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"The ice edge is lost...Nature moved it": Mapping ice as state practice in the Canadian and Norwegian North

Journal:	<i>Transactions of the Institute of British Geographers</i>
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Keywords:	Canada, Norway, Sea ice, Ice edge, Political geography, Critical cartography
Abstract:	<p>This paper explores how 'ice' is woven into the spaces and practices of the state in Norway and Canada and, specifically, how representations of the sea ice edge become political agents in that process. We focus in particular on how these states have used science to 'map' sea ice – both graphically and legally – over the past decades. This culminated with two maps produced in 2015, a Norwegian map that moved the Arctic sea ice edge 70 km northward and a Canadian map that moved it 200 km southward. Using the maps and their genealogies to explore how designations of sea ice are entangled with political objectives (oil drilling in Norway, sovereignty claims in Canada), we place the maps within the more general tendency of states to assign fixed categories to portions of the earth's surface and define distinct lines between them. We propose that the production of static ontologies through cartographic representations becomes particularly problematic in an icy environment of extraordinary temporal and spatial dynamism, where complex ocean-atmospheric processes and their biogeographic impacts are reduced to lines on a map.</p>

Abstract

This paper explores how ‘ice’ is woven into the spaces and practices of the state in Norway and Canada and, specifically, how representations of the sea ice edge become political agents in that process. We focus in particular on how these states have used science to ‘map’ sea ice – both graphically and legally – over the past decades. This culminated with two maps produced in 2015, a Norwegian map that moved the Arctic sea ice edge 70 km northward and a Canadian map that moved it 200 km southward. Using the maps and their genealogies to explore how designations of sea ice are entangled with political objectives (oil drilling in Norway, sovereignty claims in Canada), we place the maps within the more general tendency of states to assign fixed categories to portions of the earth’s surface and define distinct lines between them. We propose that the production of static ontologies through cartographic representations becomes particularly problematic in an icy environment of extraordinary temporal and spatial dynamism, where complex ocean-atmospheric processes and their biogeographic impacts are reduced to lines on a map.

Introduction

“We are not moving the ice edge. It is actually nature that is currently moving the ice edge.”

-- Erna Solberg, Prime Minister of Norway (Solberg 2015)¹

1
2
3
4
5 “Presto! More ice, just in time for an election. Gosh, even Mother Nature has been
6
7
8 cowed into co-operating with [Canadian Prime Minister Stephen] Harper’s
9
10 ambitions.”

11
12 – ‘Rogue Chimp’, online comment (Semeniuk 2015)
13
14
15

16
17 On 20 January 2015, the Government of Norway released a new map of its
18
19 northern waters (Figure 1). The map quickly became a topic of national debate
20
21 because it moved the location of the southern edge of sea ice northward by some
22
23 70 km, in comparison with an equivalent map that was issued in a report that
24
25 had been commissioned by the Government of Norway in 2003. The new map
26
27 had significant implications for Norway’s all-important offshore oil and gas
28
29 industry because Norway’s Lofoten-Barents Sea Management Plan prohibits oil
30
31 exploration in a number of environmentally sensitive zones, including ‘areas
32
33 along the edge of the marginal ice zone and the polar front’ (Ministry of the
34
35 Environment 2011, 138). Following the release of the new map, critics and
36
37 supporters of petrochemical development alike were quick to note that, with the
38
39 ice edge’s northward shift, the entire Southeast Barents Sea Offshore Oil
40
41 Province was now open for development. Indeed, environmentalists suspected
42
43 that it was hardly a coincidence that the new map was released on the same day
44
45 that Norway opened new Barents Sea exploration blocks for competitive bidding.
46
47
48 Lars Haltbrekken, Chairman of Friends of the Earth Norway, charged that the
49
50 new map was part of a relentless oil politics in the Barents Sea, where ‘anything
51
52 is done to please an industry belonging to the past’ (Norwegian News Agency
53
54
55 2015a), a position echoed by marine biologists and oceanographers (Norwegian
56
57
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60

1
2
3 News Agency 2015b; Sundby 2015) as well as opposition politicians (Andersen
4
5 2015, Bjørndal 2016). It was in response to such assertions that Prime Minister
6
7 Solberg made the statement quoted at the beginning of this article, defending the
8
9 policy change as a mandate from 'nature'.
10

11
12
13
14 *Insert figure 1 about here*
15
16
17

18
19 Just three months after the release of the Norwegian map, the
20
21 Government of Canada published a revised version of its *Atlas of Canada*. The
22
23 atlas' national map of Canada (Figure 2) also depicted the edge of sea ice.
24
25 However, in contrast with the Norwegian map, the Canadian map moved the ice
26
27 edge about 200km *southward* in comparison with the previous national atlas,
28
29 which had been published in 2006 (Figure 3). The redrawing to indicate *more* ice
30
31 is counterintuitive, given that between 1979 and 2012 Arctic sea ice extent
32
33 decreased at a rate of 3.5 to 4.1% per decade (.45 to .51 million km² per decade)
34
35 (Intergovernmental Panel on Climate Change 2013, 319). The politics behind the
36
37 new Canadian map are not entirely clear. Some, including geographer Robert
38
39 McLeman, speculated that the depiction on the 2015 map was an act of
40
41 cartographic 'fakery' that reflected Prime Minister Harper's scepticism about
42
43 climate change (Kwong 2015), an opinion that echoed popular reactions to the
44
45 map illustrated by the online comment by 'Rogue Chimp' at the beginning of this
46
47 article. Others, including Canadian Ice Service forecaster Denis Dubé, countered
48
49 that the shift was due to a well-intentioned change in methodology that, in
50
51 addition to following 'international standards', would facilitate future awareness
52
53 of sea ice reduction by better displaying its variability (Kwong 2015). Still others
54
55
56
57
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1
2
3 took a middle ground, asserting that although the new map likely was not of
4
5 devious intent its production (and subsequent consumption) could not be
6
7 separated from a broader political context. Illustrative here is an online
8
9 comment on the Canadian Broadcasting Corporation's story on the new map, in
10
11 which 'Rickinedmonton' acknowledged that although the map was not 'some
12
13 kind of right wing denialist conspiracy...some [climate change] deniers are prone
14
15 to make disingenuous use of it' (online comment in Kwong 2015).
16
17

18
19
20
21 *Insert figure 2 about here*

22
23 *Insert figure 3 about here*
24
25
26
27

28 As is discussed below, much of the reason for the differences in the
29
30 Norwegian and Canadian depictions of the sea ice edge, and the changes within
31
32 each country's depictions, stems from their use of different methodologies for
33
34 defining and depicting the limits of sea ice. Not only did Norway and Canada use
35
36 different definitions of 'sea ice' and different ways of aggregating the data to
37
38 obtain identifiable, static 'edges' (limits), but the two countries each adjusted
39
40 their methodologies over the time period in question. And of course the maps
41
42 themselves are entirely different products, designed for different purposes:
43
44 While the Norwegian map is a fairly technical object, designed to facilitate state
45
46 planning, the Canadian map was developed for popular consumption, to impart a
47
48 sense of the nation to Canadian and non-Canadian viewers.
49
50
51

52
53 Thus, our aim here is not to compare the two maps or to highlight their
54
55 different political or geophysical orientations and presumptions. In all their
56
57 differences, they defy comparability. Rather, we are intrigued by their underlying
58
59
60

1
2
3 similarity. The two maps share a common concern with knowing and showing
4 space by dividing it, in particular through the drawing of a singular boundary
5 known as the 'ice edge', which in turn imparts a specific, Western politics of
6 space. In our 'nomospheric' world (Delaney 2010), where spatial divisions
7 support legal categorisations and legal systems support spatial ordering,
8 boundary lines like the ice edge are ripe with political meaning, becoming not
9 just *boundaries* but *boundary objects*, concepts that frame social understanding
10 of the world (Star and Griesemer 1989) and that therefore set out ideas about
11 possible futures. Thus, although we focus on the two 2015 maps and their
12 antecedents, our objective is to move beyond them. Through a sustained
13 examination of these two maps – their history, their reception, and their
14 grounding in complex webs of state interests and presumptions about
15 underlying geophysical and biogeographical processes – we seek to explore the
16 challenges inherent when an ontology of fixed spaces is applied to an
17 environment characterised by an exceptional level of spatio-temporal dynamism
18 and material complexity and how efforts to address these challenges reflect and
19 reproduce institutions of social power.
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44 **Defining water, defining ice**

