

Survey
UAZ Intro to GCI

**INTRODUCTION TO GLOBAL CHANGE
GEOS 107A / HWR 107A**

(4 units)

Lecture 9:30 - 10:45 am Tues & Thur in Space Sci 308

Labs on Thur: 12:30-3:20, 3:30-6:20, or 6:30-9:20 pm in Harshbarger (Old Geol) 203

Global Change encompasses the many ways the global environmental system is changing both naturally and through the influence of human beings. Understanding how the earth's climate changes in relationship to other earth system processes is a unifying theme in Global Change studies. This course puts global environmental change problems -- such as climatic change, global warming, ozone depletion, deforestation & desertification -- into a scientific context by examining the essential components of the earth system (atmosphere, biosphere, and geosphere) and the feedbacks that link these components. This scientific context provides the basis for a critical discussion of the social, economic and political implications of global change.

Course Objectives: *This course will introduce you to the language and methods used by scientists from a variety of fields (such as Geosciences, Ecology, Atmospheric Sciences, and Geography) to study the nature of change in this complex and dynamic system that we call the Earth. We will introduce you to various hypotheses as to how and why change occurs in this system and to the logic underlying the development of theories about the nature of Global Change.*

Instructor: **Katherine K. Hirschboeck** (Laboratory of Tree-Ring Research) a hydroclimatologist whose research links local extreme events (e.g., floods, droughts) to large-scale atmospheric circulation patterns. Office: 208 West Stadium; tel. 621-6466. e-mail: hirschbo@ccit.arizona.edu

Textbooks and Readings:

- "Climate and weather: A Spatial Perspective," by Marlyn L Shelton, 1988. Kendall/Hunt Publishing Co.
 - "Global Warming Debate," special issue of *Research & Exploration*, National Geographic Society, v. 9, n. 2, Spring 1993 (available at ASUA Bookstore)
 - "On Being a Scientist," by National Academy of Sciences, 1989. National Academy Press.
- Plus a packet of supplementary articles and course manual to be purchased (details announced in class).

Grading and Exams:

Labs	25%
Paper	15%
Exam I	20%
Exam II	20%
Exam III	20%

The exams will be a combination of multiple choice, short answer and essay questions. The paper will consist of a 10 page critical review of five scientific papers on a specific environmental problem. You should choose the paper topic in consultation with your TA. Details of the paper assignment will be handed out in lab.

COURSE POLICIES

(guidelines for a happy and successful semester)

Office Hours: Students are encouraged to take advantage of the fact that both the professor and TAs hold regularly scheduled office hours during which they patiently wait for someone to come talk with them about Global Change. Office hours will be announced in class. Please take advantage of office hours to obtain extra help understanding the material or to discuss questions that may arise from the lecture or reading material.

Attendance: Attendance is expected at every lecture and lab period. Regular attendance is extremely important for this course in order to keep up with the material; furthermore exam questions will be drawn directly from lecture notes. Random attendance checks in lecture and lab will be taken periodically during the semester (*with bonus point opportunities!*). A poor record on attendance checks will have a negative effect on your grade if you are borderline at final grade time.

Lab Exercises: are due on the date announced in lab. One point per day will be taken off for late papers. *No exercises will be accepted for credit later than 1 week after the scheduled due date.*

Make-up Exams: A make-up exam will be arranged only if we are notified in person or by phone *prior* to the time of the scheduled exam *and* are given a legitimate excuse (with validation). If you do not show up for an exam and do not contact us prior to that exam, no make-up or credit will be allowed and your exam score will be zero points.

Final Exam (Exam III): All students must take the Final Exam during its regularly scheduled time -- no early final exams will be given. (See p. 16 of the Fall 1994 Schedule of Classes for official University policy on this.)

Probation? Special needs?: If you are in academic trouble or involved in any special academic program (e.g., SALT), please let us know *within the first three weeks of the semester*. If you are willing to work, we will try to do everything we can to help you achieve your goals for this course. (Do not wait until the end of the semester to inform us of your situation because by then it is too late to help you.)

Dropping: (*We hope not!*) The last day to drop the course without it appearing on your record is **September 21**. The last day to drop with a "W" is **November 2**. *To receive a W, you must have a passing grade at the time you drop the course.* (Your passing status will be determined by the % of the total possible points you have earned at the time you drop.)

