# Partitioning of terrestrial carbon sources using $^{14}CO_2$: observations and modeling

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# sensitivity to fossil fuel $CO_2$ ($C_{ff}$)

$1/\lambda_{14C} = 8223$ yr

$\Delta^{14}C‰ = (^{14}C{:}C_{sa}/^{14}C{:}C_{std} - 1)*1000$

fossil fuel $CO_2$ $\Delta = -1000‰$ *(i.e. zero $^{14}C$ content)*

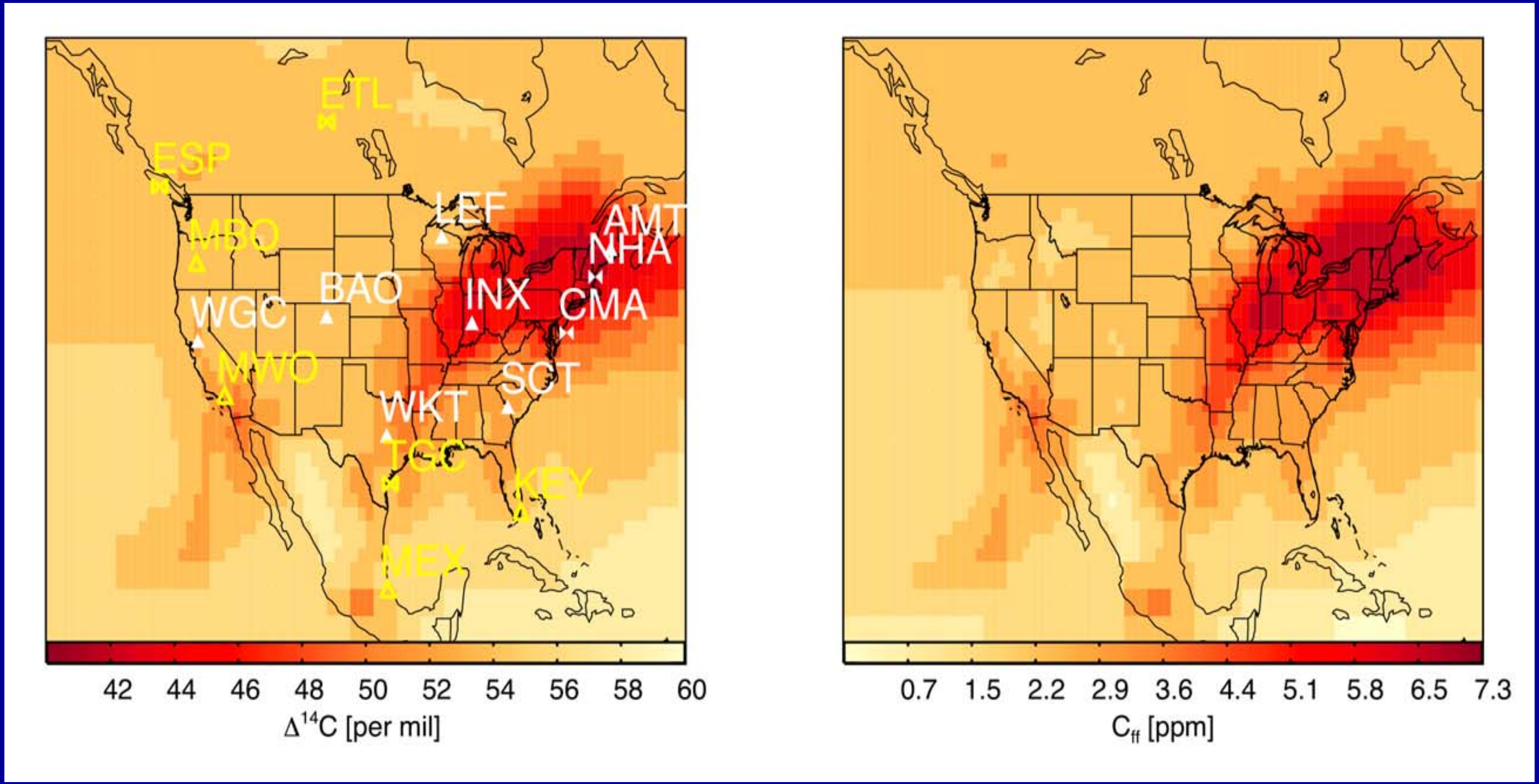
ambient atm. (*& other $CO_2$ sources*) $\Delta = \sim +50‰$

$$\frac{\Delta\Delta_{ff\text{-}atm}}{C_{atm}} = \frac{-1050‰}{390\text{ppm}} = \sim -2.7\ ‰/\text{ppm}$$

*- detection of ~1 ppm for recently-added fossil-fuel derived $CO_2$ ($C_{ff}$) requires measurement precision of ~2‰*

*- detection is unbiased if other contributions to tropospheric $^{14}C$ distribution over large land areas are small*

# $\Delta^{14}CO_2$ vs. $C_{ff}$ in TM5




- distribution of $C_{ff}$ dominates $\Delta^{14}CO_2$ signal over NH land areas (figures scaled according to mass balance relation of -2.7‰/ppm)
- small differences primarily due to terrestrial disequilibrium flux of $^{14}C$ (quantifiable)
- near-surface $\Delta^{14}C$ gradients ~14 ‰ for this week in Jan. 2006 (~8x precision)

# quantification of $C_{ff}$

$$C_{obs} = C_{bg} + C_{ff} + C_r + C_p$$

$$\Delta_{obs} C_{obs} = \Delta_{bg} C_{bg} + \Delta_{ff} C_{ff} + \Delta_r C_r + \Delta_p C_p$$

