
Continuum Mechanics

Introduction

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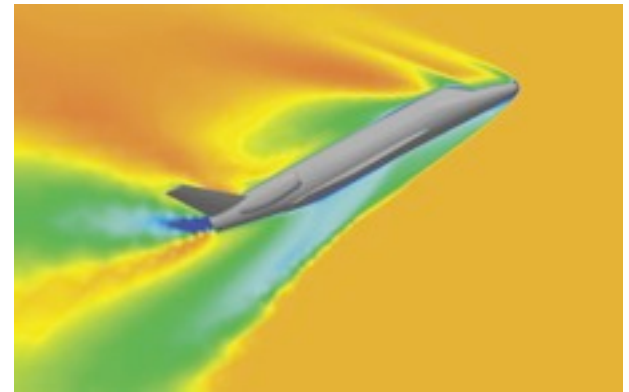
ETH

Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

Definition of continuum mechanics

Continuum mechanics is a branch of physics and engineering that deals with the analysis of the kinematics and the mechanical behavior of materials (solids, liquids and gases) modeled as a continuous mass distribution rather than as a discrete set of particles.

Theory of elasticity for solids and dynamics of fluids for liquids and gases.



What is a continuum ?

It is a region of space mapping the mass distribution of a physical object using a continuous function of \mathbb{R}^3 .

The mass of the object is just
$$M_V = \int_V dm = \int_V \rho dV$$

Definition of continuum mechanics

Continuum mechanics does not account for the microscopic structure of the object. At microscopic scales, physical systems are described as a collection of atoms and molecules. These atoms are interacting with each other using different physical interactions:

- **in solids**, atoms are arranged in a quasi-static crystal structure with interparticle separation close to the radius of an atom
- **in liquids**, molecules are moving with respect to each other at larger distances. They interact through Van der Waals forces
- **in gases**, molecules and even ionized atoms are very far from each other. They interact through long distance forces such as the Coulomb interaction.

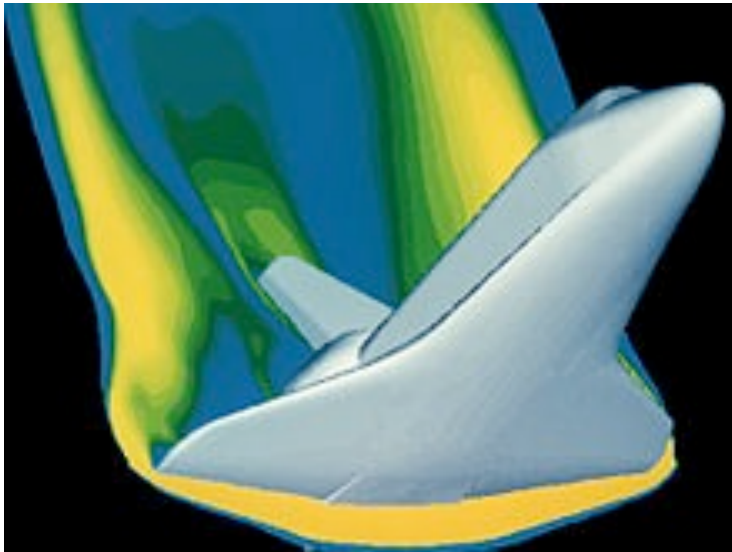
Continuum mechanics is a valid approximation on length scales much larger than the mean interparticle separation.

Continuum mechanics allows us to derive from fundamental physical laws various differential equations. These **differential equations** describe the **equilibrium states**, the **dynamics** and the **stability** of the systems under study (solids, liquids and gases).

