Speaker: Giovanni Dematteis

Title: Extreme events in deterministic dynamics with application to rogue waves

Abstract: I present a method to quantify the probability and dynamical pathway of extreme realizations of a certain observable in a deterministic dynamical system. Probability, either due to intrincic stochasticity or uncertainty, enters the problem via the statistics of random initial conditions and/or model parameters. In the framework of large deviation theory, the branch of probability that deals with events in the distribution tails, the probability of an extreme event of a given size is dominated by the probability of the most likely scenario among the events of that given size. This special scenario, the maximum likelihood pathway, is known in physics as the instanton of the problem. The method is tailored to compute the instantons associated with a given dynamics by means of numerical optimization, building on tools from large deviation theory and optimal control.

I then focus on the application to the formation of rogue waves, using the 1D focusing Nonlinear Schroedinger equation as the simplest reduction of the problem of surface gravity waves to a tractable universal model that combines nonlinearity and dispersion. I use a numerical and experimental study in a large water tank to show how the instantons have been proposed as a rigorous tool to settle a decade-long debate on oceanic rogue wave formation. Is it just dispersion, as in superposition of random linear waves, or rather nonlinearity (e.g. modulational instability)? Rather than on deciding who is right, the focus here is on the systematic methodology provided by the instanton framework, which encompasses two well-established theories in the two opposite regimes, linear and highly nonlinear.

Finally, I overview some recent applications of instantons to other wave systems of geophysical interest.