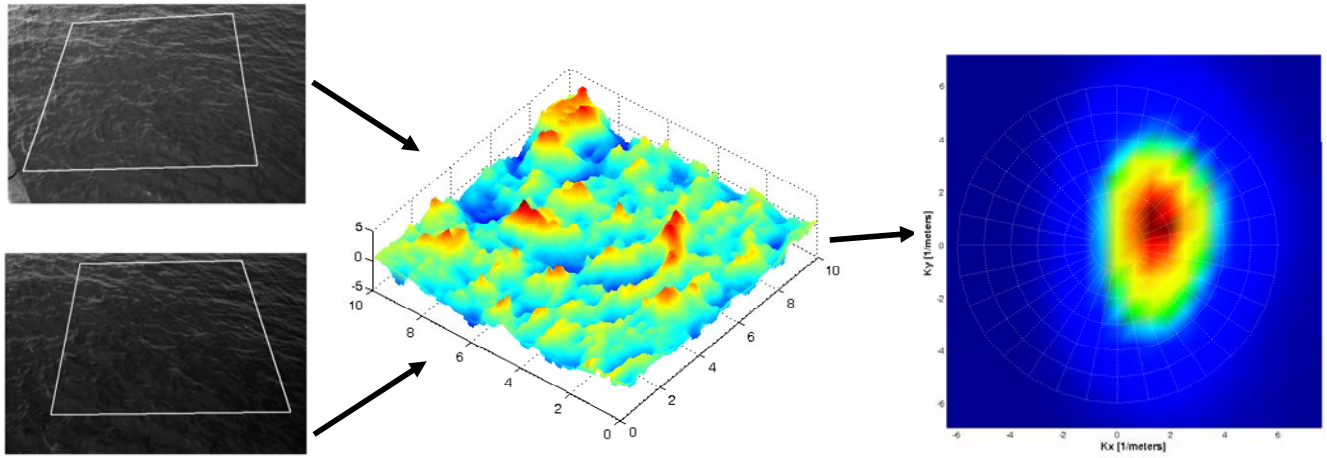
IMAGE PROCESSING & OCEAN SCIENCES MEET : 4D WAVE PATTERNS & HYDRODYNAMIC EFFECTS IN VENICE LAGOON



Francesco Fedele
School of Civil & Environmental Engineering
Georgia Institute of Technology Savannah

Anthony Yezzi & Guillermo Gallego
School of Computer & Electrical Engineering
Georgia Institute of Technology Atlanta

Georgia Tech

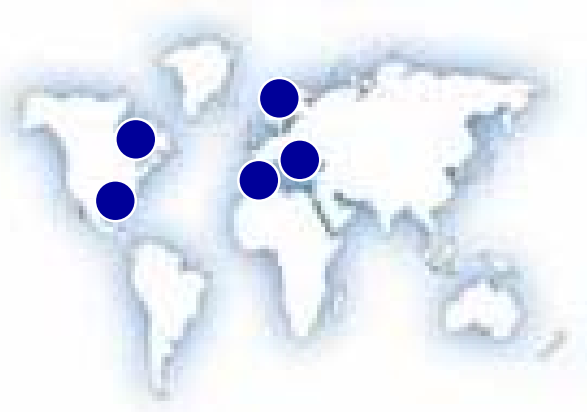
Chevron

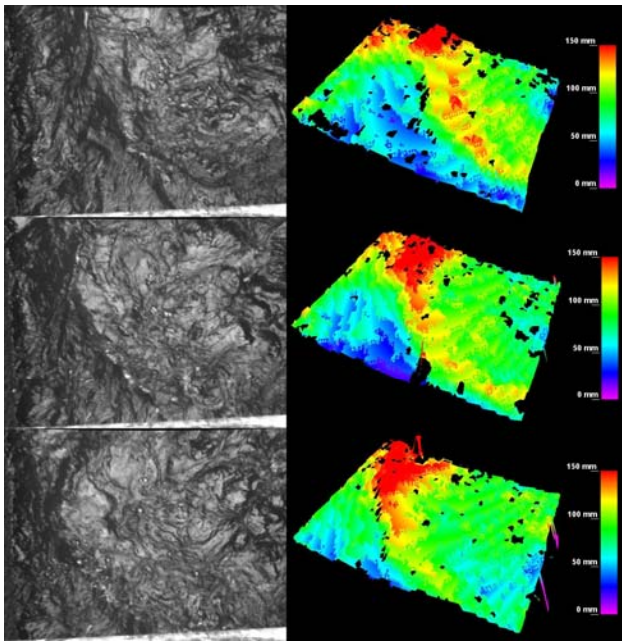
Georgia Institute of Technology Savannah

