

NITROUS OXIDE

I.L. Karol and A.A. Kiselev

Main Geophysical Observatory, St. Petersburg, Russia

Keywords: Soils, oceans, animal waste, biomass burning, greenhouse effect, concentration, trend

Contents

1. Introduction
2. Nitrous oxide sources
3. Nitrous oxide sinks
4. Distribution of nitrous oxide content in the atmosphere
5. The influence of nitrous oxide on climate
6. Conclusion. How will nitrous oxide change in the future?

Glossary

Bibliography

Biographical Sketches

Summary

The numerous nitrous oxide surface sources, anthropogenic and natural, and their expert evaluations are discussed. Its sinks and stratospheric sources due to photochemical processes are also discussed. The measurements of nitrous oxide content in the Antarctic and Greenland ice cores and its data from recent decades are presented. The annual average changes of nitrous oxide concentration from the early 1970s to the late 1990s are presented too. Nitrous oxide is a strong absorber in the infrared part of the spectrum. The nitrous oxide share in global warming (about 5%) and its indirect participation (through nitric oxide generation) in the catalytic destruction of stratospheric ozone are described. The most probable predictions of nitrous oxide content evolution are briefly discussed.

1. Introduction

Nitrous oxide N_2O is a colorless gas. It has a faint smell and sweet taste. Initially, its inhalation stimulates an excited state accompanying by laughter and irregular movements of the body, but this is followed by loss of consciousness. In earlier times nitrous oxide was used in mixture with oxygen as an inhalation anesthetic in surgical operations.

2. Nitrous oxide sources

The main source of nitrous oxide production is microbiological processes. Many types of soil contain bacteria which are able to produce N_2O from NH_4^+ and NO_3^- under anaerobic conditions. The nitrate and ammonia reach the soil as the result of dry and wet deposition. The other important source of nitrous oxide is the oceans which are a

very large reservoir of N₂O, containing about the same amount of N₂O as the atmosphere. Emissions of nitrous oxide from soils and oceans into the atmosphere are the major natural sources; their contributions to the total natural source are about 70 and 30% respectively, though with a high degree of uncertainty.

For a long time it was suggested that fossil fuel combustion was the major anthropogenic source of N₂O, but relatively recent studies have revealed numerous other anthropogenic sources. An interesting feature of these sources is that they are all small. Table 1 compiles various sources of N₂O and demonstrates that the N₂O emissions from anthropogenic sources are not well defined. Apart from the sources mentioned in Table 1, various other N₂O anthropogenic sources should be considered, such as byproducts from nylon manufacture (about 0.7 Tg yr⁻¹, 1 Tg = 1×10¹² g), from sewage (0.3-3 Tg yr⁻¹), aquifers-irrigation (0.8-2 Tg yr⁻¹), groundwater contamination, etc. Notwithstanding their significant range of variations, it is reasonable to assume that the anthropogenic part of the total N₂O source is about one third.

| Source | | Range | |
|---------------|------------------------|--------------|----------|
| Natural | Oceans | 1.4-5.2 | |
| | Tropical Soils | Wet Forests | 2.2-3.7 |
| | | Dry Savannas | 0.5-2.0 |
| | Temperate Soils | Forests | 0.05-2.0 |
| | | Grasslands | ? |
| Anthropogenic | Cultivated Soils | 1-3 | |
| | Animal Waste | 0.2-0.5 | |
| | Biomass Burning | 0.2-1.0 | |
| | Stationary combustion | 0.1-0.3 | |
| | Mobile Sources | 0.1-0.6 | |
| | Adipic Acid Production | 0.4-0.6 | |
| | Nitric Acid Production | 0.1-0.3 | |

Source: Scientific Assessment of Ozone Depletion: 1994 (1994). WMO Global Ozone Research and Monitoring Project, Report No. 37, Geneva, Switzerland, 542p.

Table 1. Estimated sources of nitrous oxide (Tg N per year).

The probability of sizable quantities of nitrous oxide being chemically generated is very small, since the direct reaction between molecular nitrogen and atomic oxygen is almost impossible.

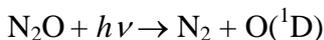
The contribution of one reaction



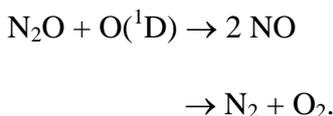
(where M is a some air molecule that is not changed in the reaction) is small in comparison with the N₂O emission from the Earth's surface.

