Title:

Impact of marine gateways evolution on the circulation and carbon cycle in the Late Eocene.

Director of studies:

Jean-Baptiste Ladant and Pierre Sepulchre (LSCE) – Yannick Donnadieu (CEREGE)

Project Summary:

The Eocene (~ 56-34 Ma) is the last period of Earth's history without perennial ice sheets at the poles. This period is first characterized by a climatic optimum in the Early Eocene, exhibiting mean global temperature about 12°C higher than modern. This optimum is followed by a long-term cooling that culminates with the glaciation of Antarctica 34 Ma ago at the Eocene-Oligocene Transition (Westerhold et al. 2020). The analysis of oxygen stable isotope data from marine cores drilled more than 40 years ago demonstrated that the marine gateways separating Antarctica from South America (Drake Passage) and Australia (Tasman Gateway) opened approximately at the same time as the Antarctic glaciation, thereby allowing water exchange between the different basins in the Southern Ocean and prompting the suggestion that the onset of a circumpolar current isolating Antarctica may have controlled the glaciation (Kennett 1977). In the following decades, this hypothesis has been progressively disproven. First, the chronologies of the Drake Passage and Tasman Gateway opening has been refined and evidence exists showing that these gateways were already opened to surface to intermediate ocean circulation up to millions of years before the Antarctic glaciation and that the "gateway opening" at the EOT were relevant only to deep sea exchange. Second, though the opening of the gateway in numerical simulations indeed cooled Antarctica by allowing the formation of an isolating circumpolar current, the cooling was not sufficient to trigger the massive glaciation inferred from oxygen stable isotope and sea level records, suggesting that another primary driving factor played a role, such as a decrease in atmospheric CO_2 concentration. Third, a long-term decrease in CO_2 concentration in the Late Eocene (from ~ 40 Ma onwards) has been documented as well as a more brutal short-term decrease at the EOT (Pagani et al. 2011, Rae et al. 2021), though with considerable uncertainty. Notwithstanding, a decrease in the atmospheric CO_2 concentration is currently mostly accepted as the main driver of the Antarctic glaciation.
However, the causes behind the decrease in CO_2 are still elusive. The aim of this PhD thesis is to numerically evaluate the hypothesis that the changes in marine gateway configurations (Drake Passage, Tasman Gateway and also the Atlantic-Arctic connection, Hutchinson et al. 2019) may have led to the decrease in CO_2 concentrations across the Late Eocene and be a primary driving factor of the Antarctic glaciation via indirect carbon cycle feedbacks linked to the reorganization of ocean circulation rather than direct climatic effects (e.g. Lear and Lunt 2016).

Workplan:

The candidate will rely on numerical modelling of paleoclimates and biogeochemical cycles. Specifically, the candidate will use the IPSL-CM5A2 Earth System Model equipped with its biogeochemical component PISCES. First, the impact of changing gateway configurations on global ocean-atmosphere dynamics and, in particular, modes of ocean circulation will be evaluated. The candidate will review the literature on the Eocene configurations of the Drake Passage, Tasman

Gateway and Atlantic-Arctic Gateway to best constrain the paleogeography used in the earth system model. An ensemble of different scenarios will be tested to understand whether teleconnections exist between gateway configurations and by which mechanisms the effects of changing the configuration of a gateway is influenced by the configuration of another. Indeed, the numerical efficiency of the IPSL-CM5A2 model (~ 75-100 years simulated / 24 hours) makes feasible to perform a large number of simulations on the TGCC supercomputer of the CEA. In a second time, the candidate will run offline biogeochemical simulations with PISCES forced by the different modes of ocean circulation obtained previously. This will allow the candidate to compare the modes of ocean circulation to ε_{Nd} and $\delta^{13}C$ data from the Late Eocene as well as to quantify how the Late Eocene marine carbon cycle is affected by the evolution of key marine gateways.

Degree and skills requirements:

- Master degree in Geosciences
- Ability and desire to work in a closely cooperating team but also independently;
- Excellent communication skills; very good writing proficiency in English;
- Familiarity with coding and running computer models, programming skills in Fortran, Python or equivalent and scripting;
- Strong knowledge in ocean-atmosphere dynamics and in biogeochemical cycles is an asset;
- Demonstrable skills with relevance to biogeochemical or Earth system modelling are an asset.

Employment condition:

The position is expected to be starting October 1st and is fully funded by the CEA. Net salary will be around 1650 euros/month. The contract is for three years with full French social security benefits (medical insurance, unemployment benefit, pension, maternity leave and child benefit).

Deadline for applications:

Applications should be submitted by email to jean-baptiste.ladant@lsce.ipsl.fr, pierre.sepulchre@lsce.ipsl.fr and donnadieu@cerege.fr. The deadline to apply is June 1st 2023 and, therefore, applications received prior to May 28th 2023 will be given full consideration. Applications should include:

- A detailed CV and a letter of motivation (English or French)
- A summary of the MSc thesis
- At least two references