UNIT-2 CLIMATE INDICES AND EXTREME EVENT

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CLIMATOLOGY

- Climatology, or sometimes known as **climate science**, is the **study of the Earth's weather patterns and the systems** that cause them. From the ocean oscillations to trade winds, pressure systems that drives temperature, airborne particles that influence local conditions and even the phases of the moon and Earth's wobble all affect the climate

  The word “climatology” comes, as may scientific words and terms do, from the Greek. **clima means “zone” or “area” and “logia” means “study”.** This means that climatology is the “study of zones” although in reality it is much more complicated than that.

Climatology: An Atmospheric Science

Atmospheric scientists often subdivide study of complexity of gaseous envelope that surrounds the earth into specific areas of interest. One such division identifies the fields of meteorology and climatology. **Meteorology** is a science that deals with motion and the phenomena of the atmosphere with a view to both forecasting weather and explaining the processes involved. It deals largely with status of atmosphere over a short period of time and utilizes physical principles to attain its goal. **Climatology** is the study of atmospheric conditions over a longer period of time. It includes the study of different kinds of weather that occur at a place. Dynamic change in the atmosphere brings about variation and occasionally great extremes that must be treated on the long term as well as the short term basis. As a result, climatology may be defined as the aggregate of weather at a place over a given time period.

There is diversity of approaches available in climate studies. Figure 1. Illustrates the major subgroups of climatology, the approaches that can be used in their implementation, and the scales at which the work can be completed.

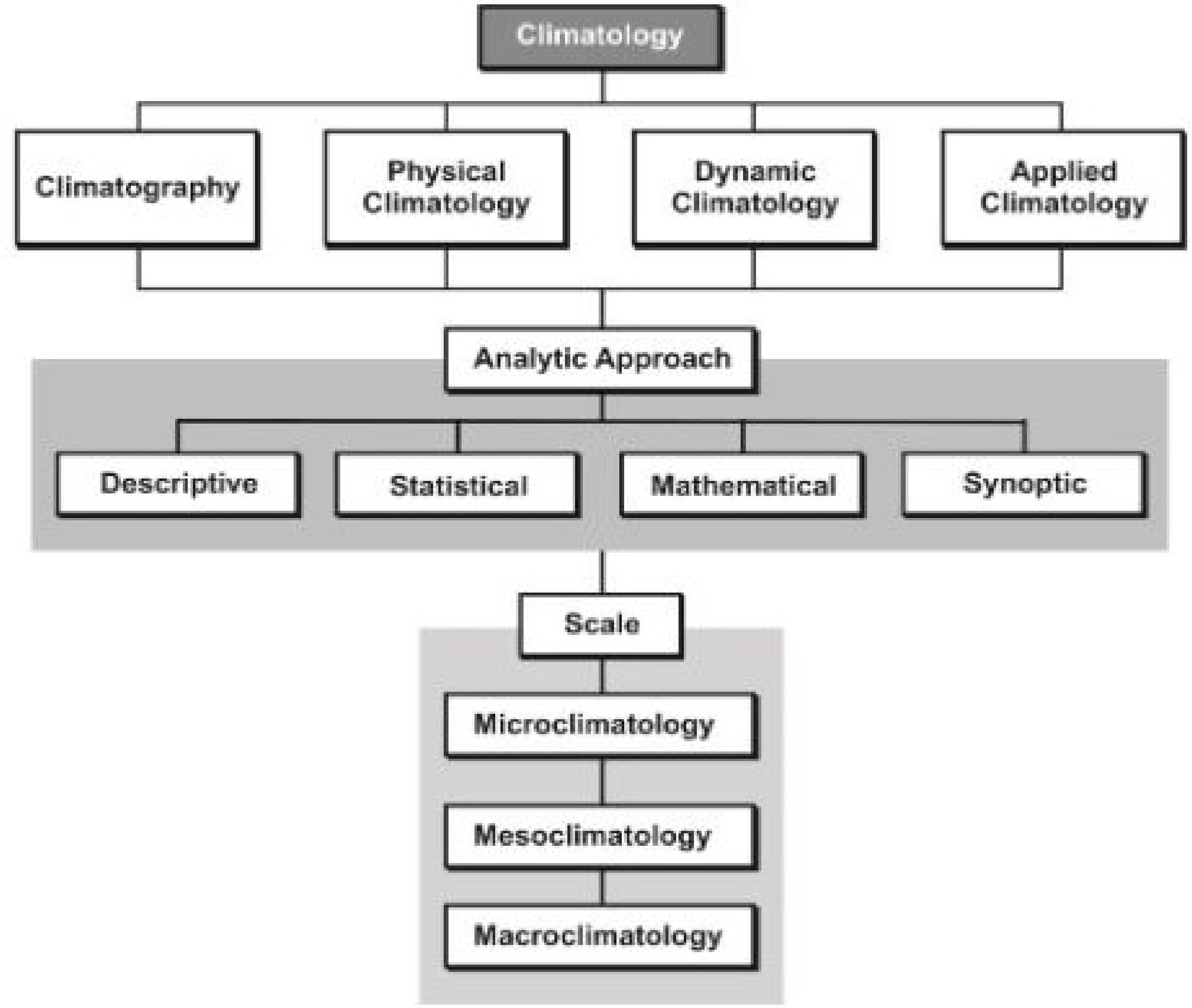


Figure 1. Subgroups, Analytical methods and scales of climatic study.
(From J. E. Olive 1981, P4 used by permission of V. H. Winston and Sons.)

WHAT DOES CLIMATOLOGY DEALS WITH?

Climatology deals with the following characteristics.

- Earth sun relationship
- Distribution of solar radiation
- Terrestrial radiation and heat balance
- General circulation of atmosphere
- Distribution of wind, temperature, pressure over the surface of the earth.

APPLICATIONS OF CLIMATOLOGY

- Climatology is a fascinating area of study. It relates directly in which the environment functions and the everyday lives of people in addition to workings and nature of the atmosphere. Applied Climatology is used to –

a) Improve efficiency of various economic activities that are influenced by climate

b) Aid in the needs of societal activities

c) Reduce the losses incurred from climatic hazards

EXAMPLES: Energy, Food, water, Health etc..

PALEOCLIMATOLOGY

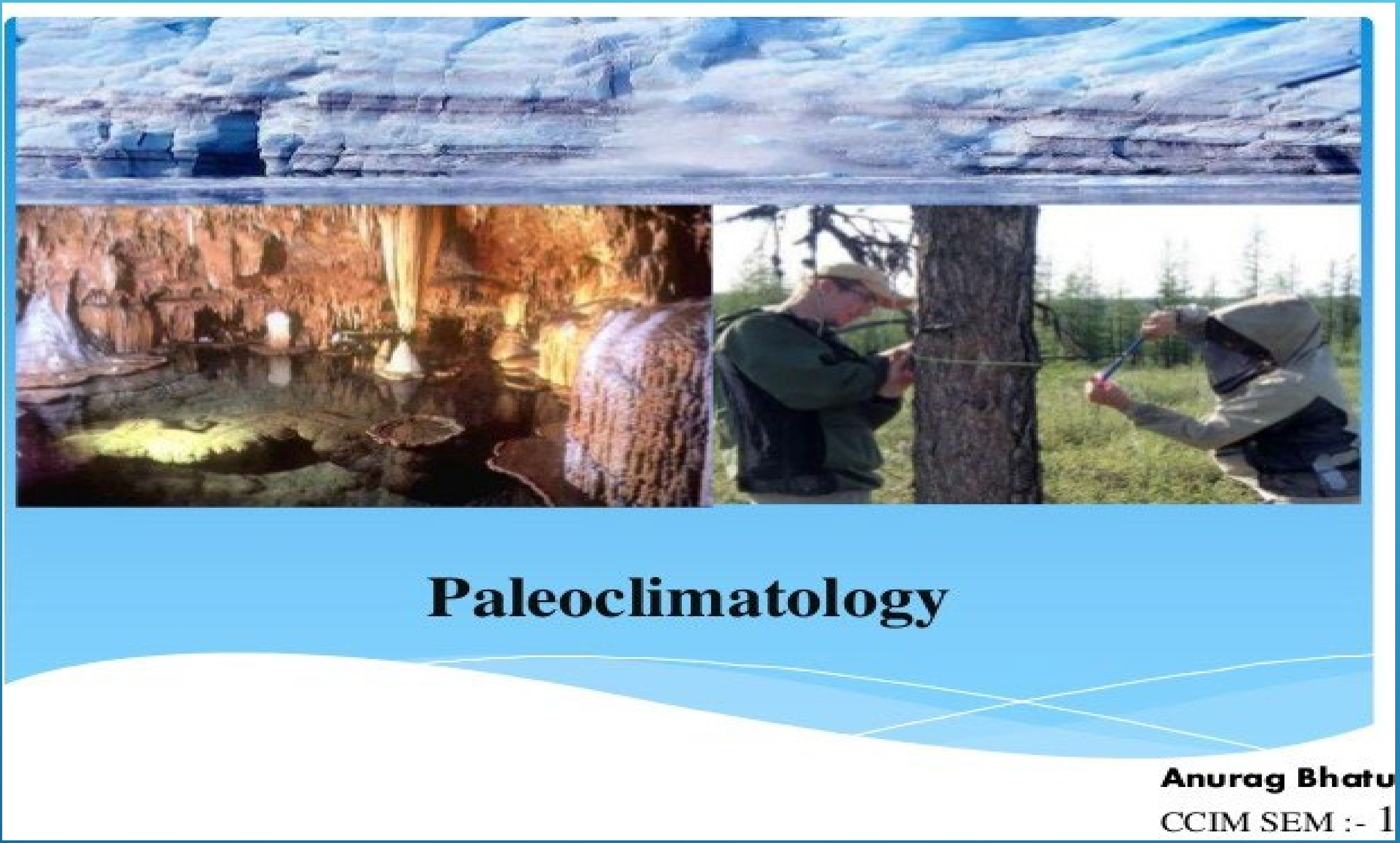
Definition

Paleoclimatology is the **study of past climates.** Since it is not possible to go back in time to see what climates were like, scientists use imprints created during past climate, known as proxies, to interpret paleoclimate.

