Interdisciplinary Science

PA1014

Near Space

University of Leicester

Contents

Welcome

The *Near Space* module looks at the science behind global climate change.

The weather, a manifestation of the local climate, is inherently changeable (particularly in England!), but there are some general trends that the weather obeys - it gets colder in the winter, and warmer in the summer, for example. On a global scale, longer term patterns and cycles can be observed. Samples from the ice caps have provided evidence for a system of warm and cold periods in our planet's history. However, current evidence points to an anomalous warming effect on a different scale, which appears to have developed very recently (geologically speaking).

You have probably heard of global warming, and the greenhouse effect; discussion of the scale of the problem and possible solutions are prominent in the international community, as extreme weather conditions become more frequent and more damaging.

Near Space is an introduction to some of the scientific concepts of the global climate system, and to the concept of anthropogenic climate change. In this module we will look at physical, chemical and biological influences on the climate.

Module Authors

Prof. Derek Raine   Dr Jörg Kaduk   Dr Jan Zalasiewicz

Dr Paul Monks

Problem Statement 01

From: Brian Stowell (b.stowell@design_dev.co.uk)
To: Development Team
Cc:
Subject: Directive from the CEO

Attachment: Leaving dogs in parked cars can be deadly.

The CEO has seen a magazine article that has caused him some concern, see the attachment. Obviously the animal welfare concerns are important but he is more concerned with the implications for human passengers. If it can happen to dogs then it might happen to a kid left in a car. Think of the PR disaster that would be!

I want you to look into the situation. How long does it take for these critical temperatures to build up? Is there anything we can do to change the design of our cars to prevent this? Any changes would have to be minor: we don't want to adversely affect the aerodynamics or security of the vehicle. Nor do we want to risk freezing the occupants during the winter months.

Yours sincerely,

Brian Stowell
(Head of Development)

Leaving dogs in parked cars can be deadly

By Stephanie Gaj - Special Correspondent July 5, 2003

NORWALK -- Leaving dogs alone in parked cars during hot summer months, even with the windows partially rolled down, can put the animals in danger.

"People think if they park in the shade or leave windows open a bit the animal will cope, but when they go back to their cars the first thing you see people do is turn on the (air conditioner) or roll down the windows. They know it's too hot for them," said Priscilla Feral, president of Friends of Animals in Darien.

Because of the greenhouse effect, sunny days can be deadly for dogs, even in moderately warm temperatures. The temperature inside the car is much higher than the temperature outside because the car traps the heated air.

"Cars can heat up to dangerous temperatures within a few minutes," said Alicia Wright, director of volunteer services at the Connecticut Humane Society.

The primary health problems that result are severe heatstroke and dehydration, according to Wright. Common symptoms include panting, lethargy, and collapse, according to Alistair Chapnick, a veterinarian at Norwalk Veterinary Hospital.

When a dog's temperature reaches above 105 or 106 degrees for five or 10 minutes, it puts the dog at risk and can cause cell death, said Chapnick.

Chapnick treated three dogs for heatstroke last summer when he worked at the Veterinary Referral & Emergency Center in Norwalk.

One dog he treated recovered well but not all are so lucky and have damage to all body cells. Some have to be euthanized, he said.

"The prognosis depends on how long the dog has been exposed." Chapnick said.

Deputy Chief Mark Palmer said the Norwalk Police Department gets two to three calls a week reporting dogs left in parking areas.

The department responds by trying to locate the owner of the vehicle through the Department of Motor Vehicles and get the pet out by using a car-opening tool if necessary, said Palmer.

In some cases the owner may receive a summons.

"Police sometimes ask (the Connecticut Humane Society) to be involved after the fact. Especially if the dog has been left for a long period of time," Wright said.

"Personally, I feel there has been a decrease in cases. There's more cognizance on the part of owners and people are more likely to call. It's well-publicized it's not a good thing to do," Palmer said.

Friends of Animals was responsible for signs in the parking lot at The Maritime Aquarium at Norwalk warning people not to leave dogs unattended in cars.

The agency also installed signs more than a decade ago when its headquarters were in South Norwalk, according to Feral. They had noticed that many tourists were leaving their pets in cars, and one dog died.

"The message to people is don't leave dogs alone in the car, ever. If you can't take the dog with you, leave the dog at home," Feral said.

Wright said her organization encourages people to call and ask about pet safety in summer.

"It's a problem that recurs year after year. We ask people to use common sense. How comfortable would you be in a mall parking lot on an 85-degree day? You'd want to get out of the car and walk around the mall," Wright said.

www.stamfordadvocate.com

Problem Statement 02

Daily Bugle
256 Fleet Street
London
EC4A 1DD

Dear Team,

I read the article in *Tomorrowday* the other day, the one about these new plants that are going to solve all our global warming problems by sucking the carbon out of the air. I reckon it's time to run another "What is Global Warming?" piece.

I'd like you to put together an article on the science - not all the GM business, I don't want to poke that hornet's nest again for a bit, we've only just shifted the last of the mail after that article about the pig with the two heads…

No, what I'd like you to do is produce a feature on the natural state of play - what's the environment like at the moment, what are these plants going to do, why are they different to 'normal' plants, etc. Then what global warming is - oh, that reminds me, I had some freelancer banging on at me at one of those do's the other day about "the greenhouse effect is a normal natural effect". Have a look into that, too, but leave out the human factors – we'll look at those in another article.

Sorry, I'm rambling again, let me summarise: what I'd like is a centre page article on the science of the global environment, and all the major factors that influence it: sun, atmosphere, oceans, plants, etc. - whatever you think is relevant (you guys are the scientists - I did History of Art at University)

If you're looking for a starting point, have a look at *Tomorrowday*'s letters page tomorrow, there's bound to be a ton of good stuff in there. Not too long, and keep it nice and simple, yeah? But for God's sake, get the science right – I don't want another "Daily Bugle dumbs things down" fiasco again…

Cheers,

PP

Joe Bluth,
Editor, Daily Bugle

Plants Breathe in to Reduce Global Warming

A team of botanists and geneticists working in Arkansas have developed two new plants that could halt global warming and remove the need for agreement on worldwide reductions in carbon dioxide production. *Silva incendium attenuosis*, the "heat reducing bush" and *Arbor spiritus velox*, the "fast-breathing tree" are the result of twelve years' study into how different plants remove carbon dioxide from the air for the production of complex molecules used in plant growth. Plants take in carbon dioxide through stomata or pores on the undersides of their leaves. These stomata are generally small, but careful combination of genes from a wide variety of plants that grow in conditions where carbon dioxide is limited has resulted in leaves with vast numbers of unusually large stomata on their undersides, allowing greater volumes of carbon dioxide to be taken up. The resulting plants can tolerate a wide variety of environmental conditions and remove carbon dioxide from the atmosphere an incredible 30-40X faster than the most proficient rain forest trees.

John Dickinson, Head of Development for the Floralgene Corporation has heralded these genetically engineered plants as the "perfect way to balance man-made carbon dioxide with natural removal processes". "It will restore the Earth's equilibrium," he said at a press conference yesterday. "Studies of atmospheric carbon dioxide levels over the last thirty years have clearly shown an increase in the amount of this greenhouse gas, one which is developing at an ever-increasing rate. The inability of countries to agree on what should be done to tackle this problem has resulted in the need to find an alternate solution. Without some action being taken now, the Earth will be plunged into a period of environmental catastrophe. Within only a few generations, a runaway greenhouse effect similar to that on Venus will be underway and mankind will be facing extinction. These plants will allow our continued evolution and development as a species, without the need to return to pre-Industrial Revolution technologies."

So why are these plants special? In addition to their ability to drastically reduce atmospheric carbon dioxide in a matter of decades, an extremely complex combination of genetic material from plants that grow naturally in extreme conditions means that they can flourish in a huge range of climates. Additionally, they can utilise nutrients that are generally considered toxic or useless to many plants, reducing other growth control factors. The ability to tolerate wide fluctuations in temperature on a daily basis further increases their global potential. Previously uninhabitable or unusable areas of land could be planted with whichever of the two plants would be most suitable for the conditions and amount of space available, allowing developing countries to continue their pursuit of industrialisation without the handicap of emissions restrictions. Other positives include the speed at which these plants grow, its longevity and its low cost. Unlike many genetically altered or engineered plants, these species are not sterile. Thus only a few plants are needed to colonise large areas over time, making this technology available to even the poorest countries. Current estimates suggest that, as these undergo four flowering cycles per year, planting just four seedlings will lead to colonisation of approximately ten acres within five years, as vast numbers of seeds are produced by each plant.

Permission to begin planting trials is currently being sought from the US Environment Agency and if received, will commence in two years.

Letters to the Editor

Our article on the genetically engineered plants that have been produced to solve the problem of global warming has provoked a rapid and emotive response. Here is a selection of the letters received:

I read your article "Plants breathe in to reduce global warning" with a mixture of horror and hysterical laughter. In the words of Professor Malcolm in "Jurassic Park" – "just because we can, it doesn't mean we should". The effects of removal of all carbon dioxide from the atmosphere would be catastrophic for the planet as a whole. It can be clearly seen from the geological record that low atmospheric carbon dioxide is directly related to low temperatures. This would plunge us into an ice age from which Earth is unlikely to recover! For the sake of the planet these plants should be banned immediately.

