NOWITECH final event 22-23 August 2017

Model testing of offshore wind turbines

Thomas Sauder
Maxime Thys

SINTEF Ocean AS

--- PUBLIC version ---

FLOATING WIND TURBINE

Thomas Sauder

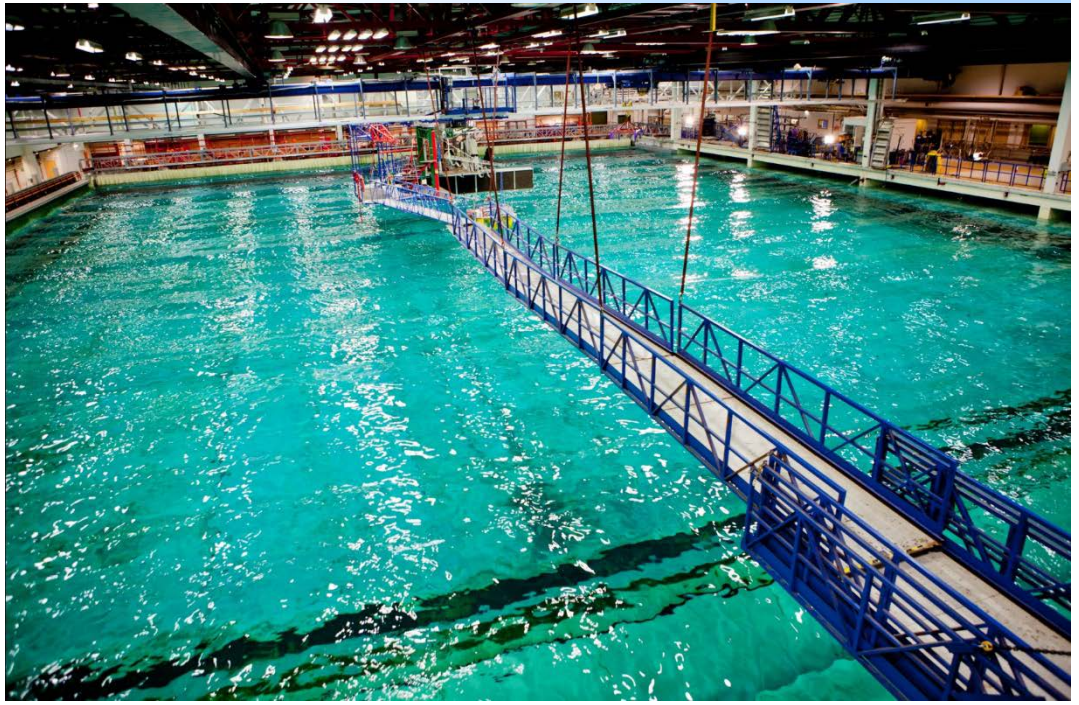
Background

SINTEF Ocean was to perform **model tests** of a FWT in the Ocean Basin

- Generate data for validation of numerical models
- Verify the 5MW CSC FOWT concept developed by NTNU

Ocean basin laboratory data:

- **Length: 80 m**
- **Width: 50 m**
- **Depth: 0-10 m**

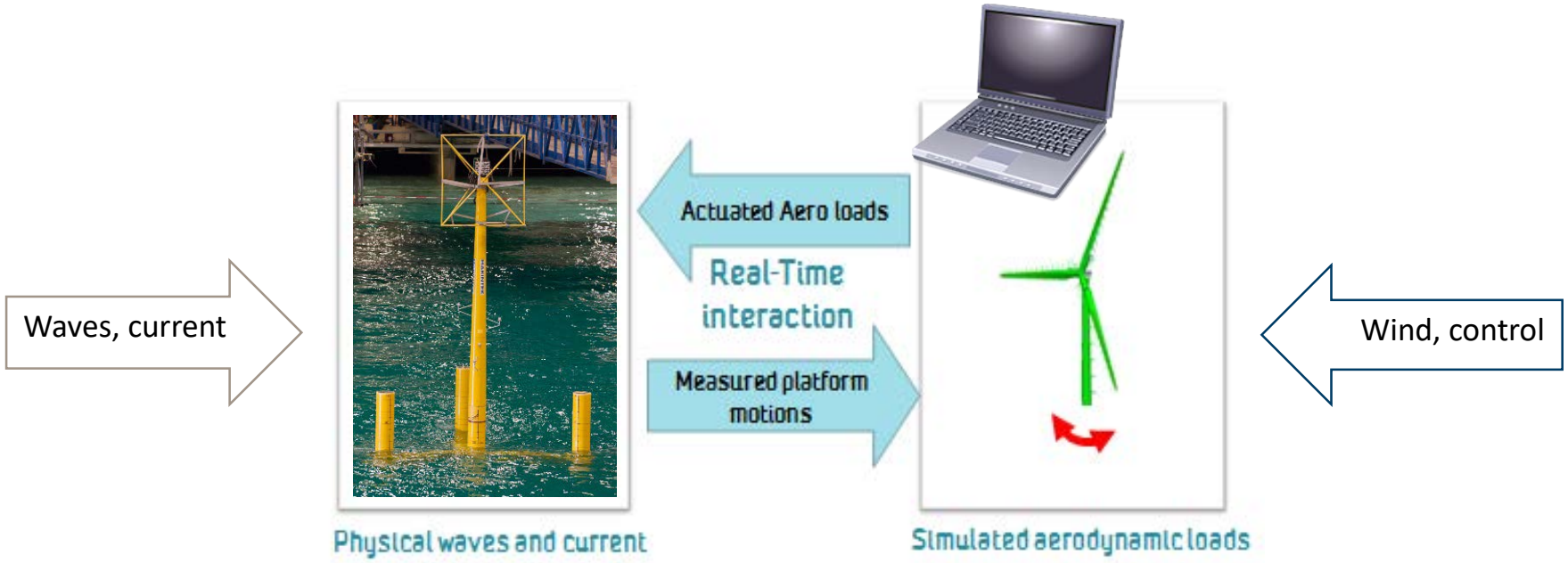


FWT testing: state of the art in 2013.

