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ACCESS

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Instrument: Collaborative Project

Thematic Priority: Ocean.2010-1 "Quantification of climate change impacts on economic sectors in the Arctic"

D2.44 – Noise propagation from commercial fishing and vessel traffic in the Arctic today and in the future

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PU	Public	X
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

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Authors: Alexander Vedenev (SIO) Mike van der Schaar (UPC) Michel André (UPC)
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1. Introduction

This report is comprised of two parts. First, in Section 2 (SIO) an accurate computation is made of the received sound level at a location in the Shtokman gas-condensate field in the Barents Sea. This location is of particular interest due to the development of its gas fields in the near future. These developments will certainly greatly increase the sound levels in the area and knowledge of the current situation is needed to assess the expected increase in sound. The sound level at the selected location is simulated by placing 77 fishing vessels, currently the main anthropogenic sound source in the area, around it and computing the transmission loss taking into account environmental conditions and bathymetry.

Second, in Section 3 (UPC) an example is provided to estimate the monthly sound exposure level in the Barents Sea area for a one year period due to shipping. The source locations and tracks were taken from an AIS database; the source levels were based on the length of the vessels. The transmission loss was estimated with a simple propagation model to speed up the computations. A more accurate estimation could be made following the model used in Section 2 when enough computing resources are available.

It is considered vital to calibrate simulation results by obtaining sound recordings preferably near the shipping lanes or in the gas field.

2. An estimation of the noise budget in the Barents Sea for present-day density of fisheries

2.1 Objectives

The warming in the Arctic area will undoubtedly cause extension of commercial fishing regions and enlarge vessel traffic due to the reduction of the sea ice cover thickness and area. The negative impact from shipping noise on high latitude marine mammals will most likely increase for these reasons. To understand to what extent the components of noise budget may relate to industrial noise, we try to estimate the trend in changing of the averaged noise levels from fishing and vessels traffic in relation to background noise originated by wind.

To estimate the noise budget we chose the area centered on the site of a future location of the Shtokman Gas-Condensate Field in the Barents Sea making the results of Task 2.4.3 (WP2) useful to Task 4.5.3 (WP4) related to acoustic impact on marine mammals from industry activities in the Arctic.

2.2 Acoustic model

To perform calculations for task WP-2.4.3, first of all we chose an acoustic propagation model and developed appropriate computer code. Propagation models utilize bathymetric databases, geoacoustic information, oceanographic parameters, and boundary roughness models to produce estimates of the acoustic field at any point far from the source. There are five main categories of acoustic propagation models primarily used in underwater acoustics: ray models, normal mode, multipath expansion, wavenumber integration (or fast field), and parabolic equation (PE). Each of these methods represents a different approach to simplifying either the acoustic wave equation (the fundamental mathematical equation that contains all the basic physics of sound propagation) or the model of the environment, or both. We have tested a few different types of models and looked at the use of different methods in the context of actual Arctic environments. As a result of model comparison we found that the most precise and effective way to calculate the transfer functions in the Arctic marine environment should be based on the pseudo-differential parabolic equation (PDPE) referred to in the West as the split-step Pade technique (Collins, 1993). This report describes the calculation of the cumulative field based on numerous sound sources near the sea surface. The calculation is performed in a one-way approximation of the pseudo-differential parabolic equations taking into account the 3-dimensional heterogeneity of the environment in to N*2D approximation, i.e., without taking the side refraction into account (Aviloff, 1992).

The Shtokman gas field is estimated to be one of the world's largest natural gas deposits. It is located in the central part of the shelf zone in the Russian sector of the Barents Sea - Fig. 2.1.

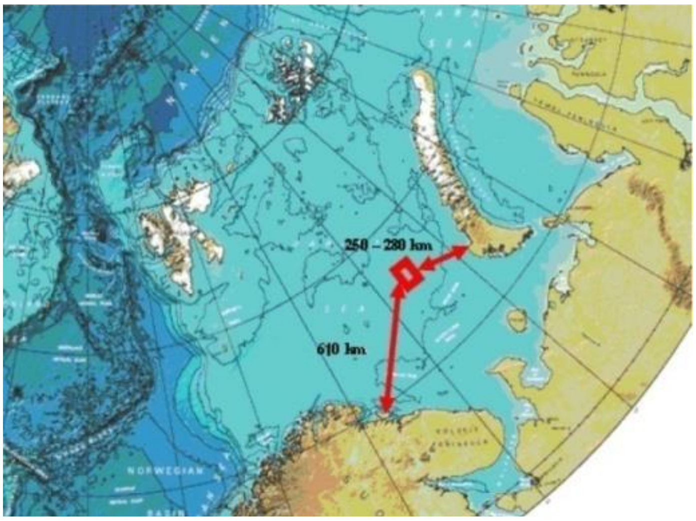

Figure 2.1. Shtokman Gas-Condensate Field in Barents Sea

The Shtokman field development program encompasses the entire cycle of field development, from research to processing and transportation. The construction plan is shown in Fig. 2.2. Recently it was announced that the start of construction of the Shtokman project will be postponed by several years for economical reasons, but the soundscape undoubtedly will change in the basin scale with the start of construction because the largest and noisiest vessels will be involved in the construction.

