Course title: Climate Change and Water			
Course code: NRC 138	**No. of credits:** 3	**L-T-P: 32**-8-10	**Learning hours:** 50
Pre-requisite course code and title (if any):			
Department: Energy and Environment			
Course coordinator(s):		**Course instructor(s):** Dr C K Singh	
Contact details: chander.singh@terisas.ac.in			
Course type: Elective		**Course offered in:** Semester 2	

Course description

Water, apart from supporting life on earth and valuable as a resource, plays a major role in affecting climate. Water cycling has a decisive impact on regional and global climate patterns. Global warming is changing the distribution and intensity of precipitation. With shifts in hydro-meteorological trends (dry regions becoming drier and wet areas wetter), increased variability and increased risk of extreme events in most regions. The importance of water resources will intensify under climate change as more frequent and intense climate extremes will increase variability in precipitation, soil moisture and surface water, eventually influencing water availability, food and energy production. Improved understanding of our water resources is needed to ensure more efficient and judicious allocation to improve access to water and reduce risks from climate change.

This course will focus on managing systemic risk and dealing with uncertainty due to climate change impacts on water resources, including monitoring known risks as well as reducing the unknown risks, through management solutions and policy interventions. The course will also focus on the identification of adaptation measures with emphasis on freshwater resources under climate change and the possible strategies to close the gap between water supply and demand to control and resolve future water resource conflicts.

Course objectives

- To understand different processes and interplay between climate system and the global water cycle
- To understand the climate change influences on water resources and the associated vulnerabilities and risks
- To understand the concept of Integrated Water Resources Management in relation to climate change
- To understand the necessity for integrated assessment, alternative policy and innovative management solutions, framework for water policy guidelines; building resilience; adaptation strategies and interventions needed in sustainable response to changing climate

Course content

Module	Topic	L	T	P
1.	General Overview of Climate Change and Global Water Cycle: Hydrological Cycle Review, Revisiting Air circulation, Ocean surface currents, ITCZ concepts, Water budget, Chemical Budget Climate variability, drivers of climate change; Observed and future changes in global patterns of precipitation and evaporation; Understanding the water cycle, global water distribution and quantitative and qualitative spatio-temporal changes	6	2	
2.	Hydrological Impacts of Climate Change and Variability: Estimating impacts of climate change on precipitation variability, extreme precipitation events, droughts, floods, evapotranspiration, soil moisture, surface and sub-surface water resources, runoff and river discharge, glacial hydrological regime, fluvial landforms	6	2	4
3.	Modelling Impacts on Hydrological Systems: Modelling climate-induced changes in hydrology; Water resource	12	4	6

	availability and demand, modelling runoff, CN method, soil erosion; concepts, factors, spatial modelling of soil erosion Socio-economic and environmental impacts; indicators of climate risks to water resources; vulnerability; Factors affecting the vulnerability of water resources			
4.	Mitigation and Adaptation Strategies for water management: Scale dependent vulnerability-local, regional, global; Vulnerability assessment and adaptation framework – all intra-national governance levels, transboundary water resources; critical knowledge gaps Importance of IWRM for adaptation; Integrated drought management; Potential water resource conflicts, Implications for policy and sustainable development; Risk management	8		
	Total	**32**	**8**	**10**

Evaluation criteria

- **Test 1: Written Test** [at the end of module 1 and 2] 20%
- **Test 2: Written Test** [at the end of module 1,2 and 3] 20%
- **Tutorial:** Literature review of climate scenarios through different models, different models for climate dependent processes, IPCC reports related to hydrological systems 20%
- **Test 3: Written Test and Practical Exam** [at the end of syllabus] 40%

Learning outcomes

By the end of the course, students will:

- Ability to perform risk assessment and suggest necessary policy interventions at various levels to improve resilience
- Apply knowledge to design or modify water management plans as an adaptation to demand management in response to supply fluctuations in future

Pedagogical approach

- The course requires understanding of modelling techniques and thus prediction scenarios
- It summarizes the impacts of climatic variability of hydrological system components
- Case Studies to design interventions under different climatic scenarios to preserve hydrological system