- Tests in wave tanks, using fans to generate the aerodynamic loading
  - Challenge 1: ensure a correct wind field above the wave field
  - Challenge 2: ensure a correct mass distribution of the RNA model
  - Challenge 3: Froude/Reynolds scaling conflict
- Rotors needed to be modified: "performance matching"
  - Still, only the thrust = f(TSR) was modelled correctly
  - The remaining components of the aerodynamic loads were erroneous
- Can we do better?

Hywind spar, 2005

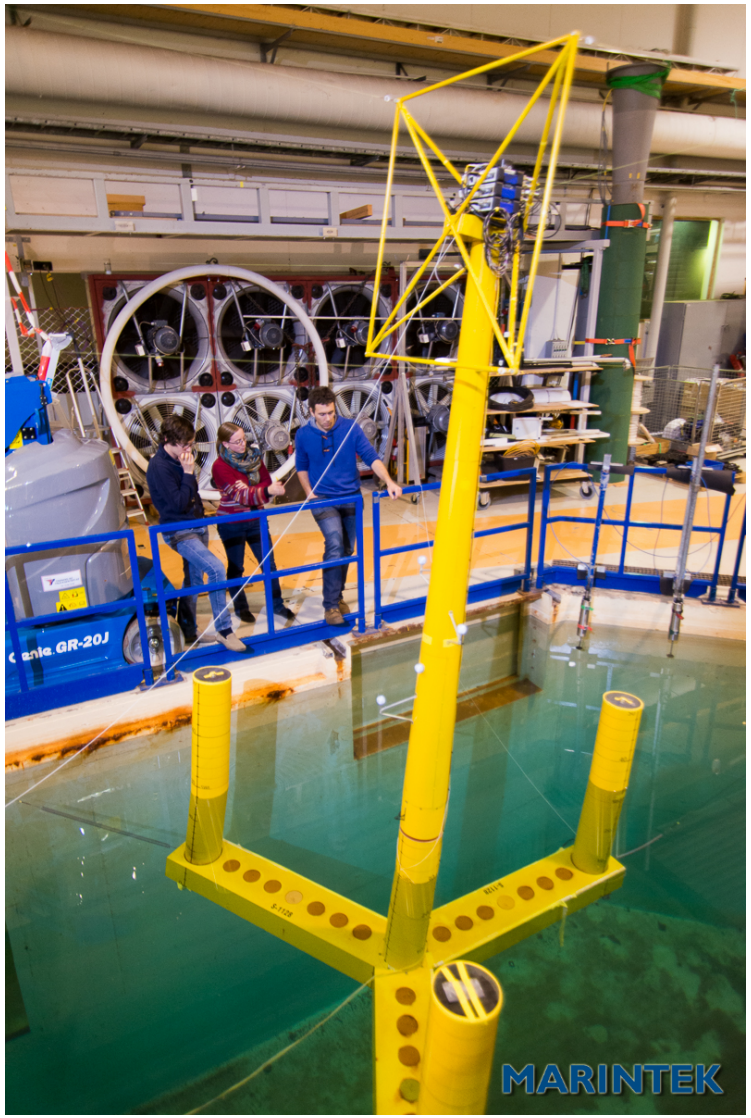
Real-time hybrid model testing



An attractive but complex method

A decisive cooperation

Hard work



Succesful ending

- We **validated the method** for model testing of FWT
- We generated **data of good quality** to be used within NOWITECH and beyond
- Valentin Chabaud **graduated** in December 2016
- The team won two **awards** for this work
- SINTEF Ocean registered the trademark **ReaTHM® testing**, and offers services based on it.
- The development of the testing method continues through two large research projects: **LIFES50+** and the **HYBRID KPN**.

NOWITECH Innovation Award 2016

OMAE2016-54435

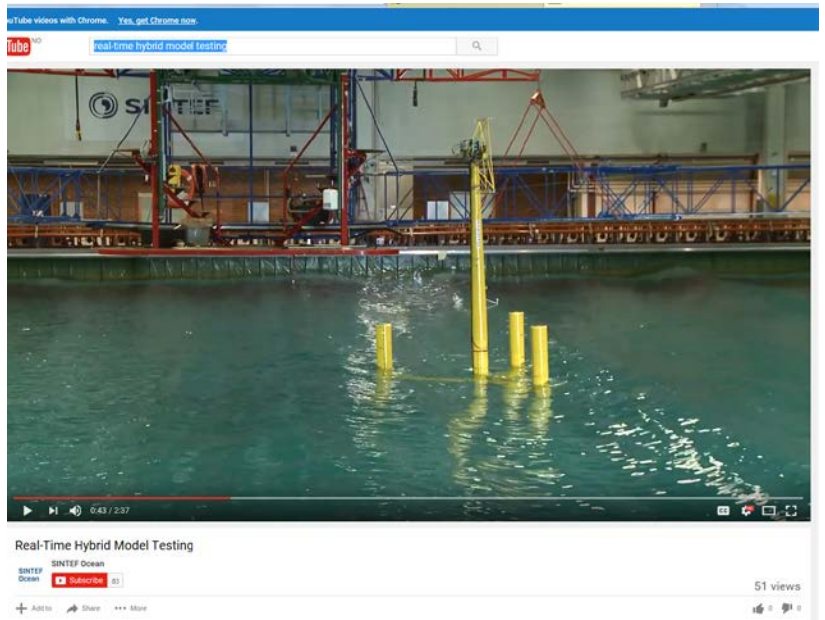
REAL-TIME HYBRID MODEL TESTING OF A BRACELESS SEMI-SUBMERSIBLE WIND TURBINE. PART I: THE HYBRID APPROACH

