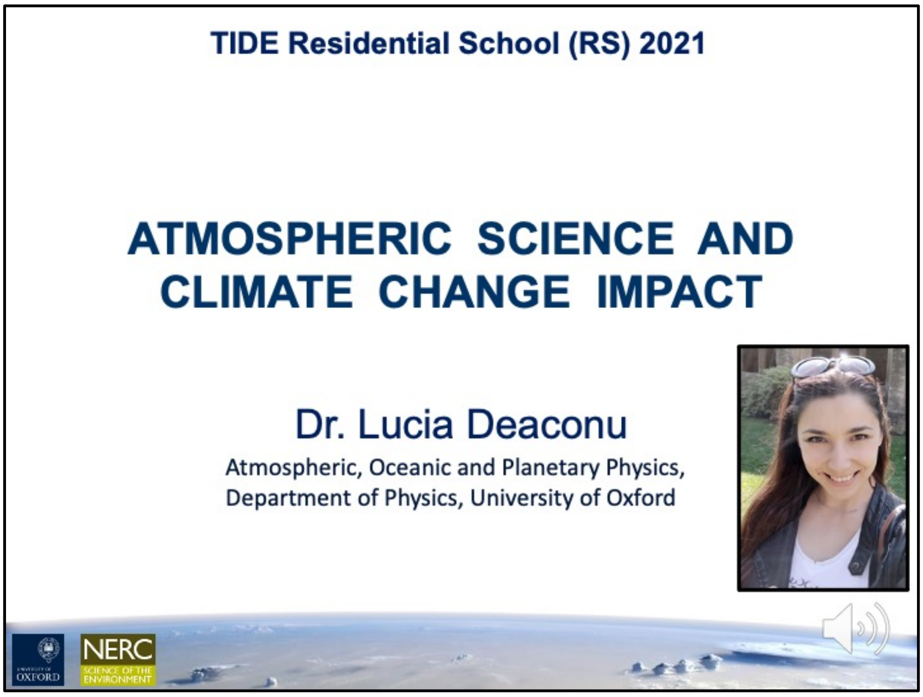
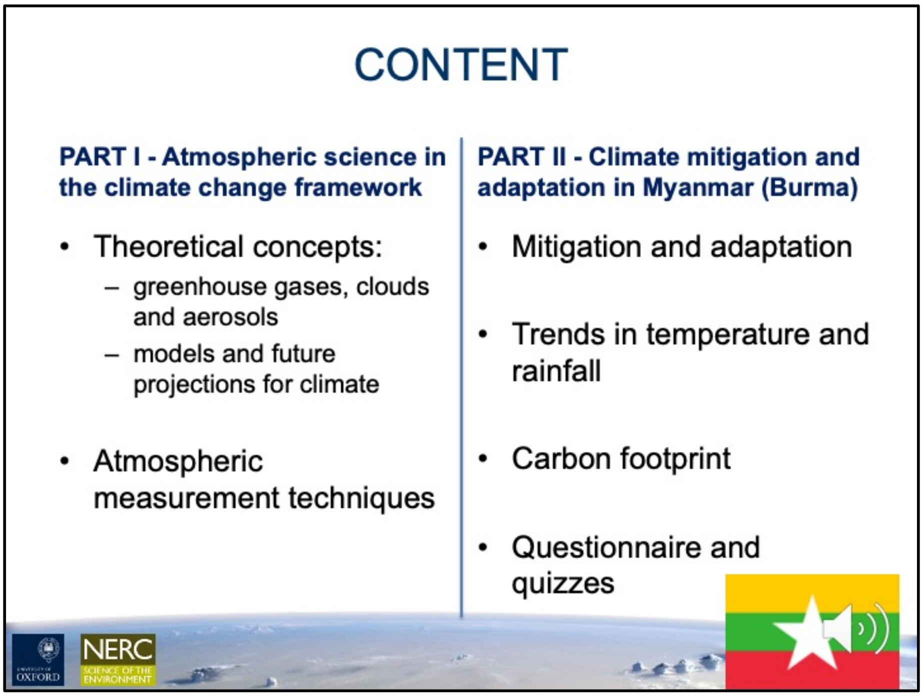


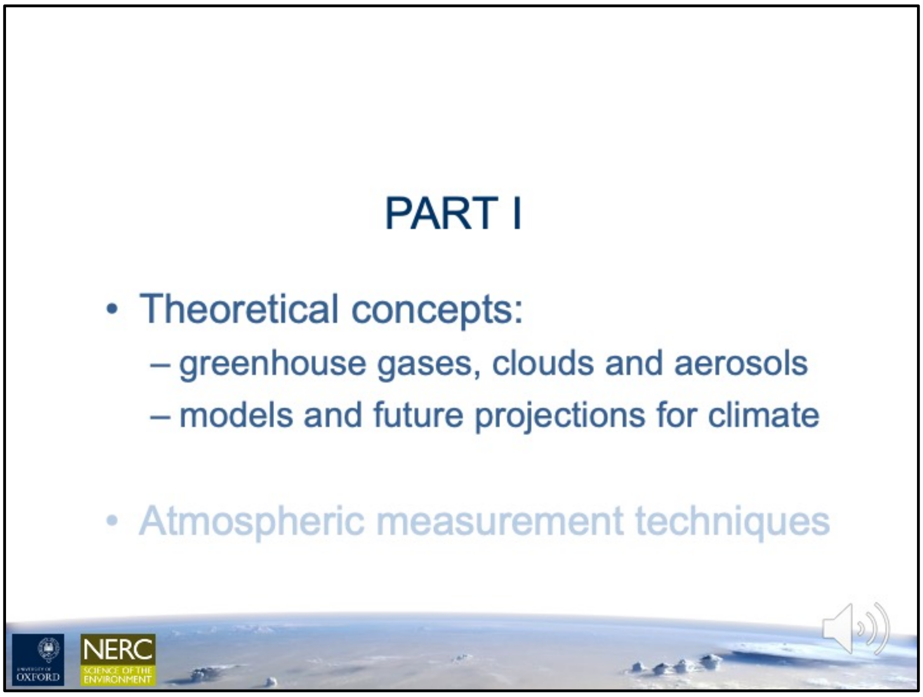
Hello everyone! My name is Lucia Deaconu, and I am a postdoctoral research assistant at the Atmospheric, Oceanic and Planetary Physics at University of Oxford and I hope you will enjoy the atmospheric science and climate change impact course that I will be teaching for the TIDE residential School of 2021.



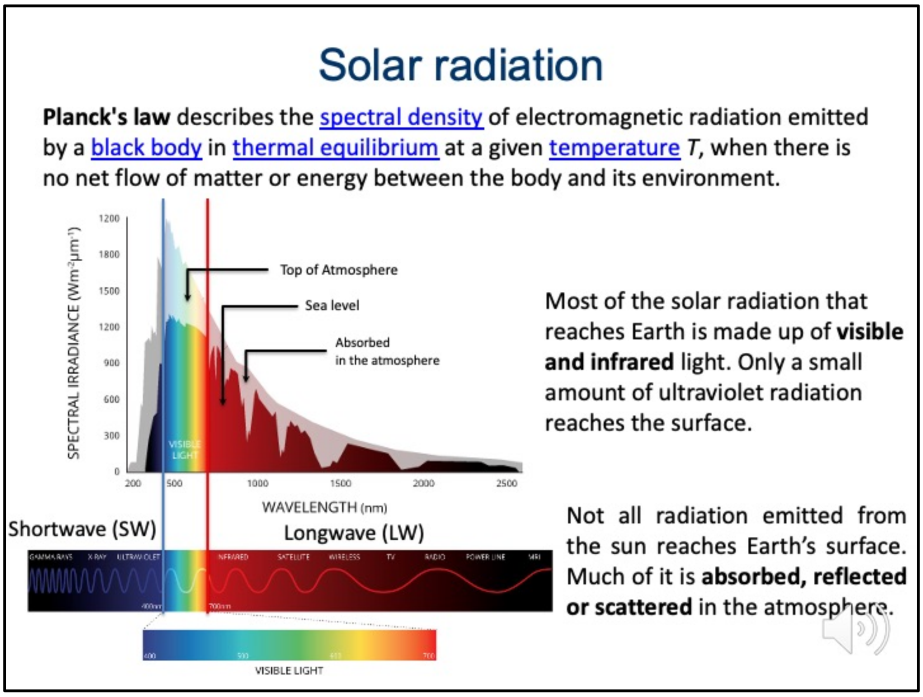
This course will be sectioned in 2 parts. The first one is focused on Atmospheric science in the climate change framework, and the second will present some notions of climate mitigation and adaptation, with a focus in Myanmar.
First part will cover theoretical concepts on greenhouse gases, clouds and aerosols as well as models and future climate projections. We will also have a short look over the most utilized atmospheric measurement techniques
Under normal circumstances, the second part should have been more interactive, but I will try and keep you engaged while we talk about mitigation and adaptation, trends in temp and rainfall, the carbon footprint and we will finish with a questionnaire and some interactive quizzes

Disclaimer

" Many of the figures presented in this talk are taken from the Intergovernmental Panel on Climate Change (IPCC) Assessment Reports [https://www.ipcc.ch/reports/] and the IPCC Special Report Global Warming of 1.5 ºC [https://www.ipcc.ch/sr15/] "



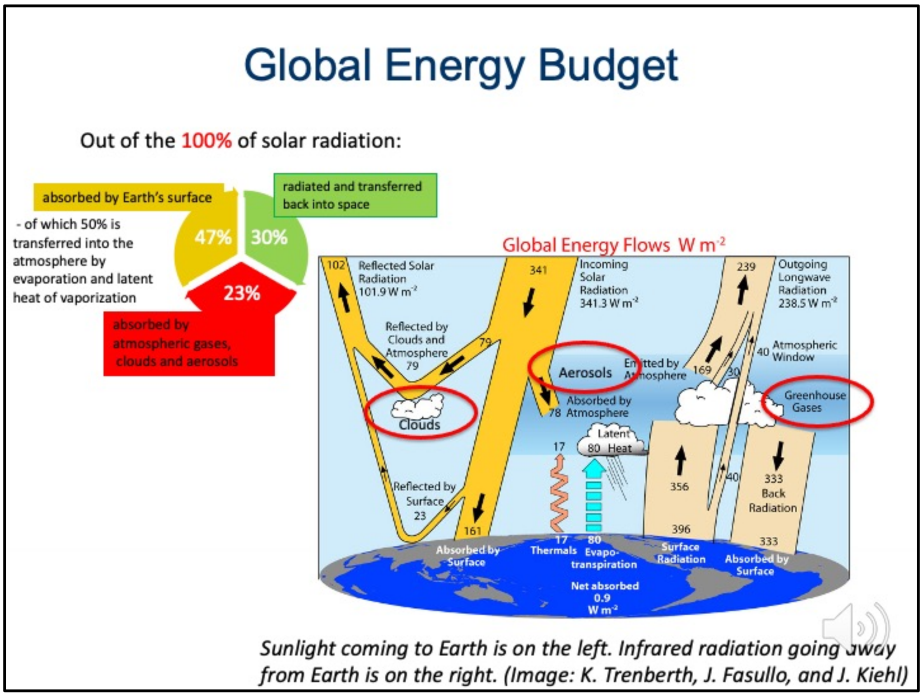
Let’s start with the first part, on theoretical concepts of atmospheric science



A black-body is an idealised object which absorbs and emits all radiation frequencies. Near thermodynamic equilibrium, the emitted radiation is closely described by Planck's law and because of its dependence on temperature, Planck radiation is said to be thermal radiation, such that the higher the temperature of a body the more radiation it emits at every wavelength.

Planck radiation has a maximum intensity at a wavelength that depends on the temperature of the body. For example, at room temperature (~300 K), a body emits thermal radiation that is mostly infrared and invisible. At higher temperatures the amount of infrared radiation increases and can be felt as heat, and more visible radiation is emitted so the body glows visibly red. At higher temperatures, the body is bright yellow or blue-white and emits significant amounts of short wavelength radiation, including ultraviolet and even x-rays. The surface of the sun (~6000 K) emits large amounts of both infrared and ultraviolet radiation; its emission is peaked in the visible spectrum.

Most of the solar radiation that reaches Earth is made up of **visible and infrared** light. Only a small amount of ultraviolet radiation reaches the surface. Not all radiation emitted from the sun reaches Earth's surface. Much of it is **absorbed, reflected or scattered** in the atmosphere.

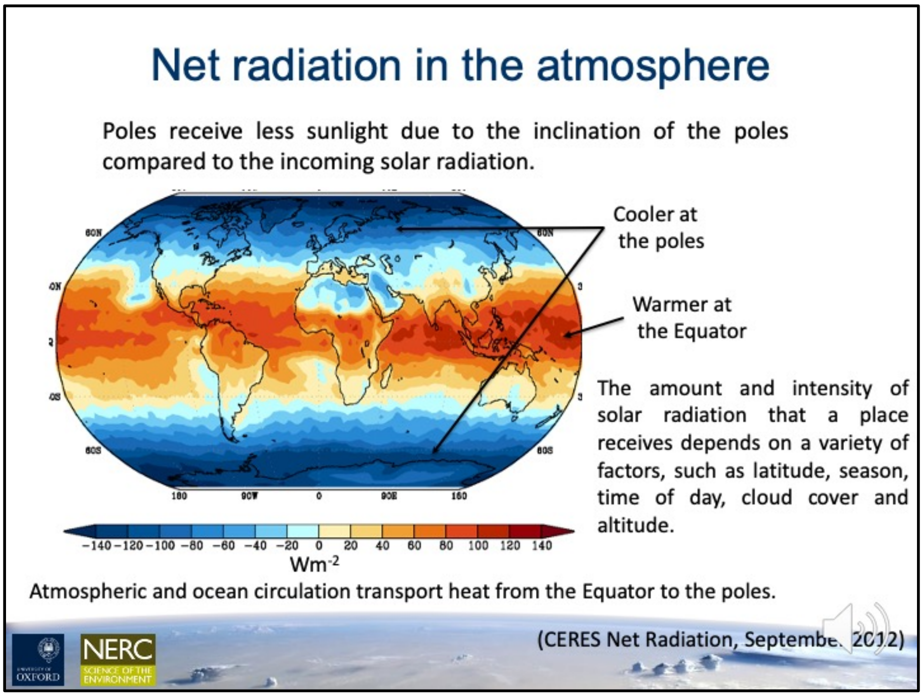


The image below shows the sunlight coming to Earth on the left. As we see, a part is absorbed by the surface, a small part is reflected by the surface (for example from bright surfaces such as ice, snow, deserts) and a larger part is reflected back by clouds and atmosphere. The infrared radiation emitted by the earth is shown on the right.

We can see that a part escaped the earth's atmosphere back to space and a part is reflected back at the surface by greenhouse gases, aerosols and clouds.

In summary, 47% of the incoming solar radiation is absorbed by the Earth's surface, 30 % is radiated and transferred back to space and 23% is absorbed by atmospheric gases, clouds and aerosols.

As you see, Clouds, aerosols and GHG are three atmospheric components that have an important role in global climate, as they interact with light by either scattering or absorbing radiation, leading to cooling or warming the Earth's system, with a high impact on different parts of the globe.



Of course the amount and intensity of solar radiation that a place receives depends on a variety of factors, such as latitude, season, cloud cover, altitude. Such, the poles will always receive less sunlight due to the inclination of the poles compared to the incoming solar radiation, compared to the Ecuator, which will always be warmer. However, in recent decades the poles have been heating up much faster than the rest of the earth, and that is mostly due to the atmospheric and oceanic circulations which transport heat from the Ecuator to the poles.

