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Contents

1 **The Energy Efficiency Gap in Maritime Transport**
Michele Acciaro, Peter Nyegaard Hoffmann and Magnus Strandmyr Eide

11 **Sea Trials of a Wave Energy Converter in Strangford Lough, Northern Ireland**
Vladimir Krivtsov, Ian Bryden, Brian Linfoot and Robin Wallace

21 **Marine Accident Analysis with GIS**
Ozkan Ugurlu, Umut Yıldırım and Ercan Yuksekyıldız

30 **Investigation of Shoreline and Topographic Change on the West Side of the Imagire-Guchi Inlet, Japan**
Andi Subhan Mustari, Shigeru Kato, Takumi Okabe and Mieko Kataoka

40 **Views from Maritime Education and Training on the Full Implementation of 2010 STCW Amendments**
Ruan Wei

47 **Role of Naval Architects in Ship Recycling**
Sivaprasad K. and Nandakumar C. G.

55 **Some Peculiarities of the Preprocessing of Spectral Data and Images**
Valentin Atanassov, Georgi Jelev and Lubomira Kraleva

61 **Investigating the Effect of Winds and Storms on Shoreline Erosion along the Coast of Tanzania**
Shigalla Mahongo and Yohanna Shaghude

Journal of Shipping and Ocean Engineering 3 (2013) 1-10

The Energy Efficiency Gap in Maritime Transport

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Abstract: There is evidence that the shipping industry could achieve energy efficiency gains through the implementation of new technologies, with considerable reductions of fuel costs and emissions to air in the sector. Although the cost reducing effects of some new technologies are well established, companies appear reluctant to innovate despite the financial and societal benefits, as a result of what is referred to as the energy efficiency gap. The global emission impacts of the shipping industry, most notably of greenhouse gases, sulphur and nitrogen oxides are increasingly attracting the attention of regulators, non-governmental organisations and the media, and shipping companies are under pressure to find new ways to reduce their emission footprint. Understanding the determinants of the energy efficiency gap in shipping is then critical in improving the environmental profile of the industry. This paper presents the results of a survey among Norwegian shipping companies aimed at gaining a better understanding of the barriers to implementation of new cost saving technologies. The paper assesses the technical barriers that have traditionally been indicated as the main cause of the energy efficiency gap in shipping. The paper results indicate that next to technical factors, important barriers are constituted also by managerial practices and legal constraints.

Key Words: Energy efficiency gap, emission reduction technologies, barriers, maritime transport.

1. Introduction

CO_2 abatement measures have beneficial effects on the company bottom line by reducing the fuel bill [1]. It would therefore be expected that these measures are adopted independently of their CO_2 reduction potential. In practice though, we observe that the degree of implementation of economically viable technologies is slower than expected if appropriate incentives are not provided.

This reluctance to adopt economically beneficial technologies is often referred to as *barriers to energy efficiency* [2] or the *energy efficiency gap* [3]. The literature on barriers in shipping is limited [3, 4] although in the last few years a few studies have been published. Gordon [5] carried out a survey among ship owners and shipbuilders in the UK. From the 69 valid responses the Author concluded that barriers in shipping are mostly related to costs and risks, low awareness of the potential of different energy options and split incentives between ship-owners and charterers. The survey focused only on five technologies[1] and four main barriers. Of those measures the most promising appeared slow steaming although in this case charter requirements turned out to be the large obstacle to implementation. The analysis is limited to only a handful of measures and for the current study it was believed that a larger set of technologies and a more detailed analysis of barriers should be performed.

In addition to Gordon [5] few other studies have conducted surveys or company analysis in shipping. Some studies are based on case studies or in depth interviews. Girard [6] makes use of multi criteria decision analysis to assess the level of barriers connected to 25 technologies in a case study involving the Grieg Shipping Group. Similarly Hoffmann et al. [7] performed an analysis on 21 measures on another

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[1] Waste heat recovery, Hull/propeller optimisation, Propeller features, Anti-fouling measures, Slow Steaming.

shipping company. Those studies identify in shipping the existence of institutional or market barriers, such as contractual arrangements, and technical barriers related to costs and complexity of installation.

Johnson et al. [8] provide an analysis of barriers in a short sea shipping company. In their study they highlighted the importance of management practice and organisational culture in achieving energy efficiency. Among the factors discussed they highlight the role of project management capabilities, ship-shore communication, division of responsibilities, access to performance measurements, and competence in energy efficiency.

These results are a further elaboration of some ideas presented in Johnson and Andersson [3, 9]. In those two studies the Authors aimed at identifying the causes of the energy efficiency gap in shipping through a set of targeted interviews. The studies highlight that in addition to the cost, uncertainty and information asymmetries in many shipping organisations the energy efficiency gap is the result of internal organisational issues, such as fragmentation of responsibility in taking action concerning energy use and organisational structures that prevent learning and innovation and can be formalised as principal-agent problems.

This paper presents the results of a survey carried out among members of the Norwegian Shipowners' Association. Respondents constitute approximately ten per cent of Norwegian ship-owners with tonnage and assessed a set of 12 CO_2 emission abatement technologies. The analysis builds on a method to rank barriers presented in Acciaro et al. [4]. Parts of the methodology have been tested using the CO_2 Abatement Screening Tool (CAST) on a shipping company with positive feedback that has highlighted that there is great value in adding a dimension of barrier scoring to the decision process related to abatement measures [7]. The results of the present paper are consistent with those of the case studies developed in Hoffmann et al. [7] and Girard [6].

The paper is structured in the following way. The next section dwells on the energy efficiency gap in shipping with reference also to other industries and provides a brief taxonomy of barriers. Section three presents the methodology and structure of the survey and the results of a preliminary study. Section four presents the main finding of the survey and section five concludes and provides indications for further research.

2. Barriers to Energy Efficiency in Shipping

On the basis of Sorrell et al. [2], Sudhakar and Painuly [10], Girard [6] and Acciaro et al. [4] this study groups barriers to energy efficiency in shipping in the following categories:

(1) *Safety and reliability*. This relates to the risk associated with the implementation of new technologies that can potentially compromise the safety of the crew, or the vessel or of operations. Reliability refers to the risk that the installed measures could affect the ability of the ship to sail.

(2) *Technical uncertainty*. Encompasses all issues related to the interaction between different ship components when new or unproven technologies are brought onboard of the ship. The maturity of the technology is another influencing factor.

(3) *Behavioural barriers*. This set of barriers is related to the interaction within the shipping firm and the availability of information across the organisation. The lack of, quality of and/or awareness of information regarding different aspects of a new measure could often be a barrier.

(4) *Market constraints*. A common example of market constraints is related to split incentives deriving from the structure of charter parties and how costs are shared between cargo owners and shipping companies. In general they refer to regulatory issues and market inter-firm practices, e.g., demurrage charges.

(5) *Financial and economic constraints*. Most measures require an upfront investment cost and their economic viability is linked to market conditions, fuel

prices etc. All cost elements will be included among this set of barriers, including capital costs, operation costs and hidden costs, e.g., maintenance, spare parts etc. A further barrier in this category might be linked to the ability of the ship-owner to access capital.

A.*Complexity*. Often new technologies are complex to install and operate. The more complex the implementation and operation of a new measure is, the more this hampers the rate of implementation. Many shipping organisations are set up to handle normal day to day operations and any added complexity will be seen as an unwanted burden. In shipping this can increase the burden on the crew.

3. Survey Methodology

3.1 Preliminary Study and Focus Interviews

In preparation of the survey a preliminary barrier analysis was performed in 2010 based on a set of structured interviews in a Norwegian ship-owning company [7]. The interviews involved eight respondents. The results of the preliminary study showed that there was a need for a better understanding of the energy efficiency gap in shipping.

3.2 Questionnaire Methodology

The analysis performed in the preliminary study was aimed at testing the barrier framework and preparing for a more elaborate study. During the spring of 2011 a new questionnaire was developed and its composition verified with DNV internal experts and representatives of the Norwegian Ship-owners' Association. The questionnaire consisted of 20 questions and its overall structure is shown below[1].

- Part 1 (question 1-11): Technology focus;
- Part 2 (question 12-13): Barrier focus;
- Part 3 (question 14-20): Respondent/company characteristics.

[1]A copy of the questionnaire is available from the authors upon request.

The first question aimed at establishing the familiarity of each respondent with a set of 12 emission reduction technologies (listed in Table 1).

The remaining ten questions in part 1 were technology focused and asked the respondents to rank different attributes on a Likert scale on 1 to 5, where 1 indicated the absence of the barrier and 5 a very high incidence of the barrier. The attributes of the technology were: expensive, effective in reducing emissions, easy to install, easy to operate, technically mature, safe for the crew and the ship, reliable, compatible with existing regulation, compatible with charter party specification, and finally suitable to the company. Question 12 required the respondents to express their agreement with 11 statements aiming at verifying their views on barriers and obtain understanding of the company strategy.

Question 13 required the respondents to rate barriers on a 1-5 Likert scale, where 1 means least important and 5 means most important. The barriers are consistent with the framework described in the section above.

The remaining questions aimed at investigating the respondent profile and collecting some characteristics of the company of the respondent.

3.3 Population and Sampling

During the summer of 2011 a list of contacts was obtained through the Norwegian Ship-owners' Association and a web-based questionnaire was developed. The questionnaire was administered through Questback © in September/October 2011. The Norwegian Ship-owners' Association groups 160 members (105 with tonnage and 55 without tonnage) for a total of 1385 vessels and 47 mobile offshore units for a total of over 27 million in tonnage as of 1st of January 2011 [11]. The questionnaire was distributed to 25 individuals that had given their availability to participate in the study, representing 19 companies, selected in order to ensure a representative sample of the association membership. We received 10 responses (response rate of 40%) from 10 different companies.

Table 1 Summary of barrier and measure scores (where "O" indicates a positive score and "X" a negative score).

Measure	Barrier										Average score	*Average std. dev.*
	Familiar	*Costs*	*Effective*	*Easy to install*	*Easy to operate*	*Mature*	*Safe*	*Reliable*	*Regulation*	*Charter party*		
1. Drag reduction technologies			O		O		O		O		2,1	0,91
2. Cold ironing	O		O						X		2,7	1,22
3. Propeller efficiency devices			X		O					O	2,3	0,94
4. Waste heat recovery											2,6	0,79
5. Main engine improvement	O		O			O		O		O	2,0	0,86
6. Wind power	X	X	X	X	X	X	X	X	X	X	3,6	0,98
7. Reduced need for auxiliary	O	O						O		O	2,0	1,00
8. Fuel cell	X	X	X	X	X	X	X	X	X	X	3,8	0,90
9. LNG		X	O	X	X				X	X	3,5	0,85
10. Solar power	X		X			X			X	X	3,0	1,07
11. Speed reduction	O	O	O	O	O	O	O	O	O		1,8	0,73
12. Voyage performance	O	O	O	O		O	O	O	O		1,9	0,80

This represents 6.3% of the association members (slightly below 10% of members with tonnage) and although the sample size is limited, it is consistent with those used in other exploratory studies of this kind.

The lack of multiple responses from the same company prevented us from analysing barriers that are internal to the company, and this remains among the objectives of future work. The sample size also does not allow strong inferences on the population and the results are limited to Norwegian Ship-owners, so that barriers may be ranked differently among ship-owners in other countries. Of 59 shipping segments we see that 17 are represented and that almost every company has indicated a different primary segment (with the exception of bulker between 60000 and 100000 DWT, which was selected by two companies).

The segment is representative of the Norwegian fleet, characterised of energy, bulk and passenger segments. Most notably the large container segment is not represented in the survey[2]. Respondents had the possibility of indicating one main segment and up to four secondary segments. Only one respondent indicated three secondary segments and none indicated a fourth, which seems to point to the fact that the survey managed to capture the multi-segment nature of some companies. Although the responding companies are rather diverse in terms of line of operation, the composition of the sample also tends to show a bias towards smaller player.

The profile of the respondents in terms of position within the company and in terms of the predominant type of contractual agreement that regulates vessel employment indicates that the majority of respondents had a technical or operations background, while less than 20% was at executive level. As far as the contractual agreements that regulate company transactions are concerned, we observe a rather uniform distribution among long term contracts, short term contracts, and liner operations.

3.3 Background on Company Strategy

In order to obtain a better understanding of the population at the end of the questionnaire a few questions on company strategy with respect to CO_2 abatement were asked. This was done in order to assess the relevance of environmental concerns for the respondents. We asked them to indicate how strategically important was CO_2 emission abatement. All respondents indicated, as it was to be expected that they consider CO_2 emission abatement as an important

[2]At a later stage the questionnaire was distributed to a large Nordic container carrier to verify consistency of answers. The results are similar to those obtained in our survey. These answers are not reported in this study.

part of their company strategy. Only 20% rated it as very high and the same amount of respondents as neither low nor high. If we compare with the answer we obtained when we asked the same company to rank the importance of fuel costs we see that the respondents are much more consistent with their judgment. Eight respondents out of ten stated that fuel costs are very important. There is one respondent, associated with an offshore drilling company who rated fuel costs as not important at all. These results are consistent with the answer to the question on how often are fuel costs borne directly by the company instead of being transferred to others.

4. Survey Results

4.1 Safety and Reliability

Safety and reliability are of paramount importance for shipping companies. The respondents perceive operational measures, such as speed reduction and voyage performance, as the safest measures available. Well-established technologies that require limited modification to the ship are also considered safe. Although on average all measures rank quite highly in terms of safety (average score is 2, median 1.5 and standard deviation 0.63) wind power, fuel cell, LNG and solar power are perceived somewhat less safe. On average the results of this part of the survey have the lowest variability among all questions.

New technologies often carry an inherent degree of unreliability. The questionnaire results show that with the exception of wind power and fuel cells, the other measures are perceived as rather reliable (average 2.4, median 2 and standard deviation 0.88). The most reliable measures are perceived as main engine improvement, reduced need for auxiliary power, speed reduction and voyage performance.

4.2 Technical Uncertainty

One of key aspects of the implementation of new technologies relates to the existence of technical barriers. In order to fully account for technical barriers the questionnaire asked respondents three questions, one related to easiness of installation, one related to easiness of operation of the measure and one related to the technical maturity.

In general we observe that the perception of respondents across the various measures is consistent. The average score for across measures is a between 2.60 and 3.08 and the average variance across the measures is around 0.8, where a low score indicates the absence of the barrier. Installation complexity emerges as the single most important technical barrier.

If we look at the specific technologies, we observe that wind power, fuel cells and LNG appear to be those measures for which the level of barriers is the highest. LNG installation is perceived as a burden, while for fuel cell the technical maturity of the measure seems to be the issue in addition to installation complexity. For wind power operation seems to score highest (although marginally). Variability among respondents with respect LNG and fuel cell installation is very limited with 65% of respondents assigned the highest score and the remaining indicate that the barrier is very high. Operational measures such as speed reduction and voyage performance appear to have low barriers, similarly to main engine improvement and reduced need for auxiliary power. The standard deviation for these measures is also limited. Drag reduction technologies and propeller efficiency have low operational barriers but high installation barriers. The variability of the answers is low, though higher for drag reduction, indicating that the sample has less coherent response on the level of barriers for this measure. Cold ironing is situated in the middle with an average score of just below 3. The variability for this measure though is very high, indicating that the respondents have very different views on the technical barriers connected to this technology. Solar power has mixed scores. One the one side respondents seem to believe that installation costs are an issue and that the technology is not yet fully mature for implementation on board of the ship. On the other side, operational barriers are perceived

low, although there is a high degree of variability on this attribute.

An important part of the questionnaire was identifying the perceived effectiveness of the measures in reducing CO_2 emissions. The average score among all measures is 2.9 (median 3) and average standard deviation of 1.24. From this question it appears that respondents all have very different opinions on the effectiveness of the measures, although they tend to think that they have some degree of success in reducing emissions. Only solar power has a median of 4, although on average it scores similarly to wind power and fuel cells. This question had the highest variability among all questions (1.24) indicating that respondents do not agree on the level of effectiveness of the measures in terms of emission reduction.

4.3 Market Constraints

Respondents were asked to rank the barriers on the basis of their perception of whether the technology would require substantial changes in regulation for being implemented or modifications in charter parties. We see that charter party is perceived as a more stringent barrier to the implementation of new technologies in general (mean 2.7, median 2.75) while regulation does not appear to have major impact on the applicability of the measures (mean 1.9, median 1). There is more agreement on regulation impact than on the charter party (standard deviation of 0.81 and 1.19).

If we look at the measures individually there seem to be a similar pattern where those measure that score highly with respect to regulation score high also with respect to the charter party. The main exceptions are drag reduction technologies, speed reduction and voyage performance, the implementation of which does not require amendments to the current regulation, but finds difficulties with respect to the charter party.

4.4 Financial and Economic Constraints

The cost component was an important part of the analysis. The questionnaire asked the respondents to rank the measures according to how expensive they perceived the measure to be in term of installation costs and procurement costs. The results are rather diverse with average score for all measures of 3.2 (median 3) and standard deviation of 0.97. We can identify three groups of measures, cheap, moderately expensive and very expensive. In the first group respondents placed reduce need for auxiliary power, speed reduction and voyage performance. Among the moderately expensive measures, respondents selected main engine improvements, propeller efficiency enhancement, cold ironing and drag reduction technologies. Among the very expensive they listed wind power, fuel cell, LNG and solar power.

4.5 Behavioural Barriers and Complexity

In order to assess the importance of barriers in the operational and investment decisions that users make with respect to implementing emission reduction technologies the respondents were asked to indicate their opinion on 11 statements. One of the interesting results of the study is the perception that there is too much uncertainty with respect to the effectiveness and the costs of the measures (statements 5 and 6). Most of the respondents argue that their organisation is ready to handle new technologies (statement 7). Safety and regulation do not appear to constitute substantial obstacles (statements 8 and 11), neither are the difficulties in operating and installing the measures (statements 3 and 4) although the variability of answers in such response is higher. With respect to regulation and the charter party responses are consistent with the previous part of the survey where charter parties appear more critical than regulation in general.

Respondents seem to indicate that the costs of operation and installation of new technologies pose some limitation on the viability of the barriers both from a technical perspective and from a cost perspective (statements 1 and 2), but the variability of answers is quite high especially as far as the costs of installation of the measures is concerned (statement 1).

Reliability of information appears also to be an issue (statement 9).

4.6 Summary of Results

The respondents were asked directly to rank on a Likert scale each barrier individually. The results confirm the findings of the other parts of the survey.

In particular reliability, safety, and cost of the new seem to be the most relevant in determining the choice of implementing a new technology. In summary if we combine the information on the barriers and the technical measure we can select those abatement technologies that appear the most promising. Operational measures, such as speed reduction, voyage performance, main engine improvements and to a lesser extent drag reduction technologies are those that appear the easiest to be implemented. Fuel cell, wind power, LNG and solar power appear among the measures with the highest barriers. It should be stressed that the degree of variability of the answers is a also an important parameter in the analysis. While for example for fuel cell there seem to be agreement on the scores, for LNG respondents appear to have diverging opinions.

The results for the other measures appear more mixed. Barriers are present but they are limited to isolated issues such as installation costs or reliability. The presence of a single barrier can in practical terms set an obstacle high enough for the company that the technology might not be implemented. Fig. 1 shows the relative importance of each barrier, so we can argue that those technologies that score badly in terms of reliability, safety and costs, will be those that will be least easy to implement. On the other side we see that for example cold ironing scores badly in terms of regulation but this may not be determinant in the uptake of the technology because the weight of the barrier appears low.

Table 1 provides a summary of the survey results where the measure with the lowest and the highest scores are listed with O and X respectively. We observe that cold ironing, solar power and drag reduction technologies have a higher variability (approximately 60%) measured by average standard deviation among the various questions. Speed reduction, voyage performance and waste heat recovery on the other side have a lower variability (40%), indicating consensus among the rating of the measures. In order to correctly assess the barriers related to a specific measure it would be important to investigate the specific characteristics of that measure in the company context. Clearly what is also relevant is not only the perception of barriers in general, but the specific conditions in which the company is operating.

Fig. 2 illustrates the average barrier for technology level in comparison with the suitability of the measure for the company and the degree of knowledge that the degree of familiarity that the respondents have on the measure. As it is to be expected there is correlation between the three variables in general, with those measures with witch the respondents feel more familiar being also those that show lower barrier and higher potential for implementation in the respondents' companies. The figure also shows though that for LNG and fuel cells, even if the respondents appear to be familiar with the measure, they do not believe they are suitable for the company and perceive that barrier levels are high. Cold ironing shows a medium barrier level although knowledge of the measure appears high (it should be noted that cold ironing shows a high degree of variability among respondents).

We observe that the results of the survey are consistent with the results of the selected interviews as far as the measures with high barriers are concerned. Barrier levels on the survey study appear to be lower for those measures with low barriers. Some discrepancies could be motivated by the aggregation (e.g., drag reduction technologies or reduced need for auxiliary power).

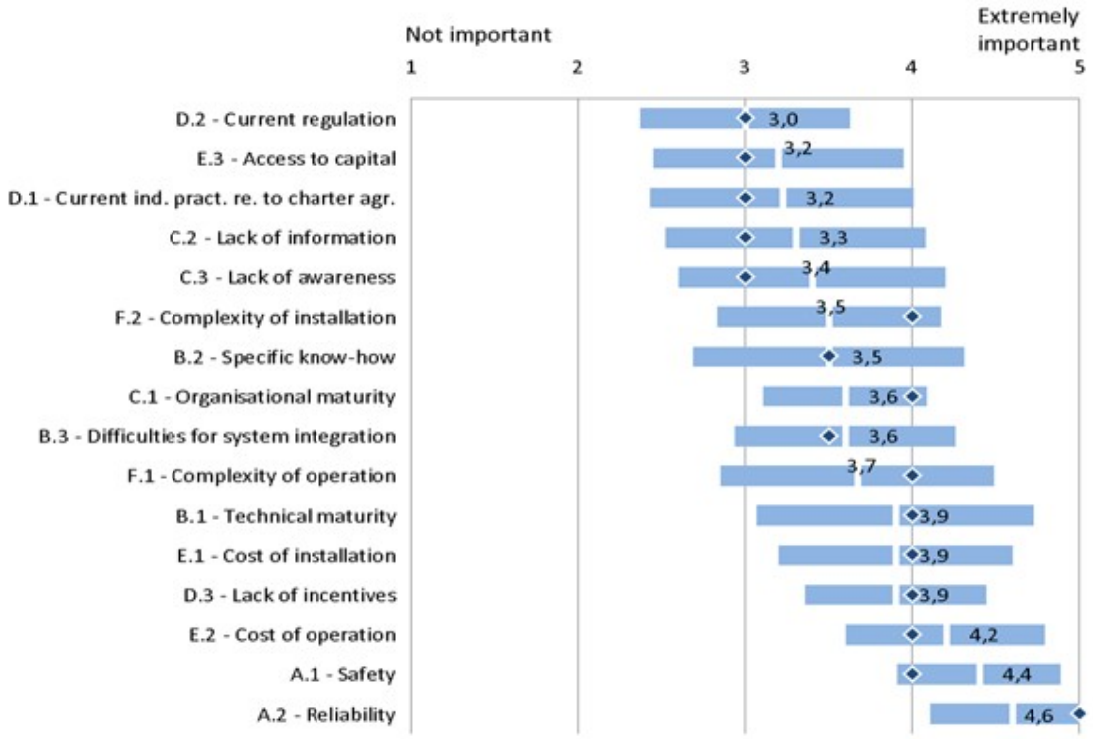


Fig. 1 Mean ranking (white mark), median (diamond) and standard deviation of the perceived barrier importance (10 respondents).

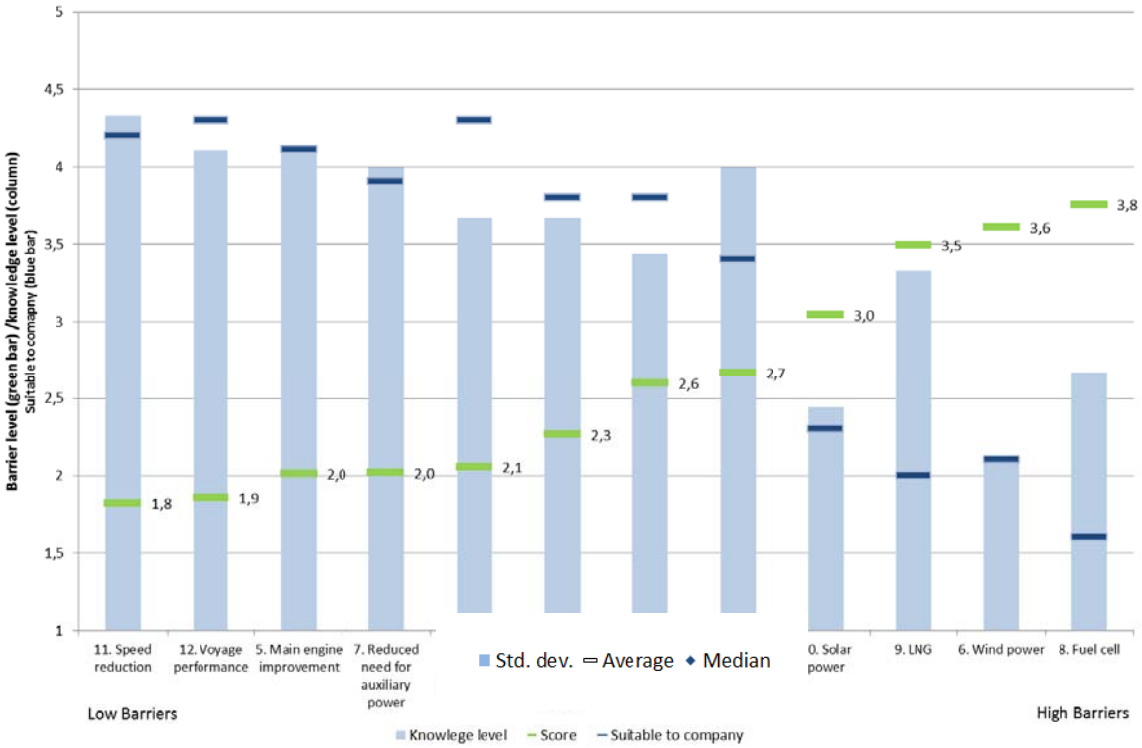


Fig. 2 Barrier level (green bar), technology familiarity (column) and degree of suitability to the company (blue bar) (all respondents).

5. Conclusions

The paper has developed and tested a categorisation of barriers to the implementation of CO_2 abatement measures in shipping, and has presented the results of a survey among Norwegian ship-owners aiming at capturing their perception of barriers.

The analysis of the results indicates that hardware measures appear to have higher barriers than operational measures. Less mature technologies appear also more difficult to implement. While on some technologies there seem to be agreement on the barrier ranking among respondents, such as voyage performance that is consistently ranked with low barriers or fuel cell that is consistently ranked with high barriers, for other technologies there seem to be a multiplicity of views, such as for onshore power supply or LNG.

In addition to cost issues many barriers are related to the reliability of the information available as well as industry practice and internal company organisational issues.

The paper proposed on the basis of the literature and interviews with DNV experts and shipping companies a set of barriers to energy efficiency relevant in the context of shipping. These barriers are:

A. Safety and reliability
B. Technical uncertainty
C. Behavioural
D. Market constraints
E. Financial and economic constraints
F. Complexity

After consultation with internal DNV energy efficiency experts a questionnaire has been developed and distributed among selected members of the Norwegian Ship-owners' Association. The respondents to the questionnaire are representative of 10% of the companies with tonnage that member of the Association. The questionnaire provided useful insight on what barriers are the most relevant for the implementation of energy efficiency in shipping. In particular we observe that operational measures appear to have lower barriers than hardware measures. Immature technologies also show higher barrier levels.

