

//Subtitles English – 73 minutes 17-02-2016

00:00:19:14,00:00:21:10,Okay
00:00:22:20,00:00:25:18,so this is to test the microphone.
00:00:26:09,00:00:28:16,My name is Simon Lamb,
00:00:29:10,00:00:34:10,I'm a scientist. In fact I'm a geologist.
00:00:39:21,00:00:42:12,I'm also a keen amateur cameraman.
00:00:42:12,00:00:46:21,So this is the crew, one cameraman,
00:00:46:21,00:00:52:04,one chap roped in to do the sound [who happened to be walking past the door
00:00:52:13,00:00:56:10,and [umm] looking like a complete idiot.
00:01:02:11,00:01:06:02,Lately I've noticed something[odd happening in the world of science.
00:01:06:11,00:01:11:04,For the first time in my lifetime|scientists are under attack.
00:01:11:06,00:01:16:06,It's junk science and it is a part of a |massive international scientific fraud.
00:01:16:20,00:01:19:21,There is no scientific basis whatsoever.
00:01:20:00,00:01:22:19,This is a fraud and a scam and a hoax.
00:01:22:21,00:01:27:03,This ridiculous nonsense that man-made CO2|is causing global warming.
00:01:27:05,00:01:32:05,These extremists, these alarmists are always|finding something wrong.
00:01:34:12,00:01:39:12,These extremists and alarmists are, of course,| scientists studying the climate.
00:01:43:11,00:01:45:03,Could these accusations be true?
00:01:45:21,00:01:49:16,Were dishonest climate scientists bringing|all of us into disrepute?
00:01:50:24,00:01:53:16,As a scientist I had to find out.
00:01:54:00,00:01:55:15,I must get my glasses.
00:02:02:01,00:02:07:01,So I decided to make a film about the scientists |at the centre of all this controversy.
00:02:09:13,00:02:13:06,It took me to the ends of the earth |and underneath it.
00:02:13:13,00:02:14:21,So Mark, where are we now?
00:02:14:23,00:02:20:08,We're in a tunnel in the Taylor Glacier in the |Dry Valleys here in Antarctica.
00:02:24:19,00:02:28:06,I've looked in to the future|and travelled back in time.
00:02:29:23,00:02:33:00,I've even been somewhere where|time seemed to stand still.
00:02:34:02,00:02:39:21,We are highlighting in blue those issues |that are within the mandate of the group.
00:02:45:24,00:02:51:23,Who are these climate scientists? |What do they do? What are they saying?
00:02:52:16,00:02:54:14,And do they know what they are talking about?
00:02:55:14,00:02:59:16,Are they searching for the truth,|or are they peddling a lie?
00:03:16:09,00:03:20:05,It so happens that my office at |Victoria University of Wellington
00:03:20:08,00:03:23:05,is just down the corridor from their |Antarctic Research Centre.
00:03:24:18,00:03:29:18,They told me if you want to meet climate scientists,| go to Antarctica.
00:03:33:22,00:03:35:18,The place is swarming with them.
00:03:51:12,00:03:58:12,Thus it was that I found myself aboard a |US Airforce C17 Globemaster
00:04:01:22,00:04:09:01,in a cargo hold full of scientists, |wondering what I'd let myself in for.
00:04:28:00,00:04:31:09,Going the very first time to the ice is |something that you can't really describe.
00:04:31:11,00:04:35:09,It's really a once-in-a-lifetime experience.
00:04:38:00,00:04:44:10,Standing on a sea ice runway |in the middle of this huge continent -
00:04:44:10,00:04:47:15,it's a feeling like landing on the moon, I guess.
00:04:47:21,00:04:49:22,I mean I've never been to the moon obviously,
00:04:49:23,00:04:53:01,but I could imagine the astronauts| would feel a similar way
00:04:56:04,00:05:02:16, But once you are there you just see the beauty|- you see this amazing continent with all its
histories,[47/56]
00:05:02:16,00:05:06:20, its secrets and it's right there in front of you |- it's truly amazing.
00:05:12:14,00:05:15:16,The New Zealanders kindly made room for me at Scott Base.
00:05:18:03,00:05:22:14,This is the permanent base that supports |New Zealand's scientific research in Antarctica,
00:05:24:02,00:05:29:02, research that covers the whole spectrum of science|from physics to biology.
00:05:36:02,00:05:38:22,The base, of course, is named after the leader
00:05:38:23,00:05:42:00, of one of the very first scientific expeditions|to the southern continent.
00:05:49:15,00:05:53:23,Scott's expeditions were very much science expeditions -
00:05:53:23,00:05:56:08,and of his team more than half were scientists,
00:05:56:15,00:06:03:21,covering a broad spectrum of science from geology |to geography, meteorology and biology.
00:06:04:21,00:06:07:19, Going to the Pole in many ways was|the means of raising the funds.
00:06:08:00,00:06:12:18, It was a sort of a carrot to attract funds|to carry out a scientific expedition.
00:06:21:10,00:06:26:10, We're at Scott's hut from his|second expedition of 1910 to 13.
00:06:27:15,00:06:34:13, Everyone compares today's records with theirs to|see how things have changed - all important stuff.
00:06:37:09,00:06:42:04, I admire their fortitude and courage|under just incredible conditions.
00:06:42:11,00:06:45:07, It's hard to imagine the deprivations |they went through.
00:06:50:02,00:06:56:12, Today the only people allowed to live and work in|Antarctica are scientists and their support staff.

00:07:02:15,00:07:06:19, I found the variety and ambition of the science quite staggering
00:07:07:05,00:07:11:20, and the common thread linking much of the research was perhaps not surprisingly...
00:07:12:00,00:07:13:14, ice.
00:07:19:19,00:07:27:24, These are ice platelets and almost fresh water.
00:07:27:24,00:07:31:22, and so we think they play a role in the growth of the sea ice.
00:07:41:01,00:07:44:21, Hey Brad - you ready for the next block? Ready.
00:07:51:01,00:07:59:02, We're looking for microbes that reside in the ice and that may respire the carbon in the ice
00:07:59:02,00:08:00:10, to form CO₂.
00:08:08:21,00:08:11:24, Last year's cores looking at the younger part of the geological record
00:08:12:12,00:08:17:00, we're able to see a record of advance and retreat of the ice shelves.
00:08:17:07,00:08:22:07, and now we're in sediments that are getting up towards 20 million years - 15 to 20 million years
00:08:22:08,00:08:24:09, so it's a much older part of the climate story.
00:08:28:18,00:08:33:18, The Antarctic Peninsula is a perfect example of a place where sea ice has disappeared
00:08:34:16,00:08:37:07, and so have Adelie penguin populations.
00:08:37:12,00:08:40:03, They really need the sea ice to do well.
00:08:43:10,00:08:49:15, Ice it turns out is not just frozen water - it's frozen history,
00:08:51:03,00:08:52:20, climate history.
00:08:59:20,00:09:02:18, I knew that climate is just average weather
00:09:03:17,00:09:09:14, and I noticed that an important daily ritual at Scott Base was the recording of the temperature.
00:09:10:09,00:09:15:16, Current temperature at the moment is minus 7.6°C.
00:09:18:08,00:09:24:06, The maximum temperature since this time yesterday is minus 6.6°C.
00:09:24:17,00:09:28:13, The minimum temperature is minus 8.2°C.
00:09:31:22,00:09:37:18, And I need to time stamp this thermograph. It's 09:02.
00:09:40:07,00:09:45:17, It's about 50 years - it was 1957 - that observations started being taken here.
00:09:45:22,00:09:49:18, They were taken every four hours. I'm lucky I only have to do them every day at 9 o'clock
00:09:50:03,00:09:54:12, But I'm conscious that I don't want to be the first science technician in 50 years
00:09:54:12,00:09:56:09, to be hung over from the party last night
00:09:56:16,00:09:58:08, and miss the observations.
00:09:59:04,00:10:03:18, And reset this, I better hold on to this properly. I don't want to let go of it
00:10:03:19,00:10:05:03, and put mercury everywhere.
00:10:06:02,00:10:10:02, It's easy to do that in winter when you're wearing big gloves.
00:10:11:01,00:10:16:24, There is a 1 degree change in the mean temperature here at Scott Base in the last 50 years
00:10:17:08,00:10:22:20, and that's reasonably significant in terms of change over a short period.
00:10:23:09,00:10:29:18, In previous parts of history there's been perhaps a four degree change every thousand years,
00:10:29:22,00:10:32:07, so one degree over 50 years is quite significant.
00:10:33:19,00:10:37:09, So people have been recording the weather in Antarctic for about fifty years,
00:10:38:09,00:10:42:11, a hundred, if you include the observations made by Captain Scott's expedition.
00:10:48:18,00:10:53:08, But on the Evans Piedmont Glacier I learnt that snow and ice
00:10:53:08,00:10:56:14, have been recording the climate for much longer.
00:10:57:14,00:11:01:03, Well, girls - pick your weapons.
00:11:02:04,00:11:05:24, Because snow is an amazing material, as it forms in the atmosphere
00:11:05:24,00:11:08:09, and falls down to accumulate here,
00:11:08:09,00:11:13:13, it captures a lot of information on the particular weather of the day, of the month, the year.
00:11:16:15,00:11:21:19, You can see these wonderful structures here in the snow, which represent annual layers.
00:11:21:23,00:11:26:23, and so by digging this snow pit we are going back about 40 years in time.
00:11:29:14,00:11:33:19, When I visited, Nancy Bertler's colleagues were carefully harvesting snow
00:11:34:04,00:11:36:20, that had fallen over the past few decades.
00:11:37:11,00:11:40:20, A period when we have records of how the climate was changing.
00:11:41:22,00:11:45:18, At the end of the day what we are measuring, its chemistry, its isotopes,
00:11:45:18,00:11:50:13, and to understand how the climate record is preserved in the snow,
00:11:50:24,00:11:53:05, we need to have some time of overlap
00:11:53:05,00:11:56:17, where we can see what the weather did and what the snow tells us about the weather.
00:11:58:00,00:12:01:15, We use then this knowledge to go back further in time with the ice core records,
00:12:01:15,00:12:03:08, where we go back many thousands of years,
00:12:04:22,00:12:09:13, but where we don't have the luxury of having meteorological observations.
00:12:16:21,00:12:20:03, I was intrigued by these ice cores that Nancy had mentioned,
00:12:21:00,00:12:26:05, and then I was told there was an American-led team of scientists drilling ice cores
00:12:26:05,00:12:28:16, up on the vast Antarctic polar ice cap.
00:12:31:16,00:12:33:22, So I hitched a ride on a logistics flight
00:12:34:14,00:12:40:02, which took a mere 2 and a half hours to cover the same ground Captain Scott struggled over
00:12:40:02,00:12:41:22, for 2 and a half months.

