Experiences from the Application of Near-Surface CO_2 and Site Monitoring Techniques at the Illinois Basin - Decatur Project

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Abstract

The Illinois Basin – Decatur Project (IBDP) is a large-scale carbon capture and storage (CCS) demonstration which completed injection of one million metric tons of carbon dioxide (CO_2), captured from an ethanol production facility, into a deep saline reservoir over a period of three years. An extensive Monitoring, Verification, and Accounting (MVA) program was developed to characterize and monitor near-surface and subsurface site conditions. A demonstration project of this scale presented an opportunity to explore emerging technology that could have long-term potential for effective monitoring of CCS sites. Three monitoring techniques used at the IBDP site are summarized here: 1) a prototype "open-path" sensor which used tunable diode laser absorption spectroscopy to continuously monitor atmospheric CO_2 levels, 2) the Greenhouse Gas Laser Imaging Tomography Experiment (GreenLITE), an automated system for measuring the 2-D spatial distribution of atmospheric CO_2 concentrations, and 3) repeat periodic aerial imagery. Technique reliability over an extended observation period was assessed at the IBDP site to evaluate their potential use in longer-term monitoring on a commercial scale. Advantages and limitations of these monitoring techniques are discussed below.

Methods

Two laser techniques and one vaerial image interpretation were evaluated as potential MVA tools at an industrial scale CCS operation. Three factors were used to evaluate these techniques:

1. Operational status for the duration of deployment/observation at the IBDP site;
2. Performance at the IBDP site; and
3. Potential application to a commercial-scale injection project.

Discussion and Results

Open Path Sensor

A prototype "open-path" sensor (OPS) which uses tunable diode laser absorption spectroscopy (TDLAS) was constructed for use at the IBDP site. It was used to continuously monitor atmospheric CO_2 levels along a line of sight approximately 100 m long (Fig 1). The sensor system is intended as a warning system to be used along pipelines and at wellheads for personnel safety and to help verify site storage conditions.

Operation at IBDP: June 16, 2012 to December 22, 2013.

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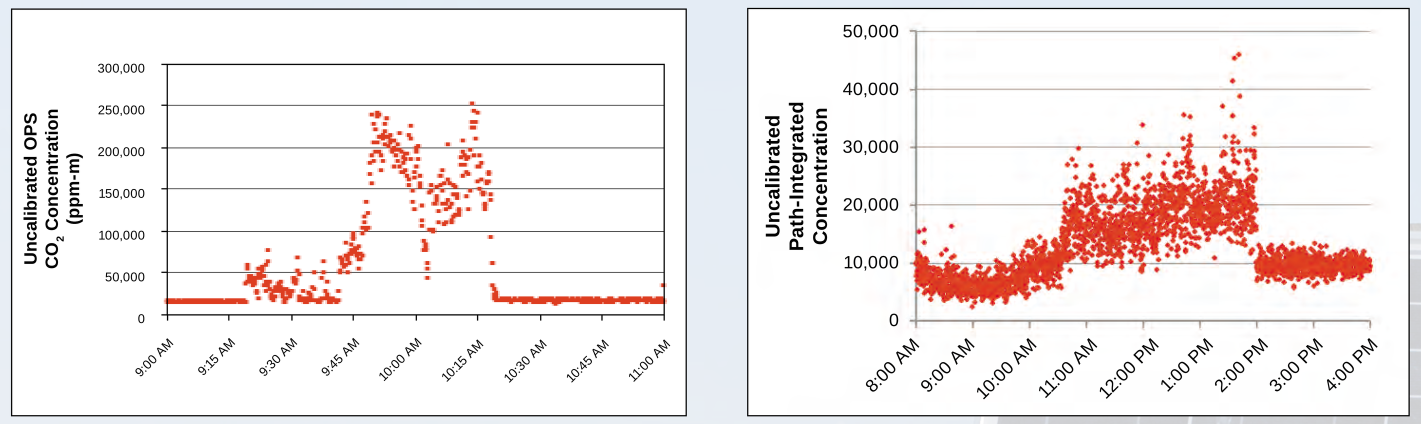
Figure 1. Prototype CO_2 Open-Path Sensor (OPS) installation at IBDP CO_2 injection wellhead in Decatur, Illinois: (a) aerial view of IBDP injection site, and (b) OPS transceiver with solar panel supply.



a b

Figure 2. OPS path-integrated CO_2 concentration monitored during routine pipeline blowdown after well maintenance (a) 9/6/2013, (b) 10/25/2013.

