Geophysical Information Providers in the Arctic

Dynamics and Developments

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Abbreviations:

MET: Meteorological Institute

ESA: European Space Agency

WMO: World Meteorological Organization

IMO: International Maritime Organization

AARI: Arctic and Antarctic Research Institute

NOAA: National Oceanic and Atmospheric Administration

DMA: Danish Marine Authority

SAON: Sustaining Arctic Observing Networks

IASC: The Inter-Agency Standing Committee

ADC: Arctic Data Committee

1. Introduction

It is widely known that climate change is moving much faster in the Artic than elsewhere. The concern about this has led to extensive research efforts trying to unravel its risks but also opportunities (ACIA 2005, Brunstad 2007, Howard 2009, Sale and Potapov 2010, Stewart et al. 2010, Smith and Stephenson 2013, Stephenson 2014). Thereby, both opportunities and challenges create a need for enhanced information services. There are four main sectors that depend on it, namely research, management, industry and military. In the past, military activity had a leading role in the Arctic but lately economic activity is increasing significantly and attracts attention all over the world. The possible future economic development in this area, fostered by an opening up of new shipping routes and undiscovered resources is thereby a popular topic (Ho 2010, DNV 2010, Harsem 2011, Lasserre and Pelletier 2011, Smith and Stephenson 2013, Lasserre 2014, Stephenson 2014, Haavisto et al. 2016). These developments awaken concern and induce researchers from many different disciplines to gain more knowledge about possible impacts, dangers and solutions (Arbo et al. 2013). To generate this knowledge, researchers themselves are in need of information and at the same time produce information whereby they further support economic development. Researchers discuss different scenarios, drivers and drawbacks of the future economic development, of which the status of the marine infrastructure is a common element. Information and their providers, especially geophysical information, play an important role and constitute an essential part of the development of the marine infrastructure. According to literature, the availability of this information plays a vital role for the overall economic development. Moreover, it is an indispensable element of the current status, portrayed by a lack of information availability, access and reliability, thereby constituting a drawback to possible economic progress in the Arctic (AMSA 2009, Lasserre and Pelletier 2011, Smith and Stephenson 2013, Haavisto et al. 2016).

Moreover, current developments in the information sector with new providers and services emerging, might lead to a rapid change of this situation and intensively support an increasing economic activity. Therefore, in order to foster a sustainable development and avoid/reduce environmental impacts it is relevant to investigate these information providers in more detail. What are the main developments? What role do partnerships, information sharing and networking play? What are their data sources and which stake does technology have in enhancing activity in the Arctic? For whom do they provide information and to what degree do the users influence developments? These and more questions need to be investigated in order to better understand information provisioning. Note that the role of military activity in the Arctic as well as the impact of their technologies becoming available for civilian usage, such as radars, is not part of this study and would need to be investigated in future research.

The investigation of information providers is particularly relevant as they have not been directly addressed in research. So far they were only mentioned in other research context, which creates major knowledge gaps. However, many of the above mentioned aspects like information sharing, technology and sustainability, etc. have been extensively discussed in literature, and a detailed study of this literature can foster understanding different elements that are part of modern information provisioning. Moreover, this information can then enable us to draw connections to the overall functioning and behavior of providers. Further, a major gap is that these studies have

not yet been seen in connection to each other even though many of these aspects play an important role in the globalizing world and its organizations. Consequently, possible relations between those aspects and their implications for sustainable economic development are possibly being neglected.

In the following, these issues will be investigated through literature research, website analysis and qualitative interviews. First, the status of current literature will be portrayed, followed by an analysis of current information providers. Then, similar ongoing research projects will be investigated based on website analysis and recommendations will constitute the final part of this paper.

2. Literature review

Investigating current literature, it very quickly becomes clear that conducted research regarding information providers in the Arctic is very scarce if not non-existent and information about them can only be found in passing comments. However, many different aspects and dynamics play a role when trying to understand the provider side. Elements like technology, sharing and partnerships, ongoing developments, users and their needs, as well as motives are key to understanding information provisioning. Further, as we are trying to analyze the relationship between economic activity and the production and provision of information, we will investigate literature regarding the possible future of the main economic sectors in the Arctic.

2.1. Economic activity in the Arctic Ocean

The Arctic Ocean is known for its remoteness nevertheless, there is a considerable amount of economic activity. Among the most relevant industries are fishing, oil and gas, tourism and transportation (noep 2015). Different studies have been undertaken researching the future development of these sectors with regards to climate change induced impacts on the Arctic environment. Generally, shipping activity in the Arctic is predicted to be increasing with a reduction in sea ice content (Ho 2010). However, it is also stated that the general conditions in the economy that would lead to an increase are not the only factor to consider. Other aspects like general infrastructure, forecasts etc. will need to be enhanced in order to allow shipping to increase. In the following we will look at the different sectors in more detail.

Transportation

Many state that climate change will reduce the amount of sea ice and with that might open up new shipping routes (Smith and Stephenson 2013, DNV 2010). Further, climate change might prolong the shipping season, make the area more accessible and due to reduced travel distances increase shipping activity (DNV 2010, Lasserre and Pelletier 2011, Peters et al. 2011, Lasserre 2014).

DNV (2010) suggests that container shipping during part of the year would be more profitable when done via the Arctic and thereby reduce emissions. Smith and Stephenson (2013) investigated the impacts of the expected geophysical conditions on shipping in the Arctic. They found that a considerable amount of new shipping possibilities will emerge by the mid-century that would have significant political,

economic and environmental implications for the region. Nevertheless, they also mention that there are significant non-climatic factors that also limit shipping and need to be improved to support new shipping developments. Lasserre (2014) supports this statement by saying that generally the sea ice is not the limiting factor anymore, due to new technologies, ice breakers and already much thinner ice. Now, it is apparently more about business choices than technologies (Niini et al. 2007, Lasserre 2010b in Lasserre 2014). The most likely much higher insurance costs, high Russian tariffs, small load factors and the overall unreliability connected to keeping time-schedules, make a high increase in shipping activity questionable (Lasserre 2014). Lasserre and Pelletier (2011) further mention that the high competition in the transport sector makes reliability and cost factors of prime importance. Apart from this, they mention a lack of intermediate markets, ports, navigation aid and the inaccuracy of nautical charts as key factors limiting an increase in shipping activity. This outline shows that the reduction in sea ice does not play such a major role for making the Arctic a more popular transportation route.

Fishery

When looking in more detail at the different industries, climate change will have likely impacts on most of them. The fishing industry is thereby expected to move northwards as some of the current fish stocks might move together with the ice edge (McBride et al. 2014). However, the high north of the Arctic has been closed for unregulated fishing in an agreement of the Arctic States (2015) until more knowledge is obtained about the changes occurring in this area and its possible impacts. Therefore, the option to move north is at this moment limited.

Further, Pfeiffer and Haynie (2012) mention that due to fuel cost and travelling times locations closest to the port are always preferred which also suggests that fishers might not necessarily move too much northwards with fish stocks. Moreover, McBride et al. claim that it is difficult to predict the development of the fish productivity due to the complex net of factors that influence it in one way or another. Brandner (2010) assumes that fish production might go down in the Arctic due to more freshwater from rivers that lead to reduced nutrient fluxes. Next to these geo- and biophysical changes, there are also other factors as pointed out by Pfeiffer and Haynie (2012). They state that next to the environmental changes also price, market conditions, management and contractual obligations are important factors. Similarly, Eide (2008) suggests that future economic activity in the Barents Sea is more dependent on management structures than on impacts of climate change. However, they generally suggest that available fishing grounds may expand with a reduction of the ice cover. Nevertheless, the actual behavior of fishers always depends on multiple factors. "*Harvesters choose where to fish by making trade-offs between the value per tonne of harvest, cpue, the distance they must travel, and the safety and availability of different areas*" (p. 1149). This means that also with regards to the fishing industry, it is difficult to predict the future economic development.

