

# Arctic Tipping Points

Carlos M. Duarte and Paul Wassmann (Eds.)



Fundación **BBVA**







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CARLOS M. DUARTE AND PAUL WASSMANN

# Presentation

If the power of a book resides in the ideas and emotions that it produces in the reader, then this book is powerful indeed. Its success lies in the mix of ingredients: a setting, the Arctic, that is of crucial importance for the future of our planet; a plot that hints at a dramatic outcome but which nonetheless leaves room for hope; and a cast of characters that runs from humble microorganisms to polar bears and marine mammals; from communities with ancestral cultures to researchers equipped with the latest technology. Each has its place in a story told in sad or beautiful but always expressive images, and in words both direct and heartfelt.

Arctic Tipping Points has something for every reader. It contains rigorous scientific information selected and explained by some of the world's foremost polar researchers, but also explorations, adventure, poems, anecdotes and reflections. Because scientists experiencing the Arctic shift constantly between the objectivity needed in their work and the emotion of knowing themselves in a unique and unquestionably fragile environment. They are looking for hard facts but it is passion that drives them. Arctic science is anything but cold. "We cry seawater", one author writes, "twenty teardrops as loaded with feeling and emotions as the information held by 20 drops of water about the ocean."

A hundred million viruses; a million bacteria; a thousand protists; 200 diatom algae are concealed within these twenty drops. And scientists know that what happens in this micro world will end up altering the quantity of light reflected off the ice, the size of the polar bear population, the customs of the Inuit people and much, much more. In the Arctic, the connections between ecosystems and between them and the geochemical processes unfolding in the atmosphere and oceans—the connections between organic and inorganic—are revealed with extraordinary clarity.

There are other reasons why the frozen north has become such a focus of interest for the human species. In the Arctic, the film of the changes sweeping planet Earth is the speeded-up version. The region is warming between two and three times faster than the world average, and the effects of this ongoing climate change are being felt much sooner. All the more reason to remember that the network of connections in the Arctic biosphere stretches far beyond the ice to encompass some of the world's most populated areas... and our own day-to-day activity. The greater the thirst for fossil fuels, the faster the spread of ice sheet thinning.

As if this weren't enough, researchers have recently discovered that not all natural processes advance at a uniform rate. Changes in nature also happen "in starts", like a gentle slope that without warning turns into a precipice. The disappearance of the winter ice cover in the Arctic Ocean, the release of methane—an extraordinarily powerful greenhouse gas—due to the melting of the permafrost, or the shutdown of the thermohaline circulation—the planet's "conveyor belt"—are processes that could suddenly accelerate. And the bad news is that when we arrive at one of these precipices, turning back is difficult if not impossible. So one of the aims of this book is to explain how vital it is to stop before such tipping points are reached.

What we see in the Arctic is the dark side of industrial progress, but of course the deal cuts both ways and the developed world too will feel the consequences of what is happening on the ice. The Greenland thaw—another of the tipping points identified—would cause sea level to rise between six and seven meters, with the resulting erosion of our coastlines and flooding in far-off territories. And that is just one example. As the authors of this book put it, "the Arctic is not at the periphery but at the core of the Earth System. Tipping points in the Arctic are of major consequence for the future of humankind".

So the pages that follow show the beauty of the Arctic and its astonishing biological and cultural richness, but also the many threats it now faces; they



describe the Inuits' curious concept of time as a circle but also the forced transformation of their way of life; they explore ecosystems in fascinating detail, but without losing sight of the global ecological, social and economic picture. What will be the consequences for the world economy of the five Arctic nations opening up new oil and gas field developments which would make the Arctic Ocean navigable all year round? A total of 25 people—scientists, photographers, journalists and poets—have exchanged cameras and pens to capture and describe the images making up *Arctic Tipping Points*. Their photographs and words convey a balanced and insightful message, which the BBVA Foundation wishes to second with its publication. The BBVA Foundation numbers among its objectives the promotion of world-class research and the transmission of its results to society. This book not only fits with this objective, it also takes its place among a series of projects and award schemes devoted to climate change studies and biodiversity conservation, among them the BBVA Foundation Frontiers of Knowledge Award in Climate Change, one of the world's most prestigious scientific prizes. We can only hope that *Arctic Tipping Points* does its bit so the global drama unfolding in the Arctic has a happy ending for the planet.

BBVA Foundation



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Photos by Arvid Sveen

# Introduction

At the dawn of the 20th century, scientists had rejected ancient tales of world catastrophe, and were convinced that our planet's climate could change only gradually, over many tens of thousands of years. But in the 1950's, a few scientists found evidence that some changes in the past had taken place over a few thousand years. During the 1960's and 1970's, other data, supported by new theories and new attitudes about human influences, reduced the time frame of these climatic events to just a few hundred years. Many doubted that such a rapid shift could have befallen the planet as a whole. The 1980's and 1990's brought proof that the global climate could indeed shift, radically and catastrophically, within a century—perhaps even within a decade.

Persistent global warming beyond that which can be attributed to natural forcing, is today an indisputable fact. This is especially pronounced in the Arctic, with records indicating a heating rate of 0.4 °C per decade— far more than for the rest of the planet. These increasing temperatures change the function of the Arctic system. Despite this, humanity is now bearing witness to a fierce debate about the various possible causes of this warming. Is it all natural variation? When did the warming start? Who or what turned up the heat? How fast will these natural or human-induced changes happen? When the Intergovernmental Panel on Climate Change issued its report in 2007, environmental tipping points were a footnote. However, in the future they will have extraordinary implications for humanity. Our customary linear or curvilinear predictions of the future are easily managed mathematically, but are they credible? *Natura non saltat* (nature does not jump) is a classic saying, but since the early days of modern physics it has become evident that nature, indeed, jumps.

Governance, economy, the depiction and interpretation of bellwethers, and the understanding of the non-linearity of the nature of the climate system are the dominant challenges of our times. This intricate combination of factors has grave consequences for humanity. A good example of the effects of nonlinearity and lacking ability to detect and react on bellwethers of abrupt change is the latest bank crisis. Many of the Earth System's tipping elements are found in the Arctic: the icecap, permafrost, methane hydrates, invading species, sudden changes in economic activities, governance and politics, to mention some. To make these tipping points accessible to all of us is the ultimate goal of this book.

## Myths and Exploration of the Arctic

In early historical times ancient people such as the Greeks already had clear views about the Arctic. When the god Apollo, the god of light, music and truth, left his shrine at Delphi in autumn, he travelled north to the ice-covered “Ultima Thule” to settle for the winter. Apollo hibernated with the Hyperboreans, a legendary people believed to live “beyond the north wind” (hyper, boreas) in a land of unbroken sunshine and continuous happiness. The Hyperboreans may be the people who have inhabited the Arctic since time immemorial. Apollo was wise to go there for winter. Contrary to popular belief, the dark season in the High North is not at all depressing, but extremely pleasant and enjoyable. The good company of friends, colleagues, fellow northerners and extensive festivities are the rule, resulting in a Mediterranean-type atmosphere—indoors.



In the early Middle Ages, the High North was already well known. The Vikings settled in Iceland and Greenland and knew about a barren land in the very north—Svalbard—the name that was later given to the archipelago dominated by the island of Spitsbergen. Towards the late Middle Ages, the High North became a place full of perils and mystery. Sea monsters inhabited the ocean, the skies were lit up by terrifying Northern Lights, and strange and dangerous tribes populated the land. The High North became a more popular region among the wealthy European nations from the late 1500's onwards. Not so its people. The entrance to hell was assumed to be in either Hekla Volcano in Iceland, or close to the North Cape in Norway. Thus Northerners were met with suspicion, as they could have been possessed by evil dissipating from hell. When countries such as The Netherlands, England or France made unsuccessful efforts to find new routes to the riches of the Far East through the Northeast or Northwest Passage the wealth of natural resources of marine mammals attracted their attention.

In those days, lamps were lit by burning whale oil and a major industry was established from the rich stocks of whales, seals and walruses. Following this overexploitation, successive waves of international wealth seekers entered the Arctic territories in the Barents Sea region as well as Arctic North America. While Denmark—after unsuccessfully looking for surviving Norse settlers on Greenland—directed its attention to the islands Inuit population. In northern Europe there was close, continuous contact with the various Sami groups. The shamanism and paganism of these indigenous people made them appear mystical and undeveloped, presenting a challenge. The Enlightenment period converted them to Christianity and engaged them more fully with the ruling societies. The Sami, better known as Laps, but in particular the Inuit, better known as Eskimos, were colonized and culturally suppressed. They achieved iconographic status, as reflected in adventure books the widespread use of Inuit terms (such as kayak, anorak, parka, igloo etc.), the use of Inuit imagery in commercial logos brands (clothing, ice cream etc.), in the names of movies and navy vessels (HMS Eskimo, British destroyer of WWII).

There were continuous attempts to exploit the riches of the High North through fishing, sealing, whaling and mining. And there were the epic attempts to explore the Arctic regions and the North Pole. The Arctic is frequently described as the last frontier, clearly indicating the invasive, northbound offensive by the resource demanding South. Yet paradoxically, this terminology reflects a lack of respect for the people of the North who have their homeland in what the south calls "the frontier". There were innumerable expeditions to lay claim to the last remaining white areas on the map of the North braving unbelievable hardships which often



From the series "**Frozen horizon**".

**157** (above) and **154** (below)

Photos by Arvid Sveen



ended in death. Side by side and yet accompanied by conflicts of interests, adventurers, wreathed in an aura of glory, adventure and heroism, and Northerners tried to eke out a living from the scarce Arctic resources.

Surprisingly, the tourism of the rich and wealthy, which continues with increasing intensity into contemporary times, already existed in the late 1800's. The physical forcing in the Arctic is extreme, and the seasons vary wildly: freezing/thawing, perpetual light/perennial darkness, abundant food starvation. This extensive climate variability exposes the Arctic people to considerable strain, sometimes bringing them to the brink of extinction. The Arctic is also periodically capable of supporting human populations and has done so since the end of the last glacial period, as can be seen with the Neolithic civilizations that thrived in the very north of Norway and Russia, long before people in southern Scandinavia even existed. However, this is life at the edge and the transition between comfortable survival and sudden demise is often both rapid and abrupt. One or another crucial element of the Earth System tips perpetually throughout the year in the High North. A flourishing civilization can quickly reach a tipping point, such as the extinction of various Inuit Dorset cultures or the Norse population on Greenland. Northerners experience a continuous sequence of tipping points (the most prominent being light), however most of them reverse with time.

Modern oceanography in the Arctic Ocean began in 1893 with the epic Fram Expedition, commanded by Fridtjof Nansen. This was followed by subsequent investigations, including fishery enquiries, but in the 1930's much of this interest diminished. The Cold War was also detrimental to exploration of the Arctic Ocean. Until the early 1990's, oceanographers believed that the Arctic Ocean was the least varied region of the planet, based upon rudimentary comprehension. Later expeditions into the central Polar Ocean led to an understanding of the considerable changes that, to begin with, were attributed to climate change, but later on were interpreted as significant natural variability. In a relatively short time span our view of the Arctic Ocean changed from believing it to be the least to being, in fact, the most variable ocean. Our point of view tipped rapidly and permanently. In the foreseeable future, global warming will transform the region in an unprecedented manner. A multitude of tipping points await us in the Arctic Ocean. The Arctic Ocean has oscillated from frozen horizons to open water since time immemorial. Global warming will make frozen horizons with crystal clear skies less common, giving way to more open water with foggy and humid skies. These transformations are illustrated in the photographs that accompany the introduction. For organisms and humans adapted to these frozen horizons, such tipping points will change living conditions forever.

## Change: Non-linear Dynamics, Thresholds and Tipping Points in Nature

Evidence is growing that many ecosystems ranging from coral reefs, coastal ecosystems, semi-arid vegetation, and even ponds can have more than one stable state. This occurrence of multiple stable states implies that the system has tipping points and can undergo sudden jumps in response to changes in external factors. Four decades of experience in ecosystem management have provided ample evidence that the general approach, embedded in both environmental legislation and managerial practices, of considering the behavior of ecosystems under pressure to be simple, linear and reversible is fundamentally flawed. Support for this bold statement derives from a critical assessment of the limited success of widely diverse efforts to “fix” environmental issues stemming from human pressures, including, among others, fisheries management, eutrophication management, and the management of the Stratospheric ozone layer. Failure to revert ecosystems to their baseline status by interventions aimed at reversing the pressures acting upon them has led to the realization that ecosystems under pressure display complex trajectories that derive from a combination of complex phenomena including non-linear responses, hysteresis when pressures are relaxed and shifting baselines due to global environmental changes. Such phenomena render the widespread ex-

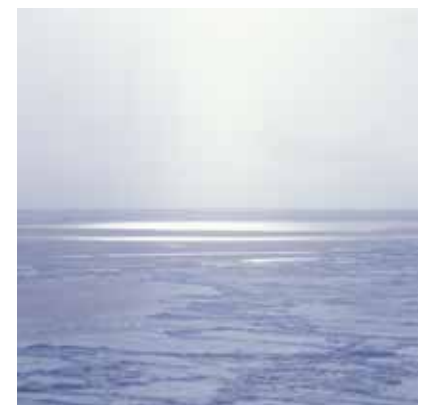


pectation that ecosystem status will reverse when pressures are relaxed an unrealistic and naïve one. The existence of ecological discontinuities and threshold effects driven by human perturbations of ecological systems has been recognized in the context of ecology as a key feature of ecosystem dynamics with significant consequences. Tipping points are thresholds of environmental forcing beyond which ecosystems exhibit abrupt changes and critical transitions. Tipping elements refer to the components of the ecosystem that cause critical transitions when subject to forcing, such as macrophytes in shallow ecosystems, whose loss triggers a shift to turbid phases in these ecosystems. Thresholds of environmental sustainability refer to the pressures that can be imposed on a given resource while maintaining acceptable levels of environmental quality. Whenever these thresholds are exceeded, the resources, services or functions affected may suddenly shift status, adopting stages that cannot be easily reverted to levels below the thresholds. More recently, ecosystem thresholds have been referred to as Tipping Points, and Tipping Elements are defined as the components of the system directly responsible for triggering abrupt changes once the tipping point is trespassed. A Point of No-return is defined as a critical value of a driver beyond which the shifts to a different regime of a state indicator shows resistance to return to the original state as the driver is reduced below the threshold.

## Arctic Tipping Elements

The Arctic ecosystem is characterized by the presence of multiple tipping elements that may lead to abrupt, catastrophic changes. The characteristic element of the Arctic ecosystem is ice, and the presence and importance of ice, at sea and on land, already determines the existence of a critical Tipping Point in the Arctic Region. This dominant tipping point is given by the temperature at which water changes from solid to liquid phase, which is 0 °C for freshwater and –1.8 °C for seawater, where the salt content lowers the freezing point. A transition across this tipping point leads to a phase shift from solid to liquid water. Accordingly, ice is a tipping element that responds abruptly to changes across this tipping point.

Trespassing the tipping point for phase transition from ice to liquid water sets all the other tipping elements contained in the Arctic region in motion. Melting of the permafrost on land, leads to the process of thermokarst formation by which solid soils become fluids and eventually ponds and aquatic ecosystems. Thermokarst lakes and ponds are formed in a depression by melt water from thawing permafrost. Depressions are often produced by the collapse of ground levels associated with permafrost thaw. Continued thawing of the permafrost substrate can lead to the drainage and eventual disappearance of thermokarst lakes, making them, in such cases, a geomorphologically temporary phenomenon. Thermokarst lakes and ponds have become increasingly common in the Arctic, including Siberia and the Canadian Arctic. Frozen soils also occur in sediments in the shallow coastal waters, overlaid by seawater.



From the series “Frozen horizon”.

162 (above) and 153 (below)

Photos by Arvid Sveen

Arctic Tipping Points

Permafrost melting increases freshwater discharge to the Arctic ecosystem, which has increased greatly in recent years, and leads to a greater input of organic materials and sediments hitherto trapped in the frozen soils. Moreover, frozen soils and sediments contain large amounts of methane hydrates. Methane hydrates are clathrate compounds. A clathrate is a structure in which water molecules freeze to form an ice-like cage that encapsulates a gas molecule, known as a guest molecule. When that guest is a methane molecule, the resulting structure is a methane hydrate, or methane trapped in frozen soils and sediments. Methane hydrates are found in sea-floor sediments and in the arctic permafrost. The total pool of methane hydrates in the Arctic is huge, estimated at about 400 Gt C (one Gt C =  $10^9$  tons C) in the permafrost alone and not less than 1,400 Gt of Carbon is presently locked up as methane and methane hydrates under the Arctic submarine permafrost. This totals more than twice the entire amount of carbon in the atmosphere and about 6 times that emitted by human activity since the industrial revolution. Methane is a powerful greenhouse gas, 20 times as powerful as a similar amount of CO<sub>2</sub>. Recent assessments have found bubbling of methane in the Siberian shelf as well as in thawing Arctic permafrost, suggesting that melting of the methane hydrates may be starting to occur. Clathrate destabilization and subsequent methane release in the Arctic is one the most serious tipping points for abrupt climate change, and an important focus of attention for research in the Arctic.

As seawater exceeds the tipping point for ice, the ice cover over the Arctic declines, with a steady decline in the minimum (reached in mid September) ice cover over the Arctic ocean from a minimum extension of 8 million km<sup>2</sup> in 1979 down to a minimum of 4.2 million km<sup>2</sup> observed in September 2007 (Fig. 1).

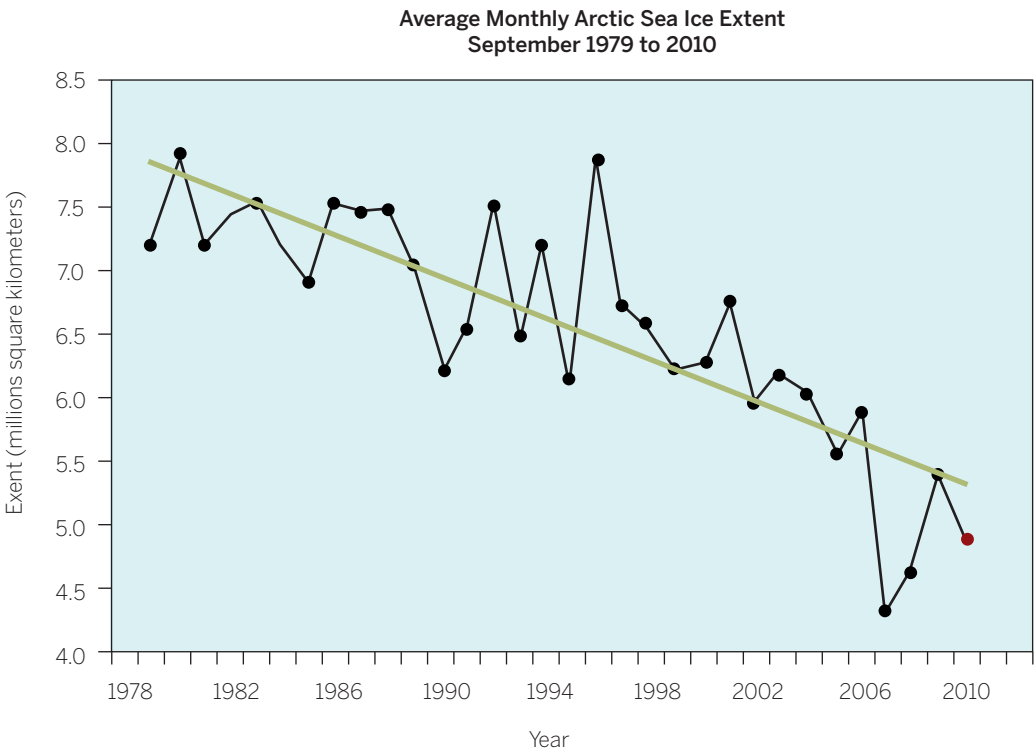


Fig. 1. Decline in minimum (September) ice extension over the Arctic.  
Source: National Snow and Ice Data Center, USA (nsidc.org).



