National Research Council of Italy

Marine Technology Research Institute

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Quando il vento soffia più forte: l'impatto dei cambiamenti climatici sul trasporto marittimo

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La risposta della ricerca CNR alle sfide ambientali – Roma 21 Dicembre 2015

Marine transport: relevant facts

Shipping and World Trade

About 90% of world trade is carried by the international shipping industry. Without shipping, the import/export of affordable food and goods would not be possible - half the world would starve and the other half would freeze!

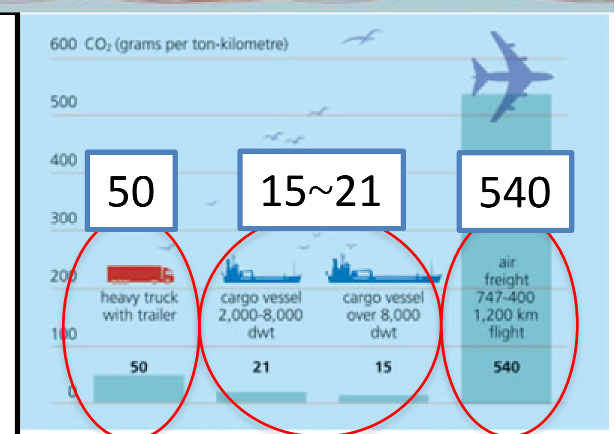
Safety and Regulation

Shipping is regulated globally by the International Maritime Organization (IMO). The harsh nature of the sea exposes ships to considerable physical risk, so a total commitment to safety pervades all deep sea shipping operations.

Environmental Performance

Shipping is the least environmentally damaging form of commercial transport and, compared with land based industry, is a comparatively minor contributor to marine pollution from human activities.

level of CO_2 emissions (grams per ton/kilometer) that emanate from the freight modes – truck, shipping and air.



The future of shipping, global trend 2050: Climate change and Environment *(DNV-GL report 2014)*

DNV·GL

According to OECD (*OCSE*), pressures on the environment from population growth and rising living standards will outpace progress in pollution abatement and resource efficiency. Already, signs of climate change, a growing scarcity of natural resources and threats to the environment have resulted in a renewed focus on environmental sustainability.

- A more hostile natural environment: Assuming GHG emissions continue to drive global temperature upward, we can predict **rising sea levels, sea states, increased frequency and severity of storm surges,** etc.
- Strained resources: Climate change will affect (varying by region) the availability of food, water and energy, with **relevant shift in production sites/trade patterns.**
- Pollution and public health: Air pollution will become the world's top environmental cause of premature mortality, overtaking lack of sanitation or dirty water. Particulate matter (as a result of power generation and transport) will rise in concentration. **Climate changes will also create new social and economic tension and competition for resources.**

Implications for shipping

Reduction of shipping footprint

Arctic shipping

New cargoes and trade patterns

Climate change adaptation:

Ship, ports and yards are all vulnerable to climate change. The expected shift in wave patterns, increased wave heights, and more severe weather conditions will call for improved design and operational safety standards. Increased intensity of wind speed, storms and storm surges represent risks to yards and port infrastructures and operation.

Implications for shipping

Safety

- **Structure**: material failure under unexpected loads, fatigue, collisions during operations, etc.
- **Hydrodynamics**: loss of stability (capsize, broaching), liquid cargo motions, etc.

Energy efficiency

- **Added resistance** in waves
- **Longer routes**

Implications for shipping

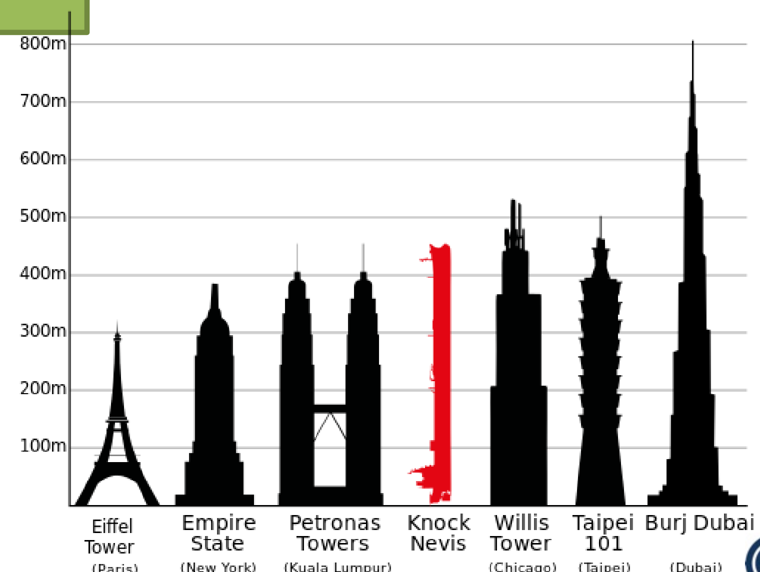
<u>Mathematical complexity</u>

- Highly non linear phenomena
- Uncertainties in the operating environment

High-Fidelity solvers (e.g. URANS, DES, LES) and Stochastic Optimization

Simpler tools will probably give the wrong answer, as well as the wrong design trend

