

OUTLINE OF ENVIRONMENTAL HAZARDS COURSE

- I. Introduction
 - A. Ecological versus Economic Approaches
 - 1. Ecological
 - a. every ecosystem has a carrying capacity and to exceed that capacity is to court disaster
 - b. open system with negative feedback
 - 2. Economic
 - a. population growth is necessary to fuel growth of the economic engine (job creation, stack'em higher and deeper)
 - b. open system with positive feedback
 - B. Population
 - 1. Greater populations mean more hazards because this puts greater pressures on available space thus pushing people into more hazardous areas
 - 2. The more complex a society the easier it is for a hazard to bring it to a halt
 - C. Systems Theory
 - 1. Principles
 - a. systems theory is based on classical thermodynamics
 - b. Laws of Thermodynamics
 - 1) First Law:
 - (a) energy is required for every activity therefore "you never get something for nothing"
 - (b) corollary - Law of Conservation - energy is neither created nor destroyed
 - 2) Second Law (Entropy) - "no matter how hard you try, you'll never break even"
 - 2. Definitions
 - a. system - set of objects together with the relationships between those objects and their attributes
 - b. system types
 - 1) isolated
 - 2) closed
 - 3) open
 - c. feedback
 - 1) positive
 - 2) negative
 - d. equilibrium in stable systems
 - 1) static equilibrium
 - 2) dynamic equilibrium - a balance of tendencies which brings about a statistical condition
 - 3) steady state
 - 4) looked at another way:
 - a) stable
 - b) unstable
 - c) metastable - must introduce the notion of threshold
 - e. equifinality - same end result from different initial conditions
 - f. ergodic hypothesis - under certain conditions space and time can be exchanged

D. Catastrophism versus Uniformitarianism

1. Catastrophism

a. definition

- 1) suspension of the "laws of nature" as some supernatural force or supernatural being intervenes in operation of Earth
- 2) grave consequences because it means that since we cannot know the mind of God we cannot therefore decipher Earth's history (i.e., Earth has no history)

b. philosophical roots of catastrophism

- 1) *deism* and *theism* both hold to a belief in God thus making both these religious variants the opposite of *atheism*
 - a) initially both of these terms were synonymous over time however, they drifted apart in meaning
 - b) theism retained the original meaning connoting religious orthodoxy
 - c) deism became a pejorative term; used mainly to denigrate those with unorthodox religious attitudes

2) deists - God created the perfect clockwork universe

a) basic beliefs -

- (1) as a synonym of theism deism therefore started out with much the same set of original beliefs
- (2) by late 18th century and early 19th century

a) technical metaphysical interpretation of deism

b) restricted to a belief in God, or First Cause who

- (1) created the world
- (2) instituted immutable universal laws
- (3) these laws preclude any alteration as well as divine immanence - i.e., the "absentee God"

(3) philosophical deists tended to deny the immanence of God

(4) historical deists in 17th and 18th centuries tended to become critical of the necessity of revelation - especially Judeo-Christian revelation

(5) "Christian deists"

b) John Locke (1632-1704) - religion is not above reason

c) Newtonian mechanics - a 17th century construct

(1) Isaac Newton (1642-1727)

(2) René Descartes (1596-1650)

d) upon application the clockwork universe does

- break down
 - (1) initially led to the discovery of other planets
 - (2) further examination in 20th century - introduction of chaos theory
- 3) theists
 - a) basic beliefs - God (*theos*) is
 - (1) personal and an therefore be conceived through images drawn from human experience
 - (2) worthy of adoration
 - (3) separate or apart from the world
 - (a) this differentiates theism from pantheism
 - (b) in pantheism the world is part of God or gods
 - (4) continuously active in the world; intervening whenever He thinks He needs to
 - (5) God created the world *ex nihilo* (i.e., from nothing)
 - b) God created an imperfect universe in order to have something to do
 - c) His interventions to set things right occasionally
 - (1) gives rise to the catastrophism
 - (2) reigned in Earth sciences until mid 19th century
- c. types of catastrophism
 - 1) classical catastrophism
 - 2) neo-catastrophism
 - 3) pseudo-catastrophism
- 2. Uniformitarianism
 - a. doesn't originate in geology but it has been in geology, with its focus on Earth history that the early battles over it were conducted
 - b. principal personalities in the rise of uniformitarian doctrine
 - 1) James Hutton (1729-1797)
 - 2) Abraham Gottlob Werner (1749-1817)
 - 3) John Playfair (1747-1819)
 - 4) Charles Lyell (1797-1875)
 - c. Lyell's view today stated as "the present is the key to the past"
 - 1) Lyell's view of uniformitarianism led him into difficult situations
 - 2) most difficult was his inability to accept the "Ice Age"
 - a) first publicly proposed by Louis Agassiz (1805-1873)
 - b) required a change in Earth's state therefore unacceptable to Lyell
 - d. analysis of uniformitarianism's problems by Stephen Jay Gould
 - 1) Gould divides uniformitarianism into two distinct parts
 - 2) methodological uniformitarianism - the following

- remain unchanged with time
 - a) laws
 - b) processes
- 3) substantive uniformitarianism - Lyell also believed that the following also remained unchanged with time
 - a) rates
 - b) state
- 4) solution: keep methodological but jettison substantive uniformitarianism

II. Nature of Science and the Scientific Method - Covered in ESSAY

A. Science - What is It?

1. defined

- a. by *Oxford English Dictionary* as a branch of intellectual endeavor concerned either with a connected body of demonstrated truth or with observed facts systematically classified and more or less fastened together by being brought under general laws
- b. philosophically - study of a phenomenon or class of phenomena about which universal agreement can be obtained (universal agreement here does not really mean agreement of everyone in the world but only of those practitioners of the study)

