# $\delta^{13}C$ record of black carbon in Daihai Lake sediments, northern China: An indicator of terrestrial environmental changes

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We measured the carbon isotope ratio of black carbon (BC) from the Daihai Lake sediment core (DH99a) in northern China to examine the effectiveness and sensitivity of the $\delta^{13}C$ values of BC ($\delta^{13}C_{BC}$) as a potential indicator of terrestrial environmental changes. We first performed a statistical study on the available data regarding carbon isotope fractionation (CIF) during the conversion of C3 and C4 vegetation to BC and observed that the mean CIF for BC produced from C3 plants is -0.3‰, whereas that for BC from C4 plants is -1.7‰. The $\delta^{13}C_{BC}$ record in the DH99a sediment core spanning the last ca 10,000 years displayed large variations from -23.7‰ to -29.2‰, which suggests that C3 plants dominantly occupied the Daihai Lake region during the Holocene. The most negative $\delta^{13}C_{BC}$ peaks coincided with high values of tree percentages and grain sizes, which occurred under relatively wetter climatic conditions during the middle Holocene (ca 6500-3200 cal. yr BP) and an interval between 1700 and 1350 cal. yr BP. In contrast, the least negative $\delta^{13}C_{BC}$ values corresponded to low values of tree percentages and grain sizes during relatively drier phases of the early and late Holocene. The generally negative correlation of the $\delta^{13}C_{BC}$ values with the tree percentages and grain sizes was thought to reflect a negative correlation of the $\delta^{13}C_{BC}$ values with the monsoon precipitation. We then developed a computational model to reconstruct the changes in annual precipitation over the Daihai Lake region. The inferred annual precipitation was highly variable, ranging from 170 mm lower to 310 mm higher than present during the middle Holocene, whereas the annual precipitation was generally ~70 mm lower than that at present during the early and late Holocene. The general features of the inferred precipitation changes are generally consistent with those reconstructed using pollen data of the same sediment core. Meanwhile, the $\delta^{13}C_{BC}$ values tend to register some extreme variations of monsoon precipitation, which were not reflected in the pollen assemblages. We conclude that the $\delta^{13}C_{BC}$ values in the Daihai Lake sediments may serve as a sensitive and reliable proxy for monitoring monsoon precipitation.

# Dissolved iron and the co-limitation of phytoplankton growth in the Beaufort Sea, Arctic Ocean

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Here we report six vertical profiles of dissolved Fe concentrations [DFe] and results of a shipboard grow-out experiment to investigate the potential for nitrate ($NO_3^-$), light, and Fe co-limitation of phytoplankton in the Beaufort Sea in late summer. A range of [DFe] from 0.11 to 2.04 nM is observed, with the maximum values occurring in subsurface waters near continental shelf sediments. Clear surface maxima in [DFe] exist at stations with freshwater input from melting sea ice.

Nitrate additions to incubation bottles enhanced phytoplankton growth, demonstrating that the late summer community was N limited. In the treatments with additions of NO3- but not Fe, biomass doubled with increasing light, indicating light limitation. In $NO_3^-$ enriched treatments, co-limitation of primary production by Fe and light was observed at light levels ≤ 10 % surface irradiance, which corresponded to depths ≥ 33 m. These results suggest that, in addition to $NO_3^-$ and light, Fe may control primary productivity in the Beaufort Sea, and seasonal changes in light, $NO_3^-$, and Fe availability may differentially control Arctic phytoplankton growth.

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