Cruise Tourism

Different studies (Hall, 2001, Stewart et al. 2005, Lemelin et al. 2010, Stewart et al. 2010, Lamers and Amelung 2010) state that tourism in the Arctic has been significantly increasing in the last decade. Further, it is stated by Lemelin et al. (2010) that this trend is likely to be kept up as a result of the "last-chance" tourism boom, where people want to see places, endangered by climate change, before they vanish. Lamers and Amelung (2010) support the likelihood of the polar tourism to increase. However, they argue that it is and will be a result of the decrease in sea ice and an opening up of the Arctic Ocean. They suggest that this will make more remote places available but also prolong the shipping season. With regards to this opening up of more remote places, Fay and Karlsdottir (2011) emphasize the need of better monitoring of cruise tourism in the Arctic due to the vulnerability of the area. However, most literature available regards tourism in Arctic Canada where an increase in cruise tourism has been witnessed over the last years (Stewart et al. 2010). Consequently, this lack in research on the other areas of the Arctic, prohibits us to make predictions about the developments in the Arctic as a whole. This is supported by the fact that researchers stated that climate change will make Arctic waters even more unpredictable and with that navigation more difficult and insecure (Hall and Saarinen, 2014; Stewart et al. 2011; Lamers and Amelung, 2010), which might prevent the industry from growing extensively. Further, with climate change the features that draw people to this area will vanish and thereby reduce its attractiveness (Lemeling et al. 2010). Unsatisfied tourists have already been a re-occurring event (Schwabe 2008, Maher and Meade 2008). This shows that also in tourism, developments are uncertain and no clear predictions can be made.

Oil and Gas

When it comes to oil and gas activities in the Arctic, AMAP (2007) states that it is defined by high operating costs, limited infrastructure, difficult working conditions due to temperatures and darkness and complex management and regulation processes. Nevertheless, researchers agree on the likelihood of an increased future activity in the Arctic (AMAP 2007, Howard 2009, DNV 2010, Harsem et al. 2011, Peters et al. 2011). They state that an increase in demand will drive the global need for stronger production. Further, expected easier accessibility of the area in the future would make exploration less difficult and costly. Moreover, climate change and a resulting reduction of the by sea ice covered area coupled with an expected high amount of undiscovered resources, make the Arctic attractive for increased production. However, climate change is also expected to lead to more extreme weather events in the area, which could make exploration more difficult (Harsem et al. 2011). AMAP further mentions that global factors such as international politics and energy demand in general and particularly in emerging countries will have a high influence on the developments in the area. What further increases complexity is the fact that all the Arctic countries have different levels of activity, different procedures, regulations and interests in this sector. Consequently, developments in each of the countries by itself are complex and can have influences on the development within the other countries. Following, all these factors taken together, it becomes obvious that we are dealing with a highly complex issue, influenced by many different aspects. Therefore, it is clear that a certain statement about the future development of the oil and gas activities in the Arctic cannot be made.

2.2. Implications of literature review for the project

The outline of economic activities summarized the standpoint of each of the four major industries with regards to their future development. It made clear that climate change is in most of the cases a driver as well as a possible drawback of increased activity. Moreover, it is by far not the only factor that will influence developments in the different sectors. Even though an increased activity is expected in all four industries it remains to be seen how and when this will happen. The reason for this are the multiple other factors that play a role and even more important the interdependency of these factors. With that no clear projections of the future can be made, however, it is clear that information will play a continuously important role in these unclear future developments. Information providers are and will remain key to tackling uncertainties and supporting sustainable and safe activities.

3. Providers: Dynamics of information provision

A website and literature research showed that there are many different information providers, which work on different scales, for different user groups, on commercial or non-commercial basis and so on. They can be broadly separated in research related information providers, operational information providers, providers of raw data such as ESA, and information sharing platforms/data management platforms. It further showed that there is a lot of development with new organizations, networks and projects emerging. These developments happen on all levels regarding information provisioning, with research networks (e.g. Arctic Science Partnership[1]), data management cooperation (e.g. Arctic Data Committee[2]), collective data provisioning (Arctic Web) and other activities emerging. As the aim of this project is to understand the connection between information provisioning and economic activity we will here focus on operational information providers.

3.1. Information Supply Chain

When it comes to information provisioning it is relevant to mention that there is not just the providers and then the users but bevor the users receive their information product there are different links. How many intermediate parts there are differs extensively. Most generally it can be said that there are data providers of raw information from satellites that then need to be interpreted by for example meteorologists. There are for example NOAA, AARI and METEOSAT that provide satellite pictures (Interview HL, MB). The European Centre for Medium-Range Weather Forecasts that provides weather forecast data, the Japan Aerospace Exploration Agency which provides weather and ice data and ESA that provides Synthetic Aperture Radar data (Interview CK, NH). Further, the National Snow and Ice Data Center plays a role and is being used by for example the AWI, as well as Universities that have own measurement stations and function as a data provider (Interview CK). Those data are then used by METs and others to produce information for the public and operations. The METs also generate their own data through own buoys, observation stations etc. (Interview HL). This information and data is then provided to end users or for further links in the information chain, such as new initiatives. These new initiatives also receive data from marine and coastal authorities (Interview MB). The initiatives then put bits and pieces from the different sources together and transform it into more personalized information. However, this supply chain is very complex and which provider uses which sources and how many, differs largely and needs to be investigated in more detail. *Figure 1* shows a simplified image of the information supply chain.

[1] http://www.asp-net.org/
[2] http://arcticdc.org/

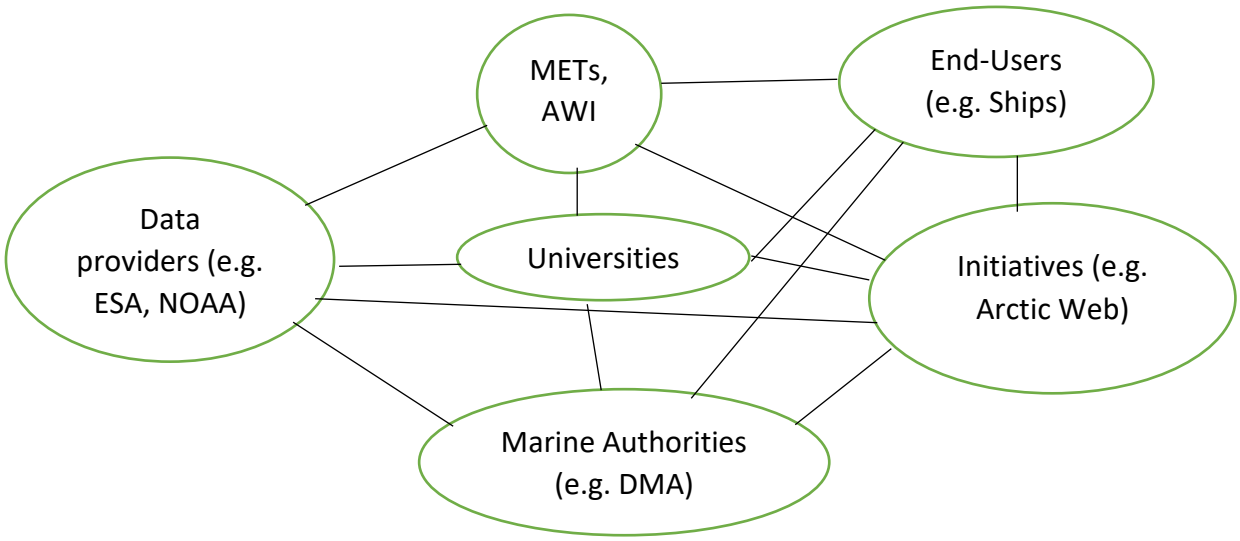

Figure 1: Information Supply Chain

3.2. Operational information providers: Organizations, initiatives and projects

According to literature, the main operational providers are in terms of weather the national MET services, INMARSAT[3] for the high waters and the WMO (AMSA 2009). For ice services, it is the national ice service centers, commercial providers and academic institutions (AMSA 2009). However, there seems to be a shift with more and more new initiatives and projects emerging in the field of information provisioning in the Arctic, such as Barents Watch, Arctic Web, EfficienSea2, Arctic Portal and Polar View.