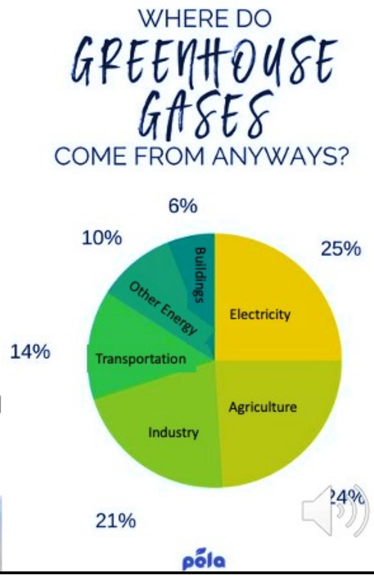
Greenhouse gases (GHG)

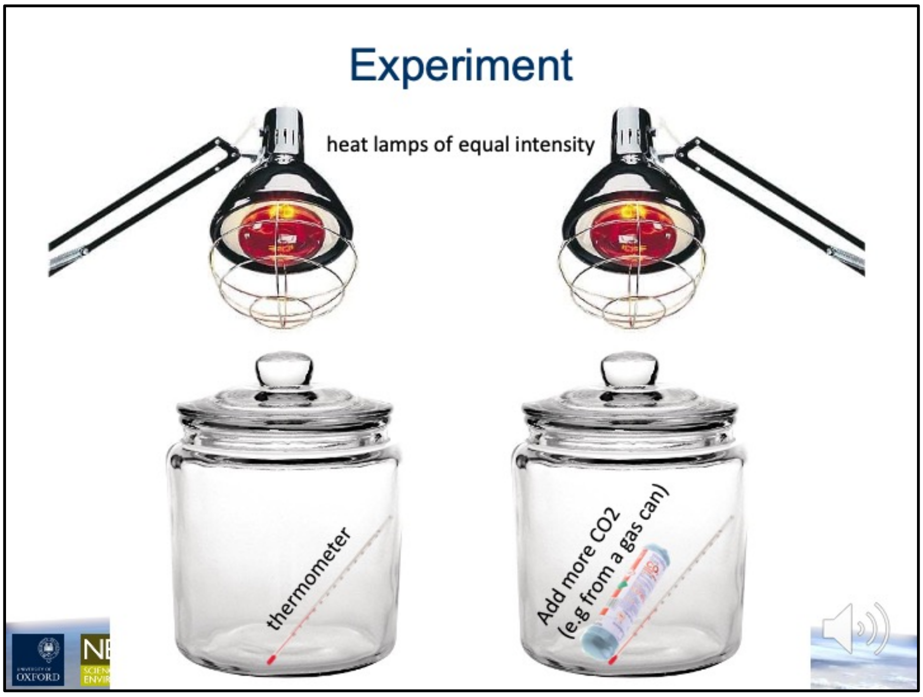
Earth's greenhouse gases trap heat in the atmosphere and warm the planet (Greenhouse effect).

Main gases responsible for greenhouse effect:

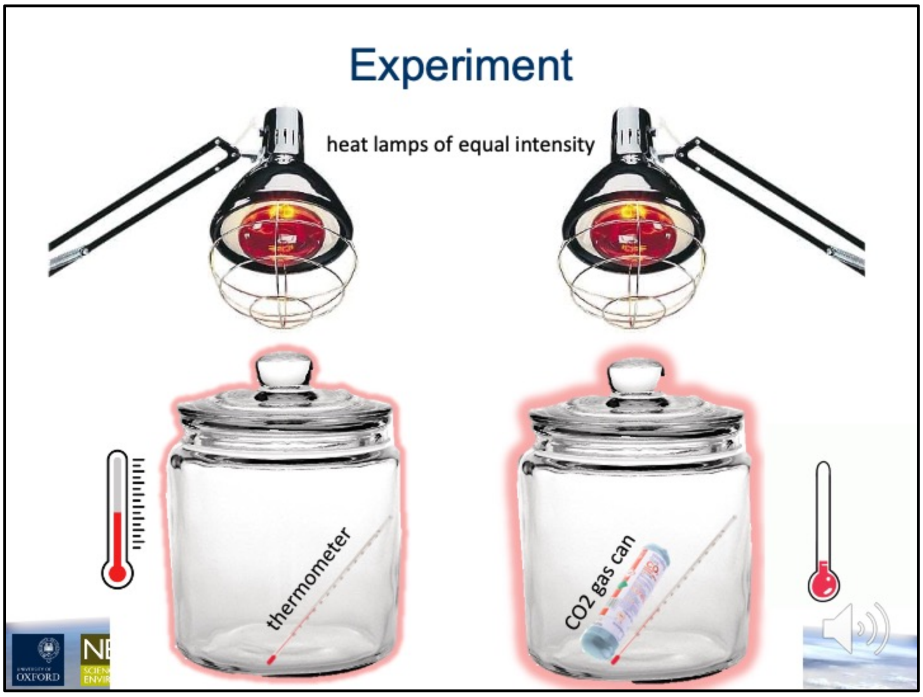
- Carbon dioxide CO_2,
- Methane CH_4,
- Nitrous oxide N_2O,
- Water vapor (which all occur naturally),

- and fluorinated gases (which are synthetic and can stay in the atmosphere for centuries).

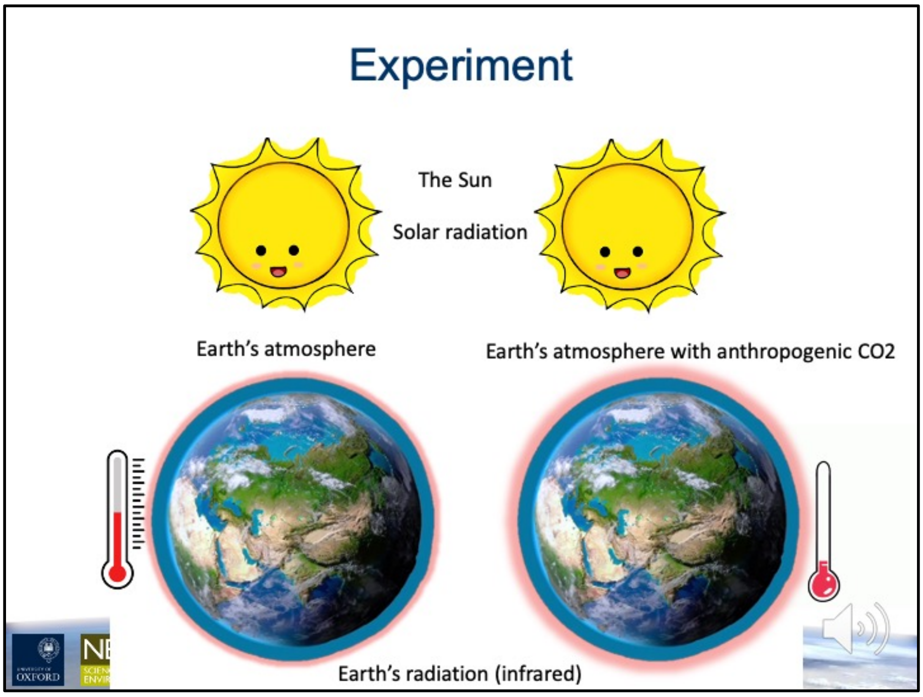




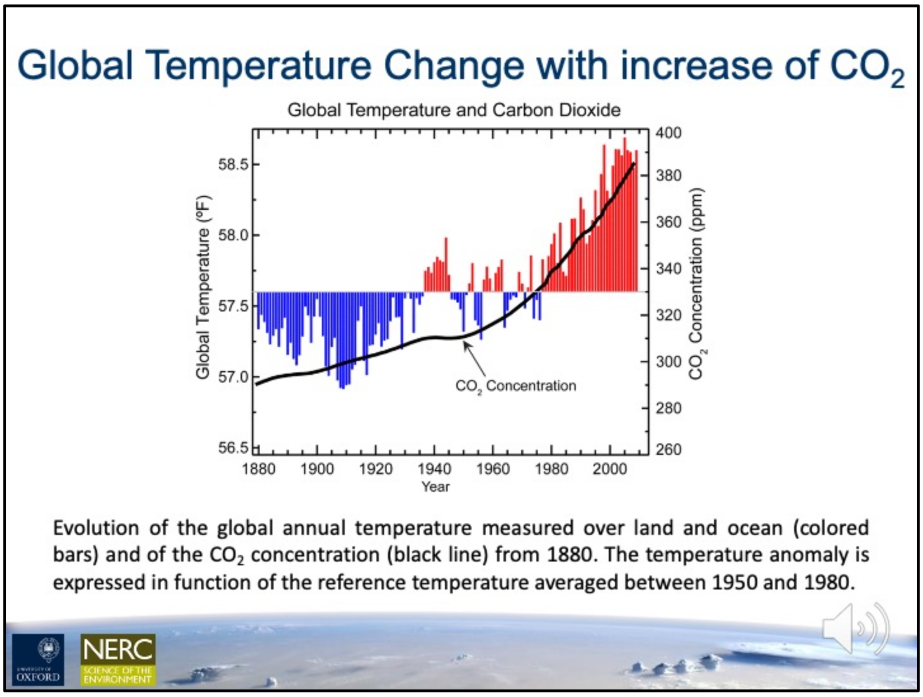
This is a simple experiment that can demonstrate the greenhouse effect. We take two lid jars of same size and volume, and we put a thermometer in both. In one of them we release additional gas, for example from a CO_2 gas can. In the meantime we turn on 2 heat lamps of equal intensity, to heat the jars.



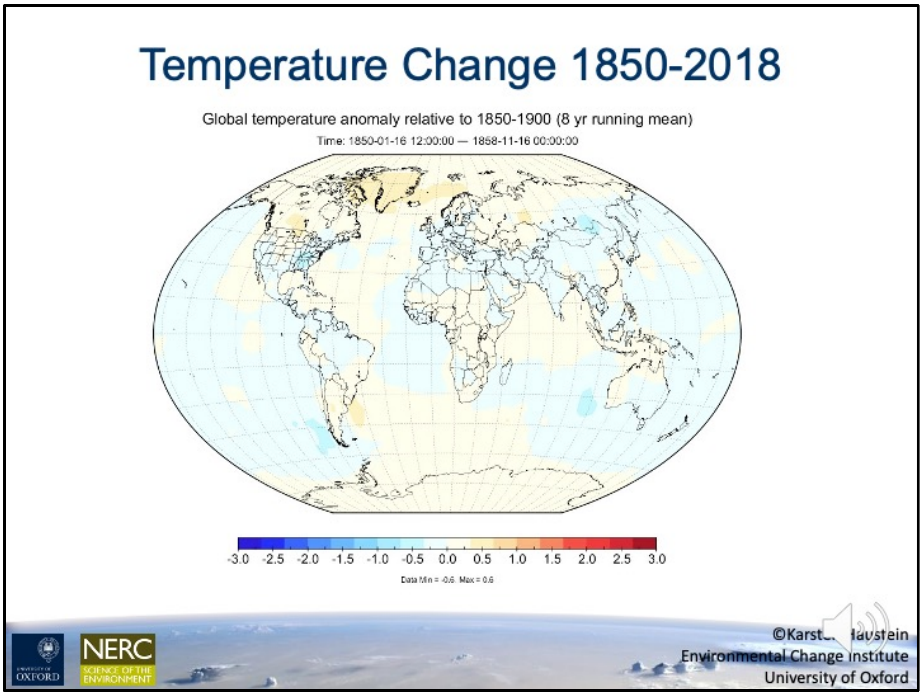
As the experiment progresses, we will notice that the temperature of the jars will increase, but the one containing the additional gas will have a more rapid and stronger increase (so larger temperatures than the other one)



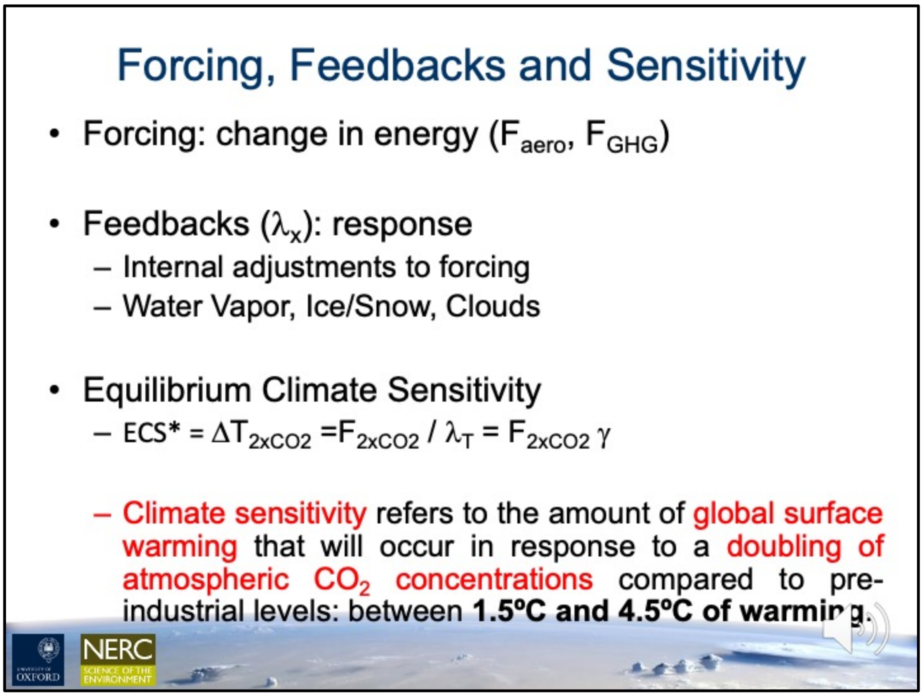
In the experiment the lamps are associated to the Solar radiation, that heats the earth' atmosphere. In normal circumstances the naturally occurring greenhouse gases—carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O)—which trap some of the sun's heat, keeping the planet from freezing. But when we have rampant CO2 (or other greenhouse gases) released from human activities (such as burning of fossil fuels), the increasing greenhouse gas levels lead to an enhanced greenhouse effect. The result is global warming and unprecedented rates of climate change.



This figure shows the evolution of the global annual temperature measured over land and ocean (in colored bars) and the CO2 concentration (black line) from 1880 to present. The temperature anomaly is expressed in function of a reference temperature averaged between 1950 and 1980. We can clearly notice an increase in CO2 concentration correlated with an increase in temperature (e.g. temperatures before 1940s were lower than the mean, while temperature after 1980s are increasingly larger than the mean.



