Climate Change, Water, and Society

Meetings: Mondays 9-12 pm
Spring 2015 Syllabus

Instructor: Dr. Prajjwal K. Panday

Course Description
Water resources in the context of changing climate are critical issues for the sustenance of nearly every society. Changes in water availability due to climate change will be further complicated by human use of water for agriculture, changes in land use, and population growth. Climate change may also increase the severity, frequency, and duration of weather extremes such as droughts and floods. This seminar is designed for graduate students and advanced senior undergraduates to investigate the impacts of historical, current and future climate and feedbacks to the various components of the global hydrologic cycle. This course primarily focuses on the role of the water cycle in the earth system which extends from short-term phenomena through seasonal cycles at the watershed and continental scales, to long-term climatic changes on a global scale. This course also examines the occurrence, major trends, and future scenarios in water budget in the U.S. and around the world. This course will focus on integration of theory, data, computational tools, and numerical modeling to address water-related environmental and societal challenges. It also discusses the environmental, economic, and social implications of floods, droughts, dams, water usage, and transboundary water issues. Students will read and introduce primary and popular literatures, critically evaluate specific methodological applications for remote sensing and climate data analysis, facilitate discussions, and debate interpretations and conclusions.

Course format
The course will be taught in a seminar format. Classes will include a combination of lectures by the instructor, presentation led by the students, few guest speakers, and in-class demonstrations for data analysis using open source packages. The readings will form the basis on which students will prepare assignments and in-class presentations.

Student Responsibilities:
As a student in this course, you are expected to attend and participate in each class meeting. Students in the course are responsible for attending class having read the assigned texts, leading paper discussions, completing independent reaction papers and conducting an independent final project. As a graduate (or undergraduate) student, if you can choose a topic that relates to your ongoing research, I highly encourage you to do so. Grades will be determined based on each of these elements as described below.

1) **Class Participation and Overall Contribution to the Course** (20%)
Owing to the nature of this course as a seminar, it is imperative that you attend class regularly and actively participate in discussions of topics. It is critical that everyone complete the readings before class and come prepared to discuss them. The more actively involved we are in discussions, the more rewarding the seminar will be for everyone.

2) **Topical Presentations** (25%)

You should 1) provide a pre-seminar distribution of thought-provoking questions pertaining to the topic; 2) provide an oral synopsis and summary of the context, issues, and findings linked to the assigned readings potentially involved an outline or presentation; and 3) facilitate the seminar discussion itself. You will lead the discussion for one half of the course period at least two times during the semester, although this could depend on the number of students enrolled for the course.

3) **Written Summaries** (20%)
Six weekly summaries are to be submitted as reviews of two of the week's readings over the course of the semester. These documents relate the student's understanding of the main points of the readings, and any associated questions or criticisms that the students may have. These structured summaries will adhere to the style of the *Journal of Biogeography* and are to be turned in immediately following the seminar for evaluation and grading by the instructor. No credit will be awarded for late assignments.

4) **Final Project & Presentations** (35%)
Students will submit a final research paper and present their finding to the class at the end of the semester. This is an opportunity for you to further your research goals as a graduate student towards a publication quality manuscript and a conference talk.

Course Website: Readings, assignments, announcements, and other documents will be placed on the Cicada course website.

Honor Code:
Clark University's policies of academic integrity apply to every aspect of this course. Please see www.clarku.edu/offices/aac/integrity.cfm if you have any questions about what this entails.

Special Needs:
Persons with disabilities or in need of special accommodations are encouraged to contact the office of Disability Services (Academic Advising Center, 142 Woodland Street) as soon as possible to request such accommodations. In addition, it would be helpful to bring this to my attention as early as possible.

