Two Examples of Reliability Updating Based on Monitoring of Structural Response Parameters

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Objective

- Address short- and long-term effects of measurements/monitoring of structural response

- Illustrate effects of monitoring/measurements for a few examples
  - Riser angles at flex-joint
  - Ship in arctic areas

- Measurements in relation to condition monitoring and prediction

Rise Monitoring-Background

- Original design parameters no longer valid
  - Larger BOPs
  - Larger vessels in harsher weather
- More BOP days
  - Increased utilization of each well
- Increased attention to wellhead fatigue as phenomenon over the past few years

Introduction

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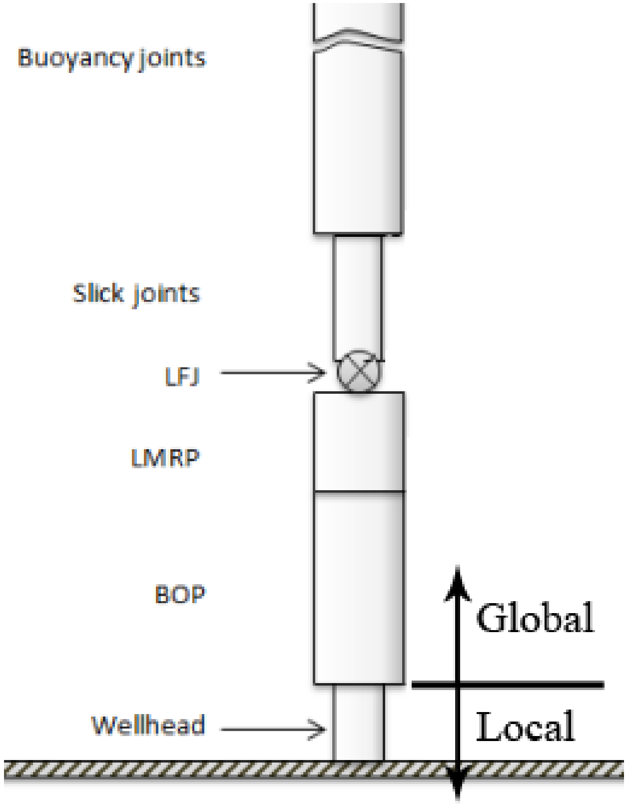
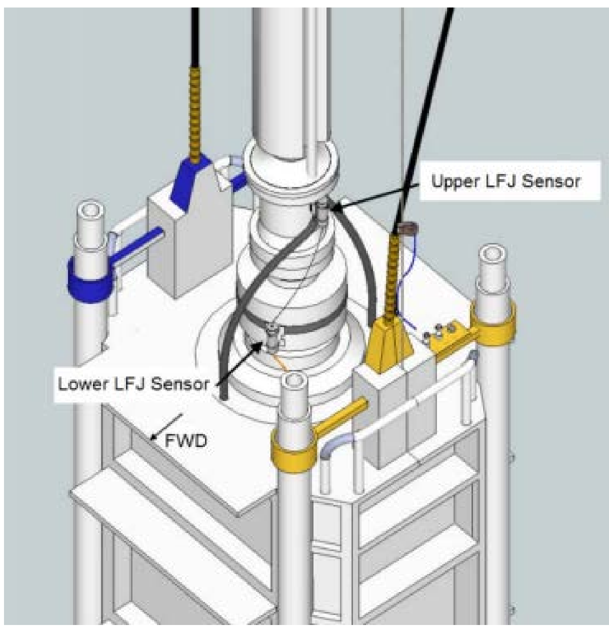
- Modelling methodology vs full-scale measurements
  - Represent physical structure in a best possible way
  - External loading
  - Vessel motion

- Recommended practice
  - Sub-divide marine riser and wellhead
    - Global model of marine riser
    - Local model of wellhead and soil interactions

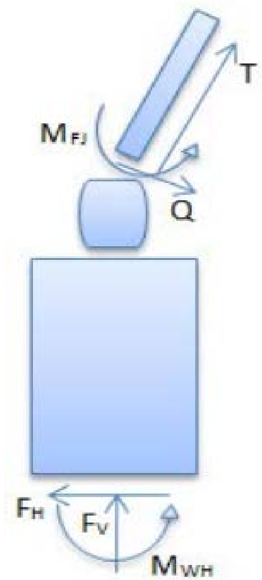


Full-scale setup

- Aker H-3 rig at 325 meter water depth in the North Sea
- Angle of marine riser above Lower Flex Joint (LFJ)
  - Inertial Measurement Units (IMU) to measure angles
  - Loads on wellhead derived from the angle.



Overview over IMU location at the Lower Marine Riser Package (LMRP)

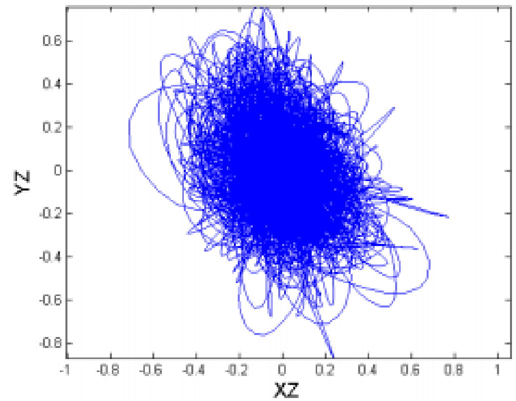


Simplified model of forces acting on the wellhead datum

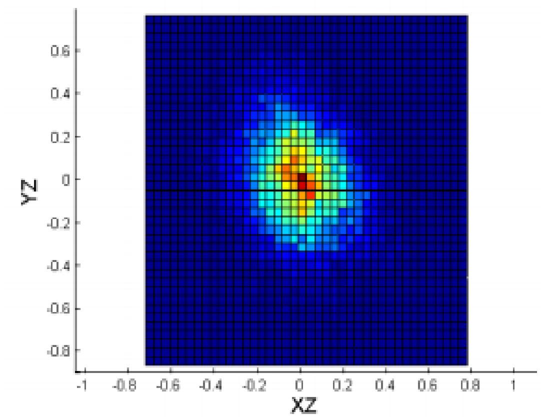
Long-crested waves?

