19th INTERNATIONAL SHIP AND
OFFSHORE STRUCTURES CONGRESS
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VOLUME 3

COMMITTEE I.1
ENVIRONMENT

COMMITTEE MANDATE

Concern for descriptions of the ocean environment, especially with respect to wave, current and wind, in deep and shallow waters, and ice, as a basis for the determination of environmental loads for structural design. Attention shall be given to statistical description of these and other related phenomena relevant to the safe design and operation of ships and offshore structures. The committee is encouraged to cooperate with the corresponding ITTC committee.

CONTRIBUTERS

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Reply by Committee:

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CONTENTS

1. DISCUSSION

1.1 Official Discussion by Carl Trygve Stansberg

1.1.1 Introduction

This Discussion is based on reading through the Draft Report (dated March 2015) from the 19th ISSC Environment Committee. The Discusser has made efforts to make a balanced review on the different parts of the Report. Still, since his own experience and competence is mainly on a part of the subjects (short-term random wave modelling and statistics), it will be natural that this subject is reviewed in more detail than the others.

The Discussion is presented in the following way: First a brief overview of the Report lay-out and structure is given. Then some overall findings from the Report are highlighted; found as particularly interesting by the Discusser. This is followed by the Discusser's particular comments and suggestions. Finally, suggested additional references are given.

The Committee Mandate is given on the Report's front page, reading: "Concern for descriptions of the ocean environment, especially with respect to wave, current and wind, in deep and shallow waters, and ice, as a basis for the determination of environmental loads for structural design. Attention shall be given to statistical description of these and other related phenomena relevant to the safe design and operation of ships and offshore structures. The committee is encouraged to cooperate with the corresponding ITTC committee".

In particular, the present Discusser considers that the phrase "a basis for the determination of environmental loads for structural design", i.e. the practical application of the findings and discussions in the Report, is of particular importance for the ISSC Community.

As seen from the Mandate, ships and offshore structures are emphasized. The recent growth of the Renewable Energy industry requires that also these applications should be addressed in line with the "classical" ship and offshore applications, and the Committee Report does in fact properly include some attention to these issues as well.

1.1.2 Report overview

The Report is a 81-page document authored by the 19th ISSC I.1 Committee, with its members:

Elzbieta Bitner-Gregersen, Norway (Chair)
Subrata Kumar Bhattacharya, India
Zhivelina Cherneva, Portugal
Sheng Dong, China
Thomas Fu, USA
Geert Kapsenberg, The Netherlands
Ning Ma, China
Christophe Maisondieu, France
Ryuji Miyake, Japan
Alan John Murphy, UK
Igor Rychlik, Sweden

About half of the Committee members, including the Chairman, remain from the 18th ISSC Committee, so it means that a large degree of continuity is to be expected in their work.

The Report is organized with the following 7 Main Chapters plus additional items:

1. Introduction
2. Environmental data
3. Environmental models
4. Climate change
5. Special topics
6. Design and operational environment
7. Conclusions

   Acknowledgements

   References

(The above numbering is assumed by the Discusser; in the report Chapters 5 and 6 were both erroneously numbered as Chapter 5).

Within each Chapter the following subjects are treated separately:

- wind
- waves
- current
- sea level
- ice and snow

In the "Special topics" Chapter the following subjects were treated separately: Hurricane; Wave-current interaction; and Resource Assessment.

A large number of journal and conference papers (around 300) are listed in the References.

1.1.3 Highlights summary

The Report presents an extensive and impressive survey of recent relevant literature, for which the Committee is commended. Some overall findings, as interpreted by the present Discusser, are:

- Substantial and increasing amounts of new and more detailed wind and wave field data are becoming gathered, both from local and remote sources. This is essential for the improved modelling. For current there are also new data reported but it appears to be more limited.
- As a result, several large-scale and global models are continuously being improved, with better resolution, more complete descriptions etc.
- Data ownership: Much existing field data have restricted access, and possible ways to obtaining more wide distributions are addressed.
- Coupled ocean models (wind, waves, current) are being developed. Joint probability models are being developed. Wave-current interaction modelling is being improved.
- Spatio-temporal knowledge and modelling are being improved, bringing new understanding of the phenomena
- There is an increasing focus on non-stationary and non-homogeneous conditions, with the development of new methods and models, although many standard models are based on stationary and homogeneity assumptions.
- Hurricanes represent particular challenges, among others with respect to non-stationarity and larger prediction uncertainties than other types of storms.
- The Report emphasizes the importance of taking into account uncertainties, such as the inherent sampling variability in finite records of random processes.
- Developments within wind data and modelling are partly driven by the growing offshore wind activities
- New field data and many theoretical, numerical and experimental investigations on extreme and rogue waves have been reported.
- The changing climate has an impact on the metocean environment, while details in the picture vary significantly geographically, and there are still large uncertainties. Melting of Arctic ice leads to new ship routes.

