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THE NEW ISO19906 STANDARD AND RELATED ARCTIC ACTIVITIES AT DNV

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ABSTRACT

ISO 19906, the new offshore standard on Arctic Offshore Structures, has been issued as International standard for the Arctic and cold regions. The standard represents consensus in the industry and the best practice on protection of personnel, the environment and assets when operating under Arctic conditions. The standard's **normative sections** set requirements for performance while the **informative sections** include specific recommendations for meeting the normative requirements.

Furthermore, Det Norske Veritas (DNV) is the Norwegian project manager for the Barents2020 project, with the objective of implementing a common set of rules and standards for health, safety and the environment in the Barents Sea. The focus is on Russian-Norwegian cooperation and the initiative is supported by the national governments. The project builds on the results of the ISO 19906 process and suggests how the results of ISO 19906 in general can be implemented in the Barents Sea region.

DNV has an ongoing Joint Industry research Project "IceStruct" with the objective of supplementing the ISO standard with a design guideline document related to calculation of ice loads and other structural design parameters for structures located in ice. Of particular focus is the ability to predict ice actions and action effects on floating installations.

This paper will present the current results of the ISO process and the relationship with the related mentioned DNV projects, with an emphasis on ice-related design issues. An example is included on how to determine, with the use of FORM, a contour in a space of two governing parameters where the contour is connected to a joint probability of those two parameters. In this example iceberg impact energy is chosen due to its simplicity. The results are compared against a probabilistic model.

ISO 19906, ARCTIC OFFSHORE STRUCTURES (ISO, 2010 and Blanchet et al., 2011).

By 2000, several factors became apparent that provided the incentive for the development of a new and global standard for arctic offshore structures. The formation of an international working group was proposed to develop an International Standard which would harmonize existing regional and national codes and standards and also update the provisions to include the latest agreed knowledge and technologies. Countries participating in WG8 agreed to view the new ISO Standard as a replacement for their existing codes and standards. Significant factors that lead to this initiative included (Blanchet et al., 2011):

- Several regional and domestic codes and standards dealing with structures in ice environments were in existence. The most advanced, from Canada (CSA, 2004), Russia (SNiP, 1982 and VSN, 1988) and the USA (API, 1995), did not provide the same guidance or the same ice load calculation methodology for the design of an offshore structure.
- The Eurocodes, developed by the European Union, were also planning to include ice actions and other subject matter related to offshore structures in ice environments. EU funded research and field data, obtained from lighthouses in the Baltic Sea from 1997 – 2002, could have caused yet another, different approach to be developed. Instead it was agreed that these data were to be added to the database from which the new global standard was to be developed. The European Standards Committee (CEN) has adopted the ISO Standard without modification.

Given incentives to develop an ISO standard, the development of an Arctic offshore structures standard was made a priority by oil and gas industry in member states within ISO. Canada, having a national committee for Arctic offshore structures, took the initiative to propose a new work item to ISO at the Milan meeting of ISO TC67 in January 2002. Technical Panels were formed to write the actual document.

As the use of language is very precise in an ISO document (ISO Directives Part 2, 2004) a clear distinction was made as to what could be contained within these elements. Specifically the use of "shall" denotes a requirement, "should" denotes a recommendation, "may" denotes a permission or option, and "can" denotes a possibility. The use of "must" is avoided because "must" is reserved for statutory issues, and such issues are outside the purview of an ISO Standard.

The main element of the standard, the normative part, contains the provisions which the designer will have to follow in order to be compliant with the ISO standard. Therefore while it contains the "shall" and "should" provisions, "may" and "can" provisions are also included. The normative provisions provide the user of the standard with requirements for conformity and guidance for expected or good practice.

The Informative part, contained in Annex A, contains informative text and commentary which assists the designer in following the normative text. It contains the methodologies, equations, descriptive notes and references to be used in the design of the structure. It also contains additional "may" and "can" provisions. The organization of the Informative text mirrors the Normative in order to assist the designer.

ISO 19906 specifies requirements and provides guidance for the design, construction, transportation, installation, and decommissioning of offshore structures related to the activities of the petroleum and natural gas industries, in arctic and cold regions environments. ISO 19906 also covers structures considered for installation in waters that may be partially or wholly covered with ice, whether seasonally or year-round ("cold regions"); except lakes and rivers.