1. The 'Acqua Alta' Team

GLOBAL TEAM

F. Fedele GATECH Savannah, Civil Engineering
A. Yezzi, G. Gallego GATECH Atlanta, Electrical Engineering
A. Benetazzo, PROTECNO srl, ITALY
A. Boscolo, Phoenix srl, ITALY
G. Z. Forristall , Forristall Ocean Engineering USA
L. Cavaleri ISMAR-CNR Venice ITALY





Chevron

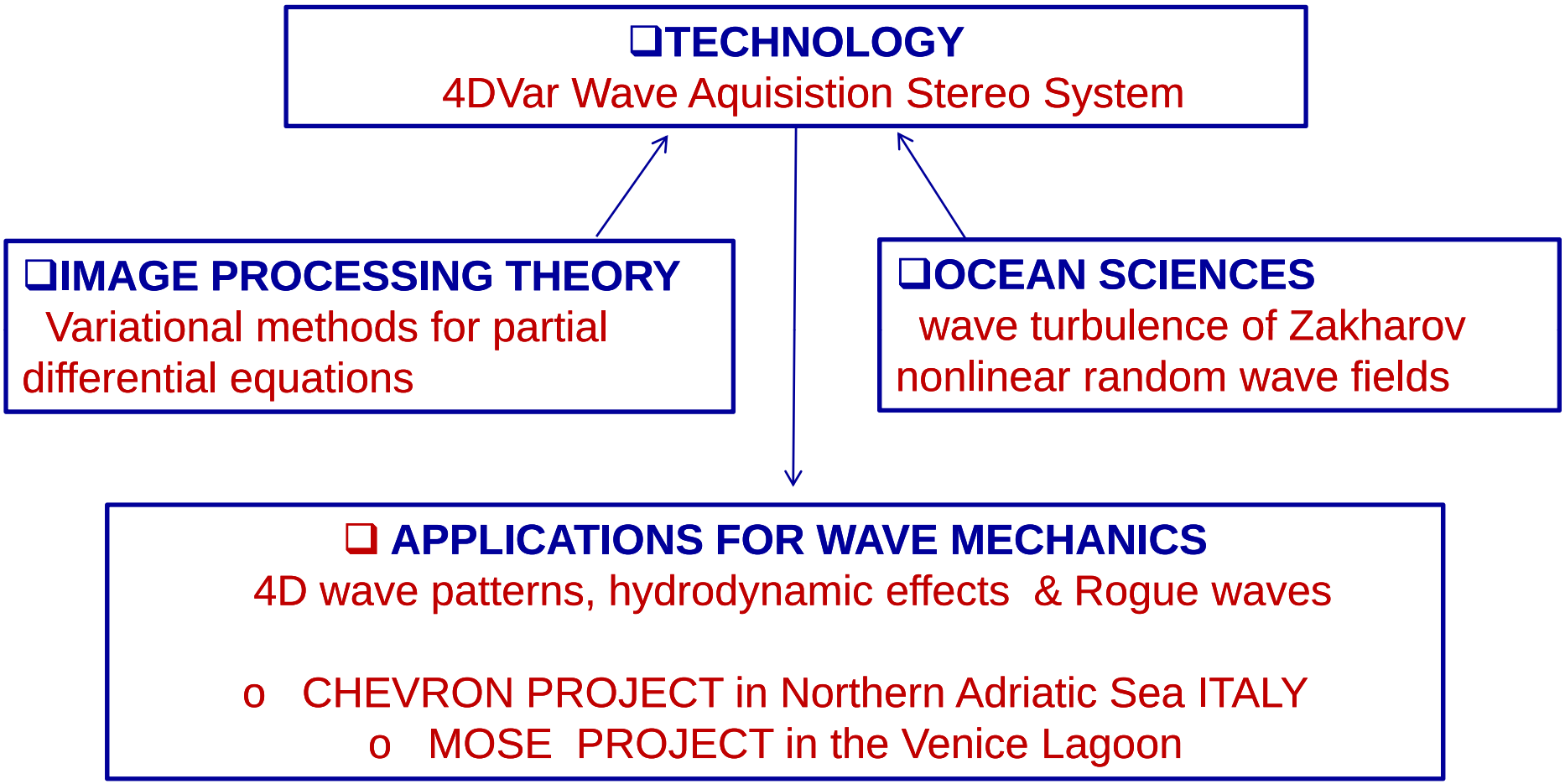
ISMAR

Georgia Tech

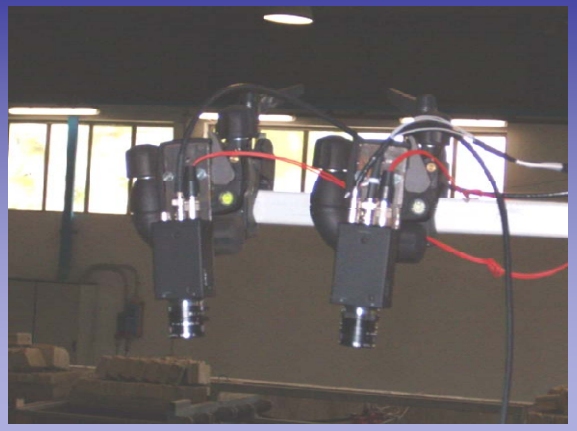
PROTECNO

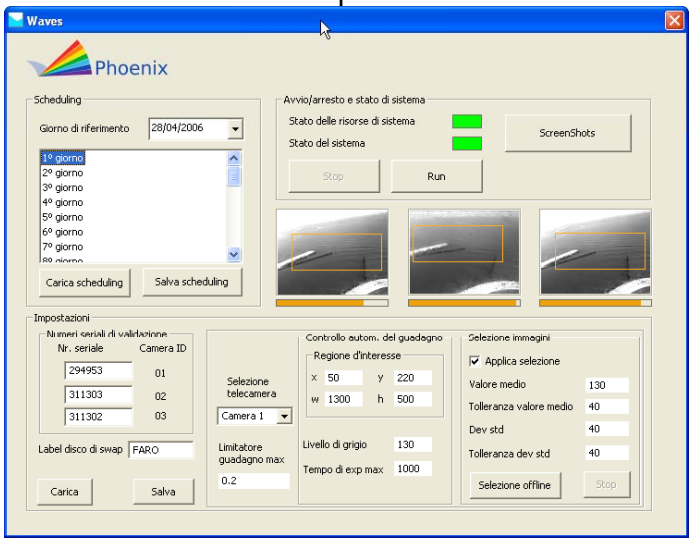
Georgia Institute of Technology Savannah

OUTLINE


❑TECHNOLOGY
4DVar Wave Aquisistion Stereo System
❑IMAGE PROCESSING THEORY
Variational methods for partial differential equations
❑OCEAN SCIENCES
