ReadMe File TGAS-Man (Trace Gas Manitoba) Archive Data for 2006 to 2016.
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Location Information: 49.64°N, 97.16°W. 235 m above sea level. Grid reference location 14U 632970.97m E 5500818.96 m N. Located at the Glenlea Research Station owned by the University of Manitoba. Location is about 15 km south of the edge of Winnipeg, Manitoba. This is in the flat (<2% slope) Red River Valley floodplain on glaciolacustrine clay with an extreme humid-continental climate (Köppen Dfb). The soils are gleyed humic vertisols (Canadian system) or typic humicryerts (U.S. system) of the Osborne and Red River Series. The surface soil is 60% clay texture, bulk density of 1.2 Mg m^{-3}, pH_{H2O} of 6.2, and 32 g organic C kg^{-1}. The fields have some poorly drained locations that can create variations in crop establishment and growth.

Experimental Design: The experimental fields are four adjacent, square 4-ha plots (2 x 2 layout) in a larger field that is planted to the same crop as the experimental plots (diagrams in Glenn et al., 2010; Tenuta et al., 2016; in Reference List Below). The two 4-ha adjacent fields on the east side were kept in a continuous rotation of annual crops (Fields 2 and 3, “annual cropping system”) for the 2006 to 2016 calendar years, whereas the two on the west side included a perennial crop phase of alfalfa/grass mixture from 2008 to 2011 (Fields 1 and 4, “annual-perennial cropping system”). Fields were managed using commonly practiced cultivation and fertilizer strategies for this area. Agronomic Information is given in Amiro et al. (2017) and Tenuta et al. (2019) in the Reference List below. A weather station was on a short-grass surface at the centre of the four fields.

Basic Measurement Method for Fluxes: The fluxes for both CO_2 and N_2O were calculated using the flux-gradient technique. Briefly, the flux density, F (μmol $m^{-2}s^{-1}$) , was measured using the flux-gradient technique such that:

$F = -K\,(\Delta C/\Delta z)$

where K is the turbulent transfer coefficient ($m^2\ s^{-1}$) and ΔC is the concentration difference (μmol m^{-3}) over the differential height Δz (m). The K value was calculated from similarity theory for momentum and sensible heat measured by sonic anemometer-thermometers at a height of 2-m in the center of each field, corrected for atmospheric stability. The concentration difference was measured by drawing air into two intakes separated vertically by 0.5 to 0.65 m, down 125 m of line to a tunable-diode-laser absorption spectrometer located in a trailer central to the fields. Switching between the intakes occurred every 12 seconds to get an average concentration difference over a 30-min period over a single field. The samples were then drawn from the next field so that each of the four fields was sampled every two hours in a clockwise rotation. Hence the flux for any given field is a 30-minute measurement during a 2-hour period. Every midnight, the sequence was lagged by 30-minutes so there was no systematic bias over a 4-day period. See Tenuta et al. (2016) for full description in reference list below.

Data Format and Instrumentation: The data are given in four files; one file for each of the four fields. The data are given for the full 2006 to 2016 period inclusive. Note that the weather station data are repeated in each file. The measurements methods are given in the papers in the Reference List below.

The data files are in csv (comma delineated) format sequentially from the start of 2006. Missing data are indicated by "NaN". The data are in 32 columns with the column label as the first row:

Year: Year of data collection

Decimal_DOY: Decimal day of year in local standard time (Central Standard Time). Note data are collected every 30 minutes as an average for that period. Time is the end of each 30-minute period.

AirTemp(C): Air Temperature in °C measured by a HMP45C probe (Vaisala Inc., Woburn, MA, USA) inside a shield (Model 41003-5 10-plate Gill solar radiation shielding, R.M. Young Co., Traverse City, MI, USA) at a height of 1.5 m at the weather station.