- Random by nature
  - Significant wave height
  - Mean wave period
  - Wave spreading
  - Mean wave direction

- Bivariate Gaussian distribution
  - Projecting planes
    - Standard deviation
    - Cycle counting



(a)



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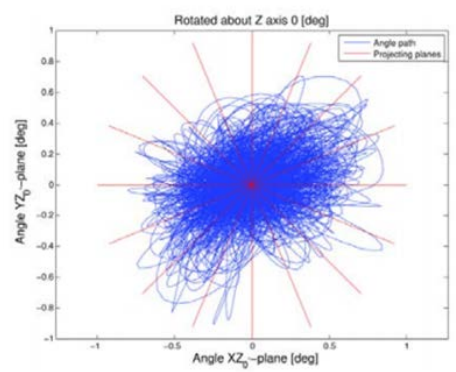

Marine riser model

- Modelled in RIFLEX (from Marintek)
  - Unidirectional JONSWAP waves
  - Unidirectional Torsethaugen waves
  - Investigation of wave spreading effect on riser response
  - Linear vs non-linear flex joint characteristics on riser response

- Riser angle above LFJ
  - Near boundary, i.e. highly dependent on boundary conditions

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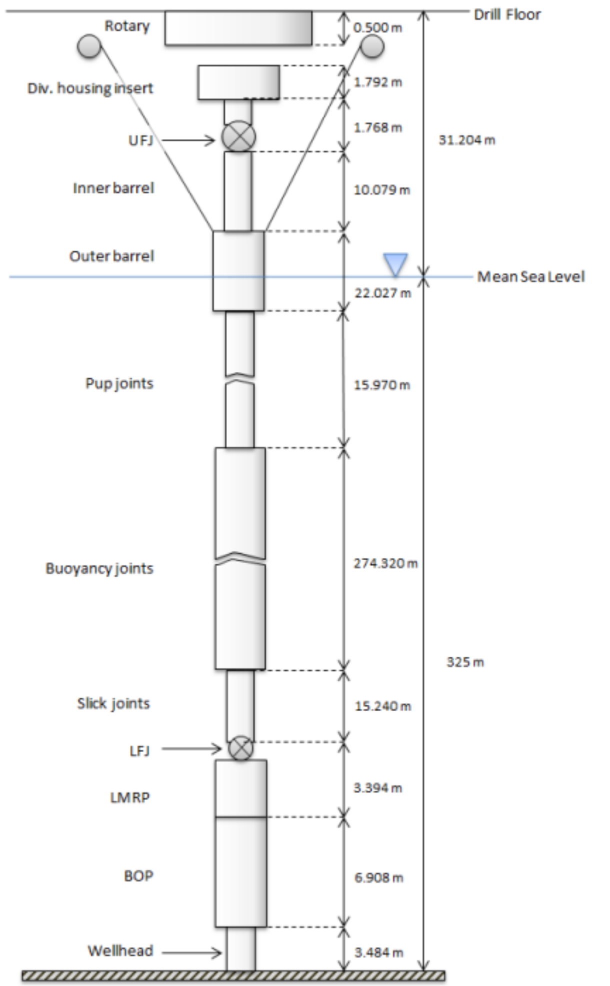

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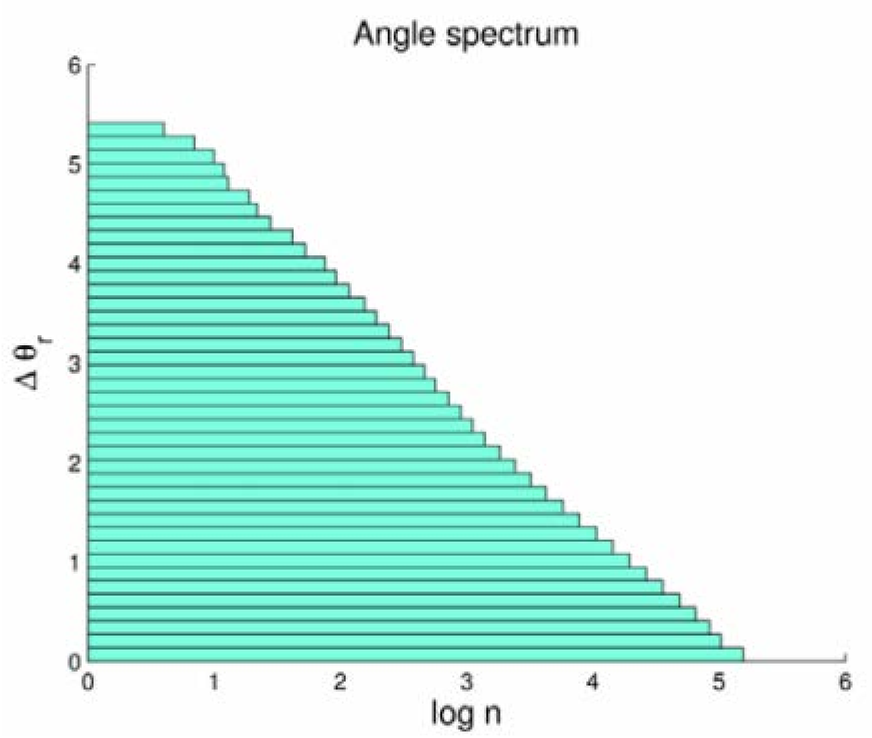
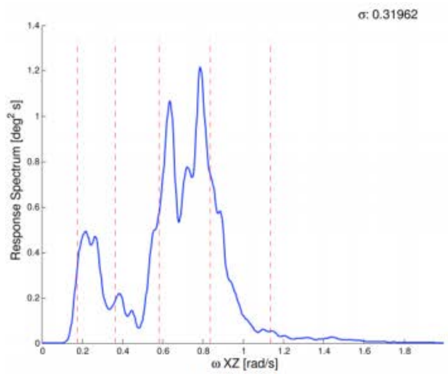
Full-scale – Long-term angle distribution

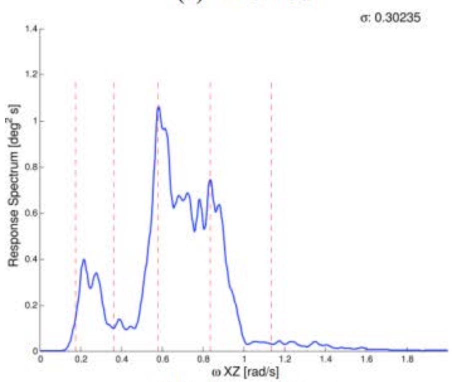
- Angle distribution
  - Cycle counting
  - 248 hours distributed over 2 months
- Shape typical for offshore loading situation
  - Weibull fit possible