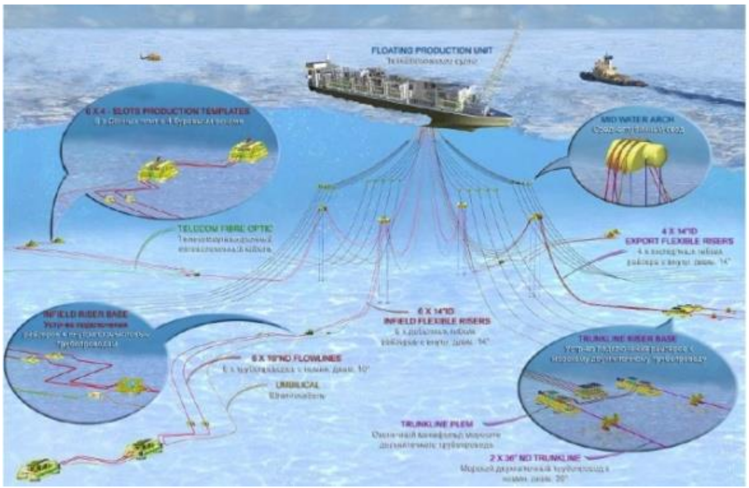

Figure 2.2. Shtokman gas and condensate field pre-development scheme

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2.3 Input data for acoustic model

The input data for needed for the calculations includes the bathymetry as well as the hydro- and geo-acoustic parameters in water and sea bottom, spectra of equivalent sources on sea surface and spectra of noise levels for fishing ships.

The bottom configuration in this areas of the Barents Sea was taken from the Etopo1 database (Amante and Eakins, 2009), the field of sound velocity in the water column is based on the data from the Atlas with 0.25- degree grid and salinity data (Monterey and Levitus, 1997) that has monthly climatic fields of temperature and salinity for the depth less than 1000 m, and annual climatic fields for bigger depths. The sound velocity in the water was calculated using the temperature and salinity data and the Chen-Millero formula (Chen and Millero, 1977). The example of the sound speed in Barents Sea water in May and September is shown on Fig. 2.3.

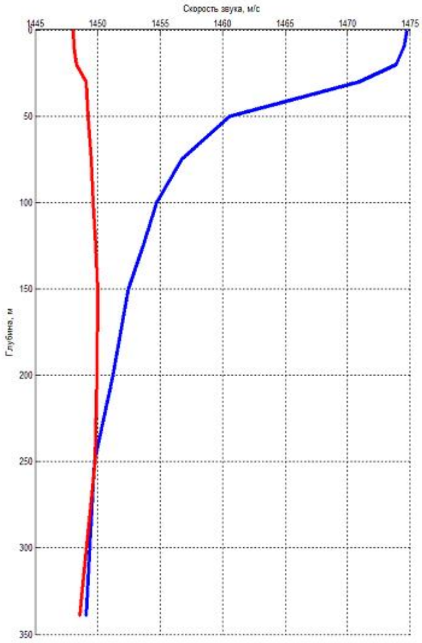

Figure 2.3. Sound speed in water column. Red curve - for May, blue - for September

The field of geoacoustic properties of the bottom (density and elasticity) in the Barents Sea is based on the generalized geologic data provided by a Shtockman development company in the open literature at the EIA process.

One example of the bottom configuration we prepared along the direction passing in close proximity to the Opasov inlet of the Barents Sea and the fields of the sound velocity in the water are shown in Fig.2.4. The vertical lines indicate the stations for hydrologic and geoacoustic data collection used to build the marine environment model. The calculation took into consideration the tracks sections before they reach shore. Given the 3-dimensional heterogeneity of the sound velocity fields and bottom configuration the data varies from track to track.

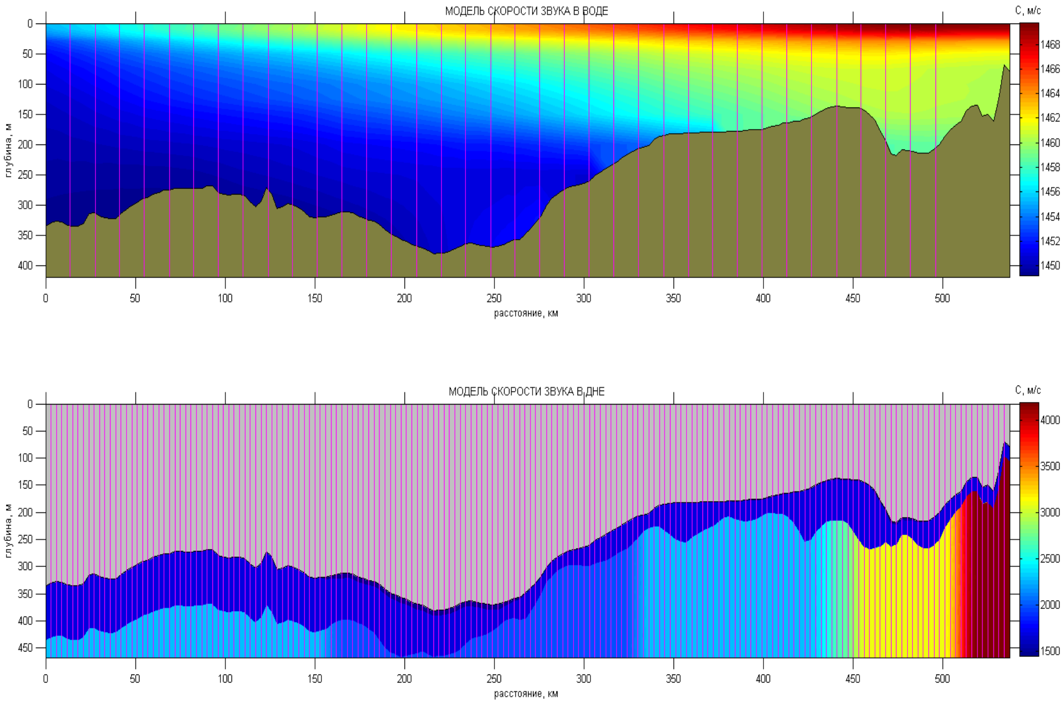

Figure 2.4. The example of the bottom configuration along the track passing in close proximity to Opasov inlet of the Barents Sea and fields of the sound velocity in the water and on the bottom along this track.