45
46 In our effort to understand the ice edge as a discursive construct with material
47 effects, we turn to materialist theories of politics, in which contests over space
48 are understood as occurring amidst the dynamic composition, decomposition,
49 and agency of material nature (e.g. J. Bennett 2010; Coole & Frost 2010; Dittmer
50 2014) and which suggest that designations of fixed categories of space must be
51 contested. To turn to a few examples, the island, which seemingly can be
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1
2
3 understood unproblematically as a body of land surrounded by water, has been
4
5 found to defy definition, as island lifeways, ecologies, and political systems
6
7 exceed the island's borders (Mountz 2015; Royle 2001). Air similarly evades
8
9 unitary definitions, as it is simultaneously medium, element, and atmosphere
10
11 (Adey 2014). Ocean scholars note how the boundaries of the ocean exceed the
12
13 limits of the shoreline (Spence 2014), and that the shoreline, which is purported
14
15 to divide the planet's surface into essential categories of land and sea, itself is
16
17 typically a series of points of exchange rather than a boundary between two
18
19 distinct spaces (Carter 1999). Furthermore, these points that unite as well as
20
21 divide are themselves in constant motion due to changes in the volume of water
22
23 and the displacement of land (Steinberg 2013).
24
25
26

27
28 Sea ice is a similarly contested concept. At one level, it is clear what sea
29
30 ice is: water of marine or oceanic origin that, because of temperature and
31
32 pressure conditions, is encountered on the surface as solid. But this definition is
33
34 complicated by numerous factors. The formal category 'sea' is itself defined by
35
36 arbitrary boundaries: What is the threshold level of salinity (e.g. where does one
37
38 draw the boundary between salt water and fresh water, and how does one
39
40 classify liminal spaces such as estuaries and salt marshes)? Beyond salinity, what
41
42 other properties, such as turbidity or the presence of marine microorganisms,
43
44 are necessary to designate water as 'sea water'? To what extent does sea water
45
46 need to be permanently distinct from underlying soil to be defined as 'sea' (e.g.
47
48 how does one classify intertidal zones or tidal pools)?
49
50
51

52
53 Even if one can delimit the sea as a spatial unit, the designation of sea *ice*
54
55 raises new questions. Sea ice comes in many forms, as sea ice glossaries
56
57 produced by scientific institutions attest (e.g. Linder 2003; Canadian Ice Service
58
59
60

1
2
3 2016), and even these typologies ignore the rich knowledge of sea ice forms and
4
5 processes held by Inuit and other indigenous northern peoples (e.g. Aporta
6
7 2011; Carey *et al.* 2016; Inuit Circumpolar Council 2008; Krupnik *et al.* 2010).
8
9 Defining sea ice is further complicated by methodological difficulties. Water that
10
11 is essentially solid frequently has puddles of liquid on its surface, complicating
12
13 efforts to use satellites to remotely sense the presence of ice from albedo
14
15 reflectivity (Breivik *et al.* 2010; Howell *et al.* 2005).
16
17

18
19 In addition, because sea ice occurs in various combinations with liquid
20
21 sea water, fresh water, land, air, and other objects, even if one can define sea ice
22
23 as a singular object it is not necessarily possible to define a *zone* of sea ice, let
24
25 alone a distinct sea ice *edge*. And even if one is able to define a linear sea ice edge,
26
27 mapping it poses challenges because it is rarely (if ever) static, moving with wind
28
29 and ocean currents from hourly to seasonal time-scales, in addition to longer-
30
31 term trends in average seasonal positions associated with climate change. And
32
33 finally, sea ice, even when formally defined, serves a range of functional
34
35 properties. The same area of sea ice may be a hazard to a ship, a highway for a
36
37 dog sled or snowmobile, and a place of refuge for a polar bear. Sea ice may
38
39 simultaneously be a barrier to movement, a surface across which movement is
40
41 facilitated, and an element, that, in its lateral drift, *is* movement (Peters 2015).
42
43
44
45

46 Thus, the sea ice that is 'mapped' in one place may be significantly
47
48 different – in form, function, permanence, and even in its elemental 'iciness' –
49
50 from that mapped somewhere else. As Steinberg and Peters (2015, 260) note,
51
52 'The phenomenology of sea ice, as a particularly dynamic form of water,
53
54 simultaneously destabilises conventional understandings of both geopolitics (as
55
56 areal) and geophysics (as static), contributing to an ontological confusion that
57
58
59
60

1
2
3 underpins much of the ongoing debate over the Arctic's future'. In its attempt to
4
5 add stability and definition to a dynamic and indeterminate environment, the
6
7 mapping of sea ice attempts to resolve this 'ontological confusion' through an
8
9 alignment of law, cartography, and science.
10

11 12 13 14 **Defining ice zones and ice edges**

15
16 Although the concept of sea ice (or ice-covered ocean) occurs with some
17
18 frequency in local law and state regulations, as well as making a brief appearance
19
20 in the United Nations Convention on the Law of the Sea (UNCLOS) (Baker and
21
22 Mooney 2012), there is no universally accepted standard for designating zones
23
24 of sea ice. Some geoscientists use data based on observation of *sea ice area* (the
25
26 number of pixels within an area of ocean with albedo reflectivity indicating
27
28 frozen water) to make determinations about sea ice presence in a large area of
29
30 ocean. However, the more commonly used statistic is *sea ice extent*, where data is
31
32 aggregated to the level of the *cell*. The website of the US National Snow and Ice
33
34 Data Center (NSIDC) helpfully likens the two measures to alternate ways of
35
36 measuring a slice of Swiss cheese: "Extent would be a measure of the edges of the
37
38 slice of cheese and all of the space inside it. Area would be the measure of where
39
40 there is cheese only, not including the holes" (National Snow and Ice Data Center
41
42 n.d.(b)).
43
44
45
46
47

48
49 When measuring ice extent, cell size is conventionally set at 25 km², so if
50
51 one is using data from a satellite with 1m² resolution there would be 625 pixels
52
53 in a cell. A cell is then said to have ice extent if the percentage of pixels in the cell
54
55 indicating ice (the ice concentration) exceeds a certain threshold. In this example,
56
57 if one is using a 15% threshold then so long as at least 94 of the pixels in the cell
58
59
60

1
2
3 indicate ice the cell is declared to be an area of ice extent. If fewer than 94
4
5 indicate ice (i.e. if the ice concentration is less than 15%) the cell is designated
6
7 open water (Kvingedal 2005; National Snow and Ice Data Center n.d.(a)).
8
9

10 While this seems straightforward, there is no evident basis, other than
11
12 convention, for choosing a 25m² cell as the standard unit of aggregation.
13
14 Additionally, designations of ice extent are likely to change as improved satellite
15
16 resolution increases the number of pixels in a cell. Perhaps most importantly,
17
18 there is no standard for defining the ice concentration threshold used to
19
20 distinguish 'sea ice extent' from 'open water'. The Canadian Ice Service sets the
21
22 threshold at 10%, the NSIDC (whose data is generally used in Norwegian maps)
23
24 sets it at 15%, and others, as the NSIDC (n.d.(b)) notes, set the threshold as high
25
26 as 30%.
27
28
29

30 Variance in data resolution and definition of the sea ice extent threshold
31
32 are matched by variance in time scale. Turning just to the three maps presented
33
34 above, the 2003 Norwegian ice edge line (the green line on Figure 1) was based
35
36 on data from a 23-year data-set, going back to 1967, when data first became
37
38 available. Using this data, the map identified ice-covered areas as those where
39
40 there was at least a 30% chance of ice occurring in April (the month identified in
41
42 the report as having maximum ice extent), using the 15% NSIDC threshold. The
43
44 2015 Norwegian line (the blue line on Figure 1) used an identical standard,
45
46 except that the 23-year data-set was expanded to 30 years to align with the norm
47
48 in climatological research. The 2006 Canadian map (Figure 3) indicated the ice
49
50 edge at the 'approximate limit of polar ice'. Subsequent discussion surrounding
51
52 the 2015 map revealed that this referred to the September minimum but left it
53
54 unclear whether data was derived from just the most recent year of observation,
55
56
57
58
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60

1
2
3 the northernmost limit ever observed over an unspecified time-period, or a
4
5 median of annual minimums observed over that unspecified time-period. The
6
7 2015 Canadian map (Figure 2) clarifies that the limit is the minimum
8
9 (September) extent, defining this as the median point over a 30-year data set of
10
11 September observations.
12
13

