Introduction to Atmospheric Science
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Lecture - 21
Lifting Condensation Level Contd…

Okay, good morning. So in the first part of today's class we will just look at this Skew-T ln P chart in little bit of detail and how the individual lines have come out and come up and so on. So I will run through this presentation for the first 5, 10 minutes so that you understand the various curves and various lines on this okay. So the coordinate system for this Skew-T ln P is like this.

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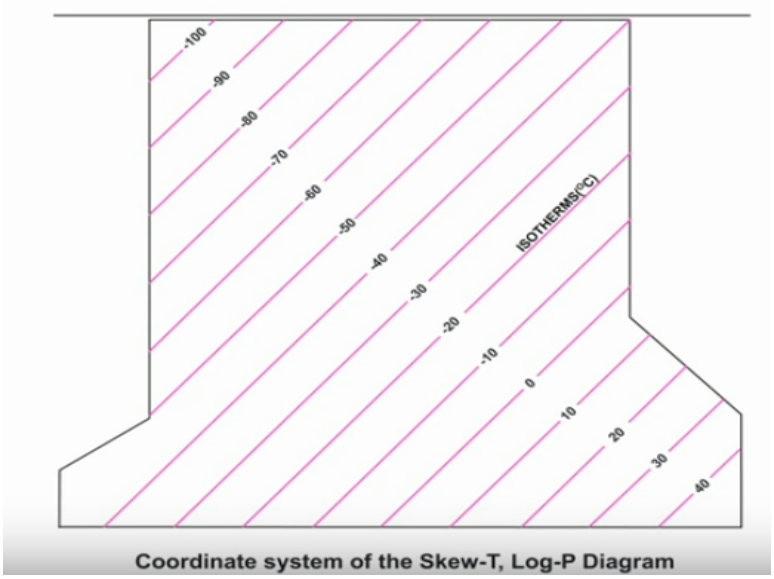

Coordinate system of the Skew-T, Log-P Diagram

The first is basically so it is rectangular and slightly there is, it is trapezoidal so to speak. So you can see that the magenta lines of the isotherms, the isotherms are skewed by about 45 degrees. So Skew-T ln P chart now the first part is Skew-T so you are able you are seeing the skewed temperature lines. So the temperature is increasing from left to right. So it is varying from - 100 degrees to + 40 degrees.

So maybe for Chennai and other places it should be 50 also. Maybe Europeans developed this okay. That is why you are Americans so alright. So the lines are like this and this is the first part of the Skew-T ln P chart and the lines are having a decadal variation, not decadal order of 10

okay 10. So you are not getting resolution of 5 then the lines will be very crowded. So you are having resolution of 10 - 100, - 90, - 80 and so on okay.

So this is the isotherm. Whenever you are tracing isothermal process you will follow, they will follow this an isothermal process or it will follow this line okay. Is it clear. Next.

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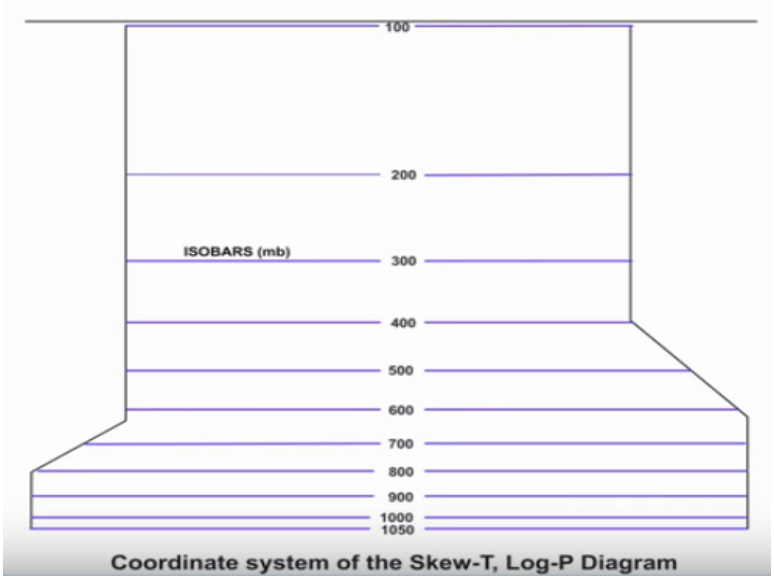

Coordinate system of the Skew-T, Log-P Diagram

Pressure basically is horizontal. So that makes it a Skew-T ln P chart and the pressure the scale is normally near. It is ln.

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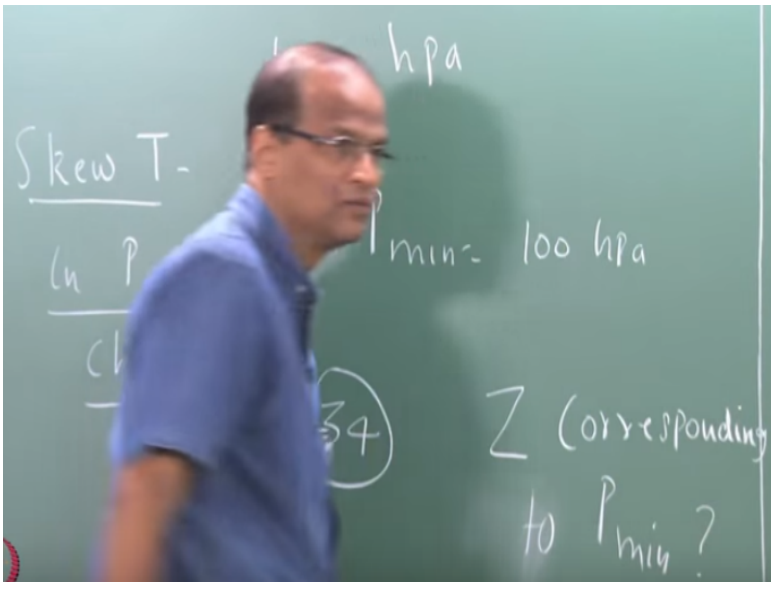

So it goes from 1050 hPa, sometimes it can be more than 1014 hPa also and we are able to reach. Problem number 34. Determine the height corresponding to the minimum pressure in this Skew-T ln P chart. Let us take about 2 minutes. T not, you can take it as 1013 right or 1014 what do we usually use 1014. What is the Z? What is the height corresponding to the P min got it?

