



HAL
open science

From Poles to Laboratories Stages in International Cooperation in Palaeoclimatology (1955–2015)

Morgan Jouvenet

► **To cite this version:**

Morgan Jouvenet. From Poles to Laboratories Stages in International Cooperation in Palaeoclimatology (1955–2015). *Revue française de sociologie*, 2016. hal-02003635

HAL Id: hal-02003635

<https://hal.science/hal-02003635>

Submitted on 14 Feb 2019

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

FROM POLES TO LABORATORIES

Stages in international cooperation in palaeoclimatology (1955-2015)

Morgan Jouvenet

Translated by Peter Hamilton

Presses de Sciences Po | « *Revue française de sociologie* »

2016/3 Vol. 57 | pages 563 - 590

ISSN 0035-2969

ISBN 9782724634693

This document is the English version of:

Morgan Jouvenet, « Des pôles aux laboratoires : les échelles de la coopération internationale en paléoclimatologie (1955-2015) », *Revue française de sociologie* 2016/3 (Vol. 57), p. 563-590.

The English version of this issue is published thanks to the support of the CNRS

Available online at :

https://www.cairn-int.info/article-E_RFS_573_0563--from-poles-to-laboratories.htm

How to cite this article :

Morgan Jouvenet, « Des pôles aux laboratoires : les échelles de la coopération internationale en paléoclimatologie (1955-2015) », *Revue française de sociologie* 2016/3 (Vol. 57), p. 563-590.

Electronic distribution by Cairn on behalf of Presses de Sciences Po.

© Presses de Sciences Po. All rights reserved for all countries.

Reproducing this article (including by photocopying) is only authorized in accordance with the general terms and conditions of use for the website, or with the general terms and conditions of the license held by your institution, where applicable. Any other reproduction, in full or in part, or storage in a database, in any form and by any means whatsoever is strictly prohibited without the prior written consent of the publisher, except where permitted under French law.

From Poles to Laboratories Stages in International Cooperation in Palaeoclimatology (1955–2015)*

Morgan JOUVENET

Abstract. Ice core science (ICS) is a palaeoclimatology speciality which aims to reconstruct the dynamics of past climates from laboratory analysis of ice samples bored in Greenland and Antarctica. Polar terrain specifics and geopolitical issues associated with these territories explain why it has been characterized, from its beginnings, by strong international cooperation. This article reports on the meaning and forms of cooperation, focusing on the organization of field campaigns by scientists, and how such fieldwork is coordinated within networks of mobilization of fragile climate archives—a globalized infrastructure connecting the poles to laboratories. The analysis of the development of ICS reveals the initial influence of the cold war on international scientific cooperation. It also shows how this speciality has consolidated its activity beyond this context, transforming the nature of the poles and contributing to the debate on global warming. The multidimensionality of the “internationalism” at the heart of this field is an empirical fulcrum that supports enquiries into the treatment of context in science studies, and the conclusion of the paper provides evidence to that effect.

Keywords. CO-OPERATION—GLOBALIZATION—PALAEOCLIMATOLOGY—SCIENCE STUDIES—TRANSNATIONAL STUDIES

Several observers (e.g. Ravetz 2006, Pestre 2010) have linked the prominence of environmental issues, since the 1970s, with a significant evolution of the place of science in society. Climatology in particular is a testament to the importance of environmental sciences—sciences of observation and complexity, the results of which are regularly commented on in the public domain. The paleoclimatic component of these results is fundamental, insofar as it makes it possible to situate the issue of climate change within the long term, supporting the understanding of its determining parameters and the projections of its probable evolutions. One of its flagship specialities, ice core science (ICS) has, since the 1960s, been able to capture the rhythms and forms of climatic variations, and to clarify the role of greenhouse gases in these phenomena. It is, however, largely absent from the literature of the

Translated by Peter Hamilton with the support of CNRS-INSHS.

This article has benefited from my discussions with Michel Dubois, Yves Gingras and Claude Rosental, the guest editors of this special issue, “Internationalization of Scientific Research” of the Revue Française de Sociologie. The comments of anonymous reviewers have also been helpful in improving it. I would like to thank them all for their suggestions, as well as Nicolas Dodier, with whom I was able to discuss a previous version. I am also grateful to all the paleoclimatologists who took part in the survey used here, and in particular to those who, as well as welcoming me into their laboratories, have provided access to important documents and observations.

academic field of Science & Technology Studies (STS), which has done very little to clarify how knowledge about past climates is produced: it is an understatement to say that, unlike the sciences of the atmosphere and oceanology. “glaciology and paleoclimatology remain under-studied.”¹ ICS researchers have gone as far back as 800,000 years by examining samples of polar ice collected at 3,000 meters below the surface (in Antarctica), with a resolution that (in Greenland) may be seasonal. The quality of the data thus produced (by analysis of the chemical composition of the ice samples and the air they contain) depends as much on the experiments performed in the laboratory as it does on a fieldwork practice that is highly structuring for the ICS community. From this point of view, it is a bipolar domain, not because its subjects come from the two poles, but because it is based on a network enabling the circulation of researchers and their objects of study between the field and the laboratory.

This network is international, and highlights the coordination work carried out across borders since this community has emerged. This article thus aims to understand the forms, meaning and issues around this constant “internationality” (as well as their development) rather than to analyse a case of the progressive “internationalization” of a scientific domain. More precisely, its goal is to answer a question that has two aspects, bearing on both the specificities of the object of research (fragile samples of polar ice) at the heart of this scientific field, and on those of the period of its development (which was when the geopolitics of the polar regions evolved and the issue of climate change started to become prominent): what sociological relations can be established between these specificities and the forms of scientific cooperation in ICS?

“By definition,” wrote one of its actors. “research in polar environments [...] is conducted in a totally internationalized framework” (Jugie 2007, p. 44). The words used by ICS researchers themselves point in the same direction: despite its small size, estimated at 200 people, “the first characteristic of this community is that it is very international” (t-NM); “It’s clear that it is a truly international science” (c-GL).² The scientific breakthroughs of the ICS are therefore presented as the outcome of large-scale international programmes, organized in the “big science” mode (Galison and Hevly 1992),³ and coordinating the deployment of field resources, the distribution of samples from boreholes (the “ice cores” [ICs]), and the division of experimental work. The ratio of international co-publications is high (see, for example, Jouzel 2013), and some famous articles have been signed by consortia such as the European Project for Ice Coring in Antarctica (EPICA), which brought together researchers and technical experts from a dozen countries (and in 2009 received the Descartes prize for science awarded by the European Union). The national flags and emblems that adorn the spectacular images of these polar campaigns illustrate this international dimension; they also emphasize the fact that scientists are funded by national institutions that can have very different reasons to support and enhance their presence at the poles. Therefore, if the process of internationalization often highlighted as being characteristic of the development of ICS can be described in

1. As noted by Robert E. Kohler in an overview of the historiography of the “field sciences” (Kohler 2011, p. 218).

2. Extracts from interviews with researchers are followed by the note c-XX, and those with technicians by t-YY. XX and YY are initials randomly assigned to an individual.

3. The institutionalization of its international cooperation mechanism after the Second World War had already led Pyne to describe polar glaciology as a “big science” even before its paleoclimatic branch asserted itself (Pyne, [1987] 2004 284). Elzinga (1993: 102) makes the same comparison.

terms of setting up a system (linking actors, institutions and instruments) whose scope and effectiveness have been enhanced by the increasing prominence of the climate change issue—such as the “vast machine” analysing the Earth’s atmosphere (Edwards 2010)—one might also assume that these flags and banners are not unimportant and think that they help us not to confuse “globalization” with the erasure of national differences. The reference to “globalization”⁴ often conceals “networks of transnational relations of inclusion (and exclusion),” which can reveal “nodes and blockages as to movement; regulation and control as much as circulation and fluidity” (Krige 2014b, pp. 229–30, p. 244);⁵ we will see in particular what the history of the ICS owes to the geopolitical stakes attached to Antarctica—and to their “sublimation” (Elzinga 1993, p. 87) within the status of scientific reserve awarded to it by a treaty signed in 1959.

The extent of the coordination and circulation networks that support the work of the ICS paleoclimatologists thus prompts a “transnational study of science” centred on “flows of people, goods, ideas or processes” (Turchetti, *et al.* 2012, p. 320), able to reveal how—by what actions and under what conditions—actors “can transform

BOX.—*Survey methods*

The empirical material used here comes from an ongoing investigation into the history and sociology of ICS in France. This survey is based on data collection combining several approaches:

—A series of interviews (of two hours on average) with researchers and technicians in this field (n = 20), men and women from three generations (from the PhD students to the CNRS Research director-emeritus), and members of the three laboratories working on ICs in Saclay, Grenoble and Aix-en-Provence.

—A series of interviews (an hour and a half on average) with climatologists (outside the ICS domain) and actors from French research institutions (n = 13).

—Ethnographic observations made in and around the laboratories: observations of measures made on experimental devices, discussions around instruments, participation in an IC cutting session in a storage warehouse, sharing of formal (project meetings, PhD defences, etc.) and informal moments (coffee, canteen, trips, etc.) in laboratory life.

—The analysis of public and private archives (1955–2015): archives of the DGRST and the French Ministry of Research (reports and evaluations, planning documents, letters, etc. concerning research policy in climatology), laboratory archives (multi-year reviews, project reports, presentations of scientific events, etc.) and those of researchers (letters, newspapers, draft publications, etc.).⁶

—Analysis (qualitative and quantitative) of documents: scientific and popular literature, communications from research organizations, amateur and professional films, press articles.

4. In Paul Edwards’s work, globalization through this “machine” describes both the expansion and intensification of international cooperation and the improvement in the coverage of scientific data.

5. Similarly, the studies collected in Malard, Paradeise and Peerbaye “highlight the

challenges and sources of conflict between the different forms of political authority brought about by the globalization of science” (2009, p. 31).