In the following we will shortly introduce some of the new initiatives and their main developments.

3.2.1. Arctic Web[4]

Arctic Web is a Danish organization that was founded in 2013 and is funded by the Nordic Council of Ministers. It started off by trying to create a tool for cruise ships to do their obligatory risk assessments. This is based on a fairly new regulation from the IMO that among others, requires cruise operators to check at least once a day 21 risk items such as wind speed, distance to other vessels etc. This new legal requirement made Arctic Web focus on the Arctic cruise ship industry by providing them a medium for better access to all the information necessary for the assessment. Arctic Web aims at incorporating the entire Arctic, however so far they focus on the Danish and Norwegian part. Their information is freely accessible on their website and consists of synthesized data from different sources aimed at giving a vessel all information it needs regarding its

[3] http://www.inmarsat.com/
[4] https://arcticweb.e-navigation.net/

specific route. This includes a route planner that enables the vessel to see safety and rescue information, other vessels in the area, weather and ice information for its specific route. It is a very personalized service that aims at reducing the data volumes and with that costs. Arctic Web has about 120 vessels as users, however the close cooperation for new developments is with a group of 6-10 vessels from Oceanwide Expeditions, Hurtigruten and Princess Vessels. In case of an implementation of a new service every user gets informed via email. Further, there is cooperation with CLIA and AECO the big organizations behind cruise tourism in the Arctic. Further, they discuss and exchange ideas with other providers such as Barents Watch and EfficienSea2. Data sources are over all the DMI that provides them with weather and ice information. (Interview MB)

3.2.2. Barents Watch[5]

Another interesting example is Barents Watch. What is particular about them is the attempt to provide information for different types of users in one platform. They have different sections and services, whereby some of them are open and others restricted. Most of their information is, however, not so much Arctic related and also weather and ice information are only a marginal part of the whole service. Their main focus is the marine territory just off the coast of Norway. They only provide synthesized information and don't produce information themselves.

There are two restricted areas where access is limited to authorities. One regards crime detection and prevention and the other facilitates rescuing. These sections and their content are determined by the cooperating authorities. As Barents Watch is part of the Coastal Administration, much of their services are focused on supporting marine authorities. What further enforces their connection to national authorities is the fact that they are financed by the government as part of the transportation plan.

Among the open ones there are services that are mainly used by cruise operators, like the wave warning service. Other services are directed at all vessels like port information. However, the most relevant user seems to be the fishing industry. For them a partly restricted area exists, that only registered fishermen may access.

They are focused on the Norwegian territory and therefore mainly cooperate with Norwegian actors. However, they also have more lose partnerships, as with Arctic Web, where it is more about inspiring each other and exchanging thoughts. (Interview ER)

3.2.3. Arctic Portal[6]

It was founded in 2006 as an IPY project and is run in a cooperation with the Arctic Council, its working groups, permanent members and others (UArctic, 2016). It is financed through assignments, such as participation in research projects, but is run as a non-for profit organization. They function as a sort of broker of information, aiming at enhancing cooperation, outreach, education and politics. They provide news regarding

[5] https://www.barentswatch.no/en/
[6] http://arcticportal.org/

the Arctic and all sorts of relevant information and data regarding for example energy, sea ice and transportation. Next to a small amount of freely accessible data such as a mapping service, they mainly work on tailor made requests. They do so through a broad network of international partners. Depending on the project they work together with modelers, satellite experts or social scientists. Further, they function as a host of different websites to enhance information sharing. (Interview KJ)

3.2.4. EfficienSea2[7]

Further interesting is a project of the Danish Maritime Authority called EfficienSea2. The overall aim is to enhance safety, efficiency and sustainability of maritime traffic through increased connectivity. To facilitate this, the project is marked by a high level of cooperation among different international public, private and governmental actors. They want to develop an e-Navigation service that combines information and services from different providers in one application. They see one of the main bottlenecks for safe and efficient navigation in the lack of full information sharing between providers and ships. One of the reasons for this they see in the poor quality of communication technology, next to a lack of high quality weather and ice information. The project is financed by the EU and regulated by the IMO. They work on new products, generate new information and synthesize existing data. So far only project partners have access to the pre-operational services and information, however, once finished this shall be openly accessible. The main users will be intermediate maritime service providers that can get the data from the DMI and make products for their users. Further, also ships will be direct users. (Interview JS)

3.2.5. Polar View[8]

This organization started as a project supported by ESA and the European Commission and was officially formalized in 2011. Their team consists of research institutes, service providers, system developers, universities and governmental agencies from different countries around the world. Their focus is satellite based information services to support global economic activities, resource management, risk management and marine operations, all with a focus on sustainable development and activity. A lot of their services are centered on sea ice related information, but they generally provide information about the Arctic and cryosphere. They provide general services as well as customized information. Access to these data happens upon request, is therefore restricted. The services they provide is financed through the users, as Polar View provides information on a commercial basis. (Polar View n.d.)

3.2.6. Others

Next to the above mentioned initiatives, there are other relevant providers that will be mentioned in the following analysis, have however not been focused on in the study. There is for example the Alaska Ocean Observing System[9] that plays a crucial role in

[7] http://efficiensea2.org/
[8] http://www.polarview.org/about/
[9] http://www.aoos.org/

terms of data generation and provisioning for the Alaskan area. Further, the Alfred Wegener Institut[10] is a relevant actor with regards to data generation and provisioning. Their focus is however on research and their data is mainly used for informing the public. In an operational sense it is mainly used by their own ships and research teams but also by others as the cruise industry (interview CK). Further, commercial providers such as StormGeo[11] or Inmarsat play a role for operational information services.

3.3. Dynamics

These new organizations and projects seem to be emerging everywhere but what are the dynamics behind these developments and how do they differ from original information providers? In the following, we will look at some of the main dynamics such as scales, access, finances, users, types of services, partnerships and drivers. Next to website and literature research, interviews will support this analysis.

3.3.1. Types of organizations

The operational information providers are spread across a broad spectrum of organization classifications. The traditional MET services are generally public and tax financed. The new providers on the other hand, are either private and run on a commercial basis such as Arctic Portal and Polar View, or public. Among the public providers different groups exist, mainly distinguished by their scale. Some operate nationally such as Barents Watch that is connected to other national governmental authorities, similarly Arctic Web, as run by the DMA. On a bilateral level such as Barents Portal[12] or internationally such as projects like EfficienSea2. This makes clear that there is not a particular legal status that fosters information provisioning activities.

3.3.2. Geographic scale

What first attracts attention when looking at the scale these new providers operate on, is that they are focused on the part of the Arctic that they are settled in. Barents Watch, a Norwegian organization thereby focuses on the Barents Sea and the part of the high Arctic that Norway is responsible for, in terms of forecasts (Interview ER). Arctic Web, a Danish organization, started off with Greenland but is now trying to incorporate Norway and more parts of the Arctic (Interview MB). Alaska Ocean Observing[13] focuses on its regional and national areas (AOOS 2016). EfficianSea2 also a Danish project, led by the DMA is so far focusing on the Baltic Sea and European Arctic (Interview JS). Another example is the Arctic Voyage Planning Guide from the Canadian government[14] building a strategic planning tool for all vessels that travel through the Canadian Arctic (Government of Canada 2016). However, we also see a trend in wanting to incorporate

[10] https://www.awi.de/en.html
[11] http://www.stormgeo.com/
[12] http://www.barentsportal.com/barentsportal/index.php/en/
[13] http://www.aoos.org/
[14]

more areas and provide services on a broader scale. Arctic Web is thereby trying to involve Canada and Russia and Barents Portal is an example for an increased cooperation in the European Arctic with a focus on integrating Russia. With regards to the commercial providers it attracts attention that they are focused on a broader area, including the entire Arctic and partly Antarctica such as Polar View (Polar View n.d.). Further, also the national MET services are focused on their territory (Interview HT). Consequently, this also partly explains the fact that new public initiatives are focused on their national territory, as the data source they use is to a large extent the national MET service. Therefore, we can assume that providing services for a restricted area is largely an effect of having different national regulations, standards and bureaucratic set ups which to some degree prevent cooperation and incorporating international territories.

