18CEO406T
Global warming and Climate change

UNIT - II
[S1 – S3]

S1: SLO 1: 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.

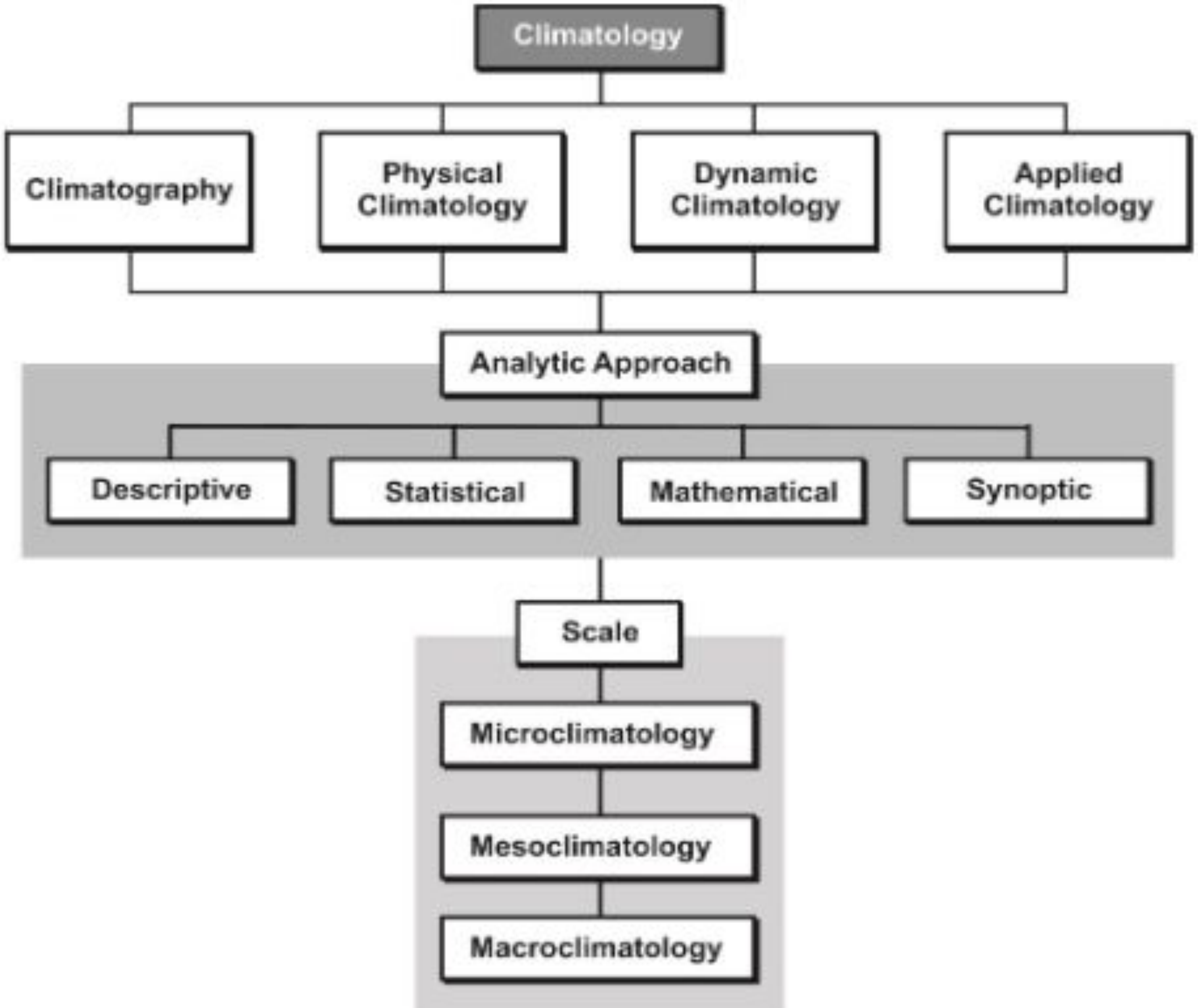


Figure 1. Subgroups, Analytical methods and scales of climatic study.
(From J. E. Olive 1981, P4 used by permission of V. H. Winston and Sons.)

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..

S1: SLO 2: 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.

S1: SLO 2: Paleoclimatology

S1: SLO 2: 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

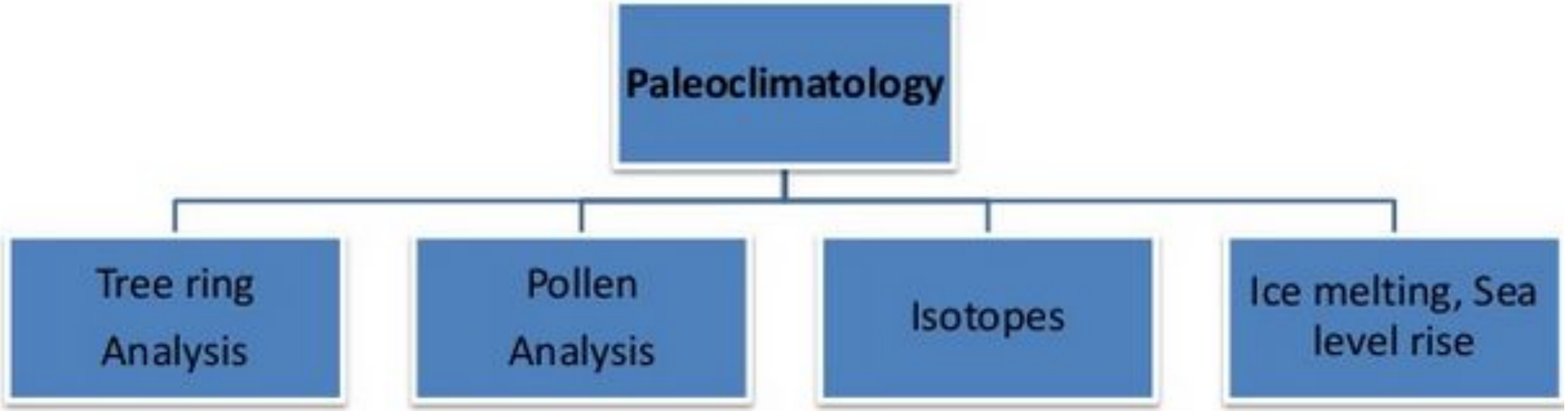
S1: SLO 2: Paleoclimatology

- 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

S1: SLO 2: 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.

S1: SLO 2: Paleoclimatology



S1: SLO 2: Paleoclimatology

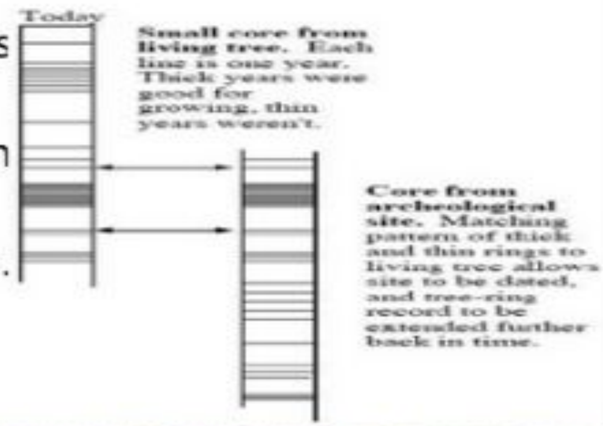
Tree Ring Analysis

- 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.

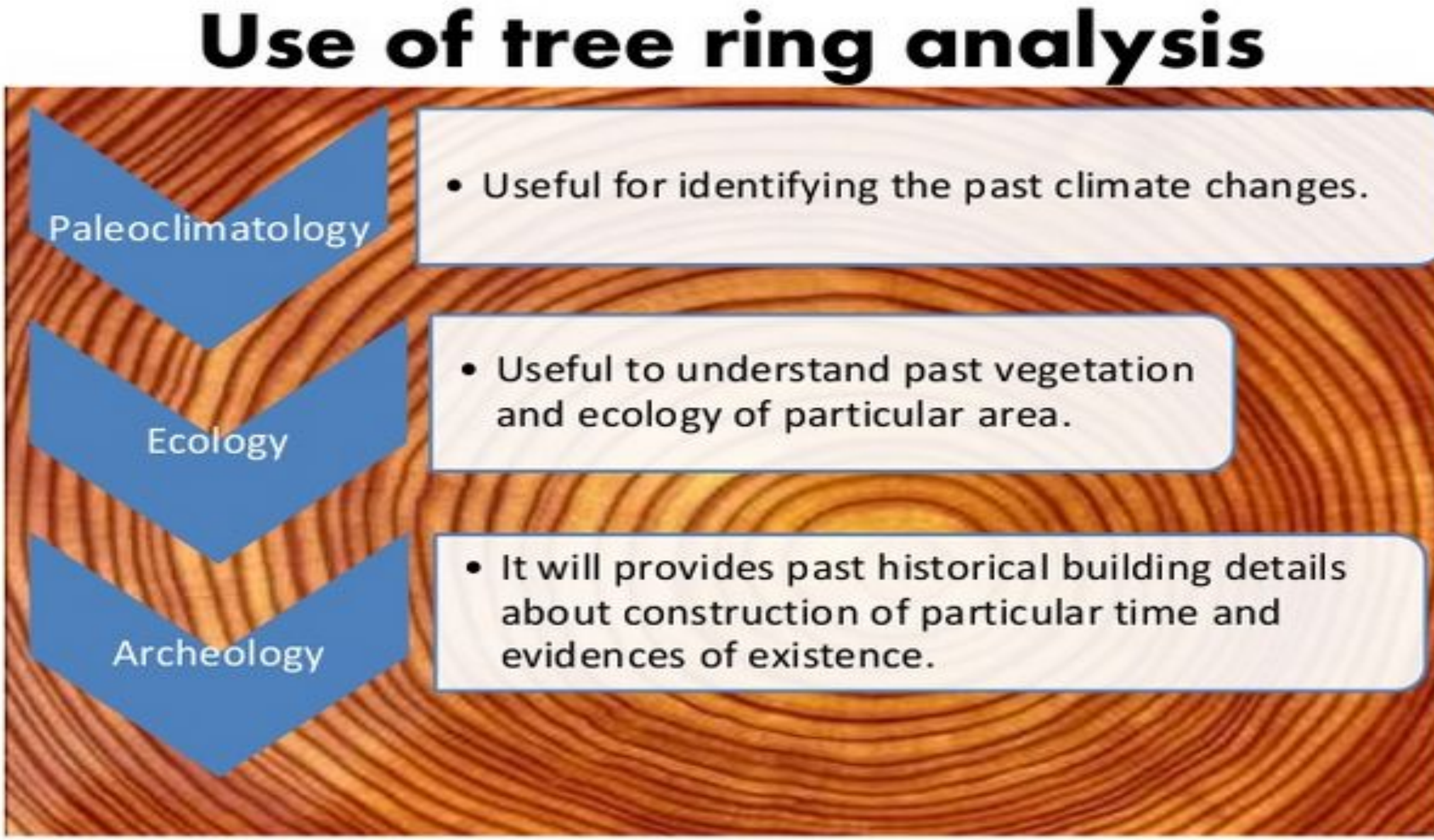


S1: SLO 2: Paleoclimatology

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

S1: SLO 2: Paleoclimatology



S1: SLO 2: 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.

S1: SLO 2: Paleoclimatology

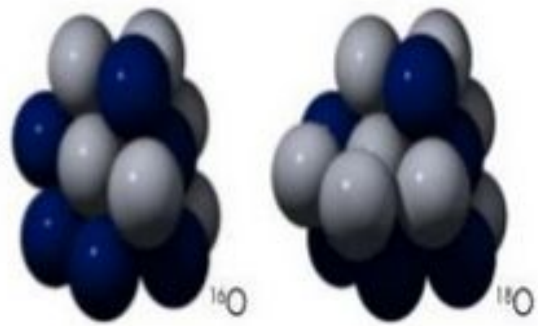
- Palaeoclimatological use of pollen records has become more quantitative and has included more precise and rigorous testing of pollen-climate calibration models with modern climate data.
- Pollen data provide of changes in vegetation , climate and human disturbances of terrestrial ecosystem.

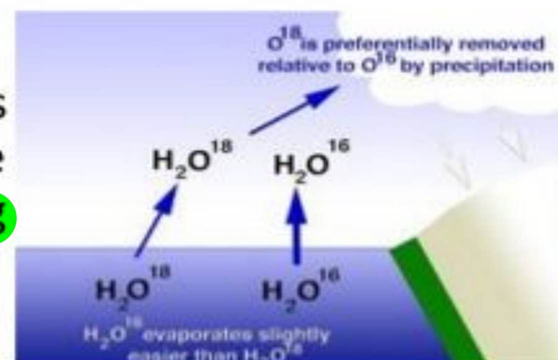
Methodology :-
1.Palynomorphs
2.Chemical Preparation
3.Analysis

S1: SLO 2: 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.





S1: SLO 2: 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

PROXY - - - PROXIES

PROXIES - the authority to represent someone else, …

Unit 1; S2 : SLO1

CLIMATOLOGY PROXIES

S2 : SLO1: 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.

S2 : SLO1: 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

S2 : SLO1: 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

S2 : SLO2: *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

S2 : SLO2: *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.

S2 : SLO2: *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

S2 : SLO2: *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

S2 : SLO2: *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.**

S2 : SLO2: *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.

S2 : SLO2: *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.

S2 : SLO2: *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).**

S2 : SLO2: *Indian climate system and their classification*

Table : Climatic Groups According to Koeppen

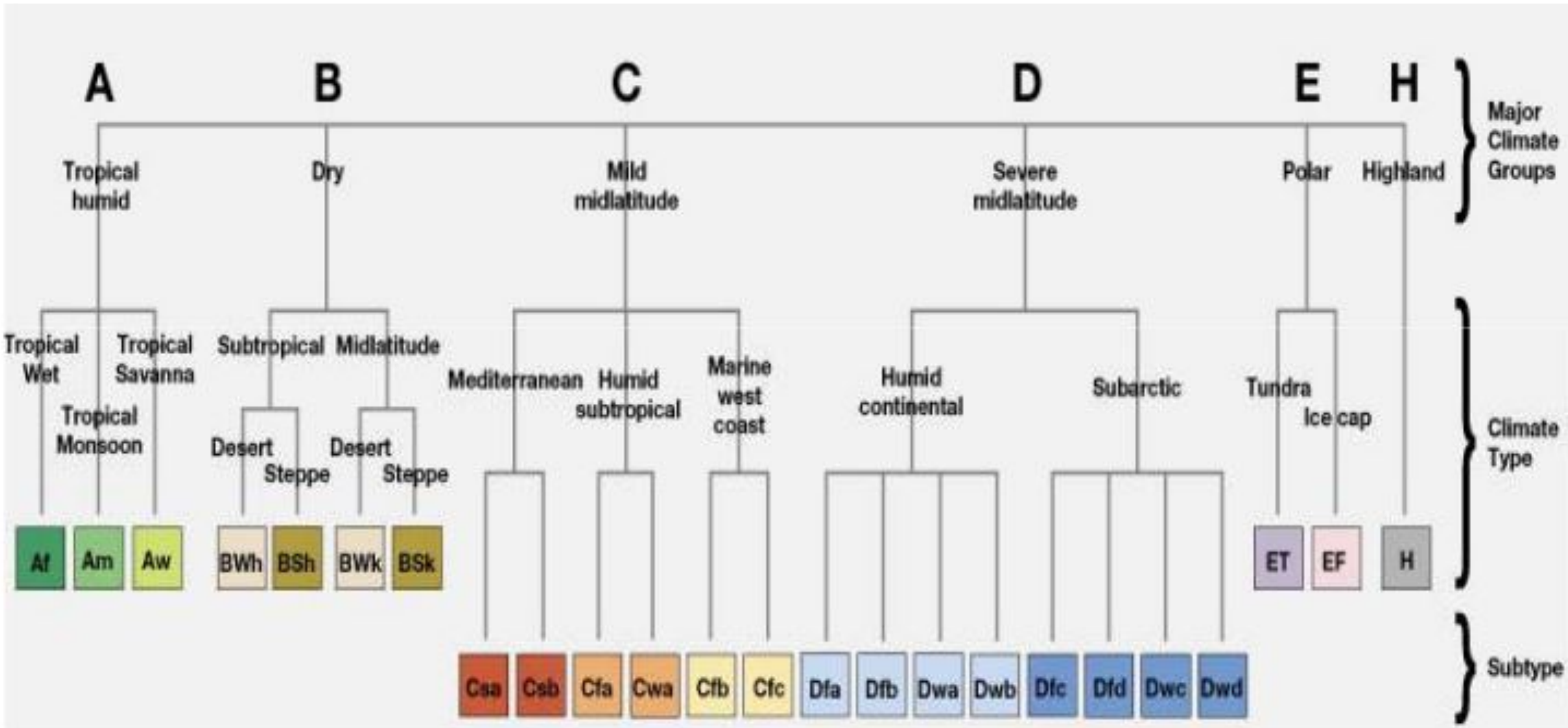
Group	*Characteristics*
A - Tropical	Average temperature of the coldest month is 18° C or higher
B - Dry Climates	Potential evaporation exceeds precipitation
C - Warm Temperate	The average temperature of the coldest month of the (Mid-latitude) climates years is higher than minus 3°C but below 18°C
D - 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

S2 : SLO2: *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

S3: SLO 1: *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.

S3: SLO 1: *Role of Land to regulate climate*

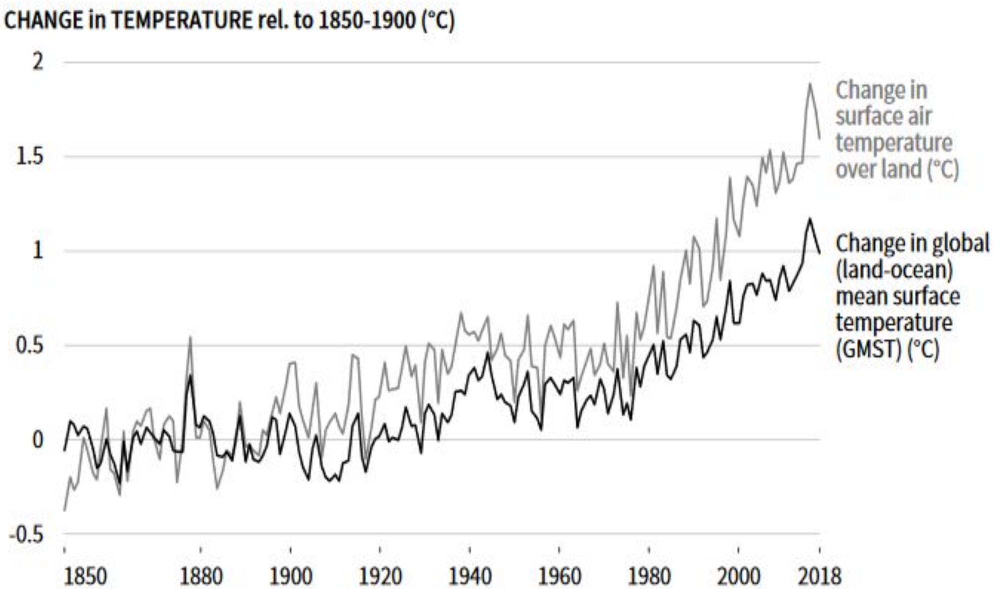
- Land is both a source and a sink of **greenhouse gases (GHGs)** and plays a key role in the exchange of energy, water and aerosols between the land surface and atmosphere.
- **Land ecosystems and biodiversity** are vulnerable to ongoing climate change and weather and climate extremes, to different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

S3: SLO 1: *Role of land to regulate climate*

Land use and observed climate change

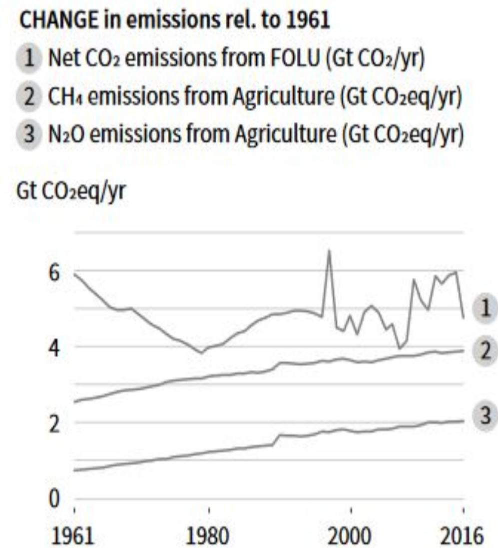
A. Observed temperature change relative to 1850-1900

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).



B. GHG emissions

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



S3: SLO 1: *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

S3: SLO 1: *Role of ocean to regulate climate*

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

S3: SLO 1: *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-climate-change-affecting-ocean-ice/

S3: SLO 1: 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

S3: SLO 2: *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

S3: SLO 2: 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.

S3: SLO 2: 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.

S3: SLO 2: 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

S3: SLO 2: 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.