6. NB: Only the private archives of researchers on the topic of international cooperation were used directly for this article.

worlds through connections they build” in frontier spaces, far from their laboratories (Pestre 2012, p. 429–30). The study of the transcontinental dynamics of the ICS shows that these conditions are both natural and socio-historical, since scientists’ practices depend as much on the properties of the polar terrain (and samples from it) as on the resources provided to them by national or international agencies. But it also illustrates how, in return, a scientific speciality can accumulate credibility and influence international relations (Weiss 2015) by helping to change (the perception of) nature. To analyse this dynamic, I will examine three levels of activity that are crucial for the ICS domain: 1) that of cooperation between scientists, in the field and in meetings that prepare for drilling campaigns; 2) that of the system for sharing polar ice samples, which ensures the circulation of them from the poles both to laboratories and between laboratories; 3) that of the international relations centred on these territories, which modulate the occupation of the scientific field according to political and strategic rationales. It is not possible here to provide a detailed account of the texture of each of these levels. The multidimensionality of the internationalism characteristic of the ICS, however, makes it possible to reflect on the context of scientific practice, on how we can articulate different sites and levels of action to grasp the development of a scientific domain, and I will present some elements of this reflection in the conclusion.

International cooperation in the field

Whilst the work of the laboratories is clearly apparent from the articles published on the analysis of ICs in *Nature*, *Science*, *Climate of the Past*, the *Journal of Geophysical Research*, the *Journal of Glaciology*, etc., the evocation of the field itself is minimal, and is expressed most often through the spatial (place, depth) and time (date of extraction, age of ice) coordinates of the IC samples used. Field practices are the kind of tacit know-how and implicit knowledge that scientific writing makes largely invisible. On the other hand, in the interviews with the researchers and in the memoirs they have published (Lorius 1993, Jouzel, *et al.* 2008, Lorius and Carpentier 2010, Petit 2013, Alley [2000] 2014, Mayewski and White 2002), the activities pursued in and around the bases, between “landscape” and “labscape” (Kohler 2002), occupy a prominent place. These stories reflect the impact of the natural features of their field on the culture of scientists. Indeed, they show how much their stays on the ice mark the mind of the researcher and the collective identity of the ICS community, because of the specificities of the natural spaces where they work, but also the collective living conditions that these impose on teams that are in most cases international. The stories about the “human adventure” of the field are therefore also indicative of an experience of the international dimension of the ICS that is both very concrete and fundamental for its researchers. I will begin by presenting the elements of a sociology of “the social drama of work” (in Hughes’s sense, 1976) in the field, making it possible to reconstruct this experience from these stories.⁷

7. As in Sharon Traweek’s “interpretative anthropology,” I am here referring to the meaning given by scientists to their activities and interactions (1992, p. 101). In her study, the aim was essentially reveal the cultural differences that are expressed around the instruments of “big science” (1988).

The scientific polis on the ice: solidarity and “extreme” science

Beyond the relatively simple actions they have to perform during drilling, field trips have obvious cognitive virtues for researchers (“we understand things merely by being on the ground and looking at the area,” c-DW). They are also moments of socialization into a specific culture and history (Rudwick 1996, refers to the “*rites de passage*” for geologists), handed down from generation to generation during interactions in isolated bases or camps. The singularity and impact of these trips for researchers travelling to Greenland and Antarctica,⁸ is explained both by the conditions of collective life on site and the harshness of the local climate—the former being largely a function of the latter. Their stories thus underline these “peculiar congenialities arising from a common pursuit and mutually shared privations and perils” (following a formula used by Herman Melville about whalers in *Moby-Dick*), and as such should be analysed in terms of the history of field sciences (Vetter 2011, p. 9).

The isolation of the polar terrain is seen as a model for testing the acclimatization and cooperation capacities of individuals (Grevsmühl 2016). For the researchers of the ICS, this experience is coupled with their encounters with different national cultures, which sheds more light on the relative deprivation of life on the spot. International comparisons thus pepper the stories of the organization of the camp’s “domestic” activities and festive moments. The strangeness of alcohol consumption,⁹ a taste for the sauna, or the musical arrangements of the Soviets, for example, have thus given rise to many considerations about the cultural diversity of the population of polar scientists and technicians. Life on site is enlivened by the discovery of national culinary or sanitary habits,¹⁰ in a schoolboy-like spirit of defying the boredom or even the cold (at the North Pole, one can “go around the world” immediately one comes out of the sauna). “It’s a cultural sharing [...] It’s sort of the great side of globalization” (c-EZ). In this perspective, international cooperation enlivens life on the ice, in a way that can appear to be anecdotal, but which is ultimately one of the essential idiosyncrasies of polar fieldwork.

The fieldwork stories are also useful as staging of the erasure of differences (that are national, but also hierarchical and statutory: the difficult conditions “smooth-out the hierarchy,” c-BS), in the collective synergy of the exploration of sites and the extraction of scientific materials. The evocation of the almost exclusive concentration on group work, and of being cut off from the hassles of daily domestic and occupational life justifies the comparison with a pleasant utopia: “it’s a life that is relatively simple: we get up, we go to work, we eat, we go to bed. It’s monastic simplicity.” (t-MI); “It’s truly pleasant.... you don’t think about your keys, you don’t think about

8. ICs can also be extracted from mountain glaciers, but the information collected does not have the same relevance for paleoclimatology, particularly because of their lower depth and more pronounced movement.

9. Simultaneously a marker of differences and a factor in social integration, alcohol occupies a special place in this folklore in which the figure of the virile adventurer is a long-standing feature.

10. “With the Italians, you know that you will be eating very, very well ... whereas the

English, they have a completely different vision of that. [...] For them, it has to be a Shackleton-like thing. A warrior thing [...] as for the Italians, they were all happy to have a shower every day. The English, if they could have one shower a week, they were thrilled! [...] it was fun to see these differences in culture.” (t-RR). “The French person will go out more often into the cold, they’re more ‘roots’ ... the Italian likes his slippers [...] he likes contact with nature to be a bit less brutal.” (c-DW).

your credit card pin number.”(t-RR); “It’s almost a utopian form of society ... an ideal way of life.” (c-HV). Researchers and technicians also insist on the strength of rapprochements and convergences between residents, which give the polar base the trappings of an idealized cosmopolitan and scientific *polis*.¹¹ Speaking back in Pennsylvania after a long ice-core drilling campaign, a US scientist wondered “why the ‘real world’ couldn’t be a bit more like” the base he had just left (Alley [2000] 2014, p. 30). Similarly, one of the researchers interviewed for the survey said that “after 9 weeks [in the field], when we met on the subway at 5 pm, I thought ‘but what are we doing here? We are completely crazy’” (t-NM).

Maybe “polar solidarity makes it easier to reach an agreement there than elsewhere?” wondered one of the pioneers of the ICS (Lorius and Carpentier 2010, p. 49). His remarks and those of his colleagues indicate that this solidarity has natural and cultural determinants, evoking both the cohesion necessary for life in extreme environments and the sharing of a scientific mission focussed on the global climate. The slogan of Richard Byrd, a US explorer, is well-known: “in Antarctica everyone had to unite against the cold” (cited in Pyne [1987] 2004, p. 351), and the stories of the accidents on the ground (falls into crevasses, fires on the bases, plane crashes ... “So basically, the plane exploded before my eyes ...,” c-LM) indeed prompts us to include the ICS among the “extreme sciences”—much as there are “extreme sports”—whose practices are particularly dangerous (Kohler 2011, p. 229).¹² If today’s researchers emphasize the relative comfort of the current bases and equipment—compared to those of the first two generations of researchers—isolation and cold, as well as the need to move away from the bases to search for new drilling sites, mean that ICS still falls within the historical tradition of the heroes of polar exploration. For Lorius, “the division between adventure and science has no place, they are the two sides of the same human curiosity” (Lorius and Carpentier 2010, p. 30), and the figure of the “scholar-adventurer” (“savanturier”, in Etienne in Hauglustaine, *et al.* 2008, p. 6) is still very important in the culture of this scientific field.

It is, however, a scientific mission that brings together men and (increasing numbers of) women on this terrain, and the concern for this mission is another pillar of the polar cosmopolitan city. This concern is reflected in a very obvious and concrete way through the collective efforts made to conduct the ice-core drilling, to carefully prepare the samples (cutting, labelling ...) for future laboratory analyses, or even to start this analysis work with the instruments (increasingly) taken to the field. An example of cooperation (or maybe “coopetition”?) Is given by teams of drillers, who, although they engage in a form of international competition that is as playful as it is fierce (“what interests us at the end of the day? It’s how many metres we have done [...] Even if we all get along, we are still happy to have gone down 5 metres more at the end of the day than our friend.” t-MI), do not hesitate to help each other in case of breakdown and blockage. The history of the ICS is marked by such episodes of scientific solidarity sealed in the field, offering a strong contrast with an “outside world” disfigured by national borders. It seems obvious that the sharing of

11. I use this term to emphasize the mythological character of this representation of an “independent political community” (see *Trésor de la langue française*, article on “Cité,” subst. fém., I.) which associates spatial proximity and simplicity of exchange in terms of the organization of collective life.

12. “On the frontier of Antarctica triumph and death are inseparable companions,” is emphatically written on the half-title page of one of the first works on science in Antarctica, dedicated to the memory of a scientist who died in the field (Lewis 1965).

difficult living conditions and the discovery of common scientific objectives, within the framework of an emerging speciality, has indeed made it possible to “forge very strong bonds, especially for those who have [had] the chance to meet in the field” (Jouzel, Lorius and Raynaud 2008, p. 109). And the contrast was certainly at its peak during the Cold War, when American, French and Soviet scientists were able to take advantage of the Antarctic Treaty framework, notably, to develop “international cooperation in a place without a homeland” (Lorius and Carpentier 2010, p. 162). The polar terrain then appears as the home of a community able to mitigate if not to protect its members from the political accidents of history. Thus, the ties established in the Antarctic between French and Soviet researchers¹³ explain why, during the collapse of the USSR in 1991, the former got together to find funding for the latter to continue their activities (as shown by several archival documents).