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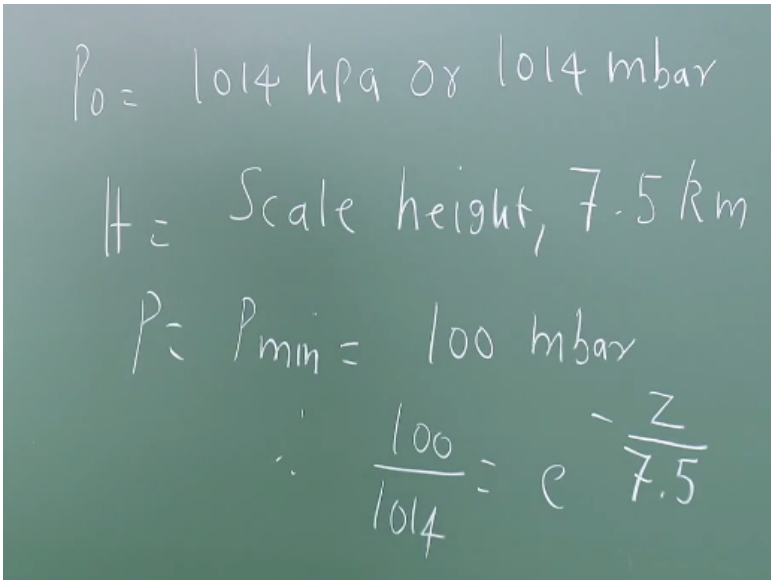

Hpa is the same as millibar or correct right okay. So P not is.

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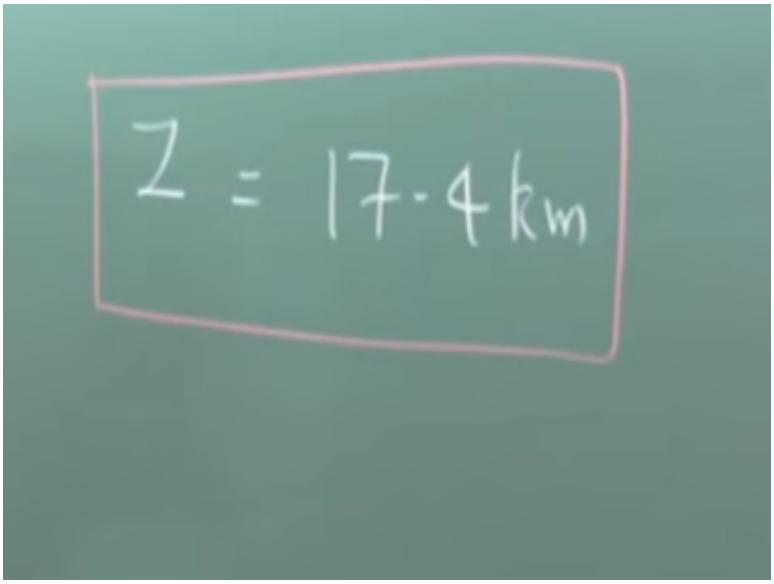

Z = 17.4 km. So it covers the whole of the troposphere and even there is big cumulonimbus there is a big thunder, there is a big storm so maximum 17, 18 km we will be able to handle all that with this chart. If some event is there some weather event is there beyond 18 or 19 km then we

cannot use it. For most of the other applications up to 17 km so you must know that the height so this height corresponds to 17 km in the atmosphere.

If you take an air parcel you can it take all the way up to 17 bring it down and do whatever you want with it. It will resaturation, it will unsaturate, it will condense okay. You can trace all the processes on this alright. So this is the isobar.

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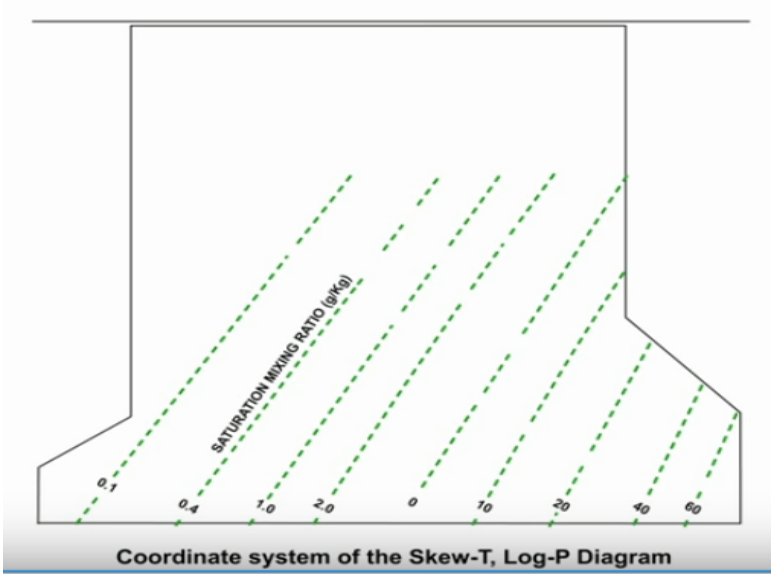

Coordinate system of the Skew-T, Log-P Diagram

The third is the saturation mixing ratio which is omega s okay. The saturation mixing ratio is an important quantity which is used for getting both the first the dew point as well as the LCL okay. The saturation mixing ratio is given in terms of g/kg. The saturation mixing ratio is in g/kg. It is sloping from left to right, is it correct? Right to left, it is sloping from right to left, it is sloping from right to left and the values are we are starting from 0.1 0.4, 1, 2 0, 10 and up to 60 g/kg.

That is too much okay. 60 g/kg is too much. So this is the range 0.1 to 60. So these are the, this is the third line. The first is isotherm, second is isobar, the third is the isosaturation mixing ratio lines. The isoomega s lines. The isoomega s lines are indicated in dashed green colour in this fine okay. How do we get the dew point for a particular case? Can I write on this, no.

So with the first 2 coordinates you can get the temperature and pressure at a particular point. Then you go all the way at 1000 this thing and find the point corresponding to omega is equal to

omega s where omega is a mixing ratio which is already specified. In the previous problem it was 10 g/kg okay. **"Professor - student conversation starts"** This 0.1, 0.4, 1, 2, 0 and 10. No there may be a typo here. It may be 5 okay. If it was redrawn, so it may be just 5 or something okay just **"Professor - student conversation ends".** So you can go all the way at 1000 millibar and you can get your dew point okay and the corresponding temperature will be the T d dew point okay.