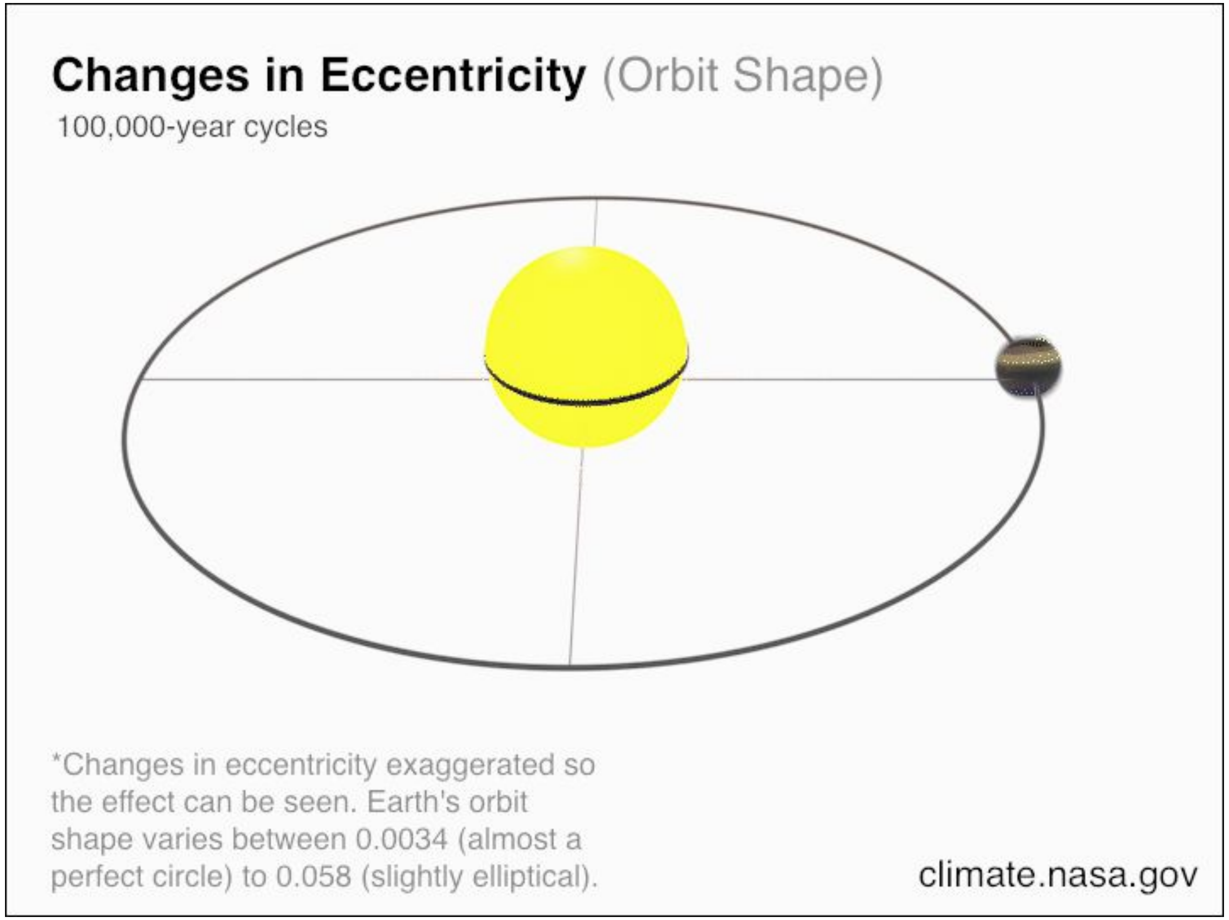
Eccentricity

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).

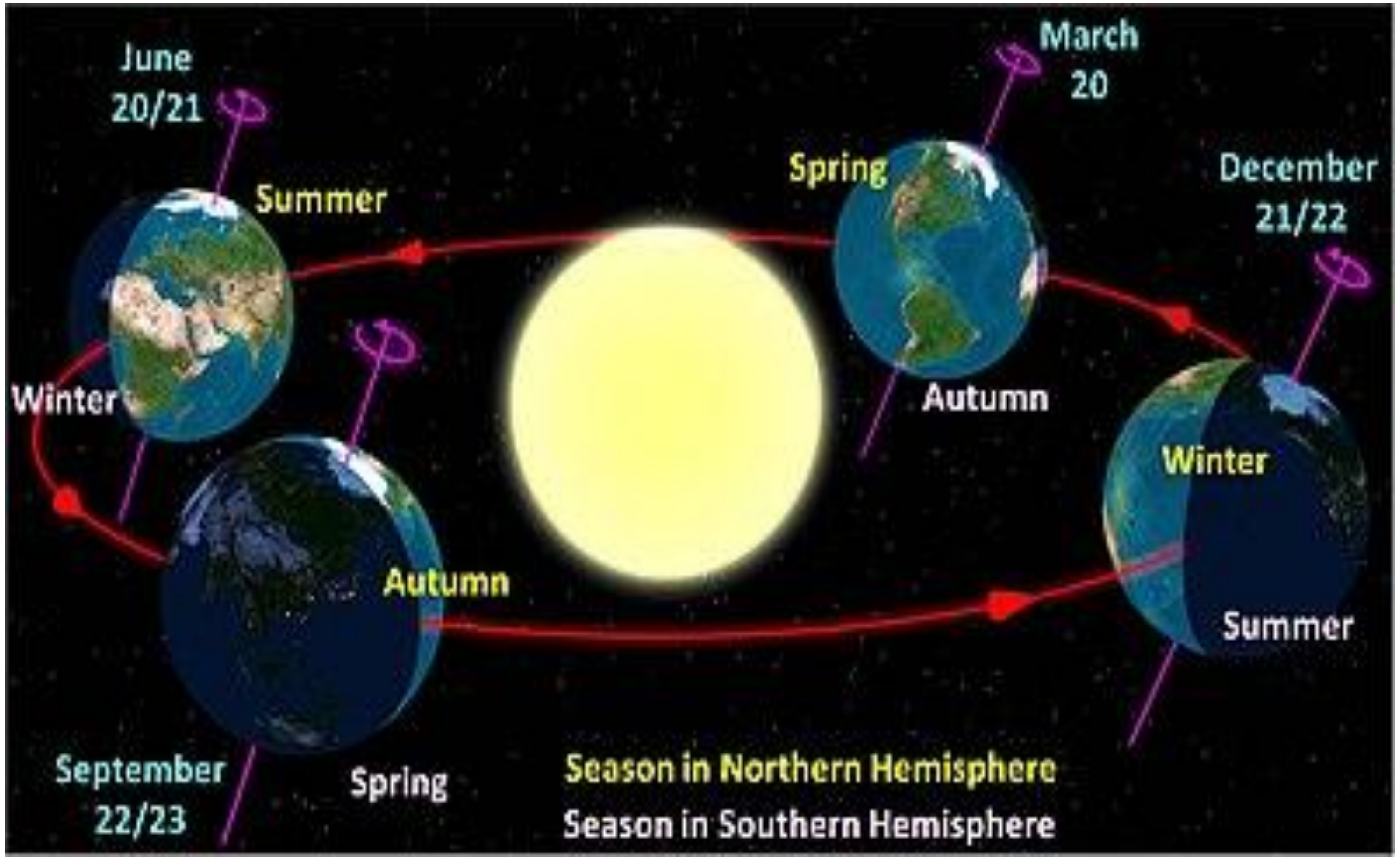
The Earth's orbit around the Sun, like other planet's orbits, is not a perfect circle. It is an ellipse. This means that the Earth is closer to and further away from the Sun at different times in the year.

- 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

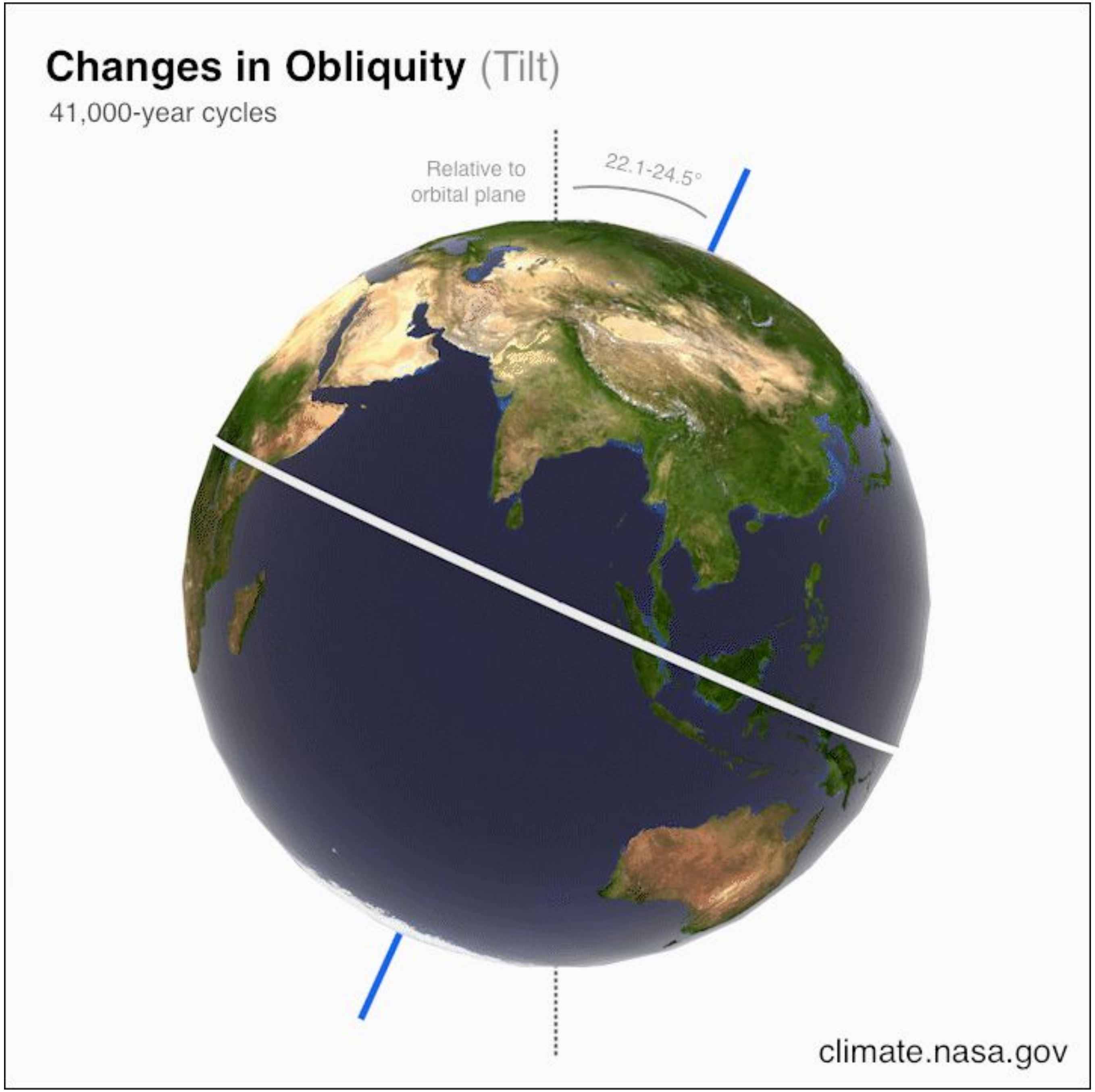


Obliquity

- 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

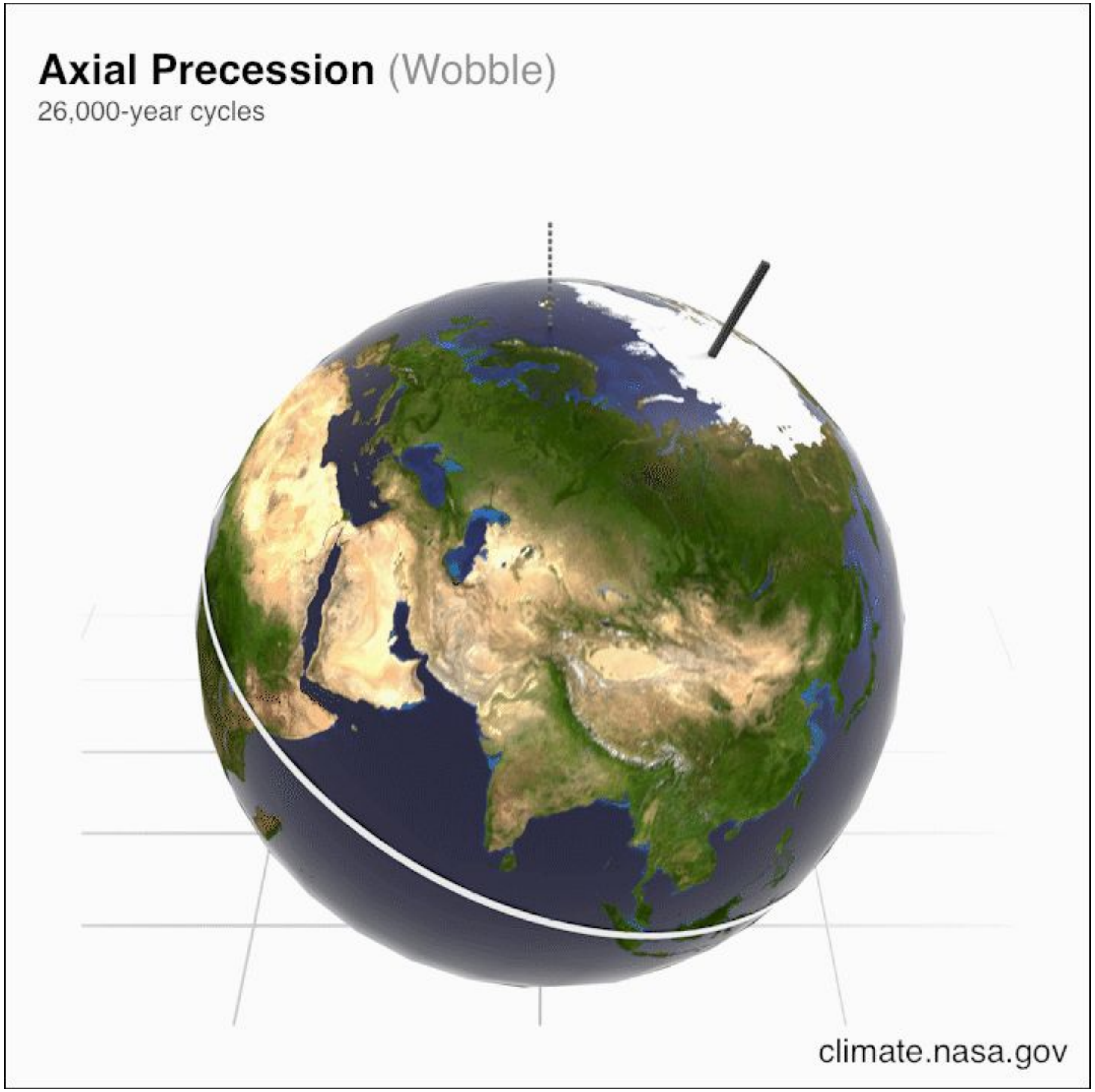
The more tilt means more severe seasons - warmer summers and colder winters; less tilt means less severe seasons - cooler summers and milder winters



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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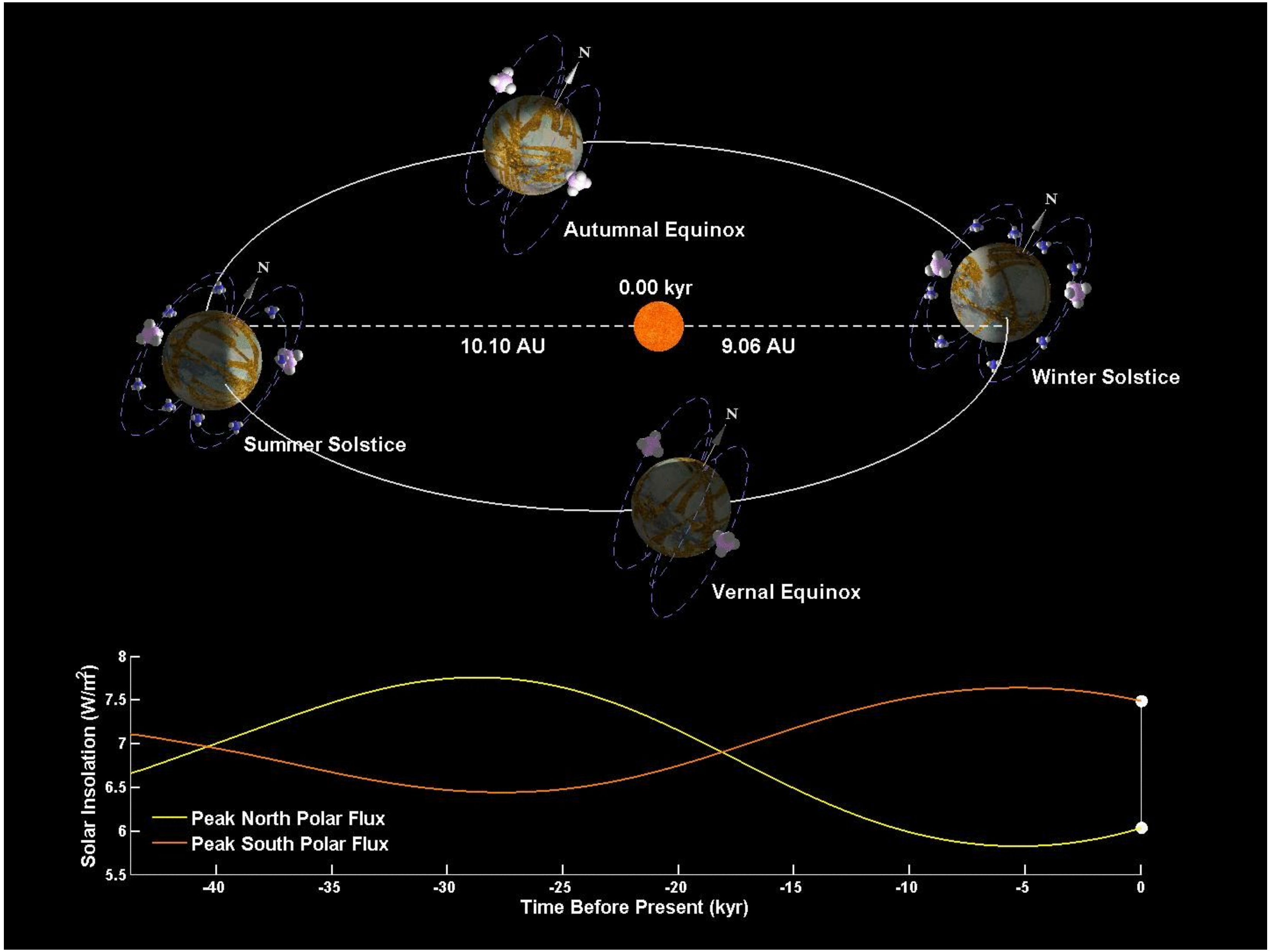


https://www.youtube.com/watch?v=wi-VEby3m9E

S5

SLO 1 - Human induced climate change (anthropogenic causes)
SLO 2- Global radiance balance of climate system

S5 – SLO 1 Human causes

- Climate change can also be caused by **human activities**, such as the burning of fossil fuels and the conversion of land for forestry and agriculture.
- Since the beginning of the Industrial Revolution, these human influences on the climate system have increased substantially. In addition to other environmental impacts, these activities change the land surface and emit various substances to the atmosphere. These in turn can influence both the amount of **incoming energy and the amount of outgoing energy** and can have both warming and cooling effects on the climate. The dominant product of fossil fuel combustion is carbon dioxide, dioxide, a greenhouse gas. The overall effect of human activities since the Industrial Revolution has been a warming effect, driven primarily by emissions of carbon dioxide and enhanced by emissions of other greenhouse gases.
- The build-up of greenhouse gases in the atmosphere has led to an enhancement of the natural greenhouse effect. It is this **human-induced enhancement** of the greenhouse effect that is of concern because ongoing emissions of greenhouse gases have the potential to warm the planet to levels that have never been experienced in the history of human civilization. Such climate change could have far-reaching and/or unpredictable environmental, social, and economic consequences.

- The Industrial Revolution in the 19th century saw the large-scale use of fossil fuels for industrial activities. These industries created jobs and over the years, people moved from rural areas to the cities. This trend is continuing even today.
- More and more land that was covered with vegetation has been cleared to make way for houses. Natural resources are being used extensively for construction, industries, transport, and consumption. Consumerism (our increasing want for material things) things) has increased by leaps and bounds, bounds, creating mountains of waste. Also, our population has increased to an incredible extent.
- All this has contributed to a rise in greenhouse gases in the atmosphere. Fossil fuels such as oil, coal and natural gas supply most of the energy needed to run vehicles, generate electricity for industries, households, etc.
- The **energy sector** is responsible for about ¾ of the carbon dioxide emissions, 1/5 of the methane emissions and a large quantity of nitrous oxide. It also produces nitrogen oxides (NOx) and carbon monoxide (CO) which are not greenhouse gases but do have an influence on the chemical cycles in the atmosphere that produce or destroy greenhouse gases

- **Carbon dioxide** is undoubtedly, the most important greenhouse gas in the atmosphere. Changes in land use pattern, deforestation, land clearing, agriculture, and other activities have all led to a rise in the emission of carbon dioxide.
- **Methane** is another important greenhouse gas in the atmosphere. About ¼ of all methane emissions are said to come from domesticated animals such as dairy cows, goats, pigs, buffaloes, camels, horses, and sheep. These **animals produce** methane during the cud-chewing process. Methane is also released from **rice or paddy fields** that are flooded during the sowing and maturing periods. When soil is covered with water it becomes anaerobic or lacking in oxygen. Under such conditions, methane-producing bacteria and other organisms decompose organic matter in the soil to form methane. Nearly 90% of the paddy-growing area in the world is found in Asia, as rice is the staple food there. China and India, between them, have 80-90% of the world's rice-growing areas.
- Methane is also emitted from **landfills** and other waste dumps. If the waste is put into an incinerator or burnt in the open, carbon dioxide is emitted. Methane is also emitted during the process of oil drilling, coal mining and also from leaking gas pipelines (due to accidents and poor maintenance of sites).
- A large amount of **nitrous oxide** emission has been attributed to fertilizer application. This in turn depends on the type of fertilizer that is used, how and when it is used and the methods of tilling that are followed. Contributions are also made by leguminous plants, such as beans and pulses that add nitrogen to the soil.

How we all contribute every day

All of us in our daily lives contribute our bit to this change in the climate. Give these points a good, serious thought:

1) **Electricity** is the main source of power in urban areas. All our gadgets run on electricity generated mainly from thermal power plants. These thermal power plants are run on fossil fuels (mostly coal) and are responsible for the emission of huge amounts of greenhouse gases and other pollutants.

