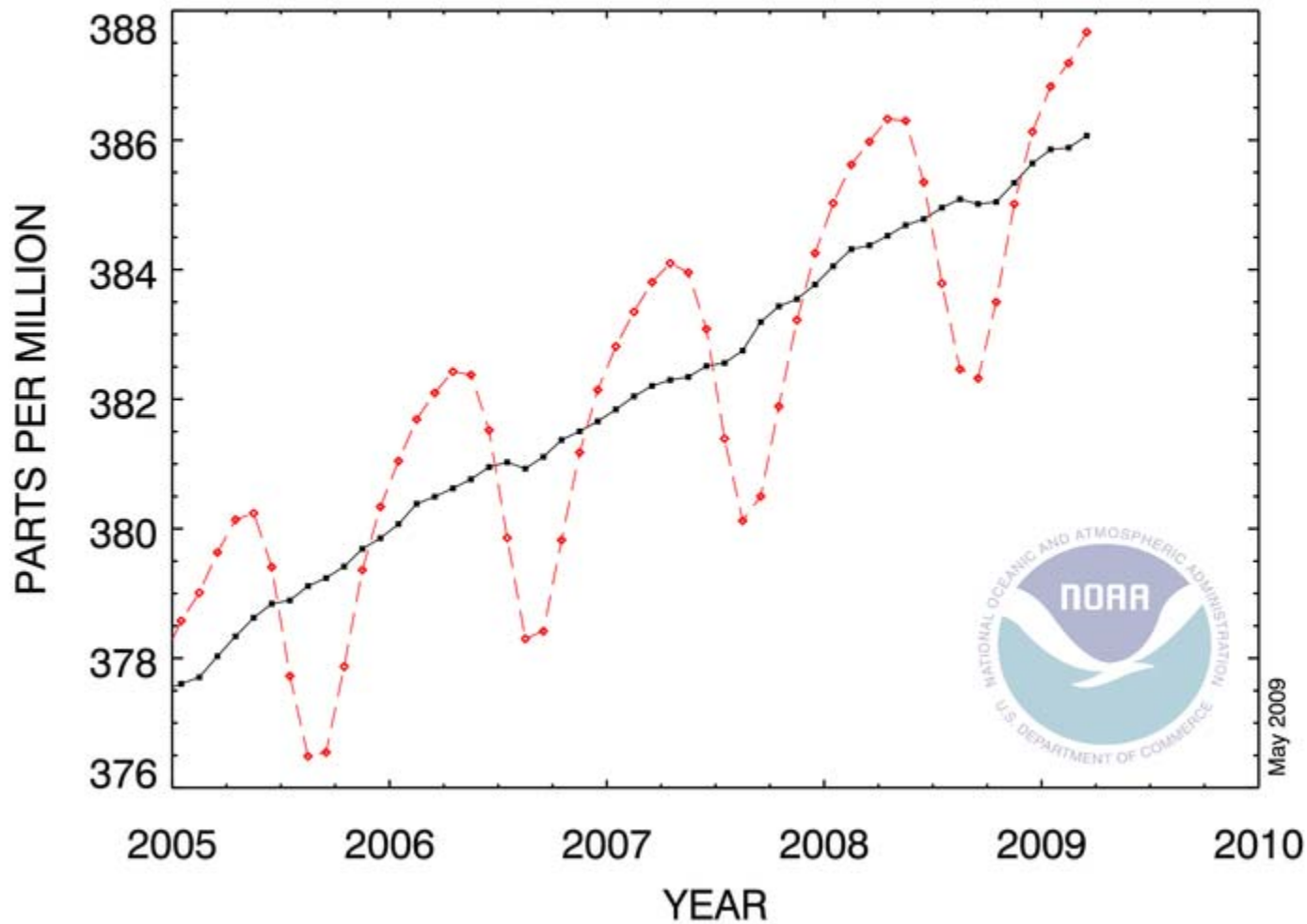


Objective Verification of Greenhouse Gas Emissions

Pieter Tans
Earth System Research Laboratory

Global Monitoring Annual Meeting
13 May 2009
Boulder, Colorado

RECENT GLOBAL MONTHLY MEAN CO₂

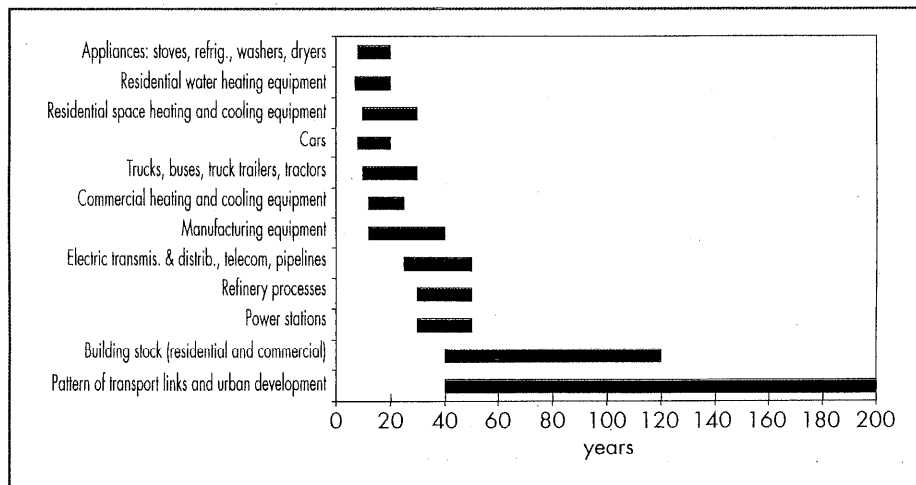


The scale of things

\$50 per metric ton CO₂ equals:

\$350 B/year for U.S., or
\$0.045 per kWh, or
\$0.50 per gallon, or
\$1,100 per capita per year

