The Voices of Glaciers

Ignacio Palomo
Sofía Lana
Antoine Rabatel
Oliver Dangles

Stories of Grief and Hope amidst shrinking Glaciers in the Tropics

unesco

IRD Editions

The Voices of Glaciers

Ignacio Palomo
Sofía Lana
Antoine Rabatel
Oliver Dangles

Stories of Grief and Hope amidst shrinking Glaciers in the Tropics

The Voices of Glaciers

Ignacio Palomo
Sofía Lana
Antoine Rabatel
Oliver Dangles

Stories of Grief and Hope amidst shrinking Glaciers in the Tropics

Work published with the support of the Mountain Research Initiative

unesco

IRD Éditions

Suggested citation: Palomo I., Lana S., Rabatel A., Dangles O. 2025 – *The voices of glaciers: stories of grief and hope amidst shrinking glaciers in the tropics*. With the collaboration of Cauvy-Fraunié S., Ceballos J. L., Adler C., Mark B., Marchant R., Morales Arnao B., Pérez Arias J. D., Aguilar Durán D. & Zimmer A. Marseille-Paris, IRD Éditions-UNESCO.

Editorial coordination: IRD/Catherine Guedj and Romain Costa
Copy editing: Elise Bradbury
Proofreading: Anne Causse

Watercolour portraits of interviewees: Mariana Vilardy
Glacier modelizations and texts about glaciers: Antoine Rabatel

Graphic design and layout: Format Tygre/Alan Guilvard
Cover photo: A Challa ceremony is held before climbing Huayana Potosi mountain, asking the Pachamama for safe passage on the climb. © Todd Antony

Editor UNESCO: Rita Marteleira
Internal review UNESCO: Anil Mishra, Patrycja Breskvar, Tales Carvalho Resende, María Rosa Cárdenas Tomažič, Nigel Thomas Crawhall, Juliette Hopkins, Emmanuelle Robert, Yiline Zhao, Hee Eun Ahn
External Review: Raúl Martín Moreno

Published in 2025 by the United Nations Educational, Scientific and Cultural Organization (UNESCO),
7, place de Fontenoy, 75352 Paris 07 SP, France,
and the **French National Research Institute for Sustainable Development (IRD)**,
44 bd de Dunkerque, 13002 Marseille, France.

UNESCO's paper ISBN: 978-92-3-100756-9
UNESCO's DOI: 10.54677/PZZT2044

IRD's paper ISBN : 978-2-7099-3073-4
IRD's PDF ISBN : 978-2-7099-3074-1
IRD's epub ISBN : 978-2-7099-3075-8

"My father told me that some voices are so true they can be used as weapons,
can manoeuvre the weather, change time."

Joy Harjo

"We think we listen, but very rarely do we listen with real understanding,
true empathy. Yet listening, of this very special kind,
is one of the most potent forces for change that I know."

Carl Rogers

Contents

Forewords

VALÉRIE VERDIER,
Director of the French Research Institute for Sustainable Development (IRD)

It gives me great pleasure to introduce this important work, published by the IRD and UNESCO to mark the International Year of Glaciers' Preservation.

On the high peaks in the tropics of South America, East Africa and Asia, over millennia glaciers have shaped landscapes, regulated water resources and inspired local cultures with their mysterious beauty. Today, however, tropical glaciers are worrying portents of the effects of climate change on our planet: the majority will have disappeared by 2050, taking with them unique ecosystems and disrupting the lives of the people who depend on them.

The striking originality of this book lies in its ambition not to limit itself to a scientific analysis of glacier retreat, but to give a voice to those witnessing and bearing the direct consequences of the disappearance of these ice giants. Through an interdisciplinary and transdisciplinary approach that brings together glaciology, ecology, anthropology, personal accounts and the arts, the little-known story of tropical glaciers and those who live in contact with them is told. Too often, environmental science is restricted to raw data measuring biodiversity loss, temperature trends and rainfall levels. But this is not the whole picture. The ecological crisis is also an urgent question of meaning and identity. How are these communities, some of the most vulnerable in the world, adapting to a life without glaciers? What does it mean for a Peruvian guide or a Tanzanian farmer to experience the loss of a glacier that has always been a part of life? This book explores these vital questions with a new and profoundly human perspective.

Taking into account the complexity of global issues and finding sustainable solutions requires science that is engaged with society. The IRD, one of the pioneering institutes in the study of tropical glaciers, has set up with its partners in Bolivia, Peru and Ecuador a network of human–environment observatories in South America that have led to major advances in our knowledge of the multiple impacts of climate change on glaciers. Today this work continues in the Andes, in the Himalayas and on the highest peaks of East Africa, where IRD scientists are involved in international programmes alongside local partners. This research is aimed at analysing and predicting glacier melting and its environmental, social and cultural consequences, as well as working with local populations to put in place solutions to prepare for the loss of ice.

With 2025 designated by the UN as the International Year of Glaciers' Preservation to launch a Decade of Action for Cryospheric Sciences, this thought-provoking book seeks to inspire reflection and to encourage action. It invites us to see tropical glaciers not simply as vestiges of the past, but as active witnesses to the changes taking place on the Earth. Its stories remind us that while science is essential to understanding our environment, emotions also serve as a catalyst to spur action for a fairer, more sustainable world.

AUDREY AZOULAY
Director-General of UNESCO

Glaciers are the silent sentinels of our planet, serving not only as archives of the Earth's past climate, but also as guardians of biodiversity and vital sources of water for communities. Nowhere is their fragility more evident than in the tropics, where they are on the front line of climate disruption. Their rapid melting threatens livelihoods, heritage and spiritual identities.

With a broad mandate spanning the environmental and cultural dimensions of our world, UNESCO is deeply committed to preserving both the ecosystems of glacial regions and the cultural traditions they sustain. We do so by fostering collaboration between water managers, hydrologists, ecologists, anthropologists, artists, policymakers and local communities.

The United Nations World Water Development Report 2025, dedicated to mountains and glaciers, revealed alarming statistics on glacier loss worldwide. For instance, the Andes, which supply half of the water flowing into the Amazon River, have lost between 30% and 50% of their glaciers since the 1980s.

While rigorous scientific work is indispensable in the fight against climate disruption, this crisis is far too often spoken about only in terms of numbers—we must also grasp its immensely personal consequences. Stories, experiences and knowledge passed down through generations can help us to do so, and can provide an essential element often missing from this fight: hope.

The Voices of Glaciers, a joint initiative between UNESCO and the IRD, brings together a diverse range of voices—scientists, Indigenous peoples, artists, mountain guides and local communities—to delve into the emotions provoked by glacial melt. From the regret expressed by Indonesian glaciologist Donaldi Permana to the message of hope from 11-year-old Colombian environmental advocate Josué Arias, the 35 stories contained in the pages that follow offer a much-needed, deeply human perspective on this issue.

As the international community observes the International Year of Glaciers' Preservation-2025 and embarks on the Decade of Action for Cryospheric Sciences (2025–2034), this book serves as a powerful reminder of the urgent need for action. By weaving together stories of grief, resilience and hope, it invites us to confront the reality of our changing planet and to reaffirm our shared responsibility in safeguarding both nature and culture for future generations. *The Voices of Glaciers* is not just a chronicle of loss—it is a call to listen, to learn, and to act.

A bit of history

The Voices of Glaciers is a collaborative effort between the French Research Institute for Sustainable Development (*Institut de Recherche pour le Développement* - IRD) and UNESCO aimed at documenting the disappearance of tropical glaciers in the Andes in South America, East Africa, and Southeast Asia and the human stories connected to them. By weaving together science, storytelling and art, the book offers a compelling testament to the urgency of glacier conservation while honouring the people whose identities and livelihoods are intricately tied to these fragile landscapes.

The book is the result of IRD and UNESCO long-standing engagement in glacier research and preservation through multiple programmes bridging glaciology, anthropology, sustainability science, and local knowledge. Structured around 35 stories of scientists, Indigenous Peoples, local communities, tourists, mountain guides, artists and scientists, the book delves into the emotional, cultural, and socio-economic ramifications of glacier melt, categorizing responses into themes of care, concern, sadness, acceptance, and hope. It presents a human-centered narrative, balancing scientific research with personal testimonies to illustrate how communities adapt, mourn, and find resilience in the face of environmental change.

The IRD, founded in 1944, is a research institution present in mainland France and beyond with a network of representations to organise its collaborations in more than 50 countries, where it contributes to strengthening the resilience of societies in the face of global upheaval. The IRD is fully committed to an inter and transdisciplinary approach, through the integration of several disciplines as well as non-academic actors. Firmly focused on the needs of local populations, the IRD's research model is based on an equitable scientific partnership, with the aim of training and co-constructing knowledge to achieve sustainable development goals. This original positioning gives the IRD a real legitimacy to lead the deployment of the Sustainability Science. Sustainability Science distinguishes itself from other scientific fields by directly confronting the major challenges facing our societies, and drawing on transdisciplinary methodologies to address them. This approach is based in particular on the co-construction of knowledge and know-how, based on collaboration between scientists from different disciplines and non-academic players, in a participatory and committed approach.

IRD's work on glaciers dates to the early 1990s with the creation of the "*Nieves y Glaciares Tropicales*" [Snow and tropical glaciers] programme - a partnership initiated in Bolivia on the initiative of Bernard Francou (glaciologist) and Pierre Ribstein (hydrologist) that has since been extended to Peru, Ecuador and Colombia. The partnership has been consolidated with the creation of the *Service National d'Observation* (SNO) GLACIOCLIM in 2002 and the *Laboratoire Mixte International* (LMI) GREAT ICE in 2011 which provide crucial long-term data on tropical glaciers. These efforts contribute to the global understanding of glacier dynamics, climate change impacts, and water resource management, supporting local and international adaptation strategies. The collected glaciological data within GLACIOCLIM are included in existing glacier databases worldwide (*e.g.*, World Glacier Monitoring Service, Global Cryosphere Watch), and the results of its

research are published in leading scientific journals and have been mentioned in the Intergovernmental Panel on Climate Change (IPCC) reports since 2007. In addition, IRD has conducted numerous studies in recent decades on the ecological effects of glacier retreat in the tropics, both on terrestrial and aquatic biota. Other work has included several studies of the socio-economic and cultural consequences of glacier loss.

UNESCO has been advocating for the protection of glaciers for more than 50 years. During the early 1960s, UNESCO supported the compilation and assemblage of data of the first worldwide inventory of existing ice and snow masses within the framework of the International Hydrological Decade (1965–1974). This initiative laid the foundation for the Intergovernmental Hydrological Programme (IHP), which was established in 1975 and remains the only intergovernmental programme of the United Nations system dedicated to water research, water governance, and capacity building. Over the years, the IHP has played a critical role in advancing scientific understanding of glacial retreat and its far-reaching impacts on water resources, ensuring that the scientific knowledge produced is translated into effective and sustainable water governance practices. This includes providing a scientific basis for national and regional strategies on climate adaptation, strengthening regional platforms to share knowledge and best practices, assessing risks to local communities of hazards such as landslides and glacier lake outburst floods, supporting research, education and capacity development to assess the impact of climate change on glaciers, as well as promoting indigenous and local knowledge systems.

UNESCO's work extends into on-the-ground conservation through its vast network of designated sites including World Heritage sites, Biosphere Reserves, and Global Geoparks. These sites serve as valuable tools for monitoring changes in glacial ecosystems and developing adaptation strategies, as well as implementing interdisciplinary approaches to comprehend and address change. By safeguarding these sites, UNESCO not only protects the natural environment but also ensures the survival of the cultural and economic systems that depend on it. Through the Local and Indigenous Knowledge Systems (LINKS) Programme, UNESCO has fostered a dialogue between scientific research and traditional wisdom, acknowledging that effective climate adaptation strategies must incorporate diverse perspectives. Many Indigenous communities hold glaciers as sacred and living entities, integral to their cultural and spiritual traditions.

As the only United Nations agency with a specific mandate in culture, UNESCO works to safeguard cultural heritage and promote cultural diversity as a force for dialogue and development. The Convention for the Safeguarding of the Intangible Cultural Heritage has been instrumental in preserving the rituals, stories, and practices that bind communities to these ice-covered landscapes. From Andean ceremonies honoring mountain spirits to Arctic traditions that acknowledge the power of ice, these expressions of intangible heritage reflect the deep cultural connections between people and glaciers.

With IRD's and UNESCO's combined commitment to preserving both natural and cultural heritage, *The Voices of Glaciers* stands as a testament to what is at stake and a call to action. As the world marks 2025 as the International Year of Glaciers' Preservation and embarks on the Decade of Action for Cryospheric Sciences (2025–2034), this book reminds us that while glaciers may be vanishing, their voices—and the knowledge they hold—must not be lost.

Prologue

The growing awareness of the importance of protecting glaciers has largely been driven by scientific research revealing the unprecedented changes driven by climate change. Yet the social, cultural, and economic dimensions of glacier loss have received far less attention. This book seeks to share the voices of those who live or work amidst tropical glaciers, the most vulnerable due to their geographical location, collecting people's testimonies of their special bond with glaciers and the necessity to make sense of and adapt to the abrupt changes taking place.

For centuries, the "voices of tropical glaciers" could be heard faintly through community practices and local knowledge about these "sacred giants". But today, tropical glaciers are at the forefront of the conversation around climate disruption, echoed in widely read publications that lament the disappearance of one of the most fragile ecosystems on Earth. This book gives voice to those involved in these well-publicised stories, but also to many others, whose stories have been mostly unheard, yet who are just as deserving of attention.

Are the days of experiencing tropical glaciers numbered? What changes are happening in the tropical cryosphere now and what will occur in the foreseeable future? What do these changes entail for the communities who live alongside tropical glaciers? What do they mean for the transmission of their cultural traditions and practices to future generations? How do different individuals face the process of glacier loss? Answering these questions demands an interdisciplinary approach from fields as far removed as glaciology and anthropology. Conversations across numerous disciplines with experts and the perspectives from people on the ground are at the core of this book and seek to answer these questions.

By 2050, nearly half of the tropical glaciers featured in these chapters will be gone. Globally, tropical glaciers will have lost around 90% of the surface area they covered during the Little Ice Age (circa 16th–19th centuries) by 2050. These tropical glaciers include sites of outstanding ecological and cultural value, including five UNESCO World Heritage Sites, four Biosphere Reserves and one Global Geopark, as well as elements of intangible cultural heritage. Reconstructions of their previous surface area based on moraines (sediment depos-ited by the glacier that shows its past extent) identified in satellite images show how much closer glaciers were to mountain communities in the past and suggest significant contributions to water flows, particularly in the dry season. The unprecedented loss that is occurring will have major environmental and social consequences that require stronger adaptation actions. This in turn requires understanding the socioeconomic and political conditions of the environments to which these adaptation policies are applied. Historical (and continuing) issues related to the unequal distribution of resources, Indigenous territorial rights, and

other conditions related to inequality in education and health, for instance, are just some of the complex issues tropical areas with melting glaciers already face. While the challenges are immense, hope remains. Through global collaboration and innovative action, the stories of resilience, reverence, and respect showcased in this publication serve as a reminder that not all is lost. Nonetheless, a broader awareness of climate change and glacier loss and their impacts on local mountain communities is fundamental.

The need to raise societal awareness of glacier loss calls for an interdisciplinary approach that, we argue, includes the arts. Art, fundamentally aesthetic and communicative, can speak where science cannot reach. While science communicates facts, it is not so successful at reaching "*hearts and guts*", as Randy Olson puts it in *Don't Be Such a Scientist*, and these so often rule human behaviour – first creating awareness, and eventually action. The photographs and portraits in this book aim to make visual the voices of glaciers. Hopefully, they will inspire the reader and general public to appreciate the irreplaceable value of glaciers and to join the collective effort to preserve them.

This book tells 35 stories that relate the emotions, perceptions, adaptations and transformations of a very diverse group of individuals whose lives are tied to tropical glaciers. For example, the story of Saúl Luciano, a Peruvian subsistence farmer and mountain guide who has brought a lawsuit against a major energy company for its role in climate change and its impact on glacier loss in Peru's Cordillera Blanca. Or the imperturbable long view of a geologist who observes tropical glacier loss as another micro-episode of the planet's history. Some are inspiring stories of dedication and commitment to safeguarding this iconic geography and to protecting communities impacted by tropical glacier loss. Others are grieving chronicles of despair about glacier loss. We heard these stories first-hand, and were sometimes involved in them. Like the opening of a new rock-climbing route where a glacier used to be on the third-highest summit in Africa, Margherita Peak (5,109 m above sea level), on Mount Stanley in Uganda. Or the composition of a piece of music that translates scientific knowledge on mountain ecosystems threatened by climate change. We share these stories as an urgent call to accelerate action against climate change, which is too little and too slow. While most tropical glaciers are condemned to disappear, the voices of those whose lives are interwoven with them will remain in the hearts and minds of those willing to listen.

As travelling the planet to collect these voices would have contributed to the loss of tropical glaciers, we used remote meetings to collect most of the testimonies. The carbon emissions for the two international trips taken by the first author of this book, accounting for the emission of less than 10 tonnes of CO_2, have been offset.

Tropical glaciers: an oxymoron under threat

Planet Earth has been called the "blue planet" because 71% of its surface is covered by water. Unlike other elements on Earth, water can be easily found in three states: liquid, gas and solid. The solid form, ice, only represents 2% of the water on Earth but covers around 10% of our planet's surface, including Greenland and the Antarctic. So quickly, in fact, that deglaciation is leading to unprecedented environmental and social consequences, particularly in the tropics. This book tells the story of tropical glaciers through the voices of those who are intimately involved with them.

Can we study tropical glacier loss by bridging various disciplines, including the arts and the humanities? Would such an interdisciplinary approach bring something new to what we already know about glacier loss and mountain communities? This book attempts to demonstrate how we can develop a more holistic understanding of what has to date been mostly seen as a geographical process with a bit of input from the social sciences. It illustrates the alarming speed at which tropical glaciers are receding, but also the many ways in which people share their life with glaciers in the tropics. Importantly, it shows how their loss is eliciting emotional responses from those who interact with glaciers. Emotions have often been ignored by academics, as within the field of psychology during the 20th century or within economics and its "*Homo economicus*" explanation of human behaviour based only on rationality. Yet as the work of the Nobel Prize winner in economics Daniel Kahneman demonstrates, people have too much confidence in human rationality and judgement. Just as economics has come to take into account that behaviour is not always rational, the study of emotions linked to the environmental crisis is starting to emerge.

Through the pioneering work on emotions and the environment of Elisabeth Kals and others, we now know that emotions are fundamental to understanding how pro-environmental behaviour develops. After decades of published "black-and-white" evidence of the global environmental crisis, it is now urgent to understand how we can move from knowledge to action. As Anne Toomey eloquently puts it, "*facts don't change minds*". This points to a critical need for cognitive science and evolutionary psychology to inform how to communicate science.

This book shows how glacier loss in the tropics is having a profound impact on mountain communities and beyond. More than their essential role in providing water and regulating temperature and precipitation patterns within their social and biophysical environments, glaciers contribute to more intangible qualities of a "good life" linked to culture, identity, well-being

and spirituality. Changes in the environment, partly resulting from rapid glacial loss, drive emotional responses such as feelings of care, concern, loss, acceptance or hope. The interdisciplinary approach this book takes, emerging from a conversation between glaciology, ecology, anthropology, environmental and sustainability science, combined with the arts, puts forward a vision of the current environmental crisis that touches our emotional side.

Glaciers in the tropics may seem incongruous at first glance. Yet this high-altitude ice at low latitudes exists in eleven diverse countries from Latin America to Africa to Southeast Asia. Tropical glaciers have long stirred the imagination. When Western explorers first encountered and reported them, there was disbelief in the scientific community of the time. Johannes Rebmann, a German missionary, was the first European to lay eyes on Mount Kilimanjaro. His publication in 1849 reporting glaciers close to the equator was initially disregarded as fantasy by the Royal Geographical Society, which suggested that he may have been suffering from malaria-induced hallucinations. A few decades later, in the tropical Andes, the German geologists William Reiss (1838-1908) and Alphons Stübel (1835-1904) hired the Ecuadorian painter Rafael Troya (1845-1921) to illustrate their geological observations of moraines to prove that glaciers existed there.

An interdisciplinary approach to glaciers

If there had been a broader scientific understanding then of how altitude influences climatic conditions, the existence of tropical glaciers would not have stirred such incredulity. Few at the time took a more holistic approach to science. Alexander von Humboldt (1769–1859) was an exception, combining several scientific disciplines such as climatology, geography and natural sciences in his studies. His famous *Tableau Physique* published in 1807 combined climatology and ecology to show how different vegetation belts exist in the tropics as elevation increases.

Today, interdisciplinarity – bringing together different fields, their concepts and their methods, to study a topic – is slowly gaining ground. This includes the interdisciplinary study of glaciers, an approach adopted in this book, which attempts to share the many stories that make up the environments where tropical glaciers exist. While the scientific literature on glaciers was long dominated by geosciences and physical geography, since the 2010s there has been an upward trend in environmental sciences (which we can consider interdisciplinary), a field which now represents a considerable portion of the studies on glaciers (Figure 1). A similar trend can be seen in mountain studies in general. The Cartesian divide between nature and culture that has dominated Western knowledge production since the 19th century has meant that only recently have the social sciences been employed to study the topic of glaciers. Between 1975 and 2023, geography was the social science most used to study glaciers, but still the 15th discipline by number of publications. In contrast, anthropology, simply defined as the study of humans, comes in 42nd. This disciplinary imbalance is also reflected in many scientific publications that demand a stronger presence of social sciences in the study of glaciers and climate change. While there is no question that disciplinary science is fundamental to gaining in-depth knowledge of our world, we argue that inter- and transdisciplinarity (the creation of knowledge by academics and non-academics) is vital to form an accurate picture of a complex reality.

The biophysical basis

But first we should start with a biophysical description of what glaciers are, and what changes they are undergoing due to climate change. Most glaciers are remnants of large ice masses that formed during the last glacial period, which ended 12,000 years ago. Over the last 150 years, climate change (or "climate disruption" or "climate emergency" to better reflect the impacts it is having on societies and our planet) has accelerated their melting. Today, tropical glaciers are broadly acknowledged as frontline sentinels of climate change due to their sensitivity to warming temperatures. When we started writing this book in 2023, tropical glaciers could still be found in 12 countries: Peru, Plurinational State of Bolivia, Ecuador, Colombia, Chile, Bolivarian Republic of Venezuela, Mexico, United Republic of Tanzania, Uganda, Democratic Republic of the Congo, Kenya and Indonesia (Figure 2). However, today La Corona glacier on Humboldt Peak in Venezuela has retreated to the point that it covers less than two hectares and has lost its status as a glacier. It has now been downgraded to an "ice body" that will soon vanish. It is very probable that by the time you read this book, the last remaining glaciers

Figure 1. Number of publications per discipline containing the term "glacier" in the topic (title, abstract or keywords) between 1975 and 2023. The graph shows the 15 most frequent disciplines.
Source : ISI Web of Science database.

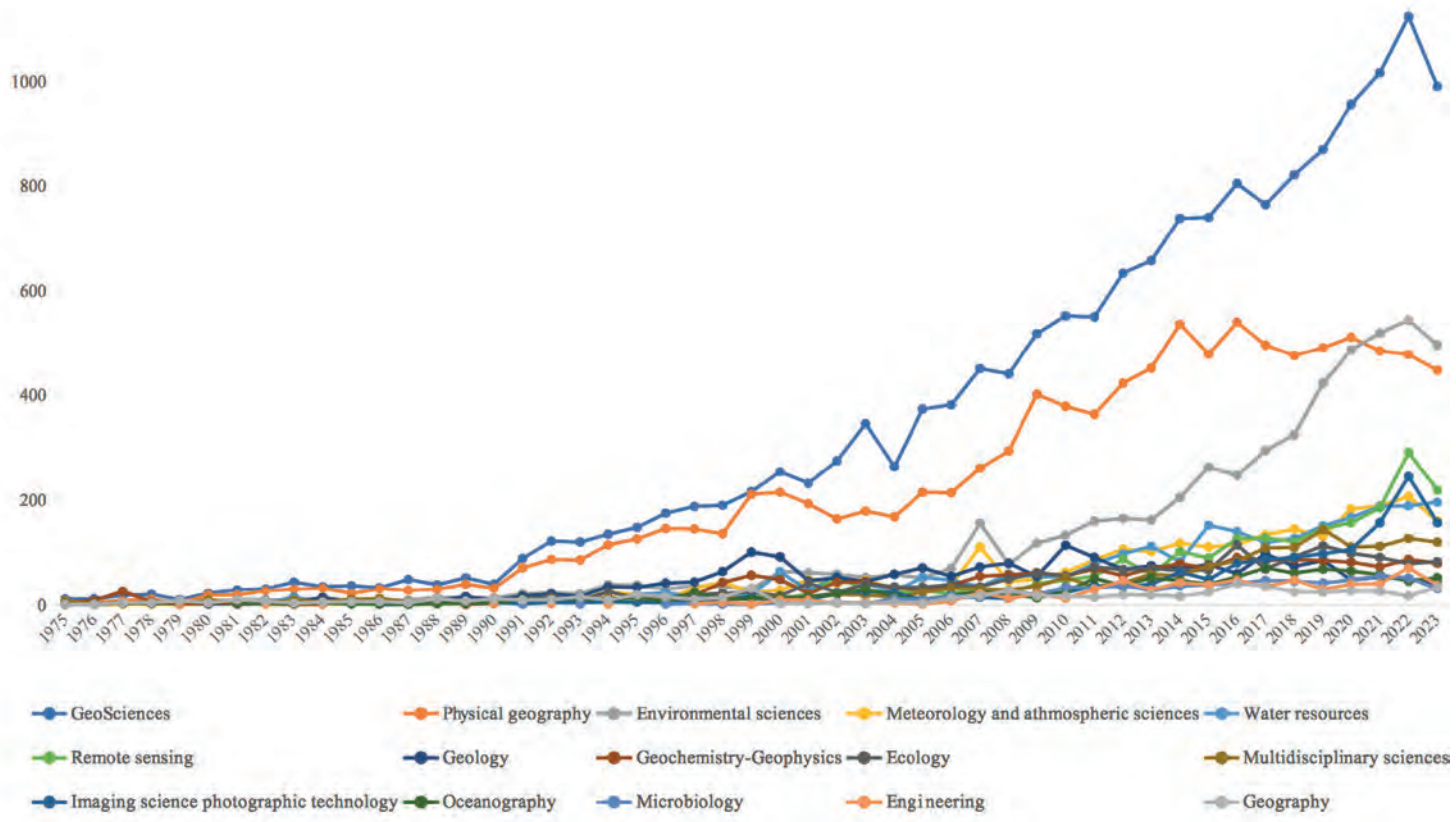


Figure 2. The location and relative surface area of tropical glaciers situated between the Tropic of Cancer and the Tropic of Capricorn (at latitudes less than 23°26' north and south of the equator). The size of the red circles is proportional to the percentage of glacier surface area for Peru (71%), Bolivia (20%), Ecuador (4%), Colombia (4%) and Mexico + Venezuela (until 2024 when La Corona, the last glacier in Venezuela, was declared extinct) + Chile + Democratic Republic of the Congo + Uganda + Kenya + Tanzania + Indonesia (1%). The map is based on the Gall-Peters projection as this more accurately represents size than the Mercator projection (which represents South America as half of its actual size, and Greenland and Africa as equivalent, whereas the latter is 14 times the size of Greenland).

on Puncak Jaya in Papua New Guinea will have vanished as well. While Venezuela is the first country to lose all its glaciers in modern times, other countries in South America are home to around 99% of tropical glaciers (in surface area), mostly Peru (71%) (Figure 2). Aside from these 12 countries, a few rock glaciers can still be found above the Tropic of Capricorn in Argentina.

Glaciers form where more snow falls than melts. They have an accumulation area, located at higher altitude, and an ablation area, where the ice melts, reducing the surface area and volume of the glacier. Glaciers also flow – slowly – downslope. Gravity does the work of moving the glacier downwards on the path of least resistance. As they move, glaciers erode the ground underneath them, shaping the landscape, cutting out valleys, creating bowl-shaped cirques, horns and ridges while leaving moraines along their edges.

But the volume and action of a glacier are reduced when the temperature rises. This is the situation we are facing with climate change. A standard indicator

Figure 3. Reconstruction of the last Glacial Maximum, roughly 21,500 years ago which was on average 6°C colder than the 20th century. © OP Mapporn.

of climate change is the concentration of CO_2 (which humans have increased by emissions from burning fossil fuels) in the atmosphere. This reached 425 parts per million (ppm) in July 2024, up from 318 ppm since measurement started in Mauna Loa, Hawaii, in 1958. Other greenhouse gases include methane, nitrous oxide and hydrochlorofluorocarbons – they all raise the temperature of the atmosphere. As a result, the average global surface temperature between 2011 and 2020 was 1.1°C higher than between 1850 and 1900 (IPCC, 2023). This may not seem like a great deal, but keep in mind that the last glaciation – the Würm glacial period (from 115,000 to 11,700 years ago) – was only about 6°C colder than the 20th century (Figure 3 shows an image of the Earth in that period). This 6°C difference alone was capable of creating immense ice caps that at their maximum extent covered a large proportion of North America and Europe, reaching, for example, the current location of Berlin. As a consequence, sea level was around 125 m lower, connecting the Islands of the North Atlantic to Europe, and allowing Neanderthals to reach what is now Britain. For another idea about what a difference even 1.1°C can make, just think of what happens to your body when it increases from 37° to 38.1°C. In contrast, the planet's average temperature is 15°C, so an increase of 1.1°C actually corresponds to a 7.33% increase. Such an increase would bring your body temperature to 39.7°C.

The Paris Agreement adopted in 2015 a target of containing warming "well below a 2°C increase", ideally at 1.5°C. Again, this might sound like a safe limit. Yet research in the last decades, particularly in

fragile ecosystems such as mountains, has shown that it is not. In fact, knowing how even subtle temperature changes affect the ecosystems of our planet, like our bodies when we have a fever, suggests this rise may be catastrophic. For tropical glaciers, this is certain. At a global scale, more than 100,000 of the world's glaciers are destined to vanish in the 21st century. This represents between 26–41% of glacier mass, depending on the climate change scenario. For tropical glaciers, the outlook is even grimmer: most will completely vanish in our century. Some of the first tropical glaciers to completely disappear will be those on Puncak Jaya in Papua New Guinea, which will most likely be gone by 2030. In Africa, glaciers on the World Heritage sites and Biosphere Reserve of Mount Kenya (Kenya) and Mount Kilimanjaro (Tanzania), and the World heritage site of the Rwenzori Mountains (Uganda) are expected to disappear by the mid-21st century. In the Andes, glaciers below 5,500 m (today they can be found at 4,850 m) will also very likely vanish within a few decades, and only those above that altitude will remain, at least for a time.

Many of the tropical glaciers we discuss in this book will likely have vanished by 2050. To understand this loss, we can compare it to the ice extent during the Little Ice Age (16th–19th centuries). From their maximum surface area in the Little Ice Age, we estimate that in the 2000s, glaciers in the tropics had shrunk to 44% of that extent in the tropical Andes, 22% in Africa, and 11% in Indonesia. This indicates that the lower boundary of tropical glaciers is now about 400 m higher in elevation. In the relatively recent past, tropical glaciers occupied larger extents, provided more water in the dry season, and had a greater visual presence in the landscape. At the current rate of change, simulations show that by 2050 glaciers will have almost completely disappeared in Southeast Asia and Africa, and that in the Andes only about 15–20% of the area covered by glaciers in the Little Ice Age are likely to remain.

The human dimensions of deglaciation

This threat has sparked alarm in people around the world, scientists and non-scientists alike. This book is a sort of last call from tropical glaciers before they disappear until the next cool period, documenting the diverse stories of those witnessing their demise. Each voice bears a unique understanding of glaciers and what their loss means. Not all communities are affected equally, and not all pay tribute in the same way. The diverse connections to tropical glaciers engender a range of different emotions and practices. Each individual interviewed experiences the loss differently, in a way that may evolve over time. Importantly, many are turning this loss into a practice of care that goes beyond glaciers and extends to the loving protection of our environment. As the social psychologist and humanist philosopher Erich Fromm (1900-1980) put it, "*Love isn't something natural. Rather it requires discipline, concentration, patience, faith, and the overcoming of narcissism. It isn't a feeling, it is a practice.*" This practice can be seen in the dedication and commitment to tropical glaciers and to the environment of many in this book.

In the West, the relationship with glaciers has changed over time. First, glaciers were seen as places of danger, then were later portrayed in the Romantic era as features that should be visited and scientifically studied. Horace-Bénédict de Saussure (1740–1799) was one of the first in this movement, which would lead to the emergence of glaciology as a scientific discipline. In our times, the Canadian anthropologist Julie Cruikshank was one of the first academics to bridge the world of glaciers and the social sciences, in work showing how glaciers actively participate in the production of

history. In her research of 19th–20th-century encounters between scientific explorers from nascent nations and Indigenous Peoples of North America, Cruikshank shows how some landscapes were (and still are) disputed, how different relationships with glaciers impact the knowledge produced about them, and whose knowledge about glaciers counts as truth. Other scholars such as Klaus Dodds have discussed how Europeans during the Little Ice Age attributed personality traits to glaciers as they advanced on their villages and wreaked havoc. The 2003 Convention for the Safeguarding of the Intangible Cultural Heritage recognizes and promotes the living heritage practices, knowledge, skills and expressions that communities have developed and passed on from generation to generation in response to their environment, including their interactions with glaciers. Such living heritage embodies human experience accumulated over centuries, while at the same time being dynamic and responsive to the contexts and needs of each generation, reinforcing a sense of identity, well-being and resilience. This book also chooses to focus on different voices and their relationships with tropical glaciers. What are glaciers to local communities, to tourists, to guardians of glaciers, to victims of risks, to scientists, to alpinists, to artists?

Of course, it is a universal constant that when something disappears, something new arrives. On 19 September 1991, two tourists hiking in the Tyrolean Alps between Italy and Austria found the body of Ötzi, "the Iceman". The retreating ice had conserved his body so well that this oldest European mummy became one of the most studied human bodies in the world. Less known is the mummy of Juanita, an Inca frozen in time found in the crater of the Ampato volcano in Arequipa, Peru, in 1995. This discovery has increased our knowledge about the Incan culture and their practices near glaciers. Glaciers liberate ground that is then colonised by new ecosystems of emerging lichens, plants and other forms of life. Some local communities are start ing to find ways to use these new ecosystems to prosper in harsh high-altitude environments.

From awareness to action

The UN International Year of Glaciers' Preservation in 2025 and the UN International Decade of Action for Cryospheric Sciences (2025–2034) provide the opportunity to engage with the public: whether in the tropics, where half of the world's population is expected to live by 2050, or elsewhere, a frequent visitor of glaciers or simply fascinated by these iconic features of our Earth. It is also recognition that glaciers are sentinels of climate change: that they are "*a critical component of the hydrological cycle and that the current accelerated melting and retreat of glaciers have severe impacts on the climate, the environment, the maintenance of human well-being and health and sustainable development*". It is clear that glaciers provide vital ecosystem functions and services, but they also hold immeasurable social value and cultural meaning, which are equally being affected by climate change. As a result, impacts on water provision, water quality or landscape aesthetics co-exist with the loss of access to ancestors, to familiar sites and to the materials required to reproduce intangible cultural heritage, which can have profound impacts on the identity, spirituality and wellbeing of communities.

Current cognitive research indicates that facts do not usually change minds. It is also necessary to engage our social minds – values, emotions and experience – to change the way we think. As the social psychologist Jonathan Haidt has eloquently put it, human decision-making can be likened to an elephant with a rider on top of it. While the rider is rational and thinks he

or she governs the elephant, in fact, emotions and instincts are also driving forces. This understanding guided our choice in this book to include personal histories of those involved with tropical glaciers, as well as photographs, to allow a fuller perception of the multidimensional impacts of glacier loss. Coupling science and art is a way of reaching both hearts and minds. Through science, personal stories and photographs we hope to give readers a better understanding of what glacier loss means, and what will happen to glaciers in the tropics and beyond – and all that depends on them – if we do not take action.

Some colleagues have asked us how we could bring these stories and their bearers to the table of negotiations at international climate fora, such as Conferences of the Parties (COPs) to the United Nations Framework Convention on Climate Change (UNFCCC)? Or how could these stories inform the preparation of National Adaptation Plans in concerned countries? In a summary, how could the emotions channelled through these stories actually make a difference in pushing for action? As human beings, we are seduced by stories, and our capacity to learn and integrate things is largely increased though stories, parables or tales, as many publications, from books for children to religious books illustrate. Creating spaces for dialogue between protagonists of this book and decision-makers in the COP and similar meetings could increase the understanding of tropical glacier loss and the need to take action.

What should our response be as we face the imminent loss of tropical glaciers? And what will emerge after they are gone? Pablo Neruda once said, "*love is so short and forgetting is so long*". A farewell should not mean forgetting. This book aims to pay tribute to the astonishing oxymoron of tropical glaciers: we hope these voices will be joined by others – maybe even yours.

WHO ARE THESE VOICES?

Future generations

by Jorge Luis Ceballos

In a talk I gave in the city of Bogotá in 2021, I explained to a group of university students how glaciers are studied and what their future is. I took the opportunity to highlight the critical condition of the glacier of the Santa Isabel volcano, located in the high mountains of the coffee region of the central Andes of Colombia, and its imminent extinction – perhaps within the next ten years. In the middle of my presentation, a student raised his hand to ask what we would do when the small Colombian glaciers vanish: a question that no doubt every glacier scholar is currently asking themselves. My answer was short: "*When this happens, I will become a storyteller.*" This phrase still haunts me, and motivates things that I want to raise with the generations witnessing the changes in high mountain landscapes.

Throughout history, climatic changes have caused the retreat or advance of ice, and with it the advance or retreat of people occupying the land. This has generated fantastic legends about beings hidden in the recesses of snow-capped mountains, evocations of danger or the occurrence of extreme events. Linked to the human fascination to reach the highest summits, a spell is cast by the dazzling white landscapes of glacial ice that results in unique connections within different cultures. The record of glaciers in watercolours, drawings, oil paintings, photographs, aerial photographs, satellite images, maps and books show their high value and are also testament to their continual evolution. These changes, shown through art, are backed by science. The history of the climate is recorded in ice, and moraines clearly show the path it has taken. Today, the evidence is overwhelming: since the 1980s, glaciers around the world have been melting at an unparalleled rate: processes associated with climate change that is becoming increasingly accentuated.

This complex and amplifying dynamic coincides with a generation of young "digital natives" who recognise the global challenges created by these environmental conditions. These are not the previous generations who grew up listening to legends of European explorers who conquered the peaks of the Andes or the Colombian mountaineers tracing their footsteps who reached the summit of Everest in 2001. This is a new generation of Colombians who are witnessing in real time – and rapidly – the dramatic reduction of equatorial glaciers.

This has given rise to diverging perspectives: some young mountaineers and mountain guides feel that tropical glaciers are no longer impressive enough for sporting conquests; others see an opportunity to transform high mountain tourism from a purely physically demanding experience to a scientific, thought-provoking, transformative experience. Needless to say, as voiced by veteran Colombian mountaineer Sergio Gaviria, "*This generation of mountaineers without glaciers will simply be a generation of excellent rock climbers.*"

In parallel, this generation's ecologists and biologists are finding new research topics that will help to understand how new ecosystems emerge and occupy spaces ceded by glaciers and the dynamics associated with rapid climate change. Yet it mustn't be forgotten that in places where glaciers and communities converge, snow

and ice are an integral part of life. For many Indigenous Peoples in the Andes, ice has a sacred character and must not be disturbed. A glacier is an element of identity and the centre of their spirituality; degrading the glacier disrupts the structure and social relations that allow the harmonious functioning of the system. Glaciers have not only an environmental context, but a cultural and historical context.

After years of listening to and answering questions about the demise of equatorial glaciers in Colombia, the conclusion I draw is that there is generally sadness and pessimism in the face of glacial melting. This indicates a recognition that mountain ice is the most sensitive and vulnerable part of nature in changing atmospheric conditions, and that its loss as an element of the landscape generates great uncertainty framed in a single certainty: their children's children will not see snow-capped mountains in their own country.

The voices of this future generation interviewed in this book are Súper Josue, Isabel Moreno, Lucía Merchant and Mariana Cárdenas.

Indigenous Peoples

by Sofía Lana

In her seminal work with the Athapaskan and Tlingit Indigenous Peoples in the St Elias Mountains in Canada, Julie Cruikshank asks: "*Are glaciers good to think with?*" In a context of growing calls from policymakers and the scientific community to produce knowledge from those inhabiting the landscapes most vulnerable to the impacts of climate change, Cruikshank reflects on the potentially faulty translations of "traditional ecological knowledge" (that is, Indigenous knowledge of environments from centuries of land-based livelihoods) into climate adaptation strategies by international organisations. She suggests that when Western scientists and policymakers try to translate Indigenous oral histories and knowledge into adaptation frameworks, this can miss what is most important to these communities in sustaining relationships with the non-human entities with which they cohabit.

Despite progress over time, Indigenous Peoples' needs and interests continue to be largely represented by the non-Indigenous actors, and their participation in international forums and panels such as the Intergovernmental Panel on Climate Change (IPCC) remains limited. As such, climate change adaptation frameworks overlook important historical processes (for example, colonisation and other ongoing forms of violence, dispossession and expropriation of land, resources and livelihoods) and structural factors (socio-economic and political) that impact land use and access and the distribution of resources such as water. Cruikshank asks:

Do glacier stories have contemporary relevance, given uncertainties about impending climate change and contentious debates about local knowledge and science? Which stories take root and which ones sink from view? And what are the consequences for Indigenous peoples and for knowledge more generally when stories deemed to have no impact in dominant regimes of knowledge are not taken seriously?

Our approach in this book takes up Cruikshank's reflections, presenting Indigenous People's testimonies of living with melting glaciers, collected through in-depth semi-structured interviews and oral histories. Rather than seeking to generate information on

"*vulnerable, bounded cultures*", or providing suggestions on how to "*complement*" traditional ecological knowledge with science as people adapt to changing living conditions, the intention is to share people's lived experiences with melting glaciers in a globalised, complex and often violent world. It seeks to suggest that Indigenous worlds and world-making practices can be taken seriously without needing to fully understand them or appropriating them as climate change solutions. Western thought, and science in particular, has long been governed by the Cartesian nature–culture divide, in which nature is viewed as a shared canvas upon which multiple cultures exist, perceive and interpret the world. Yet scholars in recent decades have sought to undo this divide, questioning a model that continues to place those we call "Indigenous Peoples" as a homogenous category of humans who represent the past, and as such, are non-modern, isolated or closer to nature. As the Potawatomi scholar Kyle Whyte defines it, "'*Indigenous Peoples' refers to the roughly 400 million persons worldwide who, prior to a period of invasion, colonisation or settlement, exercised collective self-determination according to their own cultural (cosmological) and political systems*." These many millions are not only diverse and complex, but active participants in history-making of a world that extends well beyond the reaches of their communities. This is borne out through the testimonies in this section.

The voices of the Indigenous People interviewed are: Ati Villafaña from the Arhuaco community in the Sierra Nevada of Santa Marta, Colombia; Walyuba Kube from the Bakonzo people in the Rwenzori Mountains in Uganda; John Supuk from the Masai community in Kenya; Sonia Altamirano, an Aymara from the highlands of La Paz, Bolivia; Cecilia Llusco, an Aymara from the community of Chukura, La Paz, Bolivia; and Baltazar Ushca of the Cuatro Esquinas community from Ecuador.

Tourists

by Sofía Lana

Glaciers on mountain peaks have always captivated people, albeit for different reasons. Some have seen them as the last wild frontier to conquer, or as treacherous, inhuman places that threatened expansion; others have observed them from afar with veneration and respect. In *Life and Death on Everest*, the anthropologist Sherry Ortner shows how the origins of the sport of mountaineering were intimately tied to military and scientific expeditions throughout the colonial and post-colonial periods. The sublime spiritual or quasi-religious experiences that many European explorers described in their travelogues as they trudged up high peaks often excluded mentioning those who made these expeditions possible: Indigenous guides who not only led the way but also carried their packs. While climbing and mountaineering became part of a countercultural movement in the 1960s, their roots lie in masculinised (often sexist) and racialised relations towards the landscapes and their inhabitants.

