Introduction to Earth System

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(also called Vietnam France University)
https://moodle.usth.edu.vn/course/view.php?id=326

Time commitment

Items	Lecture	Tutorial/ Exercise	Practice/ Assignment	Lab-work	Total
No. of hours	20	6	4	0	30

Evaluation and Scoring

Component	Attendance	Exercises	Practical	Reports	Midterm	Final
Percentage %	10	20	20	0	0	50

The winner takes it all

(source: internet)

Classroom Rules

- Respect yourself
- Respect others
- HONESTY
  - On time

Further reading

1. Wallace J.M and P.V. Hobbs: **Atmospheric Science, An Introductory Survey**, 2nd Edition, Academic Press, 504pp.
2. Hyndman Donald and Hydman David: **Natural Hazards and Disasters**, 2nd Edition, Brooks/Cole, 581pp.
3. IPCC assessment reports (TAR, AR4, AR5)
4. Lee R. Kump, James F. Kasting and Robert G. Crane: **The Earth System**, 3rd Edition, Pearson.

Course content

I. Introduction
II. Earth's components
III. Daisy world
IV. The radiation balance of Earth
V. Climate oscillation and climate change

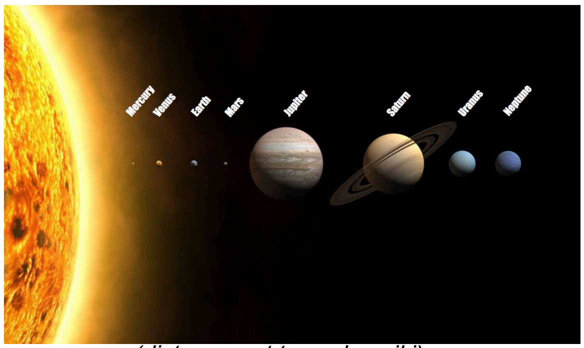
I. Introduction

Our Earth is:

- 'one point' in the universe

  Big Bang: The universe is believed to be formed ~13.8 bil. years ago in an event know as the big bang (beginning of *space-time*)

- 'one planet' in the solar system

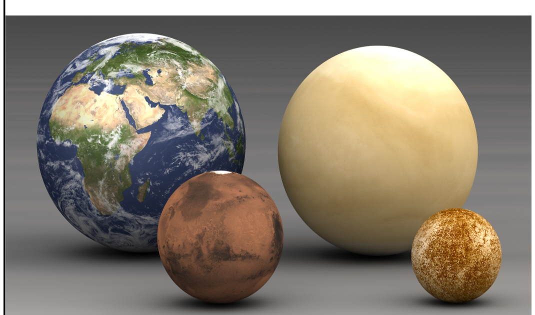


(distance not to scale -wiki)

Age: 4.568 bil. Years
Distance from the Earth to the Sun: 1 Astronomical Unit (1 AU: 150.000.000 km)

The Earth

- Only planet presently known to support life (why?)



(Earth, Mars, Venus, Mercury -wiki)

- **Formed** about 4.5 billion years old
- **Orbital period**: 365.26 days
- **Mean radius**: 6371 km (equatorial: 6378.1 km; polar: 6356.8 km)
- **Total Surface**: ~5.1 x 10^8 km^2
- **Land Surface**: ~1.49 x 10^8 km^2
- **Water**: ~3.61 x 10^8 km^2

The Earth has well-defined continents and ocean basins

Very dynamic, both internally and externally

Orbits

- **Ptolemy** (AD90-AD168, Greek): geocentric model → universally accepted for centuries
- **Nicolas Copernicus** (14783-1543): first person to propose the Earth circles the Sun
  - The planetary orbit is a circle
  - The Sun at the center
- **Johannes Kepler** (1571-1630): **3 Kepler's laws of planetary motion**
  1. The orbit of a planet is an ellipse with the Sun at one of the two foci *(1609)*
  2. A line segment joining a planet and the Sun sweeps out equal areas during equal intervals of time *(1609)*
  3. The square of the orbital period of a planet is proportional to the cube of the semi-major axis of its orbit *(1619)*