Energy infrastructure replacement time



Source: IEA World Energy Outlook 2000

INVENTORIES ARE NOT ENOUGH

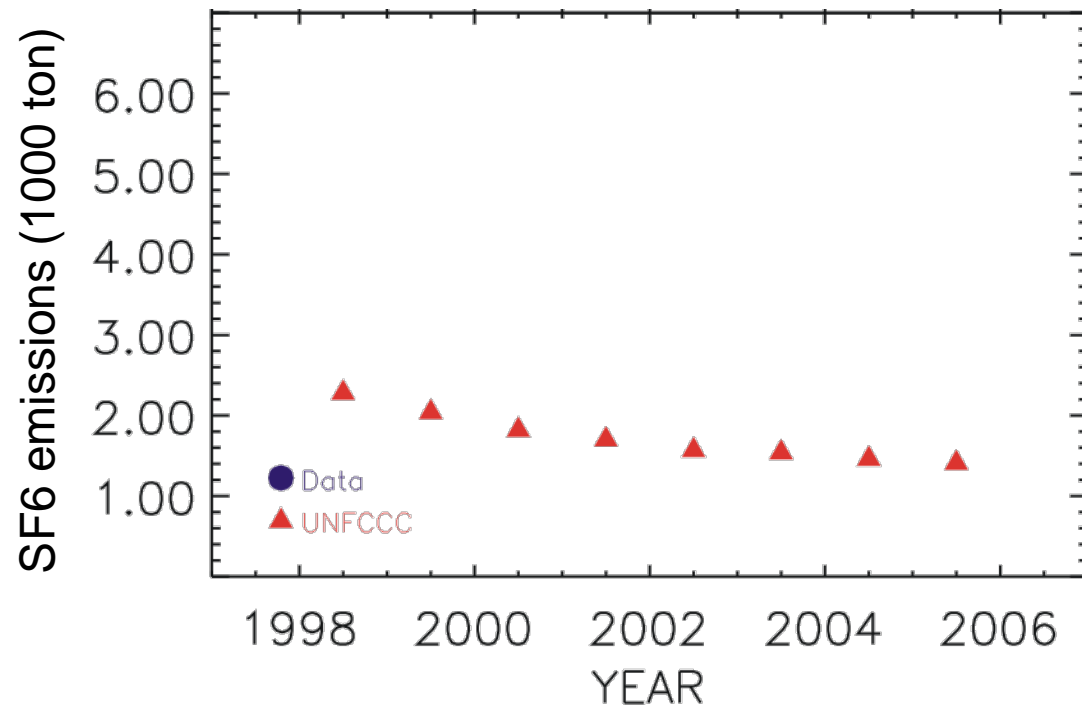
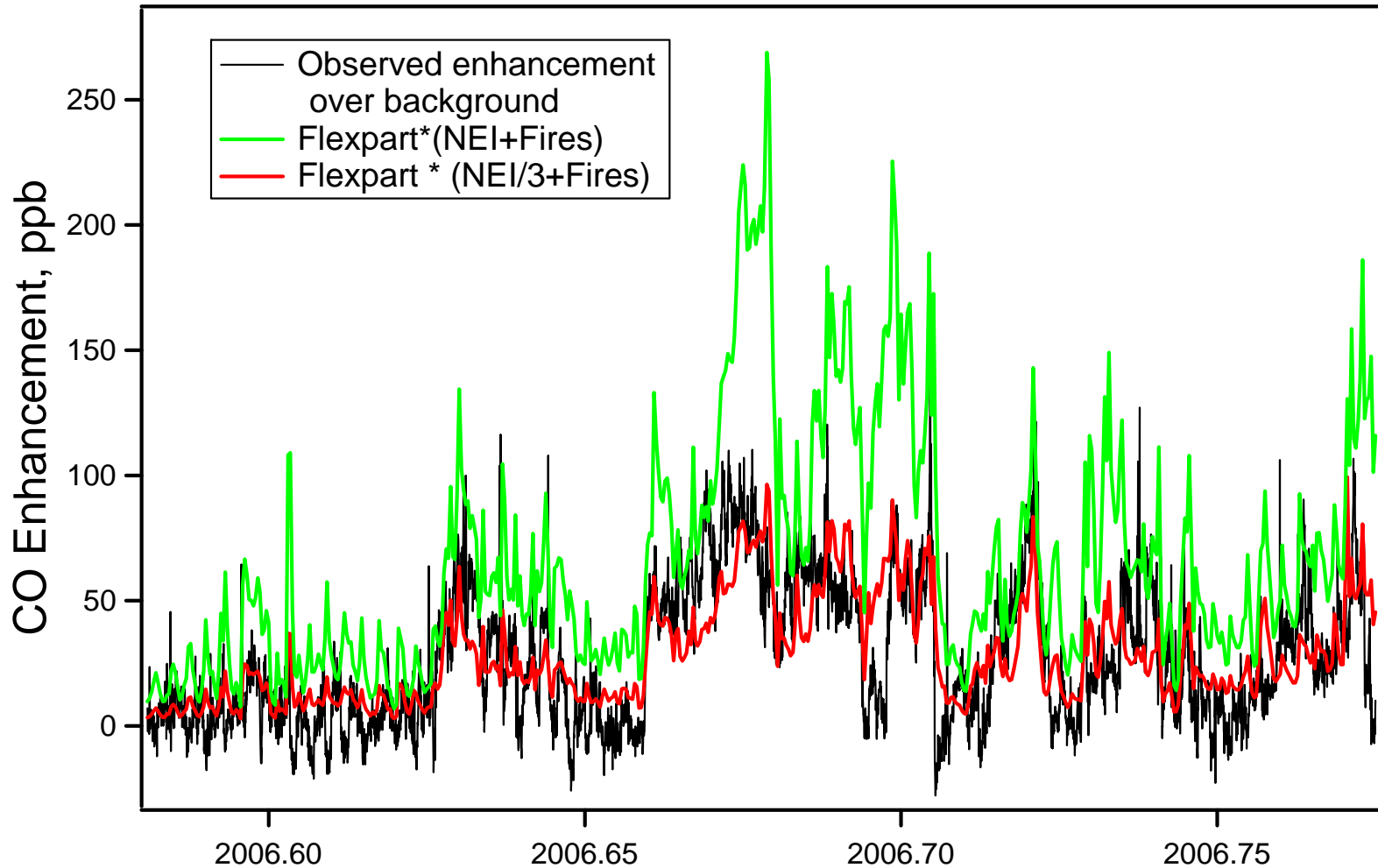


Figure:
Molly Heller
Ed Dlugokencky
Gabrielle Petron

INVENTORIES ARE NOT ENOUGH

CO enhancement at NOAA ESRL tall tower near Waco, Texas, 1 July – 15 October 2006



Source: Arlyn Andrews (data), Andreas Stohl (Flexpart model)

Expected atmospheric GHG signals:

$$\frac{\text{emissions (mol s}^{-1}\text{)}}{\text{area}} \times \frac{\text{fetch } (\sqrt{\text{area}})}{\text{wind speed}} \times \frac{1}{\text{mol m}^{-2}} = \Delta(\text{dry mole fraction})$$

	fossil fuel CO ₂			CH ₄		N ₂ O	
	MtonC/yr	ppm	ppm BL	Mton/yr	ppb	Mton/yr	ppb
U.S.	1,610	0.76	6.8	20.8	7.4	1.26	0.16
Japan	103	0.82	7.3	0.8	1.5	0.12	0.08
India	1,222	0.28	2.5	21.9	13.7	0.24	0.05
Los Angeles	20.0	0.49	4.3				
Tokyo	25.7	0.93	8.2				
Shanghai	43.7	2.5	22.0				
U.S. forest uptake	160-470	0.16-0.47					
U.S. agr. sequestr	45-125	0.05-0.13					
NEE summ. peak	~ -5,000	-2.34	-21.0				
NEE winter peak	~ 1,600	0.75	6.7				

