Indian Institute of Technology Kanpur

Proposal for a New Course

1. Course No: MTH6XX
2. Course Title: **Extreme Value Analysis**
3. Per Week Lectures: 3 (L), Tutorial: 0 (T), Laboratory: 0 (P), Additional Hours[0-2]:0(A), Credits (3*L+0*T+0*P+0*A): 9 Duration of Course: Full Semester
4. Proposing Department/IDP: Mathematics & Statistics

Other Departments/IDPs who may be interested in the proposed course: Department of Earth Sciences, Department of Civil Engineering, Department of Economic Sciences, Department of Management Sciences, Department of Computer Science & Engineering, Department of Electrical Engineering

5. Proposing Instructor(s): Arnab Hazra

Other faculty members interested in teaching the proposed course: Subhra Shankar Dhar

6. Course Description:

A) Objectives: The proposed course is intended to be an PhD-level course on Extreme value analysis and its applications in various scientific disciplines (special focus on earth sciences and finance).

B) Contents of lectures (preferably in the form of 5 to 10 broad titles):

S. No.	Broad Title	Topics	No. of Lectures
1.	Motivation and brief review on statistical inference	Examples of different types of extreme data and possible scientific questions: examples of univariate and multivariate datasets and nonstationary extremes, brief review on statistical inference: marginal and joint distributions for random vectors, measures of association, Markov chains, parametric modeling, maximum likelihood estimation, model comparison, model validation	3
2	Classical extreme value theory and models	Asymptotic model for maxima and minima: the generalized extreme value (GEV) distribution, inference for GEV distribution, examples, model generalization: the r-largest order statistic mode	5

3	Threshold models	Asymptotic model for threshold exceedances: the generalized Pareto distribution (GPD), threshold selection, inference for GPD, examples	4
4	Extremes of dependent sequences	Asymptotic model for maxima of stationary sequences, modeling stationary series, models for block maxima, threshold models, case studies with Wooster Temperature Series and Dow Jones Index Series	3
5	Extremes of nonstationary sequences	Model structures, parametric inference, case studies with Venice sea-level data and Wooster temperature data	2
6	Point process characterization of extremes	A Poisson process limit for extremes: convergence law, connections with other extreme value models, statistical modeling, connections with threshold excess model likelihood, r-largest order statistic model	4
7	Bayesian inference for extremes	Motivation: basics of Bayesian paradigm, Bayesian computing using MCMC, prior choices for GEV/GPD model parameters, posterior inference on return level	3
8	Multivariate extremes and statistical inference	Componentwise maxima: asymptotic characterization, modeling, case studies, structure variables, alternative representations: bivariate threshold excess model, point process model, asymptotic dependence and independence, computational challenges: pairwise composite likelihood-based inference, conditional extremes modeling	6
9	Max-stable processes	Definition, examples: Smith model, Schlather model, Brown–Resnick process, extremal-t process, Hüsler–Reiss process, their construction and properties	5
10	Statistical inference for max-stable processes	Computational challenges: pairwise composite likelihood-based inference, tree-based graphical models, spectral measures, Bayesian inference, Approximate Bayesian inference	5

C) Prerequisites: MTH211/MTH418/MTH755, or Instructor's consent

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

Extreme value theory (EVT) provides statistical frameworks for analyzing rare events across a wide range of univariate and multivariate settings, including climate extremes, financial crashes, and environmental hazards. Examples of univariate data include annual maximum temperatures or financial returns, whereas multivariate extremes arise in the joint modeling of variables such as wind speed and rainfall. Many such datasets exhibit nonstationarity due to trends or seasonality, necessitating the use of flexible modeling approaches. Statistical inference in EVT begins with understanding the marginal and joint distributions of random vectors, using tools such as measures of association and Markov chains. Parametric modeling is central, with maximum likelihood estimation (MLE), model comparison (e.g., AIC/BIC), and model validation techniques playing critical roles. The asymptotic distribution for maxima and minima is the Generalized Extreme Value

(GEV) distribution, which forms the basis for inference in block maxima settings. Extensions such as the r-largest order statistics model offer more efficient use of data. For threshold exceedances, the Generalized Pareto Distribution (GPD) provides a suitable limit, with careful threshold selection being crucial for accurate results. These models are applied to stationary time series using block maxima or peaks-over-threshold approaches, as demonstrated in case studies like the Wooster temperature and Dow Jones Index data. The Poisson process framework unifies several EVT models and links them with the r-largest and threshold exceedance models. Bayesian inference offers a complementary paradigm involving prior specification for GEV/GPD parameters and posterior inference via MCMC, particularly for estimating return levels. For multivariate extremes, component-wise maxima are modeled using asymptotic theory, with frameworks such as the bivariate threshold model and point process approach allowing for the treatment of dependence structures, including asymptotic dependence and independence. Advanced models include the Smith, Schlather, Brown–Resnick, extremal-t, and Hüsler–Reiss processes, each with distinct constructions and properties. Computational challenges remain, particularly for inference via pairwise composite likelihood and hierarchical Bayesian methods.

Recommended Books/Other sources:

1. An Introduction to Statistical Modeling of Extreme Values by Stuart Coles. 1999. Springer. (This book will be mainly followed for Topics 1–7)
2. Statistics of Extremes: Theory and Applications. Jan Beirlant, Yuri Goegebeur, Jozef Teugels, Johan Segers. 2004. Wiley. (This book will be mainly followed for Topic 8)
3. Max–Stable Processes: Representations, Ergodic Properties and Statistical Applications. Stilian A. Stoev. 2010. Book Chapter in Dependence in Probability and Statistics. Springer.
4. Series of papers by Richard Smith (UNC Chapel Hill), Anthony Davison (EPFL), and Jonathan Tawn (Lancaster).

8. Any other remarks:

Proposer: Arnab Hazra, Assistant Professor, Department of Mathematics and Statistics
Dated: June 25, 2025

Dated:________________DPGC Convener:_____________________

The course is approved/not approved

Chairman, SPGC

Dated:__________________________________