MANAGING RISK DNV

SEAMOCS Workshop

Implications of climate change for marine and coastal safety

Implications for marine and coastal safety, winds – waves – sea level – others

Elzbieta Maria Bitner-Gregersen
October 11-12, 2007

Picture taken by the officer on board of the **handymax bulk carrier Selkirk Settler** in the **N. Atlantic, Feb.1987**.

Objectives

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- To discuss **consequences of climate change** on **Classification Societies' Rules** and **Offshore Standards** with attention given to the **risk based approaches** based on the modern reliability methods.

- Focus is given to **met-ocean description** and in particular to **extreme waves**.

- **Some results** developed by **Alessandro Toffoli within SEAMOCS** will be shown.

Environmental Conditions and Environmental Loads

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Picture taken by the officer on board of the **handymax bulk carrier Selkirk Settler** in the **N. Atlantic, Feb.1987**.

Waves

Wind **Current** **Sea Water Level**

Environmental Loads

Input

- **Design** and **operation** of marine structures (**ships**, **offshore and coastal structures**)
- **Risk-based** goal oriented **regulations**
- **Environmental (pollution) risk** analysis, **emergency plan**

Environmental Conditions and Loads

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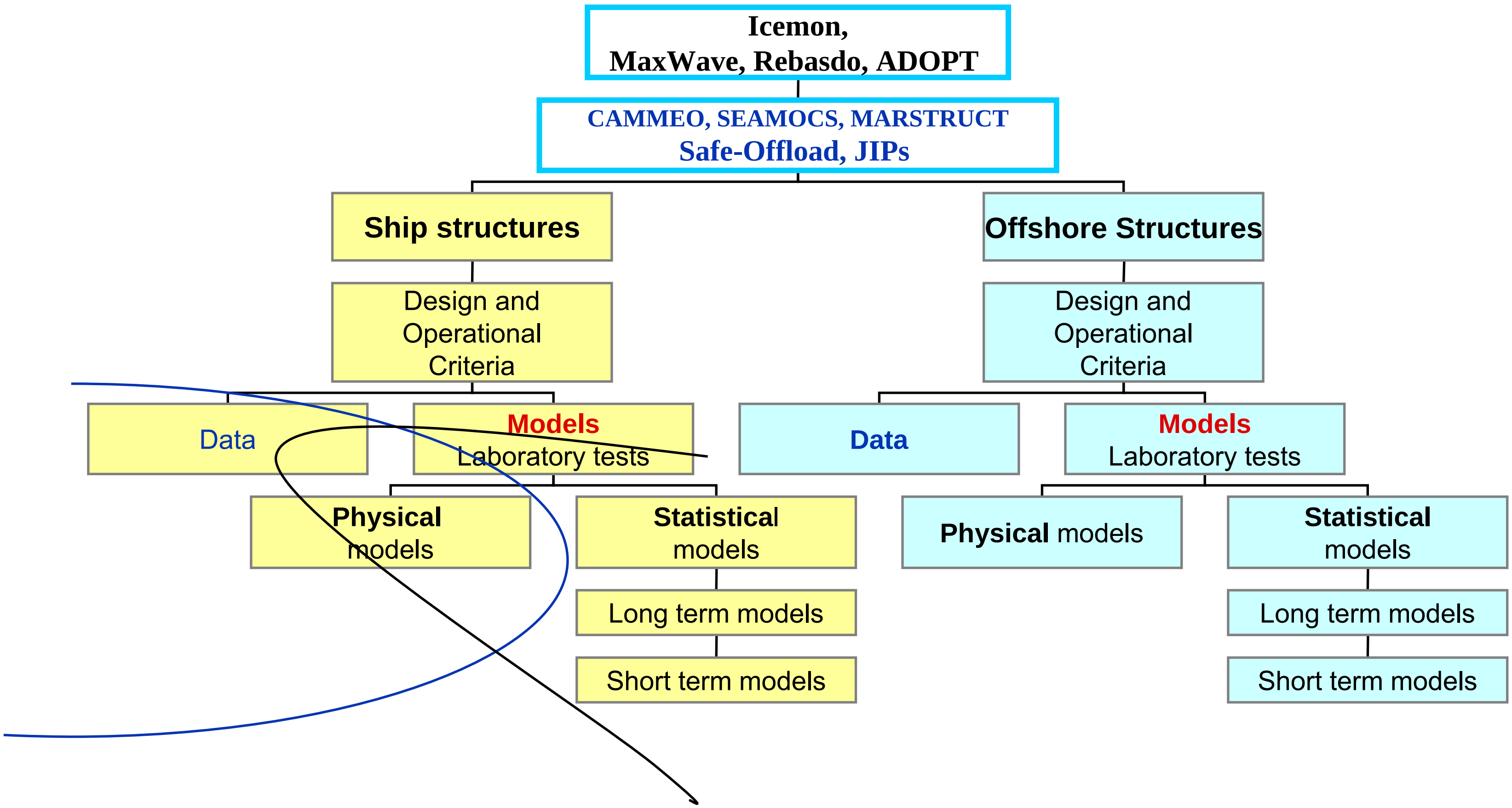