Cost considerations appear also important together with the perception that some new technologies may come into conflict with existing regulation and industry practices. In this respect an active role of the policy maker through financial incentives and through the revision of existing regulation may be effective in overcoming these barriers.

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Sea Trials of a Wave Energy Converter in Strangford Lough, Northern Ireland

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Abstract: This paper describes a campaign of WEC (wave energy converter) testing and presents a selection of the results related to the measured motions and mooring tensions. A 1:20 physical model has been successfully deployed using a three point mooring installed at sea (Strangford Lough, NI) in 10 m depth. In calm weather the overall dynamics of mooring tensions is dominated by the tidal cycle due to the progressive lifting of the heavy chain with the increase in water depth on the flood and gradual lowering on the ebb. In fresh winds the dynamics is very complex, but can be studied with the aid of mathematical modelling. A simulation model was used to assess the dynamics of the mooring lines, and the results of open water tests have been compared with the model's performance. The results indicate that, in general, the model shows a reasonable agreement with the observations. The WEC's motions and the measured loads on the leading mooring line appear to relate to the concurrent environmental conditions. The data obtained can therefore be used for the model's calibration and further improvements, which is valuable for improving the WEC's design and operational characteristics. This may be important not only in relation to the issues of reliability and power take off, but also in terms of minimising the adverse effects of mooring lines on bottom sediments, as well as indirect effects of the eroded particles on a wide range of aquatic processes.

Key words: Bottom sediments, mooring loads, meteorological data, model simulations, optimisation, Orcaflex, CRESS, wind waves.

1. Introduction

Robust moorings are indispensable for harvesting the energy of waves. Tests in wave basins and at sea help to further our understanding of the dynamics of mooring loads in relation to the sea state. Here we present a selection of the results obtained in a campaign of sea trials of a WEC (wave energy converter) in Strangford Lough, Northern Ireland. These tests followed the previous lab research, where physical models of wave energy converters were first tested in a wave basin and the results of their behaviour were then compared to the simulations performed using mathematical modelling [1, 2].

2. Materials and Methods

A 1:20 model has been successfully deployed using a three point mooring installed at sea in 10 m depth and tested in the open water conditions. A picture of the WEC and a schematic diagram of the mooing used are presented in Fig. 1 and Fig. 2 respectively.

Measurements of 6Df (degrees of freedom) motions were obtained using a MICRO-ISU BP3010 IMU (inertial motion unit) manufactured by "BEC Navigation Ltd", which was installed close to the COG (centre of gravity). The digital signal was logged to the GigalogF dasta logger via RS232 port, and after downloading processed using a suite of custom made Matlab scripts to calculate estimates of heave, pitch, roll, sway, surge and yaw. It should be noted that due to the restrictions on data storage, only 10 minutes worth of data were recorded every hour during the normal operation of the equipment.

Unfortunately, no reliable wind data were available for Strangford Lough locality per se. However, the

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Fig. 1 WEC in strong winds at Strangford Lough.

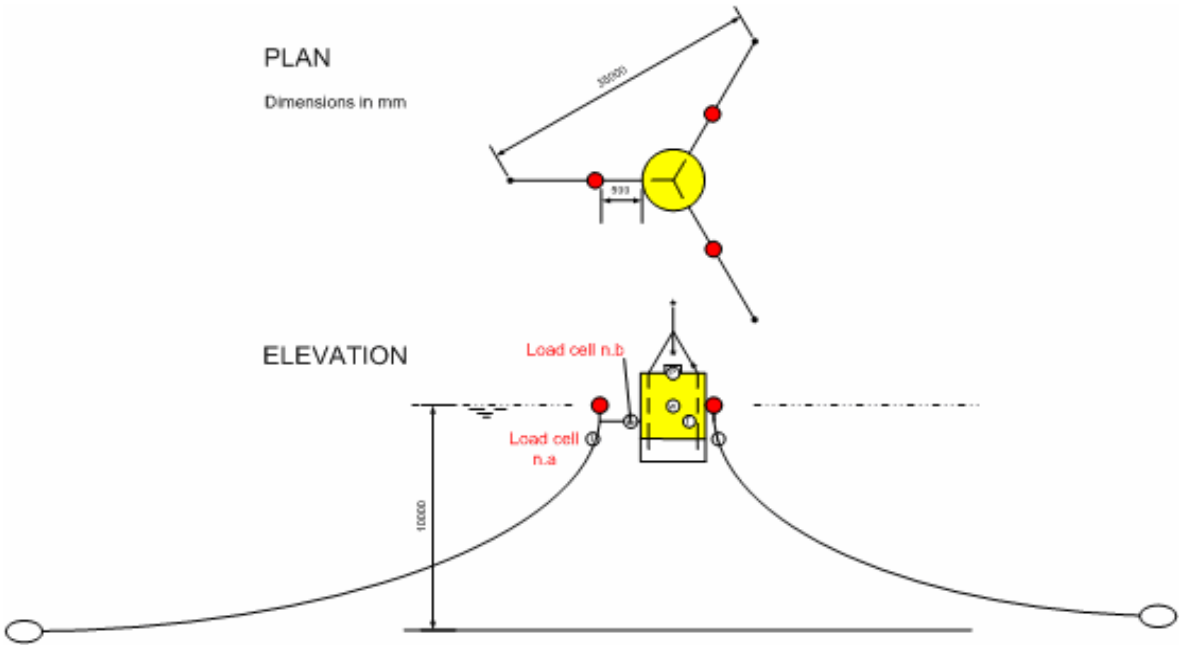


Fig. 2 Schematic diagram of the mooring, note that only one load cell was installed at this stage of the research.

winds measured at the Orlock Head weather station are of a good quality, and deemed to be broadly representative for the region. These data were downloaded (with permission) from the website of the BADC (British Atmospheric Data Centre).

An OrcaFlex modelling scenario was designed to simulate the WEC and the environmental conditions concurrent with the second set of results presented here. Estimates of the Hs (significant wave height) and Ts (average period for waves with H $\geqq$ Hs) were obtained using CRESS (Coastal and River Engineering Support System) using a variable depth fetch of 4.76 km. The typical measured value of wind strength for this period was 17 m/s. However, given that the wind measurements from Orlock are at 10 m height, that was converted using a conversion factor of 0.78 to wind at 2 m height (as used by Shaw [3], p. 251), making u = 13.265. This is still likely to be an

overestimate, hence 13 m/s was used in the CRESS calculations, giving Hs = 0.6 m and Ts = 2.86, the latter value was converted to Tp using a conversion factor of 0.95 [4], giving Tp = 3.01 s. These values of Tp and Hs were used within Orcaflex to generate an ISSC (International Ship and Offshore Structure Congress) type wave spectrum.

3. Results

The first deployment of the WEC was carried out in August 2011 using RV "Cuan Cat". The operations were carefully planned, and subsequently carried out during a suitable weather window. The weather was freshening during the deployment, and the wind was quite fresh towards the end. However, any considerable increase in wave height was apparent only after the deployment operations had finished.

The wind subsequently subsided and mainly remained light (2-8 m/s) till 11 am on Aug. 23, when it showed a considerable increase peaking at 11 m/s by midday (Fig. 3). The sea trials subsequently continued until late autumn, but were hampered many times buy harsh weather, logistics and issues of equipment failure. In particular, both the mooring and the measuring equipment were severely damaged during hurricane Katya in September. Nevertheless, the experiment yielded some interesting results, selections of which are presented below.

3.1 August Results

Mooring loads for most of this period are presented in Fig. 4, whilst a short fraction of the mooring loads dynamics is illustrated in Fig. 5. It is evident that the signal is fairly clean, and that it represents a complex interplay between motions of different frequencies. The overall dynamics of mooring tensions is dominated by the tidal cycle due to the progressive lifting of the (relatively) heavy chain with the increase in water depth on the flood and gradual lowering on the ebb. There is also an interesting pattern of sudden jerks (up to 300 kN full scale) during the flood's midtide. The peak mooring loads on the ebb are, generally, less prominent.

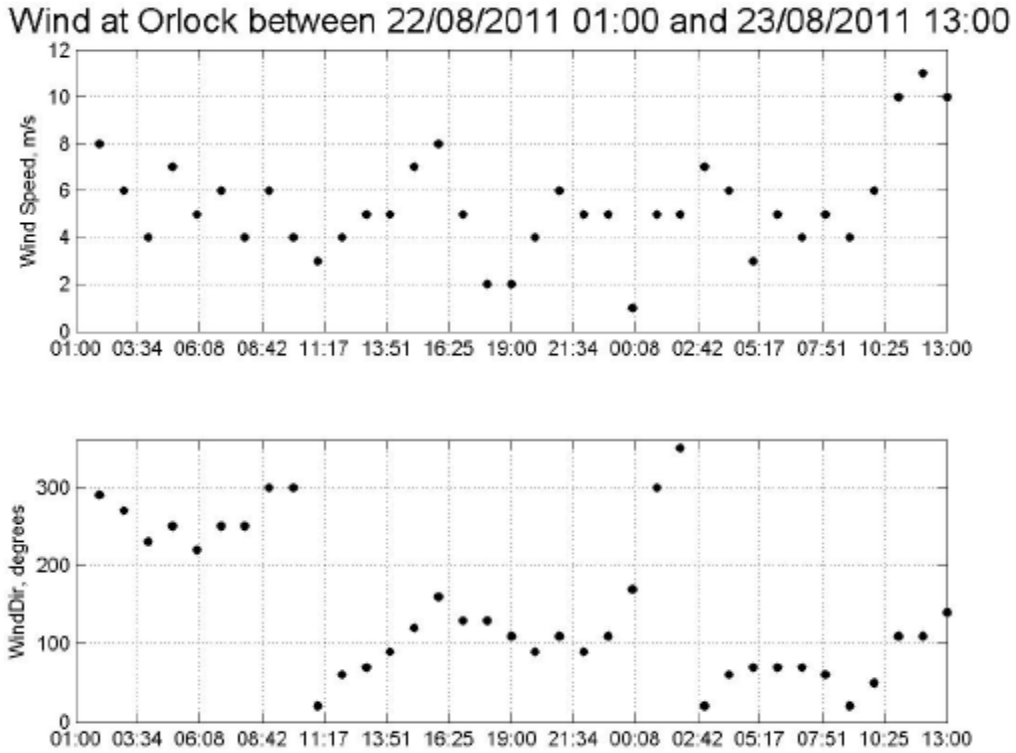


Fig. 3 Wind measurments at the Orlock Head weather station for August results.

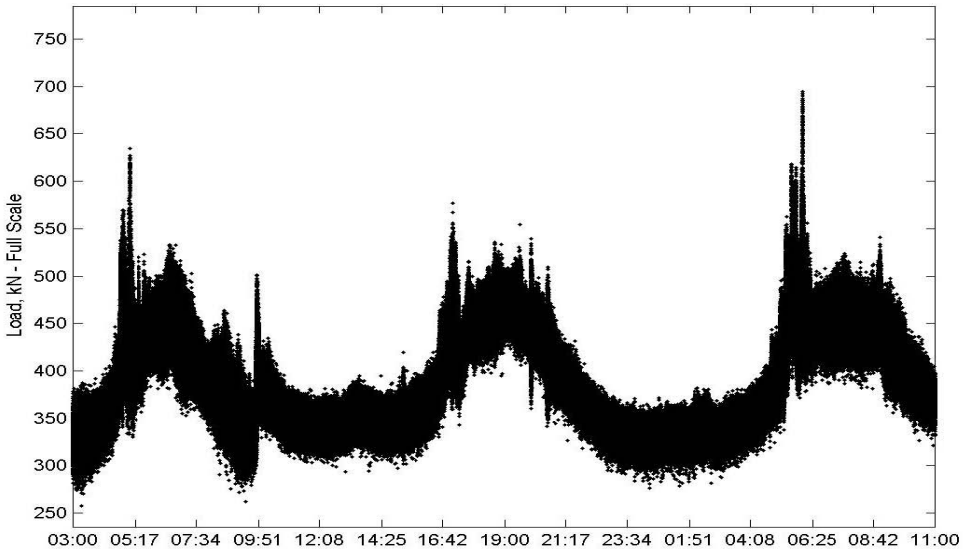


Fig. 4 Mooring loads for August results.

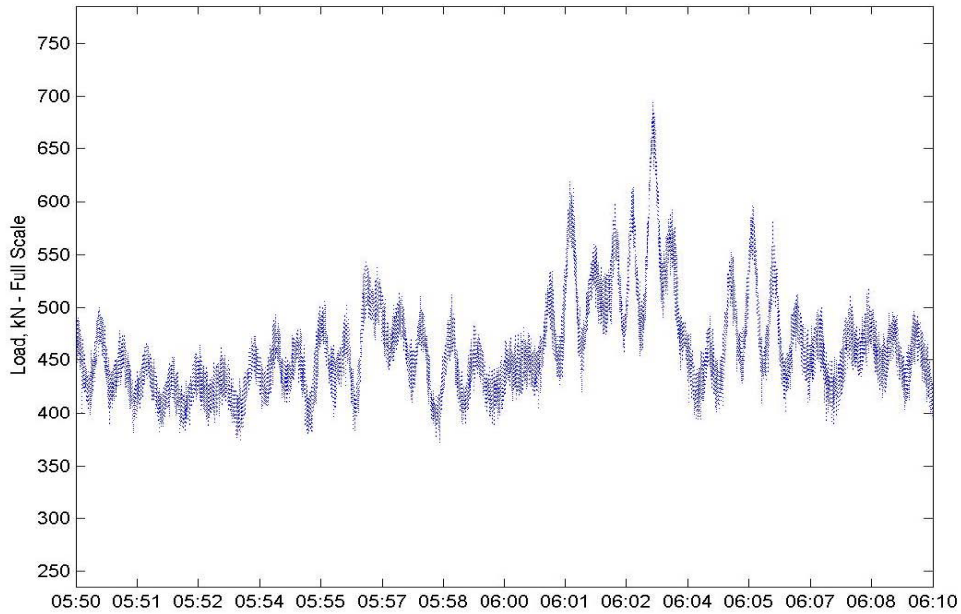


Fig. 5 An example short-term dynamics of mooring loads.

An example of the 6Df motions obtained using an IMU is shown in Fig. 6. It is obvious that in these light winds most of the observed motions of the WEC are rather limited. An exception to the above, however, is yaw, which is characterised by a low frequency wave of > 200 s period and the range of approximately -30 to 30 degrees. This motion is likely to be chiefly attributed to the interplay between the mooring's natural frequency characteristics and the resulting combination of wind and stidal forces, and should be investigated by further research.

Fig. 7 presents a relationship between mooring loads and heave, whilst Fig. 8 gives a joint density distribution for minima and maxima of the heave's rainflow cycles, all values there are recalculated for full scale.

3.2 October Deployment

After the damage caused by hurricane Katya, the equipment had to be repaired, and the mooring was subsequently redeployed in mid October. The dataset collected in October contains a period of very valuable

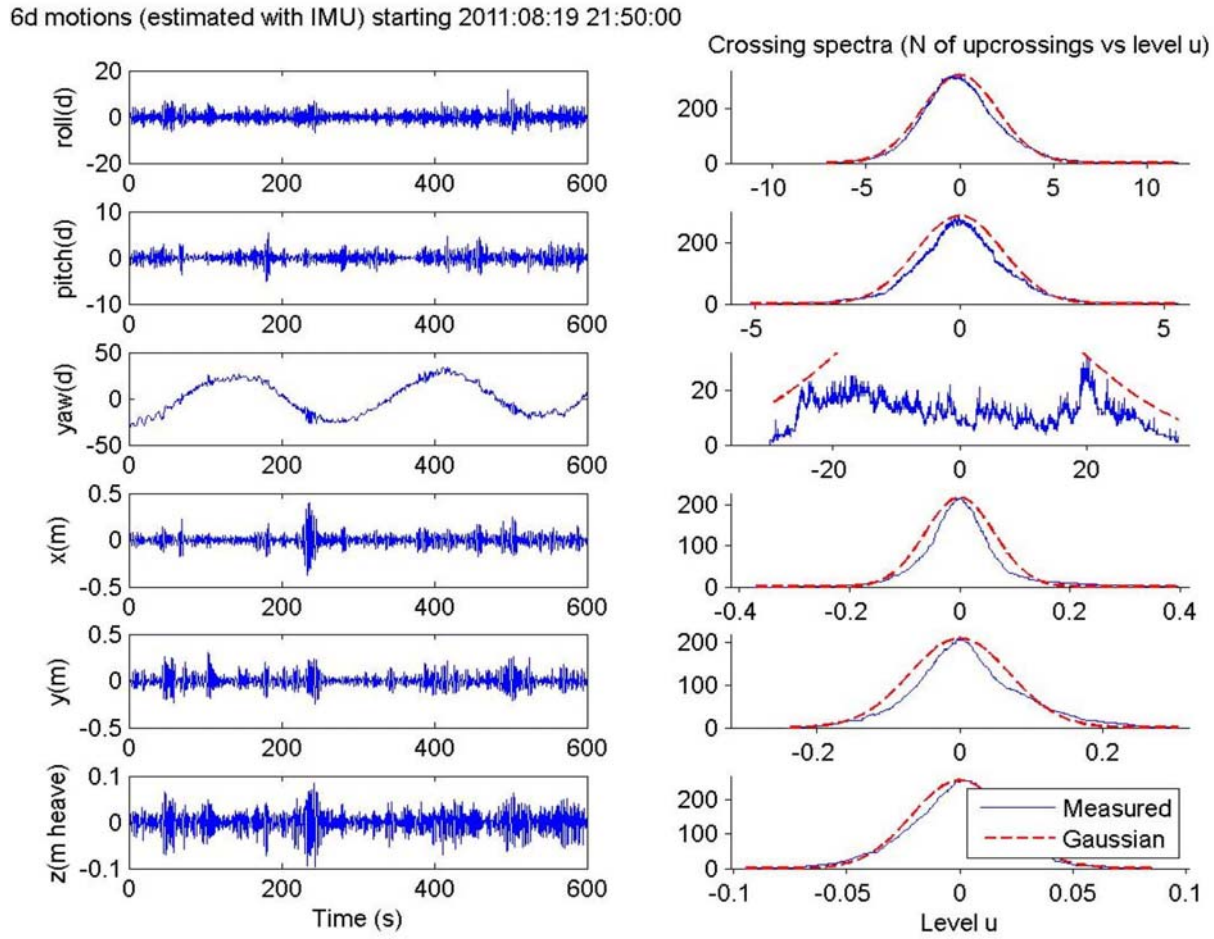


Fig. 6 An example of 6DF motions obtained using an IMU.

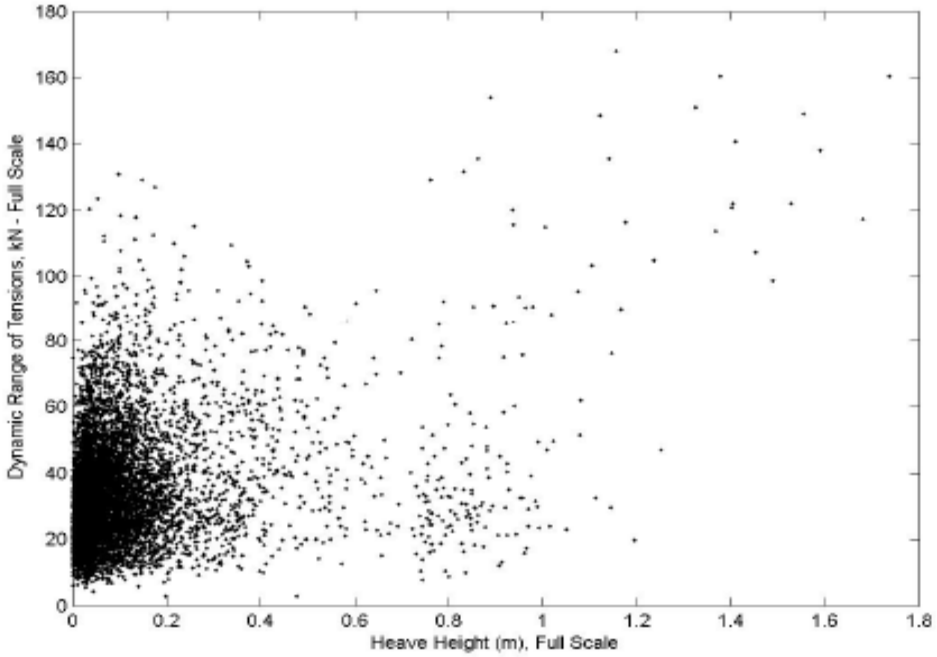


Fig. 7 Relationship between mooring loads and heave for the first set of results.

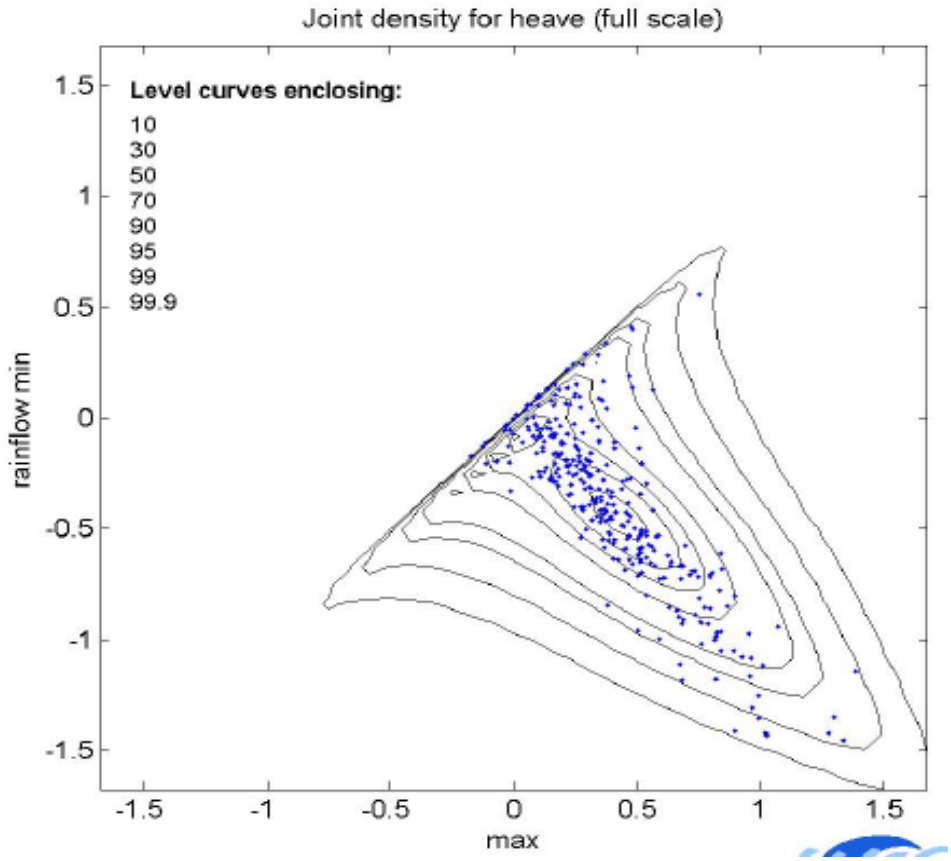


Fig. 8 Joint density distribution for minima and maxima.

data collected in fresh winds of a steady SW direction (Fig. 9). It can be seen that on Oct. 20 the wind started to increase in the late afternoon from 13 to 17 m/s, and then remained fairly steady for 6 hours (with a peak of 18 m/s at 22:00), eventually decreasing after midnight.

Summary of the mooring tensions on the leading mooring line collected during this period of fresh winds is shown in Fig. 10. During this time the mean value of the dynamic range of mooring tensions ranged between 42 and 107 N, whilst the maximum values between 112 and 292 N. A histogram for the peak mooring loads is given in Fig. 11. It is evident that only a few cases exceed 240 N.

4. Discussion

It has previously been shown that the bulk of mooring tensions may be described by either normal or logistic distribution, whilst extreme value distribution shows a reasonable fit to the tail [1]. From a preliminary inspection of our histograms it appears to be the case for the results presented here as well.

4.1 Modelling

Histogram of modelled mooring tensions for the August scenario is presented in Fig. 12 whilst a selection of modelled motions is given in Figure 13. It is evident that these figures are all of the credible order of magnitude, which gives some confidence in the model. The discrepancies between the simulated and observed ranges may be attributable to the model's simplifications, the lack of current and wind influences in the model, the limitations imposed by the sampling rate, and the differences between the observed and the simulated wave regimes.

It should be noted, however, that whilst in relatively smaller and moderate waves investigated for the purpose of this paper (e.g., Hs up to 0.6 m, which is 12 m full scale) the model's behaviour seems reasonable, in high waves (data not shown) it is

currently rather erratic (data not shown). The WEC jerks violently in high seas and the mooring tensions appear too large. Further experimental and modelling work is therefore needed to investigate these effects

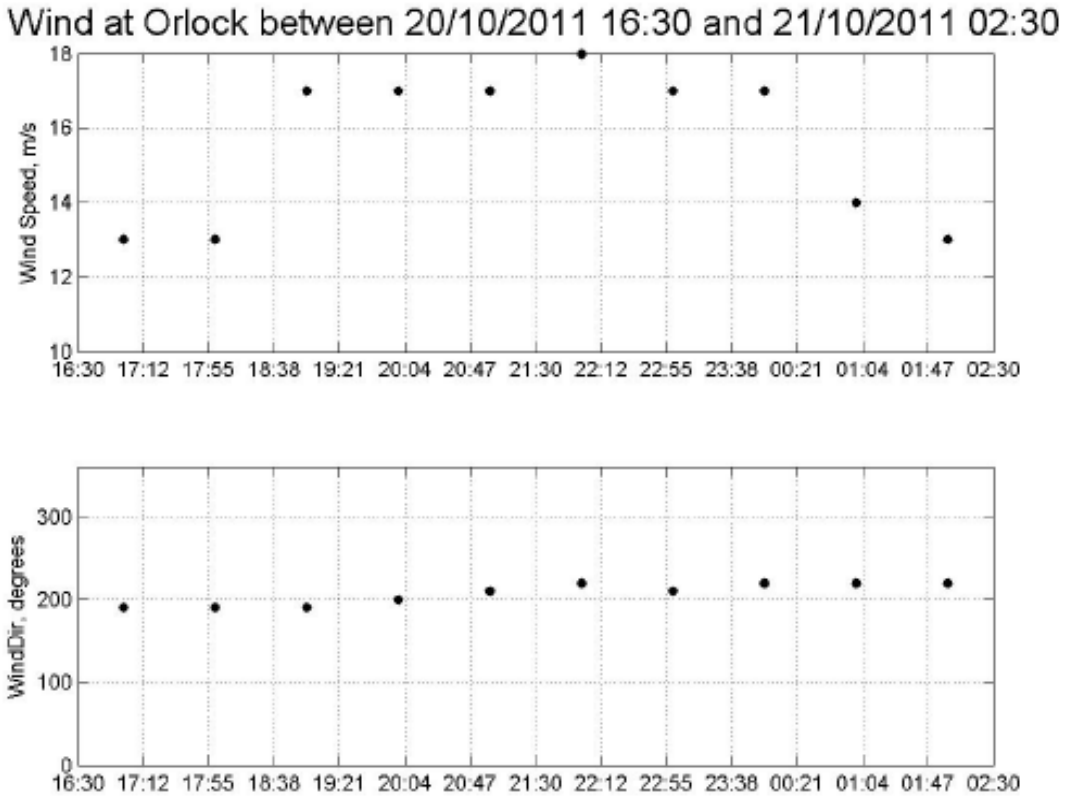


Fig. 9 Wind measurements at the Orlock Head weather station for October results.

