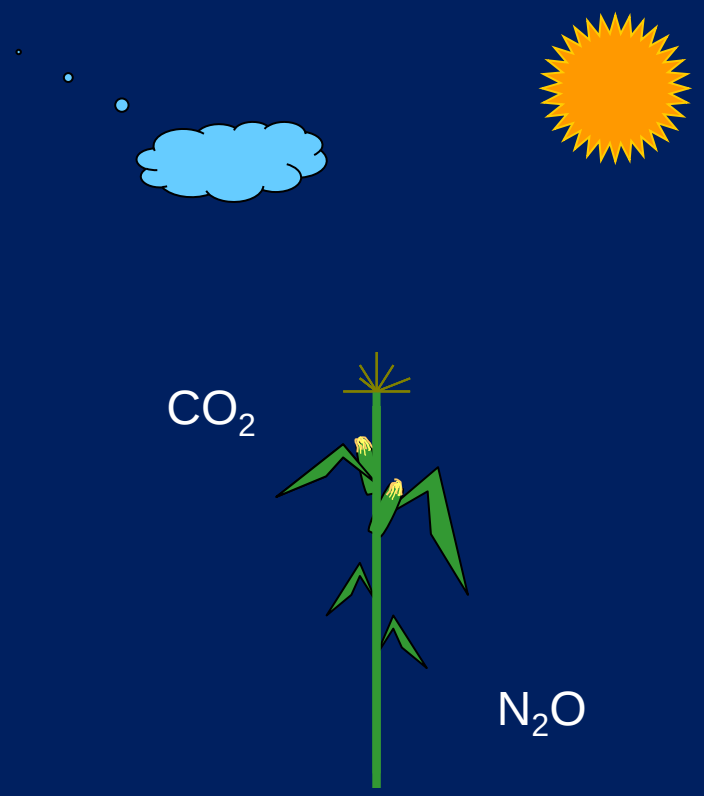
Influence of the United States Corn Belt on Regional and Global Nitrous Oxide Concentrations



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Acknowledgements

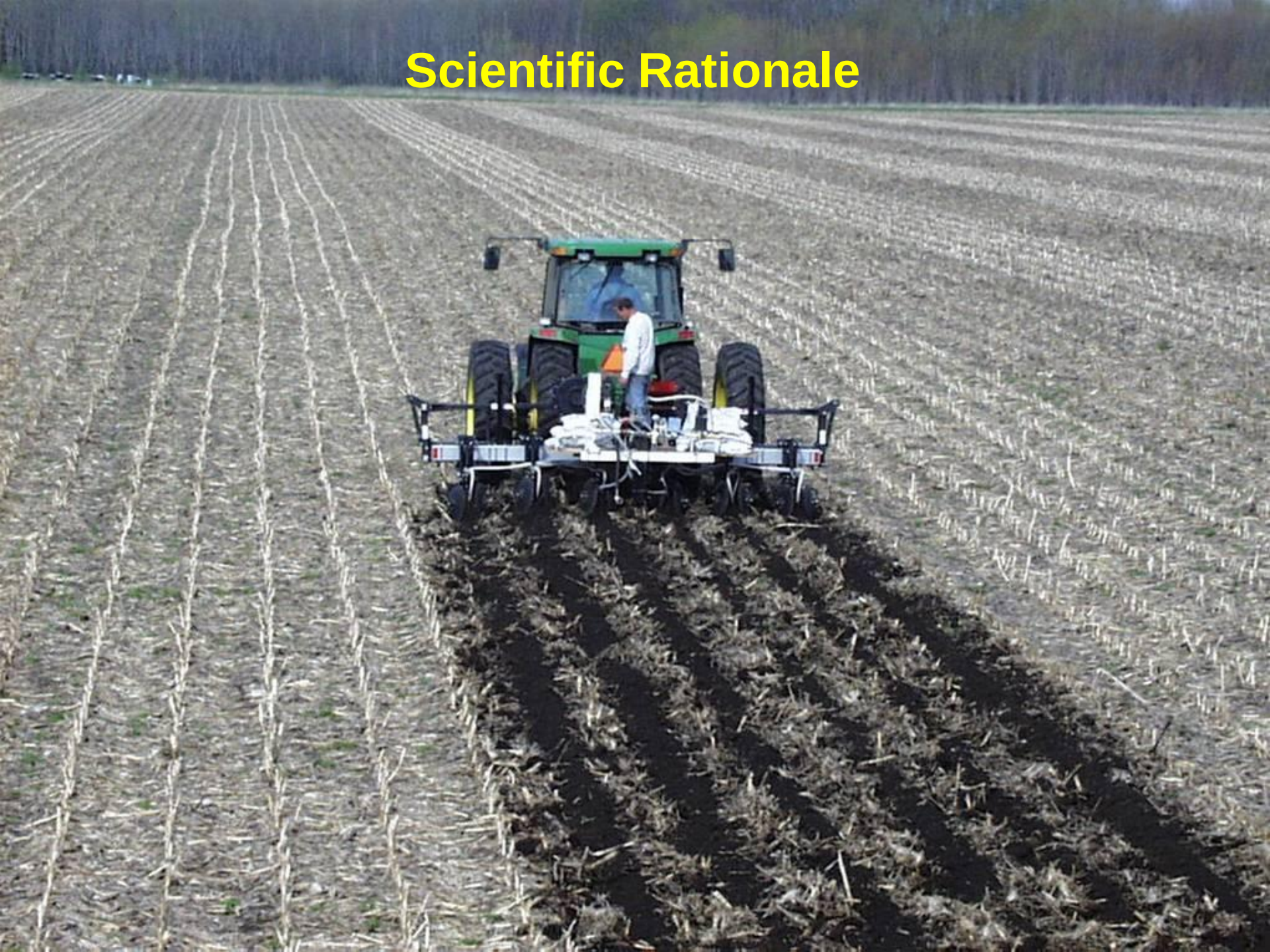
Collaborators:
John Baker, USDA-ARS & University of Minnesota
Xuhui Lee, Yale University
Dylan Millet, University of Minnesota
Rod Venterea, USDA-ARS & University of Minnesota

Graduate Students:
Xin Zhang, Peter Turner, Natalie Schultz, Ming Chen

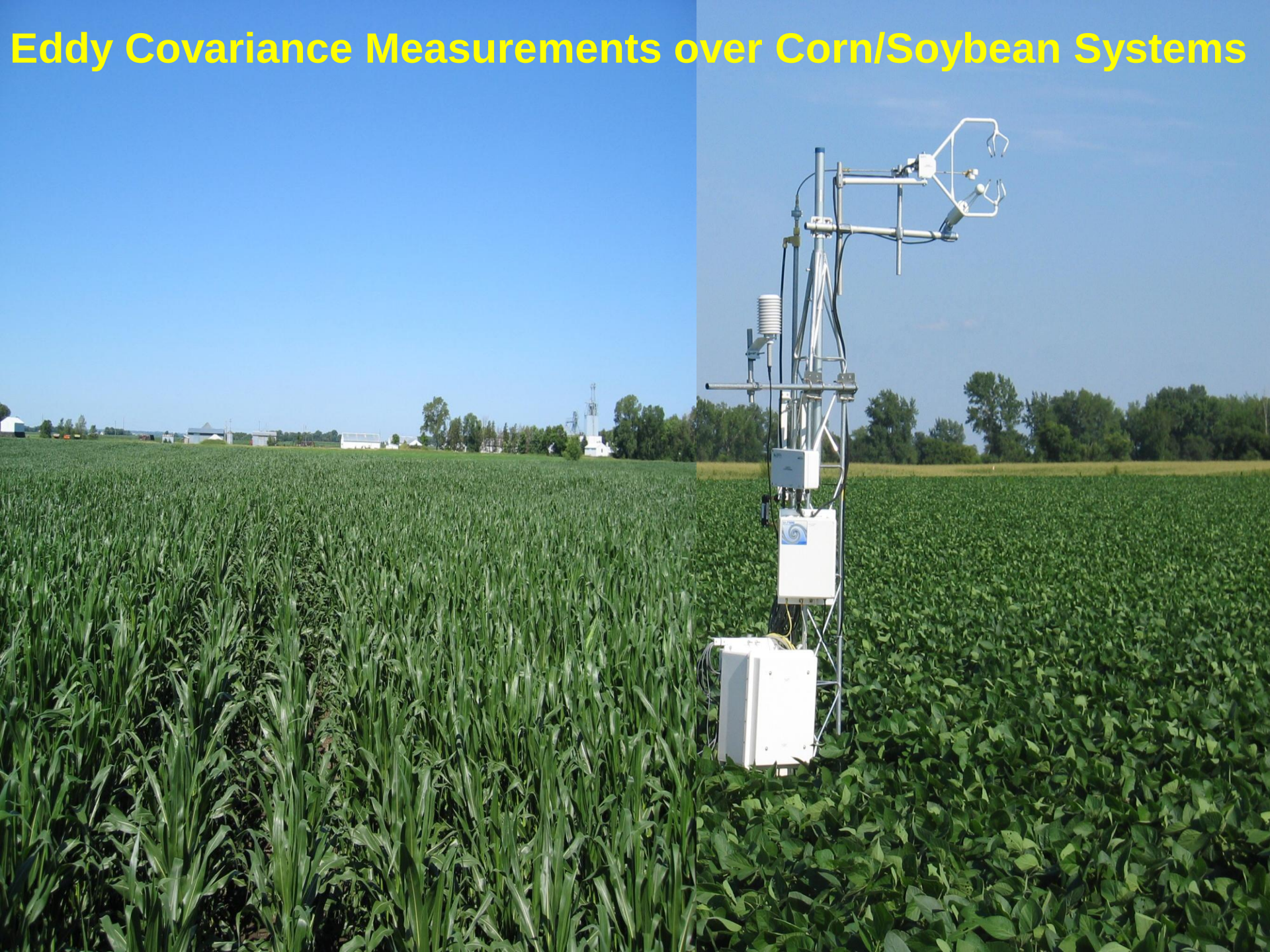
Technical Support:
Matt Erickson, Joel Fassbinder, Jeremy Smith, Bill Breiter

Financial Support:
United States Department of Agriculture – Agriculture and Food Research Initiative

