Improving Knowledge of Emissions and Sinks of Greenhouse Gases

BACKGROUND

Most countries have made commitments to limit human-caused emissions of greenhouse gases. To determine the success of these efforts, we need to use standardized methods that accurately estimate natural and human caused sources and sinks of greenhouse gases—including carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O)—at a national level. Such estimates are needed to verify an international climate treaty as well as to detect changes in natural greenhouse gas emissions (such as, large-scale release from methane hydrates) or sinks. Also, better understanding of the global distribution of black carbon (which is soot, rather than a greenhouse gas) would both improve our ability to manage its impact on human health and allow better assessment of its contribution to climate change.

METHODS FOR ESTIMATING GREENHOUSE GAS EMISSIONS

There are three primary methods for estimating emissions of greenhouse gases, all of which could be improved to reduce uncertainties in emission estimates, by implementing the Recommendations presented in the last section below.

1. National inventories of emissions and sinks. Countries report emissions to the United Nations Framework Convention on Climate Change using methods developed by the Intergovernmental Panel on Climate Change. Emissions are estimated by measuring a human activity (e.g., tons of coal burned) and multiplying by an emissions factor (e.g., CO_2 emissions per ton). This method can be applied to achieve different levels of accuracy. Relatively accurate estimates are based on country-specific emissions factors and sophisticated models of emission sources. This method is capable of producing reasonably accurate estimates of fossil-fuel CO_2 emissions and sinks, but with larger uncertainties for most other greenhouse gases.

2. Atmospheric methods. The net sum of human and natural sources and sinks can be estimated using atmospheric and/or oceanic measurements (including remote sensing from satellites) of the gases and state-of-the-art mathematical models of air and water flow. These methods offer an opportunity to provide an independent check on inventory estimates. However, they cannot yet be used to estimate greenhouse gas emissions and sinks with sufficient accuracy at the national level, because of: transport error; large and incompletely understood background fluctuations of natural emissions; and the small number and uneven geographic distribution of sampling stations. For example, current atmospheric sampling grids largely avoid major emitters like cities, making it difficult to interpret satellite observations. Moreover, air samples are not analyzed for all isotopes of interest: for example, measurements of radiocarbon [^{14}C] would enable fossil-fuel CO_2 emissions to be separated from non-fossil-fuel sources and sinks).

Black carbon, which also influences atmospheric temperatures, is generally monitored as part of air pollution programs.

3. Direct inventories for land use. Sources and sinks of CO_2 can be estimated using time series of measurements at or near ground level (e.g., above- and below-ground change in carbon content of an ecosystem), and satellite measurements of deforestation and reforestation. If all sources and sinks were measured, CO_2 from ecosystems could be estimated with sufficient accuracy. Estimates of some greenhouse gas emissions are reasonably good (e.g., methane emissions from cattle), but estimates of other greenhouse gases and sources are poor. N_2O emissions vary over space and time, depending on how the land is used (particularly the application of nitrogen fertilizer) and on the local climate, topography, and soil and vegetation properties. Improved fundamental understanding is required before accurate estimates of N_2O can be made.

RECOMMENDATIONS

The ability to accurately estimate greenhouse gas sources and sinks is a prerequisite for international agreements or national emission reduction programs to be effective. This ability depends on improved knowledge and understanding of the sources and sinks of greenhouse gases; the coordinated observation of sources and sinks from surface, airborne, and space-based systems; and open access to information from all countries. Key gaps in knowledge could be filled within a few years by refocusing existing measurement programs on greenhouse gas sources and sinks that are important in each country or region. Implementing the first two steps below would yield the capability to accurately estimate and independently verify emissions of CO_2 from fossil-fuel use and deforestation, which are responsible for about three-quarters of emissions covered under the UNFCCC. Implementing the third step would improve fundamental understanding of the carbon cycle.

1. Annual measurement and report by all countries of the greenhouse gas emissions and sinks that currently can be estimated accurately, including CO_2 emissions from fossil fuel burning and from land use and CH_4 emissions from industrial and biogenic sources. The international science community should assist some countries to build the capacity needed to create accurate inventories of these emissions and sinks.

2. International coordination and cooperation to improve the technology and methods for estimating greenhouse gas emissions and sinks and to adopt appropriate new approaches or technologies as they emerge. A concerted effort for sharing state-of-art technologies, deploying cost-effective measurement instruments around the world and in space, and collaborations for combining and analyzing ground and satellite data would speed results and also build science capacity. Such an effort requires exchanges of measurement and analysis methods and established standards for assessing data quality and estimating uncertainty.

3. International and multidisciplinary research programs should be established or enhanced to focus on understanding the possibility of changes resulting in major and/or rapid increases in atmospheric greenhouse gases. The largest risks include the potential release of CO_2 and/or CH_4 from high latitudes, ocean sediments, changes in ocean biogeochemistry and circulation, and changes in the rain forest carbon budget. It is important to analyze those greenhouse gas fluxes in the framework of global biogeochemical cycles.

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