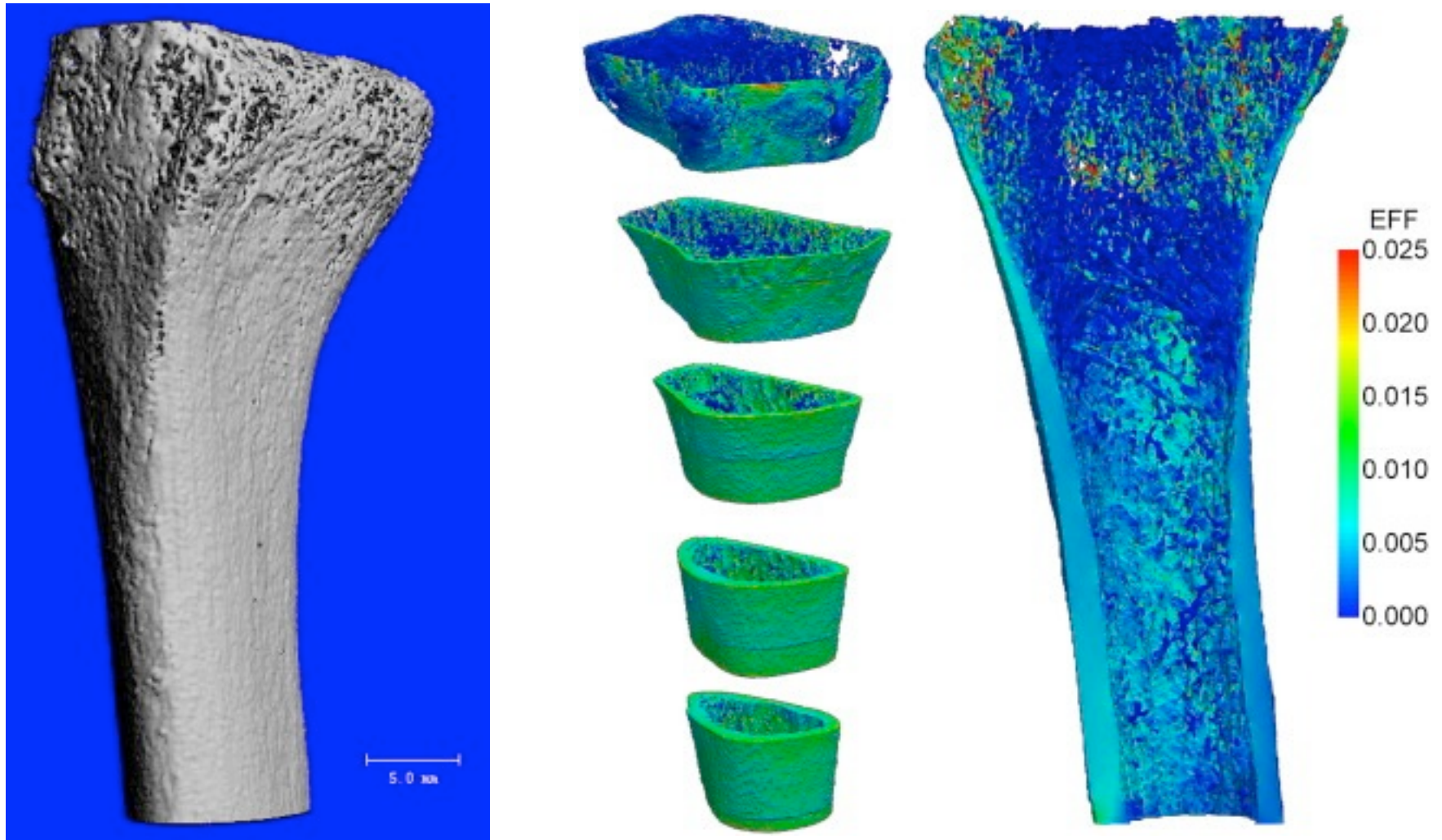
Continuum mechanics in engineering



Continuum mechanics in engineering



Continuum mechanics in medicine

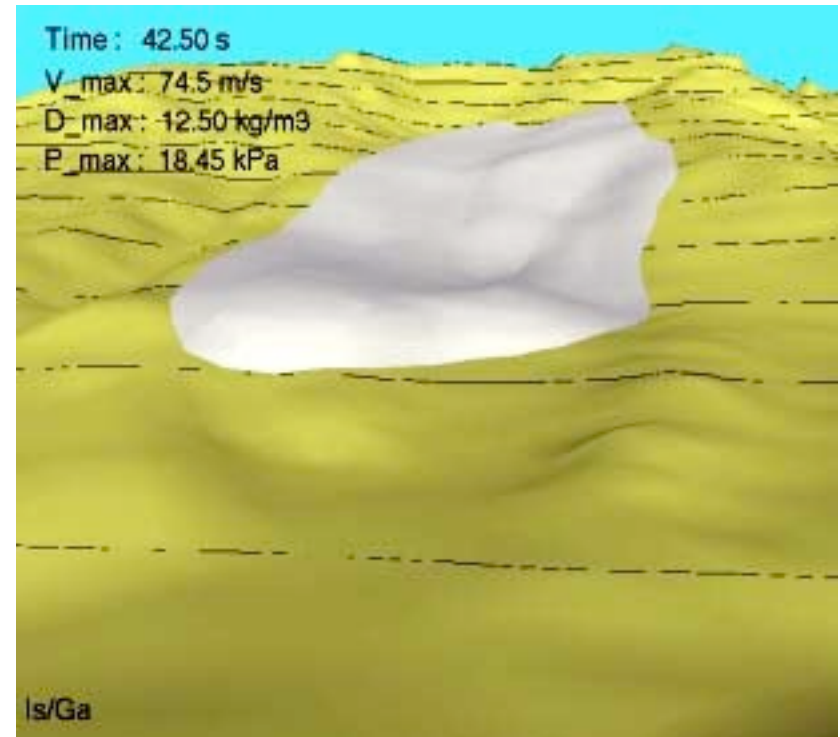


Institute for Biomechanics and Computer Science Department (ETHZ)