Materials

Compulsory Readings

1. Bates, B.C., Kundzewicz, Z.W., Wu, S. and Palutikof, J.P., Eds. (2008) *Climate Change and Water*, Technical Paper of the Intergovernmental Panel on Climate Change VI (IPCC), IPCC Secretariat, Geneva.
2. Vörösmarty, C.J., Green, P., Salisbury, J. and Lammers, R.B. 2000. *Global water resources: vulnerability from climate change and population growth*. *Science*, *289*(5477), pp.284-288.
3. Xu, J., Grumbine, R.E., Shrestha, A., Eriksson, M., Yang, X., Wang, Y.U.N. and Wilkes, A., 2009. *The melting Himalayas: cascading effects of climate change on water, biodiversity, and livelihoods*. *Conservation Biology*, *23*(3), pp.520-530.
4. Immerzeel, W.W., Van Beek, L.P. and Bierkens, M.F., 2010. *Climate change will affect the Asian water towers*. *Science*, *328*(5984), pp.1382-1385.
5. Milly, P.C., Betancourt, J., Falkenmark, M., Hirsch, R.M., Kundzewicz, Z.W., Lettenmaier, D.P. and Stouffer, R.J., 2008. *Stationarity is dead: Whither water management? Science*, *319*(5863), pp.573-574.
6. Arnell, N.W., 1999. *Climate change and global water resources*. *Global environmental change*, *9*, pp. S31-S49.
7. Arnell, N.W., 2004. *Climate change and global water resources: SRES emissions and socio-economic scenarios*. *Global environmental change*, *14*(1), pp.31-52.

8. Gosling, S.N. and Arnell, N.W., 2016. *A global assessment of the impact of climate change on water scarcity*. *Climatic Change*, *134*(3), pp.371-385.

Suggested readings

1. Aerts, J. and Droogers, P., Eds. (2004) *Climate Change in Contrasting River Basins: Adaptation Strategies for Water, Food, and Environment*. Wallingford, OX, UK Cambridge, MA, USA: CABI Pub.
2. Baba, A., Tayfur, G., Gündüz, O., Howard, K.W.F., Friedel, M.J. and Chambel, A., Eds. (2011) *Climate Change and its Effects on Water Resources: Issues of National and Global Security*. Dordrecht: Springer, pp. 303
3. Biswas, A. and Tortajada, C., Eds. (2016) *Water Security, Climate Change and Sustainable Development*. Singapore New York: Springer.
4. Dai, A., 2011: *Drought under global warming: A review*. Wiley Interdisciplinary Reviews: Climate Change, 2, 45-65.
5. Field, C.B., Barros, V.R., Dokken, D.J., Mach, K.J., Mastrandrea, M.D., Bilir, T.E., Chatterjee, M., Ebi, K.L., Estrada, Y.O., Genova, R.C., Girma, B., Kissel, E.S., Levy, A.N., MacCracken, S., Mastrandrea, P.R. and White, L.L., Eds. (2014) *IPCC, 2014: Summary for Policymakers*. 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*. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 1-32.
6. National Research Council & Committee on Population (2012) *Himalayan Glaciers: Climate Change, Water Resources, and Water Security*. National Academies Press.
7. Pelling, M. 2011. *Adaptation to Climate Change: From Resilience to Transformation*. London and New York: Routledge.
8. Quevauviller, P., Borchers, U., Thompson, K.C. and Simonart, T., Eds. (2011) *The Water Framework Directive: Action Programmes and Adaptation to Climate Change*. Cambridge: RSC Publishing.
9. Shrestha, S. (2014) *Climate Change Impacts and Adaptation in Water Resources and Water Use Sectors: Case Studies from Southeast Asia*. Cham: Springer.
10. Taniguchi, M. and Holman, I.P., Eds. (2010) *Groundwater Response to Changing Climate*. Boca Raton Fla. London: CRC Press.

Case studies/Websites

1. http://www.waterandclimatechange.eu
2. http://www.unwater.org/water-facts/climate-change

Journals

1. Climatic Change
2. Global Environmental Change
3. Journal of Water and Climate Change
4. Nature Climate Change
5. Regional Environmental Change
6. Water (MDPI)
7. Water Resources Research

Advanced Reading Material

Journal papers on case specific scenarios of different components of hydrological system

Additional information (if any)

Student responsibilities

The students are expected to submit assignments in time and come prepared with readings when provided

Course Reviewers

1. Prof. S Mukherjee, School of Environmental Sciences, Jawaharlal Nehru University. New Mehrauli Road, New Delhi.
2. Dr. Javed Mallick, King Khalid University, Saudi Arabia, Asir – Abha, P.O.Box: 960 - Postal Code : 61421.