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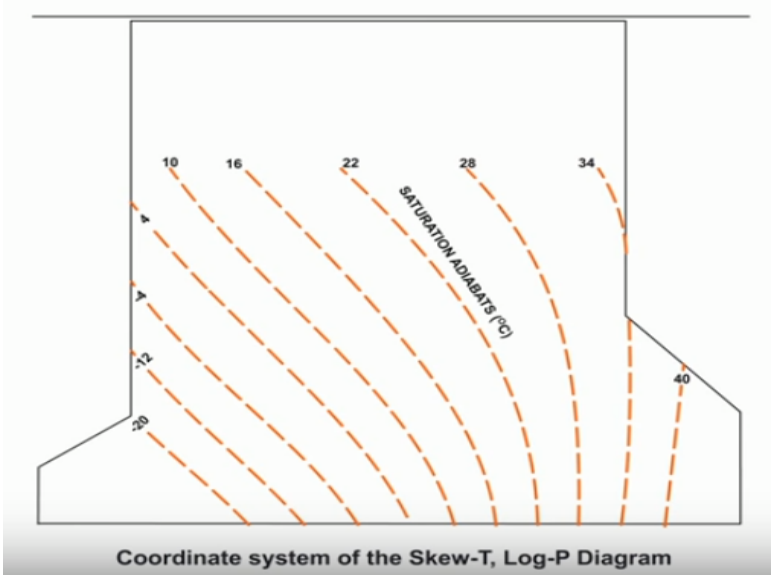

Coordinate system of the Skew-T, Log-P Diagram

The saturation adiabats are something which we have not seen so far. The saturation adiabat is the adiabatic process which is undergone very saturated air parcel. That saturated air parcel we have not discussed so far but it is curved like this so it has also the saturation adiabat is basically given like this it is and it has got it is an adiabat therefore it is also some kind of a constant temperature line correct. It is a right it is an adiabatic line. So it varies from - 20 to 40 okay to + 40. It is given by orange colour in this.

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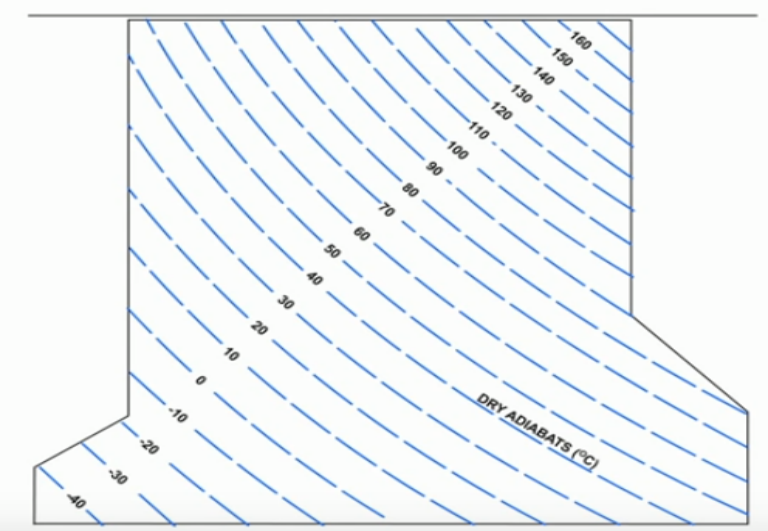

Coordinate system of the Skew-T, Log-P Diagram

The dry adiabats are lines of constant theta where theta is the potential temperature. What is potential temperature? Theta equal to T into P not by P to the power of 0.286. If it is compressed or expanded adiabatically up to 1014 millibar what will be the corresponding temperature okay. We proved it using elaborate arguments P v to the power of gamma is constant and definition and then take the first law of thermodynamics said dq equal to 0 all that we did and then we got that expression.

So you can solve problems involving potential temperature with the equation. You can also solve problems involving potential temperature with the chart. We actually did both and we found some small difference in one of the earlier problems. I do not know whether it is 25, 26, 27 one of those problem. So the saturation, the dry adiabats are going from - 40 to 160. So they are okay it is increasing from left to right on this in this presentation they are indicated by blue dashed lines.

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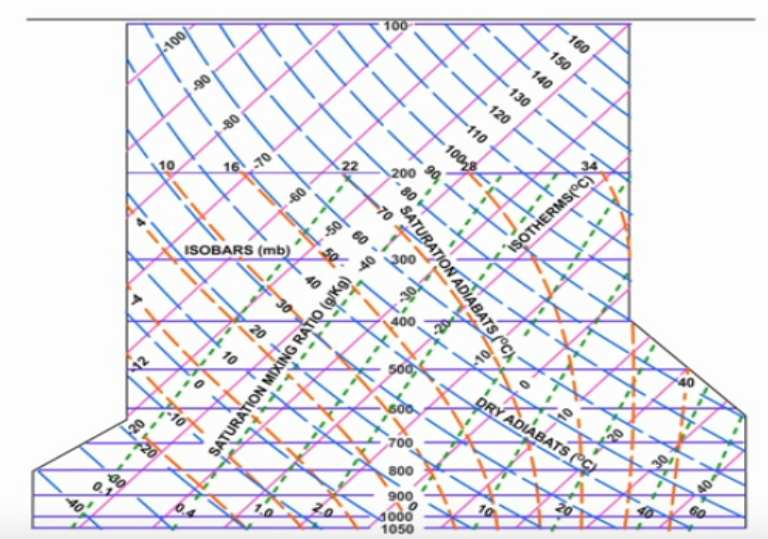

Coordinate system of the Skew-T, Log-P Diagram

Now, this is the Skew-T ln P chart. It is nice right. Somebody from our nptel office did it. So now it is quite nice. Now everything is combined. So you can see that it is got lot of use. It is very nice, very pleasant, where pleasant colours you can see all the lines. Isotherm, isobar, dry adiabat, saturation adiabat, saturation mixing ratio. Out of these 5 lines isotherm, isobar, dry adiabat, saturation mixing ratio we already studied so far okay.

Now, where is the other one? How do we do from here? Okay so I will minimize. Oh this mouse where is that now. Option 2 this is? Okay. So, let us quickly run through this. This is another way of presenting the same thing where we dynamically complicate it. What do you mean by that? Let us see.

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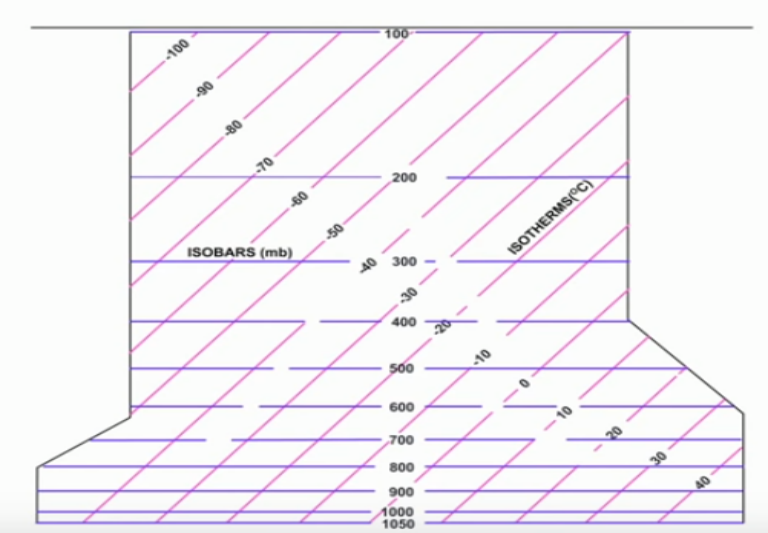

Coordinate system of the Skew-T, Log-P Diagram

Isotherm, isobar okay. So this is basic stuff. You can look at any point on this if you know the temperature and pressure okay. If you have the saturation mixing ratio and either temperature or pressure is fixed. So 2 of the 3 quantities. See only one this to look at moisture only one of the moisture parameter is required, LCL or this thing and so on right saturation mixing ratio. Saturation adiabat. That's good right. Okay.

