Agriculture and Agri-Food Canada | Agriculture et Agroalimentaire Canada

Challenges in Scaling Up Flux Measurements of CO_2, CH_4 and N_2O from Terrestrial Ecosystems

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TERENO
TERRESTRIAL ENVIRONMENTAL OBSERVATORIES

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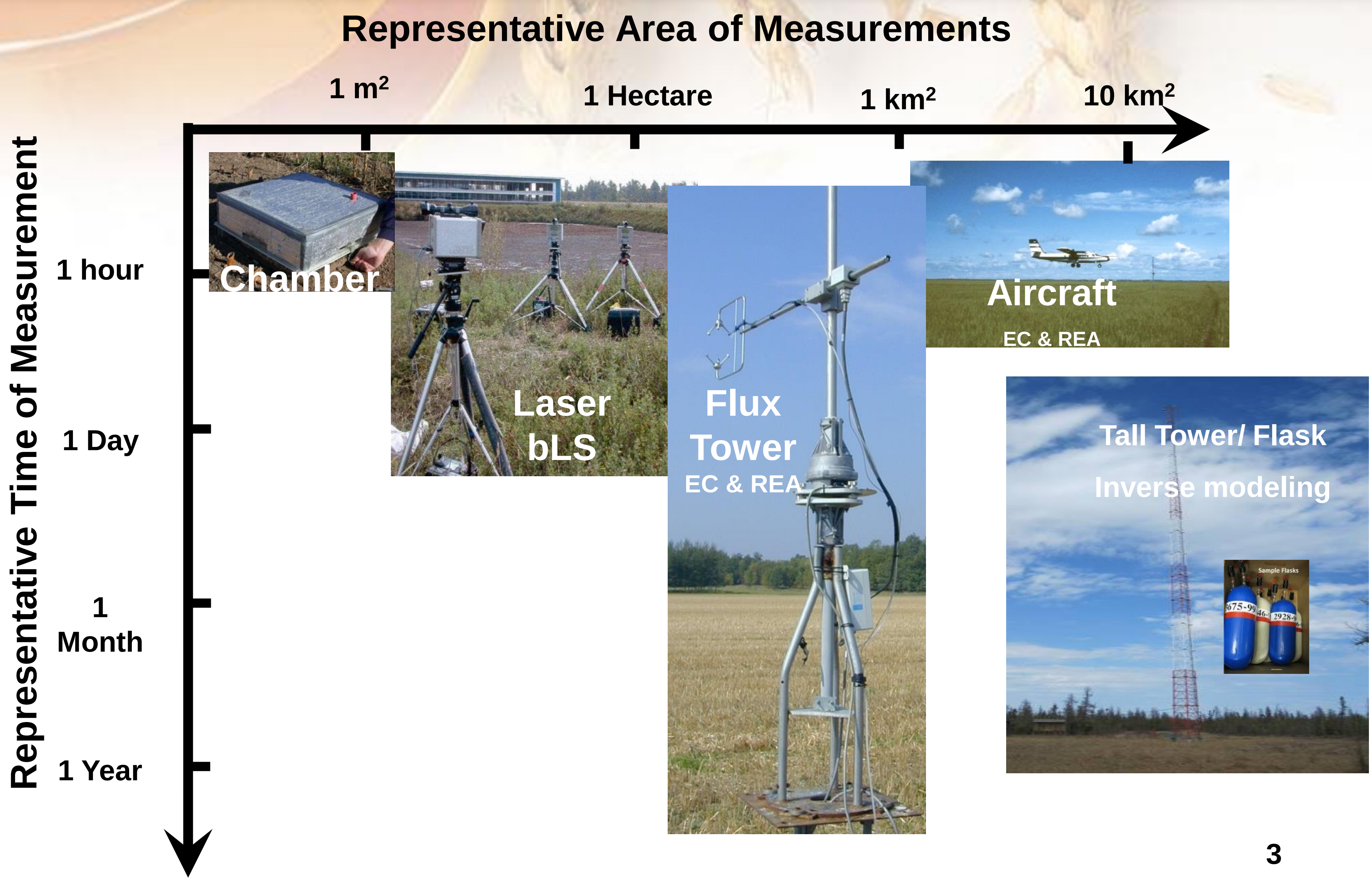
Canada

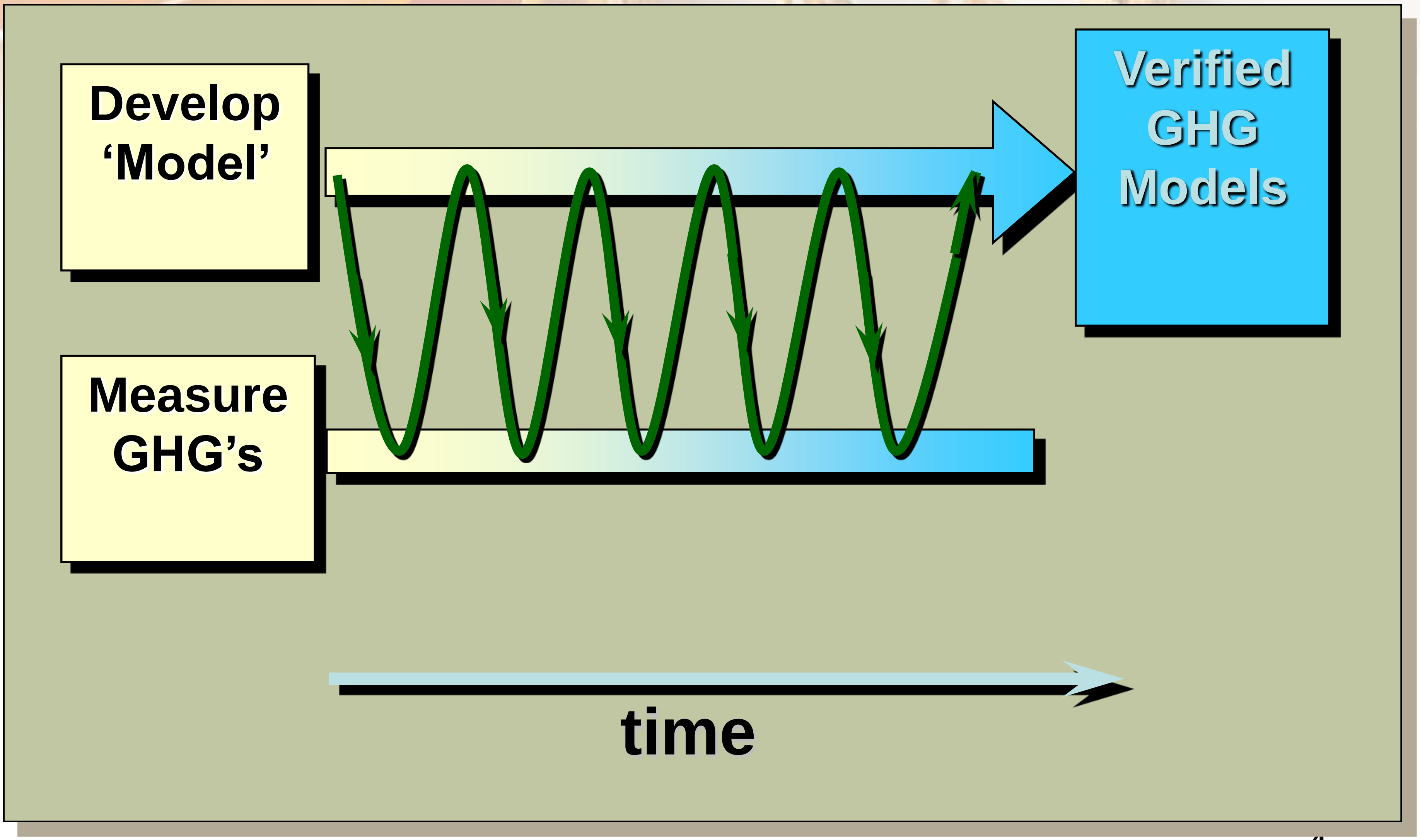
Outline

- Review GHG flux measuring systems for a wide range of scales
- Present N_2O and CH_4 flux measurements from agroecosystems.
- Discuss the advantages and limitations of various techniques.

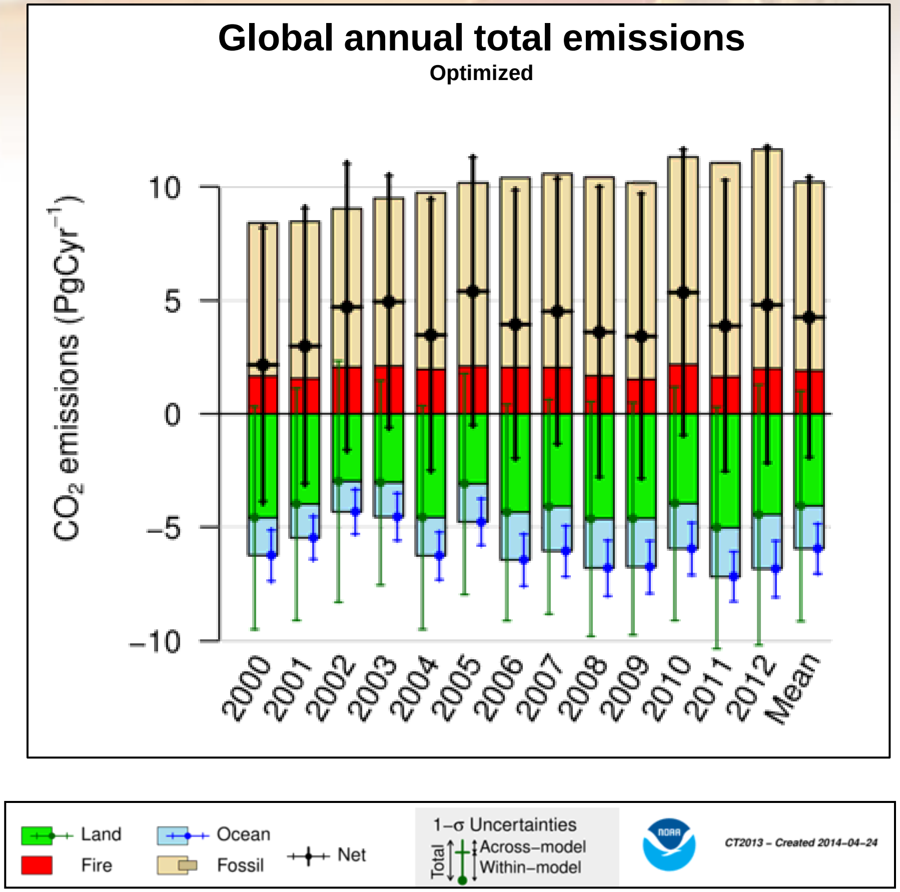
Flux measuring tools for a wide range of scales