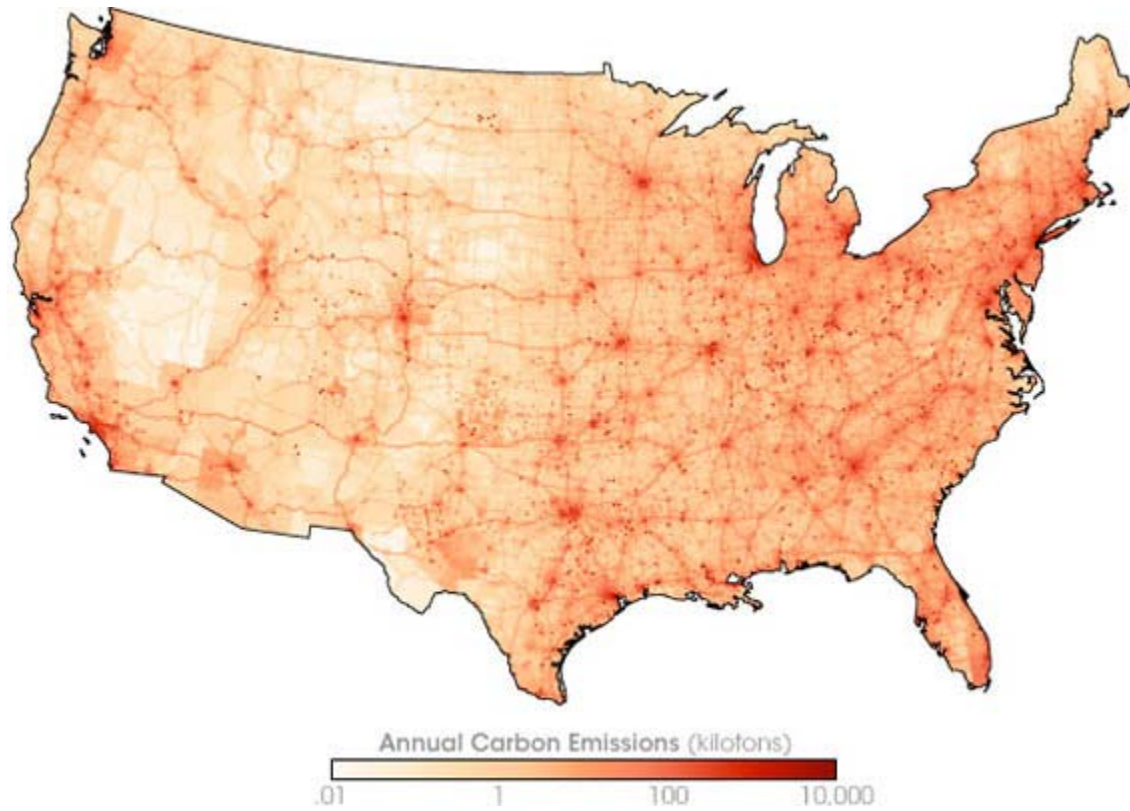
WMO comparability targets

CO₂ 0.1 ppm

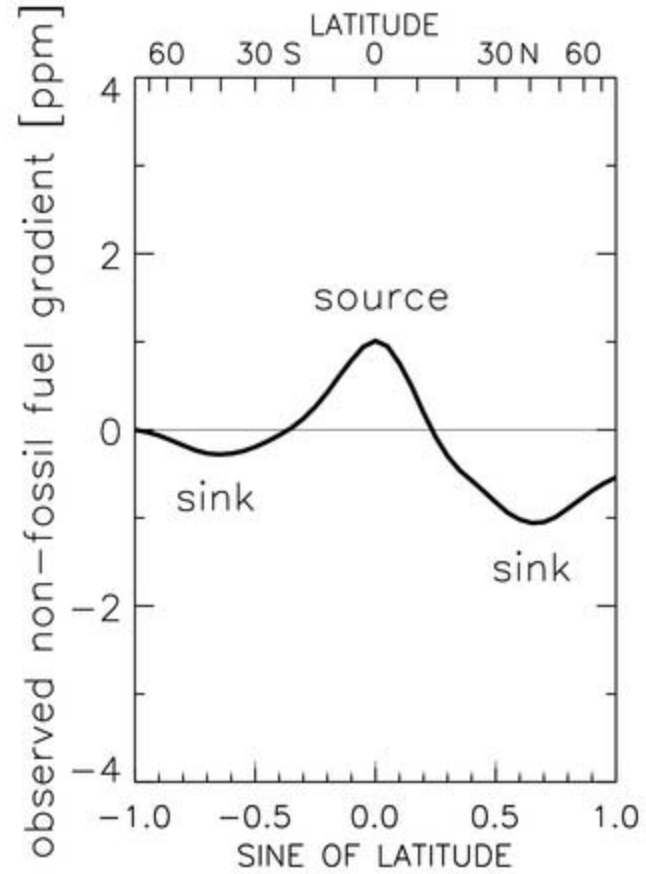
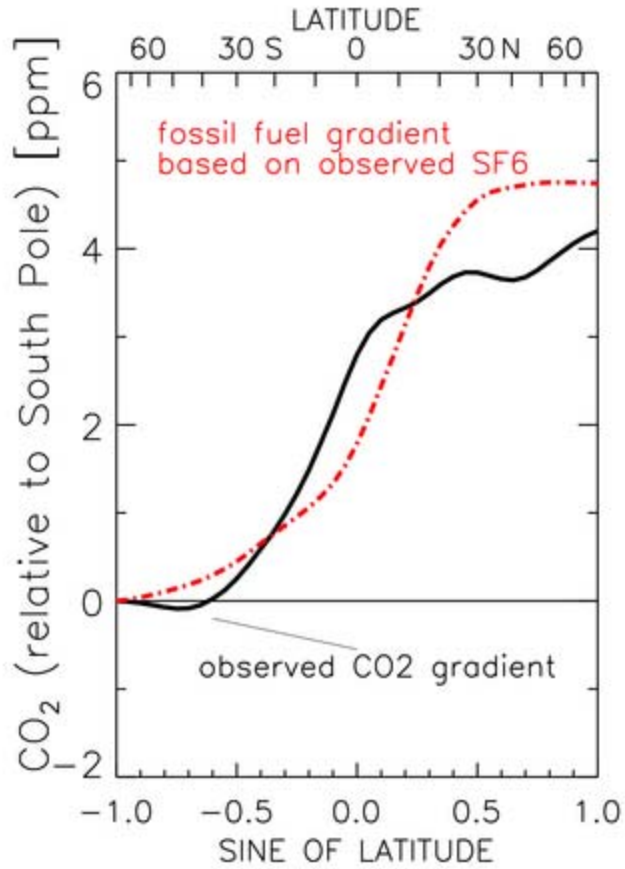
CH₄ 2 ppb

N₂O 0.1 ppb

Spatial definition of fossil fuel CO₂ sources



Again: importance of transport



Summary of problems:

Very difficult to separate fossil fuel contribution from Net Ecosystem Exchange: on annual mean basis FF combustion is 2-3 times larger than NEE, but on seasonal basis NEE is up to 4 times larger than FF.