OMAE2016-54437

DRAFT: REAL-TIME HYBRID MODEL TESTING OF A BRACELESS SEMI-SUBMERSIBLE WIND TURBINE. PART II: EXPERIMENTAL RESULTS

OMAE2016-54640

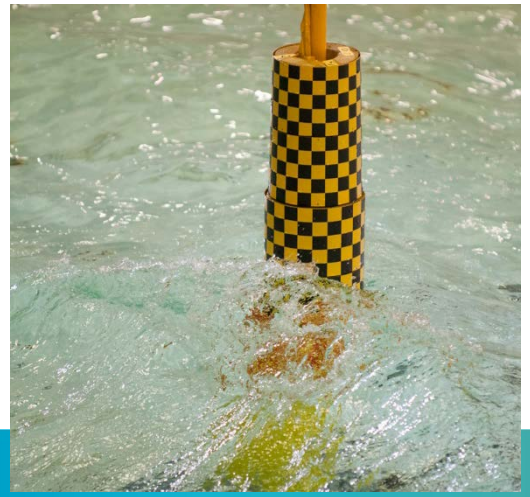
REAL-TIME HYBRID MODEL TESTS OF A BRACELESS SEMI-SUBMERSIBLE WIND TURBINE. PART III: CALIBRATION OF A NUMERICAL MODEL

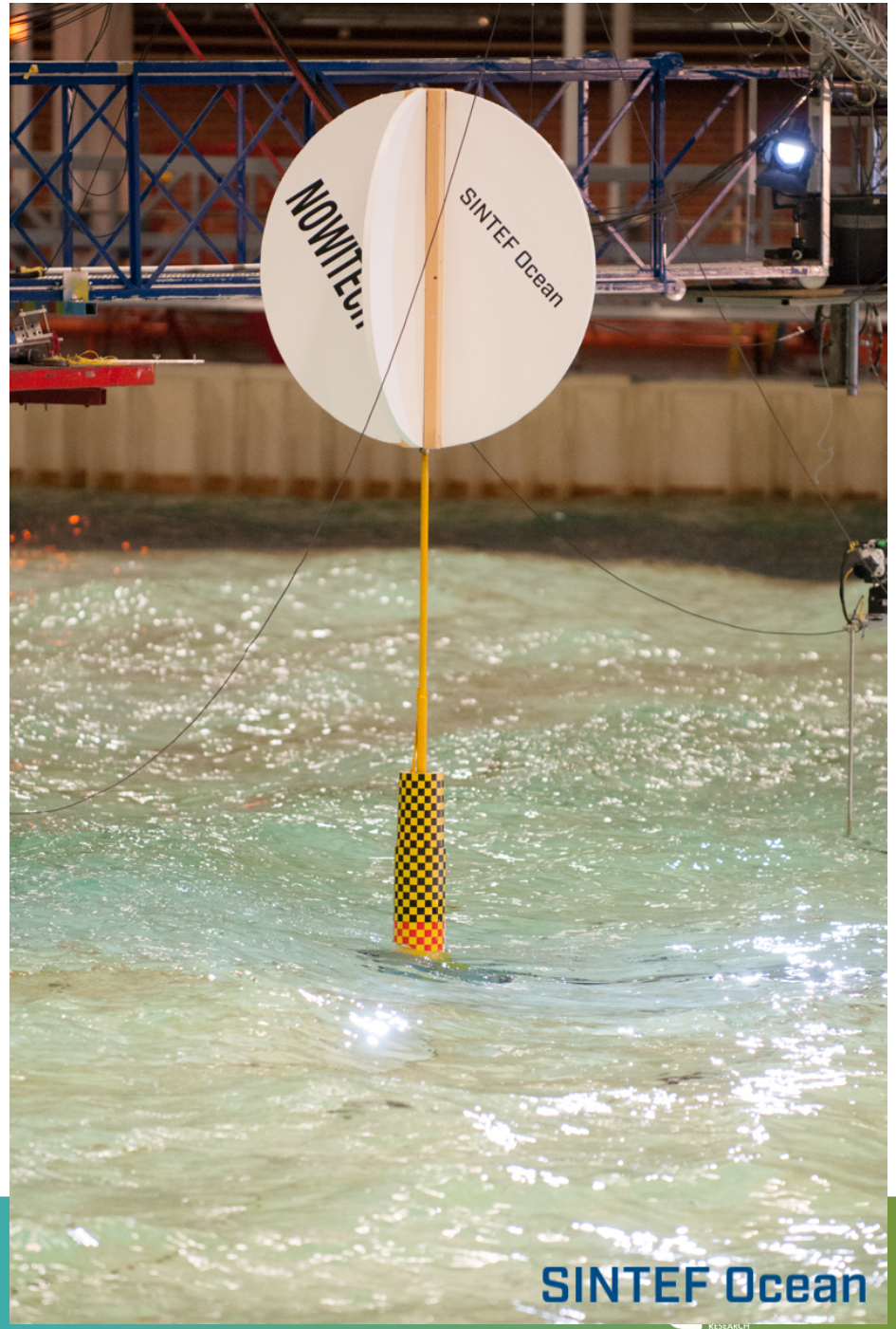


Link to video

For more details, check our
-**OMAE 2016** papers: "**Real-time hybrid model testing of a braceless semi-submersible wind turbine.**" (Part I, II and III).
-**Youtube** channel ("real-time hybrid model testing", "SINTEF Ocean")