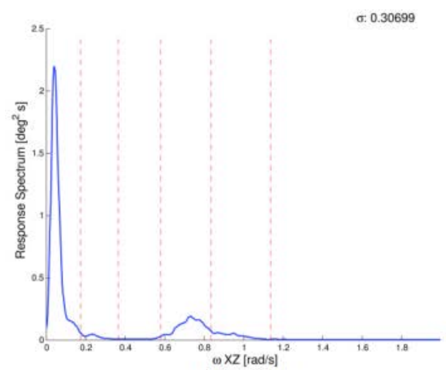
Full-scale – Spectral densities



(a) First hour

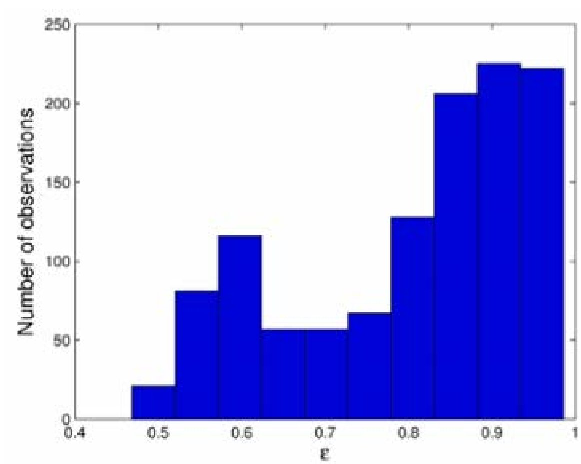


(b) Second hour



(c) Third hour

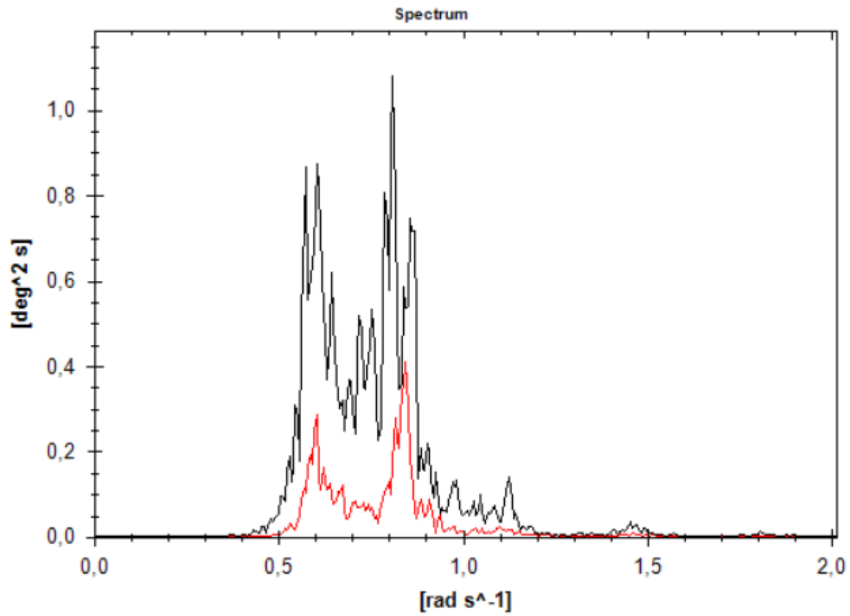
- 3 consecutive hours
  - Same variance – different shape
- Wave frequencies
  - Clearly visible first 2 hours
- Low frequencies
  - Last hour low frequency dominated
  - Periods ~1-2 minutes

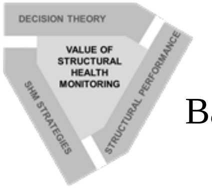


Empirical bandwidth parameter distribution

Model – Response spectrum

- No low frequency response
- Two peaks in response spectral density (for Torsethaugen spectral model)
- Slow-drift motion not included in analyses

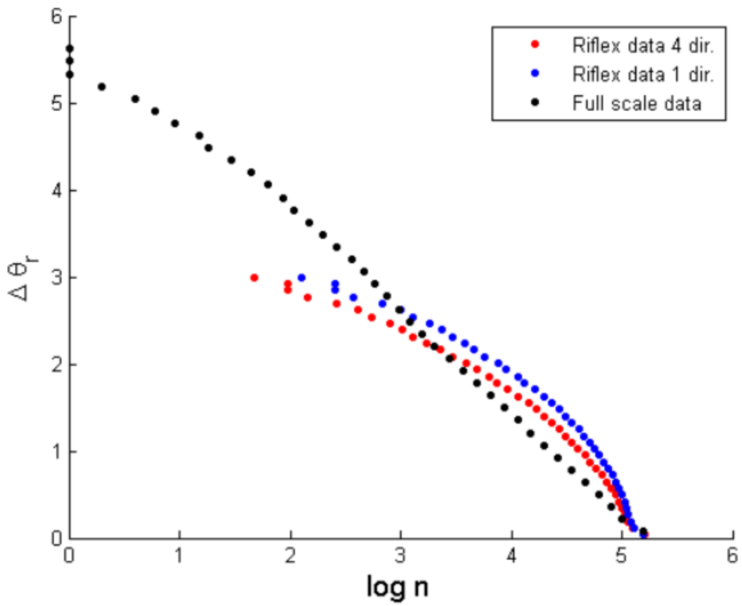


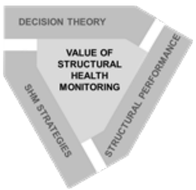


Comparing long-term angle distributions

- Weather from 1 direction vs 4 directions
  - Weighted accoring to hindcast data

