Coastal Dynamics

Surface Gravity Waves, Estuaries & Types of Tide Gauges for the Coastal Ocean

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with some slides courtesy of
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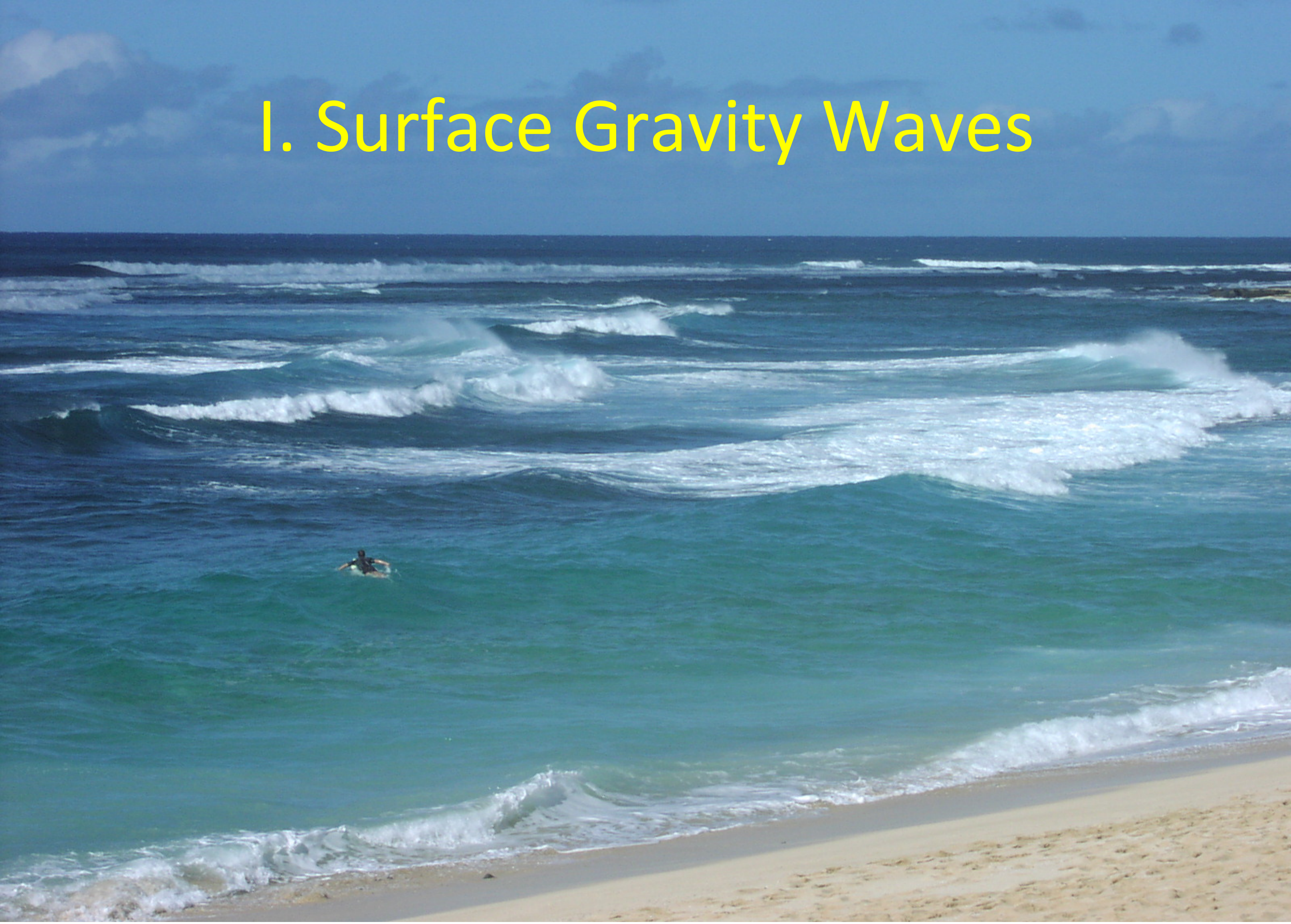
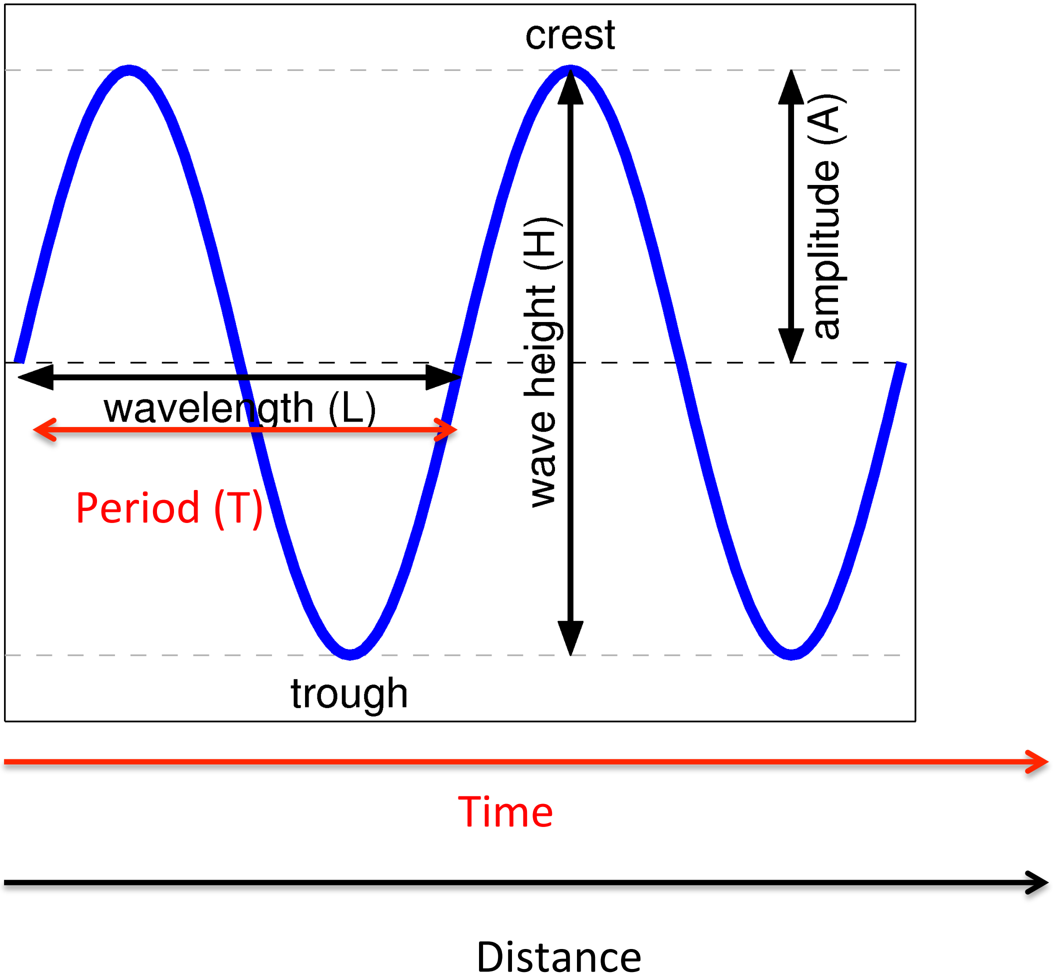
I. Surface Gravity Waves



Waves in the Ocean

Properties of Waves

Wave Height (H)
Amplitude (A)
Wavelength (L)
Wave Steepness
Wave Period (T)
Wave Phase Speed c=L/T



Some Wave Field Characterization Terms

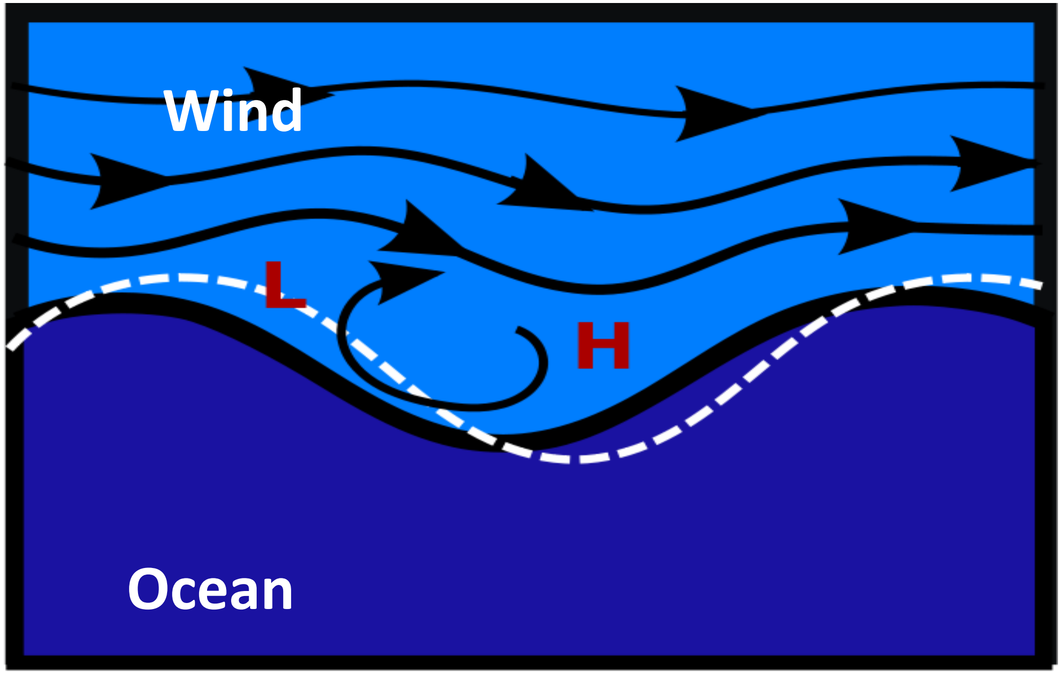
The ocean surface has waves of many different periods and wavelengths traveling in different directions. Some ways to characterize this wave field are:

- Significant Wave Height: $H_{1/3}$
  - Older: Average of the highest 1/3 of waves − similar results to what a trained observer estimates as the wave heights
  - Newer: =4*standard deviation of surface displacement
- Dominant Wave Period: Wave period with most energy

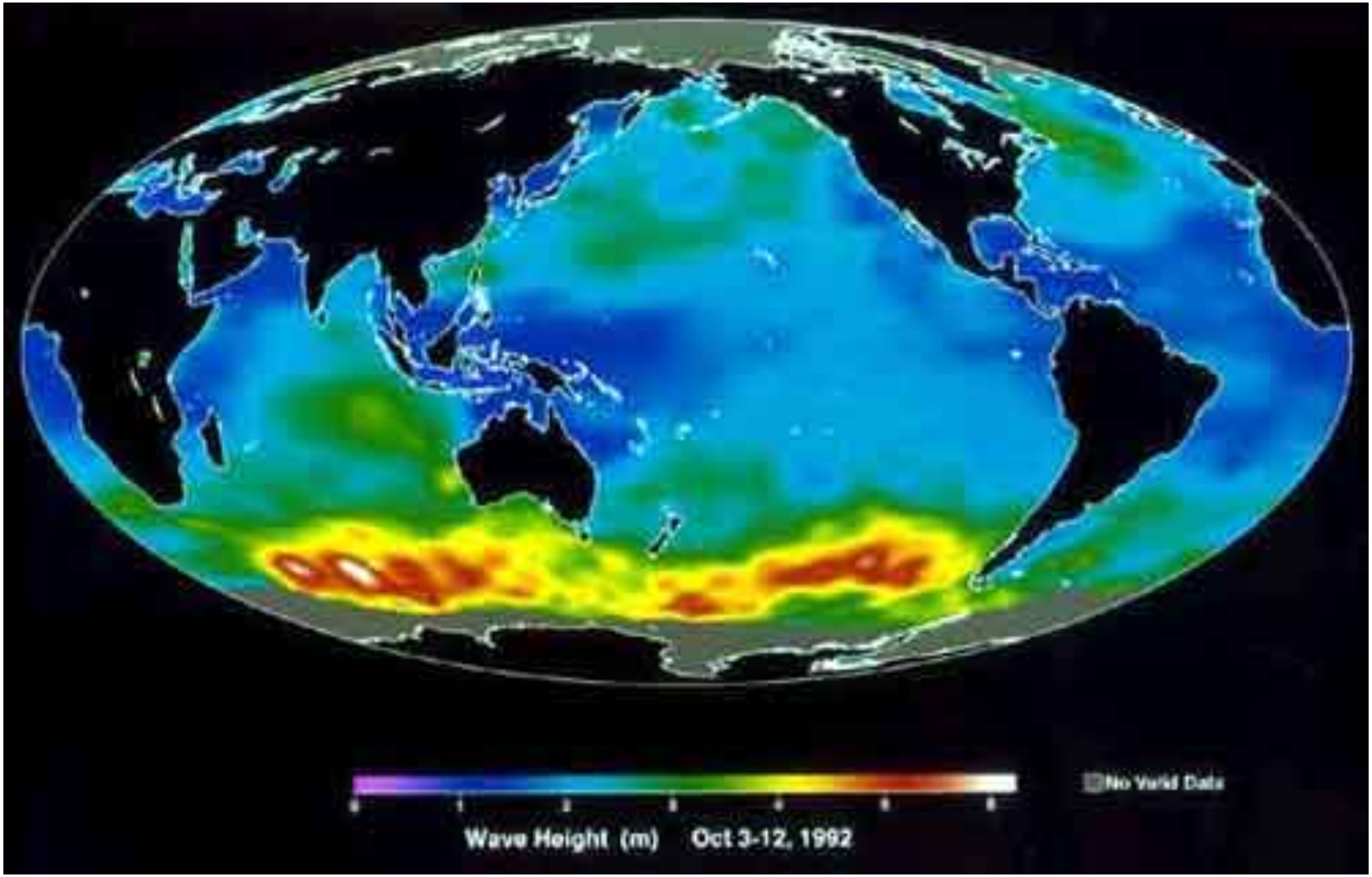
Wave Generation by Winds

Conceptual Description of Wind Wave Development

1. Wind begins blowing over calm water
2. Instabilities cause air pressure fluctuation
3. Air pressure fluctuations create small waves
4. Surface waves on ocean further perturb wind field, which leads to more wave development on the ocean surface
5. Wave-wave interactions lead to lower frequency waves

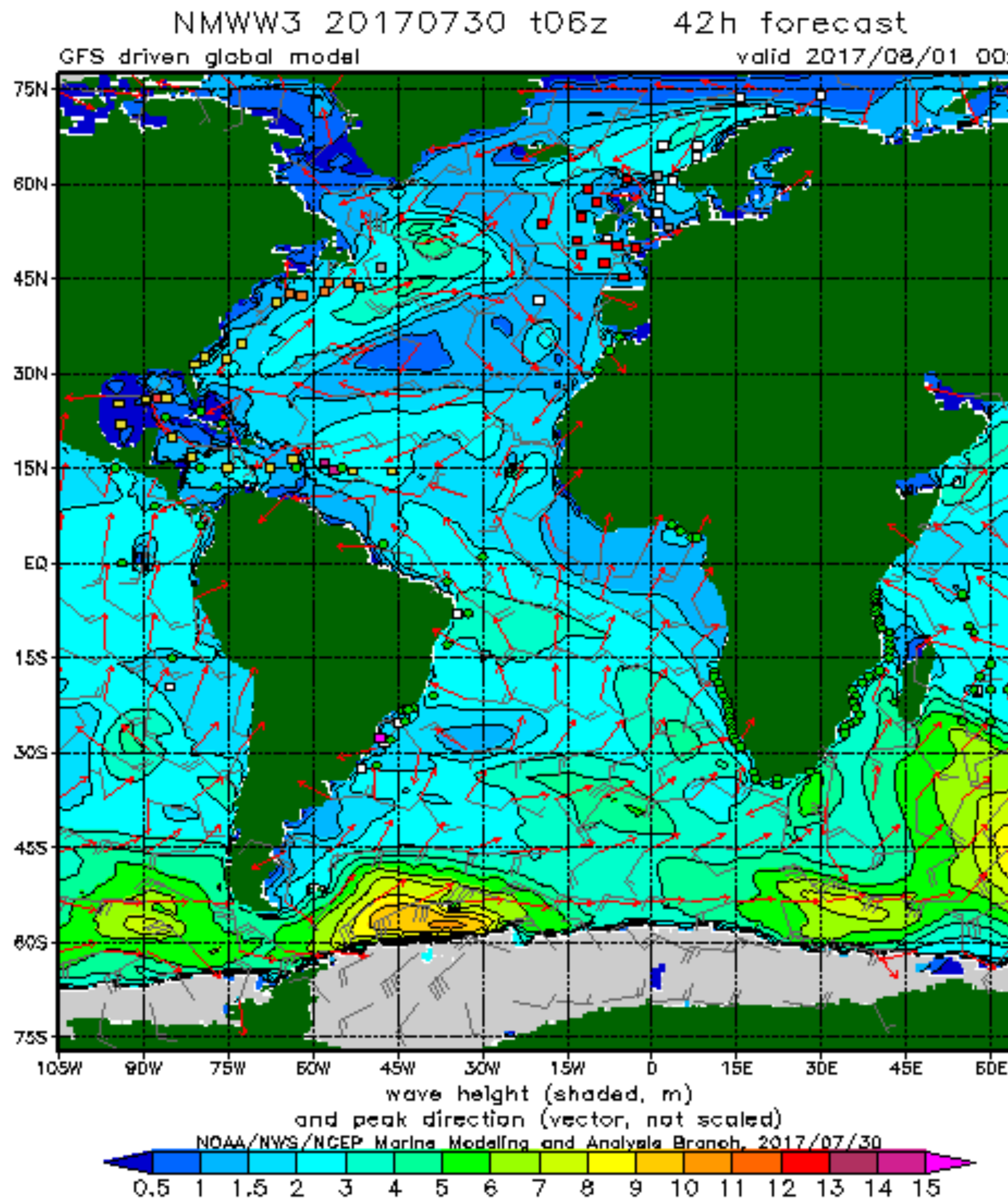


Wind Generation of Surface Gravity Waves



Wavewatch III- Surface Wave Forecast

- SO storms very energetic
- swell versus wind waves
- swell- long waves arrive first