BOTTOM FIXED WIND TURBINE



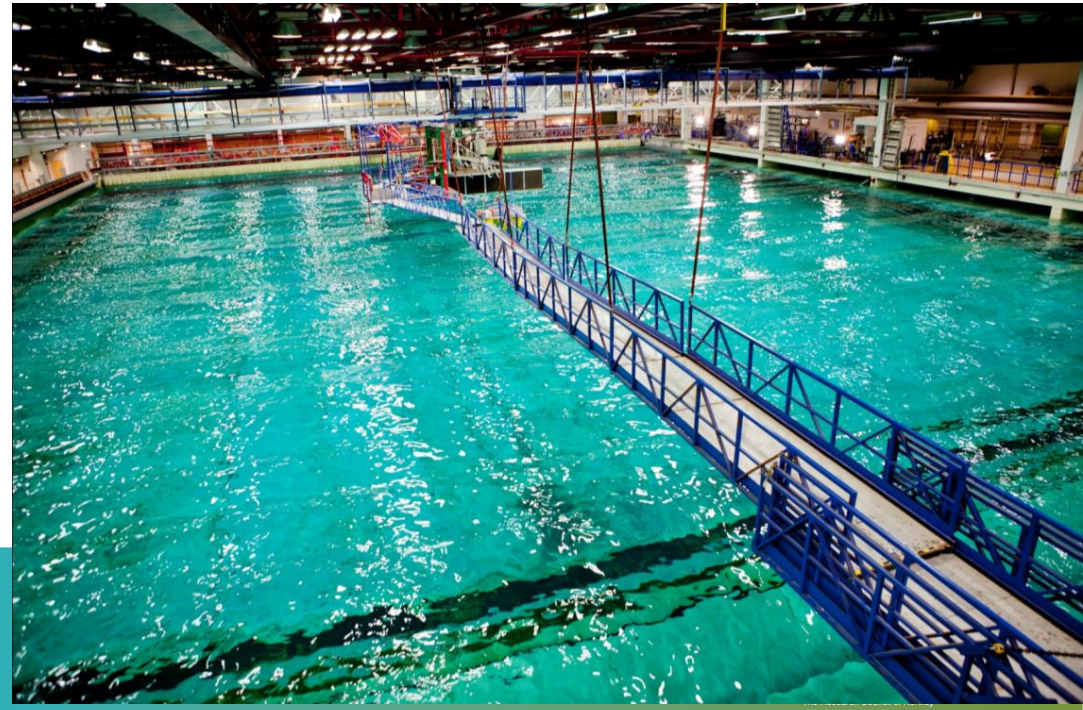


Maxime Thys

Main Objectives

Based on model tests in the Ocean Basin with a monopile (Ø7m) study physics and obtain validation fata for numerical codes:

- Second order model
- CFD calculations
- Short crested waves
- Slamming loads
- Ringing response

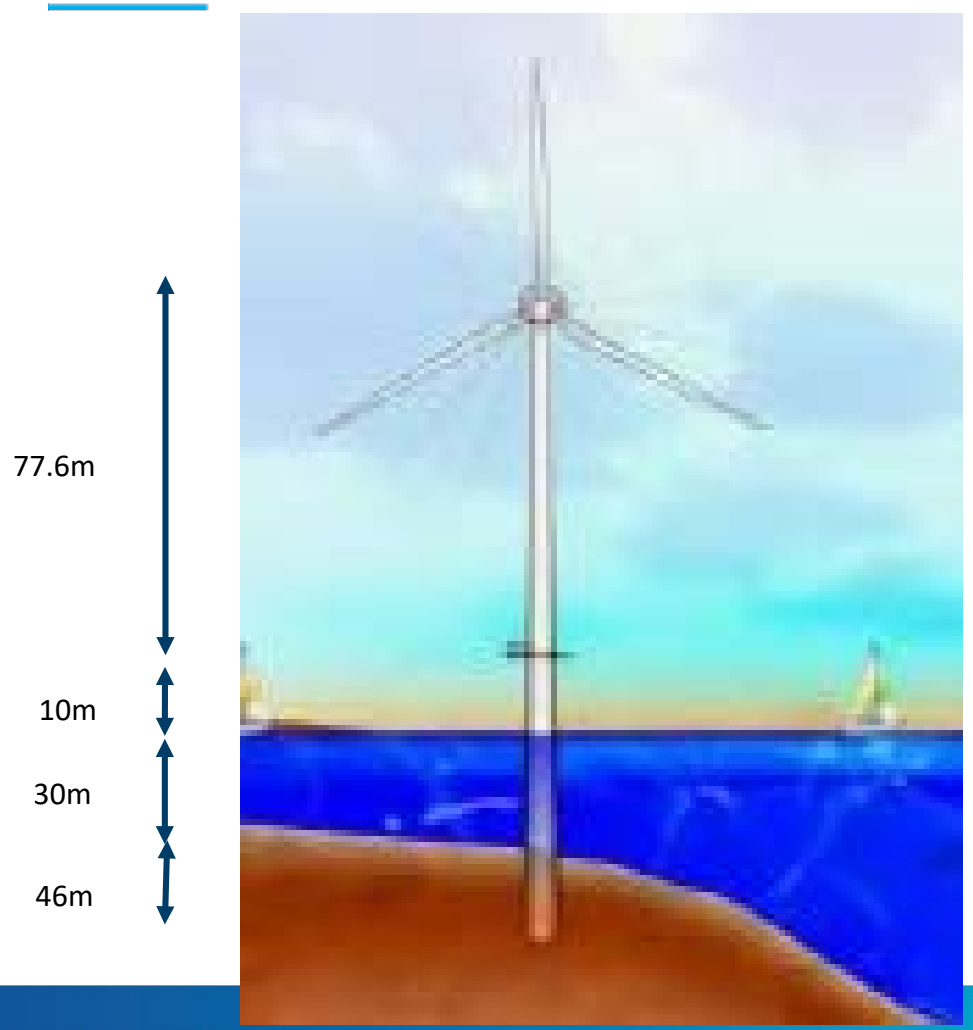


Main Objectives

Wish-list for validation data

- Wave profile and kinematics (with and without model)
- Distributed forces acting on pile
- Deflection of pile
- Global response (base shear and OTM)