2. As an activity, science

- a. is the only human endeavor that is trans-racial, cultural, national, ethnic, linguistic, etc.
- b. uses methods that are practiced and duplicated by every scientist world-wide regardless of whether they even speak the same language
- c. is an enterprise whose component parts can only be work on collectively or in collaboration with colleagues who may be in the next lab or half way around the world
- d. advances through the use of experiments (see Scientific Method, below) with results reported in peer reviewed scientific journals to a skeptical audience of other scientists
 - 1) significance of experimentation
 - a) it is a way of testing hypotheses (which are tentative statements of truth)
 - b) results of any experiment performed must be capable of replication (i.e., any second or third party should be able to duplicate its results)
 - 2) significance of peer reviewed journals
 - a) checking and double checking of methods employed and results obtained
 - b) once reported in a journal, ideas put forth are subject to further testing
 - 3) a scientific audience is not credulous but quite the contrary it is an incredibly skeptical audience
 - a) credulity is not a trait found in scientists who by training are taught to doubt everything and always keep a strong sense of detached skepticism
 - b) skepticism means that everything is always

- c) relies on a scientist's imagination and intellectual curiosity
- d) discoveries
 - (1) often remain dormant for years before any application can be made of them
 - (2) become "national capital"
- 2) applied science or technology
 - a) engineering applications of pure science to the making of things that serve humanity
 - b) when making applications of pure science
 - (1) often there are problems that arise which of necessity pose new questions that beg answers
 - (2) applied science then turns back to pure science for the answers to these questions
 - (3) answers to these new sets of questions can lead to improvements in present technology or they may lead to still newer set of questions, and so on
- c. historical science versus non-historical or "pure" science
 - 1) properties of phenomena in the universe
 - a) immanent properties
 - (1) are timeless or unchanging properties of the universe
 - (2) scientific laws are an example of immanent properties
 - (3) for example, Newton's Second Law is as valid today as it was several millions of years ago; additionally, it is as valid today on Earth as it is on Jupiter
 - b) configurational properties
 - (1) are historical or time-bound properties of the universe
 - (2) configurational properties are characterized by their uniqueness
 - (3) as examples,
 - (a) there is only one Mona Lisa because, in spite of the fact that there have been many artists, there has only been one Leonardo da Vinci
 - (b) there is only one Beethoven's Fifth Symphony because, once again, in spite of the fact that there have been many great composers, there has only been one Ludwig van Beethoven
 - 2) non-historical or "pure" science is concerned solely with the universe's immanent properties
 - a) it attempts to understand its laws and illuminating its mode of operation
 - b) examples of "pure" science

- (1) mathematics - although there are some who would include mathematics within philosophy (as symbolic logic)
- (2) physics
- (3) chemistry
- (4) certain aspects of astronomy
- (5) certain aspects of biology
- 3) an historical science:
 - a) is concerned with unraveling the sequencing of historical events (i.e., configurational properties)
 - b) is a science only in as much as it uses immanent properties to unravel the sequencing of configurational properties or events
 - c) some examples of historical sciences
 - (1) geology
 - (2) geomorphology
 - (3) paleontology
 - (4) archaeology
 - (5) paleoclimatology
 - (6) certain aspects of astronomy

B. Scientific Method

C. Nature of Scientific Revolutions

D. Measurement

- 1. Measurement is fundamental to science
 - a. without measurement there are no verifiable facts
 - b. no experimental outcomes and therefore nothing to replicate
- 2. In the universe there are only two measurable quantities
 - a. matter - possesses mass and occupies space
 - b. energy
 - 1) can be thought of as: that which allows work to be accomplished
 - 2) in physics, energy and work have the same units of measure
- 3. Energy
 - a. recall the First and Second Laws of Thermodynamics
 - b. Law of Conservation (a corollary to the First Law of Thermodynamics)
 - 1) energy is neither created nor destroyed under normal circumstances (i.e., in a test tube - this, obviously, does not include nuclear reactions)
 - 2) energy may however, be converted from one form to another
 - c. forms of energy
 - 1) mechanical energy
 - a) potential - energy possessed by a body by virtue of its position with respect to some reference level
 - b) kinetic - energy possessed by a body by virtue of its motion
 - 2) electromagnetic energy

- a) connects electricity, magnetism, and, for example, light as electromagnetic waves
 - b) as an example we can use the electromagnetic spectrum
 - (1) a continuum of wavelengths from the very longest imaginable (radio waves) to the very shortest imaginable (cosmic ray)
 - (2) most concrete or tangible example is the rainbow created as visible light is broken up into its constituent components (Red, Orange, Yellow, Green, Blue, Indigo, Violet)
 - c) electromagnetic waves require no medium for transfer of their energy (e.g., they are able to travel through the void of interstellar space)
 - d) the energy level of an electromagnetic wave is inversely related to its wavelength (i.e., the shorter the wavelength the higher its energy level)
 - e) regardless of wavelength, all electromagnetic waves travel at the same speed - the speed of light or 300,000,000 meters/second (also written as 3×10^8 m/sec)
- 3) thermal energy
4. Matter
- a. states of matter
 - 1) solid
 - a) lowest energy state
 - b) solids retain their shape and volume
 - 2) liquid
 - a) intermediate energy state (higher than that of solid)
 - b) liquids retain their volume however, they take on the shape of the container in which they are placed
 - 3) gas
 - a) highest energy state occurring on Earth
 - b) gasses retain neither their shape nor volume, they expand to occupy entirely any container in which they are placed
 - 4) plasma
 - a) highest energy state in nature
 - b) not found on Earth but in stars
 - b. changes of state
 - 1) energy exchange is required for all phase or state transformations
 - 2) during any phase change the temperature of the substance undergoing the change does not increase
 - 3) solid to liquid transformation
 - a) requires environment to provide necessary energy to break solid bonds
 - b) this heat energy is known as the heat of fusion
 - (1) the actual heat of fusion for every

