Data Release Notes: UK Geoenergy Observatories Glasgow Geothermal Energy Research Field Site (GGERFS) Ground Gas, 2018 and 2019 Surveys

Decarbonisation and Resource Management Programme

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BRITISH GEOLOGICAL SURVEY

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1 Introduction

In 2014, the British Geological Survey (BGS) and the Natural Environment Research Council (NERC) were tasked with developing new centres for research into the sub-surface environment to aid the responsible development of new low-carbon energy technologies in the United Kingdom (UK) and internationally.

Under the United Kingdom Geoenergy Observatories (UKGEOS) project, two sites were chosen, including the Glasgow Geothermal Energy Research Field Site (GGERFS) in the Cuningar Loop-Dalmarnock area in the east of Glasgow (Figure 1). The aims of the GGERFS facility include de-risking technical aspects of mine water geothermal to assess the feasibility of extracting/storing heat energy in an urbanised former coal mine setting (Monaghan 2019; Monaghan et al. 2017; Monaghan et al. 2018).

The initial phase of the GGERFS project entails installing a network of boreholes into the superficial deposits and bedrock in the Cuningar Loop-Dalmarnock area of Glasgow to characterise the geological and hydrogeological setting and assess the potential for shallow geothermal energy. The borehole network is also designed for baseline monitoring to assess the environmental status before and during the lifetime of the project.

A ground gas baseline is considered important at the GGERFS site to enable us to determine if there are significant ongoing ground gas contributions from sources such as (i) leakage from mine workings/features related to legacy mine workings (ii) gas generated from components of the made ground (building rubble, mine water, other waste) and (iii) natural soil processes. The made ground at Cuningar Loop is known to have been formed from a range of prior land uses (see Ramboll 2018 a, b) and is commonly around 10 m thick.

Ground gas measurement is an important tool for monitoring geoenergy sites since sensitive measurements of, for example, CO_2, CH_4 and associated gases can be made directly within the biosphere in which we live. Monitoring of ground gas in the vadose zone has been undertaken as part of a broader GGERFS environmental monitoring effort that includes groundwater, soil and surface water chemistry, ground movement and seismicity. The intention of ground gas monitoring, indeed the environmental monitoring effort as a whole, is to characterise pre-existing i.e. pre-operational or baseline conditions, particularly with respect to former coal mining, building demolition, waste disposal/landfill, or other industrial activities, before significant development occurs in relation to GGERFS. As such, it should be noted that the August 2018 survey precedes any development of GGERFS and can be considered 'baseline' in the conventional sense, whereas the May and October 2019 surveys were conducted alongside site construction but ahead of site operation.

Approaches to monitoring ground gas may include long term continuous monitoring using permanently deployed instruments, and discrete surveys involving mobile, wide area screening techniques (for example open path laser, cavity ring down laser) to augment high density grids of detailed point measurements.

Point measurement data from ground gas surveys conducted at the Glasgow Geothermal Energy Research Field Site (GGERFS) in August 2018, and May and October 2019 are reported. Ground gas is defined here as:

a. gas concentrations in the shallow (c.70-100 cm below ground level) unsaturated zone of the subsurface, and
b. gas flux at the soil-atmosphere interface