- Differences between full-scale and simulations





Comparison – Standard deviation

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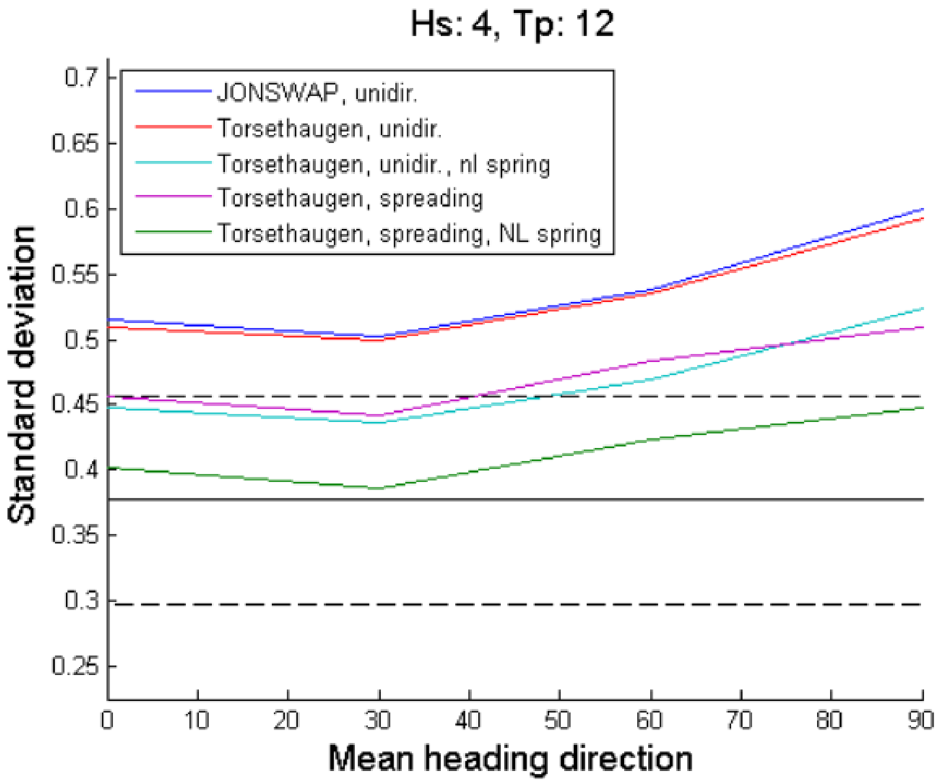
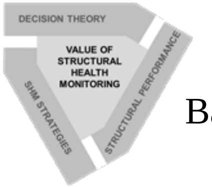
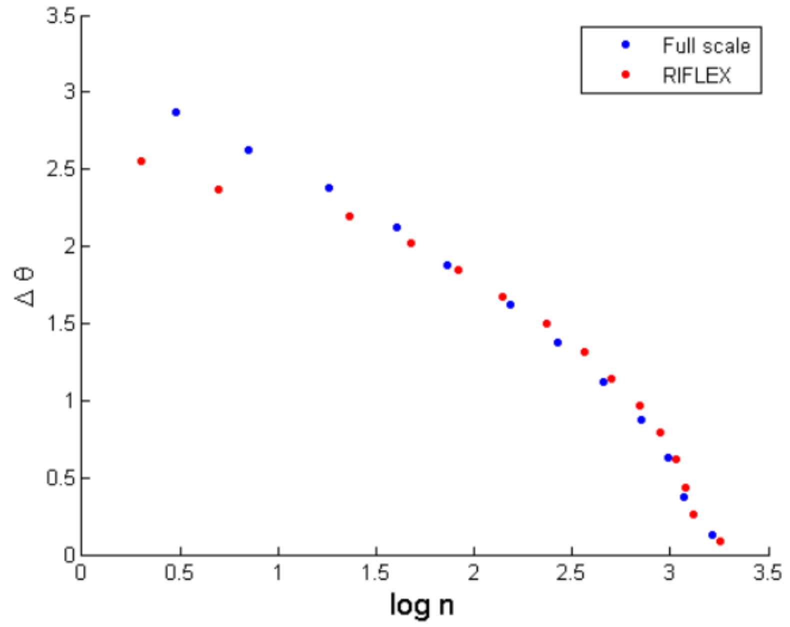
- Full-scale
  - Horizontal solid line: Mean of all standard deviations
  - Dashed lines: 2 x standard deviation confidence interval





Comparing short-term angle distributions

- Full-scale
  - Selected from measurements with very little low-frequency energy
- Riflex
  - Used same sea state based on hindcast data



Conclusions, riser monitoring

- Comparison made of standard deviation and cycle distribution for angular response

- Including more realistic conditions narrows the gap to the full-scale measurements
  - Wave spreading
  - Weather direction
  - Material properties (non-linear flex joint)

- Angle distributions still not directly comparable
  - Both max angle range and shape are different
  - Low frequency motion should be adressed

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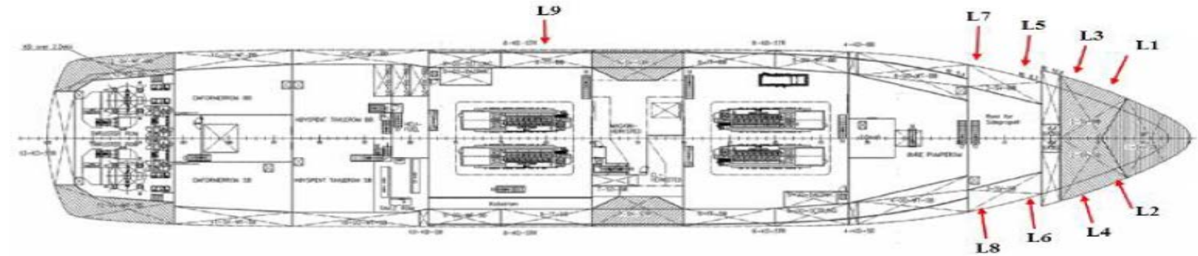
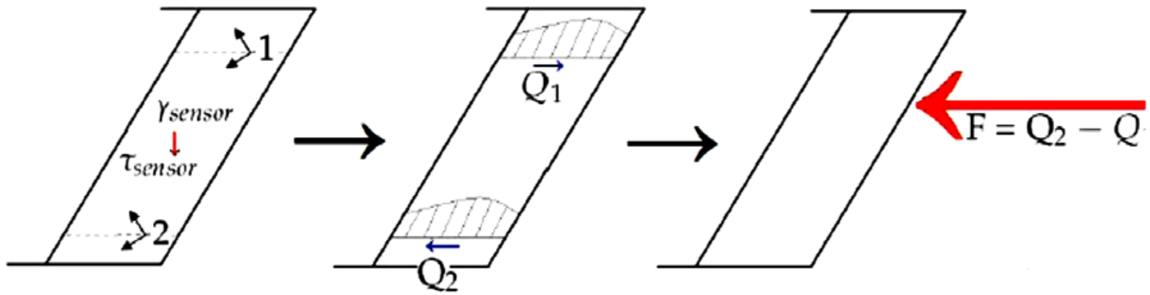
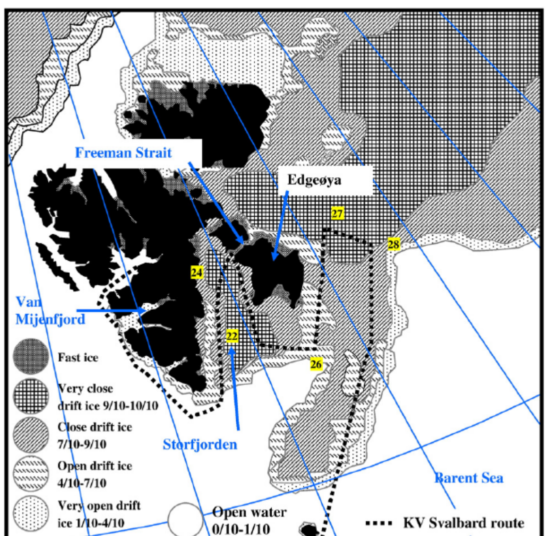
Ice-induced forces: Data from KV Svalbard 2007 expedition.



