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Measuring and Modeling N_2O Emissions from Agricultural Sources

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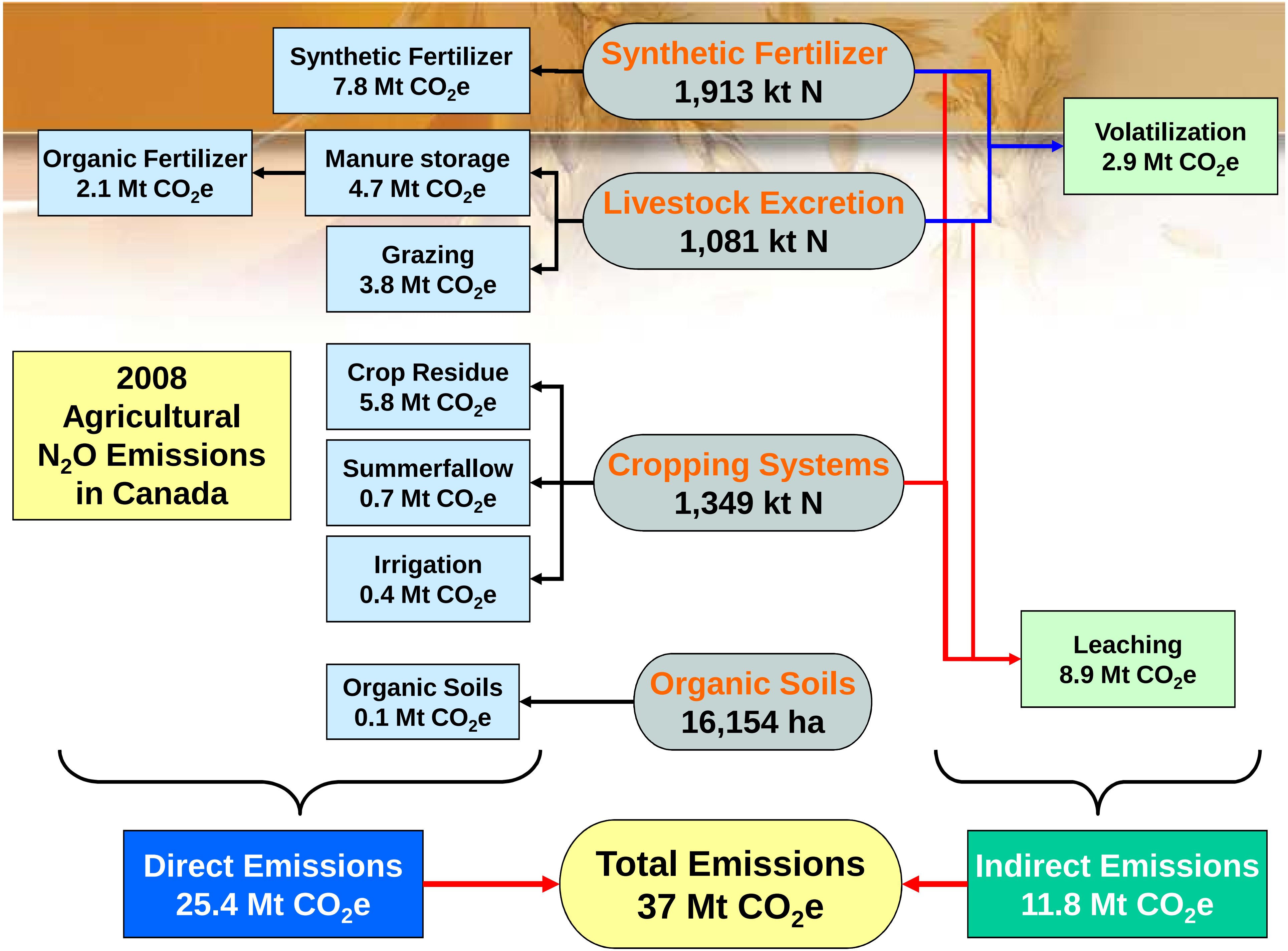


Synthetic Fertilizer
7.8 Mt CO_2e
Synthetic Fertilizer
1,913 kt N
Volatilization
2.9 Mt CO_2e
Organic Fertilizer
2.1 Mt CO_2e
Manure storage
4.7 Mt CO_2e
Livestock Excretion
1,081 kt N
Grazing
3.8 Mt CO_2e
2008 Agricultural N_2O Emissions in Canada
Crop Residue
5.8 Mt CO_2e
Summerfallow
0.7 Mt CO_2e
Cropping Systems
1,349 kt N
Irrigation
0.4 Mt CO_2e
Leaching
8.9 Mt CO_2e
Organic Soils
0.1 Mt CO_2e
Organic Soils
16,154 ha
Direct Emissions
25.4 Mt CO_2e
Total Emissions
37 Mt CO_2e
Indirect Emissions
11.8 Mt CO_2e

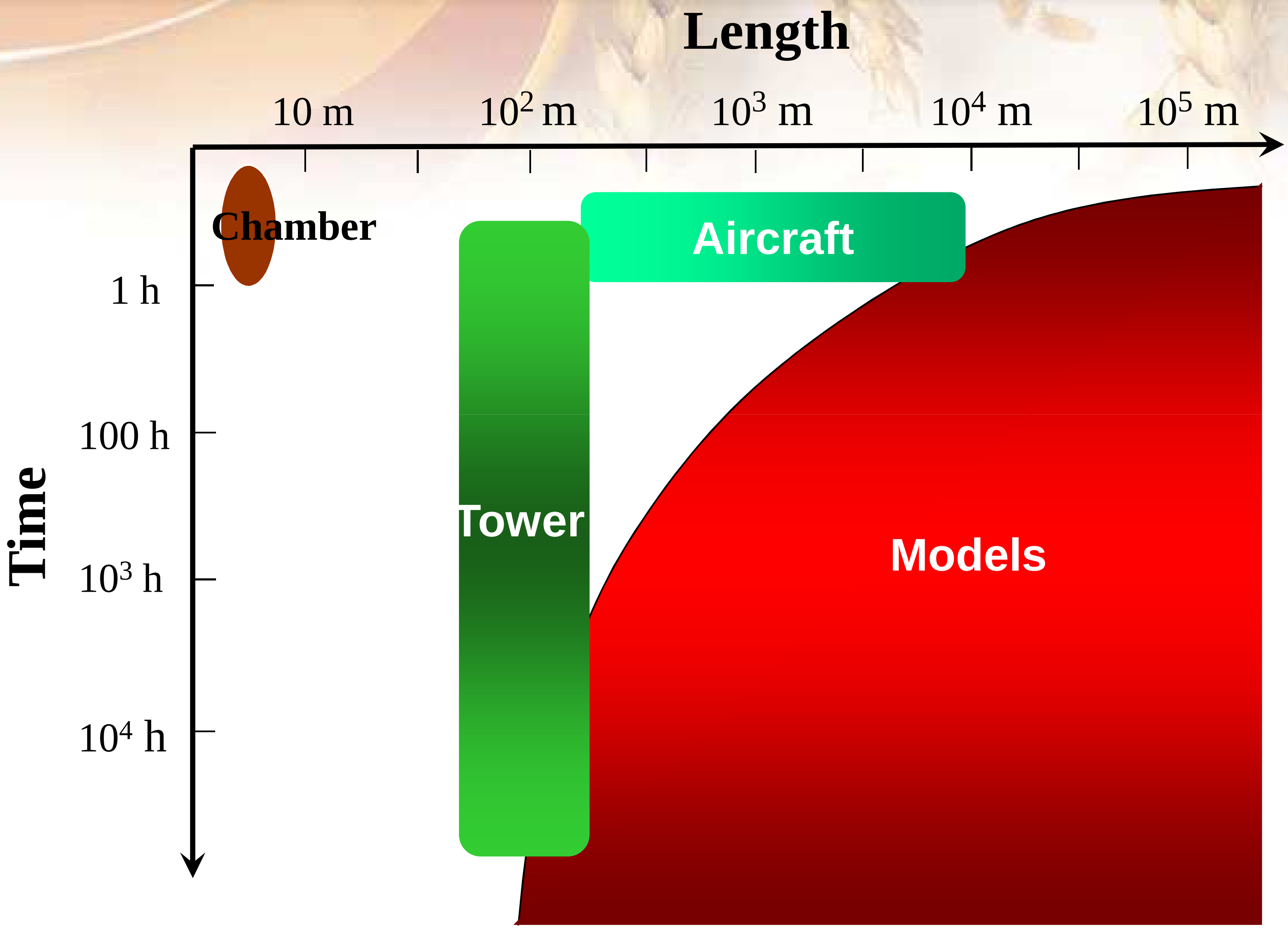
N_2O Emissions Estimates in Canada (2008)

