Air Pollution and Control
Professor Bhola Ram Gujar
Department of Civil Engineering
Indian Institute of Technology, Roorkee
Lecture 09
Meteorological Parameters & Air Pollution

Hello friends, today we will discuss about Meteorological Parameters and Air Pollution. As you know, we have discussed like emissions sources, and this atmospheric transformations or formations of air pollutants then their dispersion or diffusion their ultimate fate. But as you know even if the emissions are same, emission sources are same the concentrations of air pollutants in ambient air may be different at different places.

So, what is the difference? Basically the meteorological parameters govern all these emission sources, how much they will turn into air quality. So, today, we will discuss about the impact of meteorology on air pollution means meteorological parameters and air pollution. How do they interact with each other? And how these meteorological parameter influence the air quality around different places.

So, in this content list you can see like introduction then the brief history about different kind of meteorological parameters evolution and then the science of this particular subject. Then we will also discuss a little bit what is the atmosphere. Though we have already discussed about the atmosphere, then different boundaries of the atmosphere and horizontal moment of the atmosphere. Then equatorial heating and polar cooling, the effect of earth's rotation because, it's not the simple the wind movement from equator to pole and pole to equator there are the effect of earth's rotation, which we will see.

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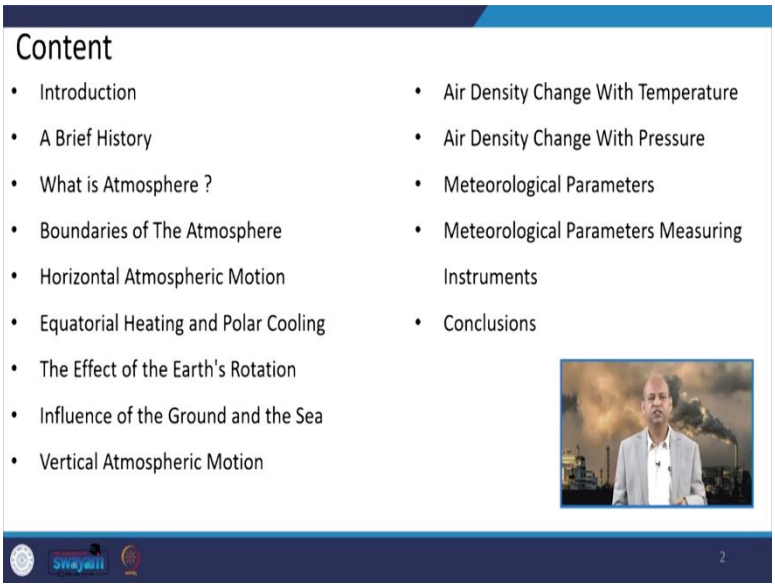

Influence of the ground surface and the sea and though the distribution of the temperature and like on the pollution dispersion. Then vertical atmospheric motion and air density change with the temperature, and with the pressure also because pressure also influences the air density. Then meteorological parameters measurements, and ultimately we will conclude this study today. So, in nutshell, we will discuss about the metrological parameters roll into the air pollution the fate of the air pollutants or decision of air pollution dispersion and the air pollution the total, the net worth of the air pollution in that sense.

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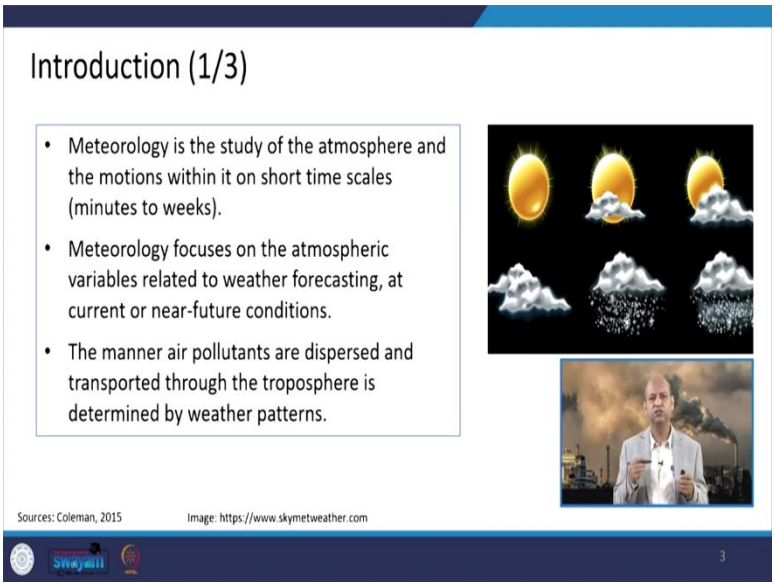

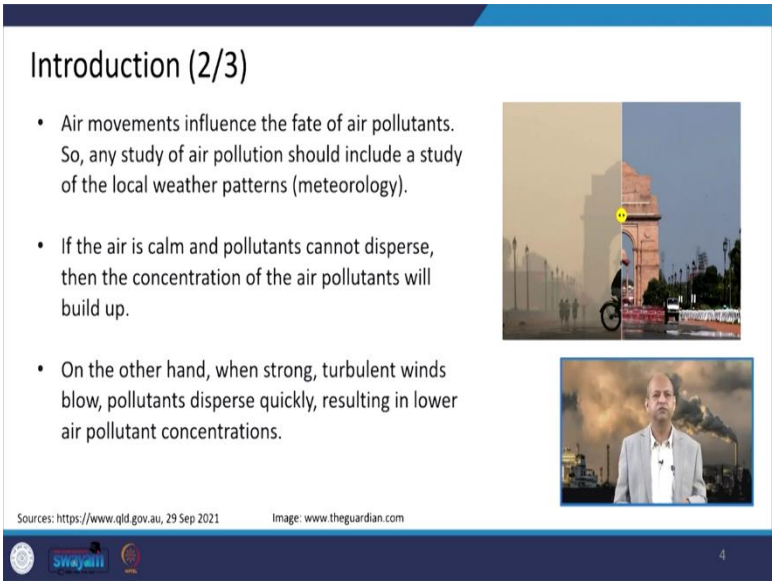

Well, meteorology basically is the study of atmosphere, and the motions within that, that like wind velocity, wind direction and then at the short timescales like minutes to weeks. So, basically it is related to the weather conditions you can say. So, the meteorology focuses on the atmospheric variables related to weather forecasting. So, like we do weather forecasting similarly, we can also do the air quality forecasting nowadays, those kind of models are available.

And within the near like current within day to day as well as near-future conditions like one week or so, something like that. The manner air pollutants are dispersed and transported through troposphere is determined basically with the weather patterns. So, meteorology is very important in that that sense to see the impact on the air pollution or air quality. And this air moments, you know, it influences the fate of the air pollutants. Last time we discussed as you remember, like air pollution transformation, maybe there. Like a phase transformation maybe there from gas to liquid or particles, but the transportation from one place to another.

And within that transportation this phase transformation may also take place. So, the ultimate fate of the air pollution or air pollutants is determined by this air movements. So, the study of air pollution is you know linked with the study of local weather patterns or meteorology in brief.

So, if the air is calm and pollutants do not disperse much, then the concentration built up of air pollutants will be high in that particular area. On the other hand, when strong turbulent winds are blowing very high-speed winds are there, so the dispersion of pollutants is quick.

Of course, if turbulence is very high, then maybe near to the source concentration may be high, because of those turbulence, very high turbulence, but if wind is blowing very rapidly then it can transport pollutant to longer distances in the downwind direction. And it can result in lower concentration of air pollutants because the dilution happens, quickly the dilution happens in the atmosphere.

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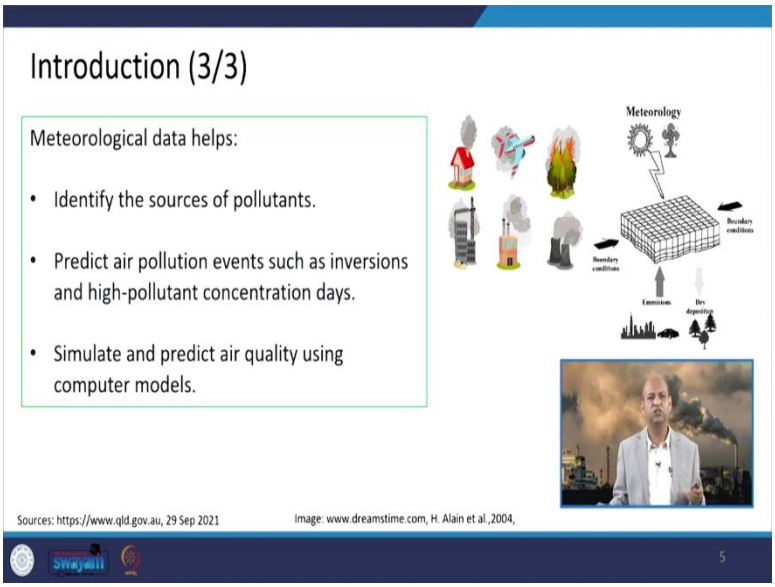

Well, so, you know these metrological data basically helps in identifying the sources of the pollutants. Because inverse modeling also you can do. For example, at a particular point you monitor and you got certain pollutants concentration very high, and you do not see much local sources then with the help of this metrological parameters that from which direction the wind is coming the up-wind direction, so, you can do inverse modeling.

And you can go like these trajectory plotting and all those things are there, which can take you to the particular source in the upwind direction. That from there, this particular pollutant is coming to this place. So, the identification of sources can also be done with the help of meteorological data. It can also help in predicting the air pollution events such as like inversion, we will discuss in detail afterwards. Inversion means, the vertical movement of the air pollutants is restricted, because of this the temperature profile is changed, when in general like temperature decreases, as we go up from the earth surface, but when it increases then it is known as inversion.

And inversion is very dangerous condition in the sense the vertical dispersion of air pollutant is completely restricted or blocked. So, high pollutant concentration may happen in that

duration. Then it can also help, these metallurgical parameters can help in simulating and predicting air quality using computer models. Because the input parameters will need like wind velocity, then, temperature gradient, all those kinds of things are there and humidity all. Means, in complex models many meteorological parameters you take into account.

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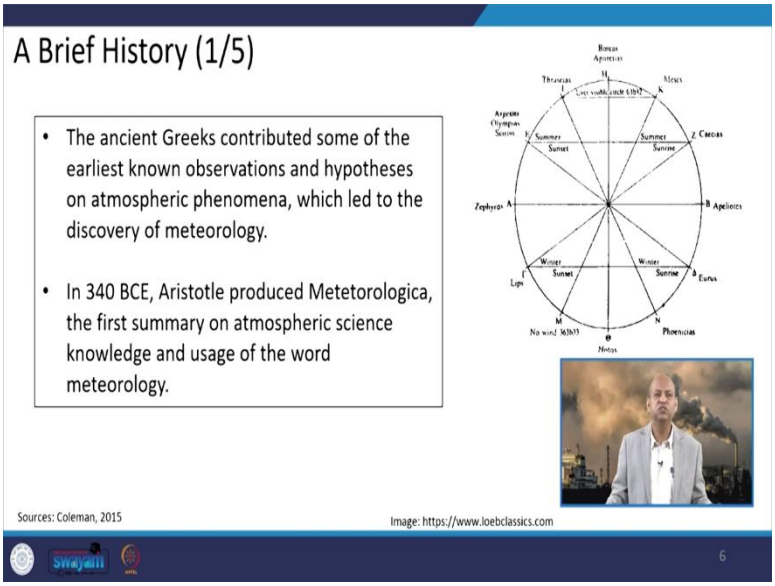

Well, when we talk about how this knowledge of metallurgy evolved over the years, so, a brief history would be worth to notice. Like in ancient Greeks period these philosophers or scientists they contributed some of the earliest known observations and hypotheses regarding atmospheric phenomena, which led to the discovery of meteorology. Like in 340, before Christ era (BCE), Irish total produced Metetorologica that the first summary on atmospheric science and the knowledge body of the atmospheric science and the uses of the word particularly of meteorology, so, that metrological was the basic the collection of those particular data in a particular fashion.

