Master of Science in Sustainability Management

SUMA PS 4145: Climate Change and Sustainable Water

Mondays 4:10 – 6:00 PM

3 credits

Elective

Instructor:	Hung Nguyen, PhD, hnguyen@ldeo.columbia.edu, 845-365-8736
Office Hours:	Tuesdays and Thursdays, 2-3 pm, via Zoom or at Lamont campus. Please check here for available times if you need to meet outside of Office Hours.
Response Policy:	I generally respond to emails within 24 hours except when traveling or during weekends.
Teaching Assistant:	Samreen, ss6730@columbia.edu
Office Hours:	Mondays and Wednesday, 12-1 pm
Response Policy:	NA

Course Overview

Through this course, students will learn about what makes the water cycle a cycle: how water is circulated through its components, and what drives these circulations. We will explore the roles of humans as an integral part of the water cycle: how we use our water resources and how our actions help shape the water cycle. In every lesson, students will be encouraged to think about how climate change will affect both us and the other components. Ultimately, students will gain insights on the world's water resources and how to manage them in a sustainable way.

A novel aspect of this course is the introduction of paleoclimate (particularly, information from **tree rings**) into the study of water resources. We will learn from the painful lesson of the Colorado River Basin, where water management decisions based on a short instrumental record, which happened to be taken over an abnormally wet period, led to water over-allocation and the severe water stresses today. We will also cover other case studies from all over the world. With help from tree rings, we will gain a much better understanding of long-term changes in the water cycle, and manage our water resources better.

The course consists of 9 lectures, 3 quantitative exercises (QEs), and a final project. From Class #2 onwards, each class will begin with a short student presentation on the readings of the previous lecture, which then leads us to the current material. For QEs, we will go through example code to analyze data in class, and students will then be asked to tailor the example code to answer a specific question of their choice. The final project will involve a research proposal (2 pages), a term paper presenting the student's research on a specific question of their choice (15 pages), and a final presentation (12 minutes). Students may make use of the example code in the QEs to guide their analyses. Depending on class size, final project can be either individual or group of 2. This elective course is open to all who are interested in water resources, including students from other programs. Knowledge of R programming is an advantage but not required. The course is offered in-person, but remote attendance can be accommodated when needed (e.g., sickness requiring isolation).

Learning Objectives

Upon successful completion of this course, students should be able to

- L1: explain the water cycle: its pools and fluxes, and how climate change affects each component
- L2: explain why human is an intrinsic part of the water cycle, and articulate the relationships between us and the other components
- L3: explain how we can infer about the water cycle in the past using tree rings
- L4: analyze and visualize climate and hydrological data
- L5: identify ways to manage water resources sustainably in the face of climate change

Readings

This reading list is subject to changes depending on interests from the class, or if new, relevant papers come out. Please check back regularly.

Required

Savenije, H. H. G. (2000). Water scarcity indicators; the deception of the numbers. *Physics and Chemistry of the Earth, Part B: Hydrology, Oceans and Atmosphere*, *25*(3), 199–204. https://doi.org/10.1016/S1464-1909(00)00004-6

van der Ent, R. J., Savenije, H. H. G., Schaefli, B., & Steele-Dunne, S. C. (2010). Origin and fate of atmospheric moisture over continents. *Water Resources Research*, *46*(9). https://doi.org/10.1029/2010WR009127

Gerrits, A. M. J., Savenije, H. H. G., Hoffmann, L., & Pfister, L. (2007). New technique to measure forest floor interception-an application in a beech forest in Luxembourg. *Hydrology and Earth System Sciences*, *11*(2), 695–701. https://doi.org/10.5194/hess-11-695-2007

Brutsaert, W. (2017). Global land surface evaporation trend during the past half century: Corroboration by Clausius-Clapeyron scaling. *Advances in Water Resources*, *106*, 3–5. https://doi.org/10.1016/j.advwatres.2016.08.014

Sun, Q., Miao, C., Duan, Q., Ashouri, H., Sorooshian, S., & Hsu, K.-L. (2018). A Review of Global Precipitation Data Sets: Data Sources, Estimation, and Intercomparisons. *Reviews of Geophysics*, *56*(1), 79–107. https://doi.org/10.1002/2017RG000574