NEE is the relatively small difference between two large terms.

Atmospheric transport is still a major source of errors.

More robust instruments for high accuracy long-term monitoring

Measurements on commercial aircraft

Fourier transform spectrometers (solar absorption)

Satellite retrievals of column CO₂, CH₄.

Aircore

Urban measurement networks

Multi-species, especially **carbon-14**

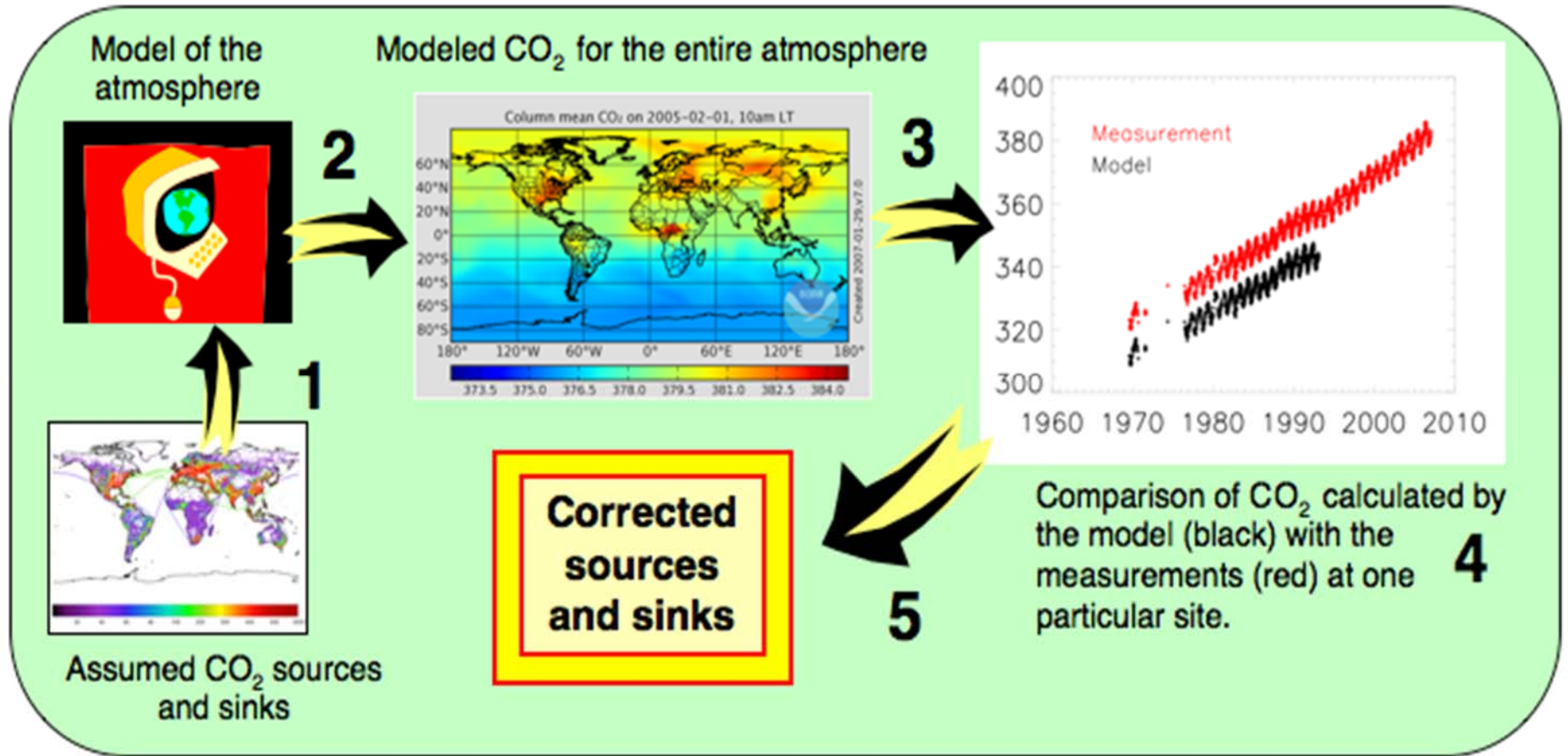