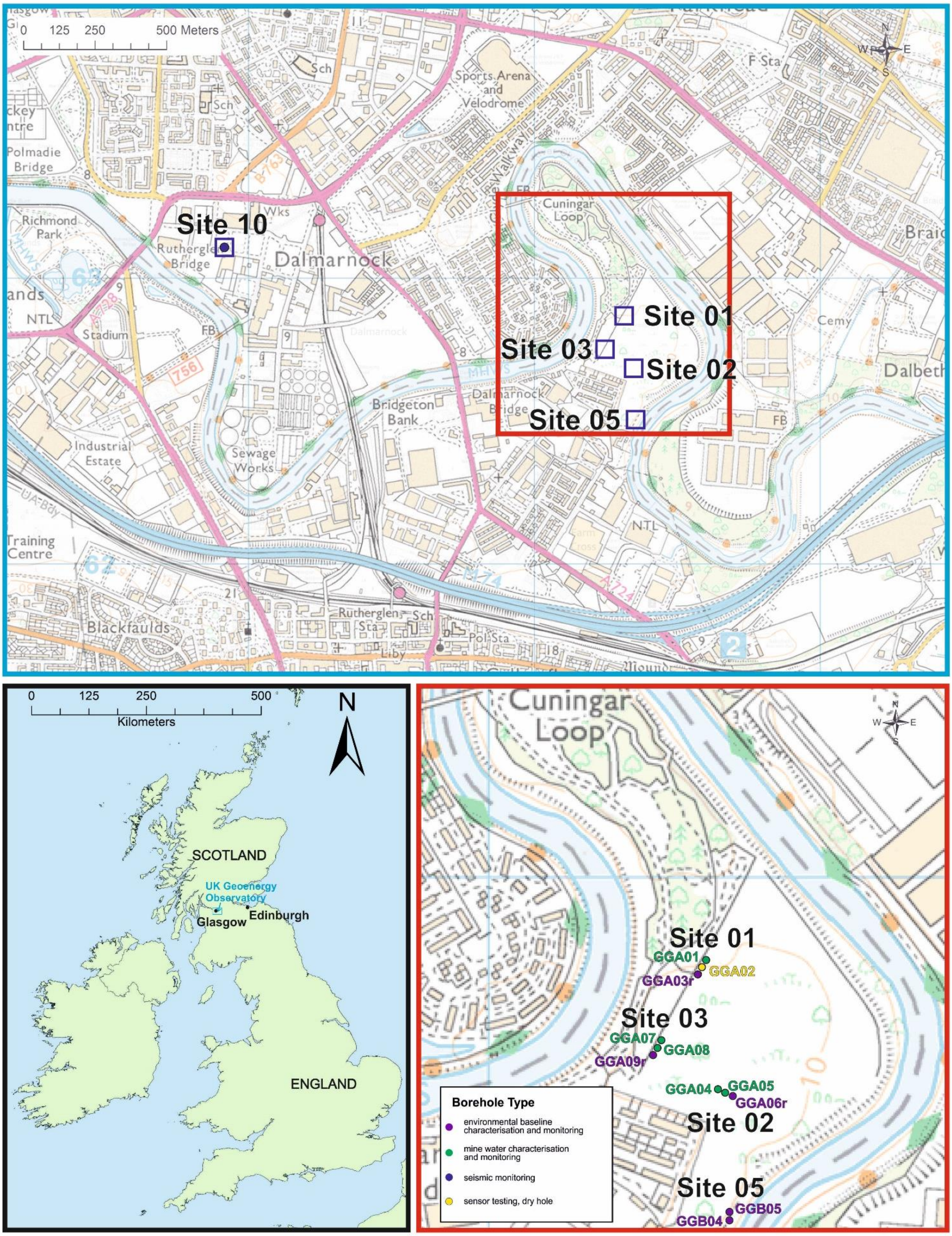

Figure 1 Location of the UK Geoenergy Observatory in Glasgow, overview of all boreholes sites (above) and details of borehole locations at Cuningar Loop (below). Base maps from Ordnance Survey data © Crown Copyright and database rights 2020.

These measurements correspond directly to concepts of 'soil gas' or 'near surface soil gas' discussed elsewhere in the literature (for example, Ball et al., 1992; Beaubien et al., 2013).

Data coverage is restricted to the vicinity of GGERFS01, GGERFS02, GGERFS03 and GGERFS05 (Figure 2).

2 Methods

Ground gas surveys consisted of up to 83 point measurements collected at 20 m spacing across four pre-determined locations within the GGERFS site located to the south of the Cuningar Loop Woodland Park (GGERFS01, GGERFS02, GGERFS03 and GGERFS05, Figure 2, Table 1) in August 2018, and May and October 2019. The coordinate system used was British National Grid. Grid coordinates are accurate to 5 m in ideal conditions i.e. where not obstructed by vegetation/tree canopy etc; where this was not possible, grid coordinates were located using measuring tape.

Ground gases were determined by positioning an 8 mm diameter steel tube in the ground to a depth of 70 cm below ground level ('standard depth', Table 3). Samples of ground gas were pumped directly to a field instrument for analysis using a Geotechnical GA5000 landfill gas analyser (CO_2, O_2, H_2, H_2S and 'residual balance', see Table 3) or a Huberg LaserOne® methane analyser. Occasional gas samples were also collected into evacuated glass vials for laboratory analysis of $\delta^{13}C$ in CO_2 to help inform the interpretation of soil gas data.

Gas flux was determined by measuring the rate of flow of CO_2 and CH_4 into an accumulation chamber of known volume (2.8 $\times 10^{-3}$ m^3) placed at the soil surface, using a portable WEST Systems Fluxmeter®.