The premises of the internationalist rhetoric of the scientific *polis* can already be found in the “field” practices of 18th century scholarly travellers (Sörlin 1993, p. 67). Among the early ice explorers, in particular, it counterbalanced another rhetoric, that of the national rivalry of the race to the poles (*ibid.*). This oscillation persisted in the scientists who followed in their footsteps in the twentieth century, and Elzinga has emphasized the gap between their internationalist ideals and the debt their research practices owe vis-à-vis the national interests that generated agreements like the Antarctic Treaty (1993, pp. 78–9, p. 83; see below. “The geopolitical instrumentalization of science”). But one might equally understand the field practices at the core of ICS as a means of paying off this debt, insofar as it is a demonstration of the effectiveness of international scientific cooperation with global benefits. In the field culture of the ICS, the polar bases thus represent a kind of border post, an outpost of civilization—where international cooperation is both necessary and transcended, in a scientific humanism centred on the future of the planet.

The organization of international campaigns: sharing and coordinating

Field work is intense because stays on the ice are relatively short: in Antarctica, from October to February, during the austral summer. In addition, the cost of drilling campaigns is very high. These constraints mean that great importance is devoted to their preparation. International cooperation thus goes far beyond the fieldwork itself and aims to define both the objectives of research and the sharing of scientific and logistical tasks. We thus have drilling equipment for which “France makes the mechanics, Italy the electronics, and Switzerland takes care of the winches.” (t-MI). This division of labour also has effects on the movement of people: “We cannot dissociate the existence of [ICs] from polar logistics [...] We need substantial logistical resources, we need boats, we need planes, we need caterpillar vehicles, we must be able to keep a team of 5 to 40 people alive and healthy in a place that is not made for humans in any way [...] And this is one of the reasons why this science is very international.” (c-BS). A scientist from another French laboratory provides an eloquent illustration: “This year, I went out with the Germans [...]. Our [equipment] came by icebreaker from South Africa to the German base. We flew out with the

13. These ties that were all the more remarkable because Soviet science was very isolated in this period with only 4% of publications being co-authored with foreigners in the early 1980s (Crawford, *et al.* 1993, p. 4)

Russians. We arrived at the Russian base and after that, we took small planes that are managed by the Canadians, in order to take us to our German base [...] it's like that, we share the logistics so that everyone can get there. (c-EZ).

Researchers stress that ties created in the field facilitate the preparation phases. The first decades of the ICS's history were punctuated by the arrangements between the few "big bosses" (PI) most active at the time ("country-to-country relations were done through a few individuals," c-VB), in a setting that could often be very informal. One of the participants remembers "that there was not much of a feeling of being under national flags while we were there" (Lorius and Carpentier 2010, p. 39), and to begin with coordination continued to be rather informal. In addition to the "working saunas" that brought them together in Leningrad, there was also a "summit meeting" in 1994 between French and Russian scientists "in Papy Garnier's little hotel at the Col de Porte" (Isère, France), with two representatives of the Antarctic glaciology programme at the US National Science Foundation (NSF), where "overnight, a new cooperation project was launched" (Petit 2013, pp. 151, p. 181–2).

Although they were able to count on the support of institutions such as the Scientific Committee on Antarctic Research and the World Meteorological Organization (Turchetti, Naylor, Dean & Siegert 2008) for these meetings that were intended to set scientific objectives and discuss the resources that would be available for the next drilling campaign, researchers nevertheless had to obtain the necessary financing from their supervisory authorities. National differences are then more pronounced, depending on the credibility given to ICS in each country. The significant presence of Soviet researchers in the history of this co-ordination should not conceal the fact, for example, that their employer (the Leningrad Mining Institute) was far more interested in drilling techniques and logistical exploits than in the production of paleoclimatic data. The friendly relations that formed in the confined spaces of the first polar camps did not prevent their French colleagues from grasping the benefits to be gained. "The science of one for the experience and the logistics of the other was in a way the basis of the deal concluded between France and the USSR" from the 1960s (Petit 2013, p. 81). One of the organizers of these rapprochements takes "great pride" (c-VB) nowadays in having American and Soviet scientists work together during the Cold War, and this cooperation is certainly a highlight of the history of ICS. However, it would be wrong to see this as the sole consequence of the ties made on the ground. Not long after this tripartite collaboration, as the United States announced its willingness to resume leadership in drilling, Lorius also noted that "if we want to benefit from the support of the NSF, which is faster and more efficient by far than the Soviet logistics, we will have to let something go, so we should collaborate. But as long as we do, we need to choose our partners, so that our areas of research do not overlap too much" (Petit 2013, p. 150). The "marriage of convenience between France and the United States" of the late 1980s was the result of this observation—which opened the door to the Soviet base at Vostok and as a result provided an access to its IC to the Americans. One of the actors in this first tripartite cooperation refers to "the Vostok dowry" brought by the French (*ibid.*, p. 157), though not without concerns as to its relational consequences on the ground. But, finally, "at the cold Pole, geopolitical tensions seemed a long way away," recalls J-R. Petit, before going into details about the happy cohabitation between researchers from the three nations (*ibid.*, p. 159).

The US participation in drilling campaigns with Europeans and the Soviets also reveals the sensitivity of international cooperation to national research policies and

priorities in a very costly logistical field such as ICS. Faced with the difficulty of convincing the National Science Foundation to fund their activities in 1987, US scientists sought a partnership with the Danes, who organized what has become a famous meeting in Boston, following which two boreholes were implemented, with shared logistical costs. Both “would start the same year and the results would be used in close collaboration” (Jouzel, *et al.* 2008, pp. 107–10). Conversely, the renewed credibility that ICS has recently acquired from research institutions in the United States has enabled their scientists to regain the foreground (Jouzel 2013, p. 2530) and has moved them away from the rest of the international community. “We do not have projects with the Americans [...] because they have budgets that are much higher than what we can get, and they manage to do their business on their own” (t-MI); “Having all the logistical means available, the Americans did not necessarily need to create a collaboration to set up a project [...] this is what might give the impression that they are a little inward-looking” (c-XB).

Coordination remains, however, very important between European nations, and with the recent newcomers to the field of ICS (Jouzel, *et al.* 2008, p. 118), and all the more so as it becomes more difficult to add significant added value to palaeoclimatic knowledge, and to produce an a priori justification for the higher costs of new deep drillings for the funding agencies.¹⁴ One of the goals set “for the next ten to twenty years” by the International Partnerships in Ice Core Science (IPICS), which brings together researchers from 23 nations, is “to access Antarctic ice formed 1.5 million years ago” (Raynaud and Chappellaz 2008, p. 133). But it is very difficult to know where to find this ice, and therefore impossible to request funds for this drilling today. “The cost of the logistics [on this project] is such that we must not make a mess of it. In the end, if we do mess it up, too bad for us, because we will not get a second chance.” (c-EZ)

The important international coordination set up around these new drilling projects is therefore on the one hand concerned with demonstrating their technical feasibility and designing new tools to assess the age of the ice more than three kilometers below the surface with relatively light and flexible equipment,¹⁵ and on the other hand about how to lobby the European Commission, so as to promote the compatibility of ICS community projects with its financing priorities (those of H2020 for example), whilst at the same time securing the support of the polar research institutions (e.g., the European Polar Board). Interviews with researchers confirmed that this dimension of international cooperation (of which one model could be that provided by the community of astrophysicists, c-NM) now needs more efforts than it did in the last decades of the twentieth century, during which the institutional credit of the ICS grew in an optimal way, following the spectacular results of the 1980s and 1990s. The creation of IPICS in 2002 was an important marker of this new phase in the history of the speciality, and one that was revealing of the new modalities and constraints of international cooperation.

14. In the 1980s. “coordination was extremely simple. Very close connections. But we were doing very rudimentary science. Now we are doing sophisticated science, and the equipment is very expensive.” (c-OT).

15. This was the aim in particular of the joint “Ice and Laser” (ERC) and “Subglacier” (ANR) projects, led by the French scientists Jérôme Chappellaz and Olivier Alemany. Swiss, British and US scientists are also developing similar instruments (see Witze 2015).

Emails mails exchanged on the IPICS mailing list dedicated to the “Oldest Ice challenge” show finally that this coordination arena is also a space of differentiation of national contributions: the discussions seek in particular to define the price of the “entry ticket” paid by different nations to this project—in other words the level of funding that participants will need to obtain from their national agencies to ensure privileged access to future ICs of record age.

The transnational mechanism for using and sharing ICs

Once extracted from the subterranean land of Antarctica and Greenland, a proportion of the ICs are stored on site, in the “best fridge in the world” (c-BS). Others are transported around the world, to laboratories where they will be analysed, or to associated storage centres where they will remain at the disposal of researchers. This network of IC “mobilisation” (Latour 1987, 1999), involving continents and countries, is another manifestation of the transnational character of ICS, an essential component of the “vast machine” (Edwards 2010) ensuring the globalization of climate knowledge—more precisely the more focussed “sharp machine” designed by the physical and institutional infrastructure of ICS.

The infrastructure of globalization: the “cold chain” of ICS

The development of ICS can be described, on another level, through the setting up of an IC sharing network, a “cold chain” which is in a sense the nervous system of the community.¹⁶ The organization of this sharing is connected with that of the drilling campaigns, and involves decisions about determining the distribution of objects and the management of their transportation, by air, sea and road—and further reinforces the international dimension of the network of the ICS.