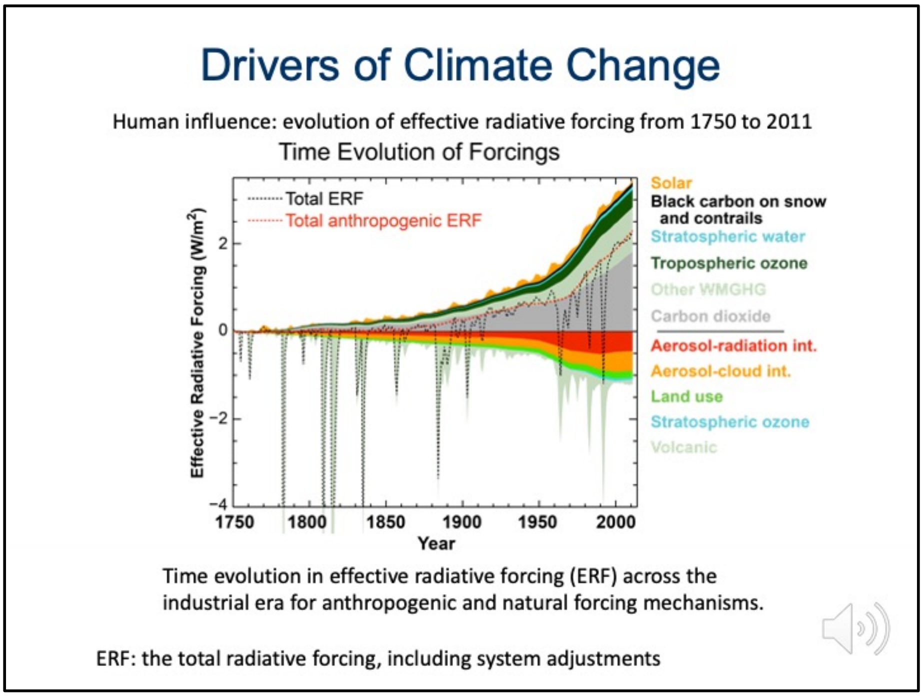
This map is taken from a model output that shows the temperature anomaly relative to 1850-1900, as 8 years running mean. While there isn't much happening until the middle of the 20th century, we can afterwards notice a rapid increase of temperatures, especially in the northern hemisphere, with the pole beings most affected by the temperature anomaly. In the year 2018, the North Pole was 3 degrees warmer than 60 years ago.



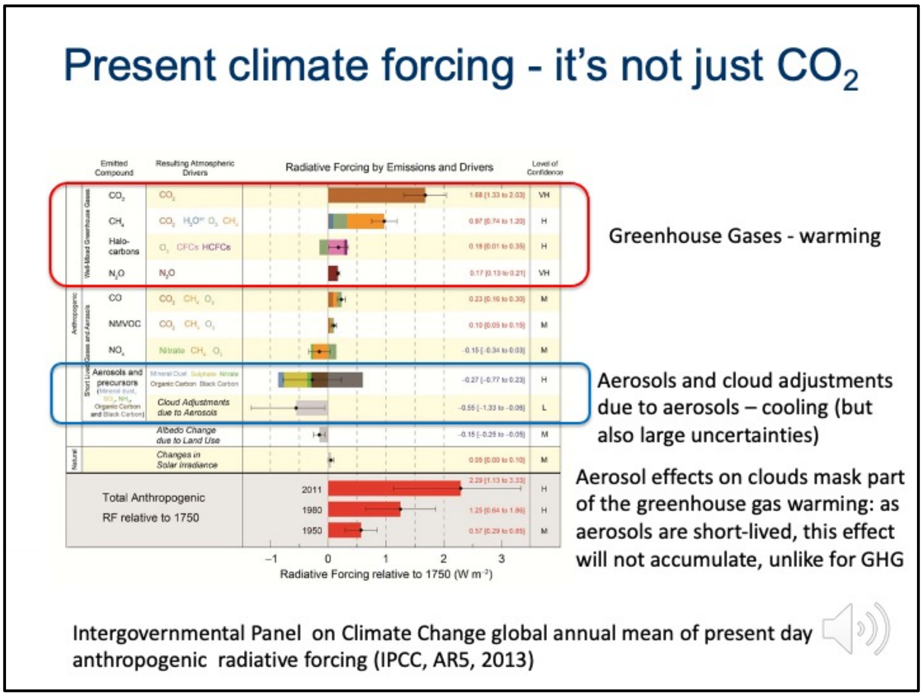
Here we will discuss a few key concepts, useful in understanding the following part of the course. There are 3 notions widely used in climate science: forcing, feedbacks and sensitivity. Climate forcing is the physical process of affecting the climate on the Earth through a number of forcing factors. These factors are specifically known as forcings because they drive the climate to change, and it is important to note that these forcings exist outside of the existing climate system. Examples of some of the most important types of forcings include: variations in solar radiation levels, volcanic eruptions, and changing levels of greenhouse gases and aerosols in the atmosphere.[4] Each of these are considered **external forcings** because these events change independently of the climate, perhaps as a result of human-caused fossil fuel combustion.

The feedback is the response of the system to different forcings. Positive (or reinforcing) feedback amplifies the change in the first quantity while negative (or balancing) feedback reduces it.

feedback processes may amplify or diminish the effect of each climate forcing, and so play an important part in determining the climate sensitivity. For example if the atmosphere is warmed by an increase in CO2, the the amount of water vapor in the atmosphere will tend to increase due to increase in evaporation. Since water vapor is a greenhouse gas, the increase in the eater vapor content makes the atmosphere warm further. This is a positive feedback. A negative feedback could be considered the increase in cloud cover which will backscatter more sunlight and reduce the warming of the atmosphere



When we discuss climate change we also have to mention the drivers. This figure disentangles the effect on the radiative forcing of different natural and anthropogenic forcings. We notice than on the positive side, the CO2 and other GHG make up for the largest increase since the industrial revolution, whilst on the negative side (forcings that tend to compensate the warming induces by GHGs) are the aerosols and their interaction with radiation and clouds. We can also see the strong negative values given by short but strong volcanic eruptions, which transport large amounts of particles in the upper troposphere and stratosphere, where they scatter much of the incoming solar radiation back to space.



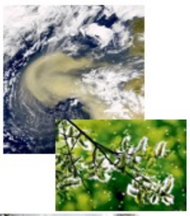
This figure shows a different representation of what I've shown before, but here it is easier to distinguish the forcings that have a warming effect, versus the forcing that have a cooling effect of the climate system, and their associated uncertainties..

Aerosols

Aerosols are all the solid and liquid particles, suspended in the atmosphere with the exception of the hydrometeors (water droplets or crystals which form clouds).

Natural sources:

90 % of the total mass (3 Gt/an)
[IPCC, 2007]



- mineral dust particles
- sea salt
- biomass burning aerosols emitted from wildfires
- volcanic ash
- biogenic aerosols (pollen, bacteria)


Anthropogenic sources:

50 % of Aerosol Optical Depth
[Satheesh et Moorthy, 2005]

- generated by human activities -

- industry
- agricultural activities
- domestic heating
- cooking
- transportation

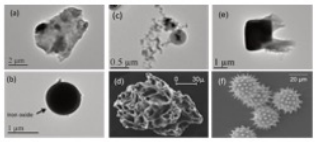

Aerosol Optical Thickness (AOT or τ)

Optical thickness (or optical depth) describes how much light passes through a material. As applied to the atmosphere, AOT describes the extent to which aerosols impede the direct transmission of sunlight of a certain wavelength through the atmosphere.
In a very clear sky, AOT can have values of 0.05 (about 95% transmission) or less. Very hazy or smoky skies can have AOT values in excess of 1.0 (about 39% transmission).

Size

- Large range - 0.01 to >10 μm
- Fine mode: soot, smoke, dust ..
- Coarse mode: pollen, dust ..

Shape



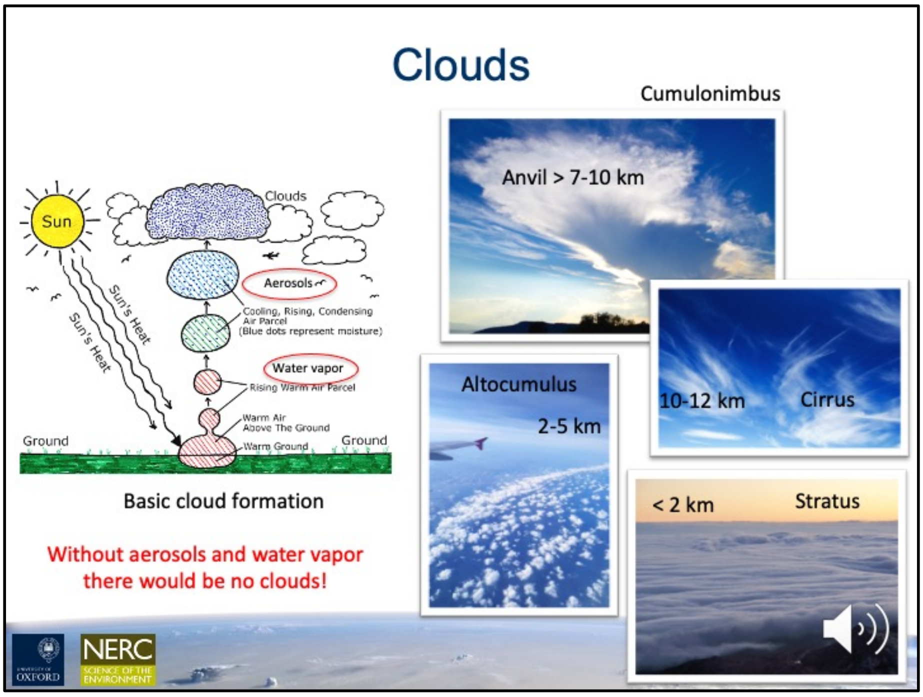
Angström Exponent (AE or α)

The AE is a parameter that describes how the optical thickness of an aerosol typically depends on the wavelength of the light. The AE is inversely related to the average size of the aerosol particles: the smaller the particles, the larger the exponent. We can estimate the AE by measuring the aerosol optical depth at different wavelengths.

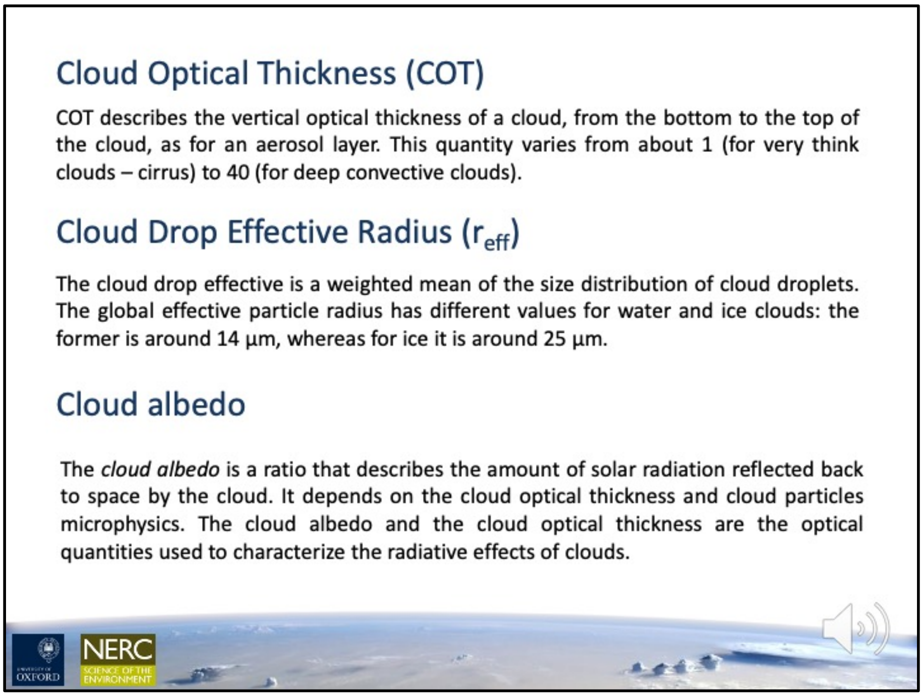
$$\frac{\tau_{,\lambda_1}}{\tau_{,\lambda_2}} = \left(\frac{\lambda_1}{\lambda_2}\right)^{-\alpha} \Rightarrow \alpha = -\frac{\ln\frac{\tau_{,\lambda_1}}{\tau_{,\lambda_2}}}{\ln\frac{\lambda_1}{\lambda_2}}$$

λ = wavelength

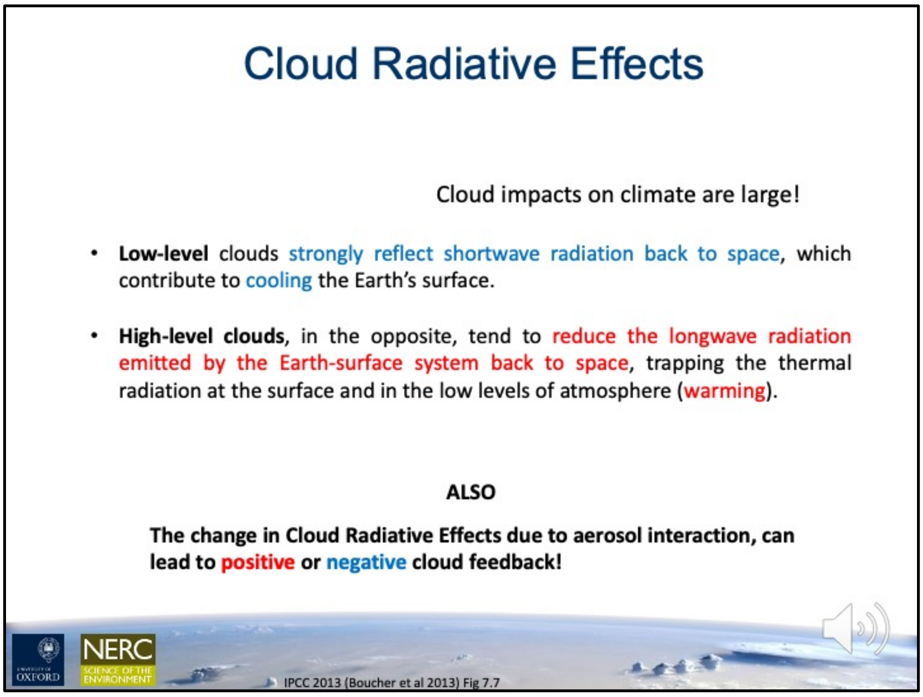
AE: for measurements of optical thickness $\tau_{\lambda 1}$ and $\tau_{\lambda 2}$ taken at two different wavelengths λ 1 and λ 2 respectively



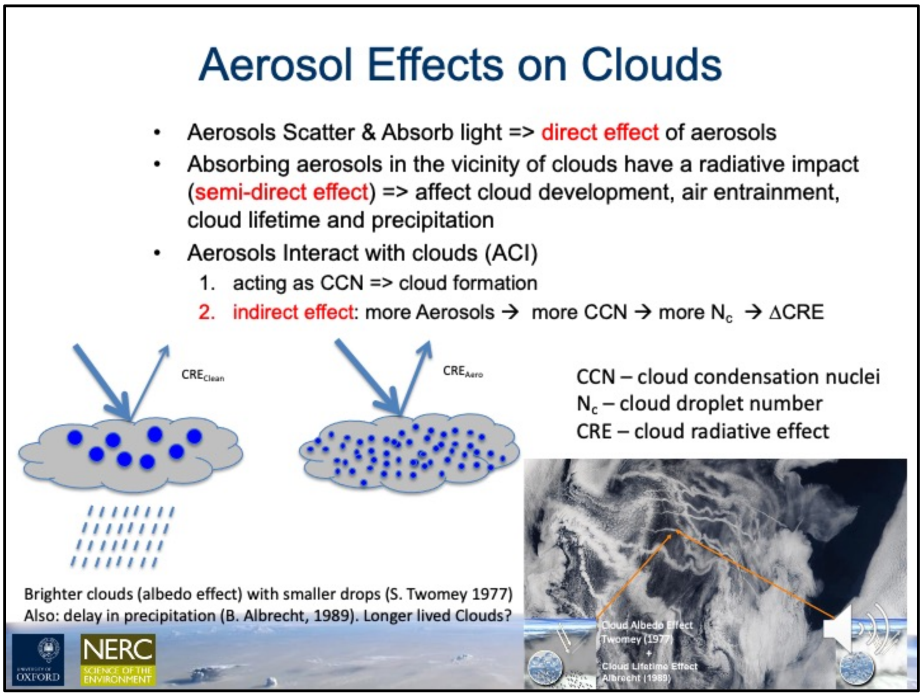
What are the initial conditions that are required for the formation of clouds? Firstly we need solar radiation, or heat, that will warm the earth's surface and the air above it. Through latent heat the warm parcel of air is lifting to higher altitudes where it can encounter water vapor. As the air lifts even higher it will cool and condense on microscopic particles suspended in the atmosphere - aerosols, resulting in cloud condensation nuclei (CCN). These nuclei can then coagulate and aggregate with others and form cloud droplets, which vary in size and can also be liquid or ice crystals. Some of the most familiar clouds are Stratus, very low clouds that live below 2 km. This is due to a temperature inversion just above the cloud. Cirrus clouds are ice clouds that are located very high in the atmosphere, and cumulonimbus, or deep convective clouds, which are also precipitable clouds that can extend across multiple km in the atmosphere.