14 As critical geographic research on the Arctic has demonstrated, the
15
16 shifting nature of Arctic sea ice, its liminal properties, and ambiguity in the
17
18 divide between sea ice and open water have complicated both Arctic politics
19
20 (Gerhardt *et al.* 2010; Strandsbjerg 2012) and the translation of Arctic science
21
22 into policy and planning narratives (Kristoffersen 2014; Veland and Lynch 2016;
23
24 Worms and Sörlin in press). Additionally, the failure of many to appreciate the
25
26 connection between these binary narratives of Arctic ice and the complexities
27
28 underlying Arctic livelihoods and scientific practices reflects the epistemological
29
30 narrowness of much research on glaciers and sea ice (Carey *et al.* 2016). In this
31
32 article, we build on these works, analysing the history of the Norwegian and
33
34 Canadian ice edge mapping projects to extend insights on the role of maps, ice,
35
36 and science as political actors that, through ordering space, order the world.
37
38
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43

44 **Mapping a chaotic world**

45
46 Central to the story of ice edge mapping is, of course, the map. Almost thirty
47
48 years after Brian Harley's (1989) foundational work in critical cartography, one
49
50 hardly needs to stress that a map is a partial depiction that, through
51
52 simplification and erasures, performs political 'work'. This perspective, however,
53
54 has itself been critiqued by those who stress that a map's power lies less in its
55
56 existence as a (misleading) representational object and more in its power as a
57
58
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60

1
2
3 more-than-representational actant that, through *purporting* to represent the
4
5 world as a static, legible object, joins with other elements to shape that world. As
6
7 networked relations emerge between the map, the reader, and the cartographer,
8
9 new spaces and subjectivities are produced as individuals use the map to locate
10
11 themselves in space (Conley 1996; Del Casino and Hanna 2006; Kitchin and
12
13 Dodge 2007). At the same time, map users reproduce the authority of the map
14
15 (and the authority of the institutions that produce the map) as well as the
16
17 dominant statist and static 'cartographic reason' that conceptualises a world
18
19 divided by visible and seemingly objective determinant lines (Pickles 2004).
20
21
22

23
24 In this article, we focus less on the map as a force that constructs
25
26 subjectivities and more on the map as an object that serves simultaneously as a
27
28 tool for communicating power (through reference to implicit understandings of
29
30 space) and an arena for contesting power. In part, this focus is mandated by a
31
32 lack of ethnographic data on individuals encountering state-produced ice-edge
33
34 maps. However it also is a choice taken in light of the rich genealogical history
35
36 that accompanies a state-produced map: a history of legal reasoning, surveying,
37
38 enabling legislation, and policy debates behind the map and the public
39
40 discourses and practices that surround its reception. In addition, the role of the
41
42 map in producing and communicating state knowledge of space is particularly
43
44 prominent in the Arctic, in part because it is a region that many individuals
45
46 (including some who have the power to shape the region) experience *only*
47
48 through maps and other mediated forms of knowledge and in part because the
49
50 actual environment there differs so significantly from these state officials'
51
52 personal experiences (Medby 2016; Steinberg *et al.* 2015; Strandsbjerg 2012).
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1
2
3 Every state map works in tandem with a spatio-regulatory framework.
4
5 For Arctic sea ice, a notable expression of this framework can be found in Article
6
7 234 of the United Nations Convention on the Law of the Sea (UNCLOS). The only
8
9 article in UNCLOS that acknowledges that sea water may have a frozen state.
10

11 Article 234 states, in its entirety:

12
13
14 Coastal States have the right to adopt and enforce non-discriminatory
15
16 laws and regulations for the prevention, reduction and control of marine
17
18 pollution from vessels in ice-covered areas within the limits of the
19
20 exclusive economic zone, where particularly severe climatic conditions
21
22 and the presence of ice covering such areas for most of the year create
23
24 obstructions or exceptional hazards to navigation, and pollution of the
25
26 marine environment could cause major harm to or irreversible
27
28 disturbance of the ecological balance. Such laws and regulations shall
29
30 have due regard to navigation and the protection and preservation of the
31
32 marine environment based on the best available scientific evidence.
33
34
35

36
37 (United Nations 1982)

38
39 As Claudio Aporta (2011) has noted, Article 234 presents a one-dimensional
40
41 view of sea ice, informed by Western maritime interests that perceive frozen
42
43 water solely as a hazard to navigation. For indigenous people in regions
44
45 characterised by sea ice, frozen water is not just an efficient transportation
46
47 surface. It is also a living space that hosts everyday activities that span areas of
48
49 land, sea, and inland water as well as sea ice. As a component of this wider
50
51 assemblage of surfaces, sea ice is essential for preserving well-being, and sea ice
52
53 processes and ecologies are incorporated into notions and practices of
54
55 community, citizenship, and sovereignty (Bravo 2010; Hastrup 2016; Inuit
56
57
58
59
60

1
2
3 Circumpolar Council 2008; Kuptana 2013). For indigenous coastal peoples of the
4
5 North, the primary concern is often not the presence of sea ice but its absence,
6
7 and this leads to an entirely different perspective on remotely sensed ice
8
9 imagery (Laidler *et al.* 2011). For instance, an Inuit hunter might set the ice
10
11 extent threshold at 85% rather than 15%, reflecting a concern with *ice-melt* as a
12
13 hazard.
14
15

16
17 In addition to its singular focus on shipping, Article 234 is notable for its
18
19 failure to define 'ice-covered areas', except tautologically as areas with 'the
20
21 presence of ice'. Much as the focus on commercial navigation forecloses
22
23 perspectives on ice that might lead to different thresholds for determining ice
24
25 extent, the binary category 'presence of ice' (in UNCLOS), or 'ice extent' (in
26
27 scientific classificatory schemes), is insufficient for capturing the ways in which
28
29 ice and the ice edge shift in time and space.
30
31

32
33 In short, the binary division between 'ice-covered areas' and 'open water'
34
35 is neither geophysically tenable nor operationally practical. Nor does it have any
36
37 definitive legal clarity (Veland and Lynch 2016; see also, Baker and Mooney
38
39 2012). Yet it has gone on to inform a range of regulatory structures, laws,
40
41 political talking points, and national ideologies (as well as maps) across the polar
42
43 North.
44
45

46
47 Summing up these points, it appears to us that sea ice is a legal category
48
49 constructed not so much by the freezing of sea water as by the mapping process
50
51 that inscribes spaces (through visual and textual narratives) into fixed categories
52
53 that obscure underlying ambiguities, transformations, and political agendas. The
54
55 sea ice map is thus, after Latour (2007), a *seemingly* immutable (but actually
56
57 quite mutable) mobile that purports to make sense out of a complex world by
58
59
60

1
2
3 assigning things to spatial categories and by carrying that knowledge into
4
5 different contexts where it then can be reassembled and applied.
6

7 Methodologically, this suggests that much can be learned from following the map,
8
9 tracing its mutations as it is conceived, interpreted, and applied in specific
10
11 contexts (the court room, the planning document, the atlas) to achieve spatial
12
13 order among a community of users (Kitchin *et al.* 2013; Sparke 1998). By
14
15 genealogically following the map, we explore not just its (mis)representations
16
17 but also how cartographic reason is applied to construct spatial order. In the
18
19 remainder of this article, we apply this approach to Norwegian and Canadian
20
21 efforts at sea ice mapping, tracing the ways in which they have constructed the
22
23 geo-legal category known as the 'ice edge'.
24
25
26
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28
29

