Lecture 9: Systems

Questions on ozone, ozone “debate”?

Start on systems & feedbacks.
- System basics
- Earth surface temperature as an indicator of climate change
- System diagrams: couplings, feedback loops

Following Chapter 2 of textbook.

For more info on misinfo…


By two respected Stanford University professors:

Scholarly correction to misinformation printed in books/newspapers about biodiversity loss, global warming, ozone depletion, etc.

System essentials - 1

system: “an entity composed of diverse but interrelated parts that function as a complex whole” (p. 18, Kump)

examples: human body, nation, ecosystem, planet, computer, internet, car, traffic

Characteristics of systems:
- multiple components
- components are somehow coupled to each other
- energy and/or matter flows through

System essentials - 2

Critical to understanding almost any system is to understand how it handles (or processes) the energy and/or matter flowing through it.

at equilibrium
\[ F_{IN} = F_{OUT} \]

where \( F \) = flow or flux

examples:
- planet/temperature (\( F \) is flow of energy)
- body/weight (\( F \) is flow of food and water)
Earth as a coupled system

System essentials - 3

Component: any individual part of a system that can be conceptually separated and described in terms of its state, its behavior, and its influence on other components.

Quite arbitrary; choice based on what makes sense – what helps us diagnose and understand the system.

Examples for a planet system: atmosphere, surface, biosphere.

State of a system: the set of important attributes that characterize the system at a particular time (p. 19)

Note: we can also speak of the state of a component.

Examples: atmosphere: CO₂ content; surface: temperature; biosphere: number of daisies.

Example state of the system: GAASST

Observed changes in the Earth's Global Annual Average Surface Temperature (GAASST) over the past 120 years.

GAASST

The main evidence that global warming is really happening is that the earth’s surface temperature has increased over the past century. What is meant by the phrase “the earth’s surface temperature”? That is, how is this quantity defined and how is it measured?

Key point: global-average and annual-average.

Why is this quantity used as an indicator of climate change? (scientific reasons, practical reasons)

Key points:
- Indicates a property of the entire planet (e.g., responds to planetary energy balance).
- Living things are very sensitive to temperature.
- People and most life is at the surface.
- Determined very accurately because random errors cancel out with millions of measurements.
Average surface temperature is the best SINGLE indicator we have of the state of the Earth's climate. But the earth's “climate” is much much more than the average surface temperature!

Describe two ways that the “climate” could change WITHOUT changing the global-annual-average surface temperature.

- northern hemisphere cools; southern hemisphere warms
- nighttime gets warmer; daytime gets cooler
- changes in precipitation, wind (hurricanes), sea level, etc.

**Variations of the Earth’s surface temperature for the past 1,000 years**

*Data from thermometers (red) and from tree rings, ice cores, sea salts and historical records (blue)*

**System Essentials - 4**

**coupling:** how one component affects another – how the state or behavior of one component influences the state or behavior of another component

*e.g.: ocean temperature -> evaporation -> coastal rainfall*

Positive coupling:
- If A goes up this causes B to go up

Negative coupling:
- if B goes up this causes A to go down
System Diagram - 1

System diagram: allows us to keep track of the various couplings within a system.

Negative feedback loop is STABLE.
Stable: tends to return to equilibrium when perturbed.
Equilibrium: steady state; temperatures are "just right".

System Diagram - 2

Feedback loop:
• count up the number of negative couplings
• odd means "negative"
• even or zero means "positive"

Feedback loop:

The wild and crazy bedroom of former President Jimmy Carter.

Equilibrium states:
"A state of a system in which forces, influences, reactions, etc balance each other out so that there is no net change."

Static equilibrium: couplings are inactive; system is at rest.
Dynamic equilibrium: couplings are active but are in balance.
Thermal equilibrium: no net heat exchange.
Chemical equilibrium: reaction and its reverse proceed at equal rates.
Mechanical equilibrium: not moving, forces balanced such that position is fixed.

Stable equilibrium: position or state is restored after small perturbation.
Unstable equilibrium: small perturbation causes change of position or state.

Welcome to Daisyworld!

Themes:
• Energy balance
• Planetary albedo
• Self-regulation
• Graphs of two functions