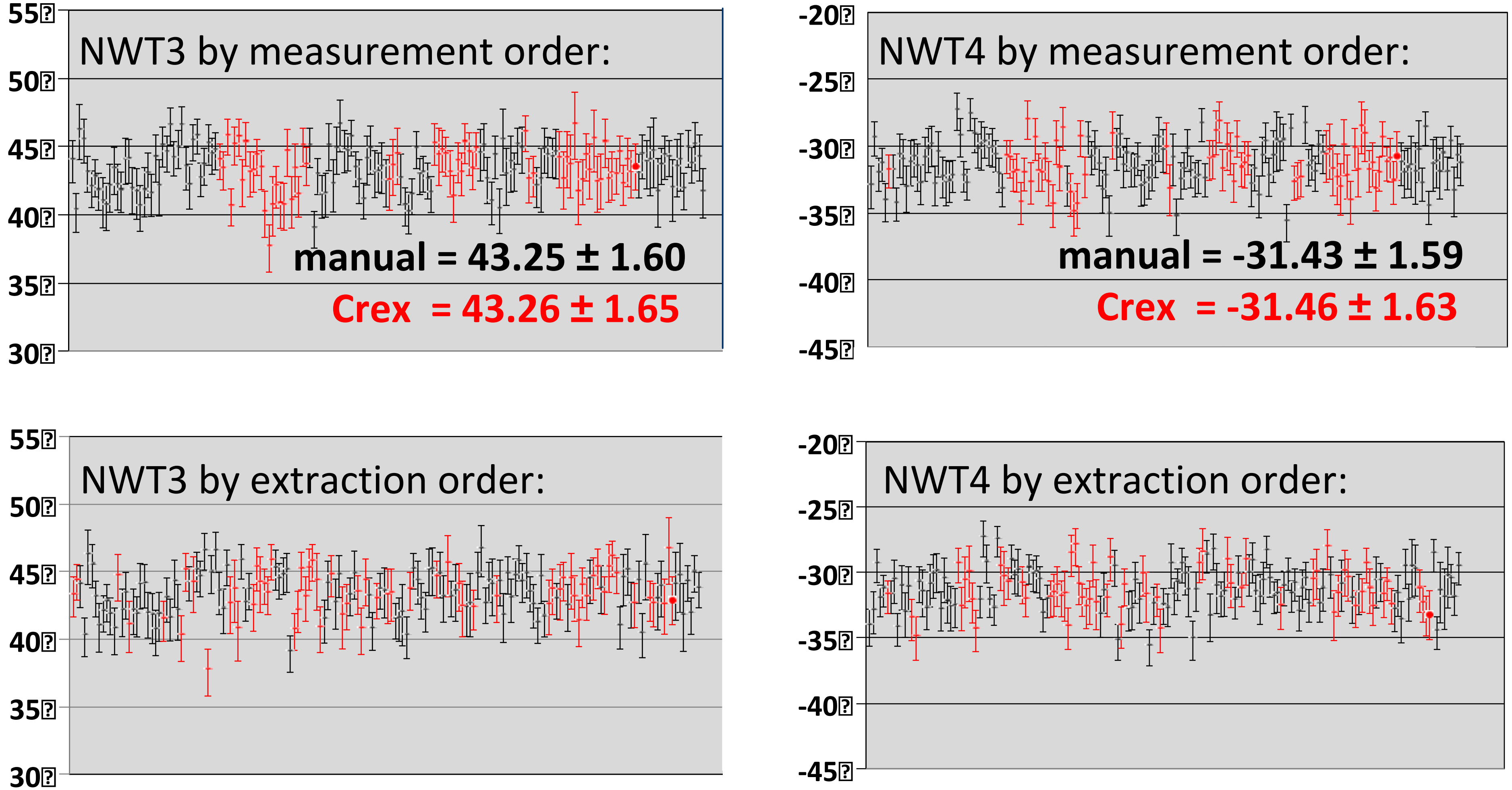
*and setting* $\Delta_p = \Delta_{bg}$ :

$$C_{ff} = \frac{C_{obs}(\Delta_{obs} - \Delta_{bg})}{\Delta_{ff} - \Delta_{bg}} - \frac{C_r(\Delta_r - \Delta_{bg})}{\Delta_{ff} - \Delta_{bg}}$$

Turnbull et al. 2006

- right hand term is correction to $C_{ff}$ of ~0.2 - 0.5 ppm (i.e., $C_r$ and $\Delta_r$ can be independently quantified)
- $C_{ff}$ detection effectively limited by quadrature sum uncertainty of two $^{14}C$ measurements ($\Delta obs$, $\Delta bg$)
- isolation of $C_{ff}$ delivers net $C_{bio}$ (w/ same uncertainty as for $C_{ff}$)