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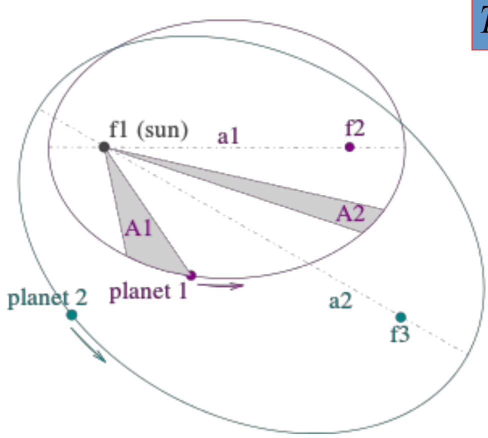
Orbits

3 Kepler's laws of planetary motion

$$\frac{a_1^3}{T_1^2} = \frac{a_2^3}{T_2^2} = \ldots\ldots = \frac{a_i^3}{T_i^2} = \ldots\ldots = K$$

$K=G\,(m_p + m_s)/\,(4\,\pi^2)$
G: gravitational constant
m_s: mass of the sun
m_p: mass of the planet



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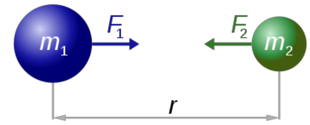
$G=6.674\times10^{-11}\ N \cdot (m/kg)^2$

Orbits

Newton's law of universal gravitation

- G is the gravitational constant (6.674×10^{-11} N · $(m/kg)^2$)



$$F_1 = F_2 = G\frac{m_1 \times m_2}{r^2}$$

Q1: At which velocity the satellite will not fall down into the Earth?
Q2: At which velocity the satellite can escape from the gravitational attraction of the Earth?
Q3: At which velocity the satellite can escape from the Sun system
Q4: At what speed does the Earth move around the Sun

Orbits

Balance between gravitational force and centrifugal force

$$mg = \frac{mv^2}{R} \rightarrow v = \sqrt{gR}$$

where $g = \frac{GM}{R^2}$

g~9.8m/s, R~6378km → v_1~7.9km/s

v_3~16.6km/s

velocity that the satellite can escape from the Sun system

Conservation of Energy (kinetic energy & gravitational potential energy)

$$\frac{mv_2{}^2}{2} - \frac{GMm}{R} = 0$$

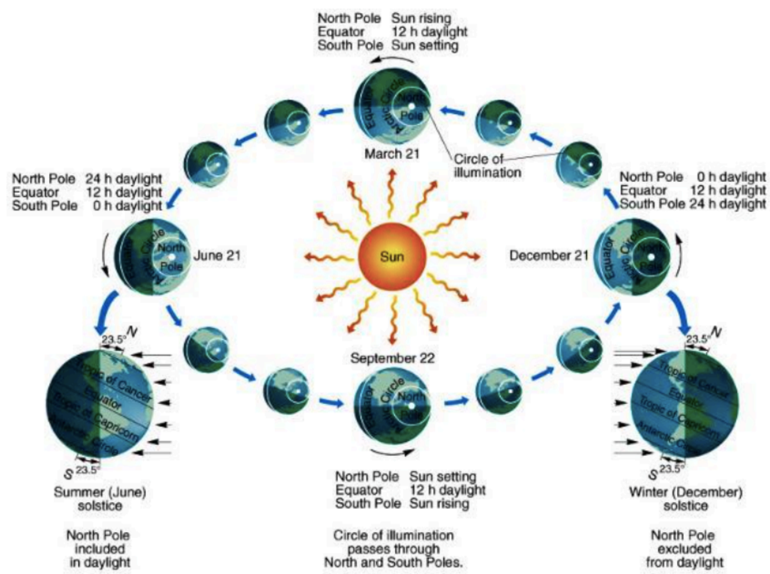
$$\rightarrow v_2 = \sqrt{2}v_1 \rightarrow v_2\text{~}11.2 \text{ km/s}$$

Escape velocity: The minimum speed needed for an object to escape from the gravitational attraction of a massive body

Further reading (homework)
- Geostationary orbit
- Polar orbit
- Low orbit

- When v_1<v <v_2 → The satellite has an elliptical orbit around the Earth
- When v_2<v <v_3 → become a satellite/planet of the Sun

