Sea Level Space and Temporal Variations and Related Processes

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Varadero Beach
Photo: Isabel L. Hernández Rivero
THE NATURE OF SEA LEVEL VARIATIONS

Sea level variations contain contributions from different physical sources that are usually distinguished by their period and space distribution (IOC, 2006)

Pugh D. (1996)

IOC (2006)
By another hand, sea level variations affect many marine and coastal environmental processes and also socio-economic processes too.
General scheme of the sea level components

\[ Z_0(t) = Z_0 + at + N + S_{a+sa} + Z_{w,p} + Z_m + e(t) \]

Mean Sea Level
Sea level long term trend
Seasonal Variability
Neap Tides
Tides
All meteorological effects
Residual effects
SURFACE GRAVITY WAVES: WIND WAVES (periods of 1 to 25 seconds)
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Havana City coasts close to the Instituto de Ciencias del Mar during the cold front with north wind
SURFACE GRAVITY WAVES AND RELATED PROCESSES: COASTAL EROSION

Waves can cause several effects as “wind set up” and “wave set up”

Coastal sector (sand beach) of the Institute of Marine Sciences during Wilma hurricane
SURFACE GRAVITY WAVES: SWELL

Waves are characterized as wind-waves or swell. Wind waves are generated by the effect of the wind on the local sea surface and have a relatively broad spectrum. Swell is produced when the waves propagate out of a storm area.

Hurricane Juan generated a powerful swell that caused the greatest flooding at Havana City coast until 1985 due to erratic behaviour in the Gulf of Mexico.
Sea level weather variations spread westward

Sea level meteorological variations during Kate influence

$Doodson_{32}$ and Running mean $(n = 361)$
Sea level weather variations spread eastward

Doodson$_{32}$ and Running mean (n = 361)
November 9, 1932, power full hurricane V Category, with northward displacement direction strait Santa Cruz settlement located at the south of Cuban Island: six meter surge and 3000 people death

Meteo Tsunami at Santa Cruz del Sur?
Mean daily sea level values are the good representation of synoptic sea level component.
SURFACE GRAVITY WAVES AND RELATED PROCESSES: COASTAL FLOODING
SEICHES (periods from minutes to hours). Local or regional.

Any body of water has a set of natural periods of oscillation at which it is easy to set up motions, which are called seiches (Proudman, 1953).

The periods of these seiches depend on the horizontal dimensions and the depth of the water, and range from less than a second for a tea-cup to many hours for the seas and oceans. The oceans of the world are particularly responsive to semidiurnal tidal forcing because the period of the forcing coincides with one of their natural periods of oscillation.
SEICHES (periods from minutes to hours). Local.

(Tomado de Tomczak M., 2000)
In case of the harbours and bays the node is found to be near to the open entrance, and the antinode is located at the closed end.

Waves with periods of several minutes, intermediate between those of wind waves (seconds) and tides (hours), are of practical importance because their period happens to coincide with that of some man-made systems.

Although the amplitudes of harbour seiches may not exceed a few centimetres, the associated currents may be relatively strong because of the short periods in which water transfers take place and then they can exert great influence on the exchange of matter and energy.

Ships moored in harbours have suffered damage because their natural period of yaw coincided with that of the harbour oscillation.

Seiches can also give rise to rapid currents in and out of a narrow harbour entrance, as the harbour levels adjust over short periods.
TSUNAMIS (periods from minutes to hours). From local to global scale

Tsunamis are wave events generated by seismic activity and as such fall outside the two principal categories of forces responsible for sea motions: tides and the weather.
Virtually all tsunamis are generated by submarine earthquakes, but landslides into the sea, and submarine volcanoes and sediments on the continental slope may occasionally be responsible. Very small tsunamis, non-destructive and undetectable without specialized equipment, occur frequently as a result of minor earthquakes and other events.

Lisbon earthquake

Volcanoes eruption.
(Indonesia in 1883: 35 m or 42 m according different sources)

There are three distinct aspects of tsunamis which may be considered: their generation by earthquakes, their propagation in deep water, and their behavior when they strike the coasts adjacent to shallow water.
TSUNAMIS AND RELATED PROCESSES

Tsunamis?

Storm surges?

Meteotsunamis?

Who is the guilty?

