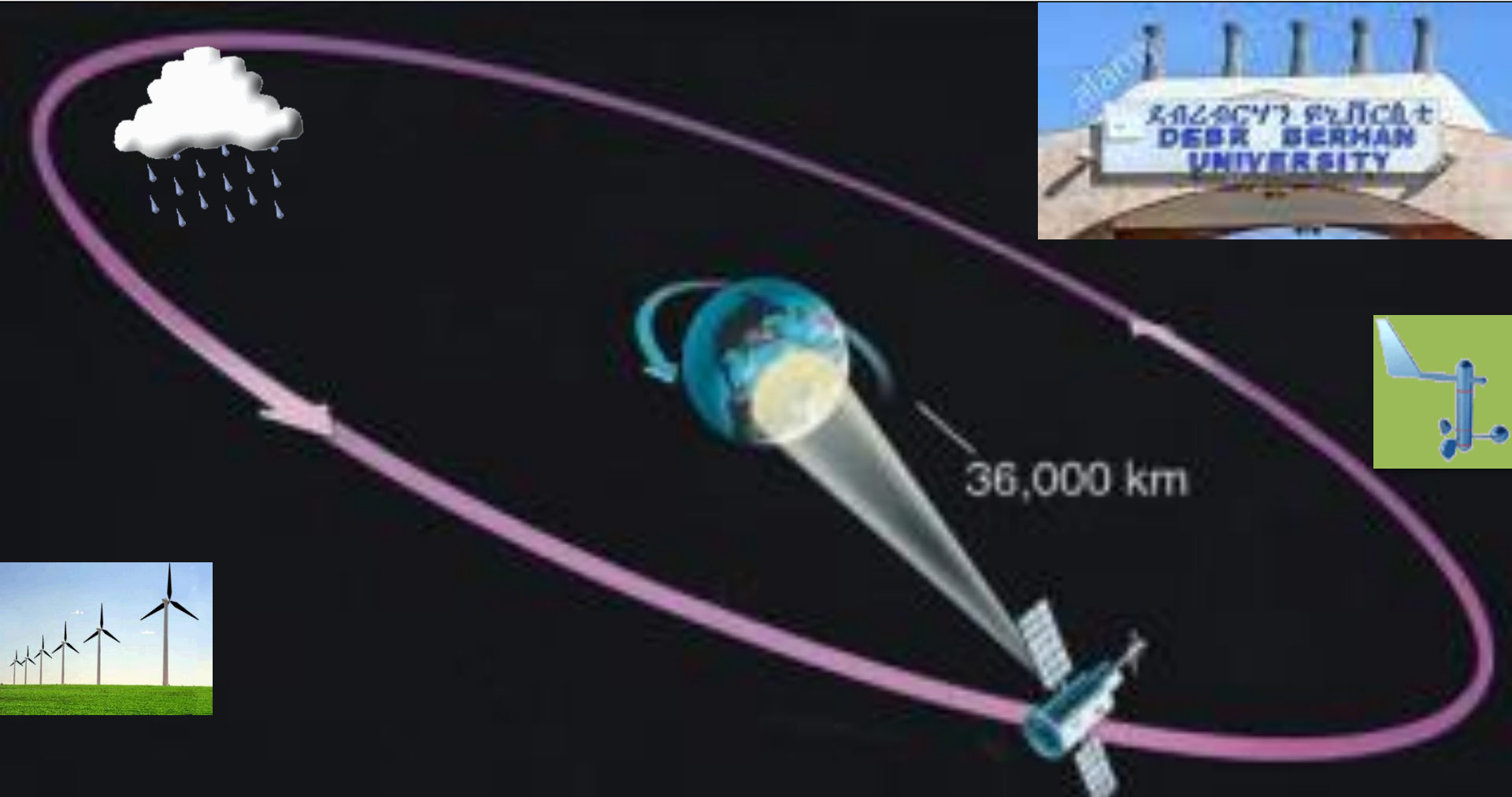




College of social Science and Humanities

Department of Geography and Environmental Studies

Introduction to Climate (GeES 2013)

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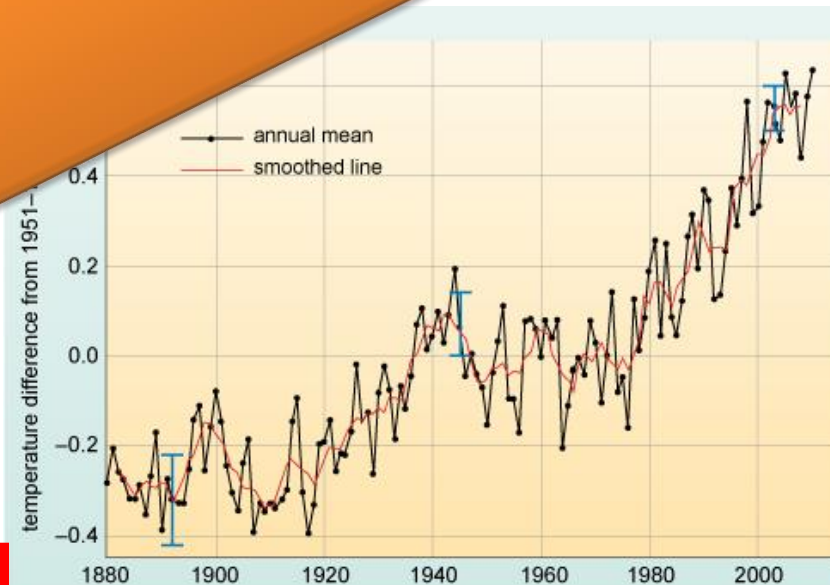
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CHAPTER ONE

