Geog 246: Special Topics in Climate & Water Resources – 3 credits

SNOW HYDROLOGY

Spring 2020
Fridays 12:00-3:00pm, Living and Learning Commons 314

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Office hours: Tuesdays 8:30-10:30, Fridays 10:00-11:00



Course description, format, and goals:

Snow is a significant component of the hydrologic cycle in high latitude and high elevation environments. In this course, we will examine spatial controls on snow accumulation and the dynamics of snowmelt processes through readings of recent research in snow hydrology, field campaigns to measure snow and snowmelt properties, and analytical exercises. Of particular interest will be the importance of snow to regional water resources in diverse geographic settings and the role of forest vegetation in modifying snow accumulation and snowmelt dynamics.

Class meetings will be divided between seminar-styled sessions in which we will discuss current research in the field of snow hydrology and laboratory sessions that will include field exercises at sites in the area and computer-based exercises to practice analytical methods for evaluating snowpack properties and processes.

Through participation in this course, students will:

- gain familiarity with current research themes in the area of snow hydrology through review and discussion of peer-reviewed scientific articles
- gain experience with field measurements techniques used to measure snow pack distribution and physical properties
- learn how to apply a range of statistical analysis and spatial modeling techniques to snow data using spreadsheet-, statistical analysis-, and GIS-software
- develop, execute and present a self-designed research project

Seminar Sessions and Reading Synopses:

Most of our class meetings will focus, in part, on a discussion of recent research in snow hydrology. To participate in these discussions, students are expected to have read assigned papers before the class session in which they are discussed. All assigned papers and weekly discussion questions will be posted on Blackboard. Students will be responsible for handing in a one page synopsis of each assigned paper. The synopsis should include (1) bullet points outlining the main points of the paper, (2) questions/comments you have on the paper (these should be things you're willing to raise and discuss in class), and (3) response to posted discussion question(s). An example of a reading synopsis is posted on Blackboard. Because this is a seminar-based course, ***students are expected to actively participate in discussions*** during seminar sessions.

Field Exercises:

Field trips will provide students with an opportunity to learn techniques for measurement of snowpack conditions and topographic and forest canopy characteristics that influence snowpacks. Each student is expected to participate in three field trips, including one full-day field trip, which can be scheduled flexibly around student schedules in the week before spring break. All measuring equipment and transportation will be provided. Students will be responsible for bringing lunch and warm clothing. A fee assessed for the course covers field trip transportation cost, equipment rental and lab fees.

Homework / Lab Exercises:

Homework and lab exercises are intended to expose students to data analysis methods used in snow hydrology and build computational skills. We will make use of the Geotechniques Lab (L203) to complete these exercises and will employ spreadsheets and GIS software. Some previous experience (typically gained through Geog 81, Geog 184, ENSC 130 or NR 143) using these software packages is expected.

Research Project:

The research project is intended to expose students to the development of primary research and provides an opportunity to work with academic and professional scientists. Students will elect a project in cooperation with the instructor and those partners. A more detailed project guidelines document and project options will be made available in mid-February. This course-based research experience[1] and the work sessions that will take place with our research partners is designed to give students exposure to how scientific research is conceived, executed and situated within a broader literature in the field. Students interested in participating in one or more research publications resulting from our project work will be invited to do so.

Evaluation of Student Performance:

Grading for the course will be based on written summaries of readings, participation in seminar, field, and laboratory sessions, completion of homework and lab exercises, and execution of a research project. Distribution of effort for these graded activities is outlined on the following table:

[1] Our approach here is guided by Bangera and Brownell, 2014. Course-based Undergraduate Research Experiences can make Scientific Research More Inclusive. CBE-Life Sciences Education, 13: 602-606. See Blackboard for a copy of this paper.

Assignments	% of final grade
Reading Synopses*	20%
Check Blackboard for updates to syllabus reading schedule - 10 points per synopsis, including main points, questions, and response to posted question.	
Seminar attendance/participation	15%
11 graded seminar sessions, 25 points each (1/17, 1/24, 1/31, 2/14, 2/21, 2/28, 3/20, 3/27, 4/3, 4/10, 4/24, 5/1) - up to 10 points for attendance - up to 10 points for evidence that you have completed assigned readings - up to 5 points for active participation in discussion - lowest score dropped	
Field exercises and project work sessions	15%
3 field trips, 25 points each (2/7, 2/29, 4/17)	
Homework/Laboratory exercises	30%
3 lab exercises with written reports, 50 points each	
Research project	20%
May be completed individually or with a group Oral presentations during exam period Each student hands in individual project paper	

Late assignments will receive a deduction of 10% per day if turned in after the due date. If you would like to contest a grade, please follow the procedures outlined in this policy:
https://www.uvm.edu/policies/student/gradeappeals.pdf

Students are expected to follow UVM's code of study conduct and comply with our policies on academic integrity. Policy statements outlining these expectations are posted at:
http://www.uvm.edu/policies/student/studentcode.pdf *and*
https://www.uvm.edu/policies/student/acadintegrity.pdf

Student Evaluation of Course:

At the end of the semester, students will be asked to complete a course evaluation, administered via an online platform. Evaluations are anonymous and confidential, and are not available to the instructor until after grades have been submitted. Feedback on the course, including constructive criticism, will be used to improve the course. Students are also invited to share feedback with the instructor throughout the semester as they feel comfortable doing so.