Category	NCGAVS Tier II	Tier I	Change
	Mt CO_2 Equivalents		
Synthetic N	7.84	9.32	-1.48
Crop Residue	5.83	6.57	-0.74
Animal Manure	2.10	1.92	0.18
Pasture, Range	[illegible]	[illegible]	0.54
Summerfallow	0.65	N/A	0.65
Irrigation	0.39	N/A	0.39
Organic Soils	0.06	0.06	0.00
Animal Waste Management	4.67	4.12	0.55
Indirect Emissions	11.79	7.48	4.31
Total	37.1	32.5	4.6

Uncertainty in national Tier II estimates is approximately +/- 40%

Source: Rochette et al. (2008); Hutchinson et al (2007)

Measuring and modeling N_2O fluxes



Chamber measurement of GHG emissions

Chambers are the most commonly used technique to measure carbon dioxide, methane and nitrous oxide emissions from agricultural sources

Manual

Automated

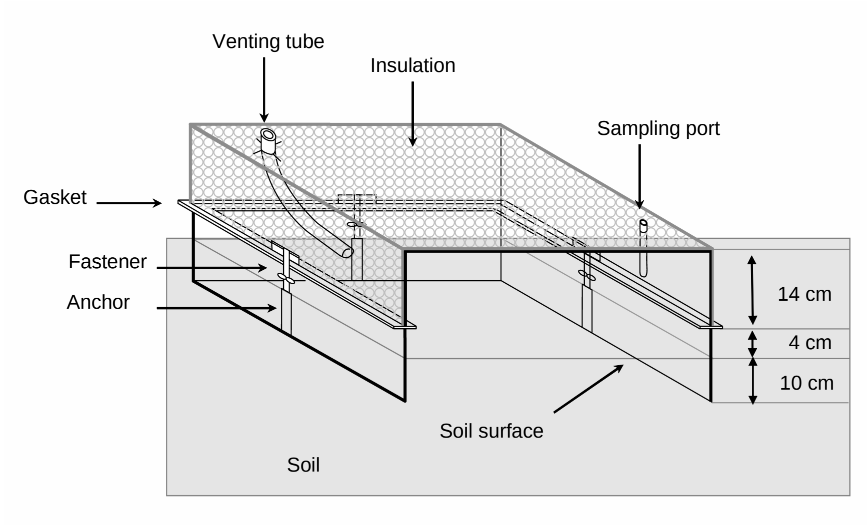
e.g. LI-COR survey chambers

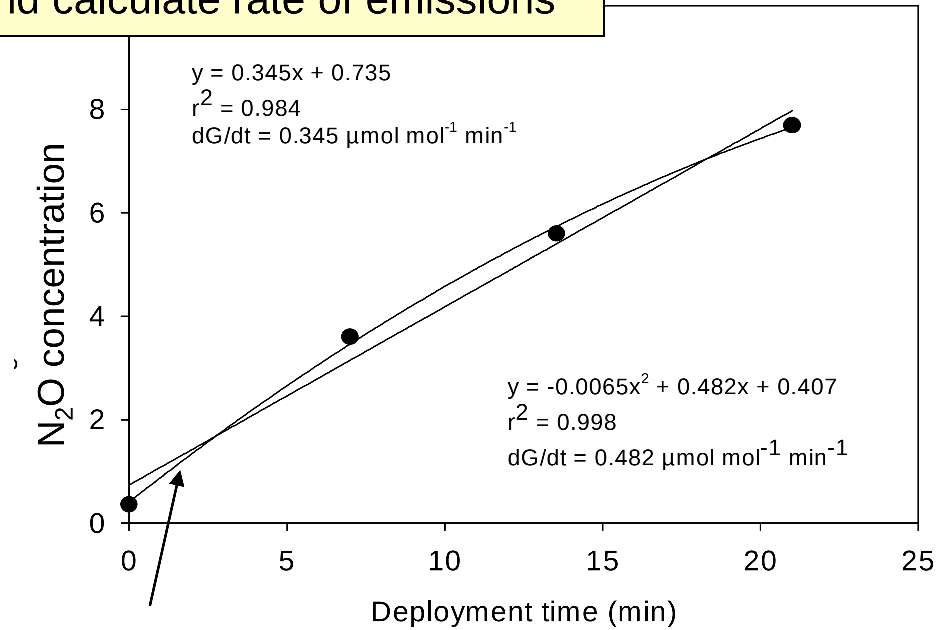
However, . . .

Rochette and Eriksen-Hamel (2007) evaluated the quality of soil N_2O emissions that have been collected using closed chambers and has suggested the confidence level in 50% of recent (2005-2007) N_2O flux measurements is low or very low owing to poor methodologies or incomplete reporting. The diurnal pattern of the emissions is ignored.

Chamber measurement : Principle of operation

- Insert collar into soil, affix chamber to collar
- Gas accumulates in head space, no replacement of air
- Sample periodically, typically at intervals of a few minutes and for periods of 15-30 minutes
- Gas samples returned to the lab and analyzed with e.g. gas chromatograph
- Plot change in concentration over time and calculate rate of emissions



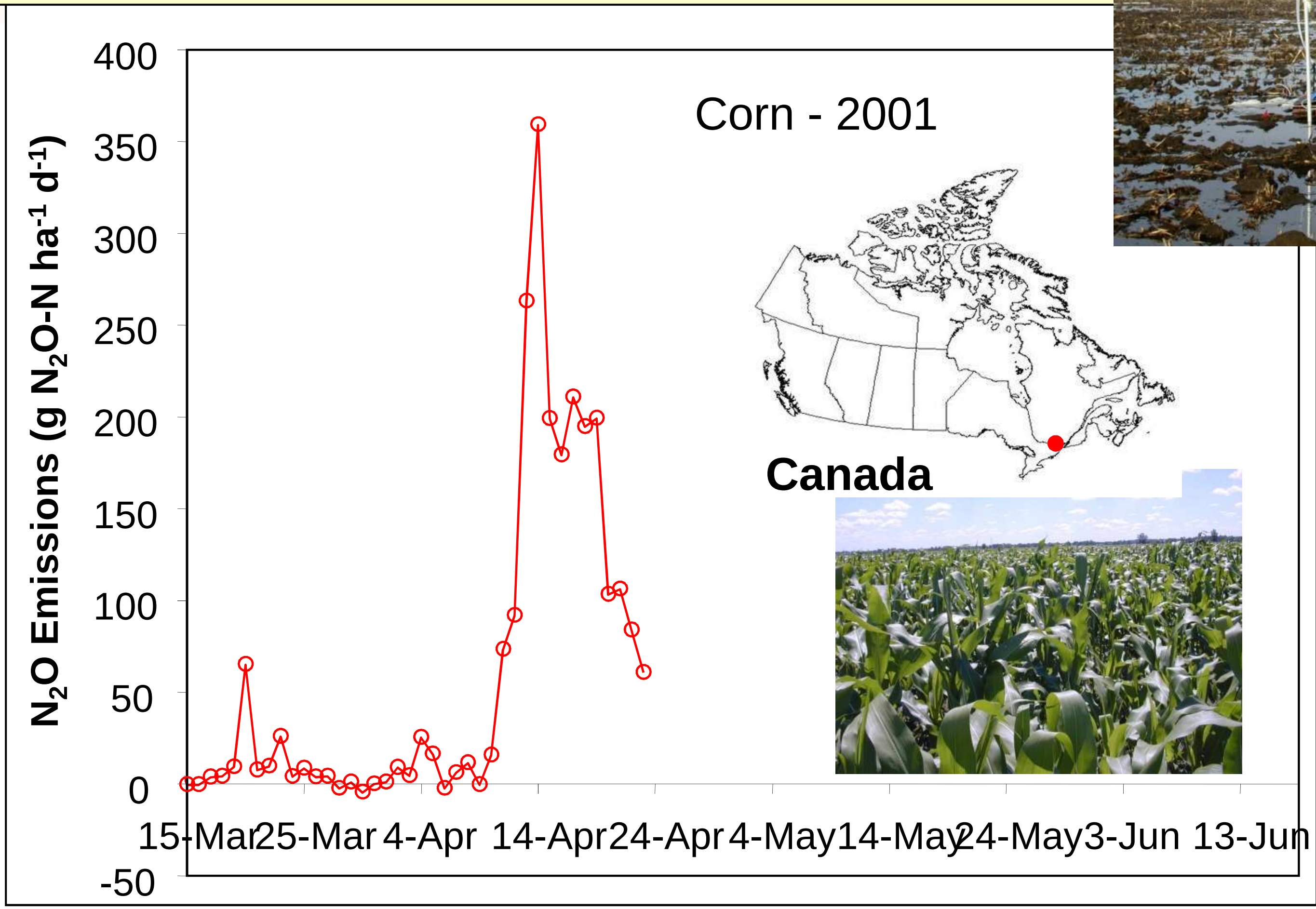


Source: Rochette and Eriksen-Hamel (2007)