Today, not much has changed regarding who summits peaks as a tourist, as a guide, and as a porter. Added to the aesthetic allure of glaciers, there is now a sense of urgency to see glaciers before they melt. The past few years have seen a rise in tourists of this type, leading some scholars to question whether this is akin to "dark tourism" (e.g. visiting Chernobyl) or "doom tourism". This desire to see the last remnants of glaciers can make them relics of climate change before they are even gone. Increased tourism can also lead to an increased impact

on glaciers, and even an increase in deaths, due to lack of expertise and a tendency to underestimate the risks of high altitude and extreme cold. Recent mountaineering seasons on some of Latin America's highest peaks have seen a rise in deaths alongside concerns over the impact of climate change on the stability and predictability of high mountain terrains. While uncertain and sometimes extreme climatic conditions pose challenges to even the most seasoned of mountaineers, many in the industry want to see the rise of amateur tourists in the high mountains experienced during the COVID-19 pandemic to continue.

So, what comes after glaciers? This question is of great concern to many local guides who fear that foreign tourists will not come to see rocks: will they come when there is no snow? The accounts of mountaineers and guides in this book show a belief that visitors will still come to the mountains, with or without glaciers. It may be that we are gripped by nostalgia for something that is changing almost faster than we can witness it. But we can learn from those who see beauty beyond what meets the eye – the stories rocks have to tell us or the imagined futures that might unfold.

The voice of glacier tourists in this book is the alpinist and writer Mark Horrell, who has travelled to several glaciers in the tropics.

Guardians of glaciers

by Sophie Cauvy-Fraunié and Ignacio Palomo

Is anyone reacting to the dramatic loss of tropical glaciers? If so, what type of actions are being taken to protect them as they shrink in volume and extent? Can there be hope for tropical glaciers considering the current trajectory of greenhouse gas emissions? Briefly put, can there be hope for the hopeless?

Indeed, things are being done, sometimes by individuals, sometimes by institutions, and sometimes even by nations. The most well-known of these actions is to protect glaciers from the relentless rays of the sun. In several parts of the world, glaciers have been covered with blankets, plastic or radiative cooling film, which could potentially reduce snow/ice melt up to 69%. Yet questions have been asked about the extent to which these solutions could be applied through time and space or the impacts they may have. These artificial covers are typically made of synthetic materials, which require considerable energy costs to produce, transport and install, and will inevitably have a limited lifespan in the extreme climatic conditions near glaciers, leading to an additional local source of supraglacial waste. It is crucial to understand case by case what these approaches intend to protect (from water flow to wanting to safeguard the identity of a mountain) and what their costs are.

Another idea was put forward in a project by Peruvian inventor Eduardo Gold that was awarded by the World Bank competition "100 ideas to save the planet" in 2009. He painted a few hectares of rock white in the area of the Chalon Sombrero in Peru, where a glacier had disappeared a few decades ago. The idea was to reflect sunlight, reducing the surface temperature and reproducing the conditions to allow a glacier to form again. While it received press coverage at the time, not much has been heard about this project since then, so we can probably assume its effectiveness in bringing glaciers back is limited. Additionally, even with the

use of "environmentally safe" paint, spreading lime on mountain ecosystems could have negative consequences, potentially reducing photosynthetic capacity or drowning and suffocating invertebrates.

In contrast to these technological solutions, the creation of protected areas such as national parks is considered one of the best strategies to conserve ecosystems. Today, 47% of total glacial areas are located in protected areas, including around 10% within over 100 UNESCO-designated sites (World Heritage sites, Biosphere Reserves, and Global Geoparks)and 17% within the area covered by the 1959 Antarctic Treaty. Protected areas alone cannot shield tropical glaciers from climate change, as its impacts transcend borders and rising temperatures cannot be halted by lines drawn on a map. However, protected areas can play a role by reducing other harmful, often local, pressures on glaciers such as mining, tourism or ski area development.

Other types of legislation can also be put in place. In India, legal personhood has been granted to two glaciers: Gangotri and Yamunotri. In Argentina, a National Glacier Act was passed in 2010. Such legal actions, also developed elsewhere in the world for other types of ecosystems, can help to raise awareness of glaciers and their existence. In her environnmental philosophy doctoral work on "Otherness" in nature, Clara Poirier invites us to meet other beings: to allow "*paths to open up to 'other than human' existences*". She looks for "*ways to open face-to-face [contact] between human and other-than-human beings, and for ways to awaken and cultivate consciousness of otherness in nature*". Her thought encourages the recognition and respect of natural beings, concepts that may have a significant impact on protecting nature in the long term.

Ultimately, most glacier protection actions have a limited, short-term impact, although they are transformative in the sense that they promote certain uses of ice and privilege certain entities that are granted authority over ice. They tend to shift governance and environmental politics while prioritising techno-scientific interventions and overlooking the value of non-human nature.

Yet at the individual level, guardians of glaciers have dedicated their energy to protecting glaciers in very diverse ways. Their voices are heard in interviews with Colombian nature advocate Marcela Fernández; Peruvian mountain guide and environmental litigant Saúl Luciano Lliuya; director of Peru's Huascarán National Park Martínez Finquín; and French scientist and alpinist Bernard Francou. All have inspiring stories that deserve to be heard.

Victims

by Bryan Mark
and Benjamin Morales Arnao

Glaciers in tropical mountains are beautiful sources of water, biodiversity and life, but they are also terrifying terrains of destruction and death. Their elevation and relief – or "verticality" – allow diverse ecological zones and the accumulation of potential energy that can provide many benefits to people living in the mountains. But mountains are only able to attain their heights through geologic forces that rip open and upthrust the lithosphere or erupt with fury; the life-giving energy they hold can also be deadly and capricious. Tropical glaciers epitomise this dichotomy. Often located in close proximity to human settlements, they have value

as a water supply, while simultaneously being central agents in deadly geohazards. These stem from the physical dynamics in these environments, resulting from the action of gravity on ice, rock and water perched on steep slopes, and include glacier lake outburst floods, avalanches and debris flows – all of which can have devastating impacts on human society. The possibility of being killed by geohazards related to glaciers is an ever-present reality in these settings. The victims are not only those who perish, but those traumatised by the loss of lives or livelihoods, homes or family, affecting whole cities and what they offer their inhabitants: markets, education, sport, culture. Given complex and uneven social dynamics and settlement patterns, exposure to risk is not equal; post-disaster housing and income levels are closely related.

Some victims suffer and die, other victims survive. In recounting the tales of disasters, there is an important reminder about human resilience in the face of destruction. One country, Peru, suffers the hazards of tropical glaciers like no other. And one tragedy in Peru was singular in its devastation: the 1970 earthquake that caused rockfall and debris to cascade from the northern summit of Huascarán, burying the city of Yungay. While this was technically not a glacier-related event, as it was caused by seismic activity and a massive rockfall, its magnitude, combined with the widespread casualties throughout the region from the earthquake, underscores the precarity of life below steep mountains capped by glaciers. It also reveals the combination of social factors that relate to disaster risk. To stay and rebuild, to devote a life to studying glaciers and protecting communities from their dangers takes a rare form of resiliency.

Why are people exposed to such risks? What are the impacts on victims? What are the prognoses for recovery? Answering these questions is not easy and requires critical scholarship in human ecology. Indeed, the various scales and interacting social and physical dynamics at play in evaluating risks in mountain environments undergoing rapid climatic change requires taking a socio-cryospheric systems approach.

There is no doubt of the impacts of such destruction on communities. The loss of stability is deeply scarring and can lead to life-long mental health impacts. Reconstruction of buildings and rebuilding livelihoods after such events can be long and difficult, influenced by overlapping social, political and economic factors. Aside from social factors, studies have documented how vulnerability to natural disasters in tropical glacier settings increases with communication problems and lack of trust between scientists, local residents and policymakers. Some do not accept being victims and have instead chosen to demand damage for losses. They seek to redress the injustice that the drivers of climate change are responsible for and the perils of glacier-lake hazards.

While tropical glaciers pose very real risks to human society, the inverse must also be considered: glaciers are also victims. With human-caused climate change transforming the natural world, glaciers are disappearing. The spaces they once occupied are now hauntingly empty, their loss in the landscape a source of grief. In their place, a “dark tourism” has arisen to mourn the erstwhile existence of moribund glaciers, victims of climate change. Historically, humans have long found mountains and glaciers places to encounter the divine – these glaciers, once revered and worshipped, are now disappearing. This may offer an opportunity to reflect on humans and nature, to reframe the perspective, since humans are not only passive victims suffering from accelerating and destabilising environmental changes, we are also implicated. We are forced to reckon with our agency in changing nature. We are causing glaciers

to disappear. The anthropologist Karsten Paerregaard, interviewing Andean pilgrims worshipping summit divinities, frames both the humans and the glaciers as victims. The glaciers are "crying", and this has consequences on communities:

In their natural state, glaciers produce a constant flow of meltwater that supplies almost one-quarter of the world's population with fresh water. But as they recede, the glaciers' tears turn into flooding and natural disasters, reminding people that the socio-natural order to which they trust their lives is breaking up. Mountain pilgrims are among the first to observe this drama, and their encounter with the retreating glaciers' bedrock exemplifies how humans become aware of climate change and its consequences for the world they live in and take for granted.

While some organisms will thrive under new climatic conditions, for example, the yareta plant (*Azorella compacta*) that grows in the Andean highlands, most of the voices in this book are victims of tropical glacier loss to some extent. One interviewed is Benjamín Morales Arnao, a living example of resilience following a tragic event that left thousands of victims.

Scientists

by Carolina Adler and Ignacio Palomo

Over the millennia, Indigenous Peoples and local communities have developed and accumulated knowledge, providing us with fundamental lessons, observations and information to understand our surroundings. This knowledge also relates to changes in the climate and the environment and has helped to shape the norms and cultural practices that today reflect how we live and relate within social communities.

Modern science took some time to become interested in tropical glaciers. Fortunately, scientific practice means that as new theories and empirical evidence come to the fore, science can correct itself, and what was believed to be false at a certain time – such as the existence of glaciers in the tropics – can later be proved to be true. Science-based knowledge has been a major driver of and contributor to human progress and our understanding of the planet. The scientific method, based on developing a testable hypothesis that can be proven or refuted, allows knowledge to build upon previously developed knowledge: as Isaac Newton put it in 1675 in a letter to Robert Hooke: "*If I have seen further it is by standing on the shoulders of Giants*."

Glaciology, hydrology, climatology, ecology, anthropology and environmental science are some of the many scientific disciplines that have engaged with the study of tropical glaciers directly or indirectly. These individual disciplines have given us many insights. But understanding glacial retreat, its impacts on nature and people, and how to adapt to it, requires taking a systems-oriented, interdisciplinary approach. This is a challenging but important endeavour to pursue and support. Interdisciplinarity requires scientists from different fields to interrelate, to understand each other's language and codes, and to be able to challenge previously held assumptions stemming from individual disciplines.

Science and policy, and their interactions, have become increasingly relevant as a way to not only inform but also engage with decision-making processes in the context of climate change. For example, the IPCC brings together and assesses the state of knowledge on the biophysical processes that lead to a changing climate,

their impacts on ecosystems and society, and ways to address these impacts. Since its creation, the IPCC has evolved from its purely biophysical science origins and currently has one working group on the physical science basis, one on impacts, adaptation and vulnerability, and one on mitigation. In its current (seventh) assessment cycle, the IPCC is placing particular emphasis on determining the scope and effectiveness of adaptation and mitigation in view of identified climate risks, including the conditions that enable decisive action. A key component of the evidence to be assessed includes Indigenous and local knowledge.

This long-standing science–policy interaction has led many scientists to realise that broad political interests are often not aligned with the scientific messaging that is based on planetary boundaries, and that global conservation objectives are often unmet. This misalignment has contributed to creating "ecological grief" and "eco-anxiety" among many – a feeling of uneasiness, frustration and alarm considering the threats to the environment and our future society and the limited concerted climate action that has been taken. This emotional response is a real issue, particularly among young people. One response is that scientists are increasingly trying to reduce the carbon footprint of their work, although we do not always succeed. Another equally important response is to challenge the dominant paradigm of scientific objectivity as devoid of values and recognise that science "requires emotions too" if we are to engage proactively and decisively to find solutions. Perseverance and a sense of purpose are key, fuelled by the convictions and emotions that motivate us to be part of the collective action that is desperately needed to at least preserve what we can for future generations.

What is the future of science on tropical glaciers once the ice is largely gone? As glaciers recede, scientists will need to adapt and formulate research questions fit for the new conditions and environments that emerge. These may relate to very different and new aspects, from the redrawing of national borders, to the uses and governance of novel ecosystems and resources that provide livelihoods for local communities, to understanding people's identity, sense-making and attachment to mountains without ice. This socio-ecological systems approach demands a broadening of scope and problem-orientation that goes beyond disciplinary and interdisciplinary research practices. In this respect, transdisciplinary research – i.e. research with and for society – plays and will continue to play a fundamental role in yielding the insights that make scientific and other ways of knowing both relatable and actionable.

The UN International Year of Glaciers' Preservation is an invitation to the scientific community not just to highlight the importance of both monitoring glacier change and the mitigation efforts needed to preserve as much ice as possible, but to go beyond this and continue moving towards inter- and transdisciplinarity. It has been recognised that we know many things about glacier loss and its impacts, but now need to accelerate adaptation and mitigation actions. In many parts of the world, particularly in the tropics, we are not prepared for the types and magnitude of risks that lie ahead. Scientists also need to adapt and step up to these new challenges and engage in processes where new research questions and hypotheses can be co-designed with societal actors and together contribute to a just transition and build resilience to these changes.

The voices of scientists interviewed in this book provide a deep dive into the lived experiences of science and scientists in practice. They include glaciologist Donaldi Permana from Indonesia; hydro-glaciologist Álvaro Soruco from Bolivia; earth scientists Isabel Moreno from

Bolivia, Benjamín Morales Arnao from Peru and Bernard Francou from France; archaeologist Constanza Ceruti from Argentina; anthropologist Mattias Borg Rasmussen from Denmark; environmental scientist Bob Nakileza from Uganda; and botanist Rosa Isela from Bolivia.

Mountain guides and alpinists

by Ignacio Palomo

In April 2014, an avalanche on Mount Everest's most commonly used climbing route tragically claimed the lives of 16 Nepalese guides. As a result, the world's highest mountain was closed to mountaineers for the remainder of the year, drawing attention to the growing risks posed by changing climatic conditions.

Since then, scientific evidence of the impact of climate change on mountaineering communities has only accumulated. There is growing evidence that permafrost degradation is increasing mountaineering risks due to a higher probability of rockfalls. Similarly, the stability of certain mountain shelters is affected by loose rocks, as is the case of the Arête des Cosmiques shelter in the Mont Blanc massif. Extreme weather events also make mountaineering a riskier undertaking, and attribution science has rapidly progressed in recent years to be able to link specific extreme events to climate change. For example, the storm that killed over 40 people on an Annapurna trek in 2014 has been associated to the higher frequency of storms in this area caused by climate change. The accessibility of summits and huts is also being affected by glacier retreat, as walking on loose or steep rocks is more challenging. Certain ice-climbing routes, such as the Diamond Couloir on Mount Kenya, are now often snowless, making climbing more difficult and exposed. The Konkordia hut in the Swiss Alps, which used to be located a few metres from the Aletsch glacier, a World Heritage Site, now requires the use of a stair to ascend a rock wall of more than 100 m.

One reason for society's limited concern with climate change is that many people do not perceive an immediate impact on their lives. Those who directly experience impacts seem to be more aware of and troubled by shifts. Studies have shown that exposure to floods and droughts in the UK has increased concern about climate change: in the words of one author, "*seeing is believing*".

Alpinists and mountain guides witnessing glacier retreat and increased rockfall are extremely aware of these events and have been adapting their mountaineering practice in response. Some are becoming climate advocates. At the 2009 UN Climate Change Conference (COP15) in Copenhagen, 27 Nepali mountaineers from the Everest Summiteers Association highlighted the environmental changes occurring in the Himalayas. In 2014, the 25zero Project was established to document and draw attention to the glaciers of 25 mountains near the equator, which are projected to diminish significantly within the next 25 years. Live footage from the peaks was beamed to the 2015 COP21 in Paris. Tim Jarvis, the environmental scientist who founded the project, said it "*focuses on tropical glaciers because they are the most susceptible to climate change, and referred to the difficulties these countries face for adaptation*". Other mountaineers are trying to make a difference individually: for example, by using more sustainable means to reach mountains, including public transport or by cycling, adding an extra challenge.

As hiking and mountaineering become increasingly popular, the inspiring stories of alpinists and mountain guides are enhancing our knowledge and helping to find innovative ways of mitigating climate change. The inspiring voices of mountain guides and alpinists from the tropics interviewed in this book include Saúl Luciano from Peru, Marco Cruz from Ecuador, Sonia Altamirano from Bolivia and Will Gadd from Canada.

Artists

by Olivier Dangles

Ice has long been a source of fascination for humans: the magic of water turning to ice, the lure of immense polar ice caps, the grandeur of snow-covered peaks, the vertigo inspired by crevasses: ice caps are the quintessential symbol of adventure. Since time immemorial, Indigenous art has also represented glaciers, which have deep spiritual and cultural significance for communities. For the Tlingit people of Alaska, glaciers are imbued with spiritual significance, depicted in carvings, totems and ceremonial objects. Their art portrays glaciers as linked to powerful ancestral spirits and as an integral part of the natural world, influencing weather patterns and ecosystems. In the Andes, the Quechua and Aymara view glaciers as sacred entities called *apus*, or mountain spirits. Their textiles, pottery and festivals frequently feature stylised representations of glaciers, showing their reverence for the role of glaciers in providing water and fertility to the land. Himalayan communities such as the Sherpa and Ladakhi create *thangka* paintings and ritual objects that depict glacial landscapes, incorporating intricate details and symbolic elements that reflect their belief in the interconnectedness of glaciers, deities and well-being.

Inspirational for their stunning beauty and profound symbolism, glaciers have served as powerful muses for artists of all kinds: painters, photographers, musicians, poets, cinematographers and more. The artistic representation of mountain glaciers has changed significantly over the centuries, reflecting both scientific and aesthetic developments. In the late 18th and early 19th centuries, glaciers began to fascinate European artists and explorers. Artists such as John Ruskin and William Turner documented glaciers in the Alps, blending meticulous observation with Romantic ideals to capture their sublime beauty and majestic power. These works portrayed glaciers as symbols of nature's grandeur and unpredictability. Later, with the expansion of scientific exploration, artists infused their work with scientific observations. Ruskin's detailed watercolours of Alpine glaciers not only captured their beauty, but served as important records for early glaciological studies. This period saw a blending of art and science, with artists such as Frederic Church participating in expeditions to document glacial landscapes. Later still, in the early 20th century, the Canadian landscape painter Lawren Harris of the Group of Seven made stylised depictions of glaciers in the Canadian Rockies using a minimalist approach, geometric forms and bold colours, reflecting modernist influences and mystical interpretations of nature in the north.

In recent decades, the artistic focus has shifted towards environmental awareness and the impact of climate change. There are examples of artistic interpretations of mountain glaciers in the face of global warming from artists around the world. Pioneering

American eco-artists Helen and Newton Harrison depicted the effects of climate change in the Tibetan Himalayas by annotating a large-scale map of the region with poetic text to spotlight an area containing 15,000 glaciers. The French artist Noémie Goudal installed a biodegradable photographic artwork on the Rhône glacier in the Swiss Alps to illustrate the change in the landscape and the fragility of glacial ecosystems. Peruvian artist Máximo Laura, known for his vibrant tapestries, incorporates themes of Andean cosmology and the impact of climate change on the mountains, reflecting a deep connection to the Pachamama ("Mother Earth") and a profound concern for its future. The Nigerian-British photographer Simon Norfolk has documented glacier retreat on Mount Kenya using lines of fire to mark historical extents. The fire symbolises the impact of burning fossil fuels on glacier melting. American photographer Spencer Tunick compared the fragility of human life without protection from clothing to that of the Earth without glaciers by creating a "living sculpture" of 600 naked volunteers lying on the Aletsch glacier in the Swiss Alps. The American composer, sound artist and eco-acoustician Matthew Burtner records natural sounds on Alaskan glaciers: snow, trickling streams and the cracks, pops and thundering as glaciers break apart and fall. The Nepali artist Jyoti Duwadi's *Red Earth, Vanishing Ice* is a site-specific installation featuring a melting block of ice surrounded by wooden containers, copper cauldrons and brass vessels with water from New York and Kathmandu. A painted canvas represents nature's regenerative powers to provide freshwater from glaciers.

From romanticised landscapes to scientifically detailed observations, from a sense of the sublime to urgent environmental commentary, the artistic representation of glaciers has continually adapted to reflect humanity's evolving relationship with these majestic ice forms. Through their artworks, artists capture the visual and emotional essence of glaciers, raising awareness – intentionally or not – about the fragility of these critical components of our planet's ecosystem. As glaciers retreat, their representation in art is an indication of their enduring impact on both our environment and our collective imagination. Art not only celebrates the beauty of glaciers, but can serve as a powerful medium for environmental advocacy and cultural expression.

The voice of artists interviewed in this book include Pamela EA from Colombia, Klaus Thymann from Denmark, and Ricky Chaggar from the UK.

New life

by Olivier Dangles

Many tropical glaciers have thawed into miniature versions of their former selves. Some are today so small that they cover an area of only a few ice hockey rinks. What new ecosystems emerge when the ice is gone? Using the analogy of hockey, four rules can summarise what drives the succession of life after ice.

Rule one: there are winners and losers. In professional hockey, a game cannot end in a tie. At the end of standard time, teams will go into overtime and, if necessary, a shootout. Someone has to lose. You might think that life will be a winner in a warmer world as retreating ice exposes more land: new available terrain to be colonised, a more stable substrate, higher temperatures. Indeed, research has shown that further from a

glacier, soils are enriched by a more diverse and abundant assemblage of microbes, plants, mosses, fungi, insects, spiders and worms. However, this overall increase in diversity is generally to the detriment of cold specialists that have adapted over evolutionary timescales to the harsh environmental conditions of glacier edges. These habitats host a myriad of cold-tolerant life forms, including bacteria, yeasts, algae, midges, ground beetles and tardigrades. The true breadth of diversity of glacier-adapted life is poorly known, but what is certain is that melting ice is not good news for these unique life forms.

Rule two: the smaller the better. This rule is based on simple physics. In hockey, shorter players have a lower centre of gravity that allows them to change direction at high speed without losing their balance. In many situations, smaller players are at an advantage during a hockey game. The situation is similar for the colonisation of glacier forelands. Most successful organisms in these environments are small. As low temperatures and rugged terrain make active dispersal such as walking or flying challenging, and upward slopes make dispersal by gravity impossible – plus, there are very few large animals to hitch a ride on (in fur, feathers or dried mud on an animal's body or feet) or inside (via its intestinal track) – most colonisers rely on wind to reach deglaciated ground. Dispersal acts like a colonisation filter, narrowing the winners down to a handful of small travellers. Of course, the colonisation of a new habitat is not simply a matter of getting there. Dispersal is just the first of two crucial steps: to establish a self-sustaining population, plants and animals need food, protection and, depending on their reproduction mode, a mate.

Rule three: play like a team. Hockey requires group dynamics and cooperation between players. Back-and-forth waves of defending and attacking players are like a murmuration of starlings shape-shifting collectively as they move across the sky. In the daunting conditions of glacier forelands, many coloniser species may need help getting established. The exposed, bare ground may overheat in the sun, the ground may freeze during clear nights, the substrate may be unstable, or food resources may be lacking. In the forelands of the rapidly melting glaciers of the tropical Andes, nurse plants such as the Azorella (which serve as protection for other organisms), lichens (which buffer temperature extremes of surface soil), and *vicuñas* (which defecate in communal, nutrient-rich dung piles), can help colonisers. Rocks, which provide refuge against wind and cold, or small depressions that accumulate water and nutrients can also serve as critical homes for newcomers. Many live tightly packed in a few safe sites scattered in an inhospitable matrix of sand and rocks.

Rule four: do not discount luck. When placing team sports on a continuum where the outcomes range from pure skill to pure luck, hockey is the sport closest to random, with luck contributing to season standings by more than half. Randomness (or stochasticity, in ecological parlance) is also a key factor at the glacier forefront. Although different organisms follow individual trajectories during the initial phase of colonisation after glacier retreat, their overall diversity is greatly influenced by stochastic drivers: the force and the direction of winds or the incidence of extreme glacial floods. Over the course of ecological succession, the importance of randomness is replaced by the skills of organisms to cope with local conditions over the long term. Thriving after glacier loss means successfully navigating along the luck–skill continuum.

New life is represented in the last "interview" in this book of a *yareta* cushion plant (*Azorella compacta*).

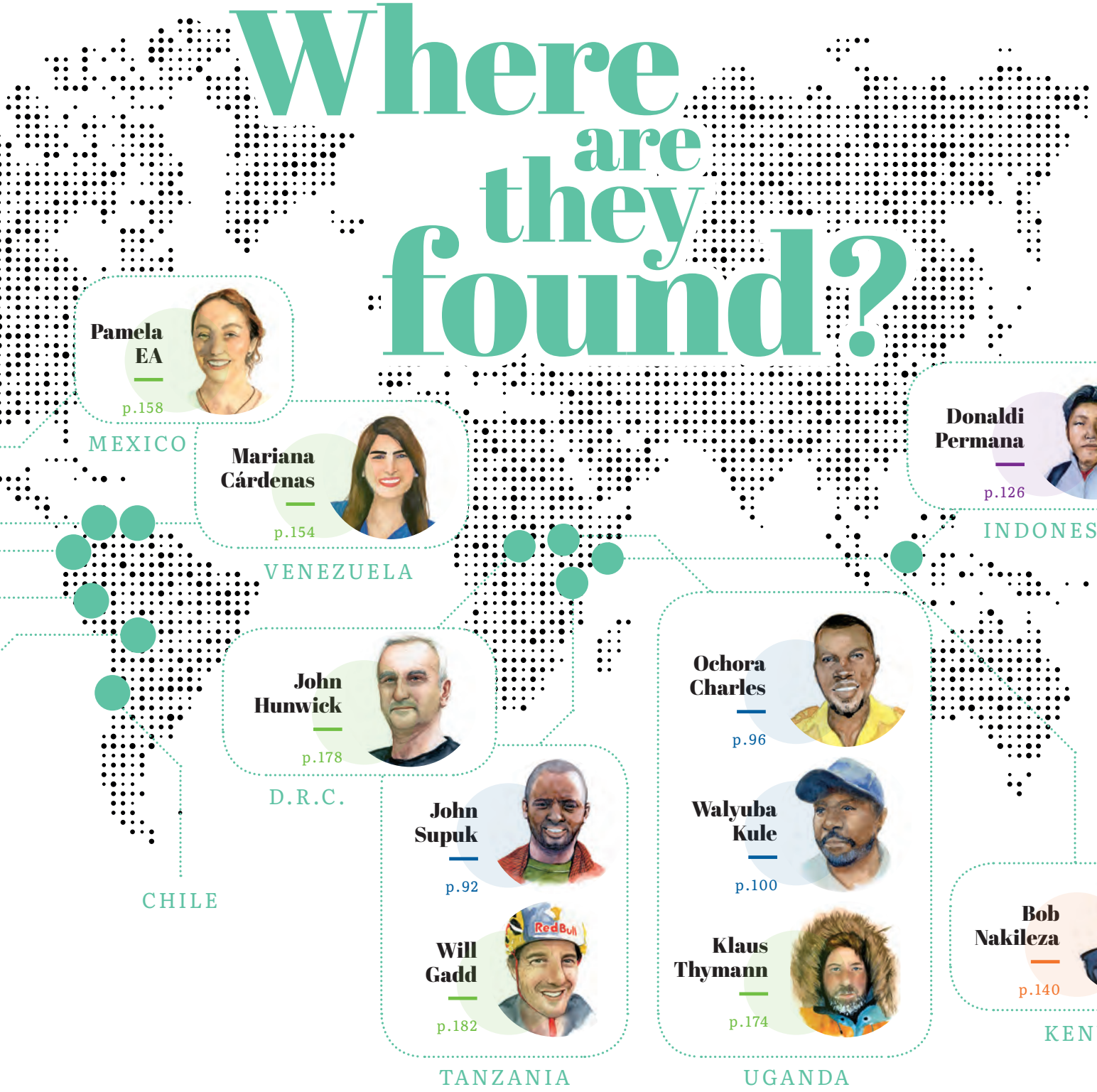
COLOMBIA

ECUADOR

PERU

BOLIVIA

Where are they found?



Pamela EA
p.158

MEXICO

Mariana Cárdenas
p.154

VENEZUELA

Donaldi Permana
p.126

INDONESIA

John Hunwick
p.178

D.R.C.

CHILE

John Supuk
p.92

Will Gadd
p.182

TANZANIA

Ochora Charles
p.96

Walyuba Kule
p.100

Klaus Thymann
p.174

UGANDA

Bob Nakileza
p.140

KENYA

The importance of emotion

Stepping away from a traditional scientific approach, the 35 testimonials in this book that arose from interviews are categorised according to different emotional responses to the melting of tropical glaciers. This choice was made in the recognition that emotions can be as vital as knowledge in relation to climate change. It should be noted that our analysis of these responses is influenced by our own subjective experiences and situated knowledge. Climate change research generally overlooks emotions as sites of knowledge production, focusing largely on graphs, charts and data. Yet many scholars have demonstrated the fundamental role that emotions play in shaping and driving climate change perception and action. Indeed, images of melting glaciers and stranded polar bears have been used since the early 2000s to elicit emotional responses from the public in relation to climate change. Yet while much research has been produced about perceptions of glacier melt (less so of experiences), little has been written about how people emotionally experience glacial loss.

As we are now well aware, climate change is much more than a physical phenomenon; its impacts are experienced in a range of ways all over the world, though unevenly distributed. Those we spoke to are very diverse – from different continents, different countries, and different places within those countries, rural or urban. Their emotions, lived experience and knowledge are intimately tied to their subjectivity and their living conditions, intersected by gender, race, ethnicity and class. Rather than categorise them along these divides, we decided to group them by the emotions they expressed, building on emotional

frameworks from recent scholarship. The intention is not to depoliticise emotions or to suggest that they are free from power imbalances – on the contrary. We believe it is necessary, along with other scholars, to question how climate knowledge generally comes to be produced and disseminated. It is important to consider how normative frameworks perpetuate a distinct way of producing knowledge (generally Western, scientific), foreclosing or obscuring other ways of knowing and experiencing climate change. We propose to think about each of the voices in this book as a different vantage point and emotional world from which to perceive melting tropical glaciers. All have lived experiences that shape their perceptions and knowledge, and we acknowledge the diversity of their worlds and world-making practices, while using emotion as a point of encounter.

These vignettes give insights into a wide range of people involved in one way or another with tropical glaciers: scientists, Indigenous Peoples from high mountain areas, local communities, tourists, mountaineers and guides, artists, and climate advocates. In their stories, we hear a spectrum of emotions, from worry to grief, resignation to hope, sometimes with one person expressing several simultaneous or successive emotions. All share a fierce commitment to the mountains they live alongside, visit, study or fight to protect. Commitment means something different for someone living in mountains with perhaps no option or desire to leave versus someone living in a city who visits mountains for whatever reason. Each has a distinct experience, shaped by historical and current circumstances, of what is now a rapidly transforming environment. Each reacts in different ways: here we share their voices.

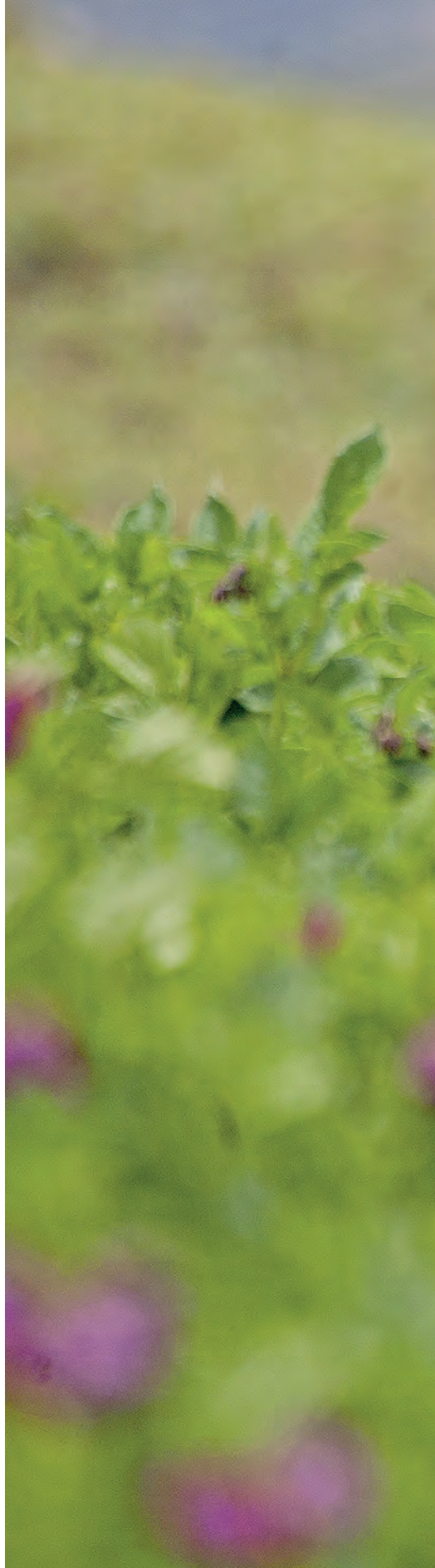
CARE

More than sadness, anger or frustration, care spurs people to action to protect others (human or non-human). People care for what they attribute value to, what matters to them, what they feel affection towards and/or are afraid of losing. How value is defined varies – it is subjective, situated and contextual. For some, feelings of care are intimately tied to one's existence, to the possibility of continuing to be a certain way with and within a particular socionatural environment. This section includes voices that express feelings of care that extend beyond glaciers. A care for mountain landscapes as they are and will be, including the new rocky landscapes that emerge out of melting ice. The care voiced is not born out of catastrophic events that threaten one's life or way of being, but from a unique and close relationship with a changing socio-environmental landscape of which they are a part.

Janina Castromonte Miranda

BRIDGING GLACIERS AND LOCAL COMMUNITIES

Janina Castromonte Miranda is a capacity-building specialist at the National Institute for Research on Glaciers and Mountain Ecosystems (INAIGEM) in Peru. She works with local communities in the highlands of Ancash, coordinating social projects with the aim of strengthening local capacity. Her approach takes into account gender, productivity and sustainable development within the Andean context.



A Quechua woman tending plants near Huancayo, Peru.
© IRD/O. Dangles


5

Janina Castromonte Miranda became fascinated by the way of life of local Indigenous communities at an early age on summer trips with her Quechua grandfather, who taught her values and lessons that have had a lasting impact. Her experiences with the Quechua in Peru's highlands motivated her to learn to speak the language and opened her eyes to their culture and local food, such as the *papa nativa* (an ancient variety of potato), "*grown organically, and so tasty*", as she puts it. Today, she works at the Peruvian National Research Institute for Glaciers and Mountain Ecosystems (INAIGEM), helping Quechua communities impacted by glacier retreat.

Working with local Indigenous communities requires building relationships, as there is often distrust at the beginning. "*First you need to approach them, get to know their leaders, build trust, and find your allies,*" says Janina. One way she does this is through participatory workshops to gather local knowledge from three different Quechua communities in Ancash, Huancayo and Huanaco in order to identify what sort of information would be useful to provide them with.

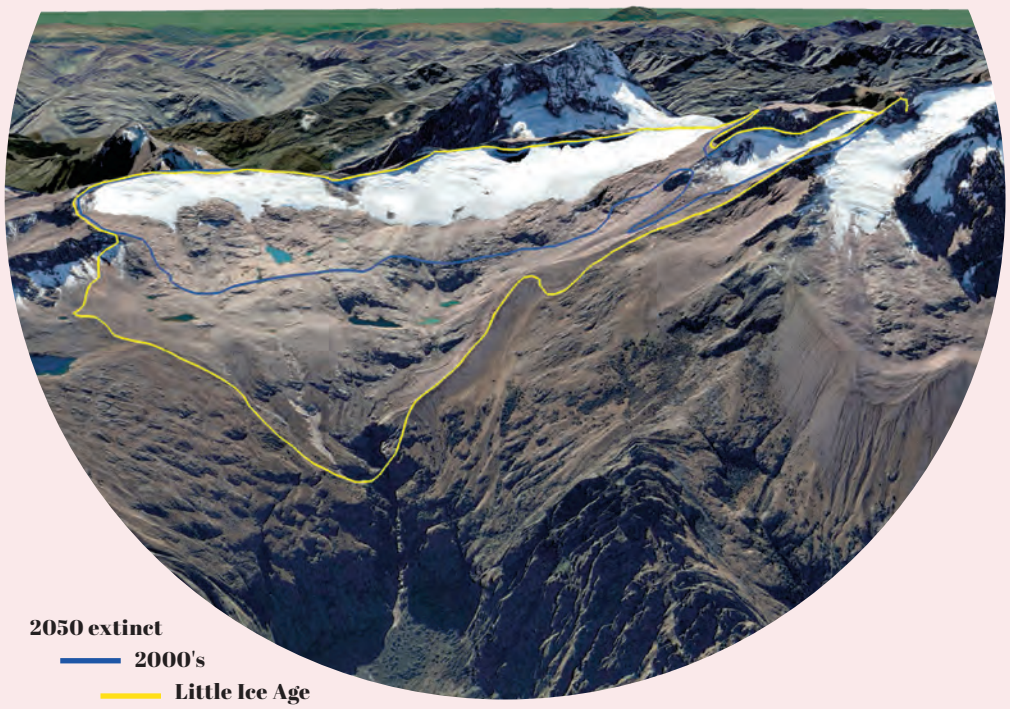
The impacts of climate change on the communities she works with are manifold. One example is water polluted with metals. Geological formations previously covered by glaciers become oxidised after glacier retreat, with metals seeping into the water, making it unusable. Another example is flooding from melting glaciers, or glacial lake outburst floods, which become more frequent in warmer temperatures. These have had devastating consequences in the past for populations downstream. While water scarcity is not yet an issue – apart from regions where the water is polluted – it will be in the near future.

"*We face several very worrying cases in our work with communities*" Janina explains. For example, around Lake Parón in Caraz, local communities do not allow government agencies to reduce the risk of floods. This is because "*charging 5 or 10 soles [the local currency] for entry to the area is lucrative for local communities, which are afraid of losing tourism revenues if the agency is put in charge of the area to regulate flood risk*". This poses a huge challenge for public safety.

Other communities have had a more positive response. The Tupacamano, whose territory was closed to tourism after a landslide in 1941, are more open to governmental agencies, and the INAIGEM is helping to build capacity for employment in Huaraz. Another positive case is Unidos Venceremos, an award-winning community that has developed several sustainable projects that combine conservation with sustainable revenue flow. "*This is the best example of how the previous mentality of local communities has changed*" continues Janina.

Yet Janina feels that engagement with local communities remains too limited. She regrets that some sectors of society are indifferent to Indigenous People's existence and their particular vulnerabilities to the impacts of climate change. "*As an agronomist, I understand and value the efforts of these high-Andean communities, their sustainable farming practices and all the impacts they face because of climate change*".

During our interview, Janina shared local knowledge that has impressed her, like the ability of elders to predict seasonal changes that are crucial for agriculture by reading the signs of nature. She has been collecting this knowledge for years, but has not yet been able to publish it, as resources are very limited in the region. She is both hopeful and lucid about this environment she cares so much about: "*The Cordillera Blanca offers an excellent opportunity to foster tourism, generate deep connections with nature and diversify the economy of local communities. It just seems unfair that international tourism is at the same time one of the causes of climate change that is impacting these communities.*"



Norte del Cerro Chicón glacier

Peru

Chicon is a peak rising 5,530 m above sea level in the Cordillera de Urubamba in the Peruvian Andes. It borders the Sacred Valley of the Incas north of Cusco, leading to Machu Picchu. Urubamba and the surrounding area are considered to have been one of the most important agricultural centres of the Inca Empire. Meltwater from the Chicón glaciers and other snow-capped peaks in the Urubamba Cordillera likely contributed to the civilisation's prosperity. (*Google Earth Satellite image from* 2023)

Bernard Francou

TOWARDS A HOLISTIC VIEW OF GLACIERS

Born in Briançon, in the heart of the French Alps, Bernard Francou spent a long period at low altitude, first in Canada, then in Africa and France, before settling at an altitude between 4,000 m and 6,000 m in the Andes. Initially a specialist in the geomorphology of erosion in high mountains, in the early 1990s Bernard turned his attention to glaciers. Through his sensitivity as a photographer and his experience as a mountaineer, he has come to acquire a holistic vision of tropical glaciers, these portents of climate change.

Pilgrimage to the sanctuary of the Lord of Quyllurit'i in Peru, an event inscribed on UNESCO's Representative List of the Intangible Cultural Heritage of Humanity.

Bernard Francou is one of the world's foremost authorities on the response of tropical glaciers to climate change; he has climbed peaks in every corner of the globe and has an encyclopaedic knowledge of the subject. This familiarity does not blunt the thrill he still experiences when he attends the pilgrimage to the Lord of Quyllurit'i (the "Snow Star" in Quechua), an event inscribed on UNESCO's Representative List of the Intangible Cultural Heritage of Humanity, when nearly 50,000 pilgrims walk from the outskirts of Cusco to the edge of the Mount Colquepunco glacier at around 5,000 m. He describes, "*Whereas in the Alps, for most people glaciers are mainly of scenic interest, in the Andes, nevados play a key role in the identity of the communities that live at their foot. These mountains are the home of the apus, and people come to pray to these spirits in the glaciers. Glaciers are an essential part of the Andean cosmogony.*"

During his last visit to Quyllurit'i in May 2012, Bernard gathered first-hand testimonies from pilgrims. "*They told me, 'If there were no water, life would end. That is why we come here, to worship the snowy one, so that we can have life and water to survive in the world.'*" From some, he sensed anguish, an awareness of the dangers threatening the sacred glaciers and a fear of the disappearance of the home of the *apus*, mountain spirits so essential to their worldview: "*We are very worried, afraid that we may lose these ice-capped mountains and lose our lives, our human species and the planet Earth. We know that if we don't take care of nature, human life will come to an end.*"

Over the decades, Bernard has witnessed how these pilgrims are taking care of nature.

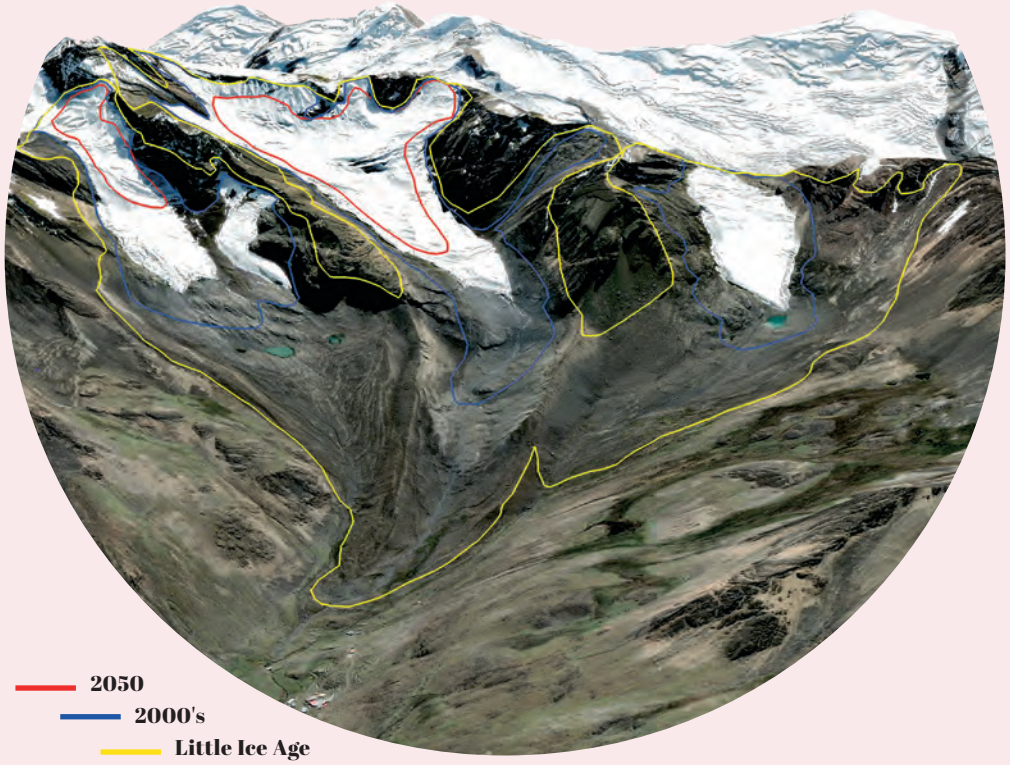
"*When I visited the Quyllurit'i in 2001, the pilgrims took ice, breaking it with stones and carrying it down on their backs for their communities. Just over a decade later, I was struck by the fact that they had abandoned this ancient ritual. They explained that they had noticed the glacier was sick, that it was receding, shrinking more and more, and that they had decided not to remove the ice in order not to worsen its condition. It made me think: our industrialised societies, which are the main drivers of climate change, need dozens of conferences to take decisions – which have still not been taken, by the way – whereas these societies, which live in contact with nature, are able to react immediately and make the right decisions … I think we could take inspiration from this example.*"

Could we learn from these communities and try to reconnect with the spiritual side of glaciers in the West, even if only through farewell ceremonies?