Note also that it is sometimes not possible to obtain data for all parameters at all sample points due to prevailing ground conditions (e.g. buried material, made ground, ongoing works). In addition to this data release, a trial wide area screen was also undertaken but, as the geographical extent is no longer directly relevant to the construction of GGERFS, data is not further used or released as part of the baseline data set.

3 Data

Ground gas data are provided as data tables in csv format for each survey. Three data files are provided:

1. *GGERFSGasSurveyAug2018.csv*
2. *GGERFSGasSurveyMay2019.csv*
3. *GGERFSGasSurveyOct2019.csv*

Details of parameters and the general approach taken to quality assurance and control (QA/QC) are given in Table 2. Soil gas survey methods fall outside the remit of BGS technical (e.g. ISO 17025 or other) accreditation, however the general principles of quality assurance and control of data are applied. Measuring equipment is subject to certified servicing and calibration by the manufacturer on prescribed schedules. In-house quality control checks, using commercially-available gas mixtures (e.g. CH_4, CO_2, O_2 and H_2S) at a range of relevant concentrations, verify the performance of portable gas analysers before deployment. Data can be provided on request. Instrument performance and ongoing data quality are monitored on an ongoing basis and re-checked, as required, in the field. Finally, data entry and transfer, and any calculations or manipulations, are independently verified before issue.

Flux data are produced by the field instrument in mol/m^2/day and are converted to g/m^2/day using the relative molar mass of CO_2 or CH_4 as appropriate. Consistent CH_4 flux was not detected in any survey (see note in Table 2) and is not therefore reported. Concentrations of the components of ground gas are reported as collected from the instrument at the time of sampling, without further calculation or conversion. Data notes, definitions of abbreviations used, and relevant comments (e.g. comment on 'standard depth') are provided in Table 3.

Note that while the coordinates for sampling grids in Figure 2 are idealised, in practice the true sample points were within 5 m of their target (see Methods). For other parameters (concentrations of soil gas components for example), limitations with the current software used for reporting data mean that the number of significant figures quoted in data tables may not be representative of actual uncertainty and data should be considered accurate to no more than three significant figures. Total uncertainty in any given ground gas measurement is likely to be several orders of magnitude higher than instrumental uncertainty due to subsurface variability arising from GGERFS' complex land-use history.

4 Using the data

Ground gas survey data forms part of a broad, multidisciplinary monitoring effort at GGERFS.

The ground gas data provided here can be used to create map layers using GIS software to examine the spatial distribution of single parameters (for example CO_2 flux based on August 2018 data shown in Figure 3), or to visualise relationships between parameters (the example in Figure 4 shows O_2 concentration plotted against CO_2 concentration for the August 2018 survey points, alongside typical relationships for dominant soil processes Romanak et al., 2012). When using the data, be aware that the number of samples (rows) and parameters (columns) differ between csv files as a result of prevailing ground conditions at the time of survey. Note also that datasets may contain non-numeric characters (e.g. 'NA', 'NG', or '‰') which may affect downstream data import and analysis.

Survey data should be considered in the context of complementary data such as water and soil geochemistry (see https://www.ukgeos.ac.uk/data-downloads) and atmospheric monitoring data where available. Data from a single ground gas survey will not, in isolation, provide a robust assessment of pre-operational ground gas. Data from surveys undertaken in different seasons (as these three surveys were) should not be combined without considering the likely effects of fluctuating natural soil processes (bacterial oxidation, photosynthesis/respiration) that are known to strongly influence apparent concentrations and migration of ground gases.

BGS considered whether the gas fluxes, and concentrations of major and trace ground gas components, measured during these three surveys indicate inputs of mine gases originating from earlier land-use. Based on the likely compositions of mine gas (principally percentage concentrations of methane and/or CO_2 with deficient O_2 (Appleton et al., 1995)) we could find no evidence to suggest ground gas was significantly impacted by mine gas:

- Methane concentrations in ground gas were generally comparable to typical background atmospheric concentrations (<3 ppm by volume) and flux of methane from soil to atmosphere was too low to be measured in most cases;
- CO_2 concentrations in ground gas were generally low; in the isolated locations where CO_2 concentrations were moderately elevated (10-20% by volume) compared to surrounding sample points in the same survey (up to 10% by volume), they coincided with reduced concentrations of O_2 in a stoichiometric relationship typical of photosynthetic production of CO_2 in soils, mixed with microbial oxidation of CH_4 to CO_2 (see example in Figure 4);
- CO_2 flux data are comparable to that of other UK rural (Ward et al., 2019) and former landfill (unpublished) sites surveyed by BGS;

