The Monsoon and Its Variability
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Lecture - 42
Concluding Remarks

Now, we come to the end of this series of lectures on monsoon and its variability. I began this lecture series with a discussion of what the monsoon means

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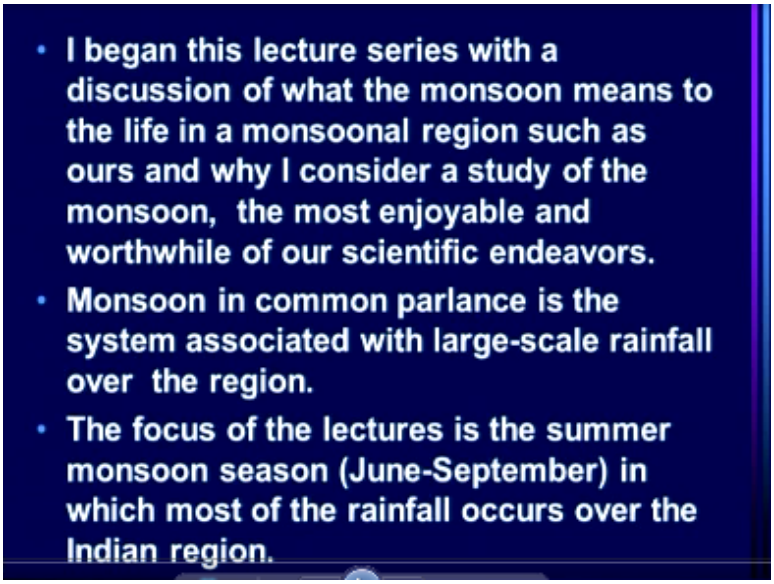

To the life in the monsoonal region such as ours and why I consider a study of the monsoon the most enjoyable and worthwhile of us scientific endeavors. Monsoon in common parlance is the system associated with large-scale rainfall over the region the focus of the lectures is the summer monsoon season June to September in which most of the rainfall occurs over the Indian region.

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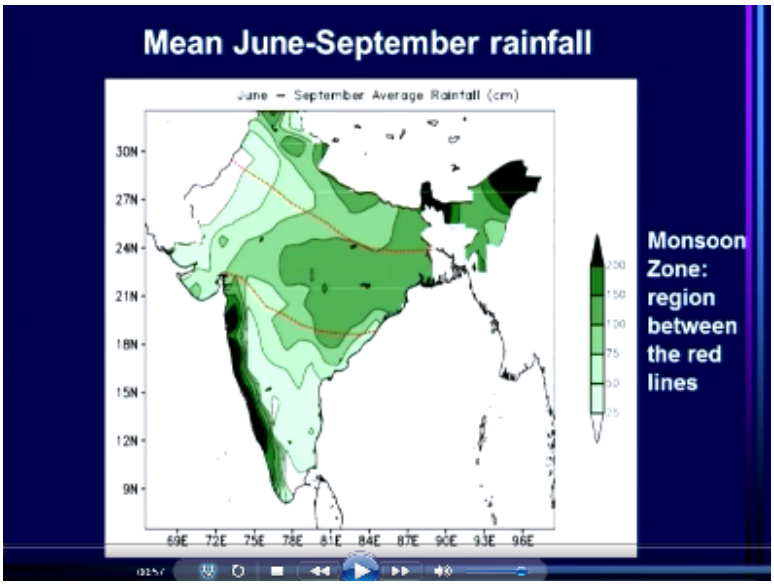

And this is the pattern of rainfall with the near the region and this is the monsoon shown where the large-scale system a monsoon system gives rainfall during the season this is of course the west coast associated with geography and north east also.

