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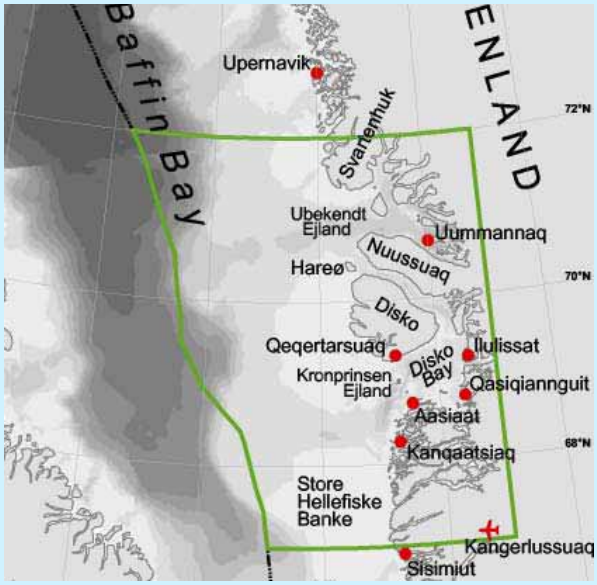

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Data sheet

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Preface

This document is a strategic environmental impact assessment (SEIA) of activities related to exploration, development and exploitation of hydrocarbons in the sea off West Greenland between 67° and 71° N (= the Disko West Area). The area was opened for applications in 2006 and licences are planned to be granted in spring 2007. The SEIA was developed by the National Environmental Research Institute, Denmark in close co-operation with the Greenland Institute of Natural Resources and the Bureau of Minerals and Petroleum of the Greenland Home Rule.

The assessment area is shown in Figure 1. This is the region which potentially could be most impacted by a large oil spill deriving from activities within the expected licence areas, although drift modelling indicates that oil may drift even further.

The assessment area is very important in an ecological context. Biological production in spring and summer is very high, there are rich benthic communities and large and important seabird and marine mammal populations. Fish and shrimp stocks in the area contribute significantly to the fishing industry in Greenland, and local communities utilise the coastal areas through subsistence hunting and fishing.

The expected activities in a 'full life cycle' of a petroleum field are briefly described. Exploration activities are likely to take place during summer and autumn, because harsh weather and sea ice hamper activities in winter and spring. However, if oil production is initiated activities throughout the year will take place. A previous study has pointed out that the most likely scenario for a production field will be a subsea well and gathering system tied back to a production facility either in shallower water established on a gravity based structure (GBS) or onshore. Produced oil will then be transported by shuttle tankers to a facility outside Greenland, most likely in North America.

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Summary and conclusions

The environment

The physical conditions of the study area are described with focus on weather, oceanography and ice conditions. The presence of icebergs and sea ice in winter and spring will make exploration and development difficult and increase the risk of accidents. Updated information on the physical properties of the environment is under preparation and will be included in an information CD prepared by GEUS (the Geological Survey of Denmark and Greenland) and NERI.

The study area is situated within the Arctic region, with all the typical biological properties of this climatic region: low biodiversity but often numerous and dense animal populations; a relatively simple food web from primary producers to top predators, and with a few species playing a key role in the ecology of the region. In the marine environment the most significant event is the spring bloom of planktonic algae, the primary producers in the food web. These are grazed upon by copepods, including the *Calanus* species which represent some of the most important and conspicuous key species in the food web.

Fish, seabirds and marine mammals represent some of the higher trophic levels in the marine environment, where polar bear and man are the top predators. Seabirds are abundant with several species present in the study area. Many species breed in dense colonies along the coasts, seaducks assemble in certain fjords and bays to moult, and in winter millions of seabirds migrate through or winter in the ice-free waters off West Greenland. Many of these moulting and wintering seabirds have their breeding grounds outside Greenland – mainly in Canada and Norway (Svalbard). See Table 2, p. 63.

Marine mammals are significant components of the ecosystem. Five species of seal, walrus, 13 species of whale, and polar bear occur in the assessment area. The assessment area is particularly important to marine mammals in winter, because vulnerable species such as narwhal, white whale (beluga), bowhead whale, walrus, and polar bear occur in significant numbers. See Table 3, p. 74. The whales are moreover suspected to acquire the bulk of their annual food intake in the assessment area.

Use of natural resources is another important issue in the assessment area. Commercial fisheries focus mainly on the large stocks of deep-sea shrimp and Greenland halibut. These two species are extremely important to the Greenland economy. About 35% of the total Greenland shrimp catch and about 80% of the Greenland halibut catch is taken in the assessment area. Other species utilised on a commercial basis include snow crab and Iceland scallop.

Local and subsistence fishery occur throughout the coastal part of the region. Capelin, lumpsucker (mainly caught for the roe), Arctic char and

several other species are fished for private consumption or sold to local factories or at local open markets.

Hunting of seabirds and marine mammals is also important in the assessment area. This is carried out mainly on a subsistence basis, but hunting products are also sold at local open markets, and processed and marketed in food stores in towns and settlements all over Greenland.

Tourism is a relatively new and growing industry in Greenland. It may be sensitive to oil spills because the main attraction in Greenland is the unspoiled nature. The most intensive tourist activities in Greenland take place within the assessment area, with the town Ilulissat as centre.

Knowledge on background levels of contaminants such as hydrocarbons and heavy metals is important in assessing environmental impacts from petroleum activities. The available knowledge on background levels of hydrocarbons in the assessment area is limited, but the general picture is that levels are low. A significant amount of data regarding other contaminants in the Greenland environment is available.

Assessment

Exploration

The environmental impacts of exploration activities will mainly be disturbance from activities associated with noise, and the impacts are expected to be relatively small, local and temporary, because of the intermittent nature of the activities. No serious impacts are expected if adequate mitigative measures are applied, activities in sensitive areas are avoided in the most sensitive periods and no accidents such as oil spills occur. The winter is particularly sensitive to exploration activities due to wintering marine mammals, but these are not expected to take place during this season. Temporary impacts of intensive seismic activity could be displacement of Greenland halibut, which again could cause reduced catches in the fisheries near affected areas. Deep-sea shrimp will not be affected by seismic activities. Marine mammals, particularly whales, may also be displaced from feeding grounds and migration routes. However, as seismic surveys are temporary such effects are expected to be of short duration (viz. weeks or a maximum of a few months). There is however a risk of oil spills from blowouts during exploration drilling (see below).

The sound pulse from the seismic array can kill or injure fish egg and larvae within a distance of 5 m. Very intensive seismic surveys coinciding with high concentrations of fish eggs and larvae in the upper part of the water column may impact recruitment to the adult stocks. However, as such high concentrations are not known in West Greenland waters and, moreover, most fish species spawn in a dispersed manner and in late winter or early spring when no seismic surveys takes place, it is concluded that the risk of effects of seismic surveys on fish stocks is negligible.

Development and production

The activities during development, production and transport are on the other hand long lasting and there are several activities which have the potential to cause serious environmental impacts. Careful Health, Safety

and Environment (HSE) procedures, and planning and application of Best Available Technique (BAT) and Best Environmental Practice (BEP) can mitigate most of these. Even though discharges and emissions can be limited, knowledge on cumulative and long-term impacts from many of the released substances is still lacking.

Development and production are energy-consuming activities which will contribute significantly to the Greenland emission of greenhouse gases. A single large Norwegian production field emits more than twice the total Greenland emission of today.

The fisheries will be affected by development and production mainly by the presence of the safety zone (of typically 500 m) around the offshore facilities.

Placement of structures and the disturbance related to these have the potential to displace marine mammals in particular. Noise from drilling platforms has displaced migration routes of bowhead whales in Alaska. Dependent on location in the assessment area, displacement of migrating and staging whales (mainly narwhal, white whale and bowhead whale) walrus and seals (bearded seal) must be expected. This can in certain areas limit the access of populations of these animals to feeding grounds important to survival, and also result in reduced availability of quarry species for local hunters.

Intensive helicopter flying also has the potential to displace seabirds and marine mammals from habitats (e.g. feeding grounds important for winter survival) and traditional hunting grounds for local people.

Development and production activities represent an issue which is difficult to evaluate when the level of activity is unknown and cumulative impacts are involved. Overall significance will depend on the number of activities, how far they are dispersed in the areas in question, and also on their duration.

Oil spills

The potentially most serious environmental impacts are related to large accidental oil spills. These may occur either during drilling (blowouts) or from accidents when storing or transporting oil. Large oil spills are rare events today due to ever-improving technical solutions and HSE-policies. However, the risk cannot be totally eliminated and in a frontier area with the presence of icebergs, the possibility for an accident may be elevated.

Oil spill modelling indicates that a spill located far offshore most likely will not affect the coast in any of the selected (likely) wind conditions. Nearshore spills will result in coastal pollution under unfavourable wind conditions, and a spill for example from a tanker wreck at a coastal facility will most likely heavily pollute the coast near the spill site. The shorelines which could be polluted according to the modelling include the outer parts of Vaigat, the southern parts of Disko Bay, the west coast of Disko Island, and up to 100 km north and south of the Disko Bay area.

In general, oil spills occurring in the coastal zone are regarded as much more deleterious than oils spills in the open sea, but there is some reser-

vation attached to this statement in an area such as Disko West. This is due to the presence of winter ice which may trap and transport oil over long distances, but which on the other hand also may limit the dispersion compared with the situation in ice-free waters. Knowledge on the behaviour of spilled oil in ice-covered waters is limited.

The coastal zone is sensitive because of the rich biodiversity present, including concentrations of breeding and moulting seabirds and spawning fish stocks (capelin and lumpsucker). But it is also related to the fact that oil may be trapped in bays and fjords where high and toxic concentrations can build up in the water. Moreover, local fishermen and hunters intensively use the coastal zone. Oil may also be buried in sediments, among boulders, in mussel beds and imbedded in crevices in rocks from where oil may seep, and may create low-level chronic pollution which may persist for decades and cause long-term effects on, for example, birds utilising these coasts.

Effects of an oil spill in the open sea are expected to be less severe than in coastal areas. However, there are some important offshore resources in the area which may be severely impacted – for example, the concentrations of wintering king eiders, white whales and walruses on Store Hellefiskebanke. Attention should also be given to potential oil spills in areas with hydrodynamic discontinuities, particularly during the spring bloom. Fronts, upwelling areas and the marginal ice zone are examples of such hydrodynamic discontinuities where high surface concentrations of phytoplankton, zooplankton, and shrimp and fish larvae can be expected. But generally it is concluded that the impact of an oil spill on the eggs and larvae of the commercially important species - Greenland halibut and deep-sea shrimp - most likely will be low and without significant effects on the recruitment to adult stocks, because only a small fraction of the population will be impacted.

Bird populations particularly at risk of being impacted by an oil spill in the Disko West area include the breeding colony of thick-billed murres at Ritenbenk, the breeding colonies of Atlantic puffins along the outer coasts, and the moulting and wintering populations of king eiders along the west coast of Disko and on Store Hellefiskebanke.

Marine mammal populations are generally regarded as relatively robust to oil spills, mainly because individuals (except polar bears) are not dependent on an intact fur layer for insulation. However, some of the species in the assessment area are particularly vulnerable, because they are sensitive even to slightly increased mortality: the stocks of narwhal, white whale and walrus are all declining. Polar bears are also sensitive to oil spills. Walrus and bearded seal feeding on benthos may also be exposed to oil through their food, if oil sinks and accumulates on the seafloor. Bowhead whales, which occur in low numbers, belong to a stock which now is slowly recovering from heavy exploitation. This recovery may be halted by even a slight increase in mortality.

There are special problems related to oil spills in ice. Sea-ice cover will in the beginning tend to contain and limit the spread of an oil spill compared with open sea. Oil is contained between the ice floes and in the rough underside of the ice. However, oil caught under the ice may be transported in an almost unweathered state over long ranges and may

impact the environment, e.g. seabirds and marine mammals, far from the spill site when the ice melts. Oil may also be caught along ice edges, where primary production is high.

Even though seals may tolerate some oil in their fur, such oiling may impact local hunters, as fouled skins are of no use and are impossible to sell.

Oil spill effects on commercial fisheries are mainly linked to the closure of fishing grounds (e.g. for shrimp and Greenland halibut) for longer periods (weeks to months) due to the risks associated with marketing polluted or tainted fish. Effects on subsistence hunting and fishing will include closure of fishing grounds and probably also temporary changes in distribution and habits of quarry species.

