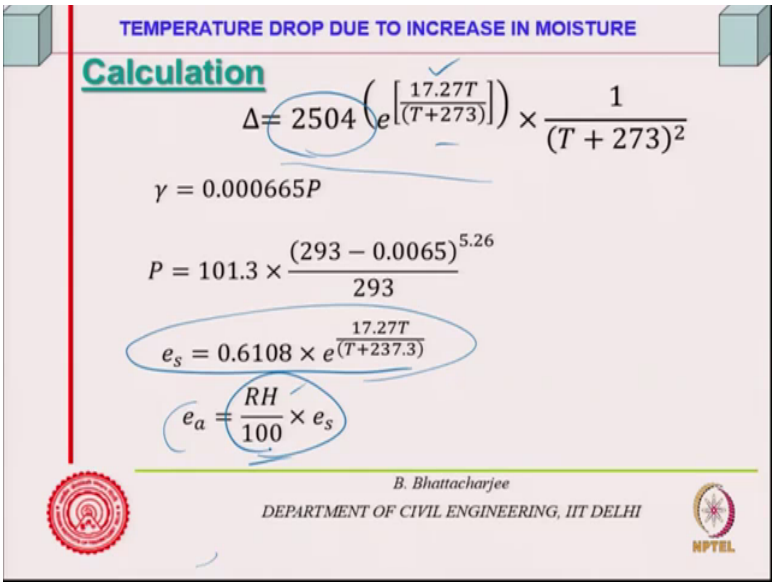
Sustainable Material and Green Building
Professor B. Bhattahrjee
Department of Civil Engineering
Indian Institute of Technology Delhi
Lecture 35
Evapotranspiration: Case Study and Surface Water Balance.

(Refer Slide Time: 00:17)

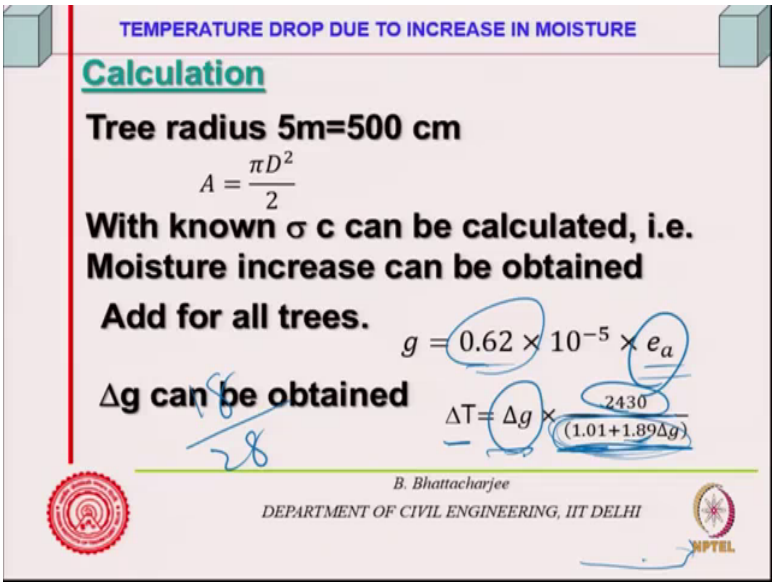


So, that we can, we can now look at the procedure of calculation. Now, delta can be obtained from this sort of formula. You know this sort of formula. This is, of course, latent heat, this is an empirical formula that is why you find this kind of, so delta you can find out from this and gamma you can find out from another equation which is 000 you know 665, this is an empirical equation obtained from cyclometric chart and P is given by this formula.

So, one can obtain this, es 1 can obtain at 2 meter height can use this sort of formula. Empirical formula not easy to remember and ea at that particular, at 2 meter height, what is the actual vapor pressure that you can find out because RH by 100, so that is in percentage, so you know, it will be fraction of this particular one.

This saturated and this is actual, so it will be fraction of that, if the relative (())(1:26) is 100 percent obviously this would be 0. So this is how one can calculate this out.

(Refer Slide Time: 1:32)



And then supposing tree radius is 500 meter, so A you can find out, with known sigma one can calculate out moisture increase you can obtain and for all trees you will find it out the moisture contained is given by this, this you can easily derived this related to this kilo Pascal, it is related to air pressure actually, this we can actually easily derived, you know, partial vapor pressure, this ea vapor pressure at that particular condition you can find out. This you can easily derive because, you know, that molecular weight of water is 18 divide by 28 molecular into water that gives you 0.622.

So moisture content is defined as a amount of moisture present per unit dry mass of the air, right. So, you know, related to the molecular weight of this, so this leads to 0.62 and from ideal gas law this can be, this relationship can be derived. PB is equal to NRT, so partial pressure for all partial, both the partial pressure it can be applied and one can imply it.

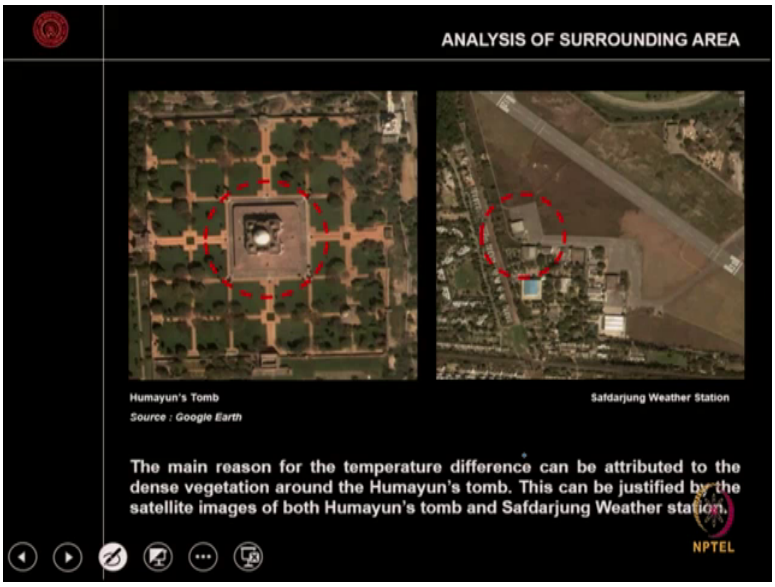
So, change in delta g you can obtain. Moisture content, you know, the partial pressure difference or evaporation that has occurred corresponding to delta g you can find out, and once you have found out delta g, moisture content change, this is the specific enthalpy or heat content of specific enthalpy of the moisture. This one 10, 1.01 is the specific heat of dry air, this is specific heat of moisture.

