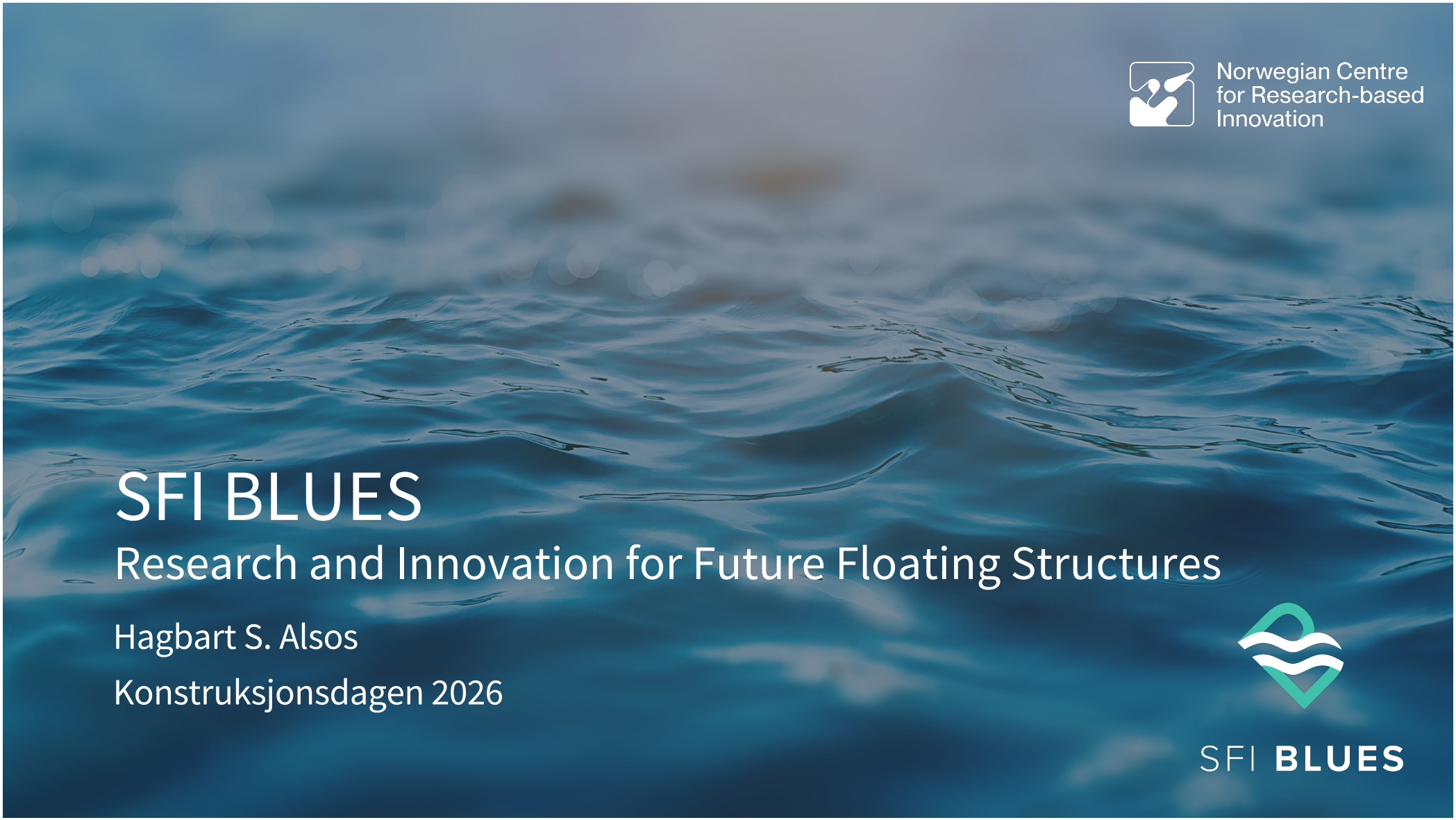

Norwegian Centre
for Research-based
Innovation
SFI BLUES
Research and Innovation for Future Floating Structures
Hagbart S. Alsos
Konstruksjonsdagen 2026
SFI BLUES

About SFI BLUES

- Centre for Research-based innovation (SFI): 2021-2028
- Overall budget 190 MNOK
- Hosted by SINTEF Ocean
- Strong consortium:
  - 11 user partners
  - 5 research partners
- Funded by the Research Council of Norway and the partners




Ocean tourism, offshore geothermal energy, plastic collection and ocean mining
Floating photovoltaics
New structure concepts and materials
Design and engineering
Instrumentation, automation and control
Floating cities and urbanization
SFI BLUES
Novel aquaculture structures
Digital models
Environmental loads
Marine physical environment
Floating offshore wind
Coastal infrastructure
Credit: AMC Diseing + Welding

SFI BLUES – Floating Structures for the Next Generation of Ocean Industries

SFI BLUES aims to enable Norwegian industry to create new types of floating stationary structures, which satisfy the needs and requirements from renewable energy, aquaculture, and coastal infrastructure



WP1 Novel technologies



WP2 Digital twins



WP3 Design optimisation



WP4 Marine environment



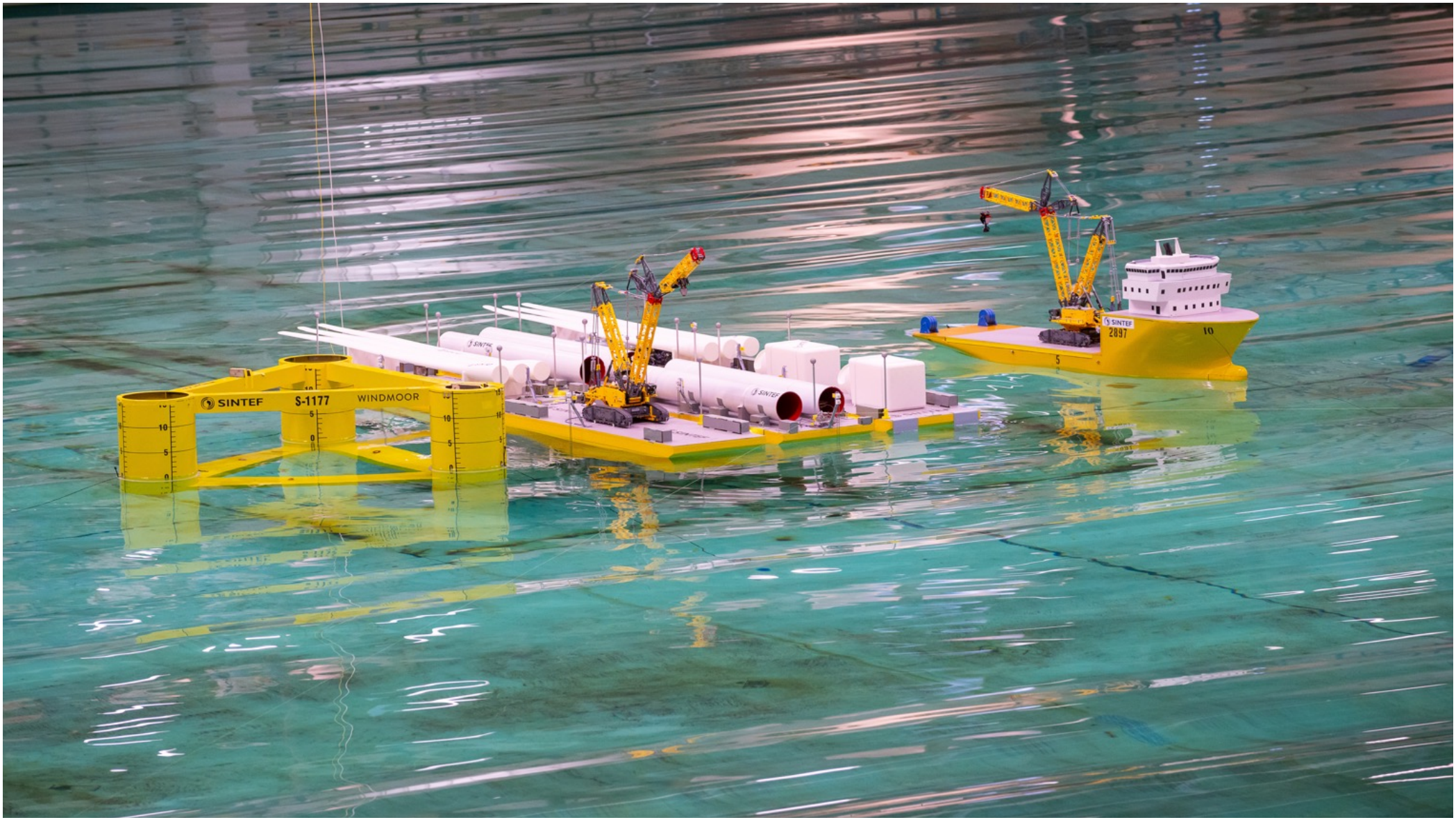
WP5 Wave structure interaction



WP6 Advanced materials technology



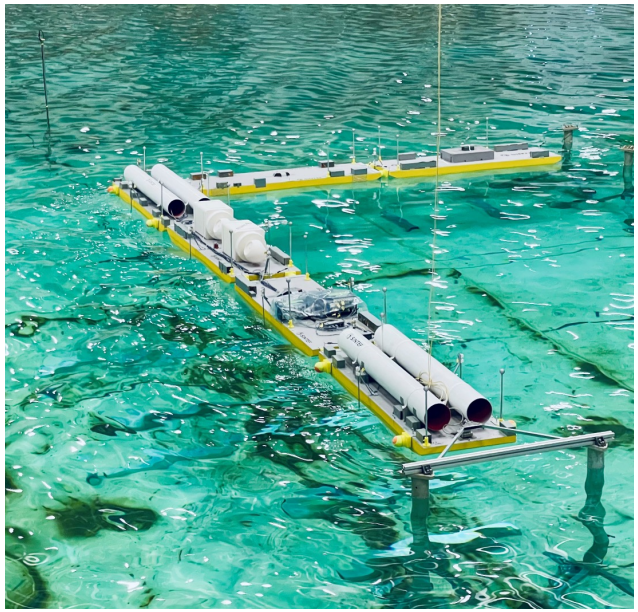
WP7 Mooring and anchors


SINTEF
S-1177
WINDMOOR
SINTEF
2897

Typically

- Focused towards renewable energy production, food production, coastal transport, etc
- Flexible and compliant structures with a high degree of self interaction
- Floating structures spread over a larger area
- Designs with larger degrees of uncertainty
  - Unmapped behavior
  - Unsolved physics
  - Lack of design tools

