Local ocean weather knowledge

Extraction and application for validation

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Preface

Inclusion of local knowledge is a novel approach for numerical model validation. This thesis examines how numerical model results can be compared with local knowledge. Professional sailors and people in leisure activity explained their experiences in semi-structured interviews. This knowledge has been prepared for validation with available and future numerical models. Several phenomena have been extracted and three of them have been applied for comparison against the computed current motion from the ROMS75 model. Wind and waves are not validated with the numerical model, since the applied model plots solely current motion and the water level. Wind and waves are however included in this paper, because they are part of the complex ocean mechanisms and indicate the reliability of local knowledge. The results of this thesis indicate consistency between the applied phenomena and the current numerical model. The applicability of local knowledge for numerical model validation therefore seems possible. Future research should increase the size of samples and volume of phenomena to strengthen this conclusion.

Acknowledgement

I would like to thank my supervisor Karina Hjelmervik for her expedient guidance through this master thesis. Working with the FjordOs project has been a pleasant experience.

I further acknowledge the contributions from the interview respondents who shared their knowledge about weather phenomena in Moss. This thesis was not possible without their engagement and willingness to contribute.

This master thesis is the latest piece in my academic career and I want to express my gratitude to my family and friends who supported me during my entire studies.

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Introduction

The FjordOs research project develops numerical models (FjordOs models) for ocean weather conditions in the Oslofjord. Those models need validation to assess the quality of generated data. Validation assures that the model meets the needs of users and indicates whether it is possible to rely on future models of this type (Project Management Institute, 2004). This thesis uses a validation approach that is rarely reported in the literature. It applies local knowledge to identify phenomena that seem hardly observable with measuring or modelling methods due to their characteristics.

Until now, several options have been used for validation of models. Technical systems for model validation include the Wave Radar system (Helzel, Kniephoff, Petersen, 2010) and Acoustic Doppler Current Profiler, which can measure current velocities. Measurements of surface velocity with drifters (Lumpkin and Pazos, 2007) and abrasion of marine components could be analysed and compared with results. Gulev, Grigorieva, Sterl and Woolf (2003) discuss the validation of wave parameters based on observations.

As described in Sutter (2012) regarding the validation of wave modelling, the "comparison of the wave model forecasts with observations is essential for characterizing model deficiencies" and they can identify areas for improvement. Local knowledge is often ignored or inapplicable in research projects. Once in a while, local people complain that their knowledge has been ignored, using phrases like "Why didn't they ask us? I would have known!" Local knowledge might be included for various topics around the Oslofjord such as oil drift forecasts after oil spill casualties (Ulrichsen, 2013, April 29).

This thesis combines the aspects of local knowledge and the requirement for model validation. It is the motivation for this research to ascertain whether or not it is possible to include local knowledge in the validation of the FjordOs models. The research also analyses, to which extent the ocean weather conditions from one existing numerical model supports the experience from local people. Generation of reliable data from the interview objects is one precondition for valid conclusion. Qualitative data from local people can be quite diversified and heterogeneous which makes the integration complex. The major challenge in this thesis is therefore the comparison of the local experience with the numerical model results.

This paper includes three research questions:

- To what extent do the ocean weather conditions from the existing model comply with the experience from local people?
- How to generate reliable data and valid conclusions that can support the results from the computer model?
- How to compare experience from local people with results from numerical models?

The data from local people requires a selection process under consideration of the large variety of responses. The reduced data must have similar characteristics as the established knowledge to enable the examination. This thesis applies different tactics in charts and matrices to compare the data sets.

The model validation process focusses on ocean currents. Data from wind, waves, and the water level is valuable because of their interdependency in the oceanographic mechanisms. The currents are dominantly influenced by tide, winds, freshwater supply, and atmospheric pressure. Their respective influence varies in time and place.

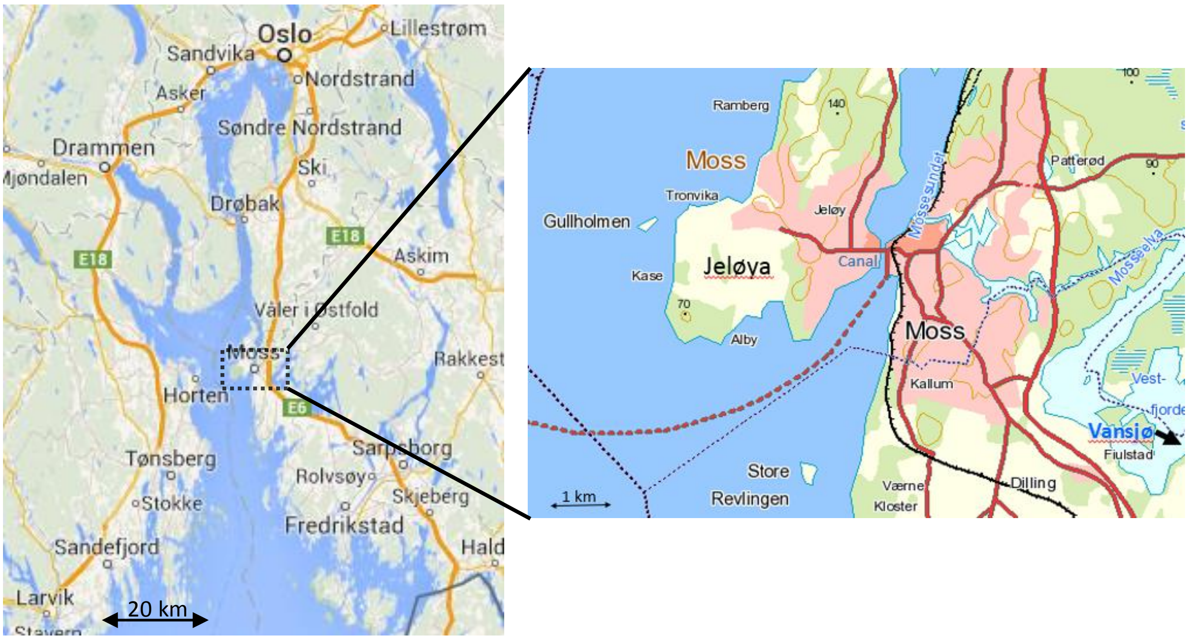

Figure 1: Chart of the Moss area. (Based on google maps and http://kart.kystverket.no).

Moss is selected as the case for numerical model validation because of the geographical characteristics. The island of Jeløya in the west of Moss is separated by a small canal, in which water can flow in northern and southern direction (Figure 1). The underwater topography with numerous relief variations, the coastal structure with islands, and the canal, influence the current flow pattern which makes it interesting for validation.

The sum of winds, waves, and ocean currents can comprise large influence on maritime activities. Moss has one of the largest container ports in the Oslofjord. The commercial port area is located on the mainland in the south-east of the canal. It includes several quays for ferries and cargo ships. The port authority has intentions to restructure and increase the size of the commercial port area. In the initial stage of planning, the considerations included the erection of a mole.

Making use of natural forces is a potential option during infrastructural planning. Shipping and port operations that is aligned with oceanographic weather conditions can help saving time and money for ship owners because of higher efficiency in the vessels' operations. Commercial operators such as Moss Harbour and shipping companies could benefit from accurate ocean weather data for adjustments in their operations. Knowing where the currents are, enables ship owners to choose sailing routes with favourable current conditions. Captains manoeuvring in the Oslofjord can try to follow current fields. Drifting with the currents could reduce the fuel consumption, which has a positive effect on the emissions to the natural environment in the Oslofjord. The results can be economical and ecological advantages.

Methodology

The objective of this thesis requires primary data from local people that can be used for validation of numerical model results. This section describes the course of action from ethical considerations up to the data acquisition and strategy planning for data comparison and validation.

The research project is registered at the Data Protection Official for Research, Norwegian Social Science Data Services (NSD) in accordance with the national research standards. This registration includes the obligation to handle any personal data during and after completion of the project in accordance with the standards provided by NSD.

Sampling Strategy

For the selection of participants, purposive sampling has been applied. Since the research objective targets the in-depth experience of local people, purposive sampling allows choosing the most suitable participants for the interviews. The participants that were chosen meet two important characteristics. All participants come from or work in the broad local area of Moss. The second characteristic is that they have a broad understanding about ocean weather conditions in this area of the Oslofjord. This knowledge may be acquired from leisure activities in the sea or professional work. The variety of backgrounds brings a valuable range of perspectives (Rapley, 2007). Besides their knowledge and local proximity, their overall attitude for cooperativeness, impartiality, willingness to share, and ability to communicate their knowledge is important. In this context, the term knowledge is used for experiences, observations, thoughts, and standpoints on particular issues. This knowledge is naturally build up in the social context of the participants' leisure or professional environment.

The recruitment process relied on various sources of contacts such as job-related and social networks, contacts given by interview participants or purposive search on specific professions such as captains in the area. Purposive sampling does not guarantee that the acquired data are complete, correct, and of any use at all. But this technique allows a greater chance of gaining in-depth knowledge. Purposive sampling is a non-probability technique, which does not allow any generalization of findings and endangers bias in the conclusions (Harding, 2013).

It should be mentioned that the variances within role domains such as the captains can be considerable. The technical specifications of the ships vary and influences the captains' perception of manoeuvring in different weather conditions.

Selection of Participants

The volume of qualitative data from the interviews is extensive and the number of interviews had to be limited. This bears the risk of excluding data, which is a general issue in data collection from unlimited data resources. Consequently, the selection of participants had to be done attentively in order to include diverse perspectives. This thesis uses data from eleven interviews. The first six interviews have been conducted during February. The second turn of interviews included five participants and has been undertaken three weeks later. Several parameters are included in the considerations for the sample size. Bryman (2012) describes factors that influence the required size of samples, such as the need for precision and the intensity of the interviews. The typical occurrence of non-response has been included in the sample size. Three enquiries for interviews have been declined by the intended participant.

For the objective of gathering ocean weather phenomena from local knowledge, the participation of eleven interview objects is considered sufficient. This size allows the participation of people with different maritime activities. At the same time, the number of respondents complies with the time and cost resources that is available.

The selected interview participants can be categorized in five role domains within the maritime environment. The largest group with six participants is the role domain of professional sailors. Two interviews have been conducted with leisure boat sailors that use their boats for free-time activities. One interview has been taken with the crew of a boat from the Norwegian Society for Sea Rescue. Respectively one interview participant has been included for their activity as leisure diver and surfer. Table 1 provides an overview of the participants and the conducted interviews.

Table 1: *Interview participants.*

Number of participants	Role domain	Participant	Duration	Location
6	Captain/ Officer/ Pilot	A1	1h 25m	HBV University College
		A2 (two respondents)	2h 33m	Onboard
		A3	1h 16m	HBV University College
		A4	1h 34m	Office in Moss
		A5	about 2h	Onboard[1)]
		A6	0h 16m	Onboard[2)]
2	Leisure boat sailor	B1	1h 27m	Office in Horten
		B2	0h 58m	HBV University College
1	Norwegian Society for Sea Rescue (NSSR)	C1 (three respondents)	1h 33m	Onboard[3)]
1	Diver	D1	1h 10m	At home of the respondent
1	Surfer	E1	1h 08m	Outside on the coastline of Jeløya[4)]

[1)] Based on field notes instead of audio recording.

[2)] Short in time due to on-board duties.

[3)] Field trip to Revlingen and Mossesundet.

[4)] With the opportunity to observe some of the described phenomena.

Some participants exercise two or more activities in the maritime environment. Those interview objects are categorized for their major maritime activity.

Interview guides

The qualitative data has been obtained through semi-structured interviews. The purpose of in-depth interviewing is to learn about the lived experience of people rather than pure testing of hypotheses (Seidman, 2013). Semi-structured interviews allow the researcher to obtain nuances of information which help the contextual understanding of the phenomena. The pattern of questions provides the guideline for the categories. The flexible structure allows the participants to talk with their natural attitude without unnecessary disruptions (Kvale, 2007). The researcher can follow up on certain issues and clarify ambiguities in an appropriate moment. Using this method, comprises the risk of losing the focus. On the other hand, it allows the participant to talk about the knowledge he knows best.

The interview guides contain the four categories of winds, waves, ocean currents, and water level. Although the order of the categories retained, the interview guides have been individualized for each role domain to correspond with his anticipated knowledge.

A brief introduction about the situation and clarification of general questions about the setting have been performed at the beginning of all meetings. During the interview, most aspects were introduced with open questions to understand the participants' initial thoughts. Throughout the interview, the questions were narrowed down to those statements which describe relevant phenomena for the research objective. At the end, a short debriefing rounds up the interview. The participant has the opportunity to state anything he considers relevant in addition or in need of explanation.

Data acquisition

Primary data has been acquired from observations by one of the captains as well as in personal meetings in the Moss area. Six interviews were executed in undisturbed settings, such as private houses or the work offices. Five interviews were arranged in locations close to the Oslofjord, including passenger ferries, a containership, a vessel from NSSR, and outside near the fjord. These vicinity to the fjord supported the understanding of descriptions given by the participants. All interview objects showed positive effort to share their knowledge and explained if they were unsure about certain parts of their statements. Two of the respondents are personally known to the researcher. This created a faithful atmosphere by itself from the start of the meeting. One participant was short in time because of his on board duty. The participant explained about his experiences, but some aspects had to be cut in extent. This interview lasted for sixteen minutes compared to eighty-four minutes duration in average.

Transcription

The interviews have been audio recorded, transcribed, and during this, cleaned for linguistic deficiencies. The linguistic cleaning does not change the statements with regards to contents, but supports the understanding and analysis of data (Rapley, 2007). Those parts, where the interview went off the topic without relevance to the thesis, have been ignored for the transcript. This approach, discussed in Gibbs (2007), admits the researchers' focus on themes with greater significance.

During some interviews, statements have been partly given in drawings. The illustrations often simplified explanations and reduced potential misunderstandings. Those drawings and short field notes taken during the interviews have been written up in the transcripts. Miles, Huberman, and Saldaña (2014) describe that this activity connects the verbal with visual statements and can remind the researcher of contextual statements which have not been taken down in either way.

Data analysis

There should be no doubt that the type of data analysis influences the results (Auerbach and Silverstein, 2003 in Harding, 2013). Even during the analysis, the researcher makes various subjective choices in how to handle the datasets for producing results. This thesis uses a method that resembles an analysis techniques described in Miles et al. (2014). It comprises three concurrent flows of activity. At the start, the relevant data from the interview transcripts will be extracted and simplified in its structure. This activity strengthens the relevant data. In the second step, the data is displayed in an organized manner, which allows conclusion drawing. This thesis uses matrices and charts to assemble the information. This is the most appropriate form in respect to the nature of the gathered data. The third step of the data analysis is the conclusion drawing and verification.

The data analysis started while the data collection was still in progress. This concurrent approach is beneficial for verification of preliminary findings. Miles et al. (2014) describe this dynamic progress with the possibilities to fill in gaps with data or test new hypotheses that come up during the analysis. This bidirectional analysis allows thinking about the preliminary results and adjusting the strategy for further data collection.

The extraction work begins with sketching relevant statements in thematic charts. These initial compilations are hand drawn and provide an early overview of the data. These thirty-three charts are optimized in clarity using computer software (Appendix A). During this work, each category has been assigned a colour. Wind related notes are plotted with red colour, waves in blue, and notes about currents in green colour. Statements about the water level have been included in the current charts, if relevant information in this category has been provided. Figure 2 provides an example of the thematic maps on single participant level.

