Transcript

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Course 1: An introduction to the science of climate and climate change

2.3 Components of the climate system

16/11/2010

Transcribed by
uktranscription.com
Typist ID: SP26

Duration: **0:25:37**

START AUDIO

Contributor: Hello there and welcome. We really hope that you're enjoying what you've seen of the course so far and that you're finding it useful. In this unit we're taking a look at the various components of the climate system and the interactions between them and how changes we make in some components affect others.

In looking at this we've got essentially this figure here which is really quite a complex figure. The climate system of course is incredibly complex and in fact the more you look at this slide the more you realise there is to see in it. So we thought that it might be useful to just lead you gradually around the figure and just say a little bit by way of a broad introduction to the components of the climate system.

And in doing that I thought it might be useful to appreciate some, just slightly different groupings of the various things illustrated on this slide. And to do that I've highlighted some things in green, some in orange, some in red and some in blue. So this is just various different groupings which we'll go through.

To begin with I've highlighted in green the various different components of the climate system. So the rectangular boxes that this is the atmosphere, the hydrosphere, the cryosphere, the biosphere and the land surface. That's the various components

that make up the climate system and we'll talk about each of these individually in just a short while.

Next I've highlighted changes in solar input and volcanic activity in orange. These are forcings, what we call climate forcings since they force the way the climate system behaves. We'll come back to those shortly.

Next the rectangular boxes with arrows coming from them I've highlighted in red and these are all the changes to the various components of the climate system. And in a little while we'll look at each of those individually and see how changes in those affect the climate. And finally in blue I've highlighted all these double headed arrows these represent interactions between various components in the climate system. So we'll come back to each of those one by one in just a short while.

Moving on though to consider the various components of the climate system, first of all we have the atmosphere which as I'm sure you're aware is a relatively thin envelope of gases around the planet which contains among other things the air that we need to breathe. The very lowest part of the atmosphere that sits on the surface we call the troposphere that extends up to about ten kilometres in height which is approximately where commercial jet aircraft fly. And that's the bit where all our weather happens. Above that is the region of the atmosphere called the stratosphere which is where most of the ozone lives. And I expect you've probably heard of the stratospheric ozone hole.

So that's one component of the climate system. We also have what's called the hydrosphere, hydro meaning water. This is simply

the collective name for all the water in the Earth's system so that's the oceans and on land, rivers and lakes. We also have the cryosphere this essentially means snow and ice, all the snow and ice on Earth so that includes the ice sheets in Greenland and Antarctica, sea ice and on land snow and ice contained in mountain glaciers.

The next component of the climate system is the biosphere which essentially refers to all living things on Earth – so trees, plants, animals and all the living things in the ocean. It's been represented here very simply by means of a diagram just of forest but it essentially refers to all living things on Earth. And the final component of the climate system is the land surface by that we also mean rock and soil and the way the land is used. For instance whether it's still native forest or where the forest has been cleared to make way for land for agriculture.

Okay so those are the various components of the climate system. Now let's have a look at the features that I've highlighted in orange which represent what are called climate forcings. And to begin with the most fundamental one if you like is solar inputs. So ultimately the energy for everything that happens on Earth comes from the sun so the main input of energy comes from the sun. The Earth receives energy from the sun by means of what's called electromagnetic radiation that just simply means that energy arrives through space from the sun by means of a wave motion. That's what I mean by radiation and we will use the terms radiation and radiative later in the course. So that's the main energy input that drives the climate system to begin with.

We also, it's worth noting here that essentially the Earth receives

more energy from the sun at low latitudes so that's near the equator and less at the cold Poles. So the atmosphere is heated differentially and gets warmer at the Equator and colder at the Poles. Associated with that are then changes in pressure between the Equator and the Poles and that drives the atmosphere to circulate for the air to move in the atmosphere, that drives the whole atmospheric circulation. The atmosphere essentially behaves very broadly speaking as a giant heat pump which is continuously trying to move heat away from the Equator and towards the Poles.

Okay the other climate forcing is volcanic activity because volcanic eruptions release large quantities of gases and particles into the atmosphere where they're very good at backscattering the solar radiation that's coming from the sun. So sunlight from the sun gets backscattered by the particles that volcanic eruptions put into the atmosphere. So generally speaking these lead to a cooling of the climate system although their effect is relatively short lived.

Even a large volcanic eruption that puts lots of particles into the stratosphere that region of the atmosphere above the trosposphere they will only do that for maybe up to two years after a volcanic eruption. So they're only relatively short lived effects on climate but they affect the amount of energy that we initially receive from the sun and that's why they're highlighted here in orange as a climate forcing.

Let's move on to those things that I highlighted red which are changes in the various components that lead to changes in the climate. To begin with let's just consider briefly the atmosphere. As I just said it's a thin envelope of gases surrounding the planet.

