Earth and Environmental Systems
SYGN 101
With Dr. Christian Shorey

FACT
• Observation or measurement of the world – data.
• Repeatable
• Example: If I drop my keys, they will fall to the floor.

Hypothesis
• A conceptual idea to explain a set of facts
• Should be testable (i.e. falsifiable)
• Can never be proved true, only proved false
• If proven false, then a new hypothesis is conceived to take its place
Occam’s Razor
• If there are a set of hypotheses that explain the facts, the simplest one is usually correct.

Theory
• A hypothesis that has been extensively tested so that we can have more faith in it.

TRUTH?
• Science is not the truth, but a search for the truth.
• Science is a systematic way of looking at our world.
• Science does not dispel the mystery of the world, it only makes that mystery deeper and more profound.

The Environment
- Geosphere
- Atmosphere
- Hydrosphere
- Biosphere

The Global Environment
- Energy
- Air
- Water
- Amenities

The Economy
- Industry (production)
- Households (consumption)

Inputs
- Raw materials
- Life support system

Outputs
- Waste Receptacle
- Water pollution
- Waste heat
- Solid waste
- Air pollution

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We shall not cease from exploration
And the end of all our exploring
Will be to arrive where we started
And know the place for the first time.
- T.S. Eliot
What is a system?

- Any isolated portion of the Universe of interest to the investigator.
  - Must define its boundaries.
  - Must track all inputs and outputs of energy and material across the system boundaries.
  - Must break down the system into component parts (subsystems) and determine relationships between these parts.

The nature of the boundary determines the system type.

1. Isolated system: no exchange of energy or material across the system boundary.
2. Closed system: energy can be exchanged across the system boundary, but material can’t.
   1. Autark=energy
   2. Independent=information
   3. Autonomous=organization
3. Open system: both energy and material can be exchanged across the system boundary.

“Isolated system” the bomb calorimeter

Closed system

Open System

It is most useful to consider the Earth as a closed system.
Living in a closed system.

1. The amount of matter in a closed system is fixed and finite.
2. Matter and energy exchanges within the system make subsystems interdependent.
3. If changes are made in one part of a closed system, the results of those changes will eventually affect other parts.

BOX MODELS

RESERVOIR(S)
A place where material is held for a period of time.

FLUX(ES)
The movement of material between reservoirs.

A Box Model for Stalagmite Growth Rate in a Cave
• The following is the box model portion that deals only with infiltration.
• The more precise you want your model to be, the more time you need to construct it, and the longer it will take your computer to run it.
• There is a general sweet spot that gives you respectable accuracy without unacceptable time constraints.

**Systems models (a.k.a. box models) terminology**

- Residence time = the average time a unit of matter (atom, molecule, compound) spends in a given reservoir.
- Turnover time = the amount of time it takes a reservoir to gain a completely new set of material.
- Source = inputs to a given reservoir.
- Sink = outputs from a given reservoir.
- Perturbation = a sudden change in the source and/or sink fluxes to/from a reservoir.

**Feedback**

- Feedback occurs when an initial change in a particular reservoir (subsystem) causes changes in other reservoirs which result in further change in the first reservoir.
- Example: a change in water content in an organism (water concentration in blood drops) causes a reaction in the endocrine system of the organism (release of activation hormones) that cause a drive in the organism (thirst) which will result in an increase in water content of the organism.

**Positive feedback**

- An initial change in a reservoir leads to changes in the system which cause a further change in the initial reservoir in the same direction.
- Examples:
  - pothole growth
  - Planetary ice cover
  - Chemical addiction
Negative Feedback

• An initial change in a reservoir leads to changes in the system which reverse the change in the initial reservoir.

• Examples:
  – Thermostat in your house
  – Homeostasis in the body
  – Gaia hypothesis

Energy and matter in the Earth’s closed system.

• Energy flows into and out of the Earth system.
  – Here we can speak of an “Energy Budget” for the Earth.

• Matter flows between the subsystems of the Earth system.
  – Here we can speak of “Biogeochemical Cycles”

“Ultimate” natural sources of Energy

1. Solar energy
   • Mass converted to energy through nuclear fusion.

2. Geothermal energy
   • Mass converted to energy through nuclear fission.

3. Tidal (gravitational) energy
   • Energy imparted to the Earth from the Sun and Moon due to Earth’s relative position to their gravitational field and the Earth’s rotation.
Thermodynamic laws you don’t need to know for this class.

• Zeroth law
  – When two systems are in thermal equilibrium with a third body (like a thermometer), they are also in thermal equilibrium with each other. Further, these bodies are all at the same temperature.

• Third law
  – For a perfect crystal at absolute zero, the entropy of that crystal is zero

Laws of Thermodynamics you do need to know:

• First law: In a system of constant mass, the energy involved in any physical or chemical change is neither created nor destroyed, but merely changed from one form to another.

• Second law: Energy always changes from a more useful, more concentrated form to a less useful, less concentrated form. i.e. Entropy always increases in an isolated system.

BIOGEOCHEMICAL CYCLING

• The movement of material between the subsystems of the ecosphere.

• Bio – life
• Geo – earth
• Chemical – elements and compounds
• Cycling – movement with repeatable periodicity

Carbon cycle.

Nitrogen cycle.

Phosphorous cycle.