The report of a drilling campaign published in *Nature* illustrates “the extraordinary logistics” that allows ICs to be transported to the “centres of calculation” (Latour 1987) that are the laboratories, and where they will be destroyed during analyses of their composition: these logistics “involved mechanics, drillers and scientists from five nations as well as the storage and transport of more than 2,500 m³ of ice. The ice was first flown from [the drilling site] to the coastal Italian station [in Antarctica], and then brought back by ship to European laboratories—at temperatures permanently below –25 °C—to preserve the climate signal in the ice. The ice cores were cut and processed [in a German research centre]” (Frezzotti 2011). It is therefore not surprising that tributes to logistics are common in the stories of researchers. For example, Richard B. Alley writes that the airborne resources

16. In a perspective “marked by field science,” Simon Schaffer demonstrated the advantages that this type of network could offer (as a “material and normative arrangement”) for the understanding of the dynamics of the “globalization” of science. (Van Damme 2014). Other historians who want to dispense with too great a focus on conceptual innovations have also analysed how a scientific community can emerge by grasping a new object and organizing its circulation between various research teams, *i.e.*, by transforming a natural object into an instrument of scientific production (see Kohler (1994) on the *Drosophila* fly: the process of exchange “defines social and moral principles,” for the community of “Drosophilists,” by creating “standard practices and a distinctive way of experimental life” (p. 168).

of the 109th US National Guard Division “have revolutionized polar research” (Alley [2000] 2014, p. 22). One of his French colleagues is as much an admirer of the US C130 Hercules freight planes as he is of the Soviet *Kharkovchanka*—a tracked snow truck weighing over 30 tonnes (Petit 2013).

One can also see, once again, that the ownership of these means of transport (most often of military origin) suitable for transporting equipment and personnel to and from the polar ice, such as the permanent bases in Greenland and to an even greater degree in Antarctica, introduces a certain asymmetry in the negotiations between scientists that is related to national differences. The geography of the domain, with its migratory flows and its decision-making and processing centres, is from this point of view quite remote from the “seamless fabric” sometimes superficially associated with the globalization of and by the sciences, but also from the idealized scientific “city” or *polis* which materializes in the eyes of the actors in the field. This finding is further reinforced when the flow of ice stored near laboratories and the modes of access to scientific objects is taken into account.

The sharing of ICs: co-operation and competition in the network

“If you have the ice, they will end up asking you as an indispensable interlocutor to discuss the terms of collaboration,” said C. Lorius after providing access to valuable ICs drilled by his Soviet friends (Petit 2013, p. 151). “To keep some control over things and to always stay in the game, not to be sidelined, you must have the [ICs],” confirms one of his colleagues (c-OT). Access to samples is now more formalized than during the first decades of ICS,¹⁷ and the question of access to scientific objects is largely decided even before the drilling process, during the preparation phase of campaigns, and depending on the projects, know-how and resources of each party. But while half of the samples “go halfway round the world on laboratory benches” (Jouzel and Debrouse 2007, p. 32), the other half are kept as archives, either in the field or in storage on warehouse shelves where they might stay for several years before being analysed.

The drilling campaigns thus aim more broadly at feeding a stock of climate archives, that are theoretically available to the entire international community. Participation in major field campaigns ensures not only direct access to ICs, but also the management of this stock, through advisory consortiums to which researchers must make their requests for the samples they are interested in. “Money and science are intertwined in a way ... [...] because to have access to an [IC], you have to have paid to begin with for logistics. And so after that it’s not just anyone who can have access to the ice and publish anything. So that’s why, it’s a kind of control on each other, [to see if] we do not exceed our borders and our rights.” (c-KS). This component of the infrastructure allows the community to manage the scientific exploitation of ICs, both within and possibly beyond the perimeter of the consortium owning them, and thus to overcome the limitations of its know-how, both synchronic (at the same time, other teams can produce alternative analyses) and diachronic (the

17. The evolution of these formalities testifies to the inventiveness of scientists in terms of the regulation of research networks. Maurice Cassier has defined a research programme on this subject, based on the analysis of a mechanism for managing competition and cooperation in a network of public and private biotechnology laboratories (Cassier 1998).

constant evolution of the instruments makes it possible to envisage that the ICs will one day be the subject of new analyses, that were unforeseen at the start) know-how.¹⁸

“There is scientific gold in the sample [...] it’s a bit like the moon rocks.” (c-LM); “When you have ice [from deep drilling], it’s a bit like having a piece of the moon or a piece of a comet ...” (c-OT) This rarity, combined with the fragility of the ice, implies a form of collective stewardship¹⁹ distributed through all levels of the community. This responsibility starts with the self-censorship of researchers, which is a form of passive regulation of the stock, especially when the coveted ice is rare (because either drilled at great depth²⁰ and /or from a place very difficult to access). “We self-censor ... because [the risk is that] a few years later, we’ll have someone who comes up with a great machine or a great idea and we will have wasted this ice for nothing.” (c-PL). Another researcher states in an additional ice request email to the scientific committee of a project, that to begin with she would prefer to request only a few deep ice samples, so as “not to spoil the ice” through the risk of storing it in a not wholly reliable place during the time it will take to conduct her experiments. “It’s rather precious. There is not much ice there, we won’t be able to go back to where we’ve already drilled because it costs millions, so we’ll always go to a new place. And suddenly, if it all goes wrong [with an IC], there will be a dip in the curve. So that puts pressure on you anyway.” (c-EZ).

E-mail exchanges between researchers involved in an ongoing international project reveal a form of coordination that reminds one of Russian dolls: for example, many discussions take place between the members of the group responsible for analyses of the gases trapped in the IC in order to collect new requests and eliminate any conflicts before submitting a request for additional ice to the consortium’s scientific committee. In these exchanges, the person in charge of the formalization of this request found that he had to warn his colleagues that: “if there are only 25 or 30 centimeters [of such a sample], we will have to discuss it ...” Another unexpected request requires him to remind researchers of the “shared policy” of keeping samples of all sections of the IC (“although I find the content of your project exciting, it also poses a problem to me insofar as it involves the use of all remaining ice in these sections”) and asking if they could continue their experiments with only two-thirds of the requested sections. These exchanges also concern the time and the means of the transfer between the field (where the conservation conditions of the ICs are perfect and inexpensive) and the laboratories; all the more so because certain experiments

18. This margin of manoeuvre can be exploited as soon as IC is extracted in the field, to add some measures to the programme defined at the start of the project. An e-mail exchange initiated by a researcher from Antarctica thus results in a request to the steering committee of his consortium’s project, in which he presents the scientific value of the measurements that he wishes to carry out on the spot, but also the ideal conditions in which he is to perform them (local temperatures, on field instruments, etc.), as well as his extensive experience in the matter.

19. I borrow the term from museum vocabulary. The ice stocked by a laboratory is

entrusted to a “curator” (the insider term, one also used in museums), who is responsible for the spreadsheet files listing the samples, their characteristics (length, provenance, etc.), places of storage, and possible attributions to research groups. I observed that these files are kept with great care and foster many exchanges of information between scientists (it is particularly crucial to know how many centimeters remain of each sample).

20. The longest ICs, i.e. those that can be traced back to the last interglacial period, are of course the rarest: seven cores were drilled in Greenland and a dozen in Antarctica (Jouzel 2013, p. 2525).

require the maintenance of the IC at very low temperatures (up to -50°C) and therefore specific means of transport and storage.

We see that this IC user network ensures the extension of international coordination of research teams well beyond the field drilling campaigns, by fostering a considerable flow of information within the community. Access to additional ice in fact requires the development of a (brief) scientific rationale to be shared with peers, to convince them of the need for the destruction of part of the glaciated archives already in store: the justifications advanced in these requests at least give visibility to other researchers' projects downstream of the fieldwork. In some cases, co-operation can emerge when similar experiments are envisaged by colleagues. Finally, while ice often circulates thanks to the services of specialized transporters, it is often the case that the researchers themselves will travel to cut it (which is another ritual, as I observed), and meetings on the spot with colleagues provide additional opportunities to discuss planned experiments, outside the more classical academic circuits as defined by colloquia and publications.²¹

The management of the flow of ICs appears from this point of view to be a collective instrument of international coordination adapted to the specificities of the objects, or even as an infrastructure allowing for the correction of the possible difficulties posed by unequal access to the field, even though scarcity of ice can lead to certain tensions in a context of classical scientific competition²² (especially when a team whose national agencies do not contribute to the drilling campaigns forgets the "customs" [t-RR] and does not hesitate to increase its demands on the "secondary market" of the IC economy).

ICS in the context of international relations: natural spaces and political projections

The international dynamics of ICS point to another level, which this time is a wider one than the organization of its scientific community. While the natural peculiarities of their favourite terrains and the objects they handle inevitably mark the occupational culture of paleoclimatologists, the geopolitical history of Greenland and Antarctica is also a factor that cannot be overlooked when grasping the forms and meaning of the internationalism in this scientific domain.

Denmark's privileged links with Greenland explain why, for example, Danish researchers have been closely involved in the Arctic history of ICS, for reasons which cannot only be due to the unchanging interest of its rulers in paleoclimatology. Similarly, the installation of a United States base in Greenland in 1958, where the first deep drilling would take place, depended less on local potential scientific resources than on its location on the most direct route between the United States and the USSR. But this geopolitical influence is perhaps even more obvious for the scientific activities that have unfolded on the most distant Antarctic continent, on which this last section of the article will focus.

21. Similarly, what constitutes "state of the art" in high energy physics is transmitted orally through talk and gossip around the instruments (Traweek 1992: 126).

22. "We are always between collaboration and competition [...] and the frontier is tenuous" (c-DW); "The competition is always there, and we feel it." (c-PL).

Geopolitical instrumentalization of science

The history of science in Antarctica is marked by two events that occurred in quick succession: the organization of the International Geophysical Year (IGY: 1957–1958), which made it possible to organize extensive field measurement campaigns and, subsequently, the signing of the Antarctic Treaty in 1959 (ratified in 1961 by twelve countries), which made this continent an area exclusively reserved for scientific activities (Pyne, [1987] 2004, Fogg 1992, Elzinga 1993, Launius, *et al.* 2010, Walton 2013). This period has since often been presented as that of the successful experiment of a geopolitical “thaw” over disputed territory of the Cold War era,²³ through the magic of international scientific cooperation.