2.4 Calculation of underwater noise level originated by wind

For the calculation of dynamic noise on the sea surface we used data on the wind distribution in the waters of the Barents Sea and the adjacent seas. At this stage we used the model with input spectra of the equivalent distributed sources of dynamic noise of the excited sea surface (depending on wind velocity) around the site of the future location of the Shtokman Gas-Condensate Field in the Barents Sea. The background noise levels in May and September were estimated.

The receivers of sound usually register numerous noises in the marine environment: dynamic noises on the sea surface, noises from vessel movement, flow noises, carrier noises etc. All of the abovementioned sources are not intercorrelated because of their different physical nature. Therefore, complete matrices of mutual noise spectra are calculated by the aggregation of contributions from separate components. Dynamic noises on the sea surface may be viewed as generated by non-correlated sources distributed near the surface. The energy spectrum of these sources is described by a phenomenological model (usually in dependence with the established wind speed). The spectrum of dynamic surface noises at the receiver is calculated by the numeric aggregation of contributions from small surface areas. These contributions are the product of squared absolute value of transfer functions of the marine environment from the equivalent source to the elementary surface area to the receiver by the phenomenological spectrum of the noise source.

The energy spectrum of equivalent sound sources from the wind-induced waves taken from (D.J. Kewley et al., 1990) is shown in Fig. 2.5. The wind velocity field is assumed to be homogeneous for the water area with values of 10 m/s (approximately Beaufort 3-4) and 30 m/s. An example of the map with tracks for the calculation of noise on the surface is given in Fig. 2.6.

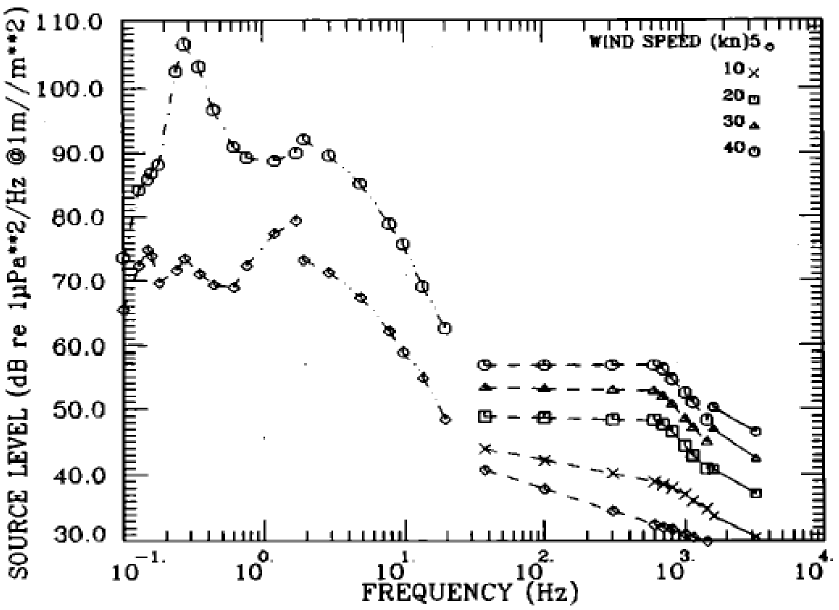

Figure 2.5. Levels of surface density of equivalent sources for the dynamic surface sound noise in dB.

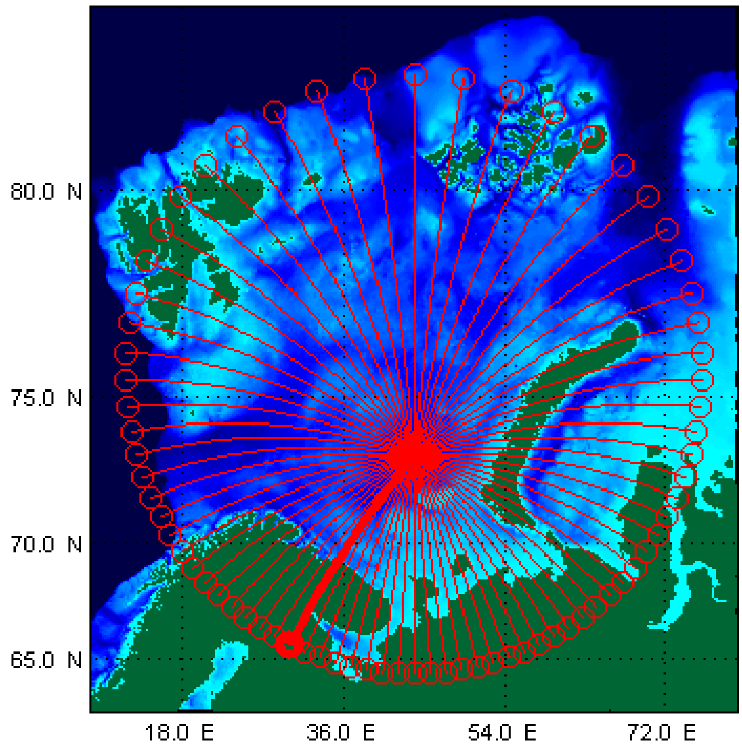

Figure 2.6. The map of tracks used for the calculation of surface noise. The Track passing in close proximity to Opasov inlet of the Barents Sea is indicated in bold.

