Physics 030
EARTH and SPACE SCIENCE - I

- This course covers, at an introductory level, the physical science topic areas of Earth and space science, with primary emphasis on the former.
- These include the traditional topic areas of geology (solid Earth science), oceanography, atmospheric science, aeronomy, and the near-Earth space environment.
- The introductory sessions include reviews of, or introductions to, some of the basic physical science and technology topic areas relevant to Earth and space science, such as: molecular, atomic, and nuclear physics; orbits and space flight; optics and spectroscopy, and remote sensing.
- This course is Part 1 of a set of two courses in Earth & Space Physical Science, originally sponsored by a NASA Aerospace Workforce Development program (AWDP) grant, by way of the DC Space Grant Consortium.
- The second semester course, Physics 031, covers the topic areas of space science (including our Moon, the Sun, and other members of the solar system; stars and the interstellar medium; galaxies, and the entire Universe).

Physics 030
EARTH and SPACE SCIENCE - I

Topics Covered

I. Introduction to Earth and Space Physical Science
- The Size and Distance Scale of the Universe
- Fundamental Properties of Matter
- Forms of Energy
- Optics and Remote Sensing
- Space Astronomy, Electronic Imaging
- Astronomical Coordinate Systems, Orbits and Space Flight, Rockets and Space Flight

II. Origins: How did it All Begin?

III. Rocks and Minerals, The Solid Earth

IV. The Earth’s Hydrosphere and Cryosphere

V. Seasons, The Earth’s Atmosphere

VI. The Near Earth Space Environment

INTRODUCTION TO EARTH AND SPACE PHYSICAL SCIENCE

OBJECTIVES

- The primary objective of this course is to provide an introduction to Earth and Space Science, and related areas of physical science, for college students planning to major in these fields (or related fields of engineering), or as background for teaching these or related subjects to pre-college students.
- Other objectives include:
    - Providing background for more advanced courses in Astronomy, Astrophysics, Atmospheric Science, Geology, Oceanography, and other sub-fields of Earth & Space Science, or for related areas of Aerospace Engineering
    - Introducing other educational resources, including books and periodicals, videos, CD-ROMs, and relevant World Wide Web sites.
- Because of the rapid rate of change in the topic areas of space and Earth science, it is impractical to designate or create a hard-copy textbook that covers all of the relevant course materials.
- Hence, we use PowerPoint presentations instead, which are easy to upgrade on a yearly (or shorter time period) basis.

INTRODUCTION TO EARTH AND SPACE PHYSICAL SCIENCE

- **Earth Science and Space Science** are truly interdisciplinary fields of science. They are based on all three of the “basic” sciences, **biology, chemistry, and physics.**
- **Earth Science** is now considered to be only a specialized area in the broader space science field of **Planetary Science**, particularly in their physical science-related aspects. (However, the emerging sub-field of **astrobiology** has further increased the commonality between the two fields.)
- Recently, NASA has integrated its Office of Space Science and its Office of Earth Science into a single Office of Science, in recognition of this fact.
- Like in most other fields of science and engineering, **mathematics** and **computer science** are also essential components.
- Therefore, the Earth & Space Physical Science course must also introduce or review many of the basic concepts of Physics and Chemistry, as well as the specialties within Earth & Space Science.

NATIONAL SCIENCE EDUCATION STANDARDS- Physical Science

- The primary topic areas in which all students should have a basic understanding, after completing course work at the high school level in Physical Science, include the following:
  - **Structure of Atoms.** Matter is made up of atoms, which are themselves composed of even smaller components.
  - **Structure and Properties of Matter.** Atoms and molecules interact with one another through bonding and forces.
  - **Chemical Reactions.** Chemical reactions release or consume energy.
  - **Motions and Forces.** Motion occurs when a net force is applied; gravitation, electricity, and magnetism are examples of forces.
  - **Conservation of Energy and Increase in Disorder.** Energy is kinetic or potential; everything becomes less orderly over time.
  - **Interactions of Energy and Matter.** Waves can transfer energy; electromagnetic waves include radio, microwaves, and infrared radiation.
- The current course provides a review of these topics, with special emphasis on their applications to Earth and Space Science.

EARTH AND SPACE PHYSICAL SCIENCE

- The first topical Earth and Space Science area covered, “The Size and Distance Scale of the Universe”, serves to introduce the vast range of sizes and distances covered, ranging from sub-atomic particles to the entire Universe.
- The second area to be covered, is a review or introduction to the most important areas of physical science of relevance to Earth and Space Science.
    - These include properties of matter and energy, optics and spectroscopy (and their applications to remote sensing), and the topics of orbits and space flight.
- The third topic area is the subject of **Origins**- of the Universe, our solar system, and Earth.
- We then cover, in more detail, the Earth and the Earth Systems, beginning with rocks and minerals, and the solid Earth; followed by the hydrosphere and cryosphere; the atmosphere; and the near-Earth space environment.

