NAÇÃO: BRASIL
ESTADO FEDERAL: CEARÁ
Prefeitura de Caucaia
Localidade "Iparana-Icarai-Parazinho"

PARQUE EÓLICO OFFSHORE CAUCAIA
N. 59 AEROGERADORES

Anexo 1.2 para o Estudo de Impacto Ambiental (EIA)

ESTUDO MODELLO CINEMATICO-DYNAMIC MODEL_LAST 2019

Empresa Proprietária

BI ENERGIA LTDA

SEDE LEGAL BI ENERGIA LTDA AV. DESEMBARGADOR MOREIRA, 2120
SALA 907, ALDEOTA - FORTALEZA - CE
CEP 60170-002

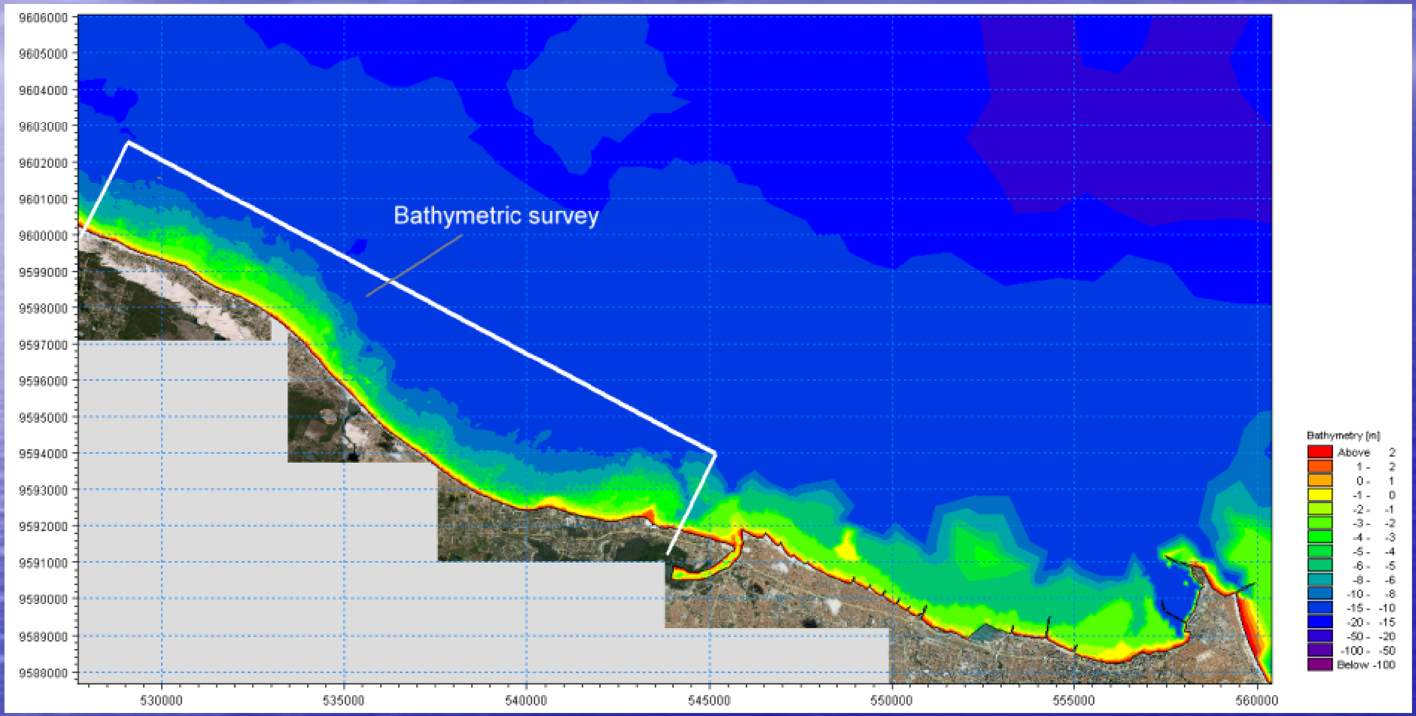
Consultoria Técnica

TENPROJECT BRASIL

SEDE LEGAL TENPROJECT BRASIL AV. DESEMBARGADOR MOREIRA,
2120 SALA 907, ALDEOTA - FORTALEZA - CE
CEP 60170-002

NOVEMBRO 2019

Dynamic model



CAUCAIA coastal area

Force action on the dynamic model

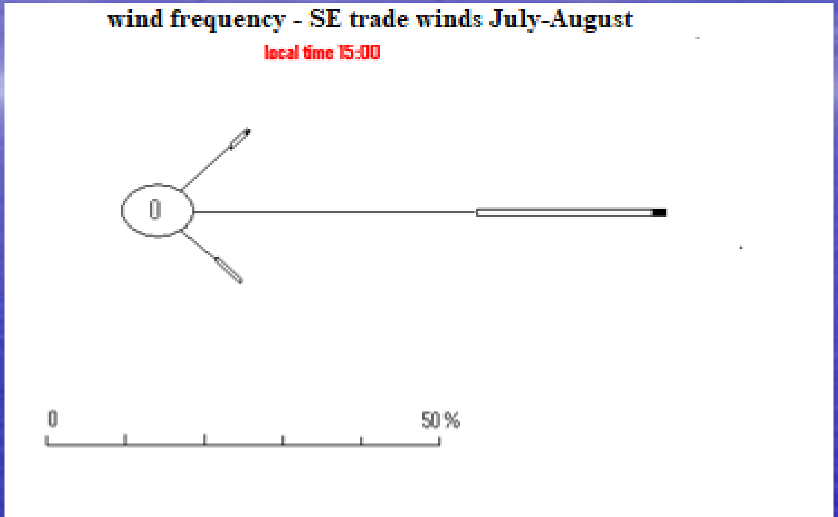
GEOPHYSICAL parameters:

Current (general circulation);
Wind (Trade Winds from E - SE)
Tide (diurnal and semidiurnal harmonics)
Tidal currents
Waves (waves deep sea, waves shallow sea)

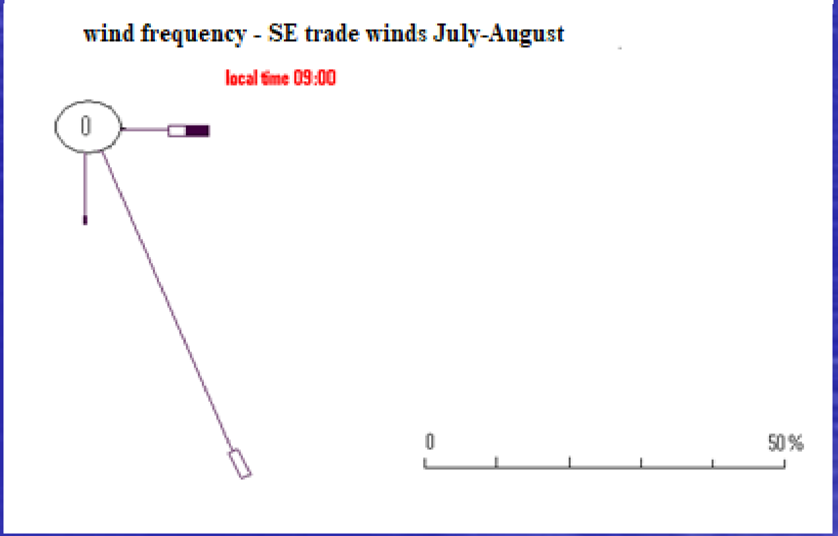
Stationary wind in the area of investigation (SE trade winds)

Statistical values of measured wind (1984-2005):

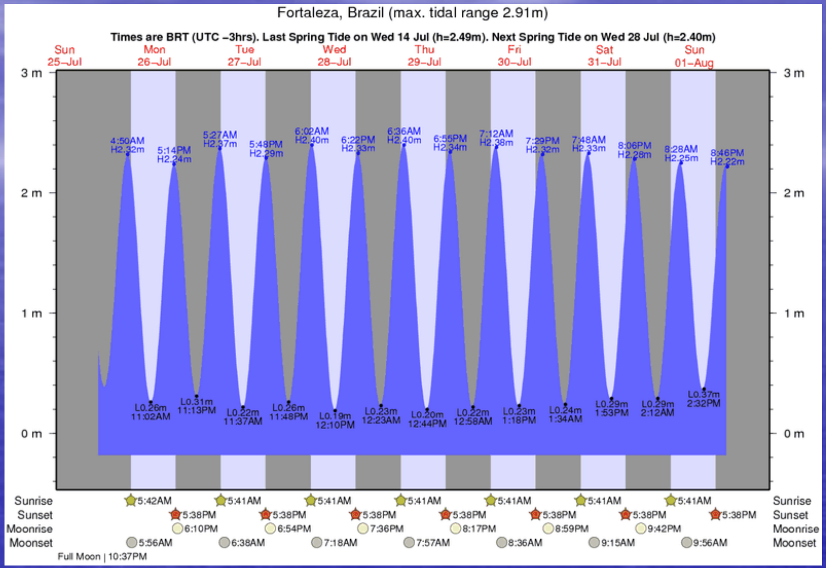
- EAST trade wins (10 - 20 knots)
  July-August (15:00 local time)