00:12:55:12,00:13:01:15, Apparently this small team is travelling right across [the Polar Plateau, drilling ice cores as they went. [54/51]

00:13:16:23,00:13:21:24, We started about 450km north of here last year,
00:13:22:04,00:13:25:08, but only managed to travel the 450km.
00:13:25:10,00:13:28:14, Typically we travel much more than 1000 in a season.
00:13:29:12,00:13:33:22, We effectively travel in three different groups. [The first is that red "Pisten Bully".
00:13:33:22,00:13:35:21, - it has a crevice detector on the front.
00:13:38:15,00:13:43:15, - then the second train will have the kitchen [and the accommodations,
00:13:44:05,00:13:47:19, it's dragging experiments looking [down into the ice.
00:13:48:00,00:13:53:00, And then the third train is made up of ice cores] and additional scientific equipment.
00:13:54:12,00:13:59:12, I'm Daniel Dickson. I'm a PhD student with [Paul Mayewski.
00:14:01:10,00:14:07:24, We're trying to understand the climate of [Antarctica for the last 200 to 1000 years
00:14:08:18,00:14:12:07, and I do this by looking at the chemistry of ice cores.
00:14:14:05,00:14:16:04, These are our two ice core drills
00:14:16:04,00:14:22:05, - one recovers about a 3 inch diameter ice core, [the other about a 2 inch diameter ice core
00:14:22:18,00:14:28:10, and they can go down about 100 to 200 metres, [allowing us to go back 200 to about 1000 years.
00:14:29:05,00:14:34:05, The way this drill works is similar to the way [you would drill a hole in the wall of your house
00:14:34:22,00:14:37:09, but the only difference is our drill bit is hollow,
00:14:37:19,00:14:41:21, and so while we are drilling, the core [is actually captured inside the drill bit.
00:14:42:08,00:14:45:13, Paul will push the core from this end,] and the chips will empty
00:14:47:20,00:14:52:08, - and here comes the core [- and there we have a perfect metre of core.
00:14:53:05,00:14:59:08, We understood from the late 1960s probably until [about 15 years ago, or believed, I should say,
00:14:59:08,00:15:02:04, that Antarctica was a very stable place.
00:15:02:13,00:15:06:12, - giant white cold mass of ice that never changed.
00:15:06:15,00:15:10:21, In the last 15 to 20 years we've learned that [this place is very dynamic.
00:15:12:09,00:15:18:03, This may be a cold spot but climatically [it's a real potential hot spot for change.
00:15:25:18,00:15:30:18, So overall we drilled 1000 metres [- that's almost a decade worth of work.
00:15:31:21,00:15:36:04, So this is our core - we're working on this one.
00:15:38:10,00:15:41:03, It's not the easiest of jobs, it's a little bit fiddly.
00:15:41:12,00:15:46:12, We set it onto a continuous melter, [which is pretty much just like a hot plate.
00:15:47:04,00:15:52:04, It melts the ice core layer by layer [back through time.
00:15:53:00,00:15:58:02, As the water is produced, it is pumped by [these pumps into these various tubes,
00:15:58:02,00:16:03:02, and this allows us to do analyses of all sorts of [things that are contained in these ice cores.
00:16:07:24,00:16:11:17, We are looking for properties of the water [that tell us about the temperature.
00:16:11:22,00:16:15:17, We are looking for dust as an indicator [of wind strength,
00:16:15:17,00:16:20:09, and where this air mass might come from] that precipitated this snow.
00:16:22:17,00:16:27:10, And so by studying how much of these] various components is in the ice,
00:16:27:10,00:16:30:23, we get a feel for what the climate was like [when the snow fell.
00:16:33:14,00:16:39:19, But what really fascinated me is that the ice cores] allow us to relate changes in past climate
00:16:39:24,00:16:43:21, to changes in the composition of [the ancient atmosphere.
00:16:44:07,00:16:50:01, In the ice cores there are little bubbles that [contain a real sample of the atmosphere through time.
[54/55]

00:16:50:06,00:16:53:17, We can release that air and measure [the greenhouse gases.
00:16:53:24,00:16:57:23, You could almost say we're taking the DNA] of the atmosphere.
00:16:59:09,00:17:05:01, Nancy and her colleagues are just one of [many scientific groups examining ice cores.
00:17:06:11,00:17:12:01, I found a lot of the original scientific papers [on the web going back over 30 years.
00:17:12:12,00:17:16:13, All the cores seem to tell the same story,
00:17:16:20,00:17:22:18, a regular pattern of cooling and warming [as the planet passes in and out of ice ages.
00:17:25:23,00:17:28:21, Yes, so we've got this remarkable record [in the ice cores,
00:17:29:13,00:17:36:02, and we see these very regular, but quite dramatic] shifts going from warm to cold, warm to cold,
00:17:36:02,00:17:37:18, warm to cold, warm to cold.
00:17:37:19,00:17:41:00, These are the glacial interglacial cycles [happening every 100, 000 years.
00:17:41:00,00:17:48:04, But what's so striking is the way that CO2 levels] show exactly the same pattern as temperature.
00:17:49:03,00:17:53:16, It's probably the best correlation in any [natural data set that I've ever seen.
00:17:54:22,00:17:58:00, The greenhouse gases also show [the same pattern
00:17:58:07,00:18:01:12, so when CO2 goes up temperature goes up,
00:18:01:12,00:18:04:05, and vice versa, when CO2 goes down [the temperature goes down,
00:18:04:05,00:18:08:22, and for all intents and purposes it looks like [they are totally locked together in step.
00:18:09:19,00:18:12:11, And it really is a remarkable piece of science.
00:18:12:15,00:18:15:06, It's revolutionised the way we think [about the climate system.
00:18:21:01,00:18:24:22, This discovery, that going back [hundreds of thousands of years,
00:18:24:22,00:18:28:15, there's a link between CO2 in the atmosphere [and temperature,

00:18:29:09,00:18:33:04, must be one of the most important things |to come out of Antarctic science.