1.1.4 Comments

– General comments

Reporting and discussing the findings from literature:

The Committee has reviewed a large selection of the relevant literature, and a lot of new information has been brought forward to the ISSC Community, both with respect to methods and quantified information. Still, it would be easier for the reader's practical use of the Report if more of the concrete findings, discussions and conclusions could have been given and discussed in the Report. In its present form, parts of contents have the form of a list of literature with only limited discussions, while other parts are in fact quite filled with findings, comments and discussion.

Report Structure:

With regard to structure of the Report, I have two main concerns that could be relevant for future Committees:

1. As expressed in the Discusser's Introduction above, the application of the Environment Committee's work in the load analysis for design and operation is an overall important issue. These matters are in fact addressed in the Report's Chapter 6 (numbered erroneously as Chapter 5) "Design and operational environment". However, the application aspect could be even more strongly emphasized as a basic background for the Committee. This could preferably be in a Chapter preceding the other main Chapters, better defining and highlighting more concretized what are the critical issues and parameters for the engineers and scientists who need the Committee's findings as input in their work dealing with the environmental load and response analysis. This could make the Committee's work even more directly relevant and applicable for the ISSC Community and related industry and academia.
2. In Chapter 6 "Design and operational environment", there are large text sections in 6.1.1 "Design" that are dealing with Met-Ocean data. I believe that much of this would rather belong to the Chapter 2 "Environmental data". Similarly, parts of the contents in Section 6.2 "Design Environment" could rather fit within Chapter 3 "Environmental models". So I recommend that the mentioned Chapters should be better coordinated. The adjusting and moving of Chapter 6 to ahead of Chapter 2, as I have suggested in item 1 above, could make this co-ordination easier and more straightforward.

Editorial issues:

Based on the available Draft Report, the editorial lay-out should be improved in some parts of the text, e.g. with regard to text formats and, to some (limited) extent, not a fully uniform structure. Also, for easier reading and avoiding confusion /misinterpretation, some of the longest text sequences could preferably be split up into paragraphs with contents that are grouped and easily distinguished from each other.

In the reference list, Toffoli et al. (2011a) and Toffoli et al. (2011b) appear to be identical.

– *Particular comments and suggestions*

Most of this Section includes suggestions for additional work that could be considered for the Committee Report.

Recent works on metocean issues in general:

Several interesting Metocean papers were presented at the Offshore Technology Conference, OTC (2015); see e.g. Perry et al. (2015) describing a comprehensive work on Autonomous Underwater Gliders. Many of the papers are focused on the Gulf of Mexico environment, relevant for the offshore industry. Furthermore the findings from the 15-year Deepstar programme (Cooper et al, 2013) would also be relevant here. Another recent work from the same area is Forristall & Conochie (2015).

Including more works from the recent significant development on description and modeling of waves and currents offshore Brazil is also recommended. Some recent works include Andrioni et al. (2012), Ceccopieri & Silveira (2012), Ribeiro et al. (2013), Pereira et al. (2014).

As reflected through several of the above references, some of the interesting works relevant for the Committee are being presented at the annual OMAE and ISOPE Conferences and should be considered. Although these Conference papers may lack some of the solid archival quality found in Journal papers, several of those publications can still be quite helpful in getting insight into recent developments in the industry as well as in academic communities.

Waves:

Some comments and suggestions are given in the following with regard to recent works on the short-term modelling of extreme waves and crests, steep and breaking waves, near-surface kinematics, and finite water waves.

Extreme waves:

Much of the discussions of extreme waves in Sections 3.2.2 and 3.2.3 are concentrated on the rogue (or "freak") waves that are connected with nonlinear modulations - the so-called "Benjamin-Feir effects". A large number of analytical, numerical and experimental works are referred to, in addition to very interesting field data. This comes on top of substantial previous findings during the last 15 years on this topic. It is not clear to me, though, what the Committee recommends today to the ISSC with regard to what should be applied in design. There does not seem to be a conclusion with this respect; more work still appears to be needed.

