



ARCTIC PREPAREDNESS PLATFORM
FOR OIL SPILL AND OTHER ENVIRONMENTAL ACCIDENTS

Climatic zones in the NPA region

Project report

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**Northern Periphery and
Arctic Programme**
2014–2020



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APP4SEA

The 21st century brought unprecedented interest in the Arctic resources, turning the region from the world's unknown periphery into the center of global attention.

Within the next 50 years, local coastal communities, their habitual environment and traditional lifestyle is expected to undergo severe changes, caused by climatic perturbations, petroleum industrial intervention and increased shipping presence.

The APP4SEA project, financed by the Northern Periphery and Arctic Programme will contribute to environmental protection of the Arctic waters and saving the habitual lifestyle of the local communities. It will improve oil spill preparedness of local authorities and public awareness about potential oil tanker accidents at sea.



Disclaimer: All reasonable measures have been taken to ensure the quality, reliability, and accuracy of the information in this report. This report is intended to provide information and general guidance only. If you are seeking advice on any matters relating to information on this report, you should contact the University of Oulu with your specific query or seek advice from a qualified professional expert.

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Summary

This report provides a brief representation of climatic zones prevalent in the Northern Periphery and Arctic (NPA) Programme region. NPA Programme is an ERDF Interreg VB funding instrument, which covers northern parts of Europe, all the way from the Nordic Countries to the British Isles, and north of it to Iceland and Greenland. This study has been conducted as part of the Arctic Preparedness Platform for Oil Spill and other Environmental Accidents (APP4SEA) project. The report includes weather pattern description of the sea areas included in the programme region, which span from North Atlantic in west to Baltic Sea in the east and from Barents Sea in north to North Sea in the south. The land areas of Northern and Western Scandinavia, Scotland, Northern Ireland, Ireland, Iceland and Greenland are included as well, as can be seen in the Figure 1, where the study area has been highlighted with purple in. The main focus of the report is however on marine areas, as the overall objective of the project is to improve the preparedness level of oil spill response in these waters.

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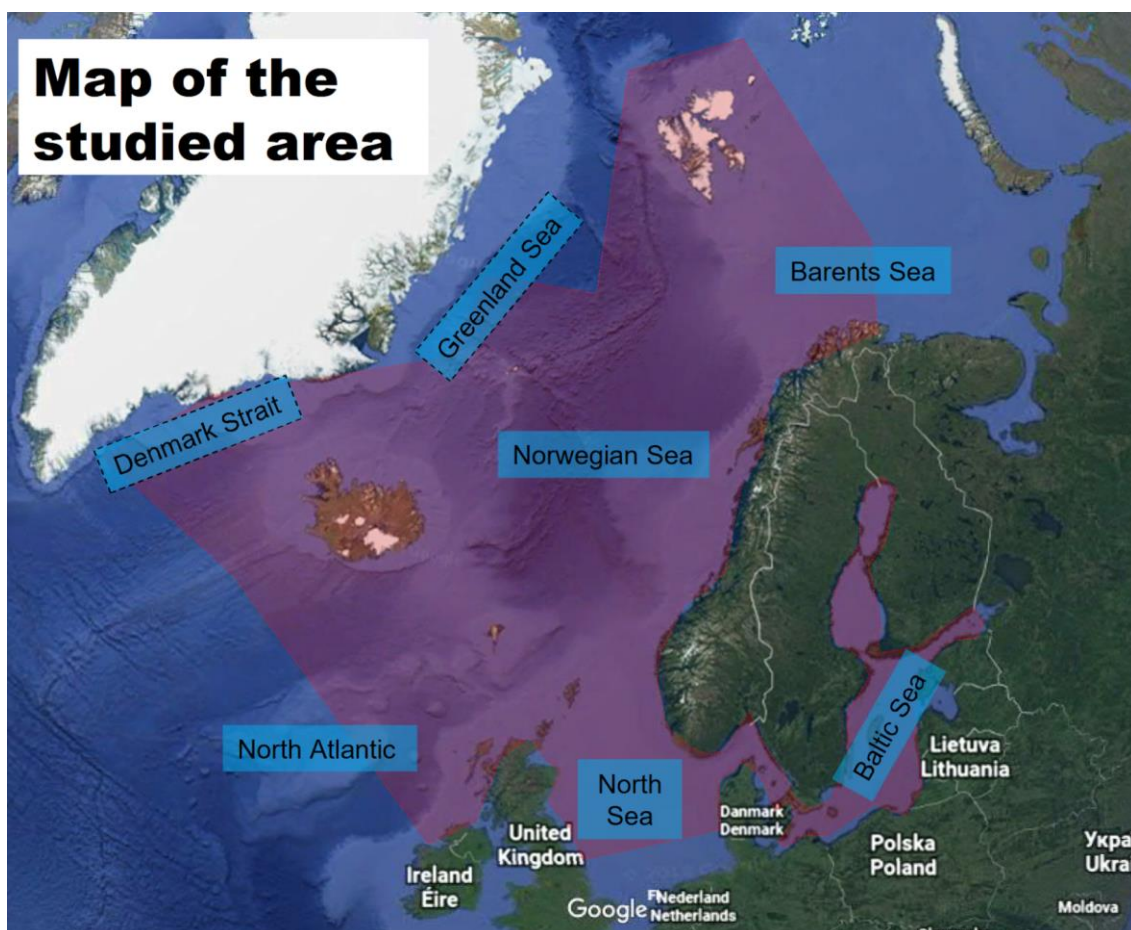


