Integrating ocean modelling to R&D projects in marine technology: future perspectives for the O&G Industry

Rafael Schiller, PhD
Department of Offshore Hydrodynamics
MARINTEK do Brasil

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SINTEF

Outline

- MARINTEK and SINTEF
- O&G Industry and the deep water environment
- A practical problem: flow-riser interaction and vortex-induced vibrations
- Integrating to ocean modelling products
- Other initiatives and conclusions

Trondheim

Bergen

Oslo

Houston

MARINTEK

Norwegian Marine Technology Research Institute

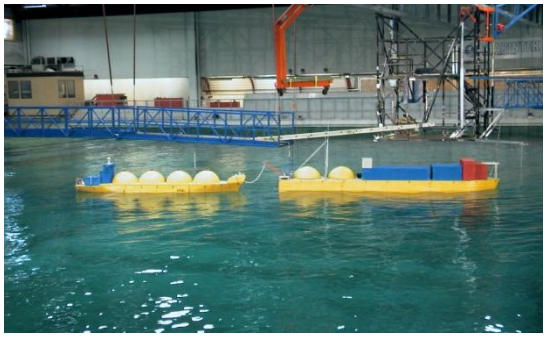
Main office in Trondheim
Offices in Oslo and Bergen
Subsidiary in Houston; MARINTEK (USA), Inc.
Subsidiary in Rio de Janeiro; MARINTEK do Brasil, Ltda.

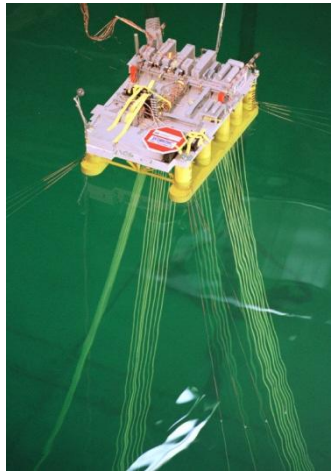
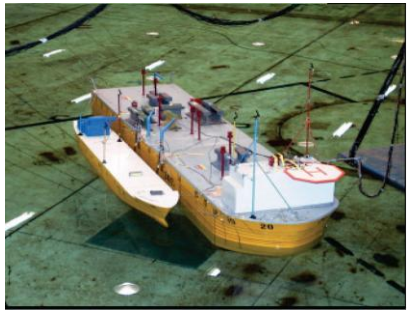
Rio de Janeiro

- **Oil and Gas**
  - **Offshore Hydrodynamics**
  - **Structural Engineering**
- Maritime
  - Ship Technology
  - Maritime Transport Systems
  - Energy Systems Technical Operation

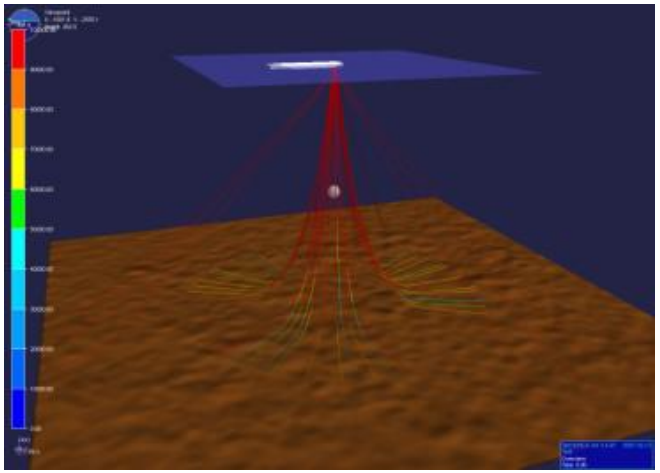
› 30 years offshore testing and analyses at MARINTEK

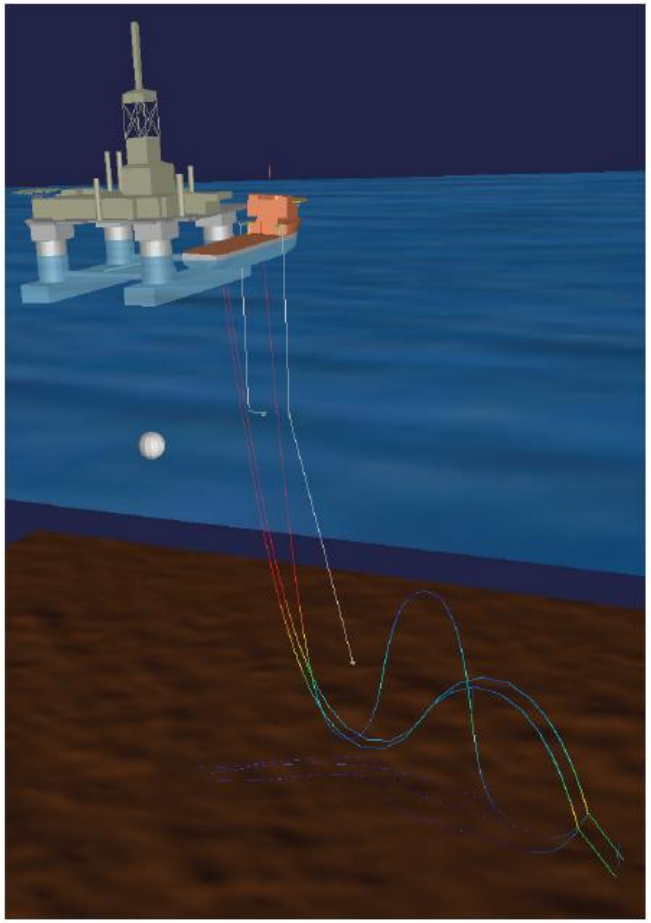


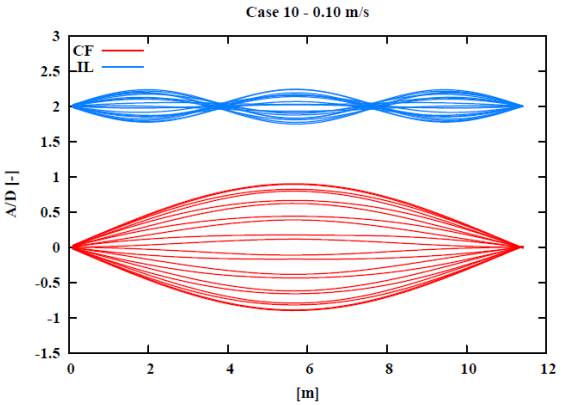


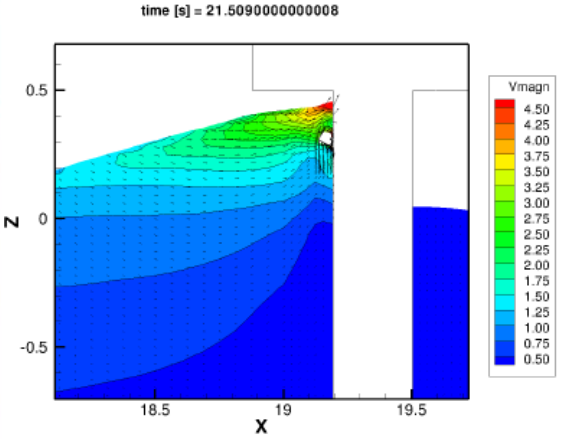




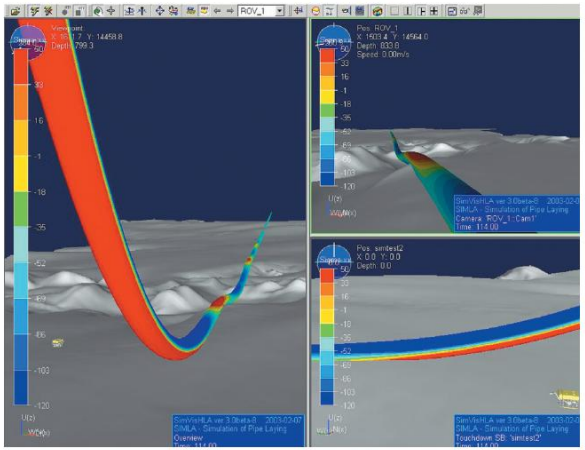

Development of software and numerical tools

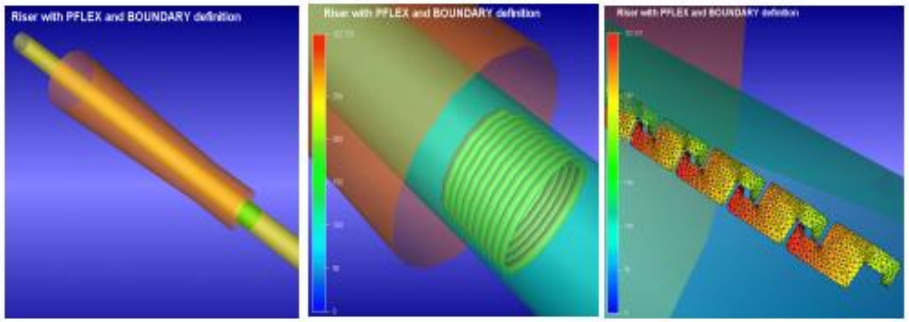


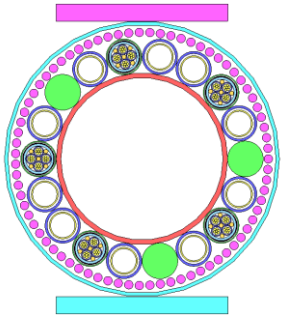






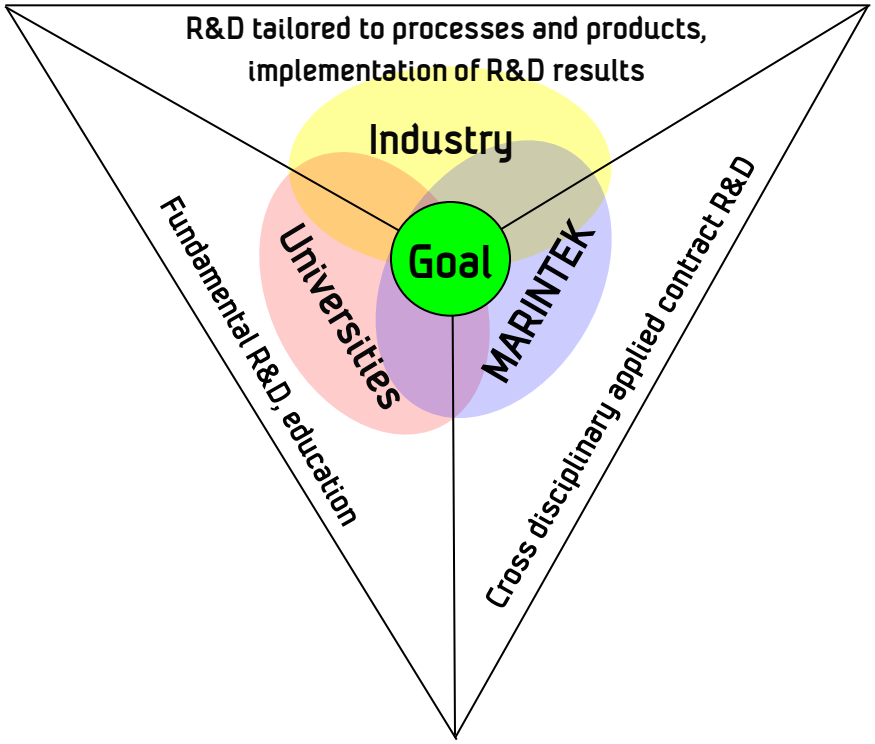






Preferred working mode: Integrated Partnership Model

Problems set and solved in the context of application



- Industrial Relevance
- Industrial Involvement
- Basic Scientific Methodology
- Integrity & Independence