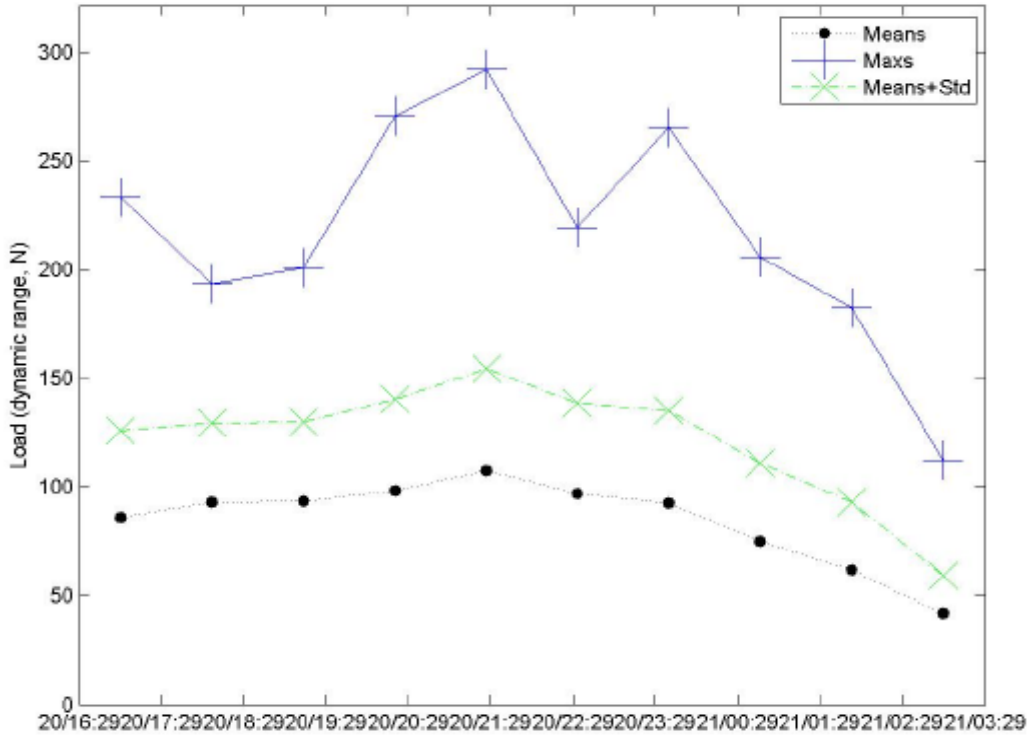


Fig. 10 Summary of mooring tensions results during the fresh winds in October.

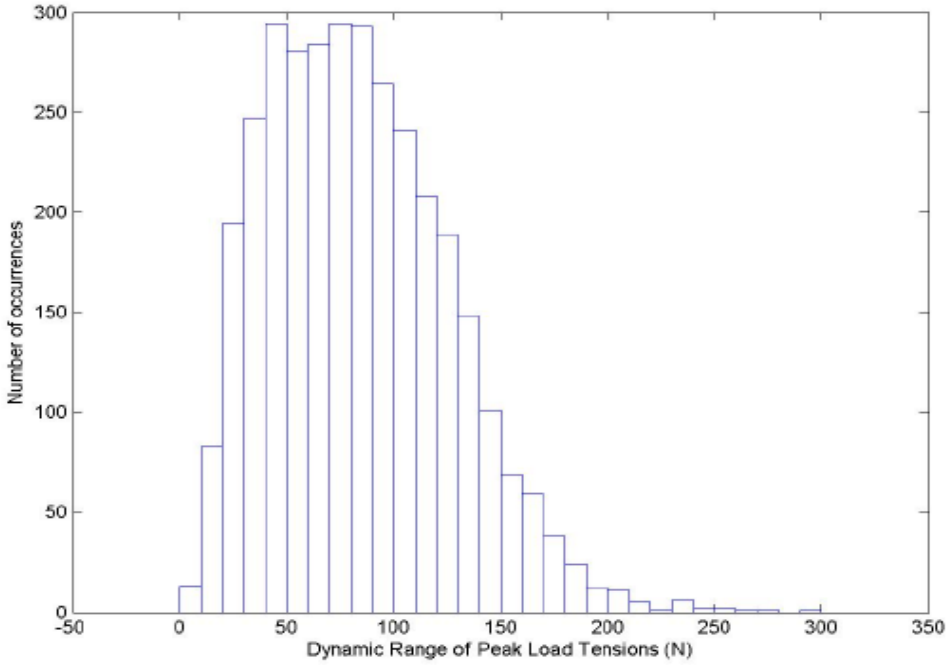


Fig. 11 Histogram of peak loads for October results.

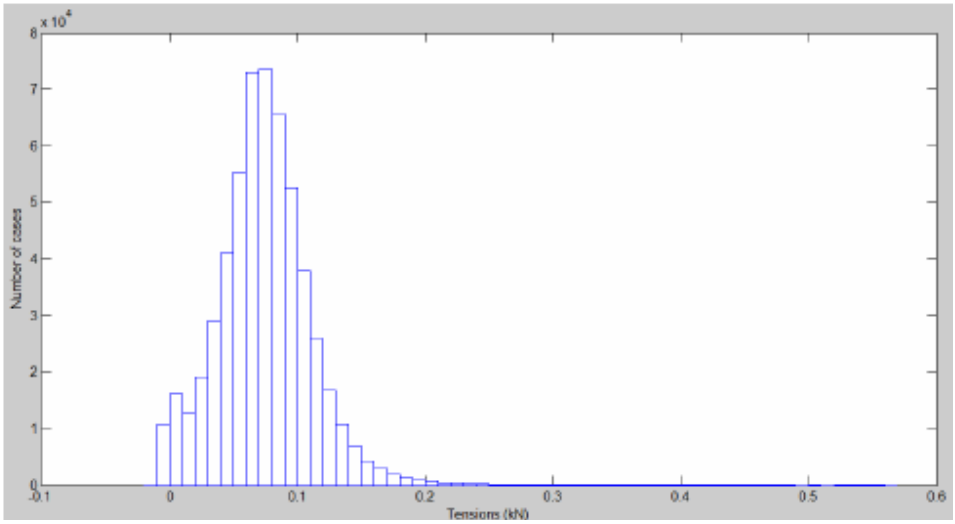


Fig. 12 Histogram of modelled peak loads in conditions simulating October results.

and improve the model, as well as to optimise the design of the mooring.

4.2 Limitations of the Study and Further work

The results of this study have been restricted by its scope, time and financial constraints, weather conditions, reliability of the equipment used, and a whole range of logistical issues. Nevertheless, the research presented here provides some important information on the behaviour of the experimental system tested. The data collected are useful for modelling, and, together with the model's results should be helpful for planning the further research and practical applications.

Considering the issues of reliability of the equipment and logistical constraints encountered during the research presented here, we suggest that the "wave tank" stage should follow by a "fresh water" stage, preferably carried out in a local sheltered reservoir located close to the laboratory to minimise logistical efforts.

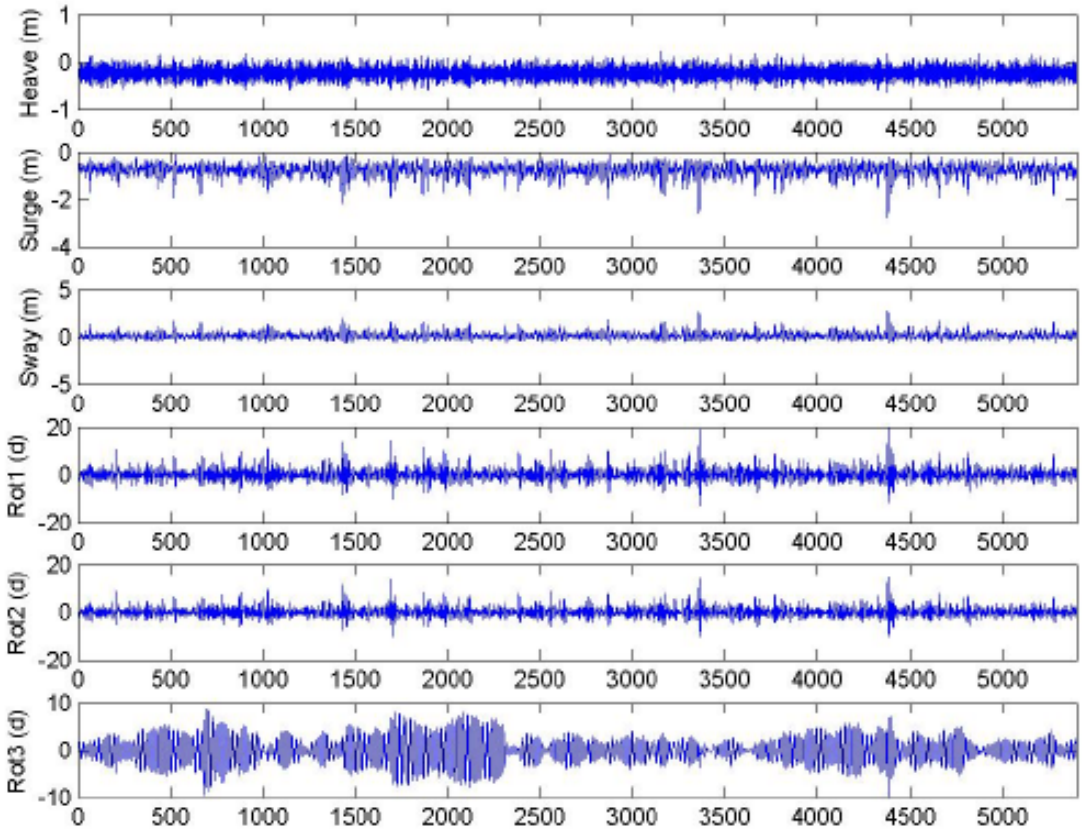


Fig. 13 Time series (0 to 5400 s) for the modelled WEC's motions in conditions simulating October results, the beginning of simulation followed a 200 s period of pre-simulation.

The extreme mooring loads in arrays of WECs may show a considerable increase compared to a single WEC installation [1]. Further research should therefore aim at measuring mooring forces in a farm of devises. It should be noted, however, that such a study will be very costly and would have to overcome some considerable increase in logistical constraints.

5. Conclusions

The WEC's motions and the measured loads on the leading mooring line appear to relate to the concurrent environmental conditions. In calm weather the overall dynamics of mooring tensions is dominated by the tidal cycle due to the progressive lifting of the (relatively) heavy chain with the increase in water depth on the flood and gradual lowering on the ebb. In fresh winds the dynamics is very complex, but can be studied with the aid of mathematical modelling. The results show that, in general, the model captures the most important aspects of the WEC's dynamics.

The data obtained can therefore be used for the model's calibration and further improvements, which is valuable for improving the WEC's design and operational characteristics. This may be important not only in relation to the issues of reliability and power take off, but also in terms of minimising the adverse effects of mooring lines on bottom sediments, as well as indirect effects of the eroded particles on a wide range of aquatic processes [5-7].

Acknowledgments

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Journal of Shipping and Ocean Engineering 3 (2013) 21-29

Marine Accident Analysis with GIS

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Abstract: In this study, marine casualties which are recorded Global Integrated Shipping Information System (GISIS) in 2007-2011, result in death, injury, economic loss and environmental pollution are discussed. The studied types of ships are container, bulk dry, general cargo, roro, ropax, passenger and tankers. The information contained in GISIS system is textual format and it is difficult to systematically analyze this information. For this reason, by creating a new data base, which is Microsoft Excel-based, ship accidents are classified according to name, flag state and type of ship, type, size and coordinates of the accidents that are evaluated by entering the Geographical Information System(GIS). In the study, all marine areas having been separated into ranges in ArcGIS 10 program, the marine areas with intensive marine accidents have been determined and marine accident chart has been created. As a result of the study, high risk marine areas are Strait of Dover and Hamburg in the North Europe, Belfast Shores in Ireland, the seas surrounding Great Belt, Kattegat and Copenhagen in Baltic Sea, In far east, Kanmon Strait, Urage Channel and Bungo Strait in Japan, Shanghai, Ningbo and Hong Kong in China.

Key words: Marine accidents, maritime transportation, GIS.

1. Introduction

An accident an undesired event that causes damage or injury [1]. Shipping accident is a term generally used for any accident results in financial loss, either in life or property or both [2]. The reasons for shipping accidents are many and complex [3]. However the main groups of accidental causes are human causes, mechanical causes, fire and explosion, structural causes, weather related causes and miscellaneous [4]. The cases of death and pollution at sea are mostly caused by human errors [5]. Studies consistently estimate that around 80% of causes in marine accidents are attributable to human factor [6].

Over the last decade, international maritime authorities have made significant efforts to promote safety at sea in the shipping transportation industry [7]. But there are still an enormous number of shipping accidents [8]. The lessons taken from marine accidents experienced in the history form a basis for the conventions and contracts produced for the prevention of marine accidents [9].

Therefore, accident research code has been accepted as an obligation in the 84th meeting of Maritime Safety Committee (MSC), which was held by International Maritime Organisation (IMO) in London on dates between 07th and 16th May 2008. Such code includes a safety research, recommended practices and international standards for marine accidents or marine incidents. Parties to the Convention shall undertake a marine safety research for each serious marine accident in accordance with that code and provide its findings in researches to be transferred to IMO. Within the internet site of IMO, a database is available, which is called as GISIS. This database includes a module by the name of marine incident and accident. This module contains marine accident reports which have been reported to IMO [10, 11].

In this study, marine accident data recorded in GISIS have been analysed, and they have been assessed by means of GIS in terms of marine accidents, accident

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type and accident density, and such marine accident areas with high risk have been determined.

2. Method

In this study, data pertaining to 585 marine accidents occurred during the years between 2007 and 2011, which have been recorded into GISIS, have been examined. The vessels include bulk dry, general cargo, container, ro/ro, passenger, passenger ro/ro, oil tanker, gas tanker and chemical tankers. A database has been created in GISIS system, having grouped the data recorded according to accident type, vessel name, flag, accident size and accident coordinates.

In the study, it has been intended to create marine accident chart for marine accidents, and for such purpose Microsoft Excel 2010 and ArcGIS 10 programs have been used. By means of Microsoft Excel 2010, the geographical coordinates in degrees, minutes have been converted into numerical values suitable with ArcGIS 10 program. To prevent any mistake, the accident data entered into the system have been analysed singly after the conversion. Marine accident chart has been created with the data processed once have been transferred into ArcGIS 10 program, and the created marine accident chart has been separated into ranges and risky areas have been determined.

3. Marine Accident Data

The study includes data regarding the marine accidents occurred in 2007-2011, which are recorded into GISIS marine accident and incident database and classified as very serious, serious, less serious. Very serious accidents are the accidents including vessel loss, loss of life and solid pollution. In the 37th meeting of Marine Environment Protection Committee (MESC), solid pollution has been defined as the pollution affecting the coast state or flag state, which generates serious destructive impacts on environment and requires preventive measures. Serious accidents are the incidents such as fire, explosion, collision, grounding, contact, heavy weather damage, ice damage, cracks within the body of vessel, hull flaw which do not have very serious accident nature. Blockage of main engine, underwater damage, accommodation deck damage, solid structural damages, pollution in small quantities, damages requiring shore assistance or tugboat use are included in this group. Less serious accidents are the accidents which are not as notable as very serious accidents and serious accidents and it aims at recording useful information [11]. All of the accidents analysed have been suffered by commercial vessels. Fig. 1 contains distribution of vessel accidents in percentages in terms of vessel type.

A hundred ninety six of such accidents have caused to loss of life, loss of vessel or serious environmental pollution (very serious accident). Three hundred twenty four of such have resulted in injury, small scaled environmental pollution or vessel's becoming unsuitable for navigation (serious accident) and the remaining 65 accidents are less serious accidents other than abovementioned accidents.

Flag state is responsible for that the vessel, which has its flag, be fitted out in accordance with international life, property safety, national and international rules. Therefore, flag state practices are an important factor for marine accidents [10]. Table 1 indicates the distribution of vessel accidents recorded in GISIS according to flag state. Among accident data which have been transferred to the database, 188 accidents have been caused by the vessels with Panama flag, 83 of them with United Kingdom flag, 30 with Denmark flag, 24 with Malta flag and 23 with Liberia flag (Fig. 2).

Marine accidents have been analysed in seven categories, including collision, grounding, fire/explosion, flooding/sinking, damages to ship or equipment, occupational accident and other accidents. As a result of examination of marine accident data, it has been found that the most frequent 3 accident types are collision, grounding and damages to ship or equipment (Table 1).

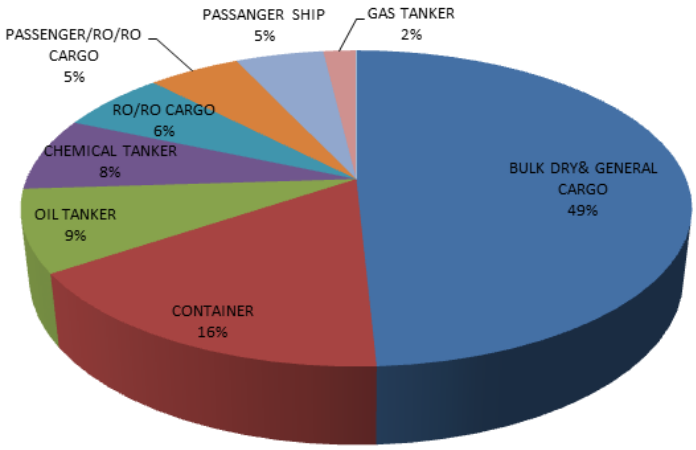


Fig. 1 Distribution of vessel accidents according to vessel type.

Table 1 Distribution of vessel accidents according to accident type [11].

TYPE of SHIP	TYPE of MARINE ACCIDENTS						
	Collision	Grounding	Damages to ship or equipment	Occupational accident	Fire/ explosion	Flooding/sinking	Other
Bulk Dry/ General Cargo	97	66	52	20	23	10	20
Container	41	12	13	19	4	2	5
Oil Tanker	14	10	4	9	6	2	4
Chemical Tanker	15	6	9	7	4	2	1
Gas Tanker	2	1	1	4	3	-	-
Passanger Ship	4	7	3	4	3	3	6
Passanger Ro/Ro Cargo	15	2	5	2	4	1	2
Ro/Ro Cargo	7	8	5	6	7	2	1
Total	195	112	92	71	54	22	39

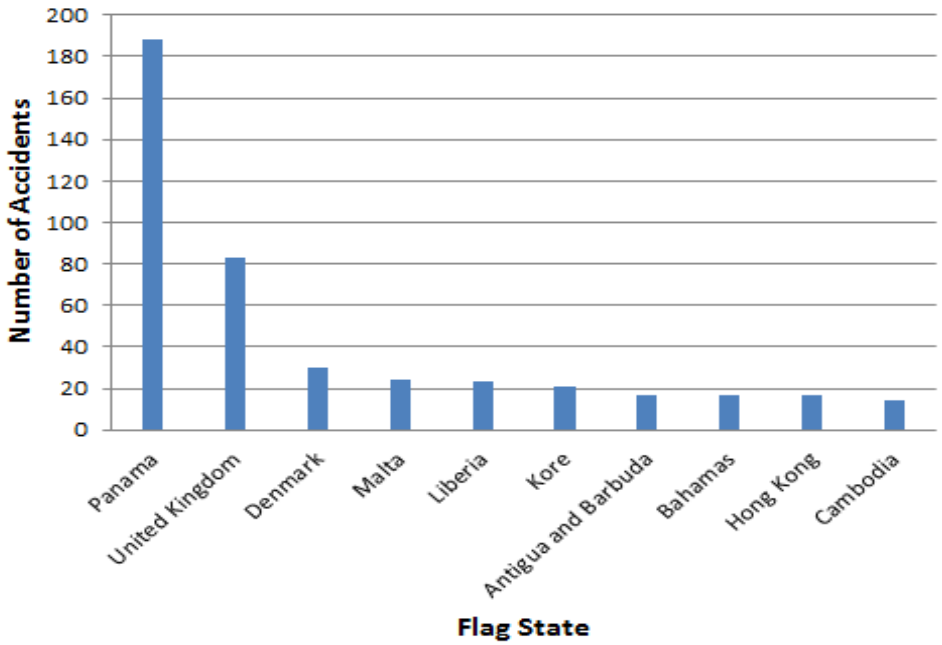


Fig. 2 Distribution of vessel accidents according to flag state.

4. GIS

GIS is an information system which performs integratedly the functions of collection, storage, processing and presentation to customer of the information, either graphical or non-graphical, which have been obtained through data or observations based on location [12]. GIS has 5 important components. These are hardware, software, data, human and method. Effective use of GIS depends on organized use of all components. The most important component is the data which requires the maximum time and cost among others [13].

Achievement of GIS project depends on availability of data with appropriate structure. In GIS, the geographical data consists of 2 main groups: verbal and graphical. In verbal data, the information, which indicates attributions of geographical data, is stored. On the other hand, in graphical data, the information, which indicates the form and location of objects in the world, is stored. Since the GIS is based on relational data model, table data and graphical data may be connected to each other. In order to transfer geographical data into computer, to process and display it in computer, said raw data must primarily be converted into a form cognizable by computer. Such a conversion is possible through conversion of data into numerical form [12, 14].

GIS technology has been a popular tool for visualization of accident data and analysis. Accident analysis studies aim at the identification of high rate accident locations and safety deficient areas [15]. The use of GIS is the most effective way of examining and evaluating the results of analyses which use a multitude of data and different criteria [16]. GIS is used to locate accidents on a digital chart and realize their distribution [17].

4.1 Implementation of GIS in The Study

Marine accidents have been analyzed in 5 stages in ArcGIS 10 program. In the first stage, marine accident chart has been created by entering marine accident data into ArcGIS 10 program. Fig. 3 indicates the distribution of marine accidents according to vessel type. In the 2nd stage, the world chart has been divided into 10 degree latitude and longitude intervals and accident density has been identified for marine accidents.

Accident density chart has been created for general marine accidents in Fig. 4, and for collision and grounding accidents in Fig. 5. In the study, marine accident areas have been classified as very high risk, high risk, risk, moderate risk and low risk marine area. Definitions are associated with quantity of accidents, depending on the size of accident area. Accordingly, ranges with density of more than 30 accidents are very high risk marine areas; ranges with density of between 20 and 30 accidents are high risk marine areas; ranges with density of between 10 and 20 accidents are risky marine areas; ranges with density of between 5 and 10 accidents are moderate risk marine areas; and ranges with density of less than 5 accidents are low risk marine areas.

In the 3rd stage, marine areas where marine accidents are intensive have been analysed. In this stage, the North Europe and Far East have been determined as the marine areas with the most intensive marine accidents. In the 4th stage, such marine areas have been focused on. Therefore, such marine areas have been divided into grids with 2 degree latitude and longitude intervals. So it has been made possible to display and interpret the marine accidents in the North Europe and Far East comprehensively (Figs. 6, 7, 8 and 9). It has been found that such process is required for determination of marine accident locations. Such created charts enable assessment of marine accidents in terms of location.

In the last stage, marine accident charts have been assessed and interpreted. In order to provide comprehensibleness of the assessment, ranges with high accident density have been numerated from 1 to 16 (Figs. 6 and 8). Table 2 indicates quantitative distribution of marine accidents according to range number.

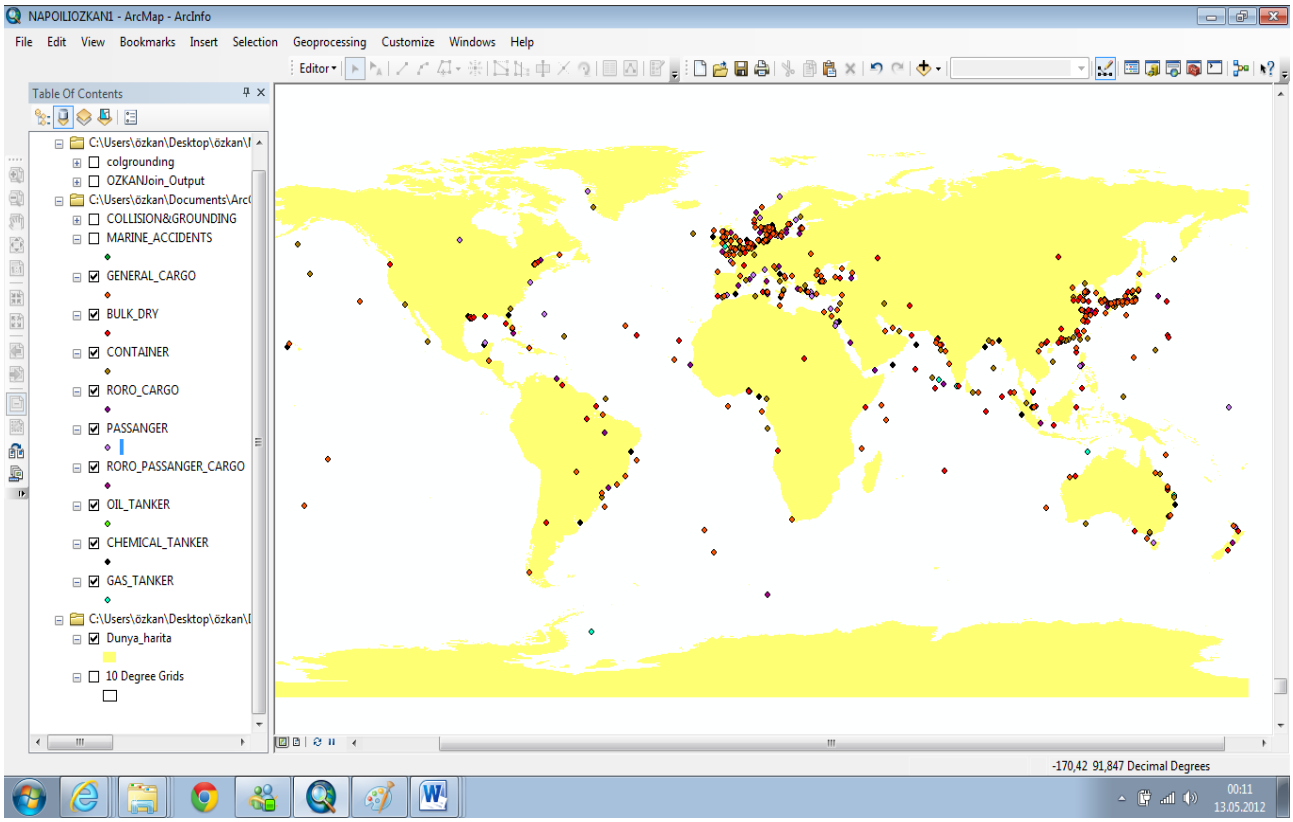


Fig. 3 Marine accidents chart for merchant ships.