LECTURE OUTLINE (Fall 1994 Semester)

- 8/25 Introduction -- On Being a Scientist
- 8/30 Week 1 Basic Principles of Matter and Energy
9/1 Basic Introduction to Our Laboratory: The Earth
9/1 Lab 1: The Scientist's First Tool: Observation (Gila Computer Lab)
- 9/6 Week 2 Energy from the Sun
9/8 Earth-Sun Relationships
9/8 Lab 2: Hypotheses, Observations and Analog Models
- 9/13 Week 3 Atmospheric Structure and Composition
9/15 Radiation Balance and Fluxes
9/15 Lab 3: Symbolic Representation in Scientific Analysis (Gila Computer Lab)
- 9/20 Week 4 Net Radiation
9/22 Temperature
9/22 Lab: Class synthesis and discussion period
- 9/27 Week 5 EXAM 1
9/29 Atmospheric moisture
9/29 Lab 4: The Interdisciplinary Field Experiment
- 10/4 Week 6 Global Moisture Fluxes
10/6 Local Radiation Balance
10/6 Lab 5: The Importance of Scale
- 10/11 Week 7 The Biosphere and Geosphere at the Boundary Layer
10/13 Deforestation
10/13 Lab 6: Forcing, Feedbacks, and Sensitivity

LECTURE OUTLINE (cont.)

- 10/18 Week 8 Desertification
10/20 Global Atmospheric Circulation
10/20 Lab 7: Model-building and Scientific Discovery (Gila Computer Lab)
- 10/25 Week 9 Ocean Circulation
10/27 Regional Climate Variations
10/27 Lab: Class synthesis and discussion period
- 11/1 Week 10 EXAM 2
11/3 Internal and External Forcing of Climate Change
11/3 Lab 8: Teleconnections and Statistical Associations
- 11/8 Week 11 General Circulation Models
11/10 The Global Warming Debate
11/10 Lab 9: Modelling as Hypothesis Testing
- 11/15 Week 12 Population and Environment
11/17 Natural Resource Consumption
11/17 Lab 10: The Human Variable
- 11/22 Week 13 Vulnerability of Natural Resources to Climatic Change
11/24 Thanksgiving Recess
- 11/29 Week 14 Policy and Decision-making
12/1 Preparing for an Uncertain Climate
12/1 Lab 11: Probabilistic Models: Assessing Risk (Gila Computer Lab)
- 12/6 Week 15 Issues in Global Change: Greenhouse Warming
12/8 Issues in Global Change: Water Supply
12/8 Lab: Class synthesis and discussion period
- 12/13 Week 16 Issues in Global Change: Ecosystems

Final Exam: THURSDAY December 15th 8 a.m. - 10 a.m.

	3-14	Spring break — no class	-	
	3-16	Spring break — no class	-	
	3-18	Spring break — no class	-	
10	3-21	Consequences of and remedies for greenhouse effect	F_5,7	Leavitt
	3-23	Biomass burning	H_122-127	Leavitt
	3-25	Detecting global change, historical records	F_58-72	Leavitt
Lab 9	3-24 & 28	Nutrient cycling in tropical forests	-	Leavitt
11	3-28	Detecting global change, ice cores	H_28-47	Leavitt
	3-30	Current measurements of global change	F_58-72	Leavitt
	4-1	Population growth, food needs	H_98-110	Leavitt
Lab 10	3-31 & 4-4	Trends in the chemistry of ice cores	-	Leavitt
12	4-4	Consumption of energy and resources		Leavitt
	4-6	Technology, standard of living	F_6	Leavitt
	4-8	Test 3	-	-
Lab 11	4-11 & 14	Daisyworld	-	Bales
13	4-11	Biological regulation of the earth	H_#2	Bales
	4-13	Video: planet earth, fate of the earth	-	Bales
	4-15	Daisyworld & GAIA	H_#2	Bales
Lab 12	4-18 & 21	Case study: Mono lake diversions	-	Bales
14	4-18	Space Shuttle Laser disc: Remote sensing introduction	-	Bales
	4-20	Slides: Measuring the earth by remote sensing	-	Bales
	4-22	Computer: SIR-C mission; remote sensing (meet in Engr 301)	-	Bales
Lab 13	4-25 & 28	Case study: salinity in Tucson water	-	Bales
15	4-25	Video: Simulating Earth's climate	-	Bales
	4-27	Video: Planet earth, the climate puzzle	-	Bales
	4-29	Western U.S. water-quality problems	H_#3	Bales
	5-2	No lab meeting		
16	5-2	Western U.S. water-quality problems	H_#3	Bales
	5-4	Western U.S. water-quality problems	H_#3	Bales
17	5-9	Final exam (1100-1300)	-	-