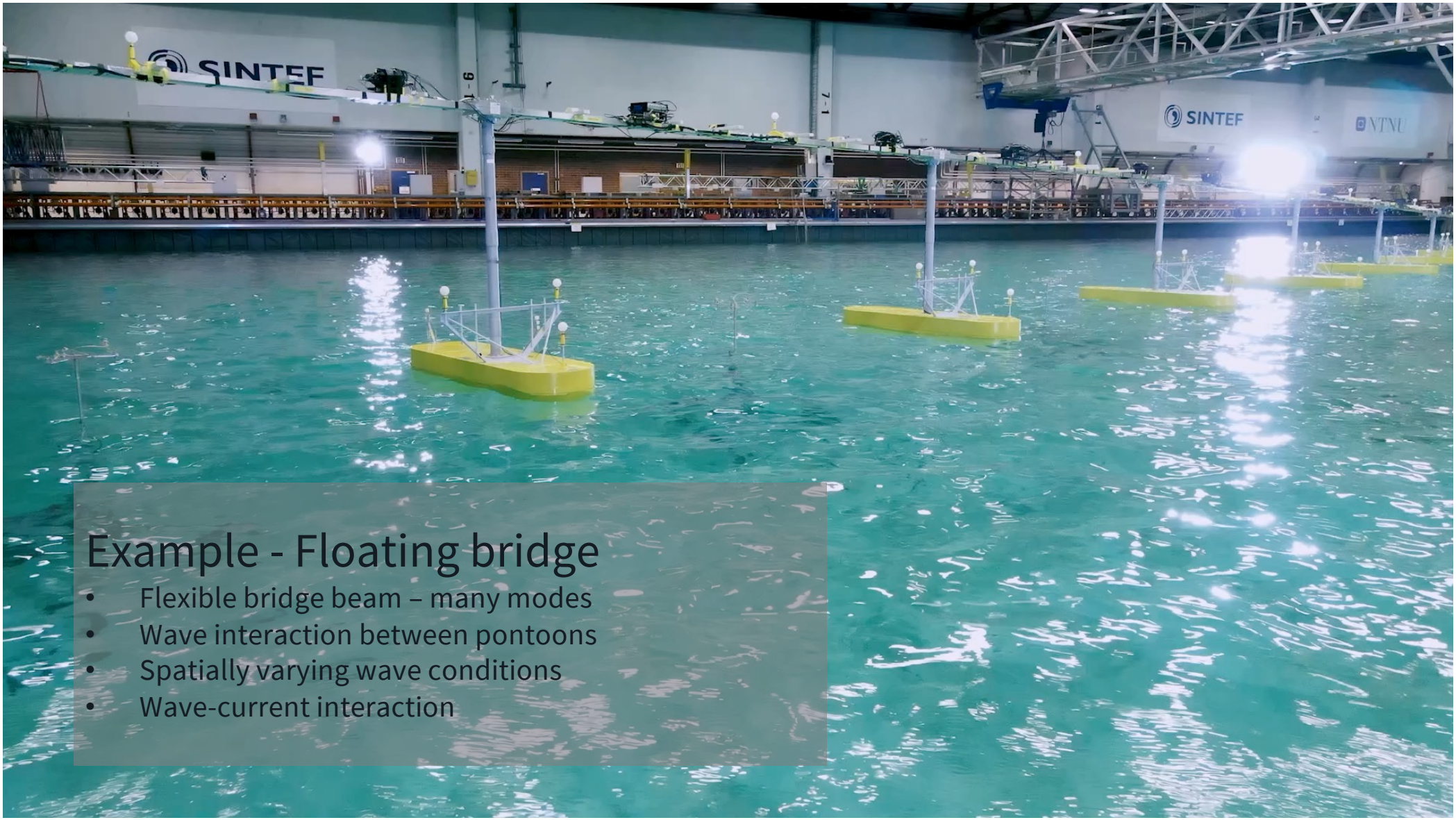








Metocean conditions and waves



Example - Floating bridge

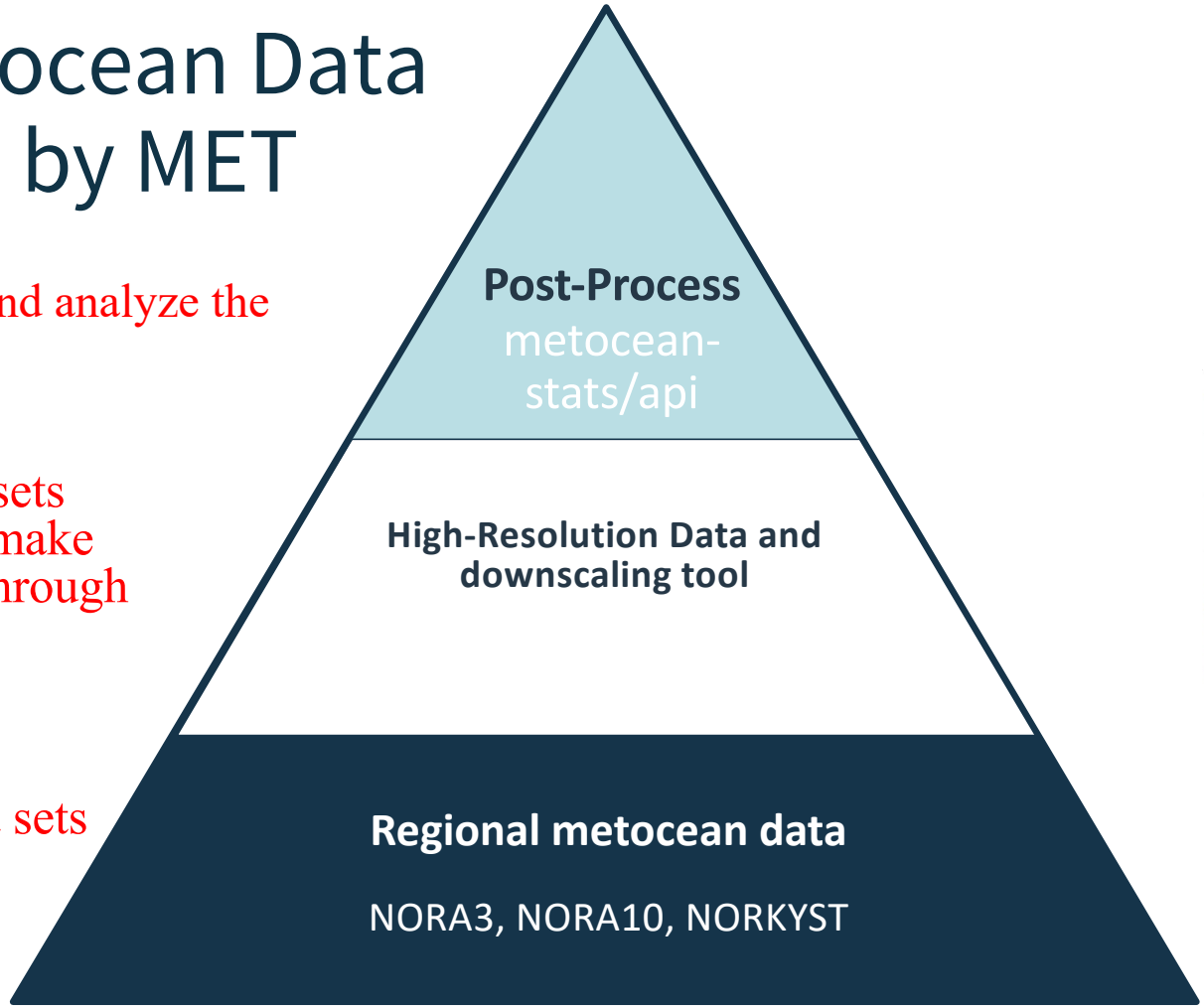
- Flexible bridge beam – many modes
- Wave interaction between pontoons
- Spatially varying wave conditions
- Wave-current interaction

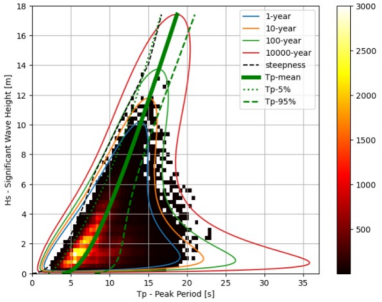
Open Metocean Data and Tools by MET

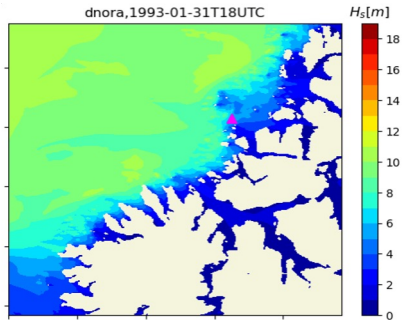
Tools to extract and analyze the data sets

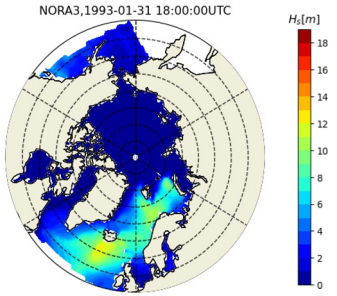
Developed data sets and software to make local hindcasts through downscaling

The existing data sets







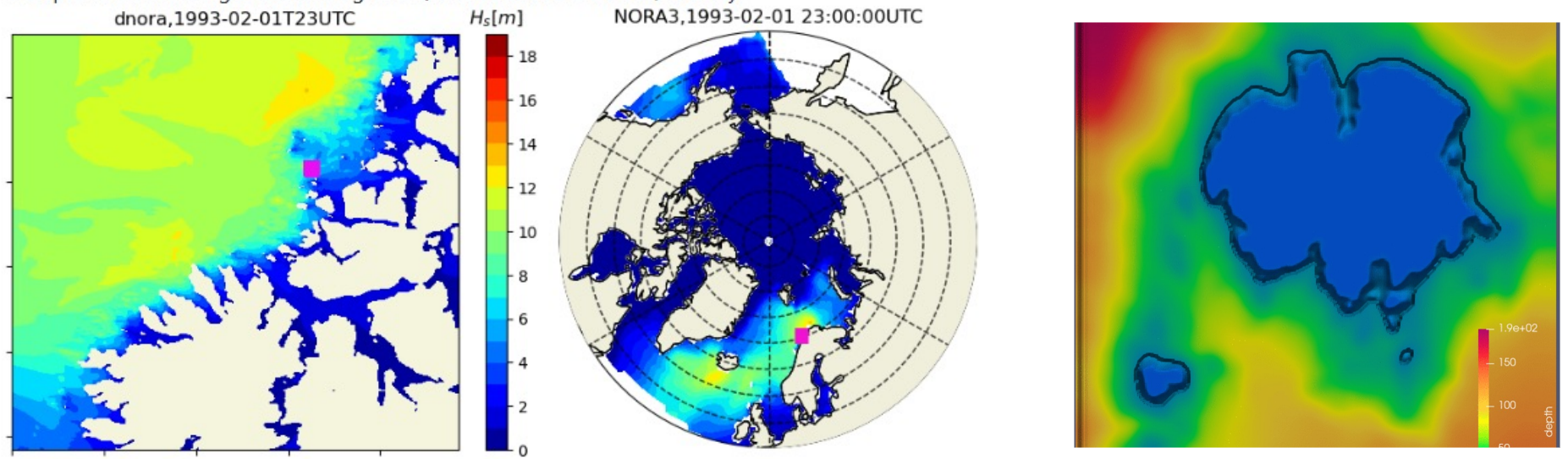


DNORA is an open-source tool for high-resolution wave simulations that uses:

- spectral boundaries & wind forcing (e.g., NORA3)
- open-access topographies (e.g., Emodnet, Kartverket)
- spectral / phase-resolving wave models:

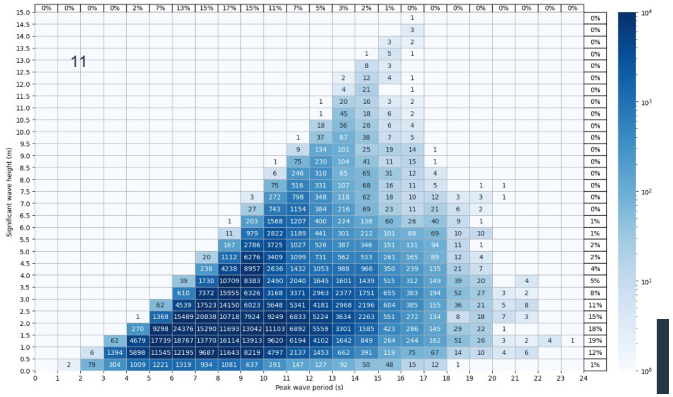
- Available on: https://github.com/MET-OM/dnora?tab=readme-ov-file

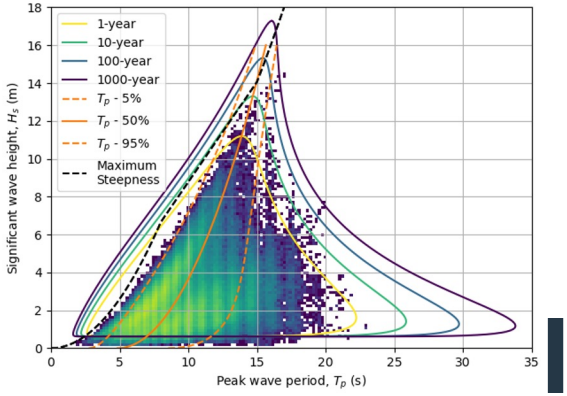
Example of downscaling NORA3 using dnora/SWAN offshore Tromsø, Norway:

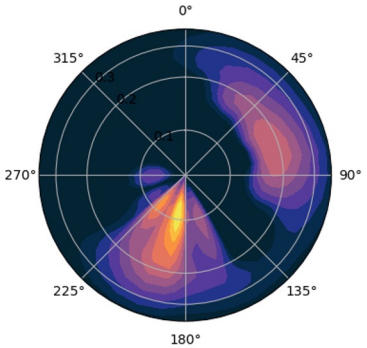


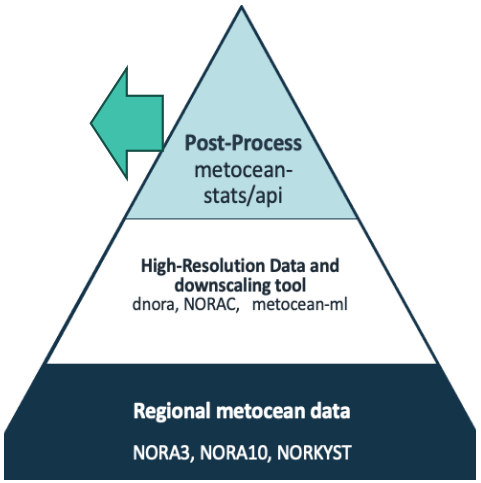
metocean-stats

- Python tool for statistical analysis and visualization of site specific metocean data (wind, waves, currents etc.)
- General and extreme statistics
- Weather windows/marine operations
- https://metocean-stats.readthedocs.io/en/latest/index.html









Realizing sea states - NWT

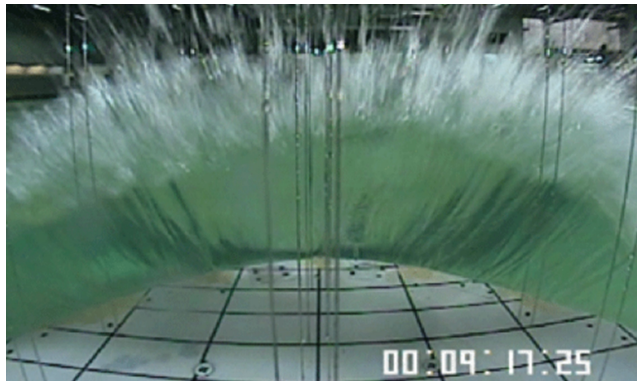
Recent trends in commercial and research projects

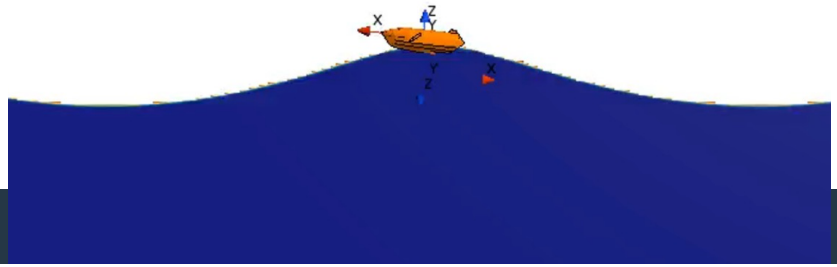
- Wave impact and run-up in deep water and coastal areas
- Green water on ships
- Nonlinear interactions between steep waves and structures
- Effect of large steep waves on the speed performance of small vessels (forward speed).