Further studies

The assessment has revealed several issues where more knowledge is needed to assess impacts of hydrocarbon activities. These are addressed in a series of studies already initiated or proposed.

In support of this SEIA, the BMP and NERI have initiated a number of background studies in collaboration with the Greenland Institute of Natural Resources and others. The studies are being conducted over the period 2005-2008.

Further studies in relation to the future opening of the northwest Baffin Bay are expected to be initiated to strengthen the knowledge base for planning, mitigation and regulation of oil activities in the assessment area and in the entire Baffin Bay area. NERI is developing a database with relevant environmental data from these background studies as well as other sources. Data include spatial and temporal distribution of key animal species and fishing areas. The data will be made available on DVDs in a Geographic Information System in ArcGIS format in support of the companies' own environmental analyses.

Dansk resume

Denne rapport er en strategisk miljøvurdering af aktiviteter forbundet med olieefterforskning og -eftersøgning i farvandet vest for Disko, Vestgrønland. Nærmere bestemt farvandet mellem 67° og 71° N (Figur 2.1). Dette område betegnes Disko West-området, et navn givet i forbindelse med den udbudsrunde, der blev indledt i 2006. Rapporten er udført af Danmarks Miljøundersøgelser (DMU) i samarbejde med Grønlands Naturinstitut (GN), og arbejdet er finansieret af Råstofdirektoratet.

Det vurderede område er større end det areal, som udbudsområdet dækker. Det skyldes, at der skal tages højde for, at oliespild kan drive meget langt og dermed også ud af udbudsområdet.

Disko West-området er meget rigt i biologisk/økologisk forstand. Primærproduktionen om foråret er meget høj, der er rige dyresamfund på havbunden og der er store og meget vigtige forekomster af både fugle og havpattedyr. Fisk og rejer i området er vigtige ressourcer for næringslivet i land og husholdningsfiskeri og -fangst er ligeledes vigtige aktiviteter i de kystnære områder.

En komplet livscyklus for et oliefelt er så vidt muligt vurderet. Men da der ikke er erfaringer med udvinding af olie i Grønland, er vurderinger af aktiviteter i denne forbindelse ikke konkrete, men bygger på erfaringer fra andre områder med så vidt muligt tilsvarende forhold.

Vurdering af aktiviteter

Efterforskning

De væsentligste påvirkninger fra efterforskningsaktiviteter vil blive forstyrrelser fra støjende aktiviteter (f.eks. seismiske undersøgelser, boring i havbunden og helikopterflyvning). Der forventes kun relativt svage, midlertidige og lokalt forekommende påvirkninger. De mere alvorlige påvirkninger kan undgås med forebyggende tiltag, som f.eks. ved at undgå aktiviteter i særligt følsomme områder eller perioder.

Vinterperioden er særligt følsom overfor støjende aktiviteter bl.a. på grund af forekomst af hvidhvaler, narhvaler, grønlandshvaler, hvalrosser og remmesæler, men efterforskningsaktiviteter forventes ikke i den tid, hvor disse dyrearter er tilstede.

Intensive seismiske undersøgelser kan formentlig bortskræmme hellefisk fra vigtige fiskeområder og dermed også påvirke fiskeriet negativt. Men undersøgelser af andre fiskearter tyder på at denne påvirkning er midlertidig. Derimod forventes ingen påvirkninger af rejebestandene. Der er desuden en risiko for at havpattedyr kan bortskræmmes fra vigtige fødesøgningsområder og trækruter, men igen forventes påvirkningen at være midlertidig (varighed uger til måneder), fordi aktiviteten ophører.

Det er påvist at trykbølgen fra de luftkanoner, der benyttes ved seismiske undersøgelser, kan slå fiskeæg og -larver ihjel ud i en afstand af

maks. 5 m. I Norge er der bekymring for at meget intensive seismiske undersøgelser i områder med høje koncentrationer kan dræbe så meget fiskeyngel, at det kan påvirke rekrutteringen til bestanden af voksne fisk. Tilsvarende høje koncentrationer af fiskeyngel kendes ikke i grønlandske farvande, og de højeste koncentrationer forekommer desuden om foråret før seismiske undersøgelser normalt udføres. Det konkluders derfor at seismiske undersøgelser ikke giver anledning til risiko for væsentlige påvirkninger af fiskebestandene.

Den væsentligste risiko for miljøpåvirkninger under efterforskning opstår i forbindelse med oliespild, som kan opstå i forbindelse med udblæsninger under prøveboringer. De mulige følger af oliespild er omtalt nedenfor.

Udvikling og produktion

I modsætning til efterforskningsfasen er aktiviteterne under udvikling af et oliefelt og produktion af olie af lang varighed (dekader), og flere af aktiviteterne har potentiale til at forårsage alvorlige miljøpåvirkninger. Disse påvirkninger kan i høj grad forebygges gennem nøje planlægning, anvendelse af anerkendte "Health, Safety and Environment" (HSE) procedurer, brug af "Best Available Technique" (BAT) og "Best Environmental Practice" (BEP). Der er dog mangel på viden om kumulative virkninger og langtidsvirkninger af de udledninger (f.eks. fra produktionsvand), der forekommer selv ved anvendelse af førnævnte tiltag.

Energiforbruget ved udvikling og produktion er meget stort, og det må forventes at anlægget af stort oliefelt i Grønland vil bidrage meget væsentligt til Grønlands samlede udledning af drivhusgasser. F.eks. udleder et af de store norske oliefelter mere end dobbelt så meget CO_2 som Grønlands samlede bidrag.

Selve placeringen af installationer og de forstyrrelser, der kommer fra disse, kan påvirke havpattedyr, sådan at de bortskræmmes permanent fra vigtige fourageringsområder eller ved at de ændrer trækruter. I Disko West-området er det især narhval, hvidhval, grønlandhval, hvalros og remmesæl, der er på tale i denne sammenhæng. Dette kan vanskeliggøre fangst på jagtbare arter.

Intensiv helikopterflyvning har også potentialet til at bortskræmme både havfugle og havpattedyr fra vigtige fourageringsområder.

Fiskeriet i de områder, hvor der vil forekomme udvikling og produktion vil blive begrænset omkring installationer på havbunden (brønde og rørledninger) og ved de forskellige typer af platforme. Normalt anlægges en sikkerheds/afspærringszone i en afstand ud til 500 m fra sådanne installationer.

Det skal påpeges, at det er meget vanskeligt at vurdere de påvirkninger eventuel udvikling og produktion kan medføre, fordi omfanget, varigheden og typen af aktiviteter ligesom de tekniske løsninger ikke er kendt.

Oliespild

De mest alvorlige miljøpåvirkninger, der kan forekomme i forbindelse med olieaktiviteter, er store oliespild. De forekommer enten fra udblæs-

ninger, hvor kontrollen med borehullet mistes under prøveboring, eller fra uheld i forbindelse med opbevaring og transport af olie, f.eks. i forbindelse med forlis af tankskibe. Store oliespild er meget sjældne nu om dage, fordi teknikken og sikkerhedsforanstaltningerne hele tiden forbedres. Men risikoen er til stede, og særligt i "frontier"-områder, som de grønlandske farvande med tilstedeværelsen af en særlig risikofaktor i form af isbjerge, er muligheden for uheld og ulykker forhøjet.

Modellering af drivbanerne for oliespild i Disko West-området viser at oliespild med oprindelse langt til havs med stor sandsynlighed ikke vil nå kysterne, som er særligt sårbare over for olie. Derimod er der stor risiko for at et spild fra en position nær kysten (f.eks. fra et udskibningssted) under uheldige vejrforhold kan forurene lange kyststrækninger på Disko, i ydre Disko Bugt og op til 100 km både nord og syd for Disko Bugt.

Oliespild i kystnære farvande regnes generelt som meget mere ødelæggende end oliespild på åbent hav. Men i et område som Disko West må denne generalisering modificeres. Det hænger sammen med vinterens is, som kan holde på olien og transportere den over lange afstande uden at den nedbrydes, men også kan begrænse et spilds udbredelse sammenlignet med et spild i isfrie farvande. Den foreliggende viden om oliespilds adfærd og skæbne i isdækkede farvande er begrænset.

Grunden til at kystnære fravande kan være sårbare over for oliespild er, at olien her kan påvirke områder med høj biodiversitet og med tætte dyrebestande, som f.eks. gydende lodde (ammassat) og stenbider eller områder med store fugleforekomster. Olien kan fanges i bugter og fjorde, hvor høje og giftige koncentrationer af oliekomponenter kan bygges op i vandsøjlen. Der er også risiko for at olie kan fanges i bundsedimenter, i strande med rullesten og i muslingebanker, hvorfra olie langsomt kan frigives til det omgivende miljø med risiko for langtidsvirkninger f.eks. på fuglebestande som udnytter kysterne. Endelig udnyttes de kystnære fravande af lokale indbyggere til fangst og fiskeri.

På åbent hav er fortyndingseffekten og spredningen på vandoverfladen med til at mindske miljøeffekterne af et oliespild. I og nær Disko Westområdet er der dog områder langt fra kysten, som alligevel er særligt sårbare over for oliespild og hvor væsentlige effekter kan forventes. Det er særligt de lavvandede partier (< 50 m) af Store Hellefiskebanke, der er tale om. Her overvintrer internationalt meget vigtige forekomster af kongeederfugl, hvidhval og hvalros. Et andet sårbart element langt til havs er frontzoner, "up-welling"-områder og de ydre dele af drivisen ("marginal ice zone"), hvor primærproduktionen er særligt høj om foråret, og hvor høje koncentrationer af planktoniske alger og dyrisk plankton (inkl. yngel af rejer og fisk) forekommer i den øvre del af vandsøjlen. Et oliespild vil dog næppe påvirke bestandene af rejer og hellefisk, de vigtige arter for det grønlandske fiskeri.

Fugle er særligt sårbare overfor oliespild på havoverfladen, og i Disko West-området er ynglekolonien af polarlomvier ved Ritenbenk og de ynglende lunder på øerne yderst i Disko Bugt udsatte. Det samme er tilfældet med de store forekomster af fældende kongeederfugle langs de ydre kyster af Disko.

Havpattedyr er generelt mere robuste overfor oliespild på havoverfladen. Men indenfor Disko West-området forekommer bestande som er sårbare, fordi de i forvejen påvirkes af andre menneskelige aktiviteter – primært fangst. Det gælder hvidhval, narhval og hvalros, hvis bestande alle er for nedadgående. Hvalros og remmesæl lever desuden af bunddyr, og kan blive udsat for at indtage olie med deres føde. Isbjørne er specielt sårbare, fordi de har en tendens til at rense olie af pelsen ved at slikke den ren og derved blive forgiftet af den indtagne olie. Grønlandshvalerne, der forekommer i området, tilhører en bestand, som først nu er begyndt at vise tegn på fremgang, efter at have været næsten udryddet i begyndelsen af 1900-tallet. Bestanden er stadig lille, og selv en lille ekstra dødelighed, kan tænkes at påvirke bestandens bedring.

Et oliespild i havområder med is vil formentlig samles i åbne revner og under isflager, hvor den kan påvirke de fugle og havpattedyr, der er afhængige af åbent vand og også yngel af polartorsk, der netop samles lige under isen.

Fiskeri og fangst kan blive påvirket ved at oliepåvirkede områder lukkes for den slags aktiviteter. Dette gøres for at hindrer at der fanges og markedsføres fisk, der har været i kontakt med olie eller som blot er mistænkt for at have været det. Der er eksempler på at oliespild har lukket for fiskeri i månedsvis. Der er også en risiko for at fangstdyr bliver sværere tilgængelige i en periode efter et oliespild, ligesom sælskind bliver umulige at afsætte hvis der er olie på dem.

Yderligere studier

Da arbejdet med denne miljøvurdering blev indledt, var det klart at der manglede væsentlig viden til at foretage vurderinger af olieaktiviteter i Disko West-området. Flere studier blev igangsat og resultaterne herfra er inddraget, i den grad de var tilgængelige. Men flere undersøgelser er ikke afsluttet endnu, og vil give resultater som skal inddrages i kommende tillæg. Endelig er der flere undersøgelser, der skal sættes i gang, når og hvis konkrete aktiviteter indledes og skal miljøvurderes.

Den nordlige del af Baffin Bugt nord for Disko West-området forventes åbnet for olieeftersøgning, og i denne sammenhæng indledes nye studier med henblik på at samle ny viden til miljøvurdering af aktiviteter i dette område.