As ice cover declines, ocean water becomes exposed and solar radiation previously reflected back to the atmosphere by the ice cover penetrates and is absorbed by the water. This alters the heat budget of the Arctic Ocean, leading to warming of the waters and acceleration of the melting of ice. Moreover, as more light reaches the seawater when ice is lost, plankton production increases, as does the release of organic compounds in the water, which adds to the increased delivery of organic matter from rivers. Organic matter dissolved in seawater strongly absorbs light and dissipates the energy as heat, thereby further increasing the warming of Arctic water once the ice cover is lost.

Increased ice melting at sea and on land leads to a higher export of freshwater from the Arctic, which adds buoyancy to the surface water mass exported south along the Greenland coast (the Greenland current), and stabilizes the water column. This added stability reduces the likelihood that the Arctic water will sink to depth to form “deep ocean water”, a phenomenon involving Arctic water just South of Greenland. The sinking of cold, dense Arctic water south of Greenland is a process that was already known to the Vikings as reflected in the *Malstrøm* myth—a saga of a whirlpool strong enough to sink Viking ships. The sinking process sets in motion the global system of oceanic currents known as “thermohaline circulation”,<sup>1</sup> which play a key role in regional climate regulation. An increase in freshwater output from the Arctic Ocean along the Greenland current may reduce sinking of water masses and slow-down or stop altogether global “thermohaline circulation”, leading to abrupt regional climate change.

The loss of ice is not confined to the sea and the thick ice sheet in Greenland is also being destabilized, as evidenced by increased ice melting and iceberg release. Loss of the Greenland ice sheet will further increase the export of freshwater from the Arctic Ocean, adding to the processes mentioned above. Moreover, the quantity of ice contained in the Greenland ice sheet is so phenomenal that loss of the Arctic ice sheet may lead to a 6 to 7 m rise in sea level. Although the time scales involved in such loss extend over centuries, the melting of the ice sheet is a process of self-acceleration. Thus destabilization of the Greenland ice sheet, which may have already started, is another tipping point of great concern with major global consequences as it will exacerbate problems of coastal erosion and flooding of low-lying areas, already impacted by climate change.

The Arctic region contains some of the key Tipping Elements of the Earth System, which—if set in motion—may generate profound global changes. Thus the Arctic is not at the periphery, but the core of the Earth System. Tipping Points in the Arctic are of major consequence for the future of human kind.

1. The term thermohaline refers to the fact that the current is due to motion set by differences in density—controlled by temperature and salinity—of water masses.



From the series “Frozen horizon”.  
150 (above). Horisont 25, Ekkerøy,  
Eastern Finnmark (below)  
Photos by Arvid Sveen

**Ice loss.** The Arctic Ocean is covered by sea ice that melts during spring and summer and freezes again from autumn onwards. Like the breath of a living being, ice acts as the ultimate pacemaker for marine life in the Arctic Ocean, regulating seasonal and interannual production and variability. The spectacular, unprecedented acceleration of Arctic ice loss in the summer of 2007, and the ensuing recovery in 2008 and 2009 towards the overall negative 1979-2009 trend line, illustrates that the Arctic Ocean can experience rapid environmental change. A tipping point was not reached, but it may have been close. At current average velocity, the ice cover is decreasing by 10% a decade. Moreover, the Arctic is warming about 2-3 times faster than the global rate and changes are likely to be seen much earlier there compared to other regions. The Arctic ice pack has been identified as one of the key tipping elements in the world climate system, making change in the Arctic significant on a global scale. The thickness of sea ice at the beginning of spring plays a role in how much ice survives the summer melt. Thus attention is given to factors such as ice motion that influence ice thickness. Ice motion is determined by winds and other factors, which in turn are influenced by weather patterns. Current ice models suggest that in two decades the Arctic Ocean may be largely ice-free in late summer, with a cover of mostly first-year ice in winter. In addition, the average thickness of sea ice has decreased steadily, whereas increases have been reported in the amount of ice and freshwater towards the outflow regions of the Fram Strait. Such extensive changes in sea ice dynamics and the ongoing declines in perennial ice cover will necessarily have effects on Arctic ecosystems, both with regard to climatic feedbacks, ecosystem structure and function.

**Albedo.** Sea ice and snow reflect sunlight, keeping the Polar Regions cool and moderating global climate. The albedo of an object is a measure of how strongly it reflects light from sources such as the sun. Compared with water, land snow and ice have a quite high albedo. Along with the decline in ice cover over the past thirty years, the albedo of the Arctic Ocean has declined too. The increasing probability of melt ponds on ice floes and “black carbon” deposition (dust from coal burning and vegetation on ice) further decreases the Arctic Ocean’s albedo. As a consequence the Arctic Ocean cools less than previously. The albedo is one of the crucial tipping elements in the Arctic Ocean Earth System, but knowledge of its role in climate feed backs in the Arctic is limited, and records of its effects in climate models are inadequate.

**Changing circulation and hydrography.** The Arctic Ocean is unique. Not only is it largely ice-covered, but it is also relatively isolated from the rest of the world’s oceans (much like the Mediterranean Sea). The central Arctic Ocean is engirdled by extensive landmasses with wide-ranging and topographic complex hinterlands drained by some of the world’s largest rivers. About 10 % of the global freshwater discharge takes place in the Arctic Ocean and with a predicted increase in run-off caused by increased precipitation and melting permafrost, a freshening of the Arctic Ocean will take place. A complex circulation system exists, with most of the water entering through the Barents Sea around Spitsbergen and leaving through the western Fram Strait, with the Bering Strait and the Canadian archipelago playing a minor role. The generic patterns of the “plumbing” and circulation system of the Arctic Ocean have only been known for about 15 years. The patterns appear to be variable, with periods of increased in or outflow, changes in the strength of return flows, variable stratification and the position and strength of deepwater formation. Physical forcing impacts the entire food web. In recent years, scientists have documented changes in the Arctic system, not only a dramatic reduction in sea ice cover, but also a weakening of the Beaufort Gyre circulation system, deep water formation in the adjacent Greenland Sea and strength of return flows, that are all attributed to climate change. Arctic Ocean physical forcing affects not only the way of life of its native people, but also those of us living “downstream,” in Europe and North America.

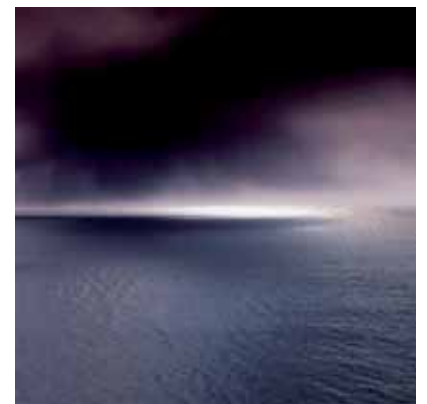


## Human Activities

After a long period of status-quo during the Cold War, the great “thaw” initiated by Gorbachev’s Murmansk speech in 1987 was followed by claims of political interests and tussles over national demarcations concerning the extension of the boundaries of exclusive economic zones of the powerful coastal nations of the Arctic. Today’s political atmosphere in the High North, peaceful as it is, does not compellingly enhance the incipient development of international efforts to better understand changes in the Arctic. Only Norway has settled its Arctic boundaries while the remaining four Arctic coastal states are staking claims over larger or smaller regions of the Arctic Ocean, based upon the Law of the Sea. Along with increasing military interests, new border claims and easier access for Arctic operations and crossings, there are various territorial claims connected to rapidly increasing economic interests in the form of oil and gas exploration, fisheries, transportation and tourism. Thus the prospects for rapidly increasing our essential knowledge of the Arctic Ocean remain unsatisfactory and will require a major impetus if we hope to prepare ourselves for sustainable management.

## Ecological and Societal Implications of Arctic Tipping Points

The rapid change in the Arctic region brought about by climate change is starting to set tipping elements into motion, with significant consequences for the Arctic ecosystem and society. Ice loss leads to the loss of critical habitat for many species, such as the polar bear, walruses and seals that depend on ice as habitat, either as hunting, resting or reproductive ground. There is already evidence that these populations are under stress, particularly polar bears and those seal species most dependent on ice. As their populations decline with ice loss, it is expected that they will hybridize with closely related species, leading to the loss of these species. Impacts are not restricted to mega fauna, but will also affect microbial and plankton communities. Psychrophilic communities, microbes that are dependent on cold water temperatures, may be lost with Arctic warming and ice loss. Experimental evidence and theoretical expectations also predict that seawater warming will lead to increased respiration rates of plankton communities relative to their photosynthetic rates, reverting the role of plankton communities from atmospheric CO<sub>2</sub> sinks to sources, further aggravating climate change. Keystone species, such as the Arctic copepod *Calanus glacialis* may be lost in a warmer Arctic, with consequent major changes in the food web, including the loss of fish and birds critically dependent on this endemic crustacean species. The



Melting Sea ice in Storfjorden  
(above). Horisont 73,  
Vesterålen (below)  
Photos by Arvid Sveen

loss of ice also entails the loss of the ice community, including filamentous algae that grow under the ice surface and a food web of invertebrates, including several species of ice amphipods, which depend on these algae. Sadly, these communities have not yet been investigated in any detail, so they may be lost before we have had an opportunity to investigate them. Changes in the Arctic are also leading to shifts in the species available to fishermen. Changes in availability between cod and shrimp, and changes in crustacean species, puts pressure on fishermen, as they result in uncertainties about the fishing equipment they should invest in, as costs are typically only recovered after years of use, and newly acquired equipment may be rendered useless when target species are replaced by other species. As these may not be accessible with the fishing equipment suited for the species they replace.

Ice loss and climate change also has an impact on Arctic communities. Melting of permafrost and thermokarstic processes are currently forcing the displacement and relocation of Arctic communities, some of whose settlements had remained in place for over 2000 years, to stable areas often hundreds of kilometers away. Traditional routes through the ice are becoming unreliable and generating risk to the lives of Inuit people, with a proliferation of incidents involving sinking of skidoos and their occupants through thin ice. Ice loss also renders Arctic marine resources, including fisheries, oil and gas, mineral resources and navigation routes linking the Pacific and Atlantic Oceans accessible to exploitation by humans. The onset of the exploitation of Arctic resources is itself, a tipping element that can shift the strategic role of the Arctic and may affect security in the region as well as global economics.

## Aim and motivation

This volume was conceived by researchers involved in, and artists connected to the European Union Framework 7 program research project *Arctic Tipping Points* (ATP) which builds upon large, integrated projects such as THRESHOLDS ([www.thresholds-eu.org](http://www.thresholds-eu.org)), DAMOCLES ([www.damocles-eu.org](http://www.damocles-eu.org)), the ARCTOS network ([www.arctosresearch.net](http://www.arctosresearch.net)) in Europe and the ArcticNet network in Canada. ATP attempts to identify elements of the Arctic marine ecosystem likely to show abrupt changes in response to climate change. The ATP project is dedicated to studying the opportunities and associated risks of economic activities dependent on the marine ecosystem of the European Arctic. Greater knowledge of what levels of warming will cause abrupt changes and when and where these may occur will enable the formulation of strategies and activities to mitigate their impact, as well as enabling profit to be gained from the opportunities such changes may bring. More broadly, ATP aims to raise awareness among policy makers and society of the existence of Arctic tipping points on global and regional scales. On a regional scale, ATP examines how both institutions and policies for the management of living marine resources, tourism and petroleum development could be adapted to cope with situations of rapid change in ecosystems driven by climate change. This is an entirely new situation that will severely test the ability of existing institutions to deliver policies that are sustainable over time. ATP aims to support the efforts of people and institutions in the Arctic region. On a global scale, an understanding of tipping points and potential regime shift in the Arctic ecosystem due to various levels of warming must be considered in negotiations toward a new international agreement for climate change regulation. ATP worked in close collaboration with the journalists and artists who joined researchers in the field during fieldwork on Spitsbergen, around Svalbard, the Barents Sea and along the coast of Greenland. This cooperation has resulted in a wealth of short films, newspaper articles, blogs and photographic exhibitions. From this work and the desire to find alternative ways to communicate knowledge to those traditionally used in science which are often inaccessible to the lay person, the idea arose to illustrate the concept of change and



tipping points in the Arctic in a form accessible to a wide spectrum of people. An approach was chosen in which artists were invited to contribute photographs and graphics to be paired with short texts written by ATP researchers, associated journalists and poets. Those invited to participate: artists, journalists and scientists all share a common passion and involvement with Polar, and particularly, Arctic ecosystems, and have directly experienced change in the Arctic and its consequences. They have been asked to translate their impressions of change into text, providing in most cases, personal accounts and feelings rather than the technical narratives that are given in the introduction to this volume. This design was developed into a book that conveys scientific findings and ideas in a manner that addresses more than the intellect appealing instead to an awareness of tipping points in the Arctic and of the imminent need for change. This book will have met its goal if the graphics and brief texts result in an greater understanding of Arctic tipping points and a feeling for the need for change. The world transforms not for the better by intellect alone, but only when human minds are reached and influenced.

CARLOS M. DUARTE AND PAUL WASSMANN



**Horisont 44**, Varangerfjorden,  
Eastern Finnmark (above).

**Kvitsjøen møter  
Barentshavet** (below)

Photos by Arvid Sveen



1

# A Changing World

## Photographers

Carlos M. Duarte

Arvid Sveen

Manuel Elviro Vidal

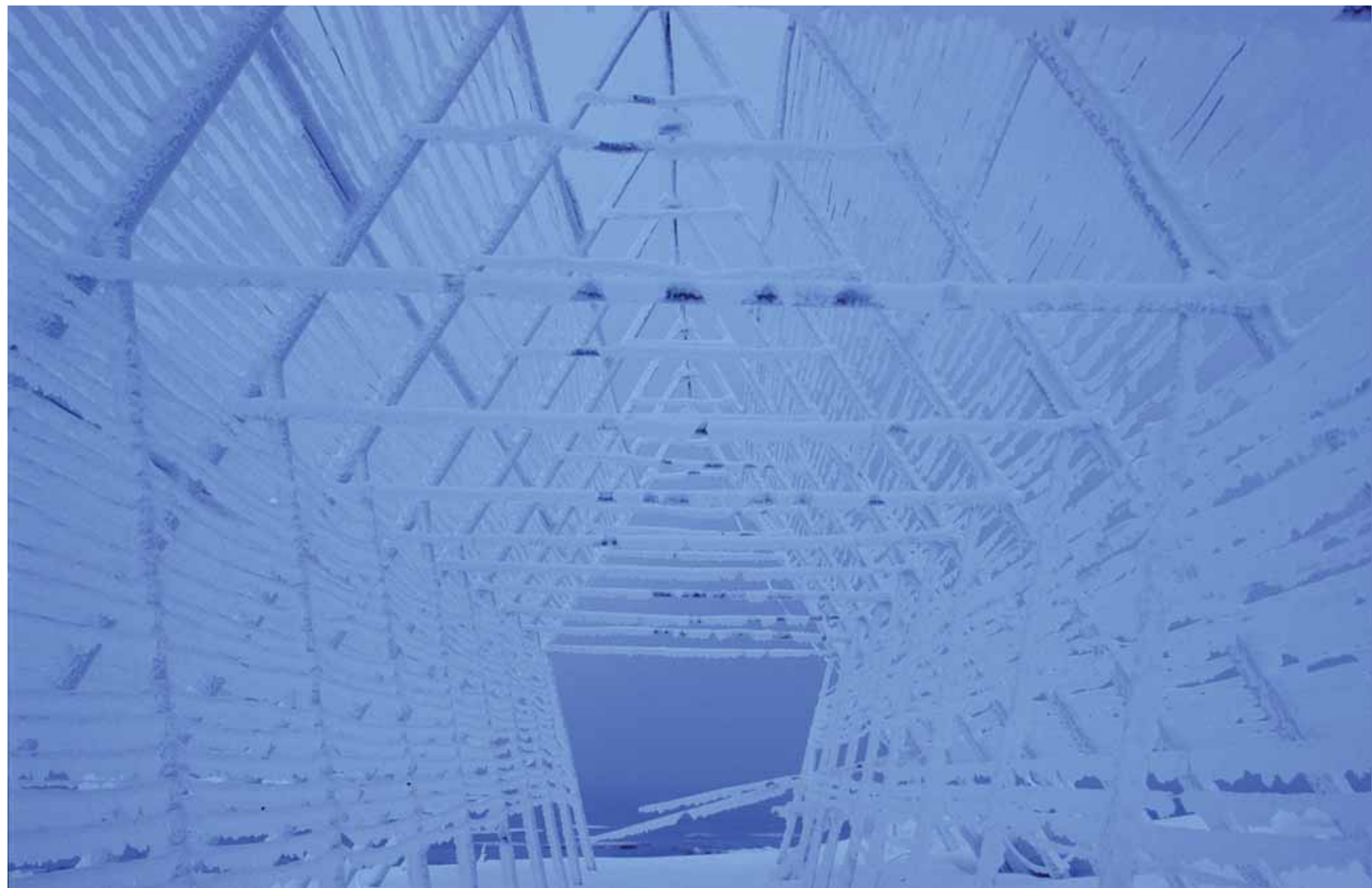
Paul Wassmann

## Authors

Carlos M. Duarte

Dorte Krause-Jensen

Isabelle Laurion



**Fiskehjell**  
Fish-drying rack used for the production of air-dried stockfish (dried cod),  
eastern Finnmark, February 1998

Photo by Arvid Sveen

# A Pentagon to Building the Future Arctic

The beams holding up this Arctic construction for the production of stockfish form a pentagon. The shape of the building resembles the Arctic Ocean, with a narrow connection to the Pacific and a broader one to the Atlantic.

The pentagonal shape of this Arctic building is also an allegory for the five Arctic nations: Russia, USA, Canada, Norway and Denmark, who have taken it upon themselves to develop and exploit the resources of the Arctic.

The Arctic has been the court of many contests over time: a contest to navigate from the Pacific to the Atlantic across the mythical Northwest Passage and the contest to be the first human to set foot at the North Pole. The current contest is however, one for ownership and control. The Arctic is now the subject of the greed of the five big Arctic nations. A summit in Greenland in 2008, followed by a summit in Canada in 2010, consolidated an agreement to distribute most of the Arctic between these five nations, greatly expanding their exclusive economic zone and rendering the international waters a tiny relict of the area they have encompassed over the past decades.

This appropriation of resources represents an additional Tipping Point in the relationship between humans and the Arctic. A utilitarian relationship where Arctic resources will be spoiled, not to address the needs of Arctic societies, but to fuel our global society's extraordinary hunger for natural resources. Tipping the balance of the respectful use of Arctic resources involves considerable risks. As I write these lines, the media is reporting the first plans to erect an oil rig on the Greenland coast. Plans that are likely to drive a surge of similar projects. Indeed, the northern limit of gas and oil exploitation has been migrating northward off the Norwegian and Russian coasts for quite some time already. Gas and oil are not the only resources sought, as the Arctic gold rush includes mineral-rich deposits, untapped but fragile fisheries, and the rights to navigate across the soon to be open and reliable northwest and northeast passages.

The Arctic five comprise a powerful Pentagon, one that defies the inadequate and weak structures humans have in place for global governance. Can the UN control this Pentagon or will it simply rubber-stamp their plans? This situation is in sharp contrast with Antarctica, which is protected by a Treaty that ensures the conservation of its ecosystems and resources as a World Heritage Site. I dream of symmetry with the Arctic, but this dream rests on thinner ice than the Arctic Ocean.

Carlos M. Duarte

## Arvid Sveen



Arvid Sveen is a visual artist, photographer and graphic designer. He is a member of The Association of Norwegian Visual Artists (NBK). His previous photographic publications include: *Helleristninger* (Rock Carvings in Alta, 1996), *Vakre Varanger* (Beautiful Varanger, about the land of the Varangerfjord, 2000), *Mytisk Landskap* (Mythical Landscape, about Sami landscape and places of sacrifice, 2003), and *Tinden: Portretter* (Portraits of Mount Tinden in Tromsø) (2006).

