Title:
Estimation of time to a tipping point

Abstract
In recent years there has been an increasing awareness of the risks of collapse or tipping points in a wide variety of complex systems, ranging from human medical conditions, pandemics, ecosystems to climate, finance and society. They are characterized by variations on multiple spatial and temporal scales, leading to incomplete understanding or uncertainty in modelling of the dynamics. Even in systems where governing equations are known, such as the atmospheric flow, predictability is limited by the chaotic nature of the system and by the limited resolution in observations and computer simulations. In order to progress in analyzing these complex systems, assuming unresolved scales and chaotic dynamics beyond the horizon of prediction as being stochastic has proven itself efficient and successful. When complex systems undergo critical transitions by changing a control parameter through a critical value, a structural change in the dynamics happens, the previously statistically stable state ceases to exist and the system moves to a different statistically stable state. To establish under which conditions an early warning for tipping can be given, we consider a simple stochastic model, which can be considered a generic representative of many complex two state systems. We show how this provides a robust statistical method for predicting the time of tipping. The method is used to give a warning of a forthcoming collapse of the Atlantic meridional overturning circulation.

References: Peter D. Ditlevsen and Susanne Ditlevsen (2023), Warning of a forthcoming collapse of the Atlantic meridional overturning circulation. *Nat Commun* 14, 4254