Resultaterne af alle disse baggrundsstudier og den eksisterende viden skal samles i en rumlig database, som bliver tilgængelig i elektronisk form for selskaber, der siden hen skal foretage miljøvurderinger af specifikke aktiviteter.

Naalisagaq kalaallisooq

Nalunaarusiaq una Kalaallit Nunaata kitaani, immami Qeqertarsuup kitaaniittumi oliaqarneranik misissuinermut ujarlernermullu atatillugu ingerlatanut tunngatillugu avatangiisinut iliuusissanut naliliineruvoq. Erseqqiannerusumik oqaatigalugu immami allorniusat 67° og 71° N (titartagaq 2.1) akornanniittumi. Tamanna Disko West-imik taagorneqarpoq, taaguut neqerooruteqarnermut 2006-imi aallartittumut atatillugu atsiunneqarsimasoq. Nalunaarusiaq DanmarkimiAvatangiisinutMisissuiffeqarfimmit (DMU) suliarineqarpoq Kalaallit Nunaanni Pinngortitaleriffik (GN) suleqatigalugu.

Naliliiffigineqartoq tamanna imartamit neqeroorutigineqartumit annertuneruvoq. Tamatumunnga pissutaavoq ooliaarluertoqassagaluarpat siaruaaffigisinnaasaa annertoorujussuussaammat taamalu neqerooruteqarfiusumit anillakaattussaassammat.

Disko West-teertugaq biologiskip/økologiskip tungaanit isigalugu pisoorujussuuvoq. Upernaakkut pinngorartitsineq annertoorujussuusarpoq, immap naqqani uumasoqatigiippassuaqarpoq aammalu timmissanik miluumasunillu imarmiunik pingaarutilerujussuarnit pilerujussuulluni. Tamanna aalisakkanut kinguppaanullu nunami inuuniutinut namminerlu atugassanik piniarnikkullu pissarsiorfittut aammalu sinerissap qanittuani ingerlatanut pingaarutilerujussuuvoq.

Oliasiorfimmi uumasutut ingerlaaseq tamakkiisoq sapinngisamik nalilersuiffigineqarpoq. Kalaallit Nunaannili oliamik qalluineq misilittagaqarfigineqanngimmat ingerlatanut tunngatillugu nalilersuineq toqqartumut tunngatinneqanngillat, kisiannili allani tamaani pissutsinut assingusuni misilittakkanik tunngaveqartinneqarlutik.

Ingerlatanik nalilersuineq

Misissueqqissaarneq

Misissueqqissaarnikkut ingerlatanit sunniutaasut pingaarnerit tassaajumaarput ingerlatat nipiliortut (nunap sajuppillatsittarneratigut misissuinerit, immap naqqani qillerinerit helikopterimillu qulaavaanerit). Ilimagineqarpoq tamaaniittunik sunniinerit annertoorsuunatillu qaangiuttussaajumaartut. Sunniinerit kingunipiloqarnerusinnaasut pinngitsoorneqarsinnaassapput pinaveersaarutaasunik iliuuseqarnikkut, soorlu immap ilaani malussajanerusumi piffissaniluunniit aalajangersuni ajoqusiiffiusinnaanerusuni ingerlatsinaveersaarnikkut.

Ingerlatanit nipiliortunit ajoqusiiffigiuminarnerpaavoq ukiuunera, taamaannikkummi ilaatigummi qilalukkat qaqortat qilalukkallu qernertat, arfiviit, aarrit ussuillu tamanna najortarmassuk, misissueqqaarnernillu ingerlatsineq uumasut tamakkua tamaaniinneranni ingerlanneqartarnissaat naatsorsuutigineqanngilaq.

Sajuppillatsisisarneq atorlugu annertuumik misissuinerit nalunanngitsumik aalisrfinnit pingaarnernit qalerallit qimaatissinnaassavaat taam-

malillutillu aalisarnermut ajortumik kinguneqassallutik. Aalisakkanulli allanut tunngatillugu misissuinerit malillugit sunniut taamaattoq sivisuujussagunanngilaq qaangiukkumaarlunilu. Tamatumali akerlianik kinguppannut sunniuteqarnissaa ilimagineqanngilaq. M imarmiut neriniarfimminnit ingerlaartarfimminnillu pingaarutilinnit tamaaniittunit tatamititaallunik qimaanissaat aarlerigineqarsinnaavortaaq, kisiannili aamma tassani sunniutip, sivikitsuinnaanissaa, ingerlatallu unitsinneqarpata qaangiutilertornissaa (sivisussusia sapaatip akunnialunnguannit qaammatinut) naatsorsuutigineqarpoq.

Paasineqarsimavoq luftkanonit sajuppillatitsisarluni misissuinermi atorneqartartut issaallatitsineratigut aalisakkat suaat aalisagaaqqallu tukerlaat pisorpallatitsiviusumiit ungasinnerpaamik 5 meterip iluaniittut toqunneqarsinnaasut. Norgemi sajuppillaatitsisarluni misissuinerit annertuallaat aalisagaaqqanik ima amerlatigisunik toqutsisinnaanerat allaat aalisakkanut inersimasunngortussanut sunniuteqarnerlussinnaanera isumakuluutigineqarpoq. Kisianni kalaallit imartaanni taama eqimatigisunik aalisagaaqarfiusartoqarneranik ilisimasaqartoqanngilaq, taamaattoqarnerpaasarfialu upernaakkut sajuppillatitsisarluni misissuinerit nalinginnaasumik ingerlanneqartarnerat sioqqullugu pisarpoq. Taamaattumik sajuppillatitsisarluni misissuinerit annertunerusumik aalisagaqatigiinnut sunniuteqarnavianngitsut inerniliineqarpoq.

Misissueqqaarnermut atatillugu avatangiisinut sunniuteqarsinnaasutut aallerinarnerpaaq tassa misiliilluni qillerinermi supisisarnertigut oliamik aniasoortitsisinnaaneq. Oliamik aniasoornerup kingunerisinnaasai ataani eqqartorneqarput.

Ineriartortitsineq tunisassiornerlu

Misissueqqaarnikkut ingerlatsinerup sunniutigisinnaasaasa akerliannik oliasiorfimmik ineriartortitsinikkut oliamillu qalluinikkut sunniutissat sivisunerusumik (ukiuni qulikkuutaajusinnaasuni) atasarput, aammalu ingerlatat arlallit avatangiisinut sunniuteqarnerlorujussuarsinnaasuullutik. Sunniutaasinnaasut tamakkua pinngitsoorneqarsinnaapput peqqissaartumik pilersaarusiornikkut iliuutsinillu "Health, Safety and Environment" (HSE) akuerisaanik aammalu "Best Available Technique" (BAT) aamma "Best Environmental Practice" (BEP) atuinikkut. Sunniutaasartunulli annertusiartortartunut sivisunerusumillu atasartunut (soorlu imermut tunisassiornermut atorneqartumut) tunngatillugu ilisimasat, aamma iliuutsinut siornatungaani taagorneqartunut tunngatillugu, naammanngillat.

Tunisassiornermik ineriartortitsinermut nukik atugaq annertoorujussuusarpoq taamaattumillu Kalaallit Nunaanni oliaqarferujussuarmik pilersitsineq Kalaallit Nunaata gassinik naatitsivimmeersutut ittunik aniatitsineranut tamarmiusumut annertuumik annertusisitsinissaa ilimagineqarpoq. Assersuutigineqarsinnaavoq norskit oliasiorfii CO_2-mik Kalaallit Nunaata ullumikkut aniatitaata marloriaataanik aniatitsimmata.

Atortut sumut inissinneqarnerata tamakkualu akornusersuutaanerisa miluumasut imarmiut sunnersinnaavaat tatamillutik neriniartarfimminniit qimagulluinnartillugit imaluunniit ingerlaartarfimminnik allannguisillugit. Disko West-imi pingaartumik qilalukkat qernertat, qilalukkat qaqortat, arfivik, aarrit ussuillu tassunga atatillugu taaneqarsinnaapput.

Tamatuma aamma uumasunik piniarneqarsinnaasunik piniarnerup ajornarnerulernera kingunerisinnaassavaa.

Annertuumik helikopterimik qulaavaajuarneq aamma neriniartarfinniit pingaaruteqartuniit timmissanik imarmiunik miluumasunillu imarmiunik nujoqqatitsisinnaasunut ilaavoq.

Tamaani ineriartortitsillunilu tunisassiorfiusuni aalisarfiusoq immap naqqani atortulersuutinit (qilleriveqarfinnik ruujorinillu aqqusersuutinik) aammalu napasulianit qilleruteqarfiusunit assigiinngitsunit annikillisinneqarumaarpoq. Nalinginnaasumik isumannaallisaanikkut/matoqqatitsiviusunut qanillinerpaaffissaq tamakkunannga 500 m ungasissuseqartinneqartarpoq.

Erseqqissarneqassaaq ineriartortitsisinnaanikkut tunisassiulersinnaanikkullu sunniutissaajumaartut nalilersuiffiginissaat ajornartorujussuummat, tassami tamakkua annertussusissaat, qanoq sivisutigisumik atanissaat ingerlatallu suunissaat aammalu teknikikkut aaqqiissutit suunissaat ilisimaneqanngimmata.

Oliaarluerneq

Oliasiornmermut atatillugu avatangiisitigut ajoqusiinerpaasussat tassa annertoorsuarmik oliamik aniasoornerit. Tamakkua supisinikkut putumik misiliilluni qilleriviusumik aqutsinerup annaaneqarnerataigut imaluunniit oliamik katersuiffimmi oliamillu assartuinermi ajutoornikkut, assersuutigalugu umiarsuup oliamik asartuutip ajunaarneratigut pisinnaapput. Ullutsinni oliamik aniasoorujussuartarnerit teknikikkut isumannaallisaanikkullu nutarteriuarnerit pissutaallutik qaqutigoortorujussuanngorsimapput. Aarlerigiuartariaqarpulli pingaartumimmi "frontier"-områder taagukkani kalaallit imartanisut ittuni iluliarsuarnit aarlerinartorsiortitsiviusuni ajutoornissaq ajunaarnissarlu aarlerigisariaqarnerusarmata.

Disko Werst-imi oliaarluernerup tissukarfigisinnaasaasa missingersuusiornerqarneranni avasiinnarsuarmi oliaarluernerup sineriak oliaarluerfigissallugu isumakulunnarnerpaaq tikissagunanngikkaa takuneqarsinnaavoq. Akerlianilli sinerissamut qaninnerusumi oliaarluernikkut (assersuutigalugu usilersorfimmi) silarlummik eqqorneqarluni Qeqertarsuarmi, Qeqertarsuup Tunuata silasinnerusuani sineriarujussuaq Qeqertarsuup Tunua avannamut kujammullu 100 km angullugu qaangerlugu annertussusilik mingutissinnaavaa.

Sinerissap qanittuani oliaarluerneq imaannarmi oliaarluernermit aseruinerujussuusartutut isigineqarpoq. Kisiannili taamatut ataatsimut isigininneq Disko West-imut tunngatillugu allatut isigineqartariaqarpoq. Taamaannera ukiumi sikuusarneranut attuumassuteqarpoq sikummi olia uninngatissinnaallugulu allannguuteqartinnagu ungasissorsuarmut angallassinnaavaa, taamaattorli aamma mingutitsinerup siaruarnerunissaralua sikoqanngitsumi aniasoornermut sanilliullugu pakkersimaarnerusimasinnaallugu. Oliap immami sikuusumi aniasoornikup qanoq pisarneranut tunngatillugu ilisimasat massakkut pigineqartut annertunngillat.

Sinerissap qanittuata oliamik aniasoornikkut sunnernerlukkuminarnerusinnaaneranut pissutaavoq tamaani oliap assigiinngitsorpassuarnik eqi-

masunillu uumasoqarfiit, assersuutigalugu ammassanik nipisannillu imaluunnit timmiarpassuallit eqqorsinnaammagit. Olia iterlanni kangerlunnilu unissinnaqavoq ilagigaalu toqunarluinnartut immap tamaaniittup ikianut tamakkiisumik akuliukkiartuaarssinnaallutik. Aarleqqutigineqarsinnaavortaaq oliap immap naqqani sananeqaatinut, sissami tuapannut uiloqarfinnullu nippussinnaalluni arriitsumillu avatangiisinut qanitaminiittunut akuliussinnaalluni sivisuumik, assersuutigalugu timmissanut sinerissamik atuisunut, ajoqutaalerluni. Sinerissallumi qanittua aamma tamaani najugalinnit piniarnermut aalisarnermullu atorneqarpoq.