1. BASIC CONCEPTS IN WEATHER AND CLIMATE



1.1. The Concepts of Weather, Climate, and Climatology



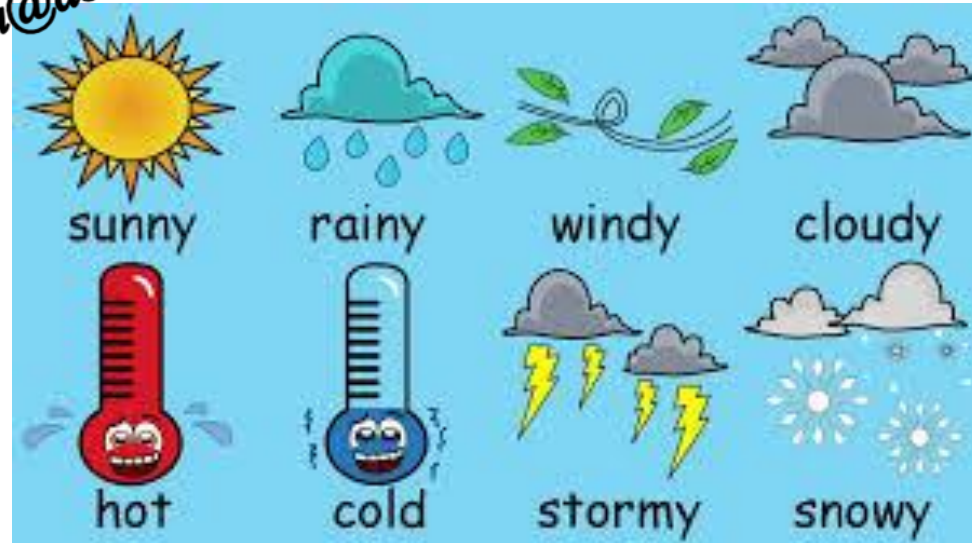
Weather

- Weather is the *day-to-day state of the atmosphere*, and its *short-term variation* in *minutes to weeks*.
- Weather is the conditions of the atmosphere experienced by humans at any given moment.
- The term also used to refer the atmospheric conditions that exist for a short duration (hours or days). These conditions *fluctuate* and *vary temporally* over a given place.



- People generally think of weather as the combination of temperature, humidity, precipitation, cloudiness, visibility, and wind.
- We talk about changes in weather in terms of the near future: "How hot is it right now?" "What will it be like today?" and "Will we get a snowstorm this week?".

- In general, Weather is the current atmospheric conditions, including temperature, rainfall, wind, and humidity at a given place.
- If you stand outside, you can see that it's raining or windy, or sunny or cloudy or different components of weather.
- You can also tell how hot it is by taking a temperature reading
- Consequently, weather is what's happening right now or is likely to happen tomorrow or in the very near future.



Climate

- Climate is the weather of a place ***averaged over a period of time***, often 30 years. Climate information includes the statistical weather information that tells us about the normal weather, as well as the range of weather extremes for a location.
- We talk about climate change in terms of years, decades, and centuries.
- Scientists study climate to look for trends or cycles of variability, such as the changes in wind patterns, ocean surface temperatures and precipitation over the equatorial Pacific that result in El Niño and La Niña, and also to place cycles or other phenomena into the bigger picture of possible longer term or more permanent climate changes.

- **Climate** is sometimes referred to as "*average weather*" for a given area.
- Geographers, meteorologists and climatologists use data such as **highs and lows temperature** and precipitation rates for the **past 30 yrs** to compile an area's "*average weather*".
- However, some atmospheric scientists think that **it needs** more than "average" weather to accurately portray an area's climatic character, variations, **and patterns must also be included.**
- Thus, climate is the ***sum of all statistical weather information*** that helps describe a place or region.
- The term also applies to large scale weather patterns in time or space such as an '*Ice Age*' climate or a '*tropical*' climate.

Meteorology

Meteorology is the study of the *atmosphere* and its *phenomena*.

Meteorology is the study of the atmosphere and motions within the atmosphere on short-time scales.

Commonly known as 'weather,' meteorology focuses on the atmospheric variables related to *current or near-future conditions*.

- It is one of the sub-field *atmospheric sciences* (*Meteorology, climatology, atmospheric physics, and atmospheric chemistry*)
- Studies in the field stretch back millennia, though significant progress in meteorology did not occur until the 18th century.
- The term itself goes back to the Greek philosopher Aristotle who, about 340 B.C., wrote a book on natural philosophy titled *Meteorologica*.
- This work represented the sum of knowledge on weather and climate at that time, as well as material on *astronomy, geography, and chemistry*.

Climatology

- Climatology derived from **Greek** word **klima**, "*place, zone*" and **logia** is the study of *climate*; scientifically defined as *weather conditions averaged over a period of time*.
- Traditionally it is regarded as a *branch* of the *atmospheric sciences* and a subfield of physical geography, which is one of the Earth sciences.
- Climatology now includes aspects of *oceanography* and *biogeochemistry*.

- The study of *contemporary* climates incorporates *meteorological data* accumulated over many years, such as records of *rainfall*, *temperature* and *atmospheric composition*.
- Knowledge of the atmosphere and its dynamics is also embodied in *models*, either *statistical* or *mathematical*, which help by integrating different *observations* and *testing* how they fit together.

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- **Climatologists**, those who practice climatology, study both the nature of climates *local*, *regional* or *global* and the natural or human-induced factors that cause climates to change.
- Climatology considers the **past** and *can help predict future* climate change.
- Phenomena of climatological interest include the atmospheric boundary layer, circulation patterns, heat transfer (radiative, convective and latent), interactions between the atmosphere and the oceans and land surface (particularly vegetation, land use and topography), and the chemical and physical composition of the atmosphere.

- Physical climatology deals with the *interpretation of factors* responsible for the *spatial* and *temporal variations* of exchange of *air circulations*, *heat* and *humidity*.
- It studies various elements of weather namely *insolation*, *temperature*, *precipitation*, *fogs*, *visibility* etc.
- Different elements are formed due to combinations of these weather elements.
- The occurrences of different combinations of these weather elements are accomplished through different *processes* and *mechanisms*.
- Thus, these processes of *exchange of heat*, *humidity*, and *momentum* between *atmosphere* and *earth's surface* are also studied thoroughly.
- It is thus, evident that physical climatology studies the *factors* and *processes* of *regional variations* of climatic conditions.

II. Regional Climatology

- Regional climatology includes the study of types, *distribution*, *pattern* and *characteristics factors* of *world climates*.
- Regional climatology is studied in three ways on the basis of spatial scale such as; *macro-climatic* region *meso-climatic* region and *micro-climatic* region

III. Applied Climatology

- Applied climatology studies the *application of climatic knowledge to solve various problems* faced by *human society* e.g. *global warming* and *climate changes*.
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- It studies the interactions between *climate* and *biosphere* i.e. how does *climate* influence and control *plants* and *animals* including *man* and in turn how does *man* modify *climate* by introducing advertent and inadvertent changes in the physical environment and by making certain weather modification e.g. *cloud seeding* and *induced precipitation*.

➤ Further, *applied climatology* includes the study of variability of climate, climatic changes, air pollution, climate and comfort, climate and health, climate and society, extreme weather events (e.g. floods, drought etc.) and their impacts, climate and recreation, climate and urban planning, weather forecasting, climate and transport and communication, weather modification etc.

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1.2. Elements and measurement of weather and climate

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1.2.1 Elements of Weather and Climate

- These are the things that *make up weather* and *climate*.
- They help one to describe the *weather* and *climatic* conditions of a place.

They include;

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Rainfall: - Refers to the *fall of rain drops* from the *clouds* that result from the *condensation of water vapour*.

- Rainfall is a form of precipitation that comes in form of *water drops*.

Temperature: - Is the *degree of hotness* or *coldness* of the *atmosphere*.