The SINTEF Group

SINTEF Building and Infrastructure

SINTEF ICT

SINTEF Materials and Chemistry

SINTEF Technology and Society

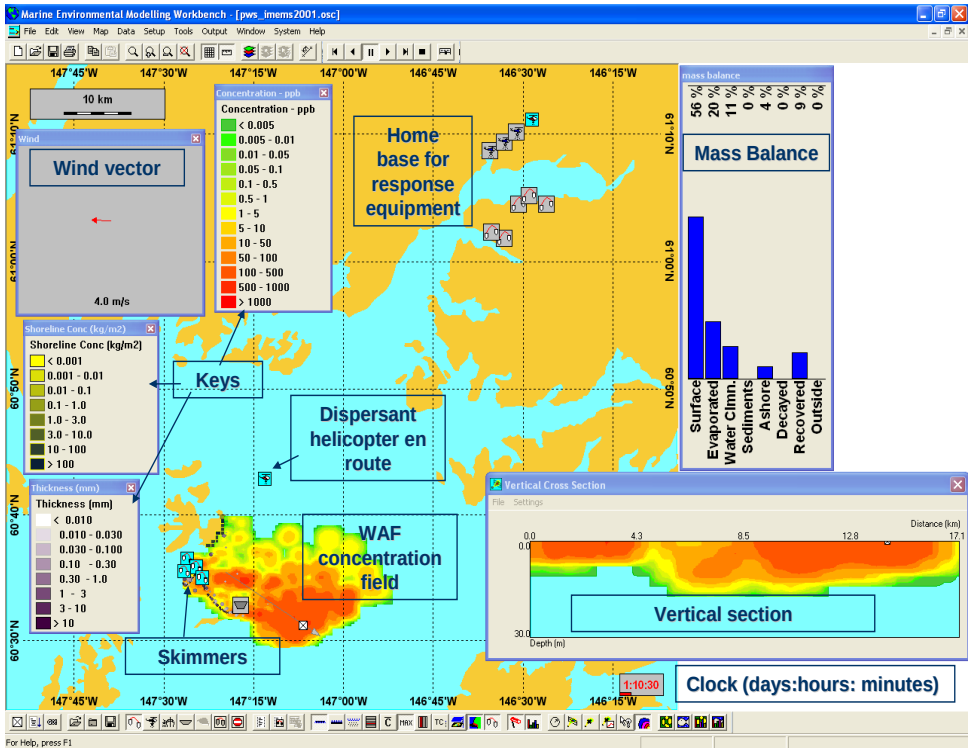
SINTEF Energy Research

SINTEF Fisheries and Aquaculture

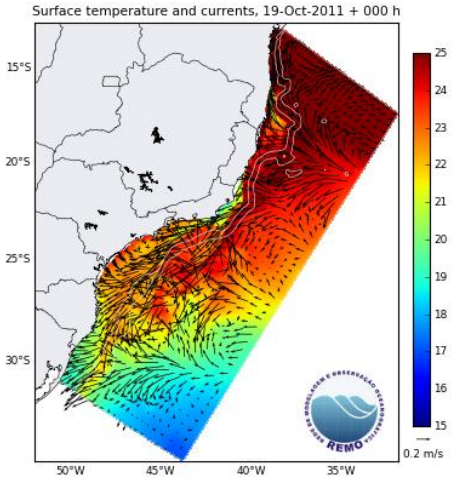
SINTEF Petroleum Research

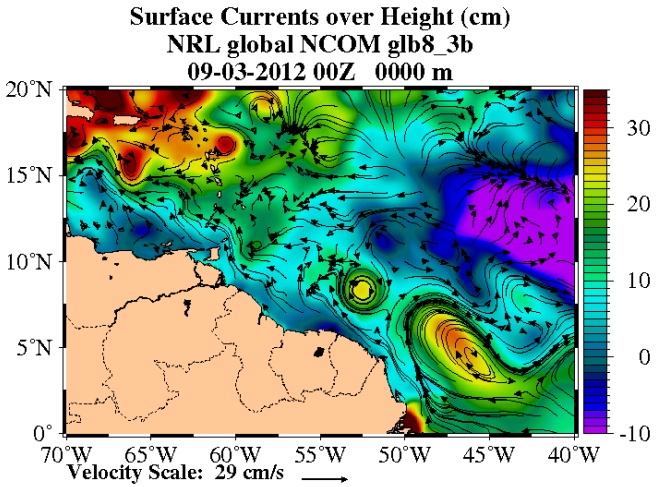
MARINTEK

Marine (Environmental) Technology Activites

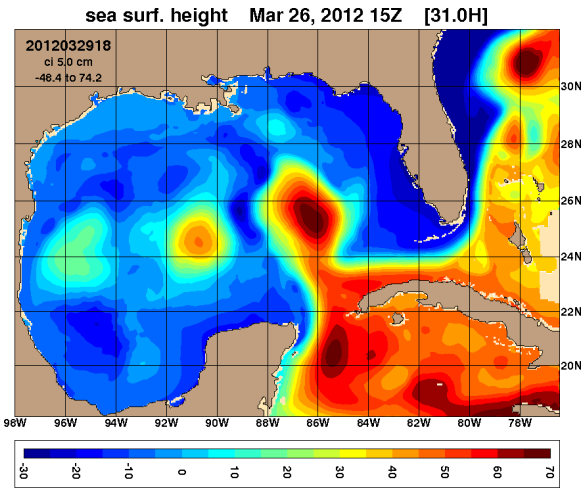


Source: REMO ROMS





Source: NRL HYCOM



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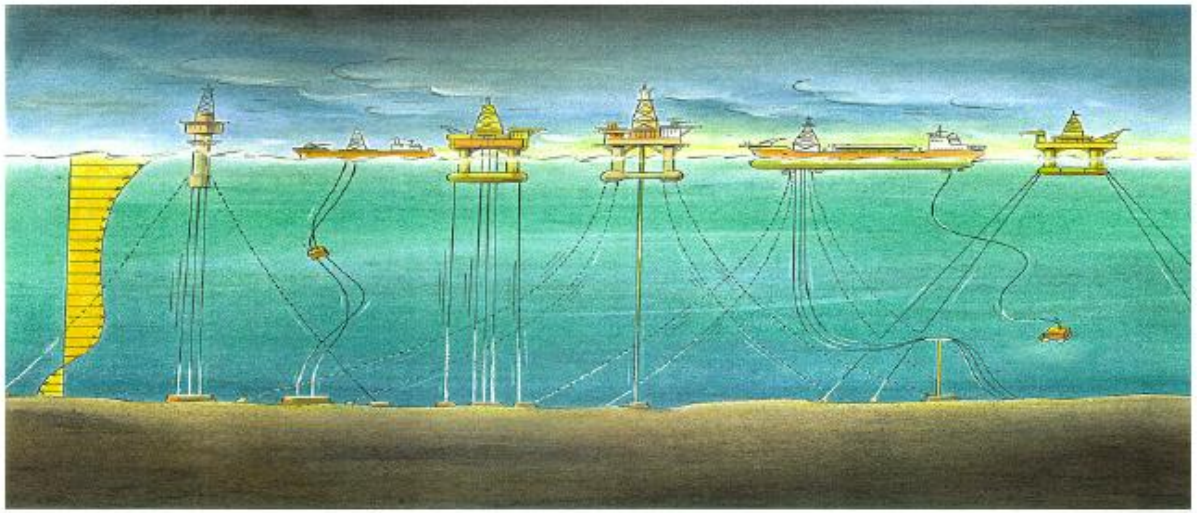
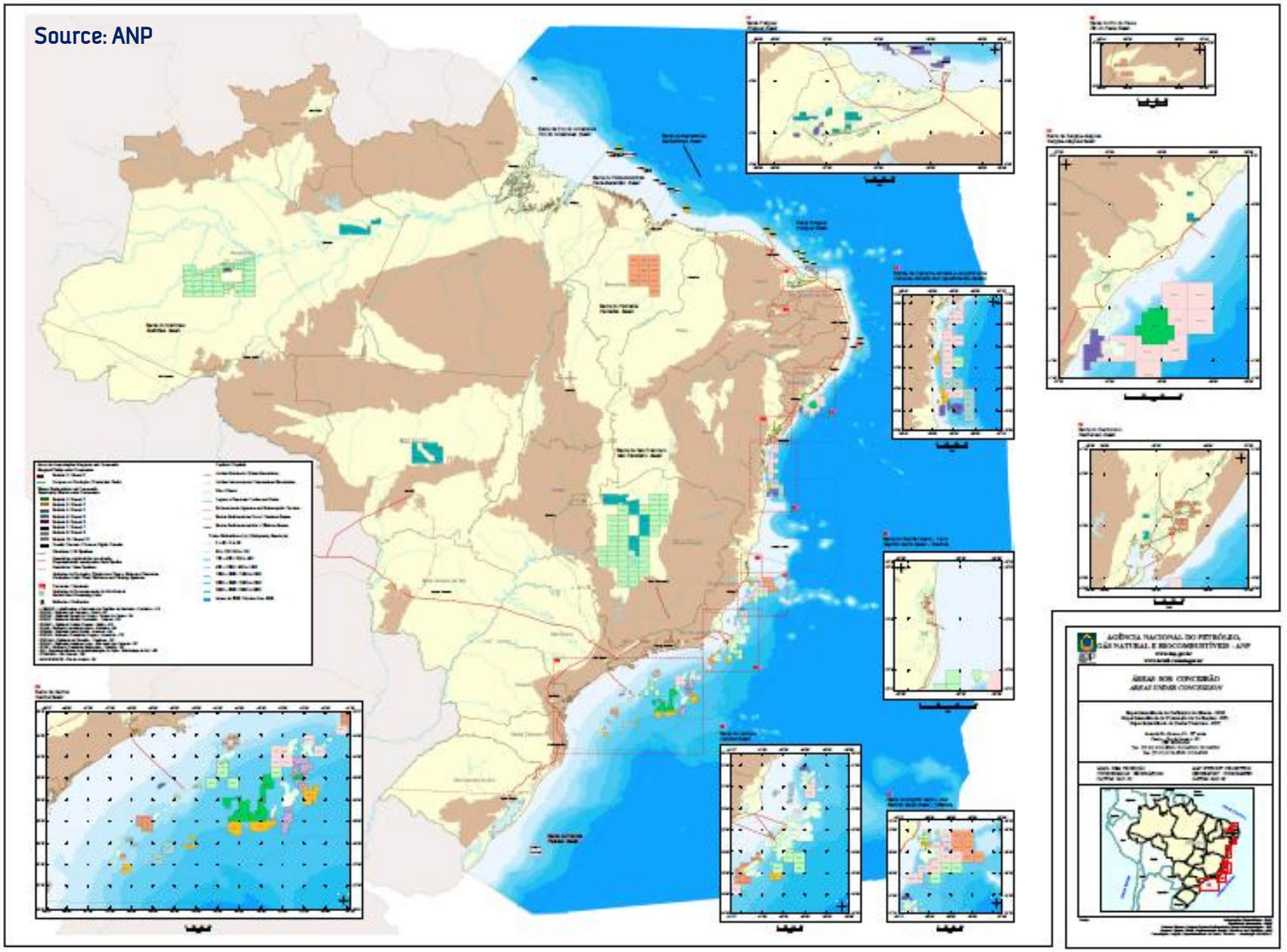
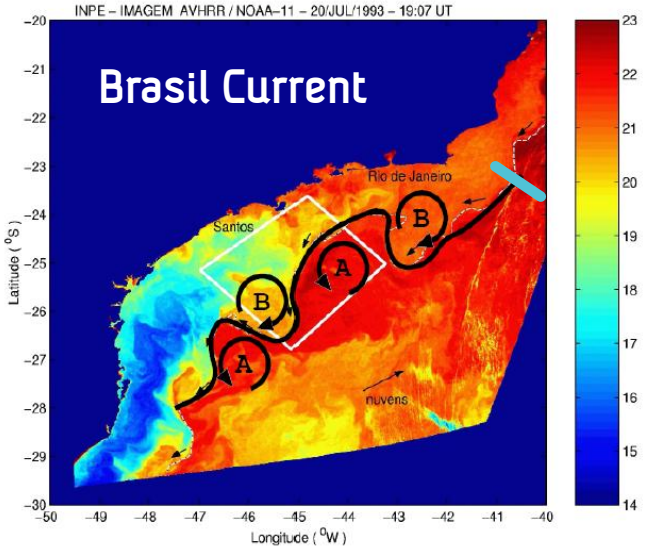
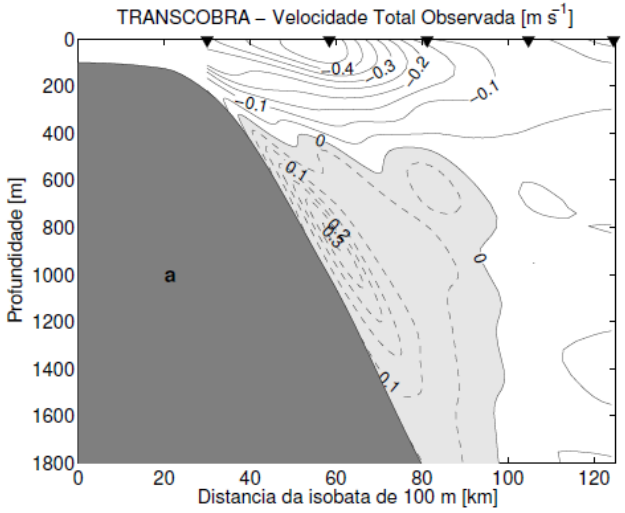