2) Cars, buses, and trucks are the principal ways by which goods and people are **transported** in most of our cities. These are run mainly on petrol or diesel, both fossil fuels.

3) We generate large quantities of **waste in the form of plastics** that remain in the environment for many years and cause damage.

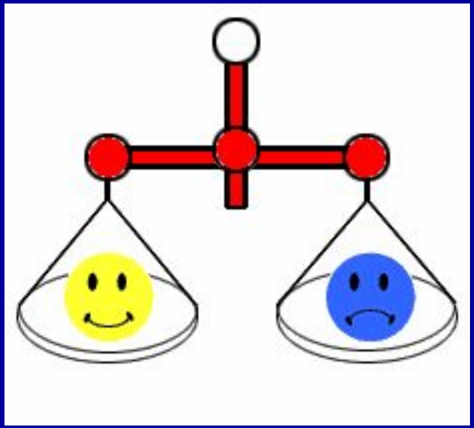
4) We use a huge quantity of paper in our work at schools and in offices. Have we ever thought about the **number of trees** that we use in a day?

5) Timber is used in large quantities for **construction** of houses, which means that large areas of **forest have to be cut down**.

6) A **growing population** has meant more and more mouths to feed. Because the land area available for agriculture is limited (and in fact, is actually shrinking as a result of ecological degradation), high-yielding varieties of crop are being grown to increase the agricultural output from a given area of land. However, such **high-yielding varieties of crops** require large quantities of fertilizers; and more fertilizer means more emissions of nitrous oxide, both from the field into which it is put and the fertilizer industry that makes it. **Pollution also results from the run-off of fertilizer into water bodies**.

Global radiance balance of climate system

Global radiance balance of climate system



Look at life as an **energy economy game.** Each day, ask yourself,

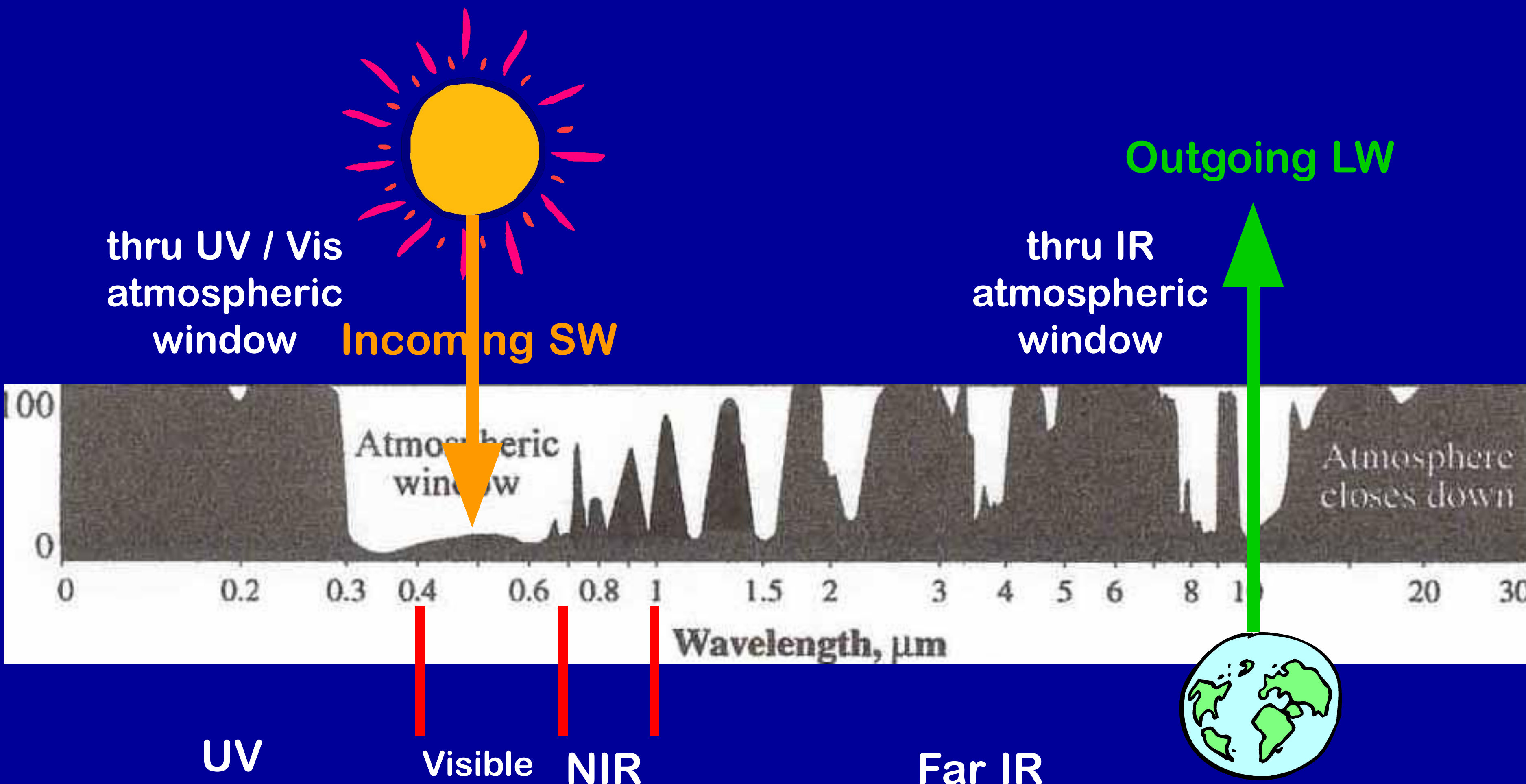
Are my energy expenditures (actions, reactions, thoughts, and feelings) productive or nonproductive?

During the course of my day, have I accumulated more stress or more peace?

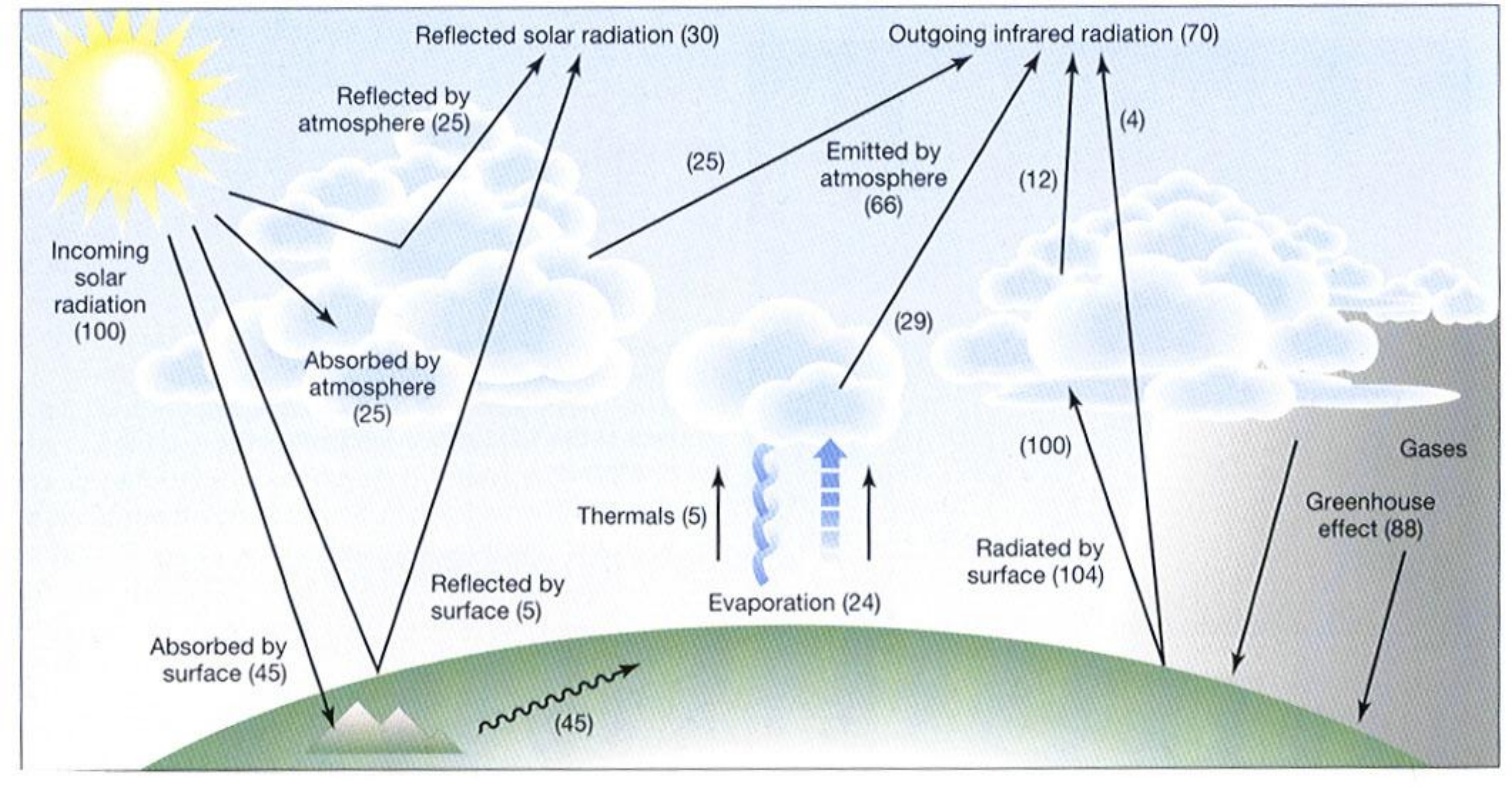
~ Doc Childre and Howard Martin

Review: Absorption curve for the "Whole Atmosphere"

OVERALL BALANCE: Incoming = Outgoing



Typical Energy Balance Diagram



mesoscale.agron.iastate.edu/agron206/animations/10_AtmoEbal.html

From SGC-I Chapter 3, p 50, Fig 3-19

Energy Balance Equation:

$$R_{net} = (Q + q) - a - Lu + Ld = H + LE + G$$

(one of several ways this equation can be written)

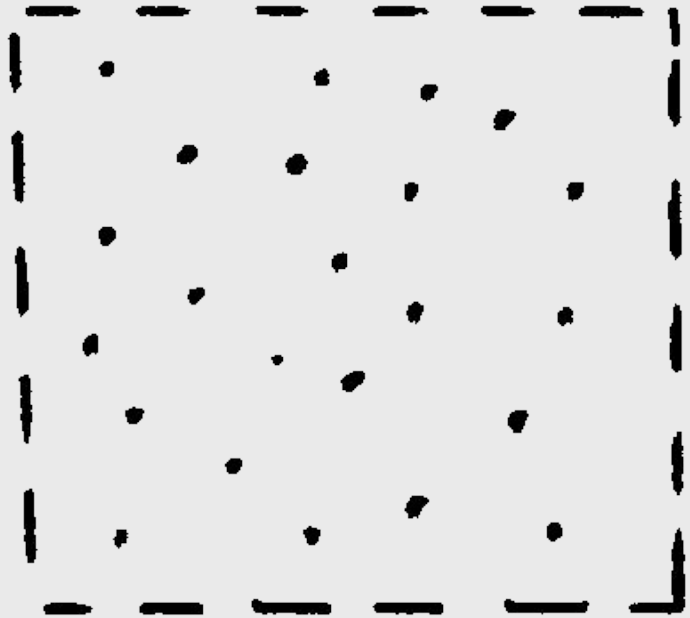
Let's try to find an easy way to understand and remember all the components of the Earth's Energy Balance

We'll use "cartoon symbols" . . .

“CARTOON” SYMBOLS:

To represent the Earth’s surface:

“CARTOON” SYMBOLS:



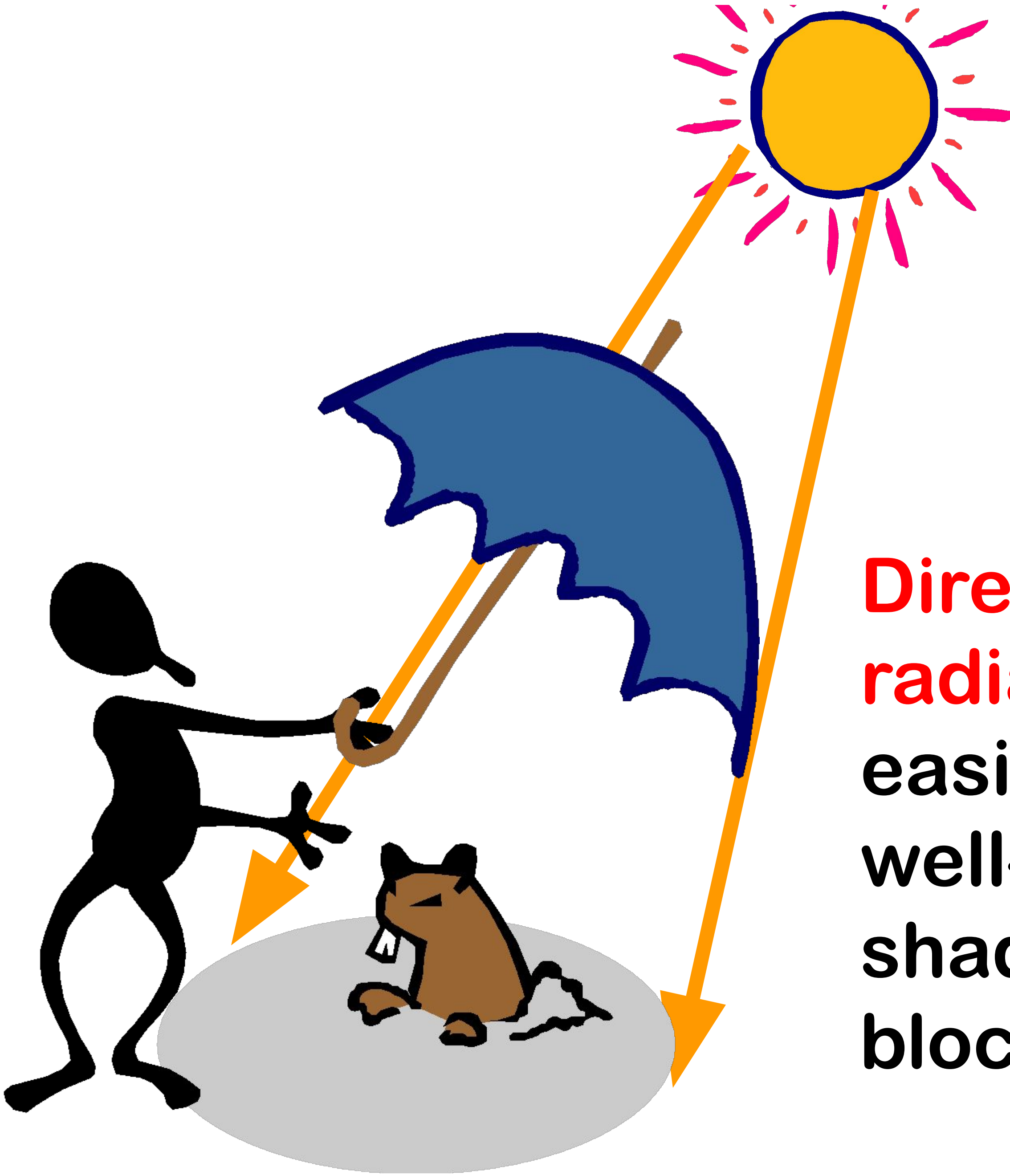
To represent the atmosphere – composed of both invisible gases, aerosols, dust and other particulate matter:

“CARTOON” SYMBOLS:

To represent CLOUDS

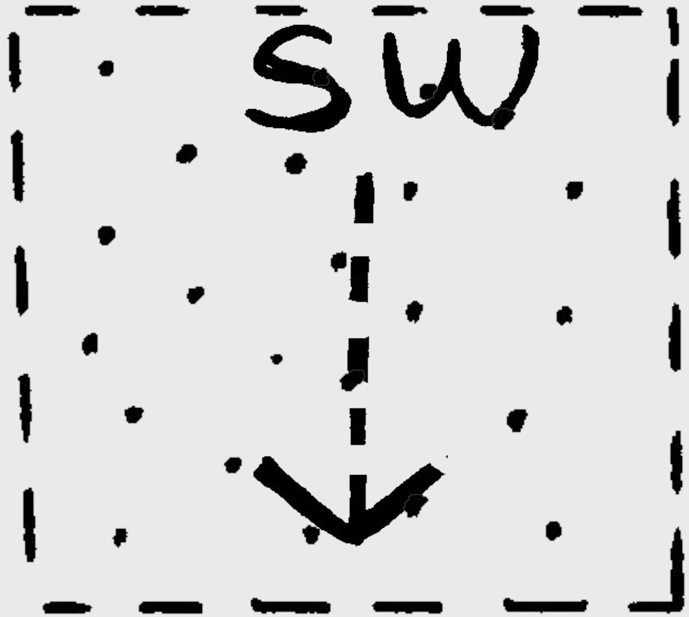
"CARTOON" SYMBOLS:

To represent SOLAR (shortwave) radiation coming in DIRECTLY.
(aka Direct shortwave radiation)



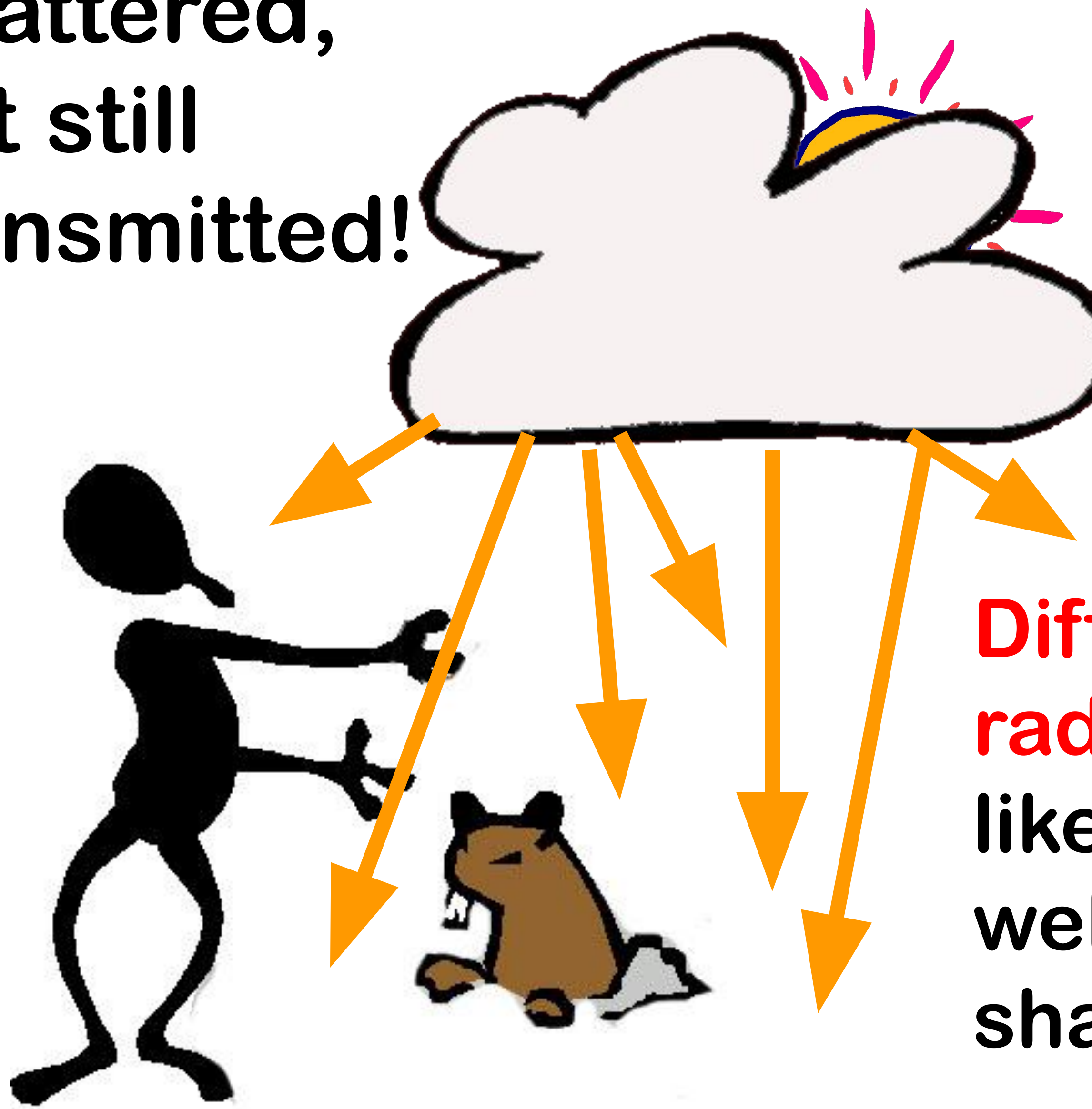
Direct SW radiation easily casts well-defined shadows when blocked

"CARTOON" SYMBOLS:

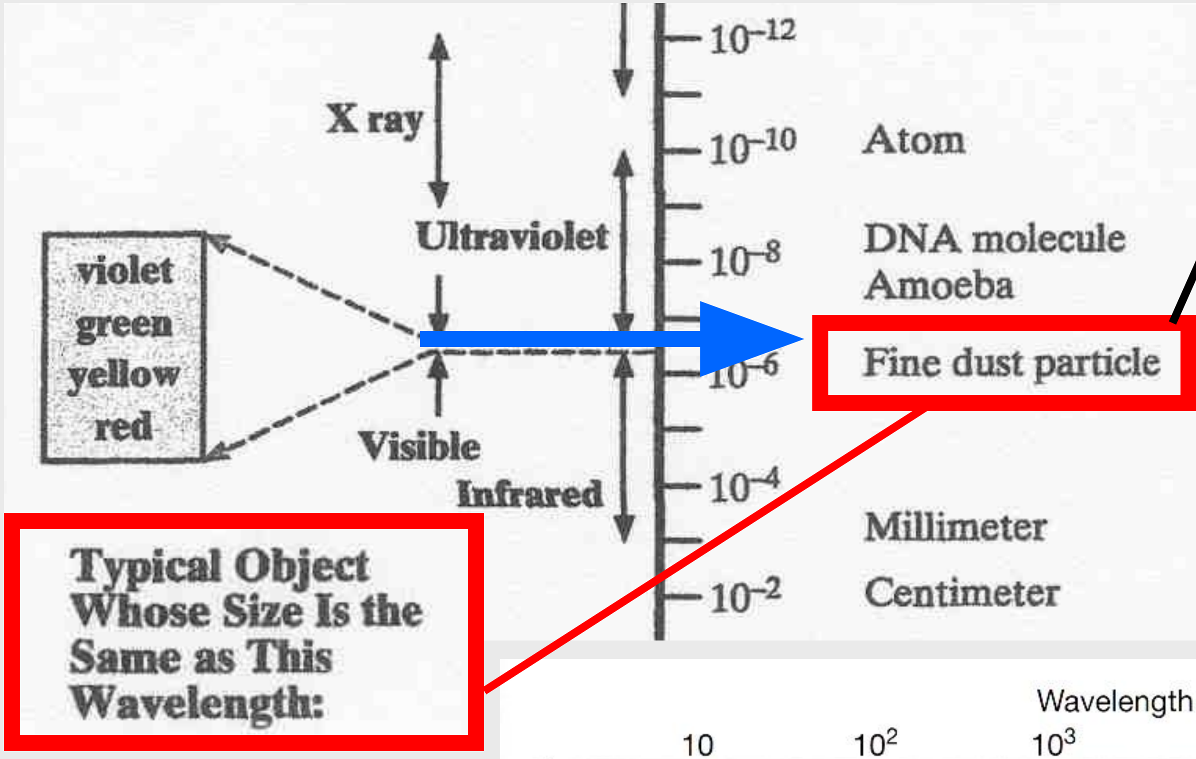


To represent SOLAR (shortwave) radiation coming in as **DIFFUSE shortwave radiation**, i.e. scattered by gases, clouds, and particles in the atmosphere.

