Patterns and Variability in $\Delta^{14}C$ of CO_2 in Northern Hemisphere Background Air

Heather Graven

Scripps Institution of Oceanography (hgraven@ucsd.edu)

Tom Guilderson, Lawrence Livermore National Laboratory

and Ralph Keeling, Scripps Institution of Oceanography

Calculating fossil fuel-derived CO_2 using $\Delta^{14}C$

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$$\delta C_{ff} = C_{meas} \frac{\Delta_{bg} - \Delta_{meas}}{\Delta_{bg} + 1000‰} + \beta$$

$$\approx \frac{\Delta_{bg} - \Delta_{meas}}{2.7‰\ \text{ppm}^{-1}} + \beta$$

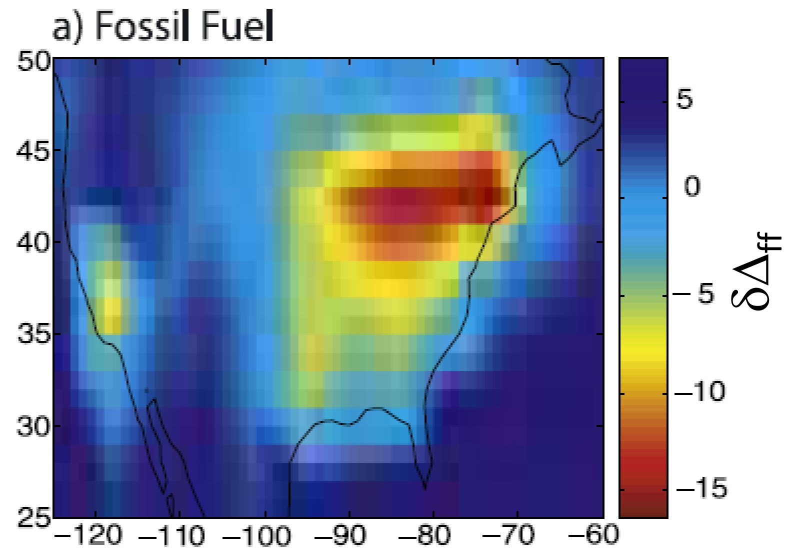
Components of uncertainty:

- measurement uncertainty in $\Delta^{14}C$
- uncertainty in non-fossil influences on $\Delta^{14}C$ (β)
- uncertainty in background $\Delta^{14}C$ for application of interest

Target precision:

Achieving ±25% in emissions requires ±2-3‰ in $\delta\Delta_{ff}$ at urban and continental scales

City	Emissions ($Mton\ CO_2\ yr^{-1}$)	Boundary Layer 1 km δC_{ff} (ppm)	$\delta\Delta_{ff}$ (‰)
Los Angeles	73.2	4.3	-12
Chicago	79.1	5.4	-15
Houston	101.8	6.4	-17
Indianapolis	20.1	2.4	-6
Tokyo	64	5.6	-15
Seoul	43	6.3	-17
Beijing	74	9.4	-25
Shanghai	112	15	-41



Pacala et al. 2010

Hsueh et al. 2007

Measurement uncertainty

- Recent efforts have achieved ±1.7 ‰ with AMS, equivalent to ±0.6 ppm in δC_{ff}, using air standards (Graven et al. 2007; Turnbull et al. 2007)