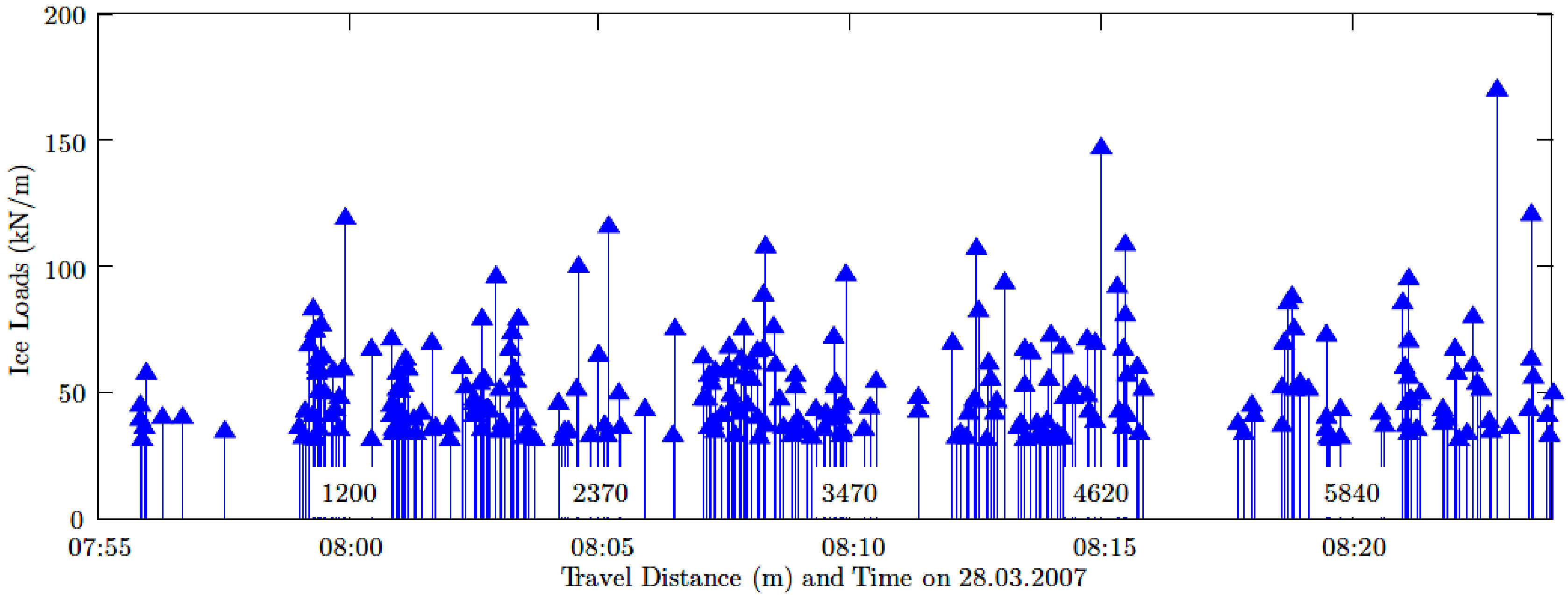


(a) (b) (c)



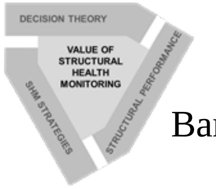
- The shear strain measured is converted into shear stress.
- The total shear force Q on the frame obtained by integration.
- The ice force F computed from the difference between the shear forces at the upper and lower part of the frame Q2-Q1.

Initial/parent distribution of the ice load peak process.

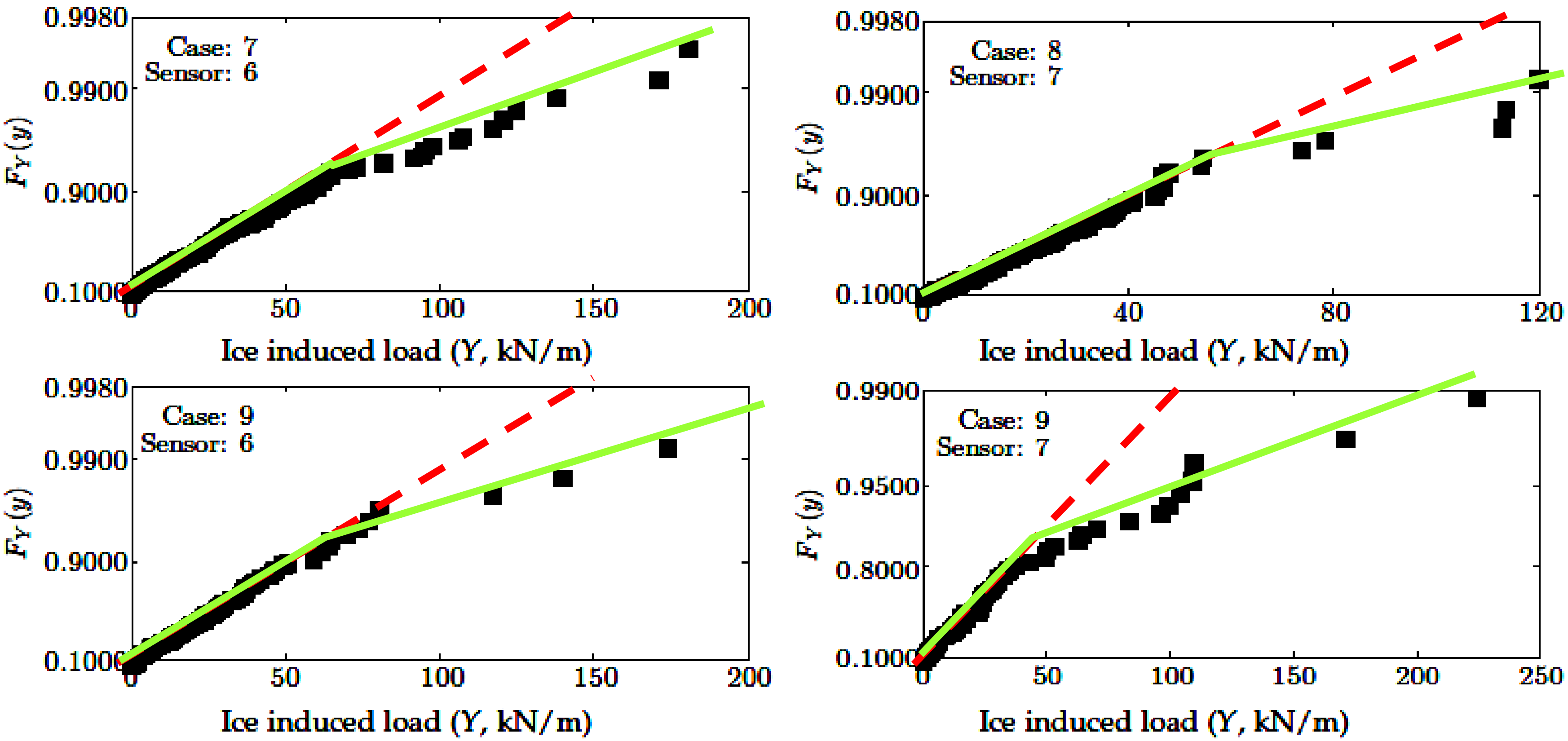


What is the statistical model for this process?

