Rock physics and computational geophysics (seismic and electromagnetic methods)

Professor: José M. Carcione
email: jcarcione@libero.it

Course objectives

This course presents the fundamentals of the physical principles and computational techniques for wave propagation in anisotropic, anelastic and porous media, including the analogy between acoustic waves (in the general sense) and electromagnetic (EM) waves. The emphasis is on geophysical applications for hydrocarbon exploration, but researchers in the fields of earthquake seismology, rock physics, and material science, -- including many branches of acoustics of fluids and solids (acoustics of materials, non-destructive testing, etc.) -- may also find the material useful. The course illustrates the use of seismic and EM modeling, with an account of the numerical algorithms for computing synthetic seismograms, diffusion fields and radargrams, with applications in the field of geophysical prospecting, seismology and rock physics, such as evaluation of methane hydrate content, upscaling techniques, detection of overpressure, Antarctic and permafrost exploration, exploration of the Earth's deep crust, time-lapse for monitoring of CO2 injection, seismic modeling in geothermal fields, seismic inversion, etc.

On completion of the course, participants will be able to:

- Understand the physics of seismic (and EM) wave propagation and diffusion fields in real media, such as rocks and geological formations.
- Solve complex problems using numerical methods, as finite-differences, Fourier techniques, and machine learning methods.
- Apply these concepts to seismic and EM applications, such as hydrocarbon prospection, earthquakes, surface radar applications, EM low-frequency methods for environmental problems, rock physics, etc.

Course content

Mechanical viscoelastics models.
The wave equation with attenuation.
Seismic anisotropy.
Seismic attenuation.
Poroelasticity.
Seismic rock physics.
Hooke's law and wave equation.
Forward modeling. Computation of synthetic seismograms.
Reflection coefficients. AVO.
EM rock physics
Maxwell's equation.
The seismic-EM analogy.
Geo-radar equations.
The diffusion equation in EM prospecting.
Machine learning methods. Neural networks, genetic algorithms, etc.

Applications:

Fluid flow in porous rocks.
Unconventional resources. Oil and gas shales.
Cross-well seismic and EM methods.
Upscaling methods.
AVO cases
Rock-physics templates.
Q and velocity anisotropy in fractured media.
Geophone-soil coupling models.
Physics and simulation of waves at the ocean bottom.
Recent advances to model waves in reservoir and source rocks

Theory, simulation and case histories for detection and quantification of gas hydrates.
Theories for pore-pressure prediction and mud-weight design, with case histories.
Seismic-modeling case histories.
Seismic inversion.
Microseismicity.
Borehole waves.
Injection of fluids and seismic and EM monitoring. Time-lapse cases.
Tools for GPR applications.

Duration: 5 days, 6 hours per day

Language: English, Italian or Spanish.