The analysis of recently de-classified archives has made it possible to specify the geostrategic bases of the “regime of cooperation” from which the “polars” benefited at the time, related to the military and commercial interest of the control of the oceans surrounding Antarctica, and the “specific threat represented by the presence of Soviet bases” there. It is only because these motivations were known only to a few diplomats that this regime could appear to be an expression of “scientific internationalism” (Turchetti, *et al.* 2008, pp. 351–2, 368).²⁴ “Antarctic science has been [...] a way in which nation states have maintained a presence on the continent [...] and collected geostrategic intelligence” (Naylor, *et al.* 2008). Thus, the definition of Antarctica as a location for scientific activity does not mean that international rivalries were suddenly erased, but rather that they were transferred to the scientific field - and ultimately mitigated by the necessities of life on the hostile ice sheet (see the earlier section on “*The scientific community on the ice: solidarity and extreme science*”).²⁵ The Antarctic Treaty is today considered to be an opportunist “political exploitation of scientific good will,” that allowed “imperial interests” to be “frozen” (according to the official pun written in its section 4) rather than “brought to an end” (Howkins 2010, 246, pp. 260–1).

These agreements created the conditions for participation in discussions about sending researchers to the area, and those in ICS may thus have the legitimate feeling of being among the beneficiaries of the Treaty (Lorius and Carpentier 2010, p. 14). If at the time “the idea that the polar icecaps contained privileged archives was still not massively present in the programmes” (Jouzel, *et al.* 2008, p. 97), it was nonetheless one being expressed by scientists (Lewis 1965, pp. 146ff.). And the research funds allocated for this occasion gave them the possibility of conducting an *in situ* exploration drawing on ideas expressed in 1954 by the Danish scientist W. Dansgaard on the isotopic composition of ice (Dansgaard 2005). These research grants “would notably make it possible to develop drillers” (Jouzel and Debroise 2007, p. 26) and, in a book devoted to science in Antarctica and written shortly thereafter, the ICs brought back in 1958 by the USS Glacier and containing the

23. See for example the preface and by Margaret Thatcher to Fogg (1992) and the afterword Michel Rocard (“La force de l’amitié a sauvé l’Antarctique” [The power of friendship has saved the Antarctic]) to Lorius and Carpentier, (2010).

24. See, for example, C. Richard Lewis and Philip M. Smith (1973), *Frozen Future. A Prophetic Report from Antarctica*, which presents

this regime as “a new experience of civilization” based on peaceful relations.

25. Similarly, the sharing of satellite data and the concept of World Weather Watch are “directly derived” from Cold War politics, in the sense that they were designed as “a counterweight to military and ideological tensions” (Edwards 2010, 14).

sections of the first deep US ICs were described as “the raw, unprocessed data for one of the most ambitious experiments of the IGY” (Lewis 1965, p. 146).

The political support then provided to the researchers who would define the cognitive and material bases of ICS was also based on the symbolic importance attached in many countries to the exploration of a territory that remained little known at the time. In this perspective, “the prowess [of scientists] could symbolize the superiority of one political ideology over another” (Naylor *et al.* 2008), to be perceived as the expression of a “soft power” (Nyen 2004) in an era when national power was closely linked to scientific and technological advances (Oreskes and Krigen 2014). The scientific expeditions were thus perceived as “national prowess, to try to show that one system was better than the other,” as a “demonstration of the ability to go anywhere, wherever you want, on the planet “(c-XB). Thus, the logic of the setting of the bases from which the researchers worked betrays the permeability of the polar sciences vis-à-vis these rationales of conquest: “the USA, for instance, claimed the symbolic South Pole as the site of one of its stations during the IGY, leaving the Soviets the much less prestigious Pole of Relative Inaccessibility and the Geomagnetic Pole” (Naylor *et al.* 2008, p. 145). On the other hand, whilst the construction of a base in the extreme conditions of the South Pole by the Americans was “a classic example of technological and scientific bravado,” this effort was no doubt surpassed by the Soviet installations at the site furthest from the Antarctic coasts (Howkins 2010, p. 255).

The spectacular logistical resource involved in polar exploration also lends itself to this type of evaluation, inscribing scientific advances in the lineage of the exploits of the first explorers (some of whom have attained the status of national heroes). The development of ICS, in particular, relied on the implementation of ice-core drilling (in remote areas, on record-breaking summits for cold and wind-speed, etc.) that could be considered a scientific and human achievement. At the end of the 1960s, the Antarctic ice sheet saw “a form of remote challenge between the drillers of the Cold Regions Research and Engineering Laboratory of the US Army and those of the Leningrad Mining Institute” (Peti 2013, p. 86). “The Soviets did everything. On principle. They were very strong in logistics. [They travelled millions of kilometers] just to raise the flag. So [...] they went to the pole of inaccessibility, [they] put up a statue of Lenin [...]. We were in the midst of the cold war, and the Americans had got down to 2,138 meters at Byrd. The program of the Soviets in Vostok was to drill in the ice. Why? To reach 2,200 meters” (c-OT). In contrast to the image of the Ideal Polis associated with the polar bases (cf. “The scientific community on the ice: solidarity and extreme science”), which offered to overcome national rivalries from the point of view of the scientists, in scientists’ eyes the status of these “national” exploits have instead helped to erase the traces of cooperation in the field.²⁶

The national interest in supporting the polar sciences, however, went beyond the symbolic level of “national radiance” (Hecht 2009 [1998]). The importance of the technical means necessary for scientists to travel to and work in Antarctica also made it possible for the military to remain there, in the background, in support of scientific activities. This support is also a way to continue the deployment of strategic resources in a muted fashion. Numerous studies have shown how research carried out in the field often benefits from the ambivalent patronage of the military

26. Krige also demonstrates this in relation to France’s celebration of the launch of its first rocket, *Véronique*, in 1959 (2014b, pp. 227–8).

(see Grevsmühl 2014): simultaneously a constraint and a resource, it allowed scientists to work during the Cold War in “semi-autonomy,” on technological experiments at the borderline between basic and applied research, military and civilian (Krige 2014a, pp. 431–3). The stories of the first-generation researchers do not mention a dialogue about anything other than the essential provision of their vehicles. Whilst this almost exclusively logistical dimension of the link between the military and ICS scientists is necessarily less constrained than is the case for their colleagues funded to work on the upper atmosphere (for rockets) or the salinity of water (for submarines),²⁷ for example, it was not without importance. Polar logistics was at the time an “important lever” for a US administration concerned with “playing a leading role in the organization of Antarctic affairs” Turchetti, *et al.* 2008, p. 353; see also Belanger 2006). And it seems obvious that the paleoclimatologist campaigns offered instructive in-situ tests for the US Air Force’s Hercules C130 aircraft and their new navigation instruments,²⁸ or for the Soviet’s impressive polar tractors. A participant in the first tripartite expeditions (France–USA–USSR) also said that “the political commissar of the [Soviet] base also came to see American planes ...” (c-VB).

Capturing the dynamics of a “field science” like ICS thus entails not only considering the natural peculiarities of the environment but also its political history, which exposes researchers to critical resources and constraints. In this case, we also understand the interests of countries that previously had a foot strategically placed in Antarctica, such as France, in supporting the involvement of its researchers in international programmes initiated with the IGY—without, however, the authorities of such countries taking a close look at the content of the research (Elzinga 1993, p. 96). The international fibre of ICS appears here in a more contrasted light, intertwining the threads of scientific and political cooperation on a canvas drawn by strategic rivalries.²⁹

ICS and the “climate regime”

Although this was unpredictable at the time the Antarctic Treaty was signed, the development of climate science would come to change this geopolitical framework. The most documented example is that of stratospheric research made at the South Pole, which revealed the existence of a “hole” in the ozone layer in 1985. The work done at the same time by ICS paleoclimatologists on climate cycles and the impact of greenhouse gases has also made a major contribution to changing the status of polar territories. Studying “the invention of the global environment,” Grevsmühl underlined “the historical role of the Antarctic region in the profound change of our global spatial conceptions, especially in discourses on the limits of the Earth

27 Naomi Oreskes (2014a) shows how difficult it has been for areas that the military has been very supportive of during the Cold War to change their “motivational context.” On the question of the autonomy of scientists in this type of context, see the analysis by Simone Turchetti and Peder Roberts (2014a, pp. 8–12).

28. “Unwittingly, the military has made tremendous progress for us in our field because they have always wanted to have electronics that

resisted –50°C. For other reasons of course. And so that was really useful in all the technology that [we scientists] used in Antarctica.” (c-GL).

29. Similarly, in the field of space technology and science in the 1960s and 1970s. “the patterns of international collaborations” are closely dependent on the foreign policies of governments, which embeds “geopolitical relationships [...] in the networks through which knowledge flows” (Krige 2014b, p. 230).

and how to understand them” (Grevsmühl 2014, p. 15). Since it was uninhabited, Antarctica was still largely unknown before the IGY (Howkins 2010, p. 245), and it might be said that from this point it rapidly became “an integral part to a world economy of knowledge” (Pyne, [1987] 2004, p. 325), or even “to have been constructed through science” (Elzinga 1993, p. 77)—a science increasingly focused on the issue of climate change (Howkins 2011).³⁰

Contrary to that of the IGY of 1957–1958, which was imbued by the cold war, the “political context” of the International Polar Year of 2007 was marked by the theme of “climate change,” as one of *Nature*’s columnists noted when it drew to an end.³¹ This observation may seem very banal nowadays. But in fact it hides a large-scale reversal, which has affected scientists’ investment in polar terrain, the political conditions for their support, and the sense of international cooperation between paleoclimatologists.

In recent decades, the issue of global environmental pollution has emerged as a major issue of public concern (see, for example, McNeill 2010). This issue “emerged publicly both as a concern in public opinion, a major issue of state policy, and a scientific domain” (Ingold 2011, p. 11), and for many observers it has significantly redefined the “Science-society contract,” and renewed the relationship between “knowledge and power” (Pestre 2010, Ravetz 2006). This evolution was very visibly expressed with the development of climate science, which during this period dispelled many uncertainties weighing on the nature of climate change and the role of greenhouse gases in the ongoing process of global warming (Weart 2008, Oreskes 2004). In the STS literature, the paradigmatic nature of this development is not only related to the increase in publications on the subject, but also to the “major political implications” of this knowledge, which explains that “a strong interaction exists today between science and political decisions, the discourses of interest groups, whether pro-industry or pro-environment” (Gingras 2010, p. 126). This interaction has led several authors to evoke the emergence of a “climate regime” (Aykut and Dahan 2014) whose genealogy is now well established, from the first world climate conference in Geneva (1979) to the signing of the Rio Framework Convention (1992), and including, along the way, the establishment of the Intergovernmental Panel on Climate Change (1988).

