Professor Dr Philippe Huybrechts is working tirelessly to better understand the relationship between the Greenland ice sheet and global sea levels, both historically and for predicting future climate change.

Can you begin by discussing what drew you to the areas of ice dynamics and sea level change?

As a kid I was fascinated by both weather and glaciers, and I was a keen mountaineer, which naturally led me to the study of physical geography. I subsequently came into contact with Belgian scientists who had participated in glaciological expeditions to Antarctica and with scientists who investigated the origins of the Ice Ages. In the 1980s, just as computers were starting to enable the development of numerical models to simulate ice sheet behaviour, I began a PhD on the behaviour of the Antarctic ice sheet during the glacial cycles.

Computational advances allowed me to link developing knowledge on past climates with geological evidence of former ice stands. At the same time, significant data regarding climate conditions on the ice sheets, ice thickness and bed elevation was becoming available. As scientific debate shifted towards anthropogenic global warming, I quickly realised the societal importance of studying land ice, and I wanted to contribute by creating novel computer models.

What is the importance of the Greenland ice sheet (GrIS) and what would be the repercussions if it were to melt?

The GrIS is a relic of the Ice Ages, currently situated in a marginal environment for its survival; it sustains itself because of the cold conditions it creates on its surface. With a warming of only around 3 °C, its surface mass balance would become negative and the sheet would no longer be sustained, leading it to melt within millennia or even centuries. If the GrIS were to melt entirely, global sea levels would rise by about 7.5 m, and only a future ice age could regrow the sheet. If current warming trends continue unabated, this process could begin by the middle of this century.

Why does the role of the GrIS on changes in sea level during the Last Interglacial (LIG) remain unclear?

We know that global sea levels were between 6 and 9 m higher during the LIG, a period which was several degrees Celsius warmer than today. Other Northern Hemisphere ice sheets had already melted, so this sea level rise could only have come from the Antarctic ice sheet or the GrIS. However, both ice sheets have left very few traces of their minimum extent. The presence of ice older than the LIG in central Greenland ice cores indicates that at least the central ice dome must have survived, but the extent to which the sheet had reduced in size must be derived indirectly from models integrating evidence from various proxy data. Ascertaining the minimum size of the Greenland ice sheet during the LIG is crucial in the debate on global warming as it provides the best analogue we have for the GrIS’s behaviour in a future warmer climate.

How can predictions be improved regarding the future of climate warming?

This largely depends on how greenhouse gas emissions develop over the coming decades. In climate projections, atmospheric concentrations of greenhouse gases are the greatest source of uncertainty and contribute to most of the variability in projected outcomes. If we are to avoid far-reaching consequences for almost every aspect of human society, mankind is well advised to drastically reduce greenhouse gas emissions.

Do you think it is possible to reverse the effects of global warming?

The main problem is the long lifetime of certain greenhouse gases, particularly carbon dioxide; it takes many centuries for the terrestrial biosphere and the oceans to absorb anthropogenic greenhouse gas emissions. As long as climate warming remains at a level higher than before the Industrial Revolution, the slow components of the climate system such as sea level and large ice sheets will continue to respond for many centuries or even millennia, making it almost impossible to reverse the effects of global warming within any reasonable human timescale.

Our recent work has suggested that global sea levels are likely to rise by at least 1.1 m within 1,000 years, and that is based on the assumption that atmospheric greenhouse gas concentrations are kept constant at the year 2000 level, which will only be achievable through drastic emission reductions. If greenhouse gas concentrations were to ultimately stabilise at the levels projected by many researchers, a committed sea level rise of more than 4 m by the year 3000 may well be inevitable.
A groundbreaking international study based at the Vrije Universiteit Brussel in Belgium is making great strides in developing and applying the next generation of three-dimensional ice sheet modelling technology.

**As greenhouse gas** emissions continue to rise, the effects of climate change become more and more evident. Hence, there is an increasing need to develop more precise models for predicting the future effects of these trends. Particularly important in climate change prediction is the accurate modelling of ice sheets – large masses of glacial ice also known as continental glaciers. The Earth’s two ice sheets are the Antarctic ice sheet and Greenland ice sheet (GrIS). The latter covers around 80 per cent of Greenland’s surface and is currently the subject of groundbreaking studies led by Professor Dr Philippe Huybrechts at the Departments of Earth System Sciences and Geography within the Vrije Universiteit Brussel (VUB) in Belgium.

Huybrechts is developing pioneering three-dimensional (3D) flow model technology which he hopes will enable him to shed light on the relationship between ice sheets and global sea level changes, both in the context of past and future climate conditions.

**Multiple considerations of ice sheet modelling**

Ice sheet models operate by replicating the fundamental physical laws which govern the movement and behaviour of ice flow, with the resulting mathematical equations being first entered into a computational grid and subsequently solved. These physical laws dictate the stresses which are placed on ice sheets and include gravity, internal ice deformation – or creep – and the mechanism by which the sheet slides over its bed at points where there is underlying meltwater. In order to complete an accurate model of an ice sheet, data regarding the elevation of the bedrock and global sea level changes, both in the context of past and future climate conditions.

**Reconstructing the last interglacial**

Huybrechts is carrying out his current research as a key collaborator on the international North Greenland Eemian Ice Drilling (NEEM) project. Alongside NEEM, the Nested modelling of the Greenland ice sheet in support of the dating and the interpretation of the NEEM ice core record (NEEM-B) project has generated a detailed model of ice flow around the drill site. The ultimate aim of NEEM-B is to create a model capable of reconstructing the climate conditions which occurred during the Last Interglacial (LIG), or Eemian, a period which lasted from approximately 130,000 years ago to around 115,000 years ago and which, due to its prevailing temperature, is widely considered to be an appropriate framework on which to base future climate projections.

“My role in the NEEM project has been to use ice sheet models in order to help with the interpretation of the ice core; in particular, to be able to correct temperature changes that are not related to climate, but instead have been caused by ice flow,” Huybrechts elucidates. In order to accurately model the LIG, Huybrechts and his colleagues have had to take into account the fact that, because the NEEM ice core was not drilled on the summit of the ice sheet, the Eemian section was originally deposited at an upstream location significantly higher than today, and has also been subject to a degree of elevation which is not connected to changes in climate.

Beyond their focus on the LIG, the research team has also attempted to generate a model which can accurately elucidate the shape and volume of the GrIS during the last 150,000 years. In order to do this, the model will need to correlate with all known constraints from the NEEM ice core in relation to other ice cores within the sheet. This information from the past can then be used to inform predictions of the future.

In two parallel projects – ice2sea and iCLIPS – Huybrechts uses new insights from the NEEM ice core to better constrain poorly known parameters and thus refine global climate
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