- *Potential flow solvers might show good prediction versus the experiments, but are unable to distinguish among design alternatives*
- *Failure of deterministic designs in off-design conditions*



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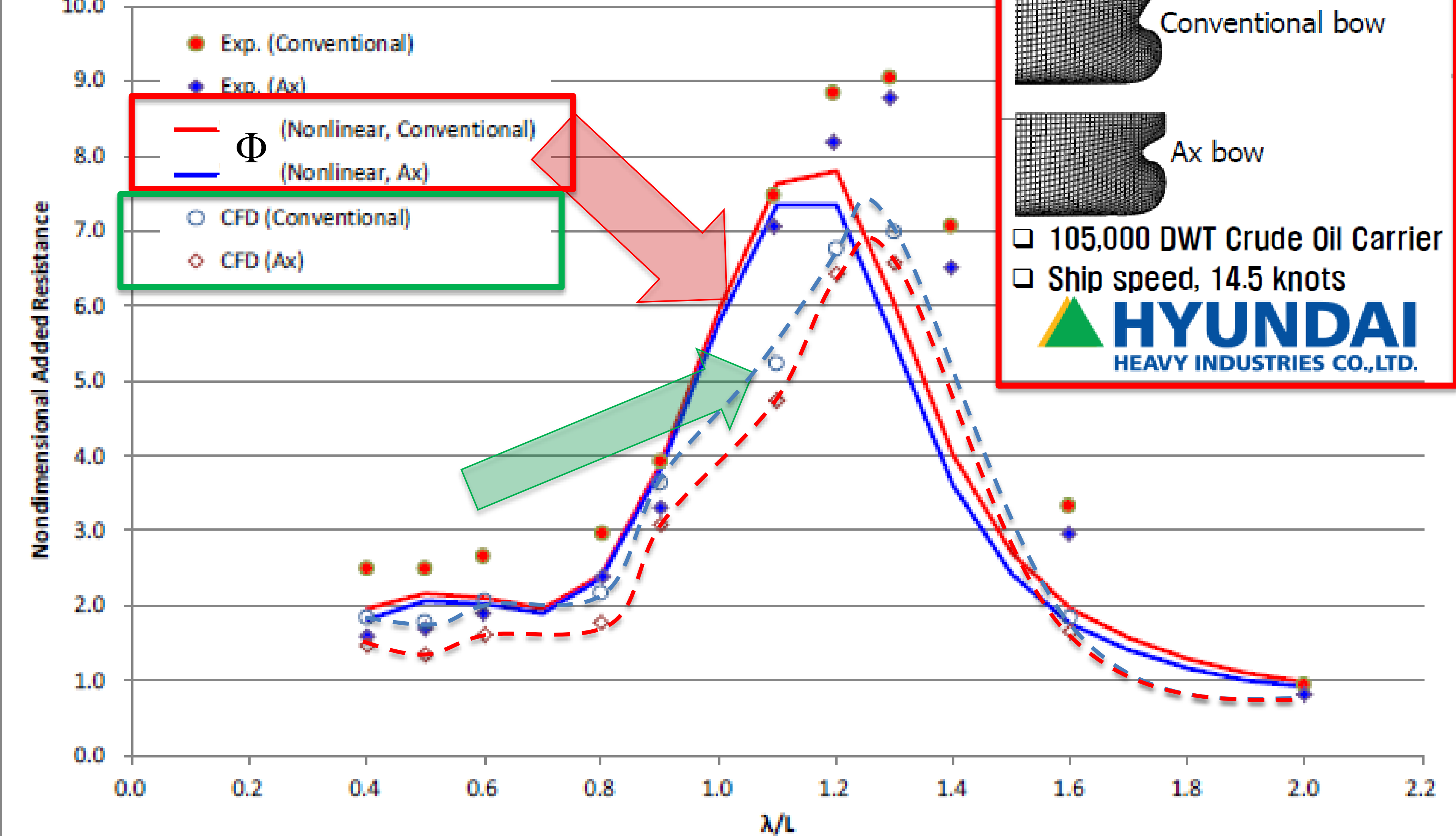