Fig. 1. Marine study area of APP4SEA project

Introduction

The most decisive factor, which dictates oil spill response operations in the northern marine environment, is the weather conditions at site. The range of weather is wide in the north. It spans from snowstorms to calm winds with no precipitation. In some parts the sea is covered with different types of ice for months, whereas large tracts of sea are ice free for the whole year. Time of the year is crucial from other point too. During the summer months there can be 24/7 sunlight and crystal visibility, whereas the polar night dominates during the winter months when it is pitch black. These factors determine what kind of equipment can be used in case of an oil spill, and how we should be prepared to deal with oil spills in the high north.

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In most cases, when an oil spill accident has happened, difficult weather conditions have actually contributed to the accident itself. Vessels do not usually run aground or into each other when visibility is perfect, nor do they break up and sink in calm waters. But as we move to north, the “bad weather” or challenging conditions became more a norm than exception. In fact, in 2017, Emergency Prevention, Preparedness and Response Working Group of the Arctic Council (EPPR), an international body that has been set up to improve oil spill response (OSR) in the Arctic region, concluded that natural climate conditions in the high north are too challenging for successful oil spill response operations. In some corners of the Arctic they are not possible at all throughout the year, whereas in some regions they are not possible during some parts of the year. There are still multiple technological limitations and no optimized strategies for oil spill abatement in the northern waters.

In this report, the following climate-related questions will be answered:

- **What kind of climate does the NPA region have?**
- **How many climatic zones are there in the NPA region?**
- **What makes one zone different from the other?**

One question, if not the main question for oil spill response operators, is whether there are any **“green” and “red” zones among the studied seas**: areas, where prevalent conditions are mostly favourable for oil spill response, and areas, where they are mostly unfavourable. All these questions are discussed below.

This work has been done as part of the Arctic Preparedness Platform for Oil Spill and other Environmental Accidents (APP4SEA) project financed by the Northern Periphery and Arctic Programme (NPA) during 2014-2020. NPA is a European Regional Development Funding instrument

and it involves remote communities of Northern Europe and aims to facilitate its sustainable development with related social, economic and environmental benefits. Figure 2 shows the partners and the four countries which are represented in the project by them. The partnership consists of University of Oulu & Finnish Environment Institute (Oulu & Helsinki, Finland); Norwegian Meteorological Institute & Norwegian Coastal Administration (Bergen & Tromsø, Norway); University of Iceland (Reykjavik, Iceland); North Highland College, Scottish Natural Heritage & Marine Scotland (Thurso, Inverness, & Aberdeen, Scotland). The lead partner is the University of Oulu (Finland).



