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Drilling for time

Ice cores and the synchronization of temporalities in glaciology, 1935-1978

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ABSTRACT

Since their emergence in the 1950's, ice cores have ventured from being scientific objects of concern to a limited number of glaciologists to becoming one of the most iconic representations of anthropogenic climate change. This thesis aims to historicize the way in which ice cores became enrolled into climate discourse, particularly emphasizing the production and representation of temporalities of the global climate that the ice cores made possible. Focusing on the ice core drillings conducted in Greenland during the International Geophysical Year 1957-1958, as well as at the American military base Camp Century in the late 1960's, the thesis explores how the ice cores became entangled in broader political geographies of Arctic science, cultural conceptions of a planetary crisis and an extension of the temporal boundaries of environmental politics. By studying ice core science as a practice of synchronization, aimed at bridging the divide between human history and natural history, ice cores are seen as a part of a larger geopolitics of temporality, in which the temporal framework of global environmental politics were produced. As the ice core expanded – materially, temporally, discursively – during the late 1960's and early 1970's, ice core scientists became authorities on subjects previously seen as outside their scope.

As ice cores today occupy a solid position in climate discourse, the temporalities and future narratives they enable have undergone a process of reification in order to fit in broader political and cultural frameworks. This thesis adds to the growing literature on temporalities within environmental humanities by highlighting the process through which ice cores were written into modern climate discourse.

Keywords: ice cores, Arctic science, temporalities, Environmental humanities, climate modelling, history of science, Willi Dansgaard, Anthropocene, synchronization, temporal regimes

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Abbreviations and acronyms

AIGE – Arctic Institute Greenland Expedition

CRREL – Cold Regions Research and Engineering Laboratory

DMI – Danish Meteorological Institute

GISP – Greenland Ice Sheet Project

GISP 2 – Greenland Ice Sheet Project 2

ICE – Newsletter for the International Glaciological Society

IGS – International Glaciological Society

IGY – International Geophysical Year

IMO – International Meteorological Organization

ISAGE – International Symposium on Antarctic Glaciological Exploration

NBSAE – Norwegian-British-Swedish Antarctic Expedition

NSF – National Science Foundation

SIPRE – Snow, Ice, and Permafrost Research Establishment

SMIC – Study on Man's Impact on Climate

SSAG – Swedish Society for Anthropology and Geography

WMO – World Meteorological Organization

1. Introduction

In 1957, the Japanese glaciologist Ukichiro Nakaya found himself far away from home. As a part of a multinational research expedition, conducted within the framework of the International Geophysical Year, Nakaya and his colleagues had arrived for a month long stay on the Greenland ice sheet. Two decades earlier, Nakaya had made a name for himself within the glaciological community after creating the first ever artificial snowflake. The expedition had travelled to Greenland in order to study the interiors of the glacial bodies they encountered and, by drilling, sampling, and digging, recover the messages hidden beneath thick layers of ice. By directing their gaze downwards, towards the ice sheet itself, they broke with a long standing tradition of polar science. In the early 20th century, polar scientists had been preoccupied with the horizontal spatiality of the cryosphere, of crossing vast distances and conquering a perceived uninhabited great white space, frozen in time. During the early years of the Cold War, and the subsequent surge in geopolitical interest in the strategically important Arctic region, a new dimension of the ice became increasingly important: its verticality. As permanent military establishments were built inside the Greenland ice sheet, material and intellectual practices aimed at understanding, inhabiting and mapping the interiority of the ice sheet began to emerge. In particular, one object that came to be seen as central to this enterprise was the ice core – a long, cylinder shaped cut-out from the ice sheet, in which layers of annual snow accumulation could be analyzed in a stratigraphic manner, revealing past temperatures and climatic conditions. Where previous research into the temporalities of glaciers had consisted of annual measurements, of tracking glacial bodies in real time, the ice core enabled a temporal shift by allowing for immediate access to decades – and later centuries and millennia – of climate data.

Today, ice cores have become iconic representations of climate change. Often portrayed as a "natural archive", they are part in producing the temporal framework in which we envision humanity's impact on the global environment as well as mapping previous climatic variabilities. Their work has implications far outside the disciplinary boundaries of glaciology. As a part of a growing concern of the politics of climate models and the narratives they enable, this thesis aims to historicize the way ice cores and their temporalities were produced, represented and enrolled into discourses on anthropogenic climate change. Rather than being "natural archives" or "time machines" – as they are popularly imagined – ice cores

emerged on the geopolitical and scientific stage through specific political geographies, material and visual technologies and temporal regimes.

As Nakaya and his colleagues watched the first ice cores materialize on the Greenland ice sheet, a lot had happened since he, two decades earlier, had stood in his Hokkaido laboratory and watched the first artificial snowflakes take form. From the 1930's, when Nakaya received his – as he called the snowflakes – "letters from high up in the sky" and learned to predict the composition of snow before it hit the ground, to the late 1950's, when Nakaya now stood on top of the Greenland ice sheet, in front of a drill that had made it possible to look hundreds of meters down into the ice, and into time itself, the relationship between him and his research object had changed. Nakaya was no longer communicating either with the clouds, or with the snow cover on the ground, but with the interior contents of the ice sheet. The turn from the horizontal to the vertical provided an even more significant analytical transformation in glaciology: an expansion of its temporal boundaries.

This thesis explores what happened in the tracks of this shift from the horizontal to the vertical, from the present to deep time. As ice cores increasingly became one of the most iconic and widely used ways to locate humanity on a geological timescale, the turn towards the vertical in the cryosphere had become part in a temporalization of the global environment. For the glaciological community, the new temporal boundaries led to new epistemological and political positions, allowing glaciologists to become authorities on subjects previously thought to be outside of their scope. Even though glaciology had a long history – dating back to the 19th century – of describing climatic changes over time, the immediate access to past climatic regimes that the ice cores made possible enabled new areas of expertise.

The way we tell the time is, in the context of a rapidly warming planet, an increasingly pressing political issue. Ice cores, and other models and representations of climatic changes, have, since the emergence of a political and cultural awareness of anthropogenic climate change, shaped the way in which we locate ourselves on the planet's timescale. In this context ice cores are more than just pieces of ice: they are part of an iconography of climate change, of a larger story in which the global climate was given its temporal boundaries.

1.1 Aim and research questions

The aim with this thesis is to trace the ice core's emergence as a scientific object and subsequent development into a representation for anthropogenic climate change. By following the way ice cores entered climate discourse, this thesis aims to show how rather than being "natural archives", the narratives ice cores have enabled are embedded in specific historical processes and geopolitical developments during the second half of the 20th century. With a particular emphasis put on the production and representation of a temporal framework for the global environment, the thesis intends to formulate a historical account of the processes that enabled the ice core's current position in climate discourse. Specifically, the thesis follows the glaciological work conducted in Greenland between the 1950's to the 1970's. It thereby aims to situate the intellectual, material and scientific practices that enabled the ice core to materialize in a broader political geography of Arctic science. Treating the temporalities ice cores enable not as naturally given, but as the results of practices of synchronization, through which humanity could be located on a geological timescale, the role of ice cores and ice core scientists can be contextualized within a broader history of the making of the global environment. Furthermore, the thesis aims to show how the temporal expansion of glaciology made new scientific subjectivities possible, as the disciplinary boundaries of glaciological research were renegotiated following the introduction of the ice core.

- Which processes, actors, and cultural conceptions were part of the ice core's transition from a scientific object to a representation for anthropogenic climate change?

- How were the disciplinary and temporal boundaries of glaciology negotiated among ice core scientists?

2. Theoretical framework

2.1 Historicizing scientific objects

The ice core is an object defined by its hybridity: it is at once natural and cultural, a product of archaic climatic processes and modern technoscience, situated and mobile, a material object and an immaterial representation. Because of this ambiguity, this multiplicity of meanings within the ice core, the theoretical framework for this thesis will draw its inspiration from multiple fields and disciplines. In this chapter my aim is to outline my theoretical and methodological considerations as well as discuss previous studies on temporality and ice in general and ice core science in particular. For the sake of clarity, I have defined two theoretical foundations that will function as the guiding light in the encounter with the ice core and the people and institutions that surrounds it.

One of my aims with the thesis is to study the ice core as a scientific object. After its materialization in the middle of the 20th century, the ice core's material and symbolic properties underwent several changes as new technologies and scientific institutions emerged and as it was negotiated into new contexts and discourses. From this perspective, the ice core, as a scientific object, is both discursive and material, rather than being either an objective, naturally given entity or a mere social construction. This view of scientific objects is prevalent within the branch of history of science and science and technology studies (STS) that deals with the materiality of knowledge and the material culture of scientific practices.[1] The ice core is from this perspective understood as active rather than passive in the production of knowledge and its material qualities are intimately intertwined with its possible meanings and representations.[2] Over the course of the 1970's, the ice core was enrolled into an emerging discourse on anthropogenic climate change and it was popularized as a representation for human impact on the earth's climatic systems. Additionally, with the

[1] The study of material culture in history of science is not a new phenomenon. For example, Steven Shapin and Simon Schaffer placed it at the center of their investigations of early modern science in *Leviathan and the Air Pump: Hobbes, Boyle, and the Experimental Life* (Princeton, N.J, 1985). Another example is Peter Gallison's *Image and Logic: A Material Culture of Microphysics* (Chicago, 1997). Historian of science Lorraine Daston have written perhaps most extensively on the sociality of scientific objects and thus serves as an inspiration for this work as well. See Lorraine Daston (ed.), *Biographies of Scientific Objects* (Chicago, 2000) and Lorraine Daston (ed.), *Things That Talk: Object Lessons from Art and Science* (New York, 2004).

[2] Donna Haraway defines an object of knowledge as something that is part in its own creation, as an "active, meaning-generating axis of the apparatus of bodily production" rather than a blank slate on which science can project its ideas. See: Donna Haraway, *Simions, Cyborgs and Women* (New York, 1991), 200.

increased interest in climate modelling and earth system sciences, the ice core also began to function as a model for predicting future climates. The ice core can therefore not be treated as solely a scientific object, but also as a part of early efforts to create models for the global climate and its relationship to human activity. There is a rich scholarship dedicated to visual representations of scientific knowledge within STS as well as an increasingly growing field of historical and sociological studies of climate modelling and visual representations of climate.[3] As Paul Edwards argues in his 2010 book *A Vast Machine*, climate modelling, and climate science in more general terms, can be understood as a sociotechnical system "that collects data, models physical processes, tests theories, and ultimately generates a widely shared understanding of climate and climate change."[4] In my thesis, the ice core, rather than being an isolated phenomenon, can be understood as an object that over the course of a few decades became a part of this larger sociotechnical system. Drawing on the theoretical framework of climate modelling as a sociotechnical practice, my hope is to locate the ice core within a larger political and scientific geography of glaciology and climate science.

In highlighting the mobility of the ice core as a scientific object as well as situating it in a broader sociotechnical system I will utilize the theoretical framework provided by the branches of STS that deal with scientific objects and climate modelling. However, I argue in this thesis, the ice core must also be understood as a temporalizing entity, which works not only to create knowledge regarding the global climate but also to localize humanity on a timescale that dates back far longer than human history. If one theoretical foundation comes from STS – as outlined above – I will, in the next chapter, present the other one.

2.2 The return of temporality in the Anthropocene

In his 2003 article "The End of Temporality", Fredric Jameson notes how the modernists' preoccupation with time were increasingly replaced with a postmodern concern for space as

[3] Peter Galison, "Visual STS" in Carusi et.al (ed.) *Visualization in the Age of Computerization* (London, 2014) introduces many of the theoretical considerations that comes with the study of visual forms of knowledge. Miyase Christensen, Annika E. Nilsson, and Nina Wormbs (ed.), *Media and the politics of arctic climate change: when the ice breaks* (New York, 2013), Joshua Howe, *Beyond the Curve*: *Science and the Politics of Global Warming* (Seattle, 2014) Maria Bohn "Concentrating on CO2: The Scandinavian and Arctic Measurements", *OSIRIS*, 26:1 (2011), 165-179, and the thematic issue "Nature's Accountability" of *Science as Culture*, 19:4 (2010) are all examples of historical studies of how climate has been produced and represented as an object of knowledge.

[4] Paul Edwards, *A Vast Machine: Computer Models, Climate Data, and the Politics of Global Warming* (Cambridge, MA, 2010), 8.

the primary dictum of interest.[5] In several fields within the humanities and the social sciences the increased activity in studies and theory concerning space have led to the popularizing of the notion of a "spatial turn". Even though this turn is most prominent within fields such as cultural geography, history of science and STS have experienced a surging interest in the study of the relationship between knowledge production and spatiality.[6] One important distinction within the theoretical framework of the spatial turn is the difference between place and space: space is commonly understood as a priori, as empty and universal whereas place is a social subsection of space, filled with meaning and subjectivity. Even though this dichotomy has been criticized for being too rigid, the sociality of place is still a useful analytical concept for understanding the relationship between scientific practice and its spatial dimensions.[7] In relation to ice core science, using place as an analytical concept can shed light on how the practices of the scientists worked not only to produce knowledge about past and present climatic regimes, but also functioned as a practice of place making, turning the previously unknown interior of the ice sheet into a place with history, plasticity and a relationship to the global climate. As Lisa Messeri notes: "Place is not an afterthought or something produced alongside science but it is intimately tied to daily practice. Producing science is producing place."[8]

However, even though ice cores are part of a process of place making in the cryosphere, their work is primarily one of temporality rather than spatiality. In the case of the ice core, time and place are closely bound together, as the making of place through ice core drilling is also a making of time and a way to materialize temporality. This thesis is primarily preoccupied with matters of temporality, but it is my ambition to not completely separate the

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[5] Fredric Jameson, "The End of Temporality", *Critical Inquiry,* 29:4 (2003), 697.

[6] Anne Buttimer and David Seamon (ed.), *The Human Experience of Space and Place* (Kent, 1980), David Harvey, "From Space to Place and Back Again: Reflections on the Condition of Postmodernity" in Jon Bird et. al (ed), *Mapping the Futures: Local Cultures, Global Change* (London, 1993) and Kern, Stephen, *The Cultures of Time and Space, 1880-1918* (Cambridge, MA, 2003) are all examples of works that conceptualizes the sociality of space and place. For examples of the spatial turn within history of science, see: Steven Shapin, "Placing the View from Nowhere: Historical and Sociological Problems in the Location of Science", *Transactions of the Institute of British Geographers,* 23:1 (1998), Richard C. Powell, "Geographies of Science: Histories, Localities, Practices, Futures", *Progress in Human Geography,* 31:3, (2007) and David Livingston, *Putting Science in its Place: Geographies of Scientific Knowledge* (Chicago, 2003).

[7] For a critique of the space-place dichotomy, see: Edward W. Soja, *Postmodern Geographies: The Reassertion of Space in Critical Social Theory* (London, 1989) and Doreen Massey, *Space, Place and Gender* (Minneapolis, 1994).

[8] Lisa Messeri, *Placing Outer Space. An Earthly Ethnography of Other Worlds* (Durham, NC, 2016), 16.

two analytical concepts, temporality and spatiality, but rather emphasize the ways in which they interact and are co-produced.[9]

Over the course of the last decade, a surging interest in the humanities has been directed towards the global environment and the emergence of the Anthropocene, a new geologic epoch in which human activity has become a geological force.[10] In the tracks of this newfound concern for the changes in the global environment, the humanities – often under the interdisciplinary umbrella of environmental humanities – have increasingly started to investigate the historical, sociological and philosophical implications of a humanity in possession of geological agency. With its interest in geological epochs and climatic changes, the environmental humanities have also meant a reintroduction of temporality as a fundamental dimension for humanist research. Andreas Malm calls it "the revenge of time". He writes:

> Over the past decades, critical theory has moved towards space, away from time as the long-favored dimension, the classical vessel of structure, causation, rupture, possibility […] Neil Smith hymns the victory of space over time in *Uneven Development: Nature, Capital, and the Production of Space,* quoting approvingly oneliners as 'we are in the epoch of simultaneity';'prophecy now involves a geographical rather than historical projection' (whatever that could possibly mean) – even endorsing Francis Fukuyama's infamous thesis of the 'end of history' by asserting that 'indeed historical time would seem to be over'. Global warming should put such fantasies to rest.[11]

Along similar lines, Michelle Bastian has identified one of the key tasks of environmental humanities to transform the temporal framework that allows nature to be de-coupled from culture.[12] In the article "Ice Cores and the Temporalities of the Global Climate" – which I will

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[9] Jon May and Nigel Thrift (ed.), *TimeSpace: Geographies of Temporality* (London, 2001) is an example of an attempt to bridge the divide between the spatial turn and the interest in temporality within the humanities and the social sciences.

[10] The term Anthropocene was coined by the physicist Paul Crutzen in an article in Nature in 2002 (Paul Crutzen, "Geology of Mankind", *Nature* 415:6867 (2002), 23. However, the term has received criticism for being apolitical and erasing the differences in vulnerability and responsibility within *Anthropos*, and other suggestions for the new geological epoch has been made in order to emphasize the political nature of the concept. Jason W. Moore has suggested Capitalocene, in order to highlight how capitalism is central to the creation of the epoch, and Donna Haraway uses the term Chthulucene – drawing inspiration from the tentacular mythological being Cthulhu as a way to emphasize how existing as an individual is rendered impossible by the new geological conditions – instead of the Anthropocene. In the thesis I have decided to use the most commonplace term, the Anthropocene, for the sake of clarity, since this thesis does not go into an in-depth discussion on the implications on the new geological epoch. For recent critique of the Anthropocene, see: Jason W. Moore, *Capitalism in the Web of Life* (New York, 2016), and Donna Haraway *Staying with the Trouble: Making Kin in the Chthulucene* (Durham, NC, 2016).

[11] Andreas Malm *Fossil Capital: The Rise of Steam-Power and the Roots of Global Warming* (London, 2016), 6.

[12] Michelle Bastian, "Inventing Nature: Re-writing Time and Agency in a More-Than-Human World", *Australian Humanities Review*, no. 47 (2009) and Michelle Bastian, "Fatally Confused: Telling the Time in the

discuss in more detail in the next chapter – Mark Carey and Alessandro Antonello notes that there has been a larger interest within environmental history and history of science in analyses of the construction of space in comparison to critical studies on the construction of temporalities. The engagement with material and spatial elements of the past has led to an underdevelopment in the study of how human temporalities are constituted and constructed within societies.[13] In this thesis, I aim to contribute to the efforts of turning towards the temporalities of the global climate and, by looking at particular cases of how temporalities have been produced through scientific practice, study the making of a temporal framework for modern climate science and political discourse on anthropogenic climate change.

In order to study the production of temporality within ice core science, I will specifically use Reinhart Koselleck's concept of "multiple temporalities".[14] In an Anglophone context, Koselleck has become known for his theoretical contributions to the German branch of conceptual history as well as a theorist of the temporal qualities of modernity.[15] Koselleck has received criticism for his perception of modernity as – in Lynn Hunt's words – "a temporal experience".[16] As a theorist of modernity, Hunt as well as previous commentators of his work assert, this categorization seems to be an insufficient and opaque way of describing a phenomenon as wide reaching as modernity itself. This criticism, Helge Jordheim argues, is partly misguided: instead of reading Koselleck as a theorist of modernity we should approach his work as a broader conceptual reimagining of periodicity in historical theory. With the concept "multiple temporalities", Koselleck introduces an alternative to the commonplace linear, homogeneous perception of time. Instead, he proposes a multilayered conception of temporality, in which overlapping temporal structures and different temporal experiences can

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Midst of Ecological Crises", *Environmental Philosophy,* 9:1 (2012), 26. Elizabeth Callaway, "A Space For Justice: Messianic Time in the Graphs of Climate Change", *Environmental Humanities*, vol. 5 (2014), 13-33, Heather Anne Swanson, "Anthropocene as Political Geology: Current Debates of how to Tell Time", *Science as Culture*, 25:1 (2016), 157-163 and Kathryn Yusoff , "Anthropogenesis: Origins and Endings in the Anthropocene", *Theory, Culture & Society*, 33:2 (2016), 3-28, are additional examples of ongoing discussions and debates on temporality within environmental humanities.

[13] Mark Carey and Alessandro Antonello, "Ice Cores and the Temporalities of the Global Environment", *Environmental Humanities*, 9:2 (2017), 186.