- SSE trade winds (10-15 nodi)
  July-August (09:00 local time)



TIDE IN FORTALEZA (one week)

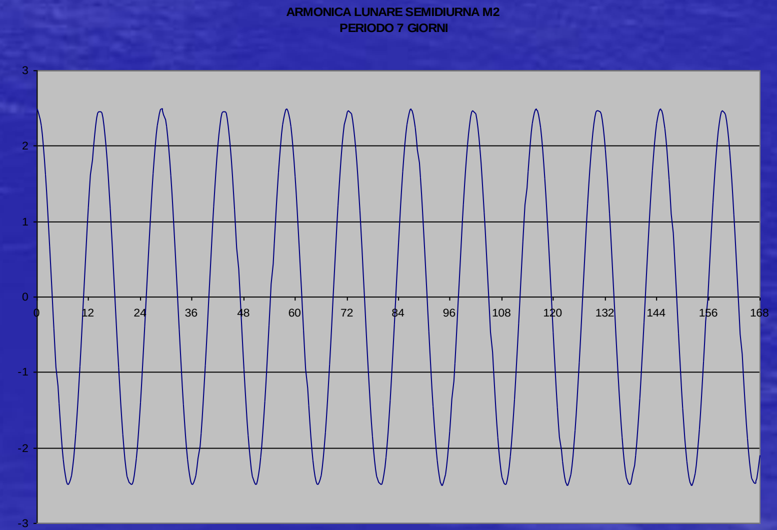


- Registered tide
- Main harmonics
- M2, S2, M1, S1, K1, O1, MS4

- Main simulated lunar harmonic M2

h=A cos(wt+β)

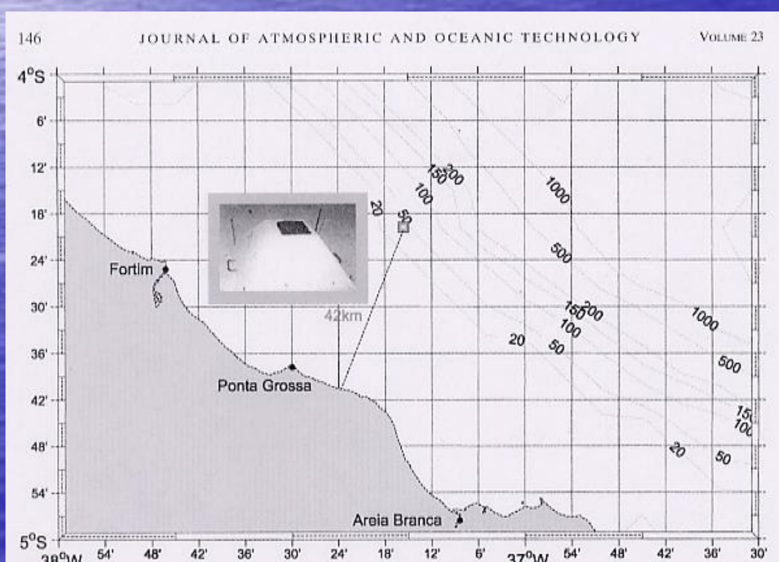
A=2.5 m, w=24.96 °/h

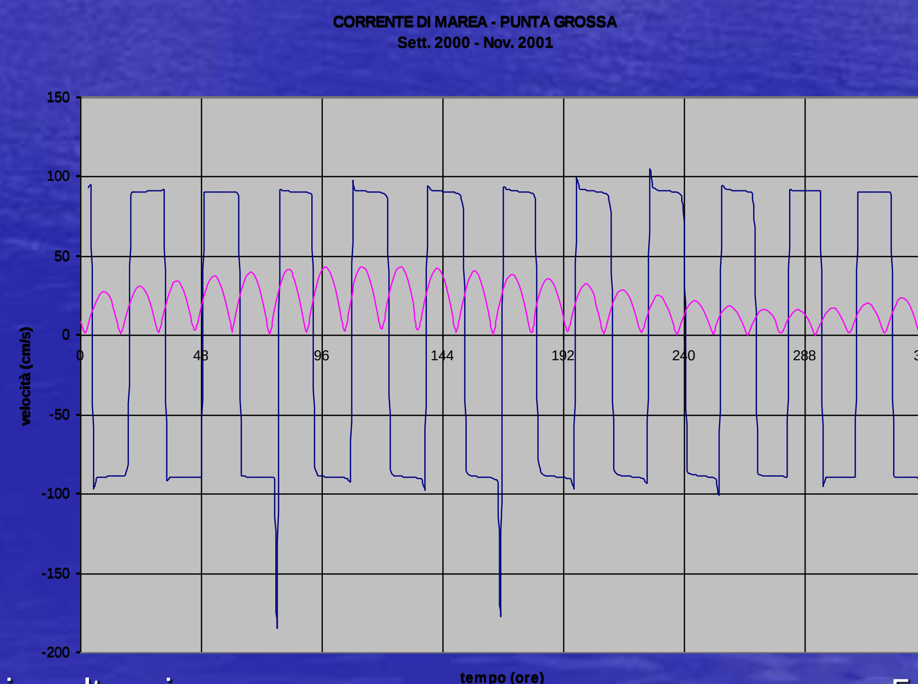


Tidal current recorded in Ponta Grossa (Brazil) Sept - Nov 2001

- Survey area south of Caucaia
- Distance 90 mg;
- dir = SE (135 °) from Caucaia

Armonics	Vel (cm/s)	phase(°)
M2	34.7	350
S2	13	266
K2	5.9	76
MKS2	16.2	160





Waves generated by wind

- Deep water waves
- Velocity [m/s]; T(Period [s])

$$V = \sqrt{\frac{g\lambda}{2\pi}} \quad [m/s]$$

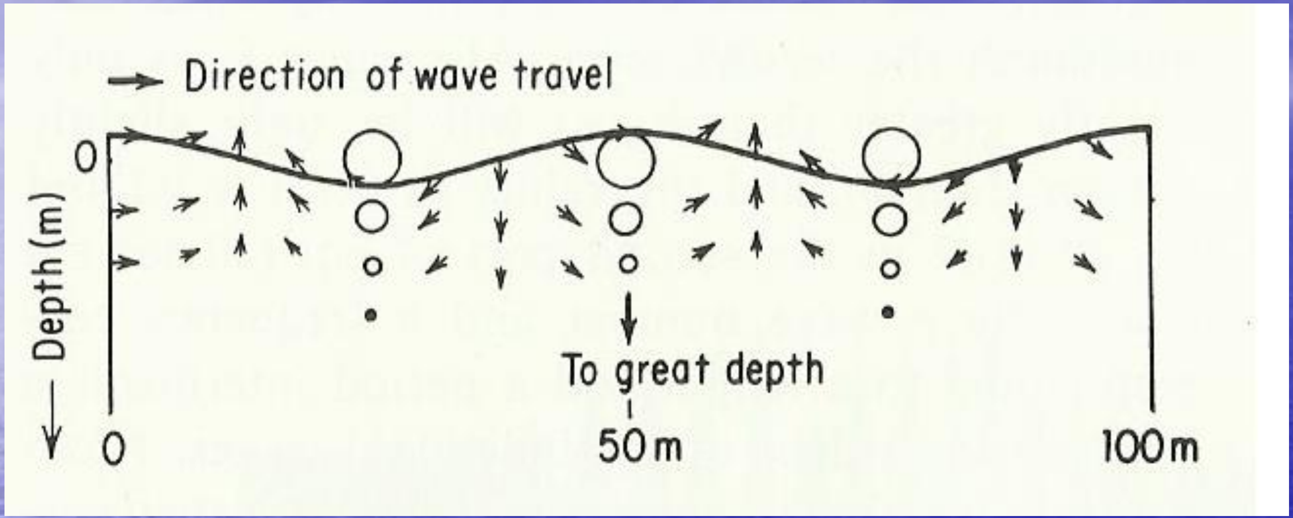
$$T = \sqrt{\frac{2\pi\lambda}{g}} \quad [s]$$