wave turbulence of Zakharov nonlinear random wave fields
❑ APPLICATIONS FOR WAVE MECHANICS
4D wave patterns, hydrodynamic effects & Rogue waves
o CHEVRON PROJECT in Northern Adriatic Sea ITALY
o MOSE PROJECT in the Venice Lagoon

WAVE **A**CQUISITION and **A**NALYSIS **S**TEREO **S**YSTEM (WASS)





- **Image acquisition**
  (Bi/Trinocular Synchronized digital cameras)

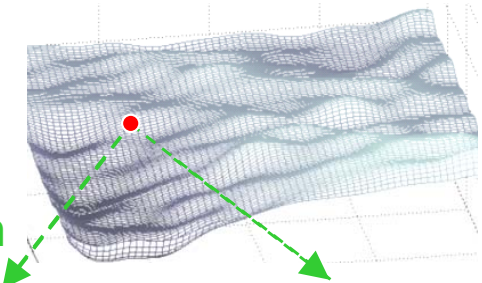
- **Image processing**
  (Epipolar /Variational Stereo method)

RECONSTRUCTION OF THE WATER 2D SURFACE FROM IMAGES

Variational stereo solution

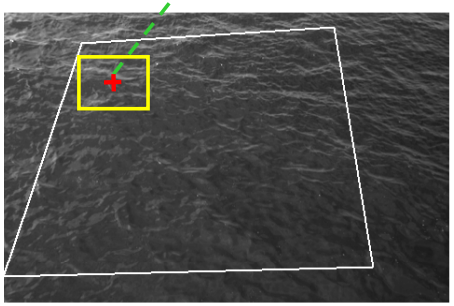
Philosophy: adjust the 3D model to the 3D world represented by the data (images) so that an energy is minimized.