Proxy data is data that paleoclimatologists gather from natural recorders of climate variability.

Example: tree rings, ice cores, fossil pollen, ocean sediments, coral and historical data.

PALEOCLIMATOLOGY



PALEOCLIMATOLOGY

- **Paleoclimatology** is the study of climates for which direct measurements were not taken.
- As instrumental records only span a tiny part of Earth history, the reconstruction of ancient climate is important to understand natural variation and the evolution of the current climate.
- Paleoclimatology uses a variety of proxy Paleoclimatology uses a variety of proxy methods from the Earth Paleoclimatology uses a variety of proxy methods from the Earth and life sciences

  Paleoclimatology uses a variety of proxy methods from the Earth and life sciences to obtain data previously preserved within rocks Paleoclimatology uses a variety of proxy methods from the Earth and life sciences to obtain data previously preserved within rocks, sediments Paleoclimatology uses a variety of proxy methods from the

S1: SLO 2: PALEOCLIMATOLOGY

- The scientific field of paleoclimatology came to maturity in the 20th century.
- Studies of past changes in the environment and biodiversity often reflect on the current situation, specifically the impact of climate on mass extinctionsStudies of past changes in the environment and biodiversity often reflect on the current situation, specifically the impact of climate on mass extinctions and biotic recovery and current global warming.
- Paleoclimatologists employ a wide variety of techniques to deduce ancient climates.
- The techniques used depend on which variable has to be reconstructed (temperature The techniques used depend on which

variable has to be reconstructed (temperature, precipitation or

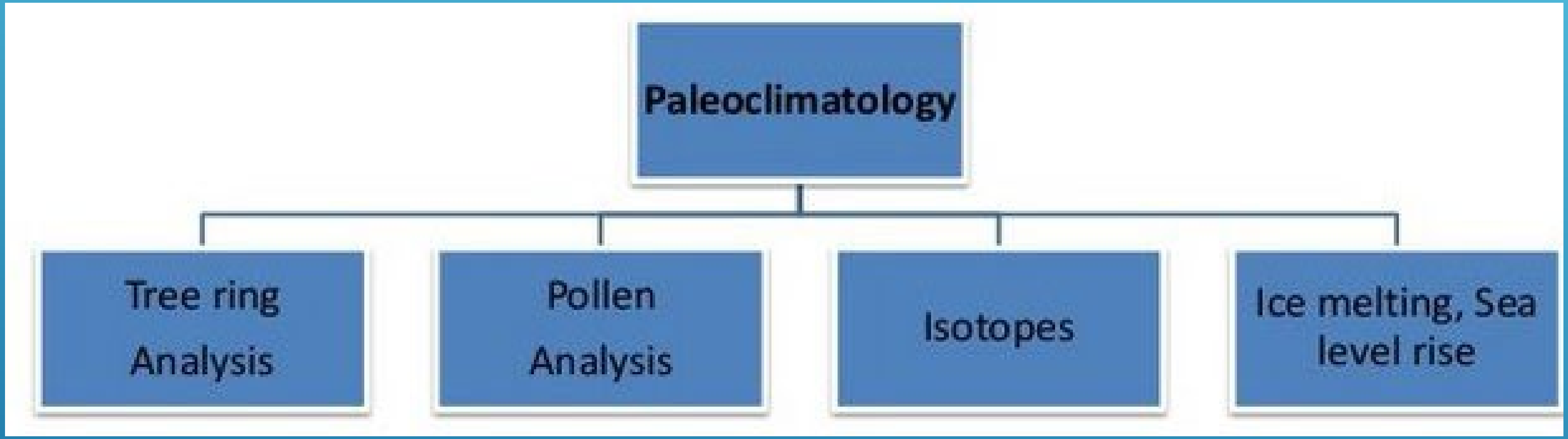
PALEOCLIMATOLOGY

- For instance, the deep marine record, the source of most isotopic data, exists only on oceanic plates, which are eventually subducted.
- **NCEI [National Centre for Environmental information]** provides the paleoclimatology data and information scientists need to understand natural climate variability and future climate change. We also operate the World Data Service for Paleoclimatology, which archives and distributes data contributed by scientists around the world

PALEOCLIMATOLOGY

- The study of paleoclimates has been particularly helpful in showing that the Earth's climate system can shift between dramatically different climate states in a matter of years or decades. The study of past climate change also helps us understand **how humans influence the Earth's climate system.**
- The paleoclimatic record also allows us to examine the causes of past climate change and to help unravel how much of the 20th century warming may be explained by natural causes, such as solar variability, and how much may be explained by human influences.

PALEOCLIMATOLOGY



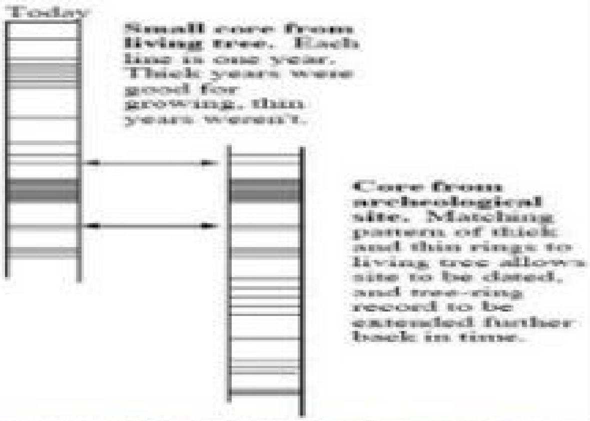
PALEOCLIMATOLOGY

Tree Ring Analysis

- Tree ring analysis is also known as dendrochronology.
- From the growth rings or tree rings we can easily predict about the past climates.
- There are mainly two type of chronologies.

Dendrochronology

- Floating Chronology
- Anchored Chronology



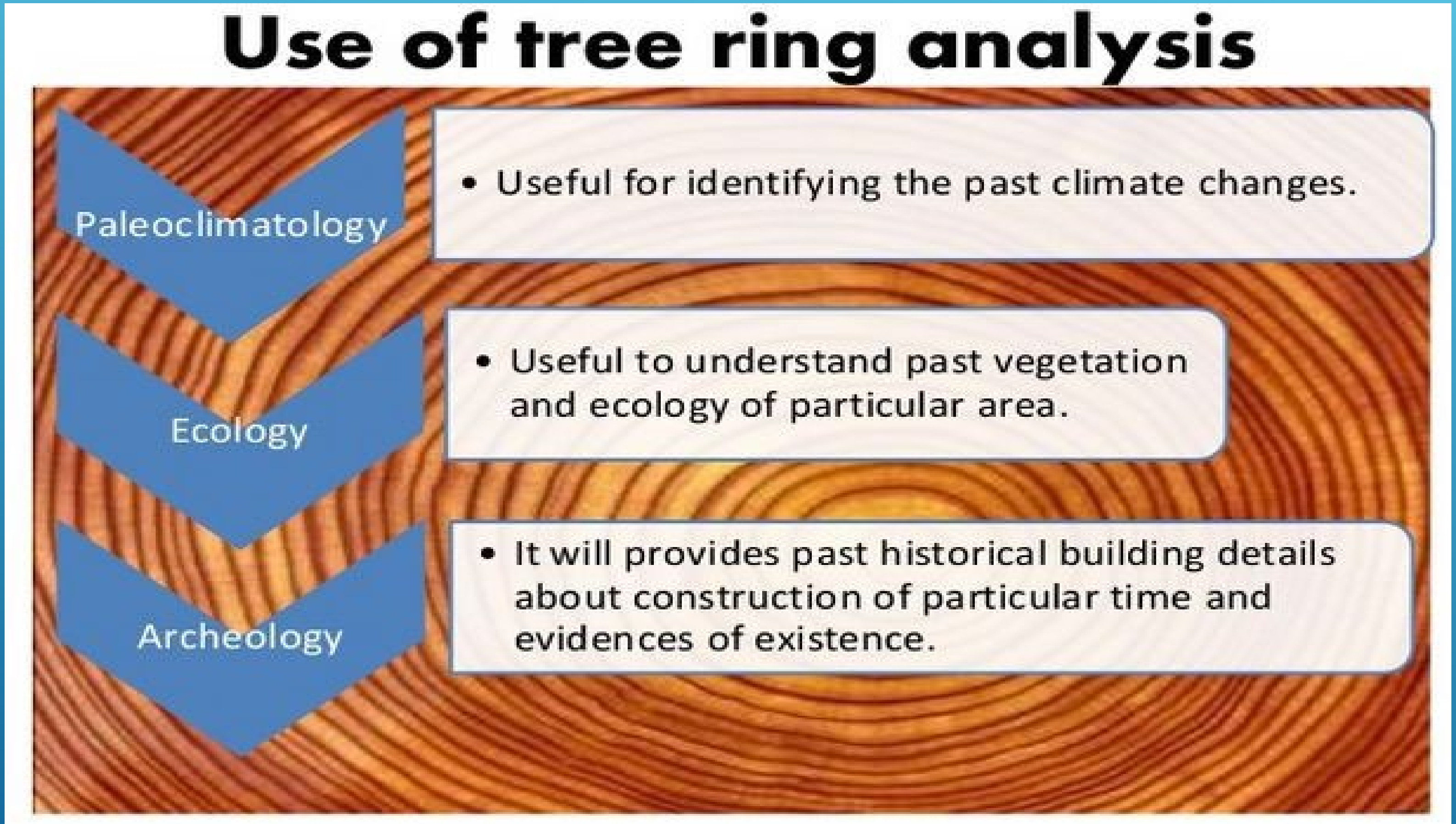
- Also the instrument which used for the taking cross section is called as Borer.

