User Guide to GHG Eddy Covariance Data

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Document Description
This document is a user guide to the greenhouse gas data captured using the Eddy Covariance analysers on the North Wyke Farm Platform (NWFP)

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Preface

Overview

The North Wyke Farm Platform (NWFP) represents a large investment by BBSRC in the future, to not only study but also improve grassland livestock and arable systems in a national and global research asset linked to real-world farming. It is a world-class facility and a key member of the Global Farm Platform network http://www.globalfarmplatform.org/ which attracts researchers from different communities and disciplines seeking to develop sustainable ruminant production systems. The NWFP provides access to a range of in situ state-of-the-art instrumentation in hydrologically isolated (sub-) catchments to better address key issues in sustainable agriculture related to:

- A reduction in energy and greenhouse gas emissions for both environmental and economic reasons.
- Using plants to manage soils and hydrology.
- Efficient nitrogen and phosphorus cycling in grassland and arable systems.
- Resilience of soil biota and their functions in land-use change.
- Impact of land management on carbon cycling and storage.
- Water resource use efficiency.
- Systems modelling to design optimal grassland and arable production systems.

Past, Current and Planned Treatments

The platform currently consists of 2 pasture-based livestock systems and 1 arable system, each of which consist of five component catchments over 21 ha. Catchments comprise single or multiple fields, that are heavily monitored to provide fine resolution data on all inputs, outputs and events. In addition, there is a housed system where cattle are reared indoors from weaning to slaughter.

The timeline of each system's treatment are as follows:
• From April 2011 to March 2013, all three pasture-based livestock farming systems were as one (permanent pasture) with no separate treatments in operation. This is the baseline period.

• From April 2013 to September 2015, two of three systems gradually transitioned into the first post-baseline phase, one re-sown with high sugar grasses (**red system**), the other re-sown with high sugar grass, white clover mix (**blue system**). The third continued as permanent pasture (**green system**) and will always do so, for long-term monitoring.

• From September 2015 to April 2019, the first post-baseline phase was in full operation across all three livestock farming systems and pasture treatments.

• From April 2019, the first post-baseline phase embarked on a transition to a second post-baseline phase, where the **red system** transitioned to an arable system growing human edible crops. Given the transition to arable cropping, cattle and sheep production are no longer associated with this system. Instead, cattle previously linked to the system are permanently housed from weaning to slaughter. This represents a fourth (**brown system**) treatment for evaluation of more intensive finishing. Sheep production is only focussed on the green and blue systems.

For more information, click on the links below:
- Core Remit and Hypotheses
- North Wyke Farm Platform Website

1 Introduction

The North Wyke Farm Platform (NWFP) was established during 2010 to 2011 and is a National Capability funded by the Biotechnology and Biological Sciences Research Council (BBSRC) to promote collaborative research, training and knowledge exchange on productivity and ecosystem responses to management practices of agricultural lowland grasslands in the UK. The platform uses state-of-the-art technology to capture data at appropriate scales of land management which can be used to model how agricultural grassland systems will respond to different management inputs and to help develop a better understanding of the underlying processes and mechanisms. The farm platform data portal [https://nwfp.rothamsted.ac.uk/] contains all the data we record on the management of the farmlets including details and metrics of the individual grazing animals to the management of the fields. This user guide is split into two main sections where we describe (a). the field events and common field operations that occur on the farm platform and (b). the grazing regimes and available animal data.