$$F_{N2O} = dC/dt \bullet V/A \bullet M_m/M_v \bullet (1\text{-}e/P)$$

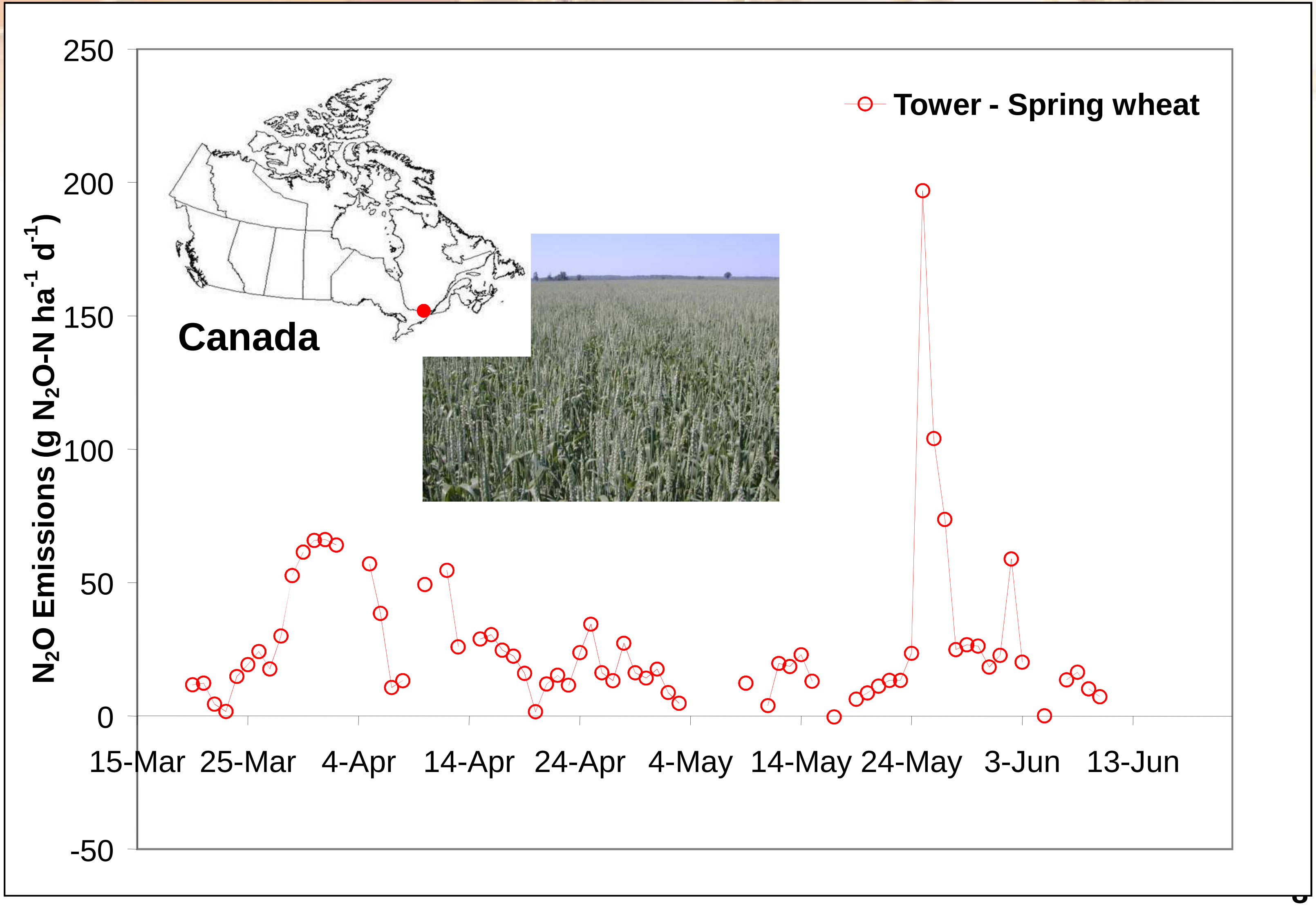
Tower-based measurements

The gradient technique is frequently used to measure nitrous oxide emissions at the field scale



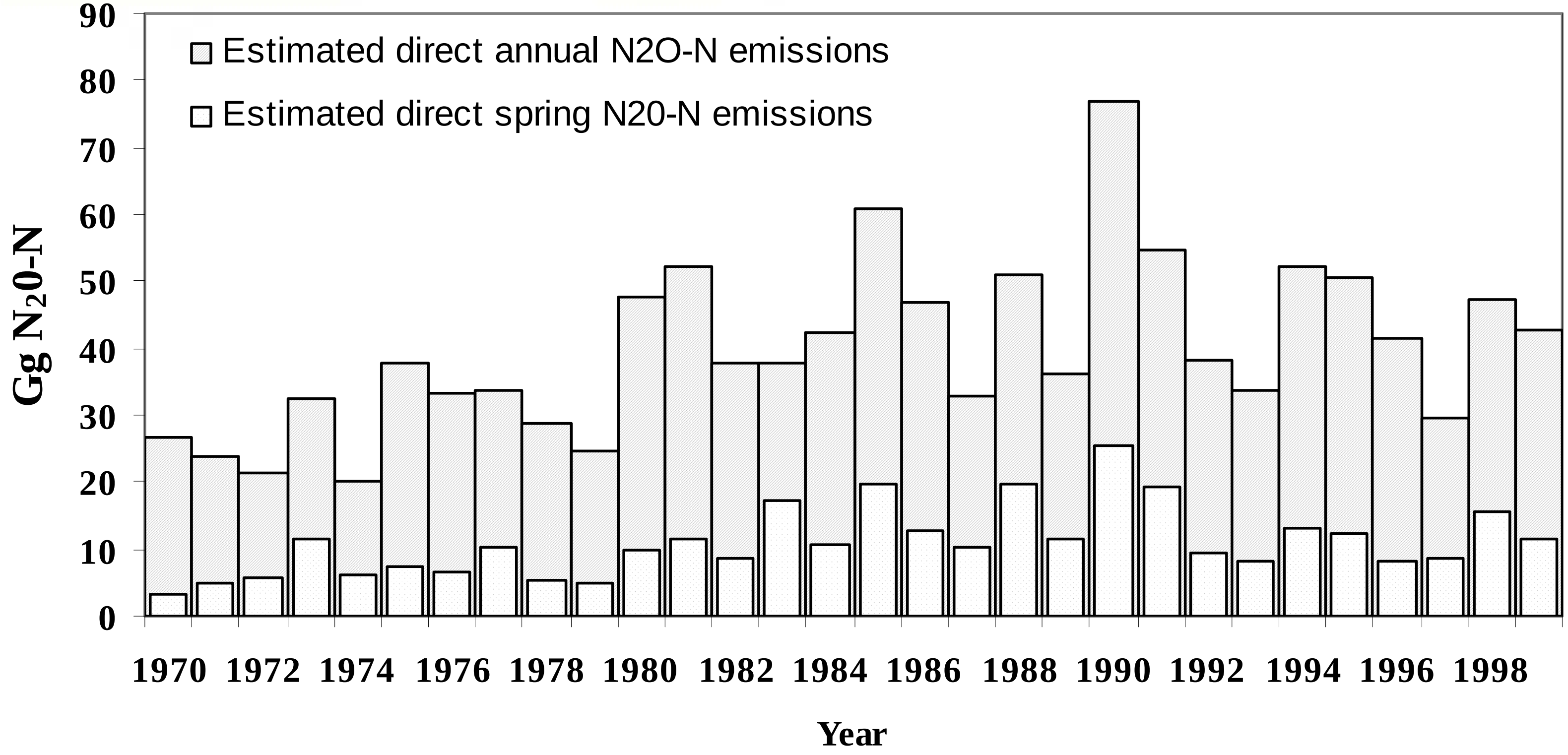
Source: Pattey et al. (2007)