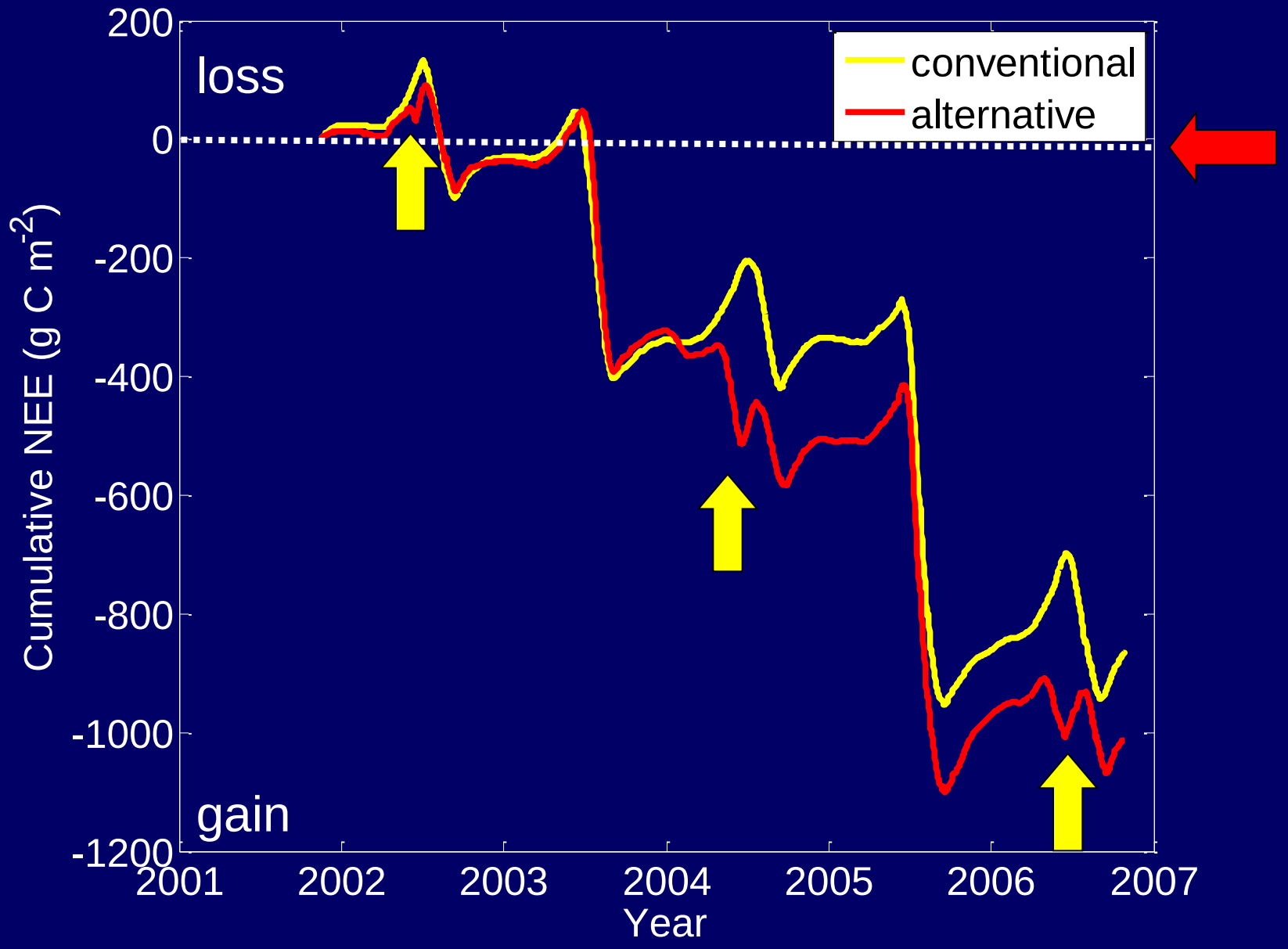
Scientific Rationale



Eddy Covariance Measurements over Corn/Soybean Systems



Cumulative Net Ecosystem CO_2 Exchange of Corn/Soybean Systems



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journal homepage: www.elsevier.com/locate/agee

Impact of reduced tillage and cover cropping on the greenhouse gas budget of a maize/soybean rotation ecosystem

T.K. Bavin [a,*], T.J. Griffis [a], J.M. Baker [b], R.T. Venterea [b]

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Cumulative N_2O losses, expressed in CO_2-C equivalents, were 12.8 g C m^{-2} higher in conventional treatment during one of the two study years. N fertilizer was the main factor that increased N_2O losses in both treatments and N fertilizer type likely had a large influence on the differences between the two treatments.

N_2O losses, when expressed in CO_2-C equivalents, totaled 38.9 +/- 3.1 g C m^{-2} and 26.1 +/- 1.7 g C m^{-2} in the conventional and alternative managed treatments…

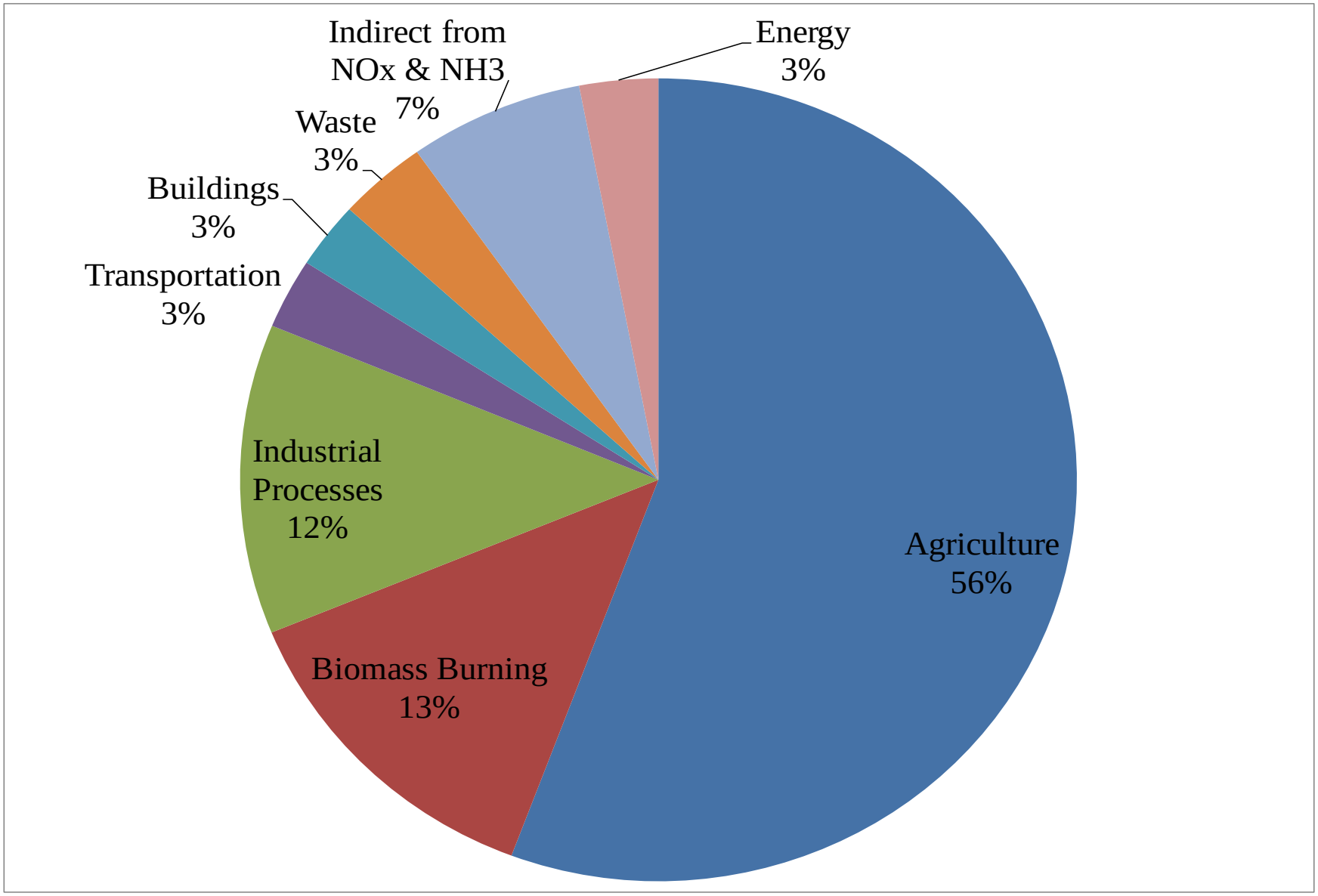
comparable to Net Ecosystem CO_2 Exchange of both systems.

There is growing evidence that N_2O losses are greater for systems using anhydrous ammonia, see recent work of Venterea et al., (2010) and Fujinuma et al., (2011)

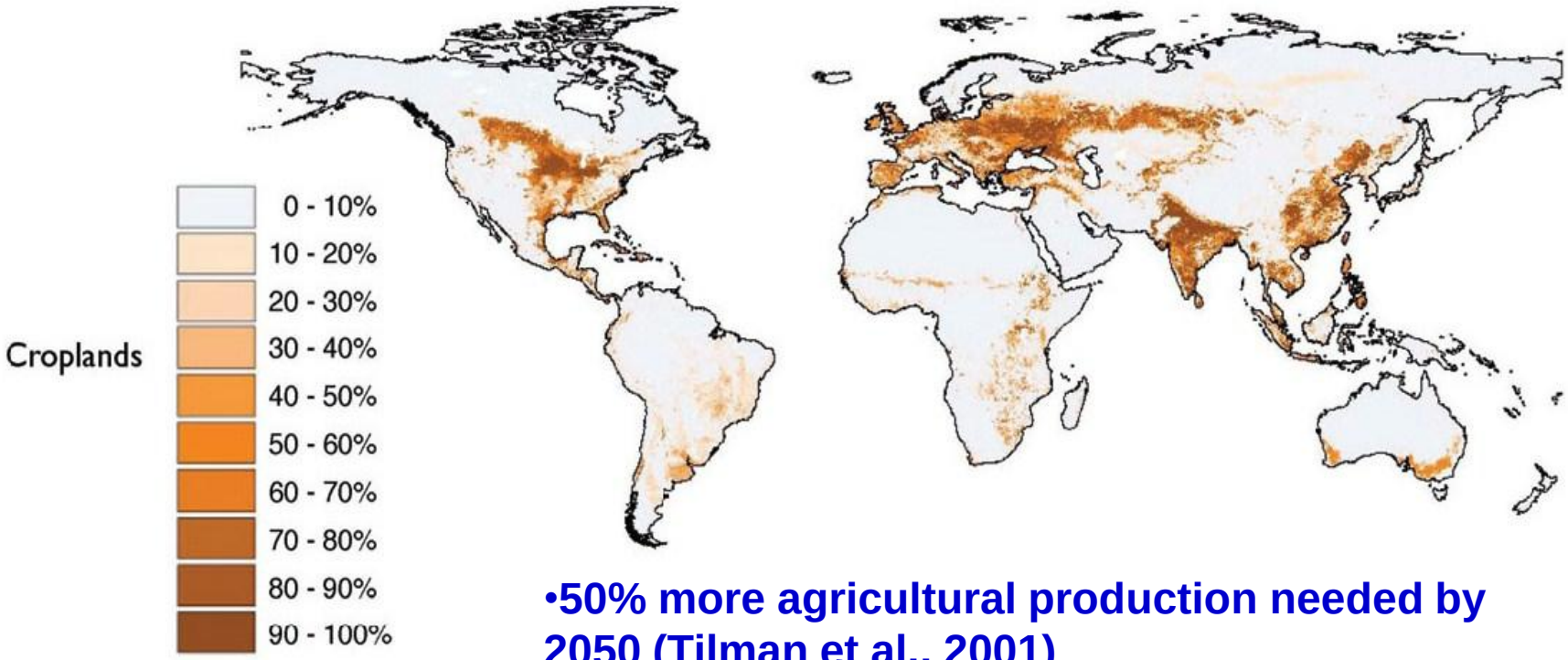
Nitrous Oxide in the Atmosphere

- Preindustrial concentration ~270 ppb
- NOAA-ESRL background site concentrations in 2010 ~324 ppb
- Increasing at ~0.26% per year or 0.73 ppb per year
- Represents ~3.5 Tg of Nitrogen added to the atmosphere as N_2O each year
- Global warming potential (GWP) ~296 times CO_2 on a 100 year time horizon
- Implicated in stratospheric ozone depletion