Need for numerical tools:

- To compute **steep nonlinear waves** as close as possible to breaking
- **Efficiently** to derive statistics (unlike “Navier-Stokes” CFD)
- Possibly with **structure interactions** (3D).





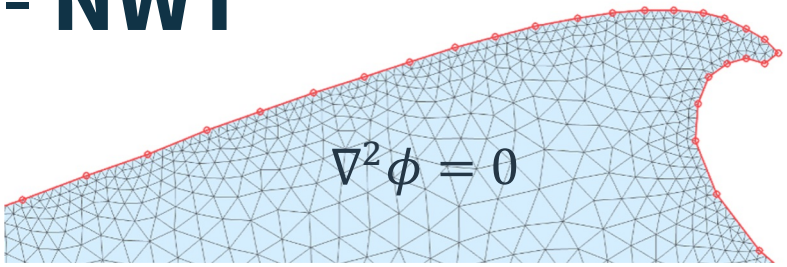


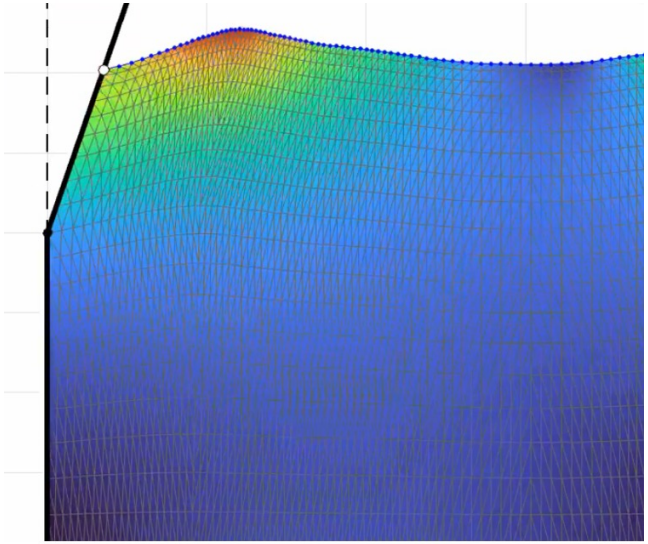
Realizing extreme sea states - **NWT**

FEM-MEL

FINITE ELEMENT METHOD – MIXED EULERIAN LAGRANGIAN

FAST AND STABLE NUMERICAL WAVE TANK FOR EXTREME SEA STATES

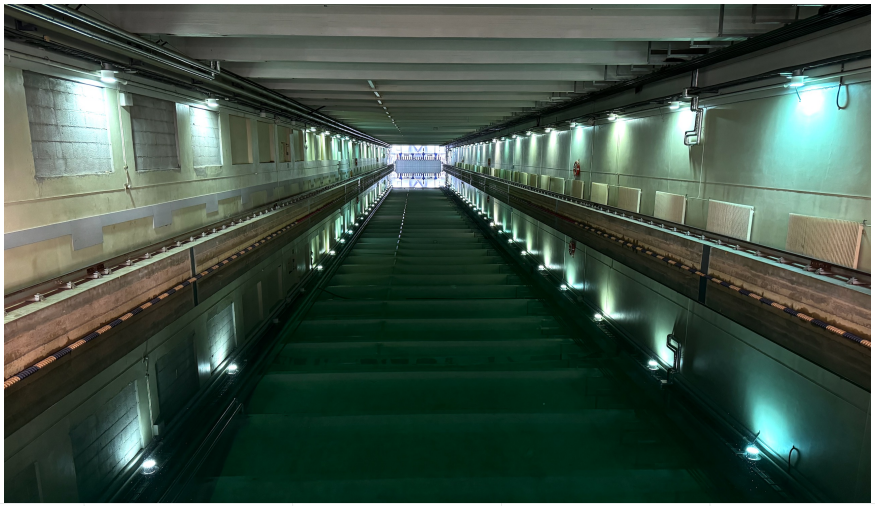


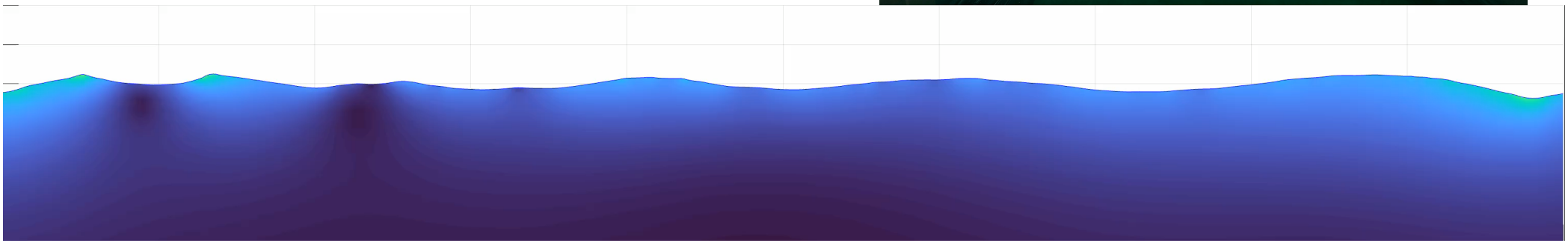


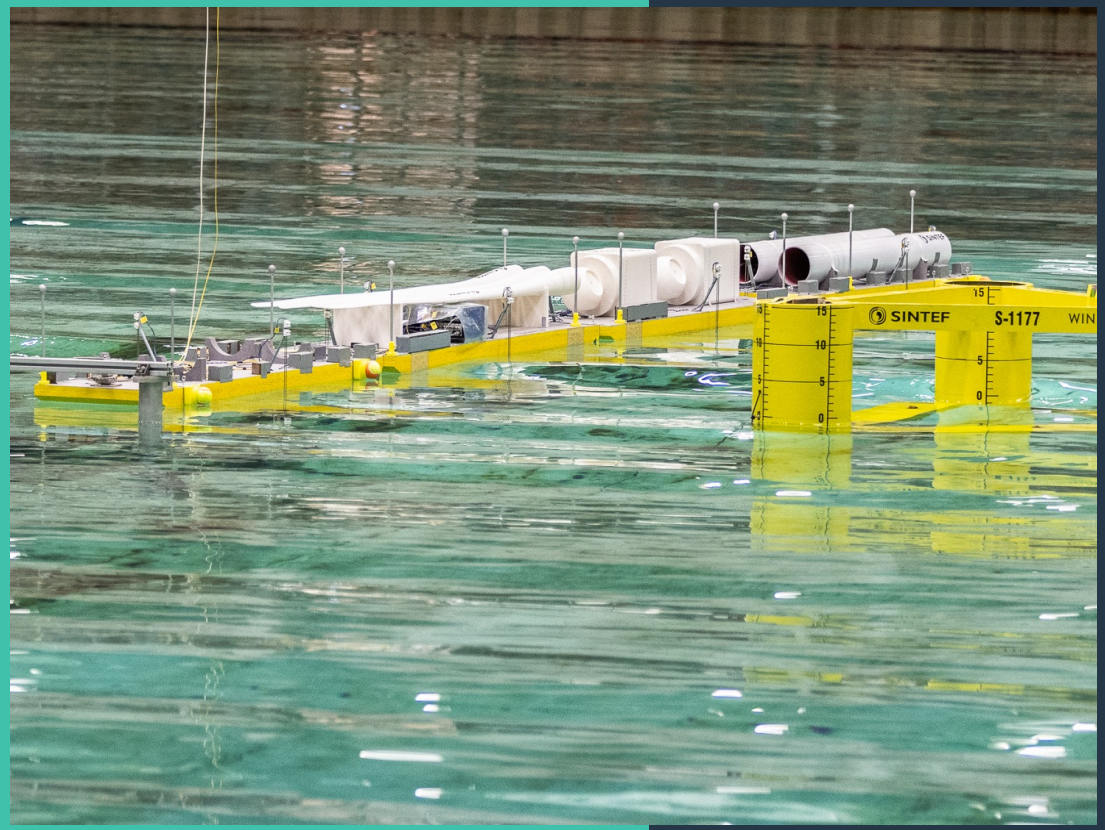
- Developed fully nonlinear potential solver to
  - propagate **steep waves** up to breaking in 2D or 3D
  - possibly with **complex boundary conditions**
  - assess nonlinear **wave-structure interactions**
  - in a similar wave as in our hydrodynamic laboratories

Ongoing work – C++ open-source version

- Benchmarked against Matlab prototype
- Wave propagation over a periodic domain: OK.
- Neumann boundary condition (wavemaker): OK
- Benchmarked against steep wave tests: OK
- Goal for 2026: 3h-simulations of steep waves.
- Goal for 2027: Parallel 2D-code (MPI) and unstructured mesh + expansion to 3D







Wave – structure interaction

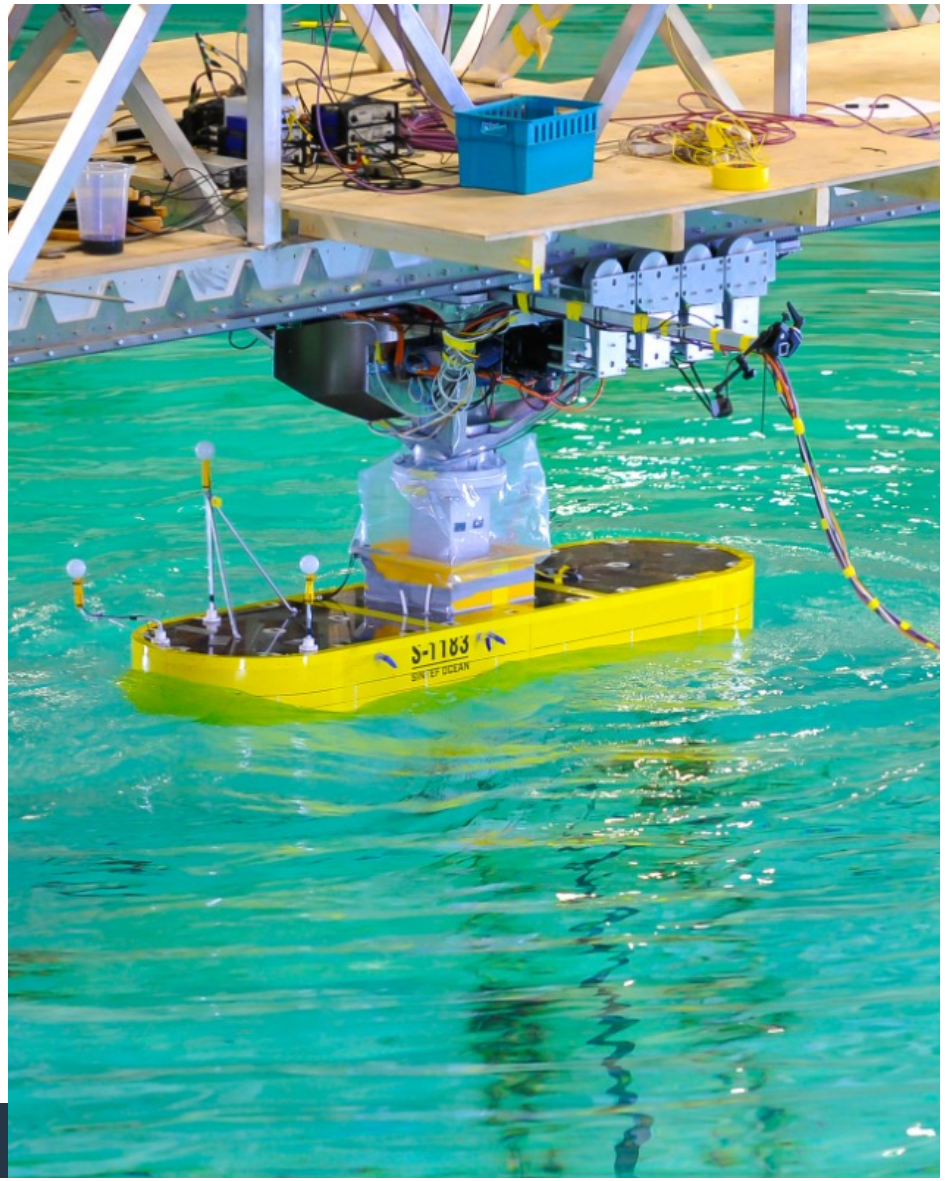
PVC3D: Potential-Viscous-Code

Potential flow at the free surface +
Navier-Stokes (CFD) in the domain

- 10-100 times faster than conventional CFD
- Robust and accurate

- Not a general tool, but game-changer for a range of applications:

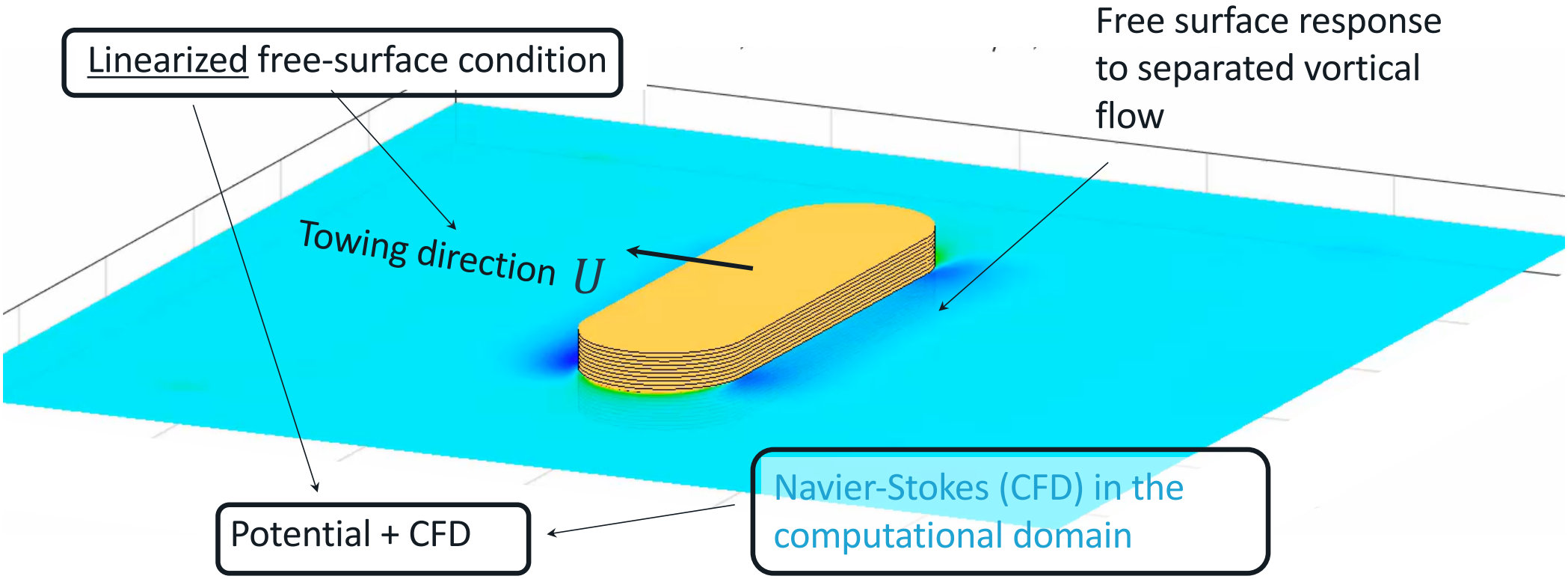
  - Second-order loads and responses (low- and sum-frequency)
  - Moonpool resonance
  - Ship roll damping
  - Maneuvering in waves
  - Wave-current-body interaction
  - Free-surface dependent drag loads



Bridge pontoon towed

(Turgut Özbar, PhD, 2026)

PVC3D



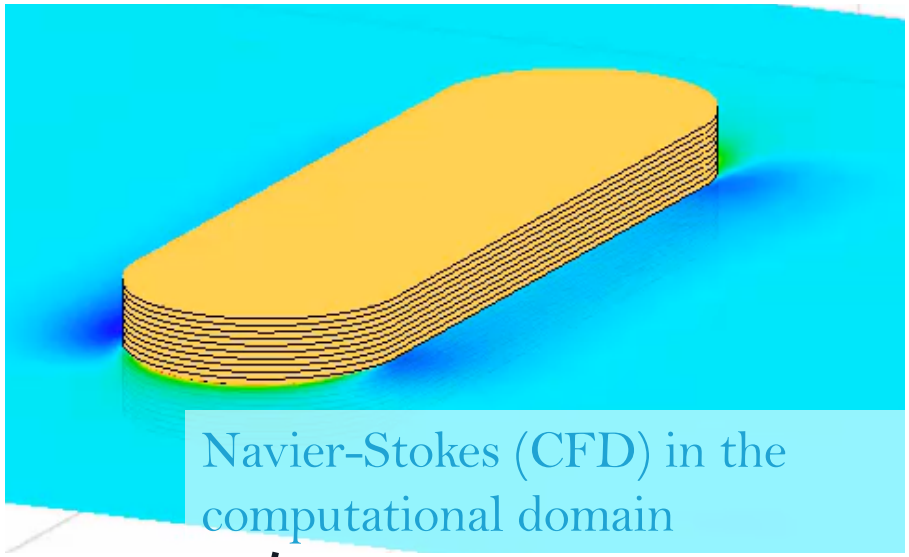
Stable – Robust - Fast

PVC3D – potential
Faster (but no viscous effects)

Potential flow in the computational domain

Mean wave loads in low forward speed
(Nikos Petikidis, PhD, 2026)

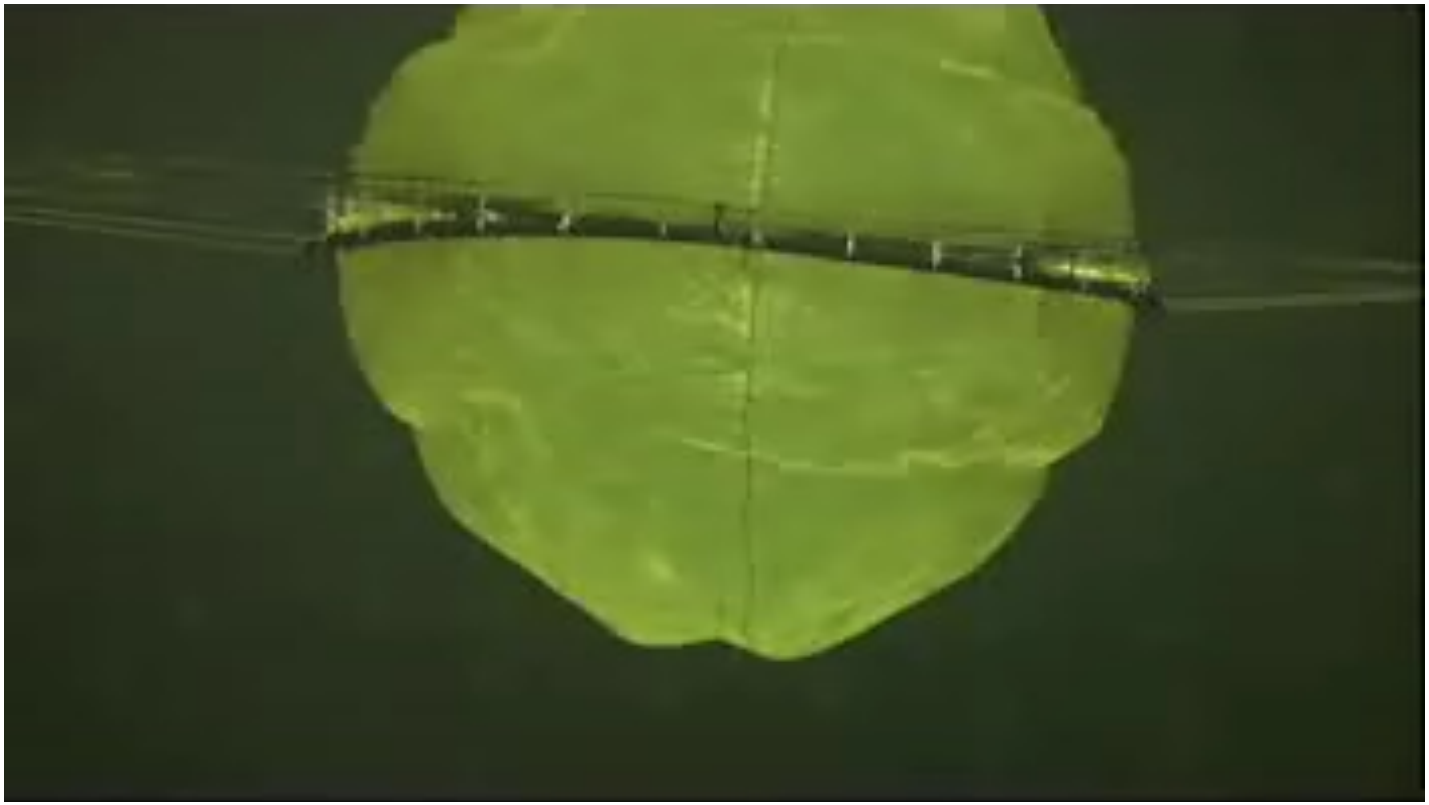
PVC3D – viscous
Still fast, but with viscous effects

