

# IGAC *tivities* NewsLetter

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## A Note From the IGAC Chair

Guy Brasseur

### The Need for Global Observations

A prerequisite for establishing the global budgets of chemical constituents in the Earth system is to measure accurately the abundance of these compounds in the atmosphere. Over recent decades, space observations have provided unique information on the global distributions and temporal evolution of key species (including ozone) in the stratosphere. A great deal has been learned about the couplings between chemistry and dynamics in this region of the atmosphere.

Much less is known about chemical constituents in the troposphere, where there is a clear lack of observational data. Few people realize, for example, that our current knowledge of trends in tropospheric ozone is based on ozone sonde measurements made at only 15 stations located mostly at Northern mid-latitudes. Due to the presence of clouds, observations from space represent a challenge, but it is likely that in the near future, with the launch of new space instruments (e.g., IMG on ADEOS, MOPITT, TES and HIRDLS on EOS platforms, and IASI and SCIAMACHY on European platforms), new and exciting information will be obtained on the behavior of key chemical constituents in the free troposphere. There is no doubt that these space observations must be complemented by *in situ* measurements as well as analyses involving advanced numerical models.

Recognizing the need for more frequent observations, specifically on the global scale, IGAC, jointly with SPARC, will organize on 20-22 May 1997 in Toronto, Canada, a topical conference on "Global Measurement Systems for Atmospheric Composition". The purpose of this conference, to be co-sponsored by several space agencies, is to establish a long-term view on scientific priorities and an international implementation strategy. The meeting will provide a unique opportunity for scientists and managers involved in space experiments to exchange their views, present new results, discuss technical issues, initiate cooperative projects, and establish closer links with colleagues involved in other measurement techniques and in modeling. Detailed information on this conference will be provided in the next issue of *IGACTivities*.

A key component of the global budgets of trace constituents is the exchanges of mass between the atmosphere and the ocean or the continental biosphere. This is a research area in which IGAC has played a major role in the past, and will continue to in the future. We are pleased to have several contributions in this issue of *IGACTivities* that summarize some past and current research on atmosphere-surface chemical exchanges.

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## In Memoriam

### Christian Junge

When Professor Dr. Dr. h.c. Christian Junge died on 18 June 1996, in Überlingen, Germany, at the age of 83, atmospheric science lost one of its most respected seniors. In 1963, he created a whole new area of research with the publication of his book *Atmospheric Chemistry and Radioactivity*. Until his retirement two decades later, he continued to be one of the most prominent researchers in atmospheric chemistry.

In the 1930s, after his formal training as a meteorologist, Christian Junge conducted some research on atmospheric aerosols until World War II interrupted these studies. Soon after the war and after his habilitation in Frankfurt, he left Germany, like many other German scientists in those days, to continue his research in the U.S. at the U.S. Air Force Cambridge Research Laboratories in Bedford, Massachusetts. In 1962, he accepted an offer from the University of Mainz to become Professor of Meteorology and returned permanently to Germany. Later on, he often described the ten years which he spent in the U.S. as a very important time in his scientific career. It was then that he made fundamental discoveries in atmospheric chemistry. In 1968, Christian Junge was elected to become Director of the Max Planck Institute for Chemistry in Mainz where he remained until his retirement in 1979 and after which he moved south to Überlingen on Lake Constance.

Christian Junge will be remembered by generations of atmospheric scientists to come for his work on atmospheric aerosol particles. He was the first to show that the atmospheric aerosol has a continuous size distribution. The work of his colleagues has established his mathematical expression for this continuous distribution as a law, the so-called "Junge Law". In 1961, he discovered the aerosol layer in the stratosphere, which is today called the "Junge Layer". But aerosol research was not the only area where he broke new ground. Other fields of interest were the cycles of atmospheric trace gases as well as the evolution of the Earth's atmosphere including the budget of terrestrial photosynthetic oxygen. Junge and his co-workers in Mainz showed that many of the atmospheric trace gases possess both direct and indirect anthropogenic as well as natural sources. They made a substantial contribution to the idea that the atmospheric trace gases, or the chemical composition of the atmosphere in general is not only an area of research interesting in its own

right, but are also relevant for the environment and thus for the conditions of life. Earlier than many of his colleagues, Junge recognized that there were not only local and regional air pollution problems but that the chemical composition of the atmosphere was changing on a global scale due to various human activities. He saw that this change would eventually have serious ecological, social, and political consequences. He also recognized that the atmosphere is not isolated but can only be understood when considered as part of an interlinked system at the Earth's surface, consisting of atmosphere, hydrosphere, pedosphere, and biosphere. This led to the conclusion that the environmental problems which continue to plague us (acid rain, photochemical smog, stratospheric ozone depletion, climate change) can only be solved with knowledge gained through an inter-disciplinary approach and that it is, therefore, necessary to cooperate with other fields of science. He took the initiative by talking with chemists, geologists, oceanographers, and soil scientists about environmental problems and how to solve them, although very often this was no easy task at that time. In the first one or two decades after World War II, meteorology dealt with the dynamics of the atmosphere and with weather forecasts, while the majority of the chemists, analytical chemists included, considered any constituents below the parts-per-thousand range as irrelevant "dirt" and refused to pay any attention to atmospheric trace constituents. Geologists claimed that the atmosphere was part of the Earth's crust but, in fact, paid no further attention to it. Oceanographers and soil scientists largely neglected the interaction of the oceans and the soil with the atmosphere. Fortunately, there were exceptions and Junge was able to broaden the thinking of several discipline-oriented scientists in the course of time. The difficulties and frustrations of the early years are probably hard to understand for the younger generation of atmospheric scientists.

Christian Junge had a talent to immediately grasp the main features of everything he tackled. He always saw the "forest rather than the trees". Also, he was an inspiring teacher and his advice was often sought. Serving the atmospheric scientific community, he held many positions such as President of the Commission on Atmospheric Chemistry and Global Pollution of IAMAP (1967 - 1975), President of the International Association of Meteorology and Atmospheric Physics (1975), and President of the "Gesellschaft für

Aerosolforschung GAeF" (1977 - 1978). Junge was a member of the German Academy Leopoldina, the Bavarian Academy of Sciences, the Academy of Sciences and Literature in Mainz, Germany, the American Meteorological Society, the American Academy of Arts and Sciences (honorary member), and the European Geophysical Society (honorary member). He was honored by the "Alfred Wegener Medal" of the German Meteorological Association, and the "Carl Gustav Rossby Medal" of the American Meteorological Society. He also received the highest German civilian service medal, the "Bundesverdienstkreuz". Furthermore, he was awarded an honorary doctor's degree by the University of Frankfurt, Germany.

Christian Junge had broad interests which went far beyond the field of atmospheric science. When he retired in 1979, he turned his attention to disciplines such as anthropology and English history but stayed in touch with his former co-workers. For a number of years, he served as the chairman of the advisory council of the Fraunhofer Institute for Atmospheric Environmental Research in Garmisch-Partenkirchen, Germany. In 1995, the area of research of which Christian Junge was a key founder finally received the public recognition it deserves with the award of the

Nobel Prize in Chemistry to P.J. Crutzen, F.S. Rowland, and M. Molina.

The rather frustrating experience of the early years led Christian Junge to form his own inter-disciplinary team of young scientists at the MPI for Chemistry in Mainz, once given the opportunity. He gave his students a lot of freedom but also provided safe guidelines when needed. Working with Christian Junge was a stimulating and challenging experience with exciting give and take. He generously shared his new ideas with his co-workers and showed them how science works. He treated his collaborators like a family and supported their efforts to build their own scientific careers. They will never forget the frequent enthusiastic and lively discussions at the MPI for Chemistry and in the home of the Junges in Mainz. Professor Junge will be remembered with great affection by his students and colleagues whom he stimulated and encouraged. Many of his students have achieved impressive distinctions in their own rights.