Scattered, but still transmitted!

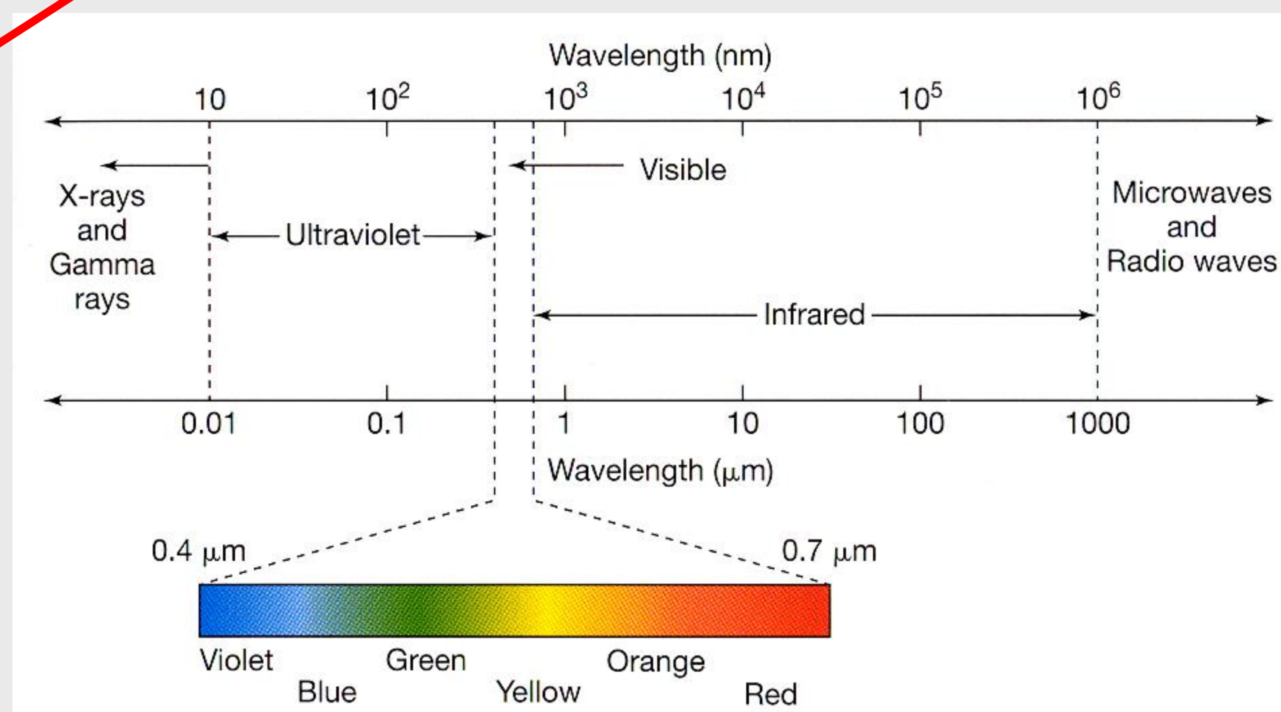


Diffuse SW radiation is less likely to cast a well-defined shadow!

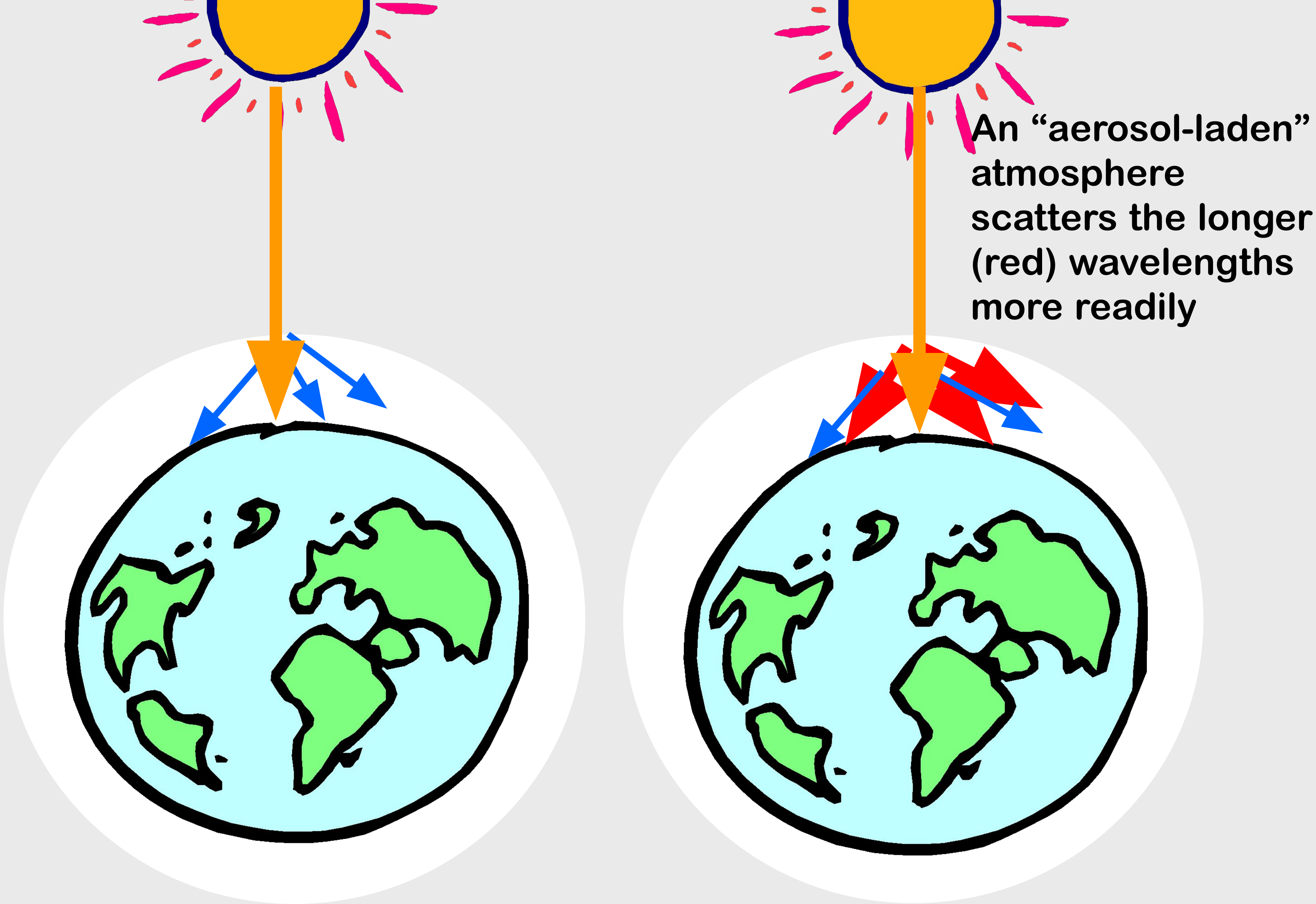


Different sized dust particles, water droplets, aerosols,

(even gas molecules themselves)



Scattering of visible light



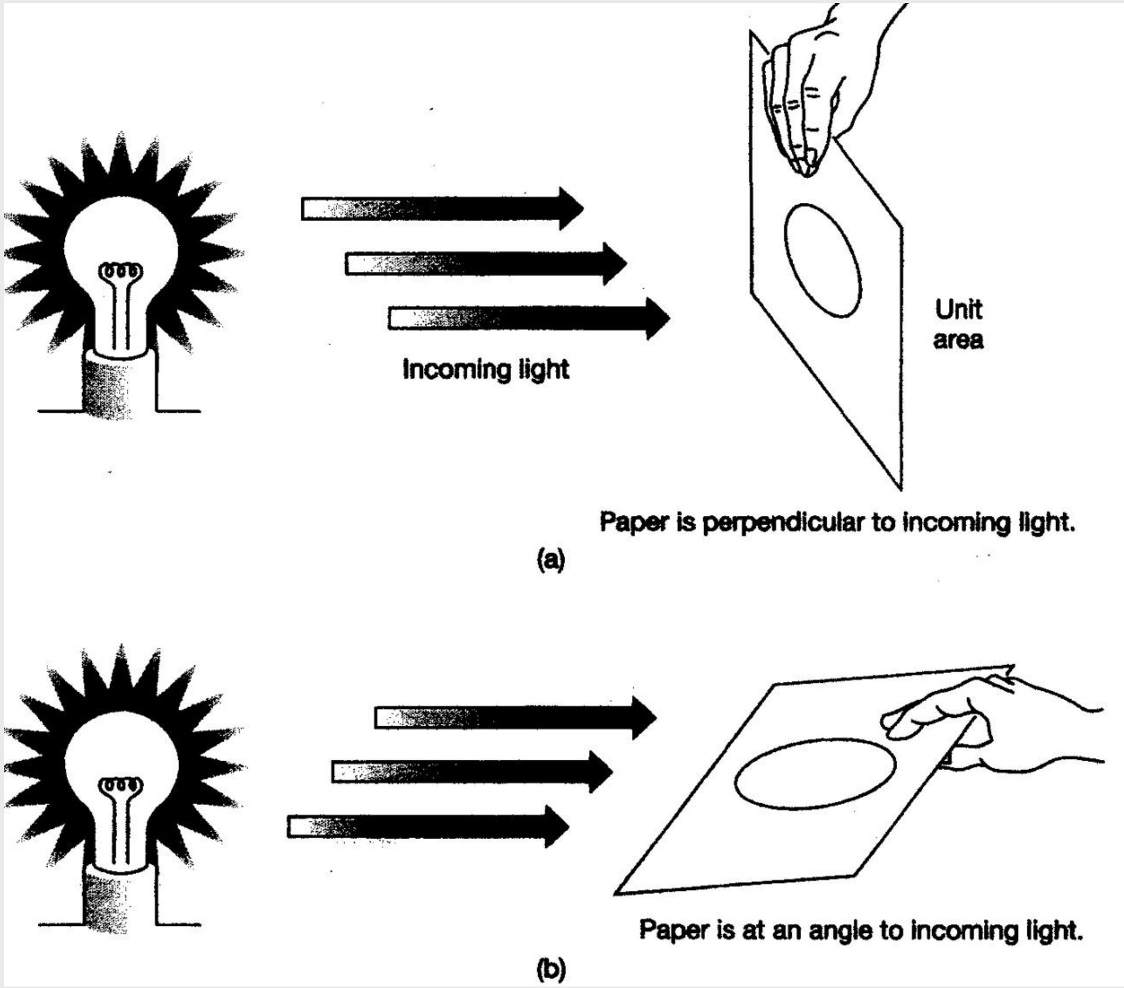
“Clear” atmosphere composed primarily of fine particles, water droplets, gas molecules

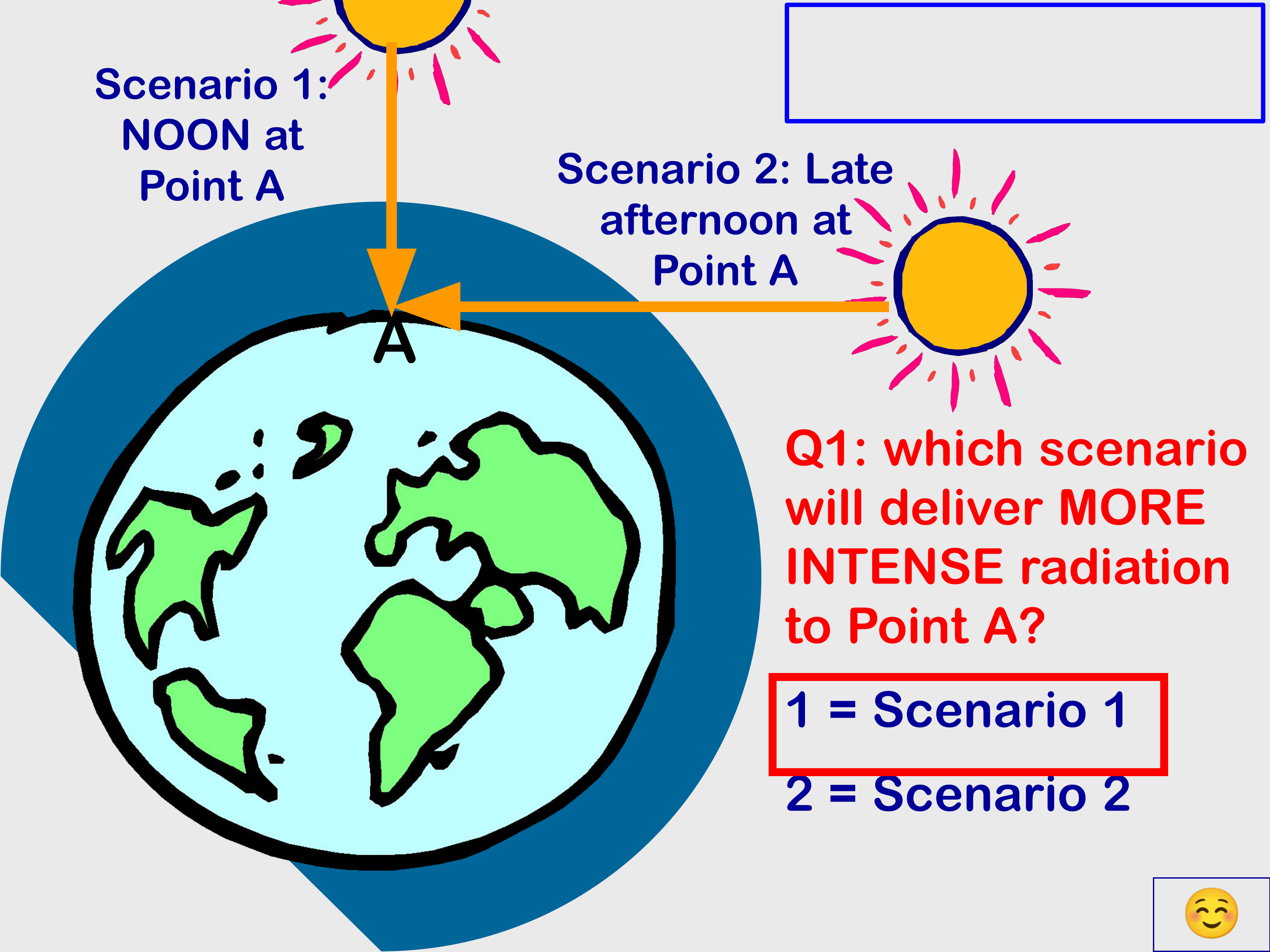
“Dirty” (aerosol-laden) atmosphere composed of fine particles, gases, & H_2O -- **PLUS larger dust particles, aerosols, pollution, etc.**

ALSO: **The angle at which direct SW radiation is intercepted by a surface makes a difference!!**

Radiation is concentrated over a small area & hence is **more intense** when it comes in **perpendicular** to the surface

Radiation is **spread** out **over a larger area** & hence is **less intense per unit area** when it comes in at an angle.




Scenario 1: NOON at Point A
Scenario 2: Late afternoon at Point A
A
Q1: which scenario will deliver MORE INTENSE radiation to Point A?
1 = Scenario 1
2 = Scenario 2

Q2 = WHY is the intensity of the SW radiation at Point A not as strong in the late afternoon as it is at noon?

1 = because as the Sun goes down close to sunset time, it gives off less radiation

2 = because the SW radiation is coming in at an angle in the late afternoon, and is not directly overhead (perpendicular) like it is at noon.

3 = because the SW radiation is being transmitted through a thicker atmosphere & hence scattered more

BOTH #2 & #3 are applicable!

☺️

“CARTOON” SYMBOLS:

To represent SOLAR (shortwave) radiation that is **REFLECTED** (or scattered) **BACK TO SPACE** by: atmosphere, clouds, Earth’s surface, etc.

New term:

ALBEDO = reflectivity of a surface

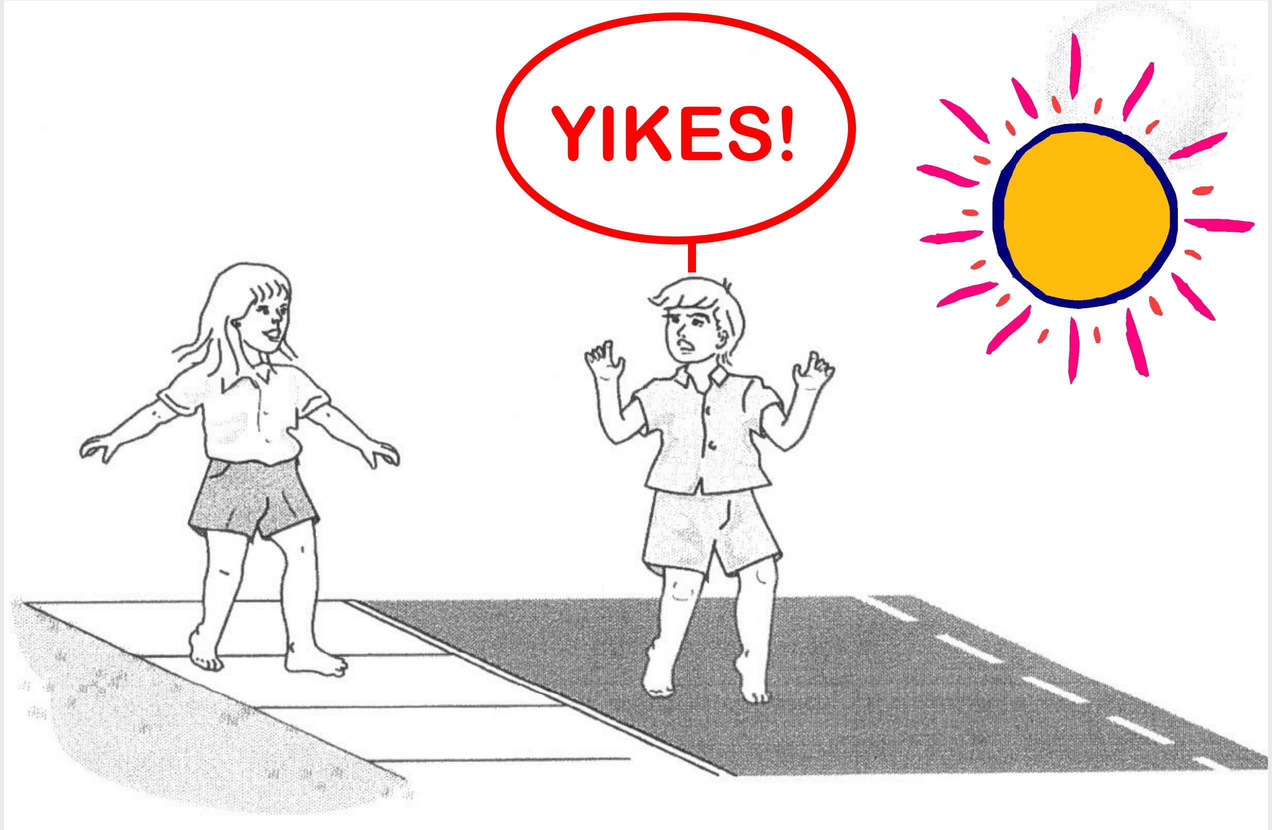
"*symbol*" = a

Represented as:

a decimal from 0 to 1.0 *or*

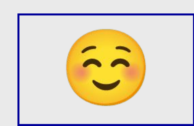
% from 0 – 100 % (perfect reflectivity)

Hence, amount ABSORBED = (1 – albedo)



If a surface's albedo is HIGH, absorption by the surface is LOW □ COOLER surface

If a surface's albedo is LOW absorption by the surface is HIGH => HOTTER surface!