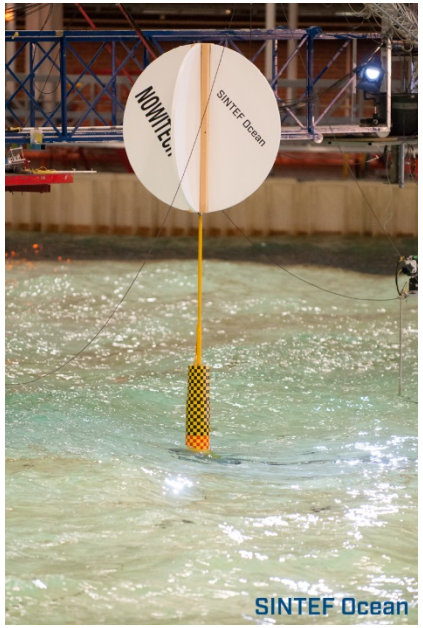
Prototype



- Designed for the experiments
- Based on NREL 5MW reference wind turbine and OC3 monopile design
- 7m Ø from embedded to base of tower
- 30m waterdepth
- Site 15 (L. Li *et al.*, 2013)
- Soil interaction
  - modelled with different soil springs
  - Simplified to single rotational spring for model tests

Model

- Scale: 40
- Simplifications
  - No wind and no rotor. Only mass of RNA.
  - Increase of structural damping by use of drag disc
  - Single rotational spring at seabed
- Elastic model



Instrumentation

- Waveprobes

Instrumentation

- Waveprobes
- Strain gauges -> measured moment
- Acceleration at different sections
- High speed video

Test Program

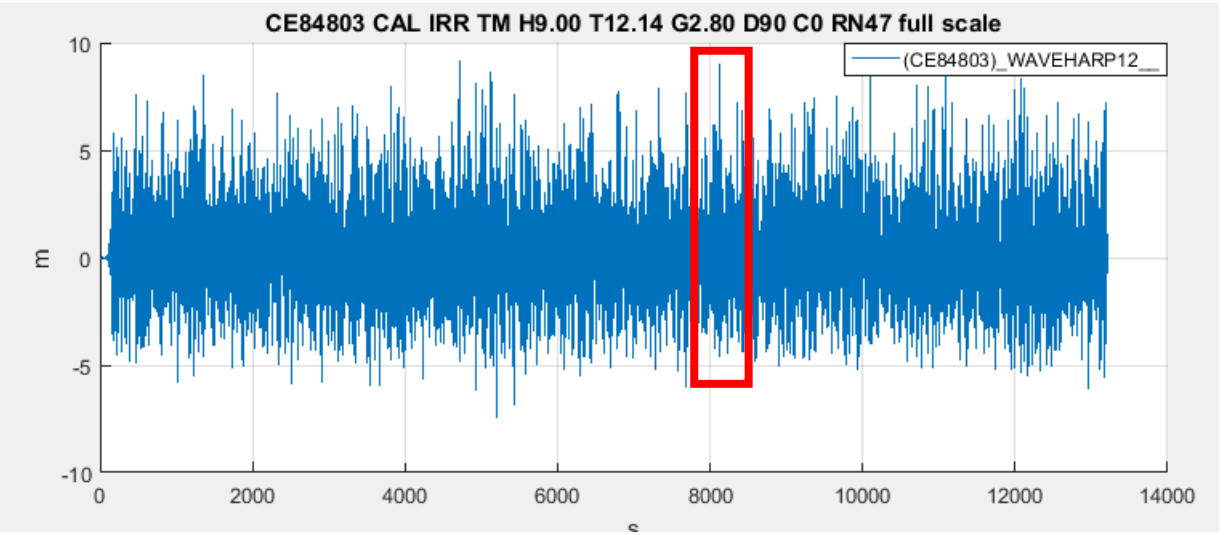
- Dry and wet documentation tests
  - Pullout: Document structural stiffness
  - Decay tests: Natural period, mode shape and damping
- Regular wave tests
  (force distribution and global response)
  - Steepness 1/30: T=6, 7, 8, …, 14
  - Steepness 1/40: T=6, 7, 8, …, 15
- White noise => RAO
  - 2 different to study possible non-linearity