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## Features

### Atmosphere-Surface Chemical Exchanges: An Introduction.

*Contributed by P.A. Matson, University of California - Berkeley, USA*

For several decades now, debates surrounding the increasing atmospheric concentration of carbon dioxide have centered on the magnitude of the secondary source (tropical deforestation) and the relative importance of terrestrial and oceanic sinks. There has been little debate about the most significant source, fossil fuel combustion. Methane and nitrous oxide also represent greenhouse gases with increasing atmospheric concentrations, but research and debate concerning them have centered on identification of sources and the search for previously unknown sinks. Each year of study of these gases has yielded newly identified sources, clearer appraisals of source

strengths, improved understanding of biological and physical processes controlling fluxes, and new approaches for minimizing emissions; IGAC science has led the way in these discoveries.

The three "feature" articles in this issue of *IGACtivities* describe some of the advances in our understanding of these trace gases — their sources, sinks, uncertainties, and anthropogenic influences. What is clear from these discussions is the critical role that multidisciplinary research has played in understanding the microbiological, physical, and chemical processes that control the production, emission, atmospheric chemistry, and ultimate fate of these gases. Moreover, these articles illustrate how improved understanding of the processes controlling atmosphere-surface chemical exchanges can aid society's ability to judge which proposed management and technological strategies for reducing emissions make sense and which do not.

## ASGAMAGE: Can't we make better measurements of air-sea exchange?

Contributed by W. Oost, Royal Netherlands Meteorological Institute and B.J. Huebert, University of Hawaii, USA

Two of the biggest unknowns in modeling the radiative forcing of climate involve our inability to precisely measure air-sea exchange rates. First, how much anthropogenic CO<sub>2</sub> goes into the oceans? In societal terms, is there any chance the oceans will save us from greenhouse warming by soaking up more CO<sub>2</sub>? Second, to what extent might the climate be altered if we inadvertently changed the viability of phytoplankton, since they produce the DMS that forms the aerosols that control cloud reflectivity? Since we don't even know how much DMS the oceans emit today to better than a factor of two, how could we predict the impact of a 20% change?

Traditional parameterizations of air-sea exchange, such as the two-layer approaches of Liss and Merlivat or Wanninkhof, rely on measuring the concentration gradient across the air-sea interface and using windspeeds and temperatures to estimate a transfer coefficient (or exchange velocity). Although most of the uncertainty is usually ascribed to the exchange velocity, the possibility of differences between concentrations at about 5 meters depth (where many ships have their research-water intakes) and the surface microlayer (whose concentration should drive the flux) is another area of concern.

The persistence of these uncertainties is the reason that one of IGAC's Activities is directed at *Marine Aerosol and Gas Exchange* (MAGE). One of MAGE's original goals is to promote the development of new flux-measuring technologies. Two of the most promising are eddy correlation (EC) and eddy accumulation (EA, also called conditional sampling). Each of these relies on fast (>1 Hz) measurements of vertical windspeed to identify updrafts and downdrafts, so that chemical concentrations can be measured in each to directly compute the flux.

These techniques measure fluxes over periods of 20-30 minutes, which is the same time scale on which changes in windspeed, temperature, and other factors occur. How long after the windspeed increases do higher emission fluxes last? Is there a depletion of the surface mixed layer, causing fluxes to decrease after an initial pulse? It may be that the fraction of DMS which evades to the atmosphere is higher when the winds come up, but that most of it is consumed in the water

when the winds are low. One often finds high particle concentrations after frontal passages: is this in part because frontal squalls drive out extra DMS? How realistic are our current parameterizations, which are based on the evasion of natural and deliberate tracers from natural waters?

Eddy correlation (EC) has been used for decades to measure surface fluxes over land, and it is recognized as the most defensible technique because it relies on direct measurements of concentrations in updrafts and downdrafts. One directly measures the amount of material moving toward a surface and away from it, and the difference is the flux. Since the eddies can be quite small, however, sensors must provide precise measurements 1 to 10 times per second, which few chemical sensors can achieve. EC has also been used over the oceans for measuring fluxes of heat, moisture, and momentum, even though the smaller marine turbulence levels make the measurements more challenging.

Attempts to measure marine CO<sub>2</sub> fluxes have been frustrated by several factors. The first is the small concentration variations over the oceans. An instrumental precision considerably greater than 0.1% is required to see these tiny fluctuations. Water vapor is also a problem. It changes the density of the air, effectively diluting the volumetric concentration of CO<sub>2</sub> in wet updrafts relative to drier downdrafts. The Webb correction for this effect is often very large, leaving a substantial uncertainty in fluxes. Water vapor also causes a small interference in the nondispersive infrared analyzers frequently used for the CO<sub>2</sub> measurement. Although these problems are being gradually resolved with further instrumental development, the considerable difference that so far has been found between transport velocities derived from EC observations (all done at or near the coast) and the more generally used values, has generated considerable skepticism of EC in the ocean carbon community.

A related technique, eddy accumulation, makes it possible to use slower sensors to measure fluxes. Fast valving directs air from updrafts and downdrafts into separate chambers, from which it can be measured by gas chromatographs and other slow sensors. While EA is less direct than EC, it reduces the demands on analytical systems and plumbing considerably, making drying, for instance, a simple alternative to the Webb correction.

The primary method by which these new techniques can be validated is to make simultaneous measurements alongside established methods under field conditions. That is precisely the aim of ASGAMAGE,

an intercomparison experiment taking place on the Dutch platform Meetpost Noordwijk (MPN; see Figure 1). ASGAMAGE builds on micrometeorological experience gained in HEXMAX (1986), the HEXOS Main Experiment, during which the impact of MPN on airflow and turbulence was well-characterized, and ASGASEX (1993). In ASGASEX the CO<sub>2</sub> EC method was considerably improved, but the difference between it and the two-layer approach still remained. It may be related, however, to the presence of CO<sub>2</sub> gradients in the upper few meters of the sea, one of many factors which will be addressed during ASGAMAGE.

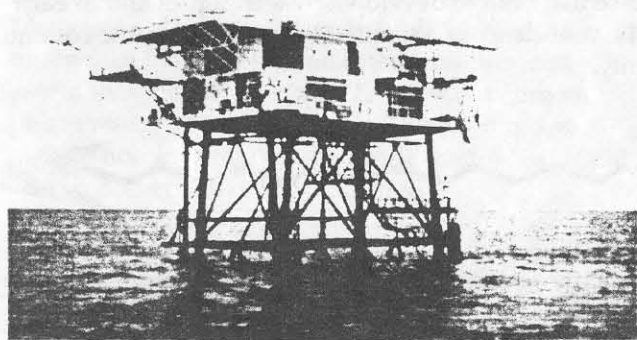


Figure 1. The Dutch research platform "Meetpost Noordwijk".

The first part of ASGAMAGE was successfully performed at MPN in May (when the maximum DMS concentrations occur) and the second experimental phase will be in October (when the winds are higher and more westerly) of 1996. It has four primary objectives:

- To test new methods for the measurement of air-sea fluxes of CO<sub>2</sub>, N<sub>2</sub>O, CH<sub>4</sub> and DMS,
- To intercompare these with established methods for estimating the transfer velocities of trace gases over the sea,
- To find relationships between the transport coefficients for the gas fluxes and relevant geophysical parameters, and
- To find out whether there can be significant vertical gradients in carbon dioxide concentration in the upper meters of the water column.

A wide variety of techniques will be intercompared:

1. Four independent EC systems for CO<sub>2</sub> fluxes will be deployed simultaneously, offering an opportunity to test the methods' reproducibility and identify the causes of differences. These will be accompanied by

EC measurements of momentum, heat, and water vapor.