I am not concerned here with detailing this evolution here, but with pointing out that the emergence of this “climate regime” has transformed international geopolitics, and thus the way states project themselves on the polar territories, as well as the relations between scientific communities and their employers. Following the Antarctic Treaty, science was used as a political adjunct to “thawing,” in order to defuse a latent territorial conflict (see above, “The geopolitical instrumentalization of science”); it has since asserted itself as a source of knowledge prompting international action, in the most cooperative possible form—and even as a reserve of “symbolic political capital,” as Elzinga rightly points out in relation to ICS (1993, p. 79). In other words, if international geopolitics has an impact on the activities of ICS, this does not have the same meaning as it did at the time of the first campaigns. Following Latour’s formula “that a Nobel Peace Prize should be awarded to the

30. For the Arctic see Doel *et al* and Martin-Nielsen (2013).

31. “The Ends of the Earth. International Polar Year 2007 Can Leave an Imprint,” *Nature*, 446, 110, 8 March 2007, p. 110.

IPCC [in 2007] is proof enough that the whole of geopolitics is shaken by the matter of mathematical modeling of the Earth's climate" (2008, p. 659). But it must also be remembered that during the Cold War, it was the sciences—and in particular the earth sciences (Doel 1997 2003, Turchetti and Roberts 2014b)—which were “shaken” by geopolitical issues.

It is certainly debatable whether this reversal is solely due to scientists (Bonneuil and Fressoz 2013). On the other hand, it seems difficult to deny that their contribution has been decisive, and ICS ranks high among the specialities that have made it possible to better understand the dynamics of the Earth's climate (notably by following the variations in the atmosphere of greenhouse gases such as CO₂ and methane) and to objectify the sensitivity of the Earth's climate to certain “forcings.” From this point of view, ICS has transformed its polar terrain and changed its perception in international relations: the work and testimonies of its researchers gave new reasons for the political protection of the poles and their sciences, by opening “a door to a problem at the heart of the concerns of our society today” (Jouzel, Lorius & Raynaud 2008, p. 280). Whereas, as Lorius points out, no one was “worried about the atmosphere of the past in 1965” (Lorius and Carpentier 2010, p. 38), the situation had become noticeably different by 1987, when *Nature* published a front cover with the results of his team on the correlation between rising temperatures and greenhouse gas content, producing graphs that then went “right around the world, including political spheres” (Jouzel, Lorius & Raynaud 2008, p. 122), and that have become “icons” of the IPCC (c-GL). “[In the mid-1970s], people were laughing! They joked and said ‘these things in the ice, it's not serious’ ... [Today] we are recognized ... we have become a science, everyone wants it. For us, it was really amazing as an adventure. Because we started from something anecdotal and became a recognized discipline.” (c-EV). In France, the level of this recognition is striking: despite its small size (about twenty tenured members plus students and postdocs), the French community has two CNRS gold medals (2002), a Niels Bohr medal (2014), a Vetlesen prize (considered as the “Nobel of Sciences of the Earth and the Universe,” 2012), an Irène Joliot-Curie prize (“Female French scientist of the year,” 2013) ... And, today, the media and politicians do not hesitate to quote from the books of ICS researchers, who, with one foot in their laboratory, another in the field,³² present polar ice as an observatory of the differences between Holocene and “Anthropocene,” “sentinels of our environment,” “windows on our planet,” a “balcony with breathtaking views of the Earth” or “witnesses and key players in global warming” (Hauglustaine, *et al.* 2008; Lorius and Carpentier 2010, Jouzel, *et al.* 2008).

Environmental historians have shown how the fluidification (in a quite literal sense) of wheat transformed both Chicago and its native lands (Cronon 1991), or how the seeds brought back from the colonies changed the “ecological” consciousness of the colonizers (Grove, [1993] 2013). Similarly, the flow of ICs between poles and laboratories has helped to change the nature of the poles.

32. The virtues of direct contact with the field provide scientists with much greater authority in what they say compared to what they would have enjoyed if they had remained in their laboratories (see White 1996; Hevly 1996). From this point of view ICS figures combine two types of credibility (on the antagonistic and intermingled history of these types, see Kohler 2002, pp. 9–10 in particular). “It's a bit like Darwin, isn't it? You go somewhere far away, you cut some ice, you discover something new.” (c-LM)

Finally, ICS appears to be a field whose leading figures have been able, from the flexible political framework shaping their initial investments in the field, to build a credibility allowing them to emancipate themselves from it within a few decades—and thus to survive the disappearance of the political rationales of mobilization dating from the Cold War. This analysis leads me to agree with Krige when he argues (versus Forman 1987) that scientists have managed to get rid of a relationship of dependence on political authorities by taking advantage of the “forms and terms of their social integration” during the Cold War (Krige 2014a, p. 431), to the extent that ICS researchers found in this loose political framework a reason to justify their research funding beyond it.³³ “We were the lucky passengers of a geopolitics we had nothing to do with. And [...] we gave the scientific justification ... that allows us to do [science] ...,” summarizes a scientist (c-EZ). The emergence of concerns about climate change and the political will to promote scientific cooperation at European level were the catalysts for this transition between the 1980s and 1990s: the results produced by the ICS in the late 1980s were so strong that “there has been a fairly spontaneous trust on the part of Europe in this scientific community” (c-BS). “The value of this area has been widely recognized,” confirms another researcher: “Europe has put a lot of money into our projects in the 4th and 5th Framework Programme” (r-LM).

That said, the impact of paleoclimatic knowledge on international relations has not been uniform: it cannot be said that it has involved all nations in the same movement to safeguard the planet. Although it is difficult for them to ignore this scientific discourse magnified by international institutions like the IPCC (which has had “significant leverage” in the credibility of the ICS, c-BS), their governments are more or less sensitive to it (Aykut and Dahan 2014). This discourse could even in the near future be caught up in new and potentially revolutionary geopolitical struggles at the polar level, if the technical difficulties (of drilling through the ice), the natural barriers (via melting ice) or the regulatory ones (including the end of the moratorium of the Madrid Protocol, signed in 1991) prohibiting the exploitation of energy resources in Antarctica were to disappear. The paradox is that the contribution of some countries to the progress of climate knowledge—and thus to the image of the poles as “climate sentinels”—has probably been based, as it still is today, on the probability of future exploitation. It can be seen once more how a great deal of international scientific cooperation in the field may be based on very diverse rationales.

*
* *

The range of empirical manifestations of the internationalism of ICS appears as a heuristic lever to reveal the influence of the specificities of the scientific object on the organization of a field of research, as well as the sensitivity of the forms of cooperation between researchers on geopolitical issues (related to the polar regions, in their case).

33. One of the themes of the book that Krige’s chapter concludes is the ability of certain research areas (oceanography, isotope geochemistry) or institutions (e.g. NASA) to legitimize their existence beyond the context of the Cold War and in the “climate regime”.

Beyond the observation of the wide range of factors in the development of scientific specialties,³⁴ the multidimensionality of the internationalism provides empirical support for reflections on the treatment of the context and historicity of science. So, to conclude this article, I would like to offer some thoughts on this curiously under-researched question in the history of science (dixit Shapin 1992, Galison and Stump 1996, Galison 2008, Oreskes 2014b). Compared with the “macro” or “micro” approaches that have punctuated the dominant alternating currents in the sociology of science in recent decades (Gingras 2013), the sociology of the “intermediate” objects constituted by scientific specialities actually encourages closer attention to the “multiscopic” formula (Rosental 1996, p. 141) which fed “the redefinition of the notion of context” in history, bringing to an end in particular the idea “that there could exist a unified, homogeneous context” and instead taking into account their plurality (Revel 1996, pp. 25–6, 30). Rather than dividing the history of ICS into “regularly spaced temporal sections to take stock of their similarities and differences,” I prefer to adopt the Braudelian model of the “moving chart” (*tableau en mouvement*) here (*ibid.*, pp. 33–4), exploiting the diversity of viewpoints on the object: this is one of the virtues of the “game of scales” (*jeux d’échelles*) that make it possible to “identify the systems of contexts” in which actors act (Lepetit 1996, pp. 79–81).

Transnational studies encourage us “to play more consciously with scales” (Pestre 2012), and the historical sociology of science sketched in this article indeed implies taking into account the “multilayered” character of the story of the development of a speciality like ICS. Each of these levels refers to different relational configurations, each with their own dynamics (and temporalities). In the case of ICS, these show that we must temper the rhetoric of fluidity and “erasure of borders” often associated with the description of scientific networks as “seamless fabrics” (see Shinn and Ragouet 2005). Analysis of the forms of internationality of ICS shows in particular that grasping the process of scientific “globalization” requires an understanding the arrangements, but also the competition, that may exist between different national communities. In this picture, borders count as places of passage and friction. Fidelity to Thomas Hughes’s “seamless fabric” formula should lead us to consider this fabric as the result of a collective work process—and not as the work plan of the actors (Gingras 1995, p. 124). In other words, even a “total history [in the Braudelian sense] of scientific activity” operates through “the integration and not the negation” of the plurality of actors and temporalities (*ibid.*, pp. 134–5).

