Global Calibration of Benthic Foraminiferal Carbon Isotope Ratios

Andreas Schmittner[1], Olivier Cartapanis[2], Lorraine Lisiecki[3], Andreas Mackensen[4], Alan Mix[1], Carlye Peterson[3]

[1]Oregon State University, [2]University of Bern, [3]University of California, Santa Barbara, [4]Alfred Wegener Institute

Data

Fig. 1: Data distribution. Water column (WC) measurements of $\delta^{13}C_{DIC}$ updated from Schmittner et al. (2013). Foram data are from the compilation of **fossil** shells from Peterson et al. (2014; P14), Duplessy et al. (1984; D84), Mix (unpublished), and Cartapanis (unpublished; Car) as well as the polar compilations from mostly **living** forams by Mackensen (2012; M12) and Mackensen (2013; M13).
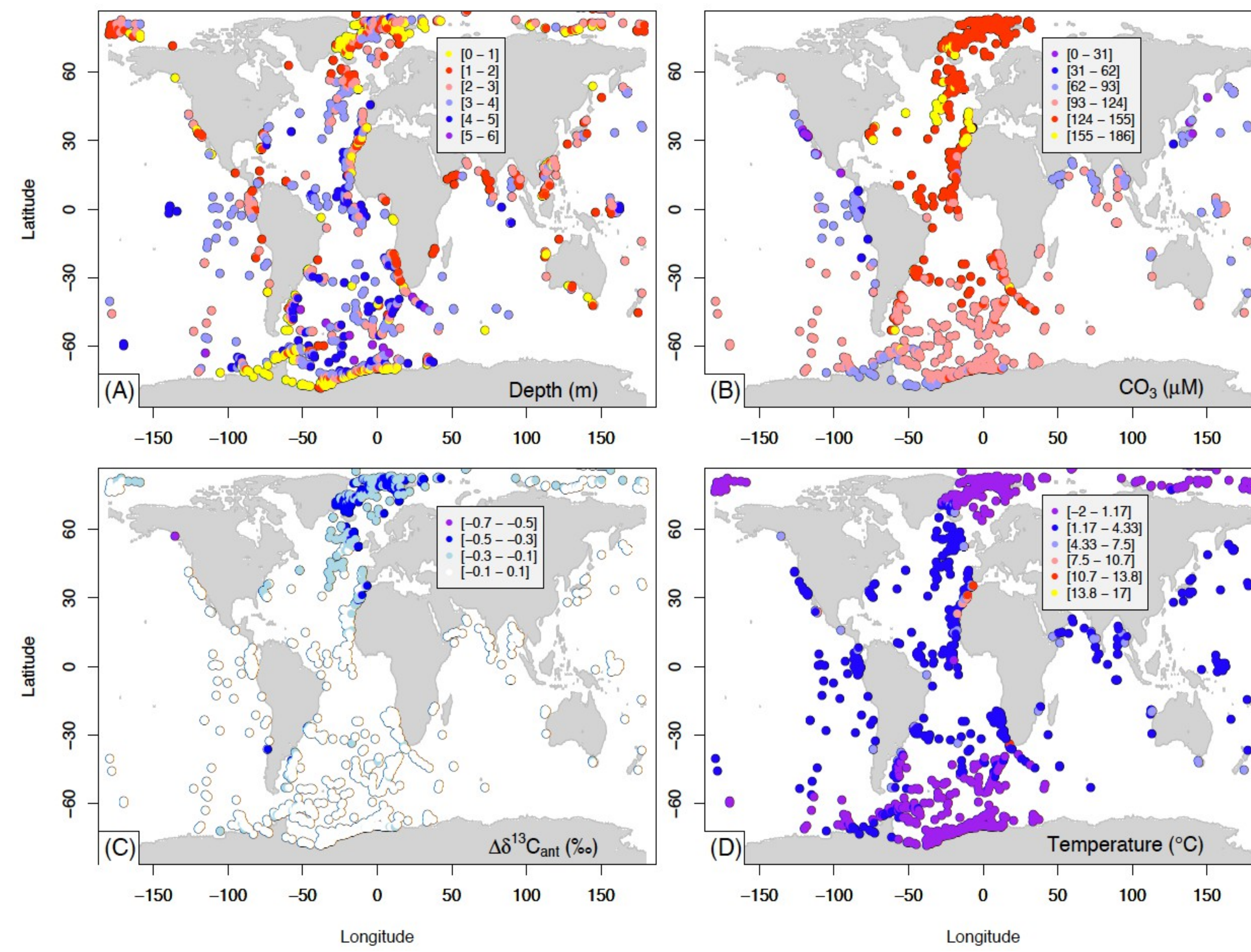
Fig. 2: Depth, CO_3, anthropogenic $\delta^{13}C$, and temperature. CO3 and temperature data were used from the same samples as the water column measurements filled in with climatologies (GLODAP, WOA05).