As a result of calculations, the integral noise levels re 1 µPa was estimated for May as: 105 dB at wind speed 10 m/s, and 113 dB at wind speed 20 m/s; for September as 102 dB at wind speed 10 m/s and 110 dB at wind speed 20 m/s.

2.5 Calculation of ships noise level for present-day density of fisheries

We made a data search on the vessels distribution, the density of vessel movement and calculations of shipping noise on data from past years. The model was tested for multiple sources of noise - fishing vessels that were distributed in the Russian sector of the Barents Sea during the 1st of October, 2010. At this stage the modifications were done of the computer code to model the propagation using of PDPE to increase the speed of calculation of multipass transfer functions of the marine environment because a lot time (weeks) was needed for these kind of calculations.

The location of fishing vessels and the lines of sound propagation towards the place of the Stockman Developments Project for the calculation of their contribution into the noise field is given in Fig. 2.7. The total of number of 77 active fishing vessels during October 2010 was the largest number of vessels at sea during a month.

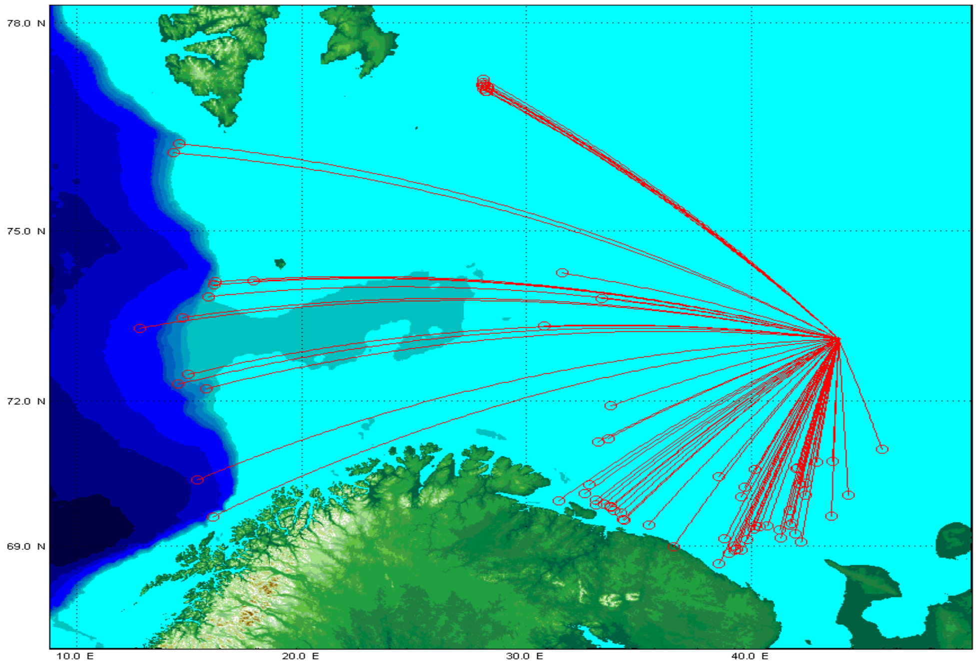

Figure 2.7. The location of fishing vessels (77) and related sound propagation lines used in our PDPE model.

We estimated today's industrial background noise levels for spring and autumn seasons at the site of the future location of the Shtokman project before the start of construction in the Barents Sea. It is assumed that in this situation the main contribution of manmade noise comes from fishing.

Spectra from typical trawlers that use different modes of operation during fishing in the Barents Sea were generalized. The noise spectrum for each vessel was taken from the guidelines on ship noise limitation (DET NORSKE VERITAS, 2010), and was based on the upper curve in Fig. 2.8. This curve corresponds to the most common mode of trawling and represents an upper estimate of the noise. Other types of vessel movement were considered unusual and negligible in terms of their contribution.

