CLIMATE 588
REGIONAL SCALE CLIMATE:
DOWNSCALING TECHNIQUES AND APPLICATIONS

Fall 2024
4 credits

Professor:
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Location and Time:
T/Th 11:30-1:30 2230 CSRB CAEN Lab
North Campus

Drop-In Hours: 10-11AM Weds (or by appt)

COURSE DESCRIPTION: Global change is impacting an increasing number of sectors in science, engineering and health, creating a need for high-resolution, future climate data used in impact assessments and mitigation plans. Despite the increase in resolution of general circulation models used for climate studies, these model resolutions are not yet consistently fine enough for local and regional scale studies. Therefore, an understanding of the appropriate data tools, including downscaling methods, are necessary for local and regional scale applications. The primary objectives of this course are to understand resolution-sensitive climate model processes and types of downscaling techniques, practice data analysis with coding tools, and understand the landscape of climate model data for specific applications. Topics will include: (1) a basic overview of atmospheric processes included in global and regional climate models, (2) information about grid structure, resolution and regional map projections, (3) data available for present-day and future climate analyses, (4) statistical downscaling, (5) dynamical downscaling, and (6) multi-model ensembles and methods for assessing uncertainty in future climate model simulations.

These goals will be met with a combination of lectures, assigned journal papers, and hands-on data analysis. For the data analysis, we will spend approximately one class period per week learning to work with and analyze climate data. A course project will involve the application of these techniques to a project of the student's choice.

Linked activity: Reparative Justice Research Group: In 2024, the course will include an environmental justice component as part of the Rackham Institute for Interdisciplinary Study Reparative Justice Research group. The Reparative Justice Research group is an interdisciplinary group of faculty and students, spanning Engineering, Public Health, Public Policy and Social Work, with the goal of conducting research and gathering data useful for making the case for reparative justice in Detroit and Southeastern Michigan. It includes working with community partners in the region to develop products that may be helpful for reparations assessments. If you are interested in this topic and would like to join these broader discussions, you can register for the Monthly Seminar (RACK 570; F 9-11AM; total of four meetings in Fall 2024 term) for one credit. I am hoping that several students in the course will participate in this interdisciplinary project and develop their final project to fit with this theme.

PREREQUISITES: The course will include an intensive data analysis component, and while some programming experience (UNIX, Matlab, other visualization software) will be helpful it is not strictly required. Previous studies in atmospheric science are not required and relevant atmospheric topics will be included in course lectures.

TEXT:
Assigned reading and discussions: There will be assigned readings for some lectures for in-class discussion. Please see the syllabus, and I will update any revised or additional readings in Canvas. I will also incorporate some readings from the Fourth National Climate Assessment (NCA4; https://science2017.globalchange.gov/) and the IPCC AR6 report (https://www.ipcc.ch/report/ar6/wg1/). Additional papers may be assigned as noted on the syllabus and will be announced and posted in Canvas.

Suggested reading for atmospheric science background:
Atmospheric Science, Second Edition: An Introductory Survey, J.M. Wallace and P.V. Hobbs, Academic Press, 2006. An excellent intro level textbook that covers all of the atmospheric science basics.

Parameterization Schemes: Keys to Understanding Numerical Weather Prediction Models, D.J. Stensrud, Cambridge University Press, 2009. While this book is written about weather models, it is a great overview of different parameterization schemes used in many general circulation models.

GRADING:

Weight	Type	Date
50%	Homework	5 Assignments
20%	Oral Presentation Final Project	3/5 December
30%	Written Final Project	Tuesday, December 17

DATA ANALYSIS COMPONENT: As noted above, programming is not a prerequisite for the course. However, the class will be very data intensive and if you are unfamiliar with large data files and visualization software, be prepared to invest the time to learn these resources quickly. Data visualization software is needed for this analysis, and the course will be taught using Python. The use of other software for the course (e.g., Matlab, IDL, R) is acceptable but will not be supported by the instructor.

ASSIGNMENTS: There will be three types of assignments in the class.

1. **CLASS READINGS:** Readings for specific lectures are noted on the course syllabus. Please read prior to the lecture and be prepared to ask questions in class.
2. **LAB HOMEWORK (50% of grade):** There will be about five lab assignments based on data visualization and analysis. Lab homework is designed to develop the skills you need to develop the analysis for the final project.

3. **FINAL PROJECT (50% of grade):** The objective of the final project is to allow you to apply your knowledge from the course to develop a hypothesis-driven project. Hopefully, this project will be relevant to your interests, either for a Ph.D. dissertation, the Rackham Reparative Justice group, or other applications. The final project will include an oral presentation (approximately 15 minutes; 20% of the grade) and a written report in journal format (30% of the grade). Rubrics for the final project and project expectations will be discussed in class. Ungraded intermediate steps to the final project (abstract, figure outline) are posted on the syllabus to help you stay on track for project completion.

HOMEWORK POLICY: Homework assignments will comprise data analysis that applies concepts learned in lab and lecture periods. Homework is due at the beginning of class on the specified due dates. You will be allowed two late homeworks (with up to a week extension) with no questions asked. Please contact me to discuss if you need additional accommodations beyond these two late homeworks. Please upload Jupyter notebooks to Canvas for grading, along with any modified input data files that you use.

HONOR CODE: This class is being taught through the College of Engineering, and thus all involved are subject to the College of Engineering Honor Code
http://www.engin.umich.edu/students/honorcode/
All policies apply, so please do not hesitate to ask questions.