Waves

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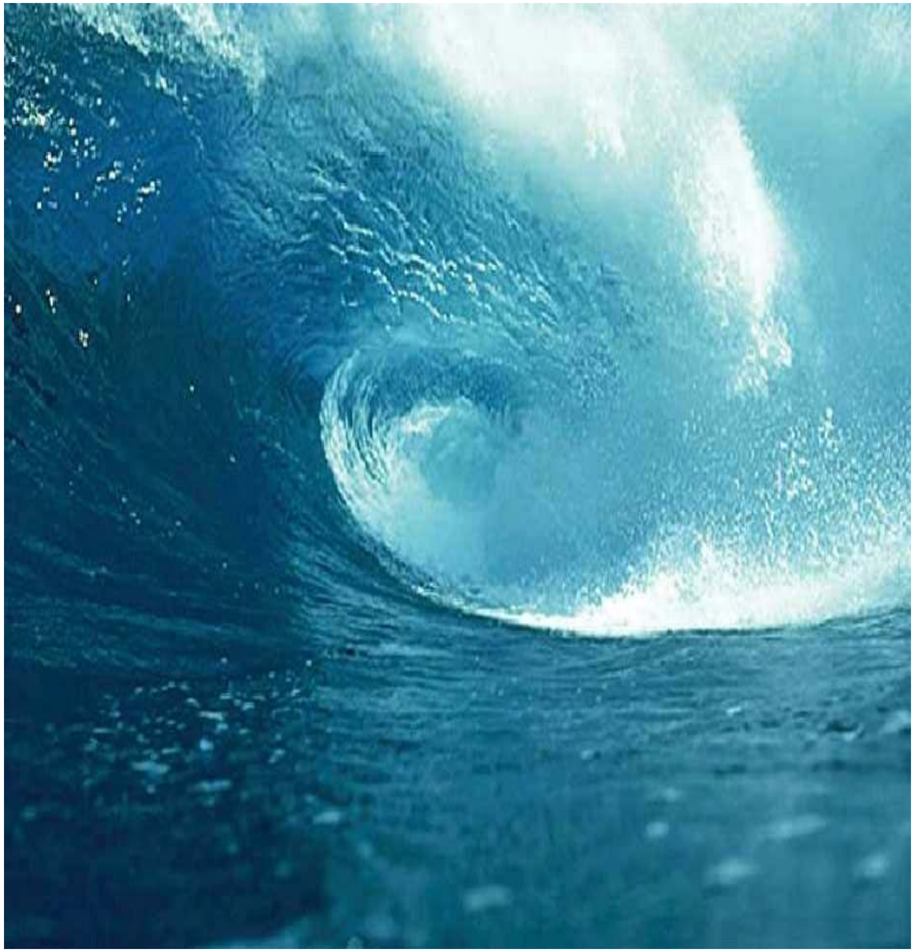

- **New measuring techniques**

  - laser, LASAR, marine radar

  - satellites

- **Directional effects** (wave spectra, long-term description)

- **Higher order wave models** (rogue waves)

- **Climate changes**

  - increased frequency of storms,

  - presence of combined seas (wind sea, swell)

  - rise of sea water level.

- ➔ **non-conservative current design/operational criteria?**

Extreme wave events

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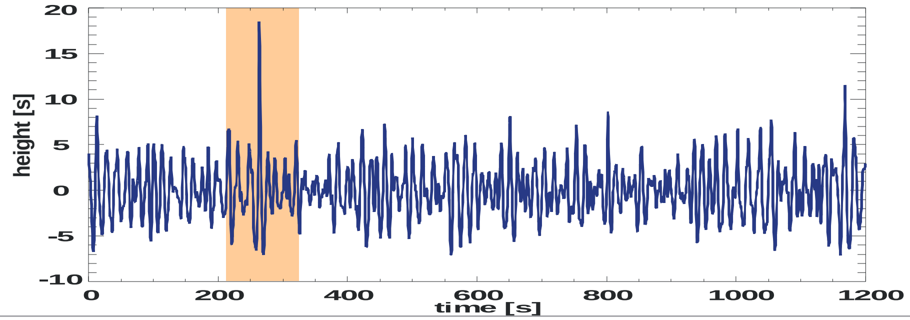
EU research project MaxWave - significant contributions to the understanding of freak waves, **several questions are open:**

- No general consensus about **<u>probability of occurrence</u> of <u>freak waves.</u>**
- Limited knowledge about **physical and statistical models** for prediction of freak events.
- No consensus reach concerning **a definition of a freak event**.
- Limited investigations - **effects of these waves on marine structures.**



Risk and reliability
State-of-the-art

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- The **design practice** has been moving over the last decades towards a more **consistent risk based approach**.
- The risk based approaches are based on the **modern reliability methods** (Madsen et al. (1986))
- The **reliability methods** allow **quantifying** in a probabilistic way the **uncertainties** in different parameters that **govern the structural integrity**.
- **Reliability-based design** of a structural component provides a mean to **satisfy target reliability** with respect to specific modes of failure. Calibration of partial safety factors in the development of LRFD codes, and development of **acceptance criteria for structural designs**, confer DNV CN 30.6 (1992), ISO 2394.
- **1st principle approaches** (state-of-the-art models) – direct calculations

Formal Safety Assessment (FSA)
IMO (1997, 2001)

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1. ***What might go wrong?***	Hazard Identification
2a. ***How often or how likely?***	**Frequencies or probabilities**
2b. ***How bad?***	Consequences
2c.	Risk = **Probability** **x** Consequence
3. ***Can matters be improved?***	Identify risk management options
4. ***What would it cost and how much better would it be?***	**Cost Effectiveness Evaluation**
5. ***What actions are worthwhile to take?***	Recommendation
IMO ***What action to take?***	**Decision**

Annual probabilities as recommended by DNV CN 30.6, DNV (1992).