So, this total is a specific heat from, you know, of course, the latent heat is equivalent specific heat of CP of moisture, where this is the moisture content. So, moisture has got us specific 1.89, I think it is kilo Jules per kg or whatever it is, and these are latent heat of evaporation.

So, latent heat of evaporation, so latent heat of evaporation divided by specific gives you because this is in, this would be Jules per kg per degree centigrade, this is Jules per kg.

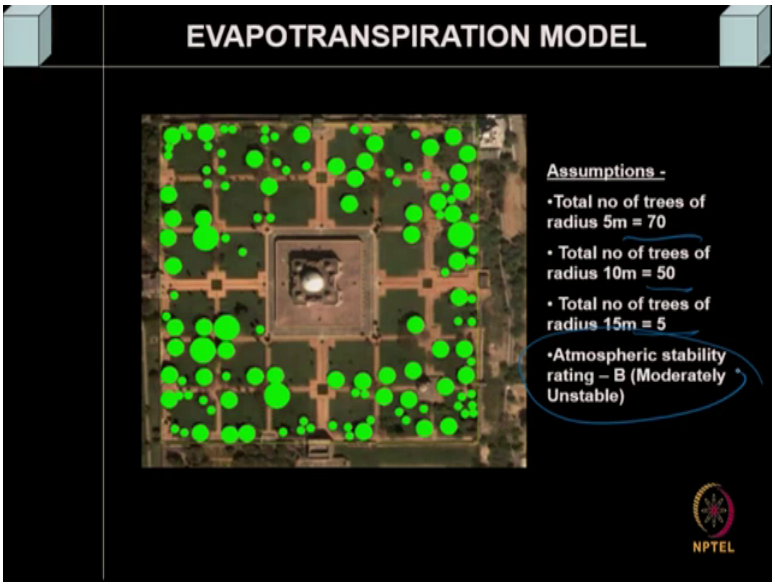
So, this would be multiplied by delta G that gives you the temperature. So one can find out what is the temperature change, change in temperature related to moisture change. Now, this is in elaborate exercise if you are trying to do, I have just told you what are the principles, so far.

(Refer Slide Time: 4:16)



Now, supposing I have, this is an example, so where I will come back to this but let us see the sight first, if I have the sight photograph. This is the sight that I am talking about example is, this is the Humayun's tomb as you see from top, and this is the main tomb and if you see this this exist somewhere away from Safdarjung Weather Station, which is, this is the flyover passing by and there is a weather station there. Where there are lot of built up areas, in this one there are so many green, right, so many green, okay we will come back to this again.

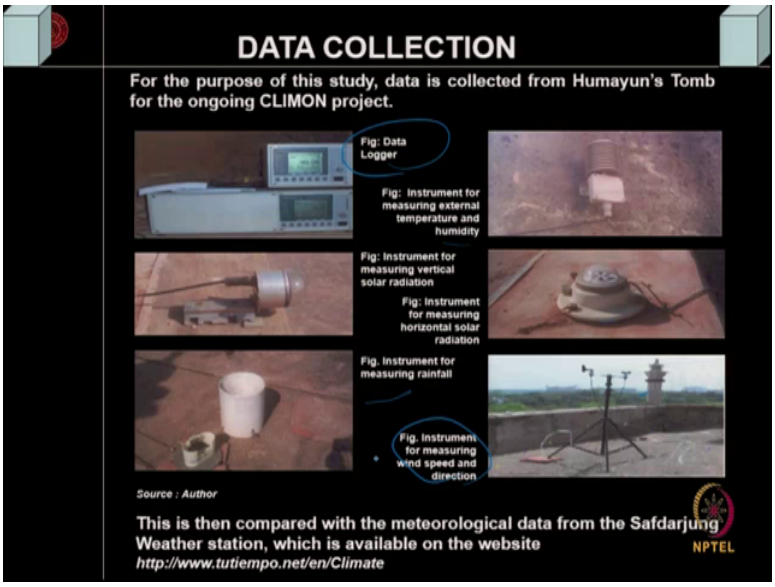
(Refer Slide Time: 5:05)



This is how it looks like from the top and the trees are like this. So these are all the tree actually the circle mark. This is the ones, the circle mark, this is the tree with the circle mark, and when circles are separately isolated this is the trees. Approximately in plain circular ground, circular ground. So, then their sizes can be measured, so one would see that total number of trees of 5 meter radius is 70, trees of 10 meter radius you have 50, and 15 meter you have 5 and this is required to calculate sigma.

A and B you know the moderately atmospheric stability, moderately unstable this is define in the same Gaussian model itself. So sigma Y and sigma X are calculated based on this. So, let me go back now.