Brian Camper, Tunbridge Wells

And what happens when there is no carbon dioxide left for the plants to remove? How long will that take? Will mankind actually live long enough to witness Earth's recovery, assuming it can actually recover at all? What do you intend to replace the carbon dioxide with? Is it not the case that Mars is cold and dead because it has no atmosphere? If the carbon dioxide is removed, surely this will thin Earth's atmosphere and consign us all to Mars' fate. Have these scientists even stopped to consider the long-term effects of their diabolical plan?

Ann DeVoi, Cambridge

Where exactly do you plan to plant these trees? We need more houses, more grazing for more animals and more crops to feed us all, not more useless vegetation!

P Manier, Oban

Well it is reassuring to know that this wonder-bush can tolerate a wide range of temperatures. I assume by that they mean it is frost-resistant, because it is going to need to be! If this bush is as resilient and rapid growing etc as is claimed, it more closely resembles an ecological and environmental time bomb than a climatic panacea. Humans have repeatedly changed their environment, either deliberately or unintentionally and failures and problems far outweigh successes. Man is the root cause of all our global warming problems – perhaps we should be examining ways of preventing the fire in the first place, rather than attempting to put it out with gasoline.

Ian Rodovic, Milton Keynes

This sounds like a fantastic idea. Too many people complain about how car manufacturers and oil companies are damaging the environment. Planting these bushes would aid employment by boosting this country's car production industry and if the car plants sponsor some fields of these bushes, it would show they are just as committed to the environment as your average tree-hugger.

I Runsial, Dagenham

As an organic farmer, I wholeheartedly endorse anything that reduces the ill-effects of mankind's existence and if it increases the natural beauty of this country, that is a bonus. However, I am concerned about the lack of land available in this country on which to grow these amazing trees and bushes. Will existing trees and bushes be dug up and replaced, or will farmers be asked to give up valuable food-producing land? If the latter is the case, then compensation packages must be devised that will provide adequate recompense, or there will be no takers.

Francis E Bouor, Northampton

The idea of producing a plant that can ameliorate the effects of human greenhouse gas production has really caught my imagination and has made we think about several things. Firstly, is there any difference in the volume of greenhouse gases produced by different countries and does the amount of carbon dioxide produced or removed by existing means vary at all across the globe or by seasons? Will the worst "polluters" be expected to grow more of these plants? What effect would that have on the developing countries that are using old, inefficient technology to catch up with the industrialised world? Can any readers shed light on these questions?

J Scarius, Bromsgrove

Problem Statement 03

From: The Office of the President

March 23 2006

Dear Sir/Madam

An advisory panel is to be commissioned to assess the current state of the global climate and to discuss the possibility of its anthropogenic alteration from Earth's natural state. This panel will be held in the presence of the President of the United States and is intended to provide him with sufficient information to accurately address the delegates at the forthcoming Earth Summit.

In order to ensure that the President is suitably prepared, it has been decided that the panel should comprise representatives from all parties with detailed knowledge of or interest in areas relevant to this issue and that position papers from each group should be submitted prior to the panel meeting.

As it is imperative that the United States be seen to be both aware of and sensitive to issues relating to the environment, your input would be strongly welcomed. Accordingly, prompt submission of papers and your attendance at the panel would be appreciated.

Details of the date, time and itinerary for the panel will follow shortly.

Yours truly

L Staff
Assistant Panel Administrator (Environmental Issues)

White House to Unveil Global Warming Plan

By JOHN HEILPRIN
Associated Press Writer
Originally published July 24, 2003, 4:59 AM EDT

WASHINGTON -- The chief goal in a White House plan to study global warming is learning more about natural causes of climate change, drawing criticism from environmentalists who say reducing industrial carbon emissions is the real problem.

The new 10-year plan and $130 million proposal to speed up research in some high-priority areas was being released Thursday by Commerce Secretary Don Evans and Energy Secretary Spencer Abraham.

The first of the 364-page plan's five goals is to study the "natural variability" in climate change. The second is to find better ways of measuring climate effects from burning fossil fuels, industrial production of warming gases and changes in land use.

Other goals are to reduce uncertainty in climate forecasting; to better understand how changes in climate affect human, wildlife and plant communities; and to find more exact ways of calculating the risks of global warming, according to plan summaries obtained by The Associated Press.

But environmentalists said the administration was focusing too much on natural causes and reopening scientific issues already well studied.

Philip Clapp, president of National Environmental Trust, predicted that "most climate scientists around the world will see this as fiddling while Rome burns. ... This would have been a great research program if it had been announced by the first President Bush 10 years ago."

"We can't move the science faster than it goes," Assistant Commerce Secretary James Mahoney, who oversees U.S. research on climate change, told the AP. "At any point in time, there can be debates about the policy, but our job is to structure our information to be the most helpful."

Mahoney said the administration also will ask Congress to approve a new $103 million, two-year initiative to speed up research on carbon pollution, aerosols and oceans and determine the best ways to compile and disseminate information about them.

That effort will be included in President Bush's budget proposals for 2005 and 2006, Mahoney said, and would draw some of its funds from the existing $1.75 billion Climate Change Science Program.

Congress in 1990 required that the nation create a 10-year climate change research plan, but no administration has complied until now. Such a plan also is supposed to be updated every three years.

The Bush administration released its first draft of a plan late last year, focusing on making better economic projections of possible climate policy changes and tighter coordination of more than a dozen federal agencies' efforts.

That draft was harshly criticized by a panel of top climate experts at the National Academy of Sciences, who said it didn't set hard priorities or provide a clear vision and specific timetable for meeting goals.

"We've tried to take all of the academy's recommendations into account," Mahoney said. "The greatest focus is on what we can deliver in the shortest period."

The plan calls for 21 reports over the next four years on a wide range of climate change aspects. Many scientists blame carbon dioxide from burning oil and coal for contributing to a "greenhouse" or warming effect on global climates.

Bush and his advisers have adopted the stance that reducing emissions through costly near-term measures is unjustified, and that scientific forecasting of climate change is too imprecise to agree to long-term, international, mandatory cuts in greenhouse gas emissions.

Mahoney said the administration has been careful to distinguish between science and policy.

Environmentalists said the administration was dragging its feet.

"It seems to me that it's an effort to postpone doing anything meaningful on the climate issue," Earth Policy Institute founder Lester Brown said, adding that the plan also seems to overlook an important link between global warming, grain production and water shortages.

Annie Petsonk, an Environmental Defense lawyer who helped craft the first President Bush's policy, said there is enough scientific certainty to begin taking action now to reduce warming.

"Where the administration has thought to take any action at all," she said, "has been to delete climate references from reports and to try to repudiate the science that says global warming is happening now."

http://www.sunspot.net/features/health

Global warming exhibits patchiness

REUTERS - Thursday, Jul 24, 2003, Page 6.

With the world sweltering through one of the hottest years on record, some icy bastions have been getting frostier in defiance of global warming.

The rare cool spots, also from Canada to China, cause headaches for policy makers seeking to impose expensive measures to curb emissions from cars and factories blamed for blanketing the globe and driving up temperatures.

"We are disrupting the entire climate system," said Rajendra Pachauri, the head of the UN's main panel on climate change. "It's not as though there is going to be a uniform warming of the entire planet."

He said that signs of global warming are overwhelming, from a heat wave in India this year with temperatures up to 49?C that killed 1,500 people, to prolonged drought in Australia.

"There are also many of these [cooling anomalies]. But merely to cite one as evidence that there is no warming is not rational," he said of lingering skepticism to the broad consensus that human pollution is warming the planet.

And experts say that apparent anomalies, such as the growth of glaciers in Norway in the 1990s, can often be explained by a wider picture of global warming because of increased snowfall.

"When the oceans get warmer, you get more evaporation so you create more clouds. Then you can have more precipitation and in some areas it can be in the form of snow," said Josefino Comiso, a senior scientist at the NASA Goddard Space Flight Centre.

He said that his research, for instance, indicated that snow was getting deeper over higher parts of Greenland. Ice and snow in some regions of Antarctica was also getting thicker. "Some climate models suggest these effects," he said.

In other areas, global warming seems to be catching up with some of the icy exceptions.

The Briksdal glacier in west Norway, for instance, has receded about 130m since a peak in 2000 when it was splintering birch trees on ground that had been free of ice for decades.

"It's shrunk a lot, though in the middle of the 17th century is was 1.5km longer than now," said Frode Briksdal, a glacier guide whose family has long lived in the area.

Climate experts say that recent hotter summers are melting the ice despite more snowfall in winter that is adding to the overall mass of the glaciers.

The UN's World Meteorological Organisation (WMO) says that 1998 was the hottest year since records began in 1860, followed by last year and the previous. It says the rise in global average surface temperatures since 1900 exceeds 0.6?C.