ACCOMMODATIONS FOR STUDENTS WITH DISABILITIES: Participants with unique learning needs are strongly encouraged to talk to the instructor as soon as possible to gain maximum access to course information. All discussions will remain confidential. The University of Michigan policy is to provide, on a flexible and individualized basis, reasonable accommodations to students who have documented disability conditions that may affect their ability to participate in course activities or to meet course requirements. Students with disabilities are encouraged to contact UM Services for Students with Disabilities (https://ssd.umich.edu/) and the instructor to discuss individual needs for accommodations.

COURSE POLICIES

Communication: Information about the course will be shared through (1) Canvas announcements and (2) a class Slack channel (link from the Canvas page). Unless your question involves a personal issue, please ask your question on Slack so that everyone can benefit from the response. For personal questions or late requests, please email me at alsteine@umich.edu and I will make every effort to respond to emails within a day.
Course Recordings: Course lectures and labs will be audio/video recorded and made available to other students in this course asynchronously. As part of your participation in this course, you may be recorded. If you do not wish to be recorded, please contact me (alsteine@umich.edu) the first week of class (or as soon as you enroll in the course, whichever is latest) to discuss alternative arrangements.

CLIMATE 588: Regional Scale Climate: Fall 2024: Tentative Course Outline

Blue = Lab Data Analysis Sessions: Homework (H) assigned (A) and due dates (D)

Wk	Date	Topic	Reading	Lab Homework
1	27 Aug	Course Introduction & Overview		
	29 Aug	LAB 1: Intro (Unix, GL cluster, NetCDF Python)		
2	3 Sept	Atm Science basics: Scale dep procs I		
	5 Sept	LAB 2: Python for data visualization		H1A
3	10 Sept	Atm Science basics: Scale dep procs II		
	12 Sept	LAB 3: Python for visualization II		H1D/H2A
4	17 Sept	Model grids: Resolution and projections		
	19 Sept	LAB 4: CDO		H2D/H3A
5	24 Sept	Data: Observations and GCMs		
	26 Sept	LAB 5: Dealing with Projections		H3D/H4A
6	***1 Oct***	***No class: ALS out of town***		
	3 Oct	Downscaling techniques: Dynamical		
7	***8 Oct***	***No class: ALS out of town***		
	10 Oct	Downscaling techniques: Statistical		H4D/H5A
8	***15 Oct***	***No class: Fall Break***		
	17 Oct	LAB 6: Regridding		H5D
9	22 Oct	Multi-model ensembles Pt 1	Abramowitz et al. (2019); Hausfather et. al (2022)	
	24 Oct	LAB 7: Project work		Abstracts due
10	29 Oct	Multi-model ensembles Pt 2 (NCA)	NCA App B; Sanderson et al. 2017	
	31 Oct	***LAB 8: Project work: ALS out***		
11	5 Nov	Uncertainty Assessment	Hawkins & Sutton (2009); Carlsaw et al. (2018)	
	7 Nov	LAB 9: Project work		
12	12 Nov	Detection and Attribution	Trenberth et al. (2015);	
	14 Nov	LAB 10 : Project work	Lloyd&Oreskes (2018); NCA Ch. 3 & App. C	Fig. outline due
13	19 Nov	Storyline Approaches	Shepherd et al. (2018)	
	21 Nov	LAB 11: Project work		
14	26 Nov	Discussion: Nat'l & Int'l Assessments	Mach &Field (2017); Slingo et al. (2022); Balaji et al. (2022); Kirchhof et al. (2019)	
	28 Nov	***No Class: Thanksgiving Break***		
15	3 Dec	**Project presentations**		
	5 Dec	**Project Presentations**		

2024 CLIMATE 588 Reading List

Fourth National Climate Assessment (NCA), Volume 1
Chapter 3: Detection and Attribution of Climate Change
Chapter 4: Climate Models, Scenarios and Projections
Appendix B: Model Weighting Strategy
Appendix C: Detection and Attribution Methodologies Overview

Journal Articles for Lecture Discussions

Abramowitz et al., 2019; Model dependence in multi-model climate ensembles: weighting, sub-selection and out-of-sample testing, Earth System Dynamics, 10, 91-105, 2019.

Balaji et al. 2022; Are General Circulation Models Obsolete? Arvix.org/pdf2204.0657.pdf

Carslaw et al. 2018; Climate Models Are Uncertain, but We Can Do Something About It, Eos, 99.

Gidden et al. 2019; Global emission pathways under different socioeconomic scenarios for use in CMIP6: a dataset of harmonized emissions trajectories through the end of the century, Geoscientific Model Development, 12, 1443-1475.

Hausfather, Z. et al., 2022; Climate simulations: recognize the 'hot model' problem, Nature, 605, 26-29.

Hawkins and Sutton, 2009; The potential to narrow uncertainty in regional climate predictions, Bulletin of the American Meteorological Society, 90, 8, 1095-1108.

Kirchhoff et al., 2019; Climate Assessments for Local Action, Bulletin of the American Meteorological Society, 100, 11, 2147-2152.

Lloyd and Oreskes, 2018; Climate Change Attribution: When is It Appropriate to Accept New Methods? Earth's Future, 5, 311-325.

Mach and Field, 2017; Toward the Next Generation of Assessment, Annual Review of Environment and Resources, 42, 569-597.

Sanderson, B.M., M. Wehner, and R. Knutti, 2017: Skill and independence weighting for multi-model assessment. Geoscientific Model Development, 10, 2379-2395. http://dx.doi.org/10.5194/gmd-10-2379-2017

Shepherd et al. 2018; Storylines: an alternative approach to representing uncertainty in physical aspects of climate change, Climatic Change, 151, 555-571.

Slingo et al. 2022, Ambitious partnership needed for reliable climate prediction, Nature Climate Change, 12, 499-503.

Trenberth et al. 2015; Attribution of climate extreme events, Nature Climate Change, 5, 725-720.