3 of the most used properties of clouds in atmospheric science are:
COD
R_{eff}
cloud albedo



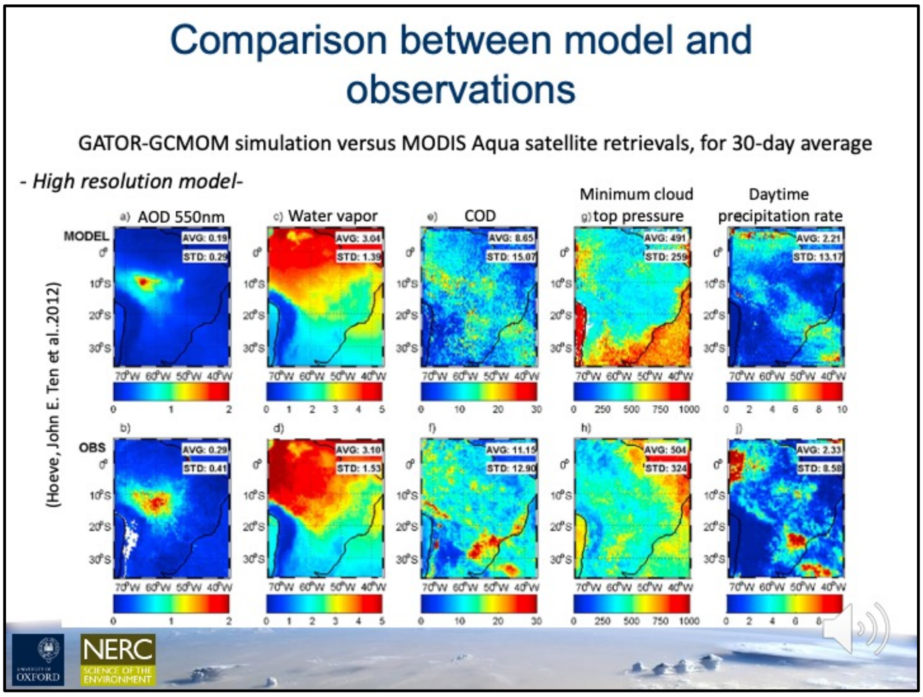
A simplifies way of understanding the clouds radiative effect is the following:
Low-level clouds reflect shortwave radiation => cooling
High-level clouds trap longwave radiation => warming



Without clouds, aerosols interact only with the light, by scattering or absorbing the incoming direct and diffuse solar radiation.

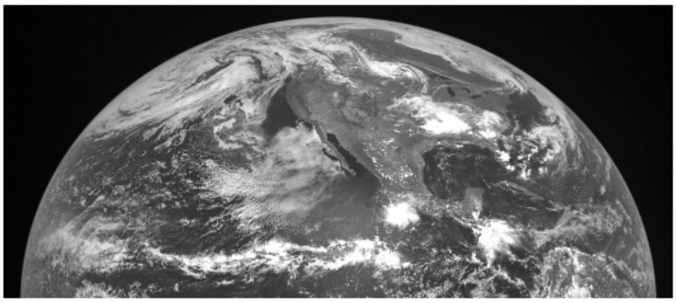
The absorbing aerosols, such as black carbon, can also impact the atmosphere's thermodynamic and impact the clouds through a semi-direct effect, without contact.

As mentioned before aerosols have an important role in cloud formation, as CCN. However, they can also affect existing clouds through the indirect effect. For example we have a precipitable cloud with a given amount of liquid droplets, and liquid water content. If more aerosols are injected in the atmosphere (for example from a ship's chimney), the aerosol concentration increases, that leads to an increase in CCN and a increase in cloud droplet number, and a decrease in cloud droplet size. The resulting clouds will be brighter, so they will reflect more sunlight back to space. This example is shown in the figure on the right, where the brighter clouds have formed where a ship has passed.



In this plot I show a comparison between a high resolution model and observations from satellite retrievals, for a 30 day average. At a first glance, it is hard to distinguish the model from the observation. But if we take a closer look we notice discrepancies between the model - the upper row, and the observations - in the row below. We notice that for the AOD, the model can simulate well the location of the source of aerosols, but the mean value across the domain is much lower, The water vapor is fairly well represented. The COD in the model is missing some very high values, corresponding to optically thick clouds, maybe deep convective precipitable clouds. We can see that the precipitation rate is also underestimated in the model. If you look closer in the observations, we can link the COD with the precipitation in the southern part of the domain, meaning those deep convective clouds also rained during the 30 day average.

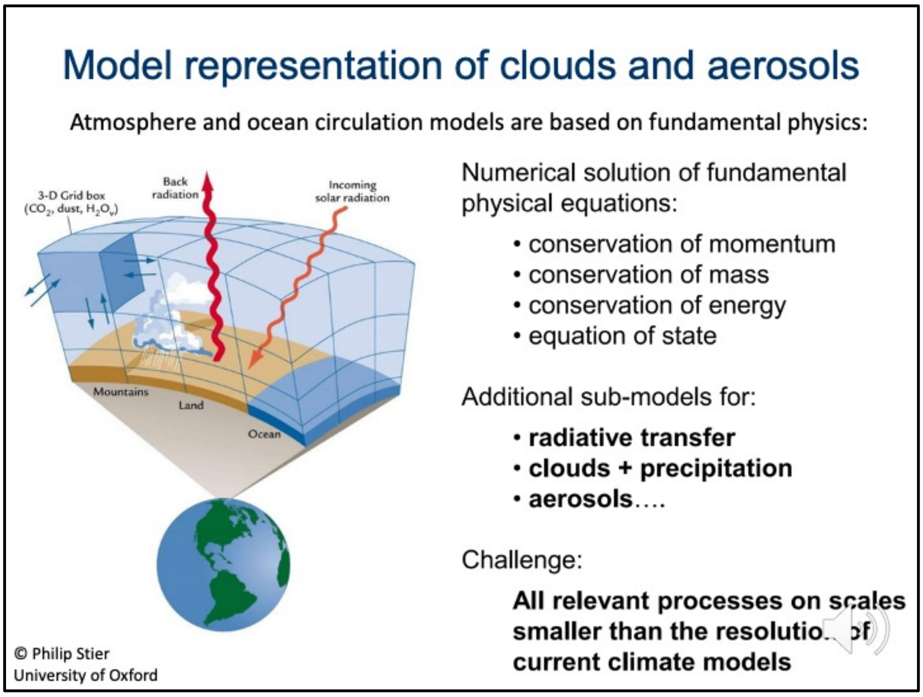
Model representation of clouds



Clouds are hard to represent in climate models, because:

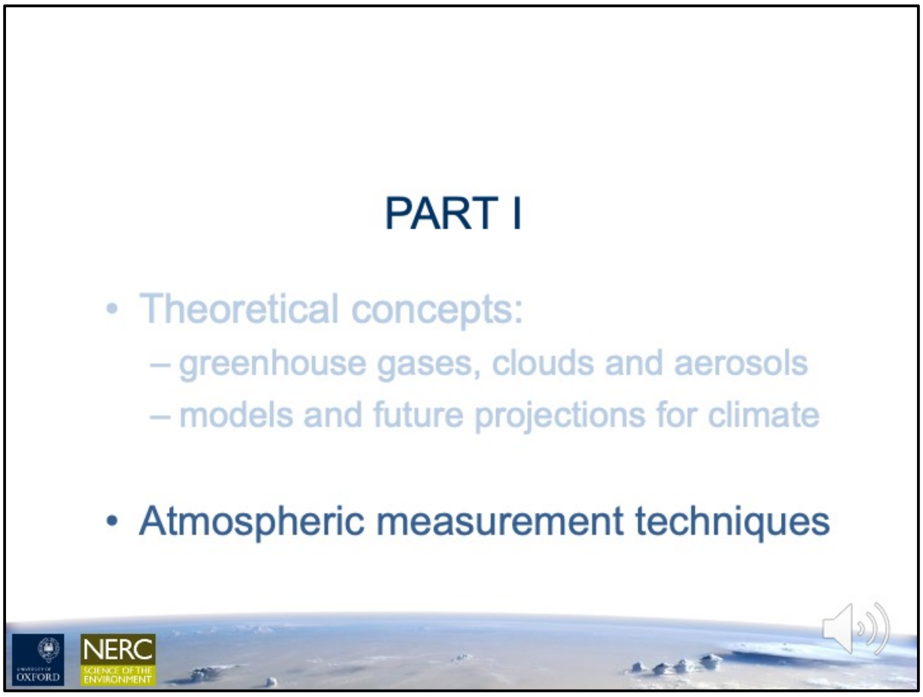
- Often thin, short-lived,
- Often produced by small-scale turbulence (e. g. cumuli),
- Complex interactions of water and ice particles
- High, thin clouds warm (greenhouse effect dominates),
- Low clouds cool (shading effect dominates).

Here is an instantaneous satellite image. We can see that clouds have very heterogeneous patterns, and that is one of the reasons why they are hard to represent in climate models.

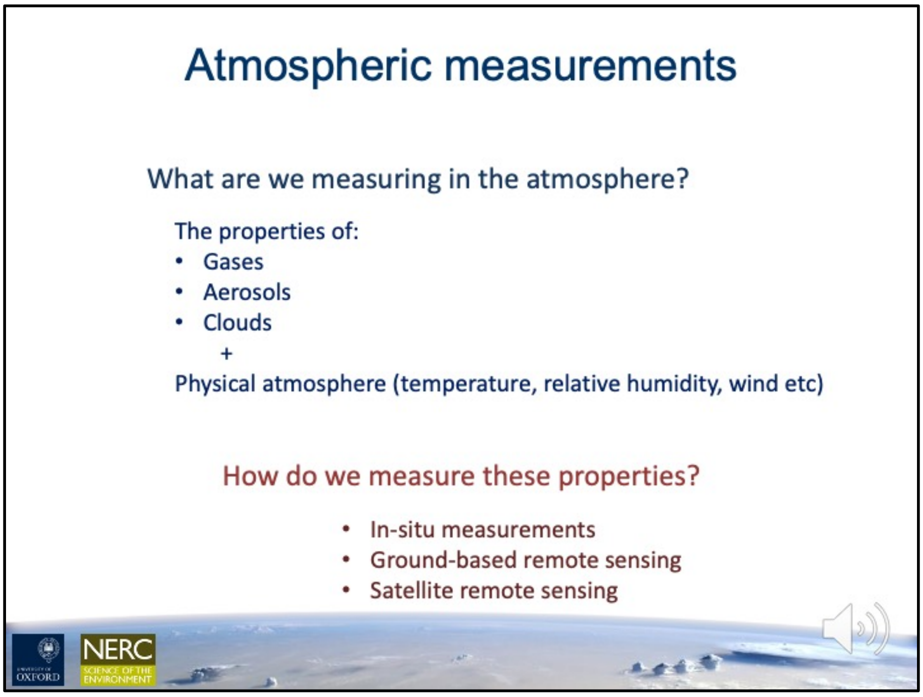


The main reason why models are struggling at representing cloud and aerosol radiative forcing and climate feedbacks is because of the model is build on parametrization on a sub-grid scale.

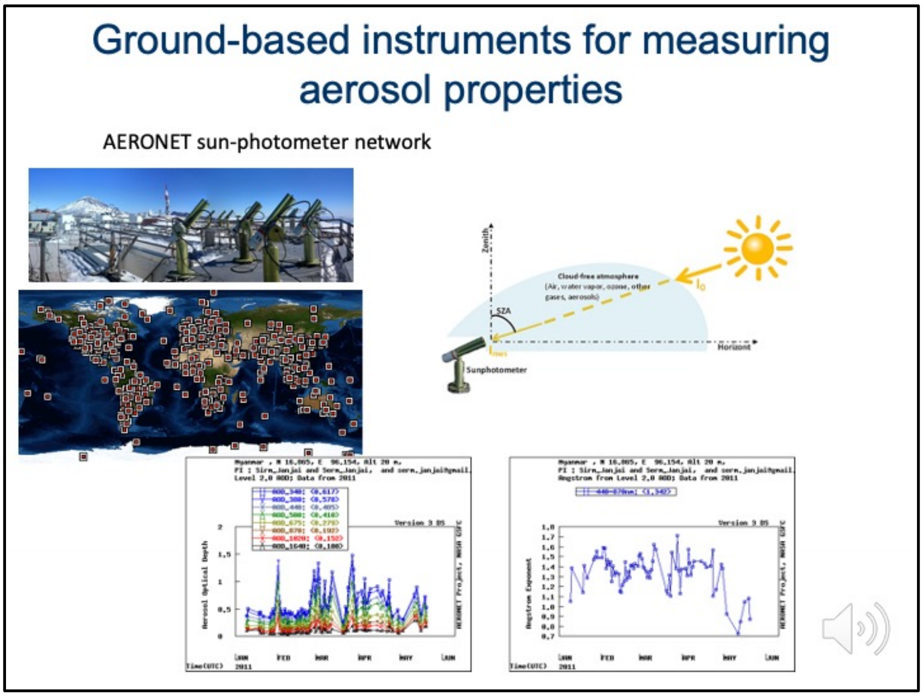
The largest uncertainty comes from the fact that we cannot represent the climate processes on a sub-grid level, therefore, on a grid scale we parametrize fundamental physical equations, such as conservation of momentum, of mass, of energy, equation of state. Additionally we have sub-models within a large coupled model, such as radiative transfer models, clouds and precipitation, aerosol and chemistry. Therefore it is hard to go at very small spatial resolution, and we usually run the models at a 1 by 1 degree latitude and longitude grids. We can of course do smaller resolutions, but that is very expensive in terms of computing processing units and very time consuming. We can also choose to use regional models, which have the advantage of going at higher grid resolutions, but these are limited due to their boundary conditions (such as the atmospheric and oceanic circulation at the boundary of their domain).