Statistical inference



A single or a compound population?

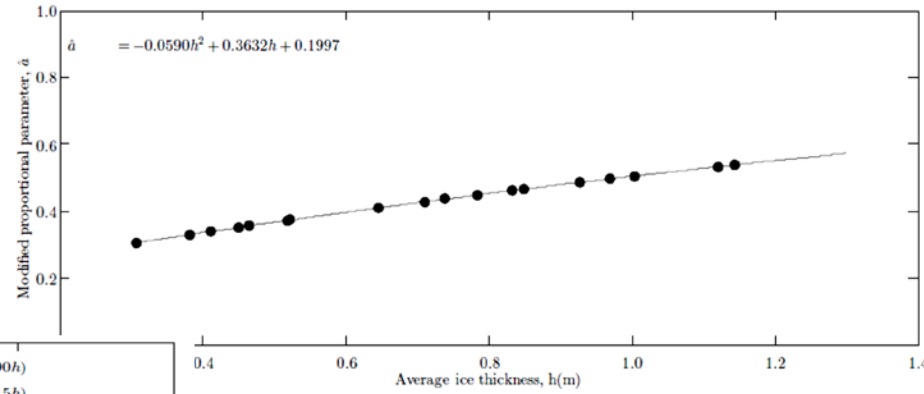


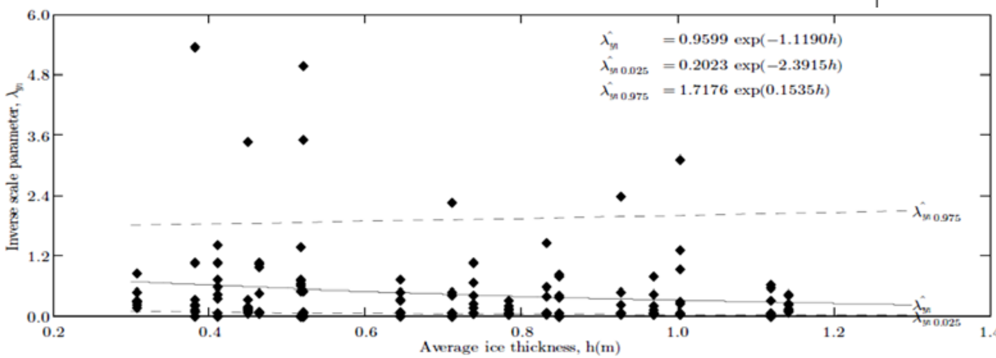
A ***generalized model is proposed***: a proportional combination of two one-parameter exponential models.

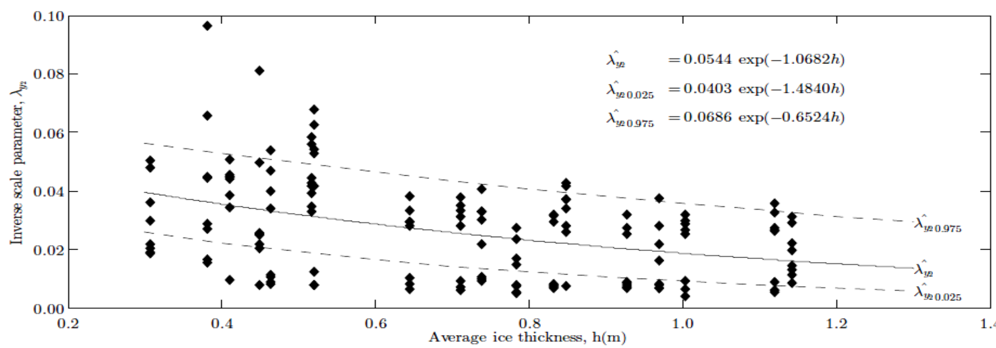
Conditional distribution for a given stationary condition

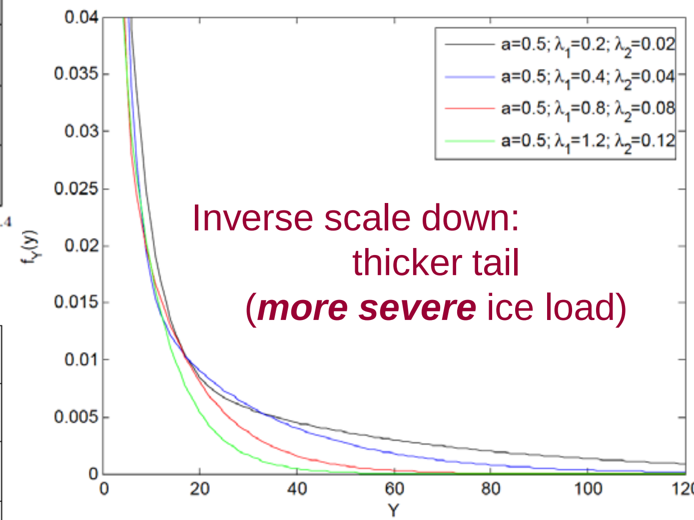
3-EXP

$$F_{Y|H_i}(y|h) = a(h)\left\{1 - \exp(-\lambda_{y_1}(h)\, y)\right\} + (1 - a(h))\left\{1 - \exp(-\lambda_{y_2}(h)\, y)\right\}$$









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How do we predict the short term extreme values?

