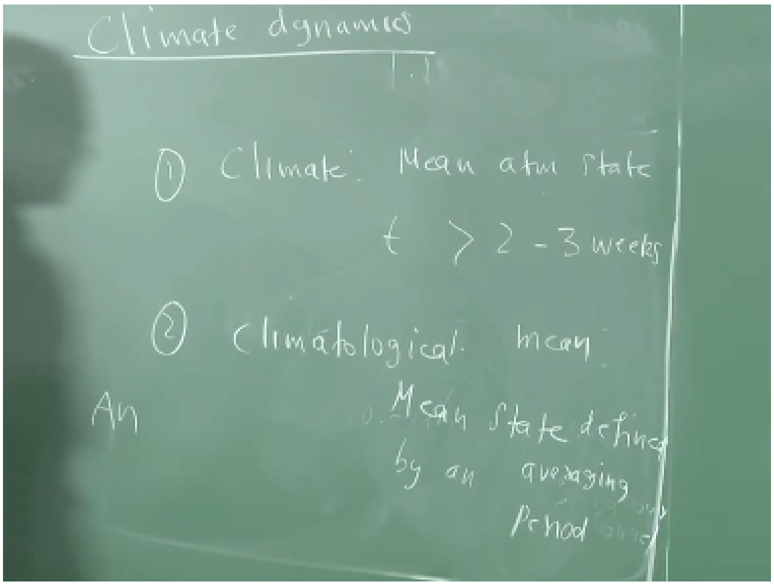
Introduction to Atmospheric Science
Prof. C. Balaji
Department of Mechanical Engineering
Indian Institute of Technology – Madras

Lecture - 38
Climate Dynamics - Introduction

So welcome back, so we are going to look at climate dynamics, okay, the next 2 hours. What is the difference between weather and climate? Climate is average weather, average over a long time, weather can change day to day right. So please take down the definition of climate. Definition: Climate: Mean state of the atmosphere and the related components of the Earth's system.

(Refer Slide Time: 01:08)



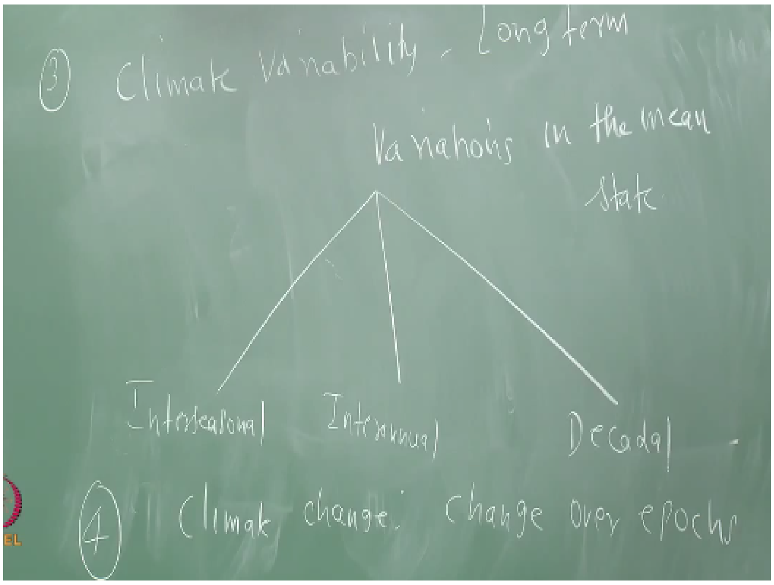
We talk of something at least greater than 2-3 weeks. The climate of Chennai during November, December, January, I mean, you cannot say the climate on November 15th right, that is not on. What is the climatological mean? The climatological mean is the mean state; you have to define the averaging period okay. What is the spelling of anomaly? sometimes difficult to spell, but when we write we can find out if there is a mistake or not, correct.

What is anomaly? some abnormal deviation from the mean, suppose it snows in Chennai, as opposed to this anomaly what is climate variability? Look at this let us take the average temperature, the daily average temperature in December in Chennai, so the daily average temperature itself found by average, so already 2 averages are there, morning to night 24 hours you take average and the one average you already done.