RH(%): Relative Humidity in % measured by a HMP45C probe (Vaisala Inc., Woburn, MA, USA) inside a shield (Model 41003-5 10-plate Gill solar radiation shielding, R.M. Young Co., Traverse City, MI, USA) at a height of 1.5 m at the weather station.

BarometricPressure (kPa): Station (local, not corrected to sea-level) barometric pressure in kPa measured by a R.M Young Co. Model 61205 pressure transducer at the weather station.

Solar_in(W/m2): Incoming Solar Radiation in W m^{-2} measured using a Model SP-Lite Silicon pyranometer (Kipp and Zonen, Delft, The Netherlands). Note that the sensor signal appears to degrade in 2011 and remains lower for the 2012-16 period than previous. We expect this sensor had a surface issue that resulted in reduced insolation measurements (this sensor was eventually replaced after 2016).

PAR_in(umol/m2/s): Incoming Photosynthetically active radiation (Photosynthetic Photon Flux Density) in μmol photons $m^{-2}s^{-1}$ measured with a PAR-Lite sensor (Kipp and Zonen, Delft, The Netherlands).

WindSpeed(m/s): Wind Speed in m s^{-1} at a Height of 3 m measured at the weather station with a R.M. Young wind monitor model 05103-10.

WindDir(deg): Wind Direction in degrees from North at a Height of 3 m measured at the weather station with a R.M. Young wind monitor model 05103-10.

Precip(mm/30min): Precipitation in mm totalled for each 30-minute period measured at the weather station using a weighting precipitation gauge (Model T-200B, Geonor Inc., Milford, PA, USA) surrounded by an Alter Wind Screen.

SoilT-2cm(C): Soil Temperature in °C measured at a depth of 2 cm at the weather station using a Campbell Scientific Thermistor Model 107B.

SoilT-5cm(C): Soil Temperature in °C measured at a depth of 5 cm at the weather station using a Campbell Scientific Thermistor Model 107B.

SoilT-10cm(C): Soil Temperature in °C measured at a depth of 10 cm at the weather station using a Campbell Scientific Thermistor Model 107B.

SoilT-20cm(C): Soil Temperature in °C measured at a depth of 20 cm at the weather station using a Campbell Scientific Thermistor Model 107B.

SoilT-50cm(C): Soil Temperature in °C measured at a depth of 50 cm at the weather station using a Campbell Scientific Thermistor Model 107B.
SoilT-100cm(C): Soil Temperature in °C measured at a depth of 100 cm at the weather station using a Campbell Scientific Thermistor Model 107B.
SoilMoist_10cm(m3/m3): Soil Moisture in m^3 water m^{-3} soil measured at a depth of 10 cm at the weather station using a Campbell Scientific (Logan, UT, USA) Model CS616 reflectometer mounted horizontally. Note that we did not calibrate this for the local soil conditions and shrinkage of the clay soil during dry periods can make measurements unreliable.
SoilMoist_30cm(m3/m3): Soil Moisture in m^3 water m^{-3} soil measured at a depth of 30 cm at the weather station using a Campbell Scientific Model CS616 reflectometer mounted horizontally. Note that we did not calibrate this for the local soil conditions and shrinkage of the clay soil during dry periods can make measurements unreliable.
Ustar(m/s): Friction velocity (u_*) in m s^{-1} measured over the field at a height of 2 m above ground using a Campbell Scientific CSAT3 sonic thermometer-anemometer.
Hvirtual(W/m2): Virtual heat flux density (not corrected for water vapour) in W m^{-2} measured over the field at a height of 2 m above ground using a Campbell Scientific CSAT3 sonic thermometer-anemometer.
Kmomentum(m2/s): Transfer coefficient in m^2 s^{-1} calculated using momentum from the sonic anemometer-thermometer over the field at a height of 2 m above ground, used to calculate the fluxes of CO_2 and N_2O between the two measured gradient heights. Methodology described by Tenuta et al. (2016) in the Reference List below.
MO_Length(m): Monin-Obukov length in metres calculated using momentum from the sonic anemometer-thermometer over the field at a height of 2 m above ground, used to calculate stability corrections to the transfer coefficient (Kmomentum).
Canopy_h(m): Canopy height in metres above ground measured periodically over the field. Note that canopy heights are missing for the 2006-2008 period.
UpperIntake_h(m): Height of the Upper Intake in metres above ground, sampling both CO_2 and N_2O. Note that intake heights are missing for the 2006-2008 period
LowerIntake_h(m): Height of the Lower Intake in metres above ground, sampling both CO_2 and N_2O. Note that intake heights are missing for the 2006-2008 period
CO2_gradient(umol/mol): Difference in CO_2 volumetric concentration in μmol CO_2 mol^{-1} dry air (note that the air was dried at the intake) between the lower and upper intakes (positive gradient indicates a higher concentration at the lower intake).
N2O_gradient(nmol/mol): Difference in N_2O volumetric concentration in nmol N_2O mol^{-1} dry air (note that the air was dried at the intake) between the lower and upper intakes (positive gradient indicates a higher concentration at the lower intake).
Flux_CO2(umol/m2/s): Flux density of CO_2 in μmol CO_2 $m^{-2}s^{-1}$. Upward fluxes are positive.
Flux_N2O(nmol/m2/s): Flux density of N_2O in nmol N_2O $m^{-2}s^{-1}$. Upward fluxes are positive.
NEPgapfilled(umol/m2/s): Net Ecosystem Production in μmol CO_2 $m^{-2}s^{-1}$. Downward fluxes are positive. The gap-filled product follows the Fluxnet-Canada protocol as described by Amiro et al. (2017) in the Reference List below.