## Carlos M. Duarte



Carlos M. Duarte is a research professor with the Spanish Council of Scientific Research (CSIC), whose participation in the Arctic Tipping Points project he heads. He led the first Spanish oceanographic expedition to the Arctic in 2007, and has led and participated in many scientific expeditions to the Arctic and Antarctica.



**Tulipan** (The name of the ship)  
Varangerfjorden, eastern Finnmark, February 1998

Photo by Arvid Sveen

# A Frozen Ship

The exploration of the Arctic is an account of ships frozen in the ice during multiple failed attempts to sail from the Pacific to the Atlantic across the Northwest Passage. Yet frozen ships are not just a part of history, but a fact of our times. Scientists often deliberately allow research vessels to be frozen in place in order to take measurements in the Arctic through an entire winter. This was the case with the Canadian research ice breaker the Amundsen, which remained frozen in the Arctic for an entire year to allow scientists to examine the dynamics of the Arctic ecosystem in winter as part of the CASES project.

A frozen ship appears immune to the passage of time and absolutely alien to the changes in the world around it. Bound to its planetary orbit, the frozen ship remains in place while at the same time navigating with the motion of the ice in which it is embedded. Many explorers also allowed their ships to be frozen in the Arctic ice. The great Norwegian explorer Fridjof W. Nansen (1861-1930) planned to reach the North Pole by navigating with his ship the "Fram", beyond doubt the giant of Arctic exploration, frozen in ice.

The smooth rotation of the Arctic ice sheet, inspiring the circular conception of time held by the Arctic people, and implicit in the circular path of time of our own clocks, will be stopped. And time, infinite as the pathway around the perimeter of a circle, will come to an end. Frozen ships will thaw.

Carlos M. Duarte





**Black on white**

Ny Ålesund is a scientific settlement on Spitsbergen island, in the Svalbard archipelago

Photo by Manuel Elviro Vidal

# The Locomotive of Progress

The locomotive steams along the tracks carrying its load of coal toward the sea. The momentum is immense as the engine pulls thousands of tons. This is the locomotive of progress. But what does progress mean in the Arctic, what cargo does the locomotive carry? What benefits for Arctic people, what benefits for human kind?

The locomotive carries greed and trouble. The wagons are ready to remove the vast resources of the Arctic to sustain wealth and prosperity, to support the very same patterns of consumption that have set in motion the changes that now threaten the Arctic ecosystem. Will it also carry the wisdom to respect and conserve the Arctic Ecosystem?

Is progress sustainable? Would we be wise enough to use Arctic resources sustainably? But, what does “sustainable” mean in a time of abrupt change? What mix of scientific knowledge, moral principles, generosity and prudence should we load along with the mineral ores, gas and oil, coal and fisheries resources the locomotive will carry?

Most importantly, who shall drive the locomotive of progress?

Carlos M. Duarte

## Manuel Elviro Vidal



Manuel Elviro Vidal is a filmmaker and multimedia artist who collaborates with the Arctic Tipping Points project and was the artistic coordinator for this book. He contributes to many projects for the dissemination of science in which he acts as an artistic-scientific filter.





ruPhone

Barenstburg was a busy window into Russian Communism in the Arctic region. Now almost abandoned, is a shadow of its former self. The telephone was working...

Photo by Manuel Elviro Vidal

# Is There Anybody Out There?

An old Russian telephone in the Arctic coal-mining settlement Barentsburg is a silent witness to time and the changes it has brought to the Arctic.

Coal mining, once the industry that drove people to Arctic Regions such as the Svalbard Islands where this phone is located, was frequently abandoned when it was realized that subsidies were too high and coal mining was a source of the heavy metals introduced into this sensitive environment. Mining ghost towns yield to blooming tourism and research facilities, more benign to the environment. But the time is approaching to once again harvest the depths of the Arctic, dig and extract, coal, gas, oil, ore...fish, seals. The interlude of prosperity based on tourism and scientific research is nearly at an end.

The telephone is silent, but is awaiting a call. The bell will soon ring again to pass on the message: a wake-up call to alert all of humanity, for the Arctic Circle unites us all in responsibility to preserve this key environment. Listen and react to the call. It is your planet that is ringing.

Is there anybody out there?

Carlos M. Duarte

Fragile  
*It has been declared, that from  
this moment, there will be sun-  
flowers in every window*  
(R. Tagore)  
Photo by Manuel Elviro Vidal



# Artificial Sunflower

The sunflower in blue rises high and lonely above the dwarf Arctic vegetation that the icy winter and the short summer keep close to the ground. This exotic species silently tells a story from the south, or maybe one of a warmer future in which Greenland becomes a greener land.

Being pale and blue in the cold doesn't prevent the sunflower from keeping its stem erect and holding its head high as if proudly convinced of being the mightiest of plants around! And this does indeed seem to hold true. But just outside the frame of the picture, large brown kelp washed up on shore decorates the beach and modestly draws attention to the giants of the sea that in size far exceed any Arctic plant on land! The hidden underwater forests attach themselves to stones and rocks on the seafloor and form a vegetation belt along the coasts. Stretching from the shallow water out as deep as the rays of sun permit. In spite of the constantly cold water, and the sea ice that efficiently switches off the light for 9-10 months per year, the kelp can measure several meters in length even in the high north. In a warmer future with less sea ice this forest is likely to gain even more strength and remain a dignified competitor to the sunflower and other plants on land.

Dorte Krause-Jensen

## Dorte Krause-Jensen



Dorte Krause-Jensen is a senior scientist at the Danish National Environmental Research Institute (NERI), Aarhus University (Denmark). She studies the ecology of sea flora at different latitudes—most recently along the Greenlandic coasts, together with colleagues from the Arctic Tipping Point project.





Sirmilk Park

Photo by Carlos M. Duarte

# Thawed Landscapes

As the liquefying glacier recedes  
melting earth gives up its organic matter,  
food for the diverse assemblage of microbes that thrive  
in the shelter of these luxuriant aquatic ecosystems;

They release part of the carbon to the atmosphere  
leaving the rest to make its way to the ocean  
in a perpetual cycle  
in which what really matters  
depends on the scale.

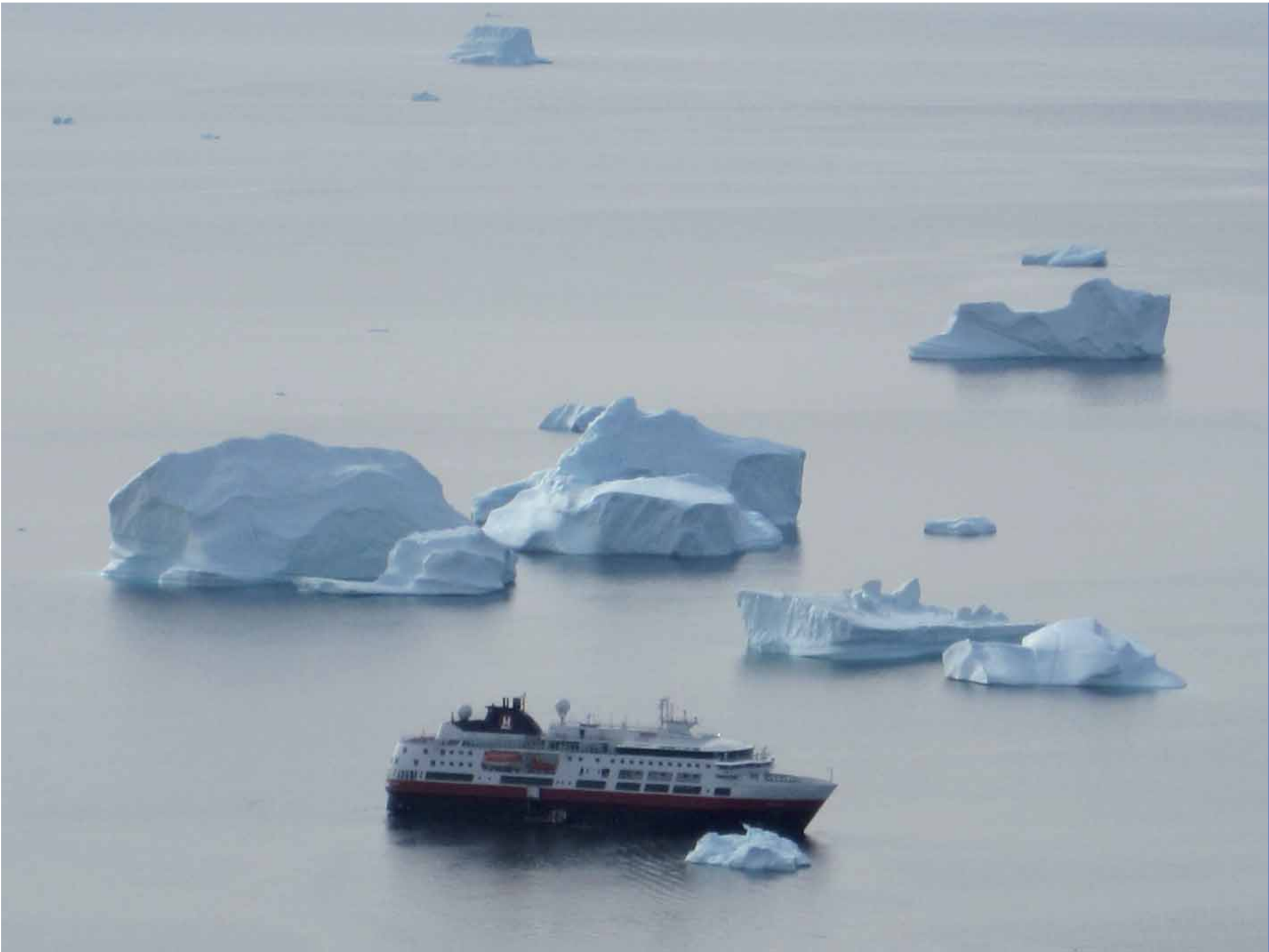
As humans,  
the scale at which we process organic matter  
has quickened the Earth's pulse.

## Isabelle Laurion



Isabelle Laurion is a professor at the Institut National de la Recherche Scientifique, Université du Québec (National Institute of Scientific Research, Quebec University, Canada) and a member of the Centre for Northern Studies and ArcticNet. She has been involved in research projects on polar ecosystems since 1992. She is particularly interested in the lakes and ponds associated with permafrost melting and their role in global carbon cycling.

Isabelle Laurion



Among giants

Photo by Paul Wassmann

# Sailing In

A tourist cruiser navigates through the gallery of icebergs, the ocean still, allowing the vessel to move smoothly around the icebergs. Some of them many times larger than the ship. The tourists on board, mostly retired, wealthy citizens of rich nations, shoot pictures to capture every angle, every shape in the icebergs sculpted into a myriad of forms by the ocean and the wind.

It is midnight, but the night sun is shining in the Arctic summer.

On board a biologist names the whales, birds and seals that approach the vessel, but no one listens, they are busy taking photos, preserving glances of the Arctic to take back home.

Peace, beauty and awe, but these cannot be captured in the snapshots Reflecting the shape, but not the grandiose nature of liquid and solid water lit by the gentle sun.

Not in their photos, but maybe in their hearts and souls: will these sensations take anchor in the souls of the tourists?

Do they realize they may be the last generation to navigate through a sea of ice in the summer?

What do the tourists bring back home? Snapshots alone?

Carlos M. Duarte

## Paul Wassmann



Paul Wassmann is a research professor at Tromsø University (Norway), and head of the Arctic Tipping Point project. He is also in charge of the ARCTOS network and has led and participated in many scientific expeditions to the European sector of the Arctic Ocean.



2

# A Sea of Ice



## Photographers

Rudi Caeyers

Manuel Elviro Vidal

Camille Seaman

## Authors

Ramon Dachs

Carlos M. Duarte

David N. Thomas

Manuel Elviro Vidal



Jagged ice

Picture taken during the iAOOS-cruise in 2007, Fram Strait

Photo by Rudi Caeyers/BFE-UIT



# Four Minimal Poems

M  
inimal poem  
irreducible  
crystal

P  
eremptory mirage  
a memory  
vanishing into the void

S  
ublunary icebergs adrift  
forging furrows in the ocean  
dissolving amid plankton

U  
ntouched  
uncharted  
exquisite world

Ramon Dachs  
(English translation by Karel Clapshaw)

## Rudi Caeyers



Rudi Caeyers is a Belgian photographer, living and working in Tromsø, northern Norway. He has worked as a photographer and designer for the Norwegian Polar Institute, the Arctic Council and the Tromsø University. He has participated in several expeditions to the Arctic and has held exhibitions in several European cities.

## Ramon Dachs



Ramon Dachs is a writer and librarian at Pompeu Fabra University in Barcelona, the city in which he was born in 1959. Dachs balances his profession with his passion for poetry. Over the last thirty years, Dachs has forged a body of work which has been published in Spain, France and Latin America. His latest book is a travel journal: *Álbum de la Antártida* (Antarctic Album) (2009).





#### Top of the world

An increase in the average temperature of up to 9 °C is expected in the Arctic during the XXI century

Photo by Manuel Elviro Vidal



# Top of the World

Art is a question mark, questioning and re-examining concepts, in a way that resembles the critical process of scientific inquiry. Art is a natural ally to Science. Artists have always had a strong bond with the environment, providing a distinct perspective on the enormous challenges ahead, on the relationship between environmental issues, and not least that between Global Change and people. A dialog to promote, catalyze, alert, challenge and respond to the unprecedented environmental challenges of our times. Artists and scientists, together, foster an interdisciplinary debate on the Impact of Human Activity on the Earth System.

But many before us have looked to the North. North is God and God is north. The Pyramid of Giza, a wonder of the ancient world, is aligned precisely with the North. For the Ancient Egyptians the Great Bear constellation portrayed the linking of the north to eternity and beyond. It was where the spirit of the Pharaoh travelled after his death. The ancient Greeks worshiped the North, the symbol of which was Olympus, meaning the highest of the highest. The sacred mountain where the gods lived in glass—possibly made of ice(?)—houses. In imperial China, it was believed that the rulers were the representatives of the Dragon God, who inhabited the North Celestial Pole. Njord, whose name means north, was God of the Sea in Norse mythology. For us, it is also a laboratory, bearing answers to pressing challenges of science.

We are the first generation living in a world in which we do not worship anything other than ourselves. We have put people on the moon. We have done all sorts of extraordinary things leading us to have a very high opinion of our own capacity. Our heroes are human heroes, a novel situation, one of human hybris. Most societies (Ode to Malinowski) had at their center the worship of something transcendent: a god, a spirit, a natural source, the universe, whatever ... This is something else I loved. We have lost this habit of worship, and I believe that perhaps the reason nature attracts us is because it provides an escape from the swarm of people, our own competitive nature and our own dramas. And that is why we enjoy seeing glaciers and oceans, because we like to feel in touch with something that is not human and yet is deeply important to us.

I faced these thoughts when I was first exposed to the Arctic and returned home to encounter a different me, to a world replaced by reproduction. A world where reality is spectacle and the citizen a client. A world whose constant conflict of values needs a romantic and idealistic vision to fight the dominant pragmatic and utilitarian values.

Myth, legend, art, literature and science are not only reflections of the environment, which have passed through the filter of human cognition, but also the means we have to determine the way ahead.

Manuel Elviro Vidal

## Manuel Elviro Vidal



Manuel Elviro Vidal is a filmmaker and multimedia artist who collaborates with the Arctic Tipping Points project and was the artistic coordinator for this book. He contributes to many projects for the dissemination of science in which he acts as an artistic-scientific filter.

Where the drift ice begins  
80°N Near Svalbard, Arctic  
Ocean, in June 2003  
Photo by Camille Seaman







# The White Sea Broke Up

The frozen sea broke up and the vast ice platform disintegrated into myriad small fragments, dancing in the waves, packed by the wind.

The wind no longer slides over the smooth surface of solid water polishing its mirror-like surface. Melted into liquid the sea now undulates into increasingly large waves that collide with the ice.

The motion of the waves pumps liquid water through the vast network of small channels that criss-cross the remaining ice floes, with the motion of a tide that melts the ice from the inside.

The solid ice, able to crash through the haul of a ship just yesterday, is now but liquid water adding to the energy of the waves that continue to charge over and over against the remaining ice.

The tipping point has been trespassed, white turns blue and the eternal white turned out to be ephemeral.

Carlos M. Duarte

## Camille Seaman



Camille Seaman is a Fine Arts photographer who has been making images in the Polar Regions for over 10 years. Her work has been widely published and exhibited globally.

## Carlos M. Duarte



Carlos M. Duarte is a research professor with the Spanish Council of Scientific Research (CSIC), whose participation in the Arctic Tipping Points project he heads. He led the first Spanish oceanographic expedition to the Arctic in 2007, and has led and participated in many scientific expeditions to the Arctic and Antarctica.





Sunset in late August near Kapp Lee  
North western Greenland, in August 2009

Photo by Camille Seaman



# Melting Away

In late summer the Arctic ice platform turns into a landscape of ponds and pools suspended in the ice.

Constantly receiving solar radiation throughout the night-less Arctic summer, air temperature can rise considerably, rising above 20 °C at the North Pole in the summer of 2007, the year the tipping point was likely trespassed.

Once the surface of the ice starts to melt, the pool of liquid water acts as a heat trap. As a liquid, water absorbs about 50% of the incident solar irradiance, while frozen-water reflects more than 80% .

Moreover, plankton starts to thrive in the newly formed aquatic ecosystems, and the organic matter they release further absorbs solar radiation, increasing the capacity of the suspended pool to trap heat.

This is one more self-accelerating process in place conducive to rapid ice melt: the more ice melted, the more heat trapped, until the end of the night-less period brings cold temperatures that break through this feed-back loop.

In July 2007, when first confronted with this landscape of pools suspended in ice, beneath seemingly perpetual sunshine, I got the impression that the polar landscape was sweating under the merciless sun.

I have never seen anything comparable in my long experience of Antarctic research; these two Polar Regions have very little in common. In the summer Antarctica will remain white, while the Arctic will sweat away all its ice to become a blue ocean.

Carlos M. Duarte



**Azur**  
Picture of newly formed sea ice, taken  
from the bow hatch on board of the  
icebreaker KV Svalbard, during  
the iAOOS-cruise in 2008, Fram Strait  
Photo by Rudi Caeyers/BFE-UIT



# The Nature of Ice

*"It is a strange sight: the dull grey sky above, the almost black water, and the dazzling white ice rising and falling on the gentle swell. The water appears like ink because it receives so little of the light which is nearly all reflected by the ice; it has the darkness of a cave."*

Sir Alistair Hardy in *Great Waters* published by Collins, London in 1967.

**G**rease ice, pancake ice, Nilas ice, first year ice, multiyear ice, ridged ice, consolidated ice, ice floe, pack ice, sea ice, frazil ice, frost flowers, columnar ice, grey ice, brown ice, finger-rafter ice are a brief selection of the multitude of descriptors for the ice created when normal seawater freezes at around  $-1.86^{\circ}\text{C}$ .

No matter which term we use, or what form the ice takes, as soon as it forms it immediately and dramatically changes the physical, chemical and biological processes on the surface of the oceans. The effect of the wind and waves is dampened. Gases do not pass from air to water, or vice versa, as quickly as they did. Salt spray is reduced, and the whole dynamic of the mixing of the surface ocean takes on a different nature and timescale. As soon as any ice forms, the amount of light penetrating the water is dramatically reduced, effectively cutting off the ability for phytoplankton to photosynthesize and grow. Not just the amount but also the quality of the light that does make it through the ice is considerably altered.

It is not a still place. The ocean currents and surface winds still move the floes and pieces of ice around. They jostle together, collide and raft on top of each other so that their edges form ridged sails and keels, which in extreme cases can be 10's meters high, or deep, respectively. Expanses of water open and close, and some freeze over quickly to form a ribbon of thin new dark ice between snow-covered ridged "land masses" of older ice. We often talk about the wonderful quiet stillness of the pack ice, but it is a rapidly changing landscape that never stays the same for more than a few moments.