Then December 1st to 31st you have daily average, then you take the average of, you take the mean of the mean, but it cannot be so mean that is what they say, I have to get serious. Now you take the mean of the mean and then there will be the mean, okay, there will be the mean temperature in December, now mean temperature in December 1965, 70, 75, 80s you see, if it is increasing then it is a variability.

So 2012 December mean temperature was 27 degrees, 2013 December it is 27.5, there is climate variability you cannot say, you have to some more data, okay, last year monsoon was good, 2 years' monsoon was not good therefore monsoon is failing we cannot say that, so you require more number of, because there is some natural variability in this, therefore climate variability is long term variation.

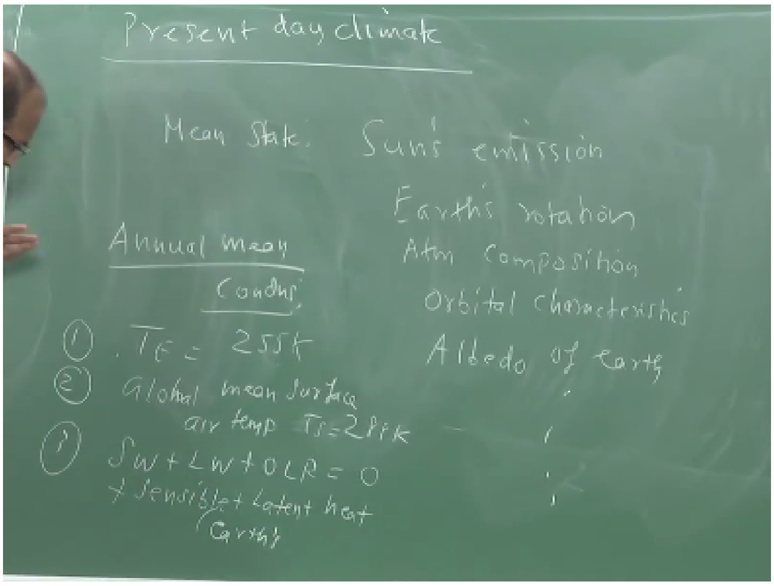
(Refer Slide Time: 05:00)



So this can be inter-seasonal, inter-annual, decadal whatever, of this order, then century scale all that, okay. Climate change, change over epochs that is the much longer time period. Sometimes there was a snowball Earth, everything was ice, then initially big bang theory they said everything is fire, then they say ice, now it is some two hundred and we worked out what it is some 255?

What is the mean temperature? we worked out in one these classes radiative transfer, so 255 is the mean temperature, okay, so what is the temperature after 1000 years, what was the temperature before 1000 years, so if you look at all this, so then you become a climatologist, if you look at dating isotopes and all that and then you look at millions and millions of years ago then you become what is called a paleo-climatologist, you look at the paleo climate and all that, okay.

(Refer Slide Time: 06:51)



What about present day climate? So the present day climate, the mean state is determined by what all factors? Can you name a few? First and foremost, Sun's emission, okay; then second? Earth's rotation, atmospheric composition, the orbital characteristics of the Earth's rotation correct, it is speed and this thing and axis, and there are various other factors, albedo. So the mean climate, what sort of problem is this?

The mean climate is a radiative transfer problem, the weather is the fluid dynamics problem, that low pressure system whether it is coming this north, east that is not climate problem, climate is overall, what is if the reflectivity changes, the Sun's emission changes and some distance changes and orbital characteristics so it is basically so climate is determined by radiation and weather is determined by the dynamics, okay, the atmosphere.

Therefore, even though we are not able to accurately predict weather beyond 7 days and people can make fun of us that you cannot even predict beyond 7 days how can you predict after 30 years or 40 years, you know the right answer to that question is it is lot easier to predict what will happen after 40 years if you assume some scenarios, we will continue to burn fossil fuels at the same rate +5%, -3% whatever, okay if you assume something.