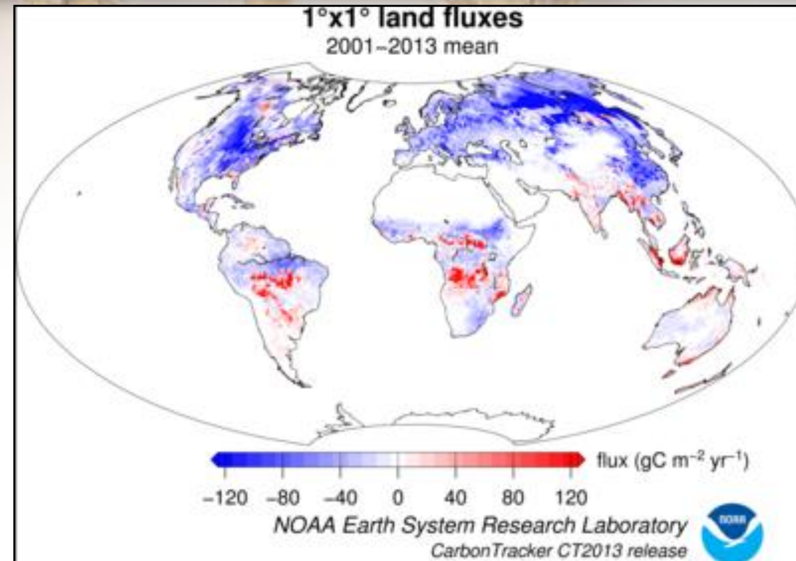


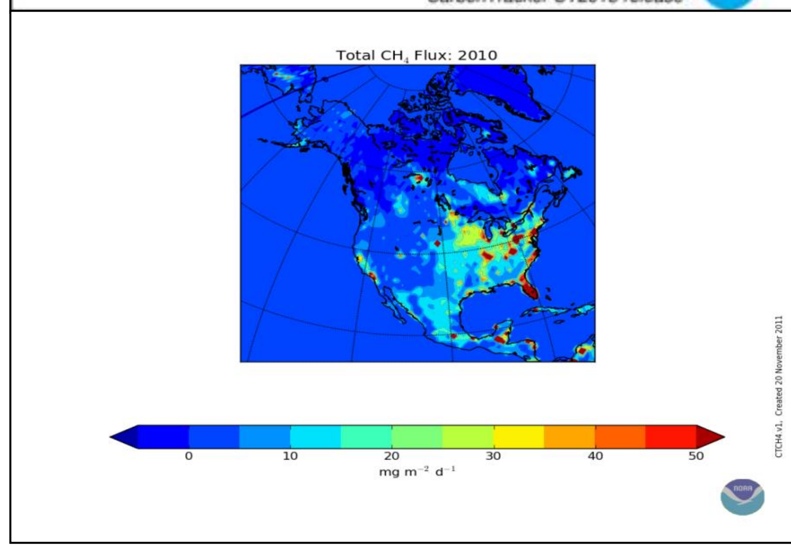
Obtaining GHG emission estimates at regional and national scales