[14] Reinhart Koselleck*, Futures Past: On the Semantics of Historical Time* (New York, 2004), 16-18.

[15] Pim den Boer, "The Historiography of German *Begriffsgeschichte* and the Dutch Project of Conceptual History", in Iain Hampsher-Monk, Karin Tilmans and Frank van Vree*„ History of Concepts: Comparative Perspectives* (Amsterdam, 1998), 14-16, offers a brief introduction to Koselleck's influence in and theoretical contributions to the history of concepts. For an example of Koselleck's theoretical approach to conceptual history in practice, see: Reinhart Koselleck, "Crisis", *Journal of the History of Ideas,* 67:2 (2006), 357-400.

[16] Lynn Hunt, *Measuring Time, Making History* (Budapest, 2008), 75.

exist simultaneously.[17] Thus, rather than viewing Koselleck's writing on temporality of historical time as a theory of periodization, Jordheim offers an alternate interpretation:

> The remarks, fragments, and more sustained theoretical reflections scattered across all of his [Koselleck's] diverse and wide-ranging essays bring out a radically different picture; taken together they amount to a theory that challenges and even defies periodization. Koselleck developed his theory of multiple temporalities, organized in the form of temporal layers that have different origins and duration and move at different speeds, as an alternative to the linear and empty time of periodization.[18]

Jordheim goes on to show how the temporality of modernity, the notion of linear progress and distinct breaks between the past, the present and the future, was itself not a natural outcome of historical processes but a result of active efforts to synchronize disparate temporalities into one temporal regime.[19] The term "temporal regime" is defined by Francois Hartog as "the temporal structure of a certain culture, historical context or moment, the socially embedded experiences or articulations of the past, the present and the future"[20]. However, in Jordheim's definition, a temporal regime is extended beyond social phenomena and also encompasses practices, technologies, and media as means of synchronizing a plurality of times. Over the last decades, the modern time regime has found itself in an increasingly precarious state: Hartog calls this situation a "crisis of time", in which a previous set of ways of understanding time is about to lose its privileged and quasi-natural position in relationship to other temporal structures.[21] The reasons behind this crisis are manifold: globalization has brought with it new temporal relations and conflicts through the encounters between the global time of multinational trade, media and technology and the temporal rhythms of particular communities. Another reason, according to Jordheim, is the increased interest in the "deep times" in the tracks of the beginning of the Anthropocene, which has expanded the temporal horizons of political actions as well as sociopolitical relationships into distant pasts and distant futures. In this context, humanity is at once operating on a human as well as on a geological timescale. As Dipesh Chakrabarty formulates this experience of temporal duality:

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[17] Helge Jordheim, "Against Periodization: Koselleck's Theory of Multiple Temporalities", *History and Theory,* 51:2 (2012) 161.

[18] Jordheim, "Against Periodization: Koselleck's Theory of Multiple Temporalities", 170.

[19] Helge Jordheim,"Introduction: Multiple Times and the Work of Synchronization", *History and Theory*, 53:3 (2014), 500.

[20] Francois Hartog, *Regimes of Historicity: Presentism and Experiences of Time* (New York, 2015), 27.

[21] Hartog, *Regimes of Historicity,* 201-202. Aleida Assmann makes a similar argument regarding the end of the modern time regime in "Transformations of the Modern Time Regime" in Chris Lorentz (ed.), *Breaking Up Time: Negotiating the Borders Between Present, Past and Future*, (Göttingen, 2013), 40-43.

"Living in the Anthropocene means inhabiting two presents at the same time."[22] Treating the modern time regime as the outcome of practices of synchronization rather than a stable entity which is now being replaced, Jordheim notes how the temporality of modernity has been continuously challenged throughout its existence, but particularly so during its emergence in the eighteenth century and its collapse in present day. In order to keep the temporal regime intact, challenges by other temporalities have been met by "attempts to compare, unify, and adapt different times, or in other words, to synchronize them into the one homogeneous, linear, and teleological time of progress."[23]

With the notion of the existence of a multiplicity of times – and the existence of practices supposed to synchronize them – the ice core can be understood as an object that does not only tell stories of past climatic regimes, but also as a materialization of different temporalities. Furthermore, ice core drilling as a scientific practice can be understood as a practice of synchronization, in the way Jordheim categorizes it, and I will therefore treat the enrollment of the ice core into a discourse on anthropogenic climate change as an enrollment into a temporal regime as well. Considering temporal regimes as being governed by sets of practices, the work of the ice core and the ice core scientists is both the production of scientific knowledge as well as the production of temporality. Kathryn Yusoff locates one of the most appealing aspects of ice cores in the popular imagination in its seemingly complete adherence to a basic, Western understanding of historical time: they seem to present a linear timeline, a frozen ruler history with a clear chronology and locatable events.[24] This sentiment is echoed in Carey and Antonello's article on ice cores and their temporalities, as they argue that ice cores, in the way their temporalities speak to "the complex textures of the Earth's past, of the past of humans as species and as civilizations, and of a narrow, frightening future" are part of a reductionist narrative that is insufficient in coordinating humans and non-humans in the age of anthropogenic climate change.[25] By closely studying the practices that enabled the ice core's existence as well as the material qualities of the cores themselves through the lens of Koselleck's notion of existence of multiple and simultaneous temporalities and Jordheim's definition of practices of synchronization, I hope to be able to trace the formation and establishment of the temporalities of the ice cores.

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[22] Dipesh Chakrabarty, "Anthropocene Time", *History and Theory*, 57:1, (2018), 30.
[23] Jordheim "Introduction: Multiple Times and the Work of Synchronization", 502.
[24] Kathryn Yusoff, "Core Histories" in Kathryn Yusoff (ed.), *BiPolar* (London, 2008), 35.
[25] Carey & Antonello"Ice Cores and the Temporalities of the Global Environment", *Environmental Humanities,* 199.

2.3 Ice, snow and the northern turn in the history of science

Ice and snow have increasingly emerged as objects of inquiry not only for natural scientists, but also for humanists and social scientists. The ice sheets in Antarctica and the Arctic are not – spatially nor temporally – situated outside the dynamics of global climatic changes caused by human activity, but rather they are enmeshed in the sociotechnical system of the global environment as well as in the geopolitical order and financial systems governing the modes of production on the planet. Ice is, in this context, not just ice. It is historical in the sense of being affected by and in return affecting the social dynamics of its surroundings.[26] Furthermore, glacier ice serves as an important measurement of climatic changes, both in a scientific context as well as in popular depictions of global warming. Historicizing the way this knowledge came to its current form is therefore also part of a larger process of historicizing climate change.[27]

In addition to the reimagining of the sociality of ice in the Anthropocene, the Arctic region in particular has been the subject of interest for historians of science, the Cold War and the environment.[28] This turn towards the north and the Arctic has led to a small, but in recent years rapidly growing, body of scholarship concerned with the production of knowledge and material and scientific practices of polar research in the 20th century.[29] Some of this research has primarily been preoccupied with the relationships between science and the geopolitics of the Cold War in the Arctic[30] while others have focused on the scientific

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[26] Sverker Sörlin has called this a cryo-historical moment, highlighting how ice and glaciers are historical and part of society in the Anthropocene. See: Sverker Sörlin, "Cryo-History: Narratives of Ice and the Emerging Arctic Humanities", in Birgitta Evengård, Joan Nymand Larsen and Øyvind Paasche. (ed.), *The New Arctic* (Cham, 2015).

[27] Sverker Sörlin & Melissa Lane, "Historicizing Climate Change – Engaging New Approaches to Climate and History", *Climatic Change*, in revision.

[28] I use the term "sociality of ice" to emphasize the interconnected relationship between social processes and the physical properties of ice in the Anthropocene. In the context of anthropogenic geological agency, ice – much like the geological strata – is social in the context of being enmeshed with human activity and human activity is in return affected by the agency of the ice. Kathryn Yusoff and Nigel Clark uses the term "geosocial formations" to describe this new relationship between the geological and the social. A sociality of ice, a cryosociality, to paraphrase Yusoff and Clark, could perhaps be a way to highlight the predicaments of the human-ice relationship in the Anthropocene. See: Kathryn Yusoff and Nigel Clark, "Geosocial Formations in the Anthropocene", *Theory, Culture & Society*, 34:2-3 (2017), 3-23.

[29] As a few examples of this turn within the history of science, see: Birgitta Evengård, Joan Nymand Larsen, and Øyvind Paasche (ed.), *The New Arctic* (Cham, 2015), Janet Martin-Nielsen, "Re-Conceptualizing the North. A Historiographic Discussion", *Journal of Northern Studies* 9:1 (2015) 51-68, Sverker Sörlin, "The Emerging Arctic Humanities" *Journal of Northern Studies* 9:1 (2015) 93-98, Urban Wråkberg, Ronald E. Doel and Susanne Zeller "Science, Environment and The New Arctic", *Journal of Historical Geography* 44 (2014), 2-14, Andrew Baldwin et. al (ed.) *Rethinking the Great White North. Race, Nature and the Historical Geographies of Whiteness in Canada* (Vancouver, BC, 2011).

[30] Some examples: Nikolaj Pedersen, "The Politics of US Military Research in Greenland during the Early Cold War", *Centaurus*, vol. 55 (2013), 294-318, Kristian H. Nielsen, Henry Nielsen and Janet Martin-Nielsen. "City

subjectivity of glaciologists and other scientists that have been involved in producing knowledge about the Arctic region.[31] The last couple of years have also seen an increase in humanist scholarship interested in the ice itself: ice is in this perspective not a neutral and passive piece of nature, but rather it is intertwined with human history, moving, melting and possessing its own kind of performativity.[32] The animate qualities of the ice have been studied on different scales: both as part of local epistemologies and indigenous knowledge systems as well as a part of a global climatic and geopolitical dynamic, existing both materially in the cryosphere and as representations in media, politics and popular culture.[33]

In comparison to the entirety of the ice sheets by the poles – and their impact on the global environment – the ice cores are in possession of rather different spatiotemporal qualities. They are part of the ice sheet, but also of an intricate geography of scientific institutions and advanced scientific practices and technologies; they are situated in the Arctic or Antarctica, but also in field science stations, cold storages and laboratories thousands of miles away from the place of their extraction, in scientific papers, policy briefings and public spaces. However, despite the spatial ambiguity of the ice core, I see this thesis as a part of the

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Under the Ice: the Closed World of Camp Century in Cold War Science", *Science as Culture*, 23:4 (2014), 443-464, Ronald E. Doel Kristine C. Harper and Matthias Heymann (ed.), *Exploring Greenland Cold War Science and Technology on Ice* (New York, 2016) and Nikolaj Petersen, "SAC at Thule: Greenland in the US Polar Strategy", *Journal of Cold War Studies* 13:2 (2011), 90-115.

[31] Sverker Sörlin "Hans W:son Ahlmann, Arctic Research and Polar Warming: From a National to an International Scientific Agenda, 1929-1952", in *Mundus librorum: Essays on Books and the History of Learning* (Helsinki, 1996), 383-398; idem, "The Anxieties of a Science Diplomat: Field Co-production of Climate Knowledge and the Rise and Fall of Hans Ahlmann's 'Polar Warming'", *OSIRIS*, 26:1 (2011), 66-88, Lisa Bloom, *Gender on Ice: American Ideologies of Polar Expeditions*, (Minneapolis, 1993), Jessica O'Reilly, "Sensing the Ice: Field Science, Models, and Expert Intimacy with Knowledge", *Journal of the Royal Anthropological Institute,* 22:1 (2016), 27-45, Bruce Hevley, "The Heroic Science of Glacier Motion", *OSIRIS*, 11:1 (1996), 66-86, Steven Bocking, "Situated Yet Mobile: Examining the Environmental History of Arctic Ecological Science", in Dolly Jørgensen, Finn Arne Jørgensen and Sara B. Pritchard, *New Natures: Joining Environmental History and Science and Science and Technology Studies* (Pittsburgh, PA, 2013), Janet Martin-Nielsen, *Eismitte in the Scientific Imagination: Knowledge and Politics at the Center of Greenland* (New York, 2013).

[32] Mark Carey, M. Jackson, Alessandro Antonello and Jaclyn Rushing, "Glaciers, Gender, and Science: A Feminist Glaciology Framework for Global Environmental Research", *Progress in Human Geography,* 40:6 (2016), 770-793, Sverker Sörlin, "Can Glaciers Speak?: The Political Aesthetics of Vo/ice" in J. Thorpe, S. Rutherford & A. Sandberg (ed.), *Methodological Challenges in Nature-Culture and Environmental History Research* (New York, 2016), Alessandro Antonello, "Engaging and Narrating the Antarctic Ice Sheet: The History of an Earthly Body", *Environmental History*, 22:1 (2017), 77-100, Mark Carey "The History of Ice: How Glaciers Became an Endangered Species", *Environmental History*, 12:3 (2007), 497–527, Mark Carey, *In the Shadow of Melting Glaciers: Climate Change and Andean Societies* (Oxford and New York, 2010), Bravo, Michael T., "Voices from the Sea Ice and the Reception of Climate Impact Narratives," *Journal of Historical Geography* 35:2 (2009), 256-278.

[33] Sverker Sörlin "Cryo-history: Ice, Snow, and the Great Acceleration" in Julia Herzberg, Christian Kehrt and Franziska Torma (ed.) *Snow and Ice in the Cold War – Histories of Extreme Climatic Environments* (New York and Oxford, 2018), in press. Within anthropology studies of livelihoods of indigenous peoples in the changing Arctic have contributed to the scholarship of human-ice relationships. See Igor Krupnik and Dyanna Jolly (eds.), *The Earth is Faster Now. Indigenous Observations of Arctic Environmental Change* (Fairbanks, 2002) and Kirsten Hastrup, *Thule på tidens rand* (Copenhagen, 2015).

turn towards the Arctic, towards cryo-history, as the practice of drilling for and interpreting ice cores has increasingly become an important part of the production of knowledge regarding space and time in the cryosphere. The performances and transformations of the ice cores during the 20th century and, in particular, their role as a temporalizing entity in the discourse of global climatic change, highlights the connections between polar science and the creation of the global environment as a narrative of the human predicament on the planet. Therefore, the ice cores, despite existing partly spatially outside the cryosphere, shows how a "northern turn" within history of science doesn't necessarily lead to an exclusive focus on certain geographical areas, but rather how the distances between the cryosphere and the rest of the world can be understood in topological terms, as relational instead of topographical.[34]

2.4 Previous research

Following the increased interest in historical studies of climate science- and models as well as the northern turn in the history of science outlined above, there have been a small number of historical, sociological and anthropological studies of ice cores and ice core science, both in historic and contemporary contexts. In this chapter, I will outline the studies that precedes this one and attempt to situate this thesis within the previous scholarship on the subject. The history of ice core science has been, at least initially, written by the practitioners themselves: Chester C. Langway, JR. who was an important figure in early attempts to recover ice cores in Greenland and later on in larger scientific projects such as GISP, has summarized the formation of early ice core science in a brief monograph.[35] Another key figure, in this thesis as well as in ice core science in general, Willi Dansgaard, has written an autobiographical account of his impressions of his years in Greenland and the scientific community of ice core scientists.[36] As ice cores have grown increasingly more well-known in the media and popular culture, there have also been a few works by glaciologists and climate scientists aimed at a broader audience.[37]

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[34] For a definition of topological spatiality in the context of science and technology studies, see: Annemarie Mol John Law, "Regions, Networks and Fluids: Anaemia and Social Topology", *Social Studies of Science,* 24:4 (1994), 645-646.

[35] Chester C. Langway Jr, *The History of Early Polar Ice Cores*, ERDC/CRREL TR-08-1, (Buffalo, NY, 2008). Richard B. Alley has also written a brief overview of the history of ice core science in: Richard B. Alley "Reliability of Ice-core Science: Historical Insights", *Journal of Glaciology*, 56:200 (2010), 1095-1099.

[36] Willi Dansgaard, Willi*, Frozen Annals. Greenland Ice Cap Research* (Copenhagen, 2005).

[37] Richard B. Alley, *The Two-Mile Time Machine: Ice Cores, Abrupt Climate Change, and Our Future.* (Princeton, NJ, 2000), Paul Mayewski and Frank White. *The Ice Chronicles: The Quest to Understand Global*

In addition to the work made by glaciologists and people who themselves have been involved in ice core science, a small number of historians, anthropologists and sociologists of science have directed their attention towards ice cores. Janet Martin-Nielsen has written several articles primarily or partly dedicated to ice core science in Greenland. Particularly her writings on the relationship between scientific practice and geopolitics at Camp Century surrounding the first surface-to-bedrock ice core in 1966 has been both inspirational and foundational for the writing of this thesis. Furthermore, Martin-Nielsen has contributed with a theoretical framework for understanding the role of ice cores in a broader conceptualization of the Arctic, and particular Greenlandic, space. Tracing how the practice of ice core drilling was part of a practice of place making in Greenland, turning, over the course of a few years in the late 1960's, the island into a place of primarily environmental concern in comparison to the previous years' emphasis on military strategy and geopolitical tension. Her work has also been part in situating ice core drilling and the ice core as a scientific object within the context of Cold War science.[38] Maiken Lolck, who is just as Martin-Nielsen affiliated with the University of Aarhus, has written the most extensive exposé of Denmark's role in ice core science, and particularly the impact of the Danish paleoclimatologist Willi Dansgaard. Since this thesis also pays a substantial amount of attention to the work of Dansgaard, Lolck's work provide a complement to Dansgaard's own account of his scientific career.[39]

The work of the ice core in a broader cultural context has also been the object of inquiry, particularly emphasizing the important role ice cores have acquired in the context of anthropogenic climate change. Kathryn Yusoff has written on the implications of ice cores in modern climate policy. Noting how the ice cores are often discursively constructed as a natural archive, she questions the presumed neutrality of the stories ice cores tell and discusses the material, geopolitical and technological circumstances that allow scientists to write narratives from the layers in the ice core. Thus, her work has illuminated the politics of the ice core and its situatedness in a geopolitical and social order.[40] Aant Elzinga has written

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Climate Change (Hanover, NH, 2002), and Jean Jouzel, Claude Lorius, and Dominique Raynaud. *The White Planet: The Evolution and Future of Our Frozen World* (Princeton, NJ, 2013).

[38] Janet Martin-Nielsen,"'The Deepest and Most Rewarding Hole Ever Drilled': Ice Cores and the Cold War in Greenland", *Annals of Science*, 70:1 (2013), 47-70, Kristian H. Nielsen, Henry Nielsen and Janet Martin-Nielsen "City Under the Ice: the Closed World of Camp Century in Cold War Science", *Science as Culture*, 23:4 (2014), 443-464 and Janet Martin-Nielsen, *Eismitte in the Scientific Imagination: Knowledge and Politics at the Center of Greenland* (New York, 2013).

[39] Maiken Lolck, *Klima, Kold Krig og Iskerner,* Speciale ved Afdeling for Videnskabshistorie, Steno Instituttet, Aarhus Universitet (Aarhus, 2004).

[40] Kathryn Yusoff, *BiPolar* (London, 2008). Even though it is not the primary objective of the article, Matthias Dörries briefly discusses the politics of the ice core in Mathias Dörries "Politics, Geological Past, and the Future of the Earth", *Historical Social Research*, 40:2 (2015), 22-36.

on the ice core's role in the context of anthropogenic climate change. The ice core, he claims, is in the context of not only a scientific object that functions as a time marker, but, with the increasing impact by human activity on the global climate, a device that measures humanity itself and its dramatic imprints on the planet.[41]

Mark Carey and Alessandro Antonello have written the only – as far as I am aware of – scholarly work that deals with the relationship between ice cores, temporality and the politics of the Anthropocene. In the article, Carey and Antonello, provides a critical analysis of the way ice cores have been not only enrolled into environmental policy, but also been part of constituting the temporalities of the global environment. In their ability to provide the deep past with texture, ice cores have increasingly also become objects with the capability to structure and predict the future.[42] However, by embodying the temporalities of a deep, event filled past and a narrow, dangerous future, the ice cores might not be helpful in the attempts to manage the increasingly warming planet. The temporalities of the ice cores, Carey and Antonello assert, tend to work in a different manner than they are intended to: even though ice cores seem to be a way to "tell the time", their temporal work might instead reinforce a deterministic perception of climate change, portraying humanity as completely subjected to climate as an exterior force, rather than existing in an intertwined, complex relationship. The temporal framework of climate discourse, and particularly the apocalyptic imaginaries of future time, has, despite the efforts to politicize anthropogenic climate change, created a socially disembodied perception of the Earth's climatic system.[43] As the ice cores have ventured from speaking solely about a past devoid of humanity to the socio-environmental politics of the present and the future, the narratives they enable are, Carey and Antonello argue, not only of interest for glaciologists and climate scientists, but for everyone who studies the increasingly complex relationship between climate, geopolitics and temporalities.[44]

Responding to Carey and Antonello's call for an increased interest in temporalities

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[41] Aant Elzinga, "Polar Ice Cores. Climate Change Messengers", in Vincent Bensuade Bernadette et. al. (ed.), *Research Objects in their Technological Setting* (London, 2017).

