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The testing of an open-path infrared laser system above naturally-occurring CO_2 gas vents (Latera, Italy): potential for atmospheric monitoring above a CO_2 geological storage site.

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Although recent research has shown that geological storage is a safe and viable technique to rapidly diminish the loading of anthropogenic CO_2 to the atmosphere, it will still be necessary to develop monitoring techniques and strategies which will allay public fears and provide early warning in the unlikely event of a CO_2 leak at surface. Such monitoring will be challenging, as it is known from natural CO_2 emissions that gas is usually released to the atmosphere from isolated, often spatially-restricted points that may be difficult to locate. The issue of detection limit is also important, as the leakage of a relatively small volume from a reservoir is unlikely to be observed with such deep monitoring techniques as 4D seismic surveys, even if this volume could potentially migrate upwards and be released to the atmosphere. Finally the issues of time and cost must also be considered, as regular or "continuous" monitoring using inexpensive techniques increases the chance of early detection and rapid intervention. One approach that has potential to address many of these issues is the measurement of atmospheric CO_2 concentrations using an open path laser. In theory this type of instrument could be permanently installed at a site and make continuous measurements, or could be vehicle-mounted and used for conducting site surveys. The present work describes tests of one such instrument above natural CO_2 leaks occurring in the Latera caldera in central Italy, research conducted within the EC funded Network of Excellence "CO2GeoNet".

The instrument used in this work was the open-path tuneable diode laser (GasFinder2.0) produced by Boreal Laser, which consists of an integrated transmitter/receiver unit and a remote, passive reflector. The laser light emitted from the

transceiver unit propagates through the air to the reflector and returns to the instrument where it is focused onto a photodiode detector. As the wavelength of the laser is absorbed by CO_2, the decrease in the amount of light returned to the detector is directly proportional to the total amount of CO_2 over the entire path length; the resultant units are in ppmm (parts per million metres). Dividing this value by the total path length gives a "path-averaged" concentration in ppm. It is important to understand this concept, as different gas distributions can yield the same path-averaged concentration; for example a 50m path length in which there is a homogeneous distribution of 300ppm CO_2 will give the same response as 10m with 1500ppm CO_2 and 40m with 0ppm CO_2 (i.e. 15000 ppmm, or a path-averaged value of 300ppm).

Experiments were conducted above two Latera sites having known release of natural CO_2 to the atmosphere. The first site consists of a sub-circular gas vent located in a flat field, where the highest flux rates are from the 5m diameter non-vegetated core while lower fluxes occur in a 20m diameter surrounding area. Experiments at this location included measuring in time the atmospheric CO_2 concentrations i) along different transects across the vent core and ii) at different heights across the centre of the vent core. The second site consists of large volumes of gas bubbles being released at the bottom of a shallow creek (creek incision about 3m wide and 1.8m deep, with only 20cm of water). Here the laser was set up on one side and the reflector was set up on the other side at progressively greater distances from the bubbling gas to understand the maximum path distance over which the leaking CO_2 can still be recognised in the signal.

The results of this work highlighted various issues that must be considered if this type of instrument is to be applied to CO_2 geological storage sites. First, the height of the laser and reflector is critical, as atmospheric dilution occurs quickly moving away from the ground surface. Second, fluctuating wind direction and strength had a significant effect on measured CO_2 concentrations due to irregular mixing of background atmospheric air with CO_2-rich gas from depth. This showed that the standard deviation, rather than absolute concentrations, may be a more reliable indicator of leakage. Finally, the tests conducted with ever increasing path lengths above a small but vigorous bubbling gas vent show that for this site and these wind conditions, CO_2 values and standard deviations dropped to background levels over path lengths greater than 80m. The results of these experiments indicate that an open path laser system like this one might be best adapted to localised monitoring of "high risk" sites like abandoned injection wells, or for vehicle-mounted survey systems.