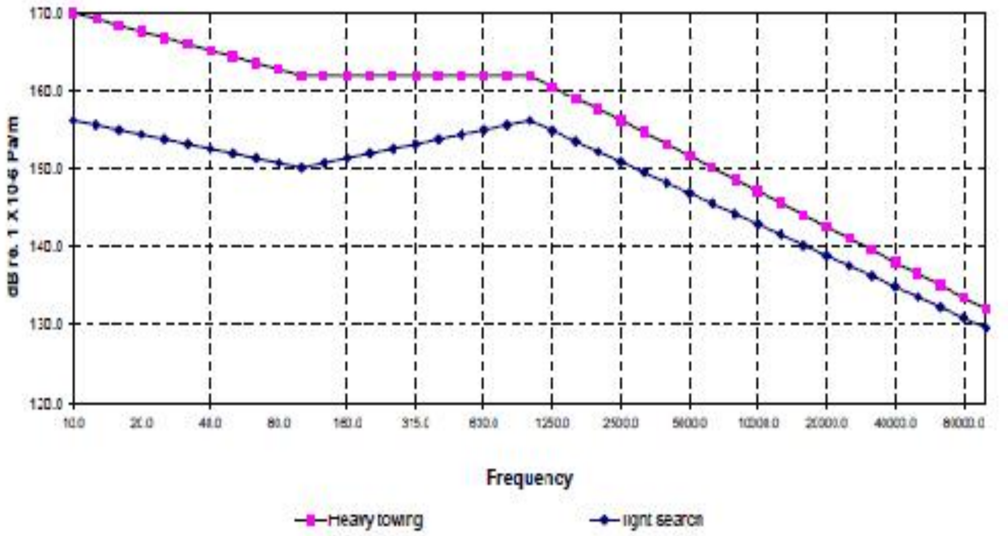

Figure 2.8. Noise level limitations for fishing vessels. The lower curve represents the transition mode. The upper curve represents the trawling mode.

As a result of calculations, the integral noise level in the area of the Shtokman field from fishing vessel movement was estimated to be about 92 dB re 1 µPa for May and 98 dB re 1 µPa for September.

2.6 Noise budget at Stockman location before construction

Estimations were made of the noise budget in the Barents Sea marine environment including 77 fishing ships realistically distributed around the Stockman Developments Project production complex in the Barents Sea and likewise, the sea surface noise was estimated at wind velocities 10m/s and 20 m/s for May and September.

Results of the calculation of the noise levels for May (depth = 100 m) are shown in Fig. 2.10. The total spectral noise density in the main frequency band around 70 dB; the noise from vessel movement is mostly low or comparable to the dynamic surface noise. A significantly dramatic increase in the estimated levels (>10 Hz) may be attributed to the optimization of geoacoustic bottom characteristics in the calculations to the frequency band of 100 Hz or higher. Fig. 2.11 shows results of the estimations for September. The difference with the previous figure is insignificant. However, the noise level is somewhat lower due to peculiarities of the near-bottom sound propagation.

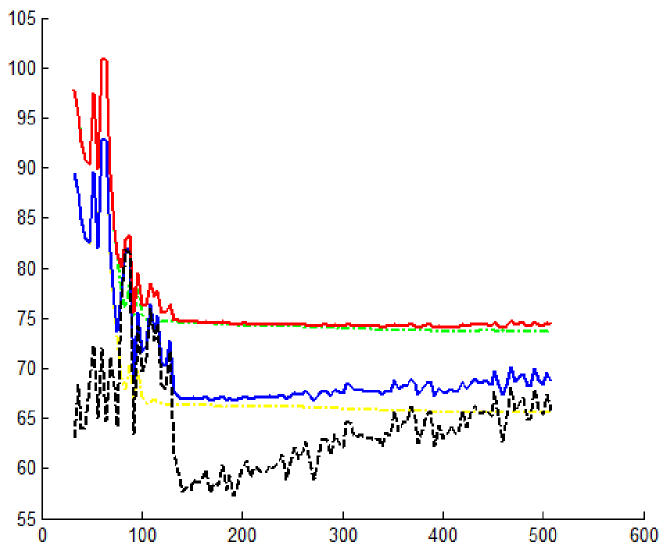

Figure 2.10. Noise budget for May, yellow represents the surface noise curve for 100 m depth at 10 m/s wind speed at the future location of the Shtocman complex; green identifies the same at 20 m/s wind speed. The y-coordinate represents the spectral noise density in dB per 1 µPa^2/Hz, the x-coordinate shows frequency in Hz. Black shows the noise from 77 vessels, the cumulative noise for 20 m/s wind speed is shown in red, the cumulative noise for 10 m/s wind speed is shown in blue. The integral noise levels re 1 µPa are: 105 dB at wind speed 10 m/s, 113 dB at 20 m/s, noise from vessel movement = 92 dB, cumulative noise level at 10 m/s = 105 dB, at 20 m/s = 113 dB.

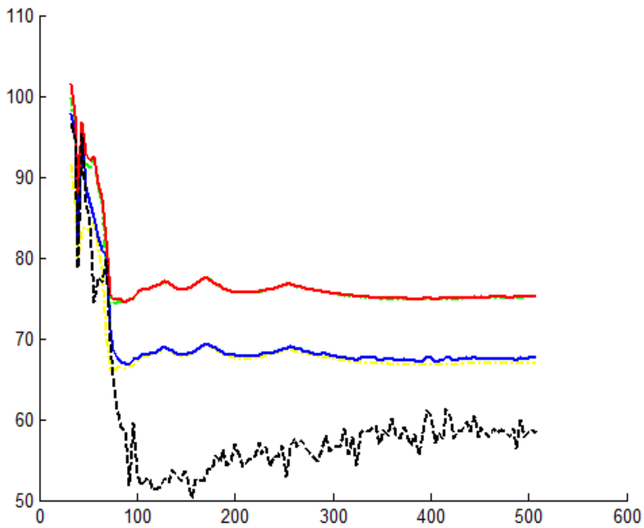

Figure 2.11. Noise budget for September, yellow represents the surface noise curve for 100 m depth at 10 m/s wind speed in the area of the future location of the Shtocman complex; green identifies the same at 20 m/s wind speed. The y-coordinate represents the spectral noise density in dB re 1 $\mu Pa^2/Hz$, the x-coordinate shows frequency in Hz. Black shows the noise from 77 vessels, the cumulative noise for 20 m/s wind speed is shown in red, the cumulative noise for 10 m/s wind speed is shown in blue. The integral levels re 1 µPa are equal: 102 dB at wind speed 10 m/sec, 110 dB at 20 m/s, noise from vessel movement is equal 98 dB, cumulative noise is equal 103 dB at 10 m/s, 110 dB at 20 m/s.