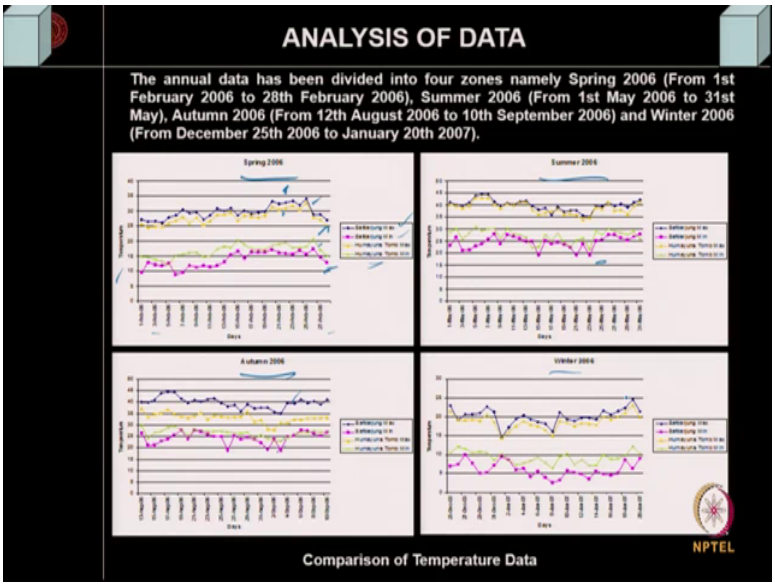
(Refer Slide Time: 6:13)



Now, one can measure the temperatures relative humidity, etc, etc. and keep recording the data to a data logger. So, you have, you know data logger stores this data simply, now this is measuring in speed kept on top of those tomb somewhere, this is solar radiation measurement, what is called a pyranometer. This is for external temperature and relative humidity, thermo hygrograph and this is instrument measure for rainfall.

So, any rain fall (())(06:55), because this was metered for a year, complete year, and this instrument for measuring vertical solar radiation. This gives you radiation on horizontal plane, this is for measuring on vertical surface, so this is how it measure on this surface, and this, of course, the data logger which will store all the data.

(Refer Slide Time: 07:20)



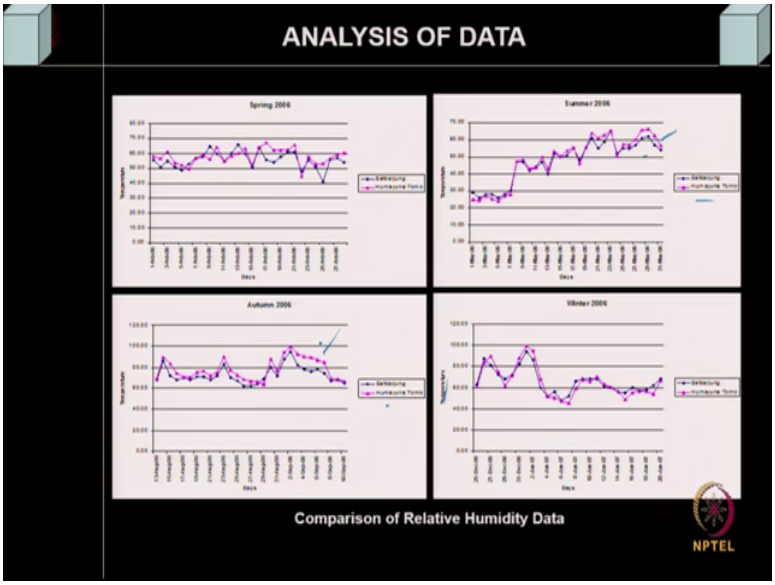
So, if you store all the data this is how it is looks like. Spring, summer, autumn and winter, because weather throughout the year. So typical once are taken. Now, the dark one also we collected the simultaneously, data were collected from the newspaper Safdarjung Airport data is available, two stations are there in Delhi, one is Palam and other one is Safdarjung, so data are available.

So, this is Safdarjung data temperature data, and this side is date wise, 1st February to 27 February, there is a minimum temperature data, and then this is Humayun's tomb maximum and there is a minimum. So, this is Safdarjung maximum, Safdarjung minimum, and Humayun's tomb maximum yellow color and Humayun's tomb minimum is green color. So, you can see that temperature of the Safdarjung station was higher for all the days, if come to summer they are similar but generally (())(08:34) temperature, you know, is somewhat the pink one is a Safdarjung.

So diurnal variation was more for where you do not have trees, tree moderates the diurnal variation that is what you can see. If you see autumn this is much higher, this is much lower and you know this month of august. Now, August means rainy season in Delhi, relative humidity will be different and autumn you can see that green color is there of the Safdarjung airport, I mean the pink is Safdarjung airport and this is the Humayun's tomb. So, there is a difference as you can see from this.

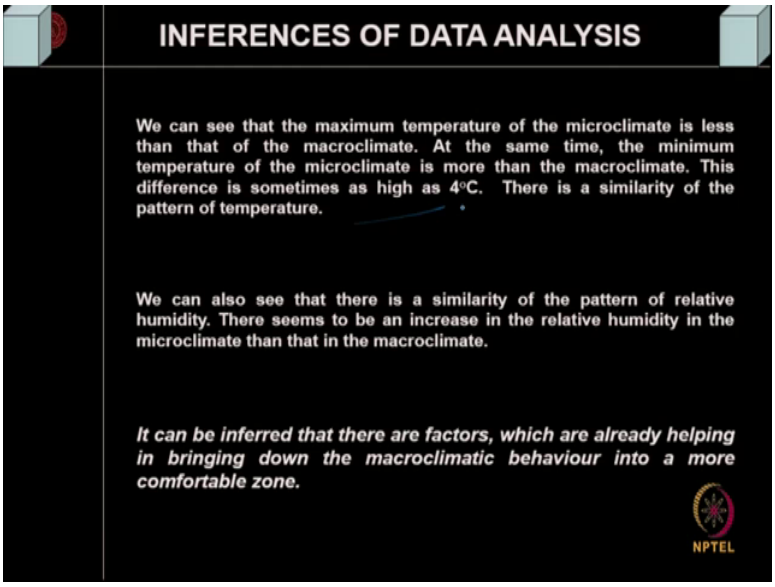
This is for winter, same. So, temperatures you can see there is a, it moderates the temperature, there is so many trees actually moderates the temperature.

