Remote Sensing and GIS for Rural Development
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Lecture 44
Remote Sensing for irrigation assessments

Hello everyone. Welcome to the NPTEL course on Remote Sensing and GIS for Rural Development. This is week 9, lecture 4. In this particular lecture series, we are looking at remote sensing tools that aid us in assessing the changes to the land and groundwater which affect rural development. There are multiple satellites and images that are available for terrestrial change assessment, but when it comes to groundwater, there is only a few. So, in the last lecture, especially we looked at, India has been the highest groundwater extractor in the world, followed by US and China.

But, if you put the water extractions of US and China together, still India's budget is much, much more. So, approximately 220 kilometer cube per year extraction or billion cubic meter per year extraction of the second and third place which is US and China together, whereas India is 245 kilometer cube or billion cubic meters. This is very unsustainable given the size of India and the size of US and China put together.

So, if we continue to access such water, there will be drastic impact on rural development, starting from drinking water, where people are forced to drink polluted water which is polluted by anthropogenic or geogenic contaminations. This is above and beyond the course, so I will just stop here on the water quality part. But quantity is very important. A lot of wells are drying up in India and people have to walk farther away from the wells to identify new water resources for extraction. This is highly unsustainable in a developing scenario. And even though the government takes multiple steps, we need to do our part in managing water resources for rural development.

So, on that note, we looked at water budgets across the world and we found Asia region has the highest groundwater extraction. And then we said, let us look at the data issues. So, groundwater data issues are tremendously high. We need to focus on methodologies to monitor groundwater leading to sustainable use of groundwater. Of that, there are data issues. So, we said, okay, let us look at some remote sensing satellites that can aid and only one satellite is available, which is the GRACE.

So, in today's lecture, we will look at in detail what is the GRACE satellite, why is there a big information around it, and what can be understood by the GRACE data mission.

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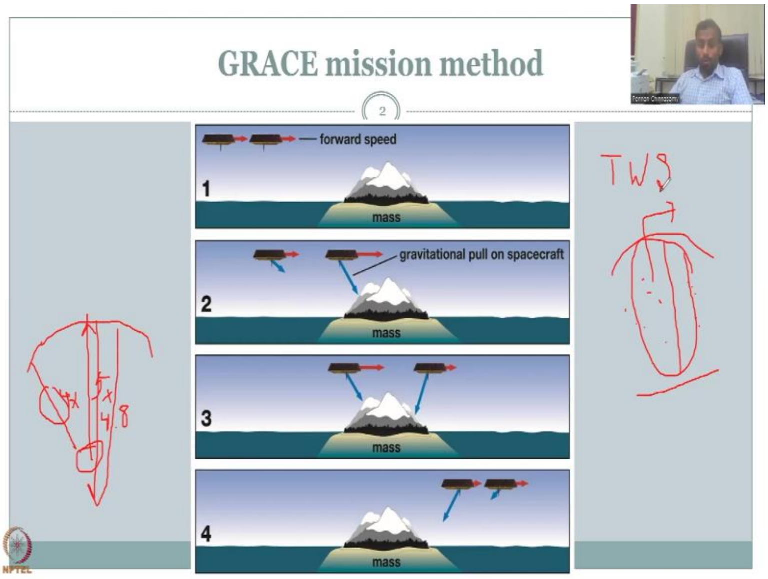

So, without further ado, let me start the GRACE mission method and then we will go into some results, etcetera. I will also share results from my previous studies as an attachment in this, one of the weeks, we will have only case studies using the datasets that we have looked upon in this lecture. So, here is the GRACE satellite. As I said, unlike other missions, the GRACE satellite has two satellites together. The mission has two satellites. And very humorously, it is named Tom and Jerry.

I hope everyone knows the cartoon Tom and Jerry. Jerry runs, Tom catches. Jerry is the mouse, Tom is the cat. So, this cartoon is a very big hit from my days also. So, a lot of people watch this cartoon and the basic simple hypothesis is the mouse runs, Tom follows and catches. So, that is the name given. So, we have Jerry in the front and Tom catching. There are multiple sensors in both these two missions. But the most important aspect about GRACE is that it is not very complicated instruments in the machine, in the satellite.

It is a very, very highly sophisticated accelerometer. What is an accelerometer? It measures the speed, change in speed and acceleration. So, that is all we have for GRACE. So, first, let us look at how satellites move around the globe. So, once a rocket takes a satellite and launches it in space, then due to the gravitational pull of the planet, the satellite gets slowly placed in orbit and then a small push is given. The centrifugal force keeps it rotating with momentum, with a constant momentum and it goes around the planet.

And one thing which is very smartly understood by the GRACE team is that the gravitational force acting on the satellite is not the same. For example, we have, some satellites are very sensitive to this gravitational force. So, that is why this mission is called Gravity Recovery and Climate Experiment. So, using gravity, how do you assess climate parameters in a very, very sophisticated way? It is very, very advanced technology, very smartly done.

It is very different from other satellites. There is no image that is taken and then produced. It is mostly every pixel, at every pixel, it is monitoring the change in mass. So, let us come back. So, this is your globe. In the globe, around the globe, the satellite goes up because of the gravitational force. And we know that the mass is not distributed across the planet evenly. For example, let me put my pointer.

So, the mass here is not the same as the mass here, because here is water, here is land. And within the land, this peak has higher mass and then the next land, this part has lower mass. So, the point is at every grid in the planet, the mass is not the same. So, if the mass is not the same, gravity is due, the gravitational force is because of the mass. So, if the mass changes, the gravitational pull also should change. Let us say this is the surface. So, it is not even surface, it is bumpy and then goes up.

So, when the satellite comes or it sees a bigger mass, it gets pulled. When it gets pulled, it moves faster on the orbit and then it goes slows down, because here it is smooth, it is almost the same mass, so it slows down. And then when it sees another big mass, it goes faster. So, this is where we need to be careful about using the gravitational force of GRACE satellite mission. So, what happens here is the planet is not having the same mass and because of the change in planet mass, the gravitational pull on the spacecraft is changing.

So, both of them go equally in a forward speed. So, this is Jerry, it runs in front because of the gravitational pull, whereas Tom only is pulled by this satellite. So, it wants to maintain a constant distance, that red arrow mark is a constant distance. So, when the satellite moves and then it sees a big gravitational mass pulling, so it gets pulled. So, you can see that Jerry is accelerating. So, this satellite accelerates in the front and then the second satellite, Tom says, Jerry is moving the front, let me catch him.

So, this also accelerates and tries to maintain the same distance that initially was there, the same distance. So, it quickly goes and then comes back. It also gets affected by this gravity, but fine, it wants to maintain that distance. So, while this is moving on the influence of gravity, this Tom monitors the acceleration and deacceleration of Jerry and that is converted to a gravity, a mass. So, now if we know the mass change, so every time let me draw it. So, every time it goes along the surface, so this is the surface and this is the core of the earth.

So, we have all this is lithosphere and until the lithosphere, the satellite says, okay, this is the mass here. Let us say this is 5 units, whatever x is, and then here it is less mass, 4x. So, now, the satellite goes slower here and faster here. So, this is how it accelerates and deaccelerates and then that acceleration is used to find the mass under the surface. So, this is fine, but people can ask, so where is the water part? You said mass, mass is fine, but where is the water part or where does the snow melt that is being reported by GRACE and or a lot of other data sources are reported by GRACE, like groundwater, soil moisture, et cetera. How is this done?

This is done on a very simple aspect that when you take the earth's surface one time, you get the mass. When you come in the next month, it takes a month for a satellite to come back to the same location. Then you have a reading, let us say you take in May and June. So, May you come, this is 5x. And then you come in June, this is 5, let us say 4.8, 4.8x in June. So, now what has happened is 0.2x has been reduced. And this change in a particular area cannot happen over anything else because the area is big, 100 kilometers.

So, if you have to affect gravity at that mass, it is not like a tree falling down, the mass changes, no. It is something big that should affect the mass. And the only thing that can affect the mass on a monthly scale is water. So, this is the very simple hypothesis that the NASA team with their collaborators found out saying that between months, the only thing that could change in the gravity field, in the mass field is the mass of water.

The mass of water could be snow, the mass of water can be glaciers, groundwater, anything, but mass of water. The other aspects like dams and stuff are small compared to how many dams, every pixel does not have a dam. So, it is about mass of water, so even the same ocean. So, there is two products for GRACE, one is land and water. So, you have not all the parts of the ocean in the same depths.

For example, the Mariana Trench is the deepest, it goes very, very deep. So, if it is going very deep, then there is a big mass of water on top. So, that mass pulls, whereas here, there is less water, it pulls less. So, this is a very smart way of getting at GRACE. And what happens is, every month, the satellite goes and the change, the change in mass, which is found out by the gravity pull, and how the satellite is moving, is converted to a water mass change. So, it is called terrestrial water storage, and change in terrestrial water storage.

So, at the end of the day, what GRACE gives you is TWS, which is terrestrial water storage in equal in water thickness, centimeters, that is the unit, okay, so it is in centimeters, but a thickness. So, for example, you have the mass here, a land, okay. And there is porous space, there is space here where water is stored. Now, if you remove the water using groundwater pump, then what happens? The weight of this land parcel changes, the height may be same, but the weight changes because now instead of water, there is air, air does not have very much mass, it is negligible.