INTRODUCTION TO EARTH AND SPACE PHYSICAL SCIENCE

MAJOR AREAS OF EARTH SCIENCE

- **Earth Science** includes scientific research on all aspects of Earth and the Earth system.
- The major sub-fields of Earth science based on physical science include:
  - **Geology** (the study of the solid Earth)
  - **Oceanography** (the study of the oceans, the major component of the hydrosphere)
  - **Atmospheric science** (the study of Earth's atmosphere, which includes *meteorology, climatology,* and *aeronomy* as sub-specialties).
- Earth science is becoming increasingly related to space science, both because of the increasing use of space as a base for Earth observations, and because we now consider Earth science to be only a specialty within the broader area of **planetary science.**

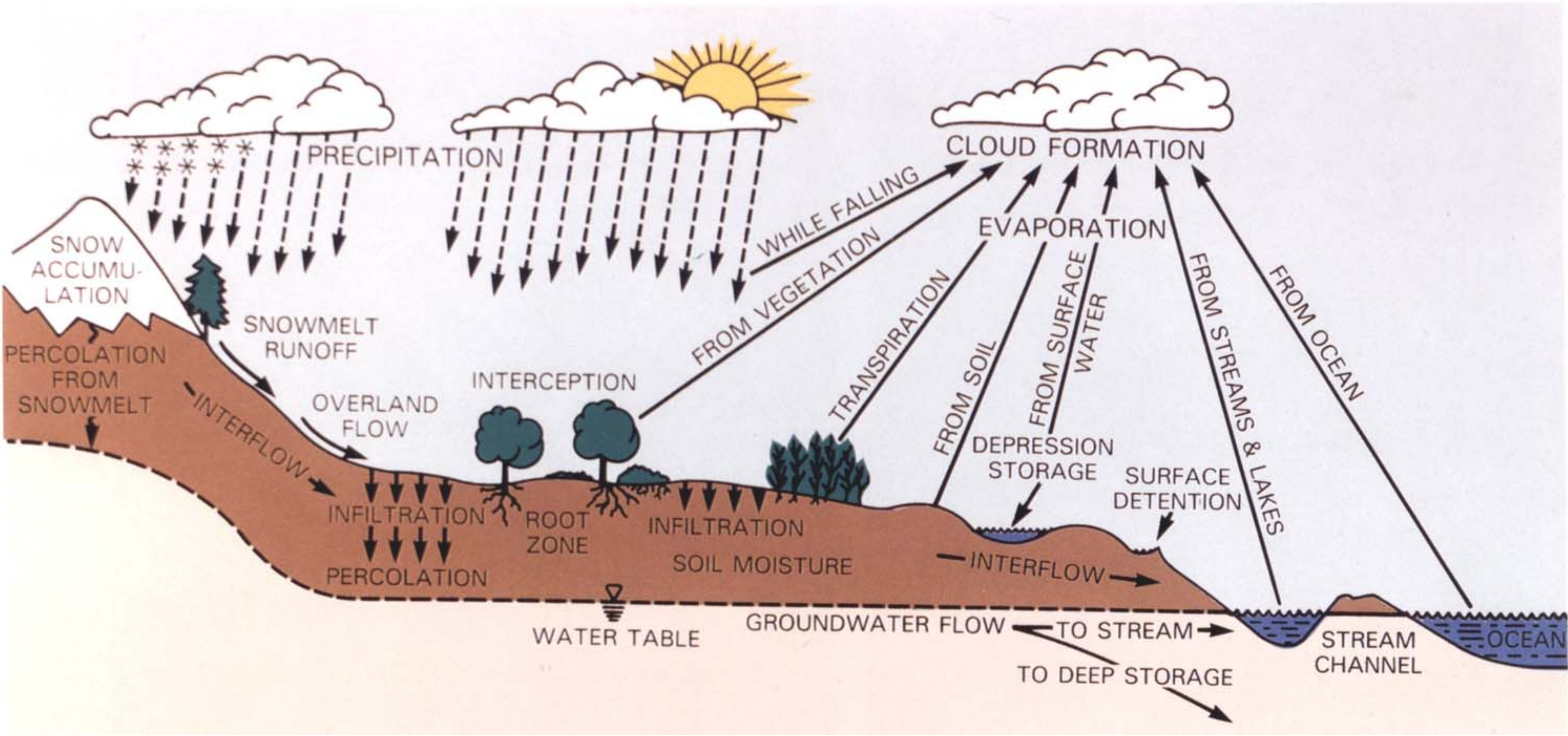
GEOLOGICAL AND GEOCHEMICAL CYCLES

- The Earth system, consisting of the solid Earth, its atmosphere, and its hydrosphere, constitute (for all practical purposes) a **closed system.**
- Therefore, although the chemical and physical states of the elements constituting the Earth can be interchanged between various physical and chemical states, **the total amount of any element or non-reactive compound is fixed.**
- Examples of **geologic cycles** of practical importance include:
  - The **Hydrologic Cycle** (the interchange of water between gaseous, liquid, and solid phases)
  - The **Carbon Cycle** (the interchange of Carbon between various chemical compounds and states, such as methane (CH_4), carbon dioxide (CO_2), and calcium carbonate ($CaCO_3$).
  - The **Rock Cycle** in which igneous rocks are weathered by water and CO_2 to form sedimentary rocks, which can be subducted (by plate tectonics) into the mantle to be converted back to igneous rocks.