So far this year, temperatures have also been high in many regions. The WMO says that average surface temperatures in May were the second highest on record.

But some question the view of Pachauri's Intergovernmental Panel on Climate Change (IPCC) that human activity is driving global warming. Many sceptics point out experts were predicting a new Ice Age in the 1970s after a long cold spell.

"There is an idea among the public that the `science is settled,'" said James Schlesinger, a Republican and former US Energy Secretary. "We are in danger of prematurely embracing certitudes."

Schlesinger said in a recent speech that the IPCC focused too narrowly on factors like human emissions of gases such as carbon dioxide, volcanoes and an 11-year sunspot cycle.

Jon Ove Hagen, professor of glaciology at Oslo University, said most glaciers from Alaska to the Himalayas were melting.

"By contrast, in 100 years' time one expects that the Antarctic ice will increase in volume because of more snow," he said.

Lynn Rosentrater, Arctic climate scientist at the WWF environmental group, said sea levels were expected to rise this century more because water in the oceans would expand with higher temperatures. Secondarily, melting glaciers in Alaska, Canada and Scandinavia would add to water in the oceans.

Among anomalies in climate change, she said that a cooling over northeastern Canada in recent years also "now seems to be stabilizing and now looking more towards warming."

http://www.taipeitimes.com/News/world

Staff

Prof. Derek Raine	Physics
Dr Jörg Kaduk	Geography
Dr Jan Zalasiewicz	Geology
Dr Paul Monks	Chemistry

Learning Objectives

At the end of this module students should have basic and advanced knowledge of/be able to:

- Thermodynamics (the physics of energy); latent heat.
- The electromagnetic spectrum; state the major regions and their approximate wavelengths.
- Interaction of radiation with matter: absorption, reflection, transmission, scattering and black body radiation.
- The Sun's radiation; the spectrum at the top of Earth's atmosphere.
- Radiation at the Earth's surface; outgoing radiation.
- State and use the Stefan-Boltzmann law to calculate the power radiated by a body at a given temperature; calculate the equilibrium temperature of a body absorbing a given power of radiation.
- State and use Wien's Lawto calculate the peak wavelength of radiation of a given body at a given temperature.
- Structure and composition of terrestrial planets (rock types limited to; carbonates, silicates and igneous rocks).
- The Earth's orbit and seasons.
- Earth's energy budget/balance.
- Structure and composition of Earth's atmosphere.
- Biological influence on atmosphere.
- Basic chemical processes of photosynthesis.
- Greenhouse effect; major contributing gases and the mechanism via which the effect is produced.
- Global warming.
- Climate change; Milancovitch cycles.
- Impact of human activity on the climate.
- Modelling, abstraction, 'reasonable' assumptions.
- Carbon cycle.
- Earth's environment as a result of life.

Reading List

Books

- Aguado, E. & Burt, J.E. (2006) *Understanding Weather and Climate, 4th Ed*. Prentice Hall: Chapter 2, 3 and 14.
- Barry, R.G. & Chorley, R.J. (2004) *Atmosphere, Weather and Climate, 8th Ed*. Routledge: Chapter 1.
- Bigg, G.R. (2003) *The Oceans and Climate*. Cambridge University Press: Chapter 1-4, 6 and 7.
- Breithaupt, J. (2003) *Physics, 2nd Ed*. Palgrave Macmillan: Chapter 4, 8, 24 and 25.
- Briggs, D., Smithson, P. & Addison, K. (1997) *Fundamentals of the Physical Environment*, Routledge: Chapter 2, 4-6, 11 & 20-22.
- Broecker, W.S. (1985) *How to Build a Habitable Planet*. Eldigio Press: Chapter 4, 5 and 7.
- Brown, T.L., LeMay, H.E. & Bursten, B.E. (2006) Chemistry the Central Science, 10th Ed.: Chapter 18.
- Campbell, N.A. & Reece, J.B. (2005) *Biology, 7th Ed*. Pearson: Chapter 10, 27-35.
- Giancoli, D.C. (2008) *Physics For Scientists and Engineers, 4th Ed*. Pearson International Edition: Chapter 17-20.
- Grotzinger, J., Jordan, T., Press, F. & Siever, R (2007) *Understanding Earth, 5th Ed*. Freeman: Chapters 11, 15, 23.
- Henderson-Sellers, A. (1986) *Contemporary Climatology*. Longman Scientific & Techincal: Chapter 7 (orbital velocity in particular).
- Lewis, R. & Evans, W. (2006) *Chemistry, 3rd Ed*. Palgrave Macmillan: Chapter 22.
- McIlveen, J.F.R. (1991) *Fundamentals of Weather and Climate*. Chapman and Hall: Chapter 4, 5 and 8.
- Smithson, P. (2008) *Fundamentals of the Physical Environment, 4th Ed*. Routledge: Chapter 2-4, 9 and 11.
- Sutton, J. (1998) *Biology*, Palgrave Macmillan: Chapter 10, 18, 28.

Tipler, P.A. (1999) *Physics for Scientists and Engineers, 4th Ed*. Freeman Worth: Chapter 18-20 and 22.

Weblinks

Here are some references for you to start your research with. Be aware of the possibility of bias in the viewpoints.

Oil Industry	**BP**	http://www.bp.com/
	Exxon	http://www.exxon.com/
	Shell	http://www.shell.com/
Environmentalist	**Green Peace**	http://www.greenpeace.org.uk/
	Friends of the Earth	http://www.foe.org/
	Car lobby	http://www.ford.com/en/company/about/corporateCitizenship/principlesProgressPerformance/our-actions/environment-climate.htm
Scientists	**New Scientist**	http://www.newscientist.com/
	UN framework convention on climate change	http://www.unfccc.de/
Alternative Energy	**BNFL**	http://www.bnfl.com
	Renewable energy	http://www.nrel.gov/
	Other resources	
Guardian	**Special report**	http://www.guardian.co.uk/climatechange/0,12374,782494,00.html
Graphics	**CO_2 Emissions**	http://www.guardian.co.uk/globalwarming/graphic/0,7367,397009,00.html
	The world in the 2050s	http://www.guardian.co.uk/globalwarming/graphic/0,7367,397048,00.html
	The greenhouse effect	http://www.guardian.co.uk/globalwarming/graphic/0,7367,397352,00.html
Interactive	**Guide to drilling for oil in the Arctic**	http://www.guardian.co.uk/flash/0,5860,534962,00.html
	Calculate your personal carbon count	http://www.bestfootforward.com/carbonlife.htm
	The Kyoto Protocol	http://www.unfccc.de/resource/docs/convkp/kpeng.html
Key resources	**Bjorn Lomborg: Are we doing the right thing?**	http://image.guardian.co.uk/sys-files/Guardian/documents/2001/08/14/warming.pdf
Additional		www.planetark.org
		http://yosemite.epa.gov/oar/globalwarming.nsf/content/index.html
		http://www.climatehotmap.org
		http://www.globalwarming.org
		http://www.ngdc.noaa.gov/paleo/globalwarming/home.html
		http://www.skepticism.net/faq/e

nvironment/global_warming
http://www.vision.net.au/~daly
http://physicsweb.org/article/world/16/5/7#pwten3_05-03

A Guide to Module Pacing

Session	Preparation	Learning Outcomes
FS01	• Physics (Breithaupt): Unit 6.	Model design.
FS02	• Physics (Tipler): pg 646-647. • Physics (Giancoli): Chapter 19 • Fundamentals of the Physical Environment: pg 22-25	Radiation physics.
ES01	Radiation Physics	
FS03	• LSI – part II Student Handbook: "Greenhouse Effect" laboratory script • Fundamentals of the Physical Environments: pg 42-51, 174-177	Greenhouse effect, Experimental design.
LS01	Greenhouse Effect	
FS04	• Independent research/ background reading.	Radiation physics, Latent/specific heat, Heat transfer.
FS05	• Understanding Earth: Chapter 15. • Chemistry the Central Science: Chapter 18. • Fundamentals of the Physical Environment: Chapters 3-9.	Atmospheric chemistry, Global warming.
ES02	Atmospheric Chemistry	
FS06	• Supplementary Materials: Spartan Pro	Spartan Pro
FS07	• LSI – part II Student Handbook: "Greenhouse Gases" laboratory script. • Fundamentals of the Physical Environment: pg 42-51, pg 174-175. • Understanding Earth: pg 246, pg 352-355. • Independent research into the properties and effect of: Water, CO_2, CH_4, N_2O, Ozone and CFCs.	Greenhouse gases, Experimental design.
LS02	Greenhouse Gases	
FS08	• Supplementary Materials: Spartan Pro	Spartan Pro
FS09	• Understanding Earth: Chapter 23	Global warming, Representing stakeholder positions.
FS10	• Fundamentals of the Physical Environment: Chapters 2 & 5. • Physics (Breithaupt): Unit 6.	Atmospheric models, Incident solar radiation.