So, water has mass. So, now this water is being taken out. And that is where the change between months is calculated as TWS, TWS, as terrestrial water storage. And from this, you can get groundwater, I will write the equation later, a very, very simple equation. And you could get groundwater thickness as a thickness and from there, you can also get groundwater levels. Those are more advanced level thinking. But terrestrial water storage is very important.

So, whatever water is stored from here, from the surface to the ground is called terrestrial water storage. It can include your lakes, your ponds, your dam water, etc. But most, as I said, not all pixels have lakes, dams and ponds. So, most of the time, it is groundwater that is changing. Groundwater plus soil moisture. So, if you remove the soil moisture and the dam water out, then you get change in groundwater storage. There is a lot of papers on this. The very, very famous ones are Nature by Rodell et al.

And that is where I picked up this particular satellite and started working and writing a lot of research articles on this satellite. It is a very, very important satellite for India, because the data, the aquifer mapping, everything that is going on consumes a lot of time and money. Whereas this is open source, you can quickly understand the principle, which is what I explained, and look at the data for groundwater estimation. So, basically, what I am saying is here that the mass is taken and the change is every month if you come in, so every time, every time the satellite pair goes, it gets pulled differently by these two masses.

So, there is acceleration, deacceleration. So, this change in acceleration, deacceleration by Jerry is monitored by Tom, that is a very, very fine, very accurate, precise accelerometer. That is all it is. An accelerometer quickly accelerates and monitors the acceleration. And that is converted to gravity and gravity is because of mass. So, now if it comes every month, so this is May and then June, now there could be some snow melted. And so, what happens is the gravity is not the same as May month.

And so, it moves a little bit slower than May. So, this change is attributed back. So, the gravity acceleration is converted to a mass equivalent. And the mass equivalent is nothing else but water because on a snow cap, this is land snow, this is the mountains and the hills, and then you have snow on the top, right? So, only the snow will change because the land is same. So, if you subtract, what happens is the land mass goes away, and only the snow part is taken in for consideration. So, this is what we will be using in explaining these data sets.

When we visualize it , you will get more information about it. So, what happens later is then there is a pre-processing of the data, which is cleaning and making sure data is correct by the JPL and NASA, Colorado team, JFC team in Germany; then what they do is they add some correction algorithms to convert it into a water thickness, terrestrial water thickness. And then they add scaling solutions and some other solutions to make it very robust.

The resolution is a bit coarse, coarse means very, very large. So, it is 100 by 100 kilometers around the equator, which is where India is there. So, it is not as useful as a plot scale analysis. But given that it is monthly, it is the only data for India that can do monthly and assess both the surface water changes, the shallow groundwater and the deep aquifers. Right now, the shallow and the deep aquifers are kind of disconnected.

When you see block estimations, you do not see a block estimation for shallow and deep, it is clubbed together. So, that is kind of tricky to understand what is happening. But here, this satellite, especially this satellite data can capture the change between the deep aquifer and the shallow aquifer using some data. So, now we do not want to use this just as a standalone, because of the resolution size, the pixel size is too big. So, for example, as I said, you have only one hectare per farm farmer, and 100 by 100 kilometers is too big, sometimes even a district does not come under 100 by 100 kilometers, you will be seeing the resolutions pretty soon when I open it up.

So, in that case, what do you have to do is, you will have to merge this data with some observation data and make a new product. And that is what we will be recommending for future researchers and scientists that just NASA's GRACE data may not capture the variability in the ground as a satellite mission. But if you mix it with observation data, it is the best data. And this is true for almost all remote sensing data. If you add this with observation data, we call it data augmentation, then our value addition for data, then the product is really, really a hybrid product, which is very good for management.

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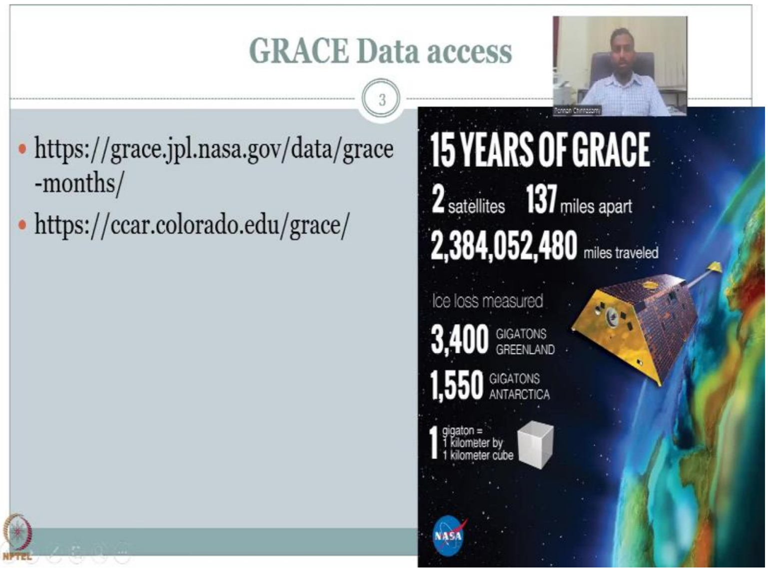

So, let us move on to see what has GRACE data been doing over the past few years. 2002, it started, now is 20 years, there was a little bit gap in between, because not 5 years, this image might be a little bit old. But there is a lot of credit for this satellite, this special mission, which I know very, very closely, I work with this data a lot. And it astonishes me how it captures the data and almost accurate when we do some calculations, which I will show in the later versions. So, there are two satellites, one that is 7 miles apart, almost 2 billion miles traveled, it is a lot of distance traveled.

It measures the ice loss in the Greenland areas. It was one of the first satellites that captured the Greenland loss of ice, just an image cannot see, an image is only qualitative. An image will show, oh, there is ice, and now there is no ice, but how much was lost? The thickness of ice lost cannot be measured, only the satellite can measure. So, that is what this was done. And it also measured how much loss in gigatons, 1,550 gigatons in Antarctic.

So, also the most inaccessible locations where observation data may not be available, this satellite can take it. And if we know that the satellite is accurate at 80 to 90 percent along the equator, along the northern America regions, then it should be also the same for the Arctic regions also. So, the Antarctic is 1,550 gigatons is lost ice, whereas in Greenland, 3,400 gigatons of ice is lost.

So, this is where when the ice melts, then it goes into the seas and oceans and the ocean level rises. When the ocean level rises, the coastal communities are getting affected. And the key coastal communities are the rural communities. Almost all communities are rural communities, except if you are in cities like Mumbai, Chennai, where there is a coastal component. But it is only very small, very small city compared to rural coverage of coastal areas.

So, moving on, I will open some links to show you how this data is available. So, let me open this particular link in a minute. So, you will see that the first link will open the data for the GRACE data months.

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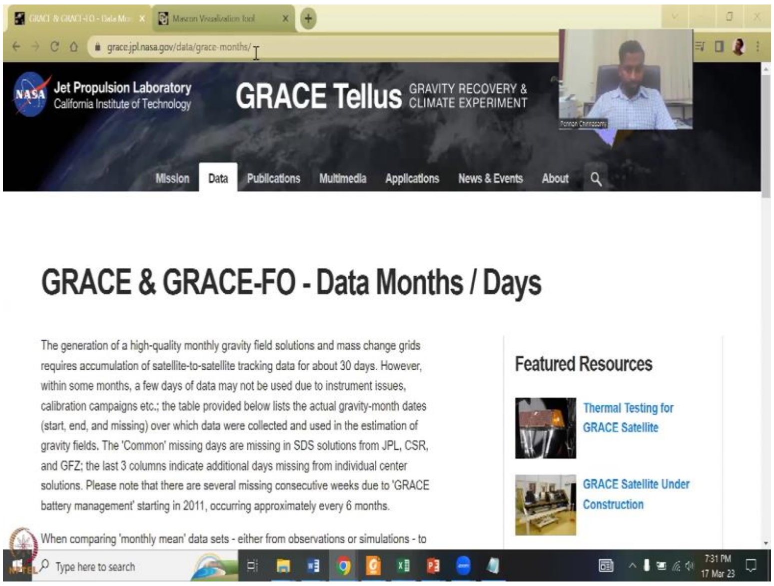

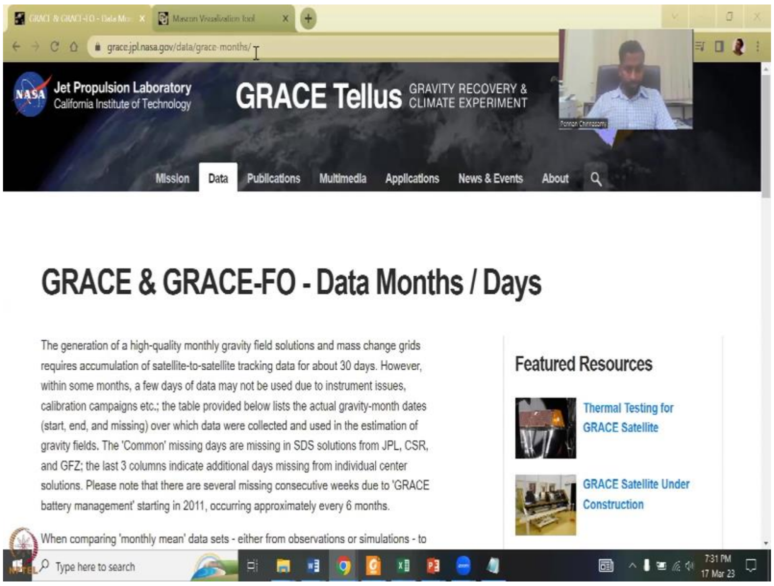

It will tell you when the months, which months' data is available. And also you will be able to and also you will be able to look at the first link I have clicked and then it looks into data months, which are the months that the data is available, which months are not available, etc. And also, you could look at where the studies are done. As I said, NASA finds new ways to monitor water loss missions at 20 years, what is the mission being doing? And there is a lot of metadata that has been done.