00:18:38:21,00:18:44:00, But to me this correlation was still not proof | of the central claim of climate scientists -

00:18:46:02,00:18:51:13, that changing levels of CO2 are actually |causing the changing temperatures.

00:18:56:01,00:19:01:01, I realised I needed to know a lot more about |what CO2 does in the atmosphere

00:19:01:11,00:19:03:05, and why it's called a greenhouse gas.

00:19:03:20,00:19:09:10, First though, I wanted to see the evidence| that CO2 levels are rising today.

00:19:10:18,00:19:13:01, I found it not far from home.

00:19:24:11,00:19:30:03, This place is a good one for CO2 measurements | because below us or south of us is ocean really,

00:19:30:14,00:19:35:07, so big southerly storms are actually what we|really like - we really get excited.

00:19:35:15,00:19:39:13, But it normally means for Wellington it's raining | cats and dogs, and it's really strong wind.

00:19:39:13,00:19:41:10, but that is when we go out here,

00:19:44:16,00:19:48:12, because that means the air is really nice, | fast flowing, and clean,

00:19:48:12,00:19:50:00, coming from the Southern Ocean.

00:19:53:04,00:19:55:08, The Southern Ocean is a huge mixing bowl

00:19:55:12,00:19:58:15, which is seeing the cleanest air that's | left on the planet.

00:19:59:00,00:20:04:08, And by looking at that, we're getting | the trends globally

00:20:04:12,00:20:07:07, in a way that you can't get

00:20:07:20,00:20:11:07, at, say, a site in the Northern Hemisphere.

00:20:16:11,00:20:20:16, This is the CO2 and oxygen room where basically | everything happens,

00:20:20:16,00:20:24:10, that is, where the oxygen analyser is, and the| CO2 analyser.

00:20:25:19,00:20:31:11, The noise here is from the pumps sucking in |the air from the outside.

00:20:39:19,00:20:44:19, We need to freeze out the moisture in the air, | because it influences our measurements,

00:20:44:22,00:20:47:16, and then this dried air goes into an analyser.

00:20:50:10,00:20:55:09, So this is the computer where everything happens, |and this is the CO2 system.

00:20:55:17,00:21:00:17, Over the last hour CO2 concentrations |and over the last four hours.

00:21:02:00,00:21:08:00, So at the moment we are measuring 385 PPM |of CO2.

00:21:11:05,00:21:15:07, The results here are also double checked |by scientists in California.

00:21:15:20,00:21:19:21, We also have some air sampling going for |Scripps Institute -

00:21:19:22,00:21:22:19, and they send us some glass flasks |which are evacuated.

00:21:24:03,00:21:29:03, In this howling gale we open one of these |glass flasks to suck the air in - hear the hiss,

00:21:30:00,00:21:36:13, and then we fast close this one with the valve, |and send it back to America to be analysed for CO2.

00:21:38:21,00:21:41:10, Again the results are easily available on the web,

00:21:42:10,00:21:49:12, and they show a steady rise in CO2 by over |50 parts per million in the last three decades or so.

00:21:54:22,00:21:59:23, The claim is that all this CO2 comes from the burning of fossil fuels.

00:22:01:11,00:22:08:02, Katja had her own evidence of this because she |also detects changes in atmospheric oxygen level.

00:22:08:08,00:22:11:13, When we say fossil fuel burning produces CO2,

00:22:11:20,00:22:16:12, in order to make CO2 out of the carbon|you need to add oxygen,

00:22:16:23,00:22:21:23, so when CO2 is increasing, |oxygen in the atmosphere is decreasing.

00:22:22:04,00:22:24:19, And before people start worrying,

00:22:24:19,00:22:28:02, it's not decreasing so much that we don't |have enough oxygen to breath any more.

00:22:28:02,00:22:31:20, There is quite a lot of oxygen around and |it is tiny changes that we are measuring.

00:22:32:00,00:22:37:10, But you can see clearly one curve, CO2,| is going up, oxygen is going down.

00:22:41:23,00:22:46:23, I've been in this job now for seven years, |and just even during this time it has changed.

00:22:47:04,00:22:53:13, I am not quite sure but I think when I started |it was at 360, 365 and now we're at 380.

00:22:53:17,00:22:57:19, So just over the time that I have been here |I see changes already.

00:23:02:03,00:23:08:17, The rise in CO2 is large, even compared to the big |swings I had seen preserved in the ice cores,

00:23:08:23,00:23:13:02, swings which are associated with big changes |in global temperature.

00:23:14:24,00:23:18:17, But on the other hand CO2 is just a trace gas |in the atmosphere.

00:23:19:10,00:23:23:05, Could it really affect the climate so profoundly?

00:23:28:17,00:23:34:22, In my quest to understand the science of |climate change it was time to talk to physicists.

00:23:38:06,00:23:43:06, We're going to try to go through in this tutorial |basically what controls the climate of the earth.

00:23:43:14,00:23:46:15, But I was rather taken aback at what they said.

00:23:46:17,00:23:50:21, The question of whether or not greenhouse gases| are causing global warming is

00:23:50:21,00:23:52:24, completely uninteresting to a physicist

00:23:52:24,00:23:54:18, Of course they are causing global warming.

00:23:55:20,00:24:02:02, It turns out that the theory of global warming, |the greenhouse effect, was worked out some time ago. [50/52]

00:24:02:18,00:24:08:18, If all we knew was that greenhouse gas levels were|going up and supposing we didn't have any record [50/48]

00:24:08:18,00:24:16:06, of temperatures over the last 50 years, we would |still expect as physicists the world to be warming [49/51].

00:24:16:13,00:24:21:14, Really what we're talking about is not so different |from the warming effect that you get from

00:24:21:14,00:24:24:00, adding fibreglass insulation to your house.

00:24:24:15,00:24:28:13, You've got a big chunky amount of [shortwave energy coming in from the sun.

00:24:29:11,00:24:34:19, If we want to understand the climate, [or particularly the surface temperature of a planet

00:24:35:01,00:24:39:03, you first have to understand something about [the connection between temperature and energy.

00:24:39:07,00:24:45:03, Temperature is loosely speaking a measure [of the energy content of something.

00:24:45:03,00:24:47:15, Something that is hotter actually has more energy inside it.

00:24:49:21,00:24:53:13, In order to determine the temperature [you need to know something about

00:24:53:13,00:24:56:14, the rate at which energy goes in, and [the rate at which energy goes out.

00:25:06:05,00:25:12:06, In 1827 it was recognised that the energy source [that maintains the earth's temperature

00:25:12:08,00:25:17:18, is not energy coming up from the interior of the planet, [but the sunlight that's absorbed.

00:25:17:21,00:25:23:08, And so if you kept absorbing all the sunlight [and you kept accumulating energy,

00:25:23:23,00:25:27:02, then the planet would just heat up, [and heat up, and heat up,

00:25:27:02,00:25:30:04, and the temperature would grow without bound [until we melted.

00:25:36:02,00:25:39:13, The other part of the equation that [determines the temperature of a planet

00:25:40:00,00:25:42:09, is the rate at which you lose energy.

00:25:42:09,00:25:48:05, Here the key insight was that the hotter [a body gets the more rapidly it loses energy.

00:25:48:07,00:25:54:24, You're receiving energy at more or less a fixed rate [from the sun. Then temperature builds up and up.

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00:25:55:03,00:25:58:19, The hotter it gets the more rapidly [you lose energy to space,

00:26:00:17,00:26:06:14, and then, bang, when what goes out equals what comes in, [that's your equilibrium temperature.

00:26:10:22,00:26:13:16, Though on reflection it's obvious, I was still struck

00:26:13:16,00:26:19:22, by the fact that to avoid burning up [the earth must constantly lose energy to space.

00:26:19:22,00:26:23:01, Given that outer space is essentially a vacuum

00:26:23:05,00:26:27:24, the only way that a planet can lose energy, [the only thing that exits from the planet, -

00:26:27:24,00:26:30:12, is light radiation, electromagnetic radiation

00:26:30:16,00:26:36:08, and light I mean broadly construed, [so there is light that we can't see - infrared.

00:26:41:05,00:26:44:20, You can actually feel the effect of infrared energy from the earth.

00:26:45:00,00:26:50:12, If you go out on a clear night in the winter, and you hold your hand above the ground

00:26:50:14,00:26:55:04, you can actually feel that the bottom of your hand feels warmer than the top.

