

Nitrous Oxide

Nitrous oxide (chemical formula N_2O), is a trace gas in Earth's atmosphere, with a mixing ratio in 2005 of 319 ± 0.12 ppb (parts per billion, by volume). Atmospheric nitrous oxide is steadily increasing due to human activities. Nitrous oxide absorbs terrestrial radiation (i.e. radiation emitted by the Earth), and consequently it is an important anthropogenic greenhouse gas; it is one of the gases targeted for control within the Kyoto Protocol. Nitrous oxide also absorbs solar radiation, which can split the molecule, releasing reactive species that contribute towards stratospheric ozone depletion.

Various natural and anthropogenic sources add nitrous oxide to the atmosphere. The main natural sources are related to biological activity in soils and the upper ocean. The largest anthropogenic source is from the use of nitrogenous fertilizer in the agricultural sector; others include combustion of fossil fuel, biomass and biofuel, and industrial processes. Nitrous oxide emissions related to biofuel production are an example of reducing emissions of one greenhouse gas (CO_2) at the expense of increasing emissions of another.

Nitrous oxide is relatively inert in the troposphere (the atmosphere's lowest 10-15 km). Higher up, in the stratosphere, energetic ultra-violet radiation starts to break the molecule apart. This photochemical destruction in the upper atmosphere removes about 0.9% of all nitrous oxide every year, determining the average atmospheric residence time of an N_2O molecule, which is currently around 114 years. This is long compared to timescales of most atmospheric transport and mixing processes, which typically range from hours to a few years. Nitrous oxide is consequently referred to as a 'well-mixed' and 'long-lived' gas.

Because nitrous oxide is well-mixed, atmospheric measurements at sites sufficiently remote from sources/sinks are representative of the whole atmosphere. For example, data collated by the World Data Centre for Greenhouse Gases shows that N_2O levels at Mace Head (Ireland) rose from c.315 ppb in 2000 to c.323 ppb in 2010. Very similar values were also recorded at Cape Grim (Australia), whereas slightly lower (by c.1 ppb) absolute values, but with the same increase, were measured at the South Pole. This recent growth in atmospheric N_2O of nearly 1 ppb/yr is a result of its sources exceeding its sinks.

For times before the era of direct measurements, atmospheric levels of N_2O can be estimated using ice cores. Air bubbles found within ice cores represent samples of past atmospheric composition, trapped shortly after snowfall. Ice core data indicate that the pre-industrial atmosphere contained 270 ± 7 ppb nitrous oxide. Over the preceding 10,000 yr, N_2O ranged between 250-275 ppb. Ice core data going back 100,000 yr indicate a range of 180-290 ppb.

The Intergovernmental Panel on Climate Change (IPCC) calculate that the increase in N_2O from pre-industrial times up to 2005 (+49 ppb) resulted in a radiative (climate) forcing of $+0.16 \pm 0.02 \text{ W/m}^2$. Radiative forcing is a measure of how much the energy balance of the Earth-atmosphere system is changed, for example by the change in concentration of an atmospheric constituent that interacts with radiation. To put the radiative forcing from N_2O in perspective, corresponding values for carbon dioxide and methane are $+1.66$ and $+0.48 \text{ W/m}^2$, respectively.

Radiative forcing provides a good measure of how changes in individual gases have influenced climate change up to present-day. However, to estimate the contribution of

a particular gas's present-day emissions towards future climate change, the Global Warming Potential (GWP) is a more useful quantity. The GWP of N₂O is the time-integrated radiative forcing following a 1 kg pulse emission of N₂O, relative to the same quantity following a 1 kg pulse emission of CO₂. The GWP time horizon must also be specified – typically it is 100 yr, but IPCC also presents GWPs for 20 and 500 yr time horizons; the choice of time horizon relates to the context in which the GWP is used. The 100 yr GWP of N₂O is 298; this means that the warming influence from emitted N₂O, integrated over the next 100 years, is 298 times larger than that of the same mass of emitted CO₂. The GWP accounts for different gases absorbing radiation with different efficiencies, and having different atmospheric lifetimes. The GWP value is essential for comparing the relative merits of emissions control strategies for different gases, e.g., within emissions trading frameworks.

Akin to the GWP, the importance of a species as a stratospheric ozone-depleting substance (ODS) is expressed by its ozone depletion potential (ODP). An ODP is the ratio of the amount of ozone destroyed by the emission of a unit mass of a substance at the Earth's surface, relative to the amount destroyed by the emission of a unit mass of chlorofluorocarbon-11 (CFC-11, CFC1₃). Ozone changes are for steady-state, over the entire lifetime of the emitted substance. The ODP of nitrous oxide is 0.017, and has only recently been calculated (2009). Successful regulation of CFCs following the Montreal Protocol now means that nitrous oxide is the dominant emitted ODS, and is likely to remain so throughout the 21st century. Despite its importance, N₂O remains unregulated by the Montreal Protocol.

See Also: Atmospheric composition, Climate forcing, Kyoto Protocol, Montreal Protocol.

Further reading:

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