At IBDP site, OPS could detect CO_2 concentration increases in the atmosphere during maintenance operations performed on the injection well (Fig 2).

Potential Application

Tunable diode laser absorption spectroscopy offers a flexible, cost-effective sensing technology for measuring target gases in complex mixtures. The OPS was deployed for one year at the IBDP site, demonstrating long-term operation of a long-path sensor for pipeline and wellhead monitoring, and showing response to changes in ambient CO_2 during maintenance procedures. With refinements, TDLAS systems such as this can be integrated as part of environmental monitoring strategies at CCS sites and may be a cost-effective method to identify anomalous temporal or spatial changes of atmospheric CO_2 concentrations indicative of leakage.

a b

Figure 3. (a) Site layout showing chords from transceivers (T1 and T2) to reflectors. (b) 2-D recreation of the atmospheric CO_2 concentrations collected from the GreenLITE system.

a b

Figure 4. (a) CIR image overflight of the IBDP site and surrounding area, acquired on September 9, 2008. The original image scale is RF 1:19,200 or 1 inch = 1,600 feet. (b) Higher resolution CIR image of the IBDP injection site acquired on September 9, 2008. The original image scale is RF 1:7,200 or 1 inch = 600 feet.

The Greenhouse gas Laser Imaging Tomography Experiment (GreenLITE)

GreenLITE is a laser absorption spectrometer system, which measures the 2-D spatial distribution of atmospheric CO_2 concentrations. This system is an emerging technology that has the ability to detect and visualize near real-time changes in atmospheric CO_2 concentrations. Because it is an automated monitoring technique, it has the potential to reduce environmental monitoring costs.

Operation at IBDP: April 1, 2015 to August 17, 2015.

The configuration of the GreenLITE system at the IBDP site (Figure 3a) consisted of a pair of laser-based transceivers, thirty retroreflectors, a simple weather station, and a set of cloud-based software tools for data processing, storage, dissemination, and the generation of 2-D maps of CO_2 concentration in near real-time. The system was designed so both transceivers could point to each retroreflector sequentially and measure the atmospheric CO_2 concentrations along each path, or "chord", in the measurement field. The monitored area did not include the injection well, but it did include the IBDP deep monitoring well known as Verification Well 1 (VW1). Figure 3b illustrates the CO_2 concentration distribution over the measurement field. Although atmospheric CO_2 concentrations in the study area were periodically larger than anticipated background concentrations (e.g., 400–425 ppm), the measured CO_2 concentrations did not detect any sustained and elevated CO_2 concentrations that would suggest leakage of stored CO_2. The observed concentrations could be correlated with prevailing wind direction and other nearby industrial activity (e.g., ethanol production).

Potential Application

The GreenLITE system offers real-time feedback of atmospheric CO_2 concentrations over large areas via a web-based interface. Its autonomous operation allows for a cost-effective method to detect CO_2 leakage should it occur. Over the five months of deployment, very few manual adjustments were needed. Thus, this system has a high potential for value-added integration into a comprehensive, commercial-scale CCS monitoring program.

Aerial Imagery

The primary objective of airborne remote sensing at the IBDP site was to provide documentation of project-related and industrial activities at the site using high-resolution, digitized aerial photography.

Operation at IBDP: Beginning in September 2008 through present.

High-resolution photographs in both color-infrared imagery CIR and natural color imagery were obtained for the IBDP site (Fig 4). The use of CIR to detect plant stresses related to potential CO_2 leakage was considered, but not used because of the overall cost of the technique and wide range and signal variability of the surface activities to be monitored.

Potential Application

Industrial activities unrelated to a CCS project have the potential to cause significant land disturbances. In addition, typical agricultural practices cause land use changes which can make leak detection by CIR imagery interpretation difficult. Therefore, storage projects and associated monitoring programs should take these variations into account and, if possible, minimize surface disturbances throughout the life of the project. Although CIR-based aerial photography was not a technique that could be applied for long-term injection monitoring at IBDP, aerial photography acquisitions became invaluable for environmental data analysis, validation, and project activity documentation.

References

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