Royal College of Anaesthetists

e-LA
e-Learning Anaesthesia

Sustainability: **Background science**

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Atmosphere structure and science

Structure

The Earth's atmosphere is divided into the troposphere (up to 10,000m), the stratosphere (10,000-50,000m) and the mesosphere (50,000m +). The so-called 'ozone layer' is within the stratosphere between 20,000 – 30,000m. The purpose of the ozone layer is to protect us from harmful amounts of ultraviolet (UV) light.

If you were to ascend through the troposphere, the temperature decreases to -50°C (as you experience on an aeroplane), however, it then stabilises and increases through the stratosphere.

There is a boundary between the tropopause and the stratosphere, which is called the tropopause. The tropopause is at an altitude of 8000m at the North and South Pole and approx. 18,000m at the equator. The variation in height is due to the change in temperature with latitude.[1] See figure 1.

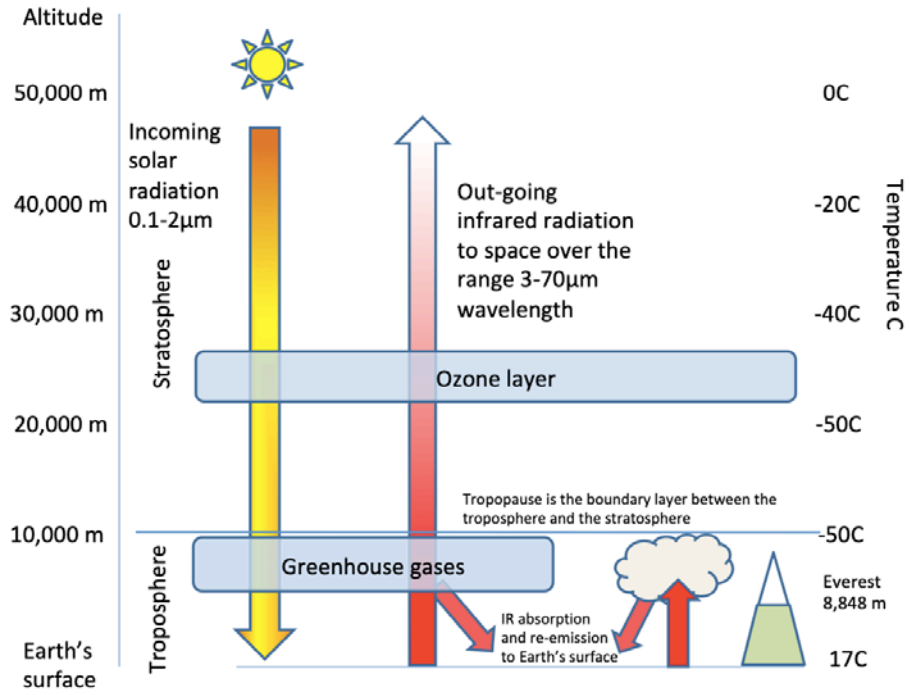

Figure 1: *A simplified diagram of the atmosphere. The first 10,000m or so is the troposphere containing most of the mass of the atmosphere and almost all of the water. This is where greenhouse gases have their effect. The next 40,000 m is the stratosphere and is where ozone exerts its UV protective effect.*
The degree of radiative forcing is calculated at the boundary layer between the troposphere and the stratosphere, the tropopause. In 2018 this was +3.101 Wm^{-2}.
Image from Tom Pierce with permission

Science

The sun's surface emits radiation mainly in the visible spectrum, this is transmitted to Earth and warms the atmosphere. The Earth emits mainly thermal infrared radiation (IR), the peak wavelength of which is around 10 µm. Diatomic molecules such as oxygen and nitrogen absorb very little outgoing infrared radiation.

A relatively transparent 'atmospheric window' exists between the wavelengths of 8 and 14 µm where little IR absorption by greenhouse gases (GHG) occurs. Outside these wavelengths, the presence of GHG absorb outgoing IR and re-emit it, some of which will return to Earth and swing the energy balance to net energy gain[1] (see figure 2 below).