Carbon Tracker Flux Estimates using an Inverse Modeling Technique

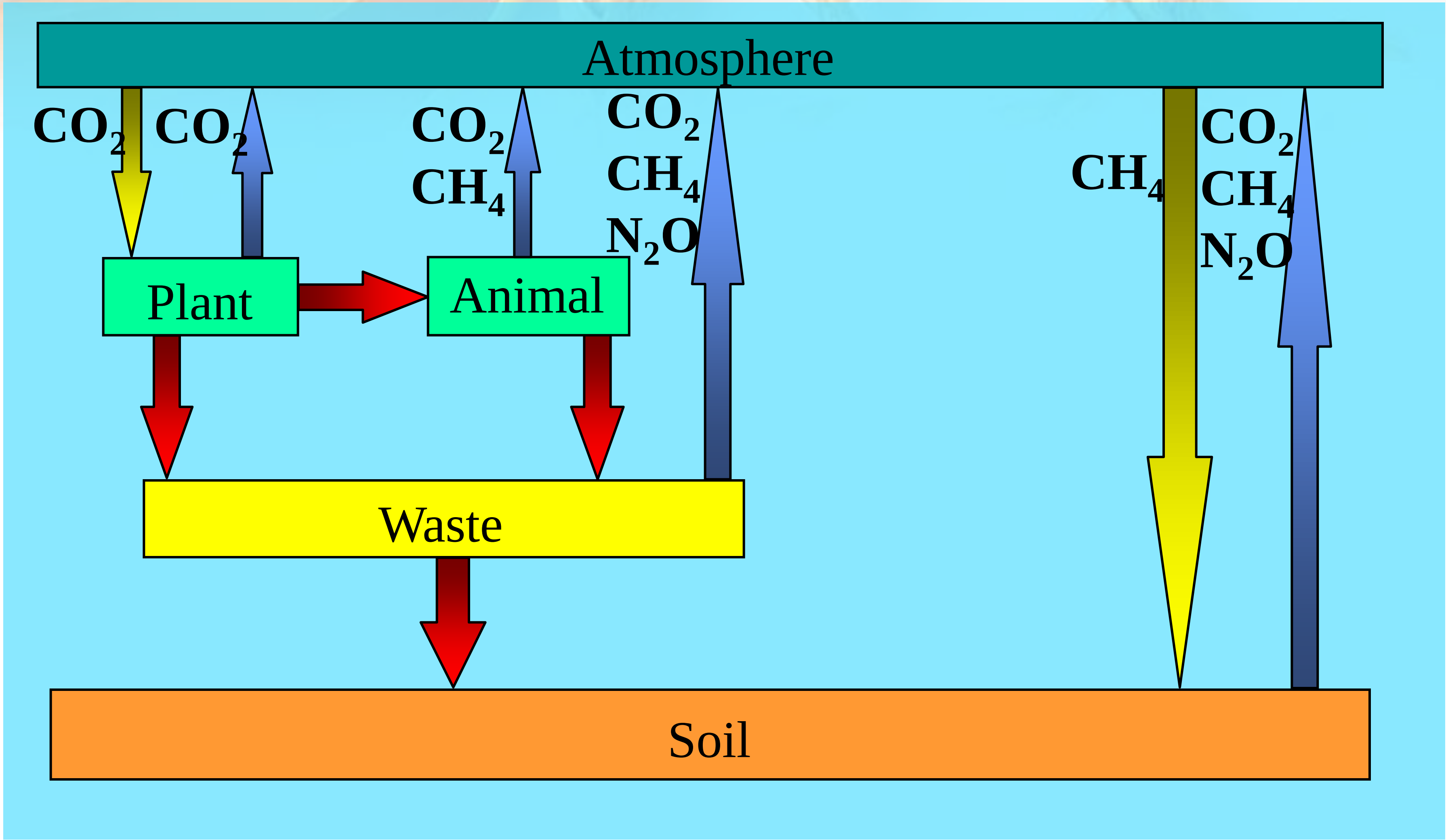




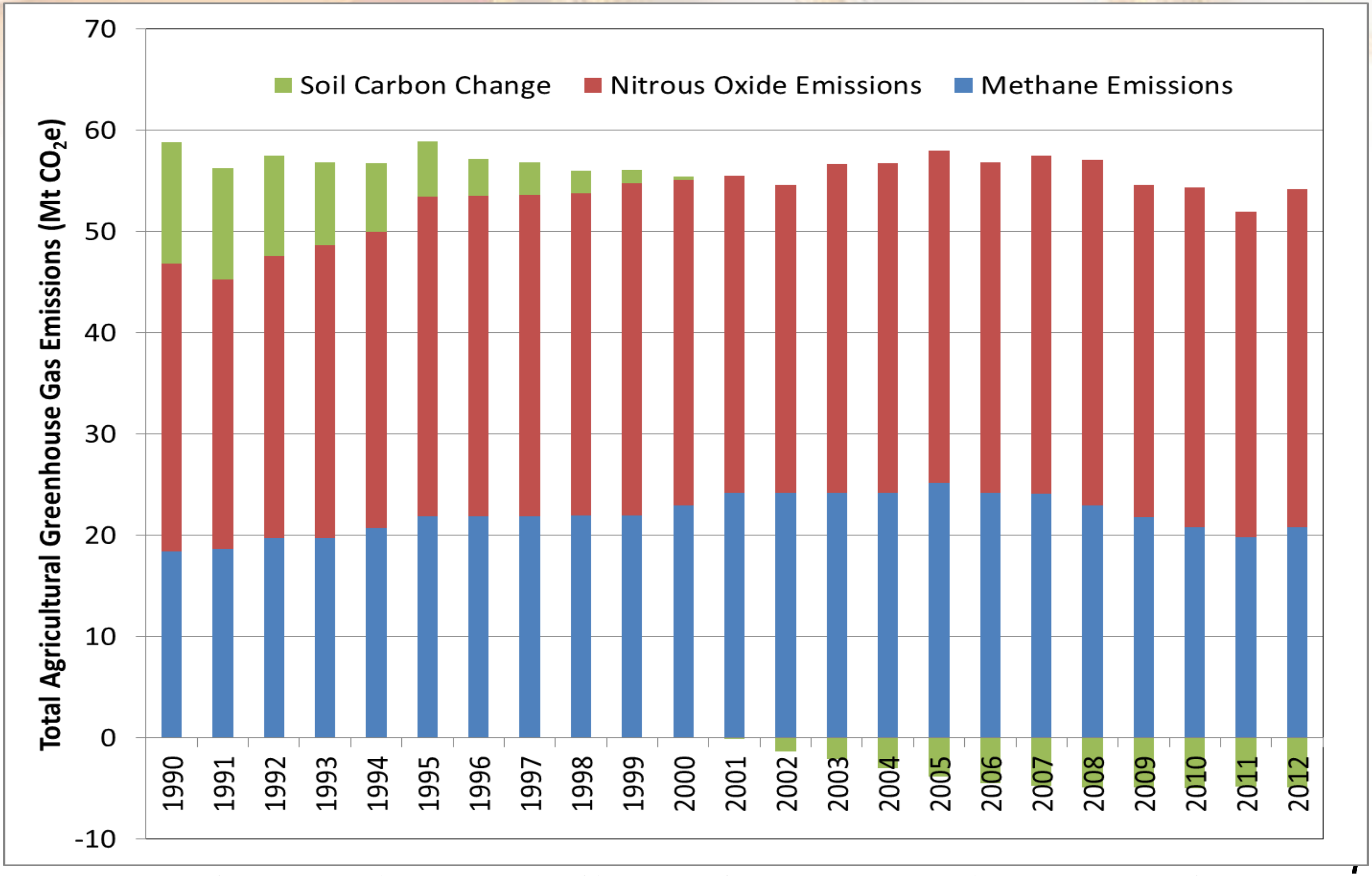


Source: CarbonTracker CT2013, http://carbontracker.noaa.gov

Agricultural GHG Emissions
Coupled processes in soil-plant atmosphere systems- S8

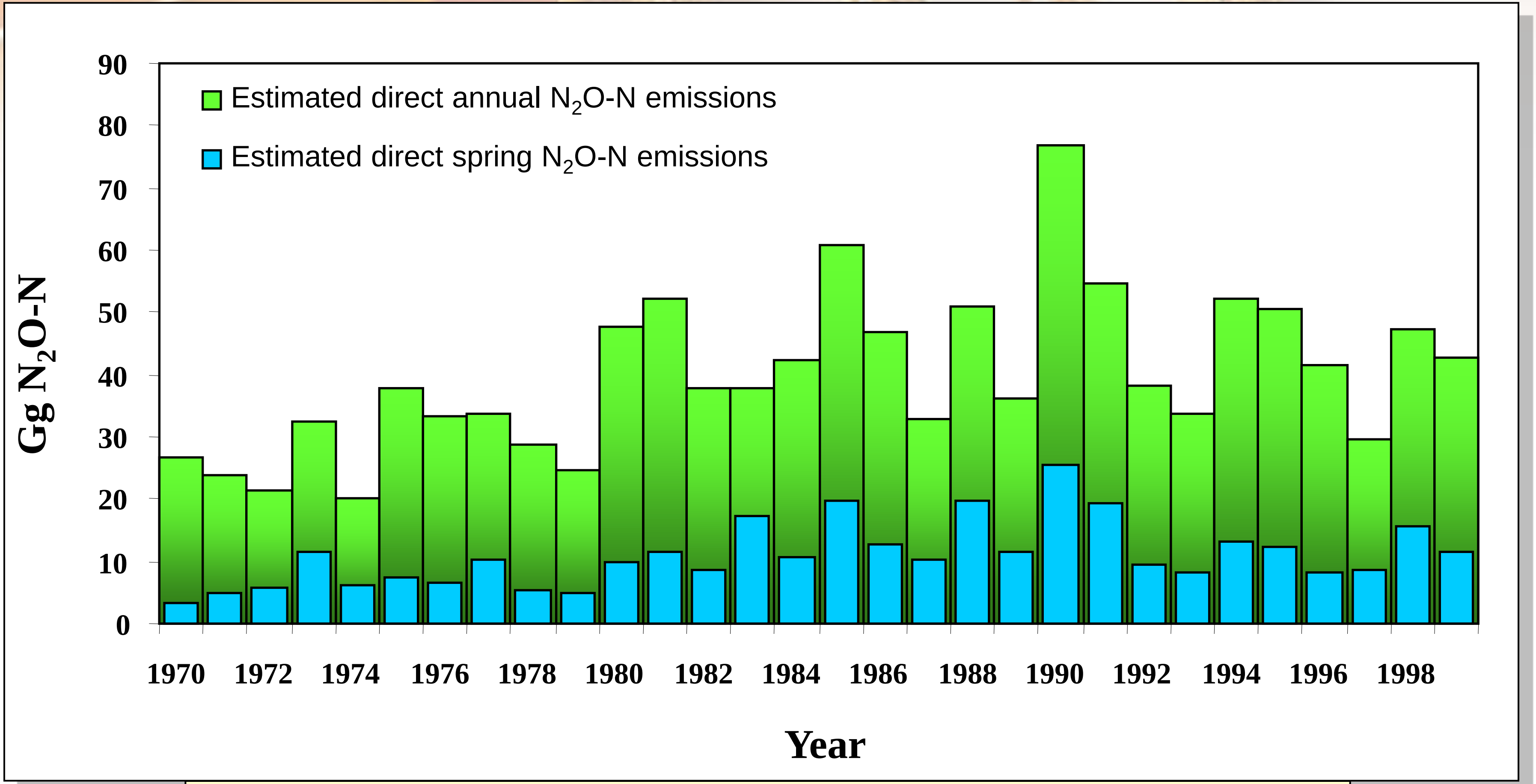


Greenhouse Gas Emission Estimates from Canadian Agroecosystems



Worth, D. E., Desjardins, R.L., MacDonald, D., McConkey, B.G., Dyer, J.A., and X.P.C. Verge 2014. The greenhouse gas indicator for agriculture AEI report Agriculture and Agri-Food Canada

Estimated Direct N_2O-N Emissions from Agriculture Soils in Canada Using DNDC (1970-1999)



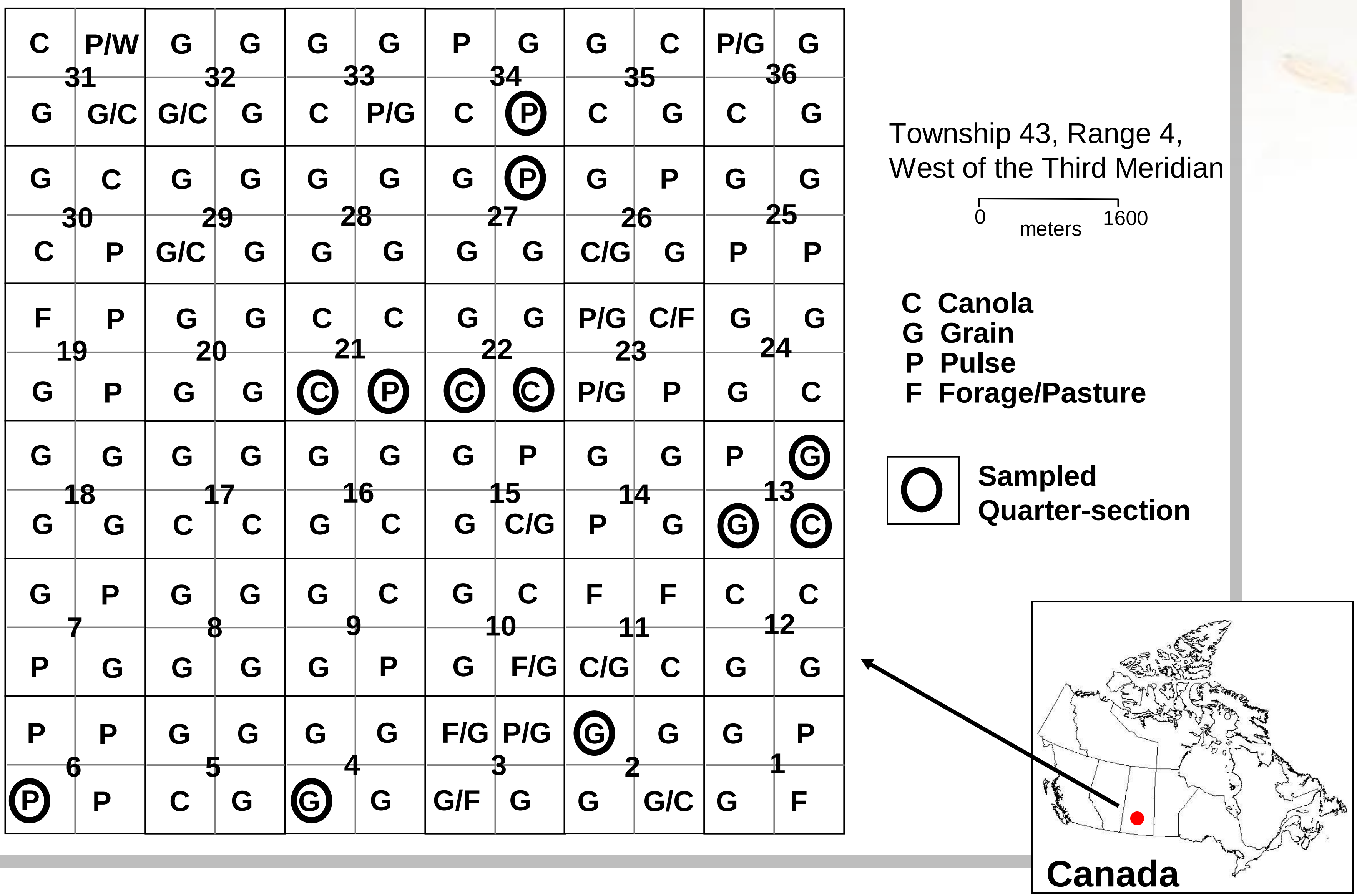
On average spring emissions represented 30% of annual emissions. The contribution of freeze-thaw cycles to annual emissions ranged from 8 to 81% in northern countries. Wang et al. (2008).

