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Measuring carbon dioxide emissions with a portable spectrometer

Masahiro Kawasaki, Masafumi Ohashi, and Gen Inoue

Optical fiber technology employed in new, compact instruments can be used to measure atmospheric carbon dioxide content in previously unrepresented regions.

Carbon dioxide (CO_2) is the most important anthropogenic greenhouse gas influencing global warming. To determine its major source and sink regions, precise and worldwide measurements of the CO_2 mixing ratio (xCO_2) are required.[1] To obtain xCO_2 values that are averaged for the whole atmospheric column (the total volume of air over a certain area), the solar spectrum needs to be measured in the near-IR region both on the earth's surface at a monitoring site and from space, with a satellite such as the Greenhouse Gases Observing Satellite (GOSAT).

Earth surface monitoring points are concentrated in the mid-latitudes of the northern hemisphere (i.e., where most developed countries are situated). Few are found in tropical regions of developing countries where CO_2 emissions are growing most rapidly. We have developed a portable, compact instrument that is capable of measuring the CO_2 of atmospheric columns, and therefore could help to mitigate this problem.[2]

Our new spectrometer uses commercially available fiber optics and a fiber Fabry-Perot interferometer (FPI), that controls and measures light wavelengths. We based our instrument on a similar CO_2 column spectrometer that uses a conventional solid glass FPI and glass optics.[3] In our fiber FPI instrument, incident sunlight rays are made parallel (collimated) through an optical filter by a fiber collimator that is installed on a small sun tracker. The light is split and passes through two separate optical components: a fiber FPI for CO_2 spectrum analysis and a reference detector for correcting the spectrum intensity due to solar intensity fluctuation.

We can control the wavelengths of the solar spectrum that are transmitted through the fiber FPI by changing its temperature. The transmitted light can thus be aligned, or unaligned, with the

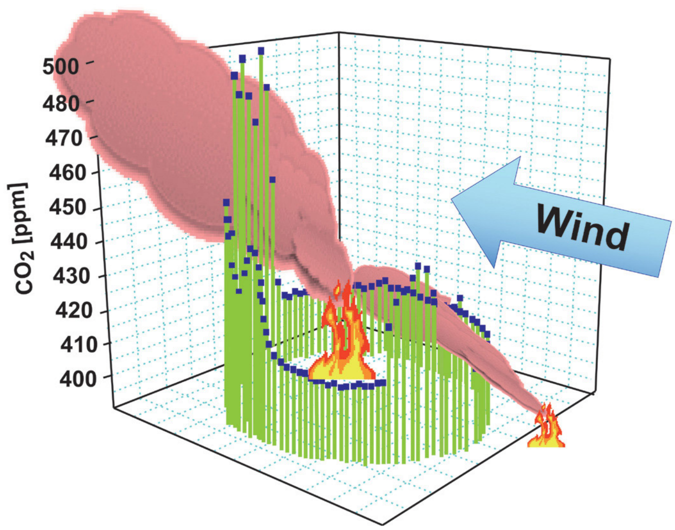

Figure 1. The latent flux method for estimating total carbon dioxide (CO_2) emitted from a targeting area. Vertical bars indicate CO_2 mixing ratios measured by an observation network that surrounds the targeting area where forest or peatland fires occur. By factoring the difference in CO_2 mixing ratios at out- and in-flow points, along with fluxes of air mass, the total CO_2 emitted from the area can be determined.

CO_2 rotational lines that are centered at 1572nm. By modulating the fiber FPI temperature 40s/cycle, we deduce the intensity of both the incident and transmitted light waves through use of the Beer-Lambert law, which relates the absorption of light to the properties of the material through which it is traveling. This allows xCO_2 to be measured with a precision of 1.3ppm under clear sky conditions.[4]

We previously reported measurements of atmospheric CO_2 columns made with a similar, precursor instrument at surface monitoring sites. This instrument consists of a solar telescope attached to a sun tracker and a commercial desktop