2. The first attempts will be made to measure fluxes of DMS (and possibly of N<sub>2</sub>O and CH<sub>4</sub>) over the sea with EC using new high-speed sensors.
3. One or two EA systems will be deployed in parallel with the EC measurements.
4. A method that allows for shipboard application is the inertial dissipation technique, which uses the inertial subrange (high frequencies) of power spectra to determine fluxes. (Ship motions can be neglected because they occur in a different frequency range.)
5. A system will be used that corrects EC data for sensor movements, enabling in this way shipboard application of the EC method.
6. Concentration measurements in the air and at several depths in water will be used to estimate fluxes using the traditional two-layer approach.
7. The evasion of multiple deliberate tracers will be used to estimate transfer coefficients.
8. The reliability of passive radiometry and thermometry (measurement of the thermal skin effect) as a means of deducing the transfer velocity of gases (excluding bubble-mediated transfer) will be tested. The use of thermal imagery offers the most direct method of studying transfer mechanisms in the sea surface layer.

During the fall period measurements will also be made from the UK ship "Challenger", operating near MPN. The vessel will be used to perform a dual/triple tracer experiment, a sophisticated and well established method to determine the transfer velocity. Simultaneously shipboard measurements of marine biogenic gases (DMS, CO<sub>2</sub>, CO, CH<sub>4</sub>, N<sub>2</sub>O, low molecular weight hydrocarbons, and halocarbons) in seawater and air will be used for two-layer flux calculations.

Since waves and bubbles are clearly central to understanding air-sea exchange, special efforts are being made to characterize them. Waves will be measured with a wave wire and a directional wave buoy, while whitecap coverage will be measured with video cameras and a directional microphone. Below the surface, breaking waves will be studied with a high frequency sector-scanning sonar and a very fine beam sonar that measures the large bubbles (high void fractions) near the surface. The vertical penetration of bubble clouds will be measured with upward-looking sonars of four frequencies, giving a parametric description of the size distribution of the bubbles vs. depth and time. The bubble size distribution will furthermore be measured at a single depth with a laser-optical instrument. Large bubbles will be measured by a video system and ultrasound.

Gradients of physical and chemical properties in the water column can affect the comparison of the two-layer method with other techniques, so these will be carefully measured. Current profiles near the platform will be measured with 1 MHz Acoustic Doppler Current Profiler and an electromagnetic current meter. Sea water temperature, salinity, fluorescence and dissolved gases will be measured from pumps at different depths. In addition, dissolved oxygen and total gas partial pressure will be measured with *in situ* instruments at several depths.

ASGAMAGE involves 14 institutes from 7 countries and the owner of Meetpost Noordwijk, the Dutch government organization of Rijkswaterstaat. The participants are from NOAA/AOML (USA), Bedford Institute of Oceanography (Canada), NOAA/CMDL (USA), NOAA/ETL (USA), KNMI (Netherlands, the

organizer of the project), MPIC (Germany), NCAR (USA), NIOZ (Netherlands), University of Newcastle-Upon-Tyne (UK), RISO (Denmark), Southampton University (UK), TNO-FEL (Netherlands), University College Galway (Ireland), and UEA (United Kingdom). The EU MAST-3 programme is the primary sponsor of the European participants.

Eddy-flux methods will ultimately provide us with the most defensible measurements of air-sea exchange. Their time resolution will permit more accurate parameterizations of fluxes than existing techniques. We cannot afford not to develop these methods because our climate models are so sensitive to air-sea exchanges that we must have accurate ways of measuring the fluxes. Experiments like ASGAMAGE are essential both to develop new techniques and to earn the confidence of a justifiably critical scientific community.



## Global Methane Budget Studies

*Contributed by W.S. Reeburgh, University of California - Irvine, USA and P.M. Crill, University of New Hampshire, USA*

The mixing ratio of methane ( $\text{CH}_4$ ) in the troposphere is increasing more rapidly than any of the other long-lived radiatively active atmospheric trace gases.  $\text{CH}_4$  has increased from a pre-industrial value near 700 ppbv to a present-day value of 1720 ppbv (IPCC, 1995). The global warming potential of  $\text{CH}_4$  results from its atmospheric lifetime of about 10 years and the fact that it is 20 to 30 times more efficient than carbon dioxide in trapping infrared radiation. A great deal of recent attention has been focused on quantifying terms in the global atmospheric  $\text{CH}_4$  budget to understand the reasons for the atmospheric concentration increase. The importance of  $\text{CH}_4$  and the amount of effort focused on understanding its budget is highlighted by the number of IGAC Activities (HESS, BIBEX, RICE, TRAGEX, BATGE, MAGE) conducting research aimed towards understanding  $\text{CH}_4$  sources, sinks, and controls.

The atmospheric  $\text{CH}_4$  budget is based on a framework of atmospheric burden, residence time, isotope, and model constraints. We know that net  $\text{CH}_4$  emission from all sources is nearly balanced by photochemical oxidation by hydroxyl radical in the troposphere, the major sink. Upland soils have been recognized

recently as a smaller sink. The tropospheric concentration increase results from a source/sink imbalance of about  $37 \text{ Tg CH}_4 \text{ yr}^{-1}$  (IPCC, 1995). Isotopic measurements are used to distinguish between fossil and modern  $\text{CH}_4$  sources ( $^{14}\text{CH}_4$ ), and to provide an additional constraint on source and sink strengths ( $\delta^{13}\text{CH}_4$ ). The contemporary atmospheric increase, which links to the ice core paleo-record, has been documented by the U.S. National Oceanic and Atmospheric Administration Climate Monitoring and Diagnostic Laboratory (NOAA/CMDL) sampling program and a number of other programs. Figure 2 (Dlugokencky et al., 1994) summarizes precise measurements on time series flask samples collected at CMDL clean air stations located at a range of northern and southern latitudes. It is a clear demonstration of the dynamic nature of the global  $\text{CH}_4$  cycle. The preponderance of Northern Hemisphere sources is evident in the interhemispheric concentration gradient. The annual cycle, driven by seasonal changes in emission and photochemical oxidation, can be discerned in the changes in the mixing ratio magnitude and the shift in phase between the Northern and Southern Hemispheres. Perhaps most important, the global concentration increase of 1% per year is evident.

The overall atmospheric  $\text{CH}_4$  budget is reasonably well known and constrained. A major problem is apportioning the contributions of the net source terms. Estimates for most of the individual terms in the budget have uncertainties of a factor of two or more. It should be kept in mind that the net atmospheric  $\text{CH}_4$  budget is an annual "snapshot", and has limita-

tions for predicting the future.

In order to understand the  $\text{CH}_4$  cycle, we must understand the source and sink processes for each of the budget terms. An example of a process that has been overlooked until recently is microbially-mediated  $\text{CH}_4$  oxidation. The global atmospheric  $\text{CH}_4$  budget is based on net emission to the atmosphere, so microbially-mediated  $\text{CH}_4$  oxidation, which is included in the net emission terms and is therefore "invisible", is not specifically identified.  $\text{CH}_4$  oxidation in soils and waters occurs at interfaces or in subsurface zones and is capable of dramatically limiting or modulating emission from well-known sources. Most aerobic, moist (15-50 wt.%  $\text{H}_2\text{O}$ ) soils are capable of consuming atmospheric  $\text{CH}_4$ . Potential consumption by these soils is high, but the supply of  $\text{CH}_4$  to subsurface sites of oxidation is diffusion-

limited. Most of the information on  $\text{CH}_4$  oxidation results from tracer measurements of oxidation rates, static chamber measurements at sites where net consumption occurs, studies involving specific inhibitors of  $\text{CH}_4$  oxidation, or manipulation of environments involving displacement of  $\text{O}_2$  with  $\text{N}_2$  or Ar. In some environments, such as landfills and wetlands with deeply lowered water tables, the zone of oxidation is too far below the surface to use these methods. Stable isotope measurements coupled with an understanding of fractionation accompanying oxidation are being explored as a means of estimating the extent of oxidation in these systems.

What is the role of microbially-mediated  $\text{CH}_4$  oxidation in the global budget? Table 1 (Reeburgh et al., 1993) estimates the importance of microbially mediated oxidation in the global  $\text{CH}_4$  budget.