Other uncertainties must also be reduced to roughly 2 ‰

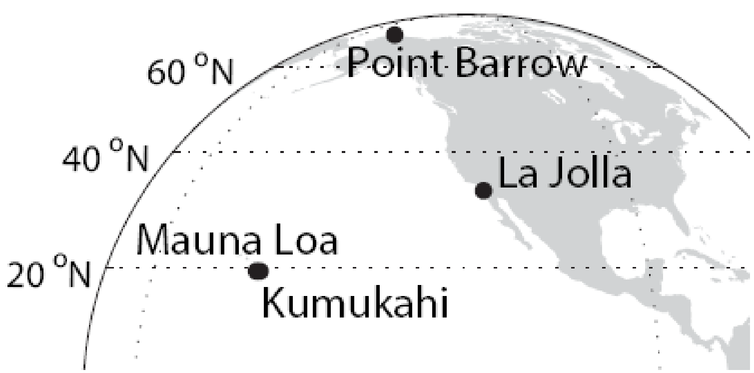
- Non-fossil influences

  Turnbull et al., JGR, 2009; Graven and Gruber, ACPD, 2011

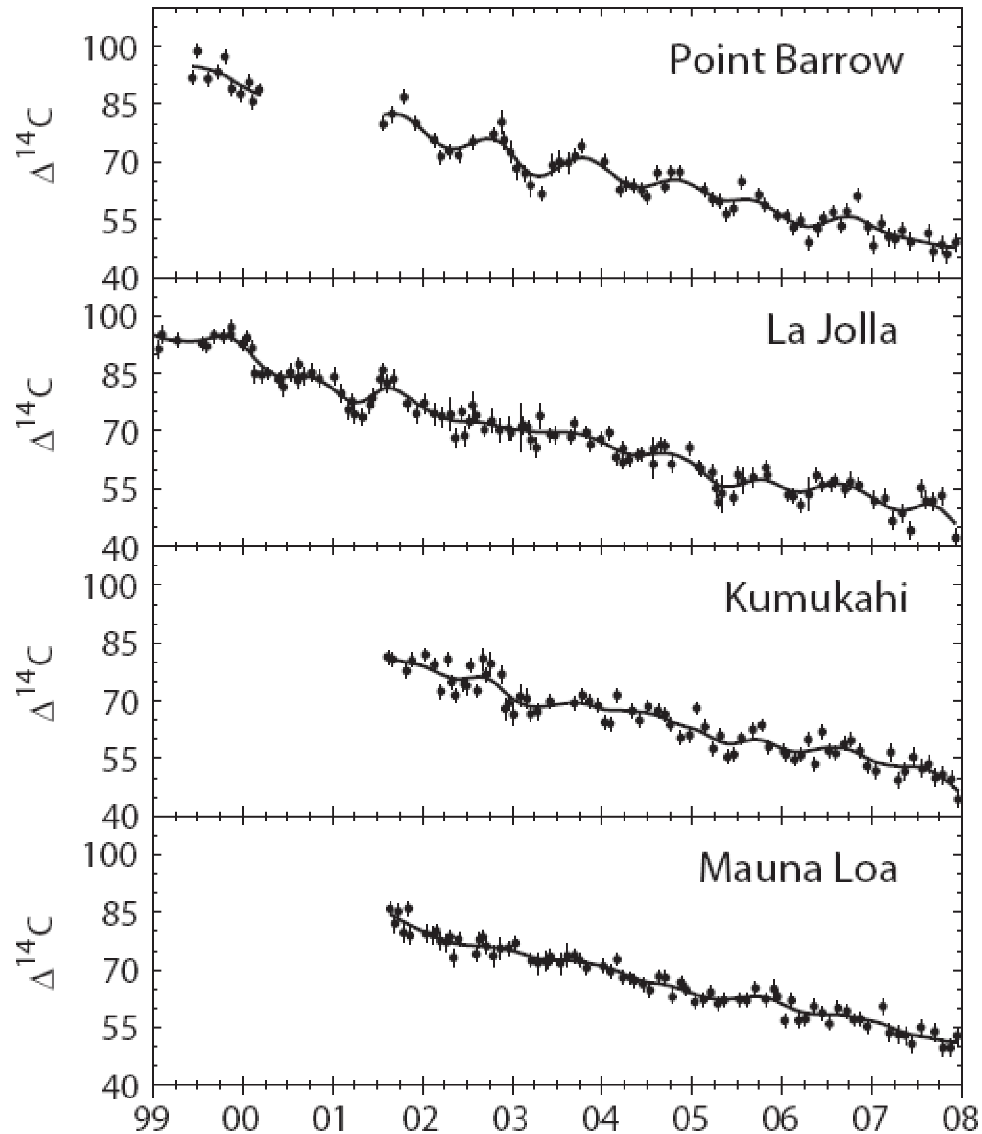
- **Background $\Delta^{14}C$**

  What is the range in $\Delta^{14}C$ for air entering North America?