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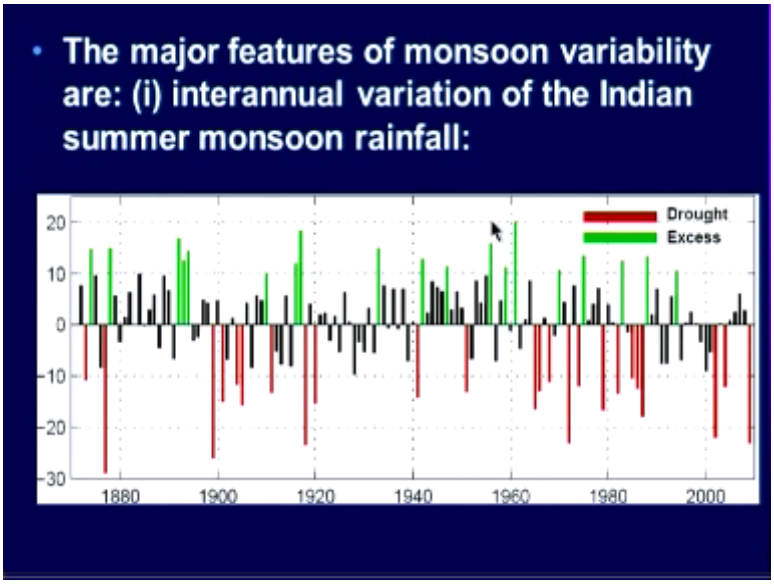

Now, the major features of monsoon variability are interring annual variation of the Indian summer monsoon rainfall you see we have a great deal of data 1876 till present and this is the nature of inter annual variability with droughts and excess monsoon years occurring with differing frequencies in the decades, so this is a major feature of monsoon variability.

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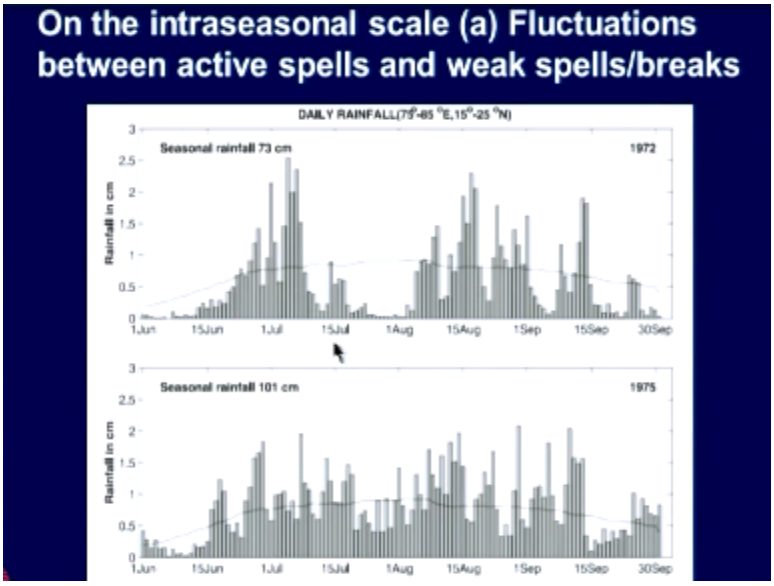

That we have looked at on the inter annual scale on intra seasonal scale new special features are one is fluctuations between active spells and weak spells which we you see year after year and active spells on a break such as one you see here. So, fluctuation between active and weak spell is another important feature of the seasonal or intra seasonal variation of the monsoon.

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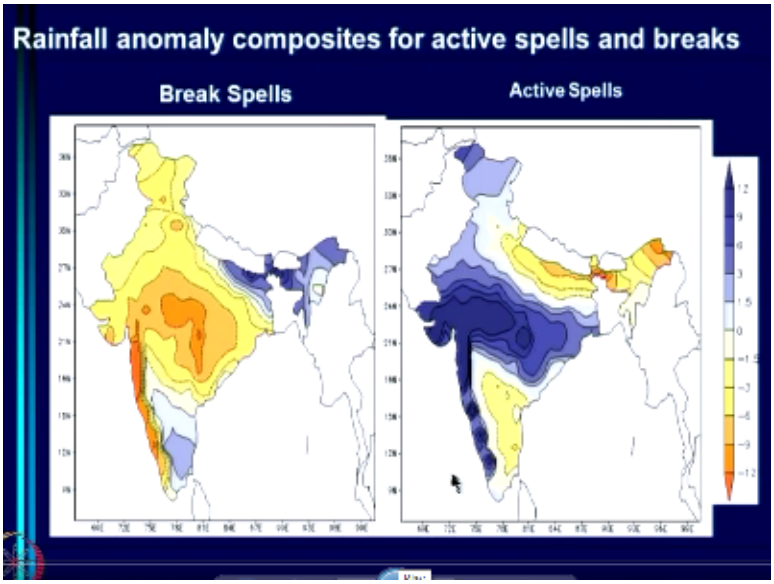