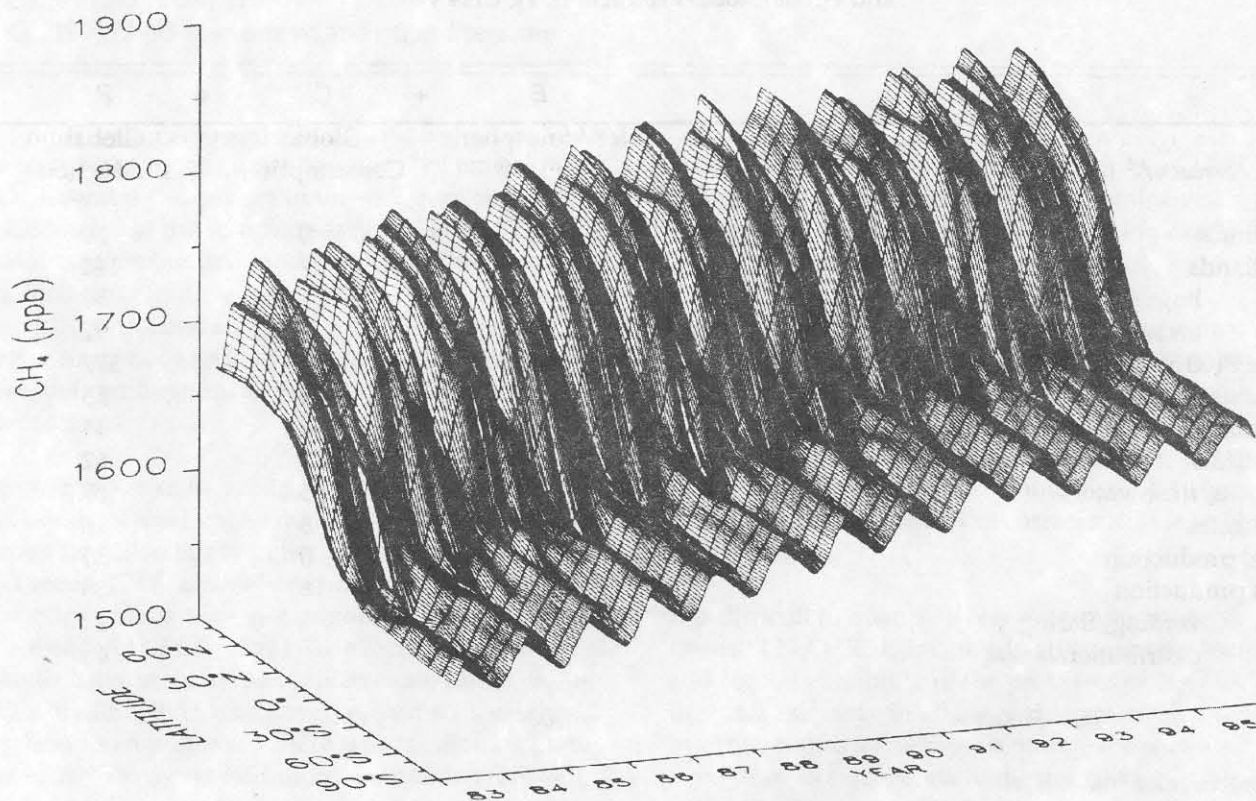


Figure 2. "Flying Carpet" diagram of distribution and growth rate of atmospheric  $\text{CH}_4$  (Dlugokencky et al., 1994).

Estimates of CH<sub>4</sub> oxidation from published measurements for each of the source terms in the Fung et al. (1991) budget are added to the net efflux terms to produce an estimate of gross CH<sub>4</sub> production. The oxidation estimates are based on limited data, and although they cannot be constrained like the atmospheric budget, they are conservative. It is instructive to view terms in the CH<sub>4</sub> budget by the relative magnitudes of production and consumption. For terms where CH<sub>4</sub> is emitted directly to the atmosphere and microbially-mediated consumption is believed to play no role (animals, biomass burning, coal production, natural gas venting and flaring), net emission to the atmosphere equals production. Microbially-mediated oxidation ranges in importance in the other sources. Oxidation can be a small portion of emission (wetlands, landfills, distribution leaks), about equal to emission (termites, hydrates), or greatly in excess of emission (rice, oceans), highlighting the need to understand microbially mediated oxidation as a control on the CH<sub>4</sub> budget. Overall, microbially-mediated CH<sub>4</sub> oxidation

is about 200 Tg yr<sup>-1</sup> larger than annual rates of emission. The responses of CH<sub>4</sub> production and oxidation to changing climate may be profoundly different, so it is important to understand CH<sub>4</sub> production and oxidation at a process level.

Measured CH<sub>4</sub> fluxes are highly variable in time and space. Fortunately, good agreement has been obtained in scaling exercises between chamber, eddy correlation, and aircraft boundary layer measurements in several field campaigns. Each of the techniques provides a unique insight into CH<sub>4</sub> dynamics. Aircraft data provide instantaneous evaluation of fluxes over very large landscapes. Eddy correlation and other micrometeorological techniques are very useful for areally integrated, temporally continuous measurements. Chamber measurements lend themselves to process studies in complex landscapes. The very best programs will integrate across these scales. Lack of an inexpensive rapid response sensor for CH<sub>4</sub> has hampered the collection of areally integrated seasonal flux data

Table 1. Net Global Atmospheric CH<sub>4</sub> Emission, Global Consumption, and Gross Global Production, Tg CH<sub>4</sub> yr<sup>-1</sup>

	<i>E</i>	+	<i>C</i>	=	<i>P</i>
Source/Sink term	Net Atmospheric Budget <sup>a</sup>		Global Consumption		Global Production
Animals	80		0		80
Wetlands	115		27		142
bogs/tundra (boreal)	35		15		50
swamps/alluvial	80		12		92
Rice Production	100		477		577
Biomass burning	55		0		55
Termites	20		24		44
Landfills	40		22		62
Oceans, freshwaters	10		75.3		85.3
Hydrates	5?		5		10
Coal production	35		0		35
Gas production	40		18		58
venting, flaring	10		0		10
distribution leaks <sup>b</sup>	30		18		48
<i>Total Sources</i>	500 <sup>b</sup>				
Photochemical oxidation	-450				
Soil consumption	-10		40		40 <sup>c</sup>
<i>Total Sinks</i>	-460 <sup>b</sup>		688.3		
			<i>Total Production</i>		1188.3

(a) Scenario 7, Fung et al. (1991);

(b) 500 - 460 = 40 Tg CH<sub>4</sub> yr<sup>-1</sup> = annual atmospheric (0.9% yr<sup>-1</sup>) increment;

(c) Soil consumption of atmospheric CH<sub>4</sub> added to the gross budget as an equivalent production term



using eddy correlation and eddy accumulation techniques, but the value of long-term continuous data sets and the ability to link fluxes to the local physical climate outweighs the cost of the sensor. Only a few long term data sets exist and most are based on static chambers and emission season data only. Most flux estimates are still based on static chambers and scaling up is based on areal distribution of habitats based on vegetation types. More sophisticated studies of plant community structure and correlations with seasonal CH<sub>4</sub> efflux is a promising area of study. There are still large gaps in coverage and the wetland data sets suffer from a North American/European bias. Future programs like the IGBP Northern Eurasia Study planned for Siberia (Steffen and Shvidenko, 1996) should provide much better coverage.

CH<sub>4</sub> dynamics of natural environments should be placed within the context of the carbon balance of the ecosystem. For example, vascular plants play a major role in providing substrate for CH<sub>4</sub> production and oxidation as well as transporting CH<sub>4</sub> to the atmosphere, bypassing the oxidation zones in many environments. One promising observation is a relationship between net ecosystem exchange of carbon dioxide (NEE) and CH<sub>4</sub> flux observed for inundated wetland plants. The observation that CH<sub>4</sub> emitted from wetlands is composed of <sup>14</sup>C-contemporary carbon points to the need for pulse-labeling studies and a focus on rhizosphere processes. Ecosystem-level models and soil climate models are giving promising initial results, and incorporation of results from process studies will lead to further improvements.