2.7 Conclusions

Based on the estimations given above, the following conclusion can be made: at the given densities of fishing vessel movements and their noise level, their contribution to the noise budget in the area of Stockman gas condensate field is noticeably lower than the contribution from the surface noise originated by wind at the typical 10 m/s wind speed (Beaufort 3-4) and, moreover, at 20 m/s wind speed. Today in the Barents Sea area, for frequencies in the band up to 500 Hz, the surface noise originated by wind and waves in general dominates over noise from fishery.

3. Cumulative Sound Exposure Level (63 Hz) from Shipping in the Barentsz Sea

3.1 Introduction

The previous section estimated the sound pressure levels (SPL) at a particular position taking into account shipping throughout the entire region and the weather conditions. Due to the shallow water and large distances to the sources the contribution of shipping to background noise levels was found to be small. Another source of environmental concern due to noise contributions in addition to SPL is the prolonged noise exposure to resident animals in the area. To this end the Sound Exposure Level (SEL) needs to be estimated which is done in this section. Based on the previous results it was not necessary to take into account shipping traffic at large distances. Instead of creating a map with SEL levels throughout the entire Barentsz Sea, the levels were estimated along the known shipping lanes, based on actual traffic that was recorded through AIS and source levels taken from literature. Propagation loss was estimated with a basic model.

To properly compute these types of noise contributions it is vital to have installed recording equipment as specified under the MSFD descriptor 11 (Dekeling et al, 2013). This would allow confirming both the source levels used for the ships and the propagation model. Unfortunately noise recordings were not available for this study. In order to obtain results comparable to those that would be presented for MSFD descriptor 11, the SEL was estimated from the third octave band centred on 63 Hz.

3.2 AIS Data

AIS data containing positional information from individual ships (April 2012 – March 2013) was downloaded from http://aisutland.aisonline.com/satAis/ using the 'Tails' interface. This function returns the tracks of the ship after processing with the "Douglas-Peucker" line simplification algorithm removing unnecessary points where a vessel was travelling along a straight line at constant speed. To obtain a track between these points new positions were inserted every two kilometres. If the distance between two AIS positions was less than 2 km or more than 500 km, the position was discarded.

3.3 Source Level Estimation

Source levels were estimated for the third-octave band centred on 63 Hz. For most ships the AIS data included its length which was linearly mapped to a SL estimate between 140 and 195 dB (Fig. 3.1). These levels are in accordance with the measurements made under SILENV and e.g. the five ship classes defined in "Research Ambient Noise Directionality (RANDI) 3.1 Physics Description" (Breeding et al., 1996). For a number of ships the length was not available, in those case a conservative source level of 120 dB re 1 μPa^2 at 1 m was used.

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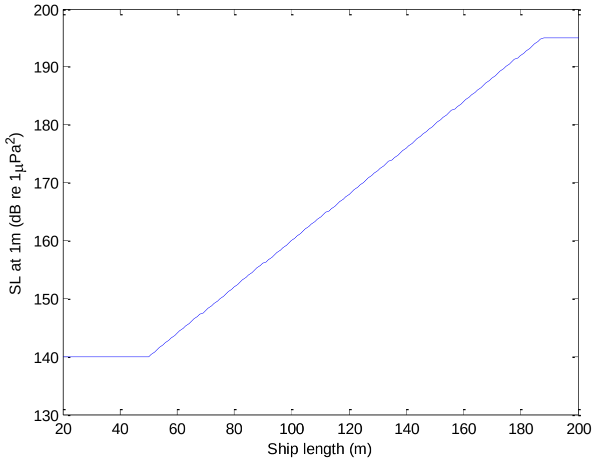

Figure 3.1. Estimation of ship source level based on its length provided by AIS data.

3.4 Propagation Loss

Figure 3.2. Overview (Google Earth) of the area where SEL was estimated.

The area under consideration (Fig. 3.2) contained shallow water zones with up to a few hundred meter depth and a deep canyon towards the east. As discussed in Section 2, the preferred propagation method is the PDPE model. But to propagate the sound from each ship position that was received by AIS during a 12 month period for such a large area would have taken an extraordinary amount of time. Therefore, the propagation was simplified by the use of a $\log r$ model. The sound speed profiles shown Section 2 indicate a fairly constant profile in spring, possibly including a surface duct leading to scattering loss from the ice layer at the surface (if present). In fall there is a diminishing sound speed with increasing depth; sound may be driven towards the seafloor, which for the Barentsz Sea can lead to exceptional losses (in an extreme case: 100 dB at 10 km for a frequency of 63 Hz according to Fig 1.16 in "Computation Ocean Acoustics", Jensen et al. (2000)). To account for possibly high propagation losses during all seasons a spherical propagation model ($20 \log r$) was used.