Continuum mechanics in avalanche modeling

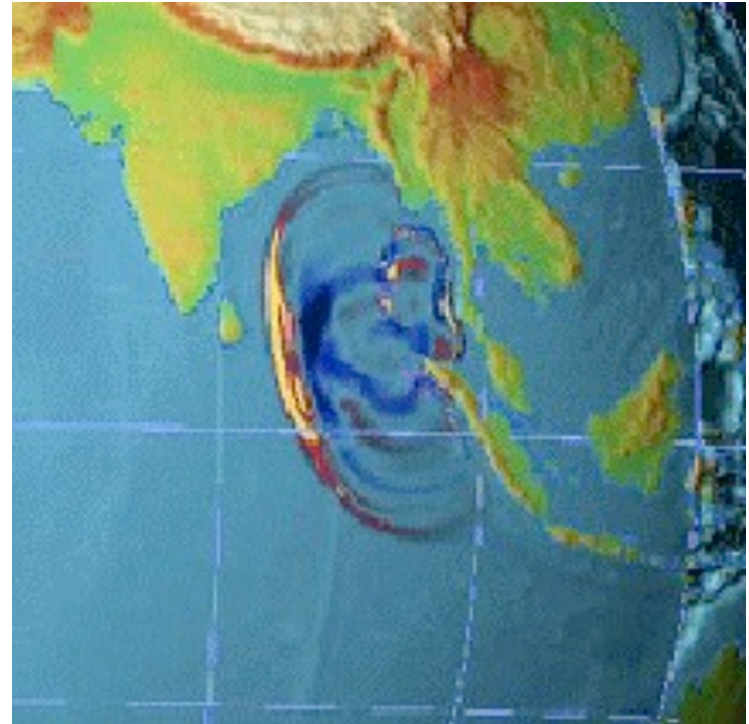
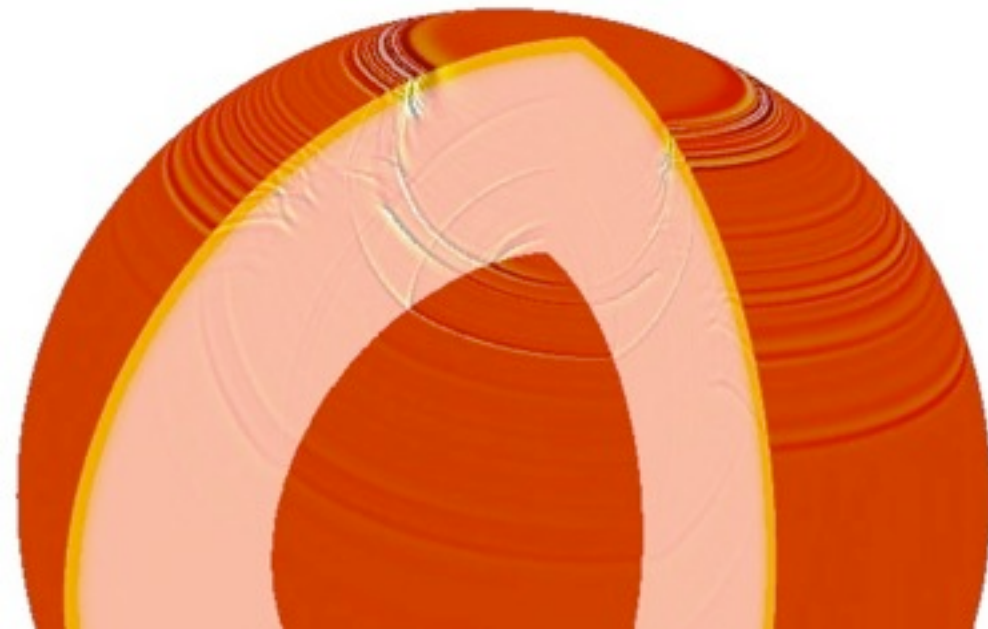


