Climate Change (AOS 1)

Time: Tuesday/Thursday, 9.30-10.45 AM
Class room: Kinsey Pavilion 1220-B
Instructor: Professor K. N. Liou, Math Sciences 7163
        E-mail: knliou@atmos.ucla.edu
        Telephone: 310-825-5039
Office Hours: Tuesday, 1-2 pm (my office), or by appointment
Teaching Assistants:
      1. Calvin Liang (cliang@atmos.ucla.edu):
        Office hours: Monday and Tuesday, 11am -12 noon (7124B)
      2. Yifan Yu (yifan@atmos.ucla.edu):
        Office hours: Friday, 10 am-12 noon (7124B)
     Note: no discussion/no office hour during the first week

General Overview:
    This course is designed for students from all backgrounds. It is intended (1) to provide the scientific background necessary to understand climate related issues, (2) to gain a scientific understanding of the human influence on climate in the past and the future, and (3) to obtain an appreciation for the role of science in shaping political debate and decision on climate issues where accurate scientific information is essential.

Course Web Site: http://www.atmos.ucla.edu/~liougst/ (AOS1, also the department)
Required Text: "Atmosphere, Climate & Change" by T. Graedel and P. Crutzen, available at the UCLA bookstore for $ 20. Additional material will be provided.
Grading: Participation 5%, Homework 20%, Midterm 30%, and Final 45%. Exams will be based on lecture material and homework assignments.

Lecture Schedule*

Lecture 1 (Tu, 4/4): Introduction and Overview
Lecture 2 (Th, 4/6): Radiation/Heat in the Atmosphere, Part 1
Lecture 3 (Tu, 4/11): Radiation/Heat in the Atmosphere, Part 2
Lecture 4 (Th, 4/13): Greenhouse Effect and Climate
Lecture 5 (Tu, 4/18): General Circulation of the Atmosphere and the Oceans
Lecture 6 (Th, 4/20): Chemistry in the Air, Part 1
Lecture 7 (Tu, 4/25): Chemistry in the Air, Part 2
Lecture 8 (Th, 4/27): Climate of the Past, Part 1
Lecture 9 (Tu, 5/2): Review and Discussion
Midterm (Th, 5/4): 9.30-10.45 am
Lecture 10 (Tu, 5/9): Climate of the Past, Part 2
Lecture 11 (Th, 5/11): Perturbation of CO2 and Trace Gases
Lecture 12 (Tu, 5/16): Carbon Cycle
Lecture 13 (Th, 5/18): Aerosols/Clouds and Climate
Lecture 14 (Tu, 5/23): El Nino and Climate Variability
Lecture 15 (Th, 5/25): Climate Impact
Lecture 16 (Tu, 5/30): Future Climate Projection and Sustainability, Part 1
Lecture 17 (Th, 6/1): Future Climate Projection and Sustainability, Part 2
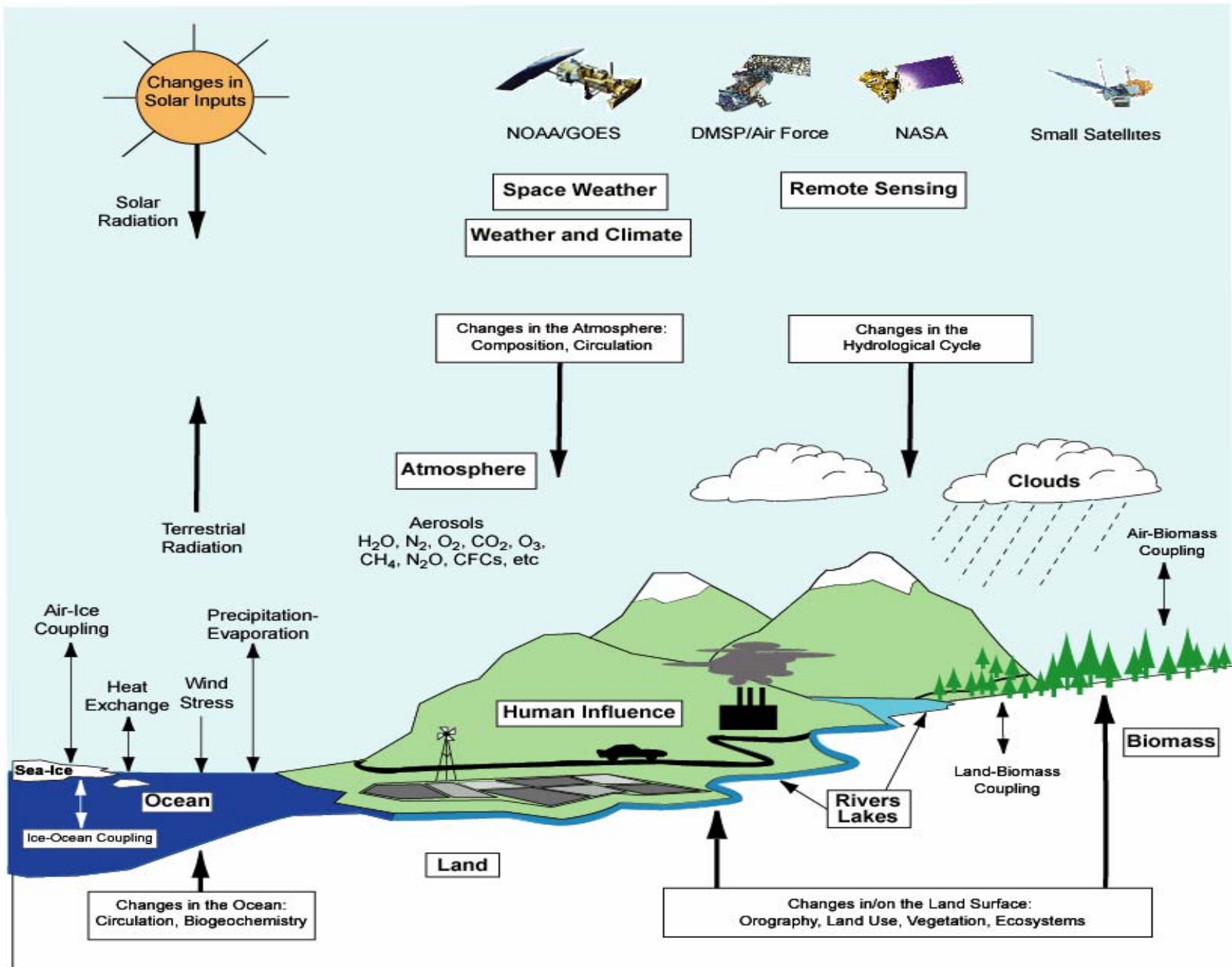Lecture 18 (Tu, 6/6): Discussion
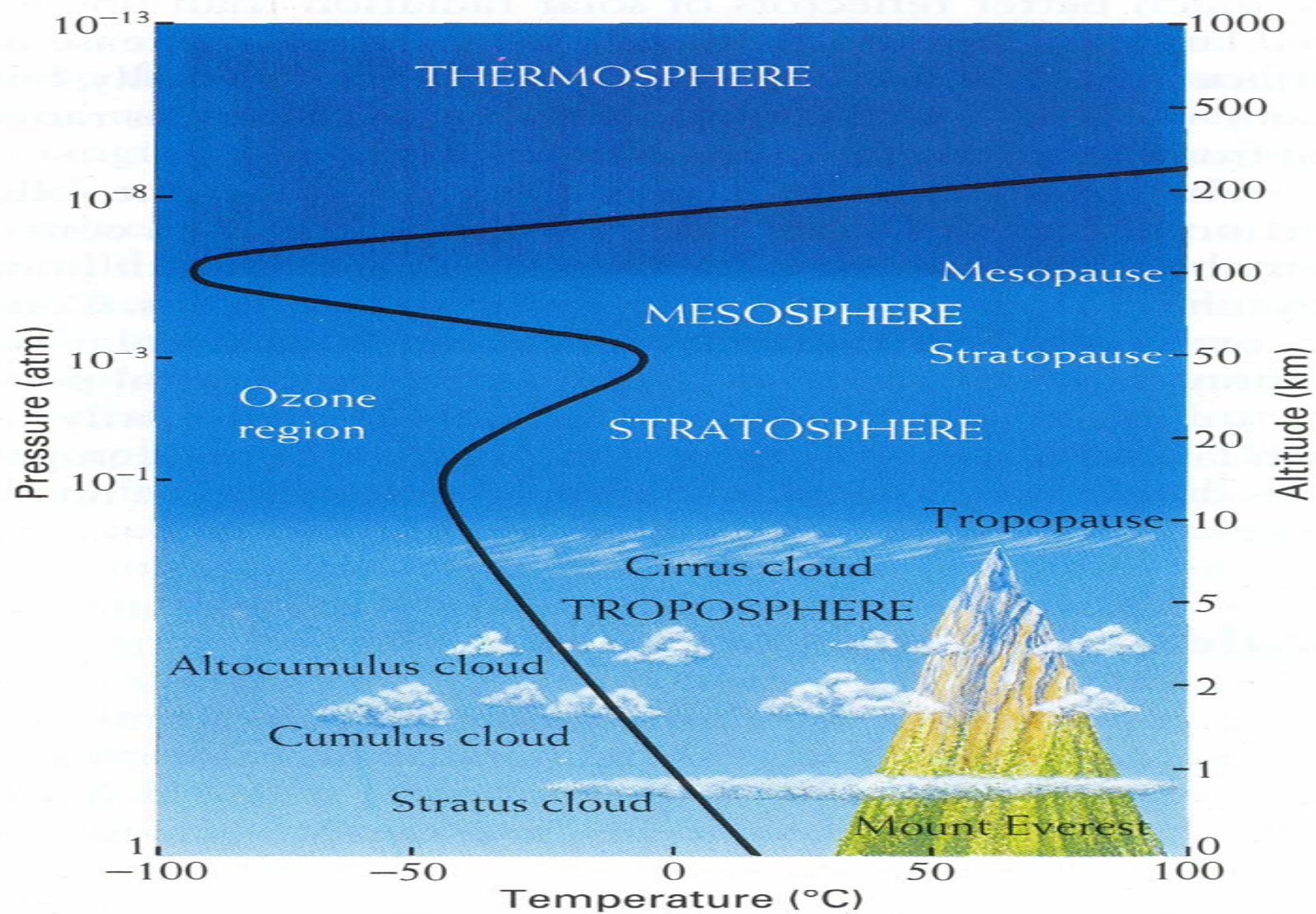Lecture 19 (Th, 6/8): Review
Final (Mon, 6/12): 3-6 pm
*The days on which the different topics are discussed may change as the course proceeds
1. Homework and lab assignments will be given one week prior to their due date and should be turned in by 5 pm on the due date to your TA's mailbox (Math Sciences 7139). No e-mail submission will be accepted. Late homework will not be accepted, except by professor's special permission.
2. Laboratory session will have additional homework assignments. See also item 1.