Reading assignments:

F	Firor, <i>The Changing Atmosphere</i> .
W	Worldwatch paper no. 94.
H_3-12	Lamb, <i>Water Quality</i> .
H_14-26	Berner & Berner, <i>The Global Water Cycle</i> .
H_28-72	Briggs & Smithson, <i>Fundamentals of Physical Geography</i> .
H_74-82	Garrels et al., <i>Chemical Cycles and the Global Environment</i> .
H_84-91	National Academy of Sciences, <i>Global Change Report</i> .
H_93-115	ReVelle & ReVelle, <i>The Environment, Issues and Choices for Society</i> .
H_117-120	Strahler & Strahler, <i>Environmental Geoscience</i> .
H_122-127	Levine, <i>Global Biomass Burning</i> .
H_129-140	Butcher et al., <i>Global Biogeochemical Cycles</i> .

INTEGRATIVE TEACHING MODULES FOR 107A COURSE

The overall objectives of the 107a class, Introduction to Global Change, are (a) to introduce students to the language and methods used by scientists from a variety of earth-science fields to study the nature of change in the complex and dynamic earth system, and (b) to introduce students to various hypotheses as to how and why change occurs in this system and to the logic underlying the development of theories about the nature of Global Change. The teaching modules in this course are developed around various aspects of scientific inquiry rather than course topics, but each is focused on scientific principles which are illustrated using hands-on data and procedures related to the course material.

1. **The Scientist's First Tool: Observation**

- (a) General Scientific Concept: Making observations about the earth in the field, from remote sensing imagery, and from computerized database imagery.
- (b) Physical/biological principles illustrated: Open to student discovery
- (c) Field component: Homework assignment wherein the students take on imaginary identities as aliens who have landed on the earth to make observations of natural processes at the local scale. Processes and patterns to be observed will be assigned (e.g. behavior of sun, changes in temperature, precipitation and evaporation, vegetation form and spatial distribution, etc.) A descriptive write-up will be required.
- (d) Data sets: CD-ROM products containing digital relief, gridded vegetation, satellite imagery, and other global data fields.
- (e) Computer exercise: Students will be introduced to the computer as an observational tool and use basic exploratory data techniques to make guided observations of the earth at the global scale, i.e. as seen from a spaceship.

2. **Hypotheses, Observations and Analog Models**

- (a) General Scientific Concepts: "The interpenetration of hypotheses and observations" (National Academy of Sciences, 1989, p. 4); using simple analog models to describe a complex reality.
- (b) Physical/biological principles: The sun as an energy source; inverse square law, solar altitude and insolation, albedo
- (c) Laboratory component: Plastic hemispheres, black and white cloths, heat lamps, and temperature probes are used to construct an analog model of solar heating of the earth's surface. Observations of temperature are taken and hypotheses developed during the data collection activity.
- (d) Data sets: Gridded data sets of global temperature, insolation, reflectivity; computed information on earth-orbital parameters over geologic time
- (e) Computer exercise: Students compare observations and hypotheses developed during analog model experiment with present global observations and modeled results for different albedos, sun angles, day-lengths, etc. to reproduce changing solar input under different Milankovitch cycles.

3. Symbolic Representation in Scientific Analysis

- (a) General Scientific Concepts: Understanding formulas, equations, and graphical representations of information.
- (b) Physical/biological principles: Electromagnetic spectrum, radiation balance and energy fluxes
- (c) Laboratory component: Using light source and various props, students develop analog models of components of the radiation balance (direct, diffuse solar radiation; surface and cloud albedo; longwave terrestrial radiation, greenhouse effect). Energy flux demonstration of conduction and free and forced convection, while students take measurements.
- (d) Data sets: Hourly, monthly, annual station data of local energy balance components; gridded global monthly and annual insolation data, cloud cover, sea surface temperatures, sensible heat, latent heat
- (e) Computer exercise: Hypercard computer visualization of energy pathways in the earth-atmosphere system. Each term in the energy balance equation is presented as a cartoon-like symbol evocative of the process (e.g. solid downward arrow for direct beam solar radiation, dashed downward arrow for diffuse solar radiation, etc.) Students work through understanding of each component and the entire balance: a) conceptually using symbols, b) graphically using local station data plotting information for different time scales, and c) spatially using maps of gridded global data. Standard scientific notation for each component is introduced gradually so that by end of exercise, student is at ease with the equation as it appears in the scientific literature.