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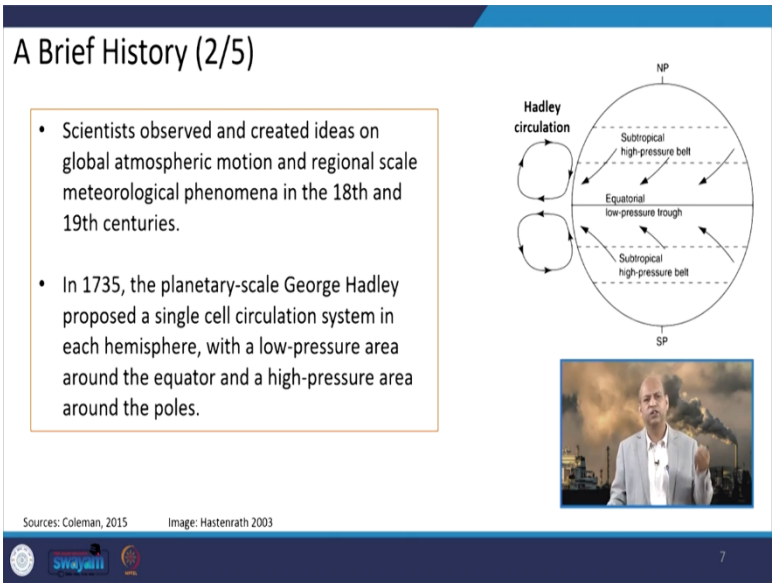

Then scientist observed after that and created ideas on global atmospheric motion and regionally scale meteorological phenomena in 18th and 19th centuries. In 1735, the planetary-scale George, this planetary-scale, single cell circulation system was proposed by scientists George Hadley. So, this is known as the Hadley single cell kind of model in that sense, but later on, it was further developed in different kinds of cells, we will see later on.

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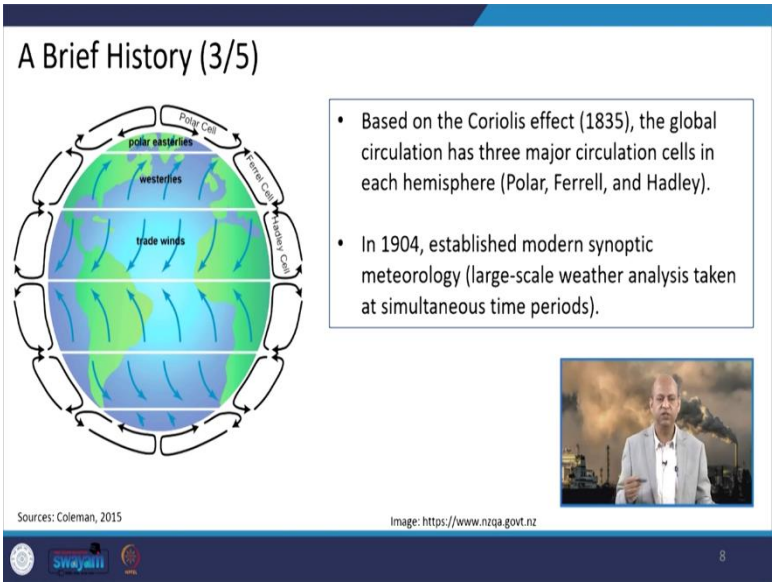

Like here you can see like, this is the Hadley sale, otherwise, the single cell was earlier proposed that at the equator air goes up because it is warm and lighter in density and then it travels towards pole. At the pole, it descends and then come down, so that kind of cell, single

cell happens, but that was very simplistic model at that time. Later on these kind of three cells were hypothesized and proved like Hadley cell, then this Ferrell cell and the Polar cell.

So, these really influence the, this circular motion of the atmospheric gases, as well as the winds and it also determines the pollution dispersion, as well as transportation of heat element and moisture from one place to another, and this global circulation happens. So, the based on this Coriolis effect. Again, from the scientist named Coriolis, the global circulation has three major circulation cycles or cells in each hemisphere like Polar, Ferrell and Hadley.

In 1904. And this, established modern synoptic metrology the large-scale weather analysis taken at simultaneous time periods. So, those kinds of evolution has happened in the metrological studies or weather-related studies.

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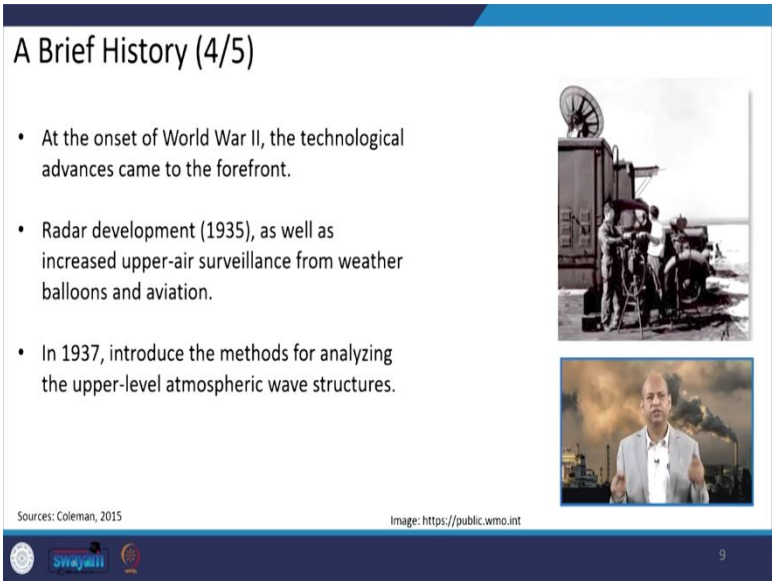

Then at the onset of World War II, the technological advances came to the forefront in this particular area. Like radar developments happened in 1935, then, as well as increased upper-air surveillance from weather balloons and aviations. So, a lot of this scientific data got gathered and the understanding of atmospheric motions increased. In 1937, this introduction of the methods for analysis of upper-level atmospheric wavy structure were also developed.

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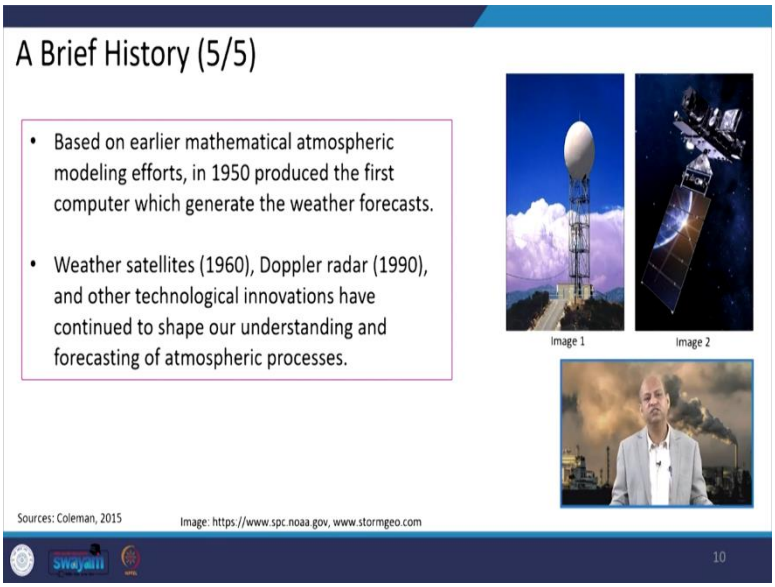

And based on earlier mathematical atmospheric modeling efforts in 1950 this first computer model was produced, which generated the weather forecast. So, weather forecasting is started in 1950s. Then weather satellites in 1960, Doppler radar in 1990, they further refined this particular exercise. And other technological innovations, they helped in containers in continuous mode to shape our understanding to evolve our understanding, and the increasing the strength or enhancing the strength of forecasting of atmospheric processes.

So, you can see technological advances and the scientific advances helped us to go further in the in this particular direction.

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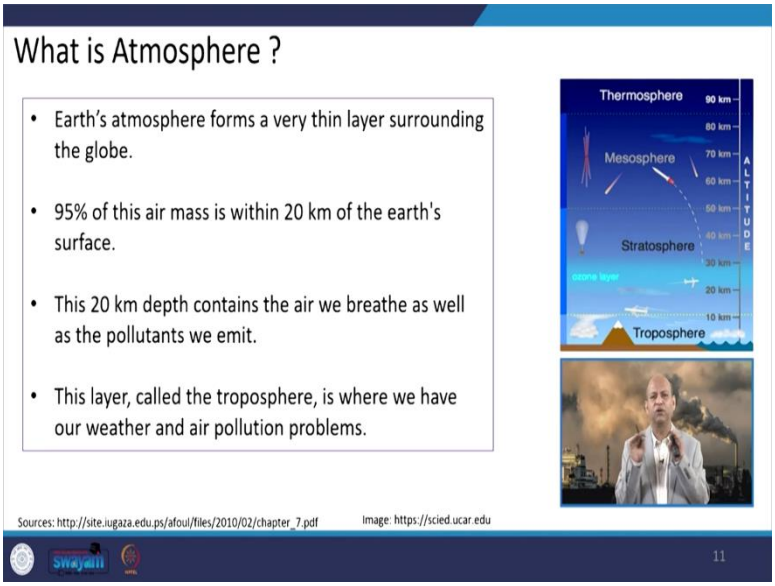

So, when we try to understand the atmosphere this earth's atmosphere, it forms a very thin layer surrounding the globe. Otherwise, if we talk about troposphere.

So, this is like 95 percent of this air mass is within the 20 kilometer of earth's surface. So, this 20 kilometer depth contains the air we breathe, as well as the pollutants we emit into and pollutants where they travel from one place to another. So, this layer called the troposphere is where we have all weather-related, air pollution related problems. You can see the troposphere it is very thin layer so, up to like some it is 10-12 kilometers somewhere up to 20 kilometer or so. So, below the stratosphere this is the layer where most of the airmass is contained otherwise upper layers are very thin atmosphere.

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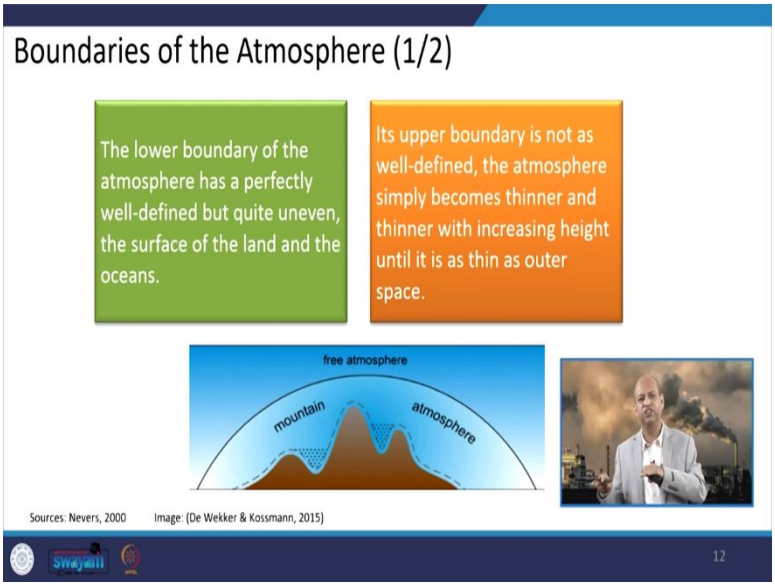

So, different boundaries of the atmosphere we can then imagine. Like the lower boundary is well defined, but of course, it is uneven. Like the surface then oceans, mountains, so that is the lowest boundary of the atmosphere. Upper boundary is not so well defined basically and atmosphere simply becomes thinner and thinner as we go up in the space, as we go up in the height. And ultimately it is very thin in the outer space.

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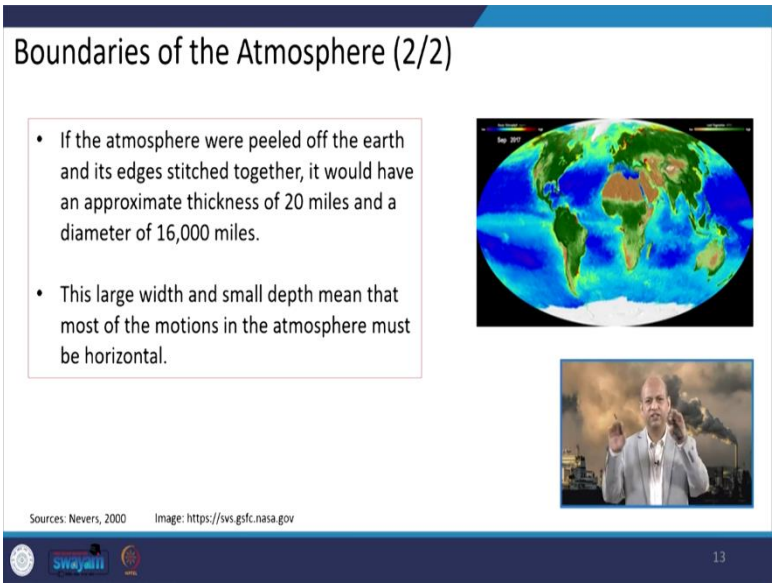

Then we talk about like atmosphere. If it is peeled off to visualize at the earth and if it is stitched and seen like a circular plate so the 20 miles is the thickness of this one and the 16,000 miles diameter kind of plate you can take. So, in that sense you can see the width of the area is very high and the thickness is very low.