GPP(umol/m2/s): Gross Photosynthetic Production in μmol CO_2 $m^{-2}s^{-1}$. Downward fluxes are positive. The gap-filled product follows the Fluxnet-Canada protocol as described by Amiro et al. (2017) in the Reference List below.

Respiration(umol/m2/s): Ecosystem Respiration in μmol CO_2 $m^{-2}s^{-1}$. Upward fluxes are positive. The gap-filled product follows the Fluxnet-Canada protocol as described by Amiro et al. (2017) in the Reference List below.

Reference Literature for the Site:

Amiro, B.D., M. Tenuta, M. Gervais, A. Glenn, and X. Gao. 2017. A decade of carbon flux measurements with annual and perennial crop rotations on the Canadian Prairies. *Agricultural and Forest Meteorology* 247:491-502.

Glenn, A.J., M. Tenuta, B.D. Amiro, S.E. Maas, and C. Wagner-Riddle. 2012. Nitrous oxide emissions from an annual crop rotation on poorly drained soil on the Canadian Prairies. *Agricultural and Forest Meteorology* 166-167: 41-49.

Glenn, A.J., B.D. Amiro, M. Tenuta, C. Wagner-Riddle, G. Drewitt, and J. Warland. 2011. Contribution of crop residue carbon to total soil respiration at a northern Prairie site using stable isotope flux measurements. *Agricultural and Forest Meteorology* 151: 1045-1054.

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Maas, S.E., A.J. Glenn, M. Tenuta, and B.D. Amiro. 2013. Net CO_2 and N_2O exchange during perennial forage establishment in an annual crop rotation in the Red River Valley, Manitoba. *Canadian Journal of Soil Science* 93: 639-652.

Tenuta, M., X. Gao, D. Flaten, and B. Amiro. 2016. Lower nitrous oxide emissions from anhydrous ammonia application prior to soil freezing in late fall than spring pre-plant application. *Journal of Environmental Quality* 45: 1133-1143.

Tenuta, M., B.D. Amiro, X. Gao, C. Wagner-Riddle, and M. Gervais. 2019. Agricultural management practices and environmental drivers of nitrous oxide emissions over a decade for an annual and an annual-perennial crop rotation. *Agricultural and Forest Meteorology.* 276-277. 107636.