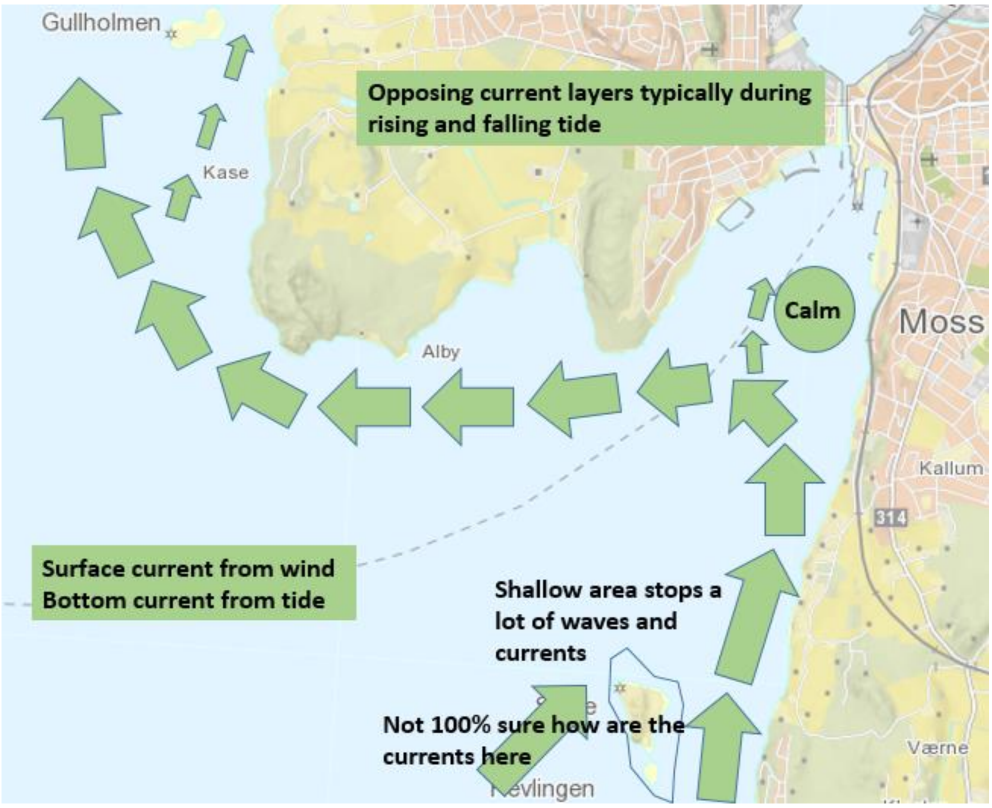

Figure 2: Thematic chart on single participant level. (Based on google maps).

From the interview data, eleven phenomena are selected. These are compared with oceanographic theories and results from measurements. This work enables the researcher to find contradictions and interrelations. Those phenomena which can be validated with the numerical model, have also been compared to the results from the ROMS75 model.

In addition to the charts, the data is assembled in conceptually clustered matrix (Miles et al., 2014). This format organizes material in a very structured manner as outlined in Table 2. It includes considerations of the design such as the number of rows and columns as well as the content. The columns list the extracted phenomena and the rows cover the participants with their role domain. The cells are filled with check symbols to mark the participants' position for the respective phenomenon.

Reading across the rows provides the researcher with an overview about the participants' perceptions and possible interrelations between his answers. Reading across the columns provides phenomenon specific comparisons between participants and also within role domains.

Table 2: *Conceptually clustered matrix.*

Role domain	**Participant**	**Phenomena**		
		P1	**P…**	**P11**
Captain/ Officer/ Pilot	A1 … A6			
Leisure boat sailor	B1 B2			
NSSR	C1			
Diver	D1			
Surfer	E1			

The reason for variances can be different knowledge, inaccurate statements or different perception. Intervening responses are taken into considerations and their relation needs to be uncovered with theory.

Established Data and Local Knowledge

This thesis distinguishes between two types of data. Established data includes theory and measurements as well as the numerical model from the FjordOs project. Theory and measurements are used to indicate the reliability of the local knowledge. The results from the numerical model are validated against phenomena of the local knowledge.

Delineation of Established Data

The theory has been selected from oceanographic and meteorological literature and measurements are taken from research projects and concerned institutions. Forecasts which are based on numerical models are used as sources for data of water levels and currents. Table 3 gives an overview about the applied secondary sources.

Table 3: *Overview of secondary sources.*

	Wind	**Wave**	**Water level**	**Current**
Theory	✓	✓	✓	✓
Measurement	✓		✓	
Numerical model	✓		✓	✓

Wind

Established knowledge from winds includes theories and measurements from a weather station near Moss. Figure 3 displays a wind rose based on measurements between 01.01.2009 and 31.12.2011. The weather station is located on the island of Gullholmen and gets shelter from land masses in the east. According to the wind rose, the most frequent and strongest winds come from north-north-east and south with near gale force. There are variations in strength and direction, depending on atmospheric pressure, time of the year and other factors.

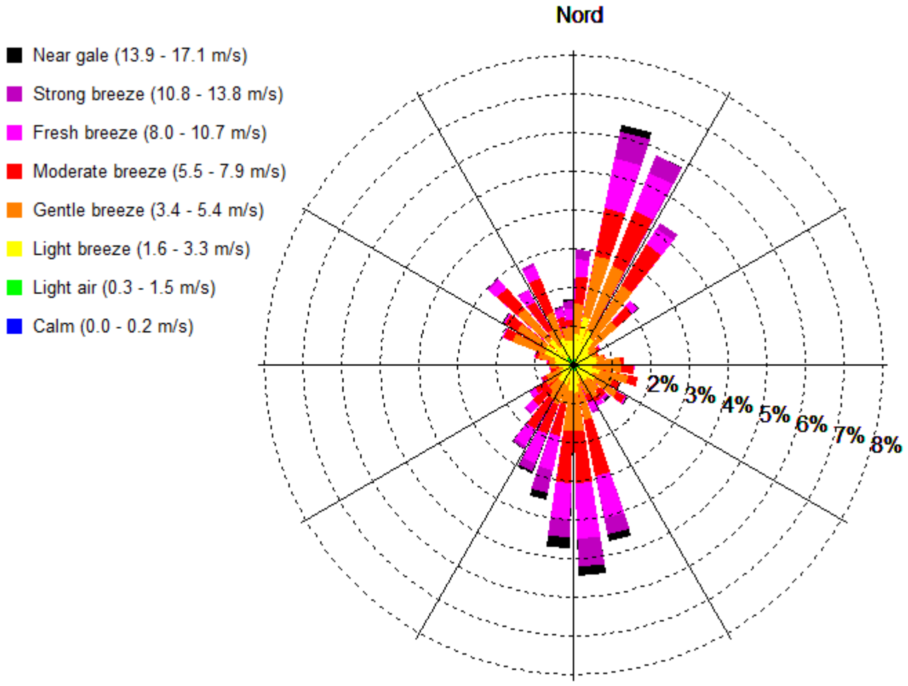

Figure 3: Wind rose from Gullholmen. (FjordOs).

The atmospheric model METNO10km forecasted similar conditions for the Moss port area, except less wind force from north due to high altitude which provides shelter. Sea breezes commonly occur on warm sunny days according to the Norwegian Meteorological Institute. In the early afternoon hours, the land has warmed up and the air follows towards the land (Trujillo and Thurman, 2013). During sea breezes, wind speed typically increases.

Wave

Wind driven waves are typically steep with short wavelength and arise when wind catches up water over a certain distance. Wave patterns are formed from various influences including the geometry of the seabed and the onshore (Reeve, Chadwick & Fleming, 2012). Figure 4 displays the seabed geometry around Moss with a 75 metre resolution. The map lacks minor inaccuracies due to numerical issues.

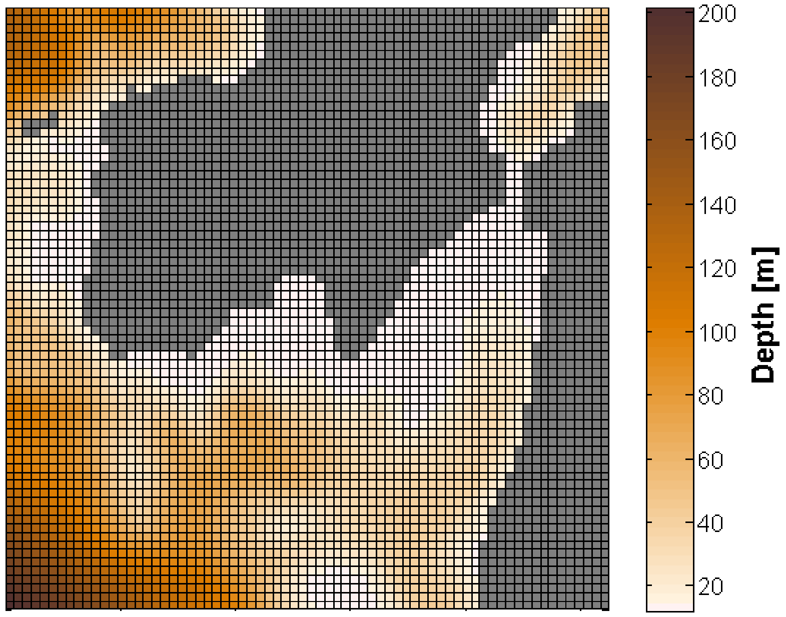

Figure 4: Moss seabed topography. (FjordOs).

Wind-against-tide conditions describe the situation when the wind blows in the opposite direction of the currents. According to Reeve et al. (2012), this will create steep and tall waves with short length similar to breaking waves approaching the shore in decreasing water levels. Wind-over-tide and waves-against-current conditions typically arise at the same time as wind often determines wave direction (Reeve et al., 2012). In case that the wave encounters the current, the wave speed reduces together with the length. Therefore, height and steepness increases up to the breaking limit. Swell waves can occur during strong and continuous southern wind in the Oslofjord. Those waves arise when winds catch up water over a large distance (Pinet, 2003).

Water level

Astronomical tide is one major contributor to cause sea level fluctuations. Tides are the periodic raising and lowering of sea levels caused by combined effects of the gravitational forces exerted by the Moon and the Sun on the Earth (Trujillo et al., 2013). The tidal range varies in height compared to the mean sea level. The average tidal range in the Moss area is about 30 cm between high and low tide (Statens kartverk Sjø, 2014).

The forecasted semi-diurnal cycle in Moss harbour on the 20th August 2009 is illustrated in Figure 5. The circles mark the times with output from the model. The red circles assign one exemplary high and low tide as well as the mean sea level during incoming and outgoing tide.

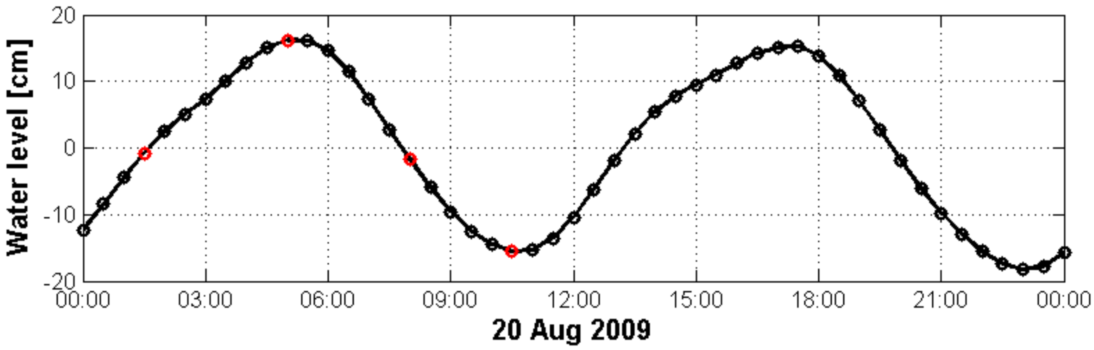

Figure 5: Modelled water level in Moss harbour during two tidal cycles. (FjordOs).

Attempts to make clear distinctions between parameters that cause sea level variation can be ambiguous. The potential contributors include the wave set-up, wind-stress on the ocean surface, and other non-tidal effects (Reeve et al., 2012). High atmospheric pressure outside the fjord in combination with high tide inside the fjord can result in storm surges, which significantly increase the water level beyond the predicted levels. Figure 6 illustrates the variation between the modelled and measured water level. The graph is based on data taken from Viker (Østfold) during October 2011.

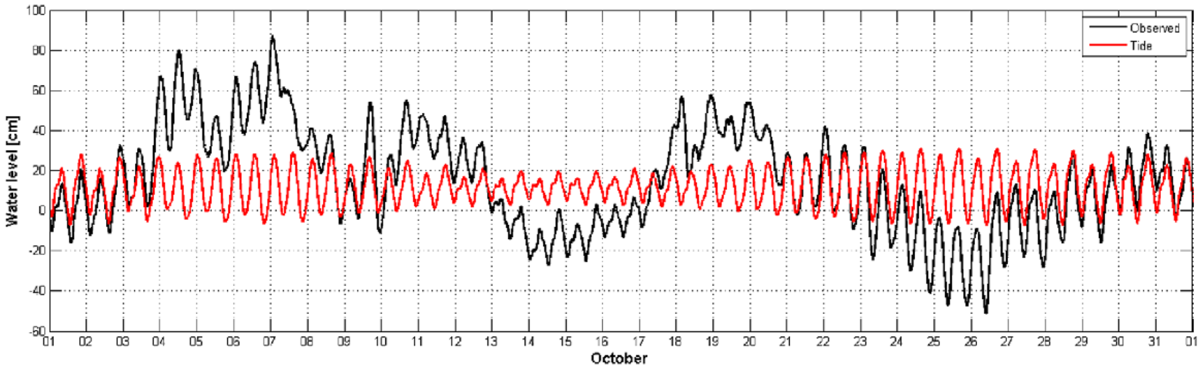

Figure 6: Water level variation in Viker, October 2011. (www.vannstand.no).

The graph shows two phases of spring (04.-07. and 21.-28. October) and neap tide (14.-16. October). The water level differs between the sole tidal influence (red curve) and the water level including all weather influences (black curve) with up to 60 cm during high tide on 07. October 2011. These phenomena occur when certain weather effects coincide with a spring period (Statens kartverk Sjø, 2014).

The spring-neap cycle reiterates approximately every fourteen days and causes spring tide with higher and neap tide with lower amplitude of the water level. Spring tide occurs when the gravitational pull from the Moon (M_2) and the Sun (S_2) act together in the same direction. Neap tide occurs when gravitational pull from the Moon and the Sun act in opposite directions (M_2 - S_2). S_2 has smaller impact on tides, due to the larger distance between the Sun and the Earth.

In addition to weather and tidal impacts, the water level in Moss is influenced by the Vansjø in the east of Moss. This lake provides the Mossesundet with variable amounts of freshwater. The lake is connected with a waterfall system which is used for power generation (Norges vassdrags- og energidirektorat, 2014). Especially during spring and early summer, ice and snow melts and flows into Vansjø. This increase of water level could result in a higher flow rate of fresh water into the Mossesundet.

