GEOG 696M Hydroclimate: Past, Present, and Future

Autumn 2017

This course is designed as a graduate level class in a *seminar* format to provide an opportunity for students to develop a deeper understanding of hydroclimate variability across a range of time scales. Topics include theoretical and model-based understanding of the processes governing hydroclimate variability in space and time, hydroclimate variability over the Common Era, recent and current trends in precipitation, drought, soil moisture, and riverflow, and projections of future hydroclimate change. Readings are from classic, foundational, and recent papers, and topics will include: hydroclimate reconstructions of the Common Era (particularly from tree rings, but also other proxies), expectations from models and theory about the sign and range of forced and unforced variability in global and regional hydroclimate systems, inferences about large-scale controls on hydroclimate variability across a range of time scales and climate states, uncertainties in observations and reconstructions of the hydroclimate system, statistical challenges in interpreting and reconstructing hydroclimate variability, and projections of future hydroclimate changes.

This syllabus and course schedule are subject to change.
Please check regularly for updated information on D2L

Locations and Times

Monday, 3:30pm to 6PM
Bannister Tree-Ring Laboratory Building, Room 424 (Large Conference Room)
Course materials online via D2L (`http://d2l.arizona.edu`)

Instructor Information

Kevin Anchukaitis
Associate Professor, School of Geography and Development
Laboratory of Tree Ring Research
Room S514, Environment and Natural Resources Building 2 (ENR2)
Room 419, Bannister Tree Ring Lab Building
Office Phone: (520) 626-8054
Email: kanchukaitis@email.arizona.edu

Office Hours

Office Hours in Autumn 2017 are by appointment

Course Information

Credits

Students may register for 2 (presentation and discussion) or 3 credits (final synthesis assignment).

Prerequisites

Continuing graduate student status or permission from instructor. Prior statistical, atmospheric science, and climate science courses are encouraged.

Course Objectives and Expected Learning Outcomes

This course has the following expected learning outcomes:

- Factual: You will acquire fundamental knowledge of the state, variability, and trends in large-scale features of global and regional hydroclimate. You will become familiar with methods for observing and modeling hydroclimate variability in the past, present, and future. You will become familiar with the terminology used to described hydroclimate variability. You will also be able to locate and acquire appropriate data and access up-to-date peer reviewed literature on hydroclimate in the past, present, and future.

- Conceptual: You will cultivate a first-order understanding of the process and physical laws governing variability in the hydroclimate system and be able to apply this understanding to generate hypotheses about the outcomes of changes in radiative forcing and the role of natural and internal variability. You will be able to identify and where appropriate qualify and quantify sources of uncertainty in theory, models, data, and projections.
- Procedural: You will gain experience and practice in gathering, summarizing, and synthesizing theory, conceptual and physical simulations, data, and inferences about hydroclimate variability from a variety of sources, including both those assigned as part of the class and other supporting articles from the literature.
- Metacognitive: You will recognize the potential and limitation of both theory and observations in predicting and understanding hydroclimate variability. You will be able to identify reasonable (and unreasonable) inferences or conclusions from your analyses. You will develop an enhanced recognition of how potential biases – including both methodological as well as cognitive – enter into analyses of hydroclimate systems. You will practice deploying both quantitative analyses and qualitative reasoning to assess likelihood and bias in published papers and how these effect the strength and utility of the inferences that can be made.

Required Texts or Readings

There is no required textbook for this course. Required readings will be posted on D2L.

Assignments and Methods of Assessment

Paper Presentations: [50%] Students will all lead at least 1, and likely 2, presentation on readings for the class. These presentation will include an introduction to the broader topic, the position of the paper under discussion within that topic, the importance and relevance of the paper, methods, results, and analyses. In most cases, the presenter will need to draw on other related literature, make connections to earlier papers, and review or introduce theoretical, observational, or methodological concepts. The presentation should be an expansive synthesis of the paper, related work, and it's larger context, include discussions of uncertainty and precedent, and be critical in a scholarly way without invective. The presentation should be no more than 30 minutes long and should draw on figures and graphics from the assigned paper(s) as well as any other resources that presenter finds useful for conveying important concepts. The quality of the presentation will be assessed and quantified by the instructor, based on a rubric available on D2L.

