Greater knowledge, better climate

Senior Scientist Valérie Masson-Delmotte has carried out comparative studies on climate variation in Greenland. Here, together with collaborators Pablo Ortega and Emilie Gauthier, she discusses their application, and the challenges associated with research on and in Greenland.

What are your respective backgrounds in environmental studies and why is your current research centred on climate change in South Greenland?

VMD: My research focuses on reconstructions of past climate variability, mostly using stable isotopes from ice cores, both from Antarctica and Greenland, and the mechanisms of past changes using climate simulations. I have worked on a variety of timescales from last centuries to glacial-interglacial variations. I also work on the present day monitoring of stable isotopes in precipitation and water vapour to understand the processes controlling the proxies used for past climate reconstructions.

PO: I studied physics and specialised in atmospheric sciences, motivated by all the intriguing and unresolved questions related to climate change. Greenland is an incredible and almost unbeatable source of information. For example, the Greenlandic ice sheet has witnessed, recorded and allowed us to reconstruct changes in surface temperature dating back 123,000 years! My current research focuses on the interpretation of ice core isotopic data in terms of the major weather regimes in the North Atlantic.

EG: I am a palynologist and archaeologist. I have been working in Greenland since 2006, with a pluridisciplinary team (sedimentologists, geochemists and diatomists) focusing on the study of lacustrine sedimentary records.

Could you outline the main aims of your current multidisciplinary project GREEN GREENLAND?

All: Our project brings together archaeologists, historians and environmental psychologists, together with experts in quantitative terrestrial climate reconstructions, climate modelling, detection and attribution of climate change, atmospheric monitoring, vegetation productivity monitoring and modelling, with the common goal of documenting Greenlanders’ perception of climate change and the local impacts of climate variability and climate change.

Our timescale of interest spans the historical period (the last millennium), the instrumental period and regional climate projections for the 21st Century. We aim to provide a firm basis for documenting and understanding Greenlanders’ perception of climate change, centred on farmers in South Greenland, and the drivers of changes in atmospheric circulation, terrestrial local climate, glacier extent and vegetation productivity.

Have your studies so far highlighted any significant discoveries on the impact of changes in atmospheric circulation and terrestrial climate on vegetation productivity?

All: In order to provide future climate information that is relevant for sheep farmers in Greenland, we have used a regional atmospheric model to downscale the results of several global climate models, selected for their skills over Greenland, for two contrasted greenhouse gas emission scenarios at 20 km resolution. This was then used to drive a local land surface vegetation model, which calculates vegetation productivity and prairie management, and therefore provides a calculation of a theoretically optimal flock density. This modelling approach has previously been applied in Europe, and is the first application in arctic conditions.

Has your team encountered any specific challenges during your investigations?

EG: Contact with Greenlandic farmers during fieldtrips was not easy because of the language barrier. We couldn’t speak Greenlandic or Danish and only some of the farmers’ wives spoke English, but our discussions with them helped us understand how they consider their activities.

VMD: We were lucky to host several students and early-career scientists within the project. Their curiosity, enthusiasm and motivation have greatly contributed to the overall success of GREEN GREENLAND to date. With respect to dissemination, we have published a review paper on Greenland and climate change, with an interdisciplinary perspective. We are also currently preparing an outreach book with contributions from 100 different authors on Greenlandic climate, ecology and society editions (in French), in press at Centre National de la Recherche Scientifique (CNRS). The project has already been presented at the University of Greenland and we will invite a range of stakeholders, teachers and policy makers to attend our final project workshop in 2015.

The GREEN GREENLAND project integrates a large training dimension for students. Are there any specific efforts in the pipeline to disseminate results to teachers, policy makers, stakeholders and the general public?

EG: We start by providing the general public with access to the results that have recently been obtained. The increased delay will also give us time to publish the results that have recently been obtained.
A green collaboration

An international, collaborative consortium, including researchers from the Laboratoire des Sciences du Climat et de l'Environnement, France, has been assessing the past, present and future impacts of Greenland’s climate variability on coastal glaciers, vegetation and agricultural activity.