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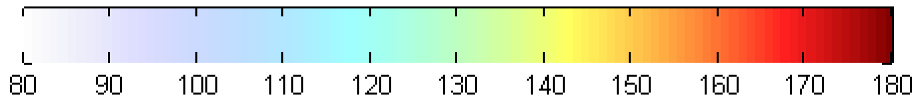
3.5 Sound Exposure Level

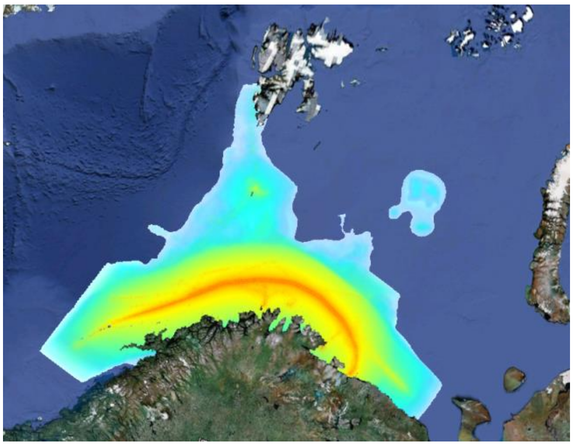
The area around a source was divided into a grid with 6.3 km spacing. The propagation loss at each grid point was computed over a distance up to 102 km away from the source. To estimate the sound exposure level in the cell where the source was present the sound level was evaluated at half the grid spacing (~3 km). The exposure time was based on the time difference between two consecutive positions in the AIS data divided by the number of points in the interpolated track between these two positions, reduced by 1: the ship was only considered to remain at the first and last position in the track half the time it spent at the other points.

To obtain the cumulative sound exposure level, the exposure levels from all ships during the month were summed. The resulting levels are shown for each month in Section 3.5.

3.6 Monthly Sound Exposure Levels 63 Hz due to shipping



SEL in dB re 1 µPa^{2}s



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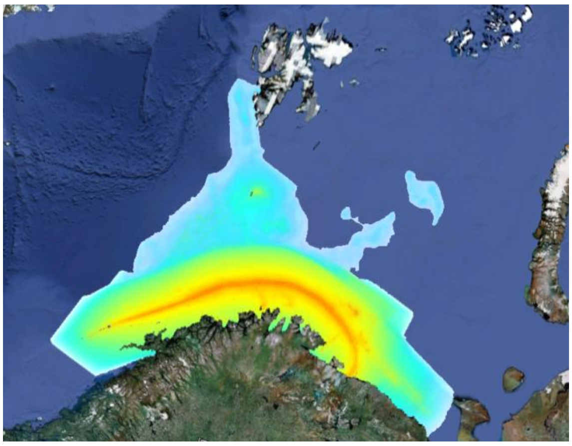

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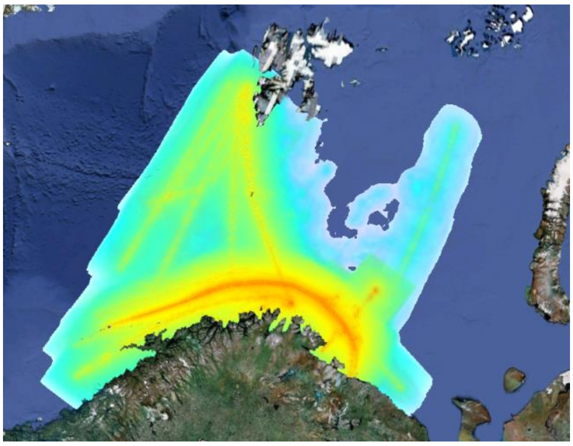

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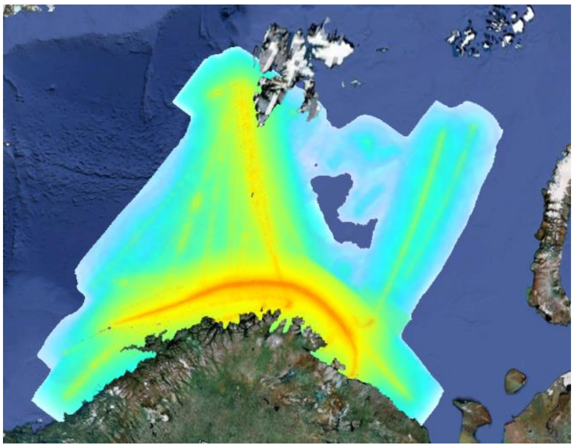

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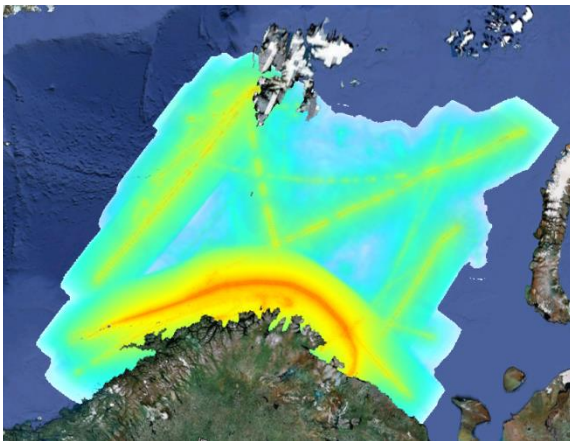

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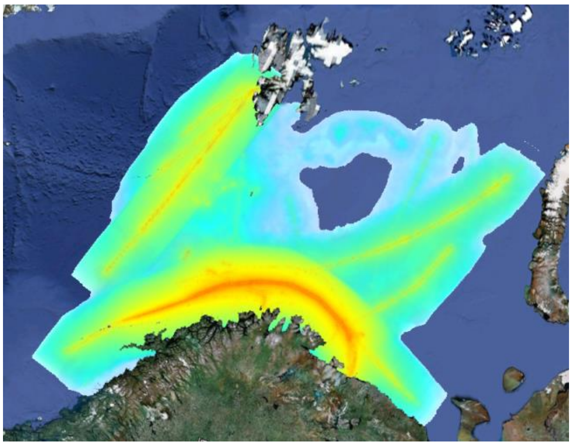