Research Questions

- How well does $\delta^{13}C$ measured in foram (cibicides) shells ($\delta^{13}C_{cib}$) represent water column $\delta^{13}C_{DIC}$?
- 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 Δd = 1,000 km (default) and Δd = 500 km and vertical distance $\Delta z = z/5$ (default) and $dz = z/10$.
- 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 $\delta^{13}C_{cib} = a + b\delta^{13}C_{DIC} + cCO_3^{2-} + dT + \varepsilon$ considering carbonate ion (CO_3^{2-}) and temperature (T) effects and neglecting errors in $\delta^{13}C_{DIC}$.
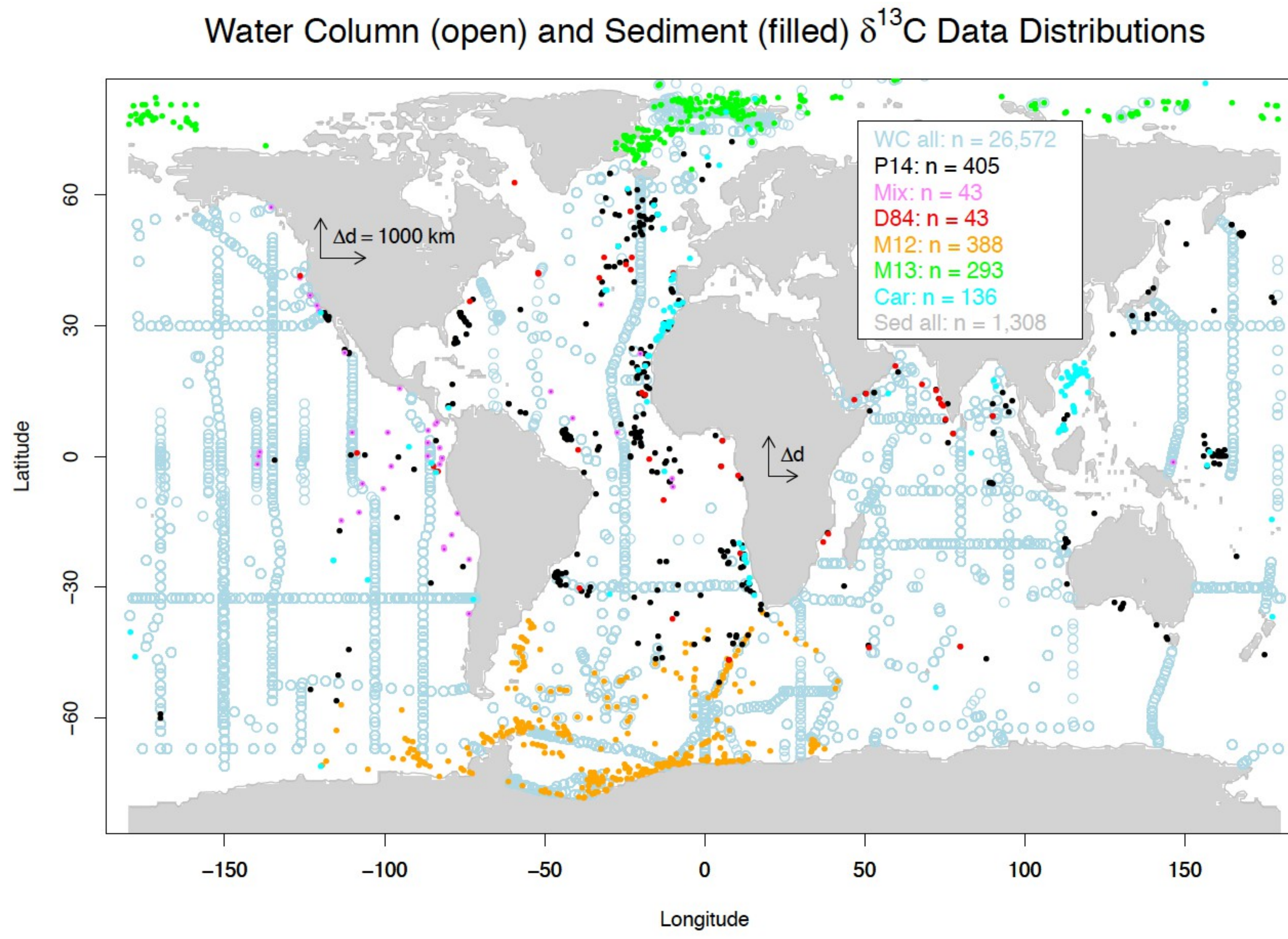