GREENLAND IS NEITHER really ‘green’, nor fully ice-covered. Its arctic location belies the fact that the country has over 56,000 inhabitants, and southern Greenland features ice-free coastal land used for agriculture and sheep farming, as well as fjords that resemble European high mountain areas. The Greenland ice sheet has in the past been studied intensively due to its tangible response to climate change and associated implications for future global sea level rise. Numerous climate archives available from deep sea and marine shelf sediments, glaciers, lakes and ice cores in and around Greenland allow researchers to place the current trends in regional climate, ice sheet dynamics and land surface changes in a broader context.

DRIVERS OF GREENLAND CLIMATE VARIABILITY

Senior Scientist Valérie Masson-Delmotte from the Laboratoire des Sciences Du Climat et de l’Environnement (LSCE) and Institut Pierre Simon Laplace (PSL) is working with a team of researchers, comprising early-career scientist Pablo Ortega (now at LOCEAN, Paris) and Professor Emilie Gauthier (Laboratoire Chrono-Environnement, Université France-Compté) among others, on ‘GREEN GREENLAND’ – a project with a multidisciplinary approach that focuses on past, present and future Greenland climate, its impacts on coastal glaciers, vegetation and agriculture, and the past and present human perception of climate variability and change.

Researchers have noticed significant changes in atmospheric and sea surface temperatures in the last decade, which stand above the variability encountered during the past 1,000 years. They now reach levels similar to those last experienced several millennia ago, when northern high latitude summer insolation was higher due to a different orbital configuration.

“The Greenlandic ice sheet has undergone record-breaking summer melting in the last few years and, if it maintains this pace, will contribute strongly to sea level rise,” discloses climate scientist Ortega. “Also, the associated freshening of the upper ocean could impact the strength of oceanic circulation in the Atlantic, with widespread consequences.”

Ortega analysed how Greenland ice cores register the imprint of weather regimes in the North Atlantic. “In the surrounding continents, their related climate influences superimpose locally on the global warming signal, sometimes mitigating and at other times reinforcing it,” he explains. “The quantification of these local impacts can help to better constrain the different spatial expressions of global climate change.”

To obtain an overview of large-scale climate change, the project researchers developed two approaches to estimate the contribution of ongoing Greenland warming associated with global warming, and identified a dominant fraction linked to changes in large-scale atmospheric circulation. “We also identified the fingerprint of changes in North Atlantic Sea surface temperature variations in a network of Greenland ice cores and used these data together with global climate simulations,” Masson-Delmotte summarises. “This approach has allowed us to understand the key role of the timing in-between large-scale volcanic eruptions, which acts as a pacemaker of bidecadal variability, both during recent decades and the last millennium.”

SOUTH GREENLAND COAST: FROM NORSE TO MODERN FARMERS

Masson-Delmotte’s project partners focused on a study of southern coast sheep farmers by looking at the link between their lives and practices and the changes in local climate. One investigation, led by Gauthier, analysed lake sediments extracted from Lake Igaliku in South Greenland, unveiling information on past changes in vegetation, climate and agricultural practices, including the environmental impacts on Norse and modern agricultural activities.

“Norse farmers benefited from the mild Medieval period to develop pastoral activities (mainly sheep, goats, cows, horses). Greenland was in fact not greener at this time than today, and our data suggest a great stability of environmental conditions – vegetation, for instance – from at least 2,500 years ago,” she asserts.

Gauthier’s investigations have unveiled a decrease in erosion and grazing pressure and the reduction of pastoralism in the Eastern Settlement – the first and largest of the three areas of Norse Greenland – by the 14th Century. At the same time, human bone isotopic studies provided by Danish archaeologists reveal a shift from a terrestrial diet to a marine diet. “Around 1450, the Eastern Settlement was definitely abandoned. The Norse tried to adapt to the harsher conditions associated with the so-called Little Ice Age by changing their way of life but did not fully succeed. Our data show that there is no catastrophic scenario of overgrazing and land degradation leading to their demise. Our record however reveals that environmental resilience was incomplete; pollen analysis uncovered that plants introduced by the Norse remained in and around the sites,” she elucidates.

Sheep farming was again introduced in South Greenland in the 20th Century. Lake sediments record the environmental impact of modern agriculture, and reveal a marked difference between two distinct periods – before and after 1980. Between 1920 and 1980, the human impact on Greenland was the same as during the Norse period, but after 1980 mechanisation and the use of fertilisers were shown to strongly enhance soil erosion and pollution. As a result, over the last 30 years, agriculture has been the...
cannot be completely ruled out. Summer temperatures during this period have a role in warming Lake Igaliku. However, the warming is the main driver of ecological change in and around Lake Igaliku. However, the role of warming summer temperatures during this period cannot be completely ruled out.