- substance is one of that substance's many physical properties
- (2) as an example, the heat of fusion for the phase change of ice at 0°C to water at 0°C is
- (a) 80 cal/gm
- (b)
5. Measurement scales
 - a. constant interval
 - b. constant ratio
 6. Types of measures
 - a. nominal
 - b. ordinal
 - c. interval
 - d. ratio
 7. Mathematics - the equalizer and the basis for science
 - a. deterministic relationships
 - b. statistical relationships (reality)
 - c. direct versus inverse relationships
 - d. illustrations of mathematical relationships
 - 1) graphic expression
 - a) Cartesian system
 - (1) rectangular coordinates
 - (2) use of x and y axes on graph paper
 - b) choice of measurement scales
 - (1) constant interval scales for both x and y axes - arithmetic relation
 - (2) constant interval scale for x-axis but constant ratio for y-axis - known as an exponential relationship
 - (3) constant ratio scale for x-axis but constant interval scale for y-axis - this is known as a logarithmic relationship
 - (4) constant ratio scale for both x and y axes - power function relation
 - 2) significance of straight lines on graph paper
 - 3) equations - simple first order equations [e.g., $Y = f(X)$]
 - a) dependent variable (usually Y) is related to the independent variable (usually X)
 - b) equations generally have the form $Y = aX + b$
 - (1) numerical value for a is the slope of the line
 - (a) $a > 0$, the slope is positive (direct relationships)
 - (b) $a < 0$, the slope is negative (inverse relationships)
 - (2) numerical value for b is the y-axis intercept (i.e., the value for Y when $X = 0$)
 - e. arithmetic functions
 - 1) direct relationship: $Y = aX + b$ or
 - 2) inverse relationship: $Y = -aX + b$
 - f. exponential functions
 - 1) direct relationship: $Y = be^{aX}$ or: $\ln Y = \ln b + aX$
 - 2) inverse relationship: $Y = be^{-aX}$ or:

$$\ln Y = \ln b - aX$$

- g. power functions
- 1) direct relationship: $Y = bX^a$ or:
 $\ln Y = \ln b + a \ln X$
 - 2) inverse relationship: $Y = bX^{-a}$ or:
 $\ln Y = \ln b - a \ln X$

III. Composition, Structure and History of Earth's Major Systems

- A. Geosphere
- B. Atmosphere
- C. Hydrosphere

IV. Endogenetic Geospheric Hazards

- A. General Outline of Plate Tectonics illustration of notion of paradigm shift
- B. Seismic Hazards
 1. Nature, causes and distribution of earthquakes
 - a. nature of earthquakes
 - 1) brittle failure versus ductile failure
 - 2) earthquakes caused by application of stress
 - a) nature of stresses
 - b) often associated with mechanics at plate boundaries
 - 3) strain induced by stress is stored in rocks as strain energy
 - 4) when strain exceeds rock strength rupture occurs
 - b. Stress regimes
 - 1) tensile stress - divergent boundaries
 - 2) compressive stress - convergent boundaries
 - 3) shear stress - transform boundaries
 - c. Types of faults
 - 1) dip-slip faults (i.e., motion or displacement has strong vertical component) -
 - a) results in elevation of one block relative to another (i.e., produces topography)
 - b) tensile stress - normal faults
 - c) compressive stress - high angle reverse, thrust, overthrust
 - 2) strike-slip faults (i.e., motion or displacement is horizontal or lateral with one block sliding past another)
 - d. global and regional patterns of seismicity - maps
 2. Energy released generates body waves
 - a. example of sound under water - produces no surface disturbance
 - b. P-waves - primary (push-pull) waves
 - 1) propagation is based on transmitting material being able to sustain a density change
 - 2) solids, liquids and gases are susceptible to density changes
 - 3) P-waves therefore pass through solids, liquids and gases
 - 4) in upper crust, P-waves travel at 6 to 8 km/sec
 - c. S-waves - secondary or shear waves

- 1) propagation is based on transmitting material's elasticity
 - 2) gas and liquid by definition have no elasticity
 - 3) therefore S-waves pass only through solids
 - 4) 3 to 5 km/sec in upper crust
3. Surface waves (Rayleigh and Love waves)
- a. example of ripples on water surface
 - b. Rayleigh waves
 - 1) cause up and down motion with a strong component in the direction of waves propagation
 - 2) can be generated in homogeneous, unlayered medium
 - c. Love waves
 - 1) motion is side to side, perpendicular to direction of propagation (snake-like motion)
 - 2) can only be generated in a layered medium
 - d. most responsible for structural damage
 - e. slowest travelers
4. Rock rupture
- a. main shock -
 - 1) geographic location
 - 2) focal mechanism - first motion
 - 3) depth of focus and meaning of focal depth
 - a) shallow focus: 0 to 100 km depth
 - b) intermediate focus: 100 to 400 km depth
 - c) deep focus: 400 to 700 km depth
 - b. after shocks
 - 1) what are they?
 - a) they are earthquakes which occur after the main shock
 - b) they represent the redistribution and dissipation of strain not released by main shock
 - 2) pattern of occurrence in space and time
 - a) occur along fault plane or in fault zone of main shock
 - b) clustered in space and time
 - c) earthquake sequence is considered over when after shock frequency becomes less than that which was occurring prior to main shock
 - d) statistically, numbers of after shocks should decrease with time
 - e) statistically, magnitudes of after shocks do not decrease with time
 - f) this means that while it is expected that the number of after shocks will decrease with time their magnitudes do not necessarily do so.
 - c. fore shocks: less than one-third of earthquakes are preceded by foreshocks thus they are not a good predictor
5. Measurement of energy release
- a. Richter magnitude
 - 1) based on Richter's seismographic device
 - 2) magnitude a function of displacement of seismograph's needle
 - 3) scale is logarithmic
 - b. Moment magnitude (Mw)