Fig. 3: Sediment (left) and WC (right) data. Top: raw data. Bottom: corrected for anthropogenic effects.

Results

- Carbonate ion, temperature, and pressure effects are affecting $\delta^{13}C_{cib}$, consistent with experimental and theoretical studies, and should be accounted for according to the following equation:

$$\delta^{13}C_{DIC} = -0.50 + 0.94 \cdot \delta^{13}C_{Cib} + 3.1 \times 10^{-3} \cdot CO_3 - 1.2 \times 10^{-3} \cdot T + 5.8 \times 10^{-5} \cdot z$$

(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 ‰
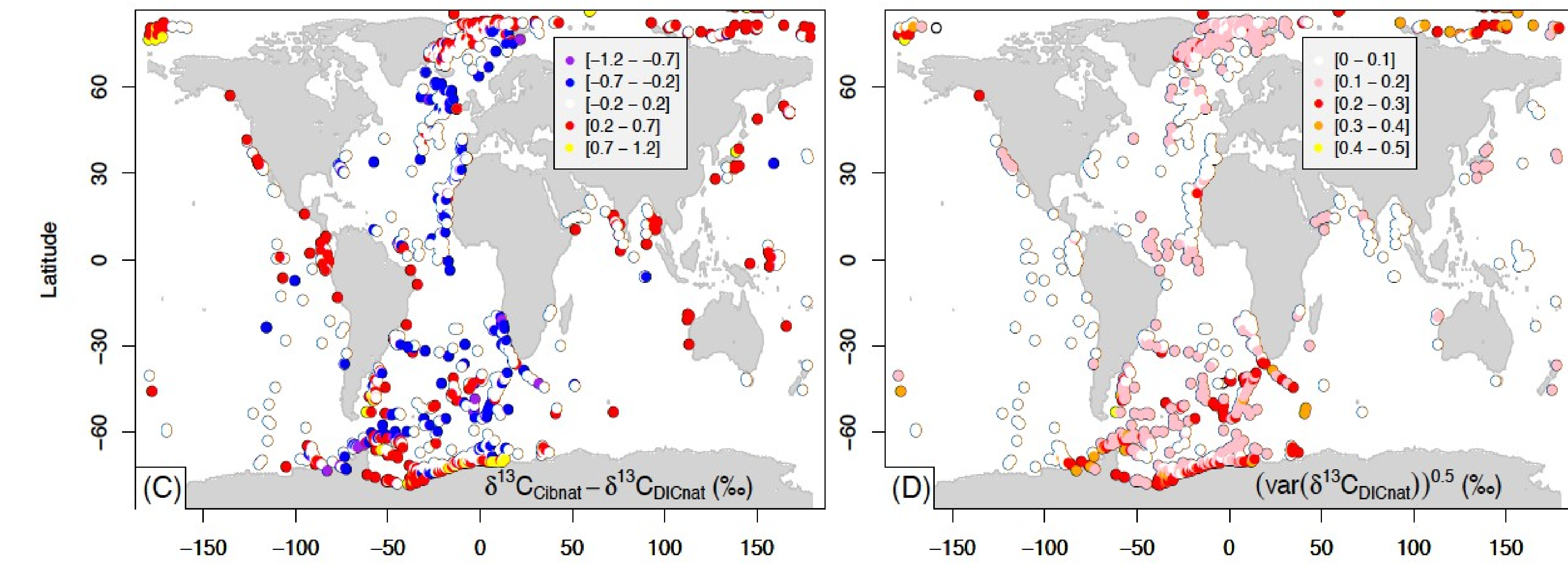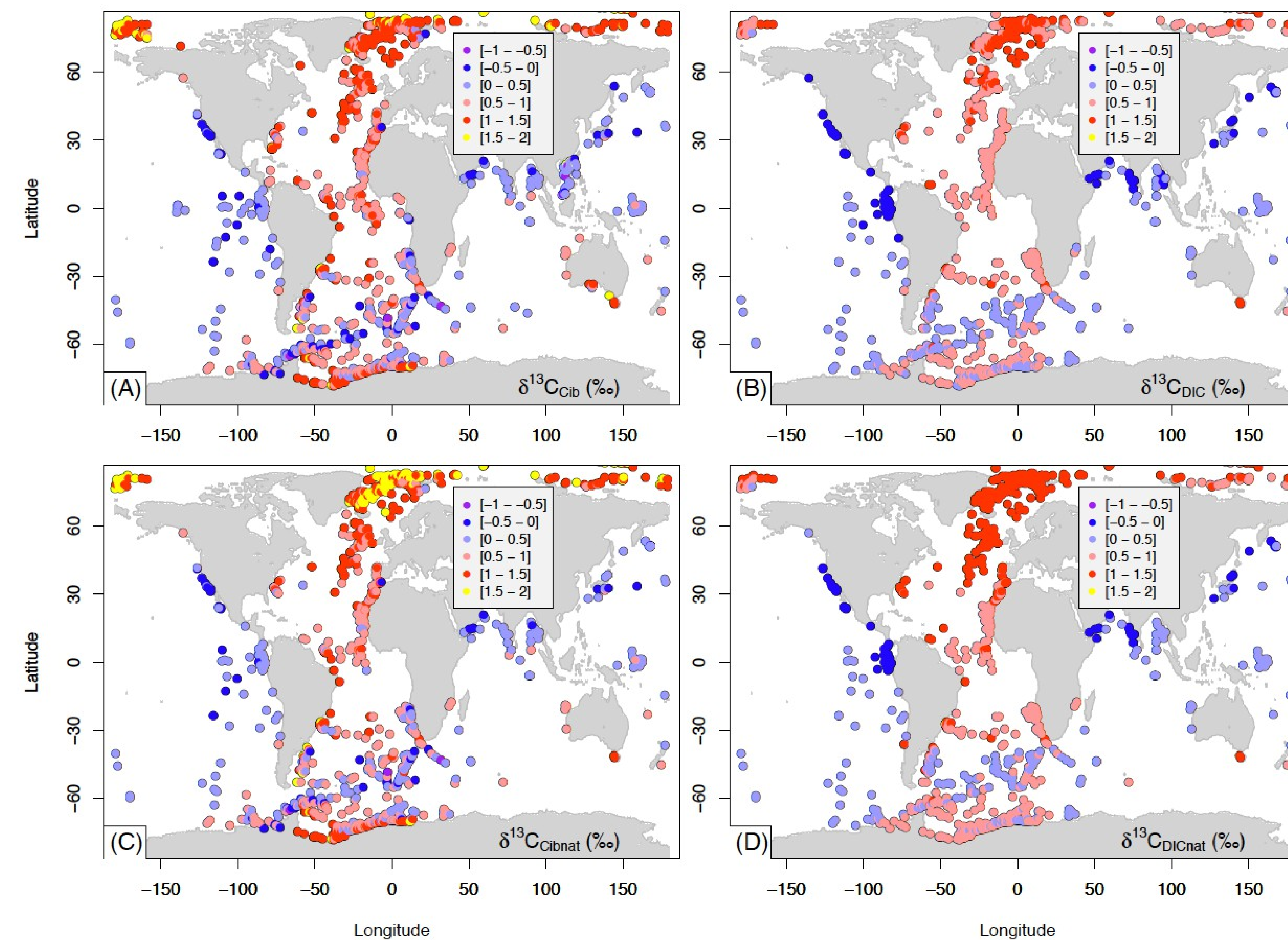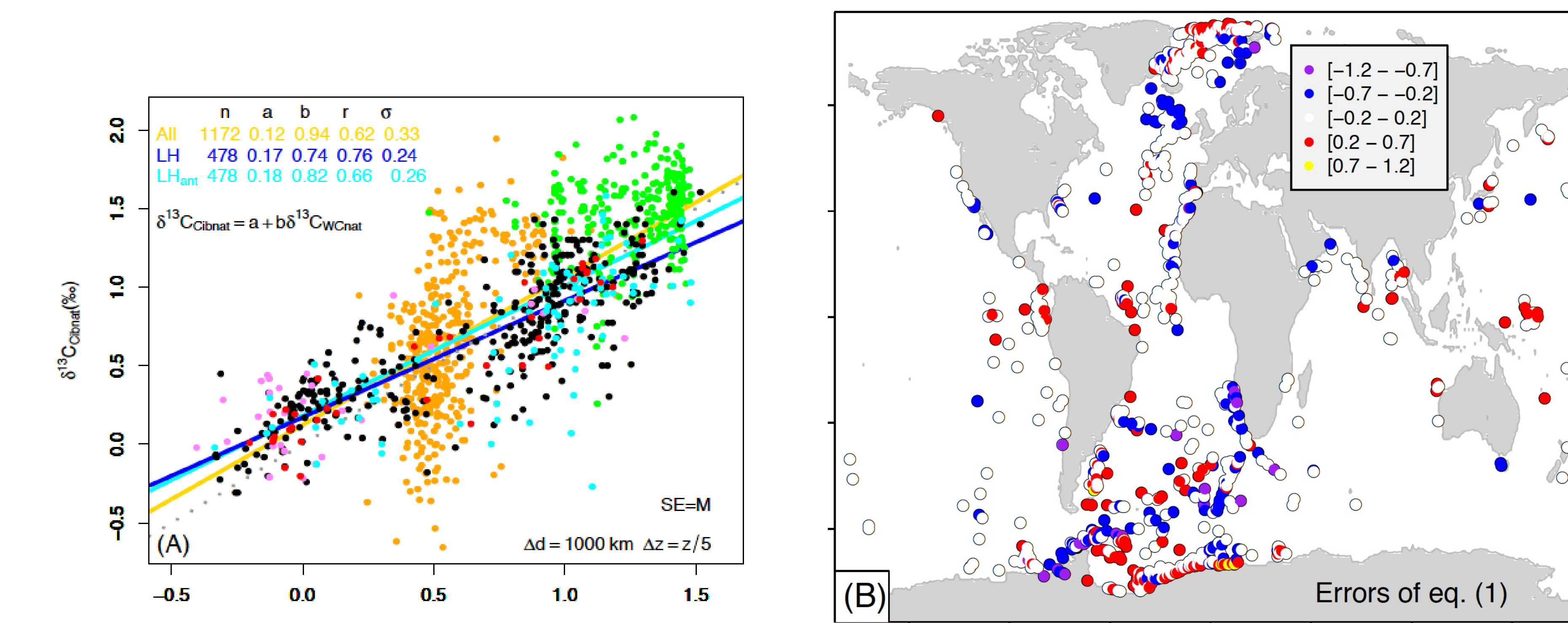