ATMOSPHERIC MONITORING

The variety of air mass trajectories towards South Greenland make it an excellent location for monitoring the variability of atmospheric composition – including the concentration of greenhouse gases and the isotopic composition of water vapour – in relation to Arctic, North American, European and North Atlantic air mass origins. By monitoring atmospheric composition, the GREEN GREENLAND team characterised seasonal to inter-annual exchanges of CO₂ between the North Atlantic Ocean and the atmosphere, and the atmospheric transport effects.

The isotopic composition of water vapour can now be measured continuously, *in situ*. “Our pioneering measurements performed in South Greenland have unveiled how the water stable isotope signal is formed, at the scale of weather systems, and challenges the earlier interpretations of Greenland ice core deuterium excess records, a parameter that carries the fingerprint of moisture evaporation conditions,” explains Masson-Delmotte. “We had the opportunity to sample the isotopic composition of surface water vapour at two Greenland sites during the major July 2012 atmospheric river event that led to widespread melt at the surface of the Greenland ice sheet.” This enabled PhD candidate Jean-Louis Bonne to demonstrate how the vapour isotopic composition preserves a signal related to the origin of water vapour.

SMART FARMING

Interviews with sheep farmers in both South Greenland and the French Alps have provided information on farmers’ perception of climate and the impact it has on their activities. Following dramatic changes in practice over the last century, Greenland sheep farmers developed a strategy to stabilise their flocks through an intensification of fodder production, the use of winter sheepfolds and food imports. Despite a recent rise in temperature since the mid-1990s, stocks have remained stable due to this practice. Farmers report positive effects associated with warmer conditions and observations of local impacts, but express concerns associated with recent drier summers.

The GREEN GREENLAND researchers are now combining climate, vegetation and pasture models to investigate future opportunities for sheep farming expansion. Global warming is projected to enhance growing season length in South Greenland, and improve vegetation productivity and therefore potential flock density. Preliminary results are paradoxical, in that they depict a potential for sheep farming expansion, but a higher vulnerability to climate variability if the sheep population grows. Adaptation will remain the keyword for Greenland agriculture.

INTELLIGENCE

GREEN GREENLAND

OBJECTIVES

To document and analyse past and present human perception of climate variability and change, vulnerability and resilience and adaptation strategies in coastal Greenland (in relationship with agriculture); to place the recent and ongoing Greenland warming in the broader context of past changes in South Greenland land climate, vegetation, sedimentation and ice history (over the past 1,500 years); to expand a South Greenland atmospheric observation station to monitor current changes in atmospheric greenhouse gases and water vapour; to build a solid understanding of the large scale drivers of Greenland climate variability using observations, reconstructions, climate models and detection/attribution statistical methods.

KEY COLLABORATORS

Pablo Ortega, Postdoctoral fellow, LOCEAN (Laboratoire d’Océanographie et du Climat, Expérimentations et Approches Numériques), Université Pierre et Marie Curie (UPMC)

Professor Emilie Gauthier, Laboratoire Chrono-environnement, Université de Franche-Comté and LIENS

Hubert Gallée, LGGE

Vincent Jomelli, LGP

Karine Weiss, Université de Nîmes

Aurélien Ribbes, CNRM-GAME

Jan Borm, CEARC

Didier Swingedouw, EPOC

Marc Delmotte, Nicolas Viovy, LSCE

FUNDING

French National Research Agency (ANR)

CONTACT

Valérie Masson-Delmotte

LSCE (CEA-CNRS-UVSQ)

Institut Pierre Simon Laplace

E valerie.masson@cea.fr

Valérie Masson-Delmotte’s research has been dedicated to the documentation and understanding of past climate and water cycle variability, using measurements performed on natural climate archives (ice cores, tree rings) and simulations. With strong international collaborations, she has co-authored numerous scientific publications, acknowledged by several research prizes (such as ‘2013 Woman Scientist’ in France). She was a coordinating lead author of the paleoclimate chapter in the IPCC Fifth Assessment Report and has also published several outreach books for children and for the general public. Since 2014, she has been a member of the French Research Strategic Council.