Albedos of Some Common Surfaces

Type of Surface		*Albedo*
Sand		0.20–0.30
Grass		0.20–0.25
Forest	Low albedo	0.05–0.10
Water (overhead Sun)		0.03–0.05
Water (Sun near horizon)		0.50–0.80
Fresh snow	High albedo	0.80–0.85
Thick cloud		0.70–0.80

- CLOUDS: 0.44 (high, thin clouds) - 0.90 (low, thick clouds)

AVERAGE PLANET EARTH = ~ 0.30

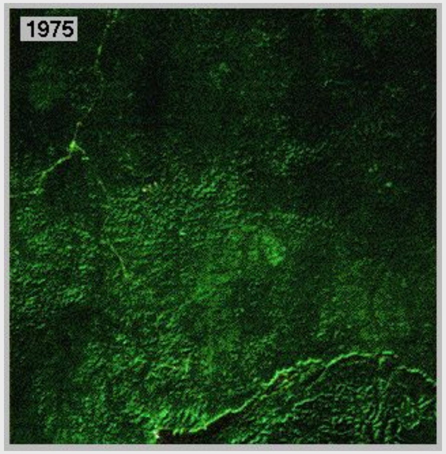
Q3: What will happen to incoming SW over the Amazon Rain Forest if parts of it are deforested?

1 = more SW will be absorbed

2 = less SW will be absorbed

SW

Before



After

“CARTOON” SYMBOLS:

To represent TERRESTRIAL (longwave IR) radiation emitted upward by the Earth’s surface or the atmosphere

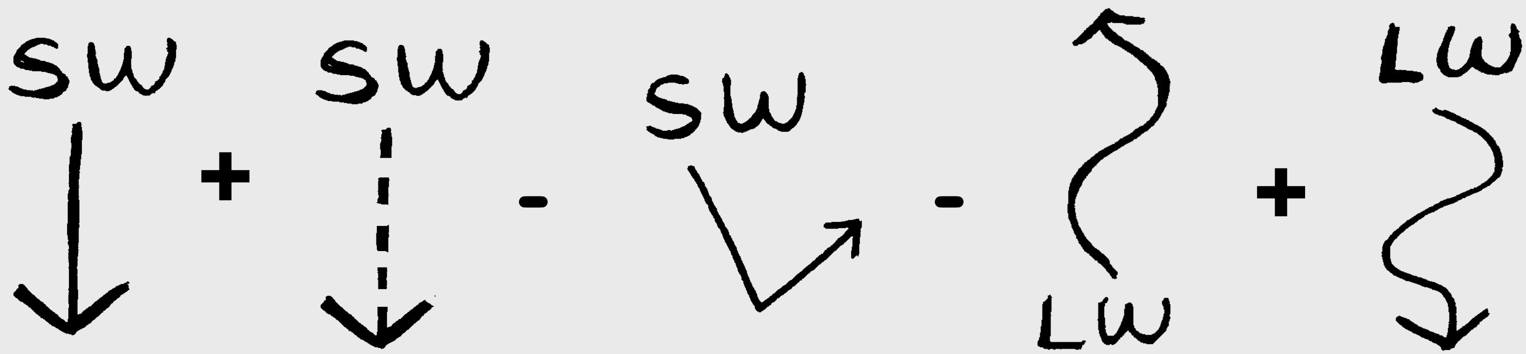
“CARTOON” SYMBOLS:

To represent TERRESTRIAL (longwave IR) re-radiation emitted downward by the Earth’s ATMOSPHERE

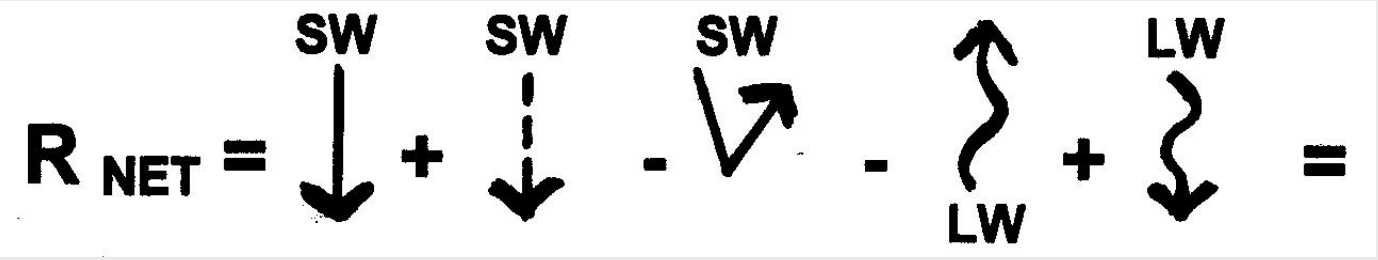
PUTTING IT TOGETHER:

Can you place + and – signs where they ought to go in the equation?

R_{NET} =



$$R_{NET} = (Q + q) - a - Lu + Ld$$



Now we'll look at the energy pathways in a bit more detail by combining the cartoon symbols in various ways . . .

First, what if . . .

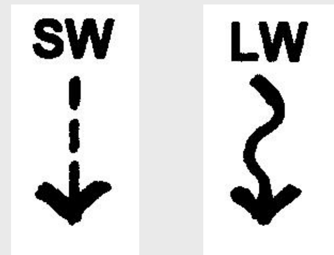
. . . The Earth didn't have an atmosphere, and therefore didn't have a greenhouse effect??

What would the energy pathways in the Earth-Sun system look like?

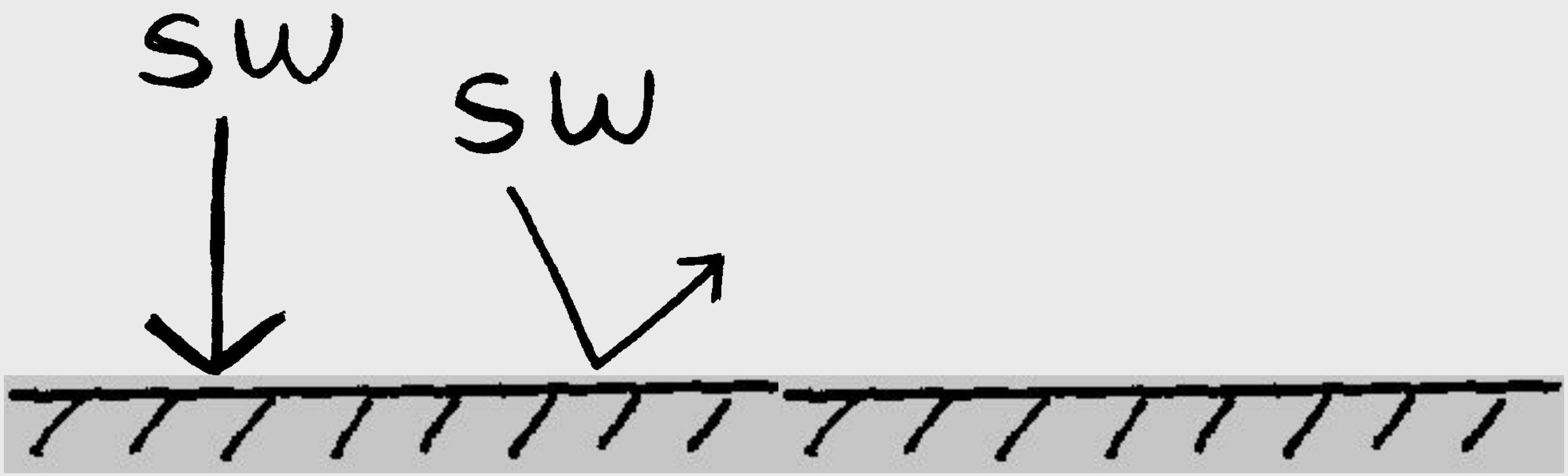
LW

Which terms are not involved?

No scattering by atmosphere

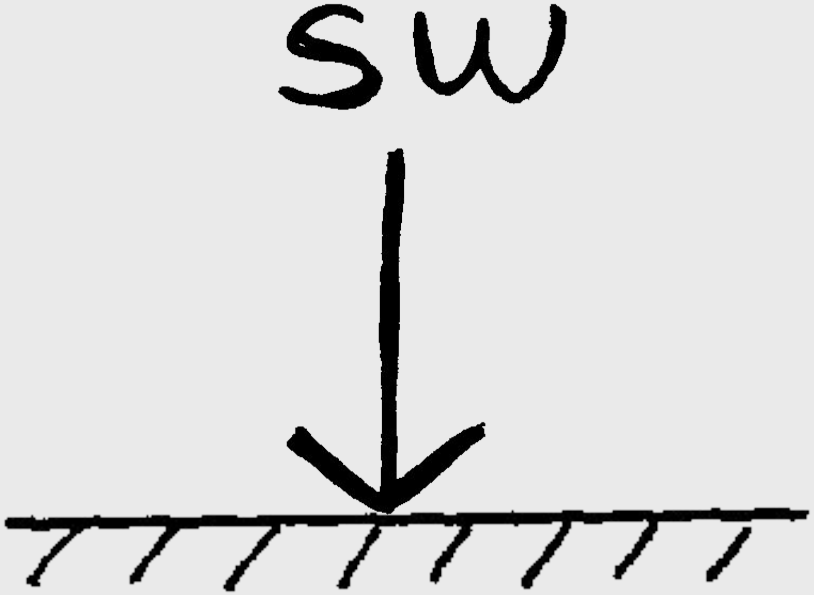


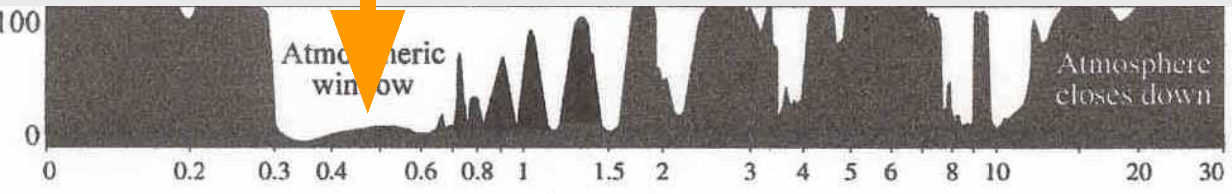
No re-radiation of infrared by GHG's



To describe the real Earth-Atmosphere system, more detail is needed in our simple representation . . . . .
We'll use our symbols to build an energy balance "model"

SW BEAMED DIRECTLY TO EARTH'S SURFACE WHERE IT IS ABSORBED:

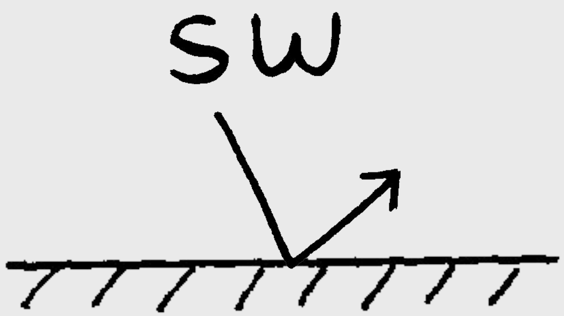




SW REFLECTED BACK TO SPACE:

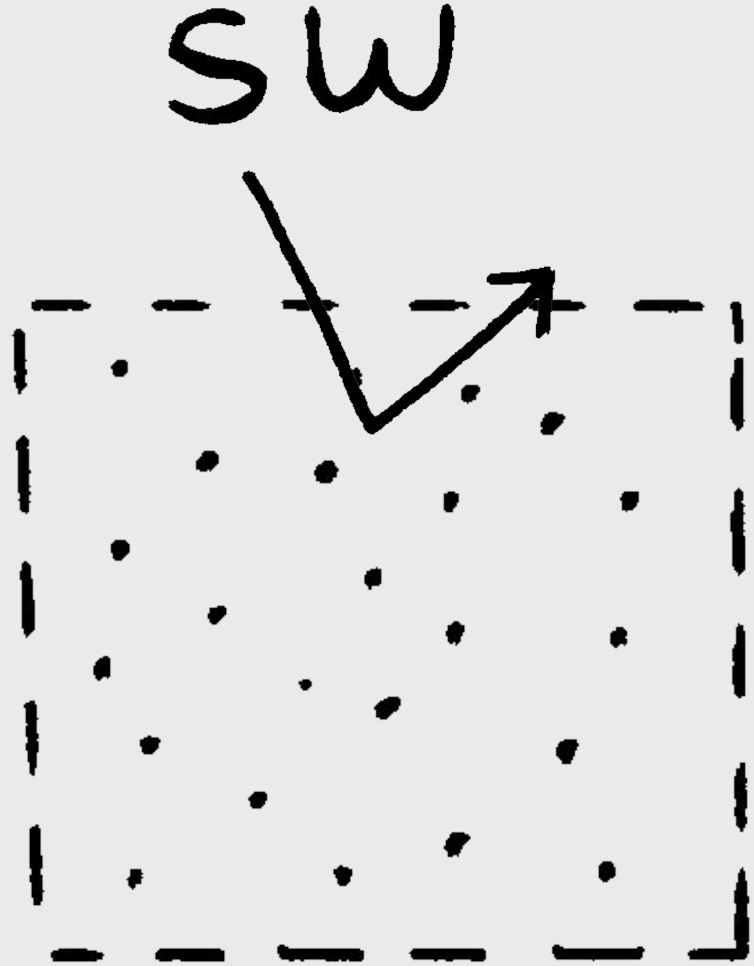
By clouds

By Earth's surface

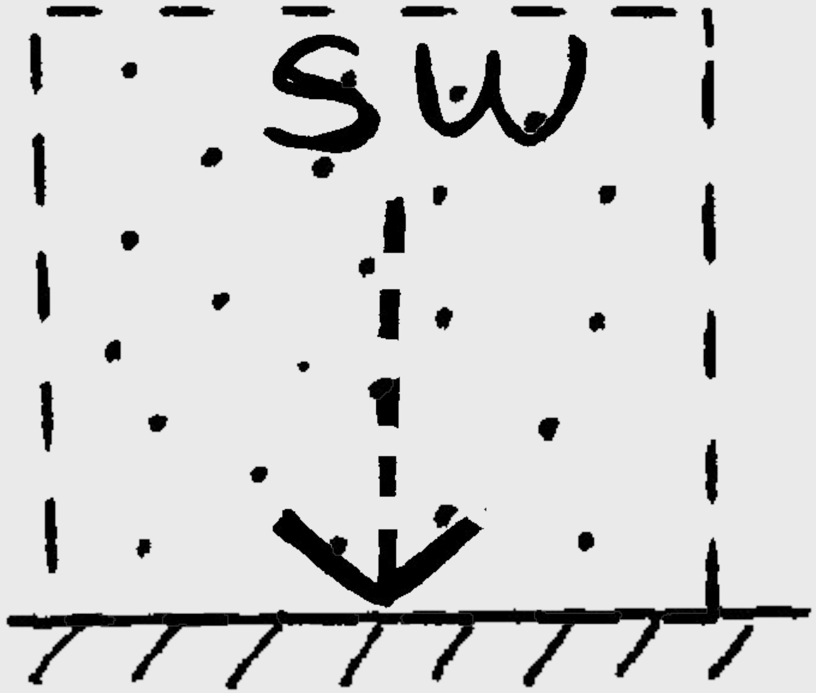


This is determined by the ALBEDO of the clouds or surface

SW SCATTERED BACK TO SPACE BY ATMOSPHERE:

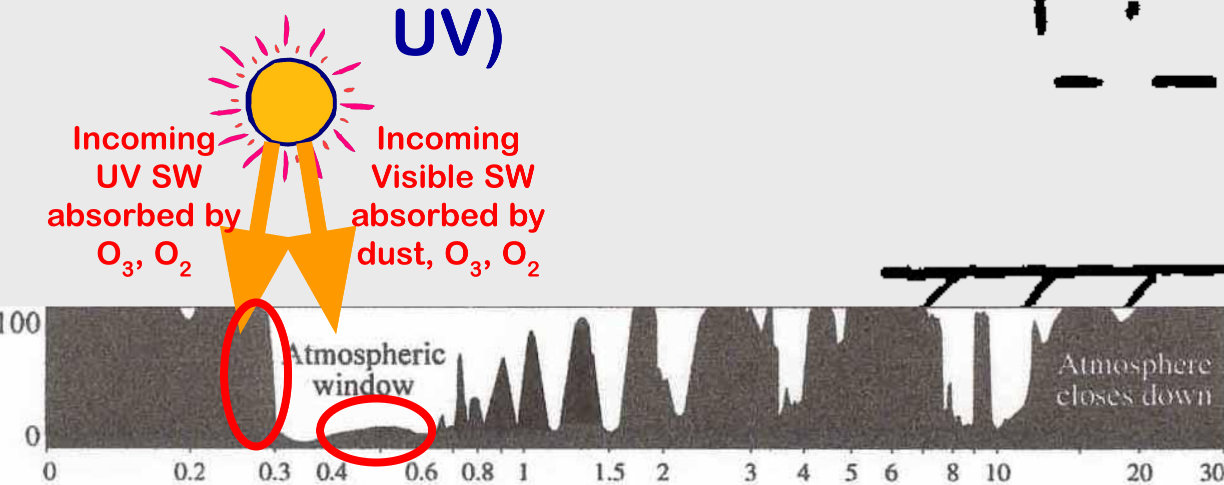


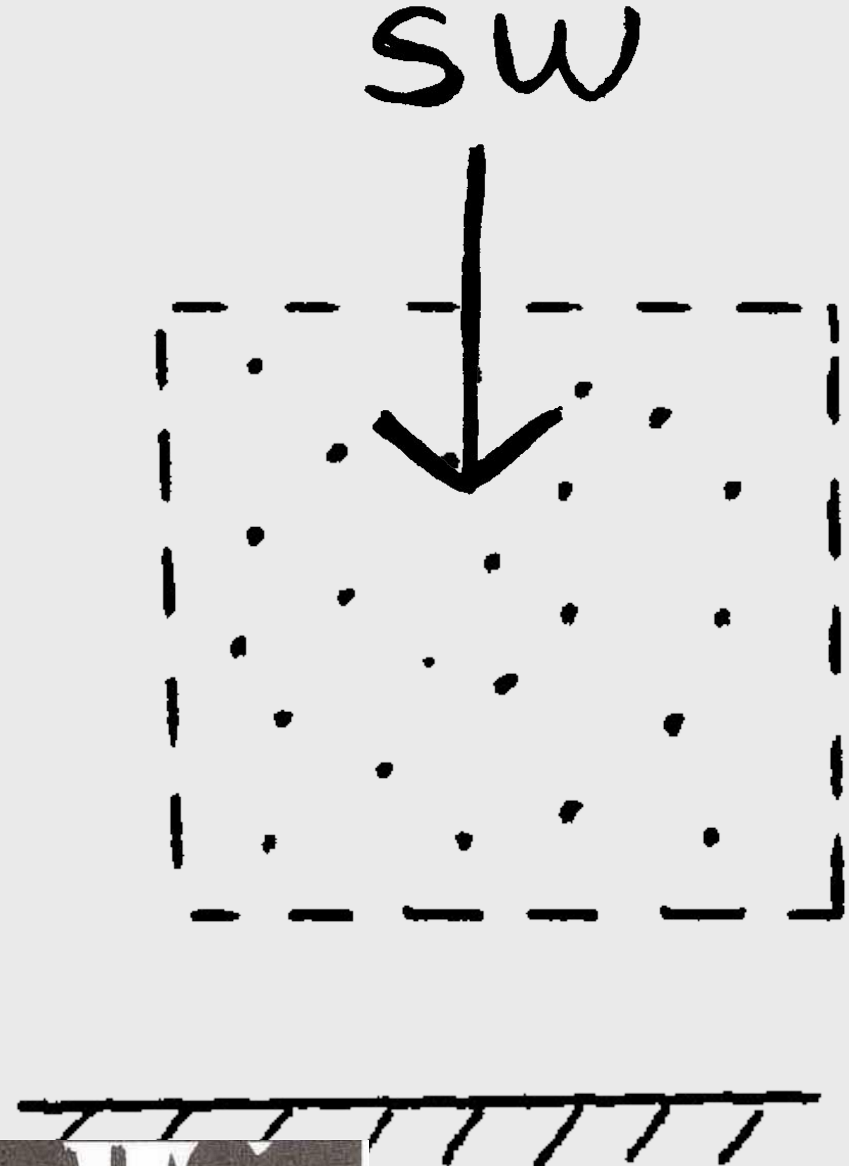
SW SCATTERED DOWN TO EARTH's SURFACE where it is absorbed



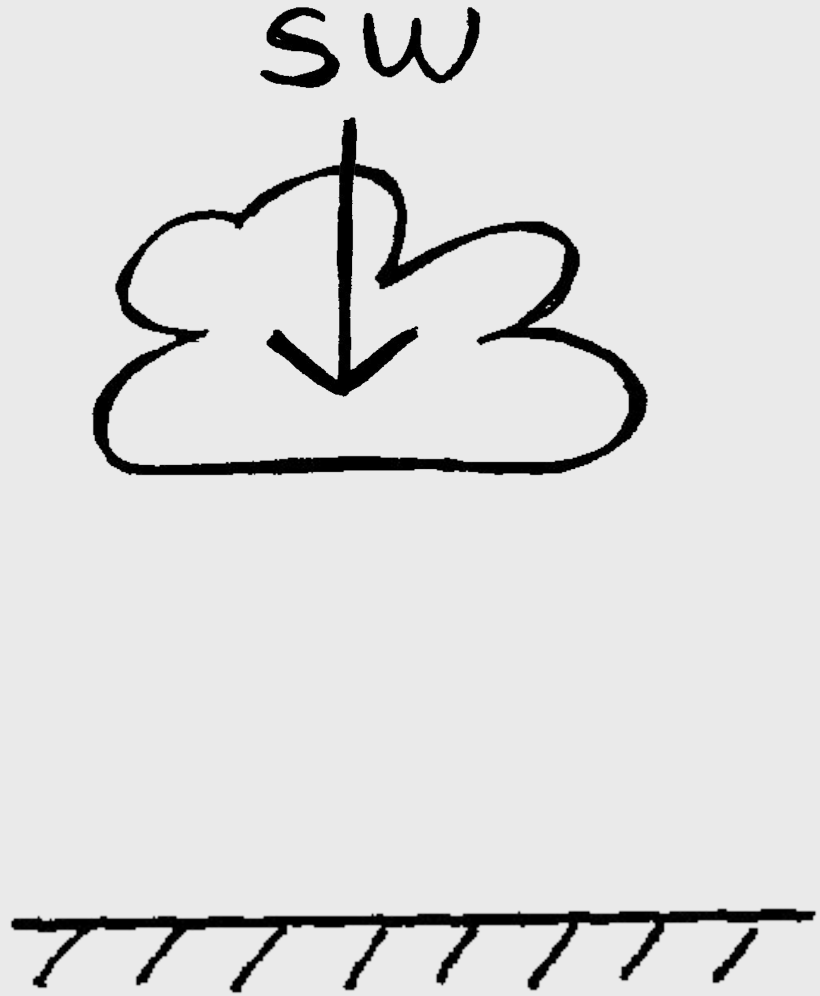
SW ABSORBED IN ATMOSPHERE BY GASES, DUST, etc.