Maxwell, J. T., Bregy, J. C., Robeson, S. M., Knapp, P. A., Soulé, P. T., & Trouet, V. (2021). Recent increases in tropical cyclone precipitation extremes over the US east coast. Proceedings of the National Academy of Sciences, 118(41). https://doi.org/10.1073/pnas.2105636118

Khan, N., Nguyen, H. T. T., Galelli, S., & Cherubini, P. (2022). Increasing Drought Risks over the Past Four Centuries amidst Projected Flood Intensification in the Kabul River Basin (Afghanistan and Pakistan)—Evidence from Tree Rings. *Geophysical Research Letters*, *49*(24), e2022GL100703. https://doi.org/10.1029/2022GL100703

Nguyen, H. T. T., Turner, S. W. D., Buckley, B. M., & Galelli, S. (2020). Coherent Streamflow Variability in Monsoon Asia Over the Past Eight Centuries—Links to Oceanic Drivers. *Water Resources Research*, *56*(12). https://doi.org/10.1029/2020WR027883

Montanari, A., Nguyen, H., Rubinetti, S., Ceola, S., Galelli, S., Rubino, A., & Zanchettin, D. (2023). Why the 2022 Po River drought is the worst in the past two centuries. Science Advances, 9(32), eadg8304. https://doi.org/10.1126/sciadv.adg8304

Stein, L., Pianosi, F., & Woods, R. (2020). Event-based classification for global study of river flood generating processes. *Hydrological Processes*, *34*(7), 1514–1529. https://doi.org/10.1002/hyp.13678

How the Dutch Make "Room for the River" by Redesigning Cities. Scientific American. https://www.scientificamerican.com/article/how-the-dutch-make-room-for-the-river/

Cook, B. I., Smerdon, J. E., Cook, E. R., Williams, A. P., Anchukaitis, K. J., Mankin, J. S., Allen, K., Andreu-Hayles, L., Ault, T. R., Belmecheri, S., Coats, S., Coulthard, B., Fosu, B., Grierson, P., Griffin, D., Herrera, D. A., Ionita, M., Lehner, F., Leland, C., … Wise, E. K. (2022). Megadroughts in the Common Era and the Anthropocene. *Nature Reviews Earth & Environment*, 1–17. https://doi.org/10.1038/s43017-022-00329-1

Sabo, J. L., Ruhi, A., Holtgrieve, G. W., Elliott, V., Arias, M. E., Ngor, P. B., Räsänen, T. A., & Nam, S. (2017). Designing river flows to improve food security futures in the Lower Mekong Basin. *Science*, *358*(6368), eaao1053. https://doi.org/10.1126/science.aao1053

Ho, M., Lall, U., Allaire, M., Devineni, N., Kwon, H. H., Pal, I., Raff, D., & Wegner, D. (2017). The future role of dams in the United States of America. *Water Resources Research*, *53*(2), 982–998. https://doi.org/10.1002/2016WR019905

Chowdhury, A. F. M. K., Dang, T. D., Nguyen, H. T. T., Koh, R., & Galelli, S. (2021). The Greater Mekong's Climate-Water-Energy Nexus: How ENSO-Triggered Regional Droughts Affect Power Supply and CO2 Emissions. *Earth's Future*, *9*(3), e2020EF001814. https://doi.org/10.1029/2020EF001814

Galelli, S., Dang, T. D., Ng, J. Y., Chowdhury, A. F. M. K., & Arias, M. E. (2022). Opportunities to curb hydrological alterations via dam re-operation in the Mekong. *Nature Sustainability*, *5*(12), Article 12. https://doi.org/10.1038/s41893-022-00971-z

Kummu, M., Ward, P. J., de Moel, H., & Varis, O. (2010). Is physical water scarcity a new phenomenon? Global assessment of water shortage over the last two millennia. *Environmental Research Letters*, *5*(3), 034006. https://doi.org/10.1088/1748-9326/5/3/034006

Optional

On evaporation

Wang-Erlandsson, L., van der Ent, R. J., Gordon, L. J., & Savenije, H. H. G. (2014). Contrasting roles of interception and transpiration in the hydrological cycle – Part 1: Temporal characteristics over land. *Earth System Dynamics*, *5*(2), 441–469. https://doi.org/10.5194/esd-5-441-2014