This is the rainfall anomaly composite corresponding to a break spell you see rainfall is huge deficit all over here and is above normal over the southern tip of the peninsula and Northeast Himalayan foot hills. This is the active spells rainfall anomaly which is almost a mirror image of the breaks.

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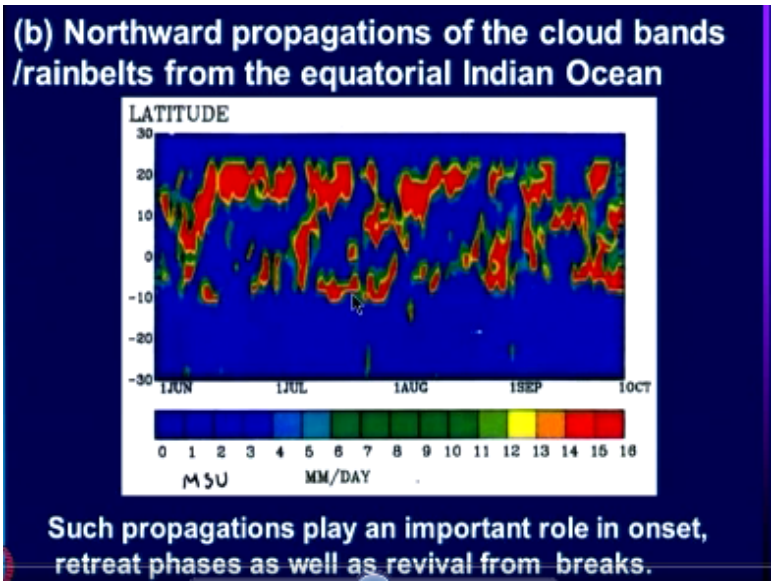

Another important feature that we looked at on the sub seasonal scale is the northward propagation of cloud bands or rain belts emanating from the equatorial Indian Ocean and moving propagating northward up to the monsoon June. Now, these propagations play a very important role we have seen in the seasonal transitions that is the onset phase from spring to summer as well as the retreat phase from summer to fall.

In fact, they also play a very important role within the season after the system is established over the monsoon zone in revival from the breaks.

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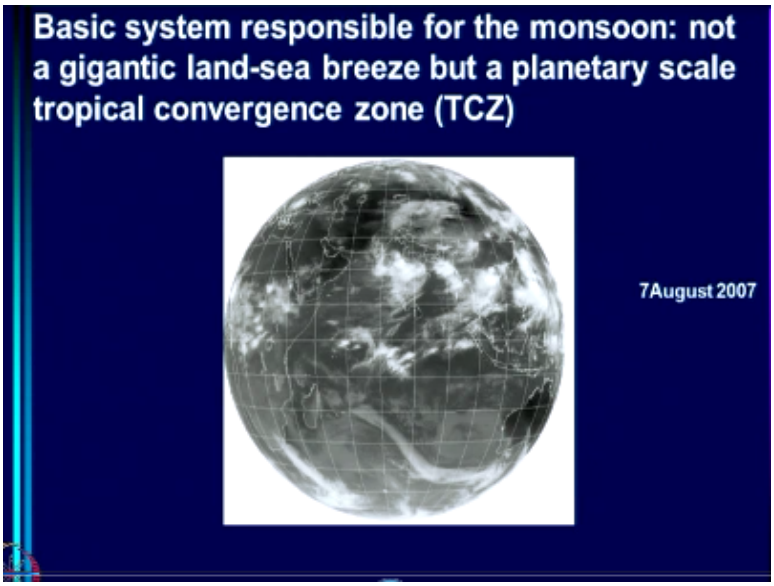

Now, this is so for is the major features of variability that we want to understand model and

predict one of the things I covered at considerable length in this lecture series was what is the basic system responsible for the monsoon because this is something that we are taught from high school onwards. And what we are taught is unfortunately not the right model we are taught that the monsoon is a gigantic land-sea breeze.