	• Physics (Tipler): Chapter 18-20 and pg 646-647.	
FS11	• LSI – part II Student Handbook: "Photosynthesis" laboratory script. • Biology (Campell and Reece): Chapter 10 • Fundamentals of the Physical Environmental: Chapters 20-23.	Photosynthesis, Global impact of vegetation, Experimental design.
LS03	Photosynthesis	
FS12	• Fundamentals of the Physical Environment: Chapters 2, 5 & 18-23. • Physics (Breithaupt): Unit 6. • Physics (Tipler): Chapter 18-20 and pg 646-647. • Understanding Earth: Chapter 11	Atmospheric models, Heating up the Earth.
ES03	Contribution of Biosphere	
FS13	• Fundamentals of the Physical Environment: Chapters 2 & 5. • Physics (Breithaupt): Unit 6. • Physics (Tipler): Chapter 18-20 and pg 646-647.	Atmospheric models, Albedo, Greenhouse effect
FS14	• Fundamentals of the Physical Environment: Chapters 2 & 5. • Physics (Breithaupt): Unit 6. • Physics (Tipler): Chapter 18-20 and pg 646-647.	Atmospheric models, Atmospheric effects, Effect of doubling CO_2.
FS15	• Independent research/ background reading.	Preparation for deliverables.
FS16	• Independent research/ background reading.	Preparation for deliverables.

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Facilitation Sessions

Facilitation Session 01

Pre Session Preparation

Read

- Physics (Breithaupt): Unit 6.

Introduction to Problem Statement 01

Group Activity: Overheating in cars

In groups locate the problem in Problem Statement 01. Read through the attachment and highlight potential issues that relate to the problem. You may like to consider the following questions:

- How are you going to construct a model of the problem; how detailed does the model have to be to give you an accurate value? What simplifications can you make?
- What existing knowledge do you have that is applicable to this situation?
- What do you need to research to solve this problem?

Facilitation Session 02

Pre Session Preparation

Read:

- Physics (Tipler): pg 646-647.
- Physics (Giancoli): Chapter 19
- Fundamentals of the Physical Environment: pg 22-25

Group Discussion: Radiation Physics

Discuss the subject of "radiation physics".

- Do you know what this topic covers?
- Can you describe the different physical processes occurring to each other?
- Are any of the processes being discussed directly relevant to deliverable 1?
- Do you understand enough about this topic to complete deliverable 1 or are there areas you are uncertain of?

Within the group produce a list of questions to ask in the Expert Session.

Facilitation Session 03

Pre Session Preparation

Read:

- LSI – part II: “Greenhouse Effect” laboratory script
- Fundamentals of the Physical Environments: pg 42-51, 174-177

Group Preparation: Greenhouse Effect

Discuss what you understand so far about the greenhouse effect and how this is a result of the interaction of radiation with the Earth-atmosphere system.

Read the laboratory script for “Greenhouse Effect” in LSI-partII. As a group design an experiment to investigate the greenhouse effect using the prompts given in the script. Throughout the design process think about how you can explore this topic and what useful results you can gain. Can you obtain results that will help you to complete deliverable 1?

Facilitation Session 04

Pre Session Preparation

- Independent research/ background reading.

Group Activity: Overheating in cars

Within your group continue working on your response to problem statement 01. By the end of this session you should have numerical evidence from your model that supports your written deliverable.

Facilitation Session 05

Pre Session Preparation

Read:

- Understanding Earth: Chapter 15.
- Chemistry the Central Science: Chapter 18.
- Fundamentals of the Physical Environment: Chapters 3-9

Introduction to Problem Statement 02

Group Activity: Global Warming Article

In groups locate the problem in Problem Statement 02. Read through the attachment and highlight potential issues that relate to the problem. You may like to consider the following questions:

- What issues do you think it is important to include in your article? Were any interesting points raised in the “letters to the editor”?
- Who is your audience?
- What level of scientific information will you have to include?

Group Discussion: Atmospheric Chemistry

Discuss the subject of “atmospheric chemistry”.

- What is the chemical composition of the atmosphere?
- Why is this particular composition important to life in Earth?
- What changes have occurred in the past and are occurring now and how do they relate to the greenhouse effect?
- What chemical reactions are occurring in the atmosphere and where to they occur?
- Do you understand enough about this topic to complete deliverables 2 and 3 or are there areas you are uncertain of?

Within the group produce a list of questions to ask in the Expert Session.

Facilitation Session 06

Pre Session Preparation

- Supplementary Materials: Spartan Pro

Individual activity: Spartan Pro

Spartan Pro is molecular modelling software available on cfs. The Supplementary Materials at the end of this module documentation will guide you through the basic functions and operation of this software. Use Spartan Pro to investigate atmospheric gases and complete the two exercises given in the text.

Facilitation Session 07

Pre Session Preparation

Read:

- LSI – part II Student Handbook: “Greenhouse Gases” laboratory script.
- Fundamentals of the Physical Environment: pg 42-51, pg 174-175.
- Understanding Earth: pg 246, pg 352-355.
- Independent research into the properties and effect of:
    - Water
    - CO_2
    - CH_4
    - N_20
    - Ozone
    - CFCs

Group Preparation: Greenhouse Gases

Discuss what you understand so far about greenhouse gases and what effect they have on the magnitude of the greenhouse effect.

Read the laboratory script for “Greenhouse Gases” in LSI-partII. As a group design an experiment to build upon the previous experiment (Greenhouse Effect) and investigate the greenhouse response of different gases of different compositions. Throughout the design process think about how you can explore this topic and what useful results you can gain. Can you obtain results that will help you to complete deliverable 1?

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Facilitation Session 08

Pre Session Preparation

- Supplementary Materials: Spartan Pro

Individual activity: Spartan Pro

Spartan Pro is molecular modelling software available on cfs. The Supplementary Materials at the end of this module documentation will guide you through the basic functions and operation of this software. Use Spartan Pro to investigate atmospheric gases and complete the two exercises given in the text.

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Facilitation Session 09

Pre Session Preparation

- Understanding Earth: Chapter 23

Introduction to Problem Statement 03

Group Activity: Stakeholders

In groups locate the problem in Problem Statement 03. Read through the attachment and highlight potential issues that relate to the problem. You may like to consider the following questions:

- What stakeholder position will you be representing and what evidence will you need to present to support your claims?

Facilitation Session 10

Pre Session Preparation

- Fundamentals of the Physical Environment: Chapters 2 & 5.
- Physics (Breithaupt): Unit 6.
- Physics (Tipler): Chapter 18-20 and pg 646-647.

Group Activity: Atmospheric Model Overview

Background: With increasing concentrations of greenhouse gases in the atmosphere, the global mean surface and near surface temperatures are expected to rise. The problems presented in four facilitation sessions will allow you to recognize and analyze how temperatures are determined by radiation, adjusted through the presence of greenhouse gases and to predict the temperature change for a doubling of the CO_2 concentration in a simple radiative transfer model of the atmosphere.

Please note: This series of activities is not an alternative to your ongoing research. These tasks should not take the whole of each session therefore you will still be expected to discuss points arising from your research. This will, however, allow you to address all the core learning outcomes for this section and should provide you with important results and numerical values for problem statements 02 and 03.

Group Activity: Researching Constants

Find a value for:

- the radius of Earth,
- the solar constant,
- the mean global shortwave albedo,
- the mean global temperature.

Group Activity: Incident solar radiation

Within your group calculate the mean incident solar radiation per m^2 on Earth.

Questions that you may like to consider:

- What assumptions do you need to make in order to construct a model?
- What is the “solar constant” (definition and numerical value)?
- What are the time and space domains you have to average over, i.e. how is

the radiation distributed over the surface of the earth?

Hint: For this activity assume that the atmosphere is completely transparent, i.e. it has no effect on the transmission of the incident radiation.

Class Discussion: Incident solar radiation

Class discussion of your progress in the facilitation session.

Facilitation Session 11

Pre Session Preparation

- LSI – part II Student Handbook: “Photosynthesis” laboratory script.
- Biology (Campell and Reece): Chapter 10
- Fundamentals of the Physical Environmental: Chapters 20-23.

Group Preparation: Photosynthesis

Discuss what you understand so far about photosynthesis and its impact upon the global system.

Read the laboratory script for “Photosynthesis” in LSI-partII. As a group design an experiment to investigate the rate of *Elodea canadensis* under a variety of environmental conditions.

Build upon the previous experiment (Greenhouse Effect) and investigate the greenhouse response of different gases of different compositions.Throughout the design process think about how you can explore this topic and what useful results you can gain. Can you obtain results that will help you to complete deliverable 1?

Facilitation Session 12

Pre Session Preparation

- Fundamentals of the Physical Environment: Chapters 2, 5 & 18-23.
- Physics (Breithaupt): Unit 6.
- Physics (Tipler): Chapter 18-20 and pg 646-647.
- Understanding Earth: Chapter 11.

Group Activity: Heating up the Earth

How long would it take for the outer 4 km of the Earth's surface (i.e. ocean and continents) to warm by 1 K if the Earth retained 1% of the incoming radiation per m^2?

Hint: For this activity assume that the atmosphere is completely transparent, i.e. it has no effect on the transmission of the incident radiation.