Improving inventories

Improving transport models

Soil profiles

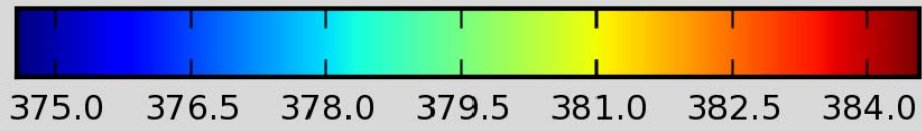
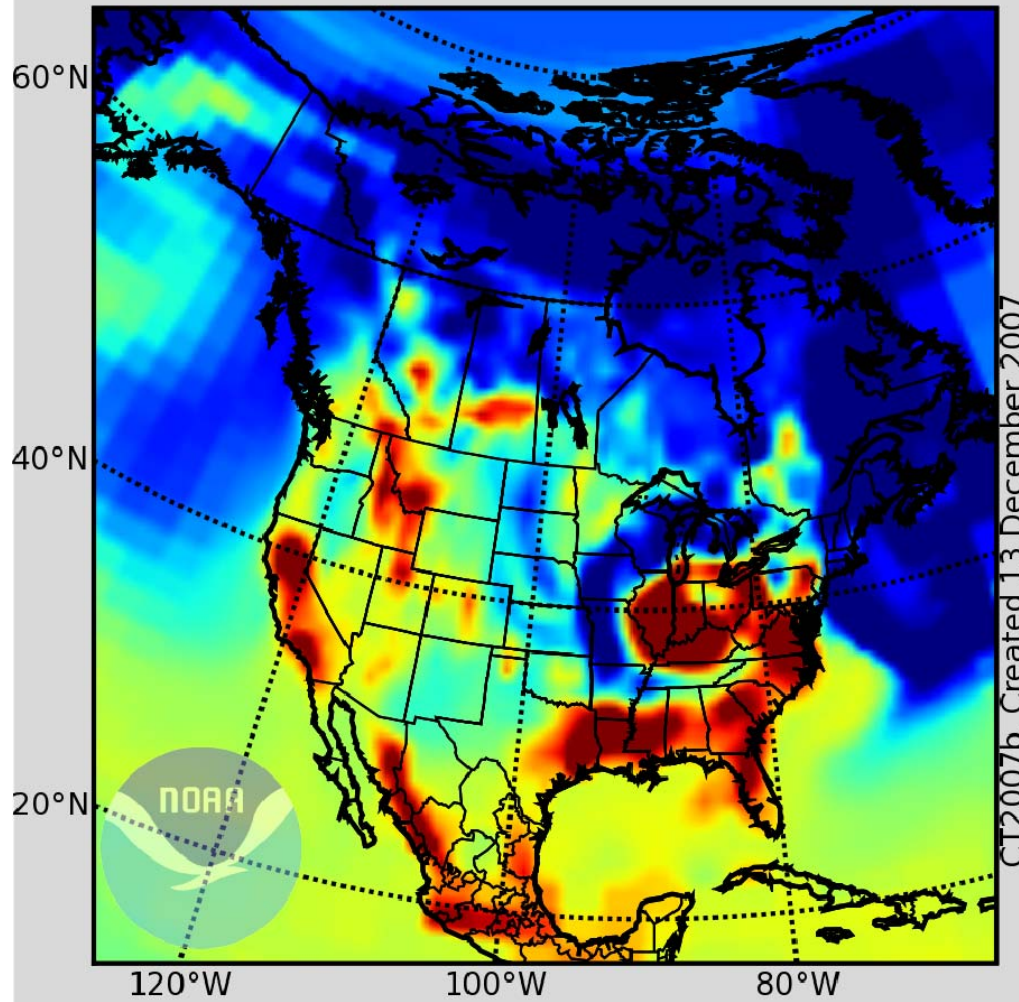
Data assimilation

Combining very different types of data, optimizing the information from each.

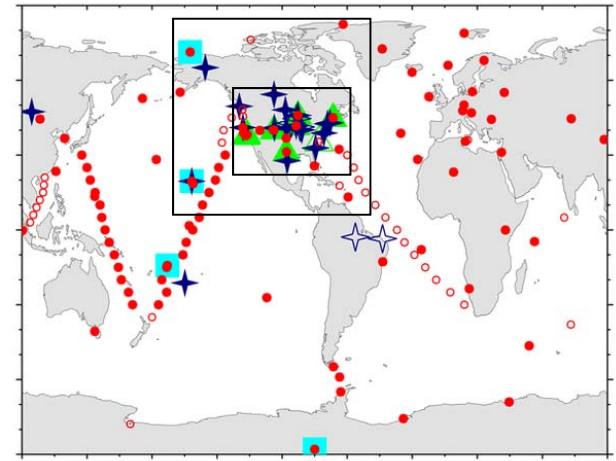


DATA ASSIMILATION

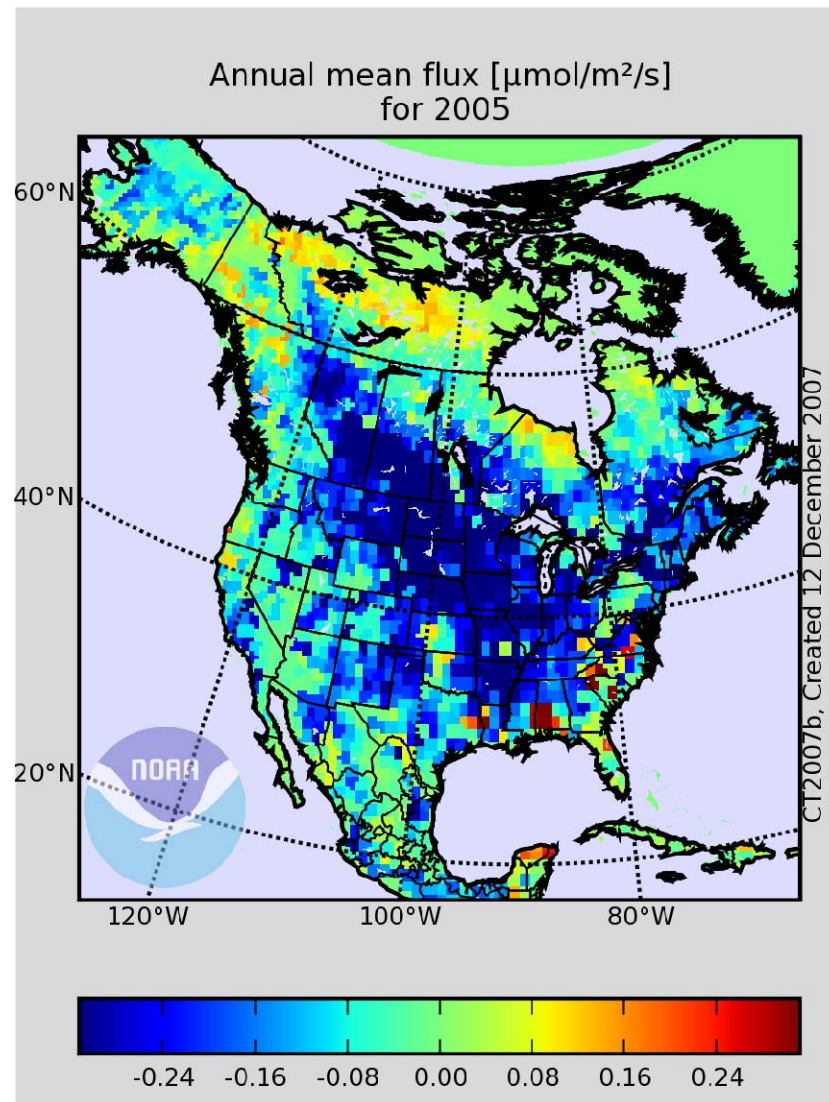
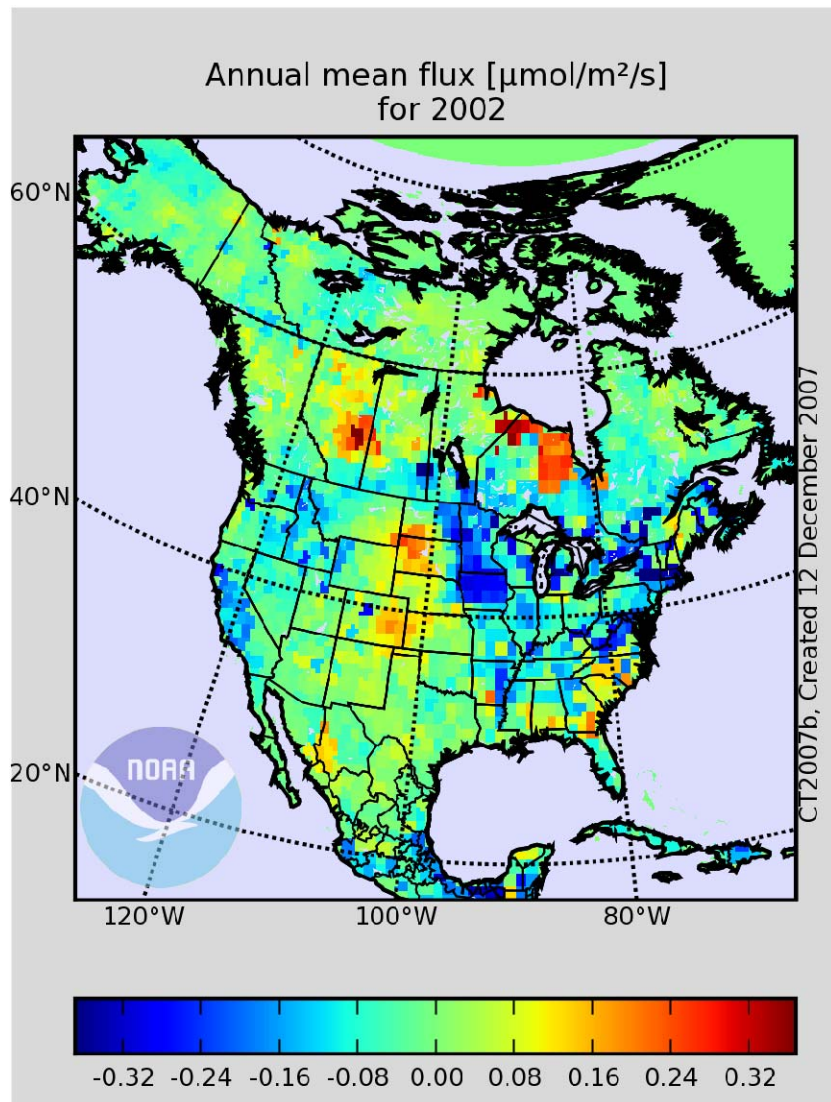
Column avg CO₂ [ppm]
on 2005-07-13, 12 GMT