Greenhouse gases can be natural or anthropogenic i.e. gases that result from or are produced by humans and their activities. Water vapour, carbon dioxide, nitrous oxide, methane and ozone are the primary (natural) GHG in the Earth's atmosphere. There are a number of entirely human-made GHG in the atmosphere, such as chlorofluorocarbons (CFCs), hydrochlorofluorocarbons (HCFCs) and perfluorinatedcarbons (PFCs).[2] All of these molecules have a loosely bound structure (containing 3 or more atoms) which makes them efficient absorbers of the long wave radiation bouncing back from the planet's surface. When they re-emit this long-wave radiation back towards Earth, this results in warming.[3]

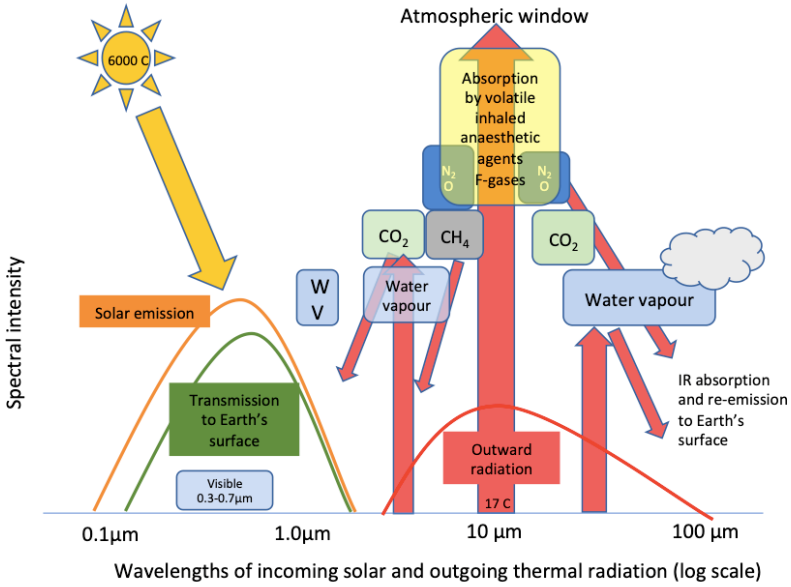

Figure 2: Simplified diagram to illustrate the incoming solar radiation and the out-going infrared radiation. The peak solar radiation to reach Earth's surface occurs at 480nm wavelength and the peak out-going is at 10µm wavelength at which little natural atmospheric IR absorption occurs (the atmospheric window). Volatile anaesthetic agent and F-gasses have their peak absorption at this wavelength and so despite their very low concentration they comprise about 10% of the total warming. The F gases include: HFC, Hydroflourocarbons; HCFC Hydrochloroflourocarbons; PFC Perflurocarbons. Image from Tom Pierce with permission

The so-called 'Greenhouse effect' is defined as the infrared radiative effect of all infrared-absorbing constituents in the atmosphere. GHG, clouds, and (to a small extent) aerosols absorb terrestrial radiation emitted by the Earth's surface and elsewhere in the atmosphere. These substances emit IR in all directions, but, as everything else is equal, the net amount emitted to space is normally less than would have been emitted in the absence of these absorbers. This is because of the decline of temperature with altitude in the troposphere and the consequent weakening of emission. An increase in the concentration of GHG increases the magnitude of this effect; the difference is sometimes called the "enhanced greenhouse effect". The change in a GHG concentration because of anthropogenic emissions contributes to an instantaneous radiative forcing. Surface and troposphere temperature increase in response to this forcing, gradually restoring the radiative balance at the top of the atmosphere.[2]

International committees, organisations and conferences

Intergovernmental Panel on Climate Change (IPCC)

The IPCC is the United Nations body for assessing science related to climate change, which it then communicates to policymakers. They present information on the potential implications and future risks of climate change, as well as possible adaptations to mitigate them in order to assist the development of climate change policies. Created by the United Nations Environment Programme (UN Environment) and the World Meteorological Organization (WMO) in 1988, the IPCC has 195 Member countries.

The IPCC does not perform its own research, but many thousands of scientists volunteer their time to review up to date papers and studies to provide thorough summaries of the current state of affairs. Areas that require further research are identified, as well as those that have strong scientific backing. The processes are designed to be transparent, involving experts and governments worldwide, in order to gain accurate and comprehensive data.

The IPCC is divided into three Working Groups and a Task Force:

- Working Group I - "The Physical Science Basis of Climate Change"
- Working Group II – "Climate Change Impacts, Adaptation and Vulnerability"
- Working Group III – "Mitigation of Climate Change"
- Task Force on National Greenhouse Gas Inventories - aims to develop and refine a methodology for the calculation and reporting of national greenhouse gas emissions and removals.[4]

More information can be found on the website: ipcc.ch/about/

World Meteorological Organisation (WMO)

Mandate: "As weather, climate and the water cycle know no national boundaries, international cooperation at a global scale is essential for the development of meteorology, climatology and operational hydrology as well as to reap the benefits

from their application. WMO provides the framework for such international cooperation."