[42] Mark Carey and Alessandro Antonello, "Ice Cores and the Temporalities of the Global Environment", *Environmental Humanities*, 9:2, 2017, 198.

[43] Erik Swyngedouw, "Apocalypse Forever? Post-political Populism and the Spectre of Climate Change." *Theory, Culture, and Society* 27:2–3 (2010), 220-221, Mike Hulme, "Reducing the Future to Climate: A Story of Climate Determinism and Reductionism", *OSIRIS*, 26:1 (2011), 262, and Luc Semal, "Anthropocene, Catastrophism, and Green Political Theory", in Clive Hamilton, et. al (ed.), *The Anthropocene and the Global Environmental Crisis: Rethinking Modernity in a New Epoch* (New York, 2017). Additional writing on climate reductionism can be found in William B. Meyer and Dylan M.T. Guss, *Neo-Environmental Determinism* (Cham, 2017).

[44] Carey and Antonello, 199.

within environmental history, I hope to complement their work on the politics of ice core temporalities and the role of the ice core in climate discourse. While their article raises important questions regarding the work of the ice core, they are primarily interested in the role the ice core has played after the 1980's and its establishment as a scientific object as well as a representation for climatic shifts in the past. By going further back in the ice core's history and its emergence and stabilization within the scientific community, I hope to show how the temporalities of the ice cores were the result of specific and situated scientific practices during a few formative years. Drawing from theories on the history of scientific objects as well as the interest in temporalities in Anthropocene research, the black boxing of the temporalities of the ice core can be studied as a historical phenomenon, that rather than being the natural outcome of scientific practice was woven into a more complex web of geopolitics, an emerging environmental consciousness, global political and scientific institutions, and a reimagining of the epistemological possibilities of glaciological research. By treating ice core science as a practice of synchronization – in accordance with Helge Jordheim's definition – I seek to utilize my theoretical framework to investigate the fixation of the temporalities of the ice core and their implementation in scientific and political discourse on anthropogenic climate change. While Jordheim primarily locates the existence of practices of synchronization within historiography, I argue that it can be a fruitful theoretical approach to the history of science as well, particularly when it comes to the various disciplines that deal with the global climate and its changes over time.[45] The geopolitics of temporality has, with the emergence of the Anthropocene, transcended previous boundaries of the natural and the cultural, turning matters of temporality in the cryosphere into the midst of political and cultural concern. With the help of the theoretical and methodological framework outlined above, my aim is to respond to Carey and Antonello's call for an increased interest in temporalities within history of science and environmental history by closely examining the processes that enabled the ice core to venture from the Greenland ice sheet to the geopolitical spotlight.

2.5 Source material

[45] Jordheim, "Introduction: Multiple Times and the Work of Synchronization", 513-514.

In order to trace the emergence of the ice core, a large part of the source material for this thesis is the output of glaciologists, paleoclimatologists and other scientists that were involved in the early attempts to recover ice cores and, later on, were part in its increasingly broadening scope during the 1970's. The first scientific journal dedicated solely to glaciology, *Journal of Glaciology,* was founded in 1936 as a part of the International Glaciological Society (IGS), and marked a further independence for glaciology in relation to adjacent disciplines. It was also in the Journal of Glaciology that many of the early discussions on ice core science took place and therefore it has been a natural entry into the scientific debates of the 1960's and 1970's. I will primarily use articles written in the late 1960's, because of the increased scientific interest in ice cores that came with the successful drillings at Greenland's Camp Century, but I will also use earlier, dating back to the early 1950's, as well as later, that stretches into the 1970's, articles in order to follow the ice core's trajectory within glaciology. Furthermore, by following *Journal of Glaciology* over several decades, long term tendencies such as the epistemological and temporal reconsiderations that were related to the increased interest in ice cores, are possible to trace in a more systematic manner. In addition to the scientific production published in the *Journal of Glaciology*, I will also examine articles on ice cores in broader scientific journals such as *Science* and *Nature*, other more specialized scientific journals such as *Quaternary Research* and *Antarctic Journal of the US* as well as popular media such as *National Public Radio* and *New York Times.*

An additional part of the source material consists of the outcome of other spaces in which ice cores were discussed. I have, for example, looked into the conference papers published for the International Symposium on Antarctic Glaciological Exploration (ISAGE) meeting in 1968 and presentations made by glaciologists in order to secure funding for ice core drilling during the International Geophysical Year (IGY) 1957-1958.

The final chapter of the thesis is oriented around the work and career of the Danish paleoclimatologist Willi Dansgaard. Since Dansgaard was one of the most well-known and published ice core researchers, his work can be found in all of the journals listed above. However, he also published two short monographs for the Danish Commission for Scientific Investigations in Greenland in 1963 and 1972, which offers an interesting look into not only the scientific practices of the time, but also into the epistemological and temporal transformations Dansgaard's work underwent during the years between the publication of the two monographs. The main part of the chapter on Dansgaard is based on his personal papers, which are archived the University Library at the University of Copenhagen. Particularly questions about temporality and the role of humanity on a geological timescale are explicitly

discussed by Dansgaard in speeches, letters and article drafts. The expansion of source material from consisting mainly of scientific article to the personal writings and correspondence of one particular actor has two beneficial aspects: firstly, Dansgaard does, in his personal writings more explicitly discuss temporality and the timeframes of his contemporary political debates than he does in his scientific production. Secondly, by studying one important actor within a broader transformation of a scientific field, Dansgaard's personal thoughts on his discipline can function as a case study into how scientific subjectivities shape and are shaped by surrounding negotiations on the field's demarcations.

I have chosen to focus on sources primarily from the 1950's, 60's and 70's, since these were the years in which the ice core emerged and stabilized as scientific object as well as a representation for anthropogenic climate change. However, in order to provide further context and as the chronology of the emergence of the ice core is not completely linear, I have also a small number of sources dating before the 1950's and after the 1970's.

2.6 Disposition

The thesis consists of three chapters followed by some concluding remarks. The first chapter outlines the early history of ice core drilling and the variety of practices that preceded the first successful attempts to recover ice cores. A strong emphasis in this chapter lies on the spatiotemporal work of the first ice cores and how the spatial and temporal imaginaries of the cryosphere were affected by the restructuring of glaciological research after the Second World War. Glaciology's turn towards vertical spatiality, of drilling into the ice sheet rather than exploring it horizontally, was a qualitative break from previous practices and the chapter traces this conceptual shift in relation to the political and scientific geographies of polar science during the 1950's. Where the first chapter stretches between the 1930's to the scientific mobilization that took place around the IGY 1957-1958, the second chapter begins where the first left off, however, rather than being a strictly chronological account for the development of ice core science, it revolves around the Camp Century ice core, which was recovered in 1966 and was the first ever surface-to-bedrock ice core. The chapter traces the events and institutional shifts that enabled the Camp Century ice core to materialize and outlines the aftermath within the glaciological community as well as in broader scientific and political circles. Paying attention to how the material qualities of the ice core enabled it to be enrolled into new contexts, the second chapter seeks to connect the – material and discursive

– expansion of the ice core after Camp Century with broader geopolitical and scientific tendencies. Especially the temporalities of the ice core, and the way they are translated and transposed into political discourses on human impact on the planet, are central to this process.

The third chapter has a slightly different form than the two previous ones, as it does not focus on the entirety of ice core science, but instead focuses solely on one particular scientist: Willi Dansgaard. The Danish paleoclimatologist Willi Dansgaard was one of the most prominent and cited ice core scientists during the first decades of large scale ice core drilling. The chapter offers a brief biography of Dansgaard and his work, but pays the most attention to how the expanded temporal horizons of his research enabled him to venture into adjacent scientific fields as well as public policy with a new scientific authority. In his private correspondence, Dansgaard also explicitly reflected upon and discussed the connections of human history and natural history in relationship to contemporary debates in environmental politics, thus the chapter also aims to describe the co-production of ice core temporalities and the emerging climate discourse. Lastly, by focusing one, single actor, my aim is to track the changes in scientific subjectivity within glaciology after the Camp Century ice core and the enrollment of ice core science into the growing concern about anthropogenic climate change.

In the concluding remarks I will discuss the results of the study in relation to the purpose and research questions posed in the beginning. I also intend to discuss the thesis in relation to current scholarship, contemporary political and scientific debates on the geopolitics of temporality in the Anthropocene.

3. The snowflake and the ice core: materializations of time in glaciology 1935-1957

In 1935, the Japanese physicist and glaciologist Ukichiro Nakaya produced the first ever artificial snowflake in his laboratory at the University of Hokkaido. A few years after the first snowflake, Nakaya and his team had learned to alter temperature and humidity in order to create a variety of snow crystal structures. Their fragile creations were photographed, documented and written into a diagram – most often referred to as the Nakaya diagram – and they became a tool for meteorologists to presume the conditions in clouds from which natural snow crystals were falling. Nakaya's artificial snowflakes became messengers from a previously unreachable place, expanding the spatial imagination of glaciology upwards into the clouds. The variety of structures in the laboratory could answer to the rapid transformations of meteorological conditions in the sky. A correspondence between the scientists on the ground and the snow in the clouds had been initiated. As Nakaya himself put it: "A snow crystal is a letter from high up in the sky"[46].

Two decades later, when Nakaya, as a part of the IGY, stood on top of the thick Greenland ice sheet, the mission was no longer to figure out what was going on up in the clouds, but to reveal the messages that lied in store for the scientists deep inside the glacier ice. [47] The IGY marked the beginning of professional and systematic drilling in the ice sheets of Greenland and Antarctica in order to retrieve ice cores.[48] Ice cores are long, cylinder shaped objects in which annual snowfall has accumulated and over the years turned into ice. Air bubbles trapped inside the ice cores can be extracted and convey information about the climate from the time in which the air became caught inside the layer of ice. Because of the ice cores' ability to reveal detailed information regarding past climate regimes over vast time scales, they have become a significant scientific object for understanding the past – and increasingly also the future – of the earth's climate.[49] In comparison to Nakaya's previous object of inquiry, the artificial snowflake, the ice core offered a different temporal and epistemological outlook: rather than mapping the present, it ranged into the deep past, it was

[46] Akira Higashi, "Obituary", *Journal of Glaciology*, 4:33 (1962), 378.
[47] James Bender, "Obituary", *Arctic Journal*, 3:15 (1962), 262.
[48] Langway, *The History of Early Polar Ice Cores*, 6. The International Geophysical Year (IGY) was an international research project taking place in 1957-1958. See chapter 3.3 for additional reading.
[49] Richard B. Alley, *The Two-Mile Time Machine: Ice Cores, Abrupt Climate Change, and Our Future* (Princeton, N.J., 2000), 31.

solid rather than soft, vertical rather than horizontal. Between the 21 years of the first artificial snowflake and the first major ice core sample in Greenland, the field of glaciology expanded its spatiotemporal imagination and introduced new practices, material and visual technologies, and spaces of scientific inquiry. In this chapter my aim is to trace this movement within the field of glaciology and the emergence of a new timescale on which the field could operate. If Nakaya's early career consisted of receiving letters from high up in the sky, the letters of his last professional years came from a very different place: from the depths of the Greenland ice sheet, from the snow that had fallen thousands of years ago.

3.1 Early glacial drilling

Drilling into the ice had been a both scientific and everyday practice in the Arctic region long before the IGY and the emergence of systematic ice core research. Ice drilling had already been a crucial part of accessing fishing waters for indigenous communities hundreds of years before the drilling became part of a scientific enterprise. However, the emergence of scientists who were interested of the interior content of ice sheets and glaciers can be traced to the middle of the 19th century, when Louis Agassiz brought mechanical drills with him in order to examine the interior of the Unteraargletcher glacier in the Swiss alps. The task quickly turned out to be too much of a challenge for Agassiz' rudimentary drill and the project was abandoned after the second attempt to drill through the glacier.[50] The most notable thing about Agassiz' project is perhaps not the attempted drilling, but rather the interest in the glacier ice itself. As a part of the emerging theory of the existence of ice ages numerous scientists began collecting glacier data in order to understand the glaciers' relationship to the general climate of its surroundings. The glaciers were seen as historical, as changing – albeit slowly – over time. Their vast physical properties, slow movement, hazardous outer conditions and unknown interior content made the glaciers objects of scientific interest and inquiry in the 19th century.[51]

The scientific field of modern glaciology, which followed in the footsteps of Agassiz and Charpentier, was a discipline particularly concerned with measuring change over

[50] Pavel G. Talalay, *Mechanical Ice Drilling Technology*, (Singapore, 2016), 8.
[51] Sverker Sörlin, "Can Glaciers Speak?: The Political Aesthetics of Vo/ice", s. 13. For a more general presentation on the evolvement of ice age theory: Tore Frängsmyr, *Upptäckten av istiden: studier i den moderna geologins framväxt = The discovery of the ice age*, (Stockholm, 1976).

time. Through the glaciers the past could be accessed and thus glaciology could become scientifically relevant for a variety of surrounding disciplines from history and archeology to geology. Early twentieth century glaciology was often incorporated into larger conceptual frameworks of heroic discovery and nationalist sentiments, in which the glaciologist's task was both to contribute to the production of scientific knowledge but also to narrate in a story about man's struggle against nature and a specific nation's superiority in relation to belligerent environments.[52] Scientific expeditions to the Arctic were, in the early twentieth century, discursively interwoven with specific notions of masculinity: the explorer was not only displaying appropriate forms of national identity and gentlemanly behavior, but his scientific validity, the trustworthiness of his investigations, were dependent on his social ability to perform this scientific persona.[53]

However, during the interwar period a new, modern form of glaciologist identity started to emerge. Stockholm based glaciologist and Chair of the Department of Geography at Stockholms Högskola, Hans Ahlmann, can be seen as an early example of this change within the field of glaciology. Arguing from a distinctly modernist perspective, Ahlmann viewed glaciology as a scientific endeavor that was not primarily an activity of writing national histories. Instead he stressed the importance stringent methodologies and scientific collaboration across national borders.[54] His expeditions to Greenland and Spitsbergen in the 1930's consisted of long sessions of data collection, hoping to provide a way to track post-glacial climatic changes in the Arctic. The data collection was not a part of building a narrative of national history, but rather a way to map the way climate could differ from year to year.[55]

Ahlmann's establishment of systematic glacier measurements and study of the annual accumulation of snow in order to track climatic changes marked a new interest in the temporality of the polar environment. At the same time as Ahlmann was conducting his expeditions at Spitsbergen, the German glaciologist Ernst Sorge, who was part of the Wegener expedition to Greenland's Eismitte 1930-1931, revisited the mission that Agassiz had abandoned almost a century ago: looking into the interior of a glacier. Using shovels

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[52] Andrew Baldwin, Laura Cameron and Audrey Kobashi, "Where Is the Great White North? Spatializing History, Historicizing Whiteness" in Andrew Baldwin, Laura Cameron and Audrey Kobashi (ed.) *Rethinking the Great White North. Race, Nature and the Historical Geographies of Whiteness in Canada* (Vancouver, BC, 2011). See Lisa Bloom, *Gender on Ice: American Ideologies of Polar Expeditions* (Minneapolis, 1993) for a more general expose of the role of scientific masculinity and nationalism in the early polar expeditions.
[53] Bruce Hevley, "The Heroic Science of Glacier Motion", 67.
[54] Sverker Sörlin, "The Anxieties of a Science Diplomat: Field Co-production of Climate Knowledge and the Rise and Fall of Hans Ahlmann's 'Polar Warming'", 240.
[55] Sörlin, "The Anxieties of a Science Diplomat", 241.

rather than drills, Sorge and his team built a 15-meter-deep pit in the snow, through which they were able to quantitatively study the near-surface snow strata[56]. Despite his position, being lowered into the snow, he was still part of a traditional horizontal outlook on the glacial landscape, immersed by the great white around him. Much like his glaciological predecessors, he perceived the ice sheet as a vast body of snow and ice on the surface of which the glaciologist could conduct his surveys and expeditions.[57] Sorge had – symbolically and literally – merely scratched the surface of the ice sheet's vertical properties. In order for the ice core to emerge, and the deep interiors of the ice sheet to be made visible, an entirely different research program was necessary.

3.2 The emergence of the ice core

After Sorge's first attempts of uncovering the stratigraphy of the Greenlandic layers of snow, it was not until after the Second World War that the ice sheet again would receive scientific attention. However, in order for inquiry into past climates to be a worthwhile scientific activity a broader reconceptualization of climate itself was necessary. During the late 19th and early 20th century, climate was considered to be a primarily spatial rather than temporal concept: other than on a geological time scale, climate was perceived as constant, varying only because of its geographical conditions. Matthias Heymann calls this perception of climate, in which climate is understood as geographically dependent and constant over vast periods of time, "classical climatology" and contrasts it against the "dynamic climatology" that emerged during the first decades of the 20th century.[58] This conceptual shift is visible in the definition of climate made by the International Meteorological Organization – that later went on to become the World Meteorological Organization – that recognized climate as "the average state of the atmosphere above specific locations within a specific period of time". The IMO argued that 30 years was a reasonable length of a "specific period of time". Climate, with this definition, was now also a temporal concept, altered not only by its geographical location but by its own periodicity.[59] This temporality of climate, measuring climatic shifts in decades, fitted well with the first attempts at tracing past climate through the stratigraphy of the ice sheets. However, as ice core science grew increasingly advanced as a part of Cold War

[56] Chester C. Langway Jr, *The History of Early Polar Ice Cores*, 11.
[57] Hevley, "The Heroic Science of Glacier Motion", 71.
[58] Mathias Heymann,"The Evolution of Climate Ideas and Knowledge", *Wiley Interdisciplinary Reviews: Climate Change 1* (2010), 581-597.
[59] Heymann, 591.

efforts to inhabit the Arctic, the temporalities of the ice core enabled new climatic patterns, speaking to longer, more dramatic shifts in the global environment.

During the Second World War expeditions to the Arctic were put on hold. When the war was over and scientists started to return to the cryosphere, they did so in new ways. The previously envisioned heroic discoverer had disappeared in favor of a modern style of scientific exploration, consisting of new technology, large research teams and international collaboration.[60] Ahlmann could perhaps be seen as a predecessor to this development that started to take place in the last years of the 1940's. In contrast to Sorge and his initial and rudimental attempts to investigate the interior of the ice sheet, the expeditions of the early Cold War had significantly more advanced equipment and increased resources. A French expedition led by Paul-Emile Victor drilled two holes on the ice sheet, reaching 150 meters and 126 in depth respectively, in the early 1950's and marked the beginning of a new form of glaciological research. It was, however, the United States that came to lead the earliest development of ice core research. The Swiss glaciologist Henri Bader was instrumental to the development and establishment of ice core research within the framework of SIPRE, of which he was the chief scientist, and the US military's presence in Greenland.[61] Using the manpower he could access from the US Army he was able to, in 1953, excavate a 53 meter deep pit in the Greenland snow in order to pursue the studies of annual layers of snow that Sorge had started in the interwar period. Even though Bader framed his endeavors in Greenland as a natural continuation of the work made by Sorge, his practices, resources and institutional support were hardly even resembling the digging Sorge had conducted two decades earlier. It was also under Bader's lead that SIPRE got the funding to pursue more elaborate attempts to not only dig deeper into the snow, but to recover ice cores from the ice sheet in order to access data about past climatic conditions. A similar endeavor was conducted simultaneously by the Norwegian-British-Swedish Antarctic Expedition (NBSAE) 1949-1952. Despite the exhaustive efforts and the relatively intricate infrastructure of the projects, the results in terms of high quality ice cores were disappointing. The ice cores were both in poor physical

[60] However, the new ideals for polar scientists did not necessarily implicate a stricter demarcation between science and politics in comparison to the heroic discoverers of the early 20th century. Rather, science became an instrument in a new geopolitical order, defined by superpower competition and the control of previously uninhabitable places. See: Peter Roberts, *The European Antarctic: Science and Strategy in Scandinavia and the British Empire* (New York, 2011), 141-142. Furthermore, despite the increasing irrelevance of the heroic polar discoverer, rather than disappearing, the masculinities of polar research took on new forms that were aligned with the scientific ethos of the Cold War. See Mark Carey, M. Jackson, Alessandro Antonello and Jaclyn Rushing, "Glaciers, Gender, and Science: A Feminist Glaciology Framework for Global Environmental Research" *Progress in Human Geography,* 40:6 (2016), 782.