But I have shown here in these lectures that it is in fact the monsoon the large-scale monsoon rainfall is associated with a planetary scale system you see this is the cloud band associated with a tropical convergence zone which is stretching across the monsoon zone over India and continues across up to the west pacific. So, this is monsoon is associated with the seasonal migration of tropical convergence zone which is a planetary scale system.

And it is not a local response to land-sea contrast the fact that this region is hotter than ocean will make a difference to the amplitude of the seasonal migration, but the basic system is not a land-sea breeze the basic system is a system which gives rainfall all over the tropics, so this is an important thing that we learn to during the course of these lectures.

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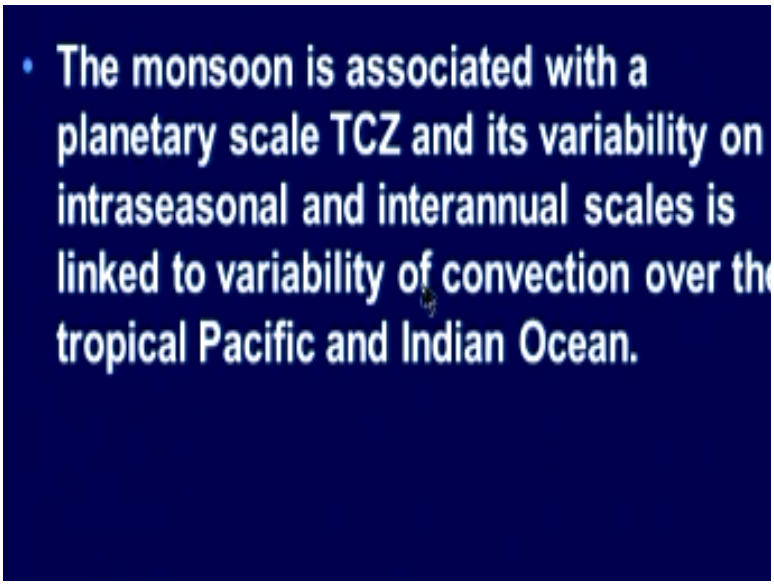

That the mountain is associated with the planetary scale the TCZ and its variability on intra seasonal and inter annual scales is linked to the variability of convection over the tropical and Pacific and Indian ocean. You already saw in that picture that in fact the monsoon is not restricted the system is by no means restricted to the Indian longitude it extends all over here and

we have also seen that it has links with the surrounding seas.

Because almost all the systems that give us rain are generated over here here or over the equatorial Indian ocean. So, there are links obviously the variability of intra seasonal and inter annual scales of the Indian monsoon is linked to variability of convection over the tropical Pacific and Indian ocean.

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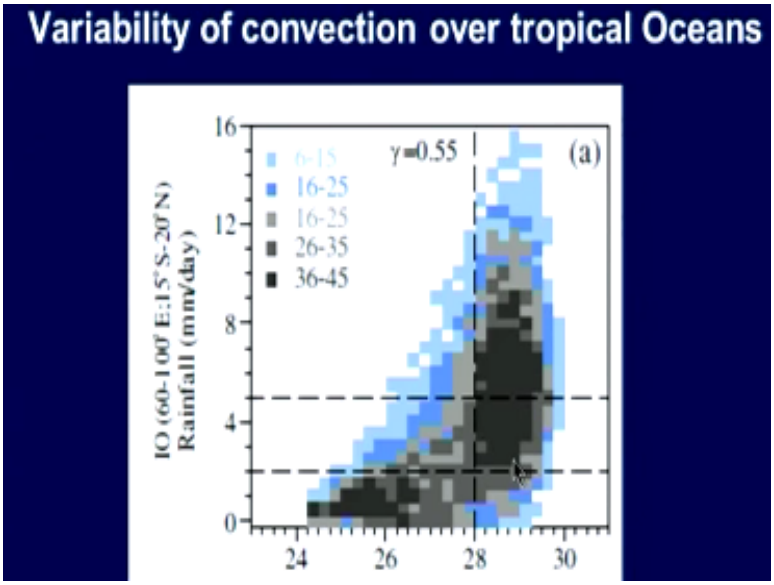

Now, that brought us to the question of what is the variability of convection governed but everybody knows that the sea surface temperature is a very critical parameter of the ocean as far as clouding or convection over the oceans is concerned. This is because the surface temperature dip determines how much water vapor is in the air near the surface of the ocean now an interesting result that we discussed in this lecture series was that.