The WMO is an agency of the United Nations that is focussed on coordinating global cooperation in all aspects of the environment, climate and weather, and the resulting water resources. They have a variety of programmes that are involved in data collection and communication, as well as maintaining the necessary worldwide standards in these areas. They also facilitate research in meteorology and activities in operational hydrology, particularly in relation to areas such as aviation, agriculture, transport and water resource management.

Service areas include:

- National Meteorological and Hydrological Services
- Technical Commissions and Research Board
- Regional Offices [5]

Further details of their programmes, projects and focus areas can be found on their website public.wmo.int/en

Climate Change Summits (COP)

The United Nations (UN) host annual climate change conferences. They are the formal meetings of the UNFCCC (United Nations Framework Convention on Climate Change). They started in 1995 and it is here where the Kyoto Protocol, amongst others, was established. The Conference of the Parties (COP) is the supreme decision-making body of the convention. They review the national communications and emission inventories submitted by Parties. Based on this information, the COP assesses the effects of the measures taken by Parties and the progress made in achieving the ultimate objective of the Convention.[6]

Some of the key protocols include:
The Montreal Protocol, which universally banned the use of chloroflurocarbons (CFCs).
The Kyoto Protocol, which aims to limit CO_2, N_2O and CH_4, as well as the greenhouse gases sulphur hexafluoride (SF_6), hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs).[2] See "*International Agreements*" e-module for more information.

Climate Change and Global Warming

The following section will cover some of the terms and concepts commonly used when discussing climate change and global warming.

Definitions

- **Radiative forcing**
  - A measure of the influence a given climatic factor has on the amount of downward-directed radiant energy imposing upon the Earth's surface.
  - Climatic factors may either be caused by:
    - Human activity e.g. greenhouse gas and aerosol emissions
    - Natural forces e.g. solar irradiance
  - For each factor, so-called forcing values are calculated for the time period between 1750 and the present day.
  - "Positive forcing" is exerted by climatic factors that contribute to the *warming* of Earth's surface, whereas "negative forcing" is exerted by factors that *cool* Earth's surface.[7]
  - Current values for radiative forcing are between +2.3 to 3.3W/m^2 as of 2018.[8]

- **Global Warming Potential (GWP)**
  - "The cumulative radiative forcing, both direct and indirect effects, over a specified time horizon resulting from the emission of a unit of mass of gas related to some reference gas"
  - GWP has been developed as a metric to compare (relative to another gas) the ability of each greenhouse gas to trap heat in the atmosphere, and is generally taken over 100 years (GWP_{100})
  - CO_2 was chosen as the reference gas to be in line with guidelines from the IPCC, which by definition has a GWP of 1.[2]

- **Carbon Dioxide Equivalents (CO_2e)**
  - Carbon dioxide equivalent is a measure used to compare the emissions from various greenhouse gases based upon their global warming potential, and allows them to be described in a common unit, i.e. it puts everything in the same scale.
  - For any quantity and type of greenhouse gas, CO_2e signifies the amount of CO_2 that would have the equivalent global warming impact.[2]
  - For example, the global warming potential for methane over 100 years is 21. This means that an emission of 1 metric ton of methane is equivalent to emissions of 21 metric tons of carbon dioxide.
  - Of note, the CO_2e of the NHS in England is calculated to be around 21MTCO_2e.[9]

- **Ozone Depleting Potential (ODP)**
  - Widely used as a measure of the effectiveness of a given compound in removing ozone, relative to a standard compound, which is taken to be Trichlorofluromethane (CFC-11).
  - By definition, CFC-11 has an ODP of 1.
  - The ODP of a compound is normally defined as the ratio of the global loss of ozone (i.e. integrated over latitude, altitude, and time) from that compound at steady state per unit mass emitted, relative to the loss of ozone due to emission of unit mass of the reference compound.
  - The ODP thus provides a relative measure of the *overall* impact of a compound on ozone destruction over the long term.[10-11]
  - Note: ODP is related to a substance's ability to destroy the stratosphere, vs GWP which is related to its ability to warm the earth. Many (though not all) GHGs will do both, though the extent of this varies between agents.
  - Aside from nitrous oxide, anaesthetic agents have negligible ODP (but high GWP). In contrast many ODP CFCs also have high GWP i.e. do both.

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