[61] Martin-Nielsen, "The Deepest Most Rewarding Hole Ever Drilled", 59.

condition and plagued with substantial gaps, which inhibited the possibility for stratigraphic analysis.[62]

3.3 The International Geophysical Year 1957-1958

It was during the International Geophysical Year of 1957-1958 that ice core science took the next significant leap forward. The IGY was as much a global coordination of research strategies – involving over 60,000 scientists from over 60 countries it has been described as a "scientific Olympics" – as well as an attempt to create a forum for global cooperation during a moment of increased geopolitical tension.[63] Henri Bader lobbied intensely to convince the National Science Foundation of the United States to fund a major ice core research program, despite the previously disappointing results, and asserted that ice cores would not only grant access to past climate conditions, but also improve the US status in the international polar science community.[64] In a presentation held before the US National Committee for the IGY in June 1957, Bader connected ice cores to contemporary issues within a wide range of scientific disciplines, from geophysics to space exploration. Furthermore, Bader drew lines between geopolitical problems and the benefits of examining the snow strata in Greenland and Antarctica:

> The Greenland and Antarctic snow layers are a treasure trove for the scientist. The tritium content of the snow can, for instance, be determined and used to estimate its age, but only for snow which fell prior to 1954. […] analysis for other radioactive contaminations in precisely dated snow layers from Greenland and Antarctica will yield most valuable data on general atmospheric circulation since the first bombs were exploded in 1945. Scientists who have been monitoring radioactive fall-out would now like to go back several years to measure some things they missed at the beginning. The snows of Greenland and Antarctica permit them to do so.[65]

Bader presented a wide temporal framework in which the ice core could do its work: it was possible to utilize for geopolitical issues – such as mapping nuclear fallout – as well as, Bader noted towards the end of his presentation, reveal climatic conditions as far back as hopefully

[62] Langway, *The History of Early Polar Ice Cores*, 8.
[63] Matthew Brzezinski, *Red Moon Rising: Sputnik and the Rivalries That Ignited the Space Age* (London, 2007). Christy Collis and Klaus Dodds , "Assault on the unknown: the historical and political geographies of the International Geophysical Year", *Journal of Historical Geography*, vol. 34, (2008) 555-567.
[64] Martin-Nielsen, "The Deepest Most Rewarding Hole Ever Drilled", 60.
[65] Henri Bader, "US Polar Snow and Ice Studies in the International Geophysical Year", presented at a special meeting of the US National Committee for the IGY, June 27, 1957, 3.

"some 2000 years".[66] After Bader's successful campaign for additional funding during the IGY, the US, in cooperation with multiple other nations, conducted new and more fruitful attempts of ice core drilling on the Greenland ice sheet. The cores extracted from the drillings affiliated with the IGY were both more successful in terms of quality ice cores as well as in a more elaborate research infrastructure, involving a heated laboratory facility – "Jamestown" – that allowed the scientists to work without being exposed to the harsh weather conditions of their surroundings. [67] In 1957, a continuous ice core, reaching over 300 meters in length, was recovered from SIPRE's field station in central Greenland and parts of it were sent to SIPRE's headquarters in Wilmette, Illinois, for additional analysis. A preliminary report by Chester C. Langway, JR. – one of the scientists present in Greenland – published in *Journal of Glaciology* 1958 declared that ice cores for the first time had been made available as research objects. Using a new drilling technology, that utilized cold compressed air in order to separate the cores from its surroundings, previous issues with severely damaged ice cores were able to be avoided.[68]

Along with similar drilling projects taking place in Antarctica during the IGY, ice core research appeared as a promising new scientific project. The climates of the past had turned out not only to be accessible, but also possible to materialize in mobile objects that could be brought back for further examination.[69] Ice cores, as mobile scientific objects, could adhere to a postwar scientific ethos that emphasized international cooperation, large research projects and the constant presence of risks posed by the Cold War terror balance. The limited physical properties of ice cores made them possible to transport across long distances. For example, the 1957 ice core from Greenland was partly brought back to SIPRE's headquarters in Illinois for further analysis. The scientific study of cryospheric spaces was therefore no longer limited to field studies – even though that was and remains central to the way glaciology is conducted – but could also take place in a laboratory, far away from the hazardous conditions of the polar regions that had been crucial in shaping the glaciological subjects of the early 20th century.[70] The vertical spatiality of the ice cores were intertwined with their mobility: because of their material properties, being small cut-outs of an immense glacier, they could be compartmentalized and enrolled into a network of scientific actors and

[66] Bader, 4.
[67] Langway, *The History of Early Polar Ice Cores*, 12.
[68] Chester C. Langway, JR. "A 400 Meter Deep Ice Core in Greenland: A Preliminary Report", *Journal of Glaciology*, vol. 3 (1958), 217-218.
[69] For a more general expose on the origins of cold war science: Jon Agar, *Science in the Twentieth Century and Beyond* (Cambridge, 2012), 330-354.
[70] Jessica O'Reilly, "Sensing the Ice: Field Science, Models, and Expert Intimacy with Knowledge", 30-31.

institutions. In comparison to the horizontal spatiality of earlier polar science, in which the entirety of the glacier was the scientific object, ice cores, through their materiality, enabled new sites of knowledge production in and about the cryosphere.

Ice core science became, with the appearance of a solid ice core that could be transported, a mobile as well as a situated scientific practice. This hybridity, in which the ice core is a product of situated material practices in the Arctic as well as a vast infrastructural system involving numerous states, research teams and field stations, can be understood as a part of a broader negotiation between the local and the international in Arctic science after World War II.[71] The mobility of the ice cores was used as an argument for additional funding by Henri Bader in his presentation for the NSF in 1957. The frozen state of the ice cores made them extraordinarily well suited to be transported back to the US, since they could be kept frozen in the same condition for long periods, enabling continuous research over time of the same scientific object. However, Bader noted, this endeavor required not only the appropriate scientific competence but also a functioning logistic system of a scale and technological advancement that it could only be provided by from one particular actor: The U.S. Naval Forces.[72]

In order for the ice core to emerge, both as a technoscientific object and as a temporalizing entity in the Arctic, the military and scientific infrastructure of the Cold War were instrumental. Rather than being a natural development of the initial studies conducted by Sorge in the 1930's, the ice core, as it emerged, developed and mobilized institutions, was the product of a specific political geography during the Cold War. The interior of the Arctic ice sheet, its vertical properties, gained military strategic interest as it offered the possibility to facilitate ballistic missiles and military personnel in geographically strategic places in relation to the Cold War terror balance. The geopolitical relevance was utilized by Bader in his pitch to the NSF as he connected the practices of ice core drilling to other contemporary pressing issues, such as the space race and the tracking of nuclear fallout. Where the Arctic as a horizontal space had encouraged heroic conquests and mobility over vast distances, the vertical Arctic space could play into narratives of scientific conquests of inaccessible places and technology's mastering over nature.[73] Early ice core drilling was in this context both a

[71] Steven Bocking, "Situated Yet Mobile: Examining the Environmental History of Arctic Ecological Science", in Dolly Jørgensen, Finn Arne Jørgensen and Sara B. Pritchard, *New Natures: Joining Environmental History and Science and Science and Technology Studies* (Pittsburgh, PA, 2013) 177-178.
[72] Bader, 5.
[73] Kristian H. Nielsen, Henry Nielsen and Janet Martin-Nielsen, "City Under the Ice: the Closed World of Camp Century in Cold War Science", 455.

place-making practice in turning the previously unreachable interiority of the ice sheet into a measurable and, eventually, livable space and a product of Cold War science's infrastructural and geographical conditions.[74] In contrast to how the historiography of the ice core is often portrayed, its materialization in the late 1950's was not solely the outcome of the interior development within glaciology, but of a broader reconceptualization of the Arctic space and geopolitical tensions that had risen after the end of the Second World War.[75]

3.4 Measuring snow, visualizing temporality

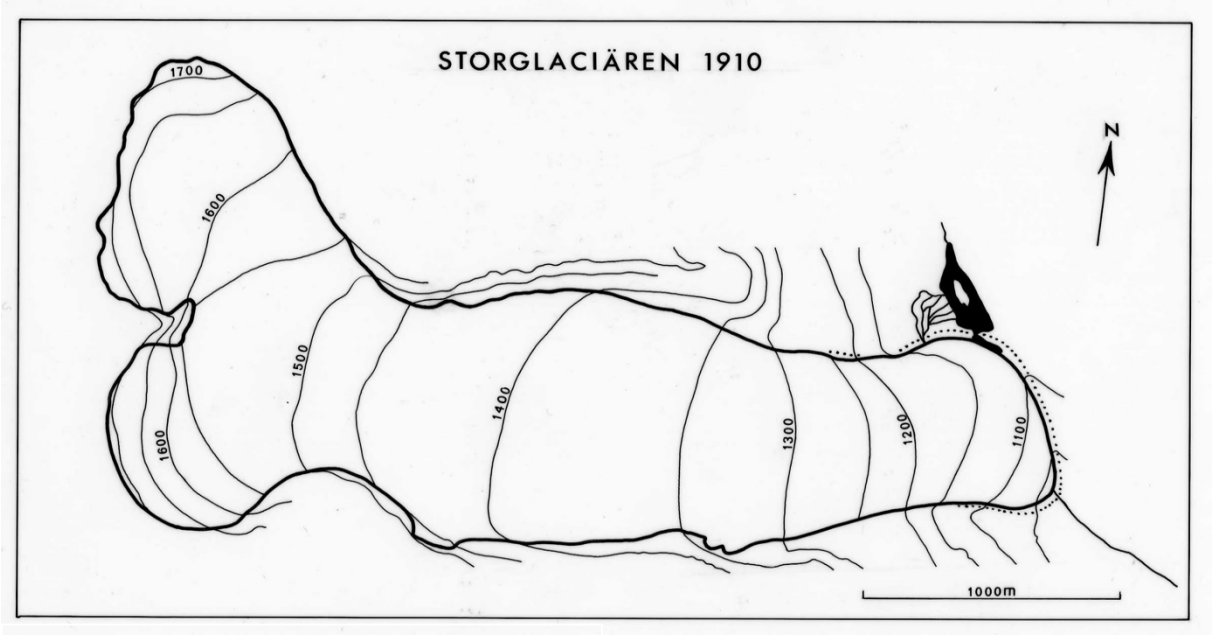
Through the ice core, from the early attempts in the 1950's to the Camp Century ice core in 1966, the glaciologists involved experienced a continuous temporal expansion of their work. As the cryosphere was increasingly perceived as in possession of a vertical spatial element, and thereby a historical quality ordered in a stratigraphic manner, the visual representations of the Arctic in particular and glacial environments in general changed too. The visual scientific output of early 20th century polar science was dependent on the ability of the glaciologist to overview a large horizontal space in order to depict it. With the introduction of large scale scientific projects in the Arctic during the years around the IGY, and the subsequent interest in drilling through the ice sheet, new ways of visually depicting the landscape was made possible. In the visual material that emerged with the first attempts at recovering ice cores, the temporality of the Arctic was pictured in novel ways in comparison to previous glaciological research. Even though glaciology had since its earliest years in the 19th century been preoccupied with determining climatic changes over time, the temporalities that could be produced and visualized through ice core science had some different qualities and highlights the shift in scientific practice between before and after the Second World War.

During the age of early polar expeditions and tales of heroic conquests in the early 20th century, one important aspect of the spatial imagination of the ice sheet was its stability. The temporal stability of the landscape became a crucial part in the narratives of the ice sheet as a challenging space of action, as a place where brave explorers could show their ability in the harsh surroundings of the sublime polar landscape.[76] However, with the emergence of modern

[74] Lisa Messeri, *Placing Outer Space. An Earthly Ethnography of Other Worlds,*11-12 for a description of science as a practice of place-making.
[75] For an example of the way this part of the history is often described: Langway, *The History of Early Polar Ice Cores*, 10.
[76] Kathryn Yusoff, "Visualizing Antarctica as a Place in Time: From Geological Sublime to 'Real Time'", *Space and Culture,* 8:4 (2005), 382.

glaciology and the systematic mapping of the movements of glacial bodies, the temporality of glaciers became subject to visual representation. In the case of the research station in Tarfala, in Northern Sweden, that were to become the main site of Hans Ahlmann's scientific practice after World War II, the glacial movements of Storglaciären were tracked by annual photographs as well as, in 1910, through using a photogrammetric theodolite. The images could be used for comparisons over time, turning the glacier into a "landscape of recorded change".[77] In the visualization of Storglaciären from 1910, the glacier is seen from above and the properties of its surface and altitude are written on the illustration. It is an image of a horizontal body, showing only the properties of the surface rather than the interior. Insofar the image shows a glacier in movement, it does so by crystallizing its properties at a certain moment in time, making it possible to compare with similar surveys conducted at different times. Through visualizations like the one of Storglaciären, the temporal performativity of the glacier became entangled with a scientific practice of annually sampling the properties of the glacial body in order to create an historical record.

[78]



Surface extension of Storglaciären, 1910.

For a glaciologist such as Hans Ahlmann, the *modus vivendi* of his scientific practice was one of waiting: at his Tarfala research station, Ahlmann and his team measured the properties of

[77] Sverker Sörlin, "A Microgeography of Authority: Glaciology and Climate Change at the Tarfala Station 1945-1980", in Helena Ekerholm, Karl Grandin, Christer Nordlund and Patience Schell (ed.), *Understanding Field Science* (2018), 257-258.
[78] Sörlin,"A Microgeography of Authority", 260.

the glacial environment surrounding the station. They measured seasonal and annual changes of the properties of the glacier for decades, making it a measurement of climatic and environmental changes taking place in real time.[79] With the ice core, things were not quite the same. Instead of having to wait for the snow to fall, for the glacier to move, the ice core researchers were able to access tens of thousands of years of climatic data in an

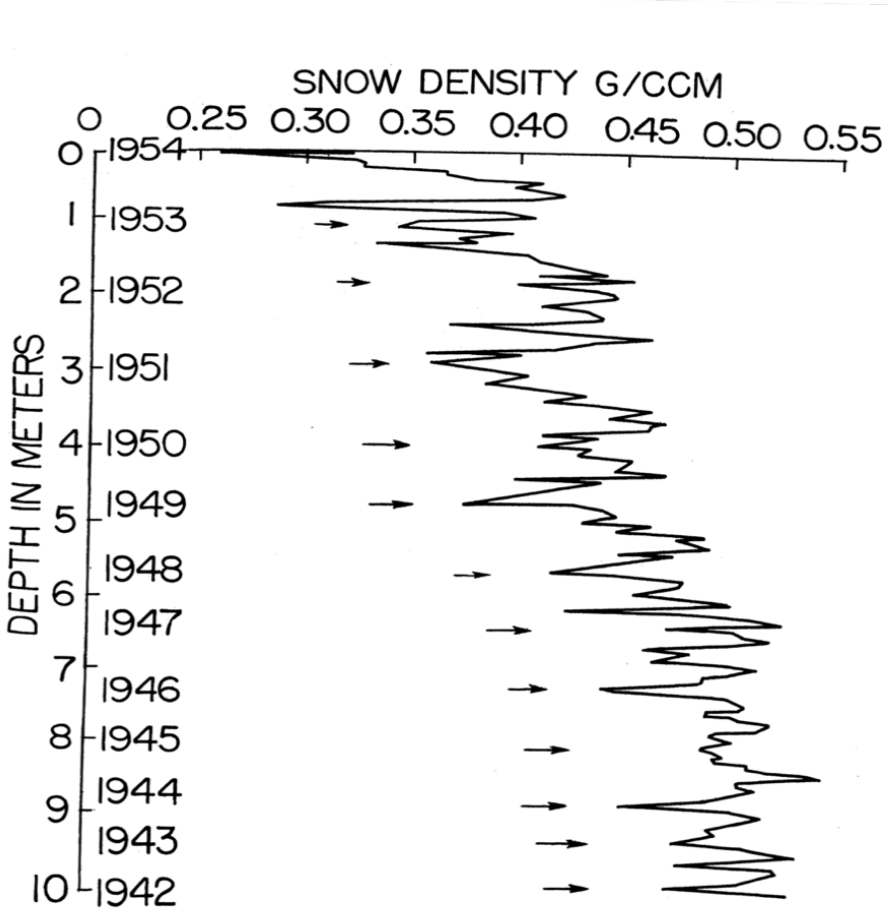


Fig. 6 Change of density with depth as in Fig.5. Detail of upper 10 meters. Arrows indicate position of estimated midsummer layers of each year. Summer layers are generally less dense than winter layers.

Henri Bader's image of the upper layers of the Greenland ice sheet, presented for the NSF committee for the IGY in 1957. [80]

[79] Sörlin,"A Microgeography of Authority", 260.

[80] Henri Bader, "US Polar Snow and Ice Studies in the International Geophysical Year", presented at a special meeting of the US National Committee for the IGY, June 27, 1957, appendix.

almost instant manner. The climatic changes that slowly manifested themselves at Tarfala, seemed, through the vast time scaled that the ice core materialized, abrupt as well as repeatedly reoccurring throughout the history of the planet.[81] Operating within an entirely different temporal regime, one that lied closer to the geological timeframe than the meteorological one, glaciology's previous temporal demarcations were increasingly in flux.

A few decades later, with the emergence of early attempts of recovering ice cores from the interior of glaciers, the visual representations of glacial temporality had changed. When Henri Bader presented for the NSF committee in order to attain funds for ice core research during the IGY 1957, he brought with him some visual material to show the committee. In one diagram, which functions both as a stylized representation of an ice core and a time scale for the upper 10 meters of the Greenland ice sheet, the altered temporality of glaciological practice is made visible. The diagram is fairly rudimentary compared to later renditions, with the x-axis showing snow density and the y-axis the annual snow accumulation, but it also conveys a new way of visually representing a glacial body. Rather than the horizontal perspective seen in the image of Storglaciären, this depiction open up the vertical as a spatial category through which the ice sheet can be understood. The temporal performativity of the horizontal image – enabling annual comparisons of the size of the ice sheet – is here transformed into an immediate access of the past 12 years of snowfall.
In Bader's the diagram, the ice sheet speaks with a new voice. It is not a vast horizontal space, but a compartmentalized and vertical piece of the glacial area. Bader does not have to wait until next year to track changes in snow accumulation since he already got access to several years' worth of snowfall. In a political sense, the diagram does additional work in enrolling the ice core in a military context, as the timeframe corresponds with Bader's argument that ice cores can track fallout from atomic bombs.

Additionally, the diagram open up the possibility to detach surveys of glacier ice from the actual experience of being there. In depicting not a full glacier, but a cut-out from a larger glacial body, Bader's diagram reinforces his argument that glaciers don't have to be exclusively studied in the field, but that ice core samples can be brought back to storages and laboratories. Enabled by an advanced military infrastructure provided by the US Naval Forces, the Greenland ice sheet could be enrolled into the global network of Cold War science. Nine years after Bader's presentation, the timescale would have expanded from 12 years to 100 000 years as the first successful drilling to bedrock took place at the US military

[81] Willi Dansgaard, Chester C. Langway, JR and J. Møller et. al, "One Thousand Centuries of Climatic Record from Camp Century on the Greeland Ice Sheet", *Science,* 166:3903 (1969), 377.

base Camp Century in Greenland. In the next chapter, I will track the temporal, epistemological and geopolitical changes in ice core science that preceded the Camp Century ice core and the discussions that followed in its tracks.