Figure 2 - NPA programme area and APP4SEA project partners

Climate zones

Global perspective

In this report we refer to the Köppen climate classification, which is the most widely used climate classification systems. It was first published by the German-Russian climatologist Wladimir Köppen (1846–1940) in 1884, and he did several modifications to it later on, notably in 1918 and 1936. Climatologist Rudolf Geiger introduced some changes to the classification system also, which is, thus, sometimes called the Köppen–Geiger climate classification system. The latest updates are shown in Figure 3, with the legend available in Figure 4. (Kottek, et al. 2006)

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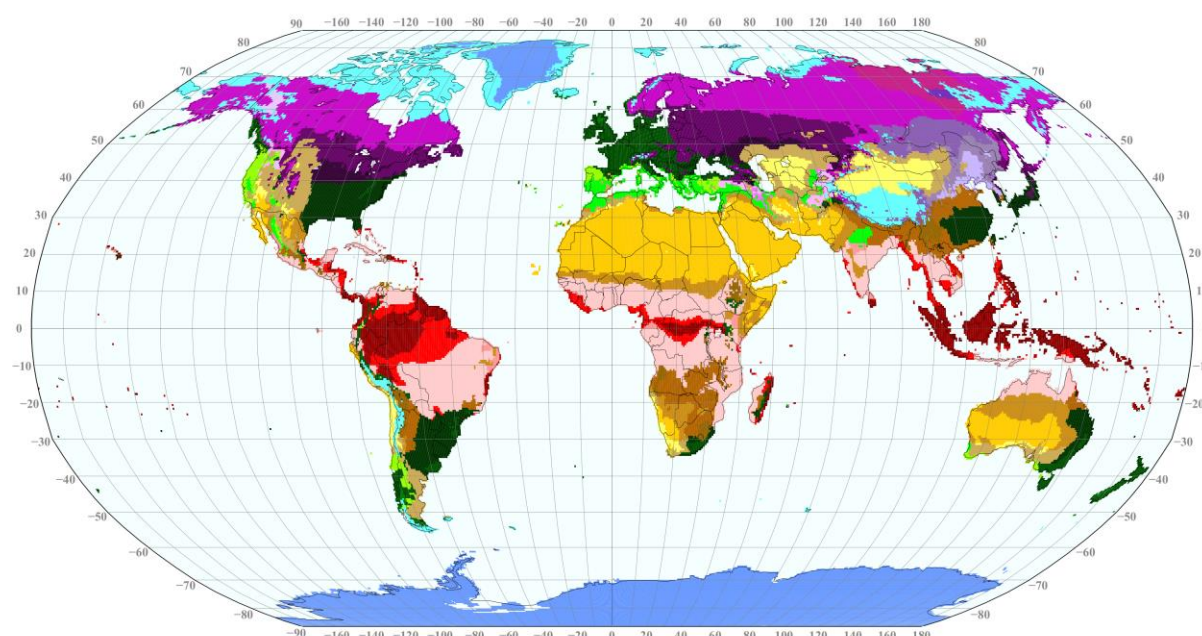


Figure 3. Global map of the Köppen–Geiger climate zones

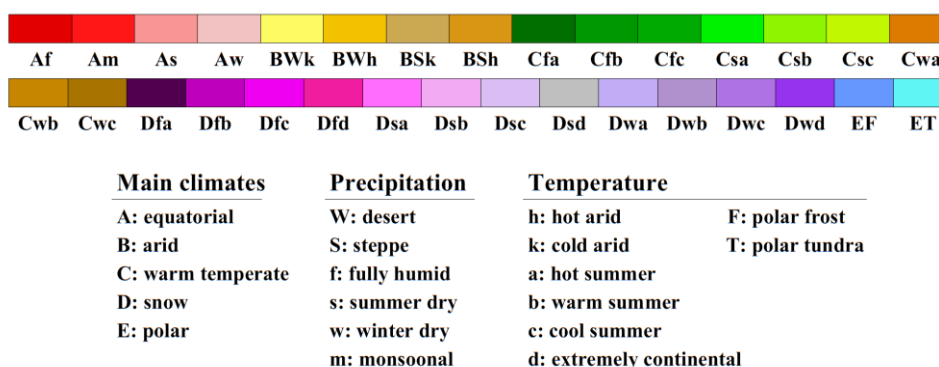


Figure 4. Legend for the global map of the Köppen climate classification

What can be seen from the map is a palette of different colors. Each color represents a pattern of weather and highlights the area where it is most common. All colors belong to the main climatic