- Temperature may be described as *very cold*, *cold*, *cool*, *mild*, *moderate*, *warm*, *hot* and *very hot*.

Wind: - This is *moving air (air in motion)*.

- It results from *differences in atmospheric pressure*.
- Winds blow from areas of *high pressure* to those of *low pressure*.
- A *light wind* is referred to as a *breeze* while a *strong wind* is a *gale*. Winds may be *global or local*.
- Global winds are referred to as *air masses*.
- Winds are named according to the *direction from which they blow* e.g. winds from the *north* are known as *northerly winds*.

Atmospheric Pressure: Is the *force exerted by the weight of air* on the earth's surface.

- ***Cold air is heavier (dense)*** and therefore ***exerts more pressure*** than ***warm air*** that tends to rise.

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Cloud Cover: Refers to the ***accumulation to tiny water droplets floating in the sky (clouds).***

- They appear ***whitish*** or ***greyish*** color.

Humidity: Is the ***amount of water vapor*** present in the ***atmosphere***.

- ***Water vapor*** results from ***evaporation or transpiration***.
- ***Humidity*** is measured in terms of grams per cubic meter (gms/m³).
- The ***amount of water vapor*** in a ***volume of air*** or atmosphere is known as ***Absolute Humidity***.
- The ***amount of water vapor present in the atmosphere (air)*** compared to that when the ***air is fully saturated*** is known as ***Relative Humidity***.
- ***Saturated air*** is air that can ***no longer hold*** any more vapor at that particular temperature.
- It is important to note that ***warm air holds more humidity*** than ***cold air***.

Sunshine: Refers to the *light* and *heat energy* from the *sun* in form of *sun rays*.

- Radiation from the sun is known as solar radiation or insolation.
- ***Sunshine*** can be considered in terms of the *intensity* or the *number of hours* received.

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Visibility: the greatest distance one can see

1.2.2 Measurement of weather and climate

- **Weather instruments** are used to take measurements of *temperature, wind, precipitation, and other atmospheric factors* that describe the *local weather and climate*.
- Different types of instruments are used to measure these parameters and there are many types to choose from.
- *Instruments measure a variety of these parameters*, such as *temperature, wind speed, wind direction, humidity, precipitation, atmospheric pressure, solar radiation*, and even *soil temperature* and *moisture*!

Temperature

- We are familiar with **thermometers** as they're very common in our daily lives (indoor & outdoor temperature, body temperature, oven temperature, etc.).
- The classic glass tube filled with **red** dyed **alcohol** – replacing toxic mercury-filled instruments (*Figure A*).

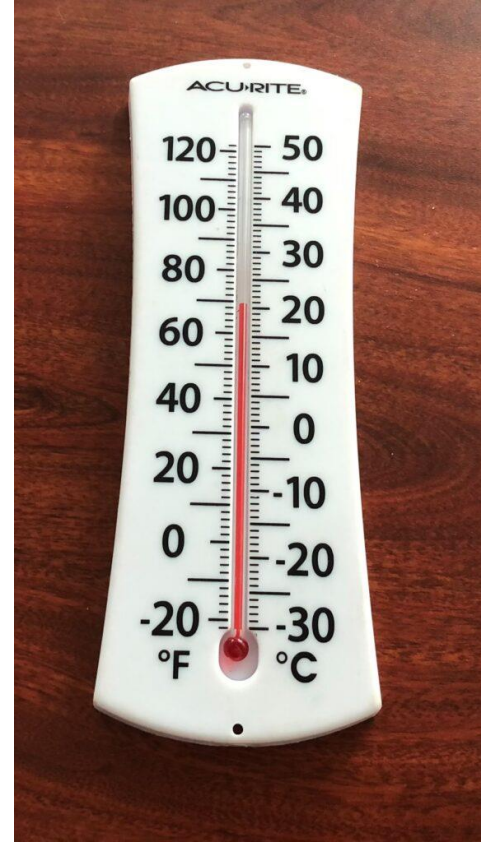


Figure A. Liquid Thermometer

- *As the temperature of the instrument changes, so too does the volume of the liquid inside of the thermometer – the red liquid rises as the temperature rises due to the liquid expanding up the tube, and falls with the temperature due to the liquid contracting back into the bulb at the bottom.*

➤ At modern weather stations, like **ECONet towers**, an *electronic temperature sensor* is used to measure the *outside air temperature* (Figure B).

➤ The temperature sensor on this device is contained within a vented unit which allows air to *flow freely across the sensor* and *measure the temperature* while *keeping the thermometer shaded* from the *direct heating of the sun*.



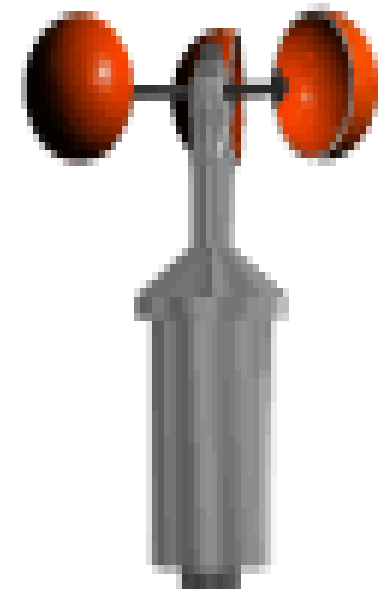
Figure B. Electronic Temperature Sensor (image from NOAA)

Wind speed & direction

- An **anemometer** is an instrument that measures *wind speed* and they're very common at *weather stations*.
- There are a few different types of anemometers, one of the most common being a *cup anemometer* (Figure C).
- As the wind blows, it pushes the cups and causes the arms to rotate at a rate proportional to the *wind speed*.
- This is great for measuring wind speed, but doesn't help us measure the wind direction.



Figure C. Left – Wind Vane; Right – Cup Anemometer (Image from NOAA)



- A **wind vane** can help us to measure which *direction the wind is coming from*
- As the wind blows past the instrument, the wind vane will point in the direction that the wind is coming from.
- It is important to note that *wind direction* is always given by where the wind is coming from, so a west (or westerly) wind is *blowing from west to east*.

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Figure D. Propeller Anemometer (Image from NOAA)



Precipitation

- A **rain gauge** is an instrument used to measure the *amount of precipitation* over a certain amount of time.
- In its most basic form, a rain gauge can be a **bucket** that collects rain water to be *measured by a ruler* (Figure E).
- For **ECONet** towers and other officially recognized weather stations, the instruments are more precise than the *bucket & ruler* method.