- 1) an attempt to make magnitude determination "scale free" or "device free"
- 2) calculates the amount of energy released based on amount of displacement of rock on opposite sides of fault plane and the area of the fault plane involved
- 3) also logarithmic
- 4) Richter magnitude and Moment magnitude (Mw) approximately equal for earthquakes below magnitudes of about 5.6
- 5) for larger earthquakes instead of a 10-fold increase (i.e., one order of magnitude increase) the increase is 30-fold.
- 6) scale of earthquakes:
 - a) strong earthquakes have magnitudes between 6.0 and 6.9
 - b) major earthquakes have magnitudes between 7.0 and 7.9
 - c) great earthquakes have magnitudes > 8.0
- c. accelerometers
 - 1) measure the ground motion as a percentage of gravity's acceleration
 - 2) \pm a percent of g (i.e., whatever goes up must come down)
- d. some statistical relationships:
 - 1) logarithm of shaking time versus magnitude - direct exponential relationship
 - 2) logarithm of length of ground rupture versus magnitude - direct exponential relationship
- e. maximum magnitude
 - 1) theoretically, because Mw is a logarithmic scale there is no upper limit
 - 2) practically however, there is an upper limit to Mw
 - a) rock is not infinitely strong
 - b) therefore, a given rock, no matter how strong, will experience brittle rupture eventually
 - c) the practical upper limit to earthquake magnitude is probably on the order of 8 to 9
 - 3) Southern California and THE BIG ONE versus A BIG ONE
6. Earthquake moment magnitude versus Mercalli scale
 - a. for any earthquake there is only one moment magnitude
 - b. Mercalli scale is designed to show distribution of earthquake effects
 - c. earthquake magnitude is recorded as a single Arabic numeral
 - d. Mercalli scale is recorded as Roman numerals
 - e. there may be numerous Mercalli intensity regions for the same earthquake
7. Hazards
 - a. ground shaking - surface waves cause collapse
 - 1) structures
 - 2) transportation infrastructure (freeways, rail, subway, etc.)
 - b. rupturing of urban infrastructure
 - 1) gas lines - fires

- 2) electrical power disrupted (your ATM card may be worthless)
 - 3) telecommunications
 - 4) water lines - inability to fight fires
 - 5) sewage contamination of drinking water
8. Examples
- a. New Madrid, MO - December 1811 and January 1812
 - 1) extremely powerful, felt as far away as New England
 - 2) part of the Mississippi embayment
 - 3) makes St. Louis, MO the highest risk seismic area in United States
 - b. Charleston, SC 1886
 - c. San Francisco, CA 1906
 - 1) ground shaking estimated to have lasted 2 minutes
 - 2) subsequent fires destroyed much of the city
 - d. 1923 Great Kanto Earthquake (Tokyo Bay)
 - 1) magnitude 8.3, ground shaking estimated to have lasted 5 minutes
 - 2) tsunami 11 meters
 - 3) collapse of mostly wooden buildings
 - 4) fires started from coals in cooking stoves
 - a) water supply disrupted by ground movements
 - b) no fire fighting ability - 12,000 home destroyed
 - 5) deaths: 140,000
 - 6) Tokyo recurrence interval for magnitude 8 earthquake - about 69±13 years
 - e. Good Friday Alaskan earthquake 1964
 - 1) magnitude 8.6 (some estimates are as high as 9.2)
 - 2) ground shaking lasted 4 to 7 minutes
 - 3) deaths: 115
 - f. Northern Peru, 1970 (Huascarán?)
 - 1) extensive collapse of unreinforced masonry buildings
 - 2) 50,000+ dead
 - g. San Fernando, CA 9 February 1971
 - 1) magnitude 6.7
 - 2) damage
 - 3) deaths: 60+
 - h. Mexico City 1985
 - 1) magnitude:
 - 2) damage:
 - a) several thousand building severely damaged in spite of employment of United States earthquake building standards
 - b) reasons for damage
 - (1) fraudulent practices
 - (2) lacustrine sediments underlying Mexico City liquified thus magnifying damage
 - 3) deaths: 10,000+
 - i. Yerevan, Armenia December 1988
 - 1) magnitude 6.8
 - 2) damage - severe to concrete slab constructed buildings
 - 3) deaths: 25,000
 - 4) 58 towns and villages destroyed

- 5) 500,000 homeless
- j. Loma Prieta, CA 17 October 1989
 - 1) magnitude 6.9, shaking lasted 30 seconds
 - 2) damage
 - 3) deaths: 63
- k. Landers, southern California desert (between Twenty-nine Palms and Barstow) June 1992
 - 1) Emerson and Camp Rock faults both ruptured revealing something never seen before namely, two faults rupturing simultaneously
 - 2) magnitude: 7.2
 - 3) resulted in horizontal displacements of up to 6 m and vertical displacements of up to 2 m
 - 4) over 55,000 aftershocks have occurred as a result of this earthquake
- l. Northridge, CA 17 January 1994
 - 1) magnitude 6.7
 - 2) damage
 - 3) deaths 57
- m. Kobe, Japan 17 January 1995
 - 1) magnitude 7.2
 - 2) damage - structural collapse and fires destroyed over 100,000 buildings as well as Kobe's infrastructure
 - 3) deaths: 5,500
- n. Izmet, Turkey
 - 1) magnitude
 - 2) damage - devastation to numerous cities in NW Turkey
 - 3) deaths: 12,000 to 20,000
- o. Central Taiwan
 - 1) magnitude 7.8
 - 2) damage
 - 3) deaths: 2,000+
- 9. Prediction attempts - China
 - a. use of animal behavior coupled with geophysical predictors
 - b. Hai Cheng, China 1975 - earthquake predicted
 - 1) city evacuated therefore deaths held to a handful
 - 2) city's buildings and infrastructure severely damaged
 - c. Tung Shung, China 1976 - earthquake not predicted
 - 1) severe damage to city's structures and infrastructure
 - 2) deaths: 250,000+
 - 3) 800,000 injured
- 10. Earthquake prediction
 - a. elements of a prediction - time, location, magnitude
 - b. must first understand the mechanism
 - 1) how strain is stored in Earth's crust
 - 2) how much strain can be stored before rocks reach their elastic limit
 - c. precursors - if they are the same for small earthquakes as for large then we will never be able to predict large earthquakes
 - d. foreshocks precede one-third to one-half of all earthquakes