16,000 miles diameter and only 20 miles in that sense very thin. So, you can say that the horizontal motions, they really play a significant role in the atmospheric motions or atmospheric dispersion of air pollutants and all other metrological parameters transportation of temperature, humidity, etc.

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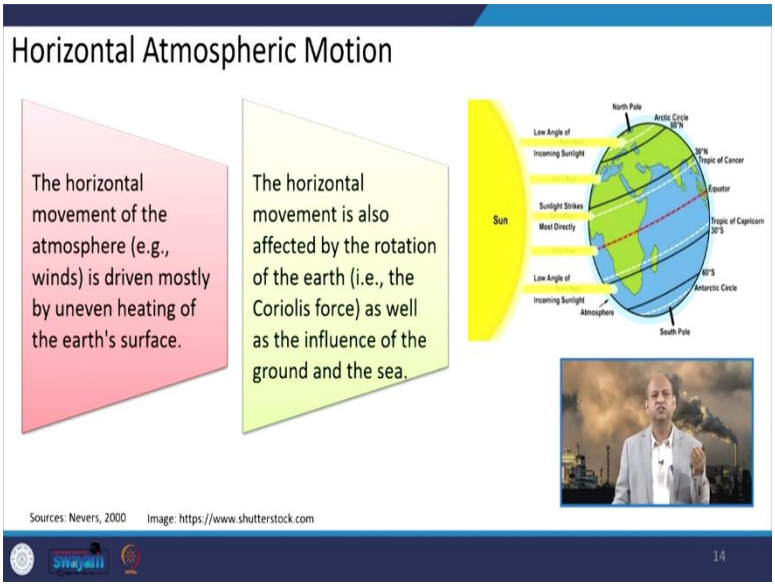

Well, so, horizontal atmospheric motion is very important to understand. And this horizontal movement of the atmosphere like winds is driven mostly by uneven heating of the earth's surface. Because, at the equator, the sunlight is very high and a lot of heating is generated and then warm air goes up. So, it is very light in the density and this gentle movement is also affected by rotation of the earth that is that this Coriolis force, as well as the influence of the ground and the sea. So, all those things really influence the horizontal motion you can say.

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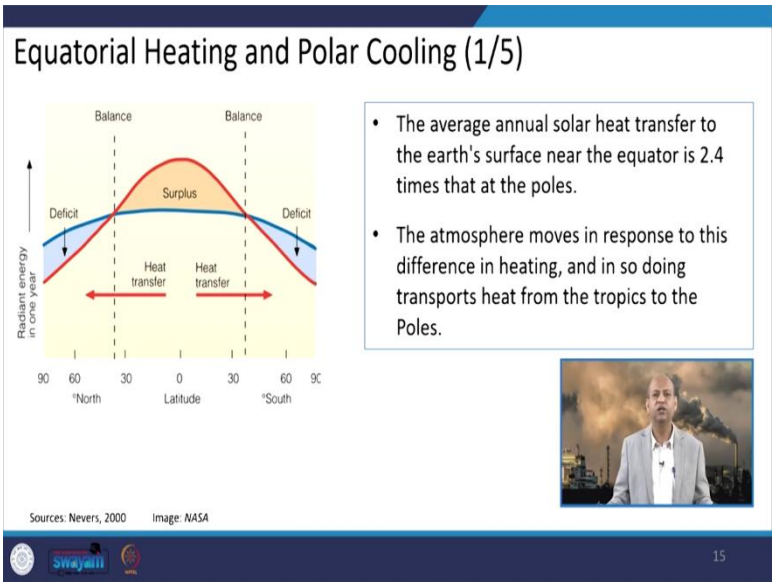

Well, the equatorial heating and polar cooling. This is also again one interesting thing, because the annual solar average annual solar heat transfer to the earth's surface near the equator is around 2.4 times that at the poles level. And you can see this excess inclination of the earth as you know, so, uniform distribution of solar radiation is not there on the entire earth's surface. It is maximum at the equator and minimum at the pole.

So, this differential in heating pattern that drives the wind movement and the transportation of other entities of atmosphere or meteorology. So, the atmosphere moves in response to this difference in heating. And in doing so, it transports heat from tropics to the poles, but it is not very simple, as initially it was assumed it is little bit complex, which we will see.

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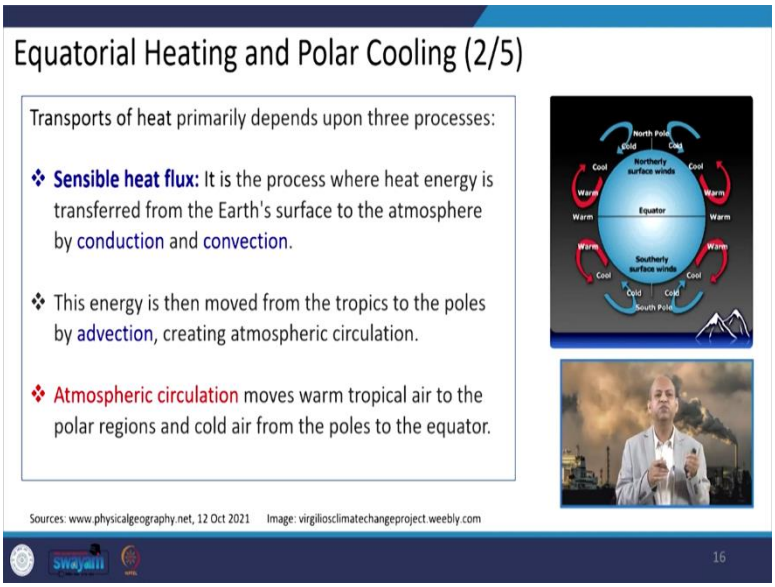

For example, you know, this transportation of heat primarily depends upon three processes. One is, like sensible heat flux, and it is the process where heat energy is transferred from the earth's surface to the atmosphere by conduction and convection. Conduction means, like, direct heating of the molecules of air, and convection means by radiation and vertical movement of this air mass. So, this energy is then moved from the tropics to the poles by advection that is the horizontal movement. Advection horizontal movement, convection is vertical movement. And this creates the atmospheric circulation or global atmospheric circulation, you can see. General circulation models are based on this fundamental concept.

And then atmospheric circulation moves this warm tropical air to the polar regions and cold air from the polar regions to the equator. So, that kind of complete cycles happen. As you can see warm air goes up, then it goes towards the pole and then cool air moves towards the equator. But as we have seen those Hadley cells and then Hadley cells and then other cells, so, there is you know these three particular cells, which really helps in this moment of temperature and other wind moments. It is not very simple. One cycle is not there, there are three cycles and in between that I can show you again.

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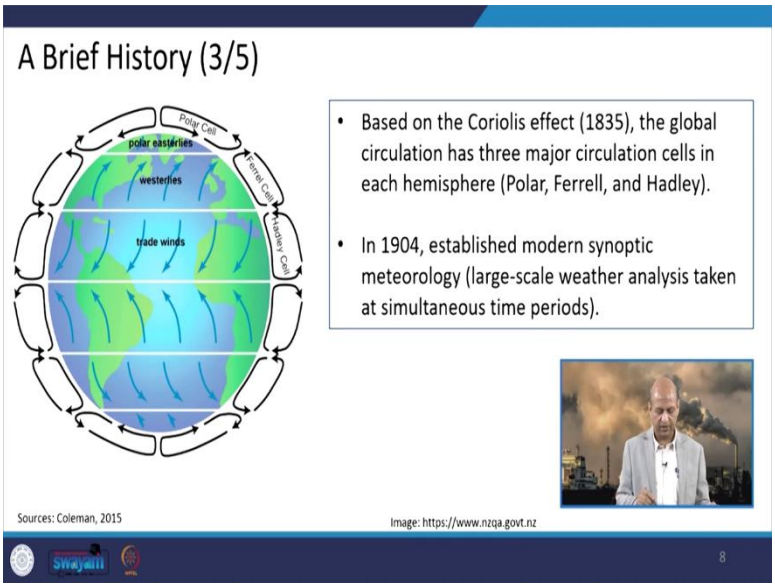

The Hadley cell and this Ferrell cell and Polar cell. So, this Ferrell cell really works like a gear otherwise movement is towards this poll, so this gear system is there for further movement of this air mass you can see.

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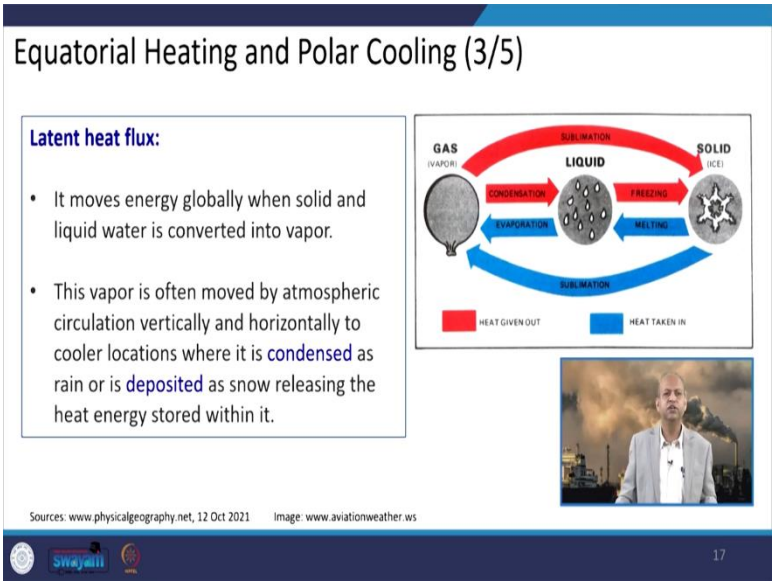

Well, so, next is Latent Heat Flux. So, we have seen the sensible heat flux, this atmospheric circulation and then this latent heat flux, and the third one is surface heat flux. So, what is latent heat flux? This basically moves energy globally when solid and liquid water is converted into vapor.

So, in vapor, because water is evaporated so the heat is in latent, in hidden kind of thing in the water vapor. So, this vapor is often moved by atmospheric circulation vertically and horizontally to cooler locations, where it condenses and it rains and it deposited at snow releasing the heat energy stored within it. So, that kind of heat transfer takes place from solid to gas or gas to solid those kinds of circulation is there.

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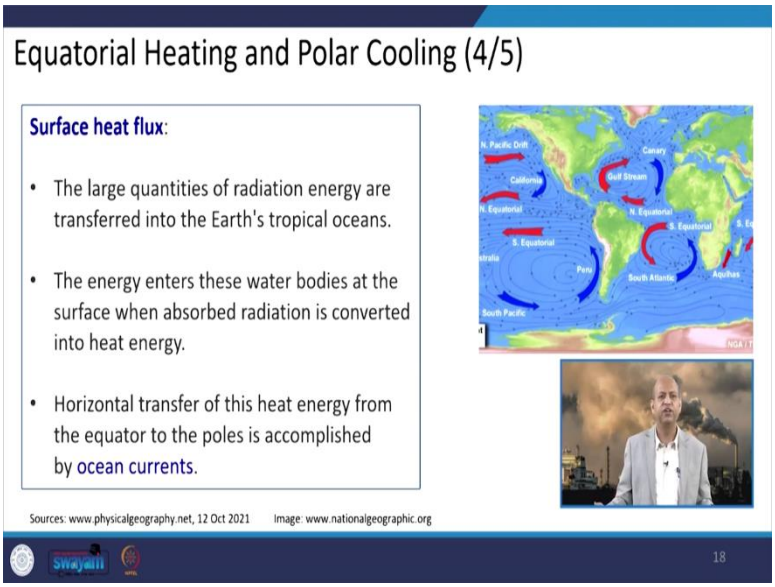

Then there is this surface heat flux. And this is the large quantities of radiation of energy, which is transferred into the earth's tropical oceans. Because the sea is a great sink of heat. So, there is circulation of these water currents also in the sea. This the warm water goes towards upper regions and the dense cold water goes in the depths, and then the big currents like big rivers are moving in the sea so this is bringing this heat, the change of the temperature and heat flux total surface heat flux is transferred through ocean currents.