PALEOCLIMATOLOGY

About tree ring analysis

- Each ring represents one year
- Records are thousands of years old in some trees
- Light colored – Spring
- Dark colored – Late summer
- Tree rings are more visible in temperate zone
- Also during studies need attention towards identifying false rings
- Fully anchored chronologies in northern hemisphere are extended upto 13,900 years

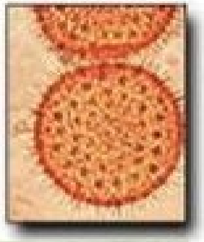
PALEOCLIMATOLOGY



PALEOCLIMATOLOGY

Pollen analysis

- Pollen analysis is also known as Palynology.
- Used for analyze the plant pollen
- Pollen grains rang size 10 to 150 µm
- In summer air is filled of pollens
- Palynologists collects core of sediment or pea date layer
- Pollen grains are well pressed in the sediment layer in pond lake and oceans
- Type of plants also identified
- pollen analysis to study long-term patterns of vegetation diversity.
- Prepared slide and add silicon oil, glycerol-jelly and observed in scanning electron microscopy. And they counts no. of grains of each pollen taxon.

PALEOCLIMATOLOGY

- Palaeoclimatological use of pollen records has become more quantitative and has included more precise and rigorous testing of pollen-climate calibration models with modern climate data.

- Pollen data provide of changes in vegetation , climate and human disturbances of terrestrial ecosystem.

Methodology :-

1.Palynomorphs

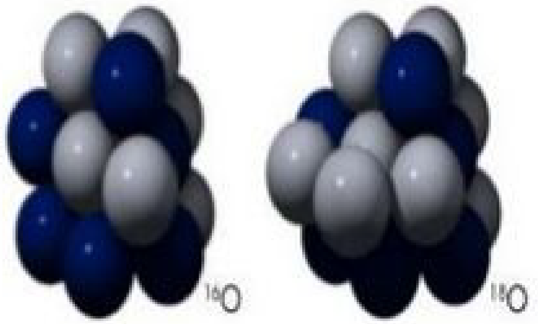
2.Chemical Preparation

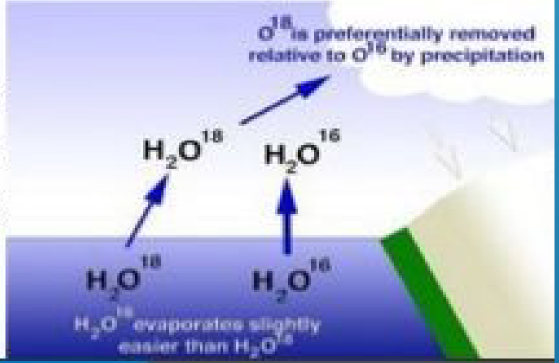
3.Analysis

PALEOCLIMATOLOGY

Isotopes

- The elements who have same atomic number but different atomic weight those elements are called as Isotopes
- Oxygen is one of the most significant element for paleoclimatology research.
- Oxygen is having three isotopes: ^{16}O, ^{17}O, ^{18}O
- Occurrence of ^{16}O and ^{18}O in water changes and their ration in marine sediments, ice cores or fossils is useful for studying paleoclimatology.





PALEOCLIMATOLOGY

Ice Malting And Sea level rise

- Sea ice influences climate because it reflects sunlight and because it influences ocean circulation.
- Less sea ice leads to acceleration of global warming
- There is evidence of ice melt, sea level rise to +5-9 m, and extreme storms in the prior interglacial period that was less than 1°C warmer than today.
- Arctic sea-ice cover is shrinking by 8.9% per decade in summer and 2.5% per decade in winter. It is also becoming thinner and there is less multi-year ice.
- Melting sea ice, in combination with melting glaciers and ice sheets, may cause major changes to global patterns of ocean circulation.
- As with snow, less sea ice increases absorption of heat from the sun, resulting in increased warming

CLIMATOLOGY PROXIES

- **Climate proxies** are preserved physical characteristics of the past that stand in for direct meteorological measurements and enable scientists to reconstruct the climatic conditions over a longer fraction of the Earth's history.
- Reliable global records of climate only began in the 1880s, and proxies provide the only means for scientists to determine climatic patterns before record-keeping began.
- A large number of climate proxies have been studied from a variety of geologic contexts.

CLIMATOLOGY PROXIES

- Proxies can be combined to produce temperature reconstructions longer than the instrumental temperature recordProxies can be combined to produce temperature reconstructions longer than the instrumental temperature record and can inform discussions of global warming and climate history.
- The geographic distribution of proxy records, just like the instrumental record, is not at all uniform, with more records in the northern hemisphere

CLIMATOLOGY PROXIES

1 Proxies
- 1.1 Ice cores
  - 1.1.1 Drilling
  - 1.1.2 Proxy
- 1.2 Tree rings
- 1.3 Fossil leaves
- 1.4 Boreholes
- 1.5 Corals
- 1.6 Pollen grains
- 1.7 Dinoflagellate cysts
- 1.8 Lake and ocean sediments
- 1.9 Water isotopes and temperature reconstruction
- 1.10 Membrane lipids
- 1.11 Pseudoproxies

INDIAN CLIMATE SYSTEM AND THEIR CLASSIFICATION

- India has tropical monsoon climate with large regional variations in terms of rainfall and temperature.
- While classifying Indian climatic regions, most geographers have given more importance to **rainfall** than to temperature as variations in rainfall are much more marked than those of temperature.
- Here we will see **two** classifications –

(i) Stamp's Classification of Climatic Regions of India

(ii) Koeppen's Classification of Climatic Regions of India

INDIAN CLIMATE SYSTEM AND THEIR CLASSIFICATION

Stamp's Classification of Climatic Regions of India

- Stamp used **18°C isotherm** of mean monthly temperature for January to divide the country into two broad climatic regions, viz., **temperate or continental zone** in the north and **tropical zone** in the south.
- This line runs roughly across the root of the peninsula, more or less along or parallel to the Tropic of Cancer.
- The two major climatic regions are further divided into eleven regions depending upon the amount of rainfall and temperature.

INDIAN CLIMATE SYSTEM AND THEIR CLASSIFICATION

Temperate or Continental India

- The Himalayan region (heavy rainfall)
- The north-western region (moderate rainfall)
- The arid low land
- The region of moderate rainfall
- The transitional zone

Tropical India

- Region of very heavy rainfall
- Region of heavy rainfall
- Region of moderate rainfall
- The Konkan Coast
- The Malabar Coast
- Tamil Nadu

INDIAN CLIMATE SYSTEM AND THEIR CLASSIFICATION

Koeppen's Classification of Climatic Regions of India

- Koeppen's Classification of Climatic Regions of India is an empirical classification based on mean annual and mean monthly temperature and precipitation data.
- Koeppen identified a close relationship between the distribution of vegetation and climate.
- He selected certain values of temperature and precipitation and related them to the distribution of vegetation and used these values for classifying the climates.
- Koeppen divided India into **nine climatic regions** making use of the above scheme

INDIAN CLIMATE SYSTEM AND THEIR CLASSIFICATION

- Koeppen recognized **five** major climatic groups,

  four of them are based on temperature and

  one on precipitation.
- The capital letters:
- **A, C, D and E delineate humid climates and**
- **B dry climates.**

INDIAN CLIMATE SYSTEM AND THEIR CLASSIFICATION

- The climatic groups are subdivided into types, designated by small letters, based on seasonality of precipitation and temperature characteristics.
- The seasons of dryness are indicated by the small letters : f, m, w and s, where
- **f – no dry season,**
- **m – monsoon climate,**
- **w – winter dry season and**
- **s – summer dry season.**

  The above mentioned major climatic types are further subdivided depending upon the seasonal distribution of rainfall or degree of dryness or cold.

INDIAN CLIMATE SYSTEM AND THEIR CLASSIFICATION

a: hot summer, average temperature of the warmest month over 22°C

c: cool summer, average temperature of the warmest month under 22°C

f: no dry season

w: dry season in winter

s: dry season in summer

g: Ganges type of annual march of temperature; hottest month comes before the solstice and the summer rainy season.

h: average annual temperature under 18°C

m (monsoon): short dry season.

INDIAN CLIMATE SYSTEM AND THEIR CLASSIFICATION

- The capital letters S and W are employed to designate the two subdivisions of dry climate:

1. **semi-arid or Steppe (S) and**
2. **arid or desert (W).**

- Capital letters T and F are similarly used to designate the two subdivisions of polar climate

