In Memoriam: Ilya Zaliapin (1973-2023), CMG Secretary

Professor Ilya Zaliapin passed away on 2 May 2023 in Reno, Nevada, at the age of 50. He is survived by his wife Elena and two sons. Professor Zaliapin graduated in Mathematics (Probability and Statistics) at the Lomonosov Moscow State University in 1995, followed by a PhD in Mathematics and Physics at the Russian Academy of Sciences in Moscow in 1999. He spent several years in the University of California at Los Angeles (UCLA), initially as a postdoc (1999-2001) in the group of Professor Vladimir I. Keilis-Borok, and then as Assistant Researcher at the UCLA's Institute of Geophysics and Planetary Physics (2001-2006). Ilya moved to the Department of Mathematics and Statistics, University of Nevada at Reno (UNR) in 2006 as Assistant Professor and was promoted to Associate Professor position in 2009 and full Professor position in 2016. He held the positions of Vice Chair of the Department and Director of the UNR Graduate Program in Statistics and Data Science between 2015 and 2023.

The primary research field Professor Zaliapin was in statistical seismology, with a focus on preparation processes of large earthquakes, understanding the limits of earthquake predictability, development and assessment of operational earthquake forecast methods, and identification and classification of earthquake clustering, including declustering techniques. His work combined development of novel statistical techniques, analysis of high-quality earthquake catalogs, data from laboratory fracturing experiments and physical modeling to improve the ability to understand the preparation process of large failure events. Also, his studies covered an emergence of scaling laws and extreme events in hierarchical geophysical systems, including geomorphologic (river and delta stream networks) and lithospheric systems. Methodologically, his research interests were in applied probability and statistic, with focus on random self-similar trees and networks, that described earthquake clusters or river networks, coalescent and branching stochastic processes, random sums of heavy-tailed variables, and multiscale methods of time series analysis.

The knowledge obtained through his research contributed to understanding natural hazards, specifically earthquakes and flooding. Professor Zaliapin made an important methodological contribution to quantitative assessment of the earthquake-related hazards and understanding the preparation processes of large earthquakes. The importance of these fundamental scientific problems was mutually recognized by the government (e.g., the U.S. Geological Survey - USGS) and academic community (e.g., the Southern California Earthquake Center - SCEC). Ilya Zaliapin introduced a novel approach to a long-standing problem of identifying earthquake clusters (e.g., aftershocks, swarms). This was done by rigorous examination of a problem-specific nearest-neighbor earthquake proximity in the time-space-magnitude domain. The developed nearest-neighbor technique quickly became known and used by the community. Computationally efficient and physically insightful, it enabled multiple independent groups to address a range of problems, including (i) quantitative assessment of earthquake clustering in Greece, Italy, Japan, New Zealand, and USA, (ii) discriminating between natural and human-induced seismicity, understanding the character and interaction of active geologic structures during earthquake swarms, and relating geodetic and seismic deformation rates. Particularly, the works by Zaliapin and Yehuda Ben-Zion published in 2013 and 2016 contributed to improved earthquake hazard assessment by developing a global classification of earthquake clusters and connecting the regional earthquake cluster style to the heat flow level and type of deformation defined by the strain rate tensor. This approach also has shown success in rock fracture experiments and well-established seismicity models, including the paradigmatic Epidemic Type Aftershock Sequence model. The nearest-neighbor cluster technique developed by Ilya Zaliapin is currently being used by the USGS in relation to one of its flagship products – the U.S. National Seismic Hazard Model. Most recently, Ilya Zaliapin, in collaboration with Yehuda Ben-Zion, developed a novel methodology for tracking progressive evolution of deformation – from distributed failures in a rock volume to localized shear zones – culminating in generation of large earthquakes. Combining basic empirical earthquake relations, analytical results from fracture mechanics, and measure-theoretic statistical technique for tracking evolution of spatial measures, this work revealed cycles of earthquake localization apparently connected to the recent largest earthquakes in California. These promising results inspired future international efforts in modeling, laboratory experiments, and analysis of observed seismicity.