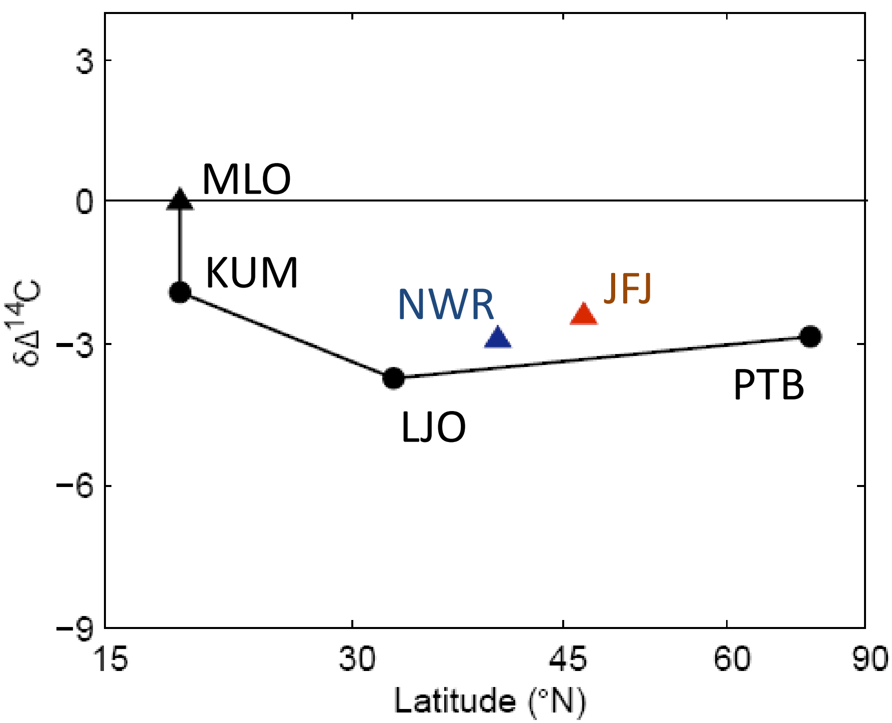
$\Delta^{14}C$ in CO_2 at Northern Hemisphere measurement sites from Scripps



Mauna Loa: 3400 m ASL
Other sites at sea level



Average NH $\Delta^{14}C$ gradients, 2002-07



Apparent positive $\Delta^{14}C$ gradient with altitude in tropics and midlatitudes, though inter-laboratory offsets possible

La Jolla shows lowest $\Delta^{14}C$ reflecting large-scale gradient, not local influences

Variation across midlatitudes and altitudes is not known

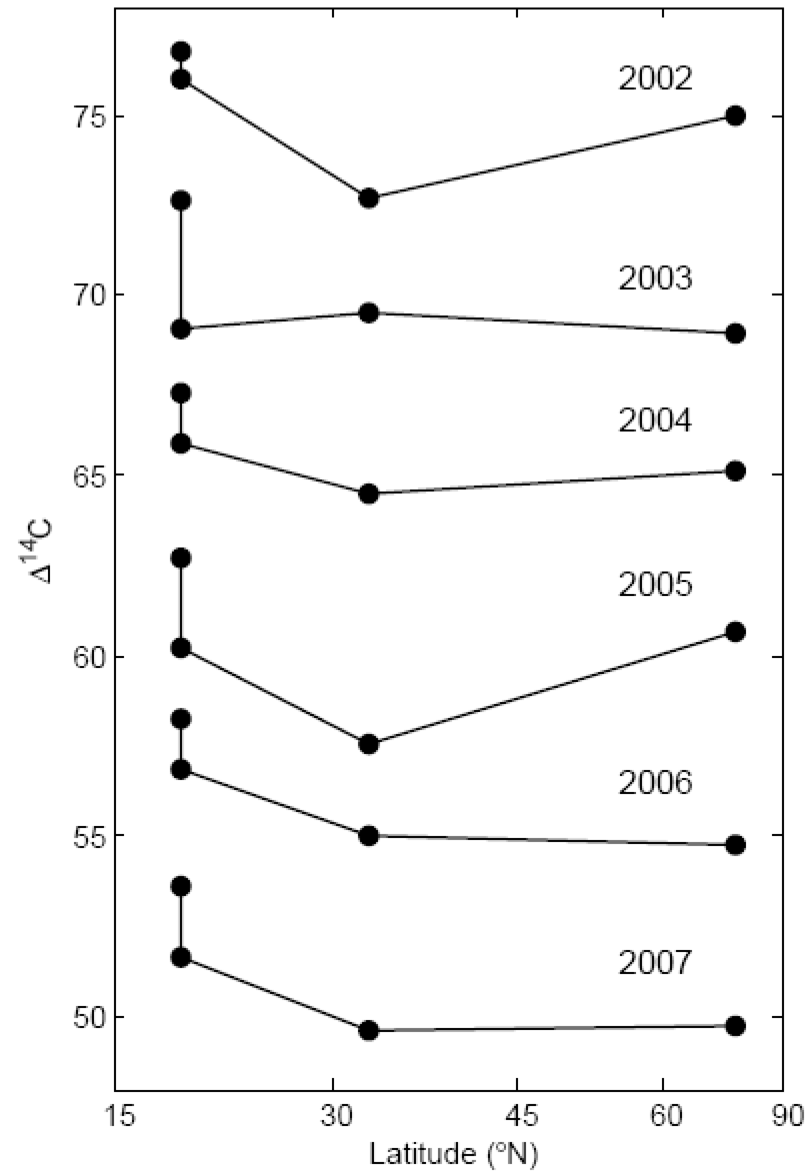
NWR data (2003-06) from J. Turnbull and JFJ data (2002-06) from I. Levin