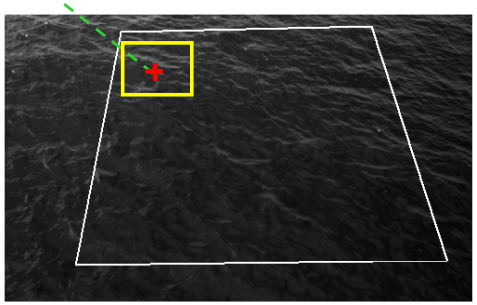
Explicit & deformable 3D model of surfaces



Deform surface until "best match" is achieved by energy minimization.

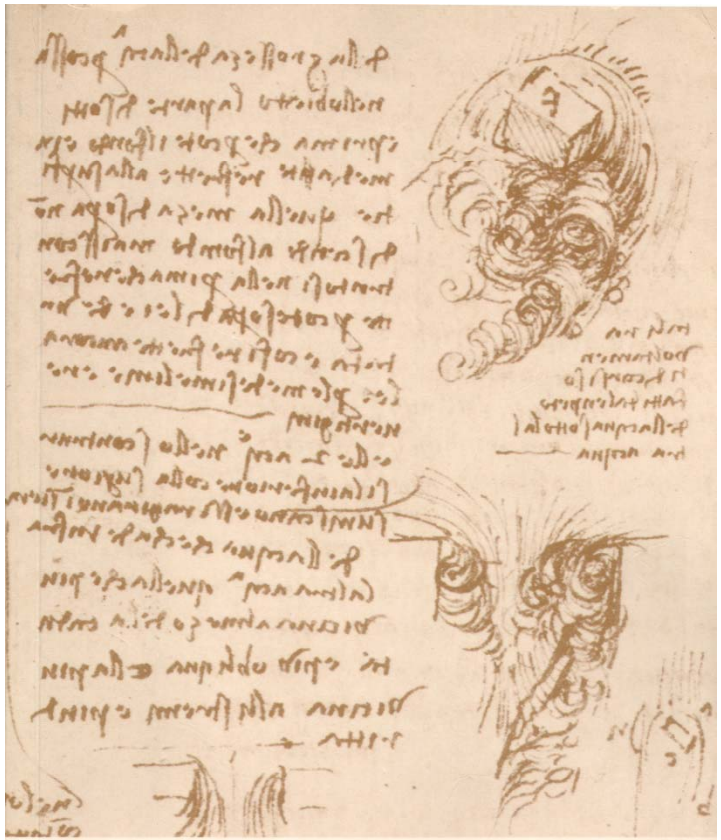
Forward projection





Left image

Right image



TURBULENCE

Uriel Frisch

1.1 Turbulence and symmetries

In Chapter 41 of his *Lectures on Physics*, devoted to hydrodynamics and turbulence, Richard Feynman (1964) observes this:

Often, people in some unjustified fear of physics say you can't write an equation for life. Well, perhaps we can. As a matter of fact, we very possibly already have the equation to a sufficient approximation when we write the equation of quantum mechanics:

$$H\psi = -\frac{\hbar}{i}\frac{\partial \psi}{\partial t}. \tag{1.1}$$

Of course, if we only had this equation, without detailed observation of biological phenomena, we would be unable to reconstruct them. Feynman believes, and this author shares his viewpoint, that an analogous situation prevails in *turbulent* flow of an incompressible fluid. The equation, generally referred to as the Navier–Stokes equation, has been known since Navier (1823):

$$\partial_t \boldsymbol{v} + \boldsymbol{v}\cdot\nabla\boldsymbol{v} = -\nabla p + \nu\nabla^2\boldsymbol{v}, \tag{1.2}$$

$$\nabla\cdot\boldsymbol{v} = 0. \tag{1.3}$$

It must be supplemented by initial and boundary conditions (such as the vanishing of $\boldsymbol{v}$ at rigid walls). We shall come back later to the choice of notation.