"*I think there's something powerful in these kinds of ceremonies, as long as we explain why glaciers are disappearing and stress our responsibility. Unfortunately, this can't always be taken for granted! In September 2023, we wanted to do a ceremony for the Sarennes glacier in the French Alps, but the managers of the ski resort and the municipality prevented us, arguing that it would be bad publicity for the valley. Many of the economic players in our mountains don't want to see the problem and are still in total denial.*"

Part of this denial stems from the fact that in the Global North our relationship with glaciers is typically built on domination and economic interest rather than spiritual or emotional grounds that engender a feeling of respect. While individuals may feel this, as is apparent in their nostalgia, such as Bernard recalling how as a boy he "*crossed the Glacier Blanc in the Ecrins massif to reach the refuge, a glacier which has receded and will soon be invisible*", many decision-makers remain reluctant to take difficult actions in response to climate change.

A dose of the wisdom of Quyllurit'i pilgrims would not be misplaced.



Monte Qullqipunku glacier

Peru

Qullqipunku (5,522 m) is a peak at the northern end of the Cordillera Vilcanota. It is the site of the pilgrimage to the shrine of the Lord of Quyllurit'i, which attracts tens of thousands of people every year. This pilgrimage combines elements borrowed from Catholicism and pre-Hispanic nature gods. The pilgrimage was inscribed on the Representative List of the Intangible Cultural Heritage of Humanity by UNESCO in 2011. Until the 2000s, blocks of ice were brought down to the valleys for their curative virtues. Concern for the receding glacier has prompted adaptations in the ritual, with guards preventing damage or removal of ice. (*Google Earth Satellite image from* 2021)

Isabel Moreno

MOTHERHOOD AND SCIENCE ON A MELTED GLACIER

Isabel Moreno is an earth scientist currently working as a research assistant at the Institute of Physical Research of the Higher University of San Andrés in La Paz, Bolivia. She has studied the paleoclimate (the climate in the past) from ice cores and, since 2011, has worked at the Chacaltaya Global Atmosphere Watch station (5,240 m) in Bolivia. This has allowed her to forge deep ties with the mountains and their inhabitants. Since 2021, she has been collaborating with an interdisciplinary team to collect the many stories that make up Chacaltaya and that continue to unfold beyond the melting of the glacier. She is also part of Ecotambo, a non-profit that connects organic producers with responsible consumers. A mother of two daughters, she lives in La Paz and loves hiking.

The abandoned ski resort building on Chacaltaya mountain (5,375 m), Bolivia.


Coca-Cola

Isabel Moreno's dream of working in the environmental sciences developed through her relationship with mountains. She began to study glaciers during her doctorate, but her focus took a turn when she realised that Bolivia's glaciers were quickly melting: "*What was I going to do studying glaciers in Bolivia?*"

She decided to accept a position as an atmospheric scientist on Mount Chacaltaya (5,421 m), northeast of La Paz, just when its glacier melted.

Beyond her job, the mountain slowly captured her: "*In the end, the mountain and I got to know each other. I feel great up there, it's a place I've always felt good in because I don't feel vulnerable, in spite of the dangers there might be. It's a place where I know that no one will hurt me, or make me feel uncomfortable. It's a place that makes me feel safe, being in the open mountains on my own.*"

Over a decade of weekly fieldwork on Chacaltaya has also led to establishing deep relationships with other people who work or live on the mountain: "*the Mendoza brothers who take care of the Andean Club [the former ski resort] cabin, the rock harvesters who share the space with the university, the university researchers who take turns sleeping on the mountain*". During this time, she became a mother and shared her experience of maternity with Chacaltaya.

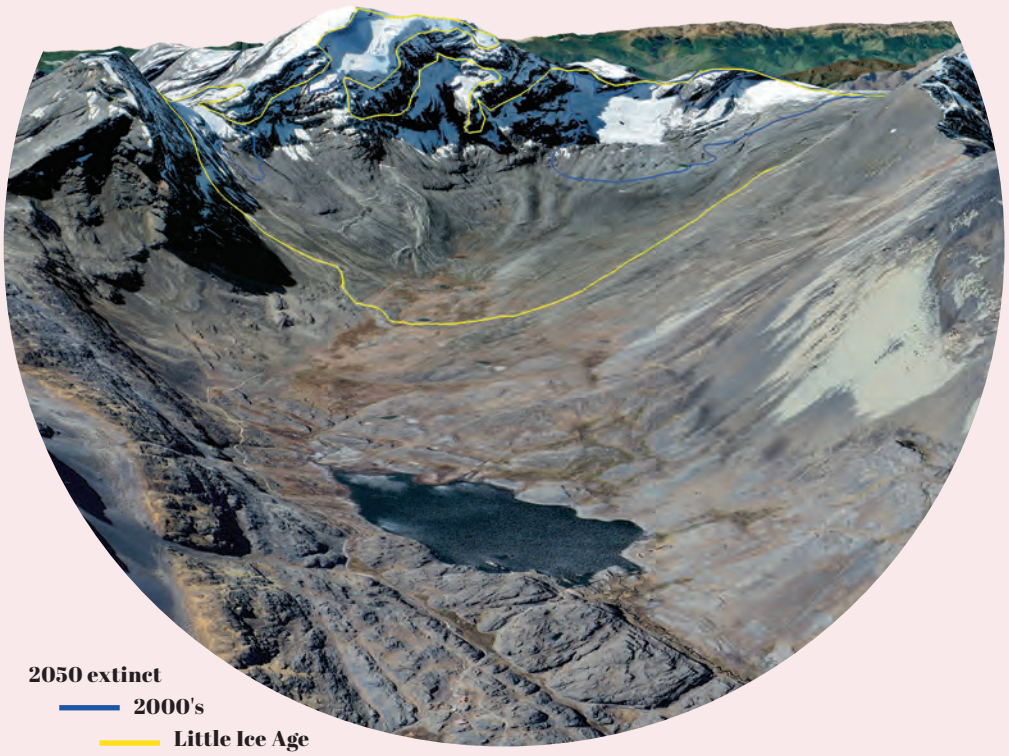
"*It was special, magical. I kept going up Chacaltaya two or three months into my pregnancy with profound joy and energy … I remember one day climbing there, on a sunny day: I felt radiant and happy to be there, carrying my baby with me in a place that was so important and special to me.*"

She continued ascending the mountain until her fifth month of pregnancy and then returned a few months after giving birth, breastfeeding her baby at high altitude and in extreme weather conditions. This mountain that became infamous in the global media after the demise of its glacier, as a symbol of endings wrought by the climate crisis, turned into one of life-giving beginnings through Isabel's story.

How does she educate her children in an increasingly challenging world?

"*I don't want to transmit to them eco-anxiety, because they will eventually have to deal with it. Whatever I do, their time will come. My daughters might not even get to know the Amazon, and that hurts me profoundly. I feel disappointed that we as scientists can't have any real impact in political decision-making, [but at the end of the day,] I am a mother. I'm a scientist only to answer questions about volcanoes that scare my little ones … to prompt their curiosity – that's as far as my science self seeps into my mother self.*"

And as a woman who works in mainly masculine, sometimes sexist, spaces – on the mountain or in the laboratory – she stresses that men also need to consider these questions: how to face climate change as fathers. It is unbalanced that women continue to be tasked with most caretaking, including caring for the Earth. She considers the stakes of this from her own perspective as a female scientist: "*We won't improve our current [socio-environmental and political] situation until we are able to change the ways in which we structure our society.*" Reflecting on the freedom, safety and well-being she experiences when she is alone in the mountains, she argues that "*we need men involved in paternity, climate change, and the upbringing of children*", not only involved in data and numbers, to bring about real, structural change as we face the challenges ahead.



Sirk'i Qullu glaciers

Bolivia

Sirk'i Qullu (5,546 m) is a peak in the small mountain range of Sierranillas Murillo, part of Bolivia's Cordillera Real. The Sirk'i Qullu glaciers feed one of the four watersheds (the Hampaturi watershed) supplying water to the city of La Paz (up to 27% of the supply in the dry season). Three dams serve as reservoirs to store water. A meagre compensation for the loss of water linked to the shrinking of the glaciers. *(Google Earth Satellite image from* 2021)

Cecilia Llusco

"LIKE FLYING ON CLOUDS": MOUNTAINEERING, GENDER AND INDIGENOUS IDENTITY

Cecilia Llusco is a co-founder of the Cholitas Escaladoras ("Cholitas Climbers"), a group of Aymara women who summit mountains wearing traditional dress. A mountaineer and trekking guide, she has been climbing mountains since she was able to walk. Born in Chukura, near Huayna Potosí Mountain northeast of La Paz, she spent her childhood herding animals, tending vegetables, and following her father as he guided tourists on the Inca Trail that passed near their home. She has reached the summit of all of Bolivia's peaks, some of Peru's, and in 2023, climbed Argentina's Aconcagua, the highest peak in the Americas. She dreams of reaching Everest's elusive summit as the first Aymara woman.

A Cholita hiking up the mountain.
© T. Anthony

"Women who wear polleras like us always carry our culture."

In 2015, Cecilia Llusco and her friend and colleague Lidia Huayas founded *Cholitas Escaladoras*, a now famous group of Aymara women mountaineers from Bolivia that climb high-altitude peaks in their traditional, multi-layered *polleras* (skirts). The group included women who worked as porters, carrying things on their backs for tourists, or cooked at camps on Huayna Potosí (6,088 m) and Illimani (6,438 m). The self-organised group of women began their first ascent to Huayna Potosí's summit on 17 December 2015. Their triumphant return was met with resistance from male guides, who feared being displaced, and felt it was against nature: "*If you go up the mountain it won't rain or snow. We won't have any more water because of you.*" Cecilia explains that this was a matter of discrimination: "*They want the work of guiding all for themselves. Women, they said, have to be at home doing laundry, cooking, and taking care of their children. As they always say, women are for the home, and they didn't like it [seeing us outside on the mountain].*"

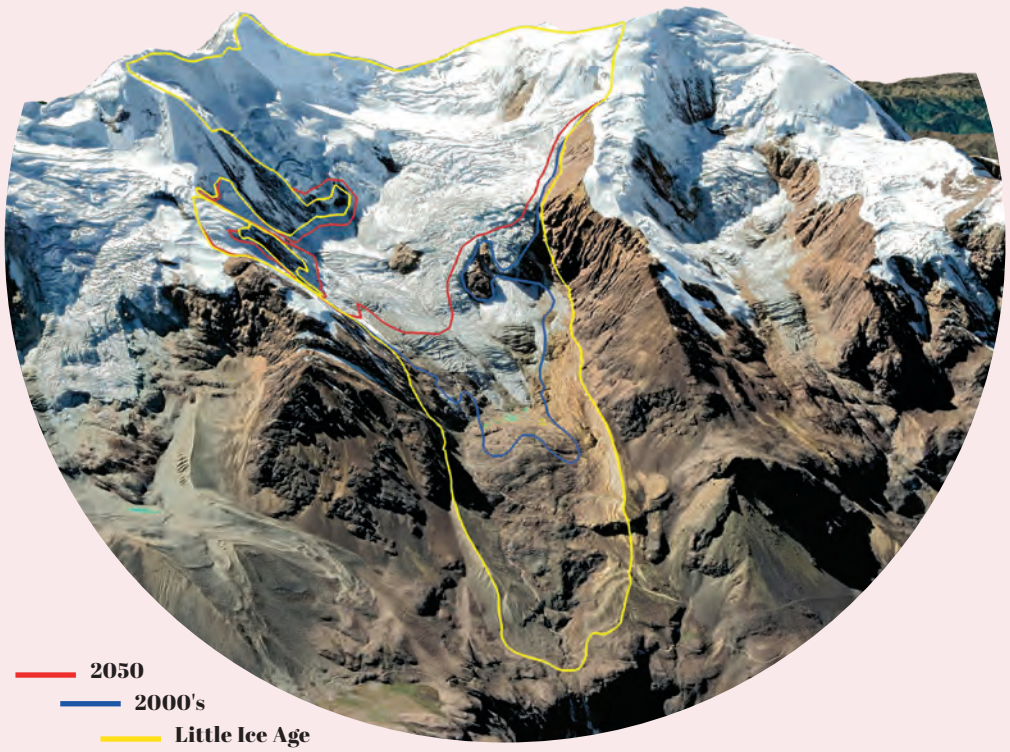
Wearing their *polleras* to climb mountains was a choice to challenge the discrimination Aymara women face, whether based on gender or race. "*Women who wear polleras like us always carry our culture, and we are always discriminated against, which I have never liked,*" explains Cecilia. A few weeks later, the story of their ascent was televised and they became famous overnight: "*That to me was a miracle that I would never have imagined.*" They would go on to ascend the highest peaks of La Paz (almost completely self-financed and organised), eventually ascending the highest peak outside Asia, Aconcagua (6,961 m).

Cecilia's story with mountains began in her childhood home, the community of Chukura, northeast of La Paz, at nearly 4,000 m. As she tended to animal grazing and potato harvesting, her father guided tourists on the El Choro Inca Trail. Today, most of the Chucura community is dedicated to tourism, an activity Cecilia believes is threatened by accelerated glacier melt: "*Not a lot of people will come, and for us, it will be a great sadness not to have work… Last year, Huayna Potosí's glacier had receded a lot – it was really black. It is sad to think that one day we might not have snow and only be able to climb rocks.*"

But then her face lit up thinking about Aconcagua, whose peak has no glacier.

"*To me, the mountain – that is my passion: to make it to the top, to see the sights, to be in nature, to feel free, to touch the sky, to fly in the clouds. It will always be the same, with or without a glacier. It will be a huge loss not to have the glacier, but I will continue climbing up mountains because it is my passion… it is the freedom that I have, to be on top of mountains.*"

Cecilia's next project is to summit Everest, the highest peak in the world: "*If we get to Everest, we would make women who wear* polleras *in Bolivia so proud… we would be the first Indigenous women of Bolivia on Everest.*" She imagines the headline: "Pollera *women make it to the highest peak in the world*". Just as she finds freedom in the mountains, she wishes the same for all who have the privilege of visiting the world's peaks, with or without ice.



Illimani glaciers

Bolivia

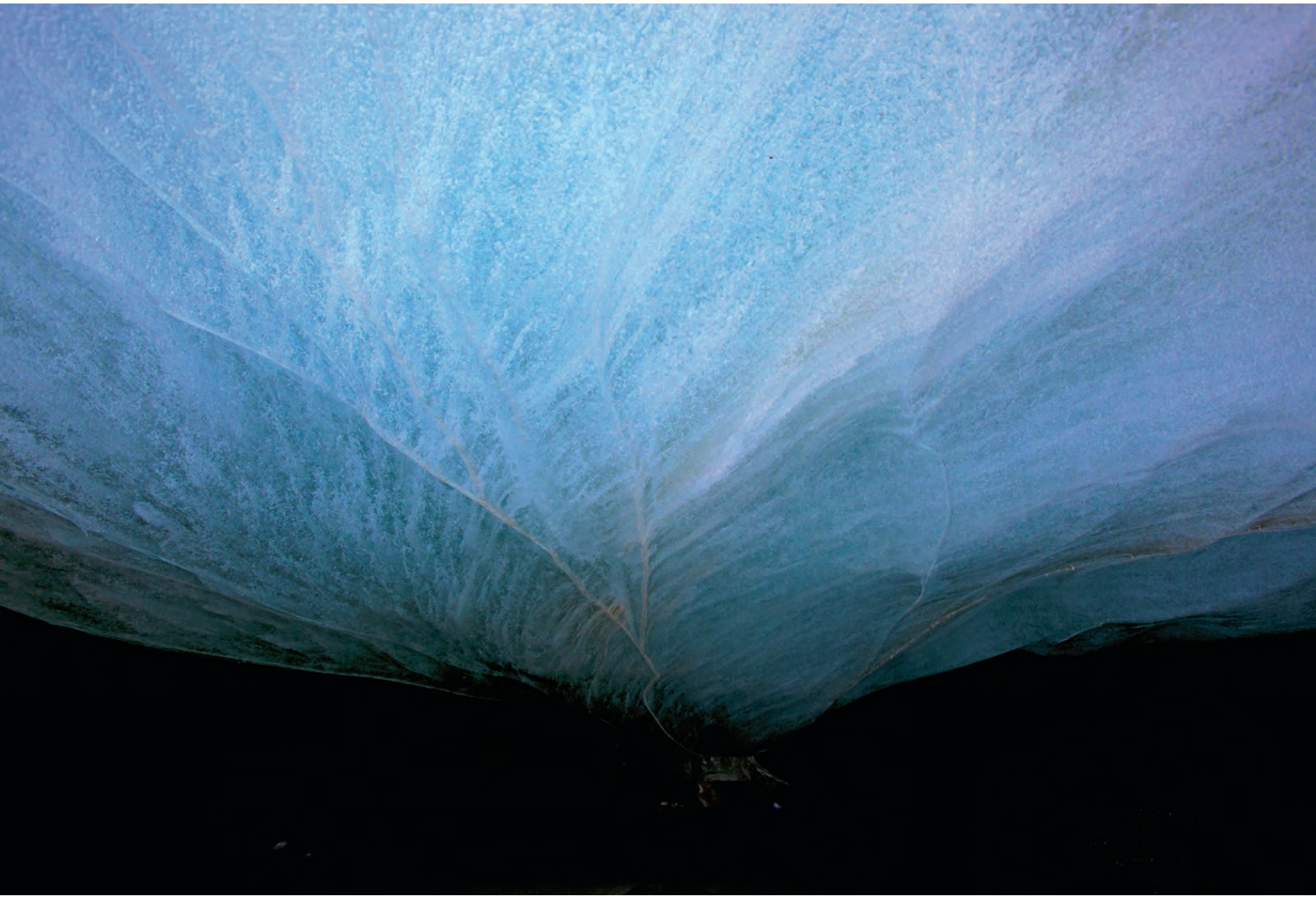
An emblematic and majestic peak, the highest point of the Cordillera Real at 6,440 m, Illimani dominates the city of La Paz and the Altiplano. Legend has it that Illimani and Mururata (a neighbouring peak) are two sons of the creator god Wiracocha. While Illimani is calm, Mururata is visceral and envious of his brother's splendour. During a conflict between the two brothers, Wiracocha is said to have interceded on behalf of his favourite son, Illimani. Before a fight, he provided Illimani with a slingshot, which Illimani used to decapitate his brother, whose head is said to have created Sajama, Bolivia's highest peak at the other end of the Altiplano. (*Google Earth Satellite image from* 2023)

Sonia Altamirano

MOUNTAINS WITHOUT GLACIERS LIVE ON

Sonia Altamirano is an Aymara mountaineer and guide born and raised at Huayna Potosí's base camp in La Paz, at 4,800 m. She and her brothers inherited their parents' base camp and high-altitude shelters, which welcome mountaineers and tourists year-round. She and her five-year-old son Leo live there, and she monitors the global seismology station. Sonia is continually expanding her mountaineering and high-mountain ecosystem knowledge in order to better understand and protect her home.

In the depths of the Zongo glacier near La Paz, Bolivia.



Sonia Altamirano came out of the base camp shelter (4,800 m) built by her parents to greet me, dressed in her mountaineering gear and cleaning gloves. A large group of tourists had left that morning, and she was getting ready for the next group of travellers attempting to climb Huayna Potosí (6,088 m) in the Bolivian Cordillera Real. Her young son Leo came out behind her, running towards me as I struggled to catch my breath. It was a sunny winter's day, and the peak was in full view. It had been a few years since my last visit, and I was shocked to see new black areas all over the mountain where before there had been ice. It is one thing to know that glaciers are receding, and another to witness this firsthand.

Sonia has seen the change over the 32 years of her life and from hearing her parents' stories from the 1970s when they first arrived there. "*My dad told me that the glaciers were massive when he arrived here in his 20s. Crossing to Zongo [the valley below the mountain pass to the north of La Paz] used to be hard because there was so much snow.*" Her father had been hired by seismologists to monitor a station at the base of Huayna Potosí. In the early days, there were no neighbours, no roads, no infrastructure. When Sonia and her brothers started going to school, they had to travel an hour and a half down to Zongo twice a week in buses from the city that would make their way through the valley. Now there are other shelters in the *plataforma* (base camp), belonging to different families from the Aymara community of Llaulini, but most do not live there permanently – many vacate their shelters in the rainy summer season (mid-December to early March).

Sonia has continued her father's contract with the seismologists, which requires constant monitoring, and keeps the shelter open year-round:

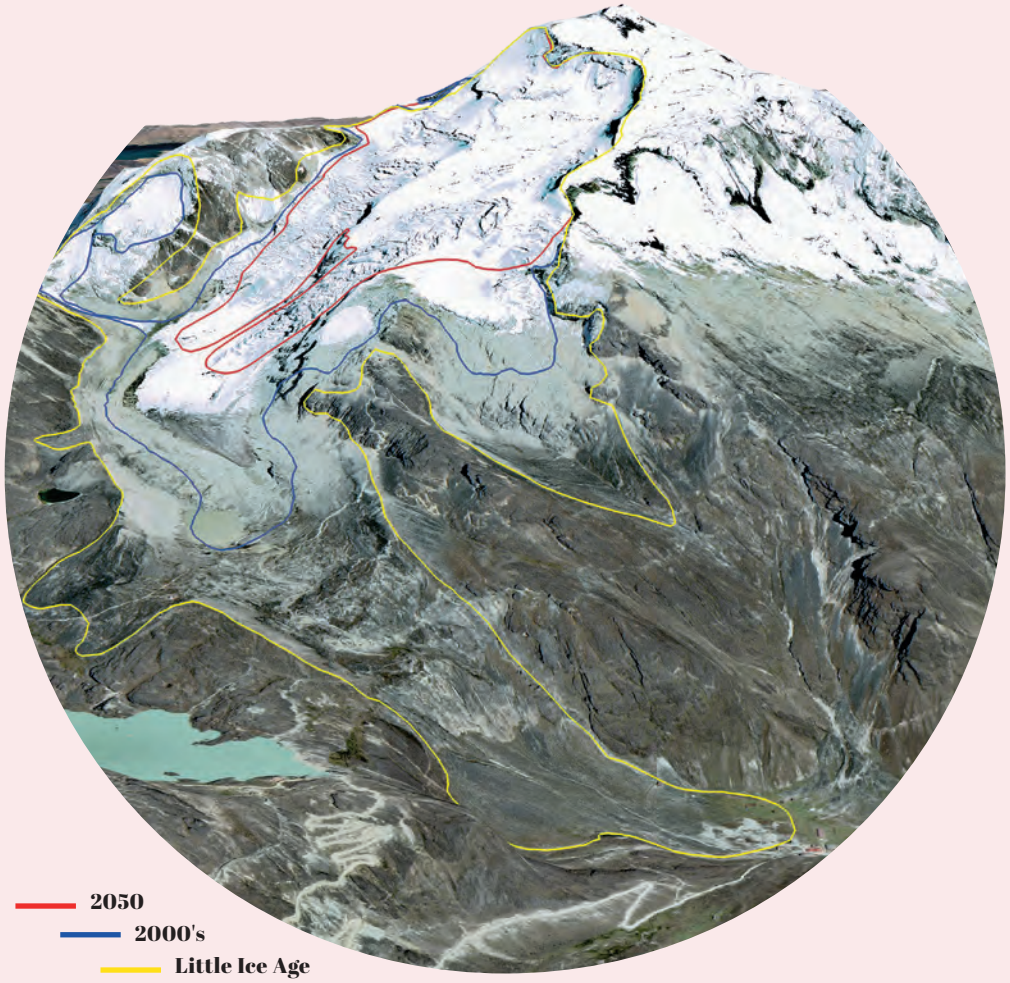
"*It's incredible how the glaciers have changed since I was a little girl. It scares me, the rate the water flows down from the glaciers now. Like everything else, we have to take charge… we are at a turning point and there's no stopping it; it will happen and we have to be prepared – politically as well.*"

Sonia has taken the matter into her own hands, dedicating her free time to researching the Andes both theoretically, through courses and collaborations, and practically, as a mountain guide and mountaineer. As an Aymara woman, her parents taught her to pay her respects to the mountain's *achachilas* or guardians: "*They are wise grandparents, petrified up there, who will share their wisdom with us… that's how my parents taught me to believe in mountains. It is a deeply rooted belief here in the Andes.*"

With her multiple ways of knowing and caring for the Andes, she rejected the idea of holding funerals for melted glaciers:

"*A person isn't what they are wearing, or their money, but what they are inside, what's in the heart. So to me, to hold a funeral for a glacier is like killing the spirit of the mountain itself. It is still a mountain that will always deserve the same respect. To me, it's like a person who has left, but will always be there because it's been there for a long time. So it's not on the surface, but what? It's gone so it's not worth anything? It sounds empty. When I see a mountain that no longer has a glacier, [I also see that] many moons ago, in another time, it grew as something different geologically speaking, beyond the glacier itself.*"

To Sonia, holding a funeral would reduce the story of an ancient being that participated in the creation of the Andes to simply its visible surface. She considers it necessary that everyone continues to visit mountains. For her, climbing mountains with or without glaciers renews her energy to continue her work as a protector, knower and lover of mountains.



Zongo glacier, Huayna Potosí

Bolivia

Among the most famous of tropical glaciers for glaciologists, Zongo flows down the southeastern slope of Huayna Potosí (6,088 m). This glacier, which has been monitored since 1991 in a joint research mission between France and Bolivia, benefits from one of the world's most comprehensive glacier measurement networks (the GLACIOCLIM observatory). Its meltwaters are channelled via a canal to a reservoir, which feeds a network of 10 hydroelectric power stations spread across the Zongo valley at altitudes ranging from 900 to 4,700 m. (*Google Earth Satellite image from* 2022)

Lucía Merchán

THE VOICE OF YOUTH

Deisy Lucía Merchán Zambrano is 28 years old. Born in El Cocuy, Boyacá, Colombia, she has combined her academic background in business and her passion for nature and the environment to build a unique career. She is a high mountain guide in El Cocuy National Park, where she educates visitors on the importance of the conservation of glaciers and high mountain ecosystems. She is part of the High Mountain Participatory Environmental Monitoring Network (MAPAM), led by the Institute of Hydrology, Meteorology and Environmental Studies (IDEAM), a government agency that collects and analyses data for the study and preservation of glaciers in Colombia.

A group of volunteers in the Participatory Monitoring Network of Colombian Glaciers poses during a working day.

© L. Merchán

"When I was 13, I witnessed the majestic flight of a condor that was released by the El Cocuy National Park Authority. This was when my love for the mountains started."

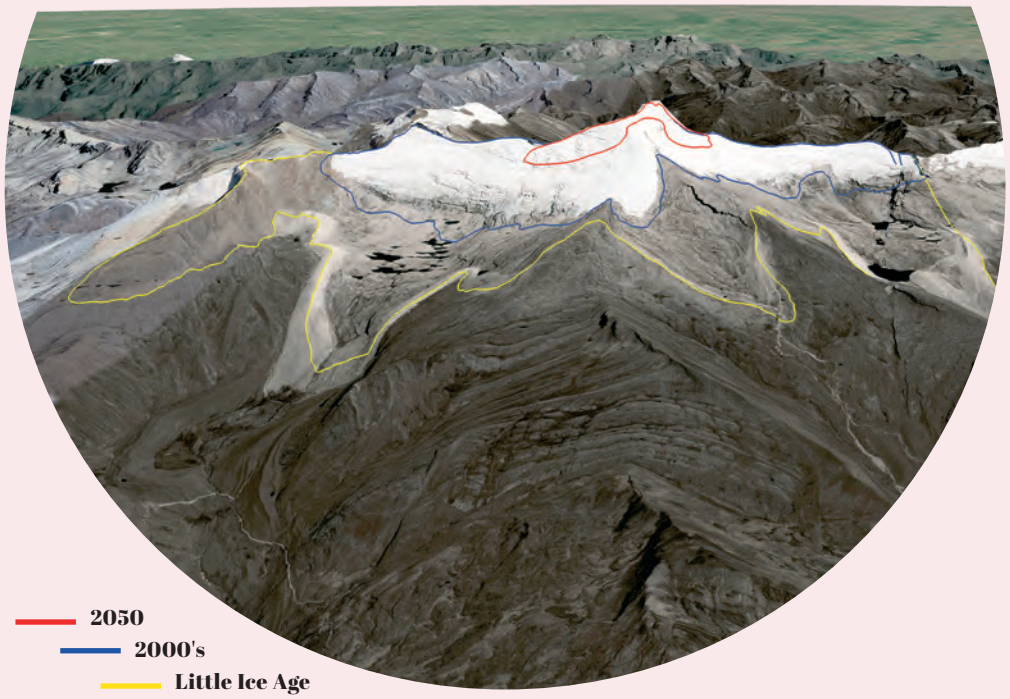
"*When I was 13, I witnessed the majestic flight of a condor that was released by the El Cocuy National Park Authority. This was when my love for the mountains started*" enthuses Lucia Merchán, naturalist guide and coordinator of the Participatory Monitoring Network for the glaciers of Ritacuba Blanco and Pan de Azúcar in El Cocuy National Park in Colombia.

She started monitoring glaciers in 2022, after a presentation by Colombian glaciologist Jorge Luis Ceballos on the challenges of the work due to lack of funds, limited expertise and difficult access. The monitoring group tries to find its way around these through a strong social network, creativity, and help from donors. "*We all have something to contribute, and nobody is excluded by age, gender or education level*" Lucia explains. The younger members of the group learn techniques from the most experienced and listen to stories of the past. They mark the retreat of the glacier with cairns and use beacons to measure the quantity of snowfall. A camera, donated by glaciologist and science communicator Heïdi Sevestre, provides pictures that are shared via social media groups. This information is used by glaciologists at IDEAM to monitor the glaciers and inform national park agencies. Lucia also brings tourists from the national park to participate in glacier monitoring, increasing their awareness of glacier retreat. Additional resources would allow them to monitor other glaciers in Colombia.

"*We know that because of climate change we won't have any glaciers left in Colombia in a few years, but it is precious to be able to share what we had before and to show the changes that our mountains have undergone*" says Lucia. The network also works with local communities: for example, monitoring precipitation with rural schools and then presenting the results of glacier monitoring with the students. Lucia is convinced of the importance of sharing scientific knowledge. While she believes local knowledge is invaluable in adaption strategies, she also fights misconceptions of the causes of glacier loss, which some locals associate with an excessive number of tourists walking on the glaciers.

Lucia says she will undoubtedly continue to visit mountains without glaciers, and tries to stay positive.

"*It's sad to witness the death of a glacier and frustrating that we can't do anything against it, particularly since we come to the glacier edge often to monitor it and can see how it is retreating continuously. However, our love for the mountains goes beyond glaciers and encompasses the conservation of mountain ecosystems in general. Now we are involved in planting* frailejones, *an endemic and charismatic plant in Colombia that plays an important role in water regulation, to protect water ecosystem services.*"



Sierra Nevada del Cocuy glacier

Colombia

The Sierra Nevada del Cocuy lies at the heart of a national park covering more than 300,000 hectares and boasting exceptional biodiversity. The highest glacier flows down the western slopes of Ritacuba Blanco (5,410 m): below lies the *páramo*, a water-rich ecosystem typical of the high-altitude tropics of Colombia, Venezuela and Ecuador. The relatively low altitude of the Sierra Nevada del Cocuy peaks means that the glaciers have almost no perennial accumulation zone. In projected climatic conditions, only remnants will persist by 2050. (*Google Earth Satellite image from 2017*)

Baltazar Ushca

THE LAST ICE MAN

Since he was 15, Baltazar Ushca has braved the harsh slopes of the Chimborazo volcano in Ecuador to harvest glacier ice. He used to be one of about 40 ice harvesters, including his brothers Gregorio and Juan. Today, the others have taken a different and more profitable path, making Baltazar the last ice man of Chimborazo. Each laborious journey, undertaken with traditional tools and his faithful donkey companions, ensures the survival of a centuries-old tradition. In November 2017, at 74 years of age, he received an honorary degree from the Mexican Institute of Leaders of Excellence.

Baltazar Ushca passed away in November 2024 at the age of 80.

Baltazar Ushca, the last ice man, on the slope of Mount Chimborazo in 2008.

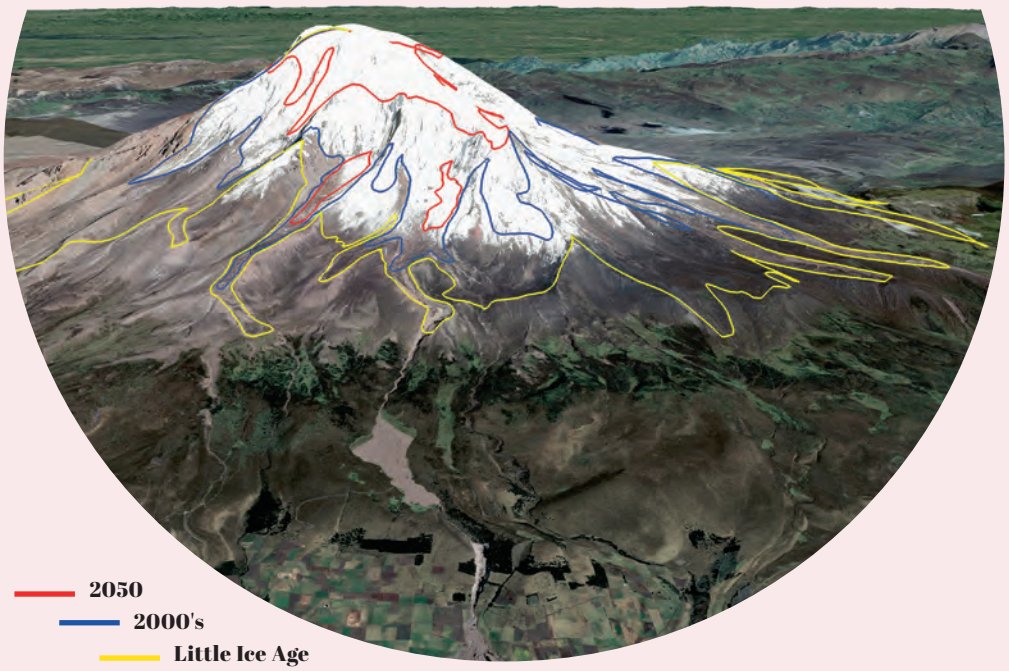
I met Baltazar Uscha in 2008 while I was working on my book *Miradas*, a photographic journal of Ecuadorians from every corner of the country, living their daily lives imperceptibly, flowing silently with the murmur of the wind, the melody of water or the songs of the forest. As I travelled around the country, from the Indigenous communities in the Amazon to the fishing villages of the Pacific coast, one of my most unforgettable memories was meeting Baltazar. This grandson of the Chimborazo volcano climbs his ancestor to collect ice from its entrails, following the same path of frost and sweat that his father, grandfather, great-grandfather, and others before them traced. When young women of the Andean *páramo* leave their home in the middle of stormy nights, it is said they risk being impregnated by grandfather Chimborazo and bearing albino children (white like the mountain's glacier). This is the story of Baltazar's grandmother: he is proud to be the grandson of the majestic mountain.

I asked him why he is devoted to such a harsh task that demands confronting the freezing winds of the *páramo*, the rain and the snow, walking up to an elevation of 5,000 m to begin the strenuous labour of hacking at the ice with a pick after asking permission from the god Taita (father in Quechua) Chimborazo, cutting it into blocks, packing them, tying them to the donkeys' backs, and bringing them back down – a 12-hour work day. After reflecting for a while, with a kind, almost naïve smile, but with some irony, he responded: "*Easy money*." I am convinced there is almost no money involved, and that it is anything but easy. Surely the answer lies elsewhere.

Perhaps it is about being part of a whole... a link in a long chain that fades into the mist of the mountains and stretches through the generations. Or perhaps it is simply about devoting himself to the only thing he learned to do. But I like to think that it is to do with being one with the wind of the *páramo*; about being faithful to himself and to the ancient gods, and by doing so, keeping a bond with his grandfather, the mountain. A bond that is harsh, yet also poetic and vital.

But not everyone feels the same way or has Baltazar's strength; and so, he is now the last ice man. His brother Gregorio became an ice cream vendor, a job less taxing and more lucrative. But Baltazar is stubborn. With his donkeys, Azulejo and Gabriela, and his dog Sargento, Baltazar Ushca maintains the tradition, continuing to defy the clouds and the frost to extract ice from the arteries of Chimborazo. At the end of a long day, he descends with his frozen centennial load on his donkeys' backs, and with some of the powerful and crystalline spirit of the mountain in his heart... and in his smile.

While Baltazar says that he is the last ice man of Chimborazo, I refuse to believe him.



Chimborazo glacier

Ecuador

The southern slopes of Chimborazo (6,240 m) are home to one of the last tropical glaciers where ice is harvested by hand for domestic use. The trade in natural ice (from rivers, lakes or glaciers) reached its peak in the 19th century with urban growth and the increasing need to store and transport food over sometimes intercontinental distances. It was not until the early 20th century that artificial ice production and refrigeration systems supplanted the need for natural ice. Throughout the Andes, *hieleros* harvested ice from glaciers over generations to supply neighbouring towns and villages. The last hieleros on Chimborazo maintained an ancestral tradition and a form of communion with nature. (*Google Earth Satellite image from* 2023)

Laura Zalazar

PROTECTING A GLACIER TO PROTECT AN ECOSYSTEM

Laura Zalazar has a PhD in geography and lives in Mendoza, Argentina. Since 2011 she has worked for Argentina's National Glacier Inventory, which she now coordinates. In 2010, Argentina approved the National Glacier Law (Law 26,639), the first of its kind in the world, intended to protect the Andes and their water resources. As a member of a small team charged with inventorying the entire Argentine Andes (over 16,000 glaciers), Laura studied the high mountains using geotechnology, traversed diverse terrain and confronted many challenges along the way. In 2018, the first Glacier Inventory was published: a monumental feat, not only because of the enormous scale of the Andes, but also because of the social, political and economic constraints faced in the process.

Sampling aquatic fauna in a high-altitude wetland (4,980 m) in the Cordillera Real, Bolivia.

© IRD/O. Dangles

"The possible impacts of glacial melt extend beyond the loss of the glacier itself."

"*I was born in central-eastern Argentina, in Mendoza, a subtropical region at the foot of the mountains. In spite of having studied geography, the term 'tropical glaciers' piqued my attention: it sounded so distant and exotic. When I finally had the opportunity to visit the Pastoruri glacier in Peru, I was fascinated by the possibility of seeing a tropical glacier with my own eyes. This feeling of awe clashed with other, contradictory feelings, because the ice was clearly retreating. I could not have imagined that a few years later, one of my favourite glaciers in Argentina would suffer the same fate as Pastoruri.*"

Laura's time in the field would lead her to many other encounters with glaciers beyond Pastoruri. It has also expanded her understanding of what glacial loss does to the environment.

"*In the beginning, when we began putting the inventory together, we would go to a glacier and measure it, then we'd look at the satellite images. All our attention was focused on the glacier, its components, its parts – we measured it every way we knew how. But after a few years, we started to notice that a small spring comes out of the glacier, so we measured the volume of water. Then you notice the vegetation, high-altitude wetlands* [vegas or bofedales], *so you ask, well, what happens to the wetland in the beginning and at the end of summer when the glacier provides more water. Then you notice the livestock people bring to graze near the glacier in the summer. You start seeing not just the glacier system, but everything it generates, and everything that surrounds it, from the natural physical environment to the human social environment: everything that happens around the glacier. This definitely changes your perspective.*"

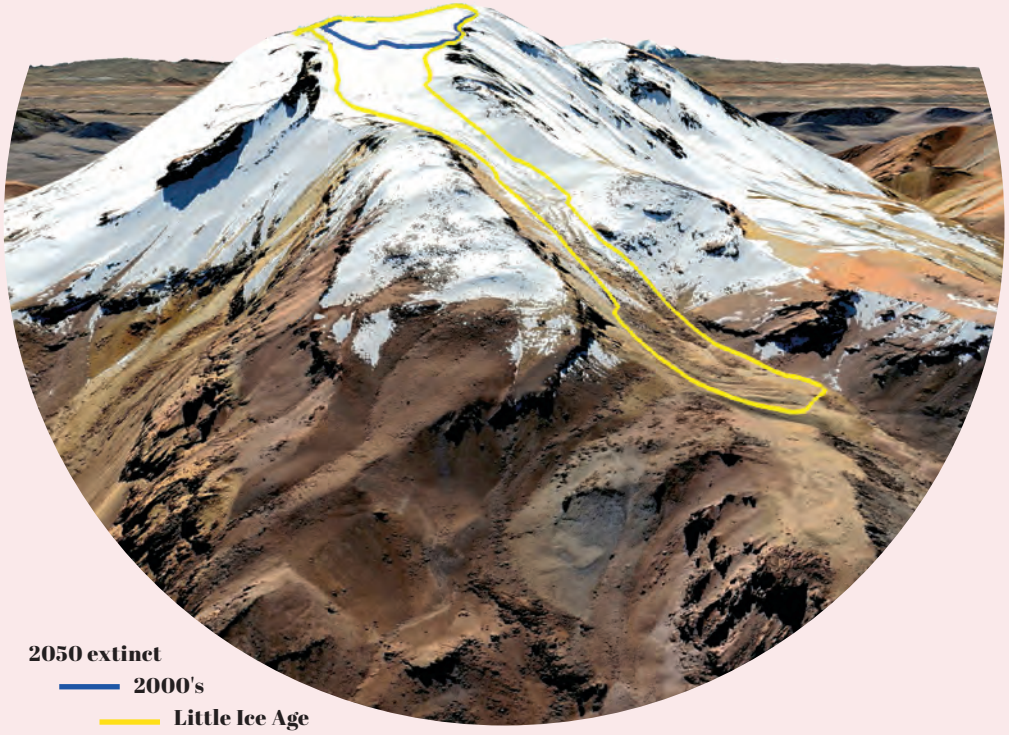
"*The question I still need to answer is what will happen to wetlands once the glacier completely melts.*" They act as water reservoirs for melting glaciers, and are vital to the way of life of those who depend on them for livestock grazing, a means of subsistence. As high mountain areas are so removed from cities, even in urban areas at the foot of mountains, people sometimes lose sight of the fact that humans and animals can depend on glaciers. The possible impacts of glacial melt extend beyond the loss of the glacier itself.

Argentina's National Glacier Law prohibits activities on glaciers with the aim of protecting waterways. However, as Laura points out, the law does not apply to wetlands that these glaciers feed, meaning that drilling activities can still take place in those areas. She argues that it is essential to see the interconnections that make up environments with glaciers, including economic and political interests in these regions, all of which play a role in what happens to meltwater:

"*We have to see these environments not only as areas to exploit economically or as empty spaces where no one lives. We have to continue working towards generating greater awareness in the population, so that people get to know these areas and begin protecting them rather than just taking from them and extracting their resources.*"

This will require considering other perspectives when producing knowledge about environments with glaciers: "*It's not only about measuring ice and where it exists – problem solved. We have to see and incorporate many other things, other visions.*"

As she contemplates a future without glaciers, she still sees the beauty in the diversity of mountain environments – with or without ice – with the certainty that each holds infinite things to experience and to learn from.