30 **Mapping ice borders in Norway and Canada**

31 *Norway*

32
33 The story of Norwegian ice edge mapping began with a 2001 civil disobedience
34
35 action at Røst in the Lofoten Islands, where the oil industry had identified
36
37 Norway's most 'prospective' hydrocarbon deposit (KonKraft 2009) and where
38
39 Norway's partially state owned oil company Hydro (now merged with 2/3
40
41 governmentally controlled Statoil) was preparing to engage in exploratory
42
43 drilling. In response to opposition from local residents and environmentalists,
44
45 and in anticipation of an election that was to occur in two months, the governing
46
47 Labour Party withdrew Hydro's discharge permit. A few months later, the new
48
49 centre-right government stopped all petroleum activities in Arctic waters
50
51 (except the only gas field in the Norwegian Arctic, 'Snow White') and asked
52
53 research institutions and governmental directorates to provide assessment
54
55
56
57
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1
2
3 reports on year-round off-shore petroleum activities in the North, with a specific
4
5 mandate to produce maps that could be used to inform subsequent management
6
7 plans. The principal report produced was *The Identification of Particularly*
8
9 *Valuable Areas in Lofoten – Barents Sea* (Olsen and von Quillfeldt 2003)², which
10
11 went on to inform the *Integrated Management of the Marine Environment of the*
12
13 *Barents Sea and the Sea Areas off the Lofoten Islands* (Ministry of the
14
15 Environment 2006, revised in 2011) that was submitted to the Norwegian
16
17 government and adopted by Parliament.
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23 *Insert figure 4 about here*
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28 While there is both a cartographic and policy continuity between the map
29
30 in the original 2003 report (Figure 4), the maps in the 2006 and 2011
31
32 management plans, and the 2015 map discussed at the beginning of this article
33
34 (Figure 1), the map underwent a series of iterations that, we suggest, speaks to
35
36 the ways in which Norwegian oil extraction policy has been advanced
37
38 concomitantly with the reduction of sea ice to a static, binary, and
39
40 cartographically comprehensible object. Importantly, although the ice edge is
41
42 noted on the map, the accompanying report indicates that its significance
43
44 emerges not because it is the southernmost point where water is frozen (i.e. the
45
46 point at which ice extent meets open water) but because it is indicative of the
47
48 location of the polar front. A close read of the text reveals that it is the polar front,
49
50 the boundary between the cold polar air masses and the warmer mid-latitude air
51
52 masses that is often broadly associated with the zone where warm southern
53
54 water meets cold Arctic water, that is the zone of vulnerability: ‘The polar front
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3 is the most important oceanographic phenomenon that creates enhanced
4
5 biological production...[where] organisms at all levels of the food chain are
6
7 concentrated' (Olsen and von Quillfeldt 2003, 56). Furthermore, the report notes
8
9 that when the warm and cold currents separate, during the spring and summer,
10
11 the retreating ice creates a 'stable, but relatively shallow surface layer' which in
12
13 turn leads to 'intense production within a belt of 20 to 50 kilometers' that
14
15 'follows the ice edge when it retreats northwards' (Olsen and von Quillfeldt 2003,
16
17 3).
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19

20
21 In other words, the significance of the ice edge emerges from its
22
23 association with the increased biological productivity that occurs when the
24
25 intersection of water masses, resulting from different air temperatures, induces
26
27 mixing that facilitates the primary production of algae. This focus is consistent
28
29 with the mandate given to the report's authors, which was to evaluate areas
30
31 where there were potential threats to 'biological production and biodiversity'
32
33 (Olsen and von Quillfeldt 2003, 2). Significantly, the report attaches no
34
35 environmental (i.e. biological) importance to the ice edge as an *object*, that is, a
36
37 distinct line (or place) where ice becomes liquid. Rather, it is mapped (and
38
39 subsequently emerges as a planning tool) only because it serves as an indicator
40
41 of the approximate location of water temperatures associated with the polar
42
43 front, which, in turn, is associated with heightened biological productivity.
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48 As the 2003 report (and its accompanying map) evolved into the 2006
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50 and 2011 reports (and their accompanying maps) a number of changes
51
52 transpired. The text of the management plans continued to highlight the
53
54 significance of the polar front. The 2006 management plan states, 'Organisms at
55
56 all levels of the food chain are concentrated along the narrow polar front. As a
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1
2
3 result, any negative environmental factors that affect the polar front may have an
4
5 impact on a substantial proportion of the populations of various species'
6
7 (Ministry of the Environment 2006, 33), and the 2011 management plan notes,
8
9 '[The polar front] is an area for various groups of organisms; it is also a natural
10
11 and dynamic biogeographical boundary, and therefore supports relatively high
12
13 biodiversity' (Ministry of the Environment 2011, 26). However, the entire
14
15 discussion is tempered by an acknowledgment that 'there are significant gaps in
16
17 our knowledge of physical and biological processes in the marginal ice zone, the
18
19 polar front and other productive areas' (Ministry of the Environment 2011, 29)
20
21 and that due to this uncertainty the precautionary principle should apply when
22
23 designing environmental management regulations for the marginal ice zone.
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27
28 This acknowledgment of uncertainty is extended from questions
29
30 concerning physical and biological processes to geographic location. Referring to
31
32 the eastern part of the zone, which previously had been disputed between
33
34 Norway and Russia, the 2011 management plan notes, 'The eastern part of the
35
36 polar front is broader and less clearly defined than it is further west. Sea ice
37
38 covers part of the previously disputed area for periods of the year' (Ministry of
39
40 the Environment 2011, 26). This would seem to suggest that in the eastern
41
42 region in particular it would be problematic to let the ice edge simply serve as
43
44 proxy for the polar front, and this was noted explicitly in a report issued by the
45
46 Ministry of Climate and Environment (the successor to the Ministry of the
47
48 Environment) that accompanied the 2015 map (Figure 1): 'The sea ice's
49
50 southernmost reach often coincides with the polar front, but not always'
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52
53 (Ministry of Climate and Environment 2015a, 24).
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3 Amidst this recognition of uncertainty surrounding both the biological
4 processes and the location of the polar front, sea ice – a tangible and seemingly
5 identifiable substance – began to rise to the forefront as a spatial management
6 tool. Whereas the initial 2003 map (Figure 4) and the text accompanying it
7 (Olsen and von Quillfeldt 2003) highlighted the April and September ice *edges* as
8 lines that needed to be identified for planning purposes, the map in the 2006 and
9 2011 management plans (Figure 5) went on to highlight the entire area between
10 the two ice edges as an ecologically significant ‘marginal ice zone’, a change that
11 likely was made to reflect an increasing realisation among biologists that the
12 relationship between marginal ice and biological productivity is characterized by
13 a series of short-term bursts in productivity caused by melting or wind-driven
14 events rather than by a stable or even seasonally predictable ice edge associated
15 with the polar front (see Drinkwater and Tande 2014). This replacement of the
16 ice edge as a distinct line (or a set of two lines) with a broader marginal ice zone,
17 and its conceptual separation from the polar front is replicated in the
18 accompanying text: ‘Both the polar front and the marginal ice zone have already
19 been identified as particularly valuable and vulnerable areas in the management
20 plan’ (Ministry of the Environment 2011, 26).
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46 *Insert figure 5 about here*
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50 While the conceptual separation of the ice edge (or the seasonal minimum
51 and maximum ice edges, or the zone between them) from the polar front is
52 scientifically justifiable, the successive cartographic and textual statements that
53 distinguished one from the other set the stage for transforming the ice edge –
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1
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3 formerly a proxy for the shifting site of intense ocean-atmospheric energy
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5 exchange – into a singular object that, in turn, could become a planning tool. As
6
7 we have seen over the twelve years between 2003 and 2015, the ‘ice edge’ was
8
9 transformed from the area between the April and September limits, with various
10
11 probabilities of ice within that zone (Figure 4, the 2003 map), to an
12
13 undifferentiated zone of ‘marginal’ ice cover (Figure 5, the 2006/2011 map), to a
14
15 single line representing the point at which there is a 30% chance of ice extent in
16
17 April using a thirty-year data set and a 15% ice extent threshold (Figure 1, the
18
19 2015 map). In the process, the ‘ice edge’ became a mappable line that could be
20
21 joined by Prime Minister Solberg to the heft of ‘nature’ to justify the delineation
22
23 of planning zones. As this occurred, the oceanic temperature variance and
24
25 hypothesised biological productivity associated with the polar front, which was
26
27 the reason why attention had been directed to the ice edge in the first place,
28
29 quite literally disappeared from the map.
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35 Although the transformation of the ice edge from a complex set of
36
37 probabilities and variances to a single line could theoretically have occurred
38
39 independent of the cartographic disappearance of the polar front, the two
40
41 reflected a common trend toward constructing the ice edge as an ontologically
42
43 distinct object that could be deployed for spatial planning purposes. Once the ice
44
45 edge was established as a distinct object – i.e. once it was transformed into a *line*
46
47 that separated water from ice, and resilience from vulnerability - this line could
48
49 be *moved*, opening up new sites for oil exploration. In short, over twelve years,
50
51 the ice edge was transformed from an indeterminate, probability-driven, and
52
53 substantively insignificant indicator of underlying ocean-atmospheric forces
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3 associated with biological productivity and environmental vulnerability into a
4
5 distinct object that could be used for planning purposes.
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8 But that is not the end of the story. Complicating the issue even further,
9
10 there is yet another definition of the ice edge used by the Norwegian government.
11
12 In its white paper *New Possibilities for Northern Norway: The Opening of the*
13
14 *Southeast Barents Sea for Petroleum Extraction*, the Ministry of Petroleum and
15
16 Energy (2012-2013) states, 'In areas closer than 50 kilometers to the [annual]
17
18 *actual/observed ice edge*, exploration drilling in oil-bearing layers will not be
19
20 allowed, in the period between December 15th and June 15th' (page 38, emphasis
21
22 added). This definition contrasts with the ice edge depicted on the 2015 map, not
23
24 least because it suggests that exploration drilling can take place much further
25
26 north, at least in years where the ice edge happens to form at a relatively
27
28 northern latitude.
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33 As of this writing, Norwegians remain divided over how to define the ice
34
35 edge. The original 2003 map, which marked the April (maximum) and
36
37 September (minimum) extents (Figure 4) has largely been abandoned. Likewise,
38
39 the 2015 map that defined only the southernmost (April) extent, using the
40
41 criteria of 30% likelihood over a thirty-year period (Figure 1), has been formally
42
43 withdrawn amidst the ongoing controversy (Sættem and Tomter 2015). Most
44
45 environmentalists and scientists call for the designation of a 'marginal ice zone'
46
47 or 'ice edge zone' (Aarskog 2015), following the depiction used in the maps
48
49 accompanying the 2006 and 2011 management plans (Figure 5). Since the
50
51 controversy surrounding the 2015 map, the various sides have strengthened
52
53 their positions. The Norwegian Polar Institute, which serves as both a
54
55 government directorate and research centre on polar issues, is calling for a
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3 definition that uses the *maximum* ice extent that has occurred during the past
4
5 thirty years (in contrast with the 2015 map's definition of 30% likelihood over
6
7 that same time period) (Norwegian Polar Institute 2014, 8). This alternate
8
9 standard, which would move the ice edge further southward, has been taken up
10
11 by opposition parties in the Norwegian parliament as well as environmental
12
13 activists. Meanwhile, the Ministry of Petroleum and Energy maintains its
14
15 commitment to the 'actual/observed ice edge' in any given year, which would
16
17 perhaps lead to the northernmost definition. Amidst all this debate, the polar
18
19 front, which was closely linked to the mapping of the ice edge in the first place,
20
21 has largely faded from public view, and the exploration licenses announced in
22
23 2015 with the new ice edge map (Figure 1) have been granted.
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27 28 *Canada*