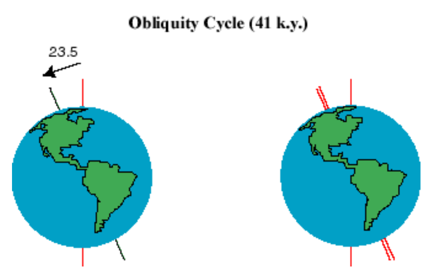
Milankovitch Theory



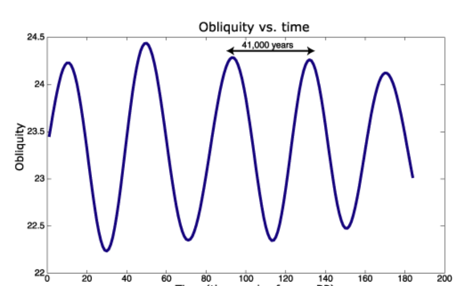
Earth's rotation and Revolution

Orbital scale: Milankovitch Theory

- **Obliquity**: the variation of the tilt of the earth's axis away from the orbital plane

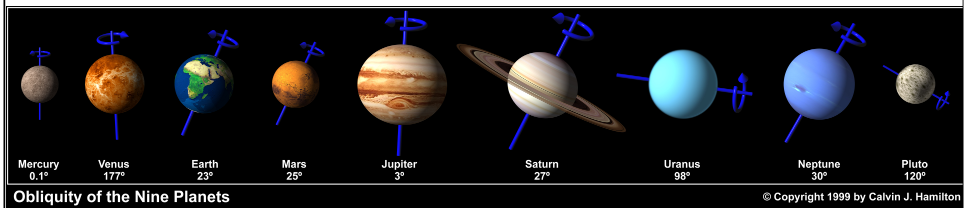


- ~41000 yrs
- Obliquity Range: 22.2º to 24.5º



- Greater tilt means stronger seasonal variations
- Most noticeable at high latitudes

Obliquity of the Planets, and the direction of spin



- *Earth & Mars*
- *Uranus, Pluto*
- *Venus*

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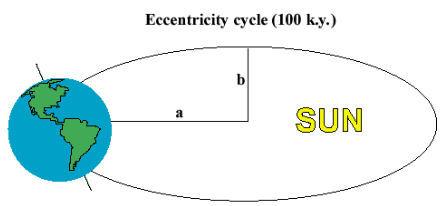
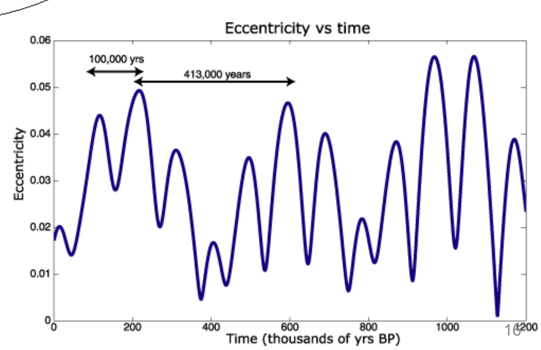
Orbital scale: Milankovitch Theory

Eccentricity: indicates the shape of Earth's orbit around the sun



- Period: 100,000 dominates and the 413,000 amplifies every 4th one

$$e = \sqrt{1 - \frac{b^2}{a^2}}$$



Eccentricity:
- -0.005 to 0.06 (0 → a circle)
- currently 0.017

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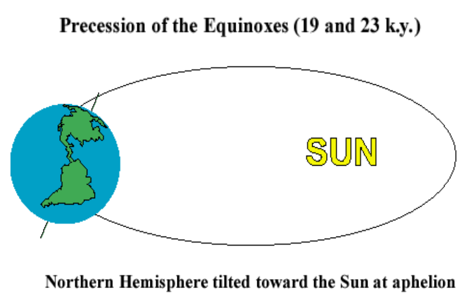
Orbital scale: Milankovitch Theory

Precession: change in orientation of the Earth's rotational axis; 19,000-23,000 years