Within the document, the design ice event, with an annual probability of occurrence of 10^{-2}, is called the extreme level ice event (ELIE) and the abnormal ice event, with an annual probability of occurrence of 10^{-4}, is called the abnormal level ice event (ALIE). If the ELIE event occurs the facility is to withstand the event with minor deformation, no loss of life and minimal pollution to the environment. If the ALIE event occurs, the facility can be damaged, but there should be no loss of life or significant pollution to the environment.

In addition, three exposure levels are considered, L1 for manned, normally not evacuated facilities or with significant potential for hydrocarbon releases and L3 for unmanned facilities with no potential for hydrocarbon release. The L2 designation is used for intermediate circumstances with respect to human safety and potential for hydrocarbon release. Additional details on the exposure levels and the ELIE and ALIE are presented in Thomas et al. (2011a).

During the international review period for the standard, the “DIS” period, calibration and case studies were conducted. The calibration of ice action factors and return periods was performed to ensure that the intended nominal target reliability was achieved. Action factors for ice actions were obtained specifically for this standard and details of the calibration effort are provided in Maes and Thomas (2011). Action factors for gravity loads, variable actions, earthquakes and resistance were obtained from other appropriate ISO standards. The calibration accounted for the distinction between ultimate limit states (associated with the ELIE) and abnormal limit states (associated with the ALIE) as it affected action factors, specified annual probabilities of exceedance, companion factors involving extreme level actions, abnormal level actions, or both, and the inclusion of system robustness/energy dissipation capacity for the abnormal limit states. Kärnä, et al. (2011) discuss the suggested ice load/action determination methodologies.

The case studies initiative was performed to see how the document was used by those not familiar with it and to identify what was missing or needed change. TP10 was formed to initiate and monitor these activities. Fuglem et al. (2011) discuss the ice criteria, structure types and ice loads/actions that were used in the calibration of the ice action factors, Thomas et al. (2011b) discuss the results of the case studies while McKenna (2011) discusses the use of the standard.

This standard was approved unanimously by ISO in December of 2010. The standard represents state of practice with respect to design of structures for the Arctic and cold climate regions. The workgroup, ISO TC67/SC7/WG8 developing the standard is standing, presently receiving comments for a possible update of the standard within, say, a five year period. The standard also encourages research and technology development to ensure that the informative appendix represents state of art within design of the structures for the relevant regions.

THE BARENTS 2020 PROJECT

Barents 2020 is a joint industry project involving Russian, Norwegian and international scientists and engineers, initiated by the Norwegian Foreign Ministry in 2007, supported by Russian authorities and with funding also from Russian, Norwegian and international industry. The purpose of the Barents 2020 project is to recommend HSE standards for common Norwegian - Russian application in the Barents Sea, for safeguarding people, environment and asset values in connection with oil and gas activities, including sea transportation of oil and gas.

Phase 1 of the project lasted from October 2007 to October 2008. The results of phase 1 were documented in five Norwegian “Position Papers”. The position papers provided the basis for further work in Phase 2, lasting from November 2008 to March 2009, resulting in seven special topics prioritized for further study in expert working groups in Phase 3, which focused on potential improvements that reduce the probability of incidents rather than to mitigate consequences. Currently the project is in Phase 4, has seven working groups with proposed deliverables (Table 1), and will be completed by the end of 2011.

Table 1: Proposed deliverables for Phase 4 of the Barents 2020 project

Group	Phase 4 deliverables
RN01	Recommendations on how Phase 4 deliverables should be structured, edited and published to fit well into the collection of existing standards, and how they can be used in revision and/or development of new ISO standards
RN02	Guidance document for design against ice loads on stationary floating structures that may serve as a common Russian-Norwegian separate supplement to ISO 19906 for the Barents Sea.
RN03	Carry out risk assessment seminars for arctic conditions with focus on experience exchange, methods and software, databases and practical applications of risk assessment for offshore activities in the design process
RN04	Guidance document in form of commentary on ISO19906 EER provisions. Two reports to be prepared on performance standards (or functional specifications) for an Arctic lifeboat and an emergency response vessel.
RN05	Guidance document as possible annex to ISO 19906, to provide industry guidance for safe working environment for personnel on board ships and offshore installations operating in the Barents Sea
RN06	Guidance document as possible annex proposal to ISO 19906, to make the ice management operations more safe and optimal from an economical and environmental point of view
RN07	A regional environmental standard for the Barents Sea to reflect MARPOL Special Area (SA) requirements for discharges and emissions from oil and gas related ship traffic and offshore units