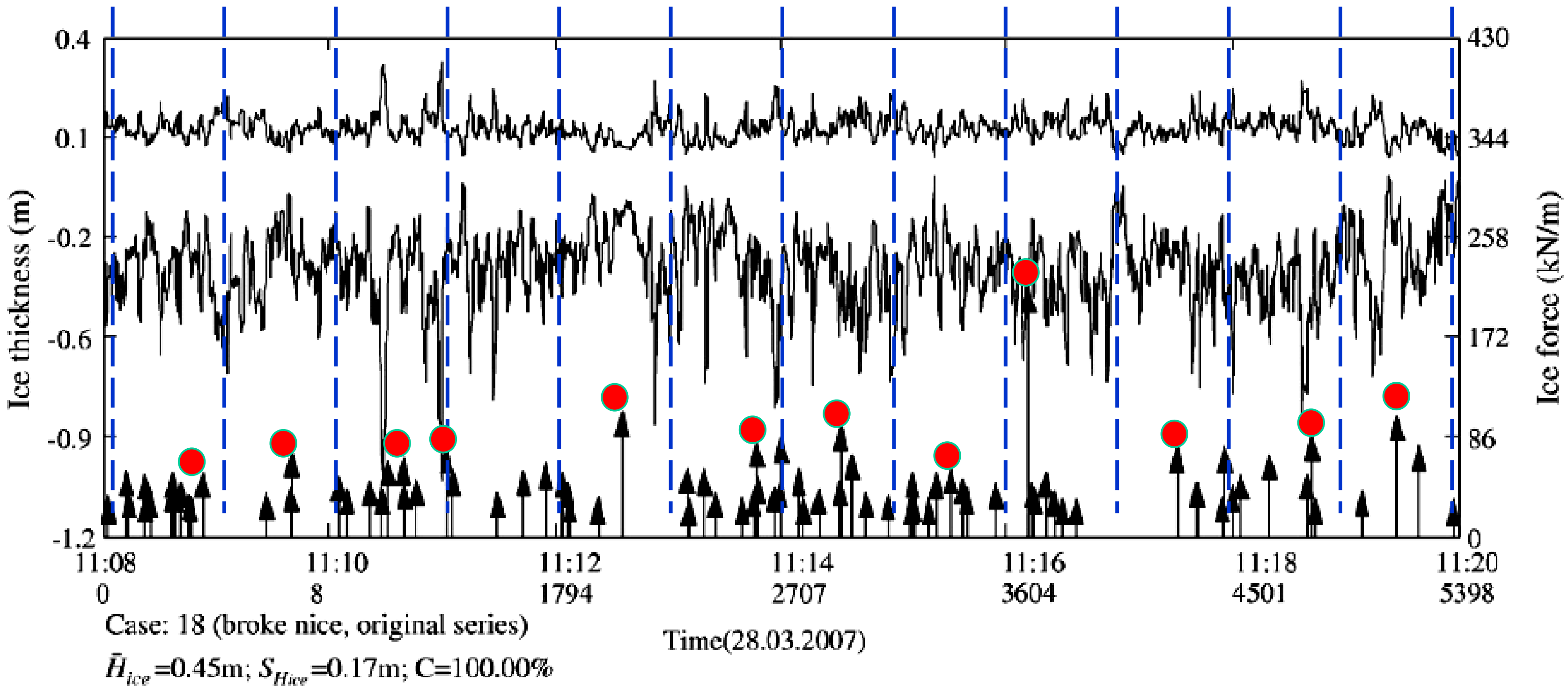
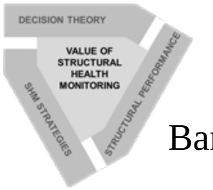


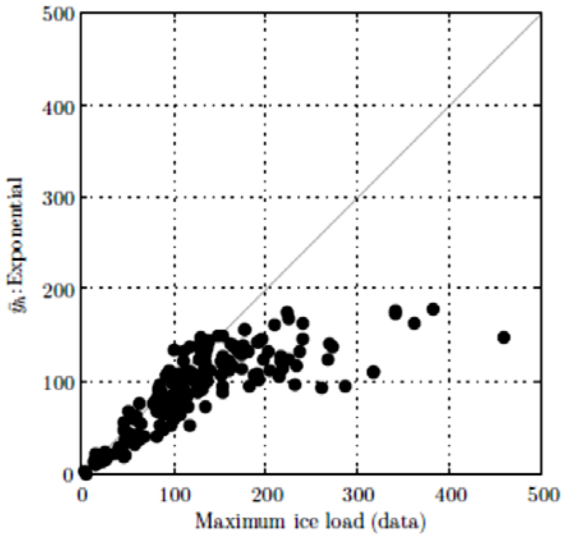
Fig. 9. Ice induced loads represented as stem plots and ice profile for the selected time interval.

Procedure:

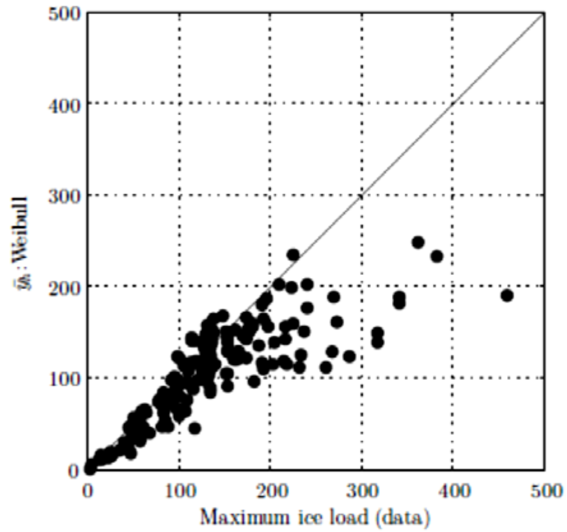
- The time history is divided into one minute intervals.
- The maxima in each interval are identified.
- Apply statistical inference → Type I extremal distribution.