CT2007b, Created 13 December 2007



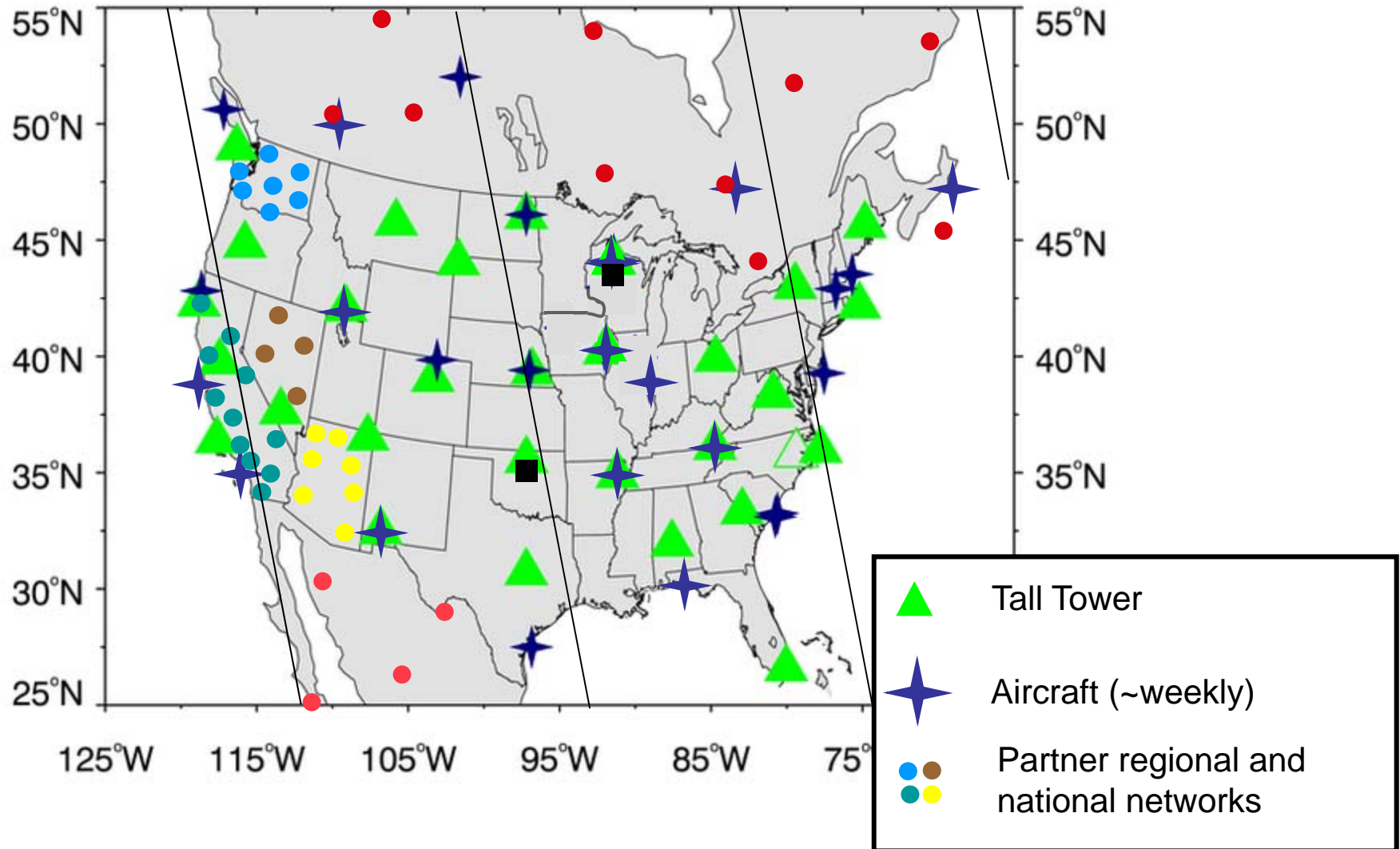
DATA ASSIMILATION



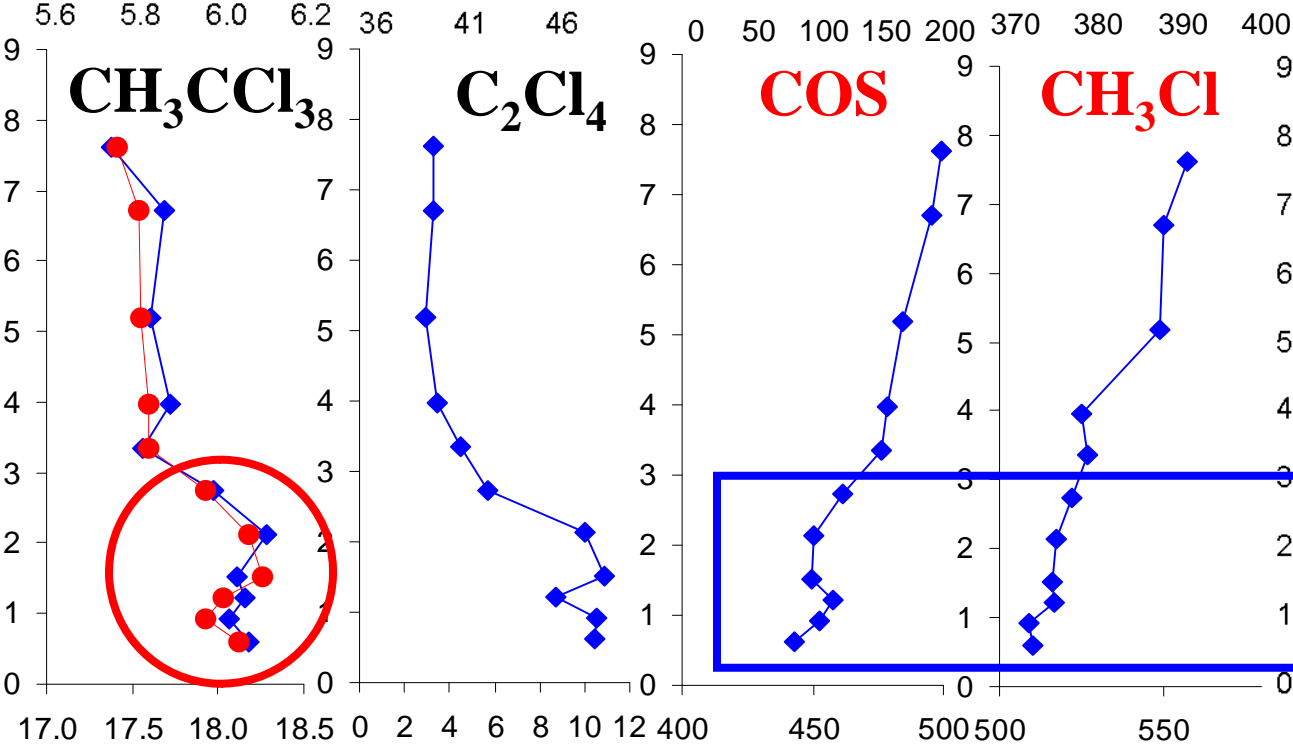