3.3.3. Accessibility

What these new initiatives seem to have in common is a tendency to be openly accessible. Nevertheless, usage in most cases requires being a registered member. This open accessibility seems to be in part explainable by the fact that they try to enhance operation in the Arctic on a broad scale. Some, such as Barents Watch and Arctic Portal however have next to the openly accessible services also restricted areas. With regards to Arctic Portal this is explained by the fact that they are a commercial provider that mainly works on tailor made services and requests (Interview KJ). Barents Watch has two restricted areas that are limited to authorities. One regards crime detection and prevention of operators such as fishing boats and only allows access to the national police, tax and related authorities. The other service facilitates rescuing by showing all available resources and is therefore restricted to national on- and offshore rescue entities such as the police (Interview ER). With regards to the national MET service and other public organizations such as the Alfred Wegener Institute[15] their information are openly accessible as it is part of their mission to inform the public and increase safety on a national level (Interviews HT, CK). However, for example the MET also provides tailor made services as for oil and gas companies which are then restricted to the users that paid for the services (Interview HT).

3.3.4. Finances

National MET services are state financed and therefore supported by taxes. Next to this they have some income from the already mentioned tailor made services (Interview HT). This income is used to enhance their information provisioning services. Also public foundations are state supported such as the Alfred Wegener Institut, which receives money from the ministry of education and research as well as from the city Bremen (AWI n.d.).

New organizations on the other hand, have funding from different sources. Barents Watch as part of the Coastal Administration is also funded by the government, receiving money from the Transportation Plan resources (Interview HT). Arctic Web is financed

[15] https://www.awi.de/en.html

by the Nordic Council of Ministers (Interview MB). Arctic Portal is financed by its customers (Interview KJ). The Alaska Ocean Observing System is funded by the US Integrated Ocean Observing System and different services such as specific maps have additional funding (seafoodsource 2016, AOOS 2016). EfficianSea2 is an EU project and receives funding from the EU Commission (Interview JS). The latter is further a funder of many current research projects that are related to this one.

1.1.1. Drivers

We can see that the information providers differ largely in the above investigated criteria. Therefore, pointing out the drivers is not that straightforward. If we take a look at the literature, technology is declared as a major driver of advancements in economic growth. Does it also play an important role in the advancements of information provisioning? In the following we will investigate what literature states about the role of technological development and finish with a look at possible drivers of the advancements in information provisioning in general.

1.1.1.1. Technology as a driver

Another interesting aspect of information provisioning is the development of technology. In our case satellites and communication technology play an indispensable role, as providers would neither have the necessary data to deliver information about nor would they have the medium to reach users on a broad scale. These technologies allow providers to support activity in the Arctic. They deliver near real time information about weather and ice for planning routes as well as access to information in remote areas, thereby enabling activity to occupy more and more so far untouched places. Moreover, it is expected that space technology will play a key role in supporting safe and sustainable activity in the Arctic (Bekkadal 2014). Further, the topic of technological advancements, ICT development in particular, and its impacts on the environment (positive and negative) are a large topic in literature (Symons, 1991, Hilty and Ruddy 2002, Berkhout and Hertin 2001, Hilty et al. 2006). For our research, this is interesting as information providers depend on these developments and are in need of innovations and improvements of current technologies in order to address the users' needs and provide more accurate, reliable and user-specific information in higher frequencies and to less costs. Berkhout and Hertin (2001) take up this discussion and investigate the connection between ICT, economic activity and sustainability. This idea is investigated in more detail by Hilty et al. (2006) who state that impacts depend on the sector and increased impacts can be expected in the transportation and freight sector where rebound effects in form of increased activity and with that increased energy consumption and emissions are likely. This would play a role in the analysis of the connections between information providers making navigation easier and safer through enhanced technology and information systems and thereby increasing activity and impacts.

1.1.1.1. Research as a driver

Whereas the traditional MET services were created to enhance safety and protect people and their belongings, changes within their services seem to come from user requests but

also research (interview HT). In the last decades researchers from different fields tried to unravel climate change and its impacts on the Arctic. Also, because researcher themselves are a main user of operational information and therefore experience first-hand where lacks in provisioning are. Their findings thereby seem to steer changes within information provisioning trying to fill the gaps. This increased research is also leading to more and more research cooperation and data sharing platforms such as the Arctic Data Committee or the Arctic Science Partnership. These initiatives are aiming at coordinating the growing amount of data. The role research plays in current developments within the information provisioning sector should therefore, not be underestimated.

1.1.2. Partnerships and cooperation

With regards to cooperation it is interesting to take a look at current literature, as the issue of integrating actors and sharing among actors has been a popular research topic. With regards to the Arctic this literature can be divided in two major parts. There is a fairly large part that deals with the issue of how to deal with community based information and data, which plays an essential role in the Arctic. The other part looks at the general relevance of achieving more information sharing and cooperation among Arctic actors. We will describe both in the following.

1.1.2.1. Literature review: information sharing

Pulsifer et al. (2011, 2012, 2014) investigated the value of indigenous knowledge, its collection, management and sharing. Johnson et al. (2014) looked at the relevance and current state of including community based knowledge in the Arctic Observation Network and Eicken et al. (2014) studied community sea ice knowledge in comparison to technological sea ice data. All these studies thereby highlighted the necessity of better including community-based knowledge into existing information systems for more sustainable and integrated development. This research further emphasizes the relevance of including different stakeholders in the information provisioning, in order to benefit from the different types of knowledge they possess, but also in order to address the manifold information needs of the different stakeholders in the Arctic. The other aspect it clarifies is that modern information providers should not only focus on technological data gain but also integrate human based data and observations for better and more holistic information provisioning. This also hints at a need for a generally higher degree of cooperation among stakeholders and more sharing of information among providers.

This topic is dealt with in a separate body of literature, which investigates this issue in more detail and from different points of view, stressing diverse reasons for increasing cooperation and sharing. For understanding providers better, this topic is relevant as it can tell us more about general trends and necessities regarding information provisioning and help to explain behavioral patterns among providers. Lovecraft et al. (2013) stresses the importance of integrating different interest groups and unifying information provisioning for a broader range of stakeholders for more effective and sustainable practices. Others, like Smith and Stephenson (2012) call for more common regulations in order to enhance management. Similarly, Brigham (2008) asks for more cooperation to support the economic growth in the Arctic. In his opinion, economic growth will not be possible if the challenges of a lack of infrastructure and too diverse

laws are not overcome. Overpeck et al. (2011) also calls for more sharing and cooperation, however, putting the focus on the large amounts of data that are available and increasing numbers of actors and interests that need to be unified. Ostrom (2010) supports this call for unification and sharing whereby he more generally talks about a need for cooperation in order to overcome global challenges like climate change. Another reason for generating more sharing is mentioned by Li et al. (2011) that see this necessity in order to enhance research activities. Further, Bertzky and Stoll-Kleeman (2009) mention the relevance of more cooperation among actors in order to guarantee better nature conservation and more sustainable practices. This list is extendable but what already becomes clear is that development in the Arctic needs stronger cooperation and sharing of information among different actors in order to support growth and enhance sustainability and nature protection.

1.1.2.2. Cooperation among information providers

Arctic information providers seem to seize on this call and many developments seem to be based to a large extent on sharing of information and cooperating with other organizations.