So it is worth looking at this and for the people who are going to study this course remotely it will be helpful alright fine. Now, show time is over. Now we have to get back. Let it be like this. So we discussing the LCL right. The LCL is the lifting condensation level. The level to which an air parcel can be lifted adiabatically till it reaches saturation okay. So we also saw how to determine the LCL okay. So these are the things right.

So you can see matha vaishnavodevi sign, weather forecast for chartham people who are doing that Uttarakhand right. So what is the forecast, India weather all this, weather services, observation. So if you go to observation okay right now right now we can look at the satellite images okay. So the satellite images, so we have INSAT-3D as well as the Kalpana okay. So we look at the Kalpana this infrared images.

It is not 4:15 am it is 4:15 GMT or UTC it is called universal coordinated time at 5.30 hours that is 9:45. The time is at 9:45 this is the satellite picture.

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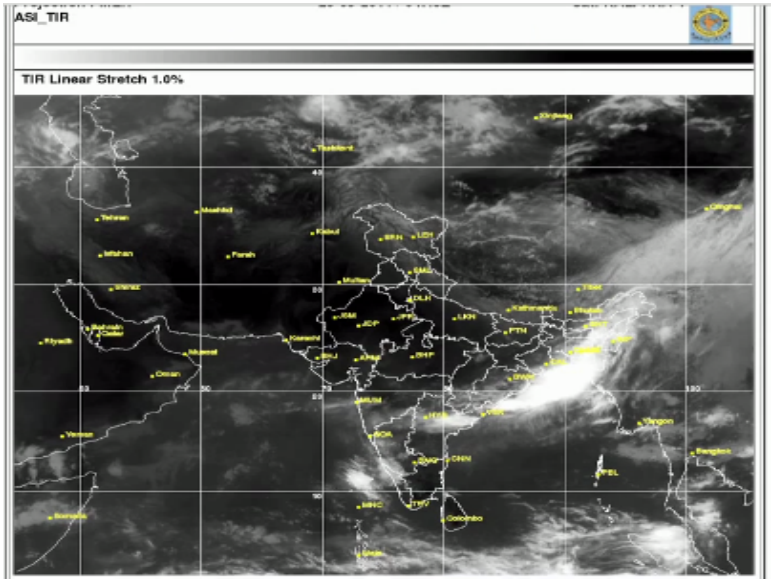

So except around Hyderabad and Vishakhapatnam it is not expected to rain anywhere now in India. This is the cloud cover. Okay now you can actually look at cloud top temperature.

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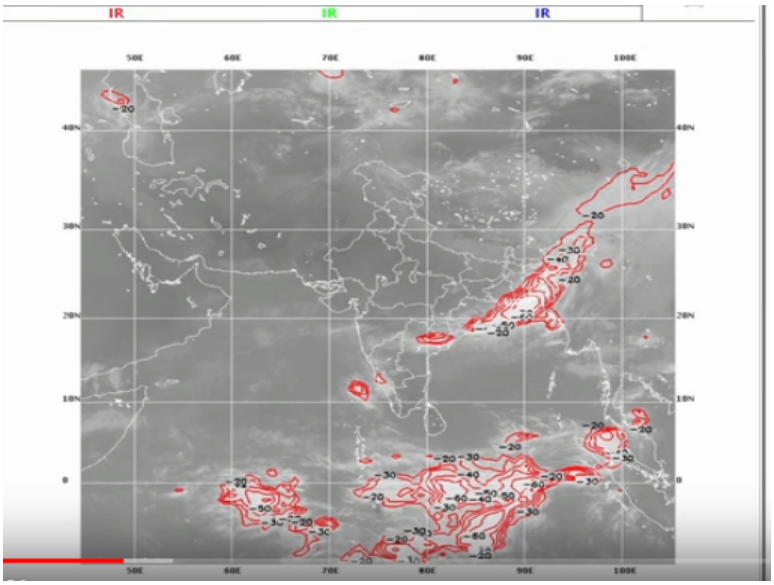

What is a cloud top temperature? That is basically e to the power of - z by h and all that. So the cloud top temperature is basically there is some activity in near Calcutta and of course this will be very active. This is the intertropical conversion, it is equatorial this thing. From that this place only the monsoon everything is coming alright. So when you have time you just go through the imd website. There is a lot of useful information and they also give quantitative precipitation estimates.

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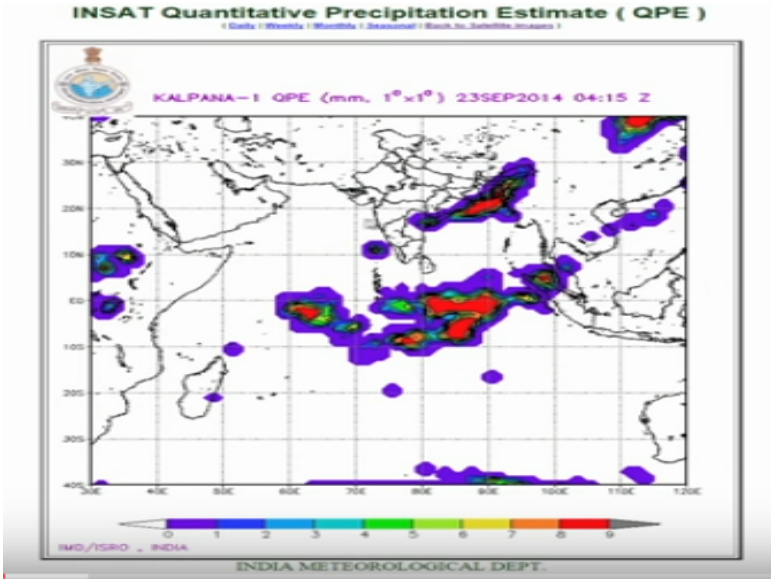

What is the likely precipitation. Now right now we are only the eastern belt. Not the Vizag and Orissa coast and the whole of Bombay, Kerala it is not raining now okay. So Singapore probably it is raining here correct. Kuala Lumpur and Indonesia all these places it is raining. So this is the quantitative precipitation estimate okay and the cloud motion vector gives the indication of the wind.

