Corso di Laurea in Fisica - UNITS

ISTITUZIONI DI FISICA PER IL SISTEMA TERRA

IFST

(138SM)

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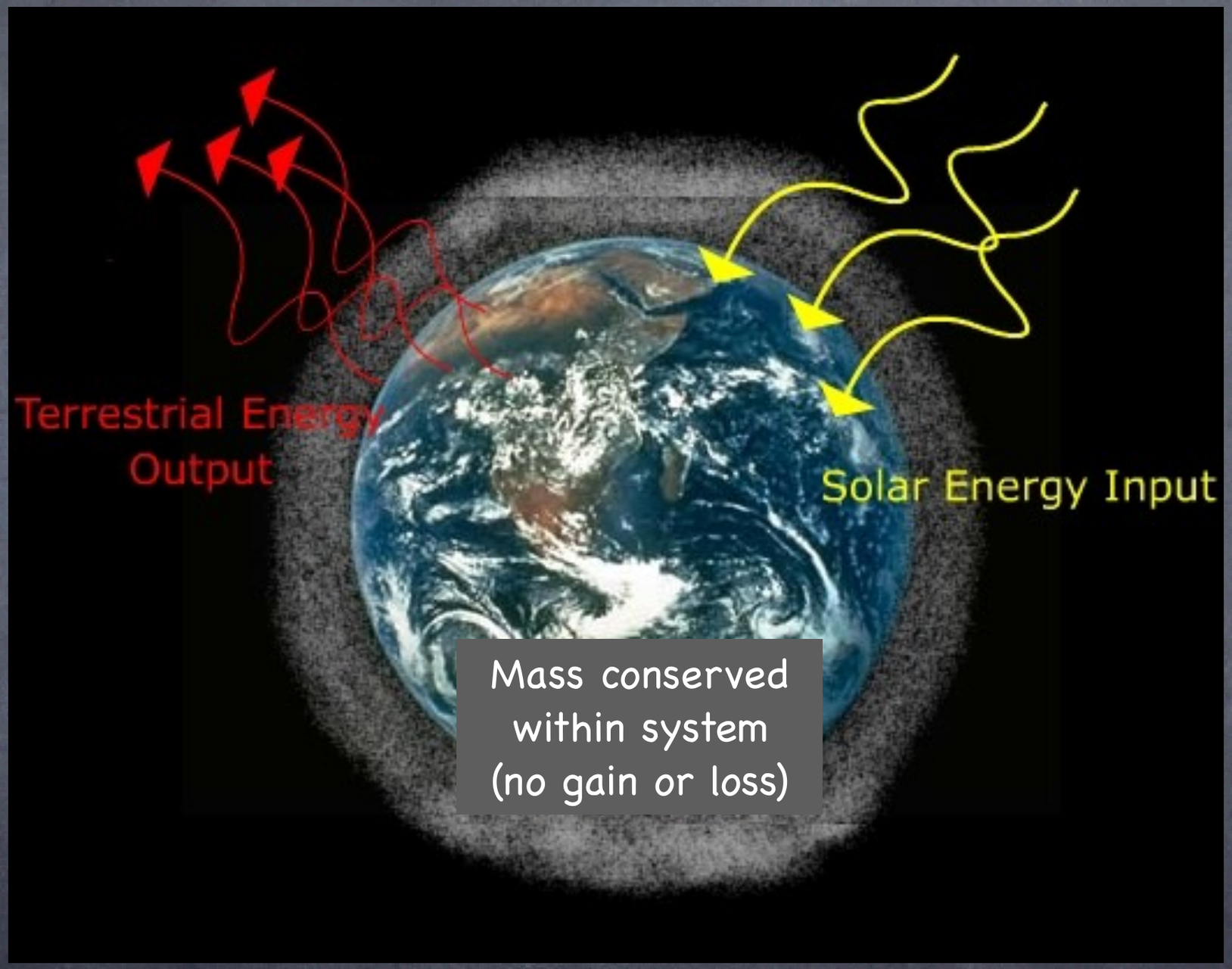
http://moodle2.units.it/course/view.php?id=16820

System

- A **system** is a set of **interacting** or interdependent component parts forming a complex/intricate whole
  - Every system is delineated by its spatial and temporal boundaries, surrounded and influenced by its environment, described by its structure and purpose and expressed in its functioning
- In engineering and physics, a physical system is the portion of the universe that is being studied (of which a thermodynamic system is one major example)
- An **open** system exchanges matter and energy with its surroundings. A **closed** system exchanges energy, but not matter, with its environment; like Earth. An **isolated** system exchanges neither matter nor energy with its environment

http://www.merriam-webster.com/dictionary/system
Citation: Pidwirny, M. (2006). "Definitions of Systems and Models".
http://www.physicalgeography.net/fundamentals/4b.html

Earth as a closed System



Closed system: exchange of energy but negligible exchange of mass with surroundings

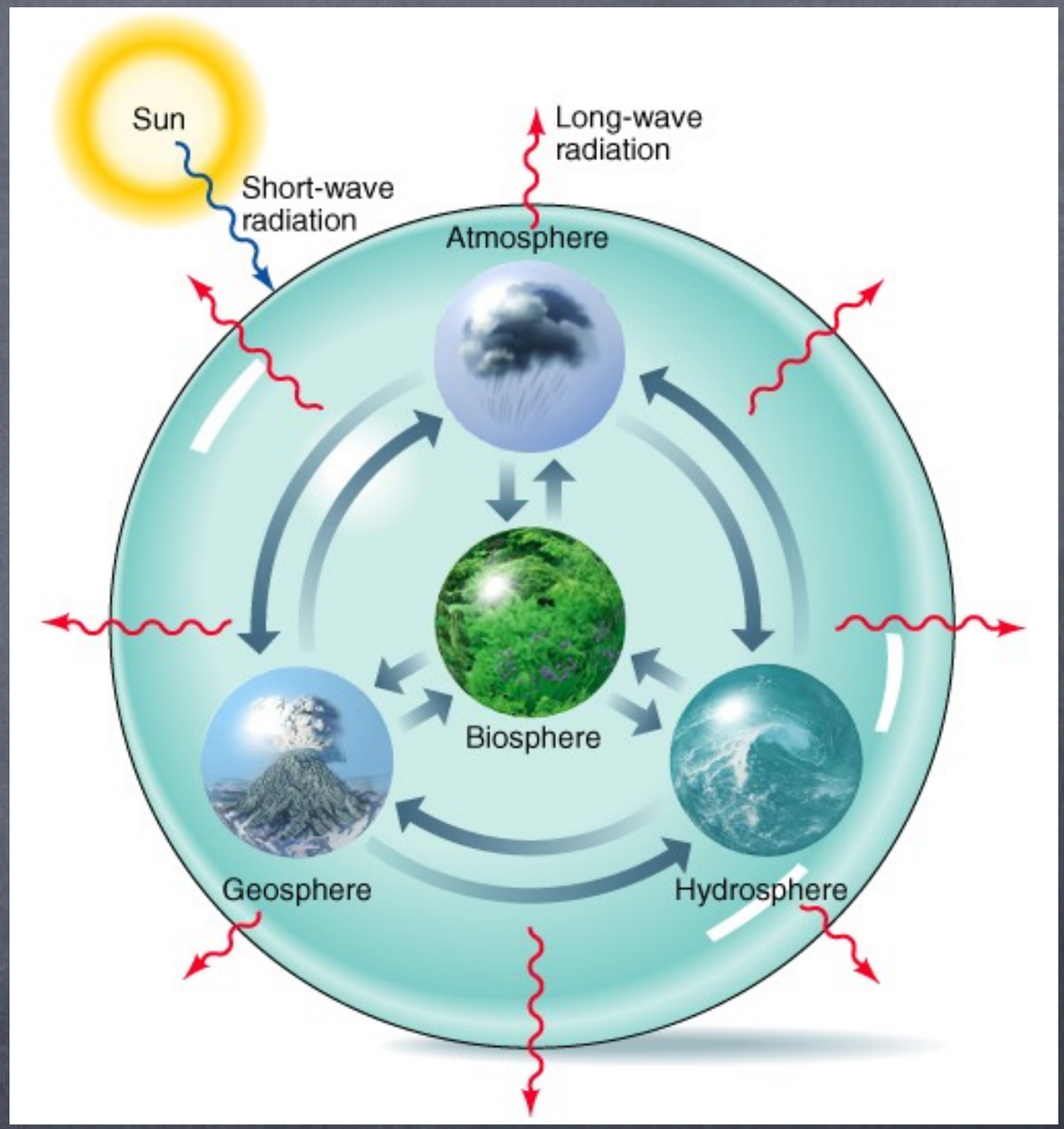
Earth System Physics

- Study the processes and interactions (cycles) among the **atmosphere**, **hydrosphere**, cryosphere, biosphere, and **geosphere** from a global to local point-of-view, and across the time scales (minutes to eons) in which these spheres interact.
- It requires the use of **physical** and chemical laws with mathematics to describe the physical, chemical and biological processes within each sphere and the interactions between the spheres.
- These descriptions are used along with observations to construct **models** through which complex interactions of the spheres are studied.
- It is through the understanding of these complex interactions that accurate, **predictive** models are developed.