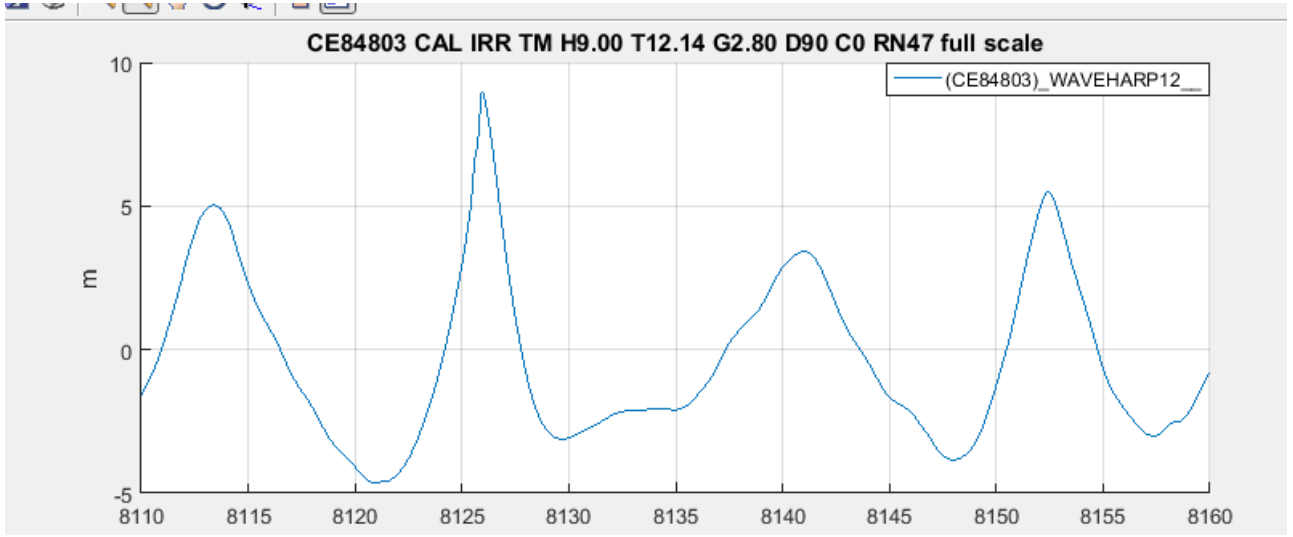
Test Program

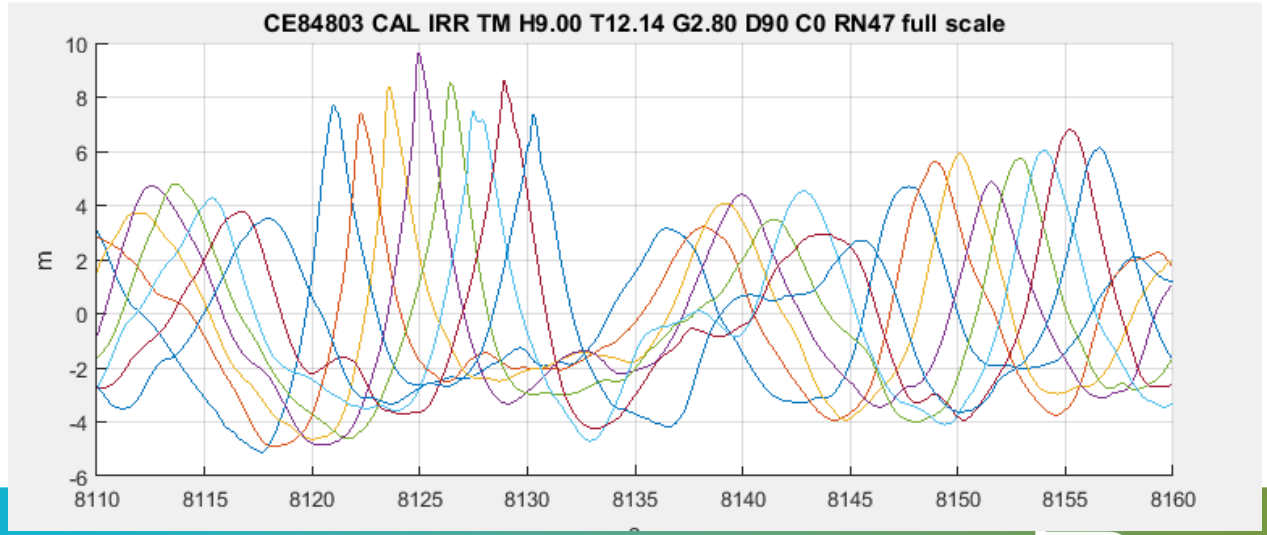
- Irregular wave tests
  - 3h realizations
  - Spectrum: TMA (*JONSWAP*Ø(ω)*)
  - One fatigue, two 25yr, 1 intermediate and five 50yr conditions.
  - Long and short crested $\cos^N(\theta)$, with N=8
  - Ewans spreading for one condition
  - 8 repetitions of long and 2 rep for short condition for uncertainty analysis

Latheef 2013: Storm: $15^o \leq \sigma_\theta \leq 30^o$ and they test 0^o, 15^o, and 30^o.
Siwansen 2016: $\sigma_\theta = 5.7^o, 12.5^o, and\ 19.1^o$ and calls it narrow, medium, and broad, respectively.

