Bouchet, Freddy: *"Large deviation theory and abrupt transitions for turbulent atmosphere jets "*

Many natural and experimental turbulent flows display a bistable behavior: rare and abrupt dynamical transitions between two very different subregions of the phase space. The most prominent natural examples are probably the Earth magnetic field reversals (over geological timescales), the Kuroshio bistability, or the Dansgaard-Oeschger events that have affected the Earth climate during the last glacial period, and are probably due to several attractors of the turbulent ocean dynamics. Recent results show that similar bistability occur also in the turbulent dynamics of atmosphere jets. Those abrupt transitions are extremely rare events that change drastically the nature of the flow and are thus of paramount importance. We will review recent researches in this subject, including experimental and numerical studies of turbulent flows. Most of the talk will focus on theoretical, mathematical, and numerical works in the framework of the quasi-geostrophic barotropic model. This is the simplest turbulence model to set up the theoretical and numerical tools to study these phenomena. From a numerical point of view, those event can not be studied directly because they are too rare. We will first discuss the use of a rare event algorithm, Adaptive Multilevel Splitting, in order to sample from direct numerical simulation such rare transitions. In quasigesotrophic models, the classical eddy-mean flow interactions are involved to explain the evolution of the large scale flow. The issue is then to understand and predict those eddy-mean flow configurations that lead to the rare fluctuations that trigger rare transitions. We will present the proper mathematical framework to analyze those rare events: large deviation theory for dynamical systems with a separation of time scales. We will discuss the development of this framework and the computation of rare transitions for the barotropic quasi-geostrophic model.