Tower based N_2O flux estimates over spring wheat, 2004

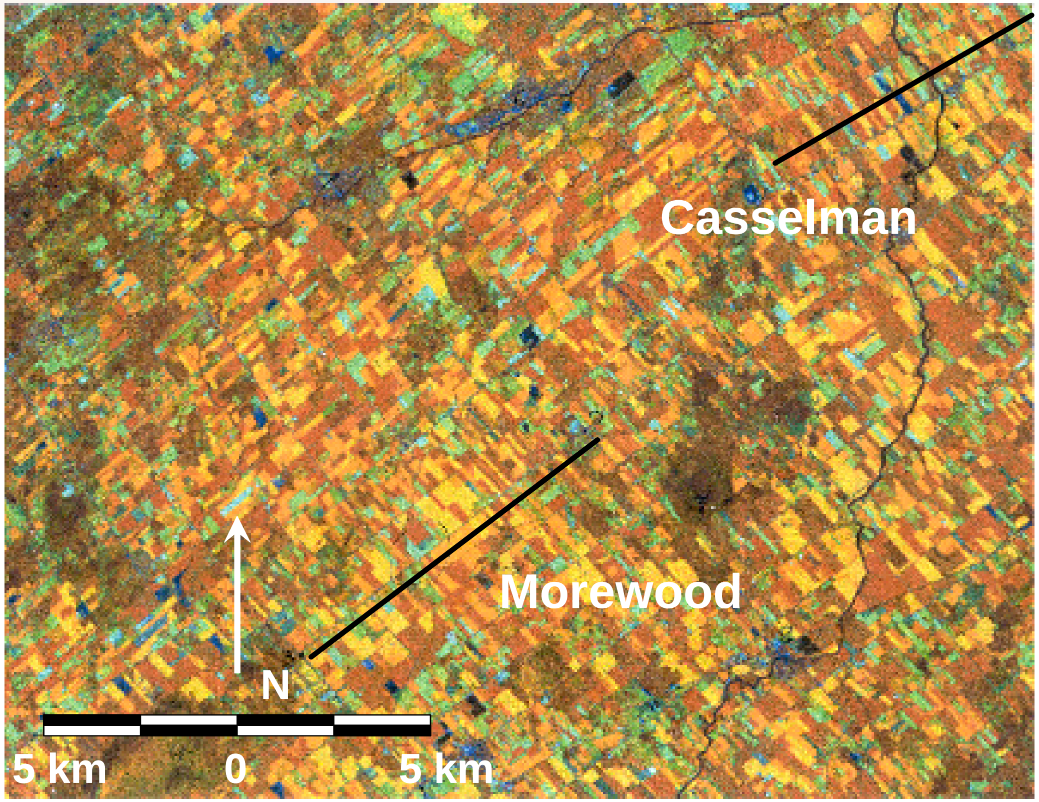


Source: Desjardins et al (2009)

Estimated direct N_2O-N emissions from agriculture soils in Canada for the period between 1970-1999 using DNDC.



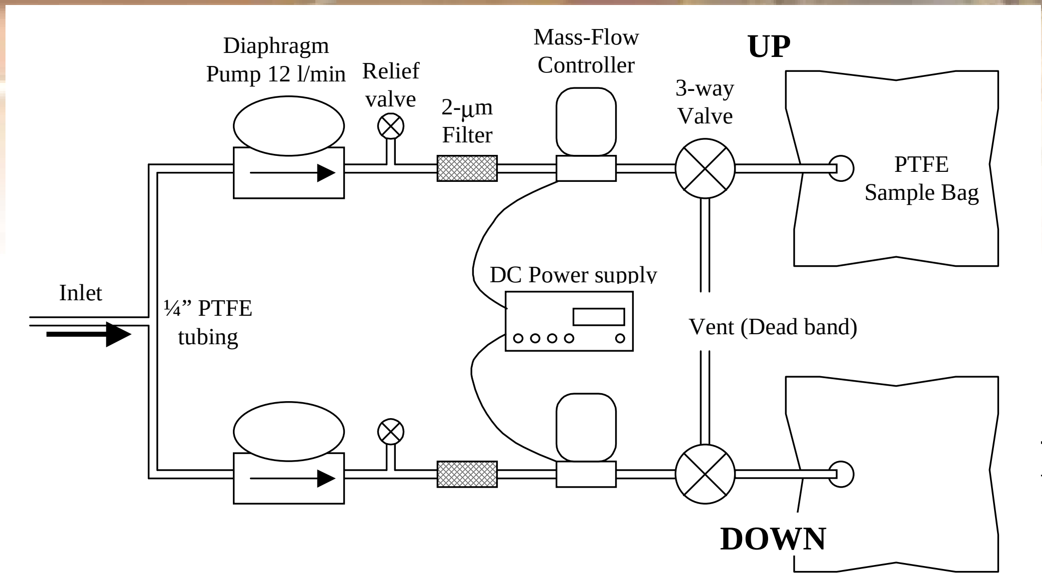
Crop types in the aircraft footprint



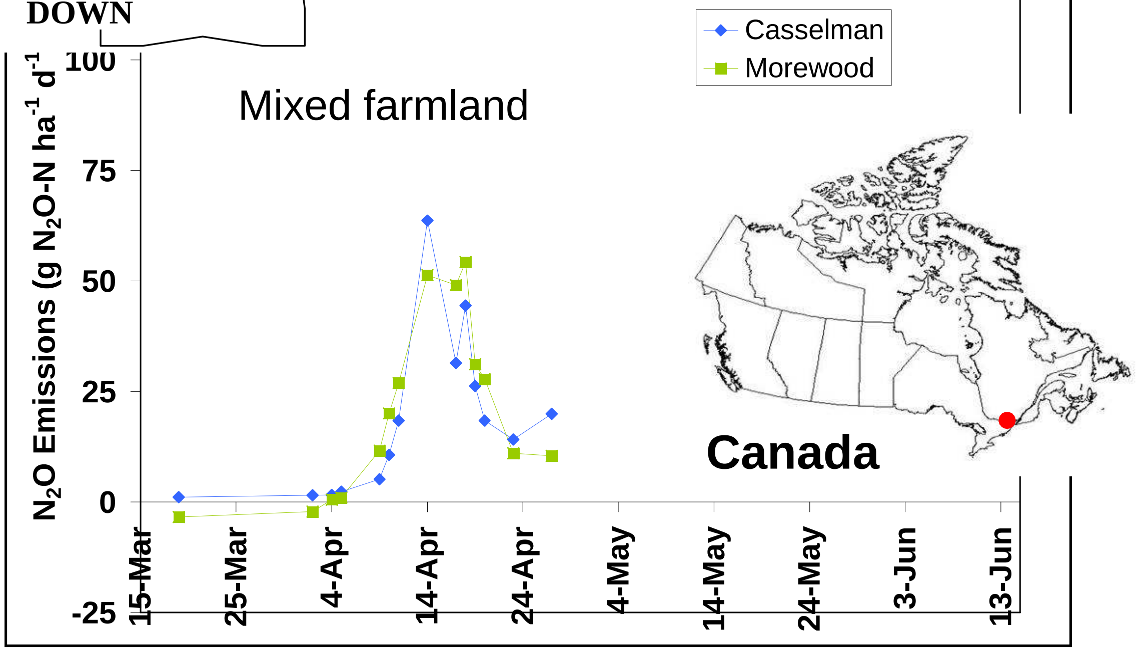
LEGEND

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

Relaxed Eddy Accumulation (REA)