The ice does not create a lifeless desert, but while it lasts it forms a unique habitat harboring a rich biology of viruses, bacteria, archaea, flagellates and algae. These in turn are a food source to protozoans, crustaceans and even fish that use the ice as a food supply during winter when there is nothing to eat in the waters below. It is this biology that often transforms the clear ice into a rich coffee color.

How will this ever-changing landscape respond in this time of rapid change? Less ice, thinner ice, more transparent ice, longer seasons without ice, no more multiyear ice, more light penetrating the water, less food for grazers in winter, maybe more snow covered ice, maybe more flooded ice floes? The predictions are many and varied, and possible outcomes are often conflicting. What is clear is that the seasonal dynamics of this moving landscape are changing dramatically. Since when it forms, ice has such profound implications for the physics, chemistry and biology of the oceans, we are witnessing—and measuring—a potentially key event in the history of the Earth System. The question is whether we have the resources and imagination to interpret the complexity, and fully understand the implications, of the measurements we make?

David N. Thomas

## David N. Thomas



David N. Thomas is professor of Marine Biology at Bangor University (United Kingdom) and a research professor at the Finnish Environment Institute, Helsinki (Finland). Over the past 20 years he has participated in many scientific expeditions to the Antarctic and Arctic where he has worked on the biology and chemistry of sea ice.

3

# Marginal Ice Zone



Photographers

Rudi Caeyers

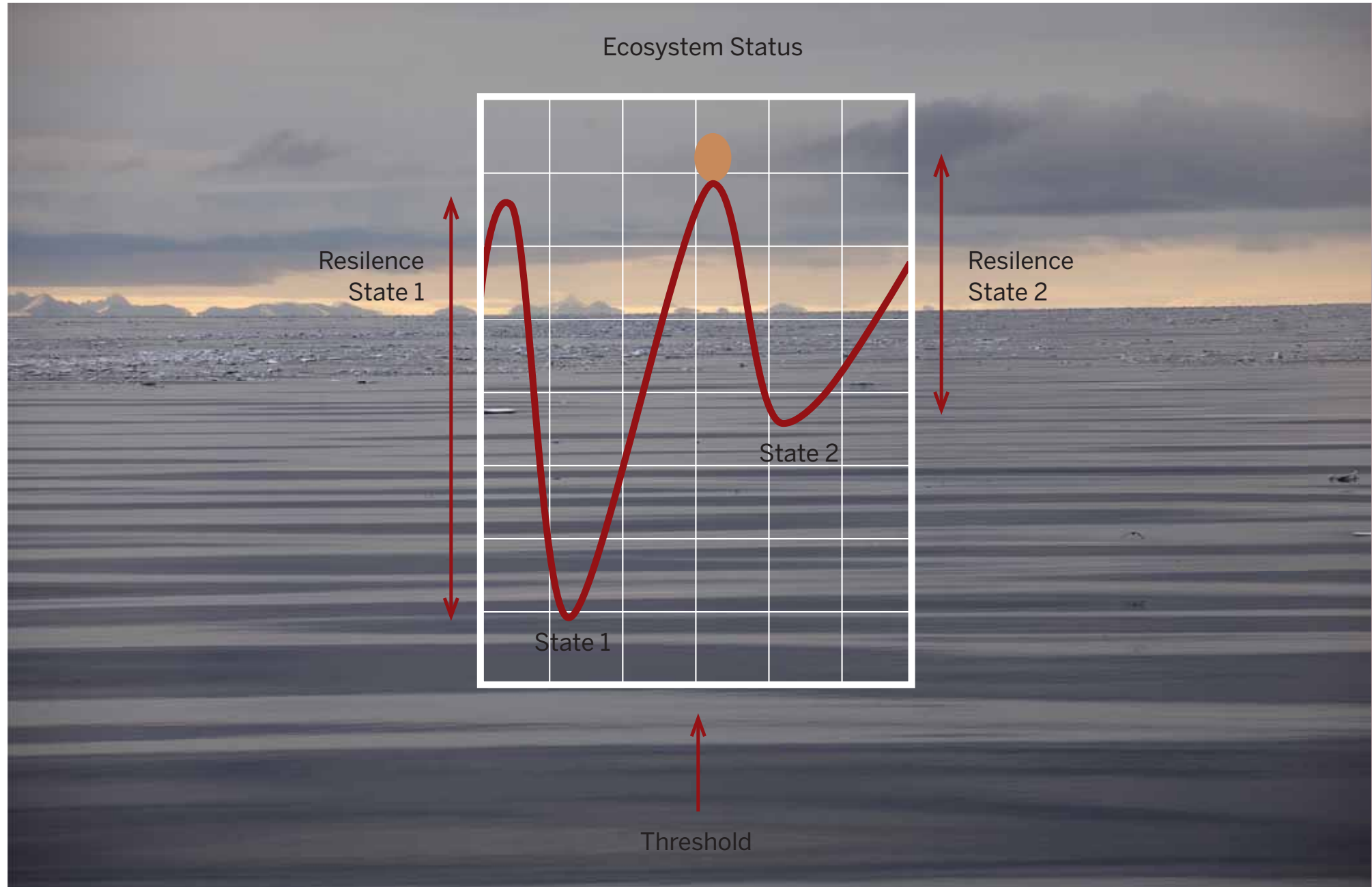
Camille Seaman

Manuel Elviro Vidal

Paul Wassmann

Authors

Paul Wassmann



**Sea of tranquility**  
Calm sea outside the West coast of Svalbard.  
Picture taken during the ATP-cruise in May 2010

Photo by Rudi Caeyers/BFE-UIT





# Bands of Floating Ice

One of the most dynamic and magical regions, characteristic of the Arctic Ocean is the marginal ice zone. This is the zone where ice cover meets open water. This region can be found between fast ice (fixed to land) and drift ice. This circum-Arctic girdle between both ice types is called *flaw polynya* (*polynya* is derived from Russian, meaning “a hole in the ice”). Between the European Arctic region and the North Atlantic Ocean, or the Bering Strait and the North Pacific, no land fast ice develops and an open water marginal ice zone is found all year long. With a maximum ice extent occurring in April and a minimum one in October. The marginal ice zone is a meeting place between two functionally different regions. Ice and snow cover prevent adequate light reaching plants, which consequently do not grow vigorously under ice. When the ice thins, ice algae grows beneath the ice. When it melts and water that has wintered under the ice is exposed to sunlight, a remarkable recurrent bloom of microscopic plants develops, tinting the water green.

When moving from open water into the marginal ice zone bands of thin ice floes often greet the scientist, making their mark on the grayish monotony of the open Arctic waters.

A pinkish-white band of light at the horizon tells a story of sunshine and clear skies characteristic of the ice-covered ocean.

Paul Wassmann

## Rudi Caeyers



Rudi Caeyers is a Belgian photographer, living and working in Tromsø, northern Norway. He has worked as a photographer and designer for the Norwegian Polar Institute, the Arctic Council and the Tromsø University. He has participated in several expeditions to the Arctic and has held exhibitions in several European cities.

## Paul Wassmann



Paul Wassmann is a research professor at Tromsø University (Norway), and head of the Arctic Tipping Point project. He is also in charge of the ARCTOS network and has led and participated in many scientific expeditions to the European sector of the Arctic Ocean.





Looking towards Ellesmere Island, Canada  
North West Greenland, in August 2009

Photo by Camille Seaman



# Light on the Horizon

In some parts of the marginal ice zone the visitor makes the acquaintance of large ice floes. The cloudy skies are reflected in the dark gray of the open water, while the afore mentioned band of light on the horizon holds the promise of brighter weather conditions beyond the outskirts of the marginal ice zone. The marginal ice zone is an important place for animals. Not only does the bloom of microscopic plants provide a sign of the abundantly good feeding conditions for many marine plankton organisms, the ice is also the resting site for a multitude of marine mammals, such as seals. The ice floes provide a birthing place for the seal pups, they are suckled for a few days on extremely fat-rich milk and it is here that they molt. This region is also the feeding ground of the invincible Polar Bear. Polar bears use the full breadth of the marginal ice zone, often travelling several hundred or even thousand kilometers away from land. Early in the season seal hunting also takes place here, which until recently was a major industry.

## Camille Seaman



Camille Seaman is a Fine Arts photographer who has been making images in the Polar Regions for over 10 years. Her work has been widely published and exhibited globally.

Paul Wassmann



**Albert Land skyline**  
North of Spitsbergen. Latitude: 79° 30' 0 N. Longitude: 11° 30' 0 E

Photo by Manuel Elviro Vidal



# Bright Days

On a crystal clear day the marginal ice zone can be seen stretching out towards the horizon. Here, close ice drift is conspicuously separated from open water while bands of fog create elongated veils above the ice. After the indifferent gray and contourless open waters south of the marginal ice zone, the blaze of color, rich detail, bright skies and ever changing forms of ice, along with the and varied wildlife provoke passion and enthusiasm in visitors, fishermen and scientists alike. The depth of the marginal ice zone can range from a few meters to hundreds of kilometers. Here we see the very beginning of a marginal ice zone.

Paul Wassmann

## Manuel Elviro Vidal



Manuel Elviro Vidal is a filmmaker and multimedia artist who collaborates with the Arctic Tipping Points project and was the artistic coordinator for this book. He contributes to many projects for the dissemination of science in which he acts as an artistic-scientific filter.





Cold soup  
Ingredients: light, shape and movement

Photo by Manuel Elviro Vidal



# Inside the Ice

The inner part of the marginal ice zone is more or less continuously covered by ice. Larger ice floes are engirdled by smaller ones or by crushed ice. The skies are frequently cloudless with air temperatures well below zero. These photographs were taken in April in the middle of the Fram Strait, between Spitsbergen and Greenland. It is  $-30^{\circ}\text{C}$  outside. The low temperature and high irradiance make it difficult to work. Sunglasses transfer the cold to the face and vapor freezes both in—and outside the glasses. Nets and bottles freeze instantaneously on leaving the water, unless precautions are taken. To work one has to proceed slow enough so as not to sweat. Even here, hundreds of kilometers from open water, walruses and Polar Bears can be encountered. Snow sparrows might rest on deck for a day or two on their recurrent voyage to Greenlandic breeding grounds.

Paul Wassmann

Pink ice  
Open drift ice, North of Svalbard. Picture  
taken during the ATP-cruise in May 2009  
Photo by Rudi Caeyers/BFE-UIT





# The Magic of Melting Sea Ice

The marginal ice zone is immensely variable in shape and appearance. In this zone small fragments of ice and debris are spread over an enormous distance: there are small melting pieces of ice as far as the eye can see. The melting ice forms a dazzling coating of freshwater that covers the surface of the entire region like a glossy skin. This surface skin of freshwater prevents the wind stirring the uppermost layer of the water and results in a rapid freeze if the temperature drops, as it does at night. This melting of ice, spread and mixing of freshwater and freeze form the complex relationship that determines the extent and thickness of sea ice.

Paul Wassmann





An ice floe, remnants of the summer sea  
Ice drifts near North West Greenland in August 2009

Photo by Camille Seaman



# Mighty Ice Keels

Sea ice in the marginal ice zone most often appears to be smooth and even on its surface, but at times the ice collides and forms ridges. In contrast, the subsurface of sea ice is rarely smooth. Rather it has a complex topography with ridges, cracks and keels. This ice floe, far from the rest of the marginal ice zone, has a strong deep keel that penetrates meters below the surface.

Paul Wassmann



**Moffen 1**  
The island of Moffen north of Svalbard. Picture taken during the ATP-cruise in May 2009

Photo by Rudi Caeyers/BFE-UIT



# Mystery of a Foggy Day

The marginal ice zone is characterized by changing weather where bright sunshine is interrupted by fog. At times blue skies appear above the fog, which is only a few meters thick. Other times various rainbow phenomena can be observed. Fog creates mysterious and puzzling scenarios.

Paul Wassmann



**Moffen 2**  
The island of Moffen in the fog, north of Svalbard. Picture taken during the ATP-cruise in May 2009

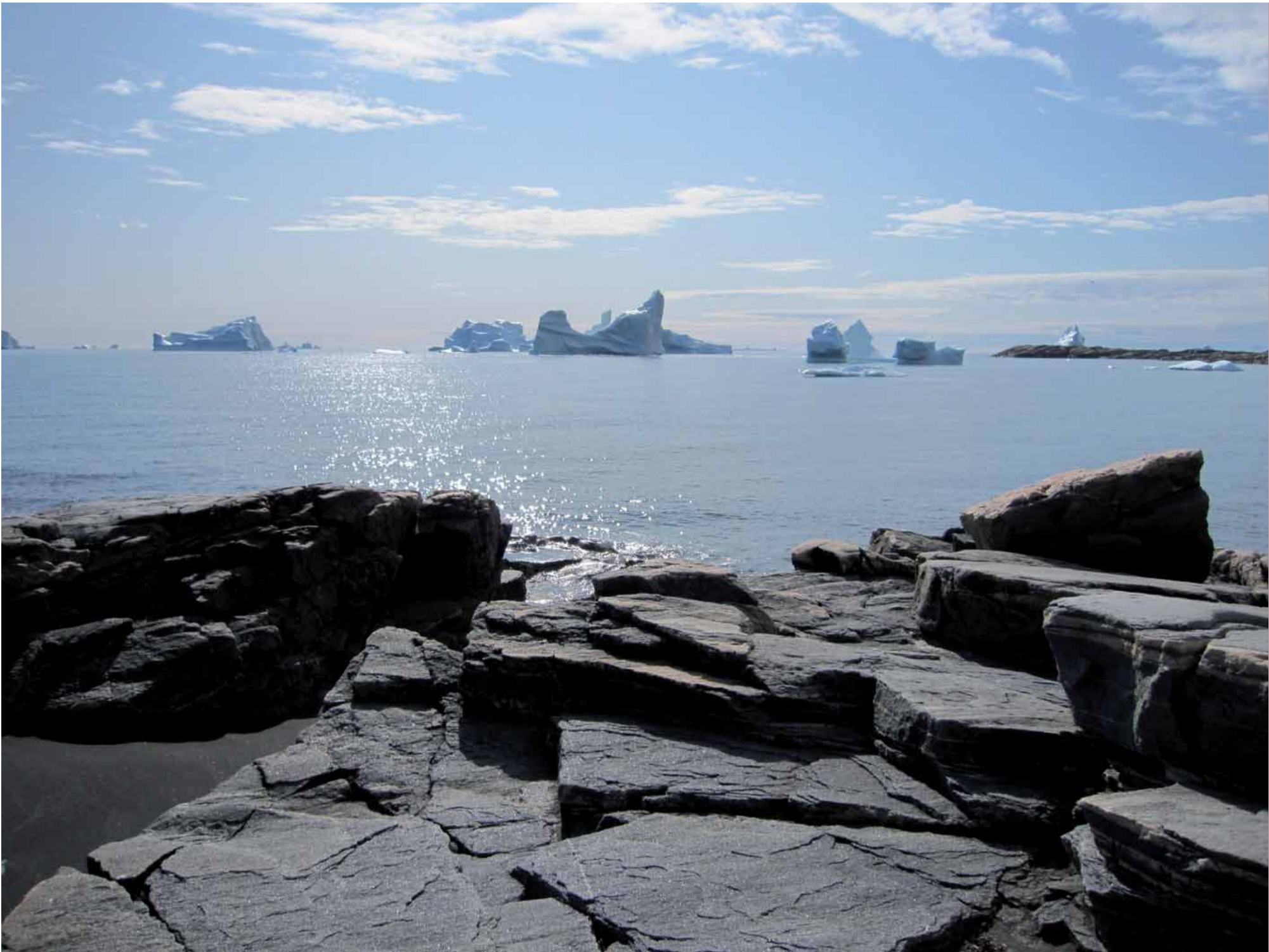
Photo by Rudi Caeyers/BFE-UIT



# White Out!

When shrouded in fog the marginal ice zone is transformed into a dazzling whiteness that confuses the vision. Contours become difficult to distinguish, distance difficult to approximate. Even with sunglasses it may be too bright to endure the blinding light for long. A perfect day for a Polar Bear! And a good day to stay on board.

Paul Wassmann



Stranded icebergs

Photo by Paul Wassmann





# Stranded Giants

Stranded icebergs in Disco Bay on Greenland during a brilliant day. The majority of icebergs, including the one that sank the Titanic, come from the Disko Bay region. They calf from the largest glacier on the Northern Hemisphere, *Sermeq Kujalleq*, close to Ilulissat, Greenland. They can be so big that they survive the slow transport from Greenland through Baffin Bay and the Labrador Sea down to the Great Banks. At this very day in August the photographer was alone on the rocky shores of Arctic Research Station of Disco Bay. Large crowds of Inuits from all over Greenland turned their backs to the vista of stranded ice giants. They eagerly followed the finals of the Greenland football championship!

Paul Wassmann



Stunning dialogue between nature and culture

Photo by Paul Wassmann



# Size is a Relative Thing

Icebergs can be gigantic in size and majestic in appearance. This one lies stranded outside the Greenlandic settlement of Ummannaq. A tourist vessel with 200 passengers demonstrates the dimension of this iceberg. Sometimes, as they slowly melt, icebergs turn over, creating quite some danger for ships and settlements close to the coast. On bright summer days like this, cascades of ice debris fall off the icebergs and plunge into the sea interrupting the eerie silence.

Paul Wassmann

4

# Glaciers and Fjords

## Photographers

Rudi Caeyers

Camille Seaman

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## Authors

Yearn Hong Choi

Paul Wassmann



**Kongsfjorden**  
View of Kongsfjorden from the scientific settlement Ny Ålesund

Photo by Manuel Elviro Vidal



# Wuthering Expectations

The Arctic coastal zone is a sensitive and important interface between land and sea, a region that provides essential ecosystems and supports indigenous human lifestyles. It is also a zone of expanding investment in infrastructure and growing security concerns. At this latitude, climate warming is expected to trigger landscape instability in the lowlands, with rapid reactions to environmental change, and increased human exposure to hazards.

The mighty mountain ranges, glaciers and fjords of west Spitsbergen rise over the horizon as one arrives from the ice-covered waters of the Fram Strait. Wide vistas let the eye search for details after the vastness and monotony of ice-covered waters. The fjords are the meeting place between the open sea, sea ice and the land. Fjords are crafted and shaped by glaciers over geologic time spans. Through the mountain ranges and often narrow fjords of the hinterland, glaciers from the interior ice cap move inevitably towards the sea to calf, often inside fjords. The regularly ice-free, relatively warm waters of the western Spitsbergen, fed by the Gulf Stream flowing from the remote Gulf of Mexico, are frequently shrouded in mist, fog and clouds. Nevertheless, fjords and ice-covered waters often experience sunshine and blue skies. This can be observed on the distant white horizon, promising that clear skies and the sun are just a few hours away after the expanse of grey misery at sea.

Paul Wassmann

## Manuel Elviro Vidal



Manuel Elviro Vidal is a filmmaker and multimedia artist who collaborates with the Arctic Tipping Points project and was the artistic coordinator for this book. He contributes to many projects for the dissemination of science in which he acts as an artistic-scientific filter.

## Paul Wassmann



Paul Wassmann is a research professor at Tromsø University (Norway), and head of the Arctic Tipping Point project. He is also in charge of the ARCTOS network and has led and participated in many scientific expeditions to the European sector of the Arctic Ocean.



Confrontation between glacier and fjord

Photo by Paul Wassmann



# Bright Front of a Glacier

The meeting of a glacier and the open water of a fjord are represented by the dramatic panorama of the glacier front, which can be more than 100 m high. Glacier fronts are monumental in size and provide impressively dynamic scenes. Global warming will result in ice melting, and some of this melt will take place in the fjords. Indeed, most of the ice on Earth is not found floating on the ice-covered seas, but lying on land in the form of glaciers.

In Arctic terms this implies first of all the Greenland ice cap, from where enormous amounts of fresh water are discharged during summer and early autumn into the sea. Alongside river water, melting glaciers are amongst the most important sources of freshwater and water stratification of the World Ocean. Climate changes will be immediately transferred to the precipitation and melting cycle that is the basis of glacier formation. Climate tipping points are transferred to glaciers, which thus can be used as bellwethers of climate change.

