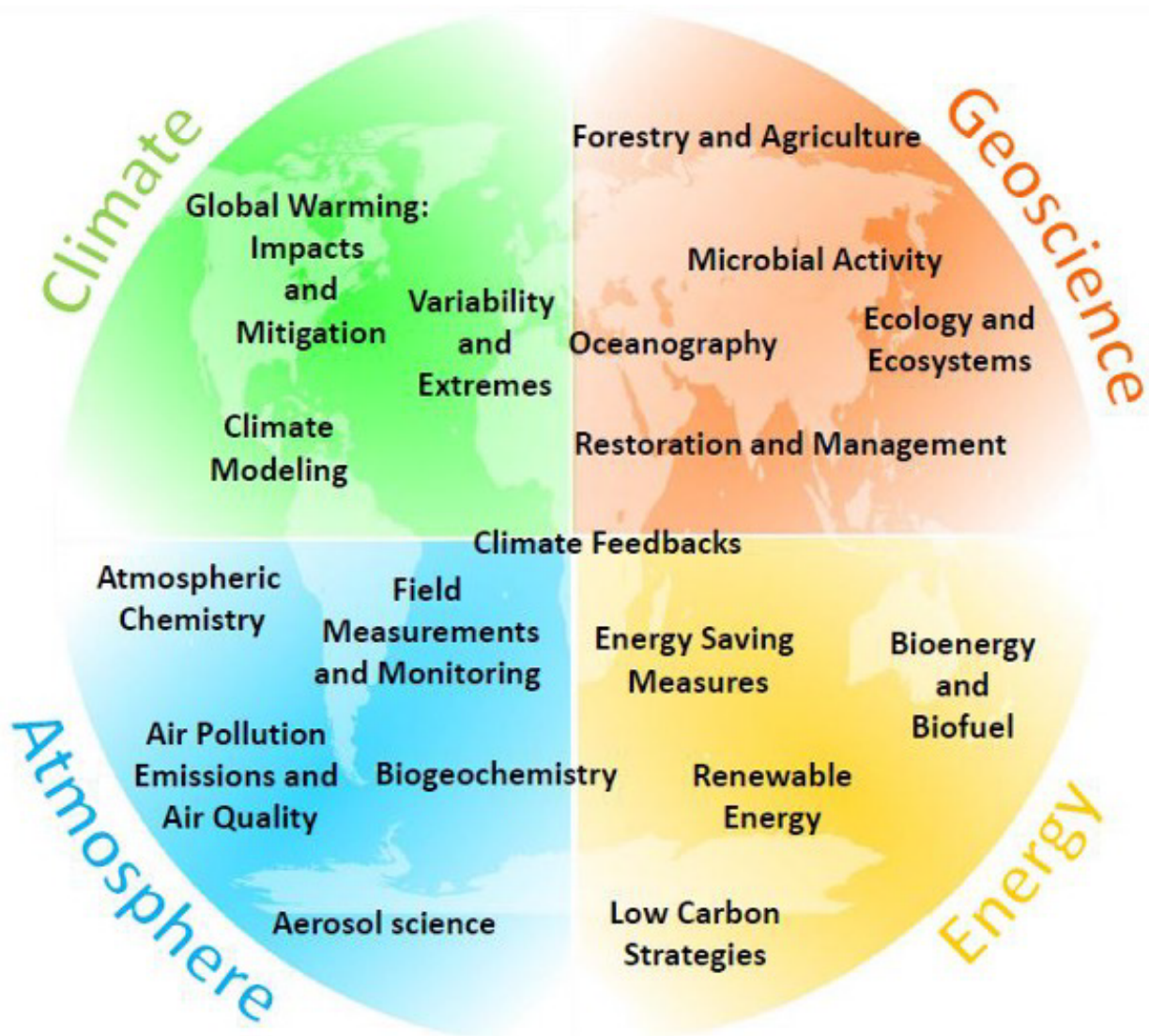


How does Earth System Sciences (ESS) Evolve ?