In my understanding, one acknowledges that these extreme modulational phenomena do exist in nature, but they are considered to be very rare, especially in short-crested seas, and are at present normally not included in design. Instead, for practical applications nonlinear effects in steep sea states are, at least within offshore technology, most often included by use of a second-order random wave model with respect to high and extreme crest heights, ref. Sharma and Dean (Forristall (1998, 2000), Stansberg et al. (2008); NORSOK (2015). Recently it has also been suggested to add a certain level on top of the second-order extreme crest heights on basis of several findings both from laboratories and some field data (Stansberg, 1999, 2011; Buchner, 2010; Buchner et al. (2011); Scharnke et al. 2012; Hennig et al 2015). The latter four references are reporting results from the Crest and the Short-Crest JIP's. Such a semi-empirical correction is to account for higher-order effects, at least to some extent. It is presently also being under discussion in NORSOK (2015). It would be smaller in short-crested waves as compared to long-crested.

For the short-term statistics related with the two observed rogue wave events as given in Table 1 (Andrea and Draupner events), it is not clear to me what was the corresponding record durations; could this be clarified?

With respect to Section 3.2.2, "Experimental description of waves", the first sentence could preferably be adjusted to: "Several laboratory tests of extreme and rogue waves have been carried out. Three such test programs are the EC EXTREME SEAS, the ShortCresT JIP (continuation of the CresT JIP), and the EC-Hydralab IV program.".

I also suggest including the paper by Toffoli et al. (2013), on the modulation of waves in finite water depth.

Kinematics:

For random wave kinematics, herein also including the near-surface particle kinematics in extreme random deep-water waves, second-order modelling following the formulation by Sharma and Dean (1981) is widely in use, at least within offshore engineering. The implementation in Stansberg et al. (2008) has been found to agree well with data and other models, ref. Birknes et al. (2013). Use of second-order kinematics modelling is also recommended in DNV GL (2014) and in NORSOK (2015). For breaking waves, however, the model is expected to underestimate the kinematics at the very top "tongue" of the crest, in which case the velocities can exceed the phase velocity. Then fully nonlinear or CFD modelling is required.

More experimental data on near-surface particle kinematics in very steep waves is needed.

Very steep and breaking random wave events:

Very steep and breaking waves are essential in the modelling of wave impact and higher-order loads such as ringing. This is a topic of growing attention in the ship and offshore industry. During the recent years, the physical and numerical reproduction of such events in random wave trains has been investigated and developed at MARINTEK, ref. Pakozdi et al. (2011, 2012, 2015); Stansberg et al. (2012), Ostman et al. (2015). The topic has also been addressed in the Short-Crest JIP (Hennig et al., 2015).

Strongly nonlinear and complex hydrodynamic phenomena are involved in this problem, and the MARINTEK referred work combines CFD and model testing in an integrated manner. Numerically, extreme random wave events (groups) identified from experiments are isolated and modelled by CFD; thus the experiments define what type of events to be modelled. Experimentally, techniques for properly selecting only the most critical events, without having to run full time series while still keeping the proper statistical sampling probability of critical events, are in development. The topic is challenging, both from a numerical (CFD) and a statistical point of view, in particular when breaking waves are involved. But when completed, the described combined methodology development is expected to significantly improve the outcome / value of model tests as well as CFD, and it will lead to more efficient testing and analysis.

Nonlinear free-surface wave loads in steep waves, leading to ringing and similar phenomena, have been analyzed using simplified Morison load models in Stansberg et al. (2013) and Bachynski & Ormberg (2015).

Finite- and shallow water random waves

Application of the second-order random wave model for short-term modelling in finite and shallow water can be challenging. Thus the validity needs to be addressed, especially in very steep and shallow cases. The use of the Ursell parameter as a check is investigated in Stansberg (2011a), and found to be a reasonable choice. For cases outside the validity range, more complete (and resource-demanding) models are required; alternatively CFD modelling of selected durations could be carried out.

Sampling uncertainty of extreme wave groups

The inherent sampling uncertainties of random wave parameters in finite records have properly been emphasized in the Committee Report. In Stansberg (2012) this issue has been particularly pointed out for the random wave groups (as described through the wave energy envelope), which are governing the slowly varying motions of large floating structures. The sampling variability of the extreme energy envelope is shown to be much higher than for linear phenomena, due to the quadratic nature.