# CU-UCI 1σ repeatability ($\Delta^{14}C$ ‰)

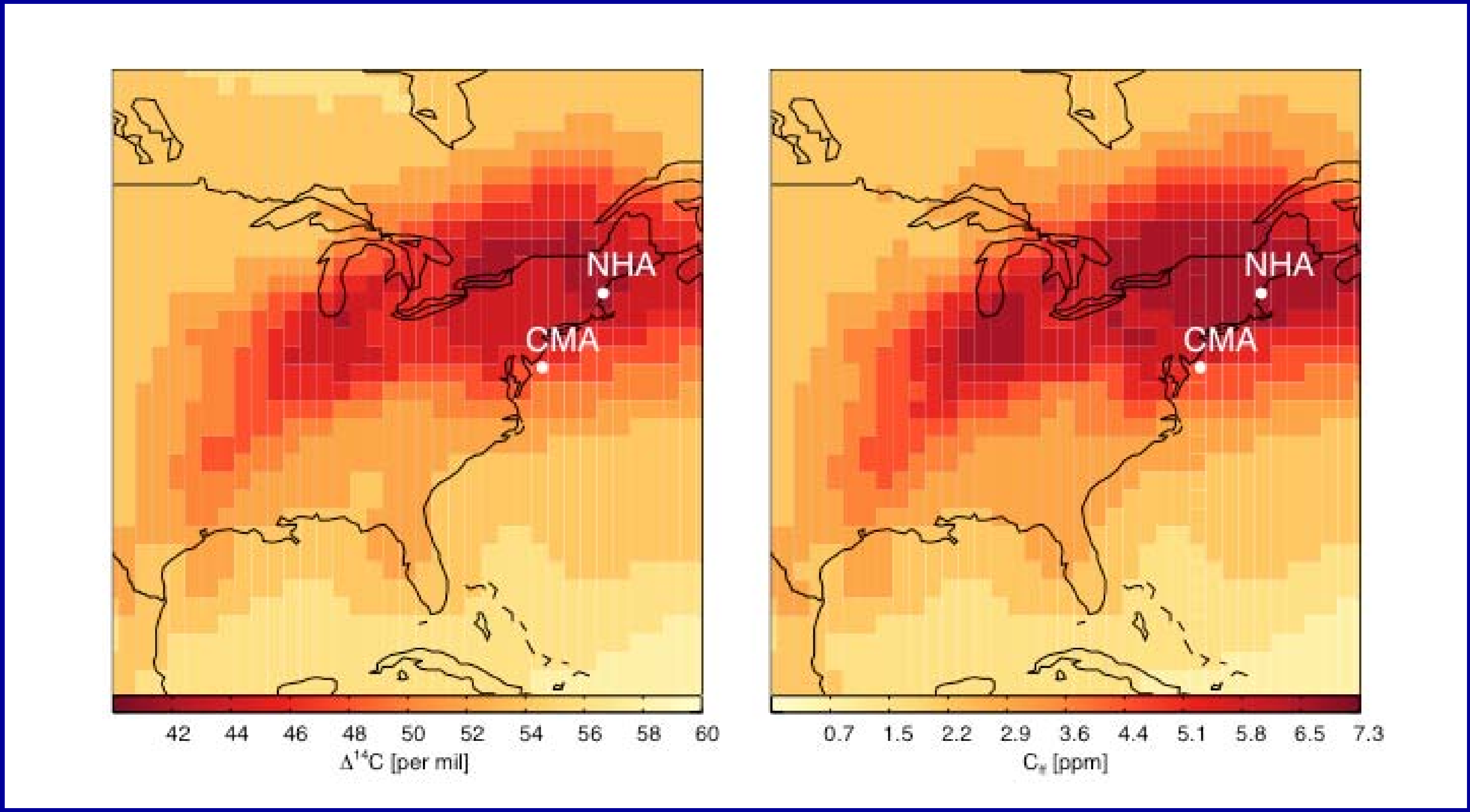



NWT3 and NWT4 replaced NWTstd (near exhaustion) in late 2009

NWTstd 1σ repeatability 2003-2009 = 1.8 ‰

report 1σ repeatability or 1σ single sample precision, whichever is larger

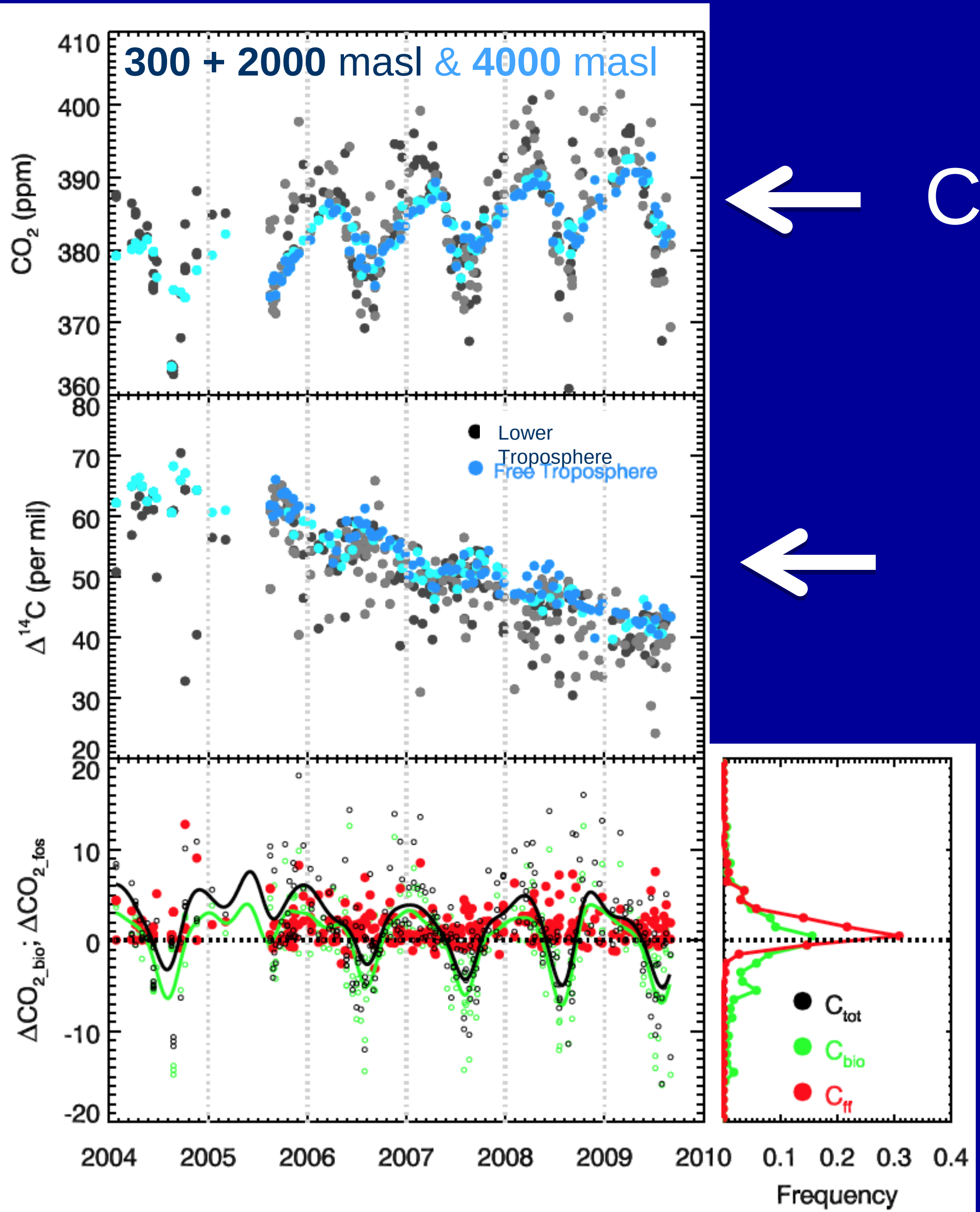
# NE U.S. example [*Miller et al. '12*]




samples from 5-6 yrs of bi-weekly vertical aircraft profiles in area of significant regional emissions and outflow