Fig. 4: Left: difference between foram and WC data (σ = 0.32 ‰). Right: standard deviation of WC data mapped on sediment core locations as an estimate of the WC data error (σ_{WC} = 0.13 ‰).

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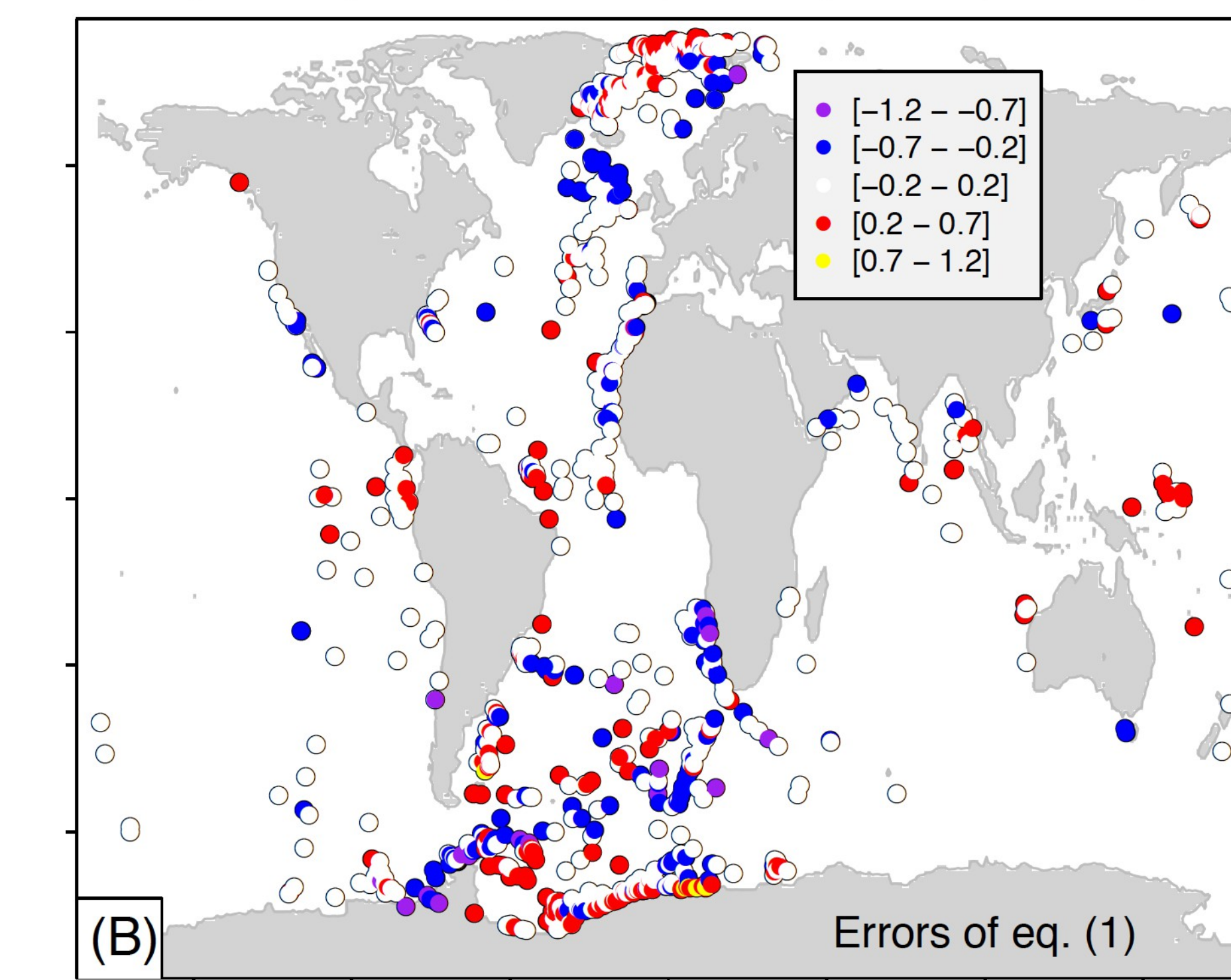