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30 Compared to the 2015 Norwegian map, the 2015 Canadian map has had a less
31
32 contested history. Certainly its reception, as well as its political import, has been
33
34 much more muted. Nonetheless, the decision to change the representation of the
35
36 ice edge in the Canadian national atlas is no less intriguing. As in Norway, the
37
38 Canadian map points to the arbitrary (and inherently political) nature of science,
39
40 as scientists, policy-makers, cartographers, and the maps that they use to
41
42 communicate with each other divide nature into categories, echoing a trend that
43
44 has been identified in Arctic planning more generally (Worms and Sörlin in
45
46 press).
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51 Maps have long had an important role in defining the scope – and identity
52
53 – of the Canadian nation, pointing the nation northward, asserting Arctic waters
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55 as part of the national patrimony, and even implying a 'natural' extension of
56
57 Canadian territory to the North Pole (M. Bennett *et al.* 2016; Steinberg 2010;
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3 Steinberg *et al.* 2015; see also Grace 2007; Sparke 1998). This sentiment was
4
5 echoed by Canada's Minister of Natural Resources in the news release that
6
7 accompanied the 2015 map: 'Maps have played an important role in building our
8
9 country...[and] this updated map will help Canadians better understand our
10
11 evolving country' (Natural Resources Canada 2015b). It was perhaps because of
12
13 this context that, for a few days after the map's release, the internet was abuzz
14
15 with speculation about the reasons behind Canada's decision to replace the old
16
17 indicator of the ice edge – the poorly defined 'limit of polar ice' – with the
18
19 'median [September] sea ice extent' figured over a thirty year period. In a
20
21 manner reminiscent of the popular frenzy that occurred when a 2011 update of
22
23 the *Times Atlas of the World* erroneously shrunk the Greenland Ice Sheet by 15%
24
25 (Black 2011; Harvey 2011), the Canadian Broadcasting Corporation story
26
27 reporting on the map (Kwong 2015) received 1,008 comments within days of
28
29 publication, a level of attention not normally granted to something as mundane
30
31 as a new edition of a national atlas.
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37 In fact, the decision to change the depiction of the ice edge in the *Atlas of*
38
39 *Canada* intersects with an on-going debate within the Government of Canada
40
41 concerning the delineation of sea ice and its use for purposes as diverse as
42
43 asserting sovereignty, guarding against environmental hazards, and promoting
44
45 transportation. Article 234 of UNCLOS, discussed above, was based on Canada's
46
47 1970 Arctic Waters Pollution Prevention Act (AWPPA), which, like Article 234,
48
49 holds that the heightened dangers of ice-covered waters justify heightened
50
51 coastal state regulation of navigation. While there certainly are legitimate
52
53 reasons for exercising exceptional regulatory measures in Arctic navigation
54
55 (both because of the hazard that sea ice and ice floes pose to ships and because
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3 of the environmental dangers associated with a potential wreck), the designation
4 of Arctic waters as 'dangerous', and therefore requiring a heightened level of
5 policing, aligns with Canada's desire to 'perform sovereignty' in the region
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7 (Dodds 2012).
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11
12 Much of Canada's argument that Arctic waters are dangerous and
13 therefore require heightened protection rely on their designation as 'ice-
14 covered', which, in turn, requires a binary, static definition of ice extent (as well
15 as the designation of an ice edge where that ice extent ends) (Steinberg *et al.*
16 2015). Designating these waters as 'ice-covered' and therefore 'dangerous' has
17 the added benefit for Canada of implying that they are not suitable for reliable
18 inter-ocean navigation, which supports Canada's argument that the Northwest
19 Passage is not an international strait and therefore should not be subject to
20 UNCLOS' international strait transit passage regime (Steinberg 2014). And finally,
21 the designation of the waters of the Canadian archipelago as ice-covered
22 supports Canada's designation of both the land *and* the (frozen) water of the
23 Canadian archipelago as essential Canadian space, an argument frequently made
24 by Canadian officials with reference to winter movement of Inuit Canadians
25 across land and frozen waters (Byers 2014; Gerhardt *et al.* 2010; Vannini *et al.*
26 2009).
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46 Given the political significance of sea ice in Canadian politics, the
47 scientists of the Canadian Ice Service, the agency within Environment and
48 Climate Change Canada that monitors sea ice, are no more insulated politically
49 than the Norwegian cartographers whose aggregation and representation of sea
50 ice data determine where oil exploration can be permitted. In the case of Canada,
51 the ice extent threshold reported by the Ice Service has historically been 10%.
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3 However, there is a history of controversy and debate concerning how the Ice
4 Service reports ice extent, and this reflects contradictions in its mission to serve
5 different branches of the Canadian government.
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8
9 During an interview with one of the authors of this article, a Canadian Ice
10 Service official acknowledged that although the Ice Service's primary mission is
11 to support Transport Canada in managing the marine transportation system, the
12 Ice Service also 'support[s] DFAIT [the Department of Foreign Affairs and
13 International Trade, now Global Affairs Canada] in terms of their use of the
14 Arctic Waters Pollution Prevention Act, the ice-covered waters, Article 234'. The
15 official went on to note that in 1985, when Canada extended the area covered by
16 the AWPPA to 200 nautical miles (so that it would be coterminous with Canada's
17 Exclusive Economic Zone), the United States protested: "There were 156 faxes
18 that went out: "Are you sure that it is really ice-covered up there for most of the
19 year," [the U.S. asked], because it is very open language'. More recently, Canada
20 instituted NORDREG, a system of mandatory registration for ships entering
21 Arctic waters. Again, Canada justified this heightened level of regulation because
22 of the presence of hazardous ice, and again the U.S. protested what it saw as
23 Canada using the presence of ice to exercise an excessive level of sovereign
24 authority in its waters. According to the official, the Canadian Ice Service was
25 once again called upon to verify the presence of ice, based on the 10% ice extent
26 threshold: 'We define it as 10% [in interpreting AWPPA and Article 234] and....
27 now it's the same question with NORDREG. [The U.S.] keeps coming back to us
28 asking if it's really ice-covered up there'.
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55 At this point, a second Ice Service employee interjected to add historical
56 perspective. In the process, he indirectly alluded to on-going tensions between
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3 Transport Canada, DFAIT, and the Ice Service regarding the different ways that
4
5 the three agencies measured and communicated ice extent:
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8 It's interesting because 20 years ago there was a discussion of the use of
9
10 the term 'ice-covered'. The decision was that we really shouldn't use the
11
12 term 'ice-covered' to describe Canadian waters, [because] that's seen as a
13
14 negative....[Other possible terms were] 'ice-encumbered', 'ice-
15
16 infested'. Now we are kind of retreating back to [saying] 'they are
17
18 definitely "ice-covered" most of the year'. [You can] see where the
19
20 pressures have changed over the years.
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24 Left unstated was that the Inuit who actually live amidst these 'ice-covered
25
26 waters' would have yet another perspective, one that emphasises that their
27
28 Arctic home is constituted by connections rather than divisions between land,
29
30 open water, and sea ice (Inuit Circumpolar Council 2009, Art. 1). Such a
31
32 perspective would lead to different mappings projecting different politics and
33
34 different understandings of space as the surfaces across which individuals move
35
36 and construct their livelihoods (e.g. Pan-Inuit Trails n.d.).
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41 **Conclusion: the politics of ice**