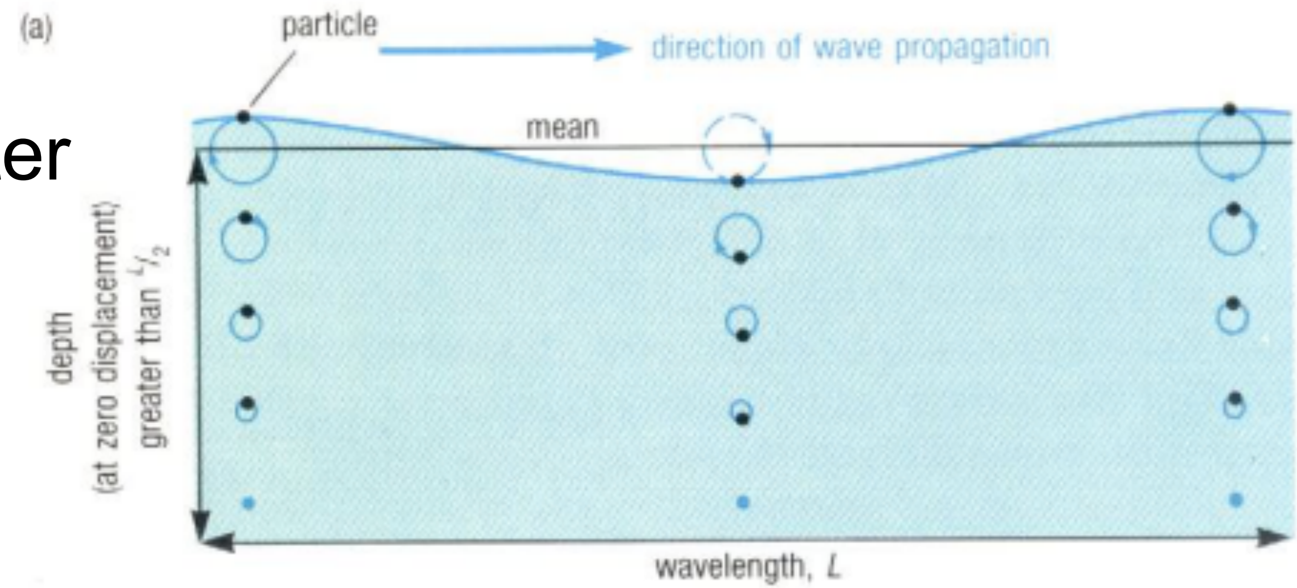


Wave Height (m)

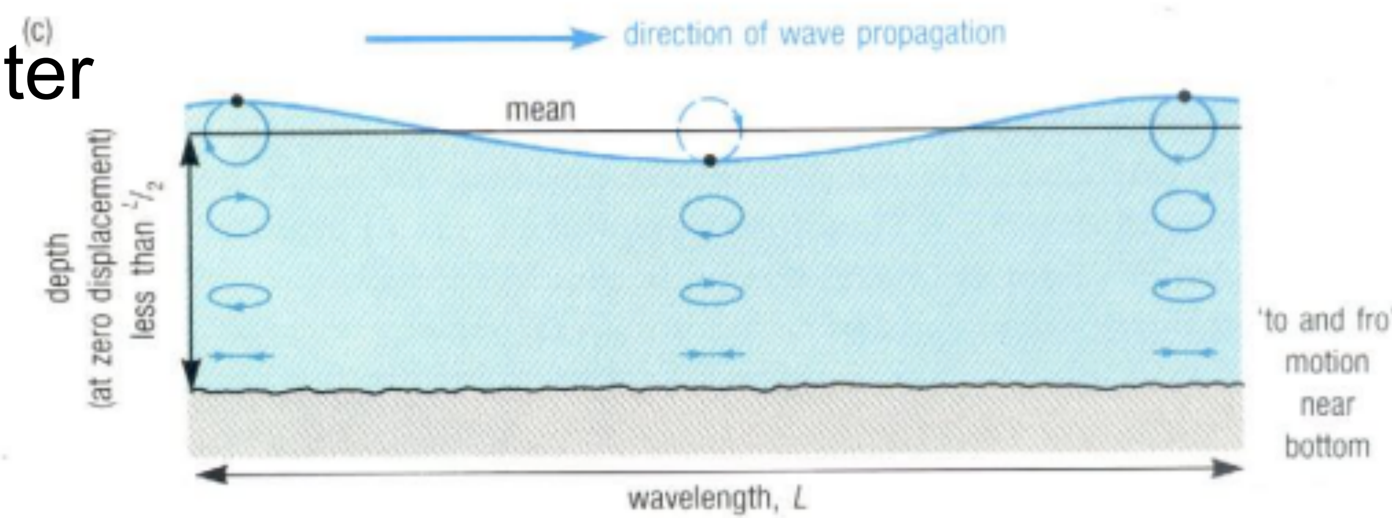
http://polar.ncep.noaa.gov/waves/

Surface Gravity Waves

Deep Water Waves



Shallow Water Waves



Surface Gravity Waves-- Wave Speed ($c=L/T$)

$$c = \sqrt{\frac{gL}{2\pi}\tanh\left(\frac{2\pi d}{L}\right)}$$

water depth

Shallow Water Waves $\frac{d}{L} << 1$

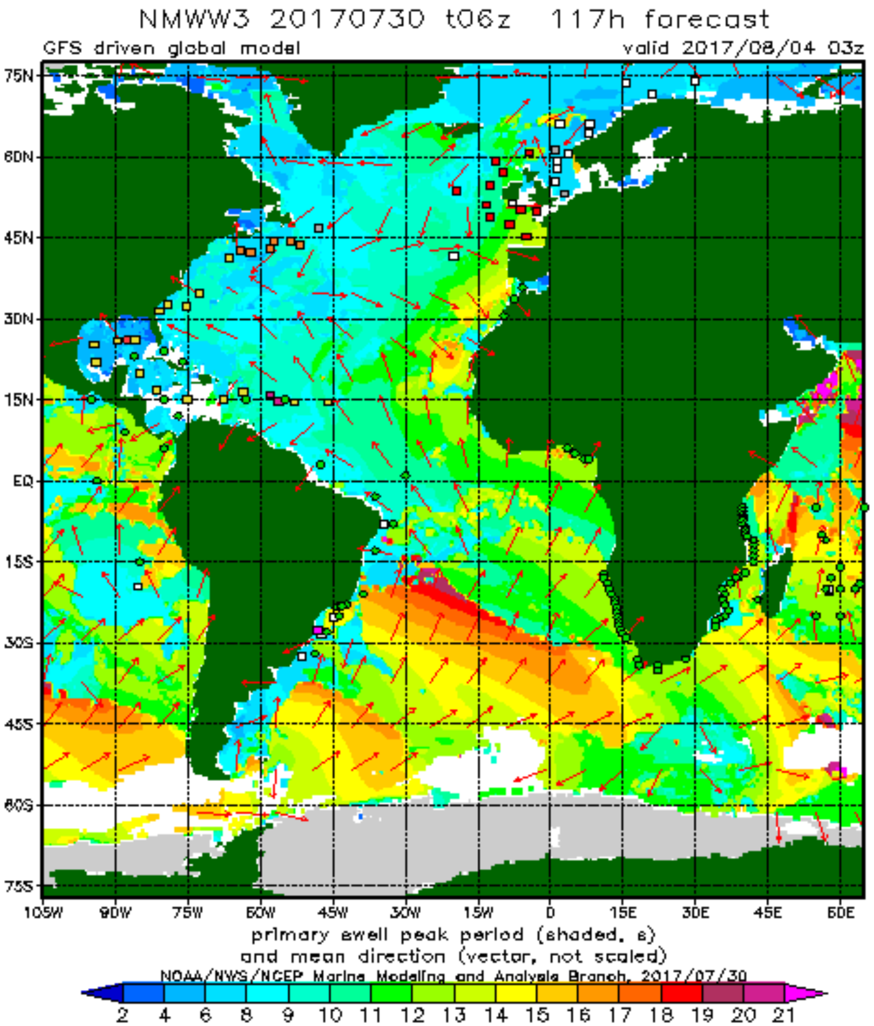
$$\tanh\left(\frac{2\pi d}{L}\right) \rightarrow \frac{2\pi d}{L}; c = \sqrt{\frac{gL \times 2\pi d}{2\pi L}} = \sqrt{gd}$$

Deep Water Waves $\frac{d}{L} >> 1$

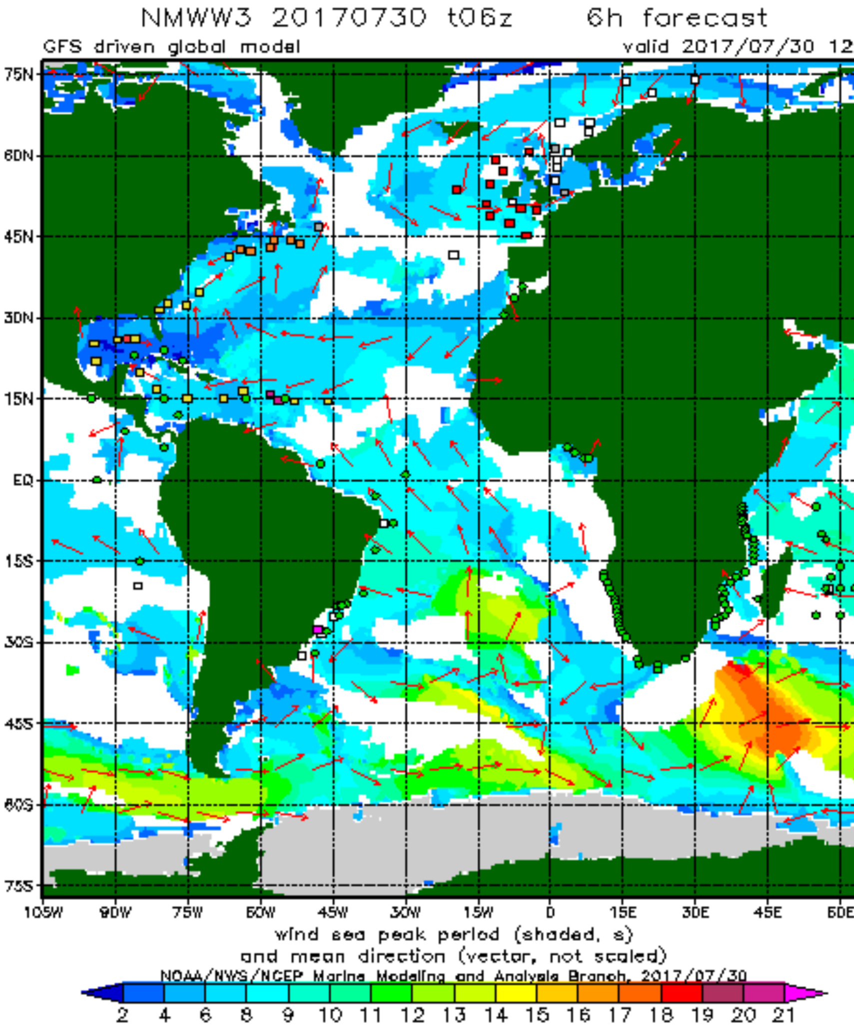
$$\tanh\left(\frac{2\pi d}{L}\right) \rightarrow 1; c = \sqrt{\frac{gL}{2\pi}} = \frac{gT}{2\pi}$$