4. The Interdisciplinary Field Experiment

- (a) General Scientific Concepts: Experimental design, collecting field observations, instrumentation, measurement error, on-site decision-making, processing of raw data.
- (b) Physical/biological principles: Net radiation, water balance, moisture fluxes, evapotranspiration, precipitation
- (c) Field component: Students visit ongoing field experiment in Sonoran desert run by Hydrology and Water Resources Department where continuous field observations of all components of radiation balance are being taken using different instrumentation and methodologies (e.g. sensors for measuring Bowen ratio to determine moisture flux, etc.) Under supervision of field scientists, students are assigned to research teams representing different disciplines and assist in taking measurements. Additional field stop at a more moist and vegetated site provides opportunity for students to develop hypotheses on how measurements would differ.
- (d) Data sets: Several months of raw and processed data from the field site, previously collected. Similar data from other site or sites representing different environments.
- (e) Computer exercise: Students enter new data and manipulate, process, and graph it, comparing it with earlier measurements by the field research team. Hypercard text component of lab addresses moisture fluxes and the role of vegetation types and evapotranspiration. Hypotheses and inferences are drawn from data and students are asked to make all the decisions for designing a similar field experiment in another biome. Students link field observations and calculations to symbolic representation of radiation balance from previous module.

5. The Importance of Scale

- (a) General Scientific Concepts: How the selection of the spatial and temporal scale of observation affects how a pattern or process is measured; aggregation and disaggregation of data, interpolation and gridded data sets; relationship between local, regional, and global-scale processes
- (b) Physical/biological principles: principles of remote sensing, ground truth, electromagnetic spectrum, reflectance, transmission, absorption, photometry, photosynthesis, net primary productivity, Normalized Difference Vegetation Index (NDVI) as a tool in global change research
- (c) Field component: A photometer is used to derive photometric spectral series for various surfaces and materials found on campus (e.g., fresh grass, brown grass, bare ground, asphalt); students are divided into research teams; readings are taken from different surfaces within a flagged area representing one pixel of a satellite AVHRR image; a study site map is constructed
- (d) Data sets: Advanced Very High Resolution Radiometer (AVHRR) imagery of campus and other sites; Landsat Multispectral Scanner (MSS) imagery (higher spatial resolution); etc.
- (e) Computer exercise: Students manipulate zoom features to experience concepts of scale and resolution on various types of imagery; field map and field observations are digitized and transformed into gridded data; comparisons are made between site measurements and satellite measurements; discussion of issue of scale and effect on measurement

6. Forcing, Feedbacks, and Sensitivity

- (a) General Scientific Concepts: Cause and effect; theory, verifiability and falsifiability; linear and non-linear behavior and data relationships; positive and negative feedbacks; internal and external forcing
- (b) Physical/biological principles: thermal infrared radiation, thermal diffusivity, biogeophysical feedback mechanisms, desertification, deforestation, anthropogenic vs. natural climate forcings
- (c) Field component: An infrared thermometer is used to take measurements of brightness temperature of surfaces with different moisture contents at same site to compare with radiometer measurements taken during previous module.
- (d) Data sets: local and satellite AVHRR-NDVI data from the HAPEX-SAHEL field study site
- (e) Computer exercise: Hypercard text tutorial illustrates concept of forcing and feedbacks in several biogeophysical feedback models; students enter and analyze collected data; thermal diffusivity and soil moisture are estimated from observations using equations provided; comparisons are made with imagery from sites around the world illustrating desertification and deforestation

7. Model-building and Scientific Discovery

- (a) General Scientific Concepts: Models and model-building; distinctions between different kinds of models, i.e., deterministic, stochastic, conceptual, numerical, analog, physically based, etc.; evolution of a conceptual model with more sophisticated observations over time
- (b) Physical/biological principles: General circulation of the atmosphere and oceans
- (c) Data sets: gridded pressure surface and upper air pressure data, SST's and ocean circulation data
- (d) Computer exercise: Hypertext tutorial leads students through development of conceptual model of the general circulation of the atmosphere, from dishpan experiment simulation of circulation to complex GCMs. A linked time-series module showing history of instrumentation, observation network, sociopolitical factors (exploration, population, wars), developing aviation and computer technologies, and notable geophysical events (droughts, floods, volcanic eruptions, etc.) is used to illustrate the importance of the historical milieu for scientific discovery and advancement.