So, the energy enters in these water bodies at the surface when it is absorbed through radiation of absorption, and convert it into heat energy. And the horizontal transport of this heat energy from the equator to the pole is accomplished by ocean currents. As I said, at the equator level, water is warm, so it comes up on the upper region and moves towards this polar region. At polar regions it goes down because the water is dense, and then this whole circulation happens.

So, after latent heat flux, now, third one is surface heat flux. So, basically in this surface heat flux, the large quantities of radiation energy are transferred into the earth's tropical oceans. The energy enters these water bodies at the surface when absorbed radiation is converted into

heat energy, and the horizontal transfer of this heat energy from the equator to the poles is accomplished by ocean currents. Because this, the transfer of the temperature happens because this large scale rotation of water in the ocean, and these are known as the ocean currents.

Well, the significance to air pollution of these particular cooling of the polar and equatorial heating these kinds of differential heating patterns is very important to understand.

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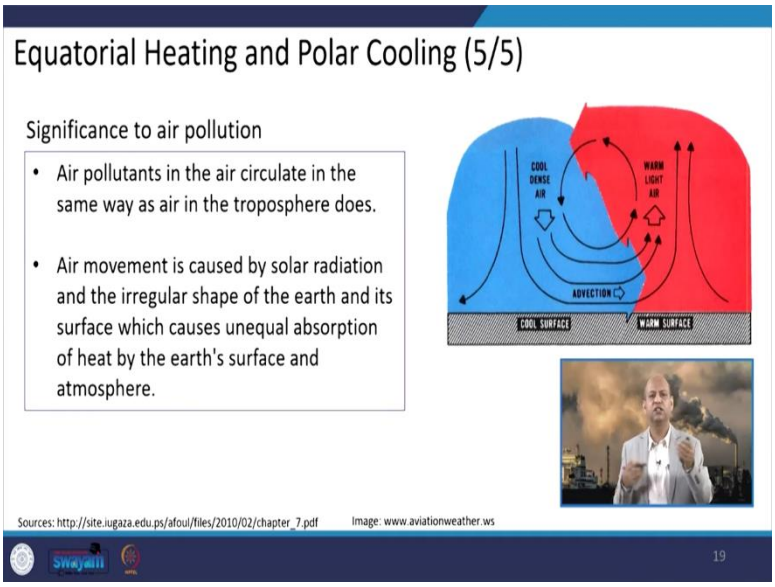

So, the air pollutants in the air it circulates in the same way as these circulation of wind occur into the atmosphere between tropical areas to the poles. And this air movement is caused because of solar radiation and the irregular shape of the earth and its surface which causes unequal absorption of the heat by the earth's surface and atmosphere.

So that is why the wind patterns are there and circulation motion occur. So, dispersion diffusion, all things happen into the atmosphere.

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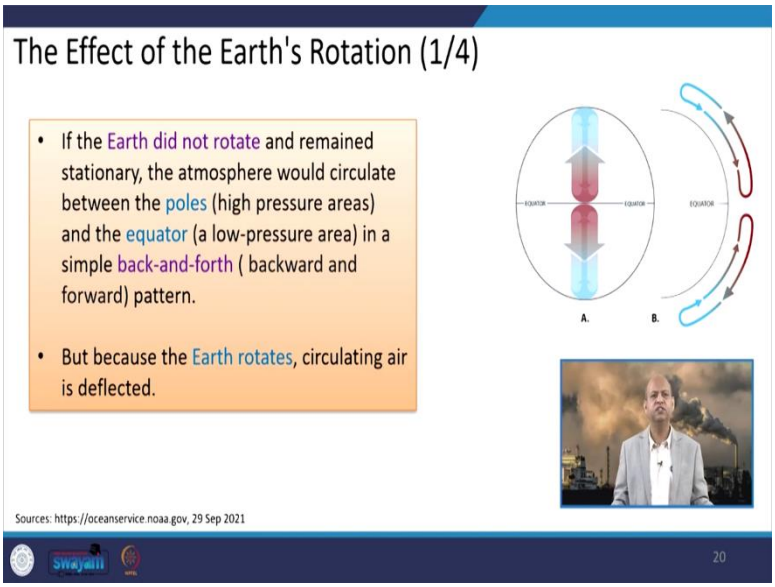

And the effect of the earth's rotation is there because it is not the simple one-directional movement or a simple circular movement. As we can see if the earth did not rotate and it remained stationary atmosphere would have circulated between the poles like higher pressure regions, high pressure areas and the equator, equator is low pressure areas.

So, it could have been like a simple back and forth backward and forward pattern, very simple moment, but it is not so. Because earth rotates that is why the circulating air is deflected, which we have seen this Coriolis forces.

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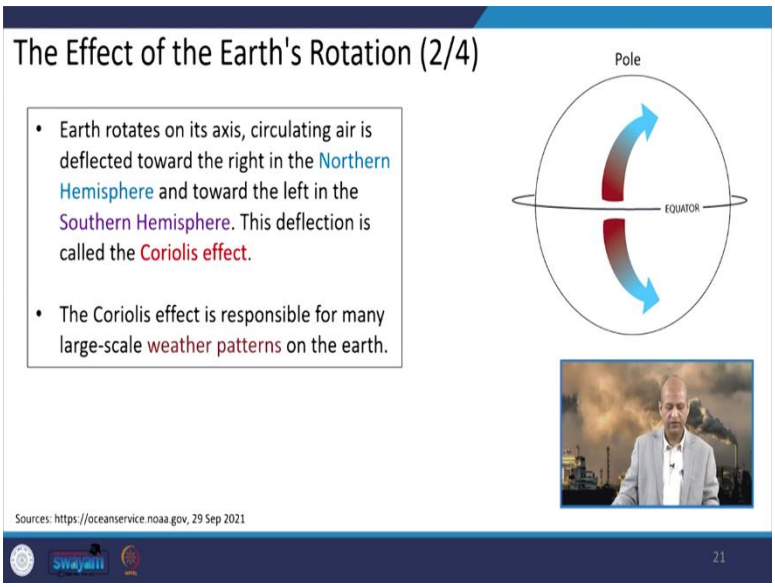

We will see again it. So, the earth rotates on its axis and it circulates the air and deflect and deflection occurs towards the right in the Northern Hemisphere and towards left in the Southern Hemisphere because earth is rotating like this, it is going eastward.

And when this wind movement is there so because of this vector, it goes towards this. This kind of circulation happens. In southern hemisphere like this. So, you can say that in the right direction in the northern hemisphere, and if you see on the equator in the left direction in the southern hemisphere, and right direction in the northern hemisphere, so, this is Coriolis Effect. And this Coriolis Effect is responsible for many large scale weather patterns on the earth. That is very important to understand.

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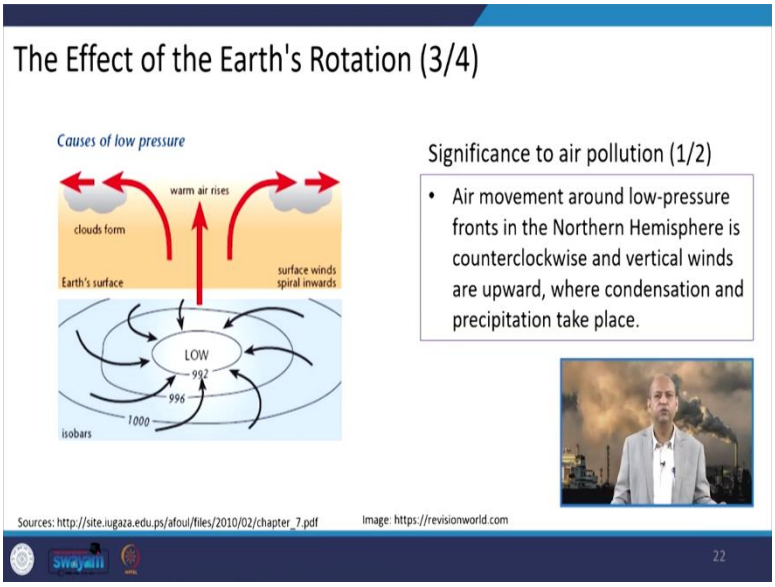

So, you can see the significance of in the air pollution of this earth rotation or air movement, so, air movement around low-pressure fronts in the northern hemisphere is counter clockwise and vertical winds are upward, where this condensation happens and precipitation also takes place. So, this kind of thing happens like you can see. On this side it goes or this side this goes and that takes the moist air towards the poles.

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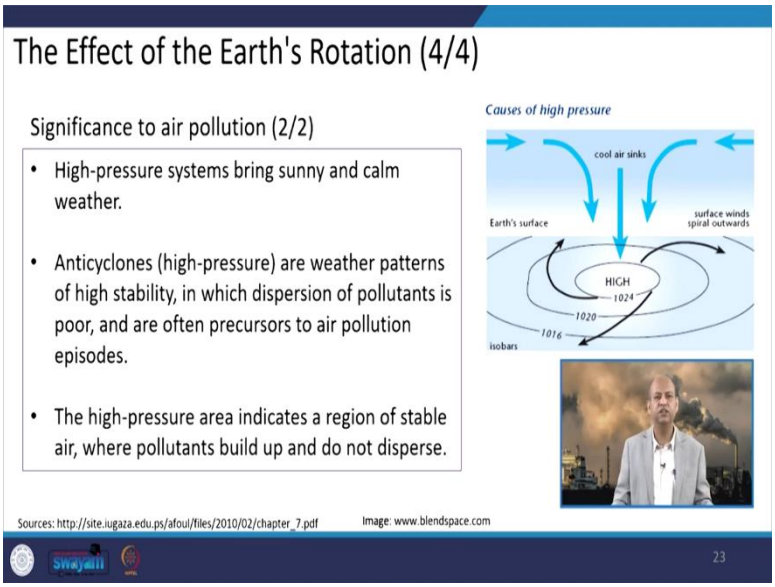

Well, the high-pressure systems bring sunny and calm weather. And the anticyclones or high-pressure or weather patterns of high stability in which dispersion of pollutants is poor. Because of this difference in the temperature profile. And these are often precursors of air pollution episodes. And sometimes this inversion also occurs.

High-pressure areas indicates this region of a stable layer, and we are pollutants built-up and do not disperse because inversion may happen in those particular areas.

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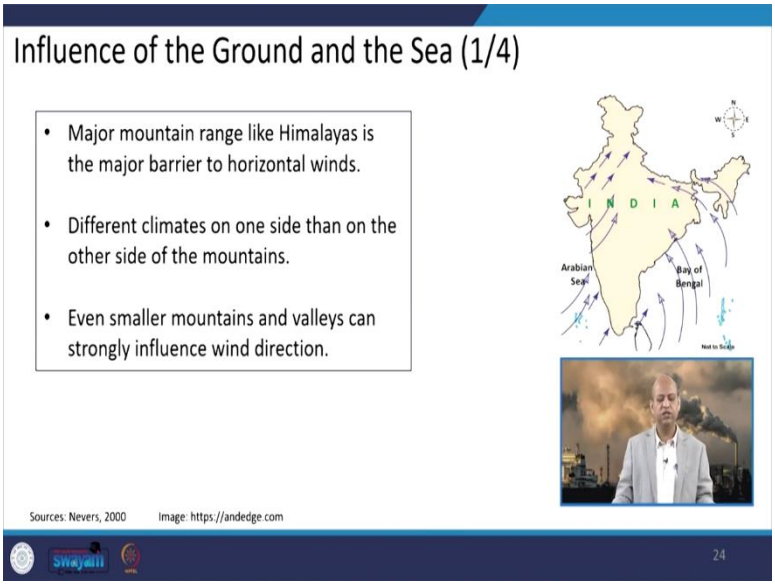

Well, the major mountain range like Himalayas they are there like barriers in the horizontal winds. And different climates on one side of this Himalayas and other side of the mountains can happen. Even smaller mountains and valleys can strongly influence the wind direction and circulation. So, accordingly the dispersion of air pollution can be affected by these patterns.