Dispersion: Deep Water Waves $c = \sqrt{\frac{gL}{2\pi}} = \frac{gT}{2\pi}$

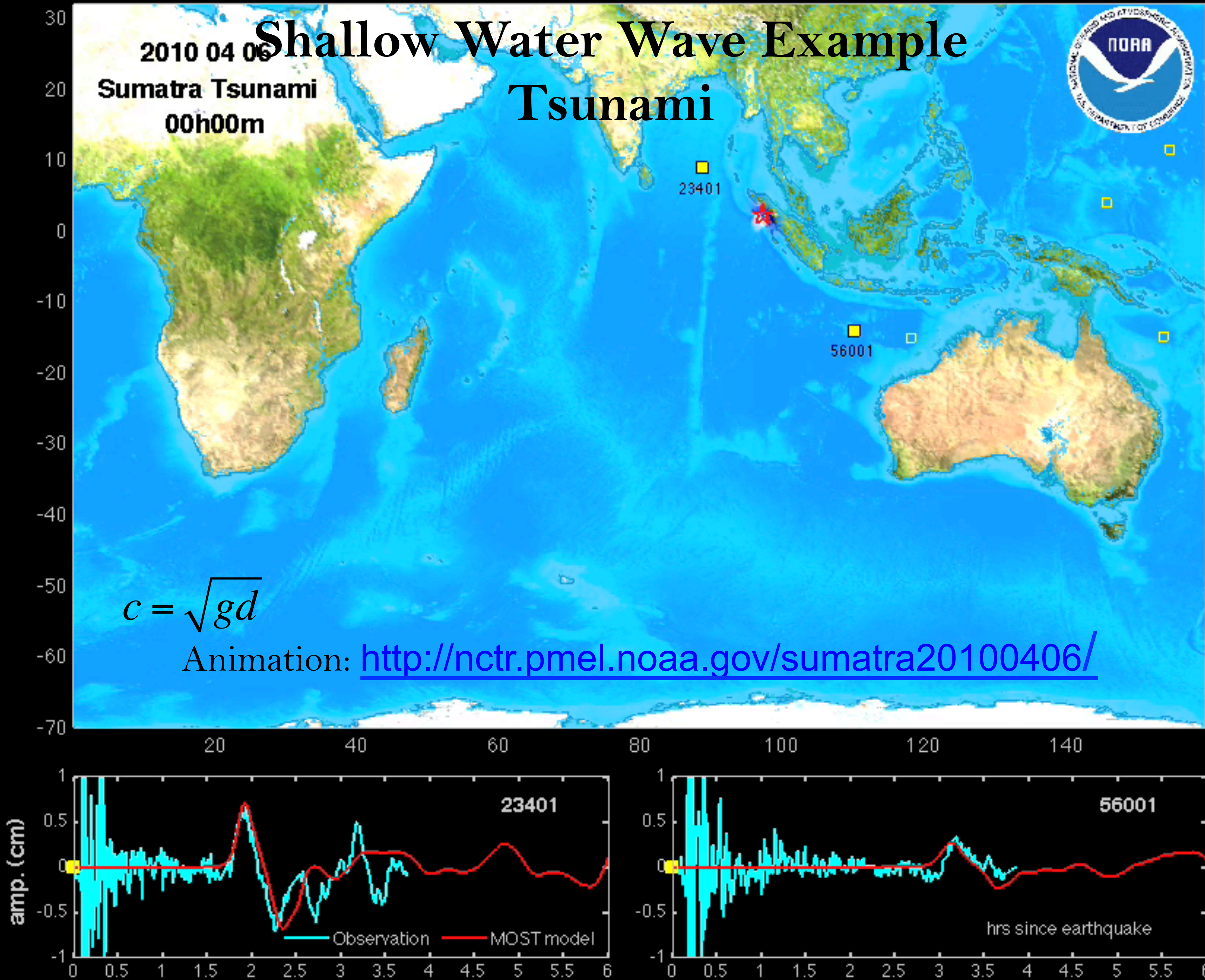
Swell Period & Mean Direction



Sea Period & Mean Direction



Shallow Water Wave Example Tsunami

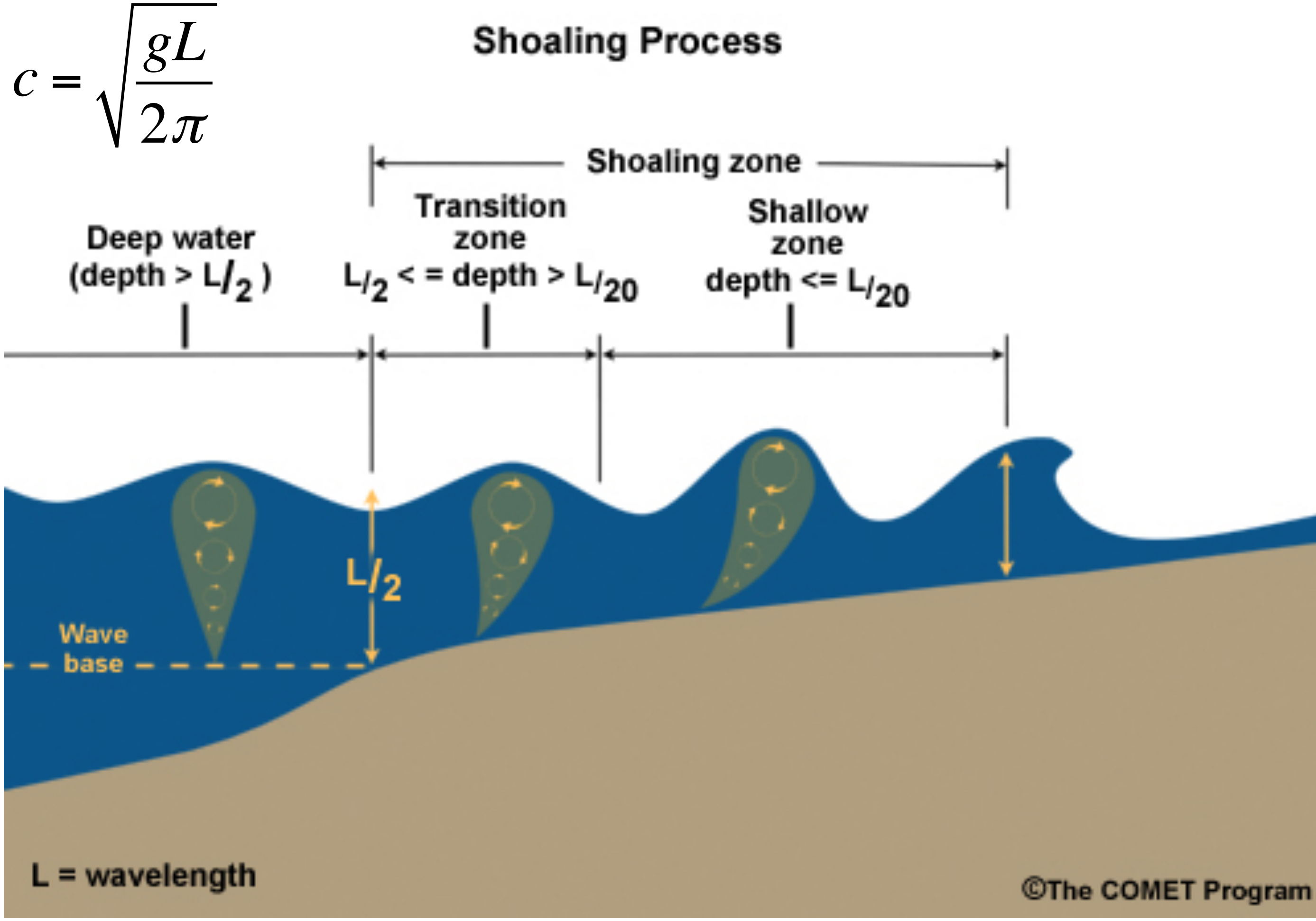


$$c = \sqrt{gd}$$

Animation: http://nctr.pmel.noaa.gov/sumatra20100406/

Wave Shoaling

$$c = \sqrt{\frac{gL}{2\pi}}$$



$$c = \frac{L}{T} = \sqrt{gd}$$

d ↓ then c ↓

Since energy density conserved, H ↑

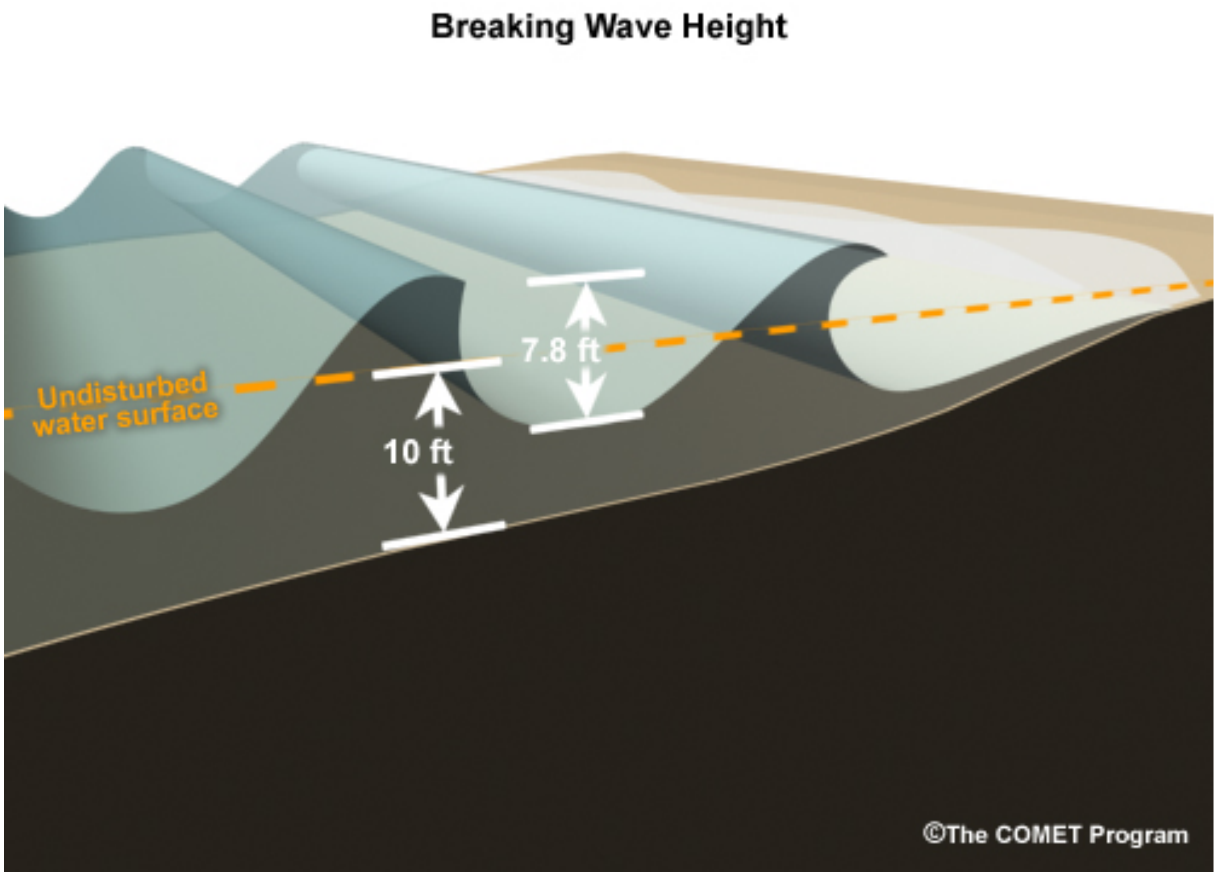
Since $c = \sqrt{gd}$ crests move faster than trough and waves steepen

Waves become steep and can break which can cause long-shore and rip currents.

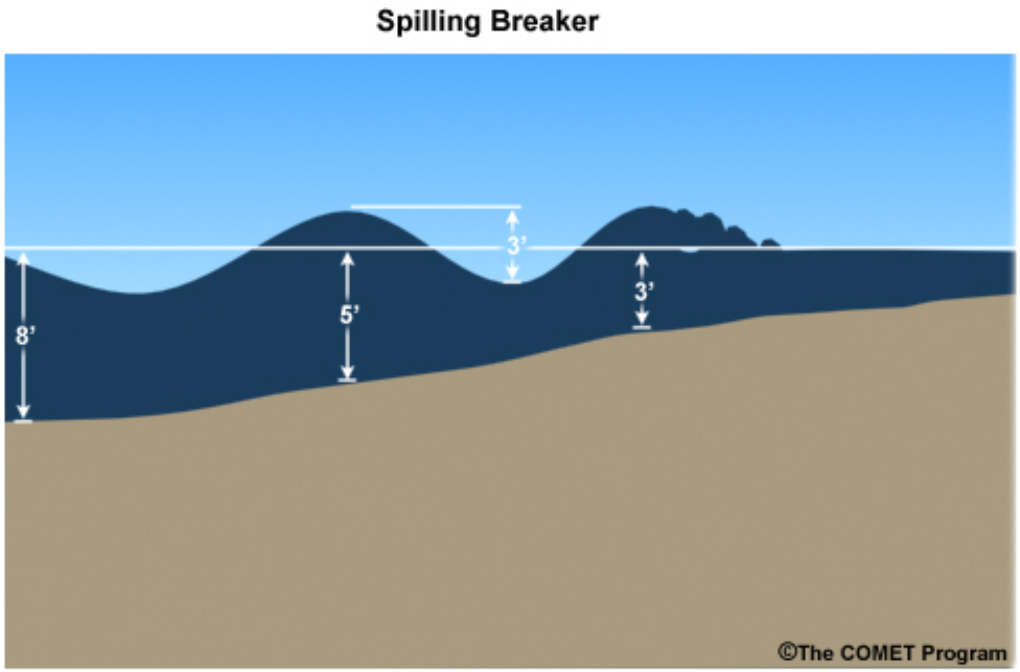
Breaking

surface waves break when the wave height is greater than 0.78 times the water depth

$H > 0.78h$



Spilling Breakers

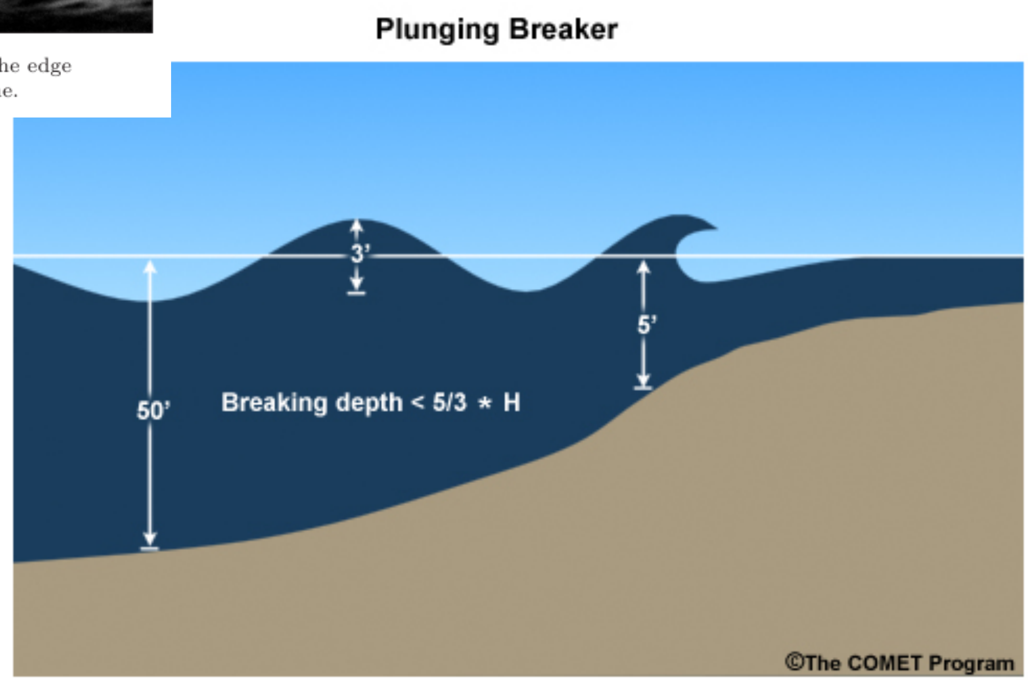


- foam,turbulence at crest
- gently sloping beach
- starts some distance from shore

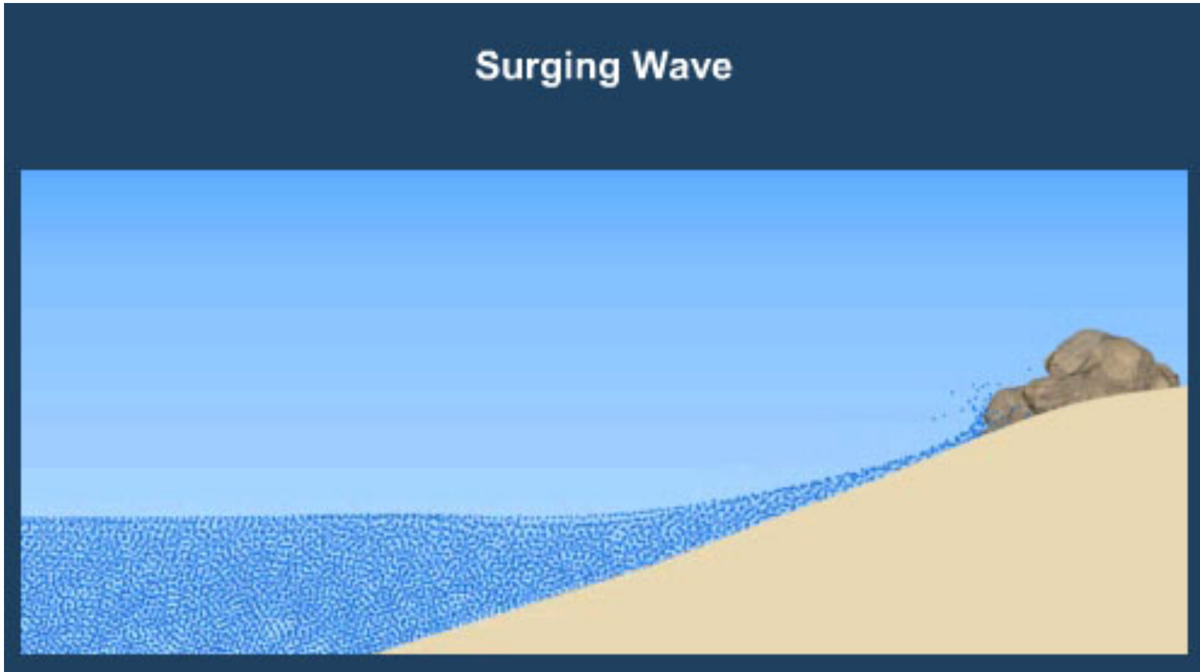
Plunging Breakers

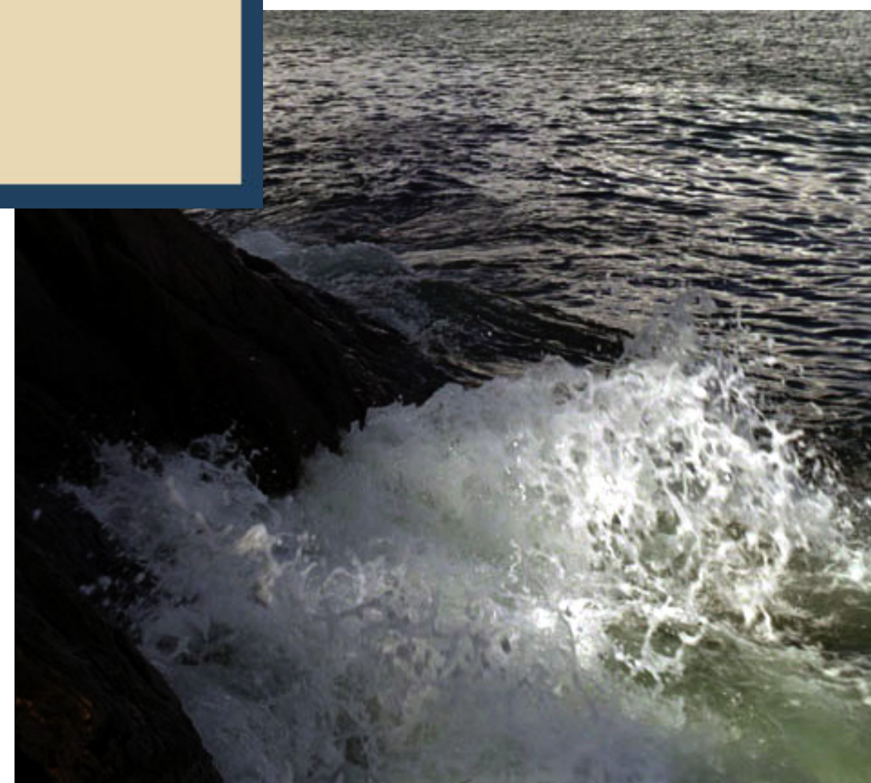
Figure 17.4 Steep, plunging breakers are the archetypical breaker. The edge of such breakers are ideal for surfing. From photo by Jeff Devine.