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Values of acceptable annual probabilities of failure		
Class of failure	*Consequence of failure*	
	Less serious	*Serious*
Redundant	Pf = 10^{-3}	Pf = 10^{-4}
Significant warning before the occurrence of failure in a non-redundant structure	Pf = 10^{-4}	Pf = 10^{-5}
No warning before the occurrence of failure in a non-redundant structure	Pf = 10^{-5}	Pf = 10^{-6}

Structure Reliability Analysis (SRA)
Limit State

- Limit state function

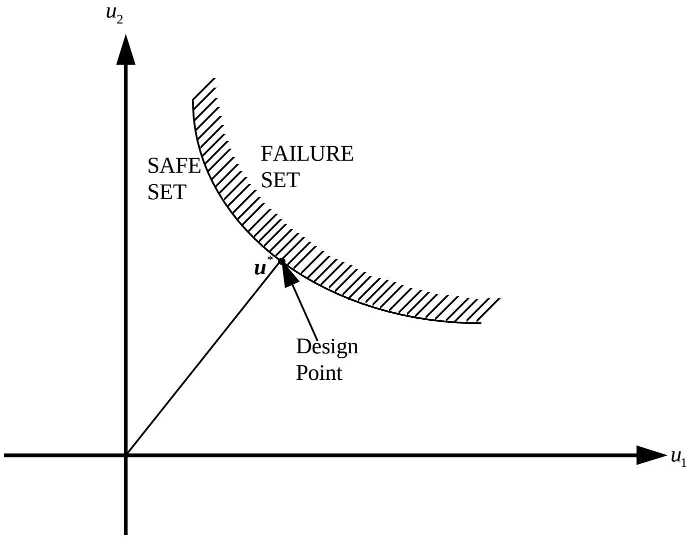
$$g = g(X_1, X_2, \dots, X_N)$$

- Probability of failure

$$P_F = P(g(X_1, X_2, \dots X_N) \le 0)$$

- Corresponding reliability index β

$$\beta = -\Phi^{-1}(P_F)$$



Uncertainty measures

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The **reliability analysis** provides two **uncertainty measures**:

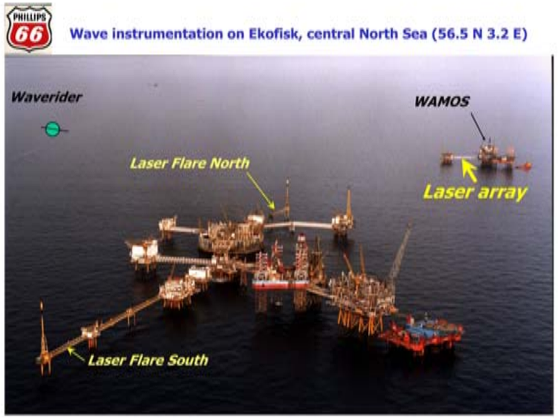
- **The Parametric Sensitivity Factors**
- **The Importance Factors**

Uncertainties that need to be addressed relate to:

environmental data and models, input data, models and procedures describing a structure system as well as loads and responses.

Uncertainties

Suggested by **Bitner-Gregersen and Hagen** in the **90-ties** (J. Marine Safety)



- **Aleatory (natural) uncertainty**

- **Epistemic (knowledge) uncertainty.**
  - Data uncertainty
  - Statistical uncertainty (sampling variability, fitting procedure)
  - Model uncertainty (adopted model to fit the data)
  - Climatic variations (different time periods which the data sources cover as well as different locations they represent).

The ***true value τ*** of a quantity considered is an ideal number which can be known only if all sources of error are eliminated.

The accuracy of a quantity characterises the extent to which a measured quantity agrees with the *true value τ*. Accuracy: **systematic error (bias**) and **precision (random error)**.

Risk and reliability state-of-the-art

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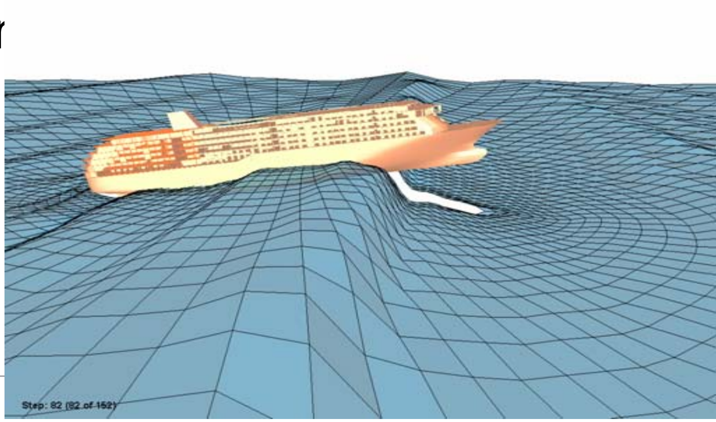
Limit state categories and **scenarios** need to be defined. In the offshore industry the following well proven terminology is applied:

- **Ultimate Limit State (ULS):** corresponding to the maximum load carrying resistance.
- **Fatigue Limit State (FLS):** corresponding to the possibility of failure due to the effect of cyclic loading.
- **Serviceability Limit State (SLS):** corresponding to the criteria applicable to normal use or durability.
- **Accidental Limit State (ALS):** corresponding to the ability of the structure to resist accidental loads and to mai performance due to local damage or flooding.