Cerro Kunturiri glacier

Chile

Kunturiri is an ice-covered volcano on the border between Chile and Bolivia. It reaches an altitude of 5,762 m. Its name comes from the Aymara *kunturi*, meaning "condor". It is part of a volcanic complex that includes Pomerape, Parinacota and Sajama, three other snow-capped volcanoes reaching an altitude of over 6,000 m. Kunturiri borders the Lauca National Park, part of the Lauca Biosphere Reserve, designated by UNESCO in 1981. In this extremely arid environment, meltwater from glaciers feeds wetlands (called *bofedales* or *vegas*) that are melting pots of biodiversity. (*Google Earth Satellite image from 2024*)

CONCERN

Studies have found that concern signals a capacity or potential for resilience in the face of change. Concern for the environment emerges in relation to people's profound relationship to the places they inhabit. For many Indigenous Peoples, threats to their lands and livelihoods have been a part of their daily lives since colonisation. Climate change presents additional apprehension about altered conditions affecting how they live on the land, or the possibility of reclaiming stolen land. Emotions such as worry are neither static nor separate from historical processes. As argued in a study on the emotional topography of climate change, shifts in the geography that makes up people's lived worlds "do not erase what has gone before. Rather, there is a layering of memories, held in bodies and places, that both nurture and create pain, the dissonance of nostalgia and solastalgia, homesickness for places that have shifted and no longer exist."

Ati Gúndiwa Villafaña Mejía

TRADITION AND MODERNITY TOGETHER

Ati Gúndiwa Villafaña Mejía is a leader from the Arhuaco community of the Sierra Nevada de Santa Marta in Colombia and a community manager of the Iberoamerican Network of Intangible Cultural Heritage. In 2022, she was a delegate of the Arhuaco people to the 17th Session of the UNESCO Intergovernmental Committee for the Safeguarding of Intangible Cultural Heritage, to advocate for the inclusion of the ancestral knowledge systems of the Kogui, Wiwa, Arhuaco and Kankuamo peoples. She works to defend the territory, identity and ancestral culture of Sierra Nevada de Santa Marta, part of which was designated by UNESCO as a Biosphere Reserve in 1979, through multidisciplinary discussions with stakeholders from diverse fields.

Commemoration of the 100th anniversary of the first visit of the Arhuacos Indigenous People to Bogota from Sierra Nevada.
© Jusezam

"*My name is Ati Gúndiwa and I am from the Arhuaco community of the Sierra Nevada de Santa Marta*," introduced Ati in a round table discussion at an ecological economics conference in Santa Marta in 2023. In a separate conversation, she would later explain the origin of her name and her connection to tropical glaciers:

"'Ati Gúndiwa' *is the name of a woman of great spiritual power who narrates the law of origin, possessed of the essence and power of fire in its different manifestations. In my village we all have a name with a meaning that is related to some element of nature, and throughout our lives we must be aware of the responsibility it conveys.*"

Ati Gúndiwa's was one of several contributions at the conference. This forum, coordinated by my friend and colleague Roldan Muradian, had no keynote speeches. Instead, local leaders discussed sustainability with researchers in front of a largely academic audience. I felt this was a refreshing approach to sustainability conferences where certain narratives still dominate and grassroots movements are often marginal.

The Indigenous Peoples of the Sierra Nevada are very concerned about environmental and climate change impacts on their ancestral lands, and have become increasingly active in communicating with the public about their land and its fragility. In the Sierra Nevada de Santa Marta, whose highest peak is called Gonawindwa or Chundwa, also known as Pico Cristóbal Colón (5,775 m), climbing the glacier is currently not allowed without permission from the Indigenous communities. Ati explains, "*We prefer tourists not to walk on the glaciers. They are very sensitive, and we have seen how tourism in general can negatively affect ecosystems, as has happened with certain species of flora and fauna such as the harlequin frog, gowna in Arhuaco, which was very close to extinction.*"

The Arhuaco are well known for their rich spiritual worldview. *Mamos*, or spiritual guides, receive a special education that lasts 15 years on average, training that Ati's brother, Alberto, is receiving at the Tiruguekun centre. *Mamos* interpret messages from the universe and work with masculine and feminine energies to make offerings in sacred spaces and sites, for example, on glaciers, in order to maintain the balance of the universe. Before undertaking a journey to a glacier, they must fast in preparation. The spiritual world of the Arhuaco is very rich, and glaciers are important to their community, as Ati explains: "*In the cosmology of the Indigenous Peoples of the Sierra Nevada de Santa Marta, when a loved one dies, their soul rests in the nevado [snow]. That's why we say 'Happy Journey to the Chundwa.'*"

Glaciers are also understood as a "brain", where information on the state of the planet's environment is found. Ati and some other members of her community believe that climate change is a message from the universe that we have done something that it does not like. This interpretation is linked to interconnectedness, which the Arhuaco describe as *umunukunu*, the invisible connections that link both humans and non-humans in a land.

The colour white is also very central to the Indigenous communities of the Sierra Nevada de Santa Marta. They dress in white, the colour of the snow-capped mountains, and the men's traditional cap, the *tutusoma*, is a representation of the peaks.

People who do not belong to the four Indigenous groups of the Sierra Nevada are referred to as *bunachu*, "younger brother", a reflection of the long Indigenous ancestral presence in the region. Ati says: "*The elders speak with nostalgia for the snow-capped mountains, and in the context of their retreat due to climate change, they want to work to protect them. That's why we want to take our message to younger people.*" The question is, is the younger brother ready to listen?

Sierra Nevada de Santa Marta, Pico La Reina glacier

Colombia

Pico La Reina rises to over 5,535 m, one of the highest peaks in Colombia located in the UNESCO-designated Sierra Nevada de Santa Marta Biosphere Reserve, which borders the Caribbean Sea in northern Colombia. The retreat of its glaciers during the 20th century has left numerous emerald-coloured lakes. Some are the site of ceremonies of the local Indigenous Peoples, who have maintained a spiritual link with nature and the glaciers in the peaks. (*Google Earth Satellite image from* 2023)

Willian Martínez Finquin

PROTECTION THROUGH NATIONAL PARKS

Willian Martínez Finquin is the director of the Huascarán National Park in Peru, a UNESCO World Heritage site and Biosphere Reserve. The park is named after its highest summit (6,768 m), sitting within the tallest mountain range in the tropics, and the one containing the largest area of tropical glaciers. Over 70% of tropical glaciers are located in Peru, with the vast majority in the Cordillera Blanca "(White range)". Willian Martinez thus plays a crucial role in protecting the region's glaciers.

Ranger Víctor Morales monitoring glacial lake water levels, which must be reported every two hours.

"I will continue to protect the national park and its mountains until the last remaining bit of ice."

Guided by my friend Felix Roca, head of the Mountain Guides Association in Huaraz, I arrived at an old building serving as the Huascarán National Park office, where I had an interview arranged with its director, Willian Martínez Finquin. This had been obtained through Edgar Vicuña and Marcos Pastor Rozas, mutual friends from the National Parks Agency of Peru with whom I work on a research project about protected areas in the country. I was interested in speaking to Willian to find out how a director of a national park is dealing with climate change. Climate change is a global phenomenon with no borders, so a national park is unable to protect itself against this in the same way as it can protect land from certain uses, for example. My conversation with Willian quickly revealed his deep concerns about the current and future impacts of climate change and his determination to do everything he can to tackle them, against all the odds. *"Climate change in our region is very worrying. Nearly everything is yet to be done. Local communities are highly vulnerable and are not prepared for future risks."*

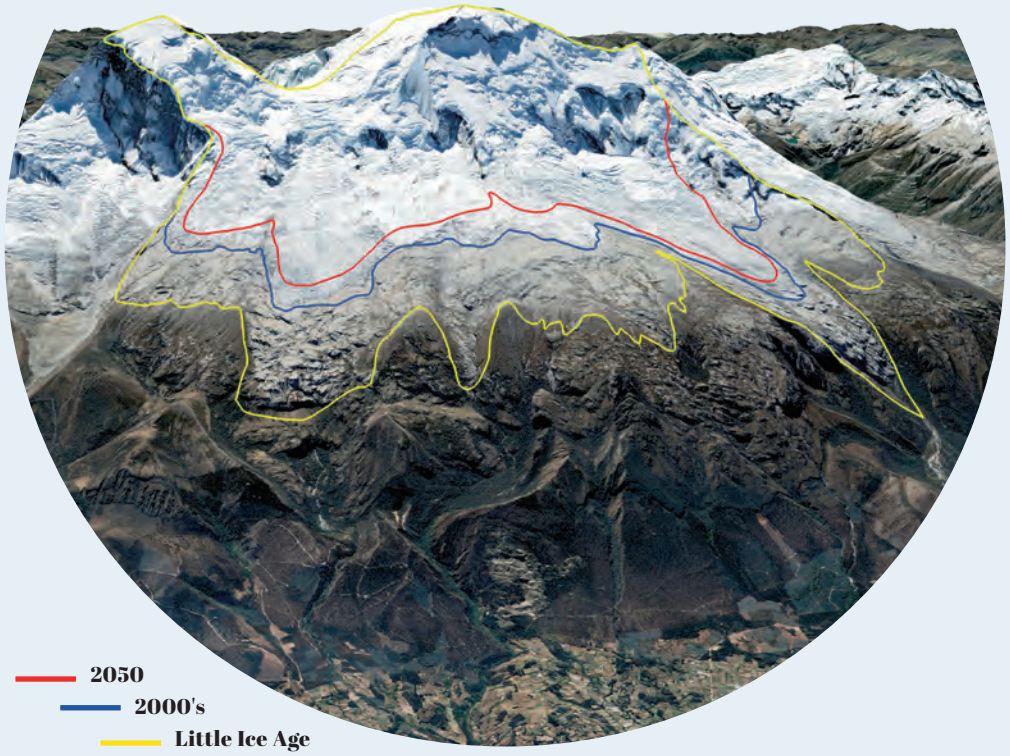
In the Ancash region, everyone knows of the devastating glacial lake flood in 1941 that killed over 5,000 people. Willian is convinced that the national park and local communities can play a role in reducing risks by slowing the melting of tropical glaciers in the Cordillera Blanca.

"We are working with communities and building capacity regarding fire prevention as a key strategy to reduce the melting of the glaciers. It is vitally important to reinforce the environmental awareness of every local inhabitant, since small actions can add up and multiply our contribution to the reduction of the global problem of climate change for humanity."

After a fire, the darkening effect of the deposition of dark organic matter on glaciers significantly reduces the albedo, or the sun radiation reflected by a surface, with the result of surface warming. Reducing local and regional fire frequency and intensity is thus key to slowing tropical glacier melt.

Willian is also concerned by the limited progress in the region on other fronts related to climate change: *"There are many studies, but very few actions on the ground to reduce glacier loss and to adapt to impacts."* As an example, he refers to *Pseudomonas syringae*, a bacteria that can enhance precipitation in the form of snow and is used in Western countries to produce artificial snow, but of which no applications have been developed in the region. *"Only if the efforts of public and private institutions and civil society are structured within the framework of good territorial management and good governance will we see significant changes to improve our environment."*

I also met Selwyn Valverde, an engineer for the national park, who shared his admiration for Antonio Raimondi, an Italian-Peruvian naturalist and explorer whose work in the second half of the 19th century helped to characterise Peru's ecosystems. Selwyn is concerned by the glacier retreat he has observed in his lifetime. Yet despite the grim projections of future tropical glacier loss, he, like Willian, is determined to do what he can to protect the mountains. *"I will continue to protect the national park and its mountains until the last remaining bit of ice"* he pledges.



Raimondi Central and South glaciers, Huascarán

Peru

Huascarán National Park, a UNESCO World Heritage site and Biosphere Reserve, is named after its highest peak (6,768 m). The western slopes of the Huascarán are the site of the Raimondi glaciers, named after the Italian naturalist who explored the valley in the mid-19th century. His name was also given to a famous local plant: the *Puya raimondii*, also known as the Queen of the Andes. The Don Bosco Huascarán refuge is the base for those planning to climb this giant of the Andes, or who simply want to take in the 3,400-sq-km protected area of the park. (*Google Earth Satellite image from* 2023)

Gladys Huerta

Alejandro Cruz

WELCOMING NEW ECOSYSTEMS

Alejandro Cruz Salvador is a farmer, livestock herder and father who lives in the sub-watershed of Río Negro in the Cordillera Blanca of Peru. He is the president of the Llama 2000 Association in the village of Canrey Chico (3,500 m). Gladys Huerta Rojas is a single mother of two children who tends crops and cares for her livestock. Both are living on land threatened by climate change. In the face of this urgent global challenge, Alejandro, Gladys and their Quechua community illustrate the determination and perseverance of the human spirit to find a way forward.

Herding llamas towards the glacier to accelerate the development of new ecosystems in the high Andes of Peru.

© A. Zimmer

Peru's Cordillera Blanca, the world's most extensively glacier-covered tropical mountain range, is on the frontline of climate change. Over the years, ice loss has created emergencies ranging from glacial lake outburst floods to drought to landslides to water contamination.

The sub-watershed of Río Negro ("Black River") has not been spared by the consequences of climate change. As we sit on a rock looking at the Uruashraju glacier and the land it is revealing as it retreats, Alejandro, who now is 73, recounts:

"*Our parents, our grandparents, used to raise* chusca *[breedless] cattle in the Pumahuacanca* quebrada *[mountain stream]. The valley was beautiful, and the stream had crystalline water. Now the water our animals drink and with which we irrigate our pastures is contaminated with iron, lead, cadmium, chromium and arsenic. The elders used to drink and wash clothes with water from the glacier. Now we can't use it for human consumption, our clothes turn yellow, and trout have disappeared.*"

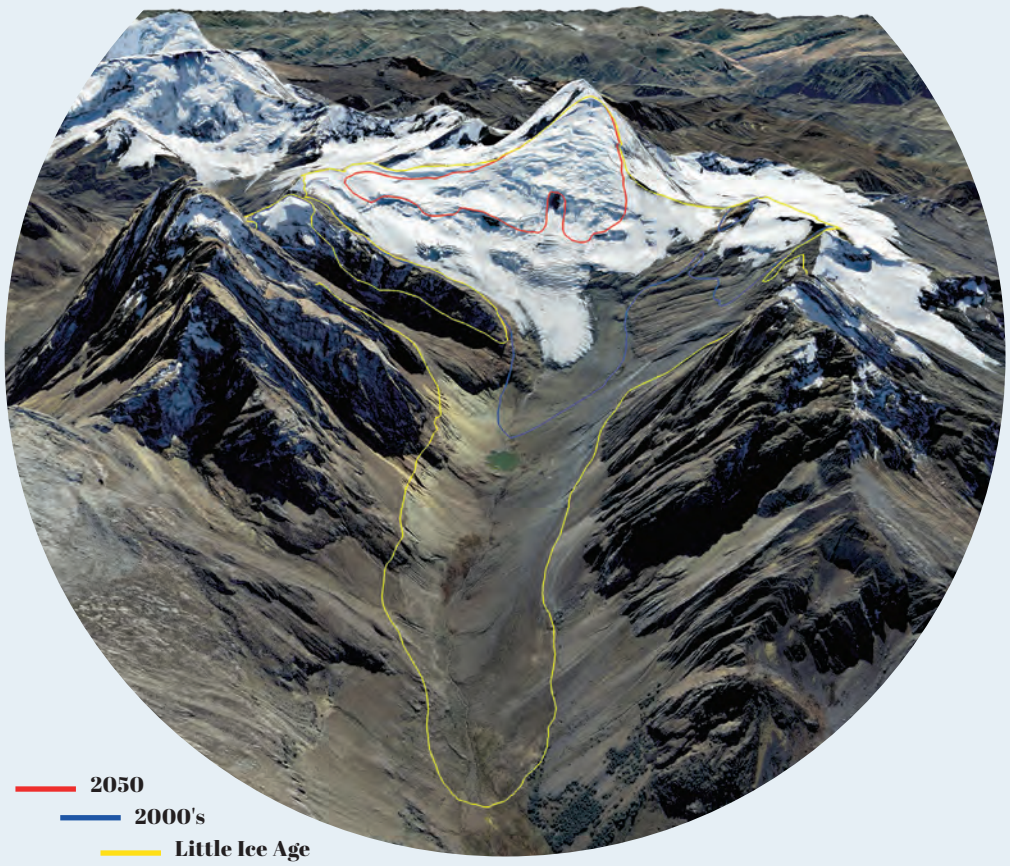
He shows me where the glacier was when he was a child, and points out the large, yellowish proglacial lake that did not exist in 1980. "*The contamination comes from the glacier retreat. Now I see the water coming out pure black, pure yellow. All the quebradas are contaminated here: Pumahuacanca, Araranca, Yanashallash and Quillon, contaminating the Río Santa.*" When the glacier melts, it exposes sulphide-rich pyrite, previously covered by the ice, to oxidation. This phenomenon, called acid rock drainage, poses a threat to water security in numerous valleys of the Cordillera Blanca.

Gladys, who is 40 and part of the next generation, also bears witness to these changes. "*When I was little, things were very different. We had more rain and it was colder.*" She worries tourists will no longer visit the mountains if there is no snow. Although the glaciers are still here today, Alejandro, Gladys and their community deeply fear a future without them. "*These are important issues for our children: where is their water going to come from in 10–15 years? All the snow is going to disappear, and what can we do? We cannot say goodbye to glaciers.*"

In June 2019, while hiking up to the land uncovered by the retreating Uruashraju glacier to conduct plant surveys we discussed vegetation colonisation challenges with Alejandro. This prompted Alejandro to suggest an unconventional solution to favour ecosystem development: bringing llamas to fertilise the soil with their dung. He belongs to the Llama 2000 Association, which aims to promote the sustainable management of llamas and vicuñas to develop community-based tourism along the Qhapaq Ñan trail, enhance the local economy, and develop climate change adaptation strategies. Within this context, the association collaborated with our scientific team to set up a llama inclusion experiment at the foot of the glacier. "*The project is helping us develop our knowledge regarding the preservation of plant resources, and it motivates us to continue to learn management techniques as the glaciers retreat*" explains Alejandro. For five years, Alejandro and other members of the association have led this experiment grazing llamas on deglaciated land and caring for them daily.

Sitting on our rock overlooking the landscape, Alejandro suggests another collaborative study: "*Without the glacier, life disappears. We must find solutions—perhaps by planting* queñuales (*Polylepis*) *to sustain water for future generations.*"

For Alejandro and Gladys's community, the impacts of global warming are visceral, dramatic and immediate. But they are taking steps to blend ancestral and scientific knowledge to cope with climate change.



Uruashraju glacier

Peru

The name Uruashraju probably comes from the Quechua *urwa* (“infertile”, “sterile”) and *rahu* (“snow-covered mountain”). The land freed up by the retreat of glaciers is poor in organic matter and not very conducive to the development of vegetation. An experiment conducted over several years by a team of international researchers in conjunction with Huascarán National Park on the deglaciated zone of the Uruashraju glacier (5,722 m) has shown that the presence of llamas and the effects of grazing, trampling and defecation boost the soil’s organic carbon and nitrogen content, significantly improving substrate fertility and the growth of plants. (*Google Earth Satellite image from* 2023)

Mattias Borg Rasmussen

A VIEW FROM THE SOCIAL SCIENCES

Mattias Borg Rasmussen is an associate professor in anthropology at the University of Copenhagen. He is interested in rural livelihoods, identity politics and resource conflicts from a qualitative, ethnographic perspective. His research focuses on the intersection between local territorial control, externally driven demands on resources, and community conflict and cooperation. He has worked extensively with communities in high mountain areas in Peru.

A group of farmers in Peru's Cordillera Negra (Black range) separating grain from straw, with the Cordillera Blanca in the background.

I wanted to talk to Mattias Borg Rasmussen because he is one of the few scientists that have engaged intensively with local communities in high mountain areas in the tropics to research aspects of identity, politics and livelihoods. Traditionally, the human dimensions of climate change have received far less attention than the biophysical ones, although this is now beginning to change.

Referring to an initiative in Peru that has opened an educational trail to the Pastoruri glacier to see the effects of climate change (the Climate Change Route), Mattias says, "*Climate change generates a new form of visibility for local communities, and in some areas, new forms of investment. However, these investment streams are not controlled by local communities, but by others who decide how this money should be spent.*" He explains how the Pastoruri glacier was a very important tourist destination in Peru in the 1980s–1990s. Being highly accessible by car, people would drive in and out in a day to ski or to sled. However, Mattias points out, most of the revenues then went to the Huascarán National Park, established in 1975; individuals in local communities only made small amounts from selling food or other products.

This situation reflects historical environmental injustices that have happened worldwide in the creation of national parks. Often established in a top-down approach, protected areas have sometimes displaced local communities and restricted their customary rights over the land. This explains protests such as the one in Peru in 2001, when locals who considered they were not receiving a fair amount of the revenues made in their ancestral territory blocked the entrance to the Pastoruri glacier. Years later, as the place lost its attraction to tourists with the retreat of the glacier, a decision was made to turn the loss into an opportunity to raise awareness. In 2014, the Climate Change Route and a museum were opened to explain the changes to visitors.

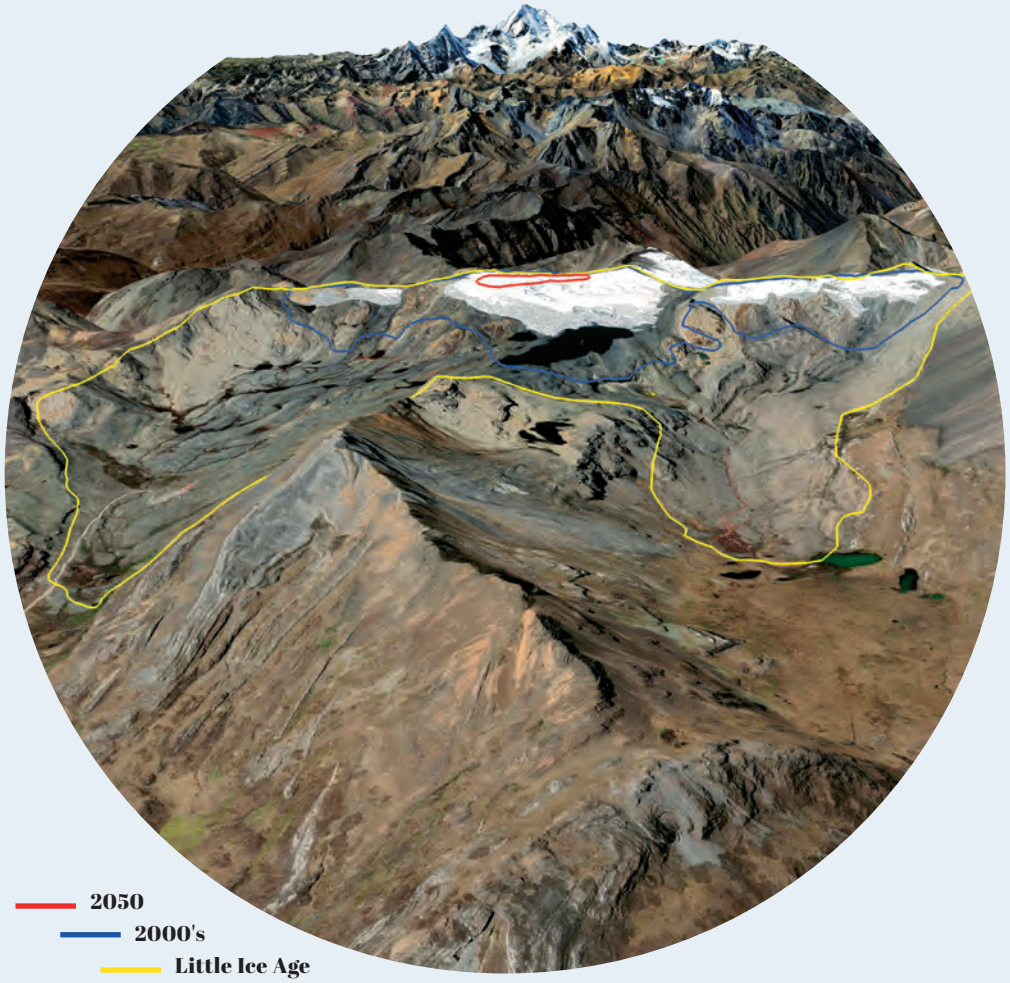
"*Although the establishment and governance of the Climate Change Route is not a radical departure from previous environmental injustices, it is a step in the right direction,*" allows Mattias. It has enabled encounters and meetings and a more open approach, all of which are fundamental in environmental management and, according to a number of studies, increase its effectiveness. Mattias adds:

"*Locals who I talk to are not against conservation at all. They think it's a good idea. But they are against being told what to do in their own home, which includes the mountains. They have a much more relational engagement with the landscape, which is not instrumentalised. Their feeling is that this relationship is not respected when someone from the outside tells you what you can and cannot do.*"

As these types of conflicts are often present in environmental management, it is important to make them explicit.

Has the Climate Change Route had an effect on visitors' awareness of climate change? Mattias says that it offers visitors an opportunity to engage with the impacts of climate change, but that awareness finally depends on the guides and the visitors themselves.

"*Glaciers are a very tangible icon of climate change that people can relate to. Local communities are deeply saddened about witnessing the retreat of glaciers within their lifetime. Some, who are evangelical Christians, see it as a sign of the end of the world. Despite diverse interpretations, people try to make sense of what they see. For local people, there is a big sense of loss that has a longer history, because they have been living with grief and loss for many, many years [around five centuries], and now they see glacier loss threatening their life in many new ways.*"



Pastoruri glacier

Peru

The Pastoruri glacier (5,250 m) is one of the most visited sites in the Cordillera Blanca. From the parking lot and visitor's centre, a path called the Climate Change Route takes less than an hour to reach the edge of the glacier. Signs along the way provide information on the evolution of glaciers, including the past positions of the glacier terminus. The glacier is at a relatively low altitude for the tropics, so little ice is expected to remain by 2050. *(Google Earth Satellite image from 2019)*

John Supuk

A MAASAI PASTORALIST'S CRUSADE TO ADAPT

The chief of a small community of Maasai pastoralists, John Supuk lives in southern Kenya some 100 m from the boundary of Amboseli National Park and just to the north of Mount Kilimanjaro in Tanzania. His community maintains the traditional subsistence livelihood of Maasai pastoralists, tending cows, goats and sheep that are used for milk, blood and meat. In recent years, this community has had to adapt to multiple societal and environmental changes. In response, the community is diversifying. John Supuk has led the challenge to come up with ways to supplement pastoralism, such as growing vegetables, beekeeping, grazing management and diverse employment and tourism activities via extended family networks.

John Supuk looks at the beehives he has put in place to diversify his livelihood to adapt to climate change.

"I myself have seen that Kilimanjaro is living."

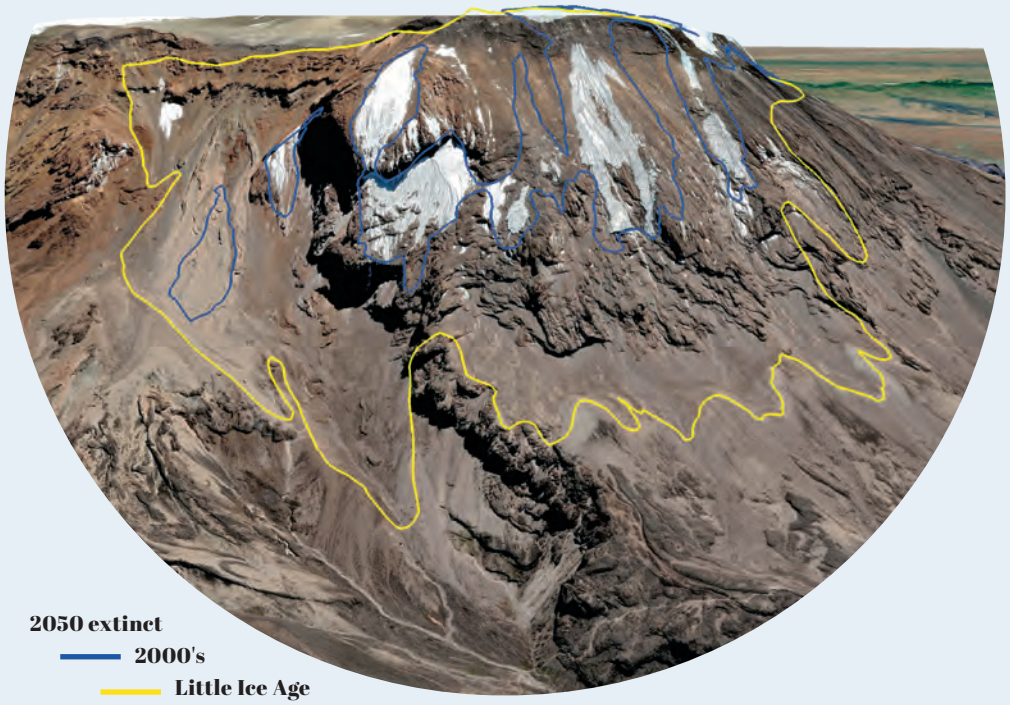
I met John Supuk some 15 years ago during one of my trips to Kenya to research the environmental history of the Amboseli basin with the National Museums of Kenya. The chance meeting, countless cups of sugar-ladened tea and plates of meat later, developed into a close friendship. Over the years I have learned much from John and his community about the realities of living near a national park undergoing profound social, political and environmental change. The Maasai call Kilimanjaro "White Mountain" and consider it of great beauty. In their traditional knowledge, its glacier is protected by the forests, and the glacier protects the mountain, which used to bring the rain. Now things have changed. "*When I was a very small boy, there used to be lots more trees, glaciers covered the mountain, and we used to have flowing water and swamps. Now the forest has gone and there is no sight of water like in the past*," John relates.

Driven by lack of opportunities, agriculturalist communities burn the forest to clear the land for agriculture. These local pressures come on top of global ones such as climate change, which is making glaciers retreat across the planet. Locals are very aware of these changes. "*Something is wrong somewhere. Our environment is changing. The glacier is shrinking. This is because of the pollution of the air, because of industrial activity... the large human population is becoming a threat to the glacier. I really fear these things*." John recalls previous times when ice, snow and water gave the mountain a changing, living aspect.

"*I myself have seen that Kilimanjaro is living. I've seen that it's like a creature, an animal, because it seems like it's moving; sometimes it's there and then not there, because of the clouds. I would like the glacier to come back. We don't want to lose it. It's so sad when we look at it and know we're losing it. We see the change, but we don't know what the problem is and what is going to happen*."

A major consequence of climate change in the region is drought. Droughts driven by global warming are affecting many parts of the world, but its consequences for vulnerable African pastoralists are dire. As John puts it, "*When it's not raining, we have drought. When the mountain gets hot and there is no snow, many people die while looking for water for their animals. They go round and round, losing energy walking with their animals, and die because of hunger*."

While grazing practices were adapted to the environment for many centuries, now deforestation and climate change are making them unsuitable. "*Pastoralists like us couldn't farm here because the land wasn't good. Now we're having problems with drought and our animals die*," John laments. Yet the local communities are taking action to try to bring the trees back and diversify their economies. The activities they have launched include beekeeping, growing vegetables within *boma* (livestock enclosures made from thorny acacia branches), tree planting, installing water tanks for drought resilience, locally managing the landscape with grazing banks, engaging in tourism activities, and supporting education and opportunities for youth through a Green Ambassadors programme. John and his community are not passively resigned to the challenges ahead, but are doing what they can with what they have. However, these local solutions and adaptations need national and international support to continue and to spread.



Mount Kilimanjaro glaciers

Tanzania

Mount Kilimanjaro (5,892 m) is called "White Mountain" by the Maasai. Its ice cover is in serious danger of becoming a thing of the past in just a few decades. The springs and streams running down the mountain's slopes, which are still partly fed by melting snow and glaciers, will soon depend solely on precipitation. This hydrological change will affect vegetation and pastoral practices on the mountain slopes, as well as the Maasai's traditional way of life. (*Google Earth Satellite image from* 2017)

Mountain guides in Uganda

AN INSIDER'S VIEW OF GLACIERS

Ochora Charles and Enock Bwanbale are head guides for Rwenzori Trekking Services, leading tours in the Rwenzori Mountains National Park in Uganda. Established in 1991, the park was declared a UNESCO World Heritage site in 1994 for its outstanding natural beauty and biological diversity. It is the only source of glacier meltwater to the River Nile. Joseph Mutinda is a former guide in the park and is now tourism warden for the Uganda Wildlife Authority. All participated in reequipping the main ascent route to Margherita Peak on Mount Stanley after it was closed due to a crevasse. Ignacio Palomo joined Ochora and Enock to open a new rock-climbing route in 2024.

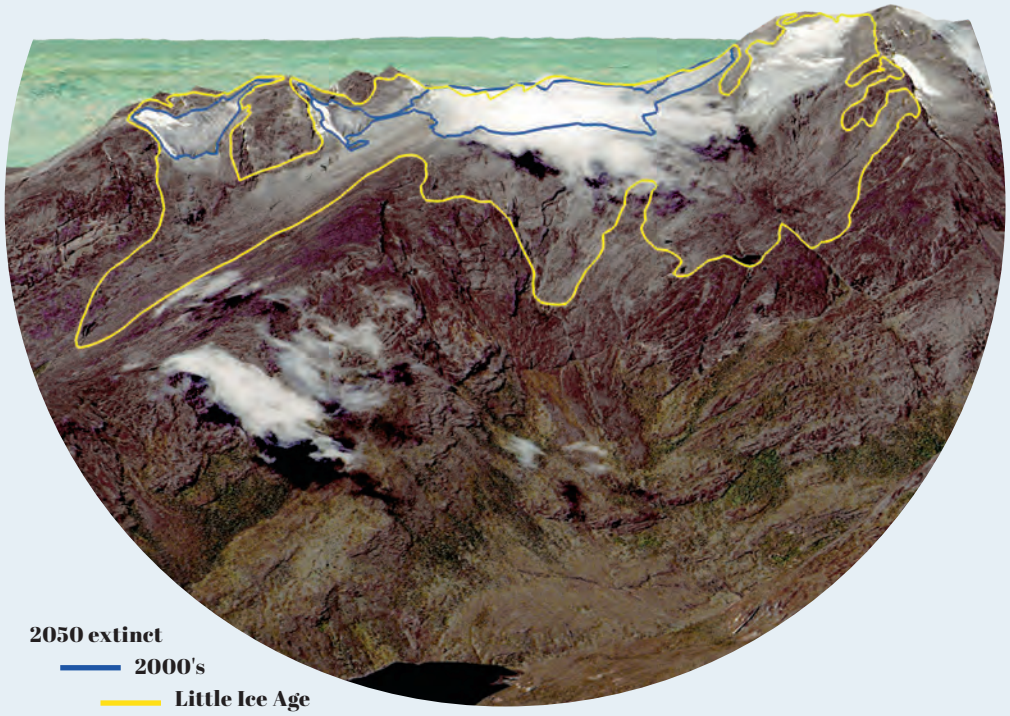
Ochora Charles climbs the second pitch of the Olhukuka route, a new climbing route to Margherita Peak opened in 2024.

I could barely believe it when Ochora Charles mentioned his record ascent: such a quick time! A trek from Muganga to Margherita Peak and back that usually takes seven days for experienced, fit trekkers was accomplished in 14 hours and 17 minutes. Maybe I shouldn't have been surprised. Before that record, Ochora had climbed five peaks between 4,000–5,000 m (Weismann, Baker, Margherita, Albert and Speke) with all the distance between them and up and down from Kilembe gate (1,727 m) in a non-stop effort of 28 hours and 19 minutes. "*I wanted to do something crazy in my life, and when I was pursuing these records I thought perhaps this is it. My dream is to one day go to the Olympics*" Ochora explains. In a place where glaciers will soon be gone, reality marches on, with hopes, dreams and challenges looming more present than changes in the climate.

But what was I doing in Uganda? I was part of a special expedition that aimed to reopen the usual route on the glacier to Margherita Peak (this had been closed by the Uganda Wildlife Authority for safety reasons after a crevasse opened in an exposed section), as well as to open a new climbing route on rocky terrain. A team of five guides (Enock, Ochora, Remegio, Edyson and Yusam) and around 26 porters would bring us to the Cheptegei and Margherita Peaks. Discussing with the guides, they say that changes in the climbing route are today quite common. Not long ago, the glacierised Stanley Plateau was connected to the Alexandra and the Margherita glaciers, and reaching Margherita basically involved traversing the glacier. Today, these glaciers have lost so much ice that they are no longer connected. "*The route has been changed between 10 and 15 times*" explains Enock Bwanbale. Sometimes a ladder would be installed on the route, until the rock face became too big and a different route had to be set.

After the main glacier route was closed, John Hunwick, the director of Rwenzori Trekking Services, had the vision of opening a new climbing route on the exposed rock that would not be constantly affected by glacier retreat. "*At least we would have that option for clients wanting to summit Margherita in case the glacier route had to be changed*" he says. Enock, Ochora, Remegio and I would open this new climbing route (130 m, 4 pitches, climbing grade IV) on the west face of Margherita Peak (5,109 m). Although John suggested we give my name to the new route, I felt it should have a name related to climate change, in the local language. In a discussion with my climbing partners, Enock came up with the name "Olhukuka route" (*olhukuka* means "rockface").

When I talked to Joseph Muhindo, a former guide and now tourism warden for the Uganda Wildlife Authority about how glacier loss will affect tourism, he answered: "*Climate change is a failure of the international community, but Margherita Peak will remain the same at 5,109 m above sea level. People will continue to come to see where glaciers were*." One of his main concerns is ensuring that tourists (7,557 visitors came to the Rwenzori National Park in 2023) can continue to come and enjoy the "*botanical garden of Africa*", as he puts it. To this end, the authority is installing wooden boardwalks (to allow walking above the mud) and more sleeping capacity. Uganda's GDP per capita is less than 1,000 US dollars per year, similar to Rwanda or Ethiopia, and the country is lacking in sanitation, education and energy, making ecotourism a key area with economic potential as well as a priority for people working in the Rwenzori Mountains.



Mount Stanley glaciers

Uganda

During the Little Ice Age, the glaciers on Mount Stanley (5,109 m), the highest mountain in the Rwenzori Mountains National Park, a UNESCO World Heritage site, were connected to each other, forming a small ice cap. In the course of their retreat, they gradually became the individual glaciers of Coronation, Elena, East Stanley and Margherita. This progressive fragmentation is a major challenge for local guides; as the ice recedes it reveals rocks polished by glacial flow and scabrous escarpments, making access to the highest point, Margherita Peak, increasingly complex. (*Google Earth Satellite image from* 2014)

Walyuba Kule

GUARDIAN OF INDIGENOUS KNOWLEDGE

Walyuba Kule is an environmental advocate, traditional knowledge holder and culture enthusiast from Kasese in Uganda. He is the director of KIWA Heritage, a cultural centre and destination for visitors to Kasese that includes hot springs, a museum and a local brewery. As a child, his uncle, a spiritual leader, conducted sacrifices near the glaciers to restore the harmony between humans and nature in the Rwenzori Mountains and their valleys.

Ochora Charles, guide in the Rwenzori, looks over the canopy vegetation to spot wildlife.
© IRD/I. Palomo

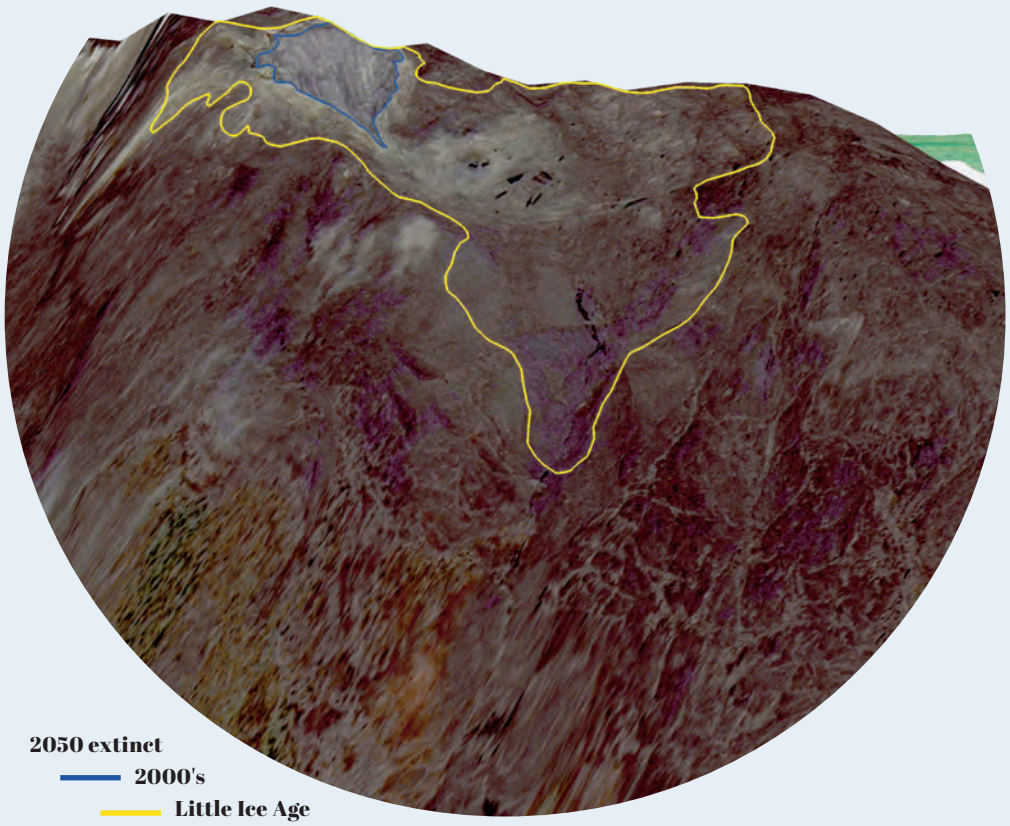
I met Walyuba Kule through a fortunate series of events. In the special expedition to reequip the route to Margherita Peak, our team was accompanied by Joseph Muhindo, a tourism warden for the Uganda Wildlife Authority, and a highly respected person in the region. When I mentioned that I would like to speak to an Indigenous knowledge holder to include his or her voice in this book, Joseph organised a meeting with Walyuba as a sign of gratitude for our small contribution to bringing more tourists to the mountains with the reopening of the climbing route. Walyuba was happy to share his knowledge about glaciers in this region: "*The glaciers in the past were no-go zones – activities were in the forests. Very few people were allowed to go up to the higher areas, essentially the priests, and the glaciers had to be left alone.*"

As a child, Walyuba accompanied his uncle, a traditional spiritual leader, to make offerings near the glaciers. "*Sacrifices were performed to bring harmony between gods and people and to maintain a peaceful land*" Walyuba explained. In the case of a miscarriage, an infestation of pests or a drought, for example, a message was sent to the gods by making offerings of bananas, sugarcane or eggs, or sometimes sacrificing a chicken. Today, the elders believe that sacrifices are not successful because society does not follow traditional rules. For example, people climb beyond the forest zone, something that is seen as impure by traditional elders. The arrival of Christianity has also contributed to the decline of rituals close to glaciers.

Walyuba is convinced of the continued importance of Indigenous knowledge. "*Before we had lots of don'ts, and nobody questioned them.*" For example, places close to rivers were forbidden for settlement. Leaders had to give permission to collect medicines from the forest. Once a medicinal plant was found – for example, close to a tree – only those between the person and the tree could be picked, and not all the plants surrounding the tree. If the advice was not followed, then the medicinal plant would lose its curing capacity. While science-based knowledge explains things differently, I cannot avoid thinking how right these cultural norms were in some sense. Their decline at a time when institutions are not effective enough to enforce sustainable development means that local communities are caught between a disappearing ancient world and a modern one that has not yet arrived. And this when climate change is increasing the frequency and magnitude of extreme events.

Walyuba explained that in the past, "*The glacier was seen as a seed that provided water, life – something like sperm. The elders did not know about the water cycle that we study in school, but they had ancient knowledge about how things worked in nature.*" The term *rwenzori* (the name of the nearby mountains) means "rainmaker" in the local language. Walyuba described how the volume of the Nyamwamba River has gone down considerably, and "*now it is either too small or too big*", referring to the alternating droughts and floods that have affected the area over the last 20 years. "*We think the glaciers are now smaller because our activities have got out of hand. If there are no longer sacrifices, how could glaciers remain the same?*"

I cannot help wondering about the seemingly implausible marriage between scientific and indigenous knowledge – that seems to have something to say to us in Rwenzori. In Walyuba's words: "*I think we need to combine spiritual and scientific knowledge to reach some harmony.*" The experiences and thoughts he has shared certainly leave me with the feeling of now having more questions than answers.