1. **tundra (T) and**
2. **icecap (F).**

INDIAN CLIMATE SYSTEM AND THEIR CLASSIFICATION

Table : Climatic Groups According to Koeppen

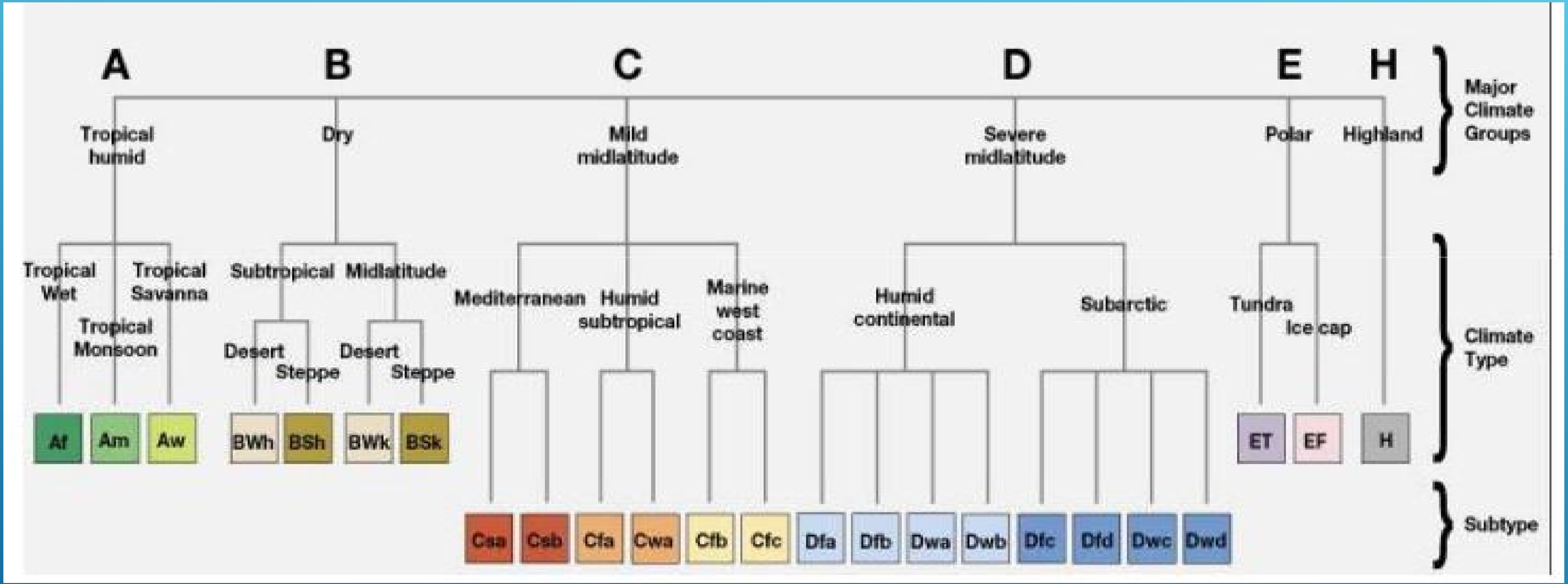
Group	*Characteristics*
A - Tropical	Average temperature of the coldest month is 18° C or higher
B - Dry Climates	Potential evaporation exceeds precipitation
C - Warm Temperate	The average temperature of the coldest month of the (Mid-latitude) climates years is higher than minus 3°C but below 18°C
D - Cold Snow Forest Climates	The average temperature of the coldest month is minus 3° C or below
E - Cold Climates	Average temperature for all months is below 10° C
H - High Land	Cold due to elevation

INDIAN CLIMATE SYSTEM AND THEIR CLASSIFICATION

Table : Climatic Types According to Koeppen

Group	*Type*	*Letter Code*	*Characteristics*
A-Tropical Humid Climate	Tropical wet	Af	No dry season
	Tropical monsoon	Am	Monsoonal, short dry season
	Tropical wet and dry	Aw	Winter dry season
B-Dry Climate	Subtropical steppe	BSh	Low-latitude semi arid or dry
	Subtropical desert	BWh	Low-latitude arid or dry
	Mid-latitude steppe	BSk	Mid-latitude semi arid or dry
	Mid-latitude desert	BWk	Mid-latitude arid or dry
C-Warm temperate (Mid-latitude) Climates	Humid subtropical	Cfa	No dry season, warm summer
	Mediterranean	Cs	Dry hot summer
	Marine west coast	Cfb	No dry season, warm and cool summer
D-Cold Snow-forest Climates	Humid continental	Df	No dry season, severe winter
	Subarctic	Dw	Winter dry and very severe
E-Cold Climates	Tundra	ET	No true summer
	Polar ice cap	EF	Perennial ice
H-Highland	Highland	H	Highland with snow cover

KOPPEN CLASSIFICATION SYSTEM



https://www.youtube.com/watch?v=xhbUflzb9yU

ROLE OF LAND AND OCEAN TO REGULATE CLIMATE

Role of land to regulate climate

According to IPCC, Intergovernmental panel on climate change

Land provides the principal basis for human livelihoods and well-being including the supply of food, freshwater and multiple other ecosystem services, as well as biodiversity. Human use directly affects more than 70% (likely 69-76%) of the global, ice-free land surface. Land also plays an important role in the climate system.

- The link between land use and the climate is complex.
- First, land cover--as shaped by land use practices--affects the global concentration of greenhouse gases.
- Second, while land use change is an important driver of climate change, a changing climate can lead to changes in land use and land cover.

ROLE OF LAND TO REGULATE CLIMATE

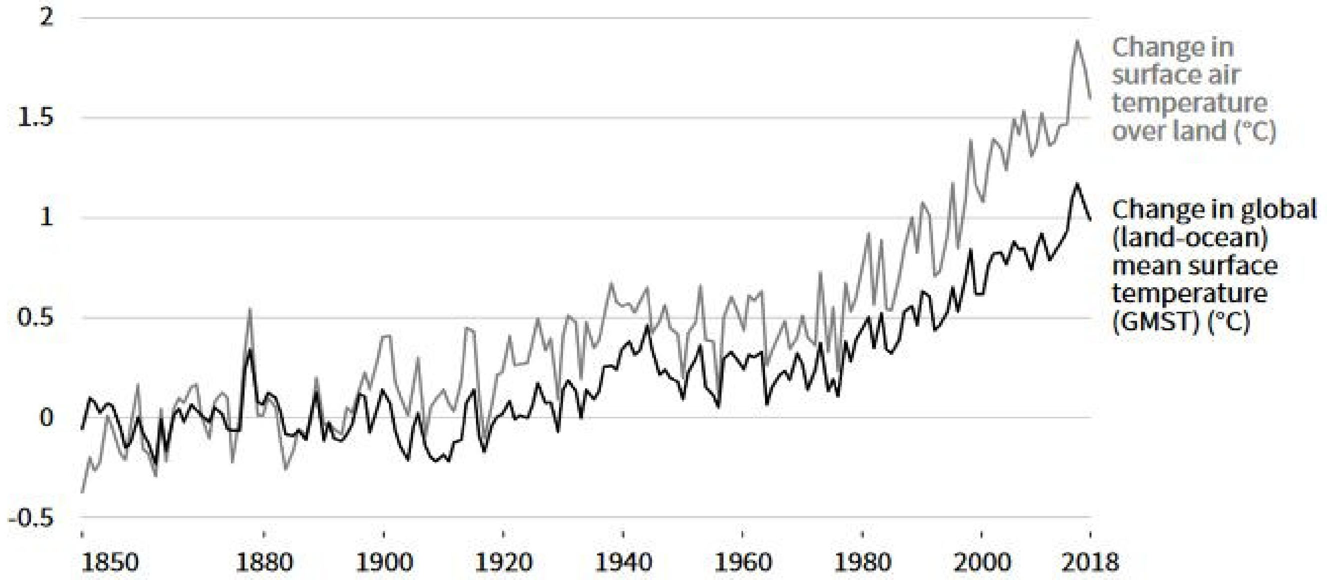
- Land is both a source and a sink of **greenhouse gases (GHGs)** and plays a key role in the exchange of energy, water and aerosols between the land surface and atmosphere.
- **Land ecosystems and biodiversity** are vulnerable to ongoing climate change and weather and climate extremes, to different extents.
- **Sustainable land management** can contribute to reducing the negative impacts of multiple stressors, including climate change, on ecosystems and societies

ROLE OF LAND TO REGULATE CLIMATE

Land use and observed climate change

A. Observed temperature change relative to 1850-1900
Since the pre-industrial period (1850-1900) the observed mean land surface air temperature has risen considerably more than the global mean surface (land and ocean) temperature (GMST).

CHANGE in TEMPERATURE rel. to 1850-1900 (°C)

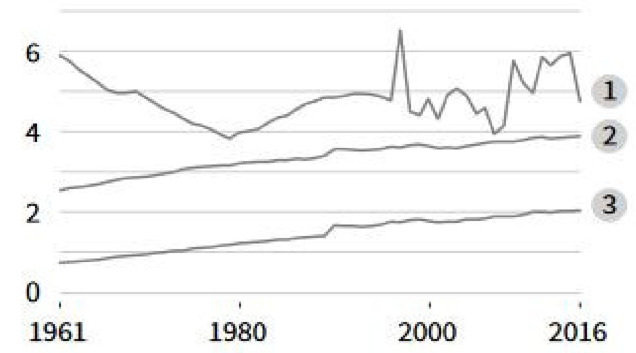


B. GHG emissions
An estimated 23% of total anthropogenic greenhouse gas emissions (2007-2016) derive from Agriculture, Forestry and Other Land Use (AFOLU).

CHANGE in emissions rel. to 1961

1 Net CO_2 emissions from FOLU (Gt CO_2/yr)
2 CH_4 emissions from Agriculture (Gt CO_2eq/yr)
3 N_2O emissions from Agriculture (Gt CO_2eq/yr)

Gt CO_2eq/yr



ROLE OF LAND TO REGULATE CLIMATE

- Since the pre-industrial period **(1850-1900)** the observed mean land surface air temperature has risen considerably more than the global mean surface (land and ocean) temperature (GMST) (high confidence).
- From **1850-1900 to 2006-2015** mean land surface air temperature has increased by 1.53°C (very likely range from 1.38°C to 1.68°C) while GMST increased by 0.87°C (likely range from 0.75°C to 0.99°C).
- Climate change can exacerbate land degradation processes (high confidence) including through **increases in rainfall intensity, flooding, drought frequency and severity, heat stress, dry spells, wind, sea-level rise and wave action,** permafrost thaw with outcomes being modulated by land management

- The ocean is an important component of the climate system.

ROLE OF OCEAN TO REGULATE CLIMATE

- It provides the surface temperature boundary condition for the atmosphere over 70% of the globe.
- It absorbs over 97% of solar radiation incident on it from zenith angles **less than 50°.**
- It provides **85% of the water vapour** in the atmosphere.
- It exchanges, absorbs and emits a host of radiatively important gases.
- It is a major natural source of atmospheric **aerosols.**

ROLE OF OCEAN TO REGULATE CLIMATE

- Thus, even a static ocean would significantly influence the climate. However, the ocean is dynamic and its surface properties will vary on all time scales, allowing great scope for feedbacks between the ocean and atmosphere.
- Over the last two decades the importance of the ocean to understanding, and predicting the evolution of, the climate system has become generally recognized.
- This development in scientific understanding of the role of the ocean in climate change can be seen in the **Third assessment reports** of the **Intergovernmental Panel for Climate Change (IPCC)**

https://www.nationalgeographic.com/environment/2019/09/ipcc-report-cli mate-change-affecting-ocean-ice/

ROLE OF OCEAN TO REGULATE CLIMATE

The Effect Oceans on Weather Systems

1. Oceans affect atmospheric pressure which then develop clouds that lead to weather change.
2. Oceans transport the heat from solar radiation to different parts of the world; regulating regional temperatures.
3. Oceans are driven largely by surface winds, salinity, and temperature differences trying to reach state of equilibrium.