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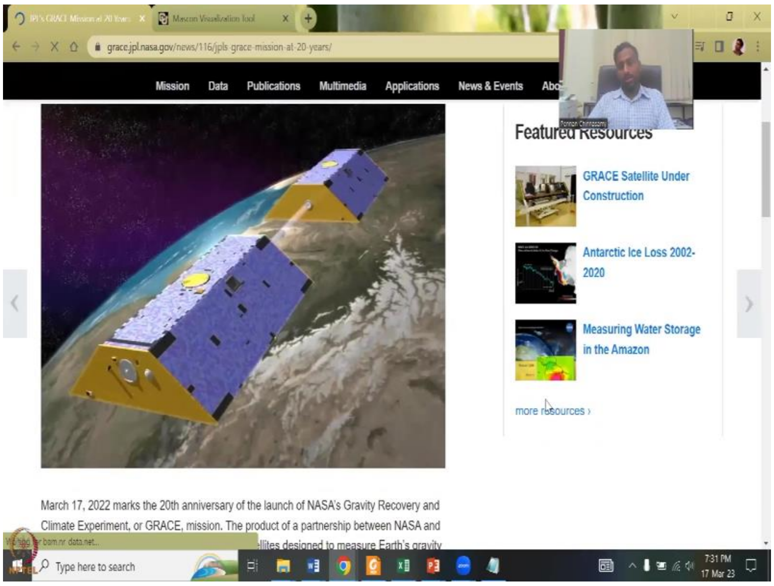

So, now the second mission is there. The first mission was from 2002 to 2016. And then there was a gap. And then another satellite was launched. While the satellite is in the last phase, so normally a satellite runs 15 years or something. So, while the last phase is being there, then NASA funds a new satellite, the same satellite with advanced features, and then they send it out. So, there is a GRACE satellite and a GRACE follow up on satellite mission. So, that is what we have.

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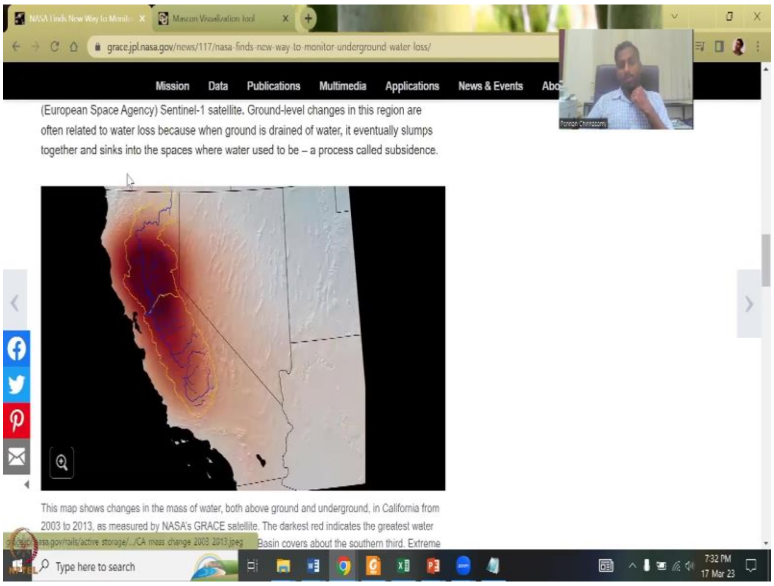

You can see that the groundwater monitoring has been very, very successful using this satellite. This is the California part where a lot of groundwater is being depleted due to growing of almonds and orchards. So, these are very, very interesting information and data that cannot be accessed in normal scenarios. So, we will have to be very careful in assessing these data and using them for a particular application. So, this is where we will be looking at in detail.

As I promised, I will show one study which was very, very important to sensitize GRACE data. So, it was the NASA satellite data for India.

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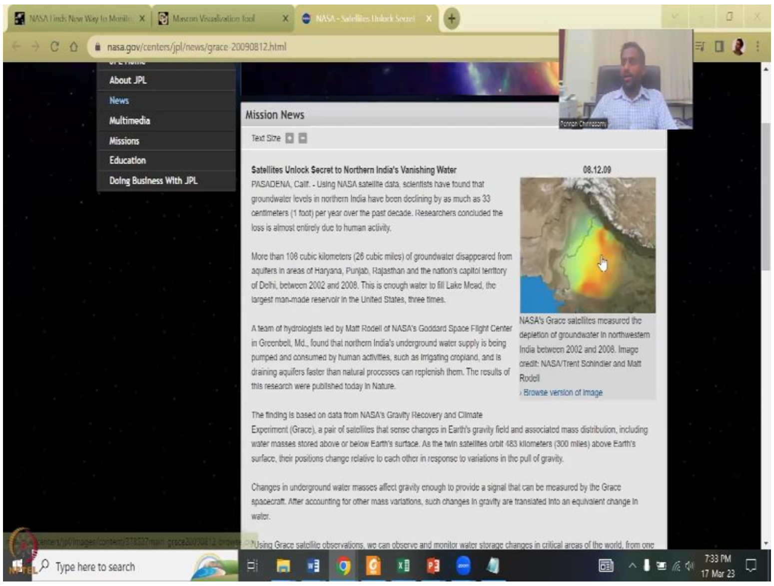

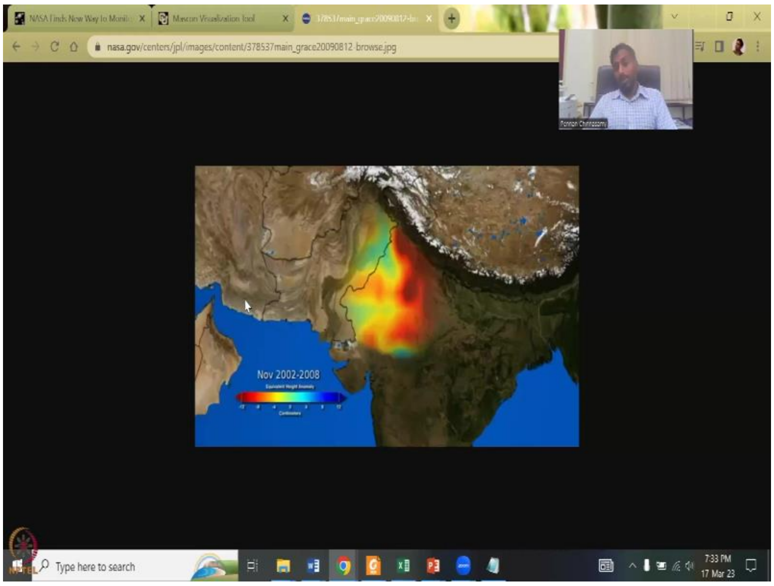

And you could see that maybe I will just open it in a browser version image. This was very, very well debated across scientific communities. And you can see that the northern region has high pumping. That is what the satellite has estimated from 2002 to 2008. There is a lot of groundwater pumping in this region. And the most scary part is, it is at very unsustainable rates. So, now if you compare this with the CGWB data, there is some correlation. So, we also saw that there is a lot of red blocks in Haryana, Punjab, and which is also showing here in this image.

So, the ways forward is, but those data is only once in 4 months. So, CGWB data is collected 4 times to 3 times in a year. Let us say 3 times. So, every quarter you get data. So, 4 times data in a year, whereas GRACE data is monthly. So, every month you get this estimate. And equivalent water height anomaly, you could see in centimeters. So, there is nothing blue, there is nothing to be happy about. Everything is red. So, over 2002 to 2008, in November, it is being red.

The change is negative, and which is not a good sign of sustainable agricultural practices. So, all this land is going to be affected by groundwater depletion and has been affected. So, it is not a prediction, but an assessment of how much water has been lost.

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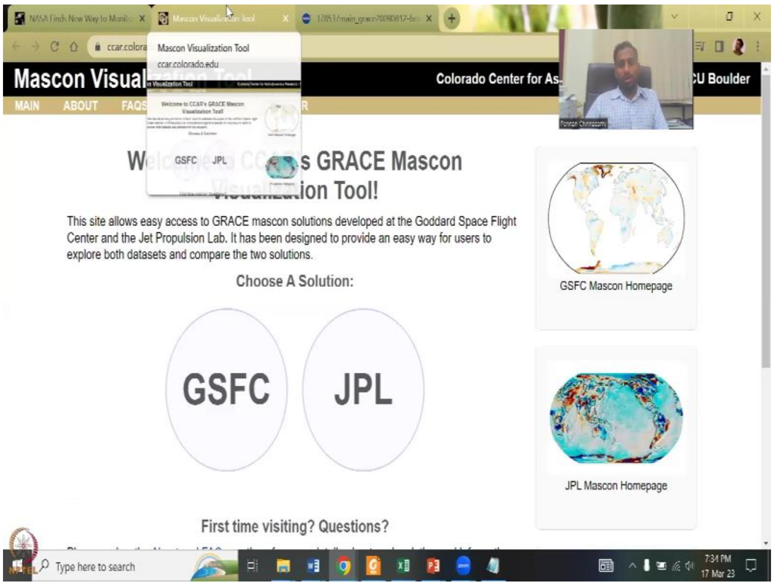

So, the second link is the CCR, Colorado dot edu dot grace. And when you open this, there is a visualization tool. So, you do not have to process the data. Everything is processed for you in this particular visualization tool. You can go to GSFC, the German algorithm. There are multiple different algorithms or the JPL, Caltech, Colorado, US version. I normally use the US version because a lot of papers have used the US version.