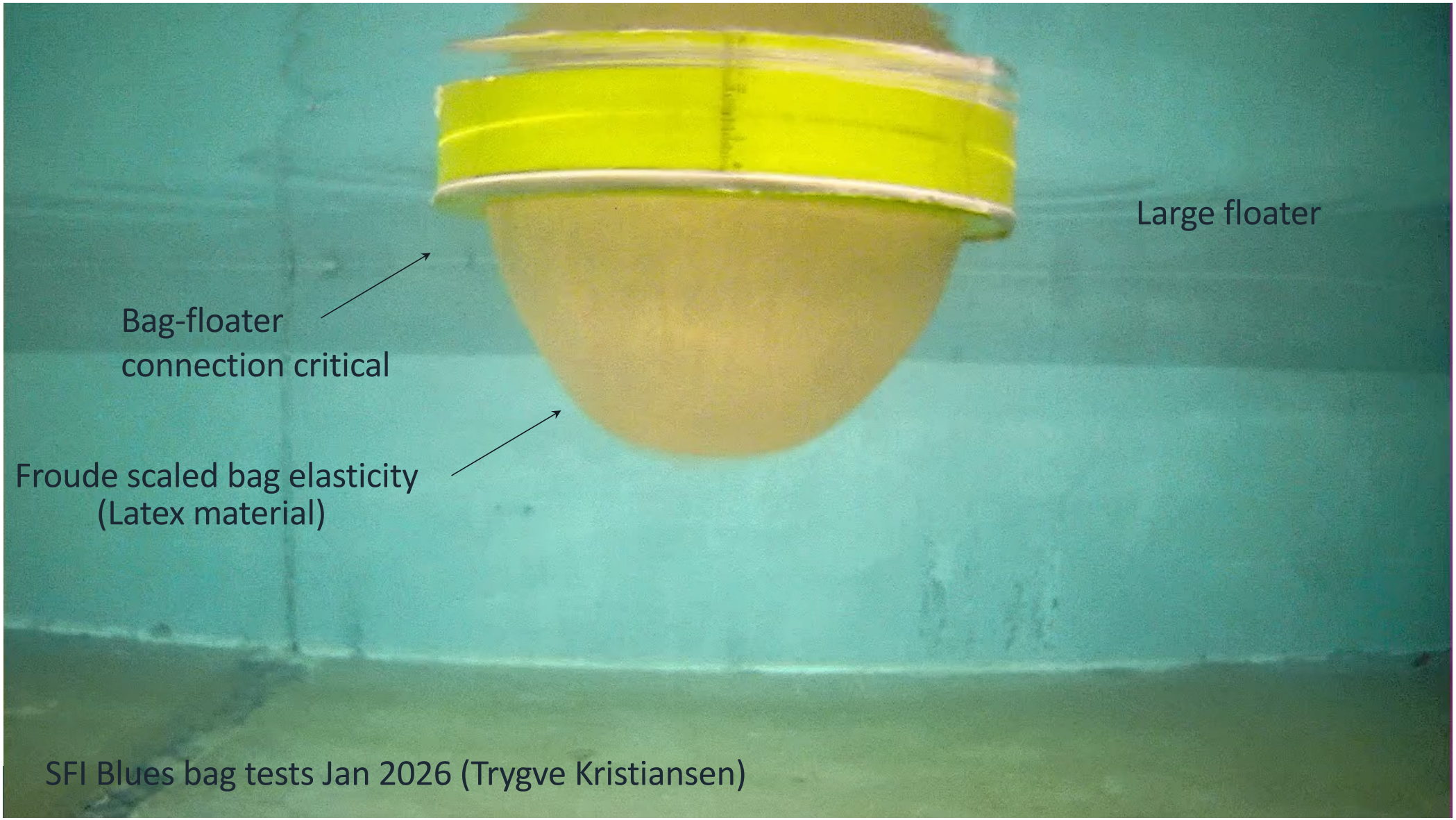


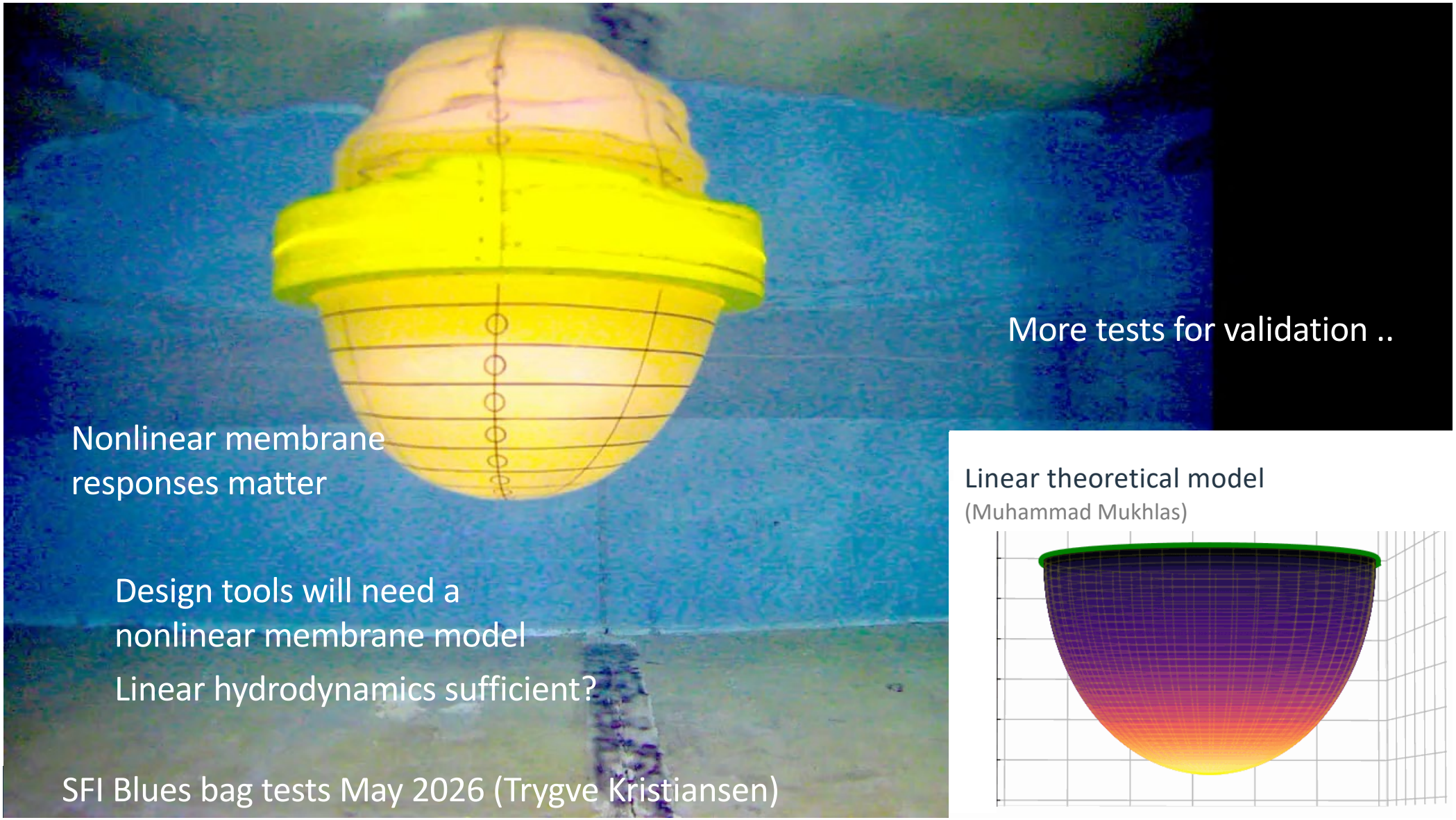
Navier-Stokes (CFD) in the computational domain

The user can choose to include viscous effects (CFD) or (traditional) potential flow

Aquaculture – testing bag solutions

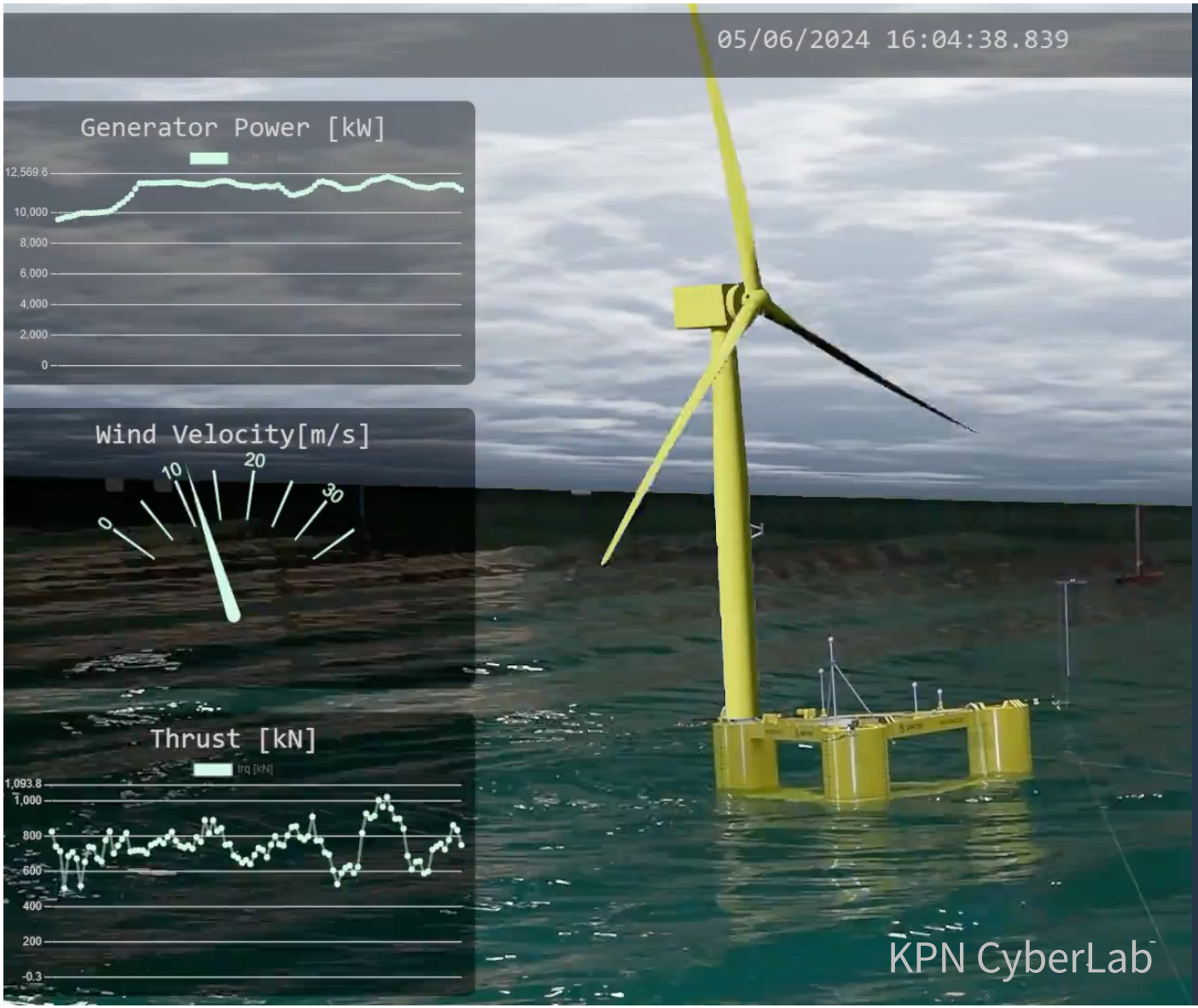



Large floater
Bag-floater
connection critical
Froude scaled bag elasticity
(Latex material)
SFI Blues bag tests Jan 2026 (Trygve Kristiansen)



Linear theoretical model

(Muhammad Mukhlas)



Digital twins and system identification

SFI BLUES

Why digital twins?

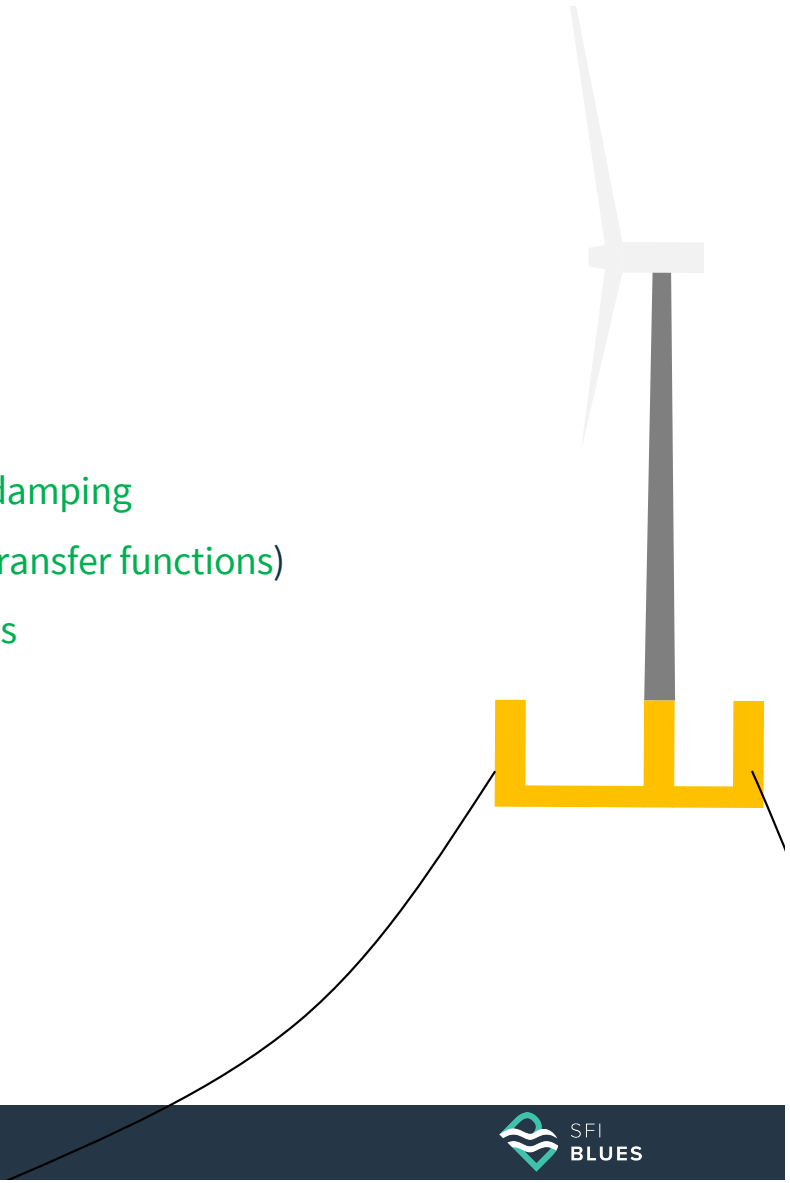
Use observations to build reliable models

Observation data can unlock substantial value—in principle.

- Motion in still water? → indicates added mass and damping
- Motion in waves → indicates wave loads (and transfer functions)
- Deformation of a flexible structure? → reveals the distributed loads

Challenges

- Measurements are often missing or inaccurate.
- Too little data—or experiments not designed for the purpose.
- Different causes can produce the same observation.



In RFQs and test programs

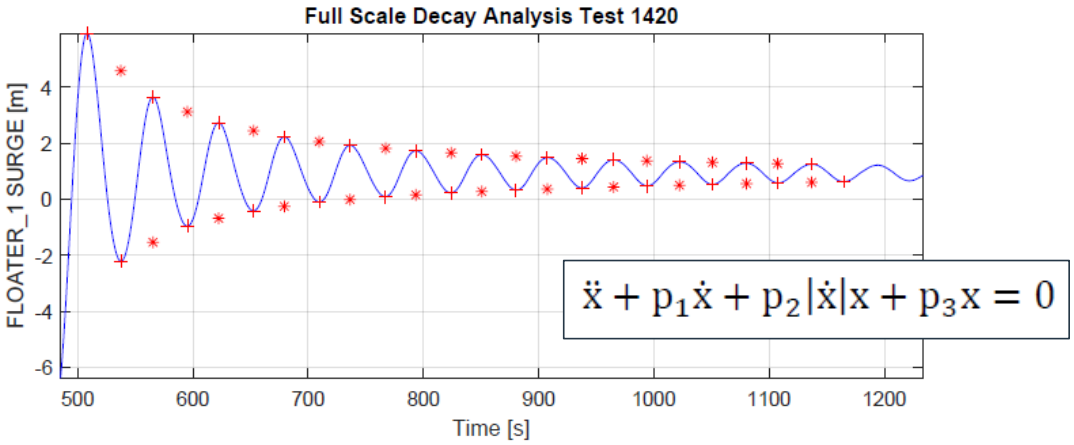
9.1.2. Decay Tests

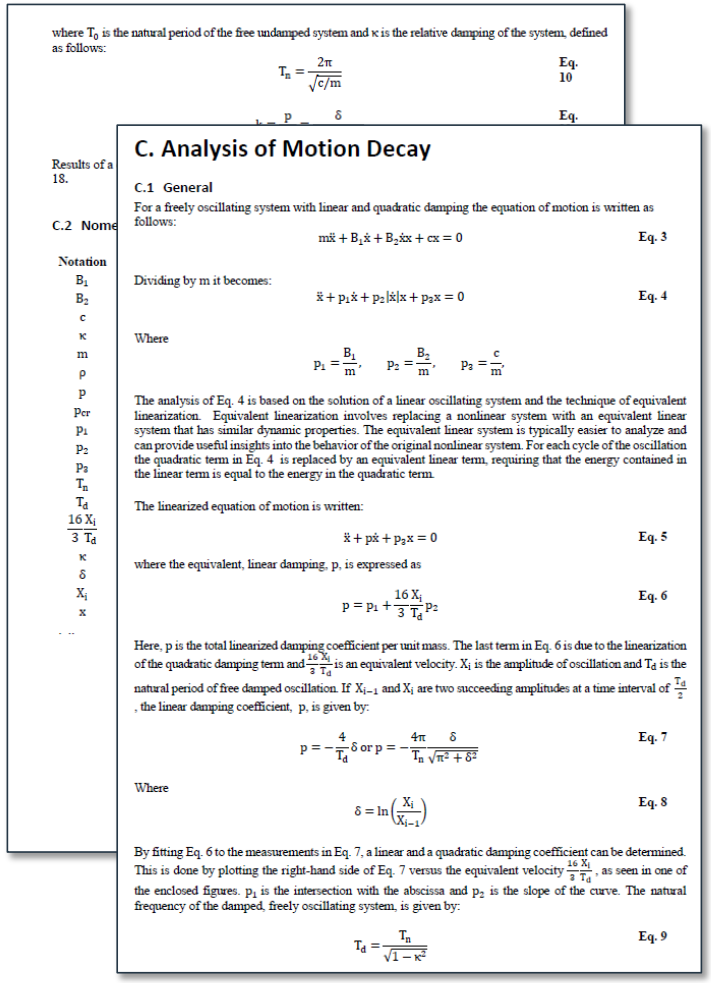
These tests shall consist in decay tests in free model, in soft mooring system and in full mooring system. SUPPLIER shall perform decay tests with all DoF that deliver a restoring force (roll and pitch only in free model, as heave decay test is very difficult to perform; surge, sway, roll, pitch and yaw in soft mooring system; surge, sway and yaw in full mooring system).