Smith, W.N., B. Grant, R.L. Desjardins, R. Lemke, and C. Li. 2004. Estimates of the interannual variations of N_2O emissions from agricultural soils in Canada *Nutrient Cycling in Agroecosystems.* 68: 37-45.

Multi-scale estimation of N_2O emissions from agroecosystems

Pattey E., Edwards, G.C., Desjardins, R.L., Pennock, D., Smith W., Grant B., MacPherson, J.I., 2007. Tools for quantifying N_2O emissions from Agroecosystems. *Agric. Forest Meteorol*.142(2-4): 103-119.

Scaling up chamber measurements of nitrous oxide emissions at the field scale in western Canada



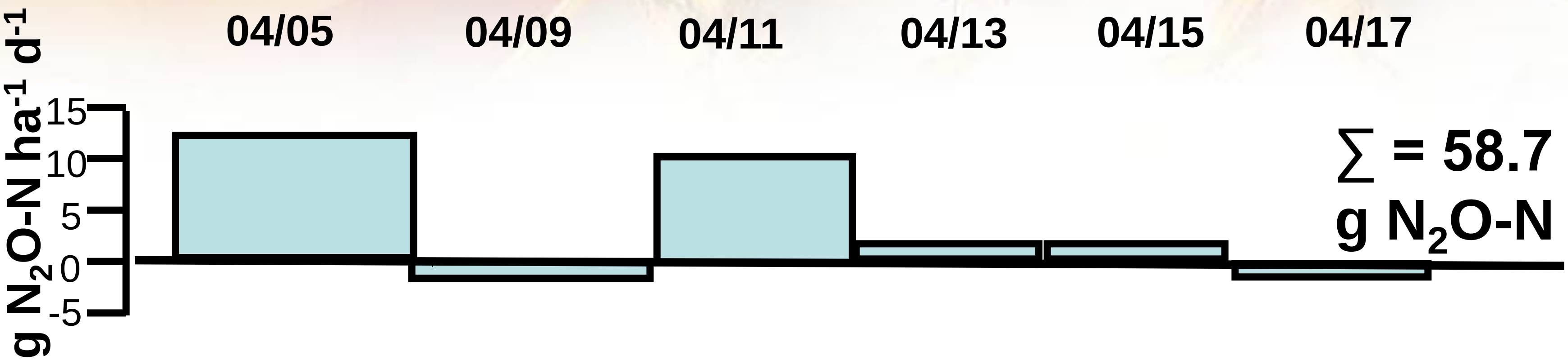
Crop Weighted Chamber N_2O Flux

Wheat	(69.3 g N_2O-N ha^{-1} x 0.58)
Canola	(31.8 g N_2O-N ha^{-1} x 0.19)
Peas	(54.1 g N_2O-N ha^{-1} x 0.17)
Manured	(254. g N_2O-N ha^{-1} x 0.01)
Total	**58.7 g N_2O-N ha^{-1}**

Pennock, D., Farrell, R., Desjardins R.L., Pattey, E., MacPherson, J. I., 2005. Upscaling chamber-based measurements of N_2O emissions at snowmelt. Can. J. Soil Sci. 85: 113-125.

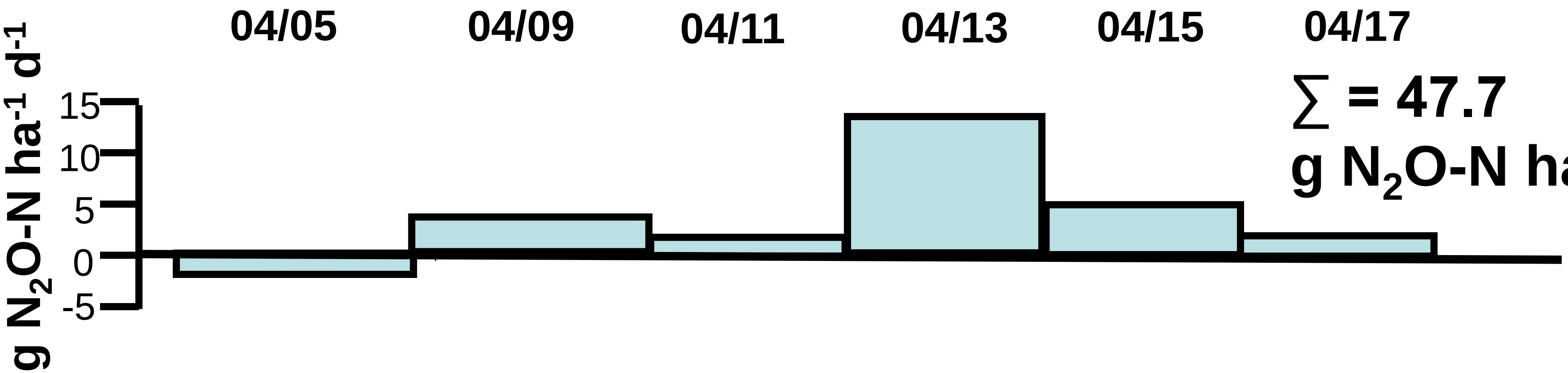
Chamber/AC N_2O Flux Comparison

Chamber



$\sum = 58.7$ g N_2O-N ha^{-1}

Aircraft



$\sum = 47.7$ g N_2O-N ha^{-1}

Pennock, D., Farrell, R., Desjardins R.L., Pattey, E., MacPherson, J. I., 2005. Upscaling chamber-based measurements of N_2O emissions at snowmelt. Can. J. Soil Sci. 85: 113-125.

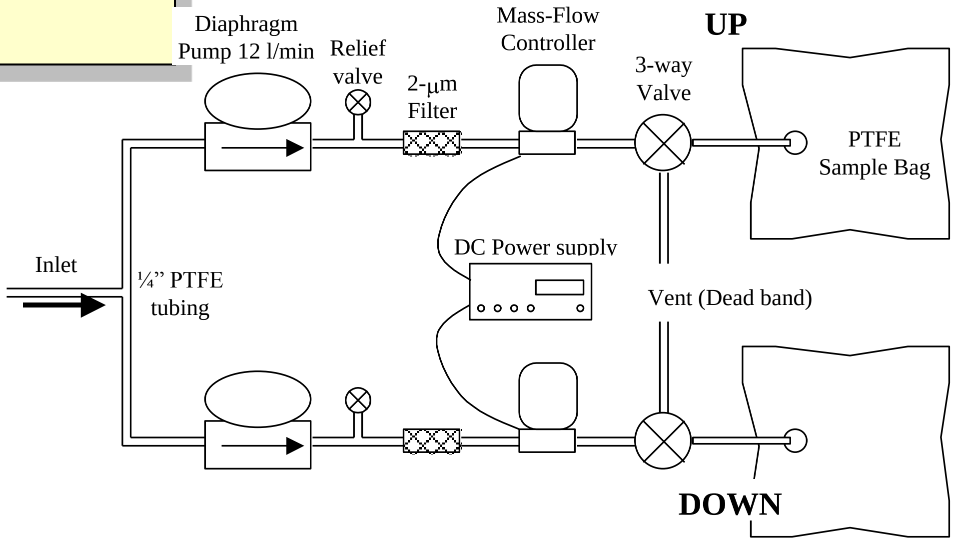
Relaxed Eddy Accumulation (REA)

- Alternate to eddy covariance technique to measure fluxes of trace gases for which fast-response analyzers are not operational
- Air samples from updrafts and downdrafts are collected in two separate reservoirs for later analysis
- In EA, sample flow rate is proportional to w; this requirement is 'relaxed' in REA (i.e., full flow into up or down reservoir depending on the direction of the vertical wind)

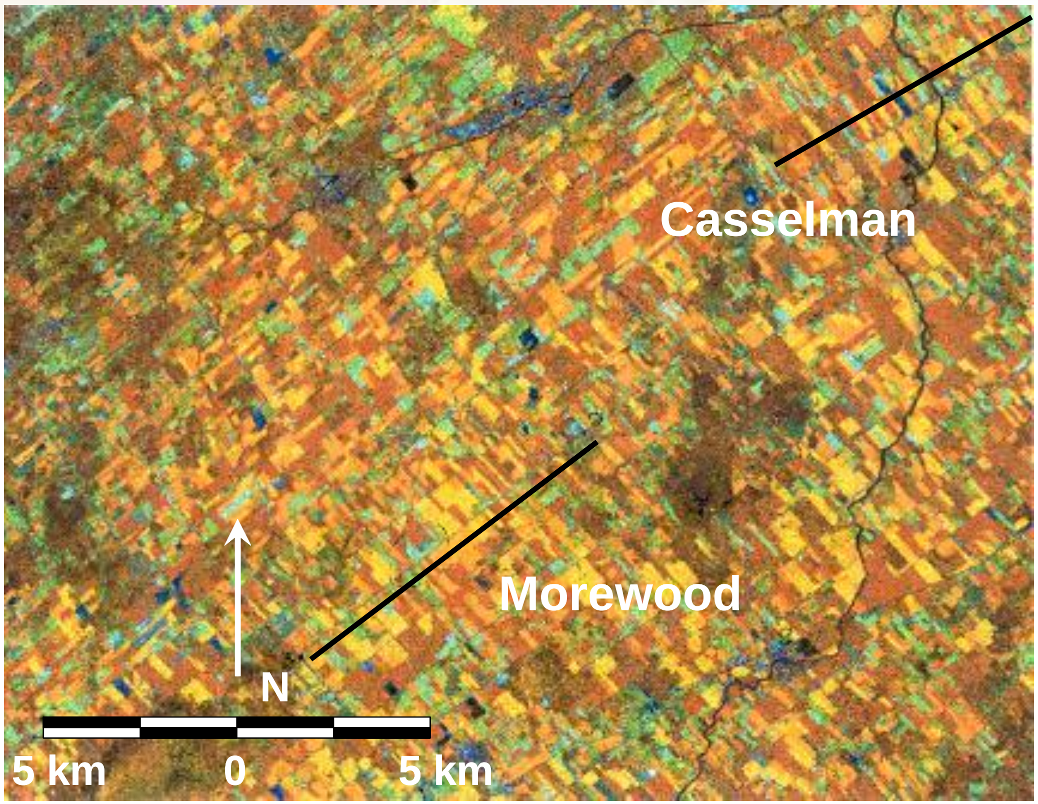
$$F_{\chi} = \overline{w'\chi'} = A\sigma_{w}\left(\chi_{Up} - \chi_{Down}\right)$$

Desjardins, R.L., J.I. MacPherson and P.H. Schuepp. 2000. Aircraft-based flux sampling strategies. Encyclopedia of Analytical Chemistry. R.A. Meyers (Ed.) pp. 3573-3588. John Wiley & Sons Ltd. Chichester.