Current

The port of Moss is part of the Oslofjord and therefore naturally influenced by ocean currents. Den Norske Los, a set of guidelines for manoeuvring in Norwegian waters, describe the nautical characteristics in Moss. It explains that currents change with tides, seasons and weather conditions. Weak currents are typical, but with unfavourable weather conditions, the currents can reach speeds of more than one knot in either direction, depending on the wind (Statens kartverk Sjø, 2014). Surface currents are the result from friction between the sea and wind on the water surface. Since Norway is on the northern hemisphere, currents typically turn a few degrees to the right of the wind direction (Statens kartverk Sjø, 2014).

The FjordOs project develops different models for current motion. This research paper uses the preliminary numerical data from the Regional Ocean Modeling System (ROMS). The data is computed with 75 metres resolution and the model results displays the surface currents. The current motion is based on tidal currents only. Other influences such as wind are not included.

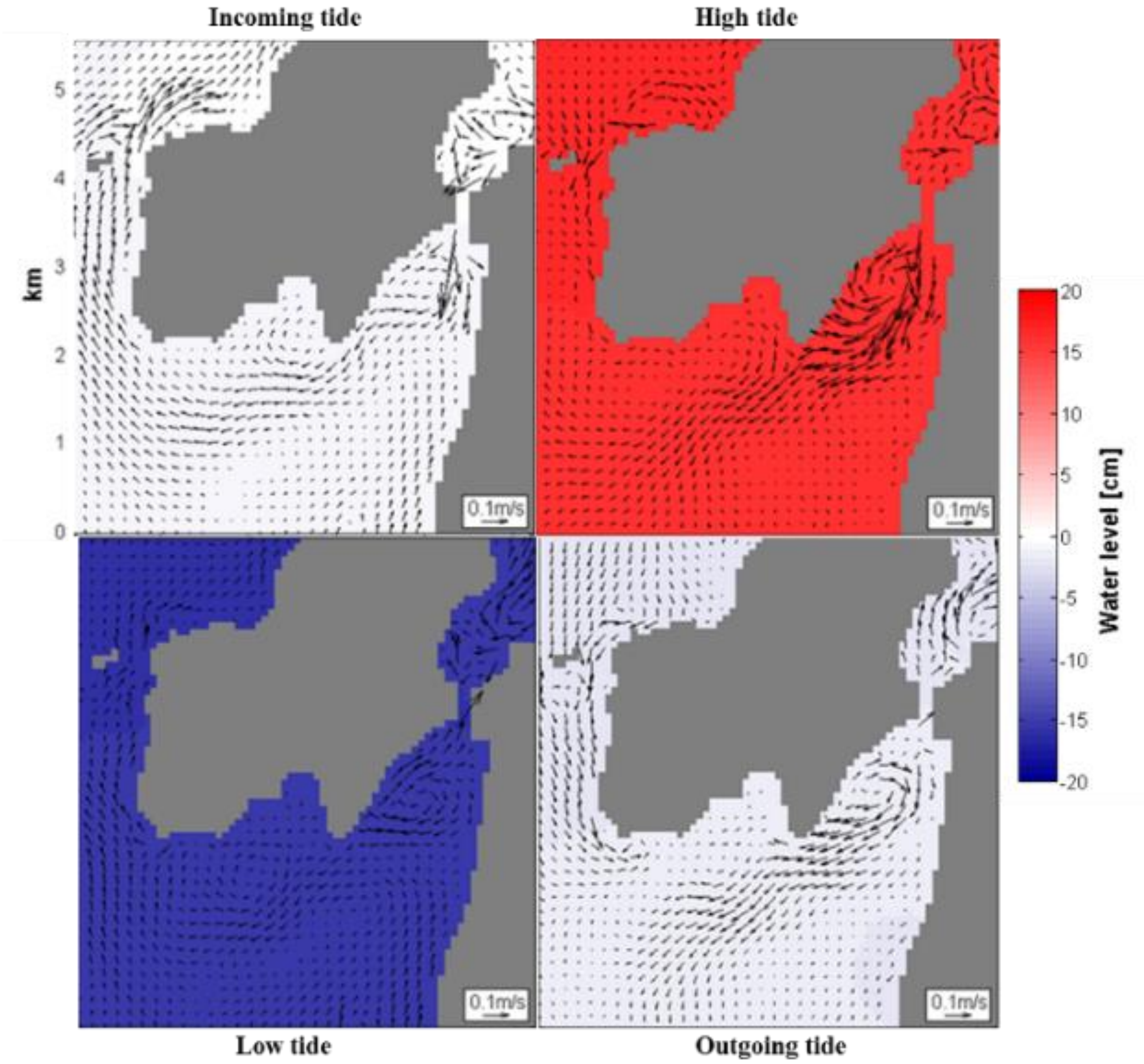

Figure 7: Current motion during one tidal cycle (ROMS75). (FjordOs).

The computed current flows during four tidal stages are shown in Figure 7. The reference vector in the ROMS75 model is 0.1 m/s. The canal forms the narrowest part for water motion between Verlebukta and Mossesundet (Statens kartverk Sjø, 2014). Due to numerical issues, currents inside the canal could not be displayed. From the narrow size it may be assumed that the current velocity amplifies inside the canal.

Delineation of Local Knowledge

The different aspects from the semi-structured interview guide are outlined in Table 4. The sequence and questions were adjusted to the anticipated knowledge of the respective participants.

Table 4: *Structure of the interview guide.*

Wind	Wave and water level	Currents
1. In what way do winds affect your activity in the fjord?	1. In what way do waves affect your activity in the fjord?	1. In what way do currents affect your activity in the fjord?
2. Dominating wind direction	2. Dominating wave direction	2. Critical current direction
3. Critical wind direction	3. Critical wave direction	3. Are currents in the canal weakest during high and low tide?
4. Are there frequently critical wind rotations?	4. Critical wave length and frequency	4. How do currents from the canal in Moss affect the Verlebukta?
5. Are there optional routes or areas to use in case of critical wind regimes? If yes, where on the map?	5. Wave heights	5. Comparison with current plots from ROMS75 model
6. Comparison with wind rose	6. Wave heights in correspondence with wind force? Is it possible to make rules of thumb?	6. Have you experienced opposite current directions in the canal and outside the fjord during incoming and outgoing tide?
7. Are waves from north smaller because the fetch in the north is smaller?	7. Typically regular or chaotic wave pattern?	7. Have you experienced the strongest currents in the Verlebukta during high and low tide (with opposite directions)?
8. Are the waves smaller when currents go in the same direction?	8. Does it create critical wave formation if currents and winds come from opposing direction?	8. Have you experienced a general current flowing from Revlingen along the harbour up along Jeløya?
9. Are the waves higher when currents go in the opposite direction?	9. In what way do water level changes affect your activity in the fjord?	9. Have you experienced a current “field” outside the Verlebukta?
10. Are there other waves with different directions and origins?	10. To which extent do you think does atmospheric pressure in the Skagerrak affect the fjord?	10. Have you experienced a quiet “field” without current motion in the Verlebukta?

During the data reduction process, several phenomena have emerged. Eleven phenomena have been selected and denoted with the acronyms P1-P11. These numbers are only nominal with no further meaning beyond the name. The phenomena will be classified into the two categories common sense and uncommon phenomena. Common sense phenomena describe experiences that can be explained with typical environmental mechanisms and follow natural law. Uncommon phenomena describe experiences that do not seem obvious to the researcher. They have the potential to generate meaning of the conclusions and are therefore used to validate the numerical model.

The phenomena of common knowledge are:

P3: Waves follow wind
P7: Currents follow wind
P10: Currents are strongest inside and around the canal

The uncommon phenomena are:
P1: Sea breezes in Moss
P2: Extreme situations during strong and steady northern winds
P4: Choppy water around south-west of Jeløya
P5: Atmospheric pressure influences the ocean weather in Moss
P6: Current along the coast from south to north
P8: Current from east to west in Mossesundet
P9: Stronger bottom currents inside the canal
P11: Strongest currents in the middle and at the north end of the canal

Some participants admitted that it is difficult to differentiate the influences of winds, waves and ocean currents. This could create ambiguities, even though clear separation of their impacts is not a key requirement in this thesis. The participants were asked to share experiences without necessarily giving reasoning or justifications.

An overview of the stated phenomena is provided in Table 5. This matrix gives an overview about the participants' statements and allows differentiation between the different types of respondents. The participants in the group of captains, officers and pilots experienced between zero and four of the selected phenomena. Two of them are related with ocean currents. Leisure boat sailors stated experiences with the selected phenomena across all categories. The surfer showed experience with respectively one phenomenon across three of the four categories.

Table 5: *Conceptually clustered matrix from local knowledge.*

Role domain	Participant	Category										
		Wind		Wave		Water level			Currents			
		P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11
Captain/ Officer/ Pilot	A1	✓			✓		✓	✓				
	A2											
	A3										✓	
	A4	✓			✓			✓				
	A5	✓										
	A6	✓										
Leisure boat sailor	B1	✓			✓							
	B2	✓				✓	✓				✓	
NSSR	C1								✓	✓		✓
Diver	D1	✓	✓	✓	✓	✓	✓	✓				
Surfer	E1	✓			✓		✓					

Three of the selected phenomena have been experienced by the crew of the NSSR vessel. All three phenomena describe issues of current motion. The diver stated experiences for seven of the eleven phenomena, two of them are related with current motion.

Wind phenomena

All participants were able to speak about winds. Some participants referred to personal experiences, others related their knowledge to public weather forecasts. The selected knowledge about wind in Moss describes the phenomenon of sea breezes and a specific ocean weather constellation.

Sea breezes in Moss (P1)

The occurrence of sea breezes was mentioned by eight of the participants. They have described the phenomenon of increasing landward winds during sunny afternoons in spring and summer.

Figure 8: Outline of a potential sea breeze in Moss. (Based on google maps).

Figure 8 illustrates the approximate direction of southern winds during sea breezes as they are diverted towards warm landmass. P1 has been categorised as uncommon knowledge, because it was uncertain whether sea breezes occur in Moss.

Extreme situations during strong and steady northern winds (P2)

One participant explained about extreme situations in Mossesundet and Verlebukta during strong and steady northern winds in combination with low or falling tide. Wind would push large water masses towards south and prevent the water inside Mossesundet to flow northwards. Pressure from the water flow would therefore concentrate inside the canal. Water levels from the different tidal stages can relief and fortify this effect.

The Mossesundet is funnel shaped as displayed in Figure 1. It is open to the sea in the north and converging in southern direction to the Moss canal. The wind rose from Gullholmen (Figure 3) shows north-north-east as one of the typical wind directions. It must be emphasized that Mossesundet is widely sheltered from landmasses.

Wave phenomena

Wave conditions have been explained by all participants. Their characteristics seem to be the most observable, due to their visual appearance. The wave patterns are described in very diverse characterisations, depending on parameters such as the area and role domain. The diver and the surfer explained that the wave pattern in the Verlebukta close to the canal is increasingly bumpy and chaotic towards the shoreline. One of the captains experienced short and cutting waves during north winds, which he did not expect.

Waves follow wind (P3)

Five of the respondents stated that waves follow the wind. This is basically established knowledge. Geographical maps reveal that especially during southern winds, the wind has a large fetch to pick up water and build up swell waves. Those wave types have been described by several respondents. In addition to the comparison with theory, P3 has been examined using an observation schedule (Appendix B). The observations have been conducted by a captain, who also participated in the interviews. The observation was executed during 13.-15. April at different times of the days. He described twelve weather conditions and the respective wave formation. It is recognizable that during five occurrences, wind came from north or north-west. During seven observations, northern wind was prevailing. This supports the measured data from the wind rose on Gullholmen. It is observable from the data that during wind with 3 m/s and incoming tide, waves have only been observed during southern and not during northern winds. The same can be identified during 4 m/s wind force and incoming tide. Waves during northern wind have only been observed at wind speeds from 5 m/s. In those situations, the wave pattern has been described as chaotic during outgoing and low tide.

Choppy water around south-west of Jeløya (P4)

Four participants have mentioned steep and cutting waves along the south-western coastline of Jeløya. The specifications about the wave characteristics vary between the participants. Figure 9 delineates the area of choppy water near the south-west of Jeløya, which is also a typical area for kitesurfing.

Figure 9: Choppy water in the south-west of Jeløya. (Based on google maps).

The excerpt from a sea chart (Figure 10) illustrates the levels of water depth in that area. The water depth decreases gently in Breidbukta, whereas the coastal structure steeply rises in Vrakbukta. This sharp upsurge in the underwater topography of south-west of Jeløya is a potential factor for the described phenomenon.

Figure 10: Sea chart Jeløya. (Based on http://kart.kystverket.no).

The reason for choppy water in that area is most presumably the result of interaction between current motion, wind and steep underwater topography. The numerical model shows strong current flows in that area in the first tidal stages after low tide and during the middle of outgoing tide. Depending on the wind direction and force, the water could get choppy.

Water level

Water level changes have been described as insignificant with few implications on the activities of the respondents. According to the participants, the influence from water level is not very significant and has few implications on the activities of the respondents. Some respondents have related the aspect of different water levels to influence from atmospheric pressure.

Atmospheric pressure influences the ocean weather in Moss (P5)

Three respondents mentioned atmospheric pressure as a parameter that influences the Moss ocean weather. The pressure level has been described as one determinant for continuity of weather conditions. Atmospheric pressure has also been mentioned in the context of spring tides. Changes of the water level from non-tidal effects have not further been discussed by the participants.

Current phenomena

Several respondents described the observation of currents and its differentiation from other influences as a challenge. The extracted current phenomena must therefore be regarded in cohesion with wind and wave phenomena.

Current along the coast from south to north (P6)

Four respondents mentioned a current along the coast in the direction from south to north. Due to the size of the phenomenon, some respondents declared uncertainty, whether the size and continuity of the current is existent. Figure 11 sketches the approximate course.

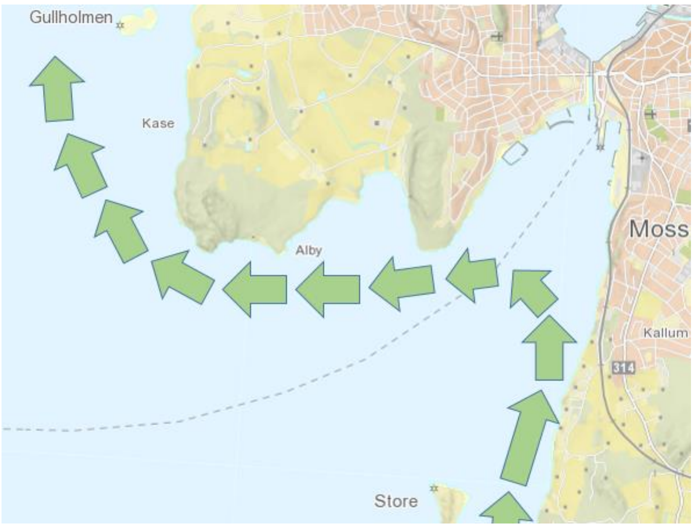

Figure 11: Current along the coast. (Based on google maps).

Currents follow wind (P7)

Four respondents explained correlation between wind and the surface current. They describe that the currents follow the wind, which is also known as Stokes drift (Holmedal, Myrhaug and Wang, 2014). This phenomenon follows law of nature and can be categorized as established knowledge.

Current from east to west in Mossesundet (P8)

One participant experienced a strong current from east to west in the south end of Mossesundet. This current would run more or less straight to the Betongen pier on the east side of Jeløya. The respondent experienced this phenomenon during one year in March and April. Figure 12 plots the potential current flow according to the stated phenomenon.