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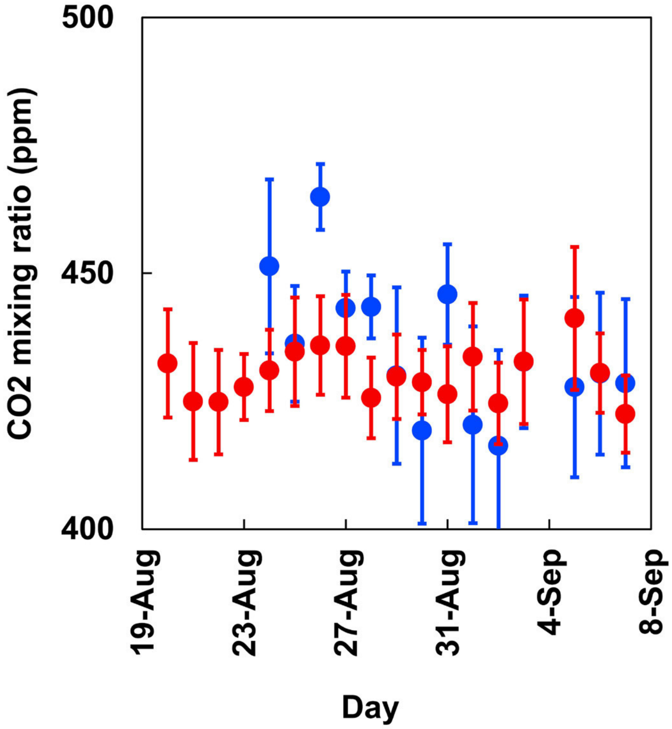

Figure 2. *Average CO_2 mixing ratios (ppm) measured at Parangka Raya (blue) and Banjar Baru (red), which are situated 95km apart at 1.12°S; 113.54°E and 3.26°S; 114.50°E, respectively, in Kalimantan, Indonesia, when forest and peatland fires occurred between 20 August and 5 September 2011.*

optical spectrum analyser (Yokogawa Meters and Instruments model AQ6370) that resolves the rotational lines of CO_2 in 30s scans and effectively provides automatic self-calibration and self-alignment.[2,5] We examined the practicality of using this instrument at a surface monitoring site in parallel with a high-resolution Fourier transform spectrometer (FTS) at the University of Wollongong, Australia. Average column densities measured by the OSA and FTS between July and October 2010 were $(8.369 \pm 0.087) \times 10^{21}$ and $(8.413 \pm 0.056) \times 10^{21}$ molecules/cm^2, respectively, and were thus in good agreement.

Due to its portability, our fiber FPI instrument can be used to measure CO_2 emissions from widely spread and unpredictable local sources, e.g., forest or peatland fires. Figure 1 shows that the local flux of CO_2 can be measured if a CO_2 observation network is constructed to surround the target emission area and if air transfer data is obtained. We used the fiber FPI instruments in central Kalimantan, Indonesia, as a part of measurement reporting validation (MRV) activities for CO_2 emission reduction. In this campaign, two sets of the fiber FPI instruments were deployed parallel to the predominant wind direction at Banjar Baru and Palangka Raya in Kalimantan, respectively. Two months of column data were automatically obtained (some of which is shown in Figure 2). Between 24 and 26 August 2011, large fires were detected by the Moderate-Resolution Imaging Spectroradiometer (MODIS) satellite, and we found large differences in the xCO_2 data between our two observation sites. The difference in CO_2 emissions between the observation sites can be evaluated after factoring in the xCO_2 difference due to wind flux.

During the dry season of El Niño years, large-scale forest and peatland fires have a high occurrence in Indonesia. It has been estimated that 0.81–2.57Gt of carbon was emitted from wildfires over the entire Indonesian archipelago between 1997 and 1998 (making up 13–40% of the world's total fossil fuel emissions).[6] The wide range of this estimate reflects the uncertainty of conventional estimation methods. We are now reviewing and continuing to implement CO_2 emission MRV activities. We are working to establish an operating structure that allows effective monitoring, especially in situations and regions where there has not yet been sufficient data collection to quantitatively assess the CO_2 emissions.

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Author Information

Masahiro Kawasaki
Research Institute for Humanity and Nature (RIHN)
Kyoto, Japan

Masahiro Kawasaki received his PhD from the Tokyo Institute of Technology in 1975. He has been a professor emeritus of Kyoto University and a visiting professor at RIHN since 2010.

Masafumi Ohashi
Department of Information Science and Biomedical Engineering
Kagoshima University
Kagoshima, Japan

Gen Inoue
Atmosphere and Ocean Research Institute
University of Tokyo
Saitama, Japan

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