In this perspective, we might follow Abbott and consider that if Braudel’s scheme offers “a starting point,” the principle of the hierarchical interlocking temporalities that drives it, allotting primacy to the long term, must be abandoned in order to open up the construction of a theory of links between levels (Abbott 2001, p. 194). No level “commands” another, *a priori*: these links are effectively changing and open to empirical investigation on the articulation of “lineages” of activity and their consequences. It is therefore necessary not only to identify processes with different rhythms that inform social entities, but also to think how these processes can “condition one another” (Abbott 1991, pp. 224–5, see the example of the Chicago School in Abbott 1999, as well as Jouvenet 2016). Thus, in the case of the development of

34. This is a classic result in science and technology studies, at least since the 1970s (see Dubois, 1999). And especially so as the study is about a form of “big science” which gives wider visibility to the social intermingling and the diversity of the resources on which scientists rely (Galison and Hevly, 1992, 17, pp. 356–7).

ICS, it is necessary to distinguish the dynamics specific to each level, but also the continually possible impact of one level on the others—by asking for example how the agreements made at the intergovernmental level (such as the Antarctic Treaty) are able to guide international cooperation among scientists, or allow analyses made from ICs taken in the polar ice sheets to help transform the nature of the poles. The durability of this speciality in the scientific landscape can be explained by an unpredictable reversal (see *supra* “ICS and the climate regime”): while at the end of the 1950s the presence of scientists in Antarctica and in Greenland depended mainly on the political issues of the cold war, their fieldwork would lead to the production of knowledge that would prove decisive in the emergence of the “climate regime” which today largely determines the international involvement in these territories. Galison’s “structured narrative” of the contextual constraints guiding the international development of a scientific field,³⁵ seems insufficient here to capture its strength: this account is effectively intertwined with another narrative, which relates the way in which scientists have exploited the organizational resources and natural connections at their disposal to gain credibility and thus autonomy.³⁶ This case also shows that we should follow David Stump when he identifies the study of the reciprocity of influences between scientific practices and their “social context” as a path that could renew the thinking in STS about contextualization (Stump 1996, pp. 447–9). Although the arrangement of political and scientific reasons is a constant of the internationality of this scientific field, its meaning has greatly evolved. This arrangement is the result of work at the border (and of boundary-work) that remain to be clarified further, in order to better restore the whys and wherefores of the cross-overs of “lineages” of interactions (in the sense of Abbott) that punctuate the development of ICS.

Morgan Jouvenet

*Laboratoire Printemps
CNRS-Université de Versailles Saint-Quentin en Yvelines
UFR des Sciences sociales
47, boulevard Vauban
78047 Gutyancourt cedex
morgan.jouvenet@uvsq.fr*

35. “Galison wants to know [...] the impositions on knowledge and action that arise [...] from a very structured story about how various projects, techniques, cliques and long-term investments of intellectual as well as material capital determine the organization of research and thereby constrain the very kinds of things that can be found out” by scientists (Hacking, 1995, p. 6). This story is structured in two ways: on the one hand, these constraints have a history and, on the other hand, they act according to distinct temporalities, which Peter Galison formulates from the Braudelian model (Galison, 1995, p. 18).

36. From this point of view, one aspect of the dispute between Peter Galison and Andrew Pickering (1995), about the latter’s rejection of the vocabulary of “constraint” in favour of that of “resource” to grasp the historicity of scientific practices, seems superficial. As indicated by the remarks of Yves Gingras (1995) and Ian Hacking (1995), the two positions can be seen as complementary rather than contradictory (especially because they refer to different levels of analysis, one that is more “micro” for Pickering: his descriptive universe being that of the experimenter having to deal with the “resistances” and “resources” of his material system in the “temporality of practice”).

REFERENCES

- ABBOTT, A., 1991. "History and Sociology: The Lost Synthesis," *Social Science History* 15: 201–38.
- ABBOTT, A., 1999. *Department and Discipline. Chicago Sociology at One Hundred*. Chicago, IL: The University of Chicago Press.
- ABBOTT, A., 2001. *Time Matters. On Theory and Method*. Chicago, IL: The University of Chicago Press.
- ALLEY, R. B., [2000] 2014. *The Two-Mile Time Machine. Ice Cores, Abrupt Climate Change, and Our Future*. Princeton, NJ: Princeton University Press.
- AYKUT, S., DAHAN, A., 2014. *Gouverner le climat? 20 ans de négociations internationales*. Paris: Presses de Sciences Po.
- BELANGER, D. O., 2006. *Deep Freeze. The United States, The International Geophysical Year, and the Origins of Antarctica's Age of Science*. Boulder, CO: University Press of Colorado.
- BONNEUIL, C., FRESSOZ, J.-B., 2013. *L'événement anthropocène. La Terre, l'histoire et nous*. Paris: Le Seuil.
- CASSIER, M., 1998. "Le partage des connaissances dans les réseaux scientifiques : l'invention de règles de 'bonne conduite' par les chercheurs," *Revue Française de Sociologie* 39(4): 701–20.
- CRAWFORD, E., SHINN, T., SÖRLIN, S., eds, 1993. *Denationalizing Science. The Contexts of International Scientific Practice*. Dordrecht: Springer.
- CRONON, W., 1991. *Nature's Metropolis. Chicago and the Great West*. New York, NY: Norton.
- DANSGAARD, W., 2005. *Frozen Annals. Greenland Ice Cap Research*. Copenhagen: Niels Bohr Institute.
- DOEL, R. E., 1997. "The Earth Sciences and Geophysics," in J. KRIGE, D. PESTRE, eds., *Science in the Twentieth Century*, London, Harwood Academic Publishers, pp. 361–88.
- DOEL, R. E., 2003. "Constituting the Postwar Earth Sciences: The Military's Influence on the Environmental Sciences in the USA After 1945," *Social Studies of Science* 33(5): 635–66.
- DOEL, R. E., WRÅKBERG, U., ZELLER, S., 2014. "Science, Environment, and the New Arctic," *Journal of Historical Geography* 44: 2–14.
- DUBOIS, M., 1999. *Introduction à la sociologie des sciences et des connaissances scientifiques*. Paris: Presses Universitaires de France.
- EDWARDS, P. N., 2010. *A Vast Machine. Computer Models, Climate Data, and the Politics of Global Warming*. Cambridge, MA: The MIT Press.
- ELZINGA, A., 1993. "Antarctica: The Construction of a Continent by and for Science," in E. CRAWFORD, T. SHINN, S. SÖRLIN, eds, *Denationalizing Science. The Contexts of International Scientific Practice*. Dordrecht: Springer, pp. 73–106.
- FOGG, G. E., 1992. *A History of Antarctic Science*, Cambridge, Cambridge University Press.
- FORMAN, P., 1987. "Behind Quantum Electronics: National Security as Basis for Physical Research in the United States, 1940–1960," *Historical Studies in the Physical and Biological Sciences* 18(1): 149–229.
- FREZZOTTI, M., 2011. "Core of Ice," *Nature Geoscience* 4: 68.
- GALISON, P., 1995. "Context and Constraints," in J. Z. BUCHWALD, ed., *Scientific Practice. Theories and Stories of Doing Physics*. Chicago, IL: The University Of Chicago Press, pp. 13–41.

- GALISON, P., 2008. "Ten Problems in History and Philosophy of Science," *Isis* 99: 111–24.
- GALISON, P., HEVLY, B., eds, 1992. *Big Science: The Growth of Large-Scale Research*. Stanford, CA: Stanford University Press.
- GALISON, P., STUMP, D., eds, 1996. *The Disunity of Science: Boundaries, Contexts, and Power*. Stanford, CA: Stanford University Press.
- GINGRAS, Y., 1995. "Following Scientists through Society? Yes, but at Arm's Length!" in J. Z. BUCHWALD, ed., *Scientific Practice. Theories and Stories of Doing Physics*. Chicago, IL: The University of Chicago Press, pp. 123–48.
- GINGRAS, Y., 2010. *Propos sur les sciences. Entretiens avec Yanick Villedieu*. Paris: Raisons d'Agir.
- GINGRAS, Y., 2013. *Sociologie des sciences*. Paris: Presses Universitaires de France.
- GREVSMÜHL, S. V., 2014. *La terre vue d'en haut. L'invention de l'environnement global*. Paris: Le Seuil.
- GREVSMÜHL, S. V., 2018 (forthcoming). "Laboratory Metaphors in Antarctic History: From Nature to Space," in C. KEHRT, F. TORMA, eds, *Ice and Snow in the Cold War: Histories of Extreme Climatic Environments*. Oxford: Berghahn Books [forthcoming].
- GROVE, R. H., [1993] 2013. *Les îles du Paradis. L'invention de l'écologie aux colonies, 1660–1854*. Paris: La Découverte.
- HACKING, G. I., 1995. "Introduction," in J. Z. BUCHWALD, ed., *Scientific Practice. Theories and Stories of Doing Physics*. Chicago, IL: The University of Chicago Press, pp. 1–9.
- HAUGLUSTAINE, D., JOUZEL, J., MASSON-DELMOTTE, V., ed., 2008. *Atmosphère, atmosphère*. Paris, Le Pommier/CNAM.
- HECHT, G., [1998] 2004. *Le rayonnement de la France : énergie nucléaire et identité nationale après la Seconde Guerre mondiale*. Paris: La Découverte.
- HEVLY, B., 1996. "The Heroic Science of Glacier Motion," *Osiris* 11: 66–86.
- HOWKINS, A., 2010. "Science, Environment, and Sovereignty: The International Geophysical Year in the Antarctic Peninsula Region," in R. D. LAUNIUS, J. R. FLEGING, D. H. DEVORKIN, eds, *Globalizing Polar Science. Reconsidering the International Polar and Geophysical Years*. New York, NY: Palgrave MacMillan, pp. 245–64.
- HOWKINS, A., 2011. "Melting Empires? Climate Change and Politics in Antarctica since the International Geophysical Year," *Osiris* 26(1): 180–97.
- HUGHES, E., 1976. "The Social Drama of Work," *Mid-American Review of Sociology* 1(1): 1–7.
- INGOLD, A., 2011. "Écrire la nature. De l'histoire sociale à la question environnementale?" *Annales. Histoire, Sciences Sociales* 66(1): 1–29.
- JOUVENET, M., 2016. "Contextes et temporalités dans la "sociologie processuelle" d'Andrew Abbott," *Annales. Histoire, Sciences Sociales*, 71(3): 597–630.
- JOUZEL, J., 2013. "A Brief History of Ice Core Science Over the Last 50 Years," *Climate of the Past*. 9: 2525–47.
- JOUZEL, J., DEBROISE, A., 2007. *Le climat : jeu dangereux. Dernières nouvelles de la planète*. Paris: Dunod.
- JOUZEL, J., LORIUS, C., RAYNAUD, D., 2008. *Planète blanche. Les glaces, le climat et l'environnement*. Paris: Odile Jacob.
- JUGIE, G., 2007. "La station franco-italienne Concordia (entretien)" in L. MAYET, ed., *L'aventure polaire*. Paris: Le Pommier, p. 37–47.