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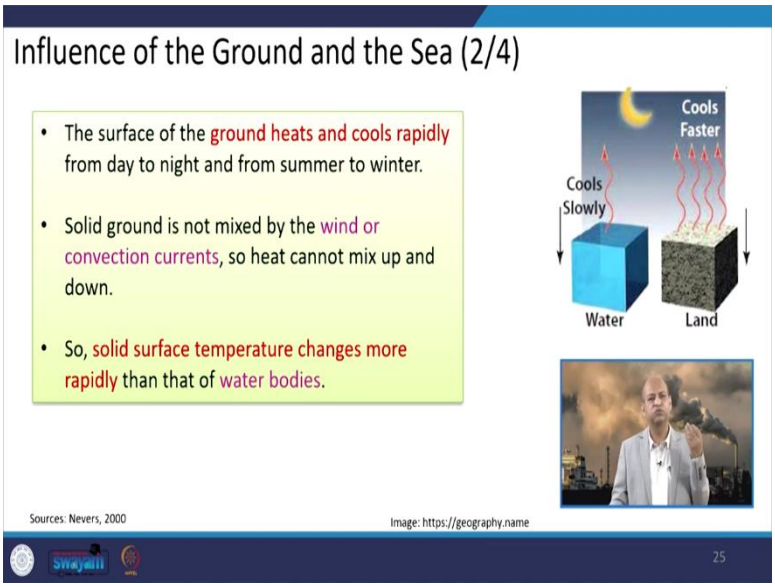

And the surface of the ground heats and cools rapidly from day to night and from summer to winter, this kind of cycle happens, but solid ground is not mixed with by the wind. And it is the convection currents. So, heat cannot mix up to this downwind or upwind direction.

So, solid surface temperature changes more rapidly than that of water bodies. So, that is why sea breeze and land breeze kind of things happen. We will discuss detail in detail later on.

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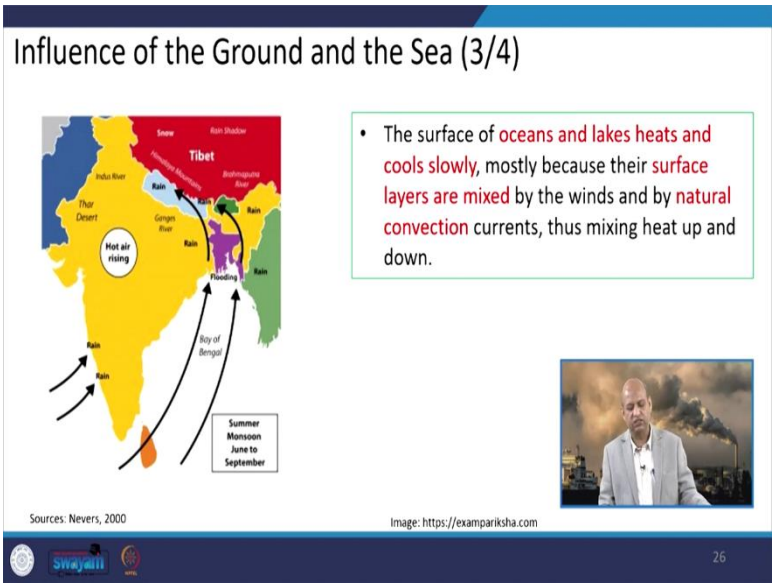

Well you can see here influence of the ground and the sea the surface of oceans and lakes heats up very slowly and cools also slowly. So, the temperature buildup and cooling is slow in water bodies. The earth's surface, it heats quickly and cools quickly. The mostly because the surface layers are mixed by the winds and by the natural convection currents and mixing heats up and down this kind of things happen.

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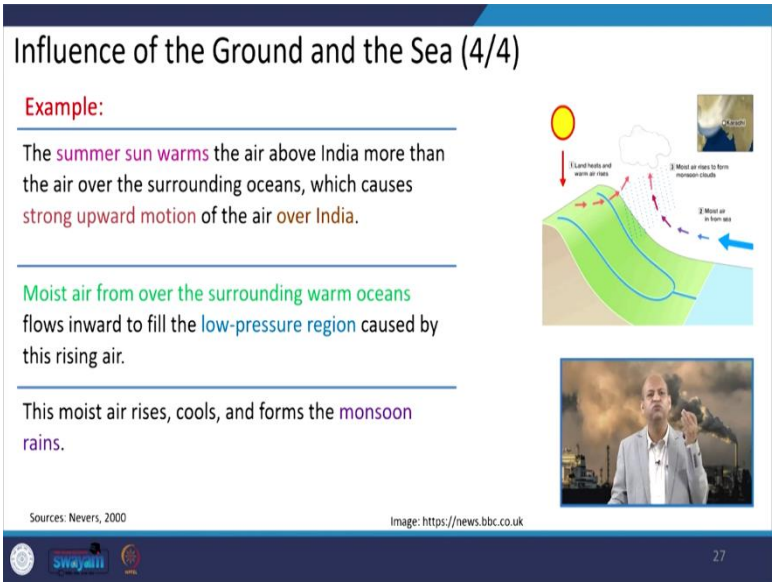

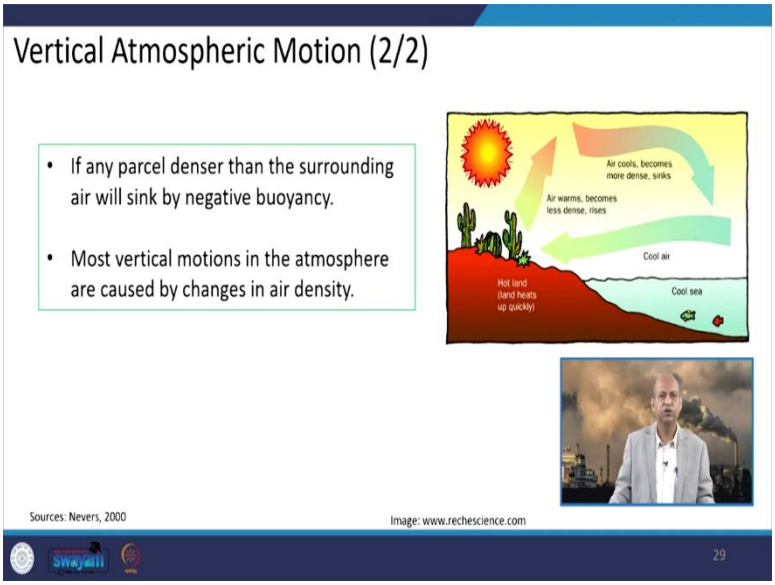

So, you can see this summer, sun warms the air above the India more than the air over the surrounding oceans, and which causes the strong upward motion of the air over Indian subcontinent. And the moisture which moves from this oceans towards the land masses of Indian subcontinent in the low pressure regions, so this air rises and that moist air comes towards these surfaces and it forms the monsoon rains.

So, this is a big pattern through thousands of years this kind of system has got developed in this particular area.

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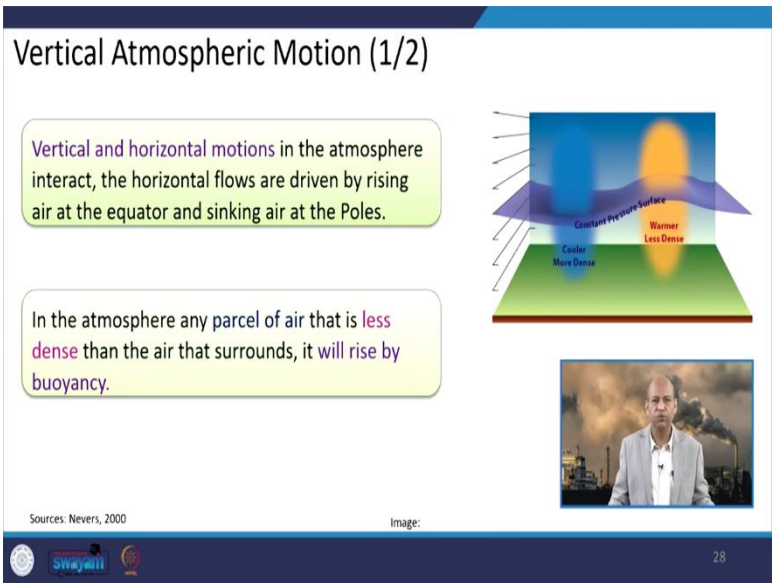

Well vertical atmospheric motion is also important. And both, of course, horizontal and vertical motions are important, but vertical motion has its own like mixing air into vertical

direction. And, in atmosphere any parcel of here that is less dense then the air of the surrounding it will rise because of buoyancy because of buoyancy and less density. So, it is lighter it goes up, and in the cooler regions it comes down. If any parcel, which is denser than the surrounding air it will sink, negative buoyancy you can call it, and the most vertical motions in atmosphere are caused by change in air density.

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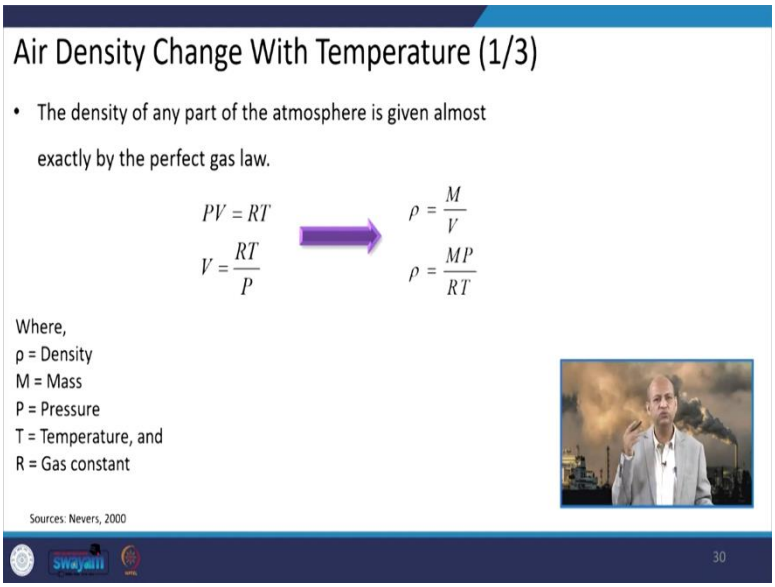

Now, you can see here the temperature and the density are inversely proportional as you know, so, the, when temperature is more, so density is less, and the lighter air goes up and denser air comes down.

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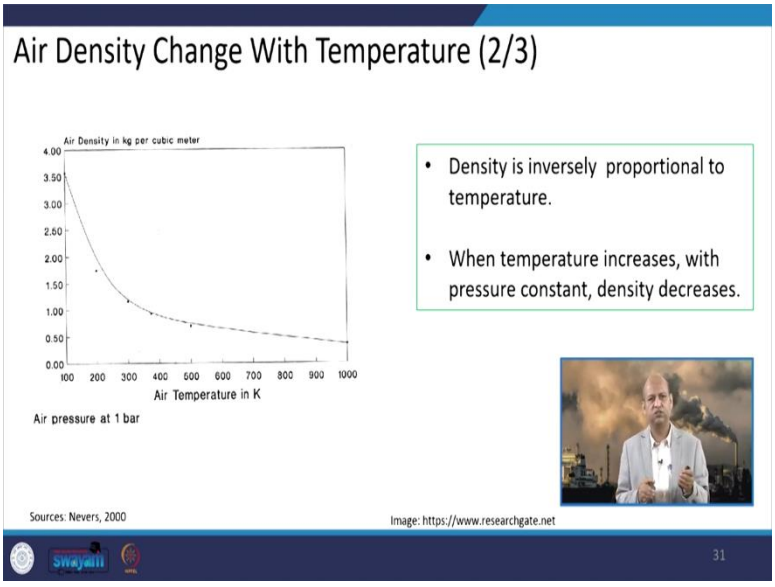

So, here you can see the temperature and the air density, this affects. Like density is inversely proportional to the temperature, temperature increases density goes down. But in pressure it is different thing.

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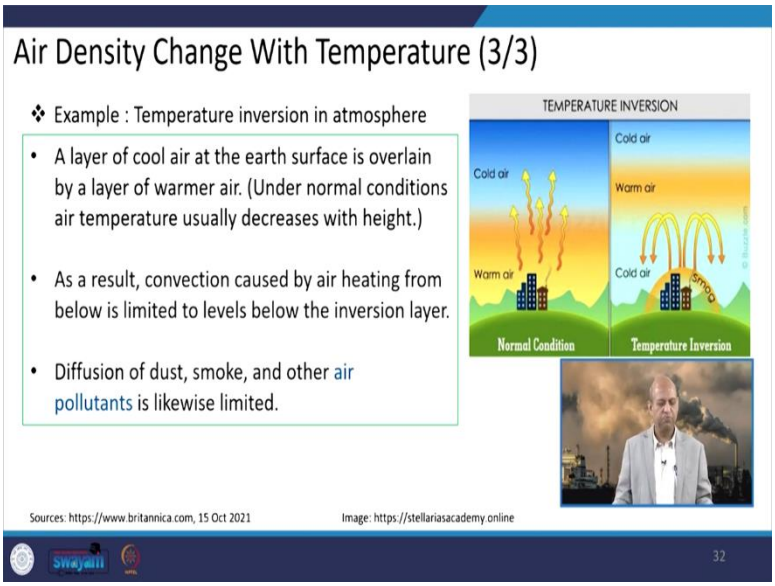

So, with temperature air density changes, and you can see this layer of cool layer at the earth surface this encompasses the layer of warmer air under the normal conditions, and air temperature usually decreases with the height, that is the normal way. Like your warm air cold air upper, so the temperature decreases as we go up. But in certain cases, this may be like this warm air is upper, in the upper regions, because of this suppression of molecules and collision and those kinds of things and cold air maybe at the lower regions. So, as a result this convection caused by air heating from the below is limited levels below the inversion layer.