Edward glacier, Mount Baker

Uganda

Mount Baker (4,844 m), or Kivanja in the Konjo language, was one of three Rwenzori peaks to host glaciers during the Little Ice Age. The three peaks of Baker, Stanley and Speke form a triangle around the Bujuku valley, in the heart of the Rwenzori National Park, a UNESCO World Heritage site. Here, as in other parts of the world, the snow-capped peaks are sacred in traditional culture. These places were frequented only by select people who performed rituals involving offerings and animal sacrifices to maintain harmony between the gods and nature. (*Google Earth Satellite image from 2014*)

SADNESS AND LOSS

One of the most salient emotions in climate change literature, art and scholarship is sadness and grief for what is being lost. The emotional distress caused by negatively perceived environmental change has even given rise to a new term: "solastagia". Whereas "nostalgia" arises from missing a place one no longer inhabits, "solastagia" involves missing what no longer exists because it has changed. Some scholars have warned against using this term as it can obscure many other past–present processes and events impacting people's worlds and well-being outside of the biophysical impacts related to climate change. Moreover, the sole use of the term may not make room for myriad of other emotions, such as feelings of betrayal, deception and anger. In this section, we aim to give voice to the range of emotions linked to glacier loss.

Benjamín Morales Arnao

A LIFE DEDICATED TO GLACIERS

Benjamín Morales Arnao is a glaciologist and geologist who studied at the National Major University of San Marcos in Lima and the Federal Polytechnic School in Zurich. He began to research glaciers in Peru with the Peruvian Corporation of Santa in 1966 and has played a leading role in many public and private geo-environmental research institutions, including the Institute of Geology and Mining (1976), the Mining and Metallurgical Geological Institute (1979), the Institute of Glaciology and GeoEnvironment (1997), the Mountain Museum Project (2009, in development), and the National Research Institute for Glaciers and Mountain Ecosystems (2015). For 25 years, he has led prevention projects against glacial outburst floods in 34 lakes in the Cordillera Blanca, one of the largest and most successful of such programmes in the world.

PRIMERA EDICION

Expreso

DIARIO DE LA MAÑANA

AÑO II Director: JOSE ANTONIO ENCINAS P. LIMA, JUEVES 27 DE SETIEMBRE DE 1962 AÑO DE SAN MARTIN DE PORRAS N° 342

Dramática revelación de científicos

DANTESCO ALUD AMENAZA YUNGAY

LOS MONTARISTAS y científicos norteamericanos David Bernays (con sombrero) y Charles Sawyer (con lentes), regresaron a Yungay después de permanecer 3 semanas a más de 6 mil metros de altura en el nevado El Huascarán. Allí estudiaron el glaciar de donde se desprendió el alud q' sepultó Ranrahirca.

SERIA 3 VECES MAYOR QUE EL DE RANRAHIRCA

YUNGAY, Setiembre 26 (EXPRESO). — El "Techo del Mundo" se ha convertido en un peligro mortal. Un alud cuyas dimensiones triplicarían el que arrasó al distrito de Ranrahirca, pende como una "espada de Damocles" sobre las ciudades de Yungay, Mancos y el lugar donde se está reedificando el pueblo desaparecido.

El peligro lo originan las rocas cuarteadas, que se encuentran a más de seis mil metros de altura sobre el Huascarán, en el glacial 511. Fue de este lugar de donde se desprendió la masa que sepultó Ranrahirca en enero del año pasado, originando 4,000 muertes.

Esta dramática revelación la hicieron ayer a EXPRESO, los alpinistas norteamericanos David Bernays y Charles Sawyer, quienes llegaron anoche después de estar a 6,200 metros de altura estudiando durante tres semanas el glacial 511 de la Cordillera Blanca. Sólo les faltó 450 metros para alcanzar la cima del pico Norte del Huascarán, n la que se dirigían por la ruta más peligrosa: Llanganuco.

Los escaladores fueron declarados en emergencia desde el 19 último, cuando durante cuatro días dejaron de transmitir las señales de luces convenidas. Recién se tuvo noticias de ellos cuando una expedición salió en su búsqueda.

(PASA A LA PAG. 4)

28

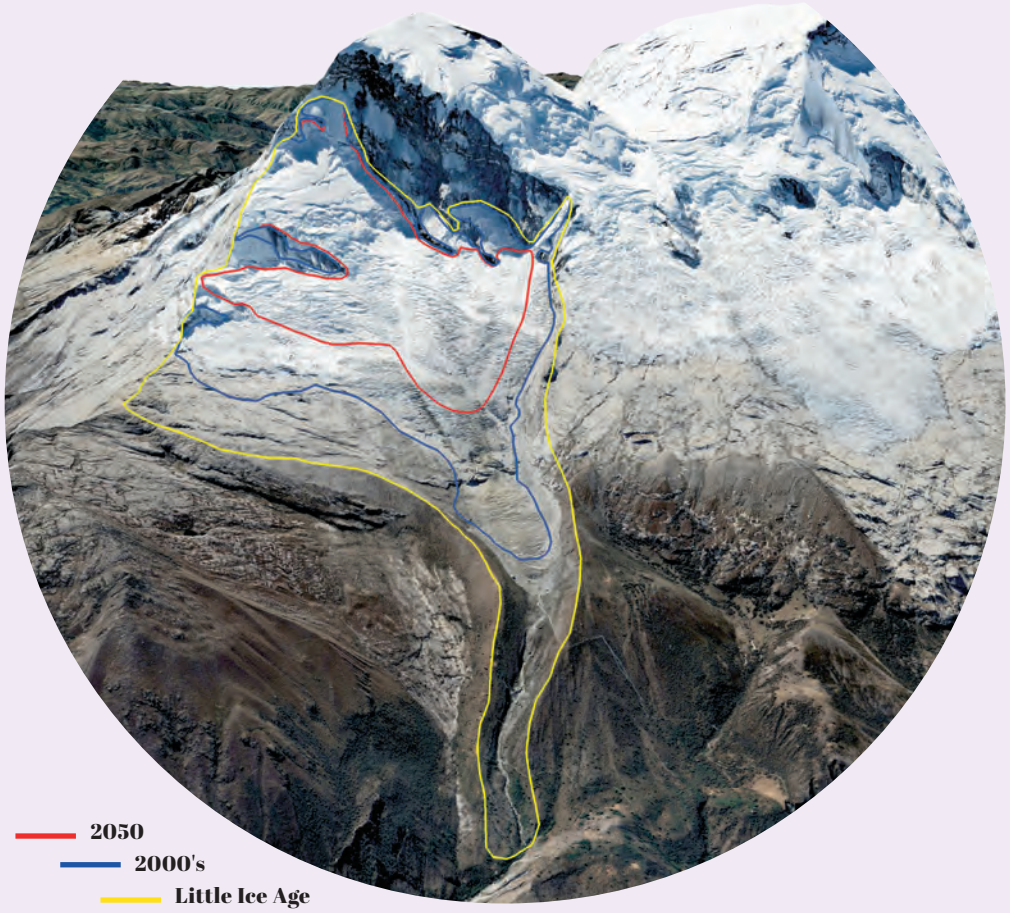
Photocollage of the Yungay earthquake disaster that claimed the lifes of several thousands of people in Peru. At the time, the scientists' warning of the potential threat "Dantesque avalanche threatens Yungay" which took place just eight years later, was left unheard.

© Left: C. Sawyer; Center: Expreso, 27 September 1962; Right: C. Sawyer.

On Sunday morning, 31 May 1970, Benjamín Morales Arnao started his day in his hometown of Huaraz with competing events on his calendar. The previous day he had met briefly with Mateo Casaverde, a geologist with the Peruvian Geophysical Institute, and a French geologist, and they planned to reconvene about a glacial lake safety project above the city. In addition, Benjamín had been invited to attend the opening of a new sporting complex since he was an avid ping-pong player. However, he decided instead to spend the day out of town with his family, which ultimately saved his life. An earthquake that very afternoon ravaged Huaraz, killing thousands of people, including 300 buried when the sports complex collapsed. Had Benjamín remained in town or been at the ceremony, he very likely would have been among the dead.

His plan was to drive down the main Santa River valley to Chancos, a popular destination for weekend day trips about 30 km north of Huaraz, to visit the hot springs of Chancos with his mother, brother and nephews. By the time they got to Yungay, it was already past 2:00 pm, so they stopped for lunch at Los Claveles, a popular restaurant serving typical dishes from the region. Inside, lots of other friends and colleagues from Huaraz were listening to the radio broadcast of the opening match of the World Cup in Mexico. Because Benjamín's mother had an appointment, they got up to leave at around 3:00 pm. Friends tried to persuade them to stay, offering to buy another round of drinks, but they resisted and headed out, stopping briefly for an ice cream in Yungay's lovely Plaza de Armas where they ran into Mateo Casaverde and the French geologist. At 3:10 pm they left the city, driving south. A mere 15 minutes later, the massive earthquake caused a rockfall-induced debris flow avalanche that would completely bury Yungay and other nearby villages. Miraculously, these series of circumstances saved Benjamín and his family (the geologists also narrowly survived the disaster by sheltering on the cemetery hill of Yungay). Today, Benjamín is approaching the age of 90, and a book he has written about his remarkable life and work to secure lakes from outburst floods will soon be published. I asked him how he feels about the accelerating loss of the glaciers now, and his resilient response is a call to action in the face of indifference: "*We must respond not with passive indifference, but action. We'll need to continue securing lakes, that remains important, but also work on creatively solving water supply and water quality issues. This will inevitably require a national programme of reservoirs, dams and even the use of desalinisation. We need many approaches, a portfolio of options, and we should not rely on just one approach.*"

"*Honestly, I do not feel hopeful about the immediate future given the passivity of people these days, as well as the corruption at higher levels of government. In the past, we have faced massive disruption and absolute societal instability. But we had good people. I have had the privilege of working with impressive and committed people, like Alcides Ames, for example. These days, there are imminent issues, like the dangerous levels of Lake Palcacocha, but a lack of reaction from the people. They act as if there is no danger, as if it is not even an issue. In this sense, things have really diminished in our societal fabric. Furthermore, the many looming geopolitical complications of the world today make actions harder to initiate locally.*"



Raimondi norte glacier, Huascarán

Peru

Huascarán National Park, a UNESCO World Heritage site and Biosphere Reserve, is home to the highest peak (6,768 m) in Peru and in the Amazon basin. The Huascarán peak was the source of the catastrophic 1970 rockfall and landslide, when a 7.8 magnitude earthquake sent an enormous quantity of ice and rock tumbling from its northern summit, generating a torrential flow that buried several villages and a large part of the town of Yungay. An estimated 6,000 people were killed, making this one of Peru's worst natural disasters in the 20th century. (*Google Earth Satellite image from* 2023)

Liz Macedo Flores

CARETAKER OF THE ISHINCA MOUNTAIN HUT

Liz Macedo Flores has been a caretaker for mountain huts in the Andes since 2014. She was born in the Cordillera Negra in the Centro Poblado de Atipayan and grew up in a rural environment. Being raised in the Cordillera Negra has made her very sensitive to changes in water availability, as farmers can only sow when rains arrive, once a year (in contrast to the Cordillera Blanca where sowing happens twice a year).

An alpinist walks towards the Ishinca hut, with the Toclaraju summit in the background.
© IRD/I. Palomo

"From the first time I opened my eyes, I saw glaciers reaching all the way down from the summits to the valleys."

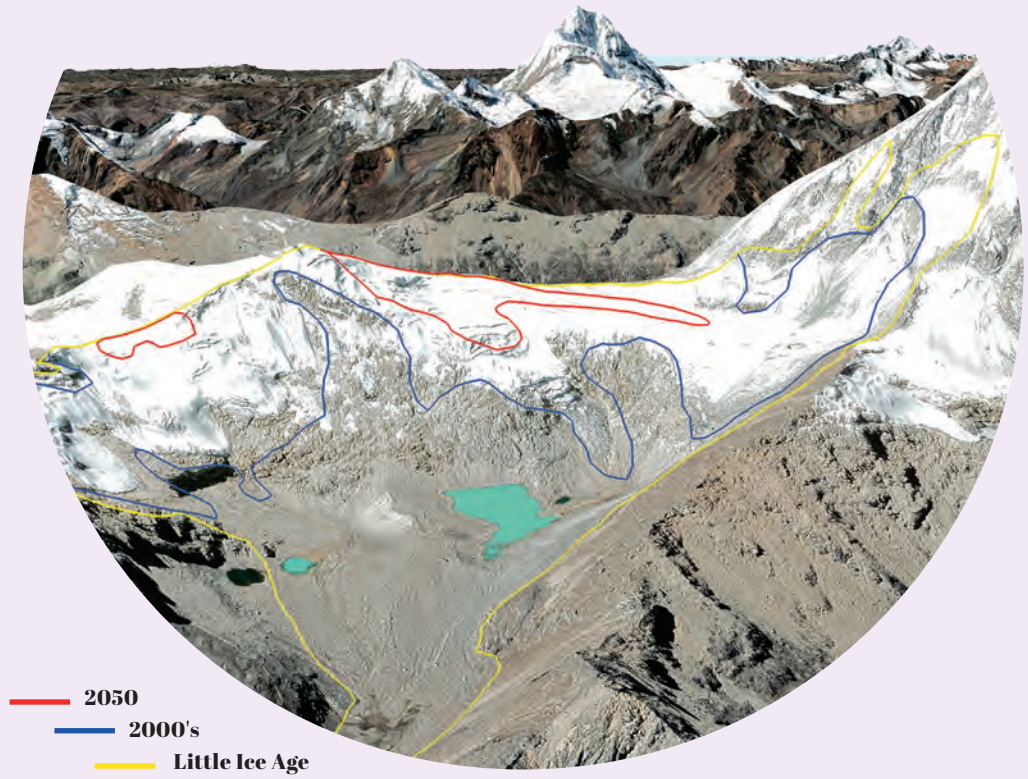
A life spent in the Andes has given Liz Macedo Flores a clear image of the changing landscape of glaciers. "*From the first time I opened my eyes, I saw glaciers reaching all the way down from the summits to the valleys. Since the 2000s, I can see how much the snow is retreating.*" She lives in the Cordillera Negra ("Black Range"), which is lower in altitude and has no glaciers, but she has a clear view of the Cordillera Blanca ("White Range"), where the rapid decline in snow is strikingly easy to observe.

Liz Macedo is a caretaker of the Ishinca mountain hut (4,350 m), located at the end of the Ishinca Valley, and close to popular climbing destinations including the peaks of Urus (5,495 m), Ishinca (5,530 m) and Tocllaraju (6,034 m). This puts her in a unique position to see how alpinism is being affected by climate change. As in other high mountains worldwide, climbing routes are being affected in the area and the routes need to be changed frequently. Crevasses are opening up and rockfall risk has increased, making mountain activities more dangerous. "*It fills me with sadness to know that in some years the Ishinca and Urus glaciers will disappear. Seeing the peaks without snow is like seeing them naked,*" she laments. From time to time, she hears the sound of ice falling and avalanches. "*It is as if the mountain is screaming. The roar of the falling ice makes me think Tocllaraju is crying for help.*"

Liz is also sad about the loss of cultural traditions in the mountains. "*Before, it was necessary to ask permission to climb the mountain,*" she says. "*Climbers used to offer coca leaves, beans and other things. But these practices are vanishing.*" Liz offers an analogy. "*To climb a mountain is to be carried on her back, and to reach the summit is to reach her heart. Climbers should show more respect for them.*"

The changes in glacier cover make it hard to be optimistic: Liz is worried about the future of the area as a tourist destination. When these summits lose their snow, she fears that fewer people will come to the hut. This would affect the entire economy of the valley: the mountain guides, the porters, the muleteers, the cooks, the taxi drivers. Nonetheless, Liz says she will continue to work in the Ishinca Valley no matter what happens, as she finds her work very fulfilling. "*I love working at the hut, there is no stress. I will always keep coming here.*"

The day after speaking to her, I rose at 3:00 am to climb the Urus peak with Hugo Deléglise, a postdoctoral researcher with whom I work at the French National Research Institute for Sustainable Development (IRD) on a research project about protected areas in Peru. Before we started, I threw some coca leaves on the ground as an offering for our climb. As we ascended the mountain, we felt privileged to be able to experience this beautiful landscape, but could not avoid thinking about the fragility of the glaciers around us.



Ishinca glacier

Peru

Nevado Ishinca (5,530 m) in Huascarán National Park, a UNESCO World Heritage site and Biosphere Reserve, is a secondary summit of the Cordillera Blanca. Very popular with Andes climbers for its easy access via the north ridge, its altitude allows acclimatisation before attempting higher ascents. All around it are magnificent peaks over 6,000 m: Tocllaraju, Ranrapalca and Ocshapalca. *(Google Earth Satellite image from 2023)*

Adolfo Mendoza

A LIFE ON HIGH

For more than 38 years, Adolfo Mendoza and his younger brother Samuel were in charge of the Bolivian Andean Club refuge and ski resort of Chacaltaya, the highest on Earth (5,400 m). Until 2009, when the ski area disappeared with the glacier, they spent weeks on the mountain operating the ski lift and attending to visitors at the alpine-style refuge. Adolfo still makes the trip up to Chacaltaya almost every day to open the hut to the few tourists who come to acclimatise to altitude or see where the glacier used to be.

Pair of photographs showing the last remnants of the glacier in Chacaltaya and the hut towards the left.

"Four decades ago we had a pretty massive glacier about 50 m thick. It had been thawing more or less since 1985. By 2006, there was almost nothing left."

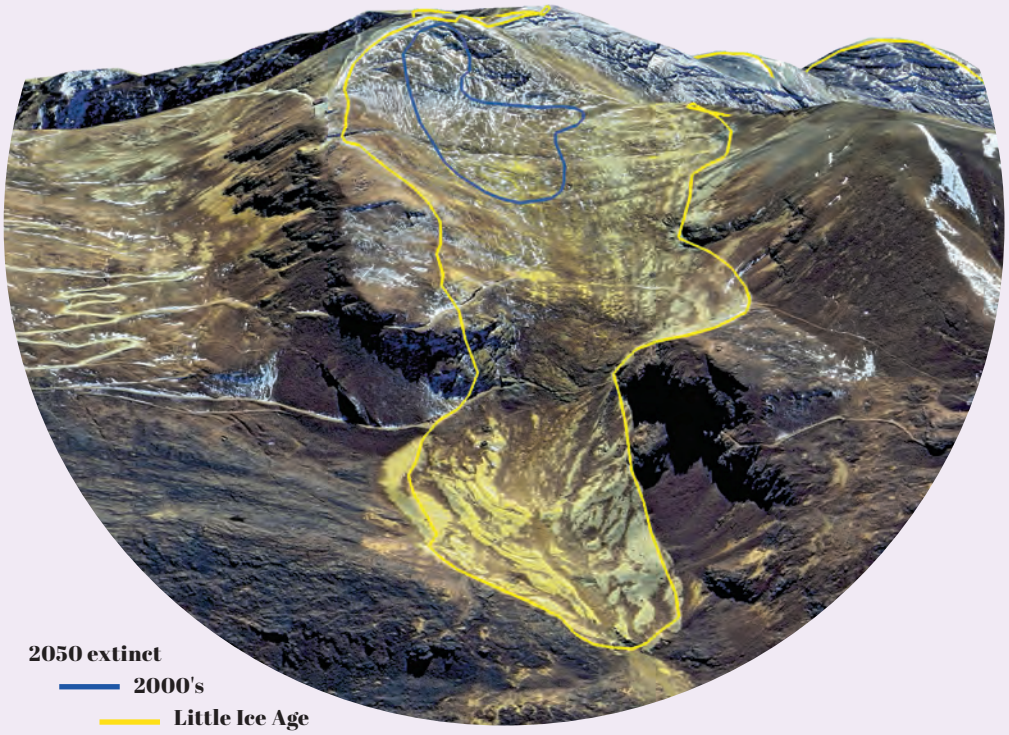
When I learned about the Epop platform (https://epop.network/en/), an international initiative that invites young people to film local testimonies about the effects of climate change, Chacaltaya immediately came to mind. In La Paz, everyone knows the tragic story of the Chacaltaya ski resort, only half an hour away from the city. When I was a child in the early 2000s, I often went there and enjoyed activities on a mountain that was snow-capped for a good part of the year. While I knew that since the last time I went the glacier had disappeared, I had never gone back there. I wanted to see the situation with my own eyes.

As I was driving towards Chacaltaya, I came across an elderly man slowly heading on foot in the same direction. I gave him a lift and soon realised that I had by chance crossed paths with someone who could be a voice in this story. Adolfo Mendoza had seen the Chacaltaya glacier disappear before his very eyes, and he knows the culprit: *"Climate change has affected us a lot. Four decades ago we had a pretty massive glacier about 50 m thick. It had been thawing more or less since 1985. By 2006, there was almost nothing left."*

Adolfo also knows that glacier melting is not the only way climate change is affecting the region. *"The entire population is affected by the shortage of water. In 10–15 years we may have no more water!"* Not only the quantity of precipitation has changed over the last decades, but its periodicity and predictability. *"This year, there was no sowing, as there normally would have been. Snowy seasons used to have certain dates, but this is changing. It starts warm, but at the same time it freezes. If it rains at the same time, there is frost. Climate change is very abrupt, and we can't anticipate it."*

He also worries about other types of damage to the mountains, such as plastic pollution: *"There is a lack of awareness and littering and rubbish everywhere. Education should start from school age, as early as possible."* He believes that education is key to changing certain behaviours. Then he announced a more active idea to revive Chacaltaya: *"We hope to relaunch skiing; installing snow-making cannons that take advantage of the meltwater we have at the refuge to bring the place back to life. It is still just a dream, but the project is being considered."*

My first reaction was that artificial snow would be a bad idea, from an energy and ecological perspective. Locally, this would only displace the problems, affecting natural water courses vital to local communities for their crops and animals. But seeing the dismay in his eyes and hearing his nostalgia for the past, I realised how deeply this man had been affected by the loss of what Chacaltaya had been, for the experiences he had loved in his life. He wanted the mountain to be as it was, full of children's laughter, the sound of skis on snow, the chatter of happy tourists.



Chacaltaya glacier

Bolivia

The Chacaltaya glacier once extended down the southern slope of Cerro Chacaltaya (5,400 m). Before its disappearance in 2009, it was the site of the highest ski area in the world, just an hour from La Paz. Next to the Bolivian Andean Club refuge, which receives far fewer visitors today, is one of the highest observatories in the world. The observatory measures cosmic particles coming from space, as well as the level of aerosols and gases present in the atmosphere. (*Google Earth Satellite image from* 2023)

Rosa Isela Meneses

DEEP CHILDHOOD CONNECTIONS

Rosa Isela Meneses is a Bolivian botanist who studies high mountain ecosystems. She was director of the National Herbarium of Bolivia and leads the Global Observation Research Initiative in Alpine Environments (GLORIA) in Bolivia, which aims to build indicators of climate-change-driven impacts on mountain biodiversity. She has authored over 70 publications, including the reference work Plants of the Cordillera Real, *which details the conservation status and traditional uses of Bolivian alpine plants by local communities. Aymara at heart, Rosa feels a vital connection with Pachamama ("Mother Earth"), in particular mountains, plants and glaciers.*

Rosa Isela Meneses identifying grasses in a *bofale* (wetland) in the Codillera Real in Bolivia.
© IRD/O. Dangles

"When choosing a place to live, one of the main factors was to be able to see at least a bit of Mount Illimani. It comforts me to see the mountains every day when I am in La Paz."

You learn more from one day in the field with Rosa than spending a month reading articles on tropical alpine plants. She literally carries a plant encyclopaedia in her head. Rosa has travelled to the most remote corners of the Bolivian highlands, taking a rigorous scientific approach to understanding the relationship between the different components of high Andean mountains (water, plants and people). Yet she retains a deeply affective bond with the ecosystems she studies. This intimate connection with nature, particularly with glaciers, has been forged since her early childhood.

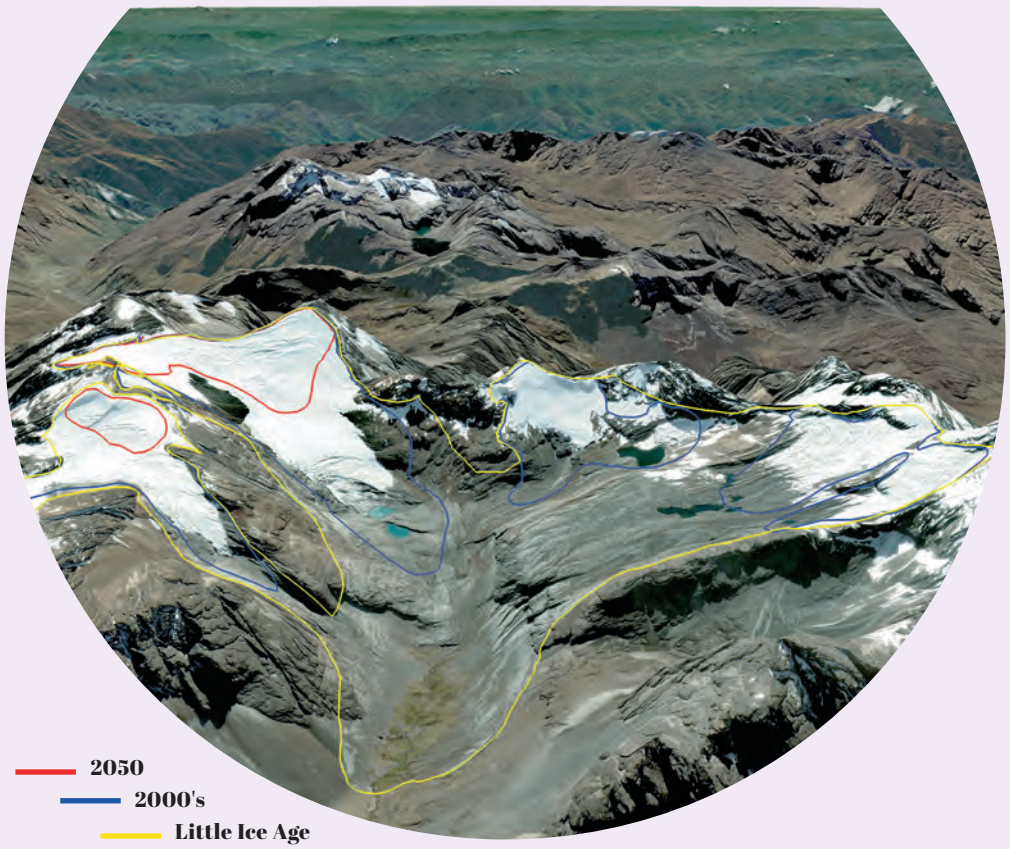
"*Glaciers are part of my life. The town where I grew up was supplied with water coming from glaciers, even if I could not see them. Sometimes my uncles took me to towns very close to Mount Illimani. It seemed so huge to me: imposing, invincible. I had heard that some people who tried to climb this mountain got lost and died; that is why we all felt respect for the glaciers. When I was 11, I came to La Paz and I could see Illimani and Mururata every day, and I liked that a lot.*"

Rosa has known since she was a girl how integral glaciers are in maintaining water cycles for people living in cities such as La Paz. Beyond this essential function, she considers glaciers an important element in her mental health and well-being.

"*When choosing a place to live, one of the main factors was to be able to see at least a bit of Mount Illimani. It comforts me to see the mountains every day when I am in La Paz. When I come back from a trip abroad, I love to see the Cordillera Real. I like to use the* gondolas (*cable cars*) *in the city: from up there I can see Illimani and Mururata. They make me feel better.*"

Rosa is deeply concerned by the rapid retreat of glaciers in the Bolivian cordillera: "*The glaciers are massively shrinking! I haven't seen a glacier disappear completely yet, but the snow on Illimani, Sajama, Mururata and Wila Lluxita is retreating a lot. It makes me very sad. The truth is that I can't imagine my city without glaciers.*"

She prefers not to think too far into the future. "*As a scientist working on glacier retreat, I know very well and can see how the mountains are losing their glaciers. I know that they will disappear in a few decades, but it is very hard for me to accept it.*" Has she ever thought about saying goodbye to tropical glaciers? She replies, "*To tell you the truth, I don't know how to do it. I'm not ready to do it.*" She says that she would still visit the mountains without glaciers, but not all mountains. "*I wouldn't go to Illimani. I have a special bond with this glacier. I don't think I'm ready to see the mountain without its ice.*" Not all glaciers are equal. Some are so meaningful to us that it is simply too sad to see them vanish.



Palcoco Valley glacier

Bolivia

The Palcoco Valley, in the heart of Bolivia's Cordillera Real, is unspoiled compared to the neighbouring valleys, which are much more accessible via roads built to access mining areas. The upper part of Palcoco Valley has remained untouched, with only a few herds of llamas grazing peacefully on the wetlands that have colonised the area following the gradual retreat of the glaciers. These features make it a popular place for ecologists to study the changes in biodiversity as the glaciers recede. (*Google Earth Satellite image from* 2022)

Marco Cruz

WHEN MAN AND MOUNTAIN BECOME ONE

Ecuadorian mountaineer Marco Cruz was born in 1945 in Riobamba, a city at the foot of Mount Chimborazo, Ecuador's highest mountain (6,263 m) and the closest point on Earth to the stars. In his treks, he has reached all the summits of Ecuador and the main peaks of South America, Asia, Africa, Oceania, North America, Iceland and Greenland. But his closest emotional and spiritual bond is with Chimborazo, where he has been a mountain guide over the last 50 years. Today, he lives at an altitude of over 4,000 m in a small lodge with a direct view of the impressive volcano.

View of Mount Chimborazo surrounded by stars at night
© S. Rodríguez

"When I was 10, they took me to see the ice; it was unreal, like a miracle."

More than 1,000 times: that is how many ascents Marco Cruz has made on Mount Chimborazo. I find it hard to believe, not because I doubt its veracity, but it just seems incredible. Like a modern-day Sisyphus, Marco has been relentlessly working his way up and down the various routes of this colossus, once considered the highest peak in the world, since he was 13, the age at which he reached the summit for the first time.

Since his youth, Marco had had a unique destiny with Chimborazo. *"When I was a kid, I used to see Chimborazo and its frozen summit from the city of Riobamba. My mother used to buy ice brought from there to make juice for us. It was something sacred; each sip was like a communion with the god Chimborazo. When I was 10, they took me to see the ice; it was unreal, like a miracle."* Twenty years later, Marco began to realise how glaciers were changing, and set about establishing a photographic archive of their rapid change.

"On Chimborazo during the last 25 years, I have witnessed how the tongues of all 18 glaciers have disappeared. In the last two years, the tongue of the Humboldt glacier was cut off from the rest of it. There is still ice at the bottom, but there is no connection with the top. Where it is melting, small lakes form and cause floods that come down with stones, debris and mud. Twice these landslides have reached the Pan-American Highway at the exit of Riobamba."

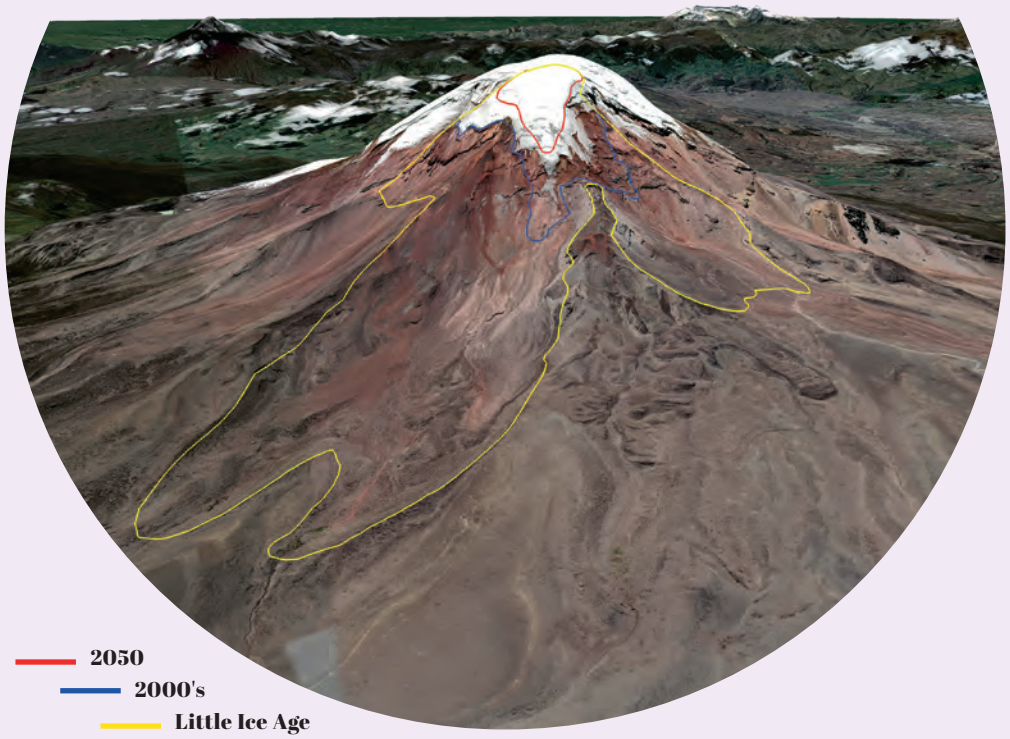
Marco paints a pessimistic picture of the glaciers' current situation. *"It is very sad. The glaciers are darkening, gradually dying, disappearing. The water comes out black and muddy; the ice of the permafrost is also melting. The ice used to be alive – moving, creaking, making sounds and breaking. But now these glaciers are dying, they are no longer alive."* What does he think about the funeral ceremonies for glaciers that are multiplying around the world as a way for people to express feelings of grief or guilt? Marco replies with a brittle tone:

"When the glacier is already dead, all these good intentions are useless. The Polytechnic University of Riobamba put a plaque on the Carihuairazo [a 5,000 m volcano just northeast of Chimborazo] to commemorate the glacier there. But we have to take action before the glaciers disappear, and also to change our attitudes. When the glacier is gone, it is already too late. What these people are doing seems very artificial to me; it doesn't seem very sincere."

Can Marco imagine Chimborazo without glaciers?

"Chimborazo's sublime grandeur is because of its ice. For the pre-Columbian peoples, this gigantic mountain that reached up to the sky was the origin of life, the origin of water. For us today, we drink water from a bottle or just turn on the tap. We don't realise how wonderful it is that this water, vital for all living things, comes from the heart of the mountain."

When all of Chimborazo's glaciers have disappeared, a bit of Marco's soul will be gone too.



Chimborazo glaciers

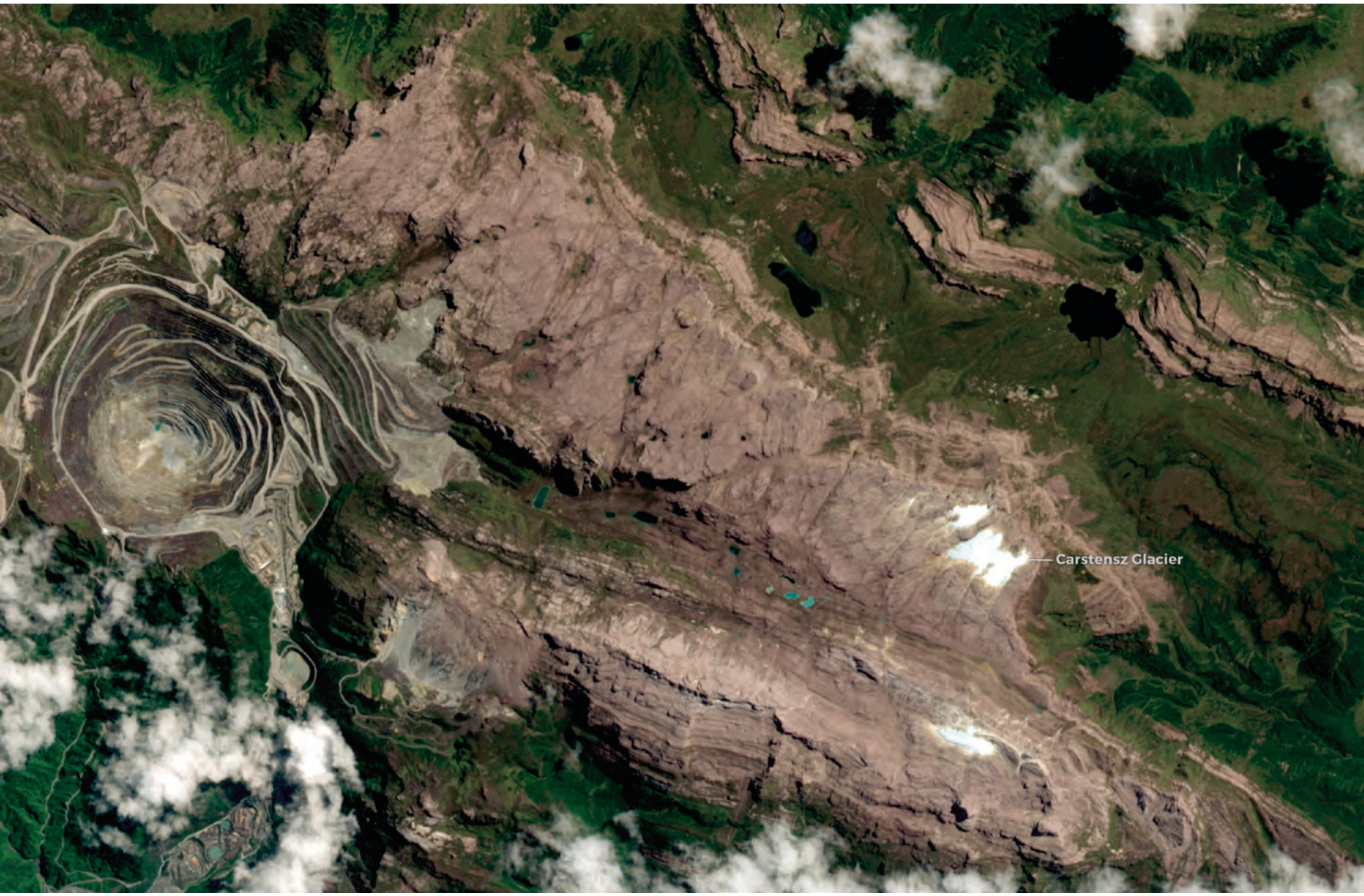
Ecuador

The top of *Taita* ("Father") Chimborazo (6,263 m) is the furthest point from the centre of the Earth. Along with Ecuador's other volcanoes, Cayambe, Antisana, Cotopaxi, Altar and Sangay, which reach heights of over 5,250 m, the summit of Chimborazo is covered by an ice cap. Following the explorations of the volcano's flanks in the 18th century by French academics led by La Condamine, and by Von Humboldt in the early 19th century, the English mountaineer Edward Whymper finally reached the summit in 1880. (*Google Earth Satellite image from* 2019)

Donaldi Permana

A GLACIOLOGIST IN INDONESIA

Donaldi Permana is a climate scientist working at the Indonesian Agency for Meteorology, Climatology and Geophysics (BMKG). He is documenting the disappearance of the last tropical glaciers in Papua, Indonesia, which lies within an area of tropical sea known by climatologists as the Western Pacific Warm Pool. He earned his PhD in 2015 from Ohio State University's School of Earth Sciences. As a student, he conducted field work along with an international research team on the high mountain glacier in Papua's Puncak Jaya peak in Lorentz National Park, a UNESCO World Heritage site, collecting ice cores to study the paleoclimate in the region. Today, he continues to monitor glacier changes in the Anthropocene.



Near Puncak Jaya in Papua, the Grasberg mine (on the left), one of the world's largest gold mines, adjacent to the Lorentz National Park, now dwarfs the country's last glacier located in the park (on the right), which is no longer connected, divided into East Northwall firn and Carstensz glacier.

"As a scientist, I feel that at least we are able to document the loss of these glaciers."

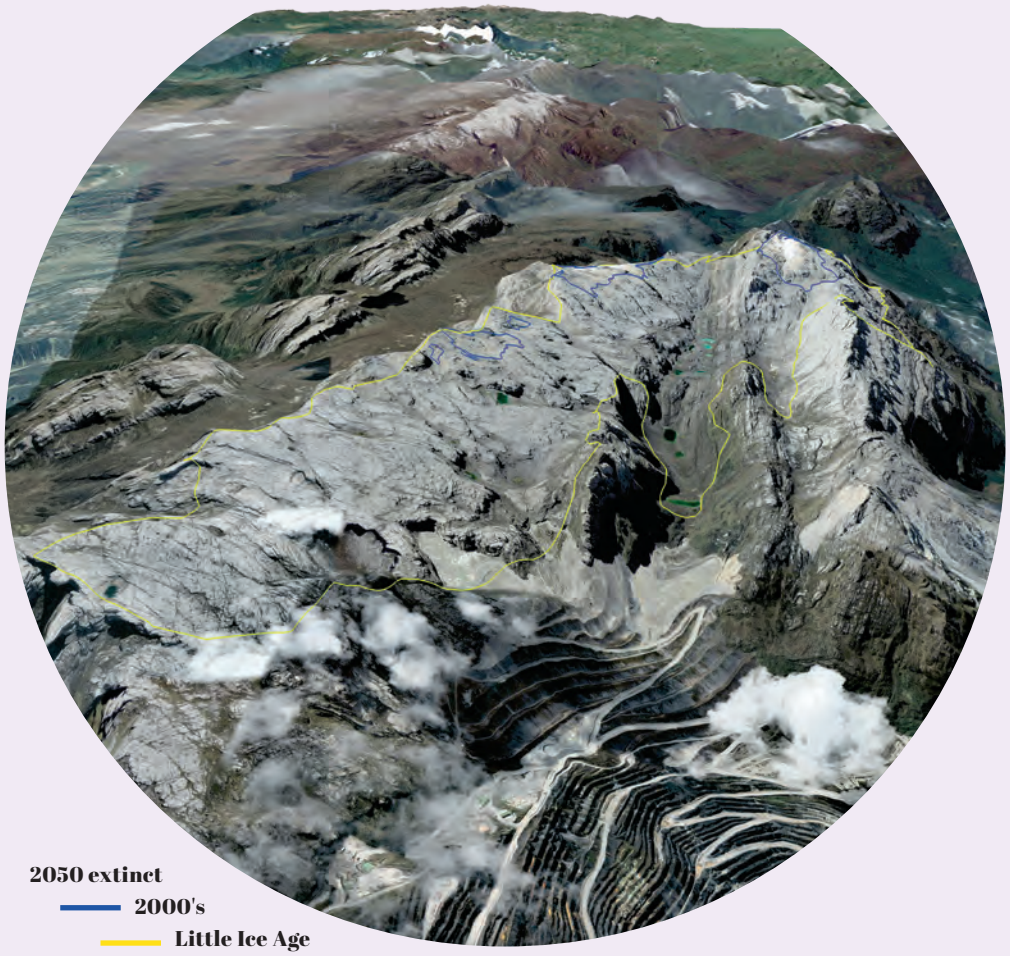
Donaldi Permana started to study the paleoclimate using ice cores from Indonesian glaciers in 2009. At the time, nobody was doing research on these glaciers and, a promising Master's student, he seized the opportunity. In 2019, he published a paper in the *Proceedings of the National Academy of Sciences of the United States of America*, a highly reputed academic journal, sharing the analysis of glacier surface area from 2002 to 2018. Glacier retreat had been so fast in those 17 years, partly due to the El Niño–Southern Oscillation (ENSO), that their disappearance was predicted as imminent. Even for someone very aware of the speed that glaciers are melting, it is still a shock to hear that these glaciers will vanish by 2026 or 2027. "*When I was a student in high school, these glaciers were called 'eternity glaciers,'*" says Donaldi, acknowledging the tragic irony.

Papua's Puncak Jaya peak in Lorentz National Park, a UNESCO World Heritage site, is also known as the Carstensz Pyramid, named after Dutch explorer Jan Carstenszoon, who reported sighting its glaciers in the 17th century. Like many others who reported the presence of glaciers in a tropical region in the 1600s, Carstenszoon was ridiculed in Europe for saying he had found snow near the equator.