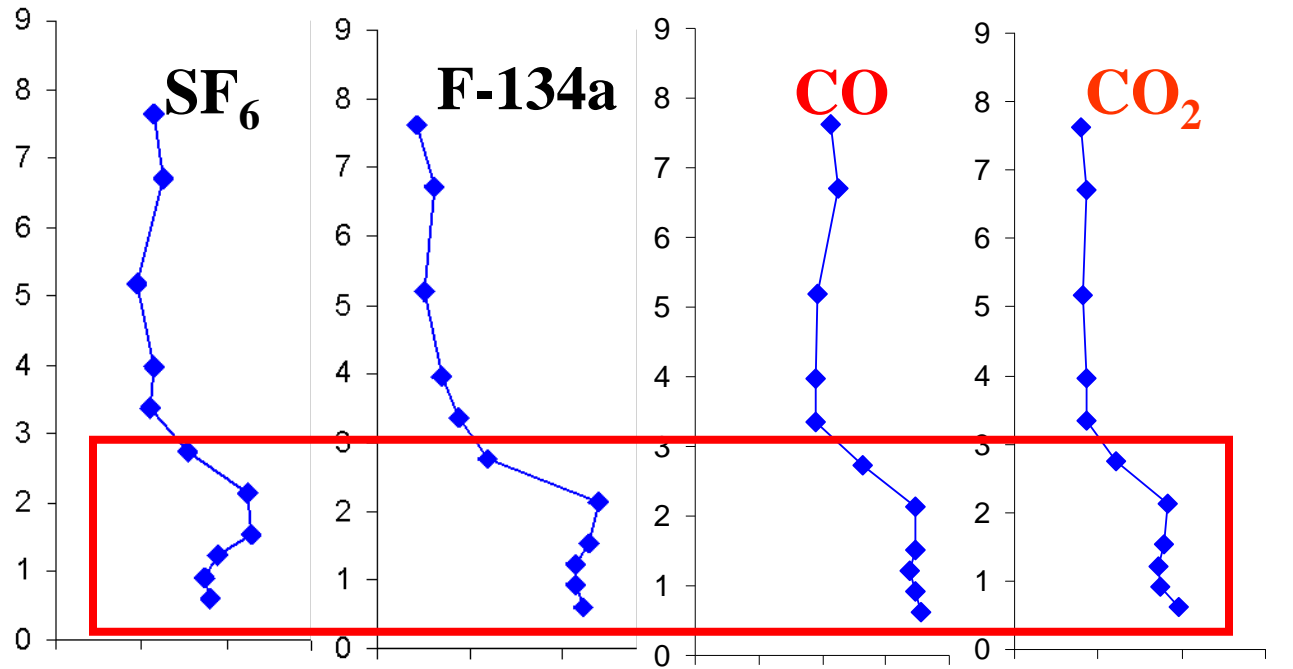
Net ecosystem flux for North America
for 2002: -0.17 Gton C