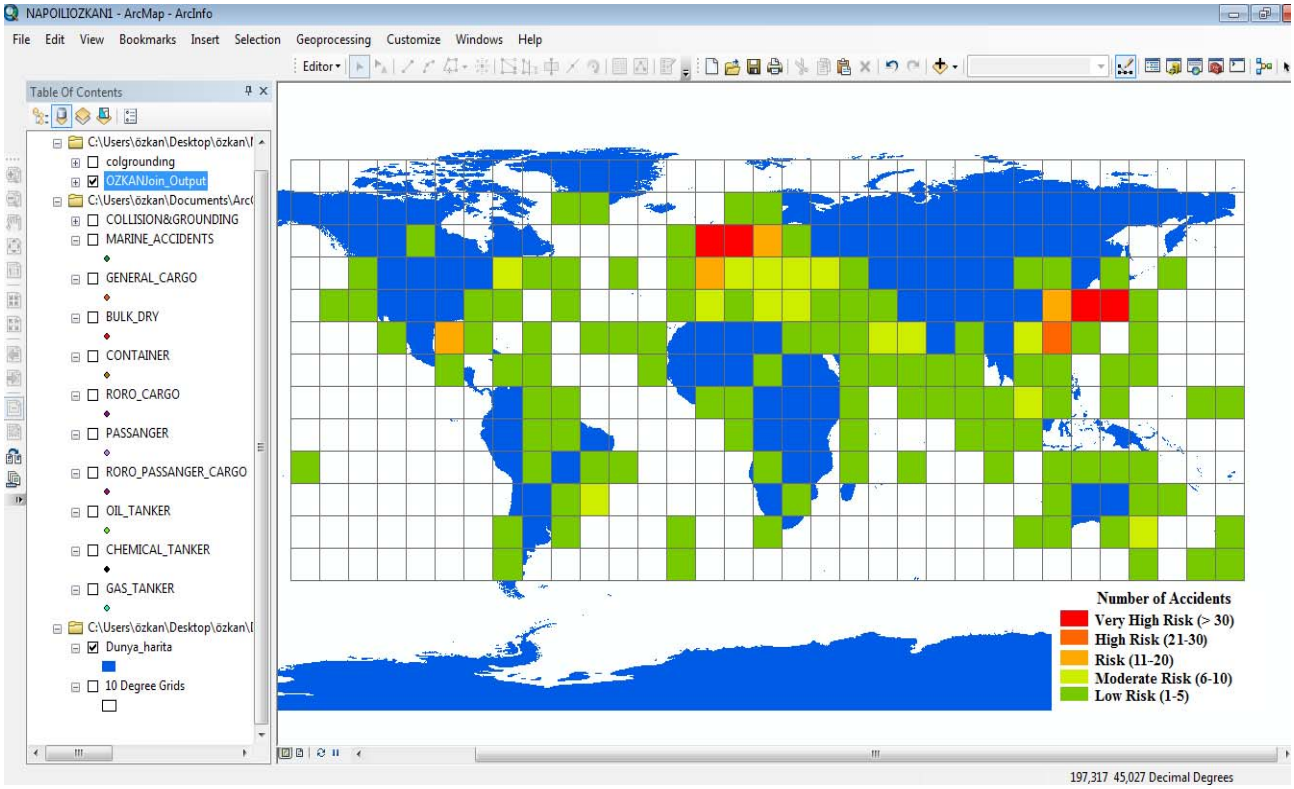


Fig. 4 Density chart for all of marine accidents.

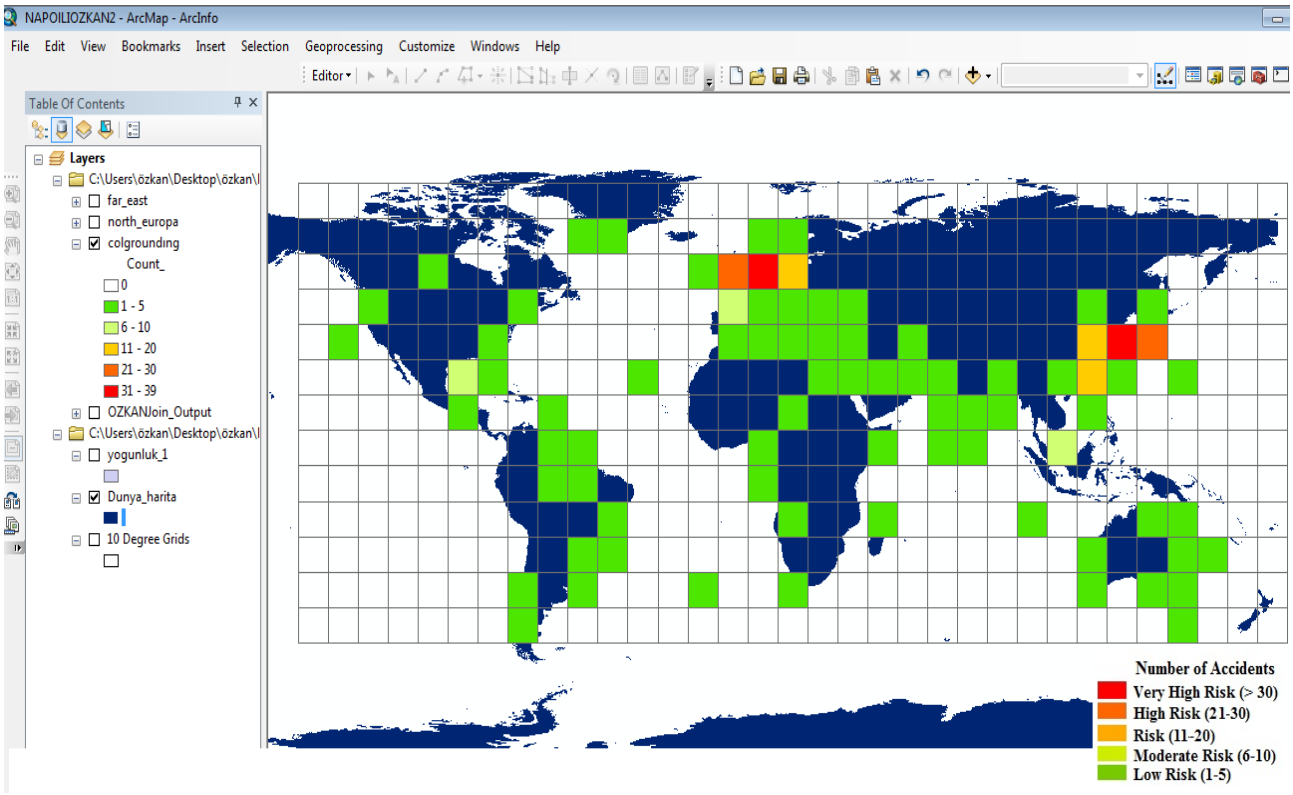


Fig. 5 Density chart for collision & grounding accidents.

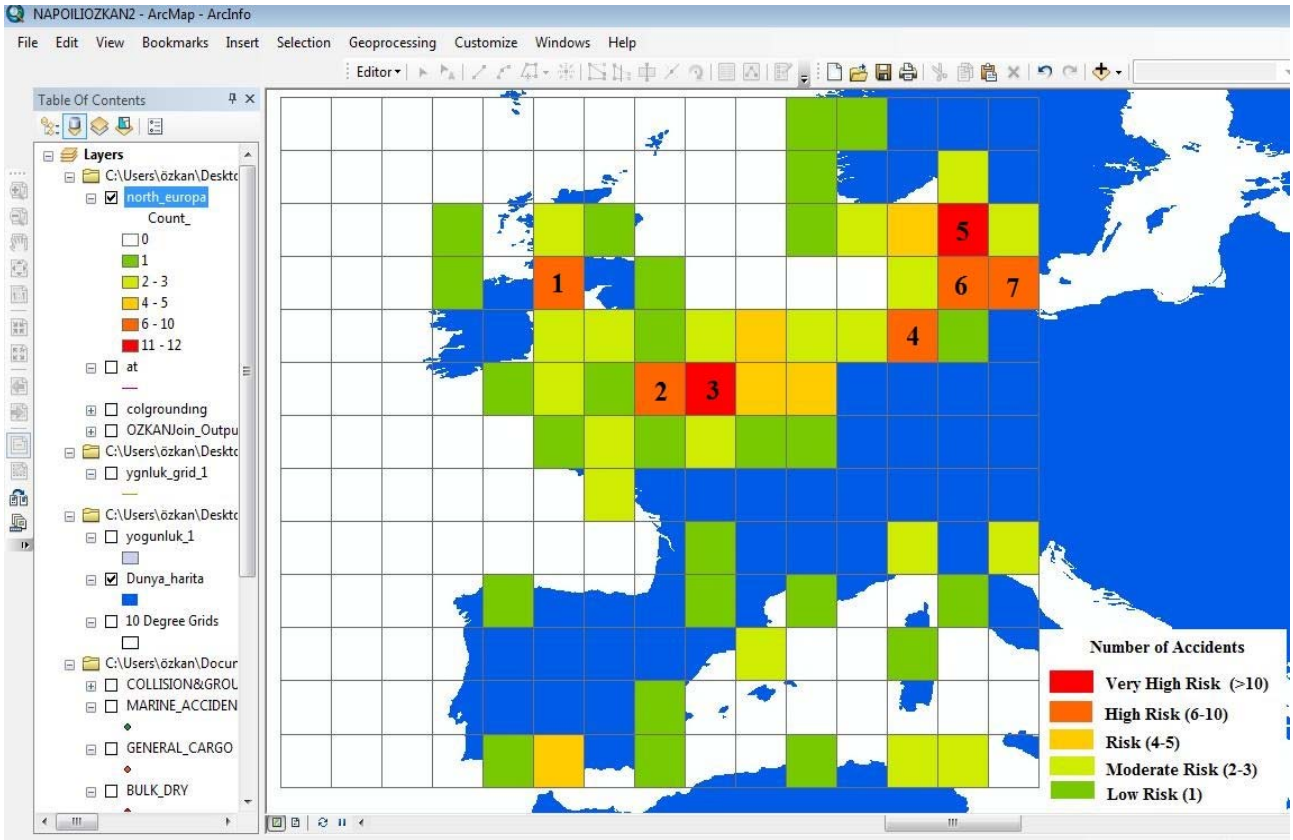


Fig. 6 Density chart for North Europa Countries.

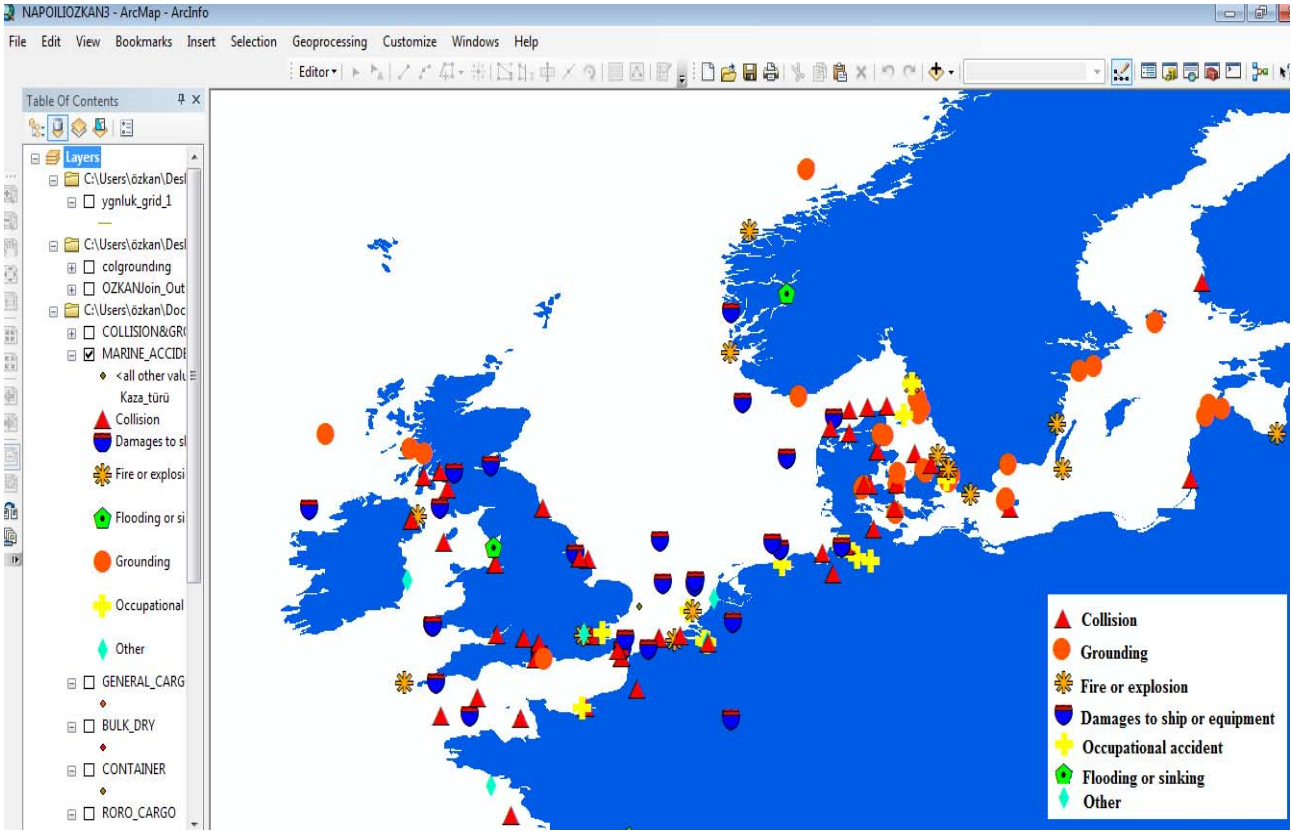


Fig. 7 General distribution of types of marine accidents in the North Europe.

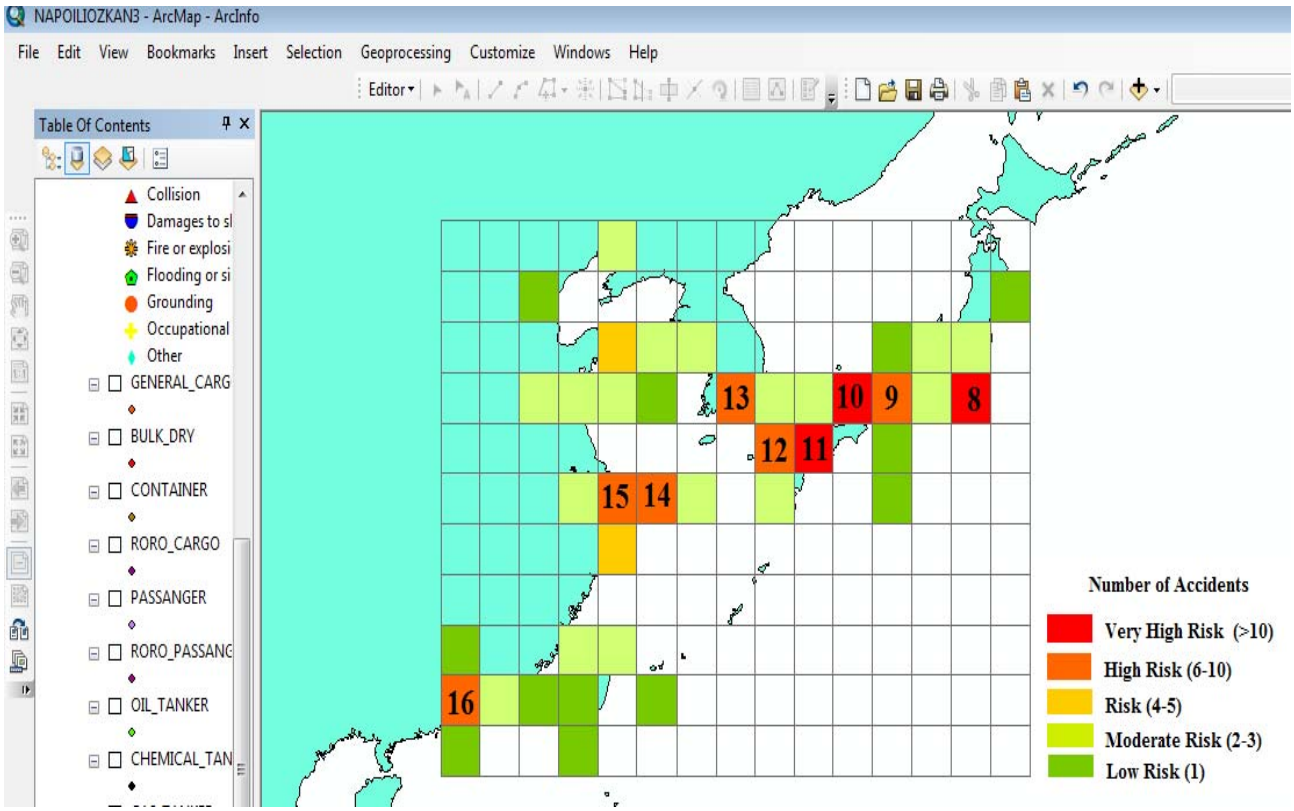


Fig. 8 Density chart for Far East Countries.

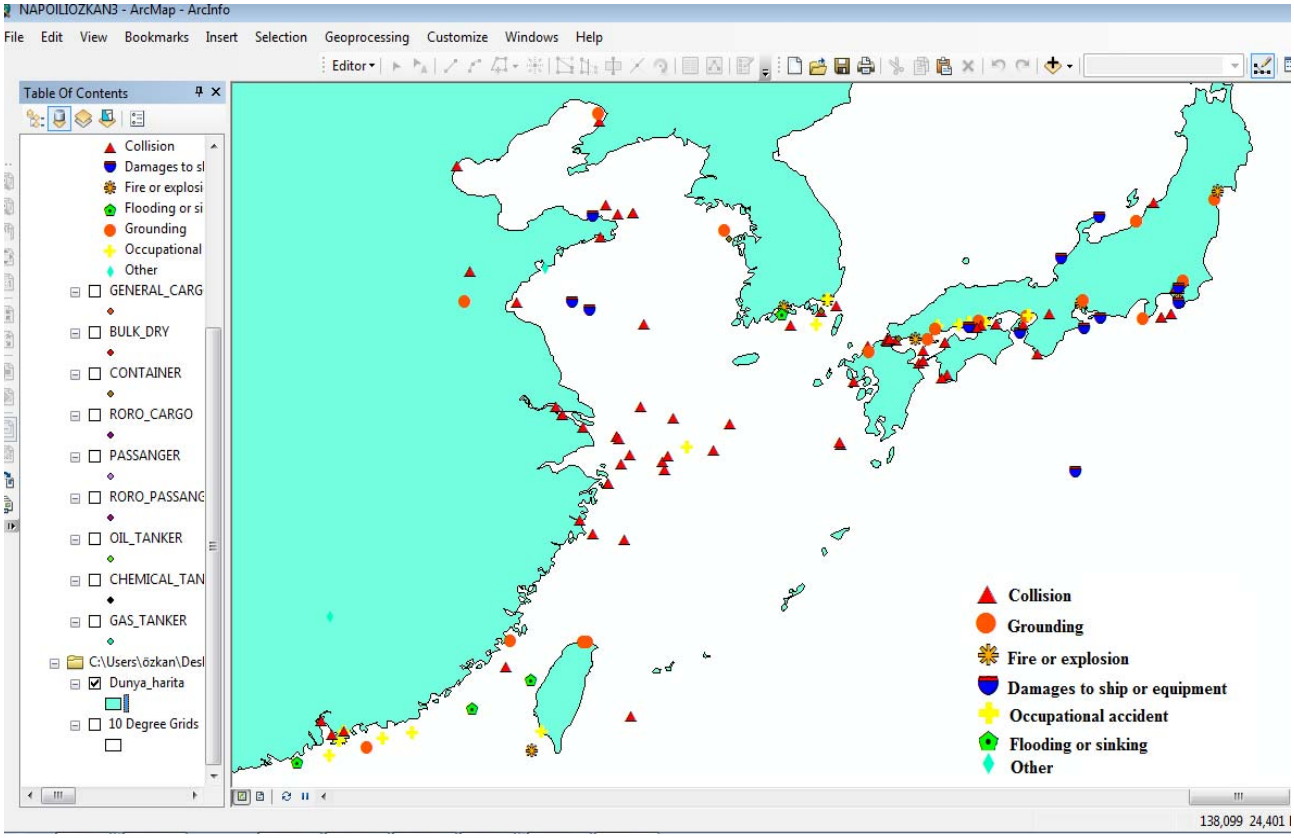


Fig. 9 General distribution of types of marine accidents in the Far East.

Table 2 Quantitative distribution of marine accidents according to range number.

	Polygon Number	Total Accident Numbers	Collision&Grounding Accident Numbers
	1	7	4
	2	7	6
	3	12	6
For Fig. 6	4	9	5
	5	12	11
	6	8	8
	7	8	5
	8	11	7
	9	8	4
	10	11	6
	11	12	11
For Fig. 8	12	8	8
	13	7	4
	14	7	6
	15	8	6
	16	7	4

5. Results

Marine areas with the highest risk, in terms of marine accidents, are North Europe and Far East.

The marine areas with very high risk and high risk in the North Europe are Strait of Dover between England and France, Belfast shores in Ireland, Hamburg in Germany, east coasts of Denmark and in the south coasts of Norway the seas surrounding Kattegat, Great Belt and Copenhagen.

Marine accidents in the Far East are intensive especially in the coasts of Japan and China.

In the Far East, marine areas with intensive marine accidents are Kanmon Strait, Urage Channel and Bungo Strait in Japan, Shanghai, Ningbo and Hong Kong in China.

As a consequence of a general assessment of all accidents, it has been found that especially collision and grounding accidents have high intensity in these areas.

6. Conclusion

GIS is a basic guide which provides interpretation of results on a chart. It enables visual interpretation of accidents. In this study, marine accident areas with high intensity have been visually interpreted. It is important for determining measures required to detect marine accident areas with high intensity and prevent marine accidents in such areas. Coastal areas and straits are the marine areas where collision and grounding accidents have the highest density.

GIS is a significant instrument for the follow-up and mapping of marine accidents. In this context, the usage of GIS in the field of maritime must be extended. It shall be important to determine the common reasons of marine accidents in the marine areas, with high density of accident, for preventing similar accidents.

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Investigation of Shoreline and Topographic Change on the West Side of the Imagire-Guchi Inlet, Japan

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Abstract: Near the Imagire-guchi inlet, which is the target area in this study, the shoreline on the west side of a jetty retreats because of a decrease in sediment supply from the east side upstream. This study attempts to analyze the shoreline and topographic changes around the inlet through analysis of GPS (global position system) measurements and digitized shoreline from aerial photographs. In addition, the DoC (depth of closure) is determined by examining datasets of cross-shore profiles and by calculations using the Hallermeier equation (1981) based on the offshore wave height and period. The results obtained by GPS indicate coastal erosion caused by waves generated by typhoons. The gradual recovery of the shoreline position after the typhoons struck was also captured by the GPS survey. However, analysis of the aerial photographs reveals that the shoreline on the west side of the jetty fluctuated widely. The cross-shore profile datasets reveal that closure depth far from the inlet was deeper than that near the inlet.

Key words: Shoreline, topographic, GPS, aerial photograph, cross-shore profile.

1. Introduction

In coastal management and engineering design, shoreline changes due to complicated processes such as coastal erosion, sediment transport, and coastal development are important concerns for coastal scientists. The impacts of these coastal changes include loss of life and property, changes in coastal socioeconomic environments, and decrease in coastal land resources. In the recent decade, greater demands for recreation and tourism have led to a significant increase in the occupation of coastal areas. Therefore, the monitoring and analysis of shoreline and topographic changes that utilize information pertaining to natural factors such as shoreline deposits, shoreline material, and slope of coastal zone have become mandatory for coastal management.

Jetties generally affect inlets and adjacent shorelines by decreasing the amount of sediment entering the inlet and by moving the sediment offshore. These structures can also affect neighboring shorelines by creating sediment deficits that result in downdrift erosion to account for the missing volume of sand. Jetties are usually constructed in navigational channels to prevent sand deposition and to provide wave protection around inlets. In case of the Imagire-guchi inlet, which is the target area in this study, the jetty has an enormous influence on shoreline conditions. The shoreline changes around the inlet affect transportation routes, communities, and ecosystems. The impact of shoreline change on coastal communities and structures can be severe and costly. Therefore, it is important for coastal residents, including those living near the Imagire-guchi inlet, to understand the conditions of their local shorelines and to determine whether it is advancing, retreating, or stable.

Several authors have presented the definition of shoreline position. For example, an idealized definition of a shoreline is that it coincides with the physical interface of land and water [1, 4, 6]. The shoreline is the intersection of water, land, and air [8]. The appropriate definition of the shoreline status depends

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on the methods used in this study. The rate-of-change value precision is dependent on the following factors: (1) accuracy of the shoreline measurement, (2) temporal variability of the shoreline, (3) number of measured shoreline positions to create data points used in rate calculation, (4) proximity of each observation to the time of the actual change in the trend of shoreline movement, (5) period between shoreline measurements, (6) total time span of shoreline data, and (7) method used for rate calculation [3].

Sediment transport around the Imagire-guchi inlet can create morphological changes through erosion or deposition. Strong offshore-bound currents strongly influence sediment transport around this inlet [12]. The shoreline may be accreted or eroded because of the movement of sediment. The sediment mechanism around the Imagire-guchi inlet has not yet been fully understood. Currents and waves are major factors of sediment transport in these waters. In rivers, the flow from upstream plays an important role in the transport process. However, in coastal areas and estuaries, the combination of currents, waves, and tides is dominant. During the erosion process, sediment transportation, in which the material is displaced from its original location, occurs. Sedimentation occurs when the inflow of the sediment supplied to a particular location is greater than that carried by the outflow from the location and can be caused by deposition or erosion along the coast. These processes, particularly sedimentation, may have significant implications for engineers working in this environment. Therefore, the shoreline must be considered in a temporal sense, and the selected time scale depends on the context of the investigation [1]. In addition, the shoreline position and its rate of change constitute the basic information required for conducting many coastal engineering studies [8]. This paper investigates the shoreline and topographic changes in the area near the Imagire-guchi inlet. Aerial photographs and cross-shore profile datasets for various years and field surveys that employ RTK-GPS (real-time kinematic-global positioning system) have been used to characterize the shoreline position trend and to investigate the closure depth around the Imagire-guchi inlet.

2. Study Area

The Imagire-guchi inlet is located in the middle region of the Enshu-Nada Coast, Japan, and faces the Pacific Ocean. The Enshu-Nada Coast is located in central Honshu. The Imagire-guchi inlet was dramatically altered in 1498AD by a tsunami generated by an 8.6 magnitude earthquake, which also shifted the estuary mouth of the Hamana Lake by approximately 3.5 km. As a result, the freshwater lake was changed into a brackish system [2]. The general description of the study area is shown in Fig. 1. The main source of sediment supply to the Imagire-guchi inlet is the Tenryu River, and the alongshore sediment is transported mainly westward on the west side of the river mouth. The Imagire-guchi inlet, which connects Hamana Lake to the Enshu Nada Coast, is 200 m wide. Hamana Lake has a surface area of approximately 74 km^2, its body stretches approximately 103 km, and its maximum and averaged depths are 12 m and 4.8 m, respectively [7]. The lake preserves about 340 million m^3 of brackish water and is acknowledged as one of the biggest brackish water regions in Japan. Numerous freshwater inflows from rivers at the northern part of the lake provide ideal habitats for aquatic creatures including clams, eels, crabs, oysters, and shrimp.