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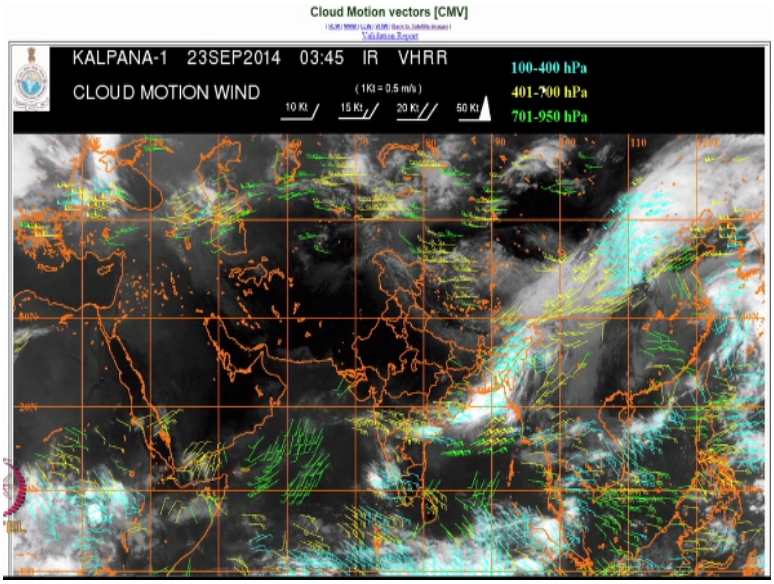

The strength of the winds now 10 knots, 15 knots, 20 knots, 50 knots you are able to see here and then it gives the winds at 3 levels 100 - 400 hPa, 401 - 700 hPa, 701 - 950. Not only for atmospheric scientist it is also required by pilots. What is the wind speed at various heights for

their cruise, for landing, takeoff many things they require this information. It is very critical for them okay. So you can see that monsoon is getting weak right.

Otherwise there will be full, winds are little weak right. So it is going to withdraw or already it is withdrawing we do not know. So you can see the whole of central India, north India the winds are not very strong. It is generally south-west. So it is coming from here okay. If you see October 15 onwards we have the retreating monsoon that is the Chennai monsoon, the north-east monsoon where the winds will start getting from here.

Once the winds start getting from here because of the Coriolis component the earth's this thing it will come close and then the rain clouds will come to Chennai, Andhra and all that and we will get rain. But because of the Coriolis component it is quite possible that some depressions and lows are formed and when they come very near suddenly they change their mind and turn eastwards. They may go to Orissa, Bangladesh, or that usually happens okay.

Now, why am I telling all this stories now we will go back to the home. There are also individual there are also if for example in the hostel you want to play football match in the evening, morning it is very cloudy what you do you go to the Doppler radar. The radar is an acting instrument which sends a signal and if it is reflected that means rain is there. If it is if there is 0 reflection then it just goes into thin air okay. Now let us choose in Chennai for example.

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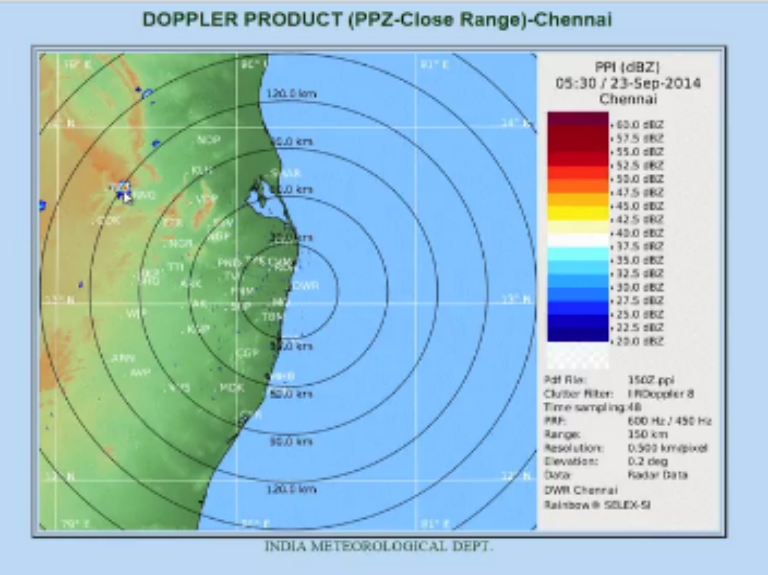

In the Chennai radar the maximum reflectivity now. This is at 5:30 in the morning that means plus 5 and half, 11 o'clock, it is very, there is absolutely no today you can do whatever you want in Chennai. It would not any activity rains will not disturb. So the if you look at it at close range there is a small rain band near Renigunta, that is in Tirupathi. Otherwise it is clean. But we do not know it may change in 3 hours because you have to read this in conjunction with the satellite map because the clouds will bring the rain.

Right now you know next few hours. That is how why MCG and SCG are able to predict rain it will come at 2 o'clock in the afternoon because one radar is 10 crores. If you populate India with 50 or 100 radars then we can do much better. So look at the these are the only radars available in India; Agartala, Bhopal, Chennai, Delhi, Hyderabad, Jaipur, Kolkatta, Lucknow, Machilipatnam, Dibrugarh, Mumbai, Nagpur, Patiala, Patna, and Vishakapatnam.

In US every 50 to 100 km they have a radar. In Europe everywhere they have radar. Such a big country. So if this infrastructure improves then we can integrate this with numerical weather prediction models or we can do a time series of the Doppler radar pictures and predict or a time series of the cloudy imaginary. All these are waiting to be students like you must take interest, write a proposal you just do anytime forecasting based on satellite imaginary next 3 hours 6 hours that is called nowcasting.

Some of you can take it as a topic for the our presentation. Nowcasting is 0 to 6 hours the air force is interested in that. Civil aviation, your Jet Airways and Indigo will be interested okay about the weather alright. Now let us go back to home. No home we have to go back only in the evening. Home I am talking about the website. Now I want to go to departmental website. There are also departmental website, Ahmedabad, Bhubaneswar, Bengaluru, now we will go to Chennai.

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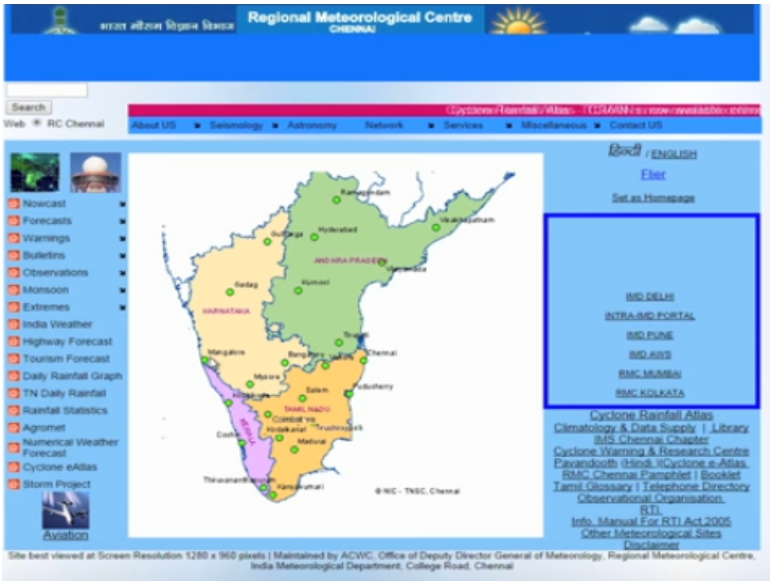

It is called RMC, Regional Meteorological Center, Chennai, RMC. It is in Nungambakkam. There are two observatories, in Nungambakkam and Meenambakkam. Meenambakkam is just opposite to the airport. Nungambakkam is in the heart of the city alright. Now observations. I go on to go to observations. Main cities, Chennai okay. Observations recorded at 8:30 am on 23rd September. Today is 23rd September, very good. Relative humidity is 79% okay.