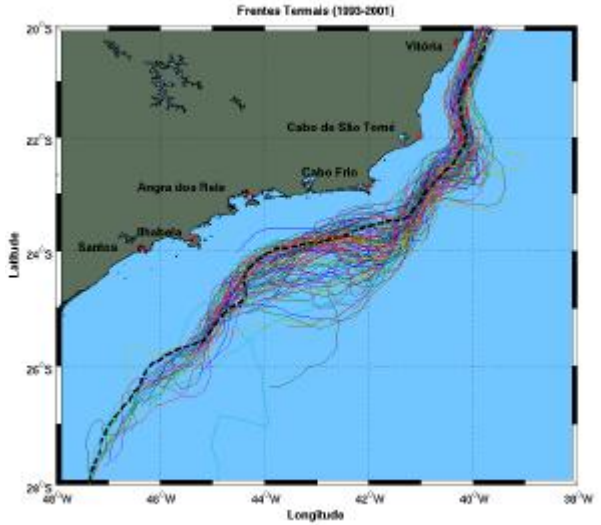

Source: ANP

"New" Environmental challenges

- Harsher waves: larger nonlinear effects, higher crests, steeper waves
- Intricate current systems, boundary current regimes



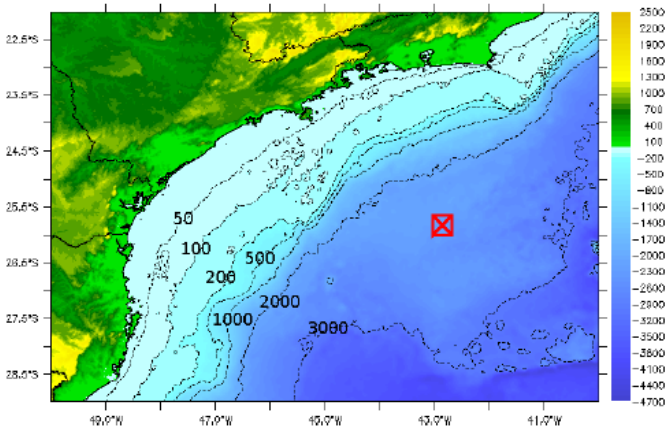


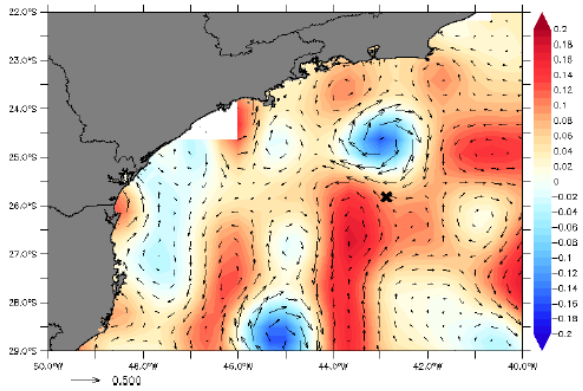


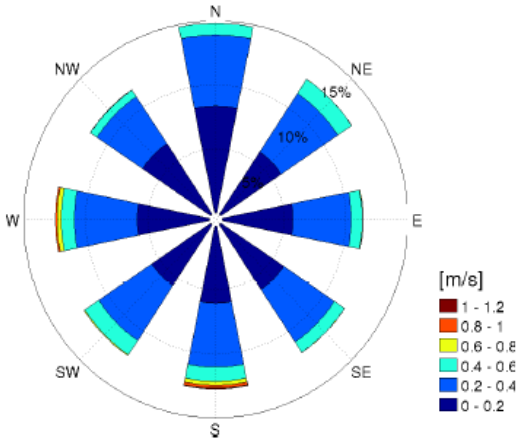
Extracted from Silveira (2007), from Godoi (2005)

Silveira (2007)

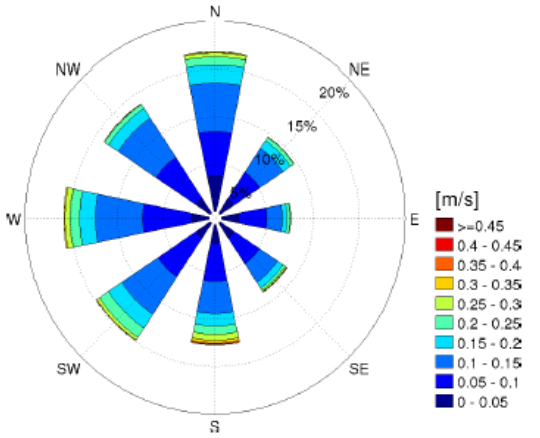
Andrioni et al. (2012 – OMAE)