With regards to the national MET services they have strong cooperation within other governmental authorities. Further, they have internationally strong cooperation with other MET and ice services through big organizations such as the WMO. Further, regional partnerships exist. The Norwegian MET for example strongly cooperates with the Swedish MET and in the future also with the Finish MET. What initiates this cooperation is sharing the same latitudes and with that similar conditions and challenges. Therefore, when tackled together they have more resources and capacities to strengthen and enhance their knowledge and services. Further, they cooperate bilaterally with Russia. The Norwegian ice service works closely together with the other North European ice services but also internationally in the Ice Charting Working Group (ICWG) and the WMO. Whereas the WMO is a formal cooperation, under the ICWG more informally information is exchanged and trainings are developed. (Interviews HT, NH)

This trend discussed in literature we can clearly see as an integral part of the dynamics in information provisioning. For the new organizations, partnerships seem to be essential. Whereas MET services partly cooperate the new initiatives seem to consist of partnerships. Especially projects such as EfficienSea2 are enacted through large international cooperation. It consists of 32 partners from a mainly maritime background, from 12 different countries (EfficienSea2 n.d.). This is also an essential element of the workings of Arctic Portal which is able to provide many of its services only through the broad network of partners that it has. Thereby partners are from research and other academic institutions, spread across all different disciplines. This way they are able to facilitate all sorts of services(Interview KJ). Further, Barents Watch is characterized through its close link to state authorities but also shares ideas and thoughts with similar initiatives, such as Arctic Web (Interviews ER, MB). The latter thereby has strong cooperation with the Danish MET, that functions as a source of data. Further, CLIA and AECO as big organizations representing Arctic Web's main user groups are important and close cooperation partners. Moreover, they have knowledge exchange relationships with project managers such as the one of the Arctic Voyage Guide from the Canadian Government and EfficianSea2 managers. Arctic Web is further

trying to enhance its partnerships also with Russian actors etc. These cooperation thereby seem to represent a way to enhance and extend their services, by integrating actors and territories thereby making more information available on a larger scale. Relevant is also, that this exchange is not thought as a one way support, trying to get information from others but rather others are also given the opportunity to incorporate Arctic Web's ideas and services. (Interview MB) This shows that increasing safety is a big motive behind these developments rather than corporal values.

1.1.2.3. Role of the WMO[16]

With regards to sharing and cooperating the WMO plays an important role. It emerged under the IMO in 1950 and was founded as a framework for global weather and climate related information exchange and cooperation. It unites the world's national Meteorological or Hydrometeorological Services which are usually represented by their directors that function as communication channels and contacts to the national governmental agencies. From its foundation onwards it has been facilitating unrestricted exchange of information but also of technology and services. It works on capacity training, policy creation, data provision and more, thereby trying to enhance weather and ice forecasting in a uniform way on a global level. (WMO 2016)

The Norwegian MET stated that with regards to ice services the WMO plays the role of a more formal cooperation partner, which is used to push national standards onto an international level and make them internationally accepted. It thereby also influences what services are provided and for which area. For example the WMO decided that the national METs should integrate iceberg and ice concentration information in the daily weather text as well as forecasts for the polar areas (Interview NH). With regards to weather services it provides a foundation to exchange knowledge and skills, they have trainings and workshops to enhance each other's competences. For example, there are currently trainings to enhance forecasting in Antarctica (Interview HT).

1.1.3. User-provider dynamics

The user dynamic is particularly interesting when looking at new information providers. It immediately attracts attention that the users play a key role in the developments of new services. Arctic Web for example stated that one of the first activities was a get together with the potential user groups in order to find out what is needed. The most urgent needs were tried to be implemented in the service thereby feedback and discussions with the users being an essential element of the development process. Also now, when new services are being created they have a group of key users that tests and gives feedback. Further interesting is that the connection between Arctic Web and the users is not only on one level but reaches from top to bottom. Meaning that the ongoing connection is on all levels, between the providers and the big umbrella organizations (AECO, CLIA), operators (Hurtigruten, Oceanwide Expeditions etc.) and individual captains. This way they seem to integrate all ends getting a holistic picture of the needs. Further, the relationship is quite clearly directed from the providers to the users. The

[16] http://public.wmo.int/en

latter only addresses the providers when asked for feedback or when the platform is not functioning well. This close relationship further makes sense when we look at the origins of Arctic Web. It was founded as a response to the new regulations for cruise operators regarding obligatory risk assessments, ice pilots etc. Their aim was therefore to provide a tool that supports them. So it was particularly created for this specific user group. (Interview MB)

Also Barents Watch works closely together with different users. However, there seem to be differences between the restricted area and the open area and the role the users play. In the restricted areas it is mainly the authorities that address the provider and tell it what is needed and should be implemented. In the open area different services are provided that are thought to be for different user groups, except for one application that is also restricted to registered users, namely the fishing industry. To this group there also exists a close cooperation in terms of discussing with fishers what is needed, how things are being done, getting feedback and so on. However, this contact mainly exists between the bigger fishing companies and Barents Watch. A reason for this is that they are more easily accessible and the bigger boats also sail further out into the high Arctic wherefore they need a broader spectrum of information services. These different relationships for the restricted and open part is explainable by the fact that Barents Watch is part of the Coastal Administration and their main function is to support marine authorities. Nevertheless, the interview made clear that Barents Watch could be a stand-alone organization and a main aim seems to be providing more integrative information. They try to reduce data amounts and duplications by combining needs, providing the same information to different users that need them for different reasons. For example, fishermen need to know in which spots nets are already in place, in order to not fish in the same location. The fishing industry on the other hand wants this information because it tells them in which areas much or little fishing activity is. Moreover, Barents Watch is also interesting as they work on a broad spectrum of services and for users. Apart from weather and ice services, they also have specific projects in which they try to respond to a specific user need. An example is a momentary close cooperation with the food authority in a project where they try to map the areas in which salmon has a too high level of a specific harmful bug. (Interview ER)

When we look at commercial providers, such as Polar View and Arctic Portal, and their users it attracts attention that they are focused on a very broad scale of user types. Thereby they include international actors from different sectors from all over the world, relevant for choosing clients is only that their interest is/the assignment is somehow connected to the Arctic Region/cryosphere. (Interview KJ)

On the public level, there are then also new providers that focus on creating services that are usable by all vessels. For example the voyage planning tool from the Canadian Authorities or EfficianSea2 that shall facilitate safer and more efficient navigation in the Arctic and Baltic Sea for all maritime actors. Especially EfficienSea2 is an additional example for the close cooperation between the developers of the service and the users. Moreover, there is another group of providers that plays a particular role with regards to user integration, Arctic Portal. It is specialized in data management and user involvement. Currently they are involved in an EU project and their role is to enhance

the user integration and use of their knowledge. They are thereby taking up the in literature often stated need of enhancing integration of different user types for a better exchange of knowledge and needs and a development of more holistic services. This development is also seen in many of the ongoing research projects that focus on the need for more standardized services to overcome the challenge of having different regulations, requirements and scales (European Commission 2015).

When we now look at the traditional MET services, we can see that they are still the most important source for all users. They were called into being with the purpose of 'saving lives and property'. Thereby serving a broad range of actors. Nevertheless, we can see that here as well developments to more user integration are visible. However, they are mainly in contact with users when it comes to bigger projects, like the EU project for smarter software. Mostly this interaction is based on telling the users about new ideas and developments, asking them for feedback. The incorporation of a new service, however, is stated to be difficult, as users might need it but only to a certain price and under certain conditions. Thereby, the costs that would emerge would come from having to install the right technology onboard while the service provided by the MET would be free of charge. Moreover, within the MET we also see an increased approach of the users. Meaning, actors asking for specific information, as in the case of Northern-light-guides. (Interview HT)

Apart from this original function, they and other METs today play another relevant role, namely as a data and information source for new providers who mainly synthesize information for users, thereby relying on reliable data sources. Therefore, one of their main users is not the end user but intermediate organizations such as the new information providers.

With regards to the MET ice service, cooperation with the users is scarce and only exists through research or in case of special inquiries from companies. In those cases, the experts sit together with the users and discuss what exactly is needed. (Interview NH)

Regarding the user-provider dynamics we see that there are different developments from user specific to integrative and educative activities and services. The trend towards user specific information provisioning seems to be axiomatic when we think about the differences between the industries. They seem to have quite different structures for example the fishing industry is a very rationalized sector whereas cruise tourism in the Arctic is very little rationalized. Further, they have very different interests in the Arctic. Consequently, these different structures and interests might lead to very different information needs. Combining services for different industries therefore seems very complex and explains that there is a trend among new providers to start off with a focus on a particular user group. Nevertheless, research suggests that information needs of different users are actually not that different (Lovecraft et al. 2013). Different projects such as EfficienSea2 and the Arctic Voyage Guide support this in trying to provide information services for all types of marine users in the Arctic (Interview JS, Government of Canada 2016). Further, we see this development within current research projects that are involved in trying to enhance user integration, standardization of information and broader cooperation (European Commission 2015).

