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Expert Team Report
2/3/17

Radiative Gases - What are they and what they do?

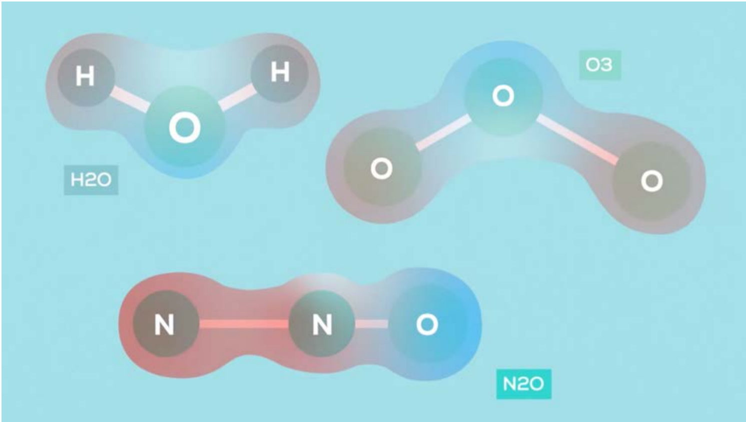
Context for Understanding Radiative Gases(Viraj): Radiative forcing is the process of energy flowing from the sun to the earth and the process of radiating that energy out back into space as invisible infrared light. The light energy that is not reflected back and warms the planet. There are many factors involved in calculating this energy balance because of variables such as albedo (the reflectivity of the planet's surface) or atmospheric makeup that either blocks radiation from the sun or prevents the escape/reflection of energy back into space. Radiative forcing is measured in watts per square meter. "Radiative Gases" are the various gaseous molecules that make up a fraction of the atmosphere and contribute to either blocking or re-radiating light. Radiative gases include Greenhouse Gases(GHGs) and Aerosols.
Source for above material: Chandler, David L. "Explained: Radiative Forcing." *MIT News*. MIT, 10 Mar. 2010. Web. 02 Feb. 2017. <http://news.mit.edu/2010/explained-radforce-0309>.

How Greenhouse gases work(Kelli): Light from the sun enters the atmosphere as UV (shorter wavelength than visible light) and hits the Earth's surface and is reflected back by the surface of the Earth as heat energy in the form of Infrared Light (IR, longer wavelength than visible light). Greenhouse Gases then absorb Infrared Light and prevent it from radiating it out into space, therefore heating the Earth.

Many greenhouse gases occur naturally in the atmosphere, such as carbon dioxide, methane, water vapor, and nitrous oxide, while others are synthetic. Those that are man-made include the chlorofluorocarbons (CFCs), hydrofluorocarbons (HFCs) and Perfluorocarbons (PFCs), as well as sulfur hexafluoride (SF6).
Source for above material: "Greenhouse Gases." *Greenhouse Gases | Monitoring References | National Centers for Environmental Information (NCEI)*. N.p., n.d. Web. 02 Feb. 2017. <https://www.ncdc.noaa.gov/monitoring-references/faq/greenhouse-gases.php>.

Understanding the physics of how Greenhouse Gases absorb Infrared Light(Viraj):
All molecules have positive (nuclei) and negative (electron clouds) regions, a molecule is dipolar and has a permanent dipole moment, if the averaged centers of its positively and negatively charged regions do not coincide. If a vibrational motion of the molecule disturbs these averages, its dipole moment can change and an appropriate energy of IR radiation can be absorbed to cause this molecular vibration.

Most components of our atmosphere do not have a charge and have a balanced number of protons and electrons. Regardless of charge, some molecules hold most of their negatively charged electrons closer to one side and positive protons to another lending them an unbalanced state allows them to absorb (IR), water vapor, carbon dioxide, methane, nitrous oxide and ozone are all lopsided so they absorb infrared radiation. While the Earth's (dry) atmosphere is predominantly composed of non-IR absorbers because they are too balanced, N_2 (78%), O_2 (21%), and Ar (~0.9%), the 0.1% of remaining trace gases contains molecules that absorb IR. Carbon dioxide and methane seem balanced as well, but when molecules hit each other and move, they become off balanced and hold their protons and electrons in different areas allowing them to absorb IR.



(Aid to visualize GHGs holding electrons and protons in different locations within the molecule and are therefore “unbalanced” and able to absorb IR light.)

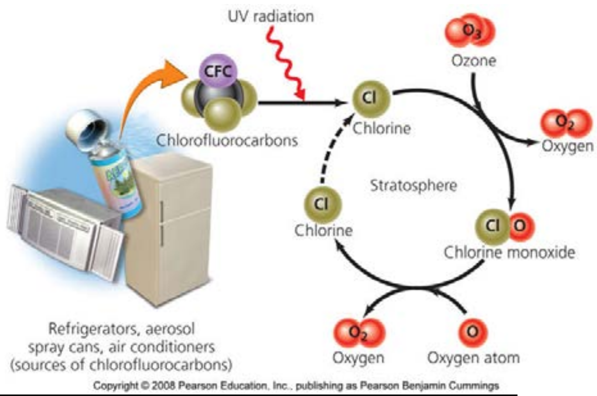
Source for above material: "What Are the Properties of a Greenhouse Gas?" *American Chemical Society*. N.p., n.d. Web. 02 Feb. 2017. <https://www.acs.org/content/acs/en/climatescience/greenhousegases/properties.html>.