In fact, the relationship between rainfall and sea surface temperature is highly nonlinear rainfall tends to be suppressed below a threshold and above a threshold there is a large variation in rainfall for a given SST range given little relationship between the rainfall and the SST. So, this is the particular relationship and we saw which is actually valid over the global tropics and we saw the implications of this for the seasonal migration of the intertropical convergence zone over Pacific Atlantic and so on and thereby finally determine the monsoonal regions of the world.

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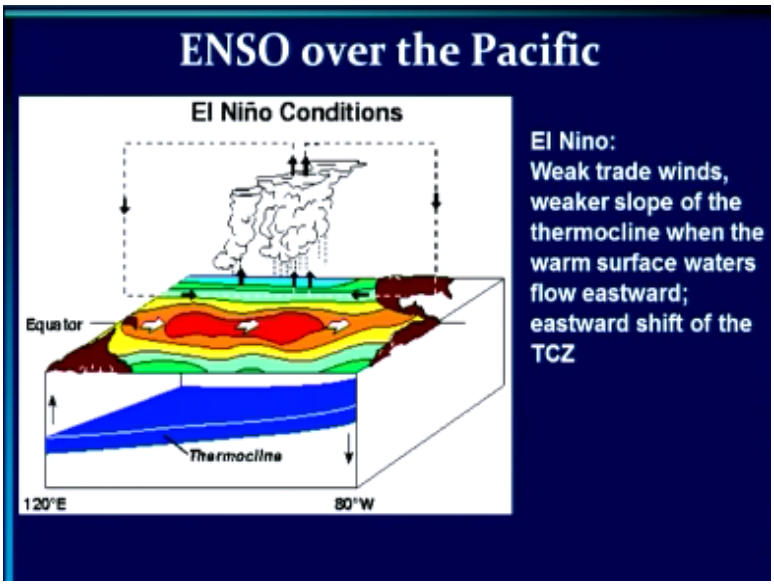

We discussed another important phenomenon which is El Nino southern oscillation for 2 reasons it is of the most energetic element of the variability of the tropical atmosphere over the Pacific, and secondly it is something about which there has been a phenomenal gain in understanding modeling and prediction from about the 90 onwards so this is why I dealt at considerable length on how this came about.

How this revolution in understating ENSO came up above and that was one reason is to try and take lessons from you know how progress was made in understanding of ENSO to try and understand. How we will go further in our understanding of the monsoon itself the second reason is ENSO is known to be linked to monsoon, so these were the 2 reasons for dwelling at length on ENSO and this is the EL Nino as you see this is one phase of ENSO.

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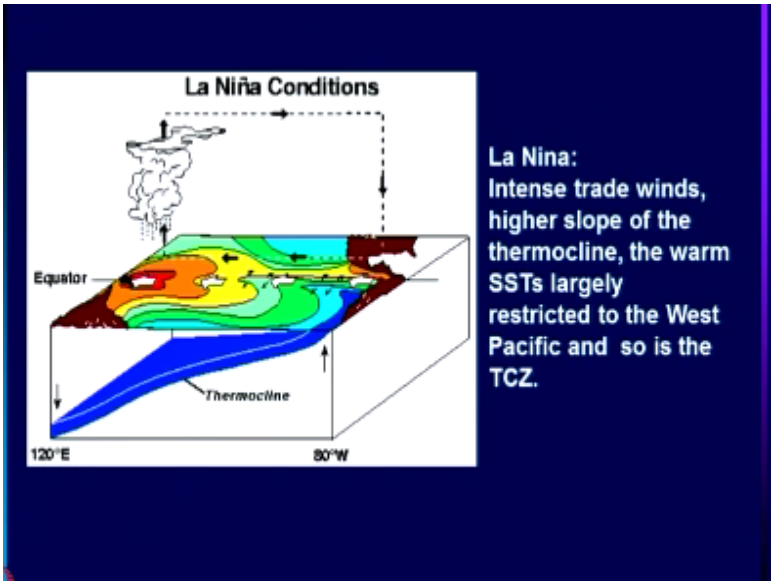

