

Introduction to climate

Definition of climate: **Averages and variations of properties of the atmosphere, land surface, and ocean**

What *properties*:

temperature

pressure

winds

humidity

clouds

rainfall, snowfall

minor (variable) atmospheric constituents: CO₂, O₃, SO₂, . . .

surface conditions: vegetation, snow cover, sea-ice extent and thickness, . . .

Averaging period:

traditionally 30 years.

must be at least one month to average over weather events

Variations with time:

(a) cyclic

day-night cycle ("diurnal cycle")

seasonal cycle

(b) non-cyclic

interannual variations (some winters are colder than others)

extremes (important practically, particularly for agriculture)

"trend": monotonic (noncyclic) change with time

Spatial scales of climate:

1. global

2. regional (monsoons, polar climates, tropical climates)

3. local (mountains, coastlines)

4. microclimate (lowest 2 meters of atmosphere; e.g. how a single tree affects the climate in the shade below the tree)

This course is concerned with global and regional climate.

Cycles that have to be taken into account in describing climate, caused by variation in flux of solar radiation energy.

cycle	period	solar energy varies by
diurnal	1 day	100%
seasonal	1 year	factor of 4 from December to June in "midlatitudes"(e.g. Seattle 47 N)
sunspots	~11 years	0.1%
<i>Earth's orbit:</i>		
"precession" (time of closest approach to sun)	20,000 years	±10% in summer midlatitude
tilt of axis	40,000 years	

The "climate system"

The climate results from interactions of several components:

atmosphere

ocean (70% of surface)

land surface (40% of NH, 20% of SH): snow, vegetation, soil

ice

solid earth (plate tectonics)

biota

Discoveries of the past 30 years

1. Meteor impacts: climate change caused mass extinction 65 million years ago.
2. A geological feedback regulates CO₂ on million-year time scales. CO₂ dissolves in rainwater and reacts with rocks, removing CO₂ from the atmosphere. The reaction goes faster at higher temperatures.
3. CO₂ oscillates with ice-age cycles.



4. "Gulf Stream" switched on and off during the last ice age, changing temperatures in Greenland by 20 degrees.
5. "Gaia": biological influences on climate, e.g. sulfur gases emitted by algae affect cloud formation
6. Moon's gravity stabilizes tilt of Earth's axis; keeps climate stable. The tilt stays within the range 22-25 degrees, and these small variations are responsible for the ice ages. The tilt of Mars varies from 15 to 40 degrees because it lacks a large moon.
7. "Snowball Earth". Oceans apparently froze all the way to the Equator 700 million years ago. This is the biggest climatic change ever in the history of the planet, yet it was discovered only a few years ago.
8. Artificial chemicals used in refrigerators in the northern hemisphere destroy ozone over Antarctica. This startling discovery in 1985 changed our worldview about the relation of humans to the global environment.

Time scales of Earth history

1 hour	Development of a thunderstorm
1 day	Day-night cycle of sunlight
1 week	Storm system crosses a continent
1 month	Several weather systems; smallest averaging period for a climatic anomaly
1 year	Seasonal cycle
	Time-scale for fallout of stratospheric aerosols from volcanoes El Niño
10 years	Sunspot cycle (11 yr)
	Response time for surface ocean (~20 yr)
100 years	
	Beginning of anthropogenic CO ₂ rise 200 yr B.P.
1000 years	
	Mixing time for deep ocean
10,000 years	
	Earth's orbital variations, ice-age cycles
100,000 years	
	Large ice sheets on northern continents beginning 700,000 yr B.P.
10 ⁶ years	Continents drift only 10 km
	Greenland became glaciated 3 Myr B.P.
10 ⁷ years	Significant continental drift: 100 km
	Antarctica became glaciated 30 Myr B.P.
10 ⁸ years	Large continental drift, 1000 km. Dinosaurs thriving 100 Myr B.P.
	Limit of ability to track continental drift (200 Myr)
10 ⁹ years	Continents unrecognizable
	Atmospheric composition changes (oxygen appeared 2.2 Gyr B.P.).
10 ¹⁰ years	Life span of solar system