Problem number 35. Did we determine the LCL at Chennai? We did not determine okay. Problem number 35. For the data given for Chennai at 8:30 am on 23rd September, determine the dew point and the LCL okay for Nungambakkam okay. Part b. Determine the approximate height corresponding to the LCL or determine the approximate height corresponding to the LCL.

So some of you may be worried why sir is saying LCL is in millibar. So we always know through the hydrostatic equation this millibar can be converted to what is that height very good. So take about 5 to 7 take about 7 to 10 minutes. Calculate this. I will solve it. Then we will okay.

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CHENNAI WEATHER		
PARAMETER	**NUNGAMBAKKAM**	**MEENAMBAKKAM**
Maximum Temperature (ºC)	33.8	33.8
Departure from normal	-0.1	-0.3
Minimum temperature (ºC)	27.0	25.6
Departure from normal	1.4	0.2
Relative Humidity	79	75
Rainfall upto 0830 hrs IST of date	0.0	tr

Okay I will tell you. Temperature is 33.8, pressure you can take 1014, RH 79. If there is a volunteer you can try on the tablet and solve the problem. You will see how prof is struggling with the tablet. Problem number 35.

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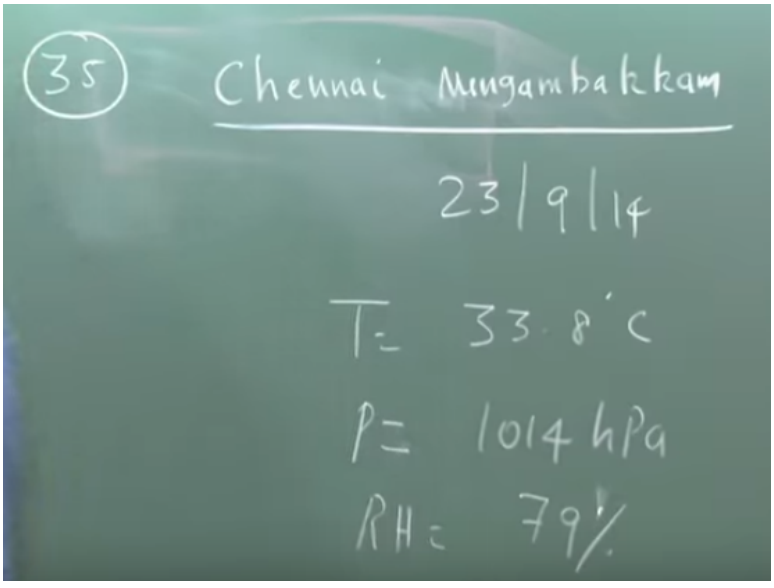

So this may be yesterday evening's data right. The maximum it has not reached, 8:30 means it has not reached 33.8. So some 24 hour period do not worry okay. Corresponding to the, but the

thing is that 33.8 and 79 may not match. There will be some time lag is it not?. Do not worry about that. Let us not do too much research okay. How do we start? You can get omega s straightaway right because at so T and P are known. Okay wait. So we will first solve on the blackboard and then I will go to the chart okay.

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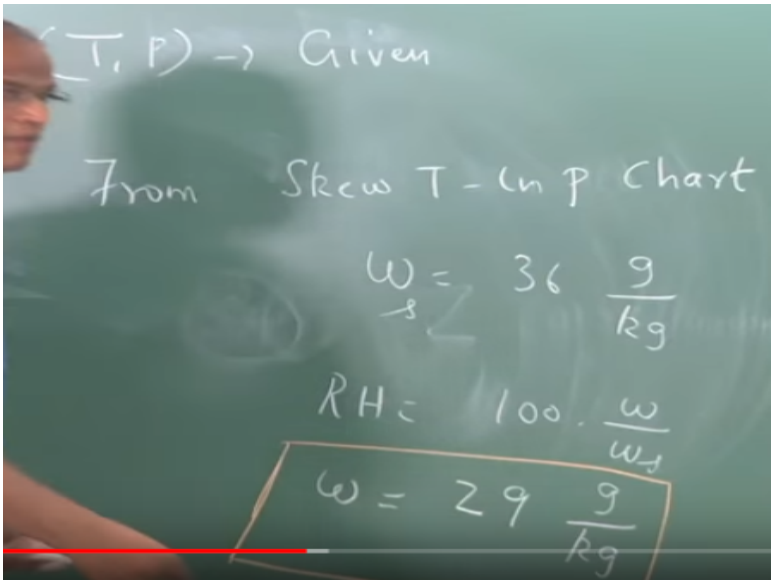

So please try to solve yourself because this will make or break your quiz 2 performance. Quiz 2 performance will depend on your skill to use the Skew-T ln P chart. I can ask many problems as you will see the next few classes we will go deeper and deeper using this Skew-T ln P chart we can do many things okay. From this Skew-T ln P chart omega is omega s no, 36? Omega is okay. Fine. What next?

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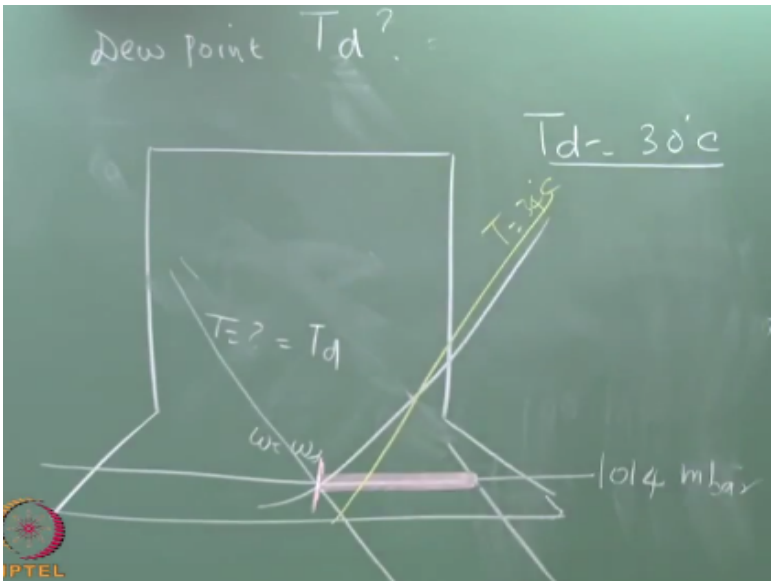

Here omega equal to omega s right. These lines are curved? Like this? Okay correct? So go back to my go back to our recommendation. Temperature dew point more than 22 degrees is uncomfortable, more than 25 degrees is sticky. Yesterday was very stick is it not, yesterday and today. That will be the typical September, October weather in Chennai. It is getting saturated. Temperature is lower but humidity is very high.