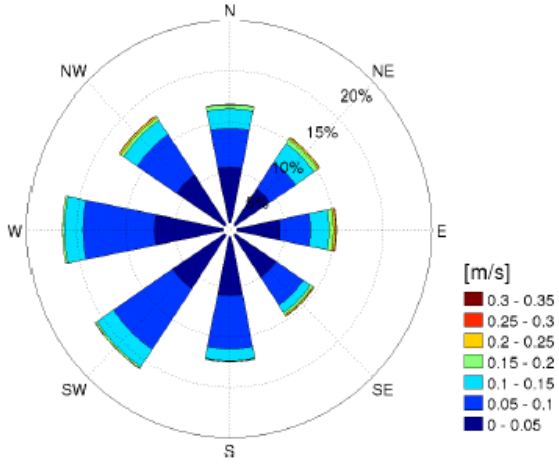




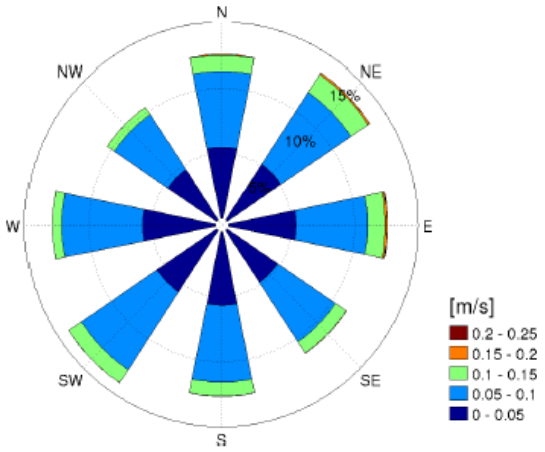
46m



376m

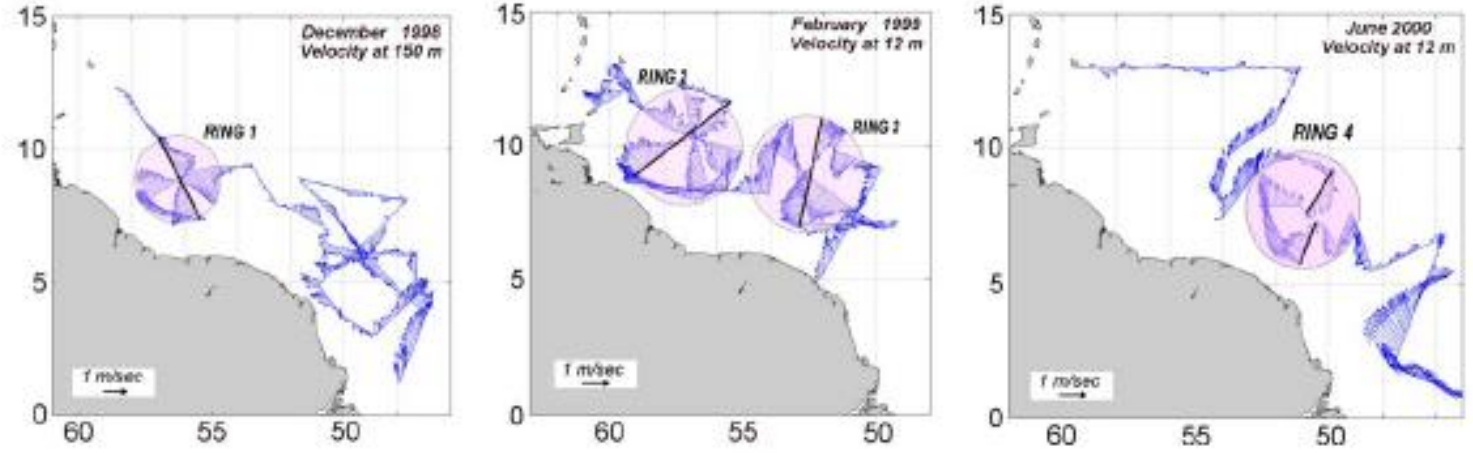


1200m

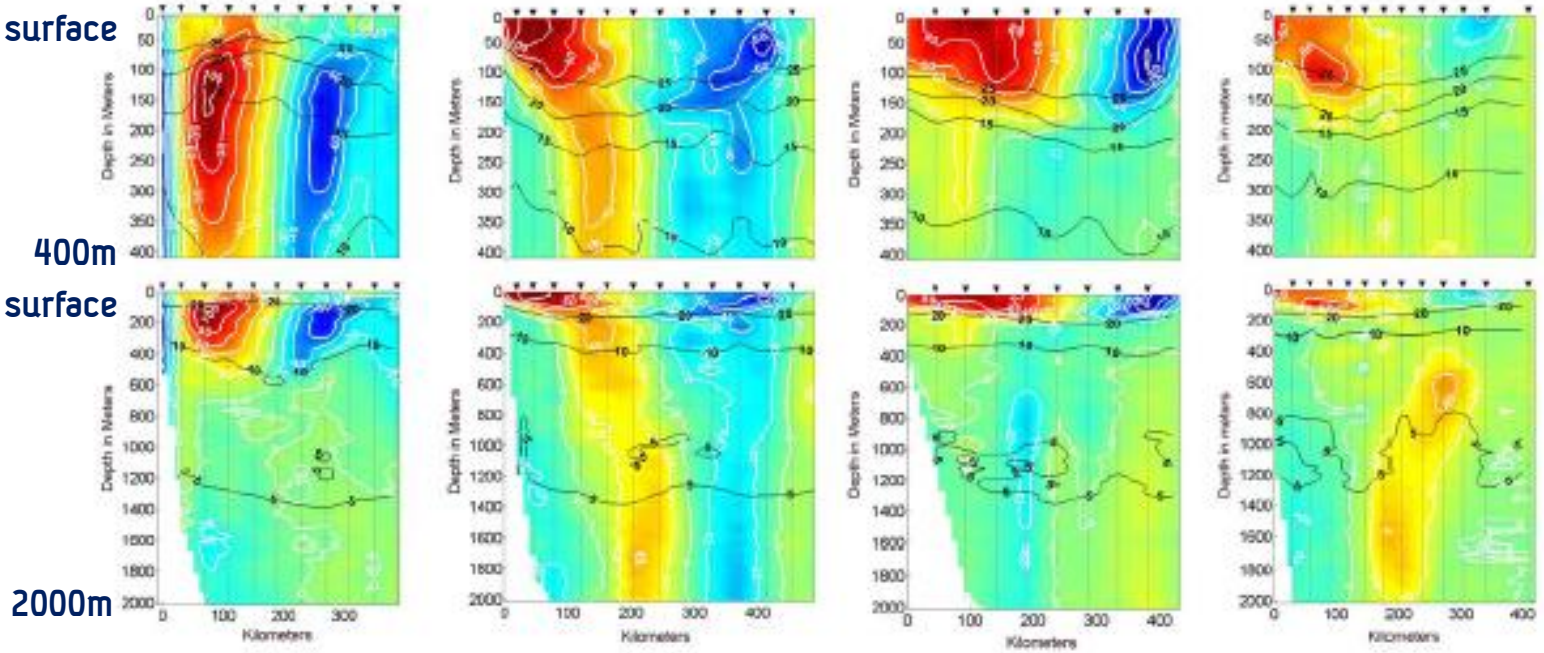


1600m

North Brasil Current and NBC Rings



Wilson et al. (2002)

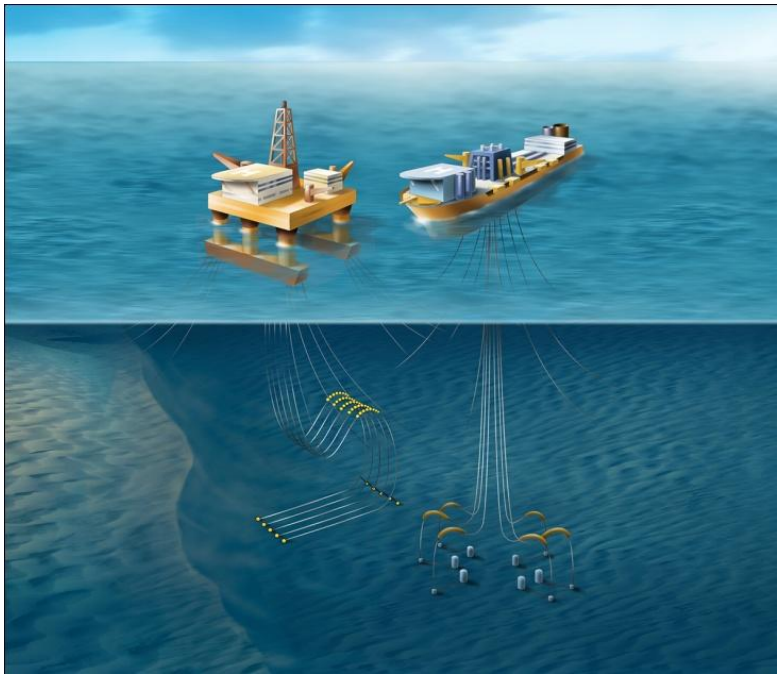


Surface trapped current
Core at 200m

Surface intensified, deep reaching

Weak surface current, thermocline intensified

- Motivation: it is necessary to develop technologies that are designed for deep waters;
- Technologies that will be subject to deep water current regimes;
- Incorporation oceanographic knowledge into R&D in marine technology.



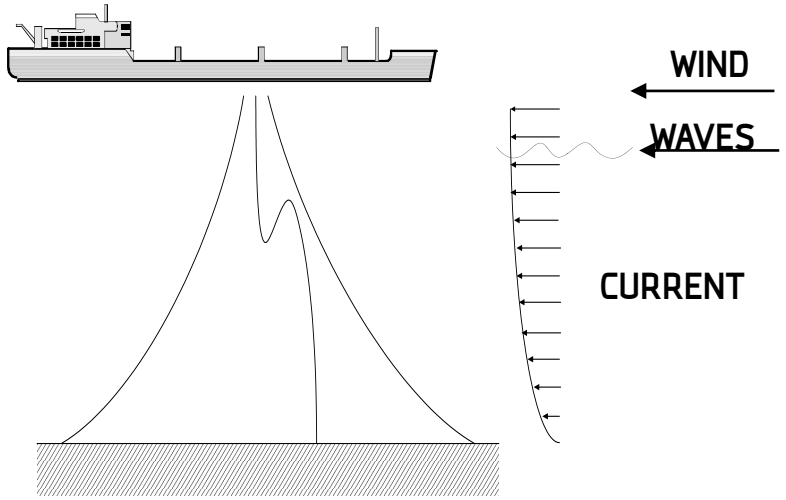
Source: MARINTEK

- Metocean observations

- Extreme value tables
- Fatigue analysis tables
- Joint distributions (direction vs speed)

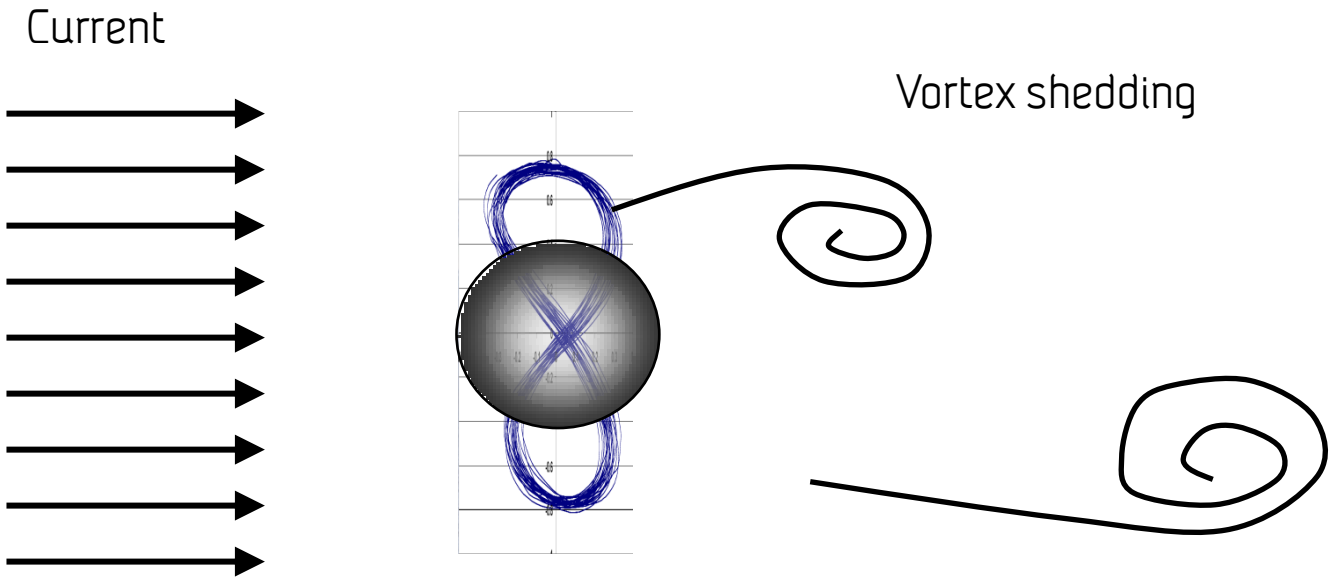
LEVEL	RETURN PERIOD (YEARS)					
	1	10	20	30	...	1000	DIRECTION
SURFACE	0.8	1.05	1.15	1.2	...	1.45	S
-50	0.8	1.05	1.15	1.17	...	1.4	S
-100	0.7	1	1.05	1.1	...	1.3	S
-150	0.6	0.9	1	1.1	...	1.2	S
-200	0.6	0.8	0.85	0.9	...	1.1	S
...	...	...	...	...	...	...	S

Environmental loads (currents, waves and winds)



- Static and dynamic behaviour of new concepts for platforms and slender structures
- Extreme value and fatigue life investigation
- Design of strategies for marine operations
- Development of new methods that are specific for deep waters
- VIV