- Shallow water waves
- Velocity [m/s];
- *h* (depth of the sea – [m])

$$V = \sqrt{gh} \quad [m/s]$$

Fenomeno rifrazione

Deep water waves or short waves

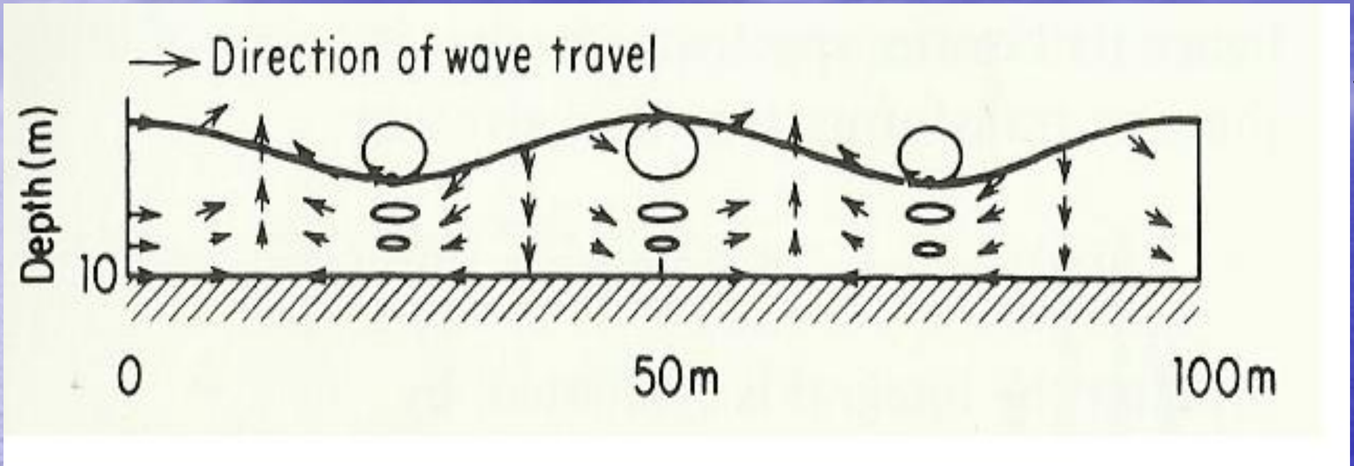


$$v = \sqrt{\frac{g\lambda}{2\pi}}$$

Instantaneous velocity vectors at time shown and orbital paths of fluid particles in a wave motion in deep water. Velocities are very small at a depth equal to one-half the wavelength

[$z = \lambda/2 \Rightarrow r = 0{,}04\ A$ m]

Shallow water waves or long waves

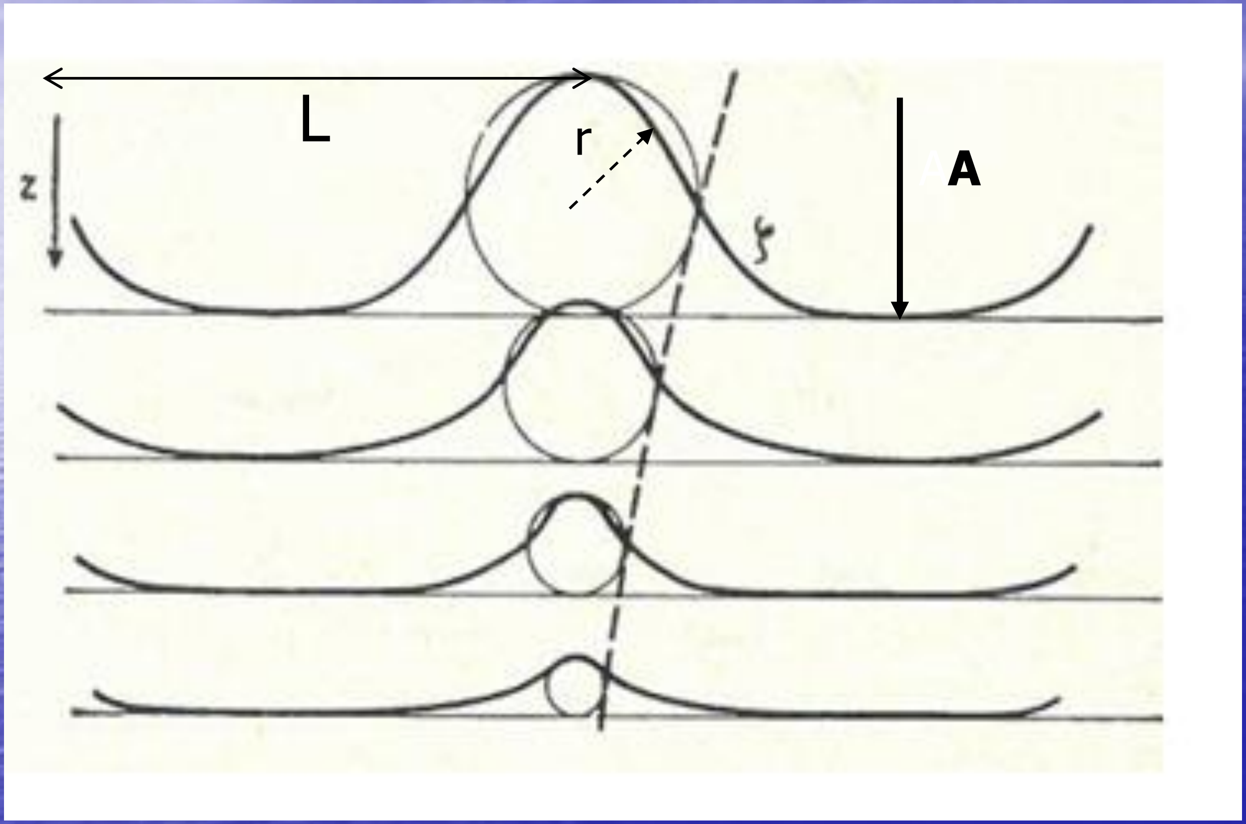


$$V = \sqrt{gh}$$

Instantaneous velocity vectors at time shown and orbital paths for one cycle of fluid particles in a wave motion in water of constant depth. Approximate conditions are shown for a wave with an amplitude of 2.5 meters and a length of 50 meters in water 10 meters deep.

$$\frac{r}{A} = e^{-\pi} = 0,043 \qquad r = 2.5[m] * 0.043 = 0,11[m]$$

Wavelength propagation with depth



L=λ/2=z

$$\frac{r}{A} = e^{-\pi} = 0,043$$

Definition of FETCH

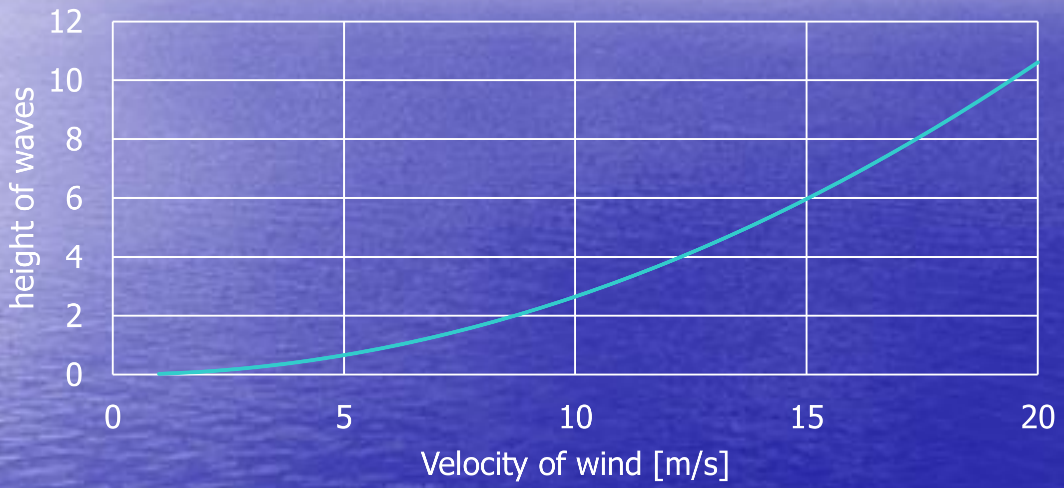
There is a way to determine how high a wave can become if the same wind blows over the sea surface for a certain period of time, above all because it is the latter that determines the evolution of the marine surface layer. The Fetch is nothing more than an area of the sea surface more or less extensive in which the wind blows with a constant or at least almost stationary direction. If there is such an area it is possible to calculate how high and long a sea wave can be.