- dissipated over short distance
- variable slopes
- shallower slopes/distant swell
- wind-- collapsing breaker



Surging Breakers



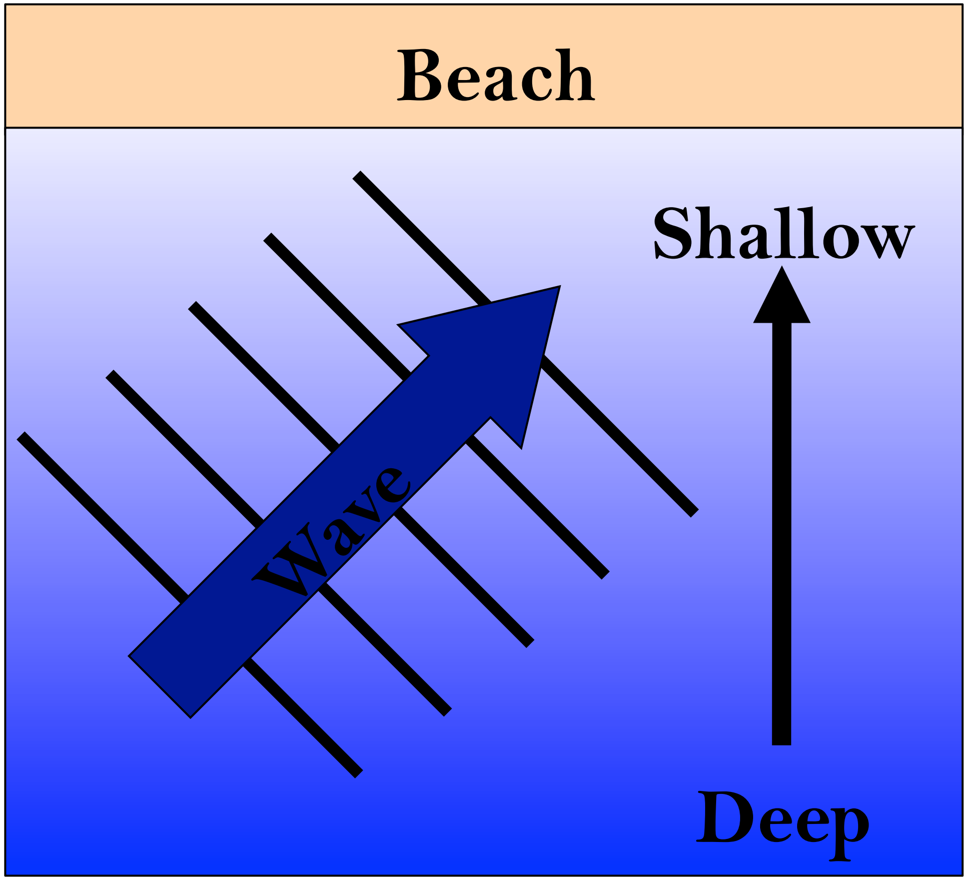


- unbroken
- steep slopes
- waves run-up beach

Refraction

What happens if a wave is incident at an angle to the shore (or the shore bends)?

$$c = \sqrt{gd}$$



Refraction

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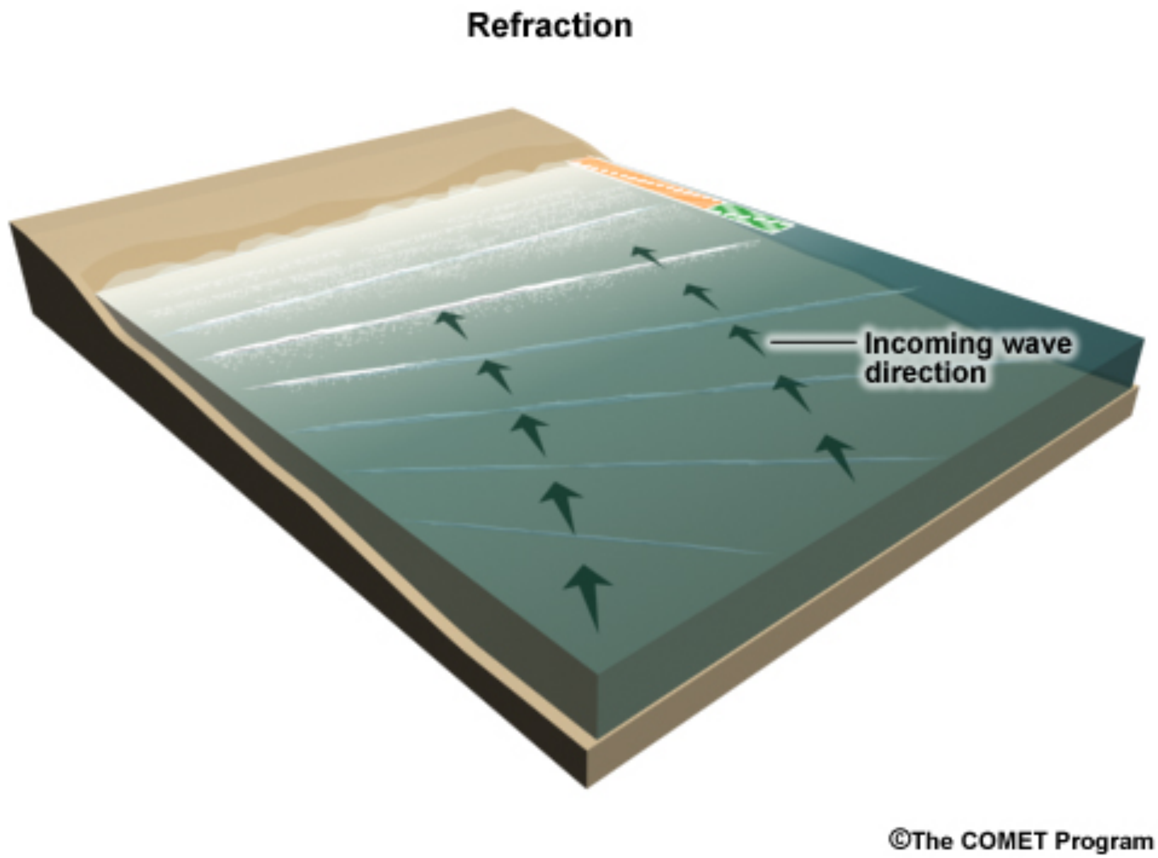


Refraction

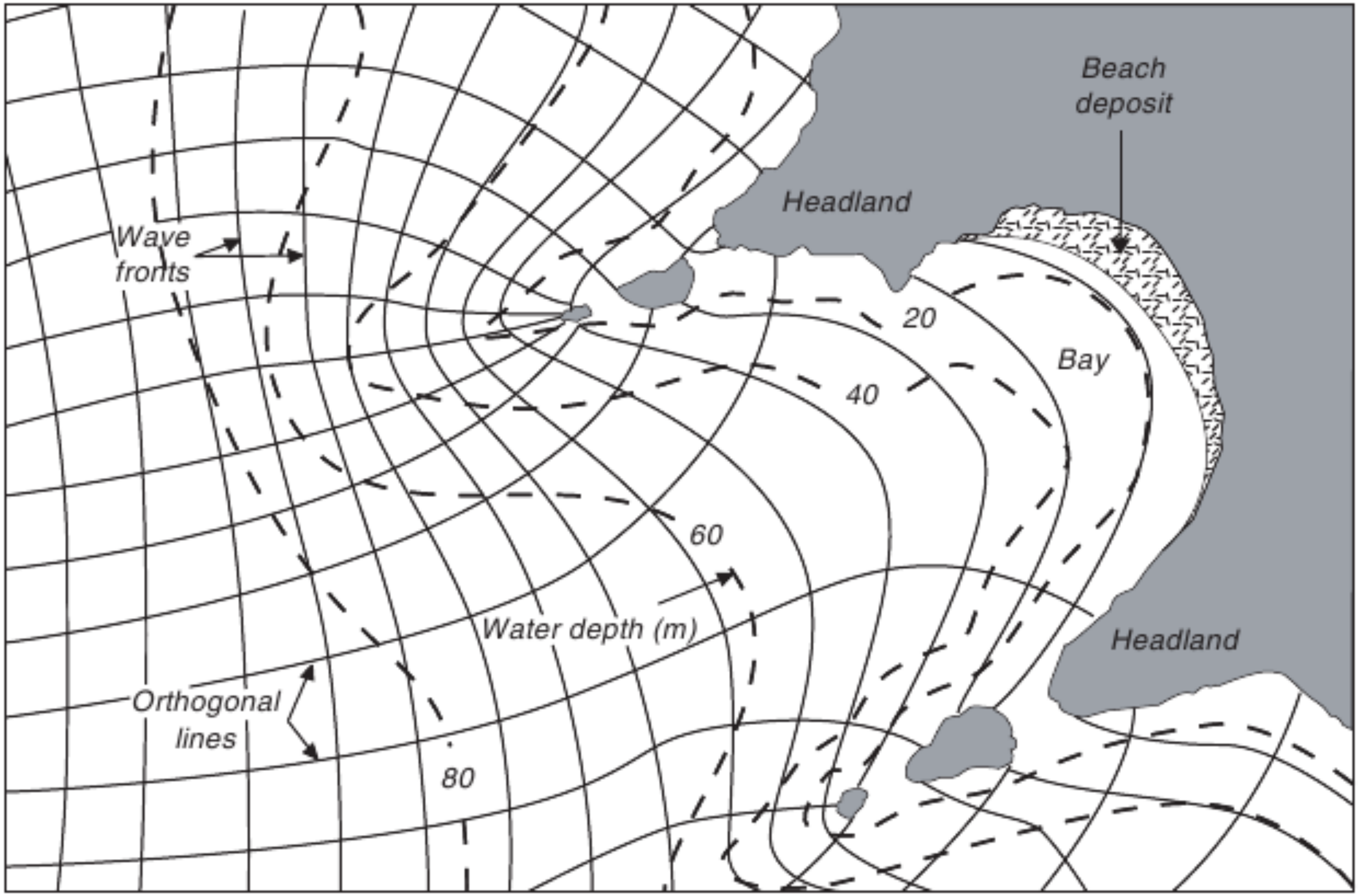
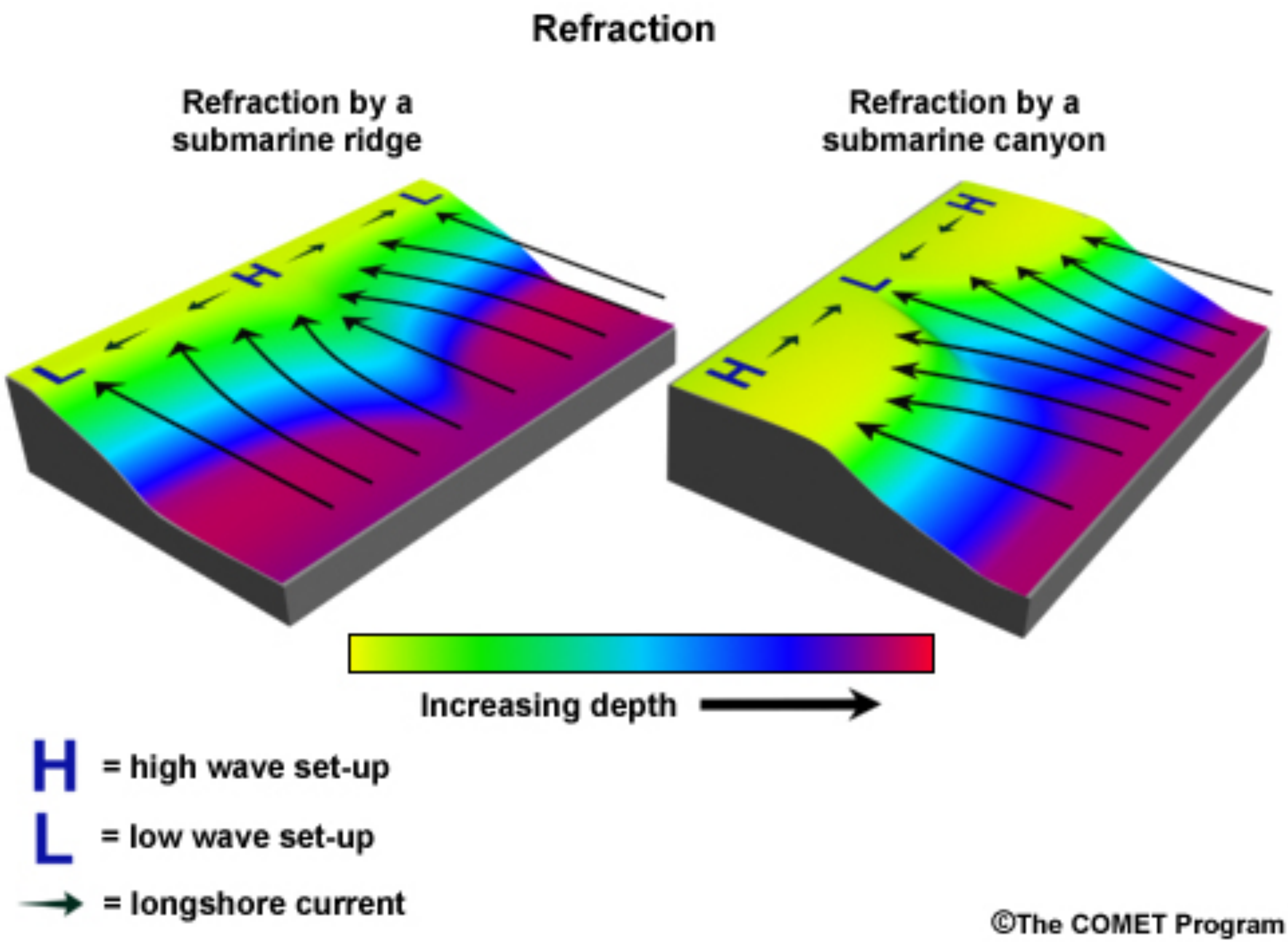
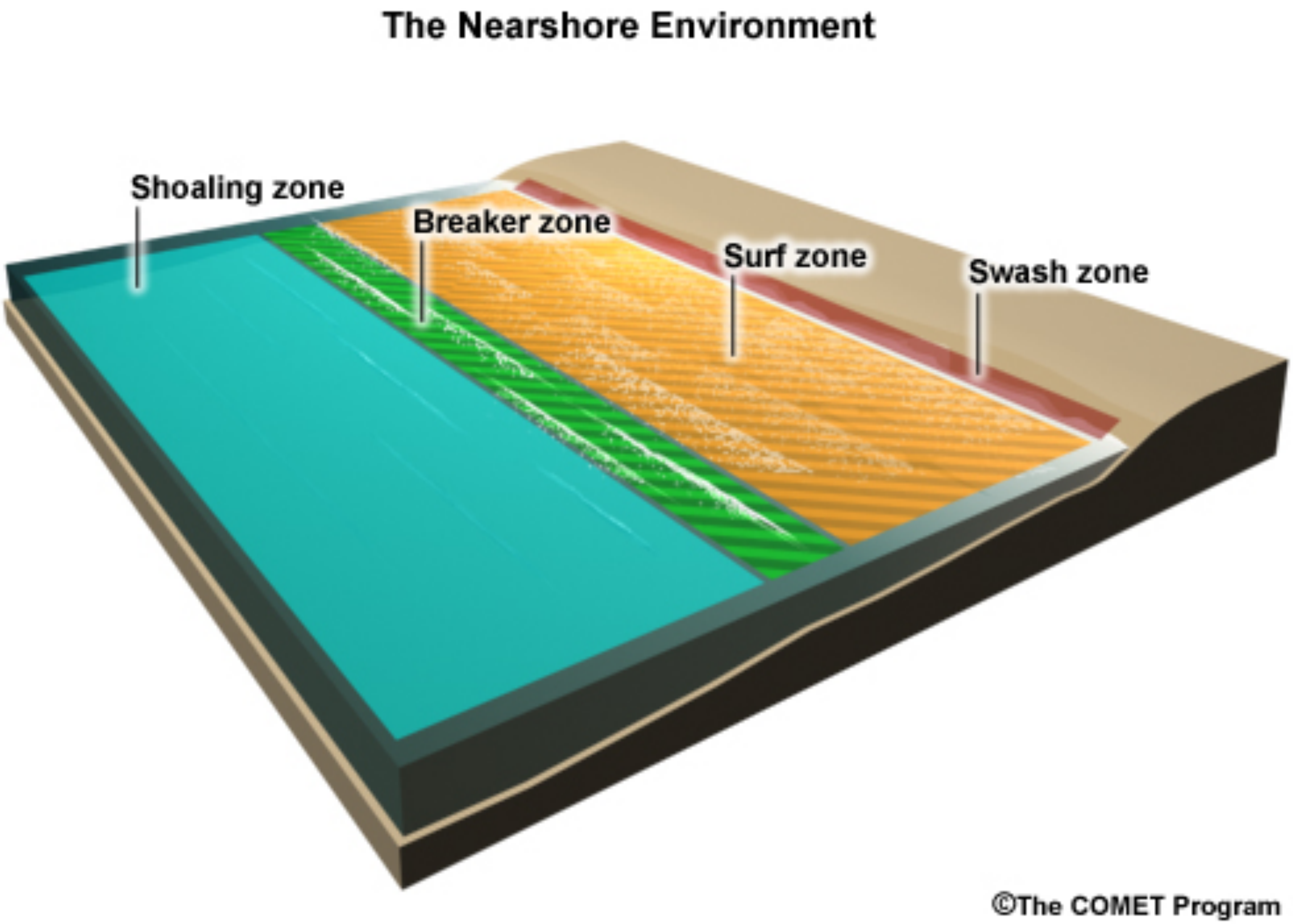