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1.2 Floor and Written Discussions

1.2.1 Tetsuo Okada (Yokohama National University)

Thank you for the excellent report on environment.

It was mentioned in the presentation that optimization in design can compensate for the steel increase caused by climate change. However, to my understanding, the industry has already made every effort to optimize structures in the current competitive circumstances, and there is no room to compensate for some 10% of steel increased. I would appreciate some additional information on the background of the committee's view on structural optimization with regard to climate change.

1.2.2 Alex Babanin (Swinburne University of Technology)

I read the report and I would like to congratulate the Committee for an excellent report, a very good overview of recent progress on environmental data and models and their applications; everything is there. The section on current, in which I was particularly interested, is very well written and includes an excellent state-of-the art-review.

1.2.3 Mirek Kaminski (Delft University of Technology)

In the presentation an impact of climate change on extreme wave conditions was shown. Climate change will impact not only ultimate limit states but also fatigue calculations. I would appreciate to hearing Committee's comments on it.

1.2.4 Agnes Marie Horn (DNV GL)

The design temperature is an important parameter when selecting and qualifying materials according to design codes for both ships and offshore structures. Several different definitions are used for setting the design temperature like; *lowest mean daily average temp*, *lowest mean daily low temperature*, *extreme low temperature* and *lowest anticipated service temperature* etc., ref. to figure below. However, the different rules and regulations define different philosophies when deriving at a design temperature to be used for selecting materials and qualification of these materials;

- In DNV rules the temperature for external structures is defined as the lowest mean daily average air temperature in the area of operation notated MDAT. This temperature should be based on a number of years of observations and are used for material selection.
  However, for fixed installation or floaters designed according to ISO, the temperature is defined as;
- In ISO 19902 / 19906 the lowest anticipated service temperature LAST shall be used when selecting appropriate material, this temperature is based on a minimum hourly average extreme-level (EL) air temperature with a probability of exceedance not greater than 10^{-2}. ISO also opens for that "The LAST value to be used in the material selection shall be in accordance with applicable regulatory requirements in the region of application". However, in general the 1 hour minimum with a 100 year return period is applied and this definition is also reflected in the updated NORSOK N-003 (which is currently undergoing industry hearing) which specifies temperatures in the Barents Sea ranging from -20C° to -40°C depending on location.

As can be seen from the figure, the difference between MDAT and LAST can be more than 20°C, which challenge the selection of offshore materials both when designing according to ISO 19902 and NORSOK.

For steel materials used offshore toughness testing by use of Charpy is required, and the specified required test temperature can be as low as -30°C below LAST (ISO 19902). Both ISO and NORSOK are refereeing to e.g. EN 10225 for steel materials which only have Charpy requirements for test temperature down to -40°C. Hence, in general when the design temperature is colder than -10°C these material standards are not applicable. It is known that when the temperature decreases, steel become more brittle. In order to prevent brittle fracture in the Arctic, the structure needs adequate toughness for the loading seen at these low temperatures.

Does the Committee have any views on what typical design scenarios which will be governed for these low temperatures reported in the Arctic? And is it possible to suggest any probability of exceedance that should be used for temperature definitions (e.g. 10^{-2}, 10^{-1} or annually) with the corresponding combination to other environmental loading as e.g. wind, waves, ice.

1.2.5 Torgeir Moan (NTNU)

First, I would like to congratulate the Chairman of the Committee I.1 with, as usual, an excellent presentation. I would like to add that I'm chairing the revision process of the NORSOK Standard N-003 "Actions and Action Effects" mentioned during the presentation. I would like to confirm that for application to wave in deck load predictions; there is a recommendation to increase the design crest height with 10% in order to take into account higher order nonlinear wave effects and the effect of area statistics. Some increase of future metocean conditions due to climate change is also suggested, but as it stands today it will be up to an operator to decide to apply it. The revised version of NORSOK will be sent for industry hearing.

2. REPLY BY COMMITTEE

2.1 Reply to Official Discusser

2.1.1 Introduction

The Committee Members would like to express their thanks to Dr. Carl Trygve Stansberg for evaluation of the Committee I.1 Report and for interesting comments.

