The Biosphere

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ESPM 2
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http://www.eduweb.com/portfolio/earthsystems/images/print_main_icon.jpg
What Will the Course Cover?

- Overview and Over Arching Principles
  - History, Perspectives, Connections, Feedbacks, Complexity
- How we study the Biosphere
- Our Place in the Universe
- Atmosphere
  - Weather and Climate
- Lithosphere/Geosphere
  - Geology and Soils
- Hydrosphere
  - Water, Oceans
- Life
  - Evolution, Metabolism, Physiology, Ecosystems, Ecology
- Biogeochemical Cycles
  - Carbon and Nitrogen
- Future
  - Global Change, Humans
- Elsewhere
  - Astrobiology
- Solving Problems
  - Geoengineering
Expectations of Berkeley

• Produce Students who are:
  • Communicative
    – Clear Writing and Oral Expression
  • Literate
    – Know the scholarly traditions and evolution of schools of thought
  • Numerate
    – Be able to compute and manipulate data, read and interpret graphs, program computers and spreadsheets
  • Creative
    – Produce New Things, e.g. ideas, music, computer code, writings
  • Investigative
    – Critical Thinking about who, what, when, how, why and will be?
Extrinsic Goals of this Class

- Fulfill Curiosity about how the World about you Works and Functions
- Critical Thinking and Understanding of Complex Systems, like the Biosphere
- Inspire Non-Declared Majors
- Produce Scientifically-Educated Citizens, for non science majors
- Provide Awareness, Hope and Solutions for Sustaining the Future Biosphere, under Assault by Human Induced Change
Navigating the Biosphere of Berkeley
Departments teaching courses with emphasis on the Biosphere

• Environmental Science Policy and Management
• Earth and Planetary Science
• Civil and Environmental Engineering
• Geography
• Landscape Design
• Integrative Biology
• Earth Resources Group (ERG)
Textbook, Readings and Discussions

• The Biosphere, Vaclav Smil
• Assorted Readings and Discussion on In Depth Analysis of Web Resources, Maps, Models, Concepts, and Current Event Readings
• Questions and Answers, Quizzes
• Discovery, Lab/Discussion Mini Projects
Tests and Grade

- 2 Midterms, 50%; 25% @
- 1 Final, 30%
- Attendance/Discussion/Quizzes, 20%
Course Admin

• Web Site: https://bcourses.berkeley.edu/
• GSIs: Rainbow DeSilva, Daniel Foster, Emily Kearney, Gabriel Lobo.
What is the Biosphere?

‘the part of the Earth's crust, waters, and atmosphere that supports Life’
We can’t study the biosphere in isolation. We need to understand its connection to the other spheres of the earth system and how these all add up. What are those connected spheres. They are the lithosphere, cryosphere, atmosphere and hydrosphere.

Think about Life. It needs water to hydrate, dissolve and transfer nutrients to cells and organs. It needs oxygen and carbon dioxide from the atmosphere to build life and maintain it. The atmosphere also regulates the temperature and provides water in the form of precipitation. We live on the soil and depend upon it for recycling material and anchoring plants. So you can start to see the connections.
Definitions

- **Atmosphere**
  - Layer of gases surrounding a planet

- **Hydrosphere**
  - Water on the surface of the Earth, consisting of oceans, seas, lakes, rivers and vapor in the atmosphere

- **Lithosphere**
  - Outer part of solid Earth that consists of the Crust and upper Mantle

- **Cryosphere**
  - The Frozen and Ice covers part of Earth
Why Study the Biosphere?

• Learn about the world you live on.
  – What is it like now?
  – How it functions?
• Learn how it came to be?
• What is its fate?
• Understand How Humans are affecting that fate
• What can we do to solve problems associated with the Biosphere, your future and your Childrens’?