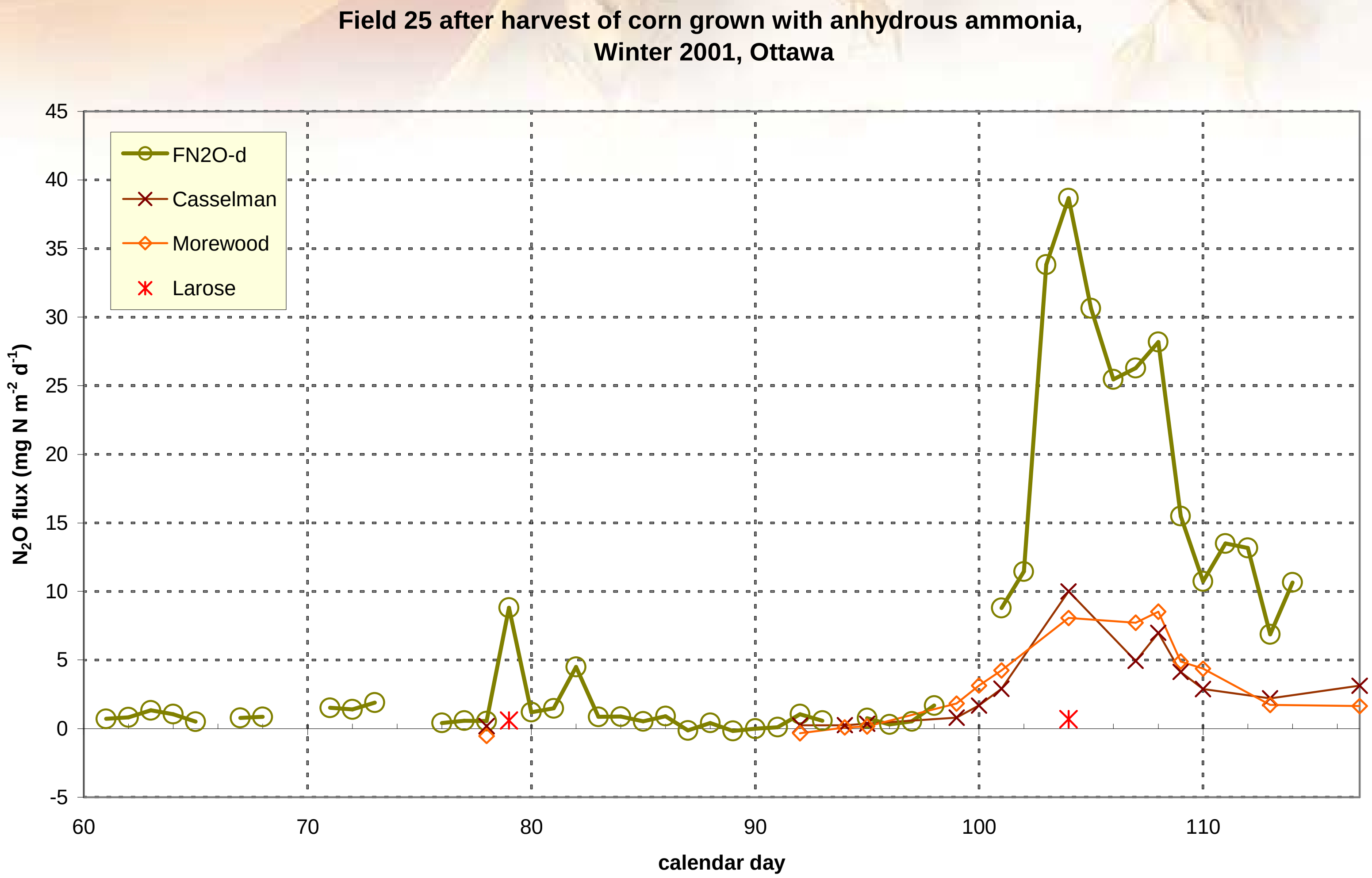


e.g. Can be used to measure the regional (≈50-100 km²) flux of N_2O from agricultural land

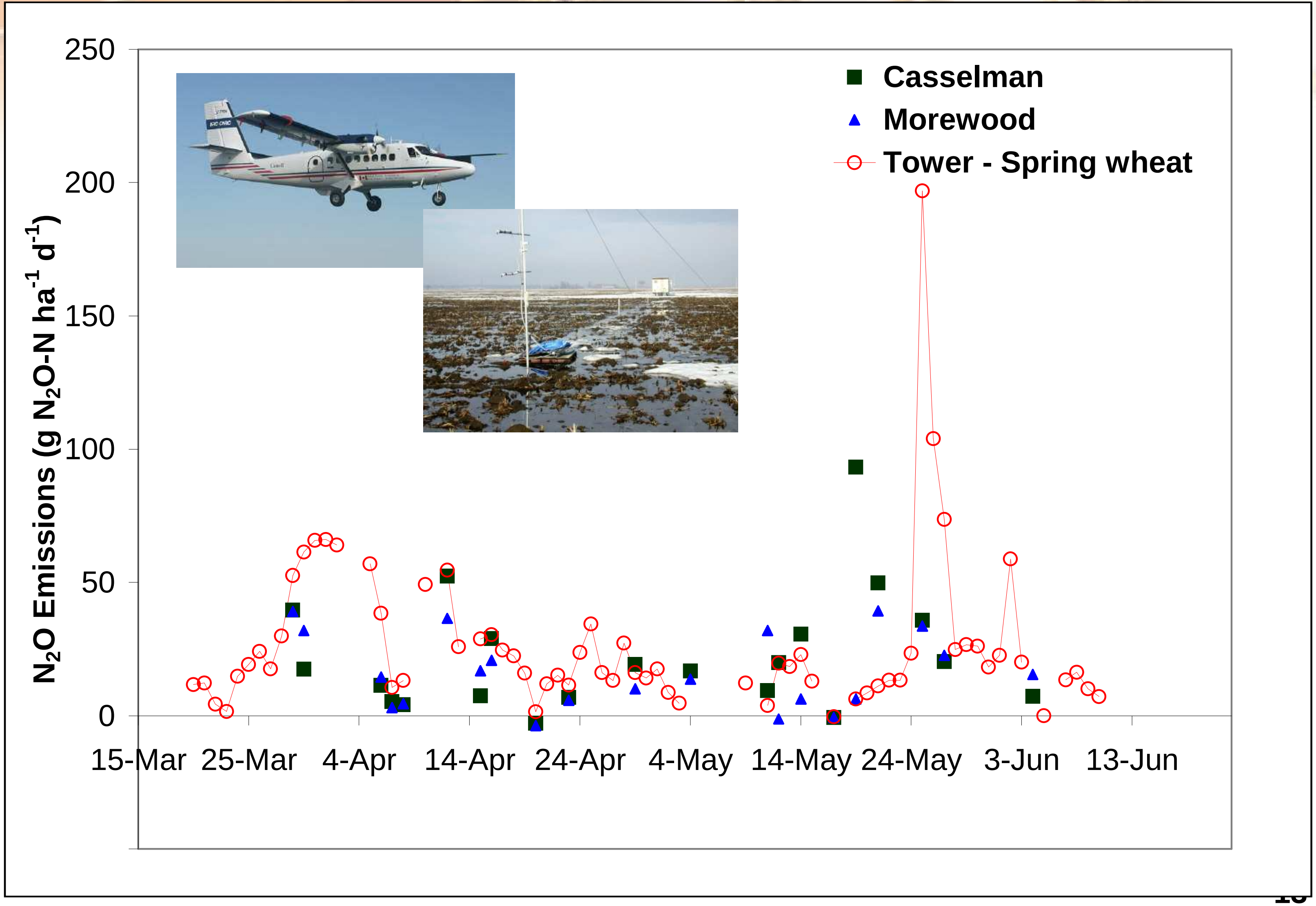


Source: Desjardins et al (2009)

Comparing tower and aircraft based N_2O emissions during the growing season: Eastern Canada study site, 2001