And this is La Nina where the cloud system is located over West Pacific in El Nino it stretches right across the Central Pacific and La Nina corresponds to the warming of the equatorial belt El Nino corresponds to warming of the equatorial belt La Nina implies cooling here more than average and warming here okay.

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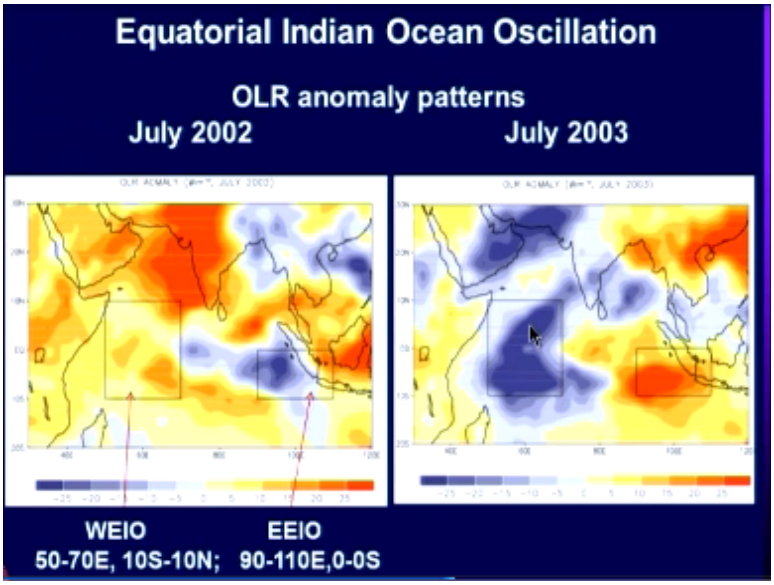

There is another interesting phenomenon we looked at and which was the Equatorial Indian ocean oscillation if you look at the outgoing long wave radiation anomaly patterns. You see that often there is a seesaw in convection between the East equatorial Indian ocean and West equatorial Indian ocean for example in this year there is excessive convection over EEIO suppressed convection over WEIO.

Opposite is the case in here where we have excess convection over WEIO and suppressed over EEIO this phenomena oscillation is known as the equatorial Indian ocean oscillation.

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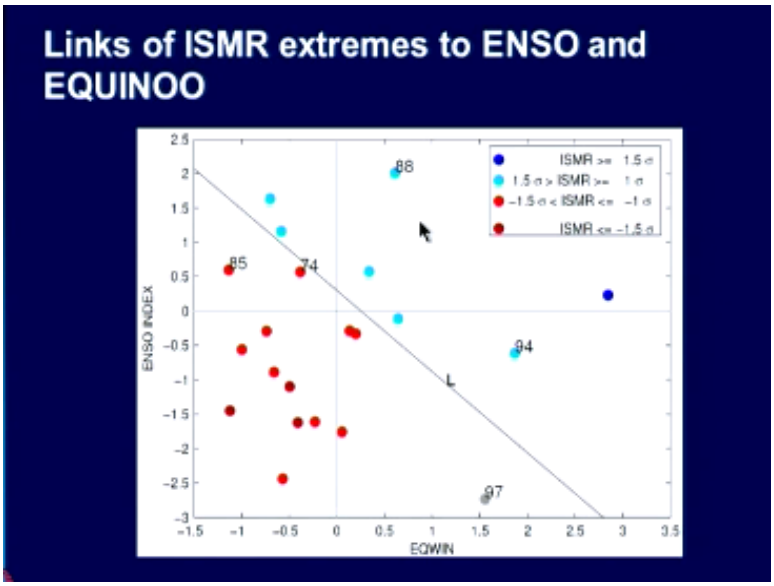

And we showed that in fact it is true that most importantly link of ISMR or Indian summer monsoon rainfall is to ENSO, but it is also linked to EQUINOO equatorial Indian ocean oscillation and if we take in ISMR of these 2 phenomena in fact and plot all the extremes of ISMR all the droughts and excess rainfall season then you see a very clean separation between dots and excess rainfall season.