4. The expansion of a scientific object: Camp Century and the new roles of ice core science

It was under triumphant forms the Camp Century ice core drill reached all the way through the Greenland ice sheet to the solid ground underneath in 1966. Led by the American glaciologist Lyle Hansen and the head of the CRREL's Snow and Ice Research Branch Chester C. Langway, JR. the first surface-to-bedrock drilling marked a validation for the prospects of ice core science and the hopefulness expressed by scientists such as Henri Bader a decade earlier. The object that emerged from the ice sheet was just a few decimeters in breadth, but with its 1387-meter length, it was by far the largest and, because of its relatively good condition, for science most useful ice core to date. The entire drilling process had taken place not on the surface of the ice sheet, but in the army base Camp Century, built within the Greenland ice sheet. As piece after piece of the ice core reached the scientists and military personnel in the camp, they were cut into small cylinders – the samples reached up to five meters in length – and placed in storage inside the facility.[82]

The ice core samples were, after their initial appearance on the surface, distributed and circulated across the scientific community. Willi Dansgaard notes in his autobiographical account of the events that the hunt for Camp Century ice core samples had the resemblance of a gold rush.[83] Particularly, the sites of the ice core became the CRREL laboratory in Buffalo, NY and Dansgaard's laboratory at the University of Copenhagen. The vast size of the ice core made it possible to split up and share over multiple laboratories and the depth it had reached made it particularly well suited for the study of climatic changes over time. The Camp Century ice core came to embody many of the things that allowed ice core science to become a part of climate change discourse: its expanded temporal and material properties giving texture to 100 000 years of climate history, its situatedness in distant and secretive spaces while, simultaneously, being mobile and possible to put into circulation in a network of laboratories and institutions. Following Paul Edwards definition of global environmental science as a sociotechnical system, the ice cores, after Camp Century and the temporalities it enabled, were increasingly drawn into a larger scientific movement of tracking global climatic patterns and a growing political awareness of the impact of humanity

[82] Lyle Hansen, and Chester C. Langway, JR., "Deep Core Drilling in Ice and Core Analysis at Camp Century Greenland, 1961-1966", *Antarctic Journal of the US* (1966), 207.
[83] Dansgaard, *Frozen Annals*, 57.

on the planet's functions.[84] The production and enrollment of ice core temporalities enabled glaciologists to speak with authority on topics that had previously been outside their scope and by writing the narratives extracted from the ice cores into human history, ice core science increasingly became entangled with the growing debate on global environmental issues. As a part of this entanglement, the ice cores themselves were not the only thing travelling from the seclusion in the Arctic to international scientific institutions. The discourse on climate changes in deep time, on ice as a marker of time, could, through the emergence of ice core temporalities, venture into new epistemic communities. With the enrollment of ice cores into the growing field of climate science in the late 1960's and early 1970's, the temporal work of the ice core was increasingly appropriated by other scientific fields.[85]

4.1 Preceding Camp Century: temporal expansions and international collaboration

Before the Camp Century ice core had materialized, the temporal framework of ice core science was still defined by uncertainty. In his 1957 presentation, Bader used the modest term "pre-industrial" as a marker of the proposed study's temporal boundaries.[86] Nine years later, the research team at Camp Century claimed to track climatic events dating 100 000 years back in time. This rapid temporal expansion needed both US army infrastructure and new technology to emerge, but also a conceptual shift in the way temporality in the cryosphere was understood.

Danish paleoclimatologist Willi Dansgaard's "Radio-Carbon Age and Oxygen-18 Contents of Greenland Icebergs", released in 1962, is an example of early discussions within the glaciological community regarding the prospects of expanding the temporal boundaries of the field. In it, Dansgaard summarized the results of a scientific expedition to icebergs around the Greenlandic coast and the expedition's attempts to uncover the content of the interior of the icebergs. The main objective of the Arctic Institute Greenland Expedition (AIGE) 1958, which was its full name, was to "determine the composition and age of ancient

[84] Edwards, *A Vast Machine*, 5.
[85] Wallace S. Broecker, "Climatic Change: Are We on the Brink of a Pronounced Global Warming?", *Science,* 189:4201 (1975), 460-463, can serve as an example of this. Broeckner, who is a oceanographer and climate scientist, referred to the Camp Century ice core in the article about the stability of the global climate.
[86] Bader, 4.

atmosphere trapped in glacier ice".[87] Even though the expedition in some aspects was a failure – instead of using ice core samples, Dansgaard and his team tried to melt the ice under vacuum and access samples of CO2 in the condensation, and the method was never sufficient in providing exact dating of the CO2 – it was part of a larger discussion regarding the possibility access "ancient atmosphere" through the glacial environments. In accordance with Bader's predictions, this expedition was also prone to larger uncertainties in their attempts of dating the interior contents of the Greenland icebergs. Dansgaard summarized: "The carbon dating indicated that the age of the various samples ranged from very young to some 3000 years. There was a prevalence of relatively young ice in our samples. Thus 9 out of 11 samples were less than 1000 years old."[88] The fluidity of the ice, in the ice sheet as well as in icebergs, was a reoccurring problem in the pre-Camp Century attempts to create a satisfying timescale of the glacial interiors. In an article in *Journal of Glaciology* from 1961, Robert Haefeli discussed the relationship between the age of the Antarctic and Arctic ice sheets and the inner movement within the glaciers. Because of the ice's animate qualities, it's inner stratigraphy is in constant flux, creating a great deal of uncertainty for those who try to extract samples from a variety of places on the ice sheets in order to create a working time scale. The vast glaciers are suddenly, when the time scale is expanded from decades to centuries, moving too fast, their inner dynamics slipping away from the scientist's attempts to nail them down. Haefeli estimated that the oldest ice, hidden close to the bedrock, could be substantially older than the other layers of the ice sheet, since it has been trapped in an ablation zone between the moving ice above and the rock underneath. Previous attempts of sampling from icebergs and various places on the ice sheets, he suggested, had not been successful in terms of understanding the age of the ice, because of this dynamic.[89]

During the years before the Camp Century core, the first surface-to-bedrock ice core, the interior of the ice sheet was still not fully accounted for, its physical properties and movements still partly shrouded in mystery. However, with the possibility to utilize the American military base Camp Century marked a distinct shift in the temporal and material possibilities of ice core drilling.

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[87] Willi Dansgaard,"Radio-Carbon Age and Oxygen-18 Contents of Greenland Icebergs", *Meddelelser om Grønland* (Copenhagen, 1962), preface.
[88] Dansgaard, "Radio-Carbon Age and Oxygen-18 Contents of Greenland Icebergs", 22.
[89] Robert Haefeli, "Contribution to the Movement and the Form of Ice Sheets in the Arctic and Antarctic", *Journal of Glaciology,* 3:30 (1961), 1146. A similar discussion can be found in R.J. Nye, "The Motion of Ice Sheets and Glaciers", *Journal of Glaciology*, 3:26 (1959), 493-506.

Greenland's location between the two nuclear superpowers made it, during the early stages of the Cold War, a place of indispensable strategic importance for the United States. Camp Century, a nuclear powered army base that could host 225 people in a vast facility built inside the Greenland ice sheet, became known as "The City under the Ice". Following its establishment in 1959, the camp was primarily intended as a precursor for larger installations of intercontinental ballistic missiles. The ballistic missiles never materialized, but Camp Century came to importance in other contexts as well: partly as a popular image of American technoscientific excellence and control of distant places as well as, during its last active years in the mid 1960's, a site for technologically advanced ice core drilling.[90] As glaciological research became a part of the daily operation at Camp Century – following the model of collaboration and division of labor proposed in Henri Bader's 1957 presentation – the possibilities to conduct large scale ice core drillings increased. In addition to the team from SIPRE, a group of Danish researchers led by geophysicist Willi Dansgaard, whose novel oxygen isotope analysis technique provided new prospects for more accurate dating of past climatic regimes, became part of a joint effort to recover the largest ice core to date.

After the Camp Century ice core was recovered, the tone as well as the epistemological certainty had undergone a few notable transitions. Rhetorically, the triumph of hitting bedrock echoed the previous language of the heroic explorers that singlehandedly had crossed the Arctic and Antarctica. Only this time, the space that humanity had conquered was vertical rather than horizontal.[91] The narrative of conquest is visible also in the medial and popular perception of early ice core research. In an article in *New York Times*, published September 22 1966, titled "Army Serves Drink Cooled With Ice 2,000 Years Old", a proud Lyle Hansen discloses that the scientists have used a small part of their ice core samples to cool Coca-Cola. Despite the age of the ice – "from about the time when Christ was born" – the Coca-Cola tasted just as it usually does.[92]

In the subsequent reports from Camp Century, the temporality of glaciology evolved simultaneously with its epistemological certainty and scope of scientific inquiry. When the results from the work done at Camp Century started to emerge in scientific publications as well as in popular media in the last years of the 1960's, the ice sheet's interior

[90] Kristian H. Nielsen, Henry Nielsen and Janet Martin-Nielsen, "City Under the Ice: the Closed World of Camp Century in Cold War Science", *Science as Culture*, 23:4 (2014), 445. Ronald E. Doel, Kristine C. Harper and Matthias Heymann (ed.), *Exploring Greenland Cold War Science and Technology on Ice* (New York, 2016), 90-115.
[91] Martin-Nielen, "The Deepest Most Rewarding Hole Ever Drilled", 69.
[92] "Army Serves Drink Cooled With Ice 2,000 Years Old", *New York Times*, September 22, 1966, 41.

was no longer treated as a great unknown, but as an archive in which the atmosphere's of the past was ordered and possible to access through modern technoscientific practices.

Dansgaard's sampling of icebergs in 1958 and Haefeli's discussion about dating methods in 1961 conveys a dissonance between the expansion of temporal framework in the cryosphere and the utility of the available scientific and material practices used to produce knowledge about these expanded time scales. The increase in time scale led to an increased plasticity of the glaciers: for example, the annual movement of the Tarfala glacier tracked by Ahlmann rendered a performativity of the ice that made it actively engaged with its surroundings, responding in real time to the conditions around it.[93] With a vastly longer time scale, the plastic qualities of the ice sheet became more prominent. Over the course of thousands of years, the vast body of ice had moved, slid and calved icebergs, it had responded to a varied array of climatic conditions and geologic phenomena. With the notion of the ice sheet as a vertical as well as a horizontal space, as a place that had undergone changes over long periods of time, the ice sheet in its entirety became too big and too plastic to study as one scientific object.

With the emergence of the ice core, and particularly the ice core that reached all the way down to bedrock, the technoscientific practice of glaciological research could answer to the new spatiotemporal imaginaries of the cryosphere. The limited spatial dimensions of the ice core – most often it was just around a decimeter in breadth – made it able to freeze time in both a literal and metaphoric sense. The animate glacial bodies that previously had been difficult to track over long periods of time, because of their immense properties and plasticity, could now be accessed in a limited and static form through the ice core. In a 1969 article in *Science*, the emergence of the new epistemological outlook following in the tracks of the Camp Century ice core's materialization three years earlier, is visible. Not only because of the previously mentioned expanded temporal dimension in regards to past time, but also, because of a, albeit cautious, prediction of the future of the earth's climate.[94] Because of the climatic patterns that can be seen through the ice core, Dansgaard et. al asserted that they were also granted a glance into the future and they related their estimations to the consequences of these climatic shifts for humankind.[95] Janet Martin-Nielsen notes that this change in scope, including both the deep past and the near future, did not gain immediate

[93] Sörlin, "A Microgeography of Authority", 201.
[94] Willi Dansgaard, Chester C. Langway, JR and J. Møller et. al, "One Thousand Centuries of Climatic Record from Camp Century on the Greenland Ice Sheet", 376.
[95] Ibid. 377.

validation among other glaciologists until the second half of the 1970's.[96] Another feature of the articles that emerged post-Camp Century is the first tendency to incorporate human history in to the story that the scientists could extract from the ice core. In the article in *Science,* references are made to the Lascaux cave paintings, Viking settlements on Greenland in the 11th century and to the Little Ice Age of the 17th century.[97]

Thus, the growth of the ice cores after drilling to bedrock in 1966 was not only physical: the ice core also grew in terms of what it was saying. It could provide a temporal texture to the deep past, predict future climates and even become connected to events in human history. In my next chapter, I will follow this material and epistemological growth of the ice cores and their enrollment into an emerging discourse on anthropogenic impact on the planet's climatic systems.

4.2 Cold War science, ice core drilling and the making of the global environment

Even though the early ice core science had an interest in the climates of the past, it was not a scientific enterprise primarily concerned with the notion of an anthropogenic impact on the Earth's climatic systems. With its embeddedness in the U.S military presence on Greenland, and the heightened geopolitical tensions in the Artic region in the middle of the 1960's, the practices surrounding ice core drilling were inevitably imagined as a part of the quest for American military control of the Arctic, rather than primarily as a material and scientific practice that existed in order to make sense of the climatic conditions of the past and present. However, as a part of a larger restructuring of resources within the U.S military and altered geopolitical conditions, the Greenlandic mission came to change drastically in the years following the Camp Century ice core. The increasingly problematic situation in Vietnam made the Arctic less interesting for military strategic purposes and the military-sponsored glaciology saw its resources, both in terms of funding and manpower, decrease substantially between 1966 and 1973. Additionally, Camp Century, which was planned to be active for at least a decade after its founding in 1959, had to be abandoned in 1967 because of the movement of the glacial ice in which it was built.[98] When the last military personnel left the camp they took with them the nuclear reactor, but the remainder of the camp – including its

[96] Martin-Nielen, "The Deepest Most Rewarding Hole Ever Drilled", 63.
[97] Dansgaard, et. al "One Thousand Centuries of Climatic Record from Camp Century on the Greenland Ice Sheet", 377.
[98] Martin-Nielsen, "The Deepest Most Rewarding Hole Ever Drilled", 61.

biological, chemical and radioactive waste – was left inside the ice sheet, in order to be "preserved for eternity". With the present rapidly changing climate, parts of Camp Century reached the surface again already in 2016, once again situating the camp in the geopolitical limelight as the American debris emerged on Greenlandic soil.[99]

Another aspect of the reconceptualization of ice core research in particular and the Arctic landscape in general was the emergence of climate modelling and a broader awareness of global environmental issues in Western political discourse. These two phenomena – the Cold War military infrastructure and the growing awareness of the planet's finite resources and intrinsic fragility – were not distinctly separated from each other, rather they co-evolved as the production of knowledge regarding a global environment was intimately entangled with practices of the military-industrial complex.[100] As part of a widening of the U.S military's spatial imagination, which during the early stages of the Cold War saw itself covering "the entire globe […] from the depths of the ocean to the far reaches of interplanetary space", the production of global environmental knowledge became a strategic as well as a political asset.[101] Particularly, the interest in prediction, and in some military circles even control, of meteorological phenomena made the earth and geophysical sciences enjoy a Cold War renaissance and a surge in available resources and public interest.[102] In comparison to the last time the earth sciences expanded, in the last years of the nineteenth century, the global, rather than the regional or national, was the geopolitical space of interest. The emergence of computational technology was foundational for the field of applied geophysics, through which the global environment could emerge as a political and scientific object.[103] Through the infrastructures of the new scientific enterprise of knowledge production about the global environment – ice core sampling can be seen as one of many practices of this kind – novel conceptualizations such as the biosphere, plate tectonics and the climate system became means through which the dynamics of the planet could be understood.

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[99] Christopher Joyce, "Melting Ice in Greenland Could Expose Serious Pollutants from Buried Army Base", *National Public Radio,* 5/8, 2016 https://www.npr.org/sections/thetwo-way/2016/08/05/488872411/melting-ice-in-greenland-could-expose-serious-pollutants-from-buried-army-base (collected 15/4 2018).
[100] Ronald E. Doel, "Constituting the Postwar Earth Sciences: The Military's Influence on the Environmental Sciences in the USA after 1945", *Annals of the Association of American Geographers*, 91:2 (2003), 635-636.
[101] Doel, 657.
[102] Katerine C. Harper, "Research From the Boundary Layer: Civilian Leadership, Military Funding and the Development of Numerical Weather Prediction (1946-55)", *Social Studies of Science*, 33:5 (2003), 675.
[103] Silke Beck et.al., "The Making of Global Environmental Science and Politics" in Ulrike Felt, Rayvon Fouché, Clark A. Miller and Lauruel Smith-Doerr, *The Handbook of Science and Technology Studies – Fourth Edition* (Cambridge, MA, 2017), 1061. For a more specific outline of the relationship between global environmental science, political institutions and knowledge production regarding changes in climate over time, see Clark A. Miller, "Climate Science and the Making of a Global Political Order" in Sheila Jasanoff, (ed.), *States of Knowledge: the Co-production of Science and the Social Order* (London, 2004).

The entanglements between the Cold War and the emergence of global environmental knowledge was contributory for the popularization of the notion of a planetary disaster, of the possibility of an erasure of all life on earth. Joseph Masco argues that the conception of a planetary crisis was popularized in an American context through the immediate threat of nuclear annihilation. The urgency of the situation of nuclear military superpowers was instrumental to both the surge of resources to the earth sciences as well as to a popularizing of the concept of planetary fragility.[104] A prospective nuclear disaster and global ecological and climatological destruction were not separate entities, instead they emerged as intertwined, sharing key notions of human vulnerability and global spatial imagination. Even though the planetary threats were of two different kinds – the atomic bomb being a technology connected to the nation state and the environmental destruction emerging in the tracks of global industrial capitalism an international matter – they intersect in the way the global was politicized and fixed as an object of scientific inquiry in the Cold War era.[105]

There are of course additional factors that need to be taken into consideration in order to grasp the emergence of a global environmental consciousness and the political and scientific institutions that co-evolved with it. The political interest in climate control and modification is one aspect that during the early 1960's attained a surging political interest because of its potentially beneficial geopolitical strategic implications. Even though these ideas were abandoned a few years later, as a part of a broader change in the understanding of human impact on climate, the notion of climate control played part in laying the groundwork for a scientific infrastructure in climate mapping, modelling and data collecting practices.[106] Another aspect that is often brought up by historians of climatology and the environmental movement is the Space Race and the surfacing of photographs of the planet taken from space. The images of the earth as a small outpost of life in an endless, dark void reaffirmed contemporary movements towards ideas about an increasingly politically and culturally global world that at the same time was at great risk of environmental collapse.[107]

There is one additional factor that, in the context of ice core science, is of particular interest: a global sense of time. Even though the notion of a global temporal

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[104] Joseph Masco, "Bad Weather: On Planetary Crisis", *Social Studies of Science*, 40:1 (2010), 9.
[105] Masco, 18.
[106] Chunglin Kwa "The Rise and Fall of Weather Modification", in Clark A.Miller and Paul Edwards (ed.), *Changing the Atmosphere: Expert Knowledge and Environmental Governance* (Cambridge, MA, 2001) 200-201. As an example of the political interest, see: John F.Kennedy, *Address before the General Assembly of the United Nations*, 25 September 1961, <http://www.jfklibrary.org/Asset-Viewer/Archives/JFKPOF-035-048.aspx> collected 10-4-2018.
[107] Sheila Jasanoff, *Science and Public Reason* (Oxon, 2012), 90-91.

understanding is far older than the Cold War context of many other environmental issues, it is a key component in the work of the ice cores. With the implementation of global standard time in late 19th and early 20th century, following in the footsteps of technological novelties such as the telegraph, that allowed for simultaneous communication over vast geographical distances, new spatial and temporal communities could be established. The compartmentalization of the planet into time zones connected vast regions solely by their longitude. Within these regions, time was no longer primarily an experience of being situated in a local place – as had been the case with solar time – but was understood as a global form of information, of locating the local experience of time within a large and abstract time zone.[108]

In order for the ice cores to function as objects and messengers of climatic changes over time, a necessary aspect is the notion of the global as a temporal as well as a spatial concept. In the variety of aspects of the emergence of a global environmental science stated above, the ice core, both as a scientific object and as a representation of climate change, served both as a producer and as a product of these larger conceptual shifts. Janet Martin-Nielsen asserts that the Camp Century ice core played a role in a larger transformation in the understanding of the Greenland ice sheet: as the military interest decreased by the end of the 1960's, the island was re-conceptualized as a, to borrow from Henri Bader's presentation from 1957, "treasure trove" for climate-oriented research.[109] Following in the tracks of the research made possible through military infrastructure and technology, glaciology in the Arctic increasingly, during the 1970's became preoccupied with matters of climatic prognosis and prediction, making it move closer to the emerging climate sciences. As a part of the greater renegotiation of Greenlandic space – from a place of military interest to one of environmental concern – the ice core, too, was, I argue, renegotiated during the 1970's. It became both a marker of climate change and, through that process, an object of interest for scientists outside of glaciology. As knowledge production regarding a global climate system began to be formalized, ice cores were no longer only a matter of interest for the glaciological community, but for a broader range of scientists interested in the global climate. With the emergence of similar dating methods – sea cores and carbon dating for example – and climate modelling, ice cores, and their temporal framework, could function in contexts outside of glaciology. The enrollment into climate science thus marks a shift in who can speak with

[108] Edwards, *A Vast Machine*, 46-47.
[109] Martin-Nielsen, "The Deepest Most Rewarding Hole Ever Drilled", 68.

authority about the cryosphere: when ice cores were seen as a part of global climate science, rather than solely glaciology, they could be adopted into new epistemic communities.[110] In the following chapters, my aim is to outline these changes. Particularly, I will emphasize the entanglements of notions of human impact on the climate and the environment and the temporal dimensions made available through the ice core.