groups: A, B, C, D and E. These are the major divisions according to the precipitation patterns and seasonal temperatures. Figure 4 explains each letter of the main five groups. A stands for equatorial climate, B – arid, C – warm temperate, D – snow (also called continental), and E – polar. Usually, each main group letter in capital is followed by additional two letters: one indicating precipitation type and the other one – temperature. For instance, BWh is a climatic zone within arid climate group (B), characterized by deserts (W) and hot arid conditions (h). This climatic zone is marked in Figure 3 with golden yellow color and covers for instance North Africa and the Arabian Peninsula. As a total number, there are 31 climate zones and its respective color shades are marked on the presented global map.

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Local perspective: NPA region

The main focus of APP4SEA project is the NPA region. Figure 5 demonstrates its location on the world climate map, zoomed in to its borders. From eastern Greenland to western Russia, there are five representable climate zones. The legend is specified in Figure 6.

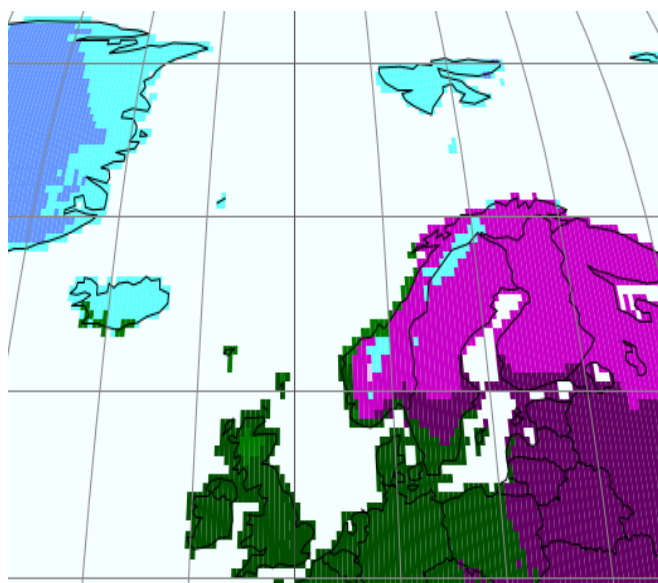


Figure 5. Northern Periphery and Arctic region: the study area of APP4SEA project

Main climates		Precipitation	Temperature	
Cfb	Cfc	f: fully humid	b: warm summer	T: polar tundra
Dfc	ET	D: snow	c: cool summer	F: polar frost
EF		E: polar		

Figure 6. Legend for the local map of the Köppen climate classification

Each climate zone refers to a certain group of the main climate classification. The included groups are C, D and E. The climate in **Group C** area is described as *warm temperate climates*. It is a type with the coldest month averaging between 0°C and 18°C and at least one month averaging above 10 °C. This can be found in central Europe – Denmark, Germany, France, Switzerland, but also in the UK and

Ireland. **Group D**, or *continental climates*, is a type characterized with at least one month averaging below -3°C and at least one month averaging above 10°C . This type is dominant in the northern hemisphere and is prevalent in continental Russia, Canada and Northern Europe – including Norway, Sweden, and Finland. **Group E**, or *polar/alpine climates*, is characterised by average temperatures below 10°C throughout the year. These cold regions can be found in north of Russia or Canada, inner Greenland, Faroe Islands, and Iceland.

Differences within the NPA region

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As can be noticed in Figure 5, there are five distinguished climatic zones in the NPA region. These are Cfb, Cfc, Dfb, Dfc, ET and EF. The specifications of the zones are the following:

- **Cfb**: warm oceanic temperate climate with average annual temperature below 22°C and at least four months above 10°C , fully humid with warm summers and evenly spread precipitations throughout the year;
- **Cfc**: warm oceanic temperate climate with coldest month at 0°C on average and one to three months above 10°C , fully humid with cold summers and evenly spread precipitations throughout the year;
- **Dfb**: snowy with coldest month at 0°C on average and one to three months above 10°C , fully humid with cold summers;
- **ET**: polar tundra with average temperature 0 to 10°C in the warmest month of the year;
- **EF**: polar frost with eternal winter, and average temperature below 0°C .