- Elevated H_2 concentrations found at GGERFS02 and 03 in May 2019 were not as evident in August 2018 or October 2019; they may be related to corroding material in the shallow subsurface or a result of transient ground conditions. Concentrations of hydrogen are in the range 0-65 ppm by volume, four orders of magnitude below the lower explosive limit for H_2 (4%), so do not pose an explosion risk.
- H_2S was not detected at concentrations greater than 1 ppm by volume in ground gas, except at two locations during the October 2019 survey where the maximum concentration of H_2S in ground gas was 38 ppm by volume, four orders of magnitude below the lower explosive limit for H_2S (4.5%).
- Since the concentrations of CO_2, CH_4 and O_2 in ground gas do not suggest a strong influence from mine gas, H_2 and H_2S are unlikely have originated from mine gas either.

5 Upcoming data releases

Data from subsequent ground gas monitoring activities at GGERFS will be released as they become available. In the longer term, once instruments have been installed on site, continuous monitoring data for CO_2 and CH_4 concentrations in soil and in the lower atmosphere should become available, along with any subsequent ground gas surveys conducted in the operational stages of GGERFS.

Table 1 Breakdown of total ground gas and flux sample points by GGERFS site

Site	Number of sample points
GGERFS01	50
GGERFS02	12
GGERFS03	12
GGERFS05	9
Total sample points	**83**

Table 2 Summary of data acquisition, rationale and release datasets for ground gas

Sample type	Near surface ground gas ('ground gas') – occasional/ad hoc walkover surveys
Detail sample type	Ground gas and surface gas flux point measurements for a range of inorganic determinands from GGERFS 01, 02, 03 and 05
Precision, accuracy and detection limits	In house quality control checks before deployment as appropriate. Accuracy by manufacturer calibration at scheduled service, typically 0.5-1% for majors CO_2, O_2 and CH_4. Precision not reported.
Release frequency of analyses	As available

Analysis	Parameter	Units	Laboratory	Accreditation	Parameter ID	Rationale for analysis
Sample point	Sample point ID	British National Grid	NA	NA	SITE_ID	
GPS location, BNG	Easting	NA	NA	NA	Easting	
	Northing	NA	NA	NA	Northing	
Date, time	Date/time of sampling	dd/mm/yyyy hh:mm in BST	NA	NA	DATE	
Field measurement at c.70-100 cm below ground surface	CH_4	volume ppm	Field	NA	Laser 1 CH4 (ppm)	Concentration of greenhouse and other gases, to establish the presence of ground gases/mine gas at the surface or near surface
	CO_2	volume %	Field	NA	GA5000 CO2 (%)	
	O_2	volume %	Field	NA	GA5000 O2 (%)	
	H_2	volume ppm	Field	NA	GA5000 H2 (ppm)	
	H_2S	volume ppm	Field	NA	GA5000 H2S (ppm)	
	Residual balance	volume %	Field	NA	GA5000 BALANCE (%)	
Field measurement at ground surface	CH_4	$g/m^2/day$	Field	NA	Not detected*/reported	Gas flux, to establish gas migration from upper soil to lower atmosphere and/or identify gas migration pathways.
	CO_2	$g/m^2/day$	Field	NA	CO2 Flux (g/m2/day)	
^{13}C in CO_2 by GC-IRMS	^{13}C in CO_2	$\delta^{13}C_{V\text{-}PDB}$ (‰)	Iso-Analytical Limited	NA	Isotope_data_d13CV_PDB_‰	Supporting information on source apportionment/provenance of ground gas CO_2

*with the exception of a single unexplained value of 0.282 $g/m^2/day$ recorded at GGERFS01-40 during the October 2019 survey.

Table 3 Notes on data

Term	Definition	Comments
NA	Not accessed/not accessible	
ND	No data	
NG	No gas	Repeated attempts to locate adequate gas flow to allow ground gas measurement failed, usually due to subsurface material preventing suitable positioning of the ground gas probe. Corresponding gas flux measurements were often still possible.
Standard depth	c.70-100 cm below ground level (b.g.l)	Standard depth of c.70 cm for collection of ground gas ensures isolation from, and dilution by, ambient atmospheric gas. Gas collected at c.40 cm or shallower risks being mixed with ambient air. It should be noted that four ground gas samples from the May 2019 survey (GG02-04, GG02-07, GG05-01 and GG05-03) were collected at c.50 cm b.g.l, and may be affected by ambient atmospheric gas.
Residual balance	Balance = 100% - (% CH_4 + % CO_2 + % O_2)	Enables an estimation of residual N_2 where: Residual N_2 = Balance - (O_2(%) x 3.76), Balance = 100% - (% CH_4 + % CO_2 + % O_2), and 3.76 is the ratio of O_2 to N_2 in ambient air i.e. 79/21