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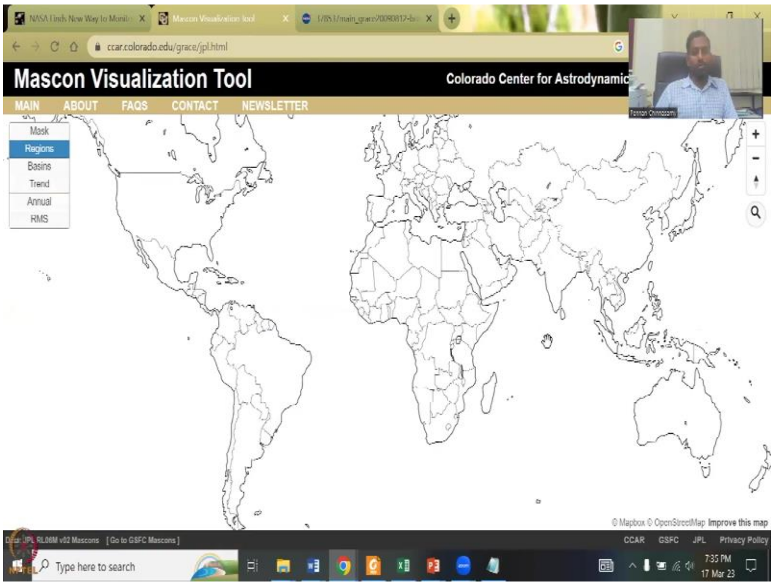

And then we will go here. Again, the boundaries are very different. So, please do not look into the boundaries, how the boundaries are made. We do not know, but we will just look at the regions. So, these are the regions. So, now the GRACE satellite data has been applied. We will show you how to access information. Let us go to basins. As I said, each pixel is 100 by 100 kilometers. I will go to show you how each pixel is. So, now the basins, the water level basins are being shown.

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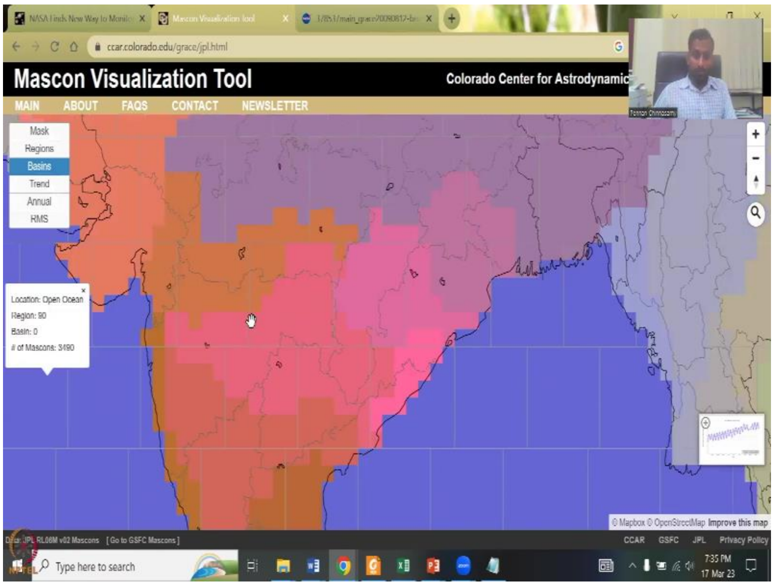

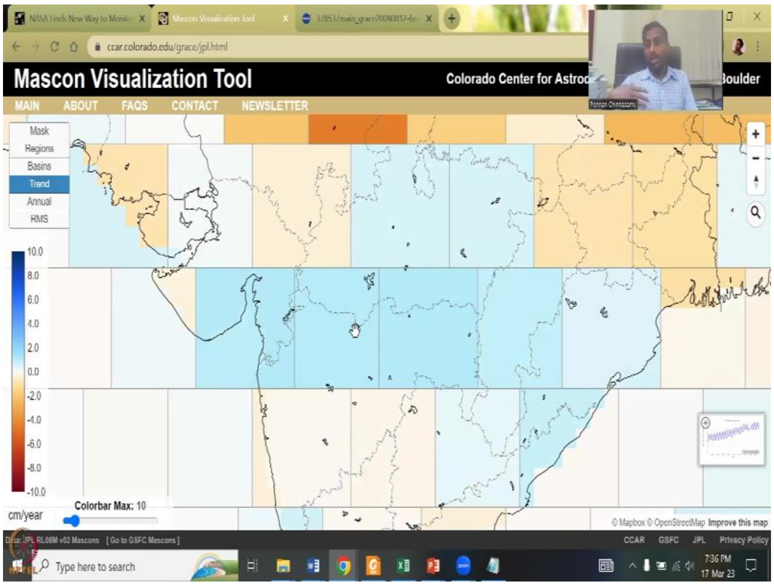

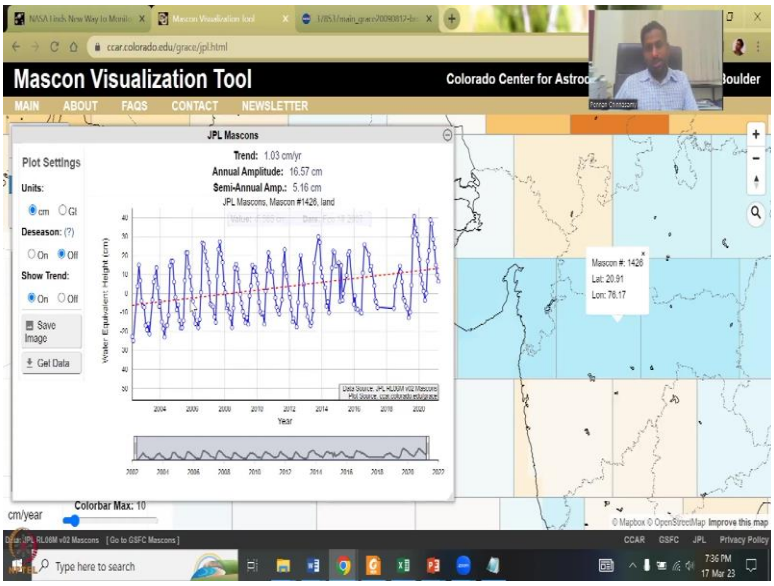

So, if I zoom in using my mouse, you will see that this is one data. So, this whole pixel is one data. And they would have done some anomaly calculations in smaller regions. So, the 100 by 100 kilometers is really, really big in terms of looking at data in a very specific format. So, let us look at, if you want trend, we can see how these are each pixels, 100 by 100 kilometer pixels. You can click on a pixel and it automatically populates the data and shows you what is the total terrestrial water storage change.

So, I am going to click and you have water equivalent. And you could see that this is the time when the satellite was decommissioned. So, there is some gap here, but on the whole, for the past 20 years, no other mission has such good data for groundwater and terrestrial water. So, you could see that you, the water resources are increasing. The net water resources are increasing over the past 20 years.

Initially, it was almost stable and it goes down. So, you can see a sinusoidal curve. It goes up, down, up, down. That is because in the monsoon, it recharges. And then in the summer season, the water is being taken off.

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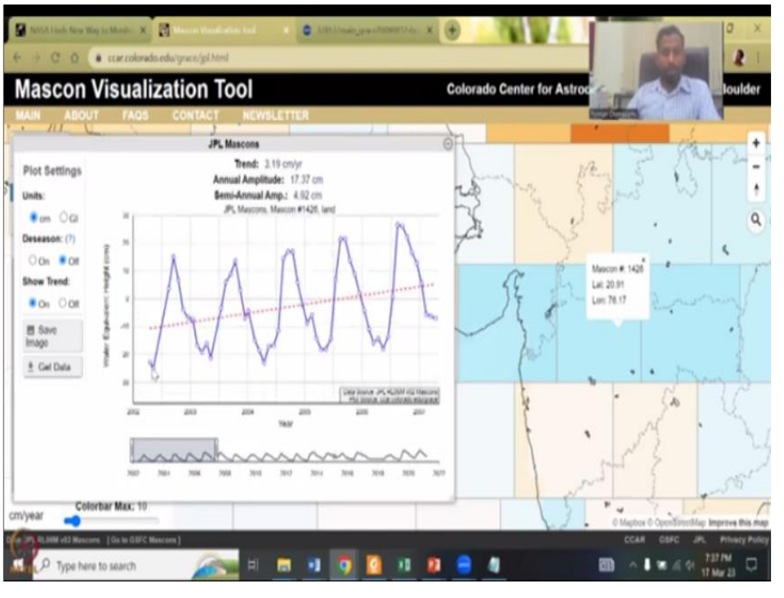

So, you could see that and you can also truncate and see which parts you want to see. So, you can just say that I want to just see this part, or maybe this part we can see just closely. So, almost every fifteenth day of the month, the data is accumulated and then these maps are made. And then you could see that fifteenth September, the peak total terrestrial water storage was there. And then if it comes down during the summer season, so this would be around May. May is the peak summer in the Maharashtra region.

