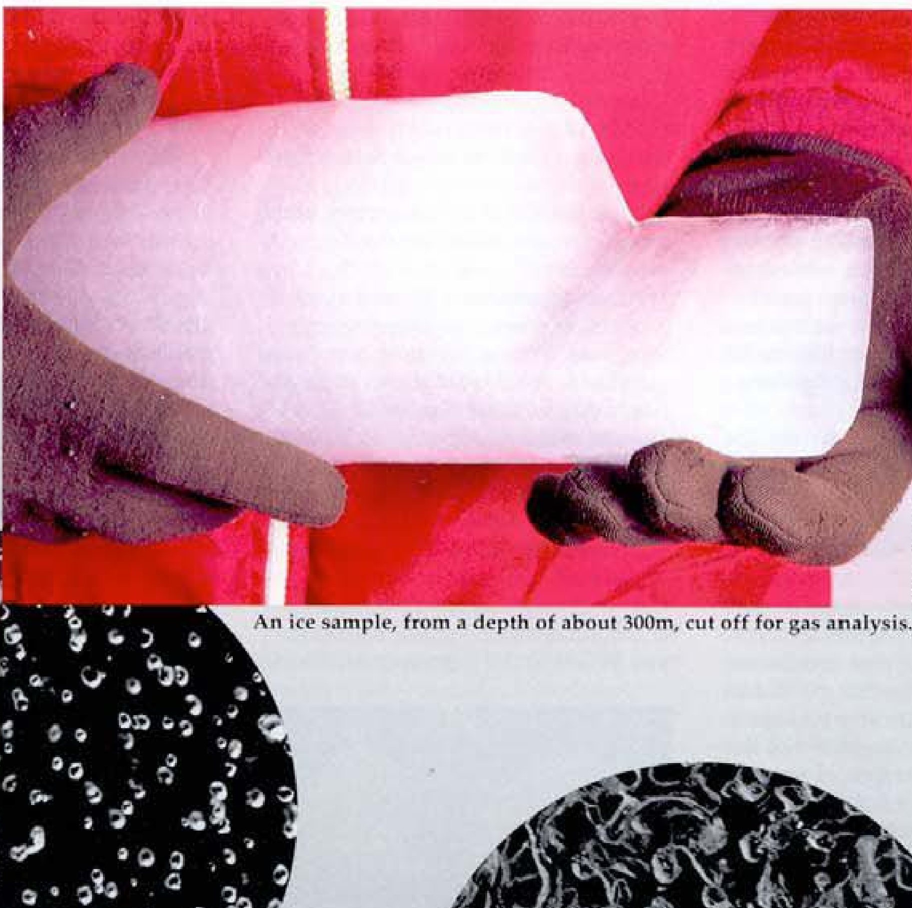
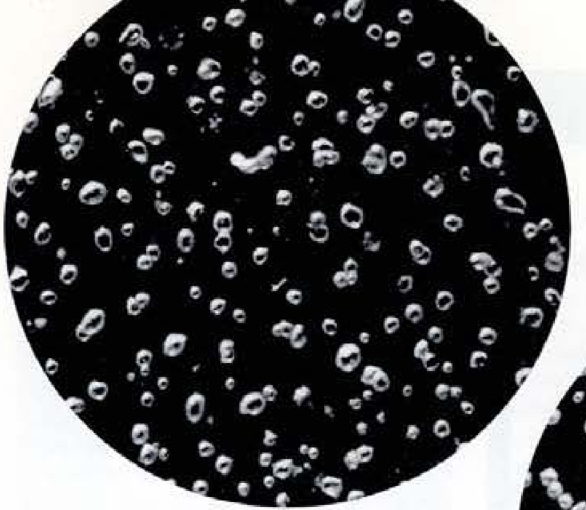
Methane change may slow the global greenhouse

