Lecture 17 Climate Change

APOLOGIES FOR THE VIDEO- ZOOM SEEMS TO WANT TO VIDEO ME AS WELL!

Slide 1

Climate change is one of the defining challenges of the 21st century. In this session, we're going to talk a little about what climate change is and how we are limited by uncertainty when we try to make projections of future climate. I will then go on to talk through a few examples of the effect of climate change in different environments.

Slide 2

So the learning outcomes for this lecture, you should be able to define anthropogenic climate change should be able to name the different greenhouse gases, especially the main four.

Understand what we mean by uncertainty in climate modelling and understand how climate change will impact different environments.

Slide 3

Since weather records began people have started to notice that it is gradually changing. Now that we have powerful computers and good weather records as well as ways to look at historical weather we can see that the global temperature is rapidly rising. Scientists have made the link with increased emissions of carbon dioxide from many human sources. In this graph, we see ice core data from Vostok in Antarctica. Ice cores are useful because they contain air bubbles in Antarctica, the oldest of these air bubbles was 800,000 years old. Testing the concentration of carbon dioxide in these air bubbles can give a timeline of average carbon dioxide concentrations at different time points. In this graph, we can see historical temperature trends on the top from 400,000 years until now. So this is the top graph, the blue. And in the middle, the green, we can see carbon dioxide.

I want you to notice two things. The first is the very close match between temperature and carbon dioxide, the highs and lows occur at the same time. The second is how the temperature line is quite smooth way back in history. So before 300,000 years ago. But as you get closer to the present, so as you move towards the right, it becomes more noisy and fuzzy. This is because as we get closer to the present day, we have better and more detailed data, more nuanced and understanding is possible.

The final thing I want to mention here is that weather and climate are two very different things. Weather is what you see in a day or season. It is short term. Climate describes long term trends and is able to show patterns and we can make projections from it. Both terms look at specific spatial areas.

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There are hundreds of gases that can prevent heat from the sun from escaping the atmosphere. This is known as the greenhouse effect. I've included a table here showing the main greenhouse gases that are of concern in climate change. Some points to note:

GWP means global warming potential. This is the amount of heat a molecule of this gas can trap in the atmosphere and it is all compared to carbon dioxide, so one molecule of carbon dioxide. A molecule of methane therefore has 84 times the potential to trap heat that a molecule of carbon dioxide has. Methane is 84 times more potent.

The second thing to notice is that the units for these concentrations are different carbon dioxide is measured in parts per million, while methane, nitrogen oxides, and ozone are measured in parts per billion. So this is much much smaller. Carbon dioxide is quite high. Halocarbons are measured in parts per trillion. So those are very small, indeed.

Look at the duration of these gases in the atmosphere. This is how long they stay before being broken down. These numbers are the main reasons that people have more concerns about some gases than others. Some have a low residence time but high global warming potential, while others have a high concentration but low global warming potential. Measures to combat climate change must take all of these factors into account.

Finally, I want to highlight water vapour. Water vapour is the most abundant gas in the atmosphere and it is very powerful. However, its global warming potential has not been formalized in the literature, it does not directly drive climate change, like the other gases but it serves as a positive feedback mechanism. That means that it increases the effect of other gases.

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In 2019 scientists warned that we have 12 years left to keep the warming to a maximum of 1.5 degrees centigrade globally. If we bypass that estimate if we warm the planet more, risks of floods, droughts extreme heat and food security loss will increase for hundreds of millions of people worldwide.

The IPCC stands for the Intergovernmental Panel on Climate Change and it is made up of scientists from all over the world. It is coordinated by the United Nations. The panel is designed to assess the science related to climate change and every five or six years they publish an assessment report that talks about where we are with climate change, which areas will see changes in temperature, precipitation patterns and wind. It also discusses the impacts on natural systems, which is our main concern in this course. I will share the latest synthesis on the natural world for your information. This is assessment report five from 2014 and the next report is due in 2021 so next year. The IPCC uses data on the climate trends to make projections of climate through the coming century.