Changes in Solar Inputs

Solar Radiation

NOAA/GOES   DMSP/Air Force   NASA   Small Satellites

Space Weather

Remote Sensing

Weather and Climate

Changes in the Atmosphere: Composition, Circulation

Changes in the Hydrological Cycle

Terrestrial Radiation

Atmosphere

Aerosols
H_2O, N_2, O_2, CO_2, O_3, CH_4, N_2O, CFCs, etc

Clouds

Air-Biomass Coupling

Air-Ice Coupling

Precipitation-Evaporation

Human Influence

Heat Exchange

Wind Stress

Biomass

Sea-Ice

Ocean

Land-Biomass Coupling

Rivers Lakes

Ice-Ocean Coupling

Land

Changes in the Ocean: Circulation, Biogeochemistry

Changes in/on the Land Surface: Orography, Land Use, Vegetation, Ecosystems

The variation of atmospheric pressure and temperature with altitude above Earth's surface. The regions of the atmosphere are noted, and the Himalayas are drawn in for perspective.

Length (Space)   Time

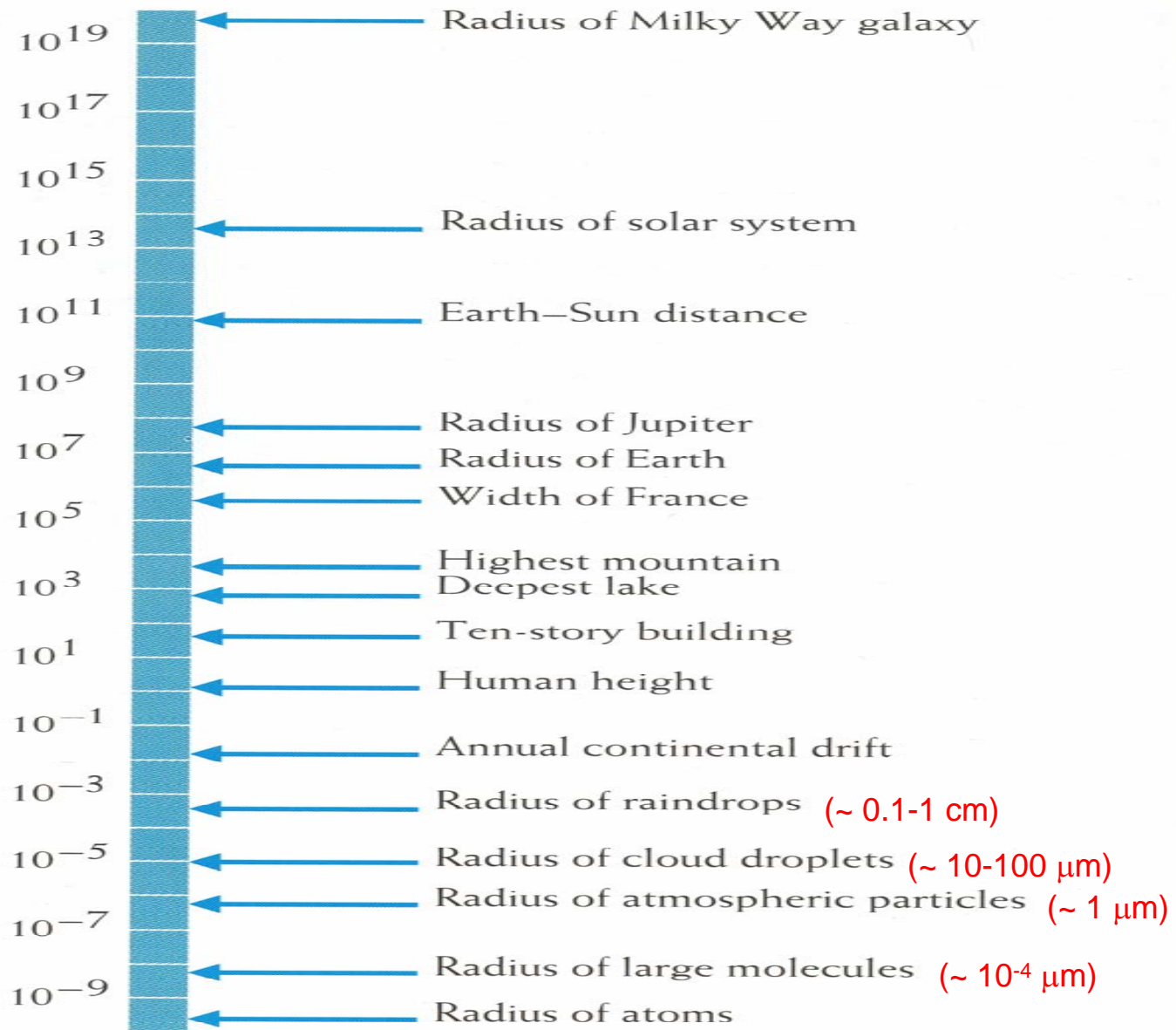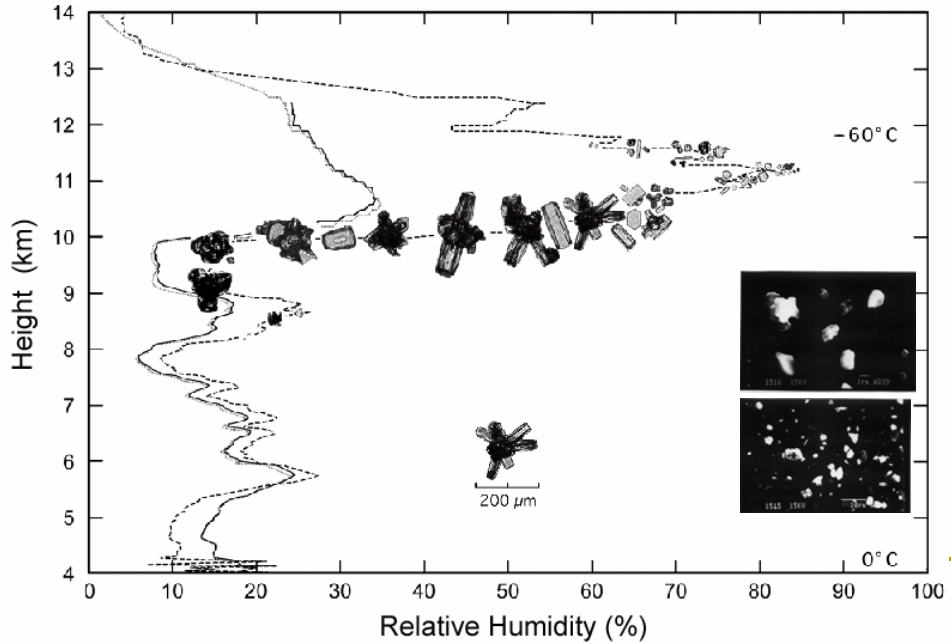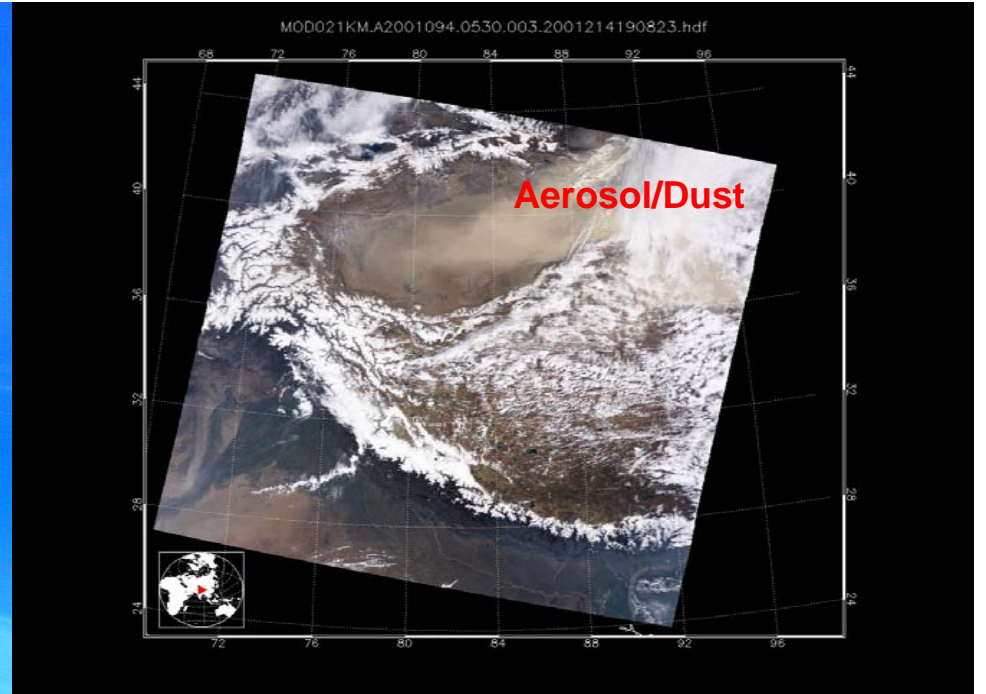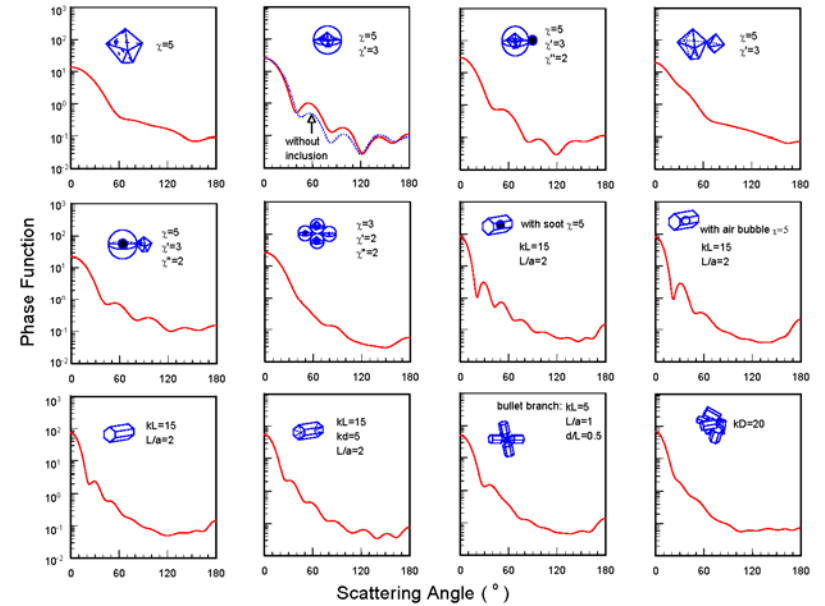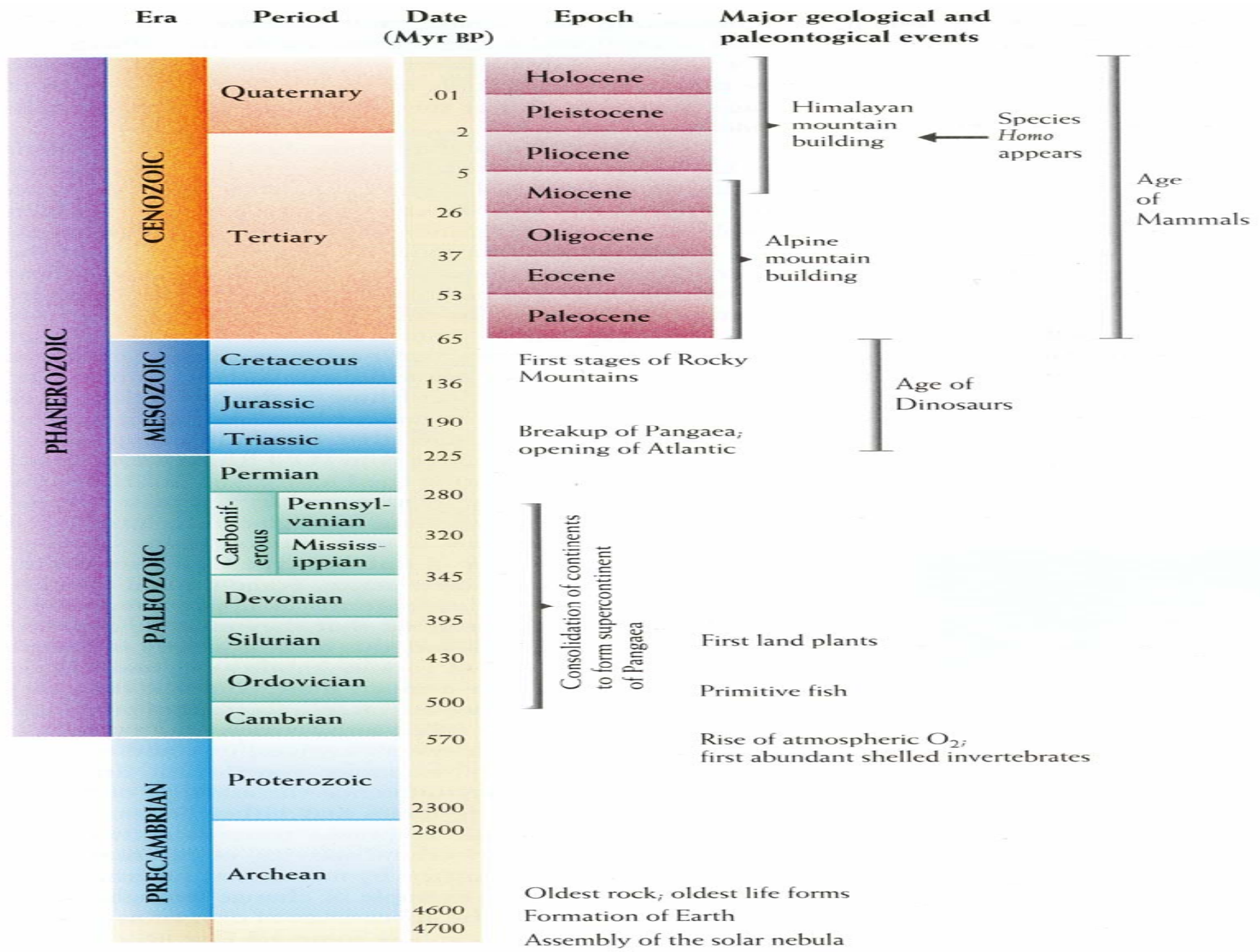| Length (Space)	Time
1 m = 100 cm	1 Year ~ 365 days
1 cm = 10^4 μm	1 Day = 24 hours
1 km = 1000 m	1 hour = 60 minutes (60s)
1 mile ~ 1.61 km	1 Month ~ 30 days
1 inch ~ 2.54 cm	1 Season ~ 3 Months
1 ft ~ 30.48 cm	1 MY ~ 10^6 Years