Year-to-year variability

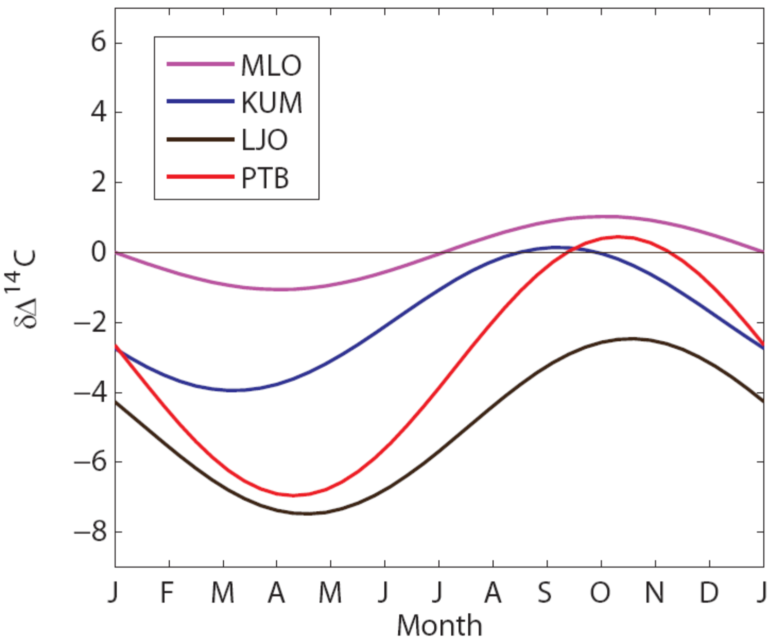
Weak NH gradients in 2003
Range in $\Delta^{14}C$: ±1.8 ‰

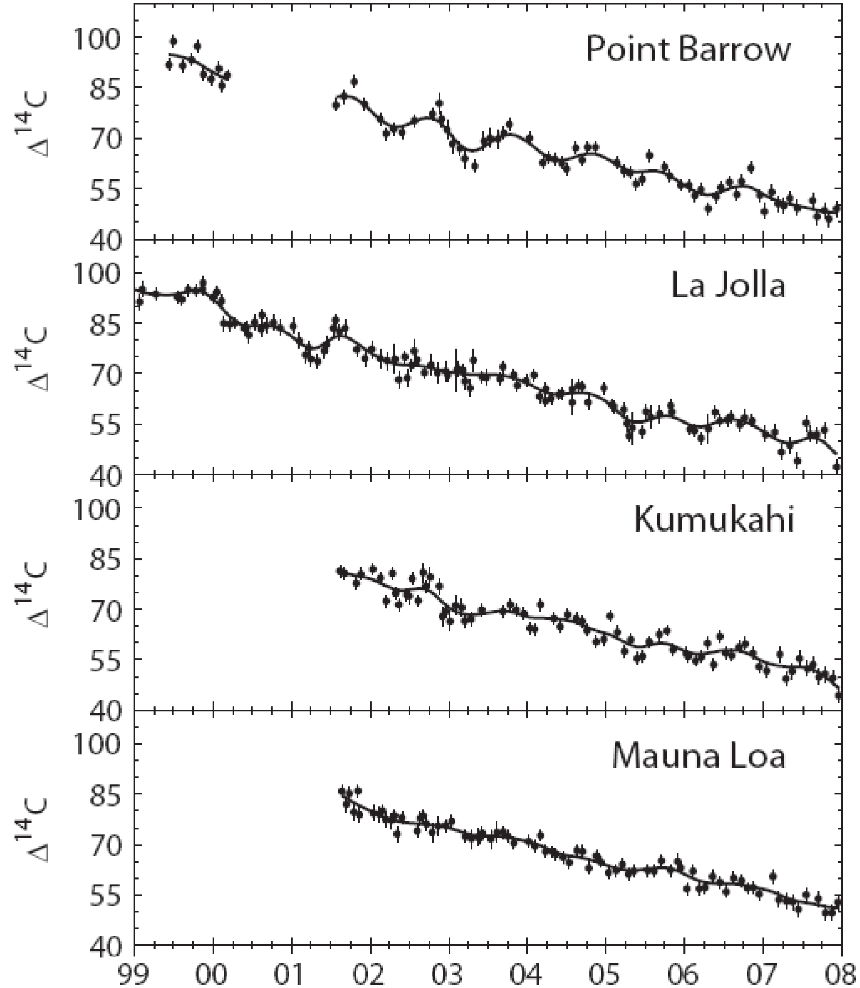
Strong NH gradients in 2005
Range in $\Delta^{14}C$: ±2.6 ‰