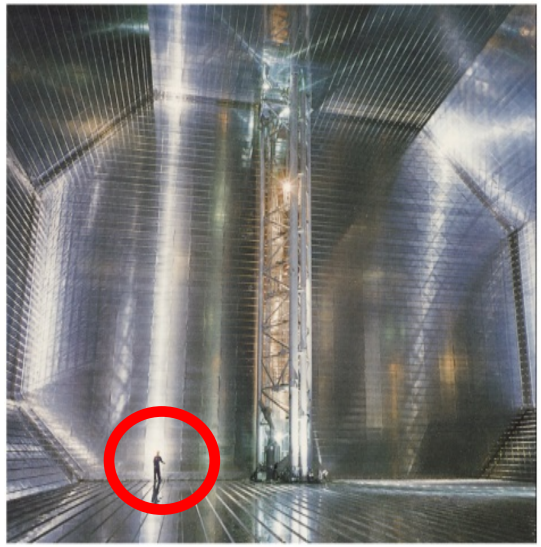
3D potential code results are not too far from the experiment. But, 3D potential code cannot show the difference between two hulls in terms of added resistance

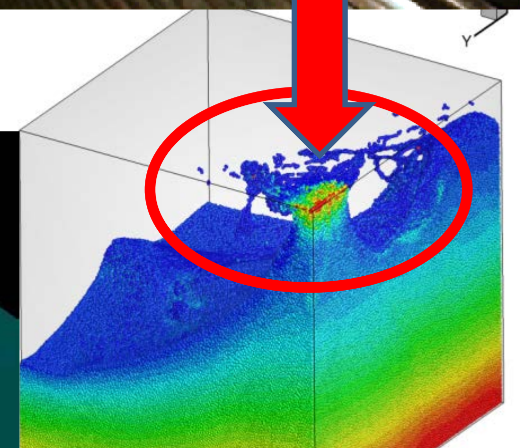
Results using CFD code give similar trend with experiment. They are smaller than experiments in all wave length but CFD can show somewhat the difference of added resistance between two bows

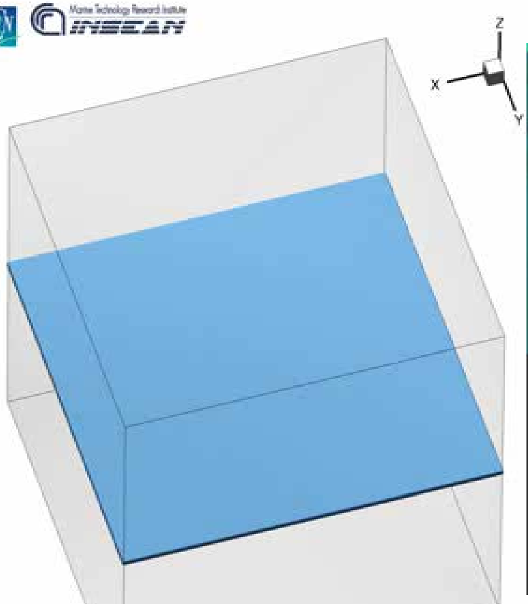
Implications for shipping

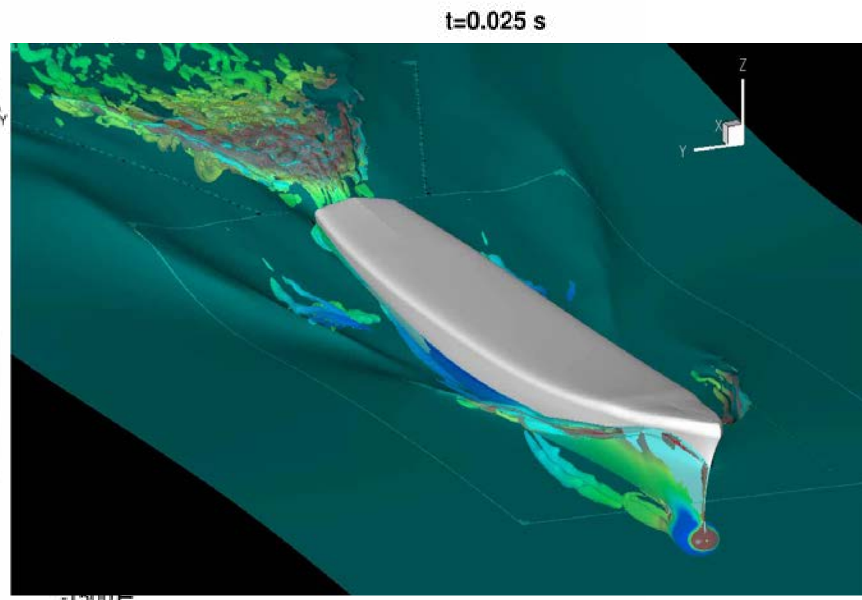
- Safety
  - **Structure**: material failure under unexpected loads, fatigue, collisions during operations, etc.
  - **Hydrodynamics:** loss of stability (capsize, broaching), liquid cargo motions, etc.
- Energy efficiency
  - Added resistance in waves
  - Longer routes