00:26:55:22,00:26:59:06, And that's the flux of infrared energy [escaping from the earth.

00:27:00:21,00:27:04:22, The reason I said it had to be a cold night in winter is [because those are some of the few conditions

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00:27:04:22,00:27:10:08, in which you actually do get radiation [escaping from the surface of the earth directly.

00:27:10:10,00:27:17:11, On most days under most conditions [the atmosphere is far too thick,

00:27:17:11,00:27:22:11, far too opaque for this infrared radiation [to escape directly to space.

00:27:22:23,00:27:25:07, And this is the thing that people have [to understand

00:27:25:07,00:27:29:05, - the atmosphere looks completely different in the infrared.

00:27:29:05,00:27:34:15, If we were wearing goggles that only allowed us [to see in the wavelengths

00:27:34:15,00:27:38:12, that the earth uses to shed energy to space,

00:27:38:12,00:27:43:12, we wouldn't be able to see very far. We'd barely [be able to see 200 yards to that college over there

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00:27:47:02,00:27:49:11, Most of the atmosphere is nitrogen and oxygen,

00:27:49:11,00:27:54:16, I mean 80% of it is nitrogen, and nitrogen [doesn't really absorb infrared radiation very well

00:27:54:16,00:27:56:16, - it doesn't absorb heat very well at all.

00:27:57:05,00:28:03:23, So anything like CO₂, which is a different type of molecule [- it has a different shape essentially

00:28:04:02,00:28:07:07, - is much, much better at absorbing heat

00:28:07:07,00:28:11:18, specifically at the wavelengths, [the parts of the colours of the spectrum,

00:28:11:18,00:28:14:07, where the earth itself is re-emitting that heat.

00:28:17:07,00:28:22:00, OK, what I am going to do is I'm going to puff [some CO₂ from this fire extinguisher into the beam

00:28:22:00,00:28:23:15, between the sun and the instrument,

00:28:23:15,00:28:26:24, and see what effect that has on the absorption. Here we go.

00:28:27:03,00:28:28:20, We'll see what that does.

00:28:29:09,00:28:32:09, So here we've got the two spectra that we measured from outside

00:28:32:11,00:28:39:09, - the black curve underneath is what happened [after we puffed CO₂ from the fire extinguisher in,

00:28:39:13,00:28:45:12, and here you can see the strong [absorption feature due to CO₂.

00:28:46:09,00:28:49:20, This shows why CO₂ is such a good [greenhouse gas

00:28:50:02,00:28:56:11, because it has such strong infrared absorption where the earth is re-emitting heat from the sun.

00:28:58:21,00:29:02:22, But the higher up you go, the more tenuous the atmosphere gets, and the thinner it is,

00:29:02:22,00:29:06:14, so there's less greenhouse gas there [just because there's less gas of any sort.

00:29:06:14,00:29:09:22, And so there's always some level where [the atmosphere finally becomes thin enough

00:29:09:23,00:29:12:14, that the radiation can escape to space -

00:29:13:03,00:29:15:10, and that is called a radiating level.

00:29:24:07,00:29:28:04, I've been doing this twice a day |for the last 40 years.
00:29:28:15,00:29:30:10, Do you enjoy doing this?
00:29:30:16,00:29:36:10,It's fascinating. You never can tell what you're |going to get on your flight, and it's always different.
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00:29:40:01,00:29:47:14,As you're going up in a balloon, you're in effect |rising through the mist, and escaping slowly
00:29:47:16,00:29:51:14, from the greenhouse blanket that envelopes |the surface of the earth.
00:29:53:01,00:29:56:09, And when you get to around 5000 metres, |you've reached that critical altitude where
00:29:56:10,00:30:00:13, energy can begin to escape to space.
00:30:03:02,00:30:05:18, And that level is colder than the ground
00:30:06:13,00:30:10:06,because the higher up you go, up to |a certain point, the colder it gets,
00:30:10:24,00:30:14:01, and that is called the radiating temperature |of the planet.
00:30:15:05,00:30:20:18,OK, the temperature plot we have here |starts at the surface at about 18 degrees
00:30:20:18,00:30:24:18, - at about 10,000 feet we go through the |freezing level.
00:30:25:01,00:30:34:11, You can see the temperature decrease up to this |point here, about 12 km, which is the Tropopause.
00:30:38:15,00:30:43:15, And then I'll be back here at midnight tonight,| and do it all over again.
00:30:50:09,00:30:54:20,That difference between the radiating temperature, | which you can measure from satellites and
confirm [51/50]
00:30:54:22,00:30:59:24, - that difference between the radiating temperature |and the surface temperature is accounted for by
00:30:59:24,00:31:01:09, greenhouses gases.
00:31:01:18,00:31:10:12,If you looked at the planet from space, it would look |as if the planet had a temperature of -18°C.
00:31:11:16,00:31:15:09, That's the temperature we would actually have |if we had no atmosphere.
00:31:15:11,00:31:23:06,But in fact we have a blanket of greenhouse gases|surrounding the earth.
00:31:23:10,00:31:28:10,What you see from space is the top of that blanket, |which - just like a real blanket
00:31:28:12,00:31:33:12,- can be much colder than the bottom. |So where we are underneath this blanket
00:31:33:15,00:31:37:13, is a nice comfortable 15 degrees on average.
00:31:38:10,00:31:44:10,No matter how much greenhouse gas we add |to the atmosphere, we will not change the
00:31:44:10,00:31:46:05, radiating temperature of the planet
00:31:46:11,00:31:51:11,because the radiating temperature is determined |by the requirements of energy balance.
00:31:51:24,00:31:57:04,So if the earth is radiating at a temperature of| minus 20 Celsius today, in round numbers,
00:31:57:22,00:32:05:12,then even after adding a lot of CO2 to the atmosphere |it will still, once it comes into balance,
00:32:05:12,00:32:07:16, be radiating at minus 20
00:32:08:17,00:32:13:22,When we add CO2 to the atmosphere we are not |primarily changing the radiating temperature -
00:32:13:22,00:32:16:18, we're changing the radiating altitude.
00:32:17:22,00:32:25:15,When we raise greenhouse gas levels, you |make the fog thicker, and the mist rises slightly,
00:32:26:06,00:32:32:11,and where you are, energy can no longer escape. |So you have to go a little bit higher.
00:32:35:04,00:32:38:16,The more greenhouse gas you stuff in the atmosphere, |the higher you have to go
00:32:38:16,00:32:44:07, before the atmosphere is thin enough to |let the infrared radiation escape to space.
00:32:46:06,00:32:51:01, So the atmosphere is radiating to space |from a higher altitude than it used to,
00:32:51:03,00:33:02:03,so that the temperature at the radiating level which |is still -20, remains at -20. But that occurs higher.
[53/53]
00:33:02:16,00:33:09:14,And since the rate at which temperature increases |as you go deeper in the atmosphere is fixed,
00:33:09:20,00:33:14:06, but you're starting at that -20 from higher up,| by the time you extrapolate to the ground,
00:33:14:06,00:33:16:09, you wind up with a higher temperature.
00:33:27:00,00:33:32:13,On average, temperature goes down about six degrees |with each kilometre that you go up,
00:33:33:00,00:33:35:17, And so, we can ask the question:
00:33:35:18,00:33:40:05,how much higher do we have to push that level |in order to get a two degree warming at the surface?
00:33:41:13,00:33:46:13,Well, to get a six degree warming you would push |that radiating level up by 1 km.
00:33:46:23,00:33:53:05,To get a two degree warming at the surface I need only |push it up a third that much, roughly 300 m
00:33:54:22,00:33:59:22,It takes relatively little increase in the |infrared murkiness of the atmosphere
00:34:00:14,00:34:06:21,to change the altitude at which infrared |escapes to space by a mere 300 metres.
00:34:08:16,00:34:14:07,And that's part of why the climate is so sensitive |to greenhouse gas concentrations.
00:34:19:18,00:34:24:18,So the link between temperature and |CO2 was basic physics,
00:34:26:11,00:34:29:09, ideas that had been around for over 100 years.
00:34:35:12,00:34:40:12, But are global temperatures really rising|in the way these ideas would suggest?|
00:34:45:16,00:34:51:10,Working out an average temperature for the whole planet |is obviously an enormous undertaking.
00:34:53:05,00:34:55:23, There are three main scientific groups who do this.
00:34:56:14,00:35:02:17,I met Professor Phil Jones who leads the British |team based at the University of East Anglia.
00:35:05:01,00:35:09:10,Phil was soon to be embroiled in a |rather strange controversy over emails,
00:35:09:17,00:35:13:05, but when I saw him that was still in the future.
00:35:14:05,00:35:18:17,One of the principal things we're known for |is the development of the global temperature record,
00:35:18:18,00:35:21:02, which we started in the early 1980s.
00:35:22:11,00:35:25:20,This involved putting together all the records |of temperature from around the world,