C. Volcanic Hazards

1. Principles
 - a. magma
 - 1) magma generation
 - 2) magma types and eruptive characteristics
 - b. energy release
 - 1) heat
 - 2) explosive blast
 - a) Tambora in 1815 released approximately 8.4×10^{26} ergs
 - b) 1816 "The year of no summer"
 - c. types of volcanoes
 - 1) basaltic shields and pyroclastic cones
 - 2) andesitic stratovolcanoes and pyroclastic cones
 - 3) rhyolitic eruptions
 - a) tholoids (plug domes) and glass flows
 - b) ash flows and nuées ardentes
2. Eruption columns and clouds
 - a. Pyroclastic debris (ash < 2.0 mm; bombs > 64 mm)
 - b. Etna sequence
 - c. St. Helens prior to 18 May 1980; eruptions after 18 May 1980
 - d. Surtsey sequence 1963
 - e. ash fall on Heimay 1973
3. Pyroclastic flows
 - a. 1968 sequence on Mayon
 - b. 18 May 1980 sequence on St. Helens
 - c. Unzen (Japan) 1991 - video
 - d. Pinatubo (Luzon, Philippines) 1991 - video
4. Lava flows and domes
 - a. maps of Hawaii
 - b. Mount St. Helens dome building
5. Lahars
 - a. nature of lahars
 - b. atmospheric effects of eruptions
 - 1) lightning
 - 2) precipitation
 - c. St. Helens sequences
 - d. Pinatubo (1991) - video
 - e. El Nevado del Ruiz, Columbia - video
6. Volcanic landslides (debris avalanches) - start of St. Helens 18 May 1980 sequence
7. Volcanic gases
 - a. African sequence - 1984, Lake Monoun, Cameroon
 - b. acidic vents
8. Jökulhlaups - Vatnajökulh eruption of October 1996
9. Volcanic seismicity
10. Atmospheric shock waves - 1883 Krakatoa released 10^{25} ergs of energy

V. Exogenetic Geospheric Hazards

A. Mass Movement

1. Concept of slope stability
 - a. most slopes are relatively stable under present environmental conditions
 - b. if they were not stable then slopes would be failing all

- the time
- c. slopes do experience failures from time to time
 - 1) something must occur to trigger this failure
 - 2) normally, most failures occur after heavy rains or during earthquakes
 - 3) less frequently, slope failure results from changes that occur over geologic time
 - a) weathering, reduces strength of slope materials and may lead to slope collapse or rock falls such as occurred in Yosemite Valley in June 1996
 - b) normal river migration may lead to slopes being undercut as a stream impinges on a slope's base
 - c) long term changes in sea level may result in waves concentrating their activity at a slope's base resulting in undercutting
2. Slope processes - nature of stable slopes
- a. example of a block on an inclined plane
 - 1) block's weight is represented by the force, F and acts vertical (i.e., aimed toward Earth's center of mass)
 - 2) degree of slope is represented by
 - b. forces involved in this simplistic situation are:
 - 1) the normal force (F_n)
 - a) acts in such a manner as to press the block against the slope surface
 - b) using elementary trigonometry normal force (F_n) becomes: $F_n = F(\cos \theta)$
 - 2) a tangential or impelling force (F_t)
 - a) this force tends to act in such a way as to try and push the block downslope
 - b) again, using elementary trigonometry this impelling force (F_t) becomes: $F_t = F(\sin \theta)$
 - 3) a frictional force (F_f) and a coefficient of friction (μ)
 - a) act in a direction opposite to the impelling force (F_t)
 - b) this force acts to retard motion
 - 4) in nature the frictional force (F_f) is normally greater than the impelling force (F_t) and for this reason slopes tend to be stable
 - c. on natural slopes we normally speak in terms of shear strength (s)
 - 1) this shear strength is analogous to the frictional force (F_f)
 - 2) the Mohr-Coulomb failure criterion
 - a) is a model which helps us understand slope stability in terms of slope material shear strength (s) perhaps leading us to an understanding of why slope failure occurs
 - b) this model is given as: $s = c + (\sigma - h_w) \tan \phi$; where:
 - c) c is cohesion
 - d) σ is normal stress which is analogous to
- normal force (F_n)

the

- e) h_w is pore water pressure (i.e., the amount of water in the slope material's pores or void spaces) which can be thought of as having three basic conditions:
 - (1) slope material completely dry ($h_w = 0$)
 - (2) slope material saturated with water ($h_w > 0$)
 - (3) slope material only slightly damp ($h_w < 0$)
- f) \tan is the angle of internal friction (analogous to the coefficient of friction)
- d. slope failure occurs because of:
 - 1) precipitation
 - a) adds moisture to a slope thus raising slope material's pore water pressures such that $h_w > 0$
 - b) this is a significant factor only if h_w is raised to a sufficiently high value so that its effect on effective normal stress will be such that shear strength is significantly reduced
 - 2) earthquakes
 - a) cause measurable ground accelerations that can be resolved into vertical and horizontal components
 - b) these components may act momentarily to reduce effective normal stress or increase the impelling force
 - 3) geologic changes
 - a) weathering of slope materials can reduce their shear strength
 - b) rivers and waves by undercutting slopes increase slope instability by removing the "buttressing" effect of materials at a slope's base
- 3. Landslides and slumps
- 4. Debris and mud flows
 - a. making a debris flow
 - 1) water plus small amounts of silt and clay when mixed together
 - a) merely make muddy water
 - b) silts and clays will eventually settle out given enough time
 - 2) however, a threshold can be crossed when significant amounts of sediment are added together
 - a) producing a "soupy" mud
 - b) if this mixture is left alone sediment does not settle out
 - c) the mass however, will eventually dry out if left long enough
 - b. immersed density (based on Archimedes principle)
 - 1) $(\frac{\rho_p}{\rho_f})$ where
 - a) ρ_p is particle density (mass/unit volume)
 - b) ρ_f is fluid density
 - 2) most sedimentary particles have densities in the range of approximately 2.65 to 2.7 gm/cc (Mg/m^3)