There are four main scenarios that the IPCC will model. They will create a mathematical model of warming. On the left of this slide is a graph showing global surface warming relative to the year 2000 on the y axis. We see this is set to zero. In the future as we move from left to right on the x axis, we see that there will be an increase in warming over time if carbon dioxide is kept constant at the 2000 level. The yellow line shows a very small increase on the way to the year 2100. The red, blue and green lines show the outcomes of different emissions, if they are very high, moderate, or low. It appears that will be 1.5 degrees centigrade hotter by the end of the century, at the very least.

On the right, we can see the different emissions scenarios in terms of surface temperature change across the world. Way back in week two, we talked about how different landmasses, mountains, rivers, and so on impacts temperature and precipitation. It is therefore important to look at the terrestrial land area in finer detail because the graph on the left is a global average, it is likely some areas like the Arctic and the far north will have much more severe warming than other areas. In these maps you can see that the Arctic at the very top is much darker, which means a much higher relative change.

Slide 6

As we cannot predict exactly what the future holds, one of the important parts of the models is incorporating uncertainty. When the IPCC presents its report, it will need to make clear where the uncertainties lie and also how much confidence they have in the model. Remember all models are wrong. They are designed to give a good fit to the available data, but we do not expect a perfect fit.

Uncertainty is a part of every model. Imagine trying to make a model to predict surface temperature of the entire world 100 years in the future. How would you go about it? Where would you start, what is a good level of spatial resolution? Is 100 km2 enough? Or should you do one km2? You will need to consider topography, elevation, water bodies and cities. This is a really enormous job. The IPCC lists three main areas of uncertainty in their models.

The first is unpredictability, which looks at the changing behaviour of humans. We can’t know what our political systems will prioritize in the future. We don't know if we will have governments that push for clean energy and low emissions or governments that maintain high fossil fuel use. And then we need to multiply this by 195 because there are 195 countries. This is very difficult. So this is where those four emissions scenarios from the previous slide come in because they have come up with four potential outcomes. In order to deal with these uncertainties, the IPCC clearly state the assumptions they have made and try a number of different models to get a sensible range.

The second source of uncertainty is structural uncertainty. Essentially, this is when your science has problems. You might be specifying your models wrongly. There might be different conceptual frameworks which is when your initial hypothetical plan for how things work is not very good. Another problem is that you might have forgotten key processes that need to be taken into account. A good example of this is modelling the carbon cycle. Up until recently, the big biogeochemical models did not include soil animals or details on soil microbes. The data was simply not there. So proxies for these processes were used. These were later shown to be insufficient, and researchers are working hard to incorporate these processes now.

The third area of uncertainty is value uncertainty, where you're not sure of the true values of processes to include in your model. This could lead to all sorts of problems. The IPCC work very hard to reduce uncertainty based on the second two of these uncertainties and to mitigate the problems caused by the first.

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I'm just going to mention briefly to weather phenomena called El Nino and La Nina. El Nino is Spanish for the little boy and La Nina is Spanish for little girl. They are opposite phases of the El Nino Southern Oscillation cycle, also known as ENSO. The ENSO cycle can occur between two and seven years, and it lasts between nine and 12 months. El Nino is characterized by a shift in weather conditions in the Pacific Ocean. The coast of South America has very cold water and causes an abundance of these anchoveta fish. The fisherman in the 1890s noticed that every few years, the cold upwelling would not appear and also the fish would be missing. This was what made people start to look at these weather patterns. Essentially in a normal year we have the wind and ocean cycles that you see and the left hand picture. On the left of this picture we have Australia and South East Asia, and on the right we have South America. The Pacific Ocean has cold nutrient rich upwellings in South America, which then travels west getting warmer and warmer before sinking near Southeast Asia. The trade winds are doing a similar thing. But while warm water sinks, warm air rises. The spinning of the earth drives the winds and the water. This is called the Coriolis effect. When we have an El Nino year, this will change. The warm water starts to move east. Storms will also head east towards South America. So, this is this picture on the right at the top. This is El Nino, you will see that the clouds and the meeting of the two winds will shift towards the centre of the Pacific Ocean. La Nina does the opposite, it is a strengthening of normal conditions. Trade winds are weak in an El Nino and strong in a La Nina. We don't really know what triggers El Nino, but we do know that with climate change, they are becoming more frequent and more severe. El Nino, is usually more frequent than La Nina.