Consequently, we see that the development of more integrative, holistic and standardized information services is a challenging but relevant topic due to three major factors. For one, providers still have to a large degree a national focus due to the underlying structures such as national regulations, jurisdictions and standards what makes international sharing complicated. Secondly, users have different needs due to their diverging structures and interests, wherefore many providers are focused on one or few users. Last, globalization and increasing global problems request collaboration to be tackled. Therefore, in order to efficiently deal with global developments such as climate change but also more global economic activities it seems highly necessary that more integrative, standardized but also personalized information services emerge. On the level of weather and ice information the WMO has been working on achieving more standardization already for years. However, in order to achieve this standardization also on a broader scale of services, actors need to work on all levels and scales on cooperation and sharing. This is what we currently witness. On the international scale, actors are trying to enhance the combinability of different national regulations and jurisdictions, as well as sectoral characteristics, by cooperating in large international and multidisciplinary projects. On the national level, providers such as Arctic Web and Barents Watch, are trying to combine information from different sources, standardizing information and thereby enhancing their compatibility on a larger scale.

So, is the user the main driver? The role the users have for sure attracts attention, as they seem to be the foundation of many new services. Therefore, declaring the users as one of the main drivers seems axiomatic. However, it is not that simple as we also saw that the approach occurs from the providers towards the users and not the other way around. Consequently, the initial idea to enhance services and provide something new seems to not come directly from the users and must have a different source. In my opinion, here also exists a strong connection to research and the increasing awareness it raises. The lack of marine infrastructure that is needed to support sustainable and safe development and activity in the changing Arctic is by now a known fact. This awareness thereby already evoked different responses in terms of new systems, technologies and regulations. For example, in the case of Arctic Web these new safety regulations for cruise operators in the Arctic were thereby one of the key drivers. A main founding reason was to create a medium for the users to deal with the new obligations.

1.1.4. Services and technologies

The type of information or services delivered by the different providers is quite diverse, with broader baseline information from MET organizations to user specific services from new providers. Thereby adequate technology and data sources seem to be indispensable for old and new developments.

With regards to the Norwegian MET we already saw that they are not directed at particular user groups and their services regard general weather and ice information for everyone and all purposes. However, the users still seem to evoke developments and changes in services. A field where changes in services can be witnessed is the area that information is provided for. Due to the increasing activity in the high north, this area was divided among Russia, Canada and Norway each receiving an area that they need to provide weather forecasts for. This increased activity further leads to other

developments such as the attempt to enhance communication services above 80 degrees north. These developments are thereby based on the changes that occur in the Arctic with climate change. More free waters mean increased needs for forecasts, information and communication possibilities. Another change in services that emerged from the user side is connected to the tourism industry. In Norway there is a new touristic trend regarding northern light viewings. In order to provide such tours the tourism industry is in need of information regarding clear skies. Therefore, before a scheduled tour they request this information in order to know which location to go to. (Interview HT)

As already mentioned, the MET also delivers commercial tailor made services. These are usually a request for very detailed forecasts and weather and ice data for a specific area. The Norwegian MET thereby only takes on requests that regard the Arctic as it is in their desire to enhance their services for this particular area. These tailor made requests are thereby always a possibility for the employees in charge to enhance their understanding and knowledge about another area. (Interview HT)

The type of ice information provided has not been majorly changing however; the technologies used have been changing over the last decades. Therefore, the information's accuracy, frequency of delivery and detail of the information has been enhanced. In that way, since the 70s paper charts have been largely replaced by digital ice charts. They were first based on satellites and geographical sources, in the mid-2000s on the Canadian radar satellites that could better deal with clouds and now the European Sentinel 1 is the major source and the others serve as a backup. In the case that the Sentinel 1 does not function, optical services need to be used that don't provide so much detail and with that impact the quality of the information the MET provides. (Interview NH)

Also new services are being developed such as automated forecasts that also deliver data on weekends; however, the unreliability of such reduces their use by and value for the users. Other than that only the information that is being delivered changes, e.g., as mentioned above more details like ice concentration and icebergs will be included in the daily weather texts, as well as information regarding a broader area. A drawback to the quality and frequency of the information provided is the limited availability of satellite data. With more data, models could be improved and with that predictions but also changes could be captured and communicated more often. With the expected increase in activity the Norwegian MET regards this increase in data availability and service quality as relevant. According to them, now operators simply calculate more safety buffers and consequently do not operate under maximum capacity. (Interview NH)

The broadness of the information delivered by MET services seems to be one of the reasons for the emerging of new providers that try to fill gaps with regards to specific needs. This is explained by the fact that we see new providers focusing on personalization thereby synthesizing information from different sources. Therefore, the gap is not so much a lack of data itself but rather the lacking possibility to get and combine small amounts of data for specific needs. This is connected to the problem of data accessibility in the Arctic Ocean. The non-availability of internet and communication services in good quality is a major problem leading to vessels not being able to download large amounts of data (Interview MB). Therefore, in order to reduce

data amounts they need for their route specific synthesized information from different sources. However, thereby the information needed is often a small percentage of the data from different sources. Consequently, new providers try to respond to this need by combing different relevant information sources and customizing it to the needs of a particular user. This, we can see in many of the new developments as they do not provide their own data but rather synthesized information collected from different sources (Interview ER). Arctic Web for example gets many baseline data from the Danish Meteorological Institute but also adds data from other vessels, infrastructural information etc. One of their main aims is trying to combine information in a way that data amounts are reduced in order to facilitate easier and cheaper data access for the users. They do so by letting the users enter specific details about their ship and their planned route. This way Arctic Web can combine data that are relevant for this particular route and ship. Next to reducing data volumes their main services are based on enhancing safety through providing information relevant for emergencies. For example, a ship can see other ships in a certain distance and relevant information about them. The amount of passenger and allowed capacity for example, which is relevant to know if the own ship is having problems and another ship needs to be boarded. (Interview MB)

Similar Barents Watch does not provide any own data but tries to incorporate relevant data from different sources on their platform. In their opinion, sustainable navigation practices can be enhanced if users have all information in one service. For the fishing industry they thereby also focus on information relevant for sustainable practices and nature protection purposes such as geological data about coral reefs and sediment specificities. The services of Barents Watch in the accessible part are apart from the fishing related services, a wave warning service mainly used by passenger ships and cruise operators, as well as port information and polar low warnings directed at all vessels. (Interview ER)

Many of the current research projects are highly connected to developing new technologies for enhanced data generation and information provisioning. The more operational projects like EfficienSea2 and the Voyage Planning Guide are similar to the Arctic Web developments in terms of trying to provide an e-Navigation tool that personalizes information for a specific user. Part of their services are for example mapping services showing among other historical ice and weather data (Government of Canada n.d.). Also Arctic Portal provides an interactive map showing Arctic related information (Arctic Portal n.d.). This is a service accessible by everyone. Apart from that Arctic Portal is more focused on taking part in research projects, data management and on providing tailor made services (Interview KJ)

Not to be neglected should be providers of essential baseline services such as ESA[17], or operational communication providers such as INMARSAT (AMSA2009). They are an essential part of the information provisioning as they provide the needed technology to generate key data that gets transformed into user specific services. Further, they provide

[17] http://www.esa.int/ESA

the technology that is needed to bring the information to the users such as internet, email and phone connection.

Following, it seems that within the operational information provisioning sector new developments are fostered by a mixture of events. For one, there is an increased exchange with users and the attempt to tackle particular needs and to respond to the rapidly changing Arctic. Moreover, research detects gaps that call for an adoption of services to and a preparation for further changes. Thereby, not only new services but also new technologies are developed. The work of research is further connected to risks and safety as it makes clear how uncertain and endangered the Arctic and activities in it are. Therefore, increasing safety and sustainability also seem to be strong motives behind new developments.