It's made up mainly of nitrogen N_2 78% nitrogen. Oxygen O_2 about 20% and the gas Argon Ar that you see on the slide there that's about 1% of the atmosphere.

It then also contains what are called trace amounts, just very small amounts of greenhouse gases. I'm sure you will see later on in this unit exactly how greenhouse gases act to keep the surface warmer than it otherwise would be. You've got the greenhouse gases listed here, H_2O is water vapour, CO_2 is carbon dioxide, CH_4 is methane, N_20 is nitrous oxide and O_3 is ozone. These are present in just small quantities for example carbon dioxide is only about .04% so very small amounts but still very important gases in the atmosphere.

Also present in the atmosphere are what are called aerosols and these are basically small particles either solid or liquid that are suspended in the air. They can be manmade arising as a result of burning fossil fuels that's burning coal, oil and gas or they can be entirely natural coming as I just said from volcanic activity or perhaps windblown mineral dust. But these are essentially particles suspended in the air which are very good at backscattering the radiation that comes from the sun, so less can get through to warm the surface when aerosols are present. Some aerosols it has to be said are of the right molecular composition to absorb solar radiation so they do have slightly different effects but we'll talk about those again later.

Okay moving on just to consider now the way changes in various components affect the climate. We've got here changes in the atmosphere for example composition and circulation. Perhaps the most talked about way in which climate can be altered is the way

that mankind is affecting the composition of the atmosphere by adding in particular the gas carbon dioxide to the atmosphere.

Since we began to become industrialised in about 1750 we know that because we've been burning so many fossil fuels - that's coal, oil and gas - to meet our energy needs for transport, for heating, for lighting, cooking etc we know that we have significantly increased the amount of carbon dioxide in the atmosphere which is a slightly, an unfortunate by-product of burning fossil fuels for energy production. So mankind has significantly increased the amount of carbon dioxide in the atmosphere since the onset of industrialisation and via the enhanced greenhouse effect that we'll look at later in this unit we know that that has had the effect of warming the climate system.

Also changes in the atmosphere, changes to the circulation. We know that as we add greenhouse gases to the atmosphere we change not just the warming of the atmosphere but also the pattern of that warming. And so that will have a knock on effect on the way that the atmosphere circulates which then has an effect on how trace gases get shifted around etc etc knock on effects on climate that way.

We also need to consider changes in the hydrological cycle, that's how water is shifted around in the Earth's system and changed from water the liquid into water vapour and held in the atmosphere. So there are, we do basically anticipate that as global warming progresses we anticipate that the hydrological cycle will get generally more vigorous that is to say that more water will be evaporated from the oceans and from rivers and lakes and held as water vapour in the atmosphere.

Now as we just saw water vapour is a strong greenhouse gas so as climate warms and we evaporate more water into water vapour we potentially warm the climate system even further because it's a strong greenhouse gas. So there's the, a sort of vicious circle there at what we call the positive feedback and warmer air can hold more water vapour than colder air as well. So there's the potential for that to feed back on itself in a positive way. The other main thing to consider with the hydrological cycle is the changes to cloudiness along with this increased vigorousness of the hydrological cycle. We expect generally to see an increase in cloudiness with more water evaporated and recondensing to form clouds.

Clouds are complicated in the way they have an effect on climate and among other things their effects depend to a large degree on the height at which the clouds are. Generally speaking high clouds are good at trapping long wave radiation that's coming out from below so generally speaking high clouds tend to have a warming effect on the climate. On the other hand low clouds are better at reflecting the sun's radiation back to space so they tend to have a cooling effect on climate. So depending on the type and the height of clouds that are formed as climate changes they will have varying effects on the climate system.

Moving on just to look at changes in or on the land surface, the first one listed here is the orography. That's the technical term for the vertical profile of the land that's essentially the hills and mountain structure. These have a fair influence on the local climate for example where moist air comes in from an ocean and is forced to rise when it meets mountains it will then dump its moisture in terms of rain on the top of the high ground and the resulting flow as it

comes away from the mountains will be drier. So the orography has a significant effect on patterns of local climate so as that changes then so will the local climate.

Land use vegetation and eco systems we can illustrate all three of those by just considering a few of the many different effects on climate that changes in land use have. If we pick in particular on the effects of deforestation that's clearing away of large areas of forest to give the land over to agriculture or other uses or just for urbanisation, building towns and whatever.

First and foremost when we remove large areas of forest we remove what's called a carbon sink because trees and plants use carbon dioxide from the atmosphere to live and grow. So they're important in removing carbon dioxide from the atmosphere and that's what we call a carbon sink. So if we are to do away with large areas of forests then we remove that sink and the amount of carbon dioxide remaining in the atmosphere is higher than it otherwise would be. So that's the first, one of the effects of the changes in land use on climate.