Adjacent seas

Despite the differences in climatic zones and prevalent weather patterns inland, there are also differences in sea ambient conditions between the seas of the NPA area. A brief overview of each sea is presented below in Tables 1 and 2: geography, oceanography, and climate. (Encyclopaedia Britannica, 2019; MKRF, 2019; One Shared Ocean, 2019)

BARENTS SEA. Climate. Climate of the sea can be described as polar, marine with changeable weather due to influence of warm Atlantic and cold Arctic Ocean currents. The amplitude of annual air temperature fluctuations is low. Summers are cold, gloomy and short whereas winters are long and moderately warm for such latitudes. Strong winds and high humidity are prevalent. Winds with speed up to 16 m/s are recorded regularly and storms are frequent. The coldest month of the year is March and the warmest is August. In Svalbard archipelago, for example, the temperature can range from freezing -22°C in winter to moderate $+6^{\circ}\text{C}$ in summer. Annual precipitation is more than 300 mm in

the north of the sea, and up to 500 mm in the south-west. The weather is cloudy for most of the year.

Ocean conditions. The sea is placed between the Atlantic Ocean and waters of the Arctic Ocean. Due to warm influence from the Atlantic in the south-west, water temperatures of the sea are rather high. In February-March, it can be up to 5°C, and in August up to 9°C. The temperatures are lower above the 74th latitude due to the influence of Arctic water mass – for example, down to -1°C in winter, and about 0-4°C in summer. Salinity stays at about 35 ppt in the south-west, 33 ppt – in the east and 32 ppt – in the north. Due to harsh climatic conditions there is also sea ice present. The ice extent is highest in April, about 75 %, which is made up mostly of drifting ice. The lowest ice presence is recorded in end of August, when ice is found above the 78th latitude. In the north-west and north-east, ice is found all year round. All-season ice-free waters are only found in the south-west of the Barents Sea.

Table 1. Overview of Barents, Norwegian and Baltic seas: N/A – information not available, W – winter, S – summer

SEA	GEOGRAPHY	OCEANOGRAPHY	CLIMATE
Barents Sea	<u>Total area, km²:</u> 2,023,335 <u>Maximum depth, m:</u> 600 <u>Washed countries:</u> Norway, Russia, Svalbard <u>Marine protected areas, km²:</u> 199,982	<u>Salinity, ppt:</u> 34 <u>Water temperature, °C:</u> -1 ^W <u>Water temperature, °C:</u> 0 ^S <u>Ice coverage:</u> present (all year round in the north)	<u>Precipitation, mm/yr:</u> 400 <u>Air temperature, °C:</u> -5 ^W <u>Air temperature, °C:</u> 10 ^S
Norwegian Sea	<u>Total area, km²:</u> 1,340,000 <u>Maximum depth, m:</u> 3,970 <u>Washed countries:</u> Norway <u>Marine protected areas, km²:</u> N/A	<u>Salinity, ppt:</u> 33 <u>Water temperature, °C:</u> 2 ^W <u>Water temperature, °C:</u> 5 ^S <u>Ice coverage:</u> absent	<u>Precipitation, mm/yr:</u> N/A <u>Air temperature, °C:</u> -4 ^W <u>Air temperature, °C:</u> 6 ^S
Baltic Sea	<u>Total area, km²:</u> 419,000 <u>Maximum depth, m:</u> 470 <u>Washed countries:</u> Denmark, Estonia, Finland, Germany, Latvia, Lithuania, Poland, Russia, Sweden <u>Marine protected areas, km²:</u> 17,150	<u>Salinity, ppt:</u> 8 <u>Water temperature, °C:</u> 0 ^W <u>Water temperature, °C:</u> 9 ^S <u>Ice coverage:</u> present (in the north from November to June)	<u>Precipitation, mm/yr:</u> 550 <u>Air temperature, °C:</u> -10 ^W <u>Air temperature, °C:</u> 17 ^S

NORWEGIAN SEA. Climate. Even though the sea is located above the Polar or Arctic Circle, the dominating climate zone is defined as marine mild with mild winters and moderately warm summers.