3-ht. sampling for $^{14}CO_2$, 9-ht. for all other gases

# isolation of $C_{ff}$ and $C_{bio}$, CMA+NHA

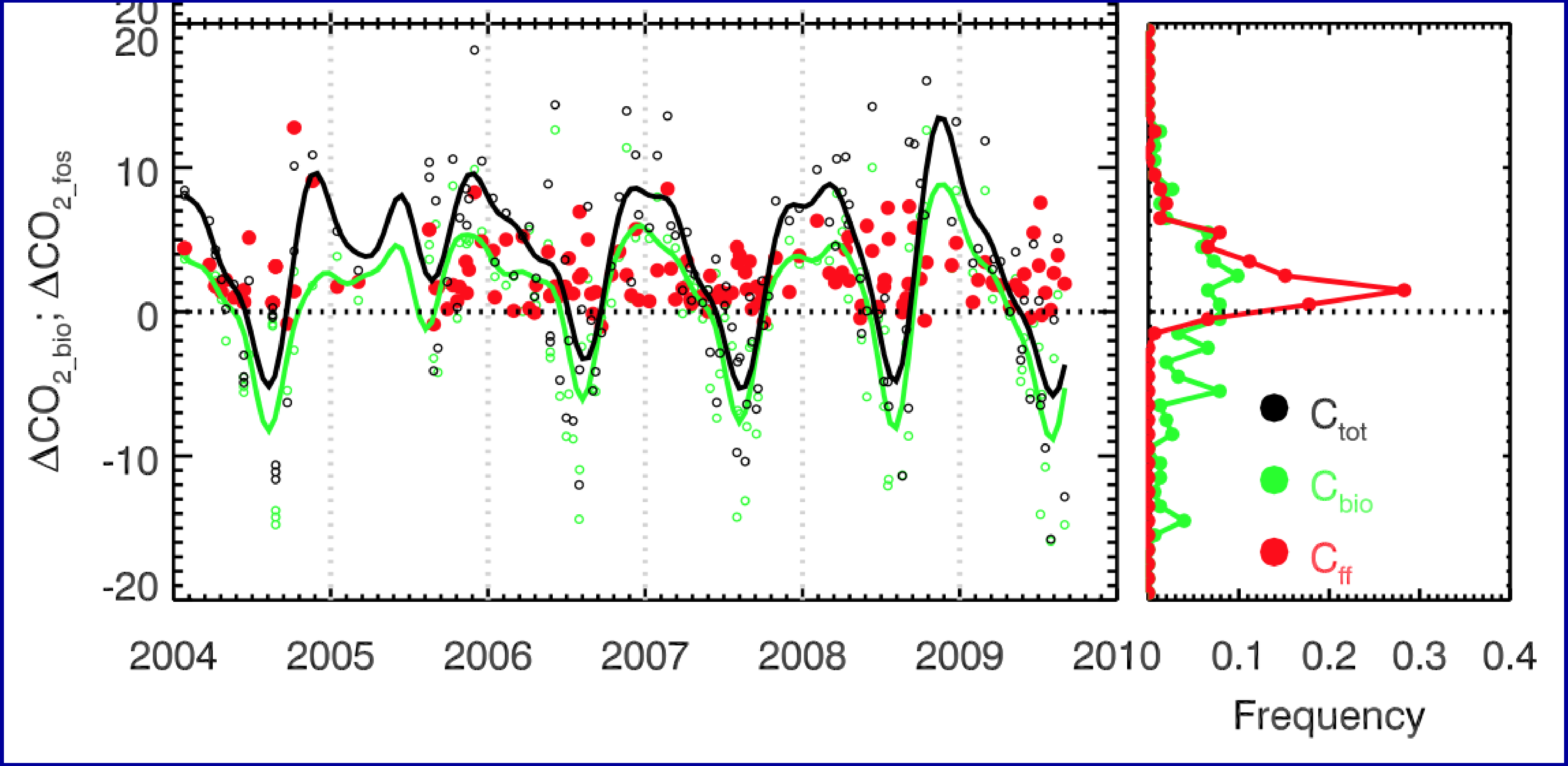



$$C_{obs} = C_{bg} + C_{ff} + C_{bio}$$

$$\Delta_{obs} = \Delta_{bg} + \Delta_{ff}$$

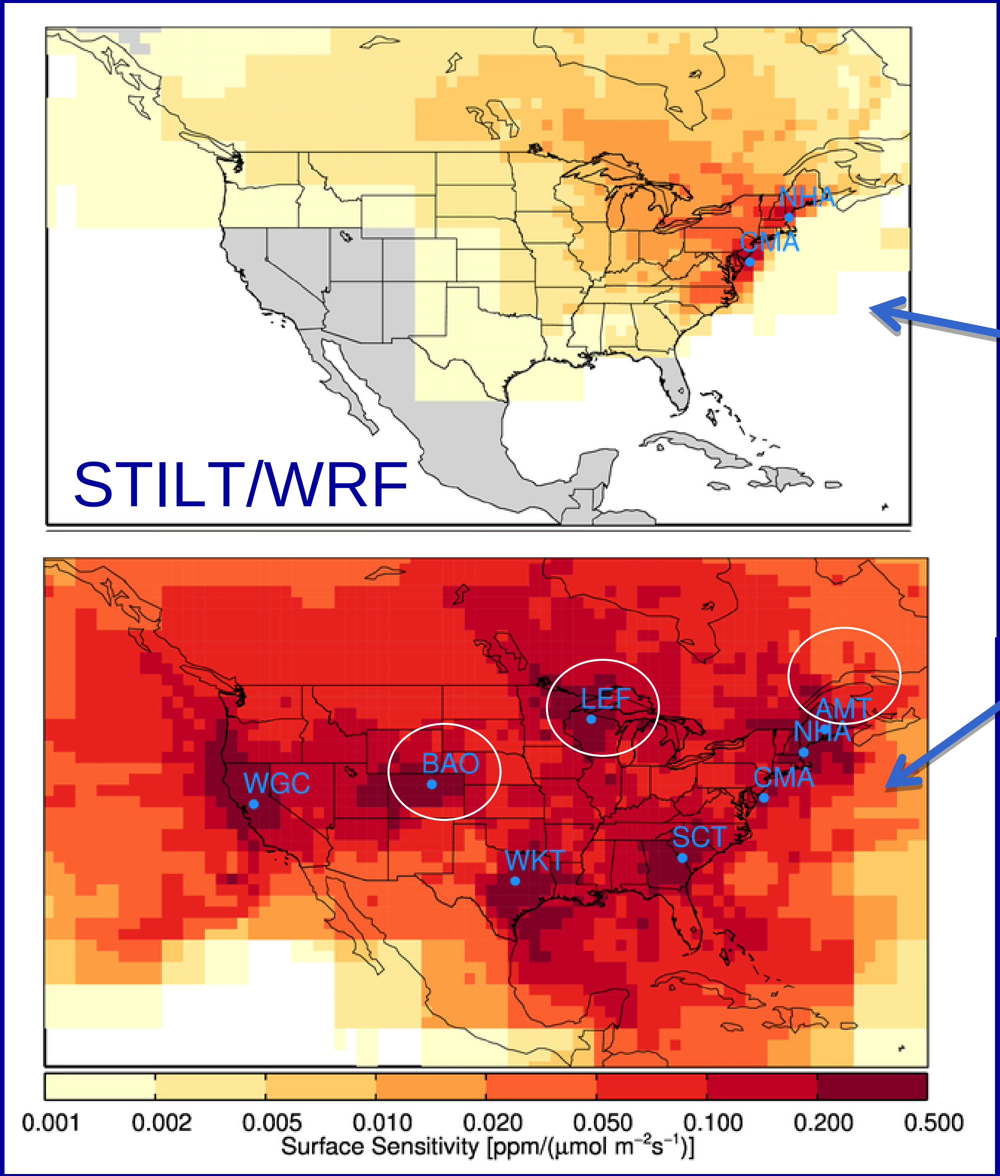
- obs fr. ~300 and ~2000 masl (vs. 4000 m 'bg' in FT)
- $C_{ff}$ detectable year round (1-10 ppm)

# 300 m obs only, CMA+NHA




- sharpens view of biospheric signal (vs. raw $CO_2$ enhancement)