How sensitive is the CH<sub>4</sub> budget to climate change? Studies along natural gradients offer the most realistic means of assessing sensitivity of terms in the global CH<sub>4</sub> budget to changes in climate. Field manipulation experiments, (air and soil temperature, carbon dioxide, water table, vegetation) are another approach and are in progress at a number of sites. Manipulations in closed systems (like Biosphere 2, which has no photochemical sink) offer potential for understanding the role of microbially mediated oxidation in model systems under altered temperature, moisture, and carbon dioxide conditions.

Anthropogenic sources of CH<sub>4</sub> are becoming better understood both as significant sources and as sources that lend themselves to mitigation efforts. For example, a recent survey (D. Blaha and K. Bartlett, unpublished data) has shown that landfills in New England are an important regional source, emitting about as much CH<sub>4</sub> as local wetlands. Globally, landfills are an uncertain term in the budget. Modern landfills in developed countries are being equipped

with CH<sub>4</sub> recovery systems, and the recovered CH<sub>4</sub> is being used for power generation and as a feedstock for synthesis of chemicals like methanol. Emissions from landfills are expected to increase in developing countries, and attention to landfill design can enhance natural oxidation in the absence of recovery systems. Studies on rice indicate that water management, as well as fertilizer and organic matter management, can have major effects on oxidation and CH<sub>4</sub> emission. A reduction in anthropogenic emissions of only 8% is sufficient to eliminate the annual increase in tropospheric CH<sub>4</sub> (IPCC, 1995). Not only are mitigation strategies needed, but measurement techniques and programs designed to evaluate the effectiveness of the mitigation efforts are required.

Which terms in the global CH<sub>4</sub> budget are increasing? What steps can be taken to reduce anthropogenic emissions? How sensitive are terms in the CH<sub>4</sub> budget to changes in moisture, temperature and carbon dioxide? At present we are unable to make *a priori* predictions of CH<sub>4</sub> flux, but current studies in a wide range of environments are developing a mechanistic understanding of processes affecting CH<sub>4</sub> fluxes. We are optimistic that incorporation of this information into models, future field programs, and mitigation strategies will lead to useful results.

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## On Sources and Atmospheric Concentrations of Nitrous Oxide

Contributed by A.F. Bouwman, National Institute of Public Health and Environment, Netherlands,  
C. Kroeze, Wageningen Institute for Environment and Climate Research, Netherlands, and  
J.A. Taylor, Australian National University

Nitrous oxide ( $N_2O$ ) is one of the greenhouse gases in the atmosphere whose atmospheric concentration has been increasing since pre-industrial times. Despite many existing uncertainties, several sources of  $N_2O$  have been identified. This paper gives a brief overview of the current knowledge on atmospheric concentrations and emissions of  $N_2O$  and discusses some aspects of future research.

Although  $N_2O$  occurs in the atmosphere in minute quantities compared to  $CO_2$  and water vapor, its contribution to the greenhouse effect is considerable. This is caused by its long residence time in combination with the relatively large energy absorption capacity per molecule. Per unit mass the global warming potential of  $N_2O$  is about 310 times greater than that of  $CO_2$ . The global annual atmospheric  $CO_2$  increase is about 3000 million ton  $CO_2$ -C, primarily from fossil fuels. Although the annual increase of the mass of  $N_2O$  in the atmosphere of 4-5 million ton  $N_2O$ -N is close to three orders of magnitude smaller than this amount, its contribution to global warming is of the same order of magnitude as that of  $CO_2$ .

Nitrous oxide is a long lived gas because it is inert in the troposphere. However, in the stratosphere  $N_2O$  is removed by photolysis and reaction with excited oxygen atoms,  $O(^1D)$ . The oxidation of  $N_2O$  according to the latter reaction yields  $NO$ , providing the major input of  $NO_x$  to the stratosphere, thus in part regulating stratospheric ozone and influencing the  $NO_x$  balance in the upper troposphere (Crutzen, 1970).

Analysis of Antarctic ice core samples indicates that the atmospheric  $N_2O$  concentration has risen from about 275 ppbv in pre-industrial times to about 293 ppbv in the beginning of the 20th century and to 311 ppbv now. Records from longer periods indicate that the atmospheric  $N_2O$  concentration was at least 30% lower during the last Glacial Maximum than during the Holocene epoch, and that present-day  $N_2O$  concentrations are unprecedented in the past 45,000

years (Leuenberger and Siegenthaler, 1992). The atmospheric  $N_2O$  concentration started to increase rapidly during this century, but an accelerated increase may have started only after 1940. The observed increase of atmospheric  $N_2O$  during the 1980s was 0.25% or 0.8 ppbv per year. However, the trends over the last decade are extremely variable ranging from 0.5 to 1.2 ppbv per year.

The annual increase of atmospheric  $N_2O$  during the 1980s of 0.25% was caused by an imbalance of sources over sinks of 4-5 million ton  $N_2O$ -N per year, accounting for 25% or more of the total annual source of 16 million ton  $N_2O$ -N. The stratospheric destruction removes 12 million ton  $N_2O$ -N per year (Minschwaner et al., 1993). The atmospheric lifetime of  $N_2O$  based on the destruction rates and the atmospheric burden amounts to 120 years.

Most of the  $N_2O$  in the Earth's atmosphere stems from microbiological processes. In soils and aquatic systems the major sources of  $N_2O$  are generally accepted to be denitrification and nitrification. In subsurface environments denitrification is the major source of  $N_2O$ . Under reducing conditions with no other available source of N,  $N_2O$  may be consumed in soils. Uptake of  $N_2O$  by the ocean surface has also been observed. At present the knowledge on the conditions at which soils and aquatic systems act as sinks for  $N_2O$ , and the parameters affecting the influx when they do so, is too limited to evaluate their importance at the global scale.

Although in recent years considerable progress has been made in the identification of source candidates, the uncertainty in the various source estimates has not been reduced (Table 2). The  $N_2O$  emissions from fossil fuel combustion and biomass burning had long been considered the major cause of the atmospheric increase. This view changed in 1988 when it was discovered that in mixtures of flue gases (such as in power plant effluent), that are stored in stainless steel canisters even during short periods, reactions occur in the presence of  $SO_2$ ,  $NO_x$  and  $H_2O$  that can produce substantial amounts of  $N_2O$ . All past work on  $N_2O$  from coal combustion had relied on stored samples and became suspect. Now it is accepted that direct  $N_2O$  emission from stationary fossil fuel combustion contributes less than 1% of the global source. However, as yet unknown amounts of  $N_2O$  may be formed in smoke plumes resulting from biomass burning, in exhaust gases from other combustion processes, and during catalytic reduction of  $NO_x$ .

Table 2. Global N<sub>2</sub>O budgets presented between 1984 and 1994. Source estimates in million ton N<sub>2</sub>O-N/year.

Source	Year		
	1984 <sup>a</sup>	1986 <sup>b</sup>	1994 <sup>c</sup>
Soils under natural vegetation	2.6-25	3.5-11.5	3.3-9.7
Agricultural soils	1.6-5.3	12-14	1.8-5.3
Animal excreta (cattle and feedlots)			0.2-0.5
Biomass burning	1-2	0.5-0.9	0.2-1
Land use changes			0.2-0.6
Oceans	1-10	1-3	1-5
Fossil fuels; stationary combustion	1-2	3-5	0.1-0.3
Fossil fuels; mobile combustion			0.1-0.6
Industry			0.5-0.9
Aquifers			0.5-1.3
Sewage & waste water treatment	1-2		0.2-1.9
Global warming			0-0.6
Atmospheric chemistry, lightning, corona processes	0-21		0.3-1.2
Total	9-67	9-22	10-17

<sup>a</sup> Banin et al. (1984).

<sup>b</sup> McElroy and Wofsy (1986)

<sup>c</sup> IPCC 1994/1995 assessment and other literature

The recent history of global "budgets" of emissions of N<sub>2</sub>O illustrates the change in views before and after the discovery of the sampling artifact (Table 2). A great number of source candidates have been identified, including fertilized agricultural soils, livestock production systems, soils under natural vegetation, aquatic sources, biomass burning, land use changes, fossil fuel combustion, automobiles, industrial and other sources.