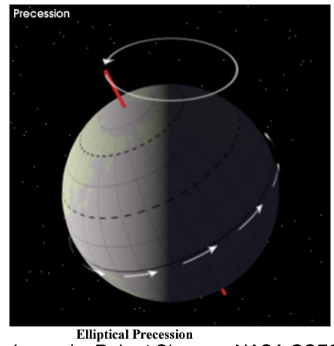
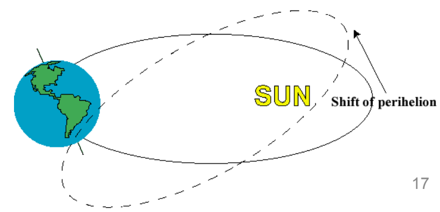
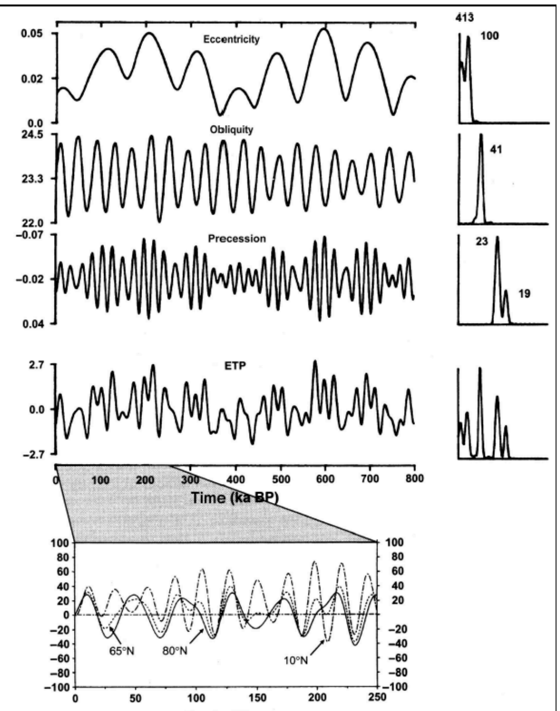


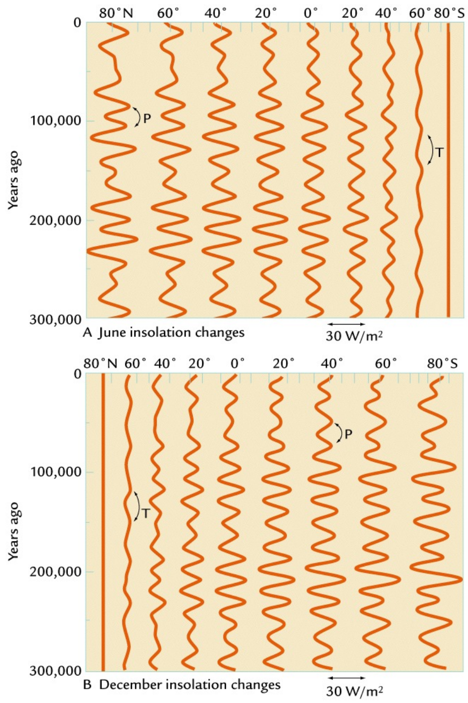
Image by Robert Simmon, NASA GSFC



Variations of eccentricity, tilt (obliquity), precession, and the combination of all three factors (ETP) over the last 800,000 years with their principal periodic characteristics indicated by the power spectrum to the right of each time series (Imbrie et al., 1993).



Time series of July solar radiation anomalies at 10, 65, and 80N (expressed as departures from 1950ADvalues). (Berger and Loutre, 1991)



Orbital scale insolation change

- Strong 23 ky (precession) and 40 k cycles (Obliquity)
- 100 ky cycle is not obvious