- $C_{bio}$ large even in winter (~60% of total winter-time enhancement) despite urban/industrial observational footprint
- $CO_2$-only methods: can not assume urban enhancements are due to $C_{ff}$
- $C_{ff}$ and $C_{bio}$ independently useful

# growing observational footprint




circled sites: collaborative w/ LLNL/CAMS

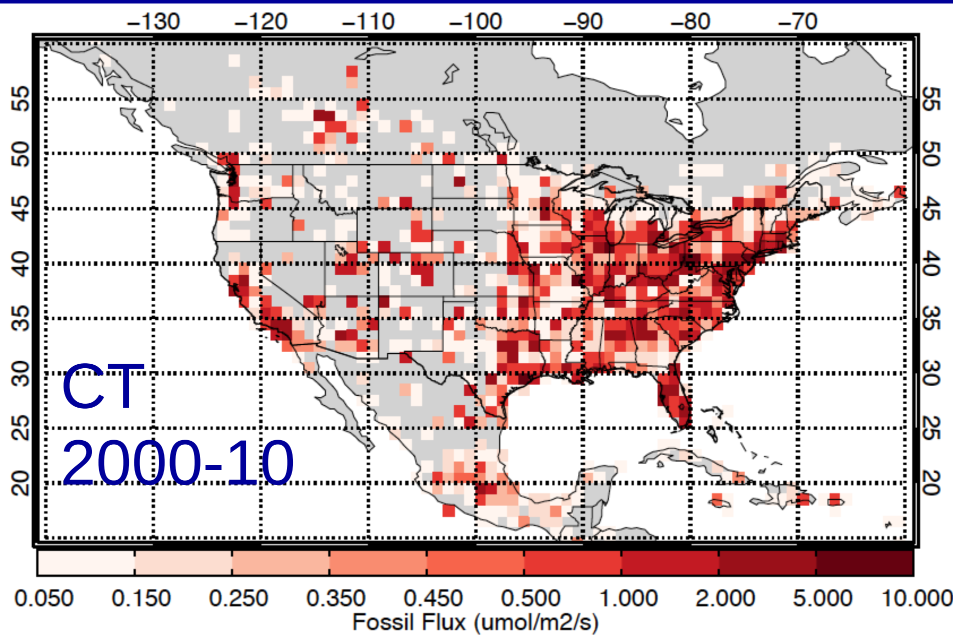
annual average sensitivity for all PBL $^{14}C$ obs

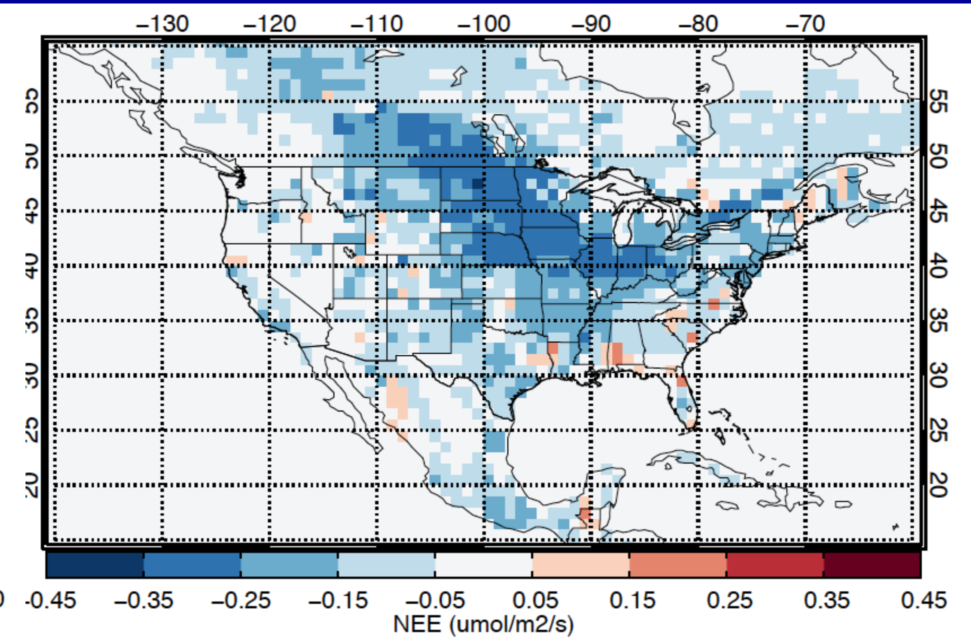
[*Miller et al.*, 2012]

since late '09 from ~thrice weekly tower (PBL) $^{14}C$ obs (excludes INX, MWO)