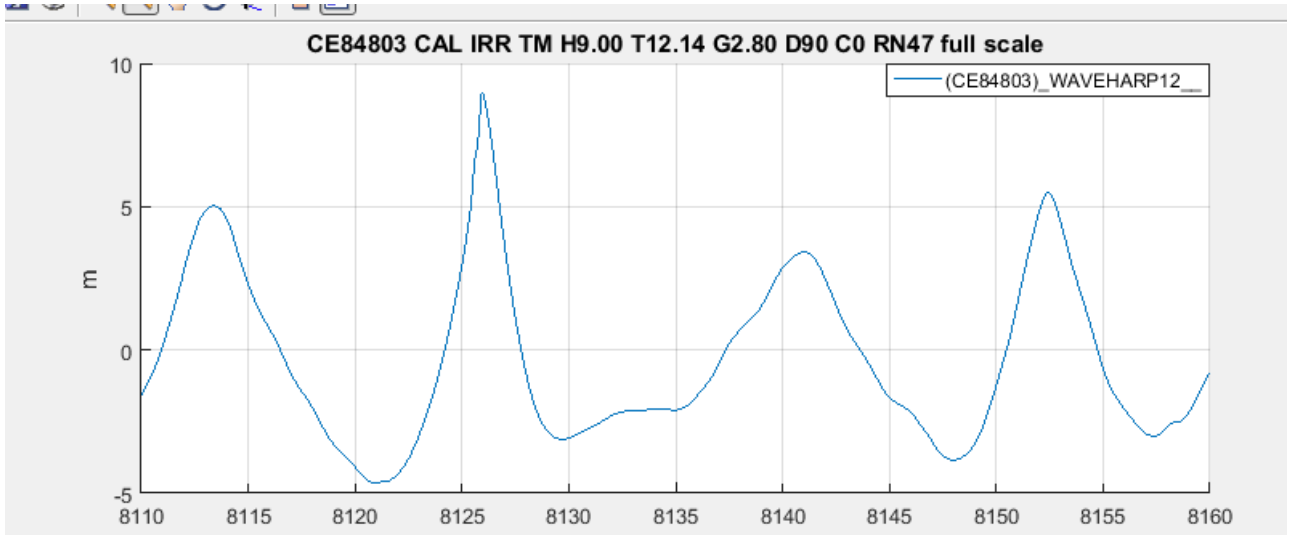
Long Crested Wave

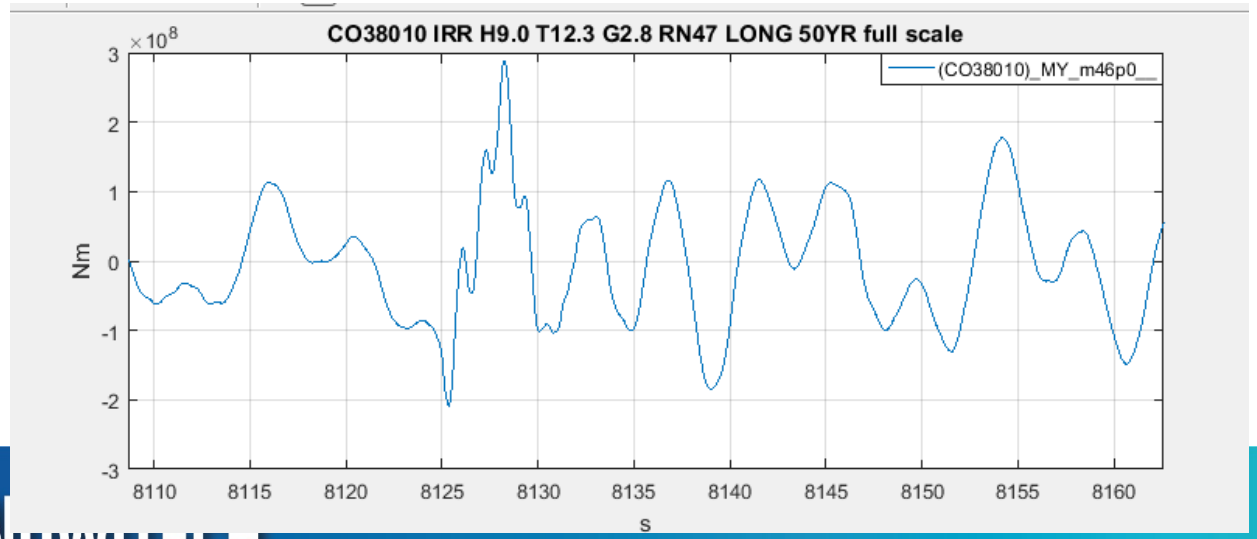


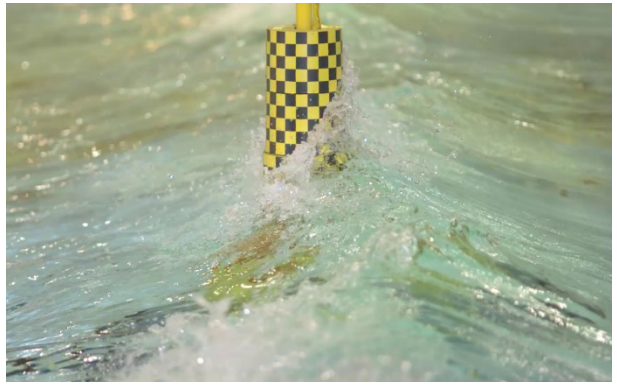


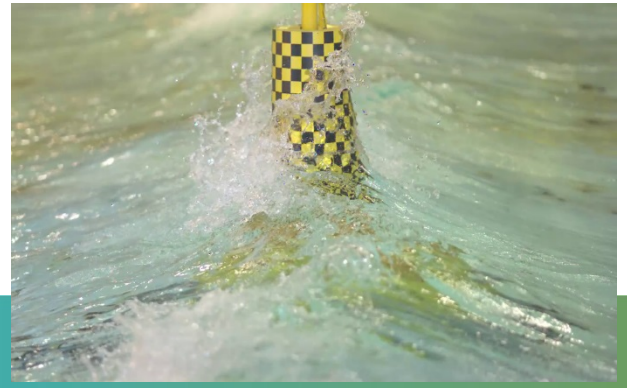


Long Crested Wave

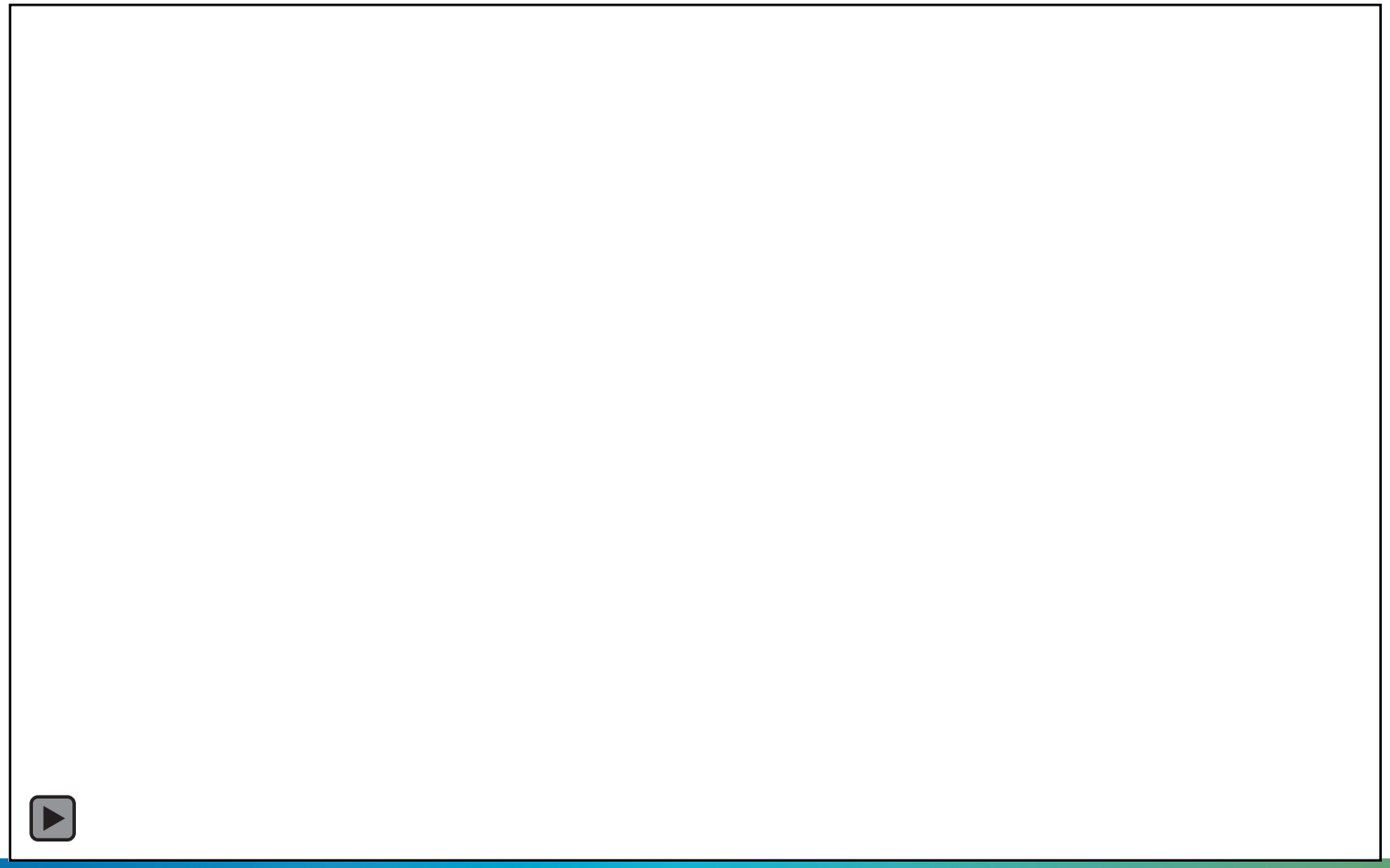






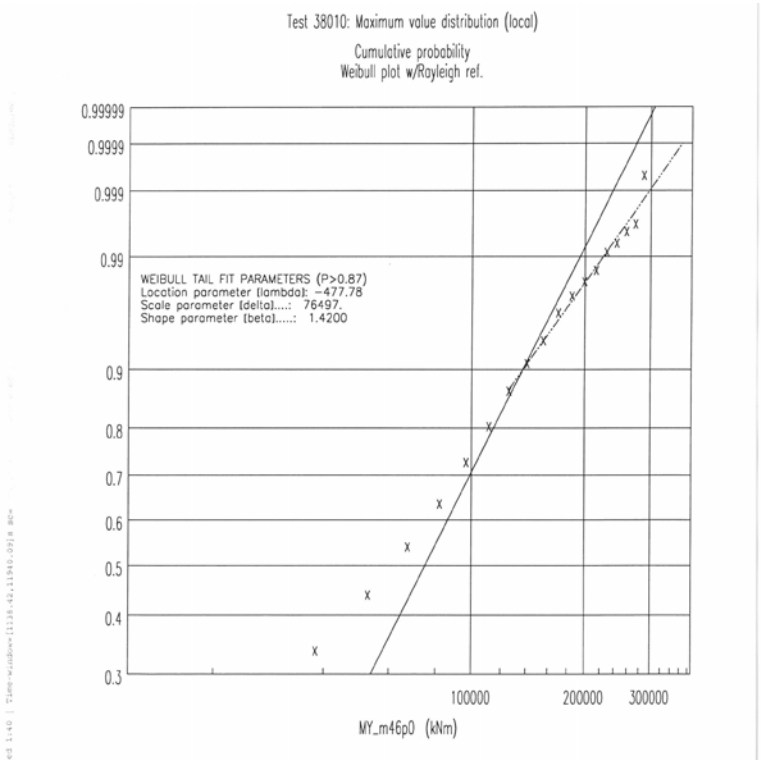