Vortex-induced vibrations

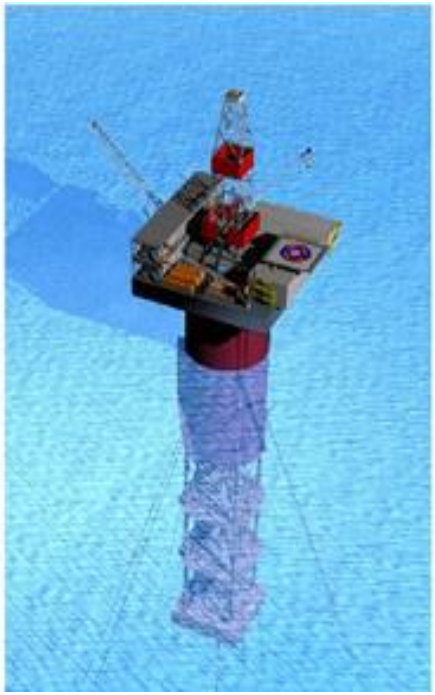


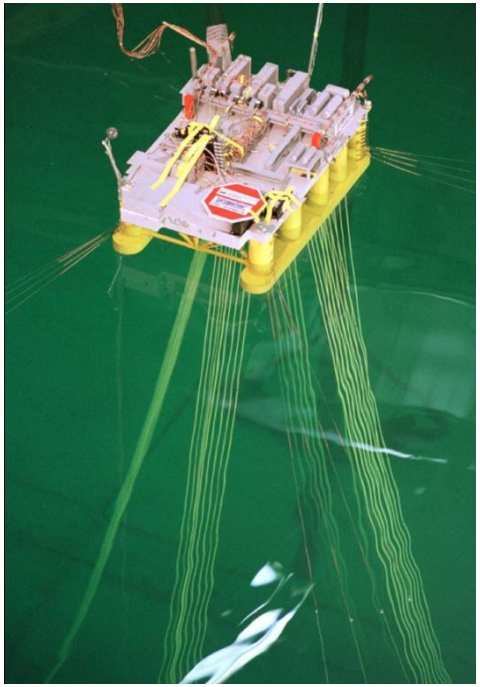
Strouhal frequency: $f_s = St\ U / D$

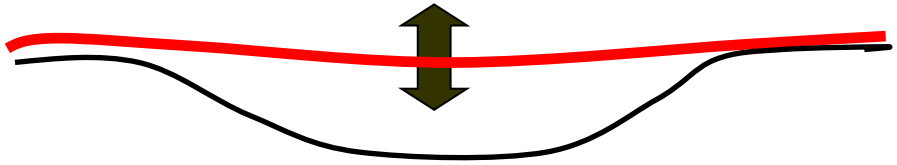
Example: Riser with D = 0.3 m, U = 1.5 m/s: f_s = 1 Hz, T_s= 1 s

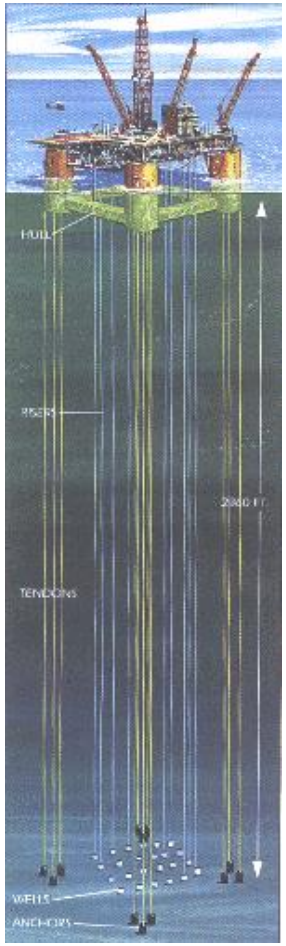
Example: SPAR with D = 30 m, U = 1.5 m/s: f_s = 0.01 Hz, T_s = 100 s

VIV problem areas







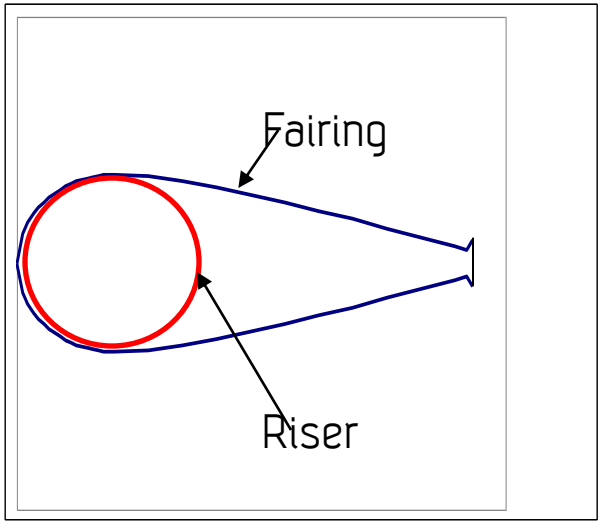


Risk of fatigue damage

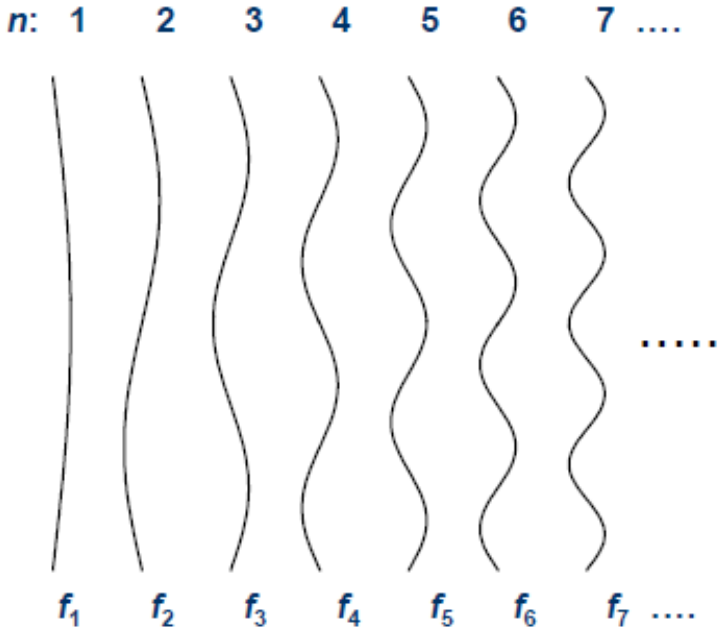
Increased current drag

Increased global motions

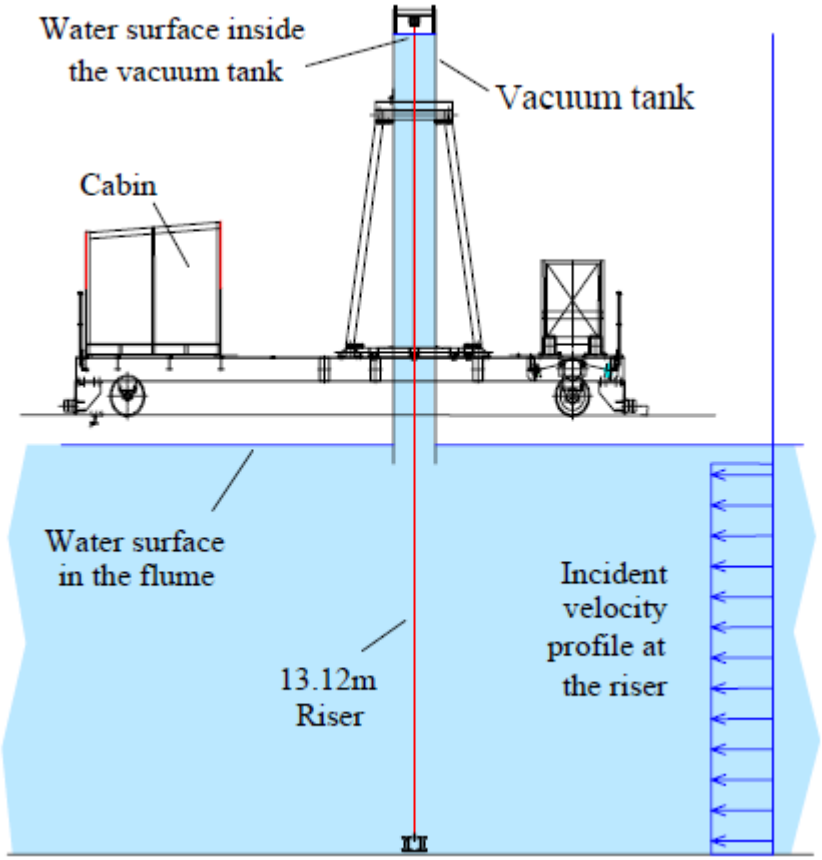
Instability of Faired Riser



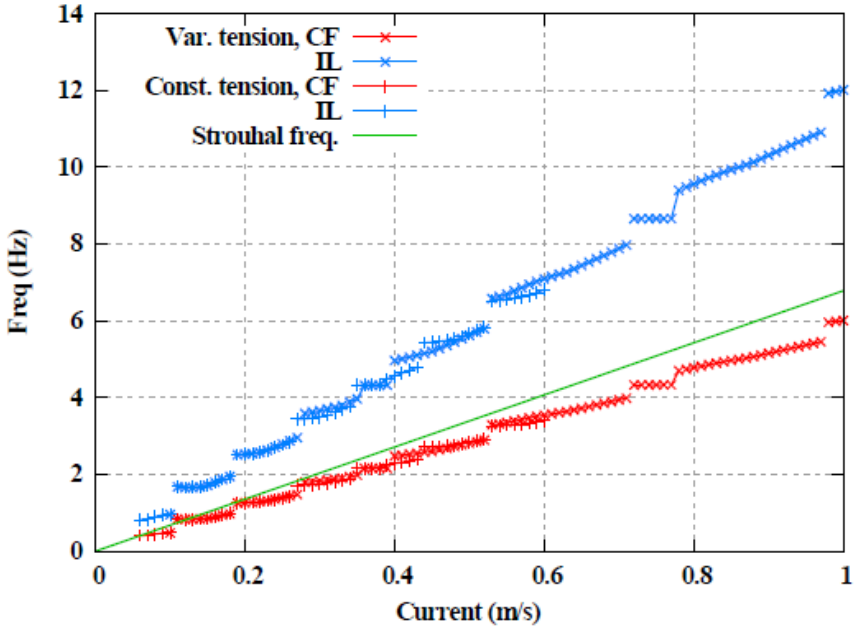
Riser eigenmodes and eigenfrequencies

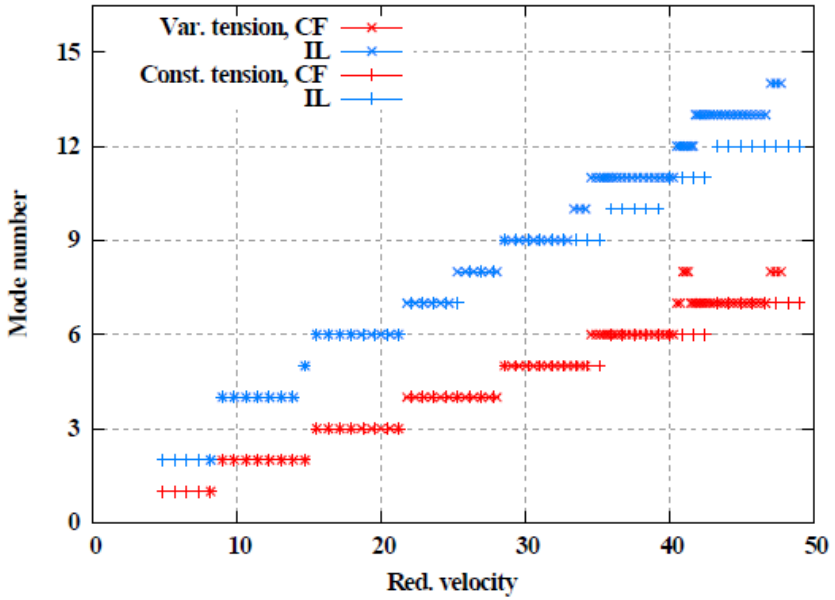


- To each mode *n* there is a corresponding eigen-frequency f_n
- The riser will oscillate when the Strouhal frequency is close to an eigenfrequency
- $f_n \approx f_s = St\ U / D$



Chaplin et al. (2007)