Test no.	Test identification	Test type	User def.	User def.	User def.	User def.	User def.	User def.	Date (dd.mm) (+/-)
1010	BENCHMARK TEST	Benchmark test							
1100	DECAY ROLL FREE FLOATING 5DEG	Decay	Roll	Free floating		5deg			+27/08
1110	DECAY PITCH FREE FLOATING 5DEG	Decay	Pitch	Free floating		5deg			+27/08

...

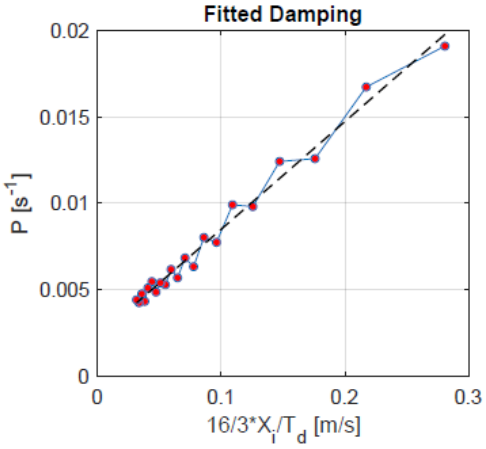




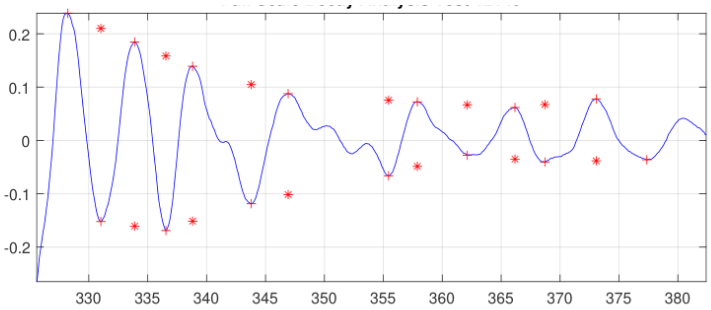


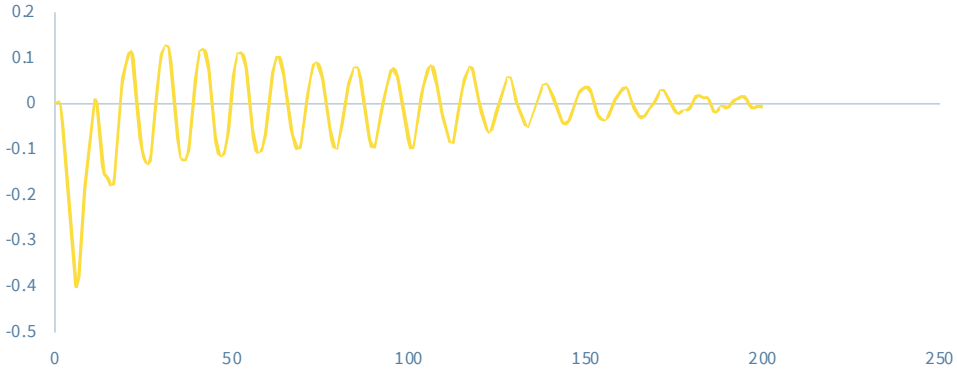
DECAY ANALYSIS RESULTS

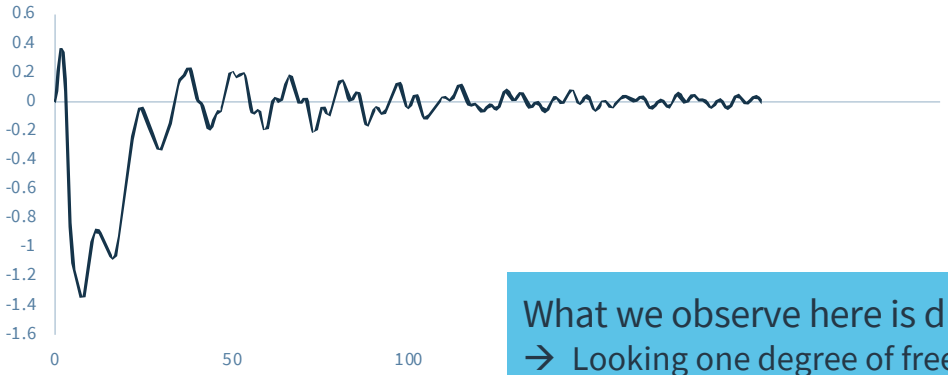
N° of crests	[-]	: 12
N° of troughs	[-]	: 12
T_d	[s]	: 56.91
T_n	[s]	: 57.02
P/P_{crit} (mean)	[-]	: 3.557e-02
P (mean)	[s^{-1}]	: 7.855e-03
P_1	[s^{-1}]	: 2.258e-03
P_2	[m^{-1}]	: 6.230e-02

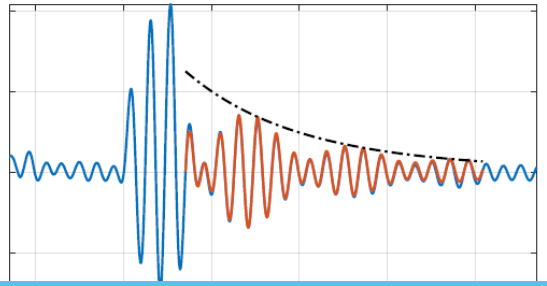


But sometimes, things don’t go as planned…









What we observe here is due to **couplings between degrees of freedom**

→ Looking one degree of freedom does **not provide enough information**

→ Trying to achieve a decay «in one given degree of freedom» is **difficult to realize in practice**

EZDK: new tool for the analysis of decay tests

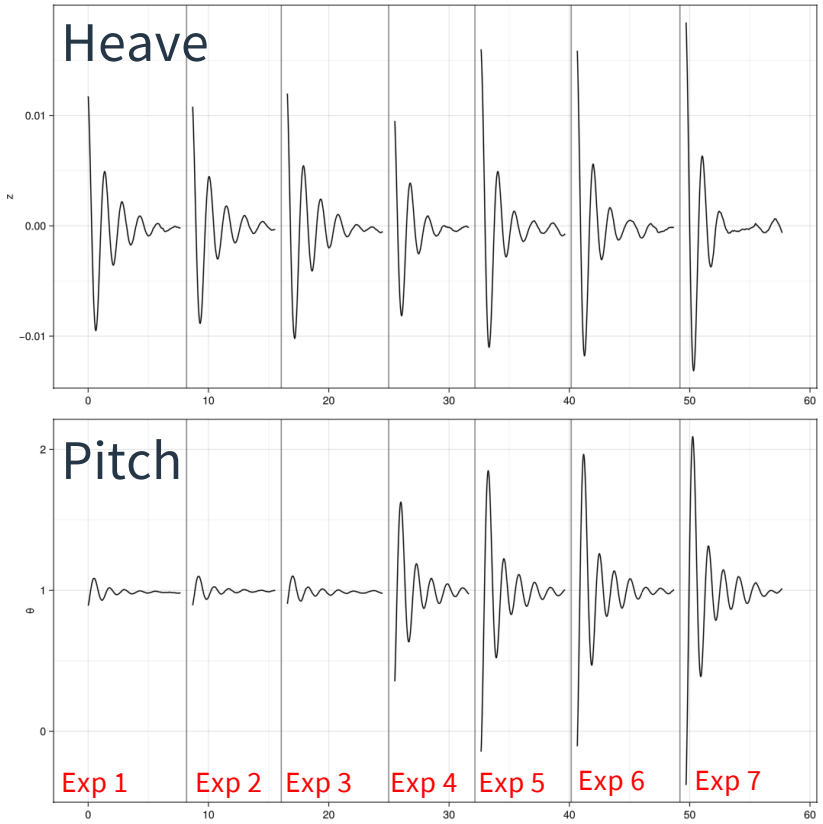
Example for a ship with strong heave/pitch coupling →

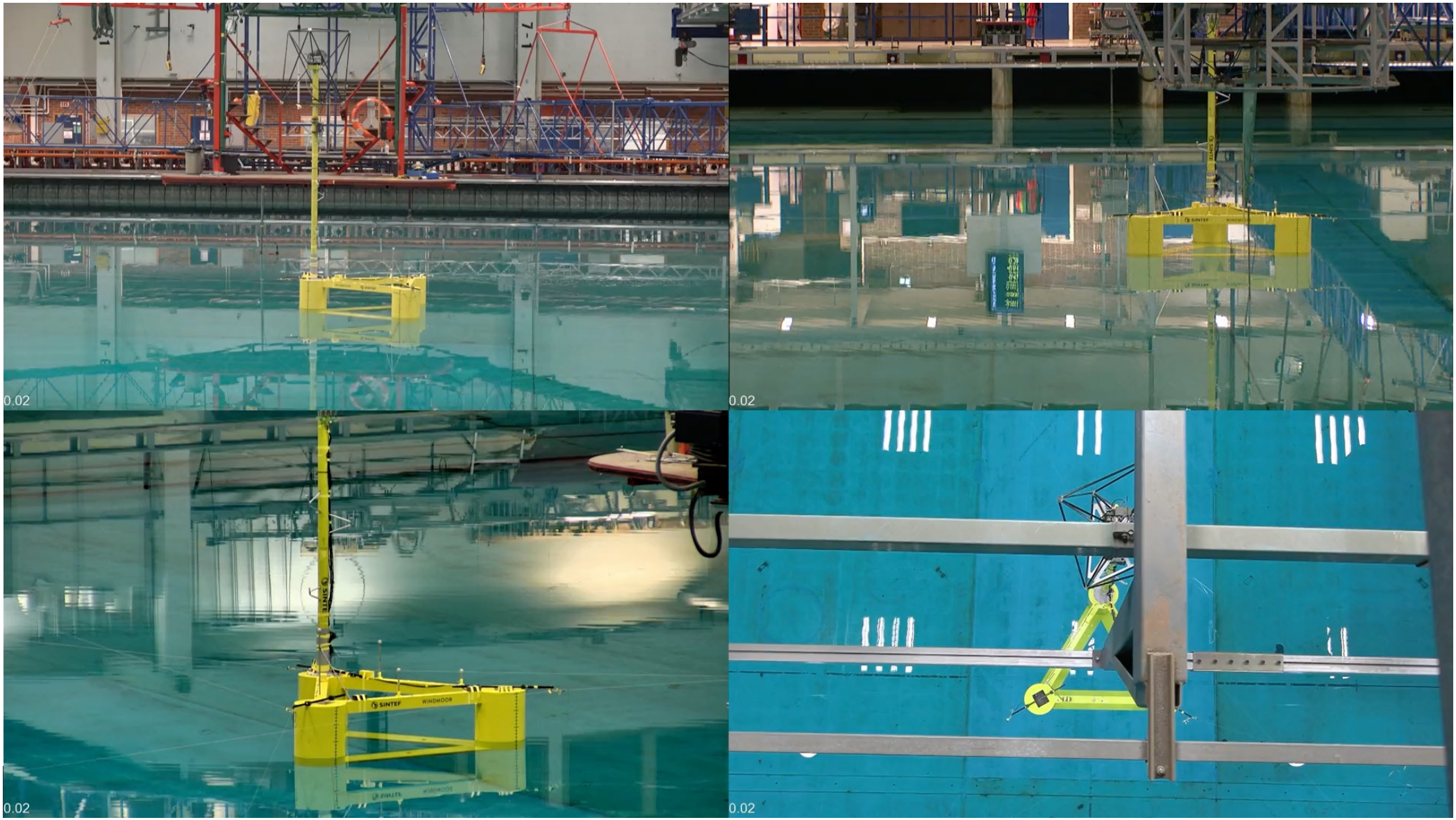
Features of EZDK:

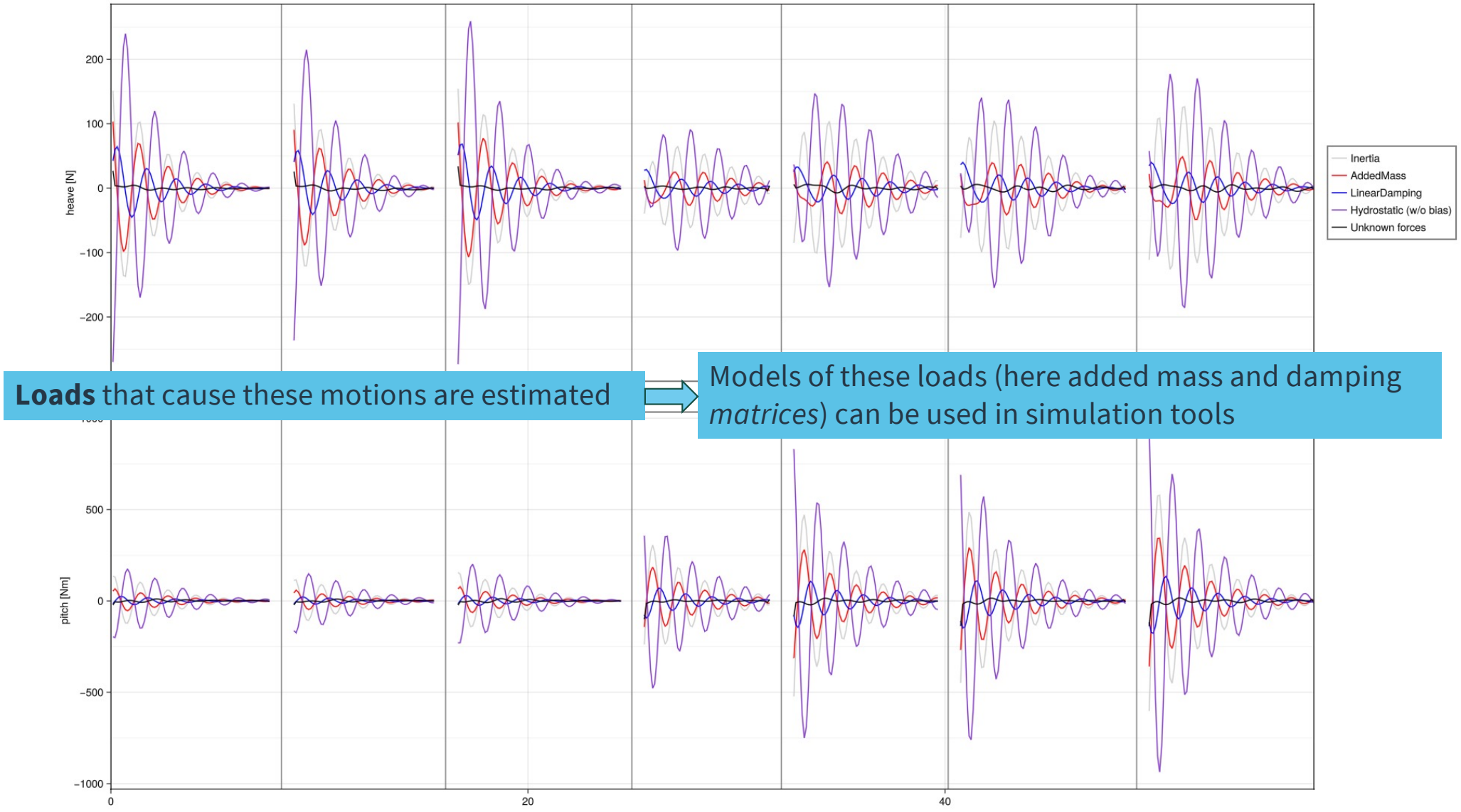
- ✓ **Several degrees of freedom** considered
- ✓ **Couplings** included
- ✓ Consider **several experiments** at once
- ✓ **Flexibility** of the physical model (not limited to linear and quadratic damping & linear stiffness)

Solves a practical challenge met for decades

(and tackled with dubious workarounds!)




0.02
0.02
SINTEF
WINDMOOR
0.02
0.02

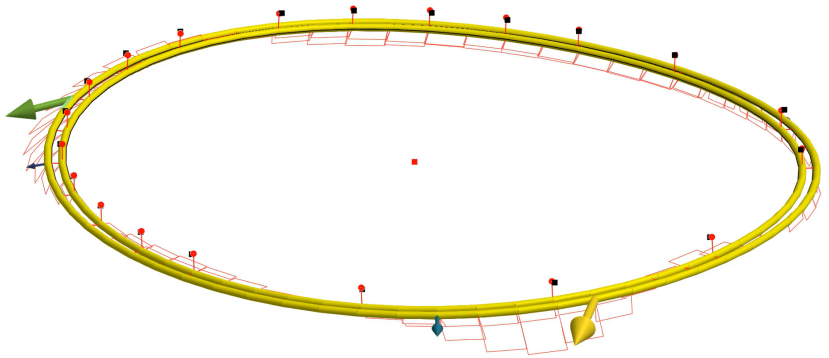


Loads that cause these motions are estimated

Models of these loads (here added mass and damping *matrices*) can be used in simulation tools

Use of inverse methods

- Extend the same theoretical approach to **flexible structures**
- Measurements from the lab include only the **motions at discrete points**
- Objectives:
  - Obtain the **full deformation field** satisfying dynamic equilibrium
  - Create **«virtual sensors»,** e.g. strain gauges, at any location.
  - **External loads** can be estimated (red bars) and **better load models** developed

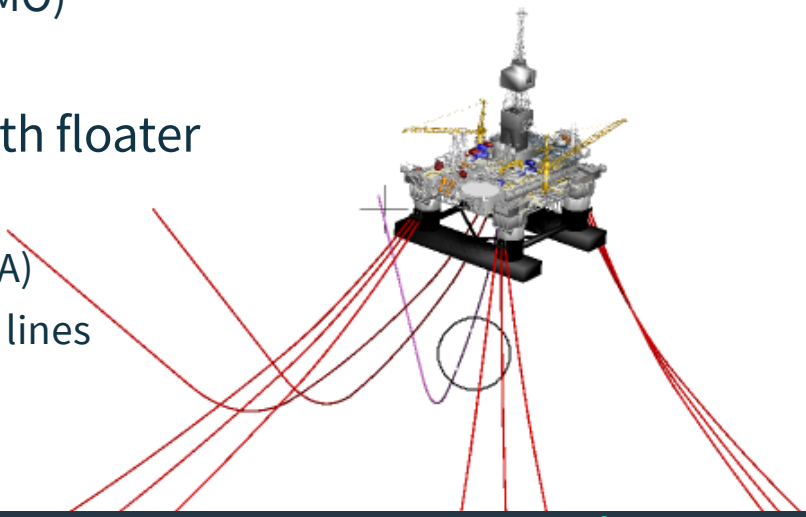




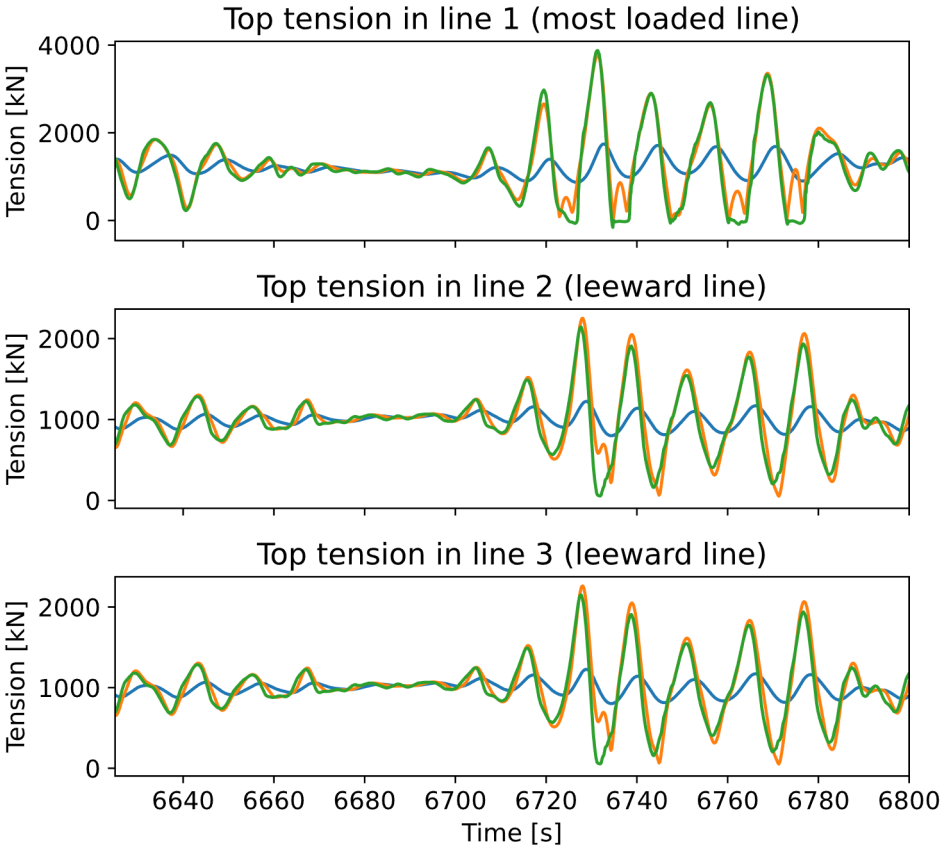
Mooring and anchors

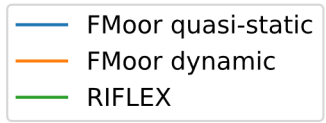
FMOOR – faster mooring analyses

- Modelling approaches as of today:
  - FEM with floater and lines (Coupled SIMO-RIFLEX)
    - Accurate, but CPU intensive
    - Not suited for massive screening and large models (shared mooring)
  - Floater with quasi-static mooring line model (SIMO)
    - Fast, but often not accurate enough
- **New:** Simplified mooring line model coupled with floater
  - Software component **FMoor**
  - To become the new mooring line model in SIMO (SIMA)
  - Simplified line dynamics and damping from mooring lines

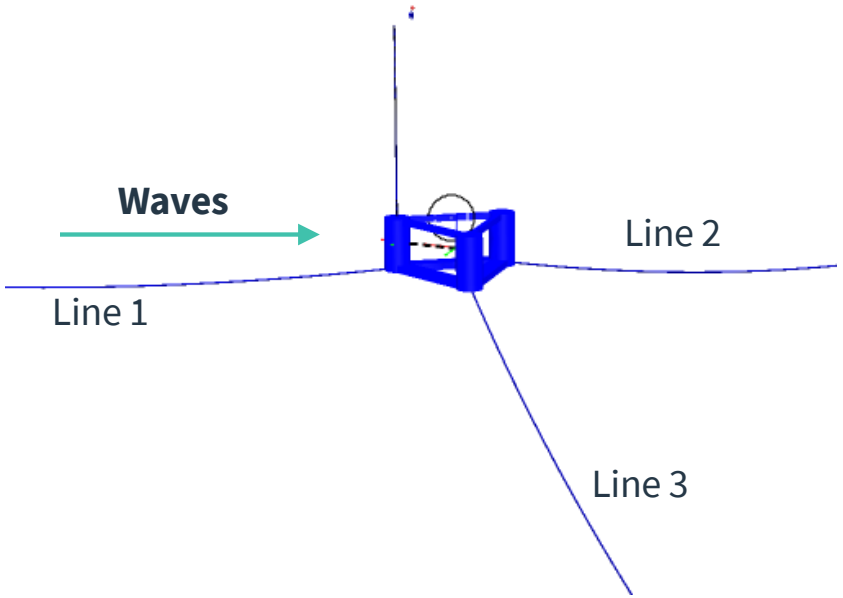


WINDMOOR Top tension - Hs=11.2 Tp=12s



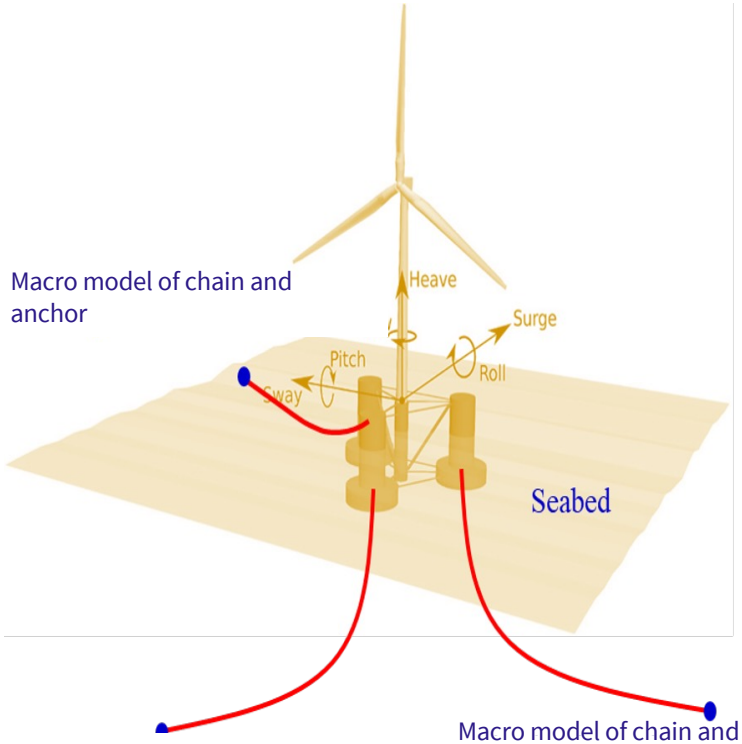


- 150 water depth
- 3 mooring lines with 3 segments
  - 25 m top chain
  - 170 m polyester
  - 500 m bottom chain

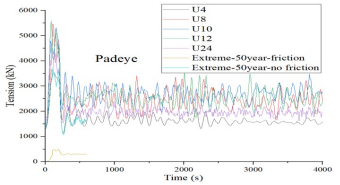


Optimal anchor solutions

- Developed numerical models for anchors and chain-soil interaction.
- Fully integrated analyses of floating structure and mooring system including the anchors and embedded chains/mooring lines.
- Prediction of potential development of seabed trenches due to mooring line motion.