And then June, the monsoon kicks in. So, June, you have this data and then July, et cetera. So, this is the monsoon comes up. And so, each time you could put a trend line to see if it is increasing or not, and then look at it. So, this is the trend.

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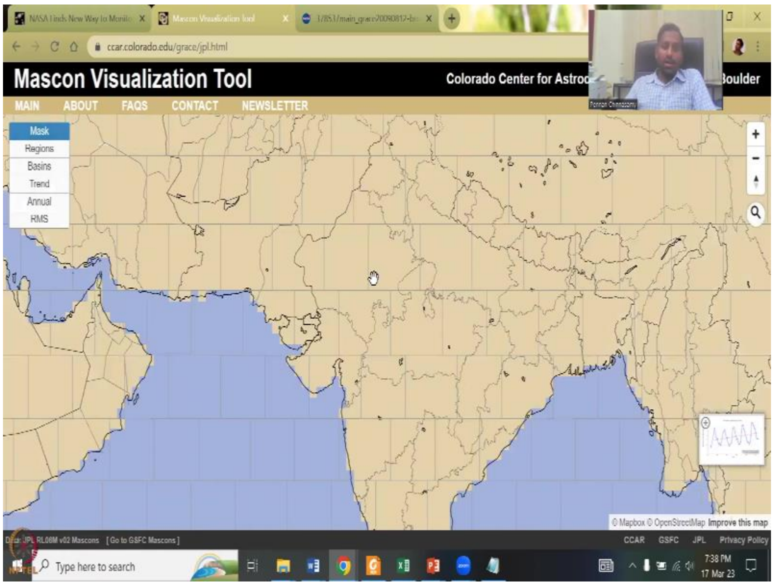

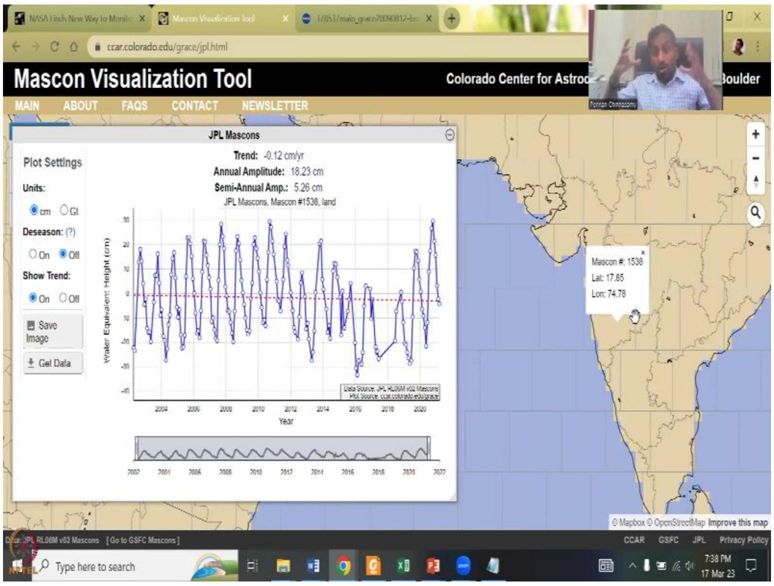

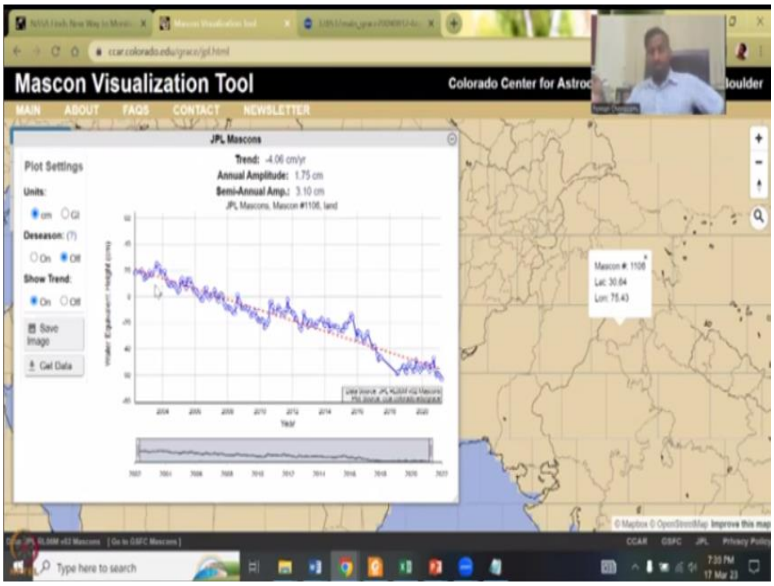

So, the first one is the mask. You can actually put a region, you can draw a mask and then take data out. So, each pixel you can click, it gives you the lat long of the pixel. Along the pixel, it is one value as per remote sensing rules. Each pixel has only one value. So, within the location, whatever value it is, you have to take it up. And then you could see that these are called MASCONS. Part of a NASA satellite GRACEs data product is called MASCONS. So, you can just download the data and work on it, or you can download the MASCONS.

MASCONS have a higher efficiency, less errors as per the NASA website. So, you could see here actually that there is a depletion, sudden depletion. And then now it is increasing in this part of the world. Let us say, Rajasthan, this part was more Punjab, and you can see definitely going down. There is no way this can be sustainable. Just look at from 2002 to now, how much of thickness of water has been gone. So, if you just do a calculation from 20 to minus 60, so around 80 meters, 80 centimeters of water has gone, almost a meter, a meter of groundwater thickness.

It is not just a groundwater fall of 1 meter. No, it is a thickness. So, if you add the land inside the specific yield calculation, so this would be around 200 meters of decline. And that is what is happening if you go to these regions. You will see if you ask the people, they will say that the groundwater declined and so we have increased the depth of the water by 100 meters or 200 meters in the last 10-15 years.

This is very unsustainable. And this is also falling in the same analysis as the CGWB data. Even here along the Punjab, Haryana, and Delhi regions, there is a lot of pumping, a lot of groundwater depletion happening. You can save the data as an image. This you can save as an image or get the data as an Excel file as a month for that particular pixel you can take and use.

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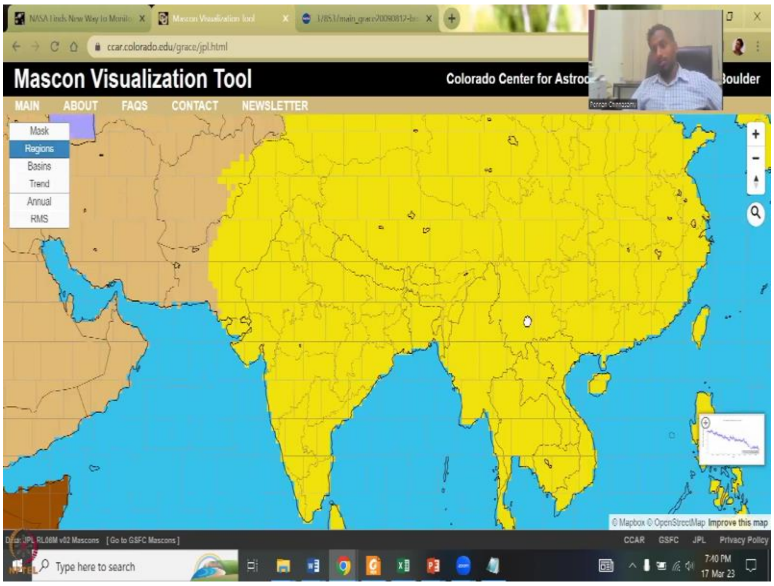

