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Development of a rapid, low-cost technique for sensitive CO_2 leakage mapping.

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The storage of vast quantities of anthropogenic CO_2 in deep geological reservoirs has the potential to make an important and relatively rapid contribution to the reduction greenhouse gas loading to the atmosphere. However in order to ensure public safety, monitor for carbon credits, or focus remediation efforts in the unlikely event of a surface leak, surface monitoring of CO_2 must be conducted above a CO_2 geological storage site.

Many methods exist which are presently being tested and applied at natural analogue and industrial sites, each with its own advantages and disadvantages. For example, atmospheric monitoring with eddy covariance techniques give continuous monitoring but are restricted by rapid dilution and a limited capability to precisely locate leakage sites; remote sensing methods have the potential to accurately locate a leak but it must have a sufficient flux rate to have an impact on surrounding vegetation; soil gas and gas flux measurements can also precisely locate a leak but because they involve point measurements a sufficiently fine grid of samples must be collected to ensure that any existing leakage points (which could be relatively small) are found; and infrared laser systems that measure CO_2 in the atmosphere may be quite useful because of their high sensitivity and the potential to vehicle mount them, however their cost is relatively high and dilution is rapid even at the relatively low measuring height of 0.5 to 1.0 m. The present paper outlines recent efforts to develop a low-cost monitoring alternative that can be used to rapidly measure CO_2 concentrations directly at ground level, with the goal of creating an instrument that is pulled behind a walking person or a vehicle for detailed mapping of large areas.

The system involves the use of an infrared detector that monitors CO_2 concentrations once every second from a tube that is dragged along the ground surface. By measuring right at the soil surface the potential for observing CO_2 that is leaking to the atmosphere is greatly increased due to reduced wind-driven dilution and thus CO_2 accumulation within short vegetation. The unit was assessed at the natural test site at Latera, Italy, where geothermally-produced CO_2 is naturally leaking to the atmosphere from various gas vents having different flux rates. A series of profiles were conducted by walking with the unit at a slow pace along a line crossing a number of vents, one with relatively high flux rates of 2,000-3,000 g m^{-2} d^{-1} and other, more-diffuse structures that emit CO_2 from slightly above background biological flux rates (10-50 g m^{-2} d^{-1}) up to 200-400 g m^{-2} d^{-1}. Measurements were conducted during the day with a gentle, irregular breeze blowing, while the grass in the studied field was dead and almost at ground surface; these would not be considered optimal conditions due to the relatively low potential for CO_2 accumulation. Direct accumulation flux measurements were also conducted every 2 – 4 m along the 250 m long line to verify the location of leaking sites.

Despite the non-optimal conditions of these preliminary tests, all transects conducted across the profile were able to locate all gas vents defined by the accumulation flux measurements. It was found that the stability of the infrared detector was critical to differentiate, with a high level of confidence, background areas from areas with only weakly anomalous CO_2 leakage; areas with higher rates of leakage yielded clearly defined anomalies. Memory effects (i.e. the time to return to background) are an issue, and thus work is focussing on instrumentation and survey protocol to minimise this problem. The same profile was then measured a number of times at different heights, and these results indicate how rapidly CO_2 is diluted at even moderate heights above the ground surface (50 to 100cm). Finally a series of profiles were conducted on three separate fields, one where the location of various gas vents is know with reasonably certainty, and another two where it was not known if vents exist. This mapping exercise, which covered approximately 80,000 m^2 with a sample spacing of about 0.75 m and a line spacing of 10m, took about 5 hours. Results highlighted all known vents and located 2 vents that were previously unknown. Work is ongoing to improve the speed of the surveys, test the instrument under different meteorological and plant growth conditions, and to better understand the detection limit of the method.