1. Cirrus Clouds- Fair weather.
2. Stratus Clouds- Steady rain.
3. Cumulus Clouds- Nice sunny weather
4. Cumulonimbus Clouds-THUNDERSTORMS!!!

https://www.youtube.com/watch?time_continue=68&v=WNpzc3SLkxs&feature=emb_logo

ROLE OF ICE AND WIND TO REGULATE CLIMATE

ROLE OF ICE TO REGULATE CLIMATE

- Sea ice is frozen water that forms, expands, and melts in the ocean.
- It is different from **icebergs, glaciers, ice sheets, and ice shelves**, which originate on land. For the most part, sea ice expands during winter months and melts during summer months, but in certain regions, some sea ice remains year-round.
- About **15 percent** of the world's oceans are covered by sea ice during part of the year.
- While sea ice exists primarily in the polar regions, it influences the global climate

ROLE OF ICE TO REGULATE CLIMATE

Sea ice in the Arctic Ocean. While sea ice exists primarily in the polar regions, it influences the global climate.

ROLE OF ICE TO REGULATE CLIMATE

- The bright surface of sea ice reflects a lot of sunlight out into the atmosphere and, importantly, back into space. Because this solar energy "bounces back" and is not absorbed into the ocean, temperatures nearer the poles remain cool relative to the equator.
- Changes in the amount of sea ice can disrupt normal **ocean circulation**, thereby leading to changes in global climate.
- **Even a small increase in temperature** can lead to greater warming over time, making the polar regions the most sensitive areas to climate change on Earth.

ROLE OF WIND TO REGULATE CLIMATE

- Winds that blow from the sea often bring rain to the coast and dry weather to inland areas.
- Winds that blow to Britain from warm inland areas such as Africa will be warm and dry.
- Winds that blow to Britain from inland areas such as central Europe will be cold and dry in winter. Britain's prevailing (i.e. most frequently experienced) winds come from a south westerly direction over the Atlantic.
- These winds are **cool in the summer, mild in the winter** and tend to bring wet weather

ROLE OF WIND TO REGULATE CLIMATE

- India lies in the region of **north easterly winds.**
- These winds originate from the **subtropical high-pressure belt of the northern hemisphere.**
- They blow **south**, get deflected to the **right due to the Coriolis force**, and move on towards the equatorial low-pressure area.
- Generally, these winds carry very little moisture as they originate and blow over land. Therefore, they bring little or no rain. Hence, India should have been an arid land, but, it is not so.
- The pressure and wind conditions over India are unique. These winds blow over the warm oceans, gather moisture and bring widespread rainfall over the mainland of India.

MILANKOVITCH CYCLE

INTRODUCTION

- The Milankovitch or astronomical theory of climate change is an explanation for changes in the seasons which result from changes in the earth's orbit around the sun. The theory is named for Serbian astronomer Milutin Milankovitch

Natural causes of Milankovitch Cycle

- Eccentricity
- Obliquity
- Precession

Who was Milutin Milankovitch?

- Born May 28, 1879, Dalj, Austria-Hungary [now in Croatia]
- Died December 12, 1958, Belgrade, Yugoslavia [now in Serbia]
- Mathematician and geophysicist
- Best known for his work that linked long-term changes in climate to astronomical factors affecting the amount of solar energy received at Earth's surface.
- Published *Kanon der Erdbestrahlung und seine Anwendung auf das Eiszeitenproblem* (1941; *Canon of Insolation and the Ice-Age Problem*).

- Earth experienced it's most recent ice ages during the Pleistocene epoch, which lasted from 2.6 million years ago to 11,700 years ago. For thousands of years at a time, even the more temperate regions of the globe were covered with glaciers and ice sheets, according to the University of California Museum of Paleontology.
- To determine how Earth could experience such vast changes in climate over time, Milankovitch incorporated data about the variations of Earth's position with the timeline of the ice ages during the Pleistocene. He studied Earth's variations for the last 600,000 years and calculated the varying amounts of solar radiation due to Earth's changing orbital parameters. In doing so, he was able to link lower amounts of solar radiation in the high northern latitudes to previous European ice ages, according to AMNH.
- Milankovitch's calculations and charts, which were published in the 1920s and are still used today to understand past and future climate, led him to conclude that there are three different positional cycles, each with its own cycle length, that influence the climate on Earth: the eccentricity of Earth's orbit, the planet's axial tilt and the wobble of its axis.

ECCENTRICITY

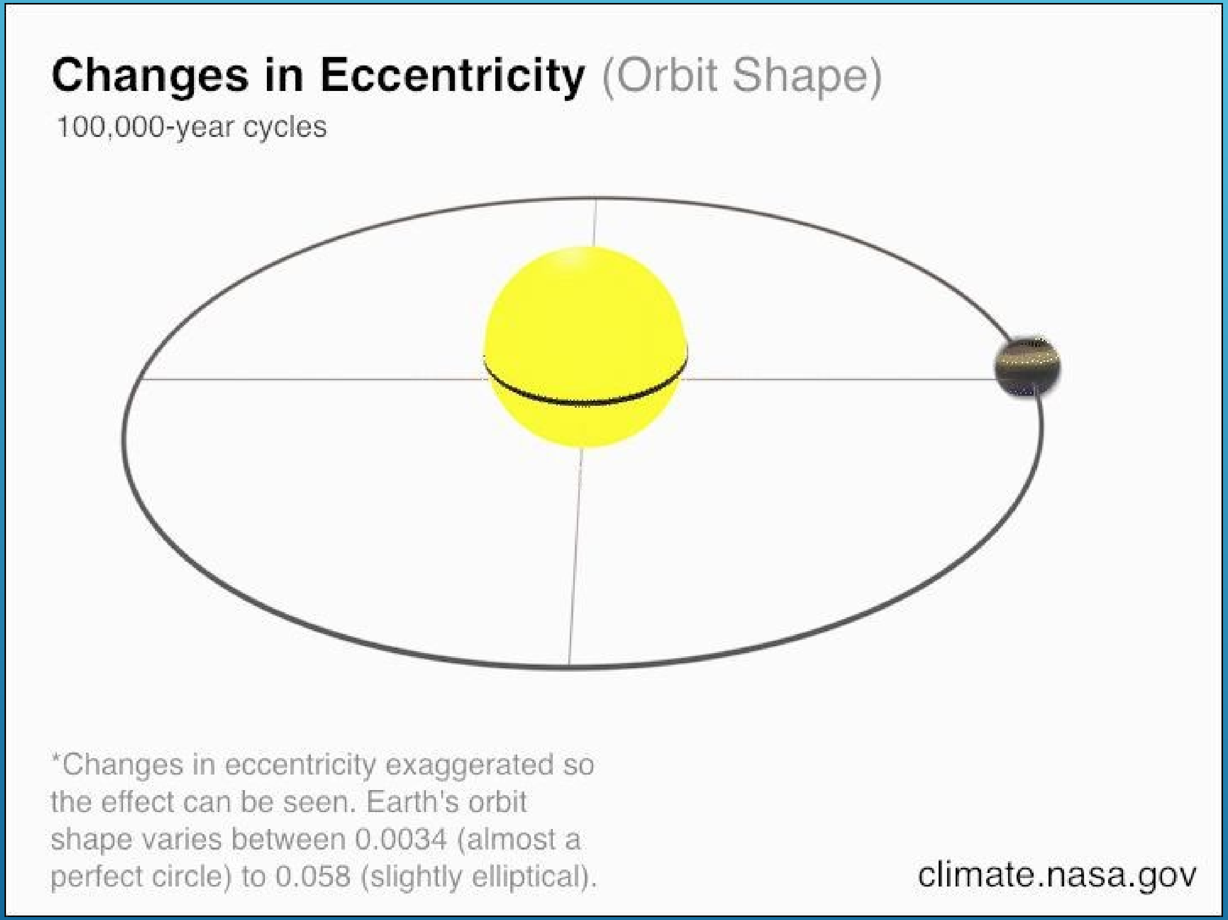
Eccentricity is a term used to describe the shape of Earth's orbit around the sun. The variation of Earth's orbit around the sun ranges from an almost exact circle (eccentricity = 0.0005) to a slightly elongated shape (eccentricity = 0.0607). The impact of the variation is a change in the amount of solar energy from perihelion (around January 3) to aphelion (around July 4).

The Earth's orbit around the Sun, like other planet's orbits, is not a perfect circle. It is an ellipse. This means that the Earth is closer to and further away from the Sun at different times in the year.