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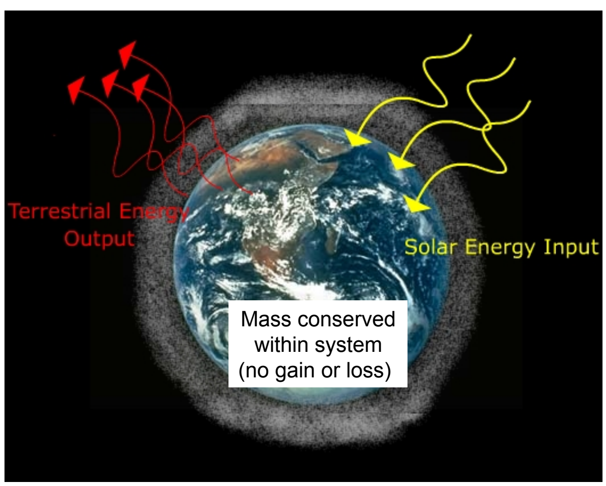
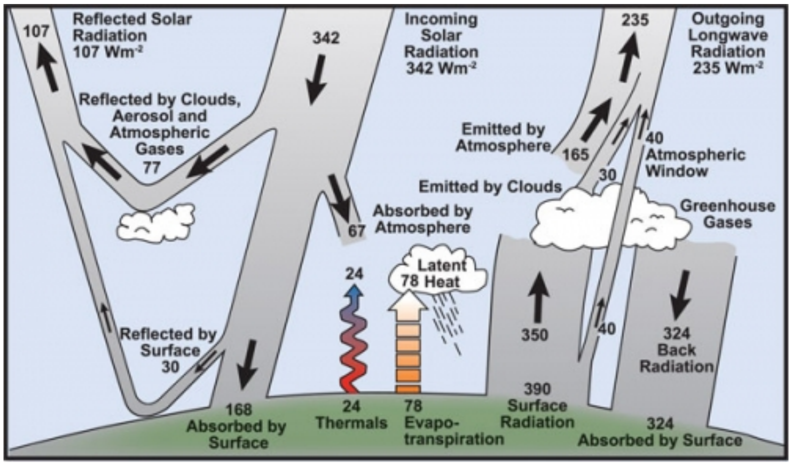
The Earth

- exchange of energy but negligible exchange of mass with surroundings



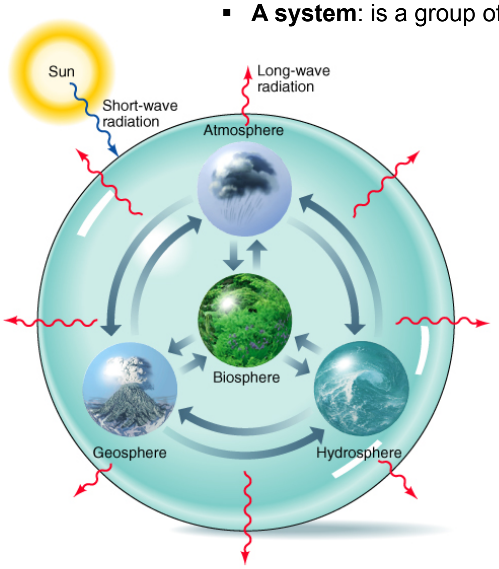
Energy balance



- When the climate system reaches steady state, i.e. temperature stops changing → amount of energy going out = amount of energy coming in
- **Radiative forcing**

Four Spheres of the Earth System

- **A system**: is a group of components that interact



4 major, interlinked components:

- **Geosphere**: includes all rocks, or consolidated mixtures of crystalline materials called minerals, and all unconsolidated rock fragments
  - ✓Core, mantle, and crust
- **Hydrosphere**: composed of the various reservoirs of water, including ice
- **Atmosphere**: a thin envelope of gases that surrounds Earth
- **Biosphere**: include all living organisms

Energy and matter are exchanged between these components.

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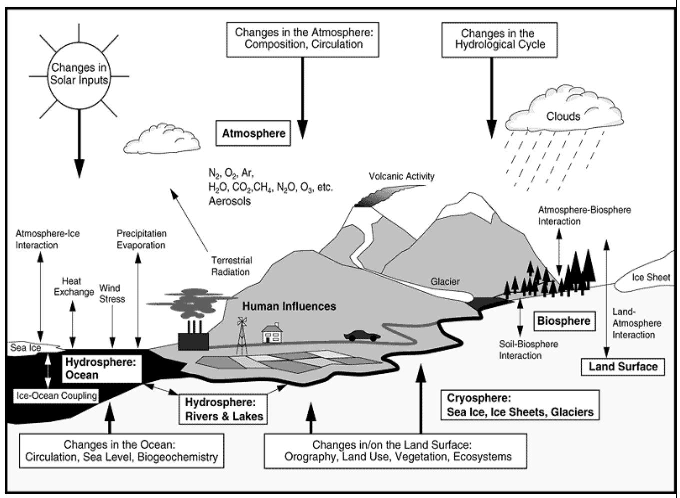
Components of the Earth System

Q: How the different components of the Earth System interact in response to various internal and external influences, or forcings?