00:35:25:20,00:35:28:11, the land areas, and from the oceans.
00:35:29:10,00:35:33:06, We weren't looking to say whether [the climate was warming at the time.
00:35:33:15,00:35:36:24, We just thought it was a good thing to [have produced a temperature data set
00:35:36:24,00:35:39:12, of the surface of the planet.
00:35:41:03,00:35:46:24, What I wasn't expecting at the time was to [continue to be doing this 30 odd years later.
00:35:49:09,00:35:52:00, Phil's office took me rather by surprise.
00:35:52:09,00:35:57:09, It was crammed with scientific publications [and there was barely room to film
00:35:58:01,00:36:00:08, but Phil seemed quite at home here.
00:36:00:15,00:36:06:07, Well, one thing we get in each month is the data [from the Met Services through the UK Met office.
00:36:07:11,00:36:10:22, Vast majority of the data comes in routinely [over the system
00:36:10:22,00:36:12:23, but one or two stations come in by email.
00:36:13:00,00:36:18:19, This is one for the South Pole and we have here [the temperatures, pressures and the wind speeds.
00:36:18:21,00:36:25:08, The average temperature for October 2008 at [the South Pole was minus 51.5 degrees Celsius.
00:36:27:02,00:36:31:04, Most climate information we have access to, not [just for temperature but for other variables too,
00:36:31:04,00:36:34:11, is collected for weather forecasting purposes.
00:36:34:18,00:36:36:21, So the primary use is weather forecasts.
00:36:36:21,00:36:40:07, You can think of climate as a second hand user [of weather data.
00:36:41:07,00:36:46:21, Phil has also collected weather data like this [going back in time more than a century.
00:36:47:00,00:36:53:10, This is the book with data from Scott's expedition [to the Antarctic for the 1909 to 1911 period,
00:36:54:03,00:37:00:23, so it contains all the temperature, pressure, [snowfall and other weather measurements taken
00:37:01:14,00:37:07:03, both at the bases along on the coast and on [his ill-fated expedition to the South Pole.
00:37:08:16,00:37:15:22, So, again we've gone through these and digitised [the data, and all this goes into our database.
00:37:18:05,00:37:21:05, So there's one of the Russian yearbooks for 1847.
00:37:22:11,00:37:29:05, And this one contains daily data and monthly data [from various places across Russia.
00:37:29:09,00:37:33:02, So here we have June 1847 for Yekaterinburg,
00:37:33:02,00:37:39:04, and it tells us temperature, and the pressure [every hour, the daily rainfall totals,
00:37:39:14,00:37:43:16, and all these in these books up until a certain time [are in degrees Réaumur.
00:37:43:18,00:37:49:23, which is a French scale where the freezing point [is zero but the boiling point was 80 degrees.
00:37:50:24,00:37:55:01, We wanted to try and put the last 150 years [in a longer context
00:37:55:10,00:37:59:08, so to go further back then you've got to look at [proxy records of climate.
00:37:59:23,00:38:09:10, In that sort of work, looking at trees and peat bogs etc., [and more recently corals and ice cores,
00:38:09:15,00:38:13:10, began in the 19th century with the Victorian scientists.
00:38:19:08,00:38:23:19, And we can also combine these with other [written records about the past.
00:38:23:23,00:38:30:10, We call these documentary records, [which is where people since the Medieval times
00:38:31:00,00:38:37:01, have written down what the weather was like, [what the harvest was like, how bad the winters were.
00:38:37:05,00:38:43:06, And these can also be put together, and especially [in countries that have long written histories.
00:38:48:01,00:38:54:08, But what you see for the last 1000 years is that [the world was relatively warm in Medieval times
00:38:54:12,00:38:57:17, particularly in the first couple of centuries [of the millennium.
00:38:57:22,00:39:02:12, There was then a cooling into about [the 15th and 16th centuries.
00:39:02:18,00:39:07:18, But when you put them all together, and [try and assign numbers to the earlier period,
00:39:07:20,00:39:13:02, you find that the warmest century of all in [the last millennium was the 20th century
00:39:13:20,00:39:15:19, and the coldest was the 17th.
00:39:19:12,00:39:23:05, To me, Phil Jones seemed a [careful and objective scientist,
00:39:24:04,00:39:28:15, so I was stunned when I heard that he'd become [the subject of claims of scientific fraud
00:39:28:15,00:39:31:00, after some of his e-mails were hacked into.
00:39:33:03,00:39:38:16, Eventually no fewer than four independent enquiries, [both in the UK and US,
00:39:38:16,00:39:42:02, cleared him of all accusations of unethical data manipulation.
00:39:45:00,00:39:48:10, This made sense - because it [did not take me long to find
00:39:48:11,00:39:51:16, the other independent estimates of [global temperature trends.
00:39:52:04,00:39:54:21, like this one compiled by NASA.
00:39:55:09,00:39:59:12, And they all had pretty much exactly [the same message about global warming.
00:40:00:08,00:40:03:22, There are one or two coolish decades [in the second half of the 19th century
00:40:03:22,00:40:05:14, and one or two slightly warmer decades,
00:40:05:15,00:40:08:06, but there's no real overall trend in temperature
00:40:08:07,00:40:13:07, on longer-than-decade time scales [until you get to the 1910s.
00:40:18:16,00:40:26:11, Then you have quite a dramatic warming [from the late 1910s to the middle of the 1940s,
00:40:27:04,00:40:32:04, which is more marked in the Arctic region [than in other regions of the world.
00:40:33:09,00:40:38:09, And after that time the temperatures [cooled slightly to the late 1970s,
00:40:38:12,00:40:40:20, and they've warmed very dramatically since.
00:40:44:20,00:40:53:03, And the top ten warmest years are all from [1997 through to 2008 with the exception of 1999.
00:40:54:20,00:41:00:06, Temperature records show that over the past few decades [the region that'd warmed fastest on earth
00:41:00:06,00:41:01:18, was the Arctic.