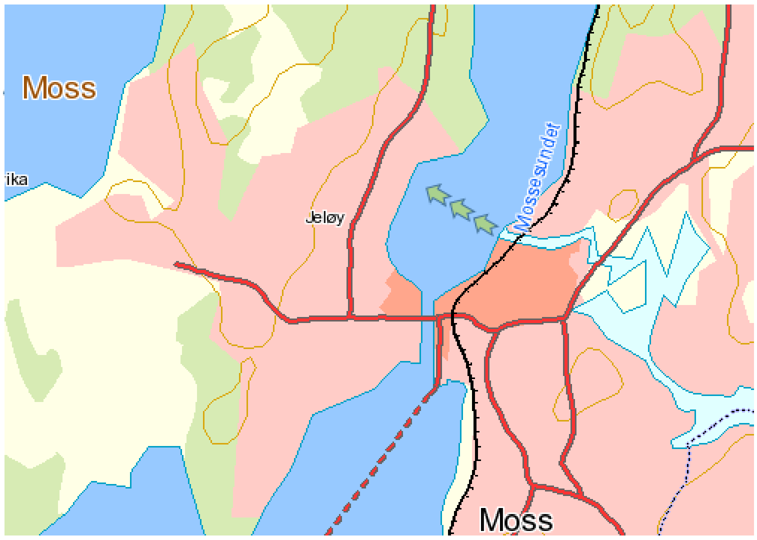

Figure 12: Potential direction of east to west current. (Based on http://kart.kystverket.no).

According to the respondent, much freshwater flows from Vansjø into Mossesundet during spring and early summer. The water is channelled in a waterfall and arrives Mossesundet with high pressure due to that slope. This induces the additional presumption that this could cause the current flows described in P8. Another factor could be the intrusion of freshwater, which reduces the salinity inside Mossesundet. Due to less density, the freshwater would be on the surface when entering Mossesundet as long as the types of water are not mixed. An important factor in this mechanism is the water temperature from Mossesundet and Vansjø.

Stronger bottom currents inside the canal (P9)

Several respondents mentioned the experience of different current layers in Moss. One participant explained that currents inside the canal are stronger at the bottom than on the surface. The participant stated that this is also the opinion of many other local people. Whether these assumptions are based on experiences is unexplained.

If one follows the presumption of freshwater influence from Vansjø, then the salt water in the bottom of the canal would flow slower than the freshwater in the canal. The described phenomenon contradicts with this potential explanation of salinity. Other influencing parameters could be wind and changing water levels. Wind could be the major driver for the surface current, following the principle of Stokes drift. Tide as key parameter for the velocity of bottom currents seems most reasonable according to current theory.

Currents are strongest inside and around the canal (P10)

Three participants stated that the currents inside and closely around the canal are the strongest currents in Moss. The exact area of "closely around" was unspecified. This can been categorized as established knowledge, since it basically follows natural law.

Strongest currents in the middle and at the north end of the canal (P11)

One participant stated that according to his experience, the strongest currents are in the middle and the north end of the canal. It was not stated whether this is related to bottom or surface currents. According to theory, the velocity is typically strongest in narrow parts, provided that no other factors influence the current motion. This would confirm the phenomenon that the currents are strongest inside the canal. The statement must be seen in cohesion with tidal current motion outside the canal. It is unclear how much of the near-canal currents actually flow through the canal. The numerical FjordOs model indicates that during high and low tide, the water level north and south of the Moss canal is similar, and the current through the canal is weak. If the water levels are unequal, water flows generally in the direction of the lower level.

Results

The data analysis identified large diversity in local knowledge and revealed several phenomena. Eleven phenomena have been extracted, but eight of them are not used for validation. The phenomena P1, P3, and P4 describe knowledge, which lacks the required characteristics for validation with the current model. Those phenomena which describe common sense (P3, P7, and P10) are excluded from the model validation, since they do not identify the genuine quality of the model. Those phenomena's individual congruence with measurements and theory has been described in the previous chapter. The phenomena P2, P5, P7, P9, and P10 are not used for validation in this paper, but could be validated using other numerical models in future research.

The phenomena P6, P8, and P11 describe distinct current motion and have been validated using the current model. Comparing these experiences with the current model identified, whether the model has the capabilities to forecast uncommon phenomena. The applied numerical model entails twenty-four plots of one tidal cycle. Respectively six of them plot current motion in high, outgoing, low, and incoming tide. The results from the validation of P6, P8, and P11 are displayed in Table 6.

Table 6: *Validation results.*

	P6	**P8**	**P11**
High tide	-	✓	-
Outgoing tide	-	✓	✓
Low tide	✓	✓	-
Incoming tide	✓	✓	-

The phenomenon P6 describes a current along the coast in the direction from south to north. The current model supports this phenomenon during low and incoming tide. P8 has been explained by one crew member of a NSSR vessel and depicts a strong current from east to west in the south end of the Mossesundet. This phenomenon is consistent with the results of the applied numerical model during the entire tidal cycle. Strongest currents in the middle and at the north end of the canal (P11), have been described by the same crew member of the NSSR vessel. High velocity of currents inside the canal follow natural law, as described in the section of the phenomena. This part of P11 is therefore seen validated with ocean theory. The applied model validates the described current motion at the north end of the canal and supports this part of P11 during outgoing tide.

The processing of the primary data revealed phenomena that were not anticipated in the initial stage of this research. In particular the effect from Vansjø was an unexpected aspect and has been discussed in the interviews with the surfer and the NSSR crew. At the beginning of the research, it was in doubt whether the island of Revlingen is of significant relevance for the ocean weather conditions in Moss. During the interviews, Revlingen was mentioned by eight respondents. The statements about the ocean weather in this area are diverse and sometimes contrary. The diver, the surfer, and one of the captains stated a calm area in the north of Revlingen. The respondents explained that the location of this area could vary with different ocean weather conditions. The same respondents mentioned that Revlingen gives shelter for wind and waves coming from south. One of the leisure boat sailors stated that the south of the island is more calm than north of this island. One captain described that currents around Revlingen are generally quite strong.

Due to this ambiguity or imprecise explanations, the phenomena concerning Revlingen have been excluded. Other experiences concerning this area describe phenomena, which are based on established knowledge. These statements include descriptions such as increasing wind speeds between Revlingen and the mainland, where the wind would follow the contour of the coastline. This knowledge does not serve the current model validation and has therefore been excluded in this paper.

Discussion

Three research questions directed the work of this paper. How to generate reliable data and valid conclusions and how to compare the experiences from local people with the numerical model results are crucial aspects in this project. They set the precondition for the answer, to what extent the ocean weather conditions from the existing model supports the experience from local people.

Semi-structured interviews have been used to acquire the primary data. This method has been chosen to allow a wide range of responses. This flexibility was necessary since it has been uncertain, which kind of knowledge would be available from local people. The interview guide had to be based on anticipated knowledge and preliminary phenomena that revealed from the current numerical model. After completion of the first interviews, the questions could be specified to the previously obtained knowledge.

Local knowledge is sometimes associated with low reliability compared to numerical facts. In order to make local knowledge a valuable and reliable source of information for validation, different procedures for obtaining and processing the data have been applied.

Internal reliability has been increased during data acquisition by two methods. Most interviews discussed several aspects of ocean weather. During this, much overlap in answers was generated. The degree of consistency from the different answers which correlate is an indicator for the internal reliability. The second method that has been used, is the division of interviews into two rounds. The first six interviews provided an indication of the kind of knowledge that is obtainable from local people. The second round included interviews with five participants. This identified a high level of correlation between the answers from the first and the second interviews. Preliminary selected phenomena have been discussed, since not mentioning from participants does not imply non-experience. Internal validity is ensured by including different sources of data from established literature and measurements. Consistency with different sources of information increases validity.

Methodological triangulation, as proposed in Miles et al. (2014), has been performed to test the meaning and quality of the phenomenon P3. One captain working on board filled out an observation schedule during three consecutive days. Comparison of this observation data with the phenomenon increases the internal validity of P3. It must be emphasized that observations can only be indicative. Wave heights and directions are approximated and observational uncertainties can be large, as described in Gulev et al. (2003).

Grinde (2011), applied measurements to validate a numerical ocean weather prediction model in the Oslofjord. Measurements are outside this thesis' scope, but could be a valuable tool for future research in cohesion with the results from this project.

During the work on this paper, the comparison of the heterogeneous data has been a challenge. To know the method of analysis before collection of the data can be a helpful advice. For this project, the obtainable data was inexplicit and did not allow precise definition of the method before several interviews have been accomplished. For the comparison of findings, the researcher prepared several maps with the results of the interviews. These charts have been helpful illustrations for the analysis process. The use of colours for different categories improved the clarity and the charts have been issued using computer software. Charts drawn by hand proved to be of insufficient clarity.

The distribution of participants over several role domains is valuable for this project, since it provides different perspectives for several phenomena. The participants are similar enough to compare their knowledge and use the variety for the common objective of the thesis. The samples in each role domain are however not large enough for generalisation of results. The phenomena P2, P3, P8, P9, and P11 have been mentioned by only one participant. This does not necessarily reduce the quality of the phenomenon. Phenomena with few respondents are considered for validation, if the description seems plausible with respect to theory or measurements.

A major distinction for the role domain of professional and leisure boat sailors could be drawn for the size of the ships. The pilot and one captain stated, that wind is the major challenge for manoeuvring in Moss, whereas the participants in leisure activities with typically smaller boats seem to be effected by the coaction of all ocean weather forces. Waves and currents in Moss do not seem to be problematic issues for the respondents in the role domain of captains, officers, and pilots.

As stated by respondents across the role domains, in particular current motion is ambiguous to identify. The distinction from wind and wave interference can be ambivalent. Hinton (2004) describes the different perception of people to see and feel as a large compounding influence in research.

The captains, officers, and pilots often possessed long experience in their activity. During the analysis it became evident, that the duration of experience is not always indicator for the richness of ocean weather knowledge. Sailors with several years of experience develop routines, which can constrict the awareness for ocean weather phenomena. This is not necessarily the case for every sailor and depends on personal attitude and on board duties. The participants A1 and A4 perform leisure activities in the Oslofjord in addition to their maritime profession. These respondents explained knowledge about waves and current motion, that is more precise compared with other professional sailors. It may therefore be anticipated, that multiple maritime activities increase the respondents' perception of ocean weather.

Some respondents use electronic instruments such as GPS in addition to their visual perceptions of natural appearances. Those devices can influence the quality of the data in either positive or negative direction. In one way it does increase the reliability of using the data, but technical support could also limit the willingness or ability to do observation at the same time. This research does not differentiate between users and non-users of such devices, as the actual benefit varies largely between participants and the genuine effect on natural observations is unclear. This equal treatment has no essential impact on the quality of the conclusions in this research.

It might be assumed, that diving allows deep insights in current motion, since the activity is entirely under water. Larger samples of divers in future research could examine whether the assumption can be supported. The two leisure boat sailors provided knowledge for all three ocean weather categories. The surfer contributed knowledge in all categories, with precise experiences for wind conditions in Moss. This sound knowledge corresponds with the researchers' anticipation, since surfers are very dependent on wind force and direction. The crew of the NSSR vessel stated knowledge for all ocean weather categories. They could contribute with experiences from the Moss canal, since the boats' dimensions allow passing through the canal. The NSSR crew frequently operates in the Mossesundet and the canal. This local focus for the Mossesundet and the canal, which other respondents do not have, seems to be one reason that P8 and P11 have both only mentioned by a member of the NSSR crew. The phenomenon P6 has been stated by respondents in four of the five role domains. This distribution over the role domains indicates, that the phenomenon is observable across many different maritime activities.

The numerical model supports P6 during low and incoming tide. Validation of the numerical model is therefore partly proven. The phenomenon P8 is supported by the results from the current model during high, outgoing, low, and incoming tide. The model is therefore sufficiently consistent to declare genuine validation for this phenomenon. P11 contradicts with the results from this numerical model during high, low, and incoming tide. This does not necessarily mean that the phenomenon does not occur. It rather seems justified from ocean theory, that currents are strongest in the northern part of the canal during outgoing water, as the water masses from the funnel shaped Mossesundet will concentrate in this area.

This paper used the three phenomena P6, P8, and P11 for numerical model validation. Future examination and validation of the interview data in cohesion with other numerical FjordOs models could reveal additional findings, which have not yet been extracted. The phenomena P2, P5, P7, P9, and P10 are not used for validation in this paper and could provide the initial position. Further extracted primary data includes potential research aspects such as

- Do currents in the north of Gullholmen intensify with increasingly deep water?
- Which is the direction and velocity of current motion inside and around the canal?
- How strong is the influence of freshwater from Mosseelva during different seasons?
- Does the combination of southern wind and outgoing tide typically effect the strongest current motion inside the canal?

Future research in these area should narrow down the focus on particular local areas, such as Revlingen. Interviews with clearly defined topics, like certain ocean weather categories, comprehend the risk of eliminating interesting aspects, which are just outside the research scope. The benefit however, can be substantial acquisition of information on a specific topic. Furthermore, it seems advisable to increase the number of samples. Inclusion of different role domains is beneficial, together with the use of purposive sampling to select respondents.

Conclusion

This paper examined local ocean weather knowledge and applied three extracted phenomena for validation with one current FjordOs model. The validation results indicate the quality and capacity of this ocean current model. The paper describes a method which allows the generation of reliable data from local ocean weather knowledge. The validation of data with heterogeneous characteristics has been enabled by essential data selection and reduction.

The analysis of the graphical illustrated results revealed, that one phenomenon from local knowledge is consistent with the results of the numerical model. One validation result is ambiguous. The described phenomenon coincides with the results of the applied model during low and incoming tide, but not during high and outgoing tide. The third phenomenon is supported by the numerical model during outgoing tide, whereas not during high, low, and incoming tide. These validation results allow the conclusion, that comparison of these heterogeneous types of data is possible. The extent of consistency between the applied model and the extracted local knowledge indicates conformity.

This model validation increases the reliability of the preliminary model results and can be used to adjust the foci of other available and future numerical models from FjordOs. The local knowledge and validation results could also assist in the ongoing Moss harbour planning process. The port authority can use the phenomena for valuable insights of local people in the Moss ocean weather conditions.