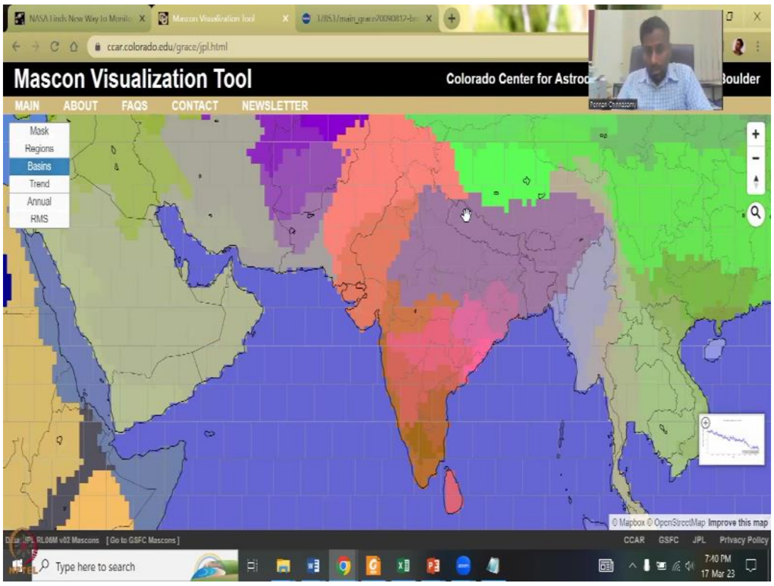

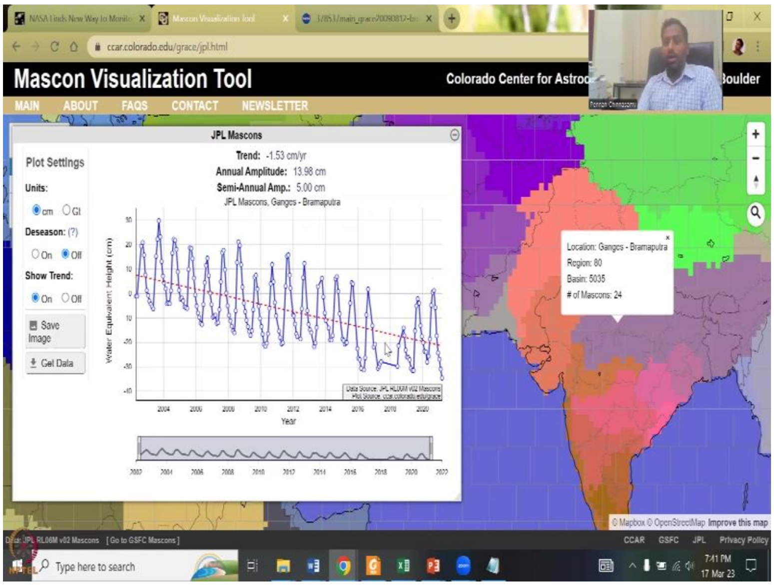

You can also do these calculations as regions. So, this is an Asian region and then see how the water has been used. But since we are focusing on India, let us look at India. So, the Ganges basin, whole of Ganges basin. So, it is an average for the Ganges basin. You can see the location says Ganges Brahmaputra location. Wherever you click, it is the same. It does not change because it is average for the Ganges region. So, if you click on the pixel, you can see that the Ganges location might say number of mask on might differ, but this does not differ.

So, if I click outside, this changes. So, Ganges, what is the overall outcome? The groundwater is depleting. It is very, very sad to see the basin which supports one seventh of the population, one billion population is depleting very, very unsustainably. So, something has to be done. It is a terrestrial water change. We need to know what is actually changing. Is it the groundwater or the surface water? So, that is the next step that one has to do in an analysis.

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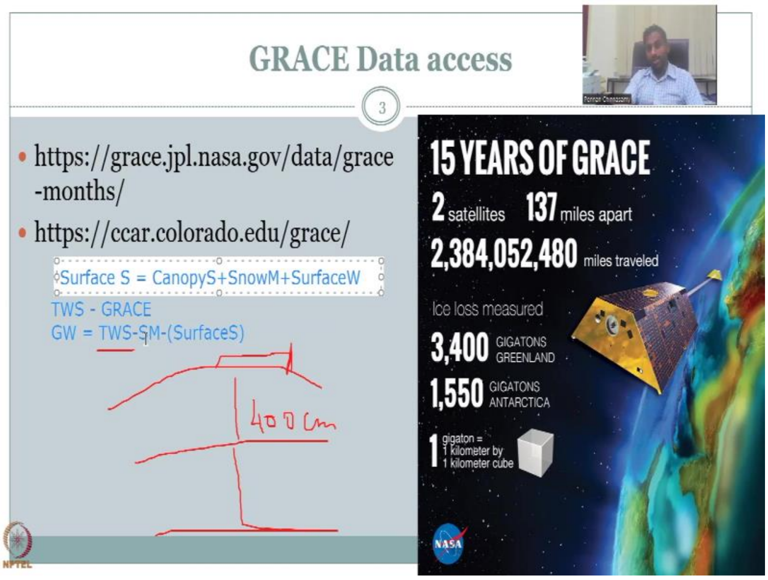

What normally is the equation of the analysis is, let me just write it down so that you can also do it if needed. So, I am just going to say, so basically your terrestrial water storage is given by GRACE. So, the change in groundwater storage is del groundwater, let us say groundwater is equal to TWS minus soil moisture minus all the storage terms, storage surface storage. So, basically, the terrestrial water storage is from here to ground.

Now I just want to need the ground, the core ground part of the groundwater, how much is gone. So, for that, what do I have to do? I have to remove the other parts. So, you have, if I draw it as layers, it will be like this. So, this is the earth surface. And then you have your dams and other water resources that is part of the surface water storage. So, that is the surface water storage you have to take out. And then a part of it is soil moisture, up to 400 centimeters.

Up to 400 centimeters, you have to take it out and after that, you can assume it is groundwater. So, your terrestrial water storage, if you remove the soil moisture, if you remove the surface water storage components, one is the dams, one is the tree water storage, canopy storage we call, the other is snow because snow is on the top, not on the ground. So, if you remove all these, and most of Indian locations do not have snow.

So, if you remove all these parts, then you get terrestrial water storage minus soil moisture minus surface storage gives you groundwater. And as I said, the surface storage can be snow melt, plus, we can also add that. As surface storage is equal to any combination of canopy storage, storage plus snow melt plus dams, surface water storage. All these are there. And where do you get the data for it?

That you will have to use observation data or GLDS, NOAA, some kind of model data for it. So, some GRACE data cannot give you all of it separately, only the total is given. And from the total, if you take out these components, you will arrive at groundwater. Groundwater is TWS minus SM minus surface storage. And these soil moisture can also be taken from your NASA satellite data, radar data, which we discussed in the earlier sections.

There are four components, you can add them and remove them from TWS to get groundwater storage. So, this is how we can actually look at different components of groundwater storage, and then see how the change happens.

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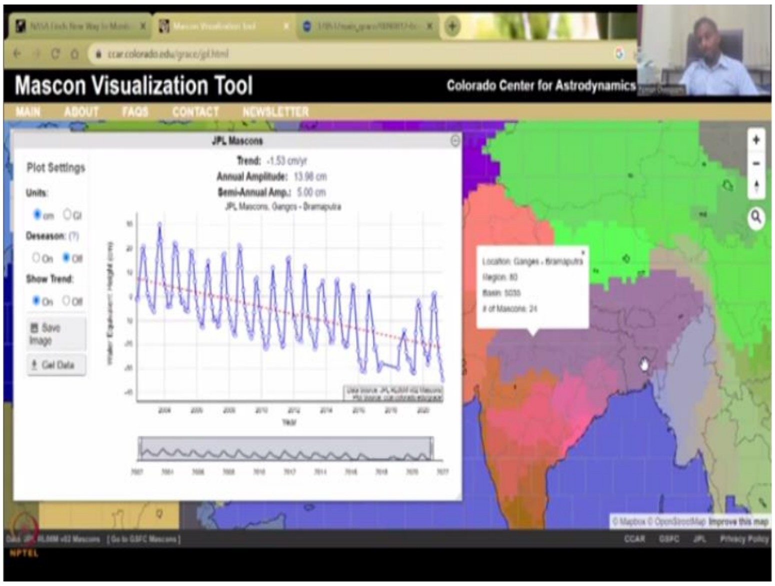