Hydro-elastic loads in sloshing LNG tanks









CNR – HYUNDAI partnership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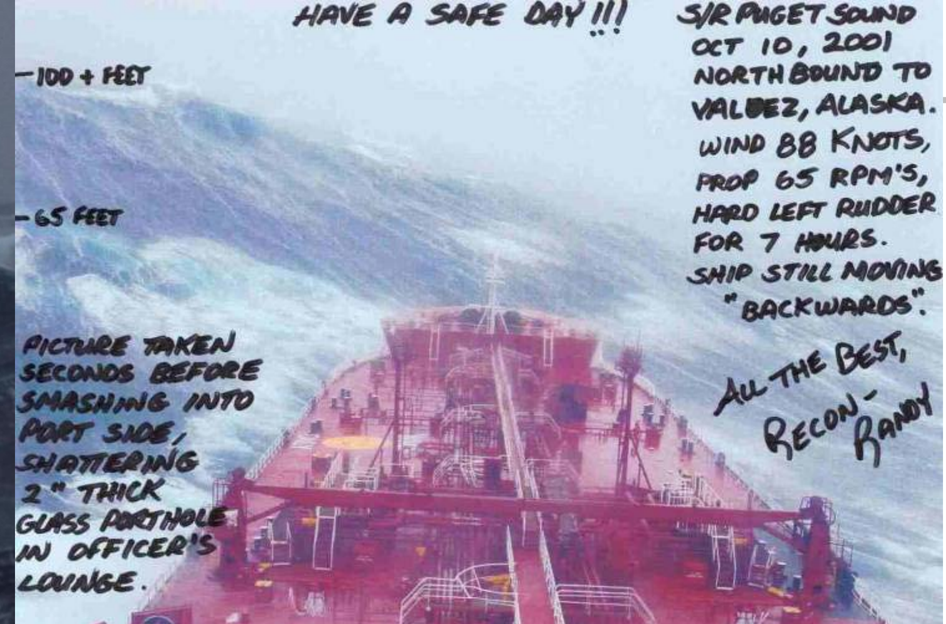
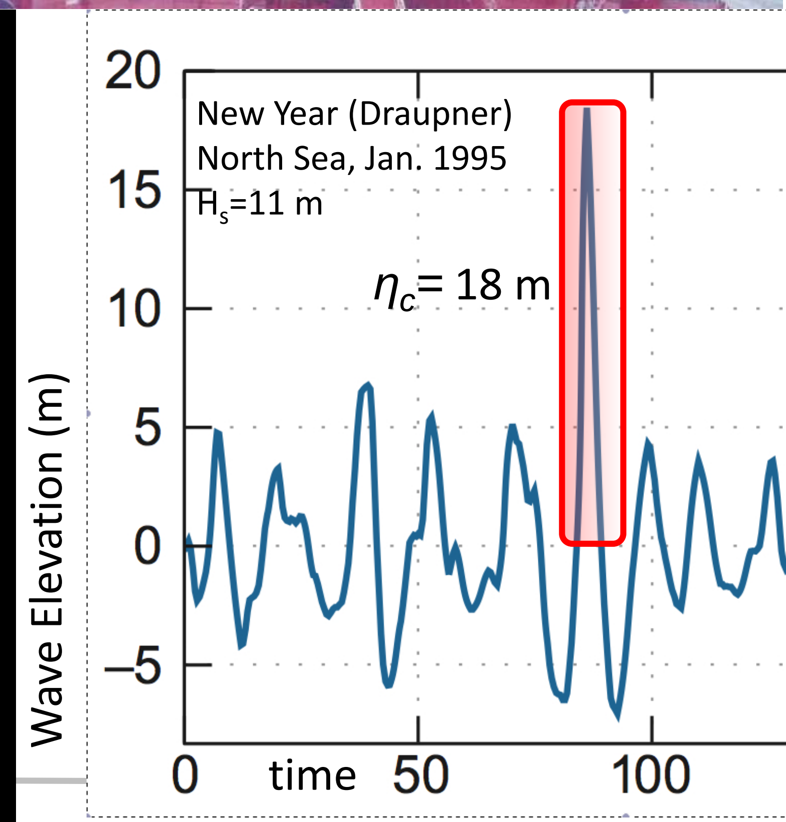
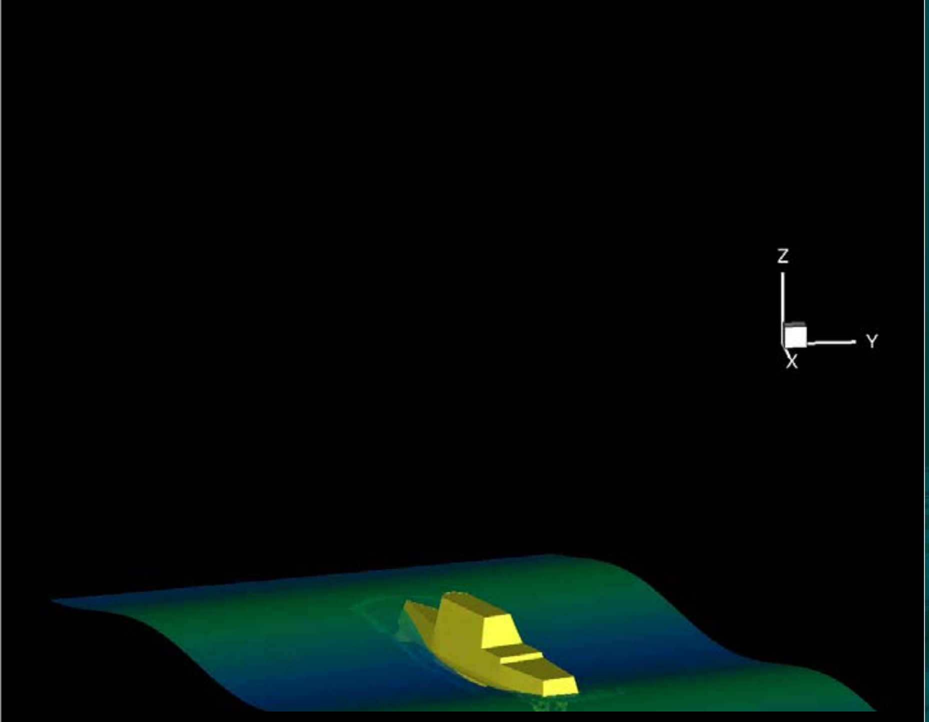