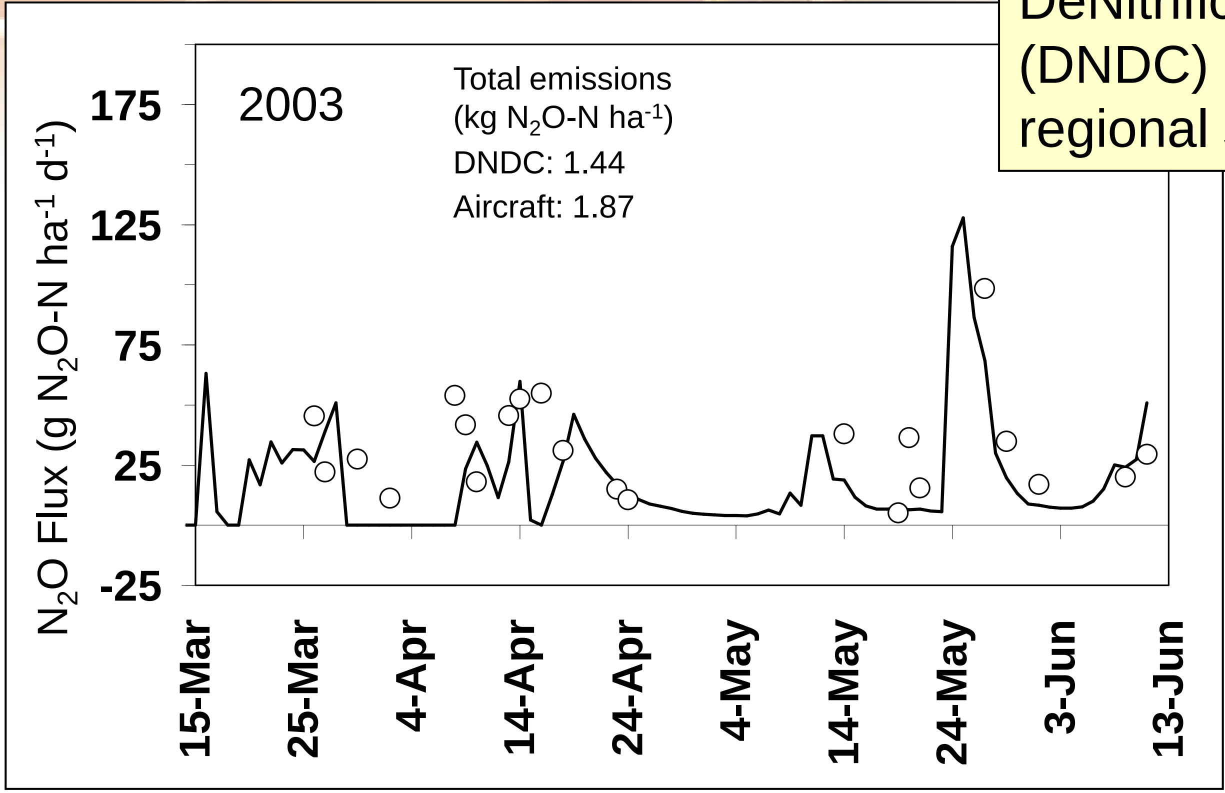


Tower/Aircraft N_2O flux comparison



Source: Desjardins et al (2009)

Model vs. regional scale measurements

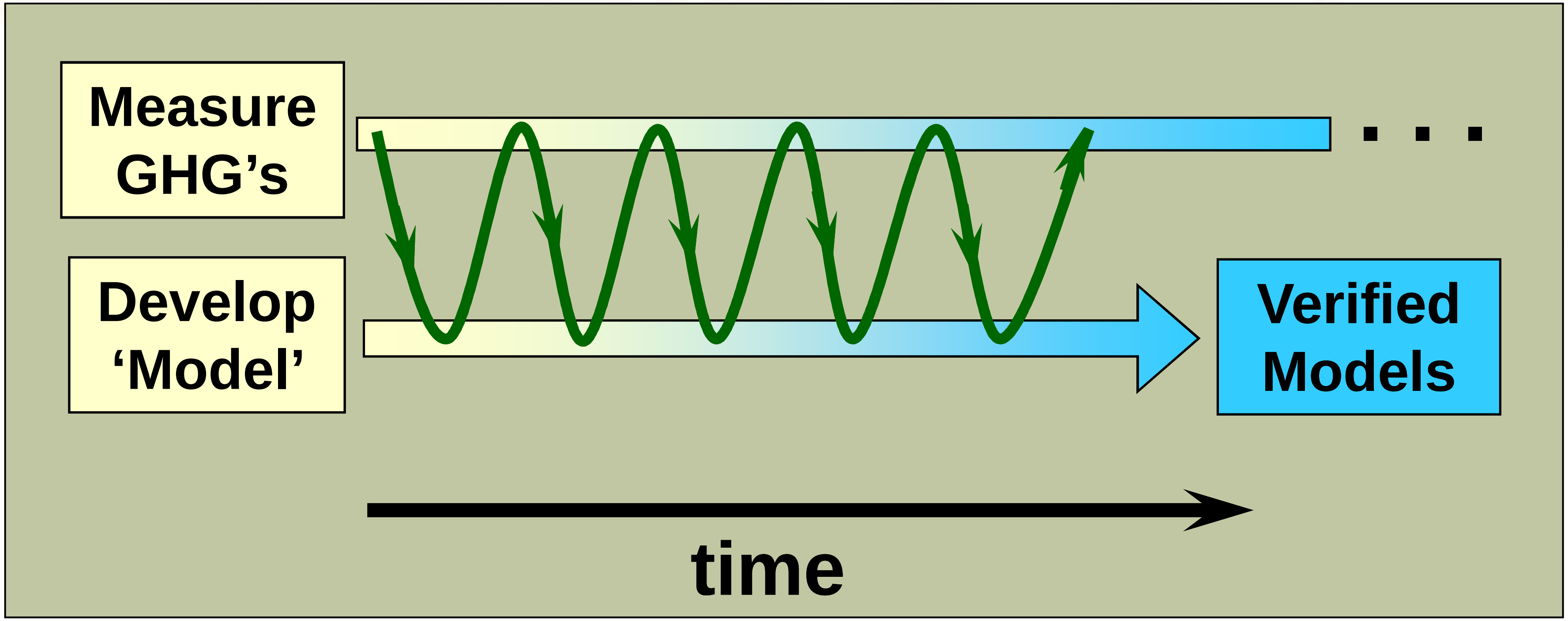


DeNitrification and DeComposition (DNDC) model and observed regional scale fluxes

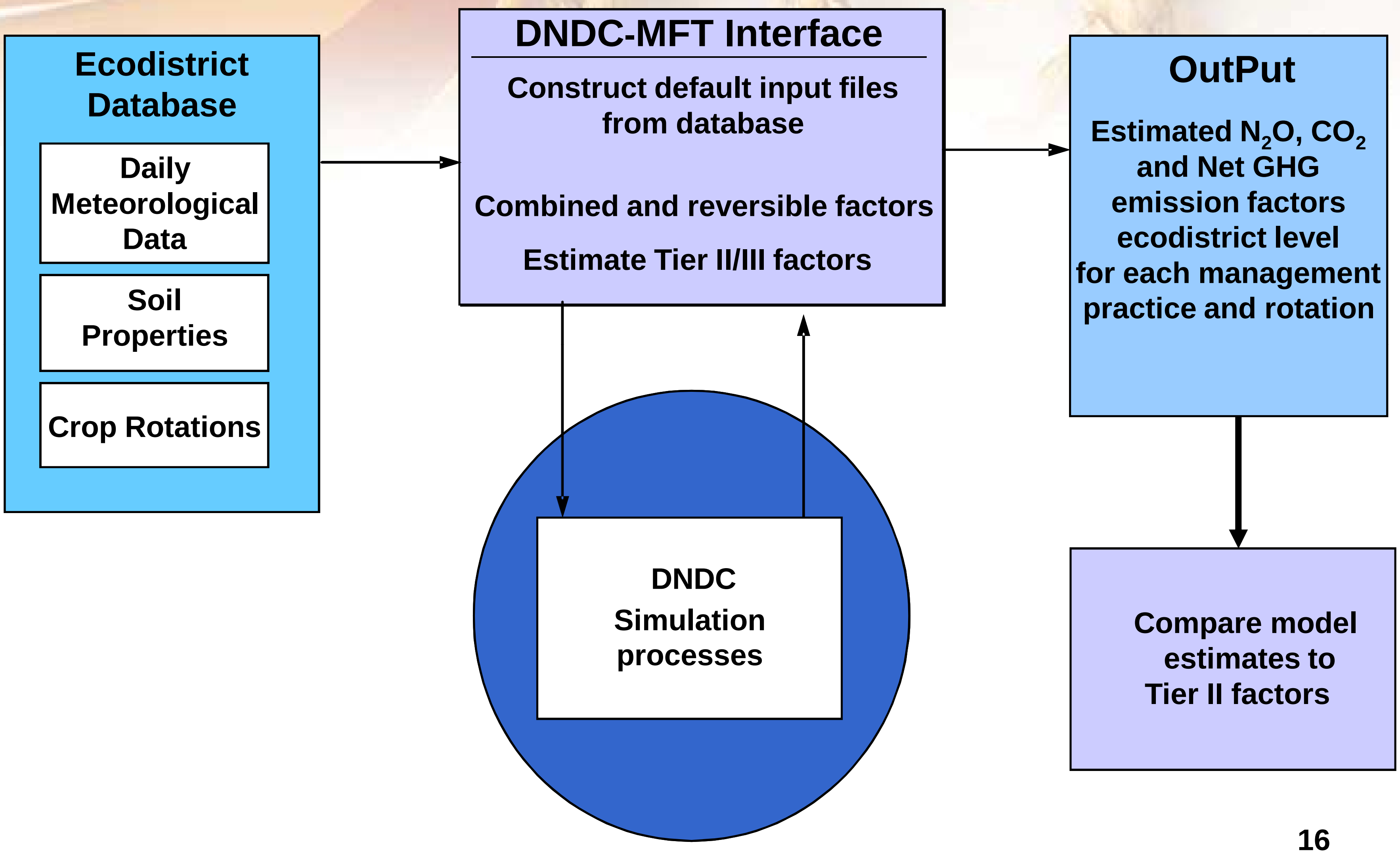
- After accounting for indirect emissions (not considered by DNDC) cumulative emission estimates are similar
- Timing of peak emissions not always accurately simulated