(Refer Slide Time: 09:37)



And if you look at temperature of this 2 one, this is actually mean temperature of this 2 for days wise, again their, sorry, this is relative humidity not temperature, this should be relative humidity. This should be relative humidity, so relative humidity comparison from time every day mean relative humidity, you will always see the relative humidity actually Humayun's tomb is pink is higher relative humidity Humayun's tomb is pink and Safdarjung is blue or whatever it is. So, generally this is higher or same, so it causes increase in relative humidity and decrease in the temperature.

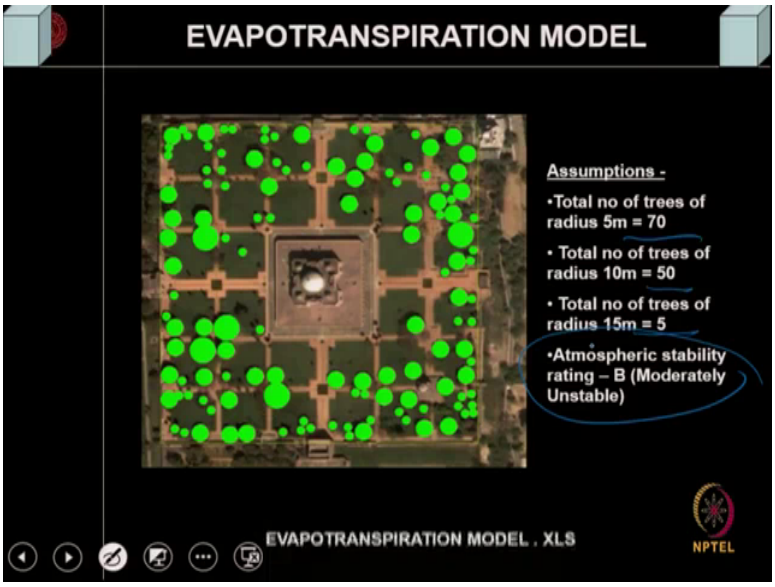
(Refer Slide Time: 10:35)

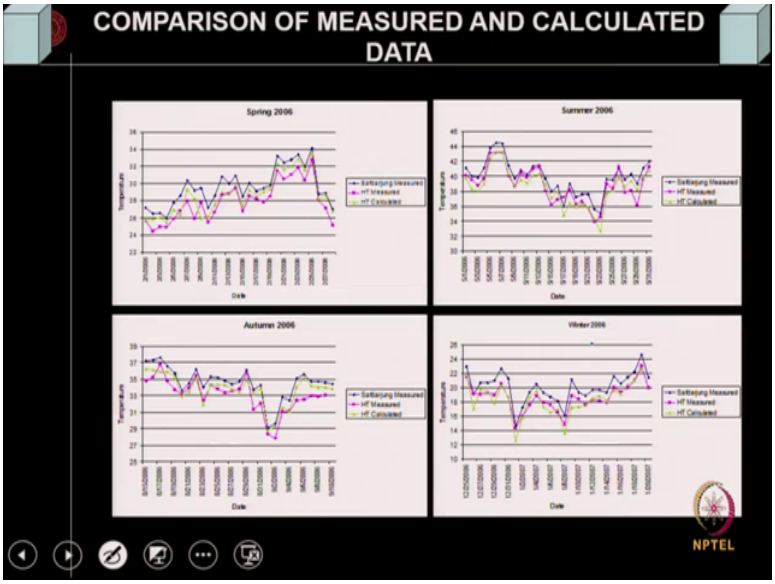


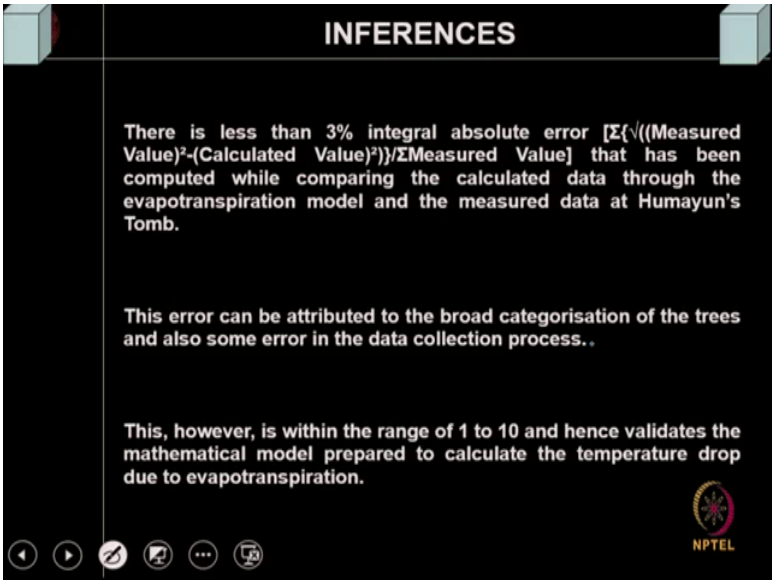
So maximum temperature of the micro climate is less than that of the macro climate, so Safdarjung can be considered to be a microclimatic scenario, you know, somewhat general daily scenario. At the same time the minimum temperature of the tomb is more than that of the Safdarjung tomb. So, micro climate this difference some time has highest 4 degree centigrade.

