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Stable isotopes from Benthic foraminifera and Fish otoliths as proxies for Orbital Climate Forcing and Seasonality Changes during the Middle Eocene to Late Oligocene in the shallow marine North Sea Basin

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The global composite oxygen isotope curve from the Middle Eocene to Late Oligocene, as reflected in the deep ocean (e.g. Zachos et al., 2001) and terrestrial records (e.g. Zanazzi et al., 2007) shows a general long-term cooling trend, modulated by short-term controlling mechanisms, and punctuated by extreme climate excursions. The present isotope study investigates these three different aspects of Eocene and Oligocene climate recorded in the shallower waters of the North Sea Basin. The overall trend from Eocene greenhouse to Oligocene icehouse conditions is elucidated using stable carbon and oxygen isotopes of carbonate from three different fossil taxa: benthic foraminifera, fishes (from otoliths) and nuculid bivalves. Temperatures gradually evolve from very warm in the middle Eocene (∼23˚C; using $\delta^{18}O_{sw}$ after Lear et al., 2004: -1‰ for Eocene and -0.3‰ for Oligocene) to much colder in the Oligocene (∼12˚C), with a rapid step-wise transition across the Eocene-Oligocene boundary that at least in part reflects ice growth. Climate deterioration is accelerated from the Priabonian on, and shows a two-step decrease in mean annual bottom water temperatures before and after the first Oligocene sequence, similar to what has been recorded in deep water studies (e.g. Lear et al., 2008).

Superimposed on this sudden drop in mean annual temperature, a shift in seasonality occurs at the same level. Mean annual range in temperature, resolved from microsampling growth rings of accretionary carbonates in fish otoliths and nuculid bivalve shells, shows a drop in seasonality from >8˚C during the Eocene and earliest Oligocene to <4˚C in the remainder part of the Oligocene. The discrepancy between this observed decrease in seasonality in the North Sea Basin and slight increase in North America (Ivany et al., 2001; Zanazzi et al., 2006) could be due to sample bias in using different taxa across the boundary, or could possibly be attributed to the constitution of the Proto-Gulf Stream at that time.

It has become generally appreciated that orbital forcing of temperature and ice volume variations leave a strong cyclic imprint on $\delta^{18}O$ data from continuous carbonate-rich records in deep sea settings (e.g. Wade and Pälike, 2004). The rhythmic clay/silt alternation in the Boom Formation has been interpreted as an expression of obliquity-dominated glacio-eustatic sea level change in the Early Oligocene (Abels et al., 2006). In order to detect the interplay of orbital parameters in the $\delta^{18}O$ signature, a benthic foraminiferal stable isotope record was generated at 7.3 kyr resolution between 30.2–32.1 Ma. These data allow a detailed examination of the Oligocene paleoceanography in a mid-latitudinal shallow marine setting and serve as a tool in analyzing the interplay between obliquity and eccentricity forcing. Alternating glacial and interglacial cycles are evidenced by distinct positive peaks in the $\delta^{18}O$ curve. The most prominent glacial episodes, positioned at in-phase 100 kyr and 400 kyr eccentricity maxima, occurred around 31.7, 31.5 and 30.55 Ma, and less obvious excursions are registered at out-of- phase 100 kyr and 400 kyr eccentricity maxima, e.g. around 30.8 Ma.