At the Imagire-guchi inlet, two jetties were constructed between 1954 and the early 1970s to stabilize the navigation channel [9]. These structures impede sediment transport, and as a result, a large amount of sediment has accumulated on the east side of the east jetty. On the contrary, the shoreline retreats on the west side of the west jetty because of a decrease in the sediment supplied from the east. These jetties have a significant impact on the surrounding coastal area. During the last 10,000 years, the Imagire-guchi inlet, the sole inlet of seawater into Lake Hamana, has been

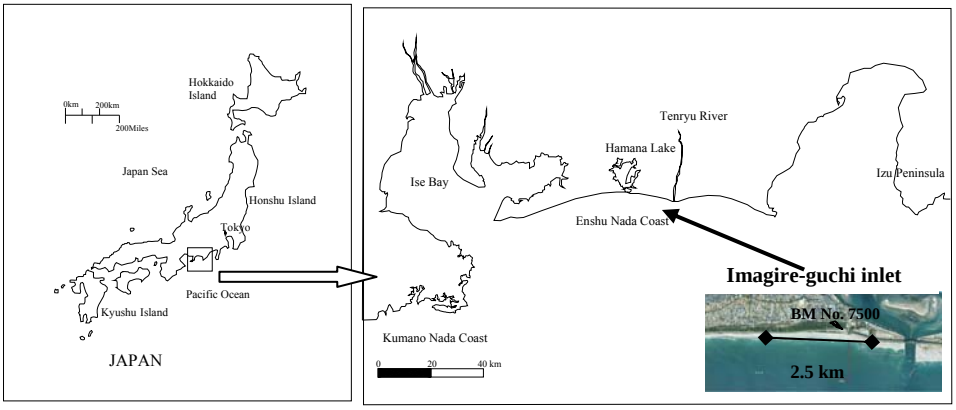


Fig. 1 Study area of the Imagire-guchi inlet located in Hamamatsu city, Shizuoka prefecture, Japan.

repeatedly opened and closed because of natural events such as fluctuations in sea level, earthquakes, and tsunamis [7]. Multiphase inlet construction projects have been applied in this region to maintain the inlet stability in terms of depth and width, and to protect the coastline and navigation channel in the area. Previous field observations at the Imagire-guchi inlet revealed that a strong offshore-bound current through the inlet strongly influenced sediment transport in the area [14]. This inlet has undergone multiphase construction modifications, which led to topographical changes and a higher water exchange rate [15].

3. Typhoon and Weather Factors at the Site

Precipitation and wind velocity data obtained by field measurements with the AMeDAS (Automated Meteorological Data Acquisition System) in the area surrounding the Imagire-guchi inlet are shown in Fig. 2. These values increased concurrently with typhoons occurring in July and September, which caused significant changes in the shoreline position.

Between June 2011 and March 2012, typhoon events occurred on three occasions near the research site. The first, typhoon No. 6 (Typhoon Ma-on), approached Japan (Fig. 3a) on July 19, 2011, with a rainfall amount of 95.5 mm and wind velocity of 9.1 m/s (Fig. 2). This typhoon caused a retreat of the shoreline, as determined from previous conditions measured earlier in the month (Fig. 4b).

The second, Typhoon No. 12 (Typhoon Talas), approached Shikoku Island (Fig. 3b) on September 2, 2011, with a rainfall amount of 10.5 mm and wind velocity 10.5 m/s (Fig. 2).

On September 21, 2011, Typhoon No. 15 (Typhoon Roke) landed in Hamamatsu near the Imagire-guchi inlet (Fig. 3c). The sea level rose about 1.4 m in Mikawa port, rainfall reached 154 mm, and wind velocity was 20.3 m/s (Fig. 2). Although all three typhoons greatly affected shoreline positions near the measurement area, Typhoon Roke caused the most significant changes in the shoreline position (Fig. 3c).

4. Potential Data Source

4.1 Field Measurement

GPS measurement was used to determine shoreline position near the Imagire-guchi inlet. The effects of seasonal variation and influence of individual storms were considered in the measurements. The shoreline changes were measured near the Imagire-guchi inlet along the 2.5 km stretch on the west side of the jetty (Fig. 1). The measurements were conducted every 50 m with the level of T.P. +88 cm using GPS with RTK (real time kinematics) (Topcon GB-500 GPS). The GPS measurement represents three dimensions of XYZ positions. A base station was set on BM (benchmark) No. 7500. The measurements of shoreline alteration were started from the BM. Two GPS rovers (mobile GPS receivers) were used for time efficiency purposes; the 0.9 km stretch from the BM on the east side was measured by the first, and the 1.6 km stretch from that

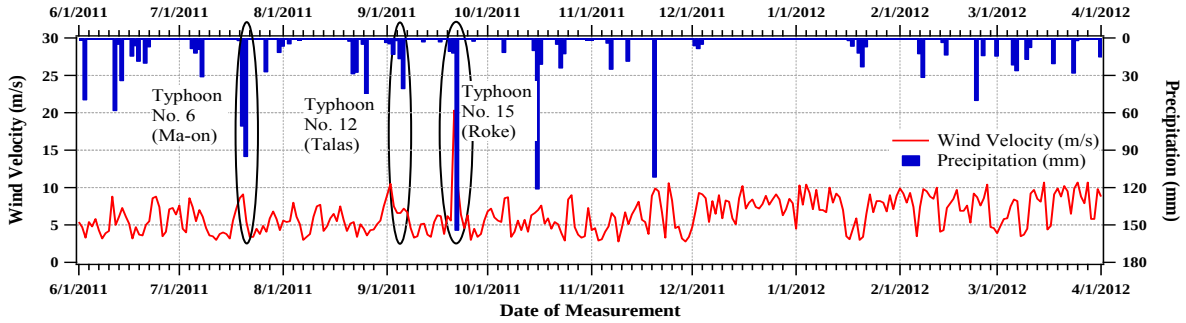


Fig. 2 Precipitation and wind velocity recorded at the study area (Japan Meteorological Agency).

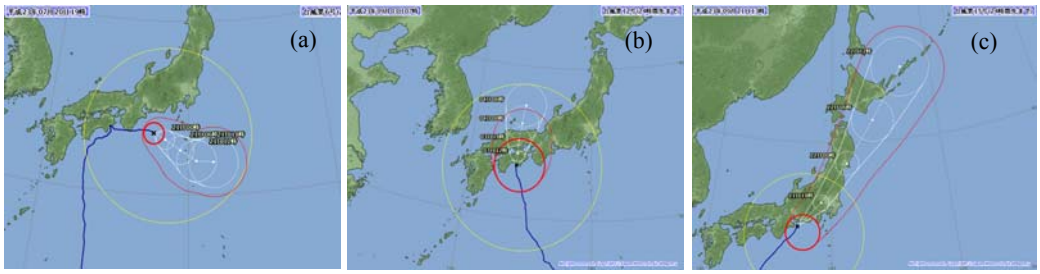


Fig. 3 Path of typhoons occurring near the study area: (a) No. 6 (Ma-on) in July; (b) No. 12 (Talas) in September; (c) No. 15 (Roke) in September (Japan Meteorological Agency).

on the west side was measured by the second.

The measurements were conducted every month at low tide conditions during spring tides beginning in June 2011. The measurement results, reveal historical shoreline changes that occurred during a 10-month period (Fig. 4a). Measurements of shoreline changes near the Imagire-guchi inlet were conducted in its western area to study the behavior of shoreline change. Water level is an important factor because it can indicate shoreline changes. Nine shoreline positions were examined at this site from June 2011 to March 2012.

4.2 Image Data

Aerial photographs of the Imagire-guchi inlet were obtained in 1900, 2002–2005, and 2007–2010 by the Hamamatsu Doboku local government office in Shizuoka prefecture, Japan. To investigate the shoreline changes on the west side of the Imagire-guchi inlet, shoreline positions were digitized in aerial photographs obtained in various years to summarize the historical shoreline movement and shoreline position around the inlet. Long-term shoreline changes were observed on the basis of these maps. Historical shoreline behavior is generally obtained by field measurements. However, in the present study, this method is supplemented by the use of aerial photographs to provide greater spatial coverage, resulting in a better indication of rates of change along the shoreline [11].

4.3 Cross-Shore Profile, Hallermeier Equation and Depth of Closure

To investigate topographic changes by the estimated DoC (depth of closure) around the Imagire-guchi inlet, comparative analysis was performed among cross-shore profile datasets in 1990, 1991, 2004, and 2006–2010. In addition, estimations were conducted using the Hallermeier equation (1981) on the basis of offshore wave height and period data obtained by using data from an 11-year period of 1999-2009, excluding 2008.

DoC is a concept widely used in the field of coastal engineering to describe the seaward limit of appreciable depth change. DoC is often used to determine seaward limits of significant cross-shore

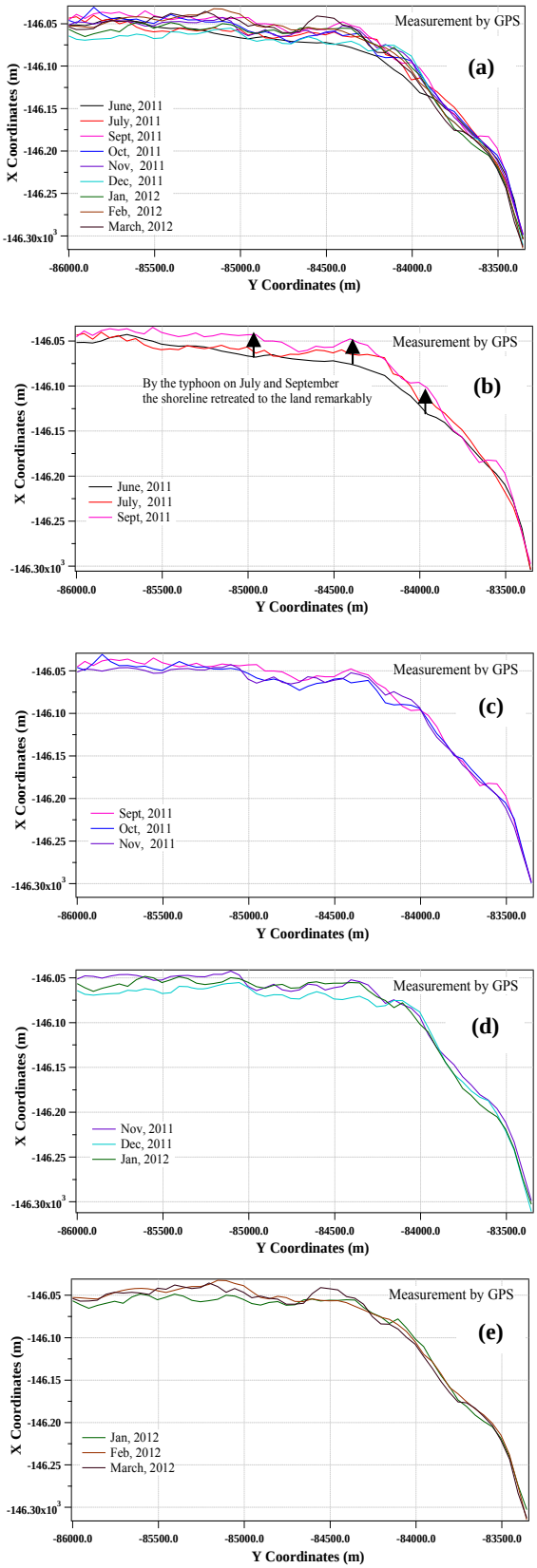


Fig. 4 Measurement of shoreline changes by GPS with real time kinematics (Topcon GB-500 GPS).

sediment transport [13]. This concept is of fundamental importance in coastal sediment budgets and associated applications such as beach and surface nourishment [5].

In engineering projects, DoC is most effectively determined through repeated accurate profile surveys. If such data are not available, an analytic method can be used to estimate the limiting depth [10]. The following analytical method used to estimate DoC has been proposed by Hallermeier (1981) on the basis of offshore wave height and period (Eq. (1)):

$$D_c = 2.28 H_s - 68.5\left(\frac{H_s^2}{gT^2}\right), \quad (1)$$

where D_C is predicted DoC (referenced to mean low water), H_s is significant wave height exceeding 12 h per year, T_s is associated wave period, and g is acceleration due to gravity. DoC can be defined for events such as storms, time interval change and time-integrated change [13].

5. Shoreline and Topographic Change Analysis and Discussion.

5.1 Shoreline Measurement

GPS measurement points showing shoreline changes from June 2011 to March 2012 are shown in Fig. 4a. The graph shows periodic shoreline erosion, which is likely caused by wave action along the measurement area generated by typhoons. Fig. 4b clearly displays significant differences among shoreline positions in June, July, and September, which coincide with typhoon events (Fig. 3). However, after two months the retreated shoreline began to gradually recover to its former position (Fig. 4c). In addition, a large amount of accretion appeared in December (Fig. 4d). In February and March, the movements of the shoreline position were similar (Fig. 4e), which indicates that the shoreline alteration near the Imagire-guchi inlet will always be in flux to achieve a dynamic equilibrium position in the natural condition.

5.2 Analysis of Aerial Photographs

For aerial photography, the actual shoreline position at any given time is dependent on the prevailing oceanographic conditions during the flight [3]. On the basis of aerial photographs obtained for this study, shoreline changes between 1990 and 2010 were investigated.

Fig. 5a shows an aerial photograph captured in 1990, depicting a wide natural sandy beach extended along the shoreline. Fig. 5b shows an aerial photograph captured in 2002 that clearly indicates beach erosion on the west side of the Imagire-guchi inlet caused by the reduction of sediment supply from the Tenryu River. A comparison of the two photographs reveals that the width of the sandy beach decreased considerably due to erosion in 2002 that was caused by a different process than that in 1990 (circle in Fig. 5b).

Figs. 5c and 5d show aerial photographs captured in 2007 and 2010, respectively. It is apparent that the shoreline changes began to recover gradually toward the initial position (Fig. 5e), which indicates that a significant amount of sediment was deposited in the area between 2002 and 2010.

This study utilizes the image data of 1990, 2002–2005, and 2007–2010 for long-term analysis (Fig. 6). To analyze shoreline changes in the spatial term, the mean shoreline position ($\bar{y}$) (Eq. (2)) and standard deviations (σ) (Eq. (3)) were calculated for every section:

$$\bar{y}(x) = \frac{1}{n}\sum_{t=1}^{n} y(x,t)\,, \tag{2}$$

$$\sigma(x) = \sqrt{\frac{\sum_{t=1}^{n}(y(x,t)-\bar{y}(x))^2}{n-1}}\,. \tag{3}$$

Fig. 7a shows the mean shoreline position around the Imagire-guchi inlet with maximum and minimum conditions of shoreline changes. The shoreline adjacent to and behind the breakwater was more advanced in 2010 than that in 1990 (Fig. 7b), which indicates that during the 20 year period (1990-2010), the western area of the Imagire-guchi inlet accumulated a significant amount of sediment.

The trends of the maximum and minimum shoreline positions show slight differences from the mean shoreline position. Some parts of the maximum and minimum positions do not follow the mean shoreline position. The range of shoreline position between the maximum and minimum were approximately 60 m on the left side and 23 m on the right side (Fig. 7a). These conditions indicate that the force on the left side was

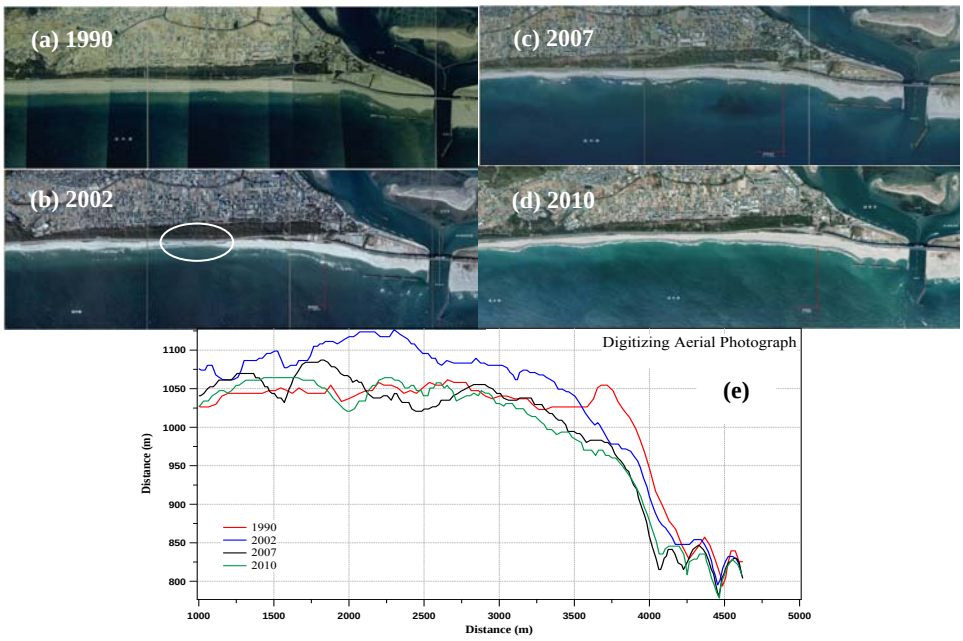


Fig. 5 (a)-(d) Aerial photographs captured in 1990 to 2010; (e) Detected shorelines.

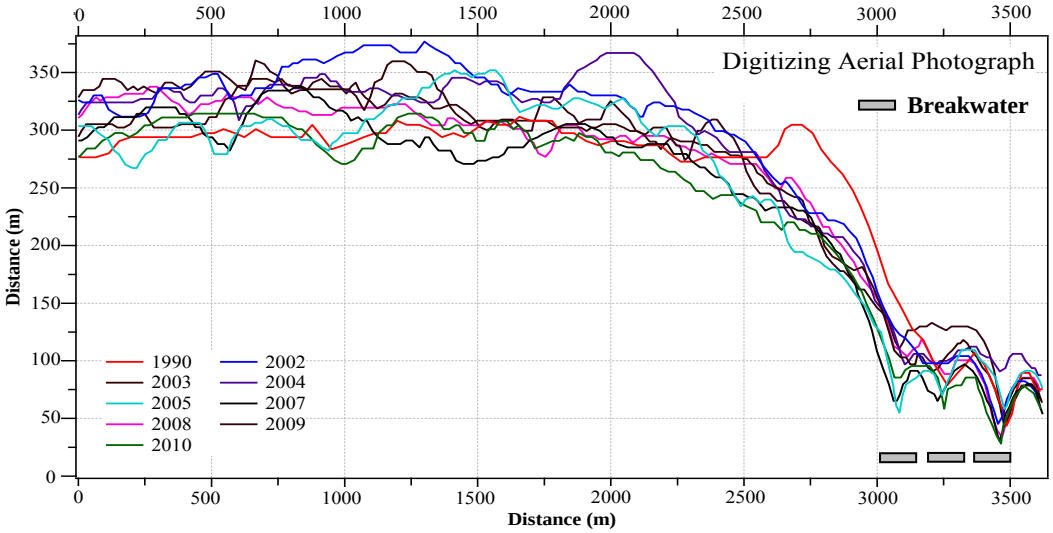


Fig. 6 Digitized aerial photographs obtained by the Hamamatsu Doboku office, Shizuoka prefecture, Japan.

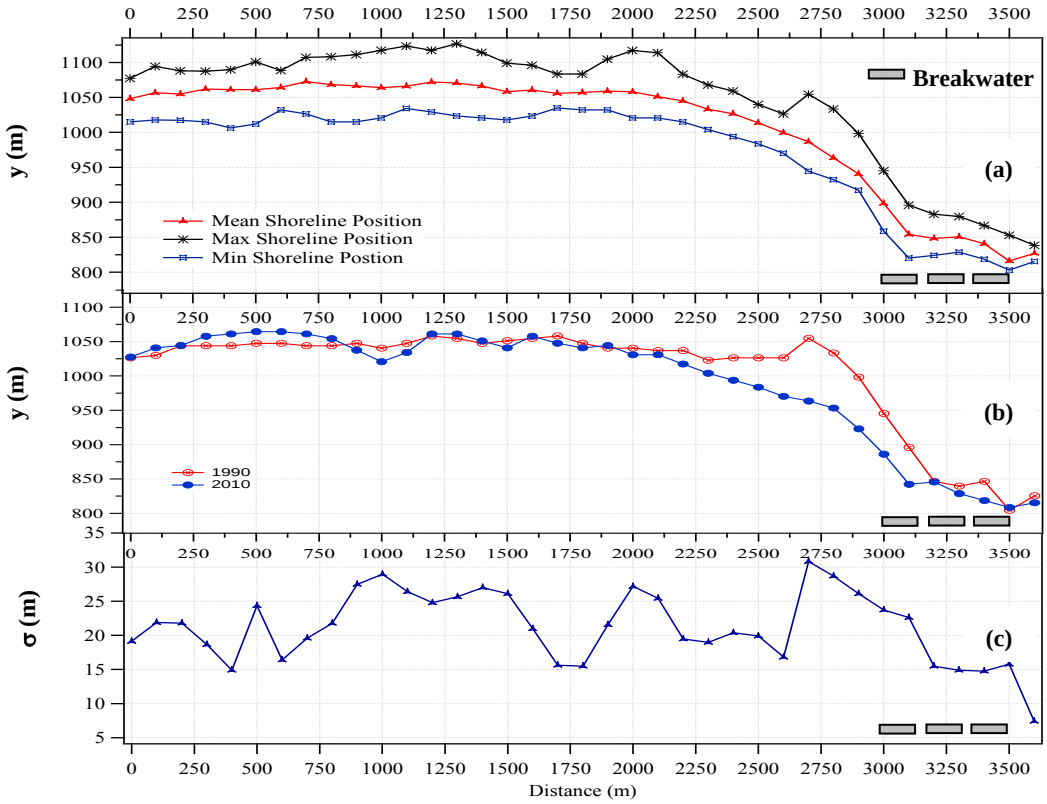


Fig. 7 (a) Max–mean–min shoreline position; (b) Shoreline change in 1990 and 2010; (c) Standard deviation.

larger than that on the right side. The standard deviation of the shoreline alteration around the inlet was approximately 20 m at the farthest point from the breakwaters (left side in Fig. 7c) and 8 m behind the breakwater indicating that the movement was more significant in the area farther from the breakwaters than that behind them. The shoreline changes near the breakwater were more stable than those in any other location. However, some parts of the standard deviation of the shoreline alteration also show a movement greater than 20 m. The magnitude of standard deviation varied from 8 m to 30 m.

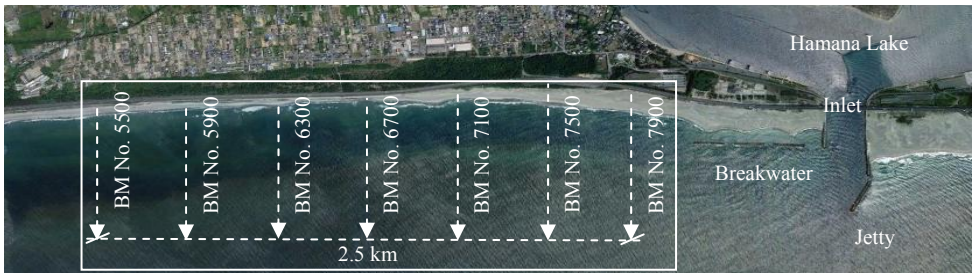


Fig. 8 Cross-shore data profile for the west side of the Imagire-guchi inlet.

5.3 Depth of Closure Determined by Using Cross-Shore Profile Data and that Estimated Using the Hallermeier Equation

The sea bottom profile is useful for determining rates of change at the sea bottom. Variations in coastal morphology alteration around the inlet have been investigated by analyzing bathymetry datasets. To determine DoC on the west side of the inlet, we selected a seven survey lines of cross-profile along 2.5 km (Fig. 8) and conducted analysis using the cross-shore profile dataset. Fig. 9 shows the cross-shore profile for each survey line. The DoC around the Imagire-guchi inlet was estimated by plotting cross-shore profile datasets from 1990, 1991, 2004, and 2006-2010 to depict changes. Two line trends were apparent by which the standard deviation approaching the DoC was decided. The application of standard deviation considers all available data to produce results with greater reliability. From this relationship, the DoC in corresponding cross-sections was estimated in BM No. 5500, BM No. 5900, BM No. 6300, BM No. 6700, and BM No. 7100 at 12 m, 11 m, 10.5 m, 9.5 m and 8.5 m, respectively, where the longitudinal profile change averaged approximately 10 m. The analytical results indicate that the DoC far from the inlet was deeper than that in other areas. Furthermore, the DoC was difficult to detect at BM No. 7500 and BM No. 7900 by the data. This condition may be influenced by the jetty construction and a set of detached breakwaters around the inlet, which significantly affect the surrounding coastal region.

The DoC was estimated using the Hallermeier equation (1981) on the basis of the offshore wave height and period data. The wave data obtained during the 11-year period of 1999-2009, excluding 2008, showed an average DoC of approximately 12 m. This result is in good agreement with the 10 m depth determined by plotting the cross-shore profile data. Offshore wave data was obtained off the Tenryu River mouth approximately 20 km from the Imagire-guchi inlet on the eastern side. This data was used in Eq. (1) to indicate offshore waves.

6. Conclusions

Shoreline and topographic change analysis conducted near the Imagire-guchi inlet was performed in this study by a combination of field measurement by GPS and examination of a digitized shoreline in aerial photographs. Shoreline alteration near the inlet was investigated by analyzing historical datasets from 1900, 2002-2005, and 2007-2010 and GPS measurement recorded during a 10-month period.

DoC was determined by analyzing datasets of cross-shore profiles obtained from 1990, 1991, 2004, and 2006-2010, in addition to calculating using the Hallermeier equation (1981) on the basis of offshore wave height and period data from an 11-year period of 1999–2009 excluding 2008. The preliminary analysis conducted to provide a better understanding of these phenomena is summarized in this section.

The results of GPS measurements indicate remarkable coastal erosion, which is attributed to waves generated by typhoons. The gradual recovery of these shoreline positions was captured by a GPS survey. Conversely, the digitized aerial photographs

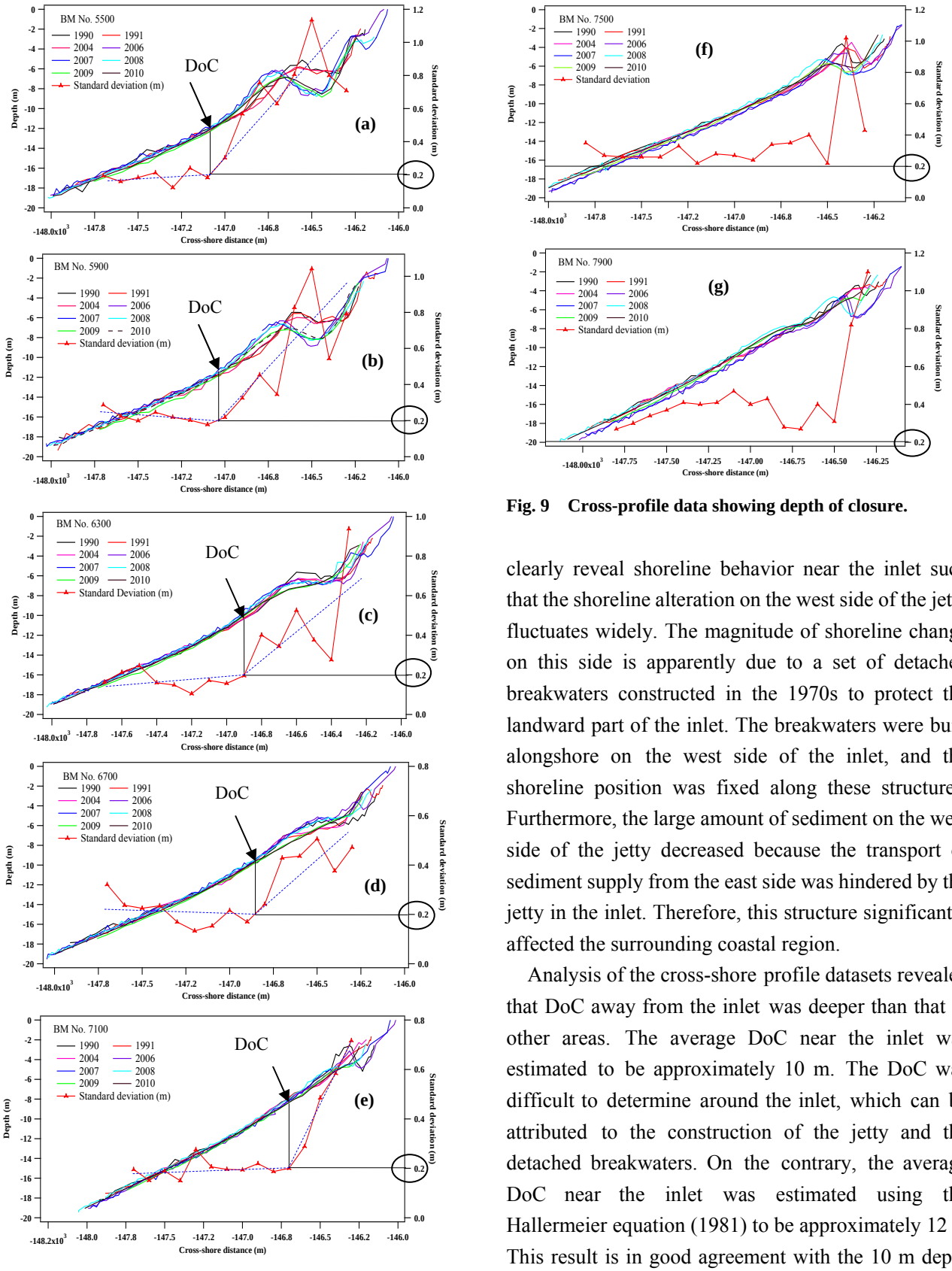


Fig. 9 Cross-profile data showing depth of closure.

clearly reveal shoreline behavior near the inlet such that the shoreline alteration on the west side of the jetty fluctuates widely. The magnitude of shoreline change on this side is apparently due to a set of detached breakwaters constructed in the 1970s to protect the landward part of the inlet. The breakwaters were built alongshore on the west side of the inlet, and the shoreline position was fixed along these structures. Furthermore, the large amount of sediment on the west side of the jetty decreased because the transport of sediment supply from the east side was hindered by the jetty in the inlet. Therefore, this structure significantly affected the surrounding coastal region.