The front of the glacier Equip Sermia close to Disko Bay in western Greenland.

Paul Wassmann



## See Hornsund on a Crisp Day, and Die!

The interior of some of the fjords of Spitsbergen can be wide and covered by thin sea ice. In this case the glaciers end on land or in the beach zone. Big floes of sea ice move away from the ice continuum. By definition, fjords have been subjected to Arctic or sub-Arctic conditions. The fjords of Greenland and Svalbard have provided shelter to Arctic fauna, and continue to do so. During periods of climate warming, Arctic fauna outside the fjords was displaced and populations were isolated inside the fjords. In

### Hornsund panorama

Sunny morning at the Polish station at Hornsund, Svalbard. Picture taken during the ATP-cruise in May 2009

Photo by Rudi Caeyers/BFE-UIT





## 4 Glaciers and Fjords



today's Spitsbergen Arctic species are confined to the innermost basins as the water outside warms up and the range of boreal species expands northwards.

The inner reaches of Hornsund, southern Spitsbergen, are engirdled by the almost alpine mountain ranges of Svalbard. A perfect day in May—a world apart from the grey and foggy misery of the waters of the west Spitsbergen Current outside the fjord.

Paul Wassmann

### Rudi Caeyers



Rudi Caeyers is a Belgian photographer, living and working in Tromsø, northern Norway. He has worked as a photographer and designer for the Norwegian Polar Institute, the Arctic Council and the Tromsø University. He has participated in several expeditions to the Arctic and has held exhibitions in several European cities.



No man's land  
North-west Spitsbergen, National Park

Photo by Manuel Elviro Vidal





# The Vista Can Be Like an Epic Canvas

Fjords can be narrow and embody dramatic, mountainous hinterlands. They can also be wide and open and encompass a meeting between a calm sea and an open sky. They can be seas of tranquility that invite to contemplation on the meaning of life.

Annually, all fjords in the Arctic go through dramatic functional changes. In late autumn, winter and spring—i.e. for most of the year—they are part of the open coastal waters. They act as embayments of the open ocean. In summer and early autumn they become regions where fresh and low-saline waters are transported in a mighty current towards the open sea, while a compensating sub-surface current moves from the sea towards the glacial front. Freshwater from the bottom of the glacier meets seawater and rises with considerable speed like a jet towards the surface. The water in front of a glacier can “boil”. Plankton and fish fry, shocked by the rapidly ascending waters and the sudden drop in salinity, become an easy prey for abundant sea birds feeding off the glacier front.

Paul Wassmann



Small sailing ship

In front of Svalbard's 14th of July Glacier, in July 2008

Photo by Camille Seaman



# A Giant's Causeway

The front of glaciers can be a dramatic sight. The sailing vessel "Noorderlicht" is seen in front of the 14 July Glacier northern Spitsbergen. The angle of the glacier demonstrates how it glides down from the land into the sea. The front is probably 60 m high and ships have to keep a security distance of three times that height because calving at the front can produce dangerous waves. The middle part of the glacier has recently calved, as seen by a fascinating, turquoise color. Compared to earlier times, almost all glaciers in the High North have withdrawn, reflecting a warmer climate and changes in the precipitation/melting relationship. The inner regions of fjords are thus steadily changing and new islands and sounds may appear.

Paul Wassmann

### Camille Seaman



Camille Seaman is a Fine Arts photographer who has been making images in the Polar Regions for over 10 years. Her work has been widely published and exhibited globally.





Tourism

The sea is like friendship, you can see the horizon, but not the end

Photo by Manuel Elviro Vidal



# Magdalena

The glorious vistas of the meeting between mountains, glaciers and the sea make fjords a charismatic goal for tourism. Spectacular sea bird colonies exist in some of the fjords. Flocks of birds fly to catch food for their chicks. Here a ship carrying tourists has entered the beautiful and spectacular Magdalenafjorden on northern Spitsbergen in bright weather. This fjord has been known to man for a long time and was home to one of the land stations during the time of Dutch whaling in the 17<sup>th</sup> century. A Dutch graveyard is situated on an island in the fjord. The permafrost pushes coffins and skeletons to the surface over time. Since the early days of Arctic tourism, which started before 1900, many visitors have removed skulls from this island to enjoy their personal, daily “to be or not to be” moment at the writing table. A fence had to be built by the Norwegian authorities to stop this unlawful and utterly disrespectful practice.

Paul Wassmann





Kongsvegen

The entire glacier is 1 km wide and has a 20 m high cliff-face at the terminus

Photo by Manuel Elviro Vidal

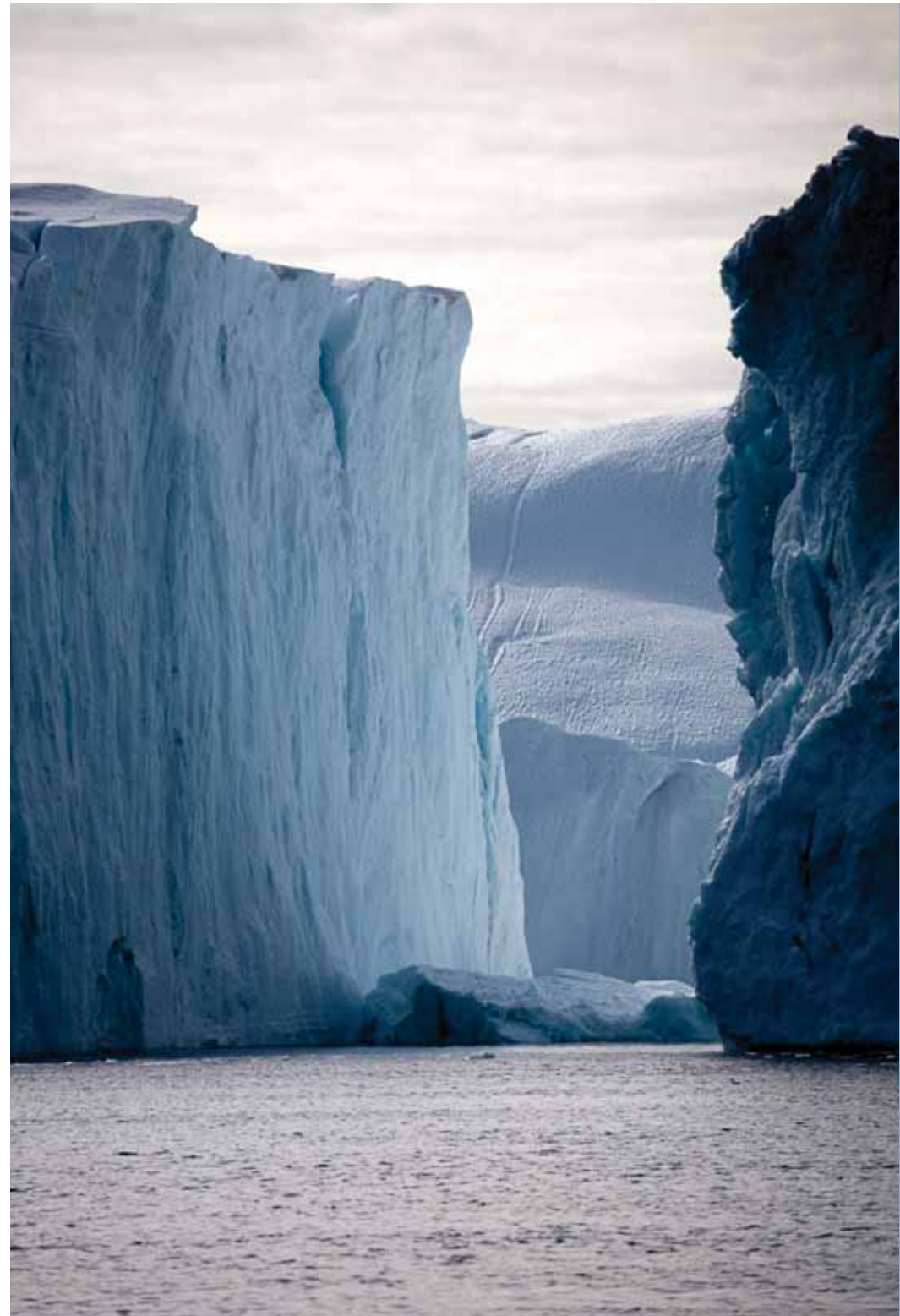




# Glaciers: Extraordinary Span of Frosty Colors

The color of freshly calved glaciers is characterized by white (snow), grey (sediment) and deep turquoise (massive ice). The milky turquoise color derives from air bubbles that are enclosed in ice during freezing. The chemical composition of the atmosphere can be determined by the analysis of these bubbles. Using this technique, up to 1 million years old samples of atmosphere from drilled cores from the central Antarctica ice cap, have been analyzed to determine their composition. We know that there has never been so much carbon dioxide in the atmosphere in the last million years. Fine ground rock—sediment—enters the fjord along with the melting ice and the freshwater plume in the glacier front. This can easily result in an rise of the sea bottom by several tenths of a centimeter per month. Life at the bottom of the Arctic fjords with glaciers is thus a continuous fight against the steady hailstorm of sediments during the melting phase, followed by calm, seawater dominated times for the rest of the year until the next melting period starts.

Paul Wassmann



**Giant icebergs**

Detail of giant icebergs in Greenland's  
Illulissat Bay, in August 2009

Photo by Camille Seaman



# Ginnungagap

In Antarctica, large glaciers may break off into the sea and these ice floes can be the size of a medium-sized European country. In the Arctic, glaciers are of more moderate dimensions. When a large section breaks free it may strand before melting. This opens dramatic gaps and gates between the open water of the fjord and the glacier behind.

The Ilulissat Icefjord on Greenland is an outstanding example of an actively calving ice sheet. It is one of the fastest and most productive ice-streams in the world, moving at 19 meters a day and annually calving more than 35 cubic kilometers of ice: 10% of the calf ice of Greenland's ice-cap. This is more than any other glacier outside Antarctica. The daily fresh water discharge out of this fjord is equivalent to the annual freshwater consumption of New York City. The wild combination of ice, rock and sea are a memorable spectacle.

This dramatic port between glacier fragments reminds on the port to helheim, the icy hell of the Norse mythology: Ginnungagap.

Paul Wassmann

Kongsvegen  
20 m high cliff-face at the terminus  
Photo by Manuel Elviro Vidal





# At the Glacier Bay

The waters are cold and blue;  
The mountains are modestly high and steep.  
The clouds are always hanging on the waistline of the mountains.  
The whales, sea lions and sea otters are the living things  
On and under the waters.  
The sound and sight of the iceberg falling into the waters  
Awaken my sleepy conscience,  
Making the solitude so deep.  
The glaciers are crying for their disappearances  
From the Earth.

Yearn Hong Choi

## Yearn Hong Choi



Yearn Hong Choi is a Korean poet based in the United States, who has published three collections of poems in English: *Autumn Vocabularies*, *Moon of New York* and *Copenhagen's Bicycle*. *At The Glacier Bay* is published in his collection *Copenhagen's Bicycle* (2010). He received a doctorate degree in environmental policy from Indiana University.





Illulissat Bay

Detail of giant icebergs in Greenland's Illulissat Bay, in August 2009

Photo by Camille Seaman





# Eternal Ice: A Key Element of Life on Earth

Ice and melting ice belong to the elements that shape planet Earth and affect our living conditions. In a warming world and with most people living in regions where ice is rare, there seems little understanding for how powerfully ice shapes our lives. Nowhere is the change between the crystalline forms of ice and fluid forms of water so obvious as in the region where glacier and sea ice meet the sea: the fjords. But major regions in central and northern Europe have been shaped by ice or the rivers deriving from glaciers. And the Arctic ice cap has an important influence on the climate of the northern hemisphere. Ice and its action are essential elements of our lives, if we see it right now or not.

Paul Wassmann



5

# Arctic Fauna

## Photographers

Rudi Caeyers

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Aqqaluk Lynge

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Mikael Sejr



**A quiet moment**

Its predators, human beings, orcas and polar bears, run their own risk.

Walruses' tusks grow to three feet (0.9 m)

Photo by Manuel Elviro Vidal



# A Brown Dot on a White Background

When you get closer you see that it is the unmistakable shape of a walrus, so clumsy with all its rolling fat, on the ice. It even rolls in its own shit—this becomes painfully clear against the shiny white crystals of snow. People are disgusted and slightly shocked when they see this for the first time. But the walrus is an efficient animal when in water, highly specialized to its environment. Does their continued existence matter or not? It resembles some ancient creature, with its teeth and wrinkles. Unfit for a competitive world. Most people never see them anyway. Or are even aware of their existence. Is it worth the effort to trying to mitigate the effects of the loss of ice? In order for walruses to continue to exist? One could argue that there is an imperative to save what exists, because the value of something that exists when compared to nothingness is infinitely higher (if you get philosophical about it like the German philosopher Hans Jonas). But maybe we all need to become a bit more philosophical about the existence of things. The challenges of our times, with the burden of today's choices have become detrimental to coming generations and demand a new paradigm for ethical standards. It is no longer sufficient to have universal ethics that take into consideration only the well being of our current equals. Do we have the right to decide what future generations may experience? If the answer is yes, then it is a heavy responsibility.

Elisabeth Halvorsen

## Manuel Elviro Vidal



Manuel Elviro Vidal is a filmmaker and multimedia artist who collaborates with the Arctic Tipping Points project and was the artistic coordinator for this book. He contributes to many projects for the dissemination of science in which he acts as an artistic-scientific filter.

## Elisabeth Halvorsen



Elisabeth Halvorsen is a Norwegian marine biologist specialized in zooplankton ecology. She is currently heading the coordinators office of the EU FP7 Arctic Tipping Points project.





**The chief**

Unperturbed at the prow of R/V Jan Mayen

Photo by Manuel Elviro Vidal





# A Polar Bear!

We saw him moving in the distance while he was approaching.

The cry of “A bear, A bear!” brought us all running to the deck of the Research Vessel Jan Mayen, all watching the animal, moving along the ice fast, without haste but with a clear objective: our ship. He stood a few meters off the hull and looked at us. He did not seem surprised or frightened, and the click-click-click sound of all our cameras shooting left him indifferent. He remained alongside the boat a long time, first to starboard and then to port. He was observing us with as much attention as we observed him.

He was the first polar bear I ever saw in the wild. I remember seeing one in the zoo in Madrid’s Retiro Park, years ago. I remember walking down the stone platform of the enclosure with its water-filled moat failing to alleviate the torrid summer heat of Madrid. He had a strange gait,, always pacing the same number of steps to the edge of the platform, where he lifted his leg up, turned and retraced his steps back to the other end of the enclosure. Endlessly repeating the short walk his prison permitted. It was sad to see it. Neither was the bear very white, but a desperate gray.

Our polar bear in the Arctic was very white. A male (young, I was told, no more than a couple of years) making deliberate smooth movements. He jumped from ice block to ice block, sat, lay down, got up, changed his position and walked a bit around the boat. I did not lose sight of the bear for a moment, full of wonder and euphoria, a novice at these latitudes.

With small dark eyes for an animal this big, he reminded somewhat of a big teddy bear. But he was anything but a toy to play with. My ignorance of the fierce, dangerous nature of these animals was such that it provoked a faked remark of concern by Paul Wassmann, our cruise leader, with his German / Norwegian sarcasm. He offered, very seriously, to explain some essential facts to me “before running the risk of losing a journalist on the cruise.”

The danger of bumping into a polar bear (people in the area are armed whenever they take a few steps away from home), the risk of aggression from these fierce animals, according to Paul Wassmann is nothing compared to the risk the fantastic polar bears now face. The fragmentation of the ice is not always a serious problem for adults, but it is a huge problem for their young, who are unable to swim much between one ice block and the next. Ice fragmentation is just one among many current threats. The loss of the icy northern sea will of course have devastating consequences for this species.

Our bear ran away when he became bored or convinced that he was not going to get food from our boat. Leaving with the same fast pace with which he had arrived, walking and jumping from one ice block to another. Any resemblance to the polar bear in the Madrid zoo was remote. But if the ice continues to disappear, if these animals are left without their habitat, they may all end up just like that poor mad creature in his prison in Madrid.

Our bear was astonishingly beautiful.

## Alicia Rivera



Alicia Rivera is a science correspondent with *El País*, a leading Spanish newspaper. Among the stories she covers are those concerned with environmental sciences and climate change. Alicia has reported on polar research in the field, both in Antarctica and the Arctic.

Alicia Rivera



**Eagerly**

A Greenland dog waits eagerly for the return of the cold and snow, Western Greenland in August 2009

Photo by Camille Seaman



# Husky

The look in its eyes projects both inquiry and accusation. A partnership of over 4,000 years coming to an end. Partners in travelling and hunting, husky and humans have explored the Arctic together. Surviving long journeys, storms and adversity. Not a pet but a companion, guarding the sleep of their human partners, courageously alerting their partners to the proximity of the much larger polar bears and chasing them away. Humans, in turn, selected huskies with an eye to improve these very same traits, loyalty, courage, endurance, sensitivity. But now have turned to other instruments. The ice-covered season shortens by the year, and the traditional old paths travelled by the huskies pulling sleds are no longer safe.

The skidoo now frequently replaces the dog sleds, which exist now as a relic of the past, a hobby and a sport. Yet, the huskies retain a prominent presence in the Arctic, still competing to be useful to their human partners, howling to be selected to pull the sled, to follow them on one more hunting trip, perhaps the last one. I have seen a team of huskies pulling a wheeled chariot loaded with tourist through the paved roads of Longyearbyen. The huskies looked happy, one more opportunity to prove useful to their human partners.

They will see change, but they shall not fear change as long as they are allowed to stay by the side of their human companions.

Carlos M. Duarte

## Camille Seaman



Camille Seaman is a Fine Arts photographer who has been making images in the Polar Regions for over 10 years. Her work has been widely published and exhibited globally.

## Carlos M. Duarte



Carlos M. Duarte is a research professor with the Spanish Council of Scientific Research (CSIC), whose participation in the Arctic Tipping Points project he heads. He led the first Spanish oceanographic expedition to the Arctic in 2007, and has led and participated in many scientific expeditions to the Arctic and Antarctica.



**The zooplankton *Calanus glacialis***

A keystone species of the Arctic Ocean ecosystem. Take note of the accumulated fat inside the body which reflects a successful grazing season and reserve for a long winter under the ice

Photo by Albert Calbet



# Tiny Grazers in Oceanic Prairies: The Arctic Marine Zooplankton

In the Arctic Ocean, when the first spring sunlight reaches the frozen sea after months of darkness, microscopic marine plants (phytoplankton, the equivalent of prairie grass on land) grow and bloom. It is time for herds of small, sometimes microscopic animals, zooplankton, to graze, grow, reproduce and be eaten by the other components of Arctic marine food webs.

A crucial group of zooplankton are copepods, probably the most abundant animals on the planet. They reach surface Arctic waters after spending the winter in deep layers, all activity suspended, with their bodies filled with reserve oil stored the previous summer by feeding on the phytoplankton bloom. The young will either attain adulthood along the summer and reproduce, or, if too young, store more reserve oil and dive again to spend the following winter in deep waters. The whole vital process takes from one to four years, depending on the species.

As a veteran with more than 40 years of experience in the study of marine zooplankton, I experienced the wonders of the Arctic summer for the first time in July 2007, when the sea-ice melted to a record low. I tried to capture, in a quick on the spot sketch, both the hardships of zooplankton sampling using classic nets while being wildly shaken by the wind, and the breathtaking beauty and colors of living Arctic copepods, such as this *Calanus*. But the future of populations of zooplankton (and of the Arctic marine ecosystems as we know it) is reliant on a delicate synchrony between marine ice melting (variable in time and depending on temperature), the light conditions (rigidly determined by latitude) that allow phytoplankton to grow, plus the migration to surface waters of deep-living copepods coinciding with the onset of phytoplankton bloom. If this synchrony is perturbed, so will be the fate of the Arctic marine ecosystems.