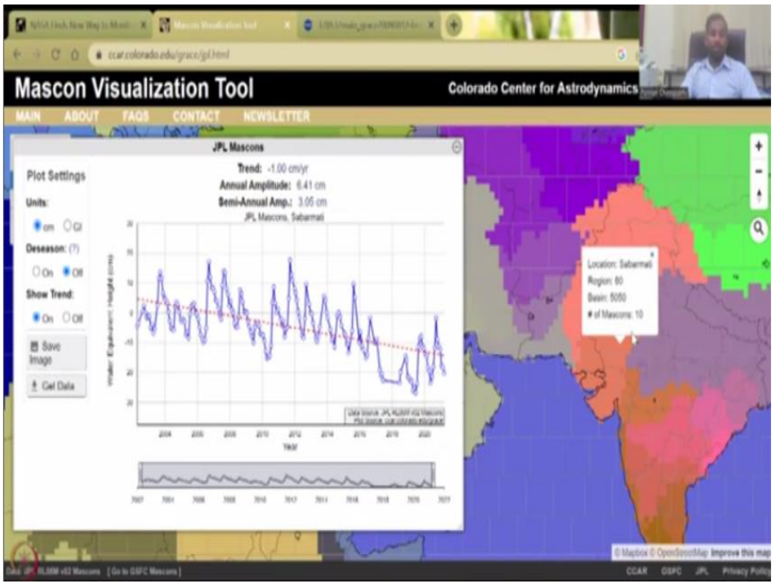

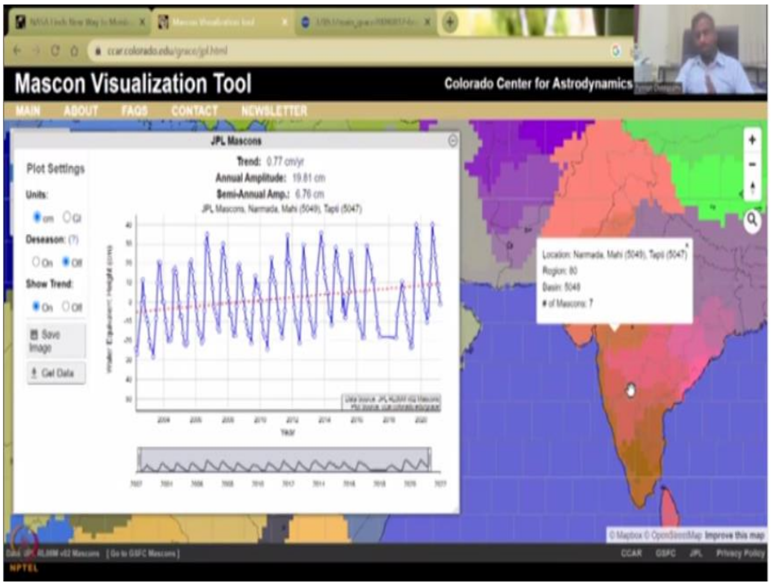

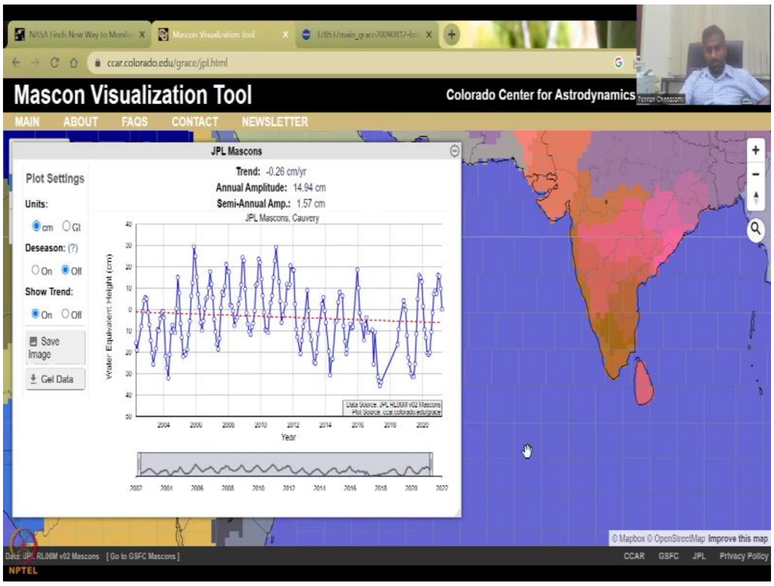

So, you can see that let us quickly look at Ganges. So, it is a transboundary in nature, you have India, Nepal, Tibet, China, and Bangladesh. So, all of it is covered by this basin. So, it is depleting. Your other basin which is depleting is the Sabarmati is also depleting. And then here is your Narmada. Narmada Mahi basin, Tapti basin is slightly increasing, which is good. And then in the central region, you have the Godavari, which is increasing, which is good.

And then you have the Mahanadi, which is also increasing slightly. It is also okay. And then the Brahmani, these are the major basins, is also stable or slightly decreasing. And then you have the Krishna basin, almost stable. And most importantly, the most widely used, Penar and Kaveri. So, if you look at Kaveri, it is almost stable, slightly declining, but see the zero. So, above the 0 is okay, at 0 is the average is equivalent, it is not changing much.

But now it is changing. So, if you come down also, it is the West Coast rivers. So, these are taken from the NIH - National Institute of Hydrology's Basins of India. So, most of the basins of India, the big basins of India are covered. And the data can be taken as an image, you can save the image of this data itself. Or you can get the data as an Excel file, SCP file and get it and then use it.

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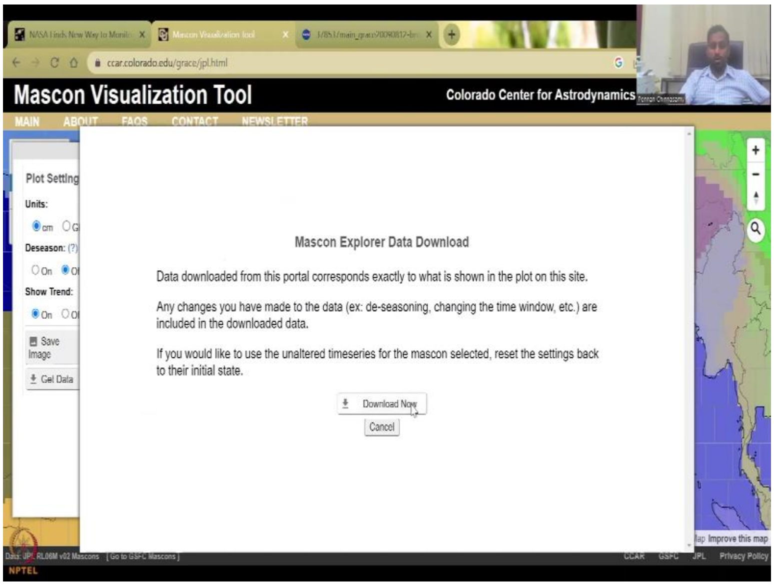

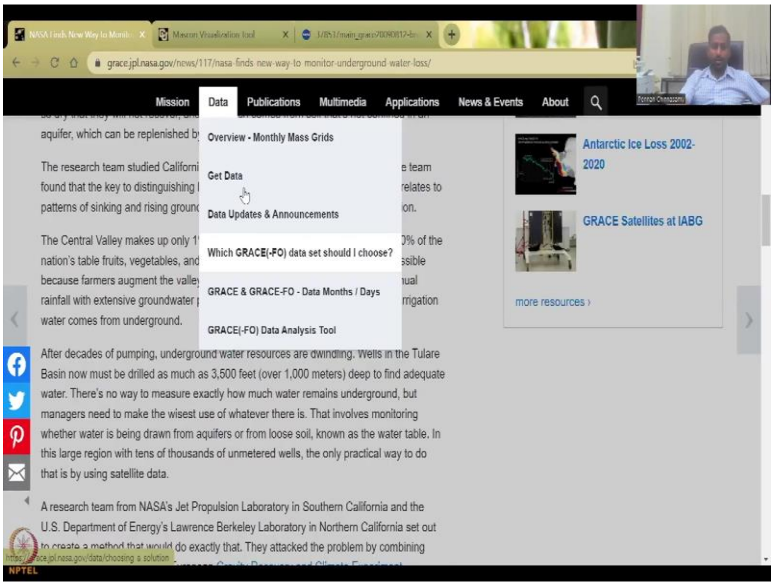

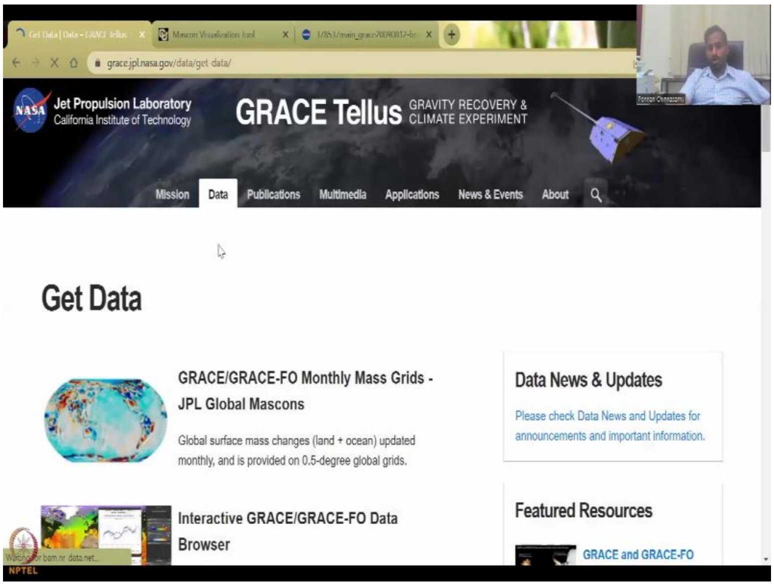

So, you have to download now or cancel if you want to download later. So, I used to download these type of data, but most of the time I use this data platforms of NASA, Get Data.

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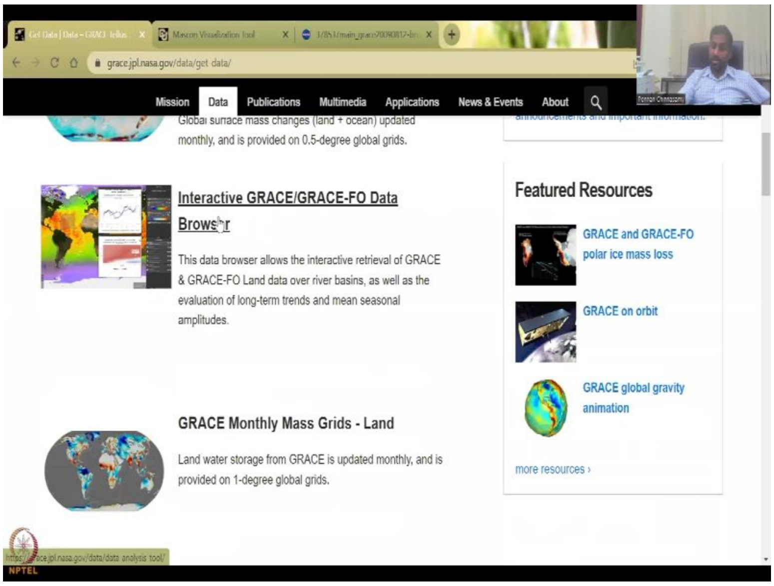