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46 "The ice edge is lost. Those who find it, please deliver it to the address: longitude
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48 81. Knipowitsch."
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50 -- Nikolai Knipowitsch, oceanographer (Sörlin and Lajus 2013, 75)
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55 "This is scientific dishonesty. Scientists need to maintain the position of their
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57 data and not move the border of the ice so that it fits into a political or economic
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3 perspective. Scientists must maintain the premises of science and not listen to
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5 what politicians think is opportunistic to them.”
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8 -- Paul Wassmann, marine biologist (Norwegian News Agency
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10 2015b)
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14 We began this article with Prime Minister Solberg’s statement that ‘nature’ had
15
16 moved the ice edge. At one level, this statement can be analysed for its
17
18 conceptualisation of nature as a distinct, pre-social force whose actions can
19
20 explain the condition of observable phenomena. Critical theorists of the nature-
21
22 society relationship have contested this view (e.g. Braun and Castree 2005), but
23
24 even if one maintains that ‘nature’ exists as something distinct from the social
25
26 world Solberg’s statement can be critiqued. One can note, for instance, that the
27
28 ‘nature’ identified by Solberg has been impacted by emissions from the carbon-
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30 based economy that the policy change associated with the relocation of the ice
31
32 edge is meant to facilitate.³
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37 In this article, however, we have focused less on the ‘nature’ that is
38
39 ostensibly doing the moving and more on the ‘ice edge’ that is being moved. In
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41 order for the ice edge to be *moved* (by nature or by any other force), it must first
42
43 be identified as an ontologically stable object, and the ice and open water that
44
45 represent the two sides of this edge must similarly be identified as distinct
46
47 elements. As we have shown, this is hardly the case. Although the ice edge has
48
49 material effects, it is a construction that emerges from a fusion of science, law,
50
51 policy, and cartography. In short, the ice edge is less a point (or series of points)
52
53 *in* space – an ontologically stable foreground object that can be mapped against a
54
55 metric background -- than it is a construction that *defines* space. And, if it defines
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3 space, then what appears to be *movement* is really a moment of discursive
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5 reconstitution.
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8 Mobility is not the only property called into question once one removes
9
10 the ice edge's ontological stability. If the ice edge does not exist as a distinct
11
12 object, can it ever be said to disappear? Can it go missing? These were the
13
14 questions asked and implicitly answered in 1930 by Russian oceanographer
15
16 Nikolai Knipowitsch when he sent his tongue-in-cheek telegram to colleagues.
17
18 Noting that the ice edge was 'lost', Knipowitsch celebrated that he had correctly
19
20 predicted that, due to higher temperatures and changes in the Gulf Stream, there
21
22 would be an almost total absence of sea ice that summer in the Barents Sea.
23
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25
26 In a similar vein, one must ask: Once one has endowed the ice edge with
27
28 the qualities of an *object* that can be seen, observed, moved, and used as a
29
30 planning tool, what else can it do? Three days after Prime Minister Solberg's
31
32 remark about nature having 'moved' the ice edge, Norwegian television viewers
33
34 learned that the ice edge can also generate satire and, in the process, become
35
36 enlisted in a seemingly unrelated political controversy. On 23 January, one of the
37
38 hosts of the Norwegian television program *Nytt på Nytt* fused the ice edge debate
39
40 with an ongoing search for a Norwegian home for Kurdish Islamicist refugee
41
42 Mullah Krekar. Mullah Krekar had recently been released from jail after serving a
43
44 prison term for death threats towards Prime Minister Solberg. Sending him back
45
46 to Iraq could well result in a death sentence, which would violate Norway's
47
48 human rights obligations. So, the *Nytt på Nytt* host satirically suggested that
49
50 instead of sending Krekar to a remote Norwegian village where he could
51
52 continue to organize his potential terrorist networks, he should be sent to the ice
53
54 edge, where he would report several times a week on its exact location.
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3 The irony here is that while it is absurd to imagine Mullah Krekar
4
5 scientifically determining the precise location of the ice edge, such precision
6
7 likewise cannot be obtained by the scientists of the Norwegian Polar Institute,
8
9 the Canadian Ice Service, or any other institution. In the second quotation
10
11 reprinted above, which was criticising Norwegian Polar Institute director Jan
12
13 Gunnar Winther for his defence of the 2015 map, Tromsø-based biologist Paul
14
15 Wassmann contends that ice edge research can and should rise above politics
16
17 (see also, Krekling 2015). We have argued, however, that the very identification
18
19 of the ice edge as a distinct boundary and the concomitant designation of sea ice
20
21 as an object that has *presence* and *significance*, and that can therefore be used for
22
23 spatial planning, is itself embedded in politics. Drawing on fieldwork with the
24
25 indigenous peoples of northwestern Greenland, anthropologist Kirsten Hastrup
26
27 (2016) has called ice 'sociable' (see also Bravo 2010). Similarly, from their
28
29 research on glaciologists Carey *et al.* (2016) have designated ice as 'gendered'.
30
31 Our studies from Norway and Canada suggest that when ice is mapped by the
32
33 state it is not only *sociable* and *gendered*; it is *political*.
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39 To conclude, we do not entirely reject the stories of the ice edge told by
40
41 those who make and use maps that feature its depiction. The ice edge that was
42
43 lost by Nikolai Knipowitsch and later found by Prime Minister Solberg had
44
45 indeed been 'moved' by nature, even if, in the latter instance, nature had been
46
47 assisted by anthropogenic climate change. Likewise, we do not question Denis
48
49 Dubé's assertion that the shift to the 30-year median on the new Canadian map is
50
51 in fact a progressive change because it presents a better baseline that can be
52
53 used for assessing future changes in Arctic sea ice and that ultimately can be
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55 used to provide a more critical perspective on climate change, its effects and, by
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3 inference, its causes. However, so long as officials and activists – in Norway,
4
5 Canada, and elsewhere – persist in efforts to map the unmappable, reducing the
6
7 temporal and spatial complexity of ocean-atmospheric processes to singular
8
9 representations, these maps, and the elements enrolled in the process of
10
11 mapping, will take on a political significance that exceeds their specific
12
13 signification about the geophysical properties of space.
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17 The solution is not necessarily to abandon the map as a planning tool.
18
19 Numerous works in critical cartography have demonstrated how alternate
20
21 knowledges, applied from perspectives other than the idealised Euclidean space
22
23 of solid land and linear time, have led to different kinds of maps that have
24
25 permitted different kinds of spatial planning, reflecting the politics and views of
26
27 peoples (whether or not indigenous) who encounter space as fluid and dynamic
28
29 (Sletto 2009; St Martin 2005). Rather, the histories of the Norwegian and
30
31 Canadian ice edge maps, and the two countries' broader histories of ice
32
33 quantification, caution us to remain critical not just about *where* borders are
34
35 mapped in complex environments but also about *what* is mapped at all.
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40 Due to its inherent variability and indeterminacy, it is impossible to
41
42 achieve the kind of state-of-the-art scientific mapping of the ice edge proposed
43
44 by Wassmann. Indeed, such a mapping may not even be desirable, as it would
45
46 assign a false ontological stability to the socially constructed, arbitrarily
47
48 delimited, and spatio-temporally variable states of solid ice and liquid water.
49
50 However, so long as ice remains embroiled in the will to map, the ice edge will
51
52 remain a potent player in the efforts of scientists and statespersons to write
53
54 power to the world.
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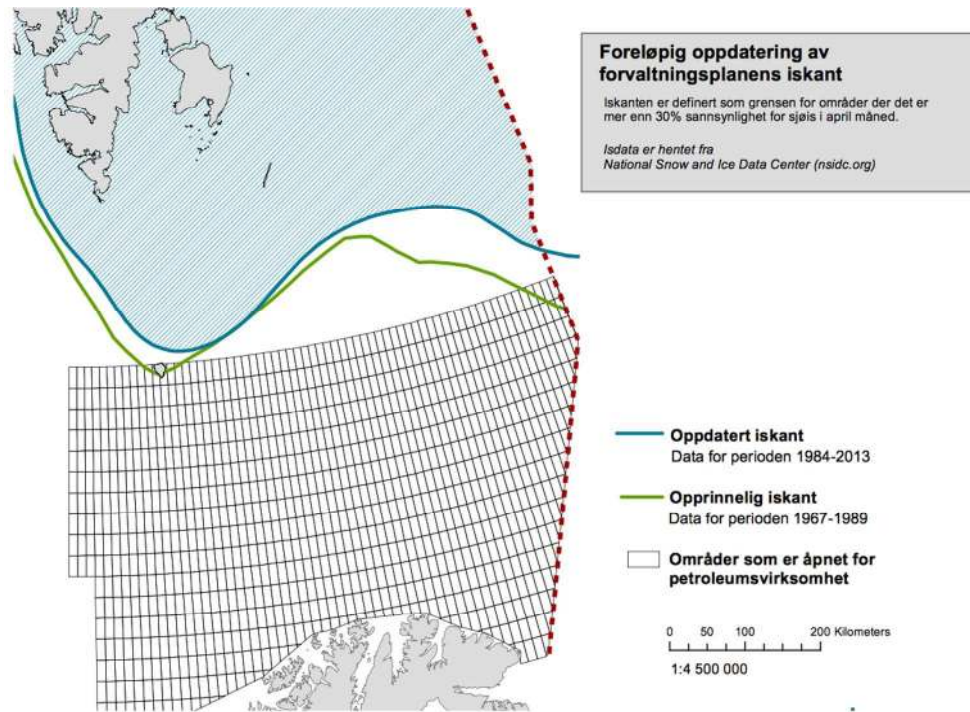
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48 (Figures 1 and 4) are reproduced in original Norwegian because their main
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50 purpose in this article is to evidence Norwegian depictions of sea ice rather to
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52 aid readers in finding precise locations.
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² See also the summary provided to Parliament that integrated findings from the series of 2003 reports (Ministry of Petroleum and Energy 2003).