- 3) in air with a density, $\rho = 1.22 \times 10^{-3} \text{ gm/cc}$ (or Mg/m^3)
 - 4) in water with a density, $\rho = 1.00 \text{ gm/cc}$ (or Mg/m^3)
 - 5) in a debris flow with a density $\rho = 2.00+ \text{ gm/cc}$ (or Mg/m^3)
5. Falls
 6. Liquifaction
 - a. thixotropicity - marine "quick clays"
 - b. "quick sand" effect
 7. Snow avalanches
 - a. powder avalanche
 - b. wet avalanche - tends to occur near end of winter season during thaw
 - c. slab avalanche
- B. Coastal Hazards
1. Principles
 - a. water waves
 - 1) wave generation - wind strength, duration and fetch
 - 2) surface restoring forces
 - a) surface tension - capillary waves
 - b) gravity waves
 - (1) oscillatory wave
 - (2) translatory wave
 - 3) progressive wave theory
 - a) variables of interest
 - (1) wave speed or wave celerity, C
 - (2) wavelength (distance from crest to crest), L
 - (3) wave period (time for one wavelength to pass a point), T
 - (4) wave amplitude or wave height, H
 - (5) water depth (seabed to still water line), h
 - b) equations for water waves
 - (1) wave speed or wave celerity, C
 - (a) $C = (gL/2) [\tanh (2 h/L)]$
 - (b) $C = (gT/2) [\tanh (2 h/L)]$
 - (2) wavelength, $L = (gT^2/2) [\tanh (2 h/L)]$
 - (3) $[\tanh (2 h/L)]$ is a hyperbolic function
 - (a) if we let $(2 h/L) = x$
 - (b) then $\tanh x = [(e^x - e^{-x})/(e^x + e^{-x})]$
 - (c) where $e = \lim (1+x)^{(1/x)}$ as x approaches 0
 - c) orbital motion of water in oscillatory waves
 - (1) motion in direction of wave movement on wave crest
 - (2) motion in direction opposite of wave movement in wave trough
 - (3) diameter of orbitals decrease exponentially with depth ultimately reaching "zero" diameter at a depth of $0.5L$

- 4) waves are defined as deep water when $h/L > 0.5$
 - a) when $h/L \sim 0.5$ or when $h \sim 0.5L$, then waves are considered deep
 - b) when $h/L > 0.5$ then $[\tanh(2h/L)] \sim 1.0$
 - c) deep water wave speed, C , becomes: $C = \sqrt{gL/2} = \sqrt{gT/2}$
 - d) deep water wavelength, L , becomes: $L = gT^2/2$
 - e) NOTE: water depth (h) plays no role in determining wave geometry
 - f) "sea" versus swell
- 5) shallow water waves
 - a) when: $h/L < 0.05$ or when: $h < 0.05L$, then waves are considered shallow water waves
 - b) when $h/L < 0.05$ then $[\tanh(2h/L)] \sim (2h/L)$
 - c) shallow water wave celerity, C_s , becomes: $C_s = \sqrt{gh} = (gTh)/L$
 - d) shallow water wavelength, L_s , becomes: $L_s = T \sqrt{gh}$
 - e) NOTE: water depth (h) plays a dominant role in determining wave geometry
 - f) wave energy is proportional to wave height
- b. currents
 - 1) oceanic circulation controlled to a great degree by atmospheric circulation
 - 2) nearshore currents
 - a) longshore currents in the transport of sediment
 - b) rip currents - seaward return flow of water that has been added to nearshore zone by breaking translatory waves
- c. sea level and tides
 - 1) sea level changes historically
 - 2) tides controlled by gravitational attraction between Earth, moon and sun
 - a) Newton's Law of Gravitation: $F_G = G(m_1m_2/d^2)$
 - b) force of gravitational attraction (F_G) varies directly as the masses (m) of the bodies involved and inversely as the square of the distance between them
 - c) in spite of the fact that the moon is considerably less massive than the sun because it is closer to Earth than the sun, the moon exerts the greatest affect on Earth's ocean tides
 - d) open coasts versus restricted inlets
2. macro-scale or long term hazards
 - a. sea level change
 - b. long term, longshore sediment transport
3. meso- and micro-scale hazards
 - a. storm surges
 - 1) principal cause of death during tropical cyclones
 - 2) example: Bangladesh Apr '91 6m surge 300,000+ killed
 - b. spring tides
 - c. storm waves

- d. tsunami
- 4. marine hazards
 - a. ice floes and icebergs
 - (1) Arctic versus Antarctic icebergs
 - (2) 1912 Titanic disaster
 - b. rogue waves
 - c. myth of the "Bermuda Triangle"

VI. Atmospheric Hazards

A. Atmospheric Processes and Distributions (Review)

- 1. Energy
 - a. solar source - receipt and disposition
 - b. temperature distribution
 - 1) global
 - 2) vertical distribution - thermal inversion
- 2. Atmospheric circulation
 - a. macro-scale - primary global circulation
 - b. meso-scale - secondary circulation (storm systems)
 - c. micro-scale
 - 1) tertiary and quaternary level or regional and local circulation patterns
 - 2) dynamic inversions
- 3. Atmospheric moisture (atmospheric stability)