Figure 17.2 sub-sea features, such as submarine canyons and ridges, offshore of coasts can greatly influence the height of breakers inshore of the features. After Thurman (1985: 229).

Refraction


Refraction
Refraction by a submarine ridge
Refraction by a submarine canyon
L
H
L
H
L
H
Increasing depth
H = high wave set-up
L = low wave set-up
= longshore current
©The COMET Program

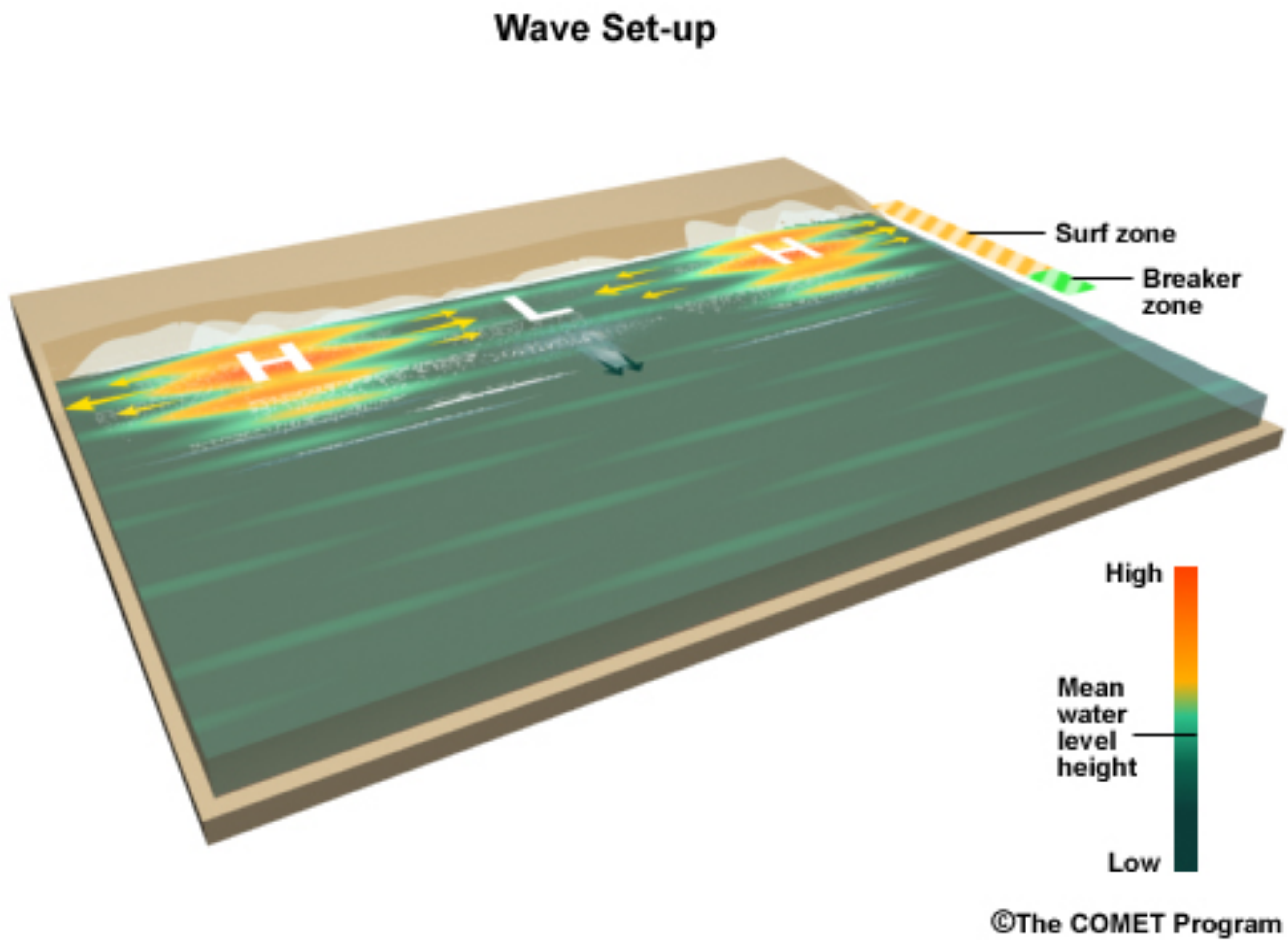
Rip Currents



waves steepen → begins to break → rolling bores

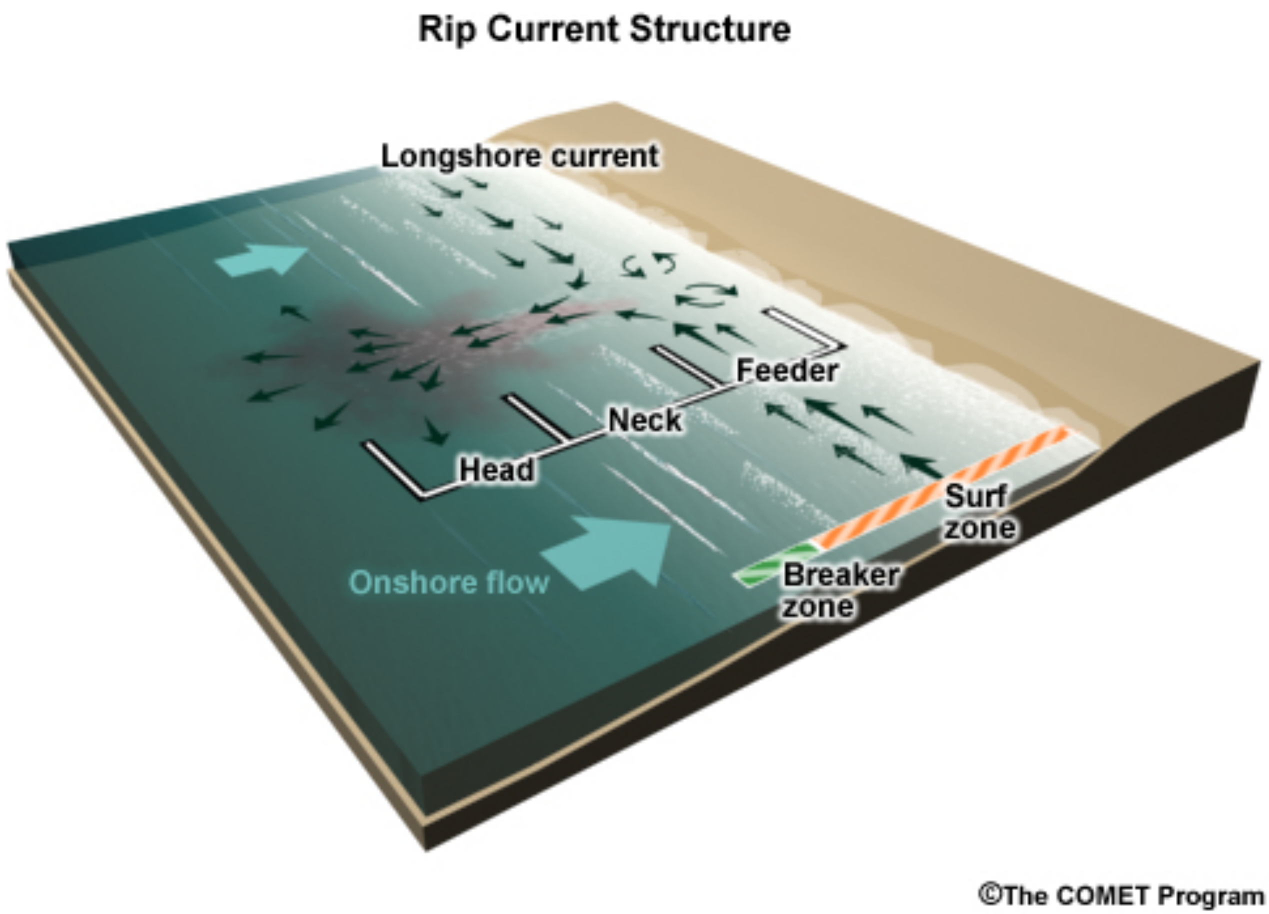
What happen to wave speed and height as waves shoal?

Rip Currents→Wave Set-Up



Variability in Breaking Zone will result in variability of the alongshore pressure gradient.

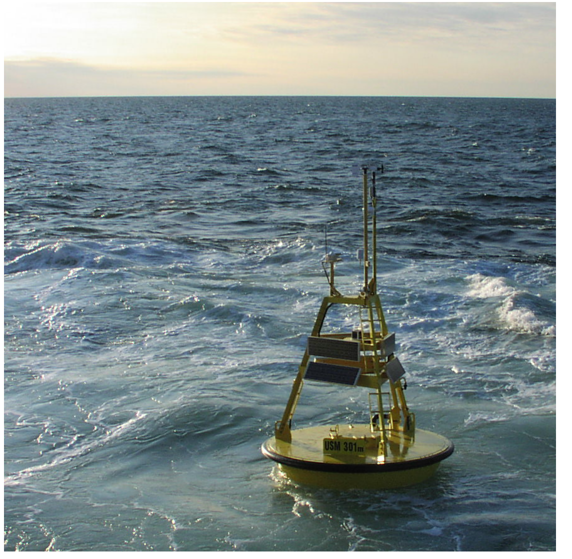
Rip Currents

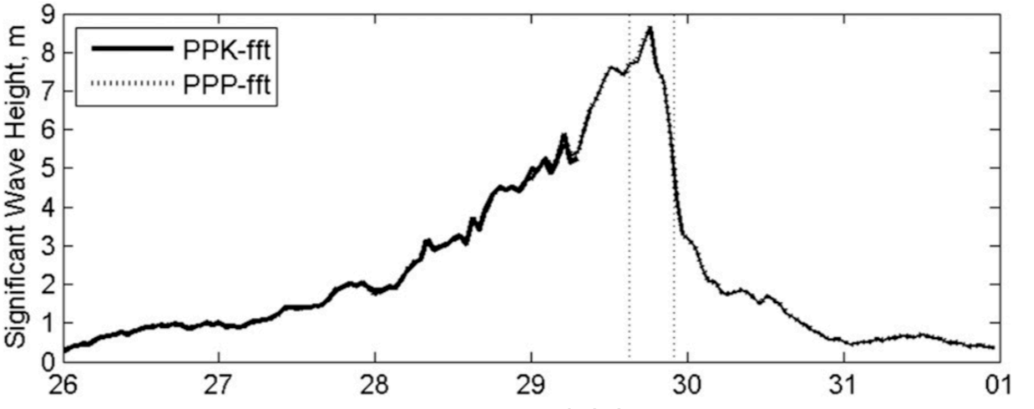


manmade & natural structures, topography, character of incident wave field, slope of the beach (steep=small surf zone= weak longshore currents)

Some Examples of Surface Gravity Wave Measurement Techniques

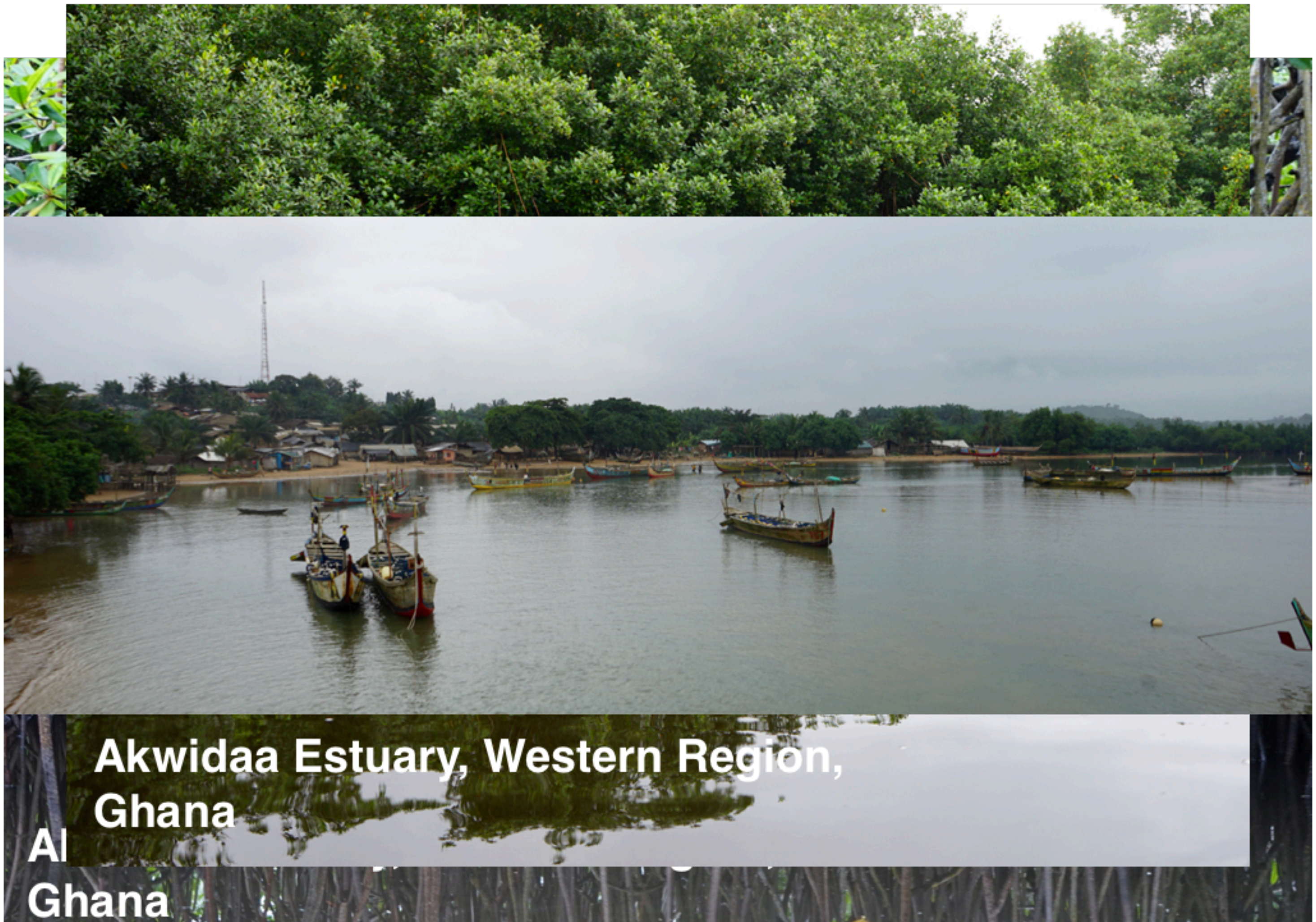
- Observers
- Pressure gauges in shallow water
- Buoys with accelerometers
- GNSS Buoys
- Acoustic Doppler Current Profilers
- Satellite Altimeters
- Satellite Scatterometers





August 2005

II. Estuaries



Definitions…

An ***estuary*** is a semi-enclosed region influenced by both **fresh** water from the land and **salty** water from the sea.