4.3 Ice cores and the geopolitics of temporality, 1967 - 1973

When the soldiers packed their stuff and left Camp Century for the last time in 1967, it marked an end for Arctic ice core science as an enterprise completely immersed in the infrastructure of the American military-industrial complex. The Camp Century ice core had been a great success for the future prospects of continuing the work in Greenland: reaching all the way down to bedrock and, additionally, recovering hundreds of meters of undamaged high quality ice for analysis had proven ice core sampling to be far from the dead end it had appeared to be during the troublesome years during the 1950's. With the withdrawal of U.S forces from Greenland and the disbandment of project Iceworm[111] the possibilities of conducting ice core research had changed significantly. However, following in the tracks of the international cooperation surrounding the Camp Century core was also the emergence of new sites of knowledge production. In addition to Chester Langway's New Hampshire laboratory, parts of the analysis of the core took place in Willi Dansgaard's Copenhagen laboratory and a team of researchers affiliated with the University of Bern, led by Swiss glaciologist Hans Oeschger came to be involved in the project as well.[112]

It was primarily the connection made by the three men – Langway, Dansgaard and Oeschger – and the unilateral funding opportunities that were rendered possible through the international nature of the group, that lay the institutional foundations for continued ice core research on Greenland. Dansgaard referred to them as the "three musketeers".[113] With

[110] Broecker, 461, and Matthias Dörries, "Politics, Geological Past, and the Future of the Earth", *Historical Social Research*, 40:2 (2015), 24-25.
[111] Project Iceworm was a military operation conducted during the 1960's, which consisted of a massive system of tunnels inside the Greenland ice sheet. The objective of the project was to deploy intercontinental ballistic missiles aimed at the Soviet Union. It is not completely clear how Camp Century and project Ice Worm related to one another, however, the two of them stemmed from the same institutional background and shared many engineering features. For additional reading on Project Iceworm, see: Nikolaj Pedersen,"The Politics of US Military Research in Greenland during the Early Cold War", *Centaurus*, vol. 55 (2013), 308-309.
[112] Lolck, *Klima, Kold Krig og Iskerner,* 101.
[113] Lolck, 117.

funding from the NSF, but also from their Danish and Swiss counterparts, GISP (Greenland Ice Sheet Project) was initiated in 1971. The objective of the project was to further investigate the possibilities of ice core drilling in Greenland and the application of different dating methods on the ice cores. Even though the military infrastructure was still of great importance – for example, one of the main sites of the drilling, DYE 3 in Greenland, was a military base – GISP had a different institutional framework in comparison to the work previously done at Camp Century. Drilling into the ice had previously existed under the patronage of Project Iceworm and the military strategic objective of placing intercontinental ballistic in the ice sheet. However, as the project fell out of fashion, the practice of drilling into the ice had to be reframed.

As a part of the series *Meddelelser om Grønland,* which was published annually between 1879 – 1979 and covered Danish scientific activity in Greenland, Willi Dansgaard argued for the benefits of ice core research in its 1973 edition. It was his second entry in the series, with the 1962 publication on the sampling of the interior of Greenland icebergs being the first. The Danish contribution to GISP accounted for 25% of the total budget and was therefore an important part of the realization of the project.[114] In comparison to the modest claims and even more modest results in the 1963 edition, the post-Camp Century Willi Dansgaard approach to the prospects of ice core research were both more positive and more expansive. As he noted on the first page: "The scope of ice core studies reaches far beyond glaciology itself."[115] He went on to list the prospective fields in which ice cores and the dating methods developed by himself and Hans Oeschger could be utilized: in addition to the more obvious benefits for glaciology, he also listed climatology, meteorology, atmospheric chemistry, solar physics and geology as sciences in which ice cores can provide new forms of knowledge.[116] Through ice cores, Dansgaard asserted, we can not only access "ancient atmospheres" reaching a few centuries back as had been the case in his 1963 entry in the series, but, among other things, track past, present and future temperature and accumulation changes, track pollution from lead and fission products, map volcanic activities, and see changes in cosmic radiation flux.[117] Over the course of a decade, the ice core's properties had grown: from being able to track some atmospheric changes over the last centuries, with a great deal of scientific uncertainty, to temporally expanding into deep time, hundreds of

[114] Lolck, 124.
[115] Willli Dansgaard, "Stable Isotope Glaciology", *Meddelelser om Grønland* (Copenhagen, 1973), 1.
[116] Dansgaard, "Stable Isotope Glaciology", 6.
[117] Dansgaard, "Stable Isotope Glaciology", 8.

centuries back, as well as widening its spatial scope, encompassing phenomena as disparate as volcanic activities, anthropogenic pollutants and solar physics. Through the work of the ice core, glaciology was able to transcend its disciplinary boundaries and the spatiotemporal limitations of previous scientific practice. Hidden in the interior of the ice sheet was not only knowledge about past climatic conditions, but also, it seems, the possibilities for new demarcations of glaciology itself. The performativity of the ice core, its ability to give immediate access to vast amount of climatic data and a texture to the deep past, opened up for new roles for glaciology in a time when the global environment was institutionalized as a scientific object. As American glaciologist Albert P. Crary put it in a speech at the ISAGE (International Symposium on Antarctic Glaciological Exploration) meeting in Hanover, New Hampshire, 1968:

> My suggestion for future glaciological studies is simple: add thin after thin dimension. Drill, drill and drill some more; know the ice-rock interface as well as the surface is presently known. Study the internal ice so that we can learn and understand the history of accumulated snow and other material that is available to us as far back as the cores takes us; drill on the continental divides, on the slopes, and on the shelves.[118]

Crary, who was the first man to set his foot on both the North and the South pole, went on to add that the bedrock beneath the ice sheet was the "next great frontier" of glaciology, echoing a long history of conquest and colonial expansion in polar science. Studies conducted in the ice-rock interface would open up for, according to Crary, increased possibilities of knowledge production about glacial surges.[119] This would not only be beneficial in terms of scientific advancement for glaciological research, but also because of its popular appeal and the prospective funding opportunities: "Man tends to be most interested, I find, in items that have considerable speed and size in comparison to his own. It would certainly help to draw attention to Antarctica if we could have one surge down there, just a little one".[120] But the prospects were still slim, "perhaps it's too much to expect, perhaps man's timespan is just too short", he went on to note. In Crary's view, glaciology seemed to have a problem with temporality. The slow voice of the glaciers did not speak on the same frequency as the rapidly changing pace of the human condition in the 20th century. The disparate temporalities of the

[118] Albert P. Crary, "Presidential address to the ISAGE meeting in Hanover, N.H 1968", in A.J. Gow, C. Keeler, Chester C. Langway, JR. and W.F Weeks, *Proceeding of International Symposium on Antarctic Glaciological Exploration (ISAGE)* (1970), 5. Excerpts of this speech is quoted by Dansgaard in "Stable Isotope Glaciology" as a part of a larger argument on the necessity of ice core research.
[119] A glacial surge is definied by the Oxford Dictionary as: "The swift and dramatic movement of a glacier, associated with the growth of ice up-glacier to unstable proportions and with severe crevassing" http://www.oxfordreference.com/view/10.1093/oi/authority.20110803095854369 (collected 10/4 2018).
[120] Crary, 1968, xiii.

ice sheet and modern society were defined as a substantial problem for the future of glaciology. Additionally, the temporal problem was intertwined with the spatial imagination:

> Though firmly convinced of the value of glaciology, I do have one reservation regarding Antarctic studies, derived mainly from recognition of the difficulty of obtaining funds for the major pay-off programmes, such as the drilling operation. We must remember that we are not dealing with an isolated continent—we are still in the ice ages, the existence of the Antarctic ice sheet being synonymous with the ice ages— and the history of Antarctica, as it is developed, must continually be correlated with the history of all other lands and oceans. [121]

As indicated in the quote above, Crary saw it as important to link glaciological research – in this case ice core drilling – to global oceanic and climatic conditions and histories, rather than isolating the results to one continent. This global dimension is connected to the notion of still being "in the ice ages", asserting that the time scale of Antarctica and its ice sheet is vastly longer than what normally is given account for and is something that glaciologists "must remember". Lastly, this attempt to reframe the temporal and spatial boundaries of Antarctica, is also connected to the opportunities for attaining funding for further inquiry.[122]

In the process outlined by Crary, in which glaciology in order to maintain its status within the broader scientific community needed to alter its temporal and spatial horizons, the ice core provided a materiality to a new prospective time scale. Through the ice core, the texture of the deep time of the polar region could not only be imagined, but also made tangible in a physical form. The lack of public and political interest in glaciology during the years around 1970 was seen, as stated by Crary, as a problem of the slowness of the glacial movements in relation human history. However, through the vast time scale visualized and materialized in the ice core, new stories of drastic changes and ice ages that came and went could appear. The dream of glacial surges that Crary mentioned in his speech could, in a different way, be realized when the time scale expanded, filling previous empty spots in the Earth's past with events and disruptions on a global scale. Deep time became, with the emergence of ice cores, as well as other dating methods such as carbon dating and sea cores, tangible and textured rather than being an incomprehensible long time outside the human

[121] Crary, vi.

[122] It should be noted however, that the funding opportunities for ice core research in the Arctic versus Antarctica differs to some extent. Even though American military presence in Greenland decreased after Iceworm and Camp Century, the location of Greenland, in the midst between North America and Europe gave it a different infrastructural framework and other prospects for funding of research. Nevertheless, funding was an issue for the research teams in Greenland and the Arctic during the early 1970's as well, with the decrease of resources becoming apparent with the military withdrawal. For example, Willi Dansgaard recalls the struggles of obtaining funds for a sufficient drill during the beginning of the GISP in his autobiography. See: Willi Dansgaard, *Frozen Annals: Greenland Ice Sheet Research*, 69.

timescale.[123] The work of the ice core, as it was presented in the scientific output from Camp Century was partly to fill empty timeframes with events, disturbances and reoccurrences, that follow different rhythms than the timescale humans usually relate themselves to.[124] In this context, the ice core is not so much a measuring device of time as it is a creator of time, turning a temporal void into a richly textured narrative about changes over time.

The timeline that emerged in the tracks of the first ice cores to reach bedrock was one filled with radical changes in climate and periods of rapid glaciation. Additionally, the significant increase in timescale enabled new rhythms of climate to emerge and a new temporal dimension for the environmental conditions of humanity. In an article in *Quaternary Research* from 1972 entitled "Speculations about the Next Glaciation", a team of ice core researchers, among them Chester C. Langway, JR. and Willi Dansgaard, utilized the information from the ice cores in order to speculate about the climatic conditions of the future. Through ice cores, and particularly the Camp Century ice core, they were able to track regularities in the climatic patterns of the deep past and they noted how the climate can change in very rapid ways. They went on to, although with a great deal of scientific uncertainty, discuss the probabilities of a future glaciation and which factors could be instrumental to an event like that occurring. In addition to phenomena such as ice surges and increased volcanic activity, they asked wheter "man's present activity is equivalent to such accidental event?"[125] Here, the increase in timescale is not only of scientific interest, but the altered timeframe of glaciology also enables a different geopolitics of temporality. Human activity, as understood through the ice core's textured deep past, could be interfering with processes of a radically different temporality. With the assertion that the climates of the past had not only been rapidly changing, but that human activity might have extended its impact far beyond its own perceived historical boundaries, makes the ice core an object that situates humanity on a geological timescale. The temporal performativity of the ice core, as it is discursively framed in the article in *Quaternary Research*, lies in its ability to locate humanity, and the modes of production that lies behind humanity's impact on the global climate, on a vastly longer time scale.

Statements about time, as philosopher Michelle Bastian has pointed out, has an intrinsic temporal performativity. They are not merely constative statements, but rather ways

[123] Mathias Dörries, "Politics, Geological Past, and the Future of the Earth", 23.
[124] Willi Dansgaard & S.J Johnsen,"Flow Model and A Time Scale For the Ice Core From Camp Century, Greenland", *Journal of Glaciology,* 8:59 (1969), visualization of the ice core's timescale on p. 226.
[125] Willi Dansgaard and Chester C. Langway, JR. et. al, "Speculations about the Next Glaciation", *Quaternary Research*, vol. 2 (1972), 398.

of locating oneself within temporal boundaries. For example, the statement "It is now 14:30 pm" has the ability to tell what time it is but also to place the utterer of the statement in a relationship with a specific way of measuring time.[126] In the case of the Camp Century ice core, it does a similar work as stating what the clock is: to state that human activity could be inscripted into the timescale of the ice core is to locate humanity within deep time and a radically different temporality. As the ice core, through this process, became not only a measurement of the past, but a messenger of humanity's impact on the planet's most fundamental functions, it also transcended its previous scientific boundaries, moving into an emerging political discourse on anthropogenic climate change. In previous narratives, popular as well as scientific, the ice cores had told stories about the past in ways that enabled humans to locate themselves on the timeline. For example, in the New York Times article about cooling Coca-Cola with 2000-year old ice, the ice was described as being from "the same time as Christ was born" and thereby connecting the age of the ice with a significant time marker in Western history.[127] However, even though this kind of narrative is a way of connecting humans – Western, Judeo-Christian and American humans that is – with the timescale of the ice cores, it does not assume that human activity was in anyway acting upon the 2000-year old ice, rather it just happened to exist at the same time as the birth of Christ[128]. In the article in *Quaternary Research* the situation is different: humans are now not only visible on the, by previous standards, excessively long timescale, they are also potentially altering its trajectory and thereby working within a vastly different timeframe. In light of this, where the ice core, as understood by Langway and Dansgaard et.al, is both measuring the climates of the deep past as well as tracking the entrance of humanity on this timescale, the work of ice cores and ice core research more generally, can be understood as a practice of synchronization.

The concept "practice of synchronization" comes from the Norwegian historian Helge Jordheim. Drawing from Reinhardt Koselleck's notion of a multiplicity of temporalities existing simultaneously, Jordheim defines a practice of synchronization as the processes through which multiple temporalities "are compared, unified, and adapted by means of elaborate conceptual and material practices."[129] The temporality of glaciology, as Crary noted,

[126] Michelle Bastian, "Fatally Confused: Telling the Time in the Midst of Ecological Crises", *Environmental Philosophy,* 9:1 (2012), 26.
[127] This connection between Western history, ice cores and the colonial ambition to claim the interior of the ice sheet as connected to specific cultural events is a significant part of ice core science in general and the narratives weaved from them in particular.
[128] "Army Serves Drink Cooled With Ice 2,000 Years Old", *New York Times*, September 22, 1966, 41.
[129] Jordheim, "Introduction: Multiple Times and the Work of Synchronization", 515.

had trouble claiming its scientific and societal importance, as its timeframe was so slow in comparison to "man's short timespan". This problem, understood through the lens of the existence of multiple temporalities, "organized in the form of temporal layers that have different origins and duration and move at different speeds"[130], can be seen as a part of the difficulties in ordering a plurality of temporalities along one, linear timescale. However, the ice core, the way it is presented by the team from Camp Century and GISP, can be an "elaborate conceptual and material practice" as described by Jordheim, situating the temporality of Western modernity on the hundred-thousand-year long timescale of the ice core.

In this chapter, my aim has been to show how the temporalities rendered possible through the work of the ice core was intertwined with a renegotiation of the demarcations of glaciology and a broader turn towards global climate within the earth sciences. Over the course of the first years of the 1970's, the meaning and message of the ice core was altered as a part of a larger, structural reconceptualization of the Arctic and Greenland ice sheet. As the infrastructure provided by the military-industrial complex decreased, the scientists had to find new ways to justify further inquiry and secure future funding. The ice core, as a technoscientific object, became enrolled – in a Latourian sense[131] – in a surging interest in global climate, climate prediction and control, and the increased awareness of possible anthropogenic climate change. Furthermore, the temporal properties of the ice core made it both a representation of the deep past – as in the *New York Times* article about cooling Coca-Cola with ancient ice – as well as an object that made it possible for glaciology to claim political urgency. With the emergence of a public awareness of a global disaster – both in the shape of a nuclear winter as well as a collapse of the environment – the narrative about rapid global changes in deep time that the ice core could reveal gained political and scientific credibility. The vast time frame, buried in material form in the ice sheet, could be weaved into a narrative of anthropogenic impact on global environmental systems as well as fill a previously empty timeline with events, bringing not only texture to deep time, but also political urgency.

For the scientists, the prospect of ice core drilling functioned as a way to broaden glaciology's influence and receive public attention. After the success at Camp Century the task that remained was to "drill, drill and drill some more". In the next chapter, I

[130] Jordheim,"Against Periodization: Koselleck's Theory of Multiple Temporalities", 170.
[131] Bruno Latour, *Science in Action: How to Follow Scientists and Engineers through Society* (Cambridge, MA, 1988).

will describe this change of scientific ethos within parts of glaciology by directing my focus to one particular actor: Willi Dansgaard.

5. Willi Dansgaard and the politics of deep time

Born in Copenhagen 1922, Willi Dansgaard remained his faithful to his hometown until his death in 2011. Apart from numerous research expeditions to Greenland, he worked his entire life at the University of Copenhagen, from which he received his PhD in 1961 with a dissertation titled *The Isotopic Composition of Natural Waters.*[132] Dansgaard, who is often considered to be one of the pioneers of ice core research and paleoclimatology more generally, described himself as being "bitten with Greenland for life" after his first encounter with the island in 1947.[133] At the time he was a student of geophysics at the University of Copenhagen and was sent to Qreqertarssuak (which during the time went under its Danish name Godhavn) by the Danish Meteorological Institute (DMI) to work at their Geomagnetic Observatory, located on Disko Island, just outside the Northwestern Greenlandic coast. As a part of the surge in interest with meteorology and accurate weather forecasting during the early stages of the Cold War, Dansgaard, with his background in geophysics, he became an active part of the meteorological community in Copenhagen, with positions at the DMI as well as at the institute for Theoretical Physics, the Rockefeller Institute. Scientifically, he was primarily interested in the possibilities of studying the isotopic composition of water molecules from rainwater in order to trace atmospheric conditions. Particularly the heavy ^{18}O isotope, which Dansgaard noticed was more prevalent in rainwater coming from the beginnings of a warm front, was of interest to his research. Through rudimentary equipment – his first device for measuring rainwater was just a funnel and an old beer bottle – he was able to make some predictions about a correlation between the isotopic composition of water molecules and the atmospheric conditions in which they had appeared.[134]

This early interest in establishing links between the properties of water and atmospheric conditions, the sea and the sky, led Dansgaard towards an interest in glacial ice and the accumulated rainwater that existed within it. In attempts to improve is oxygen isotope measurements he conducted several studies along the Greenlandic coast during his years as a graduate student, applying his methods previously used on rainwater on glacial ice. Drawing on his connections in physics – for example, Niels Bohr sponsored one of Dansgaards first

[132] Chester C. Langway, JR.,"Willi Dansgaard (1922-2011)", *ARCTIC Journal*, 64:3 (2011), 385.
[133] Dansgaard, *Frozen Annals,* 11.
[134] Lolck, Maiken, *Klima, Kold Krig og Iskerner,* 13.

expeditions to Northern Norway in 1958[135] – as well as from the emerging international community of glaciologists interested in ice core drilling. Dansgaard's 1962 entry in the *Meddelelser från Grønland* series was a result of these early expeditions to the Arctic regions and an early attempt to situate the Danish efforts in dating the ice sheet and the surrounding icebergs.[136]

However, it was with the Camp Century ice core and the work made by Dansgaard and his team at University of Copenhagen, that came to make him a well-known name within the young discipline of glaciology as well as a national authority on Greenland and paleoclimatology in the Danish public. In this chapter, I will follow Dansgaard's career as he ventured from being a young geophysicist measuring rainwater to an international expert on the expanding field of ice core research over the course of just a few years in the 1960's and 1970's. As the ice cores grew, both metaphorically and materially, so did the scope of what the researchers could claim as their domain of scientific expertise. Dansgaard, as one of the central actors around the Camp Century ice core, was in the middle of the process in which glaciology expanded scientifically, politically and temporally. As a newsletter in *ICE*, the newsletter for the International Glaciological Society, stated in 1975, Dansgaard and his surrounding group of researchers "opened up another dimension in glaciological research."[137]

After playing an important part in the dating of the Camp Century ice core, Dansgaard and his team published several articles in scientific journals, among them *Science* and *Nature*, about the results of the work made in relation to the ice core in their Copenhagen laboratory.[138] The international recognition for Dansgaard's work as well as for ice core research in general, made Dansgaard a nationally celebrated scientist and in 1971 he received the Royal Danish Geographical Society's Hans Egede Medal for his efforts in paleoclimatology. After Crown Princess Margrethe II handed him the medal he held a short speech. In the speech, Dansgaard elaborated on the benefits of knowing the climatic regimes of the past and why it during that particular moment in time was a worthwhile scientific enterprise:

[135] Willi Dansgaard, Letter to Niels Bohr, 19/4 1958, Det Konglige Bibliotek, Copenhagen.
[136] Willi Dansgaard, Willi, "Radio-Carbon Age and Oxygen-18 Contents of Greenland Icebergs", *Meddelelser om Grønland* (Copenhagen, 1963).
[137] Short news item in *ICE – Newsletter for the International Glaciological Society*, vol. 3 (1975), 6.
[138] Dansgaard, et. al "One Thousand Centuries of Climatic Record from Camp Century on the Greenland Ice Sheet", 377.