Earth System

Earth System

- A **complex** system made up of:
  - **Matter**
    - Living Things
    - Nonliving things.
  - **Energy**
  - **Processes** within Earth's
    - Matter and energy continuously cycled through the smaller systems that make up Earth's spheres.



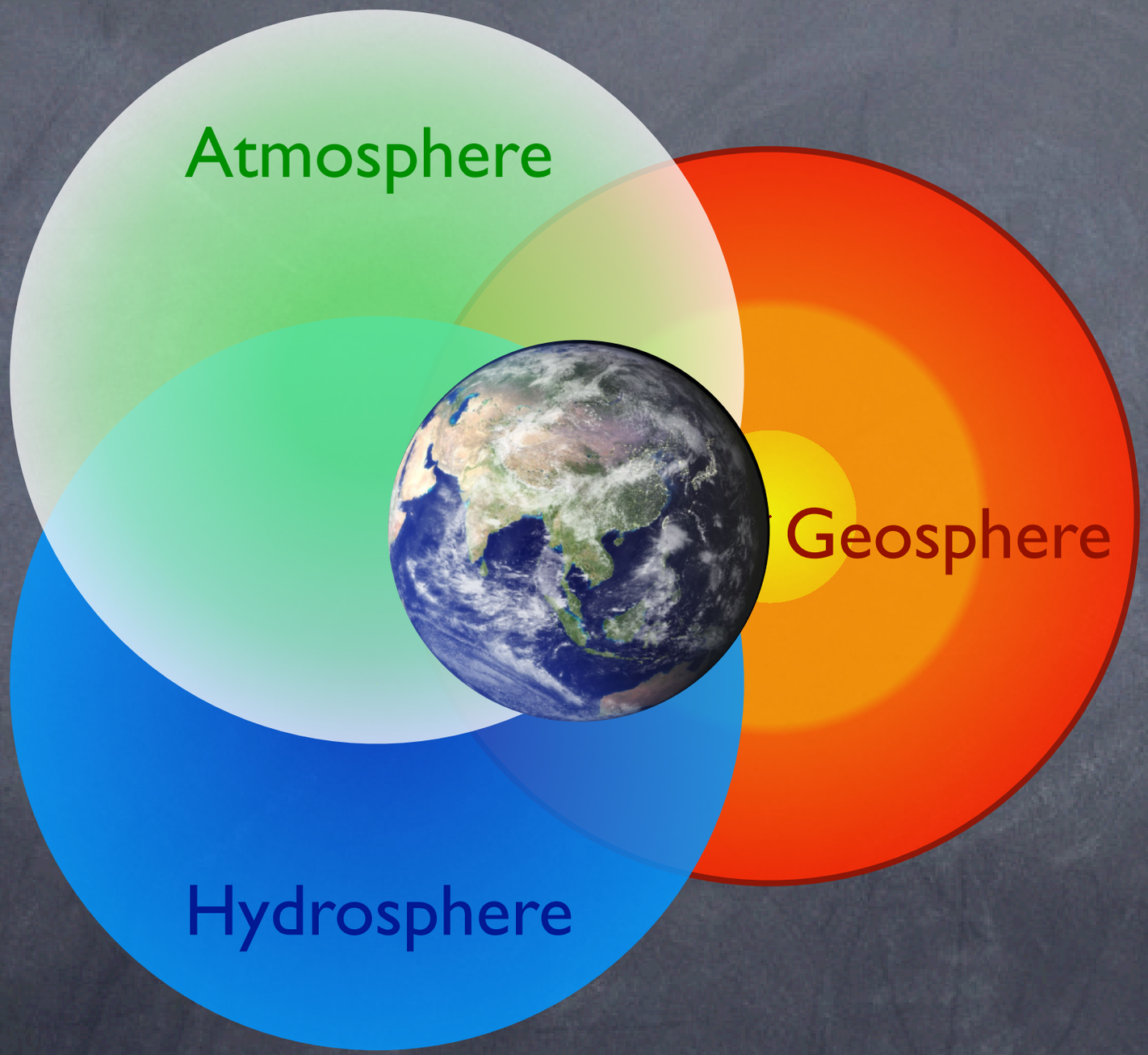
Major Themes

Scale Processes in the Earth system act on length scales of microns to thousands of kilometers, and on time scales of milliseconds to millions of years.

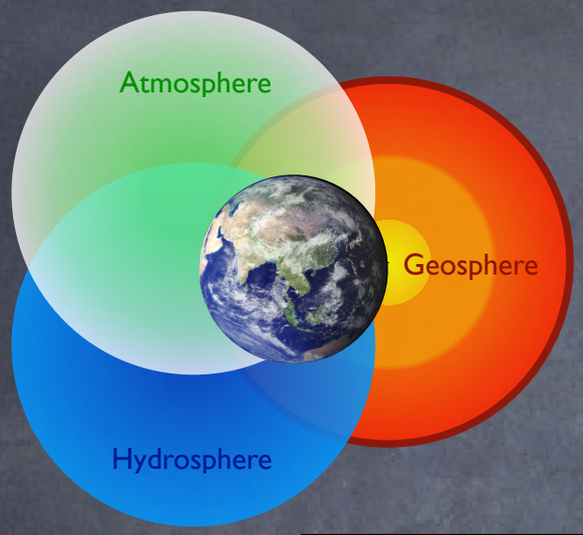
Energy The Earth system is powered by one external source (the Sun) and two internal ones: radioactive decay, and gravitational energy (heat still being lost from planetary formation).

Cycles Material in the Earth system is continually recycled in numerous overlapping cycles.