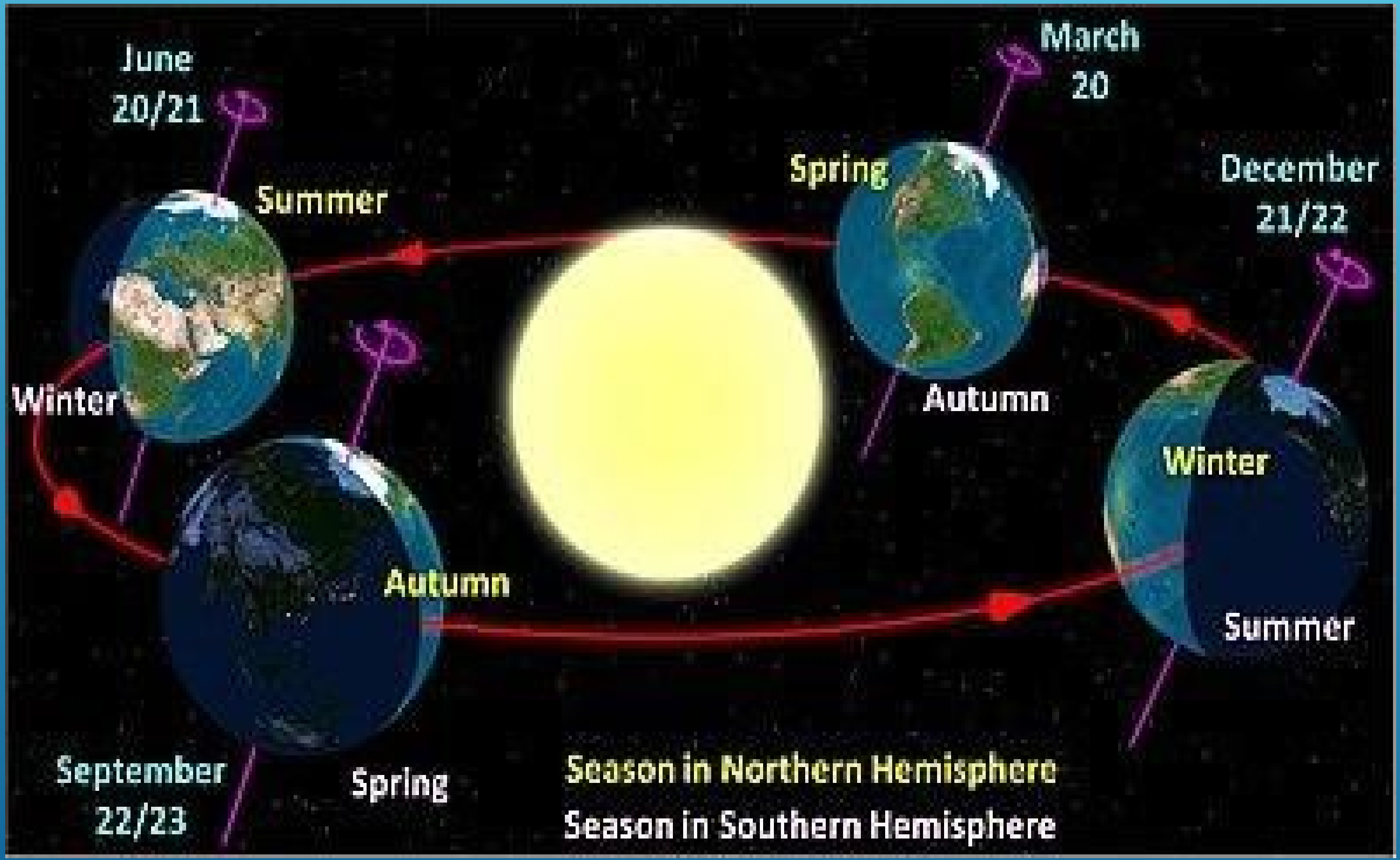
•Perihelion - when the Earth is closest to the Sun (usually happens in January)

•Aphelion - when the Earth is furthest from the Sun (usually happens in June)

CHANGES IN ECCENTRICITY



SEASON IN NORTHERN AND SOUTHERN HEMISPHERE

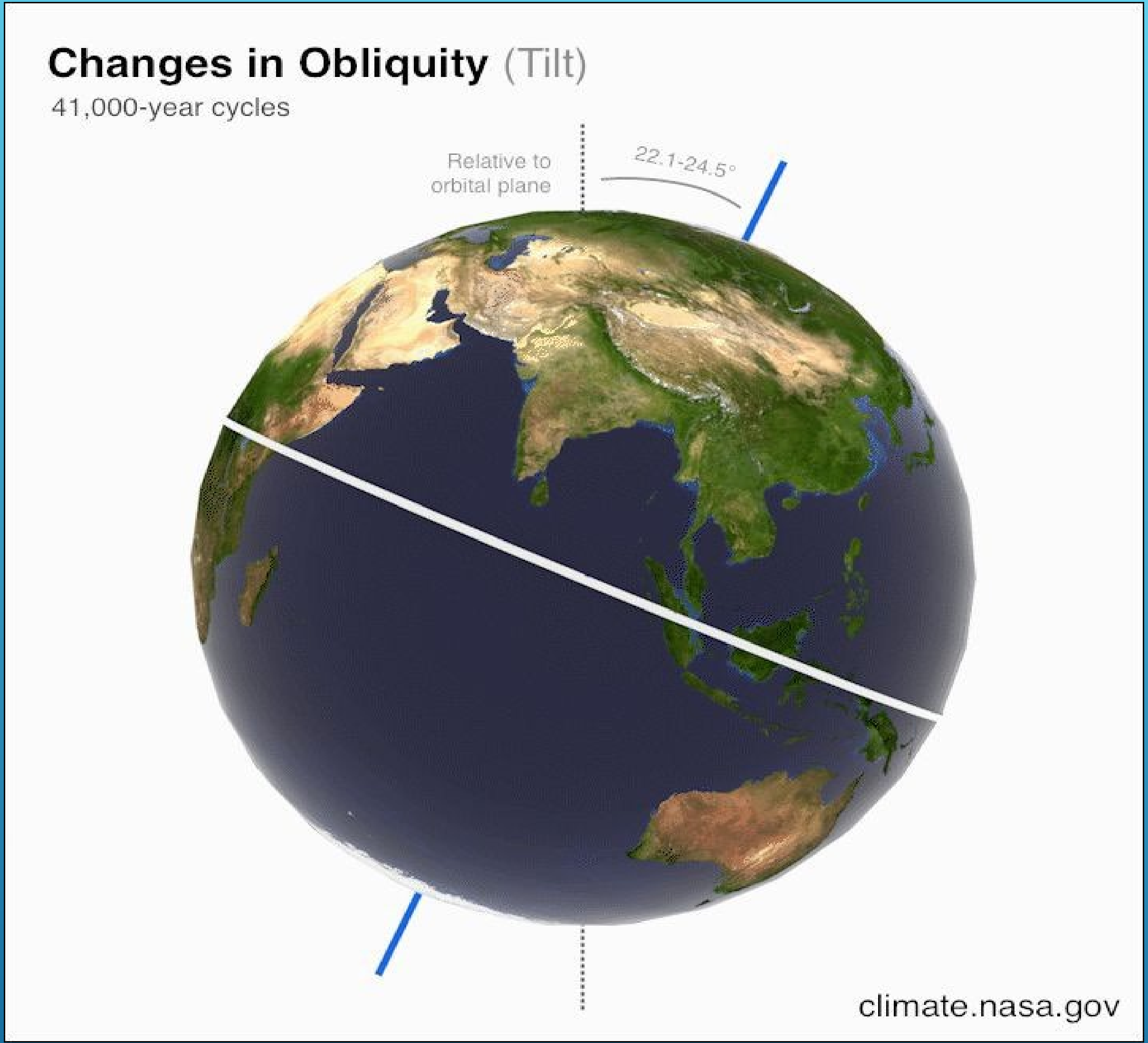


OBLIQUITY

- Obliquity is the variation of the tilt of the earth's axis away from the orbital plane.
- The tilt varies between 22.1 º and 24.5 º and the average is 23.5 º
- The obliquity changes on a cycle taking approximately 40,000 years
- Currently, the axis of rotation for the earth is tilted at 23.5°

However, this value changes from a minimum of 22.5° to a maximum of 24.5° and takes 41,000 years to complete one cycle

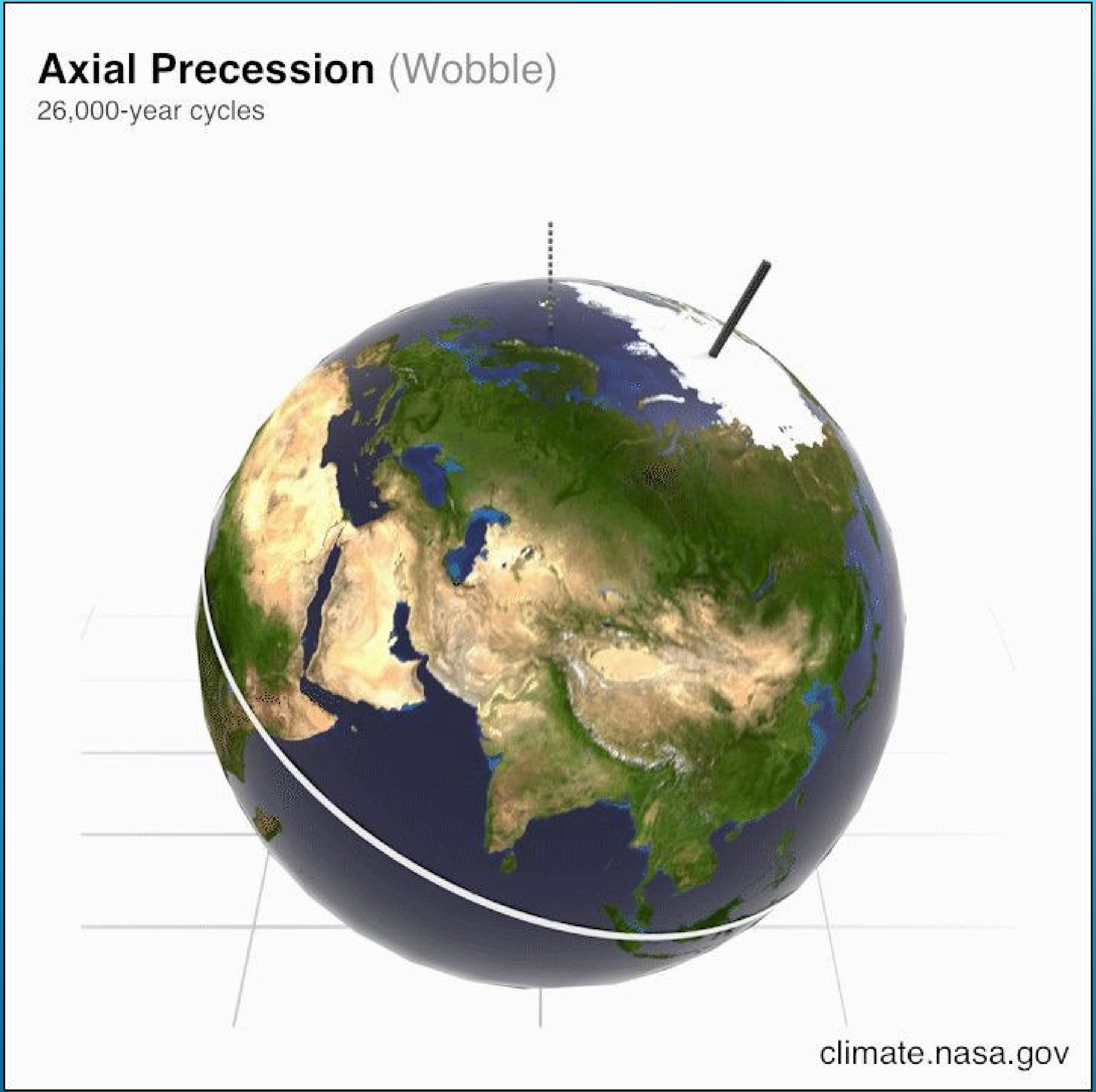
The more tilt means more severe seasons - warmer summers and colder winters; less tilt means less severe seasons - cooler summers and milder winters