All will be affected by extreme (freak) waves

Design practice - offshore

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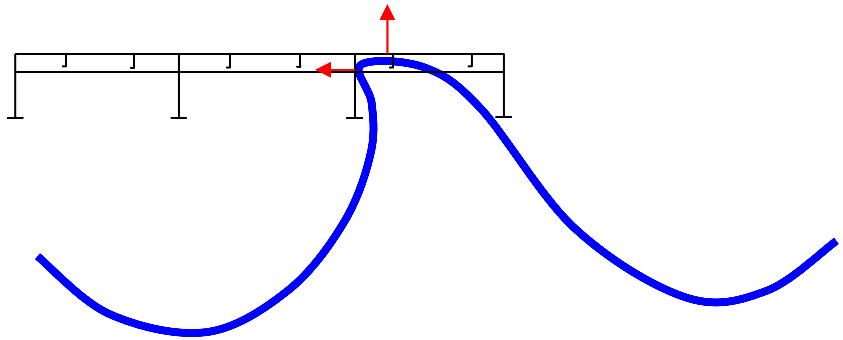
Offshore structures are designed for:

- **ULS** - a **specific location** and the **100-year wave load** with appropriate safety factors in LRFD. Alternatively in **reliability based design** a **target annual failure probability** is defined dependent on safety class.

- **ALS** - **Norwegian standards** require a sufficient air gap to ensure that **a 10 000-year wave does** not endanger **the structure integrity**, see **NORSOK Standard (1999).** Thus **exceptionally rare wave events** are taken into account in ALS.

MARIN



Design practice - ship structures

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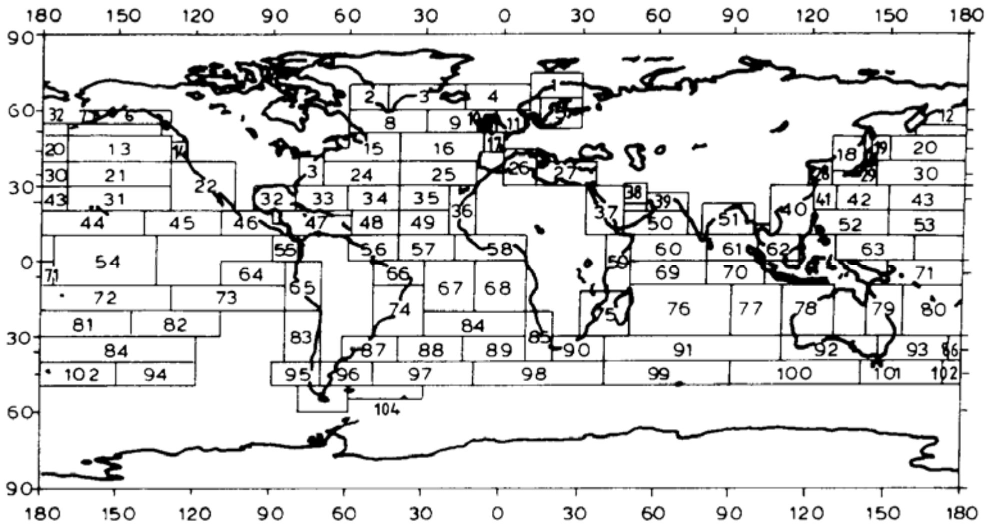
- **ULS** - 20**-year return period**

Global Wave Statistics (GWS) **visual observations of Hs and Tz**, Hogben et.al. (1986) collected since 1949.



Area 8, 9, 15 and 16

- **ALS** – fire, explosion, collision

Why rogue waves?

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- **ULS -100** year return period
- **ALS -10 000** year return period (only Norwegian Standards, NORSOK (1999), DNV)