The major sources in most N<sub>2</sub>O budgets are formed by soils under natural vegetation, followed by oceans. Despite the uncertainty in the global N<sub>2</sub>O budget, the most recent IPCC assessment indicates that agricultural activities are the most important anthropogenic source of N<sub>2</sub>O (IPCC, 1995). The increase in the use of catalytic converters in cars, which cause much higher N<sub>2</sub>O emissions than cars not equipped with catalysts, may lead to an important increase in emissions in the future. Atmospheric oxidation of ammonia (NH<sub>3</sub>) to N<sub>2</sub>O by hydroxyl radicals (OH) may be an important and increasing source.

There are a great number of poorly known, minor sources of N<sub>2</sub>O, such as lightning and corona processes around high voltage electrical transmission lines. Recently, global warming has also been mentioned as a potential N<sub>2</sub>O source (Table 2). Other minor sources not listed in Table 2 include fresh water and coastal

marine waters, effects of N deposition on soil N<sub>2</sub>O emission, the production and use of explosives, medical and industrial use of N<sub>2</sub>O, and use of N<sub>2</sub>O as an aerosol propellant.

Current global estimates of emissions and atmospheric removal do not account for other possible removal processes, such as uptake of N<sub>2</sub>O by soils and aquatic ecosystems, and the potential role of the oceans as a reservoir of N<sub>2</sub>O. If sinks of N<sub>2</sub>O turn out to be important, the source estimates need to be revised as well to obtain the correct increase in N<sub>2</sub>O concentration.

It is difficult to quantitatively determine biogenic fluxes of N<sub>2</sub>O. This is caused by the extreme temporal and spatial variability of the processes of N<sub>2</sub>O formation and exchange in all biogenic sources. In addition, in early studies a few representative measurements were used to extrapolate to the global flux. Nowadays more attention is paid to techniques of scaling. For example, terrestrial ecosystems should be stratified by delineation of functional types on the basis of soil, vegetation and terrain characteristics. Remote sensing observations are increasingly used for delineating. Similarly, functional groupings can be made in oceans on the occurrence of upwelling, temperature, concentrations of nitrous oxide, nitrate, oxygen, organic matter. For biomass burning the type of fuel and fire

intensity can be used as a basis for scaling.

Functional types can form the basis for measurement schemes, so that the variability within delineations is reduced compared to that of the whole system. Micrometeorological (e.g., eddy correlation and eddy accumulation techniques) and remote sensing techniques are used to determine fluxes for larger areas. The traditional enclosure methods, whereby the fluxes are determined from the concentration change within a flux chamber, are still needed to study the processes and their regulating factors and to develop process models to simulate fluxes. With appropriate techniques for integrating knowledge acquired at a detailed scale towards larger scale levels, and validation of the results against measurements at higher scale levels, fluxes can be extrapolated. Hence, scaling not only involves bottom-up methods, but also top-down approaches. At the global and regional scale a promising technique is inverse modeling, whereby atmospheric concentrations are used to calculate backwards where the source regions are, and to determine the fluxes from these regions. Inverse modeling of N<sub>2</sub>O is hampered by the small number of long-term monitoring stations. At present N<sub>2</sub>O records are available from 10 monitoring stations of the Atmospheric Lifetime Experiment-Global Atmospheric Gases Experiment (ALE-GAGE) and NOAA Climate Monitoring and Diagnostics Laboratory (CMDL) networks. Most of these stations are located in remote places away from major source regions, where air is thoroughly mixed, to establish global trends in concentrations. For atmospheric modeling the global coverage may not be adequate, because signals from continental sources are not recorded.

Isotopic ratios of stable isotopes are a very promising tool in top-down scaling (see e.g., Kim and Craig, 1993). The <sup>18</sup>O/<sup>16</sup>O isotopic ratios of N<sub>2</sub>O can be sensitively measured, and δ<sup>18</sup>O values for N<sub>2</sub>O derived from nitrification are lower than those for N<sub>2</sub>O from denitrification. Assuming that these isotopic differences are uniform among different systems, the process of formation of N<sub>2</sub>O may be determined. Nitrous oxide in soil and groundwater may be significantly depleted in <sup>15</sup>N and <sup>18</sup>O relative to tropospheric N<sub>2</sub>O. In surface ocean waters down to 600 m depth N<sub>2</sub>O is depleted in both heavy isotopes, but at greater depth N<sub>2</sub>O is enriched in <sup>15</sup>N and <sup>18</sup>O. Coal plant and engine exhaust have been shown to be enriched in <sup>18</sup>O relative to N<sub>2</sub>O in the troposphere and in soil and groundwater. The N<sub>2</sub>O from the stratospheric backflux to the troposphere may be heavier than tropospheric N<sub>2</sub>O. However, more determinations of

the isotopic ratios of N<sub>2</sub>O in the atmosphere are needed to identify and quantify N<sub>2</sub>O sources.

There are several options to reduce emissions of N<sub>2</sub>O. If current trends continue, global emissions may increase by 4 - 13 million ton N<sub>2</sub>O-N per year during the next century. Some of this increase can be avoided. Most importantly, emissions related to industry and stationary combustion can be reduced. In agriculture a reduction of N<sub>2</sub>O emission per hectare seems feasible in several world regions. A fast increase in food production and increasing importance of animal production is expected in the coming decades, caused by fast population increase and economic growth in large parts of the world. In addition, an increase in the number of cars equipped with catalytic converters is envisaged. These developments may lead to significant increases in N<sub>2</sub>O emissions. Hence, although there are regions where N<sub>2</sub>O emissions can be reduced considerably, it is questionable whether these reductions can avoid a further increase in worldwide emissions.

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## Announcements

### Fourth IGAC Scientific Conference

The Fourth IGAC Scientific Conference will consist of three CACGP co-sponsored symposia at the 1997 joint Assemblies of the International Association of Meteorology and Atmospheric Sciences (IAMAS) and International Association for Physical Sciences of the Ocean (IAPSO) to be held in Melbourne, Australia, in early July of 1997. Below are outlines of the symposia adapted from the joint assemblies' homepage (<http://www.dar.csiro.au/pub/events/assemblies/index.html>). To request registration information, complete the form available on this homepage or send Email to [mscarlett@peg.apc.org](mailto:mscarlett@peg.apc.org).

#### *Symposium JMP3: Chemical Processes and Climate*

##### *1. Aerosol controls on climate*

This symposium will address the roles of aerosols in direct and indirect forcing of climate. The uncertainty for the direct forcing of climate by aerosols is at least 50%, while that for the indirect effect includes even the sign of the forcing. We will address the entire range of modeling, laboratory and field approaches to reducing these uncertainties, with an emphasis on how observations can improve the depiction of aerosol radiative forcing in models.

Specific topics include aerosol nucleation and the source of new particles, the role of boundary layer vs. free tropospheric processes in controlling the indirect effect, the formation of marine aerosols from dimethyl sulfide (DMS), experimental strategies for quantifying the direct impact of anthropogenic aerosols (and their spatial extent), remote sensing methods, and recent IGAC field programs such as ACE-1.

Convener: Barry Huebert, Department of Oceanography, University of Hawaii, Honolulu, HI, USA (email: [huebert@soest.hawaii.edu](mailto:huebert@soest.hawaii.edu)).

Co-Convener: John Gras, CSIRO Division of Atmospheric Research, Aspendale, Vic., Australia (email: [john.gras@dar.csiro.au](mailto:john.gras@dar.csiro.au)).

##### *2. Air/sea exchange of particles and gases*

The exchange of particles and gases can have important impacts on the biochemistry of both the atmosphere and the oceans. For example, air-sea transfer of CO<sub>2</sub> is a large flux in both natural and man-perturbed cycles of this radiatively active gas. Further, the flux of DMS, produced by marine algae, from sea to air plays important roles in producing acidity and cloud condensation nuclei in the atmosphere. In the case of particles, the oceans are a sink for terrestrial mineral dust - a major source of iron which appears to be a limiting nutrient for marine primary production in some oceanic areas. In addition, sea-salt particles produced by bubble bursting are a site for heterogeneous reactions in the marine atmospheric boundary layer (for example, the oxidation of DMS).