From snow fractures to fully developed avalanche dynamics



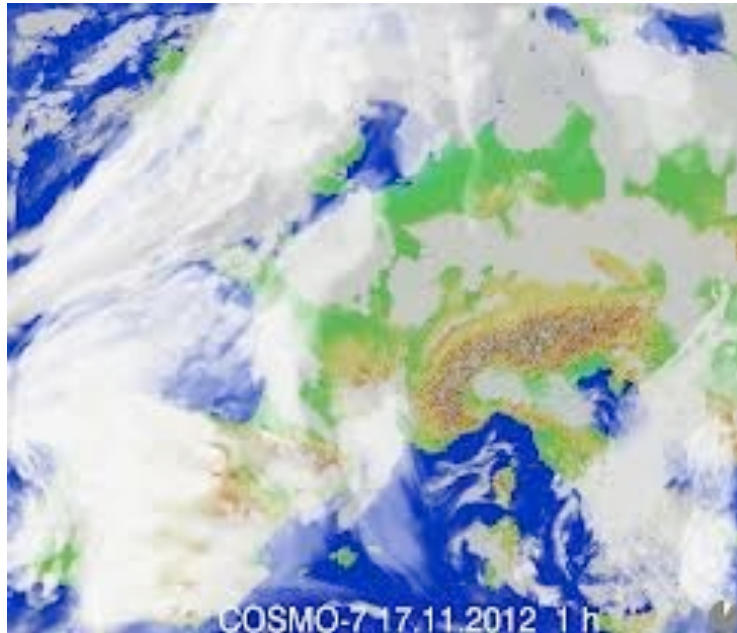
Institut fuer Schnee- und
Lawinenforschung (SLF)

Continuum mechanics in earthquake and tsunamis modeling

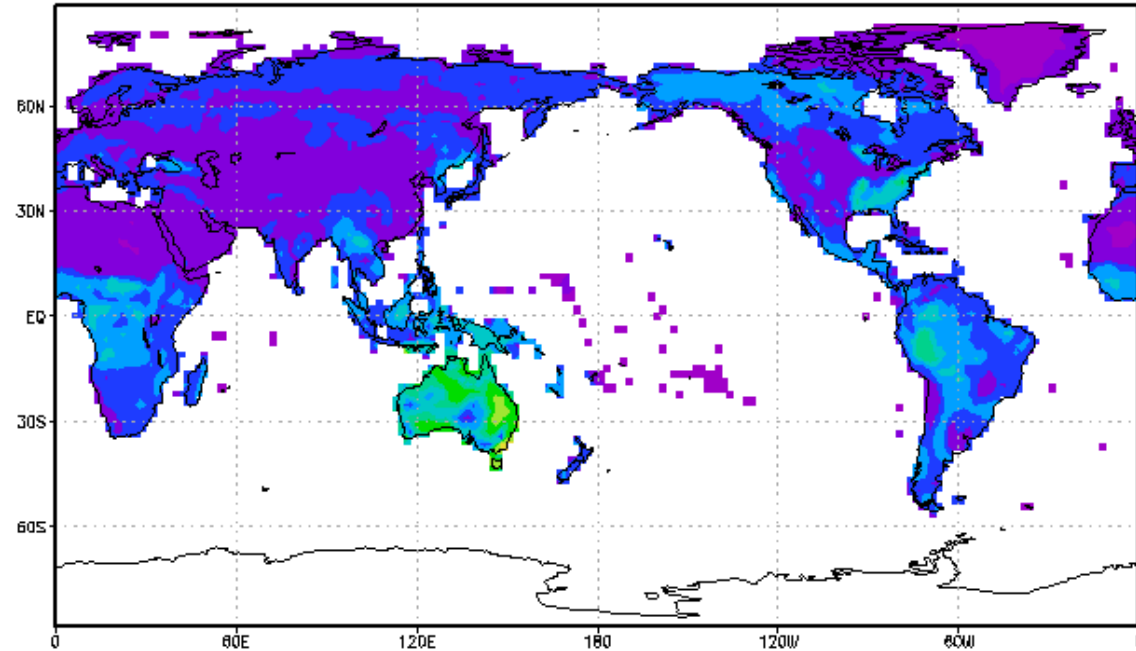


Institute of geophysics and seismology (ETH)