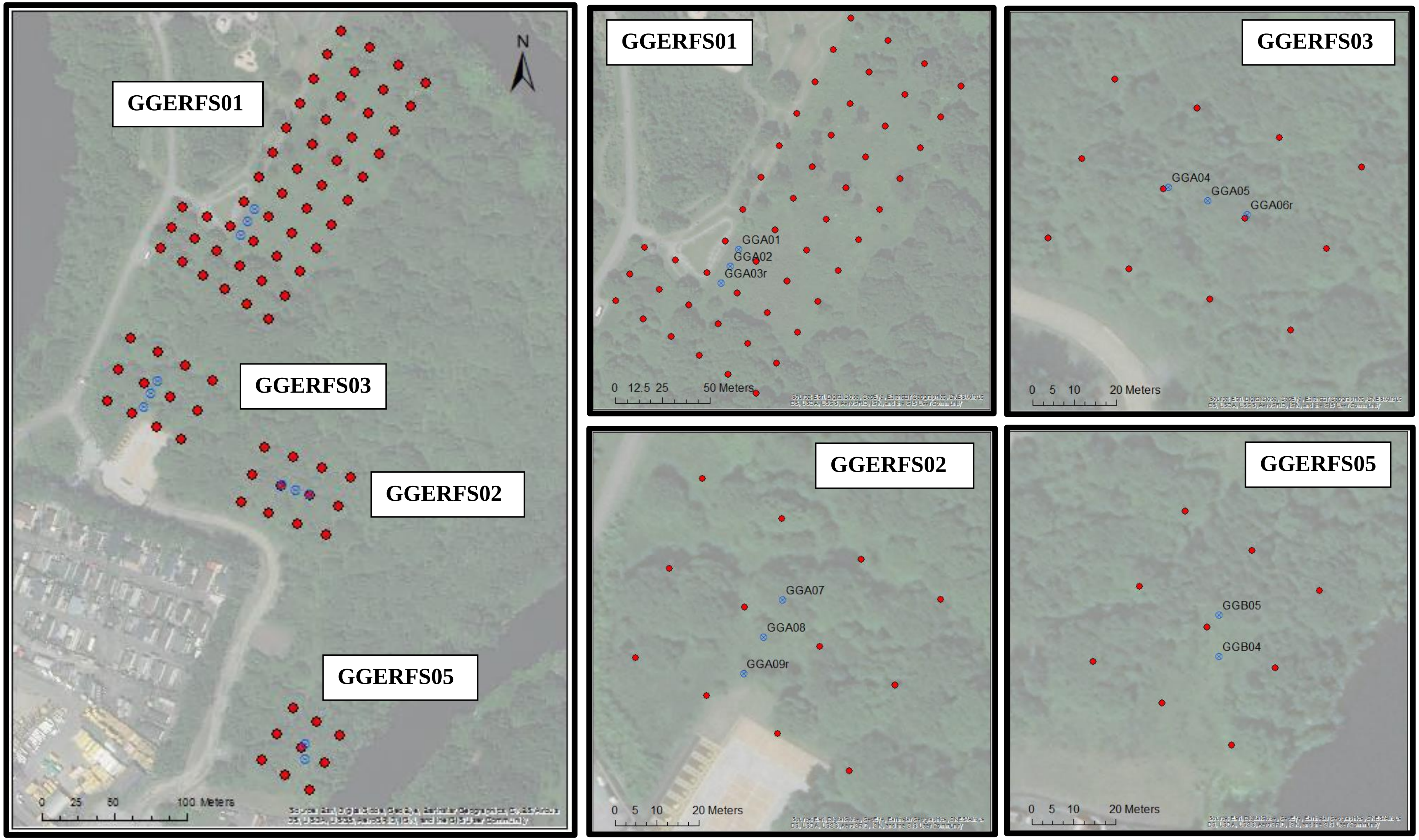

Figure 2 GGERFS01, GGERFS02, GGERFS03 and GGERFS05 point measurement grids for ground gas surveys. Boreholes shown as blue crossed circles. World Imagery Basemap Sources: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community.