Miquel Alcaraz

## Miquel Alcaraz



Miquel Alcaraz is a research professor at the Spanish Council of Scientific Research (CSIC). His participation in the Arctic Tipping Points project deals with the study of the effects of temperature rise on plankton and its consequences for the whole Arctic marine ecosystem. He has participated in scientific expeditions to Antarctica and the Arctic, amongst them the first Spanish oceanographic expedition to the Arctic in 2007.



Watercolours by Miquel Alcaraz





Polar bear 1

Polar bear mirroring in the water. Picture taken during the ATP-cruise in May 2009

Photo by Rudi Caeyers/BFE-UIT





# Across the Mirror

A Polar bear observes his reflection in the water, as if looking at a mirror and like Lewis Carroll's Alice, wondering what lies on the other side. Across the mirror of the Arctic water lays an Arctic ocean, devoid of ice in the summer, where polar bears will no longer be able to wander across the vast desolation of the Arctic ice shelf.

The bear looks at the mirror as if to wonder whether the image will remain there in the future. Is a white polar bear possible in an Arctic free of ice in the summer? Most likely not. The polar bear is, however, a relatively recent species, emerging from the great grey Grizzly and Kodiak bears sometime during the last glaciation. The polar bear is so recent that it is believed to be able to breed and yield viable, reproductive offspring on mating with the grey Grizzly and Kodiak bears, which inhabit the subarctic region further south.

Decades from now, a grey bear will look into the water and the reflection will, for a second, return the image of a beautiful, smooth, white polar bear. They will be there, hidden in the genome of the great grey bear, waiting for a new white ocean to return once humans have gone, and the Arctic sea no longer reflects ships, planes and greed.

Carlos M. Duarte

## Rudi Caeyers



Rudi Caeyers is a Belgian photographer, living and working in Tromsø, northern Norway. He has worked as a photographer and designer for the Norwegian Polar Institute, the Arctic Council and the Tromsø University. He has participated in several expeditions to the Arctic and has held exhibitions in several European cities.



**Rein ved hav**

On summer pasture in Finnmark, northern Norway. Relaxing from insect assault in the cool breeze from the sea

Photo by Arvid Sveen



# A Life of Respect

In the old days  
when we still lived our own lives  
in our own country  
we could hear  
as faraway thunder  
the caribou approaching  
two or three days in advance

On maps of the country  
we must draw points and lines  
to show we have been here  
and are here today  
here, where the foxes run  
and birds nest  
and the fish spawn

You circumscribe everything  
demand that we prove  
we exist  
that we use the land that was always ours  
that we have a right to our ancestral lands

But now it is we who ask  
by what right are you here?

Aqqaluk Lynge

## Arvid Sveen



Arvid Sveen is a visual artist, photographer and graphic designer. He is a member of The Association of Norwegian Visual Artists (NBK). His previous photographic publications include: *Helleristninger* (Rock Carvings in Alta, 1996), *Vakre Varanger* (Beautiful Varanger, about the land of the Varangerfjord, 2000), *Mytisk Landskap* (Mythical Landscape, about Sami landscape and places of sacrifice, 2003), and *Tinden: Portretter* (Portraits of Mount Tinden in Tromsø) (2006).

## Aqqaluk Lynge



Aqqaluk Lynge is a prominent Greenlandic intellectual and poet, and is currently the President of the Inuit Circumpolar Council (ICC) and collaborator with the Arctic Tipping Points project. An indigenous Kalaallit, Lynge is a member of the United Nations Permanent Forum on Indigenous Issues, a forum that examines issues such as the economic and social development, culture, environment, education, health and human rights of indigenous peoples.





**Group of male walrus**

Resting on an ice floe in Young Sound, North-Eastern Greenland

Photo by Mikael Sejr



# The Big Vulnerable Walrus

I am in a small dinghy in Young Sound, NE Greenland. We have been chasing walruses for two days. A few times they have chased us. We are trying to get close enough to the walruses so that Göran can dive with the animals, to film them under water during their feeding. It has never been attempted before. Göran is a natural photographer and has joined us because he has years of experience of polar diving. But also because nobody else wanted the job. He has been below the surface for 5 minutes now, following two males on their dive to the sandy bottom 10 m below. Suddenly both walruses surface with a sharp hissing sound. Shortly after, Göran breeches the surface slightly less elegantly. He is talking rapidly in Swedish through his mouthpiece and appears very agitated. I have no idea what he is saying, but he appears to be okay. After a while he removes his mouthpiece and yells ecstatically: “unbelievable”! Göran’s footage eventually makes it in to several documentaries on the Arctic and earns him the BBCs “Wildlife Photographer of the year” award. It also enabled us to document feeding behavior, prey selection and consumption rates of free-living walruses.

The walrus is a good example of how vulnerable the Arctic ecosystem can be. The Atlantic walrus has been hunted to near extinction since European whalers started hunting walruses in the 17th century. Today, hundreds of years later the population has still not recovered. Instead, declining sea ice cover is threatening to reduce their habitat as walruses and their calves rely on ice floes for rest during the summer when they are searching for food far from the coast.

I have been visiting Young Sound for more than a decade now. So far the walruses have been there to greet us every summer. I wonder if they will be there for the next decade?

**Mikael Sejr**



Mikael Sejr is a senior scientist at the National Environmental Research Institute at Aarhus University (Denmark). He studies the Arctic marine ecosystem focusing on the waters around Greenland.

Mikael Sejr





6

# Arctic People

## Photographers

Rudi Caeyers

Camille Seaman

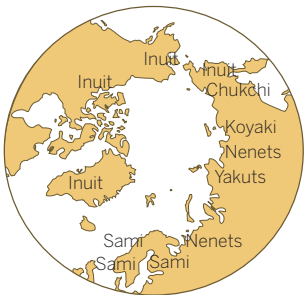
Arvid Sveen

Ellen Inga Turi

Paul Wassmann

## Authors

Paul Wassmann



**Ittoqqortoormiit**  
An East Greenland grandfather holds his grandson in the village of Ittoqqortoormiit. August 2006

Photo by Camille Seaman



# Looking with Expectation into the Future

The Arctic has been populated by small groups of people since time immemorial. Early settlers probably followed herds of reindeer, caribou, and musk oxen from Central Asia northward, and eventually adapted to the environment. One of the most widespread group of people in the Arctic are the Inuit (Inuit means “the people” in Inuktitut, the Inuit language). They are found in Alaska and Canada, as well as Greenland and Siberia. The Inuit also inhabit some regions of the North American Arctic. Perhaps the best-known people of the European Arctic region are the Sami, who live in northern Finland, Norway, and Sweden and in parts of northeastern Russia. A percentage of Sami still follow their traditional way of life as reindeer herders, or fisherman in inner coastal regions. As the Arctic is increasingly exploited for its natural resources and grows in strategic military significance, and due to traditionally close relationship the Inuit have with Finns, Norwegians, Swedes and Russians, nowadays they opt more often for higher education and train for more settled occupations.

In Siberia the native people comprise the Chukchi, Koyaki, Yakuts and Nenets. Most of whom follow traditional occupations—reindeer herding, hunting, fishing, and fur trapping. All native Arctic people have developed a unique ability to survive in their harsh environment by skillfully using the scarce resources available to them. From snow, ice, animal skins, wood and bones they have fashioned a simple technology that enables them to build shelters, weapons, and forms of transportation such as sleds and skin-covered boats (e.g. kayaks). Fish, and land and sea animals provide their main source of food. In the Arctic realm the indigenous people constitute a minority, as most of the people who have lived there for the last 100-200 years have moved there from the south to fill a wide range of occupations and start businesses. This Inuit father and child in Greenland, which was granted home rule from Denmark in 1979, enjoys good living conditions and a stable society. Greenland receives major subsidies from Denmark.

Paul Wassmann

## Camille Seaman



Camille Seaman is a Fine Arts photographer who has been making images in the Polar Regions for over 10 years. Her work has been widely published and exhibited globally.

## Paul Wassmann



Paul Wassmann is a research professor at Tromsø University (Norway), and head of the Arctic Tipping Point project. He is also in charge of the ARCTOS network and has led and participated in many scientific expeditions to the European sector of the Arctic Ocean.

Nenets relaxing  
and watching their herd  
Photo by Ellen Inga Turi (EALAT)







# What Might the Future Bring?

While non-indigenous people often describe the Arctic as the “last frontier”, this frontier with the cold, uninhabitable and unwelcoming Arctic is home to the Arctic people. It is above all, their esteemed native homeland. This antagonism is characteristic of the pan-Arctic conflict and rivalry between the “southerners” and the indigenous people. The traditional resource—and space-dependent lifestyle of the indigenous Arctic people gives rise to a fundamental conflict. While agriculture has traditionally resulted in property rights being granted to individuals or their families, indigenous people only have their traditional right to use resources and regions converted into the juridical right of individuals, family or family groups with great difficulty. Basically, Arctic states with indigenous populations (Norway, Finland, Sweden, Russia, USA, Canada and Denmark) own both the resources and the territories, leaving the Arctic people exposed to the politics and strategies of these states. Thousands of years occupying their homeland only transfers into ownership and individual rights with difficulty. All over the world, clashes between people whose way of life is based on agriculture and those that live nomadic lifestyles are evident and derive from the insensitivity of the dominant cultures towards indigenous people and nomads.

Arctic people are subjected to great pressures and challenges. Their traditional lifestyles and circular time dimension are confronted by the strategic, political and economic interests of the Arctic states, whose capitals are all a far cry from the Arctic they govern. In times of global warming, and exposed to a resource-greedy world, Arctic people face political conflicts, low socioeconomic thresholds and uncertainty. The inadequate responses of governments to their needs can propel them towards a tipping point.

A Nenets family rests in front of their tent. The Nenets have inhabited the oil-rich northwestern Russian tundra for approximately 2000 years. Their traditional nomadic lifestyle is based on reindeer herding, and their shamanistic beliefs emphasize respect for the land and natural resources. Oppression (due to the kolkhoz system and land-based oil development) has reduced their numbers and threatened the loss of their culture. Those who have been assimilated into urban life face the complete loss of their tradition and language. Those who continue their nomadic lifestyle are dependent on the freedom to travel with their reindeer, but need support to preserve their language and traditions, as recent generations have been educated within Russian-speaking environments. They are threatened both by climate warming and economic pressures.

Paul Wassmann



**Warm smile**  
A young boy in North western Greenland shares his warm smile in August 2009

Photo by Camille Seaman



# Confident

The young generation of Arctic people live in challenging times, exposed to climate warming, environmental challenges, industrialization and globalization. They all live on the verge of new realities for which the old world of their parents and grandparents cannot prepare them adequately. For who knows what will happen in the decades to come? This young Greenlandic Inuit belongs to the numerous children born after WWII. The population is clearly growing and living conditions are good when it comes to public health, standard of living and education. But what will the future bring this child? How will he tackle the multitude of changes the future holds?

Paul Wassmann



Greenlandic youth  
In Sisimiut, in August 2009

Photo by Rudi Caeyers/BFE-UIT



# Reflections

This teen-age Inuit from Greenland with his fancy sunglasses reflects not only that modern, stylish times have come to his island and community, but that due to globalization modern times can be found wherever we travel. His glasses reflect a non-Greenlandic photographer who paid the young man attention. Reflecting the conflict that arises from the intrusion of external visitors into these small indigenous communities. Greenland's young generation is seemingly no longer able to speak Danish as their first foreign language, like their parents do. They communicate in English. A tipping point has been reached with regard to the traditional connection with Scandinavia and the outcome is uncertain. While speaking English will improve their ability to communicate with their closest relatives in *Nunavik* ("place to live") in northern Quebec, the coastal region of Labrador (*Nunatsiavut*: "our beautiful land") and those in various parts of the Northwest Territories (mainly on the coast of the Arctic Ocean and formerly in the Yukon in Canada), communication with the numerous Danes living both in and outside Greenland who have a knowledge of Inuit culture will cease. While communication between the Inuit, and the English speaking world will increase. What will this mean for the complex but significant ties with Denmark and the many Danes that live in Greenland? What will this mean for the independence of Greenland and its future development?

Paul Wassmann

## Rudi Caeyers



Rudi Caeyers is a Belgian photographer, living and working in Tromsø, northern Norway. He has worked as a photographer and designer for the Norwegian Polar Institute, the Arctic Council and the Tromsø University. He has participated in several expeditions to the Arctic and has held exhibitions in several European cities.





**Japanese born Iku Oshima**

Arrived to Siorapaluk Greenland in the early 1970's with a Japanese adventure expedition, He decided to stay and has been in the far North settlement ever since (Siorapaluk, August 2009)

Photo by Camille Seaman



# A Generation that Had to Cope with Enormous Change

Older generations of the Arctic people have already experienced lots of changes. Not only has the climate become warmer with the implications this holds for their settlements, hunting and transportation. The efficient transfer of persistent organic pollutants from generally low environmental concentrations up the food web and into many Inuit food sources (such as seals, whales, sea bird eggs) faces them with the challenge that Mother Nature not only nourishes, but also decreases their health through the accumulation of toxins transported there from long distances. Improved transport in the form of regular ships, planes, helicopters, fishing vessels and outboard motorboats has brought previously unheard of mobility. Traditional and highly significant income in the form of sealskins has disappeared due to the successful lobbying of environmentalist movements to ban the export of seal products. While the general thinking among the older generation still centers around the traditional way of life, based on hunting and fishing, modern reality is vastly and increasingly different. The older generation in the Arctic needed to integrate the development of several generations in industrialized nations in one. With limited education this is rather challenging.

Paul Wassmann



**Fishingboat**

A typically red colored, greenlandic fishing boat cruising along the icebergs of Illulisat, in August 2009

Photo by Rudi Caeyers/BFE-UIT



# The Meaning of Life: Hunting and Fishing

Fishing is a major Inuit industry, in particular in Greenland where most of the country's revenue derives from shrimp and halibut fisheries.

Some decades ago cod fishies were the most significant, but cod does not spawn in the cold waters of western Greenland and fisheries depend on larvae transport with the Irminger Current from Iceland to Greenland, exemplifying once again the role of tipping points in the Arctic. It is the strength and the timing of the inflow of the Irminger Current that determines the existence of a cod fishery in western Greenland.

A small, wooden fishing vessel painted in the characteristic bright red color of Greenlandic ships.

Paul Wassmann





Sjølaksefiskere  
Store Molvik, Tanafjorden June 1993

Photo by Arvid Sveen





# What Are They?

Two fishermen from Northern Norway helping each other with a gillnet catch of salmon on a perfect summer day. Are they Norwegian, Sami or Kven (Norwegian ethnic minority descended from Finnish peasants and fishermen who emigrated from the northern parts of Finland and Sweden to Northern Norway in the 18th and 19th centuries)? Or are they a mixture of two or all three ethnicities? This is a recurrent question that arises when meeting people in the High North, Northern Norway serving just as an example. How can these fishermen be Sami, who (we think) are known to live inland living off reindeer herding? There are also sea Sami that live along the Norwegian coast, living off a combination of small boat fishing in sheltered localities, freshwater fishing and agriculture. They may be as numerous, or even more abundant than the inland Sami. As they were living in regions where Norwegian settlers from the south and Kvens from the east established themselves, the sea Sami were rapidly assimilated and lost many of their traditions, principally their language. As a result, a sea Sami will not readily speak out about their ethnic roots and thus their actual population size is unknown. This example is illustrative of a generic problem in the Arctic: the difference between indigenous and non-indigenous people. Frequently and increasingly ethnic groups mix and a clear distinction between the peoples of the Arctic is not always possible. In reality, the population in the High North comprises the people of the Arctic of which the indigenous people are a small minority.

Paul Wassmann

## Arvid Sveen



Arvid Sveen is a visual artist, photographer and graphic designer. He is a member of The Association of Norwegian Visual Artists (NBK). His previous photographic publications include: *Helleristninger* (Rock Carvings in Alta, 1996), *Vakre Varanger* (Beautiful Varanger, about the land of the Varangerfjord, 2000), *Mytisk Landskap* (Mythical Landscape, about Sami landscape and places of sacrifice, 2003), and *Tinden: Portretter* (Portraits of Mount Tinden in Tromsø) (2006).



Flaying a seal  
In Umanaaq, Western Greenland,  
in August 2009  
Photo by Camille Seaman



# Marine Mammals Are Essential Food

While most other Arctic people base their existence in the main on terrestrial food sources, Inuit life is essentially based on marine food, with the traditional Sea Sami occupying a position between these two traditions. Fish, seals and whales, but also sea birds, sea bird eggs and at times reindeer form the customary food sources of the Inuit. Food acquired by hunting is shared within the family or among groups of families, while in larger settlements it is also sold. For people used to buying their food in supermarkets it may be surprising, or even shocking, to see food sold, unpackaged and bloody, on the street.

Despite its relatively small human population and the absence of large-scale industry, pollution has been on the rise in nearly all regions of the circumpolar Arctic. The contamination of snow, waters, and organisms by pollutants transported long distances from the entire northern hemisphere is a recent phenomenon. Many Arctic organisms, adapted to storing biological energy for the long winter in the form of fat, become accumulators and concentrators of organic pollutants and toxic metals. Animals at the top of the food chain, including humans who eat local foods, may carry pollutant concentrations far higher than levels in the ambient environment. Being exposed to far higher life time poison concentrations than would be acceptable in most countries. Traditional food sources now pose similar danger to the Inuit as that of radioactivity for the Sami, Nenets and others during the era in which nuclear weapons were tested in the atmosphere and following the Chernobyl disaster.

Paul Wassmann





Sorting out reindeer

Photo by Ellen Inga Turi (EALAT)



# Reindeer Herding: Lifeline of Life in Northern Siberia

More than 20 different indigenous ethnic Arctic peoples in Norway, Sweden, Finland, Russia, Mongolia and China herd 2.5 million semi-domesticated reindeer over 4 million square kilometers. Reindeer pastoralism is a traditional livelihood that sustainably exploits and manages northern terrestrial ecosystems. It is based upon accumulated experience, adapted to the climatic, political and economic systems of the north.

Industrialization represents an increasing threat to the Arctic. Today, pollution of international significance is generated in just a few areas of the Arctic regions. The most significant of these at present are the highly industrialized Kola Peninsula and White Sea regions of northwestern Russia, and the large metallurgical and wood processing complexes of north-central Siberia. Each of these areas contributes to circumpolar pollution; the prevailing winds carry airborne pollutants over the central Arctic Basin, and the rivers deliver their contaminants to the Arctic Ocean. Other potential Arctic sources of pollution are the areas of present or potential hydrocarbon production and transport in Arctic Russia, Arctic Canada and Alaska. The potential of damage to sensitive Arctic ecosystems by routine or accidental oil spills, or the disposal of radioactive waste is a serious concern for indigenous people and others, who make use of, or value, the Arctic's marine and aquatic resources.

Paul Wassmann





The deceased are close to people and need a good view

Photo by Paul Wassmann



# Memento Mori

In the circular time modus in which many indigenous people live, the dead are in concert with the living, they are an integral part of reality. With two equally real manifestations: life and death. The dead are thus an integral aspect of life. There is no life without death and vice versa, the shaman being the mediator. The beating of the drum ensures safe passage to the other side. Therefore ancestors enjoy high status among the living Inuit. They are buried close to settlements in beautiful places with excellent views, like here in Upernavik on Greenland. The graves are adorned and treated with respect, even on remote former settlements. The last judgement, the final and eternal judgment by God that will take place after the resurrection of the dead and the Second Coming of Christ, is based on a different, finite, linear understanding of time. In a circular time worldview, the living and the dead enjoy a similar interest for life and the living, from two different forms of existence. Thus they have to be close to each other and share joint pleasures and sorrows. Human existence requires the good will and support of the powers of the other world.

