505 **
- Richard Bernknopf et al. (2018). "The value of remotely sensed information: The case of a GRACE-enhanced drought severity index". *Weather, Climate, and Society* 10.1, pp. 187–203 **

- CWT Ch 8 **
- Ralph Dubayah et al. (2020). "The Global Ecosystem Dynamics Investigation: High-resolution laser ranging of the Earth's forests and topography". *Science of Remote Sensing* 1, p. 100002 **

Week 13: Nov 16
Active sensing applications: (1) flood & sea-level risk (2) oil spills (3) building height/population estimation (4) soil moisture & groundwater depletion

Quiz 2: Course Content Wrap-Up (exact day to be announced in class)

- Trent W Ford and Steven M Quiring (2019). "Comparison of contemporary in situ, model, and satellite remote sensing soil moisture with a focus on drought monitoring". *Water Resources Research* 55.2, pp. 1565–1582
- Donald W Vasco et al. (2019). "Satellite-based monitoring of groundwater depletion in California's Central Valley". *Scientific reports* 9.1, pp. 1–14 **
- Scott A Kulp and Benjamin H Strauss (2019). "New elevation data triple estimates of global vulnerability to sea-level rise and coastal flooding". *Nature communications* 10.1, pp. 1–12 **
- Ben DeVries et al. (2020). "Rapid and robust monitoring of flood events using Sentinel-1 and Landsat data on the Google Earth Engine". *Remote Sensing of Environment* 240, p. 111664
- Fernando S Paolo et al. (2024). "Satellite mapping reveals extensive industrial activity at sea". *Nature* 625.7993, pp. 85–91
- Sheila Masson et al. (2026). "A robot-assisted pipeline to rapidly scan 1.7 million historical aerial photographs". *npj Heritage Science* 14.1, p. 123

Thanksgiving Break: Nov 21 - 29

Week 14: Nov 30
Student Presentations on Term Projects, Open Topics

Week 15: Dec 7
Open Topics/Work on Final Project Reports (AGU week)

Wed, Dec 9 - Last Day of Class
Sat, Dec. 12 by 5:25 PM — Final Project Reports Due (in lieu of a final exam)