00:41:08:13,00:41:11:24,I wanted to find out what the people who live there had experienced
00:41:12:13,00:41:16:10, so I jumped at the chance to visit northern Norway.
00:41:31:05,00:41:36:05,Exactly how long the Sami people had been here seems to be a matter of debate.
00:41:39:02,00:41:42:20,The Sami has been reindeer herders |very very long time
00:41:43:13,00:41:51:10, - some scientists say 400 year, and of course it is |several thousand of year, not only 400 years.
00:41:53:20,00:41:58:12, All their culture, their identity and so on, |is connected to reindeer husbandry.
00:41:58:23,00:42:07:24,Of course it is very close we live to the environment |and also it's a way of life to live with
00:42:08:10,00:42:15:10,all the changes in the environment. As you know |in Arctic we have a lot of changes in the climate.
00:42:22:01,00:42:30:16, Trees are growing in the tundra. |It's bad because trees, they kill lichen.
00:42:31:18,00:42:38:11,The reindeer don't like it - and of course it's also |covered with more snow, when it is wind.
00:42:39:16,00:42:42:24, So the snow will be very hard.
00:42:47:16,00:42:56:08, My granddad and the generations before that |have all been here in the mountains
00:42:56:24,00:43:03:07, for - I don't know - maybe 300 years, we have done that.
00:43:05:16,00:43:10:16, But not so cold any more, like 20 years ago.
00:43:12:18,00:43:19:18, It was normally [-] 40 degrees. That was normal.
00:43:26:02,00:43:31:02, Snowmobile - it's a good thing to use in this work.
00:43:32:16,00:43:47:09,Maybe I am a part of destroying nature, a little part of it. |But that's just like it is...like it is.
00:44:06:23,00:44:12:20,I asked Uvlla Henrich about climate - how he feels it has been. |He feels it has been a big change.
00:44:15:11,00:44:25:08,Earlier, it was very common with long periods |- already in December, January, February
00:44:25:08,00:44:29:18, with temperatures between 35 to 40 below Celsius,
00:44:30:04,00:44:38:08,and now it's very common with rain in December. |So he feels there has been a big change.
00:44:47:02,00:44:52:16, Probably it has been warmer earlier, but in the |last ten years they have really noticed changing.
00:44:57:11,00:45:02:09, By now I felt I had seen a lot of evidence |that the earth is actually warming,
00:45:02:23,00:45:06:18, and that rising levels of CO2 |a part of the explanation,
00:45:07:04,00:45:08:19, if not the whole thing.
00:45:09:14,00:45:14:24,But everything I'd learnt so far was about the past. |What about the future?
00:45:15:24,00:45:19:04, I knew scientists were making predictions |about global temperatures
00:45:19:04,00:45:21:18, at the end of this century and beyond.
00:45:23:16,00:45:26:01, Could they really be so confident?
00:45:36:01,00:45:39:15, Two thirds of the earth is covered by water
00:45:40:14,00:45:46:19,so it's what happens to the oceans that will determine |the future of the world's climate.
00:45:47:01,00:45:51:05, The ocean stores an enormous amount of heat.
00:45:52:04,00:45:56:11,In order to warm the planet we ultimately |have to warm the whole ocean
00:45:56:24,00:46:02:22, and to warm the whole ocean is an enormous thing.
00:46:09:09,00:46:12:14, So what is happening to the world's oceans?
00:46:13:02,00:46:19:00,With a slightly sinking stomach, I accepted |an invitation to join the RV Tangaroa,
00:46:19:00,00:46:21:18, New Zealand's deep water research vessel,
00:46:22:10,00:46:25:01,on a cruise to the Southern Ocean.
00:46:28:12,00:46:32:22, I am sure I'm preaching to the choir here |- anybody who's sailed in the Southern Ocean has
00:46:32:22,00:46:34:06, felt its turbulence.
00:46:35:03,00:46:41:24, For any yachtsman sailing around-the-world yacht races, |the big bogie is always the Southern
Ocean.[48/50]
00:46:45:06,00:46:48:15, Oceanography covers a whole range of disciplines.
00:46:48:17,00:46:55:13, so you have to have some knowledge of chemistry, |of the climate, of the geology, and of the biology
[50/51]
00:46:56:03,00:47:01:03, There's a whole range of things in the back of |your mind when you go to sea.
00:47:02:00,00:47:05:13, But I do get seasick and that's the fact of life.
00:47:08:13,00:47:12:02, As soon as that ship leaves port we're in business.
00:47:16:15,00:47:21:00, Because we're running 24 hours a day, |we have one team doing 12 hours,
00:47:21:00,00:47:23:01, the other team doing the second 12 hours.
00:47:24:21,00:47:32:05, When we reach the first of our scheduled survey points, |I like to say "All hell breaks loose".
00:47:41:21,00:47:43:22, We take lots of water samples,
00:47:43:24,00:47:52:16, and we are constantly recording the depth of the ocean, |along with surface water temperature.
00:47:53:18,00:47:59:14, Temperature is fairly constant down to about 30-40 metres. |Then it slowly starts dropping off,
00:48:00:02,00:48:02:05, and the deeper we get the lower the temperature.
00:48:07:18,00:48:14:06,We have a range of instruments: current meters, |temperature loggers, sediment traps,
00:48:14:09,00:48:17:02, instruments for measuring CO2 in the water.
00:48:18:06,00:48:22:19,This is the probably close to the 20th time |we have visited this site.
00:48:24:18,00:48:31:18,There is really no other way to get a time series |of measurements from the depths of the ocean.
00:48:32:08,00:48:36:07, So we're turning it around, replacing the instruments,
00:48:36:09,00:48:39:06, and we'll be leaving it again now for another eight months.
00:48:41:11,00:48:46:22, I love my work, I suppose I shouldn't say, |but I've been doing this for almost 20 years,

00:48:47:03,00:48:53:24, and I really enjoy coming out to sea. |It's what makes being an academic fun.
00:48:56:11,00:48:59:18, You cannot do the science without knowing |where your samples come from.
00:48:59:20,00:49:02:00, You can ask people to bring you home samples,
00:49:02:02,00:49:06:23, but if you don't actually see where things are coming from.
00:49:07:06,00:49:10:06, It's easy to miss the subtleties in what you're looking at.
00:49:18:12,00:49:22:23, The warming, which initially affects the atmosphere| and the near-surface ocean,
00:49:22:23,00:49:26:13, is slowly penetrating down into the ocean depths
00:49:26:18,00:49:32:14, The ocean is acting as a brake on the surface warming. |It's holding surface temperatures down.
00:49:32:23,00:49:35:13, The planet hasn't caught up|with what we've already done,
00:49:35:19,00:49:42:19, so emissions in the past mean that we're going to see |further warming through the century anyway.
00:49:43:18,00:49:50:10, So we shouldn't expect the climate change that |we've seen so far to be all we're committed to
00:49:50:23,00:49:53:15, as a result of the greenhouse gas|emissions we've made so far.
00:49:53:15,00:49:59:07, In fact it's probably.. maybe over half, but probably |only around two thirds, of what we're committed to.
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00:50:02:09,00:50:06:24, But as I talked to the scientists aboard the Tangaroa,
00:50:06:24,00:50:10:10, it became clear that the ocean is not simply a |passive recipient of global warming
00:50:10:10,00:50:12:20, It itself plays an active role
00:50:12:22,00:50:16:23, in determining how much of the CO2 we emit into the atmosphere
00:50:17:00,00:50:19:00, stays there.
00:50:20:01,00:50:25:23, The deep ocean contains about 60 times more CO2 |than the whole of the atmosphere.
00:50:26:02,00:50:31:08, There's this huge reservoir, this huge pool of CO2.
00:50:33:00,00:50:41:00, In a nutshell, the temperature and the salinity of the ocean |control how much CO2 can get stored
00:50:41:00,00:50:44:11, and dissolves in the ocean surface,
00:50:44:22,00:50:47:24, and a cold ocean allows more CO2 into it.
00:50:47:24,00:50:52:16, You can think maybe about molecules |bouncing around less,
00:50:52:16,00:50:57:12, it makes it a more attractive environment |for a gas to slip down into,
00:51:00:05,00:51:05:19, and the way it absorbs CO2 is a function of |a whole set of processes.
00:51:06:19,00:51:09:04, It's due to waves in the ocean.
00:51:10:18,00:51:14:23, As waves break they push down bubbles,
00:51:15:02,00:51:18:02, and that's one process that helps take gases into the ocean.
00:51:18:15,00:51:24:02, It's due to the life in the surface of the ocean, |and how much - in particular, photosynthesis
00:51:24:02,00:51:26:19, - goes on right in the surface layer.
00:51:30:21,00:51:33:18, When the CTD comes on board,
00:51:33:20,00:51:36:24, there are many scientists using the water.
00:51:37:03,00:51:40:18, Everybody has a bottle allocated to them.
00:51:43:21,00:51:47:23, When you look at the water with your naked eye,
00:51:48:00,00:51:50:01, you can't see the particles in the water.
00:51:50:06,00:51:52:07, But once you filter it,
00:51:52:09,00:51:57:03, the particulates captured on the filter |are quite green-coloured.
00:51:57:06,00:52:02:06, I have prepared one of these filters earlier.
00:52:02:20,00:52:08:14, This filter has had one litre of sea water from 10 metres depth |filtered through it.
00:52:09:00,00:52:13:13, One litre of water produces that much phytoplankton.
00:52:14:15,00:52:23:03, When you compare it to the filter before |anything is put through there is quite a contrast.
00:52:29:12,00:52:33:05, These organisms are really |the invisible forests of the ocean.
00:52:33:07,00:52:38:24, They're acting as sponges for CO2, yet we just |don't see them very well with the naked eye.
00:52:39:03,00:52:46:19, But there are millions - in one millilitre of sea water |there can be between 10,000 to a million cells.
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00:52:47:07,00:52:53:01, They are phenomenal in scale. They have this |incredible impact on the carbon cycle,
00:52:53:10,00:52:57:05, more so even than the forests that we can see |and walk around in.
00:52:57:12,00:53:03:08, But because of their individual cellular size |we don't appreciate their importance.
00:53:10:08,00:53:18:05, So life plays a crucial role in pumping CO2 down |into the deep ocean - termed the biological pump.
00:53:21:10,00:53:29:16, The ocean is absorbing at its surface about a third of |the CO2 that we now emit into the atmosphere.
00:53:33:02,00:53:40:02, But less and less of that CO2 will get absorbed into the ocean| as we continue to heat the world up.
00:53:40:11,00:53:42:16, As less gets absorbed
00:53:42:18,00:53:46:17, more CO2 stays in the atmosphere, making the ocean warmer,
00:53:46:19,00:53:48:17, which means even less getting absorbed.
00:53:48:17,00:53:51:20, So you start to see these kind of feedback mechanisms
00:53:51:22,00:53:56:22, which are some of the really scary parts of modern global warming.
00:54:00:14,00:54:06:05, My time at sea made it clear that |predicting the future of the climate
00:54:06:05,00:54:07:20, was not just a matter of physics.
00:54:09:15,00:54:15:02, Somehow we needed to incorporate what |biologists, oceanographers and chemists
00:54:15:06,00:54:18:10, were learning about CO2 in the environment.