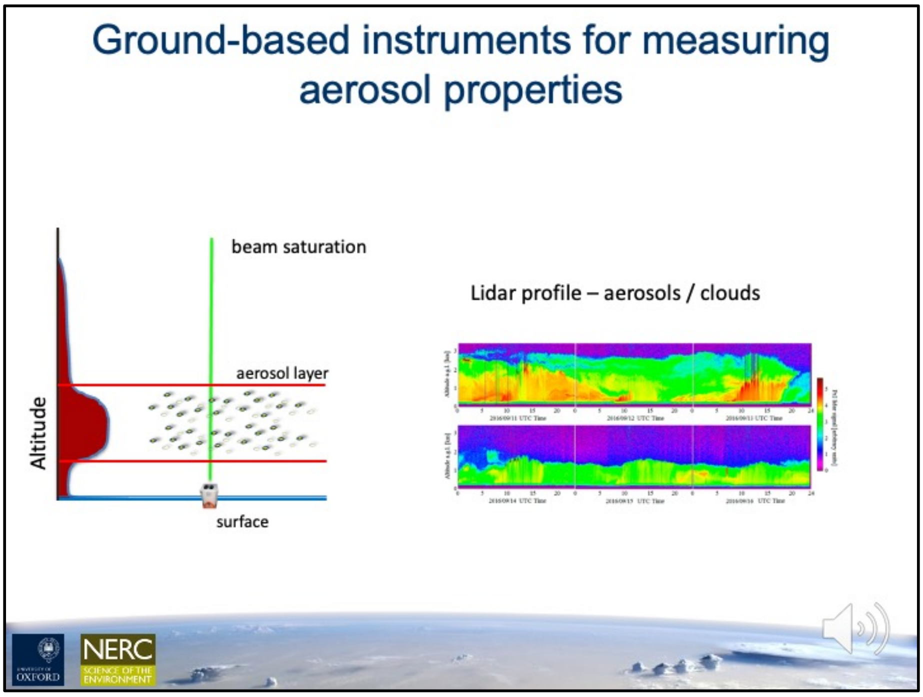
We continue with some notions on atmospheric measurement techniques



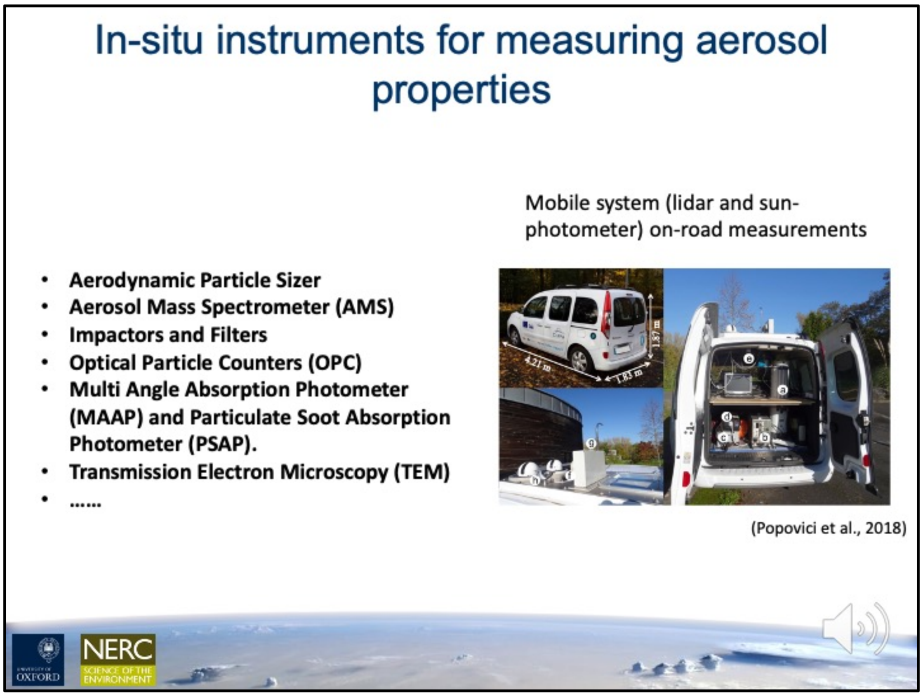
In the atmosphere we measure the properties of gases, aerosols and clouds additionally to the physical atmosphere (temperature, humidity, winds etc.). We measure these properties using in-situ measurements, ground based measurement and satellite remote sensing.



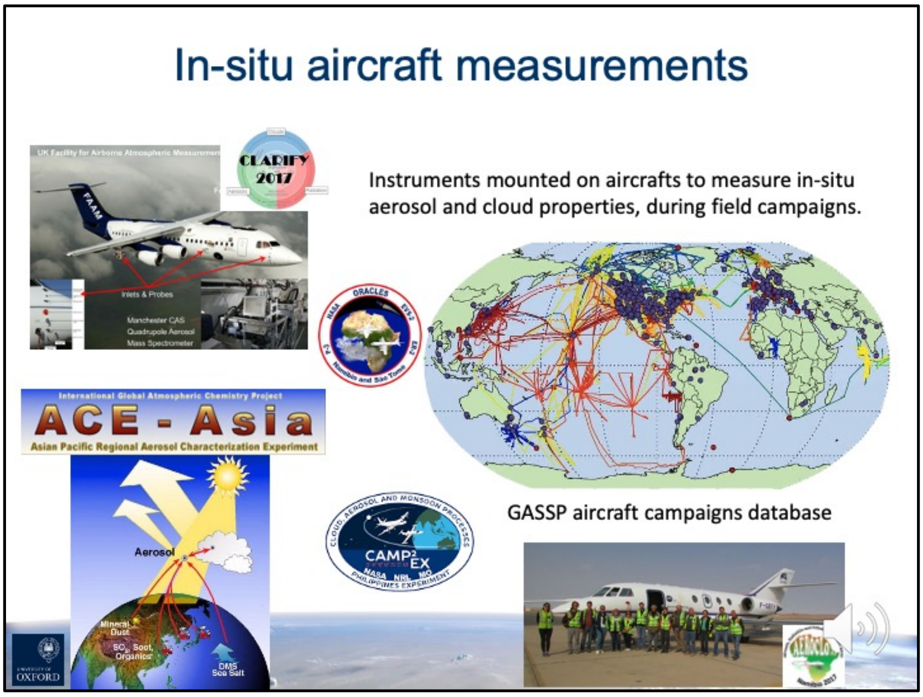
We start by looking at some ground based instruments and techniques. AERONET network is using sun-photometers to measure aerosol properties in cloud-free atmosphere, when sunlight is available. Therefore, we call these instruments passive instruments, because they use an external source of radiation for their measurements. As you can see, there are hundreds of stations scattered across the globe, which gives us a very good idea of the aerosol distribution across the globe. Below is an example of AOD measurements in Yangon at different wavelengths for one year. We notice there are some peak values above 1, close to 1.5, which tells us the atmosphere in those days was very hazy, and large concentrations of aerosols was present in the air. The angstrom values were calculated between two wavelengths and shows values mainly above 1, up to 1.8, which are characteristic to fine particles, mainly from burning of fossil fuel and biomass burning.



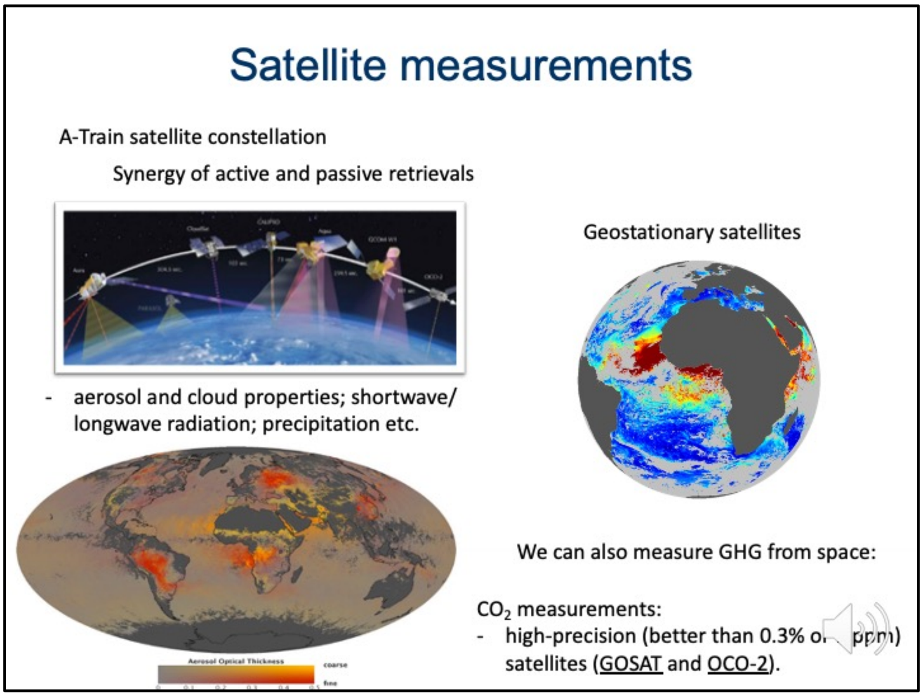
Another instrument that measures aerosol (and also cloud properties) is the Lidar. This is an active instrument, as it emits a beam of radiation at specific wavelengths and measures the backscattered light that encounters particles in its path. Compared to the sun-photometers that give us an integrated column value of aerosol properties, the lidar profiles tell us the exact location of the aerosols present in the atmosphere and their variable concentration.



There are many in-situ instruments that are used in atmospheric science. They can be installed on fixed locations, such as buildings, or they can be installed on mobile systems. In this case I show a car that has been transformed in a mobile laboratory equipped with many instruments.



The in-situ instruments can be loaded on aircrafts and there are many field campaigns that also consider flight measurements. Some of the campaigns also installed a lidar on the aircraft looking down, so that they have also the vertical profile measurements of the atmopshere.

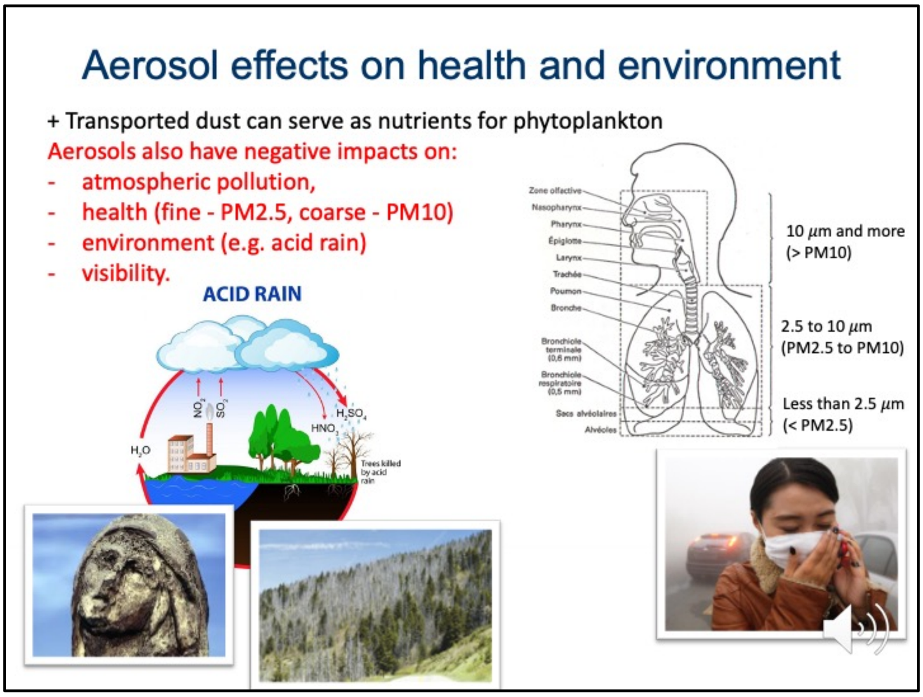


Lastly we have the satellite measurements, that come from polar satellites (that move across the globe) and geostationary satellites, that have a fix position and always measure over the same spot. Satellite can also have either passive or active instruments

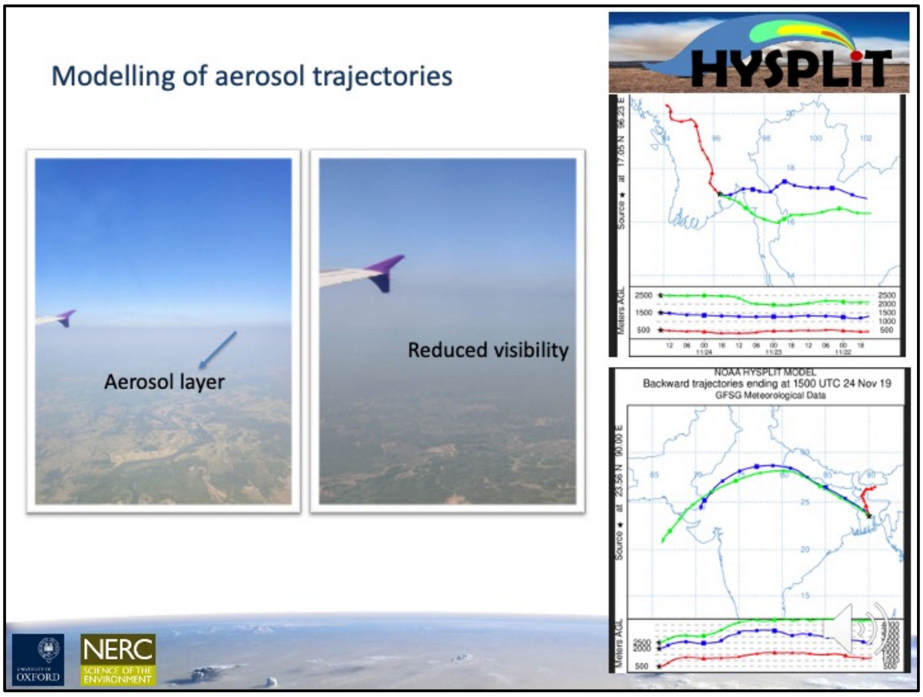
●**Passive imagers** – sensors that measure the amount of radiation reflected and emitted by the Earth. The solar radiation backscattered by the Earth's atmosphere and surface is measured by spectrometers aboard the satellites (e.g. OMI (Aura), MODIS (Aqua/Terra));

●**active sensors**: such as the radar or the lidar which send pulses of light from the satellite toward the surface and a fraction of this light is reflected, or scattered back to the spacecraft from thin vertical segments of the atmosphere (e.g. CALIOP (CALIPSO), CATS (ISS)).

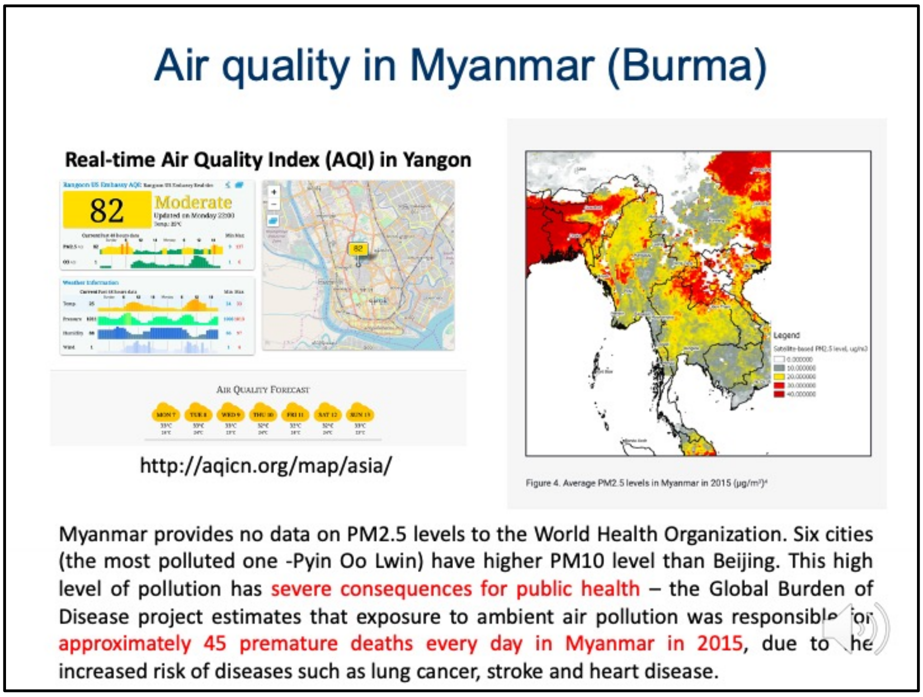
Some of the satellites are flying in constellations, so they can measure the same parcel at a distance of a few minutes. This is an advantage when different types of instruments with different sensitivities and that are focused on different properties of either aerosols, clouds or gases can measure the same location, as it allows for a better understanding of the atmospheric processes.