B. Atmospheric Hazards

- 1. Macro-scale
 - a. global warming
 - 1) causes - CO₂, CH₄,
 - 2) consequences
 - b. ozone depletion
 - 1) causes
 - 2) consequences
- 2. Meso-scale (Regional)
 - a. Extratropical or migrating waves cyclones
 - 1) weather of the mid-latitudes
 - 2) cold fronts - ice storms, hail, thunder and lightning
 - 3) "Nor'easters"
 - b. Tropical cyclones
 - 1) Terminology
 - a) Atlantic and eastern Pacific Oceans - Hurricanes
 - b) western Pacific - Typhoons
 - c) Indian Ocean - Cyclones
 - 2) developmental requirements or causes
 - a) formation over tropical oceans (e.g., for eastern United States they form off the coast of west Africa, very close, but not on the equator)
 - (1) driven by latent heat (heat of vaporization and heat released during condensation)
 - (2) sea surface temperature is must be > 26.6°C (> 80°F)
 - b) absence of strong wind shear aloft allows convection cells to attain great height
 - c) nonequatorial location - Coriolis force must

- play a role
- d) these conditions give rise to moist unstable air
 - (1) moist or wet air is close to being saturated (i.e., relative humidity is almost, if not already, 100%)
 - (a) recall that warm air holds more moisture than colder air
 - (b) wet or moist air is also lighter than dry air
 - (2) unstable means that this tropical air's rate of temperature change with increasing elevation is greater than 10°C/1000 m (this is the dry adiabatic lapse rate)
- 3) developmental sequence
- 4) size and internal structure
 - a) diameter of tropical cyclones may reach 1,000 km
 - b) they tend to be as thick as the troposphere
- 5) energy release by an average hurricane
 - a) equivalent to about 3 megatons TNT/min
 - b) Hiroshima atom bomb was a 10 kt device - therefore in an average hurricane the energy equivalent of 300 Hiroshima bombs is released every minute
- 6) triple hazard from tropical cyclones
 - a) high winds capable of moving large amounts of debris
 - b) storm surge (coastal flooding) caused by high onshore winds and lowered pressure at storm's center
 - c) heavy precipitation that can cause river flooding (especially flash floods)
- 7) Classification
 - a) tropical depression - maximum sustained surface winds speed upwards of 63 kph (39 mph)
 - b) tropical storm - winds from 64 to 118 kph (40 - 73 mph)
 - c) tropical cyclone - wind speeds greater than 119 kph (74 mph)
- 8) Tropical Cyclone Categories (**Saffir-Simpson Scale of Hurricane Intensity**)
 - a) Saffir-Simpson scale is based on several factors
 - (1) central pressure (recall - average sea level pressure is 1013.2 mb or 29.92 in of mercury in a mercurial barometer)
 - (2) sustained wind speeds
 - (3) storm surge
 - b) **Category 1** hurricanes are weak tropical cyclones with
 - (1) central pressure 980 mb (28.94 in)
 - (2) sustained wind speeds of 119 to 152

- kph (74 to 95 mph)
 - (3) storm surge between 1.2 and 1.6 m (4 to 5 ft)
 - (4) principal effects consists of minor flooding, damage to mobile homes and trees
 - c) **Category 2** hurricanes are moderate tropical cyclones with
 - (1) central pressure between 965 - 979 mb (28.5 - 28.91 in)
 - (2) sustained wind speeds of 153 to 176 kph (96 to 110 mph)
 - (3) storm surge between 1.7 and 2.6 m (6 - 8 ft)
 - (4) some houses will be damaged, small boats break moorings
 - d) **Category 3** hurricanes are strong tropical cyclones with
 - (1) central pressure between 945 - 964 mb
 - (2) sustained wind speeds of 177 to 208 kph (111 to 130 mph)
 - (3) storm surge between 2.7 - 3.7 m (9 - 12 ft)
 - (4) principal damage consists of flooding which destroys coastal housing, destruction of mobil homes
 - e) **Category 4** hurricanes are very strong tropical cyclones with
 - (1) central pressure between 920 - 944 mb (27.17 -27.88 in)
 - (2) sustained wind speeds of 209 to 248 kph (131 to 155 mph)
 - (3) storm surge between 3.8 - 5.5 m (13 - 18 ft)
 - (4) extensive damage to houses, major beach erosion
 - (5) most recent example of a Category 4 hurricane is Hurricane Andrew which struck southern Florida during the hurricane season of 1992
 - f) **Category 5** hurricanes are rare, devastating tropical cyclones with
 - (1) central pressure < 920 mb (< 27.17 in)
 - (3) sustained wind speeds > 210 kph (> 155 mph)
 - (3) storm surge > 5.5 m (> 18ft)
 - (4) extensive damage to most buildings, massive evacuation is required
- 9) Representative tropical storms
 - a) for United States
 - (1) strongest of the 20th Century - Hurricane Camille (Category 5 hurricane), 1969; devastated Gulf Coast states of Louisiana and Mississippi
 - (2) costliest of the 20th Century -

- Hurricane Andrew (Category 4 hurricane), August, 1992; \$30 billion in damage to south Florida - 63,000 homes destroyed, 26 killed
 - (3) deadliest of the 20th Century - 1900, Galveston, TX, 6,000+ killed
 - (4) Hurricane Ineki (Category 4 hurricane) which struck Hawaii in August, 1992 causing severe damage particularly to the island of Kauai
 - (5) Hurricane Alesha which struck the Texas Gulf coast city of Houston causing extensive damage to windows in tall downtown buildings
 - b. Bangladesh - 1972, tropical cyclone directly responsible for the deaths of 300,000 people; another 700,000 thousand probably died as a result of diseases and starvation
 - c. El Niño-Southern Oscillation (ENSO)
 - (1) effects
 - a) droughts in SE Europe, NW Africa, NE Brazil - flooding in Philippines
 - b) flooding in W US, droughts in Australia
 - (2) mechanism
 - d. Jet stream perturbations
3. Micro-scale
 - a. convective storms
 - 1) at any given moment there are about 2,000 thunderstorms occurring globally; many of these t-storms are in the tropics
 - 2) supercells, severe storms that may spawn tornadoes
 - 3) wind shear and downdrafts (D-FW 1985?)
 - 4) precipitation - hail
 - 5) lightning
 - a) what is it? - a discharge of static electricity
 - b) properties of lightning bolts
 - (1) approximately 10^7 volts
 - (2) 10,000 to 50,000 amps
 - (3) bolt itself is 2-3 cm wide
 - (4) bolt may be several hundred kilometers long
 - (5) lightning bolts have temperatures five times hotter than sun's surface (i.e., $30,000^\circ$ K)
 - (6) when discharge of electricity occurs it does so at a speed of about one-third that of light (i.e., at about 100×10^6 m/sec)
 - c) presumed cause
 - (1) large falling ice particles circulating within cumulonimbus clouds gain extra negative (static) electricity from smaller ice particles