Ilya Zaliapin together with Corné Kreemer elucidated the nature of long-term seismic energy release and its relation to geodetic observations, hence informing efforts in resolving a well-known seismic moment deficiency paradox. This was achieved by developing a statistical approximation technique for sums of heavy-tailed random variables, which now has found applications way beyond seismology in fields as diverse as economics, finance, epidemiology, and mobile networks. Professor Zaliapin with his students introduced a thought-provoking concept of hyperbolic geometry of earthquakes. Synthesizing the areas of hyperbolic geometry, network theory, and seismology, this representation provides an unconventional view of earthquake dynamics and adapts powerful tools of hyperbolic network theory to the problems of statistical seismology.

Professor Zaliapin provided a rigorous foundation, via a theory of random self-similar trees, for the Horton's laws and other ubiquitous scaling laws found in river networks. This ultimately led to a stochastic model that analytically reproduced multiple empirical geomorphological laws (e.g., Horton laws, Hack's law, Tokunaga scaling) with realistic values of exponents that have been reported during the past 80 years of river studies. These findings have important implications to assessment of peak flows in rainfall-runoff events and flood hazards. Ilya Zaliapin significantly contributed to development of the quantitative theory of self-similar river stream networks. The hierarchical organization of river basins has been the topic of extensive theoretical and applied research in hydrology and geomorphology starting with the Horton's pioneering work (1945), where quantitative relations for physical stream attributes have been derived. Despite their importance and ubiquity, the Horton laws remained an empirical finding and their appearance in natural dendritic systems was unsettled. Zaliapin initiated a cross-disciplinary collaboration to untangle this problem, which resulted in several exciting articles published in the Journal of Geophysical Research (JGR) between 2010 and 2013. The results of his analysis suggested a rigorous definition of tree self-similarity that unifies the key existing approaches, formulating sufficient conditions for the Horton laws in general tree-like systems, and introducing a family of critical Tokunaga trees that explains the specific Horton laws and scaling relations empirically discovered in river networks during the past decades. These results bridge the theoretical and modeling evidence accumulated by the community within a mathematically tractable and computationally efficient framework. Zaliapin's results also facilitated development of quantitative theory of river deltas.

Many of the above results in statistical seismology and river networks are rooted in the theory of random self-similar trees that has been developed by Ilya Zaliapin together with Yevgeniy Kovchegov during the past decade. The theory synthesizes mathematical rigor and flexibility to explain multiple symmetries and structural constraints discovered in dendritic systems of hydrogeomorphology, seismology, phylogenetics, and neurobiology.

Professor Zaliapin's research was focused on well-recognized practically important problems, as reflected by continuous support his group received from the U.S. National Science Foundation, USGS, SCEC, and the U.S. Department of Energy. A substantial part of this funding was used for training the next generation of scientists.

Ilya Zaliapin played notable scientific leadership roles via his various professional services, including the American Geophysical Union (AGU) and the International Union of Geodesy and Geophysics (IUGG). He was an inaugural Secretary of the AGU Section on Natural Hazards helped immensely in establishing this Section in 2009-2012, and since 2016 was an JGR's Associate Editor. Ilya was Secretary of the IUGG Union Commission on Mathematical Geophysics since 2013 and significantly contributed to organization and success of four IUGG Conferences on Mathematical Geophysics held in Mexico (2014), France (2016), Russia (2018), and the Republic of Korea (2022). He co-convened international workshops in Italy, Mexico, South Africa, and USA, and many special sessions and symposia at AGU, IUGG, and other national and international meetings. Professor Zaliapin was the trailblazer in mathematical and statistical geophysics. His research achievements were stunning, and his original works earned him international recognition and stature. When the history of modern mathematical and statistical geophysics comes to be written, Ilya Zaliapin's pivotal work will be praised as a landmark.

We lost a bright mathematician and scientist, excellent colleague, good friend, and a very kind person.

Alik Ismail-Zadeh (Chair) and Executive Committee Members of
the IUGG Union Commission on Mathematical Geophysics