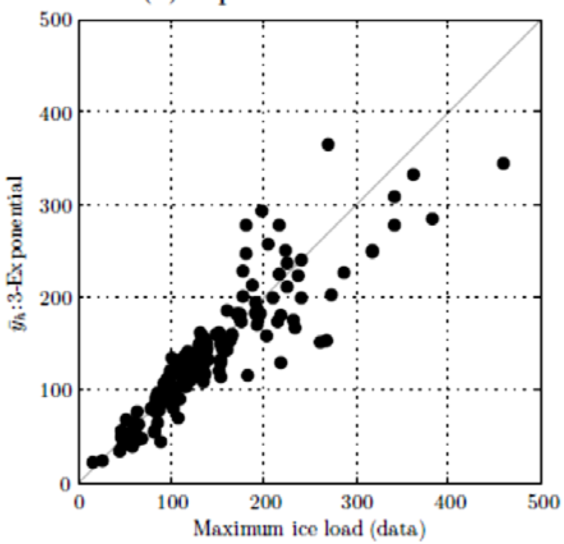
Comparison: asymptotic & exact vs. data



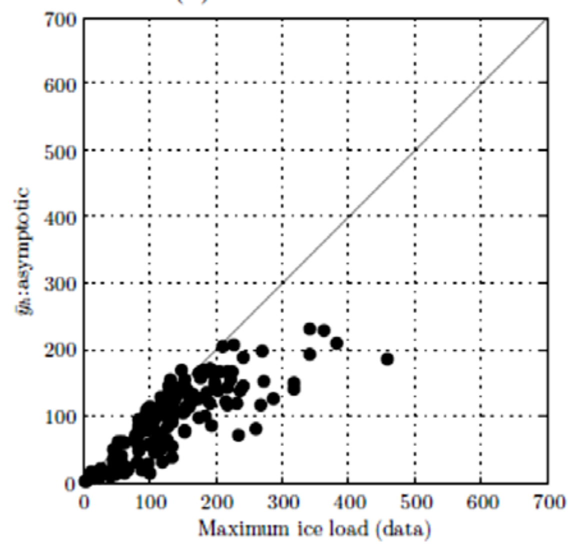
(a) Exponential vs. data



(b) Weibull vs. data



(c) 3-Exponential vs. data



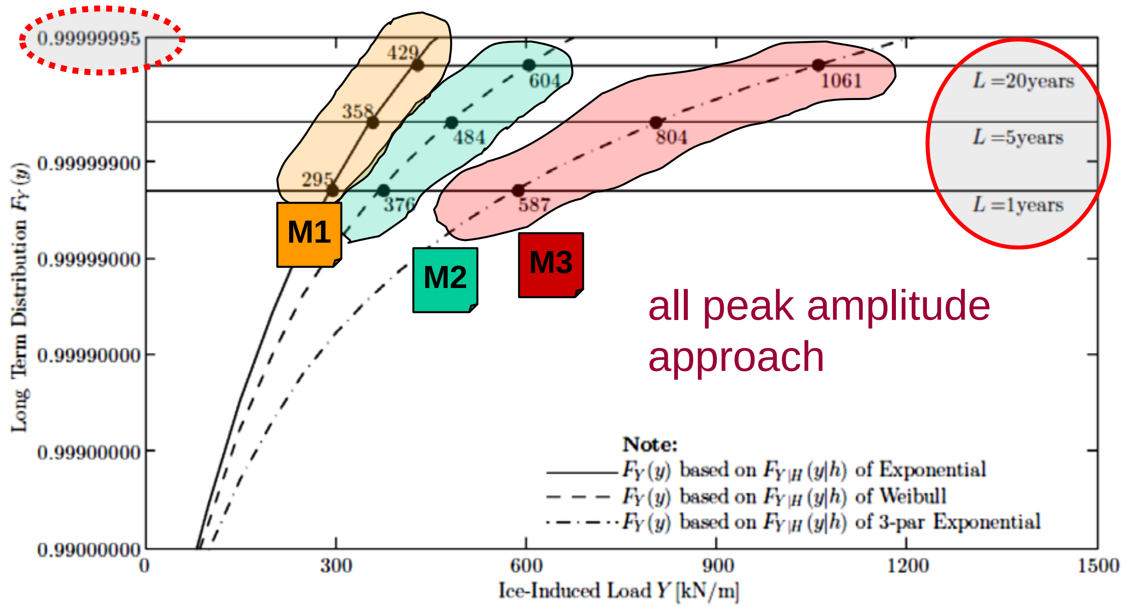
(d) Asymptotic vs. data

- The return period T_h varies according to the duration of the time series.

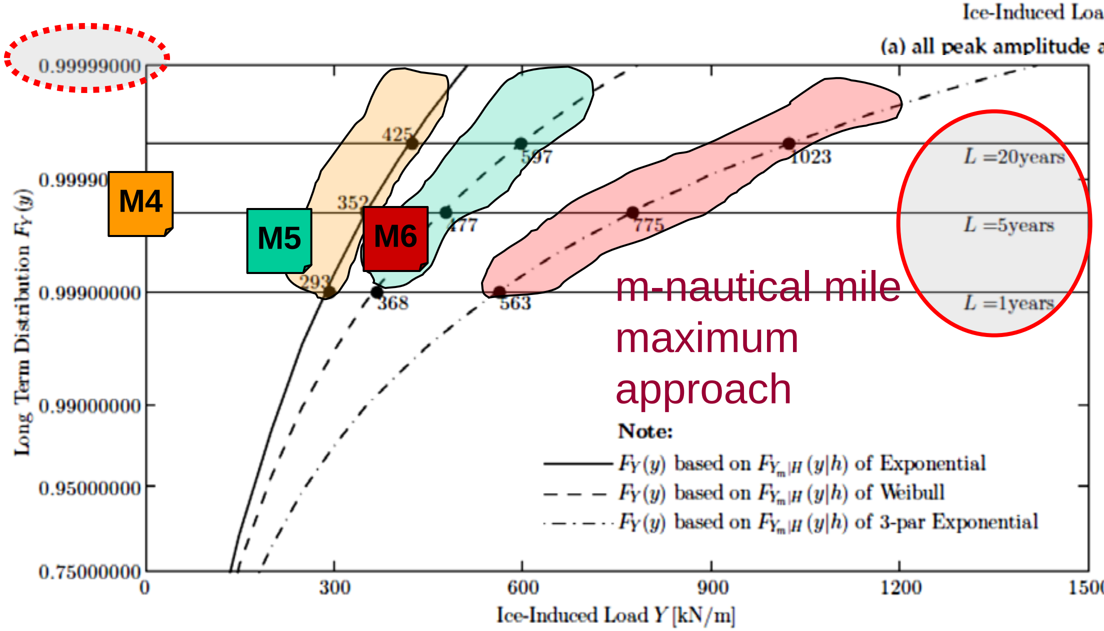
Long term statistics: **all peak amplitude** versus **m-nautical mile maximum** approaches.

Comparison of 6 models:

1. *All peak amplitude*:
   1. Exp
   2. Weibull
   3. 3-Exp
2. *m-nautical mile maximum*:
   4. Exp
   5. Weibull
   6. 3-Exp



(a) all peak amplitude approach.



(b) m-nautical mile maximum approach.

Both approaches give **the ≈same extreme value**.

CONCLUDING REMARKS:

- ☑ *Initial/parent distribution of the ice load peak process.*
- ☑ *Short term extreme statistics of the ice load.*
- ☑ *Long term extreme statistics of the ice load.*
- ☐ *Fatigue damage prediction due to ice action*.

Credits: A. Renner (blogs.esa.int)

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Concluding remarks, overall

- Instrumentation technology increasingly advanced
- Monitoring and data acquisition greatly facilitated and can be performed both on-line and off-line
- Application to two different types of structures is illustrated
- Important to identify which failure modes that can be monitored and that can not be monitored for a given instrumentation system

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Acknowledgements

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- 4Subsea is acknowledged for making riser response data available
- DNV is acknowledged for making strain measurements from KV Svalbard available