Religious Holidays:

Students have the right to practice the religion of their choice. If you need to miss class to observe a religious holiday, please submit the dates of your absence to the instructor in writing by the end of the second full week of classes. You will be permitted to make up work within a mutually agreed-upon time. https://www.uvm.edu/registrar/religious-holidays

Student Learning Accommodations:

In keeping with University policy, any student with a documented disability interested in utilizing accommodations should contact SAS, the office of Disability Services on campus. SAS works with students and faculty in an interactive process to explore reasonable and appropriate accommodations, which are communicated to faculty in an accommodation letter. All students are strongly encouraged to meet with their faculty to discuss the accommodations they plan to use in each course. A student's accommodation letter lists those accommodations that will not be implemented until the student meets with their faculty to create a plan. For more information contact SAS: A170 Living/Learning Center; 802-656-7753; access@uvm.edu | www.uvm.edu/access

Promoting Health & Safety:

The University of Vermont's number one priority is to support a healthy and safe community. Student seeking support are welcome to speak with the instructor about resources available. Listed below are important campus support services

Center for Health and Wellbeing: https://www.uvm.edu/health

Counseling & Psychiatry Services (CAPS): Phone: (802) 656-3340

If you are concerned about a UVM community member or are concerned about a specific event, we encourage you to contact the Dean of Students Office (802-656-3380). If you would like to remain anonymous, you can report your concerns online by visiting the Dean of Students website at https://www.uvm.edu/studentaffairs.

Statement on Alcohol and Cannabis in the Academic Environment

As a faculty member, I want you to get the most you can out of this course. You play a crucial role in your education and in your readiness to learn and fully engage with the course material. It is important to note that alcohol and cannabis have no place in an academic environment. They can seriously impair your ability to learn and retain information not only in the moment you may be using, but up to 48 hours or more afterwards. It is my expectation that you will do everything you can to optimize your learning and to fully participate in this course.

Course schedule and readings: (subject to change given weather conditions that may impact trip timing)

Week / Date	Topic/Readings
1 / Jan 17	**Course Introduction: The Changing Cryosphere** • A G Fountain, J L Campbell, E A G Schuur, S E Stammerjohn, M W Williams, H W Ducklow, 2012. The Disappearing Cryosphere: Impacts and Ecosystem Responses to Rapid Cryosphere Loss. *BioScience* 62:4, 405-415. • M Huss, B Bookhagen, C Huggel, D Jacobsen, RS Bradley, JJ Clague, M Vuille, W Buytaert, CR Cayan, G Greenwood, BG Mark, AM Milner, R Weingartner, M Winder, 2017. Toward mountains without permanent snow and ice. *Earth's Future* 5:418–435.
2 / Jan 24	**Changing Snowpacks in a Warming World** • T G Huntington, G A Hodgkins, B D Keim, R W Dudley, 2004. Changes in the Proportion of Precipitation Occurring as Snow in New England (1949-2000). *Journal of Climate*, 17: 2626-2636. • A J Catalano, P C Loikith, C M Aragon, 2019. Spatiotemporal Variability of Twenty-First-Century Changes in Site-Specific Snowfall Frequency Over the Northwest United States. *Geophysical Research Letters* 46:16, 10122-10131.
3 / Jan 31	**Synoptic climatology of winter weather** • P A Sisson and J R Gyakum, 2004. Synoptic-scale precursors to significant cold-season precipitation events in Burlington, Vermont. *Weather and Forecasting*, 19: 841-854. • H M Archambault, D Keyser, L F Bosart, 2010. Relationships between Large-Scale Regime Transitions and Major Cool-Season Precipitation Events in the Northeastern United States. *Monthly Weather Review* 138:9, 3454-3473.
4 / Feb 7	**Measuring Snowpack Depth and Water Content** Trip 1: Jericho Research Forest ○ Chapter 4 in *Principles of Snow Hydrology* (no synopsis due this week)
5 / Feb 14	**Sampling Schemes for Assessing Spatial Variability in Snowpack Conditions** • S R Fassnacht, and J S Deems, 2006. Measurement sampling and scaling for deep montane snow depth data. Hydrological Processes, 20: 829-838. • J I López-Moreno, J Revuelto, S R Fassnacht, C Azorín-Molina, S M Vicente-Serrano, E Morán-Tejeda, G A Sexstone, 2014. Snowpack variability across various spatio-temporal resolutions, Hydrological Processes, 29 (6): 1213-1224. Lab session 1: Examining spatial autocorrelation of snowpack properties