There are many statistical formulas to do this (Stevenson, Molitor, Irribarren, Sverdrup-Munk), which essentially depend on the wind speed and essentially (the stronger the wind and the higher the wave will be) for the same fetch. The wave cannot grow to infinity: there is a limit by which energy can be transferred from the atmosphere to the ocean imposed by the presence of friction and gravity. Just to use some numbers, with a fetch of 300 kilometers and a wind of 60 km / h we can get waves of 4.5 m in height, while to get the same height with 100 km of fetch we should have a wind of 80 km / h.

H (m) = *F*(H(dimesion of fetch,t (h), v (velocity of wind)

Oceanic Fecth

SVERDRUP- MUNK - Wave height: developed sea

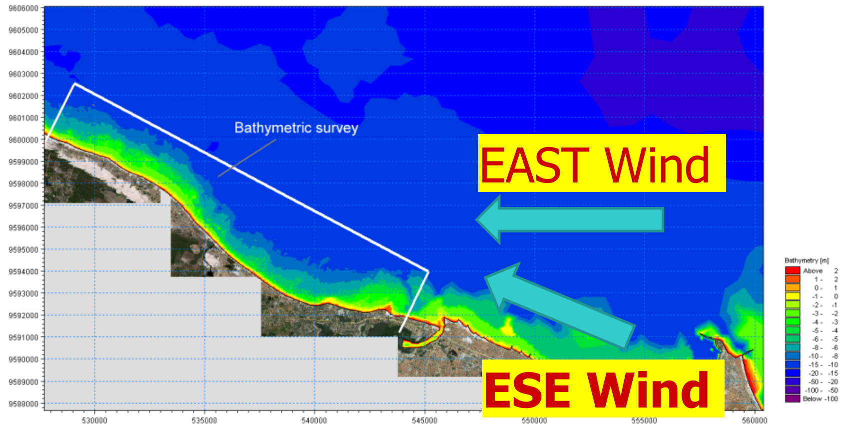


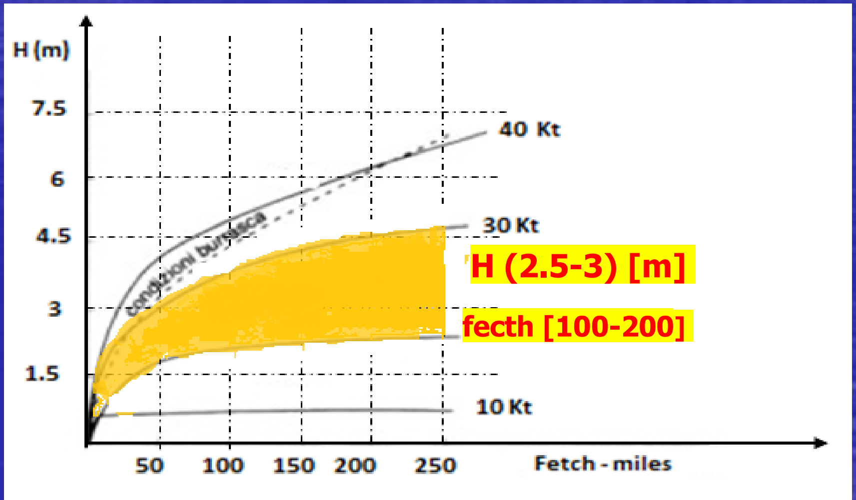
$$H = 0.26\frac{V^2}{g}$$

Relation between wavelength [λ], period [T], velocity [V] in ocean								
λ [m]	6	25	56	100	156	225	306	396
T [s]	2	4	6	8	10	12	14	16
V[m/s]	3	6	9	12.5	16	19	22	25

FETCH - Area Caucaia
(significant wave development)

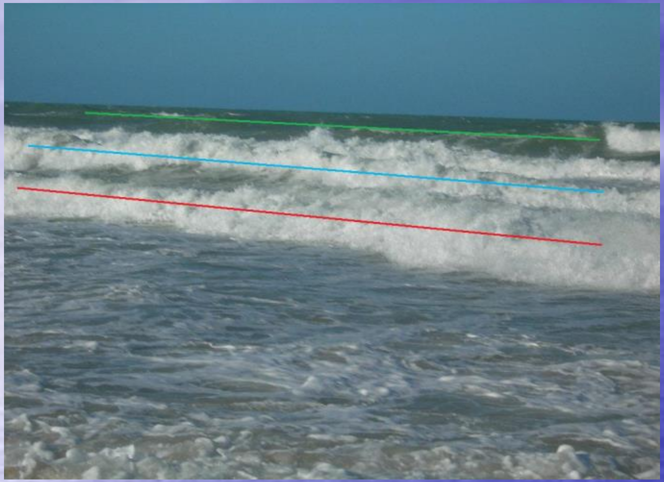
- The Fetch represents the area of the more or less extensive sea surface in which the wind blows with constant direction and speed (steady state). There are statistical formulas that allow us to calculate how high and long a sea wave generated in deep waters can be
- (**Deep water waves)**

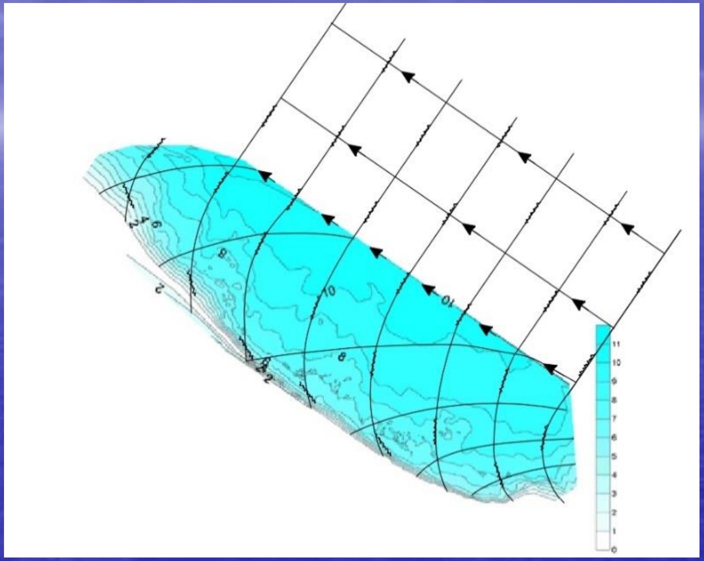




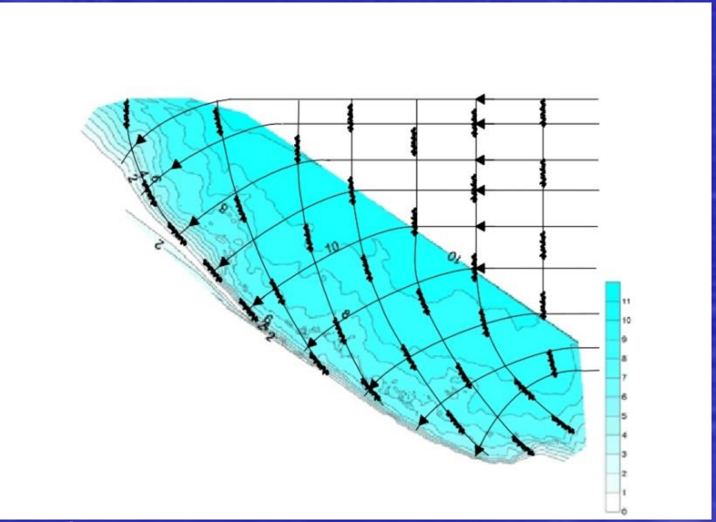
Wave plane (wave refraction)

