COLLOQUE DE PHYSIQUE

Lundi 22 avril 2024, 12h30

École de Physique, Auditoire Stueckelberg

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« Metastability Properties of the Earth's Climate: a Multiscale Viewpoint »

The ultralow frequency variability of the Earth's climate features an interplay of typically long periods of stasis accompanied by critical transitions between qualitatively different regimes associated with metastable states. Such transitions have often been accompanied by massive and rapid changes in the biosphere. Multiple transitions between the coexisting warm and snowball climates occurred more than 500 Mya and eventually led to conditions favourable to the development of multicellular life. The coexistence of such states is due to the instability associated with the positive ice-albedo feedback, Yet, this behaviour repeats itself across a wide range of timescales, spatial domains, and physical processes. Building on Hasselmann's program, we propose here to interpret the time-evolution of the Earth system as a trajectory taking place in a dynamical landscape, whose multiscale features describe a hierarchy of metastable states and associated tipping points. We introduce the concept of climatic Melancholia states, saddle embedded in the boundary between the basins of attraction of the stable climates and explain under which conditions they act as gateways of noise-induced transitions. Using a hierarchy of numerical models, we discuss in detail the dichotomy between warm and snowball climate by bringing together the deterministic and stochastic viewpoint on the related global stability properties. We then discuss the paleoclimatically-relevant case where multiple competing climatic states are present and show the relevance of our angle for interpreting proxy data. Finally, if time allows, we will present some very recent results suggesting that our viewpoint might explain some intriguing aspects of the dynamical features of the tipping points of the Atlantic Meridional Overturning Circulation.

V. Lucarini and T. Bodai, Transitions across Melancholia States in a Climate Model: Reconciling the Deterministic and Stochastic Points of View, Phys. Rev. Lett. 122, 158701 (2019)
G. Margazoglou et al., Dynamical landscape and multistability of a climate model, Proc. R. Soc. A.477 210019 (2021)
D. D. Rousseau et al., A punctuated equilibrium analysis of the climate evolution of cenozoic exhibits a hierarchy of abrupt transitions. Sci Rep 13, 11290 (2023)
V. Lucarini and M. D. Chekroun, Theoretical tools for understanding the climate crisis from Hasselmann's programme and beyond, Nat. Rev. Phys. 5, 744–765 (2023)
J. Lohmann et al., Multistability and Intermediate Tipping of the Atlantic Ocean Circulation, Sci. Advances, in press (2024)

Une collation en compagnie du conférencier sera offerte après le colloque.