00:54:20:08,00:54:26:04, Fortunately I had a rendezvous with scientists |who were trying to do just that.
00:54:39:15,00:54:44:10, I am Malte Meinshausen. I am a researcher at the |Potsdam Institute for Climate Impact Research.
00:54:44:23,00:54:52:11, We humans are pouring CO2 into the atmosphere, |and we do this experiment for the first time.
00:54:52:14,00:54:57:06, No other animal, no other humans before us |have done this experiment,
00:54:57:08,00:55:01:08, so there are a range of possibilities of |how the earth system is going to react.
00:55:01:10,00:55:06:01, We know it is going to be warmer, we know |it's going to be wetter in some places,
00:55:06:02,00:55:08:03, we know it's going to be drier in other places
00:55:08:04,00:55:15:24, but there is a range of possibilities, and we don't know |exactly how the climate system will respond.
00:55:36:17,00:55:43:10, We can do the experiment with the earth only once |but a computer can simulate it thousands of times.
00:55:46:21,00:55:52:13, We want to simulate the oceans, atmosphere, biosphere, |and all the interconnections in between,
00:55:52:15,00:55:59:04, and that's why it takes so long, even on |these powerful computers, weeks and months
00:55:59:04,00:56:01:20, to project the climate for a couple of hundred years.
00:56:04:05,00:56:08:03, Back when this science was relatively young, |in the 1980s,
00:56:08:03,00:56:11:08, they predicted the warming we should expect
00:56:11:10,00:56:15:07, to be associated with the rate of increase in |greenhouse gases that we've observed.
00:56:15:09,00:56:20:08, and they predicted it to be 1 to 2/10's of a degree per decade,
00:56:20:08,00:56:23:17, and that's exactly what we've seen since that time.
00:56:23:22,00:56:31:08, So this was a 20 year weather forecast that appears |to have been remarkably successful.
00:56:34:06,00:56:41:04, The big question the models are designed to answer is |how sensitive is climate to this warming,
00:56:41:15,00:56:45:10, the so-called forcing of increased CO2.
00:56:46:18,00:56:51:19, The answer the models suggest is that |if we double the level of CO2
00:56:51:19,00:56:56:10, the world will warm by 3 degrees Celsius, |or thereabouts.
00:56:57:01,00:57:00:01, But if we continue as we are doing,
00:57:00:07,00:57:05:07, by the end of the century CO2 may well be |four times higher than pre-industrial levels,
00:57:06:10,00:57:12:13, implying a world of 6 degrees Celsius |(11 degrees Fahrenheit) warmer.
00:57:15:13,00:57:19:11, But can the models be trusted so far from experience?
00:57:19:22,00:57:23:04, Have they really got the climate sensitivity right?
00:57:24:18,00:57:30:17, This is Matt Huber, a paleoclimatologist |from Purdue University, Indiana.
00:57:31:01,00:57:35:07, A lot of people are sceptical of climate models |and it's very good to be sceptical of them.
00:57:36:02,00:57:45:23, But here's a question. If you push the model toward |a warmer world, is the model too sensitive?
00:57:46:00,00:57:49:22, You push it a little bit, and the model goes crazy, |and it gets way too warm.
00:57:50:13,00:57:56:13, Or if you push the model it doesn't budge nearly as |much as it should, and just moves a little bit.
00:58:00:24,00:58:07:15, You can look at the past 100 years to try and infer |what the true value of climate sensitivity should be.
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00:58:08:04,00:58:16:03, Right now we don't know whether that value is |1 degree of global climate change per doubling
00:58:16:03,00:58:21:06, of CO2 concentrations, or 5 degrees of |warming per doubling of CO2.
00:58:22:12,00:58:26:23, The paleoclimate record is providing a |lot of really useful insights into
00:58:26:23,00:58:30:20, which of those numbers is closer to the truth|- is it 1 or is it 5?
00:58:32:17,00:58:37:23, So what I've done in my research and what |others have done in my field of research
00:58:37:23,00:58:40:03, is look at past periods of global warming
00:58:40:03,00:58:45:09, as a way of understanding the ways in which |models produce warmer climates
00:58:45:11,00:58:50:08, - also the degree to which they reproduce |the magnitude and pattern of warming correctly
00:58:50:08,00:58:52:10, based on comparison with paleoclimate data.
00:58:54:12,00:58:58:14, Here's the amazing thing. This is the world |as it was in the Eocene 50 million years ago.
00:58:59:06,00:59:01:18, There were crocodiles near the North Pole
00:59:02:11,00:59:07:11, and also fossils of tortoises and |a whole variety of subtropical plants.
00:59:07:12,00:59:12:12, This was clearly a subtropical swamp environment |during the warmest periods in the Eocene,
00:59:12:14,00:59:15:05, more like the coast of Florida than the North Pole is today.
00:59:18:03,00:59:24:02, That the climates have changed so dramatically in the past |is the strongest evidence for the reality.
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00:59:24:04,00:59:29:16, The correctness of our understanding of climate sensitivity |in terms of principles of energy balance.
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00:59:29:18,00:59:35:23, If you had a situation where the climate just remained |rock solid for the past billion years,
00:59:36:16,00:59:43:05, then you would have a strong argument that |some stabilising feedback was keeping climate stable
00:59:43:16,00:59:52:08, But we do know that 55 million years ago the climate |was substantially warmer than it is today.
00:59:53:01,00:59:57:03, There was no ice essentially anywhere on the planet|- no permanent ice
00:59:57:07,01:00:02:13, and we know that the only thing - the only lever - |we have over climate
01:00:02:24,01:00:07:24, that can cause that kind of change is the |green-house gas composition, a change in the CO2.
01:00:08:00,01:00:12:06, We even know to some extent what the |greenhouse gas concentrations were.
01:00:14:05,01:00:20:01, So there are a variety of techniques for estimating |the past atmospheric CO2 concentrations
01:00:20:03,01:00:29:02, but the one that I find the most convincing is |a mineral that forms only under high CO2 conditions
01:00:29:13,01:00:35:18, and that mineral "nahcolite" is actually known |to have been forming 50 million years ago

01:00:35:19,01:00:38:00, and not subsequently after that.

01:00:40:24,01:00:49:20, Setting the models up with the conditions as they were 50 million years ago, including higher CO₂,

01:00:49:20,01:00:55:05, the modelled temperatures are distinctly warmer than climates produced by the models for today

01:00:56:00,01:00:57:20, - but they are not warm enough.

01:00:59:03,01:01:06:05, And that indicates that the models tend to be not sensitive enough to forcing due to CO₂.

01:01:10:16,01:01:16:01, That's what the paleoclimate record indicates - that sensitivity is more towards the high end,

01:01:16:05,01:01:23:10, 4 or 5 degrees of warming per doubling of CO₂ as opposed to 1 or 2 degrees.

01:01:24:22,01:01:29:10, So if anything the climate models may underestimate the future pace of global warming.

01:01:30:07,01:01:36:06, It seems likely that over the next decade or two climate change will begin to accelerate.

01:01:37:07,01:01:43:15, To find out what that might mean for the planet, I took one last trip back in time.

01:01:49:09,01:01:56:17, I found what I needed sitting on the sea ice in the middle of McMurdo Sound in Antarctica.

01:01:57:17,01:01:59:22, ANDRILL.