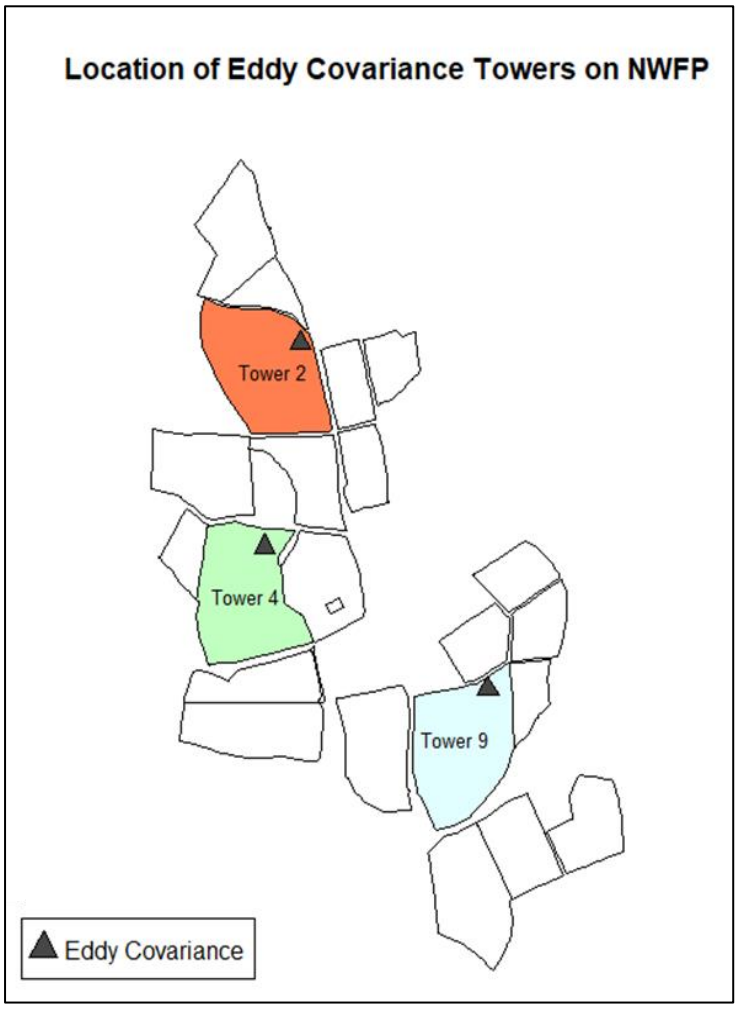
2 Automated Greenhouse Gas Measurements

There are three Li-Cor Eddy Covariance analysers on the NWFP, measuring CO_2 and CH_4. They are situated on the larger fields: Catchment 4 (green), Catchment 9 (blue) and Catchment 2 (red). The Carbon dioxide (CO_2) measurements have been ongoing since January 2017; with the Methane (CH_4) measurements added in January 2018.

2.1 NWFP Fields with Eddy Covariance measurements

The map (Figure 1) shows the locations of the Eddy Covariance towers on the Farm Platform (Tower numbers correspond to Catchment numbers). All are positioned to the Northeast to maximise the time the towers are measuring from the field; as wind direction is predominantly West or Southwest.

Figure 1 Location of Eddy Covariance Towers



2.2 Field Events

These fields are grazed by livestock (cows, sheep and lambs) and can be used for silage. Animal counts and field event data are available elsewhere on the NWFP data portal.

Ploughing, reseeding and fertilization events take place on the fields which can affect greenhouse gas measurements. These are recorded elsewhere on the NWFP portal. As much as possible, greenhouse gas measurements continue to capture these events, but in some cases data gaps exist where equipment has been removed e.g. in order for ploughing to take place.

3 Eddy Covariance

The NWFP has three Li-Cor Biosciences Eddy Covariance towers, one on each treatment (Green, Blue and Red). All three towers have an enclosed CO_2/H_2O analyser (LI-7200RS) and a sonic anemometer (Gill Windmaster Pro). Two of the systems also have an open path CH_4 analyser (LI-770). From January 2018 to June 2019, these were on the Red and Green treatments. From July 2019 to present, these are on the Green and Blue treatments. A Nitrous oxide (N_2O) analyser is expected to be deployed in the near future.

All the towers also have Li-Cor biomet systems to measure meteorological variables from the soil and atmosphere, which can be used for gap-filling and interpretation of flux data. Table 1 summarises what data has been collected in which year and field. These data will all be available on the Data Portal in due course. There are gaps in this data, from hours to weeks, at times when maintenance or analyser service has been required.

Table 1 Summary of data availability

	2017			2018			2019			2020		
	Red	Blue	Green	Red	Blue	Green	Red	Blue	Green	Red	Blue	Green
CO_2/H_2O	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Biomet	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
CH_4				✓		✓	✓		✓		✓	✓
N_2O												

3.1 Field Position

The towers are on three of the larger farm platform fields: Catchment 4, Catchment 9 and Catchment 2, as shown on the map (Figure 1). Precise location is shown in Table 2. From January 2017 to June 2019, the analysers were positioned at approximately 1.6m above the canopy (i.e. grass or crop) height. In July 2019, they were raised to approximately 2.6m above canopy height.

The towers and peripheral biomet sensors are kept within fenced enclosures approximately $8m^2$ within the fields, to protect them from being damaged by livestock.

Table 2 Precise location of the towers

Treatment	Catchment name	Field name	Field size (ha)	Longitude	Latitude	Elevation (m)
Green	Catchment 4	Burrows	6.39	-3.90613	50.7698	154.4
Blue	Catchment 9	Dairy South	6.49	-3.89857	50.7669	167.0
Red	Catchment 2	Great Field	6.65	-3.90513	50.7739	149.9

3.2 Data Collection and Processing

Eddy covariance data is available with CO_2/H_2O fluxes from January 2017 to present. CH_4 data was added for two towers from January 2018.

Raw flux data is processed using EddyPro® software from Li-Cor Biosciences. This computes fluxes from the raw data and outputs 30-minute averages, recorded at 0 and 30 minutes past the hour. All data is in Universal Standard Time, kept correct by GPS units on the analysers. The data available for download on the NWFP is presented in the European Fluxes Database format (http://www.europe-fluxdata.eu/home/guidelines/how-to-submit-data/variables-codes). A description of the columns is included in Table 3.

This format has information useful for QCing the data, including quality flags, friction velocity (u-star) and footprint location information. We have not removed or replaced any data from these files, so occurrence of low-quality data should be expected and filtered by the user.

Depending on the wind speed and direction, the footprint being measured at any individual timestamp may not be fully within the field. This will be evident from the footprint variables. However, the position of the towers was chosen in order to maximise the amount of time the footprint was within the field, given known windspeed and direction typical for the area.