Analysis of the cross-shore profile datasets revealed that DoC away from the inlet was deeper than that in other areas. The average DoC near the inlet was estimated to be approximately 10 m. The DoC was difficult to determine around the inlet, which can be attributed to the construction of the jetty and the detached breakwaters. On the contrary, the average DoC near the inlet was estimated using the Hallermeier equation (1981) to be approximately 12 m. This result is in good agreement with the 10 m depth

determined by plotting the cross-shore profile data. Offshore wave data was obtained off the Tenryu River mouth, which is approximately 20 km from inlet on the eastern side.

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Views from Maritime Education and Training on the Full Implementation of 2010 STCW Amendments

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Abstract: The full review of The International Convention on Standards of Training, Certification and Watch keeping for Seafarers (the STCW Convention) has been accomplished by International Maritime Organization (IMO) and the new amendment, which is also named as Manila amendment, has been effective since 2012, with a transitional period of 2012-2017.

Based on the system engineering context consisting of "Human, Machine and Environment", human factors at sea, i.e., those factors relevant to the seafarers, are consistently underlined. STCW convention is the unique but systematic international maritime legislation looking after the "professional competency standards" of seafarers. The amendment thereto is of great significance for the Maritime Education and Training (MET) systems, which should be fully understood so as to respond to it effectively.

The paper analyzes major impacts brought by the amendment, with purposes to raise recommendations for MET systems to implement the amendment effectively.

Keywords: Maritime education and training, 2010 STCW amendments, seafarers training, maritime strategy.

1. Overview of the New STCW Amendment

STCW 78/95 was amended for the reasons of fast development of world shipping industry, more applications of new maritime technologies onboard, higher standards and stricter management regime in maritime safety and pollution prevention, more importance of human factors in maritime technical operations, and the latent flaws in the current version of the code.

A number of important changes have been made to each chapter of the Annex and Codes of the convention. The most influential advancements for MET institutions are:

- Improved measures to prevent fraudulent practices associated with Certificates of Competency and strengthen the evaluation process;
- Revised requirements on hours of work and rest and new requirements for the prevention of drug and alcohol abuse, as well as updated standards relating to medical fitness standards for seafarers;
- New certification requirements for able seafarers deck and engine;
- New requirements relating to training in modern technology such as Electronic Charts Displaying and Information Systems (ECDIS);
- New requirements for marine environment awareness training and leadership and teamwork training;
- Updated competence requirements for personnel serving on board all types of tankers, including new requirements for personnel serving on liquefied gas tankers;
- New requirements for security training, as well as provisions to ensure that seafarers are properly trained to cope if their ship comes under attack by pirates;
- Introduction of modern training methodology including distance learning and e-learning;
- Complete revision of Chapter V;
- Simplification of celestial navigation standards;

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- Addition of new requirements of Vessel Traffic System (VTS) training for masters, chief officers and Officer Of Watch-keeping for maritime safety;
- Introduction of standards of electrical-electronic officer training;
- Improved and more systematic maritime security training;
- Incorporating compulsory Bridge Resource Management (BRM) and Engine-room Resource Management (ERM) training requirements by transferring relevant requirements from section B-VIII/2 to A-VIII/2;
- Updated IMO model courses such as those on Automatic Identification Systems, Familiarization Training for Liquefied Natural Gas (LNG) tanker operations, basic training in marine environment awareness, Integrated Bridge System (IBS), Liquefied Petroleum Gas (LPG) Tanker Cargo and Ballast Handling Simulator, Liquefied Petroleum Gas (LPG) Tanker Cargo and Ballast Handling Simulator.

The amendments reflect general future development of STCW convention and codes, i.e., more focuses on the development of technology-application onboard, the occupational and professional skills of seafarers (management, teamwork, leadership, security, environment protection awareness, etc, as required by the Chapter VI), the special training (as proved by the complete revision of chapter V). In addition, more "transparency" of management in terms of certificate of competency and informatization for MET activities are proposed throughout the process of reviews and debates.

2. Major Impacts upon MET Systems

2.1 Academic Activities of MET

The amendment impacts directly upon the MET activities with the above-mentioned changes. All the relevant academic processes and activities are affected including:

- adjustment and updating of curriculum, training syllabi, textbooks, etc., including the designing of curricula for new STCW courses.
- updating of maritime training facilities;
- refreshment of qualifications of maritime instructors, in particular the sea-going experience thereof;
- re-designing of the academic management system for maritime students;
- updating of the examination and assessment system for seafarers (theoretical and practical skills);

The amendment brings also indirect impacts upon the MET systems through the ways of, for instance, accordingly-changed national regulations for seafarer's certification, examination and assessment, regulations for the quality system of Maritime Safety Administrations, and the competitiveness of the MET graduates in the international seafarer manpower market.

2.2 Certification Arrangement

To duly certify the students or trainees is the key aim of MET activities. Therefore changes in certification arrangements for seafarers need to be diligently observed and handled. The certification arrangement in maritime nations has to be modified as per the STCW. For MET institutions, the deletion and addition of certain certificates, the transferring and equivalent arrangement of certificates of seafarers, the order of issuing various certificates, the requirements and ways of combing theoretical education, practical skill training with sea-going experience, etc,. are most influential.

For instance, certificates of seafarers are clearly categorized into three levels by the new amendment, i.e., Certificate of Competency (CoC), Certificate of Proficiency (CoP) and Documentary Evidence (DE), and the relationship between CoC and CoP has been established for the certification of relevant officers and engineers, which signifies the order of training that CoP courses must go before those for CoC.

Also, there are higher standards than those in STCW in some existing national certification systems - Ratings forming part of a navigational watch may be certified with CoC while the convention requires a CoP only and BRM and ECDIS training can be certificated with an independent CoP while the convention incorporates relevant requirements in the table of "Knowledge, Understandings and Proficiency" (KUP). This hints that training courses need to be updated, created and phased out.

Lastly, attention should be paid to the transitional period arrangements for seafarers' certification required by the national maritime administration in accordance with the new STCW amendment. In most of maritime nations, such transitional period arrangements are mainly done through new and individual courses.

The curriculum, training syllabi, textbooks, etc., of maritime education and training courses are therefore affected, and possibly the mode the MET.

2.3 "Flexibilities"

The amendment, as required by the principles of full review set up by the IMO at the very beginning of amending STCW, created more flexibilities for the convenience of shipping companies and seafarers. The first type of "flexibility" can be seen in balancing "approved training" and "sea-going experience". For instance, Regulation III/1 provides that Engineer officers can be certified "when they have completed combined workshop skill training and an approved seagoing service of not less than 12 months as part of an approved training programme which includes onboard training which meets the requirements of section A-III/1 of the STCW Code, or otherwise have approved seagoing service of not less than 36 months". The second type can be witnessed by "equivalent transferring". Able seafarers can be acquired from ratings with sufficient sea-going experience, and the Electro-Technical Officers can be transferred from "a suitably qualified person", or an Engineer officer certified as per the new amendment since the new amendment has incorporated electric and electronic KUPs into that of the engineer officers, except the exclusive training for ETOs according to Section A-III/6 "*Mandatory minimum requirements for certification of electro-technical officer"* of the code.

What should be the responses of MET systems then? The above-mentioned flexibilities will of course lead to the diversity of MET training courses, the existence and development of MET programs, co-operations between MET institutions and shipping companies, competitiveness of students and trainees in different MET programs. The MET institutions should therefore keep close watch for such.

2.4 Special Training

The complete revision of Chapter V such as the new regulation V/1-1 and V/1-2, and "competence requirements for personnel operating Dynamic Positioning (DP) systems"; "Training requirements for ships operating in ice-covered waters"; "Training requirements for personnel in charge of — or involved in — anchor-handling operations", and "Training requirements for personnel serving on board offshore supply vessels" signifies the close attention of the organization and industry and great potential of special training.

The contemporary commercial shipping business is indicating by and large that the special transportation is the effective strategy of enhancing the competitiveness of a shipping enterprise. Meanwhile, special training can be understood as a strong aid for the achievement of "high-level, professional and specialized" MET. More and more shipping companies start such business and MET institutions are thus involved. In such a circumstance, the complete revision of the Chapter V exerts great impacts on those MET institutions running or to be running special courses, in the respect of qualified maritime instructors, special training facilities, and an approved bank of maritime expertise.

2.5 Quality Management Activities

The new amendment reinforces the requirements of quality management practices in MET. The new Regulation I/8-2 reads "This evaluation shall include all changes to national regulations and procedures in compliance with the amendments to the Convention and STCW Code, with dates of entry into force later than the date information was communicated to the Secretary-General". It will increase the frequency of a member state to communicate the IMO for such a matter. Furthermore, a relevant requirement is added to the B-I/6.12 of the new amendment as a guideline, which requires that "Each Party should ensure that a register or registers of approved training providers, courses and programmes are maintained and made available to Companies and other Parties on request".

It can be concluded that the training and certification of seafarers will be more and more "informatized", "traceable" and "transparent", for which a continuous and effective quality management system can be helpful through its documentation and record mechanism. The current quality management system in MET systems should be updated and enhanced to enforce the above.

2.6 Medical Standards

Medical standards (I/9 and A-I/9) are relevant to MET institutions traditionally. Substantial changes have been made to them and raise the "level of entrance" generally for the prospective seafarers, affecting the enrollment of the students, as well as the possibility of completing all training subjects and their seafaring profession. Additional attention should be paid to the "potential and future" requirements on the "physical standards".

The MET institutions should attentive for the possible reduced number the student enrollment while adjusting or inventing physical and medical standards for the students to be registered. Institutions should increase the time of physical training and exercises by modifying the curriculum or other activities effective for the maintenance and promotion of the fitness of maritime students and trainees.

2.7 Distance Learning and E-Learning

Use of distance learning and e-learning in MET is once again encouraged by the new amendment (B-I/6-11). The amendment provides two complete paragraphs "the Guidance for training by distance learning and e-learning" and "Guidance for assessing a trainee's progress and achievements by training by distance learning and e-learning".

MET practices accomplished through distance learning and e-learning are not popularized and not applicable for mandatory certification of seafarers currently due to the lack of approved training facilities, monitoring systems and facilities, control of MET quality, control of the examination and assessment, etc,.. In such a circumstance, the above provisions in the amendment constitute important technical support, and more and more distance learning and e-learning activities may come up then.

3. Summary and Strategies

The new amendments would be applicable generally in next 8-10 years by estimate. It will play important roles in keeping maritime safety and preventing pollutions at sea by guaranteeing the quality of the special group of people — seafarers onboard modern ships.

The amendment sets up new standards of training and competency, bringing in not only opportunities for development, but also challenges to the global MET system. individual MET institutions need to be ready in all respects, from the top-level designing, to strategic development, to the details such as training facilities and equipment, teaching staff, quality management and maritime expertise, etc,.

As a general principle to respond to the new amendment, MET institutions should rely on the understandings above, and also bear in mind those on the "quality shipping" and shortage of quality seafarer

manpower worldwide, which is kept being indicated by the industry.

3.1 Full Review MET Activities

The MET institutions shall analyze fully the new amendments and national laws and regulations, the implications of "quality shipping" and balance between the international seafarer manpower demand and supply. Then, take measures to respond them all. For such a purpose, the new amendment creates a necessity to fully review the context where MET institutions are being operated. The ranges of such a review are as follows:

- General capability of the institution in implementing the STCW convention and codes, in terms of quality, quantity and type of training;
- Mode of training;
- Curricula and training plans for relevant maritime courses, especially new training training programmes such as ECDIS, able seafarer deck and engine, electro-technical officer and maritime security;
- Training facilities, in particular for professional and special training, various facilities and installations such as LNG and LPG training facilities should be considered;
- Qualification of maritime instructors and teaching staff related;
- Existing maritime expertise;
- Quality management system being operated internally, including its substantial and procedural requirements and arrangements.

Based on such a review, demand analysis, necessity analysis and gap analysis can be carried out so as to set up new goals, objectives and strategic directions of the organization, to identify the key shortcomings and operations of MET. Individualized approaches will follow up then for each identification.

3.2 Full Compliance with the STCW

Full compliance can be achieved in two alternatives: fully meet with the requirements of national regulations which are transferred and developed from the STCW new amendment, or implementing directly the STCW. However for MET institutions in both cases, the benchmark or scale of standards for such a "full compliance" is exclusively derived from their "ultimate MET practices" — The MET institutions affect the competency of seafarers as a "decisive practitioner" through the execution of the objectives of training, the proper uses of curriculum, textbooks, examination and assessment questions.

This signifies MET institutions should be diligent and professional in the said key points for full compliance. However, it should be noted furthermore during the development of the above, the KUP standards affecting the competency of seafarers in STCW amendment may be interpreted in different ways, owing to the fact that, for instance, the STCW amendment does not provide the exact requirements of hours for a certain competency. Documentation ad evidences should be made in place anyway.

The IMO model courses, which are continuously accentuated not only by the IMO but the whole industry, aim to provide guidelines for the unanimous and authentic interpretation of the KUPs. They are to be referred to in day-to-day MET academic activities. MET institutions may be also benefited from such practices since model courses are made to assist in the implementation of the convention and codes, and approved by the IMO.

3.3 Higher Than STCW Standards

IMO has been devoting to a systematic safety framework for maritime safety, maritime pollution prevention and security through the SOLAS, MARPOL and other conventions and rules. Today, there are more and more new issues popping up on technical applications for maritime safety and pollution prevention, exceeding the requirements of STCW new amendment. The new developments in IMO currently are:

- Long Range Identification Tracking system (LRIT);
- E-Navigation;
- Green-House Gas Emissions from Ships ;
- Goal-Based Standards (GBS);
- Ship-recycling;
- Energy efficiency management;
- Ballast Water Management;
- Noise from commercial shipping and its adverse impacts on marine life;
- Formal Safety Assessment and risk management;
- Human element;
- Harmful anti-fouling systems for ships;
- Port of refuge
- …

Understandably the development above requires MET institutions to dedicate themselves to a comprehensive or "systematic" MET — developing multi-discipline knowledge, or the capability of co-ordinating various maritime expertise and resources. "Systematic MET" means in more details a cross-reference or utilization of multidiscipline knowledge. Maritime students can thus be offered with a much more systematic and qualified maritime competency, such as a combined knowledge system with navigation, logistics, economy and maritime laws. It will contribute to not only the implementation of STCW, but also the higher quality of MET, the creation of new maritime knowledge branches and applications and the capability of innovation.

3.4 Co-operating and Networking

The revised standards of STCW, the fast development and application of modern maritime technologies, the specialized and professional sea transportation, and the requirements of "quality shipping" are presenting a high level and comprehensive needs of "quality MET" as a whole. But the number of maritime institutions providing "systematic MET" is small after all. For the vast majority of MET institutions, embarrassment will be encountered during the implementation of the new amendment in respect of installation of training simulators and equipment, development of maritime human resources and maritime expertise. Co-operations and networking between MET institutions become thus recommendable in such a case.

4. Conclusions

STCW convention is the unique legal document for the competency of seafarers. It is bringing great impacts upon the maritime industry, including the MET systems. Conversely, the practices of MET institutions affect the effectiveness of implementation of the convention, the quality of seafarers, the global distributions of seafarer labor services, and general level of safety and pollution prevention, because MET institutions are the "ultimate and decisive" entities for the achievements of such competency.

The new STCW amendment is being practiced worldwide, with aim to serve the industry better by more qualified seafarer. It is important to understand and assess first of all the impacts of the new amendment, to identify the keys on "full implementation", and then to take correct actions.

Based on the STCW amendment and for the purpose of higher level implementation, ideally, an assessment for the comprehensive impacts exerted by the adoption of ILO MLC 2006, the comprehensive development of SOLAS, MARPOL and other international conventions and rules, shortage of qualified seafarers, the stricter PSC and FSC inspections, as well as the changing needs of the industry needs to be done, for the purpose of seeing more clearly the picture that MET systems are facing with and making proper strategies therefor.

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Role of Naval Architects in Ship Recycling

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Abstract: The paper identifies twelve elements of ship recycling and highlights their respective roles and duties in a proposed ship recycling system. The source and items of knowledgebase for ship recycling have been brought out. A new philosophy focusing clean and safe ship recycling namely *design for ship recycling* has been introduced based on principles such as ecofriendliness, engineering efficiency, energy conservation and ergonomics. The role of naval architects in ship recycling industry has been described based on the above factors. The paper brings out the role of naval architects in ship recycling the way it has been practiced worldwide and proposed by regulatory bodies. The authors have brought out the new concept of *design for ship recycling* and various aspects of it. The role of naval architects in the practice of this new design philosophy which is ready to be embraced by the maritime industry has been reiterated.

Key Words: Ship recycling, naval architect knowledgebase, design for ship recycling.

1. Introduction

The last life cycle stage of a ship is its dismantling at any of the ship recycling yard. Ship dismantling has been treated as a hull steel recovering operation, which involves no major engineering activity other than gas cutting of the steel components. Ships carry a wide range of material onboard which sometimes include hazardous materials like TBT, PCB etc.,. In some cases the cargo residues may be high pollutants to the marine environment. The case of obsolete French Aircraft Carrier, Clemenceau which carried quite a lot of asbestos as insulating material and arrived for dismantling at the Indian coast is a typical example. Basel Convention organised by United Nations Environment Program (UNEP) considers obsolete ship as a hazardous waste [2]. It has been the presence of such banned and polluting component in the ships ready for dismantling that brings the concerned industry to notice of environmentalists and the legal system. Once the media and the social activists get involved in this, various issues including the engineering aspects and the risks of dismantling operators came into limelight. Institutions like International Maritime Organisation (IMO), regulatory bodies like the ship classification societies, the academics and the intelligentsia deliberated on this and efforts are made to give the dismantling of obsolete ships, the status of a decent engineering industry. The efforts of IMO and other stake holders of the maritime sector have brought out a significant change in the industry by introducing the concepts of recycling during the end of life activities of obsolete ships and designating the name ship recycling to end of life disassembly activities carried out as per IMO Guidelines on Ship Recycling [5] in a ship dismantling yard. Ship recycling is a wider concept compared to ship dismantling as it envisages the ways and means to identify and classify various products and processes involved in dismantling of obsolete vessels and to formulate best practices for carrying out various processes leading to clean and safe end of life operations. In this context it may specially be noted that IMO has defined ship recycling as the best option for all time expired vessels.

Ship as an industrially designed and constructed product is essentially an output of the efforts of naval architects. The role of naval architects in various life cycle stages except in ship recycling has been well established and their duties are performed in a

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systematic manner. Very few research attempts have been made in the field connected with the role of naval architects in ship recycling: Alkaner et al. [1] have compared the similarities of ship production and ship recycling highlighting the role *design fors* such as *design for environment* and *design for dismantling* in ship design. This paper has envisaged the need of extending the life cycle stage of ships to the end of life dismantling, going beyond the conventional life cycle concepts. However no specific remarks has been pointed out showing explicit role of naval architects in ship recycling processes Dilok et al. [3] have discussed the characteristics of the product structure in shipbuilding and the concept of *design for* dismantling of ships. Though no direct reference have been made on the role of naval architects in end of life ship recycling activities, some of the suggestions included in the deliberations have proved the essentiality of having principles of naval architecture and shipbuilding incorporated in ship recycling. Shahid [7] has stressed the need of having some of the important naval architectural calculations as a part of preparations for ready for recycling certification. IMO in its historic resolution on ship recycling [5] incorporated design for recycling as one of the important ship recycling guidelines. The topics covered under the guidelines underline the role to be played by naval architects in the matters connected with sustainable ship recycling. Sivaprasad et al. [9] have presented the importance of allotting a sustainable index for all ships based on product features of ships such as environmental friendliness, safety aspects and naval architectural & ship design attributes.

2. Elements of Ship Recycling System

Ship recycling has to be conceived as the reverse engineering process of modern shipbuilding and some efforts have been made here to connect the missing links between ship recycling and modern shipbuilding. The combination of the roles played by the following major elements identified in the ship recycling domain and their mutual interactions can be formulated as an ideal system of ship recycling.

Ship owner is either an individual or a firm who has got the legal ownership of the vessel just before she is dismantled. As on today the ship owner has no role and responsibility in the issues related to ship recycling. Once he sells the vessel to the ship dismantling broker, he simply vanishes from the turbulent scene to be followed. Role of obsolete ship owners ends with selling of the ship and the owner is not a party to any of subsequent ship recycling activities, for the time being in the ship recycling industry.

Ship Recycling Brokers are international agents who participate in the auction bid and take over the charge of the ship before it is delivered to the recycling site. Ship recycling broker is yet another intermediate owner of the obsolete ship and his role is limited to negotiation of bids in the early stages of ship recycling activity. They are, just agents seen in these business ventures, and are not concerned about any issues related to ship recycling other than the monitory benefits.

Ship Classification Societies are very active and authoritative in other life cycle activities of seagoing vessels since their inception. However, at present their role in ship recycling is limited to preparing proposals, attending meetings and conducting research studies.

Ship Recyclers are supposed to provide all infrastructural facilities which regard to safe and eco-friendly dismantling of vessels and they constitute a strong link in the ship recycling chain. They work closely with other promotional and statutory bodies to deliver safe and smooth ship recycling. Currently, most of the ship recyclers are just providers of plot and basic infrastructure to the next element in the recycling chain.

Ship Recycling Subcontractors provide manpower and machines for the actual dismantling. They are responsible for employing trained personnel for dismantling operations involving risk and hazard. The work force employed by the subcontractors, the biggest

contingent of the ship recycling, and they are called as ship recycling workers.

Statutory Maritime Bodies, which have otherwise lot of statutory powers, are not actively involved in the ship recycling issues. The obsolete ship loses the status of a sea worthy vessel and comes out from the purview of maritime regulatory bodies. At present statutory maritime bodies seldom appear in the ship recycling scene unless and otherwise requested by the concerned legislative bodies and courts of law.

Promotional Bodies provide land, expertise, infrastructural facilities, man power training, transport, logistics support to the ship recyclers and the subcontractors. They are the custodians of important statistics regarding ship recycling activities including the accident rates, pollution effect, health hazards etc.,.

Pollution Control Boards/Safety Councils work as advisory bodies at present. Their roles and responsibilities are limited as far as safe and clean ship recycling is concerned These agencies now work in tandem with the promotional bodies to create a clean, safe and productive ship recycling system and at present they attain active partner status along with statutory maritime department type institutions.

Steel Re-Rollers enjoy maximum benefit out ship recycling in all the major ship recycling countries and they usually set the national agenda for ship recycling. This is the case with almost all major recycling nations. They do not seem to contribute back to the development of ship recycling infrastructure... Re-rollers are one of the powerful links in the chain and with the current information their role is yet to be defined clearly.

Supply Chain Brokers include the agents who purchase various equipment and other onboard items which are kept for auction by the recycler/subcontractor after dismantling. These auctioned items are sold out as pre-owned or pre-used items. Most of these item and equipment re enter the domestic and industrial market through shop/shelf.

Non Governmental Green Organizations are the international organizations involved in green issues and are active in ship recycling. There is a constant pressure from these NGOs on ship recyclers. They are now targeting ship owners than the ship recyclers for the lack of eco-friendliness in the issues in ship recycling. The presence of these Green NGOs has significantly influenced the functioning of the ship recycling promotional bodies and the ship recyclers.

Worker Forums are the trade unions and similar associations involved in this industry. They are actively participating in all the issues related to improving the status of present day ship recycling from the point of view of worker welfare and green issues. However their voice is not powerful. If these worker forums couple their activities with stronger international NGOs working in ship recycling and gain stronger position in bargaining.

3. Duties of Elements of Ship Recycling

Duties of the above mentioned elements of ship recycling can be generally classified based on the technical and nontechnical content in their field of activity. Activities of the technical elements are further divided into categories such as ship recycling processes undertaken during pre-dismantling, dismantling, statutory & regulatory operations as well as technical procedures and dealings involved supply chain of recycled products. Agenda of various programmes of the voluntary organizations associated with ship recycling sector are of activist nature and the corresponding elements of the system can be treated as nontechnical.

The important duties of owners of obsolete vessels and vessel brokers who are involved at pre dismantling stage can be identified as arranging documents and drawings necessary for making their vessels ready for recycling. The process includes preparing comprehensive list of all mandatory certificates and documents as prescribed by Green Passport requirements and relevant data regarding conditions of various systems of the obsolete vessels. All important

drawings such as General Arrangement, Access Plan, Tank Plan, Painting Scheme etc.,. are to be refurbished and kept ready for before the ship is decommissioned. The owners shall recognize that the information generation has to be accomplished with an active support from naval architects with good experience in ship design and life cycle management. A systematic and thorough inspection procedure has to be undertaken by a team of marine experts lead by a naval architect to assess and arrange the *"as is"* condition information of the ship ready for recycling. They should also ensure that this exhaustive obsolete ship status data have to be passed on to the broker so that the same will reach the ultimate ship recycling destination.

Ship recyclers and ship recycling subcontractors are the major elements of ship recycling system who are actively involved in the actual dismantling process. Since these two elements have to take the blame of any untoward incidents that may occur during ship recycling, they have to be fully aware of steps involved in the ship recycling process. The ship recyclers attain key role in the ship recycling system with a major thrust on responsibilities leading to clean and safe ship recycling. Ship recycler is responsible for implementation of statutory and classification rules on ship recycling and thereby it becomes essential that the ship recyclers fully understand the importance of best practices to be followed during the dismantling. Presence of naval architects is seen as an essential requirement, as statutory and classification rules are better appreciated and interpreted by them. Apart from imparting proper training on clean and safe ship dismantling they can guide the recyclers and subcontracting work force regarding the recyclability aspects of the dismantled products. This will ensure effective ship dismantling as far as the subsequent supply chain activities is concerned. The ship recyclers should be mindful that proper process planning of ship dismantling can be achieved only with the active participation of naval architects with ample shipyard experience.