IPCC, 2001

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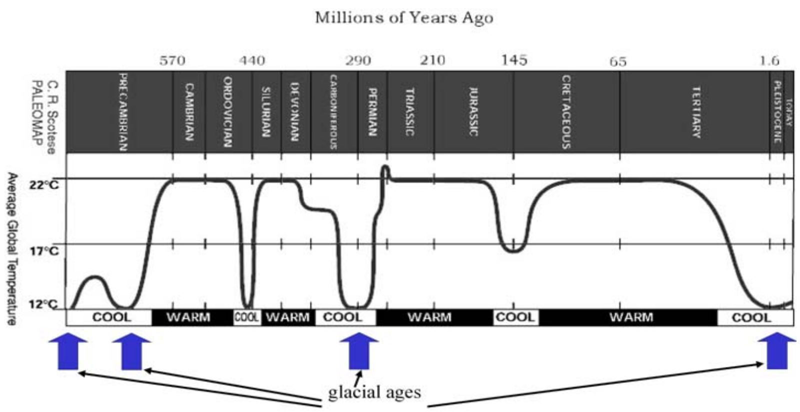
Temporal scales

- **millions/billions of years**: evolution of solid earth structures, atmosphere
- **Millions of years**: tectonic, species distributions, etc.
- **Thousands years**: evolution of Earth's orbit
- **Decades to centuries**: physical climate system, biochemical processes like carbon, nitrogen
- **Days/seasons**: weather, plant growth, decay
- **Day**: heating & cooling, volcanoes, earthquakes, etc.

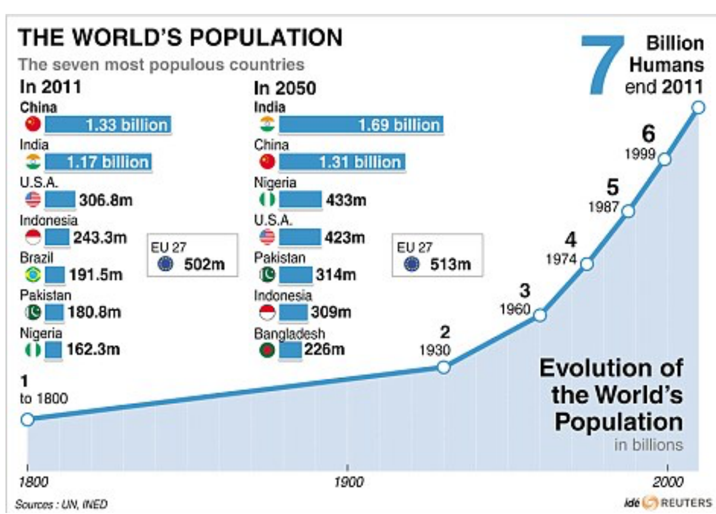
I. Introduction

Temporal scales



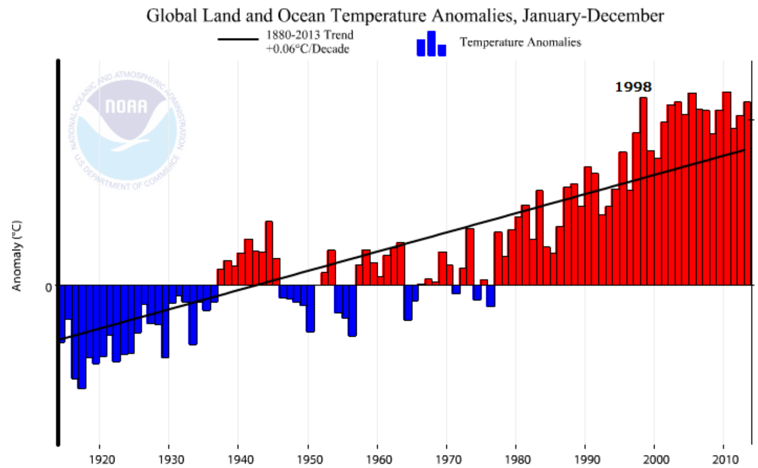
The Earth is changing

7.7 billion (2019)



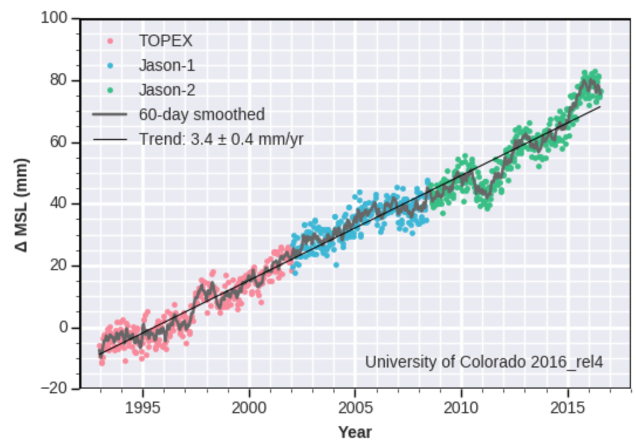
The Earth is changing

Why?