The renewable energy installations are not mentioned explicitly in the Committee I.1 mandate as the ISSC 2015 Committee V.4 Offshore Renewable Energy is addressing the topic. However, the increased use of renewable energy sources has encouraged the Committee I.1 to put some attention to these issues but focusing on metocean description only. In the final version of the report the Committee I.1 suggests extension of the I.1 mandate in the future by giving renewable energy installations an equal status with ships and offshore structures. This needs to be done in communication with the ISSC Committee V.4 Offshore Renewable Energy.

The official discussion is based on the draft version of the ISSC 2015 I.1 report. In the final version of the report several points mentioned by Dr. Stansberg are accounted for. A detail reply to the points raised by Dr. Stansberg is included in the following sections.

2.1.2 Report overview

The Committee I.1 has none comments to the report overview given by the Official Discusser.

2.1.3 Highlights summary

We appreciate to hearing that the Report presents an extensive and impressive survey of recent relevant literature.
The listed by Dr. Stansberg overall findings of the Committee I.1 correspond well to the main conclusions of the Report I.1.

2.1.4 Comments

– *General comments*

Reporting and discussing the findings from literature:

The Committee is pleased to hear that the Report I.1 brings a large selection of the relevant literature, and a lot of new information to the ISSC Community, both with respect to methods and quantified information.

The information given in the report has been prepared having engineering applications in mind. We may agree that, it would be easier for the reader's practical use of the Report if more of the concrete findings, discussions and conclusions could have been given and discussed in the Report. It needs to be mentioned that the ISSC organization has not the same tradition as the ITTC organization which provides recommendations in forms of procedures for metocean data and models to be utilized in model tests. The ISSC I.1 reports have not had traditionally a form of recommended practices but have been providing the state-of-the-art reviews of the relevant literature published in the 3-year periods of the courses of the ISSC I.1 Committees. The focus in the ISSC 2015 Report I.1 is giving to new development in metocean data and models being of importance for design and operations of marine structures as well as to recommendations for future research needs for academia and the marine industry. Further, the marine structures are outside the mandate of the Committee I.1 Environment.

We agree that some parts of the Report's contents include more limited findings and discussions compared to others. This is partly related to the fact that none progress on some topics, in relation to applications, has been found since the last ISSC 2012 Committee I.1 Report was issued, and partly due to the priority the Committee I.1 has given to different topics covered by the Report.

Report Structure:

We thank for the comments.

1. We agree that not all results presented in the report have the form of recommended practices; however, we believe that they provide still important information for engineering applications. E.g., the given review of the recent updates of metocean databases is valuable for marine structural design and marine operations. In practice it is up to the offshore and shipping industry to decide which database is chosen for assessment of loads and responses of a marine structure. The present knowledge about metocean data does not allow recommending one database as prior to the other ones for all engineering applications but it is possible to point out limitations and advantages which application of different databases brings.

   The Report's Chapter 6 (numbering has been corrected in the final version of the Report) "Design and operational environment" includes the findings where clear recommendations for the marine industry can be given today while previous Chapters are addressing the state-of-the-art reviews of environmental data and models, having in mind engineering applications. We would like to recommend that the suggestions of Dr Stansberg are considered by the next ISSC 2018 I.1 Committee.
2. We agree that some text presented section in 6.1.1 "Design" dealing with metocean data could belong to Chapter 2 "Environmental data". However, the content of Section 6.1.1 refers directly to design while Chapter 2 is addressing state-of-art findings on environmental data in the course of the ISSC 2015 Committee I.1. E. g. the Global Wave Statistics Atlas recommended by IACS to be used for design of ships has not been updated since 1986.

Further, parts of the contents in Section 6.2 “Design Environment” could fit within Chapter 3 “Environmental models” but as mentioned earlier we distinguished the state-of-art knowledge of the topics addressed by the Report form the models which are used already by the marine industry. Again, we leave to the decision regarding possible coordination of the chapters to the next ISSC 2018 I.1 Committee.

Editorial issues:

In the final version of the Report I.1 the editorial issues mentioned by Dr. Stansberg have been improved. In the reference list Toffoli et al. (2011b), mentioned twice, has been removed.

– *Particular comments and suggestions*

We would like to thank Dr Stansberg for the suggestions for additional work that could be considered for the Committee Report.