Pattey, E. Strachan, I.B., Desjardins, R.L., Edwards, G.C., Dow, D., and MacPherson, I.J. 2006. Application of a tunable diode laser to the measurement of CH_4 and N_2O fluxes from field to landscape scale using several micrometeorological techniques. *Agric. Forest Meteorol*.136: 222-236.



Measuring N_2O flux at a regional scale

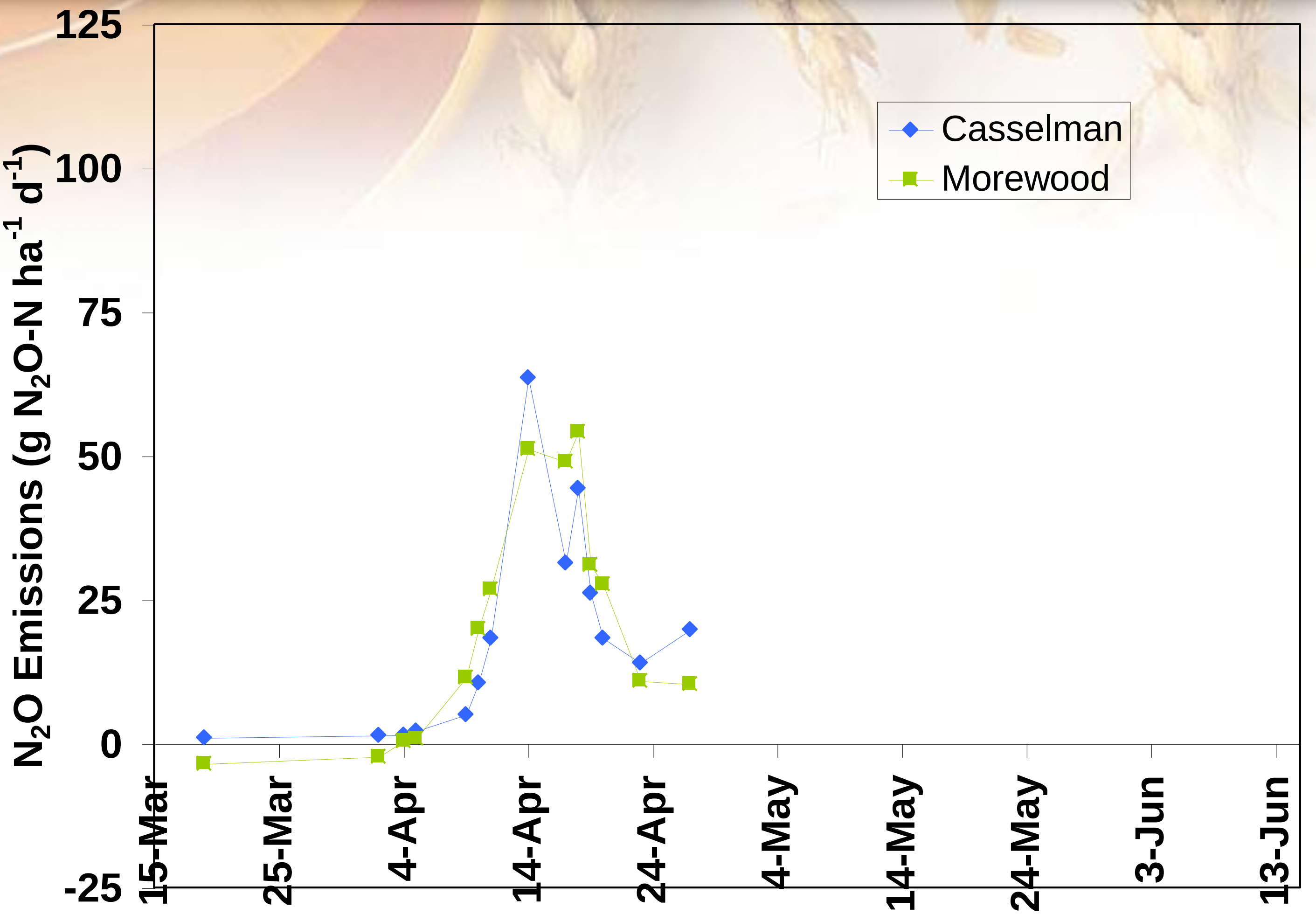


LEGEND

- cereals
- pasture/grass
- alfalfa
- forest
- soy
- corn
- town

Pattey E., Edwards, G.C., Desjardins, R.L., Pennock, D., Smith W., Grant B., MacPherson, J.I., 2007. Tools for quantifying N_2O emissions from Agroecosystems. *Agric. Forest Meteorol*.142(2-4): 103-119.

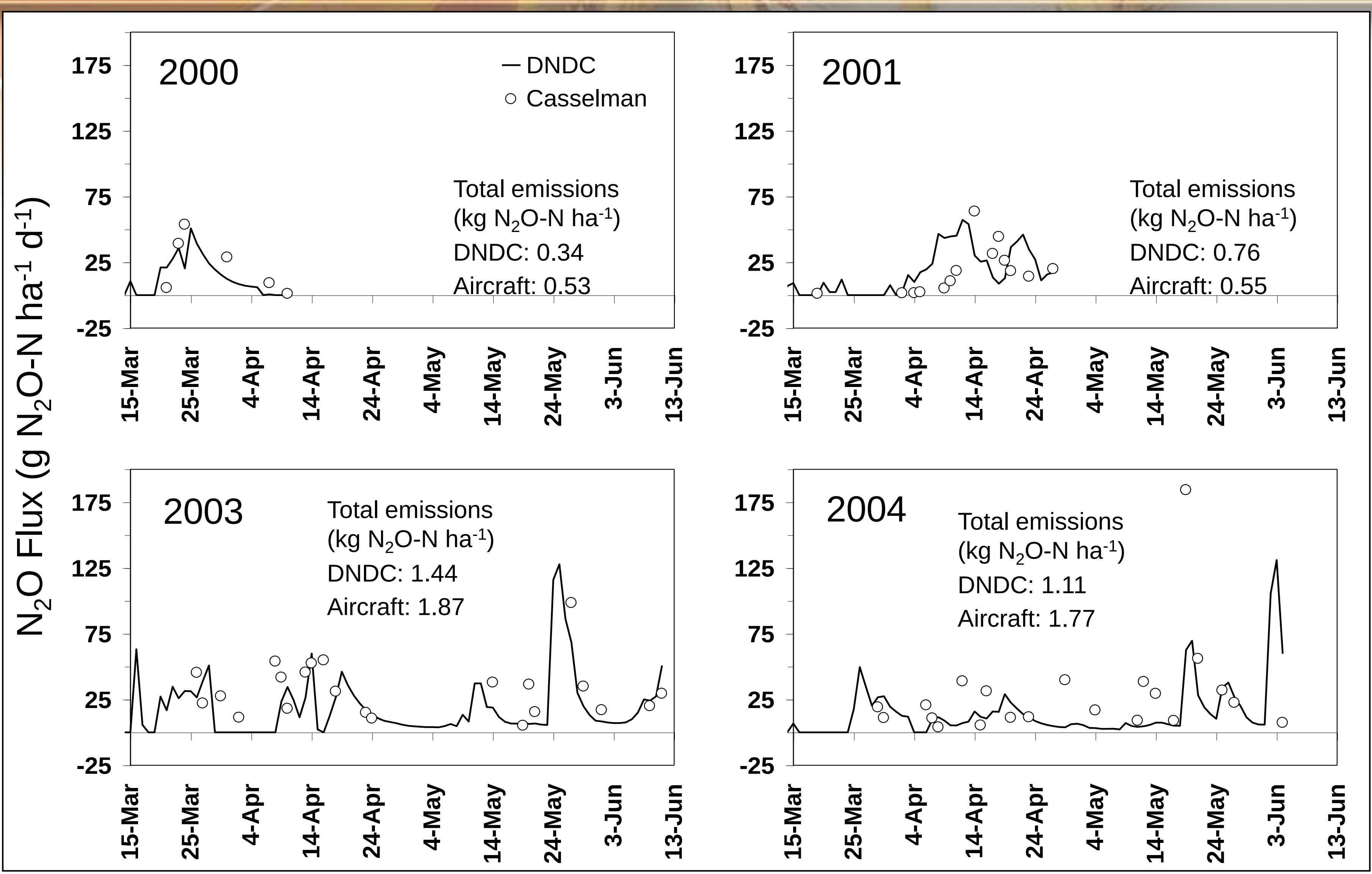
Regional N_2O fluxes during and right after snowmelt at the Eastern Canada study sites in 2001 using the REA technique



Each data point represents the average of 3 samples, collected during two consecutive 10 km flight legs (total flight distance for one data point is ≈ 20 km)

Pattey E., Edwards, G.C., Desjardins, R.L., Pennock, D., Smith W., Grant B., MacPherson, J.I., 2007. Tools for quantifying N_2O emissions from Agroecosystems. *Agric. Forest Meteorol.*142(2-4): 103-119.

Multi-year comparison of N_2O emissions using aircraft-based systems and model estimates



Desjardins, R.L., Pattey, E., Smith, W.N., Worth, D., Grant, B., Srinivasan, R., MacPherson, J.I., and Mauder, M., 2010. Multiscale estimates of N_2O emissions from agricultural lands. *Agric. Forest Meteorol.*, 150: 817-824.

