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Journal of Geology & Geophysics

ISSN: 2381-8719

Perspective

Technology and Applications of CO_2 Remote Sensing

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DESCRIPTION

A key volatile of the Earth system, carbon dioxide (CO_2) is regularly transferred between the hydrosphere, atmosphere, and solid Earth (mantle and crust). The relevant CO_2 degassing mechanisms from the solid earth (i.e., geological CO_2). 600 Metric tons of CO_2 yr^{-1} is a conservative estimate of the total flux of lithospheric CO_2 degassing. Volcanic (magmatic) CO_2 and non-volcanic CO_2 are two types of geological CO_2. Magmatic CO_2 is mainly released through volcanic and geothermal sites, where it can either be visible and easy to see due to the concurrent emission of condensing water vapour, or it can beinvisible and hard to see. Non-volcanic CO_2 is produced by a variety of processes, such as metamorphism, carbonate hydrolysis, or deep burial mechanical disintegration of carbonates. It is released through mud volcanoes, sedimentary volcanism, faults and fractures, seeps, geysers, or mountain ranges. CO_2 emissions from various sources may mix. While Lake Nyos in Cameroon is categorized as a non-volcanic CO_2 emitter, co-emitted Helium points to a magmatic CO_2 source beneath the lake.

Some molecules, such as CO_2, absorb or emit photons of a particular wavelength when light interacts with them. Changes in the optical depth at that wavelength are a direct result of this interaction. This interaction is investigated using the physical analytical technique known as optical spectroscopy. By detecting changes in optical depth, optical remote sensing (hence referred to as RS) is a type of spectroscopy that is applied to a target that is far away from the analyzing device and can be used to estimate the amount of gas present.

Due to interference from other gases, particularly water vapour, not all of the discrete regions of the near and mid infrared optical spectrum where CO_2 significantly absorbs are usable for remote sensing of CO_2. Prior to developing a remote sensing platform, system analysis is essential to determining the best absorption band and the ideal absorption line within the band in order to improve Signal-to-Noise Ratio (SNR) and sensitivity (precision). A compromise between the best spectroscopic characteristics, the technology at hand, and spectroscopic factors such minimal parasitic absorption by other gas species or temperature dependency of absorption strength must often be made when selecting an absorption line.

The majority of RS methods produce absolute molecule number densities of some kind, either range resolved volume number densities (m^3) or route averaged number densities (path densities for horizontal paths, column densities for vertical paths, in cm^2 or m^2). Number densities are frequently converted to mixing ratios for simpler comparison with ambient concentrations (in ppm.m for path averaging, ppm for range resolving techniques). Knowing the (dry) air number density is necessary for this since it affects the measurement path's air pressure, temperature, and humidity profiles. By simultaneously detecting air oxygen and connecting the CO_2 concentration to the oxygen concentration, it is simple and easy to eliminate this dependence.

Aerial coverage to find new vents or diffuse degassing, which opens the door to studying related earth phenomena like volcanic flank degassing, are just a few of the significant advantages of remote sensing of CO_2. Remote sensing offers a safer measuring distance and a faster measurement than traditional *in-situ* approaches, enabling simple time-lapse observations. For instance, changes in a volcano's degassing strength over a period of months that would have gone unreported otherwise could be found, and the source mechanism responsible could be looked into.

The ground-based differential absorption lidar and the ground-based solar open-path Fourier transform spectroscopy are the most accurate (sensitive) remote sensing devices. Optical remote sensing often gives a lower measurement precision than traditional *in situ* techniques and may suffer significantly from ambient noise sources, such as aerosols.

All six applications, such as study on the carbon cycle and warning and forecasting of volcanic eruptions, may benefit even though pure CO_2 remote sensing is of limited utility for Earth science investigations that need multi-gas data (e.g. CO_2 and SO_2).

There are currently very few turnkey systems for remote sensing that are also commercially available. Additionally, these remote sensing packages are typically far more expensive than *in-situ*

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Received: 29-Nov-2022; Manuscript No. JGG-22-21113; **Editor assigned:** 01-Dec-2022; PreQC. No. JGG-22-21113 (PQ); **Reviewed:** 15-Dec-2022; QC. No. JGG-22-21113; **Revised:** 22-Dec-2022; Manuscript No. JGG-22-21113 (R); **Published:** 29-Dec-2022, DOI: 10.35248/2381-8719.22.11.1057.

Citation: Liu D (2022) Technology and Applications of CO_2 Remote Sensing. J Geol Geophys. 11:1057.

sensors. Open-path Fourier transform spectroscopy-based commercial systems stand out because they may offer exceptional measurement precisions, multi-gas detection, and high measurement repetition rates.

Although optical remote sensing has several drawbacks, it can be viewed as an addition to traditional gas measuring techniques rather than a complete replacement for them in the near future.

Satellite-borne remote sensing platforms that measure near-surface CO_2 concentrations are very appealing to Earth scientists because they offer free preprocessed data, a broad geographic reach, aerial coverage, and relatively high measurement repetition rates of the order of days and possibly hours in the future, despite the fact that their spatial resolution does not fit all reviewed Earth science problems. Currently available satellite-based remote sensing technologies, such the Orbiting Carbon Observatory (OCO-2), have measurement precisions and spatial resolution suitable for a variety of Earth science topics connected to CO_2 degassing with significant user potential.