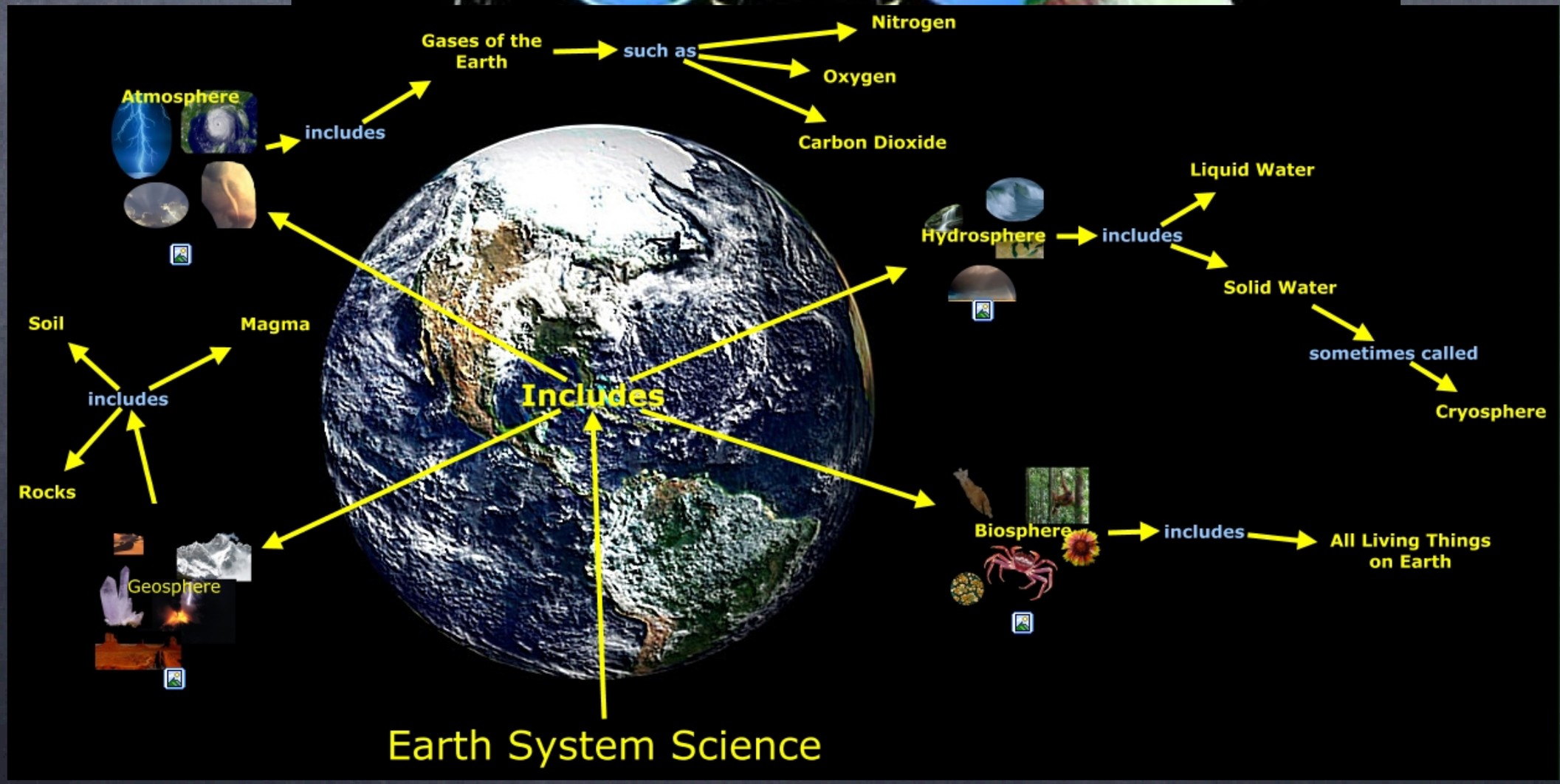
Earth System



Earth system

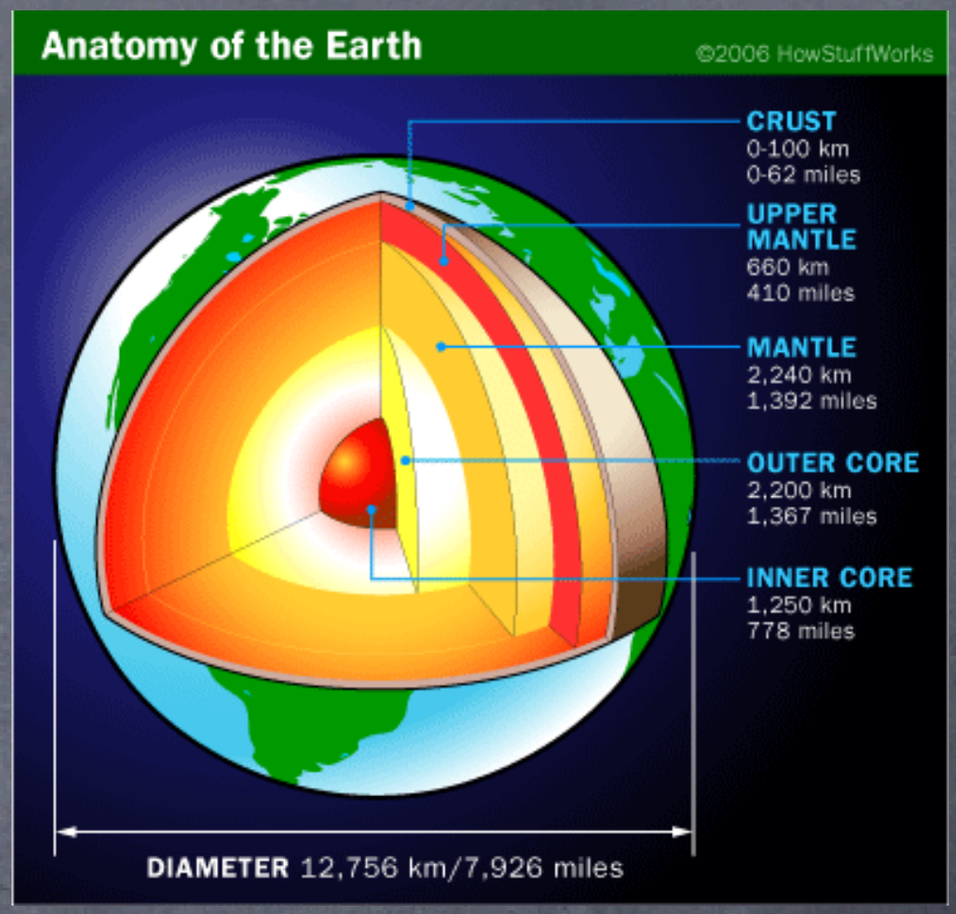






What is the Earth's Geosphere?

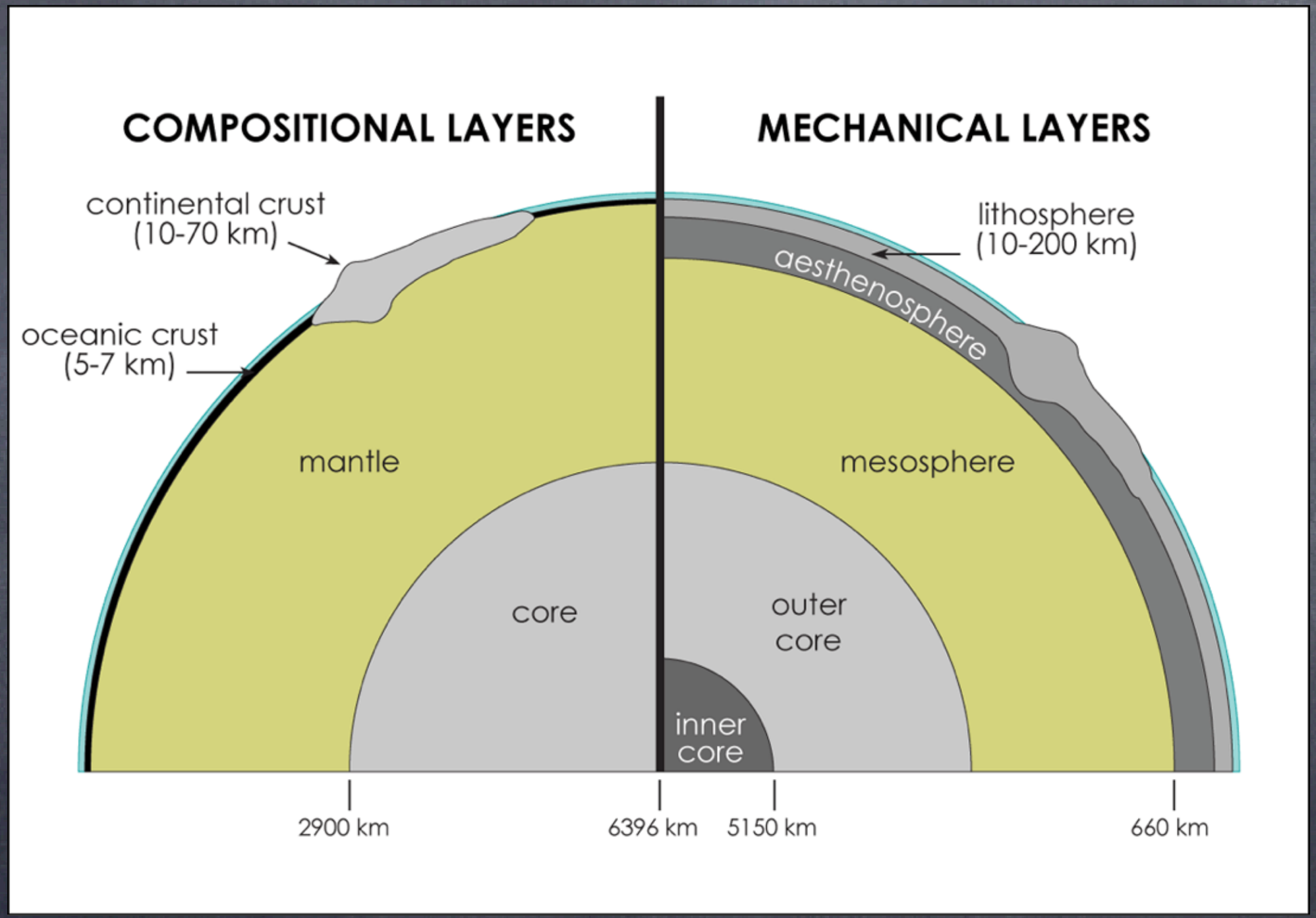
- **Geosphere**
  - Mostly solid, rocky part of the Earth.
  - Divided into 3 Layers
    - 1. Crust
    - 2. Mantle
    - 3. Core
      - a. Inner Core
      - b. Outer Core

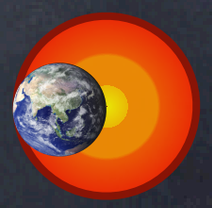






Earth system: geosphere





Earth layers

Composition

Primarily silica plus light metallic elements →

Primarily silica plus iron and magnesium →

Primarily iron and nickel →

crust

mantle

core

Mechanical Characteristics

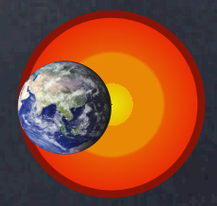
lithosphere ← brittle solid

asthenosphere ← solid (but nearly liquid)