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Appendix A

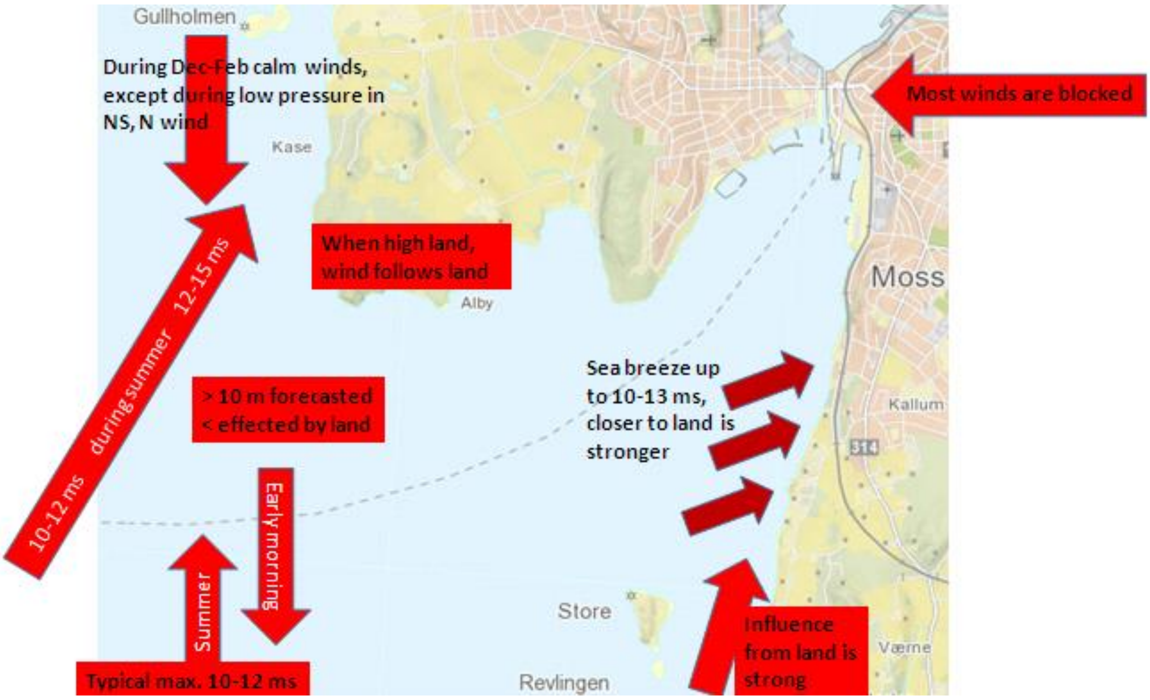

Figure A1: Thematic chart of wind from participant A1.

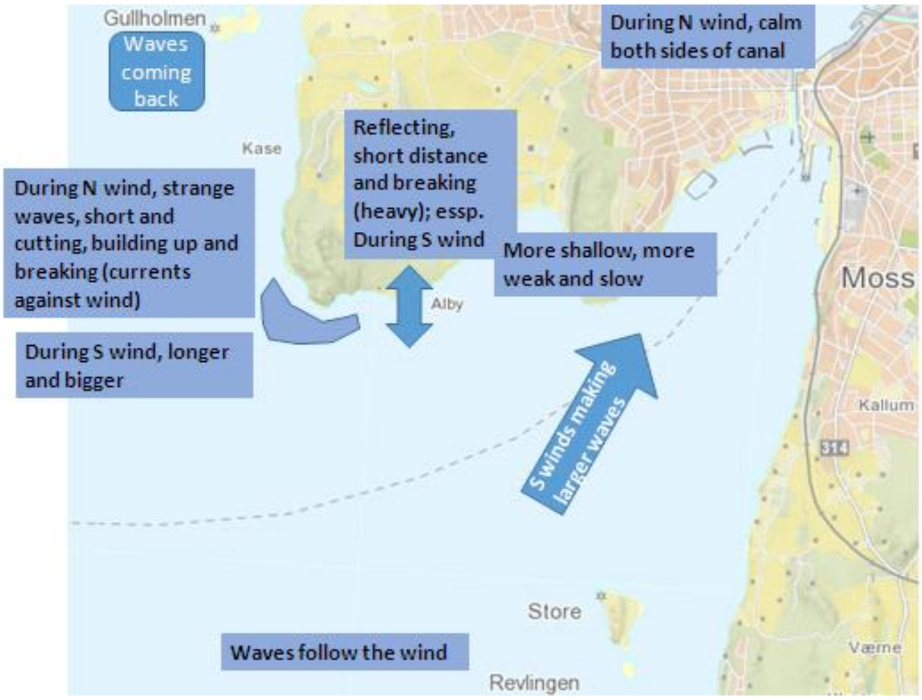

Figure A2: Thematic chart of waves from participant A1.

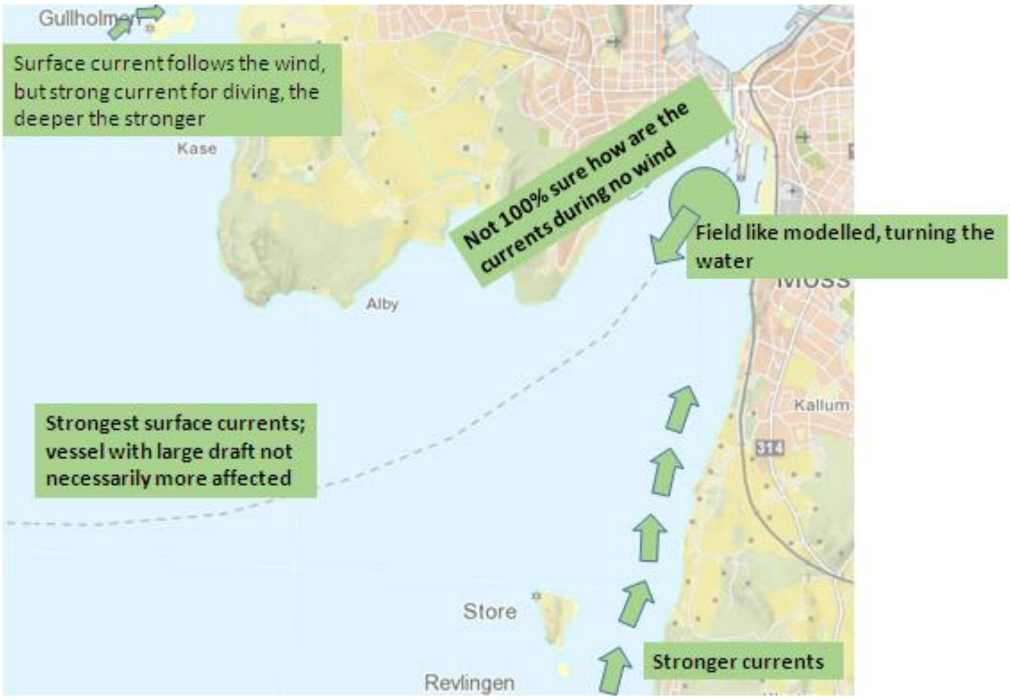

Figure A3: Thematic chart of currents from participant A1.

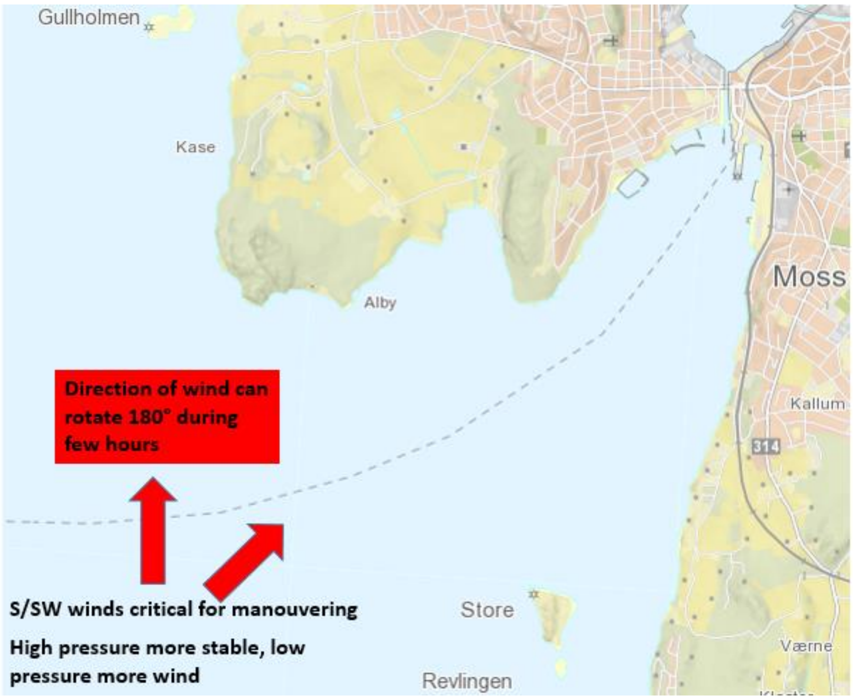

Figure A4: Thematic chart of wind from participant A2.

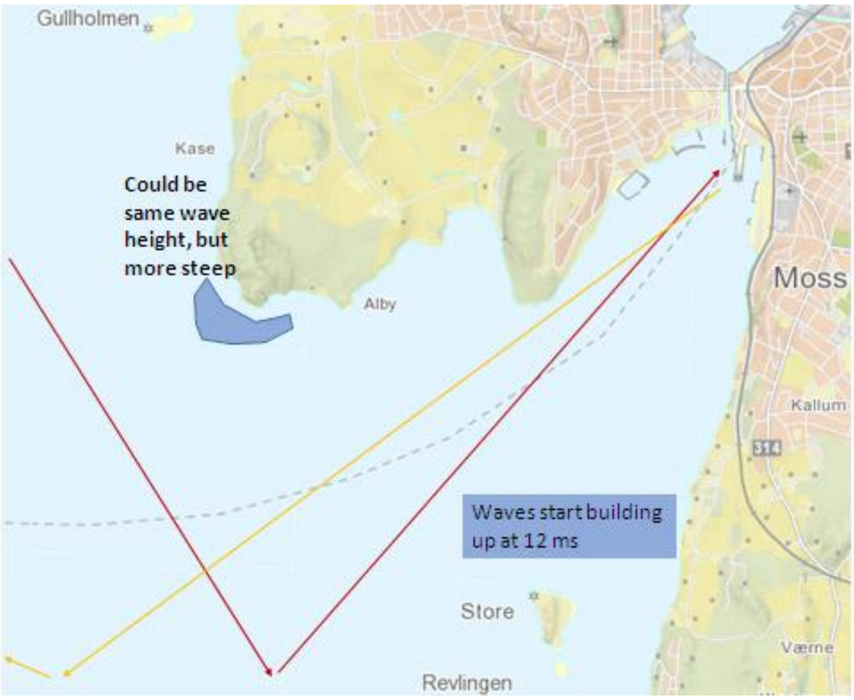

Figure A5: Thematic chart of waves from participant A2.

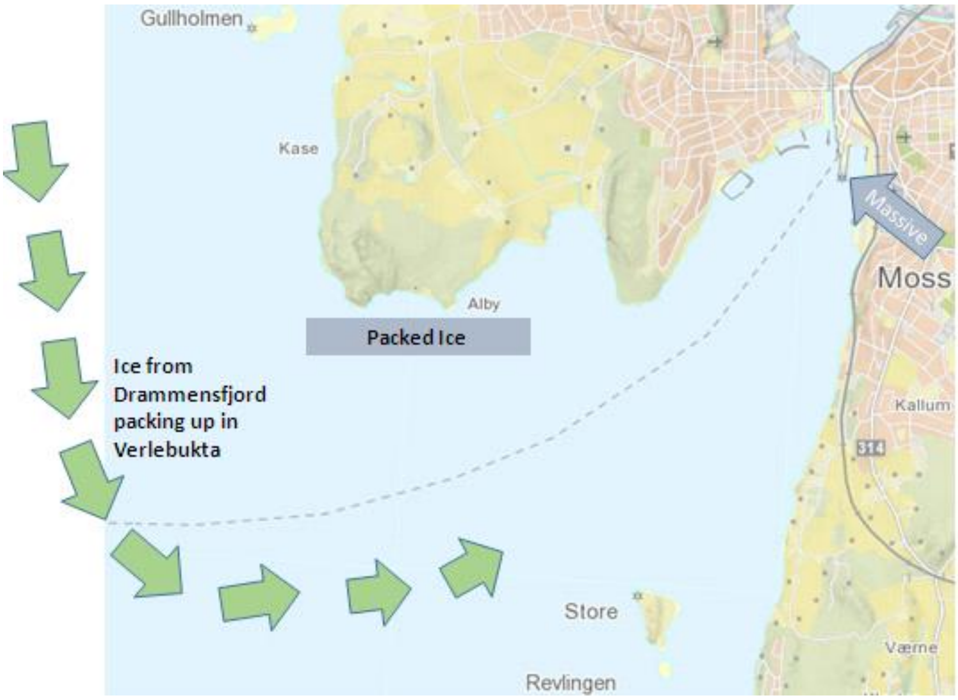

Figure A6: Thematic chart of currents from participant A2.

Figure A7: Thematic chart of wind from participant A3.

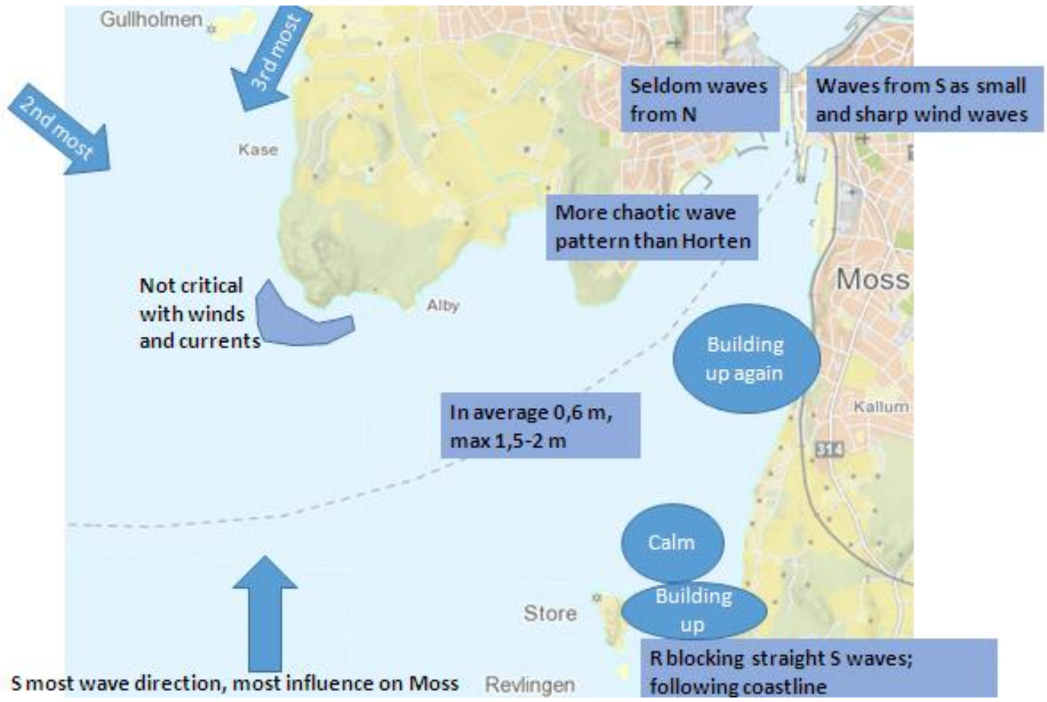

Figure A8: Thematic chart of waves from participant A3.

Figure A9: Thematic chart of currents from participant A3.