We already worked out some problems geometry progression all that, do you remember it will come in dreams, so you remember know 3 months back we have done all that, right, so we can assume various scenarios and you are on track, it is easier to predict the climate, but it is very difficult to predict the weather, so it is an unfair criticism so to say that you cannot even predict for 10 days, how can you predict for 30 years.

Our answer is very easy to, long term it is very easy to predict rather than the short term. What will be the reliance stock tomorrow is very difficult to say, but we can say over the next 3 months or 6 months are okay, but as Alan Greenspan says the irrational exuberance of the stock markets cannot be explained. Alan Greenspan by the way was the chairman of the Federal Reserve that is the RBI of US.

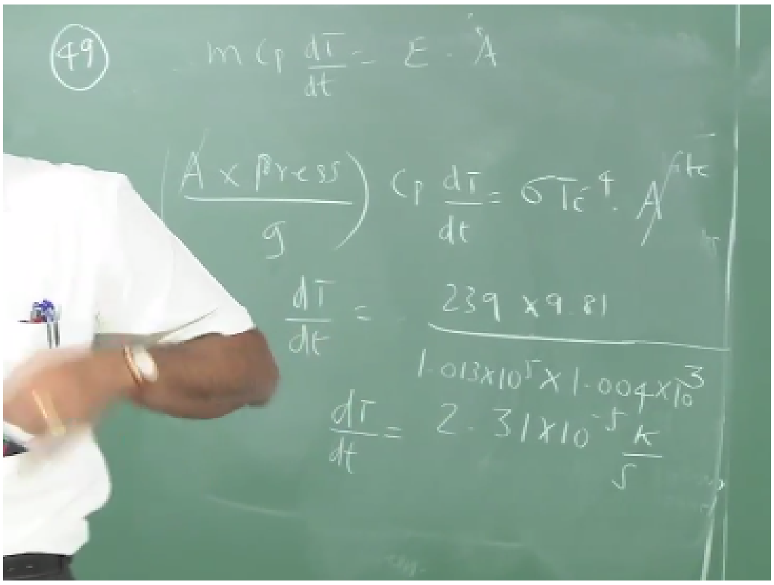
Now mean state is this, what are the annual mean conditions? Black body temperature of the Earth is 255, global mean surface air temperature 288 kelvin. Surface air temperature, air near the surface, okay. Then, the algebraic sum of the short wave radiation, long wave radiation, outgoing long wave radiation plus sensible heat + latent heat all that put together I gave you 279 watts per meter square is entering on 130 is transpiration evaporation, cooling all that we have done.

At Earth surface is 0, okay, some equilibrium is there, okay, then the globally average net radiation at the top of the atmosphere is also 0, so you can take that these are net radiation TOA, top of atmosphere is also equal to 0, okay. OLA outgoing long wave radiation I showed you that picture know, outgoing long wave radiation, all are in watts per meter square.

Problem #49, if the Earth's atmosphere emitted radiation to space as a blackbody and if it were completely insulated from the underlying surface at what mass average rate will it cool during the night? You understand the question? How much cooling the Earth as a whole will undergo during a 12-hour night, yeah please solve.

So it is Earth's atmosphere, do not find the density of the Earth and this thing it is the rho CP of the atmosphere, do not take 6370 kilometer * 4/3 pi 2 q, do not do all that.