*$^{14}C$ footprint sufficient for meaningful guidance of CarbonTracker, using both $^{14}C$ and $CO_2$ as obs constraints*

# use of $^{14}C + CO_2$ in CT to improve NEE




$F_{ff}$ *prior* (given 0 uncertainty)

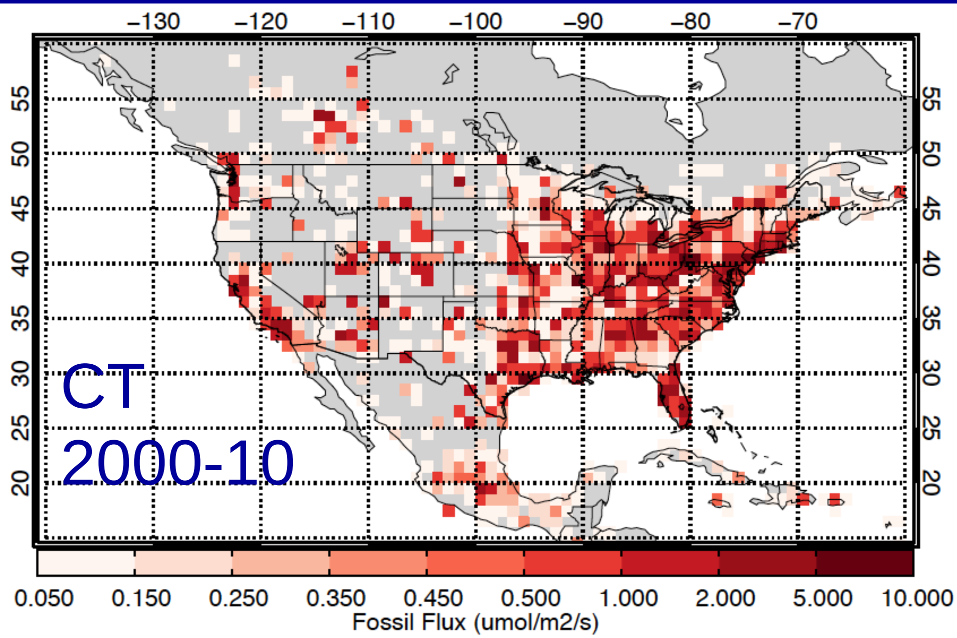
NEE *posterior* retrieval

deviation $F_{ff}$ prior from actuals will lead directly to bias in retrieved $F_{bio}$ (NEE) from inversion of $C_{obs}$

$$dC_{obs}/dt = F_{ff} + F_{bio} + F_{fire}$$

$F_{ff}$ is large *w.r.t* net annual $F_{bio}$, and.. extrapolation of $F_{ff}$ inventories will not capture $F_{ff}$ anomalies associated with sustained heat and cold waves

# use of $^{14}C + CO_2$ in CT to improve NEE

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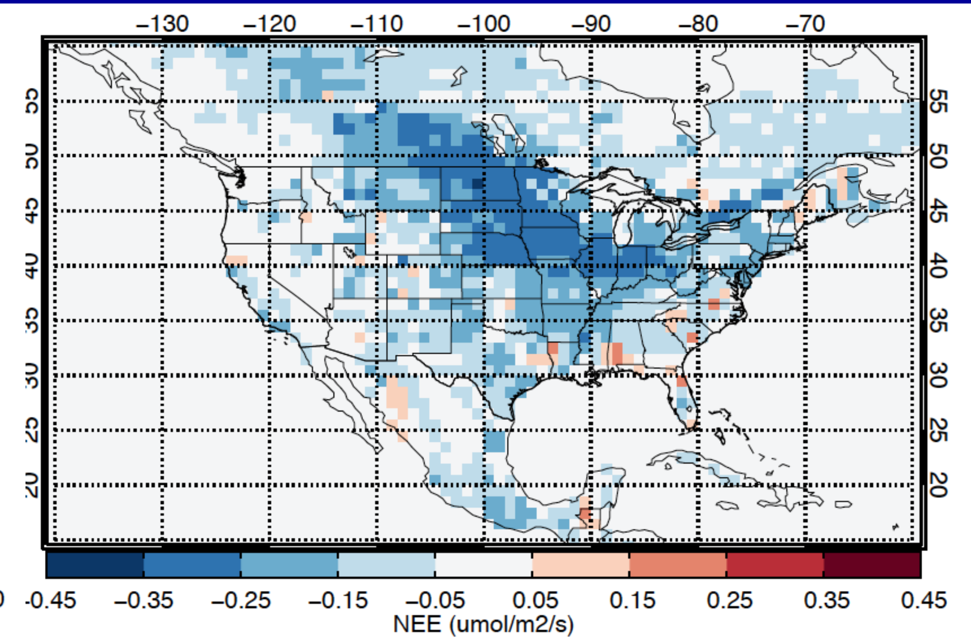