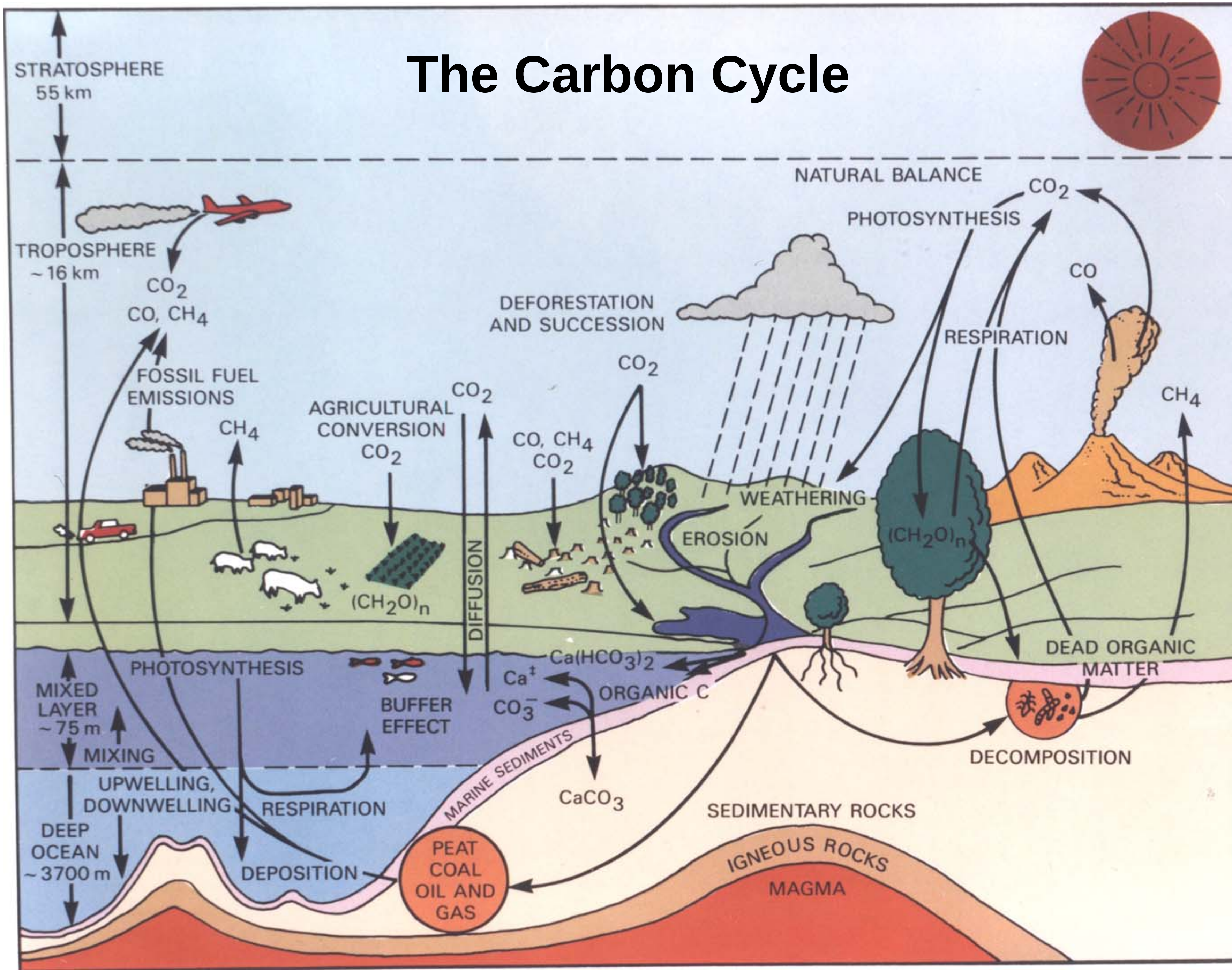
GEOLOGICAL AND GEOCHEMICAL CYCLES

- The **Hydrologic Cycle** is responsible for precipitation (rain and snow) and resulting erosion of land areas
- The **Carbon Cycle** is responsible for the recycling of carbon between the oxidized states (such as CO_2) and the reduced states (such as living organisms and fossil fuels).
- Both of these are of great practical importance to humans and other inhabitants of Earth, but potentially can be altered in undesirable manners by human activities.
- Other cycles include the **Rock Cycle**, which is the means by which the original (igneous) rocks of Earth interact with Earth’s hydrosphere and atmosphere to create sedimentary rocks, but also has had major effects (throughout Earth’s history) on the atmosphere and hydrosphere, as well.
- An important area of current research in Earth & Space Science is to determine the actual and potential effects of both natural phenomena and human activities on these cycles, and of these cycles on each other, constituting the new field of **Earth System Science**.
- This includes two subsystems, **physical climate** and **bio-geochemical cycles**, which are linked by the global hydrologic cycle.