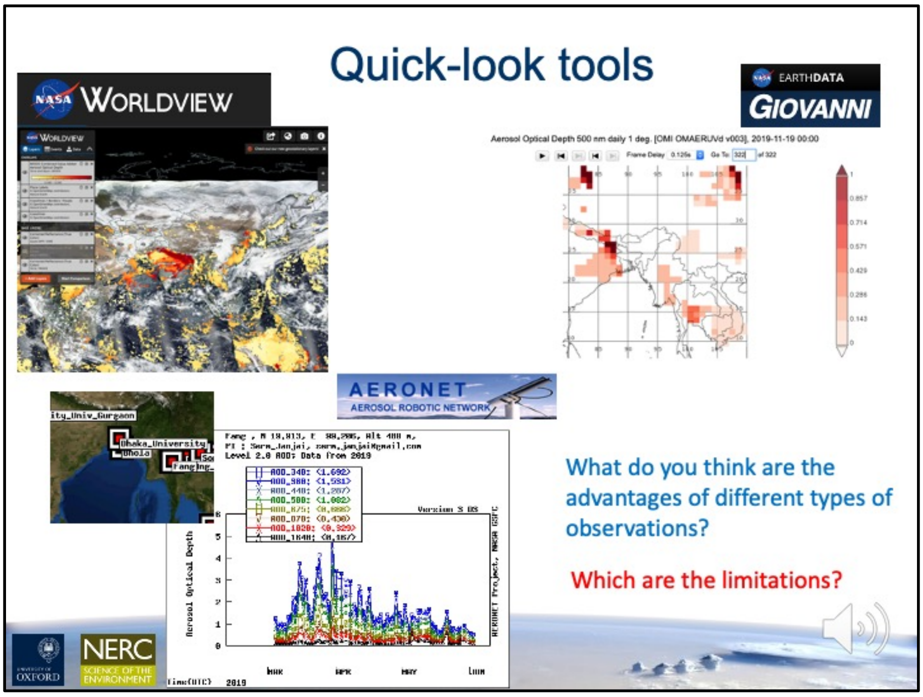
When we talk about aerosol effect on health and environment we first have to consider the type of aerosols and their size. The man-made aerosols have the strongest impact on the environment, for example sulfate and nitrates can produce acid rains that can destroy vegetation and also corrode buildings. The very small particles can be inhaled and produce health problems, ranging from a cough to asthma and pulmonary diseases. The smaller the particles the deeper they reach into the respiratory system. So particles of 2.5 micrometers or less can reach the pulmonary alveoli and even enter the blood stream.



Here are two pictures I took while flying across Myanmar in 2019. You see that the visibility was reduces, meaning there was a strong aerosol layer at those altitudes. When I arrived in the hotel I wanted to know where this aerosol layer was coming from, so I used a back-trajectory model, that requires as input meteorological conditions. This model showed that most of the aerosols were transported across from India, whilst a part was from local sources. Looking at the fire maps, it was confirmed that many of the biomass-burning fires in India were responsible for the aerosol layer that was transported over Myanmar.



There are not many air quality stations in Myanmar, but you can check the real-time air quality index in Yangon. For example you can see that in the early morning hours when traffic is at its maximum, the level in PM2.5 is quite high, which leads to a risk in human health. The link where you can check the real-time AQI is http://aqicn.org/map/asia/

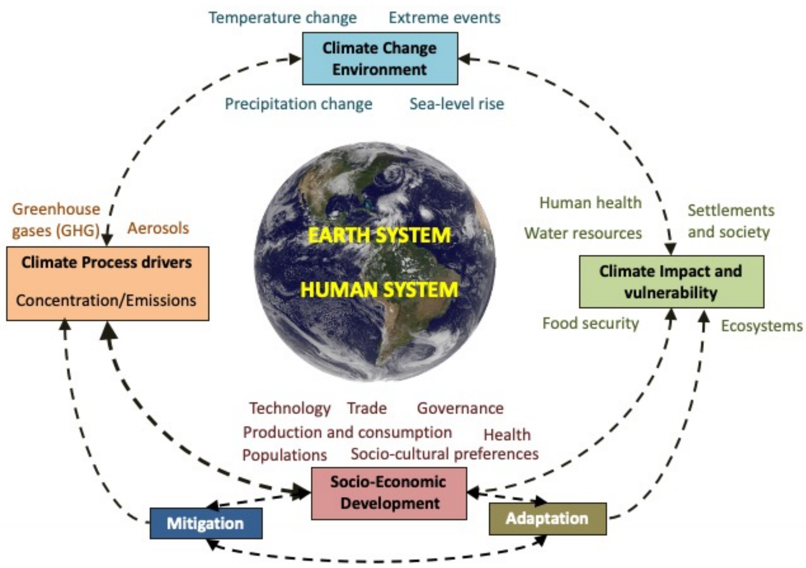


Unfortunately I cannot show you pop-up browser tabs, but you can check the Worldview and Giovanni earth data websites, where you can select different types of instruments (mainly satellite) and different parameters to have look across the globe.

END PART I

PART II

Climate mitigation and adaptation in Myanmar (Burma)

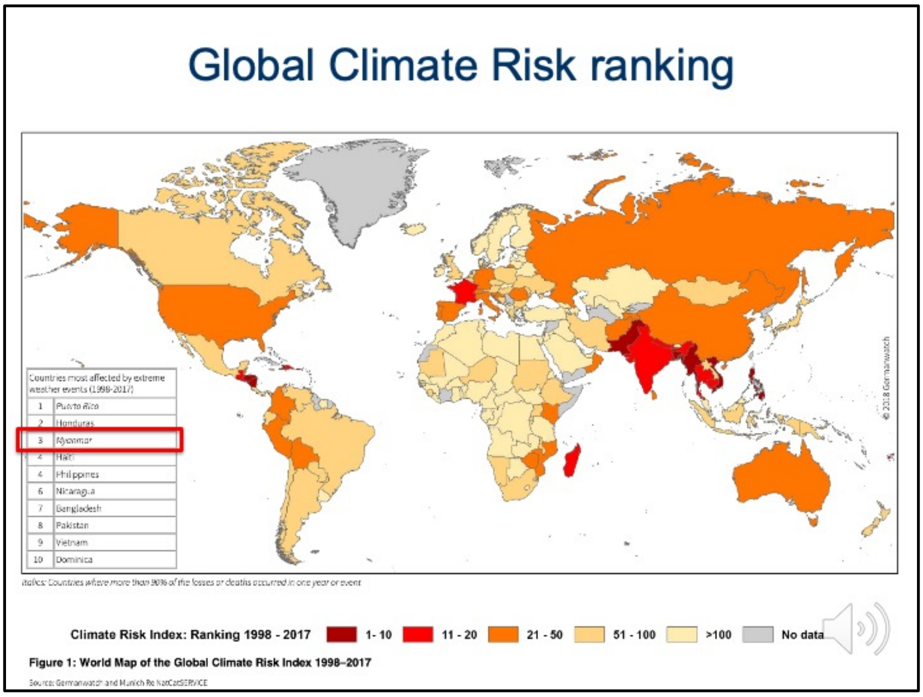


Framework of interactions between climate change, climate processes, impacts, and socio-economic development, with feedbacks between systems can occur along any arrows.

Pachauri and Reisinger (2007)

Take a look over the connections that exist between the earth system and the human system. We see that everything is linked.

For example, if we start at the Climate Processes drivers, or the increase in concentration of different of GHG and aerosols, we will see an impact on the environment and climate change. So there will be more temperature extremes, changes in precipitation, sea-level rise etc. These changes will then lead to climate impact and vulnerability. Water resources and food security can be affected by draughts, or extreme events, shifts in monsoon patterns etc. Ecosystems and human health can be affected, as society is put under different levels of stress, that will affect the social-economic development of the society. Also, if we consider the mitigation or adaptation capabilities of different societies, they depend a lot of the available technology, the governance, the economic power of that society, the consumption and production etc. For example a rich country will also consume more resources and maybe produce more emissions than poorer countries, but they also have strong economies to work on adaptation or mitigation plans, and to implement cleaner technologies. So it is not fair to request the same involvement from all countries, and richer countries should take more responsibility and allow poorer countries to develop.



This is the global map of climate risk for the period 1998-2017. We can see that Myanmar is in top 3 most vulnerable and affected countries to climate change. And this is not only due to the geographical position of the country, but also to it's economic power to mitigate and adapt to a changing climate, with extreme temperatures, extreme rain events and sea level rise.

These are just a few headlines related to the devastating impact that climate change already has in Myanmar.

How much climate change?

That will be determined by how our emissions continue and also exactly how our climate system responds to those emissions. Despite increasing awareness of climate change, our emissions of greenhouse gases continue on a relentless rise.

Responding to climate change involves a two-pronged approach:

1. **Mitigation – reducing climate change – involves reducing the flow of heat-trapping greenhouse gases into the atmosphere**, either by reducing sources of these gases (for example, the burning of fossil fuels for electricity, heat or transport) or enhancing the "sinks" that accumulate and store these gases (such as the oceans, forests and soil).

2. **Adaptation – adapting to life in a changing climate – involves adjusting to actual or expected future climate.** The goal is to reduce our vulnerability to the harmful effects of climate change (like sea-level encroachment, more intense extreme weather events or food insecurity). It also encompasses making the most of any potential beneficial opportunities associated with climate change (for example, longer growing seasons or increased yields in some regions).

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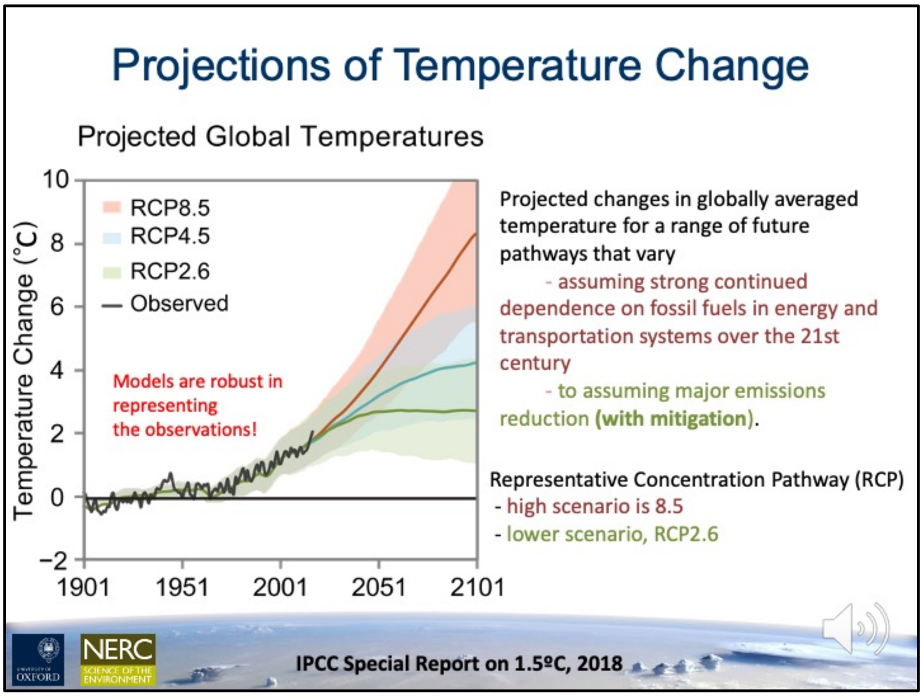
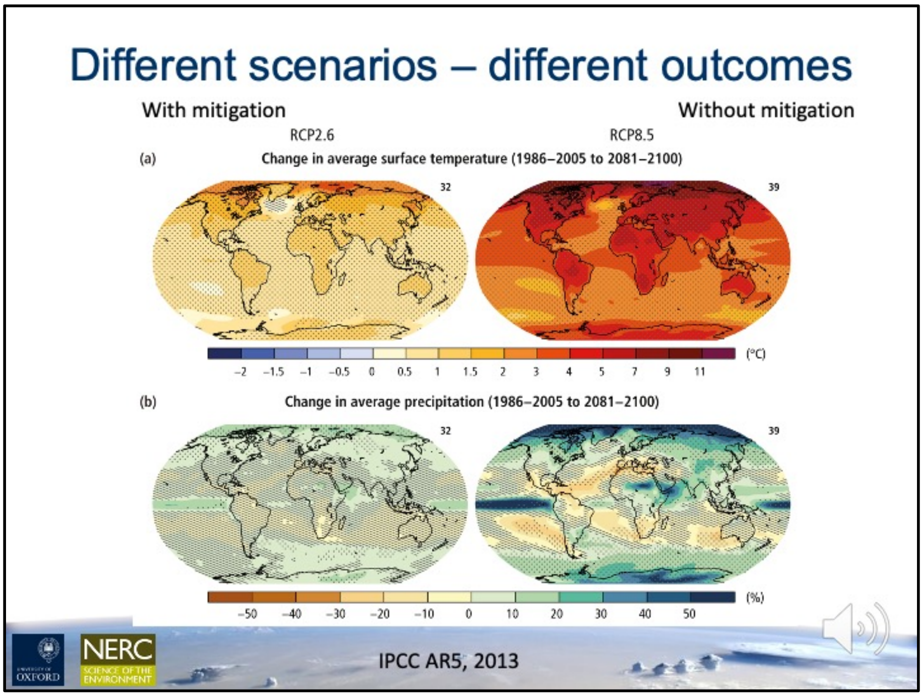
https://climate.nasa.gov/solutions/adaptation-mitigation/



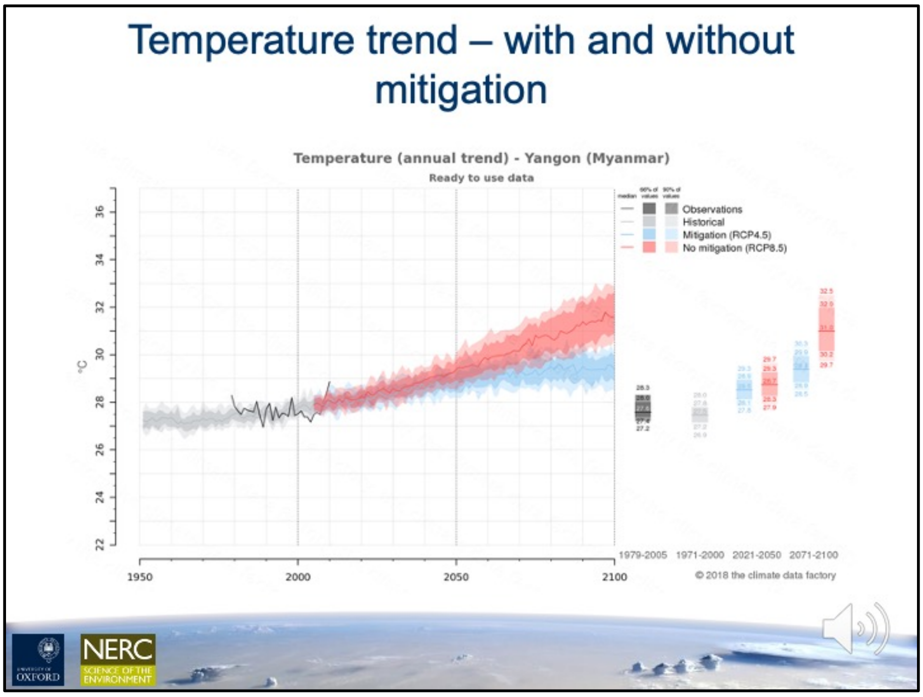
This figure shows the observed temperature change since 1900 in black line, and several projected pathways that the temperature could take, depending on our choices for the future.