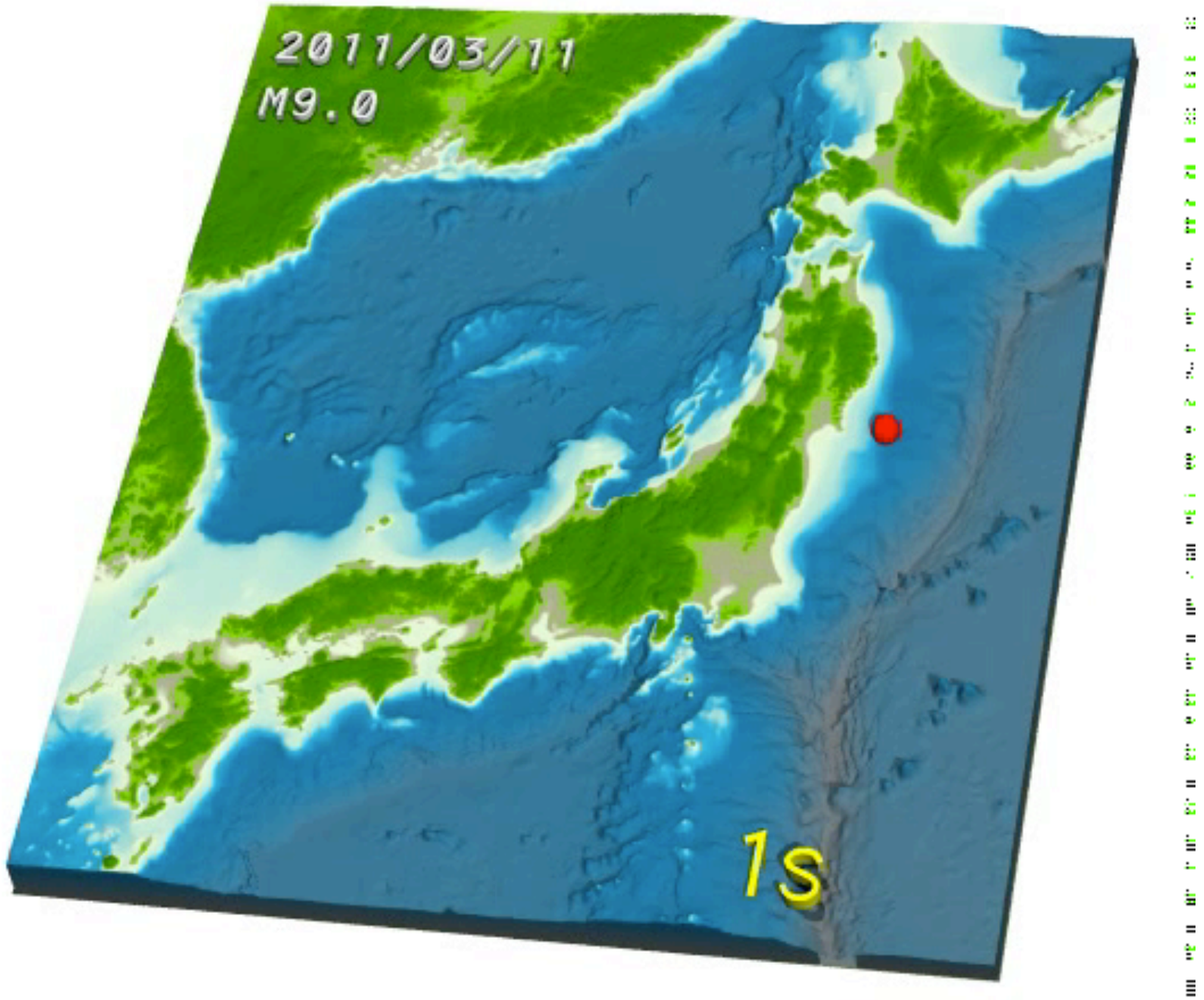
mesosphere ← solid

outer core ← liquid

inner core ← solid



Ground motion animation: time scales...



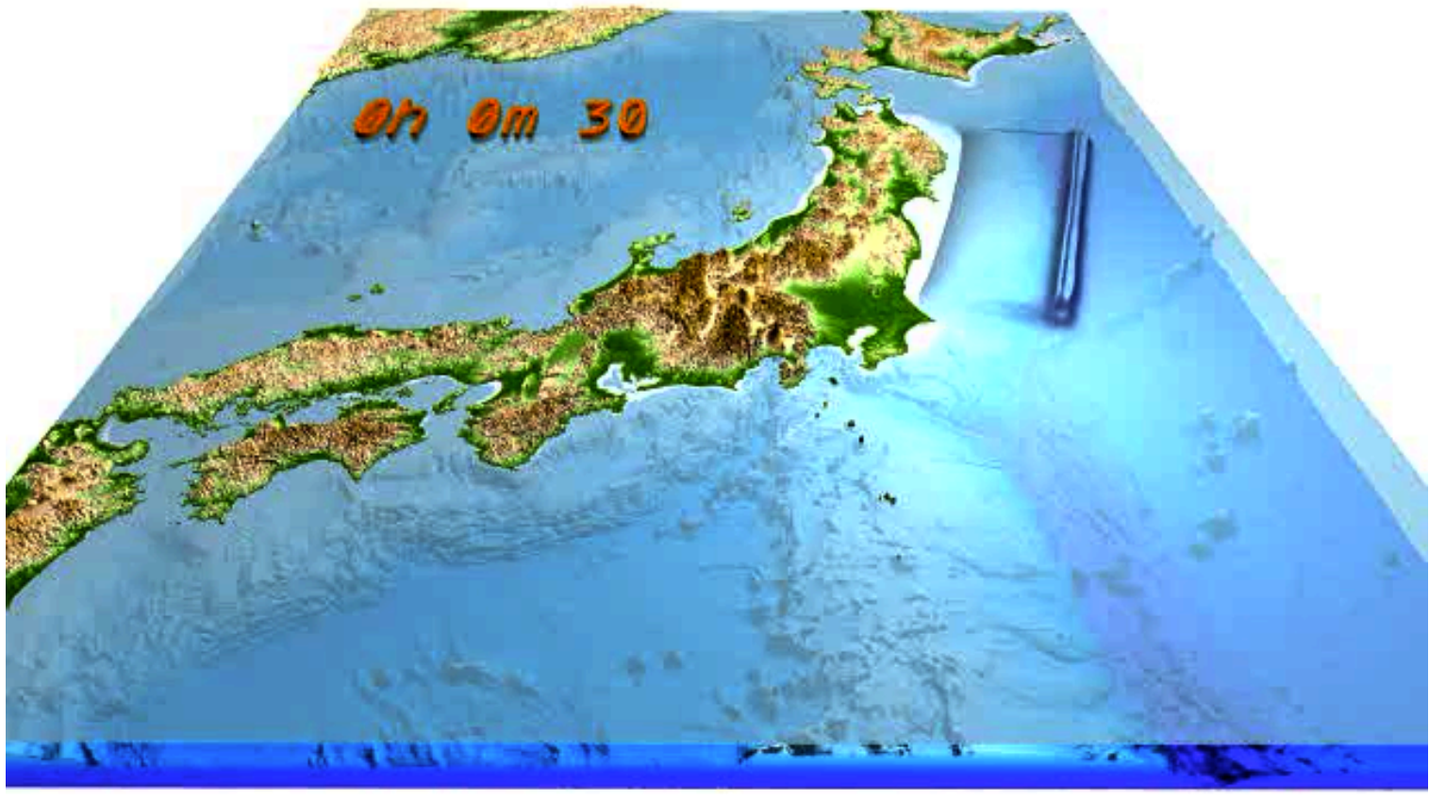
Courtesy of Takashi Furumura

Tsunami animation: time scales...