Emission Database for Global Atmospheric Research (EDGAR) Anthropogenic Sources



Global Distribution of Agricultural Ecosystems

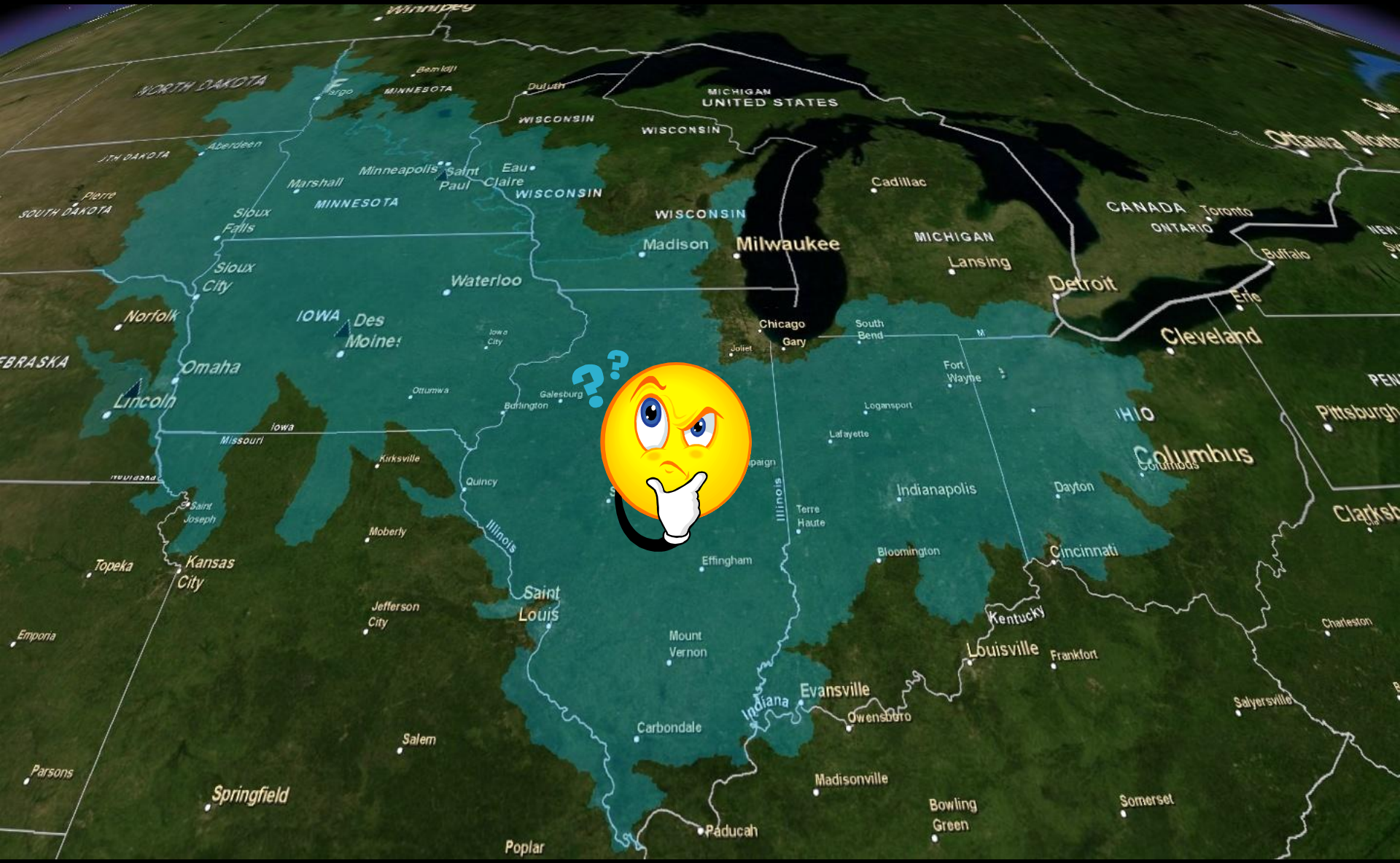


- **50% more agricultural production needed by 2050 (Tilman et al., 2001)**

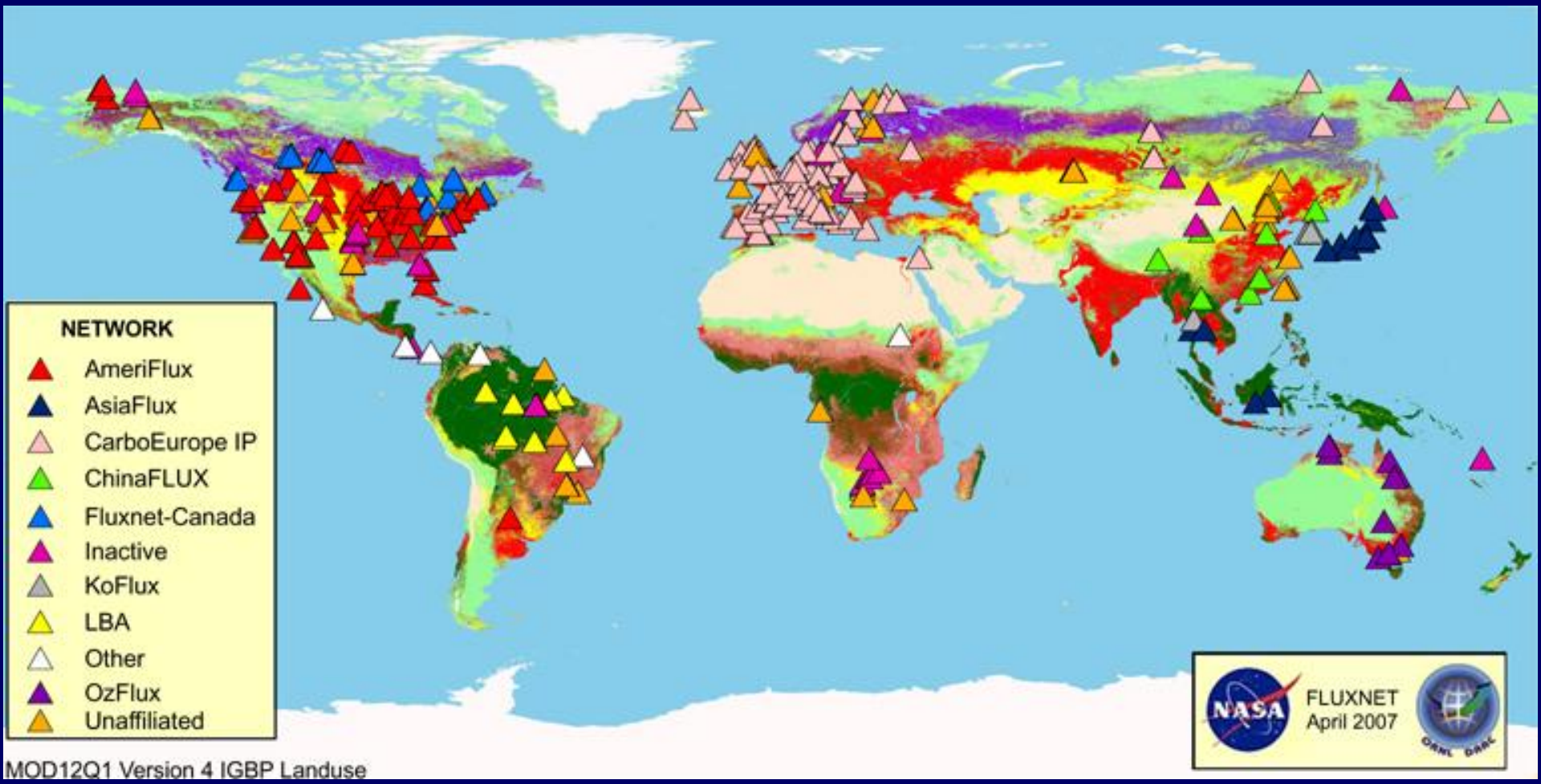
- **Bringing crop yields to their potential will require more chemicals, nutrients, and water (Licker and Foley, 2010)**

Foley et al., 2005, Science, 309: 570-574

United States Corn Belt



FLUXNET: Worldwide CO_2 Flux Measurements



Baldocchi, 2008, Australian Journal of Botany, 56: 1-26

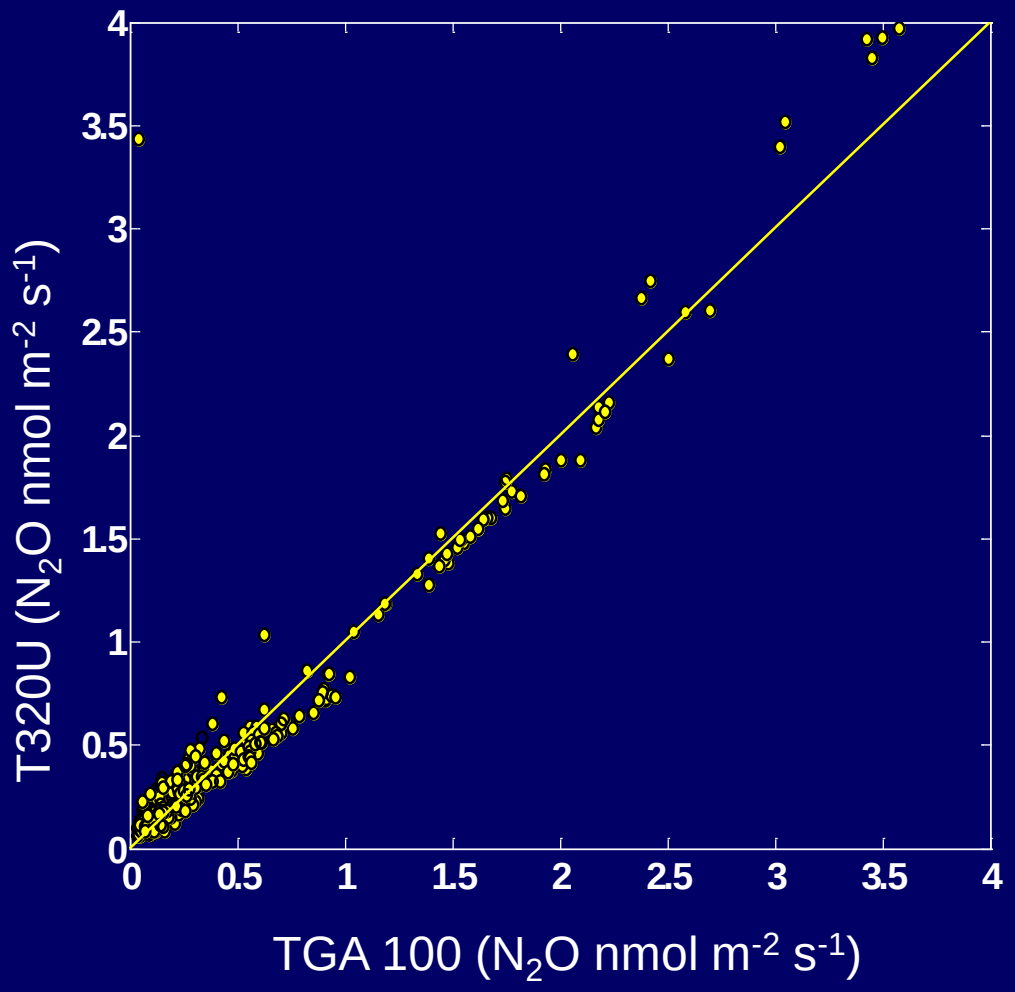
Constraints on the Land-Atmosphere N_2O Flux