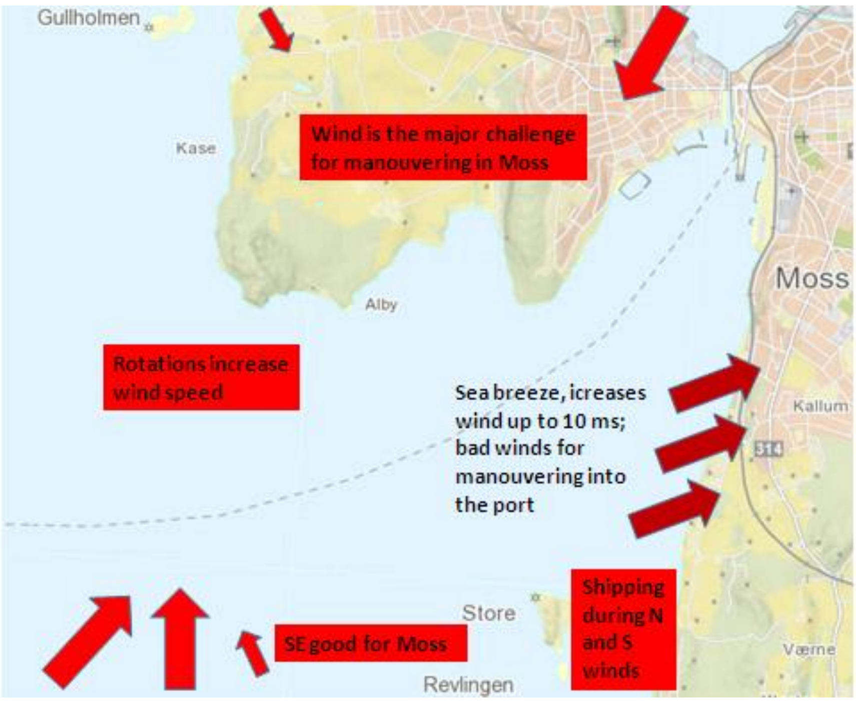

Figure A10: Thematic chart of wind from participant A4.

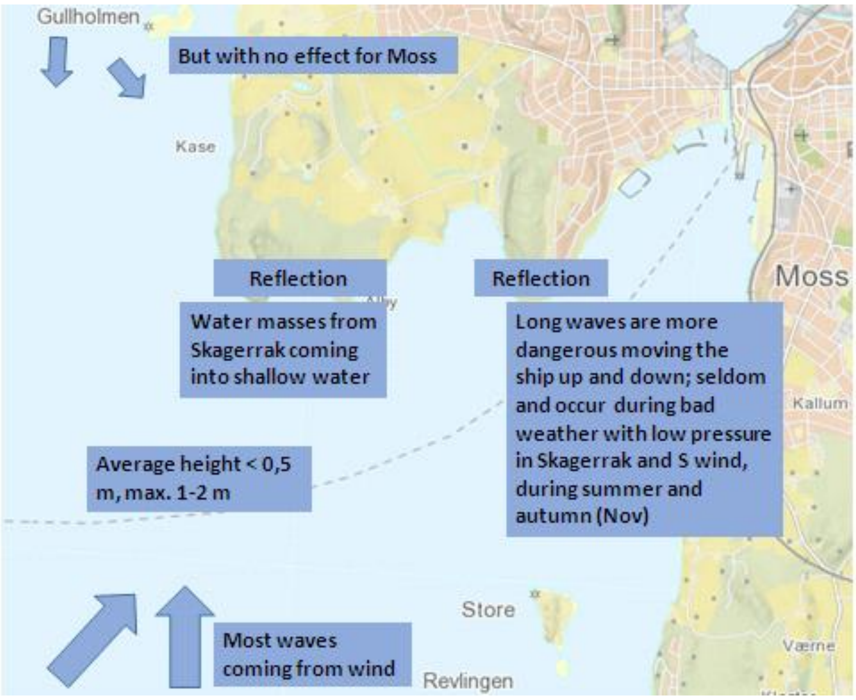

Figure A11: Thematic chart of waves from participant A4.

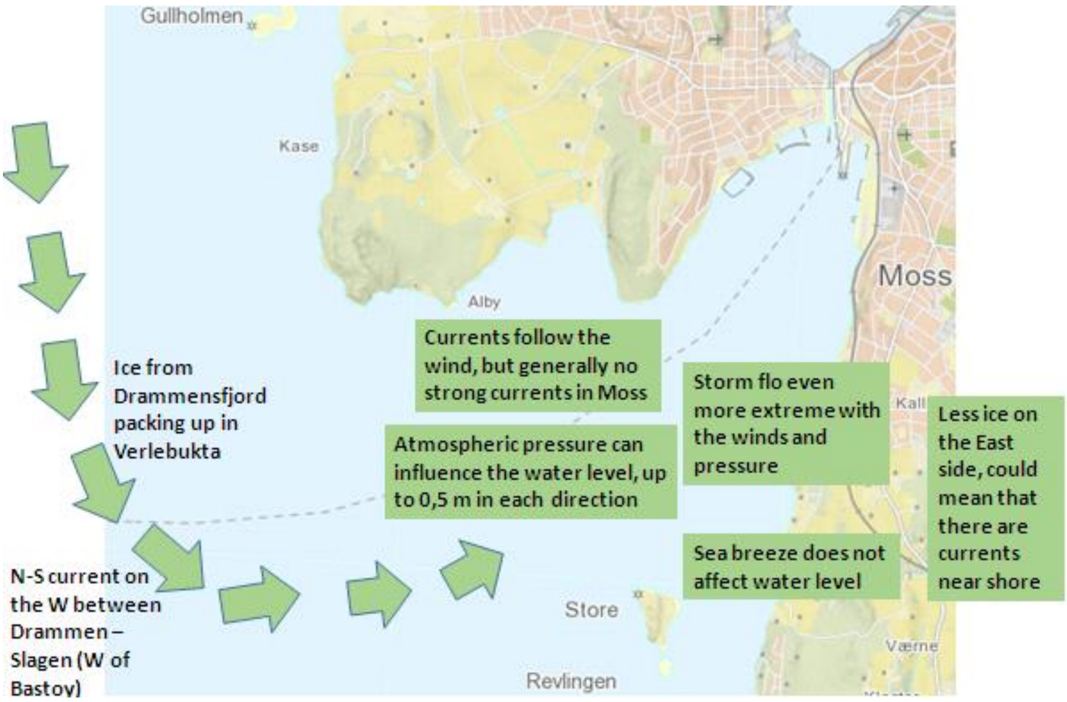

Figure A12: Thematic chart of currents from participant A4.

Figure A13: Thematic chart of wind from participant A5.

Figure A14: Thematic chart of waves from participant A5.

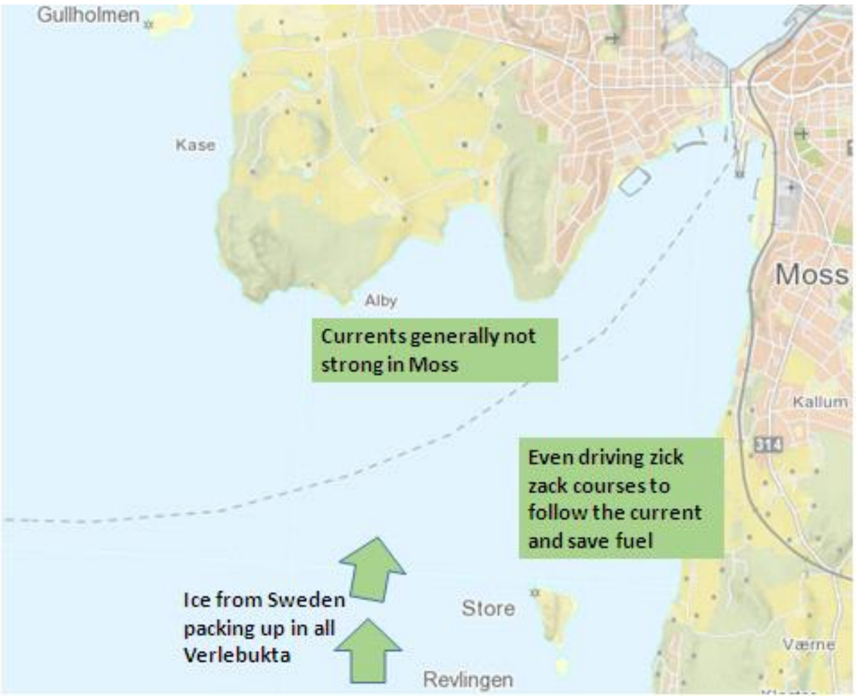

Figure A15: Thematic chart of currents from participant A5.

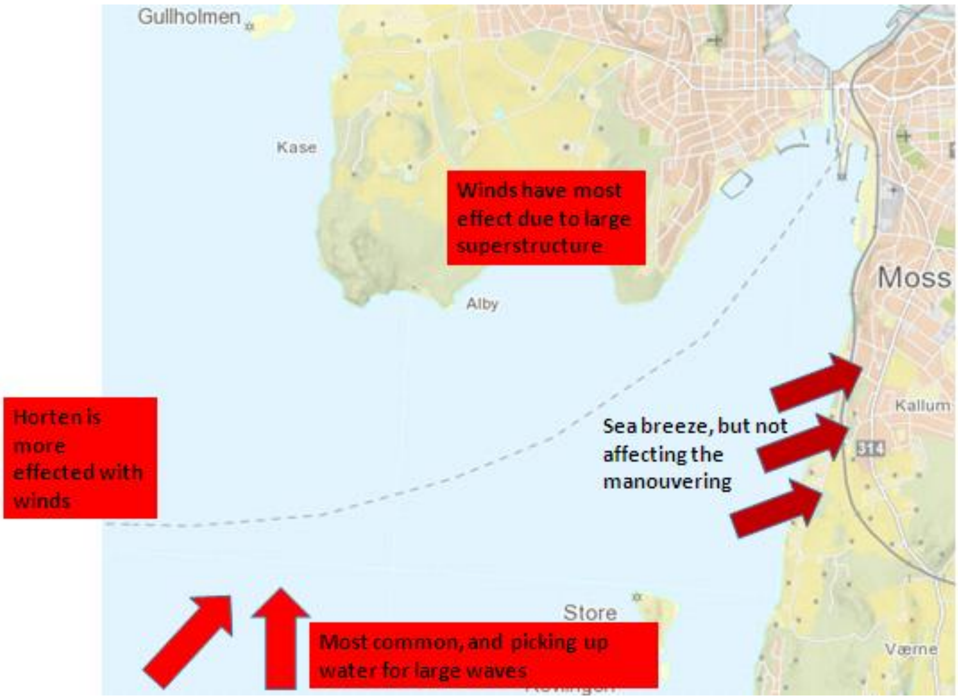

Figure A16: Thematic chart of wind from participant A6.

Figure A17: Thematic chart of waves from participant A6.

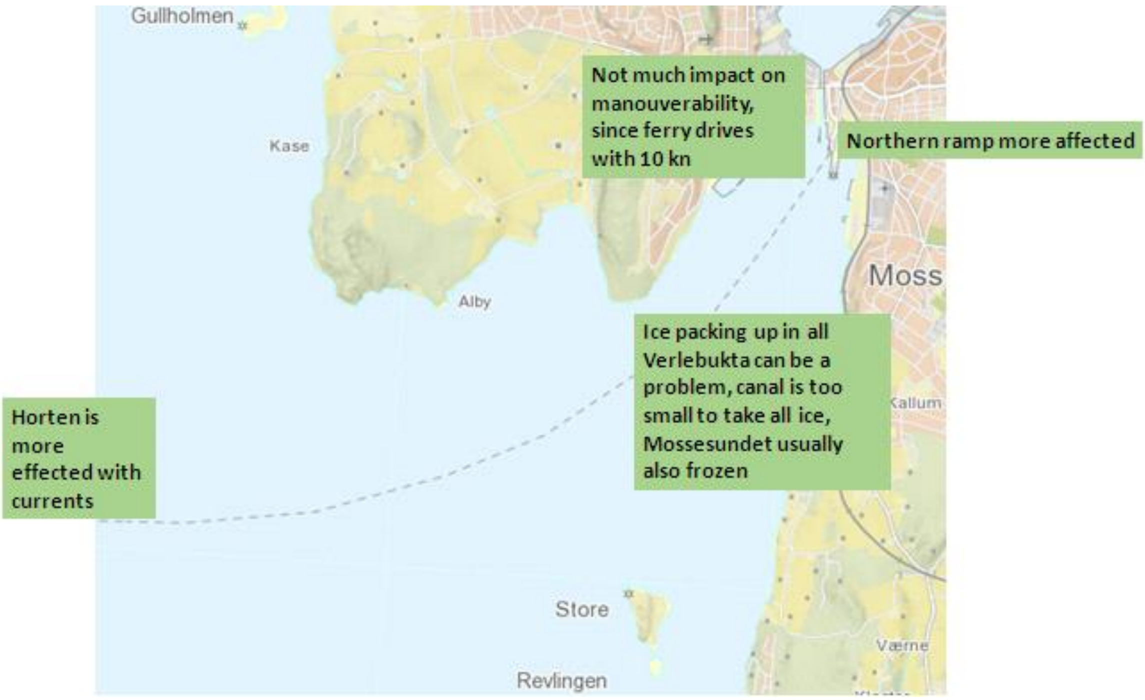

Figure A18: Thematic chart of currents from participant A6.

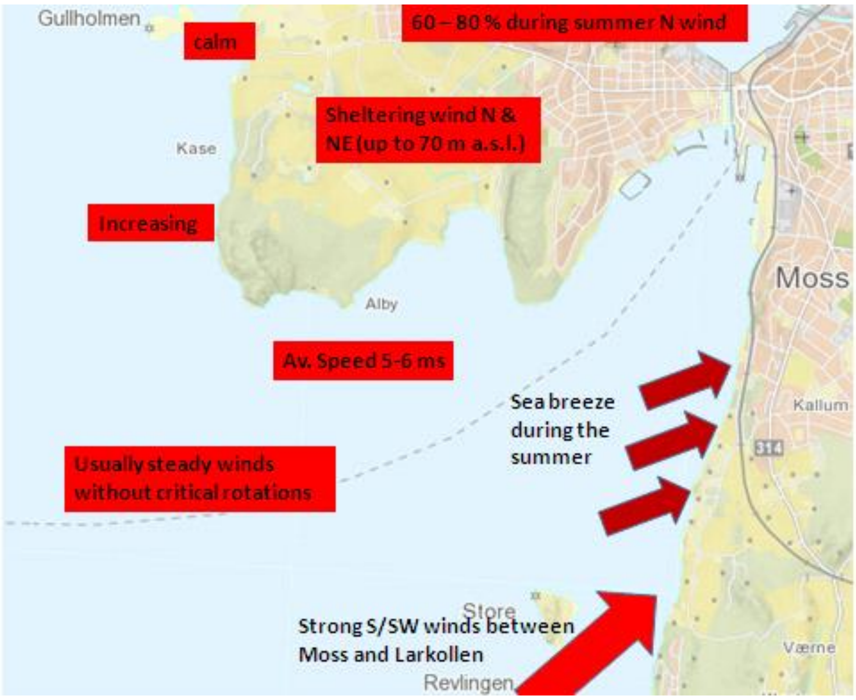

Figure A19: Thematic chart of wind from participant B1.