- Wavefront propagation from ESE



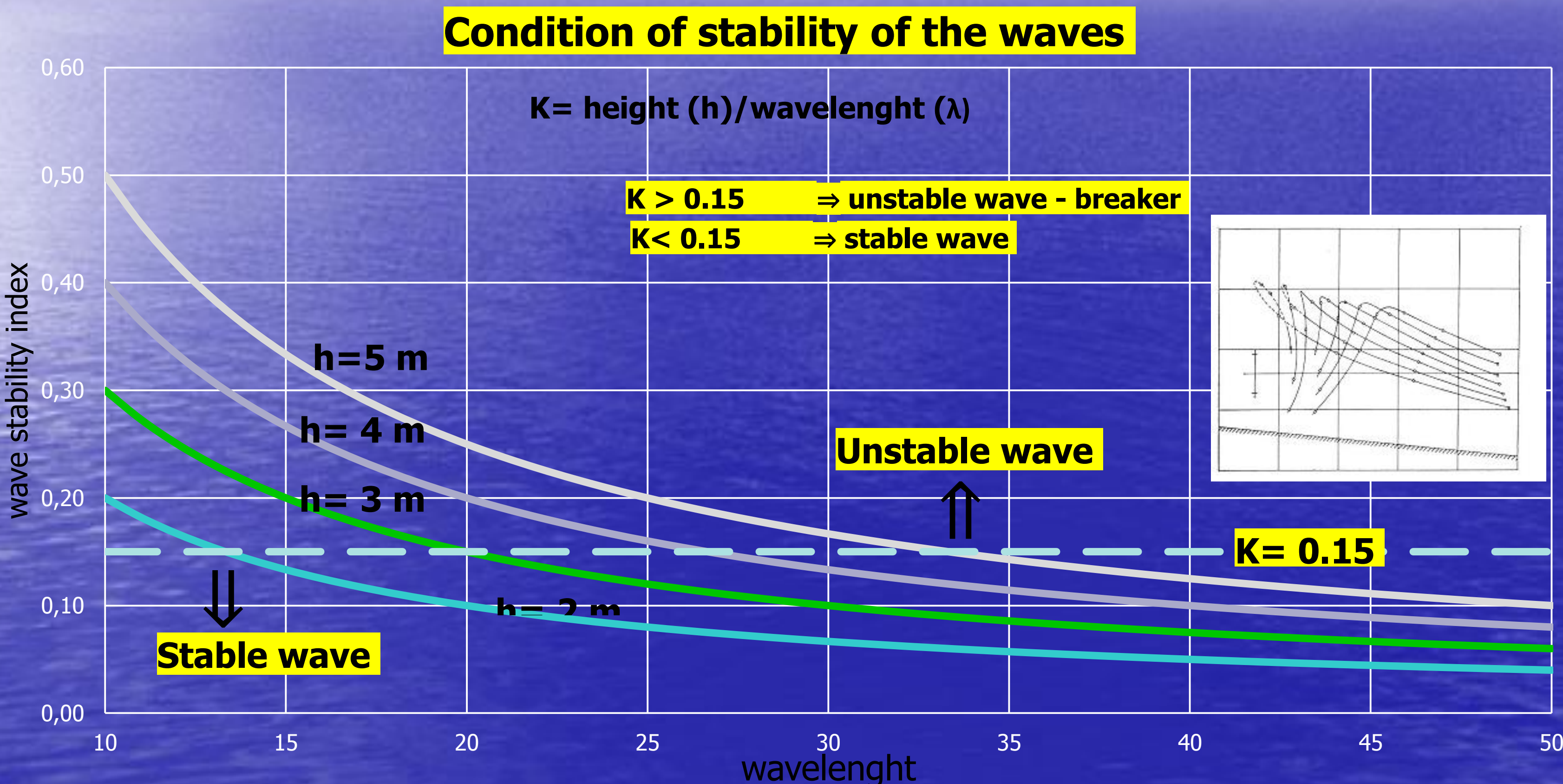


- Wavefront propagation from E (East)