Today, it is the longevity rather than the existence of the glacier that is in doubt. Studying it is a real challenge due to access issues and changing weather. Donaldi had to partner with a nearby Indonesian mining company for logistics to reach the glacier by helicopter. There are also security issues, and local communities inhabiting some of the land below the glacier have restricted access to their ancestral territories in the past. No studies have yet been published on these local communities and the glaciers. "*In terms of water provision, impacts of glacier loss on these communities won't be high, as it will be in South American countries in the dry season. Papua is very rainy and wet*," Donaldi explains. However, the cultural and spiritual impacts of glacier retreat on local communities have not been formally assessed. "*As a glaciologist, I would like to study impacts on these communities, but so far I have not been able to identify how.*"

What will Donaldi work on once the glaciers are gone? Looking to the future, he regrets that many people in Indonesia will only learn about these glaciers once they disappear. "*As a scientist, I feel that at least we are able to document the loss of these glaciers, which could provide lessons for other tropical countries that will soon face the same situation*" he says. He hopes that it will also be a call to climate action in non-tropical countries with larger glaciers that are also melting fast. Donaldi is planning to write a book about Indonesian glaciers and their disappearance to pay tribute to them and to raise awareness of their importance.

I met Donaldi online – one of the rare positives of the COVID-19 pandemic was the rise of virtual meetings, avoiding unnecessary travelling and the related carbon emissions. The loss of other tropical glaciers in the recent past such as Chacaltaya in Bolivia have received great attention. When the glaciers in Indonesia are gone, no tropical glaciers will remain in Asia. What we will learn from this call to action remains to be seen.



Carstensz glacier, Papua

Indonesia

Puncak Jaya (4,884 m) peak in Lorentz National Park, a UNESCO World Heritage site, is the highest point of the Maoke Mountains on the island of New Guinea and the highest peak in Indonesia and Oceania. Today, two small glaciers, including the Carstensz glacier, whose days are numbered, represent the last relics of an ice field that once covered several square kilometres of this limestone syncline. Exploration of this region came rather late, and the first ascent of Puncak Jaya was not made until the early 1960s.
(Google Earth Satellite image from 2022)

ACCEPT ANCE

An emotion that has received less attention in terms of climate change is acceptance. Apathy is much more commonly identified, yet this emotion tends to imply lack of concern or care. Acceptance moves past the nostalgia that comes with loss, or the frustration from feeling unable to stop the impacts of climate change. Rather than dwelling on circumstances that cannot be modified, or in a past–present that will no longer be, acceptance allows us to focus on what is and will be. Feelings of acceptance can help to redirect energy towards more attainable goals, while allowing us to continue finding beauty in places in transformation, accepting that change is also part of life.

Alvaro Soruco

A GLACIOLOGIST FIGHTING FOR RESOURCES

Alvaro Soruco is a professor in glaciology and hydrology at the Higher University of San Andrés in La Paz, Bolivia. In 2009, he obtained an award for best thesis from the French National Research Institute for Sustainable Development (IRD) on work he conducted at the University of Grenoble Alps, France. Since 2010, he has been Bolivia's National Correspondent for the World Glacier Monitoring Service. He also leads GLACIOCLIM monitoring of the country's Zongo glacier. He has published over 50 scientific articles and has participated in numerous conferences.

An ice core drilled from the Illimani glacier in the "Ice Memory" project, in which Alvaro Soruco participated.


ICE
MEMORY

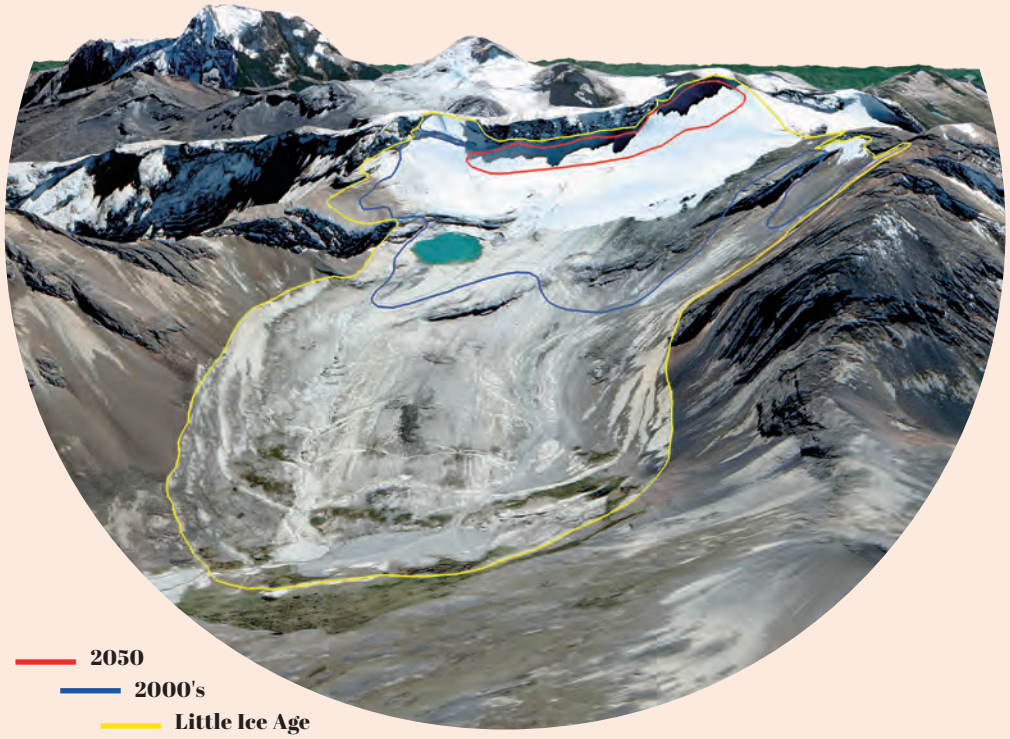
Since 2010, Alvaro has been leading, with very limited resources, glaciological monitoring in Bolivia. Of the Latin American countries containing tropical glaciers, this is the poorest, and the one with the largest extent of urban areas in the Andes. La Paz, with a population of 1.8 million, lies only a few kilometres away from several glaciers that provide it with water, particularly in the dry season. It seems worrying that the responsibility of assessing glacier change and its impacts on water availability for such a large population relies on a small, under resourced team, no matter how skilled it is.

Rather uncommonly for a glaciologist, Alvaro's first research aims focused on fossil fuel extraction. However, luck, as he puts it, led him to accept a Master's on glaciers and hydrology. In his view at the time, in such a poor country, it did not make much difference whether he worked on one topic or the other, as long as it allowed him to improve resources for the population.

As a young graduate, he obtained a grant to study French and do a PhD in France with the support of the IRD. During his doctoral work, he was able to quantify the contribution from glaciers to the water run-off that feeds La Paz: an annual average of 15% and as high as 27% in the dry season. After his postdoctoral work, he moved back to Bolivia to become a professor at the Higher University of San Andrés. "*It was the largest mistake I have ever made in my entire career*" he regrets, explaining how scarce research resources are in Bolivia. "*The university provides us with an annual research budget of 400 US dollars per project, which barely covers all the work we need to do*" Through his collaboration with the IRD, he is able to monitor the Zongo and Charquini glaciers, allowing a detailed analysis of glacier loss over the decades.

In 2017, he participated in the Ice Memory expedition on Mount Illimani, a research project in which ice cores were drilled in various glaciers around the world so they could be preserved for future study, using more advanced research methods and with different research questions. "*At Illimani, we were able to drill to a depth of 180 m, which allowed us to reconstruct the climate of the last 18,000 years*" explains Alvaro. Despite the global interest of such projects, funding them is not easy. A big part of the costs included paying local porters to carry metre upon metre of drilled ice cores down the mountain.

When I ask Alvaro how he feels about tropical glacier loss, he answers that he likens it to being a forensic pathologist. "*At the beginning, I was impacted by witnessing all these rapid changes. Now I am used to them, although it is still frustrating*" he says. As a geologist, his experience of tropical glacier loss differs from other glaciologists who may have a more short-term understanding of this process. "*Geologists understand the magnitude of time. We have had periods in history without glaciers, and other periods with vast glaciers. Tropical glacier loss would have a positive side if it at least raised awareness regarding the major environmental destruction we are causing.*" Alvaro is concerned about all of what scientists call direct drivers of change, which include deforestation and pollution. With his long view into the past, he has on his mind the five major global extinctions that have happened so far in our planet's history. These should not be forgotten, he concludes, with a worrying reflection that the loss of tropical glaciers is just the tip of the iceberg: "*When Antarctica starts melting, then we'll start to see really large changes. That's when the existence of the human species will be at risk.*"



Charquini Sur glacier

Bolivia

The glacier on the south side of Cerro Charquini (5,392 m) is small (with a surface area of just 0.25 sq km). It lies near the Zongo glacier. Monitoring of the glacier began in 2001–2002 by the GLACIOCLIM Observatory (a joint project between French and Bolivian researchers). The presence of a series of very well-preserved moraines (sediment deposited by the glacier that shows its past extent) has made this glacier one of the key sites for the study of the fluctuations of tropical glaciers during and since the Little Ice Age (16th–19th century). The multi-century chrono-sequence of the glacier's evolution has enabled pioneering studies of vegetation colonisation following the glacier's retreat and insights into the paleoclimate (the climate in the past). *(Google Earth Satellite image from 2021)*

Mark Horrell

A MODERN-DAY MOUNTAIN ADVENTURER

The British mountaineer and travel writer Mark Horrell defines himself more as a walker than a climber. He has explored the world's greatest mountain ranges, including 25 that are over 6,000 m, such as Everest, Aconcagua and Chimborazo. His writing is a unique blend of personal anecdotes, historical insights and practical advice, providing readers not only with a window into the exhilarating world of high-altitude climbing, but an alternative and "irreverent look at the world of adventure travel for those who love mountains and don't take their climbing too seriously".

Mark Horrell trekking on various mountains in different destinations









"We all have to accept change."

Unlike many climbers seeking their next personal challenge on the planet's highest peaks, Mark's entry into the world of mountains had more to do with writing than compiling a list of ascents. He began globetrotting 20 years ago and writing about his experiences, accounts inflected with humour about his encounters and adventures along the way. A self-described "*mountain history geek*", his stories often reference previous explorers from the 19th and early 20th centuries and their accounts of the places he visits. When he does his research prior to or after an ascent, the past shapes his experience of the mountain and how it has changed:

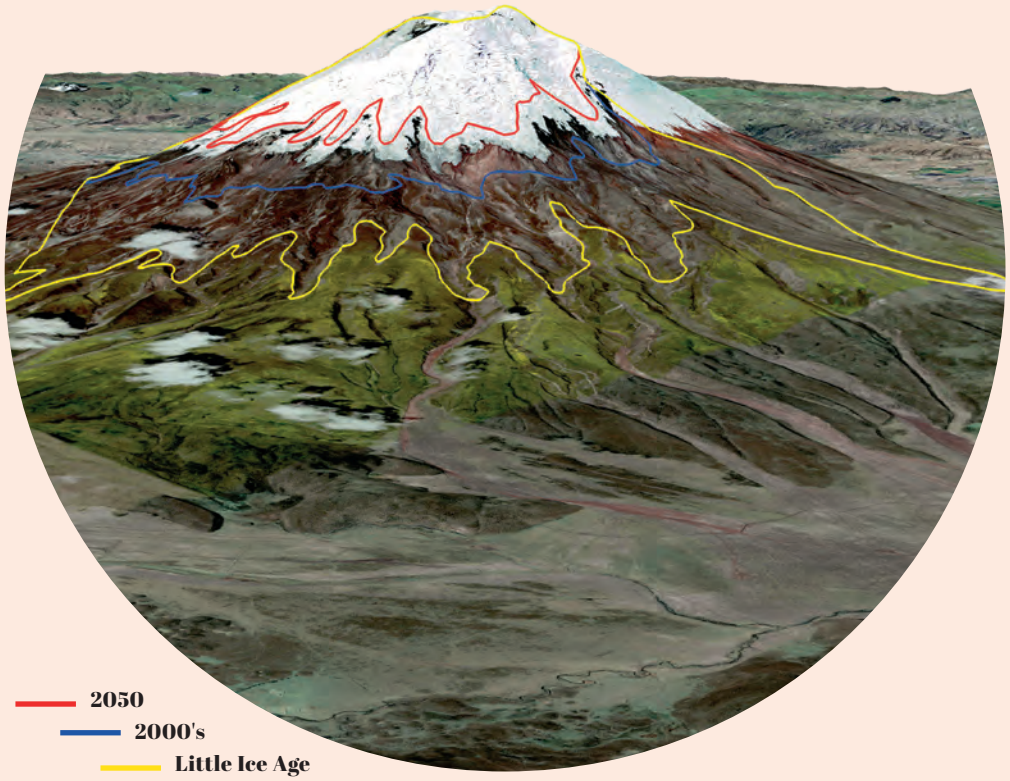
"*Explorers like Hans Meyer [a German geographer and the first European to reach the summit of Mount Kilimanjaro] had to climb massive glaciers – there were areas where you couldn't walk up. The first time he tried to climb it, he couldn't because there was too much ice there. He went back with a climber who could teach him the skills to get up the glacier. This was the end of the 19th century and there was a massive glacier there. Now, 100 years later, when you climb up Kilimanjaro, the glacier is gone.*"

His perspective on the loss of glaciers is drawn more from historical accounts than his own experiences of visiting these areas. Yet rather than being nostalgic for a past that is long gone, a perspective of much climate change discourse in the media, Mark takes the long view, and rather than grieving, approaches the present-day situation with curiosity. When he visits mountains that had large glaciers in the past, he asks himself: "*What happened to this glacier?*" Aware that he is trekking across what "*used to be a glacier and is now a completely transformed landscape*", he looks for signs of how the past has made its mark on the present:

"*I did a trek around a glacier in the Sierra Nevada [in Colombia] called Cocuy, and there was a really interesting section where we were going over just slabs, black slabs of rock. This is a very vegetated region and there were some tiny plants growing in the cracks, but it was very obvious just looking at it that it had been a glacier until very recently – so recently that the vegetation hasn't taken over yet.*"

Mark's historical knowledge of mountains gives him a unique perspective regarding the accelerated rate of glacial melt, particularly in tropical regions:

"*In some ways we are past a point of no return, and we have to start accepting that the glaciers in Ecuador aren't going to be around for much longer. In the Himalayas they'll be around for a bit longer. It's something that us tourists have to accept. It's not what it was – Kilimanjaro won't be what it was in Hans Meyer's time. We all have to accept change. That's probably not the typical answer – a lot of people are saying that it's an absolute disaster. It is probably an absolute disaster for those mountain communities, but not for us really as tourists. Things change... Kilimanjaro without a glacier is still a fantastic mountain to climb. We don't know what it was like 100 years ago except by reading about it, and we still enjoy it. If in 100 years most peaks don't have glaciers, people will still be climbing them.*"



Cotopaxi ice cap

Ecuador

A stratovolcano with a near-perfect cone, Cotopaxi (5,897 m) towers almost 3,000 m above the surrounding terrain. It has erupted numerous times since the 16th century. The most recent was a minor eruption in 2015. During the strongest eruptions, part of the ice cap melts, giving rise to lahars: dense mud flows resulting from the rapid melting of snow and ice, loaded with debris (ash, silt and rock). These debris flows have the potential to be highly destructive. This volcano is therefore closely monitored for glacio-volcanic hazards, particularly due to the proximity of Quito, Ecuador's capital.
(Google Earth Satellite image from 2021)

Bob Nakileza

HIGH-ALTITUDE ENVIRONMENTAL SCIENCE IN AFRICA

Bob R. Nakileza is a senior lecturer in the Department of Geography and Environmental Management at Makerere University in Uganda and is involved in diverse research activities in environmental management, geoinformatics and climatic sciences. Bob is a long-serving coordinator of the Mountain Resource Centre launched in 1996 within his department at the university to spearhead mountain research and education in the region. He also participates in international networks working on global mountain issues such as the Mountain Partnership (MP) and the Mountain Research Institute (MRI). He is on the coordination committee of the International Geographical Union's Commission of Mountain Studies (IGU-CMS).

Sunrise in Mount Kenya.
© Wandering Nomad

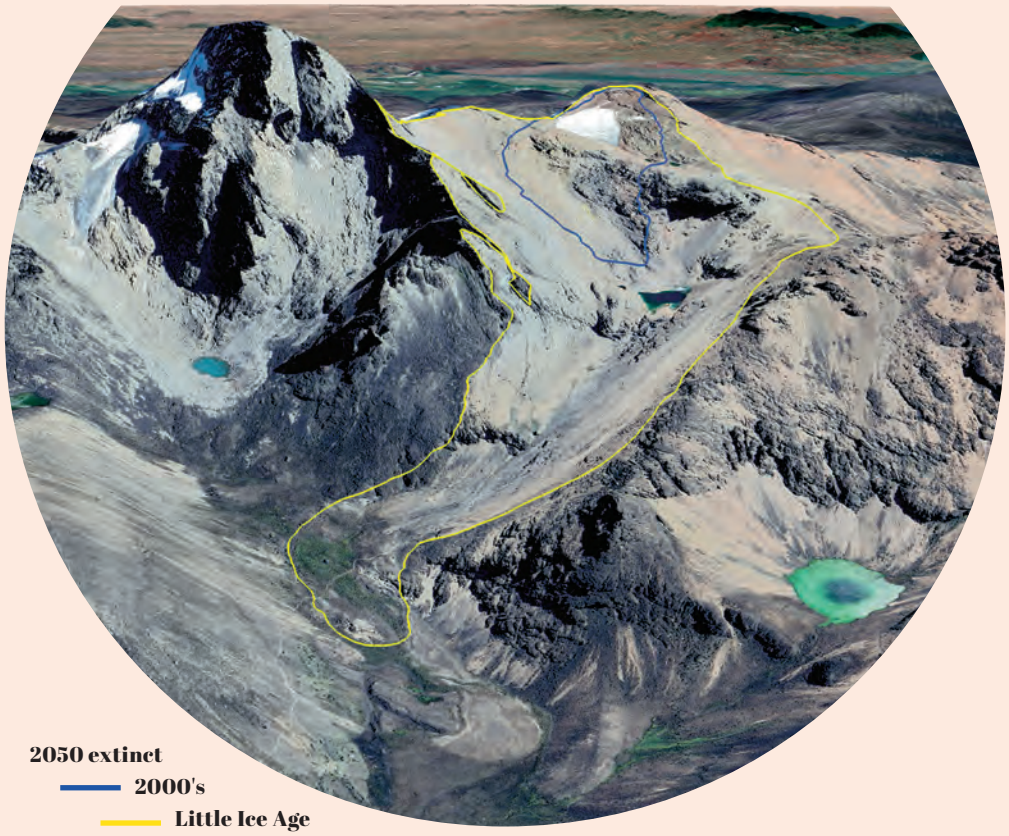
"Preserving glaciers, but how?"

"*It's all gone!*" Bob Nakileza exclaims when I show him a picture of my recent ascent of Mount Stanley's Margherita Peak in Uganda's Rwenzori Mountains National Park, a UNESCO World Heritage site. The last time he had been up to the ice was in 2006, when there was one single glacier – it is now separate smaller glaciers with walls of rock between them. Bob has studied glaciers and mountain systems in East African mountains, including Kilimanjaro, Mount Kenya and Rwenzori, for several decades. He takes an interdisciplinary approach, examining the intersection between mountains, ecosystem services and society, and how climate change in mountains affects people. With East African glaciers rapidly disappearing, the 2025 UN International Year of Glaciers' Preservation highlights the urgency of the issue, as Bob bluntly asks: "*Preserving glaciers, but how?*"

Bob did his PhD at University of Cape Town. This is unusual for Ugandan scientists, as South Africa has very good universities, and the cost of living is relatively low. Research on mountains in East Africa also relies on international collaboration. "*When there is local funding to study glaciers in Africa, it is absolutely minimal. Without international help, research on this topic would be impossible*" Bob explains. He then traces the history of research on East African glaciers since the 1970s, with the main results coming from Western countries (the US, UK, Italy, Germany, etc.) that brought in the resources to carry out the studies. One example was the 2016 Italian-funded project and film "*In the footsteps of Abruzzi*", which retraced the expedition of Luigi Amedeo, Duke of the Abruzzi, who climbed and mapped these mountains in 1906. The 21st century project collected precious information allowing an evaluation of how the glaciers have changed over a century. Yet there are gaps in the record, with many years lacking major research data, which should not be a surprise considering the funding issues that African scientists confront.

Research on East African mountains not only faces challenges of insufficient funds, but equipment can be stolen or vandalised – this occurred at a weather station close to Mount Speke, for example. In order to document glacier retreat in this region and the impacts of this on populations downstream, international projects are invaluable, such as a current research proposal for European funding by Rob Marchant from the UK on enhancing socio-ecological resilience of East African mountain systems through nature positive futures (AFRI-CAN).

Bob Nakileza and I discuss common research interests and agree to continue the conversation to work together: for example, through a Master's project. Funding or not, collaboration is already taking place, searching for solutions one step at a time.



Lewis glacier, Mount Kenya

Kenya

Mount Kenya (5,200 m), the second tallest mountain in Africa, located in Mount Kenya National Park, a UNESCO World Heritage site, is a 3-million-year-old volcano that lies directly on the equator. When British geographer Sir Halford Mackinder and two companions reached its summit in 1899, it was covered by some 15 glaciers. Today, one of the last remnants is the Lewis glacier, a thin strip of ice less than 200 m long. Its contemporary history is well documented, as the glacier has been almost continuously monitored since the 1930s. In the century since then, it has almost completely disappeared. (*Google Earth Satellite image from* 2023)

HOPE

Much literature related to climate change tries to understand what motivates people to act in the face of impending threats. While the answers are varied, authors have noted that emotions of care and concern are greater motivators of action than solely availability of information. Indeed, facts alone can incite fear, helplessness and apathy more than action. Many voices in this book have chosen action to protect or care for mountain environments in various ways that are shaped by their power, resources or circumstances. The voices in this section are those that express hope that these actions can lead to change for the better. They are hopeful that a different sort of future is possible for the generations to come.

Super Josué

A YOUNG ENVIRONMENTAL ADVOCATE ON A MISSION

Josué Arias, nicknamed "Super Josué", was born in Colombia in 2013. At his young age, he has already become a well-known environmental advocate, raising awareness about the effects of climate change and why we should conserve nature through platforms on television and social networks as well as in the press. He has participated in several national and international conferences and has received recognition such as Colombia's "Planeta Azul" award. He is the youngest member of the environmental NGO Cumbres Blancas and is very involved in the conservation and restoration of the páramos (alpine tundra ecosystems): for example, through the replanting of the frailejon, a native highland plant.

Super Josué posing with a replanted *frailejon* seedling.
© Y. Arias

"He communicates with much more hope than other environmental advocates."

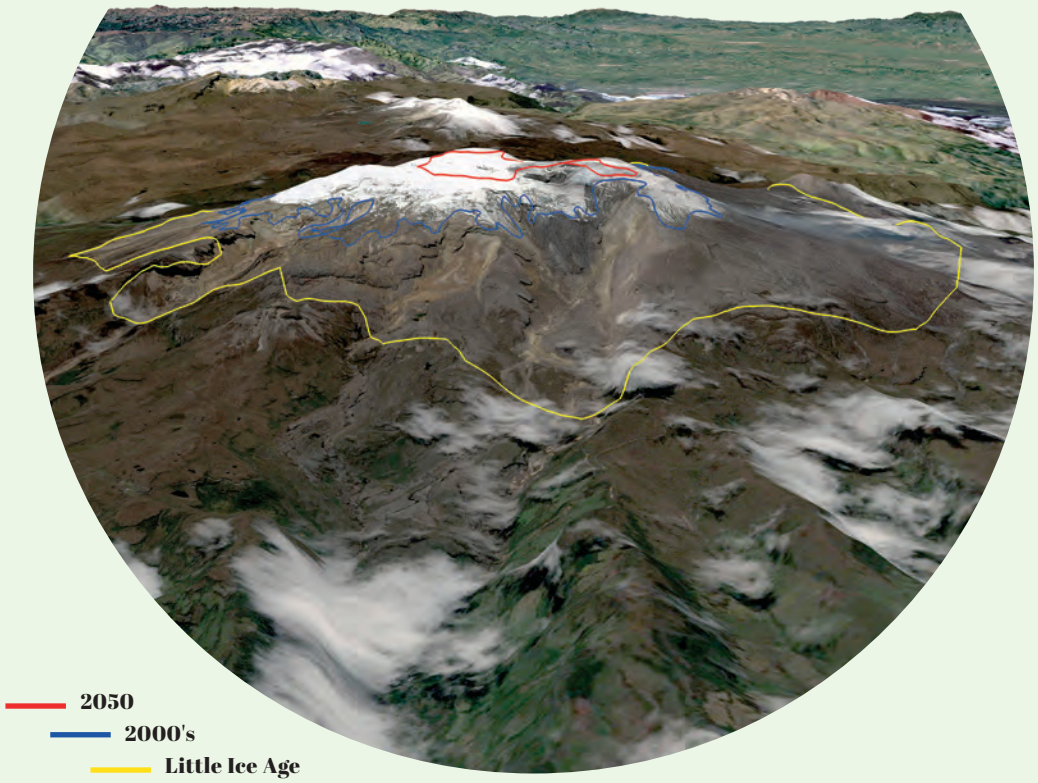
This was the only interview for this book of both a father and son. The father, Yober Arias, leads the Cumbres Blancas collective, and his eldest son is Super Josué, a pre-teen who has become famous in Colombia for his activism on climate change and conservation. This 11 year old has over 20,000 followers on social media, where he posts about subjects such as glaciers and his favourite plant, the native *frailejon*. He is writing a book on *100 things you might not know about glaciers and* páramos that portrays superheroes who study nature and try to protect it.

Super Josué's first contact with glaciers was on Santa Isabel in Colombia when he was six. Since then, he has been increasingly committed to the environmental cause. Today, he participates in the *Don frailejon* project, which aims to restore the *páramos*, a unique highland ecosystem that contributes to the provision of water downstream during the dry season. This is a logical step, considering how glacier loss will put millions of people at risk of water scarcity in Latin America.

His father says that Josué dedicates many hours to studying and practising his talks. He thinks that one of the secrets of Josué's success is that he communicates with much more hope than other environmental advocates, giving bold recommendations on how society should transform to a low carbon economy – perhaps because of the naivety of youth. "*He can disconnect from the anxiety and guilt that others feel regarding carbon emissions, precisely because at his young age he has barely contributed to this problem.*" Yober laughs that Josué will play outside at a conference, just like other kids, but in his case it would be after giving a keynote.

I ask Super Josué about his relationships with other people his age. "*I feel better around adults than kids of my age, as adults are a more receptive public*" he says. But he adds that adults are too perfectionist, and that this hinders the adoption of more ambitious measures to curb climate change and protect nature. What do his schoolmates think about his role as an environmental advocate? Josué says they don't understand it, and that some make fun of it. "*Sometimes I feel excluded, and I fear that others judge me*" he continues.

He knows that in Colombia, some environmental activists have been actively pursued and attacked, and hopes that the adverse reaction from some of his schoolmates is preparing him for the future, when he might face stronger opposition or even threats. In a context in which an average of nearly 200 environmental advocates have been killed worldwide per year since 2012, there is a fundamental need to protect those who work against environmental degradation.



Los Nevados National Park

Colombia

Nevado del Ruiz (5,320 m) lies in the heart of Los Nevados National Park, where in 2017 the NGO World Conservation Society (WCS) launched a project to restore *fraile-jones* actively, through planting, and passively, through building fences. In 1985, this volcano was the source of a major catastrophe. An explosive eruption melted part of the ice (around 10% of the total volume) on the snow-capped peak, generating a series of lahars – debris flows of meltwater laden with ash and volcanic deposits. These caused massive damage to the town of Armero and surrounding villages, claiming the lives of some 25,000 people. *(Google Earth Satellite image from 2015)*

Marcela Fernández

AN INFLUENCER FOR THE ENVIRONMENT

Marcela Fernández is an environmental advocate in Colombia who founded the NGO Cumbres Blancas ("White Summits") in 2019 to raise awareness about glacier loss. In 2023, she was named one of the 100 most influential women globally by the BBC for her commitment to this cause and her work in multiple countries to protect glaciers. She is also very involved in the restoration of degraded páramos *in Colombia.*

Marcela Fernández hugs a *Frailejón*, a plant from the *Espeltia* genus that lives in the *páramos* where it contributes to the regulation of water flows.

© S. Giroux

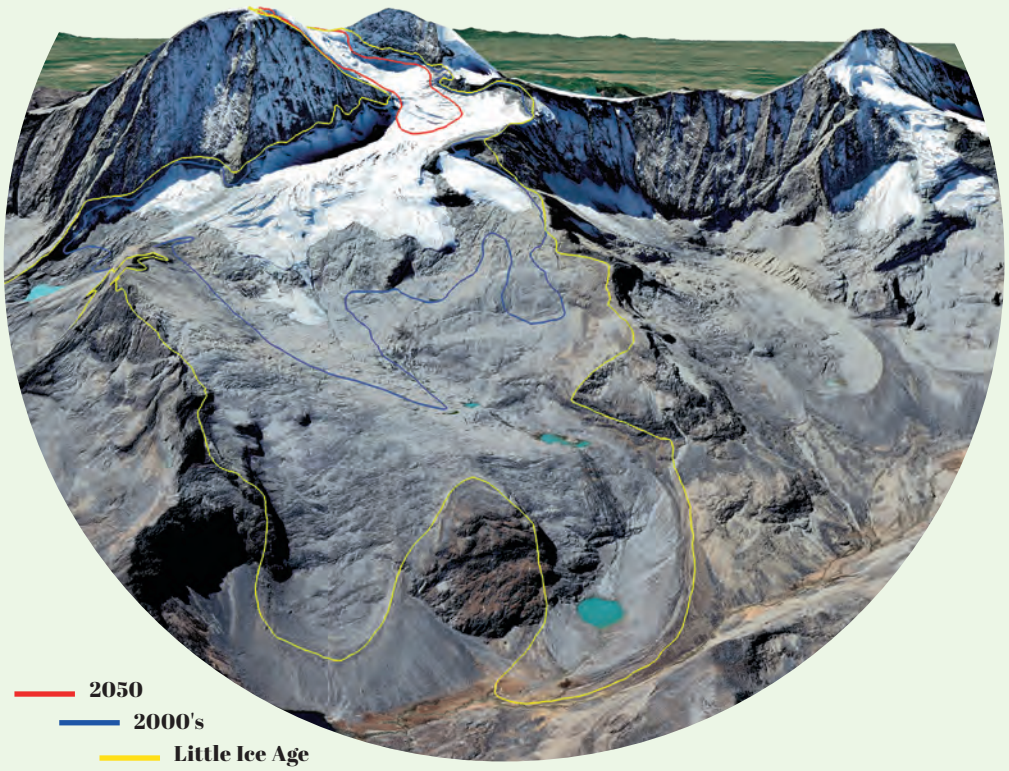
"I felt ignorance, impotence and frustration to learn of the existence of glaciers in Colombia at the same time as the fact that these glaciers could soon disappear."

Marcela Fernández's energy for protecting glaciers is contagious. Within the first five minutes of meeting her, we are already discussing possibilities for doing joint projects in Africa, where she is trying to set up a local group to raise awareness of glacier loss. Cumbres Blancas, the NGO she founded in Colombia in 2019, is now present in several countries and working with hundreds of experts and volunteers to preserve glaciers. A book has been published about the NGO's work in Colombia, including more than 50 interviews and incredible photographs, and a documentary is planned to come out soon. Marcela's passion for glaciers started in 2018, when she learned through a local newspaper that there were six glaciated areas in Colombia, and that these were receding rapidly. "*I felt ignorance, impotence and frustration to learn of the existence of glaciers in Colombia at the same time as the fact that these glaciers could soon disappear*" she says. "*It was a turning point for me.*" From that day on, she committed herself to paying tribute to glaciers and to do what she could to prolong their existence.

The very next year, in 2019, she assembled an expedition to the Conejeras glacier in Los Nevados National Park with experts on glaciers, alpinists and citizens committed to the protection of mountains. That expedition was the start of Cumbres Blancas. By September 2023, the Conejeras glacier was declared extinct. Yet the NGO continued its work, expanding to different countries. It is run by groups of people who volunteer their time to protect glaciers. One of the many things they do as an organisation is to install cameras on tropical glaciers to monitor them – this is important, as many local universities do not have the capacity to monitor glaciers. "*One of the drivers of Cumbres Blancas is citizen science*" explains Marcela.

She believes she is giving glaciers a voice – that they are asking to be heard. "*My generation will witness how the last remaining bits of glacier ice in Colombia melt*" she says with frustration. Nonetheless, she is committed to doing everything she can to protect nature. Today, she is focusing her efforts on restoring the *páramo* ecosystems in Colombia, where the native *frailejon* plant plays a fundamental role in the regulation of the water flow that supplies several Colombian cities.

"*For me, the hardest part regarding glaciers is not so much that they are melting, but that this could happen without people noticing*" says Marcela. "*I think the biggest achievement of Cumbres Blancas has been bringing glaciers into people's hearts and making them aware of their loss.*" She will continue to bring her message to people all over the world in the hope of inspiring them so that every country has its own Cumbres Blancas movement.



Pico Colón glacier
Sierra Nevada de Santa Marta

Colombia

Rising from the Caribbean coast to summits over 5,775 m high, the Sierra Nevada de Santa Marta is the highest coastal mountain range in the world and includes a UNESCO-designated Biosphere Reserve. Reaching its ice-covered peaks is a real challenge, as the local Indigenous People watch over this jewel of biodiversity and seek to preserve harmony between human beings and nature. In the early 2020s, the cumulative surface area of Sierra Nevada's glaciers was just over 5 sq km, less than 7% of their extent during the Little Ice Age (16th–19th centuries). *(Google Earth Satellite image from 2024)*

Mariana Cárdenas

PARSING THE POETRY OF GLACIERS

Mariana Cárdenas was born in Venezuela, but raised in Colombia, where she did her undergraduate degree, and today is a PhD student at the University of Minnesota in the United States. She works on the dynamics of lichens and mosses in glacial retreat zones in Colombia and Ecuador. Mariana did her Master's in Venezuela, where she was part of an interdisciplinary team studying vegetation succession following the retreat of the country's last remaining glacier on Pico Humboldt. This was the root of her scientific interest in – and her love for – glaciers.

Last remaining of La Corona Glacier in Humboldt peak in Venezuela. The glacier was declared extinct in 2024 following further retreat.

© S. Rodriguez

For Mariana Cárdenas, talking about glaciers brings to mind the legend of the five white eagles.

"Caribay, the first woman, daughter of the sun and the moon, saw five white eagles flying across the sky. She fell madly in love with their snow-white feathers and followed their flight over the valleys and mountains. When the eagles landed on the ground, each on a different mountain ridge, Caribay tried to catch them to get their feathers, but each eagle froze and turned into a huge mass of ice. The five eagles represent the five snow-capped peaks of the Venezuelan Andes: Pico el Leon, Pico el Toro, Pico la Concha, Pico Bolívar, and Pico Humboldt."

Today the reality of Venezuela's glaciers is far less poetic. Of the five mentioned, the first three became extinct some time ago, and Mariana remembers seeing another die before her eyes. In 2018, from her bedroom window in Mérida, northwestern Venezuela, she spotted a small, almost imperceptible white patch on the summit of Mount Bolívar, Venezuela's highest peak (4,978 m).

"My mind went into shock. I hoped that there might still be some ice on the south face of the mountain, but a few days later, I confirmed that this was not the case. I saw it disappear."

With Pico Bolívar the country's fourth glacier to disappear, there was now only one left for Mariana to encounter personally. The glacier on Pico Humboldt (4,925 m) in the Sierra Nevada has also been fatally wounded by global warming, thawing into a miniature version of its former self. Today only a tiny remnant remains, but Mariana clearly remembers her feelings when she saw it for the first time in December 2019, after a two-day trek with a group of ecological researchers to study glacier retreat: *"The undeniable sensation of witnessing something that perhaps many have seen, but few have contemplated with this level of reflection; it took me back to other times in the life of our planet, when humans had not yet set foot on this or any other land."*

Reality brought her back down to earth when the group began to set up the various studies they were going to carry out on the glacier foreland. Mariana was in charge of little-studied lichens, which she suspected were key players in the colonisation of life after ice. Several happy, busy days of work passed – when she had the time to look up, she could see the imposing white glacier.

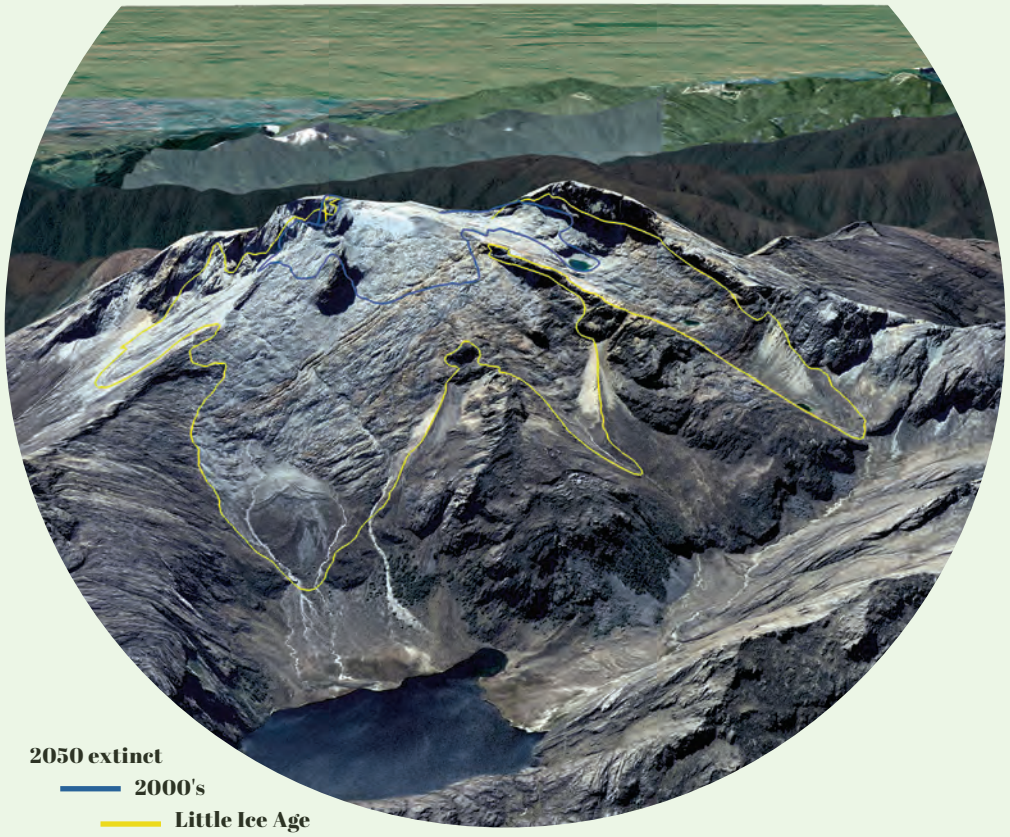
But all good things must come to an end. After ten days, the team went back to the city. It was a difficult moment for Mariana:

"Every step took me a little further from the glacier. I kept stopping and looking back, searching for its unmistakable white colour. With a last sigh stolen by the altitude, I said goodbye to the glacier, knowing that I might never see it again."

Did Mariana feel that she was able to bid farewell properly?

I don't think there is a right or wrong way to say goodbye to something as special as a glacier. It is a bittersweet feeling. It is made sweeter by the thought that once the glacier is gone, we will welcome the new life that blooms, perhaps in shapes and colours we have never seen before. I have a feeling that I will return, or at least relive this moment when I tell my niece stories about the glacier on Humboldt. But a bitter feeling arises when I think that maybe she will never be able to see with her own eyes this white giant that has driven my dreams and taught me that nothing is impossible if you manage to find love in something as small as a lichen that colonises the rocks at the glacier's edge.

In the spring of 2024, Pico Humboldt's glacier, the last of the five eagles, was officially declared extinct. With it, Venezuela and its people have certainly lost much more than ice.



La Corona glacier Pico Humboldt

Venezuela

The La Corona glacier on the slopes of Pico Humboldt (4,940 m) in the Sierra Nevada de Mérida was the last in Venezuela. In 2024, with a surface area of less than 2 hectares, it lost the status of glacier. In the vain hope of preserving what remains, 35 rolls of polypropylene (a thermoplastic polymer 80 m long and 2.75 m wide) were flown in by helicopter to cover the ice and limit melting. Yet the demise of the ice is inevitable given the warming temperatures. (*Google Earth Satellite image from* 2023)

Pamela EA

INTEGRATING ART AND ADVOCACY

Pamela Elizarraráz Actores, known as Pamela EA, is a documentary photographer and young climate leader from Mexico. She has built a body of visual work around climate justice and gender equality, and has co-founded organisations including Climate Words and Latinas for Climate. She studied photography and product design at Parsons School of Design in New York and photojournalism at University of the Arts London and today combines these backgrounds to tell compelling stories from the frontlines of climate change and encourage optimism. In 2019, she was part of the effort that led to New York being the first city to declare a climate emergency.

Environmental advocate Daniela Balaguera photographed by Pamela EA (during the COVID-19 pandemic in an online interview) juxtaposed on a background image related to her. The photograph was exhibited at COP26 in Glasgow, Scotland.

I came across Pamela EA's work through Klaus Thymann, an artist and explorer working on climate change communication. In his words: "*She's fantastic, you have to meet her.*" One of the many achievements to date of this young woman is the co-founding of Climate Words, a platform that promotes climate literacy by building an extensive lexicon of definitions written by experts on the frontlines of climate change. Words make a difference – for example, society has progressively shifted from the use of "global warming" to "climate change" (as it is not only the temperature that rises but the frequency and intensity of extreme events) and now "climate emergency" or "climate crisis" to reflect its catastrophic consequences and the need for rapid action. I wanted to talk to Pamela to collect her voice for this book.

Most of those concerned about the environment have a story relating how they became connected to nature. Pamela's engagement with the environment started as a child in Mexico observing plastic pollution on the coasts. Her first reaction was to create drawings of this and its impacts to show them to local communities and make them aware of the consequences. However, she soon realised that the plastics industry was also responsible for the pollution – perhaps even more responsible than the community members she had initially talked to. She would take her interest in both art and the environment to the United States, where she did a design degree and helped to mobilise the effort that led to New York declaring a climate emergency in 2018. Every Friday, she went to the climate strike in front of the United Nations building. "*I was influenced by the fact that the movement was only reported when famous people came to participate, so I decided to take pictures to document the process*" she says.

When the COVID-19 pandemic started, she found a way to keep telling stories by photographing 21 young environmental advocates and pairing their photographs with an environmental image that connects with the organiser's work. From over 2,000 applications to present artistic works at the COP26 conference, her work was selected among 70 artists. She regrets the limited space for art in these types of conferences. "*People need to think outside of their research and their immediate tasks, and art allows that possibility.*"

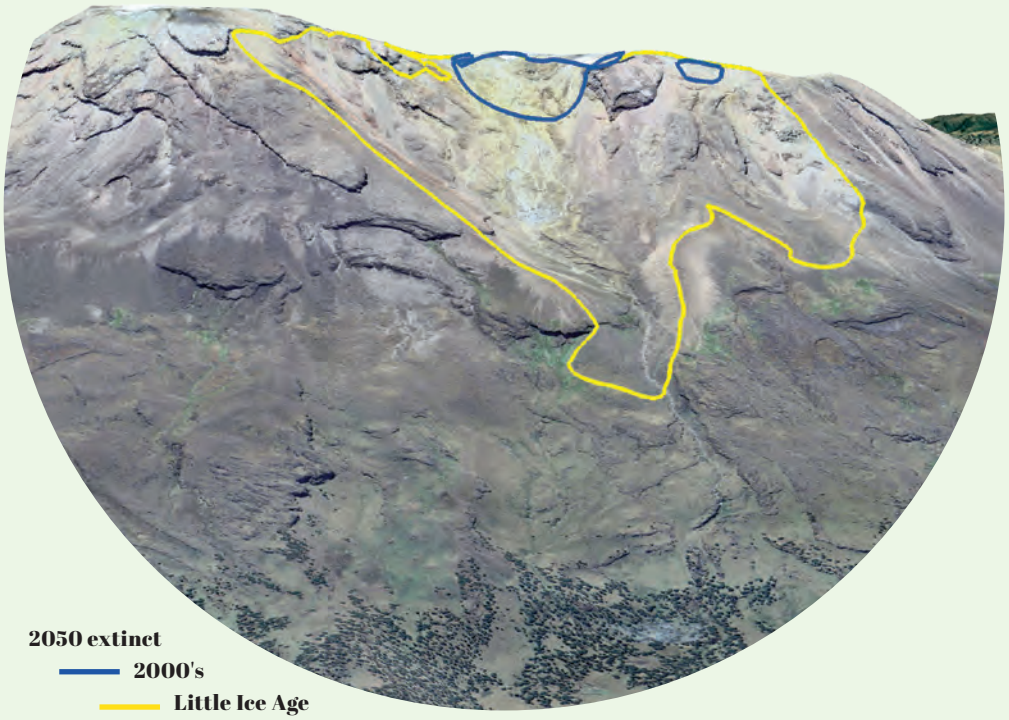
Pamela got the idea to found Climate Words at COP26, when she noticed that key environmental terms were being disregarded because people did not understand them. She read studies that show that climate literacy is very low, and that this literacy is correlated with climate action. She then reached out to experts to define certain terms. When asked what her favourite term from the project is, she chooses "3.5%", defined by Bill McKibben:

"*This significant number comes from the work of Harvard political scientist Erica Chenoweth, whose global database of nonviolent social protests finds that when that percentage of citizens engage in a peaceful civil uprising, they are nearly certain to win.*"

She also mentions 'solastalgia', defined by the American environmentalist Isaias Hernandez:

"*As people increasingly experience climate-induced drought, rising sea levels, hurricanes and wildfires, they're not only losing their environment – they're also losing cultural landmarks, identity and practices. The term 'solastalgia' has emerged to describe the feelings of anxiety and sorrow that follow immediate impacts to our environments.*"

Pamela believes that solastalgia is a term that applies particularly to glaciers, as people are witnessing the loss of ice, both tropical and non-tropical, at unprecedented speeds all over the planet.