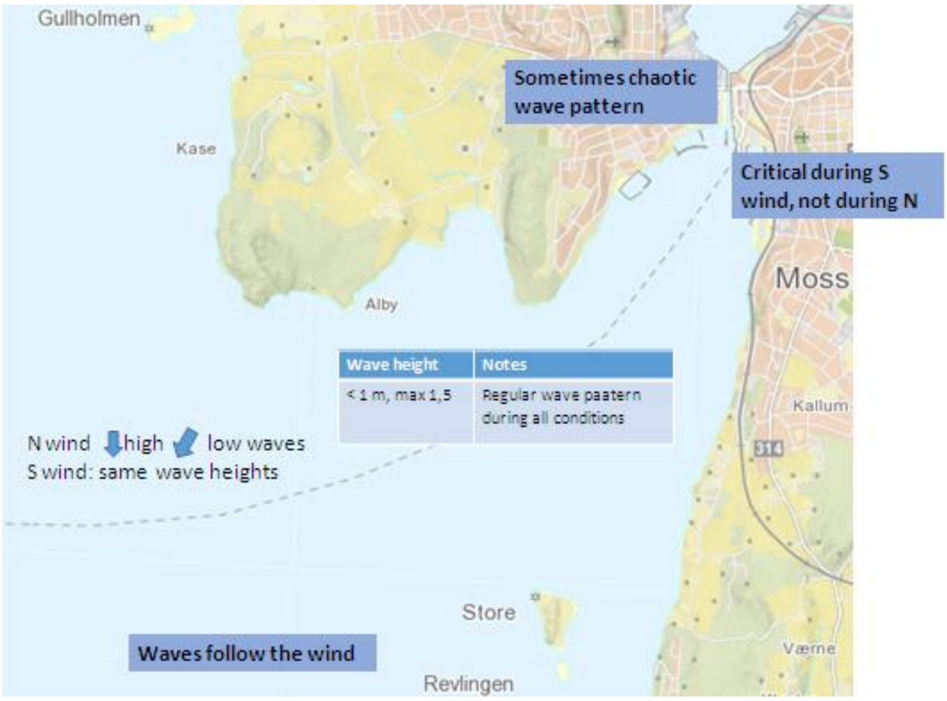

Figure A20: Thematic chart of waves from participant B1.

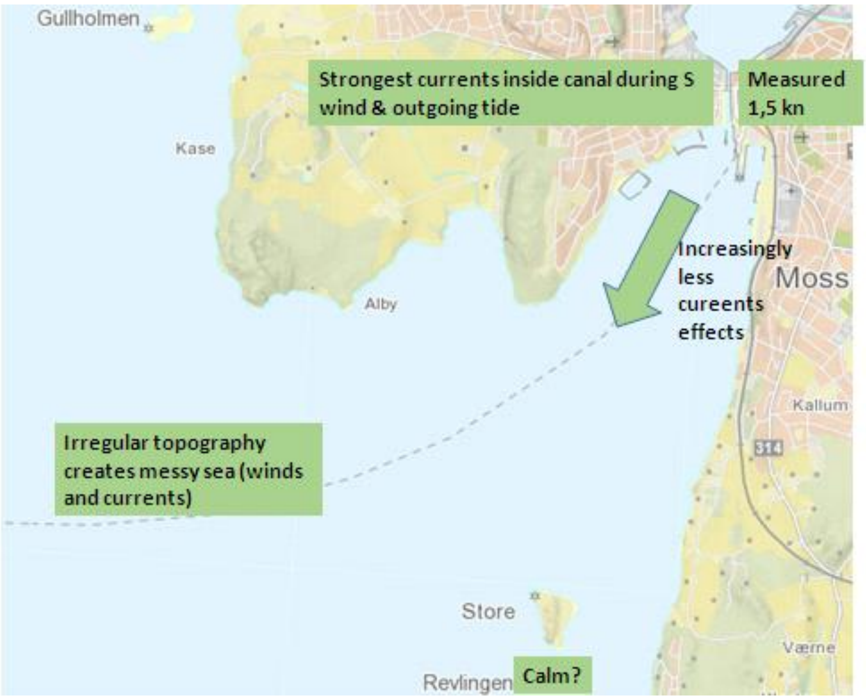

Figure A21: Thematic chart of currents from participant B1.

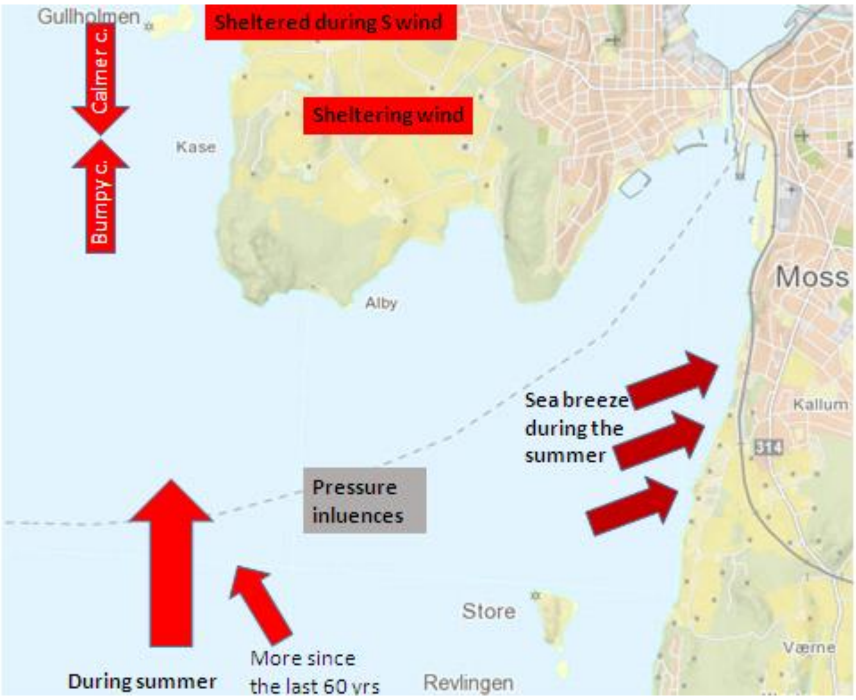

Figure A22: Thematic chart of wind from participant B2.

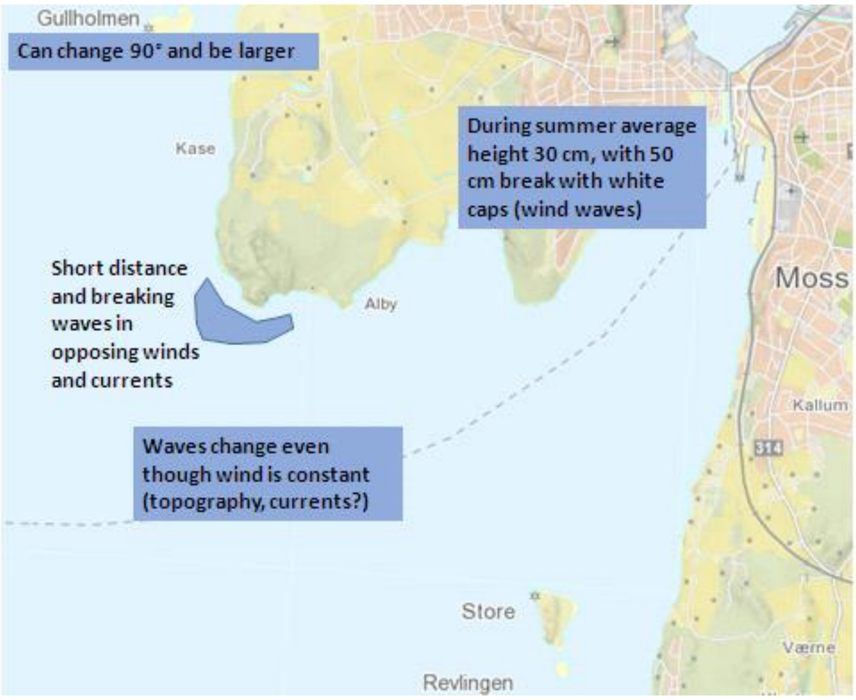

Figure A23: Thematic chart of waves from participant B2.

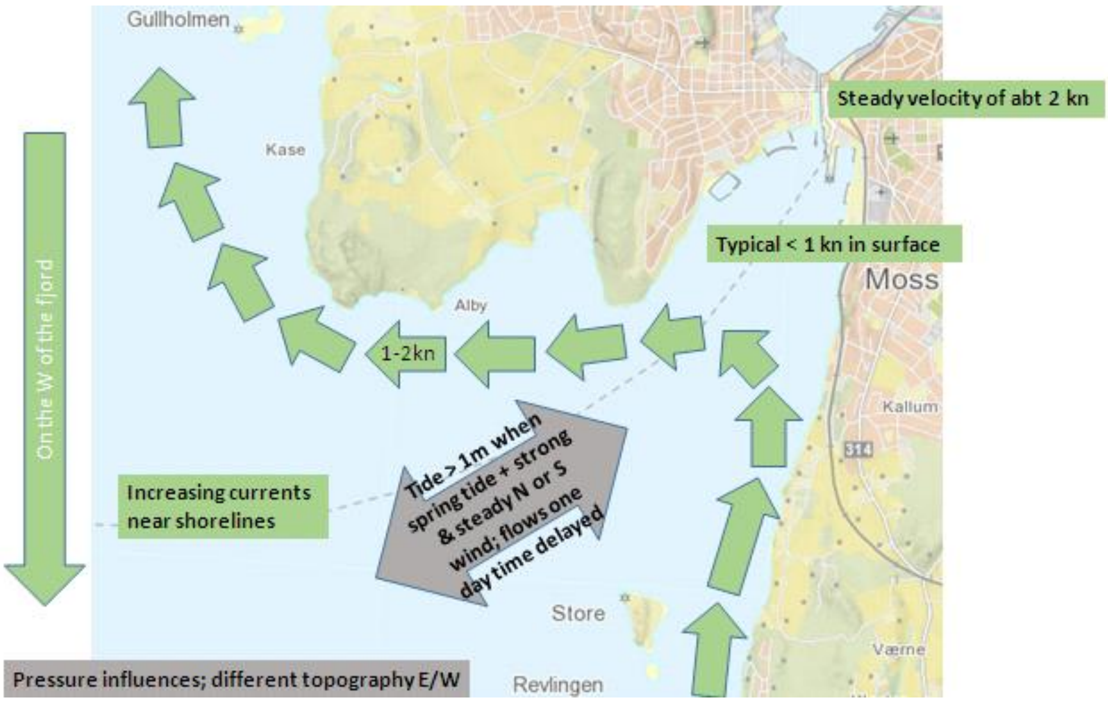

Figure A24: Thematic chart of currents from participant B2.

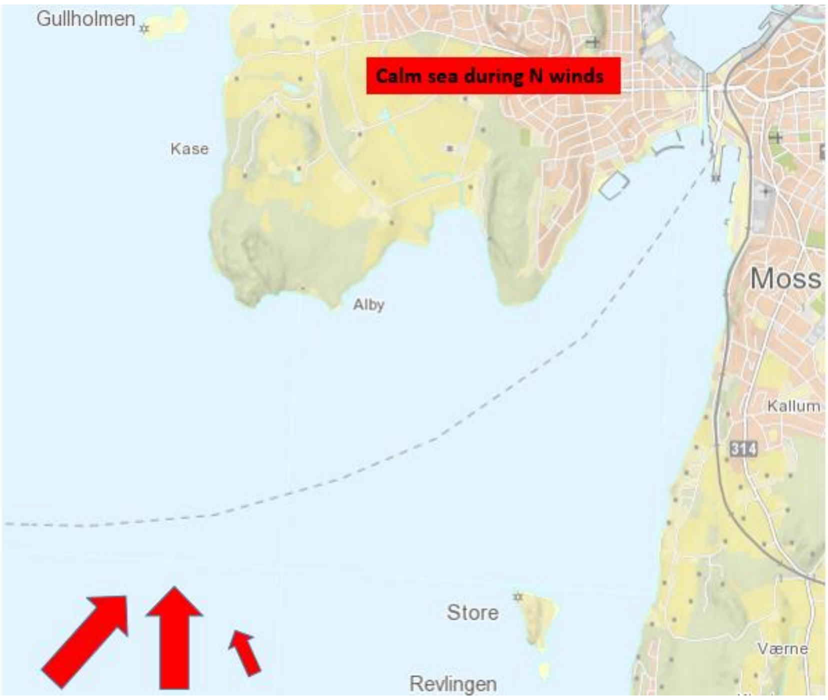

Figure A25: Thematic chart of wind from participant C1.

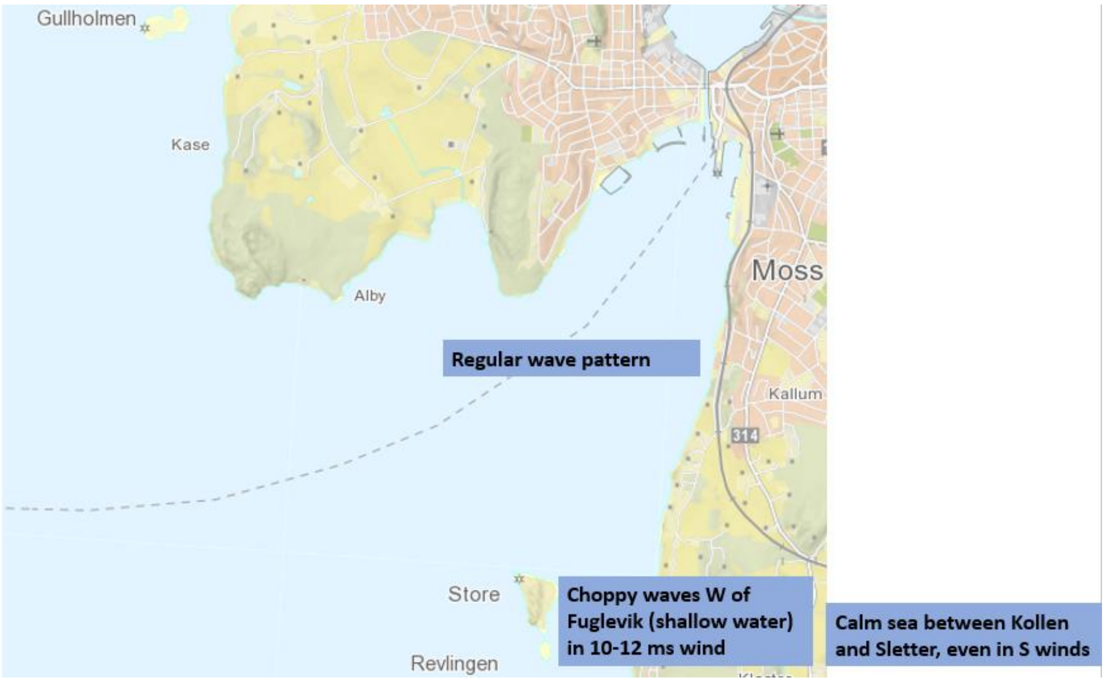

Figure A26: Thematic chart of waves from participant C1.