Table 3 Details and description of columns in downloaded data

Variable Name	Unit	Group on Portal	Description (European Fluxes Database)
CH4_1_1_1	[nmolCH4 mol-1]	CH_4	CH_4 concentration
CO2_1_1_1	[mmolCO2 mol-1]	CO_2	CO_2 concentration
Datetime	[dd/mm/YYYY HH:MM:SS]		
FC_1_1_1	[umolCO2 m-2 s-1]	CO_2	CO_2 flux
FC_SSITC_TEST_1_1_1	[#]	CO_2	Quality check – CO_2 flux (0=high, 1=medium, 2=low quality)
FCH4_1_1_1	[nmolCH4 m-2 s-1]	CH_4	CH_4 flux
FCH4_SSITC_TEST_1_1_1	[#]	CH_4	Quality check – CH_4 flux (0=high, 1=medium, 2=low quality)
FETCH_70_0_0_1	[m]	Footprint	Fetch at which footprint cumulated probability is 70%

FETCH_80_0_0_1	[m]	Footprint	Fetch at which footprint cumulated probability is 80%
FETCH_90_0_0_1	[m]	Footprint	Fetch at which footprint cumulated probability is 90%
FETCH_MAX_0_0_1	[m]	Footprint	Fetch at which footprint cumulated probability is maximum
FN2O	[nmolN2O m-2 s-1]	N_2O	N_2O flux
H_1_1_1	[W m-2]	Air	Sensible heat flux
H_SSITC_TEST_1_1_1	[#]	Air	Quality check - sensible heat flux (0=high, 1=medium, 2=low quality)
H2O_1_1_1	[mmolH2O mol-1]	Air	H_2O vapor mole fraction
LE_1_1_1	[W m-2]	Air	Latent heat flux
LE_SSITC_TEST_1_1_1	[#]	Air	Quality check - latent heat flux (0=high, 1=medium, 2=low quality)
LWIN_1_1_1	[W m^2]	Meteorological sensors	Longwave Radiation Incoming
LWOUT_1_1_1	[W m^2]	Meteorological sensors	Longwave Radiation Outgoing
MO_LENGTH_0_0_1	[m]	Air	Monin-Obhukov length
PA_0_0_1	[kPa]	Air	Atmospheric pressure
PPFD_1_1_1	[µmolPhoton m^2 s]	Meteorological sensors	Photosynthetic Photon Flux Density Incoming
RH_0_0_1	[%]	Air	Relative humidity
RH_1_1_1	[%]	Meteorological sensors	Relative Humidity
RN_1_1_1	[W m^2]	Meteorological sensors	Net Radiation
SHF_1_1_1	[W m^2]	Meteorological sensors	Soil Heat Flux Sensor 1
SHF_2_1_1	[W m^2]	Meteorological sensors	Soil Heat Flux Sensor 2
SHF_3_1_1	[W m^2]	Meteorological sensors	Soil Heat Flux Sensor 3
SWC_1_1_1	[m^3 m^3]	Meteorological sensors	Soil Water Content Sensor 1
SWC_2_1_1	[m^3 m^3]	Meteorological sensors	Soil Water Content Sensor 2
SWC_3_1_1	[m^3 m^3]	Meteorological sensors	Soil Water Content Sensor 3
SWIN_1_1_1	[W m^2]	Meteorological sensors	Shortwave Radiation Incoming
SWOUT_1_1_1	[W m^2]	Meteorological sensors	Shortwave Radiation Outgoing
T_SONIC_0_0_1	[deg C]	Air	Sonic temperature
T_SONIC_SIGMA_0_0_1	[deg C]	Air	
TA_0_0_1	[deg C]	Air	Air temperature
TA_1_1_1	[K]	Meteorological sensors	Air Temperature
TAU_1_1_1	[kg m-1 s-2]	Air	Momentum flux
TAU_SSITC_TEST_1_1_1	[#]	Air	Quality check - momentum flux (0=high, 1=medium, 2=low quality)
TS_1_1_1	[K]	Meteorological sensors	Soil Temperature Sensor 1

TS_2_1_1	[K]	Meteorological sensors	Soil Temperature Sensor 2
TS_3_1_1	[K]	Meteorological sensors	Soil Temperature Sensor 3
U_SIGMA_0_0_1	[m s-1]	Wind	Standard deviation of velocity fluctuations (towards main-wind direction after coordinates rotation)
USTAR_0_0_1	[m s-1]	Wind	Friction velocity
V_SIGMA_0_0_1	[m s-1]	Wind	Standard deviation of lateral velocity fluctuations (cross main-wind direction after coordinates rotation)
VPD_0_0_1	[hPa]	Air	
W_SIGMA_0_0_1	[m s-1]	Wind	Standard deviation of vertical velocity fluctuations
WD_0_0_1	[Decimal degrees]	Wind	Wind direction
WS_0_0_1	[m s-1]	Wind	Wind speed
WS_MAX_0_0_1	[m s-1]	Wind	Maximum wind speed
ZL_0_0_1	[#]	Wind	Stability parameter