(including Ozone absorbing shortwave UV)

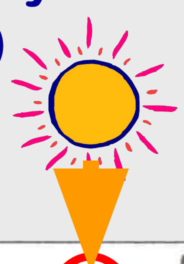




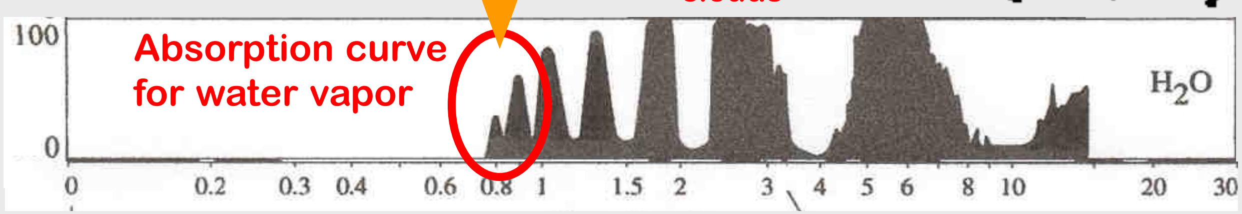
SW ABSORBED In ATMOSPHERE BY CLOUDS & H2O vapor:



(NOTE: clouds are made up of tiny droplets of water surrounded by lots of water vapor)

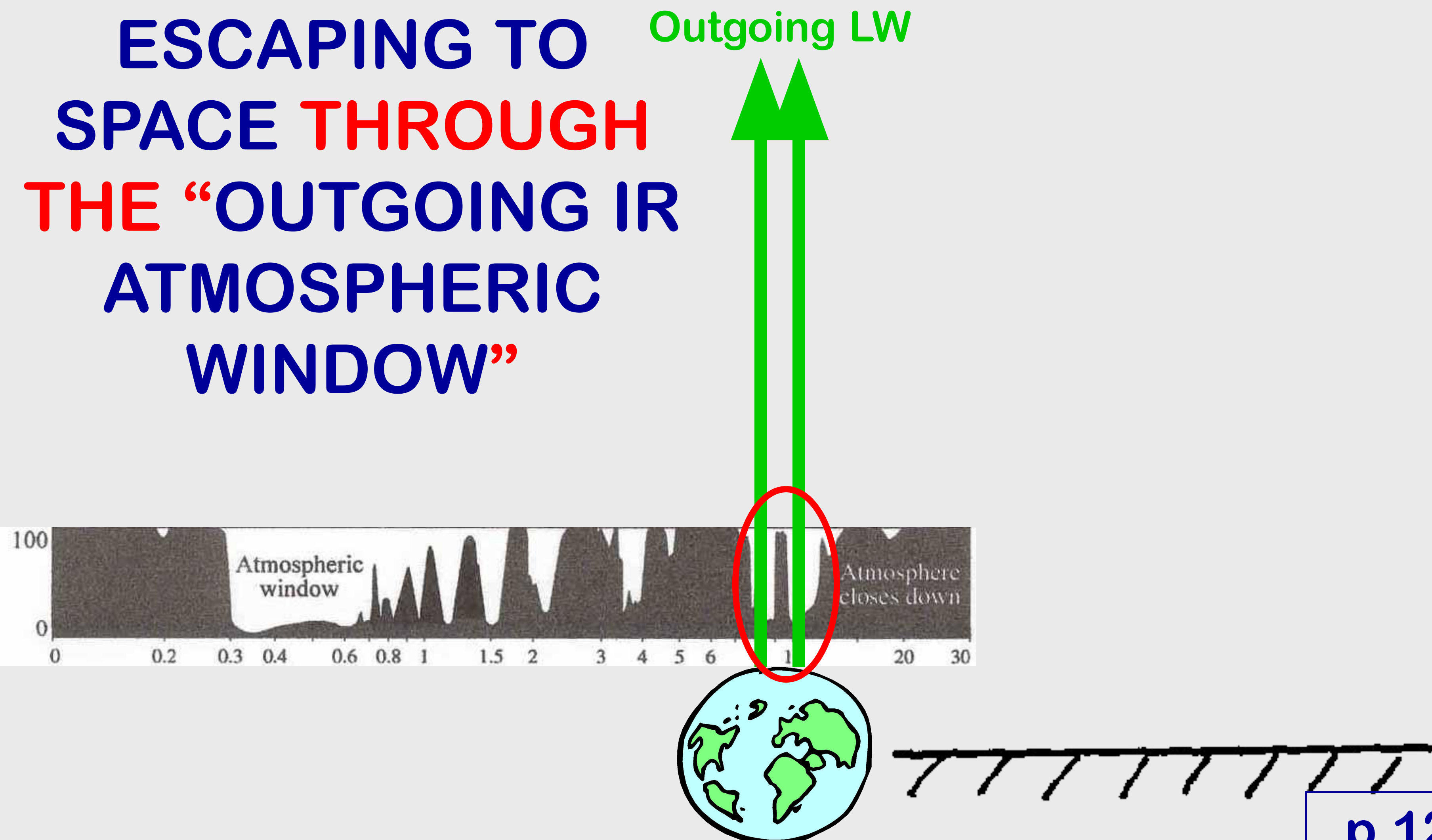


Incoming Visible & Near IR SW absorbed by water vapor & clouds

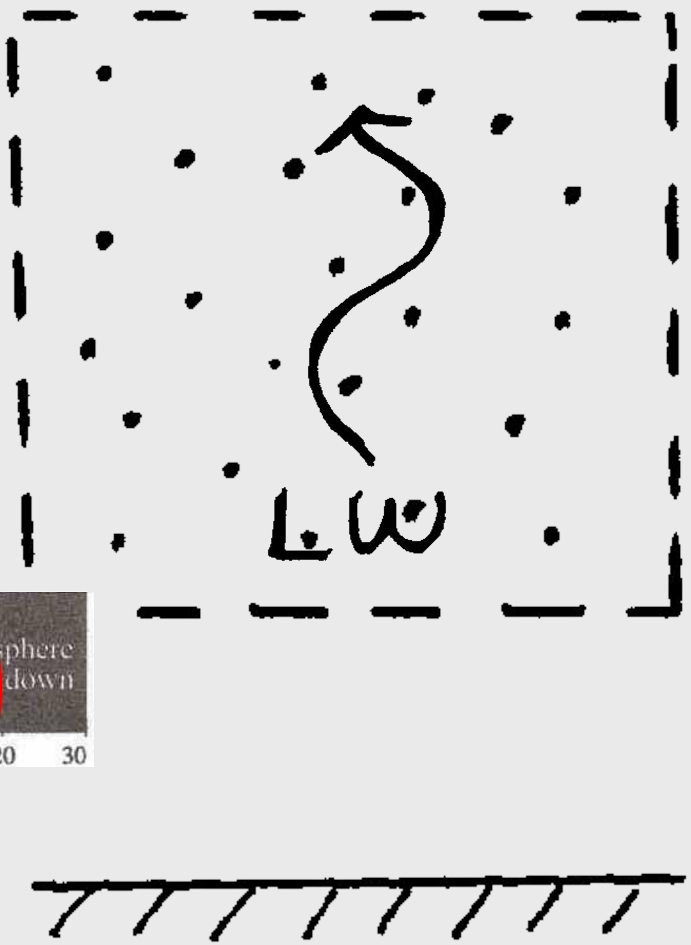


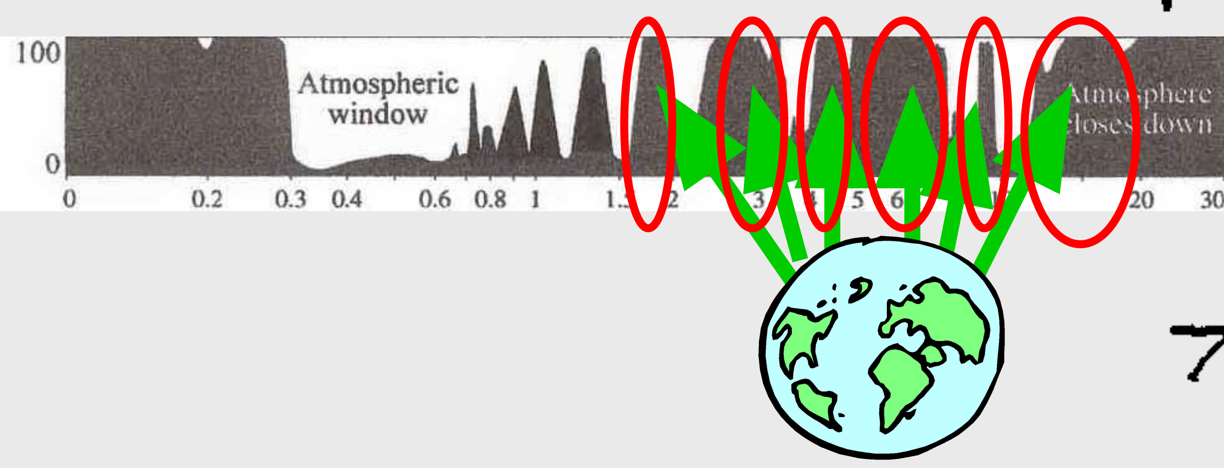
LW

LW (IR) EMITTED FROM EARTH'S SURFACE ESCAPING TO SPACE THROUGH THE "OUTGOING IR ATMOSPHERIC WINDOW"

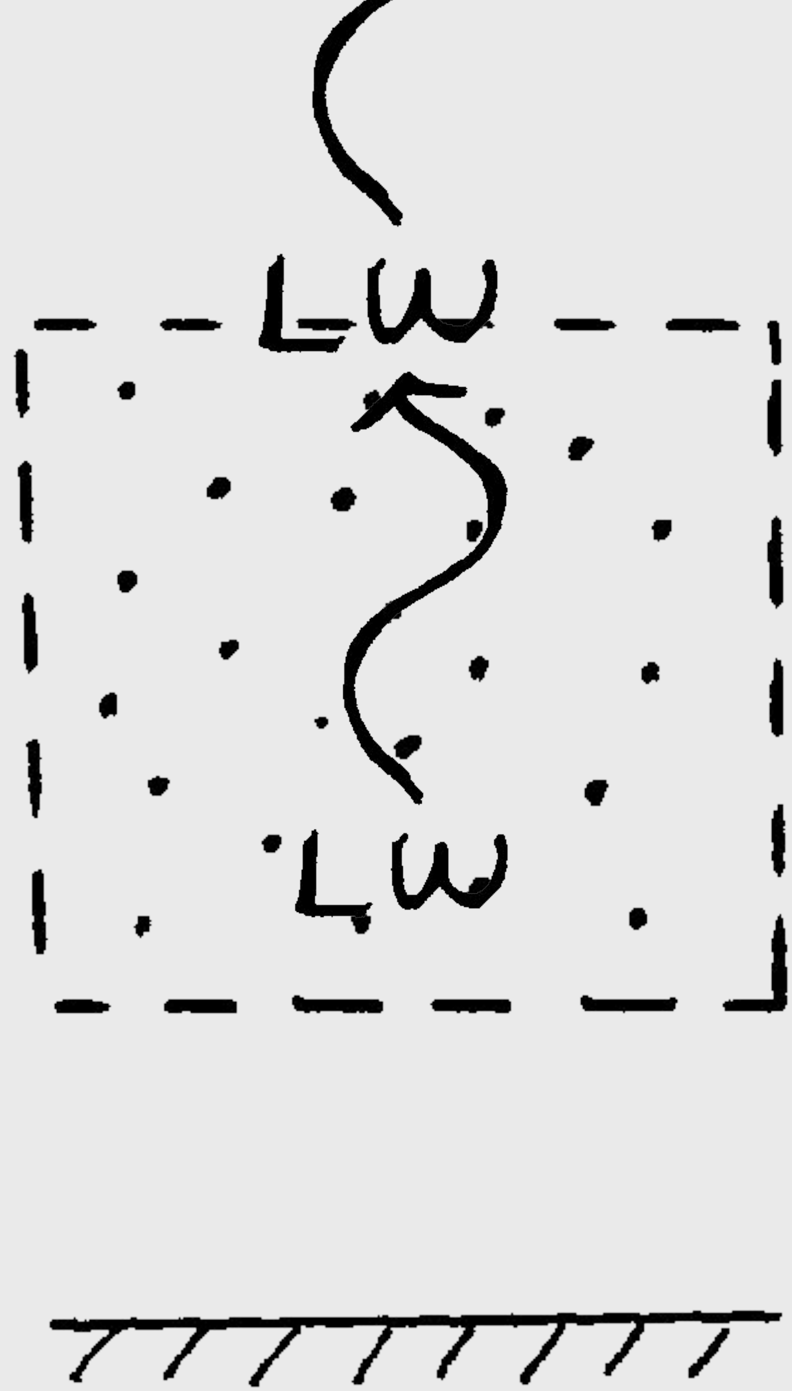


IR EMITTED FROM EARTH'S SURFACE BUT ABSORBED IN THE ATMOSPHERE BY GREENHOUSE GASES (H_2O, CO_2, CH_4, ETC.)





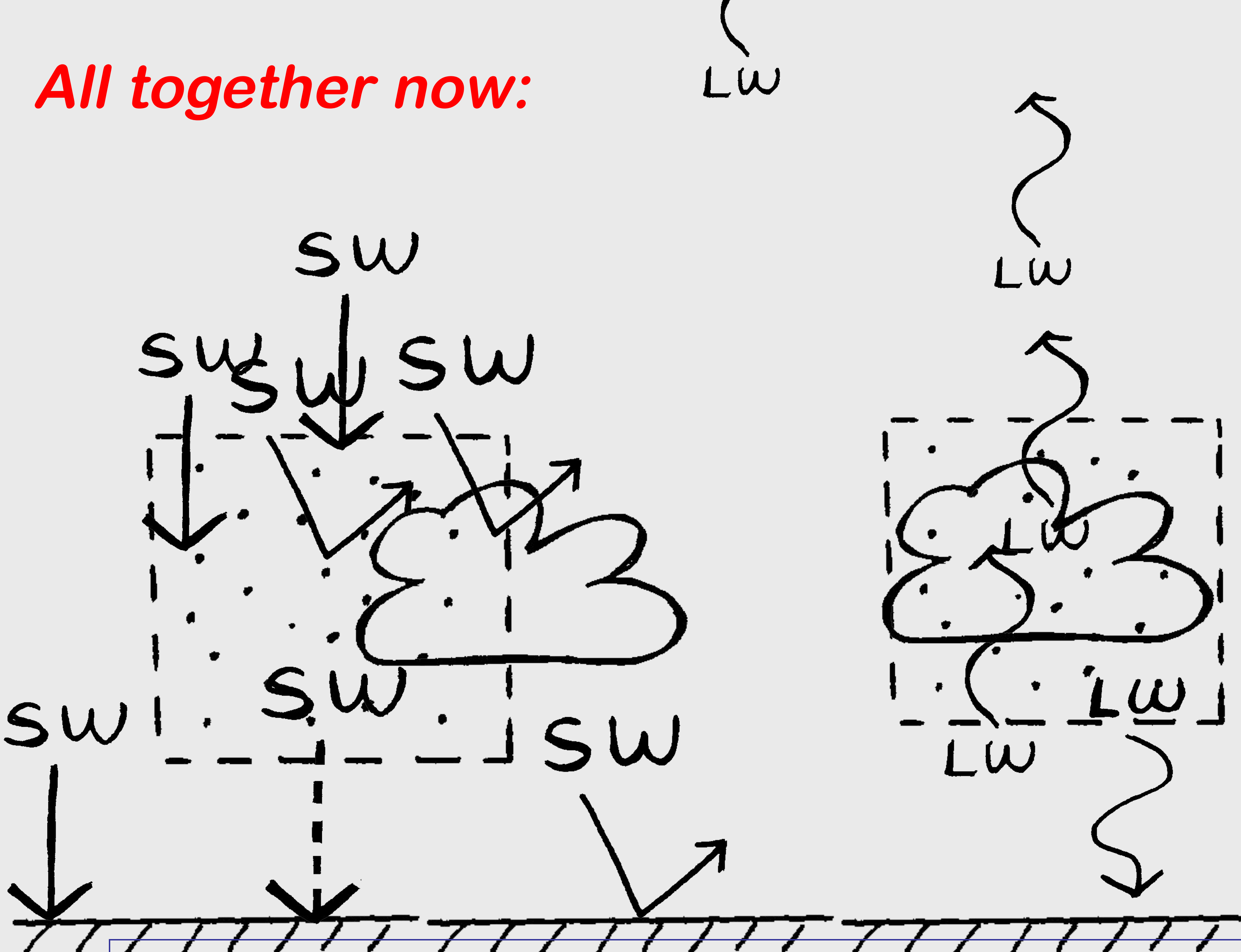
IR EMITTED FROM ATMOSPHERE ESCAPING TO SPACE



IR EMITTED FROM ATMOSPHERE AND RADIATED BACK TO SURFACE WHERE IT IS ABSORBED

p 124

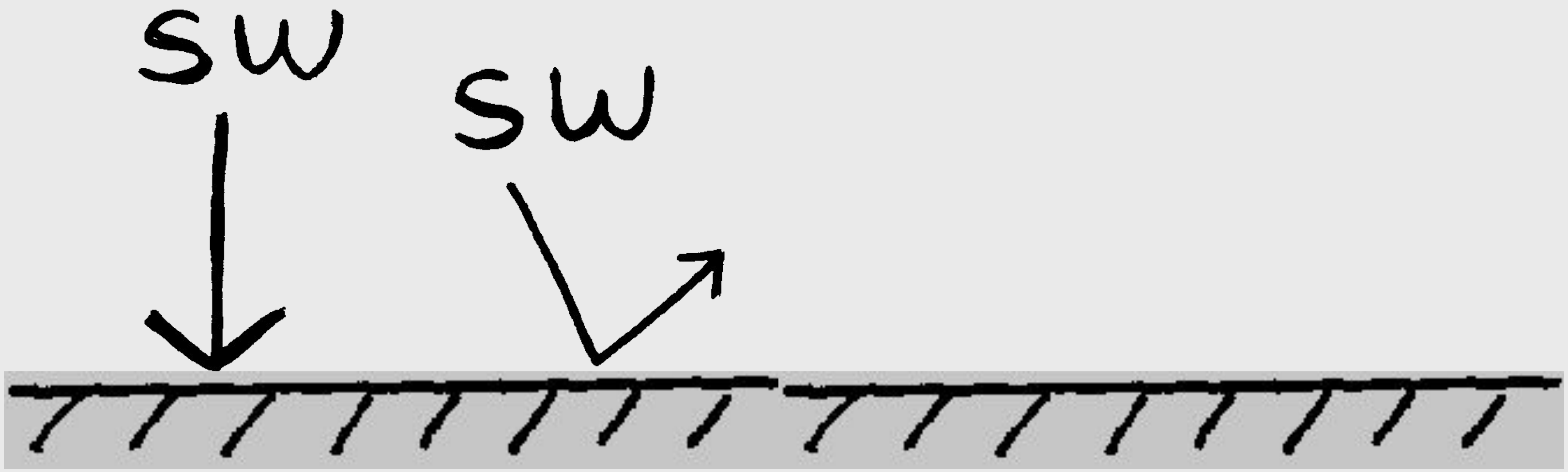
All together now:



Can you sketch all the pathways in yourself? p 124

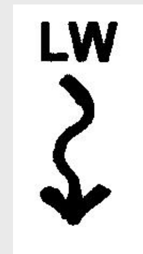
LW

Compare with simpler model of energy balance with NO atmosphere:



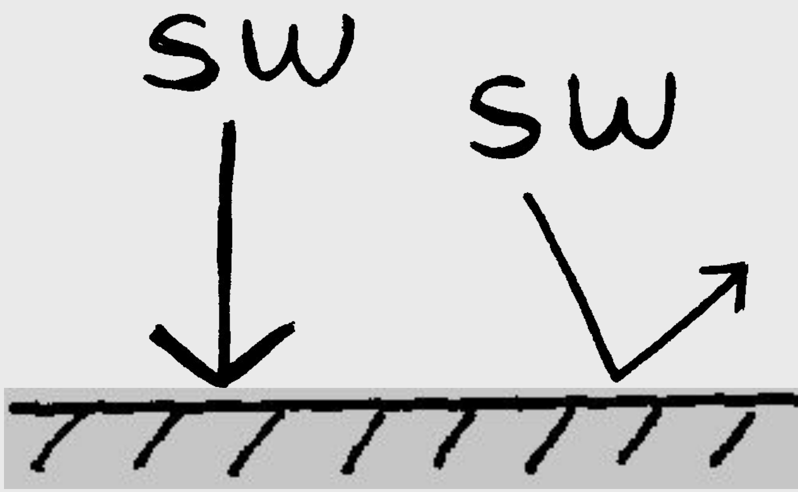
Which terms are not involved?