La Panza glacier, Iztaccíhuatl

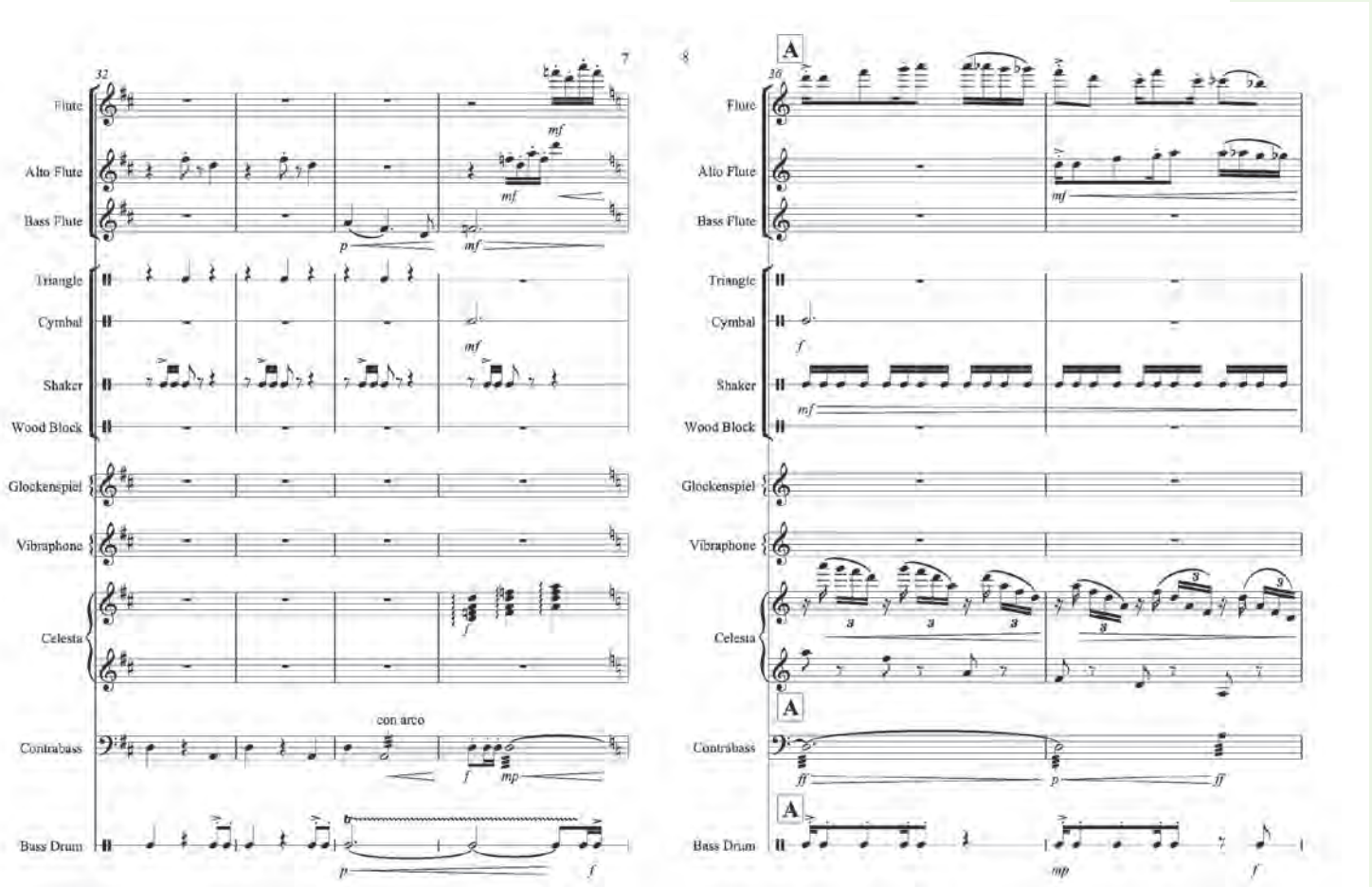
Mexico

Iztaccíhuatl is Mexico's third-highest mountain (5,230 m), nestled within the Los Volcanes Biosphere Reserve and the historic Izta-Popo Zoquiapan National Park. The name means "white woman" in Aztec. Archaeological evidence suggests that pre-Columbian peoples climbed it. In Aztec mythology, Iztaccíhuatl was a princess in love with one of her father's soldiers. The king sent the soldier off to war, promising his daughter as his wife if he returned victorious. Princess Iztaccíhuatl was led to believe that her lover was dead, and she died of grief. On his return from war, he learned of the princess's death. Unable to bear the loss, he also died. The gods turned them into mountains covered with snow. (*Google Earth Satellite image from* 2024)

Ricky Chaggar

COMPOSING THE MUSIC OF CLIMATE CHANGE

Ricky Chaggar is a singer-songwriter who has composed instrumental and background music for television and films worldwide. In 2024, he earned a PhD in music at Anglia Ruskin University in the UK. His research explores how evoking audiences' emotions through music can help to create a memorable experience. Combining this approach with information about climate change might raise awareness and inspire change. As an artist, Ricky wants to play a role in protecting and caring for the planet, ensuring that it can be a home for those who come long after us.



Extract from the third movement of *Andean wetlands*: a signal of climate change composed by Ricky Chaggar. In this part of the piece, the flowing rhythm and melody of the wetlands is suddenly interrupted by an extreme weather event.

In the spring of 2023, I received an unexpected email from the composer and music artist Ricky Chaggar, who said that he had been inspired by a scientific paper I co-authored on Andean wetlands facing extreme climatic events and glacier retreat and had composed a piece of music based on it. His work *Andean Wetlands: A Signal of Climate Change* would be installed in listening booths with interactive information screens at the 2023 Cambridge Festival. Ricky recalls, "*I knew relatively little about glaciers or wetlands at first and was curious. I then became concerned after reading a study about how climate change impacts glaciers. I wanted to help provide a 'voice' for them through emotional music. To share their signals to a wide audience.*"

While Ricky did not have first-hand experience with glaciers, the process of composing worked its own transformation on him:

"*As I composed, I felt like I was an interpreter for the glaciers. I began thinking of them as living entities with their own personality; wise with age, and trying to fulfil important duties to support life forms. I feel like they're being attacked by extreme weather and need our help. Now I feel like more than just an interpreter, but a friend trying to help them out.*"

In his music, Ricky communicates his own feelings of "*sadness, worry and loss*" about glacier retreat. But he also points to the responsibility of political leaders in the climate crisis:

"*I feel disappointed that the previous government in my country made decisions that not only seemed to neglect the need for urgency, but to make matters worse. For instance, they moved back the deadline for selling new petrol and diesel cars and recently granted new oil and gas extraction licences. This can't be good for global warming and the glaciers.*"

Despite the gloomy future that seems to await glaciers worldwide, Ricky remains determined to do what he can to save them.

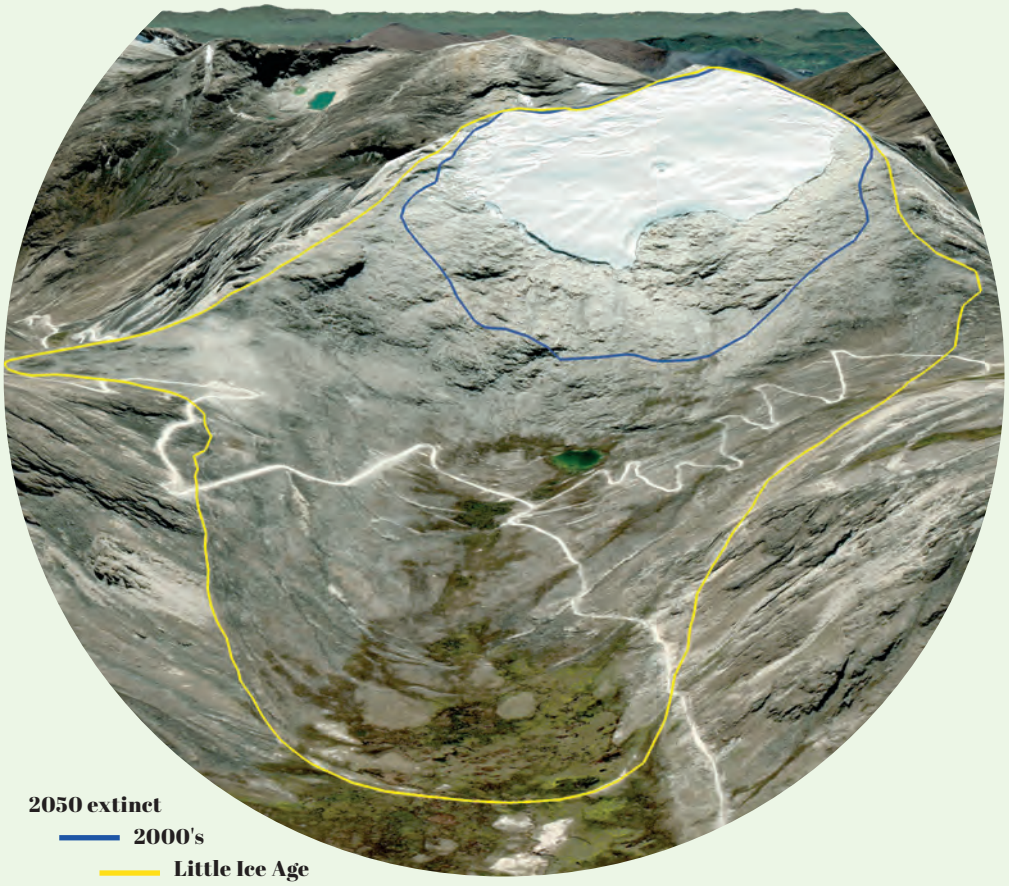
"*Rather than thinking about saying goodbye to glaciers, I prefer to think about the possibility that they can be preserved, and the regions with glaciers restored to a healthier existence. We must try to understand each other's circumstances and ways of thinking.*"

As art is a powerful, universal medium that can reach individuals everywhere, he strongly believes in the role of artists to help face the climate crisis:

"*As artists, we already have an audience. It's a great platform that invites others to emotionally connect. To think and feel more deeply about climate change. Perhaps a business leader or policymaker might be more inspired by a message via art than the spreadsheets they are used to. Perhaps it might inspire a school student to become a scientist to help meet the challenge of the effects of climate change.*"

But while he is convinced about the benefits of art in weaving a shared sense of awareness and responsibility about climate change, Ricky stresses that this must be driven from the heart, from a genuine concern for our planet: "*Although art can naturally encourage engagement, it must be sincere. The artist should not see it as an opportunity to shine the spotlight on themselves. That's not to say audiences shouldn't value your craft. Rather, we should use our art as an opportunity to shine the spotlight on the topic of climate change.*"

Whether an artist, a politician or a scientist, humility is required to address the challenges of global warming and glacier retreat.



Wila Lluxita Glacier

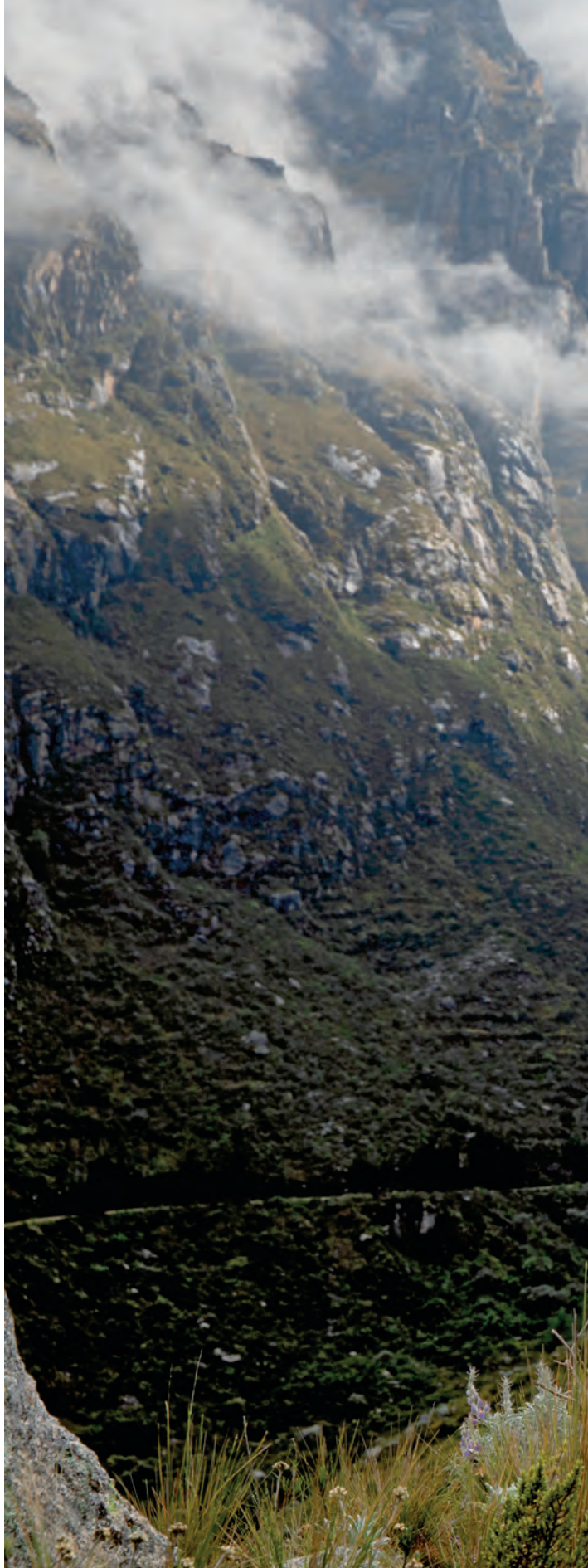
Bolivia

Cerro Wila Lluxita (5,250 m) is a small secondary summit in the Cordillera Real, easily accessible via a road that leads up the Ichu Kota valley from the Altiplano. At the foot of the glacier, the road splits into two branches. Each crosses a pass on either side of the ice and then plunges down towards the Amazon. These roads mainly lead to mining villages and mines on the eastern side of the cordillera. Given its relatively low elevation in a tropical zone, the days of this small glacier are numbered. (*Google Earth Satellite image from* 2022)

Saúl Luciano Lliuya

LITIGANT FOR CLIMATE JUSTICE AND MOUNTAIN GUIDE

Saúl Luciano Lliuya is a Peruvian farmer and mountain guide who was born in 1980. He is a member of the Association of Mountain Guides of Peru and the International Federation of Mountain Guide Associations. He is internationally recognised for filing a lawsuit against an energy multinational based in Germany, citing its role in climate change and its impact on glacier loss in Peru's Cordillera Blanca. Glacier meltwater threatens to make Lake Palcacocha overflow.



Saúl Luciano in a valley near his home in Llupa, Peru.

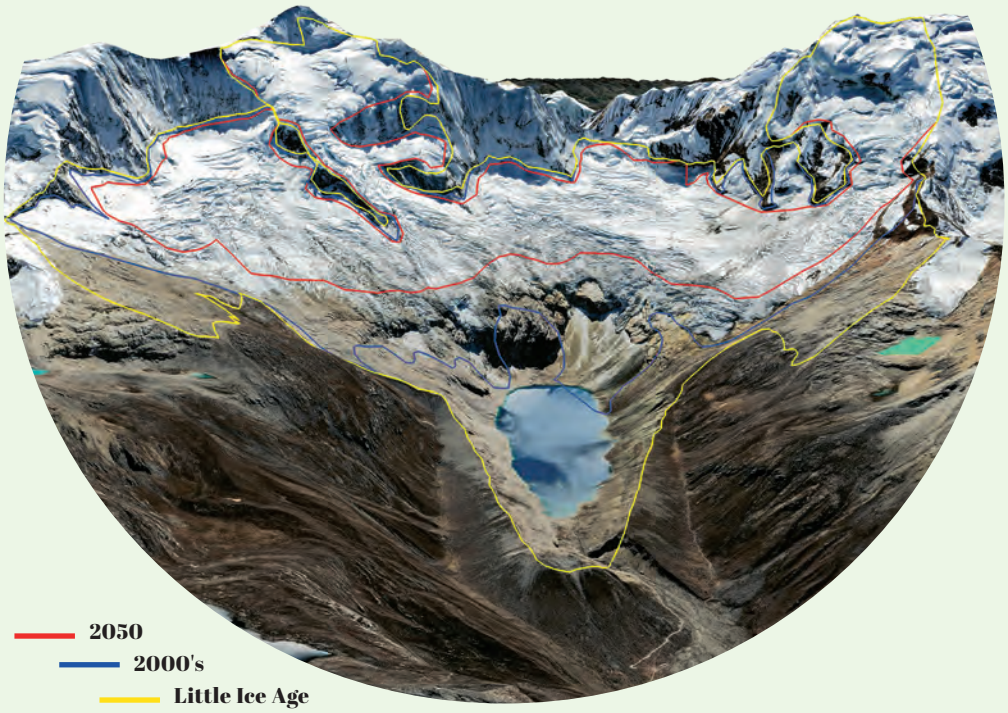
"Our lawyer told us that our lawsuit had a slim – 10% – chance of being accepted."

I was recently in Peru for a research trip to identify priority areas for conservation to cover 30% of the country's land area, in collaboration with Peru's Ministry of the Environment and the World Conservation Society. Following the signing of the Kunming-Montreal Global Biodiversity Framework in 2022, which recommended that countries increase their protected areas, Peru was seeking to add to its existing 17% of protected areas. As I was in Lima, I decided to travel north to Huaraz to meet Saúl Luciano Lliuya, whose story has received media coverage worldwide by major press organisations. Saúl invited me into his home in Llupa, a tiny village above Huaraz, where he grows his own vegetables to complement his work as a mountain guide.

Like a number of people in his village, Saúl is very concerned by glacier retreat and the impacts it causes, from water scarcity to glacial lake outburst floods (GLOFs). This has led him to launch a lawsuit against an energy multinational based in Germany for contributing to climate change. His village is at direct risk of flooding from Lake Palcacocha due to the rapid melting of the Palcaraju and Pucaranra glaciers. The flooding of this lake could have devastating consequences for the populations and infrastructure downstream, as was the case in 1941 when a GLOF killed several thousands of people. His case presents a significant challenge: how could a single individual, even with the help of the NGO German Watch (which coordinated the lawsuit), bring a legal claim against a major giant energy company, especially in the context of a global landscape with multiple greenhouse gas emitters worldwide?

"*Our lawyer told us that our lawsuit had a slim – 10% – chance of being accepted*" Saúl says. While the lawsuit was only seeking 20,000 US dollars to build a dyke in Lake Palcacocha to avoid a future flood, winning such a case could set a clear precedent for global climate responsibility that could lead to similar cases elsewhere. The first lawsuit was rejected, but a second was accepted, and a German judge travelled to Peru to study the case with a team of scientists. "*At the beginning I wasn't very optimistic*" Saúl admits. "*How can we make those who pollute responsible*?" But the German judge coming to Peru makes him think that they have a chance of winning the case.

This long path has not always been easy, and initially, some of Saúl's neighbours thought he was just trying to enrich himself. Nonetheless, he remains positive about the process. "*If there was another NGO interested in doing something similar, it would be a good idea*" he feels. With this ongoing case, for which a resolution is expected soon, Saúl is showing a possible new way to protect high mountain communities.



Palcaraju and Pucaranra glaciers

Peru

Palcaraju (6,274 m) and Puncaranra (6,147 m) are peaks towering over the end of the Quebrada Cojup, a 20-km-long almost linear valley above Huaraz, the main town at the foot of the Cordillera Blanca. Glaciers flowed down the southwestern flanks of these peaks during the Little Ice Age. When the glaciers retreated, they left behind an impressive moraine complex and Lake Palcacocha. In 1941, a portion of the glacier fell into the lake, breaching the moraine and causing an outburst flood of several million cubic metres of water and mud. In around 15 minutes, the mudslide reached the town of Huaraz, a disaster that killed between 6,000 and 7,000 inhabitants. (*Google Earth Satellite image from 2023*)

Constanza Ceruti

A LIFE DEDICATED TO ALPINE ARCHAEOLOGY

The Argentinian archaeologist Constanza Ceruti belongs to Argentina's National Scientific and Technical Research Council (CONICET) and is a professor at the Catholic University of Salta. She has made more than 100 expeditions to summits above 5,000 m. In the 1990s, she helped to lay the foundations of high-altitude archaeology, a discipline initiated a few decades earlier by her mentor, the Swiss-Argentinian Juan Schobinger. She was the first – for decades the only – female expert in this field, and has authored 25 books and more than 200 publications. Member of the National Academy of Sciences of Buenos Aires, Constanza has received numerous prizes, among them the Gold Medal of the International Society of Women Geographers.

The mummy Juanita, "girl of the ice", was discovered on the Ampato volcano in 1995 in the Peruvian Andes. She was an Inca believed to have been sacrificed in a ritual more than 500 years ago.

While melting ice signals the end of some things, it also offers new possibilities. In recent decades, archaeologists have become the beneficiaries of finds emerging from thawing ice around the world. These well-preserved remains from the past are an unexpected treasure for scientists. Ötzi, the "Iceman", was a prehistoric human found at 3,200 m in a gully of the Italian Alps in 1991. Juanita was a girl from the Inca Empire who was sacrificed to the gods at the top of Mount Ampato in Peru and mummified in the ice. As glaciers retreat, hundreds of archaeological gems have helped scientists learn more about human evolution and past cultures. Observing the incredibly well-preserved Inca mummy in the museum in Arequipa, Peru, with her clothing intact, is a deeply moving experience that forges a link with our most distant ancestors.

For high-altitude archaeologist Constanza Ceruti, glaciers are *"of enormous anthropological and historical importance, as reservoirs of the most fragile material evidence of the past and of incalculable scientific value"*. In 1999, she conducted excavations with American anthropologist and archaeologist Johan Reinhard on the top of Llullaillaco volcano (6,739 m), the second-highest active volcano on Earth. *"We discovered three excellently preserved ice mummies, accompanied by a vast collection of offerings from the Inca period"* she recalls.

While the changing climate is helping to reveal these archaeological treasures, Constanza also warns of the threats to these remains, especially in the contexts where she works:

"In the northern hemisphere, the work of fellow glacier archaeologists is facilitated by the retraction of snow and ice packs, which allows them to find arrowheads and organic remains associated with ancient hunting activities. However, the design of surveys in the Andes is different; here the main factor negatively affecting high mountain sites is destruction by predation and looting, as well as excessive mining and tourism."

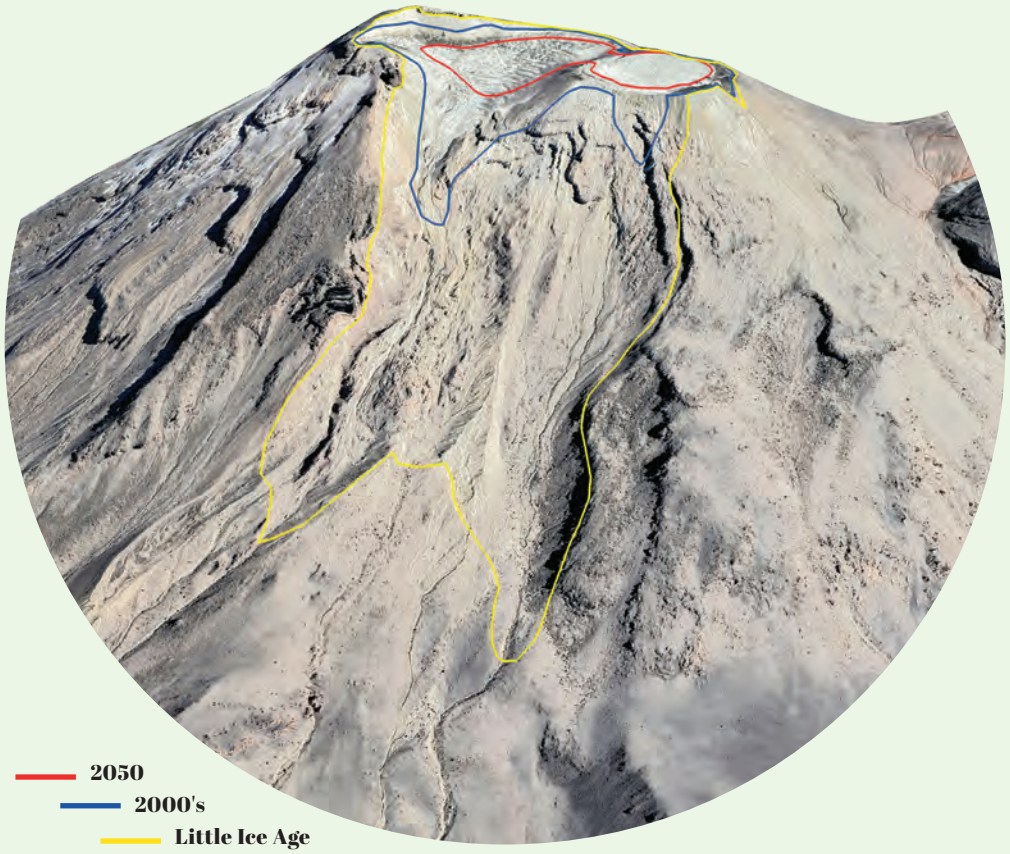
Constanza does not consider herself a hunter of frozen treasure, exploiting the legacy of dying glaciers. Her research is driven by a profound respect for peoples of the past and a passion to learn about their relationships with mountains, and whether and how they have changed today.

"I have been documenting the pilgrimages traditionally – and still – undertaken by tens of thousands of faithful from Andean communities to the glaciers in southern Peru. It is admirable to see the effort of some pilgrims who ascend to the glaciers and cross their dangerous crevasses wearing only ponchos and sandals, as their ancestors, the Incas, did in the past."

The rapid glacier retreat in the Andes does not impact most of Constanza's archaeological work, as the sites where ancient peoples left traces tend to be at lower elevation:

"Many high-altitude ritual sites are located on volcanoes without glaciers or in sectors below the permanent snow line. This is why, as a high-altitude archaeologist, I consider it essential not to neglect the study of mountains without glaciers. Nonetheless, glaciers stand out as supports of transcendent symbolic and social meanings, which continue to spiritually nourish the communities that live at their feet."

Could the narratives and emotions transmitted by the emerging traces of cultures from the past provide some consolation for the impending loss of our spiritual connection with glaciers?



Ampato volcano

Peru

Ampato (6,300 m) is a volcano in the Arequipa region of southern Peru. In 1995, the eruption of Sabancaya, a neighbouring volcano, deposited dark ash on the snow and ice, accelerating melting and causing a major loss of glaciers at the summit of Ampato. Following this, the mummy of a young girl preserved in the ice for over 500 years was discovered near the summit by anthropologist Johan Reinhard. The girl, who was given the name Juanita, had been sacrificed during a period of drought in Inca times, between 1435 and 1450 Common Era (CE). *(Google Earth Satellite image from 2023)*

Klaus Thymann

EXPLORER, ARTIST AND CLIMATE ADVOCATE

Klaus Thymann is a Danish photographer, filmmaker, scientist and climate advocate. In 2008, he founded the charity Project Pressure, which creates impactful projects that triangulate art, science and environmental advocacy. He has curated several art exhibitions, including "Voices of the Future" at the UN Climate Action Summit in 2019 and "Meltdown" at Vienna's Natural History Museum. Project Pressure has received coverage in major news outlets, including The Guardian, BBC, New York Times, CNN, Le Monde, Wired *and* National Geographic. *Klaus has participated in expeditions to remote places around the world and received numerous photography awards.*

Pair of photographs of Mount Stanley with the Margherita Peak (5.109 m) and its glaciers in 1906 (top) and 2012 (bottom).

"Public pressure has already driven many environmental changes – except for the most damaging pollutant we have created. Public acceptance of emitting CO2 has to be changed."

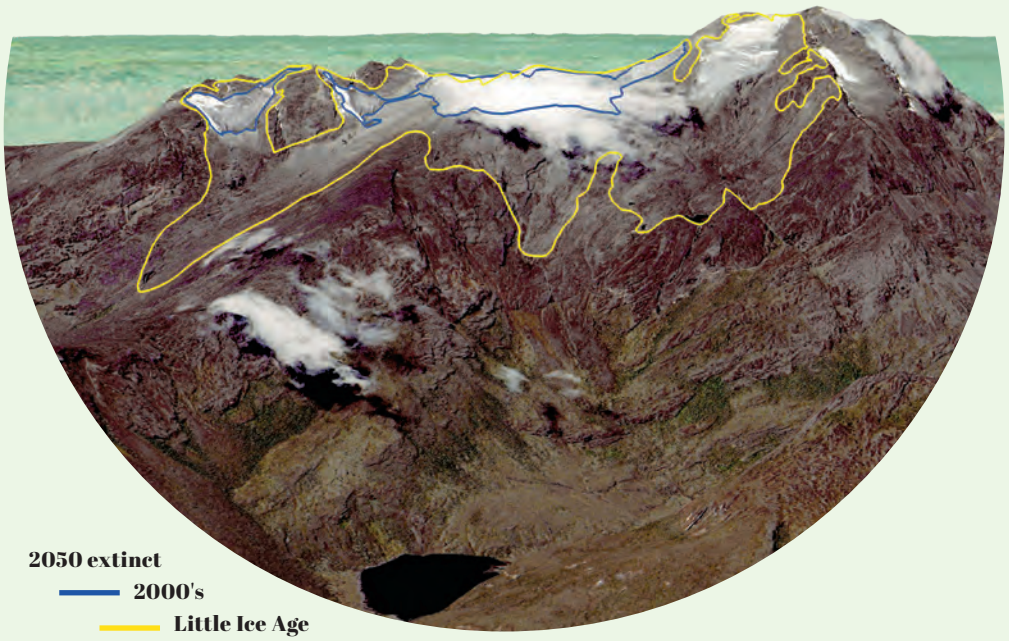
Klaus Thymann, an *active explorer*, committed artist and climate advocate, seeks through his work to bring attention to the climate crisis. "*Art helps people engage with subjects they would not engage with otherwise*" he says. During our conversation he reflects on how the frequency of crises in the news, moving from one disaster to another in one place or another, has the end effect of reducing the importance of these tragic events. "*To a certain degree, you can overcome that frantic speed with art – in the sense that art has a more eternal significance.*"

I am interested in Klaus's art because of its commitment to climate change and its appeal to viewers. His photographs from his expedition to the Rwenzori Mountains between the Democratic Republic of the Congo and Uganda provide a rare testimony of glacier loss in this remote region. "*A lot of the focus of my practice as an artist is in lesser-explored places, which takes me to underreported regions*" he explains. In one work, he paired his glacier photographs of Rwenzori with a photograph from 1906 by an Italian explorer to show glacier loss. These images of different moments in time offer striking visual evidence of climate change, a technique that has been applied worldwide.

When asked about the impact of his project in the Rwenzori range, he says he honestly doesn't know, but he hopes "*to provide greater focus that climate change is happening and that there are vulnerable communities that suffer the consequences*". In 2024, he came back to these mountains to create a 3D image of the ice caps and quantify the volume of the glacier. This will help estimate the contribution of glacier run-off to the water supply of local communities downstream, for which there is limited information. Klaus is very aware that climate change impacts are disproportionately suffered by poorer communities: "*Copenhagen and New York can build sea walls to adapt to sea level rise, but many other cities and villages do not have this capacity.*"

I ask him about his vision of the climate crisis. "*Before, we thought that if we had enough data, action would follow. Today, we know that's not the case.*" He admits that he doesn't know what should be done, but that perhaps a "*completely different response is needed in which agency is removed from destructive powers*".

Since progress on tackling climate change has been insufficient despite decades of scientific and policy efforts, it is interesting to hear from an artist what options might be possible. Art is not only creative, but can also be insubordinate. Klaus compares the need for more radical climate action to how society has shifted to ban practices that were previously considered normal, such as smoking in hospitals or dumping waste in seas. "*Public acceptance of emitting CO2 has to be changed*" Klaus concludes. "*Public pressure has already driven many environmental changes – except for the most damaging pollutant we have created.*"



Margherita glacier, Mount Stanley, Rwenzori Mountains

Uganda

Mountain areas everywhere are considered natural water towers, and in Uganda the Rwenzori massif is no exception. Its name means "water maker" in Toro or Konjo, the local Bantu languages. This massif, on the border between Uganda and the Democratic Republic of the Congo, is said to correspond to the mythical "Mountains of the Moon" mentioned by Ptolemy as the source of the Nile. Mount Stanley's Margherita Peak (5,109 m.), located in the Rwenzori Mountains National Park, a UNESCO World Heritage site, was first climbed by Luigi Amedeo, Duke of the Abruzzi, in 1906. (*Google Earth Satellite image from* 2014)

John Hunwick

A CLIMATE-AWARE ENTREPRENEUR IN AFRICA

John Hunwick once served in the military, and today is an explorer and an entrepreneur who moved from Australia to Uganda to teach permaculture in 1987. He is the director of Rwenzori Trekking Services (RTS), one of the two main companies that guide tourists in the Rwenzori Mountains, whose highest peak, Margherita (5,109 m), is the third-highest point in Africa. John is a capacity builder and a major investor in Uganda, with RTS employing around 600 people, from guides to porters, trail maintenance teams to administrators. He lives in Fort Portal, in the northern part of the Rwenzori range.

An armed guard accompanying a group of trekkers in Rwenzori to guarantee their safety.

"Ten years ago, there was never rain in the peaks, just snow. Now, it rains on the glacier."

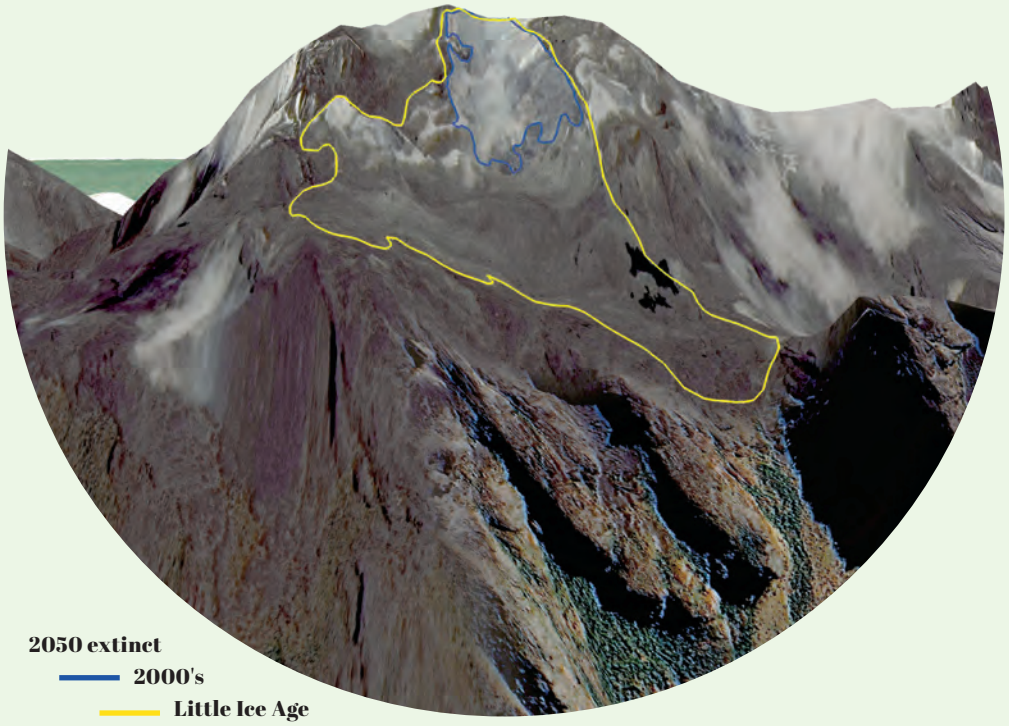
The locals in Uganda used to call John Hunwick "Abraham", like the prophet, as he came all the way from Australia with a unique vision and was able to implement it with the help of the community. He is known for having a management style that doesn't discriminate in terms of social status: "*If a person from a low-income or low-education background is willing to learn, he takes them on and pays for their training*" an RTS guide told me.

John initially planned to stay in the country for just a couple of years to teach permaculture, the development of agricultural ecosystems intended to be sustainable and self-sufficient, but he was given the possibility to restore an old building into a backpackers' hostel. "*I liked the Ugandan people very much*" John says. "*When I arrived, it was right after the Ugandan Bush War [1980–1986], and everybody was very welcoming*."

Working with local communities, he started to develop tours for visitors, and then won a concession from the Uganda Wildlife Authority (UWA) to develop a new trail to Margherita Peak. It took six years of work to identify and open old trails and potential areas for campsites. Through this process, he discovered several waterfalls and created a majestic trail where visitors can admire a succession of vegetation zones (Afromontane forest, bamboo forest, Afroalpine moorland and the rocky-glacier zone). Trekkers had to sleep in tents until 2019, when rudimentary but comfortable huts were built at all campsites. Today, in good years, RTS guides around 1,000 tourists, a considerable number for Uganda, in one of the wildest mountain ranges in Africa.

John is highly concerned by the impacts of climate change on the Rwenzori. "*Ten years ago, there was never rain in the peaks, just snow*" he worries. "*Now, it rains on the glacier.*" He also points out how animal habitats are shifting in elevation: chameleons are now found at higher altitudes. He shows me pictures of how the glacier has changed, and I wonder how much ice remains up there and how long it will last. John does his best to reduce the environmental impact of tourism. This includes using less plastic, building campsites from wood, and adopting ecological stoves that use volcanic rocks instead of charcoal or wood (their price starts at around 100 dollars). He plans to apply to have one of the first green tourism certificates in Uganda.

Ten days before my trip to the Rwenzori Mountains, the normal route to Margherita Peak was closed by the UWA after a small part of the glacier collapsed, leaving an open crevasse on exposed terrain. When John heard I was a rock climber, he asked if I would help establish a new route. He picked me up at the Entebbe airport, allowing me to hear his story. Now John is developing a new hiking trail on Mount Elgon (4,321 m), on the border with Kenya. At the age of 77, he has impressive energy and initiative. While some locals are already worried about planning the next phase after John's departure, it would not surprise me if he lives beyond the time when glaciers in the Rwenzori are just history.



Alexandra glacier Rwenzori Mountains

Democratic Republic of the Congo

The Alexandra glacier flows down the western slope of Margherita Peak in Mount Stanley (5,109 m), the highest point in the Rwenzori Mountains. Its position on the western slope places it within the Democratic Republic of the Congo, making it the eleventh country in the tropics with glaciers. However, this status is in danger of disappearing, as the glaciers in this range will very likely vanish within the next decade or two. (*Google Earth Satellite image from* 2014)

Will Gadd

ICE CLIMBER, ADVENTURER AND "MOUNTAIN HERO"

Will Gadd is a world-class ice climber, mountain guide and paraglider from Canada. He has established some of the hardest mixed ice-climbing routes and was the first person to climb the ice-covered rock wall of the Niagara Falls. He is also an avid public speaker about the impacts of climate change on the cryosphere. The United Nations has recognised him as a "Mountain Hero" for his work to raise awareness on climate change.

Will Gadd climbs a chunk of ice on Mount Kilimanjaro.

"We need to make people excited about the possibilities to engage with climate change."

An extremely accomplished professional ice climber, Will Gadd has been named a United Nations Mountain Hero, in recognition of athletes who also dedicate their time to raising awareness on environmental issues. He has climbed ice all over the world and so is very aware of how climate change is impacting the cryosphere. During the talks he regularly gives to professionals and executives at major companies, he always starts with: "*Imagine one day you show up at work and half of your office is not there; this is what regularly happens to me*."

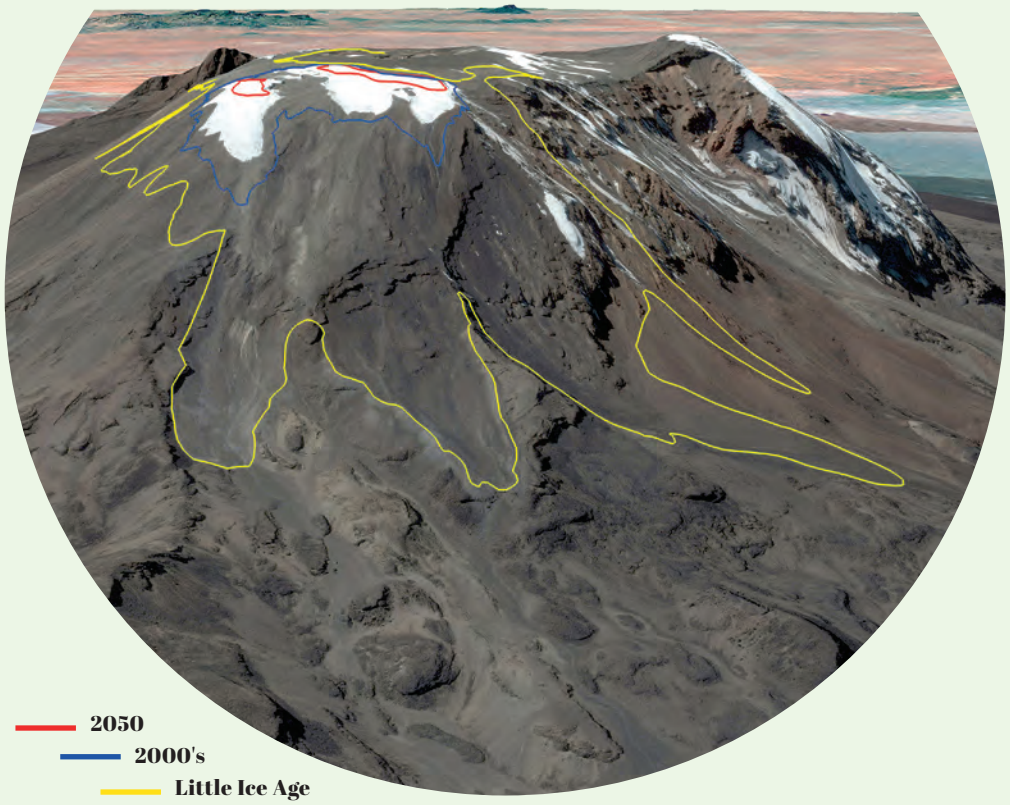
His expedition to ice climb on Mount Kilimanjaro with photographer Christian Pondella in 2020 was a sobering reminder of how fast glaciers are disappearing. "*I'm used to maps showing glaciers being outdated in Canada, but in Africa the maps were very inaccurate – entire glaciers were gone*" Will observes. The Messner ice fall that he intended to climb there, which was a permanent feature of the landscape in the past, does not form regularly now, as the glaciers that used to be the source of the water that created it are much smaller. Big chunks of the ice fall were simply missing, making climbing it impossible. Additionally, due to the melting permafrost, the risk of rockfall on that route has increased considerably, making a night start of the climb mandatory. Regardless, there is still a very high risk of rockfall. "*It's not only that there is less ice, but there is much more variability*" explains Will. "*Whether you are a farmer in Tanzania or an ice climber, you have to adapt to that variability.*"

Will feels he has a role to play as an environmental advocate. "*The world doesn't need ice climbers*" he says. "*I seek to make a difference not only by reaching those who are already working to solve climate change, but those who are not. As an athlete and ice climber, I am a sort of platform for doing that.*"

The travelling associated with elite athletes takes a toll on the climate, and Will speaks frankly about the dilemma of the carbon emissions from his trips. He has been through the different phases of grief: from denial, to acceptance, and now to taking action. He believes we need to be transparent about our own emissions and contribute in different ways to solving the problem. One way in which Will engages is by compensating for his carbon emissions from travelling through forest restoration programmes. "*I want to have an answer for my kids when they ask me: 'Dad, you're a professional ice climber, so what did you do about climate change?'*" he says.