Assuming constant meridional gradients could introduce biases



Seasonal variation





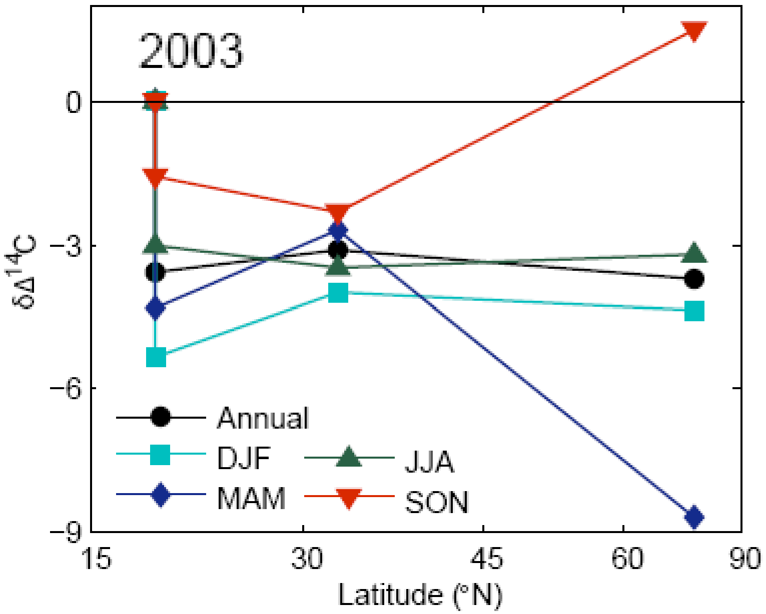
Seasonal maximum in fall

Amplitude increases with latitude

Smallest range in Sept-Oct, at the seasonal maximum

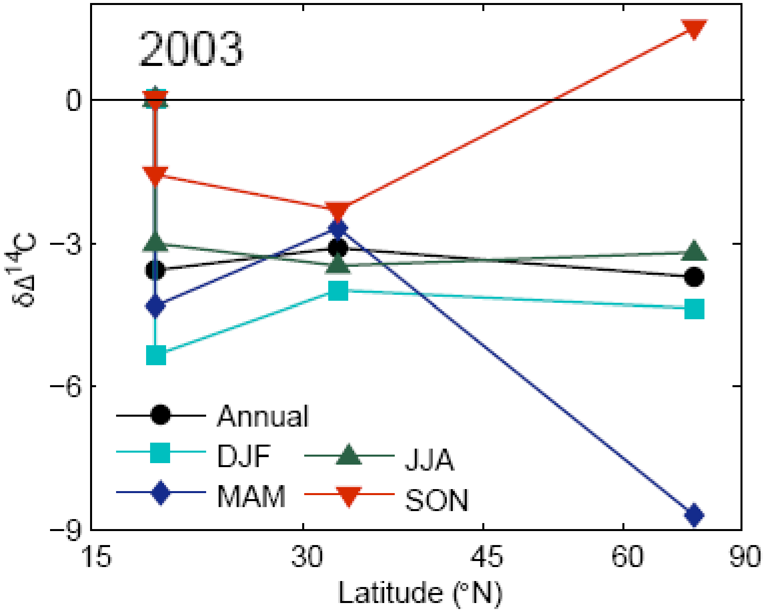
Variability in seasonal cycles