Estuaries are thus regions of ***property exchange*** between the continent and the ocean.

The ***unique dynamics*** of estuaries control property exchange and transport and thus are critical to pollutant dispersal.

Estuaries provide many important ***ecosystem services,*** including habitat/nurseries for commercially valuable species, improve coastal water quality, support tourist actives, form the basis of many major shipping lanes.

Motivations…

Container ship in a US estuary

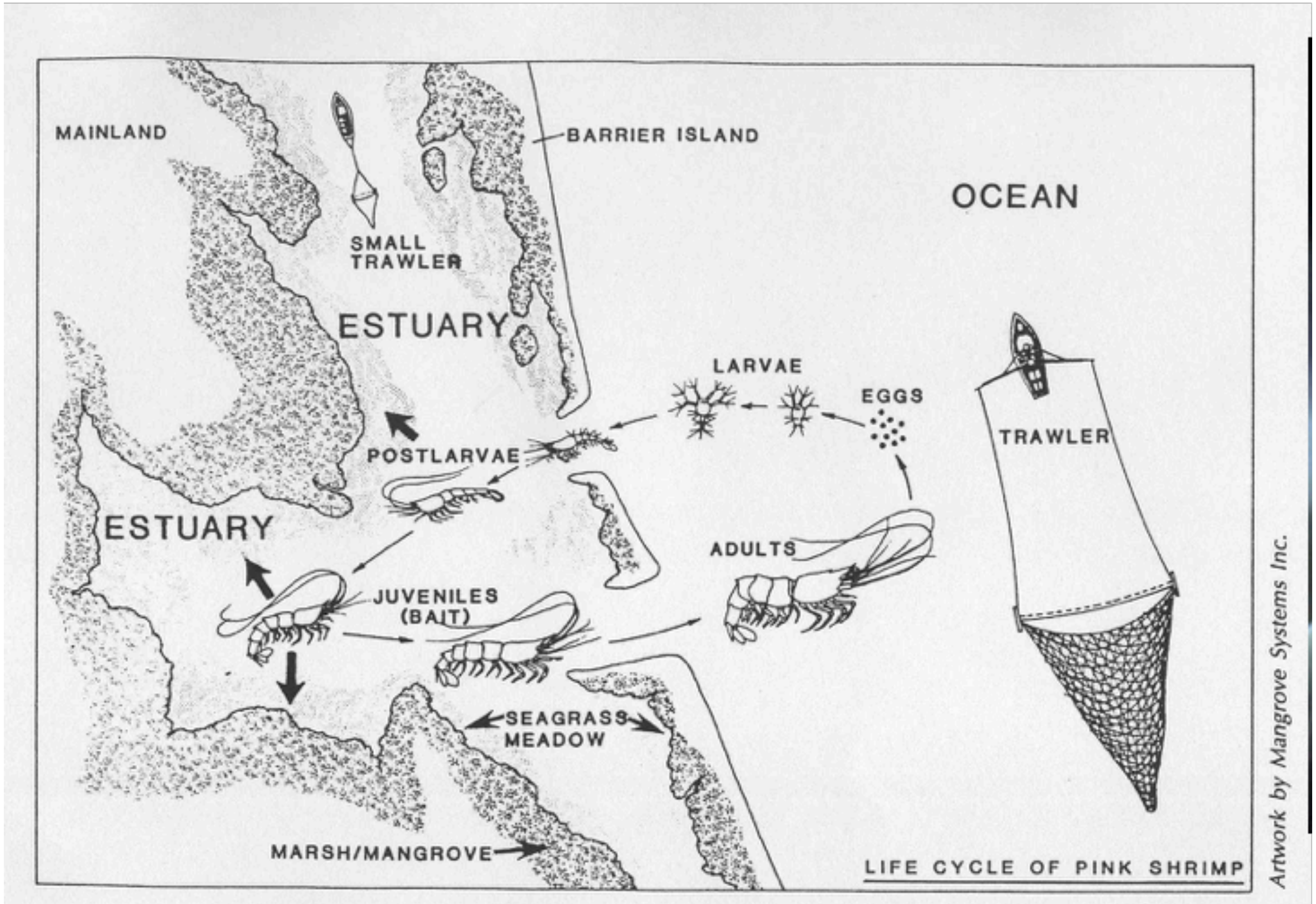
Many of the largest coastal cities are located where rivers meet the sea. Estuaries are major routes of transport and are often heavily influenced by human activities.

Motivations…

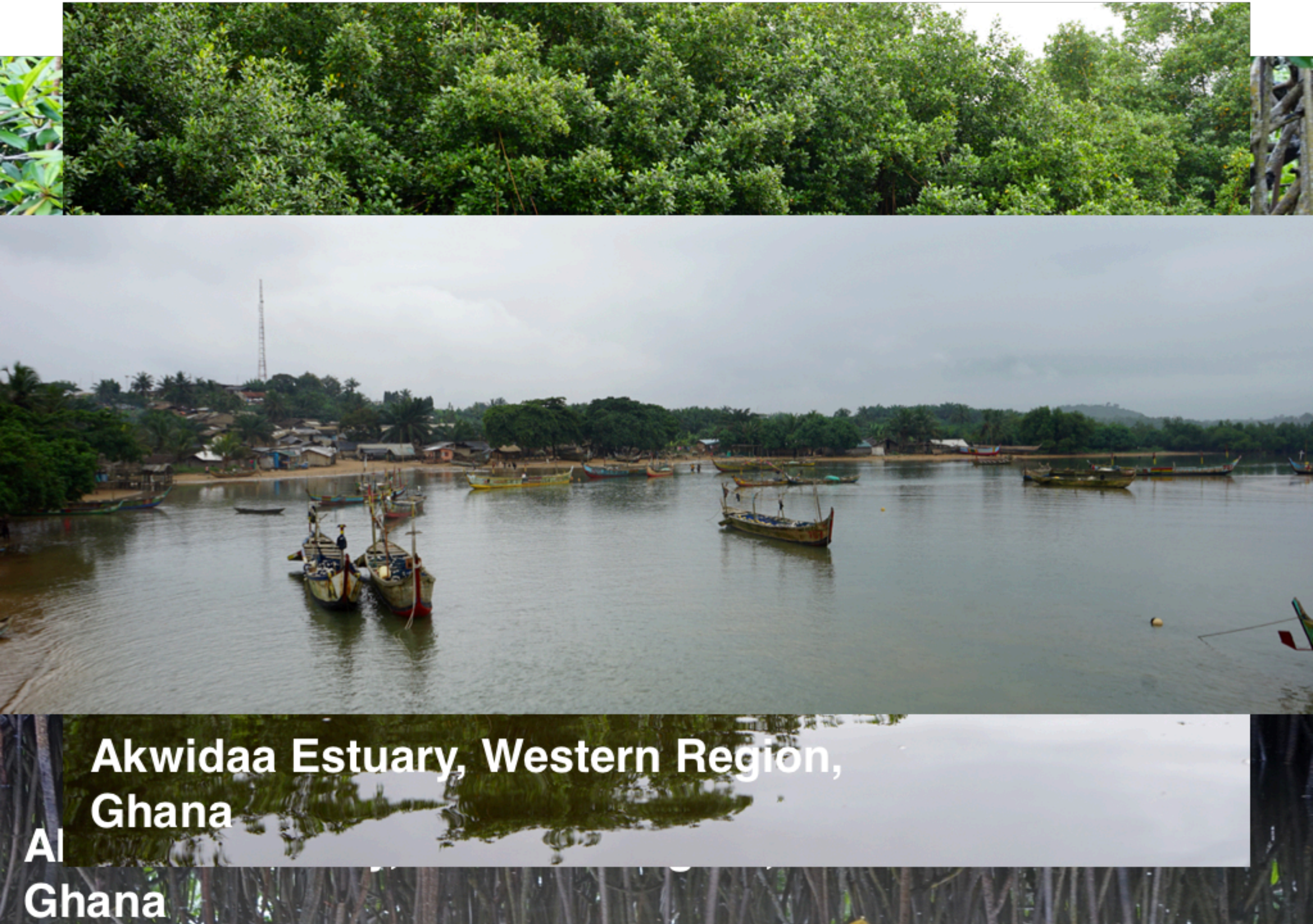
"After Blaze, Sewage Floods City Rivers" – *New York Times* 07/22/2011

Estuaries often receive intentional and unintentional discharge of effluent (sewage), industrial waste, storm water, and other pollutants.

Motivations…



Many commercially valuable fish, shrimp, crab species, etc. live or breed in estuaries. Also home to many birds and marine mammals. Human activities include fishing and tourism.



Akwidaa Estuary, Western Region, Ghana

Al
Ghana

The river water is fresh and the sea water is salty. What happens when the river water encounters the sea water?

The ***unique dynamics*** *of estuaries control property exchange and transport and thus are critical to pollutant dispersal.*

Estuaries are thus regions of ***property exchange*** between the continent and the ocean.


Akwidaa Estuary, Western Region, Ghana

Estuary Classification: Geological

- Coastal plain estuaries were formed at the end of the last ice age. As the ice melted and the waters warmed, sea level rose. The rising seas invaded low-lying coastal river valleys. These valleys are usually shallow with gentle sloping bottoms. Their depth increases toward the river's mouth.

- Bar-built Bar-built estuaries are formed when sandbars build up along the coastline. These sand bars partially cut off the waters behind them from the sea. Bar-built estuaries are usually shallow, with reduced tidal action. Wind is frequently the most important mixing tool for the fresh and salt water.

Estuary Classification: Geological

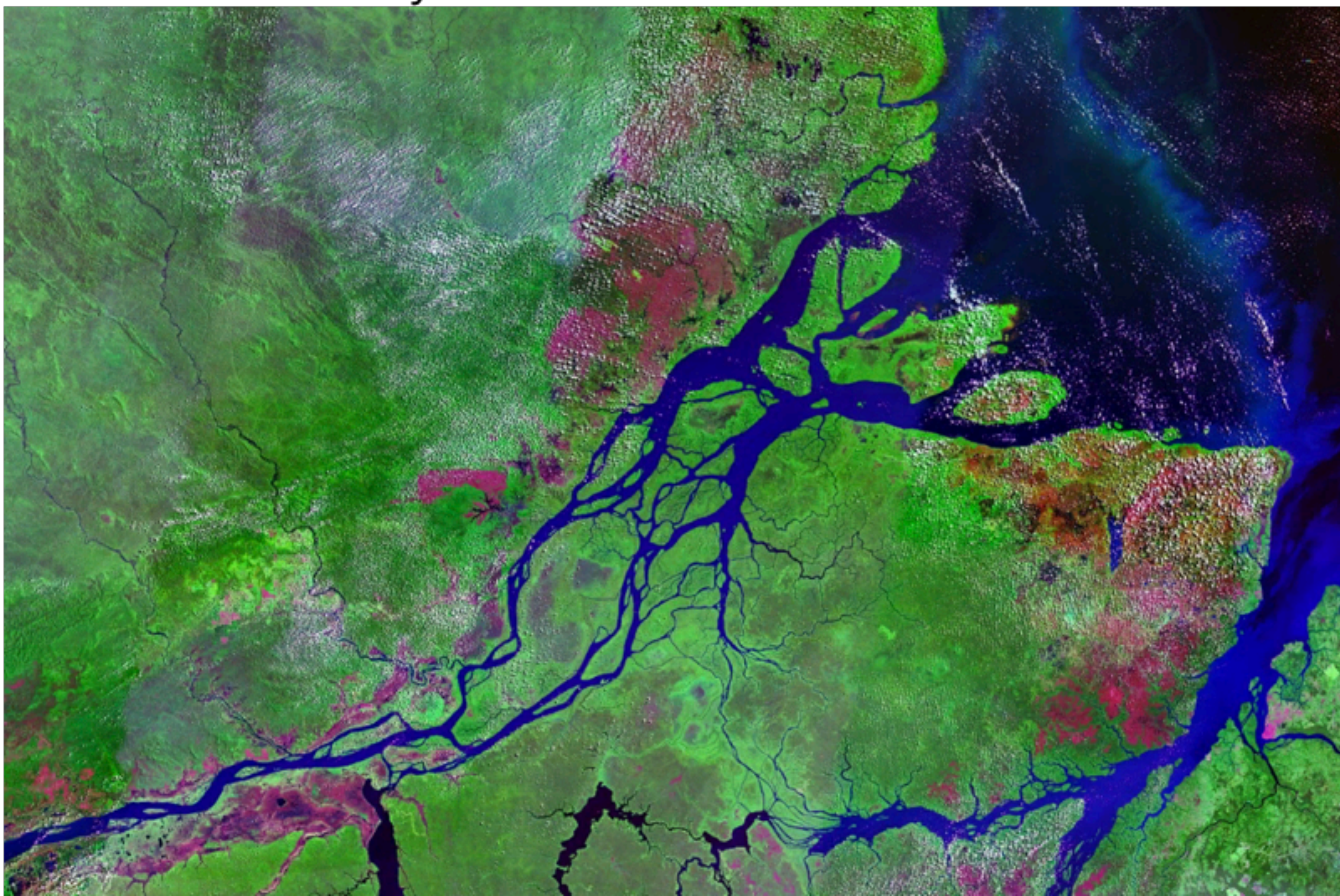
San Francisco Bay

- **Tectonic:** Tectonic estuaries are created when the sea fills in the "hole" or basin that was formed by the sinking land. San Francisco Bay is a good example of this type of estuary.

- **Fjords:** Fjords are valleys that have been deepened by moving glaciers. They have a shallow barrier at their mouth that limits exchange between the waters of the fjord and the sea. They are narrow with steep sides and usually straight and long.

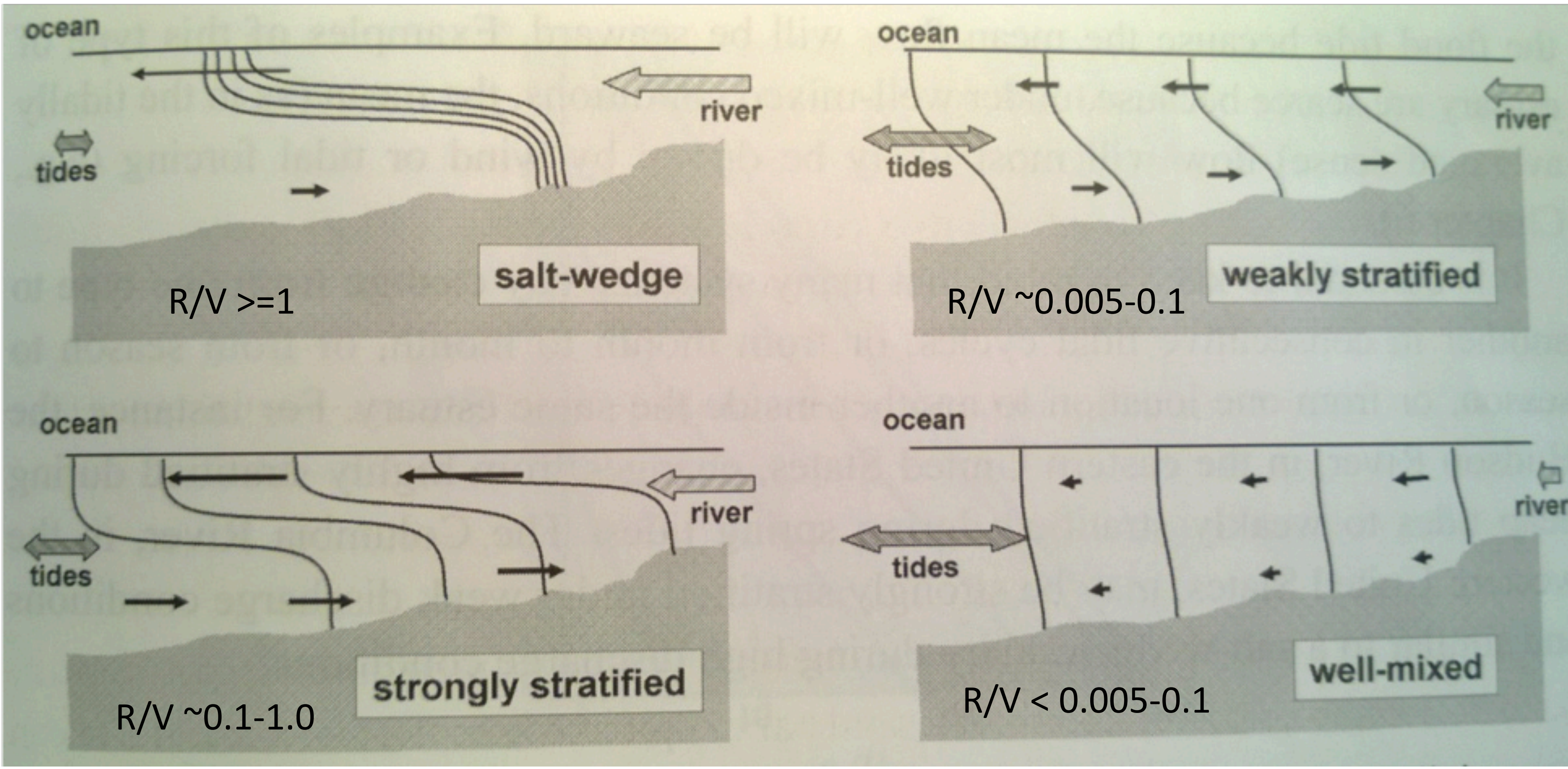
Estuary Classification: Geological

- Delta:Delta estuaries are formed when rivers flow out into the ocean and the sediment load falls out as the velocity of the water decreases.