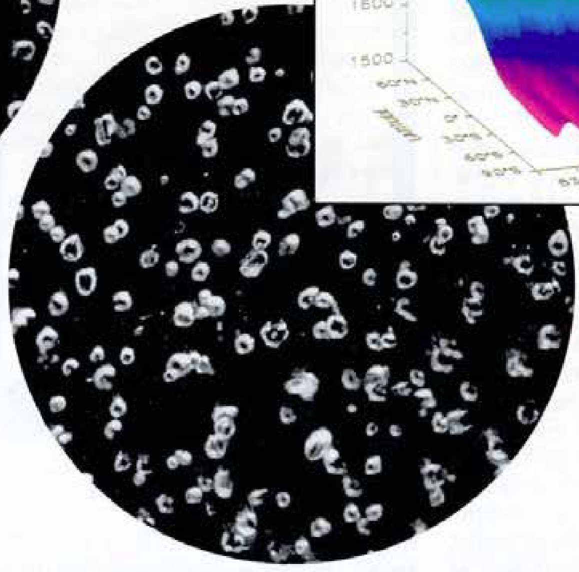
More efficient use of fossil fuels may be reducing the potential impact of one important greenhouse gas, methane, on global warming



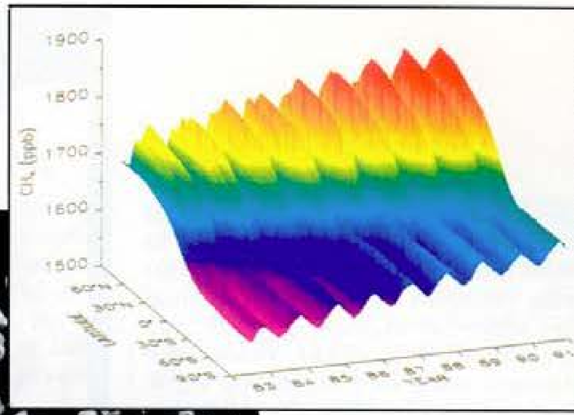
David Whillas

An ice sample, from a depth of about 300m, cut off for gas analysis.





Air bubbles in the DE08 ice core.



Ken Masarie, NOAA/CMDL, U.S.A.

Methane's flying carpet: a coloured-coded three-dimensional representation shows the broad features of the global distribution of atmospheric methane since 1983. Features include the wave-like variation from season to season, the higher values in the Northern Hemisphere and the long-term rise in methane concentrations during the 1980s.

The long-term build-up of atmospheric methane, a powerful greenhouse gas, appears to be slowing globally and may peak within 15 years, according to the findings of a group of overseas and CSIRO scientists. The causes of the apparent slow-down are unknown, although the most likely explanation is human; recent international efforts to conserve energy may be having a significant impact on methane trends. If a slow-down is occurring, it raises new hopes for limiting or delaying possible climate change due to the enhanced greenhouse effect.

Methane (CH_4) has been described as the 'hidden greenhouse gas' — overshadowed by carbon dioxide (CO_2) and less well understood on a global scale, and hence more worrying for scientists and policy-makers set the task of coping with possible impacts of the enhanced greenhouse effect. Some researchers have suggested that it may become the prime greenhouse gas within 50 years.

David Etheridge

The barren, blizzard-swept terrain of Law Dome — an ideal locality for exploring the ice-core records of the global atmosphere.

Although only occurring in trace quantities in the atmosphere, methane is a potent atmosphere-warming agent and is accumulating rapidly — almost doubling its concentration since the early 1800s. It also contributes to higher levels of other gases — tropospheric (lower atmosphere) ozone and stratospheric water vapour — that add to global warming, and consumes hydroxyl (OH), the chief oxidiser of pollutants in the lower atmosphere.

While carbon dioxide has caused most of the increase during the last 200 years in the atmosphere's capacity to trap heat and energy (radiative forcing is the precise term), methane is thought to be directly responsible for about 17% of the rise (almost one-third of the contribution made by CO_2). Stratospheric water vapour — from the decomposition of methane — contributes another 6%.