No scattering by atmosphere

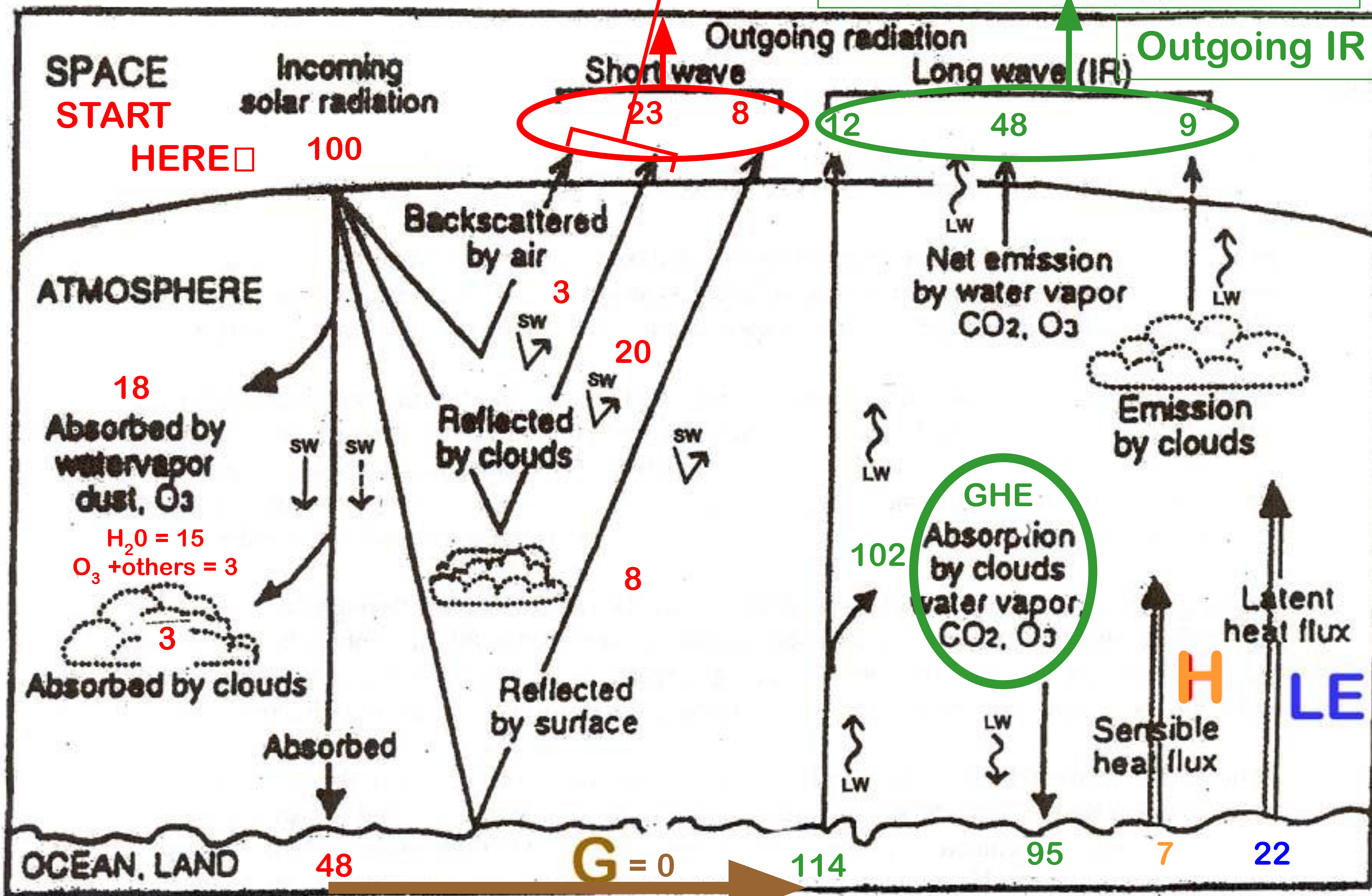


No re-radiation of infrared by GHG's

NOTE: Technically, the SUN <u>does</u> give off incoming <u>longwave</u> infrared radiation (in addition to shortwave UV, visible, etc.) – but if we view the incoming LW symbol above as TERRESTRIAL radiation that has been absorbed and RE-RADIATED BACK TO EARTH by the GHG's in the atmosphere, this simplification is correct.



Earth's average albedo: 23 + 8 = 31   12 + 48 + 9 = 69



G + H + LE

48 □ - 114 □ + 95 □ = 29 □ 0 + 7 + 22 = 29 =

Two Energy Balance Animations

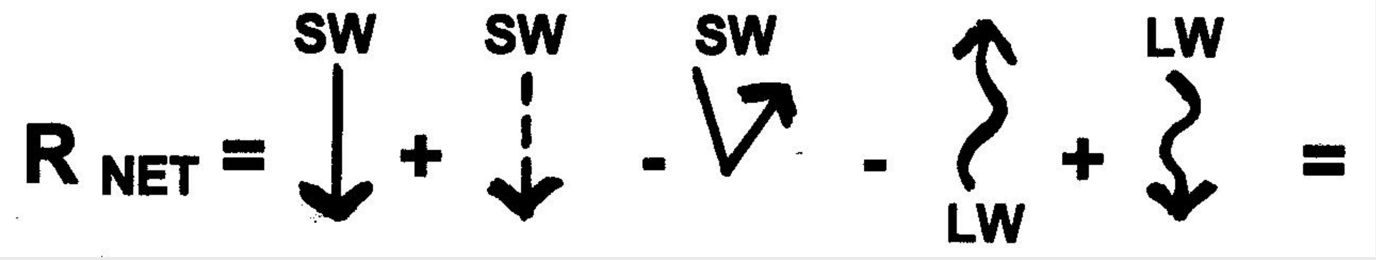
showing energy flow pathways & "units" of energy that eventually balance out:

GLOBAL ENERGY BALANCE & PATHWAYS:

http://earthguide.ucsd.edu/earthguide/diagrams/energybalance/index.html

SHORTWAVE & LONGWAVE ENERGY FLOW & BUDGET:
http://mesoscale.agron.iastate.edu/agron206/animations/10_AtmoEbal.html

NET RADIATION = In – Out = Whatever is left over



If some energy is "left over," it can be used to **DRIVE WEATHER & CLIMATE** through **HEAT TRANSFER** processes or it can **STORED** by the Earth (in the ground or ocean).

FINAL PART OF TOPIC #10:

The RIGHT side of the ENERGY BALANCE EQUATION . . .

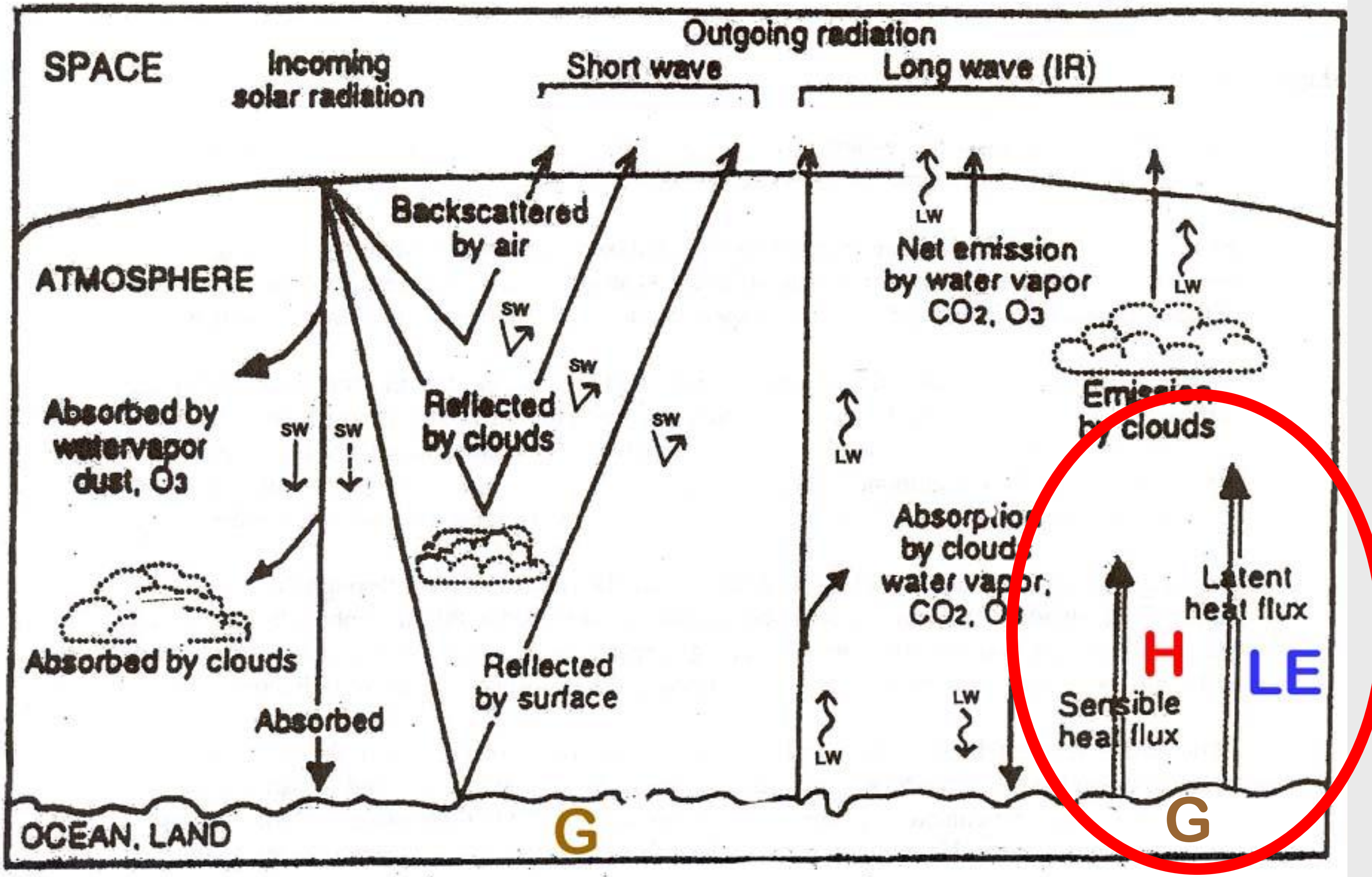
Left side of equation

$$R_{NET} = \overset{SW}{\downarrow} + \overset{SW}{\downarrow} - \overset{SW}{\nearrow} - \underset{LW}{\uparrow} + \overset{LW}{\downarrow} = H + LE + G$$

Right side of equation

R net = "net" left over energy can be used to **DRIVE WEATHER & CLIMATE** through <u>**HEAT TRANSFER**</u> processes or it can **STORED** by the Earth (in the ground or ocean).

$$R_{NET} = H + LE + G$$



SPACE
Incoming solar radiation
Outgoing radiation
Short wave
Long wave (IR)
Backscattered by air
ATMOSPHERE
SW
LW
Net emission by water vapor CO_2, O_3
Absorbed by watervapor dust, O_3
Reflected by clouds
Emission by clouds
Absorption by clouds water vapor, CO_2, O_3
Latent heat flux
Absorbed by clouds
Reflected by surface
Absorbed
H
LE
Sensible heat flux
OCEAN, LAND
G
G

Global temperature changes

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.

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.

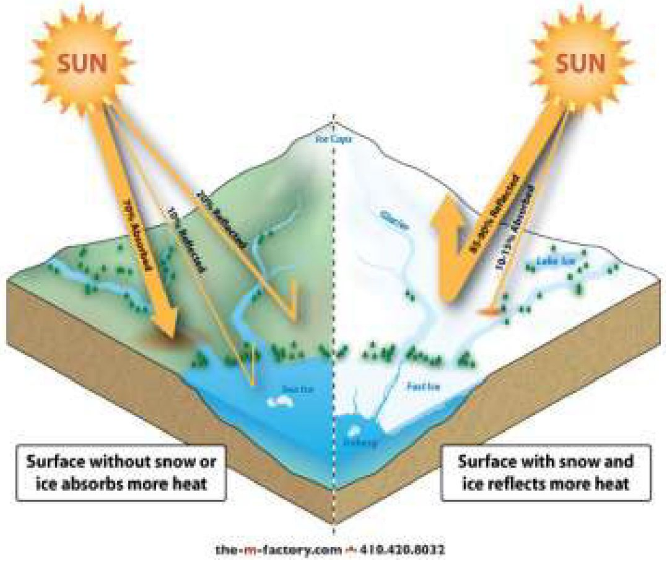
Ice melting :Global overview

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.

OCEAN ACIDIFICATION

- As carbon dioxide (CO_2) dissolves in sea water, it forms **carbonic acid**, decreasing the ocean's pH, a process collectively known as ocean acidification.
- Present ocean acidification occurs approximately **ten times** faster than anything experienced during the last 300 million years, jeopardising the ability of ocean systems to adapt to changes in ocean chemistry due to CO_2.
- Ocean acidification has the potential to **change marine ecosystems** and impact many ocean-related benefits to society such as coastal protection or provision of **food and income**.
- Increased ocean **temperatures and oxygen loss** act concurrently with ocean acidification and constitute the 'deadly trio' of climate change pressures on the marine environment.
- To combat the worst effects of the deadly trio, CO_2 emissions need to be cut significantly and immediately at the source.
- Sustainable management, conservation, restoration and strong, permanent protection of at least 30% of the ocean are urgently needed.

What is the issue ?

Ocean acidification is a direct consequence of increased human-induced carbon dioxide (CO_2) concentrations in the atmosphere. The ocean absorbs over 25% of all anthropogenic emissions from the atmosphere each year. As CO_2 dissolves in sea water it forms carbonic acid, thereby decreasing the ocean's pH, leading to a suite of changes collectively known as ocean acidification. Ocean acidification is happening in parallel with other climate-related stressors, including ocean warming and deoxygenation. This completes the set of climate change pressures on the marine environment – **heat, acidity and oxygen loss** – often referred to as the 'deadly trio'. Interaction between these stressors is often cumulative or even multiplicative, resulting in combined effects that are more severe than the sum of their individual impacts.

Why is it important ?

Present ocean acidity change is unprecedented in magnitude, occurring at a rate approximately **ten times faster** than anything experienced during the last 300 million years.

This rapid timeline is jeopardising the ability of ocean systems to adapt to changes in CO_2 – a process that naturally occurs over millennia. Changes in ocean pH levels will persist as long as concentrations of atmospheric CO_2 continue to rise. To avoid significant harm, atmospheric concentrations of CO_2 need to get back to at least the 320-350 ppm range of CO_2 in the atmosphere.

Compared to other similar events in Earth's history, ocean acidification, over hundreds of years, has been happening very fast. However, its **recovery has been very slow** due to the inherent time lags in the carbon and ocean cycles.

Ocean acidification has the potential to change marine ecosystems and impact many ocean-related benefits to society such as coastal protection or provision of food and income. Although more knowledge on the impacts of ocean acidification on marine life is needed, changes in many ecosystems and the services they provide to society can be extrapolated from current understanding. Some of the strongest evidence of the potential effects of ocean acidification on marine ecosystems stems from experiments on calcifying organisms.

Increased sea water acidity has been demonstrated to affect the formation and dissolution of calcium **carbonate shells and skeletons** in a range of marine species, including corals, molluscs such as oysters and mussels, and many phytoplankton and zooplankton species that form the base of marine food webs.

Changes in **species growth and reproduction**, as well as structural and functional alterations in ecosystems, will threaten **food security, harm fishing** industries and decrease natural shoreline protection. They will also increase the risk of inundation and erosion in low-lying areas, thereby hampering climate change adaptation and disaster risk reduction efforts.

Increased ocean temperatures are likely to have direct effects on the physiology of marine organisms and influence the geographical distribution of species. Some species such as reef-forming corals, already living at their upper tolerance level, will have more difficulties 'moving' fast enough to new areas. Drastic changes in ocean temperature can also lead to coral bleaching events, where corals expel the symbiotic algae living in their tissues, causing them to turn completely white. The role of coral reefs in buffering coastal communities from storm waves and erosion, and in supporting income generation (fisheries and tourism) for local communities and commercial businesses, is jeopardised. The potential recovery of such bleaching events is hampered due to the declining calcification rates on reefs caused by ocean acidification.

What can be done?

The long time lags inherent in the marine carbon cycle put an added penalty on delaying **limits on CO_2 emissions** and a premium on early action if the worst damages associated with ocean acidification are to be avoided. While climate change is the consequence of a range of greenhouse gas (GHG) emissions, ocean acidification is primarily caused by increased concentrations of atmospheric CO_2 dissolved in sea water. It becomes evident, however, that the objective of the United Nations Framework Convention on Climate Change (UNFCCC) to achieve 'stabilisation of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system' cannot be encapsulated by a single 'one-size-fits-all' climate indicator. The current emissions targets need significant tightening if they are to tackle the issue of ocean acidification and ocean warming. Limiting the global average temperature increase to well below 2°C, rather than a lower level, will significantly harm the ocean life on which we all depend in some form or another. Scientists even suggest that a **healthy ocean needs an atmospheric carbon concentration of much less than 400 ppm**. This benchmark has recently been exceed.

Other initiatives such as the Ocean Acidification international Reference User Group (OAIRUG), composed of scientists and various stakeholders, need to be engaged as a key means of conveying scientific results. The OAIRUG examines in detail the types of data, analyses and products that are most useful to managers, policy advisers, decision makers and politicians, and ensure an appropriate format and distribution pathways.

Sustainable management, conservation and restoration of the ocean are needed. At the IUCN World Conservation Congress 2016, IUCN Members approved a resolution calling for the protection of 30% of the planet's ocean by 2030.

The Biological Impacts

Ocean acidification is expected to impact ocean species to varying degrees. **Photosynthetic algae and sea grasses may benefit from higher CO_2** conditions in the ocean, as they require CO_2 to live just like plants on land. On the other hand, studies have shown that lower environmental calcium carbonate saturation states can have a dramatic effect on some calcifying species, including oysters, clams, sea urchins, shallow water corals, deep sea corals, and calcareous plankton. **Today, more than a billion people worldwide rely on food from the ocean as their primary source of protein**. Thus, both jobs and food security in the U.S. and around the world depend on the fish and shellfish in our oceans.

Pteropods

The pteropod, or "sea butterfly", is a tiny sea creature about the size of a small pea. Pteropods are eaten by organisms ranging in size from tiny krill to whales and are a food source for North Pacific juvenile salmon. The photos below show that a pteropod's shell dissolves over 45 day when placed in sea water with pH and carbonate levels projected for the year 2100.

In recent years, there have been near total failures of developing oysters in both aquaculture facilities and natural ecosystems on the West Coast. These larval oyster failures appear to be correlated with naturally occurring upwelling events that bring low pH waters undersaturated in aragonite as well as other water quality changes to nearshore environments. Lower pH values occur naturally on the West Coast during upwelling events, but a recent observations indicate that anthropogenic CO_2 is contributing to seasonal undersaturation. Low pH may be a factor in the current oyster reproductive failure; however, more research is needed to disentangle potential acidification effects from other risk factors, such as episodic freshwater inflow, pathogen increases, or low dissolved oxygen. It is premature to conclude that acidification is responsible for the recent oyster failures, but acidification is a potential factor in the current crisis to this $100 million a year industry, prompting new collaborations and accelerated research on ocean acidification and potential biological impacts.

Coral

Many marine organisms that produce calcium carbonate shells or skeletons are negatively impacted by increasing CO_2 levels and decreasing pH in seawater. For example, increasing ocean acidification has been shown to significantly reduce the ability of reef-building corals to produce their skeletons. In a recent paper, coral biologists reported that ocean acidification could compromise the successful fertilization, larval settlement and survivorship of Elkhorn coral, an endangered species. These research results suggest that ocean acidification could severely impact the ability of coral reefs to recover from disturbance. Other research indicates that, by the end of this century, coral reefs may erode faster than they can be rebuilt. This could compromise the long-term viability of these ecosystems and perhaps impact the estimated one million species that depend on coral reef habitat.

https://www.youtube.com/watch?v=6SMWGV-DBnk

https://www.youtube.com/watch?v=mQ10xBl8XMQ

PRECIPITATION PATTERN

Major types for rainfall by - Convectional rainfall – orographic rainfall – Cyclonic rainfall

There are many types of precipitation: **rain, snow, sleet, and hail,** to name a few. In this lesson we will learn about the mechanisms that produce various types of precipitation. It is important to note that the presence of clouds and their associated condensation nuclei alone do not always produce precipitation. Very specific conditions must occur in order for a cloud to produce precipitation

In order for cloud droplet to form a non-equilibrium condition, where condensation exceeds evaporation, must exist. The curvature of a cloud droplet affects its rate of evaporation. The more curved the droplet, the more evaporation that occurs. Smaller cloud droplets will evaporate quickly unless the air is *supersaturated* (the relative humidity exceeds 100%). Because of the curvature effect, air that is saturated with respect to a flat surface is unsaturated with respect to a curved cloud droplet. An ordinary cloud droplet 100 times smaller than raindrop.

Though supersaturation is required in order for cloud droplets to sustain themselves, relative humidity rarely approaches 101%, even in very wet clouds. How do cloud droplets ever grow to raindrop size? The answer lies in the *Hygroscopic* nature of certain condensation nuclei.