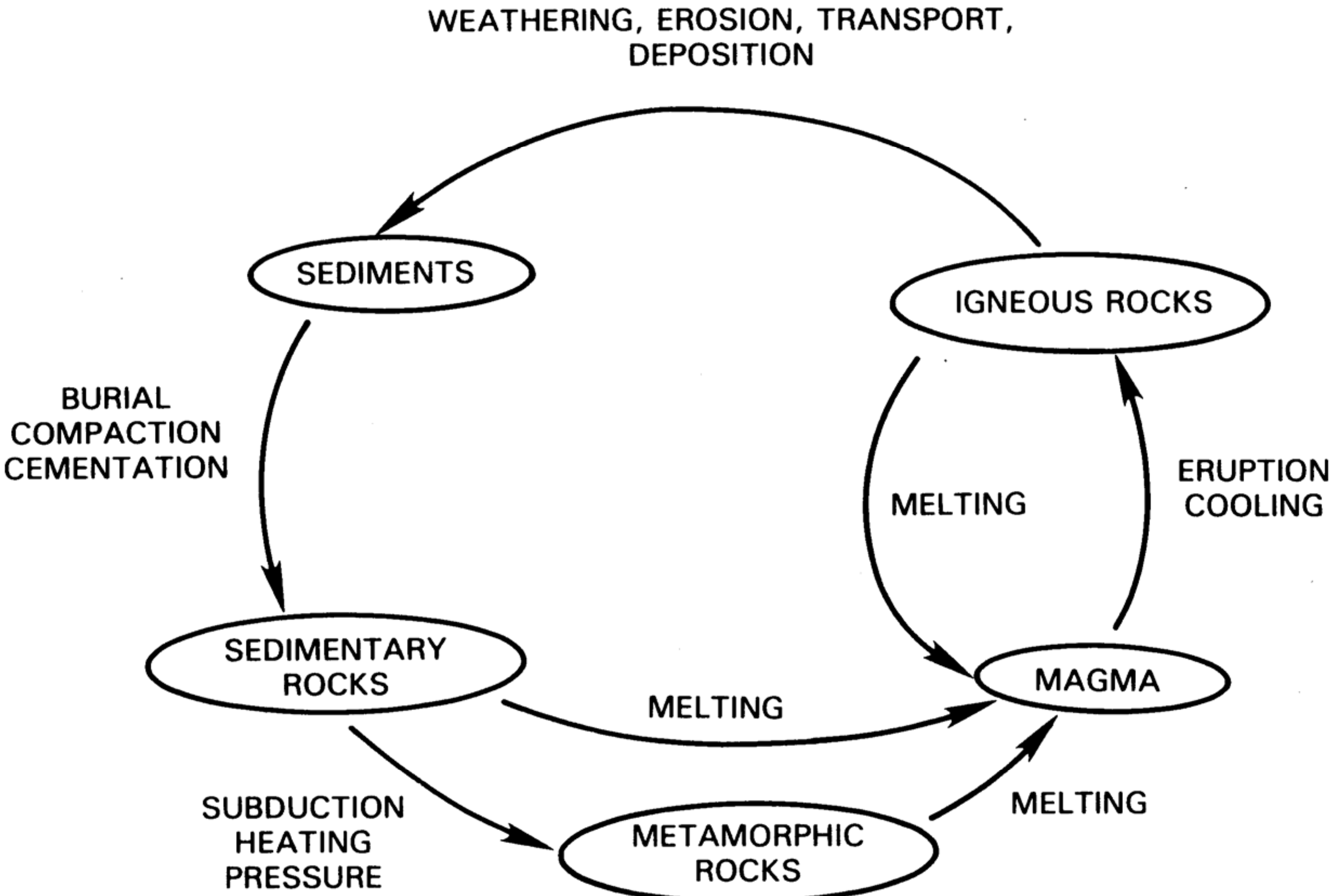
The Hydrologic Cycle



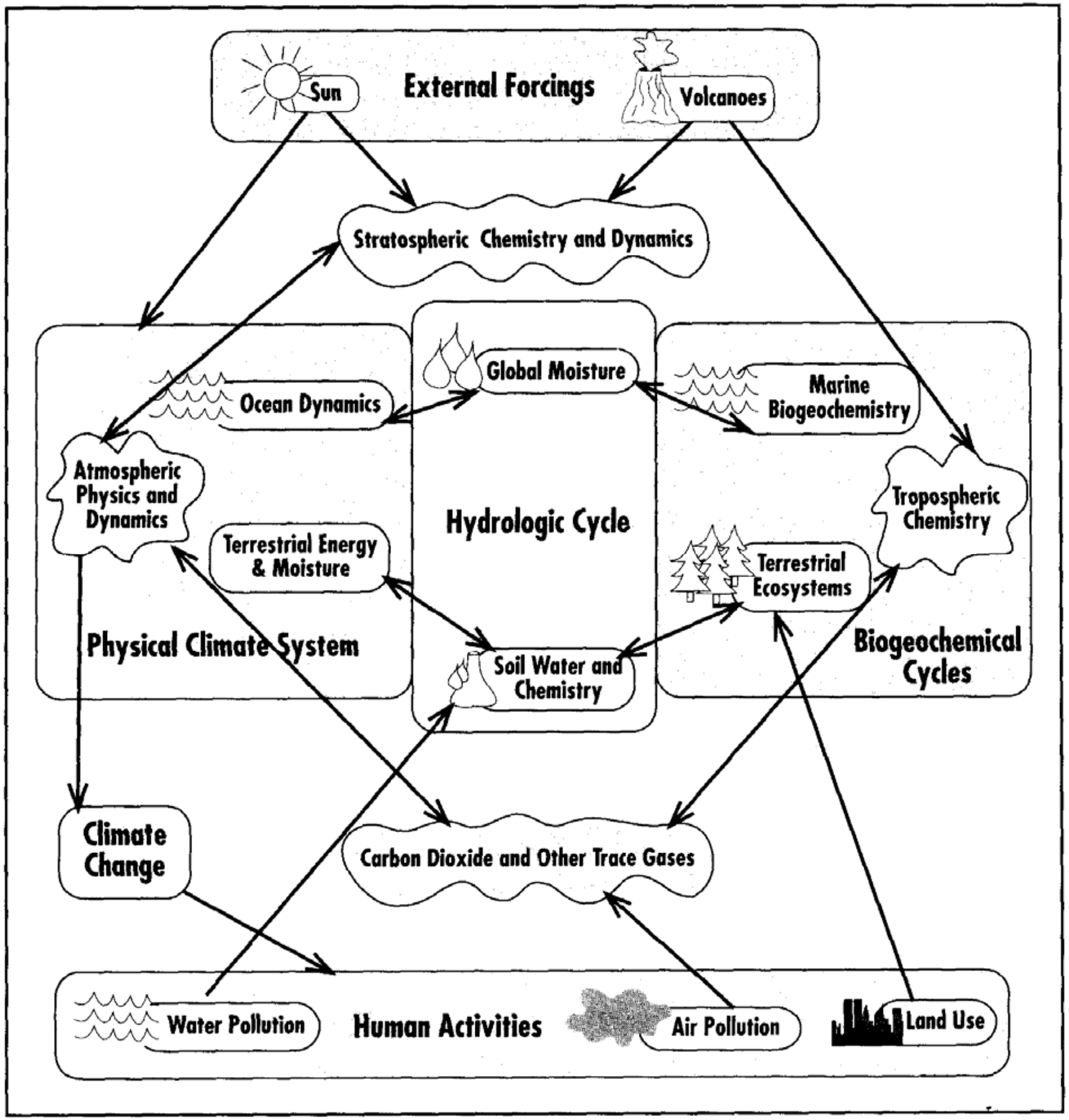
The Carbon Cycle



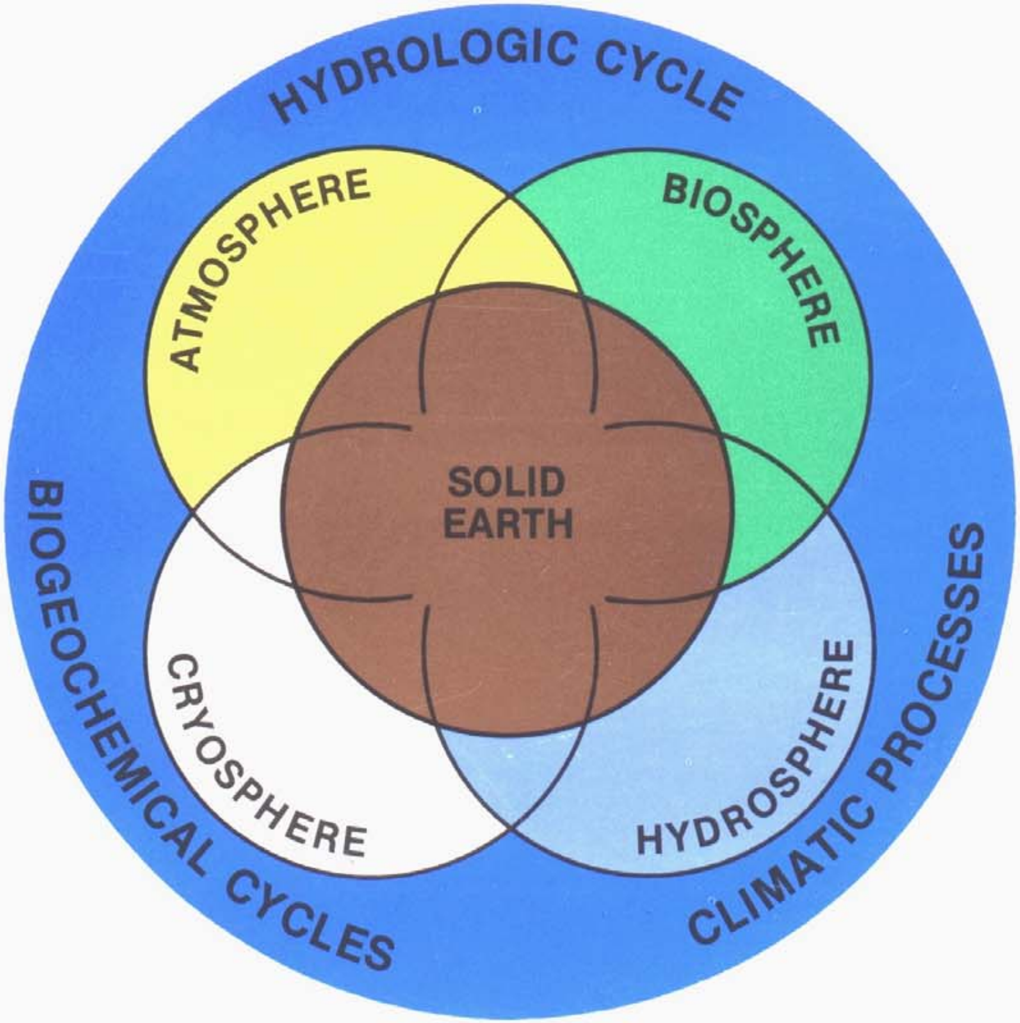
The Geologic Rock Cycle



THE EARTH SYSTEM



EARTH OBSERVING SYSTEM



INTRODUCTION TO EARTH AND SPACE PHYSICAL SCIENCE

SPACE SCIENCE

- **Space Science** is any field of science which studies objects in, or properties of outer space (the region beyond Earth's lower and middle atmosphere), and/or requires a space base of operation.
- Space science includes both **remote sensing** studies of distant objects (or the near-Earth space environment), and **in-situ** measurements of the space environment (including the upper atmosphere of Earth).
- Earth science investigations requiring Earth observations from space are also considered to be part of space science as well.
- Space science also includes studies of the effects of the space environment (including microgravity) on biological processes and organisms (including humans).
- Space science fields include aspects of all of the basic sciences (biology, chemistry, and physics) as well as mathematics and computer science.

INTRODUCTION TO EARTH AND SPACE PHYSICAL SCIENCE

MAJOR AREAS OF SPACE SCIENCE

- Here, we concentrate on those areas of space science based on **remote sensing** techniques. These include the following:
  - **Earth science from space,** includes studies of the solid Earth, its biosphere, oceans, and atmosphere, and the near-Earth space environment.
  - **Solar system science,** includes studies of the Sun, planets, and smaller objects (including asteroids and comets), and the interplanetary space environment
  - **Astronomy,** the study of the entire Universe outside of Earth and the solar system: stars, the interstellar medium, galaxies, and cosmology
- Astronomy and solar system science include the topic areas of **astrophysics**, the application of physics to such topics as star formation, structure, and evolution; and **astrochemistry**, the application of chemistry to studies of stellar and planetary atmospheres, and the interstellar medium.
- A more recent topic area, not as yet having an actual data base, is the subject of **astrobiology**, the study of life and its origin and evolution in regions beyond Earth.