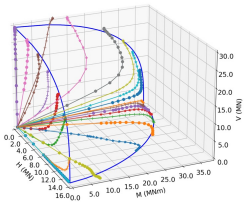


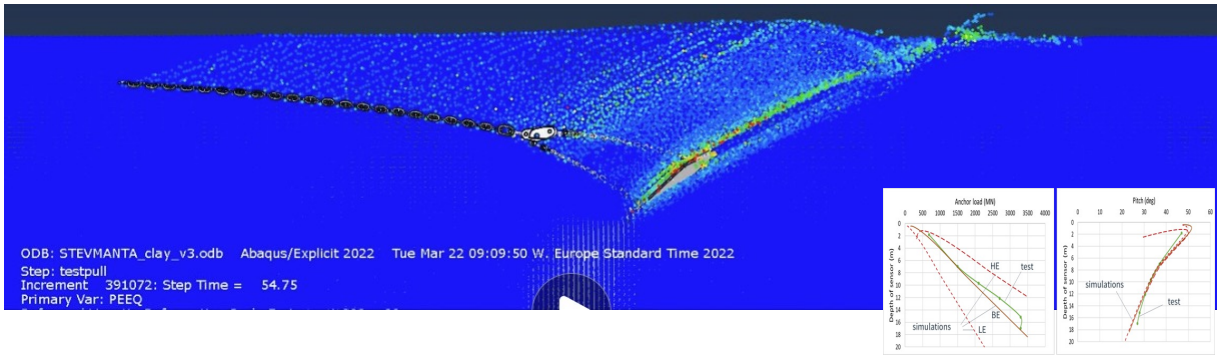
Macro model of chain and anchor

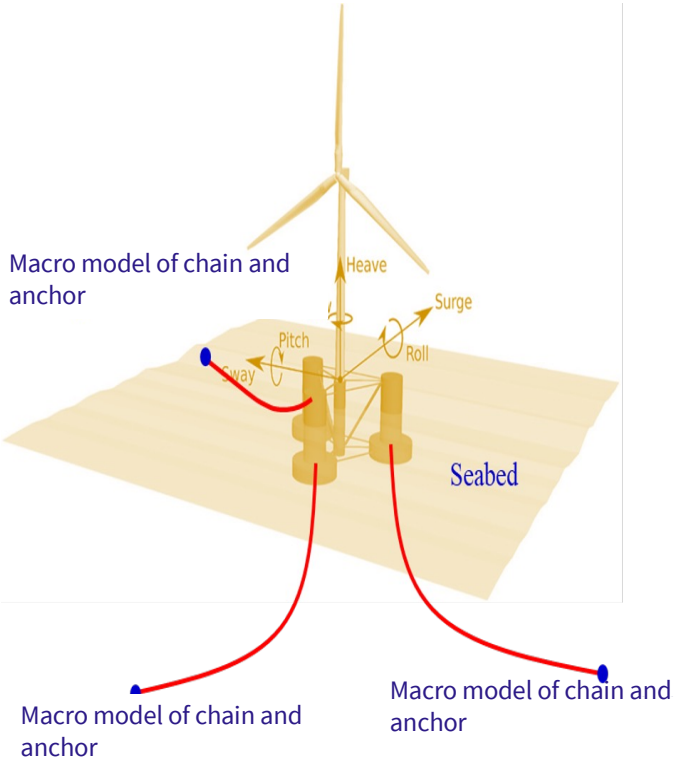


Numerical test tank of anchors

- Numerical model for all type of anchors
  - Macro-model concept
- Calibration of the model by numerical simulations
  - Import of anchor geometry
  - Streamlined process of load probing
- Verification by model and field tests









In summary

A large set of open source tools developed

FEM-MEL
FINITE ELEMENT METHOD – MIXED EULERIAN LAGRANGIAN
FAST AND STABLE NUMERICAL WAVE TANK FOR EXTREME SEA STATES

PVC3D
POTENTIAL VISCOUS CODE – SECOND ORDER

Metocean-Stats
STATISTICAL ANALYSIS & VISUALIZATION OF METOCEAN DATA

EZDK
EASY DECAY
ESTIMATE HYDRODYNAMIC COEFFICIENTS FROM MULTI-DOF DECAY TESTS

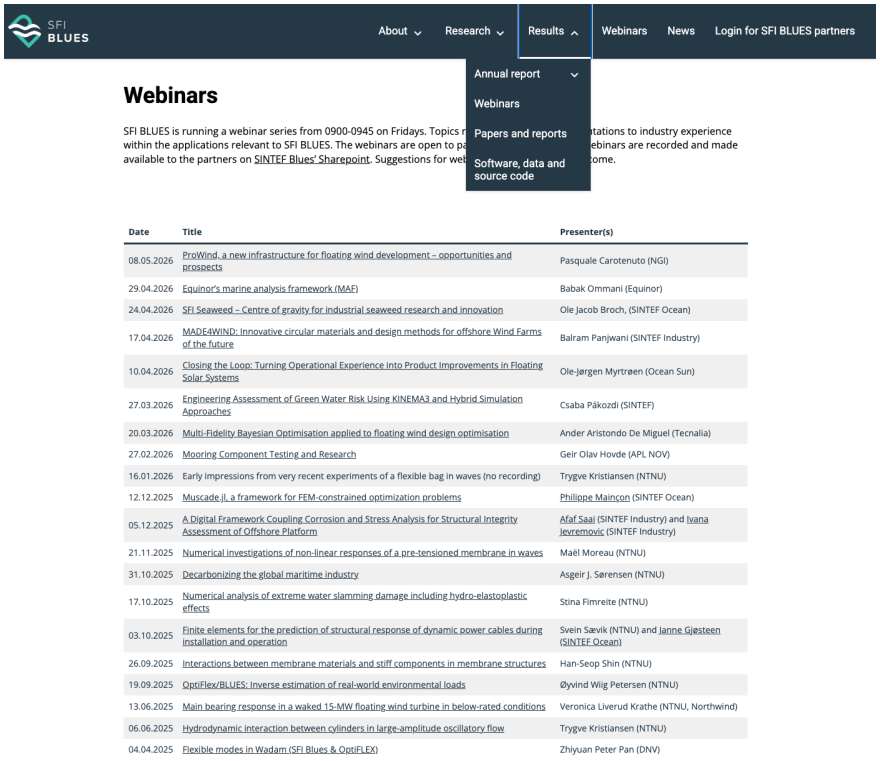
FMOOR
EFFICIENT TIME DOMAIN MODELS
FOR COUPLED MOORING LINE/FLOATER SIMULATIONS

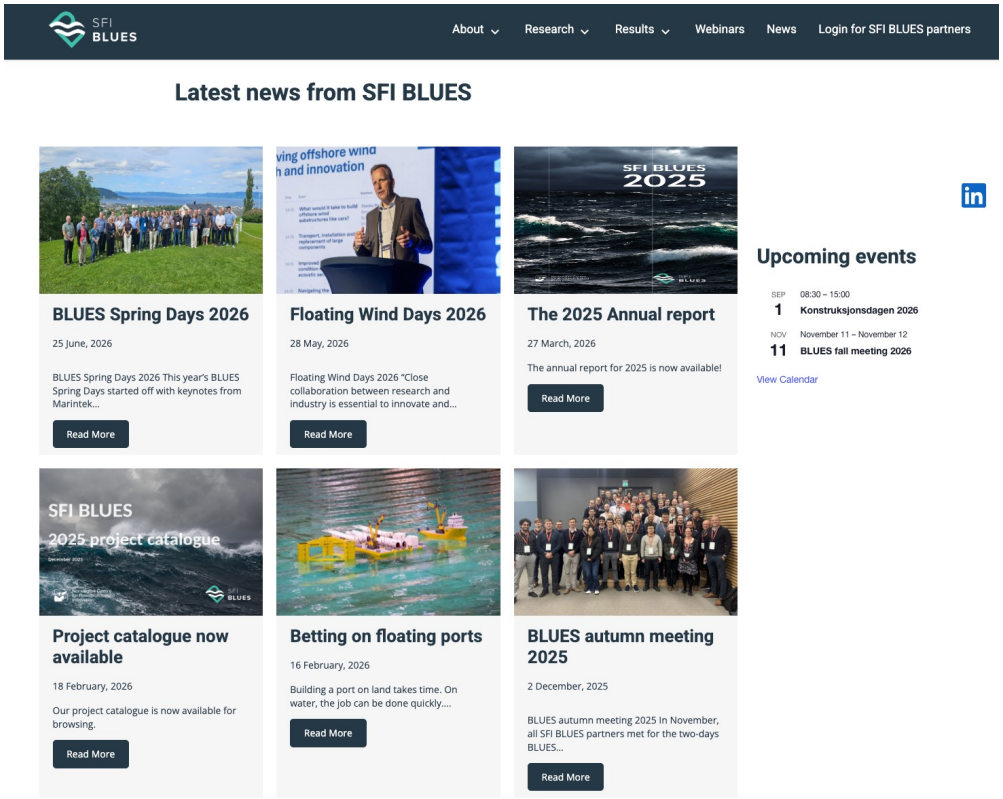
Muscade.jl
CREATE AND SOLVE OPTIMIZATION-FEM MODELS



Tools and software – open source and accessable on git

Knowledge exchange and meeting arena







Next phase

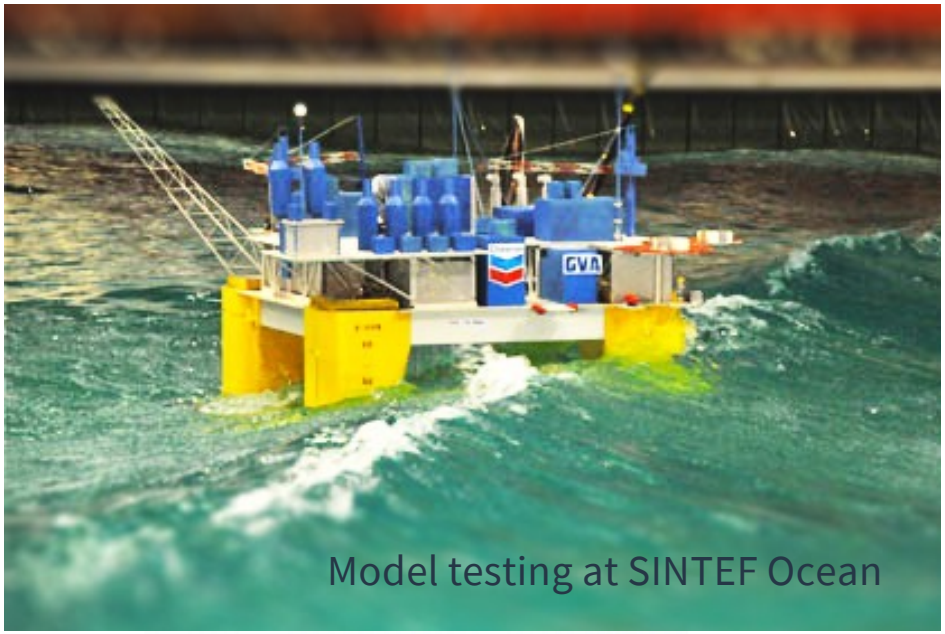

SINTEF
NTNU
Petrosenter lifeX
Life Extension of Offshore Structures
Maxime Thys, Hagbart Alsos, Bård Nyhus
Bjørn Skallerud, Jochen Köhler,
Øyvind Wiig Petersen, Vegard Aune

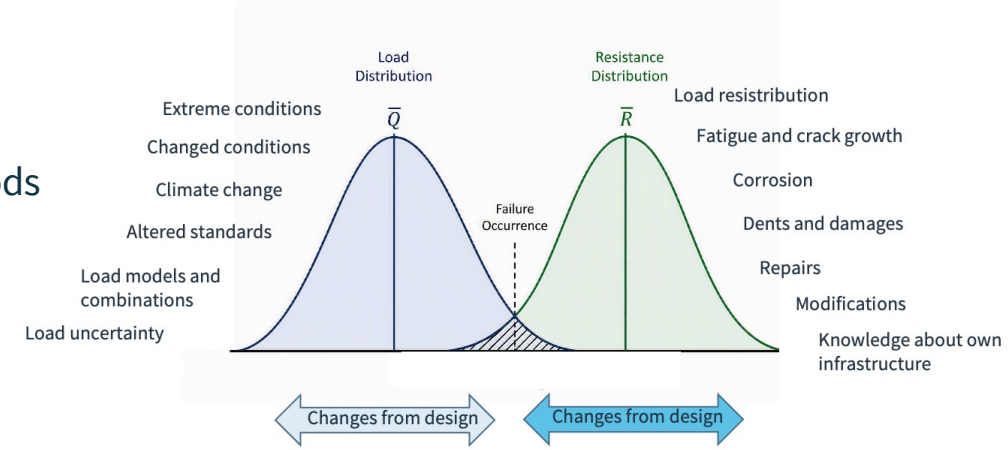
LifeX in a nutshell

LifeX is a long-term research and competence centre for safe lifetime management and life extension of offshore infrastructure

Addressed disciplines

- Materials, degradation and ageing
- Structural response and capacity
- Environmental loading and load uncertainty
- Structural reliability, risk and safety
- Monitoring, inspection and condition-informed methods





A centre of gravity for offshore lifetime extension

- Build the leading innovation-driven research centre for life extension and structural reliability.
- Develop the methods, tools and best practices
- Shape future engineering practices and educational programmes.
- Educate the next generation of engineers, researchers and specialists.
- Accelerate innovation, deployment, spin-offs and industrial uptake of new technology.





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