Bailey, K., Szejner, P., Strange, B., Monson, R. K., & Hu, J. (2023). The Influence of Winter Snowpack on the Use of Summer Rains in Montane Pine Forests Across the Southwest U.S. Journal of Geophysical Research: Biogeosciences, 128(9), e2023JG007494. https://doi.org/10.1029/2023JG007494

von Schuckmann, K., Palmer, M. D., Trenberth, K. E., Cazenave, A., Chambers, D., Champollion, N., Hansen, J., Josey, S. A., Loeb, N., Mathieu, P.-P., Meyssignac, B., & Wild, M. (2016). An imperative to monitor Earth's energy imbalance. *Nature Climate Change*, *6*(2), Article 2. https://doi.org/10.1038/nclimate2876

Vicente-Serrano, S. M., Miralles, D. G., McDowell, N., Brodribb, T., Domínguez-Castro, F., Leung, R., & Koppa, A. (2022). The uncertain role of rising atmospheric CO2 on global plant transpiration. *Earth-Science Reviews*, *230*, 104055. https://doi.org/10.1016/j.earscirev.2022.104055

Assignments and Assessments

Assignments include:

- 3 quantitative exercises (QEs). QEs 1 and 2 involve analyses of global data sets of precipitation (QE1) and droughts (QE2). In class, we will go through example code to analyze these data sets, and students will then be asked to tailor the example code to answer a specific question of their choice. QE3 will have a personal touch: students will be asked to calculate their water footprint – the amount of water they consume, both directly and indirectly (via energy and food) in a typical year.

- Class participations: in class and online discussion
- Class presentation of required readings (one reading per student)
- Final project, which involves a preliminary proposal (max 2 pages, ungraded), a term paper presenting the student's research on a specific question of their choice (max 15 pages), and a final presentation (12 minutes + 3 minutes Q & A). Students may make use of the example code in the QEs to guide their analyses. Depending on class size, final project can be either individual or group of 2.

The final project is meant as an avenue for students to apply what is learned in class, particularly the quantitative exercises, to explore and address a climate-related water resource challenge in a specific region of interest. Each student will identify the region of interest (could be anywhere in the world), the water resources challenges of that region, and one specific problem to be addressed. The student will then proposal several solutions and discuss the pros and cons of each one.

The problems to be addressed could be of a scientific nature—a knowledge gap that could be solved by a new research project, in which case the proposed solution could be a research proposal. Alternatively, the problem could be of an applied nature, in which case the proposed solutions could be an engineering one (a hard solution) or a management one (a soft solution).

Grading

The final grade will be calculated as described below:

FINAL GRADING SCALE

Grade	Percentage
A+	98–100 %
A	93–97.9 %
A-	90–92.9 %
B+	87–89.9 %
B	83–86.9 %
B-	80–82.9 %
C+	77–79.9 %
C	73–76.9 %
C-	70–72.9 %
D	60–69.9 %
F	59.9% and below

Assignment/Assessment	% Weight	Individual or Group/Team Grade
QE 1	10%	Individual
QE 2	10%	Individual
QE 3	10%	Individual
Class participation	10%	Individual
Class presentation	10%	Group
Term paper	25%	Group
Final presentation	25%	

Course Schedule/Course Calendar

Note: this is the first time this new syllabus is implemented, so you can expect some flexibility in the content, and we will adapt along with the semester.

All readings are due by next class

Date	Topics and Activities	Readings	Assignments
9/11	**Lecture 1: the water cycle** • An overview of the water cycle. • Pools and fluxes (showcase the new USGS water cycle diagram and their online resources, e.g., the pools and fluxes in the water cycle interactive chart) • Global moisture circulations • The terrestrial water balance.	Savenije (2000) van der Ent et al. (2010) Abbot et al. (2019)	
9/18	**Lecture 2: Evaporation & Forests** • Basics of evaporation processes • Basics of climate change • How climate change affects evaporation • How evaporation is measured and estimates • The role of forests in the water cycle • Climate change impacts on forests • Introduction to dendrochronology • Case examples	Gerrits et al. (2007) Brutsaert (2017)	
9/25	**Lecture 3: Precipitation** • Basics of precipitation types and processes • How precipitation is measured • Global precipitation variability • Teleconnections (with ENSO) • Climate and climate change change impacts on precipitation • Case examples	Sun et al. (2018) Maxwell et al. (2021) Khan et al. (2022)	
10/2	**QE 1: Precipitation Variability Worldwide** • Types of global precipitation products (gauged-based, satellite-based, reanalysis, and hybrid).		