The Intergovernmental Panel on Climate Change (IPCC) estimated in a report published this year that, on current trends, atmospheric methane concentrations would rise quickly from 1720 parts per billion (p.p.b.) at present to something like 3000 p.p.b. within the next 50 years, by which time its total contribution to radiative forcing would have doubled.

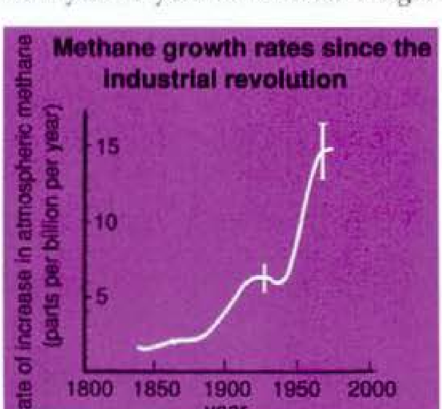
Much of the concern about methane arises from the lack of a detailed understanding of the quantities emitted by the major known sources. Human activities apparently account for some 60% of all emissions — currently estimated at about 500 million tonnes a year. The chief sources are rice-fields, biomass burning (including bushfires and burning-off after forest clearance and crop harvests), tropical swamps and wetlands, termites, livestock and animal waste, landfills and fossil fuels. According to a recent study by a team of American and CSIRO researchers, global emissions from the mining, processing and distribution of fossil fuels (coal, oil and gas) in the 1980s amounted to 80 million tonnes a year or about 16% of all emissions.

Most of the gas is oxidised in the lower atmosphere by the ubiquitous hydroxyl radical (OH) into carbon dioxide and water, while a small amount (about 2%) is absorbed by soil. The researchers point out, however, that wide variations in emission rates from one region to another, coupled with poor knowledge of the atmospheric chemical reactions that destroy methane, make it very difficult to derive a 'global budget' that accurately shows losses and gains in the methane cycle.

Environmental scientists at the United States National Oceanic and Atmospheric Administration and the University of Colorado have for some years been conducting a painstaking global study of methane concentrations, based on more than 10 000 air samples collected since 1983 at about 45 fixed and shipboard sites around the globe. The study leader, Dr Paul Steele, now works at the CSIRO Division of Atmospheric Research in Melbourne.

After decades of accelerating growth in methane concentrations, Dr Steele's measurements show a substantial slowing in its accumulation rate between 1983 and 1990. In other words, methane levels are still growing but the growth is decelerating — the rate of increase is going down. If the 8-year trend continues, global concentrations of methane will reach a maximum in about 2006 and decline thereafter.

The study estimates that the global CH_4 annual growth rate fell from about 13·3 p.p.b. in 1983 to about 9·5 p.p.b. in 1990. Earlier research by Dr Steele and others showed a deceleration in methane accumulation at individual sites in the Southern Hemisphere, but the latest findings indicate that the trend is truly global. The reported deceleration is at odds with findings by another American group suggesting that, from 1980 to 1988, the growth rate in global methane underwent large fluctuations from year to year but without a significant trend in the average rate. That study, however, was based on measurements at only six sites.



The ice record shows an apparent stabilisation between 1920 and 1945, possibly associated with a downturn in fossil fuel production.

Law Dome — a good place to extract cores due to a very high snow accumulation rate.

Dr Steele's results are highly significant whether or not the deceleration continues. If it does, methane will become less important than previously thought in terms of global warming. The IPCC estimate of a temperature rise of about 3°C in the next 100 years is based on the assumption that methane levels will continue upwards; a decline after 2006 would reduce the expected rise by as much as 1°C. From a policy point of view, a decline in methane could 'delay' global warming by 5–10 years. (Scientists typically describe global warming in terms of the impact of a doubling of atmospheric CO_2. Carbon dioxide levels are expected to double by 2080, but when the other greenhouse gases — including methane — are considered, an effect equivalent to a doubling of CO_2 has been expected by 2030.)