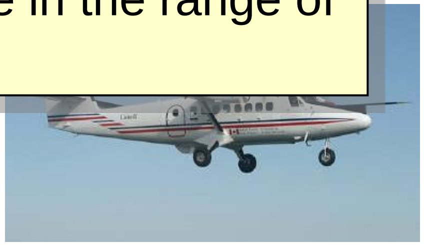
Comparing total measured and modeled N_2O flux estimates

	Measured	Modeled (DNDC)	% difference
	kg N_2O-N ha^{-1} $period^{-1}$		

In three out of the four measurement years, measured emissions exceeded modeled emissions by an average of 26%. In 2001, DNDC predicted a longer ‘spring burst’ than was measured, and total modeled emissions were 38% greater than measured emissions.

2003	1.87	1.44	+22

Measurements incorporate indirect emissions, whereas DNDC does not. In the IPCC methodology we assume that indirect emissions are in the range of 25 to 30% of total emissions.



Agricultural Sources of Methane in Canada in 2011

Enteric fermentation (digestion) by ruminant animals 18 Mt CO_2e per year

Management of animal manures 3 Mt CO_2e per year

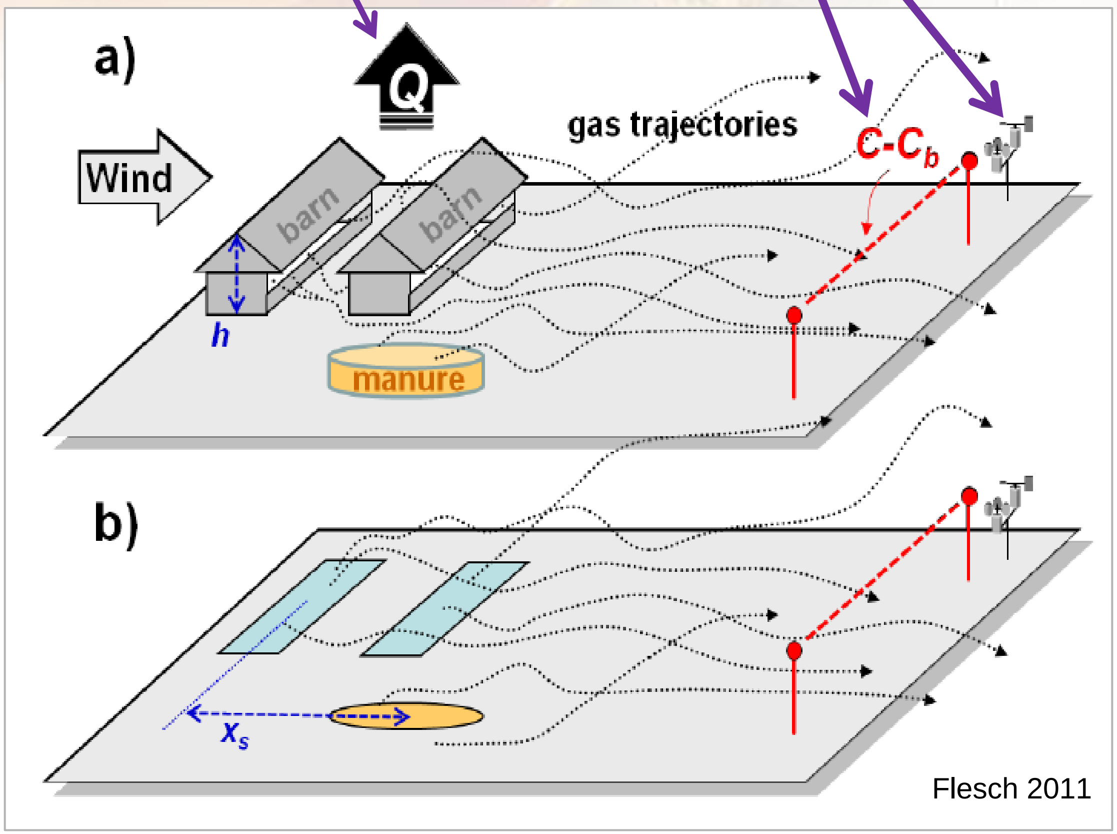
Worth, D. E., Desjardins, R.L., MacDonald, D., McConkey, B.G., Dyer, J.A., and X.P.C. Verge 2014. The greenhouse gas indicator for agriculture AEI report. Agriculture and Agri-food Canada.

Methane emissions from farms

- bLS inverse-dispersion technique

Unknown

Measured



Boreal lasers and reflectors

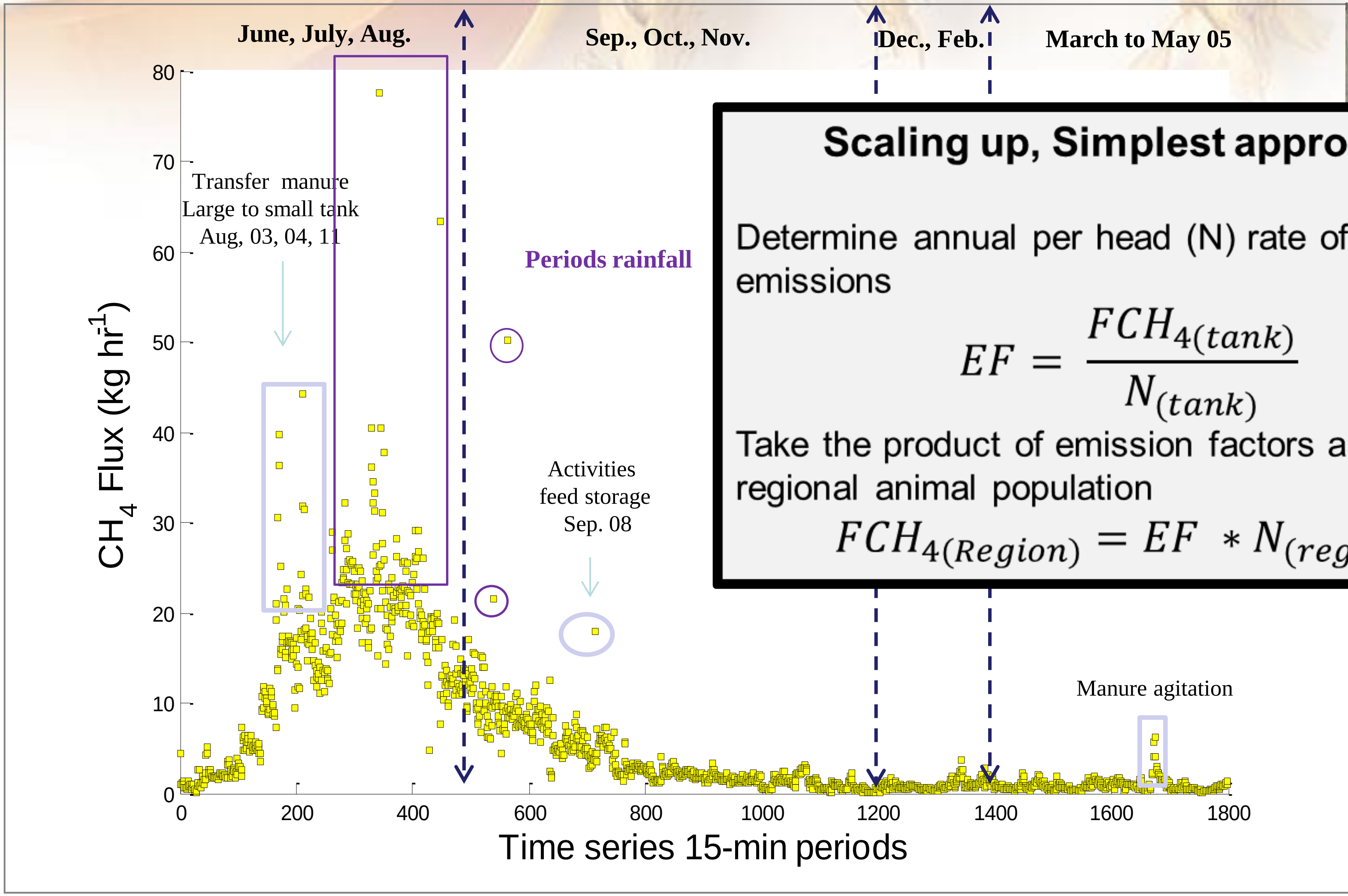
Ultrasonic Anemometer

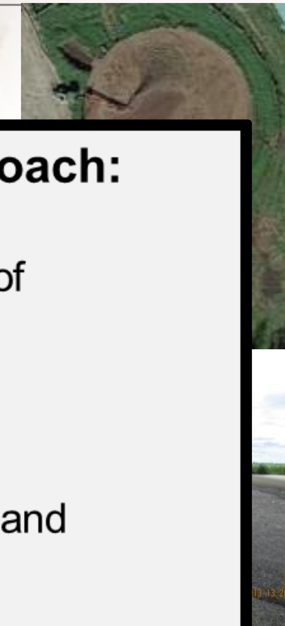
- **CH_4 concentration and wind data synchronized**
- **WindTrax model**

Flesch, T.K., Harper, L.A., Desjardins, R.L., Gao, Z., and Crenna, B.P. 2009. Multi-source emission determination using an inverse-dispersion technique. Boundary layer Meteorology.