	• Analyze and compare global precipitation data sets. • We will demonstrate a global analysis in class, and students will choose a specific region to analyze as homework. **Final project introduction**		
10/9	**Lecture 4: Runoff Generation and Streamflow** • Runoff processes • Streamflow measurement • Types of rivers • River engineering • Climate change impacts on streamflow	Nguyen et al. (2020) Montanari et al. (2023)	
10/14	**Lamont Open House**		
10/16	**Lecture 5: Floods** • Floods & extreme value analysis • Flood risk management & flood control infrastructure • Flood recession & baseflow	Stein et al. (2020) Room for the river	QE 1 (4 PM)
10/23	**Lecture 6: Droughts** • Types of droughts • Drought duration and severity analysis • Megadroughts and paleo droughts • Climate change and drought	Cook et al. (2022)	
10/30	**QE 2: Drought Atlases** Analyze the drought atlases to identify past megadroughts **Final project Q & A**		Preliminary proposal (11/3 5 PM)
11/6	University Holiday - No class		
11/13	**Lecture 7: Reservoirs and Dams** • The role of reservoirs in water resources management and the water cycle • Reservoir operations and management • Ecological implications • Risks and disasters • Case studies • Dam removal • The future of dams	Sabo et al. (2017) Ho et al. (2017)	QE 2 (4 PM)
11/20	**Lecture 8: The Water-Energy-Food Nexus** • The concept of water-energy-food nexus: how one resource is used to make another. • Integrated water resources management • The concepts of “hard” and “soft” solution • Climate resilient infrastructure • Case studies	Chowdhury et al. (2021) Galelli et al. (2022) Kummu et al. (2010)	
11/27	**QE 3: Water Footprint**		

	Calculate individual water footprint, both direct and indirect (via energy and food consumption) and compare with global and regional averages. **Lecture 9: Climate Change and Sustainable Water Management** In this class we will consolidate all learning so far. We begin with a recap of all lecture materials and findings from the quantitative exercises, followed by an open discussion.	
12/4	Final presentations	
12/11	Group work	QE 3 (4 PM) Term paper (12/15 5 PM)

Course Policies

Participation and Attendance

As the course content involves the human dimension, discussions are crucial, both in-person and online. You are expected to be prepared for class discussion by reading last week's materials, and if possible, skimming through the current week's slide deck. During class you should ask questions, express and defend your point of view, and challenge the point of view of others, in a respectful and constructive manner.

I strongly encourage you to post your questions on the discussion boards instead of emailing me, so that your classmates can participate in answering and benefit from the answers. Posting and answering questions on the discussion board count towards your class participation.

If you need to miss a class for any reason, please discuss the absence with me in advance. If you miss an experience in class, you miss an important learning moment and the class misses your contribution.

Late work

We all face unforeseen circumstances in life. Therefore, everyone gets ONE late pass, which you can use to extend the submission deadline of one *individual* assignment by one week. If you wish to use your late pass, just tell me any time before the deadline, no explanations needed. However, if you have used your late pass, no extension is allowed for future assignments, so use it wisely. Late submissions without the late pass will have their grades deducted by 10% each day.

Citation & Submission

All written assignments must use standard citation format (e.g., MLA, APA, Chicago), cite sources, and be submitted to the course website (not via email).

You are encouraged to discuss the assignments among each other. If you received help from a classmate, acknowledge it in your submission. Using someone else's work without acknowledging and without their consent is deemed as plagiarism.

Special Policy on ChatGPT

You are *allowed* to use ChatGPT in your work, **but** you **must** provide a **reflection** on **how you used it**, and **your experience** throughout the process.

School and University Policies and Resources

Copyright Policy

Please note—Due to copyright restrictions, online access to this material is limited to instructors and students currently registered for this course. Please be advised that by clicking the link to the electronic materials in this course, you have read and accept the following:

The copyright law of the United States (Title 17, United States Code) governs the making of photocopies or other reproductions of copyrighted materials. Under certain conditions specified in the law, libraries and archives are authorized to furnish a photocopy or other reproduction. One of these specified conditions is that the photocopy or reproduction is not to be "used for any purpose other than private study, scholarship, or research." If a user makes a request for, or later uses, a photocopy or reproduction for purposes in excess of "fair use," that user may be liable for copyright infringement.