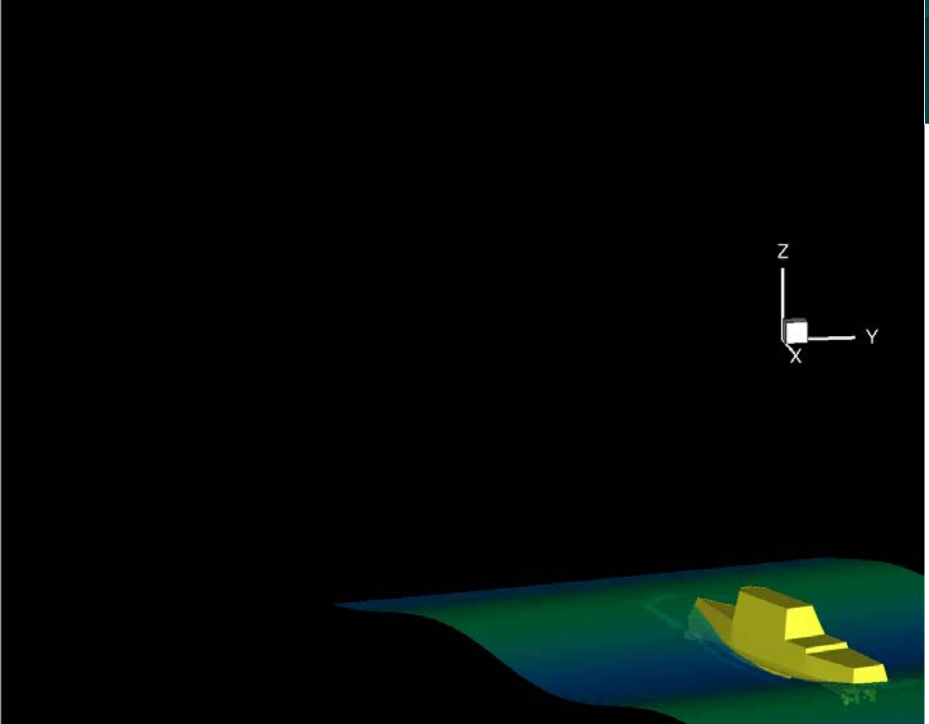
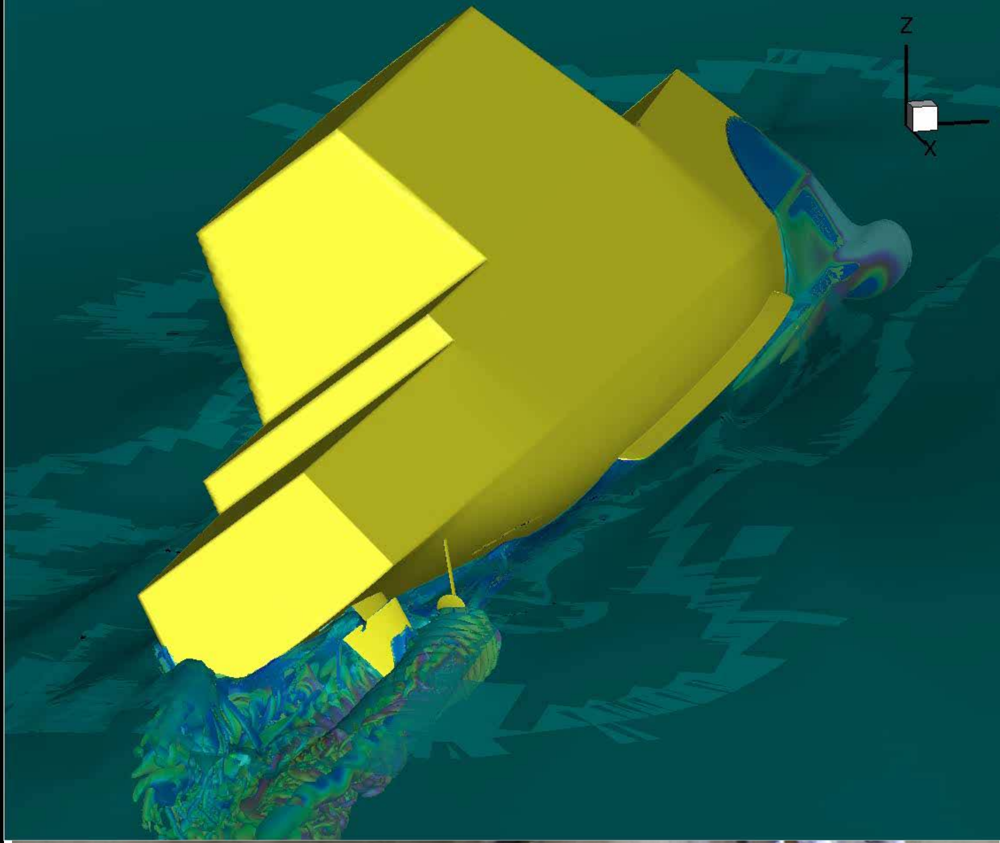
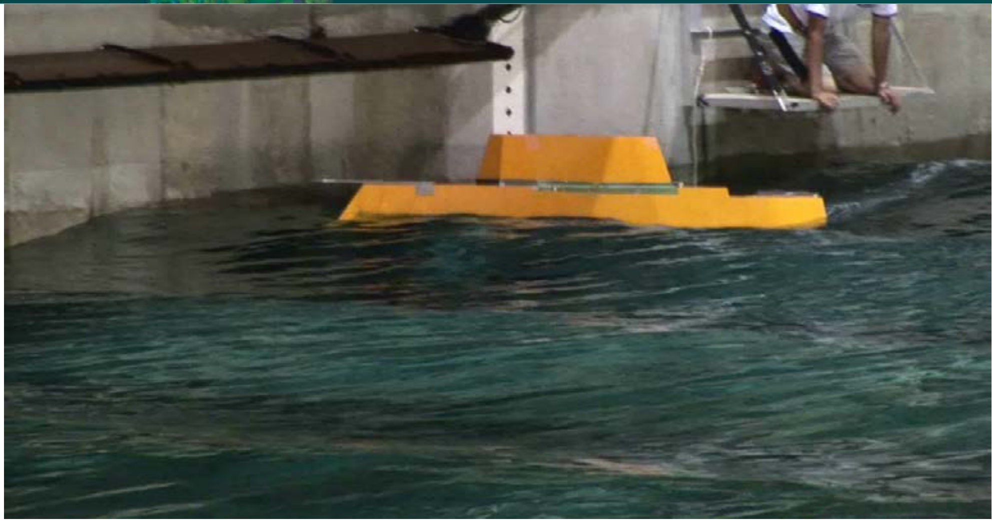