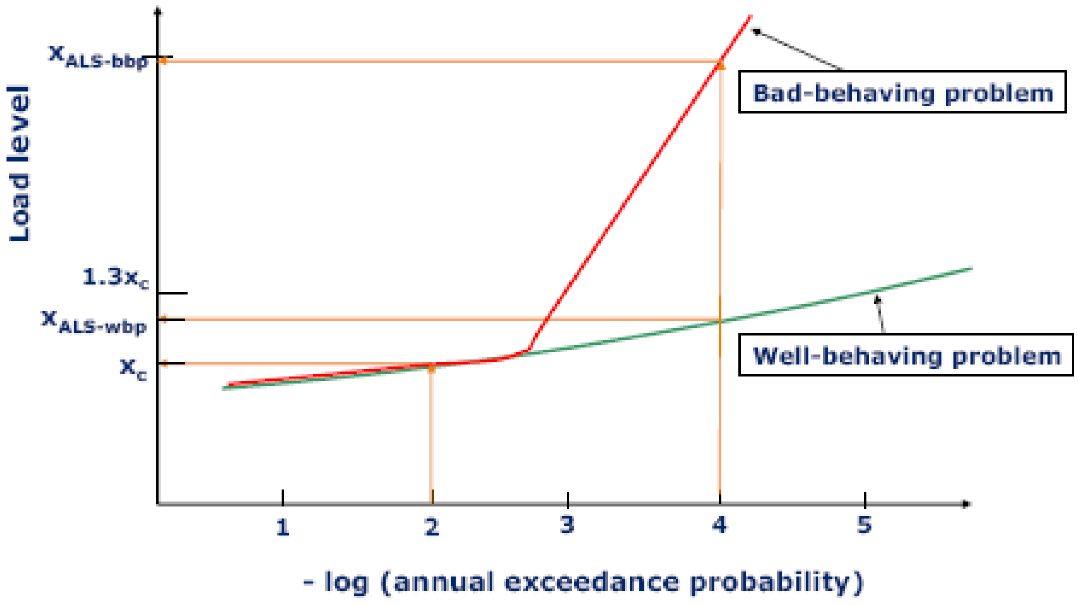

Illustration of ULS control for two types of load mechanics, figure taken from Haver (2004).

Rogue waves – DNV activities

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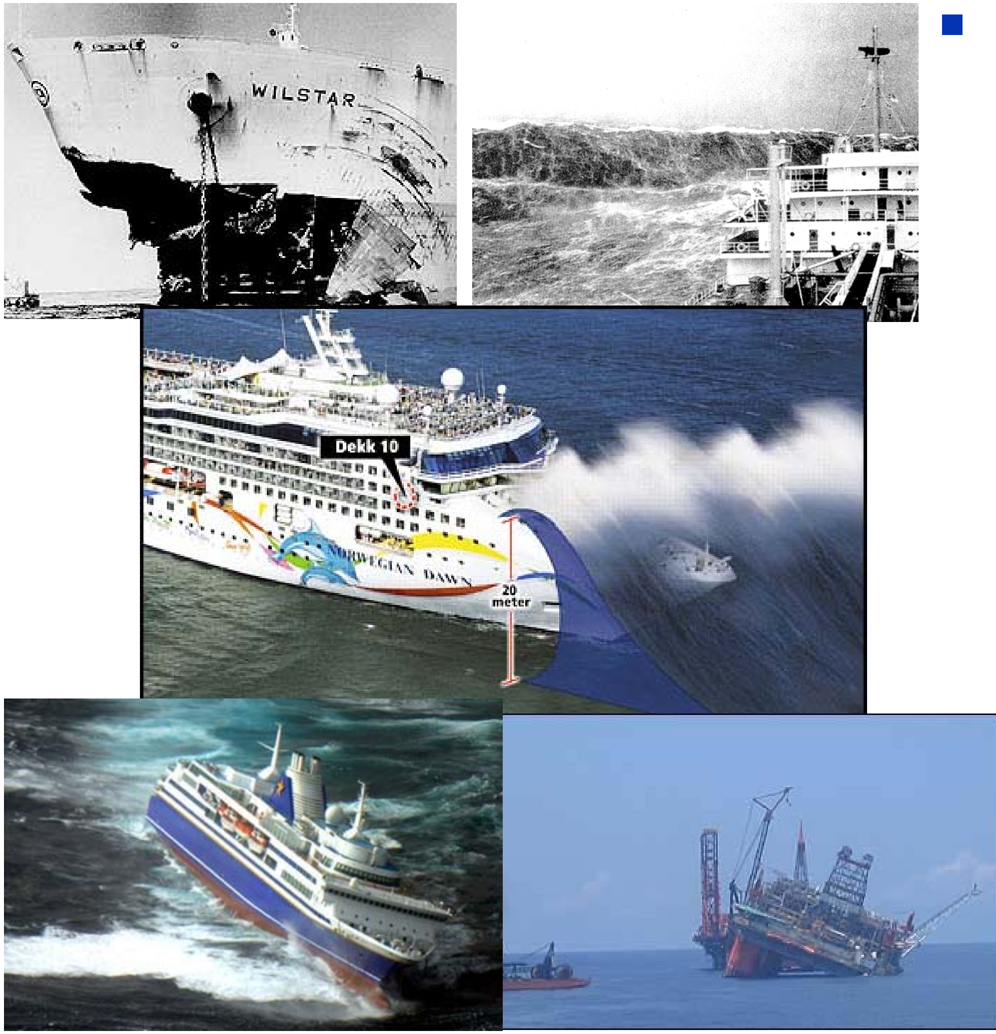
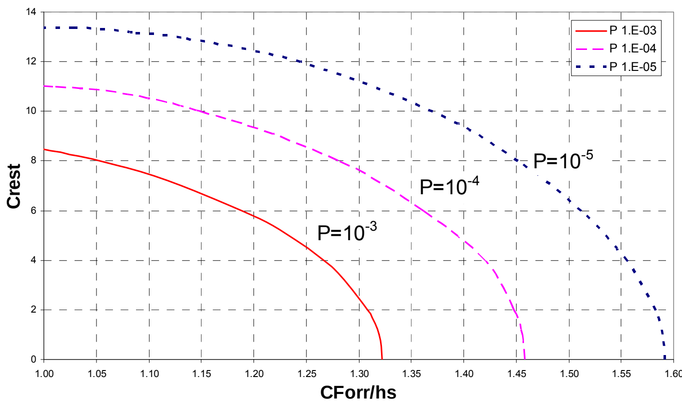
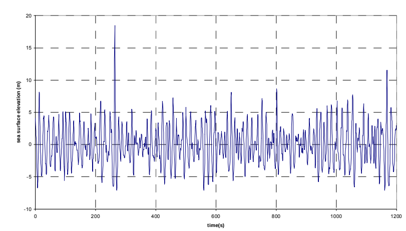