³ In fact, in the report that accompanied the 2015 map, the Ministry of Climate and Environment (2015a, 26) noted that future ice-cover in the Barents Sea is critically dependent on the level of global greenhouse gas emissions.

For Peer Review



31 Figure 1: Map released by the Government of Norway, January 2015, indicating previous and revised
32 locations of the ice edge, as well as Norway's Southeast Barents Sea Offshore Oil Province (Ministry of
33 Climate and Environment 2015b). Reprinted with permission of the Norwegian Ministry of Climate and
34 Environment.

35 Translation of Norwegian text is as follows: Grey textbox: 'Preliminary update of the management plan's ice
36 edge – The ice edge is defined as the boundary of the area where there is greater than 30% probability of
37 sea ice in April. Ice data retrieved from National Snow and Ice Data Center (nsidc.org)'; Blue line: 'Updated
38 ice edge – Data for the 1984-2013 period'; Green line: 'Original ice edge – Data for the 1968-1989 period';
39 White outline: 'Areas open for petroleum activities'.

40 430x304mm (72 x 72 DPI)



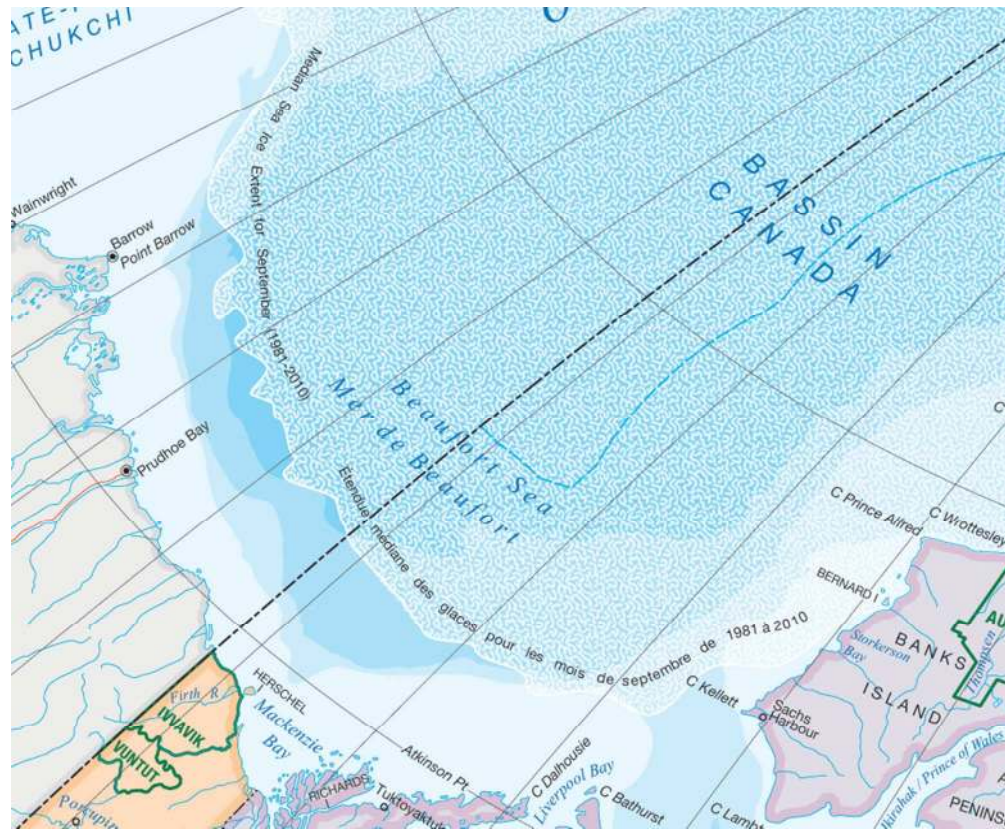


Figure 2: Detail from the national map in the 2015 edition of the Atlas of Canada, depicting the 'Median Sea Ice Extent for September (1981-2010)' (Natural Resources Canada 2015a). Reprinted courtesy of Open Government Licence - Canada.