Oliamik mingutitsineq imaannarmiikkaangat kimikilliartortarnerata immallu qaavatigut siaruarnerata avatangiisinut kingunipilugisinnaasai annikillisinneqartarput. Disko West-imi tamatumalu qanittuani sinerissamiit avasikkaluaqisumi taamaattoq oliamik mingutitsinikkut immikkut ajoruseruminartunik peqarmat sunniuteqarsinnaanera ilimagineqarsinnaavoq. Pingaartumik Store Hellefiskebankemi ikanneqarfiit (50 m inorlugit itissusillit) tassani pineqarput. Tamaaniipput nunarpassuarnut pingaarutillit mitit qingallit, qilalukkat qaqortat aarrillu ukiiffigisartagaat. Eqqoruminartut allat tassa frontzone-t, ”up-welling”-eqarfiit (sarfap pikialaarfii) sikut tissukartut sinaavanniipput (”marginal ice zone”) uumassusilinnik tunngaviusunik upernaakkut immap qaavani pinngorarferujussuit algenik tappiorarnartunik uumasunillu tappiorarnartunik (aamma kinguppaat aalisakkallu piaraannik tukerlaanik) annertuumik pinngorarfiusut tamaaniipput. Inerniliisoqarporli oliaarluernerup kinguppannik qaleralinnillu, kalaallit aalisarnerannut pingaaruteqarluartunik, ajoqusiinissaa ilimanarpallaanngitsoq.

Timmissat immap qaavani oiliaarluernikkut ajoquserneqarnissaat aarleqqutissaanerusarpoq, Disko West-imilu appat siggukitsut Appani erniorfeqartut qilanngallu Qeqertarsuup tunuata paani qeqertani erniortut ajoqusigaanissaat assut aarlerinarluni. Aamma Qeqertarsuup avalernani mitinut qingalippassuarnut isasartunut taamaappoq.

Miluumasut imarmiut immap qaavani oliamik mingutitsinermit eqqornerlunneqanngitsinnerusarput. Disko West-illi iluani tamakkua ilaqarput inuit ingerlataannit allanit – pingaartumik piniarnermit – sunnersimaneqareernermikkut eqqornerlunneqarsinnaasunik. Tamakkua tassaapput qilalukkat qaqortat, qernertat aarrillu tamaani ikiliartoreersut. Aarrit ussuillu imap natermiunik nerisaqqartuupput taamaattumillu nerisaminnut ilanngullugu oliamik iijoraasinnaallutik. Nannut eqqornerlukkuminartorujussuupput oliaarluernerminnik aluttuisaramik taamalu oliakku iijorakkamikkut toqunartortaqalersinnaasarlutik. Arfiviit tamaaniittut uumasoqatigiinnut 1900-ikkut ingerlanranni nungutaangajalluinnarsimagaluarlutik aatsaat siumut saannialersuupput. Arferit tamakkua ikittuinnaapput aammalu toqorarnerulernerup annikikkaluartup arfeqatigiit naqqikkiartulernerat sunnernerlussinnaavaa.

Immami sikulimmi oliaarluerneq qularnanngitsumik imarnersani sikutallu ataanni katersuutissaaq taamaalillunilu timmissanut miluumasunullu imarmiunut imarnersanik eqalugaasallu piaraannik sikup aterpiannguaniittartunik pisariaqartitsisunut sunniuteqassalluni.

Aalisarneq piniarnerlu oliarasattut taamaattunillu ingerlatsiviusut matuneqarnerisigut sunnersimaneqalersinnaapput. Taamaaliortoqassaaq

aalisakkat oliarasattumiinnikut taamaattumiissimasinnaasulluunniit pisaralugillu avammut nittarsaanneqanngínnissaat siunertaralugu. Oliaarluernikkut aalisarnerup qaammaterpassuarni mattunneqartarneranut assersuutissaqarpoq. Aarleqqutigineqarsinnaavortaaq oliaarluernerup kinguneranik piniagassat ajornarnerulernerat aammalu puisit amiisa oliakoqalersimarnertik pissutigalugu tunineqarsinnaajunnaarnerat.

Misissueqqinnerit allat

Disko West-imi oliasiornissamut tunngatillugu avatangiisinik nalilersuilluni sulineq aallartimmat ilisimasanik pingaarutilinnik nalilersuinermut atorsinnaasunik amigateqarneq erseqqissivoq. Misissuinerit amerlanerusut aallartinneqarput tamatumanilu paasisat pissarsiarineqarsinnaariaraangata nalilersuinermut ilaatinneqartarlutik. Misissuinerilli arlallit suli naammassinngitsut angusaqarfiujumaarput ilaatinneqartariaqartunik. Kiisalu misissuinerit amerlanerusut aallartinneqartariaqarput ingerlatassat erseqqissut aallartinneqassariarpata avatangiisinullu tunngatillugu nalilersuiffigineqassappata.

Misissuinerni ingerlasuni angusat misissuieqqissaarfigineqareerpata avatangiisinut nalilersuinerup uuma ilassutissaa saqqummersinneqarumaarpoq.

Disko West-ip avannaani Baffin Bugtip avannarpasinnerusortaata oliamik ujarlerfigissaa ammaanneqassasoq ilimagineqarpoq, tassungalu atatillugu misissuinerit nutaat aallartinneqassapput ilisimasanik nutaanik tamaani ingerlatat avatangiisinut tunngatillugit nalilersuiffiginissannut atugassanik.

Tunuliaqutaasunik tamakkuninnga misissuinermit inernerit ilisimasallu pigineqareersut databasemut annertuumut katersorneqassapput ingerlatseqatigiinnit elektroniskimik iserfineqarsinnaanngorlugit taakkua kingusinnerusukkut ingerlatanut assigiinngitsunut tunngatillugu avatangiisinik nalilersuisinnaaqqullugit.

1 Introduction

In 2006 the waters off West Greenland between 67° and 71° N (= the Disko West Area) were opened for hydrocarbon exploration and licences are expected to be granted in March 2007. The area includes the north-eastern part of the Davis Strait and the southeastern part of Baffin Bay, with Disko Island as the most prominent landscape on the Greenland coast.

This document comprises a strategic environmental impact assessment (SEIA) of expected activities in the Disko West area. It is developed as a co-operation between the Bureau of Minerals and Petroleum (BMP), the National Environmental Research Institute (NERI) and the Greenland Institute of Natural Resources (GINR). In support of the SEIA a number of background studies have been initiated.

We have in the assessment used many sources of knowledge, including impact assessments of oil activities from more or less similar areas. Especially the recent assessment from the Lofoten-Barents Sea area in Norway (Anonymous 2003) has been drawn upon for comparison of potential impacts, because the environment there is in many respects comparable to West Greenland waters.

Several studies were initiated to supplement the background knowledge and fill data gaps relevant to this assessment. Some of these are still in progress and only preliminary results have been available for this assessment.

This assessment was prepared by Anders Mosbech, David Boertmann and Martin Jespersen (all NERI).

It is important to stress that a SEIA does not replace the need for site-specific Environmental Impact Assessments (EIAs). The SEIA provides an overview of the environment in the licence area and adjacent areas which may potentially be impacted by the activities. It identifies major potential environmental effects associated with expected offshore oil and gas activities. The SEIA will also identify knowledge and data gaps, highlight issues of concern, and make recommendations for mitigation and planning. An SEIA forms part of the basis for relevant authorities' decisions, and may identify general restrictive or mitigative measures and monitoring requirements that must be dealt with by the companies applying for oil concessions.

Finally, an important issue in this context is climate change. This affects both the physical and the biological environment; for example, the ice cover of the Disko West Area is expected to be reduced, which again will impact wildlife dependent on ice, such as polar bears. Much of the data used for this SEIA has been sampled over a number of decades and as oil activities, particularly development and exploitation, may be initiated more than 10 years from now, the situation then may be very different from that when data was sampled.

1.1 Coverage by the SEIA

The offshore waters and coastal areas between 67° N to 72° N (from Sisimiut town and northwards to southern Upernavik district) are in focus, as this is the region which potentially can be most affected by the activities, particularly from accidental oil spills (Figure 1) originating from the licence areas within the Disko West area. The area will be referred to as 'the assessment area'. However, the oil spill trajectory model developed by DMI indicates that oil may drift further, outside the boundaries of this area (Nielsen et al. 2006).

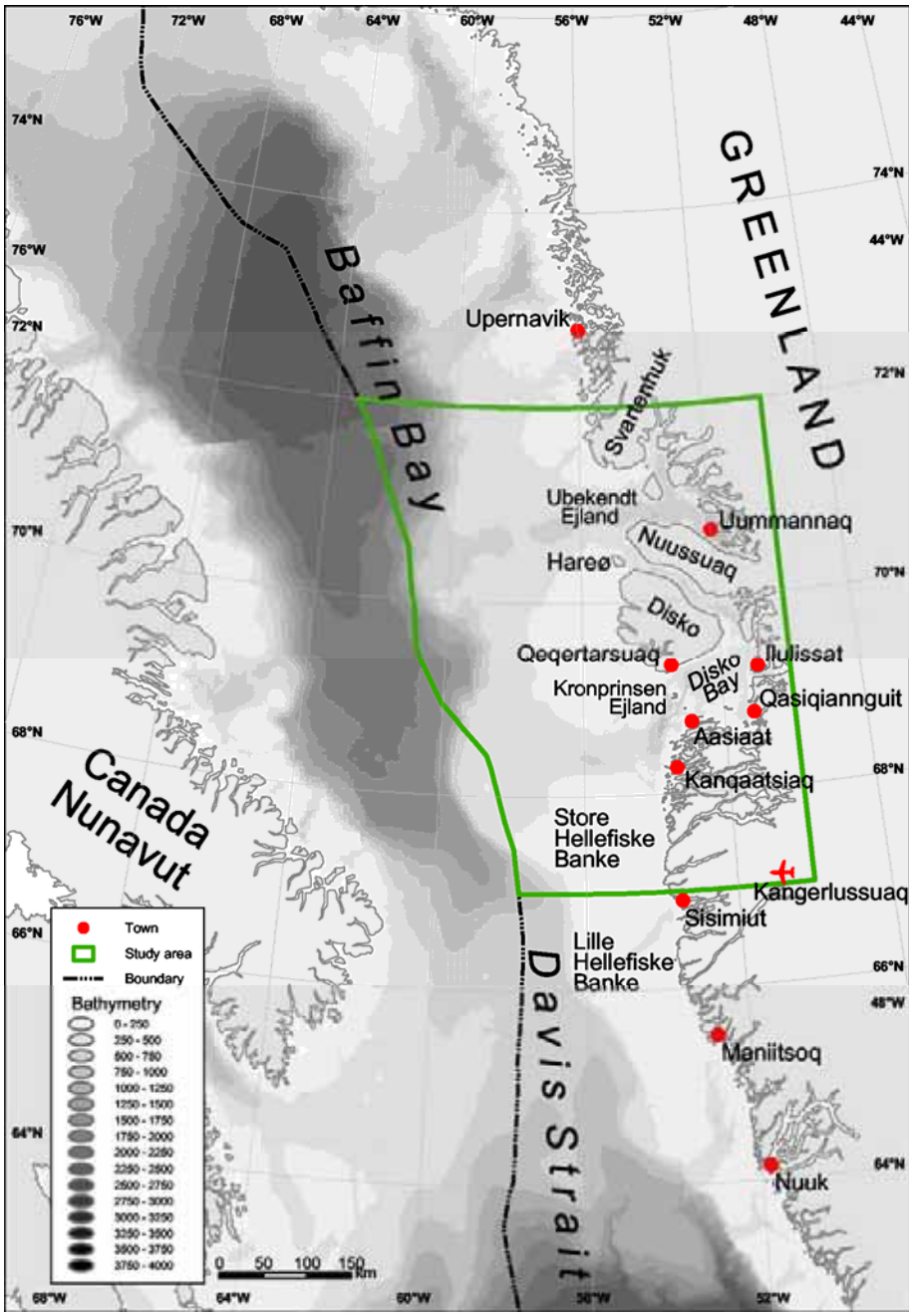


Figure 1. The assessment area and adjacent land areas and waters.