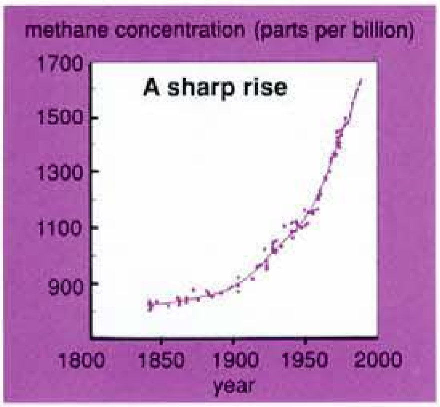
Even if the deceleration does not continue, the results show that stabilising methane levels may be much easier than policy-makers have assumed until now. The study estimates that the total amount of methane in the atmosphere is growing by about 34 million tonnes a year. If we assume that methane molecules have an average atmospheric lifetime of 11 years (the current best estimate), then the evidence suggests methane emissions from all sources are growing by between 1·4 and 6 million tonnes a year, depending on whether the concentration of OH has increased or remained constant during the last decade. Recent calculations suggest that global levels of OH have risen by 1% a year during this period. That means a cut in global emissions by 1·4% a year at most could stabilise the concentration of atmospheric methane.

To date, policy-makers have assumed that cuts of 10–20% would be needed to halt the rise in methane levels. In Australia, for example, which is responsible for about 1% of global methane, the intergovernmental Australian and New Zealand Environment Council has suggested cuts of 50% in emissions from landfills and natural-gas leaks, among a range of strong actions aimed at stabilising total emissions. While such actions may have substantial benefits in their own right — methane is a valuable and relatively clean source of energy — the new findings indicate that global stabilisation or reduction could be achieved quickly with relatively mild environmental measures in most countries. Reducing methane levels might also become a cost-effective way to offset rises in other greenhouse gases.

Dr Steele does not know the cause of the apparent slowdown in methane accumulation, although the study shows the deceleration is two or three times more rapid in the high Northern Hemisphere (30–90°N) than in the other semi-hemispheres, suggesting a dramatic slowdown in CH_4 emissions occurred there during the 1980s. Given that the high Northern Hemisphere contains most of the world's coalfields and gas-producing areas, about half the oilfields and almost all the population of the developed world, it would be reasonable to speculate that recent efforts to conserve energy or burn (previously wasted) methane for electricity generation in the countries of that region have had a marked effect on global methane emissions.

In addition, oil exploration and production practices have changed. Once natural gas (chiefly methane) was considered a nuisance on the oilfields and simply 'vented' to the atmosphere or flared. Now it is more commonly mined in its own right or pumped back into the ground to assist oil extraction. As human and animal populations have continued to grow in the last decade, it is unlikely there has been a cut in methane emissions from sources such as rice production and belching by ruminants. Fossil fuel and landfill sources look to be the prime candidates. Dr Steele is not a speculating type and simply comments that 'direct human actions may have slowed the increase of CH_4'.

Further evidence of human involvement in the methane slow-down comes from research on ice-cores by



The air extracted from the DEO8 ice core shows a steep increase in atmospheric methane concentrations between the 1800s and 1978. The dotted line shows more recent CH_4 concentrations measured at Cape Grim in Tasmania.

Mr David Etheridge (formerly of the Australian Antarctic Division), Dr Graeme Pearman and Dr Paul Fraser, all of the CSIRO Division of Atmospheric Research. In 1987, the Australian Antarctic Division drilled an ice core to a depth of 234 metres in a very-high-snowfall area near Casey in eastern Antarctica. The core (called DE08) was found to contain a remarkably fine historical record of trapped air pockets spanning about 140 years. Analysis of the ice core by the researchers has revealed a profile of methane levels in the Earth's lower atmosphere, extending from the early 1800s until 1978.