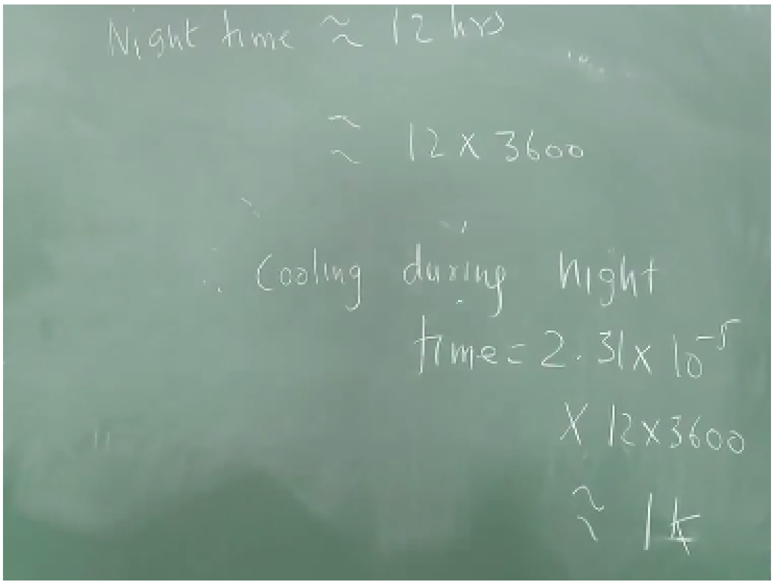
(Refer Slide Time: 15:20)



What is the governing equation? #49, the rate of change of enthalpy of the atmosphere is equal to the energy emitted into the area. So the mass, area * pressure is the force, that is like the weight m * g/g will give m, correct. What is heat capacity of the atmosphere? So with pressure you can solve, you are able to solve with pressure, dT/d tau is pressure * Cp that is okay.

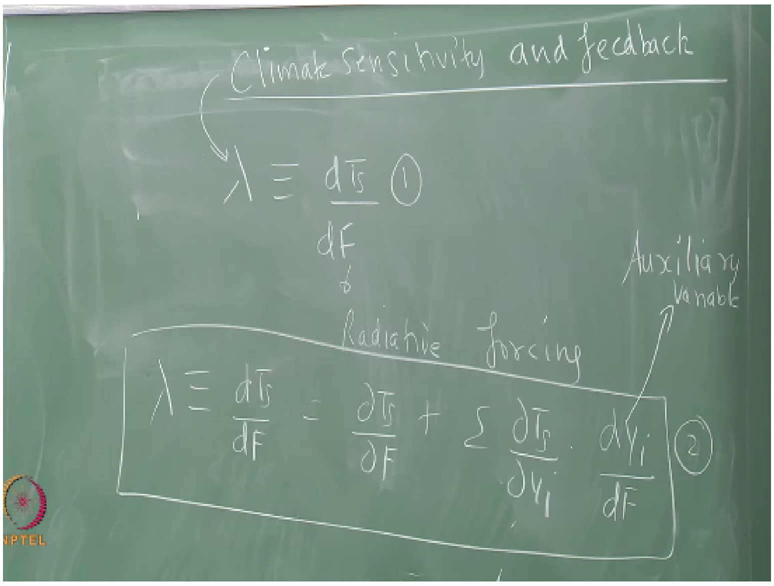
How much is it? No, no sigma T to the power of, 239 * 9.8 * Cp, yeah how much is it, it will be kelvin per second alright. You are not able to comprehend this some value, but hang on you got this, 1 hour is 3600 seconds, the night is 12 hours so multiply by 3600 *12 during night you find out what is the cooling.

(Refer Slide Time: 19:09)



1 kelvin, in the absence of other things like wind and these things so radiative cooling itself is 1 kelvin okay. So next we have to look at climate sensitivity and feedback. The sensitivity of the climate is given by the rate of change of temperature with respect to F, okay, F is basically the radiative forcing.

(Refer Slide Time: 20:00)