> Det turde imidlertid være indlysende, at før man ved hvordan og i hvilken udstrækning naturen selv ændrer klimaet, kan man ikke forudse eller forstå hvordan menneske eventuelt vil gøre det. Derfor bliver studier af naturliga klimasvingninger i fortiden et centralt afsnit af den forskning, som FN vil tage initiativ til.[139]

As a part of the broader reimagining of Greenland as a space for environmental rather than Cold War geopolitical concern, Dansgaard here aligned himself with the mobilization taking place around global environmental politics within transnational institutions such as the UN. A year later, in 1972, Stockholm would host the first ever UN conference on the global environment, under the title "Only One Earth".[140] Over the course of the 1970's, Dansgaard became an active part in the discussion on anthropogenic climate change, an issue that was represented in the curriculum in Stockholm during the Only One Earth-conference, but in a very limited capacity, as well as at the Study on Man's Inpact on Climate (SMIC) conference in 1971.[141] In numerous articles in popular and scientific journals, in national as well as international publications, Dansgaard argued for the urgency of increasing the knowledge about climatic changes and grew, from the rather careful statement in his acceptance speech in 1971 to statements in the late 1970's, an increasingly ardent supporter of political action in relation to anthropogenic climate change. In this transformation, Dansgaard was far from unique, as a part of a more general circulation of knowledge concerning environmental issues and political advocacy within the scientific community in the 1970's.[142] However, I argue, because of the properties of the ice core, and the temporal work it does, Dansgaard's way into the environmental debate had some different characteristics in comparison to that of other scientists of his time.

Four years after Dansgaard received the Hans Egede Medal from the Royal Danish Geographical Society he received a new award, this time, from the Swedish equivalent. 1975 he was the recipient of the Vega Medal, awarded by the Swedish Society for Anthropology and Geography, and this time he held a speech that echoed many of the same sentiments as the one he gave in 1971.

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[139] Willi Dansgaard, Speech held at the ceremony for Danish Geographical Society's Hans Egede Medal, 1971, Det Konglige Bibliotek, Copenhagen. Translation: "It should however be obvious, that until we know how and to what extent nature itself alters climate, we cannot predict or understand how humanity might do so. Therefore, studies of natural climate swings in the past is a central part of the research that the UN now wants to initiate."
[140] Spencer R. Weart,"The Evolution of International Co-operation in Climate Science", *Journal of International Organization Studies*, 3:1 (2012), 49.
[141] Bert Bolin, *A History of the Science and Politics of Climate Change: the role of the Intergovernmental Panel on Climate Change* (Cambridge, 2007), 29.
[142] Joachim Radkau, *The Age of Ecology: A Global History* (Cambridge, 2014), 89-90.

> ”Menneskets forurening av naturen har nu antaget et omfang, som meget vel kan få alvorlige konsekvenser for klimabalancen. Den fare som det menneskelige samfund derved udsættes for tåler sammenligning med faren ved den nukleare oprustning, der i det mindste erkendes af alle ansvarlige. Derfor er det absolut nødvendigt at man hurtigt får klarhed over forureningens klimatiske konsekvenser. Ingen tror vel på alvor at for eks. Forureningen af atmosfæren med kuldioxid kan stanses, men man her vel at håbe på at den efterhånden vil kunne kontrolleres og evt. begrænses af viden.”[143]

Compared to the 1971 speech, Dansgaard seemed to take a firmer stance regarding the political urgency of the prospect of anthropogenic climate change. The problem of an altered climate balance was not, according to Dansgaard, receiving enough political and scientific interest considering the magnitude of the potential threat it poses. In 1975, the ice core was, as the quote above indicates, fully enrolled in a process of making sense of human impact on the climate. Furthermore, Dansgaard, as a way of stressing the importance of acknowledging the political significance of anthropogenic climate change, likened it to the threat posed by nuclear weapons.[144] As shown by Joseph Masco, notions of environmental destruction and nuclear winters were often framed within a similar imagery and co-evolved as the two issues gained political weight.[145] When Dansgaard used this comparison, it also highlights the temporality of climate change as he frames it, turning it from a gradual change, something that could be happening in a distant future, into an event, into something that could occur with the same force as – at least metaphorically speaking – a nuclear blast. The meta-event of climate change – involving a multiplicity of parameters, events, and measurements – can through the nuclear metaphor become understandable as one, singular phenomenon.[146] The climatic changes that Dansgaard could visualize through the ice cores were also of an event character, showing drastic changes over, in relationship to the timescale, short periods of time.

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[143] Willi Dansgaard, Speech at the award ceremony for the Vega Medal, Stockholm, 24 April, 1975, Det Konglige Bibliotek, Copenhagen. Translation: ”Mankind’s pollution of the planet have now reached proportions that might have severe impact on the climate balance. The danger that this poses to society can be compared to the nuclear armament, and that should at least be recognized by those who are responsible. Therefore, it is absolutely necessary that we will rapidly get clarity of the climatic consequences of pollution. No one does seriously think that, for example, the release of carbon dioxide into the atmosphere can be stopped, but that it at least can be controlled and limited through science.”

[144] In addition to the speech in Stockholm 1975, this retorical figure is used by Dansgaard in other contexts around the same time. For example: Willi Dansgaard, Draft to a debate article for Information, 1975, Det Konglige Bibliotek, Copenhagen and Dansgaard, Willi, Acceptance Speech after recieving the International Glaciological Society’s Seligman Crystal, Peter Hall, Cambridge, 15 September, 1976, Det Konglige Bibliotek, Copenhagen.

[145] Masco, ”Bad Weather: On Planetary Crisis”, 14-15.

[146] The notion of climate change as meta-event is introduced by Miyase Christensen, Annika Nilsson and Nina Wormbs in ”Globalization, Climate Change and the Media”, in Miyase Christensen, Annika Nilsson and Nina Wormbs (ed.) *Media and the Politics of Climate Change* (New York, 2013), 7.

5.1 Politicizing the past: the case of the Vikings

In addition to Dansgaard's efforts to address the urgency of human impact on the world's climate, his scientific production during this time was also occupied with human's relationship to climatic changes in the past. In the acceptance speech held when he received the Vega Medal, he connected the current problem of anthropogenic climate change with how previous cultures had dealt with rapidly altered climatic conditions. Specifically, he used the example of a Viking settlement on Greenland, that abruptly disappeared in the 15th century, without any clear reason why. According to Dansgaard, one way of solving the mystery of the disappearance of the settlement was to use the records in the ice cores to track if changes in the climate was a factor.[147] The same argument was also made in an article in *Nature* during the same year.[148] In this case, the narratives that could be constructed from the ice core data transcended previous boundaries by making bold statements about events in human history. In the story about the collapse of a Viking settlement, the work of the ice core is to invoke the notion of inevitability, of removing the social sphere from the equation and describe the Vikings as victims of circumstances outside of their control.[149] However, using the Vikings as an example of a society that was severely hit by climate changes had an additional function in the broader argument made my Dansgaard, as he likened it to current environmental issues: "But quantitatively it [the climatic changes causing the settlement's collapse] was a rather insignificant event compared to what has happened in other parts of the world – and happens today."[150] The politics of the ice core was in this case not only the possibly reductionist story of a society collapsing due to exterior factors, but also a temporal extension of what can count as a political event. Through Dansgaard's reading of the ice core, and the temporal rhythms it reveals, a Viking settlement in the 15th century became entangled with current threats of pollution and altered levels of carbon dioxide in the atmosphere. On the vast timescale of the ice core, the Greenland settlement and current climate were closely located to each other, but in the temporalities of late 20th century geopolitics the temporal distance to the Vikings is an almost incomprehensibly long time.

[147] Dansgaard, Speech at the award ceremony for the Vega Medal, Stockholm, 24 April, 1975.
[148] Willi Dansgaard, S. J. Johnsen, N. Reeh, N. Gundestrup, H. B. Clausen, and C. U. Hammer, "Climatic Changes, Norsemen, and Modern Man." *Nature,* 255 (1975), 24-28.
[149] Carey and Antonello, "Ice Cores and the Temporalities of the Global Environment", 192.
[150] Dansgaard, et. al, "Climatic Changes, Norsemen, and Modern Man.", 26.

In the process of transforming the ice core from a disciplinary limited scientific object to a representation of climate change in a broader political sense, one aspect is the synchronization of multiple temporalities. As Dansgaard asserts in his anecdote about the settlement on Greenland, the emergence of anthropogenic climate change had made events in a, by political standards, far past into urgent matters of concern. In this context, the ice core did not only expand timescales in a general sense, but worked in a specific way to reframe the way in which environmental issues were addressed politically. Dansgaard entered the political discussion of climate change with the temporality of the ice core as his conceptual framework and the stories it told about rapid changes in climate with dramatic consequences. Climate change, as framed in the example with the Vikings as well as in the article on the next glaciation in *Quaternary Research*, appeared not as a meta-event, but as one singular event that left its mark in the ice sheet. With this perception of the temporality of the global climate, Dansgaard could use the, at the time popular, rhetorical figure of the threat of nuclear armament, as it followed a similar temporal structure with one event that threatened the living conditions on the planet.

Dansgaard's preoccupation with matters of temporality becomes even more pronounced in a letter he sent to the Danish professor of History, Kristof Glamann, as a response to an essay Glamann wrote on the relationship between historical thinking and natural sciences. In the essay, entitled "Den kronologiske uskyld", Glamann reflects upon the time horizons of contemporary historical theory and discusses how, in the 20th century, the natural sciences have been increasingly preoccupied with matters of time. He references the work done at Camp Century and how the work by Dansgaard and his team opened up "new periodicities" that reaches further back than what was thought possible. Glamann sees the ice core as a part of a larger process of expanded temporal horizons made possible through natural sciences, creating a divide between the incredibly short historical timescale compared to the enormous proportions of the timescale of natural sciences. Clio, the patron saint of historical sciences, Glamann speculates, might be feeling a sense of vertigo looking at the ever increasing expansion of the timescale.[151] In his letter to Glamann, who by Dansgaard is addressed as a "disciplinary neighbor", Dansgaard expanded on some of the themes brought up in Glamann's essay, particularly the relationship between the timescales of natural sciences and history. Dansgaard saw the ice core, which get blurrier and trickier to adequately

[151] Kristof Glamann,"Den kronologiske uskyld", in *Ikke bare om Norden. Festskrift til Frantz Wendt i anledning af 70 års fødselsdagen den 24. Februar 1975* (Copenhagen, 1975), 50.

date the further down one goes, as analogous to history, that tends to tell more vivid outlines of events closer in time. However, he was skeptical to the tendency, as he sees it, of history to overlook prehistorical times just because of the temporal distance: "…svårt att forestille mig, at f.eks istidsmalerierne i Sydfrankrig blev skapt af en primitiv kultur med overlevalse som eneste mål. Jeg ser dem som egn på overskud i en tilværeslse, der måske ikke var meget foskellig fra de nordamerikanske indianernes for 300 år siden".[152] In Dansgaard's view, the timescale used by historians is too short, and unnecessarily so. Towards the end of his letter, he objects to Glamann's assertion of a split between the timescales of human history and of natural sciences. For Dansgaard, the difference between them isn't that clear, he writes: "Forholdet mellem den naturhistoriske kæmpe-tidskale og den humanhistoriske lilleputsskala er sandelig svimlende. Men mon ikke det vil vise sig at være i hvert fald en størrelse orden mindre end det gøres til?"[153]

In the middle of the 1970's, Dansgaard pursued expanding the boundaries of what the ice cores can tell us. In the article in *Nature*, as well as the correspondence with Kristof Glamann, Dansgaard no longer strictly adhered to examining events outside of human history, but rather used the ice core as a way to address phenomena that lied seemingly far away from the objectives of glaciology. The expansion of the ice core and its enrollment into a growing concern for environmental problems caused by human action made it possible for Dansgaard to speak with authority on matters that normally would fall outside of his scope.

The temporal problem of glaciology, that A.P Crary pointed out in 1968, relied on the disparate temporalities of glacial movements and human society. In his letter to Glamann, Dansgaard addressed this problem from a different perspective. With the introduction of human activity as a possible parameter for climatic changes, and the emergence of humanity in the records of the ice cores, the different rhythms are no longer as far away from one another as previously perceived. A.P Crary wished for a glacial surge, "just a little one", in order to highlight the public importance of the work of glaciology and synchronize "man's timespan" with that of the glaciers.[154] With the emergence of human activity inside the ice cores, and the possibility to use the ice cores to explain events in human

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[152] Willi Dansgaard, Letter to Kristof Glamann, 7 February, Copenhagen, 1978. Det Konglige Bibliotek, Copenhagen. Translation: "I have a hard time imagining that, for example, the iceage paintings in Southern France were created by a primitive culture with survival as its only objective. I see it as a region were a surplus was produced, not very far from how the North American Indians lived some 300 years ago."

[153] Dansgaard, Letter to Kristof Glamann, 1978. Translation: "The difference between the enormous timescale of natural science and the tiny one of human history is in truth vertiginous. But I wonder if it will not turn out to be at least one size smaller than it is now being perceived as?"

[154] Albert P. Crary, "Presidential address to the ISAGE meeting in Hanover, N.H 1968", vii.

history, this synchronization appeared, albeit not in the form that Crary had expected. When Dansgaard suggested that the timescales were not, in fact, so far away from each other, he also offered glaciology a seat at the table in the early discussions on environmental policy and human impact on the global climate. The expansion of the ice core involved an expansion of the scientific authority for those who could interpret their message. In the case of Willi Dansgaard, his ability to speak with confidence about matters that a few years earlier would have seemed farfetched and, possibly, unscientific, was entangled with the rise of global environmental institutions and the synchronization of temporalities that was made possible through the ice core. Additionally, the temporalities of the ice core, when enrolled into an emerging discourse on anthropogenic climate change, took on, as shown by Dansgaard, a similar narrative structure as contemporary debates on nuclear armament.

6. Conclusion

6.1 Temporalizing the global environment: ice core science as a practice of synchronization

As the ice cores went from telling stories about the climate some hundred years ago, as was the case in the first drilling attempts in the 1950's, to some hundred thousand years ago in the last years of the 1960's, the temporal boundaries of glaciology underwent rapid changes. In his speech at ISAGE in 1968, glaciologist A.P Crary noted that it was hard to engage the broader public as well as potential funders due to the slow pace of the glacial movements in relation to the brief lifetime of humans. He went on to wish for a glacial surge in Antarctica, because a surge's rapid development could increase the general interest in glaciologist research and temporally adhere to the pace of the rest of the world. In the same speech, he also declared his support for increased ice core research and the possibilities of conquering the interior of the ice sheets, "the next great frontier", and the information of past climate regimes stored there. This temporal expansion, the opening of a "new dimension" as it was called in the IGS's newsletter *ICE* in 1975, functioned not only, I argue, as a way to explore the climates of the past, but to synchronize the temporality of glaciology with the temporality of the emerging debate on anthropogenic impact on the Earth's environment. By speaking to a growing concern of the possibility of a planetary crisis, ice core temporalities could be enrolled into a discourse on environmental politics in a way that other glaciological scientific practices, that made the glacial movements to appear slow and intangible, could not.

Helge Jordheim defines practices of synchronization as the processes through which multiple temporalities "are compared, unified, and adapted by means of elaborate conceptual and material practices."[155] In the case of the ice cores, the deep time they materialized and rendered visible, could be synchronized with a linear, Western understanding of time through their enrollment into human history. In the article in *New York Times*, in which Lyle Hansen uses ice "from the time of Christ" to cool his Coca-Cola or when the collapse of the Viking settlement on Greenland can be explained through ice cores, the temporal structure of the ice cores is synchronized with already held conceptions of

[155] Jordheim, Helge, "Introduction: Multiple Times and the Work of Synchronization", 515.

Western human history. This practice of synchronization had concrete effects for the possibility for glaciology to gain influence within climate discourse and broaden its scope to include human history as well. Paradoxically, the introduction of humans into the ice core records seems to have had the effect of further separating humans and climate, turning past civilizations into victims of an exterior and omnipotent climatic force. The enrollment of ice cores into climate discourse can in this case be seen as matter of synchronization, in which the deep time of the ice core could be understood within the temporal framework of a prospective planetary crisis, and thereby shaping their politics within climate discourse.

The materiality of the ice core, and the spatial dimensions of the cryosphere it opened up, was, I argue, one important factor in the way it could be enrolled into climate science and politics. Being a mobile scientific object, possible to relocate and circulate, the ice core enabled studies of glaciers without forcing the scientist to be physically present by the ice. By providing a vertical cut-out of a glacier, other scientists than the glaciologists in the field could speak with authority of the temporal work the ice core did. When the oceanographer Wallace Broecker used the Camp Century ice core in his 1975 article in *Science*, the ice core was understood not as an object unique to the Arctic, but as a small part of a large system of measurements tracking the global climate. This can be interpreted as a larger spatiotemporal shift in the way the Arctic was understood: in early ice core drilling, ice cores functioned as a way to give temporal texture to past climates in the Arctic, but as the ice core temporalities expanded and were synchronized into a broader temporal regime they began to speak to the global climate rather than the local. The ice core was now part of a global system, the cryosphere enmeshed into planetary dynamics, making it possible to interpret for people outside the geographically limited field of glaciology. Both early glaciology and indigenous epistemologies had relied on embodied encounters with the ice in order to produce knowledge, however, as the ice core were enrolled to climate science, glacier ice could be seen as a spatially ambiguous and disembodied phenomenon, located in a global system rather than in enclosed areas.

Another aspect of the work of synchronization is the temporal expansion of what can count as a politically relevant event. When Willi Dansgaard received the Vega medal, he used the example of the Viking settlement on Greenland not only as a case study of a climate disaster, but by noting how the climatic changes they went through were possibly milder than what was coming up ahead. Through the timeline of the ice cores, the distance between the Greenland settlement and the late 20th century was virtually non-existent even though they, in the context of international environmental policy, were hardly seen as

temporally close. The case of the settlement was not the only example of an event in the past that became politically charged through the temporal framework of the ice cores, but climatic changes further back in time, such as past glaciations, were also enrolled into contemporary issues regarding human impact on the Earth's climate. As Dansgaard noted in his speech, human activity could possibly be one of the forces that would affect the outcome and timing of the next glaciation, thus placing it in relation to forces in possession of a temporality so slow that they had not previously been known. The work of the ice core became, in this context, to situate humanity on a new, much longer timescale and to try to synchronize the notion of human agency on a planetary level with the political framework for environmental policy. Incorporating the ice core temporalities within a modern time regime, and the conceptual apparatus of a planetary crisis, was not, I argue, a natural outcome of the knowledge ice core science made available, but the process of elaborate practices and intellectual work. In his letters to Krystof Glamann, Dansgaard shows how the relationship between humanity and the geological timeline, in his view, was not stabilized, but open for interpretation. However, as ice cores became a part of the conceptual and institutional framework of global environmental politics, they underwent a process of blackboxing as their temporalities were standardized in a broader context.