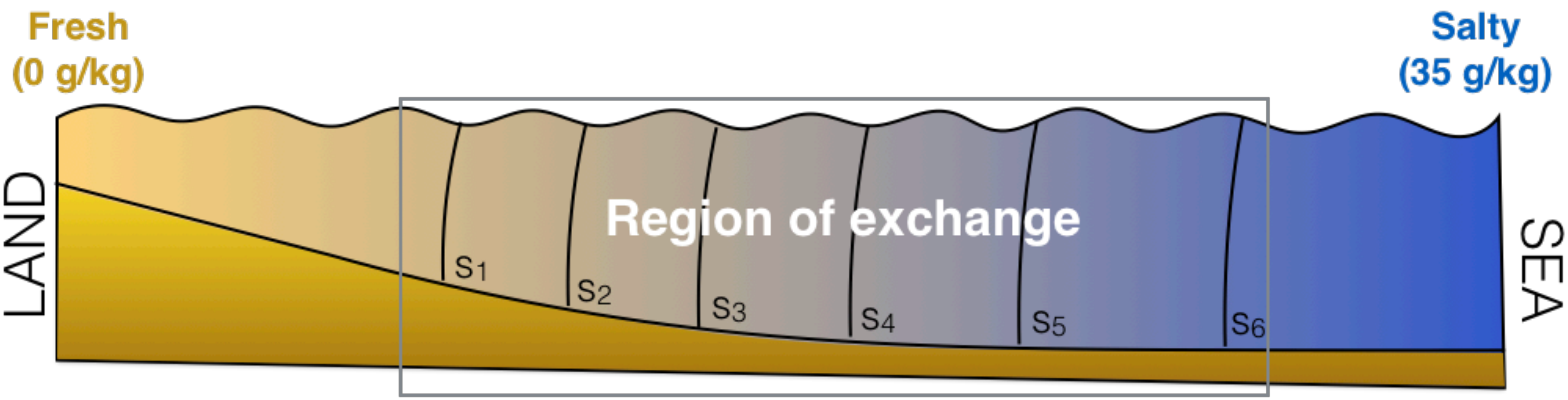


Estuary Classification: Hydrodynamics

River inflow volume R to Tidal inflow volume V: R/V



Schematic estuaries: Vertically homogenous

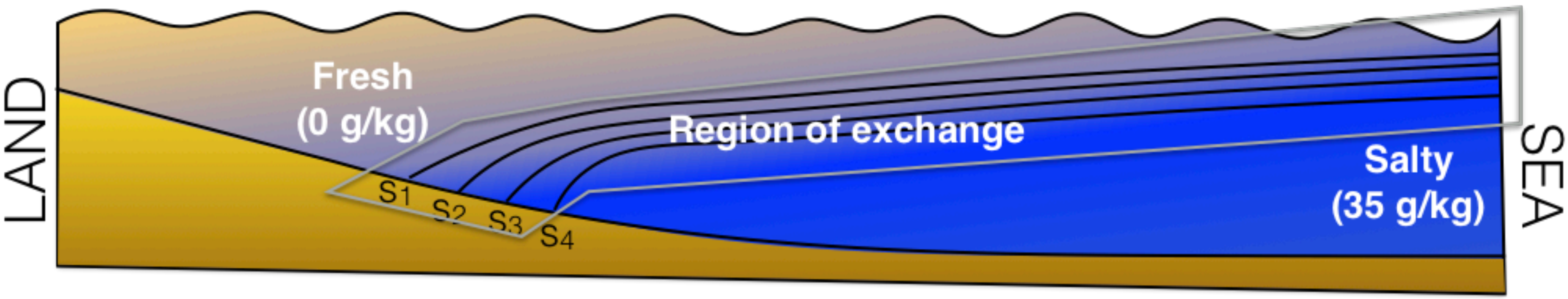


“Well-mixed estuary”

$S_1 < S_2 < S_3 < S_4 < S_5 < S_6$

The Hudson River Estuary, New York City, USA

Schematic estuaries: Vertically stratified

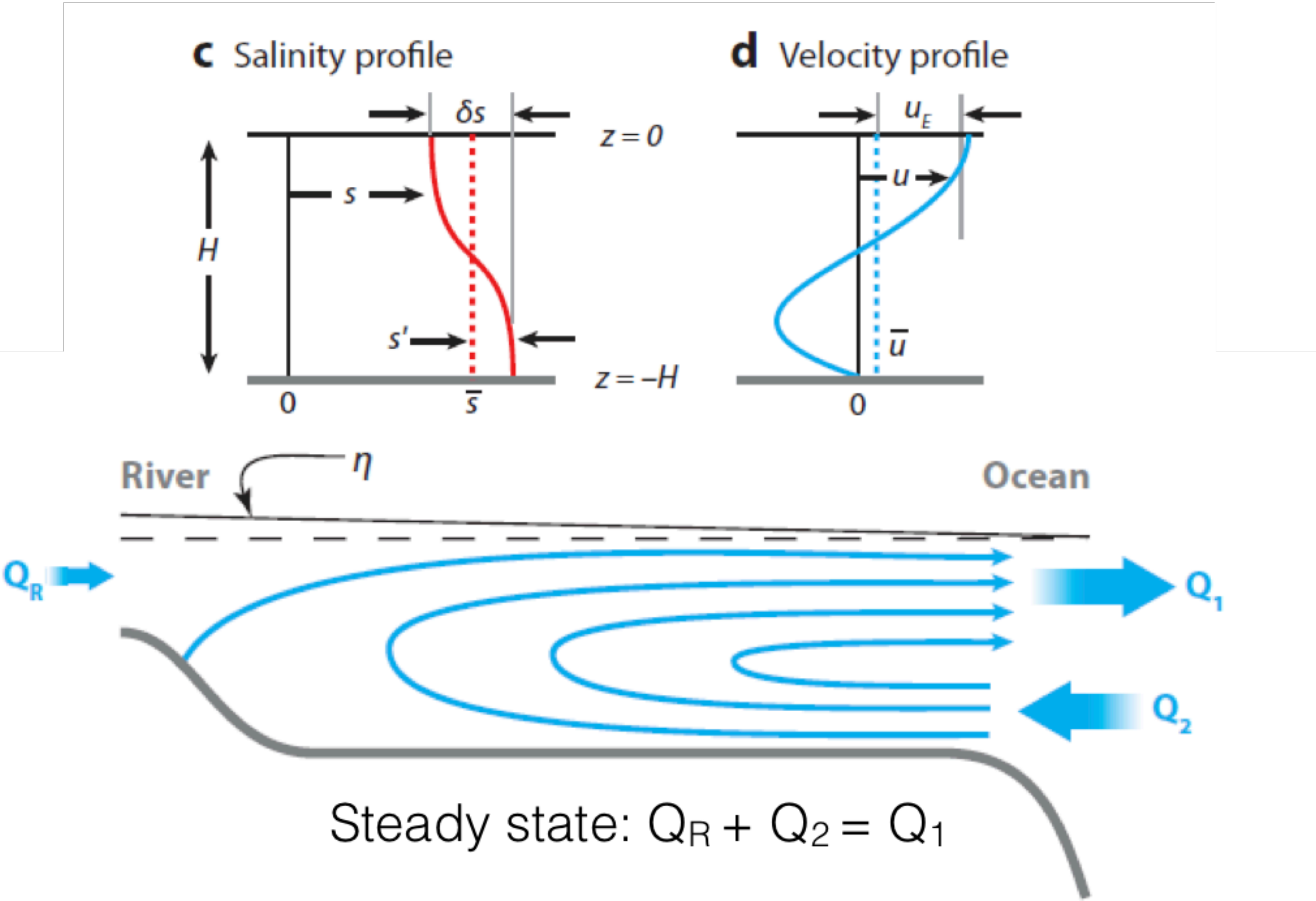


"Salt wedge estuary"

$S_1 < S_2 < S_3 < S_4$

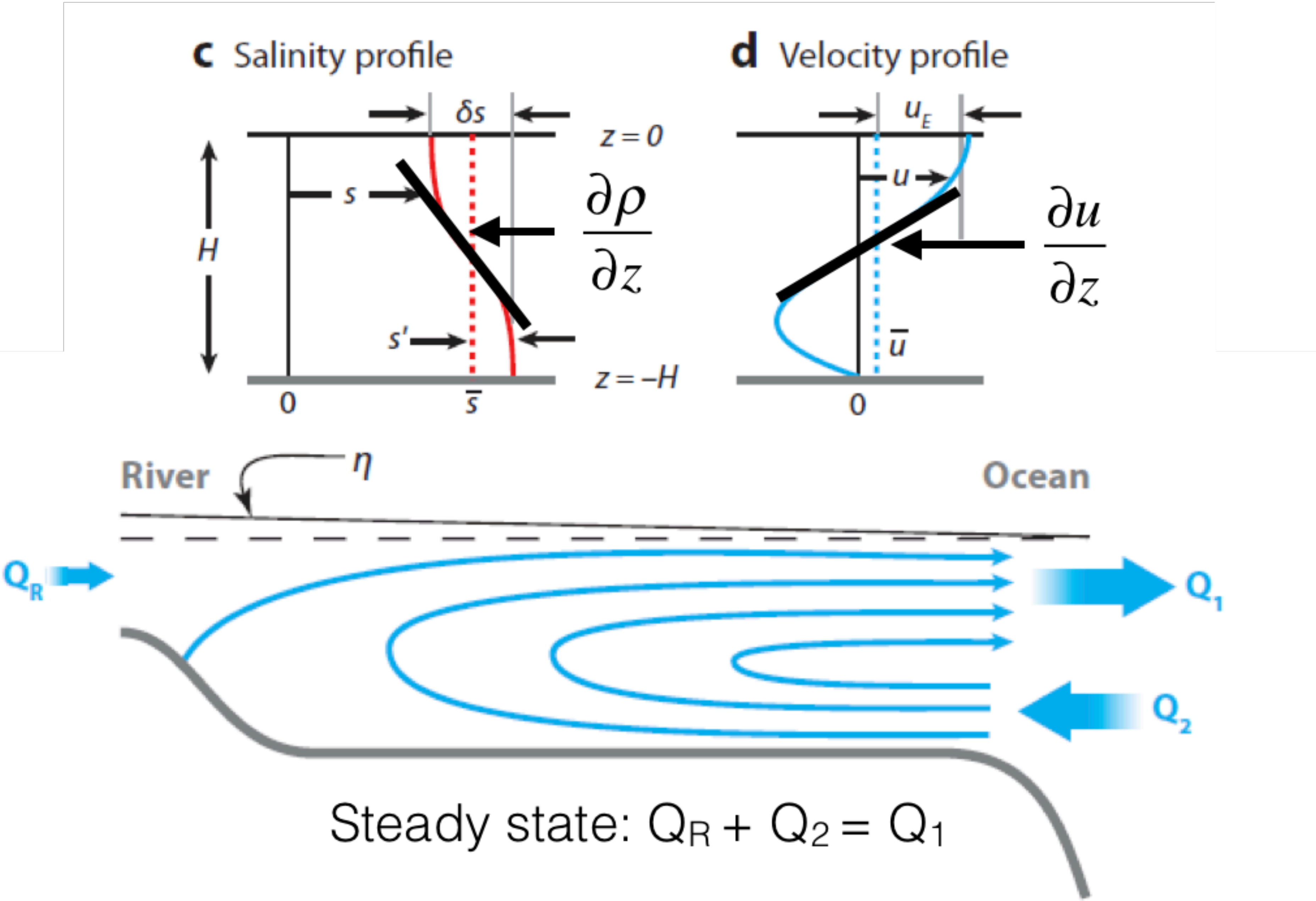
The Rio de la Plata, Argentina

Idealized, tidally averaged, partially mixed estuary



Steady state: $Q_R + Q_2 = Q_1$

Idealized, tidally averaged, partially mixed estuary



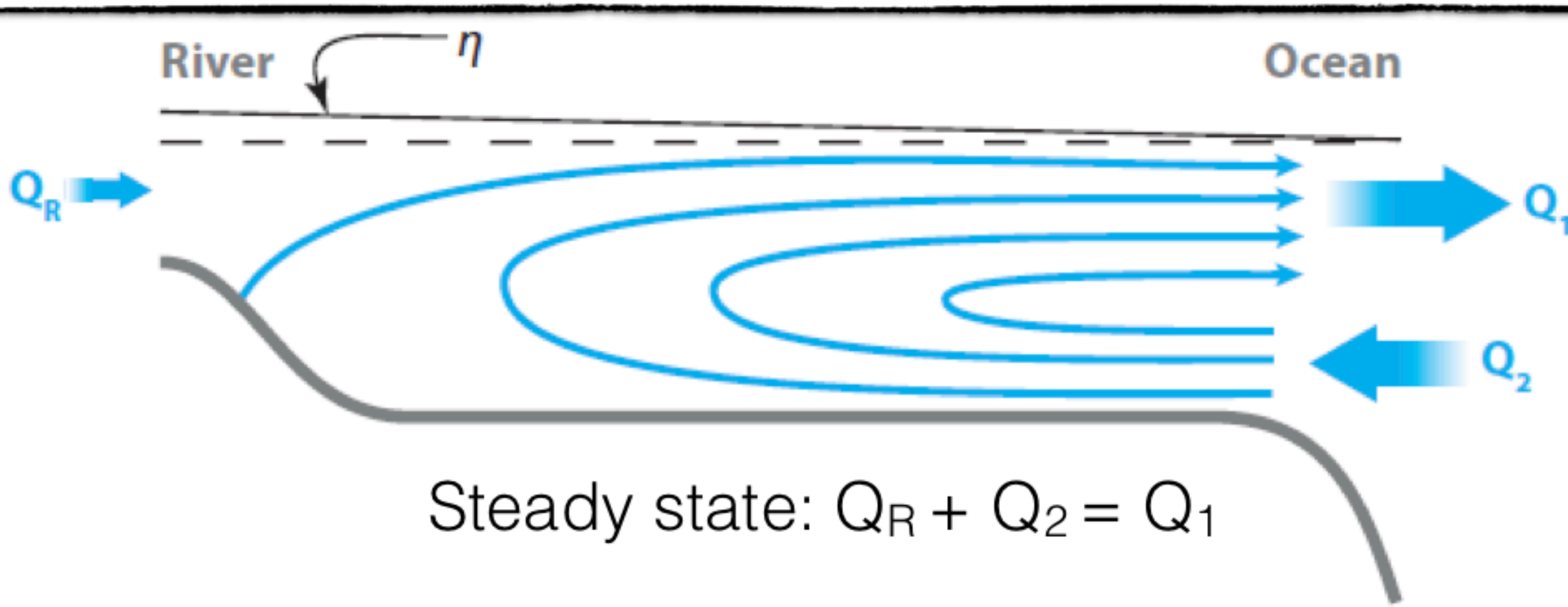
Steady state: $Q_R + Q_2 = Q_1$

Idealized, tidally averaged, partially mixed estuary

c Salinity profile

d Velocity profile

Richardson Number (Ri) = $\frac{N^2}{S^2}$



Steady state: $Q_R + Q_2 = Q_1$

III. Tide Gauges for Coastal Tidal Measurements

- Visual Sensors (tide poles and staffs)
- Mechanical Sensors (float buoyancy)
- Pressure sensors (diaphragm, bubble, piezoelectric, vibration, strain gauge)
- Acoustic sensors (air acoustic and water acoustic)
- Electromagnetic
  - Capacitive and resistive staffs,
  - Altimeter
  - RF sensors
  - GNSS receiver on buoys
  - …