So, this kind of that many number of trees 5, 15 meter trees 15, 10 meter trees and 75 meter diameter they could reduce down the temperature by 4 degree on an average over the space that we consider and we can see there is similarity of paternal relative humidity. Relative humidity, tend to actually increase. So, therefore, they bring down the temperature but increases the humidity.

(Refer Slide Time: 11:25)



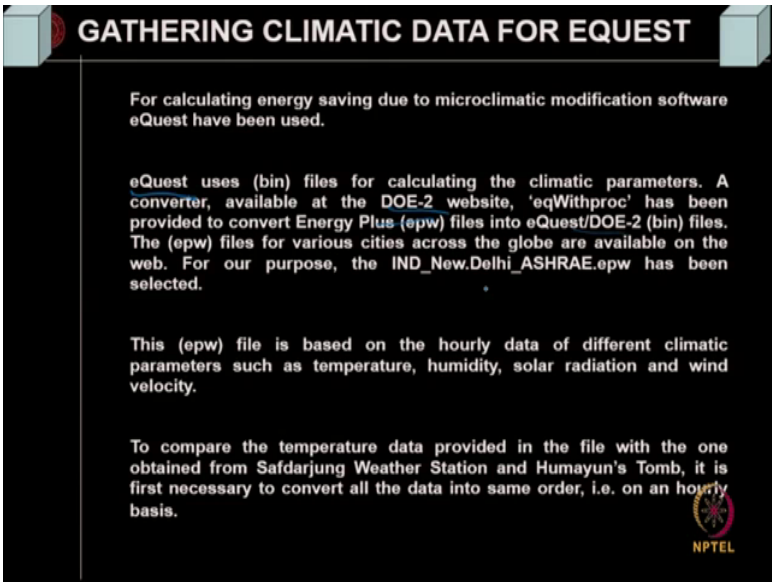




This is what has been shown, this is what you can see. This is the trees, so these trees are modeled in this manner, tree are model using this same model that I talked about and here temperature is a same thing again shown here right. So there is less than 3 percent absolute error, from measured value minus calculated value, one can calculate, you know, estimate this measured values are available to us, but we could calculate it using the model that I talked about. First you find out the evapotranspiration for the given type of plant, trees which are there, and there are all similar kind of trees.

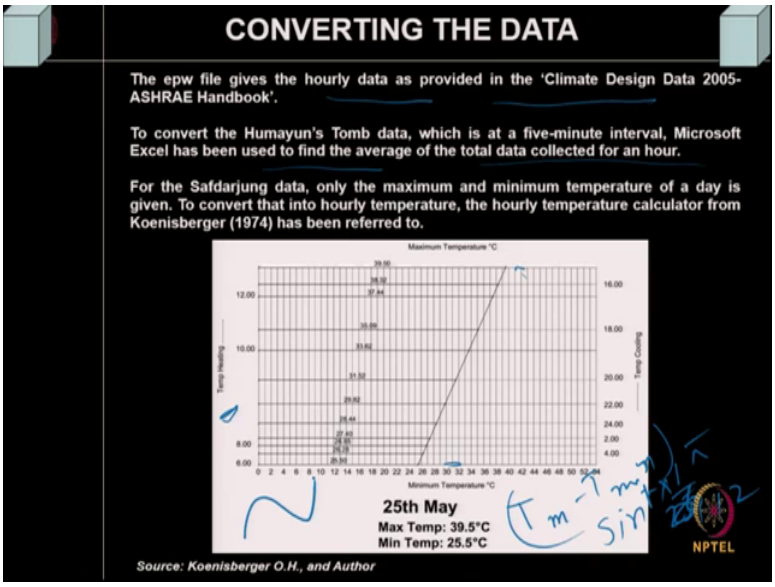
Multiply that by the clock factor etc. And then use Gaussian dispersion model to find out the moisture content in that volume that you have taken and what we find is that model prediction measure temperature relatively well. So, that is what it is, so however, within the range of 1 to 10 and hence it actually it is acceptable.

(Refer Slide Time: 12:45)



One can actually calculate out the energy saving because of this. Supposing I calculate out the annual energy consumption using some, here, of course, we use a software, open source software like eQuest, those who are used or interested can look into the software, it is open source software developed in U.S. department of environment DOE 2.

(Refer Slide Time: 13:09)

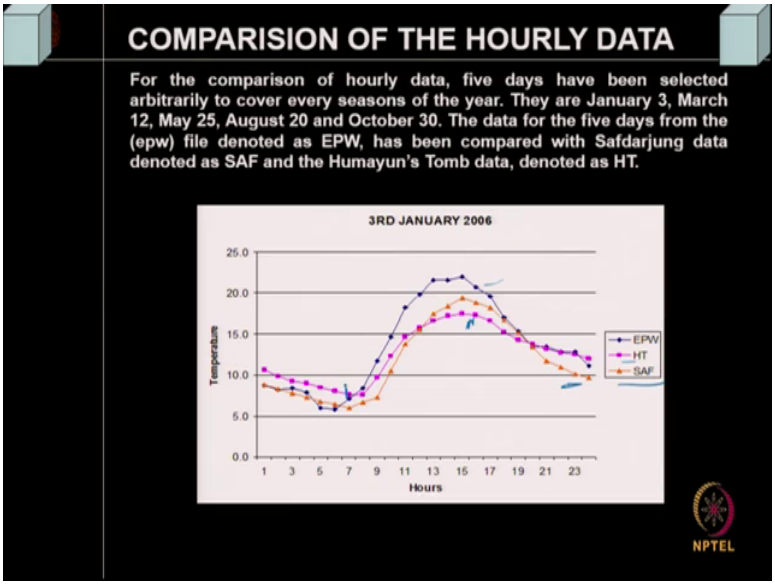


So you can use this and if you calculate this out, it will show you that hourly data provided climate design etc. convert the humayun's tomb which is that 5 minute interval etc. For Safdarjung only maximum and minimum temperature of the day is given. So, 1 can compare the minimum daily temperature to through a char, for example, there is a chart available in

Koenisberger book, if you know the minimum temperature maximum temperature, assuming sinusoidal variation one can find out what will be the hourly temperature.