3. Nitrous oxide sinks

The photochemical destruction of nitrous oxide in the atmosphere is due to its photolysis (by ultraviolet radiation with wave length lower than 337 nm ($1 \text{ nm} = 1 \times 10^{-9} \text{ m}$))



and due to reaction with excited oxygen



The photolysis rate depends on both the season (namely on solar angle) and air temperature, and drops sharply with reduction of altitude. Figure 1 illustrates the intensity of these reactions at the various atmospheric heights. Here the diurnally, annually and globally averaged intensities are calculated for the solar angle equal to 60° ; and for the reaction between N_2O and $\text{O}({}^1\text{D})$ as a sum of both branches. Figure 1 depicts that the reaction with $\text{O}({}^1\text{D})$ completely prevails over the N_2O photolysis in the troposphere. But in the middle and upper stratosphere, the N_2O photolysis contribution comes to about 90% of the total photochemical sink of nitrous oxide. The major sink of N_2O , the photodissociation in the stratosphere, is estimated approximately as $12.3 \text{ Tg N per year}$ with range from 9 to 17 Tg N yr^{-1} .

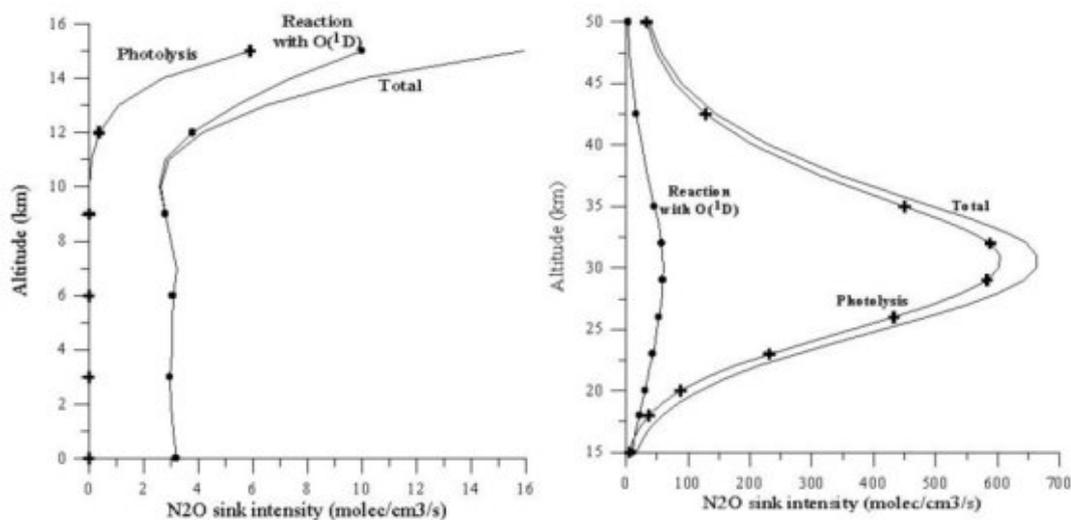


Figure 1. Model vertical distribution of the annually, diurnally and globally averaged photochemical sink of N_2O ($\text{molec cm}^{-3} \text{ s}^{-1}$) in the troposphere (left) and stratosphere (right).

There is important evidence of N_2O consumption by soils, but reliable data of this removal of nitrous oxide removal are as yet insufficient, and it is difficult to evaluate whether the soil provides a significant global N_2O sink. The large range of N_2O atmospheric sink intensities indicate analogous uncertainty for its lifetime which is estimated as 120 ± 30 years.

-
-
-

TO ACCESS ALL THE 9 PAGES OF THIS CHAPTER,
Visit: <http://www.eolss.net/Eolss-sampleAllChapter.aspx>

Bibliography

Hofmann D.J., Peterson J.T. (Eds), (1998). *Climate Monitoring and Diagnostics Laboratory* (1998). No. 24, Summary Report 1996-1997. Boulder, Colorado, USA, 166 p. [This contains atmospheric species measurement results during the last decade.]

Houghton J.T., Callander B.A., Varney S.K. (Eds) (1992). *Climate change 1992* (1992). *The supplementary report to the Intergovernmental Panel on Climate Change scientific assessment*. Cambridge University Press, UK, 200p. [This contains the improved scenarios of probable emissions of greenhouse gases, including methane, during the first half of 21 the twenty-first century, and with estimates of their effect on climate.]