2. Relevant developments and projects

Apart from this study, there are currently other ongoing research projects of relevance to this topic. Interesting research projects and other activities will be introduced in the following.

The first one is a research effort undertaken by the Finnish meteorological institute. ***Towards better tailored Weather and marine forecasts in the Arctic to serve Sustainable Economic activities and infrastructure*** (TWASE) started in September 2014 and shall be finished in August 2018. Its aim is to adapt the operational weather and marine services to meet the needs of an increased activity in the Arctic. In the project first the users' needs in information to develop economic activity sustainably are being investigated. The second part consists of improving the predictability of weather, marine and sea ice conditions. Last these improvements will be evaluated and optimized in close cooperation with the users. A first paper that has been published describes the necessity of improved weather and marine services under specific developments. Six scenarios were created to evaluate the need and in five out of the six scenarios weather and marine services were important for future developments. While this project looks more into the technological part of weather and ice services, it is highly connected to this study and a cooperation could be beneficial for both sides. The TWASE project fills one of the often mentioned gaps, namely qualitatively poor weather and ice services and forecasts. Further, listed as one of the criteria that needs to be fulfilled in order to increase economic developments in the Arctic. Therefore, their outcomes will likely have influence on the information providers and their services, wherefore it is relevant to keep up with the developments of the projects. Moreover, the outcomes of this study can also be beneficial for their project by clarifying who should be integrated in these developments and in the later implementation of these enhanced services.

The second project is part of the EU Horizon 2020 package. ***An Integrated Arctic Observation System*** (INTAROS) will be led by the Nansencenter in Bergen. The aim is to build a holistic and integrative observation system for the Arctic that includes all international partners and indigenous people. Knowledge of the latter shall be integrated and combined with new technology and research. Key points are to enhance interoperability, to standardize data and control quality of existing information. The

project shall further help to fill observational gaps and to improve accuracy of models. New technology will be developed to enhance observations and modelling. The access to data will be free and open. This project, is in that sense relevant for us, as it supports the in literature found needs for increased cooperation in data gathering and sharing. If this will be achieved on a broad scale, information providers might profit from it and enhance their services but also start broader cooperation, standardizations and sharing with other providers. Therefore, developments in this project need to be followed and kept in mind.

Also part of the EU Horizon 2020 is the project Blue-Action or ***Impact of Arctic changes on the weather and climate of the Northern Hemisphere***. It is coordinated by the Danish Meteorological Institute together with different partners. The aim is to deliver better climate services. To achieve this it is attempted to better understand climate change in the Arctic and the effects it has on weather and its extremes. As the Arctic is one of the places on earth that is most effected by climate change it is relevant to understand what impacts these changes have on the environment and particularly on creating extreme weather events. A transdisciplinary approach with input from different important stakeholders shall enable the development of better forecasts. Models shall be improved and activities should contribute to the Year of Polar Prediction (YOPP) and enable enhancing predictions form the Copernicus Climate Change Service (C3S). Important is also the cooperation with other projects connected to this topic and Horizon 2020, next to Arctic and non-Arctic partners. Enhanced climate services would play a crucial role for information providers in terms of being able to improve services for operational actors. The latter would be able to plan routes more in advance, which would increase reliability and make the Arctic more interesting for transport.

Also of interest for this project, is the development of the ***Arctic Data Ecosystem Map (ADEM)***, an activity led by Peter Pulsifer. This project is part of the efforts of the Arctic Data Committee (ADC)[18] to create a data management platform in the Arctic. The ACD is the result of the merging of SAON and IASC and the aim to establish one holistic data management tool for all members. The ADEM is relevant as it tries to map all actors connected to information gathering and provisioning for the Arctic, from research to operational organizations. Thereby, also showing the geographical regions and scales they work on and how different organizations are interlinked. This creates an important basis for understanding who is active where and which organizations actually belong together in big umbrella organizations such as the WMO.
It is necessary to get an overview over providers for this study and decide where to start and which providers to integrate. Nevertheless, as the ADEM is only a draft and by far not containing all organizations, it is important to only use it as a first starting point from which on to investigate further. Findings from our study can, reciprocally, be used to enhance the ecosystem map.

Further, ***ArcticSat***, a project financed by ESA and conducted by Marintek and partners declares that more accessibility of the Arctic is leading to actors looking into ways to use this new space for resource exploration, shipping etc. To increase situational awareness in this area they suggest that space technologies should be used in a more integrated way. Further they state that the application of space technology plays a critical role in

[18] http://arcticdc.org/

three areas: the use for information accessibility, communication and for monitoring actors' positions and reacting upon them (ESA 2016). The goal of the project is to develop customized services that enhance the situational awareness.

The multiplicity of projects dealing with the future of information provision alone signalizes the relevance of this topic. Further, that there are many ongoing activities regarding this topic shows that there are many sides from which to tackle it. Each of the above mentioned projects might have impacts on operational information providers. Thereby, possibly influencing their structure (creating broader networks) as well as their services (new technologies, strategies). Moreover, these developments, according to literature, would fulfill some of the criteria mentioned as necessary to enhance increased economic activity in the Arctic, meaning more users and extended territories, and with that more need for information services. Therefore, as mentioned before, in the course of this project it is highly relevant to keep updated about the projects but also developments in the economic sectors.

3. Recommendations

This research provides an insight into the complex relationship between information providers, research, users and technology. For an enhanced understanding of the workings of operational information providers, it is a prerequisite to further investigate the different dynamics. Thereby, services and technologies, partnerships and users seem to be key elements. Further, the role of research is not to be neglected especially with regards to the manifold ongoing projects. It seems important to closely cooperate with other ongoing projects as it could foster deeper understanding, more effective working and lead to clearer results. Sharing and cooperation are also widely called for in literature and basing this project on such an approach seems like a good foundation for a successful and efficient research.

To get a clear picture of the relationship between information provisioning and economic activity it further seems to be particularly necessary to understand how much information services really foster activity. Therefore, a clear investigation of what the key industries really use is important. Partly it may still be a current practice of operators to navigate by calculating extra safety buffers and in that sense activity takes place also where no information is available. Nevertheless, with regards to the changing Arctic it is a prerequisite that activity is steered in a more sustainable direction and in this relation information seems to be a key element. Only when operators know where ice and weather conditions are unsafe but also locations of endangered species etc. are, navigation practices can be adopted. Without knowledge, a change in behavior is unlikely. Further, as the literature review showed the industries' future development in the Arctic is still very uncertain and much more information is necessary about the further climatic changes and its implications. However, the fact that the industries do not seem to have structured plans for their further developments in a clear manner also creates an opportunity to steer it into a sustainable direction by providing the right information and services.

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5. Appendix

5.1. List of interviewees

Representatives of the following institutions, initiatives or projects were interviewed.

- Norwegian Meteorological Institute
- Barents Watch
- Arctic Web
- Alfred Wegener Institut
- EfficienSea2
- Arctic Portal

5.2. Interview questions

1. Actors
   Background information about the organization
   - ➔ What is the main function of your organization?
   - ➔ Is this organization public or private?
   - ➔ Who regulates it?
   - ➔ How is the organization mainly financed?
   - ➔ What are the main motives behind developments within the organization? (User-driven, research etc.)
   - ➔ What are the main problems faced in the provisioning of the service?
   - ➔ How could services be enhanced?

2. Type of information
   - ➔ What type of information do you focus on?
   - ➔ Do you produce new information or do you synthesize information from others in order to enhance usability/access?
   - ➔ How is this information shared?
   - ➔ About which geographical area do you provide information?
   - ➔ Why is it limited to this area?

- ➔ Is your information accessible for all?
- ➔ Why is the access limited?
- ➔ Which are the main technologies used?
- ➔ Who is the provider of the models/technologies you use?

3. User
   - ➔ For which actors is your information produced?
   - ➔ How do you chose users for conversations about what is needed etc.?
   - ➔ What industries are they from?
   - ➔ Are they small or big businesses?
   - ➔ Do they also address you with requests they have?
   - ➔ How frequently do you talk to them/get feedback?
   - ➔ How do you decide if a request is important enough to implement it into your system?
   - ➔ If you implemented something new do you have specific users that test it and give you feedback?
   - ➔ What are the main differences between the information available for all and the one for a restricted audience?