PRECESSION

- Precession is the change in orientation of the Earth's rotational axis. The precession cycle takes about 19,000 - 23,000 years.
- Earth wobbles just slightly as it spins on its axis, similarly to when a spinning top begins to slow down. This wobble, known as precession, is primarily caused by the gravity of the sun and moon pulling on Earth's equatorial bulges. The wobble doesn't change the tilt of Earth's axis, but the orientation changes. Over about 26,000 years, Earth wobbles around in a complete circle, according to Washington State University.
- Now, and for the past several thousands of years, Earth's axis has been pointed north more or less toward Polaris, also known as the North Star. But Earth's gradual precessional wobble means that Polaris isn't always the North Star. About 5,000 years ago the Earth was pointed more toward another star, called Thubin. And, in approximately 12,000 years, the axis will have traveled a bit more around its precession circle and will point toward Vega, which will become the next North Star

- As the Earth completes a precession cycle, the orientation of the planet is altered with respect to perihelion and aphelion. If a hemisphere is pointed toward the sun during perihelion (shortest distance between Earth and sun), it will be pointed away during aphelion (largest distance between Earth and sun), and the opposite is true for the other hemisphere. The hemisphere that's pointed toward the sun during perihelion and away during aphelion experiences more extreme seasonal contrasts than the other hemisphere.
- Currently, the southern hemisphere's summer occurs near perihelion and winter near aphelion, which means the southern hemisphere experiences more extreme seasons than the northern hemisphere.


Axial Precession (Wobble)
26,000-year cycles
climate.nasa.gov

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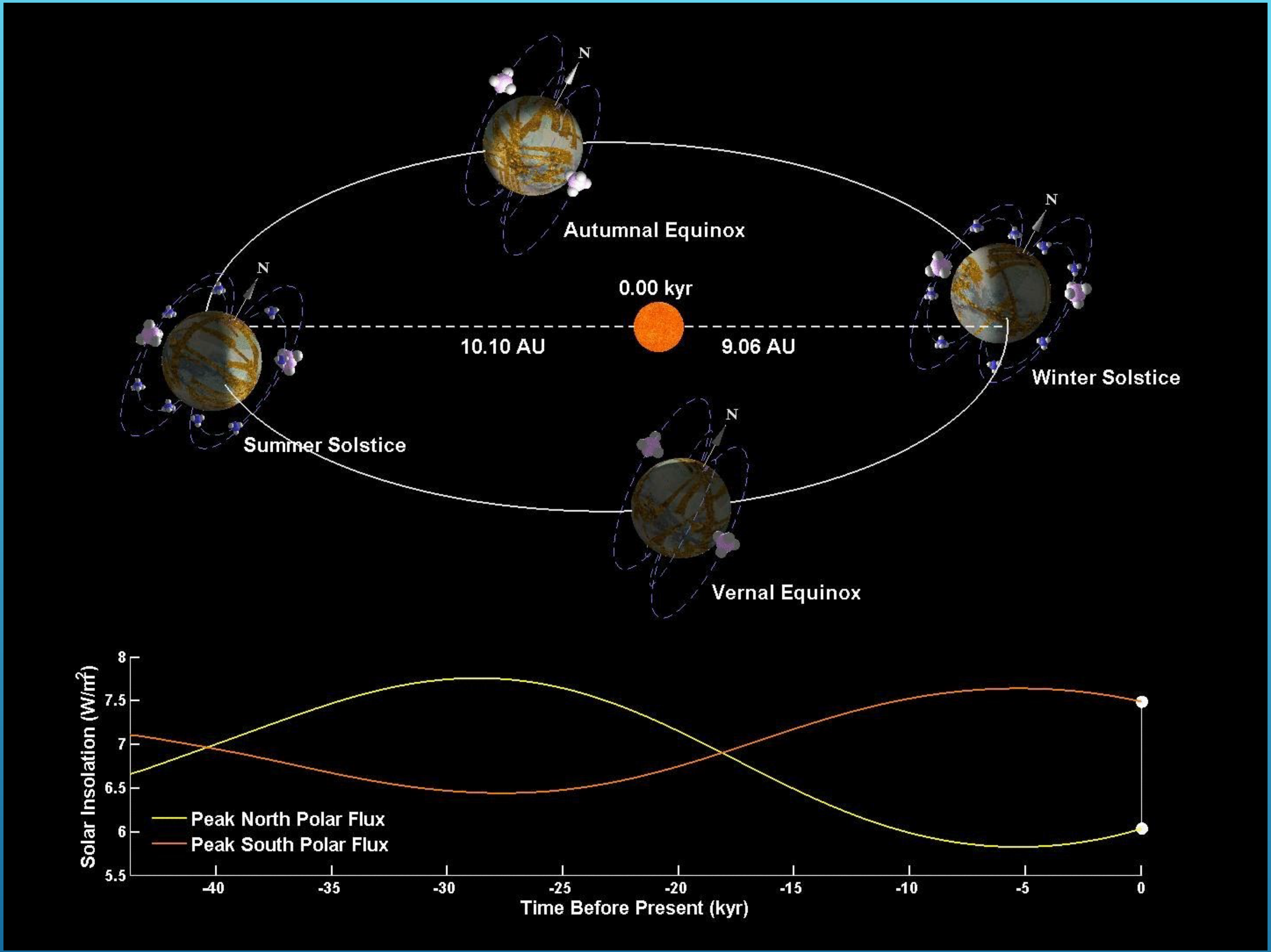
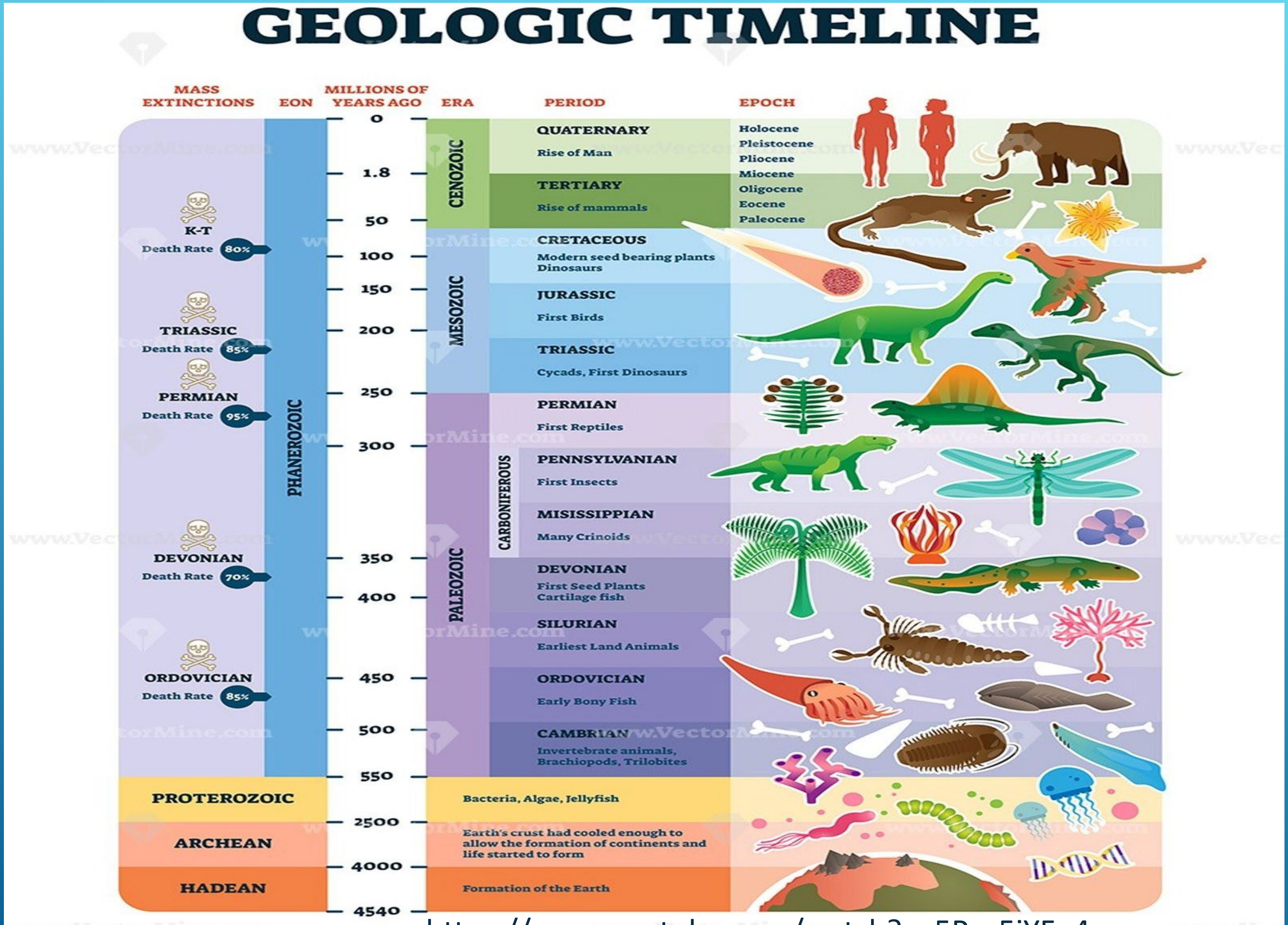


https://www.youtube.com/watch?v=wi-VEby3m9E

GLOBAL TEMPERATURE CHANGES



https://www.youtube.com/watch?v=5Prp5iYFu4w

GLOBAL TEMPERATURE CHANGE: HIGHLIGHTS

- The relentless global heat continued as average surface temperature on Earth in July 2020 was the second warmest on record

- In 2019, the average temperature across global land and ocean surfaces was 0.95°C above the twentieth-century average of 13.9°C, making it the second-warmest year on record.