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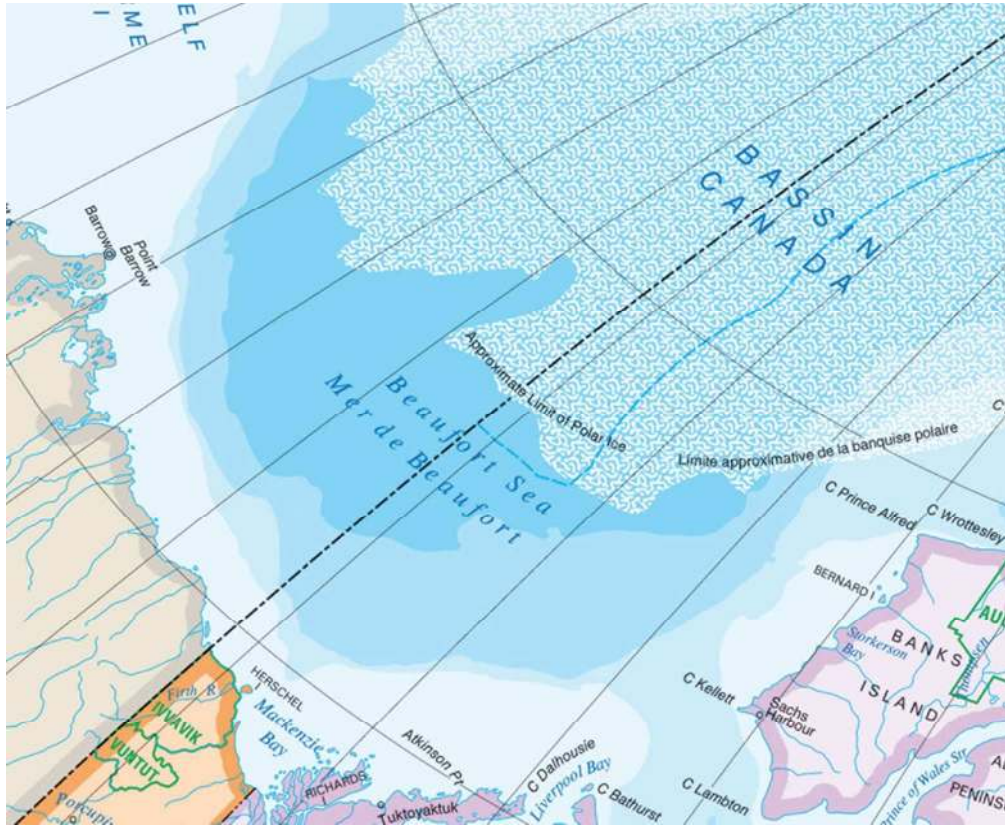
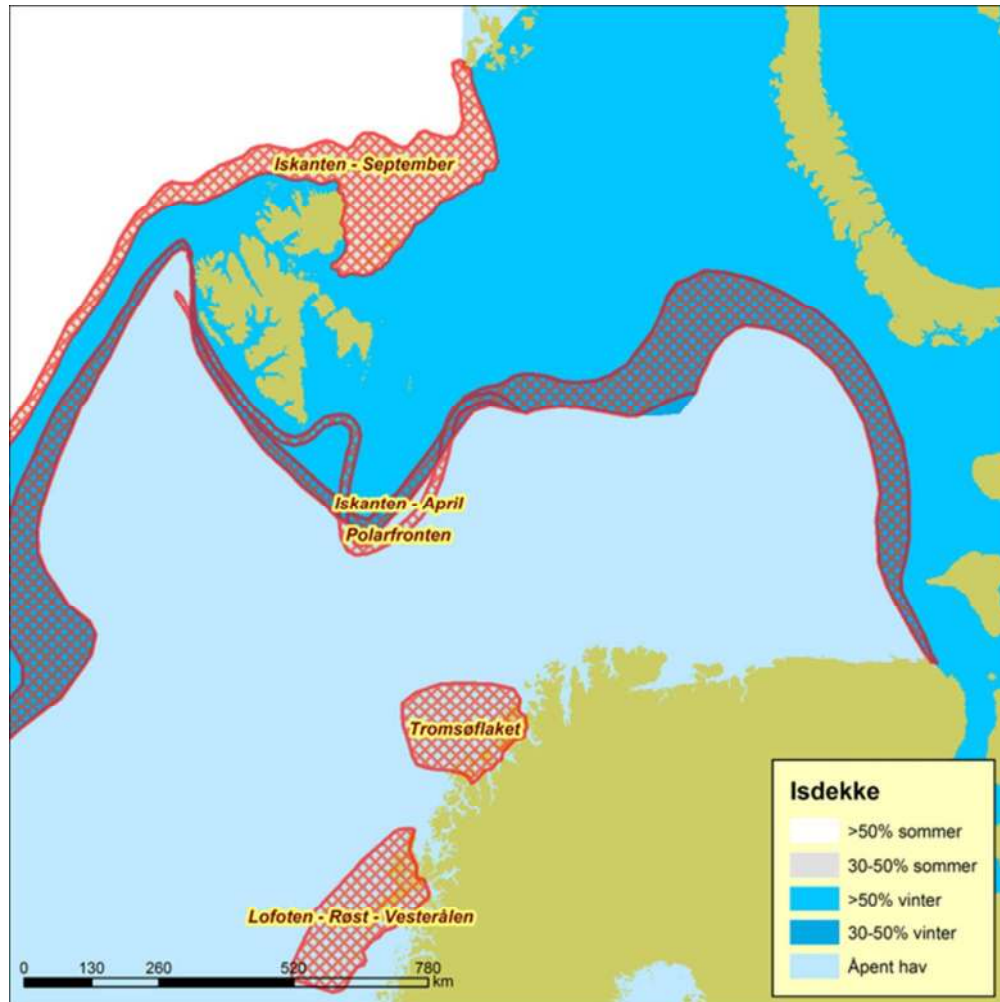


Figure 3: Detail from the national map in the 2006 edition of the Atlas of Canada, depicting the 'Approximate Limit of Polar Ice' (Natural Resources Canada 2006). Reprinted courtesy of Open Government Licence - Canada.

view



40 Figure 4: Figure from The Identification of Particularly Valuable Areas in Lofoten – Barentshavet (Olsen and
41 von Quillfeldt 2003, 62). Reprinted with permission of the Norwegian Institute of Marine Research.

42 The four 'especially valuable areas' that crucial to supporting the region's biodiversity are identified on the
43 map with red hatching, from south to north: (1) Lofoten – Røst – Vesterålen, (2) the Tromsø sheet
44 (Tromsøflaket), (3) the Polar Front (Polarfronten), and (4) the September (minimum) and April (maximum)
45 ice edges (Iskanten). Translation of Legend: 'Ice cover: >50% Summer; 30-50% Summer; >50% Winter;
46 30-50% Winter; open water'.
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48 226x226mm (72 x 72 DPI)
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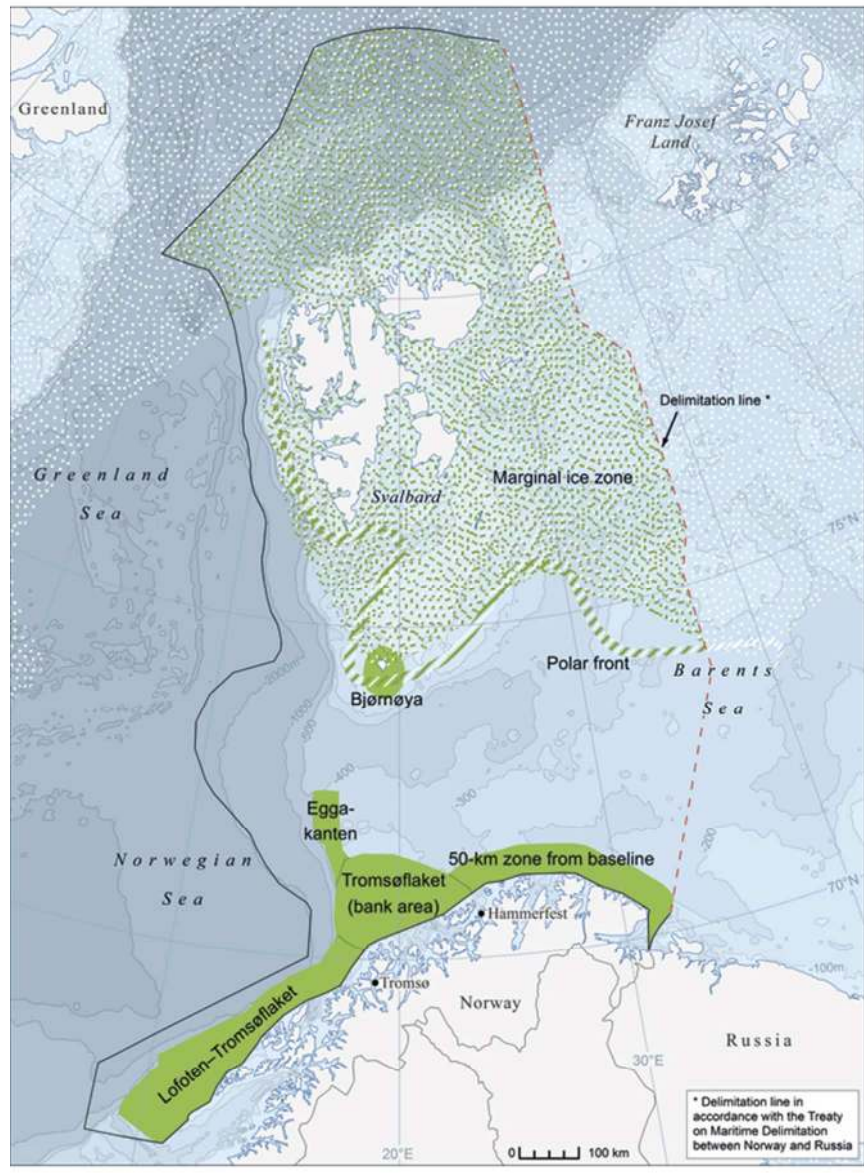


Figure 5: Particularly valuable and vulnerable areas in the Barents Sea – Lofoten area (Ministry of the Environment 2011, 24). Reprinted with permission of the Norwegian Ministry of Climate and Environment.

218x306mm (72 x 72 DPI)