The RCP2.6 pathway is the most optimistic, and it assumes major emissions reduction and behavioral changes. This is the lower emission scenario, and leads to a stabilization of the increase in temperature by 2100 at about 2 deg Celsius (with the associated uncertainties).

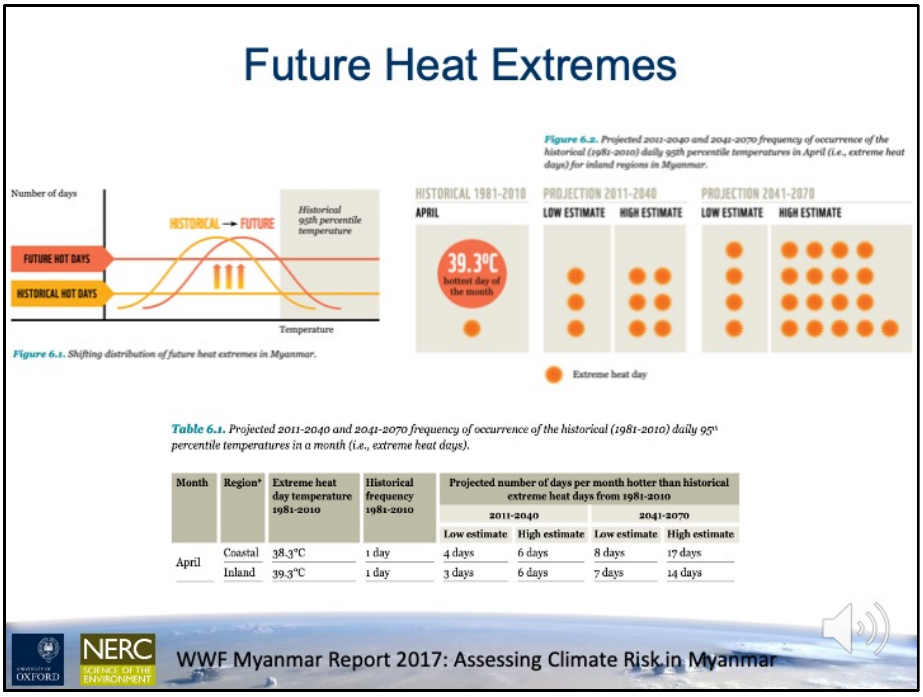
The RCP8.5 assumes we continue to depend strongly on fossil fuels in energy and transportation over the 21st century. This shows a rapid increase in temperature, with values that are larger than 8 deg Celsius. This is the worst case scenario!



This is how the average temperature and precipitation would be distributed for the two scenarios. I would like to focus only on the RCP8.5, which shows massive increases in temperature, amplified in the polar regions. These will lead to melting of the ice caps and increase in sea-level. Many coastal settlements could be under water in less than 50 years. Moreover, the precipitation pattern is changing towards extreme values. So for example, in some places we have an increase in precipitation with more than 50%, while others will see less that 30-40 percent rain. It is said that wet regions will become wetter, and dry region will be drier. All these changes will impact human society at unprecedented levels, as many people will look to relocate to escape either the boiling temperatures and the constant droughts, or the never-ending rain.

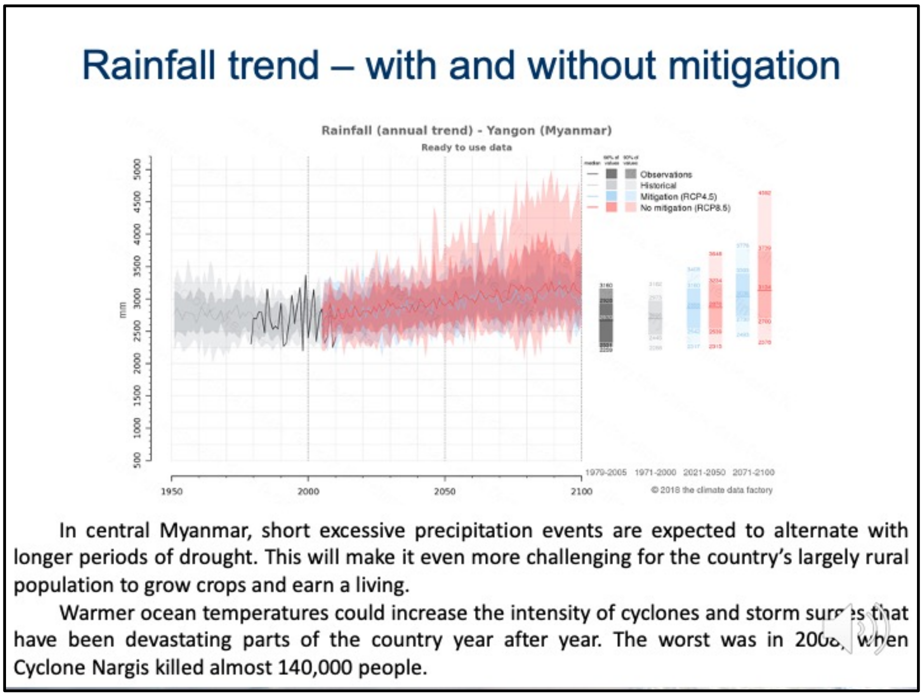


We have the same figure I shown before, but adapted for Myanmar. We see that the average temperature in the 1950 was around 28 deg Celsius. With climate change this temperature will increase, but it depends if we allow it to reach 30 degrees or 32 degrees Celsius. It doesn't look like much, but I remind you this is an average temperature that has increased by either 2 degrees or 4 degrees. That means there are more extreme events with high temperature driving the increase in temperature.



Month	Region*	Extreme heat day temperature 1981-2010	Historical frequency 1981-2010	Projected number of days per month hotter than historical extreme heat days from 1981-2010			
				2011-2040		2041-2070	
				Low estimate	High estimate	Low estimate	High estimate
April	Coastal	38.3°C	1 day	4 days	6 days	8 days	17 days
	Inland	39.3°C	1 day	3 days	6 days	7 days	14 days

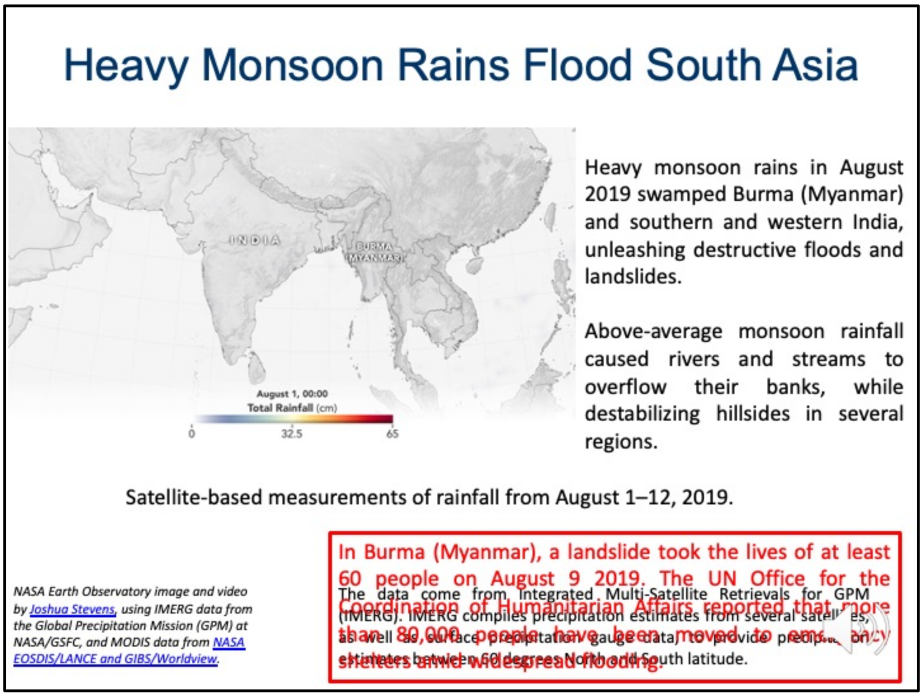
And this is how.
If we take the hottest historical day in in the hottest month of the year – April - between 1981 and 2010, the temperature value was 39.3 deg. In the optimistic scenario, we will have maximum of 4 days with a temperature of 39 degrees in April by the end of the century. However, if we look at the worse case scenario, out of 30 days, 17 days will have temperatures higher than 39 degrees in April. And that is how the mean is shifted. This will be felt by population, animals, ecosystems. The risk of heat stroke and other related diseases will increase.



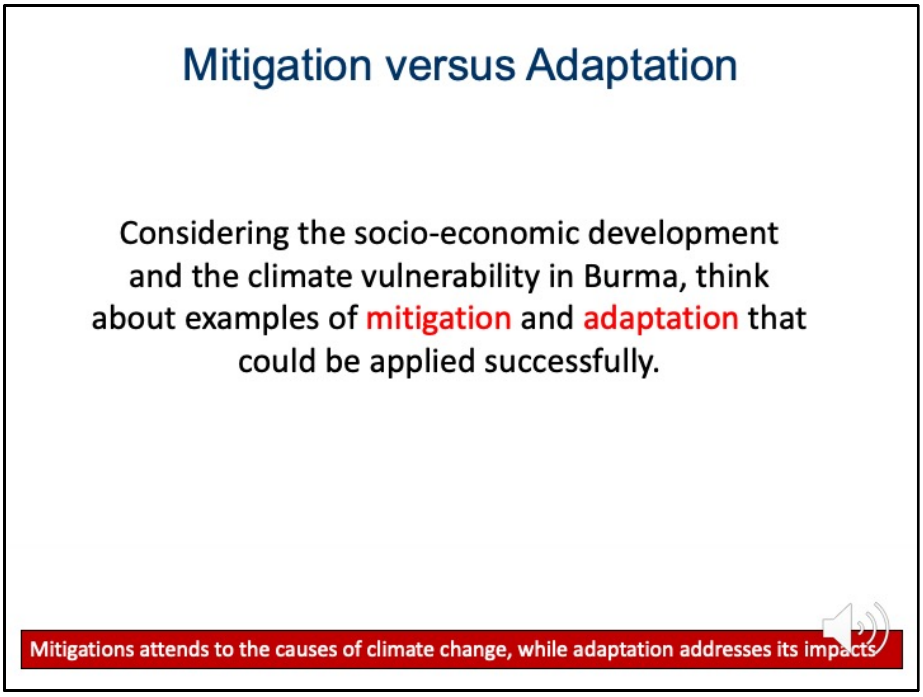
The rainfall trend is a bit more noisy and it is not as clear as the temperature trend, but we can see that the spread in rainfall is larger, meaning there can be more extreme events, such as the one I will show next.

In central Myanmar, short excessive precipitation events are expected to alternate with longer periods of drought. This will make it even more challenging for the country's largely rural population to grow crops and earn a living.

Warmer ocean temperatures could increase the intensity of cyclones and storm surges that have been devastating parts of the country year after year. The worst was in 2008, when Cyclone Nargis killed almost 140,000 people.

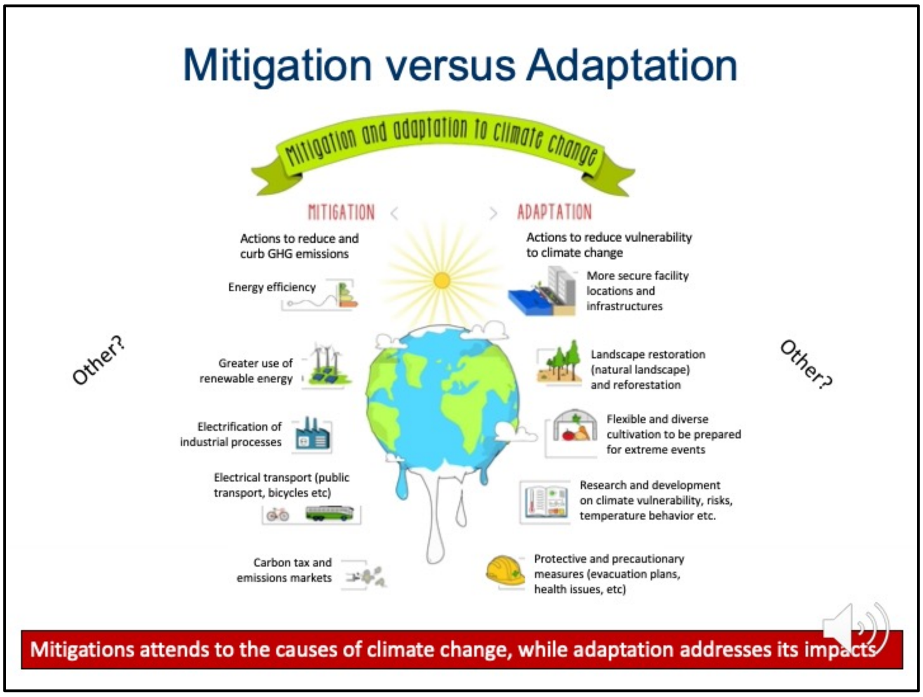


I am showing precipitation estimates from several satellite instruments between august 1-12 2019. Heavy monsoon rains in August swamped Myanmar and southern and western India, unleashing destructive floods and landslides. In Burma, a landslide took the lives of at least 60 people on august 9 and 80000 people have been moved to emergency shelters because of the flooding.



The goal of mitigation is to avoid significant human interference with the climate system, and "*stabilize greenhouse gas levels in a timeframe sufficient to allow ecosystems to adapt naturally to climate change, ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner*" (from the IPCC 2014 report on Mitigation of Climate Change).

Considering the socio-economic development and the climate vulnerability in Burma, think examples of Mitigation and adaptation that could be applied successfully.



Here are some examples of mitigation and adaptation.

Individual carbon footprint

Calculate your carbon footprint

What is the carbon footprint?

A **carbon footprint** is historically defined as the total emissions caused by an individual, event, organization, or product. Greenhouse gases can be emitted through land clearance and the production and consumption of food, fuels, manufactured goods, materials, wood, roads, buildings, transportation and other services.

https://www.carbonfootprint.com/measure.html

How does your everyday lives impact on climate change

Food – agriculture is a major source of carbon emissions

Transportation – uses fossil fuels

Waste - all products and services have environmental impacts, from the extraction of raw materials for production to manufacture, distribution, use and disposal

What kind of actions would you take to reduce the carbon footprint?