- The vast majority of N_2O flux measurements have been chamber-based
- Typically performed manually/very labor intensive
- Poor temporal and spatial coverage
- N_2O emissions are highly episodic
- N_2O budgets remain highly uncertain
- There is a need for near-continuous measurement at multiple scales
- Monitoring networks for N_2O? (http: // www.n2o.net.au)

Tunable Diode Laser and Automated Chamber System

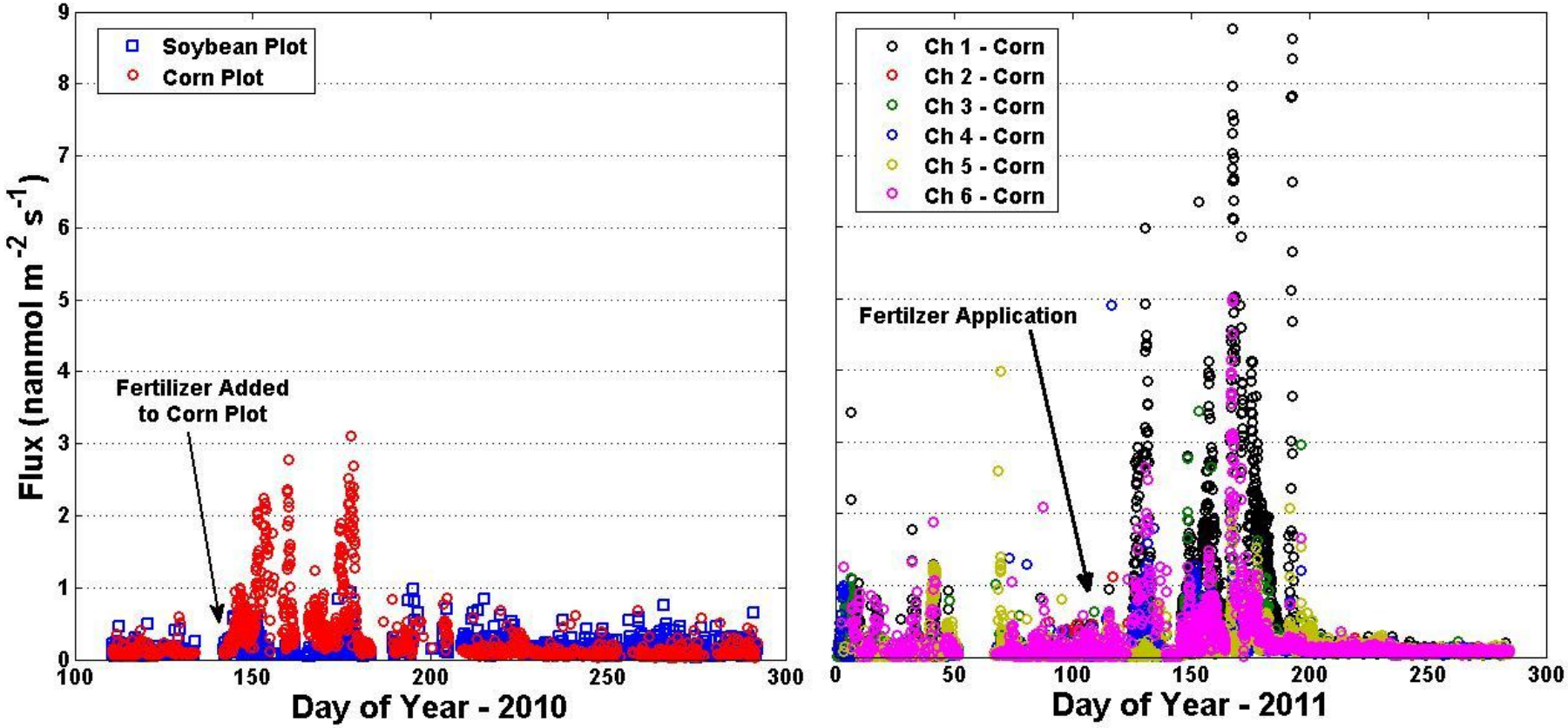
Automated Low-Power Chamber System for N_2O Flux Measurements

- Gas filter correlation analysis (Teledyne Model T320U)
- Lower cost and lower power requirements
- Flux resolution, ~0.05 nmol m^{-2} s^{-1}



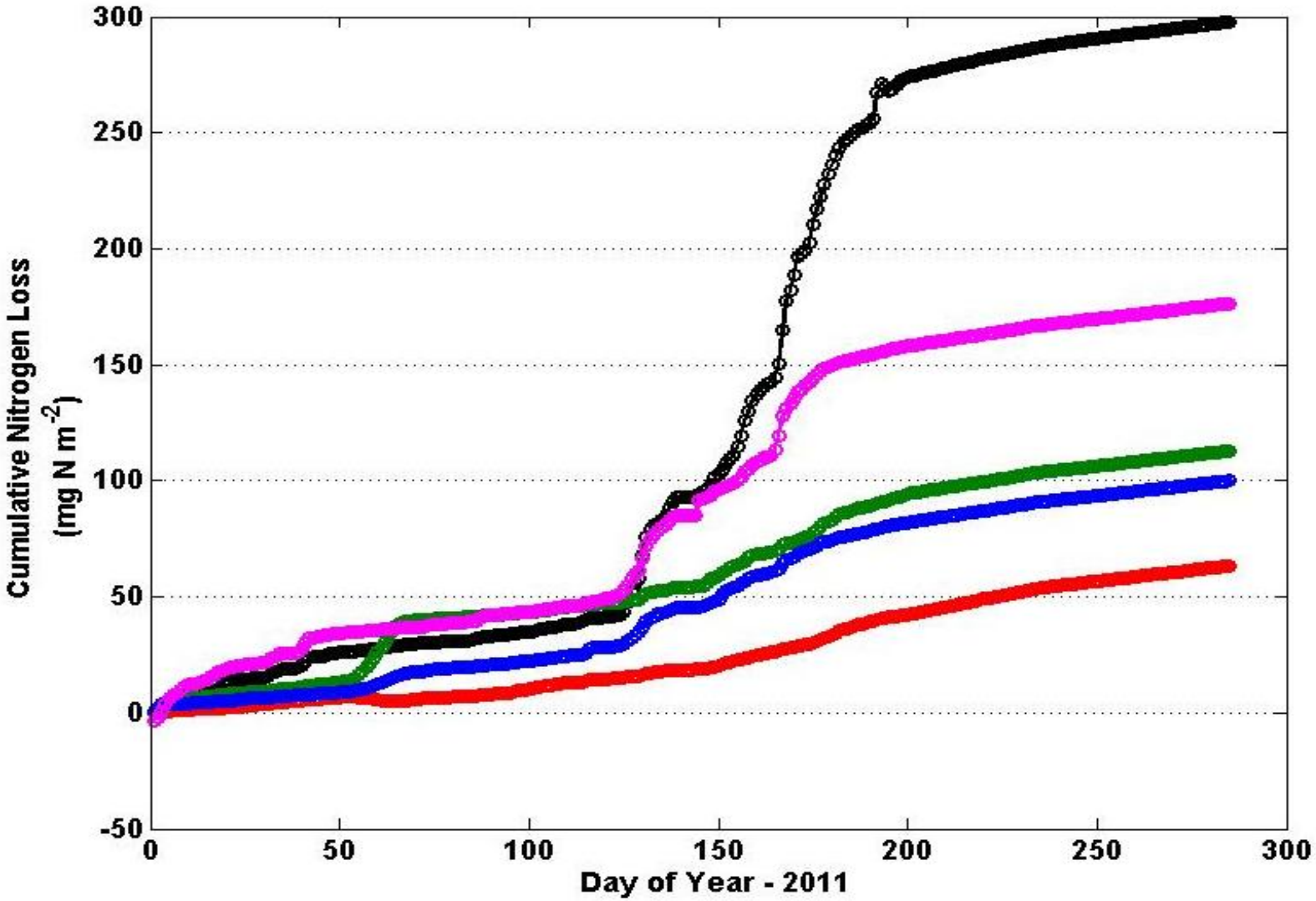
Spatial Resolution?