1.2 Abbreviations and acronyms

BAT = Best Available Technique
bbl = barrel of oil
BEP = Best Environmental Practice

BMP = Bureau of Mineral and Petroleum, Greenland Homerule Government
BTX = Benzene, Toluene and Xylene components in oil
DMI = Danish Meteorological Institute
EIA = Environmental Impact Assessment
FPSO = Floating Production, Storage and Offloading unit
GEUS = Geological Survey of Denmark and Greenland
GINR = Greenland Institute of Natural Resources
GBS = Gravity Based Structure
HSE = Health, Safety and Environment
ICES = International Council for the Exploration of the Sea
LRTAP = Convention on Long-Range Transboundary Air Pollution
MARPOL = International Convention for the Prevention of Pollution from Ships
NAO = North Atlantic Oscillation
NERI = National Environmental Research Institute, Denmark.
OSPAR = Oslo-Paris Convention for the protection of the marine environment of the Northeast Atlantic
PAH = Polycyclic Aromatic Hydrocarbons
PLONOR = OSPARs list over substances which Pose Little Or No Risk to the Environment
PNEC = Predicted No Effect Concentration
ppm = parts per million
ppb = parts per billion
SEIA = Strategic Environmental Impact Assessment
TPH = Total Petroleum Hydrocarbons
USCG = United States Coast Guard
VOC = Volatile Organic Compounds
WSF = Water Soluble Fraction.

2 Summary of petroleum activities

All activities of an oil/gas field include several phases which to some degree overlap. The phases include exploration, field development and production, and finally decommissioning. The main activities during exploration are seismic surveys, exploration drilling and well testing. During field development, drilling continues (production wells, injection wells, delineation wells), and production facilities, pipelines and shipment facilities etc. are constructed. Production requires maintenance of equipment and, during decommissioning, structures and facilities are abandoned or removed. These phases will occur over many years, usually several decades. For example, in the North Sea, oil exploration started in the 1960s and petroleum activities still continue today.

The purpose of seismic surveys is to locate and delimit oil/gas fields, to identify drill sites and later during production to monitor developments in the reservoir. Marine seismic surveys are usually carried out by a ship towing a sound source and a cable with hydrophones which receive the echoed sound waves from the seabed. The sound source is an array of airguns that generates a powerful pulse at 10-second intervals. Sound absorption generally is much lower in water than in air, causing the strong noise created by seismic surveys to travel very long distances, and the potential for disturbance of marine animals is high. Regional seismic surveys are characterised by widely spaced (many kilometres) survey lines, while the more localised surveys (2D and 3D seismics) usually cover small areas with densely spaced lines. Vertical seismic profiles (VSPs) are essentially small-scale seismic surveys carried out during exploration drilling. They are highly localised and of short duration (a few days), and their effects will be covered by the discussion of seismic surveys in general.

Exploration drilling will follow the seismic surveys. Offshore drilling takes place from drill ships or semi-submersible platforms and, to date, both types have been used in Greenland waters. Jack-up rigs, on the other hand, stand on the seabed, and most of the potential oil exploration areas in West Greenland waters are too deep for this kind of rig. It is assumed that the drilling season in the waters west of Disko Island is limited to summer and autumn by the presence of ice and harsh weather conditions during winter and spring. Drilling requires the disposal of cuttings and drill mud. In the strategic EIA of the Lofoten-Barents Sea area it is assumed that approx. 450 m^3 cuttings are produced and approx. 2,000 m^3 mud is used per well (Akvaplan-niva & Acona 2003). Energy consumption is very high during drilling, resulting in emissions of combustion gases such as CO_2, SO_2 and NOx.

Many other activities take place during the exploration phase and may have environmental impacts; among these is helicopter transport.

Well testing takes place when a well has been drilled and the presence of hydrocarbons and the potential for production is to be evaluated. The testing activities normally imply the use and release to the sea of different chemicals, occasionally including radioactive compounds.

Field development also includes extensive drilling activities: delineation wells, injection wells, etc., and drilling will take place until the field is fully developed. An oil development feasibility study in the sea west of Disko (APA 2003) assessed the most likely scenario to be a subsea well and gathering system tied back to a production facility either in shallower water established on a gravity-based structure (GBS) or onshore. From the production facility crude oil subsequently has to be transported by shuttle tankers to a transshipment terminal, most likely in Canada.

Environmental concerns during the development will mainly be related to seismic surveys, to drilling, to the construction of the facilities on the seabed (wells and pipelines) and to discharges to sea and emissions to air.

Concerns during production relate to the large amounts of production water, which can contain oil residues and other chemicals, which have to be disposed of, and again to the large amounts of greenhouse and other combustion gasses from machinery and the flaring of excess gas.

Ship transport of produced oil will be an integrated part of the production phase. The APA (2003) assessment estimates that ships containing 1 million bbl will depart, within a 5-day cycle, from a highly productive field off Disko.

Decommissioning is initiated when production wells are terminated, and will generate large amounts of waste material which have to be disposed of or regenerated.

Serious and acute environmental concerns arise during accidents and off-normal operations. A large oil spill has the potential to impact the environment over an extensive area and for many years particularly in the coastal marine environment.

3 Physical environment

The assessment area lies within the Arctic climate zone, which means that the average July temperature does not exceed 10° C. The Arctic zone is divided into the low Arctic (average July temperature higher than 5° C) and the high Arctic (average July temperature below 5° C). The northern part of the assessment area is close to the high Arctic. The most significant feature in the physical marine environment is the presence of icebergs and sea ice throughout a large part of the year (Section 4.5) and inland permafrost is widespread. The assessment area is north of the Polar Circle; therefore, continuous daylight is present for a period in summer, and in winter there is a period of near continuous darkness.

The offshore parts of the assessment area are the northeastern Davis Strait and southeastern Baffin Bay. The shelf is the rather shallow waters (depths less than 200 m) near the coast. This shelf includes several large shoals or banks, which typically range between 20 and 200 m in depth (Figure 1). In the southern part of the assessment area the shelf is up to 120 km wide, while in the northern part it is narrower and less well defined towards the deep sea. The shelf is traversed by deep troughs, which separate the fishing banks. There is deep water down to 2,500 m to the west of the shelf.

3.1 Weather

The weather conditions in the area are influenced by the North American continent and the North Atlantic Ocean, but also the Greenland Inland Ice and the steep coasts of Greenland have a significant impact on the local weather. Many Atlantic depressions develop and pass near the southern tip of Greenland and cause frequently very strong winds off West Greenland. Also more local phenomena such as fog or polar lows are common features near the West Greenland shores. The probability of strong winds increases close to the Greenland coast and towards the Atlantic Ocean. Detailed descriptions can be found in the sensitivity map of the region prepared by NERI. Link to sensitivity map

3.2 Oceanography

3.2.1 Currents

Along West Greenland the West Greenland current flows with two principal components. Closest to the shore, water from the East Greenland Current (with cold polar water) moves northward. On its way, this water is diluted by run-off water from the various fjord systems. The other component is from the North Atlantic Current deriving from the Irminger Sea. This relatively warm and salty water can be traced all the way along West Greenland from Cape Farewell to Thule (Qaanaaq). See Figure 2. The East Greenland Current component loses its momentum on the way northward, and at the latitude of Fylla Bank (64^{o} N) it turns westward towards Canada where it joins the Labrador Current.

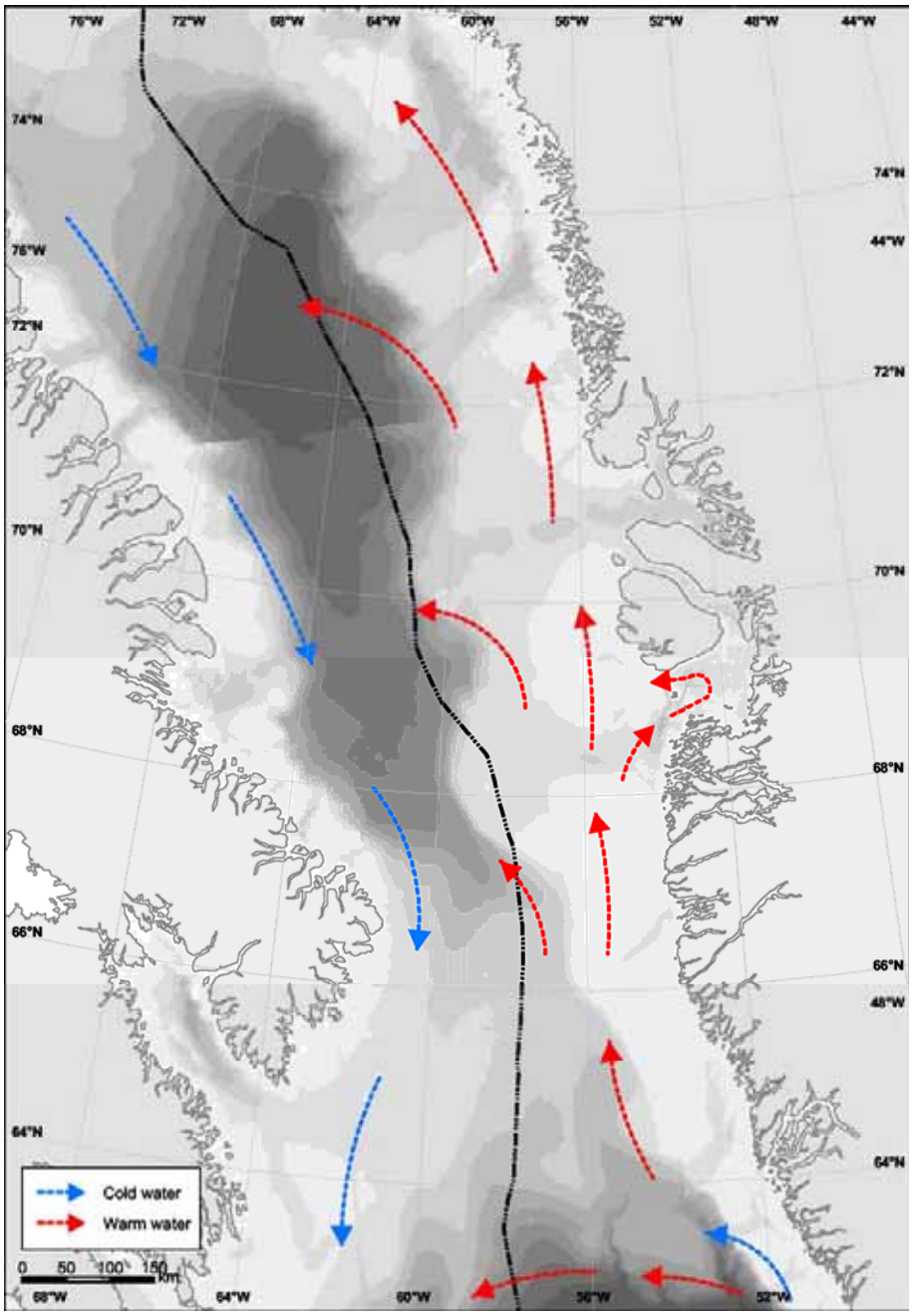


Figure 2. Overall current pattern in Davis Strait and Baffin Bay. Red indicates relatively warm water from the Atlantic, which mixes with relatively cold water (from the East Greenland Current) along the West Greenland coast to form the West Greenland Current. The cold water moving southwards in eastern Baffin Bay is the Baffin Current, which further south becomes to the Labrador Current.

The polar water inflow is strongest during spring and early summer (May-July). The inflow of Atlantic water masses is strongest during autumn and winter explaining why the waters between 62° and 67° N usually are ice free during winter time.

A fifty-year long time-series of temperature and salinity measurements from West Greenland oceanographic observation points reveals strong inter-annual variability in the oceanographic conditions off West Greenland. However, in recent years there has been a tendency towards increased water temperatures and reduced ice cover in winter (Hansen et al. 2006, Stirling & Parkinson 2006).

3.2.2 Hydrodynamic discontinuities

Hydrodynamic discontinuities are areas where different water masses meet with sharp boundaries and steep gradients between them. They can be upwelling events where cold nutrient water is forced upwards to the

upper layers, fronts between different water masses and ice edges inclusive the marginal ice zone. Upwelling occurs often along the steep sides of the fishing banks driven by the tidal current, with upwelling thereby usually alternating with downwelling. Hydrodynamic simulations performed as part of this assessment programme reveal a significant upwelling area around Hareø in the mouth of Vaigat and a prominent upwelling area at the northeast corner of Store Hellefiskebanke, where a deep wedge cuts southwards between the bank and the coast.(Figures 3 and 4). Further model simulations south of the assessment area predict that upwelling also occurs west of the banks and, to a lesser extent, in the deep channels separating the banks (Pedersen et al. 2005).