Source: Desjardins et al (2009)

Measuring and modeling N_2O

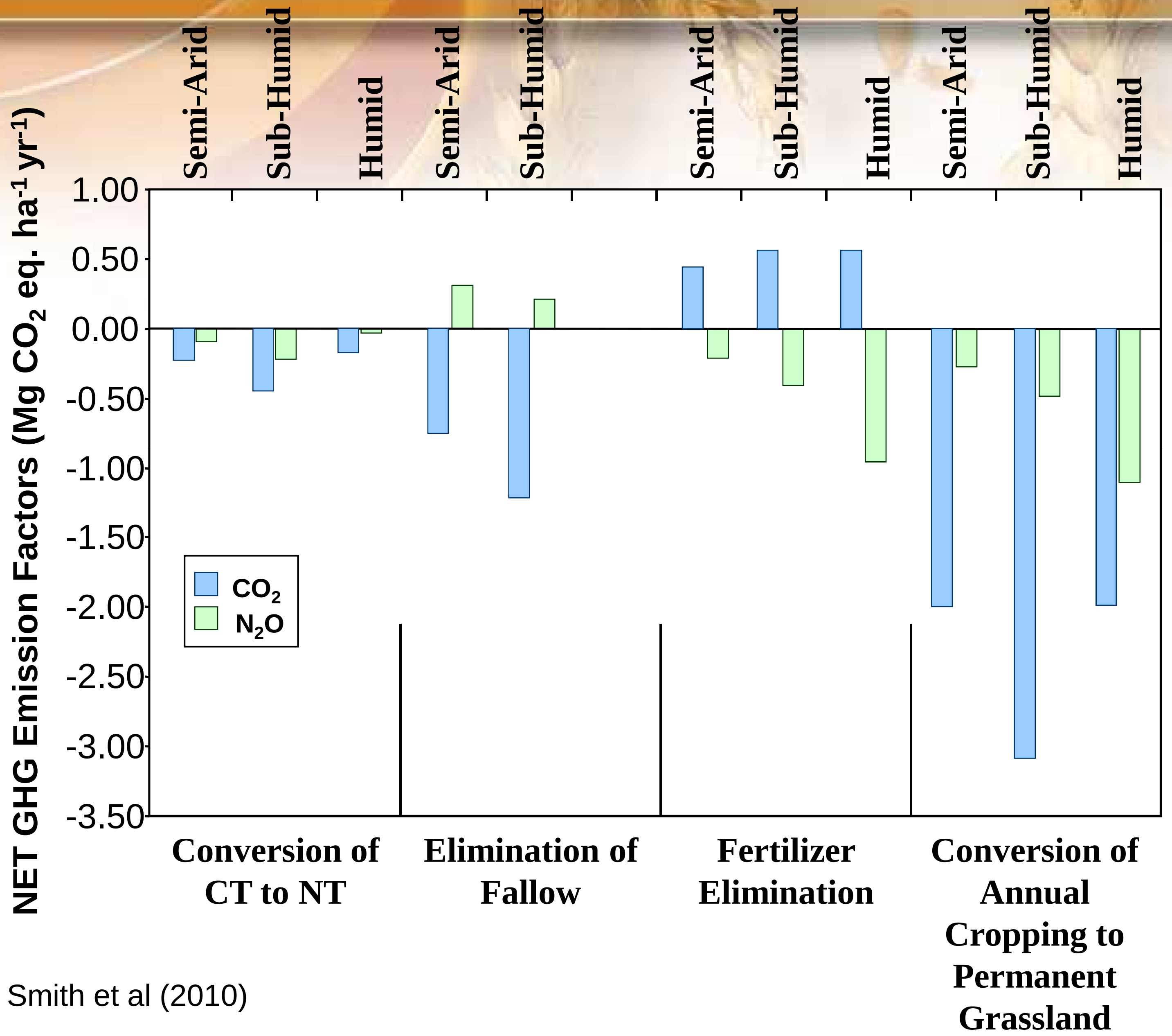


Using process based models to generate emission factors for changes in management practices (Ecodistrict Level)



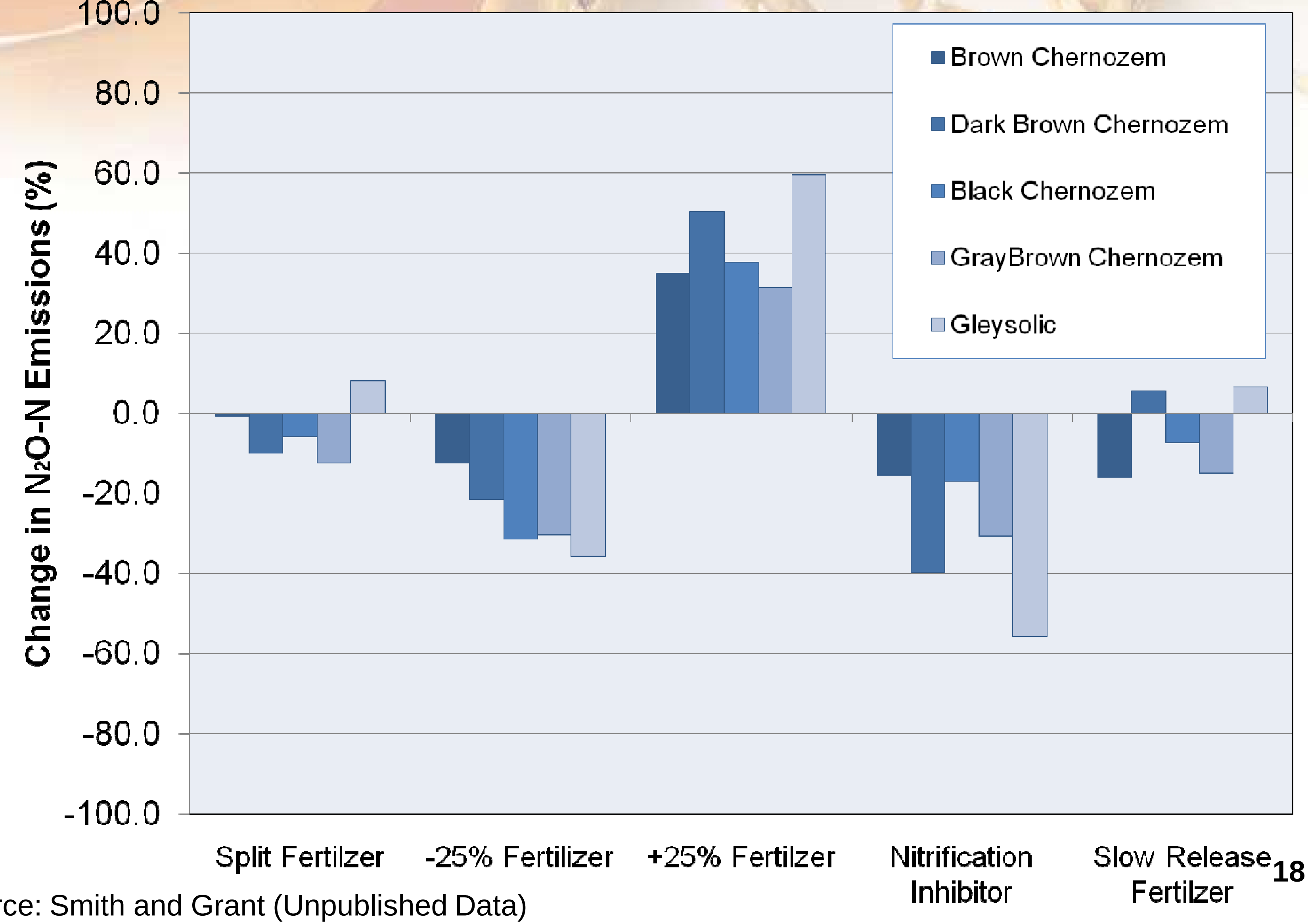
Source: Smith et al (2010)