- KOHLER, R. E., 1994. *Lords of the Fly. Drosophila Genetics and the Experimental Life*. Chicago, IL: The University of Chicago Press.
- KOHLER, R. E., 2002. *Landscapes and Labscapes: Exploring the Lab-Field Border in Biology*. Chicago, IL: The University of Chicago Press.
- KOHLER, R. E., 2011. "History of Field Science. Trends and Prospects" in J. VETTER, ed., *Knowing Global Environments. New Historical Perspectives on the Field Sciences*. New Brunswick, NJ: Rutgers University Press, pp. 212–40.
- KRIGE, J., 2014a. "Concluding Remarks" in N. ORESKES, J. KRIGE, eds, *Science and Technology in the Global Cold War*. Cambridge, MA: The MIT Press, pp. 431–41.
- KRIGE, J., 2014b. "Embedding the National in the Global: US-French Relationships in Space Science and Rocketry in the 1960s" in N. ORESKES, J. KRIGE, eds, *Science and Technology in the Global Cold War*. Cambridge, MA: The MIT Press, pp. 227–50.
- LATOUR, B., 1989. *La science en action*. Paris: Gallimard.
- LATOUR, B., 2008. "Pour un dialogue entre science politique et *science studies*," *Revue Française de Science Politique*, 58(4): 657–78.
- LAUNIUS, R. D., FLEMING, J. R., DEVORKIN, D. H., eds, 2010. *Globalizing Polar Science. Reconsidering the International Polar and Geophysical Years*. New York, NY: Palgrave MacMillan.
- LEPETIT, B., 1996. "De l'échelle en histoire" in J. REVEL, ed., *Jeux d'échelles. La microanalyse à l'expérience*. Paris: Gallimard/Le Seuil, pp. 71–94.
- LEWIS, R. S., 1965. *A Continent for Science. The Antarctic Adventure*, London, Secker & Warburg.
- LEWIS, R. S., SMITH, P. M., eds, 1973. *Frozen Future. A Prophetic Report from Antarctica*. New York, NY: Quadrangle Books.
- LORIUS, C., 1993. *Glaces de l'Antarctique. Une mémoire, des passions*. Paris: Le Seuil.
- LORIUS, C., ed., 2007. *L'aventure polaire*. Paris: Le Pommier.
- LORIUS, C., CARPENTIER, L., 2010. *Voyage dans l'anthropocène*. Arles: Actes Sud.
- MALLARD, A., PARADEISE, C., PEERBAYE, A., eds, 2009. *Global Science and National Sovereignty*. New York, NY: Routledge.
- MARTIN-NIELSEN J., 2013. "The Deepest and Most Rewarding Hole Ever Drilled: Ice Cores and the Cold War in Greenland," *Annals of Science* 70(1): 47–70.
- MAYEWSKI P. A., WHITE F., 2002. *The Ice Chronicles. The Quest to Understand Global Climate Change*. Hanover: University Press of New England.
- MCNEILL, J. R., 2010. *Du nouveau sous le soleil. Une histoire de l'environnement mondial au XX^e siècle*. Paris: Champ Vallon.
- NAYLOR, S., DEAN, K., SIEGERT, M., TURCHETTI, S., 2008. "Science, Geopolitics and the Governance of Antarctica," *Nature Geoscience* 1: 143–5.
- NYE, J., 2004. *Soft Power. The Means to Success in World Politics*. New York, NY: Public Affairs.
- ORESQUES, N., 2004. "Beyond the Ivory Tower: The Scientific Consensus on Climate Change," *Science* 306(5702): 1686.
- ORESQUES, N., 2014a. "Changing the Mission: From the Cold War to Climate Change" in N. ORESKES, J. KRIGE, eds, *Science and Technology in the Global Cold War*. Cambridge, MA: The MIT Press, pp. 141–87.
- ORESQUES, N., 2014b. "Introduction" in N. ORESKES, J. KRIGE, eds, *Science and Technology in the Global Cold War*. Cambridge, MA: The MIT Press, pp. 1–9.

- ORESQUES, N., KRIGE, J., eds, 2014. *Science and Technology in the Global Cold War*. Cambridge, MA: The MIT Press.
- PESTRE, D., 2012. "Debates in Trans-National and Science Studies," *The British Journal for the History of Science* 45(3) 425–42.
- PESTRE, D., 2010. "Dix thèses sur les sciences, la recherche scientifique et le monde social, 1945–2010," *Le Mouvement Social* 233: 13–29.
- PETIT, J.-R., 2013. *Vostok. Le dernier secret de l'Antarctique*. Paris: Paulsen.
- PICKERING, A., 1995. "Beyond Constraint: The Temporality of Practice and the Historicity of Knowledge" in J. Z. BUCHWALD, ed., *Scientific Practice. Theories and Stories of Doing Physics*. Chicago, IL: The University of Chicago Press, pp. 42–55.
- PYNE, S. J., 2004 [1987]. *The Ice*, London, Phoenix.
- RAVETZ, J., 2006. *The No-Nonsense Guide to Science*. Oxford: New Internationalist.
- RAYNAUD, D., CHAPPELLAZ, J., 2008. "Des gaz dans la glace" in D. HAUGLUSTAINE, J. JOUZEL, V. MASSON-DELMOTTE, eds, *Atmosphère, atmosphère*. Paris: Le Pommier/CNAM, pp. 117–37.
- REVEL, J., 1996. "Microanalyse et construction du social" in J. REVEL, ed., *Jeux d'échelles. La microanalyse à l'expérience*. Paris: Gallimard/Le Seuil.
- ROSENTAL, P.-A., 1996. "Construire le "macro" par le "micro" : Fredrik Barth et la *microstoria*" in J. REVEL, ed., *Jeux d'échelles. La microanalyse à l'expérience*. Paris: Gallimard/Le Seuil, pp. 141–59.
- RUDWICK, M. J., 1996. "Geological Travel and Theoretical Innovation: The Role of 'Liminal' Experience," *Social Studies of Science* 26(1): 143–59.
- SHAPIN, S., 1992. "Discipline and Bounding: The History and Sociology of Science as Seen Through the Externalism-Internalism Debate," *History of Science* 30: 333–69.
- SHINN, T., RAGOUET, P., 2005. *Controverses sur la science. Pour une sociologie transversaliste de l'activité scientifique*. Paris: Raisons d'Agir.
- SÖRLIN, S., 1993. "National and International Aspects of Crossboundary Science: Scientific Travel in the 18th Century" in E. CRAWFORD, T. SHINN, S. SÖRLIN, eds, *Denationalizing Science. The Contexts of International Scientific Practice*. Dordrecht: Springer, pp. 43–72.
- STUMP, D., 1996. "Afterword: New Directions in the Philosophy of Science Studies" in P. GALISON, D. STUMP, eds, *The Disunity of Science: Boundaries, Contexts, and Power*. Stanford, CA: Stanford University Press, pp. 443–50.
- TRAWEEK, S., 1992. "Big Science and Colonialist Discourse: Building High-Energy Physics in Japan" in P. GALISON, B. HEVLY, eds, *Big Science: The Growth of Large-Scale Research*. Stanford, CA: Stanford University Press, pp. 100–28.
- TRAWEEK, S., 1988. *Beamtimes and Lifetimes. The World of High Energy Physicists*. Cambridge, MA: Harvard University Press.
- TURCHETTI, S., HERRAN, N., BOUDIA, S., 2012. "Have We Ever Been Transnational? Towards a History of Science Across and Beyond Borders," *British Journal for the History of Science* 45(3) 319–36.
- TURCHETTI, S., NAYLOR, S., DEAN, K., SIEGERT, M., 2008. "On Thick Ice: Scientific Internationalism and Antarctic Affairs, 1957–1980," *History and Technology*, 24(4) 351–76.
- TURCHETTI, S., ROBERTS, P., 2014a. "Introduction. Knowing the Enemy, Knowing the Earth" in S. TURCHETTI, P. ROBERTS, eds, *The Surveillance Imperative Geosciences during the Cold War and Beyond*. New York, NY: Palgrave MacMillan, pp. 1–19.

- TURCHETTI, S., ROBERTS, P., eds, 2014b. *The Surveillance Imperative Geosciences during the Cold War and Beyond*. New York, NY: Palgrave MacMillan.
- VAN DAMME, S., 2014. "Laborieuse nature. Penser le travail des sciences exactes avec Simon Schaffer," *La vie des idées*, 27 May 2014, <http://www.laviedesidees.fr/Laborieuse-Nature.html>
- VETTER, J., 2011. "Introduction" in J. VETTER, ed., *Knowing Global Environments. New Historical Perspectives on the Field Sciences*. New Brunswick, NJ: Rutgers University Press, p. 1–16.
- WALTON, D. W. H., ed., 2013. *Antarctica: Global Science from a Frozen Continent*, Cambridge, Cambridge University Press.
- WEART, S. R., 2008. *The Discovery of Global Warming. Revised and Expanded Edition*. Cambridge, MA: Harvard University Press.
- WHITE, R., 1996. "Are You an Environmentalist or Do You work for a Living?: Work and Nature" in W. CRONON, ed., *Uncommon Ground: Rethinking the Human Place in Nature*. New York, NY: W. W. Norton & Co, pp. 171–85.