This symposium will include papers dealing with the processes of exchange of gases and particles in moving between the atmospheric and oceanic reservoirs. In addition, contributions dealing with the distributions and mechanisms of producing and exchanging gases and particles in both air and sea water are encouraged. Also welcome are papers discussing the effects of these transfers on the physico-chemical and biological properties of atmosphere and oceans, as well as on global biochemical cycling. The examples given above are intended to illustrate the likely scope of the session; they are not exhaustive and contributions on other relevant topics are very welcome.

Co-Conveners: Peter Liss, School of Environmental Sciences, University of East Anglia, Norwich, UK (email: [p.liss@uea.ac.uk](mailto:p.liss@uea.ac.uk)) and Robert Duce, Dean, College of Geosciences & Maritime Studies, Texas A&M University, College Station, TX, USA (email: [rduce@ocean.tamu.edu](mailto:rduce@ocean.tamu.edu)).

##### *3. Ozone as a greenhouse gas*

This symposium will address the role of ozone as a greenhouse gas and its global contribution to radiative forcing. Papers on observations and theoretical and numerical modeling are invited. Particular focal points will be: (1) The temporal and spatial distribution of surface and tropospheric ozone and the vertical distribution of ozone in the troposphere. Papers based on recent field campaigns and remote sensing techniques are welcome. (2) Sources and sinks of ozone

and chemical processes governing the distribution of ozone. Papers assessing the anthropogenic contribution to ozone formation are invited. (3) Ozone and climate relationships. Papers aimed at modeling the effect of ozone on radiative forcing are very welcome.

These themes are not exhaustive and papers on allied topics are encouraged.

Convener: Roseanne Diab, University of Natal, Dalbridge, South Africa (email: diab@mtb.und.ac.za).

Co-Convener: Ian Galbally, CSIRO Division of Atmospheric Research, Aspendale, Vic., Australia (email: ian.galbally@dar.csiro.au).

### ***Symposium IM7: Tropospheric Chemistry and Related Air/Surface Exchange in Polar Regions***

Polar regions make important contributions to global atmospheric chemistry and regulation of climate through direct influences on global albedo, as regions of active atmosphere-ocean exchange of relevant chemical species such as CO<sub>2</sub>, DMS, and a wide range of other reactive gas and aerosol species, and through influences on climate and atmospheric chemistry at lower latitudes. Polar snow and ice cores also provide unique data on past climate variations through a wide variety of paleoclimate indicator species that provide temporal information at time scales ranging from seasonal to a few hundred thousand years. Addition-

ally, polar regions, though inhospitable and remote, are not free from impact by the continuing expansion of human activities world-wide. The Arctic especially is now heavily impacted by long-range transport of industrial atmospheric effluents, though long-term consequences for the region's atmospheric chemistry and climate are largely unknown.

The purpose of the symposium is to draw together current knowledge on polar atmospheric chemistry and composition and air/surface exchange, relevant to all of these issues. Both modeling and observational studies are welcome, with studies highlighting the similarities and differences between the Arctic and Antarctic regions being particularly welcome.

Convener: Greg Ayers, Division of Atmospheric Research, CSIRO, Aspendale, Vic., Australia (email: greg.ayers@dar.csiro.au).

Co-Conveners: Martin Manning, National Institute of Water and Atmospheric Research, Lower Hutt, New Zealand (email: manning@gaia.grace.cri.nz); Leonard Barrie, Atmospheric Environment Service, Downsview, ON, Canada (email: lbarrie@dow.on.doe.ca) and Robert Delmas, Lab. de Glaciologie et Geophysique de l'Environnement, St. Martin d'Hères, France (email: delmas@glaciog.grenet.fr).

### ***Symposium IM22: Closing the Budgets of CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O***

This symposium is also being co-sponsored by the IGBP's Global Change and Terrestrial Ecosystems (GCTE) Core Project. The topics that will be examined include: (1) The ocean and the terrestrial biosphere as sinks for CO<sub>2</sub>, (2) Natural sources of CH<sub>4</sub> from wetlands, and (3) N<sub>2</sub>O emissions from terrestrial systems. Special emphases will be on: (a) Determination of regional source and sink strengths by direct measurement or by inverse methods using atmospheric and oceanic observations; (b) Ecological controls on production, sequestration, and destruction of these long-lived radiatively active species within terrestrial ecosystems; and (c) Decade-to-century time scale changes in ecosystems due to climate and other changes, and the influences of these changes on trace gas emissions.

Convener: Paul Fraser, CSIRO Division of Atmospheric Research, Aspendale, Vic., Australia (email: paul.fraser@dar.csiro.au)

Co-Conveners: Mary Scholes, University of the Witwatersrand, South Africa (email: mary@gecko.biol.wits.ac.za), and Robert Scholes, CSIR Forest Science and Technology, Pretoria, South Africa (email: bscholes@forestek.csiro.co.za).

## **IGACTivities Newsletter**

*Edited by Alex Pszenny and Elaine Robbins  
Logos by Linda Kubrick*

*Newsletter requests and change of address  
information should be sent to:*

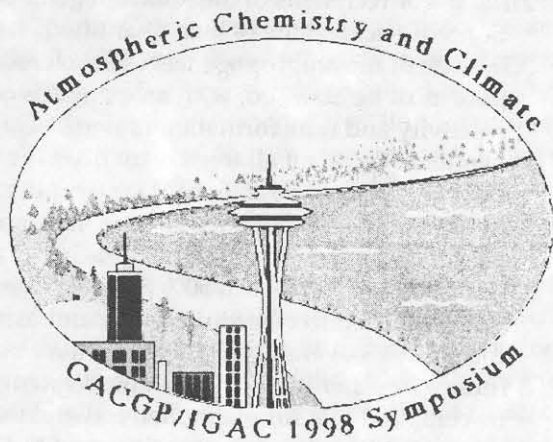
*The IGAC Core Project Office  
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WWW: <http://web.mit.edu/igac/www/>*

*IGAC is a Core Project of the International Geosphere-Biosphere Program (IGBP). The IGAC Core Project Office is currently supported by the U.S. National Science Foundation with contributions from the U.S. National Oceanic and Atmospheric Administration and the U.S. Department of Energy.*

# FIRST ANNOUNCEMENT

## Joint International Symposium on Global Atmospheric Chemistry



Ninth Symposium of the IAMAS Commission on Atmospheric Chemistry & Global Pollution (CACGP)

and

Fifth Scientific Conference of the International Global Atmospheric Chemistry Project (IGAC)

Seattle, Washington, USA  
19-25 August 1998

### Scientific Program:

Contributed papers are solicited on field and modeling studies related to tropospheric chemistry in nonurban areas. A major theme for this Symposium will be "Atmospheric Chemistry and Climate Change". In addition, papers on results of IGAC-sponsored activities will be highlighted.

### Topics include:

- Results of recent international field experiments in the following areas: Marine atmosphere; Continental/marine interactions, e.g., NARE, APARE, ACE-2; Tropical regions; High-latitude and polar regions; Aerosol chemistry and climate effects, e.g., SCAR-B, TARFOX.
- Chemistry of the past atmosphere, as observed in ice cores. Emphasis on past 100 years; CO<sub>2</sub> and CH<sub>4</sub> cycles for past 1000 years.
- Evaluation and application of global models focusing on chemistry-climate interaction with human perturbations. Latter includes: Deforestation and land-use changes; Biomass burning; Pollution aerosols; Aviation impacts.
- Satellite-based studies of tropospheric chemistry and related land and oceanic processes.
- Distributions and fluxes of greenhouse gases.
- Aerosol-cloud-radiation interactions.
- Sulfur and nitrogen biogeochemical cycling.

Tentative Abstract Deadline - March 1998. Look for further announcements in the IGAC *Activities* Newsletter and on a forthcoming Symposium homepage.