Amplitude high at PTB, low at LJO

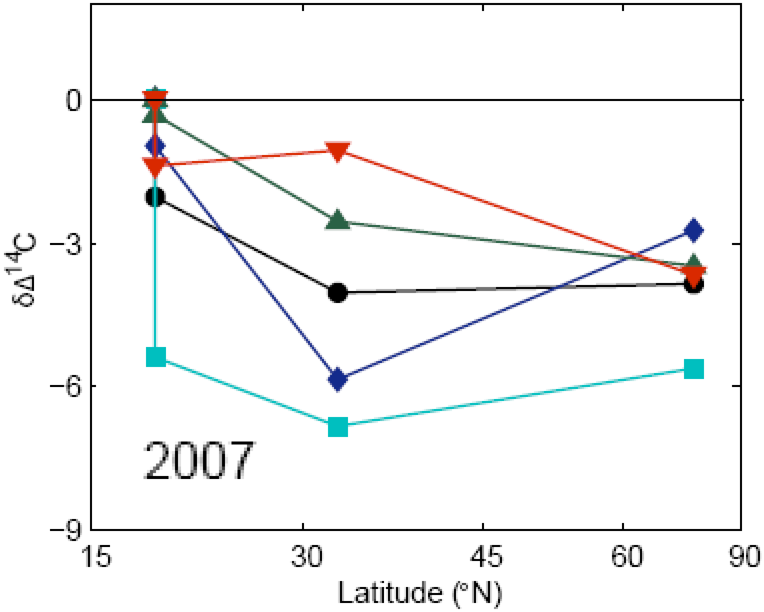


Variability in seasonal cycles

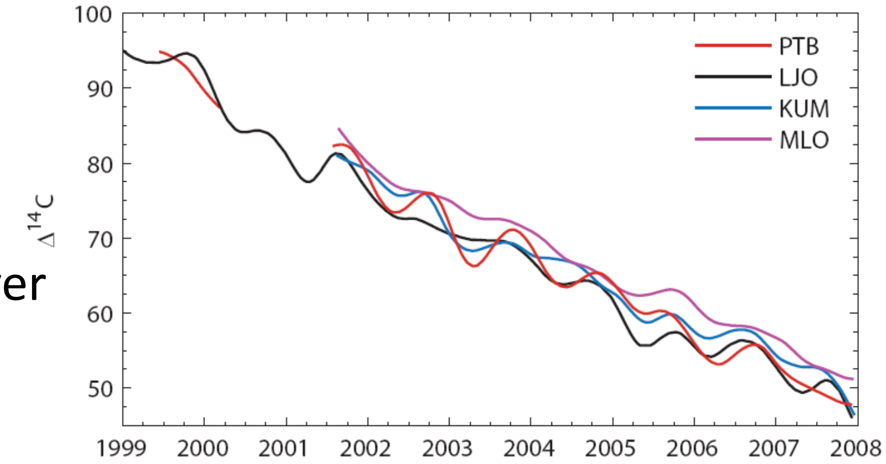
Amplitude high at PTB, low at LJO



Amplitude low at PTB, high at LJO



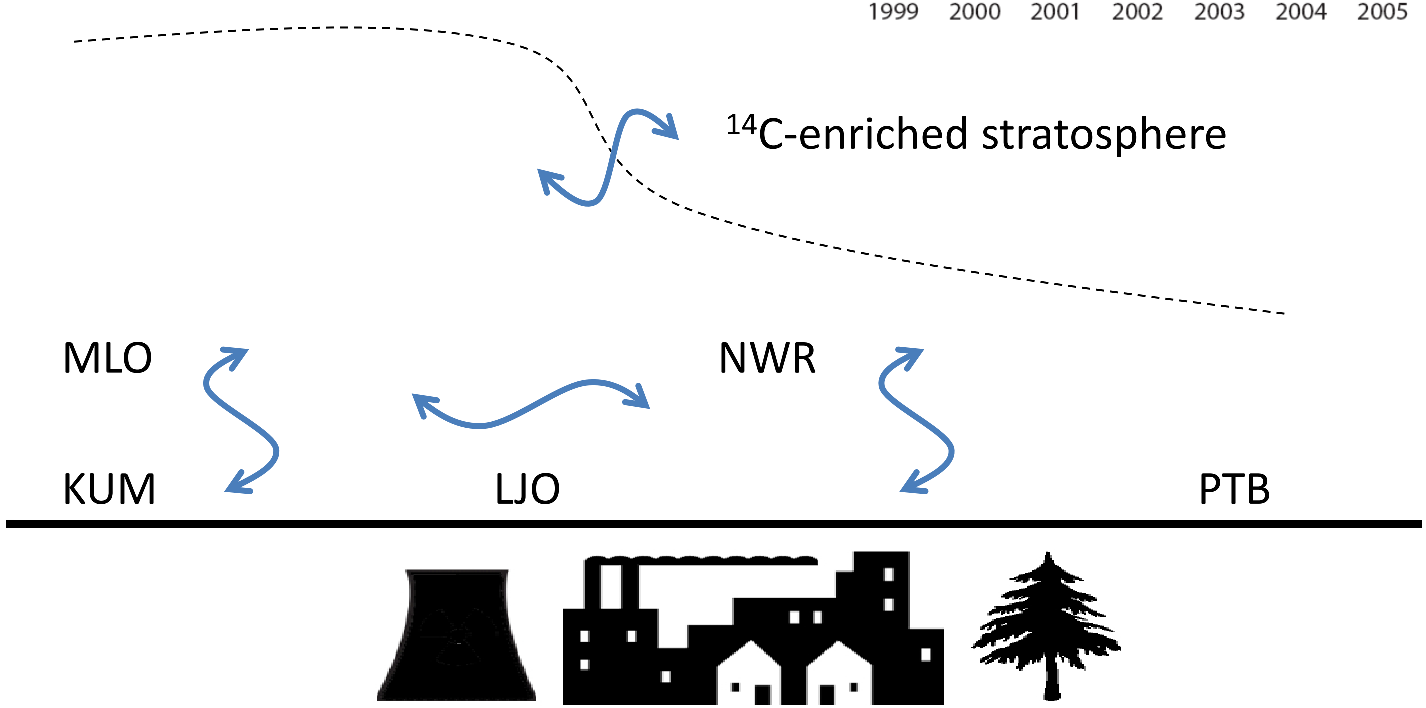
What's driving the patterns and variability? Can it be simulated with models?