We are expecting 9 Billion inhabitants in your life time. How can we better sustain earth to feed everyone, provide enough fresh water and not pollute the air and water to maintain a desirable quality of life?
The Understanding of Earth before Suess and Vernadsky was without Life. The mindset was that the Environment was perfect for being hospitable for life. It did not recognize or reflect Life and the Environment co-evolved and were dependent upon one another.
The biosphere is not an isolated concept, it is connected to the atmosphere, hydrosphere and lithosphere. It affects their state and fate, and vice versa. Let’s discuss some of these feedbacks. How do plants affect the Atmosphere?; Vice Versa, etc, etc. Also note that life is effectively everywhere and inhabits these other spheres. Microbes, plankton, algae, fish, invertebrates live in the hydrosphere. Roots and microbes penetrate deep into the soil and lithosphere. The atmosphere is full of insects, birds, microbes, viruses, pollen and spores.

Understand these interactions to better Manage and Sustain the Biosphere. It is in our Self Interest. We need to be better Stewards, Conservationists. Learn how and why. Limits towards our Engineering of the Biosphere.
History

- Aristotle
- Von Humboldt
- Suess
- Vernadsky
- Lovelock
- Keeling
- Apollo/NASA
  - Tucker, Sellers...
- Biosphere 2
Aristotle

- Nature was defined in terms of states of four elements:
  - earth (cold and dry)
  - fire (hot and dry)
  - water (cold and wet)
  - air (hot and wet).

Aristotle is one of the most famous Greek philosophers. Aristotle and other Greek philosophers did not use Experimentation to prove his theory, as do modern scientists. Instead, Aristotle used teleology, introspection and conjecture to explain Nature. Aristotle would investigate Nature by asking such questions as: what is the material involved, what is its form and how did it get that form, and, most important of all, what is its purpose? He and other Greek philosophers came to believe that Nature was defined in terms of states of four elements: earth (cold and dry), fire (hot and dry), water (cold and wet), and air (hot and wet).

Aristotle's methods would endure of over 2000 years, and stifle further scientific development, for various reasons. Reasons most often cited include the burning of the Alexandria Library, the demise of the Roman Empire and its destruction by the Barbarians, ignorance associated with the Dark Ages and the taboo on questioning Authority that was imposed by the Church, Kings and minor rulers.
Alexander von Humboldt (1769-1859)

“the world was a single, weblike, interconnected organism.”

“was the first to explain the fundamental functions of the forest for the ecosystem and climate: the trees’ ability to store water and to enrich the atmosphere with moisture, their protection of the soil, and their cooling effect. He also talked about the impact of trees on the climate through their release of oxygen. The effects of the human species’ intervention were already ‘incalculable,’ Humboldt insisted, and could become catastrophic if they continued to disturb the world so ‘brutally.’”

Andrea Wulf, 2015
Biosphere

- Term was first coined (1875) by Eduard Suess, 1831-1914, Austrian Geologist

Eduard Suess, Austrian geologist, recognized life is and should be a component of the Lithosphere.
A field is defined when there is a text book. Vernadsky wrote such a book on this title, circa 1926
The Science of the Biosphere starts with Vernadsky

Wrote Biosfera, 1928

‘The biosphere may be regarded as a region of transformers that convert cosmic radiations into active energy in electrical, chemical, mechanical, thermal and other forms’

What do we mean by this? In simple terms ‘life eats sunlight’ and takes that energy to support life and metabolism. This philosophy is at the heart of my thinking and teaching of my biometeorology and ecosystem ecology courses...how we quest to capture the energy of sunlight and use it.
Pt 1 is why my lab measures solar radiation and tries to understand how it varies with time and across the globe
Pt 2 leads us to do a considerable amount of work on the soil and the transformation of organic matter in litter and the soil back into CO2 or methane
Pt 3 is the basis of trying to perform global ecology with use of satellite remote sensing and models and is behind efforts to manage the biosphere from disturbances
Pt 4 is why my lab works so, so much on measuring and modeling trace gas exchange

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**Ideas of Vernadsky, Biosfera**