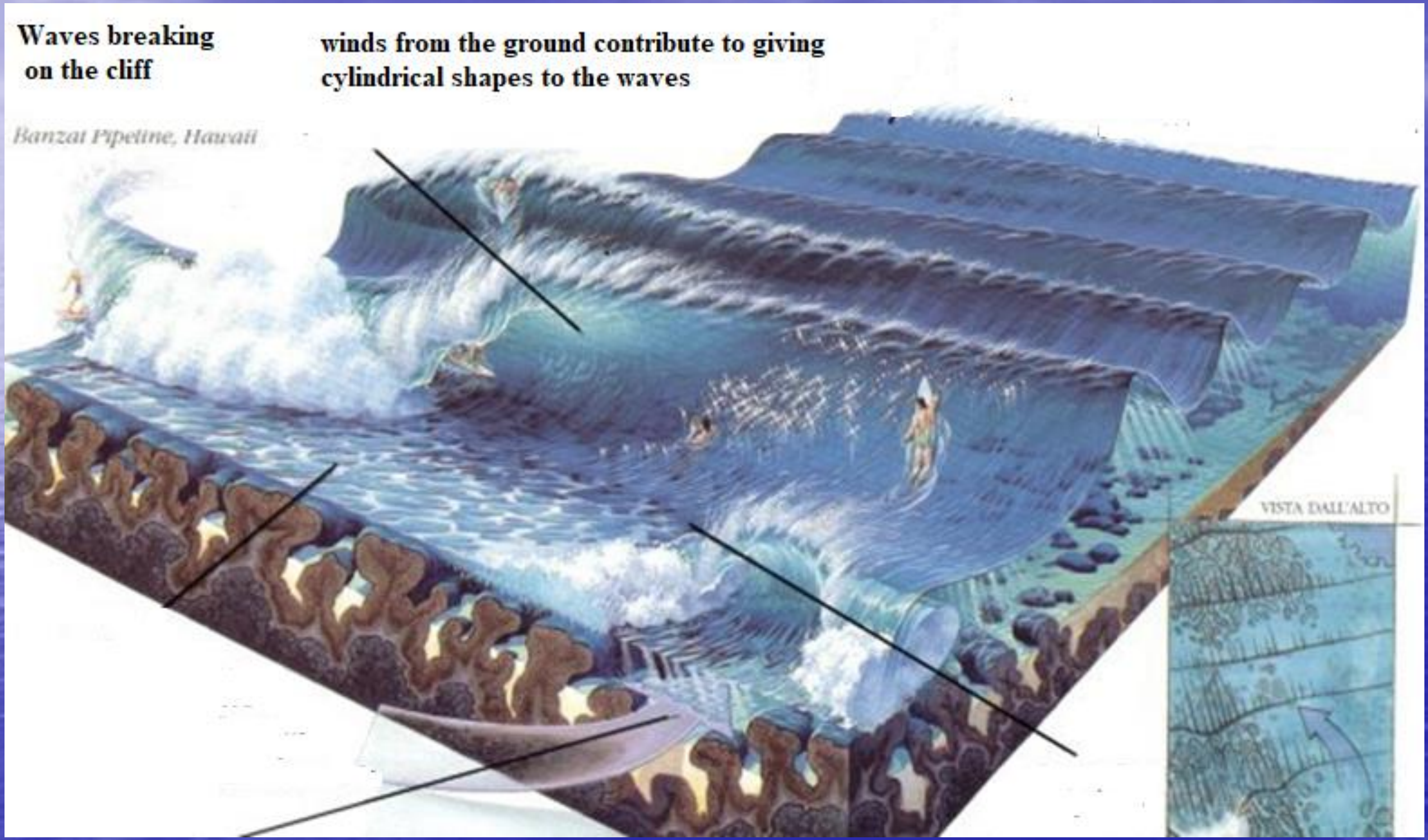


Short wave transformation in long wave

The wave breaks when the height / lengthwave ratio is >1/7 (h/λ)=0.15

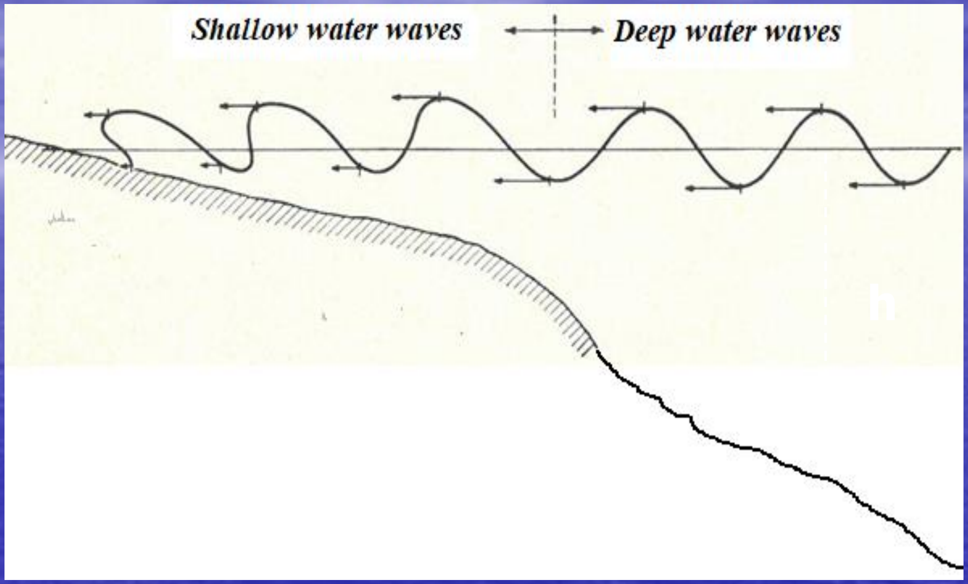


Example Transformation of waves into shallow waters



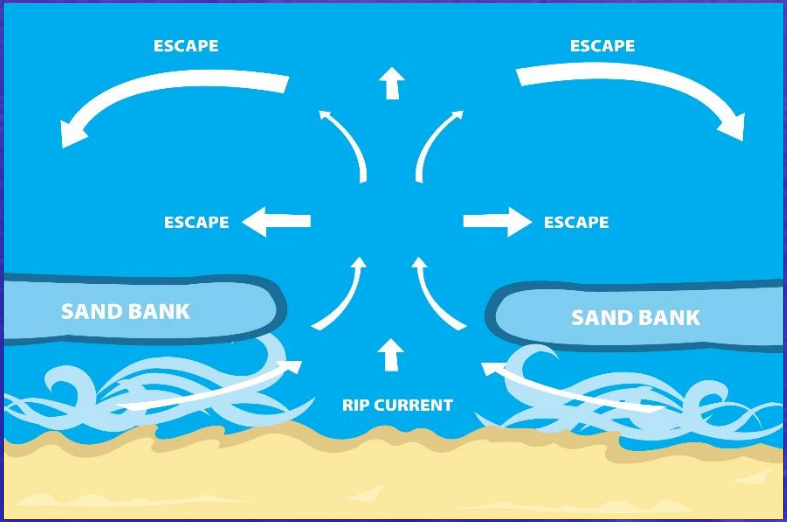
Transformation of waves into shallow waters

Example of transformation of a wave near the low coast, coastal area. The speed of the wave depends, in general, on the depth (greater in the crests than in the valleys). In deep sea the speed of the wave depends only on the wavelength (λ).



Rip currents

A **rip current**, often simply called a **rip**, is a specific kind of water current which can occur near beaches with breaking waves. A rip is a strong, localized, and narrow current of water which moves directly away from the shore, cutting through the lines of breaking waves like a river running out to sea, and is strongest near the surface of the water. Rip currents can be hazardous to people in the water. Swimmers who are caught in a rip current and who do not understand what is going on, and who may not have the necessary water skills, may panic, or exhaust themselves by trying to swim directly against the flow of water. Contrary to popular belief, neither rip nor undertow can pull a person down and hold them under the water. A rip simply carries floating objects, including people, out beyond the zone of the breaking waves.



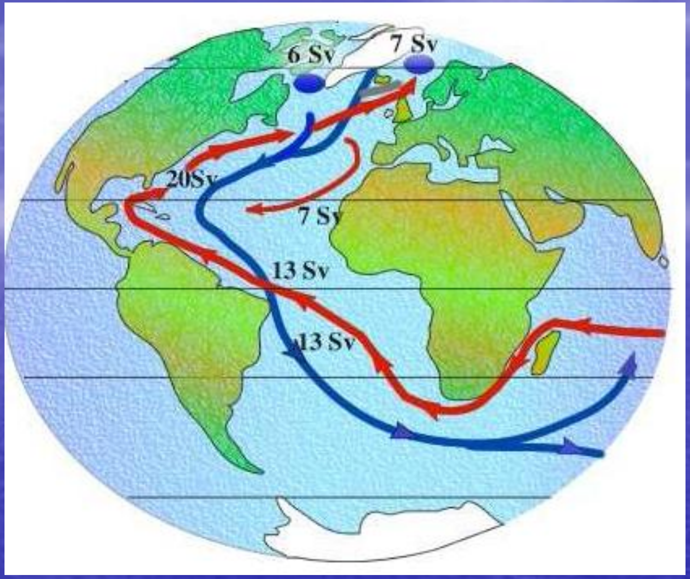
Rip currents

Technical explanation

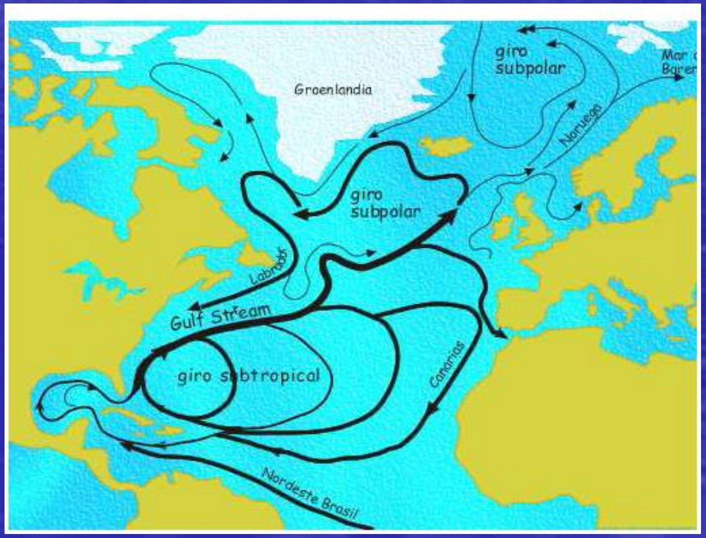
A more detailed description involves radiation stress. This is the force (or momentum flux) exerted on the water column by the presence of the wave. As a wave shoals and increases in height prior to breaking, radiation stress increases. To balance this, the local mean surface level (the water level with the wave averaged out) drops; this is known as *setdown*. As the wave breaks and continues to reduce in height, the radiation stress decreases. To balance this force, the mean surface increases — this is known as *setup*. As a wave propagates over a sandbar with a gap (as shown in the lead image), the wave breaks on the bar, leading to setup. However, the part of the wave that propagates over the gap does not break, and thus setdown will continue. Thus, the mean surface over the bars is higher than that over the gap, and a strong flow issues outward through the gap.

General circulation

Water current atlantic surface

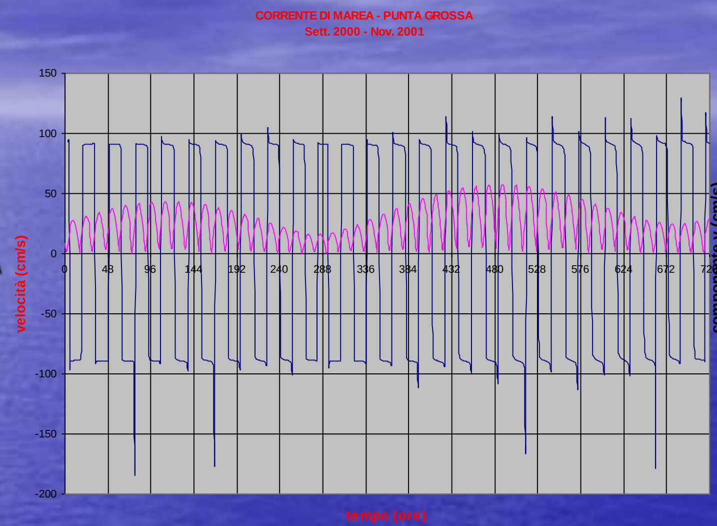


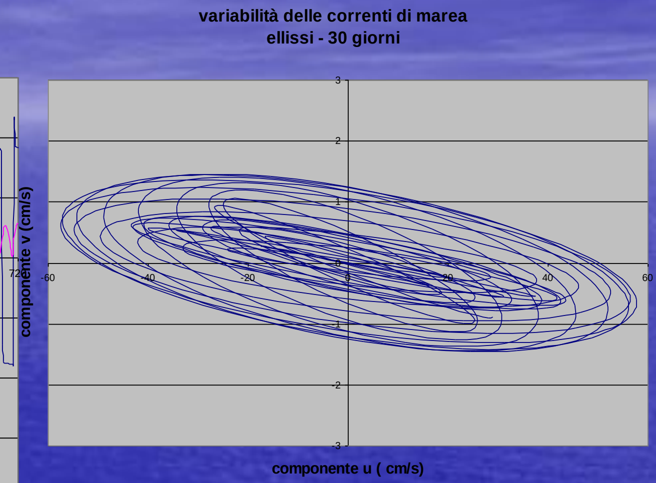
Surface current (stable flow)
Brazilian coasts (Guaiana current)
Average speed 50 -75 cm / s
(p> 75%)



Variability of tidal currents

Tidal current recorded in Ponta Grossa
90mg to ESE of CAUCAIA
Period = 720 h (30days)
C (syzygies 55 cm / s)
C (quadrature 35 cm / s)





$$c=\sum_{i=1}^{4}\left[u_i\cos(\omega_i t+\alpha_i)+v_i\,sen(\omega_i t+\beta_i)\right]$$

M2, K2, S2, MKS2

t ε [0,720]

Modello dinamico

- Restoration of the shorein Caucaia: numerical simulations;
- Giovanni Sgubin and Stefano Pierini;
- Dipartimento di Scienze per l'Ambiente;
- Università di Napoli - Parthenope.