Soil N_2O Flux from Automated Chamber System

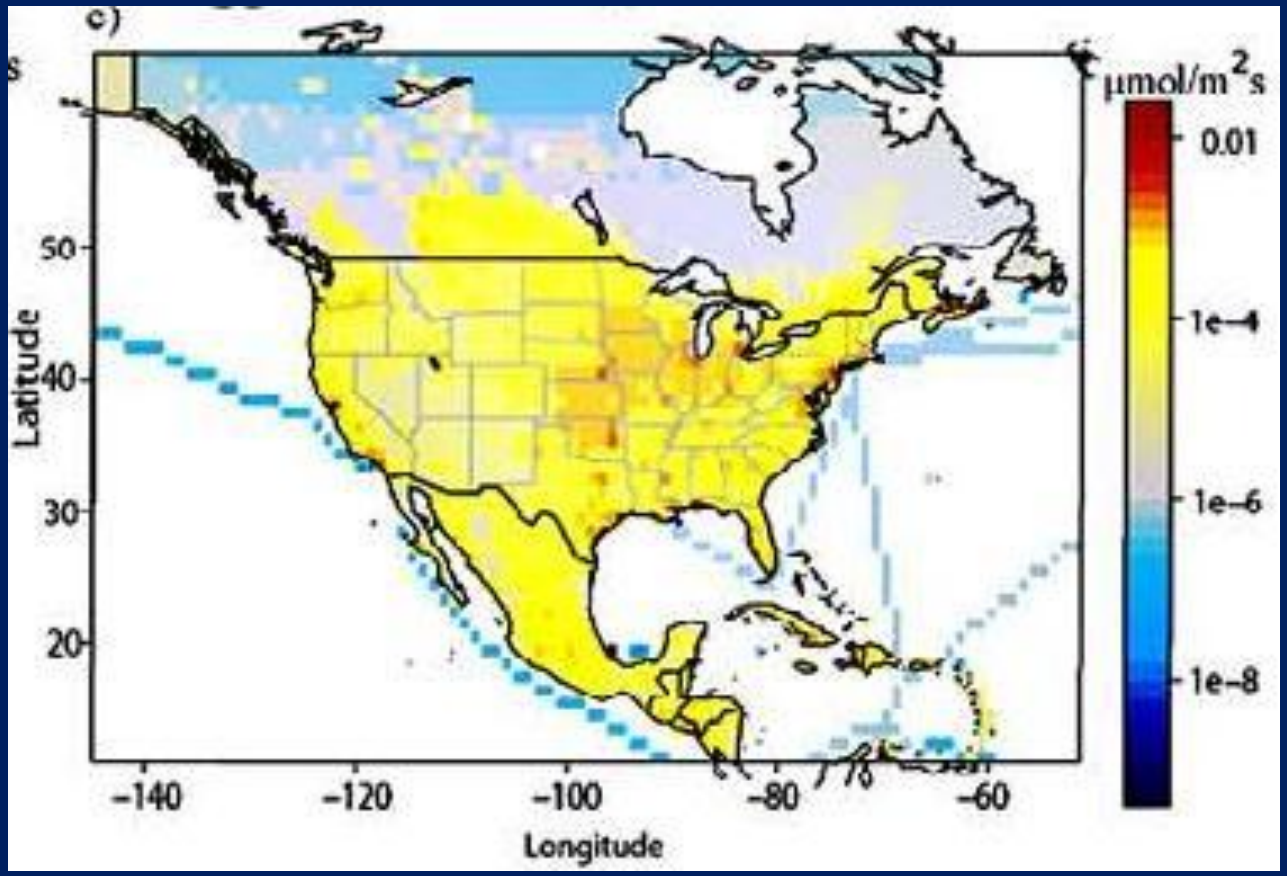


Mean flux = 0.22 nmol m^{-2} s^{-1}, Coefficient of variation > 200%

Cumulative N_2O Flux from Automated Chamber System



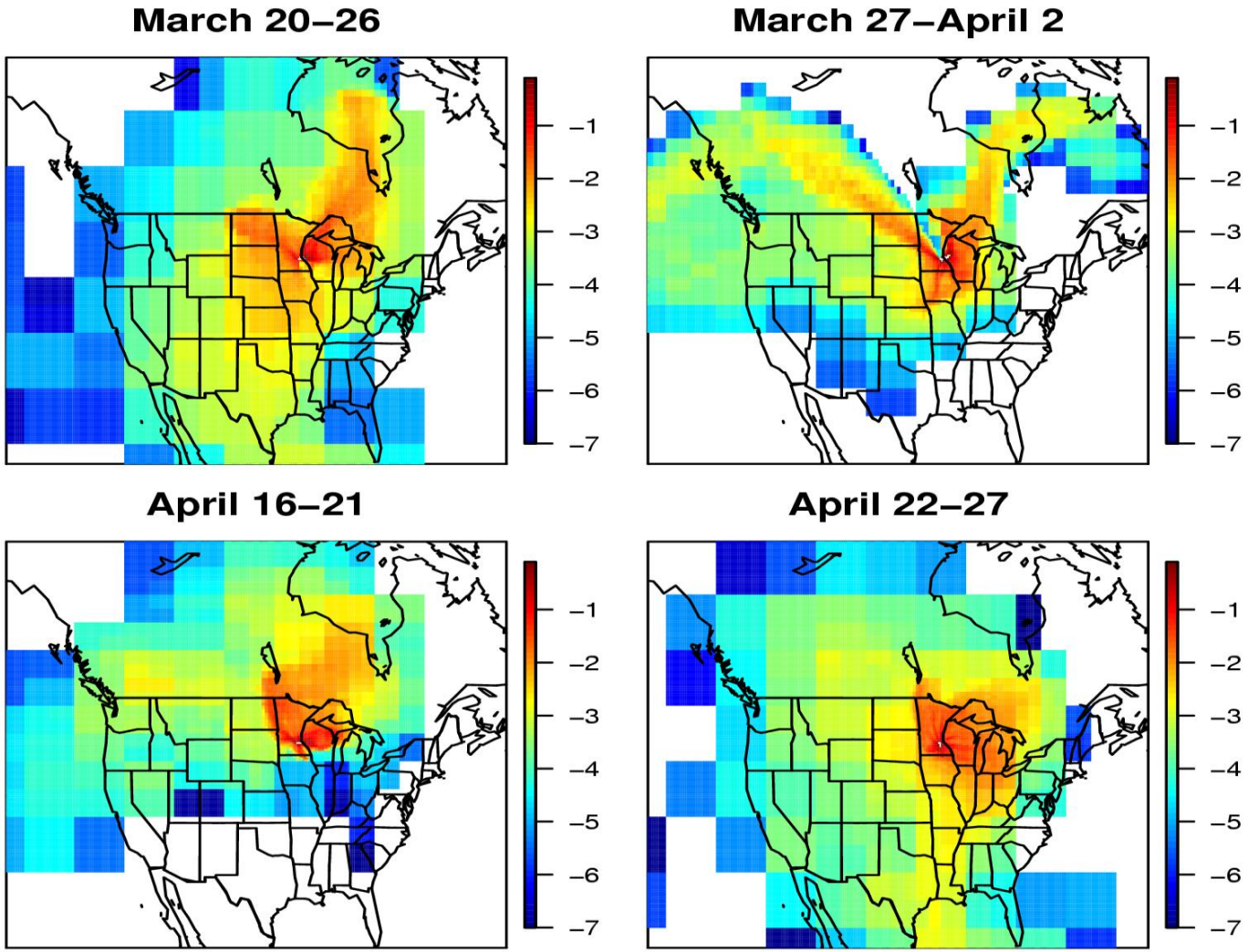
Aircraft and STILT Campaign over North America: A Snapshot in Time



Kort et al., 2008, Geophysical Research Letters, 35, 2008GL034031

- **Emission estimates from EDGAR and EGIA were too low by a factor of 2.6 to 3.0**
- **Seasonality of agricultural emissions?**
- **Lack of aircraft flask measurements?**

Near-Continuous Tall Tower Measurements



STILT analysis: Dylan Millet, University of Minnesota and Xin Zhang, Yale University

Research Questions

1. How do N_2O concentrations in the United States Corn Belt compare to global background concentrations?

2. What is the sink/source strength of N_2O for the region?

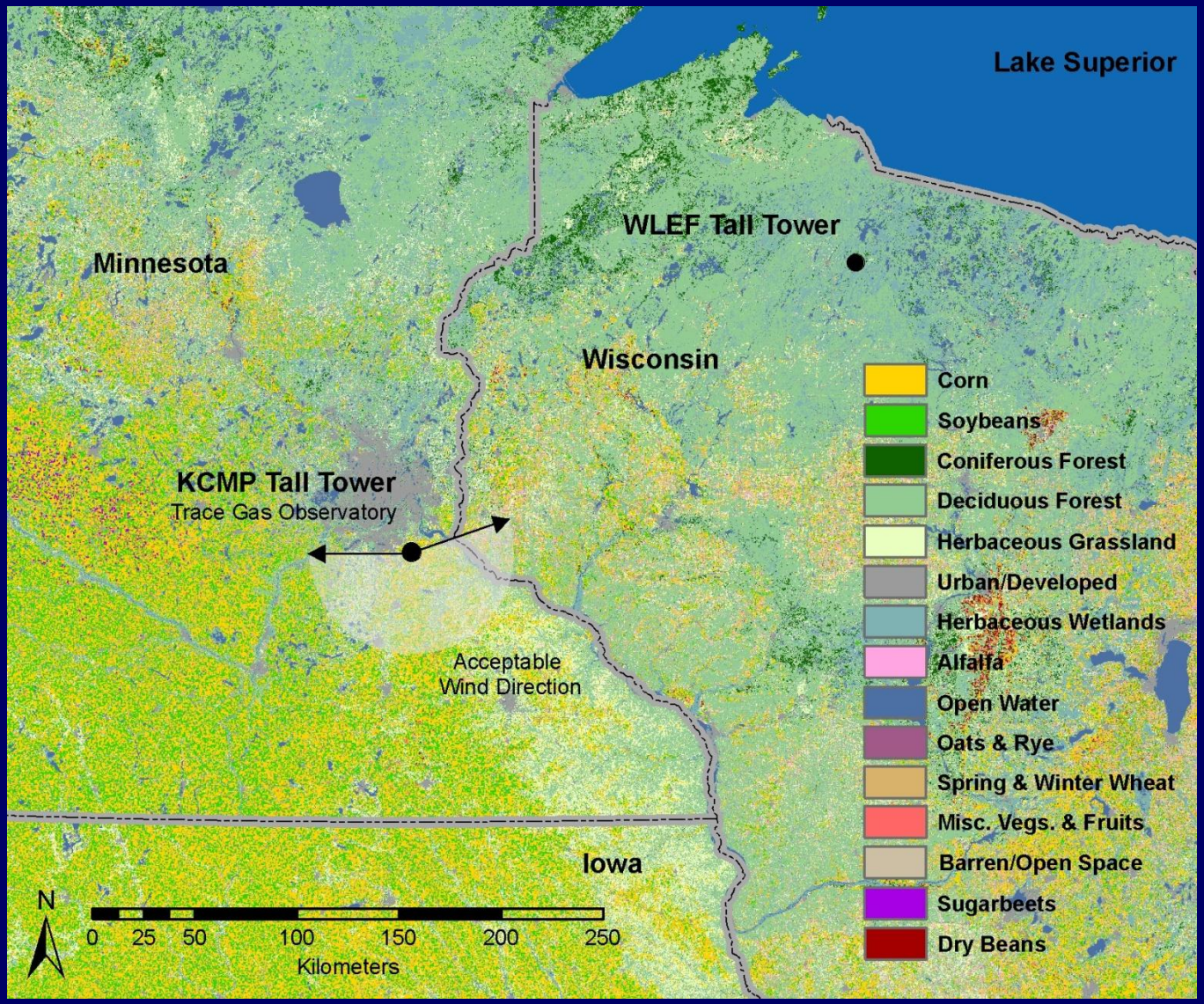
3. How does this compare with EDGAR or IPCC emission estimates?