As with the Barents Sea, the range of seasonal air temperature variations is low. There is high humidity, large cloud coverage but also long-lasting fogs. During the winter there is 10 m/s south-western winds, which often turn into storms. Average winter temperatures are in the range of -4 to +4°C, respectively in the north and in the south. During summer, the temperatures vary between +6°C in the north and +12°C - in the south. Winds blowing from the north are frequent, but they usually come from west or south-west directions and reach speeds of 5-6 m/s. **Ocean conditions.** The sea is strongly affected by the warm Gulf Stream waters from the Atlantic Ocean, making it practically ice-free all year round. Some drift ice, however, can be brought down from the north, either from the Barents Sea or the Greenland Sea. Water temperatures in winter are about 7°C in the south and 3°C – in the north, while in the summer they are respectively 3°C and 7°C. Salinity stays in the range 34-35 ppt in winters, while it drops down to 32-33 ppt in summers. The latter is caused by surface runoff from Scandinavia.

BALTIC SEA. Climate. The Baltic Sea has mild marine climate with some continental features. In autumn-winter time, it is usually rainy and windy. In February, the mean air temperature is -10°C in the north of the sea, -3°C – in the centre, and -1°C – in the south. Occasionally, not very often though, temperatures can drop down to -35°C due to cold Arctic air masses coming from the North. Weak western winds bring cold and wet weather from the Atlantic in summer. July air temperature is about +15°C in the north – the Gulf of Bothnia, and +18°C – in the south. Sometimes air masses brought from the Mediterranean Sea cause temperature increases up to 24°C. Precipitations range from 400 mm in the north up to 800 mm in the southern parts of the sea. Southern regions are also characterized by fogs (60 days/year). In the north, these are recorded only on 22 days a year on average. **Ocean conditions.** Freshwater surface runoff has the greatest impact on the Baltic Sea of the studied seas. Its salinity level is four times lower than in the Barents, Norwegian, Greenland and North Seas – staying in the range of 7-8 ppt. In terms of sea water temperature, it is also warmer than the other seas, especially in the summer. In August, the water in the southern parts of the Baltic Sea can warm up to 20°C. In the north the water temperature is still rather moderate and reaches only up to 9-13°C. In winters, temperatures of about 0°C are reported in bays and 1-3°C in the high seas. Ice formation starts in November by the coast and later in the winter also offshore. The ice can cover most of the northern part of the sea – the Gulf of Bothnia, with thickness of up to 1 m. Thickness of drifting ice can be from 0,4 to 0,6 m. The melting season starts in March from the south of the Baltic Sea and the last remaining ice pockets in the north have melted by June. (MKRF, 2019)

GREENLAND SEA. Climate. The climate is influenced by the Icelandic depression, the Arctic anticyclone and high atmospheric pressure areas above Greenland. In winters, winds blow from north and north-

eastern directions, with speeds up to 8 m/s. Storms are 15% probable in autumn-winter time. As with the Baltic Sea, different parts of the sea can have different climatic patterns. Thus, January is characterized by air temperature of -2°C by Iceland and -26°C in the north-west of the sea. In July it can be 8°C by Iceland and 1°C in the north-west. In summertime, winds blow with up to 5 m/s from variable directions. Most of annual precipitation takes place in wintertime. The annual amount is from 200 mm in the north up to 1,000 mm in the south. ***Ocean conditions.*** Water temperature vary greatly within the area: in the north, sea water temperature of about 0°C is recorded during summer, while in the south temperatures up to 8°C can be reached. In winter the temperatures are -1.8°C in the west and 2°C in the east. Salinity in the summer is about 32 ppt by Greenland and 34 ppt in the north-east. In winter it ranges between 33-35 ppt. Drifting icebergs and sea ice are present at sea all year round. and in winters, local ice can be formed at the surface. The largest sea ice presence is found in February-April and lowest in September.