It is very simple, this is not very, see because T max minus T mean multiplied by sin theta, theta is basically T, you can say T multiplied by 1 by 24 into pi, 24 into pi. Pi corresponds to, 2 pi corresponds 24 hours pi by 12. 24 hours is a full cycle, so one can very consider sinusoidal variation of temperature and this can be obtained because the meteorological data available here only maximum and minimum.

(Refer Slide Time: 14:27)

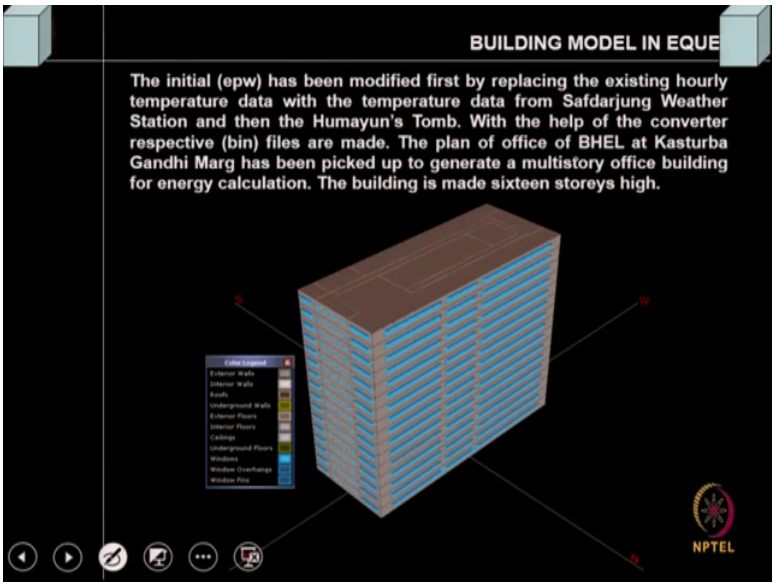


So one could calculate out the heat load, cooling load for a building located close to that environment and one could calculate out the cooling load that can be there if the building was close to all those that many number of trees and it shows actually just for 5 days it is been done. So, it would show that the temperature actually for Safdarjung airport is this color. The Humayun's tomb is this color and this the one is the sub data of 5 days from the software that is used. So, one would give, there is a Humayun's tomb temperature, peak temperature set down and minimum peak is also raised because the diurnal variation are lower.

(Refer Slide Time: 15:24)

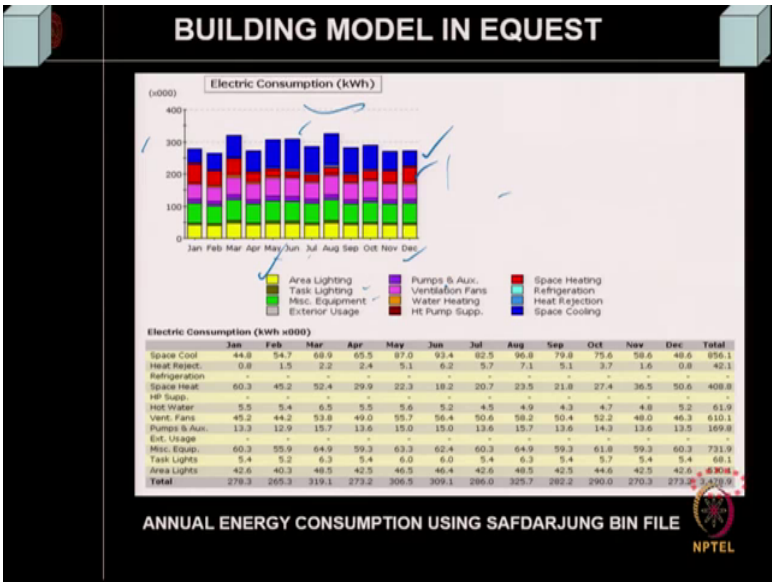
So, by even doing a kind of energy calculation for buildings located in this 2 area, this can show there is a lot of energy saving. So, one can find out the quantity of temperature variation, this is for Humayun's tomb, the pink is for Humayun's tomb, this is for Safdarjung airport. The temperature actually reduces down.

(Refer Slide Time: 15:51)



And this is our, the building that is model existing our hourly temperature etc. from the data, you know, data is available I need to show you that there can be actually an energy saving.

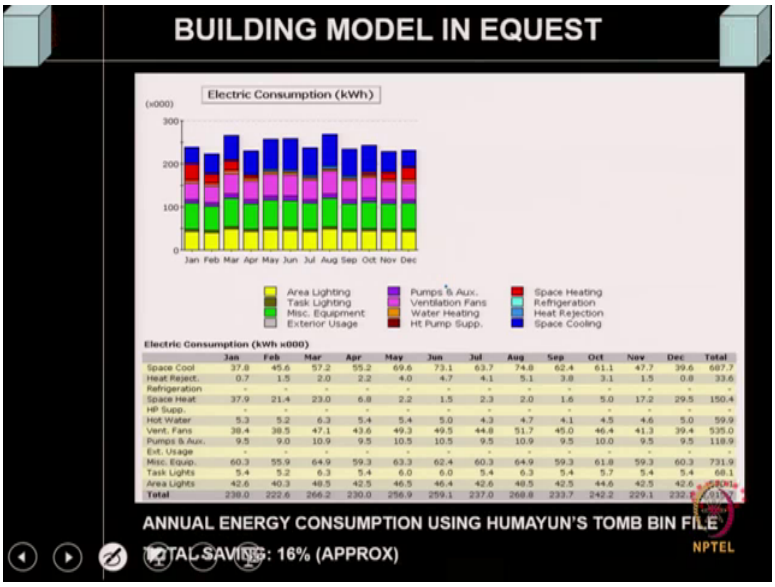
(Refer Slide Time: 16:04)



So, this is the software I would put actually to shows that electricity consumption actually get reduced if you plant that number of trees. So, this one is total, actually total electricity consumption kilo watt hour from the software was used. So this component shows space cooling, this is space heating if required, different month December, so you can see that in May, June you got lot of heating, cooling.