Research Site and Background

Tall Tower Trace Gas Observatory
University of Minnesota

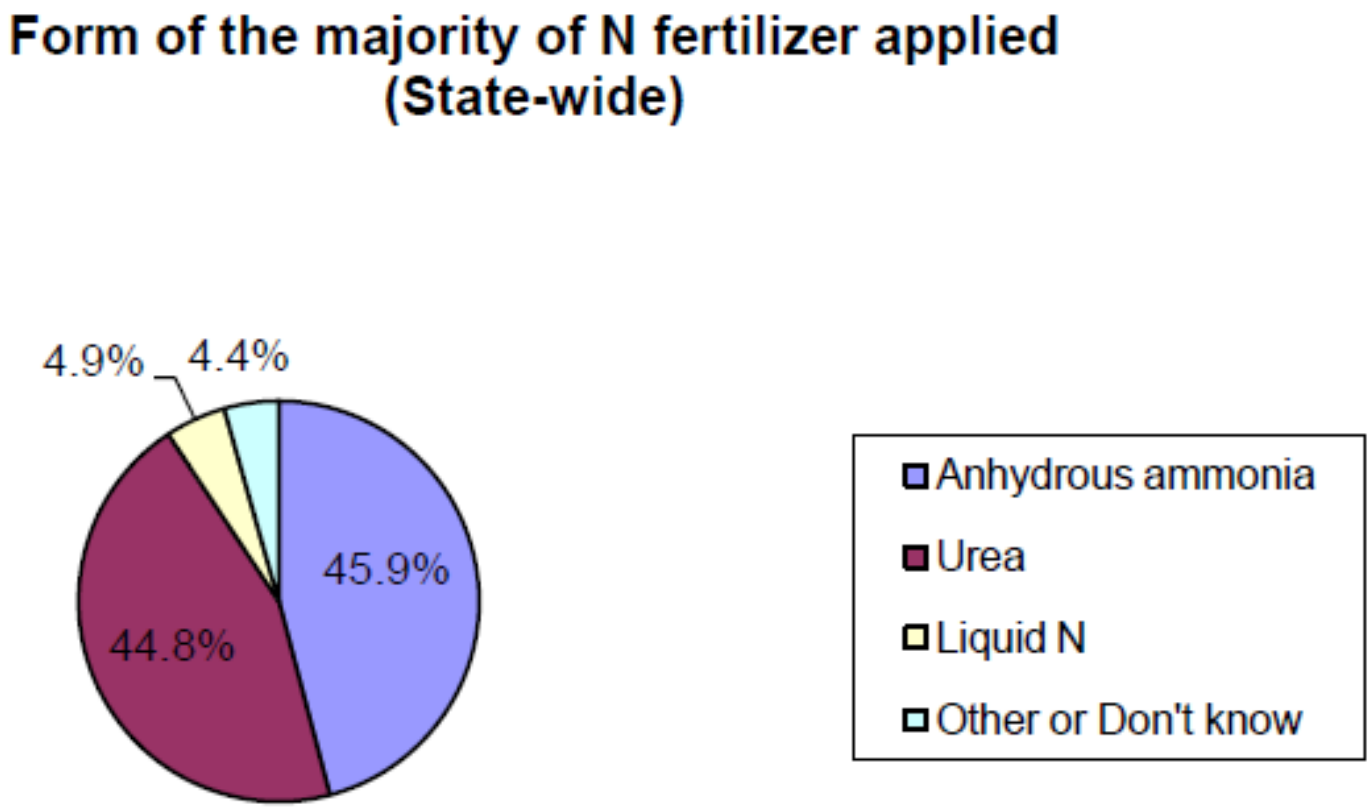
Regional Perspective

Land-use Characteristics



USDA-NRCS Geospatial Data Gateway (http:www.datagateway.nrcs.usda.gov)

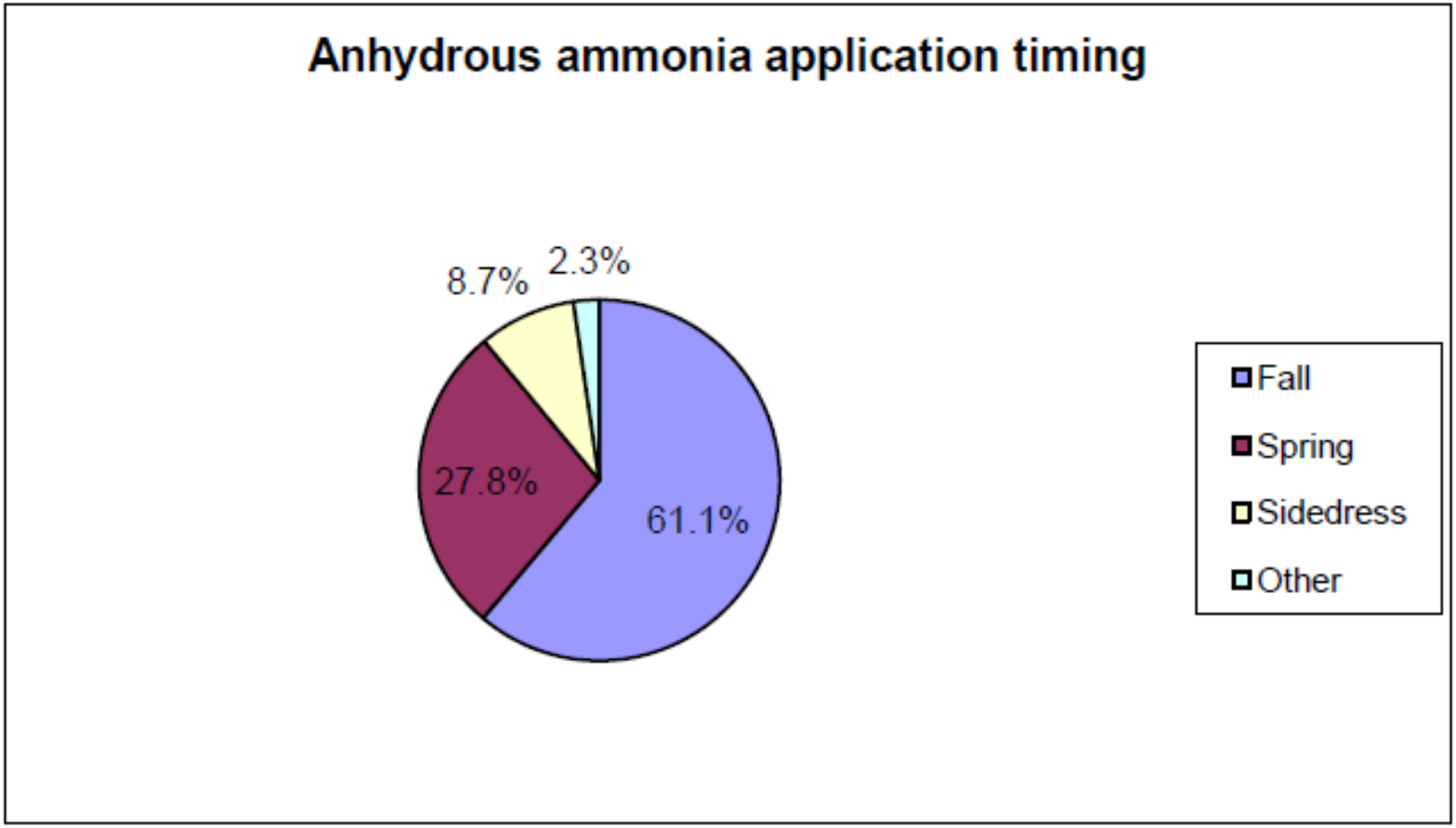
Fertilizer Survey for Minnesota



Beirman et al., Agricultural Systems, in press

In the United States, anhydrous ammonia has decreased by 15%, while urea has tripled over the last 3 decades

Fertilizer Survey for Minnesota

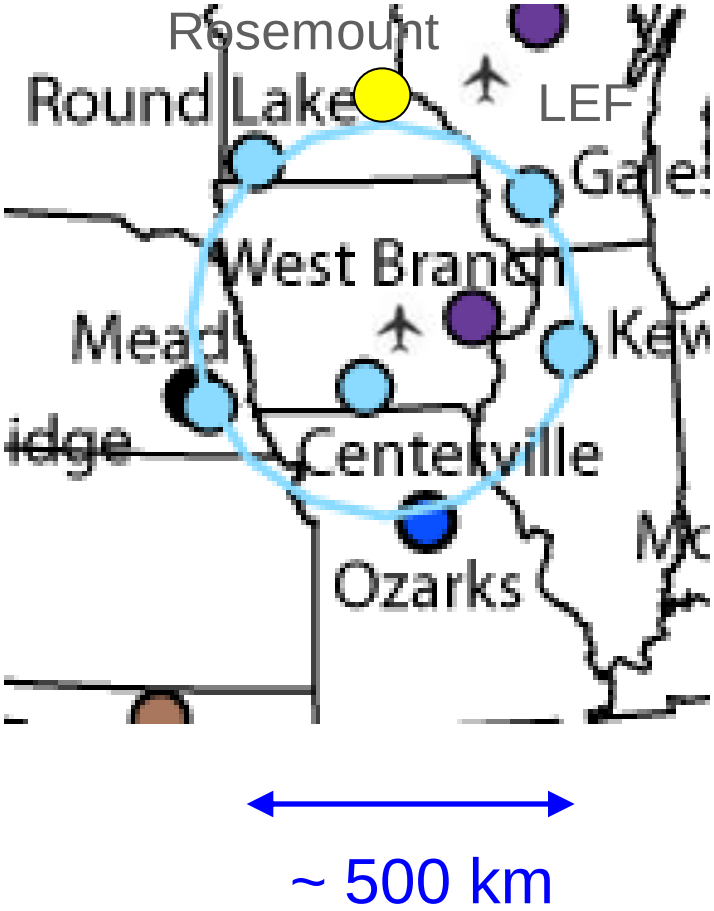


Beirman et al., Agricultural Systems, in press

NON-FLAMMABLE GAS

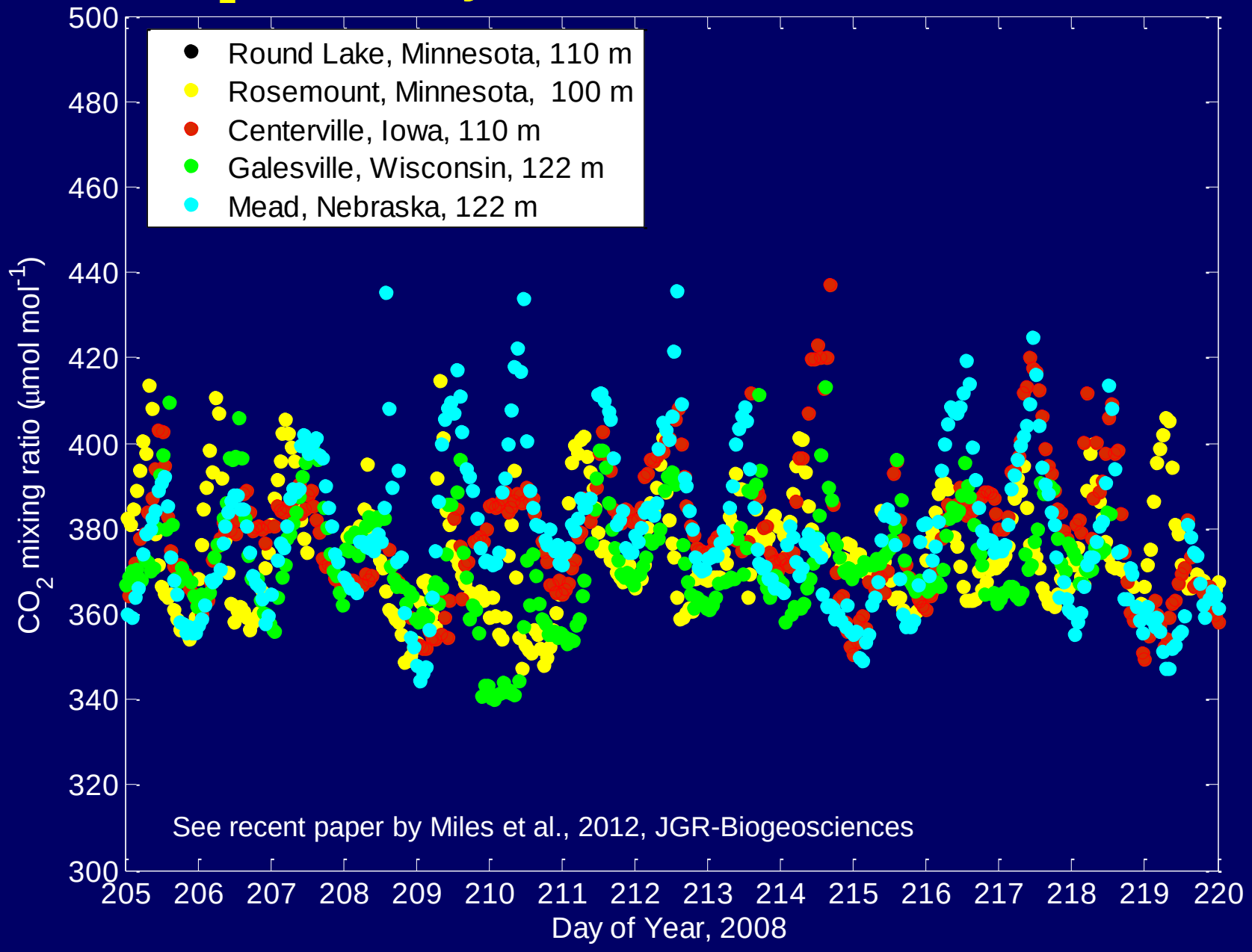
North American Carbon Program
Mid Continental Intensive