Emission factors for changes in management practices based on DNDC



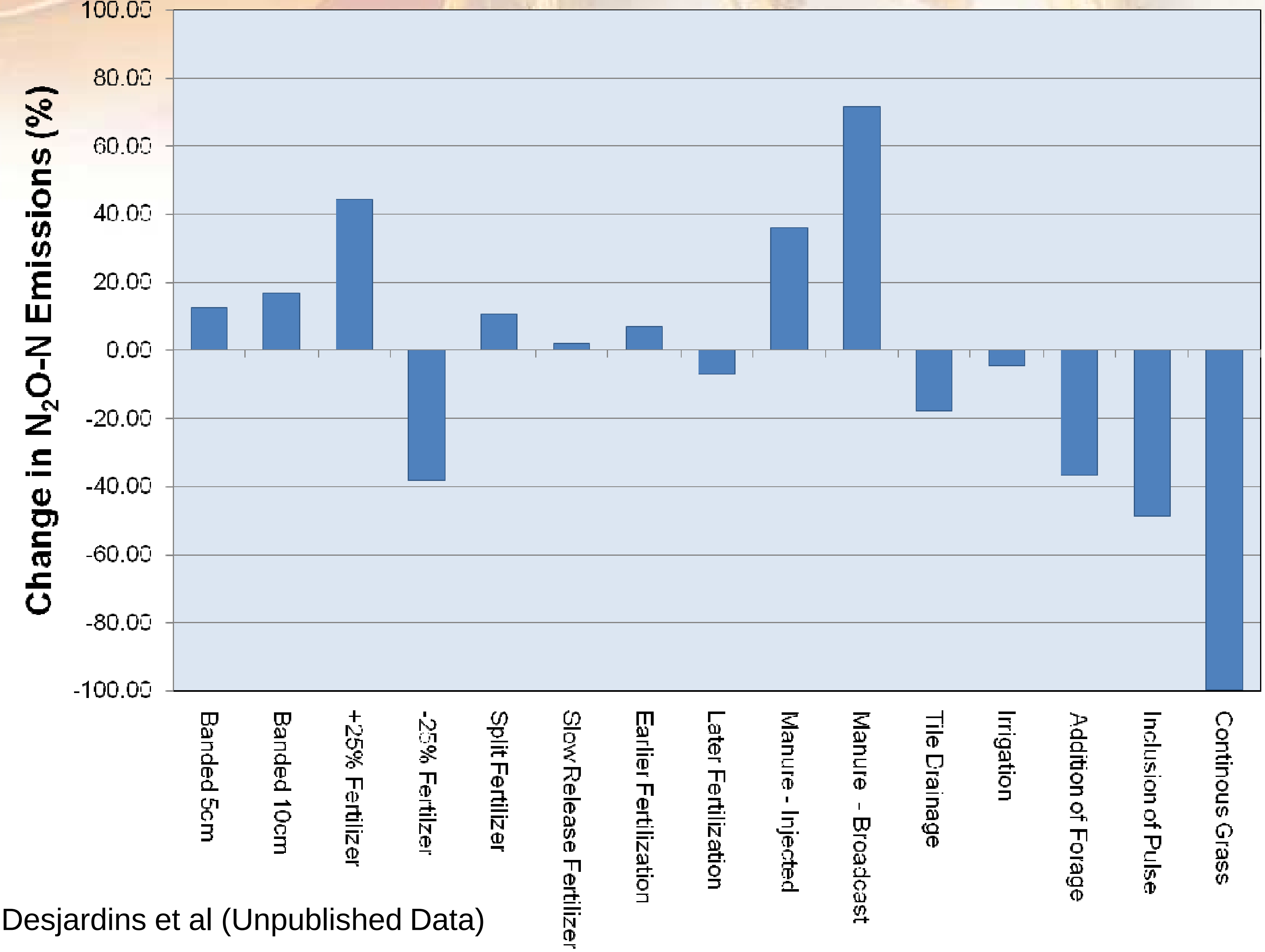
Source: Smith et al (2010)

Estimated effect of N fertilizer use on Nitrous Oxide emissions using DNDC for different soil types



Source: Smith and Grant (Unpublished Data)

Estimated effect of management changes on N_2O emission for a Corn-Barley Rotation in Eastern Canada (Ecosys)



Source: Desjardins et al (Unpublished Data)

Comparison of linearly additive factors for conversion of CT to NT and removal of fallow versus factors for the combined management change

Rotation	N_2O-N Factors (20 years) Combined	Additive (kg ha^{-1} y^{-1})	Change (%)	Carbon Factors (20 years) Combined	Additive (Mg C ha^{-1} y^{-1})	Change (%)
A-A-A-A-Sf-Ws-C	-0.14	-0.19	29.5	0.122	0.129	5.4
Gr-Sf-Ws	0.47	0.60	26.1	0.085	0.080	-5.2
P-C-Sf	-0.06	-0.10	53.7	0.091	0.092	0.4
Ws-Sf-P	-0.11	-0.14	22.2	0.091	0.091	0.3

Note: A, alfalfa; Sf, summer-fallow; Ws, spring wheat; P, peas; C, canola; Gr, grain.

Source: Smith et al. (2010)

Conclusions

- Several tools are now available to measure N_2O emissions from agroecosystems.
- Most process-based models (Ecosys, DNDC, Daycent, etc) used to estimate N_2O emissions from agroecosystems include algorithms to estimate the impact of a wide variety of management on emissions.
- Most of these algorithms depend on soil type and climatic conditions, hence it is not surprising to read all the conflicting results reported in the literature.
- It is clear that process- based models for predicting N2O emissions are getting better but they still to be improved and to be field tested over a wide range of conditions.

Canada

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GHG emission factors: DNDC compared to Tier II/III

Climatic zone	CT to NT		Elimination of SF		Remove Fertilizer		Permanent cover	
Nitrous oxide (kg ha^{-1} y^{-1})								
Semi-arid	-0.20	-0.05	0.63	0	-0.44	-0.13	-0.56	-0.23
Sub-hum	-0.45	-0.17	0.43	0	-0.85	-0.42	-1.00	-0.67
Humid	-0.07	0.24			-1.96	-1.02	-2.27	-1.57
Carbon dioxide (Mg C ha^{-1} y^{-1})								
Semi-arid	-0.06	-0.10	-0.21	-0.30	0.12		-0.54	-0.55
Sub-hum	-0.12	-0.15	-0.33	-0.30	0.15		-0.84	-0.54
Humid	-0.05	-0.09			0.15		-0.54	-0.71
Combined N_2O and CO_2 emissions (Mg CO_2 eq. ha^{-1} y^{-1})								
Semi-arid	-0.32	-0.39	-0.44	-1.10	0.23		-2.27	-2.13
Sub-hum	-0.67	-0.63	-1.01	-1.10	0.15		-3.57	-2.31
Humid	-0.21	-0.21			-0.40		-3.10	-3.37

DNDC (shaded)	Tier II/III

Source: Based on Smith et al (2010)