Secondly when we clear the forest away we change what's called the surface reflectance which as the name suggest is essentially just a measure of how reflective the surface is. Generally speaking dark-coloured surfaces such as evergreen forest absorb more solar radiation than light coloured surfaces such as desert or light-coloured concrete. So if we remove areas of dark forest and replace them with lighter-coloured areas then we actually increase the reflectiveness of the surface and reflect more of the sun's rays back to space.

Thirdly if we remove forests then we remove the habitat for all sorts of species and we affect the very finely balanced ecosystems that surround the way they can survive and grow. And of course living things have an effect on what's called the carbon cycle because of their use and reuse and recycling of carbon. So that will affect the amount, again affect the amount of carbon dioxide remaining in the atmosphere.

And one other final influence of or effect of removing forest is that essentially we change what's called the roughness length. That's a measure of how the roughness of the very lowest level of the atmosphere lying on the surface that basically what that means is that basically affects turbulence and the way that weather systems form at very low levels. So if we remove forests then we have the capacity to change the way that weather systems evolve at very low levels which will have further knock-on effects on climate.

And finally in this red section, changes in the ocean. We've got listed here circulation, sea level and biogeochemistry. The oceans are responsible for transporting huge quantities of heat via their various different circulation patterns. One of the ways in which that could be changed is that as climate alters and more rain falls in one place than another you could see a freshening of seawater which will ultimately lead to changes in the way the ocean circulates which in turn will lead to the way heat is transported in the ocean. So that's what that is saying there.

Sea level of course is hugely important and sea levels are projected to rise generally speaking under climate change, global warming situations. And of course that could be potentially extremely devastating for many people in the world who live in low

lying coastal communities. The sea level is affected by various things but it's affected because of the thermal, what we call the thermal expansion of the ocean, simply the fact that as climate warms the ocean water expands which will make the sea level rise.

But also of course as a warming climate melts more snow and ice then this all runs off into the oceans and helps to raise sea level globally. So that's one, another knock-on effect of climate change. And biogeochemistry refers to essentially all the physical, biological and chemical processes occurring among the living things in the ocean and how those will change under a changing climate system.

Okay and finally I just wanted to address the areas on the figure that I've highlighted blue which was to say a few words about the interactions between some of the different components. Some of these we have just touched on briefly but we'll run through these in turn. So here we see the atmosphere/biosphere interaction. In essence this is saying that as we noted earlier trees and plants use carbon dioxide to live and grow, they remove it from the atmosphere so they have a very direct effect on the composition of the atmosphere. They will take carbon dioxide out of the atmosphere.

The land/atmosphere interaction again we just talked about that briefly just now. The way the land is used has an effect on the atmosphere because in various different ways but one of them is the surface reflectance how much of the sun's rays reflect how reflective the surface is and how much of the sun's radiation is reflected back to space. That will affect how much of the sun's energy is available to heat the atmosphere.

The soil/biosphere interaction, the trees and plants and vegetation clearly require a certain supply of moisture in the soil to be able to grow properly. So as climate alters and we maybe see systematically wetter or drier levels of soil moisture that will affect the biosphere. Atmosphere/ice interaction, a warming climate will essentially melt more snow and ice because of the temperature of the air and also because of directly the rays from the sun will melt snow and ice. But the snow and ice because they're very bright white in colour they're very reflective so as we get less snow and ice we get less sunlight reflected. So again we see a sort of positive feedback there as the climate warms we get less sunlight reflected back to space so even more warming.

Heat exchange this is essentially illustrating the exchange of heat between the lowest layers of the atmosphere and the upper layers of the ocean. As climate alters and these systematically change then clearly the exchange of heat between the atmosphere and the ocean will change. Wind stress, the winds from the very lowest layers of the atmosphere provide what's called a wind stress on the upper layers of the ocean and they stir it up and help to change the way how well mixed the upper layers of the ocean are. So again systematic changes in the circulation at the bottom of the atmosphere will change the degree to which upper layers of the ocean are mixed.

And finally precipitation and evaporation as we noted earlier we generally expect with changing climate or with global warming that we'll have a more vigorous hydrological cycle with more water vapour being evaporated into water vapour and condensing to form clouds more of that activity and more rain generally speaking. Although of course it's really the geographical pattern of how that's

distributed that will probably have the most significant impact on humankind.

So I hope that was useful. That's given you a bit of a tour through this particular figure which as I said is a complicated figure. The climate system is incredibly complex. I hope that has been useful to help you to identify those different regions of the figure and to begin to think about the way in which the various different components interact.

In the next section you'll find an extended activity which encourages you to think about the sort of things that we've discussed here and come up with your ideas of the way in which the various components of the climate system interact.

END AUDIO