Figure E. CoCoRaHS Rain Gauge (Image from NWS)

- Specifically, ECONet rain gauges are known as **tipping bucket gauges** (Figure F)
- When the gauge fills to a certain level (0.01"), the gauge **tips** and **empties** so as to avoid **overflowing** or **clogging**.
- The number of bucket-tips are **counted** and the **precipitation** is **calculated**.
- For example, if the bucket tips 25 times over the course of the day, we can calculate that it rained 0.25" that day.
 - In order for rain gauges to be as precise as possible, they need to be placed in open areas with **no obstructions** like **trees** or **buildings**.
 - The goal in measuring weather is always **accuracy**, but sometimes real-world weather conditions impede our measurements.
- During **hurricanes** or **strong thunderstorms** **high winds** can **prevent the rain** from falling into the **gauge** or even blow debris into the instrument, **blocking the gauge's opening**.



Figure F: Tipping Bucket Rain Gauge at Bearwallow Mountain

Atmospheric pressure

- **Atmospheric pressure**, or **air pressure**, can be measured using a **barometer**.
- An **aneroid barometer** (*Figure G*), one of the most common types, uses a sealed container of air to *detect changes in the atmospheric pressure* outside of the container.
- As the *atmospheric pressure increases*, it pushes down on the container and it is slightly reduced in volume, moving an *indicator needle* towards *higher pressure*.
- *If* the *atmospheric pressure decreases*, the *container expands slightly* and the *needle* indicates *lower pressure*.
- Most weather stations, including **ECONet towers**, now use **digital barometers** as they're *much easier* to maintain and **collect data**.

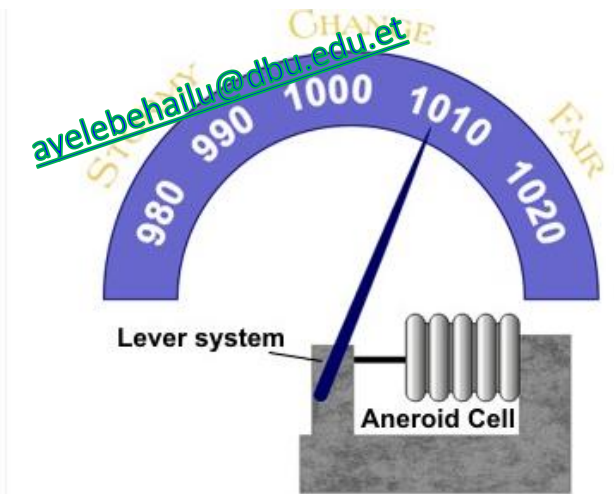


Figure G. Aneroid Barometer Diagram (Image from NWS)

- *Why is it important to measure **atmospheric pressure**?*
- Measuring pressure is important because it is related to ***volume, density***, and ***temperature***.
- In the atmosphere, **warm surfaces** can ***heat the air above*** them ***causing the air to become less dense*** and to **rise**.
- This leads to ***low pressure*** and can eventually result in ***clouds*** and ***precipitation*** in the areas of rising motion.

On a large scale, these ***low pressure systems*** can become large storm systems, such as ***hurricanes***.

- On the other hand, ***high pressure*** in the atmosphere causes the ***cold air*** to ***compress*** and ***sink***, leading to ***clear skies*** and ***calm conditions***.
- Notice the associated weather on the barometer in *Figure H*.



Figure H. Modern Aneroid Barometer (Image from Wikimedia Commons)

Humidity

- *Humidity* is the *measure of moisture in the air*.
- While humidity can be measured in *grams of water per kilogram of air* (*absolute humidity*), it's more practical to work with *relative humidity* as it can give us a better sense of *how the weather* might be *affected by the water* in the air.
- If the *relative humidity* is measured to be 100%, the *air is saturated*.

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- If the *relative humidity is 50%*, the air contains *half of the water vapor* required *to be saturated*.
- It is important to keep in mind that *relative humidity* is also *dependent on air temperature*.
- For example, *if the water vapor content stays the same* and *the temperature drops*, the *relative humidity increases*.
- If the water vapor content stays the same and the *temperature rises*, the relative humidity decreases.
- This is because *colder air doesn't require as much moisture* to become saturated as *warmer air*.

Hot air has the capacity to hold more water than cooler air -- so if the temperature rises and there's no extra moisture added to the air, the relative humidity will go down.

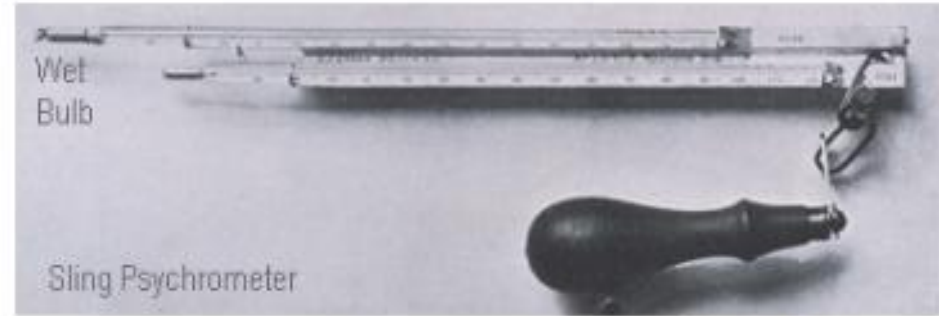


Figure 1. Sling Psychrometer (Image from NASA)

- ***Relative humidity*** can be measured using a **hygrometer**.
- There are many different types of **hygrometers**, but they're all similar in that they measure the temperature in two different ways – using a **dry-bulb** thermometer and a **wet-bulb** thermometer.
- The dry-bulb thermometer will simply measure the air temperature while the wet-bulb measures *evaporative cooling*.
- Evaporative cooling is the reason you feel cold after getting out of a swimming pool or the shower.
- The water uses heat energy from your body and your skin cools to the wet-bulb temperature (which is why you feel a chill until the water evaporates).

A **Sling Psychrometer** (*Figure I*) is a common type of *hygrometer* used to determine *relative humidity*.

- Sling psychrometers use two thermometers (*one dry-bulb, one wet-bulb*) to measure and compare the air temperature versus the evaporative cooling.