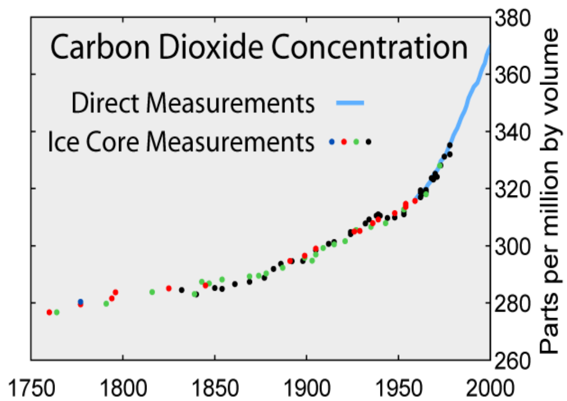
The Earth is changing

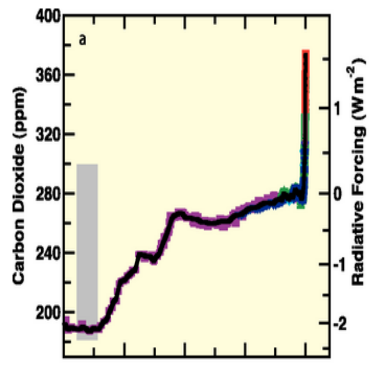
Why?



The Earth is changing

Why?

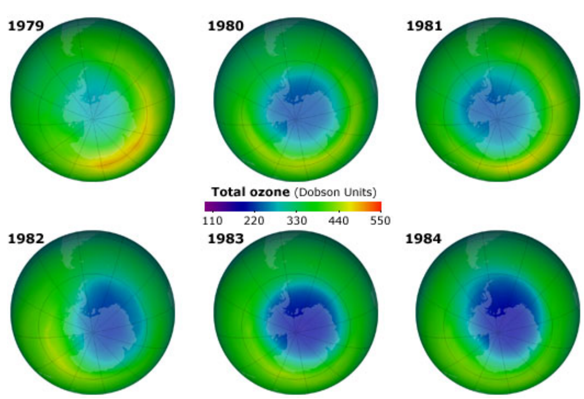




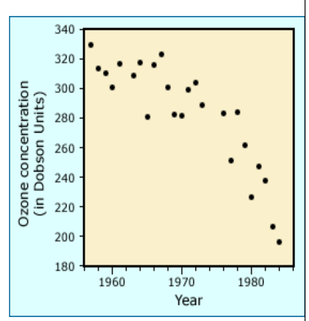
Credit: *Robert A. Rohde and the Global Warming Art project.*

The Earth is changing

Why?

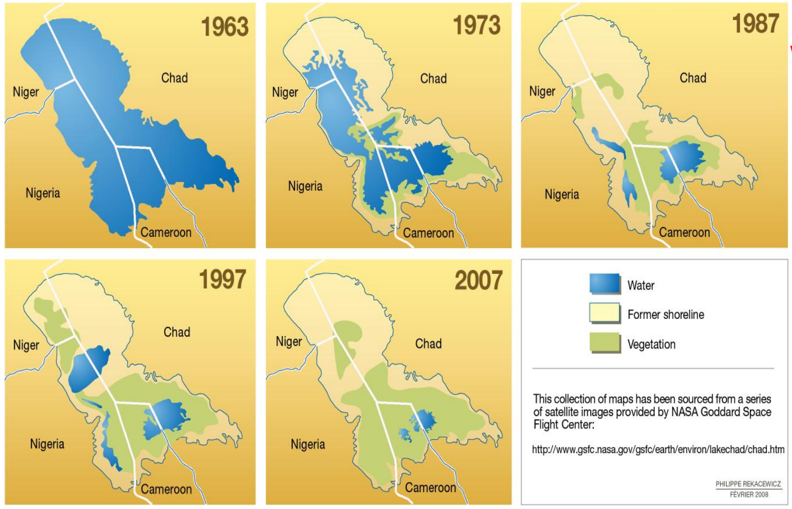


http://undsci.berkeley.edu



Average October ozone levels recorded by Farman's group at Halley Bay, Antarctica