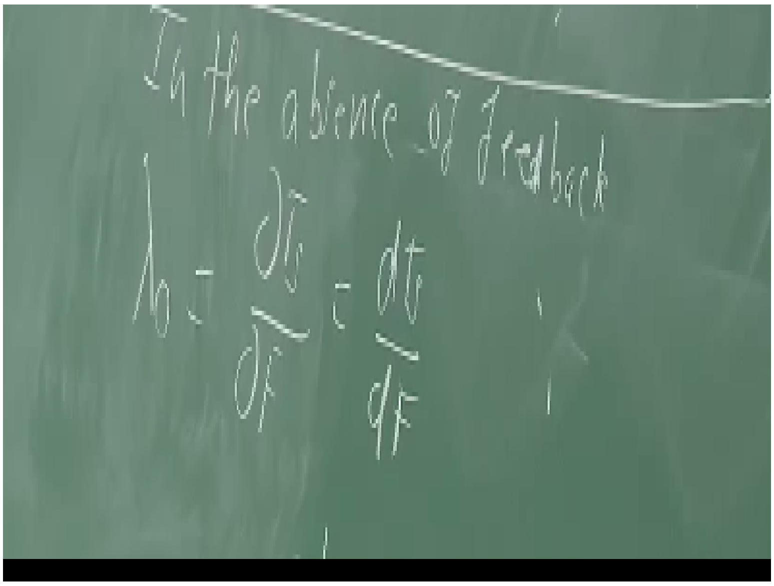
Please take down the definition of radiative forcing: The radiative forcing F is the net downward flux density or irradiance at the top of the atmosphere, net downward at the top of the atmosphere are you getting the point, at the top of the atmosphere it is coming down into the atmosphere, that would result if it were applied instantaneously, okay, so lambda, yah this is a very important relation.

So the climate sensitivity lambda which is the derivative of the temperature, the surface air temperature/dF where F is the radiative forcing can be given as dou T/dou F + sigma dou Ts/dou Yi/dou F, where Y is an auxiliary variable, okay, examples, examples are 1, concentration of water vapour; 2, cloud cover; 3, fraction of Earth's surface covered by snow and ice, okay is that okay; 4, greenhouse gases, you can keep on adding.

What these climate change experts are all doing is they are evaluating all these coefficients, they are evaluating all these partial coefficients and they are adding and saying then they are finally you will arrive at a scary figure for the lambda, lot of research has to go on to get all these factors, okay.

Okay, now in the absence of any feedback, so they are all feedback. If the concentration of water vapour changes, the dy/dF will be nonzero, then you will have to multiply this by what is the rate of change of temperature with respect to i, like that and some have a feedback effect, more water vapour, then this thing something will happen then it will have a, there will be cross correlation between the variables.

(Refer Slide Time: 25:50)

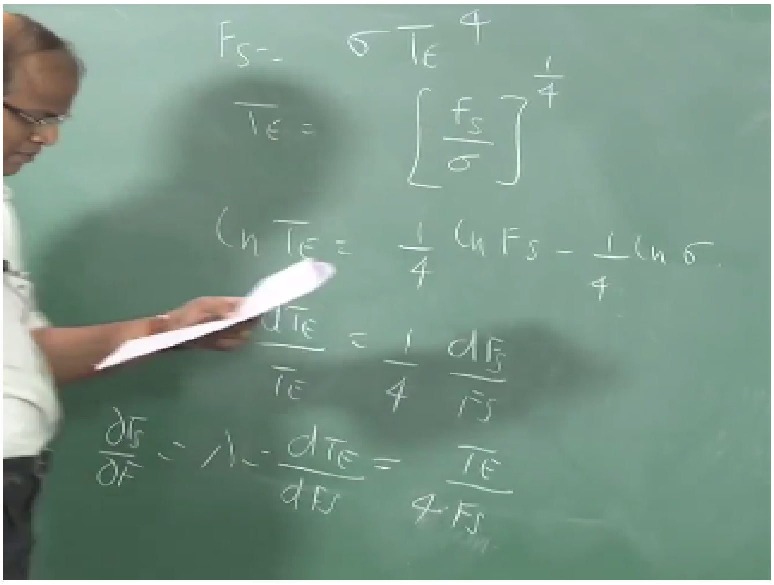


In the absence of feedback lambda not is just the first term, now watch, in the next class, now we will solve a problem and stop in 10 minutes. In the next class what we are going to do is we will take the ratio of lambda/lambda not, what is the sensitivity of the climate if many factors, many auxiliary variables are present divided by lambda not which is the baseline when no feedback is present.