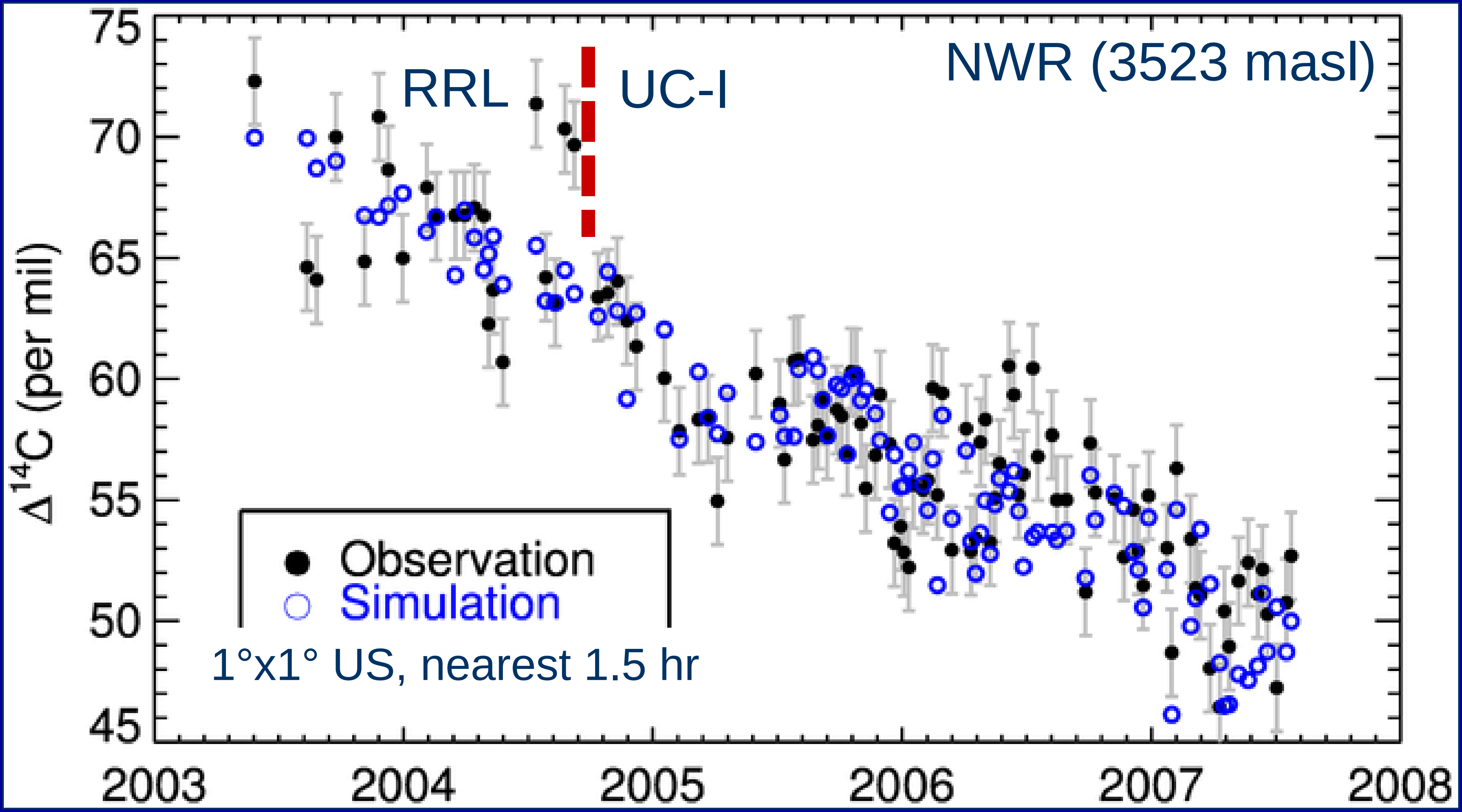

NEE *posterior* retrieval

deviation $F_{ff}$ prior from actuals will lead directly to bias in retrieved $F_{bio}$ (NEE) from inversion of $C_{obs}$

$$dC_{obs}/dt = F_{ff} + F_{bio} + F_{fire}$$

relax $F_{ff}$ prior uncertainty to permit guidance by $^{14}C$ obs where available