INTRODUCTION TO EARTH AND SPACE PHYSICAL SCIENCE

- Advantages of a space-based location for **Earth science** measurements include the following:
  - A satellite in orbit around Earth can provide **global coverage and monitoring** which would be difficult or impossible with aircraft, ship, or ground-based platforms. **Weather satellites** are an important practical application.
  - A satellite in near-Earth space can make remote-sensing measurements of Earth's upper atmosphere, in **ultraviolet, X-ray, and infrared wavelengths** which do not penetrate the lower atmosphere and hence cannot be studied from the ground.
  - A spacecraft in near-Earth space can also make **in-situ measurements** of the very high altitude regions of the atmosphere and the near-Earth space environment, and the effects of the Sun (and time variations) thereof.
- Recent and current Earth science missions include the *LandSat* series of satellites; and the currently operational *Terra, Aqua,* and *Aura* research satellites, which are major parts of NASA's Earth Observing System (EOS).

INTRODUCTION TO EARTH AND SPACE PHYSICAL SCIENCE

- **Lunar science** (the study of our Moon) was the first field of planetary science to benefit from space missions.
- Studies of the Moon, by remote sensing and by study of rocks brought back to Earth by the *Apollo* astronauts, also help us to understand Earth's early history (largely erased by water and atmospheric erosion, and geologic activity), since both are in the same region of the solar system.
- **Planetary Science** involves space flight missions to other planets, comets, and asteroids in our **solar system**, as well as remote-sensing observations of these objects using instruments in near-Earth space, such as the Hubble Space Telescope.
- Planetary science uses measurement techniques very similar to those used in Earth science (including Earth observations from space) and lunar science to study other objects in our solar system, and to compare them with our Earth and Moon.

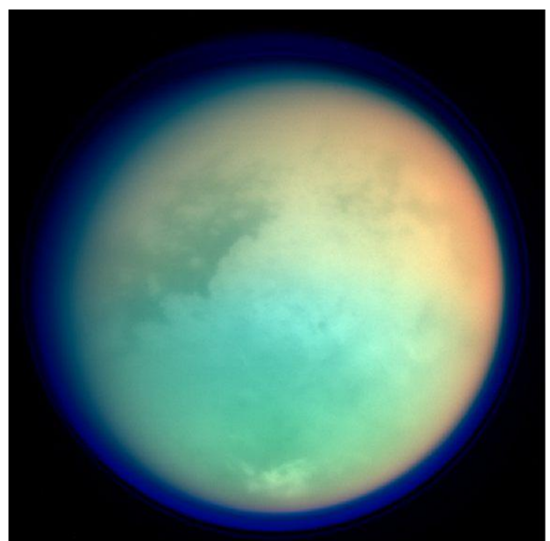
INTRODUCTION TO EARTH AND SPACE PHYSICAL SCIENCE

- **Planetary flight missions** have now visited all of the other planets in our solar system except Pluto.
- These missions have used a combination of **remote-sensing** measurements (imaging and spectroscopy) and of **in-situ** measurements (mass spectrometer measurements of gases, chemical measurements of soil and rock samples). The *Apollo* missions to the Moon also brought back rock samples for analysis in Earth-based laboratories.
- Other major past and current planetary missions include the *Viking, Mars Global Surveyor, Mars Odyssey, Mars Pathfinder,* and *Mars Rover* missions to Mars, the *Magellan* mission to Venus, and the *Voyager, Galileo*, and *Cassini-Huygens* missions to the outer planets and their satellites.

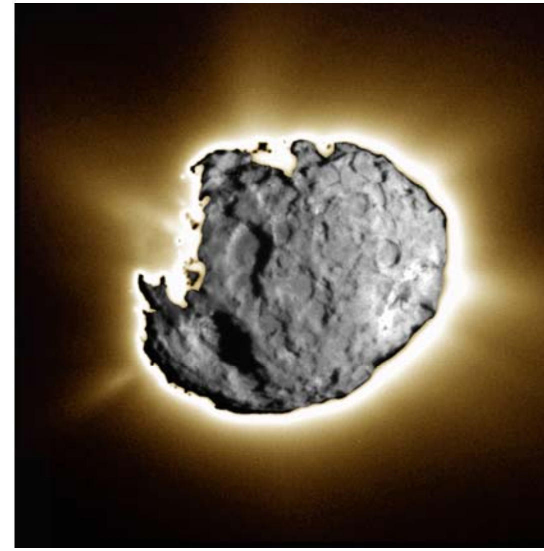
Current Solar System Exploration Missions