http://outreach.eri.u-tokyo.ac.jp/eqvolc/201103_tohoku/eng/

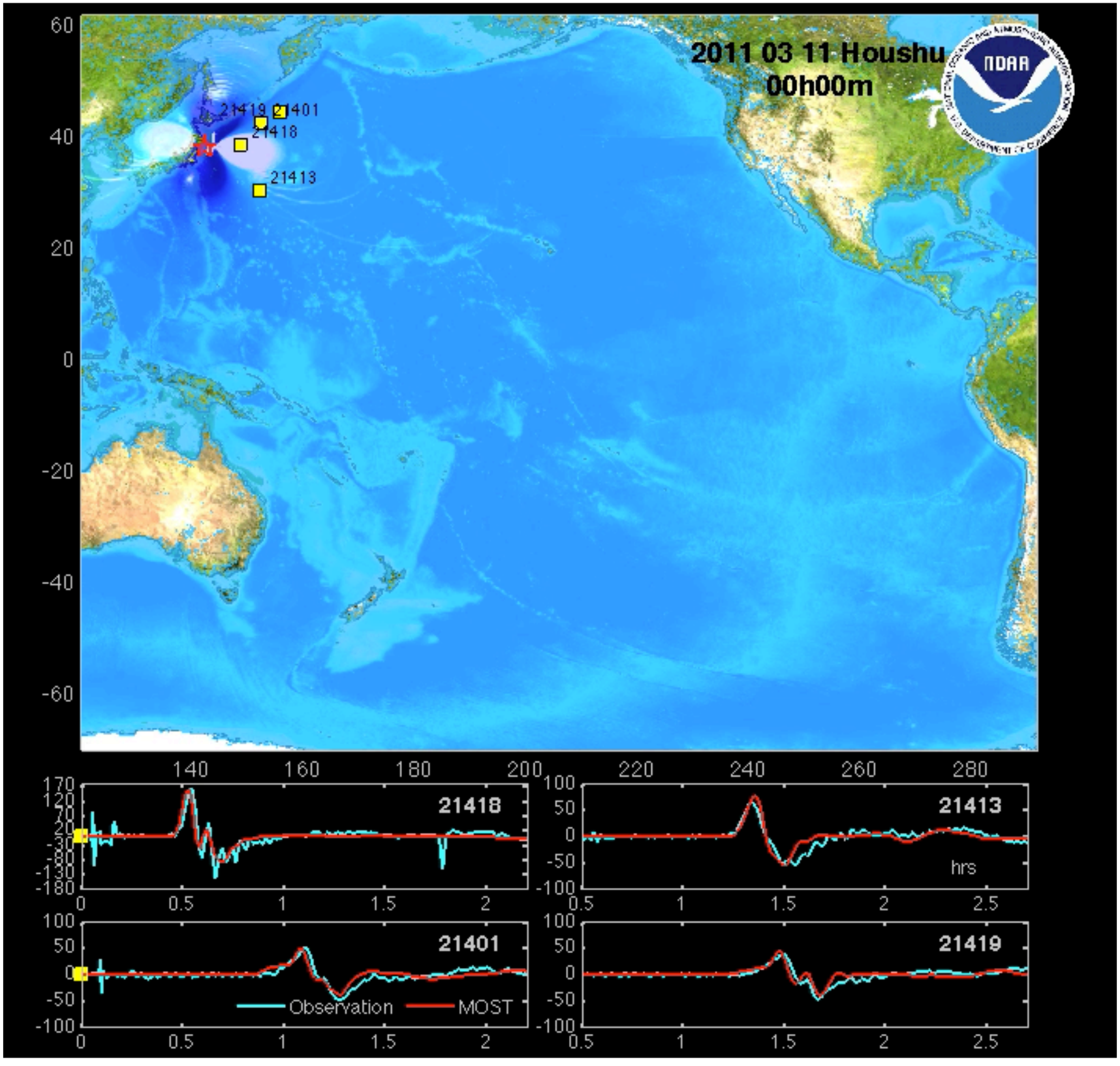
http://supersites.earthobservations.org/honshu.php

http://eqseis.geosc.psu.edu/~cammon/Japan2011EQ/



"Earthquake Research Institute, University of Tokyo, Prof. Takashi Furumura and Project Researcher Takuto Maeda"

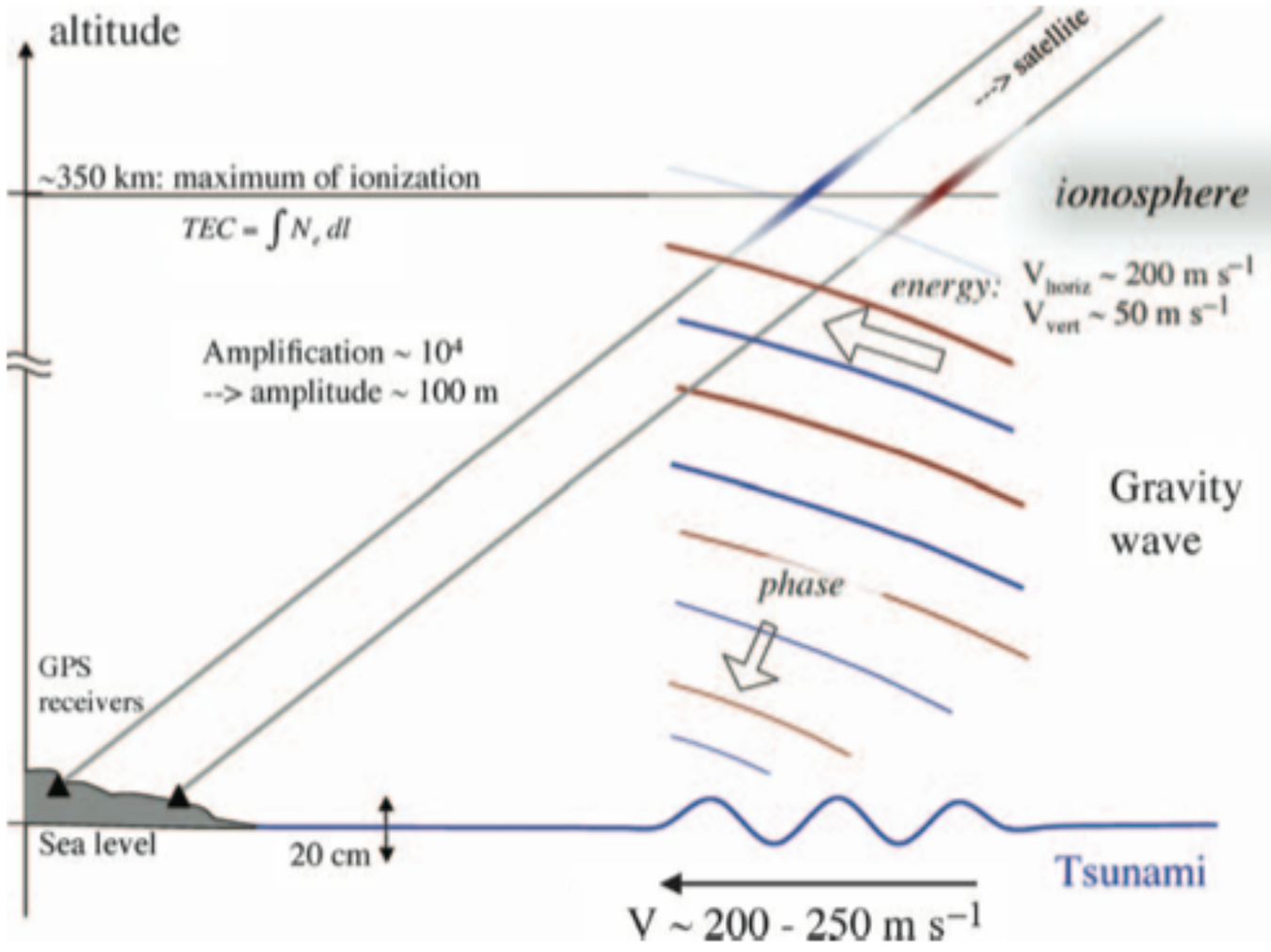
Tsunami animation - NOAA



Tsunami signature in the ionosphere

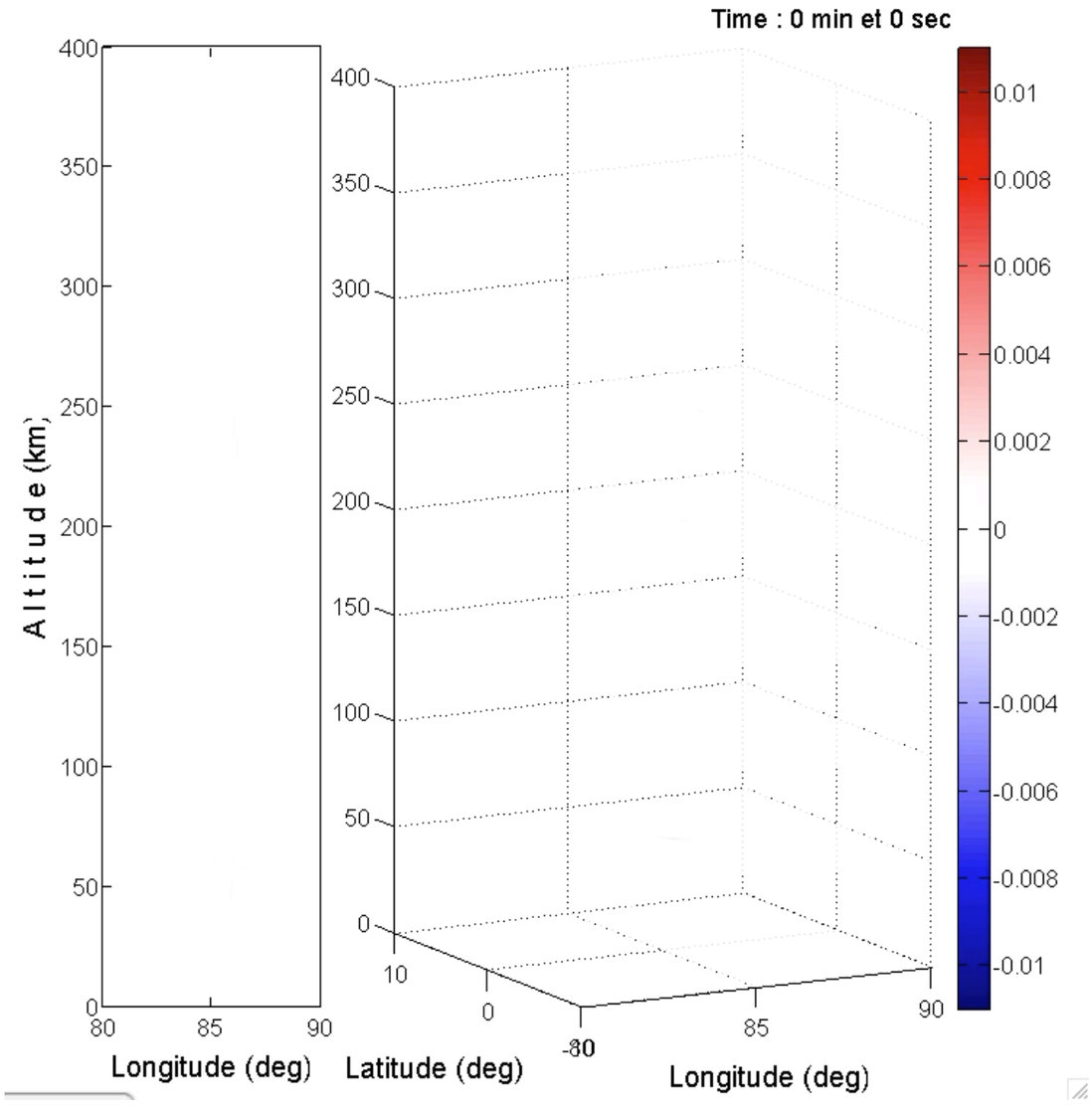
By dynamic coupling with the atmosphere, acoustic-gravity waves are generated