Paper Discussant and Class Participation: [50%] Students will elect to serve as the discussant for at least one paper presentation. The discussant will be in charge of starting and guiding the discussion following the paper presentation itself. The discussant should have an in-depth familiarity with the paper(s) under discussion, associated literature, terms and physical process discussed in the primary papers(s), and should prepare a series of motivating questions in order to stimulate discussion. All students are also expected to participate actively in all paper discussions, read all assigned papers, and familiarize themselves with the material prior to class. The quality of the discussant's role and the overall participation in the class will be assessed and quantified by the instructor, based on a rubric available on D2L.

Final Project: For those students registered for 3 credits for the course, a final culminating and synthetic project is required. This assignment can be an original manuscript, literature review or annotated bibliography, an original analysis of hydroclimate data, or another written or analytical project approved by the instructor. The assignment is **due on D2L no later than Thursday, December 7th, 2017, at 5:00pm Arizona time**.

Grade polices and Letter Grade Distribution:
University policies regarding grades and grading systems are available at:
`http://catalog.arizona.edu/2015-16/policies/grade.htm`

Grade distribution for this course:
A: 90% and above
B: 80% to 89%
C: 70% to 79%
D: 65% to 69%
E: below 65%

Requests for incomplete (I) or withdrawal (W) must be made in accordance with University policies, which are available at `http://catalog.arizona.edu/policy/grades-and-grading-system#incomplete` and `http://catalog.arizona.edu/policy/grades-and-grading-system#Withdrawal` respectively. Please be aware of deadlines for requesting these grades. Any requests for reconsideration of a grades must be made to the instructor no later Monday, December 11th at 5pm.

There is no final exam for this course.

Late work
Assignments that are not completed or handed in on time, without prior arrangement with the instructor, will receive no credit. Presenters and discussants are expected to fulfill these rolls on the days they select at the start of the semester.

University Policies

Course Communications
All communications concerning class are via official UA email addresses. It is the student's responsibility to regularly check for email communications concerning class information and policies, and to contact the instructor from the student's official UA email address.

Course materials
Course materials will be available online via D2L (`http://d2l.arizona.edu`)

Absence and Class Participation Policy
The UAs policy concerning Class Attendance, Participation, and Administrative Drops is available at `http://catalog.arizona.edu/policy/class-attendance-participation-and-administrative-drop`. The UA policy regarding absences for any sincerely held religious belief, observance or practice will be accommodated where reasonable: `http://policy.arizona.edu/human-resources/religious-accommodation-policy`. Absences pre-approved by the UA Dean of Students (or deans designee) will be honored. See `http://uhap.web.arizona.edu/policy/appointed-personnel/7.04.02`.

Active participation in the course is vital to the learning process. As such, attendance is strongly encouraged at all meetings of the class.

Because the course is for graduate students, who often may have to travel for fieldwork or professional conferences, please make arrangements with the instructor **before** you anticipate being absent for one of these reasons. Seminar classes depend on the active participation of the students, and attendance may be reflected in the final course grade.

Assignment and Grading Policy for Students Who Register Late
Students who register late for the course will be required to take on the same number of presentation and discussant roles as other student.

Classroom Behavior Policy
To foster a positive learning environment, students and instructors have a shared responsibility. We want a safe, welcoming, and inclusive environment where all of us feel comfortable with each other and where we can challenge ourselves to succeed. Students engaging in disruptive activity will be asked to cease this behavior. Those who continue to disrupt the class will be asked to leave lecture or discussion and may be reported to the Dean of Students.

Threatening Behavior Policy
The UA Threatening Behavior by Students Policy prohibits threats of physical harm to any member of the University community, including to oneself. See `http://policy.arizona.edu/education-and-student-affairs/threatening-behavior-students`.