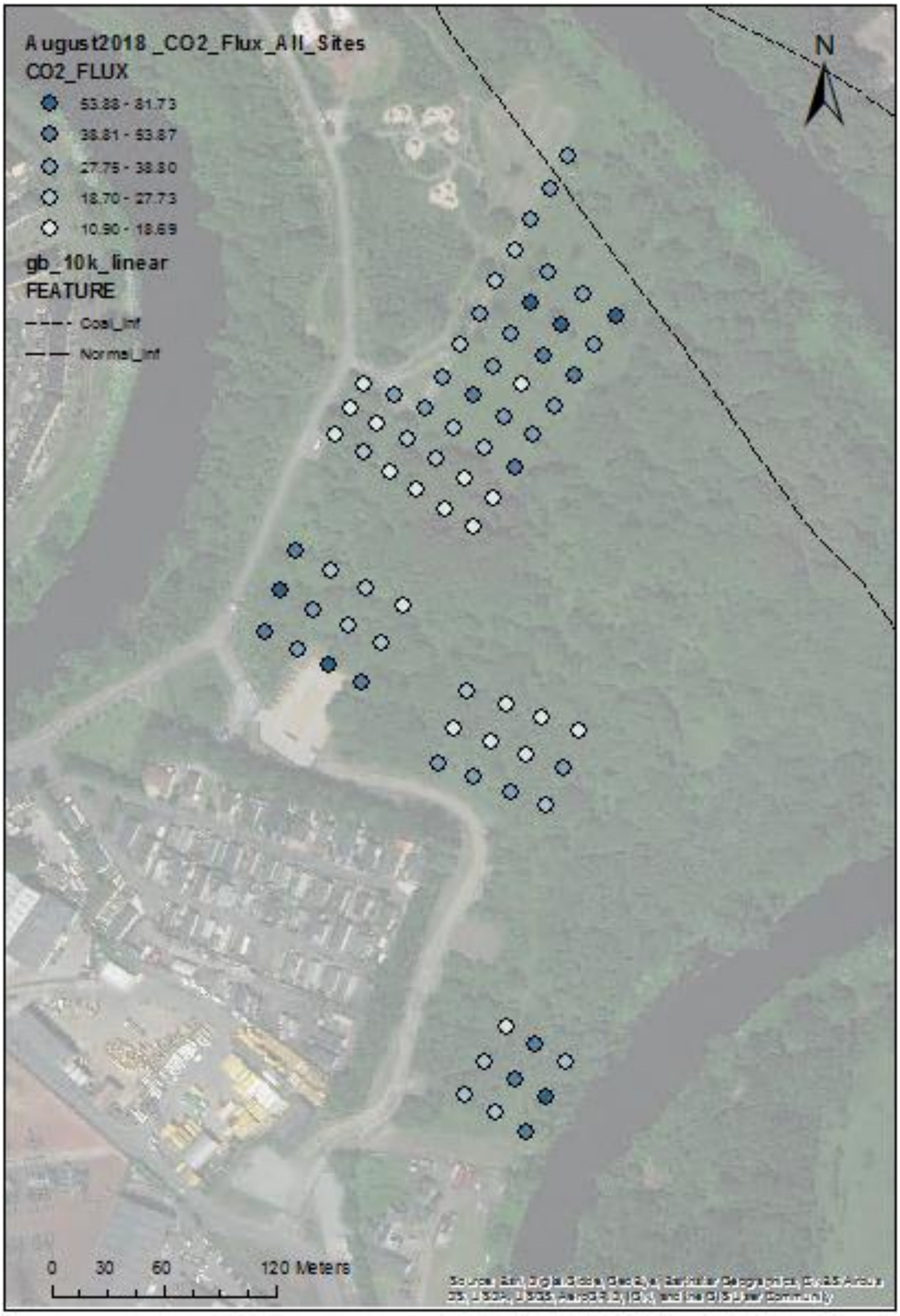

Figure 3 Example geospatial mapping of CO_2 flux in ArcMap® based on August 2018 survey data. World Imagery Basemap Sources: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community.

