# Probabilistic Digital Twins: Inferential Conceptual Frameworks for Evolutionary Problems in the Geosciences, Biology, Social Systems

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**Abstract**: Bayesian estimation methods are ideal frameworks for digital twins that have inferential utility, given rational models, observations, expert knowledge, and all of their inherent uncertainties. I will start with an overview of the general principles and challenges that their applications pose and offer some avenues for how these are addressed. The focus will be on dynamic systems that are far from equilibrium. Along the way I will describe some novel ways to handle inherent nonlinear/non-Gaussianity, as well as sparsity in observations, as well as on-going work on handling epistemic errors.
Three problems, electric grid resilience, adaptation in biological systems, and climate dynamics, will serve to show a variety of ways in which probabilistic digital twins can deliver nuanced inferential outcomes which, though very computationally intensive, easily couple to consider complex interaction systems. I will discuss my more recent work, which employs mathematical arguments to guide in quantifying and understanding resilience in the context of a changing climate and biological systems response via adaptation to stresses.

**Short biography:** Prof. Juan M. Restrepo is the section head of the Mathematics in Computation Section at Oak Ridge National Laboratory. His research focuses on the development and application of data-driven statistical physics approaches to machine learning, ocean and climate processes as well as to biological systems. He is also a professor of mathematics at the University of Tennessee, Knoxville.
Prior to coming to the Lab, he was a professor of mathematics and physics at Oregon State and at the University of Arizona. Among his awards are the Career Prize in Geoscience at SIAM, DOE Young Investigator. He has been recognized as Fellow of the American Physical Society, APS, and of the Society of Industrial and Applied Mathematics, SIAM.