Net ecosystem flux for North America
for 2005: -0.76 Gton C

Proposed observing network for North America



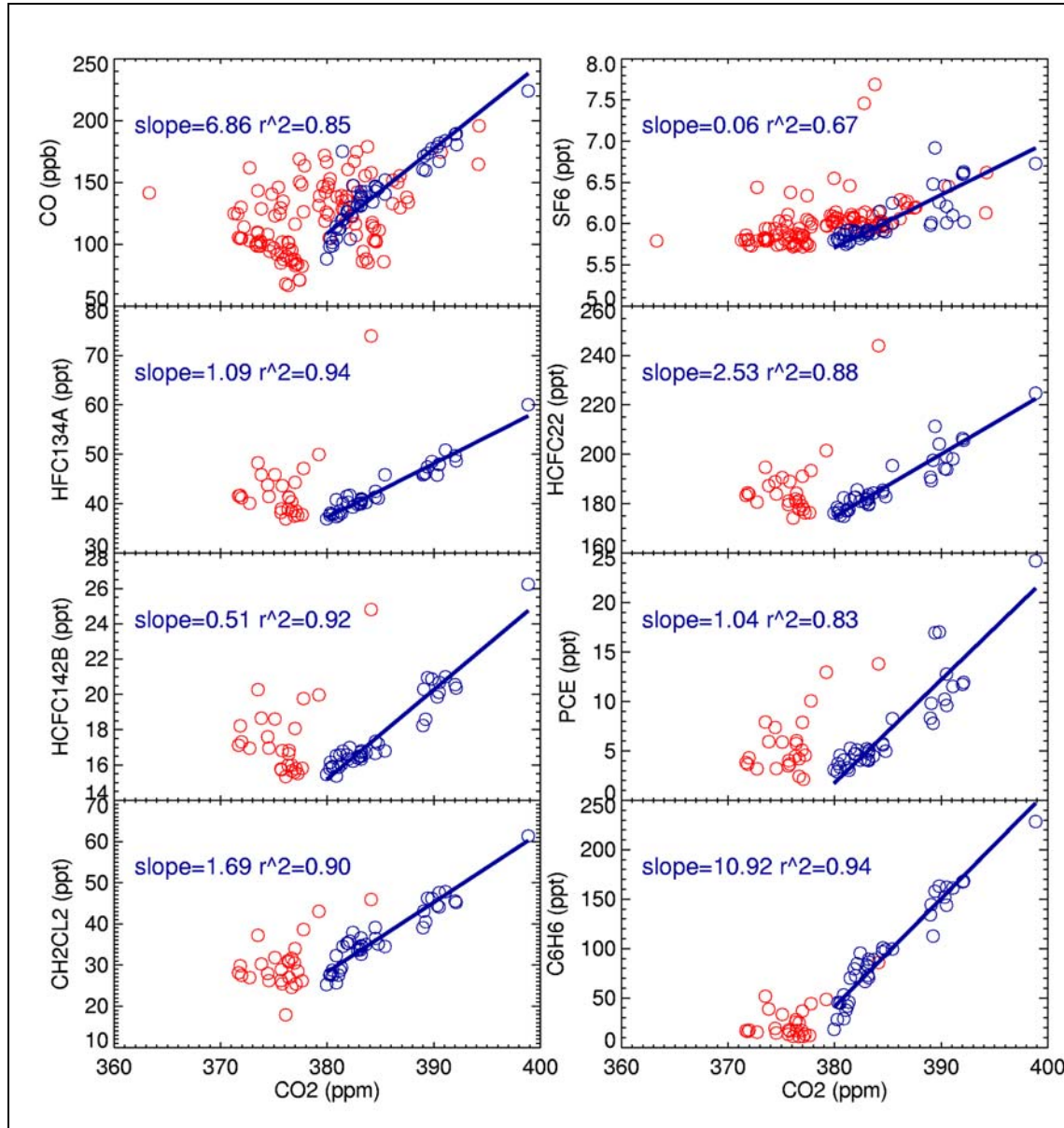
Sampling Altitude (above sea level, km)



Eastern USA
(NHA)
Nov 2005
Black = industrial gases

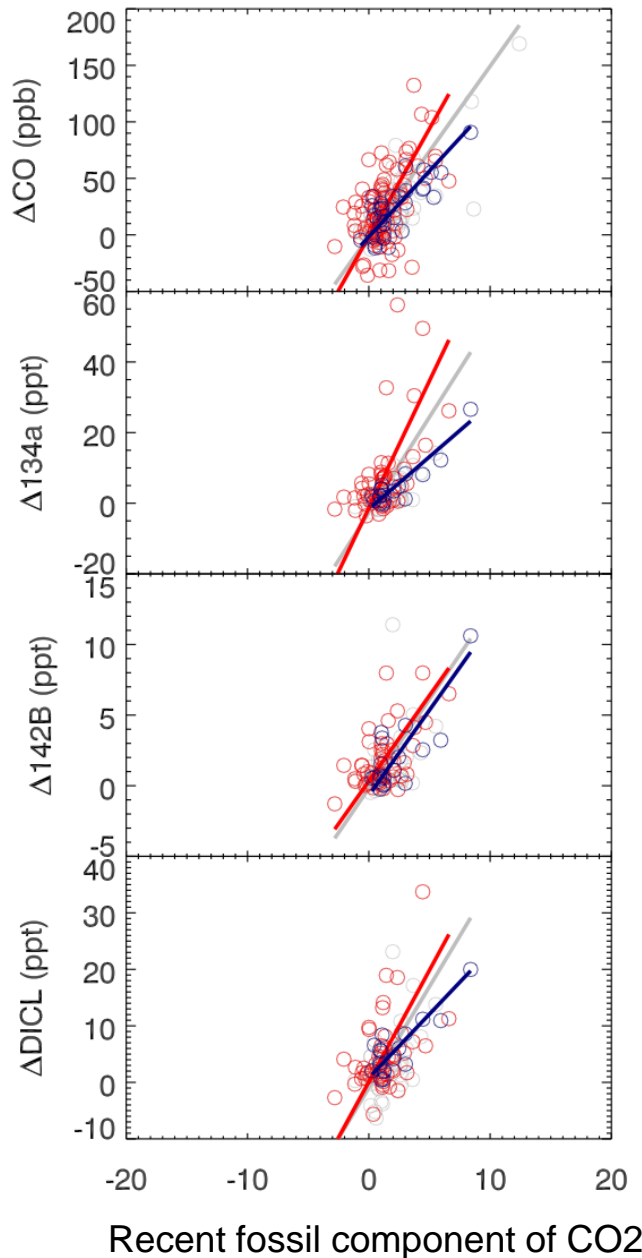
Urban influence is clear—continued emissions of CH₃CCl₃

Source: Steve Montzka, ESRL

CO₂ vs. anthropogenic gases

blue: winter

red: summer



Observed
emissions ratios:

$m=19$ ppb/ppm

$m=12$ ppb/ppm

Red=Summer
Blue=Winter

$m=7.2$ ppt/ppm

$m=3.0$ ppt/ppm

$m=1.2$ ppt/ppm

$m=1.2$ ppt/ppm

$m=4.0$ ppb/ppm

$m=2.3$ ppb/ppm

$$m_{\text{gas}} \times E_{\text{ff}} = E_{\text{gas}}$$

Observing system simulation experiment with 10,000 ^{14}C in CO_2 measurements per year is underway...