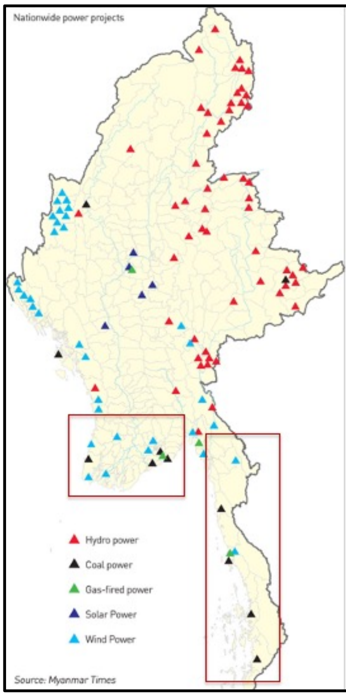
Waste less food

Insolate houses

Drive less, biking, use public transport

Reduce, Reuse, Recycle, Refuse

Change diet to more plant based

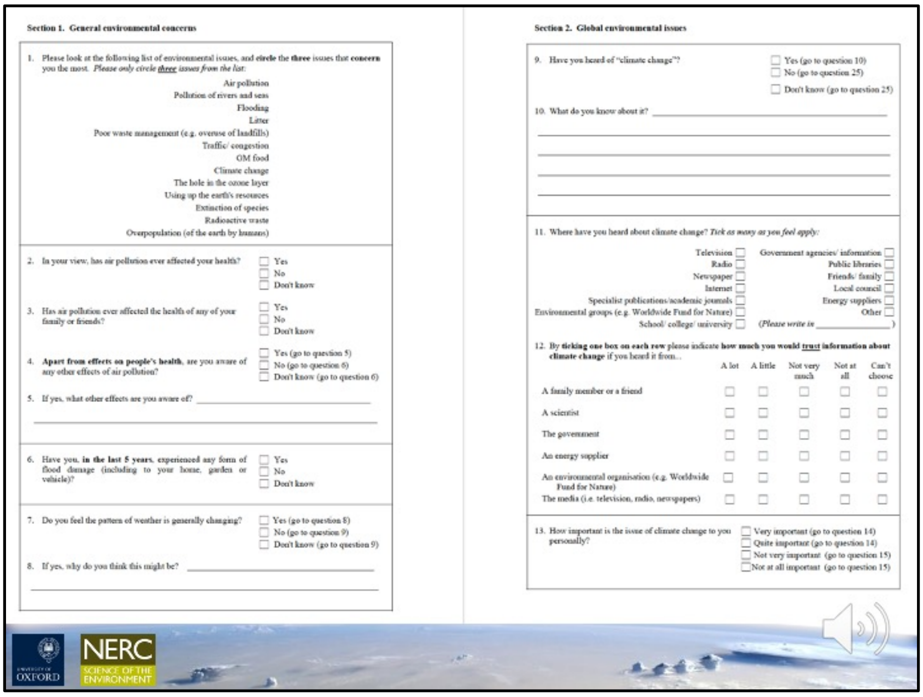


Power sector in Myanmar

- Myanmar needs more electricity. But there is a risk to take the wrong path – coal.
- Building coal power might satisfy short-term energy needs but will cause irreparable damage in the long run.
- The effect would be an increase in particulate matter and ozone pollution levels in Myanmar and neighbouring countries, elevating the risk of diseases such as stroke and lung cancer.
- The coal power plant emissions could be responsible for a total of 7,100 premature deaths each year.
- While around **75% of Myanmar's electricity is already supplied by hydro-energy**, especially its southern part also has a **strong potential for solar energy**.
- Myanmar's first solar power plant opened in October 2018 in Magwe Region. If run successfully, others are planned to follow in Sagaing, Mandalay and Naypyitaw.

Questionnaire

Climate change awareness survey is a questionnaire to understand public perception about climate change and to identify key factors, challenges and barriers to environmental and climate conscious behaviour.



Section 1. General environmental concerns

1. Please look at the following list of environmental issues, and **circle** the **three** issues that **concern** you the most. *Please only circle __three__ issues from the list:*

   Air pollution
   Pollution of rivers and seas
   Flooding
   Litter
   Poor waste management (e.g. overuse of landfills)
   Traffic/ congestion
   GM food
   Climate change
   The hole in the ozone layer
   Using up the earth's resources
   Extinction of species
   Radioactive waste
   Overpopulation (of the earth by humans)

2. In your view, has air pollution ever affected your health? ☐ Yes ☐ No ☐ Don't know

3. Has air pollution ever affected the health of any of your family or friends? ☐ Yes ☐ No ☐ Don't know

4. **Apart from effects on people's health**, are you aware of any other effects of air pollution? ☐ Yes (go to question 5) ☐ No (go to question 6) ☐ Don't know (go to question 6)

5. If yes, what other effects are you aware of? ______________________

6. Have you, **in the last 5 years**, experienced any form of flood damage (including to your home, garden or vehicle)? ☐ Yes ☐ No ☐ Don't know

7. Do you feel the pattern of weather is generally changing? ☐ Yes (go to question 8) ☐ No (go to question 9) ☐ Don't know (go to question 9)

8. If yes, why do you think this might be? ______________________

Section 2. Global environmental issues

9. Have you heard of "climate change"? ☐ Yes (go to question 10) ☐ No (go to question 25) ☐ Don't know (go to question 25)

10. What do you know about it? ______________________

11. Where have you heard about climate change? *Tick as many as you feel apply:*

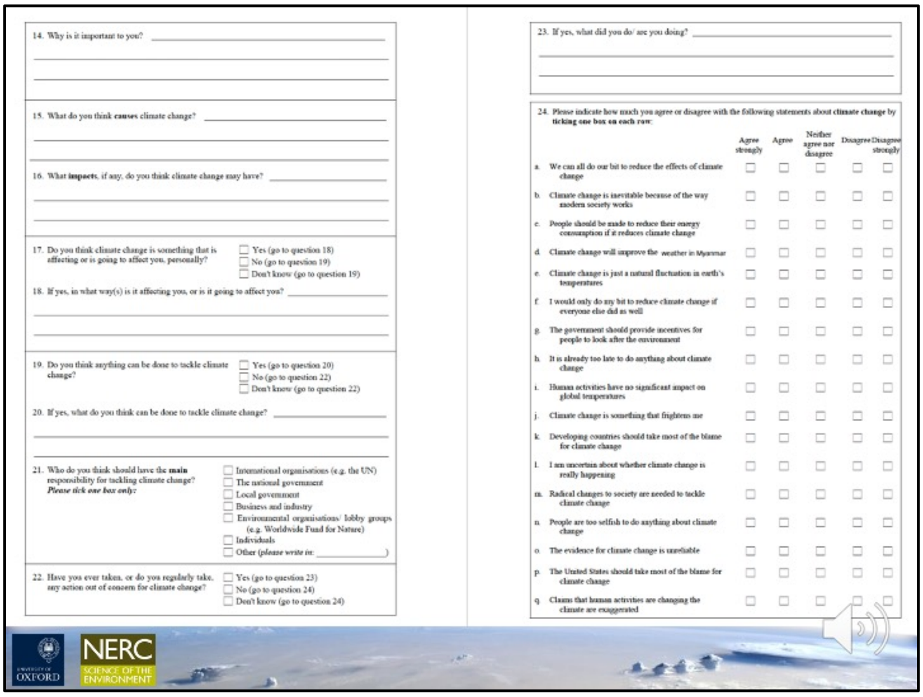
    Television ☐ Radio ☐ Newspaper ☐ Internet ☐ Specialist publications/academic journals ☐ Environmental groups (e.g. Worldwide Fund for Nature) ☐ School/ college/ university ☐
    Government agencies/ information ☐ Public libraries ☐ Friends/ family ☐ Local council ☐ Energy suppliers ☐ Other ☐ (*Please write in* ____________)

12. By **ticking one box on each row** please indicate **how much you would __trust__ information about climate change** if you heard it from...

	A lot	A little	Not very much	Not at all	Can't choose
A family member or a friend	☐	☐	☐	☐	☐
A scientist	☐	☐	☐	☐	☐
The government	☐	☐	☐	☐	☐
An energy supplier	☐	☐	☐	☐	☐
An environmental organisation (e.g. Worldwide Fund for Nature)	☐	☐	☐	☐	☐
The media (i.e. television, radio, newspapers)	☐	☐	☐	☐	☐

13. How important is the issue of climate change to you personally? ☐ Very important (go to question 14) ☐ Quite important (go to question 14) ☐ Not very important (go to question 15) ☐ Not at all important (go to question 15)

I have put here some examples of questions that can be used in a questionnaire.
Feel free to answer them individually



14. Why is it important to you? ____________________

15. What do you think **causes** climate change? ____________________

16. What **impacts**, if any, do you think climate change may have? ____________________

17. Do you think climate change is something that is affecting or is going to affect you, personally?
- ☐ Yes (go to question 18)
- ☐ No (go to question 19)
- ☐ Don't know (go to question 19)

18. If yes, in what way(s) is it affecting you, or is it going to affect you? ____________________

19. Do you think anything can be done to tackle climate change?
- ☐ Yes (go to question 20)
- ☐ No (go to question 22)
- ☐ Don't know (go to question 22)

20. If yes, what do you think can be done to tackle climate change? ____________________

21. Who do you think should have the **main** responsibility for tackling climate change? ***Please tick one box only:***
- ☐ International organisations (e.g. the UN)
- ☐ The national government
- ☐ Local government
- ☐ Business and industry
- ☐ Environmental organisations/ lobby groups (e.g. Worldwide Fund for Nature)
- ☐ Individuals
- ☐ Other (*please write in:* ____________)

22. Have you ever taken, or do you regularly take, any action out of concern for climate change?
- ☐ Yes (go to question 23)
- ☐ No (go to question 24)
- ☐ Don't know (go to question 24)

23. If yes, what did you do/ are you doing? ____________________

24. Please indicate how much you agree or disagree with the following statements about **climate change** by **ticking one box on each row**:

	Agree strongly	Agree	Neither agree nor disagree	Disagree	Disagree strongly
a. We can all do our bit to reduce the effects of climate change	☐	☐	☐	☐	☐
b. Climate change is inevitable because of the way modern society works	☐	☐	☐	☐	☐
c. People should be made to reduce their energy consumption if it reduces climate change	☐	☐	☐	☐	☐
d. Climate change will improve the weather in Myanmar	☐	☐	☐	☐	☐
e. Climate change is just a natural fluctuation in earth's temperatures	☐	☐	☐	☐	☐
f. I would only do my bit to reduce climate change if everyone else did as well	☐	☐	☐	☐	☐
g. The government should provide incentives for people to look after the environment	☐	☐	☐	☐	☐
h. It is already too late to do anything about climate change	☐	☐	☐	☐	☐
i. Human activities have no significant impact on global temperatures	☐	☐	☐	☐	☐
j. Climate change is something that frightens me	☐	☐	☐	☐	☐
k. Developing countries should take most of the blame for climate change	☐	☐	☐	☐	☐
l. I am uncertain about whether climate change is really happening	☐	☐	☐	☐	☐
m. Radical changes to society are needed to tackle climate change	☐	☐	☐	☐	☐
n. People are too selfish to do anything about climate change	☐	☐	☐	☐	☐
o. The evidence for climate change is unreliable	☐	☐	☐	☐	☐
p. The United States should take most of the blame for climate change	☐	☐	☐	☐	☐
q. Claims that human activities are changing the climate are exaggerated	☐	☐	☐	☐	☐

	Agree strongly	Agree	Neither agree nor disagree	Disagree	Disagree strongly
r. If I come across information about climate change I will tend to look at it	☐	☐	☐	☐	☐
s. There is too much conflicting evidence about climate change to know whether it is actually happening	☐	☐	☐	☐	☐
t. Leaving the lights on in my home adds to climate change	☐	☐	☐	☐	☐
u. Climate change is a consequence of modern life	☐	☐	☐	☐	☐
v. The effects of climate change are likely to be catastrophic	☐	☐	☐	☐	☐
w. Nothing I do makes any difference to climate change one way or another	☐	☐	☐	☐	☐
x. Pollution from industry is the main cause of climate change	☐	☐	☐	☐	☐
y. I tend to consider information about climate change to be irrelevant to me	☐	☐	☐	☐	☐
z. Recent floods in this country are due to climate change	☐	☐	☐	☐	☐
aa. It is too early to say whether climate change is really a problem	☐	☐	☐	☐	☐
bb. The media is often too alarmist about issues like climate change	☐	☐	☐	☐	☐
cc. Flooding is not increasing, there is just more reporting of it in the media these days	☐	☐	☐	☐	☐
dd. There is no point in me doing anything about climate change because no-one else is	☐	☐	☐	☐	☐
ee. Experts are agreed that climate change is a real problem	☐	☐	☐	☐	☐
ff. Nothing I do on a daily basis contributes to the problem of climate change	☐	☐	☐	☐	☐
gg. Industry and business should be doing more to tackle climate change	☐	☐	☐	☐	☐
hh. For the most part, the government honestly wants to reduce climate change	☐	☐	☐	☐	☐
ii. I do not believe climate change is a real problem	☐	☐	☐	☐	☐
jj. The government is not doing enough to tackle climate change	☐	☐	☐	☐	☐
kk. I feel a moral duty to do something about climate change	☐	☐	☐	☐	☐

Section 3. General views about the environment

25. Now please indicate how much you agree or disagree with the following **general statements** by **ticking one box on each row:**

	Agree strongly	Agree	Neither agree nor disagree	Disagree	Disagree strongly
a. Jobs today are more important than protecting the environment for the future	☐	☐	☐	☐	☐
b. I am unwilling to make personal sacrifices for the sake of the environment	☐	☐	☐	☐	☐
c. If my job caused environmental problems, I'd rather be unemployed than carry on causing them	☐	☐	☐	☐	☐
d. Having a car is part of having a good lifestyle	☐	☐	☐	☐	☐
e. Humans have the right to modify the natural environment to suit their needs	☐	☐	☐	☐	☐
f. Humans are severely abusing the planet	☐	☐	☐	☐	☐
g. Plants and animals have the same rights as humans to exist	☐	☐	☐	☐	☐
h. Nature is strong enough to cope with the impact of modern industrial nations	☐	☐	☐	☐	☐
i. Humans were meant to rule over the rest of nature	☐	☐	☐	☐	☐
j. The balance of nature is very delicate and easily upset	☐	☐	☐	☐	☐

26. The following is a list of activities that you may do. For each one **that you do regularly**, please indicate **your reason or reasons** for doing so. *Tick as many as you feel apply:*

	Convenience	To save money	To protect the environment	For my health	Habit	Moral obligation	Another reason (please write in)
Walk or cycle to work	☐	☐	☐	☐	☐	☐	______
Use public transport	☐	☐	☐	☐	☐	☐	______
Turn off lights I'm not using	☐	☐	☐	☐	☐	☐	______
Buy energy efficient light bulbs	☐	☐	☐	☐	☐	☐	______
Buy organic food	☐	☐	☐	☐	☐	☐	______
Recycle glass	☐	☐	☐	☐	☐	☐	______
Recycle other items	☐	☐	☐	☐	☐	☐	______
Take part in a campaign about an environmental issue	☐	☐	☐	☐	☐	☐	______

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https://climate.nasa.gov/earth-apps/
https://climate.nasa.gov/climate_resource_center/interactives/quizzes
https://climate.nasa.gov/interactives/climate-time-machine
https://climate.nasa.gov/earth-now/

END

Thank you for your attention!

Useful links

https://myanmarccalliance.org/en/climate-change-basics/impact-of-climate-change-and-the-case-of-myanmar/

http://aqicn.org/city/maynmar/rangoon/us-embassy/

https://www.hbs.edu/environment/climate-change/Pages/effects-of-climate-change.aspx

https://climate.nasa.gov/climate_resource_center/interactives/quizzes

https://climate.nasa.gov/interactives/climate-time-machine

https://climate.nasa.gov/earth-now/?vs_name=air_temperature&dataset_id=820&group_id=46&animating=f&start=&end=

https://climate.nasa.gov/earth-apps/