All Russian-Norwegian working groups (which in Phase 4 truly are international working groups), except RN03 and RN07 are focusing on additional guidance to ISO 19906. During Phase 3 RN02 had the objective to "*recommend standards for design of stationary offshore units against ice loads in the Barents Sea*". The working group concluded then that (Moslet et al. 2010):

"*ISO 19906 is the standard best suited to meet the objectives of the working group and ISO 19906 shall be used as basis for design and operations of stationary units in the Barents Sea. Most of the Russian standards deal with fresh water ice and are not directly applicable for use in the Barents Sea, whereas the guidance in the most relevant national standards such as API RP 2N and CSA S471-04 has been integrated into the more recent ISO/DIS 19906. Internationally approved (direct translations) of the ISO 19906 are to be implemented as national standards.*"

There is a continued focus in Phase 4 of the project to supply additional information and guidance to the use of ISO 19906. Naturally in order to do so, the Barents 2020 project has in Phase 3, through working group RN02, identified where additional guidance might be needed for the design of structures in the Barents Sea (Figure 1). The intent was to highlight where further effort was needed within the objective of the Barents 2020 project. After the completion of Phase 3 some of this has been clarified through publications by the developers of ISO 19906 (e.g. Kärnä et al., 2011; Maes and Thomas, 2011). The results from Phase 3 are publicly available (DNV, 2009) and this will also be the case for Phase 4 once the work has been completed. DNV hope that the results from the different phases in the Barents 2020 project can be used in supplement to the ISO 19906 standard and that the results also will contribute to a future update of the standard.

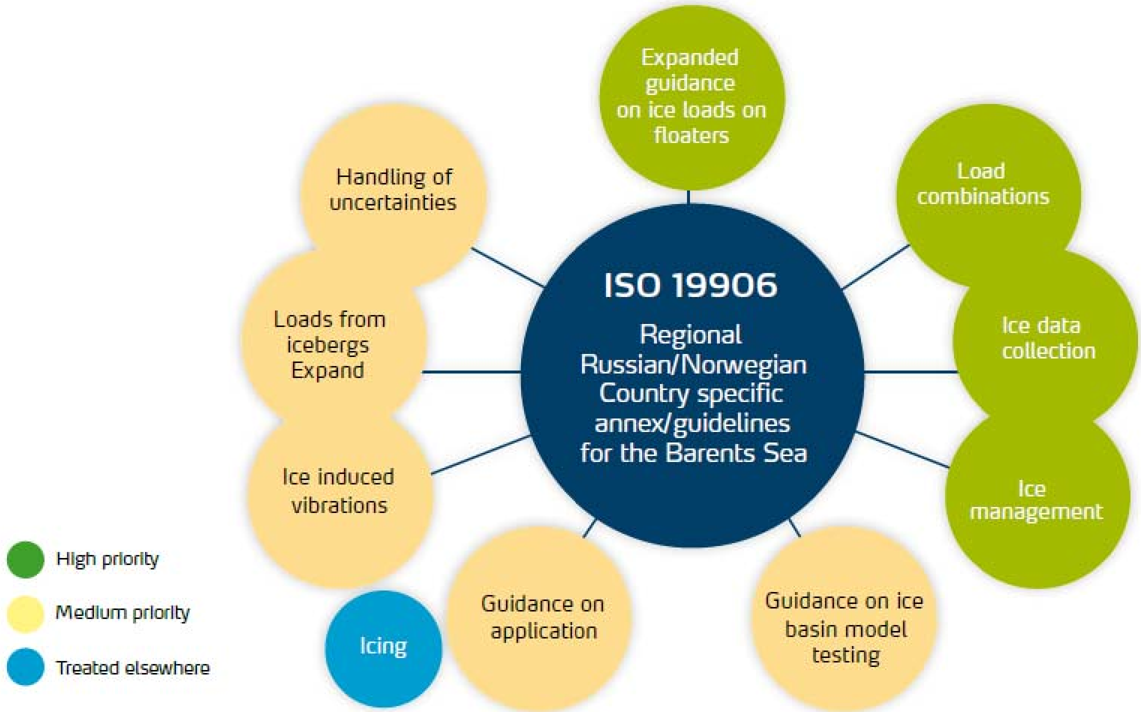

Figure 1: Ten prioritized topics of group RN 02 identified in Phase 3 of the Barents 2020 project.