HAVE A SAFE DAY!!!
S/R PUGET SOUND
OCT 10, 2001
NORTH BOUND TO
VALDEZ, ALASKA.
WIND 88 KNOTS,
PROP 65 RPM'S,
HARD LEFT RUDDER
FOR 7 HOURS.
SHIP STILL MOVING
"BACKWARDS".
100 + FEET
65 FEET
PICTURE TAKEN
SECONDS BEFORE
SMASHING INTO
PORT SIDE,
SHATTERING
2" THICK
GLASS PORTHOLE
IN OFFICER'S
LOUNGE.
ALL THE BEST,
RECON-
RANDY


New Year (Draupner)
North Sea, Jan. 1995
H_s=11 m
η_c= 18 m
Wave Elevation (m)
time
20
15
10
5
0
−5
0
50
100

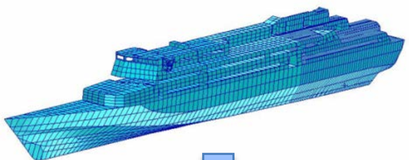


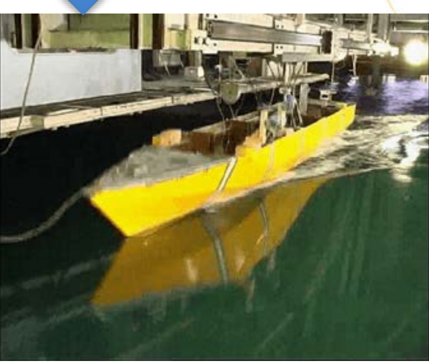






Carrica et al. 2011





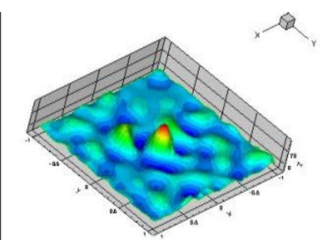
Ritmare

DEPARTMENT OF THE NAVY
ONR
Science & Technology

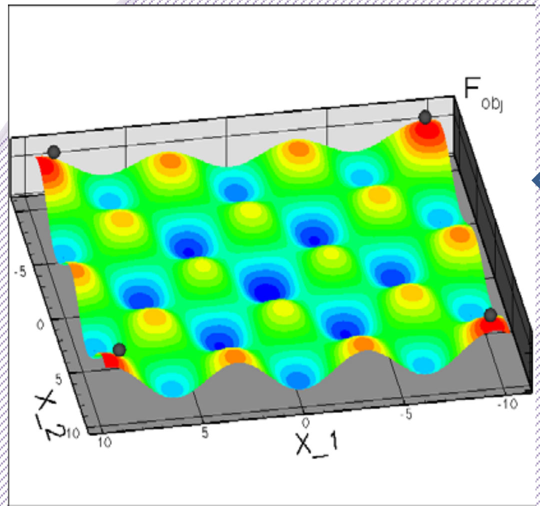
Stochastic Simulation-Based Design Optimization

High Performance Computing

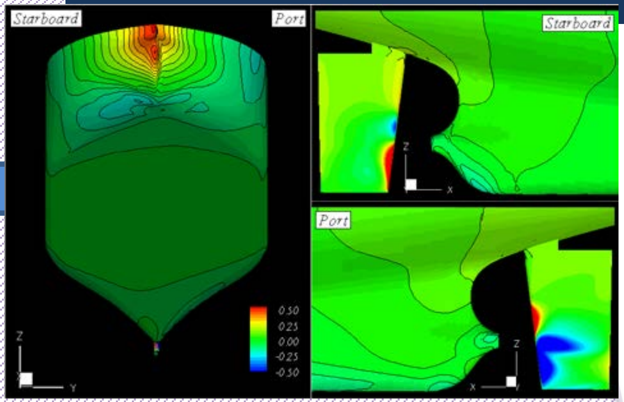
EFD check



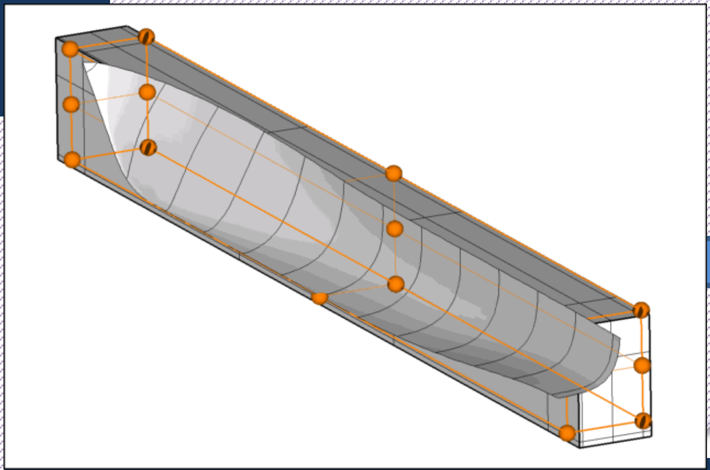
Dynamic Metamodels



Optimization algorithms



Accurate simulations



Automatic geometry and mesh deformation

Deterministic vs. Stochastic formulation

Input:

- *Unknowns u*
- *Design vector d*

u = velocity & pressure

x = ship's speed, R = Ship's total resistance

Deterministic

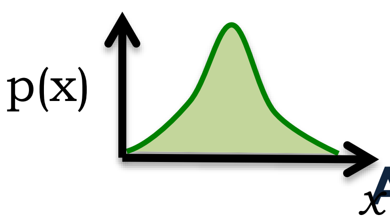
Input ***x*** *fixed*

Solve $\mathbf{R}(\mathbf{u},\mathbf{d},\mathbf{x})=0$

Stochastic

Input:

$\mathbf{x} := \mathbf{x}(\omega)$ *are random variables with known PDFs* $p(x)$

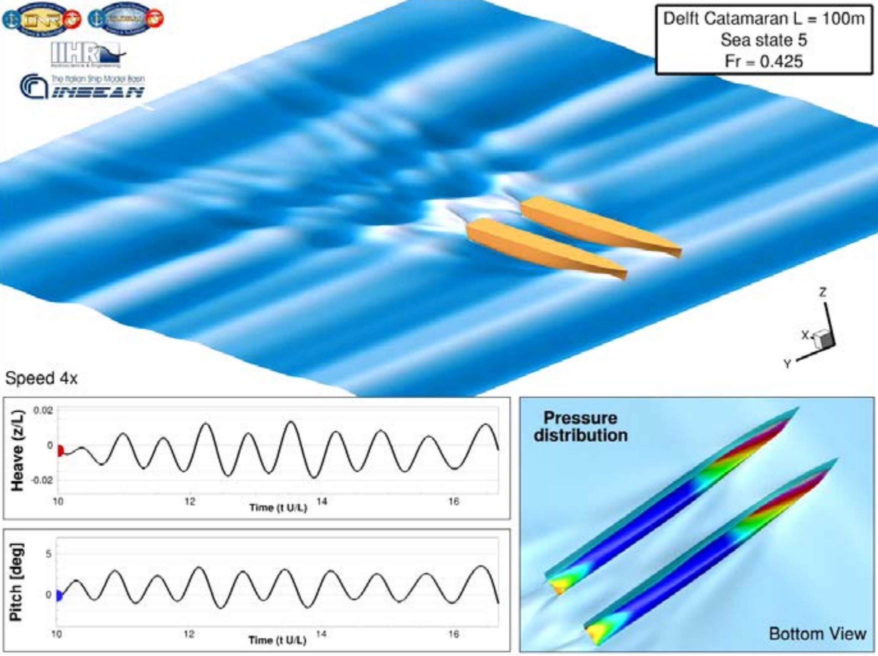


$$E(R) := \int_U R(u(x), d, x)\, p(x)\, du$$

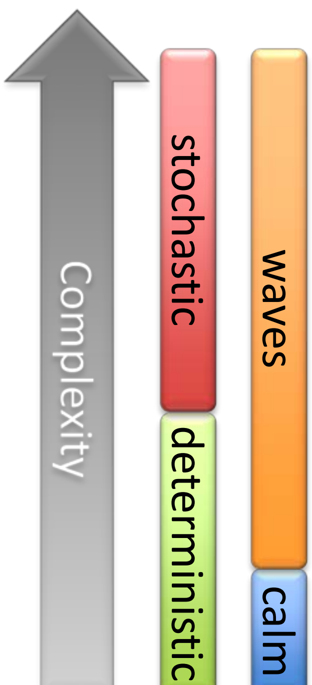
$$\sigma^2(R) := \int_U \left[R(u(x), d, x) - E(R)\right]^2 p(x)\, du$$

Analyze the sensitivity to input variations: Uncertainty Quantification (*UQ*)

Solution of hierarchical problems: computational complexity



- Optimization achievements are significant for all problems
- The average improvement is 26.1%



Opt. problem	Type	Objectives --- design conditions	Stochastic distributions for design conditions	Optimization achievements (best design for each problem) ΔF_1 [%]	ΔF_2 [%]
Problem #1	Multi-objective, stochastic	F_1 = EV(R_T) in head wave F_2 = O% (operability) --- variable Fr (0.115<Fr<0.575) and sea state; for each sea state, the wave frequency is variable	- Fr: uniform - wave frequency: based on Bretschneider spectrum (assessed by 1D UQ model) - sea state: as per North Pacific data	-11.8	-5.70
Problem #2		F_1 = mean R_T in head wave F_2 = SMF based on SSAs --- Fr = 0.425, sea state 5 with variable wave frequency	- wave frequency: based on Bretschneider spectrum (assessed by 1D UQ model)	-23.9	-83.6
Problem #3	Multi-objective, deterministic	F_1 = mean R_T in head wave F_2 = SMF based on SSAs --- Fr = 0.425, deterministic wave representative of sea state 5	n.a.	-26.0	-22.3
Problem #4	Single-objective, deterministic	F_1 = R_T in calm-water --- Fr = 0.5	n.a.	-9.63	-

Computational cost

1.5M CPU h
171 years

960k CPU h
100 years

100k CPU h
11 years

100k CPU h
11 years

Acknowledgements and partners

Department of the Navy – United States of America

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AleniaAeronautica – A Finmeccanica Company

BOEING

Italia Coni

DASSAULT AVIATION

DSO National Laboratories

European Defence Agency

esa – European Space Agency / Agence spatiale européenne

FINCANTIERI

Marina Militare

PIAGGIO AERO

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