

Indian Institute of Technology, Kanpur

Proposal for a new course

1. **Course No:** KSS 6XX
2. **Course Title:** AI for Hydroclimate: Processes and Applications
3. **Per Week Lectures:** 3(L), Tutorial: 0 (T), Laboratory: 0 (P), Additional Hours: 0 (A)
4. **Credits** (3*L+0*T+P+A): 9
5. **Duration of Course:** Full Semester
6. **Proposing Department:** Kotak School of Sustainability
Other Departments which may be interested in the proposed course:
Civil Engineering, Centre for Environmental Science and Engineering
7. **Proposing Instructor(s):** Prof. Sarosh Alam Ghausi (KSS), Prof. Tushar Apurv (Civil Engineering)
8. **Course Description:** The hydroclimate system connects the atmosphere, land, and oceans through water and energy exchanges, critical for sustaining biosphere but remain challenging to represent and model. Advances in data science and AI now offer new opportunities to address key gaps in improving process understanding and enabling reliable predictions. This course builds the physical and methodological foundations needed to apply these tools effectively in hydro climatology, covering essential hydroclimate processes alongside statistical, and machine learning methods, with applications to prediction, downscaling, extremes, and climate impacts.

A) **Objectives:** On completing this course, students will be able to:

- Understand key hydroclimate processes and their interactions.
- Analyze diverse hydroclimate datasets (in situ, satellite, reanalysis, model).
- Apply statistical, machine learning, and deep learning methods for hydroclimate prediction, downscaling, and develop hybrid AI-physics approaches.

B) Contents

S. No	Broad Title	Topics	No. of Lectures
1.	Introduction to the Hydroclimate System	Components, interactions, and scales of variability; types of climate datasets, framing AI opportunities in hydroclimate research.	2
2.	Energy Balance in the Earth System	Radiation budget, greenhouse effect, role of water vapor and clouds; temperature variations, modelling and observational challenges and the applications of data-driven methods in estimating temperatures and fluxes	4
3.	Atmospheric Circulation and Precipitation Processes	General circulation of the atmosphere, vertical motion and convection, mechanisms of precipitation formation, challenges in modelling; statistical and ML-based methods for rainfall estimation using satellite, radar and ground data.	3

4.	Role of Oceans in the Hydroclimate System	Ocean circulation and heat transport, air–sea interactions, major modes of variability and their impacts on regional and global hydroclimate, use of SST reanalysis and clustering methods to identify variability patterns	3
5.	Land–Atmosphere Interactions	Evapotranspiration, soil moisture dynamics, boundary layer processes; land-surface models, hybrid modelling for parameter estimation	3
6.	The Indian Monsoon	Fundamentals of monsoon dynamics and variability; role of circulation patterns, and moisture transport; seasonal cycle, variability across timescales, and associated prediction challenges.	3
7.	Surface Hydrology	Water balance and runoff generation processes, river flow dynamics and streamflow response; data-driven approaches for rainfall–runoff modelling and flow prediction	3
8.	Climate Change and Variability	Physical basis of climate change, natural vs. anthropogenic drivers, hydroclimate impacts, climate sensitivities; ML/DL for change detection and pattern recognition	3
9.	Extreme Hydroclimate Events	Floods, droughts, heatwaves, compound extremes; extreme value theory and ML for early warning and risk mapping	3
10.	Hydroclimate Data and Numerical modelling	Ground observations, remote sensing, reanalysis; preprocessing, quality control, governing equations, model coupling	2
11.	Climate Models and Downscaling	Statistical and dynamical approaches, uncertainty analysis; ML/DL for high-resolution downscaling	2
12.	Data-driven models for Hydroclimate Applications	Supervised and unsupervised learning methods for hydroclimate prediction and classification, deep learning for spatiotemporal data and key challenges related to interpretability and physical consistency	3
13.	Hybrid Modelling	Approaches that combine physical principles with data-driven learning; physics-informed AI, process-guided ML, and data assimilation for improved prediction and understanding	3
14.	Group mini-project presentations	AI-based analysis of a hydroclimate problem (e.g., rainfall – runoff modelling, flood risk mapping, monsoon variability), involving data processing, model development, and evaluation.	3

C) **Pre-requisites:** Basic knowledge of mathematics, statistics, and programming (Python, Matlab, or equivalent)

D) **Short summary for including in the Courses of Study Booklet:**

This course covers the hydroclimate system and its key processes, including the monsoon, land–atmosphere and ocean interactions, climate variability, and extremes. It emphasizes the use of statistical, machine learning, and hybrid AI–physics approaches for prediction, downscaling, and risk assessment, with hands-on experience through group mini-projects using real hydroclimate datasets.

9. **Recommended books: Textbooks:**

- Wallace, J.M., and P.V. Hobbs (2006). *Atmospheric Science: An Introductory Survey*.
- Hartmann, D.L. (2016). *Global Physical Climatology*.
- Subramanya, K. (2017). *Engineering Hydrology*.
- Wilks, D.S. (2019). *Statistical Methods in the Atmospheric Sciences*.
- Camps-Valls, G., Tuia, D., Zhu, X.X., and Reichstein, M. (2021). *Deep Learning for the Earth Sciences: A Comprehensive Approach to Remote Sensing, Climate Science, and Geosciences*.

10. **Any other remarks:** Students from other departments like Civil Engineering, Centre for Environmental Science and Engineering and Earth Sciences may be interested in this course.

Dated: 27/8/25 Proposer: Sarosh

Dated: 28/8/2025 DUGC/DPGC Convener: Mell V

The course is approved / not approved

Chairman, SUGC/SPGC

Dated: _____