Accessibility and Accommodations
Our goal in this classroom is that learning experiences be as accessible as possible. If you anticipate or experience physical or academic barriers based on disability, please let me know immediately so that we can discuss options. You are also welcome to contact the Disability Resource Center (520-621-3268) to establish reasonable accommodations. For additional information on the Disability Resource Center and reasonable accommodations, please visit `http://drc.arizona.edu`. If you have reasonable accommodations, please plan to meet with me by appointment or during office hours to discuss accommodations and how my course requirements and activities may impact your ability to fully participate.

Code of Academic Integrity
Students are encouraged to share intellectual views and discuss freely the principles and applications of course materials. However, graded work must be the product of independent effort unless otherwise instructed. Students are expected to adhere to the UA Code of Academic Integrity as described in the UA General Catalog. See `http://deanofstudents.arizona.edu/academic-integrity/students/academic-integrity`.

For written exercises, the University Libraries have some excellent tips for avoiding plagiarism, available at: `http://www.library.arizona.edu/help/tutorials/plagiarism/index.html`.

UA Nondiscrimination and Anti-harassment Policy
The University is committed to creating and maintaining an environment free of discrimination; see `http://policy.arizona.edu/human-resources/nondiscrimination-and-anti-harassment-policy`. Our classroom is a place where everyone is encouraged to express well-formed opinions and their reasons for those opinions. We also want to create a tolerant and open environment where such opinions can be expressed without resorting to bullying or discrimination of others.

Additional Resources for Students
UA Academic policies and procedures are available at: `http://catalog.arizona.edu/policies`.

Student Assistance and Advocacy information is available at: `http://deanofstudents.arizona.edu/student-assistance/students/student-assistance`

Confidentiality of Student Records
Please see the University's policy on the confidentiality of student records here: `http://www.registrar.arizona.edu/ferpa/default.htm`

Subject to Change Statement
Information contained in the course syllabus, other than the grade and absence policy, may be subject to change with advance notice, as deemed appropriate by the instructor.

Course Schedule

Date	Reading and Discussion Topic
Session 1 — August 21	Course introduction and overview
Session 2 — August 28	Global Theory and Hydroclimate Fundamentals
Session 3 — September 11	Global Theory and Hydroclimate Fundamentals
Session 4 — September 18	Intertropical Convergence Zone and Storm Tracks
Session 5 — October 2	Internal Variability
Session 6 — October 9	20th Century Observations
Session 7 — October 16	Streamflow
Session 8 — October 23	Streamflow
Session 9 — October 30	Snow and Streamflow
Session 10 — November 6	Common Era Paleoclimate
Session 11 — November 13	Common Era Paleoclimate
Session 12 — November 20	Future Projections
Session 13 — November 27	Future Projections
Session 14 — December 4	Future Projections and Summary

Session 2: *Global Theory and Hydroclimate Fundamentals I* — August 28

Soden, B. J., Held, I. M. (2006). An assessment of climate feedbacks in coupled ocean-atmosphere models. Journal of Climate, 19(14), 3354-3360. Jonathan Jessie

O'Gorman, P. A., Schneider, T. (2008). The hydrological cycle over a wide range of climates simulated with an idealized GCM. Journal of Climate, 21(15), 3815-3832. Kai Garrison

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Session 3: *Global Theory and Hydroclimate Fundamentals II* — September 11

Chou, C., Neelin, J. D., Chen, C. A., Tu, J. Y. (2009). Evaluating the "rich-get-richer" mechanism in tropical precipitation change under global warming. Journal of Climate, 22(8), 1982-2005. Matt Kai

Chadwick, R., Boutle, I., Martin, G. (2013). Spatial patterns of precipitation change in CMIP5: Why the rich do not get richer in the tropics. Journal of Climate, 26(11), 3803-3822. Elizabeth Jonathan

Byrne, M. P., O'Gorman, P. A. (2015). The response of precipitation minus evapotranspiration to climate warming: Why the "wet-get-wetter, dry-get-drier" scaling does not hold over land. Journal of Climate, 28(20), 8078-8092. Jonathan Garrison

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Session 4: *Intertropical Convergence Zone and Storm Tracks* — September 18