WEEK	TOPIC	READINGS
1	Course Overview & Discussion ▪ Outcomes and Expectations ▪ Climate change, water resources, societal issues ▪ Goals of participants	Nijssen et al., 2001 Vörösmarty et al., 2000 Bates et al., 2008 Gleick, P. 1989
2	Global Hydrological cycle & Water Resources, ▪ Following the Hydrologic Cycle ▪ Global Water Resources	Bonan, G. 2002, Ch 11-13 Jiménez Cisneros et al., 2014 Oki et al., 2006
3	Changes in Climate as They Relate to Water ▪ Observed Hydrological Changes due to Climate Change ▪ Climatic & Non Climatic Drivers of Change	Barnett et al., 2008 Piao et al., 2010 Trenberth 2011
4	Extreme Events I: Droughts	MacDonald, 2010 Tomasella et al., 2013 Kelley et al., 2015 Trenberth et al., 2014
5	Extreme Events II: Flooding	Bamber et al., 2013 Woodruff et al., 2013 Tebaldi et al., 2012
6	Land Cover Change, Hydrology, & Climate Feedbacks ▪ Impacts on Water Resources ▪ Feedbacks to Climate	Bala et al., 2007 Bonan, G., 2008 Jung et al., 2010 Coe et al., 2009 Panday et al., 2015
7	Water Resources Monitoring & Assessment	Wood et al., 2011 Van Dijk et al., 2011 Sahoo et al., 2011 Pan et al., 2012
8	Cryospheric Changes & Feedbacks ▪ Large Ice Sheets, and Mountain Glaciers ▪ Climate Change Impacts on Snowmelt Hydrology ▪ Climate Feedbacks (e.g. Melting permafrost, Declining Sea Ice) ▪ Changes in Polar Hydrology	Adam et al., 2009 Peterson et al., 2002 Kehrwald et al., 2008 Immerzeel et al., 2010 Shepherd et al., 2012
9	Conflict and Cooperation ▪ Transboundary Water Management Issues ▪ Dams and Power Generation in the Context of Climate Change	Cooley et al., 2011 Stickler et al., 2012 Christensen and Lettenmaier, 2007 Haddeland et al., 2014
10	Groundwater Depletion	Rodell et al., 2009 Famiglietti et al., 2011 Scanlon et al., 2013 Taylor et al., 2013 Aeschbach-Hertig and Gleeson, 2012
11	Future Climate & Water Management ▪ Climate Scenarios ▪ Changes in Extremes ▪ Using Climate Projections for Management	Schewe et al., 2014 Rajagopalan et al., 2009 Grafton et al., 2013
12	Water-Food-Energy Climate Nexus	Lobell et al., 2008 Bazilian et al., 2011 Lal 2013 Waughray 2011
13	TBD	
14	TBD	
15	Final Project Presentations	
16	Final Project Presentations	

Week 1: Course Overview

Bates, B., Z. W. Kundzewicz, S. Wu, and J. Palutikof (2008), Climate change and water, Intergovernmental Panel on Climate Change (IPCC).

Gleick, P. H. (1989), Climate change, hydrology, and water resources, Rev. Geophys., 27(3), 329-344.

Nijssen, B., G. M. O'Donnell, A. F. Hamlet, and D. P. Lettenmaier (2001), Hydrologic sensitivity of global rivers to climate change, Clim. Change, 50, 143–175.

Vörösmarty, C. J., P. Green, J. Salisbury, and R. B. Lammers (2000), Global water resources: vulnerability from climate change and population growth, Science, 289(5477), 284-288.

Week 2: Global Hydrological cycle & Water Resources

Bonan, G. B. (2002), Ecological climatology: concepts and applications, Cambridge University Press.

Jiménez Cisneros, B.E., T. Oki, N.W. Arnell, G. Benito, J.G. Cogley, P. Döll, T. Jiang, and S.S. Mwakalila, 2014: Freshwater resources. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White (eds.)]. Cambridge University Press, Cambridge, United Kingdomand New York, NY, USA, pp. 229-269.

Oki, T., and S. Kanae (2006), Global hydrological cycles and world water resources, Science, 313(5790), 1068-1072.

Week 3: Changes in Climate as They Relate to Water

Barnett, T. P., D. W. Pierce, H. G. Hidalgo, C. Bonfils, B. D. Santer, T. Das, G. Bala, A. W. Wood, T. Nozawa, and A. A. Mirin (2008), Human-induced changes in the hydrology of the western United States, Science, 319(5866), 1080-1083.

Piao, S., P. Ciais, Y. Huang, Z. Shen, S. Peng, J. Li, L. Zhou, H. Liu, Y. Ma, and Y. Ding (2010), The impacts of climate change on water resources and agriculture in China, Nature, 467(7311), 43-51.

Trenberth, K. E. (2011), Changes in precipitation with climate change, Clim. Res., 47(1), 123.

Week 4: Extreme Events - Droughts

Kelley, C. P., S. Mohtadi, M. A. Cane, R. Seager, and Y. Kushnir (2015), Climate change in the Fertile Crescent and implications of the recent Syrian drought, Proceedings of the National Academy of Sciences, 112(11), 3241-3246.

MacDonald, G. M. (2010), Water, climate change, and sustainability in the southwest, Proceedings of the National Academy of Sciences, 107(50), 21256-21262.