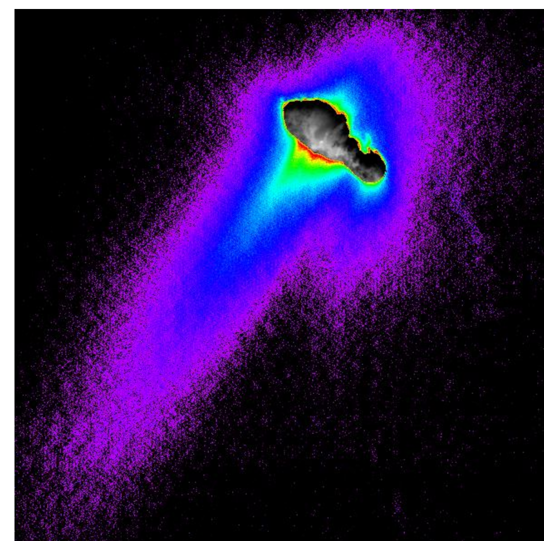
Mars Rovers

Cassini /Huygens to Saturn and Titan



Comet Missions





INTRODUCTION TO EARTH AND SPACE PHYSICAL SCIENCE

- **Space Astronomy** benefits from being outside Earth's atmosphere, *not* by getting closer to the objects to be studied.
- Earth's atmosphere interferes with astronomical observations because it **absorbs** much of the broad spectrum of electromagnetic radiation (of which visible light is only a very small portion).
- The atmosphere prevents study, from the ground, of **ultraviolet, X-ray, and gamma radiation** (more energetic than visible light) and of **infrared and microwave** radiation (less energetic than visible light).
- These provide important information about **very hot** and **very cool** objects, respectively.
- Thermal (infrared) **emission** by Earth's atmosphere (even at night) also interferes with infrared astronomical observations of cool objects or their atmospheres.
- Earth's atmosphere also **scatters** incoming radiation from distant sources, and **distorts and smears the images** of distant objects, even in visible light, when viewed with ground-based telescopes.

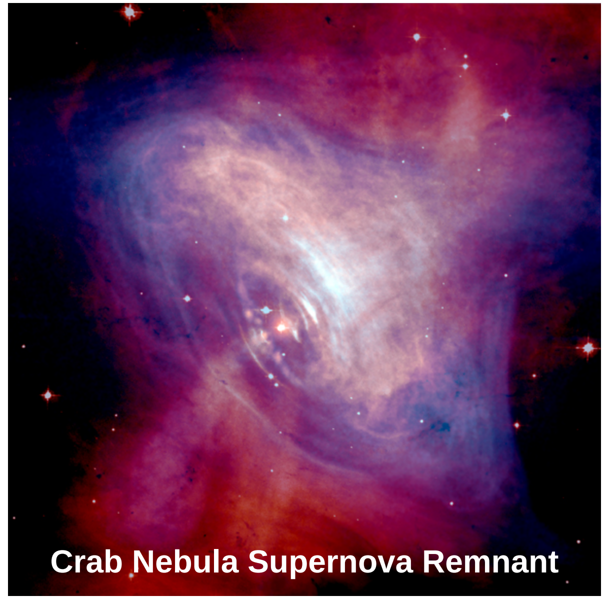
INTRODUCTION TO EARTH AND SPACE PHYSICAL SCIENCE

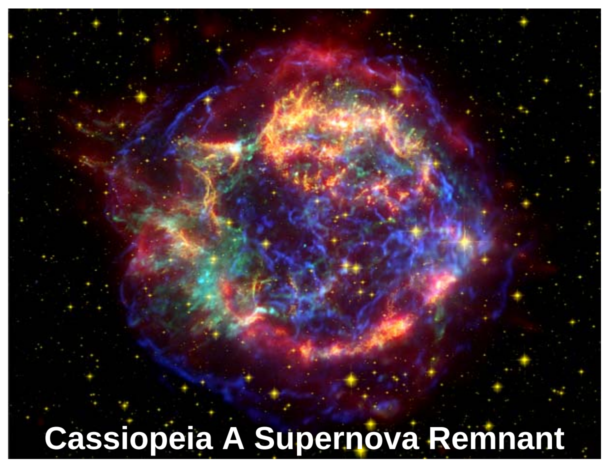
- Several major space-based astronomical observatories (such as the *Hubble* Space Telescope**,** the *Chandra* X-ray telescope, the *Compton* gamma-ray observatory, and the *Spitzer* infrared space telescope), and smaller space-based instruments have been used, or are planned for near-future use, to utilize the advantages of observations from space, and thereby to improve our understanding of our Universe and Earth.
- The *Earth Observing System* satellites, *Terra, Aqua,* and *Aura,* are very similar in design and utilization to the spacecraft being sent to study other planets and minor members of our solar system.
- The design, construction, and utilization of these instruments require scientists and engineers in a wide range of scientific and technical specialties (not just “rocket science”).
- Not only professional scientists and engineers, but college students (and even high school students) can be, and have been, participants in these projects by way of various summer or part-time student employment programs, provided by NASA, other government agencies, and university participants.

Recent Deep Space Science Mission Discoveries

Hubble Space Telescope

Chandra X-Ray Telescope





Spitzer Infrared Telescope