Academic Integrity

Columbia University expects its students to act with honesty and propriety at all times and to respect the rights of others. It is fundamental University policy that academic dishonesty in any guise or personal conduct of any sort that disrupts the life of the University or denigrates or endangers members of the University community is unacceptable and will be dealt with severely. It is essential to the academic integrity and vitality of this community that individuals do their own work and properly acknowledge the circumstances, ideas, sources, and assistance upon which that work is based. Academic honesty in class assignments and exams is expected of all students at all times.

SPS holds each member of its community responsible for understanding and abiding by the SPS Academic Integrity and Community Standards posted at https://sps.columbia.edu/students/student-support/academic-integrity-community-standards. You are required to read these standards within the first few days of class. Ignorance of the School's policy concerning academic dishonesty shall not be a defense in any disciplinary proceedings.

Diversity Statement

It is our intent that students from all diverse backgrounds and perspectives be well-served by this course, that students' learning needs be addressed both in and out of class, and that the diversity that the students bring to this class be viewed as a resource, strength and benefit. It is our intent to present materials and activities that are respectful of diversity: gender identity, sexuality, disability, age, socioeconomic status, ethnicity, race, nationality, religion, and culture.

Accessibility

Columbia is committed to providing equal access to qualified students with documented disabilities. A student's disability status and reasonable accommodations are individually determined based upon disability documentation and related information gathered through the intake process. For more information regarding this service, please visit the University's Health Services website: https://health.columbia.edu/content/disability-services.

Class Recordings

All or portions of the class may be recorded at the discretion of the Instructor to support your learning. At any point, the Instructor has the right to discontinue the recording if it is deemed to be obstructive to the learning process.

If the recording is posted, it is confidential and it is prohibited to share the recording outside of the class.

SPS Academic Resources

The Division of Student Affairs provides students with academic counseling and support services such as online tutoring and career coaching: https://sps.columbia.edu/students/student-support/student-support-resources.

Columbia University Information Technology

Columbia University Information Technology (CUIT) provides Columbia University students, faculty and staff with central computing and communications services. Students, faculty and staff may access University-provided and discounted software downloads.

Columbia University Library

Columbia's extensive library system ranks in the top five academic libraries in the nation, with many of its services and resources available online.

The Writing Center

The Writing Center provides writing support to undergraduate and graduate students through one-on-one consultations and workshops. They provide support at every stage of your writing, from brainstorming to final drafts. If you would like writing support, please visit the following site to learn about services offered and steps for scheduling an appointment. This resource is open to Columbia graduate students at no additional charge. Visit http://www.college.columbia.edu/core/uwp/writing-center.

Career Design Lab

The Career Design Lab supports current students and alumni with individualized career coaching including career assessment, resume & cover letter writing, agile internship job search strategy, personal branding, interview skills, career transitions, salary negotiations, and much more. Wherever you are in your career journey, the Career Design Lab team is here to support you. Link to https://careerdesignlab.sps.columbia.edu/

Netiquette *[Only applies to courses using online platforms]*

Online sessions in this course will be offered through Zoom, accessible through Canvas. A reliable Internet connection and functioning webcam and microphone are required. It is your responsibility to resolve any known technical issues prior to class. Your webcam should remain turned on for the duration of each class, and you should expect to be present the entire time. Avoid distractions and maintain professional etiquette.

Please note: Instructors may use Canvas or Zoom analytics in evaluating your online participation.

More guidance can be found at: https://jolt.merlot.org/vol6no1/mintu-wimsatt_0310.htm

Netiquette is a way of defining professionalism for collaborations and communication that take place in online environments. Here are some Student Guidelines for this class:

- Avoid using offensive language or language that is not appropriate for a professional setting.
- Do not criticize or mock someone's abilities or skills.
- Communicate in a way that is clear, accurate and easy for others to understand.
- Balance collegiality with academic honesty.
- Keep an open-mind and be willing to express your opinion.
- Reflect on your statements and how they might impact others.
- Do not hesitate to ask for feedback.
- When in doubt, always check with your instructor for clarification.