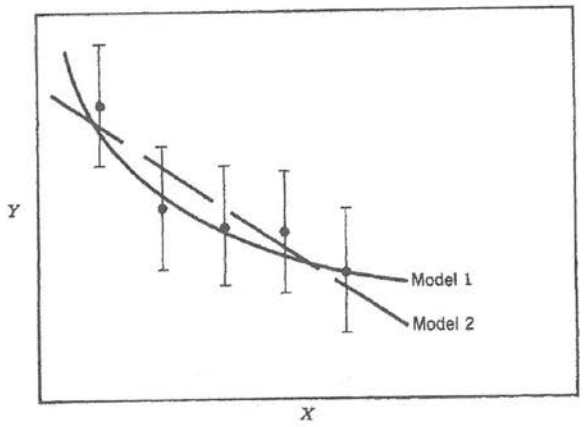
Long Crested Wave

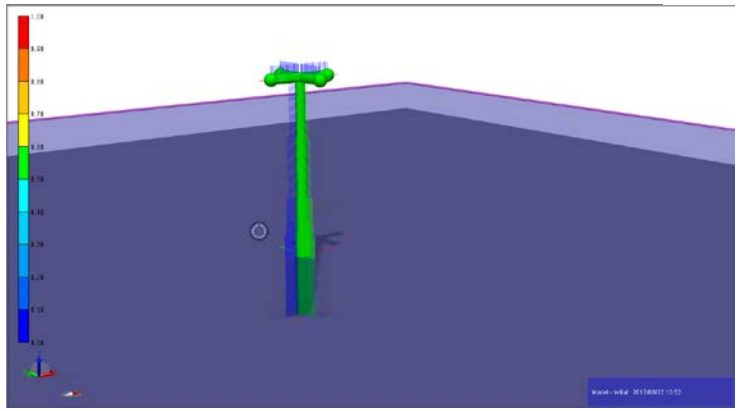


Much more to analyse

- Derivation of loads from response
- Extreme values
- Uncertainty on experimental results
- Comparison with simulations







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