Statutory & regulatory bodies which are connected with ship recycling sector play an important role in inflicting major developments in promoting the present inferior industrial status of ship recycling industry. The statutory & regulatory bodies which participate in the ship recycling system are statutory maritime bodies such as state maritime departments, pollution control boards, industrial fire and safety inspectorates, maritime development agencies and ship classification societies representing the national and regional governments. These statutory bodies which are to be associated with the ship recycling industry have to recognize that they should work in a similar fashion like their sister departments operating in various other important ship life cycle stages such as design, construction, operation, repair and survey. The statutory & regulatory bodies linked with ship recycling can achieve a lively role only by involving naval architects and marine technology experts well experienced in various maritime industrial operations. Ship classification societies which are employing naval architects and marine engineers with sound marine technology background are not yet ready to deploy their human resources in day to day functioning ship recycling yards. These agencies should take initiative to distribute important functions related to ship recycling to naval architects who can contribute positively to improve the status of the industry with proactive steps to implement both short spanned ship recycling process planning & control and long term sustainable development oriented policy decisions [11] in this sector.

Steel re-rollers and dealers of other dismantled products are included in the supply chain category. They have a secondary role in the ship recycling system as they operate partially outside the actual ship recycling base. Still they should recognize their role in the process and participate actively in the ship recycling activities. Guidance from consulting naval architects and marine engineers can be better utilized by the supply chain operators for deciding the

recyclability options [10] of dismantled products such as steel items, main engine, onboard equipment and systems.

Organizations such as NGOs and ship recycling workers forums should develop strategic action plan that will ensure fruitful participation of interested and experienced naval architects to find solutions to their problems and to formulate new proposals for sustainable ship recycling aiming at improved industrial status.

Present day issues related to the performance of ship recycling yards can be partially attributed to nonparticipation of naval architects and marine technology experts in the core topics in ship recycling. The general approach of ship classification societies possessing substantial resources in marine technology is reported to be not promising and this situation has really created a vacuum in the ship recycling industry as far as involvement of naval architects are concerned.

4. Information, Knowledge and Expertise of the Ship Recycling System

Ship recycling is an engineering industry where various branches of knowledge such as science & technology, engineering, management, law, economics, commerce and political science have been involved. Information base of these branches of knowledge as applicable to the development of a comprehensive knowledgebase of ship recycling and the expertise required for developing it have been identified and presented in Table 1. The role of naval architects as a knowledge engineer in ship recycling activities has been clearly brought out in this table. The duties of the element of the ship recycling can be effectively put into performance only with the personnel with knowledgebase as indicated above.

The knowledgebase of the ship recycling .system can be effectively utilized by the industry, if an expert system is made out of it. Computer based expert system helps to provide recommendations for improving the situation in the ship recycling industry domain by collecting and analyzing data from the ship recycling system domain.

An expert system can be developed for the ship recycling practices which generally has major elements, like, data base regarding ship (Ship Data), codes, regulations and guidelines (Rules) and disassembly processes in ship recycling (Practices). The information model for such an expert system which has been developed for ship recycling activities is given in Fig. 1 and the role of naval architects as source of knowledgebase has been rightly brought out in this. The details of the development of the expert system are available elsewhere [8, 13]. Recommendations for best practices in ship recycling have been envisaged as the output from the expert system.

Table 1 Information base identified for development of knowledgebase of ship recycling.

Information Base	Knowledge	Expert
Innovation	R&D	Naval Architects, Production & Structural
Environment	Pollution and Hazards	Ecologists
Safety	Human /System factors	Safety & Production Engineers
Production Technology	Technology of Dismantling	Naval Architects
Information	Knowledge Base Engineering	Naval Architects and IT Specialists
Recycling	Energy	Production Engineers
Management	Recycling, Planning and Plant Layout	Naval Architects
Marketing	Demand Forecasting	Market Research Analysts
Finance	Cost and Accounts	Economists, Accountants
Regulation	Rules, Acts and Laws	Lawyers
Green Topics	Socio-environmental Impact	Green Activists

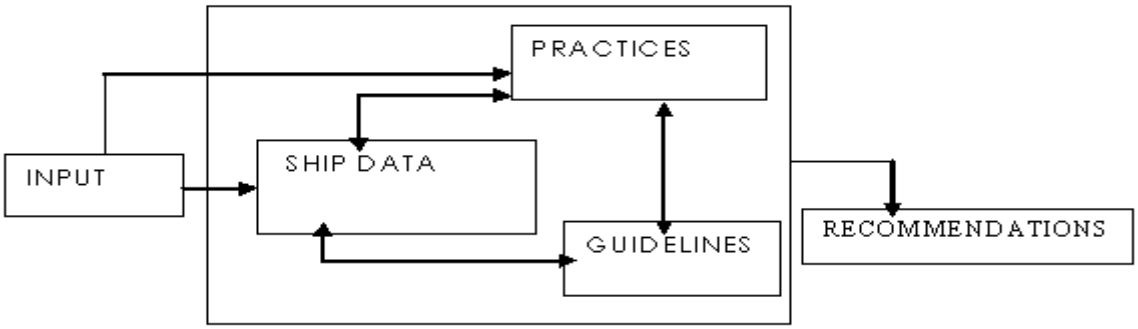


Fig. 1 Information Model of the Expert System.

5. Design for Ship Recycling Philosophy

In recent IMO conventions emphasis has been attributed to producing ships which are safe and environment friendly during their regular operation conditions [4]. Marine Safety Committee (MSC) a subsidiary of IMO in its 80th session calls for safety and environmental friendliness of the vessels in specific damage conditions too [6]. This requirement envisages a proper *design for recycling* which caters to the specific demands of IMO, i.e., minimizing marine pollution and reducing accidents causing loss of life and damage of property. The IMO guidelines on design for recycling of ships should be integrated with the ship life cycle system and can be called as *design for ship recycling* [12]

This *design for ship recycling* philosophy can be broadly based on the hull structural design, equipment manuals, knowledgebase on recycling, environmental factors, onboard materials, equipment & systems and general arrangement of ship.

5.1 Scope of Design for Ship Recycling

The scope of *design for ship recycling* in this context has been defined as various aspects that should come under the purview of *design for ship recycling* philosophy which will improve the efficiency of recycling of ships.

5.1.1 Design Philosophy

Happenings at the end of life of the vessels are not taken into serious consideration during initial stages of design and in the follow up activities in the life cycle by the designers. Designers are still working around *design for production* and its contemporary *design fors*. Marine pollution related issues have created awareness among designers towards *design for environment*. Similar awareness has to be developed in recycling oriented design attributes as well. *Design for ship recycling* is the best way to address the environment and safety problems related to ship recycling. Implementation of *design for ship recycling* philosophy is essential for achieving sustainable development of international maritime sector.

5.1.2 Product Design and Development

Design for ship recycling envisages product design and development with easy parts and components assembly procedures. It gives more focus on integrated assembly of various identical parts. Simple product structure will always enable easy disassembly activities which in turn makes end of life dismantling of onboard equipment and parts less cumbersome. Dilok et al. [3] has discussed the characteristics of the product structure and concept of design for dismantling of ships. The scope of this concept has to be extended by incorporating five objectives of *design for ship recycling*, viz, environmental orientation and safety during operations, energy consciousness, use of state of art technology and ergonomics in all onboard operations including final and partial dismantling. Active and mandatory involvement of naval architects is essential for effective implementation of these attributes in ship life cycle operations.

5.1.3 Common Industrial Standards

Quality requirements of various industrial products for marine application are more stringent. Onboard systems are complex owing to the high standard of safety requirements and accessibility problems due to onboard space constraints. These characteristics of marine quality parts make recycling of equipment and components different from the common recycling processes adopted in civil construction. *Design for ship recycling* emphasizes common industrial product standards. Naval architects will have to seriously consider this concept while attempting different ship design spiral operations Recycling activities and reusability of dismantled products with common standards can be easily compared. This will make recycling of ships less complex and more acceptable.

5.1.4 Product Standardisation

Product standardisation ensures improved quality and productivity in design and manufacturing in shipbuilding and this concept has been developed to support simplifying ship design procedures, minimizing different types of inventories in ship production, compatibility of component replacements in ship repair and ensuring implementation of essential international rules and recommendations by agencies such as IMO and IACS... This can be better achieved by introducing the fundamentals of naval architecture and shipbuilding in end of life ship recycling activities.

5.1.5 Process Standardisation of Ship Recycling and Proposing Best Practices

Standardisation of ship recycling process is as important as the product standardisation. For ship recycling to be more effective, both product and process standardisations should go in tandem. Process standardisation focuses on development of best practices for ship recycling operations. Ship recycling yard organisation, infrastructure support and lay out management of recycling yards constitute one part of the process standardisation. This part has been included in International Standardisation Organisation (ISO) standards [ISO/DIS 30000:2008]. This process standard covers all yard oriented issues in ship recycling. Best practices for ship recycling activities, right from towing of the obsolete vessels to dismantling of the last component, constitute the second phase of the process standards. Process standards for the later part have been developed by Sivaprasad [8]. Ship General Arrangement (GA) design attributes such as accessibility, water/weather/fire tightness, availability of light, ventilation and features of materials and components act as fundamental frame work for the development of the best practices.

5.1.6 Environmentally Contraband Materials

Presence of environmentally contraband materials in hull structure, outfit items and machineries are considered as the most serious issue by the agencies involved in uplifting the status of ship recycling industry. Dets Norske Veritas has developed an onboard material inventory recording database, Green Passport addressing this special ship recycling issue. Participation of naval architects in the process of *design for ship recycling* can widen the scope of this inventory recording mechanism by proposing an extended green passport. Various characteristics of common onboard materials and cargo residues with respect to ship recycling activities can be prepared and can be used as a an effective knowledgebase for safe and green shipbuilding.

6. Conclusion

The necessity for changing the ship recycling industry into sustainable industry based on 4E principles, i.e., ecofriendliness, engineering efficiency, energy conservation and ergonomics has been emphasized with due support from new concept of design of ship recycling. The role of naval architects as contributory elements to sustainable ship recycling and as the knowledgebase for ship recycling system has been identified and presented. The authors have brought out the new concept of *design for ship recycling* and various aspects of it. The role of naval architects in the practice of this new design philosophy

which is ready to be embraced by the maritime industry has been reiterated.

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Some Peculiarities of the Preprocessing of Spectral Data and Images

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Abstract: Remotely sensed spectral data and images are acquired under significant additional effects accompanying their major formation process, which greatly determine measurement accuracy. In order to be used in subsequent quantitative analysis and assessment, this data should be subject to preliminary processing aiming to improve its accuracy and credibility. The paper considers some major problems related with preliminary processing of remotely sensed spectral data and images. The major factors are analyzed, which affect the occurrence of data noise or uncertainties and the methods for reduction or removal thereof. Assessment is made of the extent to which available equipment and technologies may help reduce measurement errors.

Key words: spectrometry, spectral data and images, preliminary processing**.**

1. Introduction

Remote sensing of the Earth from Space occupies an exclusively important place in the development of modern science and technologies. The application scope of remotely sensed spectral data and images is expanding continuously to involve new areas, such as ecological monitoring of endangered areas, monitoring of the global changes of natural resources and the environment, climate changes, coastal area monitoring etc. The conclusion may be drawn that spectral images make it possible to map with unprecedented accuracy biophysical and biochemical changes in the Earth's surface and atmosphere status.

Imaging spectrometers are a relatively new remote sensing instrument which, during the recent decades, ranked among the top instruments used in these studies. This high ranking is due to the numerous advantages they offer to remote sensing, the most important of which are: complexity of obtained spectral data, i. e. ability to form spectral data in a great number of continuous spectral channels, fast spectral data acquisition rate, high spectral and spatial resolution etc.

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But, alongside with these convincing advantages, the data obtained thereby are subject to numerous non-uniformity effects and noises caused by the instruments' operation and data formation principles, the parameters of data-containing storage, the atmospheric conditions under which the data were acquired, the detector's operation mode (usually, a CCD matrix) and the control electronics, the data conversion and storage systems etc. [1-5]. Each case in which non-uniformity has appeared in acquired data requires the adoption and application of an appropriate strategy for preliminary processing of the acquired spectral data. Therefore, the vast information potential of spectral images may be used in subsequent scientific and practical applications only following an appropriate preliminary processing of the initially acquired spectral data.

2. Methods for Preprocessing of Data and Correlations with Imaging Spectrometer Measurements

In Imaging spectrometers using the principle of light flow dispersion and pushbroom type of scanning, spectral data for each image line with width of one pixel are obtained simultaneously; thus, the whole image is built line by line to make the entire image (Fig. 1). The

radiation passing through the input slit and corresponding to one line (with width of one pixel) from the surface of the examined object then falls onto a dispersing element, which decomposes it spectrally. The points along the length of the input slit corresponding to one line of the examined object's image are displayed as spectral lines in the imaging spectrometer's spectral plane (Fig. 2). They may be recorded by a matrix detector (usually, a CCD matrix). The whole process is repeated after the platform on which the imaging spectrometer is located moves forward along the carrier's track to a distance equal to one spatial resolution element.

While conventional images have two coordinate axes, x and y, spectral images also have a third coordinate axis, λ. Thus, the so-called "spectral cube" is formed, in which each plane perpendicular to the spectral axis λ constitutes a spectral image for a definite electromagnetic spectrum wavelength band (Fig. 3). Therefore, the spectral image is not built at once, but in series, through a scanning process, as a result of which it is subject to a greater extent to the additional destructive influences of the conditions under which the image is built and which form the image's non-uniformity.

Generally, these non-uniformity effects may be expressed in: missed individual pixels and/or lines in the acquired data resulting from the available bad pixels in the used detector, reading errors, electronics failures, spatial and spectral direction irregularities caused by the generation of the so-called keystone and smile effects induced by the optics etc.

Spectrometric data require correction in the three major aspects – spatial, spectral, and radiometric.

2.1 Spatial Non-uniformity

It should be noted that the effects of spatial non-uniformity are manifested to a greater extent by airborne imaging spectrometers, whose platforms are more unstable, so, these instruments are designed to feature greater spatial resolution.

The real imaging spectrometers of the pushbroom type are affected by various effects of spatial non-homogeneity, such as loss of individual pixels, lines or columns, generation of the so-called keystone and smile effects induced by the optics, point spread function non-uniformity etc.

During the correction of spatial non-uniformity, the image within a given pixel must be restored, which is made by choosing an appropriate restoration strategy.

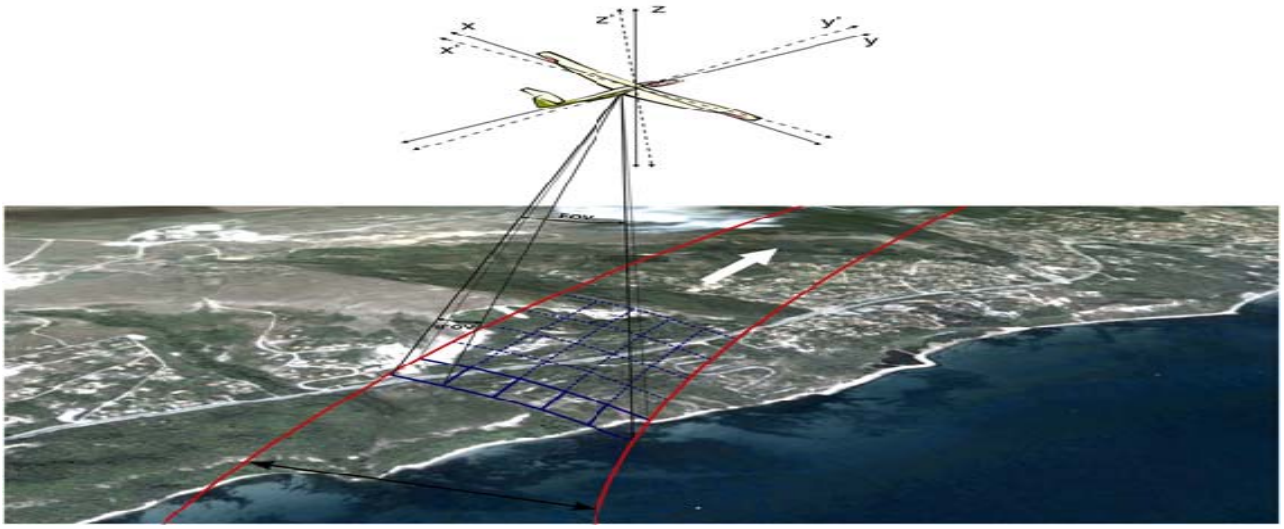


Fig. 1 Observation geometry.

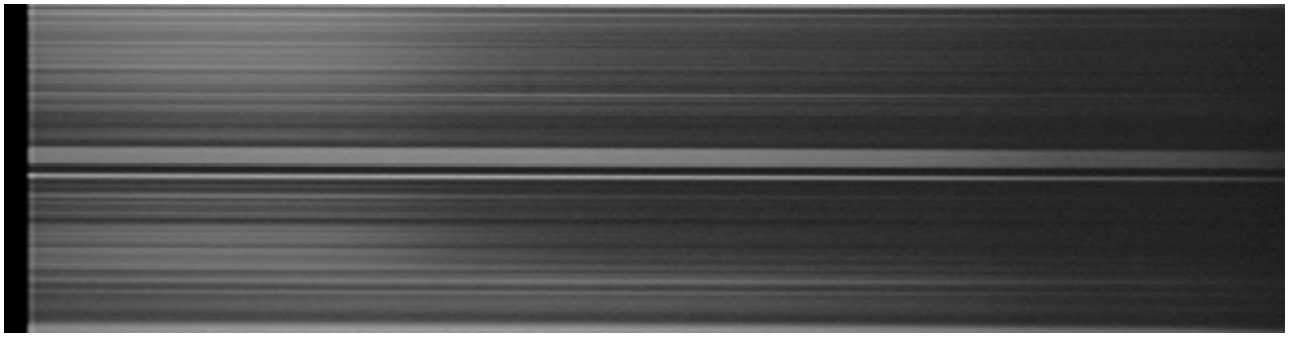
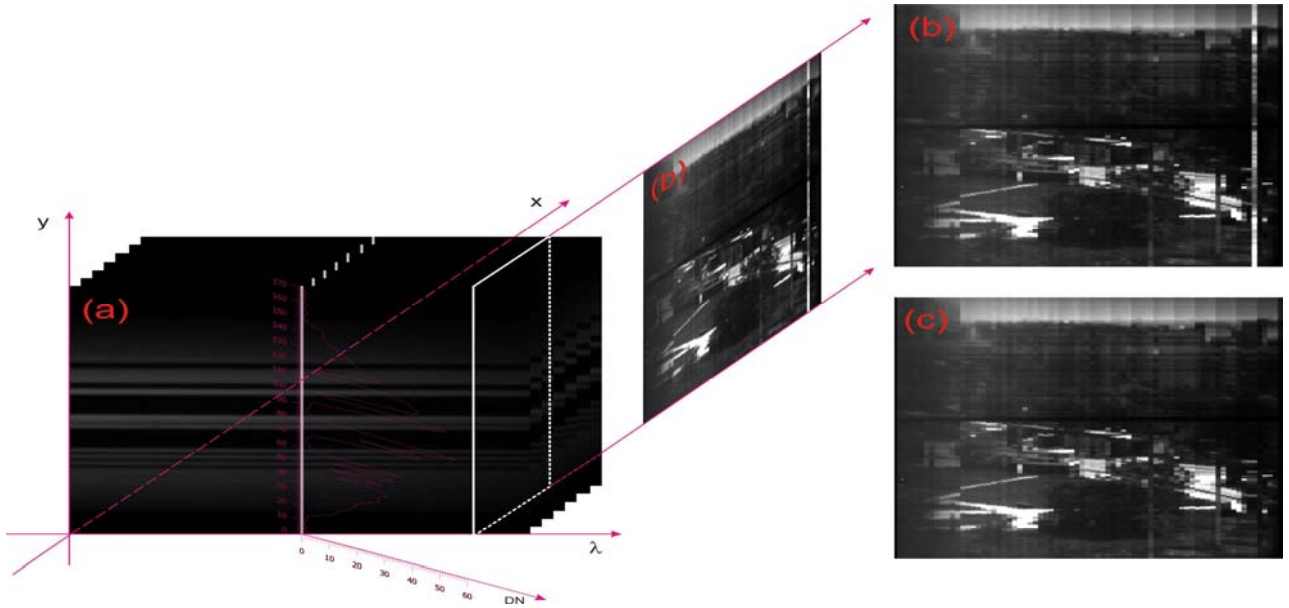


Fig. 2 Spectral data for one line of the spectral image.



(a) **(b)**

Fig. 3 (a) Spectral data forming the so-called "spectral cube", (b) spectral images.

The most common image restoration methods are: nearest neighbour resampling, linear interpolation, bilinear interpolation, triangulation method. They have been examined thoroughly and their application for various specific cases is described in literature [6, 7].

The chosen restoration method depends on the type of the examined image, as classified by parameters, such as sensor location height, sensor resolution, details of the examined object, whereas the results are nor always unambiguous. Therefore, in studying restoration methods, a somewhat different approach should be applied during the subsequent preprocessing procedures whereas the methods applied on images shall be assessed depending on the correlation links between the elements within the image itself.

Another line along which further studies will proceed is related with the fact that the impact of these methods on the accuracy in the spectral and radiometric aspect has not been paid sufficient attention. Additional studies are needed to assess the impact of spatial restoration methods on the spatial accuracy of spectral images in the spectral and radiometric aspect. For instance, one spatial pixel shift of 0.5 pixels within the image may result in errors of the order of up to 10% in the spectral aspect [8].

To provide for the used restoration methods' effectiveness (least squares mean [LSM] $\leq$ 2%), the procedures should be performed within a distance of a couple of pixels ($\leq$ 3 pixels), which imposes the following requirements:

• to the platforms' stability – deviation between 0.1° and 0.5°;

• to the carrier's velocity – overlapping between 0.1 and 0.3 pixels;

• to the detector's quality – reduction of the number of bad pixels and the size of bad areas, improvement of the uniformity of pixels' response;

• to the control electronics.

2.2. Spectral Non-uniformity

The spectral non-uniformity of the instrument's response is determined by the instrument's uniform response over the entire spectral range; usually, it is described by the width (normally, FWHM) (Fig. 3) and position (central wavelength λn) (Fig. 4) of the spectral channels. Therefore, the introduced spectral non-uniformity in the data (axis λ in the spectral cube) is the result of errors in the width and position of the individual channels. It may be caused by the instrument's operation conditions, temperature, pressure, as well as by the stability of the characteristics of the instrument itself.

The instrument's spectral response function is determined in laboratory conditions during the calibration process. The spectral response function is used to describe the instrument's response to input impact — monochrome light [9]. In most cases, the spectral function may be approximated by a Gaussian model or polynomial approximation (Fig. 4).

Requirements for reduction of spectral data non-uniformity:

• strict requirements for the instrument's design;

• laboratory calibration;

• envisaging of appropriate procedures for on-board calibration;

• choosing appropriate algorithms for correction of SRF non-uniformities.

It should be noted that the correlation links between the elements along the spectral axis are manifested better.

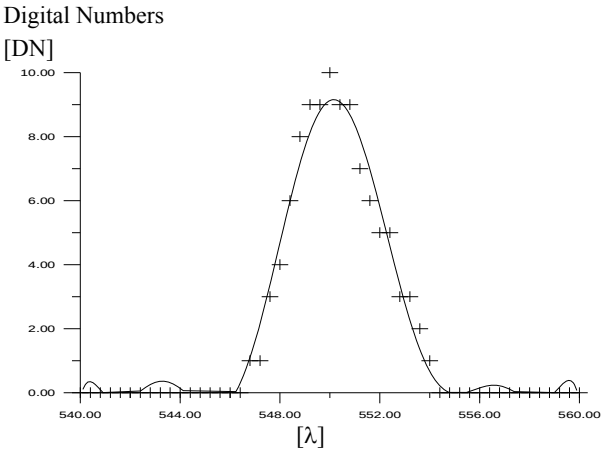


Fig. 3 Spectral response function for the 550 nm channel (polynomial approximation) of a video spectrometer ($\Delta\lambda_{in}$ 1.65 nm).

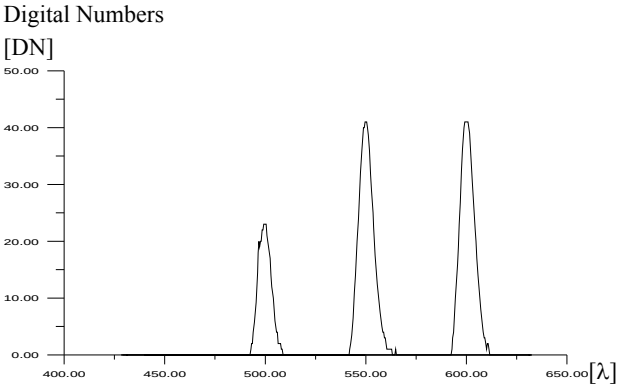


Fig. 4 Determination of the spectral range. Instrument's response to input impacts with central wavelengths λ_0 of 500 nm, 550 nm and 600 nm.

2.3 Radiometric Accuracy

Radiometric non-uniformities in these systems are generated by the same above-described factors, which determine spatial and spectral non-uniformity:

• the conditions under which the image was acquired: changes in the scene's illumination, atmospheric conditions, observation geometry etc.

• stability of the instrument's response characteristics.

• Radiometric corrections:

• accounting for the seasonal position of the Sun with respect to the Earth;

• accounting for the distance between the Sun and the Earth.

• accounting for the spectral distribution of solar radiation energy.

Thus, the acquired data are normalized depending on the Sun's illumination conditions.

Another radiometric correction involves transforming the acquired values measured in digital numbers (DN) to represent them in absolute units W/(m^2.sr.nm). This correction is required to make data comparable when reflected radiation has been measured at different times by different instruments.

Requirements:

- detectors: constructed and calibrated in laboratory conductions and featuring linear dependence of the response function on incident spectral radiation;
- stability of the characteristics, so that this linear dependence may be preserved during the experiment's performance;
- envisaged on-board calibration procedures with appropriate hardware;

The achievement of high spectral and spatial resolution with this type of instruments is also related with the sensors' operation under the conditions of low energy levels of the radiation collected at the sensor's input. The sensors' operation in such modes results in generation of radiometric non-uniformities. Several approaches are available to reduce such radiometric non-uniformities:

- the first of them, naturally, consists in technological improvement of the sensors themselves, improvement of quantum efficiency, reduction of the number of bad pixels, improvement of the pixels' response uniformity;
- another, quite often used approach consists in improvement of sensor integration time, for instance, from x10 μs to x10 ms, whereas the restriction imposed here originates from the instrument's spatial resolution and the carrier's movement velocity, so that the overlaid image be not greater than 0.1 to 0,3 pixels of the examined scene;
- apart from the above restriction, this method also imposes a restriction originating from the dark current levels, which increase with increase of integration time, and the saturation effects in some individual image pixels [10] resulting in the so-called fuzzy image areas whose size should not exceed several pixels;
- the use of TDI instruments, in which sensitivity is increased by summing up several image lines, however, at the expense of resolution.