Spatial scales in Earth system science. The ordinate is logarithmic, so each step up from the bottom represents a distance (in meters) 10 times that of the segment just below it.

Cirrus/Contrail

Aerosol/Dust

Radiative Transfer/A Unified Theory for Light Scattering by Ice Crystals and Aerosols

| Era	Period	Date (Myr BP)	Epoch	Major geological and paleontogical events
PHANEROZOIC / CENOZOIC	Quaternary	.01	Holocene	
		2	Pleistocene	Himalayan mountain building — Species *Homo* appears
	Tertiary	5	Pliocene	
		26	Miocene	
		37	Oligocene	Alpine mountain building
		53	Eocene	
		65	Paleocene	Age of Mammals
MESOZOIC	Cretaceous	136		First stages of Rocky Mountains
	Jurassic	190		Age of Dinosaurs
	Triassic	225		Breakup of Pangaea; opening of Atlantic
PALEOZOIC	Permian	280		
	Carboniferous — Pennsylvanian	320		Consolidation of continents to form supercontinent of Pangaea
	Carboniferous — Mississippian	345		
	Devonian	395		
	Silurian	430		First land plants
	Ordovician	500		Primitive fish
	Cambrian	570		Rise of atmospheric O_2; first abundant shelled invertebrates
PRECAMBRIAN	Proterozoic	2300		
		2800		
	Archean	4600		Oldest rock; oldest life forms
		4700		Formation of Earth — Assembly of the solar nebula

The geological time scale, expressed in millions of years before the present (Myr BP); the vertical scale is not linear. The boundaries between the eras and periods are defined by changes in fossil species types or abundances or by transitions from one major rock