Modello-dinamico

VIDEO 1-2-3

Dynamic model of water circulation in front of Caucaia

Remarks:

- The results obtained from the dynamic model on the general circulation in the area facing the study region of Caucaia are based on the application of a monostatic model to which the following boundary conditions have been applied:

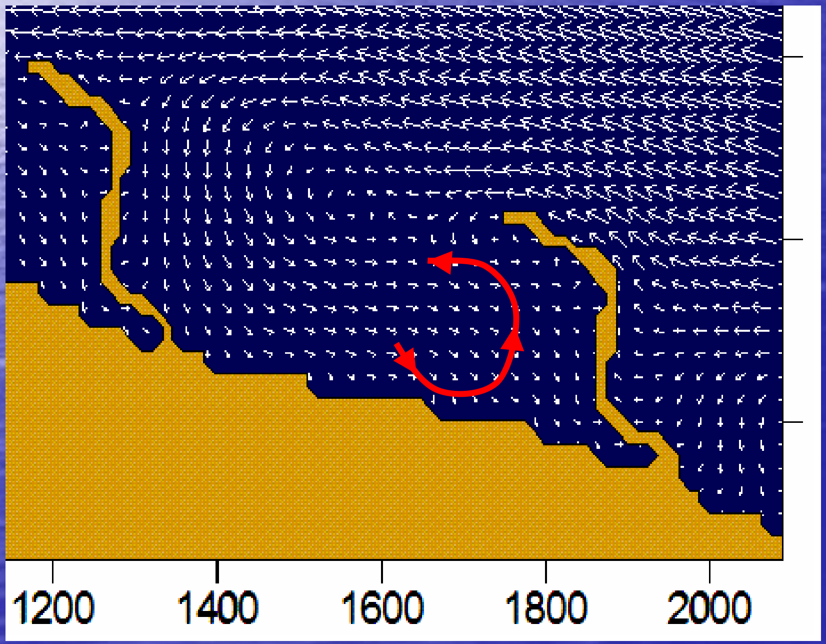
- stationary wind from the East;
- tide measured at fortaleza (July 2010);
- tidal current relative to the semidiurnal lunar harmonica;
- integration grid 12.5 m.

Dynamic model of water circulation in front of Caucaia

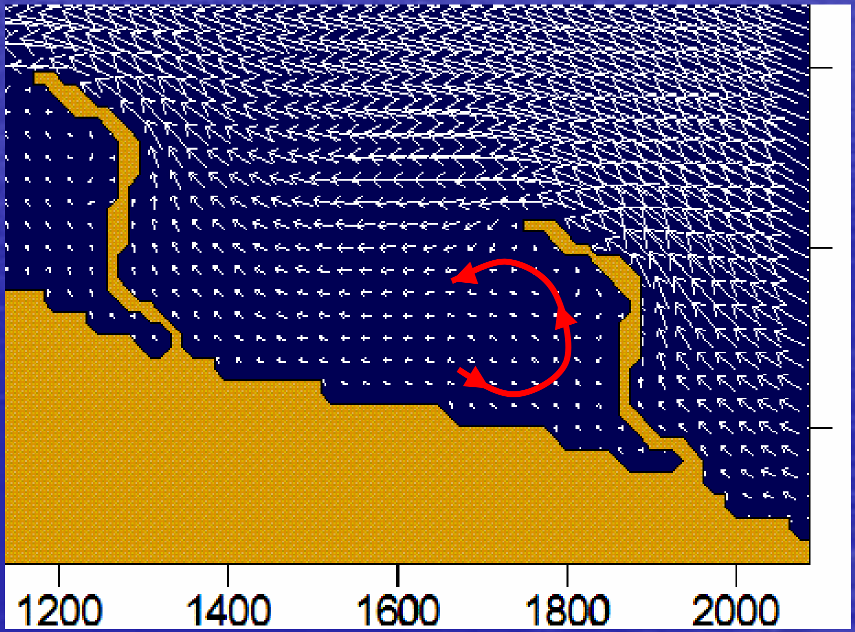
- From the general report, some representations of the circulation of water within the breakwaters relating to the processing interval (T = 12h) for the different 4 sectors were extracted and represented below:

Model of water circulation inside breakwaters

- **Sector 1 – Δt=0**

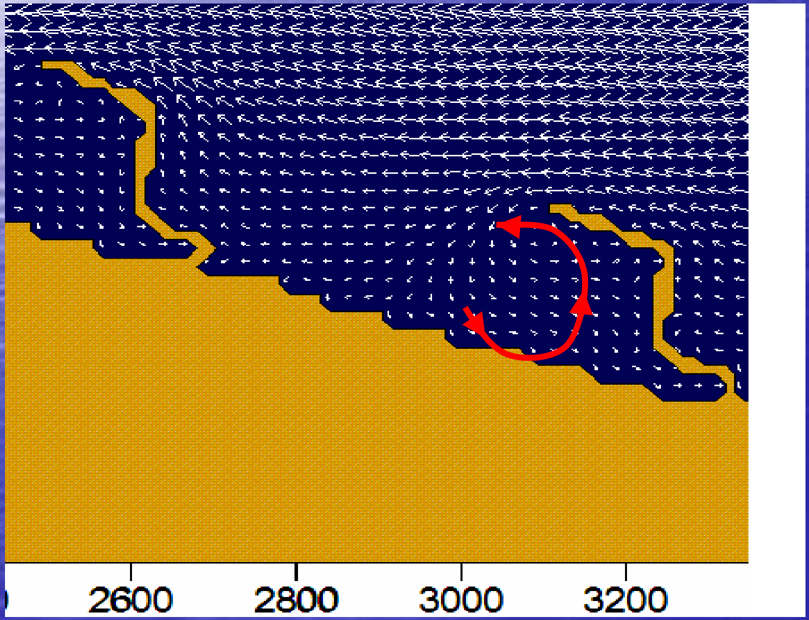


Sector 1 – Δt= 8

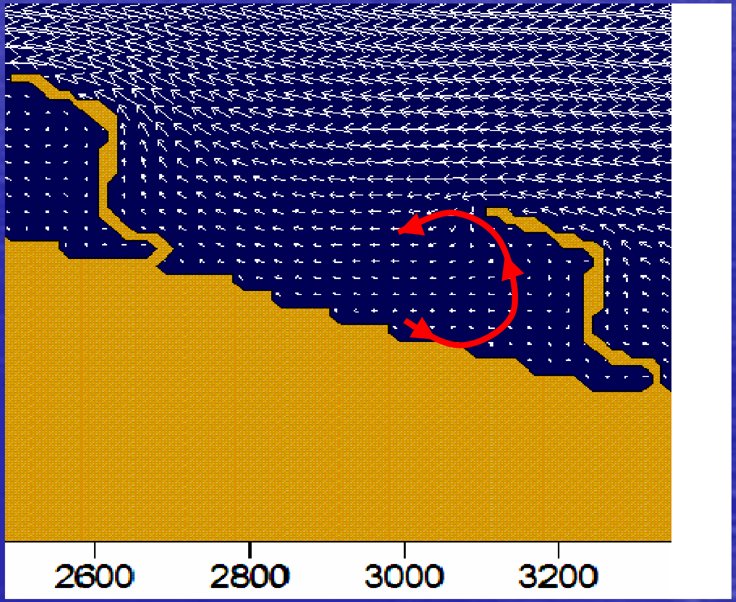


Model of water circulation inside breakwaters

- **Sector 2 – Δt = 8**

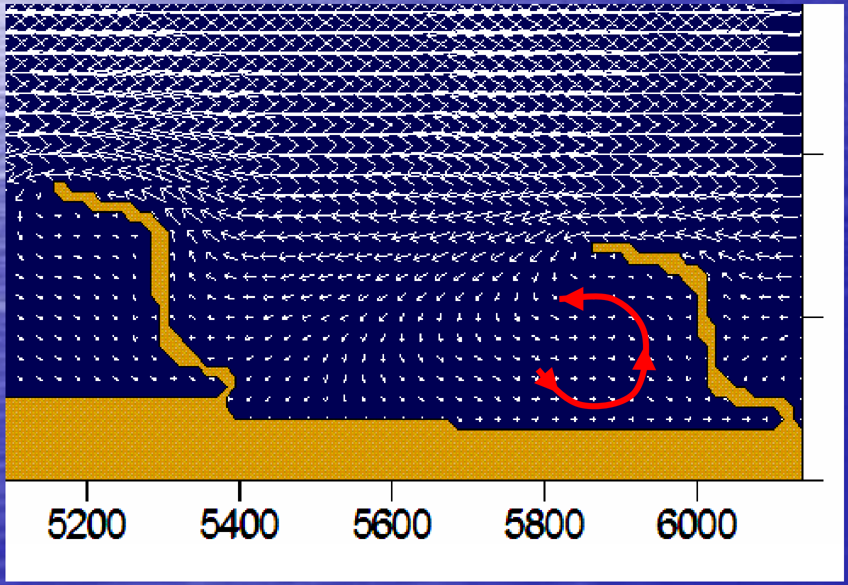


Sector 2 – Δt = 10

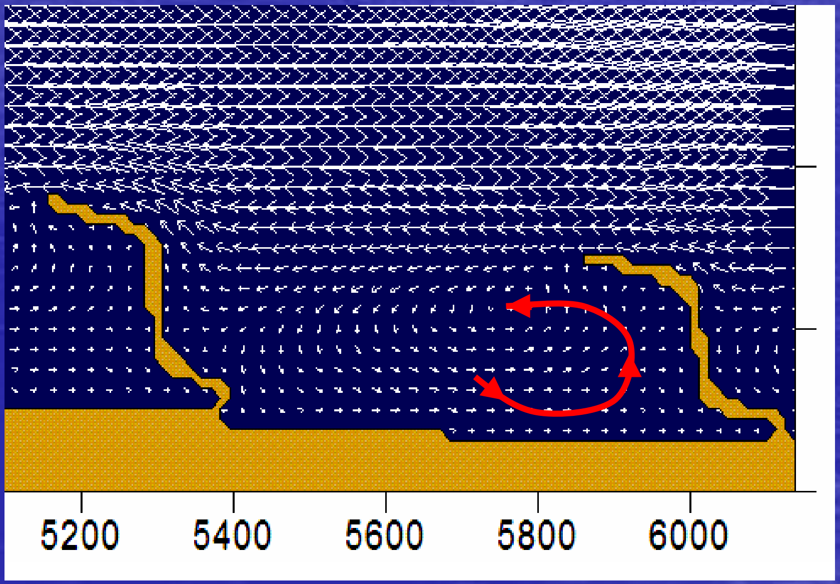


Model of water circulation inside breakwaters

- **Sector 3 – Δt = 8**

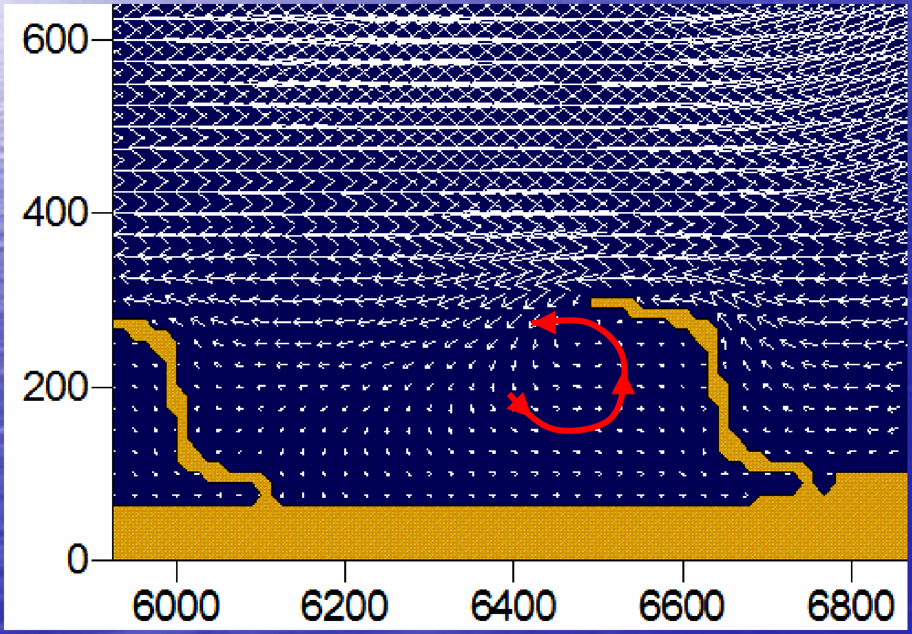


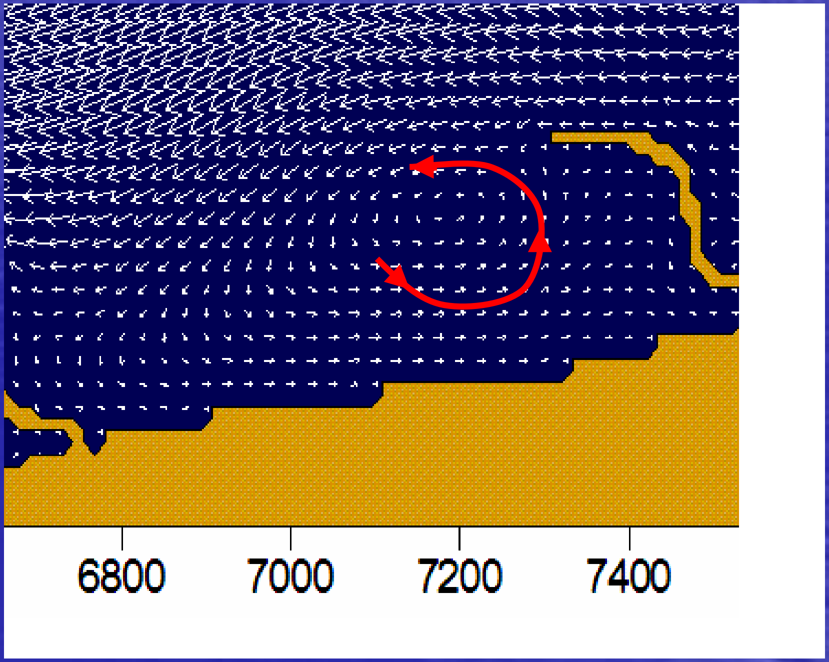
Sector 3 – Δt = 10



Model of water circulation inside breakwaters

- **Sector 4 – Δt = 8** **Sector 4 – Δt = 10**





Model of water circulation inside breakwaters

- **Within the breakwaters, bearing in mind that the main feature is represented by the tidal periodicity produced by the main lunar semidiurnal harmonic (M2), some first conclusions can be deduced on the motion of water in the area affected by the dynamic study;**
- **The model developed shows the generation of a vortex circulation in the area bounded by breakwaters with a periodicity linked to the tidal current; there are also areas of convergence of circulation near the coast line and breakwaters;**

Model of water circulation inside breakwaters

- Outside the interested area (coastal area delimited by breakwaters), the circulation of the waters has the same characteristics as the general current (Corrent of Guaiana) whose speed is affected by the semidurnal tidal component; for the simulated period, however, there were no reversals of directions but only speed reduction;
- In all four sectors, in which the coast has been subdivided, there are vortex circulations, in a counter-clockwise direction, at low speed (order of magnitude 5 cm / s);
- The low speed will facilitate the accumulation of sedimentation inside the area bounded by breakwaters;
- Within the area bounded by the breakwaters there is no possibility of formation of rip currents.
- The model should however be calibrated with real measurements and above all by introducing the real tidal current.