So it is very uncomfortable is it not and that it will not go from your body, it will stick. That makes you very uncomfortable alright. LCL, now next is LCL.

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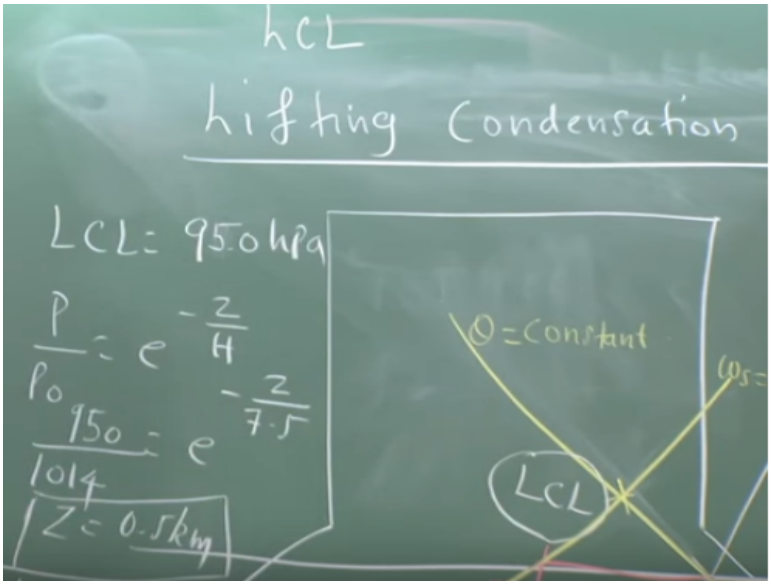

So we got the, from here you have to take the dry adiabat is it not. Dry adiabat is right side or how does it go? Isotherm was going like the other one no. Did I draw it? Why did you not tell me? Isotherm is going like this no? Now and from here correct. What is the LCL? Nine hundred and 950? So if clouds are to be formed the cloud based temperature will be or sorry what will be the height sorry 0.5 km but we did not see any cloud yesterday no. So.

Somewhat funny that is okay alright okay. I think the 33.8 and 79 do not correspond to each other. That could be the possibility right. Because usually the humidity is at 5:30 in the evening. 5:30 in the evening the temperature might have been 31 and you would have got some better result, does not matter. If you got 33.8 and 79% relative humidity this is the result alright. Now, we have to go to another important concept called wet bulb temperature okay.

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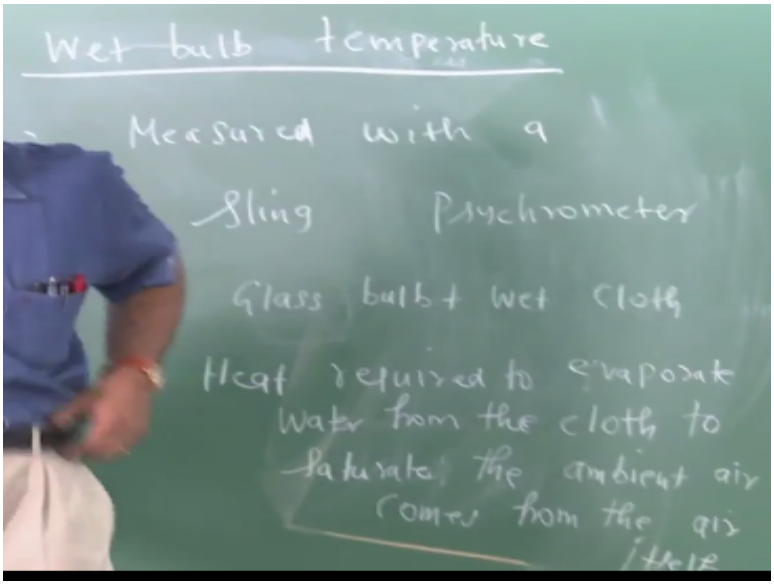

The wet bulb temperature is another quantity involving the temperature which will be extremely useful when you look at when you study moist air thermodynamics okay. So it is measure with an instrument called the sling psychrometer okay. So glass bulb, glass bulb there is a glass bulb covered with a wet cloth. Then the sling psychrometry we keep on doing like this. What will happen is it will get saturated.

You are taking the air to saturation and then this cloth will come to some temperature, equilibrium will be established and that temperature is called the wet bulb temperature. If you

measure without a moist cloth a normal thermometer that is called the dry bulb temperature or temperature DBT dry bulb temperature WBT wet bulb temperature okay. So the heat required to evaporate the water from the moist cloth okay wet bulb okay so please note this carefully.

The heat required to evaporate the water from the moist cloth to saturate the ambient air comes from the heat required to evaporate water from the cloth to saturate the ambient air surrounding it. From where is the heat coming? There is no burner there is no flame there is nothing ah that is the point. So the heat required to evaporate water from the cloth to saturate the ambient air comes from the air itself.

So there is a depression in the temperature corresponding to the dry bulb and that is manifested as wet bulb temperature. That heat is drawn from the air and that is converted into latent heat that evaporates the water from the moist cloth. So there is a heat transfer which is taking place. So there is a sensible heat loss from the air which is manifested as a latent heat loss from the cloth and water evaporates because there is some amount of latent heat required to evaporate the water from the moist cloth. Is it okay? So it is little hard to understand but it is there are I think you are able to follow it right.