You might need in the night depending upon the situation and the temperature that you have maintained inside the room. So, yellow one is lighting and task lighting etc. So, it gives all those, so you can see that the comparison would show that, that actually there can be a saving in the energy if you have actually planted this. So, there can be reduction in this.

(Refer Slide Time: 17:02)



So annual energy consumption using Humayun's tomb bin file and this is the consumption using Safdarjung file, if I use those, then I find the values search somewhere 300 something peak is 300 plus something. Let us see how much is this here this is 200 something. So there is a saving in energy if you plan that many number of trees, there is a saving in energy if plant that many number of trees etc.

So this is related to how trees effect. Now doing this exercise of course it is a significant time would be required but I have just given you the principle, which you can understand and this also shows to a demonstration exercise that, you can actually reduce down the cooling load you can actually reduce down the cooling load, but there is a negative effect as well.

If you do too much of greening we have to see essentially, if it is everybody is using air conditioning system, you know, an active cooling and heating system, then planting tree has got a meaning it would actually reduce down the energy load but, if the society is changing in a way say and you have planted lot of trees what will happen is earlier when it was dry summer people are using more of what is called a desert cooler now there as the humidity increases with this you cannot use desert cooler anymore.

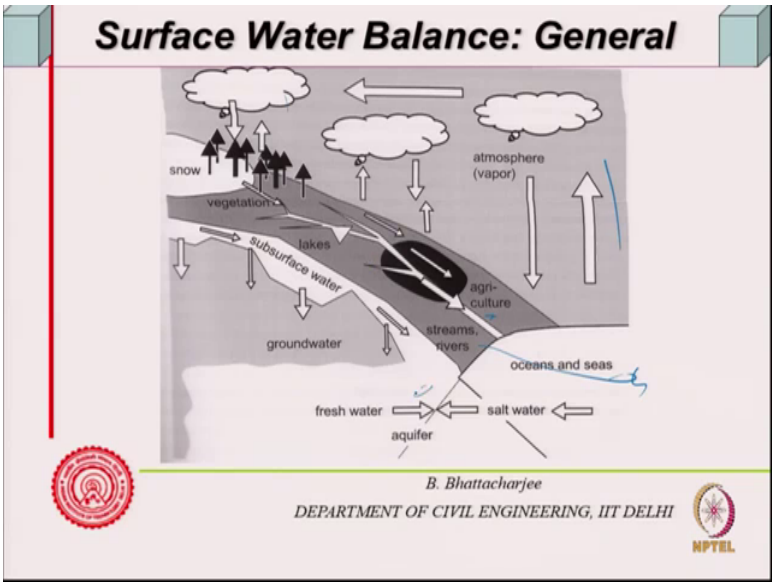
So because desert cooler is ineffective which uses evaporative cooling, dryer comes to it absorbs, dryer comes through, you know, a fan drives it, exhaust fan drives it and you have got finally the divided water particles which evaporates and latent heat of evaporation it takes

from the same air itself, with sense cooler have to the room which will consumer on 200 wats and not more than that.

So, if you are humidity increase this becomes ineffective because AR is no longer dry. So in such situation infecting your cooling load will increase because people will tend to use the air conditioner if they have the purchasing power. So, in a society which has got, you know, which is somewhat affluent, earlier they would have been doing with a desert cooler, now they will all change toward to air condition.

Which might actually complete city if you look at it, might increase your energy consumption. So, thus other social aspects is there but already using let us say air conditioner, now you have planted lot of trees obviously cooling load will come down or commercial places cooling load will come down. So this must be looked into together the social situation.

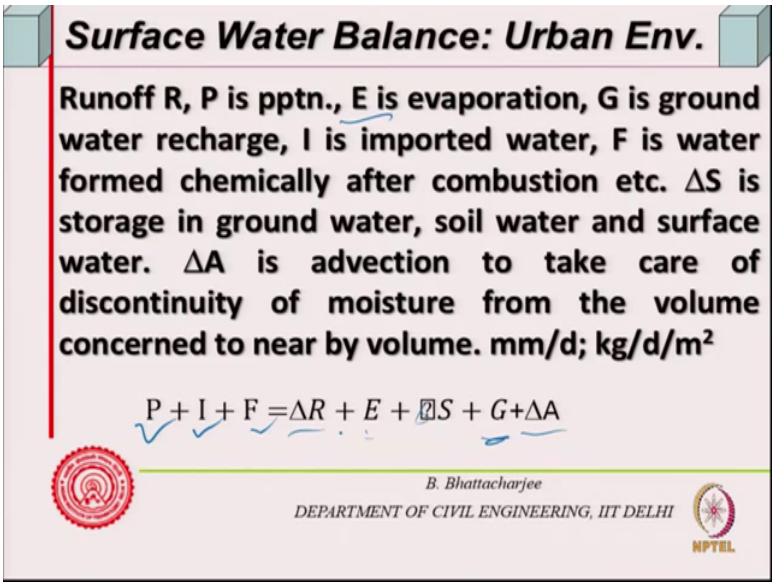
(Refer Slide Time: 20:14)



Quickly the last part of the discussion is surface water balance, so few slides, we can see that because you do water harvesting, you do water harvesting, you know, you would like to utilize the water as much as possible very first slide that I showed you. So, if you see the surface water these are the streams or rivers, this is a, you know, rain precipitation or snow that could be there melting and rivers coming in.