THE DNV ICESTRUCT JIP

The objective of the DNV IceStruct JIP is to produce a guideline on Ice Effects on Arctic Offshore Structures. The guideline aims to assist the non-specialist designer in following the normative provisions given by ISO 19906 for the safe design of Arctic offshore structures. The JIP aims to present a common and documented approach to achieve acceptable safety levels for offshore structure designs in cold climate regions, by adhering to the normative provisions of the Standard and by supplementing the Informative part of the Standard through the provision of practical design recommendations and case studies.

The issue of determining appropriate reliability levels, and therefore also design values of ice actions, can only be properly addressed by considering both environmental actions and structural resistance within the framework of a complete structural reliability analysis (SRA). The subject of structural resistance is beyond the scope of the JIP, so within the context of ice actions and design loads, the JIP guideline will be concerned with appropriate methods for the determination of characteristic values of ice actions.

CHARACTERISTIC ICE ACTIONS FOR ICEBERG IMPACTING A FLOATING STRUCTURE

For fixed structures there exist much experience, data and methods that can be used to predict ice actions on fixed structures in ice, compared to that available for floating structures. This is reflected in ISO 19906. Ice actions on fixed structures can be expressed by a series of closed-form expressions making it possible to use probabilistic methods, including Monte Carlo simulations, in order to calculate a large number of ice action values that can be used to determine ice actions at different given return periods. For floating structures in ice this is not possible to the same extent mainly due to the complicated response characteristics of the mooring or DP system and their effect on the dynamic ice-structure interaction. It is not only the non-linearity of the response that makes this difficult; the changing interaction geometry also contributes so that the dominant ice failure mode cannot always be identified *a priori*. This can be the case for, say, a spar platform with relatively low metacentric height, or a FPSO during ice drift reversal events. Due to the complex dynamic interaction, the most common method for determining ice actions on floating structures is by conducting ice basin model tests. DNV acknowledges the use of ice basin model tests, but also recognises the main challenges, being the scaling and modelling of all governing parameters in the same test. For example, obtaining target values for both flexural and compressive strength at the same time is more or less impossible with the current model ice technology and for the scales commonly used (though for testing of ships running ahead this is not an issue since the predominant failure mode is bending, not to mention the large amount of full scale data which is available). Jensen et al. (2011) describe an interesting method for adjusting model test results based on an advanced numerical calculation model. Once calibrated, the numerical model can also be used to simulate so called target scenarios.

Generally there seems to be a general understanding that testing under environmental conditions at a given return period yields ice actions at the same return period. This is however not always correct. The main challenge with both model test results and calculation results is that only a limited effort appears to have been made towards finding the relationship between (i) the results from testing with, say, 100 year return period environmental conditions, and (ii) the corresponding 100 year return period characteristic action effect, which is the value that would be needed for design.

The following describes a methodology, based on a design approach for floating structures in waves, which can be used to appropriately determine characteristic actions on floating structures from a limited set of tests or calculations. The methodology is shown through a simplified example which involves a series of assumptions. Some of the assumptions are strictly speaking not correct, however they are nevertheless used mainly in order to simplify the example. The annual rate of occurrence of iceberg encounters is not taken into account, and for the validity of the example below it is assumed that one iceberg interaction occurs annually.

Consider now iceberg interaction with a floating structure. A characteristic impact action with a predetermined return period is needed for determining an appropriate design action. In this case, the return period is taken as 100 years, corresponding to an annual probability of occurrence of 10^{-2}.

The initial kinetic energy, E_k, of an arbitrary iceberg impacting on a structure is a function of iceberg mass, M_i, and interaction velocity v_i:

$$E_k = \frac{1}{2} M_i \, v_i^2 \qquad (1)$$

The initial kinetic energy should be reduced due to eccentric impacts (ISO 19906 Clause A.8.2.4.7.2), but in this exercise all impacts are assumed to be centric. It can be assumed that enough information exists in order to establish well defined long-term distributions of iceberg mass and drift velocity. Clearly, the interaction velocity is not equal to the drift velocity. The actual interaction velocity is, amongst other factors, dependent on the particular sea state, iceberg mass, structural properties and mooring properties/compliance. In addition, there is hydrodynamic interaction (ISO 19906 Clause A.8.2.4.7.4) between the iceberg and the structure. All of these effects combined may result in a complex non-linear formulation which can introduce practical difficulties in conducting a Monte Carlo simulation. It may also be that not all effects can be expressed by closed form solutions, thus requiring advanced numerical analysis and methods.