- **2nd order wave model**, e.g. Birknes and Bitner-Gregersen (2003)



Bitner-Gregersen and Hagen (2004)



Draupner platform

semi-submersible platform Thunder Horse (Hurricane Dennis)

Projects: EU MAXWAVE, Network SEAMOCS

An extreme wave not necessarily a dangerous wave

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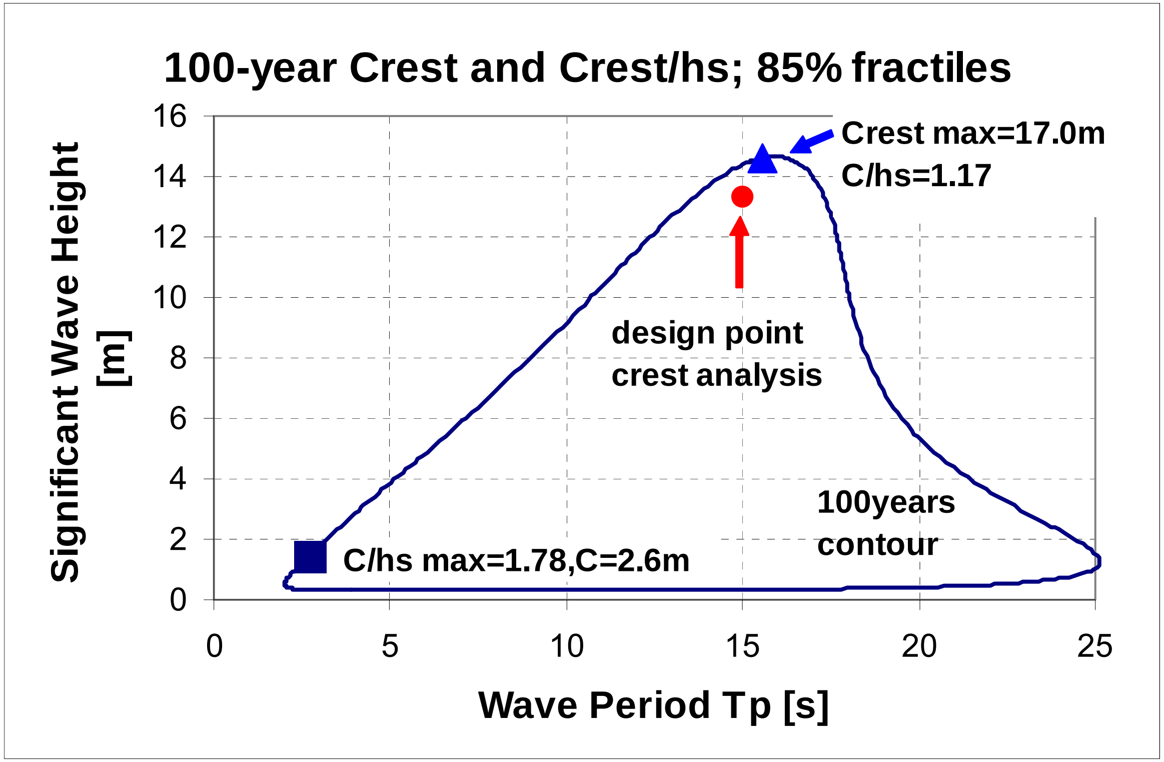
- **Environmental contour line** for the Northern North Sea at the **100-year** return period level, Bitner-Gregersen and Hagen (2004).



Rogue waves – DNV activities
field data

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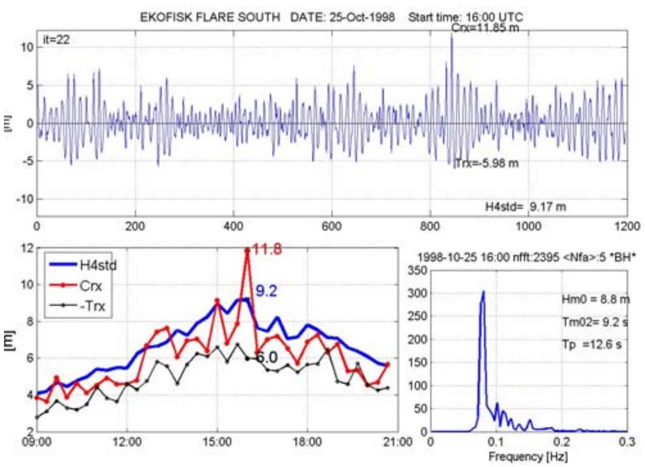
Design values of extreme wave conditions

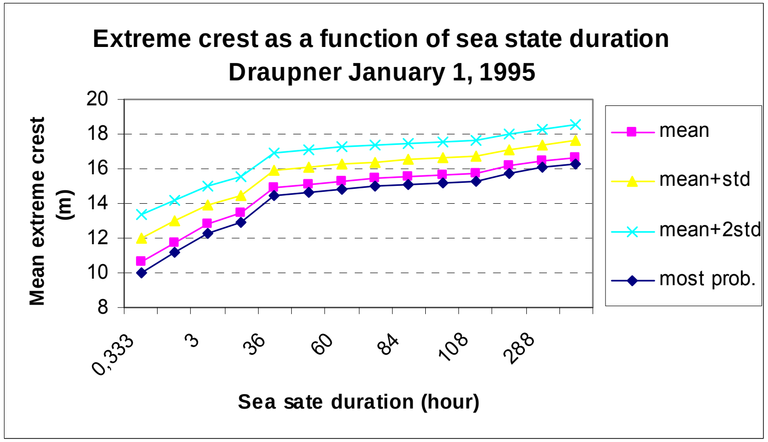
- **long-term** analysis
- **n-year extreme sea state** condition (storm condition).