So, inversion occurs means temperature rather than decreasing temperature increases with the height. And that is very dangerous phenomena when we talk about vertical movement or vertical dispersion of air pollutants. We will see in detail later on, but this is the concept of inversion basically.

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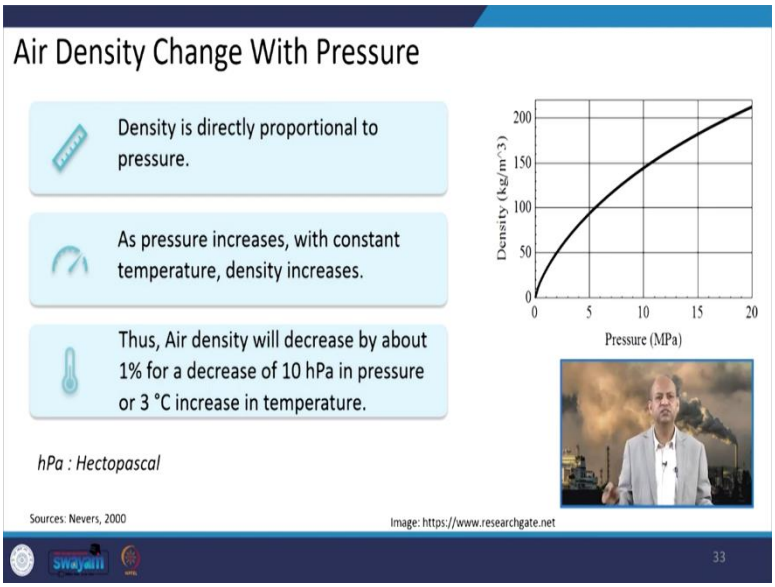

So, you can see here it is given that the air density will decrease by about 1% for a decrease of around 10 hectopascal pressure or 3 °C increase in the temperature. So, those kinds of things happen in atmosphere.

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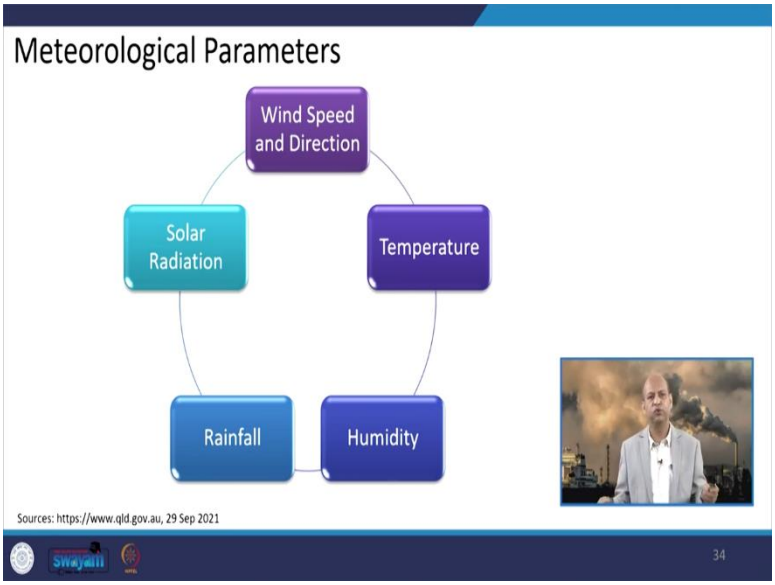

So, in nutshell we can say that meteorological parameters which are very important from air pollution point of view, like wind speed and direction, because it will take the pollution further in the downward direction, then the temperature or the humidity and the rainfall and solar radiation. All these important parameters are there, which will influence the air pollution dispersion and buildup of the pollution at certain locations.

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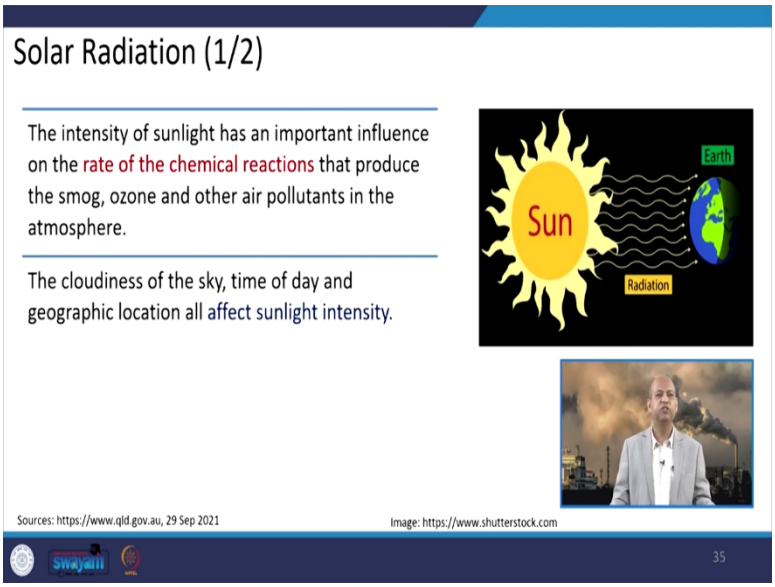

So, when we talk about these parameters individually, like solar radiation, so, the intensity of the sunlight has an important influence on the rate of chemical reactions, as we have seen earlier also, like photochemical reactions occur in the presence of sunlight. And smoke formation, maybe their ozone formation maybe there.

And the cloudiness of the sky and time of the day and geographical location, all these affects the sunlight intensity. So, accordingly the pollution buildup or the nature of pollutants may also differ from place to place.

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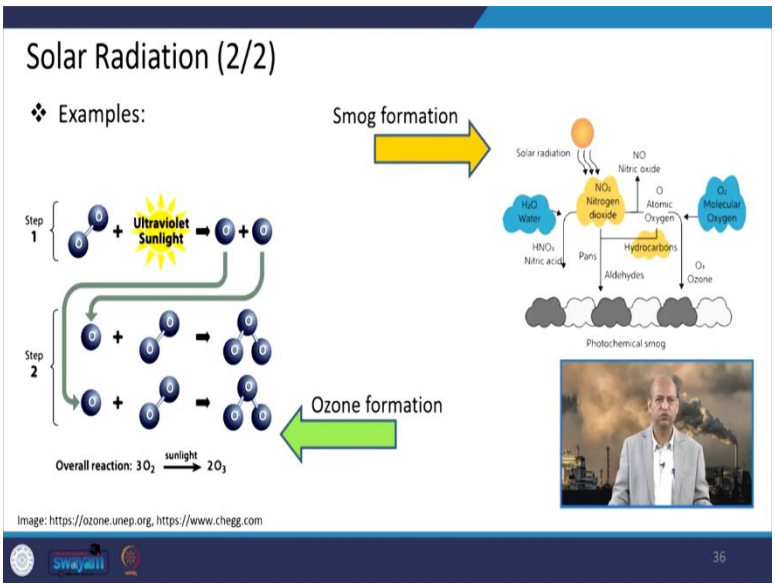

And you can see the smoke formation which we have earlier also seen how does this happen like ozone formation and other pollutants built-up can be there.

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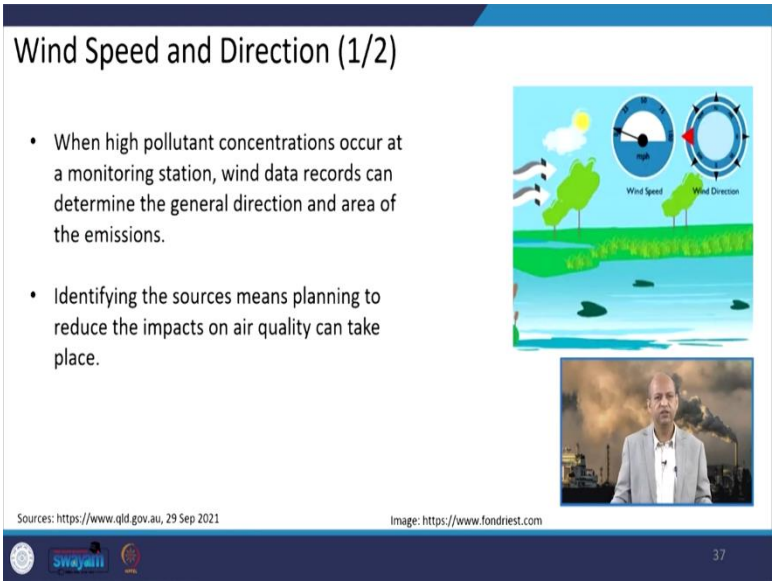

When we talk about wind speed and direction, then the high pollutant concentrations occur at the at those places where wind is calm and those kinds of things. So, sources and other things can be and the dispersion of the pollutants can be related to the, these wind the speed and the direction.

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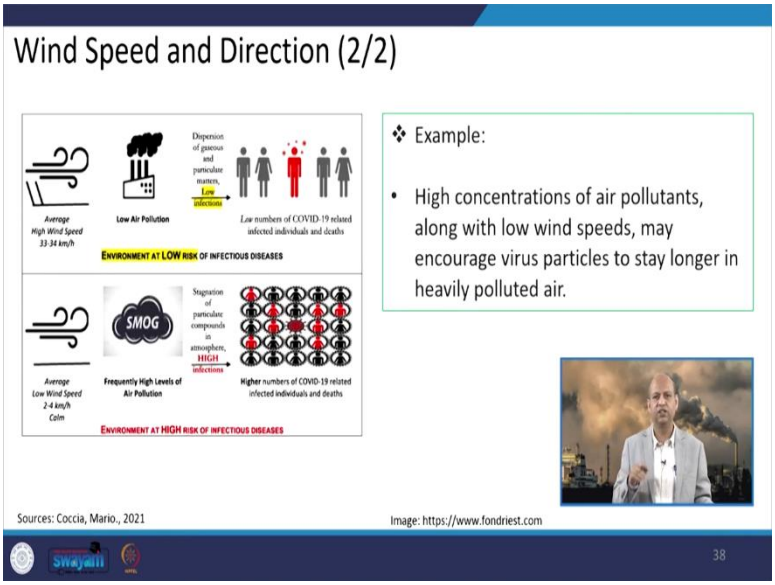

And you might have known about that when we talk about wind rose diagram, which gives the direction of the wind and the fluctuations or frequency of the velocity of the wind, all

those things are there which influences the dispersion of pollutants in a particular direction. So, in recent studies also say that like dispersion of particles, which can carry some like bacteria or virus, so, that also depends upon the wind velocity, wind direction, all those things.

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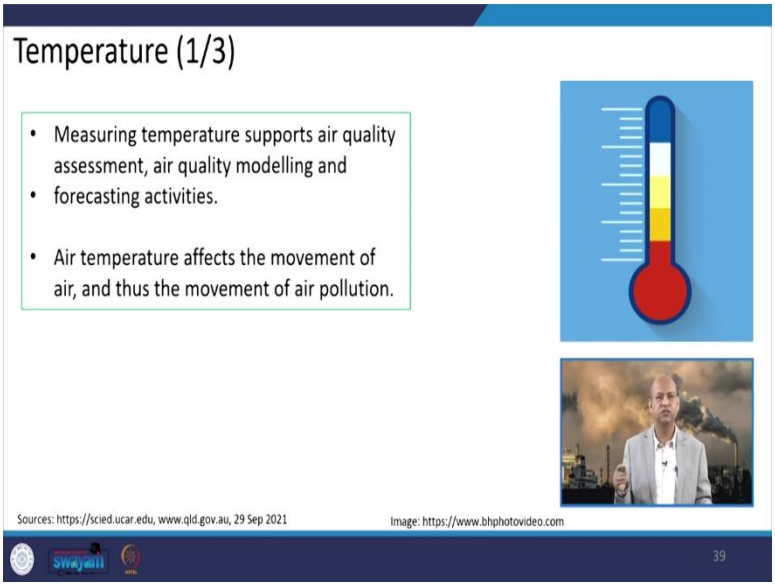

Well, temperature is also very important, as we have seen, because the temperature influences the dispersion because of differential heating patterns. And then the air quality assessment, air quality modeling, forecasting all these are done with the help of moisture as well as temperature. Those kinds of things are there as a part of modeling input parameters.