And this is a very surprising result it seems to say that extremes of such a complex system are mainly governed by 2 modes EQUINOO and ENSO, but this understanding also then again lead us into some ideas as to how to predict monsoon extremes with models now why are the extremes important.

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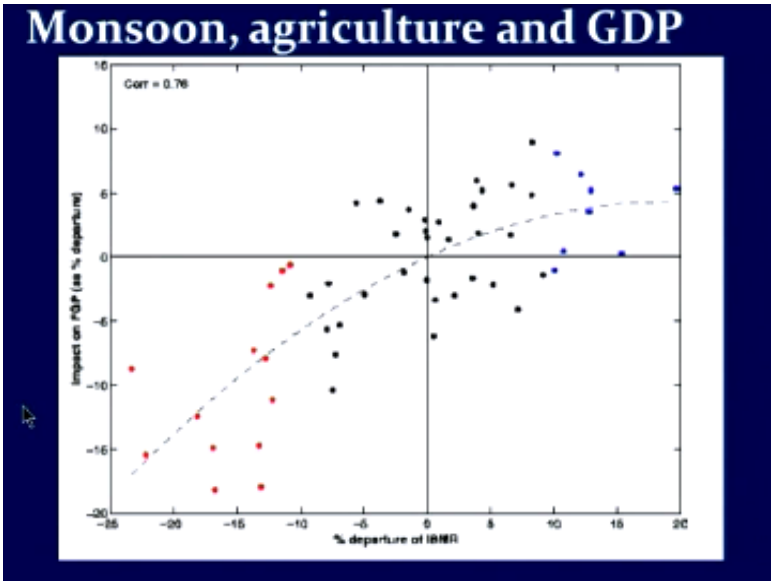

I talked as I said at length about monsoon variability in agriculture and I also gave one lecture on monsoon agriculture in GDP. The result of that study which was a quantitative assessment of the impact of monsoon and agriculture and GDP was as follows this is the food grain production the impact on food grain production and rainfall anomaly. And what you see is that the relationship is highly non-linear that if you have a ISMR anomaly of a given magnitude say -10.

Okay, you will get a large deficit of food grain production but the positive anomaly of the same magnitude +10 does not really give as large an advantage of having more rain as the disadvantage of having less rain. So, it is a highly nonlinear thing, and this is for food grain production but the same relationship for GDP as well now in fact where we showed in that lecture that this kind of you know farmer not being able to reap benefit of good monsoon years.

But suffering the loss due to poor monsoon years this is asymmetry can be to some extent mitigated if prediction of extremes is available.

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- Asymmetry in response; larger amplitude for deficit ISMR than for positive ISMR anomaly:
- To rectify-need predictions of extremes.
- How good are the predictions of extremes with state of art coupled models?
- They are reasonable, but not good enough.
- Should get there in the next few years

So, this leads us to the importance of prediction of extremes this imagery asymmetry in response as I mentioned larger amplitude for deficit ISMR than for positive ISMR anomaly to rectify we need prediction of extremes. So, that got us to the question how good are the predictions of extremes with state of art coupled models now we find that there are reasonable but not good enough.