For the present case, example distributions of iceberg mass and drift velocity are shown in Figure 2 and Figure 3. The distributions are assumed to be uncorrelated. The mass distribution is deduced from a distribution of iceberg length and includes some natural variability in the data, but has not been adjusted for unrealistically small icebergs.

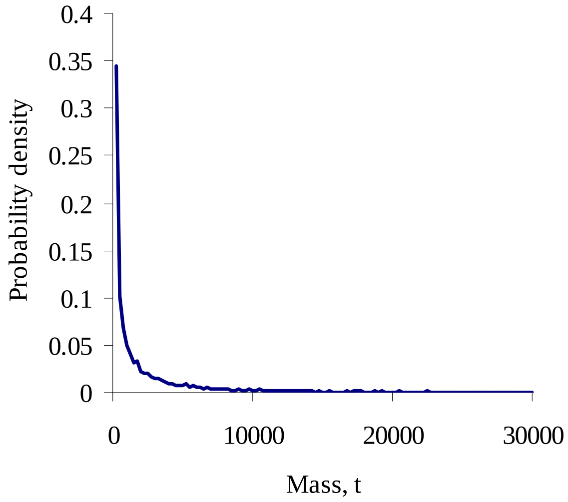

Figure 2: Iceberg mass distribution

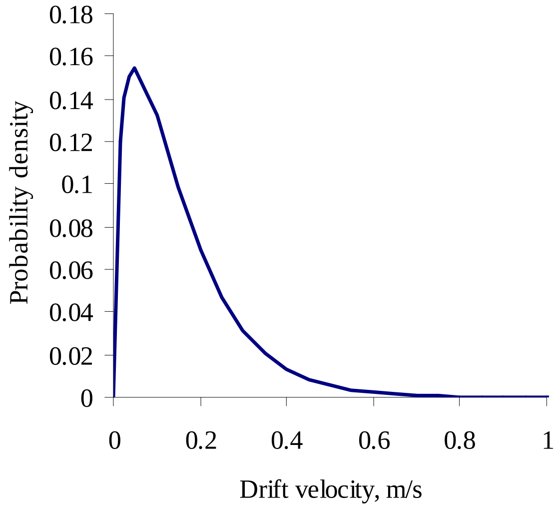

Figure 3: Drift velocity distribution

The values for iceberg mass and drift velocity related to 10^{-2} annual probability of occurrence are approximately 23 000 tonnes and 0.5 m/s, respectively, which yield initial impact energy of 2900 kJ. Using a so called “100-year iceberg” in combination with a nominal value for drift velocity, selected here as 0.15 m/s, gives an initial impact energy of 270 kJ. Clearly it is not correct to use these values in order to find a characteristic value for the initial kinetic energy, but they are included as examples of deterministic calculations.

Since both mass and drift velocity distributions are available, it is possible to run a Monte Carlo simulation (Figure 4 shows the calculated combinations of mass and drift velocity) to find the distribution of the initial kinetic energy (Figure 5). Based on 10^4 samples, the initial kinetic energy with an annual probability of occurrence of 10^{-2} is about 1160 kJ. Actually, the kinetic energy of 2900 kJ found above would roughly correspond to a 1.8×10^{-3} probability of exceedance, even though a larger number of samples should be included in the Monte Carlo simulation for establishing the correct exceedance probability for such large energy values.

For a given sample of the Monte Carlo simulation, it is possible to trace the iceberg mass and drift velocity that gave a specific value of the kinetic energy, and for different samples it would be possible to gather an arbitrary selection of mass and drift velocities that all yield the same probability of occurrence for impact energy. This selection could be used for further analysis to find the actual action and response, however it can not be ensured that all combinations of mass and drift velocity that yield the same annual probability of occurrence of impact energy can be identified this way.