GEOLOGIC TIME
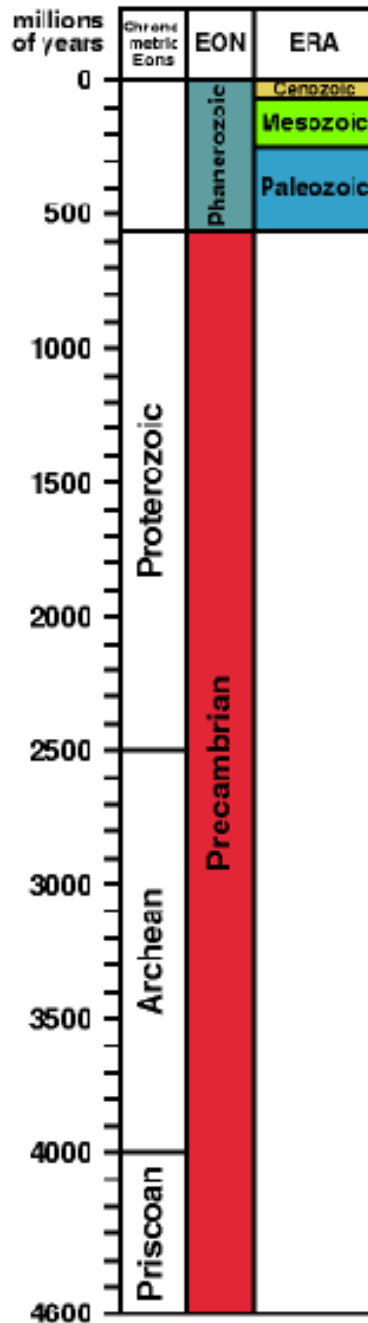
The earth is approximately 4.6 billion years old and has undergone large changes throughout its lifetime. The earliest forms of life may have appeared as early as about 4 billion years ago, with bacteria and algae-like creatures appearing about 2.5 billion years ago. Evidence has emerged recently that about 600-700 million years ago, the Earth was probably completely ice-covered more than once (**snowball earth**). Then, about 540 million years ago, the **Cambrian Explosion** occurred. This marks the first appearance of creatures with hard skeletons and is associated with a striking increase in biological diversity.
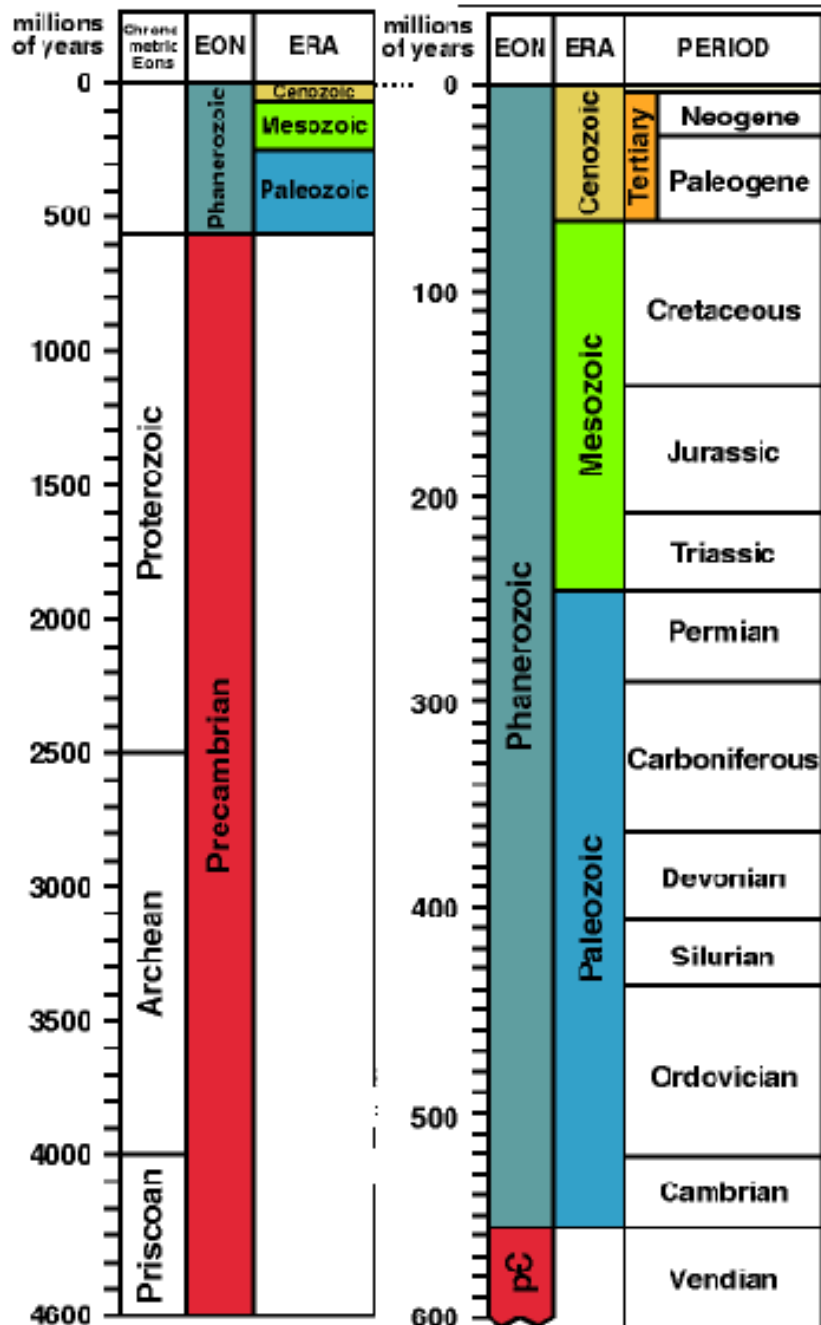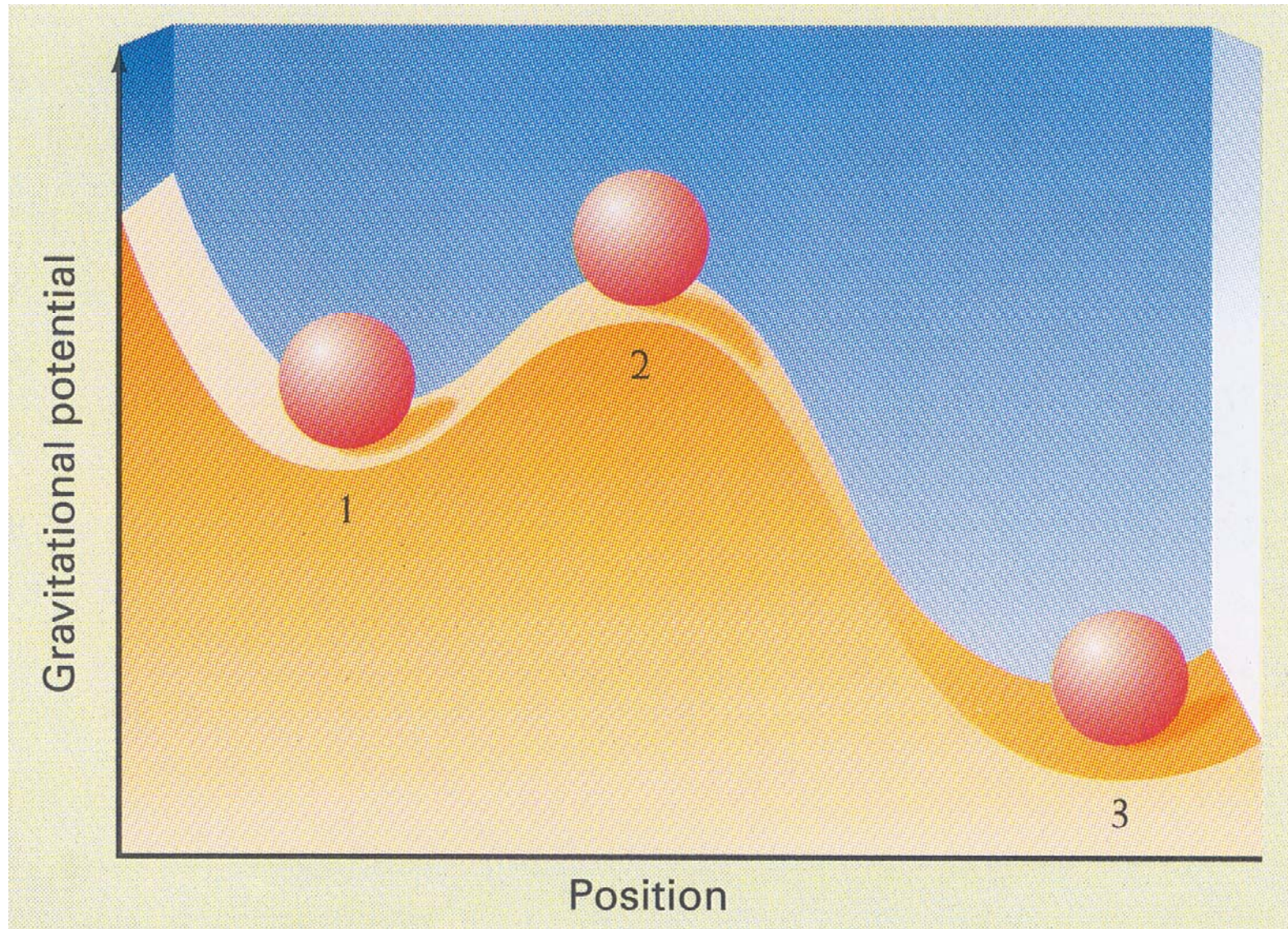
The period since the Cambrian explosion is known as the **Phanerozoic** and is divided into three eras: the **Paleozoic**, the **Mesozoic**, and the **Cenozoic**. These eras are further subdivided based on discontinuities in the fossil record (i.e. extinctions).