Bubbles of air form as fallen snow is squeezed by the weight of fresh falls above it. As the snow becomes denser, turning to firn and then to ice, the bubbles are trapped and 'closed-off' from the outside air, thereby preserving a small sample of air with essentially the same composition as that of the atmosphere. The faster the snow falls in a particular area, the faster the bubbles form and hence the faster the enclosed air becomes isolated from the atmosphere. The very high average snow-accumulation rate at DE08 (1·2 tonnes per sq. m per year) has made it possible to extract air trapped as recently as the late 1970s.

Scientists can determine the age of the ice enclosing the air bubbles by analysing it for hydrogen peroxide (H_2O_2), electrical conductivity and the ratio of oxygen isotopes in the water molecules. Each of these three parameters varies with the seasons, allowing researchers to count the number of years backwards to the age of a particular ice sample. (One irregular event recorded by a big change in the electrical conductivity of DE08 was, the researchers believe, the violent volcanic eruption of Tambora in Indonesia in 1815.) The enclosed air is somewhat younger than the ice because of the time it takes for the fallen snow to become dense enough to form sealed air bubbles.

From a total of 105 ice-core samples, the scientists determined that methane levels rose almost continuously from a low of 823 p.p.b. in 1841 to 1481 p.p.b. in 1978. The lone exception to the rapid growth during that period occurred from 1920 to 1945, when the growth rate stabilised. Having ruled out changes in the snow-accumulation rate or condition of the ice at DE08 as possible causes, the researchers believe the observed stabilisation is a genuine atmospheric feature caused by a change in the level of CH_4 emissions, or the rate at which OH destroys methane or both. While global changes in the atmospheric concentration of OH may be responsible, such changes do not fit with the calculated trends for OH levels during that period.

The most likely explanation, says Mr Etheridge, is a change in the strength of global methane emissions between 1920 and 1945. The extraction and use of fossil fuels have generated significant amounts of atmospheric methane since the beginning of the Industrial Revolution, but the rate of emissions from these sources has not been constant. Other researchers have noted changes in carbon dioxide emissions associated with a downturn in fossil-fuel production during the two World Wars and the Great Depression of the 1930s. Why not methane too?

This, Mr Etheridge concedes, is speculative and dependent on better information about possible changes in the other sources of methane during those years. No discernible change related to atmospheric CO_2 concentrations is apparent for the period, probably because of the longer atmospheric lifetime of the gas (about 60 years) and the ocean's role in buffering changes in CO_2 levels. Methane concentrations, on the other hand, would respond much more rapidly to a change in emissions from fossil fuels.

The issue may be resolved, he believes, by high-precision isotopic studies on the air from the DE08 ice core. Because methane of fossil-fuel origin has a lower proportion of the carbon-13 isotope than that from other sources, it may be possible to identify the cause of the change in methane growth rates at that time.

Taken together, the observations of possible slow-downs in methane accumulation (the first in 1920–45, the second in 1978–90) make an inconclusive but highly intriguing picture. Methane reduction alone will not halt global warming, but it may hold the key to getting one early vic-

Extracting methane from coal reserves

In a $10 million research project, CSIRO is collaborating with the minerals giant MIM Holdings Ltd to develop economical methods to extract methane from the vast black coal reserves of Queensland.

The Bowen Basin coal deposit alone is estimated to contain almost 4 trillion cubic metres of trapped methane, several times the total known reserves of Australia's conventional natural-gas fields. The methane — trapped within the deep coal seams — escapes to the atmosphere as the coal is recovered and processed.

A research team at the CSIRO Division of Geomechanics, led by Ms D'Arcy Horner, is studying the factors that control the rate of release of methane from coal seams. Researchers will drill experimental wells in the Bowen Basin to test the feasibility of methane recovery at rates high enough to make production commercially viable.

If the 3-year research project succeeds, MIM plans to build a 10-megawatt gas-fired power station in Queensland that would draw methane from about 200 wells, and develop a plant to convert methane to methanol — a valuable liquid fuel and chemical feedstock.