Recent works on metocean issues in general:

We would like to mention that the articles published in journals and conference proceedings not available to the Committee in the final forms by March 2015, are not covered by the Report. Therefore several references mentioned by Dr Stansberg published in 2015 are not included in the Report, but should be considered by the ISSC 2018 Committee I.1

The Deepstar programme (Cooper et al, 2013) is mentioned in the final version of the Report.

The Committee agrees that the works from the recent development on description and modelling of waves and currents offshore Brazil is of great importance for the marine industry. The references mentioned by Dr Stansberg are included and commented in the final version of the Report.

Furthermore, the Committee I.1 agrees that several interesting works relevant for the Committee are being presented at the annual OMAE and ISOPE conferences. Only some of these papers are included in the Report I.1 due to the requirement for the limited number of pages of the Report.

Waves

Extreme waves:

We agree that much of the discussions of extreme waves in Sections 3.2.2 and 3.2.3 are concentrated on the rogue (freak) waves that are connected with nonlinear modulations - the so-called “Benjamin-Feir effects”. The linear and second-order wave models have been discussed in the previous ISSC 2009 and ISSC 2012 Committees’ reports and the reference is made to these reports as none significant progress on the topic has been found since the last ISSC 2012 Committee I.1 Report was issued. We’ve found the recent findings on rogue waves being of great importance both for the marine and renewable energy industry as well as for academia.

As mentioned in the Report despite recent achievements, a consensus on the probability of occurrence of rogue waves has not been reached yet within the shipping and offshore industry. Such consensus, however, is essential for a systematic evaluation of possible revision of classification society rules and offshore standards, which currently do not include rogue waves explicitly (apart from some exceptions mentioned below). The EC EXTREME SEAS project has contributed to new findings on probability of occurrence of rogue waves which need to be further explored. These investigations indicate that sea states which can prone formation of rogue waves are not so rare in nature. The findings of EXTREME SEAS and CresT/ShortCresT contributed to initiation of the adaptation process to rogue waves in the marine industry. STATOIL has already introduced an internal requirement accounting in a simplified way for rogue waves, see (ISSC, 2013, 2015). This requirement is now under discussion for possible implementation in the revised version of the Norwegian Standard NORSOK. Further, as a result of the EXTREME SEAS project the DNV GL rules for superstructures of passenger ships have been revised to include the effects of rogue waves (Bitner-Gregersen et al., 2015). Apart from reaching consensus on probability of occurrence of rogue waves also a systematic impact of these waves on loads and responses of different types of ships, offshore platforms and renewable energy structures is still lacking. The shipping and offshore industry needs tools that can be used for assessment of loads and responses in situations with very steep nonlinear waves such as rogue waves (https://www.dnvgl.com/technology-innovation/latest-publications.html).

Although different opinions may exists regarding existence of modulational phenomena in nature, several authors mentioned in the Report have observed the phenomenon in the ocean. We are aware that today the offshore industry, instead of applying of rogue waves, is for practical applications accounting for nonlinear effects in steep sea states by using of the second-order random wave model with respect to high and extreme crest heights. Further, we are aware that recently based on findings of

(Stansberg, 1999, 2011) and CresT/ShortCresT (Buchner, 2010; Buchner et al. (2011); Scharnke et al. 2012; Hennig et al 2015) it has been suggested to add a certain level on top of the second-order extreme crest heights (the internal STATOIL requirement mentioned above) being under discussion for implementation in NORSOK. This is mentioned in the ISSC 2015 Report I.1.

Further, we agree that as shown by several authors (for reviews see the ISSC 2009, 2012 and 2015 Reports) modulational instability is suppressed in short-crested waves as compared to long-crested. However, the recent investigations of Bitner-Gregersen and Toffoli (2014) show that occurrence of rogue waves in the crossing seas can occur not only for narrow-banded wave directional spreading but also when it is broader.

The records duration of the Andrea and Draupner events is ca. 20-minutes. This information is included in the final version of the Report.

We fully agree that the EC-Hydralab IV program has contributed significantly to getting better insight into extreme and rogue waves. The Chairman of the Committee has participated in this program. The EC-Hydralab IV program is mentioned in the final version of the Report.

The paper by Toffoli et al. (2013) was included in the draft Report but by a mistake not in the reference list. It is included in the reference list of the final version of the Report.

Kinematics:

Wave kinematics is a topic which belongs rather to the ISSC I.2 Committee than to the ISSC I.1 Committee, because it is closely linked with wave induced loads. Therefore kinematics is mentioned only in a limited form in the ISSC 2015 I.1 Report, mainly in connection with rogue waves.