- Overall goal of Mid-Continental Intensive: Seek convergence between top-down and bottom-up estimates of the regional flux
- "Oversample" the atmosphere in the study region
- Atmospheric results
  - Purdue Univ / NOAA ALAR (aircraft) Campaign
  - NOAA aircraft program
  - 9 tower sites (NOAA, PSU, U of Minn)
  - NOAA Carbon Tracker
  - CSU SiBcrop-RAMS model
  - Comparisons to agricultural and satellite data

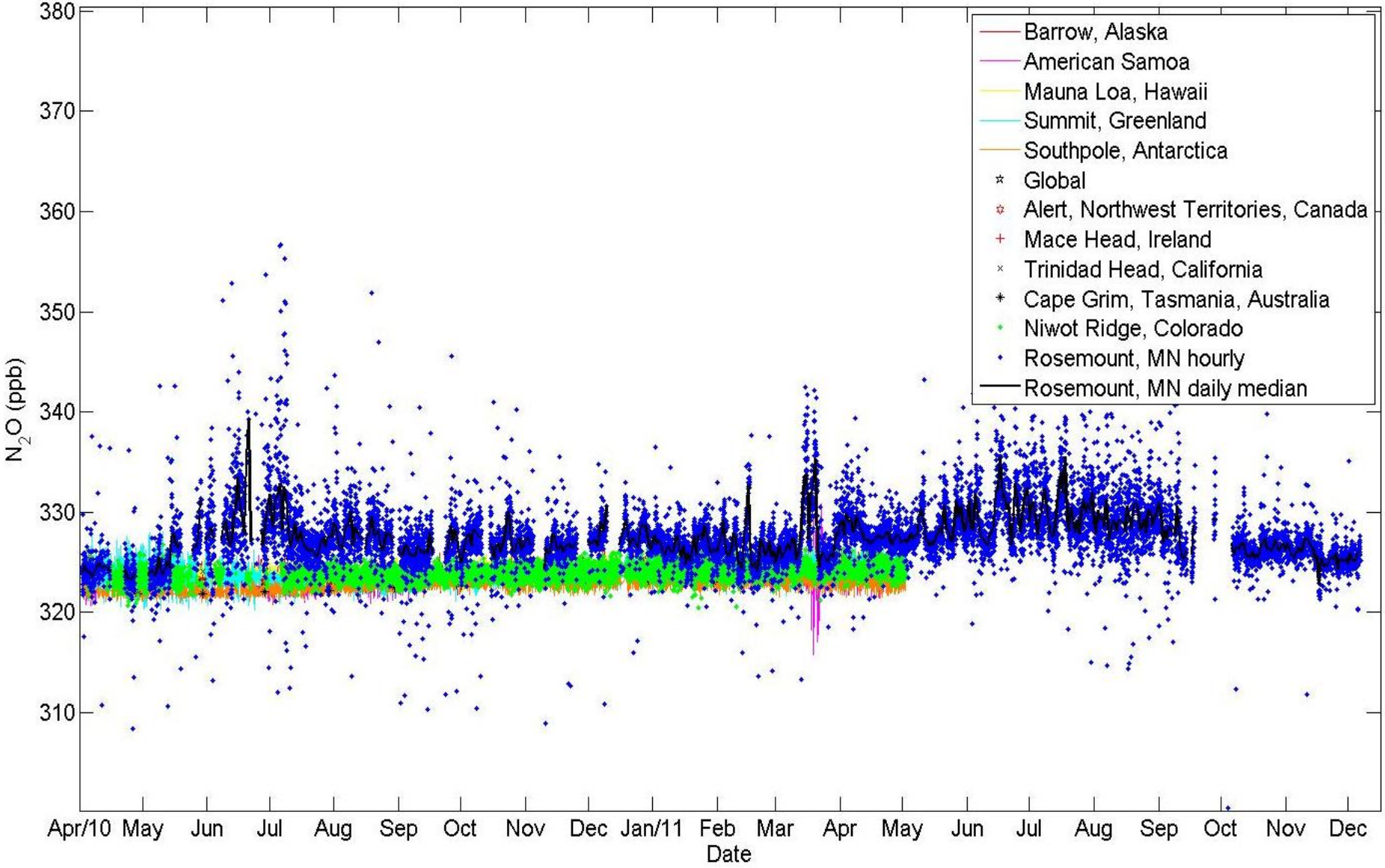


Slide courtesy of Ken Davis and Natasha Miles, Penn State University

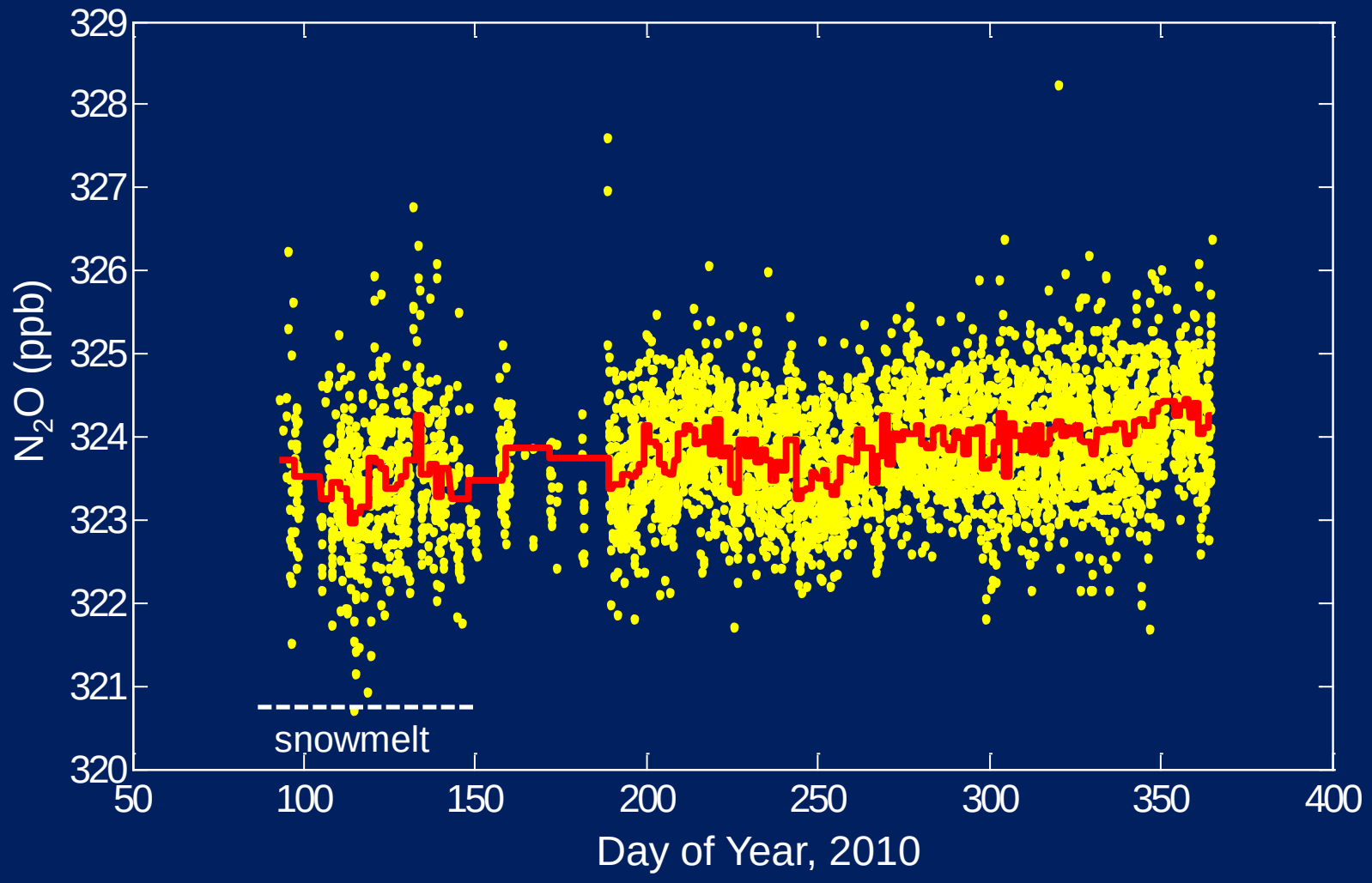
CO_2 Diurnal Cycle at the Tall Tower Network



