"Climate switches explored through delay equations"

Courtney Quinn
Early Stage Researcher
University of Exeter

The Quaternary period (2.6 myr BP - present) is characterised by a series of slow glaciations and rapid de-glaciations all of varying lengths and extents. External orbital forcing (i.e. the Milankovitch cycles) explains these oscillations only in part, as there are still unresolved events such as the mid-Pleistocene transition and the "stage 11 problem" [1]. It is then natural to look at internal processes to study these irregularities. In low-order conceptual models typically used to describe palaeoclimate processes, feedback loops associated with the transport of mass or energy can be expressed using mathematical delays [2]. I will discuss the benefits of modelling these climate switches with semi-discrete Boolean delay equations (BDEs), using this as a platform to incorporate the delays through more physical delay differential equation (DDE) models. A BDE model of Quaternary climate variability [3] will be revisited, and its conversion to a DDE system is analysed.

[1] Paillard, D., 2001. Glacial cycles: toward a new paradigm. *Reviews of Geophysics, 39(3)*, pp.325-346.

[2] Krauskopf, B. and Sieber, J., 2014, September. Bifurcation analysis of delay-induced resonances of the El-Nino Southern Oscillation. In *Proceedings of the Royal Society of London A: Mathematical, Physical and Engineering Sciences (Vol. 470, No. 2169, p. 20140348)*. The Royal Society.

[3] Ghil, M., Mullhaupt, A. and Pestiaux, P., 1987. Deep water formation and Quaternary glaciations. *Climate dynamics*, 2(1), pp.1-10