Atmospheric transport, including:

- Vertical transport from the stratosphere
- Vertical transport from the boundary layer
- Meridional transport

Biospheric and nuclear sources



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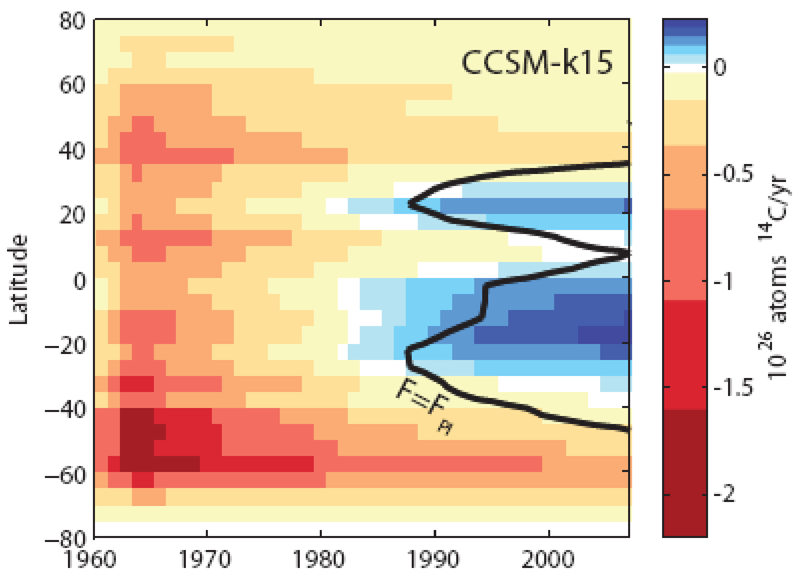
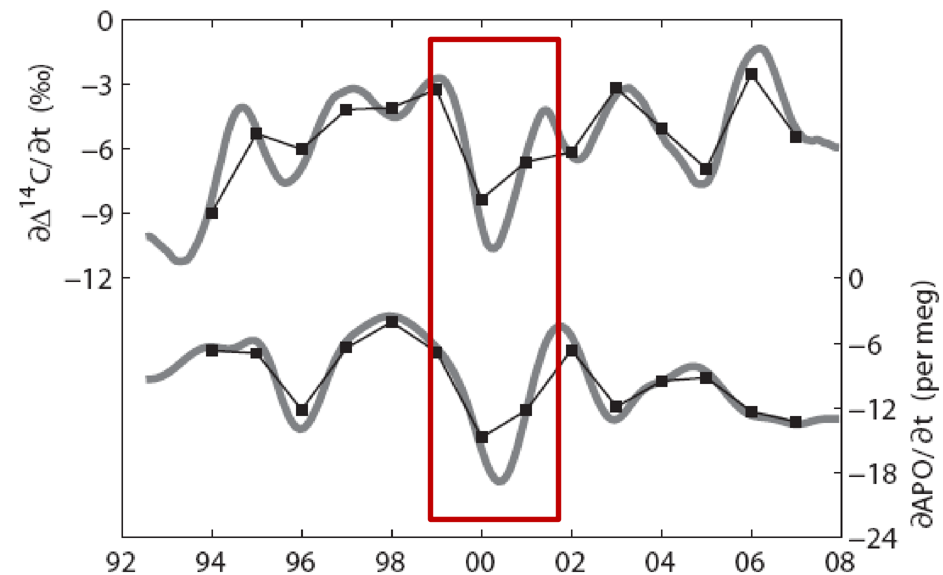
Air-sea fluxes, including:
Evolving oceanic ^{14}C exchange



Graven et al. in prep

Variable outgassing in the N. Pacific



Hamme and Keeling, 2008;
Graven et al. submitted

Variation in background $\Delta^{14}C$ can also provide a measure of global emissions, if non-fossil influences and inter-hemispheric transport are understood