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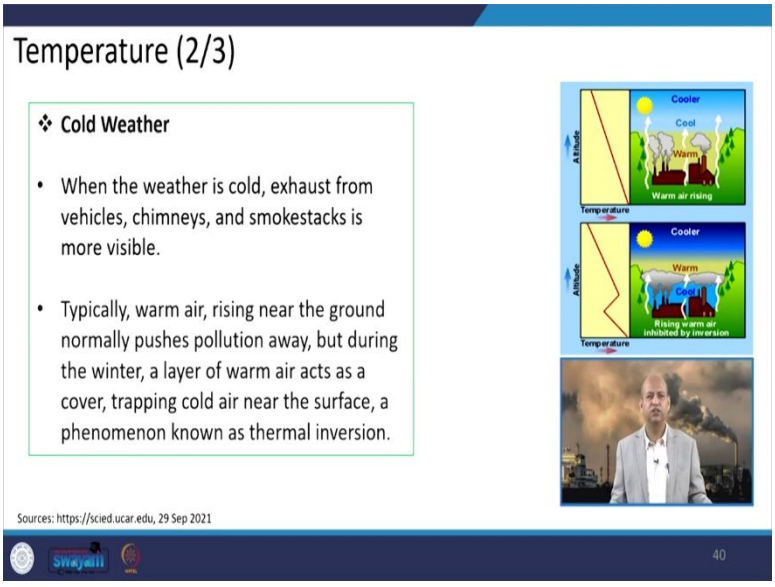

Well in the cold weather, when the weather is having the cold atmosphere and the exhaust of vehicles are more than dispersion may be very less. And warm air rising near the ground, it takes pollutants away, so dispersion happens with the temperature. These kind of temperature, things we will see like this is the inversion where a lot of buildup of pollutants will be there. And in this case dispersion of pollutants may be very simple and it can go upward direction.

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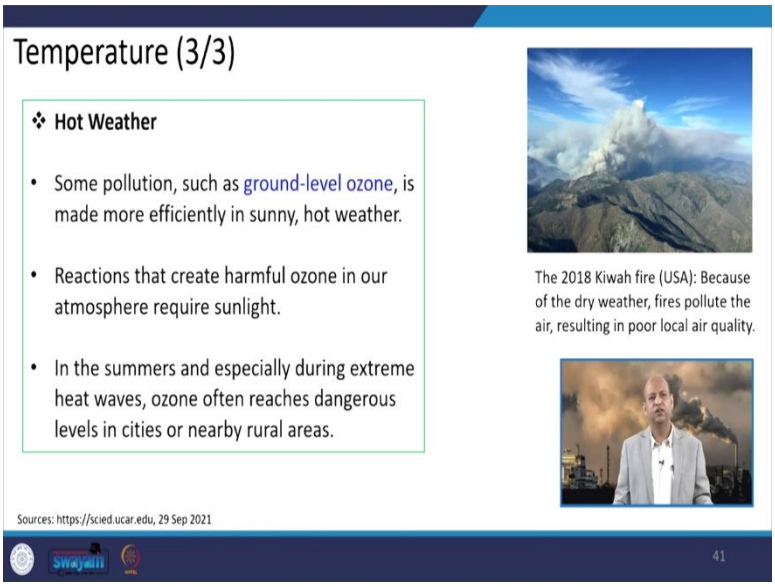

In hot weather, well, some pollution such as ground level ozone, it is made up more efficiently as sunny and hot weather and reactions that create harmful ozone in our atmosphere requires sunlight as you know. So, in the summers and especially during extreme heat waves ozone often reaches dangerous levels in cities and nearby rural areas. So, that is again the effect of the temperature and heat flux.

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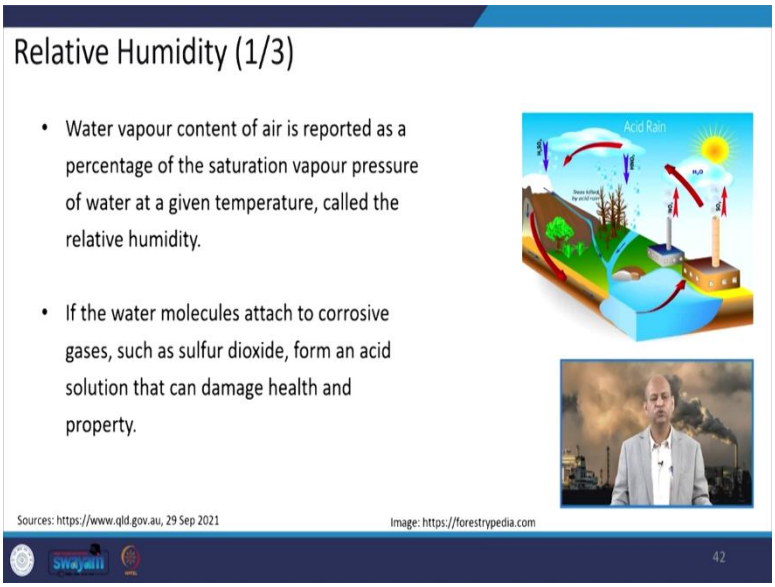

Relative humidity is also very important because it will decide how much moisture is available in the atmosphere and that can react with the SOx or NOx and then the acid rain related phenomena may occur.

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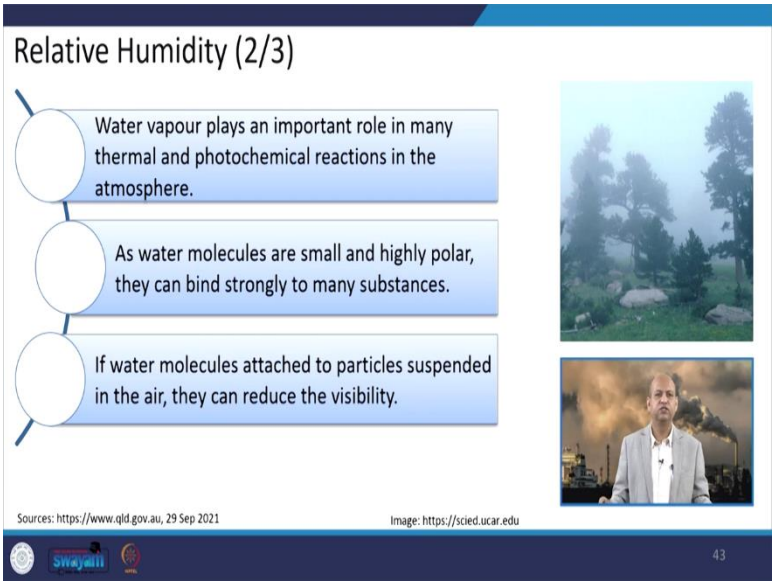

So, the water vapor plays important role in many thermal and photochemical reactions in the atmosphere. And as water molecules are small and highly polar they can really bind strongly to many substances. So, that is why this pollution level is affected by these. And the water molecules are attached with the particles, suspended in the air, and they can also reduce the visibility because of the scattering of the light.

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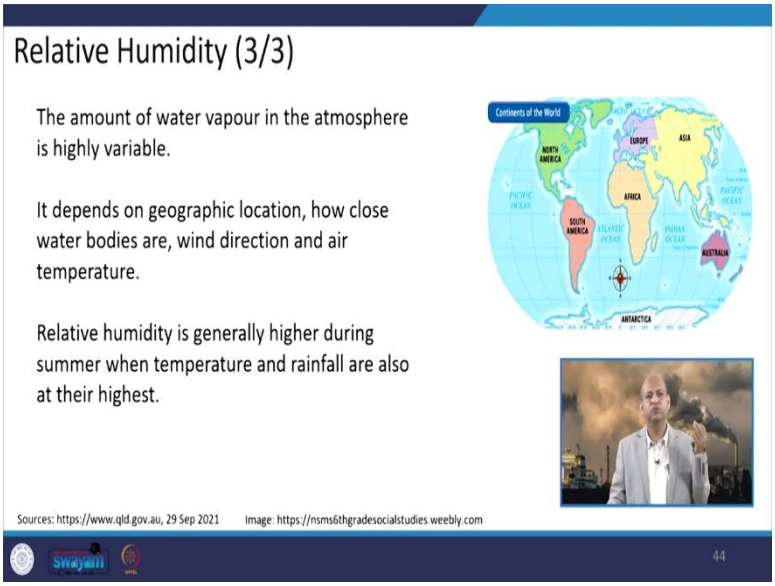

Well, the amount of water vapor in the atmosphere is highly variable depending upon the location and the solar radiation. So, it depends upon what is the geographical location and how close it is near to the water bodies. What is the wind direction? Intensity of the wind speed and the temperature of the air. So, the relative humidity generally higher during summer when temperature is more so, warmer air can hold more water basically, and rainfall or all at their highest in that particular season.

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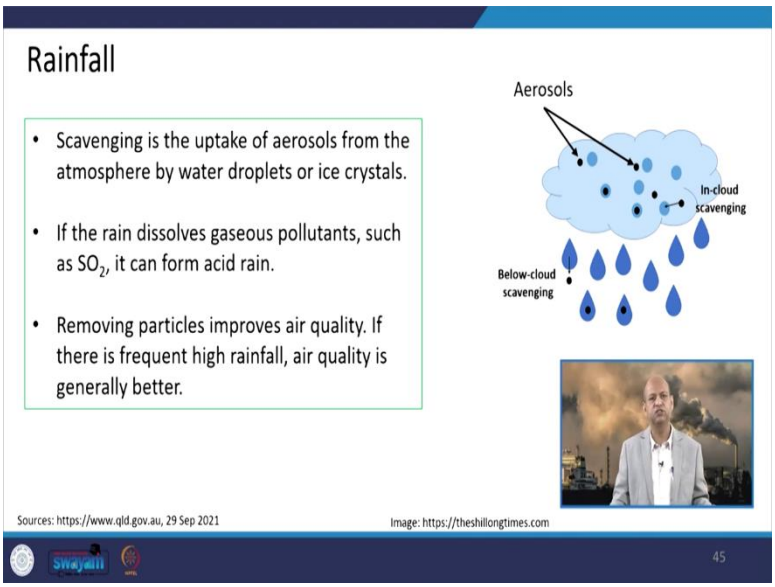

Well, it also helps like rainfall is really helping in where deposition or with the precipitation. The aerosols comes down even gaseous pollutants also comes down in the form of acid rain

and so. So, the removing of particles improve air quality, it cleans the atmosphere, so that way there it is the positive role of the rainfall.

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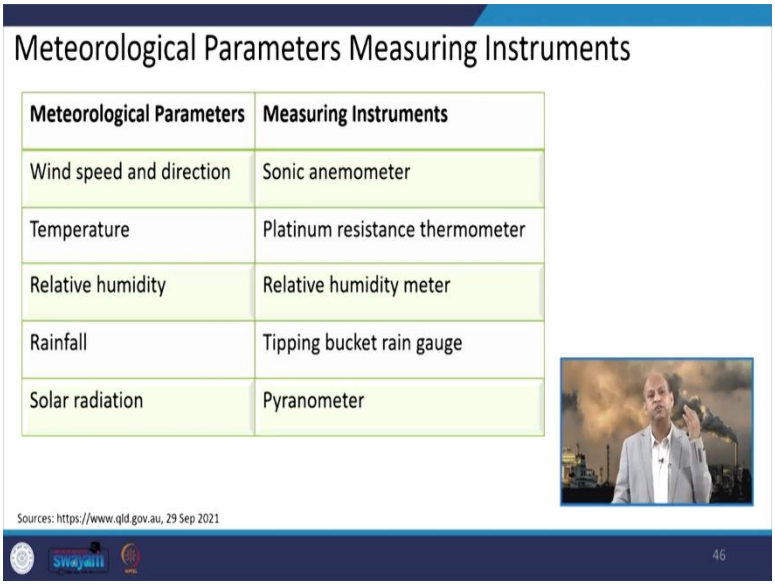

Well, when we talk about studying the meteorological parameter, so need to measure them. When we want to use them in the models etc, so we need to have their values. So, their values comes from the measurements, and the measurements are done by some particular instrument.