Table 2. Overview of Greenland Sea and North Sea: N/A – information not available, W – winter, S – summer

SEA	GEOGRAPHY	OCEANOGRAPHY	CLIMATE
Greenland Sea	<u>Total area, km²:</u> 1,195,000 <u>Maximum depth, m:</u> 5,527 <u>Washed countries:</u> Iceland <u>Marine protected areas, km²:</u> N/A	<u>Salinity, ppt:</u> 33 <u>Water temperature, °C:</u> -1.8 ^W <u>Water temperature, °C:</u> 0 ^S <u>Ice coverage:</u> present all year round	<u>Precipitation, mm/yr:</u> 500 <u>Air temperature, °C:</u> -10 ^W <u>Air temperature, °C:</u> 5 ^S
North Sea	<u>Total area, km²:</u> 690,041 <u>Maximum depth, m:</u> 725 <u>Washed countries:</u> Belgium, Denmark, France, Germany, Netherlands, Norway, Sweden, United Kingdom <u>Marine protected areas, km²:</u> 16,846	<u>Salinity, ppt:</u> 33 <u>Water temperature, °C:</u> 8 ^W <u>Water temperature, °C:</u> 13 ^S <u>Ice coverage:</u> N/A	<u>Precipitation, mm/yr:</u> 1,000 <u>Air temperature, °C:</u> 0 ^W <u>Air temperature, °C:</u> 13 ^S

NORTH SEA. Climate. Climate of the sea can be described as mild due to large influence of the Atlantic. The weather is unstable and variable in all seasons. Winters are short and mild, but with strong south-western and western winds, large presence of clouds and frequent precipitations. Summers are cold and cloudy. November to March is the storm season. February has mean temperature of 0°C in the east, and +5°C in the west. In August temperature varies from 15°C in the north to 17°C in the south. Annual precipitations range from 700 mm in the south to 1,000 mm in the north. Fog is frequent.

(MKRF, 2019) **Ocean conditions.** The sea is affected by three water bodies: the Atlantic Ocean, the Baltic Sea and local surface runoff. The largest influence is attributed to the warm and saline seawaters from the Atlantic Ocean. Sea water temperature varies a lot between seasons. By Danish coast, it can be 18°C in summer and 2°C in winter, while in the north-west of the sea those values vary from 13°C to 8°C accordingly. Offshore salinity on average stays around 35 ppt. However, close to the brackish water of the Baltic Sea, the salinity drops to 25 ppt. (MKRF, 2019)

“Red” and “green” zones

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After having conducted a review of climate conditions of the studied seas, three general groups of parameters are found to have influence on oil spill response operations. One relates mostly to the specific water conditions at place: wave heights, strength of sea currents and the presence of ice. Second perspective focuses more on the atmospheric parameters of wind, temperature, humidity and visibility. The third one is a combination of these both.

Wave height, ice coverage, ocean currents, wind direction, temperature at surface, and natural light presence are among the most crucial marine and aerial parameters, which contribute to operational deployment of oil spill response methods and technologies. As a complete set, they create multiple combinations of possible outcomes, how an oil spill can behave on the water surface. These conditions also dictate, what kind of techniques can be taken for its removal. Below is an example of limiting factors for equipment at sea, summarized in Table 3.

Table 3 - Environmental challenges of primary OSR methods at sea

OSR LIMITING FACTORS	IN SITU BURNING	MECHANICAL CLEAN-UP	DISPERSANTS USE
Air temperature, °C	-11	-18	+5
Ice coverage, %	40 or 90 (for oil-in-trap)	60	70
Wind speed, m/s	10	15	12
Sea current, m/s	0.5	0.5	no limit
Wave height, cm	100	200	400
Precipitation	rain/snow storm	snowstorm	rain/snow storm
Visibility at sea, m	pitch black darkness during Polar Night periods		
	300	1,800	900

Some of the above-mentioned methods fare better in cold, winter conditions, which last for several months in large parts of the NPA seas areas. Mechanical oil clean-up with booms and skimmers, for instance, endures the coldest temperatures before losing its operability altogether. Also, ice presence that exceeds 60% of the sea surface, strong winds of more than 15 m/s and waves exceeding 2 m will bring mechanical clean-up operations to halt. Low visibility combined with precipitation storms will have the same impact. All these factors – either individually or as a combination– can prevent efficient OSR operations. The use of chemical dispersants and thermal oil treatment via burning have their own parameters, under which conditions they can be employed successfully.