The work of Birknes et al. (2013) addressing the second order effects in deep water and related kinematics is included in the final version of the Report. We are aware that use of second-order kinematics modelling is recommended by DNV GL (2014) and NORSOK (2007). The Committee recognizes the significant contribution made by Dr Stansberg to modelling of second order waves and wave kinematics.

Further, we agree that to get a correct picture of wave kinematics when wave breaking is present the fully nonlinear or CFD modelling is required. Some findings obtained using the fully nonlinear wave models are reported by the ISSC 2015 Committee I.1. As pointed out by the Official Discusser more experimental data on near-surface particle kinematics in very steep waves is still needed for validation purposes.

Very steep and breaking random wave events:

We thank Dr. Stansberg for the comment but a discussion of modelling of wave impact and higher-order loads such as ringing is outside the mandate of the Report I.1; it belongs to the ISSC 2015 Committee I.2.

We recognized significant contribution MARINTEK made to use of CFD in modelling of strongly nonlinear and complex hydrodynamic phenomena and we thank Dr. Stansberg for the valuable comments regarding this topic. As mentioned by the Official Discusser, the topic is challenging, both from a numerical (CFD) and a statistical point of view, in particular when breaking waves are involved. The references mentioned addressing loads are outside the mandate of the Committee I.1.

Finite- and shallow water random waves

The Committee thanks for the interesting comments and the reference. The Report I.1 includes primarily the papers published in the period September 2012 - March 2015. We would like to mention that also models beyond the second order can be used in finite and shallow water depth, as the ones reported by the ISSC 2012 and 2015 Committees I.1.

Sampling uncertainty of extreme wave groups

We appreciate to hearing that the inherent sampling uncertainties of random wave parameters in finite records have been emphasized properly in the Committee Report. We thanks for the interesting reference Stansberg (2012) which is included in the final version of the Report. More investigations addressing the sampling variability of the extreme energy envelope is still welcome by the Committee.

2.1.5 References

The Committee thanks for all references, some of them are included in the final version of the Report. The present Report included primarily the papers published in the period September 2012–March 2015. The papers addressing loads and responses are outside the mandate of the Committee I.1.

2.2 Floor and Written Discussions

2.2.1 Tetsuo Okada (Yokohama National University)

The Committee I.1 thanks Prof. Tetsudo Okada for the interesting comment. The Committee agrees that the industry has already made efforts to optimize structures in the current competitive circumstances. However, it might be still possible to increase the hull girder strength in some cases, e.g. for tankers a steel weight in a deck area could be reduced by modifying a current frame spacing or number of stiffeners as discussed by Bitner-Gregersen et al. (2015).

Bitner-Gregersen, E. M., Eide, L. I., Hørte, T. & Vanem, E. (2015). Impact of Climate Change and Extreme waves on Tanker Design. *SNAME Transactions 2014, vol. 122, pp. 177-200.*

Further, in the EC EXTREME SEAS project, coordinated by legacy DNV of Norway, the Portuguese ship yard ENVC has demonstrated innovative design of three vessels built lately by ENVC (Ro-Pax Ferry, Heavy-Lift Container and Asphalt Tank Carrier), and has shown that extra building costs related to accounting for rogue waves could be marginal or none, depending on how initial design and High Strength steel quality is used (see Bitner-Gregersen et al. (2015). This approach could also be adopted to account for climate change effects.

2.2.2 Alex Babanin (Swinburne University of Technology)

The Committee appreciates the comments of Prof. Alex Babanin and thanks for them.

2.2.3 Mirek Kaminski (Delft University of Technology)

The observed and projected climate changes of metocean conditions will also impact fatigue calculations due to changes of shape of joint distributions of significant wave height and zero-crossing/spectral wave periods. Very limited investigations addressing effects of climate changes on fatigue have been carried out so far.

2.2.4 Agnes Marie Horn (DNV GL)

A discussion of design scenarios in combination with the corresponding combination to other environmental loading as e.g. wind, waves, ice, is outside the mandate of the ISSC 2015 I.1 Environment Committee. This question should be addressed to the ISSC 2015 V.6 Arctic Technology Committee.

2.2.5 Torgeir Moan (NTNU)

The Committee would like to thank Prof. Torgeir Moan for the valuable additional information.