Paul Wassmann



# 7 Research

## Photographers

Susana Agustí

Rudi Caeyers

Manuel Elviro Vidal

## Authors

Susana Agustí

Irene Fernández

Carlos M. Duarte

Elisabeth Halvorsen

Johnna Holding

Isabelle Laurion

Connie Lovejoy

Warwick F. Vincent





#### Measuring Ice

A scientist measuring the thickness of the ice sheet in the Fram Strait.  
Picture taken during the iAOOS-cruise in April 2007

Photo by Rudi Caeyers/BFE-UIT





# Peering into a Hole

Funny scientist  
Peering into a hole  
Hoping to understand  
Nature's marvels  
  
Moment of bliss  
at seeing his face reflected in nature  
  
Unity of all things

Isabelle Laurion

## Rudi Caeyers



Rudi Caeyers is a Belgian photographer, living and working in Tromsø, northern Norway. He has worked as a photographer and designer for the Norwegian Polar Institute, the Arctic Council and the Tromsø University. He has participated in several expeditions to the Arctic and has held exhibitions in several European cities.

## Isabelle Laurion



Isabelle Laurion is a professor at the Institut National de la Recherche Scientifique, Université du Québec (National Institute of Scientific Research, Quebec University, Canada) and a member of the Centre for Northern Studies and ArcticNet. She has been involved in research projects on polar ecosystems since 1992. She is particularly interested in the lakes and ponds associated with permafrost melting and their role in global carbon cycling.



**Sediment trap sampling**

Scientists from the University of Tromsø taking in sediment trap samples.

Picture taken during the iAOOS-cruise in April 2007

Photo by Rudi Caeyers/BFE-UIT



# What's Going on Down There?

Seen from above. Like down a peek hole. 4000 m deep. What's going on down there? Impossible to grasp directly. But we use fragments. Organisms, pieces of matter collected in a plastic cylinder. And movement. And the mystery can be unraveled, like a giant three-dimensional puzzle. This fascination that drives scientists to explore the extremes. To see what is beyond the reach of the eye. Too small to be seen, but we can see it indirectly. Because of how it interacts with visible things. And so it is possible to tell the story after all. The story about the beginning? And the continuation? Impossible for man to make an impact down there, from above. Or?

**Elisabeth Halvorsen**



Elisabeth Halvorsen is a Norwegian marine biologist specialized in zooplankton ecology. She is currently heading the coordinators office of the EU FP7 Arctic Tipping Points project.

Elisabeth Halvorsen



**Science crew**

Scientists from the Norwegian Polar Institute preparing for a field trip on the ice during the iAOOS-cruise in April 2007

Photo by Rudi Caeyers/BFE-UIT



# Stepping Out onto the Arctic Ocean

Stepping out onto the Arctic Ocean, and the reassuring crunch of snow boots on thick ice.

I can imagine this day, a chance to work away from the ship, dropped off by helicopter, or perhaps a long walk to a distant lead for sampling.

Now, at last, it's quiet enough to hear the ice; crystals of polar light shine from all directions.

Connected, working together, finding things out, this is a place that tells our future.

Are we the last generation to walk on summer ice?

**Warwick F. Vincent**



Warwick F. Vincent is a professor and Canada Research Chair at Laval University, Québec City (Canada), where he also directs the Centre for Northern Studies (CEN), a centre of excellence for research and training in northern science and engineering. He has worked in the Polar Regions for more than 30 years and has a special interest in how climate change affects high latitude lakes, rivers and coastal seas.

Warwick F. Vincent



Old building on Hopen  
Visiting the Hopen Meteorological Station  
during the ATP-cruise in May 2010  
Photo by Rudi Caeyers/BFE-UIT





# Open Your Eyes and See... Hopen: Your Ice and Sea...

That's what you have to do if you come to the Arctic. Open your eyes as much as you can, look and learn how life and nature can be one. And I cannot find a better place to show it than Hopen, that tiny beautiful island in the south of Svalbard.

Climate change is changing the Arctic, but climate change allowed us to go offshore in Hopen this year. Usually the island is covered in ice until June, but we were able to reach the coast without any problems... at the beginning of May! Of course something is happening, and the four inhabitants of Hopen are the most privileged witnesses of what is happening. Arctic ice is melting faster than before, scientists' data say so, but in Hopen you don't even need scientists, you don't even need data... You just open your eyes and see. You just Hopen: your ice and sea.

When you speak to Hopen's family of four, something becomes clear: The Arctic is, above all, a state of mind. "Polar sickness", they call it, "Arctic virus"... All of them have been there before, and all of them want to return. For Kåre, the chief of the meteorological station, this is his fourth time in Hopen, and he says he will apply again next year... Why? I asked him. Because he says, he loves Arctic nature; he loves living surrounded by ice, close to polar bears... And then I wonder: if Arctic ice keeps on melting, is it possible that a day will come when Kåre is unable to find a reason to apply anymore?

Anyway, after meeting the inhabitants, after my Arctic journey with the ATP cruise. I think I also caught the "virus" somehow. And I like it, because now I'm sure I will definitely go back to that wonderful (and hopefully still white) world. To Hopen: my ice and sea. To open my eyes and see... To tell of the changes. To be aware of what is worthwhile and what is not. To not forget that all the changes the Arctic is undergoing will become changes in our lives (Kåre's application is our assurance, Hopen's ice is ours). To remember, at the end of the day, that we live fragile lives on a more and more fragile planet.

Irene Fernández

## Irene Fernández



Irene Fernández is an environment correspondent with the television channels Cuatro and CNN+ in Spain. Among the stories she covers are those concerned with environmental sciences and climate change. Irene has twice reported on polar research in the field in the Arctic, including the 2009 ATP cruise to the Arctic Ocean.



**Life in your hand**

This small crustacean is a very important link in the Arctic food web

## 20 Tears

We explore the future of the Arctic by carrying out experiments on tiny volumes of water. Every milliliter of these samples is a precious item for the scientist involved in evaluating the responses of planktonic communities to warming.

With these samples we must measure changes in dozens of different properties (from bacterial mortality to CO<sub>2</sub> release by the planktonic community), each of them fundamental for the future of the Arctic ecosystem. The volume of water each measurement requires ranges from 2 liters to measure changes in the structure of the silica valve of diatoms, to 10 milliliters to assess bacterial abundance and production.

The reader will surely wonder what can be learnt from a few milliliters of water, how can the observation of a few milliliters of water deliver any meaningful insight into the effects of phenomena of on a planetary scale, such as climate change and its impacts on the Arctic?

One milliliter is equivalent to about 20 drops, or if you prefer, 20 tears, as our tears have the same ionic composition as seawater. In fact, as the Spanish poet Federico García Lorca says in his poem "The Seawater Ballad" (1919), we cry seawater:

Photo by Manuel Elviro Vidal



“...  
These salty tears,  
Where do they come from, mother?

I cry, my Lord, the water  
From the oceans.  
....”

Twenty tear drops are as full of particles and loaded with as much feeling and emotions as the information held by 20 drops of water, one milliliter, about the ocean.

Twenty tear drops of seawater contain nearly 100 million viruses, 1 million bacteria, 1,000 protists, 200 diatom algae, all embedded in an environment that, on the scale of these organisms, is viscous, containing particles, gels and polymers. Each of our 20 liter experimental tanks contains a bacterial population four times greater than the number of human beings populating the entire Earth.

Tiny as they are, planktonic microbes conceal many of the keys to how the functioning of the Earth's biosphere will react to anthropogenic disturbances, such as climate change. Diatoms and other photosynthetic algae in the Arctic Ocean range from 1 micron to a tenth of a millimeter in length, but, through their photosynthetic activity, they can produce organic matter and remove CO<sub>2</sub> from the atmosphere. Indeed, diatom growth at the onset of the Arctic summer can reduce the partial pressure CO<sub>2</sub> in seawater to four fold below atmospheric equilibrium, driving a large flux of CO<sub>2</sub> from the atmosphere into the Arctic Ocean. Contributing to removing some of CO<sub>2</sub> produced by human activity. Bacteria, along with protists, fulfill the opposite function, decomposing organic matter through their respiratory activity to release CO<sub>2</sub> and consume oxygen.

The relative changes in the abundance and activity of algae, bacteria and protists in response to increased temperature in our experiments will allow us to confirm if, as expected from modeling studies, CO<sub>2</sub> release by bacteria and protists will increase more rapidly than its capture by plankton photosynthesis. The delicate balances between these important, but opposite processes determine to a large extent whether a warmer Arctic Ocean will continue to act as a sink for atmospheric CO<sub>2</sub> or whether, to the contrary, it will act as a source of CO<sub>2</sub> to the atmosphere.

The capacity to regulate the composition of the atmosphere we breathe rests, to a large extent, with the activity of the tears of the Arctic Ocean.

Carlos M. Duarte

### Manuel Elviro Vidal



Manuel Elviro Vidal is a filmmaker and multimedia artist who collaborates with the Arctic Tipping Points project and was the artistic coordinator for this book. He contributes to many projects for the dissemination of science in which he acts as an artistic-scientific filter.

### Carlos M. Duarte



Carlos M. Duarte is a research professor with the Spanish Council of Scientific Research (CSIC), whose participation in the Arctic Tipping Points project he heads. He led the first Spanish oceanographic expedition to the Arctic in 2007, and has led and participated in many scientific expeditions to the Arctic and Antarctica.



**Scale**

Konstantin Soloviov (SIO RAS-Russian Federation) studying zooplankton on board R/V Jan Mayen

Photo by Manuel Elviro Vidal





# Scientific Research is Discovery

Scientific research is discovery; we want to find new things, understand how objects interact and change under different conditions. We observe, we count, and we quantify, eventually making abstract models or proposing hypotheses that we can test. The earliest observations were records of human senses, taste, smell, vision, hearing and touch. The urge to probe and find deeper understanding propelled by the inventiveness and social interdependence of human beings led to greater and greater extensions of those senses and the capacity to record details that build a far more complete picture than any one human could hope to gain in a lifetime. All of these inventions, which are products of civilization and human society, enable a scientist to work alone, to observe deeper and make individual discoveries; to attain a sense of being. In the Arctic no one person can survive without technology inherited from the interactions of many and maintained as cultural knowledge. But as with scientific discovery, the moments alone, in the open, watching the sea and ice, bring a sense of being. To be able to do both is a privilege.

**Connie Lovejoy**



Connie Lovejoy is associate professor at the Department of Biology, Laval University, Québec City (Canada). Her primary focus are the molecular microbiology and processes of the Arctic Ocean, coastal and inflowing waters, and she has participated in many research expeditions to the Arctic.

Connie Lovejoy



Spanish researchers take ice samples during the ATOS-Arctic Expedition

Photo by Susana Agustí



# On the Ice Floe

His hands were frozen, but he could not help it because he had removed the gloves (they did not let him work), staying on the ice, the red color of his frozen skin contrasting with the white surface, reflecting the sun, which was very intense that day. A gust of wind blew, but he felt comfortable inside the warm suit. The radio, although distant, sounded once saying *“quick, come back soon...”* He looked around and saw Monica with one knee on the ground, the rifle in her hands scouting 360 degrees around the iceberg for polar bears. Everything was calm, no polar bears within site.

This Iceberg has a slight hill in a corner, and some have gone up there to explore, their red robes in sharp contrast against the ice. The quiet environment was perturbed by the noise of the engine, spinning and spinning on the ice. The radio rang again: *“Stop Activities, come back to the vessel”*—*“Not yet!”* He thought, and grabbed the handles harder, the engine continued to swirl, spinning...The ice was very hard to cut, compacted after years of accumulating snow and extreme temperatures, resisted the engine’s power. In fact, the ice floe they were sampling had been part of the permanent ice cover until just recently. That summer, July 2007, had been especially warm and the permanent ice was broken into pieces, sliced, melted and disappearing. *“We must take another ice core”,* he thought, *“we have cut two but this is not nearly enough, we want to start an experiment with the melt water from this iceberg, this cool treasure”*.

Suddenly the engine noise changed...—*“We got it! I got it!”*—Everyone ran towards him. Under the cutting cylinder, the ice core appeared, clear, full and solid, hard, just a few seconds before it disappeared into the storing cylinder. The radio resumed, *“everyone immediately outside on the ice, we have a situation as the fog is rapidly approaching!”* They ran, and quickly picked up the equipment and ran again, while the radio called with the commander’s voice urging them once again to return, although he could not hear well what he was saying as he ran. Suddenly, the fog appeared before his eyes like a dark curtain, dense, but he already had one foot inside the boat, which almost immediately set sail towards the research vessel. Then he looked up and saw the vessel, it was very close, no risk at all. Up on the bridge on their wings, he saw some scientists taking photographs. Far away, the fog completely hid the ice floe where until just a few seconds ago, the sun shone dazzlingly.

## Susana Agustí



Susana Agustí is a research professor with the Spanish Council of Scientific Research (CSIC). She leads examinations the impact of changes in the Arctic Tipping Points project. She has led and participated in multiple scientific expeditions to the Arctic and Antarctica and led the first Spanish oceanographic expedition to the Arctic in 2007.

Susana Agustí



Johnna & Ulrike  
Working in the UNIS laboratories in Svalbard  
Photo by Manuel Elviro Vidal





# “Real” Arctic Water

From the moment we stepped off the plane, everything happened so fast. Once we had found our missing trunk, separated from us somehow during the journey, and containing essential equipment for our experiments on board, it seemed like only minutes before we had all our equipment mounted and tethered down. We built our incubators on deck, we had the instruments calibrated, the reagents prepared. Seasickness came and went, and we all still waited patiently. All that was missing from the cruise was real “Arctic water.” For me on my first cruise any water with ice would suffice as “Arctic Water,” but now I know that Arctic water is defined by certain temperature and salinity parameters. Certain essential organisms can only be found in real Arctic water. This is what we were all searching for. But I had waited for what seemed like an age for my first glimpse of the ice-filled “real Arctic water.”

Finally, it came. Time slowed down as if it was intent on leaving me with an impression for years to come. At first only small cubes floated by. Soon the cubes became blocks big enough for small birds to rest on. I was mesmerized by the shifting shapes and sizes, and my mind was suddenly opened to so many more startling shades of white and blue as the ice continued to grow bigger. Each piece told a story, whether in its isotopic signature, or the fresh bear prints pressed into its snowy surface.

I was lulled to sleep that night by the comforting sound of ice scraping past the hull, not knowing that sleep would be a rare luxury on this trip. We worked long hours in the lab under the cover of the ship, because we had to take advantage of every minute of this 12 day cruise and every drop of Arctic water.

Yet, I always found time to steal myself away from the titrations and the hum of the engine to where it was quiet and all that could be heard was the sound of ice breaking under the jumping bow. I would let my thoughts drift away, content, as we cut through the vast fields of ice, but I couldn't keep myself from asking how long I would have to wait to find “real Arctic water” next time I return...

Johnna Holding

## Johnna Holding



Johnna Holding is a PhD student at IMEDEA (CSIC-UIB), Mallorca (Spain), working on the impact of climate change on polar ecosystems. She has completed two Arctic cruises and two experimental campaigns, all within the Arctic Tipping Points project.





**ColdLab**

Jorge Felipe (CSIC) working in his cold laboratory ( $-2^{\circ}\text{C}$ ) zooplankton on board R/V Jan Mayen

Photo by Manuel Elviro Vidal



# Simulating a Warmer Arctic

Although we are able to imagine a warmer, ice-free Arctic Ocean, imagination is an insufficient basis on which to ascertain how such an ocean would function and what role it will play in the Earth System.

We run experiments, enclosing Arctic plankton communities into tanks, warmed 1, 2, 3... 10 °C above Arctic water temperatures. How will they respond?

In the temperature-controlled rooms, the tanks nurse their plankton communities while they change. Species die and others grow to replace them.

The scientists monitor these changes and, after 12 days, believe they have a reply to their question: smaller forms of plankton will grow, the larger crustaceans will be lost, and the community will be dominated by tiny bacteria, breaking away organic matter and turning it back into CO<sub>2</sub>. The tipping point will be met at 4 °C above background temperatures. Thirty, Fifty years from now?

The prediction is set, the models are run and the future Arctic recreated in computers and scientific reports.

Our 20 liter Arctic microcosms serve as a window to the future.

An experiment, a guess, at a future fast approaching.

Carlos M. Duarte

**Multinet**

Marine biologists sampling small  
creatures with a multinet during the  
iAOOS-cruise in April 2007  
Photo by Rudi Caeyers/BFE-UIT





# A Net to Collect

A set of nets rises over the ice landscape, hanging from the crane it is about to be lowered into the depths of the ocean, in search of the planktonic animals that represent the core of the Arctic Ecosystem.

The set of nets looks like an atmospheric balloon soon to ascend to gauge the chemistry of the atmosphere, but instead it will descend and explore the depths.

Copepods and amphipods among the crustaceans and pteropods, the beautiful sea butterfly, among the mollusks, are the targets for the net. They are large and turn the photosynthetic products of their algal prey into the larger biomass organisms the whales, birds, and fish depend upon.

These tiny animals are the link between the microbial life of the ocean and the giants that populate the Arctic.

But they are under threat, warming will impact on the large Arctic copepods, replacing them with smaller ones, and the acidification of the Arctic waters, receiving CO from the atmosphere, will impact on the elegant sea butterflies.

Life will continue, but without these key players in the Arctic, the Arctic ecosystem will be something else and the nets, emerging from the depths, will return something else, a different community, a different ecosystem, in a different world.

Carlos M. Duarte

[

8  
Time



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**En stein-labyrint**

Sør-Varanger, Finnmark, August 1995

Neolithic stone circles are common along the coast of Finnmark, northeastern Norway and the Kola Peninsula in northwestern Russia. They

are often close to burial grounds. To acknowledge the mysterious transition between life and death, labyrinths may have had a ritual role conveying the dead in and out of circular time

Photo by Arvid Sveen





# Time is Circular

Time is considered differently in many cultures. Contemporary modern cultures consider time to be a line or a path that is followed. Time *runs* and is strictly limited, as reflected by calendar, agendas and schedules. “At the end of the road” is a rather common phrase. Punctuality and efficiency are vital aspects of modern life. Older cultures, and those of contemporary indigenous Arctic cultures such as the Inuit, Sami or Nenets have a circular vision of time. Time is a cyclic phenomenon. Time comes and there is plenty of it. Dealing with seasonal events and people are more important than agendas. Several things can be done simultaneously and plans can be continuously changed. Reality here and now is more important than schedules and plans. Among the indigenous people of the High North the linear time concept assaults that of circular time. The modern conception of time is a source of fundamental conflict between “southerners” and the indigenous populations. There is a threshold between circular and linear time. There is a phase shift between two antagonistic forms of existence.

