Data

Fig. 1: Data distribution. Water column (WC) measurements of $\delta^{13}C_{\text{DIC}}$ updated from Schmittner et al. (2013). Foramin data are from the compilation of fossil shells from Peterson et al. (2014; P14), Duplessy et al. (1984; D84), Mix (unpublished; M), and Cartapanis (unpublished; Car) as well as the polar compilations from mostly living forams by Mackensen (2012; M12) and Mackensen (2013; M13).

Fig. 2: Depth, $\text{CO}_3^2-$, anthropogenic $\delta^{13}C$, and temperature: $\text{CO}_3^2-$ and temperature data were used from the same samples as the water column measurements filled in with climatologies (GLODAP, WOA05).

Fig. 3: Sediment (left) and WC (right) data. Top: raw data. Bottom: corrected for anthropogenic effects.

Fig. 4: Left: difference between foram and WC data ($\sigma = 0.32 \, \%$). Right: standard deviation of WC data mapped on sediment core locations as an estimate of the WC data error ($\sigma_{\text{WC}} = 0.13 \, \%$).

Fig. 5: Linear regressions neglecting carbonate ion, temperature, and pressure effects.

Fig. 6: Errors of eq. (1). $\alpha = 0.29 \, \%$. Compare with Fig. 4C.

Fig. 7: Residuals ($\epsilon$) from the linear regression analyses as a function of the fitted values $\delta^{13}C_{\text{DIC}}$.

Research Questions

- How well does $\delta^{13}C$ measured in foraminiferal (cibicides) shells ($\delta^{13}C_{\text{cib}}$) represent water column $\delta^{13}C_{\text{DIC}}$?
- Are there carbonate ion and other complicating effects?
- What are the errors and uncertainties?

Methods

- Mapping of WC to sediment core locations using great circle horizontal distances $\Delta d = 1,000 \, \text{km}$ (default) and $\Delta d = 500 \, \text{km}$ and vertical distance $\Delta z = z/5$ (default) and $\Delta z = z/10$.
- Anthropogenic $\delta^{13}C$ (Suess Effect, SE) was removed from WC and living foram data using model results (SE=M; Schmittner et al., 2013).
- Multiple linear regression analysis $\delta^{13}C_{\text{DIC}} = a \delta^{13}C_{\text{cib}} + b \delta^{13}C_{\text{DIC}} + c T + d z$ considering carbonate ion ($\text{CO}_3^2-$) and temperature ($T$) effects and neglecting errors in $\delta^{13}C_{\text{DIC}}$.

Results

- Carbonate ion, temperature, and pressure effects are affecting $\delta^{13}C_{\text{cib}}$, consistent with experimental and theoretical studies, and should be accounted for according to the following equation:
  \[
  \delta^{13}C_{\text{DIC}} = -0.50 + 0.94 \delta^{13}C_{\text{cib}} + 3.1 \times 10^{-3} \cdot \text{CO}_3^2- + 1.2 \times 10^{-5} \cdot T + 5.8 \times 10^{-5} \cdot z
  \]
  (the depth dependence has been deduced by regressing the residuals to $z$ (errors decrease by $-10\%$, Figs. 4 & 7).
- Errors are $0.2-0.3 \, \%$, except in the South Atlantic where they are larger -- $0.4 \, \%$.

References:

- Duplessy, J.-C., L. Lisiecki, J. V. Stern (2014), Deglacial whole-ocean $\delta^{13}C$ change estimated from 480 benthic foraminiferal records, Paleoceanography, 29(6), 549-563.
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- Petzschmann, A., L. Lisiecki, J. V. Stern (2014), Deglacial whole-ocean $\delta^{13}C$ change estimated from 480 benthic foraminiferal records, Paleoceanography, 29(6), 549-563.
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