8. Teleconnections and Statistical Associations

- (a) General Scientific Concepts: demonstrating various degrees of statistical association; dependent and independent variables; trends, jumps, periodicities; continuous time series vs. event information
- (b) Physical/biological principles: teleconnections, air-sea interactions; circulation indices; effect of explosive volcanism on climate; ENSO events
- (c) Data sets: For selected climatically sensitive regions: continuous time series of atmospheric pressure, SSTs, temperature, precipitation, atmospheric optical depth, etc.; event time series of ENSO events, explosive volcanic eruptions, floods, droughts, famines, and other environmental extremes
- (d) Computer exercise: In a series of Hypertext exercises, students are led through basis of how statistical associations are made between time-dependent and spatially dependent geophysical data sets, from "wiggle matching" to a non-technical introduction to the goals of time series analysis, geostatistics, geographic information systems, and other methodologies.

9. Modelling as Hypothesis testing

- (a) General Scientific Concepts: Models as a means to test hypotheses for scientific discovery about complex systems; model assumptions; model predictions and how they should be used
- (b) Physical/biological principles: land surface-atmosphere effects and global change; atmospheric loading of trace gases and global warming;
- (c) Data sets: input data for use in simple energy balance climate model; GCM output for different climate change scenarios; global, Northern and Southern hemisphere temperature curves, Historical Climate Data network, times series of atmospheric loading of various trace gases, long-record tree-ring width series and climate reconstructions from sensitive sites
- (d) Computer exercise: Students manipulate simple climate models to test hypotheses about energy and moisture balances; students compare various GCM approaches and evaluate utility of GCM output results for impact assessment; students develop data activities and tests to evaluate the global and hemispheric temperature curves within the context of both natural climate variability and anthropogenic effects

10. The Human Variable

- (a) General Scientific Concepts: The human factor cannot be separated from science; the value and challenge of the social science approach to discovery
- (b) Physical/biological/social science principles: Sustainability; population and environment; socioeconomic factors; power, diversity and gender issues; spatial relationships; historical and cultural context
- (c) Laboratory component: A role-playing exercise takes place wherein students are assigned to different nations and are provided with a proportionate amount of natural resources, commodity goods, industrial development, and environmental pollution in the form of colored tokens or candies. Students buy and trade resources, goods, etc. (at different assigned costs) depending on their allotted national wealth. They are allowed to make private deals and alliances. After several scenarios of the exercise are played out, a discussion takes place about successful strategies, disparate experience of different nations, and whether this is a realistic model of the real world.
- (d) Data sets: Global atlas database with maps and information by country on natural resources, agriculture, commodity goods, industrial development, population, etc.
- (e) Computer exercise: Students use the computer database to become familiar with their assigned country. A computer game is used to reenact the same exercise as above, based on a simple computer algorithm which allows no innovation or creative solutions. Outcomes and results from the two modes of role-playing are compared and contrasted.

11. Probabilistic Models: Assessing Risk

- (a) General Scientific Concepts: Probability and inherent assumptions; extrapolation and interpolation; how change is detected, when change makes a difference; dealing with extreme events, risk
- (b) Physical/biological/social science principles: Climate change and water supply; local, regional, and global scales of impact; recurrence intervals of extreme events
- (c) Data sets: GCM impact assessment output; time series of gaged mean monthly and peak streamflow data; reconstructed streamflow, paleoflood and paleodrought datasets
- (d) Computer exercise: Hypercard tutorial leads students through simple concepts of probability and risk assessment; students split up into groups and use flood data to calculate flood risk in the Gila, Mississippi, and Ganges-Brahmaputra basins using different periods of record and/or paleo-information; recurrence interval of hydrologic drought in the Southwest is calculated based on gaged and reconstructed data sets. Computer exercise allows testing of different strategies for dealing with excesses and deficits of water supply in different parts of the world.

Reference: National Academy of Sciences, 1989. On being a scientist. National Academy Press, Washington D.C., 22 p.)