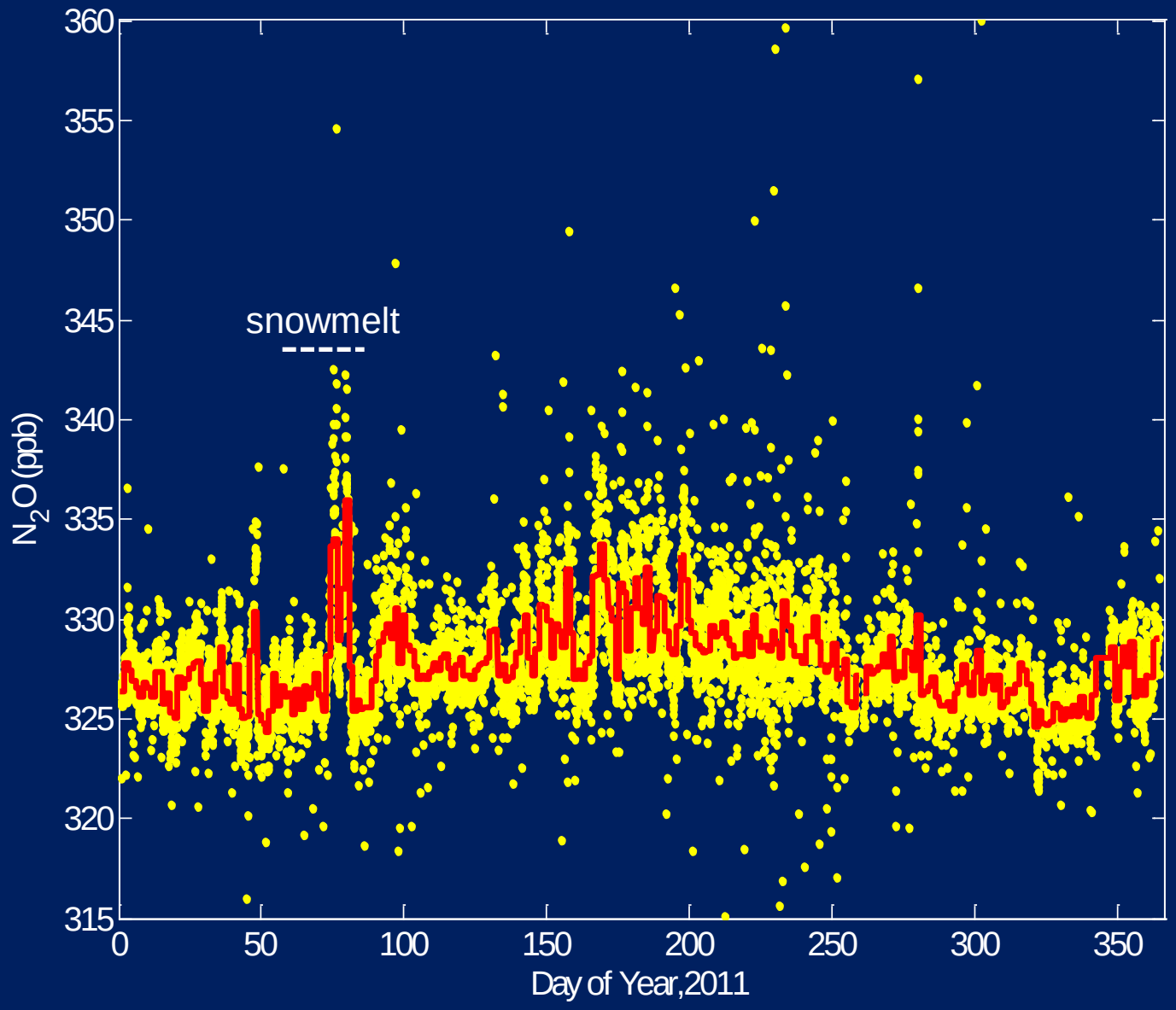
NOAA-ESRL Background N_2O Concentrations



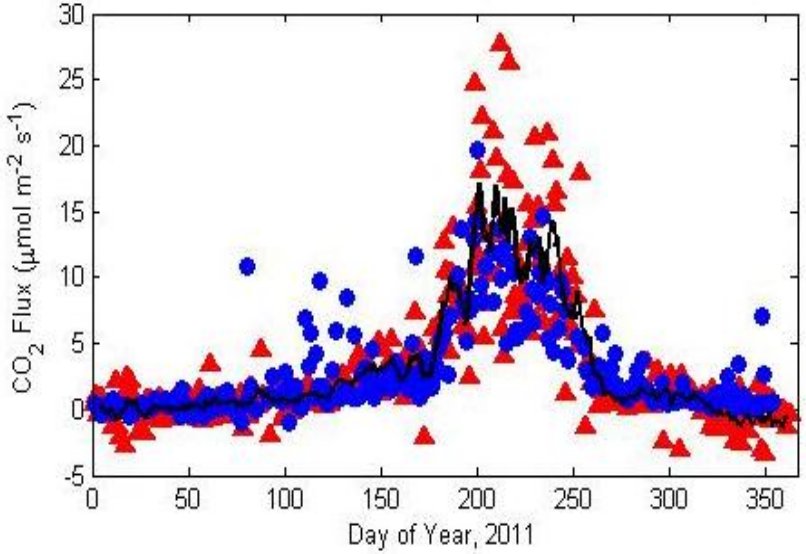
Niwot Ridge Background Site: Hourly Concentrations, Wavelet Decomposition and the Seasonal Cycle

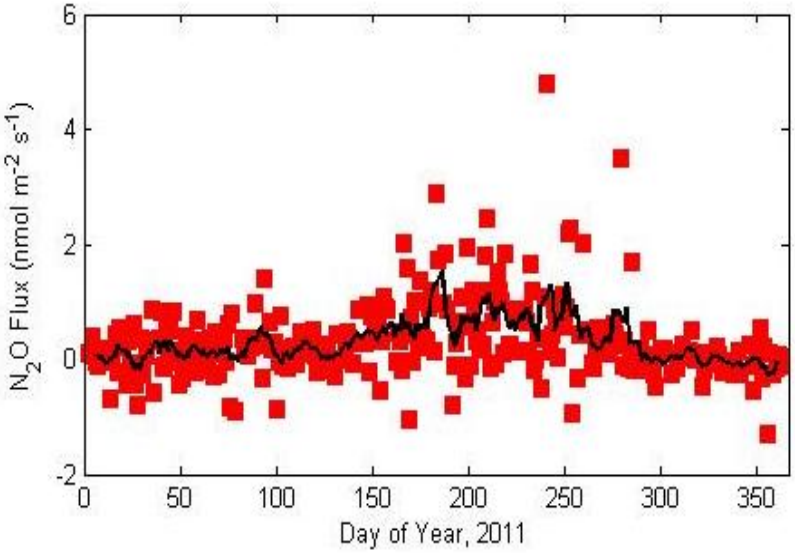


Tall Tower: Hourly N_2O Concentrations, Wavelet Decomposition and the Seasonal Cycle

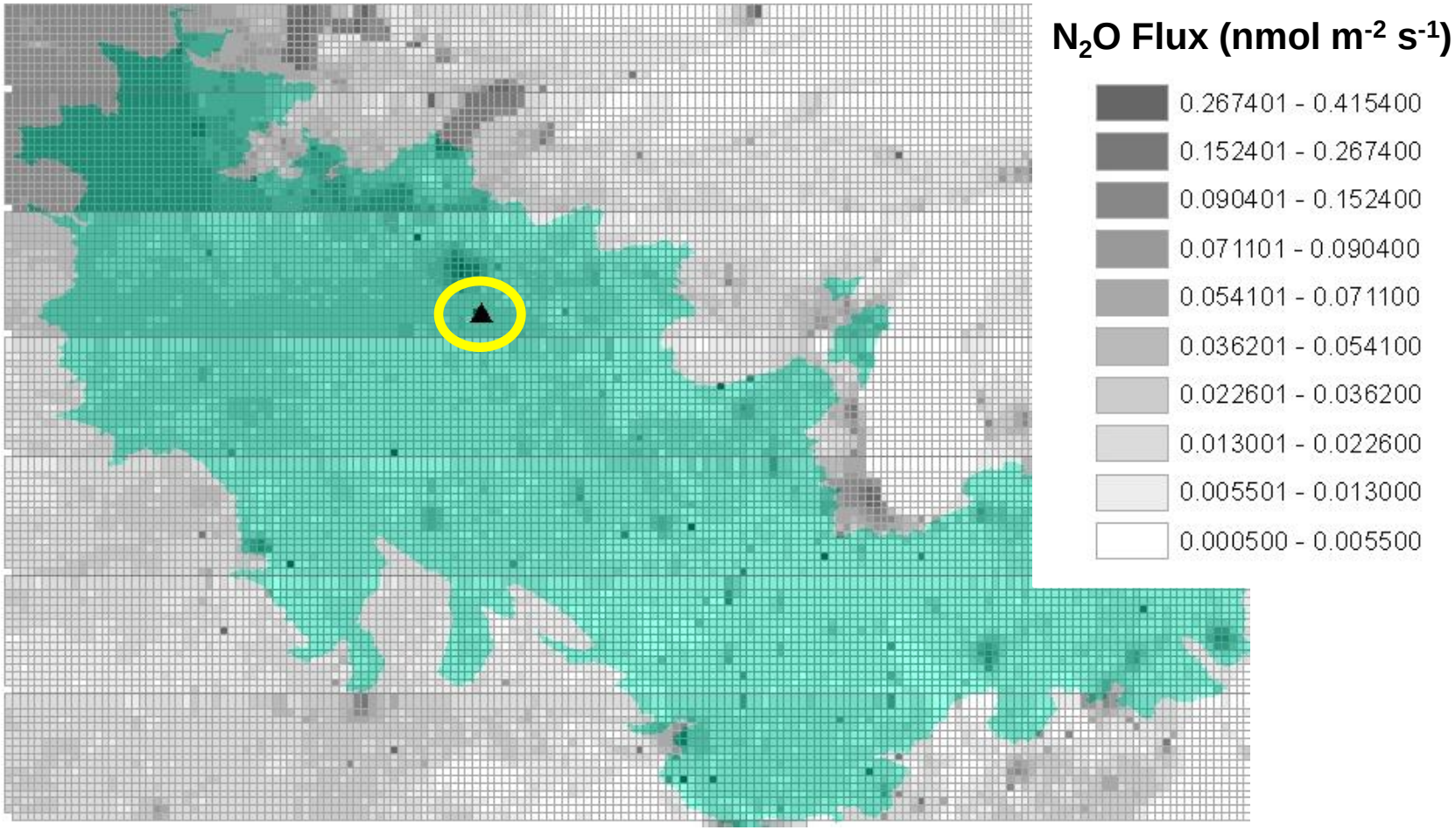


Tall Tower Nocturnal Boundary Layer Budgets





Annual EDGAR N_2O Emission Estimate for the Corn Belt



Preliminary Comparison to Emission Scenarios

- Mean annual N_2O flux from NBL budget method, ~0.33 nmol m^{-2} s^{-1}
- Corn Belt N_2O emission, ~218 Gg N_2O y^{-1}
- EDGAR (2008) mean annual anthropogenic N_2O flux near tall tower, ~0.12 nmol m^{-2} s^{-1}
- EDGAR (2008) total anthropogenic N_2O flux from corn belt, ~76 Gg y^{-1}
- EDGAR is about 3-fold lower than direct observations
- Very similar to the result presented by Kort et al., (2008) using an independent aircraft approach

Regional and Global Perspective on N_2O Budget

Based on these preliminary budget numbers…

- Corn Belt N_2O flux represents about 4% of the annual N_2O-N atmospheric sink (4% of the annual increment)
- Approximately 5% of total nitrogen fertilizer application to the Corn Belt

Next Steps

- Daytime convective boundary layer budget estimate
  (i.e. is there a nighttime bias?)

- Comparison with other tall towers
  (i.e. do emission scenarios consistently underestimate the observations)

- Completion of STILT analyses

Thank you