Fajas costeras con huracanolitos/tsunamolitos

- Up to six cubic meters
- Up to three cubic meters

**TIDES (tides centred around 1/2 and 1 day)**

*Have been determined 390 components*

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VI CARIBE-ews Short Course on Sea Level Station Installation, Maintenance and Leveling, Quality Control and Data Analysis

26 February – 2 March 2018, UNAM, Ciudad de México, México

TIDES

From Lorenzo, S.L., 2007)
TIDES AND MANGROVES
**Bore**

Is a tidal wave which propagates as a solitary wave with a steep leading edge up in certain rivers. Formation is favoured in wedge-shaped shoaling estuaries at times of spring tides. Temporary reverse the flow of these rivers and appears as a wave crest traveling up river. Other local names include Eagre (England, River Trent), Pororoca (Brazil), Mascaret (France).
SEASONAL TO MONTHLY VARIATIONS

Variabilidad estacional del nivel del mar en presencia del ENOS.
Siboney 1997 - 1998

Fecha [mes,año]
MONTHLY VARIATIONS

Ciclo anual de La Coloma. 1997-98

Valor medio mensual (cm)

Meses del ciclo anual

1997

1998

CAM
VI CARIBE-EWS SHORT COURSE ON SEA LEVEL STATION INSTALLATION, MAINTENANCE AND LEVELING, QUALITY CONTROL AND DATA ANALYSIS

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SEASONAL AND MONTHLY VARIATIONS AND RELATED PROCESSES

“It is likely that mangrove inland expansion progressed in pulses, driven by the warm phase of the ENSO anomaly, which can episodically add 20 cm or more to the background trend for sea-level rise” (Xavier Lo´pez-Medell’in, Exequiel Ezcurra, Charlotte Gonzáˇlez-Abraham, Jon Hak, Louis S. Santiago & James O. Sickman (2011). Oceanographic anomalies and sea-level rise drive mangroves inland in the Pacific coast of Mexico. Journal of Vegetation Science 22 (2011) 143–151).

COASTAL FLOODING  ECOSYSTEM MIGRATIONS
While sea level had remained almost stable during the last two millennia, subsequently to the last deglaciation that started years ago, tide gauge measurements available since the late nineteenth century have indicated significant sea level rise during the twentieth century.
SHORT TO LONG TERM PERIODS VARIATIONS AND RELATED PROCESSES

Coral reef bank “Buena Esperanza”

Input increase of biogeochemical substances to shelf shallow waters could affect coral reef and other ecosystems

Permanent flooding areas by 2100
SHORT TO LONG TERM PERIODS VARIATIONS AND RELATED PROCESSES

We can expect gradual displacement of sand sediment inland
SHORT TO LONG TERM PERIODS VARIATIONS AND RELATED PROCESSES

We can expect an increase damages of coastal and marine of infrastructure and of maintenance cost and investment increase consequently.

Sea level rise + sea level anomalies + tides + surface waves
SHORT TO LONG TERM PERIODS VARIATIONS AND RELATED PROCESSES

Sandy beach regeneration
SHORT TO LONG TERM PERIODS VARIATIONS AND RELATED PROCESSES

(Tomado de Lorenzo – Sánchez, 2007)
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**SHORT TO LONG TERM PERIODS VARIATIONS AND RELATED PROCESSES**

- **Sediment accumulation:** 50 hectares
- **Coastal line retreat:** 22m in 42 years
- **Coastal line retreat:** 90m in 42 years
Successive retreating and flooding processes

Coastal erosion

Migrations of animals, plats and humans

SHORT TO LONG TERM PERIODS VARIATIONS AND RELATED PROCESSES

We can expect gradual flooding of marine terraces

Tidal niches
Every year

From weather waves and tsunamis to sea level rise risk
FINAL REMARKS

Sea level variations represent the most transcendental events and processes for humanity from the ancient times. Most of the great civilizations and populations settled in the coastal areas and in the rivers near the sea. This situation is not different at the present days. The richest ecosystems on the planet are also exposed to the direct or indirect influence of sea level.

In this sense, countries with shores open to the Intra Americas Sea, should pay special attention to the development of predictive knowledge of sea level variations of all temporal and space scales.
Gracias por su atención!

Thank you, for your attention!

Varadero Beach
Photo: Isabel L. Hernández Rivero