6 / Feb 21 **Forest Canopy Influences on the Snowpack**

(*choose 2 of following papers*):

- C D Murray, and J M Buttle, 2003. Impacts of clearcut harvesting on snow accumulation and melt in northern hardwood forest. Journal of Hydrology, 271: 197-212.
- S W Woods, R Ahl, J Sappington, W McCaughey, 2006. Snow accumulation in thinned lodgepole pine stands, Montana, USA. Forest Ecology and Management. DOI:10.1015/j.foreco.2006.08.013.
- J I Lopez-Moreno and J Latron, 2007. Influence of canopy density on snow distribution in a temperate mountain range. Hydrological Processes. DOI: 10.1002/hyp6572.
- C A Penn, B C Wemple, and J L Campbell, 2012. Forest influences on snow accumulation and snowmelt at the Hubbard Brook Experimental Forest, New Hampshire, USA. Hydrologic Processes, 26, 2524–2534, DOI: 10.1002/hyp.9450.

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7 / Feb 28 **Topographic influences on snowpack distribution - measurement & mapping**

- J Hosang, and K Dettwiler, 1991. Evaluation of a water equivalent snow cover map in a small catchment area using a geostatistical approach. Hydrological Processes, 5: 283-290.
- S P Anderton, S M White, B Alvera, 2004. Evaluation of spatial variability in snow water equivalent for a high mountain catchment. *Hydrological Processes*, 18: 435-453. doi:10.1002/hyp.1319.

Sat., Feb 29 Trip 2: Mt. Mansfield – depart 9:00am, return 5:30pm (alternate scheduling possible)

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8 / Mar 6 No class meeting; make up day for Mt Mansfield snow survey; project meetings with instructor

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9 / Mar 13 *Spring Break*

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10 / Mar 20 **Regional to global mapping of snow cover**

- A W Nolin, and C Daly, 2006. Mapping "At Risk" Snow in the Pacific Northwest. *Journal of Hydrometeorology*, 7: 1164-1171, doi.org/10.1175/JHM543.1
- J CHammond, F A Saavedra, S K Kampf, 2018. Global snow zone maps and trends in snow persistence 2001-2016. *International Journal of Climatology* 38:12, 4369-4383.

Lab session 2: Mapping snow cover across topographic gradients

11 / Mar 27	**Snowpack and Meltwater Chemistry** • S.D. Sebestyen, et al., 2008. Sources, transformations, and hydrological processes that control stream nitrate and dissolved organic matter concentrations during snowmelt in an upland forest. *Water Resources Research*, 44, W12410, doi:10.1029. • N J Casson, M C Eimers, S A Watmough, 2012. Impact of winter warming on the timing of nutrient export from forested catchments. *Hydrological Processes*, 26: 2546-2554. doi:10.1002/hyp.8461.
12 / Apr 3	**Modeling Snowmelt Processes** • K S Jennings and N P Molotch, 2019. The sensitivity of modeled snow accumulation and melt to precipitation phase methods across a climatic gradient, Hydrology and Earth System Sciences, 23, 3765–3786, https://doi.org/10.5194/hess-23-3765-2019. Lab session 3: Snowmelt energy balance modeling
13 / Apr 10	**Economic Implications of Changing Snow Cover** • D Scott, J Dawson, B Jones, 2008. Climate change vulnerability of the US Northeast winter recreation– tourism sector. *Mitigation and Adaptation Strategies for Global Change* 13, 577–596. doi:10.1007/s11027-007-9136-z • Marc Pons, Juan Ignacio López-Moreno, Martí Rosas-Casals, and Èric Jover, 2015. The vulnerability of Pyrenean ski resorts to climate-induced changes in the snowpack. *Climatic Change* 131:4, 591-605.
14 / Apr 17	**National Snowcover Mapping and Runoff Prediction** Trip 3: National Weather Service, Burlington Airport
15 / Apr 24	**Ways forward – Society, Adaptation and Integrated Research Agendas** • G McDowell, C Huggel, H Frey, FM Wang, K Cramer, V Ricciardi, 2019. Adaptation action and research in glaciated mountain systems: are they enough to meet the challenge of climate change? *Global Environmental Change* 54:19–30. https://doi.org/10.1016/j.gloenvcha. 2018.10.012. • M Carey, O C Molden, M B Rasmussen, M Jackson, A W Nolin, B G Mark, 2016. Impacts of glacier recession and declining meltwater on mountain societies. Annals of the Association of American Geographers, 107:2, 350-359, https://doi:10.1080/24694452.2016.1243039.
16 / May 1	**Course wrap-up and final project work session**
Tues., May 5	**Final project presentations and papers due during exam session,** 4:30-7:15pm