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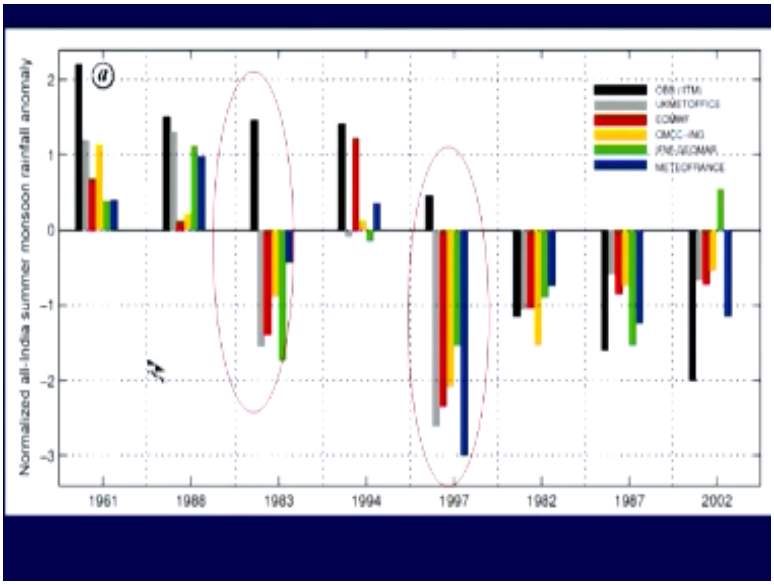

So, in fact this is an example of a state of the art couple models in the European community and black is the observed and rest are different models, and these are the different extremes 61 was a very large excess year and 88 and so on and so forth. We show in the showed in that lecture that vast majority of the extremes are now simulated by the model simulated in the sense at least they

are getting the sign of the ISMR anomaly right.

But there are 2 years 83 and 97 in which all the models are giving huge false alarms they are predicting droughts for 83 several of the models and all the models are predicting deficits when actually it was in excess monsoon year for 97 which was a strong EL Nino year all the models are predicting droughts whereas it turned out to be about normal, so these are 2 years in which things went wrong.

And then we discussed why they went wrong and diagnose the problem that the problem had to do with the models not being able to simulate the link with EQUINOO although they simulated well the link with ENSO So, given that kind of an analysis we came to the conclusion that if now we pursue this path of trying to fix where all models irrespective of their parametrization terms and scheme their numerical schemes.

And so, on are going wrong if we can fix those years then the performance of the model will indeed improve, and our hope was that we will get there in a few years.

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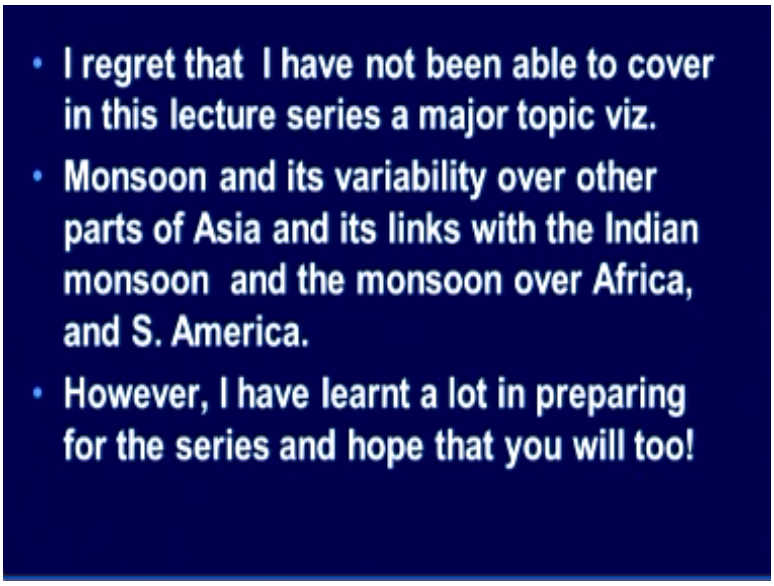

So, this is a very brief summary of the kind of things that I have covered in the lectures in the beginning I thought 40 lectures would be a lot of lectures and I should be able to cover most of the important facets but at the end I find that I regret that I have not been able to cover one major

topic in this lecture series namely I have not been although I did spend some time in defining the monsoonal regions of the world and so on.

I have not had a chance to discuss monsoon and its variability over the other parts of Asia or the Asian monsoon and its links with the Indian monsoon this is a very important topic I also could not cover the monsoon over Africa, South America and so on. So, this will have to be left as it is but on the whole, I am pretty satisfied with what I have been able to cover, and I have learnt a lot in preparing for this lecture series and very much hope that you will also learn something from me. Thank you.