CH$_4$ emissions from manure storage

- From June 2013 - May 2014





Scaling up, Simplest approach:

Determine annual per head (N) rate of emissions

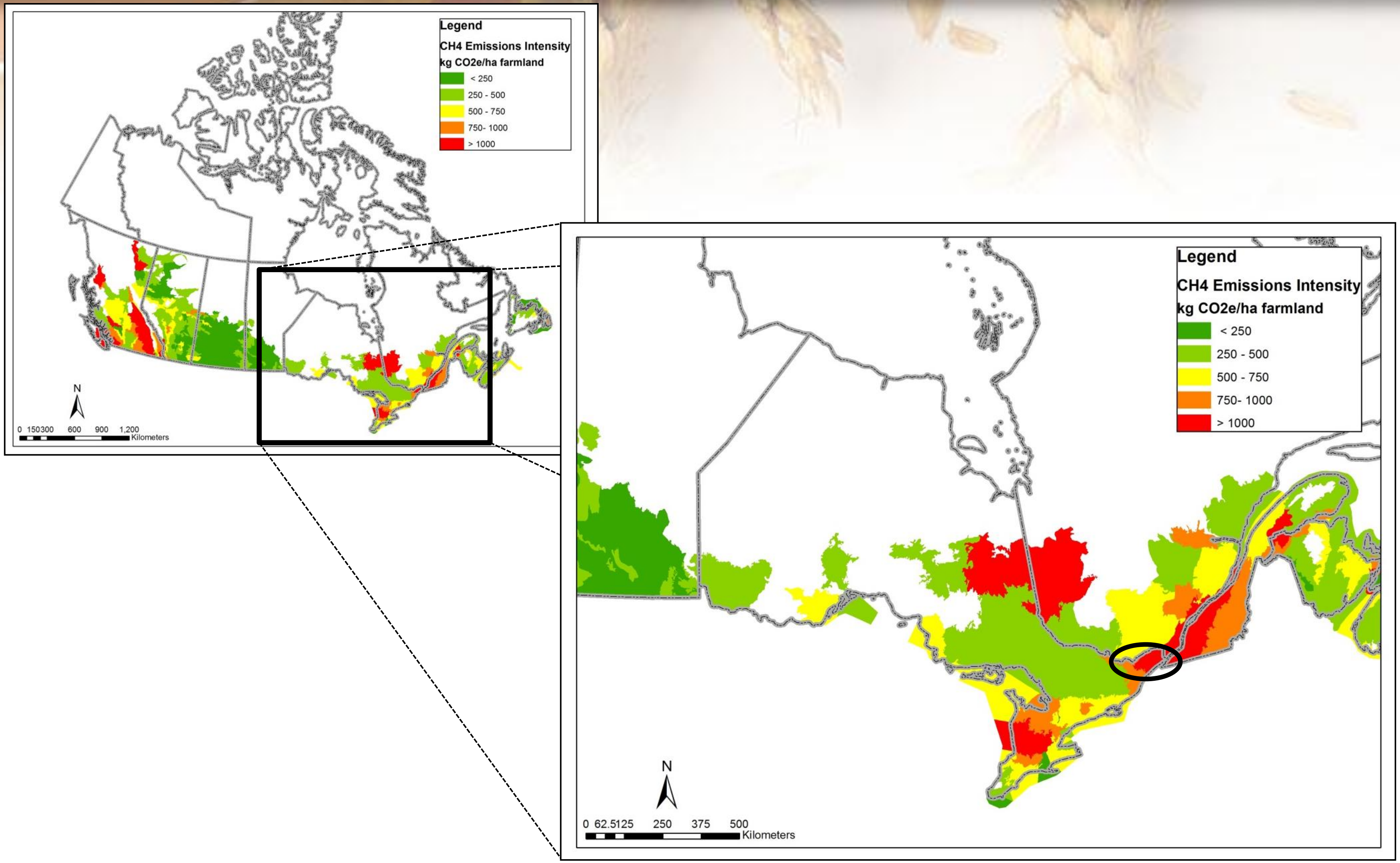
$$EF = \frac{FCH_{4(tank)}}{N_{(tank)}}$$

Take the product of emission factors and regional animal population

$$FCH_{4(Region)} = EF * N_{(region)}$$

Balde, H., VanderZaag, A.C., Desjardins R. L. 2014 .Measuring on-farm methane emissions (in preparation).

CH_4 emission estimates at a regional scale (2011)

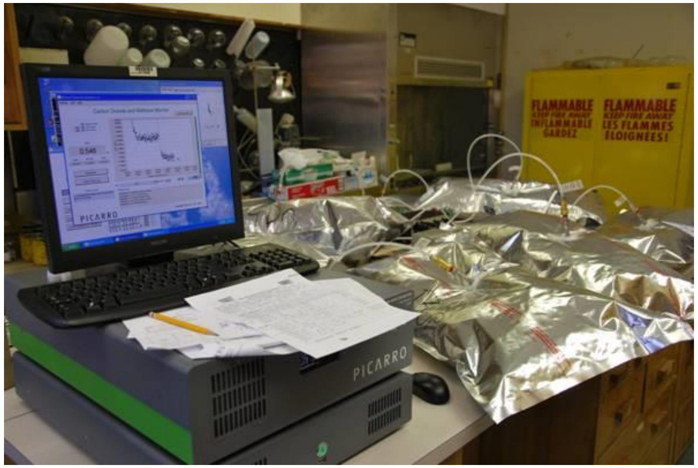


The NRC Twin Otter

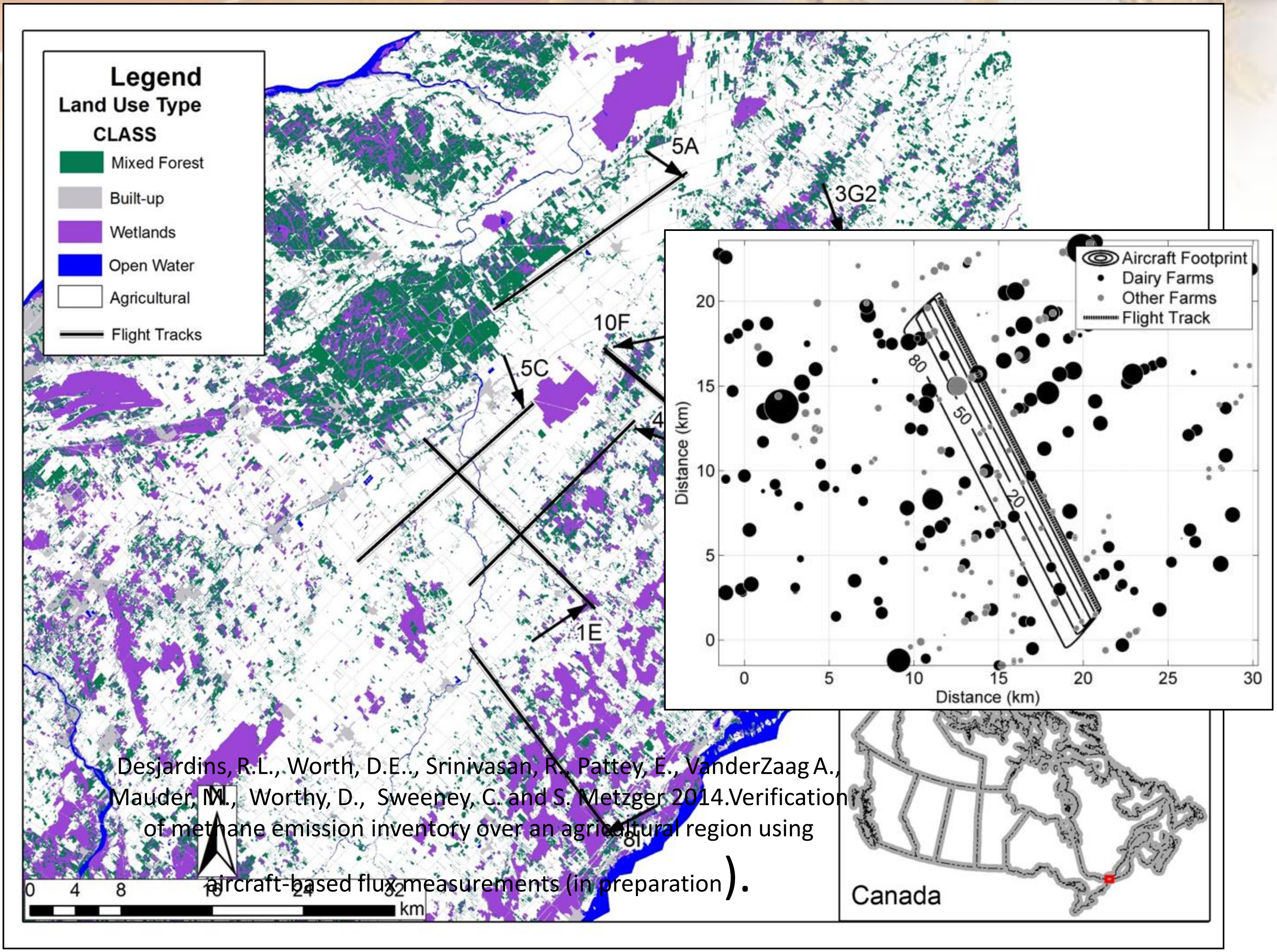
Instrumented nose boom

CH_4 Analyzer (G2301) and real-time display

in-flight REA sample collection & post-flight REA sample analysis using Picarro G1301