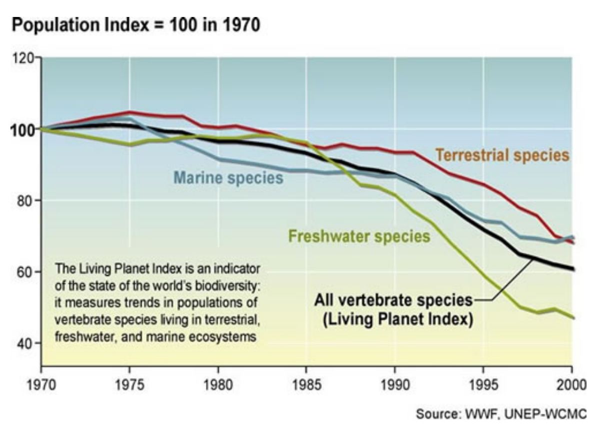
The Earth is changing



Why?

Lake Chad: Freshwater **lake** located in the Sahelian zone of west-central Africa at the conjunction of **Chad**, Cameroon, Nigeria, and Niger

The Earth is changing



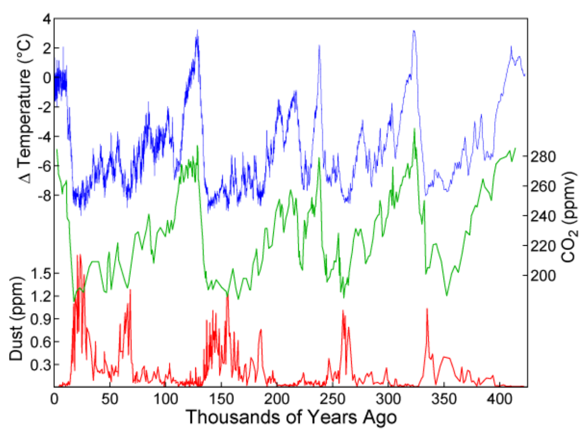
Biodiversity: The rate of extinction is now ~100 times greater than the natural rate → our modern period is often called "The Sixth Mass Extinction" with reference to biodiversity loss

- Our world maybe changing faster than it ever has
- What is the cause?
  - Human activity

Among the following changes, which should be the most serious problem?
✓ Global warming
✓ Ozone depletion
✓ Biodiversity changes (e.g. the loss of tropical species)

To answer the above question, one way of judging the severity of a problem is to estimate how long it would take Earth to recover

Vostock ice core 3623 m (Antarctic) → 420 k yr ago



Q: period of these natural cycles?
Q: relationships: dust, CO_2, Temperature?
Q: why there is such a cycle for CO_2?

Homework 1

1. Describe the water exchange within the 4 components of the Earth System

2. Go to the following site to download the monthly CO2 data measured at Mauna Loa from March 1958: ftp://aftp.cmdl.noaa.gov/products/trends/co2/co2_mm_mlo.txt, use Excel and/or other softwares that you can to answer the following questions:
   - Where is the Mauna Loa Observatory?
   - Comment about the seasonal cycle of the concentration of CO2
   - Comment about the trend of CO2 during 1958-present

3. Download another set of CO2 data observed at the South Pole

http://scrippsco2.ucsd.edu/assets/data/atmospheric/stations/flask_co2/monthly/monthly_flask_co2_spo.csv

   – Plot and compare with the data at Mauna Loa

Preparation for Practical's session

HOW TO INSTALL PYTHON

1. Download the latest version at: https://www.python.org/downloads/
2. Install additional packages numpy, matplotlib

- **Windows:**

Open cmd (https://www.wikihow.com/Open-the-Command-Prompt-in-Windows); go to the folder Python (cd "link_to_the_folder"), then enter the folder Scripts, type:

```
pip install numpy
pip install matplotlib
```

- **MacOS and/or Linux:**

Open Terminal and type:

```
python3.6 -m pip install numpy
python3.6 -m pip install matplotlib
```