So this lambda/lambda not is called the g which is the gain, just leave a feedback (()) (26:43) I will define it in the next class and the g has a function of these feedback some of these feedbacks and all that whether we go for an infinite sensitivity or 0 sensitivity or moderate sensitivity so that will decide the fate of how stable the Earth's climate is now, it is a control's problem.

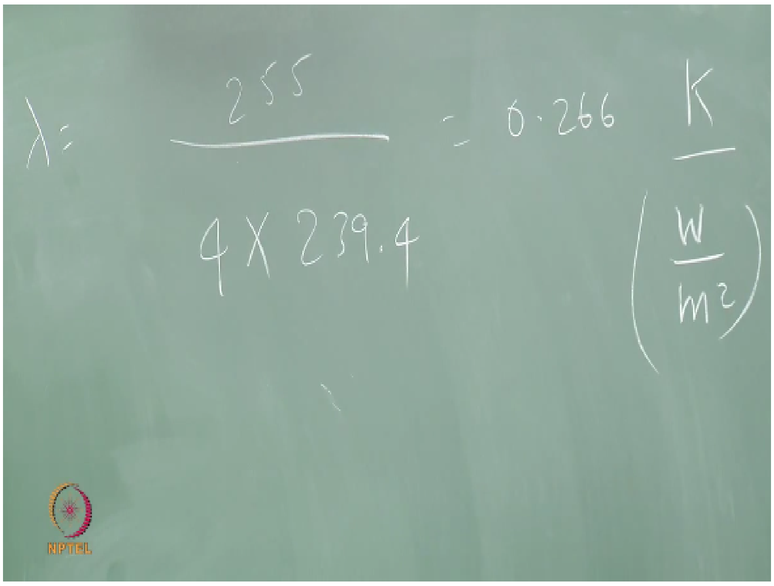
Now so, we can take it as dt equivalent blackbody temperature, we can make that simplification for this assuming there is a blackbody temperature and the TS are related. Problem number #50, half century, okay, very good. Estimate the sensitivity of the Earth's equivalent black body temperature to a change in the solar radiation Fs incident upon the top of the atmosphere.

(Refer Slide Time: 28:40)



Okay, let us do this, in the interest of time I will start working out. Correct the solar flux density = sigma T to the power of 4, **"Professor - student conversation starts"** yeah, equivalent black body temperature of the Earth, we are working out problems with that right, last problem also with that only we took 239, okay, **"Professor - student conversation ends"**

(Refer Slide Time: 30:12)



Okay, what is the lambda now? 255, what if Fs 239.4, in simple English, if the solar forcing changes from 239.4 to 240.4 the Earth's temperature will change by 0.266 kelvin in simple English, if the solar flux Fs changes from 239.4 to 240.4 the Earth's temperature will increase by 0.266.

What is interesting is the reciprocal of this, to have a 1 kelvin change in the temperature of the equivalent blackbody temperature of the Earth 1/0.266 that is 3.76 watts per meter square of forcing is required to change the Earth equivalent blackbody temperature by 1 kelvin, so they are always looking at this, climatologist are always, climate change experts are always looking at, scientists are looking at this F.

2 watt per meter square, 1 watt per meter square, 0.5 watt per meter square they will put sigma of all this and then say it is 3, 4, 5, 6. If it is 3.76 watts per meter square then it will change the equivalent blackbody temperature of the Earth by 1 kelvin, okay you can write down this, the Earth's equivalent blackbody temperature with that we close.

The Earth's equivalent blackbody temperature rises by about 1 kelvin for every 3.76 watts per meter square of downward radiative forcing at the top of the atmosphere, but I want to emphasize it is a downward at the top okay. So we will take attendance today 2 classes, we will meet on Tuesday, so we will continue with the climate change, climate change we will finish.

We will solve 1 or 2 more problems, feedback and all that, ocean how it changes, that is on Tuesday, Thursday and Friday very quickly we will look at atmospheric dynamics. I will teach you cyclone approximation and geostrophic approximation, how to calculate the maximum velocity inside a cyclone if you know the pressure feed, that simple problem we will solve.