Continuum mechanics in weather and climate modeling

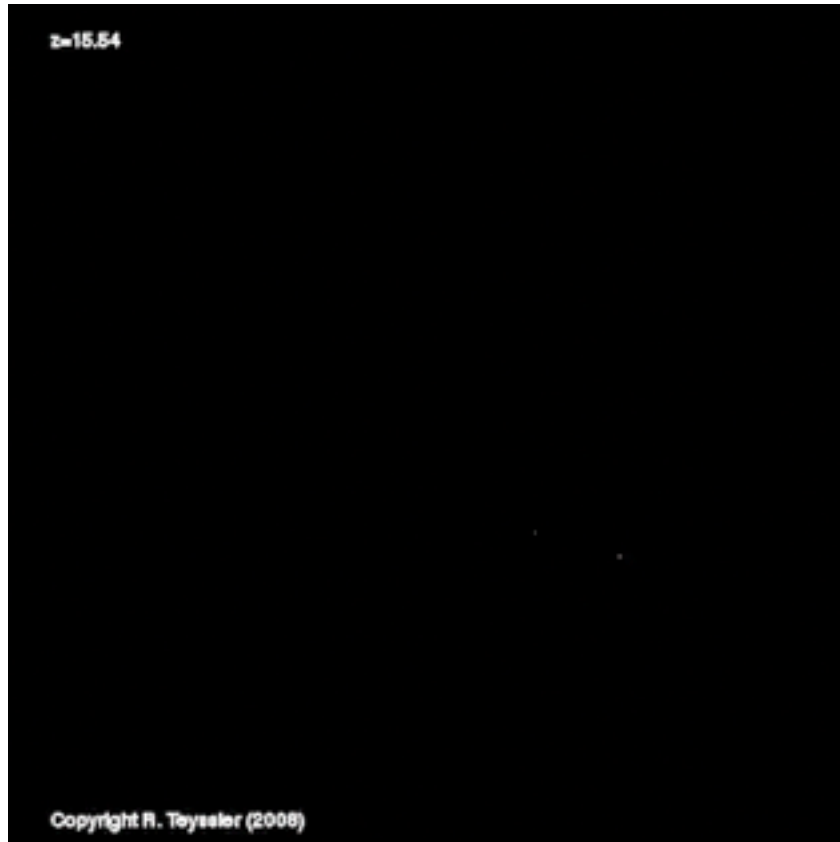


Meteo Swiss



Center for Climate System Modeling (ETH)

Continuum mechanics in astrophysics



Institute for Theoretical Physics (University of Zurich)

Literature

Theoretische Mechanik: Punkt- und Kontinuumsmechanik, H. Stephani und G. Kluge, Spektrum Akademischer Verlag.

Lehrbuch der Theoretischen Physik VII: Elastizitätstheorie, L.D. Landau und E.M. Lifschitz, Akademie Verlag.

Mechanik der deformierbaren Medien, A. Sommerfeld Band II, Verlag Harri Deutsch.

Theoretical Mechanics of Particles and Continua, A.L. Fetter and J.D. Walecka, Dover Publications Inc.

Feynman Vorlesungen über Physik, Band II, R.P. Feynman, R.B. Leighton and M. Sands, Oldenburg Verlag.

Einführung in die Kontinuumsmechanik, J. Altenbach und H. Altenbach, Teubner Studienbücher.

Lehrbuch der Theoretischen Physik VI: Hydrodynamik, L.D. Landau und E.M. Lifschitz, Akademie Verlag.

Hydrodynamik, W. Greiner und H. Stock, Verlag Harri Deutsch.

Fluid dynamics for physicists, T.E. Faber, Cambridge University Press.

Fluid mechanics, P.K. Kundu, Academic Press Inc..

Strömungslehre, H. Schade und E. Kunz, de Gruyter Lehrbuch, Berlin.

Outline of the course

- **Lecture 1**: basic concepts of solid mechanics, stress and strain tensors
- **Lecture 2**: theory of elasticity, isotropic materials, equilibrium solutions
- **Lecture 3**: elastic waves and dislocations, earthquakes and beams
- **Lecture 4**: fluid dynamics, conservation laws, general fluid properties
- **Lecture 5**: ideal fluids, Kelvin's theorem, vortices, Bernoulli theorem
- **Lecture 6**: waves in fluids, sound and gravity waves, fluid instabilities
- **Lecture 7**: theory of 2D potential flows, complex potentials, lift force, Kutta-Joukowski theorem
- **Lecture 8**: incompressible viscous flows, Couette and Poiseuille flows, boundary layer theory, turbulence
- **Lecture 9**: magnetized flows, ideal magneto-hydrodynamics, conservation laws, Alfvén waves, magnetic resistivity