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The weather conditions can be a mixed blessing, as rough seas can break up potential oil spill slicks quite fast and thus make active OSR actions unnecessary. This is good news, since – as was pointed out above – the methods might not be usable at all in these conditions, neither would it make sense to danger lives and vessels to deal with the spill. It does not make sense to risk causing further spills, if the conditions do not allow secure OSR operations. If air temperature is below -18°C, wind is 15 m/s, wave height is 4 m – it is pitch black and visibility is less than 0,3 km at sea – responders won't head out. Other factors are at play too and ice is naturally the most significant factor in this OSR "game", especially in the NPA region. During the winter, parts of the Baltic Sea, Greenland Sea and Barents Sea get solid ice coverage. In the Baltic Sea there is extensive shipping also in icy conditions, as ice breakers are employed to keep the traffic going. However, there is not similar kind of regular traffic in the ice-covered parts of Greenland Sea and Barents Sea. Combating oil spills in ice is a difficult task, but drift ice, which can find its way to south, can cause issues for OSR in other sea areas too.

Because of these factors, some regions even within the NPA region can be branded as "red" zones for employing OSR actions, at least during some parts of the year. When the limiting values are exceeded, the methods cannot be employed successfully anymore. And when the forces of nature have overpowered all the available methods, then OSR actions are not possible at all. Based on the previously recorded weather data, it is possible to calculate, during which time of the year successful OSR operations are possible and when they are not. In Table 4 below, ice coverage is taken as an example of limiting factor for OSR operations. Due to its coverage of the seas in winter and circum-winter season, green and red colours indicate when OSR actions are possible based on existing ice coverage. The sea areas are vast, so this does not refer to whole area. Some parts of the same sea can be green on the same month as some other part is definitely red.

Table 4. Favourable and unfavourable conditions at the studied seas based on their ice coverage: BrS – Barents Sea, NrS – Norwegian Sea, BS – Baltic Sea, GS – Greenland Sea, NS – North Sea

SEA/TIME	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEP	OCT	NOV	DEC
BrS												
NrS												
BS												
GS												
NS												

But ice is just one factor, the above table does not include seasonal storm conditions neither Polar Night nor other climatic perspectives. However, it clearly demonstrates how inaccessible some of the seas of the Northern Periphery and Arctic region can be. For instance, Greenland Sea, besides its possible winter storms, regular precipitations and -26°C in the north-west of the sea, is also well covered by ice with drifting icebergs all year round. All these make it “red” and a difficult spot where to deal with a potential oil spill accident. Similar conditions are found in the Barents Sea. The “greenest” sea of all in the NPA area is the Norwegian Sea. Although OSR operations in this sea should not be hampered by ice, the Polar Night season lasts there from November to January. Pitch black darkness that lasts 24 h a day causes other kind of difficulties for OSR actions.

Conclusion

This report has studied the similarities and differences in climate, which are found in the NPA region. An effort has been made to answer the questions placed in the introduction:

1. What kind of climate does the NPA region have? The vast scale of the region defines its climate variability from area to area. The climatic zones vary from warm temperate climate of the British Isles to continental one in Fennoscandian peninsula and to polar one that is found in Greenland and Iceland.

2. How many climatic zones are there in the NPA region? There are five distinguishable zones, which in accordance with the Köppen climate classification are *Cfb*, *Cfc*, *Dfb*, *Dfc*, *ET* and *EF*.

3. What makes one zone different from the other? Average annual temperature, humidity, spread and amount of precipitations throughout the year, length of winters and summers, and other parameters make every individual climatic zone unique.

4. Are there any “green” and “red” zones among the studied seas when looking from the perspective of successful oil spill response? Oil spill response is a multi-variable equation. It includes all ambient parameters and characteristics of the environment but also oil properties of the spilled substance. Fool proof assessments cannot be made, whether one area is 100% favourable and another 100% unfavourable, even though Arctic Council has addressed this issue systematically. APP4SEA project has only scratched the surface of this issue, the project has not carried out any in-depth research regarding this. Therefore, should the reader be interested in going beyond the general outlines laid down in this report, the reader should refer to Arctic Council’s report, that is mentioned in the references.

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**Northern Periphery and
Arctic Programme**

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