Traveling Ionospheric Disturbances (TID) can be detected and monitored by high-density GPS networks

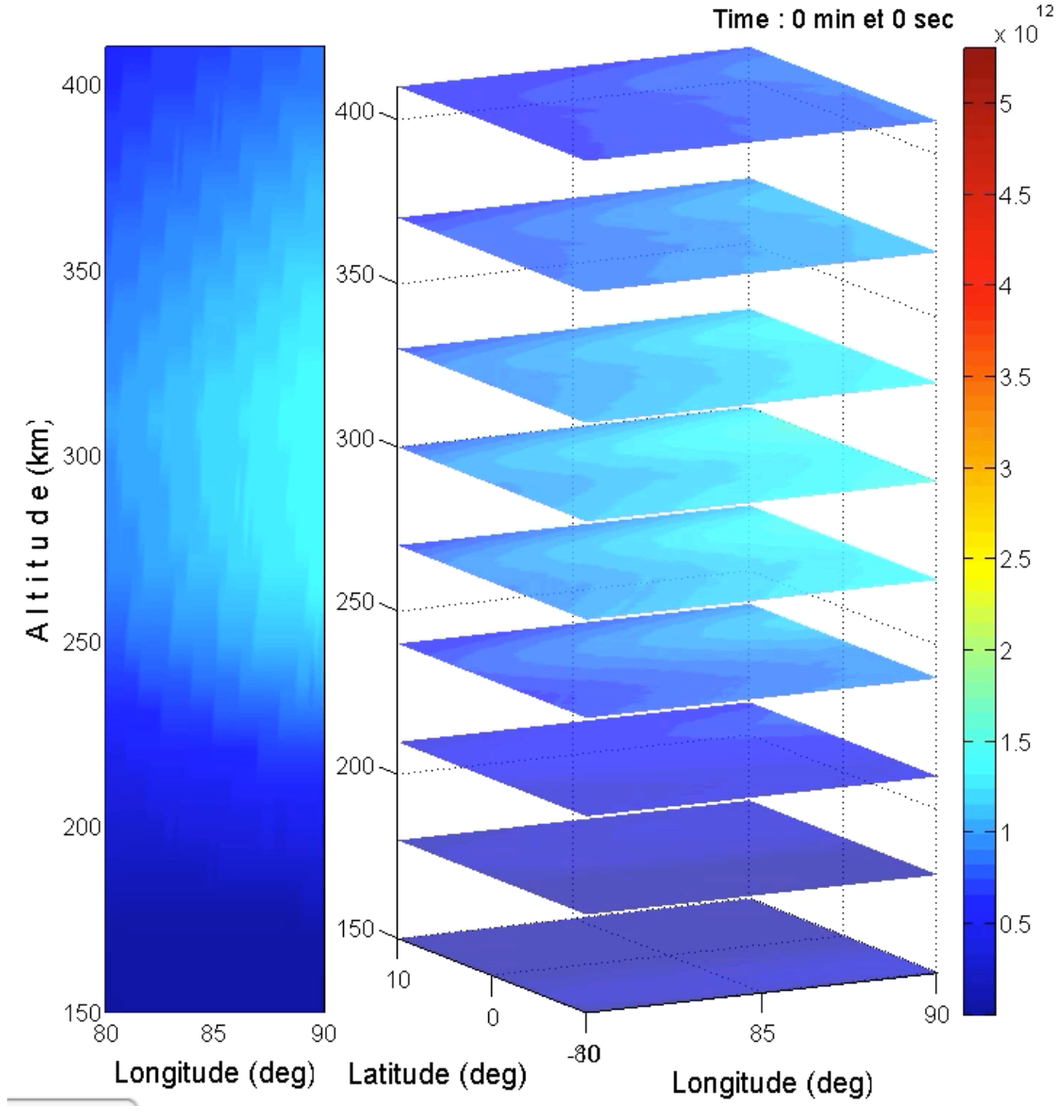


Tsunami signature in the ionosphere

Tsunami-generated IGWs and the response of the ionosphere to neutral motion at 2:40 UT.



Normalized vertical velocity



Perturbation in the ionospheric plasma

Mathematical reference: PDE

Second order Linear PDE of two variables
can be written in the form:

$$a\frac{\partial^2 f(x,y)}{\partial x^2} + b\frac{\partial^2 f(x,y)}{\partial x\,\partial y} + c\frac{\partial^2 f(x,y)}{\partial y^2} + d\frac{\partial f(x,y)}{\partial x} + e\frac{\partial f(x,y)}{\partial y} = F(x,y)$$

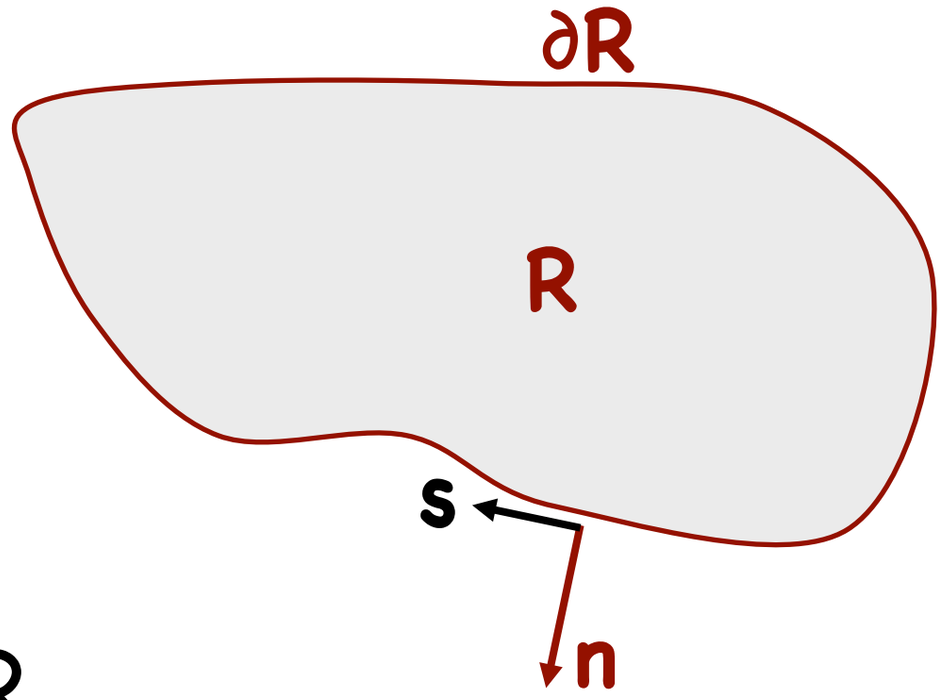
that can be classified according to:

Discriminant	TYPE	Example eqn.	Soln. Behaviour
$b^2-4ac<0$	ELLIPTIC	Laplace	stationary
$b^2-4ac=0$	PARABOLIC	Diffusion	spreading flow
$b^2-4ac>0$	HYPERBOLIC	Wave	propagation

Boundary and Initial conditions

Initial conditions: starting point for propagation problems

Boundary conditions: specified on domain boundaries to provide the interior solution in computational domain



$$\begin{cases} \text{Dirichlet:} & u = f \text{ on } \partial R \\ \text{Neumann:} & \dfrac{\partial u}{\partial n} = f \text{ or } \dfrac{\partial u}{\partial s} = g \text{ on } \partial R \\ \text{Robin:} & \dfrac{\partial u}{\partial n} + ku = f \text{ on } \partial R \end{cases}$$

Elliptic PDEs

Steady-state two-dimensional **heat conduction** equation is prototypical **elliptic PDE**