The project is part of a world-wide trend to make greater use of the methane released by coal-mining, landfills and sewage. The United States derives nearly one-tenth of its domestic gas from coal-bed methane, while Australia's largest sewage farm at Werribee, near Melbourne, has recently installed equipment to collect and burn the methane emitted from the farm's biological lagoons for power production. The gas will produce enough electricity to power 2000 homes.

Methane burns more cleanly than coal and oil and produces less carbon dioxide, the chief greenhouse gas, for each unit of energy generated. Burning methane also reduces its potential contribution to the enhanced greenhouse effect.

tory against what has been described as our greatest environmental challenge. Unlike carbon dioxide, methane is a valuable fuel that can be readily tapped for cheap energy. And what the research to date appears to show is that a modest cut in methane emissions — due to energy conservation or other measures — can have an impact on the enhanced greenhouse effect, and in effect buy time for further research.

Brett Wright

More about the topic

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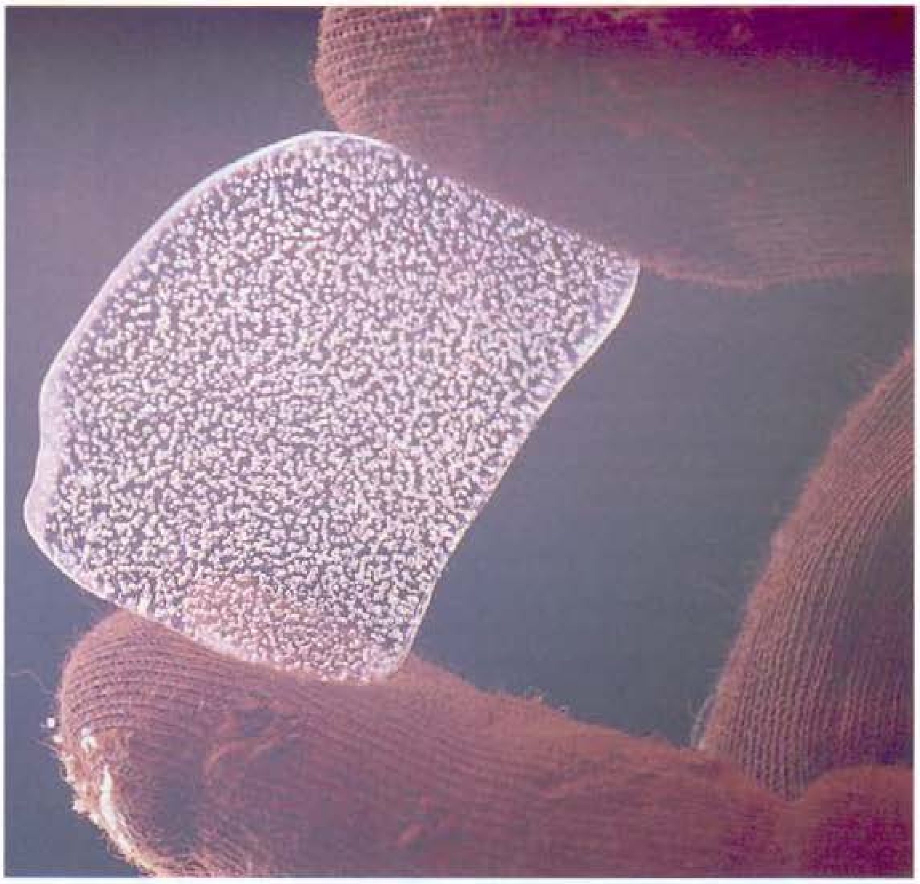

David Whillas

Bubbles in ice, dated to 1819, extracted from a depth of 217m. The scientists have calculated that the air in the bubbles was trapped in 1854.

David Etheridge

Drilling for air: the DEO8 drill site at Law Dome in Antarctica.