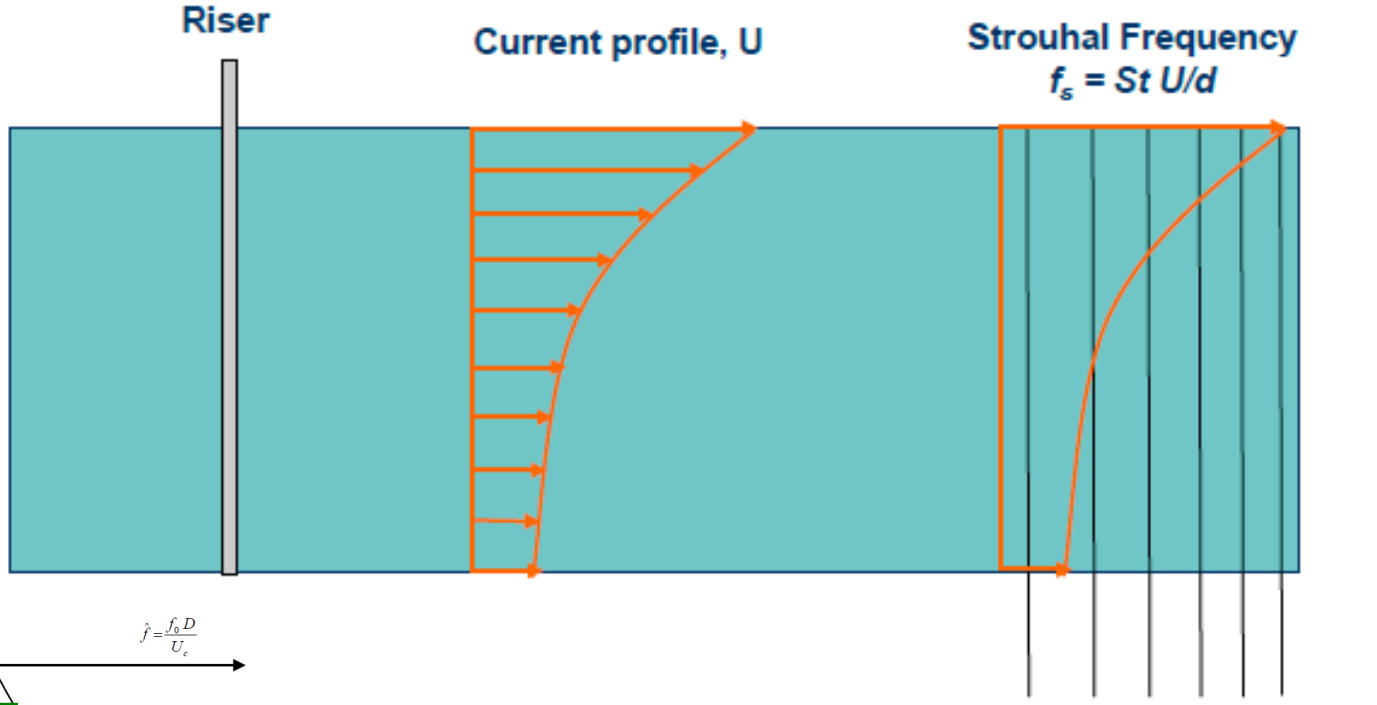


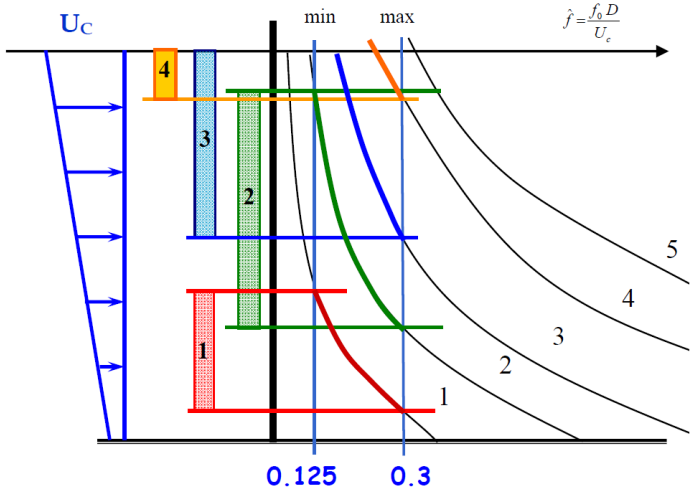


Passano et al. (2012 – OMAE)

Complex hydroelastic interactions for long risers in sheared flow

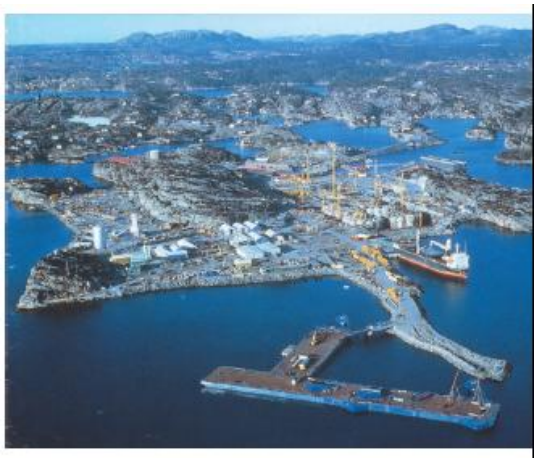
Varying current profile
- Many possible frequencies of oscillation exist.
- "Competition" between modes.
- Difficult to predict frequency.

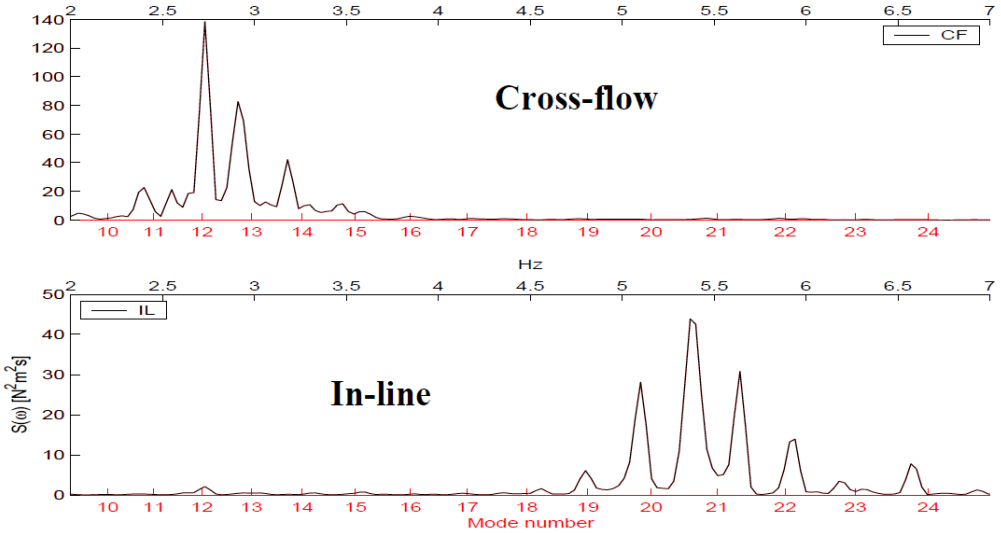


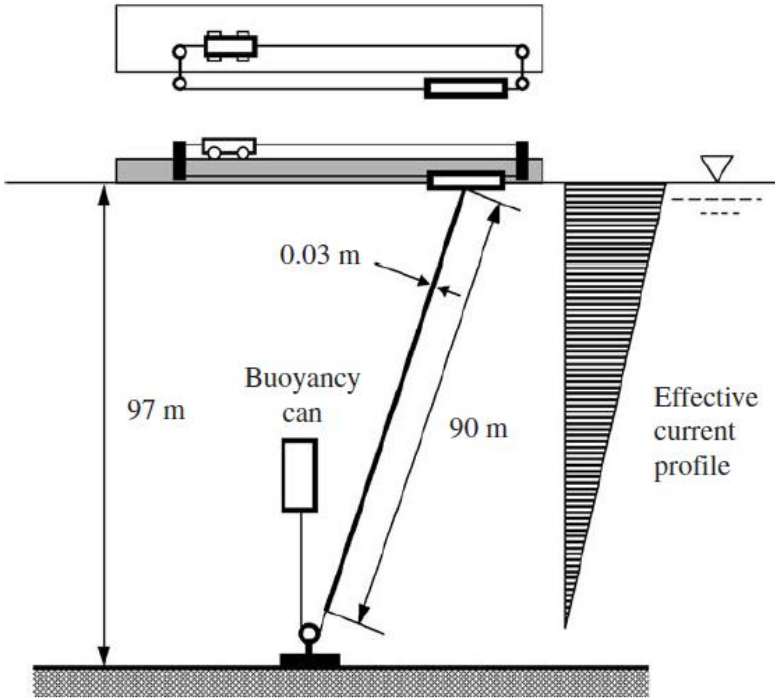


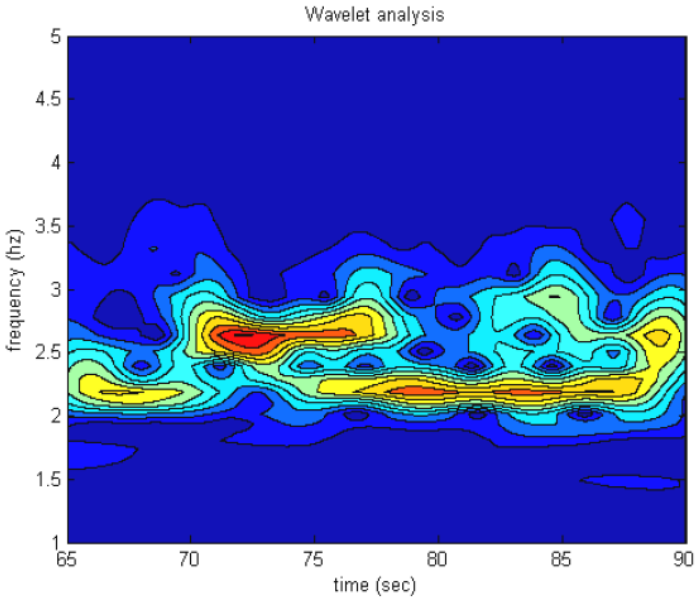
Hanøytangen large-scale experiment

Extracted from Larsen (2011)







