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Near Surface Gas Simulator (NSGS): A Visual Basic program to improve the design of near-surface gas geochemistry surveys above CO2 geological storage sites

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If CO2 were to leak from a geological storage site and be released to the atmosphere, where would it occur and how large would the leak be in terms of dimension and flow rate? There are many options available to monitor storage sites, including deep and shallow geophysical or geochemical methods, biological markers, or remote sensing techniques, each with its advantages and disadvantages. However only the direct measurement of CO2 at the earth's surface, that is soil gas or gas flux analyses, can give a definitive answer to these questions. Considering that these methods involve point measurements, the question has be raised regarding the sampling density that would be needed to locate a leak above a storage site, or, conversely, to ensure that a leak does not exist.

To address this issue we have written a program in Visual Basic which uses highly-detailed, gridded synthetic data (with user-defined gas leakage areas) to study the link between sampling density and anomaly size and to find a sampling strategy which minimises the number of samples collected while maximizing the probability that an anomaly (i.e. a leak) will be found. At the beginning of a run the user is asked to define the location, size, and intensity of leakage areas; these areas are then superimposed on a grid (1 x 1 m step size) of normally-distributed background CO2 flux values. Then the user is asked to provide a series of sampling densities (for example, x = 10, 50, 100, 500, and 1000 samples km-2) and the number of simulations that must be conducted for each sampling density (e.g. y = 100). The program then uses a nested loop structure whereby the synthetic dataset is randomly subsampled at the sampling density "x" for a total of "y" times – each of these smaller datasets is then analysed statistically and spatially using subroutines from the programs Statistica and Surfer, and the resultant data from each simulation for that "x" sampling density is combined to define its statistical distribution. This procedure is then repeated for each specified sampling density.

As expected the range of values for a given sampling density decreases with increased density, however of particular interest was the fact that the trend shows that a logistically-realistic level of sample density is reached that has an acceptably low enough error to give realistic and trustworthy results. The size and type of the anomalies are also critical, and thus will be site dependant and will require integration with geological, structural, and geophysical site characterisation data. Larger, less intense, and more diffuse anomalies can be delineated with reasonably low density regional surveys, whereas small intense gas release points would obviously need higher densities. As such one possible approach may be conduct regional surveys during site assessment work to search for diffuse degassing along gas permeable faults in the area of a potential storage site, whereas more detailed surveys would have to be conducted during the actual monitoring phase on areas that were defined as having a higher potential for leakage pathways (defined during the regional survey or with other means).