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So what does this mean for Southeast Asia? In the top map here we can see the sea surface temperature difference in an El Nino year compared with a normal or neutral year. White in the sea means no difference. Red is hotter than normal. Blue is colder than normal. We see that the normal sea temperatures in the Pacific have effectively switched so that South American waters are hotter than the red and Southeast Asia is very slightly cooler.

El Nino brings drier weather to Southeast Asia which increases the risk of forest fires and more smoky haze. These maps at the bottom show the rainfall in Southeast Asia and an El Nino year on the left and La Nina on the right. Brown is lower rainfall than average, green is higher. So La Nina may result in flash floods and soil erosion, as well as crop failures.

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I've included this map to show the consequences of an El Nino year. In South America on the right, we see that we have widespread marine animal deaths, crashes of fisheries, we lose the marine life and sea birds. On the Southeast Asia and the Australia side we have droughts and we have fires.

Slide 10

There are several trends and weather that we generally expect as a result of climate change. The IPCC AR5 synthesis report tells us that there is no longer any doubt that humans are accelerating climate change, and that climate changes we have already seen are having impacts on natural ecosystems. We are seeing an increase in global average temperatures. And most of this is triggered by the warming in the ocean. Because of this, the ocean is becoming more acidic and I will talk more about this in a minute. We are losing ice from the ice sheets at the poles, which means that we've had a rise in sea level. We're also seeing a lot more extreme weather events such as tornadoes, flooding and other kinds of storms.

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So what does climate change mean for ecosystems? We've seen that predicting climate is difficult and subject to uncertainties and a lot of year on year variability. Many species are adapted to a relatively small set of climate conditions, called a bioclimatic envelope. Back in week two, we talked about the oak, caterpillar and the blue tick chicks. If climate changes and spring comes earlier, they may not all appear at the same time, and the chicks or the caterpillars or both might starve. Climate change seems to be getting faster. Species will be subject to rapidly changing conditions. For some, this might be survivable. For others, the bioclimatic envelope they are adapted to might move, they must either move with it or adapt to the new conditions. The other option could be extinction.

Scientists are particularly concerned about organisms that cannot easily move, including plants or sessile organisms like barnacles. Especially those that disperse randomly, like grass seeds, it would be luck only if the grass seeds are blown in the right direction.

And other general question is what if there is nowhere to disperse to? If the species needs to move to a cooler place as the local area warms then it would need to move either away from the Equator, or it would need to move up in elevation. So up a mountain, for example. But what about those already on the north coast of the landmass? Or the top of a mountain? These species are at risk of extinction.

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I'm going to go into three examples of the effect of climate change on ecosystems. My first example is the distribution of the very economically important hard wood teak. It is a very expensive word and Myanmar has nearly half of the world's naturally occurring teak. Teak occurs in two ecoregions, India and Myanmar-Laos. They have different genetic origins. This study by Deb looked at modelling the future suitable climate space for teak. At present, the extent of teak distribution is shrinking, partly because of deforestation and partly because of climate change. The maps we see here are the results of the model that Deb and colleagues created of two potential different scenarios. Teak needs wet soil, lots of light and high calcium, so teak is a very fussy tree.

Looking at these maps, we have projections of mid-range climate change in RCP 6.0 so that's fairly moderate, and extreme climate change as RCP 8.5. They fitted models for 2050 and 2070 using ArcGIS, which is a mapping tool. The data is at one kilometer square resolution. These maps show weather the models suggest a gain or a loss in climate space in 2050 and 2070.

The first thing that we can see is that there's going to be very big changes in all the scenarios either positive or negative. So we have the orange is a loss in climate space and the green is a gain in climate space. If you add it all together, that is a large amount of change.

The study presents a plan for forest management over the next 50 years in order to maximize this important economic crop. For effective decisions habitat managers will also need to consider the likely actions of people in terms of fragmenting habitat and building space for homes and other living, as well as these appropriate climatic regions for teak.