Questions that you may like to consider:

- What percentage of the Earth of covered by oceans?
- How can you calculate the volume of the oceans and continents?
- What heat capacity will you use for the oceans and the continents? If you chose to use an average value why did you choose it and how did you calculate it?

Class Discussion: Heating up the Earth

Class discussion of your progress in the facilitation session.

Facilitation Session 13

Pre Session Preparation

- Fundamentals of the Physical Environment: Chapters 2 & 5.
- Physics (Breithaupt): Unit 6.
- Physics (Tipler): Chapter 18-20 and pg 646-647.

Group Activity: Albedo

Building on your previous work determine the surface temperature of the Earth with an albedo of a) 0 and b) a realistic value. Instead of the 1% energy retention used in the previous exercise assume that the Earth retains any energy that it does not reflect.

Hint: For this activity assume that the atmosphere is completely transparent, i.e. it has no effect on the transmission of the incident radiation.

Questions that you may like to consider:

- What is albedo?
- What does an albedo of 0 represent? Why is this not realistic?
- What value of albedo will you use in part b)? If you chose to use an average value why did you choose it and how did you calculate it?

Class Discussion: Albedo

Class discussion of your progress in the facilitation session.

Facilitation Session 14

Pre Session Preparation

- Fundamentals of the Physical Environment: Chapters 2 & 5.
- Physics (Breithaupt): Unit 6.
- Physics (Tipler): Chapter 18-20 and pg 646-647.

Group Activity: Atmospheric Effect

Up until know we have ignored the effect of the atmosphere in our models. In reality the atmosphere is not transparent for radiation, it absorbs radiation. Mainly long wave radiation due to the greenhouse gases in the atmosphere. How would you modify the calculations in the previous activity to take this into account?

Group Activity: Doubling Atmospheric CO_2

Using the model you have constructed so far calculate how the global mean surface temperature would increase if the CO_2 concentration doubled from 360 ppmV to 720 ppmV. Why is this important?

Class Discussion: Doubling Atmospheric CO_2

Class discussion of their progress in the facilitation session.

If you have not calculated a value by the end of the session then you should consider the points raised in this discussion and finish the calculation in time for the next session.

Facilitation Session 15

Pre Session Preparation

- Independent research/ background reading.

Group Activity: Deliverable 02 & 03

Within your groups continue working on deliverable 02 and 03. By this stage you should have some draft material for deliverable 02 and 03 to show and discuss with the facilitator.

Facilitation Session 16

Pre Session Preparation

- Independent research/ background reading.

Group Activity: Deliverable 02 & 03

Within your groups continue working on deliverable 02 and 03. By this stage you should have some draft material for deliverable 02 and 03 to show and discuss with the facilitator.

Deliverables

Please name your deliverables in accordance with the standard naming convention (see the handbook for details). A sample filename is provided for you to cut and paste - please complete with submission date and username/group letter as appropriate.

All deliverables to be submitted to iscience@le.ac.uk

Please note that although deliverable deadlines (except for CLEs) are at the end of the module, you are strongly urged not to leave all work on the deliverables until the final weekend! In particular, if you would like formative feedback on your works-in-progress from your facilitator and/or experts, please provide them with draft copies in good time.

DELIVERABLES	TYPE	FILENAME	DUE	WEIGHTING
CLE01:	I	PA1014_I_CLE01_*username_date*.pdf	Week 2, Day 1	30%
CLE02:	I	PA1014_I_CLE02_*username_date*.pdf	Week 3, Day 1	
CLE03:	I	PA1014_I_CLE03_*username_date*.pdf	Week 4, Day 1	
CLE04:	I	PA1014_I_CLE04_*username_date*.pdf	Week 5, Day 1	
D01: Heating in cars	G	PA1014_G_D01_HeatingINCars_*groupletter_date*.pdf	Week 5, Day 1	25%
D02: Global Warming Article	G	PA1014_G_D02_GlobalWarmingArtcle_*groupletter_date*.pdf	Week 5, Day 1	25%
D03: Stakeholder Summary	I	PA1014_I_D03_StakeholderSummary_*username*_date.pdf	Week 5, Day 1	10%
D04: Stakeholder Presentation	I	-	Week 5, Day 1	10%

Core Learning Exercise 01

1. a) Find the density of moist air with specific humidity $15\ gkg^{-1}$ (grams of water vapour per kilogram of air), temperature $15°C$ and pressure $1010\ mbar$. The Gas Constant of dry air is $287\ Jkg^{-1}K^{-1}$ and the Gas Constant of water vapour is $462\ Jkg^{-1}K^{-1}$. [5]

   b) Compare your result with the density of dry air at the same temperature and pressure. [2]

   c) What is the temperature at which a sample of dry air would have the same density as a sample of moist air, assuming both samples are maintained at the same overall pressure? *Note that this last temperature is known as the "Virtual Temperature" of moist air. This value can be used to predict the buoyancy of cloud formations.* [3]

2. The heat capacity of the Arctic Ocean limits the change in temperature of the region during the course of the year. Describe how this effect changes with the freezing and melting of the arctic sea ice at different times of year. [10]

3. a) Briefly describe the processes of Conduction and Convection. [5]
   b) What is the critical difference between the two and how does this lead to a difference in heat transfer in different states of matter? [5]

4. a) Assuming a constant value of g and a constant density of $1.2\ kgm^{-3}$, calculate the height of the Earth's atmosphere given that average atmospheric pressure is $101\ kPa$ at sea level. [3]
   b) Compare your result with the actual atmospheric height of $100\ km$. What does this tell you about the density of the atmosphere? [2]

5. Explain mathematically why the pressure of a gas falls if:
   a) its volume is increased at a constant mass and temperature. [2]
   b) its temperature is reduced at constant mass and volume. [2]
   c) By calculating the relative r.m.s. speeds of Hydrogen and Oxygen molecules, explain why the Earth's Atmosphere retains Oxygen but not Hydrogen. You may take the molar mass of Hydrogen to be $0.002\ kg$ and the molar mass of Oxygen to be $0.032\ kg$. [6]

6. The solar power received at the top of the atmosphere can be described by the relation:

$$S \propto \frac{1}{D^2}$$

   where S is the received Solar Power and D is the distance between the Earth and the Sun.

   For mean solar distance ($D_{Avg} = 149.5x10^6\ km$) the power flux at the top of the atmosphere can be taken as $1.35\ kWm^{-2}$. Using this information, calculate the power received at the top of the atmosphere when:
   a) the Earth is at perihelion ($D = 152x10^6 km$).
   b) the Earth is at aphelion ($D = 147x10^6 km$). [5]

7. A black-and-white cat is lying in strong sunlight. Describe its appearance when viewed by a radiometer sensitive to the far infra-red whose display renders strong radiators white and weak radiators black. [5]

8. Estimate how much energy is required to raise the average temperature by 1^{o}C, of;
   a) the atmosphere [5]
   b) the oceans [5]

9. Determine the blackbody radiation (in Wm^{-2}) emitted from an object with a temperature of:
   a) 6000K [5]
   b) 300K [5]

   You may take the Stefan-Boltzmann constant to be $\sigma = 5.67x10^{-8}\ Wm^{-2}K^{-4}$.

10. Using Stefan-Boltzmann's Law, show that the effective temperature of the Earth is approximately *255 K*. The Earth emits radiation at a flux of approximately *240* Wm^{-2}. [5]

11. Starting with the shortest, place the following spectral ranges in the correct order of wavelength: Visible, X-ray, Ultraviolet, Microwave, Infra-Red. [5]