01:02:14:08,01:02:16:10, We made a hole 84m deep,

01:02:16:12,01:02:19:01, then we lowered our pipe through the ice shelf

01:02:19:03,01:02:23:14, and a further 850 metres down to the sea floor.

01:02:29:12,01:02:33:11, And from there we drilled back in time 14 million years

01:02:33:15,01:02:35:18, through sedimentary layers of rock.

01:02:36:10,01:02:38:08, When we got to the bottom of the hole

01:02:38:12,01:02:41:15, we had drilled 1284 metres of core.

01:02:48:17,01:02:52:21, We bring up these layers core barrel by core barrel, very laborious.

01:02:54:00,01:02:59:00, All this information is absolutely vital to reconstructing a picture

01:02:59:06,01:03:00:23, of what our planet looked like

01:03:00:23,01:03:05:23, at a time which is probably a very good example of where we're heading to.

01:03:10:21,01:03:16:06, The rock cores are a treasure trove of information about past conditions in the Ross Sea.

01:03:29:22,01:03:37:21, Back at McMurdo representatives of each research team stake their claims to sections for analysis.

01:03:41:03,01:03:44:04, What actually came out of that hole had our eyes out on organ stops.

01:03:44:06,01:03:52:01, We were just staring at this core and seeing these dramatic changes from full-on glacial conditions.

01:03:52:05,01:03:58:10, then going up through half a metre of core we were into green algal blooms.

01:03:59:03,01:04:01:06, And the characteristics of many of these blooms

01:04:01:10,01:04:04:24, indicate temperatures were 2 to 3 to 4 degrees warmer than they were today.

01:04:06:07,01:04:16:21, We are building a picture of a very different Ross Sea and West Antarctica during past warm periods.

01:04:25:17,01:04:35:22, It's a cautionary tale to be able to look back and realise that only under slightly higher CO₂ values

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01:04:35:22,01:04:41:20, these elements are incredibly sensitive - the West Antarctic ice sheet is a very sensitive feature.

01:04:43:19,01:04:48:12, You don't have to do a lot to destabilise it, and we are doing a lot right now.

01:04:48:23,01:04:51:01, We just haven't seen the consequences.

01:04:54:23,01:04:59:00, If the temperatures of the ocean increase by up to five degrees

01:05:00:08,01:05:03:17, the West Antarctic ice sheet will collapse, it will disappear.

01:05:03:20,01:05:06:15, and sea level will be at least five metres higher -

01:05:07:00,01:05:09:21, and I'd guess we'd have to assume Greenland would be gone as well,

01:05:09:21,01:05:11:08, so ten metres higher.

01:05:13:18,01:05:23:02, In the next 100 years we'll be pushing CO₂ up to levels last seen around 45 or 50 million years ago,

01:05:23:11,01:05:29:03, when there was no ice at either Pole, and crocodiles were swimming off Greenland's coast.

01:05:32:10,01:05:36:21, Where we're headed into the future, we have an idea where we may go by looking back at the past.

01:05:37:18,01:05:41:22, If you looked across here five million years ago you would see no ice in the sea,

01:05:42:01,01:05:46:12, you'd see not so much ice on the hills. You might see green over there.

01:05:47:16,01:05:51:07, Going back 15 million years ago you'd see a whole different biota down here.

01:05:51:07,01:05:55:24, You'd probably see porpoise and dolphins swimming out there rather than killer whales.

01:05:59:10,01:06:04:18, It seems we are on course to take our planet back millions of years.

01:06:07:08,01:06:12:24, It's unlikely that much of the natural world we know will survive the transition.

01:06:15:22,01:06:20:06, What will happen to human society is impossible to say.

01:06:21:01,01:06:28:14, I look at my kids and I look at the way people behave - people are pretty adaptable, resilient

01:06:28:16,01:06:33:22, and so I don't worry that we are going to all get killed by this thing.

01:06:34:15,01:06:44:15, I do worry that our children will not thank us for the headache we'll give them if we stay on this path

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01:06:45:12,01:06:49:10, because if we don't get out of this, they will have to.

01:06:50:04,01:06:57:00, And every decade we postpone doing anything about global warming

01:06:57:02,01:07:03:18, is another 100 billion tonnes or so of carbon into the atmosphere,

01:07:03:23,01:07:11:18, and we are that much closer to the sort of climate where we can't predict where warming will stop.

01:07:20:07,01:07:27:10, If sensitivity to CO₂ variations is something like four or five degrees per doubling,

01:07:27:12,01:07:36:04, that means we actually need to reduce human emissions of CO₂ to zero in the next 50 years,

01:07:37:01,01:07:46:13, a far more radical kind of policy than most politicians and governments are talking about.

01:07:46:22,01:07:52:16,It's quite important to realise that [if we want to stabilise the climate,
01:07:52:16,01:07:58:14,there is no way other than to aim for] zero CO2 emissions in the long term.
01:08:00:06,01:08:06:09, How do we get from our emissions today to down here| where we want to be at the end of the century
01:08:06:11,01:08:08:06, which is basically zero emissions?
01:08:11:19,01:08:18:04,We can either go in a straight line, continue to increase,| and then you have a crash landing,
01:08:18:17,01:08:24:17, or we can slash emissions now so that we |burden future generations with less later.
01:08:24:22,01:08:32:10,If we don't know how to do it, why should we |bet on miracles that the future generations can?
01:08:34:20,01:08:41:07,Today the main effort to manage CO2 emissions |is the UN convention on climate change.
01:08:41:24,01:08:50:24,I hereby declare open the third meeting of the |ad hoc [LTCA] Working Group under the Convention.
01:08:50:24,01:08:55:19,Thank you, Chair, Distinguished Delegates. |The objective of the convention requires
01:08:55:19,01:09:01:00, keeping global warming as far as possible |below 2 degrees
01:09:01:09,01:09:04:14, I spent a few days filming the negotiations.
01:09:05:11,01:09:07:23, It was a rather depressing experience.
01:09:08:14,01:09:11:14, So this is my final attempt.
01:09:12:22,01:09:16:20, I put square brackets around everything in the Annex.
01:09:16:24,01:09:24:19,I have never seen this done before but I am |trying in order not to let the process collapse.
01:09:27:10,01:09:29:07, Is that acceptable?
01:09:30:20,01:09:38:21, It was clear to me that getting the whole world to |agree on reducing CO2 emissions is very difficult.
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01:09:40:09,01:09:45:14, But what finally cheered me up was the |experience that I'd had with climate scientists
01:09:47:04,01:09:48:21, learning about their science.
01:09:53:16,01:09:57:07, Over three years I'd met dozens and dozens of scientists.
01:09:58:13,01:10:01:00, I was convinced that they had not been lying.
01:10:01:04,01:10:03:03, There is no hoax.
01:10:04:02,01:10:06:17, In fact I was impressed by the breadth of the subject,
01:10:07:03,01:10:12:24, how carefully the scientists went about collecting |their data excluding all possible sources of error,
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01:10:13:05,01:10:16:15, and how open-minded they were about their conclusions.
01:10:18:02,01:10:20:01, This was science at its best
01:10:20:23,01:10:22:24, and it has given us a great gift,
01:10:23:19,01:10:28:09, the ability to look in to our future and shape it.
01:10:29:15,01:10:34:15,The sooner that we begin to reduce our impact |on the climate system the better off we are.
01:10:35:00,01:10:41:07,That said, I think we have the opportunity for an |exciting future. We understand there's a problem,
01:10:41:16,01:10:48:05, we understand the direction that we're going, |and we need fixes that are going to be valuable.
01:10:48:10,01:10:56:20, I like feeling my research, which on some days |feels like endless tedium in the lab,
01:10:57:19,01:11:05:12, at the end of the day is going to go some way |to improve our understanding of climate change,
01:11:05:12,01:11:09:07, and knowing how we can, hopefully, |do something about it.
01:11:10:00,01:11:16:23, And I try and feel optimistic about the science| - there are a lot of people working this.
01:11:17:07,01:11:23:09, Often I go and talk to school groups, and I come |away wondering whether I've just scared them.
01:11:24:04,01:11:31:00, I think it's important to tell them - Don't be afraid |- here's something that we're going to get through,
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01:11:31:00,01:11:37:00, But for you kids, take it seriously. Don't be |alarmed or afraid, but join in this effort.
01:11:37:14,01:11:43:21, Become the best scientists or engineers you can |- and let's solve this problem.
01:13:23:01,01:13:25:09,Okay, well I think that's done it now.