By directing attention to the way the temporalities of ice cores were negotiated and synchronized with a modern time regime, I hope to have exemplified how an important part of the creation of the global environment was the temporal work of, in this case, ice core scientists. In including human history on the ice core timeline, scientists such as Dansgaard, tried to bridge the divide between deep time and human history and thereby expanding the temporal boundaries of political issues. The processes and practices that enabled the global environment to take on its temporal form in a political and cultural context was not solely the result of scientific certainty, but of elaborate negotiations on how to synchronize the multiplicity of temporalities rendered visible through ice core science and similar disciplines. In the process of transforming the ice core from a scientific object to a representation for climate change, the work of synchronization made the ice core possible to enroll in an emerging climate discourse. The material conditions of early ice core drilling – the spatial reconceptualization of the cryosphere taking place as a part of the political geographies of the Cold War, multinational glaciological research projects, the possibility to examine ice cores in laboratories instead of in the field – were foundational for ice core science to become a practice of synchronization, enableing a new temporal framework and scientific subjectivities.

With the surging theoretical interest in the Anthropocene that has taken place during the last decade, an increasing body of scholarship has started to pay attention to temporality and the implications of humans acting within a geological timescale. As temporality has, as Andreas Malm and Michelle Bastian claim, returned as an analytical category for understanding the present moment of severe environmental problems and anthropogenic geological agency, it seems increasingly important to study and historicize the way the temporalities of the global environment has been produced, reproduced and represented. Drawing from Reinhardt Koselleck's notion of a multiplicity of temporalities existing simultaneously, the case of the ice cores show how the temporalities of the global environment were negotiated in a cultural and sociopolitical context and that the narratives they enabled were partly a process of a work of synchronization, that aimed to make the ice cores adhere to temporal regime.

6.2 Reducing the past to climate icons

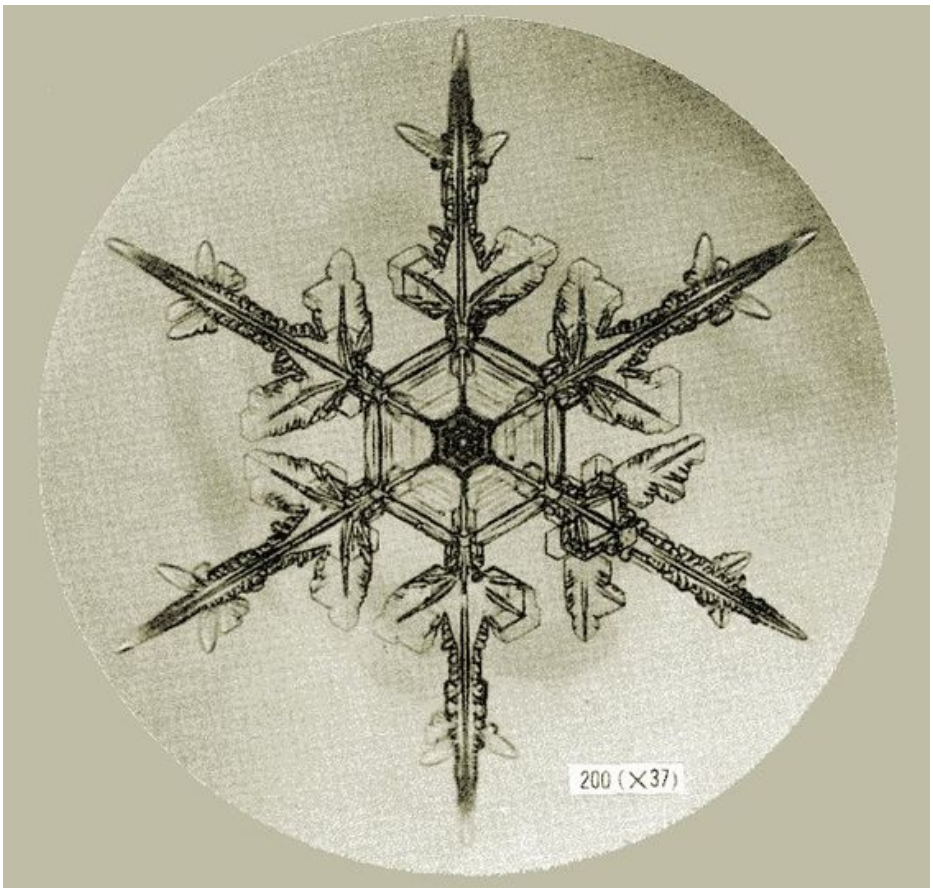

Figure 1. Model of an artificial snowflake by Ukichiro Nakaya, 1935. [156]

The global climate is a system of immense complexity. From the standpoint of a single individual, its properties, its spatial and temporal dimensions, are impossible to grasp. With the increasingly interwoven relationship between human activity and climatic changes things have gotten even trickier. The only way to know the global climate is through reduction; through models, visualizations, diagrams, representations. Anthropogenic climate change has, since its emergence on the political stage in the early 1970's, not only been a political and environmental problem, but also a sociocultural phenomenon, an initially abstract concept that has been stabilized and reduced into a form that renders it conceivable within a popular imagination. As institutions such as the IPCC and numerous multinational climate summits have attempted, with very limited results, to create a global policy to interfere with the current dramatic damage made to the planet's environment, they have also been part of a process of creating a visual library of iconic images of climate change.

[156] Ukichiro Nakaya, *Snow Crystals: Natural and Artificial* (Cambridge MA, 1954).

As a part of a broader effort to historicize climate change, in seeing the way knowledge about it has been immersed into geopolitical, scientific and cultural systems, climate models and representations are objects of great interest. Through them, knowledge regarding climate change has been reified and stabilized through an assemblage of global and national institutions and material, literal, and visual technologies. The temporal and spatial properties of the global climate can, through processes of translation and reduction, become tangible, even familiar. Climate models are not neutral representations of natural phenomena, but rhetorical devices, products of specific material conditions and scientific practices, sites and institutions. In contemporary climate discourse, a small number of models and measurements – the Keeling curve, the "hockey stick", the sea ice coverage, ice core timelines – have become archetypical images in themselves, not only as ways to know the climate but as icons of climate change. They are detached from the context in which they were produced, as they have gotten increasingly naturalized in a global visual culture of anthropogenic climate change. As Mike Hulme has argued, there is a tendency to reduce the future to climate within neo-environmentalist approaches to climate change, seeing climate as an exterior force that will act upon humanity and thereby determining the outcome of future climate disasters.[157] Hulme traces the epistemic status of climate modelling, in relation to other forms of knowledge concerning human societies' abilities to adapt to new environmental circumstances, as one of the reasons for the tendency to adhere to reductionist narratives within climate discourse.[158]

Reduction is a necessary intellectual practice in order to make sense of and grasp the complex socio-natural system that is the global climate. The immense amount of data, of variables, measurements, projections, has to be condensed into forms that can be understood despite their internal complexity. However, a process like this involves many actors and points of translation, in which the knowledge is made to adhere to narrative and visual structures that are familiar. As Hulme shows, the reductionist approach can have a tendency to push ourselves out of the situation we are very much a central part of, creating a socially disembodied climate and a future controlled by climatic changes rather than humanity's response to those changes. Climate models creates futures, the stories they enable have wide-reaching effects on the way anthropogenic climate change is addressed politically,

[157] I use the term neo-environmental to point to the political tendency to see climate change as a problem that should be addressed through technological solutions rather than through political action. See Meyer and Guss, *Neo-Environmental Determinism*, 89-91.
[158] Mike Hulme, "Reducing the Future to Climate: A Story of Climate Determinism and Reductionism", *OSIRIS*, 26:1 (2011), 264.

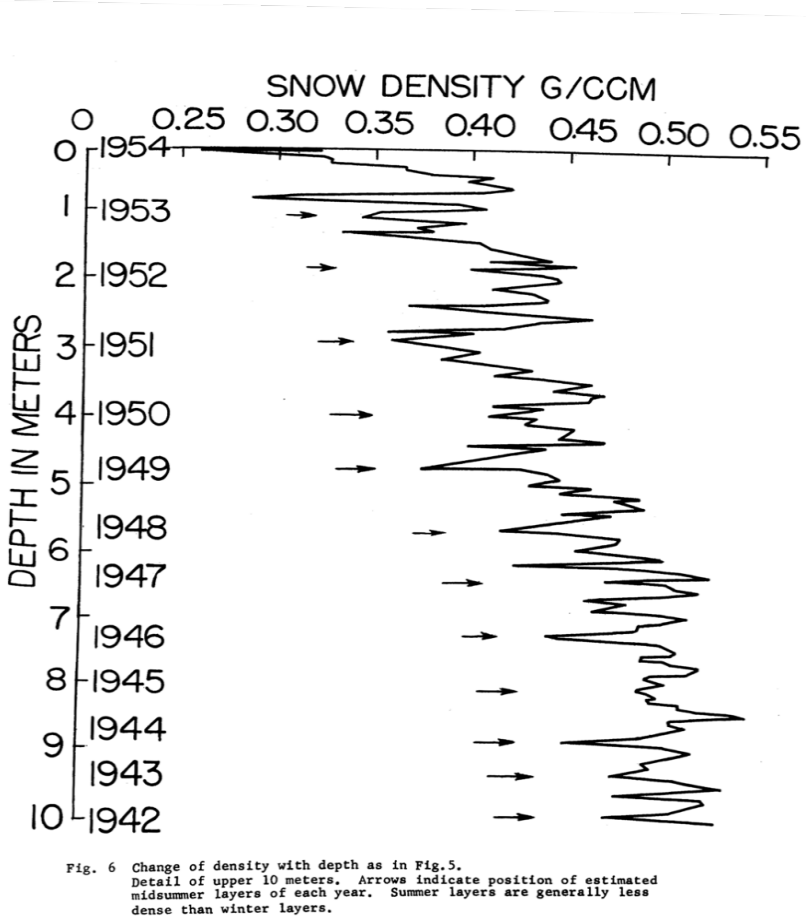

Fig. 6 Change of density with depth as in Fig.5. Detail of upper 10 meters. Arrows indicate position of estimated midsummer layers of each year. Summer layers are generally less dense than winter layers.

Figure 2. Henri Bader's diagram of the Greenlandic snow cover from 1957. [159]

culturally and scientifically. As the notion of human impact on the climate is no longer new, but rather an intertwined aspect of environmental geopolitics – 2022 will mark the 50th anniversary of the first UN summit on the global environment, the Only One Earth-conference held in Stockholm 1972 – the social history of climate models has undergone several transformations. In this thesis I have payed attention to the way ice cores became enrolled into an emerging climate discourse and how their temporalities were made to fit narratives of planetary disasters previously associated with the Cold War nuclear terror balance. The way ice cores became iconic markers of climate change was not a neutral process, but the outcome of highly specific events, institutions and political circumstances. However, as climate models are reified and stabilized within political discourse, their historical situatedness as well as their politics are made invisible. Therefore, I see this

[159] Henri Bader, "US Polar Snow and Ice Studies in the International Geophysical Year", presented at a special meeting of the US National Committee for the IGY, June 27, 1957, appendix.

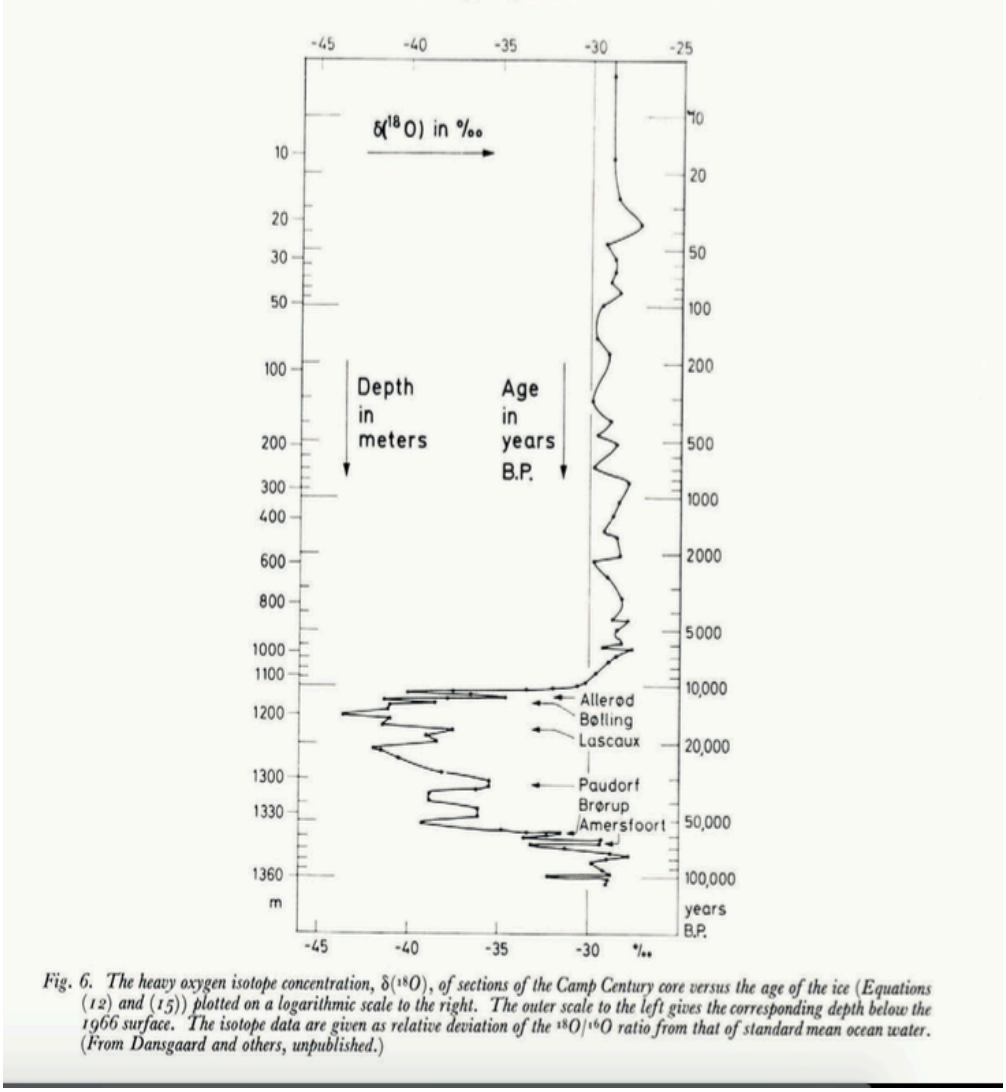

Fig. 6. The heavy oxygen isotope concentration, δ(18O), of sections of the Camp Century core versus the age of the ice (Equations (12) and (15)) plotted on a logarithmic scale to the right. The outer scale to the left gives the corresponding depth below the 1966 surface. The isotope data are given as relative deviation of the 18O/16O ratio from that of standard mean ocean water. (From Dansgaard and others, unpublished.)

Figure 3. Camp Century timescale. [160]

thesis as an, albeit small and limited, contribution to the work of critically examining the tendency to not only reduce the future to climate, but to reduce the past to climate icons.

When Ukichiro Nakaya created his artificial snowflakes in the 1930's, the models he created enabled him to create a temporal bond between the atmospheric conditions and the snowflakes that hit the ground. Glaciology could, through the worlds he made visible, expand its spatial imagination upwards to the sky. 20 years later, when Nakaya visited

[160] Dansgaard & Johnsen, "Flow Model and A Time Scale For the Ice Core From Camp Century, Greenland", *Journal of Glaciology,* 8:59 (1969), 226.

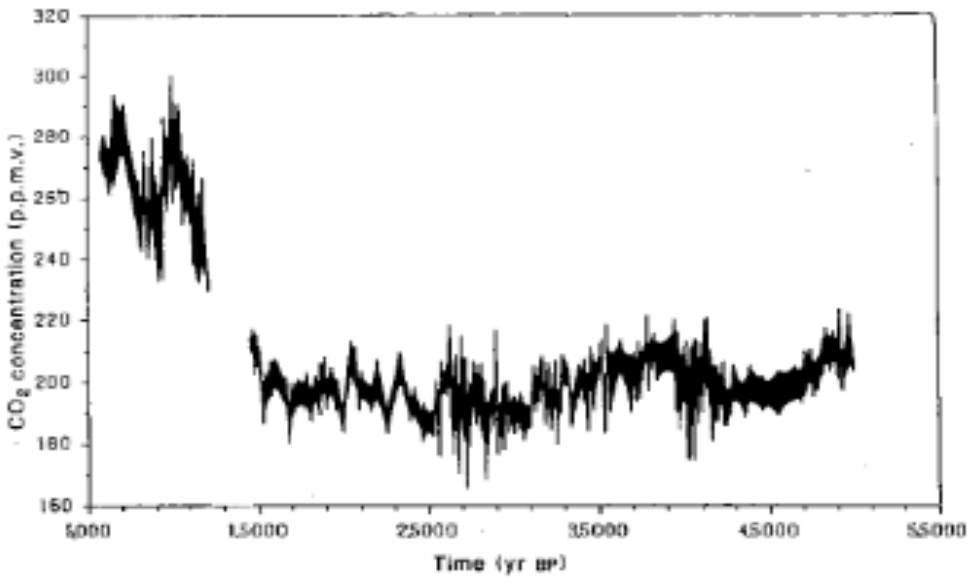

Figure 4. CO2 record from the BYRD ice core, 1988. [161]

Greenland, new scientific practices and geopolitical conditions had redirected his gaze from the sky to the ground, from the present to the past. As the ice cores began to materialize and draw attention to the possibilities of the interior environments, of the verticality of the cryosphere, they were also beginning to be represented in a visual form, modelling the new spatiotemporal conceptualizations that had emerged. From Henri Bader's rudimentary diagram presented before the NSF committee in 1957 to the timescale published after the Camp Century ice core in 1969, the ice core was finding its form as a representation for changes in – as is the case in Bader's diagram – the Arctic's climate as well as – in the Camp Century timescale – the global environment. In the timescale published after the Camp Century ice core (figure 3) had been recovered, the vast temporal framework and the more complex relationship between depth and time makes it a representation that can transcend its location in the Arctic. While following the same vertical spatiality as Bader's diagram, the Camp Century timescale does however, by invoking and situating previous glaciations and interstadials from the Quaternary period (Allerød, Bølling, Lascaux etc), add a new horizontal dimension: the ice core is not isolated to the ice sheet it is immersed in, instead the verticality of the ice core is connected to global phenomena appearing at various moments in deep time. This representation enables an analytical back and forth between vertical and horizontal, the local and the global.

[161] H. Neftel, and H. Oeschger et. al., "CO2 Record in the Byrd ice core 50,000 – 5000 years BP", *Nature*, 331:6157 (1988), 611.

Lastly, looking at later visual representations of ice cores, as exemplified in the CO2 record from the Byrd ice core, recovered from the Antarctic ice sheet in 1988, the vertical form from the IGY as well as Camp Century has been substituted for a horizontal outlook. The year count has wandered from the y-axis to the x-axis, making it visually adhering to other iconic models – such as the Keeling curve – in its form. In this thesis, I have not had the space to venture into the later history of how ice cores have been utilized, visualized and enrolled into climate policy and discourse during the 1980's and onwards. However, future research could further investigate the ways in which ice cores have been brought into climate discourse and which temporalities, geographies and politics they have made possible after the 1970's. I also hope that this thesis, albeit in a limited way, has shown how it can be a worthwhile activity to study the scientific production of temporalities, particularly with regards to climate change and the Anthropocene.

As the global climate is undergoing drastic, anthropogenically caused, changes, the way we get to know the temporalities of the global climate is increasingly a matter of concern outside the natural sciences. By historicizing the ways in which the temporalities of climate change were produced, represented and enrolled into broader conceptual assemblages, historians of science can add important perspectives to the debates on how to tell the time in the Anthropocene.

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