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Coral reefs are extremely diverse, but the animals that make up the coral are extremely sensitive to changes in abiotic conditions. In the Pacific Ocean, the average sea surface temperature has increased by 0.3 degrees centigrade and by 2100 it is projected to rise by another 3 to 4 degrees centigrade. At the same time, carbon dioxide in the atmosphere is dissolving into the water. This is a problem because it increases hydrogen ions and begins to turn the sea more acidic. Coral lives at the surface of the water, so it's exposed to this change in very shallow water. So pH is measured on a logarithmic scale so 0.1 points on this scale is actually a very big change in acidity. It works out at a 26% increase in hydrogen ions. Coral and other organisms that make shells and structures from carbonates are in big trouble in a more acidic sea.

In this photograph, there is a coral reef and all of these different structures are corals that have built a backbone structure from carbonate. As the ocean acidifies it will dissolve these carbonates, the coral will die and all of the enormous diversity that relies on it will be lost.

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This is an image of the structure of coral. It is a small animal that builds a carbonate skeleton. The animal is in a symbiotic relationship with algae, which is called zooxanthellae and it's found in the gastrodermis. Zooxanthellae, which photosynthesize like plants, create sugars for the coral. The carbon will get up to 90% of its nutrients from the zooxanthellae. In return, the zooxanthellae get carbon dioxide and scarce nutrients from the coral, as well as refuge inside the tissues. However, when the seas warm the zooxanthellae become damaged and cannot photosynthesize. This seems to trigger an immune response in the coral. The coral will either digest or eject the zooxanthellae, which means that will release it back into the sea. The coral will then starve without its partner and this is called coral bleaching. Some corals may recover from bleaching, but it is a widespread concern. There are also many bacterial diseases that affect coral and these are also increased in warm temperatures. Therefore, increased sea surface temperatures and elevated carbon dioxide can cause a wide range of negative effects on coral.

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My third example is the Arctic tundra. The tundra is very far towards the North Pole and it has very cold temperatures and short growing seasons. The ground is frozen in permafrost, and it receives very little precipitation. Because of this, the trees are very small and it is classified as a desert because it is so dry. If you remember our lecture on enzyme activity and the temperatures needed to get them to cycle nutrients you will realize that the tundra is an area of very low microbial activity. When plants die or shed tissues, It does not break down fast at all. This means that there are extremely deep layers of organic material that have not been decomposed. Tundra is therefore an important carbon sink. A carbon sink is a place that takes up and stores more carbon than it loses to the atmosphere. By having such low microbial activity rates, the tundra has enormous amounts of carbon stored as dead plant material and is therefore a globally important carbon sink. However, if the climate begins to warm and the microbes become more active and break down the dead material, the tundra may become a carbon source. The organisms that live here are very sensitive to environmental stresses like reduced to snow cover and warmer temperatures. And so the animals and plants might start to change their composition.

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This is a map of the Arctic tundra. In the centre is the North Pole with Canada on the left, and Russia on the right. The white bits are either ocean or unmeasured parts of the land. The colours are the amount of soil organic carbon in the top three meters of the soil. The black dots are the sites that have been measured. So this is an enormous amount of work. Most of these areas are permanently frozen permafrost. If they begin to warm and defrost, this will release carbon and methane, which are trapped in the permafrost or part of the organic carbon pool. This could lead to what is known as a positive feedback where increased gas release leads to more warning, which then leads to more gas release.

Slide 17

So in summary, climate change is caused by a number of different gases which all have different properties.

Climate change predictions are subject to uncertainties and from a different a range of number of sources. So we must model major scenarios. Effects must be might be unpredictable and stronger in some areas than others.

There are thousands of scientists working on all sorts of different ecosystems and organisms, and

the different effects of climate change. So they're looking at temperature, looking at moisture, and looking at interactions between temperature and moisture, and we’re starting to get a picture of how ecosystems and habitats are going to respond to climate change. And this means that we will be able to target our efforts to preserve them as climate change continues.

Reading

Begon Chapter 2 part 9- pages 52-57.

IPCC State of Nature

IPCC AR5 synthesis

Schuur tundra paper

Fry et al. chapter on microbiomes under climate change.