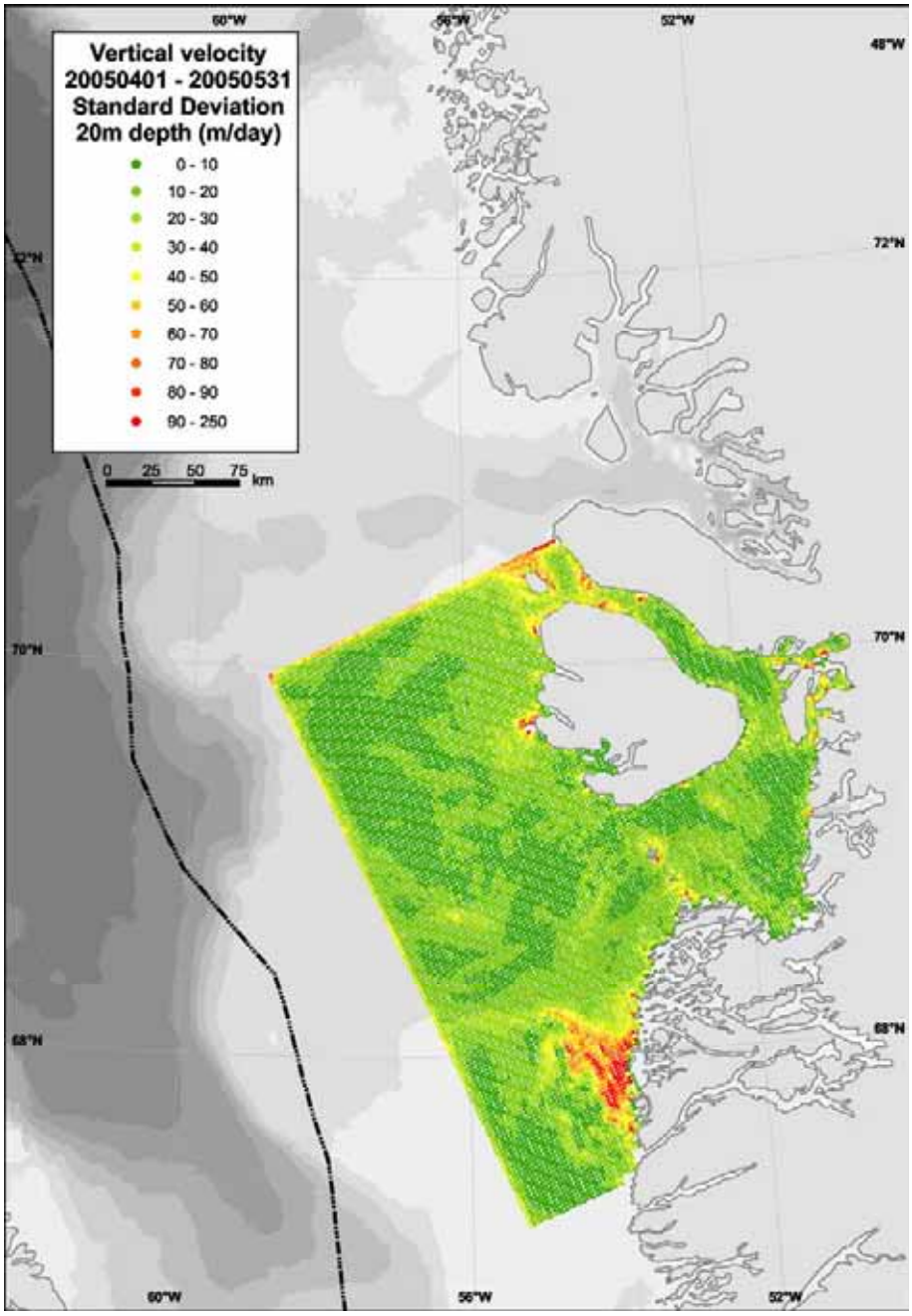


Figure 3. Areas with high rates of upwelling and downwelling as indicated by the standard deviation of the vertical speed. The standard deviation is calculated based on all the raw hourly data from the fine scale DMI-model (DIS) within the period from 20050401 to 20050531 (at 20 m depth), in total 1463 time steps of 1 hour (NERI/DMI).

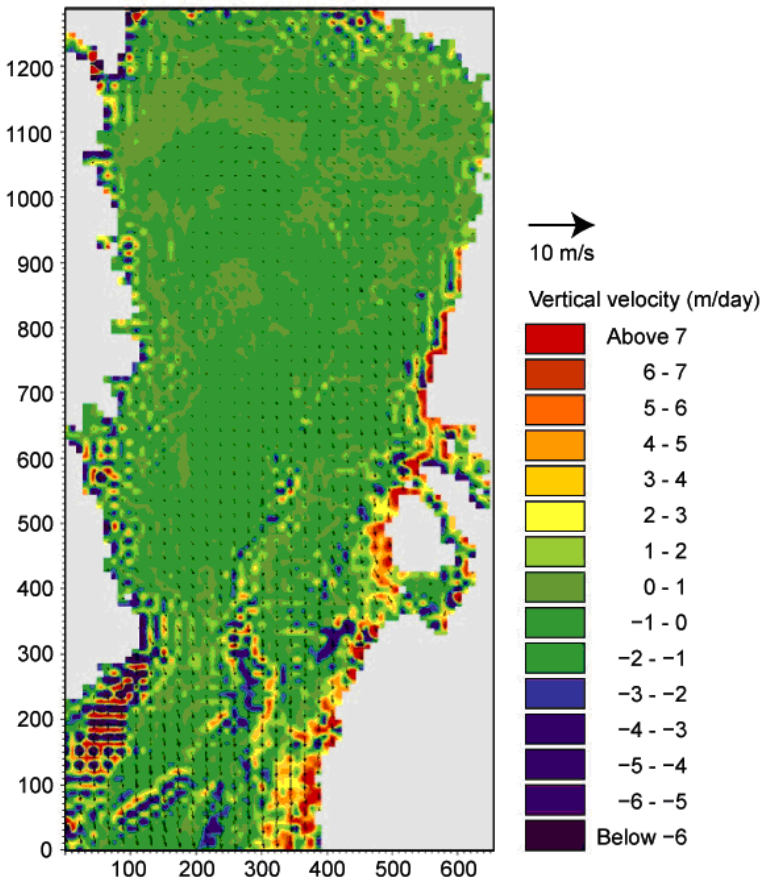


Figure 4. Model results, when using a Hybrid Coordinate Ocean Model (HYCOM), showing the daily mean value of vertical velocity at 20 m. depth, and wind speed in Baffin Bay. The present figure show daily mean value on the 24th of April, 2005, but it shows a frequent model feature during spring. The colour scale shows the daily mean value of upwelling velocity (m day-1), and the arrows show wind speed. Large vertical velocity suggests up/down-welling or large mixing at 20 m. depth. For this specific date there is strong upwelling along the Greenland west coast, especially near the Store Hellefiskebanke, which has an approximate coordinate on the map at (300,300). Large vertical velocities as presented here is a very common model feature during late winter and spring 2005. The present model set up is described in detail in Ribergaard et al. (2006).

3.3 The coasts

South of Disko Bay the coasts are dominated by bedrock shorelines with many skerries and archipelagos. Small bays with sand or gravel are found between the rocks in sheltered areas. In western Disko Bay and further north, the coasts are straighter and often made up from sediments like sand or gravel. On Disko Island and Svartenhuk Peninsula there are several large river deltas with extensive tidal flats.

In terms of shoreline length, the 'rocky coast' is by far the dominant shore type (61%). 'Rock' is the dominant substrate (71%); 'inclined' is the dominant slope (58%) and 'semi-protected' is the dominant exposure type (60%). The majority of the coasts within the 'archipelago' shore type are rocky coasts. Together the 'archipelago' and 'rocky coast' shore types constitute 72% by length of the total investigated shoreline within the assessment area (Mosbech et al. 2004).

3.4 Ice conditions

Two types of sea ice occur in the assessment area: fast ice, which is stable and anchored to the coast, and drift ice, which is very dynamic and consists of floes in varying size and degree of density. The drift ice is often referred to as 'The West Ice' because it is formed to the west of Greenland. In addition to sea ice, icebergs originating from calving glaciers are very frequent. The description of ice conditions given here is based on a DMI contribution to the Oil Spill Sensitivity Atlas covering the assessment area (Mosbech et al. 2004). As part of the preparations for

oil activities in the assessment area, BMP has initiated a number of new studies of sea ice distribution, and thickness and movements of ice floes; so the information on ice condition presented in this section will soon be updated and will be available on the information CD prepared by GEUS and NERI.

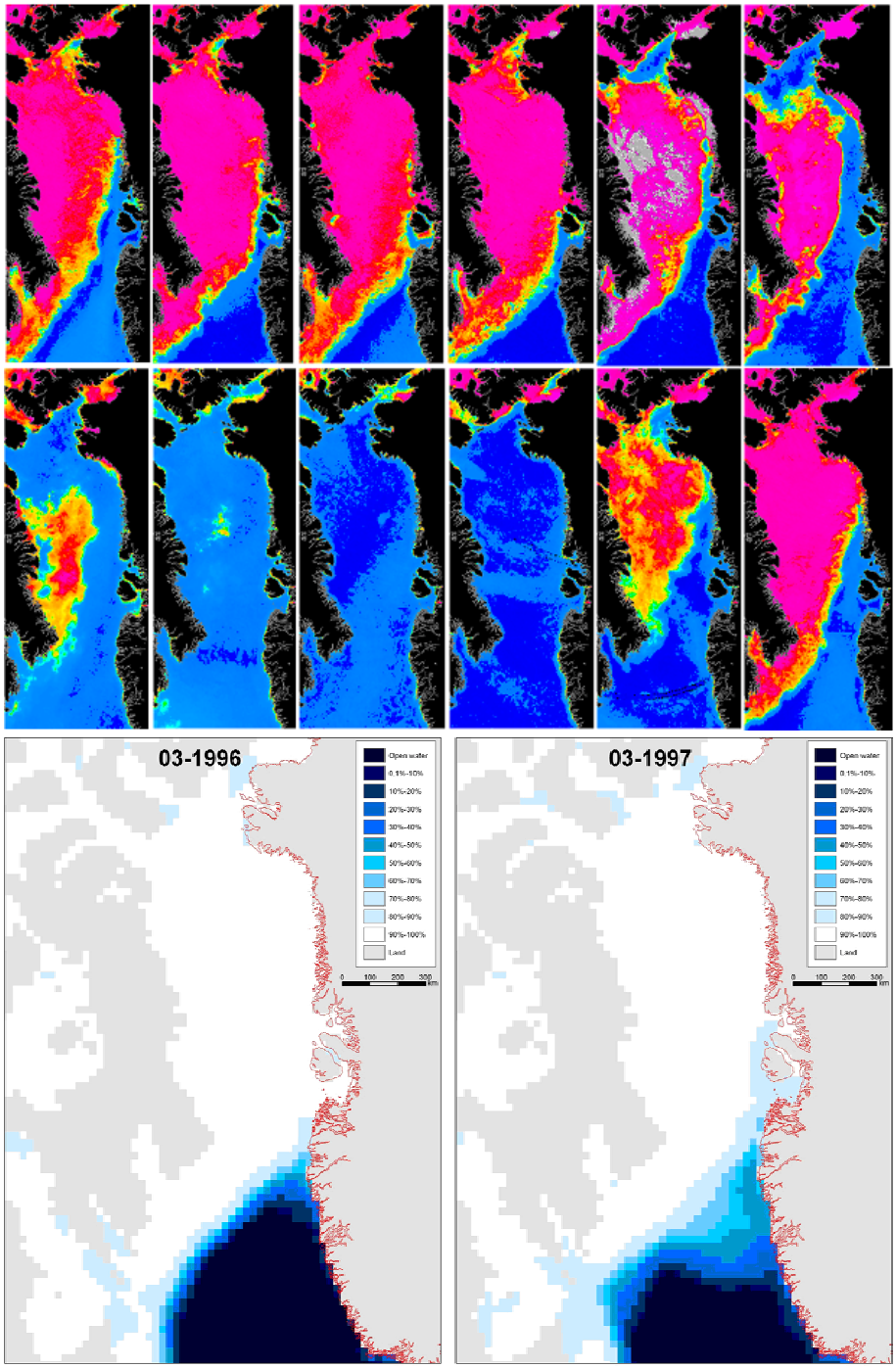
The West Ice

The ice conditions between 60° N and 72° N are primarily determined by the relatively warm north or northwest flowing West Greenland Current and the cold south flowing Baffin Current. The West Greenland Current delays the time of ice formation in the eastern Davis Strait and results in an earlier break up than in the western parts. The Baffin Island Current conveys large amounts of sea ice from Baffin Bay to the Davis Strait and the Labrador Sea for most of the year, especially during the winter and early spring months. During this period sea ice normally covers most of the Davis Strait north of 65° N, except areas close to the Greenland coast, where a flaw lead (open water or thin ice) of varying width often appears between the shore or the fast ice and the drift ice offshore as far north as latitude 67° N. South of 65-67° N, sea ice-free areas dominate throughout the year. The marginal ice zone of the drift is normally oriented to the southwest towards Hudson Strait or the Labrador Coast. In the beginning of the melt season a wide lead- or polynya-like feature often forms west of Disko Island and in front of Disko Bay. The eastern part of the Davis Strait, south of Disko Island, is free of sea ice during this period (Figures 5 and 6) whereas drifting ice dominates to the west and north.