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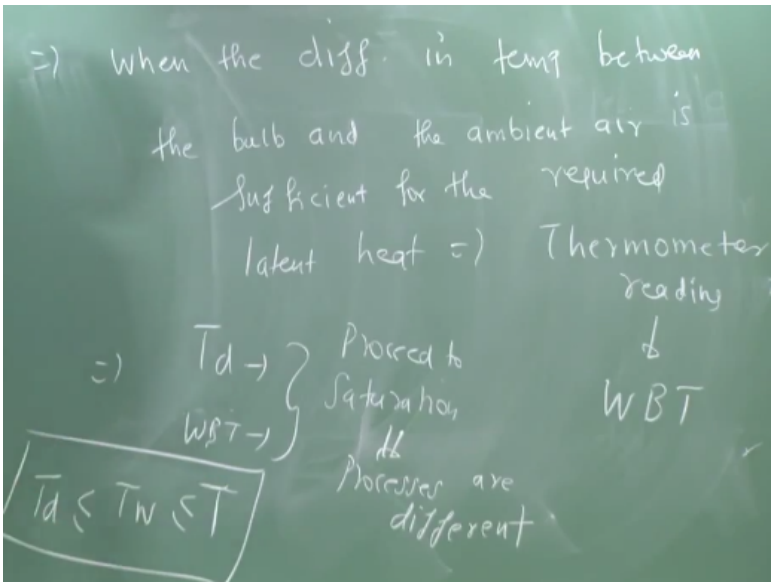

So when the difference in temperature so when the difference in temperature between the bulb and the ambient air is sufficiently is sufficient to let the water evaporate from the moist cloth, the

thermometer which is in contact with the moist cloth will show a temperature. That temperature is called the wet bulb temperature, called the wet bulb temperature. Consider a raindrop which is falling.

Consider a raindrop which is falling through the atmosphere which has got a constant wet bulb temperature. What will be the final temperature of the raindrop? If raindrop is allowed to fall for a sufficiently long duration of time surrounding air as a wet bulb temperature T w the raindrop will also reach the temperature of T w, enough time must be given. The falling raindrop will attain the wet bulb temperature. Now confusion starts.

Sir, dew point temperature also we are going horizontally for to saturation correct and here also you are saying it is saturation. Then why have a dew point, why have a wet bulb temperature if they are not the same. Which is more, which of the two is more? Is the question clear? The dew point temperature you are not proceeding along adiabatic saturation, isobaric.

The dew point temperature we are going along the isobar but here it is going you are doing it adiabatically okay. So that is the difference between dew point temperature and okay. What we call T, WBT both processes are different. I did not solve the Chennai problem on chart? Okay so we will do it now okay. So T d, the lowest is the dew point. The highest is the dry bulb temperature and the wet bulb temperature is in between these.

For a fully saturated air, for an air fully saturated with respect to a plain surface of water T w, T d and T are all same. I come again. If it is 100% saturated dry bulb temperature, dew point temperature, wet bulb temperature everything is the same. If the RH is not 100% then we have to work out the individual quantities. A simple rule of thumb which you should not use in the exam is T w is equal to T + T d/2 okay. That can be used, please use it only for cross checking your answer okay.

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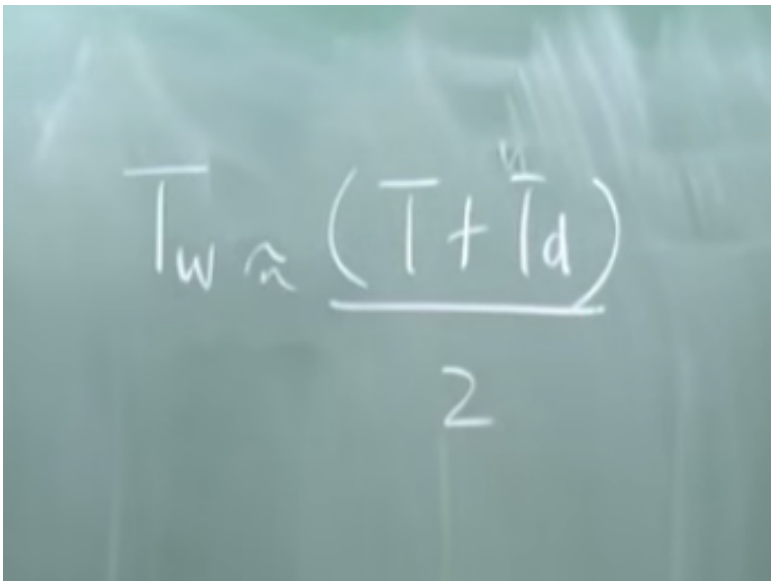

The difference between the wet bulb and the dry bulb temperature is also a good indication of whether an air cooler or a desert cooler will work. In a place like Chennai already the humidity is very high that potential is very less the air cooler will not work. In a place like Hyderabad or Vijayawada where there is the RH is very low you can proceed along adiabatic saturation and reduce the temperature of the surroundings by a few points without using the air conditioner.

There also the latent heat is used because you put water or ice cubes okay. That technology will work not work in Chennai. You have to use a compressor you have to come to ME 1100 thermodynamics you should work done and all that you have to input work and all okay. So we want to be able to calculate the wet bulb temperature of Chennai corresponding to 23rd September, we will do that okay.

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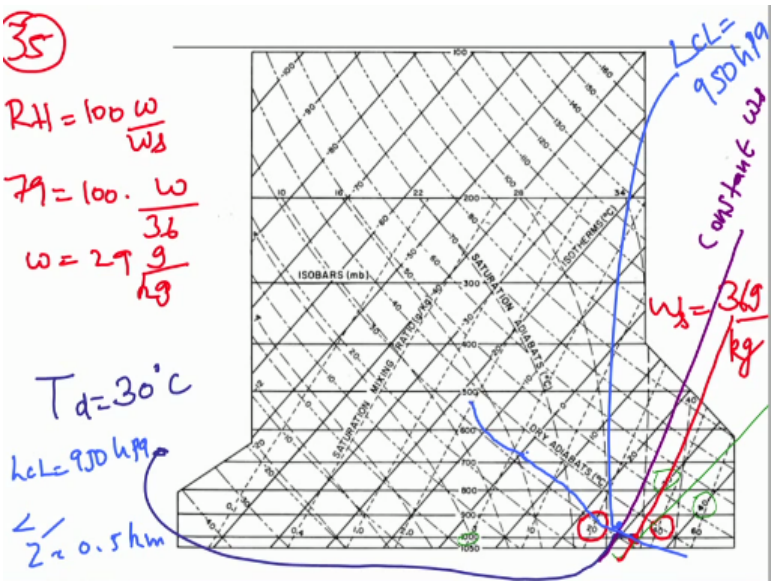

So what is that 33.8 this is so 30 is here 40 is here okay and pressure is let us say 1014 is somewhere here. You are not able to see that right? That rangoli is Chennai okay. What Marius, you know what is rangoli, please find out okay. Now chalo what is the next step. What is the saturation mixing ratio? Where is this oh. So what did you guys tell me, W s equal to, problem number 35. So we go all the way up to 29 okay. The dew point is, what is the dew point?

So another. So from the dew point we will draw line of constant saturation mixing ratio correct to find the LCL. We will use the magenta. What is the next one? Dry adiabat. Oh, that is bad. Where are they meeting, here? Okay. So alright 11:51. So we will stop. So tomorrow we are going to find the wet bulb temperature. I told I have not explained told you how to do it on the Skew-T ln P chart. There is the funda of doing it. That we will do and saturation mixing ratio all that I will explain then we will start working out more involved problems. Thank you very much.