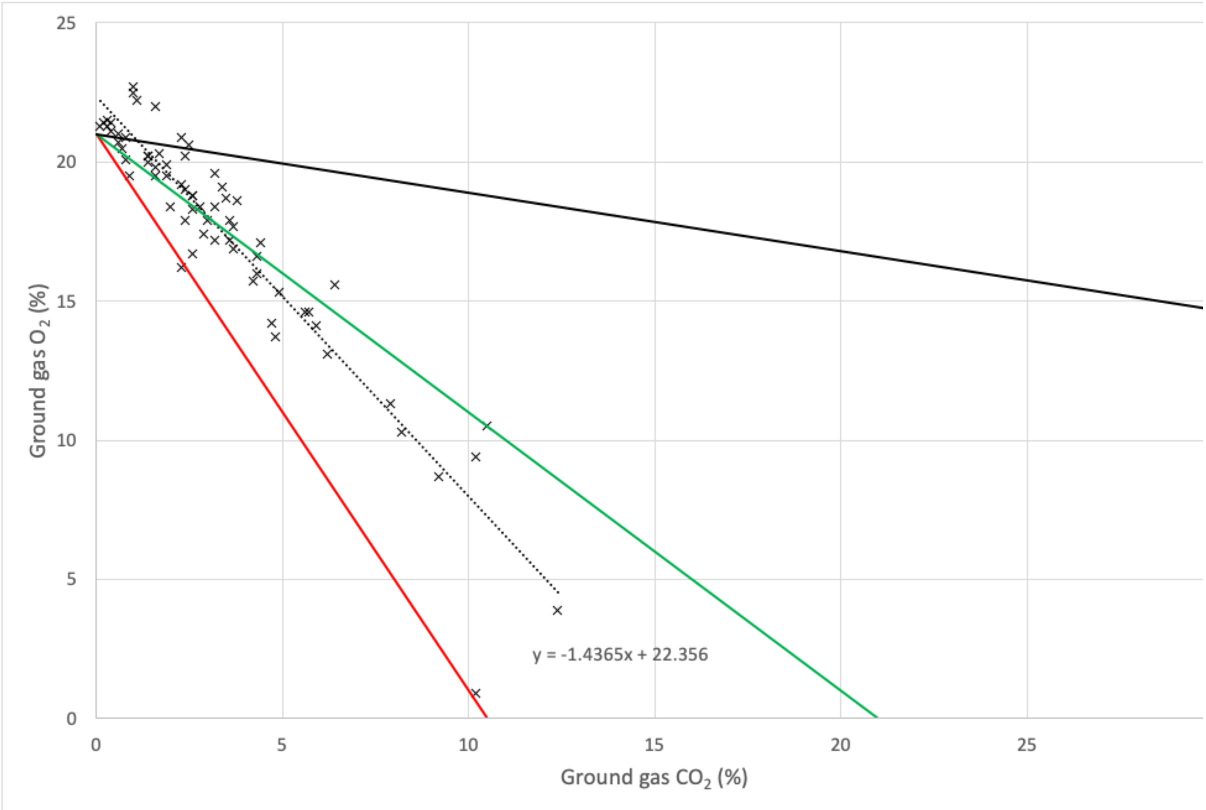

Figure 4 Example O_2 concentration plotted against CO_2 concentration for August 2018 survey points (black crosses) with linear regression (broken black trendline and equation), alongside typical stoichiometric relationships for dominant soil processes: solid red = bacterial oxidation of methane to CO_2; solid green = photosynthetic production of CO_2, solid black = input of external source of CO_2.

6 References

APPLETON, J D, HOOKER, P J, AND SMITH, N J P. 1995. Methane, carbon dioxide and oil seeps from natural sources and mining areas: characteristics, extent and relevance to planning and development in Great Britain. *British Geological Survey Technical Report*, WP/95/1 (Keyworth, Nottingham).

BALL, T K, PEACHEY, D, AND VICKERS, B P. 1992. Geochemical Methods Handbook, Volume 3: Soil gas techniques for use in geochemical surveys overseas. *British Geological Survey Research Report* SI/92/3 (Keyworth, Nottingham).

BEAUBIEN, S E, JONES, D G, GAL, F, BARKWITH, A K A P, BRAIBANT, G, BAUBRON, J C, CIOTOLI, G, GRAZIANI, S, LISTER, T R, LOMBARDI, S, MICHEL, K, QUATTROCCHI, F, AND STRUTT, M H. 2013. Monitoring of near-surface gas geochemistry at the Weyburn, Canada, CO_2-EOR site, 2001–2011. *International Journal of Greenhouse Gas Control*, Vol. 16, Supplement 1, S236-S262.

ROMANAK, K D, BENNETT, P C, YANG, C, AND HOVORKA, S D. 2012. Process-based approach to CO_2 leakage detection by vadose zone gas monitoring at geologic CO_2 storage sites. *Geophysical Research Letters*, Vol. 39, L15405.