- **Biosphere as a region of transformation of cosmic energy**
  - Living matter transforms energy of the sun to active chemical energy of the biosphere
  - Whole living world is connected to this green part of life by a direct and unbreakable link

- **The composition of the Earth, and particularly its crust, has implications that transcend purely geological phenomena.**
  - Life is disturbing chemical inertia on the surface of the planet
  - Without life the crustal mechanism of the Earth would not exist

- **The diffusion of living matter by multiplication is the most important manifestation of life in the biosphere**
  - Diffusion of life is a sign of internal energy—the chemical work life performs—and is analogous to the diffusion of a gas
  - The energy of life unifies the biosphere; it becomes apparent by the ubiquity of life.
  - Life transports and moves matter

- **Organisms cannot exist without the exchange of gases**
  - The intensity of life can be judged by the rate of gas exchange
The CO2 record started by Charles David Keeling, and inspired by Roger Revelle, at Mauna Loa in Hawaii, circa 1956, provided breakthrough information on the large scale breathing of the biosphere and started to document the rise in CO2 due to fossil fuel combustion.
The space age gave us an unprecedented view of Earth and was the start of recognizing its isolation and fragility. It also made us understand we are not infinite, we have borders and can affect its state. And you know it is important when the idea becomes a stamp!
This Blue Marble photo is another iconic view of Earth from space. What do you see in this image?

Water, land, dry land, green land, clouds, swirls, snow
This image gives us perspective of our role in the universe. We are just a point of light as our space ship starts to leave the solar system. We are not the center of the Universe!! Or the Solar System. We are expendable, and in time will be. So make the most of your life while on Earth! Also stresses the isolation and vulnerability of our planet.
Lovelock was the proponent of the Gaia hypothesis. His genius was realizing that we did not need to see little green men on a distant planet to detect life. Rather the chemical signal of the atmosphere, in chemical disequilibrium, would suffice. This would be in the form of various reduced greenhouse gases that represent metabolism and redox.

Kirchner criticized various modes of Gaia: Influential, Coevolutionary, Homeostatic, Teleological and Optimizing. Kirchner advocates the weaker version. Life shapes the physical environment and vice versa.
The era of global ecology can probably be dated back to the work of Jim Tucker and his use of data from AVHRR sensor on the fleet of NOAA GOES weather satellites. Tucker realized we could deduce information about the greenness of the surface from the relative reflectance of light in the red and near infrared wavebands, yielding the widely used index NDVI.
Pioneered the Merging of Satellite Sensors, Land Surface and Climate Models to Quantify the Breathing of the Earth

Piers Sellers, 1955-2016, Biometeorologist, Astronaut, Biosphere Pioneer
Biosphere 2 can be consider a failure, but in a positive sense. It showed we did not know what we did not know about the biosphere. There was a degree of arrogance that it could be packaged up like animals in a zoo and function. This tiny biosphere has oceans, deserts, tropical forests, etc to ‘function’ as the whole on this small patch of land in the Arizona desert. Sounds crazy today.

http://media.azpm.org/master/img/bdy_img/biosphere_wide_600_240.jpg

Biosphere 2 was only used twice for its original intended purposes as a closed-system experiment: once from 1991 to 1993, and the second time from March to September 1994. Both attempts, though heavily publicized, ran into problems including low amounts of food and oxygen, die-offs of many animals and plants included in the experiment, squabbling among the resident scientists, and management issues.

https://en.wikipedia.org/wiki/Biosphere_2
Formalization of the Biosphere

- Life plays a major role in Regulating the Earth System, via coupling of the Atmosphere, Lithosphere, Hydrosphere, and vice versa
Overview/Take Home Points

• Over-Arching Definition

• History
  – Modern Science, Started with Vernadsky, 1920s
  – CO2 Record
  – Space Age and View of Earth, the Blue Dot
  – Gaia
  – Biosphere 2

• Better Manage the Biosphere for our Sustainable Futures