Lu, J., Vecchi, G. A., Reichler, T. (2007). Expansion of the Hadley cell under global warming. Geophysical Research Letters, 34(6). Matt Elizabeth

Bony, S., Bellon, G., Klocke, D., Sherwood, S., Fermepin, S., Denvil, S. (2013). Robust direct effect of carbon dioxide on tropical circulation and regional precipitation. Nature Geoscience, 6(6), 447. Talia Will

Byrne, M. P., Schneider, T. (2016). Narrowing of the ITCZ in a warming climate: Physical mechanisms. Geophysical Research Letters, 43(21). Garrison

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Session 5: *Internal Variability* — October 2

Hawkins, E., Sutton, R. (2011). The potential to narrow uncertainty in projections of regional precipitation change. Climate Dynamics, 37(1-2), 407-418. Kashja Jonathan

Deser, C., Knutti, R., Solomon, S., Phillips, A. S. (2012). Communication of the role of natural variability in future North American climate. Nature Climate Change, 2(11), 775-779.

Deser, C., Phillips, A. S., Alexander, M. A., Smoliak, B. V. (2014). Projecting North American climate over the next 50 years: Uncertainty due to internal variability. Journal of Climate, 27(6), 2271-2296. Jessie Garrison

Session 6: *20th Century Observations* — October 9

John, V. O., Allan, R. P., Soden, B. J. (2009). How robust are observed and simulated precipitation responses to tropical ocean warming?. Geophysical Research Letters, 36(14). Kashja Will

Gu, G., Adler, R. F. (2015). Spatial patterns of global precipitation change and variability during 1901–2010. Journal of Climate, 28(11), 4431-4453. Pablo Talia

Salzmann, M. (2016). Global warming without global mean precipitation increase? Science Advances, 2(6), e1501572. Garrison Matt

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Session 7: *Streamflow I* — October 16

Milly, P. C., Betancourt, J., Falkenmark, M., Hirsch, R. M., Kundzewicz, Z. W., Lettenmaier, D. P., et al. (2008). Stationarity is dead: Whither water management?. Science, 319(5863), 573-574.

Milly, P. C., Betancourt, J., Falkenmark, M., Hirsch, R. M., Kundzewicz, Z. W., Lettenmaier, D. P., et al. (2015). On critiques of 'Stationarity is dead: whither water management?'. Water Resources Research, 51(9), 7785-7789. Sarah Bethany

Montanari, A., Koutsoyiannis, D. (2014). Modeling and mitigating natural hazards: Stationarity is immortal!. Water Resources Research, 50(12), 9748-9756. Grace Sarah

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Session 8: *Streamflow II* — October 23

Woodhouse, C. A., Gray, S. T., Meko, D. M. (2006). Updated streamflow reconstructions for the Upper Colorado River basin. Water Resources Research, 42(5).

Meko, D. M., Woodhouse, C. A., Baisan, C. A., Knight, T., Lukas, J. J., Hughes, M. K., Salzer, M. W. (2007). Medieval drought in the upper Colorado River Basin. Geophysical Research Letters, 34(10). Will Sarah

Vano, J. A., Udall, B., Cayan, D. R., Overpeck, J. T., Brekke, L. D., Das, T., et al. (2014). Understanding uncertainties in future Colorado River streamflow. Bulletin of the American Meteorological Society, 95(1), 59-78. Sarah Kashja

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Session 9: *Snow and Streamflow* — October 30

Li, D., Wrzesien, M. L., Durand, M., Adam, J., Lettenmaier, D. P. (2017). How much runoff originates as snow in the western United States, and how will that change in the future? Geophysical Research Letters.

Harpold, A. A., Molotch, N. P. (2015). Sensitivity of soil water availability to changing snowmelt timing in the western US. Geophysical Research Letters, 42(19), 8011-8020. Will Kai

Berghuijs, W. R., Woods, R. A., Hrachowitz, M. (2014). A precipitation shift from snow towards rain leads to a decrease in streamflow. Nature Climate Change, 4(7), 583.

Barnhart, T. B., Molotch, N. P., Livneh, B., Harpold, A. A., Knowles, J. F., Schneider, D. (2016). Snowmelt rate dictates streamflow. Geophysical Research Letters, 43(15), 8006-8016.