Tide Poles and Staffs

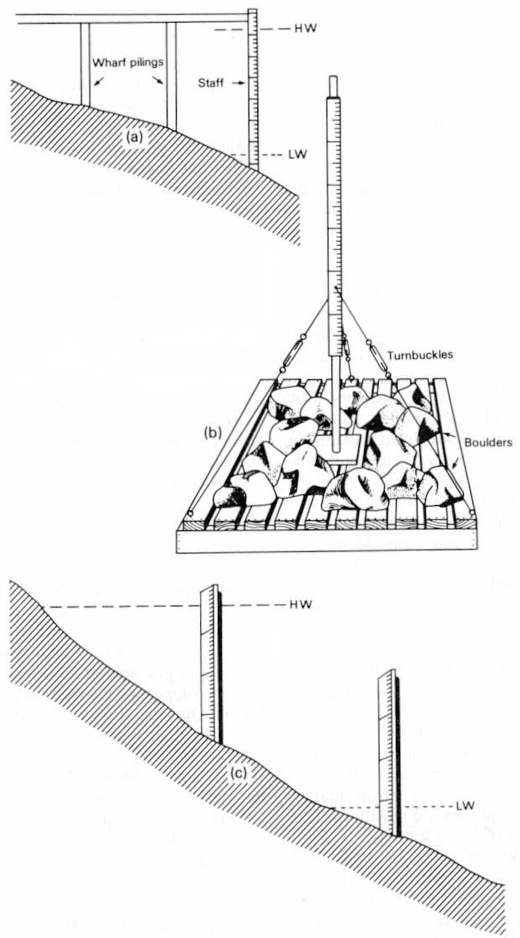


Fig. 49. Staff gauge installations (a) on wharf piling, (b) on submerged platform and (c) on long sloping beach.

InSitu Level Troll 700 Pressure Sensor

General	Level TROLL 500
Temperature ranges [1]	Operational: -20-80° C (-4-176° F) Storage: -40-80° C (-40-176° F) Calibrated: -5-50° C (23-122° F)
Diameter	1.83 cm (0.72 in.)
Length	21.6 cm (8.5 in.)
Weight	197 g (0.43 lb)
Materials	Titanium body; Delrin nose cone
Output options	Modbus/RS485, SDI-12, 4-20 mA
Battery type & life [2]	3.6V lithium; 10 years or 2M readings
External power	8-36 VDC
Memory	2.0 MB
Data records [3]	130,000
Data logs	50 logs
Fastest logging rate	2 per second
Fastest output rate	Modbus: 2 per second SDI-12 & 4-20 mA: 1 per second
Log types	Linear, Fast Linear, and Event

Sensor Type/Material	Piezoresistive; titanium
Range	Gauged (vented) 5 psig: 3.5 m (11.5 ft) 15 psig: 11 m (35 ft) 30 psig: 21 m (69 ft) 100 psig: 70 m (231 ft) 300 psig: 210 m (692 ft) 500 psig: 351 m (1153 ft)
Accuracy [4]	±0.05% FS at 15° C ±0.1% FS at 0 to 50° C
Resolution	±0.005% FS or better
Units of measure	Pressure: psi, kPa, bar, mbar, mmHg, inHg, cmH20, inH20 Level: in., ft, mm, cm, m
Temperature Sensor	**Silicon**
Accuracy	±0.1° C
Resolution	0.01° C or better
Units of measure	Celsius or Fahrenheit

Float Gauge

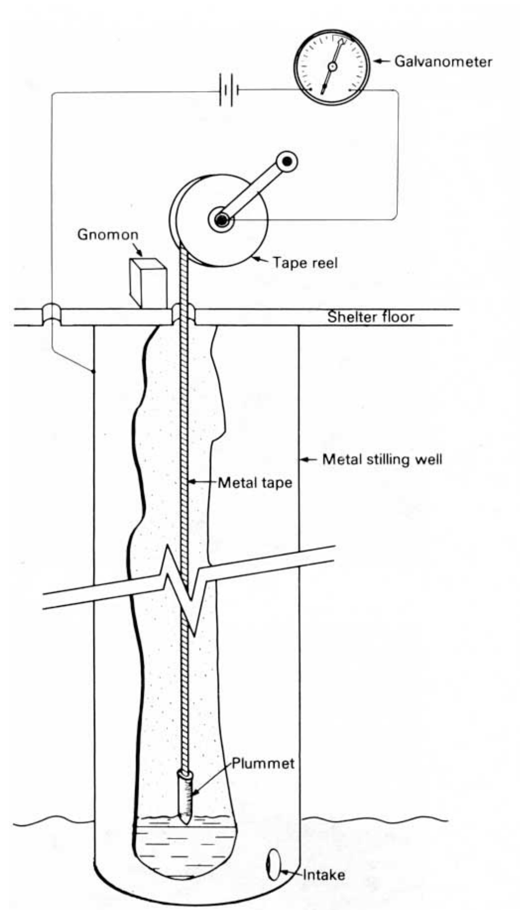
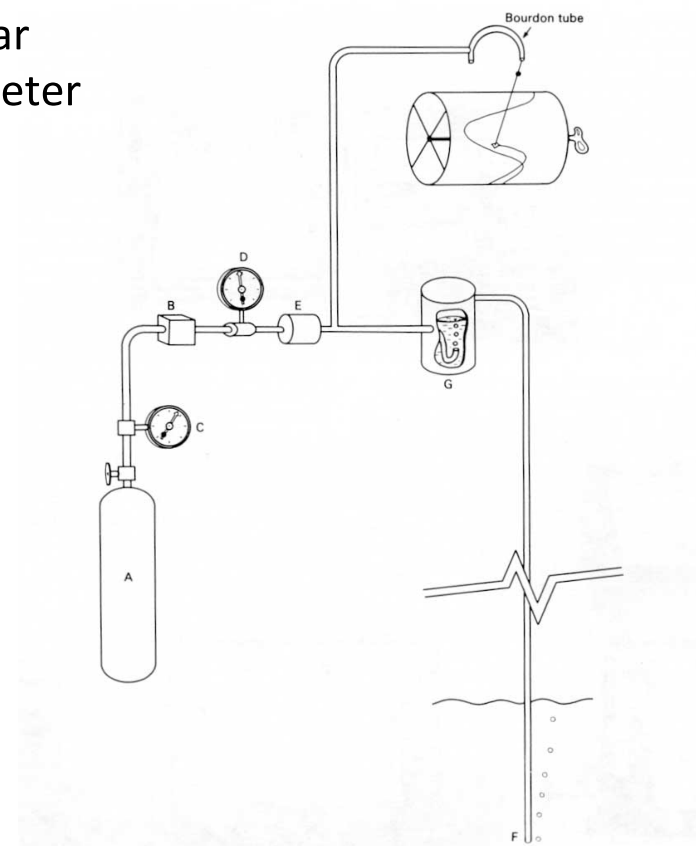
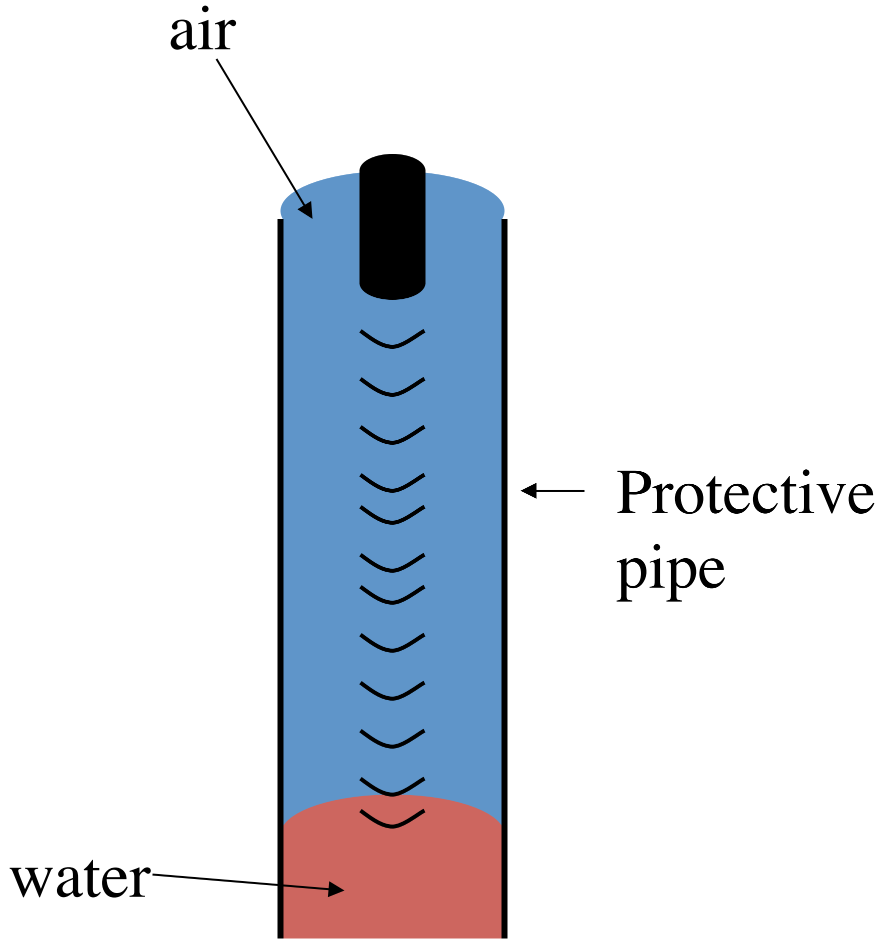


FIG. 50. Electric sight gauge, with metal stilling well.

Bubbler Pressure Gauge



Ultrasonic 2 way travel time measurement: Downward looking air acoustic measurement

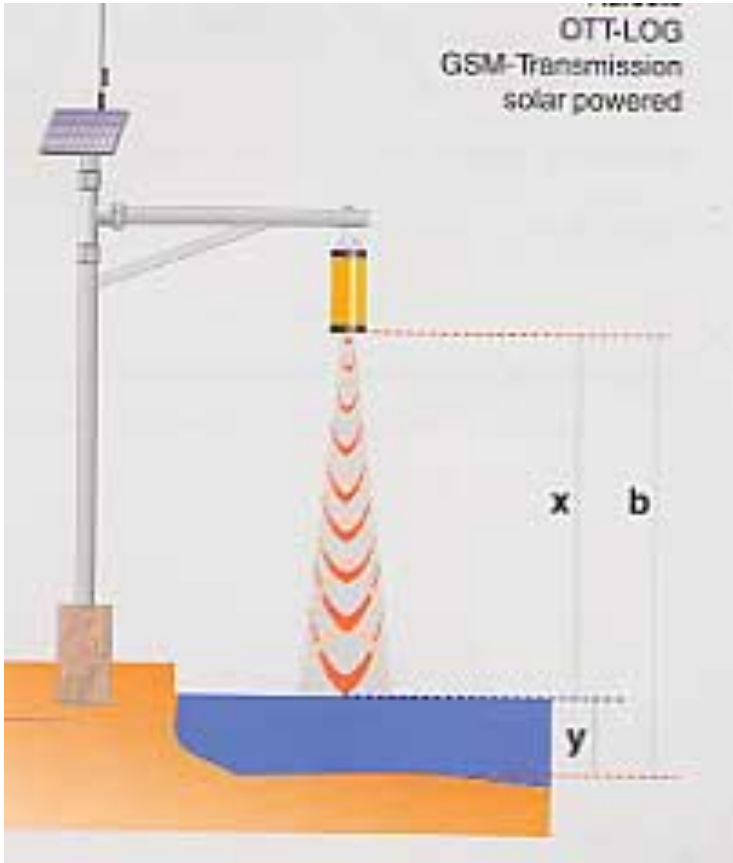


Sutron ultrasonic sensor

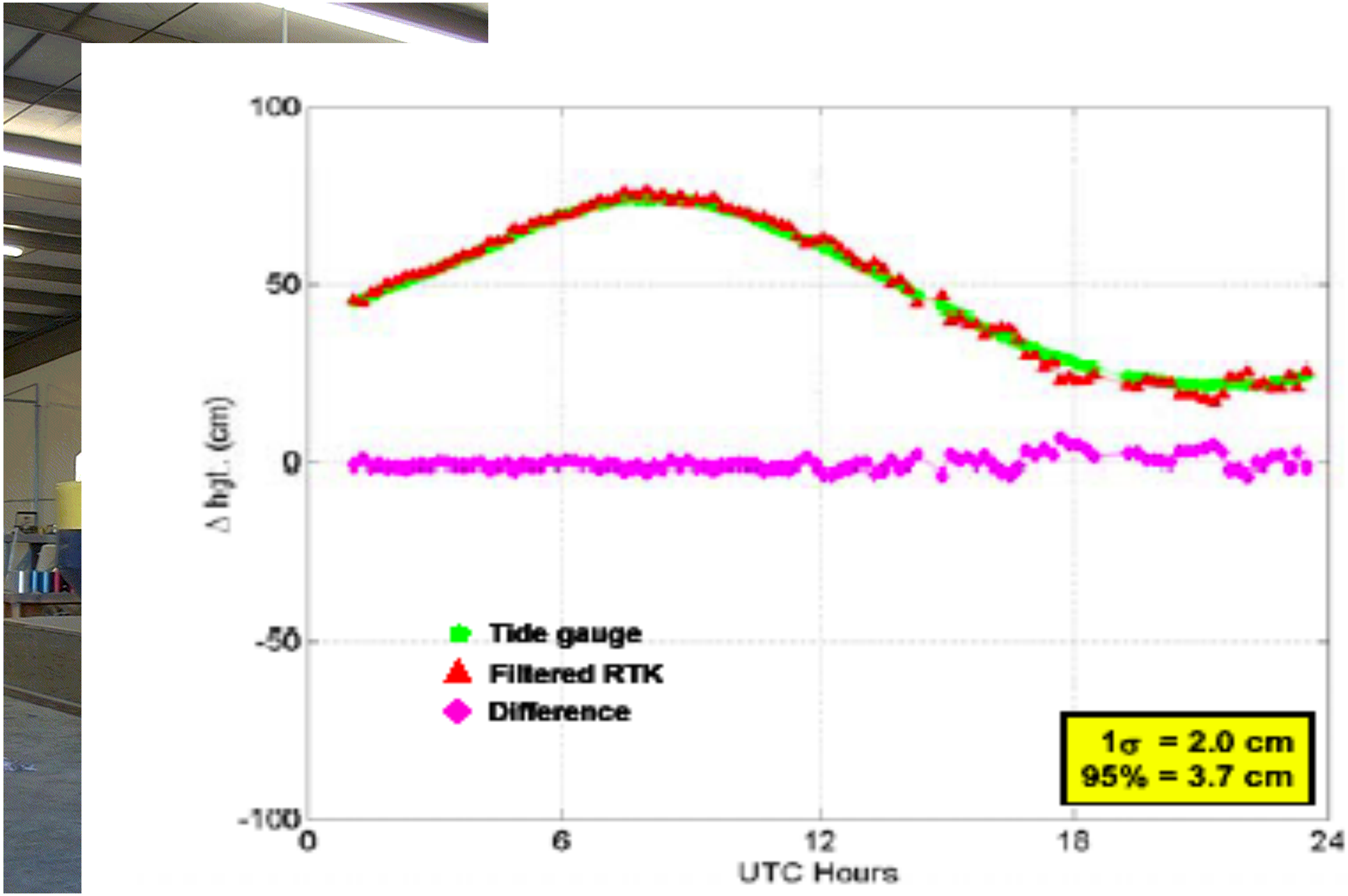
Aquatrak Ultrasonic

Electromagnetic Sensors

Microwave radar measures 2-way travel time between sensor and sea surface. High frequency waves filtered through software. Accuracy ~ +/- 1 cm.



GPS or GNSS Buoy



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