**Earth's most recent major ecological catastrophe...**

...occurred 65 million years ago.

The fossil record changes abruptly before and after this moment. It indicates that the dinosaurs disappeared at this time. In addition, the majority of other ocean and land animals went extinct.

What happened? The evidence supports the idea that the Earth was struck by an asteroid. Asteroids are constantly colliding with planetary bodies, as evidenced by craters on their surfaces.

Since the beginning of the **Cenozoic era**, the climate has cooled. The Antarctic ice sheet developed. Ice sheets grew and decayed intermittently in the northern hemisphere as well during the last two million years (a period known as the **Pleistocene**). The periods of northern hemisphere glaciation are known as the **ice ages**.

Stability diagram for a mechanical system. The curved surface indicates the boundary of the "states" allowed by the system. The ordinate parameter is the gravitational potential energy. Position 1 is a metastable state, position 2 an unstable state, and position 3 a stable state.
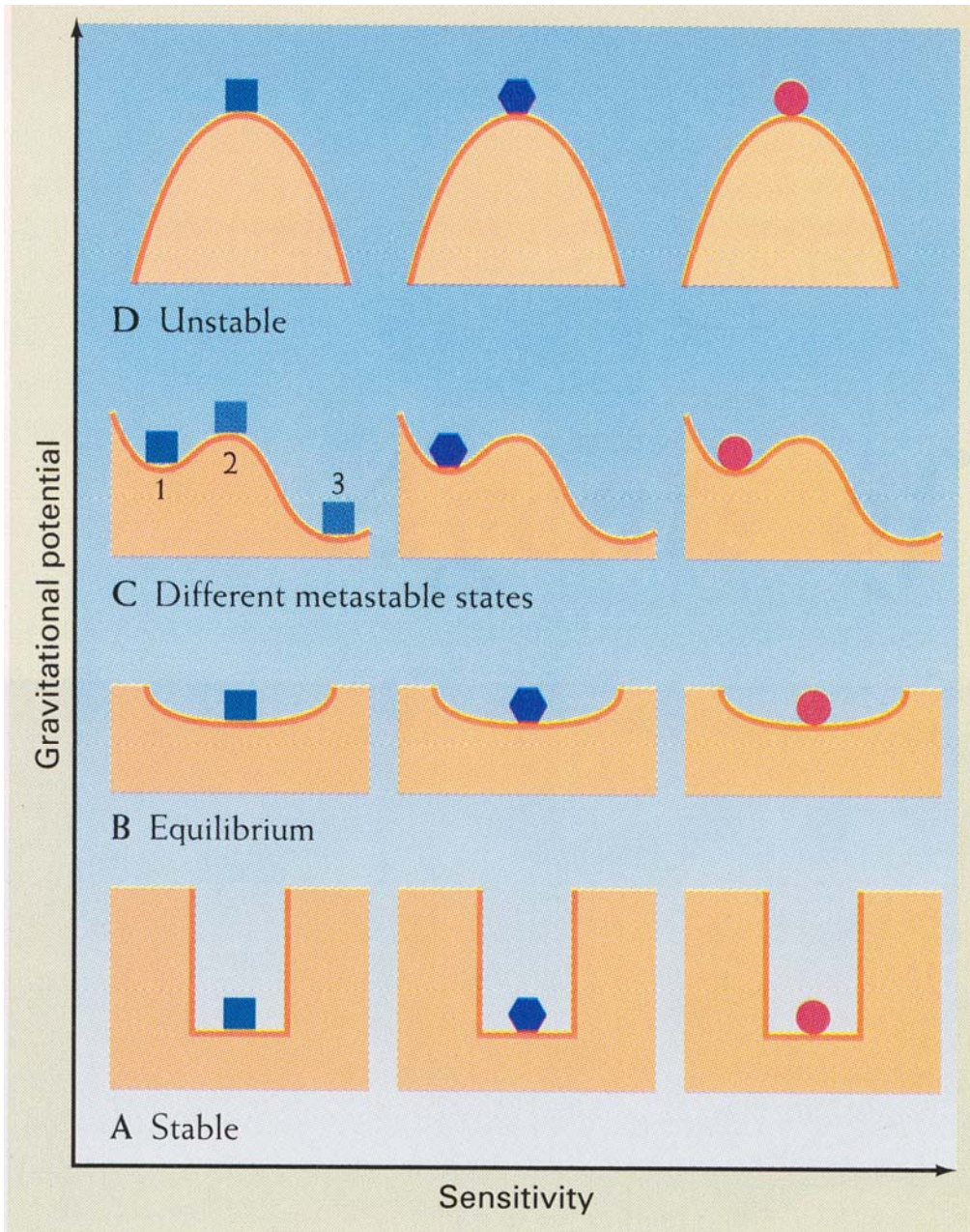
Conceptual diagrams of stabilities for systems of different types and sensitivities. Instability increases from bottom to top; sensitivity to perturbation (suggested by the shapes of the figure) increases from left to right (at least for B, C, and D). The meanings of "small") and "large") are functions of the sensitivity of the system.