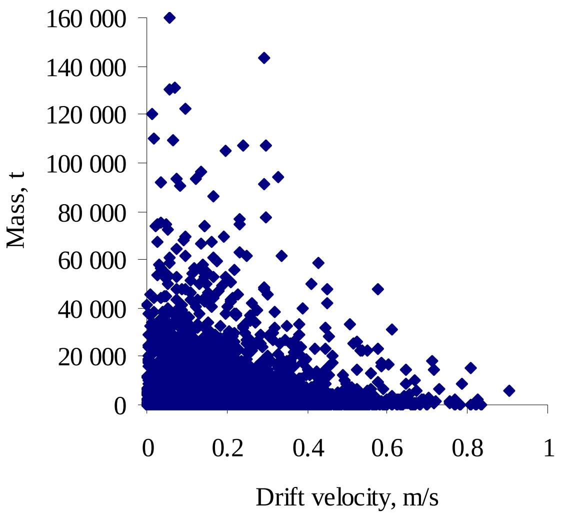

Figure 4: Results from probabilistic model

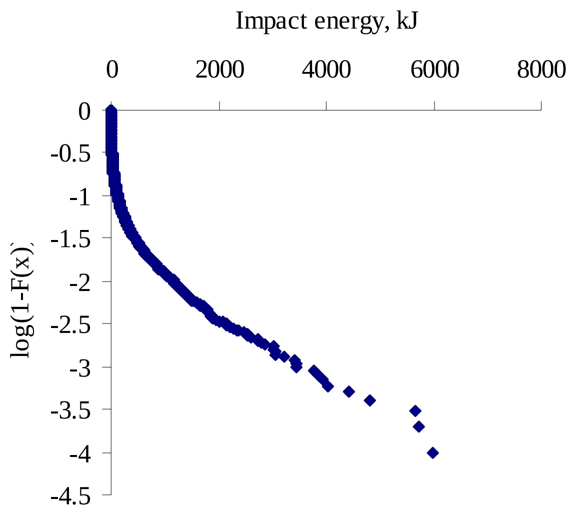

Figure 5: Sorted results of impact energy

In order to explore the joint probability further, distributions of mass (simplified relationship to length was used without natural variability) and drift velocity are used to find the combinations that give the same probability for occurrence. This is possible by establishing a contour, through e.g. inverse FORM (First Order Reliability Method) (DNV, 1992). This requires only well defined input distributions, and only very few calculations are necessary. A contour was established for this example (Figure 6), where each point on a given contour represents a pair of values of iceberg mass and drift velocity associated with a given joint probability. For example, in Figure 6, the probability of observing an interaction event is less than 10^{-4} for any particular pair of values of velocity and mass above the blue stapled line.

The initial impact energy was then calculated for all combinations along the contour and the maximum calculated value was found to be 1080 kJ, which corresponds to 1.1×10^{-2} annual probability of occurrence from the Monte Carlo simulation. The contour approach immediately identifies the offending iceberg resulting in this maximum initial impact energy as having a mass of 17 000 tonnes and a drift velocity of 0.36 m/s. The main advantage of this approach over the Monte Carlo simulation is that the combinations of mass and drift velocity identified along the contour can be subsequently used in more advanced numerical models that cannot be described by closed form expressions, and that these other combinations can be used to determine other maximum response values. Clearly, the ideal situation would be to run a fully probabilistic analysis; however this is not always practically feasible; on the other hand, the contour approach is efficient and sufficiently approximate.

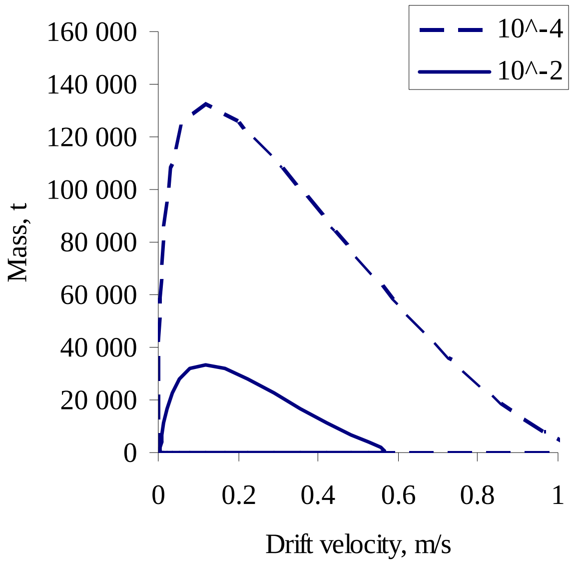

Figure 6: Contour established by inverse FORM for 10^{-2} and 10^{-4} annual joint probability for occurrence

The approach described above is not part of the IceStruct JIP or of the Barents 2020 project, but it represents a general alternative for finding combinations of governing parameters that can be used further to establish characteristic ice actions for floating structures based on a reduced number of simulations. The approach is well known in other fields of application, such as for structures in waves (DNV-RP-C205, 2010), where the maximum response (structural stress, motions etc.) are determined in the H_s (significant wave height) and T_p (peak wave period) space; however the authors have not seen it applied for ice-structure interaction before.

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