So, this particular table gives a list of these measuring instruments which are used for measurements of different metallurgical parameters like wind speed and direction the sonic anemometer is used temperature this platinum resistance thermometer. Relative humidity relative humidity meter is there, so that way rainfall, solar radiation are measured by different instruments.

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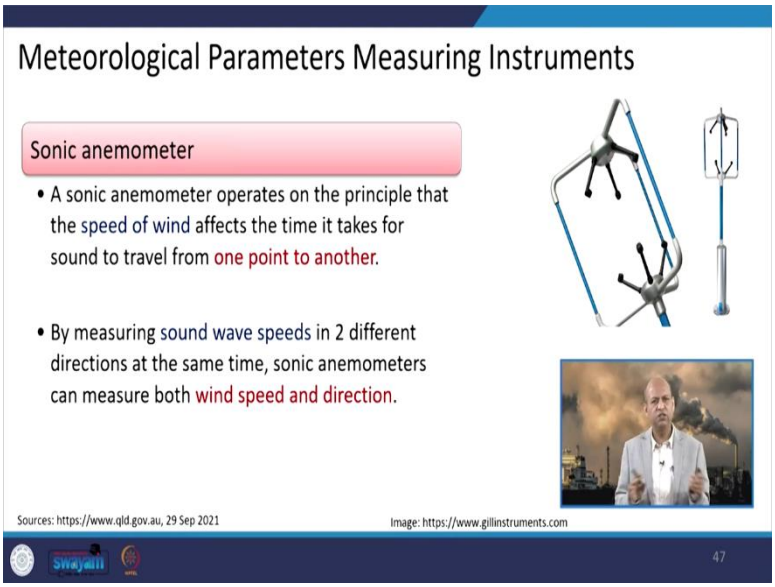

So, you can see these different instruments details here and very simple details are given. You can go through later on about these instruments a lot of information are available. So, the sonic anemometer basically operates on the principle that the speed of wind affects the time it takes for the sound to travel from one point to another so that is why it names also like that.

And by measuring the sound wave which speeds in two different directions at the same time, so the sonic anemometer can measure both wind speed and the direction. So, that we there are the usage of this particular instrument for wind direction and wind speed measurements.

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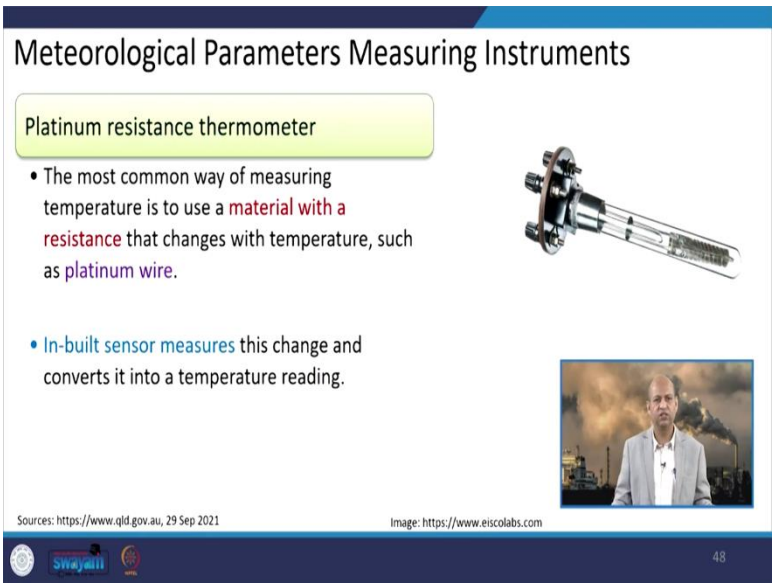

This is this platinum resistant thermometer, which is used for measurement of the temperature. So, you can see like this metal with the resistance that changes with the temperature and that is the basic principle behind this, and inbuilt sensor measures these chains and converts it into temperature readings. So, those kinds of things are there.

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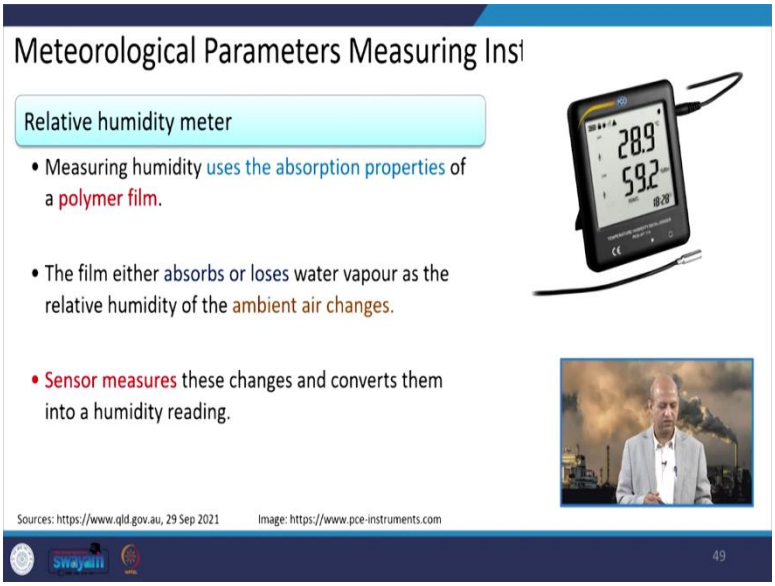

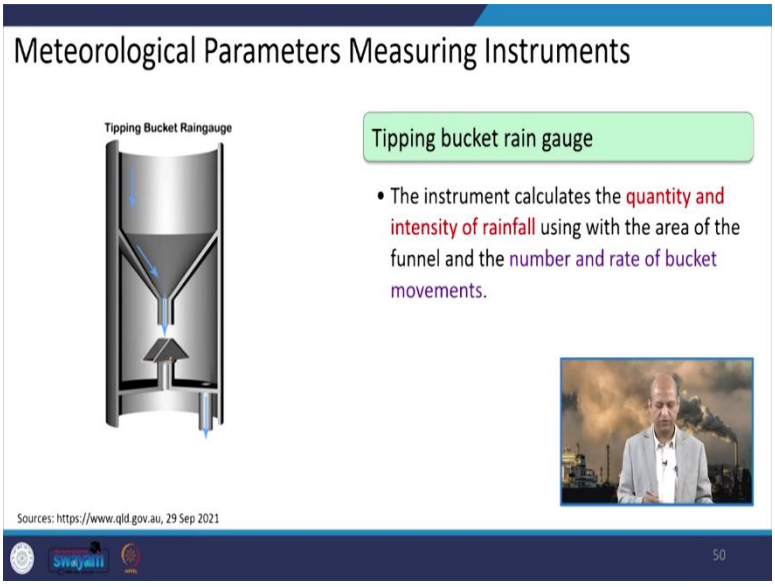

Similarly, you can see these instruments which are measuring like relative humidity and then this for the rainfall intensity you can see, very simple instrument is there. So, in funnel this is stored and then the rate of bucket movements all those play role in measurements of this particular entity of rainfall.

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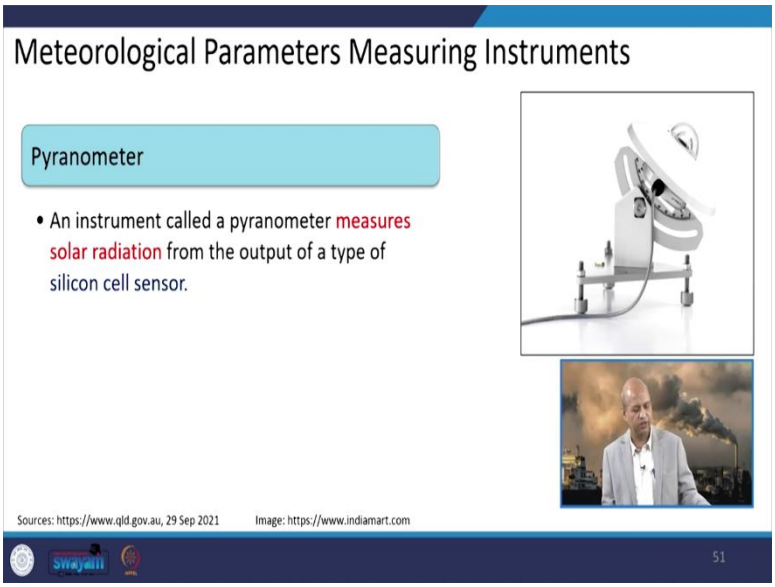

So, this is for measuring of the solar radiation. So, you can see all these instruments are important in that sense.

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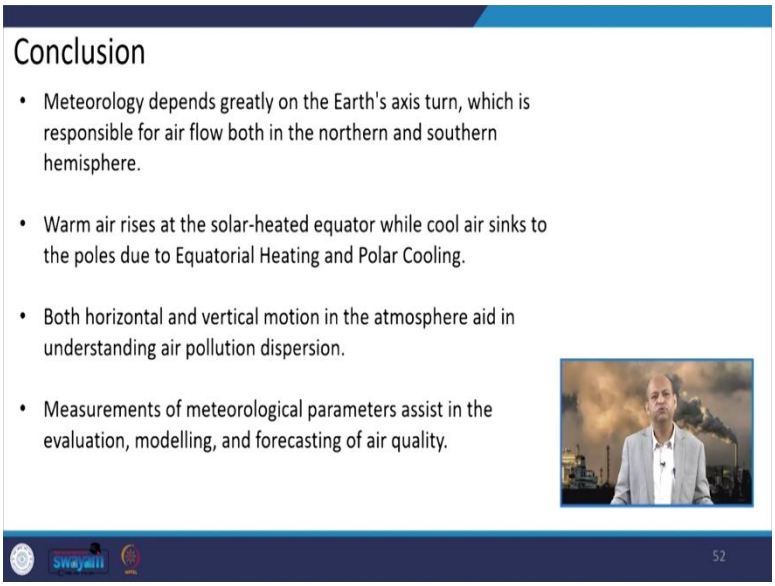

Well, so in conclusion we can say, that the meteorology plays very important role and it influences this because of earth surface and the axis turn which is responsible for both the northern and southern hemisphere, the patterns of the wind and temperature differences. Warm air rises at the solar heated equator with cool air sinks at the poles due to this equatorial heating and polar cooling, but there are different cells as we have seen where it is.

And one important thing is there, like at 30 degree latitude where this Headley cells are going down warm air is basically without much moisture, and that is why you will find that the around the earth globe at 30 degree latitude the deserts are there, because there is no rain. So that is also very important we should remember.

Then this both horizontal and vertical motion in the atmosphere it aids in understanding air pollution dispersion. And the measurements of meteorological parameters they really play a role for evaluation and modeling and forecasting of air quality. So, these are very introductory thing in that sense. Later on, we will see these things how they are utilized in modeling efforts and understanding various phenomena of air pollution.

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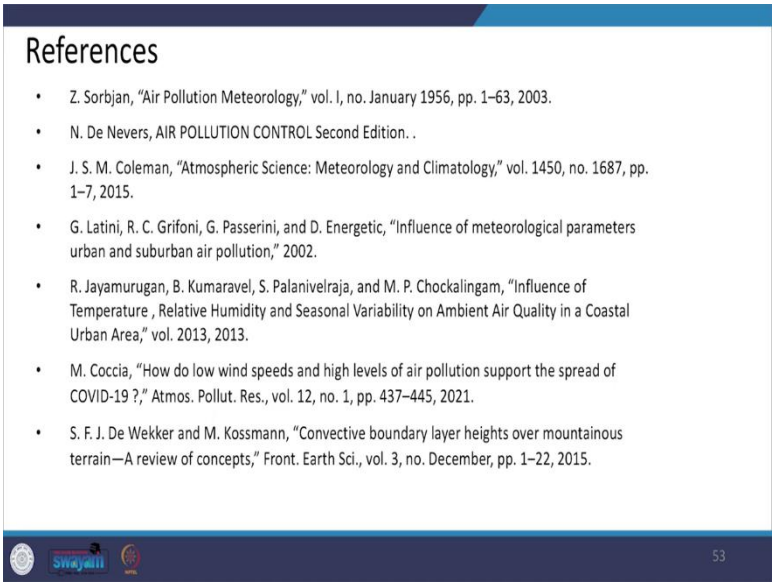

So, this is all for today. Thank you very much for your kind attention. This is the reference list for additional. So see you again, in the next lecture. Thanks again.