Paul Wassmann

## Arvid Sveen

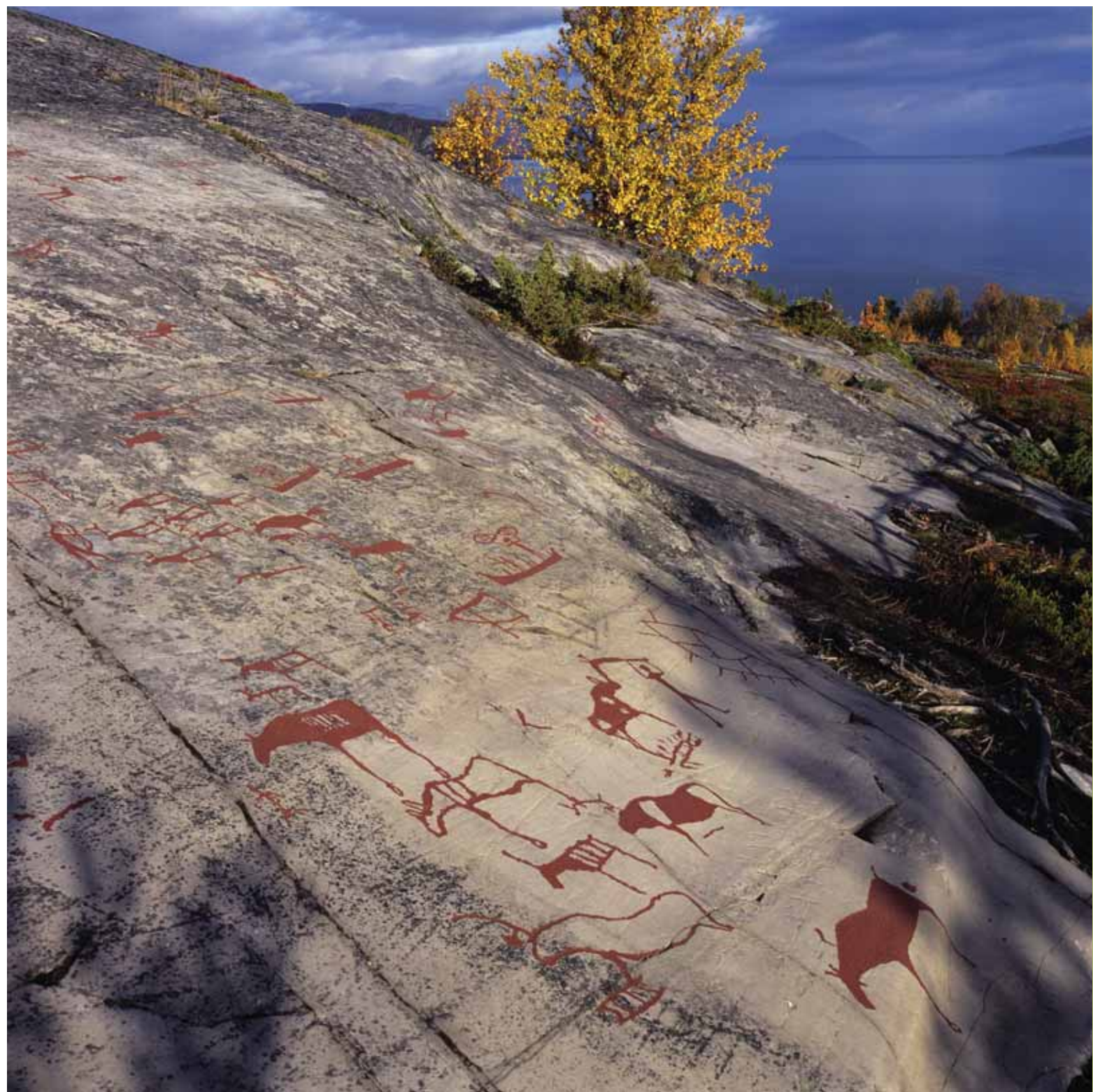


Arvid Sveen is a visual artist, photographer and graphic designer. He is a member of The Association of Norwegian Visual Artists (NBK). His previous photographic publications include: *Helleristninger* (Rock Carvings in Alta, 1996), *Vakre Varanger* (Beautiful Varanger, about the land of the Varangerfjord, 2000), *Mytisk Landskap* (Mythical Landscape, about Sami landscape and places of sacrifice, 2003), and *Tinden: Portretter* (Portraits of Mount Tinden in Tromsø) (2006).

## Paul Wassmann



Paul Wassmann is a research professor at Tromsø University (Norway), and head of the Arctic Tipping Point project. He is also in charge of the ARCTOS network and has led and participated in many scientific expeditions to the European sector of the Arctic Ocean.



**Helleristninger**

Rock carving from 4200-3600 BC,  
Alta, Finnmark, September 1995

Photo by Arvid Sveen



# The Magic of Depicting Life

A circular understanding of time was predominant in the Arctic until the arrival of modern cultures. Neolithic people lived in northern Canada and Norway after the decline of the last glacial age. They arrived very early in northern Norway as reflected by Neolithic rock carvings at Alta, one of the Worlds largest rock carving sites (UNESCO Heritage Site). These people lived a comfortable life along the coastal zone between the glaciers of the hinterland and the sea. At that time the sea was warmer and encompassed a rich fauna. Rock carvings are evidence of the varied marine and terrestrial nutrition that these people enjoyed over several thousand years. The Arctic is not just a hostile region for humans, but can be nourishing and supportive of a great variety of life. Following circular time the Sami, Inuit, Nenets and others follow the seasons and adapt to nature's extreme variability.

Paul Wassmann





Stallo

A Sami sacred stone,  
Kvalsund, Finnmark,  
September 1995  
Photo by Arvid Sveen





# Phallic Stones and the Sacred, Indispensable Sacrifice

Indigenous people in the Arctic, in essence, followed shamanistic religions that were deeply embedded in their circular understanding of time. Their faith was animism (also to be found in religious beliefs such as Shinto, Hinduism and Sikhism), with nature perceived as being possessed of gods and forces. To take part in the seasonal cycle and to be supported by nature demanded that the Sami made sacrifices to deities that populated the real, but hidden world behind the visible, concrete one. The Sami and Inuit were forced to give up Shamanism, converting to a strict and puritanical Protestantism. Sami sacrificial stone sites continued to be inhabited by gods and forces. Children were taught about the sacred places and learned the taboos and standards of behavior in the landscape. Sacrificial stones are prominent features along the North Norwegian coastal zone and inland. They are still respected, but stand void of their original function. Sacrifices were necessary to continue to be part of live-supporting nature and ensure that circular time continued. Time does not exist *per se*, one has to sacrifice to make it persist. In our modern cultures sacrifices to the spiritual world are not necessary for persistence. We have tipped out of the realm of nature and exploit it.

Paul Wassmann





**Lone kajak**

Local Inuit observing tourists at Kullorsuaq, Greenland during a Hurtigruten-cruise in August 2009

Photo by Rudi Caeyers/BFE-UIT



# A Gone Bye Way of Life

The mother of the sea is the protagonist of the Inuit cosmos. She suffers from the actions of humans and she cannot wash her face or comb her hair, as she has no fingers. As a consequence she hides the sea animals away. A shaman takes a trip to see the mother of the sea and washes her face and combs her hair. After his spiritual voyage the mother of the sea releases the animals, and the shaman returns to his settlement.

In circular time man and animals exist together. The animals are not killed, they let themselves to be hunted. If the hunt is carried out according to animistic beliefs the animals experience a “resurrection”. The hunt is a sacred act. The mother of the sea hides the sea animals in winter and after the voyage of the shaman she releases them again in summer. The hunter has to take the change of seasons carefully into consideration. Time comes because of sacrifices and contact with the spiritual world. The world has to be kept in a state of balance. The Inuit call it *silap ingerlasia*—the balance of the World Tipping points are not part of the cosmos, but balance points were.

The mother of the sea myth clearly points towards the basis of Inuit life: marine resources. And that makes them special among the indigenous people of the Arctic.

Paul Wassmann

## Rudi Caeyers



Rudi Caeyers is a Belgian photographer, living and working in Tromsø, northern Norway. He has worked as a photographer and designer for the Norwegian Polar Institute, the Arctic Council and the Tromsø University. He has participated in several expeditions to the Arctic and has held exhibitions in several European cities.

**Sami Elder Arne**  
Lives near Nord Kapp in Norway and  
has been herding reindeer all his life.  
Now he shares his favorite reindeer  
with tourists by the side of the road  
(Nordkapp, Norway, 2009)  
Photo by Camille Seaman







# The People with the Čiehgahpir, the Four Winds Hat

A Sami creation myth, directly related to their harsh environment, tells the story of the monstrous giant Biegolmani, the Wind Man. In the beginning of time, Biegolmani created the Sápmi region by taking two huge shovels, one to whip up the wind and the other to drop such huge amounts of snow that no one could live there. One day, however, one of Biegolmani's shovels broke, the wind died down, and the Sami were able to enter Sápmi, the Sami homeland.

In a mythical poem the Daughter of the Sun favored the Sami and brought the reindeer to them. In a related myth, the Son of the Sun had three sons who became the ancestors of the Sami. At their deaths they became stars in the heavens, and can be seen today as a belt in the Orion constellation.

A sudden change in the in the harsh nature of their environment made human existence possible. A threshold was passed and a tipping point reached. And the World was never the same again.

Paul Wassmann

## Camille Seaman



Camille Seaman is a Fine Arts photographer who has been making images in the Polar Regions for over 10 years. Her work has been widely published and exhibited globally.



Snowmobiles “oversummer”  
Outside Longyearbyen, Svalbard

Photo by Carlos M. Duarte



# Outskirts of an Arctic Metropolis

The intrusion into Arctic regions, of modern non-indigenous cultures with their linear concept of time opened up a wide field of conflicts for cultures with a circular conception of time and. The option of going back and forth between a traditional culture and a modern one is a great challenge. Basically the circular time modus is disappearing. With its technology, modern times have brought a continuous food supply, health services, efficient transportation based upon non-renewable resources, education etc. Once these modern times reached the indigenous communities a point of no return was highly likely.

Snowmobiles parked for the summer season in Longyearbyen, the largest settlement on Spitsbergen, Norway. And two older versions from the Russian settlement of Barentsburg. There is more than one snowmobile per inhabitant in Longyearbyen and, during the peak of snow mobile use, the air quality in late spring, in the middle of the pristine Arctic, is comparable to larger, central European cities.

Paul Wassmann

## Carlos M. Duarte



Carlos M. Duarte is a research professor with the Spanish Council of Scientific Research (CSIC), whose participation in the Arctic Tipping Points project he heads. He led the first Spanish oceanographic expedition to the Arctic in 2007, and has led and participated in many scientific expeditions to the Arctic and Antarctica.







Two cultures meet  
In the Nenets region

Photo by Svein D. Mathiesen (EALAT)



# Opportunities for Two Cultures

Nothing has changed the Arctic region as much as the advent of modern exploitation of natural resources. Starting with whaling, followed by sealing and the fur trade coal mining became an important industry. Today the oil and gas industry looks north as 25 % of the World's undiscovered resources are assumed to be found in the Arctic. The decrease of ice cover will make sea-based exploitation possible. But also on land big changes are to be expected. The continued piece-meal development will substantially reduce grazing grounds in coastal areas, also without additional petroleum development. When coupled with extensive petroleum development an additional 21000 km<sup>2</sup> will be deteriorated as grazing grounds for reindeer in the Barents region. This is equivalent to the size of 2/3 of spring and summer ranges in the northernmost county of Norway, Finnmark that accommodates the most significant reindeer herding in the Arctic region.

Economic tipping points have been experienced in the Arctic since several hundred years, but the Arctic and its inhabitants will have to face hordes of new ones in the nearest future.

Oil drilling towers on the tundra of pastures used by Nenets in northeastern Russia

Paul Wassmann





**Kubrick's tribute**

The wind carries distant sounds down from the mountains that transform into the orchestral work of "Thus spoke Zarathustra" by Richard Strauss

Photo by Manuel Elviro Vidal



# Conserving Change

While time passes by and anthropogenic global change takes its course Humanity is concerned about the irreversible loss of plant species and genetic diversity. In order to fight this danger the United Nations Organization coordinates seed storage for the entire World in the Arctic: The Svalbard Global Seed Vault. In tunnels drilled deep into the permafrost close to the settlement of Longyearbyen, Spitsbergen, seeds from all over the World are stored to prevent losses of species and genetic diversity. At  $-18^{\circ}\text{C}$  they can rest safe and sound without external energy support. The Svalbard Global Seed Vault's mission is to provide a safety net against accidental loss of diversity in traditional gene banks. While the popular press has emphasized its possible utility in the event of a major regional or global catastrophe, it will certainly be more frequently accessed when gene banks lose samples due to mismanagement, accident, equipment failures, funding cuts and natural disasters. Such events occur with some regularity. In recent years, some national gene banks have also been destroyed by war and civil strife. The Svalbard Global Seed Vault is an attempt to conserve the effects of unavoidable change and to attempt to stop the consequences of time.

The entrance to the seed storage facility where plants are removed from the inevitable cycle of genetic change.

Paul Wassmann

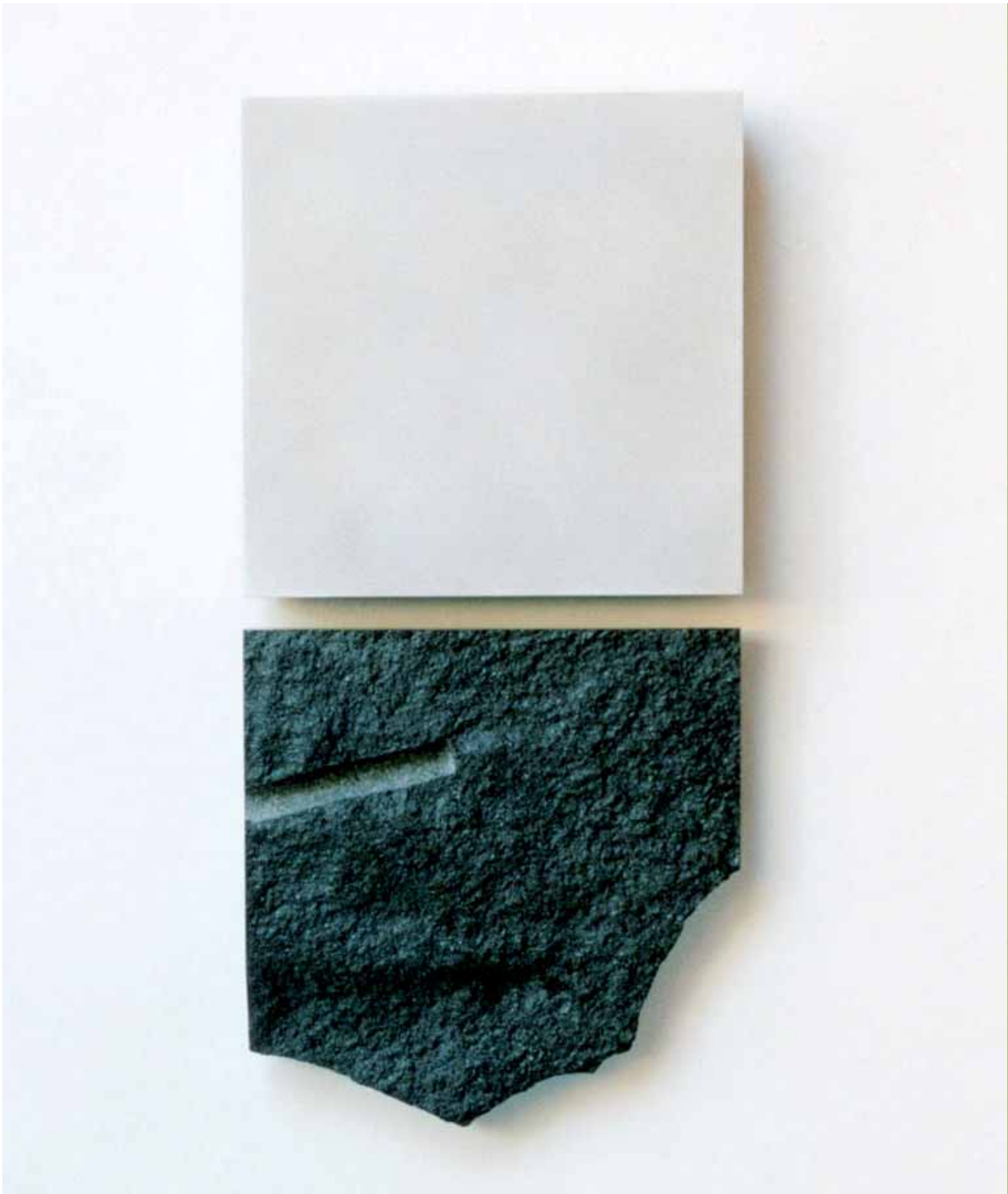
## Manuel Elviro Vidal



Manuel Elviro Vidal is a filmmaker and multimedia artist who collaborates with the Arctic Tipping Points project and was the artistic coordinator for this book. He contributes to many projects for the dissemination of science in which he acts as an artistic-scientific filter.



QUADRATI 2005  
Aluminium and stone 60x29x5 cm  
Photo by Terje Roalkvam





# Interaction between Nature and Technology

Over time, Humanity has become exposed to an increasing contrast between nature and technology. Circular time with nature's cycles at its foundation meets linear time, which brings with it technology. This contrast sustains a balance—imbalance cycle between nature and modern culture. This is reflected in the work of the Norwegian sculptor Terje Roalkvam. His works balance between the antagonistic nature of light and dark, warmth and cold, nature and culture. Thus the basic forms of objects are divided in two in a way that is never accurate, but an interaction between real nature and industrial artifact. Both parts approach and move away from each other. There is a pendulum in this process, balancing around a threshold.

Terje Roalkvam

## Terje Roalkvam



Terje Roalkvam is a Norwegian sculptor, based in Oslo. Educated at The State School of Art and Craft, Oslo (Norway), and The Art Academy in Warsaw (Poland). His work is represented in museums and private collections and he has had solo exhibitions in Scandinavia and several other European countries.



**Nordlys**  
Finnmark, Oktober 1995  
Photo by Arvid Sveen





# Northern Light: Bridge between Worlds

What will the future of the Arctic region be like when more and more activity in the High North is based upon the principle of linear time? How will ecosystems cope with the imprint that mining, drilling for oil and gas, tourism and exploitation of marine resources leaves in the region? How can man provide for sustainable development in the Arctic? These are rhetorical but profound and multifaceted questions that can only be solved with great difficulty because of our limited comprehension of Arctic ecosystems. What will the future bring? What are the bellwethers of approaching tipping points of change that we wish to prevent?

Throughout time the Northern Lights provide a breathtaking vision for man in the polar night and raise questions about the meaning of life and time. Bridges between circular and linear time have to be cultivated and balances found to live in the Arctic in a sustainable manner.

Paul Wassmann



Just a few hundred meters from the shores of Qeqertarsuaq Greenland  
This large iceberg (30+ meters) rolls over as its mass becomes inbalanced  
(August 2009).

Photo by Camille Seaman



# The Tipping Arctic Opera

Disko Bay is where I grew up. It is the conduit for millions and millions of pieces of ice that originate in the Ilulissat Icefjord and eventually rock their way out to the Davis Strait and North Atlantic Ocean. The Ilulissat Icefjord has been a UNESCO World Heritage Site since 2004, because even for someone like me who grew up in the region, the fiord, packed full of gigantic icebergs, is a breathtaking site to behold. The *Sermeq Kujalleq* glacier feeds this fjord. *Sermeq Kujalleq* makes its way from Greenland's icecap and with the force of gravity inches its way over the edge, where it breaks off and plunges thunderously into the sea below. This mighty glacier is now melting at an unprecedented rate. Not only are large icebergs breaking off the edge, but water is now pouring over it as well.

One day I was hunting near one of these magnificent icebergs out in Disko Bay. I remember it possessing brilliant colors with peaks rising high into the beautiful blue sky. At the time I imagined it to be large-scale version of the Sydney Opera House. I was, luckily, *not* in a kayak but in a small, motorized boat along with a friend. Even luckier, there was another motorized boat with two other companions in it. The *opera house* towering above us suddenly began to heave and groan, it started to tip one way, then it tipped the other. I had never been so dangerously close to a tipping and calving iceberg before. We powered away. But only a minute later, my motor stalled. The other boat saw us in trouble, swung back, threw us a rope and pulled us slowly away from the iceberg that was now tipping back towards us, no more than 50 meters away. I kept pulling the starter rope on the engine over and over. Finally it started and pulled away. I looked back and a huge rolling wave came at us and under us, propelling us forward. Again fortunately, the engine picked up speed and away we raced. When I dared to slow the boat down, we looked back and saw nothing but thousands of small floating freshwater pieces of ice where the tipping Arctic opera house once floated.

Which way is my Inuit homeland tipping? Will it disappear just as the calving iceberg that shattered into pieces on that beautiful Arctic summer day?

## Aqqaluk Lynge



Aqqaluk Lynge is a prominent Greenlandic intellectual and poet, and is currently the President of the Inuit Circumpolar Council (ICC) and collaborator with the Arctic Tipping Points project. An indigenous Kalaallit, Lynge is a member of the United Nations Permanent Forum on Indigenous Issues, a forum that examines issues such as the economic and social development, culture, environment, education, health and human rights of indigenous peoples.

Aqqaluk Lynge



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