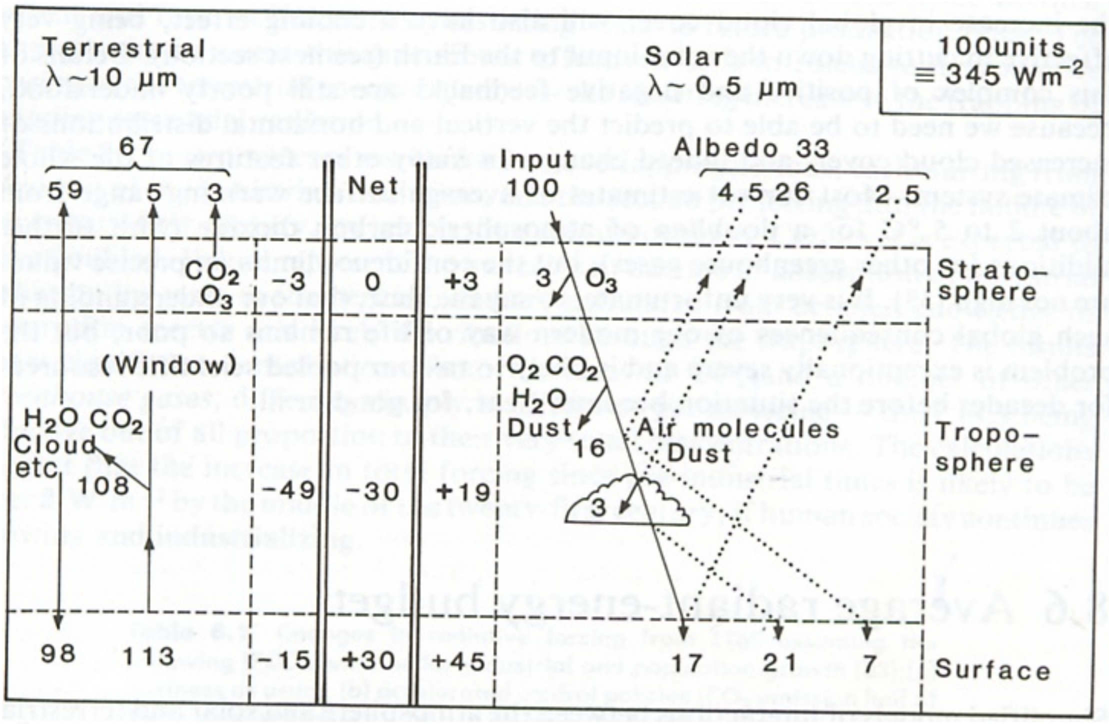
12. a) Assuming that the peak-intensity wavelength of light emitted from the sun is *500 nm*, use Wien's law to achieve an estimate for the sun's surface temperature. [2]
    b) Given that the intensity of solar radiation at the Earth is $1.4\ kWm^{-2}$ and that the Earth orbits at a distance of $1.5\ x\ 10^{11}\ m$ from the sun, calculate an estimate for the energy radiated by the sun every second. [3]
    c) Hence estimate the emissivity of the sun, assuming the sun to be a perfectly spherical emitter with a diameter of $1.4x10^{9}\ m$. [5]

    The Stefan-Boltzmann constant is given as $\sigma = 5.67x10^{-8}\ Wm^{-2}K^{-4}$.

13. Why is the photodissociation of N_2 relatively unimportant, compared to the photodissociation of O_2? [2]

Core Learning Exercise 02

1. The following diagram shows the inflow and outflow of radiation to and from the Earth's surface.



Assuming that the fluxes of terrestrial radiation, shown in the diagram above, are otherwise unchanged, what rate of heat loss do you expect from the night-side surface of the Earth when

a) the sky is clear? [5]
b) the sky is overcast by low cloud? [5]

2. Why is a hydrofluorocarbon potentially less harmful to the ozone layer than chlorofluorocarbons? Draw the Lewis structure of $CFCl_3$. [5]

3. Explain why increasing the concentration of CO_2 in the atmosphere affects the distribution of radiation emitted from earth's surface, but does not affect the radiation entering from the sun. [5]

4. Explain why O_2 and N_2 are not greenhouse gases whereas CO_2, H_2O, and CH_4 are. [10]

5. The Humidity Mixing Ratio of air rises when there is evaporation from the land below. What surface activity could make the Humidity Mixing Ratio fall?

[5]

Describe how this effect would change above an oceanic or frozen surface.

[5]

6. Describe how both the Earth's surface and atmospheric temperatures might change if all convection and advection in the atmosphere suddenly ceased.

[10]

7. Describe how the climate at the Earth's surface is affected by cloud cover in terms of:

   a) cloud albedo [5]
   b) cloud volume [5]
   c) surface albedo [5]

8. Explain how conduction and convection distribute heat between the atmosphere and the Earth's surface. [5]

   What role does the emission and absorption of long-wave radiation play in this process? [5]

Core Learning Exercise 03

1. What is the typical preindustrial storage of carbon in the atmosphere, the ocean and the biosphere? What subcomponents should be considered and why? [10]

2. Define the terms: photosynthesis, biological net production, net ecosystem uptake, autotrophic respiration and heterotrophic respiration. [10]

3. What are the main carbon stores in the land biosphere and in the ocean biosphere? On land and in the ocean which organism groups turn over the most carbon? [15]

4. What are the typical preindustrial net and gross CO_2 exchanges per year between the atmosphere and the oceans and the atmosphere and the land biosphere? [5]

5. How does the atmospheric CO_2 concentration vary seasonally, interannually and on time scales of 10000s – 100000s of years? [5]

6. What are the main players determining the atmospheric CO_2 concentration variations seasonally, interannually and on time scales of 10000s – 100000s of years? How can you show this? [5]

7. Characterise the relationship of the atmospheric CO_2 concentration and the global mean surface temperature over the last 650000 years. [5]

Core Learning Exercise 04

1. What do the sizes of the atmospheric carbon pool and of the exchange fluxes with the other global carbon pools imply for the sensitivity of the atmospheric carbon content to changes in the exchange fluxes? [5]

2. What is the fractional content of ^{12}C, ^{13}C and ^{14}C isotopes in air, biomass and the surface ocean? How is the ^{13}C content usually expressed? [5]

3. How can you use the isotopic composition of the different carbon pools and fluxes to show that the recent increase in the atmospheric CO_2 concentration results manly from fossil fuel burning? [5]

4. What is the contribution of road transport (commercial and private) to the emissions of CO_2? [5]

5. What is the per capita CO_2 emission in the Australia, US, UK, Russia, India, China, Brazil and Kenya from fossil fuel use? [5]

6. What is the UNFCCC? What does Article 2 say? [5]

7. What is the evidence for recent anthropogenic climate warming? [5]

8. What temperature rise is considered to be “dangerous interference with the climate system”? [2]

   When will this temperature be reached in the recent IPCC predictions according to the scenarios A1, A2, B1 and B2? [8]

Deliverable 01: Heating in cars

As a group you must write a response to the head of development outlining your investigations, conclusions and recommendations. This report should be ~3000 words and must contain any relevant calculations.

Deliverable 02: Global Warming Article

As a group you must write a feature article on global warming

(Guidance: ~3000 words).

Deliverable 03: Stakeholder Summary

Produce a summary of your stakeholder position on global warming; this should not exceed one side of A4.

Stakeholder positions will be chosen from the following list:

- Oil Industry
- Car Industry
- Environmental groups
- Scientists
- Renewable energy industry
- Developing countries
- United Nations
- Nuclear power industry

Each of the above stakeholder positions should be represented within the class, however, some stakeholder positions may need to be represented more than one given the class size.

Deliverable 04: Stakeholder Presentation

All class members will take part in a roundtable discussion on the issue of global warming.

You will be expected to present your stakeholder position in a 5 minute statement to the group. Once you have completed your presentation other stakeholders and moderators will be allowed to question you or present information that counters your claims. Similarly you are expected to question other stakeholders.

Stakeholder positions will be chosen from the following list (the same choice as deliverable 03):

- Oil Industry
- Car Industry
- Environmental groups
- Scientists
- Renewable energy industry
- Developing countries
- United Nations
- Nuclear power industry

Each of the above stakeholder positions should be represented within the class, however, some stakeholder positions may need to be represented more than one given the class size.

Supplementary Material

Spartan Pro

Note: This exercise has not been timetabled as a laboratory session and should therefore be completed in your own time. However, you should record your progress as you would for a standard laboratory experiment.

Spartan Pro is molecular modelling software. Molecular modelling is a means to predict the structure of a molecule using a set of mathematical and chemical rules. Molecular modelling reduces the cost of research by limiting the number of physical experiments needed to be performed. By having a reasonable idea of the structure of a molecule, a researcher will know if a molecule will prove useful for the goals of the research or if another molecule should be tested. A variety of modelling methods may be used in Spartan Pro.

Our main aim is to experimentally calculate the vibrational frequencies of gases present in the atmosphere; this will allow us to distinguish between those atmospheric gases which contribute to the green house effect, i.e. the so called 'greenhouse gases' and those which don't.

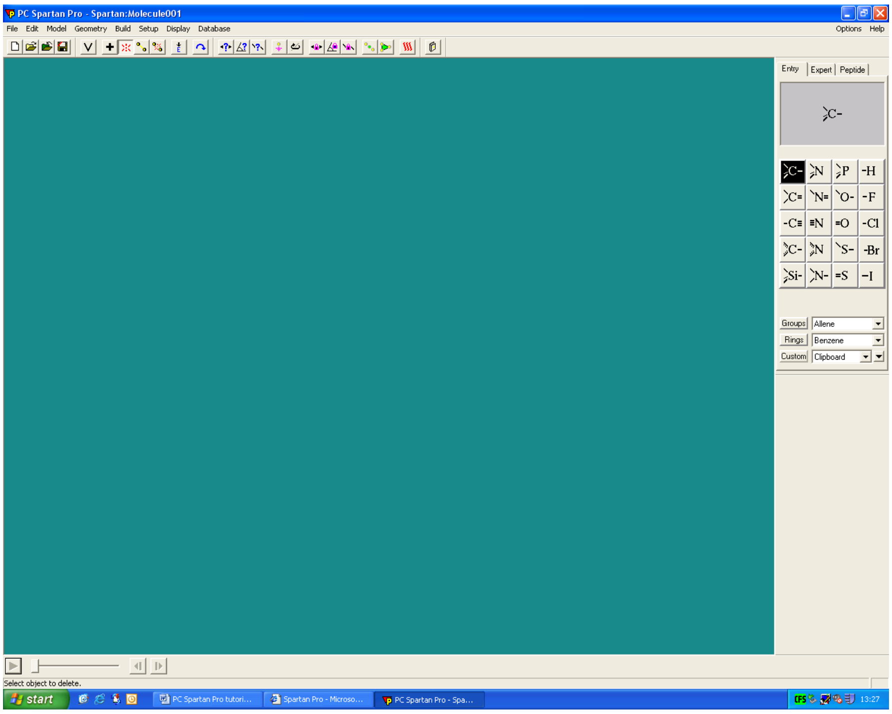
Greenhouse gases have vibrational modes which allow them to absorb radiation in the infrared region. This absorption of energy, rather than it's release from the atmosphere causes the atmosphere to warm up.