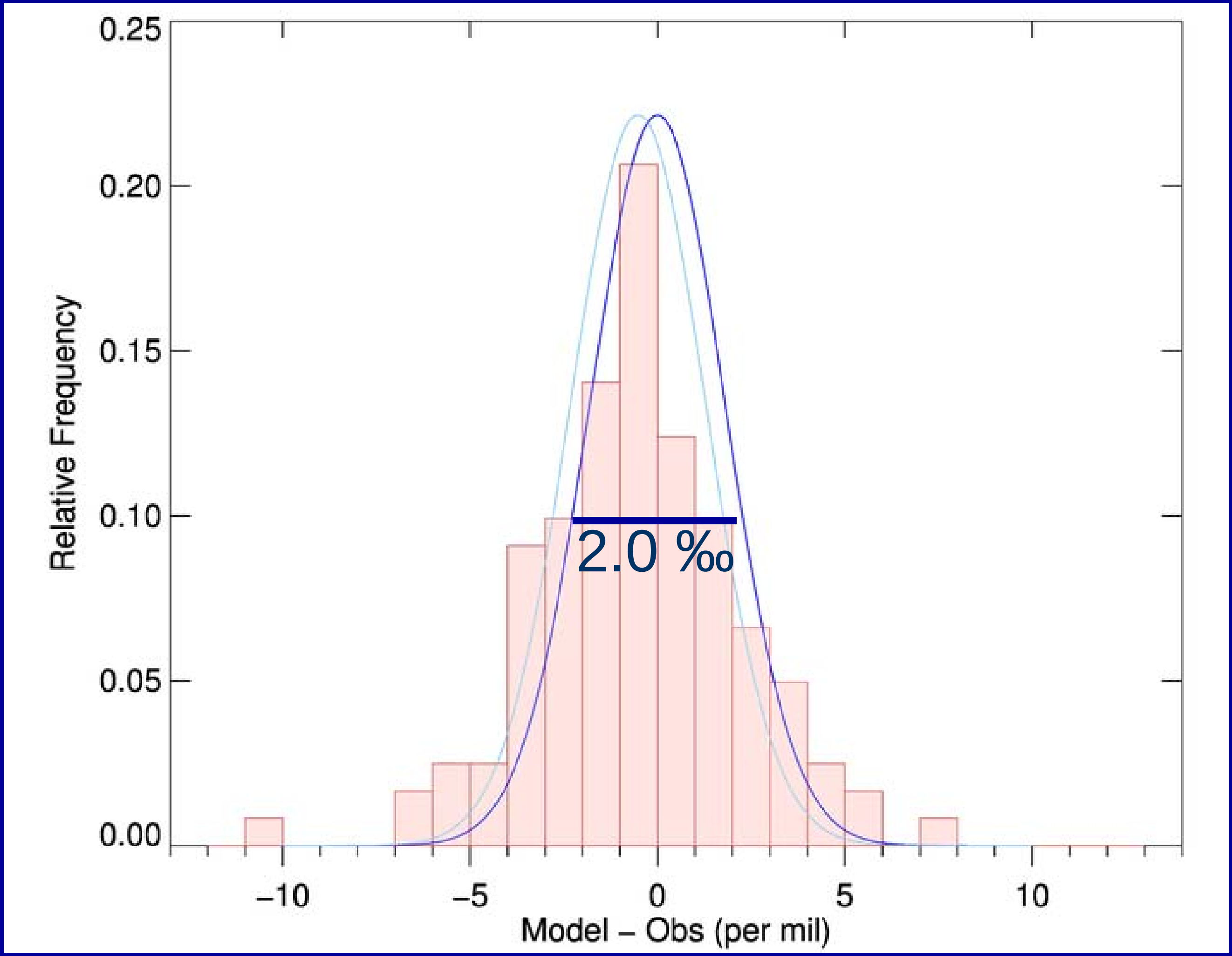
# TM5-$^{14}$C vs. NWR (FT) obs




$$C_{atm} d\Delta/dt = (\Delta_{foss} - \Delta_{atm}) F_{fos} + \Delta_{dis} F_{surf\text{-}gross} + isoF_{cosm} + isoF_{nuc}$$

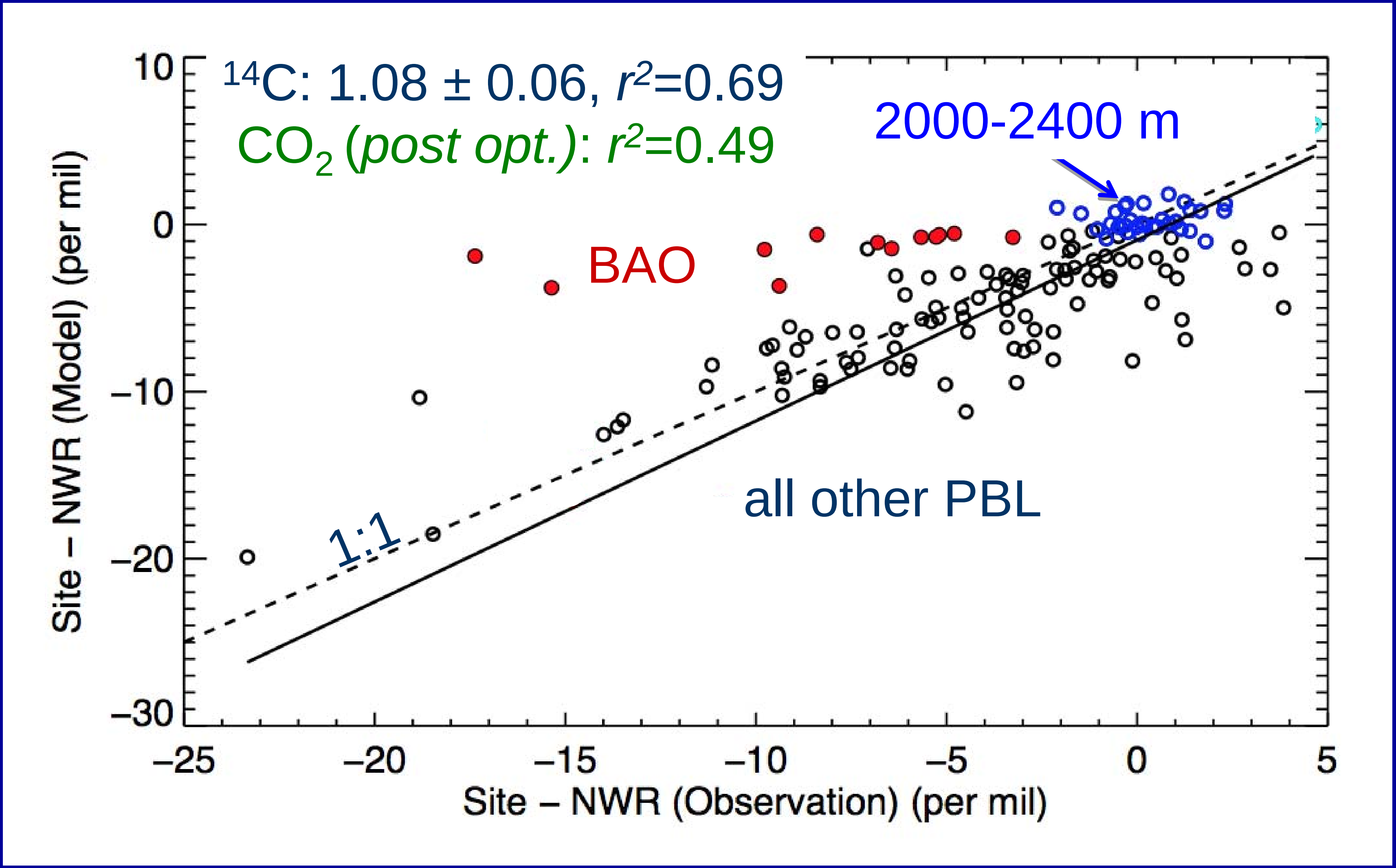
$^{14}$C fluxes from *a priori* geophysical estimates & CT FF (no tuning): *budget terms properly balanced, if not correct*

# residuals, NWR




90% within measurement error,  bias = -0.5 per mil

# TM5-$^{14}$C vs. Lower Trop. obs, US




monthly mean Site-NWR gradients, $F_{foss}$ from CT

(climatological m_m obs = 132 site_mos fr. ~2500 obs)

# summary

- developed scientifically meaningful $^{14}C$ measurement capability
- expanded observational footprint to US national scale (and elsewhere)
- propose moving forward w/ $^{14}C$ and $CO_2$ as dual observational constraints in CarbonTracker (for NEE, $C_{ff}$ emmisions verification)
- evaluating tracer:$C_{ff}$ emissions ratios [Miller *et al.*, JGR-A, 2012] nationally, updating absolute emissions estimates for correlate gases