FLUIDS 2

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ENEOS
龍 泉 洞
Ryusendo Cave
51Km
三 王 岩
Sannoiwa Rocks
20Km
浄 土 ヶ 浜
Jodogahama Beach
4Km
シートピアなあど
Seatopia Naado
1Km

2005 - Jan 14 - 00:00
currents [m/s]
1.2
0.8
0.4
0.0

FLUIDS 2

1. Waves

2. Instabilities

3. Chaos

4. Turbulence

I. WAVES

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I. WAVES

I.1. Introduction

I.2. General properties of Waves

I.3. Different type of ocean waves

I.3.1 Surface Gravity Waves

I.3.2 Internal Waves

I.3.3 Acoustic Waves

I.4. Ray Theory

Bibliography

- Whitham (1974) : *Linear and nonlinear waves*
- Leblond-Mysak (1977) : *Waves in the ocean*

Definition of a wave:

- *A wave is a recognizable signal that is transferred from one part of the medium to another with a recognizable velocity of propagation. The signal may be any feature of the disturbance, such as a maximum or an abrupt change in some quantity, provided that it can be clearly recognized and its location at any time can be determined*. [Whitham: « Linear and nonlinear waves »]
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Definition of a wave:

- *Restoring force and a continuous medium to transport oscillation*

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- *Restoring force and a continuous medium to transport oscillation*

http://hal.elte.hu/fij/wave/pmwiki.php?n=Main.Model

Ocean Waves

- A wave results when fluid is displaced from a position of equilibrium.
- The restoration of the fluid to equilibrium will produce a movement of the fluid back and forth, called a wave orbit.

Ocean Waves

- Waves propagates energy but do not transport water

Ocean Waves

Schematic energy spectrum of ocean variability [Leblond & Mysak]

Ocean Waves

Different type of waves are classified on the basis of:

- Disturbing force
- Restoring force
- Wavelength
- Free wave Vs forced wave

Ocean Waves

	Disturbing Force	Restoring Force	Wavelength	Periods
Acoustic waves		Pressure (compressibility)	1 mm - 10 km	< 1 s
Capillary waves		Suface tension	1 mm - 1 cm	< 1 s
Surface gravity waves	Wind, boat, earthquake, etc.	Gravity	1 cm - 100 km	1 s - 1 day
Internal waves	Tides, Wind, Topography, etc.	Gravity (stratification) + Coriolis	1 m - 100 km	1 s - 1 day
Rossby waves		PV (variation of Coriolis with latitude)	100 km - 1000 km	Days - Months
Kelvin wave		Pressure gradient + Coriolis	10 km - 100 km	Days - Months
Equatorial Waves		Pressure gradient + Coriolis	10 km - 1000 km	Days - Years

Ocean Waves

Schematic energy spectrum of ocean variability [Leblond & Mysak]

Ocean Waves

a
Processes/Platforms:
Time and Space Scales
Time Scales
100 years
10 years
1 year
1 month
1 week
1 day
1 hour
1 min
1 sec
Diurnal
CLIMATE
Decadal Oscillations/
Fish Regime Shifts
ENSO
Fronts,Eddies&Filaments
Mesoscale
Phenomena
Phytoplankton
Blooms
Seasonal
MLD &
Biomass
Cycles
Coastally
Trapped Waves
Synoptic Storms,
River
Outflows, & Sediment
Resuspension
Plankton
Migration
Langmuir
Cells
Surface
Tides
Internal
Tides
Individual
Movement
Turbulent
Patch Size
Inertial/Internal
& Solitary Waves
Molecular
Processes
Surface Waves
1mm
1cm
1dm
1m
10m
100m
1km
10km
100km
1,000 km
10,000 km
Horizontal Spatial Scales

Ocean Waves

Azimuthally-averaged 2D frequency-wavenumber spectra for SSH in California Current

I.2.1 Simple Wave example

- Mathematically two main classes of waves:

Hyperbolic waves and **dispersive waves**

Hyperbolic waves

1. Hyperbolic waves are formulated in terms of hyperbolic partial differential equations, for example:

$$\eta_t + c\nabla\eta = 0 \qquad \eta_{tt} - c^2\nabla^2\eta = 0$$

Hyperbolic waves

1. Hyperbolic waves are formulated in terms of hyperbolic partial differential equations, for example:

$$\eta_t + c\nabla\eta = 0 \qquad\qquad \eta_{tt} - c^2\nabla^2\eta = 0$$

- With general solutions in the form:

$$\eta = f(x - ct) \qquad\qquad \eta = f(x - ct) + g(x + ct)$$

- Very frequent in acoustics, elasticity, electromagnetism, etc.

Hyperbolic waves

1. Examples of **Hyperbolic waves**

- Flood wave, tidal bores

- Shock wave

Dispersive waves

2. Dispersive waves come from a variety of partial differential equations, they are characterized principally by their dispersion relation:

$$\omega = f(k)$$

Connecting the frequency and the wave number.

They are visualized as a group of waves where the different Fourier components propagate at different speeds

Dispersive waves

Source: https://www.youtube.com/watch?v=uii9clp_DSg

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I.2.2 Planar Wave example

I.2. General properties

I.3. Different type of ocean waves

I.3.1 Surface gravity waves

I.3.1.1 Long waves

I.3.1.2 Short waves

I.3.1.3 The general case

I.3. Different type of ocean waves

I.3. Different type of ocean waves

I.3.1 Surface gravity waves

I.3.1.1 Long waves

I.3.1.2 Short waves

I.3.1.3 The general case

I.3.1.1 Long waves

Example of long waves:

- **Tsunamis**
- **Tidal bores**

I.3.1.1 Long waves

I.3.1.1 Long waves

Tsunami detection buoys have been placed around many tectonically active locations. M
Map is from NOAA Tsunami Detection website http://www.ndbc.noaa.gov/dart.shtml

I.3.1.1 Long waves

I.3.1.1 Long waves

Example of long waves:

- **Tsunamis**
- **Tidal bores**

A tidal bore is a wall of water that surges upriver with the advancing high tide.

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I.3.1.1 Long waves

I.3.1.1 Long waves

I.3.1 Surface gravity waves

I.3.1.1 Long waves

I.3.1.2 Short waves

I.3.1.3 The general case

I.3.1 Surface gravity waves

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I.3.1.4 Capillary waves

1. Surface waves

With surface tension effects:

I.3.1.4 Capillary waves

https://www.youtube.com/watch?v=BCW6_LAq6qs