### International Science Steering Committee (ISSC):

P. Artaxo, T. Bates, I. Fung, P. Quinn, F. Raes, A. Thompson (Chair)

Ex Officio: H. Akimoto (Vice-President, CACGP), G. Brasseur (Chair, IGAC Scientific Steering Committee), L. Barrie (Secretary, CACGP), H. Rodhe (President, CACGP)

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### Suggestions for additional Topics can be sent to:

Dr. Anne Thompson, ISSC Chair  
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# CALL FOR PAPERS

International Workshop on Dissipation of N from the Human N Cycle and Its Role in Present and Future N<sub>2</sub>O Emissions to the Atmosphere

Oslo, Norway, May 8-11, 1997

Under the auspices of the Norwegian Research Council and the TRAGEX activity of IGAC, and in co-operation with the OECD secretariat for greenhouse gas inventories, the Norwegian Research Council, the Agricultural University of Norway, Norsk Hydro, and the Norwegian Department of Environment are pleased to sponsor an international workshop on anthropogenic nitrogen and atmospheric nitrous oxide.

The biosphere receives a significant amount of fixed nitrogen (N) from various anthropogenic sources, such as industry, combustion engines, and biological N fixation in agriculture. Unless counteracted by increased levels of denitrification, this anthropogenic N input will result in an temporary increase in various organic N pools (including biomass) in the environment, until balanced by denitrification (via mineralization and nitrification). A "nitrogen problem" builds up somewhere, but the distribution and the turnover rates of the accumulated N needs clarification in order to assess immediate and future effects in the biosphere. This N enrichment is a truly global problem, in as much as it is a potential source of increased emissions of nitrous oxide (N<sub>2</sub>O). The increased emissions will presumably persist long after a possible shut-down in further N pollution.

Fertilizer use in agriculture is often assumed to be the largest anthropogenic N source, and many efforts have been focused on emissions of N<sub>2</sub>O from agricultural soil. However, since much of this N ends up elsewhere in nature, and since there is likely to be a significant time lag between the actual N pollution and its stimulation of N<sub>2</sub>O emissions, we are convinced that realistic estimates of present and future N<sub>2</sub>O emissions due to anthropogenic N must adopt a "cradle to grave" approach. In 1995 the IPCC/OECD/IEA Program on National Greenhouse Gas Inventories initiated steps to develop a methodology for the estimation of N<sub>2</sub>O from agricultural soils which incorporated this concept. This workshop will serve to provide the opportunity to improve this methodology.

As a point of departure, the workshop will use the result from a detailed analysis of the N flows and N dissipation from the Norwegian society as a whole because it is the first attempt (to our knowledge) of a complete analysis of a whole society according to topics 1 and 2 below. We encourage potential participants to

present similar analyses of other societies, if such data exist. The following topics for discussions are suggested:

1. N dissipation from the human society to the environment must be assessed, by tracing the N flows and routes of losses.
2. The major recipients of the anthropogenic N must be identified and the N load quantified.
3. The fate of the anthropogenic N in each recipient pool must be assessed, with an emphasis on its reactivity and transformation rate to N<sub>2</sub>O. Dynamic modeling of all transformations involved can probably not be achieved, for a number of obvious reasons. But a reasonable minimum would be an assessment of possible inert storage time, half life (time until 50% has been denitrified or transported to other recipients), and estimates of the system's overall N<sub>2</sub>O/N<sub>2</sub> emission ratio.
4. These assessments for all relevant recipients should be compiled in a simple model, constructed to assess the time dependent emission of N<sub>2</sub>O as induced by anthropogenic N.

Experts on the various recipients of anthropogenic N are invited to the workshop to present "state of the art" assessments of the fate of anthropogenic N as outlined above (point 3). We also invite others to contribute oral papers or posters to this topic. We acknowledge that such assessments must be made at a very aggregated level, involving a series of assumptions without firm experimental evidence. A final session of the workshop will be devoted to discussing strategies for compiling a complete model according to point 4 above. An author group will be formed by the organizers, with the task of completing this work in an adequate form, depending on the outcome of the whole workshop. Selected contributions together with the final compilation text is to be published as a special volume of *Nutrient Cycling in Agroecosystems* as soon as possible after the workshop. Organizing committee: L. Bakken, Department of Soil and Water Sciences, Agricultural University of Norway; M. Bleken Department of Economics and Social Sciences, Agricultural University of Norway; O. Bockman, Norsk Hydro; B. Lim, OECD Environment Directorate, Paris, France; A. Mosier USDA/ARS, Ft. Collins, Colorado, USA.

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## Ideas for Future Field Programs of the IGAC Focus on Atmospheric Aerosols

A pamphlet describing the plans for implementing IGAC's new Focus on Atmospheric Aerosols (FAA) is nearing completion and should be available in printed form and on the IGAC homepage in September. With two major field programs already in data analysis phase and a third to take place in mid-1997 (see *IGAC Activities* No. 5, June 1996), ideas are already being discussed for additional field programs needed to achieve the initial goal of the FAA. A first ad hoc meeting to begin development of ideas for future FAA field programs was held during the ACE-1 data workshop in Seattle, WA (USA) on June 26, 1996. Approximately 60 people attended the two hour meeting.

Two possible experiments were discussed at some length. The first was to study the aerosol plume from Asia as it is advected out over the North Pacific Ocean. Asia is currently the largest source of sulfur emissions to the atmosphere. These emissions are projected to increase in the future with continued economic development on this continent. The plume of aerosols emanating from Asia is clearly visible in AVHRR satellite imagery in the March-April time frame. Limited available data indicate that this aerosol contains appreciable soot, such that its single scattering albedo is lower than that typical of industrial aerosol and markedly different from either European or North American aerosol. Discussion of this proposed experiment yielded two additional research avenues (i.e., extending those of ACE-1 and ACE-2): 1) an SO<sub>2</sub> mass balance to determine the percentage of SO<sub>2</sub> that is incorporated into the aerosol, and 2) a study of aerosol deposition to determine aerosol lifetimes. The evolution of the Asian plume with distance from coastal regions offers an excellent

natural laboratory for quantifying removal processes — something not emphasized in ACE-1 or ACE-2.

The second proposal was for an experiment over Central/Eastern Europe. This is currently one of the most polluted regions in the Northern Hemisphere with a calculated direct aerosol forcing of climate of 2-4 W m<sup>-2</sup>. Germany is prepared to take a leading role in funding this experiment through its new Aerosol Research Focus (AFS). The AFS is scheduled for 6 years and will begin in 1997 at a level of US\$2.5 million per year. This experiment could take place in the year 2000. Two pre-campaigns are currently planned: the "Lindenberg Experiment" in 1996 and the "Berlin Plume Experiment" in 1998. Further information on these experiments is available from Dr. Jost Heintzenberg at the Institute for Tropospheric Research, Leipzig.

Several other possible intensive projects were suggested at the Seattle meeting, including studies of mineral (desert dust) aerosols and organic aerosols.

The Seattle meeting was the beginning of the development process for future FAA field campaigns. As this newsletter goes to press in mid-August, other open meetings are planned during the 14th International Conference on Nucleation and Atmospheric Aerosols (26-30 August 1996, Helsinki, Finland; Contact: J.L. Gras, Fax: (+61-3) 9239 4444, Email: john.gras@dar.csiro.au), the 15th Annual Meeting of the American Association of Aerosol Research (AAAR; 14-18 October 1996, Orlando, Florida, USA; Contact: B.J. Huebert, Fax: (+1-808) 956-9225, Email: huebert@okika.soest.hawaii.edu), the Joint IAMAS/IAPSO Assembly (1-9 July 1997, Melbourne, Australia, Contact: J.L. Gras, Fax: (+61-3) 9239 4444, Email: john.gras@dar.csiro.au), and in late 1996 or early 1997 at one or two Asian locations to be determined. Persons unable to attend these meetings may communicate expressions of interest or other ideas for future FAA experiments to the IGAC Core Project Office.