Laplace equation - no heat generation

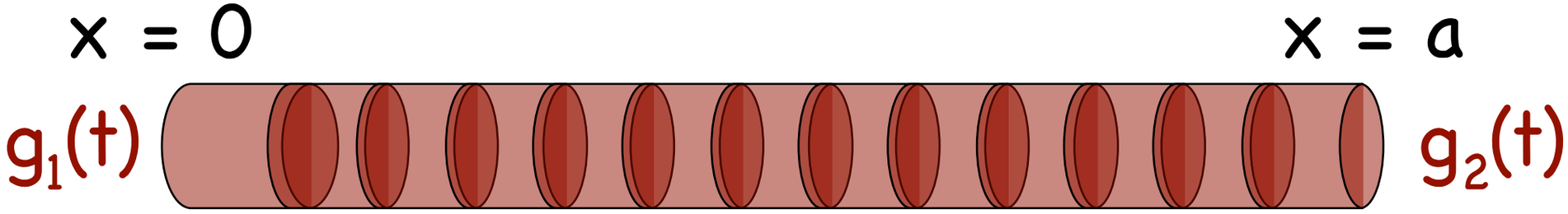
$$\frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial y^2} = 0$$

Poisson equation - with heat source

$$\frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial y^2} = f(x, y)$$

Parabolic PDE

Heat transfer in a one-dimensional rod



$$\frac{\partial u}{\partial t} = d\,\frac{\partial^2 u}{\partial x^2} \qquad 0 \le x \le a, \quad 0 \le t \le T$$

I.C.s $\quad u(x,0) = f(x) \qquad 0 \le x \le a$

B.C.s $\quad \begin{cases} u(0,t) = g_1(t) \\ u(a,t) = g_2(t) \end{cases} \qquad 0 \le t \le T$

Hyperbolic PDE: wave equation

$b^2 - 4ac = 0 - 4(1)(-c^2) > 0$: **Hyperbolic**

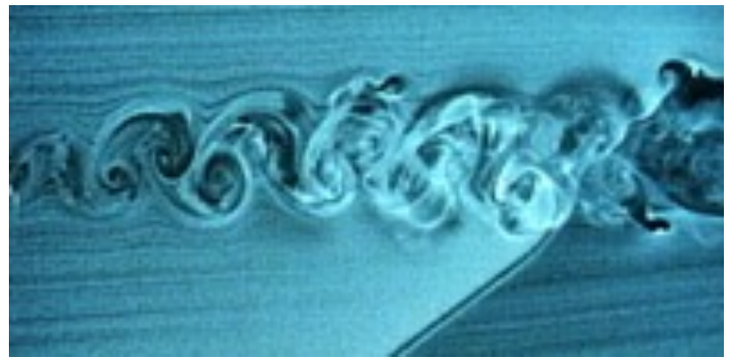
$$\frac{\partial^2 u}{\partial t^2} = v^2 \frac{\partial^2 u}{\partial x^2} \qquad 0 \le x \le a, \quad 0 \le t$$

$$\text{I.C.s} \quad \begin{cases} u(x,0) = f_1(x) \\ u_t(x,0) = f_2(x) \end{cases} \qquad 0 \le x \le a$$

$$\text{B.C.s} \quad \begin{cases} u(0,t) = g_1(t) \\ u(a,t) = g_2(t) \end{cases} \qquad t > 0$$

Coupled PDE

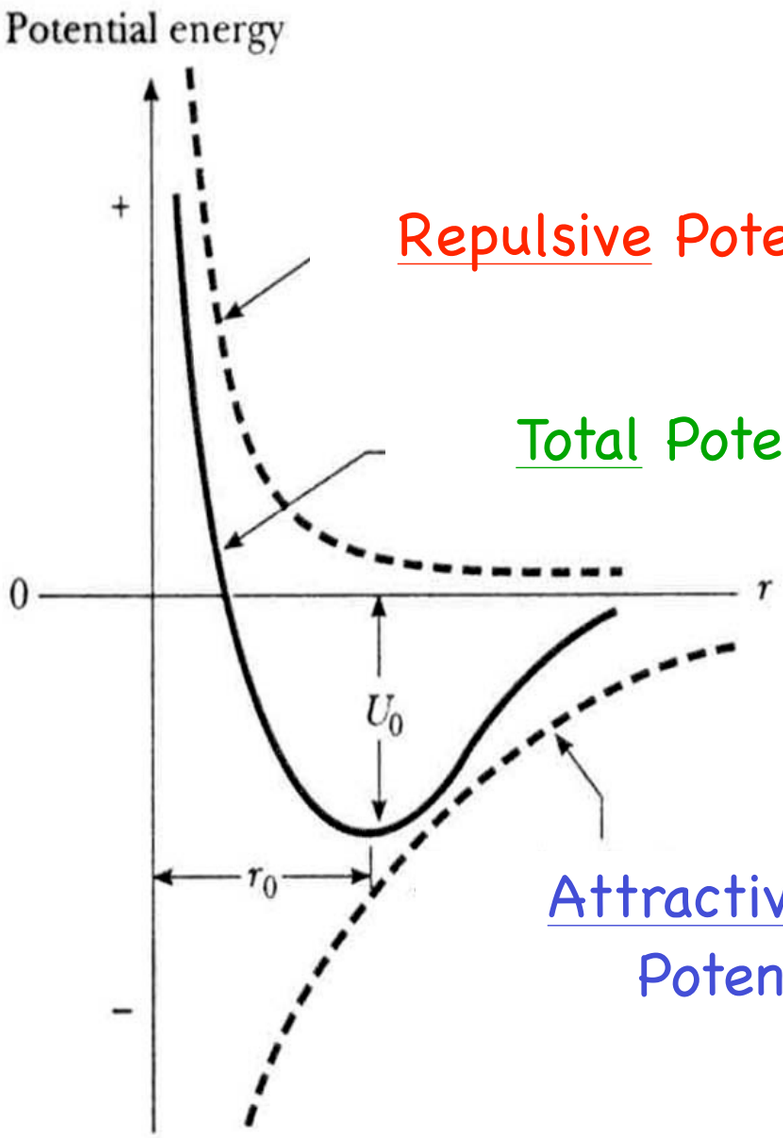
Navier-Stokes Equations



$$
\begin{cases}
\dfrac{\partial u}{\partial x} + \dfrac{\partial v}{\partial y} = 0 \\
\dfrac{\partial u}{\partial t} + u\dfrac{\partial u}{\partial x} + v\dfrac{\partial u}{\partial y} = -\dfrac{1}{\rho}\dfrac{\partial p}{\partial x} + \nu\left(\dfrac{\partial^2 u}{\partial x^2} + \dfrac{\partial^2 u}{\partial y^2}\right) \\
\dfrac{\partial v}{\partial t} + u\dfrac{\partial v}{\partial x} + v\dfrac{\partial v}{\partial y} = -\dfrac{1}{\rho}\dfrac{\partial p}{\partial y} + \nu\left(\dfrac{\partial^2 v}{\partial x^2} + \dfrac{\partial^2 v}{\partial y^2}\right)
\end{cases}
$$

What is a **wave**?

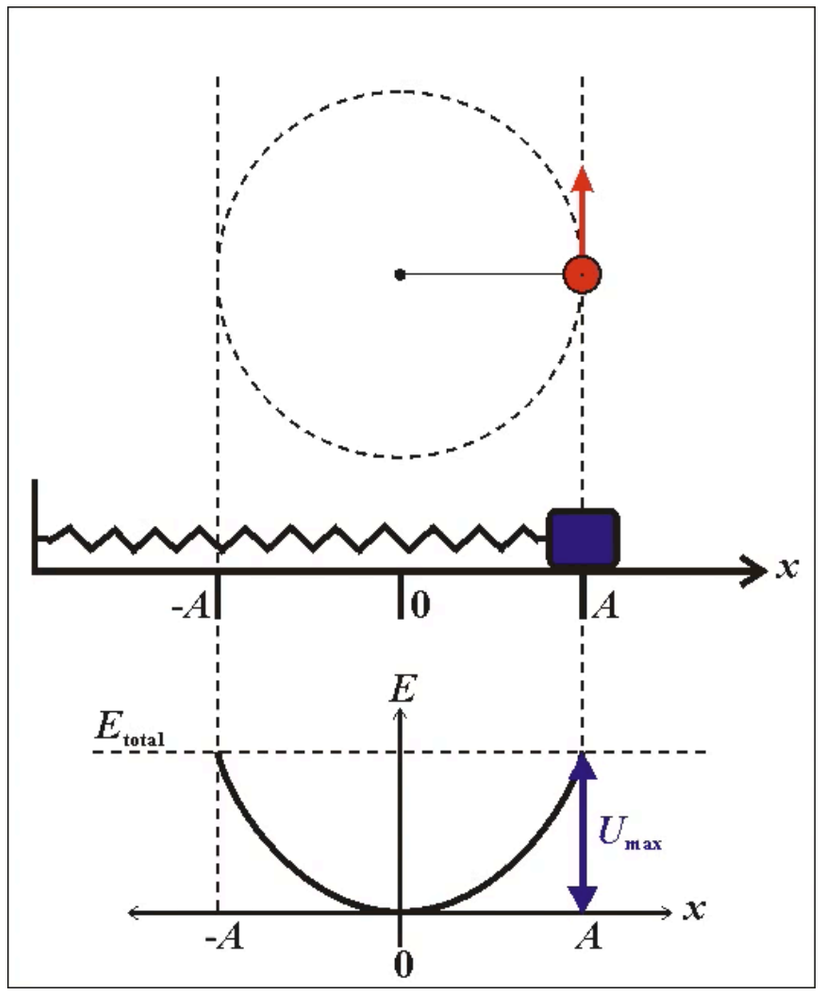
Small perturbations of a **stable** equilibrium point → **Linear restoring force** → **Harmonic Oscillation**