The predominant sea ice type in the Davis Strait and Baffin Bay is first-year ice. Small amounts of multi-year ice of Arctic Ocean origin drift to the western parts of the area from Lancaster Sound or Nares Strait; however, the multi-year ice from these waters does not usually reach the West Greenland shores. At the end of the freeze-up season, first-year ice in the thin and medium categories dominates in eastern parts (up to about 100 km from the Greenland coast). The western and central parts of the Davis Strait and southern Baffin Bay are dominated by medium and thick first-year ice categories, mixed locally with small amounts (1-3 tenths) of multi-year ice.

The dominant size of ice floes range from large floes of about 1 km wide to vast floes larger than 10 km. Near the marginal ice zone in the Davis Strait, the size of the common floes are reduced to less than 100 metres as a result of melting and break up by waves. These floes are often consolidated, forming extensive areas without any open water. In recent years both the extension of the winter ice and the ice cover period have been reduced (Stirling & Parkinson 2006).

Figure 5. Monthly sea ice cover in 2004 and maximum (March) extend of sea ice in 1996 and 1997. Based on Multichannel Microwave Radiometer (AMSR and SMMR) and Defence Meteorological Satellite Program (DMSP). There has been less ice cover in the recent decade.



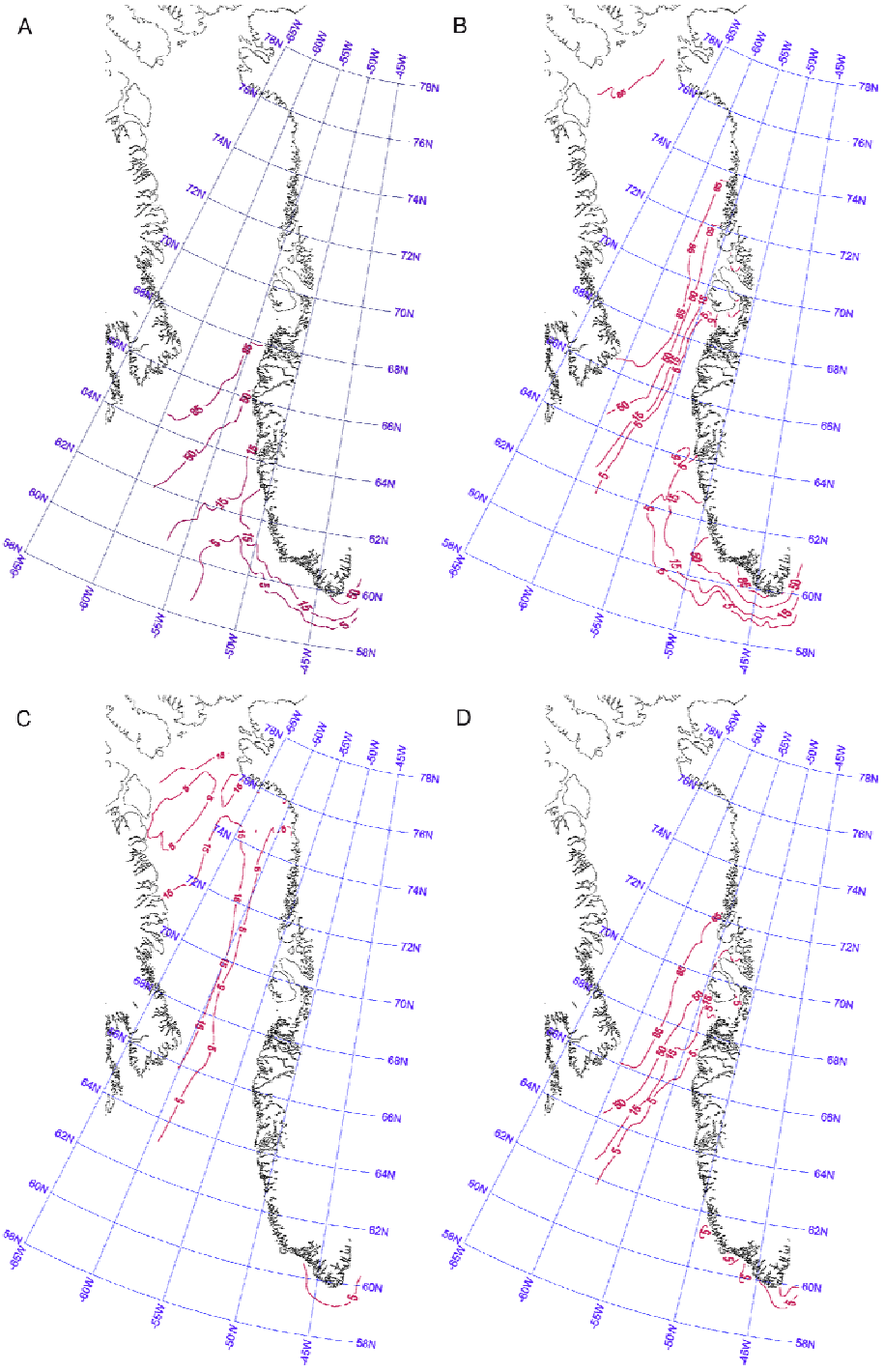


Figure 6. Probability of sea ice in West Greenland waters based on data from the period 1960-96. (A) March 1st, (B) June 4th, (C) September 3rd and (D) December 3rd (Data sources: Danish Meteorological Institute and Canadian Ice Service).

3.4.1 Sea ice drift

The drift pattern of the sea ice off West Greenland is not very well known. The local drift is to some extent controlled by the major surface current systems, the West Greenland Current and Baffin Island Current; however, the strength and direction of the surface winds also affect the local drift of sea ice, especially in the southern waters.

Isolated from the offshore ice conditions, sea ice forms locally throughout the winter in most of the fjords and coastal waters of the region. Generally freeze-up begins at the inner parts of the fjords in November or December, but very low temperatures can significantly affect the ice formation, or a formed ice cover can be reduced by very strong winds in the fjords throughout the winter.

In recent years ice has not formed, or only reduced amounts and for limited time periods, in Disko Bay and in Uummannaq Fjord. Although large local differences are to be expected, the southern shorelines (Disko Bay) are generally free of sea ice from late May until November or December. Towards the north (Uummannaq Fjord) the ice-free periods generally persist from mid-June until November.

In April 2006 two satellite transmitters were deployed on the sea ice, west of Nuussuaq Peninsula. Their purpose was to track the movements of the drift ice. One was tracked until June, when it had moved approx. 500 km in total (entire length of track line), but overall it had only moved 66 km towards the southwest. The second transmitter was only tracked for a couple of days, when it moved 21 km towards the south (Figure 7).

3.4.2 Polynyas

Polynyas are open waters in otherwise ice-covered waters. They are predictable in time, and are of a high ecological significance.

The entire open water area along the southwest Greenland coast acts as a large polynya despite that is open to the south, but further north along the coast there are several areas where open water is always present, or at least in spring. During a typical spring these are progressively included in the open waters advancing from the south. The most significant polynyas are found in fjord mouths where the tidal currents keep the water free of ice, as for example in the mouth of Vaigat. Also the open waters in the Disko Bay mouth may be a polynya, although they are often connected to the open waters further south.

3.4.3 Icebergs

Icebergs differ from sea ice in many ways:

- they originate from land
- they produce fresh water on melting
- they are deep-drafted and with appreciable heights above sea level
- they are always considered as an intense local hazard to navigation and offshore activity

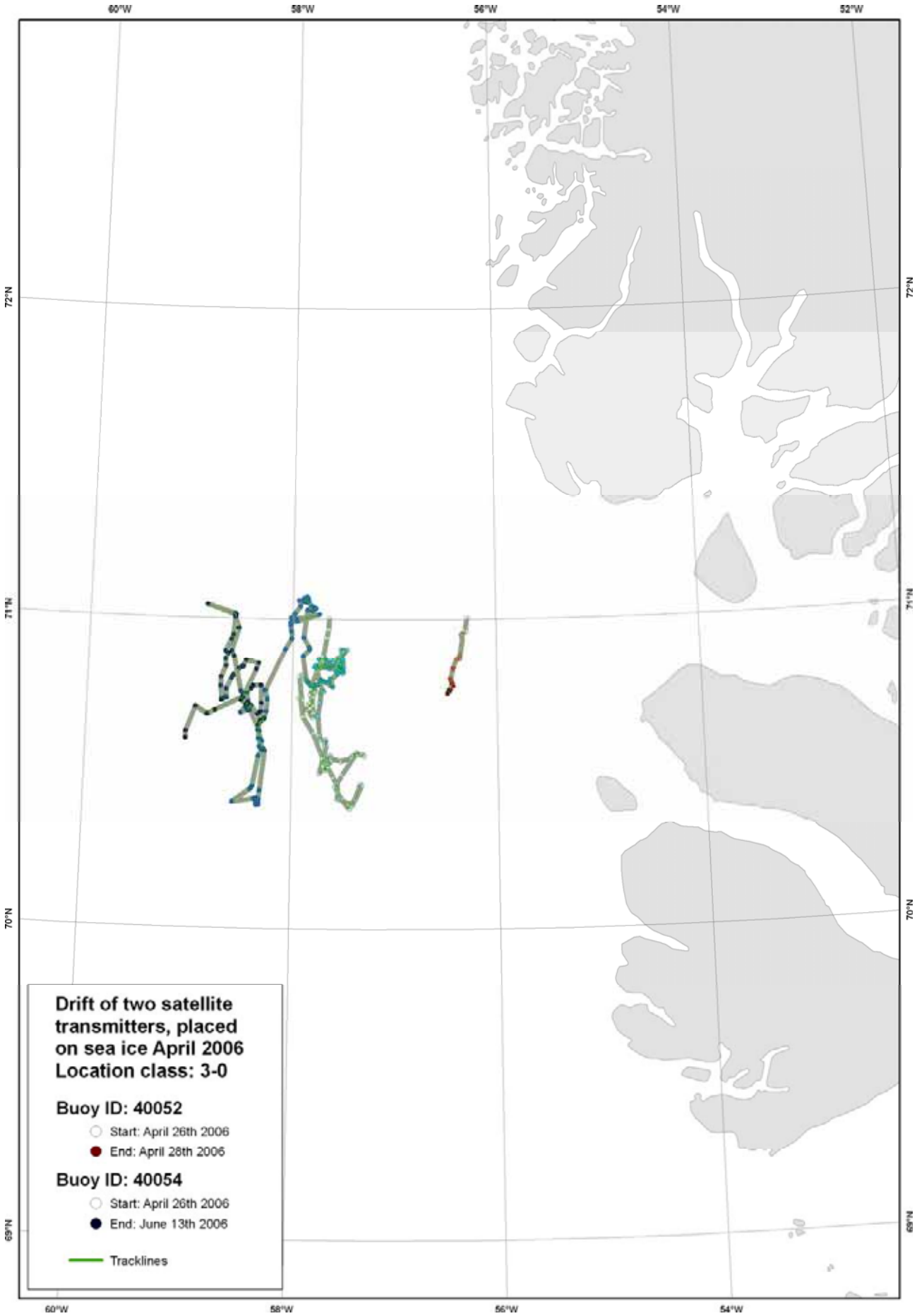


Figure 7. Drift pattern of two satellite transmitters placed on sea ice on 27th April 2006. One (ID 40052) stopped transmitting after 2 days when it had moved 21 km southwards. The other transmitter ID 40054)) was tracked until June 13th. The drift track is app. 500 km, but over all it moved 66 km towards southwest (Study carried out at the request of BMP and GEUS).