Jones R.I., Pyle J.A. (1984). Observations of CH₄ and N₂O by the Nimbus 7 SAMS: A comparison with *in situ* data and two-dimensional numerical model calculations. *Journal of Geophysical Research* **89**, 5263-5279. [This contains the nitrous oxide satellite data.]

Khalil M.A.K., Rasmussen R.A. (1995). The changing composition of the Earth's atmosphere. Chapter 3 in: *Composition, Chemistry, and Climate of the Atmosphere* / Ed. Singh H.B. - Van Nostrand Reinhold, A Division of International Thomson Publishing Inc., USA, 50-87. [This work is devoted to the evaluation and analysis of trends of basic climate forming gases and their atmospheric chemistry.]

Prinn R.J., R.F. Weiss, F.N. Alyea, D.M. Cunnold, P.J. Fraser, P.J. Simmonds, A.J. Crawford, R.A. Rasmussen and R.D. Rosen (1994). Atmospheric CFC-11 (CCl₃F), CFC-12 (CCl₂F₂) and N₂O from the ALE/GAGE network, 396-420. In *Trends'93: A compendium of data on global change* /Eds. Boden T.A., Kaiser D.P., Sepanski R.J. and Stoss F.M. - ORNL/CDIAC-65, Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, Oak Ridge, Tennessee, USA. [This contains measurement results and their analysis from paleoperiods up to 1993.]

World Meteorological Office (1994). Scientific Assessment of Ozone Depletion: *WMO Global Ozone Research and Monitoring Project*, Report No. 37, Geneva, Switzerland, 542p. [This presents the inventory and expert estimates of nitrous oxide sources.]

Biographical Sketches

I.L. Karol was born on 27 July 1927 in Leningrad, USSR. In 1944 he entered the Hydrodynamics Dept. of Leningrad State University, Mathematics and Mechanics Faculty, graduating in 1949. He passed postgraduate studies from 1949 to 1952, when he received a scientific degree of Candidate in Maths & Physics. After three years of lecturing in mathematics at the Ural University in Sverdlovsk, in 1956 he entered the Institute of applied Geophysics USSR Academy of Sciences in Moscow as a senior scientist. In 1959 he was transferred to Institute of Experimental Meteorology of USSR Hydrometeorological Service in Obninsk, near Moscow, where he was nominated as chief of laboratory in 1970. Since 1972 he has been with Main Geophysical Observatory of USSR Hydrometeorological Service in Leningrad (now St. Petersburg) after receiving the USSR scientific degree of Doctor of Math & Physics, presenting in 1970 his theses, which was published in 1972 as a book by Gidrometeoizdat Publishing House "Radioactive isotopes and global transport in the atmosphere". This book was translated into English and published in 1974. Since 1953 I.L. Karol has published 10 scientific monographs and more than 140 papers individually or with co-authors. The original papers are dealing with modeling of global atmospheric composition and climate changes due to natural and anthropogenic causes. During several

periods he served as a member of various international commissions and committees of the International Association of Meteorology and Atmospheric Physics, of the World Meteorological Organization, of the World Climate Research Program Joint Scientific Committee. Since 1974 he has been the USSR (now Russian) co-leader of the joint project: "Composition of the atmosphere and climate changes" of the US-Russian Cooperation in Environmental Protection. He was the author or co-author of numerous scientific reports, which he presented at international and national scientific meetings throughout his scientific career.

A.A. Kiselev was born on 26 April 1953 in Leningrad, USSR. In 1970 he entered and in 1975 he graduated from the Hydrodynamics Dept. of Leningrad State University. From 1977 to 1981 he passed postgraduate studies at the Mathematics and Mechanics Faculty. In 1986 he received scientific degree of Candidate in Maths & Physics after presenting the candidate theses in geophysics. In 1975 he entered in the Main Geophysical Observatory of USSR Hydrometeorological Service in Leningrad as a junior scientist. Since 1990 he took position of senior research scientist in Main Geophysical Observatory. Since 1975 A.A. Kiselev has published about 30 papers individually and with coauthors. He is a contributor to the Intergovernmental Panel on Climate Change Reports of 1990 and 1999. The original papers are dealing with modeling of photochemical processes in the atmosphere, of global atmospheric composition change due to natural and anthropogenic causes.