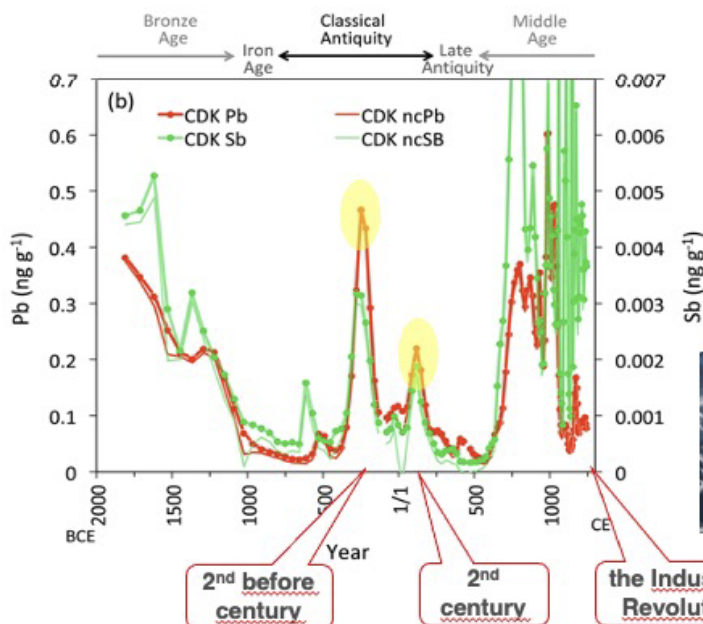
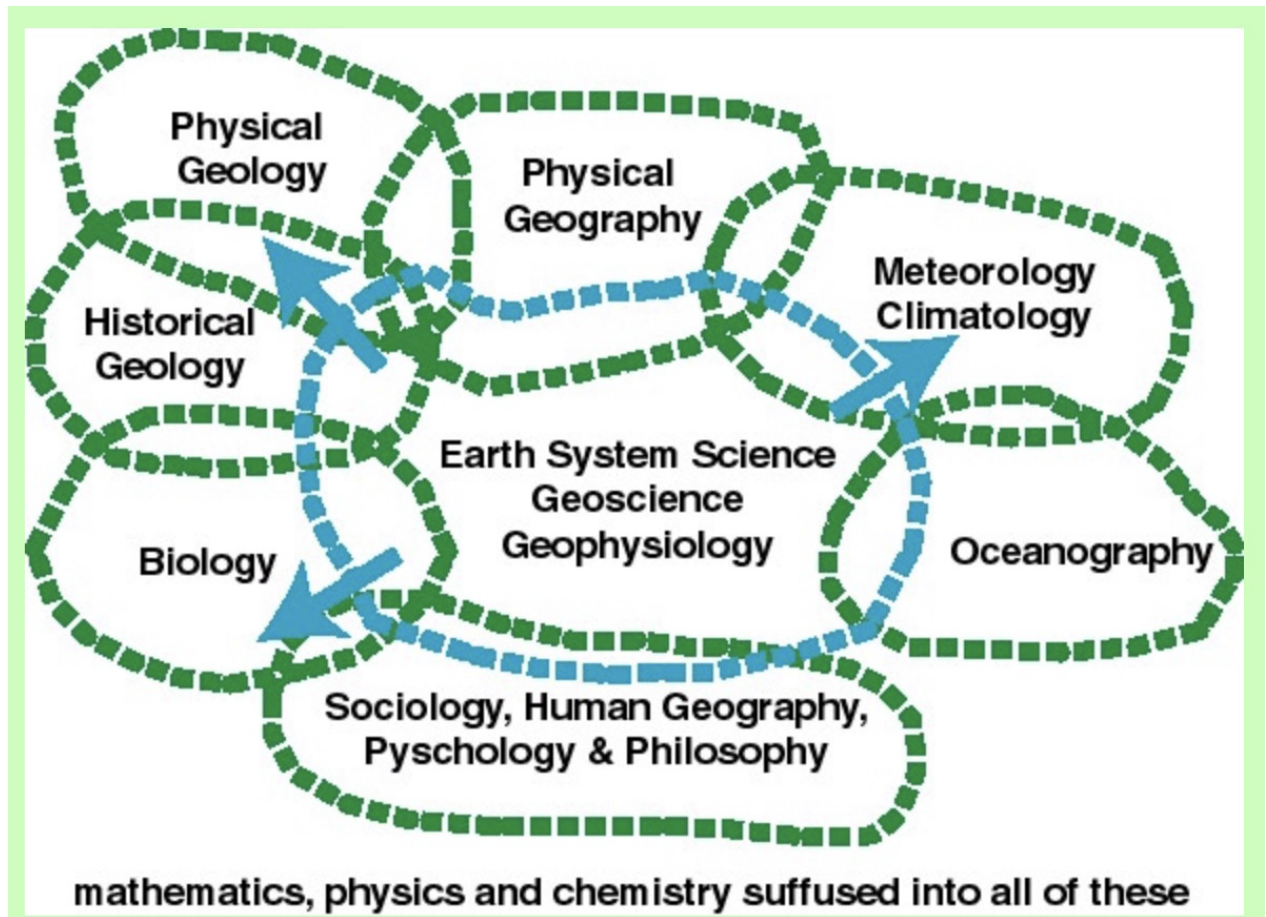


Earth system sciences

- Earth System Science (ESS) is a rapidly emerging **transdisciplinary** endeavour aimed at understanding the structure and functioning of the Earth as a complex, adaptive system.(Will Steffen et. al. 2020)
- Transdisciplinary endeavour



<http://www.phd-ess.org/>



Lead and Antimony in Basal Ice From Col du Dome (French Alps) Dated With Radiocarbon: A Record of Pollution During Antiquity, 2019



Romans' extensive mining and smelting of heavy metals between 350 BCE and 175 CE



French Alps



A Roman legionary supervises workers in a tin mine in Britain in around 50 AD

The development of ESS is the evolution of humans understanding of global change.