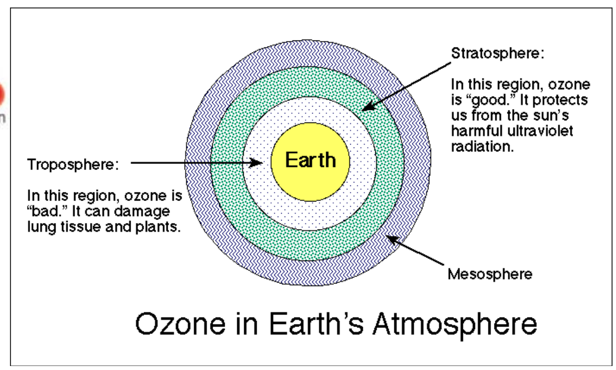
Understanding how Different GHGs compare(Viraj): Gases are measured using a helpful metric, GWP (global warming potential, which is a measure of how much energy a greenhouse gas would add to the atmospheric warming in a given time compared to CO_2). The atmospheric lifetime of the molecule, the strength of the relevant absorptions and the wavelengths where the molecule absorbs inform the GWP. (See chart) Methan has a 20 year GWP of 72, so injecting 1 kg of methane in the atmosphere would have 72 times more warming than a kg of CO_2 in the atmosphere. CO_2s lifetime is very dependent on environmental conditions. A list of the major GHGs can be found below (see chart).

		GWP time horizon		
Gas	Lifetime, yr	20 yr	100 yr	500 yr
Carbon Dioxide, CO_2	see text	1	1	1
Methane, CH_4	12	72	25	7.6
Nitrous Oxide, N_2O	114	289	298	153
CFC-12, CCl_2F_2	100	11,000	10,900	5,200
HFC-23, CHF_3	270	12,000	14,800	12,200
HFC-134a, CH_2FCF_3	14	3,830	1,430	435
Sulfur Hexafluoride, SF_6	3,200	16,300	22,800	32,600

Source for above material: "What Are the Properties of a Greenhouse Gas?" *American Chemical Society*. N.p., n.d. Web. 02 Feb. 2017. <https://www.acs.org/content/acs/en/climatescience/greenhousegases/properties.html>.

Ozone vs other Greenhouse Gases(Kelli): Most of the ozone is stratospheric (~90%), so it is found 6-10 miles above earth's surface, in the stratosphere. The width of the stratosphere is ~30 miles long. This ozone forms during a reaction between ultraviolet light and oxygen. This is the part that we usually refer to when we say "the ozone layer" and "ozone depletion" Stratospheric ozone helps to protect us from harmful UV rays. When chlorofluorocarbons (CFCs) are released by human activity, CFCs react with UV light and produce chlorine. Chlorine catalytically destroys ozone (see graphic below). A lesser amount (~10%) (but may be growing) lies in the first ~10 miles above the earth's surface in the troposphere. Tropospheric ozone can have detrimental effects on forest growth, crops, and even human health. This ozone is a big component of smog. This ozone reacts strongly with other molecules and can be toxic. The Montreal Protocol attempts to protect the stratospheric ozone layer.





(Courtesy of http://www.umich.edu/~gs265/Ozone.gif)

Source for above material: Gleason, Karin. "Science - Ozone Basics." *Science - Ozone Basics*. NOAA, 20 Mar. 2008. Web. 02 Feb. 2017. <http://www.ozonelayer.noaa.gov/science/basics.htm>.

The forgotten Radiative Gas- What are aerosols and how do they work? (Kelli):

Aerosols are suspended particles in gas. There are many different varieties of aerosols produced naturally and by human activity. Volcanic aerosols include Sulfur Dioxide(SO2), hydrochloric acid(HCL), and ash. Sulfur Dioxide commonly contributes to acid rain. Aerosols scatter sunlight back into space and (roughly a quarter total), often having a net cooling effect. Pure sulfates and nitrates reflect back all sunlight, while black carbon(soot) absorbs sunlight but simultaneously shades the surface below. Desert dust is another aerosol that has been known to block or scatter sunlight. Large fraction of human made aerosols come in the form of sulfate aerosols created by the burning of coal and oil. These sulfates cause acid rain as well as reflect sunlight. The cooling caused by aerosols tends to be more regionally dependent compared to the warming effect of greenhouse gases. In the arctic, aerosols from wildfires and industrial emissions hasten melting of ice.

Source for above material:"Atmospheric Aerosols: What Are They, and Why Are They So Important?" *NASA*. NASA, 1 Aug. 1996. Web. 02 Feb. 2017. <https://www.nasa.gov/centers/langley/news/factsheets/Aerosols.html>.