- The global annual temperature has increased at an average rate of 0.07°C per decade since 1880 and over twice that rate (+0.18°C) since 1981.

- The five warmest years in the 1880–2019 record have all occurred since 2015, while nine of the 10 warmest years have occurred since 2005.

- From 1900 to 1980 a new temperature record was set on average every 13.5 years. Since 1981, it has increased to every 3 years.

Conditions in 2019

According to the 2019 Global Climate Report from National Oceanic and Atmospheric Administration (NOAA) National Centers for Environmental Information, 2019 began with a weak-to-moderate El Niño event in the tropical Pacific Ocean. Temperatures were warmer than average across most global land and ocean areas during most of the year.

https://www.ldeo.columbia.edu/~martins/irvine/ms/sld001.htm

Effects of global warming

- **Ocean Warming**
  - Thermal expansion
  - Coastal erosion
  - Arctic erosion
  - Warmer bottom water
  - Coral die off
- **Ice loss**
  - Melting glaciers and permafrost
  - Melting ice sheets
- **Climate change**
  - Extreme temperatures
  - Drought
  - Wind events like cyclones, tornados etc.
  - Severe rainfall
- **Sea level rise**
  - Due to thermal expansion, ice loss, melting of glaciers etc.

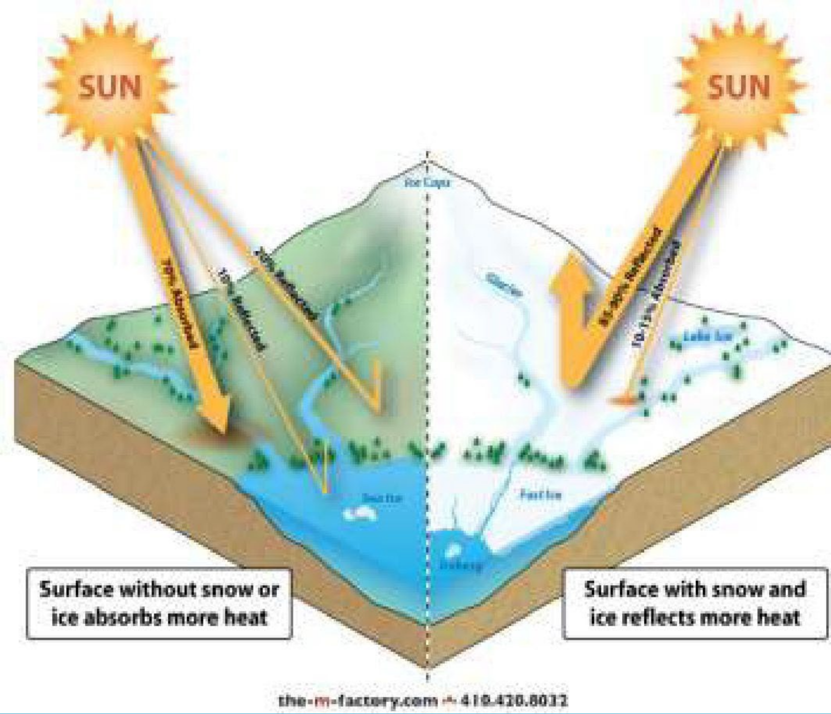
ICE MELTING :GLOBAL OVERVIEW

Sources of melting ice

- Greenland ice sheets: 286 gt/y
- Antarctic ice sheets: 127 gt/y
- Glaciers (excluding Greenland and Antarctica ice sheets): 335 gt/y

ALBEDO

- A measure of how much of the Sun's energy is reflected off an object back out to space compared to how much is trapped in Earth's atmosphere.
- Snow, ice and clouds have a relatively high Albedo so generally reflect more of the Sun's energy back to space which has a cooling effect on the Earth.
- Cirrus clouds have a lower Albedo transmitting more radiation through to Earth's surface and trapping **Earth’s reflected radiation**. This increases the temperature on Earth.
- Changes in the polar regions can cause more warming in the entire planet earth system through feedback effects. One such effect is the reduction of ice and snow due to warmer temperatures.
  - When the snow and ice disappears, less sun rays are reflected out and instead the heat is absorbed by land and sea - which causes further increase in the warming.
- Change to the Earth's Albedo is a powerful driver of climate.
- When the planet's Albedo or reflectivity increases, more incoming sunlight is reflected back into space. This has a cooling effect on global temperatures. Conversely, a drop in Albedo warms the planet.



MEASURING ALBEDO

Albedo is measured in scale from 0.0-1.0

- 1.0 being the most reflective.
  - For example an Albedo of 1.0 would be reflecting back 100% of light.
- Albedo of fresh snow is about 0.9
- 0.0 being the most absorbing surface.
  - For example and Albedo of 0.0 would be absorbing 100% of light.

Terrestrial effects

Trees: Because trees tend to have a low Albedo, removing forests would tend to increase Albedo and thereby could produce localized climate cooling. In seasonally snow-covered zones, winter Albedo of treeless areas are 10% to 50% higher than nearby forested areas because snow does not cover the trees as readily .

Snow: Snow Albedo can be as high as 0.9; this, however, is for the ideal example: fresh deep snow over a featureless landscape. If a snow covered area warms, snow tends to melt, lowering the Albedo, and leading to more snowmelt.

Water: Water reflects light very differently from typical terrestrial materials. At the scale of the wavelength of light even wavy water is always smooth so the light is reflected in a locally specular manner. Although the reflectivity of water is very low at low and medium angles of incident light, it increases tremendously at high angles of incident light such as occur on the illuminated side of the Earth near the terminator. However, waviness causes an appreciable reduction. Since the light specularly reflected from water does not usually reach the viewer, water is usually considered to have a very low Albedo in spite of its high reflectivity at high angles of incident light.

Clouds: Cloud Albedo is an important factor in the global warming effect. Different types of clouds exhibit different reflectivity. Albedo and climate in some areas are affected by artificial clouds, such as those created by the contrails of heavy commercial airliner.

IMPACTS

- Much of the sunlight reflects back when it reaches the earth surface, if it's not reflected then its absorbed, and that's why the temperature increases
- This melts the ice and increases the global temperature to a few degrees, when ice melts, it can cause flooding in some areas.
- Exposed water or exposed land is darker in colour and it absorbs more energy from the sun. When the ice melts, more land is exposed, this absorbs more heat, melting more ice.
- The snow and ice play a important role. Without them the sunlight will not reflect back and temperature will rise causing global warming due to an imbalance of light being reflected and absorbed.

IRREVERSIBLE CHANGES

- Human influence on the climate system is confirmed.
- Recent anthropogenic emissions of Green house gases are the highest in history.
- Recent climate changes have had widespread impacts on the ecosystems.

Observations

- Atmosphere and ocean have warmed
- Snow and ice amounts have reduced
- Sea level has risen
- Ocean pH has decreased by 0.1

RISK AND IMPACTS

- Continued emission of greenhouse gases will cause further warming and long-lasting changes in all components of the climate system.
- It will increase the likelihood of severe, pervasive and irreversible impacts for people and ecosystems.
- All emission scenarios project increase in surface temperature causing more and longer lasting heat waves
- Extreme precipitation events will become more intense and frequent in many regions
- The ocean will continue to warm and acidify
- Global mean sea level to rise.

SEA LEVEL RISE AND ITS IMPACT

- Sea-level rise due to global warming occurs primarily because **water expands as it warms up**.
- The melting ice caps and mountain glaciers also add water to the oceans, thus rising the sea level.
- The contribution from large ice masses in Greenland and Antarctica is expected to be small over the coming decades. But it may become larger in future centuries.
- Sea-level rise can be offset up by irrigation, the storage of water in reservoirs, and other land management practices that reduce run-off of water into the oceans.
- Changes in land-levels due to coastal subsidence or geological movements can also affect local sea-levels.

SEA LEVEL RISE: HIGHLIGHTS

- Sea level has risen 8–9 inches (21–24 centimetres) since 1880.
- In 2019, global sea level was 3.4 inches (87.61 mm) above the 1993 average—the highest annual average in the satellite record (1993-present). This is an increase of 0.24 inches (6.1 mm) from 2018.
- The rate of sea level rise is accelerating: it has more than doubled from 0.06 inches (1.4 millimetres) per year throughout most of the twentieth century to 0.14 inches (3.6 millimetres) per year from 2006–2015.
- In many locations along the U.S. coastline, high-tide flooding is now 300% to more than 900% more frequent than it was 50 years ago.
- Even if the world follows a low greenhouse gas pathway, global sea level will likely rise at least 12 inches (0.3 meters) above 2000 levels by 2100.
- If we follow a pathway with high emissions, a worst-case scenario of as much as 8.2 feet (2.5 meters) above 2000 levels by 2100 cannot be ruled out.

THANK YOU