The infrared area of the spectrum occurs at wavelengths between 750 nm and 1 mm. You may wish to consider which frequencies this corresponds to, in order to compare the frequency of vibration of the molecules you look at with the infrared frequencies.

In this activity you will be using Spartan Pro to 'build' the molecule design tools, and then continuing with the appropriate calculations.

Access Spartan Pro:

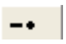
First of all Spartan Pro must be downloaded on to your cfs account, after this click on the PC Spartan Pro icon to access the software. Click on 'File' then 'New' and the following window should appear.



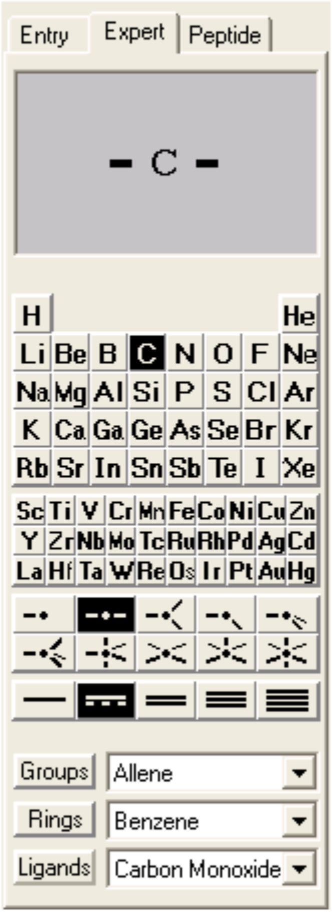
On the right hand side of the screen there are options to build a molecule, click on the EXPERT mode in the model kit area.

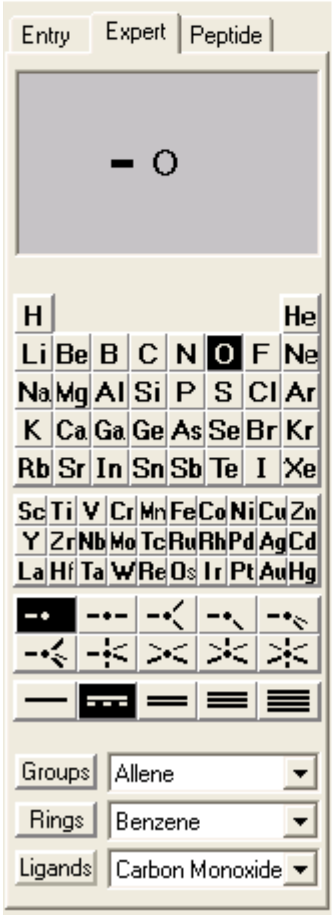
- This mode gives the periodic table, enabling you to choose your elements
- Ball and stick representations are given allowing you to choose the geometry of your molecule, as well as a list of bond types: single, partial double, double, triple and quadruple.
- Finally, there is a further list highlighting, Groups, Rings and Ligands.

Exercise 01

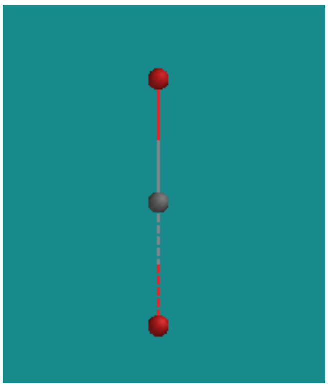
Using these tools, construct a molecule of CO_2. To do this you must first select the C atom, with a linear  (sp hybrid) comprising of a partial or double bond. The outline of the C atom will appear on the screen. Following this, select the O atom, mono bonded , again with a partial or double bond. If you make a mistake, the delete key is .

See example below,

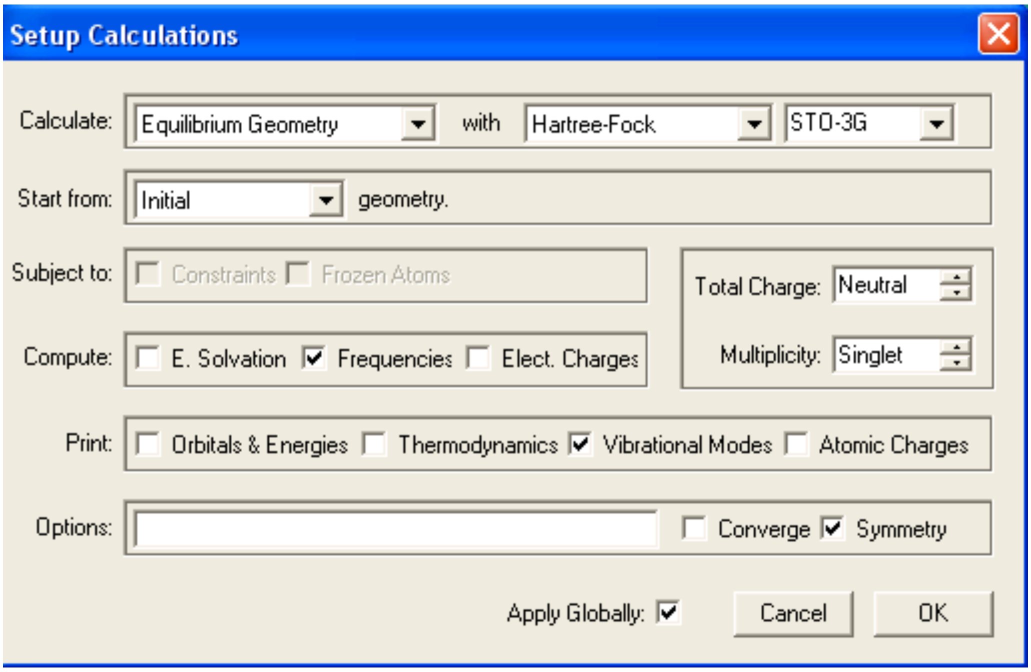




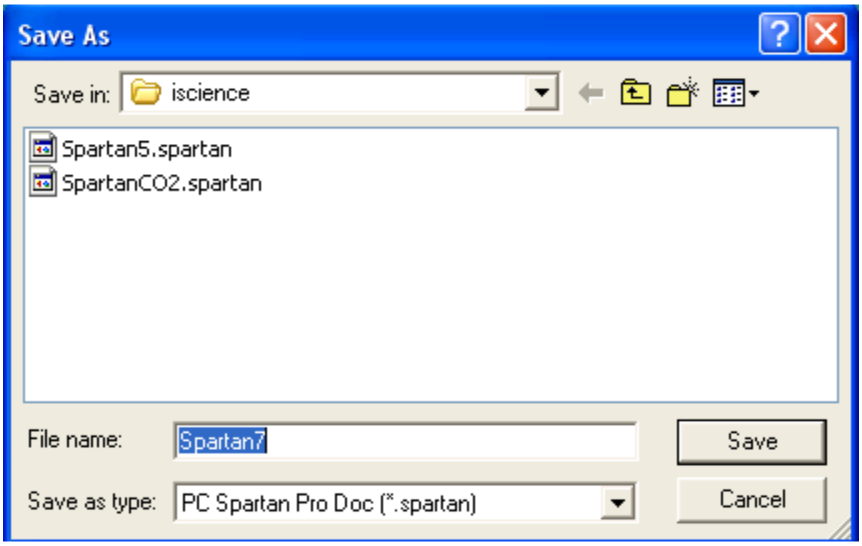
Once the O atom parameters have been selected, use the mouse to click at the end of each C bond, resulting in the formation of the CO_2 molecule.