Tomasella, J., P. F. Pinho, L. S. Borma, J. A. Marengo, C. A. Nobre, O. R. Bittencourt, M. C. Prado, D. A. Rodriguez, and L. A. Cuartas (2013), The droughts of 1997 and 2005 in Amazonia: floodplain hydrology and its potential ecological and human impacts, Clim. Change, 116(3-4), 723-746.

Trenberth, K. E., A. Dai, G. van der Schrier, P. D. Jones, J. Barichivich, K. R. Briffa, and J. Sheffield (2014), Global warming and changes in drought, Nature Clim. Change, 4(1), 17-22.

Week 5: Extreme Events - Flooding

Bamber, J. L., and W. Aspinall (2013), An expert judgement assessment of future sea level rise from the ice sheets, Nature Clim. Change, 3(4), 424-427.

Tebaldi, C., B. H. Strauss, and C. E. Zervas (2012), Modelling sea level rise impacts on storm surges along US coasts, Environ. Res. Lett., 7(1), 014032.

Woodruff, J. D., J. L. Irish, and S. J. Camargo (2013), Coastal flooding by tropical cyclones and sea-level rise, Nature, 504(7478), 44-52.

Week 6: Land Cover Change, Hydrology, and Climate Feedbacks

Bala, G., K. Caldeira, M. Wickett, T. Phillips, D. Lobell, C. Delire, and A. Mirin (2007), Combined climate and carbon-cycle effects of large-scale deforestation, Proceedings of the National Academy of Sciences, 104(16), 6550-6555.

Bonan, G. B. (2008), Forests and climate change: forcings, feedbacks, and the climate benefits of forests, Science, 320(5882), 1444-1449.

Coe, M. T., M. H. Costa, and B. S. Soares-Filho (2009), The influence of historical and potential future deforestation on the stream flow of the Amazon River–Land surface processes and atmospheric feedbacks, JHyd, 369(1), 165-174

Jung, M., M. Reichstein, P. Ciais, S. I. Seneviratne, J. Sheffield, M. L. Goulden, G. Bonan, A. Cescatti, J. Chen, and R. De Jeu (2010), Recent decline in the global land evapotranspiration trend due to limited moisture supply, Nature, 467(7318), 951-954.

Panday, P. K., M. T. Coe, M. N. Macedo, P. Lefebvre, and A. D. de Almeida Castanho (2015), Deforestation offsets water balance changes due to climate variability in the Xingu River in eastern Amazonia, JHyd, 523, 822-829.

Week 7: Water Resources Monitoring and Assessment

Pan, M., A. K. Sahoo, T. J. Troy, R. K. Vinukollu, J. Sheffield, and E. F. Wood (2012), Multisource estimation of long-term terrestrial water budget for major global river basins, J. Clim., 25(9), 3191-3206.

Sahoo, A. K., M. Pan, T. J. Troy, R. K. Vinukollu, J. Sheffield, and E. F. Wood (2011), Reconciling the global terrestrial water budget using satellite remote sensing, Remote Sens. Environ., 115(8), 1850-1865.

Van Dijk, A., and L. Renzullo (2011), Water resource monitoring systems and the role of satellite observations, HESS, 15(1), 39-55.

Wood, E. F., J. K. Roundy, T. J. Troy, L. Van Beek, M. F. Bierkens, E. Blyth, A. de Roo, P. Döll, M. Ek, and J. Famiglietti (2011), Hyperresolution global land surface modeling: Meeting a grand challenge for monitoring Earth's terrestrial water, Water Resources Res., 47(5).

Week 8: Cryospheric Change and Feedbacks

Barnett, T.P., Adam, J.C., and D.P. Lettenmaier, 2005. Potential impacts of a warming climate on water availability in snow-dominated regions. Nature, 438, 303-309

Immerzeel, W. W., L. P. H. v. Beek, and M. F. P. Bierkens (2010), Climate change will affect the Asian water towers, Science, 328, 1382–1385.

Kehrwald, N.M., Thompson, L.G., Tangdong, Y., Mosley-Thompson, E., Schotterer, U., Alfimov, V., Beer, J., Eikenberg, J., and M.E. Davis, 2008. Mass loss on Himalayan glacier endangers water resources. Geophysical Research Letters, 35, 1-6

Peterson, B. J., R. M. Holmes, J. W. McClelland, C. J. Vörösmarty, R. B. Lammers, A. I. Shiklomanov, I. A. Shiklomanov, and S. Rahmstorf (2002), Increasing river discharge to the Arctic Ocean, Science, 298(5601), 2171-2173.