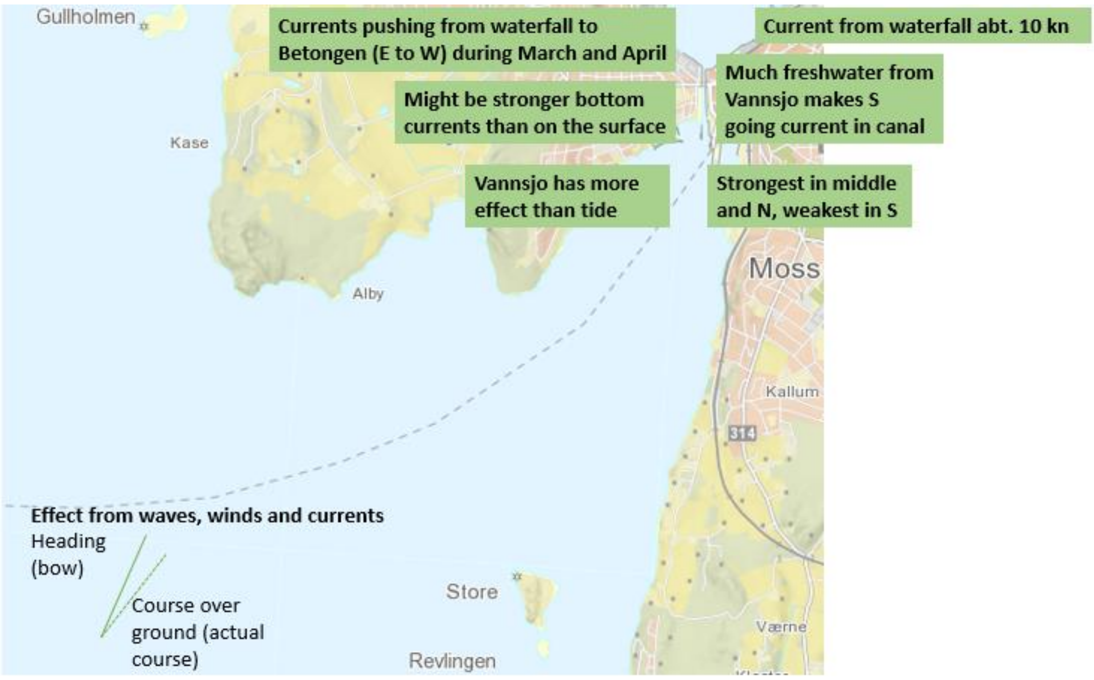

Figure A27: Thematic chart of currents from participant C1.

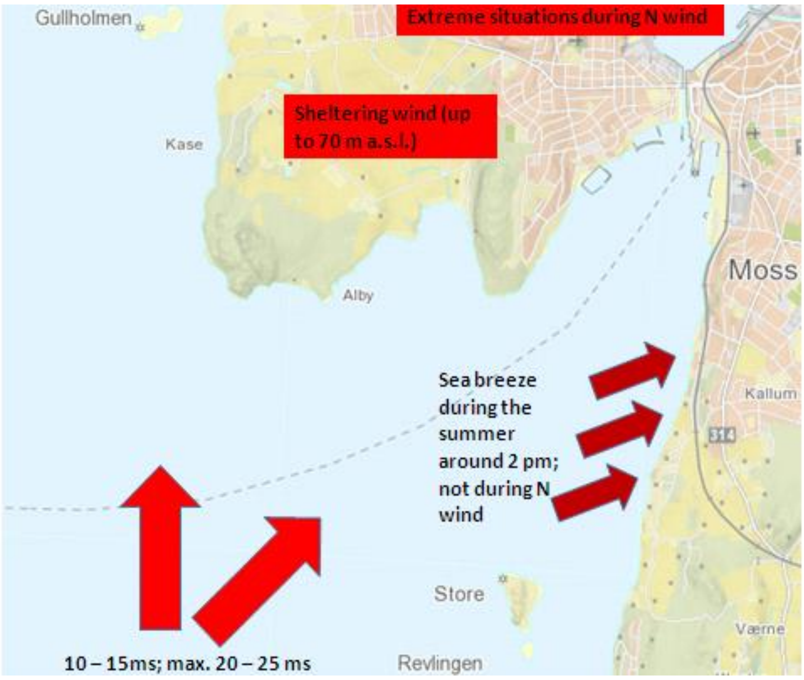

Figure A28: Thematic chart of winds from participant D1.

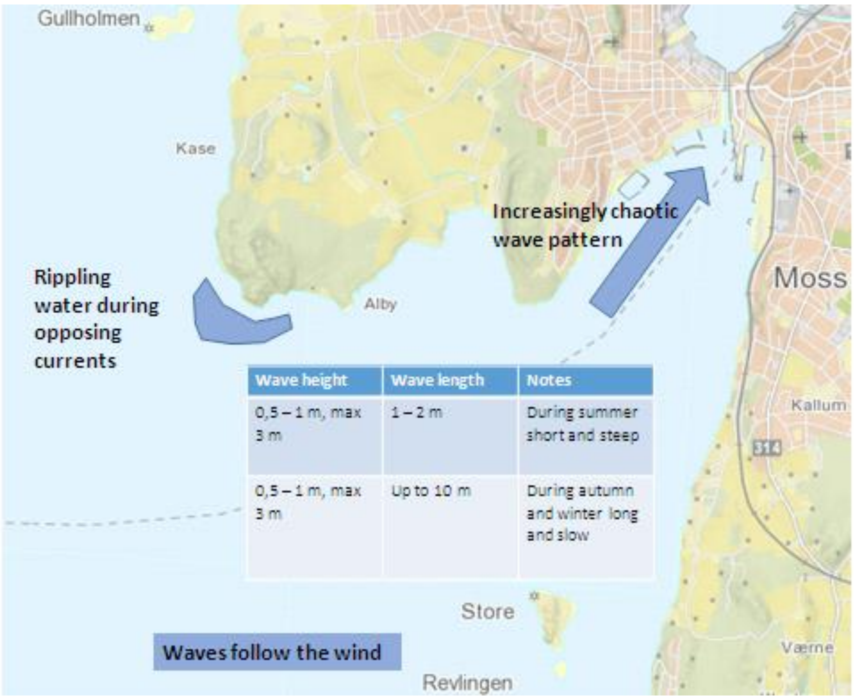

Figure A29: Thematic chart of waves from participant D1.

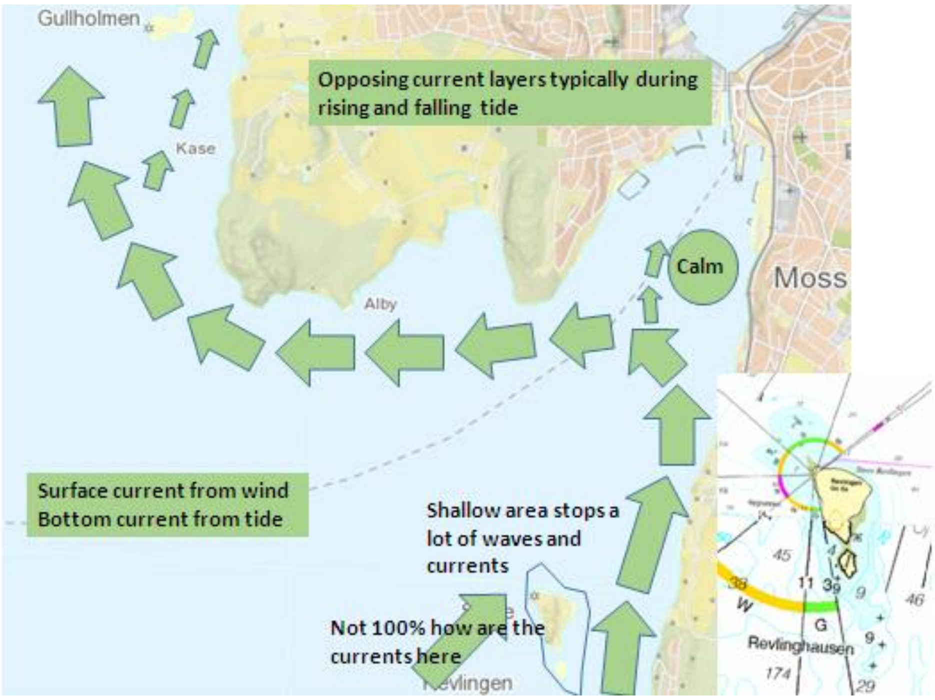

Figure A30: Thematic chart of currents from participant D1.

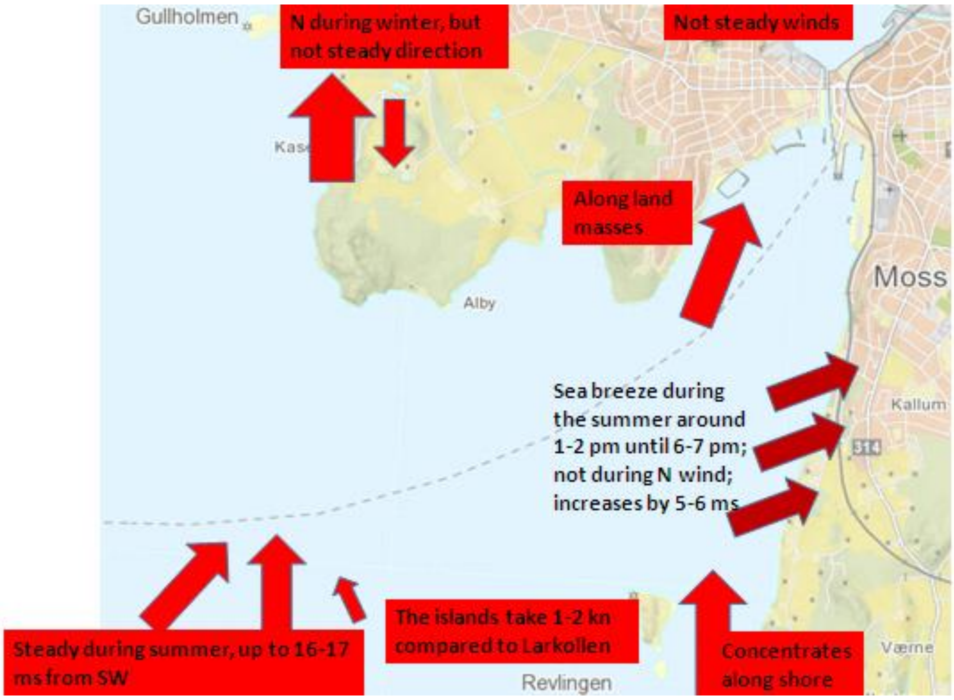

Figure A31: Thematic chart of winds from participant E1.

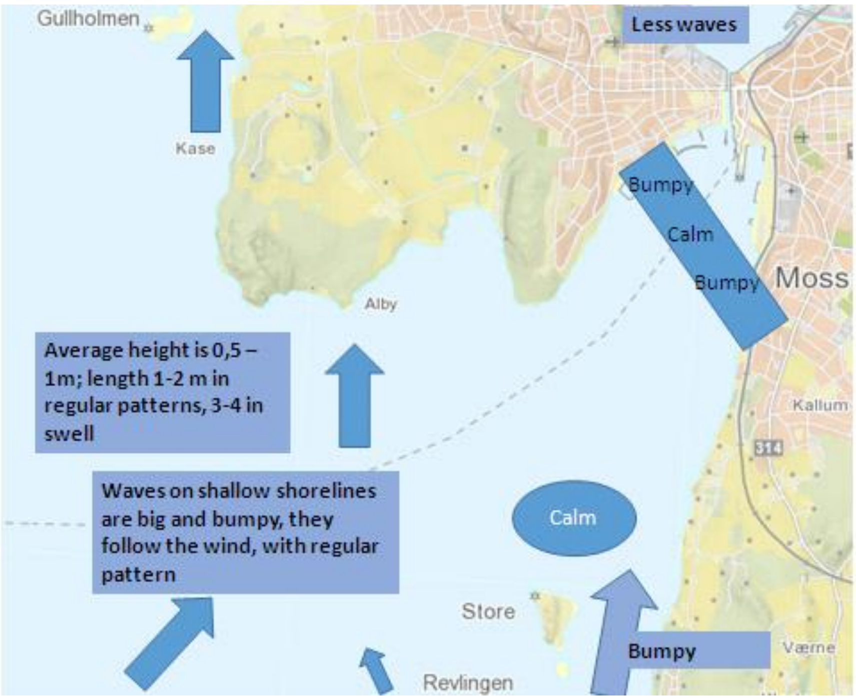

Figure A32: Thematic chart of waves from participant E1.

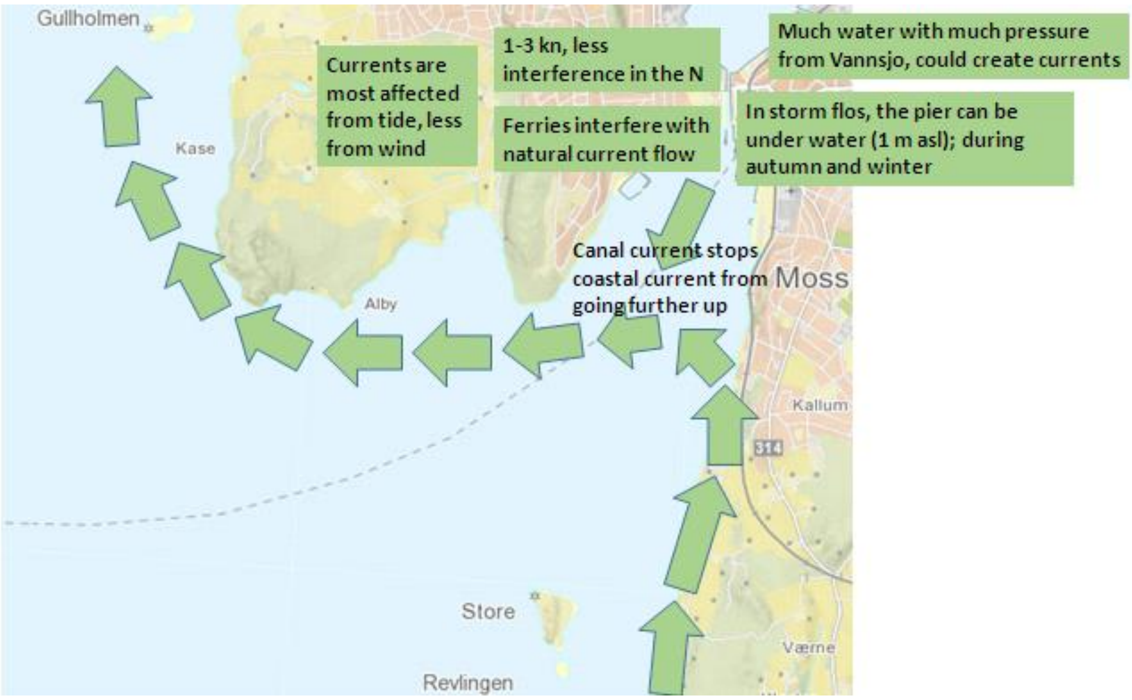

Figure A33: Thematic chart of currents from participant E1.

Appendix B

Observation schedule of ocean weather conditions during 13.-15. April 2014.

Time	Area	Wind		Wave			Tide	Notes
-	-	Direction (from)	Force (m/s)	Direction (from)	Height (m)	Pattern (chaotic or regular)	Incoming, High, Outgoing, Low	-
1430	Moss	Sw	4	sw	0,5	reg	Incoming	13 april
1600	„	w	4	ssw	0,5	reg	incoming	„
1700	**M**	sw	3	w	0,5	reg	incoming	„
1800	**M**	sw	3	w	0,5	reg	incoming	„
2000	**M**	sw	3	w	0,5	reg	high	„
1100	**M**	N	3		0		low	14 april
1400	**M**	N	4		0		Incoming	14 april
1800	**M**	N	3		0		Incoming	14 april
0900	M	N	5	N	0.5	Chaotic	outgoing	15 April
1200	M	N	5	N	0.5	Chaotic	low	15 April
1500	M	N	3	N	0		Incoming	15 April
1800	M	N	1	N	0		High	15 April