Kai
Grace

Session 10: *Common Era Paleoclimate I* — November 6

Lehner, F., Wahl, E. R., Wood, A. W., Blatchford, D. B., Llewellyn, D. (2017). Assessing recent declines in Upper Rio Grande runoff efficiency from a paleoclimate perspective. Geophysical Research Letters, 44(9), 4124-4133.

Elizabeth
Grace

Cook, E. R., Woodhouse, C. A., Eakin, C. M., Meko, D. M., Stahle, D. W. (2004). Long-term aridity changes in the western United States. Science, 306(5698), 1015-1018.

Coats, S., Smerdon, J. E., Cook, B. I., Seager, R., Cook, E. R., Anchukaitis, K. J. (2016). Internal ocean–atmosphere variability drives megadroughts in Western North America. Geophysical Research Letters, 43(18), 9886-9894.

Garrison
Kai

Session 11: *Common Era Paleoclimate II* — November 13

Pederson, N., Bell, A. R., Cook, E. R., Lall, U., Devineni, N., Seager, R., et al. (2013). Is an Epic Pluvial Masking the Water Insecurity of the Greater New York City Region? Journal of Climate, 26(4), 1339-1354.

Jessie
Talia

Newby, P. E., Shuman, B. N., Donnelly, J. P., Karnauskas, K. B., Marsicek, J. (2014). Centennial-to-millennial hydrologic trends and variability along the North Atlantic Coast, USA, during the Holocene. Geophysical Research Letters, 41(12), 4300-4307.

Pablo
Matt

Cook, E. R., Seager, R., Kushnir, Y., Briffa, K. R., Bntgen, U., Frank, D., et al. (2015). Old World megadroughts and pluvials during the Common Era. Science Advances, 1(10), e1500561.

Grace
Elizabeth

Session 12: *Future Projections I* — November 20

Berg, A., Findell, K., Lintner, B., Giannini, A., Seneviratne, S. I., Van Den Hurk, B., et al. (2016). Land-atmosphere feedbacks amplify aridity increase over land under global warming. Nature Climate Change, 6, 869-874.

He, J., Soden, B. J. (2017). A re-examination of the projected subtropical precipitation decline. Nature Climate Change, 7(1), 53-57.

Matt
Jonathan

Cook, B. I., Ault, T. R., Smerdon, J. E. (2015). Unprecedented 21st century drought risk in the American Southwest and Central Plains. Science Advances, 1(1), e1400082.

Milly, P. C., Dunne, K. A. (2016). Potential evapotranspiration and continental drying. Nature Climate Change, 6, 946-949.

Bonfils, C., Anderson, G., Santer, B. D., Phillips, T. J., Taylor, K. E., Cuntz, M., et al. (2017). Competing influences of anthropogenic warming, ENSO, and plant physiology on future terrestrial aridity. Journal of Climate, (2017). Talia Pablo

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Session 13: *Future Projections II* — November 27

Mankin, J. S., Smerdon, J. E., Cook, B. I., Williams, A. P., Seager, R. (2017). The curious case of projected 21st-century drying but greening in the American West. Journal of Climate, (2017). Talia Jessie

Musselman, K. N., Clark, M. P., Liu, C., Ikeda, K., Rasmussen, R. (2017). Slower snowmelt in a warmer world. Nature Climate Change, 7(3), 214-219.

Berg, N., Hall, A. (2017). Anthropogenic warming impacts on California snowpack during drought. Geophysical Research Letters, 44(5), 2511-2518. Kai Kashja

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Session 14: *North American Monsoon* — December 4

Cook, B. I., Seager, R. (2013). The response of the North American Monsoon to increased greenhouse gas forcing. Journal of Geophysical Research: Atmospheres, 118(4), 1690-1699.

Meyer, J. D., Jin, J. (2017). The response of future projections of the North American monsoon when combining dynamical downscaling and bias correction of CCSM4 output. Climate Dynamics, 49(1-2), 433-447. Jonathan Pablo