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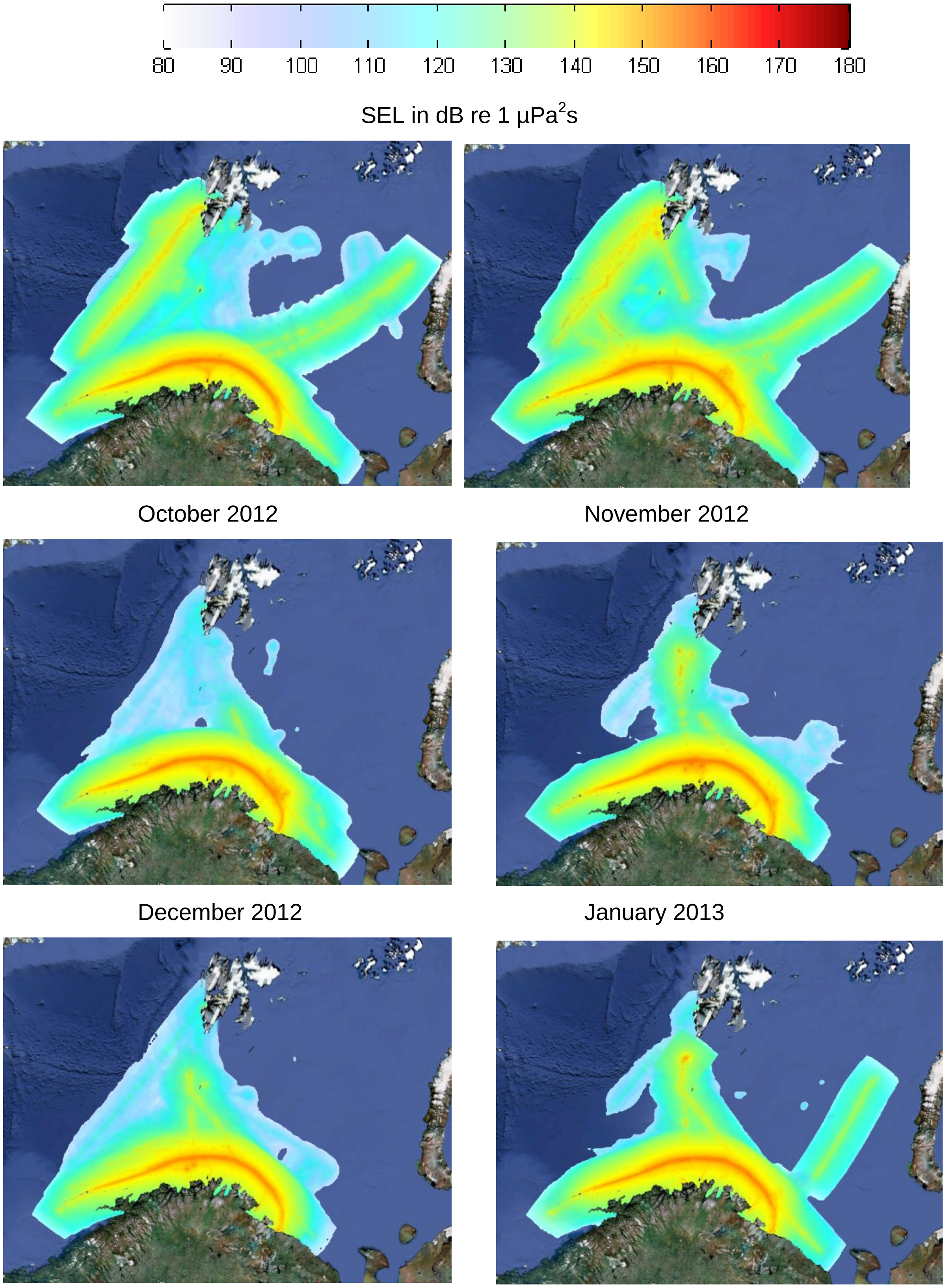

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February 2013 March 2013

3.7 Conclusion

The monthly sound exposure level based on background noise alone using the levels found in Section 2 would be around 160 dB re 1 μPa^2(100 dB + 10*log(T) where T is the number of seconds in a month). Following the above maps, looking at the cumulative exposure during one month, animals would experience an exposure to higher than normal noise levels in orange/red zones. There is no SEL threshold (in terms of an increase over background noise sound exposure levels) known that would cause displacement or harm, or that would be considered ‘safe’. However, it does not seem likely that animals outside of the direct shipping lanes are affected by cumulative shipping noise. Of course, it could be found that in a shorter time frame (hourly or daily) the SEL levels were significantly higher than what normally would be experienced from the background noise, e.g. during the passage of a particularly noisy ship. But it is not likely that such a short event would have caused permanent displacement.

As mentioned in the above introduction, the noise level estimations from shipping and the losses from propagation should be confirmed with recordings before any real conclusion can be drawn. After confirmation of the modelling of the current situation an extrapolation could be made to a future scenario that includes an increase in shipping traffic or other economic activities in the region.

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