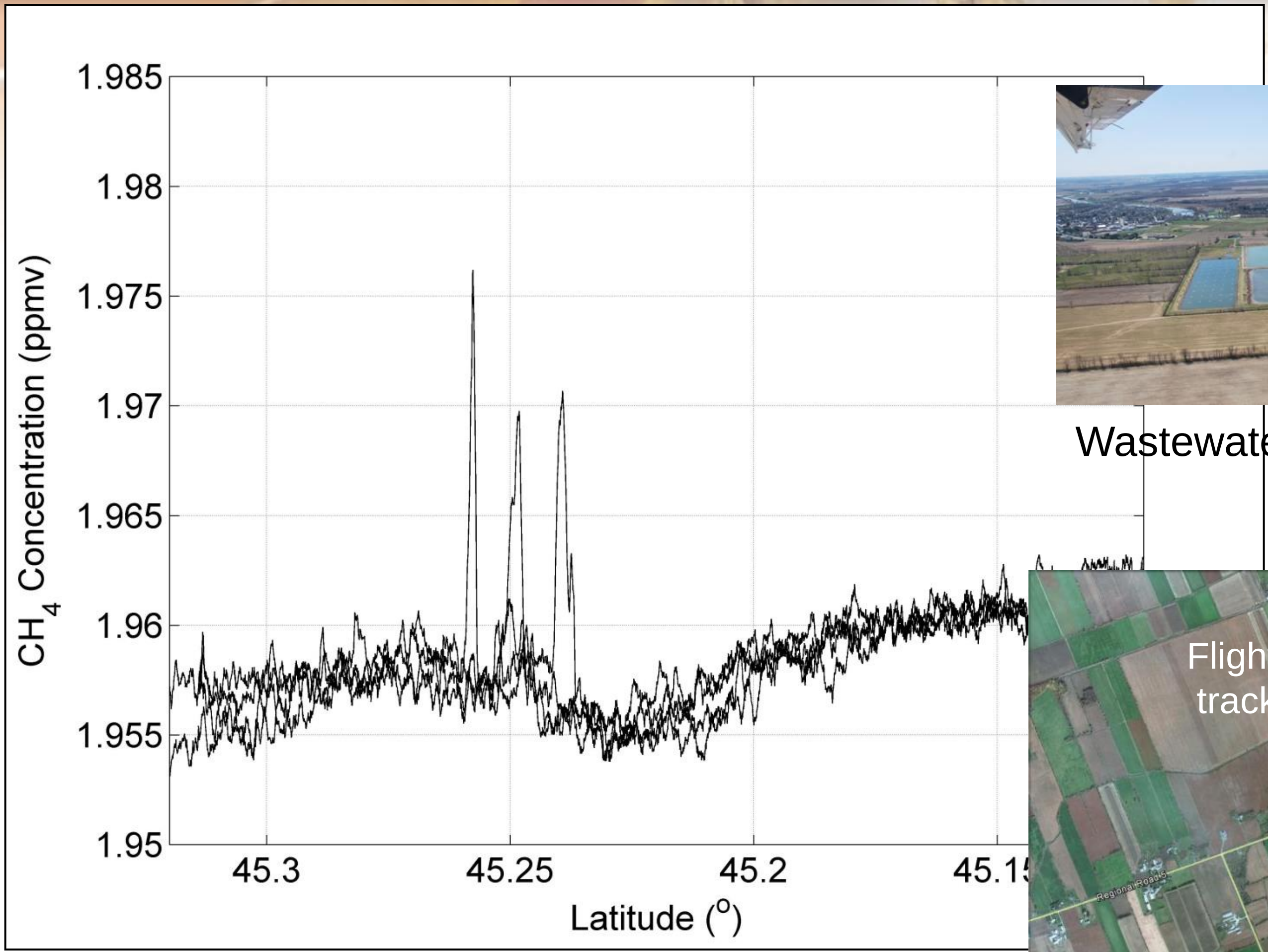


Location of the 7 transects flown at 150 m high

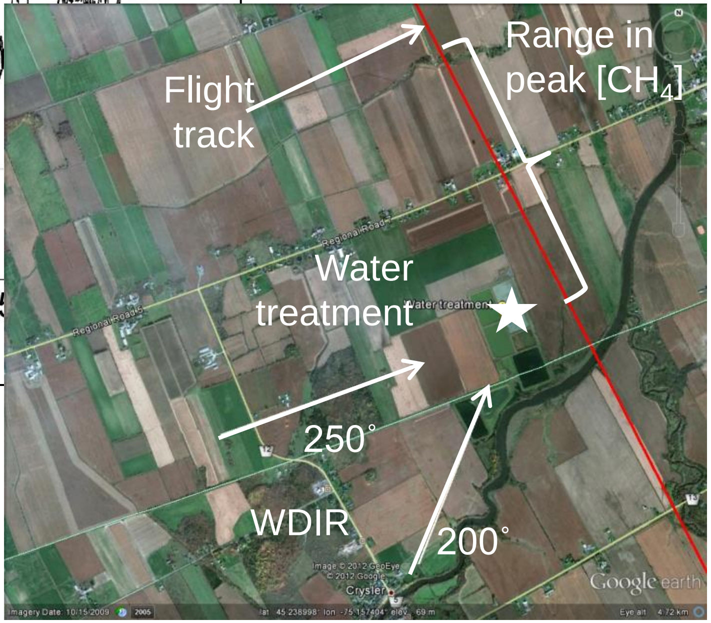


Desjardins, R.L., Worth, D.E.., Srinivasan, R., Pattey, E., VanderZaag A., Mauder, M., Worthy, D., Sweeney, C. and S. Metzger 2014.Verification of methane emission inventory over an agricultural region using aircraft-based flux measurements (in preparation).

Water treatment facilities associated with increase in methane concentration

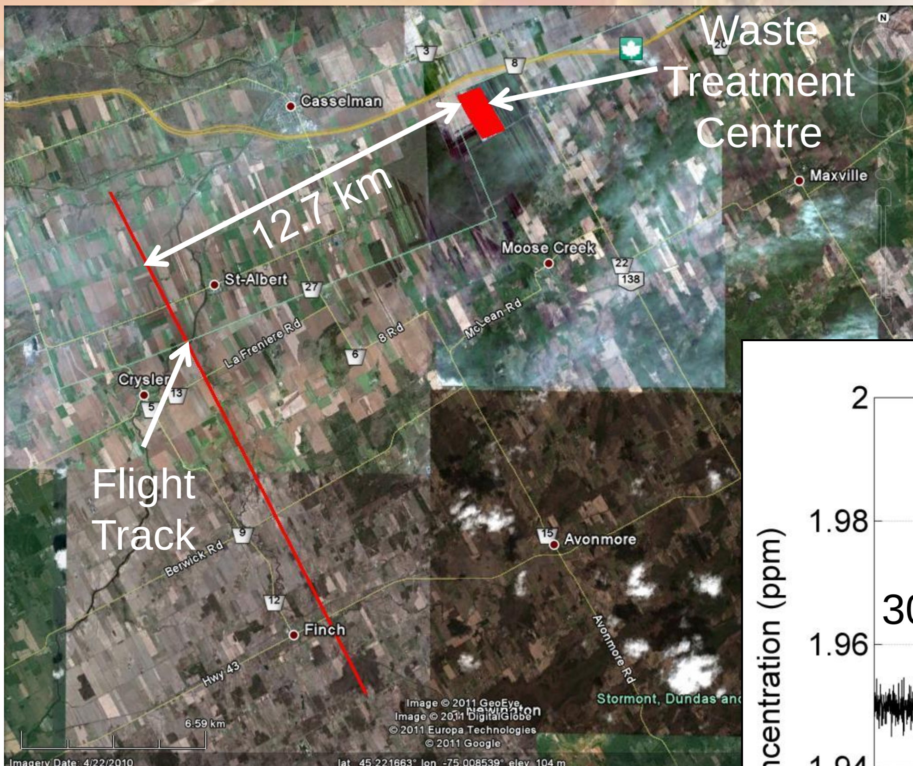


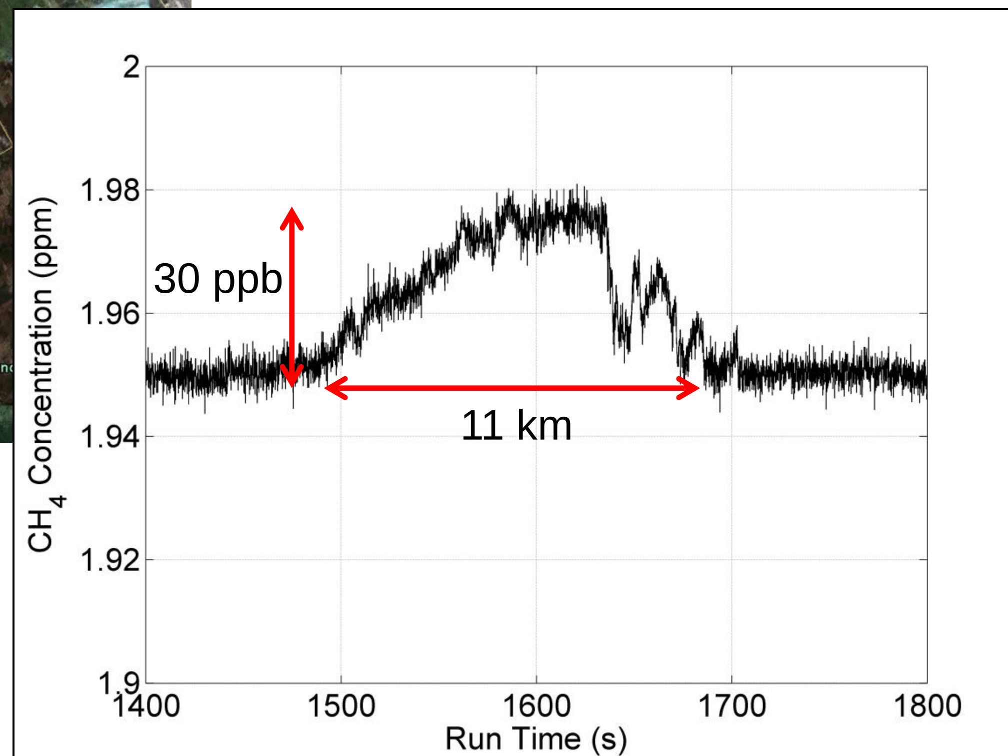
Wastewater treatment



Flesch, T.K., Desjardins, R.L. and Worth, D. 2011. Fugitive methane emissions from an agricultural biodigester. Biomass and Bioenergy. 35: 3927-3935.

Waste treatment centres affect CH_4 concentration over large areas





Cai, X., Flesch, T.K., Desjardins, R.L. Worth, D.E. VanderZaag, A. Measurement and modeling of methane emissions from a large waste treatment facility. In preparation.

Summary

- Presented GHG flux measuring systems for a wide range of spatial and temporal scales- models are essential to integrate
- Presented some examples of comparisons between flux measuring techniques- There are some challenges but most of the differences observed are explainable
- Presented measurements of nitrous oxide emissions using an aircraft-based system. The combination of nitrous oxide emission estimates using aircraft- based flux measurements and the DNDC model provided an independent estimate of indirect emissions assumed in the IPCC methodology
- The aircraft-based methane flux measurements showed that methane emission inventory estimates for agricultural sources appear reasonable. It confirmed that some agricultural regions include other methane sources such as wetlands, biodigesters, waste treatment plants, etc. that can be quite large. This could put in question some of the sector-based methane emission estimates using atmospheric inverse modelling techniques.

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