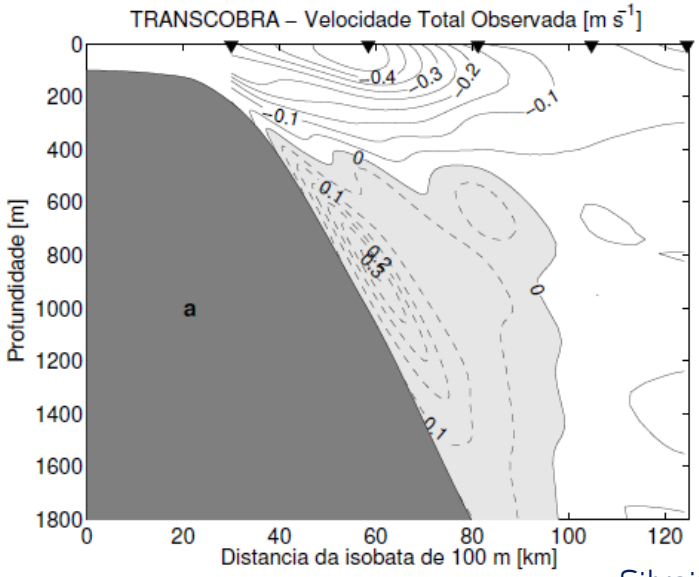


Non-stationary behavior in sheared current – Time sharing process

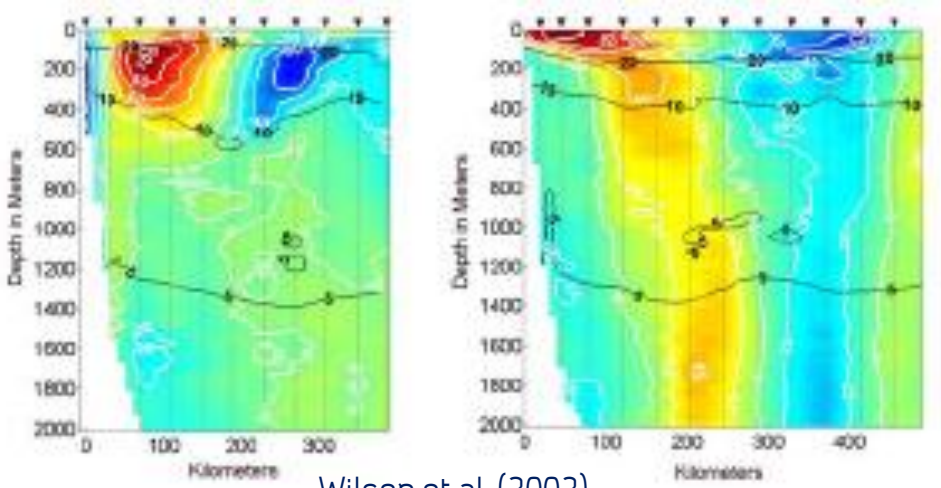
What is the impact of offshore current profiles over the development of VIV?

- Vertical variability wrt:
  - Directionality
  - Shear
- Temporal variability:
  - Meso-scale
  - Sub-mesoscale
- Patterns associated with boundary current systems

- **Response frequencies**
- **Fatigue life and damage**
- **Re-assess level of conservatism used by the Industry**



Silveira (2007)

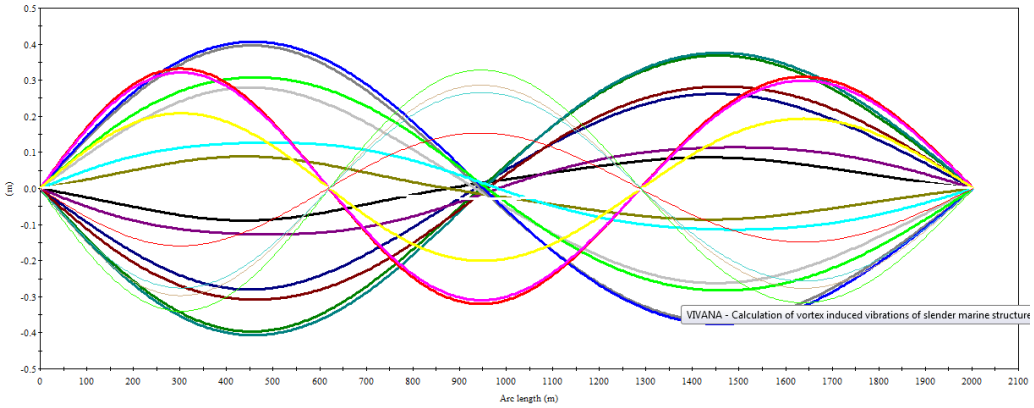


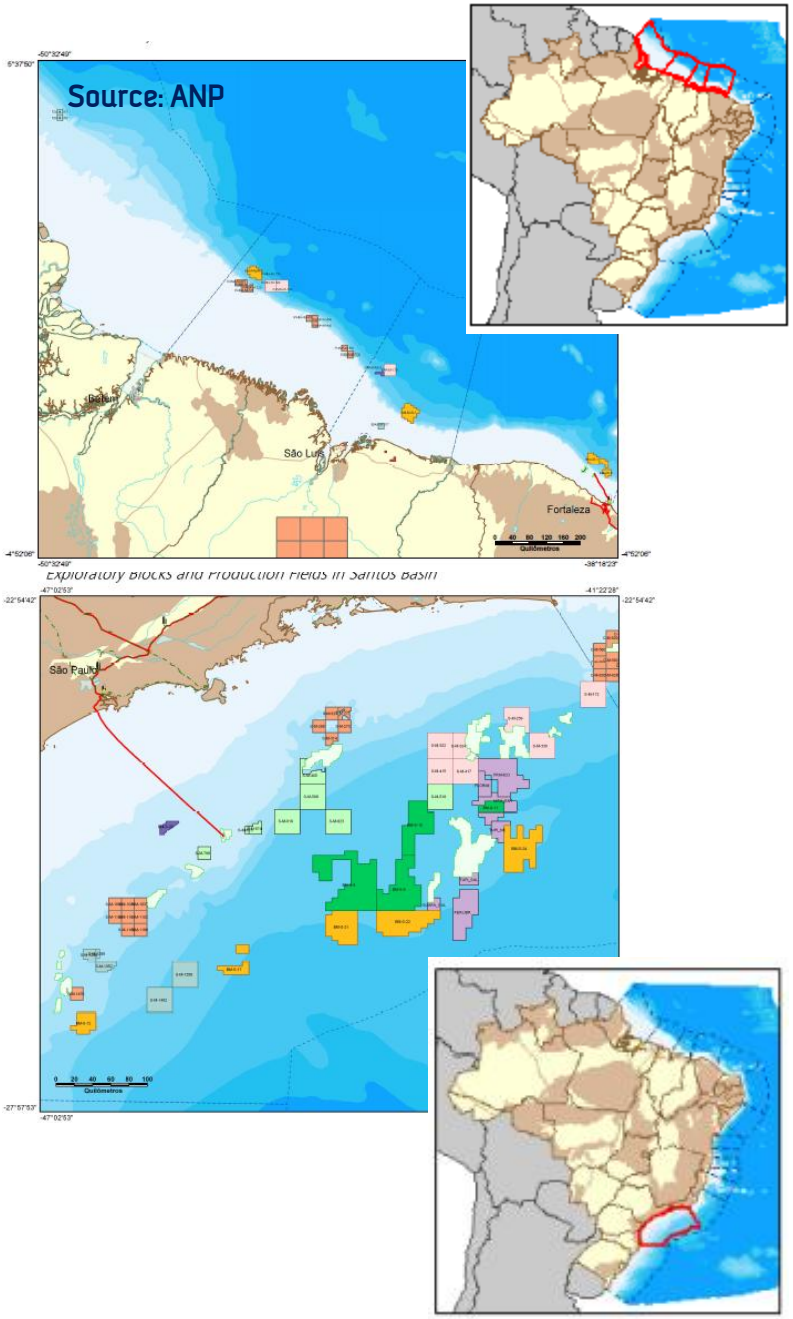
Wilson et al. (2002)

The initiative:

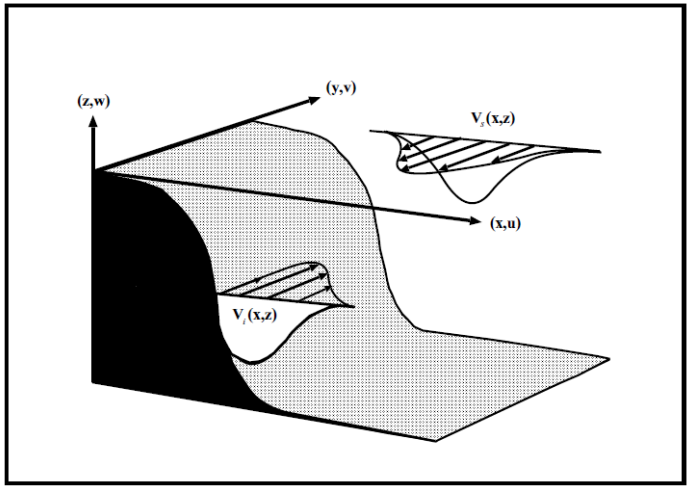
- Observations
- High-resolution regional ocean modelling

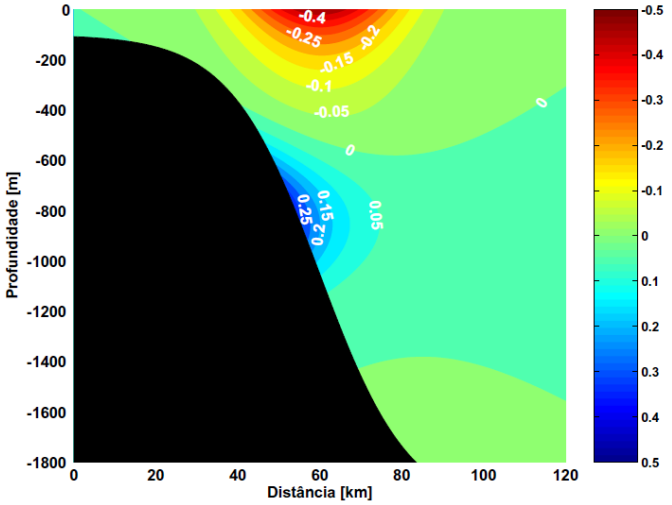
- Hydrodynamic information to VIVANA (freq. domain, semi-empirical model for VIV calculation)



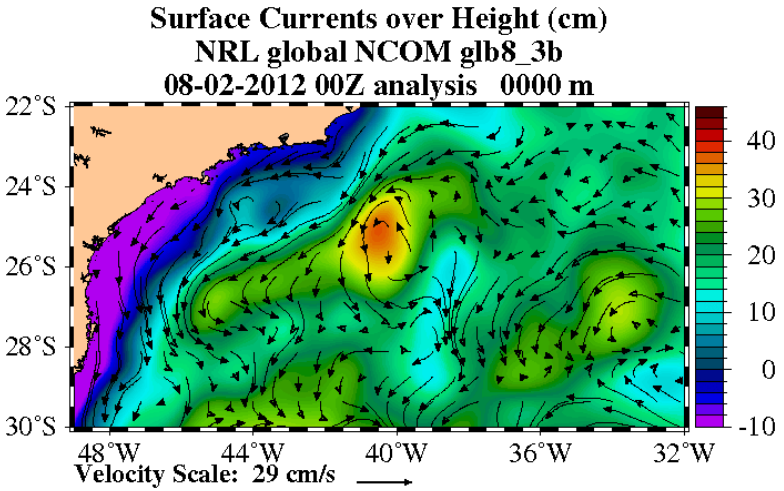


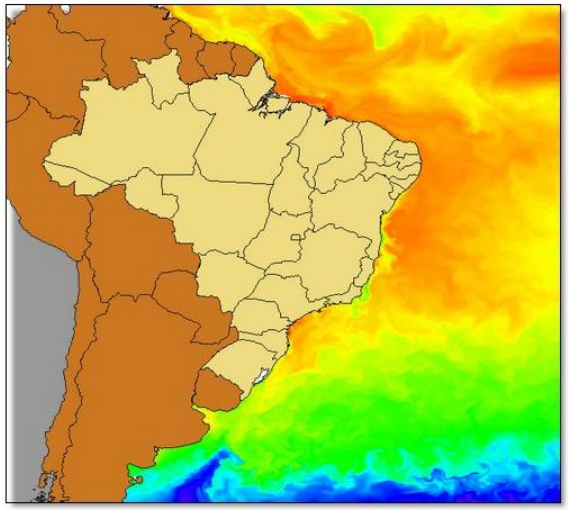
Schmidt et al. (2007)