4. Partner, Networks, Associations
   - ➔ With whom do you mainly cooperate?
   - ➔ Do you have any international cooperation? With whom?
   - ➔ From which organizations do you use data/input to deliver your service?

5. Global change
   - ➔ How does climate change influence your work?
   - ➔ Is the information production process influenced?
   - ➔ Is the type of information provided changing?

Name	Type of organis	Scale	Services	Target group	Funding source	Drivers	Access	Partners	Data providers	Main uncertainties
Barents Watch	public initiative	Norwegian territory mainly for the area off the coast of the mainland	Coordinates and combines data to provide picture of activities in and conditions of sea	Public administration, industry, research	Norwegian government part of Transportation plan	User driven	Open and restricted areas	39 public agencies	MET, Coast guard, governmental organizations	Data from other sources
Norwegian Meteorological Institute	public	National	Meteorological services for private and public sector, aviation, military, research for private and public	Public and private sector	state financed	Needs to serve Norwegian society-safe lifes and property	Open	Swedish Met, European center for Medium Range Weather forecasts, NOOA and METEOSAT for satellite images, radar from ESA	ESA (Sentinel-1), MDA (Radarsat-2), and eGeos (Cosmo SkyMed). Use of buoyes.	Few observations in Arctic influencing accuracy of weather forecasts, Poor SAR coverage, lack of reliable sea ice thickness information, and lack of reliable sea ice/iceberg drift forecast models. There is also an issue with unreliable sea ice parameters derived from satellite data
ArcticWeb	Public	International (Greenland, Norway, Canada, US)	Synthesised information, personalized, risk assessment, personal routs, emergencie, vessel trekker	Vessel operators, mariners, authorities	Nordic Council of Ministers	New safety regulations, user driven	Open	DMI,	AARI, Danish Maritime Authority and DMI	Data uncertainties, AIS updates
EfficienSea2	public	International focus on Baltic Sea Region	MET forecast data,stan	intermediate maritime service provider and end user such as captains	EU Commission	User driven	Currently restricted to partner-when finished open	32 partner from 12 countries , mainly maritime services and administrations from european countries	Mainly DMI also WMO, EUMETSAT, EuroGOOS	full sharing between provider and user and availability of real time data

Polar View	Private / NGO	International	operational satellite based monitoring of the Arcticsea ice, ice edge and iceberg, glacier monitoring, snow coverage, data can be customized	broadly every industy in need of information for resource extraction, environmental protection, safety, sustainable economic growth	was funded by ESA, now operates independently	User driven	commercial	ESA, EU Comission, Canadian Space Agency, Universities, research		
Polar Commons	Non-for-profit organization	International	provide a wide range of information about polar regions to the public, raise awareness about threat of climate change, promote cooperation and scientific debate. Organize IPY collected data. Goal is to put pressure on governments and corporations to change to more sustainable behaviour.	researcher, authors, organizaitons, individuals	Corporate, private, governmental sponsors and donors	Goals and environmental concerns	Open	Different associations, (non) governmental organizations	researcher, scientists, authors, individuals, organizations	

EU Polar Net	Consortium of European research institutions	International	develop and deliver a strategic framework and mechanisms to prioritise science, optimise the use of polar infrastructure, and broker new partnerships, co-ordination of polar research and infrastructure creation for integrated polar research programm, policy advice	Polar research institutes	Horizon 2020 funded EU project	coordinate research, enhance cooperation	Project members	International research institutes, EPB		
Barentsinfo	public	Barents Region	foster cooperation in the Barents region, exchange of data for environmental management of Barents Sea	authorities and manager from the region	national financinc sources, Nordic or EU programs	enhance cooperation for better development and environmental proteciton	restricted to memebers but also much open information	Cooperation of Barents Euro Arctic Council and Regional Council members (Russia, Finland, Norway, Sweeden), Barents organizations, academic institutes and media from the region, financial institutions		
Alaska Ocean Observing	Regional Association	Regional	gather and provide data and information that provide understanding about the status of Alaska's marine ecosystem for better decision making	all regional and national actors in need of ocean information	different services are funded by different organizations, also received 2.5 million US Dollar from the US Integrated Ocean Observing System	Environmental issues	open	Alliance for Coastal Technologies, Integrated Ocean Observing System, Southeastern Universities Research Association		
Arctic Data Committee	Merge of IASC and SAON	Pan-Arctic?	arctic related data, foster cooperation to provide open data access	polar researcher, manager, residents	no own funding, voluntary basis	data driven, fill gabs promote collaboration	open	members of SAON and IASC	data banks members	

Alfred Wegener Institut	Public Foundation	International	Polar and Marine Research	Society, politics, research Community	German Ministry of Education and Research, federal state Bremen	Science driven	Open	Universities, other research centres, broad international cooperation	ESA, DLR, Nasa, NSID	Lacking data, shortcommings in personnel
Arctic Portal	Non-profit organization	International	Arctic related information and data, mapping service, hosts websites	science, education, policy	income from projects/ commissions	business, research	mainly restricted	Arctic Council, participants, observer, other stakeholder	own and partner	
Arctic Science Partnership		Trilateral (Greenland, Canada, Denmark)	research cooperation, want to become a leading consortium on climate, cryosphere, ecosystems, and human interactions through research, monitoring and education	Polar researcher from the member countries	by the members?	climate change, enhance research	open to members	mainly ASP related actor, some other research bodies as the UiT		
Canadian Government Fisheries and Oceans	public	Canadian Arctic	**Arctic Voyage Planning Guide**: strategic planning tool a compilation of data and services like for rescue options, routes, showing historical ice data	All mariners navigating in Canadian Arctic	state financed?	user?	open	Canadian authorities, governmental agencies	Canadian MET, ice service etc.	
Norwegian Polar Institute	public	International	environmental research, mapping and monitoring	authorities	state financed	research	open data platforms such as MOSJ, restricted services for authorities	Many national marine authorities, governmental departments, research institutions	data from research partner, own data	

CAFF	Working group of Arctic Council	International	accurate and timely information to inform processes of mutual interests, mainly biodiversity related information	Scientists, policy makers, working groups		Research	Open	Many like Arctic Council, IASC, EU, NOAA	Arctic Biodiversity Data Service, Circumpolar Biodiversity Monitoring Program	
INMARSAT	private-commercial	International	operational communication provisioning	initially mariners, now all businesses that need special communication technology	commercial	set up by IMO to enhance safety of ships	restricted	distribution partner all over the world	own technology	
StormGeo	private-commercial	International	weather services	operators with difficult environmental work conditions onshore, offshore, in air	commercial	research	restricted tailor made services			
WMO	public	global	Framework for international cooperation of meteorological and hydrological national institutes, generating weather forecasts, climate predictions, water data; trainings for members to enhance forecasts etc., standardization of data, technological advancement of all members	all national meteorological and hydrological etc. institutes	assessed contribu-tions, including member contributions, regular income from rental activities and interest earnings	safety, well-being and economic benefit of all nations	members	governments, international organizations, meteorological and hydrological bodies etc.	WIGOS, WIS, GWC, GIPPS ? Satellites, morred buyos, drifting buyos, aircrafts, ships, landbased observation stations	

European Polar Board	EU organization	European	strategic advisory agency for polar research, high-level facilitator of cooperation between European national funding agencies, national polar institutes and research organisations	funding organizations, research institutes, policy	member organizations contributions	research	members and authorities	international polar and research institutes		
Barents Portal	public	Bilateral Russian-Norwegian	tool for publishing environmental data, strengthen cooperation in ecsosystem based management. Few weather/ice data mainly data on pollution etc.	Norwegian and russian Arctic scientists and authorities		nature protection, sustainable develpment	member			

Provider of new data, also foster cooperation, advice
Provider of synthesized data for operations
Commercial information provider
Projects

Coordination of research and data, fostering cooperation