Storm history



Bitner-Gregersen & Magnusson (2004)

Sea state duration



Bitner-Gregersen (2003)

DNV activities
combined seas, directional effects

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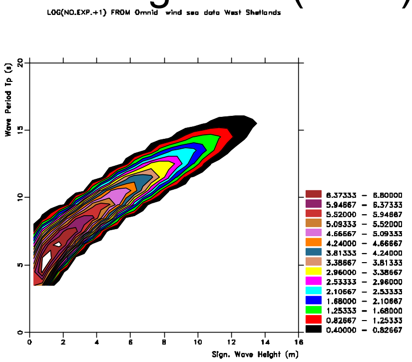
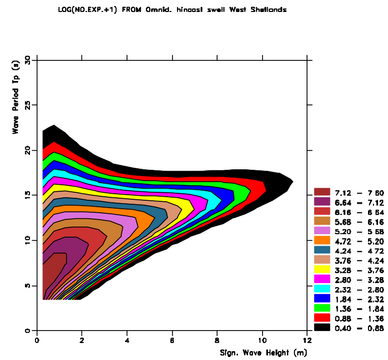
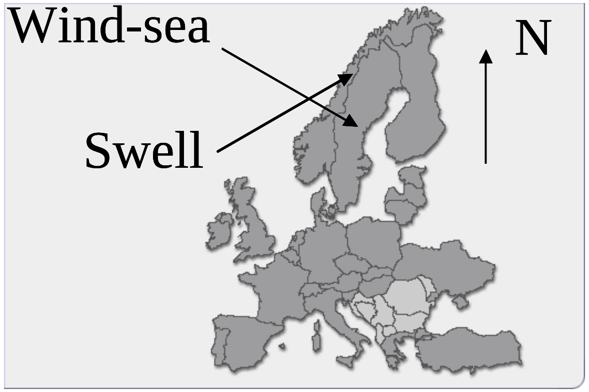
- **Energy** spreading for **swell (**Bitner-Gregersen and Hagen (2002)) **.**
- **Modelling** of **w**ind **s**ea and **swell** (Bitner-Gregersen (2005))

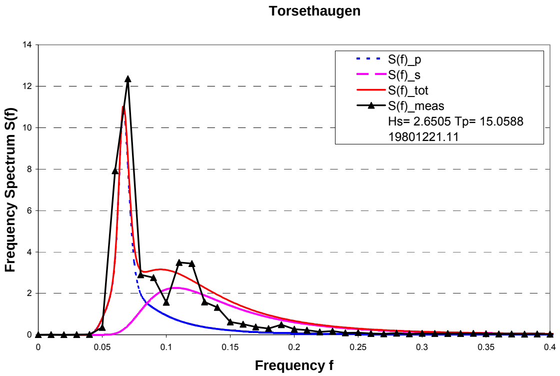


wind sea



swell





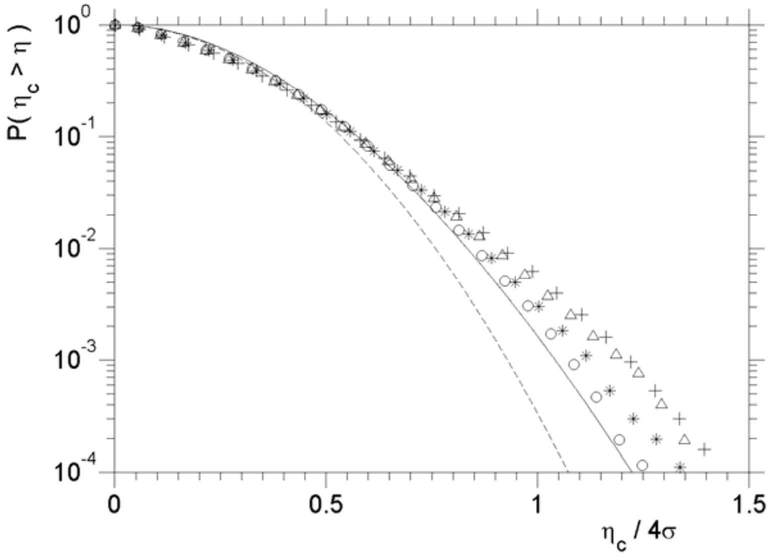
- **Consensus** has **not been reached** within the **industry** concerning **directional-band criteria**
- **EU projects: REBASDO and SafeOffload**

Higher order solutions
Study developed by A. Toffoli at DNV

- “**Surface gravity waves from direct numerical simulations of the Euler equations: a comparison with second–order theory**” **A. Toffoli,** M. Onorato, E. Bitner–Gregeresen, A. R. Osborne and A.V. Babanin (2007) *(submitted to Ocean Engineering*)