WARD, R S, SMEDLEY, P L, ALLEN, G, BAPTIE, B J, BARKWITH, A K A P, BATESON, L, BELL, R A, BOWES, M, COLEMAN, M, CREMEN, G, DARAKTCHIEVA, Z, GONG, M, HOWARTH, C H, FISHER, R, HAWTHORN, D, JONES, D G, JORDAN, C, LANOISELLÉ, M, LEWIS, A C, LISTER, T R, LOWRY, D, LUCKETT, R, MALLIN-MARTIN, D, MARCHANT, B P, MILNE, C J, NOVELLINO, A, PITT, J, PURVIS, R M, RIVETT, M O, SHAW, J, TAYLOR-CURRAN, H, WASIKIEWICZ, J M, WERNER, M, AND WILD, S. 2019. Environmental Monitoring - Phase 4 Final Report (April 2018 - March 2019). British Geological Survey Open Report OR/19/044.

MONAGHAN, A A, Ó DOCHARTAIGH, B E, FORDYCE, F M, LOVELESS, S, ENTWISLE, D, QUINN, M, SMITH, K, ELLEN, R, ARKLEY, S, KEARSEY, T, CAMPBELL, S D G, FELLGETT, M, MOSCA, I. 2017 UKGEOS: Glasgow Geothermal Energy Research Field Site (GGERFS): initial summary of the geological platform. Nottingham, UK, *British Geological Survey Open Report,* OR/17/006. http://nora.nerc.ac.uk/id/eprint/518636/

MONAGHAN, A A, STARCHER, V, Ó DOCHARTAIGH, B E, SHORTER, K M, BURKIN, J. 2018. UK Geoenergy Observatories: Glasgow Geothermal Energy Research Field Site: science infrastructure. Nottingham, UK, *British Geological Survey Open Report,* OR/18/037 http://nora.nerc.ac.uk/id/eprint/521444/

MONAGHAN, A A, STARCHER, V, Ó DOCHARTAIGH, B E, SHORTER, K M, BURKIN, J. 2019. UK Geoenergy Observatories : Glasgow Geothermal Energy Research Field Site: Science Infrastructure Version 2. Nottingham, UK, *British Geological Survey Open Report*, OR/19/032 http://nora.nerc.ac.uk/id/eprint/522814/ http://nora.nerc.ac.uk/id/eprint/518636/

RAMBOLL for GGERFS planning application for South Lanarkshire Council, 2018a. GLASGOW GEOTHERMAL ENERGY RESEARCH FIELD SITE: CUNINGAR LOOP, GGERFS01-05 PHASE I ENVIRONMENTAL REVIEW. Available online at https://publicaccess.southlanarkshire.gov.uk/online-applications/caseDetails.do?caseType=Application&keyVal=P7OTP9OPHQJ00

RAMBOLL for GGERFS planning application for South Lanarkshire Council, 2018b. UK GEOENERGY OBSERVATORIES: GLASGOW GEOTHERMAL ENERGY RESEARCH FIELD SITE ENVIRONMENTAL REPORT. Available online at https://publicaccess.southlanarkshire.gov.uk/online-applications/caseDetails.do?caseType=Application&keyVal=P7OTP9OPHQJ00

ROMANAK, K D, BENNETT, P C, YANG, C, AND HOVORKA, S D. 2012. Process-based approach to CO_2 leakage detection by vadose zone gas monitoring at geologic CO_2 storage sites. *Geophysical Research Letters*, Vol. 39, L15405.

WARD, R S, SMEDLEY, P L, ALLEN, G, BAPTIE, B J, BARKWITH, A K A P, BATESON, L, BELL, R A, BOWES, M, COLEMAN, M, CREMEN, G, DARAKTCHIEVA, Z, GONG, M, HOWARTH, C H, FISHER, R, HAWTHORN, D, JONES, D G, JORDAN, C, LANOISELLÉ, M, LEWIS, A C, LISTER, T R, LOWRY, D, LUCKETT, R, MALLIN-MARTIN, D, MARCHANT, B P, MILNE, C J, NOVELLINO, A, PITT, J, PURVIS, R M, RIVETT, M O, SHAW, J, TAYLOR-CURRAN, H, WASIKIEWICZ, J M, WERNER, M, AND WILD, S. 2019. Environmental Monitoring - Phase 4 Final Report (April 2018 - March 2019). British Geological Survey Open Report OR/19/044.