Some would get vaporized, some goes to the sub surface, water ground water, right and finally water goes to the ocean and sea. So, that is the basically water balance right and sub-surface water also finally reaches the ocean and sea.

(Refer Slide Time: 21:10)

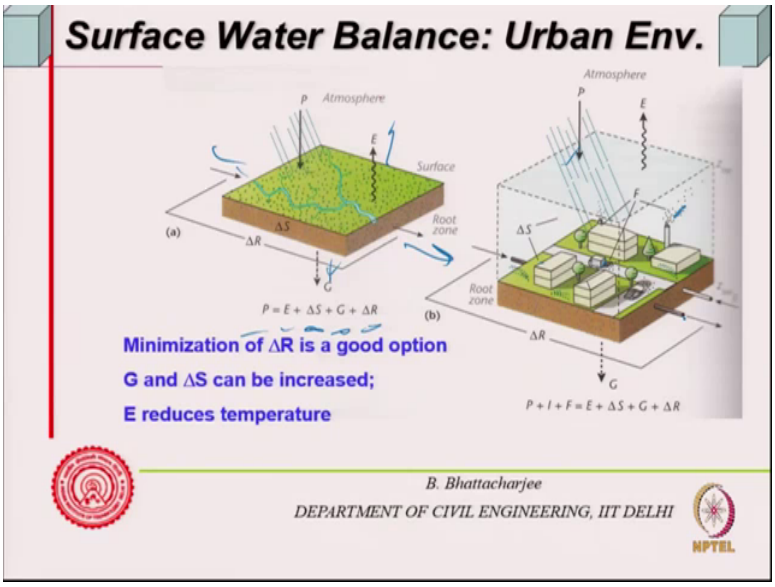


So runoff is R, P is the precipitation E is the evaporation, so I am trying to do a balancing, G is the ground water recharge, I is imported water because the city will import water, Delhi imports water from Ganges, in fact, beside Yamuna, Yamuna anyways a part of it is flowing through it but it import water from Ganges canal, because there is a upper Ganga canal and this is Muradnagar near to as you go towards Haridwar, there is a place called Muradnagar where there water dam, from there the actually canal that get the water.

So imported water, F is the water formed chemically after combustion. So, if the factories are there or any other combustion water vapor will be released and soil water, and delta is advection any kind of discontinuity of moisture basically flow through porous system there could be advection or deficient of moisture vapor can also (())(22:16). So, this is the kind of an equation, precipitation plus imported water plus water formed chemically that is added to moisture vapor added.

Must be equals to you know evaporation E is the evaporation, this is delta S actually, G is the ground water recharge. So delta S is a storage, delta S is the storage in the (())(22:44) or something like that, and delta R is runoff which we like to minimize which we like to minimize because all others are use full runoff is quickly going.

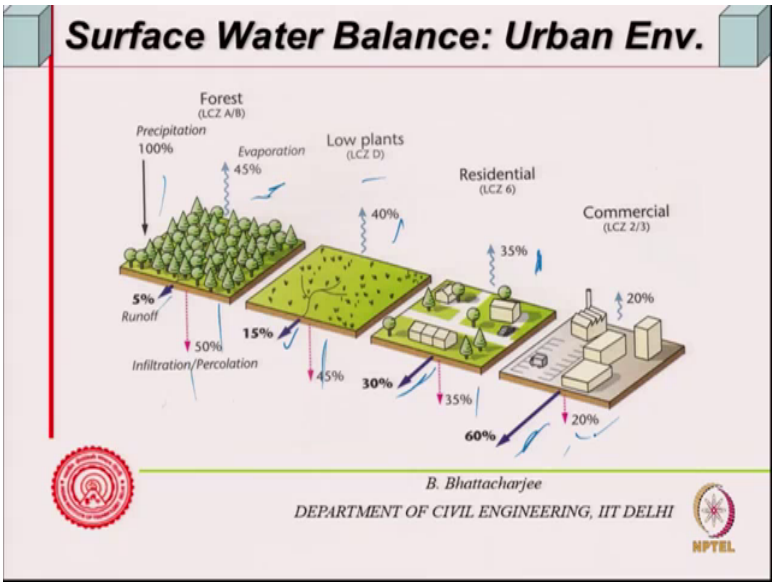
(Refer Slide Time: 22:58)



So this is the diagram, this diagram shows you the precipitation equal to evaporation plus storage plus ground water recharge plus runoff. So, surface evaporation root zone G is the ground water recharge, delta R is the runoff what is coming out. Coming in coming out. So, in rural area, of course, there is a stream, the precipitation is here. Urban area this is also be arranged through combustion. There is F through the combustion, vehicle also moisture evaporation occurs, delta S is a storage in the system, urban system I am talking about, P is the precipitation and this is the equation that I showed.

So minimization of delta R is a good option because that is not getting utilize. G and deltas S can be increased, G is the ground water recharge and storages required would be E reduces temperature. So R is the thing which is not useful, that is why if you see any rating, energy and environment rating they would talk in terms of ground water recharge and so on.

(Refer Slide Time: 24:13)



So this is a, if you look at the rural and urban scenario, we have 5 percent runoff where you have a forest, 45 percent evaporation precipitation is what is charging it actually, if you have low plants 40 percent 15 percent is runoff increasing and residential with lot of greenery is actually 30 percent and too much congested commercial area etc. 60 percent is runoff. 45 percent goes to percolation to the ground 45 percent 50 percent near 35. So, this is how actually it occurs and that is why utilizing the water as much as possible other than runoff that is the best option okay that is end of our discussion.