SCIENCES & BIOENGINEERING SCIENCES

The Research Group

Physical Geography

has the honor to invite you to the public defense of the PhD thesis of

Jonas Van Breedam

to obtain the degree of Doctor of Sciences

Title of the PhD thesis:

Modelling the early Cenozoic Antarctic ice sheet history

Promotor:
Prof. dr. Philippe Huybrechts (VUB)
Co-promotor:
Prof. dr. Michel Crucifix (UCLouvain)

The defense will take place on
Wednesday, September 7, 2022 at 16h in auditorium D.2.01, Promotiezaal

(Please request details to jonas.van.breedam@vub.be in case you would like to attend the live stream)

Members of the jury

Prof. dr. Matthieu Kervyn de Meerendre (VUB, chair)
Prof. dr. Steven Goderis (VUB, secretary)
Prof. dr. Wim Thiery (VUB)
Prof. dr. Lauren Gregoire (University of Leeds)
Prof. dr. Anna von der Heydt (University of Utrecht)

Curriculum vitae

Jonas Van Breedam (23/06/1991) started as a full-time teaching assistant in the Department of Geography, combining a PhD in glaciology and paleoclimatology in the Ice and Climate research group with teaching activities in physical geography (i.e. modelling of glacial systems, climatology and meteorology, physical geography, paleoclimatology, topography and geodesy, global geomorphology).

During his PhD, Jonas (co-)authored ten peer-reviewed international papers, of which one appeared in Nature. He shared his research at several international conferences and during media interviews. Additionally, he conducted glacier fieldwork for eight times in the Alps (Switzerland), once in the Caucasus (Russian Federation) and twice in the Tian Shan (Kyrgyzstan) to help colleagues and students gathering their data.

Abstract of the PhD research

It is generally believed that the Cenozoic Antarctic ice sheet history started at the Eocene-Oligocene boundary (34.44-33.65 Ma), when small isolated ice caps grew into a continental-scale ice sheet. Evidence pointing towards the appearance of the large terrestrial ice sheet are a ~1.2-1.5‰ increase in the global benthic oxygen isotope stack, the deposition of ice-rafted debris close to the Antarctic continent at around 34 Ma and a global sea-level fall of about 50 m. The decisive factors for climate cooling on the Antarctic continent have been disputed for a long time and are attributed to a general declining trend in the atmospheric carbon dioxide concentrations and/or to the thermally isolating effect from the developing circumpolar Antarctic current when the Drake Passage and the Tasman Gateway started to open.

In this thesis, the early Cenozoic ice sheet evolution is investigated with a novel coupling approach using an emulator to couple an ice sheet model and a climate model on a multi-million-year timescale. The use of an emulator allows the detailed prediction of the actual forcing based on a large number of preliminary climate model runs. Additionally, the uncertainty for a given climate state can be quantified. The novel coupling method is applied to the late Eocene to investigate the ice sheet behaviour prior to the Eocene-Oligocene boundary up to the Oligocene. Recent interpretations from geochemical and geomorphic proxies suggest that during the late Eocene, the Antarctic ice sheet might have temporarily reached a continental scale. Our modelling approach, forced with the latest set of carbon dioxide reconstructions, shows that the Antarctic ice sheet could grow during the late Eocene for CO_2 values between 600 and 900 ppmv, a wide range determined by uncertainties in the elevation of the underlying topography. The threshold for deglaciation is 170-190 ppmv higher than the glaciation threshold. This difference is attributed to the hysteresis behaviour of ice sheets and arises because the continental-scale Antarctic ice sheet has a much lower surface temperature compared to an ice-free continent. The hysteresis effect can also be expressed in terms of a mean annual temperature difference needed to melt or initiate the ice sheet growth on the Antarctic continent and ranges between 3.5˚C and 5.5˚C.

The increase in the benthic oxygen isotopes at the Eocene-Oligocene boundary provides information on the magnitude of terrestrial ice volume expansion and oceanic deep-water cooling. To disentangle the signal, the ice sheet oxygen isotope content has been modelled. It is found that the late Eocene benthic oxygen isotope excursions can be explained by an increase in the ice volume on the Antarctic continent. Our simulations indicate that the ice volume expansion on the Antarctic continent at the start of the Oligocene explains about 2/3rd of the total benthic oxygen isotope excursion. Hence, cooling of the ocean water should have been responsible for the remainder 1/3rd of the global change in the benthic oxygen isotopes.