History of Earth system sciences

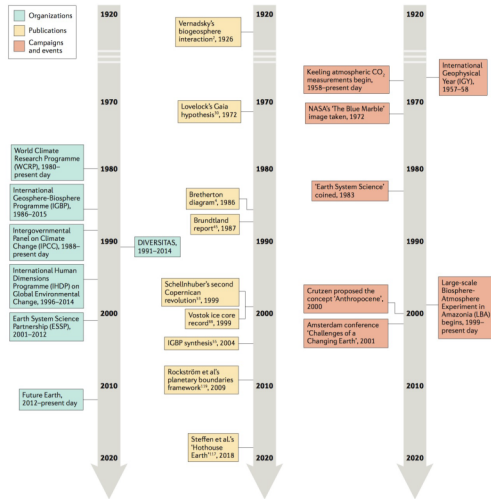
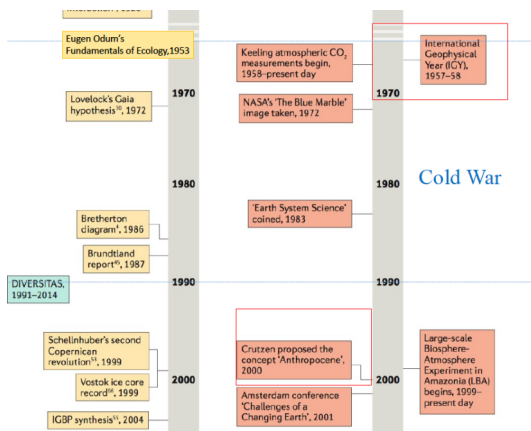


Fig. 1 | Timeline illustrating the development of Earth System Science from the mid-20th century. The figure shows the key organizations, events and concepts that have helped to define and develop Earth System Science.

- Vernadsky 'The Biosphere'



- International Geophysical year
- Eugene Odum , Father of Modern Ecology
- Gaia Hypothesis
- The Bretherton Diagram

The wisdom accumulated in this process has introduced new concepts and theories that have altered our understanding of the Earth System, particularly the disproportionate role of humanity as a driver of change.

One of the most influential concept is that of the Anthropocene.

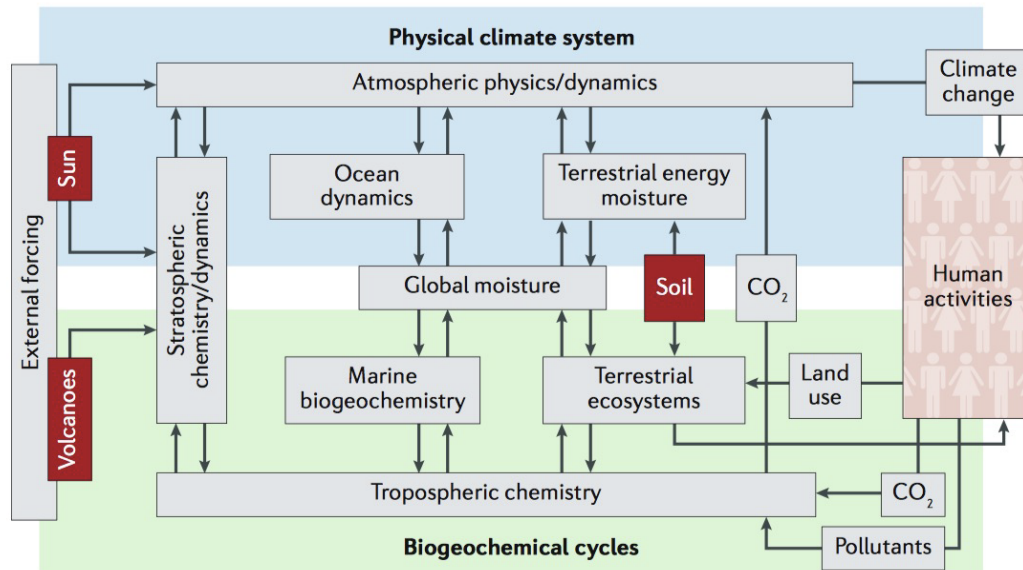


Fig. 2 | **The NASA Bretherton diagram of the Earth System.** The classical, simplified depiction of the Earth System and its interactions. The focus is on the interactions between the geosphere and the biosphere, with human forcings represented as an outside force affecting the geosphere–biosphere system. Reproduced with permission of National Academies Press from NASA (1986) Earth System Science Overview. A program for global change. Prepared by the Earth System Sciences Committee, NASA Advisory Council. 48pp. (REF.⁴), permission conveyed through Copyright Clearance Center, Inc.

One result from NASA ESSC is The Bretherton diagram, which epitomized the rapidly growing field of ESS through its visualization of the interacting physical, chemical and biological processes that connect components of the Earth System and through the recognition that **human activities were a significant driving force** for change in the system.