Week 1: The Earth System and Global Change (Chap. 1) - Overview

“Earth system” - approach to understanding global changes (changes are the focus of modern climate science, as opposed to traditional climatology)

Three global-scale changes for the human era:
- **ozone hole** (dramatic thinning of stratospheric ozone during Spring (Oct) over Antarctica and surrounding regions; associated with CFC’s)
- **loss of biodiversity** (habitat destruction causing many species to go extinct)
- **global warming** (carbon dioxide from fossil fuel burning causing Earth’s surface temperature to rise)

Three global-scale changes from an earth history point of view:
- **ice-ages** (oscillations over past 4 million years between warm conditions, like the present, and cold conditions with massive ice-sheets in Northern Hemisphere)
- **mass extinction events** (several documented in the fossil record; some of these – like the dinosaur extinction - probably due to asteroid impacts)
- **brightening sun** (gradual increase by about 30% over last 4 billion years)

Key evidence of change:
- atmospheric CO₂ increase (Mauna Loa record; ice-cord record), surface temperature increase, stratospheric ozone decrease (in October), tropical deforestation (e.g. satellite pictures at different times)
- Ice-cores record, geological record, various dating methods

Scientific method: powerful but imperfect
- example: sophisticated ozone satellite (TOMS) “missed” the ozone hole
- example: difficulty of determining global-annual-average surface temperature and how it has changed in the past

Time scales of global changes:
- human-scale vs earth history
- times scales associated with solving different environmental problems

The three human-scale problems illustrate
- i. that human activities are capable of altering the earth system – in particular, when the effects tend accumulate in the environment
- ii. that the earth behaves as a complex, coupled system - changes imposed in one place can lead to responses in some other part of the system and responses that play out over long periods of time
- iii. science has a growing but still quite limited ability to anticipate how the earth system will respond to human perturbations

The three global-scale changes from the earth-history illustrate
- i. that change – even drastic change – is natural for the earth system
- ii. that the earth system – including the biosphere as an integral part of that system – probably has some capacity to stabilize the climate
Key terms and concepts

*anthropogenic vs natural*

atmosphere, biosphere, hydrosphere, lithosphere (components of Earth system)

*biodiversity*: the number and variety of species in an ecosystem and on the planet as a whole; considered a critical measure of the health of the biosphere

*chlorofluorocarbons (CFCs), carbon dioxide (CO₂)*: compounds added to the atmosphere by human activities that accumulate over decades to centuries with potentially major, global-scale environmental consequences

*climate vs weather*: the former is the average weather over decades or more

*deforestation*: destruction of forests by humans; causes loss of habitat and adds CO₂ to the atmosphere

*Earth system, systems approach*: studying the earth as a coupled system

*forcing* a coupled system (vs simple cause-effect)

*fossil fuels*: fuels derived from ancient organic matter, including coal, oil, and natural gas.

  Burning fossil fuels transfers organic carbon from the lithosphere to CO₂ in the atmosphere.

*Gaia hypothesis*: the theory of planetary self-regulation with life as an active participant

*glacial period vs interglacial period* (hint: we are presently in an interglacial period)

*global warming vs greenhouse effect*: the former is anthropogenic, the latter is natural, but now being augmented by human activity

*greenhouse gases (GHGs)*: gases that make up only a very small fraction of the Earth’s atmosphere (trace gases) but that play a critical role by trapping heat, thereby causing the surface to be much warmer than it would be otherwise. GHGs bring about the greenhouse effect. Most GHGs (e.g. most CO₂) in the atmosphere today are natural, but they have been augmented significantly by human activity.

*reductionism vs integration* (in science): reductionism breaks a larger problem down into many small pieces, each of which can be studied very carefully; integration is the process of putting the pieces back together. The scientific community tends to excel at reductionism and have a much harder time with integration. Understanding the Earth system requires both.

*ozone (O₃), ozone hole, ozone layer*: Ozone in the stratosphere (the ozone layer) protects life from harmful ultraviolet radiation from the sun. A “hole” in the ozone layer (that is, a dramatic thinning of it) occurs each October over Antarctica since about 1985 and has been linked to anthropogenic CFCs

*photosynthesis*: Plants and certain bacteria grow by taking CO₂ out of the atmosphere and converting it to organic material. Requires sunlight as a source of energy.

*solar luminosity*: the energy output of the sun, which has risen about 30% since the origin of life about 4 billion years ago