Quantum version of the
The Nonlinear Schrödinger (NLS) equation

$$i\frac{\partial u}{\partial t} + \frac{1}{2}\frac{\partial^2 u}{\partial \xi^2} + k|u|^2 u = 0$$

cousin
of
the Korteweg-de Vries Equation

$$\frac{\partial u}{\partial t} + \frac{\partial^3 u}{\partial \xi^3} + ku\frac{\partial u}{\partial \xi} = 0$$

...moreover for deep water narrowband waves the Zakharov equation reduces to the NLS equation...

$$i\frac{\partial u}{\partial t}+\frac{1}{2}\frac{\partial^2 u}{\partial \xi^2}+k|u|^2 u=0$$

INTEGRABILITY

Non-chaos

Nonlinear interaction of waves and solitons

NONLINEAR FOURIER ANALYSIS

NON-INTEGRABILITY

Chaos

PERIODIC ORBIT THEORY

Turbulence: walk through a repertoire of recurrent patterns- Cvitanović, GATECH

Oceanic turbulence of Zakharov → Nonlinear interactions of '*stochastic wave groups*'?

What happens in the neighborhood of a point x_0 if a large crest is recorded in time at x_0 ?

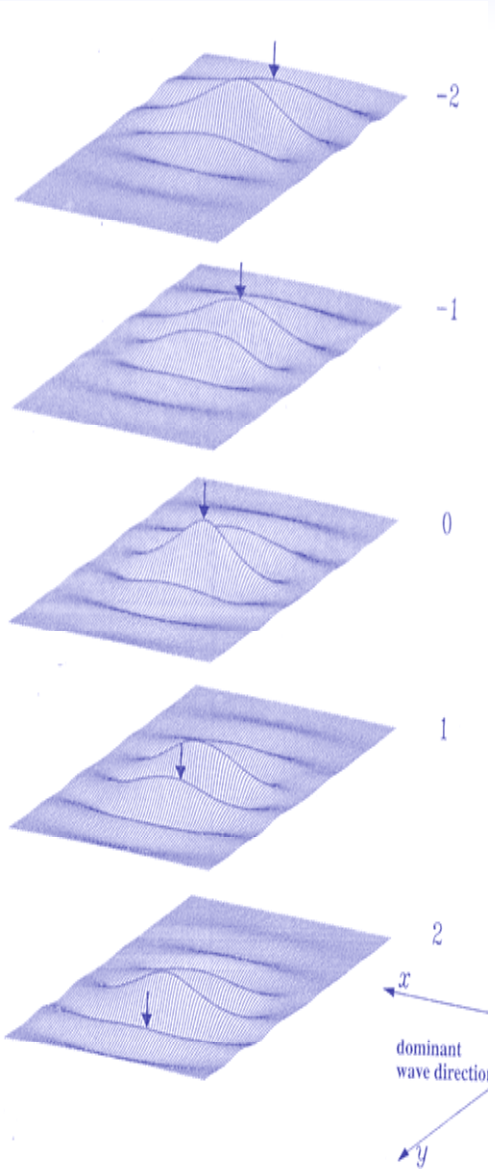
$$\{\eta(\mathbf{x},t)|\eta(\mathbf{x_0},t_0)=h\}=h\,\Psi(\mathbf{x}-\mathbf{x_0},t-t_0)+\Delta$$