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Dry-Bulb Temperature (°C)	Relative Humidity (%)															
	Difference Between Wet-Bulb and Dry-Bulb Temperatures (°C)															
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
-20	100	28														
-18	100	40														
-16	100	48														
-14	100	55	11													
-12	100	61	23													
-10	100	66	33													
-8	100	71	41	13												
-6	100	73	48	20												
-4	100	77	54	32	11											
-2	100	79	58	37	20	1										
0	100	81	63	45	28	11										
2	100	83	67	51	36	20	6									
4	100	85	70	56	42	27	14									
6	100	86	72	59	46	35	22	10								
8	100	87	74	62	51	39	28	17	6							
10	100	88	76	65	54	43	33	24	13	4						
12	100	88	78	67	57	48	38	28	19	10	2					
14	100	89	79	69	60	50	41	33	25	16	8	1				
16	100	90	80	71	62	54	45	37	29	21	14	7	1			
18	100	91	81	72	64	56	48	40	33	26	19	12	6			
20	100	91	82	74	66	58	51	44	36	30	23	17	11	5		
22	100	92	83	75	68	60	53	46	40	33	27	21	15	10	4	
24	100	92	84	76	69	62	55	49	42	36	30	25	20	14	9	4
26	100	92	85	77	70	64	57	51	45	39	34	28	23	18	13	9
28	100	93	86	78	71	65	59	53	47	42	36	31	26	21	17	12
30	100	93	86	79	72	66	61	55	49	44	39	34	29	25	20	16

Figure J. Relative Humidity Chart (Image from NWS)

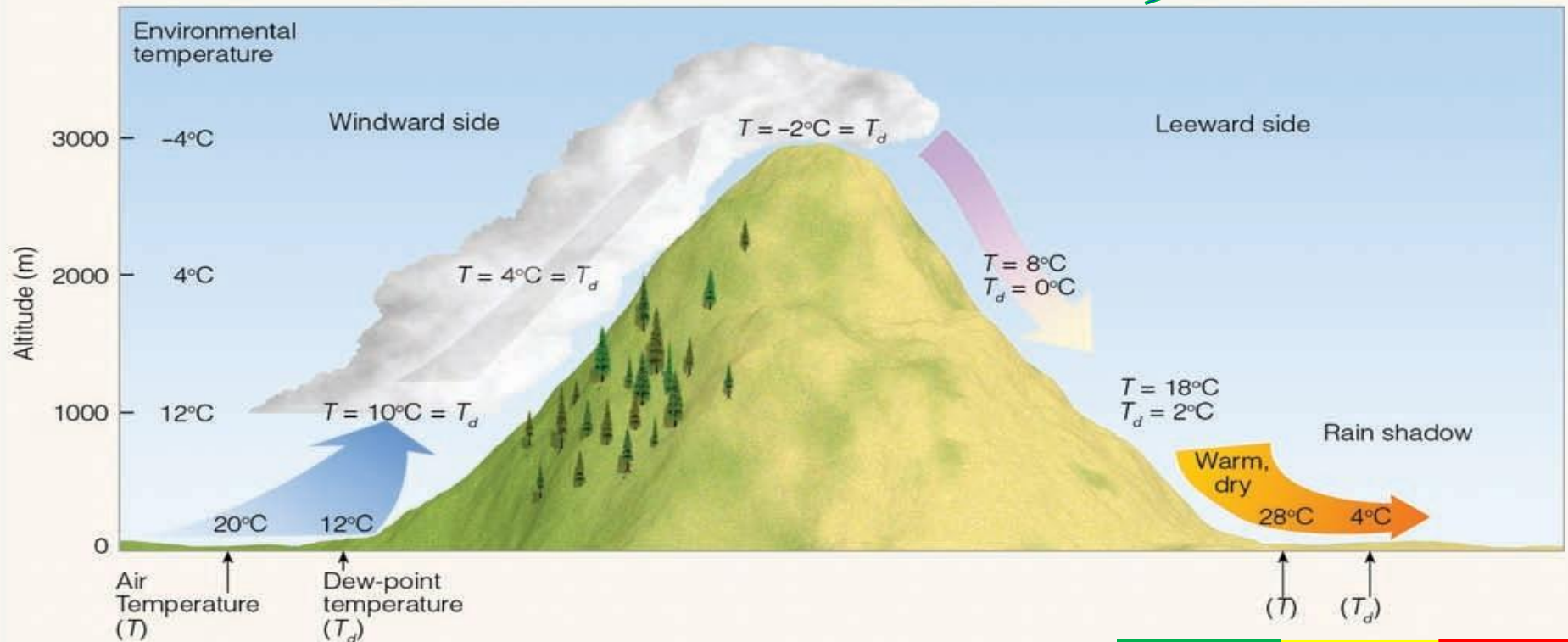
1.3. Controls of weather and climate

Relief: Highlands or mountains lead to the formation of **relief rainfall** on the **windward side** and **dry conditions** on the **lee ward side**.

- Highlands experience lower temperatures than low lands.
- The higher one goes the cooler it becomes.

Pls. have a look of the ff. Vid.Tut.

<https://youtu.be/iM@dbu.edu.et>
[ayelebehalu4dShS74w](https://youtu.be/iM@dbu.edu.et)

