Variability in leaf carbon isotopes and implications for paleoclimate

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We have projections, but . . .
We’ve been wrong before

Hungate et al. 2003, Science
and isn’t extrapolation dicey?
What about the past?
Changes in Greenhouse Gases from ice-Core and Modern Data

Time (before 2005)

Carbon Dioxide (ppm)

Radiative Forcing (W m$^{-2}$)

IPCC 2007
Let’s go farther back...
PETM

- > 5 °C warming
- < 10k years

Zachos et al. 2001,
Gingerich et al. 2006, *Trends in Ecology and Evolution*
Carbon isotope excursion (CIE)

- Recorded in organic matter, carbonates, forams

\[ \Delta \delta^{13}C \approx 3 - 6 \text{ permil} \]
How is the CIE useful?

Arens et al. 2000, Paleobiology

13C of OM preserved in rocks

\[ \delta^{13}C_p = 1.05 (\delta^{13}Ca) - 18.72 \]

\[ r^2 = 0.91 \]
Why is the CIE of the atmosphere important?
Not so fast . . .

Arens et al. 2000, *Paleobiology*
Plants are changing too . . .


<table>
<thead>
<tr>
<th></th>
<th>Conifer</th>
<th>Dicot</th>
<th>Monocot</th>
<th>Ginkgo</th>
<th>Pteridophyte</th>
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<tbody>
<tr>
<td></td>
<td>N</td>
<td>%</td>
<td>N</td>
<td>%</td>
<td>N</td>
</tr>
<tr>
<td>Earliest Eocene (post-PETM)</td>
<td>4794</td>
<td>0.75</td>
<td>1477</td>
<td>0.23</td>
<td>49</td>
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<tr>
<td>PETM</td>
<td>0</td>
<td>0.00</td>
<td>1985</td>
<td>0.99</td>
<td>8</td>
</tr>
<tr>
<td>Latest Paleocene</td>
<td>16506</td>
<td>0.76</td>
<td>5043</td>
<td>0.23</td>
<td>92</td>
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Finally, some leaf isotope data

Figure 2. $\delta^{13}C_{TDC}$ values from our dataset of modern deciduous angiosperms and evergreen conifers. The mean difference between the two groups is 3.1% and is statistically significant (t-test; p<0.01).

Diefendorf, Mueller unpublished

(58 species, 28 genera, 25 publications)
Leaf $^{13}$C as a functional trait?

- Leaf $^{13}$C = $C_i/C_a$ $\sim A/g_s$ (WUE)

- Relative to Gymnosperms, angiosperms have . . .
  - lower leaf longevity, thinner leaves, higher leaf nutrients (higher $A_{\text{max}}$), but . . . greater water use
  - lower WUE
What does this mean for the PETM?

Wing et al. 2005, Science
If plant community Δ accounts for 2 permil of the CIE . . .

the amount of CO2 needed to drive a 5 °C change is less

+ the climate sensitivity to CO2 is greater

Pagani et al. 2006, Science
So the past is messy too . . . let’s do both
Thanks

• GCEP
  – debt for Stable Isotopes course paid off?

• Co-authors at Penn State
  – Aaron Diefendorf
  – Clayton Magill
  – Katherine Freeman (co-advisor)