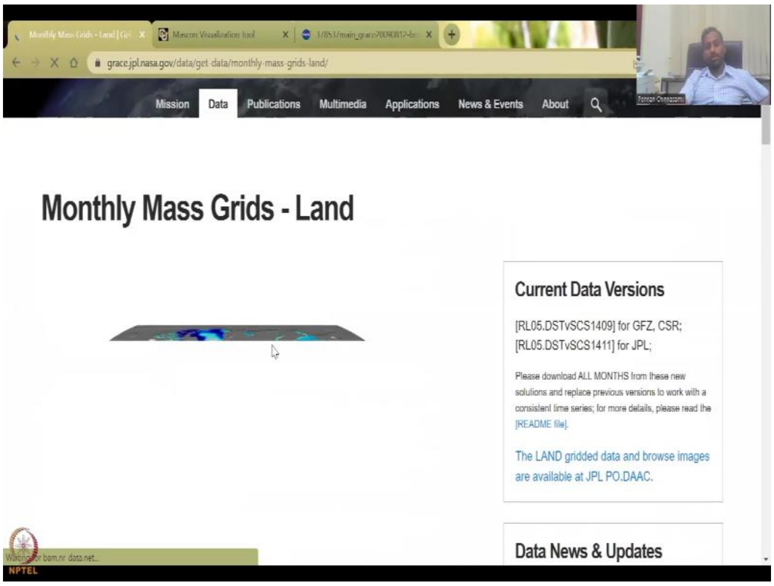

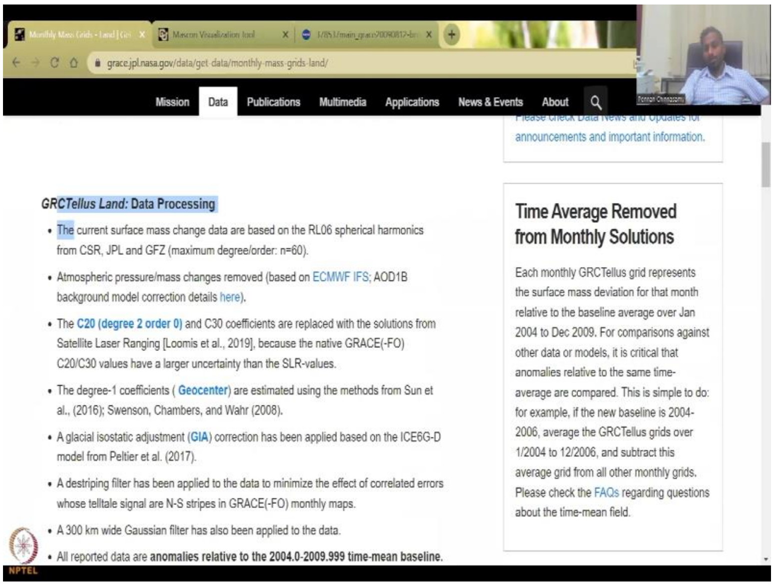

And then it will ask you which type of solutions do you want, you want the interactive browser, this is another interactive browser also you can use, I will go to monthly mass grids. And then in the monthly mass grids, as I said, please read this, this is the metadata of the data, it will tell you what are the corrections that you need to do, what are these are more advanced level, you have to correct the data, they do not want to give you the corrected data, they will give you the data, raw data, plus the correction term, you will have to multiply it so that you understand the process.

And then you get the scaling data also how to scale it. And when it is not usable, what not suitable, etc. And then citations, you can cite these people who have developed data and software, and you can download the data. So, you can also pick the months that are given and get the data. Okay, so this is this is very important, you can take each of these solutions and get the data. And as a net CDF, or ASCII. Net CDF is a combination of remote sensing images, you can download the data from here.

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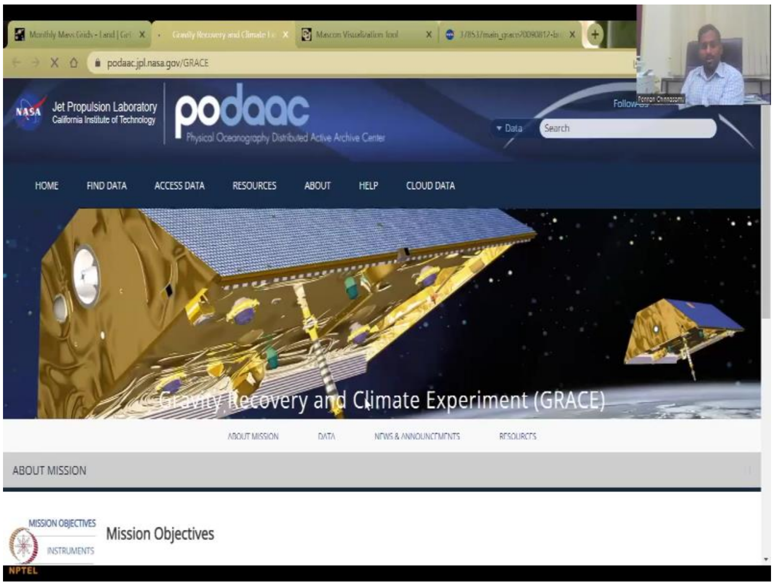

You can also use the previous Earth Explorer data sources, GLDS, GES disk that we use in the previous versions to collect the data. As I said, there are multiple, multiple ways to collect the data, you can go here, GRACE mission, and then download the data. Each level is highly advanced. So, you always have to go for the highly advanced level. So, 2002 to April 17, April 17 to present is the data.

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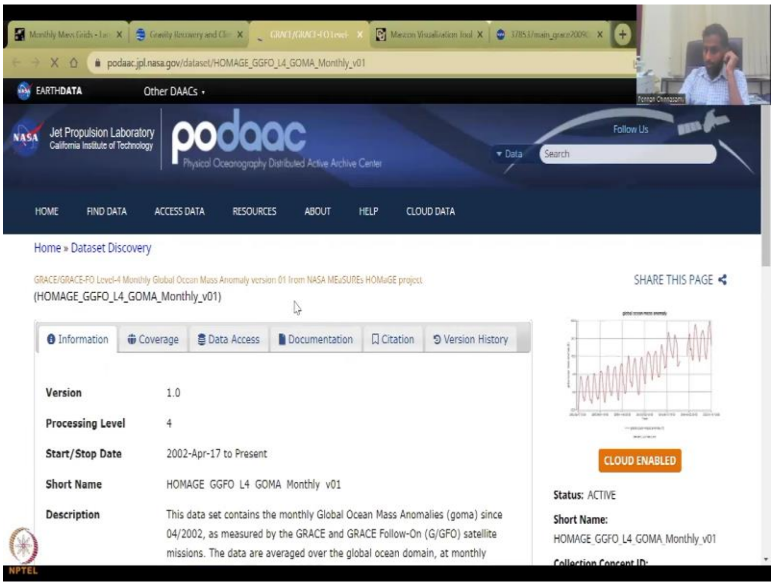

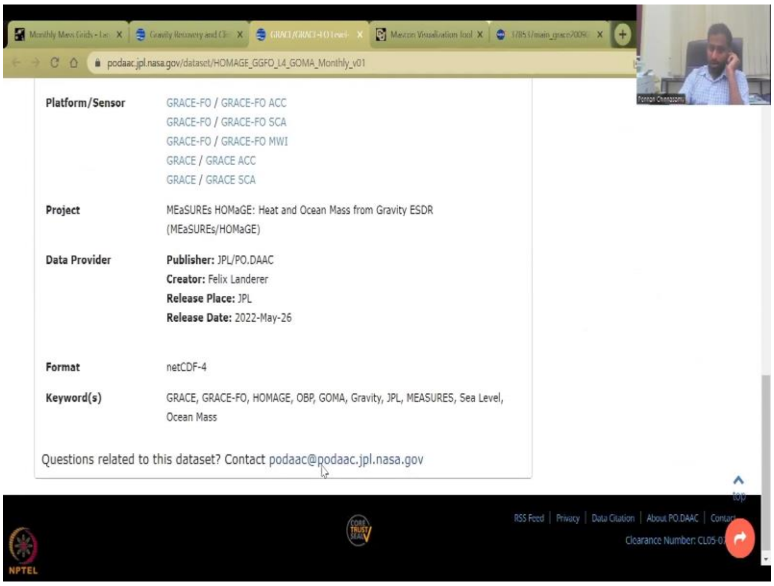

So, I can click here. If you want ocean, ocean data is given separately, because that is also a mask, and you are given the land data also separately, you can pick and choose which data you want to use and use it for your study. Because you can also do a lot of people do mask changes in the oceans that can be done.

So, there is a lot of platforms where you can download the data, you can also email them, they are pretty good in emails, you can have direct access, just granules, which is the each tile you can take out, search the tiles and take it out in Earth data as I said, the earth data is also working. And you can also download the subsets. So, sometimes it does not work. All systems may be upgrading.

So, just wait for it to open out. And then you will have some good data. So, with this, I hope you have understood a very, very complex data system, but very, very useful data. So, you can see here, the data explorer that we have used in the past, I just get the link for data explorer, it comes and there is two data from 2004 to 2020. And then you can just download all and all this data will come.

With this, I would like to conclude today's lecture, we did a little bit more than the current timing. I hope you enjoyed the session on GRACE data analysis. In the next lecture, I will see you with more remote sensing data. Thank you.