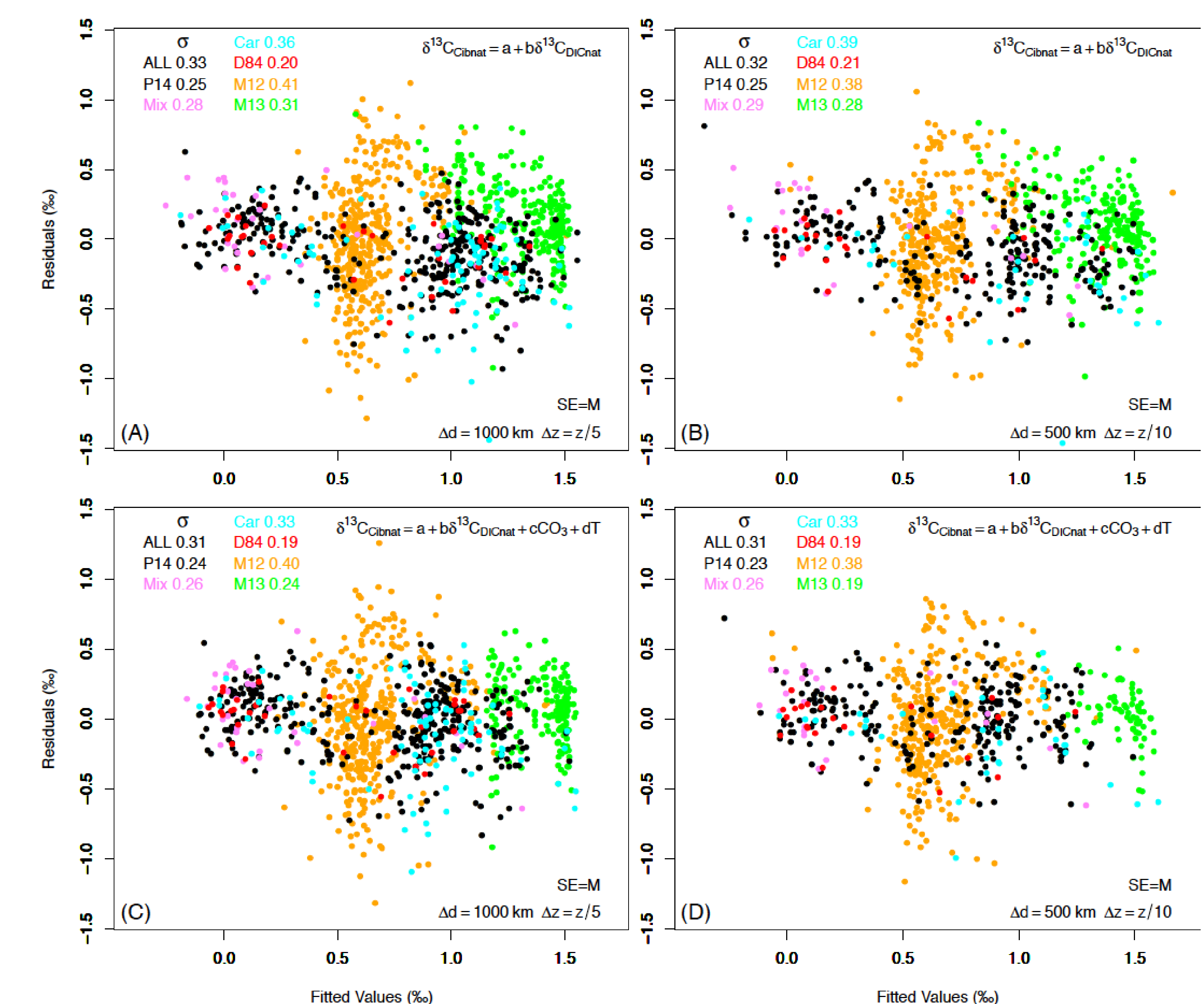**Fig. 6**: Errors of eq. (1). σ = 0.29 ‰. Compare with Fig. 4C.

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

References:

- Duplessy, J. C., N. J. Shackleton, R. K. Matthews, W. Prell, W. F. Ruddiman, M. Caralp, and C. H. Hendy (1984), C-13 Record of Benthic Foraminifera in the Last Interglacial Ocean - Implications for the Carbon-Cycle and the Global Deep-Water Circulation, Quaternary Res, 21(2), 225-243.
- Hesse, T., D. Wolf-Gladrow, G. Lohmann, J. Bijma, A. Mackensen, and R. E. Zeebe (2014), Modelling delta C-13 in benthic foraminifera: Insights from model sensitivity experiments, Marine Micropaleontology, 112, 50-61.
- Mackensen, A. (2012), Strong thermodynamic imprint on Recent bottom-water and epibenthic delta C-13 in the Weddell Sea revealed: Implications for glacial Southern Ocean ventilation, Earth Planet Sc Lett, 317, 20-26.
- Mackensen, A. (2013), High epibenthic foraminiferal delta C-13 in the Recent deep Arctic Ocean: Implications for ventilation and brine release during stadials, Paleoceanography, 28(3), 574-584.
- Peterson, C. D., L. E. Lisiecki, and J. V. Stern (2014), Deglacial whole-ocean delta C-13 change estimated from 480 benthic foraminiferal records, Paleoceanography, 29(6), 549-563.
- Schmittner, A., N. Gruber, A. C. Mix, R. M. Key, A. Tagliabue, and T. K. Westberry (2013), Biology and air-sea gas exchange controls on the distribution of carbon isotope ratios (δ13C) in the ocean, Biogeosciences, 10(9), 5793-5816.