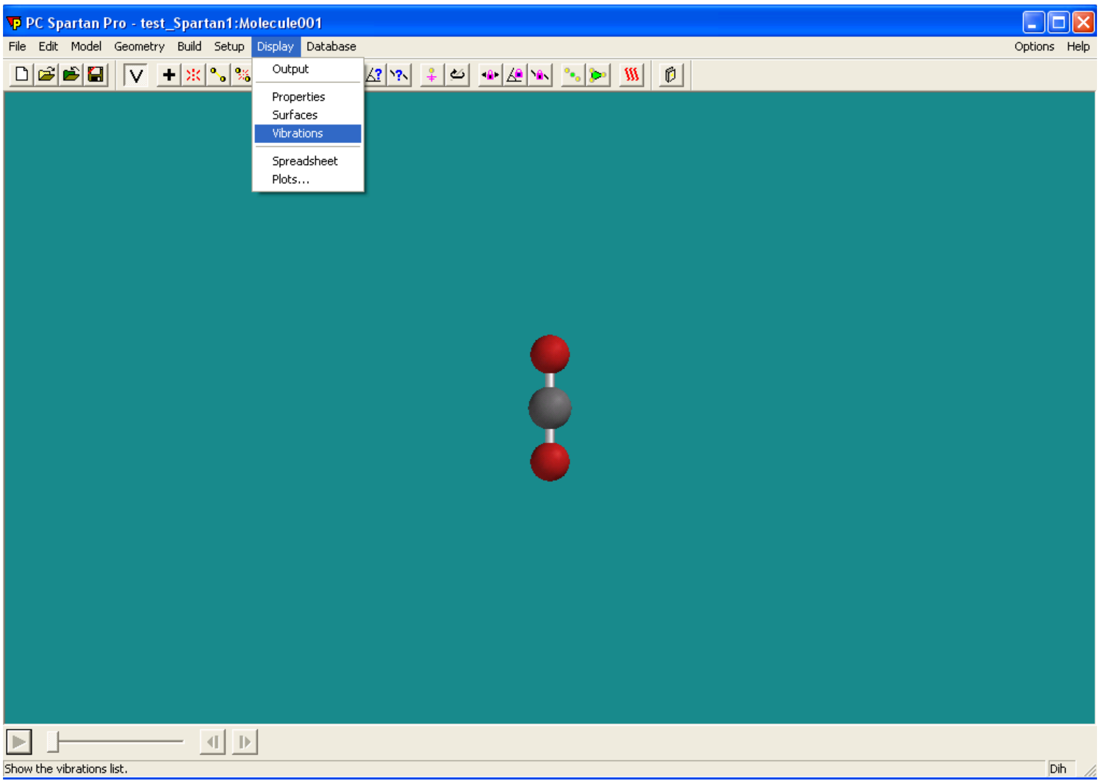
Following this, click on the 'set up' menu and go to 'calculation.' Select the setup calculations following parameters as demonstrated below and finally click ok. This tells the computer to calculate the frequencies of the vibrational modes for CO_2.



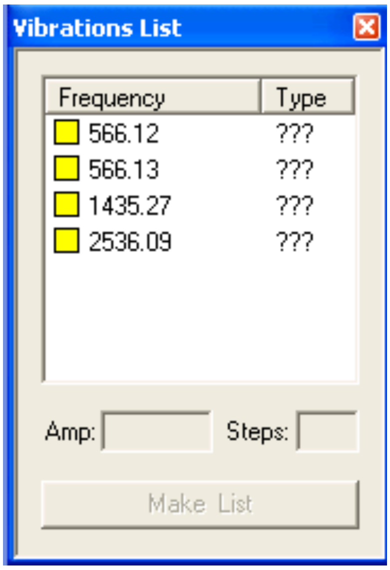
After this go back to ‘Setup’ and click ‘Submit’. The software will most likely ask you to save your file,



The programme will then start to calculate the frequencies; the calculation times may vary depending on the size of the molecule. Once the calculation have finished, click on the ‘Display’ icon and go to ‘Vibrations.’



The following, or similar vibration list should appear,



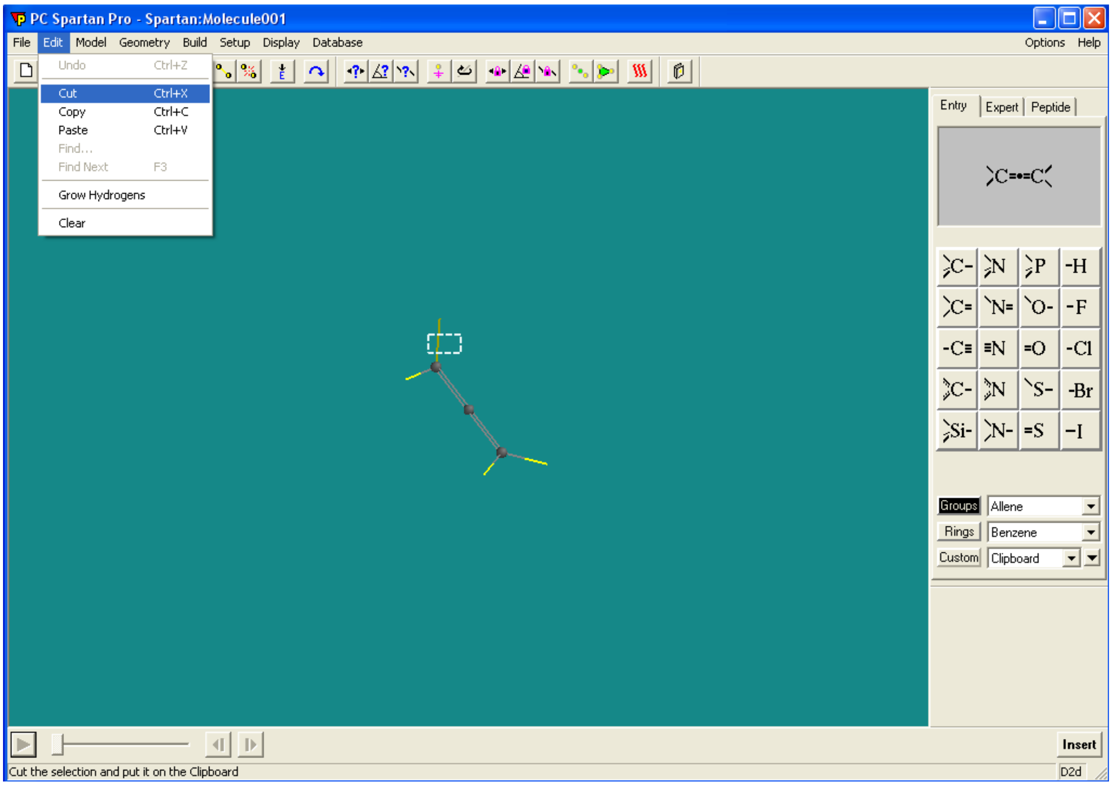
As you see there are four vibrational frequencies produced for CO_2, the first two are almost identical ~566.13 cm^{-1}. These correspond to the bending vibrational modes which are degenerate, or of equal energy. The second vibrational frequency at 1435.27 cm^{-1} represent the symmetric stretch and finally the intense asymmetric stretch can be observed at 2536.09 cm^{-1}.

View the vibrational modes by selecting the small yellow boxes one at a time to observe the vibration of the molecule.

Exercise 02

After making all the observations from CO_2, you will now need to carry out the same procedure with nitrous oxide (N_2O) and methane (CH_4), oxygen (O_2), nitrogen (N_2), water (H_2O) and also to consider the atom argon (Ar), also present in the atmosphere.

Hint: As nitrous oxide is a linear molecule it is best drawn by, first selecting **'Entry'** in the model kit area and click **'Allene'** from the groups menu. After this, click on the turquoise screen so that the molecule is displayed and delete the four free valences. (This can be achieved by holding down the left hand button on the mouse and then using the right button to highlight the area to be deleted. Finally go to 'Edit' and click 'Cut.' See example, below.



Following this step, bring up the **'Expert'** model kit and select N from the periodic table and double click on the two adjacent carbons. Next, select O and double click on the remaining carbon. Finally, repeat the vibrational frequency calculations for your molecule and compare results with experimental data.

National Institute of Standards and Technology

Enter a Google search for http://webbook.nist.gov/chemistry/

Click on 'NIST Chemistry WebBook' on the search options click on 'Name'

1. Type in the name of one of the greenhouse gases i.e. Carbon dioxide
2. Click SI
3. Select IR spectrum
4. Finally click on 'Search'
5. Scroll down to IR Spectrum, and click the link to 'GAS….' to view the IR spectrum of CO_2

By analysing the information from Spartan and from the NIST database, comment on

(i) Whether you think the molecules/atoms you have looked at are technically 'greenhouse gases' i.e do they absorb in the infrared, and,

(ii) Whether you think they have contributed to the warming of the atmosphere in recent years.

Meta tags

Author: Kaduk, J.; Monks, P.; Raine, D.; Zalasiewicz, J.

Owner: University of Leicester

Title: Interdisciplinary Science Near Space Student Document

Classification: PA1014 / Near Space

Keywords: Chemistry; Earth Sciences; Geology; Geography; Physics; Problem-Based Learning; Systems; sfsoer; ukoer

Description: *Near Space* is an introduction to some of the scientific concepts of the global climate system, and to the concept of anthropogenic climate change. In this module we will look at physical, chemical and biological influences on the climate.

Language: English

File Size: 1.8MB

File Format: PDF

Version: 1.0

Additional Information

This module pack is the open student version of the teaching material. An expanded module pack for facilitators and additional information can be obtained by contacting the Centre for Interdisciplinary Science at the University of Leicester. http://www.le.ac.uk/iscience

This pack is the Version 1.0 release of the module.