Present uncertainty:	Trend $\partial\Delta^{14}C/\partial t$	North – South Gradient $\delta\Delta^{14}C$
Total non-fossil-CO_2	3.5 ‰/yr	3.0 ‰

This represents a potential precision of about ±25% in global fossil fuel emissions, but it could be improved

Levin et al. 2010

Development of Δ^{14}C-based δC_{ff} observations

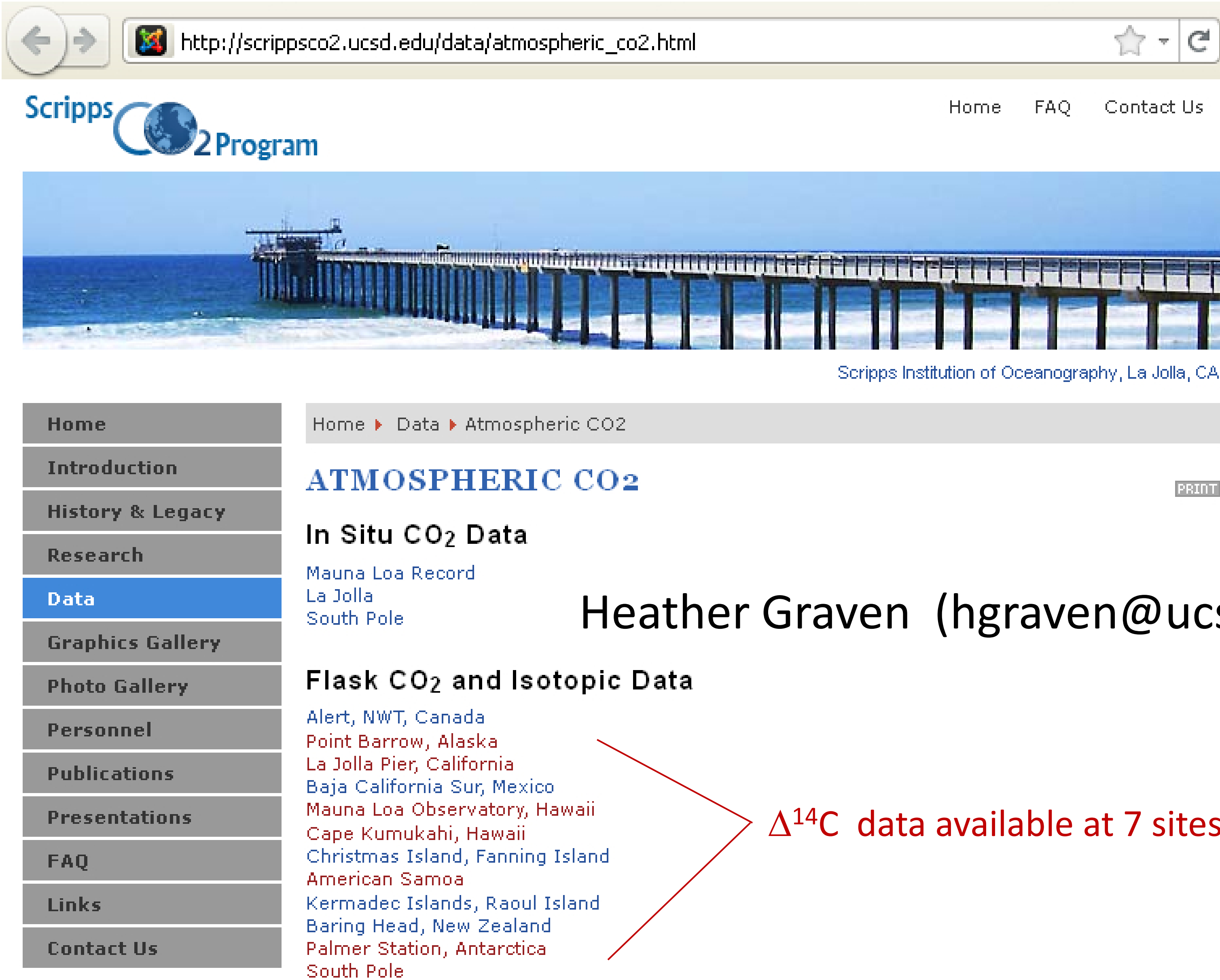
$$\delta C_{ff} \approx \frac{\Delta_{bg} - \Delta_{meas}}{2.7\text{‰ ppm}^{-1}} + \beta$$

Accomplishments

- Improvements in measurement precision
- Qualitative understanding of contributions to β

Challenges

- Indentifying appropriate Δ_{bg}
- Observing and understanding variability and trends in Δ_{bg} and β



Heather Graven (hgraven@ucsd.edu)

$\Delta^{14}C$ data available at 7 sites

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