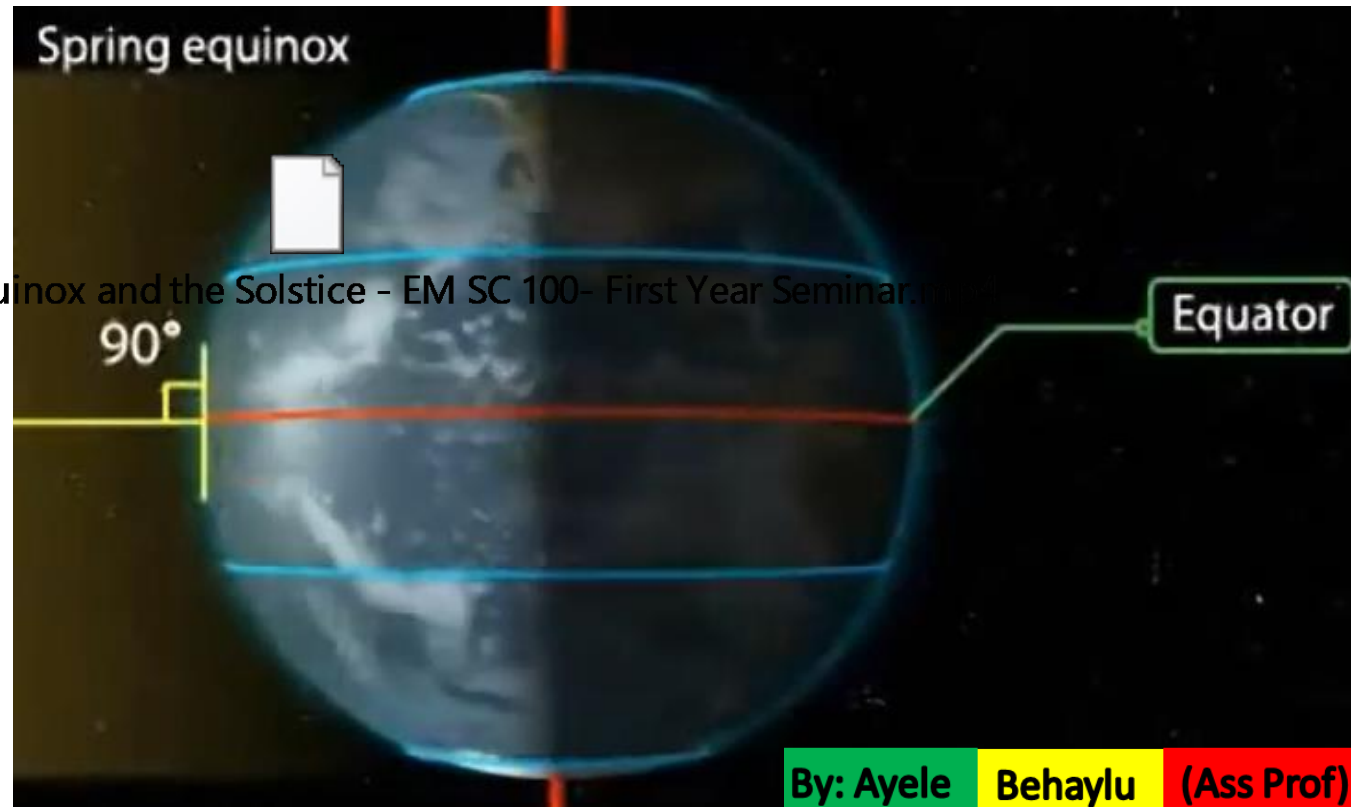


Latitude: - The ***tropical areas*** i.e. areas of ***low latitude*** experience higher temperatures and ***rainfall***.

- Areas of ***higher latitude*** e.g. the ***temperate*** and ***Polar Regions*** experience ***lower and very much temperatures*** respectively.

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Understanding the Equinox and the Solstice - EM SC 100- First Year Seminar



Water Bodies: - Nearness to a large water body influences the climate of the area.

- ***Water bodies*** are sources of ***atmospheric moisture*** through ***evaporation*** and areas ***near*** them experience ***higher rainfall***.

Natural Vegetation:- ***Forested*** and ***wetland*** areas ***contribute*** to the ***atmospheric vapour*** through ***transpiration*** leading to the ***formation of rainfall***.

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- Areas ***without vegetation*** or ***limited vegetation*** experience ***less rainfall***.

Prevailing Winds: - *Moist prevailing winds* bring in rainfall unlike *dry winds*.

- Winds also help in the distribution of temperatures i.e. *warm winds* bring in *warm conditions* while *cold winds* bring in *cool conditions*.

Ocean Currents: - These are *moving ocean waters*. They may be cold or warm i.e. cold and warm ocean currents.

- *Warm ocean currents* lead to the formation of high rainfall on the adjacent coastal areas.
- *Cold ocean currents* lead to low rainfall and formation of *marine deserts* in the adjacent coastal areas e.g. the *Namib Desert*.

Man's Activities: - Activities like *deforestation*, *swamp reclamation*; *industrialization*, etc. lead to *semi arid* and *arid* conditions through the *process of desertification*.

- In addition *environmentally unfriendly* human activities lead to *global warming*.

1.4. Weather and climate data

➤ Weather and climate data are collected to monitor all *physical*, *biological*, *chemical* and *hydrological* properties of the *earth*.

The following are the *significance of weather and climate data*.

- Helps in describing the climate of a place; weather it is *equatorial climate* or *tropical climate* among other climatic types.
- Helps farmers to *plan when to plant* their crops and *when to harvest them*.
- Important in the *aviation industry*, in that it *helps pilots* to know when to *take off* and *when to land*.

- Helps *sailors at sea* to *schedule* their journeys.
- Helps *people* to plan *what to put on or dress* for the day for example they will know whether or not to put on a sweater or jacket and whether or no to *have an umbrella*.
- Helps the *government* to *prepare for disasters* like *floods, drought, and very strong winds* among others.

➤ ***Weather*** and ***Climate*** observations are collected by a diverse suite of ***networks***, including data from ***satellites*** in regular orbits, from ***aircrafts***, from ***ground-based stations*** scattered around the globe, and from ***ships*** or autonomous ***drifting floats*** moving around the global oceans.



- There *are four types of weather observations* based on the *location of the observation* or *type of instrument* used.

- These include:

- *Surface observations;*
- *Upper air observations;*
- *Radar observations;* and
- *Satellite observations*



Surface Observations

- When the *point of observation* is at the *Earth's surface*, the observation is called a *surface observation*.
 - These observations include the *standard airport based reports*, *local networks that are often used by television weathercasters*, and *temperature and precipitation data from National Weather Service cooperative observers*.
- **Standard airport-based observations** always include values for *wind direction, wind speed, surface visibility, present weather or obstructions to vision (if occurring), sky condition, temperature, dew point temperature, altimeter setting, and sea level pressure*.
- Additional data on *peak wind speed and direction, precipitation amount, maximum/minimum temperature*, and 3-hour pressure change, among other parameters, are included when they occur or at specified times.