Repulsive Potential ∝ $1/r^m$

Total Potential

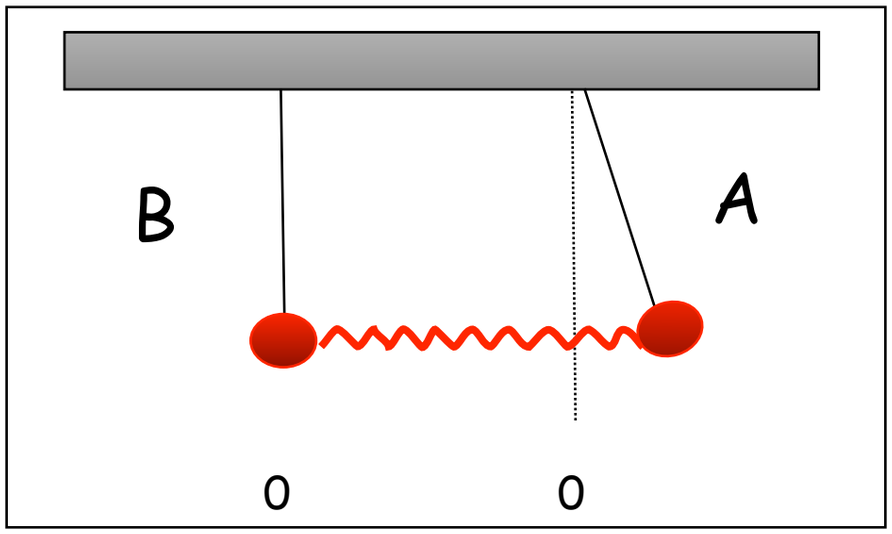
Attractive Coulombic Potential ∝ 1/r



What is a **wave**? - 2

Small perturbations of a **stable** equilibrium point → **Linear restoring force** → **Harmonic Oscillation**

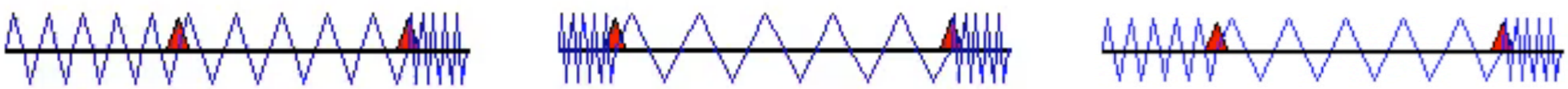
Coupling of **harmonic oscillators** → the disturbances can **propagate**



What is a wave? - 2

Small perturbations of a **stable** equilibrium point → **Linear restoring force** → **Harmonic Oscillation**

Coupling of **harmonic oscillators** → the disturbances can **propagate**, **superpose** and **stand**



Normal modes of the system

What is a **wave**? - 3

Small perturbations of a **stable** equilibrium point → **Linear restoring force** → **Harmonic Oscillation**

Coupling of **harmonic oscillators** → the disturbances can **propagate**, **superpose** and **stand**

General form of LWE

$$\frac{1}{v^2}\frac{\partial^2 \psi}{\partial t^2} = \frac{\partial^2 \psi}{\partial x^2}$$

WAVE: organized **propagating imbalance**, satisfying differential equations of motion

What is a **wave**? - 3

Small perturbations of a **stable** equilibrium point → **Linear restoring force** → **Harmonic Oscillation**

Coupling of **harmonic oscillators** → the disturbances can **propagate**, superpose, stand and be **dispersed**

WAVE: organized propagating imbalance, satisfying differential equations of motion

Organization can be destroyed, when interference is destructive

non linearity → **Turbulence**

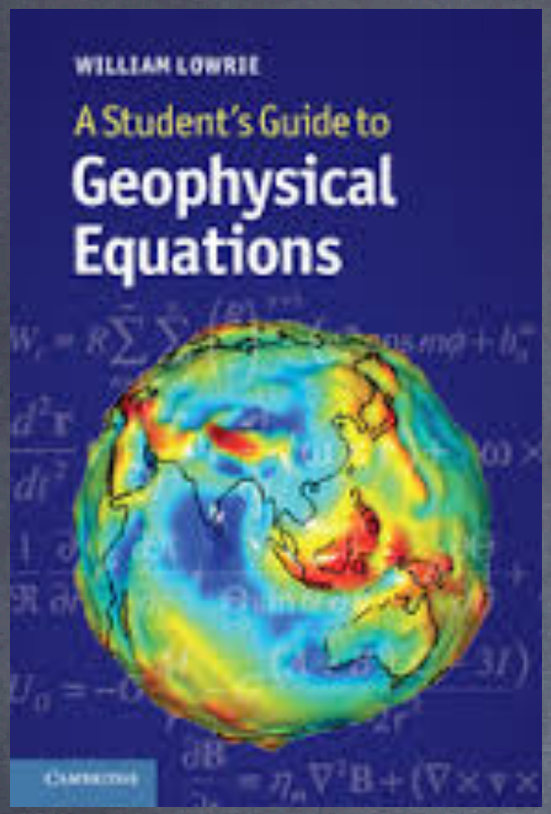
strong scattering → **Diffusion**

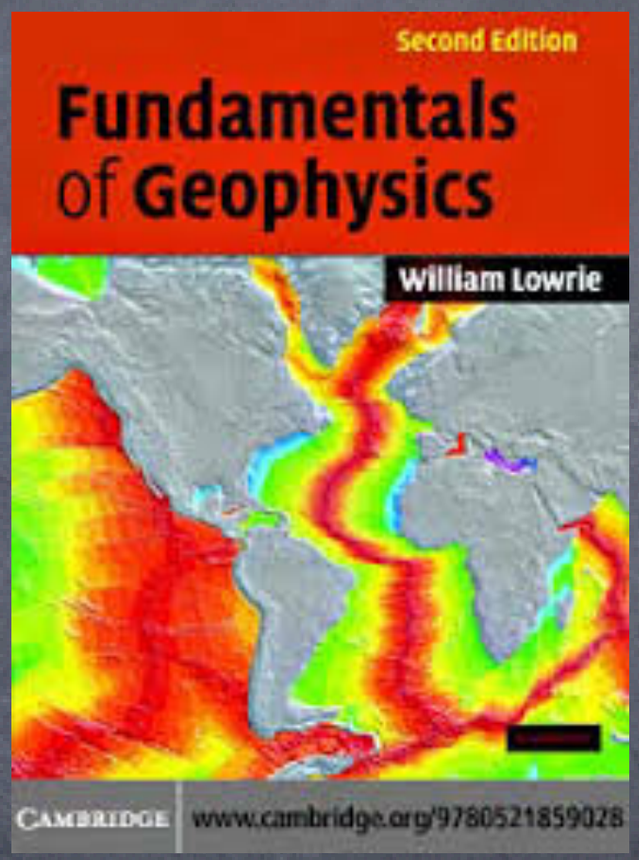
Exceptions

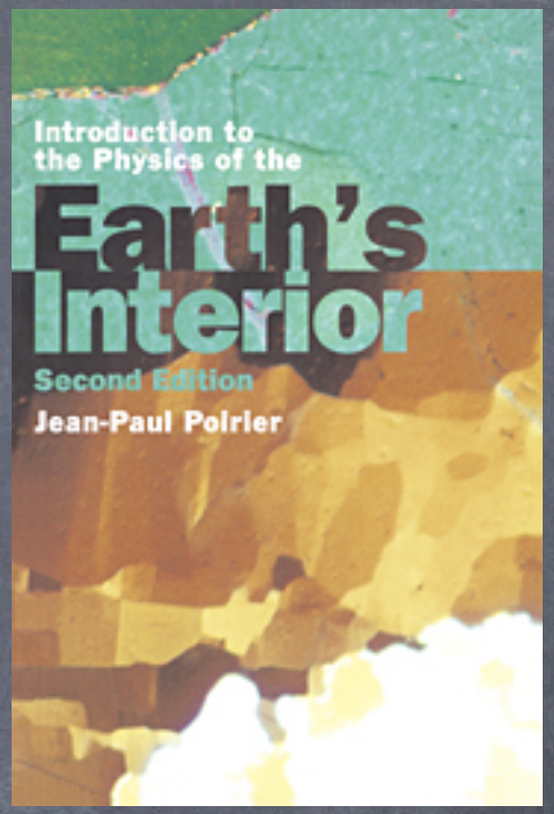
Solitons

Phonons

Alcuni Links







http://www.physicalgeography.net/fundamentals/contents.html