A. Stable. Nothing except destruction of the system can cause a change of state.

B. Equilibrium. A perturbation can temporarily modify a state, but the system can never move far from its position on the vertical axis.

C. Different metastable states. If a large enough perturbation is applied, then a new metastable state is achieved.

D. Unstable. A small perturbation causes a radical change of state.

Forcing: e.g., Changes in solar energy and/or atmospheric composition

System's sensitivity: An equal addition of heat causes a greater temperature change in the atmosphere than in the ocean

Weather vs Climate

Weather is the short-time-scale (< a few days) evolution of the of the atmosphere.

Climate is the statistics of weather. It refers to the mean (or average) weather and the deviation from the mean during a particular period.

Weather prediction. The evolution of the state variables of the atmosphere is governed by nonlinear dynamics (i.e. "chaos"), and is therefore inherently unpredictable beyond a certain period of time.

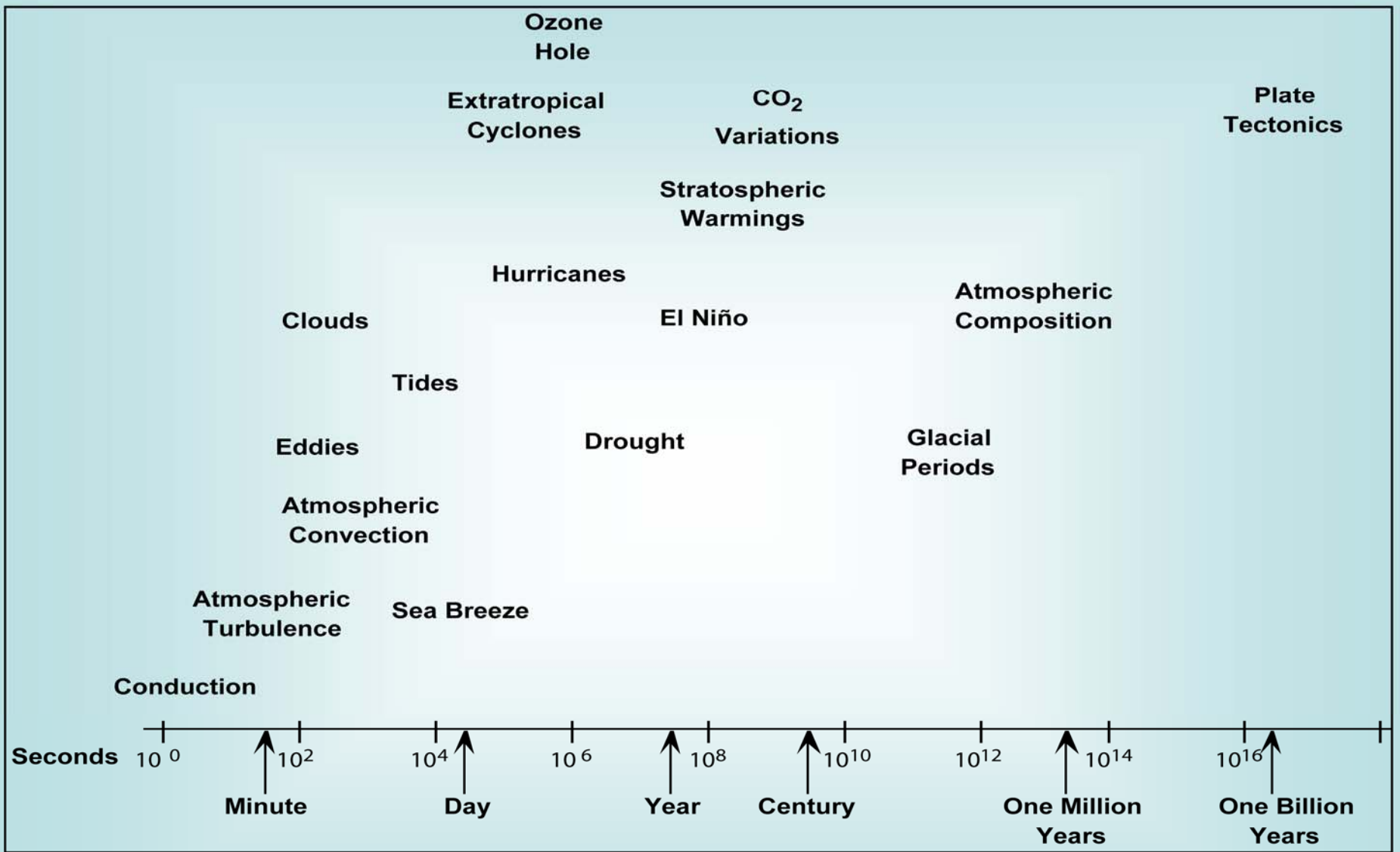Climate prediction. There is no reason to doubt the predictability of the statistics of weather.