Upper Air Observations

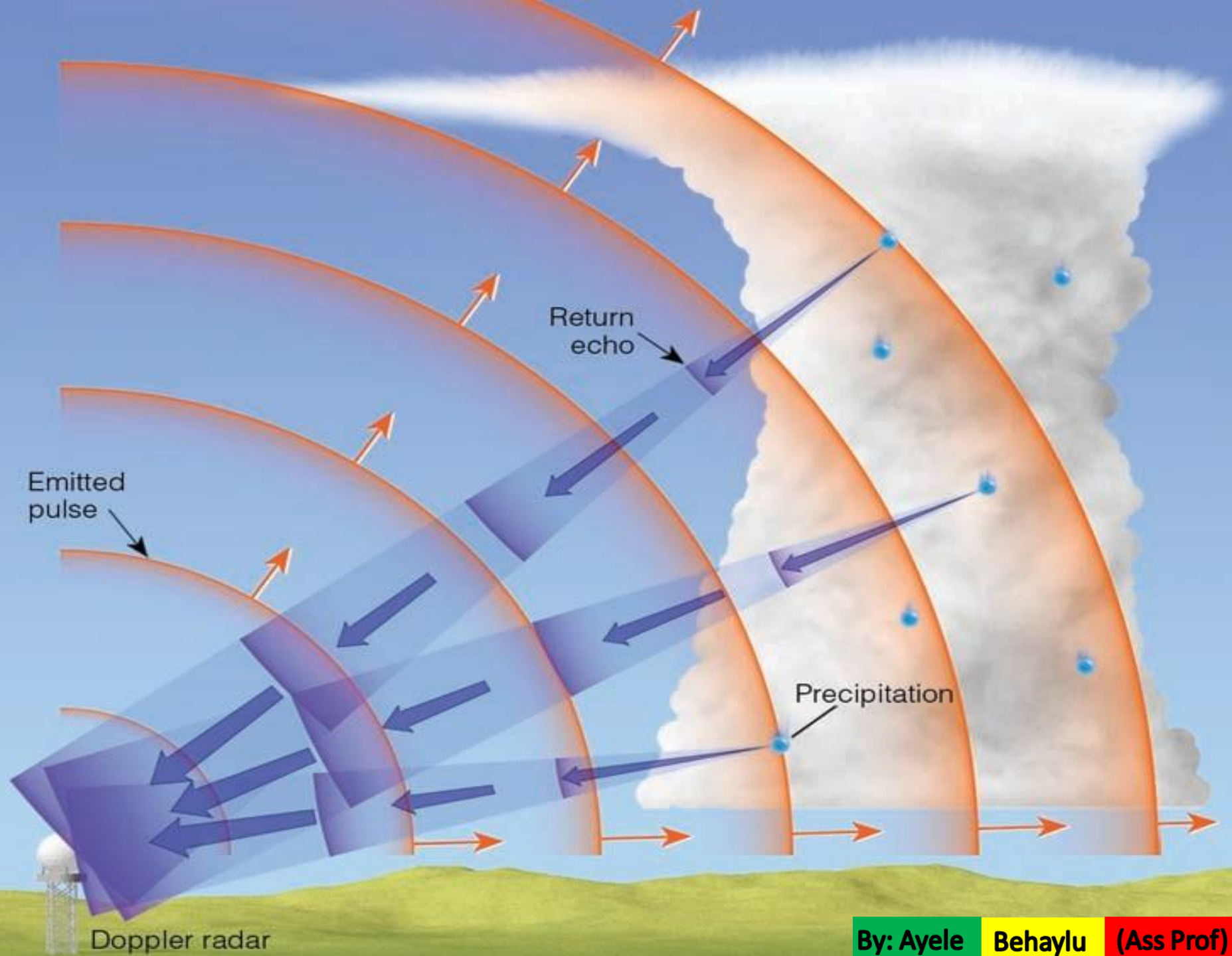
- When the point of observation is ***above the Earth's surface***, somewhere in the atmosphere, the observation is called an ***upper air observation***.
- These observations routinely include ***balloon-borne radiosondes*** and ***commercial aircraft data*** (ACARS).
- Radiosonde data include **temperature, dew point temperature, pressure, and wind** as a function of height.
- Upper level wind data are also available from the weather ***radar network***, the experimental profiler network, and satellite data.

•

RADAR Observations

- Each radar unit emits energy at a series of elevation angles in order to sense what is happening in a volume of the atmosphere above the Earth's surface.
- These data are fed into a set of algorithms that produce a variety of interpretative parameters.
- All data produced by the ***radar network*** are ***digital*** and are available to anyone.

- Atmospheric scientists use **RADAR** (radio detection and ranging) to examine the *inside of a cloud* in much the same way that *physicians use X rays to examine the inside of a human body*.
- Essentially, the radar unit consists of a transmitter that sends out *short, powerful microwave* pulses.
- When this energy encounters a foreign object—called a *target* a fraction of the energy is *scattered back toward the transmitter* and is *detected by a receiver*.



- There are companies that process these data into products that are often seen on ***television weathercasts***.
- One example of what can be done with these digital data is the regional radar composite where data from several sites are combined into a product covering several states or the entire nation.
- Sometimes ***radar data*** are combined with ***digital satellite*** to produce a combination display.

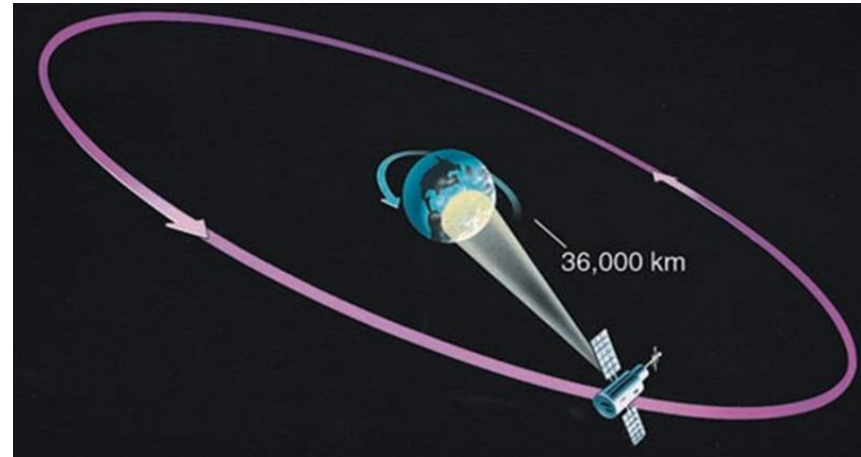
Satellite Observations

- The weather satellite is a *cloud- observing platform* in *Earth's orbit*.
- It provides extremely valuable images of clouds over areas where there are no ground-based observations. Because water covers over 70 percent of Earth's surface, there are vast regions where few (if any) surface cloud observations are made. Before weather satellites were available, tropical cyclones, such as hurricanes and typhoons, often went undetected until they moved dangerously near inhabited areas. Residents of the regions affected had little advance warning. Today, satellites spot these storms while they are still far out in the ocean and track them accurately.

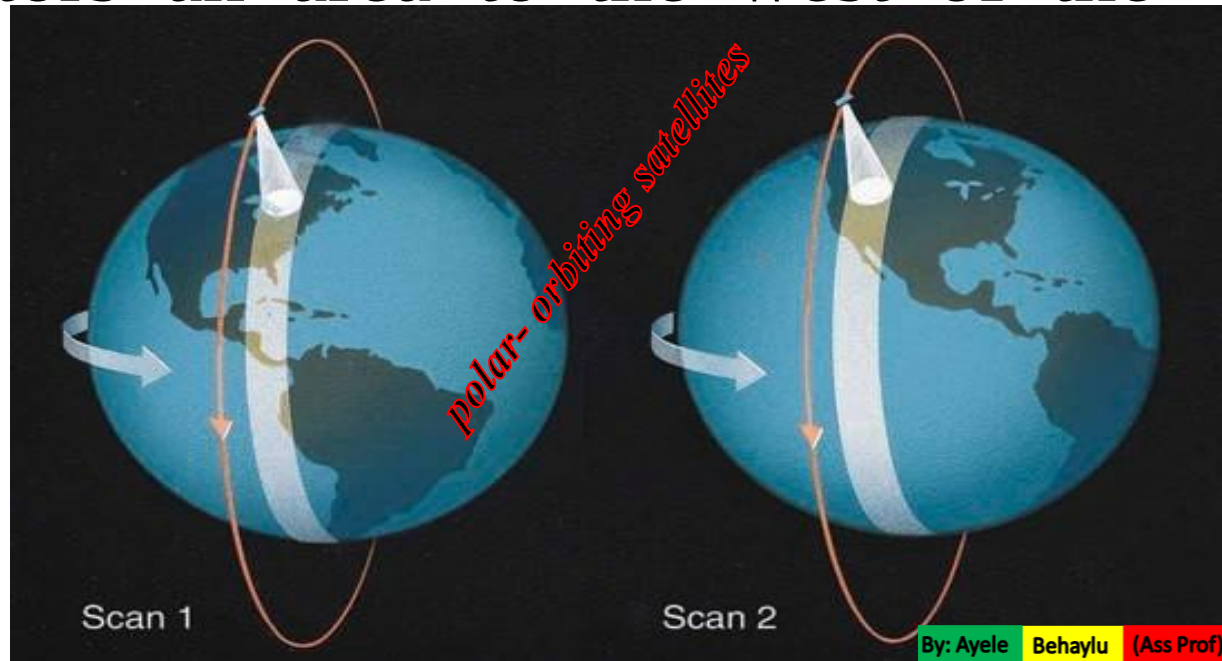
- *Two primary types* of *weather satellites* are used for *viewing clouds*.
- The first type are called *geostationary satellites* or *geosynchronous satellites*) because they *orbit the equator* at the same rate Earth spins and, hence, remain above a fixed spot on Earth's surface, at an altitude of nearly 36,000 km.
- This positioning allows continuous monitoring of a specific region.