Besides giving talks to raise awareness, Will also invites the media to the Athabasca glacier in Canada, where he can show the impacts of climate change locally. "*I could be guiding clients to earn money, but when I have the opportunity, I prefer to bring the media here to show what's happening – and I don't need to fly to get here!*"

Will also engages in research projects: for example, by helping scientists measure fire ash in glacier crevasses in Canada to track how they are changing over time. The theme that runs through everything he does is revealing possibility: he knows that inspiration is key to encourage action on climate change. "*People don't leave my talks sad. We need to make people excited about the possibilities to engage with climate change.*"



Mount Kilimanjaro glacier

Tanzania

The highest point on the African continent sits in the homeland of the Maasai, semi-nomadic herders. Kilimanjaro (5,892 m) is a stratovolcano with three main peaks: Shira, Mawenzi and Kibo, located in the Mount Kilimanjaro National Park, a UNESCO World Heritage site. Only the western side of Kibo, the massif's highest peak, is still partially covered by glaciers, whose surface area has shrunk considerably in recent decades. The area above 2,700 m has been a national park since 1973 and hosts exceptional flora and fauna. (*Google Earth Satellite image from 2015*)

Yareta cushion plants

LIVING AT THE LIMITS

In the South American Altiplano, the bright green mounds of the cushion plant yareta (Azorella compacta) *stand out in stark contrast to the mineral landscape. This species can grow at altitudes of up to 5,250 m, making it one of the highest occurring woody plant species in the world. The yareta can ameliorate environmental conditions in places where glaciers have retreated, facilitating the colonisation, establishment and survival of other plant species. However, this plant may need centuries to grow, while the rate of glacier retreat today is on the order of a few decades or even years.*

A large *yareta* (*Azorella compacta*), likely hundreds of years old, and Mount Sajama (6,542 m) in Sajama National Park in Bolivia. Other plant species can grow on yaretas, such as the grasses seen here.

Greetings, Azorella. Can you shed light on how glacier retreat affects your existence in the high Andes?

I would say that I am a testament to nature's adaptability, a species that can thrive in the highest parts of the Andes. While the habitats I dominate share stressful conditions – low temperatures, fierce winds, and seasonal droughts, the changing climate poses additional challenges to my existence, like water shortage. Vanishing glaciers means less water in already stark landscapes.

How does your distinctive cushion structure aid in your adaptation to extreme conditions?

My compact cushions are a masterstroke of nature's engineering. By minimising the surface-to-volume ratio, this structure reduces water vapour loss and conserves heat, mitigating exposure to harsh external conditions. My cushions also provide a sanctuary for other species in the shifting dynamics exacerbated by glacier retreat.

Tell us more about how your presence supports the growth of other plant species.

In the high Andes, dozens of different plant species, including valerians and fescue grasses, find refuge on my cushions. After glacier retreat, I can facilitate plant colonisation through a system of cooperation and mutual benefit. About one-third of plants living in my surroundings prefer my cushions to the bare ground.

Are there any other ways you facilitate plant colonisation after glacier retreat?

The accumulation of nutrients under my cushions enhances soil fertility. This nutrient enrichment supports the diverse plant life that seeks refuge on or near me. This capacity is linked to my size and age, with larger cushions offering richer humus and superior wind shelter.

Considering your vulnerability to overheating, how will climate change impact your survival at high altitudes?

While my compact cushions provide resilience in extreme conditions, they are extremely vulnerable to overheating. My survival is contingent on not exceeding acceptable limits of global warming in mountain areas. Climate change may compromise my very existence.

As large, old *yareta* become increasingly rare, what concerns do you have for the future of your kind?

The challenges are undeniable. While my population has somewhat recovered since the heavy harvesting of Azorella cushions in the first half of the 1900s to burn them for fuel, I am still highly vulnerable. In the face of rapid changes in the tropical Andes, it is uncertain whether I will continue to survive and grow large enough to provide hospitable terrain for other organisms.

What message would you convey to those who hold the power to shape the course of climate change?

Listen closely, caretakers of the Earth. The guiding principle of high-altitude ecosystems is interconnectedness. The glaciers are not mere ice; they are integral to the resiliency of ecosystems that have thrived over the ages. Choose your path mindfully, for the decisions you make will resonate across the planet and through time. My advice is to seek a harmonious coexistence with wild spaces, to preserve natural environments on peaks and in valleys, to protect the intricate dance of life.

Interview created with the assistance of ChatGPT based on scientific prompts and edited

Mount Baker, Uganda, and its remnant glacier within a densely vegetated landscape.

Some concluding thoughts

What lessons can we draw from listening to these voices affected by the inexorable decline of tropical glaciers? In the introduction we highlighted the importance of interdisciplinarity to truly understand the consequences of changes in the cryosphere and the loss of tropical glaciers. The science is clear: nearly 90% of the surface area covered by tropical glaciers in the Little Ice Age will be lost by 2050. As we have seen, it is not only ice that is disappearing. To borrow the title of the book by Ben Orlove et al. on glacier retreat, it is much more than *Darkening Peaks*. Other aspects – from ecosystem services such as the provision of water, to the aesthetic enjoyment of ice, to people's sense of place and cultural heritage, to name just a few – are also being impacted by these changes. This gives rise to the diverse emotions expressed in this book, ranging from sadness to hope, which in turn shape the ways individuals respond to climate change. Taking all these aspects into account in an interdisciplinary approach is the best course to get close to the real picture of glacier loss and its impacts.

This multifaceted approach includes the need to integrate the art s in climate change communication. The photographs that illustrate these individual stories aim to offer a more direct encounter with the realities surrounding these places and people, to create a connection between them and readers. UNESCO-designated sites, such as Biosphere Reserves and World Heritage sites, offer vital platforms for monitoring glacial change, promoting climate adaptation, and preserving the cultural and ecological significance of high mountain environments. These sites serve not only as scientific observatories but also as living landscapes where local knowledge, tradition, and nature converge in the face of a changing climate.

In concluding this book, we may ask: what do the voices of those who share their lives with tropical glaciers teach us? Perhaps the first thing is that the effects of climate change need to be understood in their local context. The physical process of rising temperatures that lead to glacier melting is intimately intertwined with a social reality that is both collective and individual.

Collective social aspects including culture, education, distribution of wealth, property rights, governance, among others, shape how people respond to the loss of ice. Their capacity to react to environmental changes is influenced by these forces and by their circumstances. The manifold local realities, and issues related to glacier loss, must be understood within this broader social context.

There are also individual realities. While social elements impact these, each person processes and filters the reality around them in their own way. The diverse voices in this book, the different actions taken to adapt, and the range of emotions – care, concern, sadness, acceptance, hope – show varying reactions to glacier retreat. Beyond distress, more positive reactions are also possible.

Within these social and individual realities, how much agency do we have to take action in the face of environmental change? Baruch Spinoza (1632–1677) claimed that "[...] human freedom, which all boast that they possess, [...] consists solely in the fact that men are conscious of their own desire, but are ignorant of the causes whereby that desire has been determined". Yet the philosopher David Hume (1711–1776) argued that humans have the "power of acting or not acting,

according to the determinations of the will". We argue that individuals do have agency and the capacity to act according to their will; nonetheless, the reality of climate change is being imposed on communities that live in the tropics and elsewhere, resulting in vulnerability that goes beyond individual agency.

The voices in this book offer a window into a variety of human experiences and reactions to "darkening peaks", as well as the constantly evolving reciprocal relationship between people and their environments. These include acts of stewardship: for example, of Marcela Fernández, a Colombian activist and founder of the NGO Cumbres Blancas. She expresses hope despite the fast-approaching disappearance of Colombia's glaciers, which lie below 6,000 m. This no doubt emerges from her strong bond with the land and commitment to protecting nature. Raising awareness of climate change and fostering relationships of care of these mountainous landscapes are aspects that can remain beyond glaciers' existence.

Listening to these voices, it is impossible not to discern an underlying topic that permeates the stories: social justice. For example, Baltazar Ushca, who twice a week made the journey to continue the tradition of collecting blocks of ice from the slopes of Ecuador's Chimborazo, a sacred place in his culture. He was deeply attached to this arduous work, collecting blocks of up to 45 kg in freezing temperatures. Each year, the ice moved higher and further from reach, and loosened rocks made his ascent harder and riskier. Given that the Global North is responsible for 92% of historical CO2 emissions, Baltazar's story illustrates the injustice of climate change. There are those fighting back against such injustice, such as Saúl Luciano Lliuya, a smallholder farmer and mountain guide in Peru, who filed a lawsuit against a multinational energy company to pay to protect his village from future climate change-driven flooding. The case is still in court after ten years, with a judgement expected soon. How should the international community – including individuals – respond to climate change and the injustice inherent to it? As Mikel J. Sandel explores in his book *Justice: What's the Right Thing to Do?* several approaches can be taken. One is a "veil of ignorance", suggested by the philosopher John Rawls (1921–2002), which involves envisioning a just organisation as if you know nothing of your individual attributes or social position. The idea is that this impartial decision-making would lead to a more egalitarian society, as no reasonable person would find it fair to be in a disadvantaged minority. Would this result in greater equity in our considerations regarding climate change, how to mitigate it, and how to adapt to it?

Discussions about equity become inescapably interwoven with human freedoms, fundamental rights recognised in the Universal Declaration of Human Rights adopted by the United Nations in 1948. As the impacts of our activities become more evident, how do we balance our freedoms against the freedoms of others? In considering social justice through a "veil of ignorance", do we also need to consider Aristotle's virtue ethics? That is, it is not only maximising the common good that matters, as in a utilitarian approach to justice, but the question of what a well-lived life entails. How should we define "a good life" and what virtues should we develop to contend with climate change? What's the right thing to do in the face of the deglaciation of the tropics and the forewarning this signals for all glaciers and for those who depend on them?

This is food for thought as we conclude this book. In our conviction that human behaviour can be influenced by both heart and mind, we hope that the voices presented here serve as a source of inspiration for readers to reflect and to act on climate change.

Methodology

To identify the 35 voices included in this book, the co-authors built on the knowledge gained through years of research on tropical mountains and their surroundings. While some of these voices are well known within environmental and glaciological circles and have received media attention, others are only known locally. Several were new to the authors of this book, and we only encountered them in the process of writing this book and discussing with colleagues and collaborators. We prioritised online interviews to reduce carbon emissions from travelling. Semi-structured or open interviews were conducted, with a few pre-defined questions set in advance, but most arising from the interview process. This flexibility allowed each interviewee's thoughts to be explored in a unique way.

The images of changes in glacier extent show their maximum extent during the Little Ice Age (circa 16th–19th centuries), which was established on the basis of moraines (rocky debris deposited by glaciers during periods of advance). These moraines are most prominent and visible in the landscape if the upstream zone of the glacier is overhung by rock faces from which debris collapses, which is then transported by the glacier and accumulates on the edges of the ablation zone and at the glacier front. In the case of domed glaciers or ice caps, moraines are less developed, so there is greater uncertainty as to past glacier extent.

The glacier extent in the early 2000s was derived from satellite images.

The projections of glacier extent in 2050 were based on modelling, but a proviso should be made that there are uncertainties about certain variables. The modelling methodology was as follows: (1) An initial state of the glacier in the current period served as a starting point for modelling. However, significant uncertainties exist, particularly concerning the distribution of ice thickness. This variable is unknown (unmeasured) on the vast majority of the world's glaciers, although it has been estimated by various studies: we used the most recent estimates. (2) Glacier thickness loss rates quantified over the 2000–2019 period were used to extrapolate these for the coming decades. However, the rates of thickness loss measured over the last two decades do not, in essence, take into account the different future climate change scenarios developed by the IPCC: that is, different trajectories associated with higher or lower reductions in greenhouse gases over the next few years/decades. It is therefore essential to emphasise that our projected glacier extents are probably optimistic. The loss of glacier surface area in the tropics between now and 2050 illustrated in the figures is likely the minimum loss to be envisaged. In most cases, the loss is likely to be greater: in some cases, complete disappearance.

Acknowledgements

Ignacio Palomo: I would like to thank all those who agreed to be interviewed, as well as the photographers and artists who were involved in this book. Many of these contributors were unknown to us before this project, and their engagement from the beginning has been invaluable. I am also grateful to IRD Editions and UNESCO for their continuous support, and for the funding from the French National Research Agency's *Programme d'Investissements d'Avenir* – Make Our Planet Great Again (grant no. ANR-19-MPGA-0009).

Sofía Lana: I am grateful to the Wenner-Gren Foundation, the Fulbright Student Program, and the National Science Foundation (Grant No. BCS-2116197) for funding my doctoral dissertation research, the contents of which are my sole responsibility. An immense thank you to Olivier Dangles for inviting me to join the "Life without Ice" project, a pivotal opportunity in my goal of seeking transdisciplinary bridges in the study of glaciers, as well as Ignacio Palomo for so generously making space for me to participate in this book. Long conversations with both have taught me that bridges begin when we take the "other" and their world-making practices seriously, and we allow our own worlds to be challenged. I thank those without whom I would have nothing to say – those interviewed in this book and the many others who have entrusted me with their life stories and knowledge over the years. I am profoundly grateful to those who are taking care of the mountains that appear in this book in their daily lives.

Antoine Rabatel: Many thanks to Victor Ramseyer for his work on the simulations of glacier extent in the future.

Work published with the support of

The Mountain Research Initiative (MRI)

Life Without Ice (LWI), funded by BNP Paribas

L'Institut des géosciences de l'environnement (IGE)

L'Observatoire des sciences de l'univers de Grenoble (OSUG)

The funders had no role in study design, data collection and analysis, decision to publish or preparation of the manuscript. This project was in compliance with the opinion of the IRD's Comité éthique on the modalities of implementation of development research funding from foundations and private actors (26 June 2024). In particular, this funding was respected the full autonomy of the researchers within the framework of the agreement signed with the donor.

References

Prologue

Olson R., 2018 – *Don't Be Such a Scientist: Talking Substance in an Age of Style*. Washington, D.C., Island Press.

Walker-Crawford N., 2021 – "The moral climate of melting glaciers". In Sillitoe P. (ed.) *The Anthroposcene of Weather and Climate: Ethnographic Contributions to the Climate Change Debate*. New York, Berghahn Books: 146.

Tropical glaciers: an oxymoron under threat

Castree N., 2016 – Broaden research on the human dimensions of climate change. *Nature Climate Change*, 6 (8): 731.

Cruikshank J., – *Do Glaciers Listen? Local Knowledge, Colonial Encounters, and Social Imagination*. Vancouver, UBC Press.

Dangles O., 2023 – *Climate Change on Mountains: Reviving Humboldt's Approach to Science*. Berlin, Springer Nature.

De Saussure H. B., 1796 – *Voyages dans les Alpes*.

Egan P. A. & Price M. F., 2017 – *Mountain ecosystem services and climate change: A global overview of potential threats and strategies for adaptation*. Paris, UNESCO.

Fromm E., 2000 – *The Art of Loving: The Centennial Edition*. London, A&C Black.

Gagné K., Rasmussen M. B. & Orlove B., 2014 – Glaciers and society: Attributions, perceptions, and valuations. *Wiley Interdisciplinary Reviews: Climate Change*, 5 (6): 793–808.

Haidt J., 2012 – *The Righteous Mind: Why Good People Are Divided by Politics and Religion*. New York, Pantheon.

Kahneman D., 2011 – *Thinking, Fast and Slow*. New York, Farrar, Straus and Giroux.

Kals E. & Müller M. M., 2012 – "Emotions and environment". In Clayton S. (ed.) *The Oxford Handbook of Environmental and Conservation Psychology*. New York, Oxford University Press: 128–147.

Martín-López B., Leister I., Lorenzo Cruz P., Palomo I., Grêt-Regamey A., Harrison P. A., Lavorel S., Locatelli B., Lucque S. & Walz A., 2019 – Nature's contributions to people in mountains: A review. *PloS One*, 14 (6): e0217847.

Palomo I., 2017 – Climate change impacts on ecosystem services in high mountain areas: a literature review. *Mountain Research and Development*, 37 (2): 179–187.

Palomo, I., 2018 – Test climate targets using fragile ecosystems. *Nature*, 553 (7686): 155–156.

Permana D. S., Thompson L. G., Mosley-Thompson E., Davis M. E., Lin P. N., Nicolas J. P., Bolzan J. F., Bird B. W., Mikhalenko V. N., Gabrielli P., Zagorodnov V., Mountain K. R., Schotterer U., Hanggoro W., Habibie M. N., Kaize Y., Gunawan D., Setyadi G., Susanto R. D., Fernández A. & Mark B. G., 2019 – Disappearance of the last tropical glaciers in the Western Pacific Warm Pool (Papua, Indonesia) appears imminent. *Proceedings of the National Academy of Sciences*, 116 (52): 26382–26388.

Rounce D. R., Hock R., Maussion F., Hugonnet R., Kochtitzky W., Huss M., Berthier E., Brinkerhoff D. J., Compagno L., Copland L., Farinotti D., Menounos B. & McNabb R., 2023 – Global glacier change in the 21st century: Every increase in temperature matters. *Science*, 379 (6627): 78–83.

SCHOOLMEESTER T., JOHANSEN K. S., ALFTHAN B., BAKER E., HESPING M. & VERBIST K., 2018 - *The Andean Glacier and Water Atlas – The Impact of Glacier Retreat on Water Resources*. Paris, UNESCO and GRID Arendal.

Toomey A. H., 2023 – Why facts don't change minds: Insights from cognitive science for the improved communication of conservation research. *Biological Conservation*, 278: 109886.

UNESCO & IUCN., 2022 - *World Heritage Glaciers: Sentinels of climate change*. Paris, UNESCO; Gland, IUCN.

Vuille M., Carey M., Huggel C., Buytaert W., Rabatel A., Jacobsen D., Soruco A., Villacis M., Yarleque C., Timm O. E., Condom T., Salzmann N. & Sicart J. E., 2018 – Rapid decline of snow and ice in the tropical Andes – Impacts, uncertainties and challenges ahead. *Earth-Science Reviews*, 176: 195–213.

Zimmer A., Beach T., Riva Regalado S., Salcedo Aliaga J., Cruz Encarnación, R. & Anthelme F., 2023 – Llamas (Llama glama) enhance proglacial ecosystem development in Cordillera Blanca, Peru. *Scientific Reports*, 13 (1): 15936.

Who are these voices?

Future generations

Brugger J., Dunbar K. W., Jurt C. & Orlove B., 2013 – Climates of anxiety: Comparing experience of glacier retreat across three mountain regions. *Emotion, Space and Society*, 6: 4–13.

Cauvy-Fraunié S. & Dangles O., 2019 – A global synthesis of biodiversity responses to glacier retreat. *Nature Ecology & Evolution*, 3 (12): 1675–1685.

Ceballos J. L., Euscátegui C., Ramírez J., Cañon M., Huggel C., Haeberli W. & Machguth H., 2006 – Fast shrinkage of tropical glaciers in Colombia. *Annals of Glaciology*, 43: 194–201.

Knight P. G., 2019 – *Glacier: Nature and Culture*. London, Reaktion Books.

Macfarlane R., 2009 – *Mountains of the Mind: A History of a Fascination*. London, Granta.

Orlove B. S., Wiegandt E. & Luckman B. H., 2008 – *Darkening Peaks: Glacier Retreat, Science, and Society*. Berkeley, University of California Press.

Rabatel A., Ceballos J. L., Micheletti N., Jordan E., Braitmeier M., González J., Mölg N., Ménégoz M., Huggel C. & Zemp M., 2018 – Toward an imminent extinction of Colombian glaciers? *Geografiska Annaler: Series A, Physical Geography*, 100(1): 75–95.

Rounce D. R., Hock R., Maussion F., Hugonnet R., Kochtitzky W., Huss M., Berthier E., Brinkerhoff D. J., Compagno L., Copland L., Farinotti D., Menounos B. & McNabb R., 2023 – Global glacier change in the 21st century: Every increase in temperature matters. *Science*, 379 (6627): 78–83.

Indigenous peoples

Callison C., 2021 – Refusing more empire: utility, colonialism, and Indigenous knowing. *Climatic Change*, 167 (3): 58.

Cameron E. S., 2012 – Securing Indigenous politics: A critique of vulnerability and adaptation approach to the human dimensions of climate change in the Canadian Arctic. *Global Environmental Change*, 22: 103–114.

Cruikshank J., 2005 – *Do Glaciers Listen? Local Knowledge, Colonial Encounters and Social Imagination*. Vancouver, UBC Press.

Cruikshank J., 2012 – Are glaciers good to think with? Recognising Indigenous Environmental Knowledge. *Anthropological Forum*, 22 (3): 239–250.

De Castro E. V., 2004 – Perspectival anthropology and the method of controlled equivocation. *Tipití: Journal of the Society for the Anthropology of Lowland South America*, 2 (1): 3–22.

Harada T., 2022 – "Indigenous peoples and international institutions: Indigenous people's diplomacies at the United Nations". In Postero N. (coord.) *Routledge Handbook of Indigenous Development*. London, Routledge.

Hastrup K., 2013 – Anthropological contributions to the study of climate: past, present, future. *Wiley Interdisciplinary Reviews: Climate Change*, 4 (4): 269–281.

Nutall M. M., 2009 – "Living in a World of Movement: Human Resilience to Environmental Instability in Greenland". In Crate S.A. & Nuttall M. (eds.) *Anthropology and Climate Change: From Encounters to Actions*. New York, Routledge: 292–310.

Schilling-Vacaflor A. & Gustafsson M.-T., 2022 – "Indigenous-led spaces in environmental governance". In Postero N. (coord.) *Routledge Handbook of Indigenous Development*. London, Routledge.

Whyte K., 2016 – "Is it a Colonial Deja Vu? Indigenous Peoples and Climate Injustice". In Adamson J., Davis M. & Huang H. (eds.) *Humanities for the Environment: Integrating Knowledges, Forging New Constellations of Practice*. London, Earthscan Publications.

Tourists

Bloom L., 1993 – *Gender on Ice: American Ideologies of Polar Expeditions*. Minneapolis and London, University of Minnesota Press.

Carey M., 2007 – The history of ice: how glaciers became an endangered species. *Environmental History*, 12 (3): 497–527.

Jackson M., 2015 – Glaciers and climate change: narratives of ruined futures. *Wiley Interdisciplinary Reviews: Climate Change*, 6 (5): 479–492.

Logan J., 2011 – *Aconcagua: The Invention of Mountaineering on American's Highest Peak*. Phoenix, University of Arizona Press.

Ortner S., 2001 – *Life and Death on Mt. Everest: Sherpas and Himalayan Mountaineering*. New Jersey, Princeton University Press.

Varnajot A. & Salim E., 2024 – The hauntology of climate change: glacier retreat and dark tourism. *Tourism Geographies*: 1–18.

Guardians of glaciers

Anacona P. I., Kinney J., Schaefer M., Harrison S., Wilson R., Segovia A., Mazzorana B., Guerra F., Farías D., Reynolds J. M. & Glasser N. F., 2018 – Glacier protection laws: Potential conflicts in managing glacial hazards and adapting to climate change. *Ambio*, 47: 835–845.

Bosson J. B., Huss M. & Osipova E., 2019 – Disappearing world heritage glaciers as a keystone of nature conservation in a changing climate. *Earth's Future*, 7 (4): 469–479.

Bosson J. B., Huss M., Cauvy-Fraunié S., Clément J. C., Costes G., Fischer M., Poulenard J. & Arthaud F., 2023 – Future emergence of new ecosystems caused by glacial retreat. *Nature*, 620 (7974): 562–569.

Carey M., Barton J. & Flanzer S., 2022 – "Glacier protection campaigns: what do they really save?" In Dodds K. & Sörlin S. (eds.) *Ice Humanities*. Manchester, Manchester University Press: 89–109.

Christel L. & Torunczyk D., 2017 – Sovereignties in conflict: Socio-environmental mobilization and the glaciers law in Argentina. *European Review of Latin American and Caribbean Studies/Revista Europea de Estudios Latinoamericanos y del Caribe*, (104): 47–68.

Clouse C., 2022 – Glacier blanketing: Two approaches in the European Alps. *Journal of Landscape Architecture*, 17 (3): 70–83.

Hannah L., 2008 – Protected areas and climate change. *Annals of the New York Academy of Sciences*, 1134 (1): 201–212.

Li J., Liang Y., Li W., Xu N., Zhu B., Wu Z., Wang X., Fan S., Wang M. & Zhu J., 2022 – Protecting ice from melting under sunlight via radiative cooling. *Science Advances*, 8 (6): eabj9756.

O'Donnell E. L., 2018 – At the intersection of the sacred and the legal: Rights for nature in Uttarakhand, India. *Journal of Environmental Law*, 30 (1): 135–144.

Palomo I., Montes C., Martin-Lopez B., González J. A., Garcia-Llorente M., Alcorlo P. & Mora M. R. G., 2014 – Incorporating the social-ecological approach in protected areas in the Anthropocene. *BioScience*, 64 (3): 181–191.

Poirier C., 2023 – *L'altérité dans la nature. Chemins pour s'ouvrir aux existences autres qu'humaines*. Doctoral dissertation, University of Montpellier.

Rounce D. R., Hock R., Maussion F., Hugonnet R., Kochtitzky W., Huss M., Berthier E., Brinkerhoff D. J., Compagno L., Copland L., Farinotti D., Menounos B. & McNabb R., 2023 – Global glacier change in the 21st century: Every increase in temperature matters. *Science*, 379 (6627): 78–83.

Senese A., Azzoni R. S., Maragno D., D'Agata C., Fugazza D., Mosconi B., Trenti A., Meraldi E., Smiraglia C. & Diolaiuti G., 2020 – The non-woven geotextiles as strategies for mitigating the impacts of climate change on glaciers. *Cold Regions Science and Technology*, 173: 103007.

Victims

Baraer M., Mark B. G., McKenzie J. M., Condom T., Bury J., Huh K. I., Portocarrero C., Gómez J. & Rathay S., 2012 – Glacier recession and water resources in Peru's Cordillera Blanca. *Journal of Glaciology*, 58 (207): 134–150.

Carey M., 2005 – Living and dying with glaciers: people's historical vulnerability to avalanches and outburst floods in Peru. *Global and Planetary Change*, 47 (2-4): 122–134.

Carey M., 2010 – *In the Shadow of Melting Glaciers: Climate Change and Andean Society*. Oxford, Oxford University Press.

Carey M., McDowell G., Huggel C., Marshall B., Moulton H., Portocarrero C., Provant Z., Reynolds J. M. & Vicuña L., 2021 – "A socio-cryospheric systems approach to glacier hazards, glacier runoff variability, and climate change". In Haeberli W., Whiteman C. A. & Shroder J. (eds.) *Snow and Ice-related Hazards, Risks, and Disasters*. Amsterdam, Elsevier: 215–257.

Carrivick J. L. & Tweed F. S., 2016 – A global assessment of the societal impacts of glacier outburst floods. *Global and Planetary Change*, 144: 1–16.

Cluff L. S., 1971 – Peru earthquake of May 31, 1970; engineering geology observations. *Bulletin of the Seismological Society of America*, 61 (3): 511–533.

Hewitt K., 2013 – Environmental disasters in social context: toward a preventive and precautionary approach. *Natural Hazards*, 66: 3–14.

Hewitt K., 2016 – "The human ecology of disaster risk in cold mountainous regions". In Cutter S. (ed.) *Oxford Research Encyclopedia of Natural Hazard Science*. Oxford, Oxford University Press.

Huss M. & Hock R., 2018 – Global-scale hydrological response to future glacier mass loss. *Nature Climate Change*, 8 (2): 135–140.

Keya T. A., Leela A., Habib N., Rashid M. & Bakthavatchalam P., 2023 – Mental health disorders due to disaster exposure: a systematic review and meta-analysis. *Cureus*, 15 (4).

Larsen L. S., 2018 – *Climate Blame below the Glaciers: Challenges to Climate Justice in Peruvian Mountains and German Courts*. Master's thesis. Lund University.

Oliver-Smith A., 1990 – Post-disaster housing reconstruction and social inequality: a challenge to policy and practice. *Disasters*, 14 (1): 7–19.

Paerregaard K., 2020 – Searching for the new human: Glacier melt, anthropogenic change and self-reflection in Andean Pilgrimage. *The University of Chicago Press Journals: HAU Journal of Ethnographic Theory*, 10 (3).

Price M., 2015 – *Mountains: A Very Short Introduction*. Oxford, Oxford University Press.

Varnajot A. & Salim E., 2024 – The hauntology of climate change: glacier retreat and dark tourism. *Tourism Geographies*: 1–18.

Scientists

Achten W. M., Almeida J. & Muys B., 2013 – Carbon footprint of science: More than flying. *Ecological Indicators*, 34: 352–355.

Adler C., Wester P., Bhatt I., Huggel C., Insarov G., Morecroft M., Muccione V., Prakash A. et al., 2022 – Cross-Chapter Paper 5: Mountains. *Climate Change 2022: Impacts, Adaptation, and Vulnerability*. IPCC.

Allison E. A., 2015 – The spiritual significance of glaciers in an age of climate change. *WIRES Climate Change*, 6 (5): 493–508.

Cunsolo A. & Ellis N. R., 2018 – Ecological grief as a mental health response to climate change-related loss. *Nature Climate Change*, 8: 275–281.

Gratiot N., Klein J., Challet M., Dangles O., Janicot S., Candelas M., Sarret G., Panthou G., Hingray B., Champollion N., Montillaud J., Bellemain P., Marc O., Bationo C.-S., Monnier L., Laffont L., Foujols M. A., Riffault V., Tinel L., Mignot E., Philippon N., Dezetter A., Caron A., Piton G., Verney-Carron A., Delaballe A., Bardet N., Nozay-Maurice F., Loison A.-S., Delbart F., Anquetin S., Immel F., Baehr C., Malbet F., Berni C., Delattre L., Echevin V., Petitdidier E., Aumont O., Michau F., Bijon N., Vidal J.-P., Pinel S., Biabiany O., Grevesse C., Mimeau L., Biarnès A., Récapet C., Costes-Thiré M., Poupaud M., Barret M., Bonnin M., Mournetas V., Tourancheau B., Goldman B., Bonnet M. P. & Soret I. M., 2023 – A transition support system to build

decarbonization scenarios in the academic community. *PloS Sustainability and Transformation*, 2 (4): e0000049.

Huss M., Bookhagen B., Huggel C., Jacobsen D., Bradley R. S., Clague J. J., Vuille M., Buytaert W., Cayan D. R., Greenwood G., Mark B. G., Milner A. M., Weingartner R. & Winder M., 2017 – Toward mountains without permanent snow and ice. *Earth's Future*, 5 (5): 418–435.

Mooney H. A., Duraiappah A. & Larigauderie A., 2013 – Evolution of natural and social science interactions in global change research programs. *Proceedings of the National Academy of Sciences*, 110 (supplement_1): 3665–3672.

Palomo I., González-García A., Ferraro P. J., Pascual U., Arboledas M., Bullock J. M., Bruley E., Gómez-Baggethun E. & Lavorel S., 2025 – Business-as-usual trends largely miss 2030 global environmental targets. AMBIO, 54: 1–13.

Schipper E. L. F., Maharaj S. S. & Pecl G. T., 2024 – Scientists have emotional responses to climate change too. *Nature Climate Change*, 14 (10): 1010–1012.

Steffen W., Richardson K., Rockström J., Cornell S. E., Fetzer I., Bennett E. M., Biggs R., Carpenter S. R., de Vries W., de Wit C. A., Folke C., Gerten D. Heinke J., Mace G. M., Persson M., Ramanathan V., Reyers B. & Sörlin S., 2015 – Planetary boundaries: Guiding human development on a changing planet. *Science*, 347 (6223): 1259855.

Whitmarsh L., Capstick S., Moore I., Köhler J. & Le Quéré C., 2020 – Use of aviation by climate change researchers: Structural influences, personal attitudes, and information provision. *Global Environmental Change*, 65: 102184.

Zimmer A., Beach T., Riva Regalado S., Salcedo Aliaga J., Cruz Encarnación R. & Anthelme F., 2023 – Llamas (Llama glama) enhance proglacial ecosystem development in Cordillera Blanca, Peru. *Scientific Reports*, 13 (1): 15936.

Mountain guides and alpinists

Clayton S., Devine-Wright P., Stern P. C., Whitmarsh L., Carrico A., Steg L., Swim J. & Bonnes M., 2015 – Psychological research and global climate change. *Nature Climate Change*, 5 (7): 640–646.

Herring S. C., Hoerling M. P., Kossin J. P., Peterson T. C. & Stott P. A., 2015 – Explaining extreme events of 2014 from a climate perspective. *Bulletin of the American Meteorological Society*, 96 (12): S1–S172.

Huggel C., Clague J. J. & Korup O., 2012 – Is climate change responsible for changing landslide activity in high mountains? *Earth Surface Processes and Landforms*, 37 (1): 77–91.

Mourey J., Marcuzzi M., Ravanel L. & Pallandre F., 2019 – Effects of climate change on high Alpine mountain environments: Evolution of mountaineering routes in the Mont Blanc massif (Western Alps) over half a century. *Arctic, Antarctic, and Alpine Research*, 51 (1): 176–189.

Mourey J., Perrin-Malterre C. & Ravanel L., 2020 – Strategies used by French Alpine guides to adapt to the effects of climate change. *Journal of Outdoor Recreation and Tourism*, 29: 100278.

Ravanel L., Deline P., Lambiel C. & Vincent C., 2013 – Instability of a High Alpine Rock Ridge: the Lower Arête Des Cosmiques, Mont Blanc Massif, France. *Geografiska Annaler: Series A, Physical Geography*, 95 (1): 51–66.

Ritter F., Fiebig M. & Muhar A., 2012 – Impacts of global warming on mountaineering: A classification of phenomena affecting the alpine trail network. *Mountain Research and Development*, 32 (1): 4–15.

Spence A., Poortinga W., Butler C. & Pidgeon N. F., 2011 – Perceptions of climate change and willingness to save energy related to flood experience. *Nature Climate Change*, 1 (1): 46–49.

Temme A. J., 2015 – Using climber's guidebooks to assess rock fall patterns over large spatial and decadal temporal scales: An example from the Swiss Alps. *Geografiska Annaler: Series A, Physical Geography*, 97 (4): 793–807.

Weber E. U., 2013 – Seeing is believing. *Nature Climate Change*, 3 (4): 312–313.

Artists

Dangles O., 2023 – *Climate Change on Mountains: Reviving Humboldt's Approach to Science*. Berlin, Springer Nature.

Detwiler F., 2014 – "Moral Foundations of Tlingit Cosmology". In Harvey G. (ed.) *The Handbook of Contemporary Animism*. Abingdon, Routledge: 167–180.

Gagné K., Rasmussen M. B. & Orlove B., 2014 – Glaciers and society: Attributions, perceptions, and valuations. *Wiley Interdisciplinary Reviews: Climate Change*, 5 (6): 793–808.

Gambino M., 2013 – *Art Chronicles Glaciers as They Disappear*. Smithsonian Magazine, 27 November 2013.

Inkpen D., 2024 – The Iconography of Ice: The history and politics of glacier photography. *Natural History*, 132 (2): 36–42.

Knight P. G., 2004 – Glaciers: art and history, science and uncertainty. *Interdisciplinary Science Reviews*, 29 (4): 385–393.

Kothe E. L., Maute M. J. & Brewer C., 2015 – Vanishing ice: Art as a tool for documenting climate change. *Art Education*, 68 (2): 48–54.

Matilsky B., 2015 – *Vanishing Ice: Alpine and Polar Landscapes in Art, 1775–2012*. Seattle, University of Washington Press.

New life

Anthelme F., Cavieres L. A. & Dangles O., 2014 – Facilitation among plants in alpine environments in the face of climate change. *Frontiers in Plant Science*, 5: 387.

Cauvy-Fraunié S. & Dangles O., 2019 – A global synthesis of biodiversity responses to glacier retreat. *Nature Ecology and Evolution*, 3: 1675–1685.

Dangles O., 2023 – *Climate Change on Mountains: Reviving Humboldt's Approach to Science*. Berlin, Springer Nature.

Ficetola G. F., Marta S., Guerrieri A., Cantera I., Bonin A., Cauvy-Fraunié S., Ambrosini R., Caccianiga M., Anthelme F., Azzoni R. S., Almond P., Alviz Gazitúa P., Ceballos Lievano J. L. Chand P., Sharma M. C., Clague J. J., Cochachín Rapre J. A., Compostella C., Cruz Encarnación R., Dangles O., Deline P., Eger A., Erokhin S., Franzetti A., Gielly L., Gili F., Gobbi M., Hågvar S., Kaufmann R., Khedim N., Meneses R. I., Morales-Martínez M. A., Peyre G., Pittino F., Proietto A., Rabatel A., Sieron K., Tielidze L., Urseitova N., Yang Y., Zaginaev V., Zerboni A., Zimmer A., Diolaiuti G. A., Taberlet P., Poulenard J., Fonaneto D., Thuiller W. & Carteron A., 2024 – The development of terrestrial ecosystems emerging after glacier retreat. *Nature*, 632: 336–342.

Jacobsen D. & Dangles O., 2017 – *Ecology of High-altitude Waters*. Oxford, Oxford University Press.

Rosero P., Crespo-Pérez V., Espinosa R., Andino P., Barragán Á., Moret P., Gobbi M., Ficetola G. F., Jaramillo R., Muriel P., Anthelme F., Jacobsen D., Dangles O., Condom T., Gielly L., Poulenard J., Rabatel A., Basantes R., Cáceres Correa B. & Cauvy-Fraunié S., 2021 – Multi-taxa colonisation along the foreland of a vanishing equatorial glacier. *Ecography*, 44 (7): 1010–1021.

Zimmer A., Beach T., Riva Regalado S., Salcedo Aliaga J., Cruz Encarnación R. & Anthelme F., 2023 – Llamas (Llama glama) enhance proglacial ecosystem development in Cordillera Blanca, Peru. *Scientific Reports*, 13 (1): 15936.

The importance of emotions

Albrecht G., 2005 – "Solastalgia": A New Concept in Health and Identity. PAN: *Philosophy Activism Nature*, 3: 44–59.

Barnett J., Ellis N., Lawrence C., Tschakert P., Tuana N., New M., Elrick-Barr C., Pandit R. & Pannell D., 2017 – Climate change and loss, as if people mattered: values, places, and experiences. *WIREs Climate Change*, 8: 1–19.

Born D., 2019 – Bearing witness? Polar bears as icons for climate change communication in National Geographic. *Environmental Communication*, 13 (5): 649–663.

Brosch T., 2021 – Affect and emotions as drivers of climate change perception and action: a review. *Current Opinion in Behavioral Sciences*, 42: 15–21.

Davidson D. J. & Kecinski M., 2022 – Emotional pathways to climate change responses. *Wiley Interdisciplinary Reviews: Climate Change*, 13 (2): e751.

Farbotko C. & McGregor H. V., 2010 – Copenhagen, climate science and the emotional geographies of climate change. *Australian Geographer*, 41 (2): 159–166.

Haraway D., 1988 – Situated knowledges: the science question in feminism and the privilege of partial perspective. *Feminist Studies*, 14 (3): 575–599.

Hermann E., 2017 – "Climate Change and Worries over Land: Articulations in the Atoll State of Kiribati".

In Dürr E. & Pascht A. (eds.) *Environmental Transformations and Cultural Responses: Ontologies, Discourses, and Practices in Oceania*. New York, Palgrave Macmillan.

Salama S. & Aboukoura K., 2018 – "Role of emotions in climate change communication". In Leal Filho W., Manolas E., Azul A. M., Azeiteiro U. M. & McGhie H. (eds.) *Handbook of Climate Change Communication: Vol. 1: Theory of Climate Change Communication*. Cham, Switzerland, Springer: 137–150.

Wang S., Leviston Z., Hurlstone M., Lawrence C. & Walker I., 2018 – Emotions predict policy support: Why it matters how people feel about climate change. *Global Environmental Change*, 50: 25–40.

Weber E. U., 2006 – Experience-based and description-based perceptions of long-term risk: why global warming does not scare us (yet), *Climatic Change*, 77: 103–120.

Wright S., Plahe J. & Jack G., 2023 – "Feeling climate change to the bone: emotional topologies of climate". In Jakimow T. (ed.) *Affect, Emotions and Power in Development Studies Theory and Practice*. Abingdon, Routledge.

Conclusion

Aristotle, 2020 – *The Nicomachean Ethics*. Translated by Adam Beresford. New York, Penguin Classics.

Hickel, J., 2020 – Quantifying national responsibility for climate breakdown: an equality-based attribution approach for carbon dioxide emissions in excess of the planetary boundary. *The Lancet Planetary Health*, 4 (9): e399-e404.

Hume, D., 1779 – "An enquiry concerning human understanding". In Hume D., *Essays and Treatises on Several Subjects*, Vol. 2.: 3–212

Orlove, B. S., Wiegandt, E. & Luckman, B. H. (eds.), 2008 – *Darkening Peaks: Glacier Retreat, Science, and Society*. Berkeley and Los Angeles, University of California Press.

Rawls, J., 1971 – *A Theory of Justice*. Cambridge (Mass.), Harvard University Press.

Sandel, M., 2010 – *Justice: What's the Right Thing to Do?* New York, Farrar, Straus and Giroux.

Spinoza, B., 1677 – *Ethics*.

Methodology

Farinotti D., Huss M., Fürst J. J., Landmann J., Machguth H., Maussion F. & Pandit A., 2019 – A consensus estimate for the ice thickness distribution of all glaciers on Earth. *Nature Geoscience*, 12 (3): 168–173.

Hugonnet R., McNabb R., Berthier E., Menounos B., Nuth C., Girod L., Farinotti D., Huss M., Dussaillant I., Brun F. & Kääb A., 2021 – Accelerated global glacier mass loss in the early twenty-first century. *Nature*, 592 (7856): 726–731.

Millan R., Mouginot J., Rabatel A. & Morlighem M., 2022 – Ice velocity and thickness of the world's glaciers. *Nature Geoscience*, 15 (2): 124–129.

Achevé d'imprimer
sur les presses de l'imprimerie Sepec - 24884250404
Péronnas, France

Dépôt légal : mai 2025

As glacier melting continues unabated at all latitudes, the loss of glaciers in the tropics provides an early glimpse of how a world without ice might be. This book gives voice to 35 diverse individuals whose lives are tied to tropical glaciers, relating their feelings, perceptions and experiences, as well as how they are adapting to a transforming reality. These testimonies, ranging from local Indigenous voices, rangers, tourists, scientists, alpinists, artists and more, with perspectives from disciplines from anthropology to glaciology to sustainability science, provide a unique window on the felt effects of glacier loss. The images showing the loss of ice of glaciers in Africa, Latin America and Southeast Asia over the last 175 years tell their own powerful and incontrovertible story.

By 2050, nearly half of the tropical glaciers in this book, including five UNESCO World Heritage Sites, four Biosphere Reserves and one Global Geopark, will be gone, and the majority will have lost around 90% of the surface area they covered during the Little Ice Age (circa 16th–19th centuries). This is a stark illustration of the impacts of climate change already occurring in some of the planet's most vulnerable regions, and a bellwether of the future of glaciers elsewhere, and the people that depend on them, if we fail to mitigate it.

30 €

9 782709 930734

IRD Éditions

FONDATION BNP PARIBAS

MOUNTAIN RESEARCH INITIATIVE

unesco