Recall that condensation on hygroscopic particles will commence when the relative humidity is below 100%. This is known as the *solute effect.*

Consider a parcel of air unsaturated air rich with condensation nuclei. As the air cools the relative humidity increases. At some point below 100% saturation, condensation commences on the most hygroscopic of the available nuclei. These nuclei continue to grow as the air cools further and the relative humidity approaches 100%. The curvature effect becomes negligible for larger droplets but remains appreciable for smaller nuclei. The rise in relative humidity within the air mass is slowed by the fact that the larger particles begin to remove lots of water vapor from the air. Soon, the particles are removing water vapor from the air as fast as it can be replaced from external sources. At this point the relative humidity actually begins to decrease. Condensation in clouds is such an inefficient precipitation producing process that it is very unlikely to produce, by itself, precipitation in any appreciable amount. Another mechanism is clearly responsible for producing precipitation from clouds. Two additional mechanisms are responsible for producing precipitation from clouds the *collision-coalescence process,* and the *ice-crystal process.*

The collision-coalescence process occurs in warm clouds. As cloud droplets form within clouds they become electrically charged. The cloud droplets grow larger by sticking to each other in the aftermath of collisions due to electrical attraction. As time passes the droplets grow larger and larger. Updrafts help keep the droplets suspended in the cloud longer. If the cloud is thick the droplets will also stay suspended longer. Finally, the droplets will grow large enough that they can no longer remain suspended and will begin to fall. As soon as they leave the cloud base they begin to shrink due to evaporation. Raindrops that reach the ground are smaller than those leaving the base of the cloud.

The ice-crystal process occurs in colder clouds that exist mainly in the middle to high-latitudes. Even in these extremely cold clouds there are liquid water droplets (existing well below freezing). These are referred to as *supercooled* water droplets. The temperature of a cloud, in fact, must exceed -4O°C in order for it to consist entirely of ice crystals. Such clouds are referred to *glaciated.*

When the temperature drops low enough within a cloud, large numbers of water molecules begin to bond in a rigid form within supercooled liquid water droplets. This leads to the formation of *ice embryos,* i.e., small ice crystals in the center of supercooled water droplets

The water molecules must have very low rms speeds in order for ice embryos to remain intact since even slight thermal motions disrupt them. Even colder temperatures enable the crystal to become a *freezing nucleus*. The presence of these ice embryos enhances the freezing process. The presence of *ice nuclei* also enhance the freezing process. Ice nuclei may be clay (kaolinite), biological material, or anything that looks like an ice crystal. *Contact freezing* is another important method by which ice crystals to form in a cloud, involving collisions between ice nuclei (freezing nuclei) and supercooled droplets.

As we have seen, when precipitation first begins to fall it is usually in a frozen state. Often precipitation begins in the form of either *graupel* or *snowflakes*. Snowflakes are an aggregation of ice crystals. Much precipitation falling at middle latitudes, even in mid-summer, falls as snow flakes in the beginning. Graupel is formed by collisions between supercooled cloud droplets and ice crystals.

In a precipitation theory known as the *Bergeron Process* all raindrops begin as ice crystals. When the ratio of ice crystals to water droplets in clouds is on the order of 1:100,000, conditions are right for precipitation to begin. When there are too few ice crystals, the existing crystals grow large and fall out of the cloud, leaving it unaffected. When there are too many crystals, a cloud of ice crystals is formed, and no precipitation occurs because the individual crystals are all too small to fall to the ground.

Cloud seeding is an important process used quite often in the winter to create precipitation. The object is to find clouds that are deficient with ice crystals and inject artificial ice nuclei to produce the ratio of 1:100,000. (Silver iodide is usually the artificial ice nuclei used because it resembles an ice crystal so well.) A cold cloud is needed for this to work effectively.

Drizzle is a liquid drop with diameter **less than 0.5mm**. Virga is precipitation that doesn't reach the ground. If updrafts in a cloud change to downdrafts rainfall amount may increase to a shower. If a shower is excessively heavy it is referred to as a cloudburst.

Rain is liquid drop precipitation with diameter greater than or equal **to 0.5mm.**

Snow consists of **frozen ice** crystals falling to the ground. Because snow scatters light more effectively than rain one may easily observe where snow changes to rain below a cloud (above the freezing line is darker). If, however, one looks directly up into the precipitation from below the snow appears lighter because it scatters light in all directions below the cloud. As a result the bottom of a rain cloud appears much darker than a cloud with snow in it.

Fallstreaks are a virgalike phenomenon consisting of snow rather than rain.

Flurries are brief snow showers, typically from cumuliform clouds. A *snow squall* is a more intense snow shower, essentially the equivalent of a cloudburst. Continuous snowfall is associated with nimbostratus and altostratus clouds. A *blizzard* is a snowstorm accompanied by low temperatures, strong winds, blowing and drifting snow.

Sleet is melted snow that re-freezes into a tiny ice pellet. *Freezing rain* occurs when raindrops fall through a freezing layer that supercools them and subsequently freeze on contact with the ground.

Freezing drizzle is freezing rain with drop diameters less than 0.5mm. *Rime* is an accumulation of small, supercooled cloud droplets that are milky and granular in appearance. *Snow grains* and *snow pellets* are the solid equivalent to drizzle. Snow grains have a diameter of less than 1 mm and stick upon hitting a surface, while snow pellets have diameters of greater than 5mm and bounce upon hitting a surface.

Hail is produced when **large, frozen raindrops**, graupel, etc. act as accretion nuclei. In order for a hailstone to form, the accretion nuclei must remain in a cloud a long time and thus travel a large distance within the cloud. This process is facilitated by strong updrafts of the type common within cumulonimbus clouds. Hail is most often associated with such clouds and is therefore more common during the spring and summer than in winter. *Hailstreaks* are long narrow bands of land struck by hail as the precipitating cloud moves along.

About 80 per cent of the precipitation that falls on Idaho each year is in the form of snow. It takes about one foot of snow to make one inch of water when it melts. Since water is Idaho's single most important resource a system has been developed to measure snow depths in the mountains of Idaho. This system almost guarantees that water will be used efficiently, and that it will be well conserved so that everyone will have enough water each year. We all rely on the water that falls on our state each year, not just the farmers who use it for irrigation. We also use water for power, to fish in, and to help wildlife survive. Idaho's industries need water to operate and you and I need it to drink, to bathe in, to do our dishes and to water our lawns.

In addition to water supply, precipitation plays a significant role in shaping the landscape around us.

The state precipitation map at left underscores the greatest natural deficiency suffered by the West. The region lacks sufficient precipitation for most of the basic needs of human beings. It has been responsible for the treeless plains and, naturally, the desert. In the Snake River Valley for example there is a yearly average of only eight inches. Where the annual amount is less than fifteen inches and irrigation is not possible, dry farming and grazing are the dominant agricultural activities

The highest amount of precipitation ever recorded in Idaho was on Deadwood Summit in Valley County in the winter of 1964-65. Precipitation of 98.6 inches was recorded that year. Much of that precipitation was in the form of snow (if it takes one foot of snow to make one inch of water when it melts, imagine how much snow fell on Deadwood Summit that winter).

Just 75 miles to the east of Deadwood Summit, Challis has the lowest average yearly precipitation in Idaho, just 7.09 inches. Of the larger cities and towns in Idaho, Boise has an average precipitation of less than 12 inches and Wallace in Shoshone County has the heaviest annual precipitation of 41.64 inches. Snow depths vary widely throughout the state, ranging from skiffs in the lower dry areas to very deep in the central mountains.

FLOODS

FUNDAMENTAL CONCEPT

Floods are always newsworthy whether it is a locality or a town isolated by swirling waters or a major disaster attracting attention of whole world.

Although man has been responding to flood since time unknown and is also leaving in the process much more is to be understood by the hydrologists, engineers, policy makers, farmers and town planners and above all by ***common people***. Therefore, it is necessary to understand the phenomenon of flood.

MEANING, DEFINITION & TYPES

The word *"flood"* comes from the Old English flod, a word common to Germanic languages. Deluge myths are mythical stories of a great flood sent by a deity or deities to destroy civilization as an act of divine retribution, and they are featured in the mythology of many cultures.

The *European Union (EU)* Floods Directive defines a flood as a covering by water of land not normally covered by water.

Thus, flood is a state of high water level along a river channel or on the coast that leads to inundation of land, which is not usually submerged. Floods may happen gradually and also may take hours or even happen suddenly without any warning due to breach in the embankment, spill over, heavy rains etc.

TYPES OF FLOODS

i. Areal Floods

The floods that happen on flat or low-lying areas when water is supplied by rainfall or snowmelt more rapidly than it can either infiltrate or run off. Areal flooding begins in flat areas like floodplains and in local depressions not connected to a stream channel, because the velocity of overland flow depends on the *surface slope*.

Fig. Areal Floods

ii. Flash Floods

Fig. Flash Floods

The floods are generally the events of hill areas where *sudden heavy rain* over the limited area can cause a strong flow. Flash floods also occur when a temporary blockage in hilly areas impounds water which when released suddenly creates havoc.

iii. River Floods

The floods occur due to *heavy inflow* of water from heavy rainfall, snowmelt and short intense storms.

Fig. River Floods

iv. Coastal Floods

Fig.Coastal Floods

The floods are caused due to heavy rainfall from cyclones or due to tsunamis.

v. Urban Floods

Urban flooding is the inundation of land or property in a built environment, particularly in more densely populated areas, caused by rainfall overwhelming the capacity of *drainage systems*, such as storm sewers.

Fig.Urban Floods

vi. Catastrophic Floods

Catastrophic riverine flooding is usually associated with major *infrastructure failures* such as the collapse of a dam, but they may also be caused by drainage channel modification from a landslide, earthquake or volcanic eruption.

CAUSES OF FLOODS

There are several causes of floods and differ from region to region. The causes may vary from a rural area to an urban area. Some of the major causes are:

Heavy rainfall: It is the primary cause for floods in India. Especially, rainfall in a short span of time is of much concern as they are leading to flash floods. For instance, in July 2017, Mount Abu received the heaviest rainfall in over 300 years in a span of 24 hours. The hill station received an unprecedented 700 mm of rain in 24 hours. As per a study instituted by the United Nations, climate change phenomenon is believed to be behind flash floods across the globe.

Siltation of the Rivers: Heavy siltation of the river bed reduces the water carrying capacity of the rivers and streams leading to flooding. For instance, as a result of siltation, the Brahmaputra has been expanding – ranging from 2 km to 14 km – leading to frequent flooding in the North East region.

Blockage in the Drains: Blocked drains are the primary cause for the floods in urban areas, especially in metros. For instance, failure of the drainage system is believed to be one of the primary causes behind the Chennai floods in December 2015 that led to the death of more than 400 people.

Landslides: They are the major reason behind floods in hilly areas of the north and northeast. For instance, in June 2013, landslides caused a blockage of flow of streams and rivers in Uttarakhand and caused major floods, causing 5748 deaths. Apart from the above reasons, natural hazards like cyclones and earthquakes and encroachments of river banks and water bodies cause flooding.

Impact of recurrent floods

The most important consequence of floods is the loss of life and property. Structures like houses, bridges and roads get damaged by the gushing water.

Some of the negative impacts of recurrent floods are given below –

Impact on Agriculture: Recurrent floods impact the agriculture sector adversely. Due to recurrent floods, fields get submerged and lead to the loss of harvest increasing the vulnerability of farmers to indebtedness. The loss is not only for the farming community but also the common man is hit hardly due to persistent inflation. Besides, the threat to life of milch animals impact the farming community adversely.

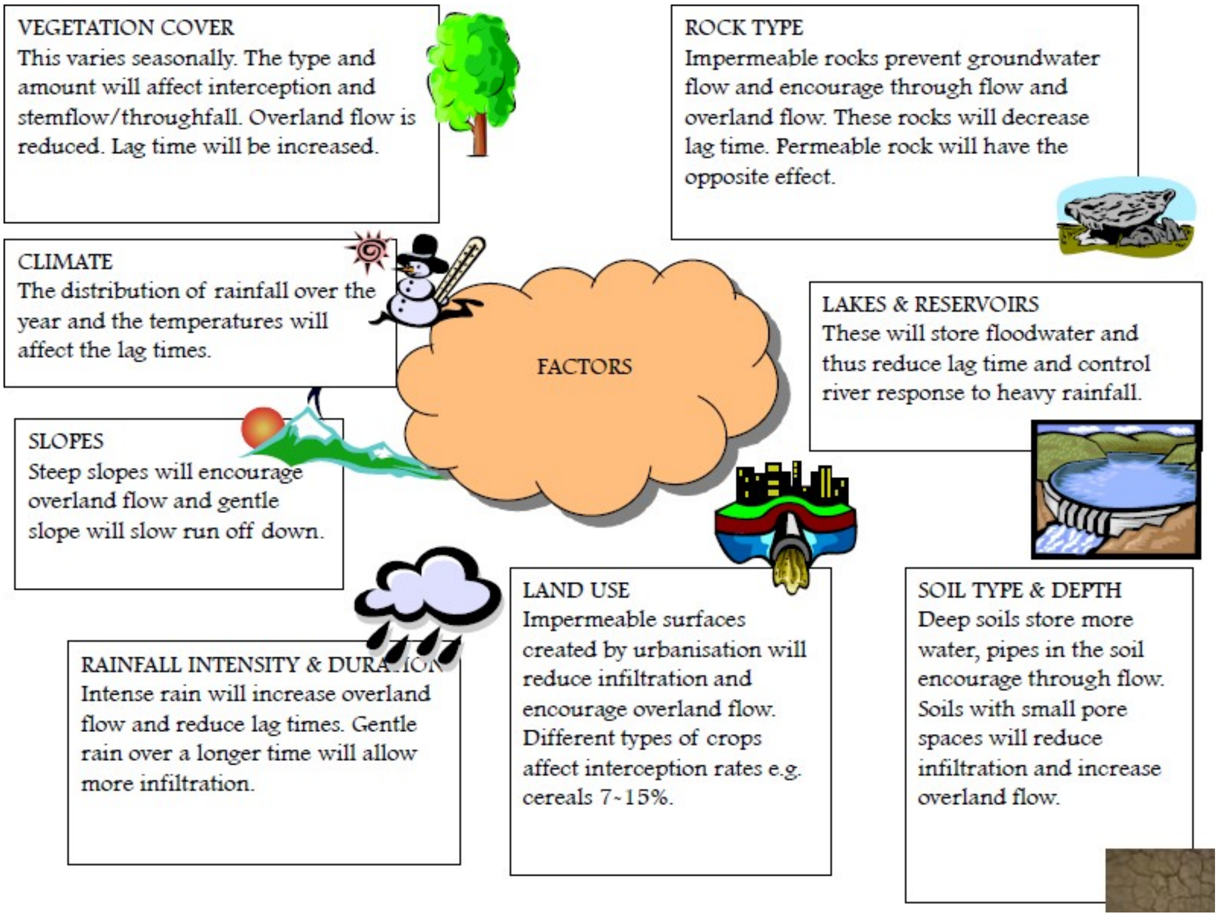
Moreover, floods may also affect the soil characteristics. The land may be rendered infertile due to erosion of top-layer.

Damage to infrastructure: Recurrent floods cause severe damage to economic infrastructure like transportation networks, electricity generation and distribution equipment, etc.

Outbreak of diseases: Lack of proper drinking water facilities, contamination of water (well, ground water, piped water supply) leads to out break of epidemics like diarrhoea, viral infection, malaria and many other infectious diseases. The probability of outbreak of diseases in highly densed areas of India is high.

Besides the above, strain on the administration, cost of rescue and rehabilitation of the flood affected population are other causes of concern.

FACTORS RESPONSIBLE FOR FLOODS



1.2 IMPACTS OF FLOODS

- Human Loss
- Property Loss
- Affects the Major Roads
- Disruption of Air / Train / Bus services
- Spread of Water-borne Communicable Diseases
- Communication Breakdown
- Electricity Supply Cut off

➢ Economic and Social Disruption

➢ Increase in Air / Water Pollution

FLOODS IN INDIA

FLOODS PRONE AREA IN INDIA

Fig. Major flood prone areas in India

- Floods cause damage to houses, industries, public utilities and property resulting in huge economic losses, apart from loss of lives.
- Though it is not possible to control the flood disaster totally, by adopting suitable structural and non-structural measures the flood damages can be minimised.

VULNERABILITY TREND

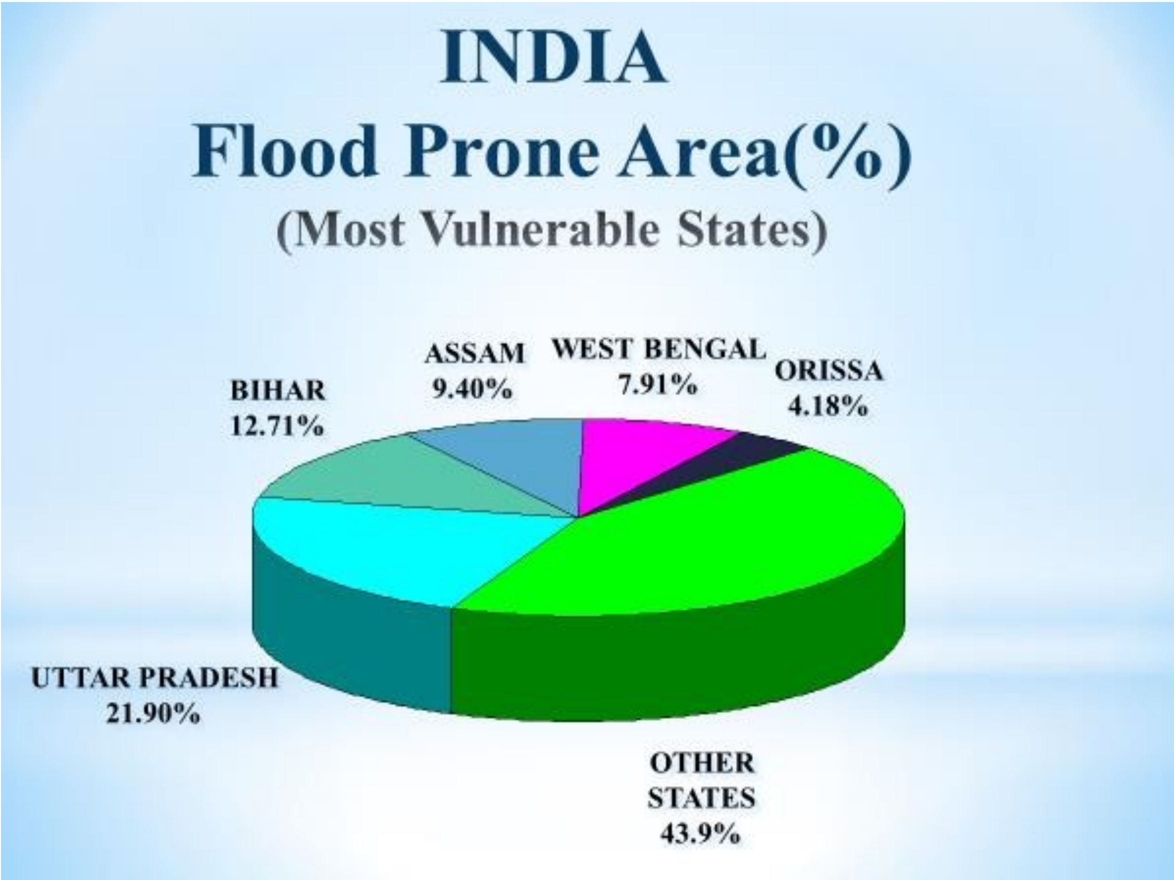


Fig.State wise vulnerability trend in India

MAJOR FLOODS IN INDIA

1. Bihar floods, 1987

- Bihar floods in 1987 remain one of the deadliest to have been seen in India since independence.
- In one of the worst floods in Bihar, 1,399 people and 5,302 animals lost their lives, and nearly 29 million people were affected in 30 districts, 382 blocks, 6,112 panchayats, and 24,518 villages.
- The damage to crops was calculated to be 68 billion Indian rupees and damage to public property was at 68 million rupees.

2. Gujarat floods, 2005

- Gujarat flood accounted for a loss of more than 8,000 crore rupees.
- The floods also caused a great financial and economic loss to the nation.
- More than 123 deaths were recorded and a total of 2,50,000 people were evacuated.
- The day is referred to as a 'BLACK DAY' in Indian History.

3. Maharashtra floods, 2005

- In the Maharashtra floods, approximately 1,094 people died.
- It occurred just one month after the June 2005 Gujarat floods.

- 52 local trains, 37,000 autos, 4,000 taxis, 900 'BEST' buses and 10,000 trucks were either damaged or spoiled.
- The financial cost was calculated to be 550 core rupees.

4. Assam floods, 2012

- The worst floods since the year 1998, Assam floods took the lives of more than 120 people.
- The flood also affected 1,744 villages across nine districts and 70,000 hectares of cropland.
- It was reported that more than five million people were evacuated.
- Flooding significantly affected Kaziranga National Park, where about 540 animals died.

4. Uttarakhand floods, 2013

- In the Uttarakhand floods, the destruction of bridges and roads left about 1,00,000 pilgrims and tourists trapped.
- The Indian Air Force, the Indian Army, and paramilitary troops evacuated more than 1,10,000 people from the flood-hit areas.
- More than 5,000 people were presumed dead.

6. Jammu & Kashmir floods, 2014

- Caused by torrential rainfall, in September 2014, the Kashmir region suffered disastrous floods across many of its districts.

- According to the Home Ministry of India, 2,600 villages were reported to be affected in Jammu and Kashmir -- out of which 390 villages in Kashmir were completely submerged.

Droughts:

Everything needs water. Even when we don't need water, humans tend to use much more water than is necessary on a daily basis. This is why a water shortage is so difficult for us.

Obviously, the drought will impact the agriculture industry. In order to save his crops, the farmer may have to spend money on new irrigation plans. Since he's now paying more money to provide the crops, he will have to charge more for the produce to make a profit. As a result, the public will have to pay more for food. Some foods will also become "scarce"— meaning the cost of goods will rise.

There will also need to be water outages in order to preserve water. Sometimes, public places like schools, offices and restaurants will have to close when they don't have water, which can affect the country's productivity.

During droughts, there may also be an increase in the number of forest fires or bush fires because of the dry conditions.

There are some other issues which result from droughts:

- Affects education since schools have to be closed if there's no water
- Reduces fire fighting capability and also, there's now a risk to public safety from fires or any other accident that requires large volumes of water immediately.
- High food -cost foods cause dietary deficiencies

Potential for conflicts (Water user conflicts, Political conflicts, Management conflicts)