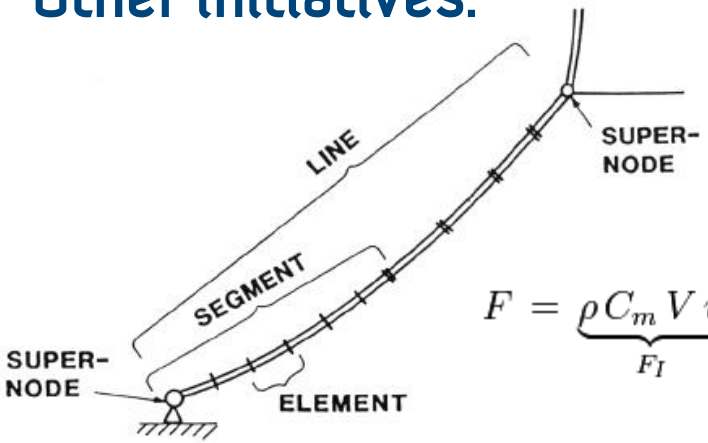
- Process-oriented investigation
- Nested simulations



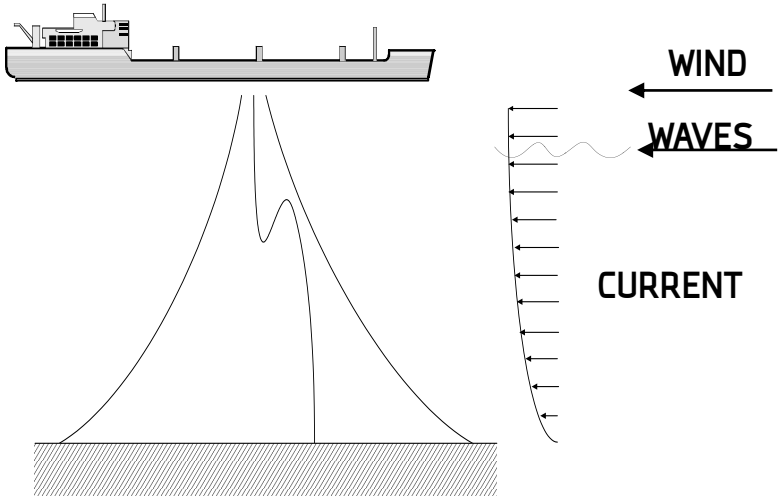


Source: Brazilian Navy HYCOM

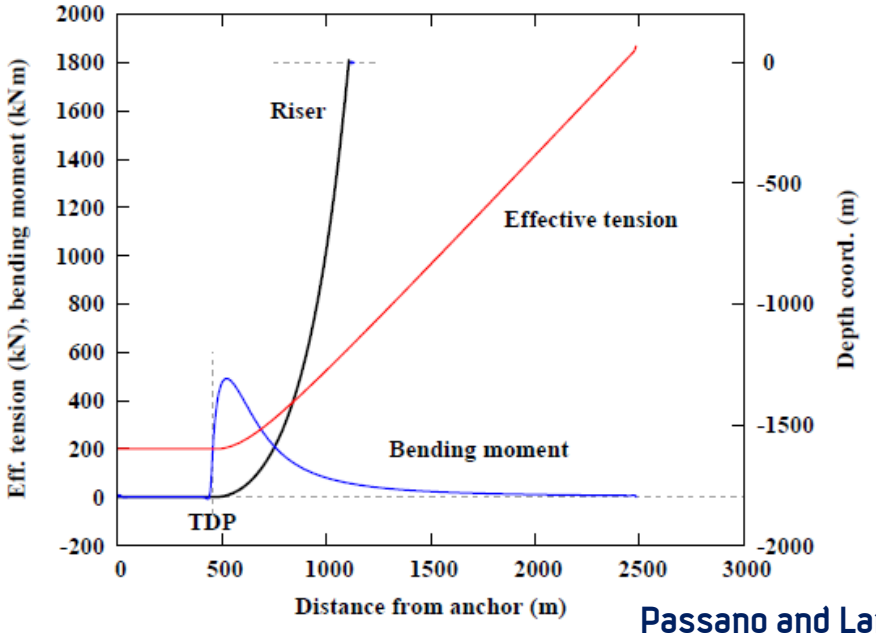
Other initiatives:



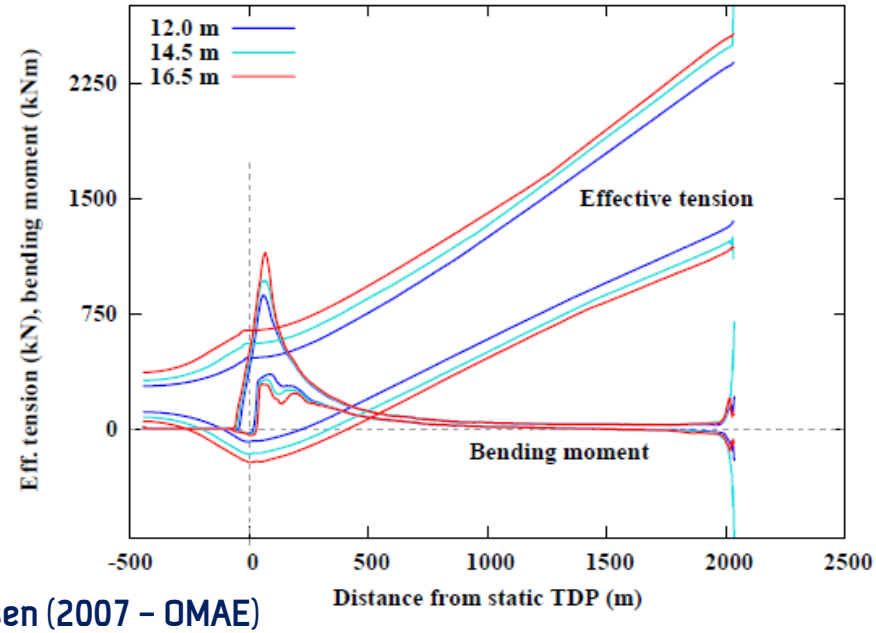
$$F = \underbrace{\rho C_m V \dot{u}}_{F_I} + \underbrace{\frac{1}{2}\rho C_d A u|u|}_{F_D},$$



Static behavior



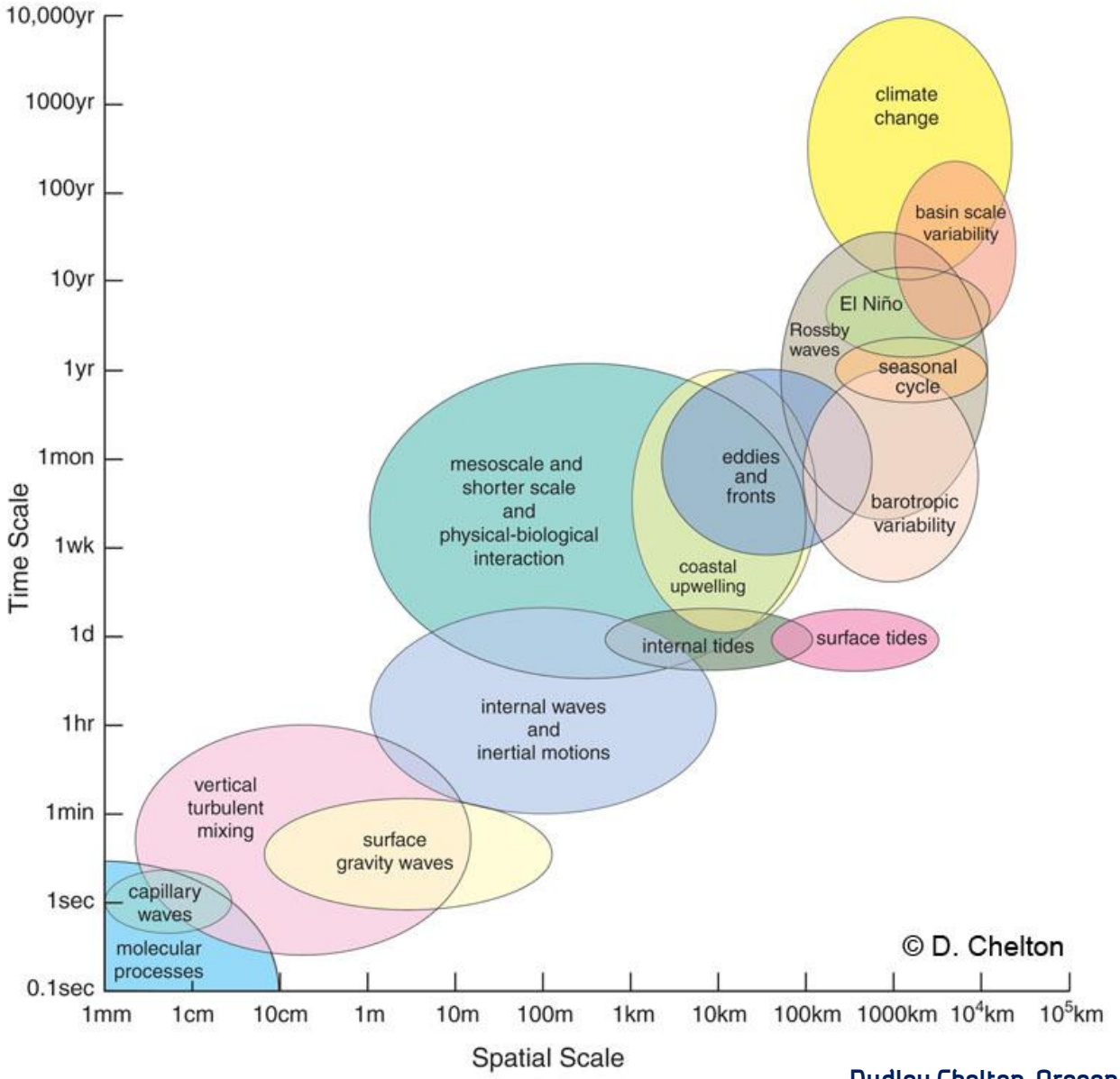
Dynamic behavior



Passano and Larsen (2007 – OMAE)

Concluding remarks

- As offshore production of oil and gas moves offshore, marine operations become more complicated.
- Spatial and temporal variability of hydrodynamic processes become more important in design and planning.
  - Large-scale ocean currents, meso-scale activity, internal waves, rougher sea states (surface waves)
- Impacts on operations (drilling, installation, etc), fatigue lifetime, VIV, among others, are not fully understood.
- Increasingly demand to establish well-formulated, design conditions for marine structures/operations in environments with complex hydrodynamic patterns.
- Detailed metocean observations and more advanced numerical studies are a key factor.



Dudley Chelton, Oregon State University

Thank you

Rafael.Schiller@marintek.com.br

Marintek do Brasil Ltda.
Rua Lauro Müller, 116 – Suite 2201
CEP 22290-160 Botafogo, Rio de Janeiro, RJ
Tel: 2025-1811
www.marintek.com.br