- etc.
- c) **F1** intensity tornadoes are also weak
 - (1) winds vary between 116 and 179 kph (73-112 mph)
 - (2) cause moderate damage particularly to house trailers
 - (3) F0 and F1 tornadoes account for approximately 69% of all tornadoes occurring in the United States
 - d) **F2** intensity tornadoes are strong
 - (1) wind speeds vary between 180 and 251 kph (113-157 mph)
 - (2) F2's cause considerable damage - roofs torn off houses, etc.
 - e) **F3** intensity tornadoes are also strong
 - (1) wind speeds vary from 252 to 330 kph (158-206 mph)
 - (2) F3's cause severe damage - e.g., cars lifted off the ground, etc.
 - (3) F2 and F3 tornadoes account for approximately 29% of all tornadoes occurring in the United States
 - f) **F4** intensity tornadoes are violent
 - (1) winds in F4 tornadoes vary from 331 to 416 kph (207-260 mph)
 - (2) F4 tornadoes cause devastating damage - e.g., houses destroyed
 - g) **F5** tornadoes are extremely violent and extremely rare events
 - (1) F5 tornado winds vary between 417 and 509 kph (261-318 mph)
 - (2) these tornadoes cause incredible damage - e.g., destruction of steel structures, wood frame houses completely removed from their foundations; asphalt stripped from roads, etc.
 - (3) **F4** and **F5** tornadoes are extremely rare; accounting for about 2% of all tornadoes occurring in the United States
- 4) tornado outbreaks - occurrence of swarms of tornadoes
- a) in 1965 - 50 tornadoes occurred in one day in the central United States
 - b) in 1974 - 148 tornadoes occurred in one day with a record number of **F4** and **F5** tornadoes
- d. Santa Ana (Chinook or Föhn winds) - hazards
- 1) wind blown debris
 - 2) low humidity often sets stage for wildfire - NOTE: Santa Ana winds often precede the southern California fire season
- e. inversion layers - allow for the build up of fog (reduced visibility) and smog (health hazard)
- 1) thermal inversions
 - a) conditions and thermal profile

- b) coastal fog (marine layer) a prominent aspect of coastal California's spring and summer weather pattern
- c) valley or "tule" fog a prominent aspect of the winter weather pattern in California's Central Valley
- d) winter, the smog season in the Intermountain West
- 2) dynamic inversions
 - a) conditions and thermal profile
 - b) smog and air pollution - a prominent aspect of southern California's summer weather pattern

VII. Hydrospheric Hazards

A. Hydrologic Processes

1. Relationship between rainfall and runoff
 - a. precipitation intensity (e.g., cm/hr)
 - b. infiltration rate/infiltration capacity (e.g., cm/hr)
 - c. when precipitation intensity is less than infiltration capacity then no surface runoff occurs - water eventually gets to channels via throughflow
 - d. water which infiltrates becomes
 - 1) soil moisture which is transpired back into atmosphere by plants
 - 2) excess soil moisture either evaporates or, if present in great enough quantity, percolates to greater depths eventually becoming groundwater
 - e. when precipitation intensity exceeds infiltration capacity surface runoff occurs as overland flow (e.g., what occurs in parking lots)
2. Groundwater - provides the source of stream channel runoff for perennial streams
3. Stream flow
 - a. stream gauging
 - b. flood prediction
 - 1) determination of channel size
 - 2) the modal flood event
 - c. river behavior during high flow events
4. Environmental/Climate change
 - a. Pleistocene 1.6 my BP
 - b. latest interglacial (Holocene) 10,000 BP
 - c. drought conditions in SW 900-1300 CE
 - d. Little Ice Age 1400-1700 CE
5. **ENSO**

B. Flood

1. A flood is any event that causes to be delivered to a stream channel more water than the channel can contain. Definition begs some explanations
 - a. what is meant by stream channel
 - b. necessity to recognize environmental change and consequences for channel size
 - c. what determines size of contemporary channel
1. Most common environmental hazard
 - a. affects probably 75 million people a year world-wide
 - b. geographical aspects

- 1) global distribution of population
 - 2) distribution of floodplains
 - 2. Natural flooding
 - a. precipitation induced (i.e., precipitation intensity exceeds infiltration capacity)
 - 1) ground already saturated
 - 2) slick rock desert flash floods
 - b. seasonal changes (e.g., snowmelt induced)
 - 1) ground still frozen
 - 2) ice jams
 - c. other - e.g., volcanic eruption resulting in rapid melting of an ice cap (Iceland, October 1996)
 - 2. Human induced
 - a. urbanization (southern California)
 - b. river modifications
 - 1) Mississippi summer '93
 - 2) Achafalaya
 - 3) dam collapse
 - a) 1928 St. Francis dam failure in San Francisquito canyon, southern California
 - b) 1965 Vaiont Dam disaster in Italy
 - c) Teton Dam failure in Idaho 197?
 - d) Glen Canyon dam
- C. Droughts
 - 1. Natural - ENSO associated
 - 2. Human induced desertification