Shepherd, A., E. R. Ivins, A. Geruo, V. R. Barletta, M. J. Bentley, S. Bettadpur, K. H. Briggs, D. H. Bromwich, R. Forsberg, and N. Galin (2012), A reconciled estimate of ice-sheet mass balance, Science, 338(6111), 1183-1189.

Yang, D., D. L. Kane, L. D. Hinzman, X. Zhang, T. Zhang, and H. Ye (2002), Siberian Lena River hydrologic regime and recent change, Journal of Geophysical Research: Atmospheres (1984–2012), 107(D23), ACL 14-11-ACL 14-10.

Week 9: Conflict and Cooperation

Cooley, H., J. Christian-Smith, P. H. Gleick, L. Allen, and M. J. Cohen (2011), Climate change and transboundary waters, in The World's Water, edited, pp. 1-22, Springer.

Christensen, N. S., and D. P. Lettenmaier (2007), A multimodel ensemble approach to assessment of climate change impacts on the hydrology and water resources of the Colorado River Basin, HESS, 11(4), 1417-1434.

Haddeland, I., J. Heinke, H. Biemans, S. Eisner, M. Flörke, N. Hanasaki, M. Konzmann, F. Ludwig, Y. Masaki, and J. Schewe (2014), Global water resources affected by human interventions and climate change, Proceedings of the National Academy of Sciences, 111(9), 3251-3256.

Stickler, C. M., M. T. Coe, M. H. Costa, D. C. Nepstad, D. G. McGrath, L. C. Dias, H. O. Rodrigues, and B. S. Soares-Filho (2013), Dependence of hydropower energy generation on forests in the Amazon Basin at local and regional scales, Proceedings of the National Academy of Sciences, 110(23), 9601-9606.

Week 10: Groundwater Depletion

Taylor, R. G., B. Scanlon, P. Döll, M. Rodell, R. Van Beek, Y. Wada, L. Longuevergne, M. Leblanc, J. S. Famiglietti, and M. Edmunds (2013), Ground water and climate change, Nature Clim. Change, 3(4), 322-329.

Aeschbach-Hertig, W., and T. Gleeson (2012), Regional strategies for the accelerating global problem of groundwater depletion, Nature Geosci, 5(12), 853-861.

Famiglietti, J., M. Lo, S. Ho, J. Bethune, K. Anderson, T. Syed, S. Swenson, C. de Linage, and M. Rodell (2011), Satellites measure recent rates of groundwater depletion in California's Central Valley, Geophys. Res. Lett., 38(3).

Rodell, M., I. Velicogna, and J. S. Famiglietti (2009), Satellite-based estimates of groundwater depletion in India, Nature, 460(7258), 999-1002.

Scanlon, B. R., C. C. Faunt, L. Longuevergne, R. C. Reedy, W. M. Alley, V. L. McGuire, and P. B. McMahon (2012), Groundwater depletion and sustainability of irrigation in the US High Plains and Central Valley, Proceedings of the National Academy of Sciences, 109(24), 9320-9325.

Week 11. Future Climate and Water Management

Grafton, R. Q., J. Pittock, R. Davis, J. Williams, G. Fu, M. Warburton, B. Udall, R. McKenzie, X. Yu, and N. Che (2013), Global insights into water resources, climate change and governance, Nature Clim. Change, 3(4), 315-321.

Rajagopalan, B., K. Nowak, J. Prairie, M. Hoerling, B. Harding, J. Barsugli, A. Ray, and B. Udall (2009), Water supply risk on the Colorado River: Can management mitigate?, Water Resources Res., 45(8).

Schewe, J., J. Heinke, D. Gerten, I. Haddeland, N. W. Arnell, D. B. Clark, R. Dankers, S. Eisner, B. M. Fekete, and F. J. Colón-González (2014), Multimodel assessment of water scarcity under climate change, Proceedings of the National Academy of Sciences, 111(9), 3245-3250.

Week 12: Water Food Energy Nexus

Bazilian, M., H. Rogner, M. Howells, S. Hermann, D. Arent, D. Gielen, P. Steduto, A. Mueller, P. Komor, and R. S. Tol (2011), Considering the energy, water and food nexus: Towards an integrated modelling approach, Energy Policy, 39(12), 7896-7906.

Lal, R. (2013), Food security in a changing climate, Ecohydrology & Hydrobiology, 13(1), 8-21.

Lobell, D. B., M. B. Burke, C. Tebaldi, M. D. Mastrandrea, W. P. Falcon, and R. L. Naylor (2008), Prioritizing climate change adaptation needs for food security in 2030, Science, 319(5863), 607–610

Waughray, D. (2011), Water security: the water-food-energy-climate nexus, Island Press.