SPACE-TIME covariance

Δ **random residual**, h **Rayleigh variable**

" stochastic wave group "
Boccotti 1989

" Slepian model "
Lindgren 1972, Adler 1981

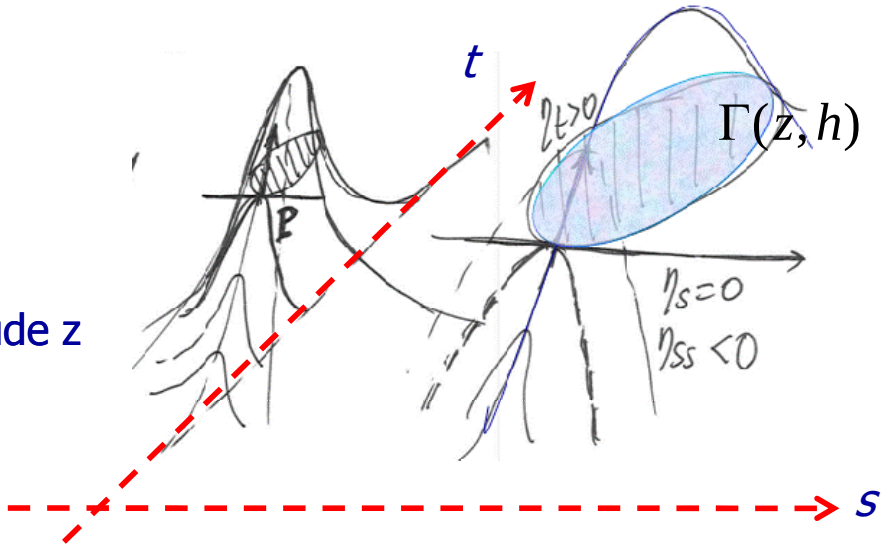


$$S\,\Pr[\eta > h] = \int_h^\infty EX_{\max}(z)\,\Gamma(z,h)\,dz$$

stochastic wave group at focusing & Excursion set {η>h}

EXmax(z)=

expected number of
maxima with amplitude z



$$\Pr[\text{crest} > h] \propto \int_h^\infty EX_{\max}(z)dz = \int_h^\infty \frac{S}{2\pi}\sqrt{\partial_{tt}F\cdot\partial_{ss}F}\,\frac{d^2\Pr(\eta > z)}{dh^2}dz$$

ACQUA-ALTA PROJECT – funded by CHEVRON

Northern Adriatic Sea

Stereo analysis of waves propagation

Deep waters

Italian National Research Council

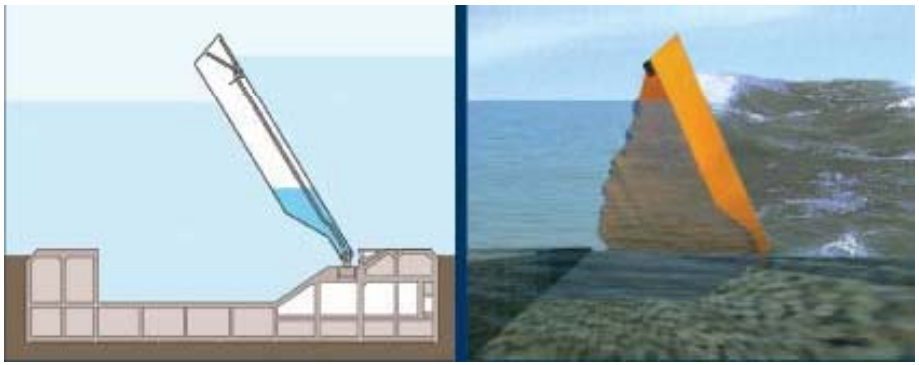
Oceanographic platform

" ACQUA ALTA "

MOSE PROJECT – VENICE – funded by PROTECNO

MOSE mobile flood barriers for the defence of Venice

Analysis of wave 2D pattern ➔ water level and hydrodynamic forces



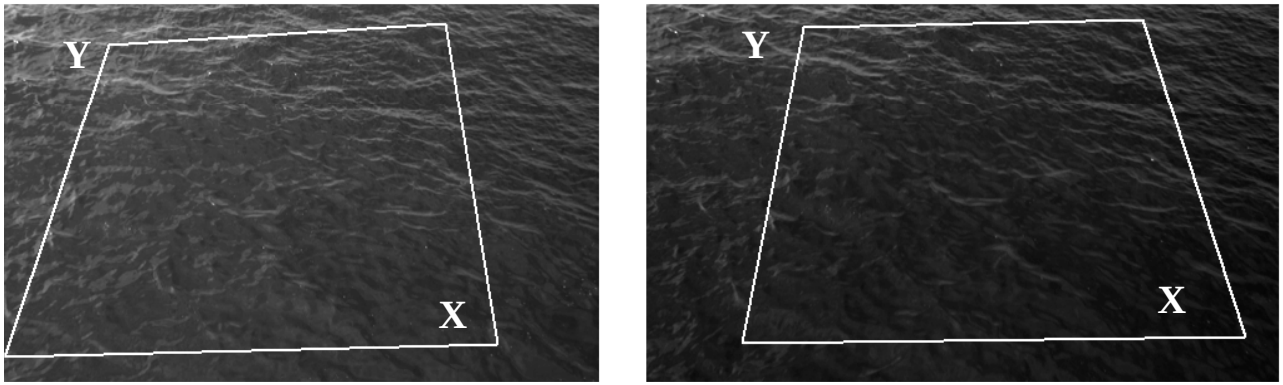
Venice harbour Authority

Analysis of ship generated waves on Venice hystorical buildings


Hör zu Moses,
lass den Scheiß!!

VARIATIONAL WAVE ACQUISITION STEREO SYSTEM (VWASS)

Input stereo pair images. The rectangular domain (8 m x 8.7 m).
The height of the waves is in the range ±0.2 cm.



Reconstructed wave surface