3. Conclusions

(1) The available non-uniformities in acquired spectral data require the application of appropriate preliminary processing of such data. Preliminary processing is a mandatory procedure, if such data will be used for further processing and analysis.

The application of preliminary processing reduces greatly and in certain cases eliminates completely non-uniformity effects on spectral data, which results in increasing the efficiency/cost factor of spectrometric data use.

(2) It should be noted that preliminary processing cannot compensate the omissions or inaccuracies made during the instrument's construction. Therefore, based on the performed analysis during preliminary processing, requirements for the specific parameters of spectrometric systems under construction are formulated which should be satisfied.

Acknowledgments

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Journal of Shipping and Ocean Engineering 3 (2013) 61-69

Investigating the Effect of Winds and Storms on Shoreline Erosion along the Coast of Tanzania

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Abstract: Wind data spanning 28 years (1977-2004) from four meteorological stations (Tanga, Zanzibar, Dar es Salaam and Mtwara) were analyzed to elucidate the effect of winds on coastal erosion along the coast of Tanzania. The investigation entailed wavelet analysis of the time series of winds which were related with past erosion events at each site. The study also analyzed qualitatively the incidences of tropical storms in relation to coastal erosion events along the coast. The results revealed that most of the critical erosion incidents in the past few decades were associated with periods of occurrence of extreme wind speeds and tropical storms. Furthermore, the results indicated that the wind speeds and the frequency and intensity of tropical storms had generally been increasing during the past three decades. The findings were consistent to those recently reported for the coast of Dar es Salaam. The increasing trends of winds and storms are considered to have direct impact on the wave climate with increased risk of shoreline wave-induced erosion that is already affecting relatively many parts of Tanzania.

Key words: coastal erosion, shoreline change, winds, tropical cyclones, Tanzania.

1. Introduction

Shorelines which mark the boundary between the coastal lands and oceans/seas are among the most dynamic features of the coastal environment, whose changes are influenced by a complex interaction of natural processes and human induced activities. The natural processes influencing shoreline changes include: the combined action of waves, long-shore currents, winds, sea level variations and changes, local tectonics and episodic atmospheric changes such as storm surges, tsunamis and water waves caused by submarine landslides [1-5].The coastal vulnerability to change due to the influence of natural agents of erosion such as waves and tidal currents is also dependent on the coastal geology and the nearshore bathymetry proximal to the coastal section [6, 7].

Anthropogenic activities influencing shoreline changes include: the disruption of hydrological cycles such as mining along river beds, draining to the coastal beaches, beach sand mining, beach rock blasting, clearing of coastal vegetation, building of coastal structures along the shoreline and destruction of offshore barriers such as blasting of coral reefs [2, 8]. Shoreline change, particularly coastal erosion has been affecting many sites along the Tanzanian coast [2, 9], and among the most seriously affected sites include the coastal sections of Msasani-Kunduchi (Dar es Salaam), Mwambani, Kigombe and Pangani (Tanga), Mikindani Bay (Mtwara), Lindi Bay, Kilwa Masoko and Kilwa Kisiwani (Lindi) and various parts of Zanzibar such as Jambiani, Paje, Maruhubi and Nungwi [2, 6, 10].

Documented literature on coastal erosion along the Tanzanian coast indicates that the present state of shoreline erosion in Tanzania had been active even before 1940s [11].The problem of coastal erosion in Tanzania, particularly the causative factors of coastal erosion had remained one of the least understood subjects [7]. Reference [12] carried out an investigation into the causes and effects of beach erosion in Dar es Salaam, and concluded that sand

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extraction from seasonal streams was not the main cause of erosion.

Dynamite fishing was also rebutted by Reference [12] and Reference [8] as the main cause because at spring high tides and during storm surges when most erosion occurred, the fringing reefs were submerged and could not therefore expect to interfere with the fetch and consequently the force of incoming waves. Reference [1] drew attention to the disappearance of Maziwi Island in Tanga during 1978, attributing the disappearance to the rise in sea level. The most significant loss of beaches was first observed during 1960's as evidenced by uprooting of casuarina trees and that by 1970's the life of turtles in the island was already under threat. However, Reference [7] rebutted these findings and associated the disappearance to anthropogenic clearing of the island vegetation. Reference [13] also used results of sea level reconstruction from tide gauge and satellite altimetry [14] to show that sea level change was not the main factor for the disappearance of the island. Reference [15] undertook a study to explore the factors that influenced coastal erosion along Kunduchi beach in Dar es Salaam and noted that the rates of erosion at this site had a direct linear relationship with changes in the monsoon winds.

Other recent studies at the Kunduchi site, Dar es Salaam showed evidence of increasing wind speeds in Dar es Salaam during the last 25 years, suggesting that the observed erosion at Kunduchi could possibly be associated with a change in wind regime with a corresponding change in wave dynamics [16, 17]. However, these studies were not scaled up to include other coastal sections of Tanzania.

Severe coastal erosion problems generally occur during the Southeast (SE) monsoons [1, 2, 18]. In general, the SE winds which prevail from April to October, are stronger than the Northeast (NE) winds that blow from November to March [19-21]. Occasionally, the SE monsoons are associated with epidemic events such as storms and cyclones, which have devastating erosional effects on the coast. Although cyclones are fairly common and frequently strike nearby Mozambique and the Mascarene Islands, they rarely make landfall on the coast of Tanzania.

The changes in wind regime often have a direct influence on the currents and wave dynamics, thereby serving as an important agent for coastal erosion. The effect of erosion may be stronger when extreme wind speeds coincide with spring high tides. Along the coast of Tanzania, the mean spring tidal range is around 3 m, while the maximum spring tide slightly exceeds 4 m [22, 23]. Nevertheless, the seasonal difference in sea level is rather small with an average range of only about 6 cm [24], which may therefore not be important in influencing erosion.

The recent changes in the global climate are also advocated to have both direct and indirect effects on coastal erosion. The direct effect is related to the rise in the thermal expansion of the oceans and increased melting of the ice sheets and glaciers, thus leading to changes in mean sea level [25]. The change in global climate is also a complex and spatially inhomogeneous process which also manifests itself through changes in the wind climate [26] and through the increase in the frequency and magnitude of extreme events such as tropical storms [27]. During the past few decades, significant changes in the wind regime have been recorded in various regions of the earth including the western Indian Ocean islands of Zanzibar [21] and the Maldives [28].

The purpose of the present study was to investigate the wind climate regime in selected sites along the coast of Tanzania and its possible linkages to coastal erosion incidents. The study utilized a method of wavelet analysis which was applied on the time series of monthly wind speeds. The study is shading further light complementing to other recent research findings on shoreline changes in Tanzania. The study assumes that although storm-induced erosion such as that due to extreme wind speeds is generally sporadic, its impacts on coastal erosion may be quite significant.

2. Sources of Data and Analytical Methods

Wind speed data spanning 28 years (1977-2004) recorded in the mornings and evenings (0900 and 1500 hrs local time) from three meteorological stations along the Tanzania mainland coast (Tanga, Dar es Salaam and Mtwara) and one on the Zanzibar Islands (Fig. 1) were obtained from the Tanzania Meteorological Agency. The instruments are usually serviced and calibrated annually, and are located sufficiently away from direct physical obstructions. The data from all the four stations are uniform in quality, method of collection and publication, and therefore fairly comparable. The four stations which span from the southern to the northern part of Tanzania with the inclusion of one station from one of the Tanzania's major Islands are considered to be representative of the wind field over the near-shore coastal domain of Tanzania.

Prior to the analysis, the data sets were cleaned by removing significant spikes that stood out as outliers. The analysis was carried in three major steps. Step one involved simple averaging of the three-hourly wind speeds at each station to obtain the corresponding daily and monthly means. Secondly, the monthly means were subjected to linear regression analysis to determine long term changes at each meteorological station. Finally, wavelet analysis was used to explore the time series of monthly wind speeds at each station. While the time series may contain dominant periodic signals, these signals can vary in both amplitude and frequency over long periods of time. This technique therefore allows decompositions of the time series into time–frequency space, and can thus show the evolution in the relative strength of the dominant modes with time. The analysis [29] was carried out using MATLAB software to determine the continuous wavelet transform of the time series data at each station. The compatibility of the results was then assessed against other documented information on shoreline erosion events at those sites.

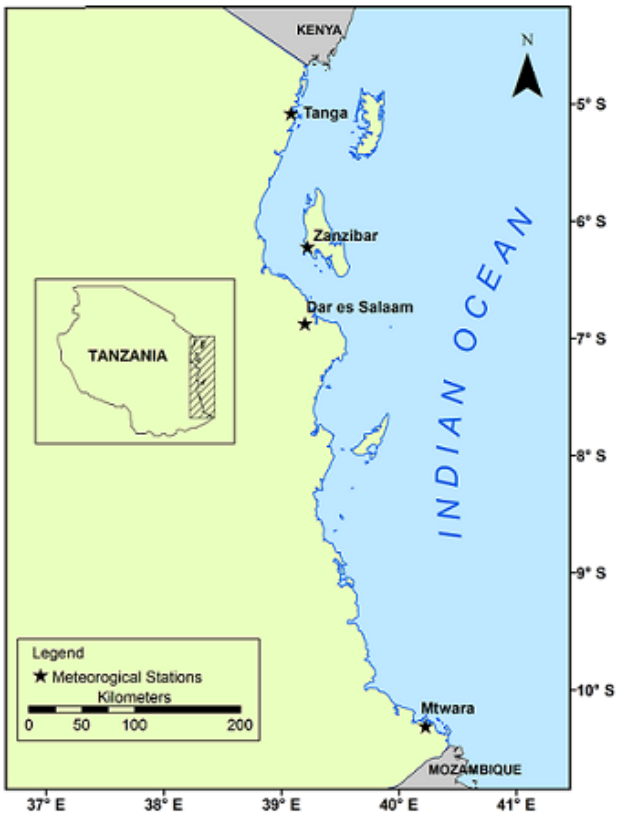


Fig. 1 Map of the coastal Tanzania showing the sites of meteorological stations.

3. Results

The monthly variations of wind speeds are depicted in Figs. 2 and 3. The speeds are highest all year round at Mtwara than at any of the other coastal sites. At each station, the winds are generally stronger during the evenings at 1500 hrs than in the mornings at 0900 hrs, except at Mtwara where the morning wind speeds exceed 7 m/s for the months of June and July.

The mean wind speeds in the evenings average 6.0 m/s (Mtwara), 5.0 m/s (Zanzibar), 5.2 m/s (Tanga) and 4.9 m/s in Dar es Salaam, while in the mornings, the average speeds are relatively lower, averaging 5.1 m/s (Mtwara), 3.3 m/s (Zanzibar), 3.2 m/s (Tanga) and 3.1 m/s (Dar es Salaam), respectively.

There are also two minima at each station generally occurring during the months of March/April and November, which also represent periods of transition between the NE and SE monsoons. The 28 years wind

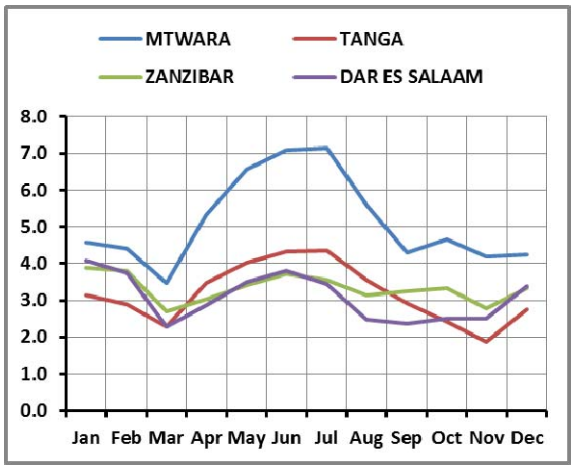


Fig. 2 The seasonal mean wind speeds recorded at 0900 hrs local time (GMT+3). The left axis represent the speed (m/s).

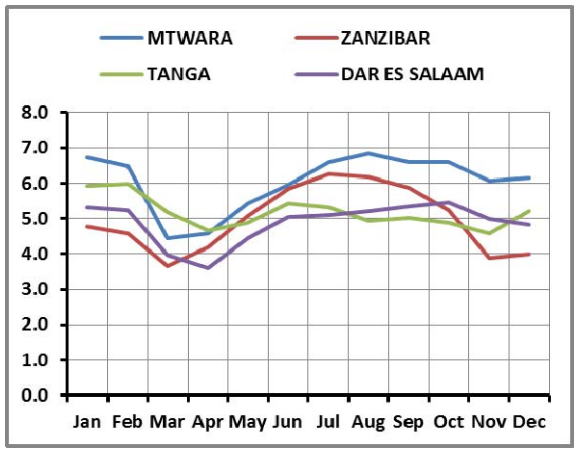


Fig. 3 Same as in Fig. 2, but for 1500 hrs local time.

speed dataset of the four meteorological stations covered by the present study revealed a general rising trend during both the morning and evening periods (Figs. 4 & 5). The annual rates of increase of the monthly wind speeds over the 28 year period were about 0.05 m/s and 0.04 m/s at 0900 and 1500 hrs local time, respectively.

The time series oscillations of mean wind speeds are depicted in the Morlet wavelet spectra (Fig. 6). The wind speeds reveals prominent annual peaks, with less prominent semi-annual peaks. It is interesting to note from Table 1 that the time of occurrence of the annual and semi-annual peaks differ appreciably from one station to another. Three meteorological stations (Tanga, Zanzibar and Dar es Salaam) have at least 3

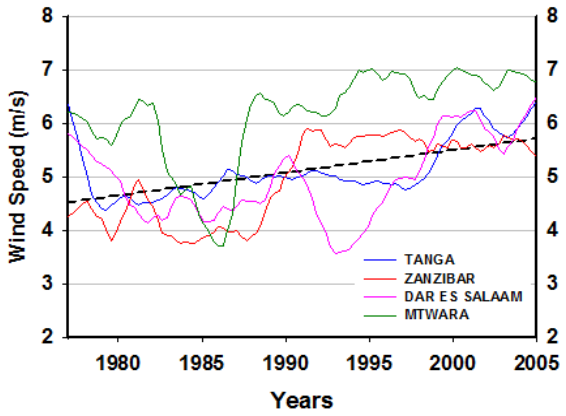


Fig. 4 Loess smooth curves of the monthly mean wind speeds recorded at 1200 hrs local time. The dotted bold line represents the combined linear regression trend for all the stations.

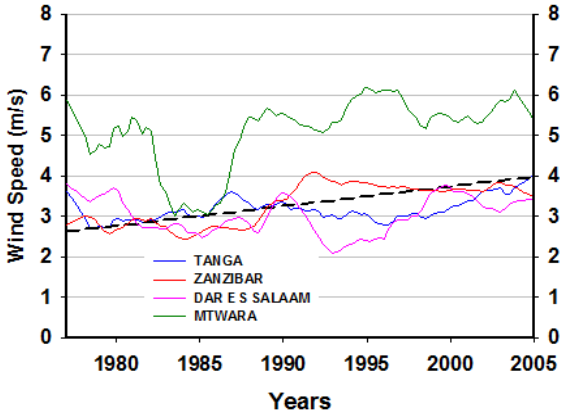


Fig. 5 Same as in Fig. 4, but for 1200 hrs local time coincides with the reported instances of severe coastal erosion.

peaks, while Mtwara meteorological station is an exception with only one peak.

4. Discussion

4.1 The Annual Cycle of Wind Speed

The annual and semi-annual patterns of monthly mean wind speeds presented above may be associated with the major patterns of the prevailing wind regime along the coast of Tanzania. The annual cycles are associated with the annual monsoon wind cycle (which changes between NE and SE on annual basis), while the semi-annual cycles may be associated with the periods of transition of the two monsoon wind systems [30]. The difference in wind patterns during

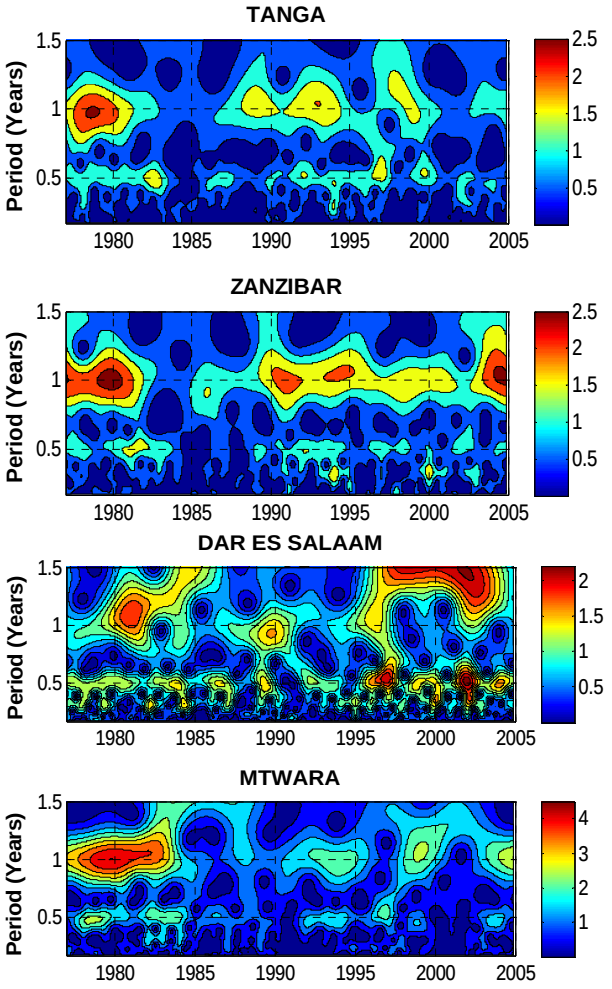


Fig. 6 The Morlet wavelet spectra representing mean wind speeds (0600 and 1200 hrs) in the annual timescale. The legends on the right indicate wind speeds in m/s and the bottom axis shows the data span (1977-2004).

Table 1 Peak wind speeds cycles (indicated by cross symbol) at the four meteorological stations along the coast of Tanzania during 1977-2004.

Year	Tanga	Zanzibar	Dar es Salaam	Mtwara
1977-1982	x[1]	x[2]		
1978-1983				x
1980-1982			x[3]	
1988-1991		x	x[4]	
1991-1993	x			
1994-1996		x[4]	x[4]	
1996-1997	x			
2001-2002			x[5]	
2003-2004		x[6]		

[1, 2, 3]Severe erosions at Maziwi Island, RasNungwi& beach hotels in Dar es Salaam; [4]Tropical storms in 1989 and 1994, Source: Reference [10]; [5,6]Tropical cyclones in 2002 and 2004.

the mornings at 0900 hrs and evenings at 1500 hrs reflect the effects of local land and sea breezes on the general circulation during those periods, respectively [31]. Along the Msasani – Kunduchi coastal section, the longshore beach sand drift caused by the monsoon currents have been reported to be disrupted by the tidal current forces from the Manyema tidal Creek [32]. Over the last three decades, the tidal channel and the associated sand spits had assumed various courses and forms respectively. The delta platform of the Manyema tidal Creek is dominated by migratory and elongate sandbanks [32] and the mode of migration of the migratory sandbanks to the northern shore and their subsequent welding to the beach has resulted into major changes in the distribution of sand along the beaches, giving rise to years of sand 'starvation' followed by years of sand 'abundance'. The above cycles are probably linked to the wind pattern variability discussed in the present study.

4.2 Peak Wind Speeds, Tropical Cyclones and Known Cases of Shoreline Erosion

The presented timings of the peak wind speeds in Tanga meteorological station (Table 1) may be associated with the reported incidence of disappearance of the Maziwi Island, off the Pangani river delta, in the northern coast of Tanzania [1, 7]. Reference [1] had attributed the disappearance of the Island to sea level rise, but a later study [7] attributed the disappearance of the Island to wave erosion after intentional vegetation clearance on the Island. The period of disappearance of Maziwi Island in Tanga coincide with the peak wind speeds that occurred in 1977-82 at Tanga meteorological station (Table 1).

This view is consistent with the conclusions earlier put forward by Reference [7] and Reference [13] that the Island may have disappeared due to factors other than the purported rise in sea level which were opposed to the earlier assumption by Reference [1] who had ruled out the possibility of extraordinary heavy storm events after interviewing four fishermen.

Here it is contended that, apart from the peak wind speeds, the Lily and Honorine cyclones which are reported to hit the northern coast of Tanzania during 1966 and 1974 respectively (Table 2), might have contributed to the increased rates of erosion on the Island as well.

Similar linkages between peak wind speeds and incidences of erosion are also found in Zanzibar and Dar es Salaam. In the case of Zanzibar, critical incidences of shoreline changes during 1977-1989 had been reported at Nungwi, the northern tip of the Island [2], the period which coincides with the occurrence of peak wind speeds at Zanzibar, reported by the present study (Table 1). In Dar es Salaam, the disappearance of Africana Hotel during 1980s and 1990s had been attributed to serious coastal erosion that started in the early 1980s [33]. The erosion at the beach in front of Silver Sands Hotel was reported to have started at around 1988 with a net erosion of up to 5 m per year by 2000 [4]. These periods are also closely linked to the occurrence of peak wind speeds in Dar es Salaam during 1980-82, 1988-91 and 1995-96 (Table 1).Other coastal establishments that started witnessing serious erosion during the peak wind speeds in 1988 were Rungwe Oceanic, Bahari Beach and Kunduchi Beach hotels [33]. In Mtwara however, there seems to be no documented information on the periods of occurrences of beach erosion which can possibly be related with peak wind speeds events.

In the southwest Indian Ocean, the region between $l0^{o}$S and 30^{o}S is prone to tropical cyclones [27]. About 15-20 cyclones are formed annually from October through April due to temperature gradients of surface seawater and differences in atmospheric pressure. Historically, Tanzania is not prone to cyclones since only three cases have been reported to make direct landfall since 1872 (Table 2). Most of the cyclones that head towards Tanzania lose their energy before arriving at the coast. Some of the cyclones are either intercepted by Madagascar, or curve southwards into the Mozambique Channel. Table 3 lists the cyclones that approached the coast of Tanzania since July 1944, most of them being in the southern coast (near Mtwara station).

The cyclones that approach or strike the coast are accompanied by severe damaging winds, torrential rains and flooding. However, the winds from tropical cyclones do not present the most serious erosion hazard. Instead, it is the waves and storm surge associated with the cyclones that cause the major damage to the coast through release of enormously large energy. It is worth noting that the storm damage by tropical storms or cyclones along the coast of Tanzania (Table 2 & 3) coincides with the reported instances of severe coastal erosion.

Although modelling guidance rarely exists on possible changes in tropical cyclones affecting the southeast coast of Africa [34], a closer look at the cyclone tracks that form and prevail in the region clearly shows an apparent increase in the frequency and intensity of these systems since 1944/45 (Tables 2 & 3). It is here contended that this trend is continuing, leading to increased threat of coastal erosion hazard along the coast of Tanzania.

Mtwara in the southern coast of Tanzania experiences the strongest wind speeds than any of the other coastal stations. Apparently, the effect of tropical cyclones that strike or make an approach to the coastline of Tanzania is also much greater in the southern coast. Accordingly, since peak wind speeds and storm surges associated with cyclones have enormous impact on erosion, it is therefore expected that the rates of erosion along the southern coast should be larger than those in the north.

Our findings are consistent with the findings of Ref. [11] and Ref. [35], who observed that although erosion along the north-eastern coast of Tanzania was discontinuous, there was a southward increase in intensity. The authors attributed the geographical disparity in erosion to non-uniform rate of coastal uplift, which was believed to be relatively higher in the north than in the south. However, Ref. [11] and

Table 2 Recorded cyclones that made landfall on the Tanzanian coast.

S/N	Cyclone Name	Date of strike	Affected areas	No. of Deaths
1	Zanzibar[1]	15 Apr 1872	Zanzibar, Mafia, Bagamoyo, Kilwa	>200
2	Lindi[2]	15Apr 1952	Kilwa, Lindi, Mtwara	34
3	Atang[3]	13 Nov 2002	Mtwara	0

Sources: [1]The New York Times, 6 June 1872; [1, 2]Reference [10]; [3]www.australiansevereweather.com

Table 3 Recorded tropical cyclones that approached the Tanzanian coast.

S/N	Cyclone Number/Name	Cyclone Date	Year	Nearest coastal Position
1	196003	01 - 10 Dec	1959	11.3S 40.5E
2	Lily	22 Apr - 01 May	1966	07.0S, 41.6E
3	Bernadette	16 - 28 Oct	1973	12.1S, 42.6E
4	Honorine	14 - 23 Apr	1974	07.1S, 40.7E
5	197621	10 - 12 Mar	1976	10.8S, 41.5E
6	Bettina	22 Nov - 01 Dec	1980	11.8S, 40.8E
7	198802	20 - 26 Nov	1987	10.2S, 42.0E
8	Nadia	17 Mar - 2 Apr	1994	14.5S, 40.6E
9	Josta	04 - 12 Mar	1995	12.5S, 41.5E
10	200502	24 - 29 Oct	2004	08.2S, 41.0E
11	Anita	29 - 30 Nov	2006	11.0S, 41.6E
12	Bondo	16 - 26 Dec	2006	10.0S, 42.0E
13	Jokwe	02 - 12 Mar	2008	14.5S, 42.8E

Data source: http://www.australiasevereweather.com

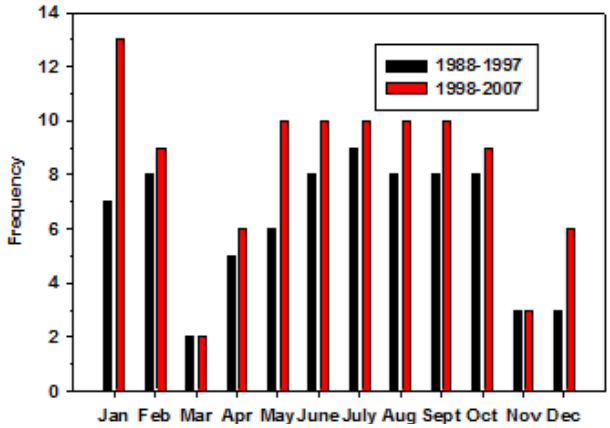


Fig. 7 Frequencies of monthly averages for the morning/evening surface wind speeds exceeding 10 knots (~ 5.14 m/s) at Zanzibar. Source: Reference [36].

Ref. [35] lacked quantitative evidence on land movements along the coast of Tanzania.

4.3 Long Term Changes

The results of the present study at Zanzibar Meteorological station are similar to those reported by Ref. [36] and Ref. [24] who affirm a general increasing trend of wind speeds from 1988- 2007 (Fig. 7) and 1985-2004, respectively. As for the Dar es Salaam meteorological station, the results of the present study are also consistent with those reported by unpublished [17] who observed that the total number of days with wind speeds exceeding 10 knots (5.14 m/s) were significantly higher during the decade spanning from 1995 to 2004 than those in the previous decade. The rates for the annual increase of mean wind speeds observed in the present study are similar to those reported in the Mozambican Channel over the period 1950-1987, which did not exceed 0.1 m/s [37]. According to Reference [38] however, a longer record of at least 50 years is needed to ascertain the relationship between ocean environmental trends and changes in the global climate system.

5. Conclusions

This study highlights the importance of sporadic events on shoreline changes, and it is here contended that most of the observed coastal erosion along the coast of Tanzania during the last three decades is

mainly associated with peak wind speeds corresponding with storm events. Accordingly, the observed trends of increasing wind speeds may have ramifications for augmented risk of shoreline erosion. Moreover, the observed increase in the frequency and intensity of tropical storms, which will presumably continue due to on-going changes in the world climate, may likely amplify further the risk of erosion hazard along the coast of Tanzania.

Acknowledgments

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