The process of calving from the front of a glacier produces an infinite variety of icebergs, bergy bits and growlers. Icebergs are described by their size according to the following classification:

Type	Height (above sea level)	Length
growler	less than 1 m	up to 5
bergy bit	1 to 5 m	5 to 15 m
small iceberg	5 to 15 m	15 to 60 m
medium iceberg	16 to 45 m	61 to 120 m
large iceberg	46 to 75 m	121 to 200 m
very large iceberg	Over 75 m	Over 200 m

The production of icebergs on a volumetric basis varies only slightly from year to year. Once calving is accomplished, meteorological and oceanographic factors begin to affect the icebergs. Icebergs are carried by sea currents directed by the integrated average of the water motion over the whole draft of the iceberg. However, wind also plays an important role, either directly or indirectly.

Iceberg sources

Glaciers are numerous in West Greenland; however, the productive glaciers are concentrated between Nares Strait and Disko Bay. Although icebergs occur throughout the West Greenland waters between 60° N and 72° N, they are rare in some areas, e.g. off Sisimiut. In other areas, e.g. in Disko Bay, hundreds of icebergs are always present (Figure 8).

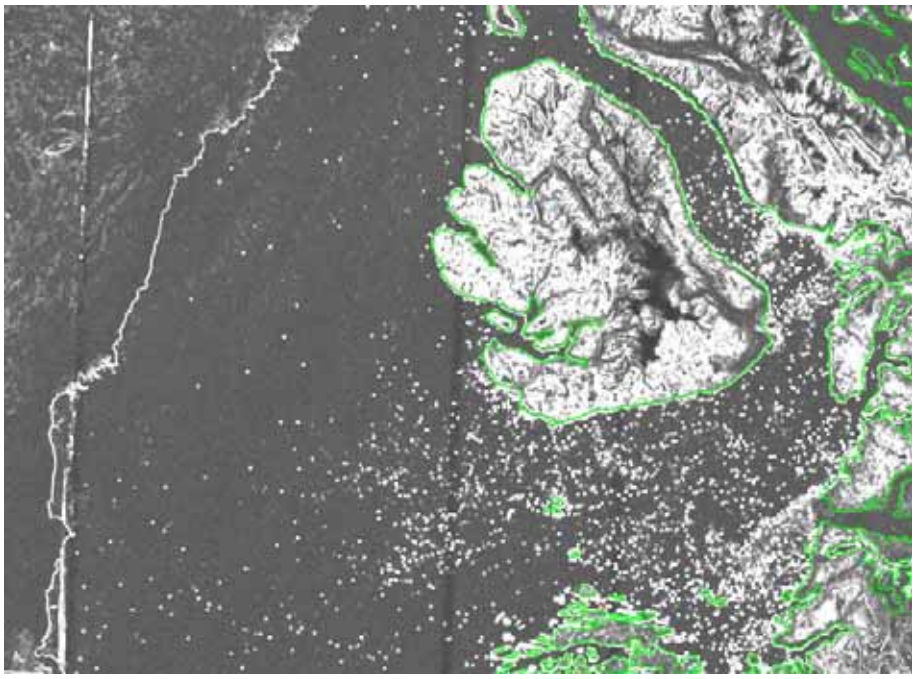


Figure 8. Radarsat PMR-filter image from June 14th 1999 20 UTC of the Disko Bay area showing the distribution of large icebergs (white dots).

Melville Bay north of Upernavik municipality is a major source of icebergs. Over 10,000 icebergs are calved from 19 major glaciers each year (Figure 9). Some of these are capable of producing icebergs of about 1 km in diameter. Several active glaciers in Uummannaq Fjord and Disko Bay produce 10-15,000 icebergs per year, and they are very important for the iceberg input to the northern Davis Strait and Baffin Bay. The most active glacier is located near Ilulissat, moving at the rate of 20 m/day. This glacier produces over 20 km^3 of ice per year. The total annual production of icebergs calved in the Baffin Bay and the northern Davis Strait is esti-

mated to be about 25-30,000; estimates however vary, up to as high as 40,000. Surveys conducted by the USCG International Ice Patrol decades ago indicate that the total number of icebergs in Baffin Bay and the northern Davis Strait are of the same order of magnitude. Almost no icebergs are produced south of Disko Bay. Here the fjords are longer, narrower and shallower than in the northern areas of the Greenland west coast, and the calving is in the form of growlers and bergy bits rather than icebergs. Growlers and bergy bits nearly always melt before reaching the open sea.

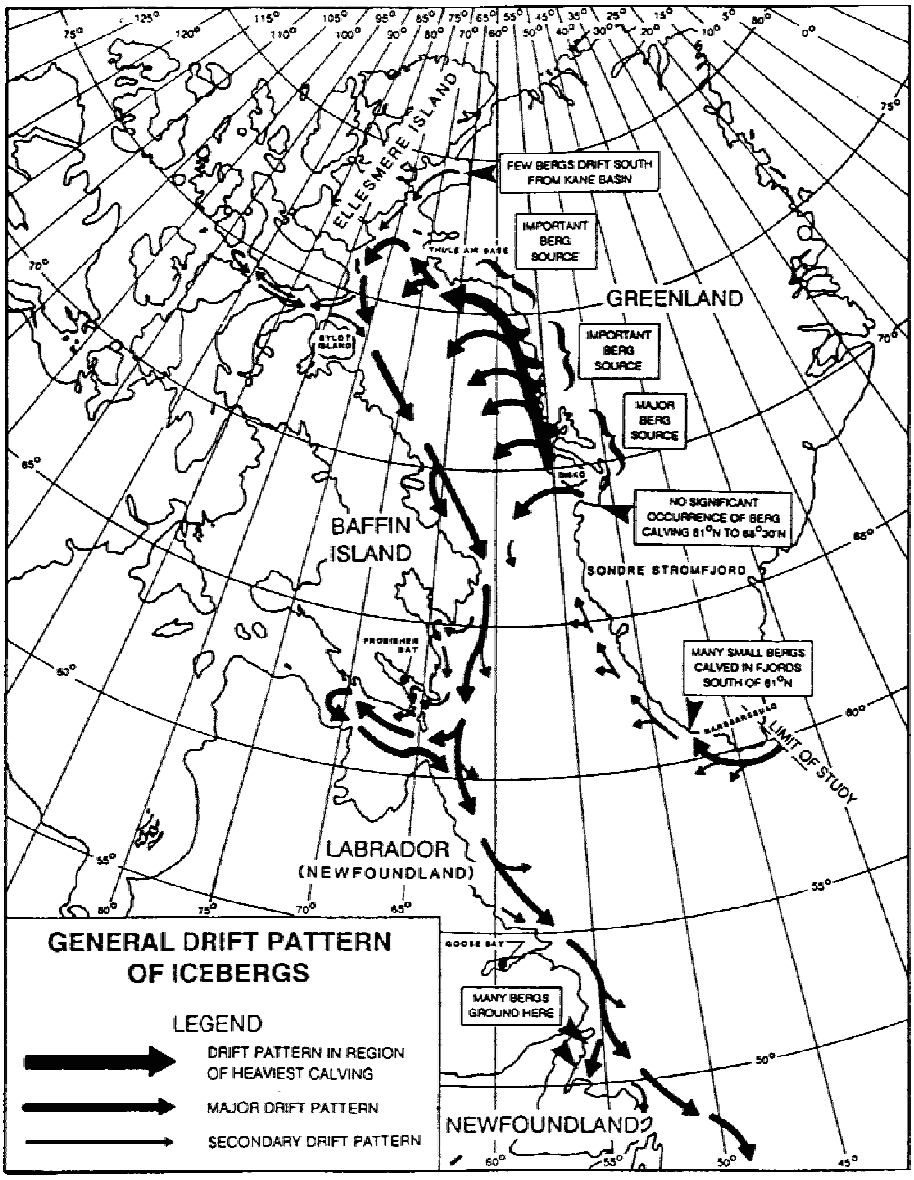


Figure 9. Major iceberg sources and general drift pattern in the West Greenland Waters. (US National Ice Center, Washington DC).

Iceberg drift and distribution

On a large scale the basic water currents and drift of icebergs in Baffin Bay and the northern Davis Strait are fairly simple. There is a north-flowing current along the Greenland coast and a south-flowing current along Baffin Island and the Labrador coast, giving an anti-clockwise drift pattern. However, branching of the general currents causes variations, and these can have a significant impact on the iceberg population and their residence time. Although the majority of icebergs from Disko Bay are carried northward to northeastern Baffin Bay and Melville Bay before

heading southward, icebergs have also been observed to be diverted into one of the west-branching eddies without passing north of 70° N. Most of the icebergs from Baffin Bay drift southward in the western Davis Strait, joining the Labrador Current further south, although some may enter the eastern Davis Strait area west of Disko Island instead. Icebergs produced in Disko Bay or Baffin Bay generally will never reach the Greenland shores south of 68° N. Many icebergs produced in the Disko Bay enter the Davis Strait, partly to the north of Disko Island through Vaigat and partly along the southern coast of Disko Island. Some icebergs manage to drift towards or into southern Disko Bay from the Davis Strait due to the onshore component of the currents west of Aasiaat. Icebergs south of Sisimiut are of East Greenland origin.

In a study in the late 1970s, the lowest iceberg densities in West Greenland were found at the northern part of Lille Hellefiskebanke and at the southern part of Store Hellefiskebanke between 65° and 66° N. Iceberg densities increased both towards north and south. The density of icebergs in Disko Bay was significantly higher than outside the bay, with maximum concentrations of icebergs occurring in the northeastern part of Disko Bay (Figure 8). The iceberg density generally was highest in early summer, except in the area near Disko Bay where the highest density was seen in late summer, probably due to higher calving activity of the glaciers during the summer months. A similar distribution can be derived from data from USCG International Ice Patrol and the Canadian Ice Service and can also be observed by shipping companies operating in the area.

Iceberg dimensions

The characteristics of iceberg masses and dimensions off the west coast of Greenland are poorly investigated, and the following is mainly based on a Danish study in the late 1970s.

In the eastern Davis Strait the largest icebergs were most frequently found south of 64° N and north of 66° N. South of 64° N, the average mass of an iceberg near the 200 m depth contour varied between 1.4 and 4.1 million tonnes, with a maximum mass of 8.0 million tonnes. Average draft was 60-80 m and maximum draft was 138 m. Between 64° N and 66° N, average masses were between 0.3 and 0.7 million tonnes. The maximum mass was 2.8 million tonnes. Average draft was 50-70 m and maximum draft is estimated to be 125 m.

The largest icebergs north of 66° N were found north and west of Store Hellefiskebanke. The average iceberg mass was about 2 million tonnes with a maximum mass of 15 million tonnes. In Disko Bay, the average mass of icebergs was in the range 5-11 million tonnes with a maximum recorded mass of 32 million tonnes. Average draft was 80-125 m and maximum draft was 187 m. It is worth noting that many icebergs are deeply drafted and, due to the bathymetry, large icebergs will not drift into shallow water regions.

Maximum draft can be evaluated by studying factors which limit the dimension: glacier thickness, topographic factors which cause icebergs to be calved in 'small' pieces, and thresholds in the mouths of the fjords with glaciers. The measurements of iceberg drafts north of 62° N indicate that an upper limit for a draft of 230 m will only be exceeded very rarely;

however, no systematic 'maximum draft measurements' exist and the extremes remain unknown. Several submarine cable crushes or breaks have occurred at water depths of about 150-200 metres; the maximum depth recorded was 208 metres, southwest of Cape Farewell. The large icebergs originating in Baffin Bay are expected to have a maximum draft of about 250-300 metres. The largest icebergs recorded in a study in Baffin Bay in 1997 were characterised by a draft of more than 260 metres, a mass of up to 90 million tonnes and a diameter of more than 1,400 metres. Icebergs from the productive Ilulissat glacier pass a sill which allows for a maximum draft of 250 m.