Climate Record [Winter Rainfall Anomalies Southern California Coast (NCDC Climate Region 30)]
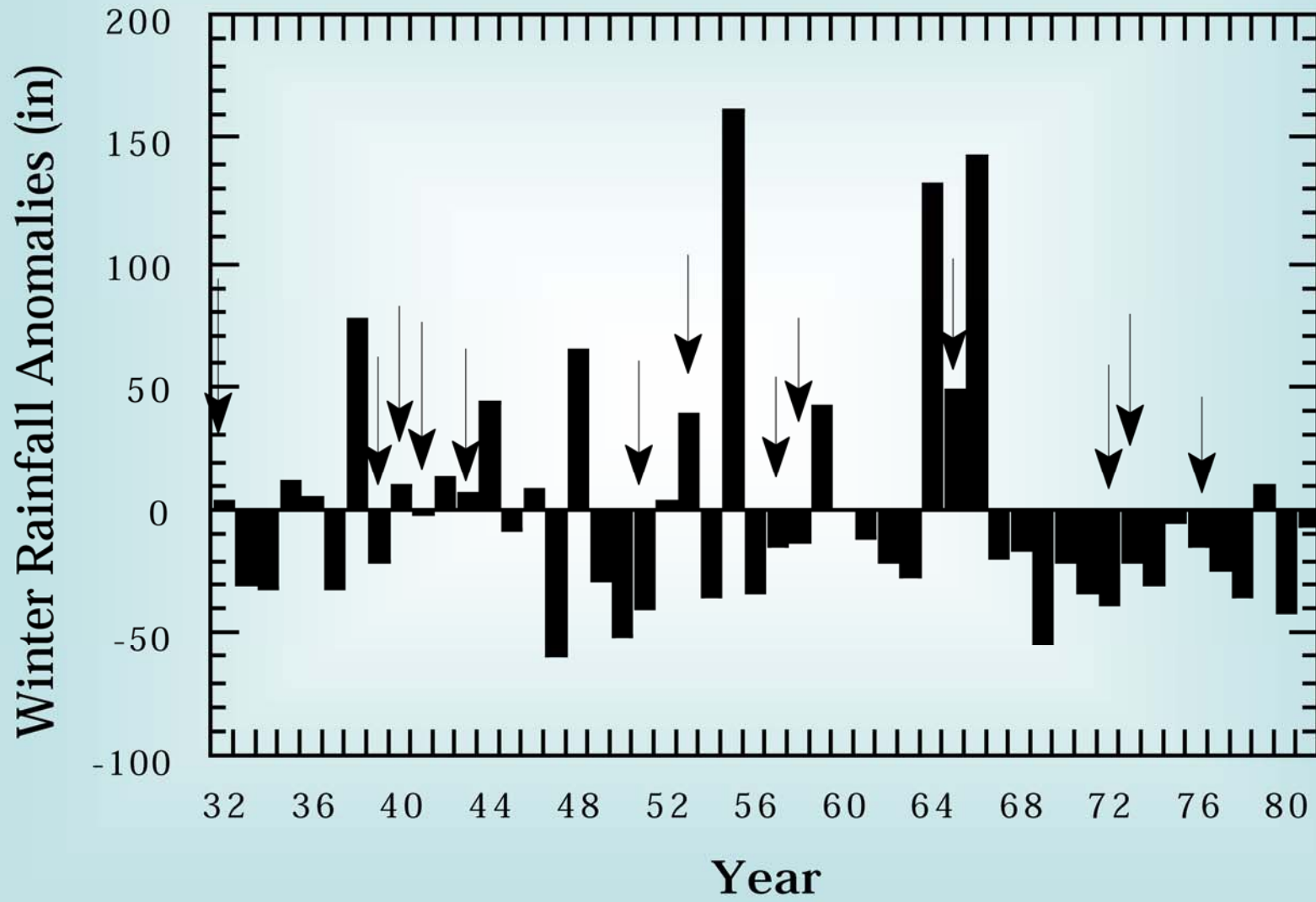
Arrows indicate El Niño events
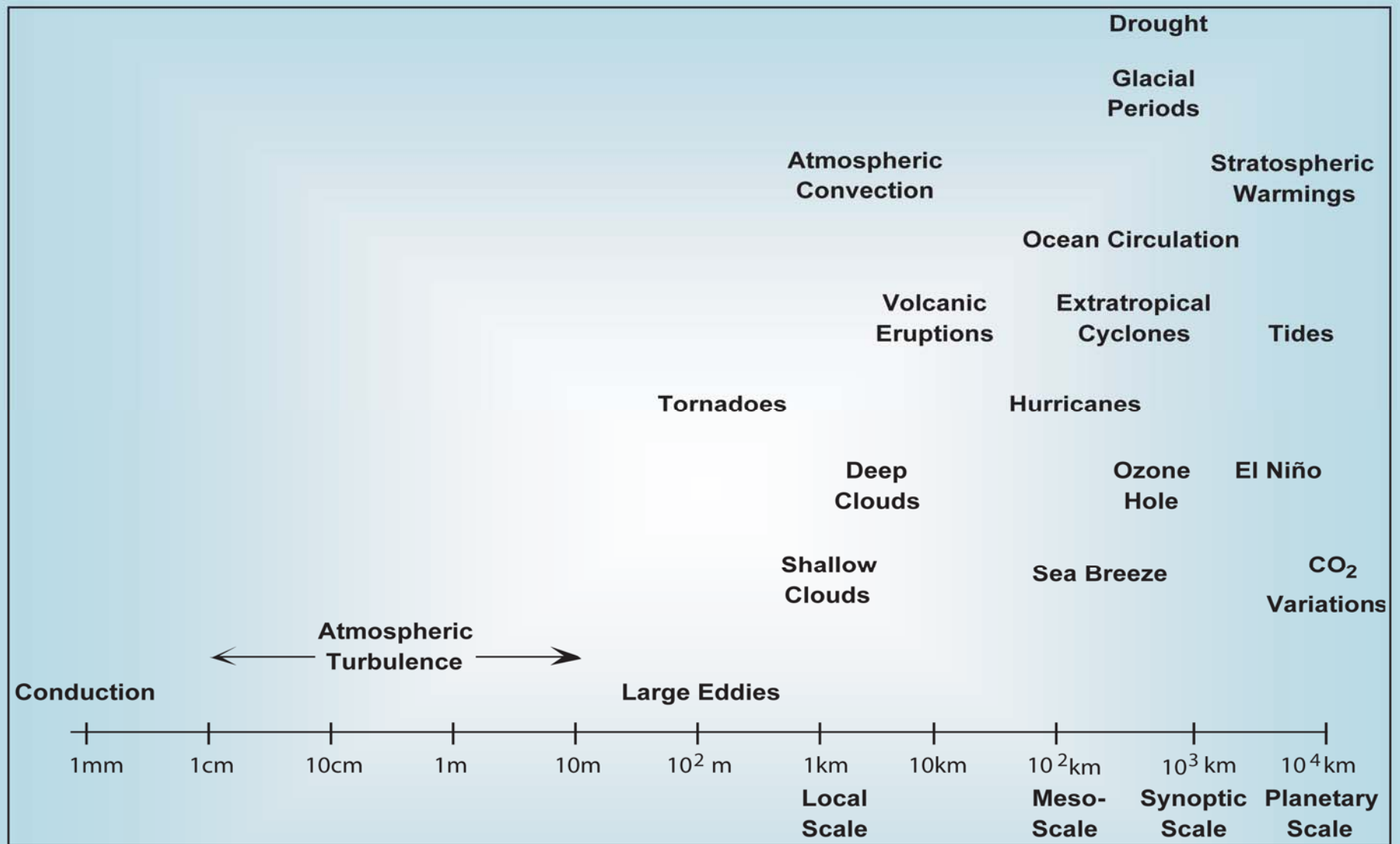
Schematic showing characteristic space scales for various phenomena observed in the Earth-atmosphere system

Schematic showing characteristic time scales for various phenomena observed in the Earth-atmosphere.