Geostationary satellites are also important because they use a real-time data system, meaning that the satellites transmit images to the receiving system on the ground as soon as the image is taken. Successive cloud images from these satellites can be put into a time-lapse movie sequence to show the cloud movement, dissipation, or development associated with weather fronts and storms..

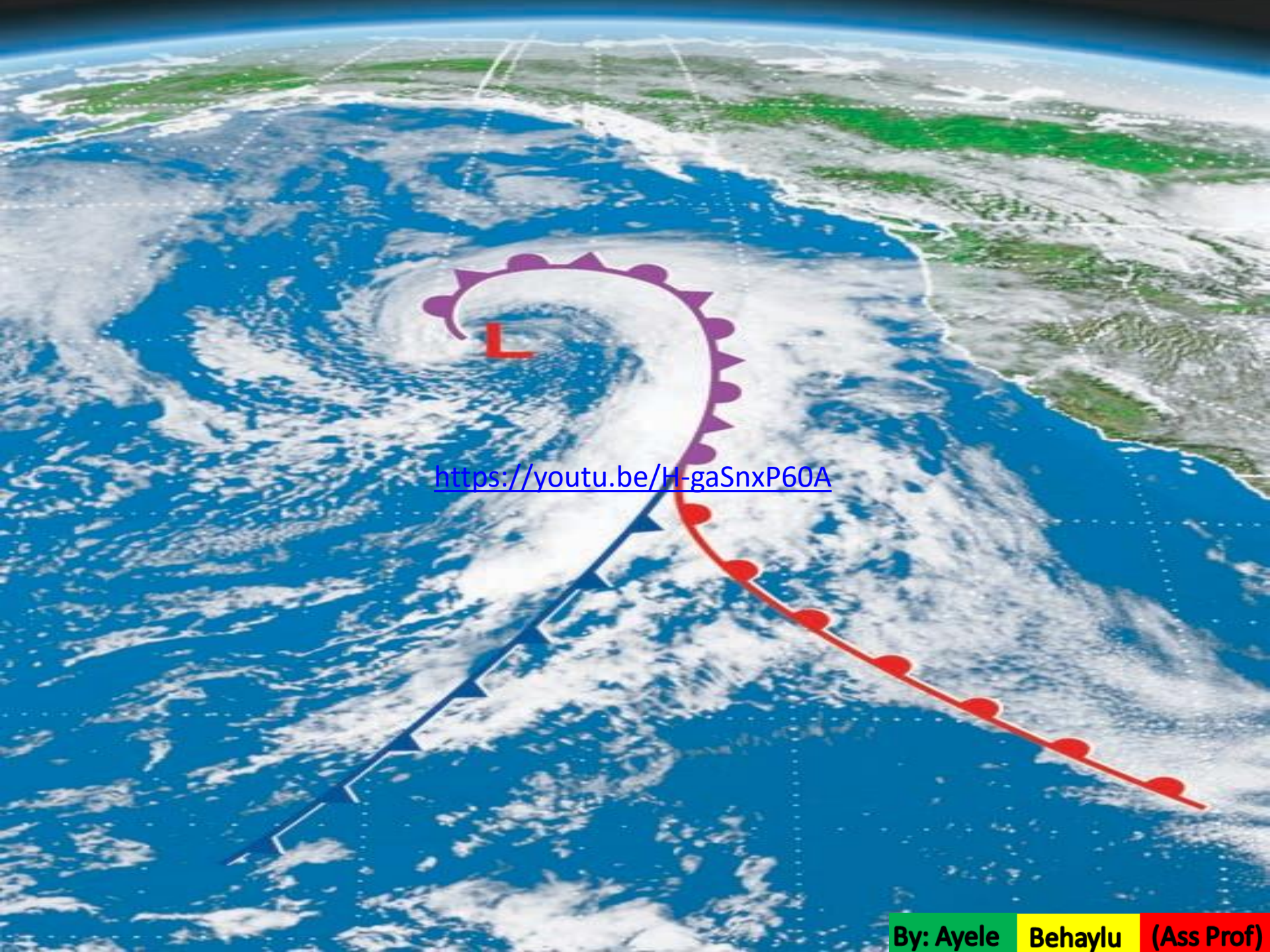
- This information is a great help in monitoring and forecasting the progress of large weather systems.
- Wind directions and speeds at various levels may also be approximated by monitoring cloud movement with the geostationary satellite



- Complementing the geostationary satellites are *polar-orbiting satellites*, which closely parallel Earth's meridian lines.
- These satellites pass over the north and south polar regions on each revolution.
- As Earth rotates to the east beneath the satellite, each pass monitors an area to the west of the previous pass.



- Although there are active sensors on satellite platforms, the ***satellite imagery*** most used by weather analysts are passive in nature.
- These include ***visible images***, ***infrared (IR) images***, and ***water vapor images*** (WV).
- ***Visible images*** show the solar radiation reflected from the Earth's surface.
- Visible imagery is routinely available during daylight hours.
- ***IR images*** show the ***thermal infrared radiation*** emitted by the ***Earth*** and ***clouds*** below.
- ***WV imagery*** represents the ***emission of electromagnetic energy*** by the ***water vapor*** in the ***middle to upper troposphere***.
- Higher moisture values are usually shown at the white end of the scale with drier areas depicted by the darker end of the scale.



<https://youtu.be/H-gaSnxP60A>