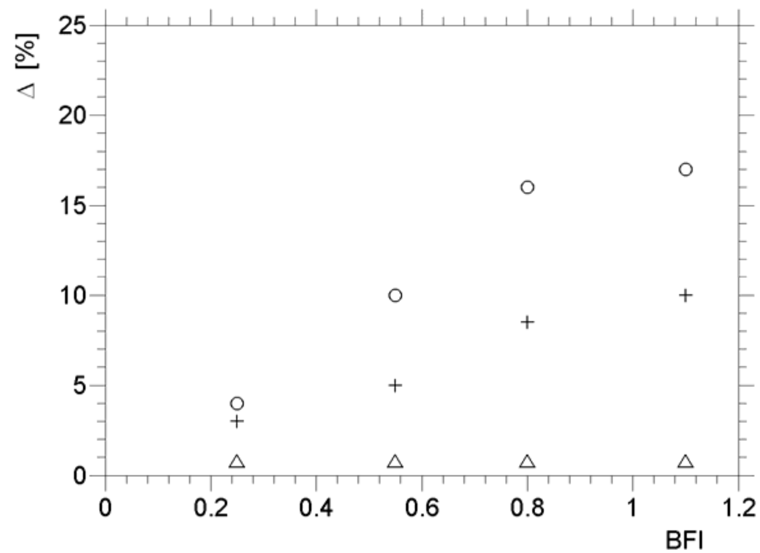
Crest distribution from direct numerical simulations (HOSM) of the Euler equations, unidirectional case;

BFI =0.25 (o); BFI=0.55 (*); BFI=0.80 (Δ); BFI=1.10 (+)



Relative difference Δ between wave crests simul. with HOSM and 2nd order model at

prob. level 0.1 (Δ); 0.01 (+); 0.001(o)



Implications for marine and coastal safety

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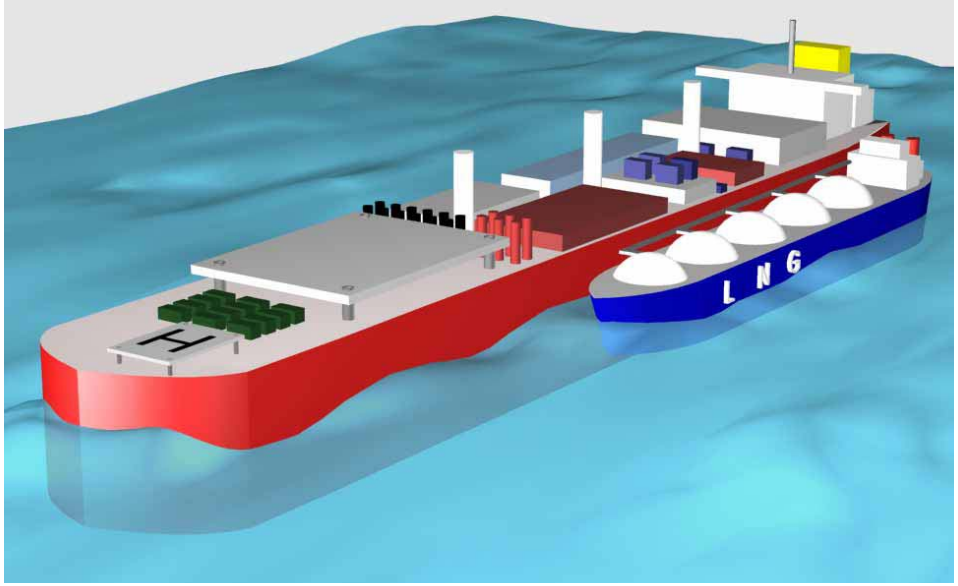
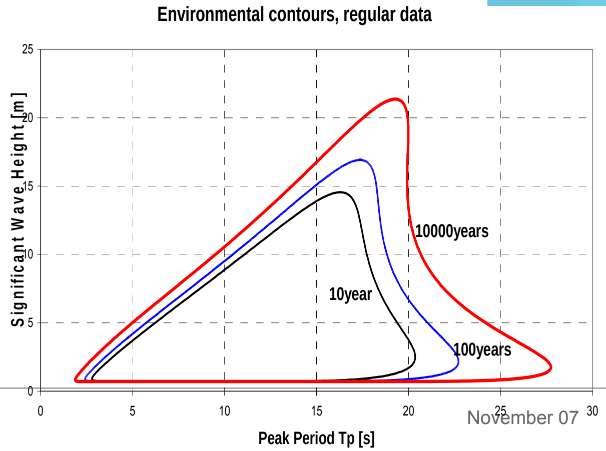
Operational criteria

- directional effects (spreading, combined seas)
- rogue waves
- wind
- sea water level
- current





EU Safe Offload project

Remaining research challenges

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- **Consistent wave description** accounting for extreme waves and abnormal wave conditions for use in risk and reliability analysis. **Higher order solutions**.
- Consensus about **probability of occurrence** of abnormal wave events and a definition of a rogue event.
- **Clarity** with respect to what is considered during the design phase, which **limit states** and **scenarios** should be included in design for extreme wave events and abnormal wave conditions.
- To provide **consistent approaches** for load and **response description** for the identified limit states and scenarios.
- **Demonstration effects** of **extreme waves** on marine structures.

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