1. Research activity (max 1.000 words)

Biota producing carbonate sediments (e.g. corals, coralline algae, green algae) and ecosystems of the oceans (e.g. reefs, seagrasses) have the highest biodiversity and yet are some of the most threatened ecosystems on Earth, mostly due to warming produced by release of greenhouse gases in the atmosphere. The greenhouse effect produces a dramatic increase of surface waters and associated changes in pH. Direct measures of the response of seagrasses and reefs to modern environmental changes reveal how global warming impacts these systems. Seagrasses and reefs are also two key depositional environments of Cenozoic carbonate platforms. Gaining a better understanding of these ecosystems response at geological timescale would be valuable fundamental information to understand the near future evolution of Earth and of the oceans.

The Middle Eocene Climatic Optimum (MECO), recorded at ~40 Ma, was one of the most intense short-term global climate perturbations of the Cenozoic, with a 4-6 °C global temperature increase lasting between 400 and 500 kyr. The warming event is recognized by a distinct negative shift in $\delta^{18}O$ values of deep-sea cores of the Southern Ocean (Bohaty and Zachos, 2003), subsequently identified also in the Atlantic Ocean (Bohaty et al., 2009). This enigmatic event represents an abrupt reversal in the long-term Eocene cooling which eventually brought to the development of the icehouse climate, characterized by the polar glaciation, by the early Oligocene (Zachos et al., 2008). The MECO is called "enigmatic" since it does not show the same signal in the isotopic record compared to the other Eocene climatic aberrations. In fact, unlike the Paleocene-Eocene Thermal Maximum (PETM), a large negative $\delta^{13}C$ excursion is not associated with the MECO event. During the MECO instead, the $\delta^{13}C$ values increase and remain relatively stable, except for a brief negative excursion (~0.5‰) during the final stages of warming (fig. 1). In contrast, the major warming during the PETM (~55 Ma) is characterized by a high-amplitude, negative $\delta^{13}C$ excursion, which is hypothesized to have resulted from methane hydrate dissociation and the massive input of ^{12}C-enriched carbon to the ocean-atmosphere system (Dickens et al., 1995). The lack of a negative $\delta^{13}C$ excursion at the onset of the MECO suggests that an increase in pCO_2 from the oxidation of large volumes of clathrate-sourced methane (with a $\delta^{13}C$ value of ~-60‰) was not responsible for initial greenhouse warming (Bohaty and Zachos, 2003).
In addition, the temporal pattern of warming during the MECO suggests that this event was different from the preceding transient hyperthermal events in the late Paleocene and early Eocene. Specifically, in contrast to the PETM event (Kennett and Stott, 1991), the MECO began with gradual warming and terminated with abrupt cooling. The MECO is also roughly 2–4 x longer in duration (~500 ka) than the PETM (~150–170 ka from Abdul Aziz et al., 2008). These differences in both the duration and pattern of warming further suggest that the underlying causal mechanisms were vastly different for these two events. As such, it is clear that the MECO represents a unique event in the Cenozoic climate history.
The carbonate MAR (Mass Accumulation Rates) records compiled for various sites of the Atlantic and Pacific Ocean (fig. 1) provide a history of local and global CCD variation during the late middle Eocene.

The key observation from the combined records is evidence for a brief global CCD shoaling that is precisely synchronous with the peak of the MECO warming. Dissolution is the most likely explanation (Lyle et al., 2008) for the reduction in carbonate accumulation. These observations suggest that the low-carbonate intervals in these sections result primarily from a change in the carbonate chemistry of deep waters to more acidic conditions.

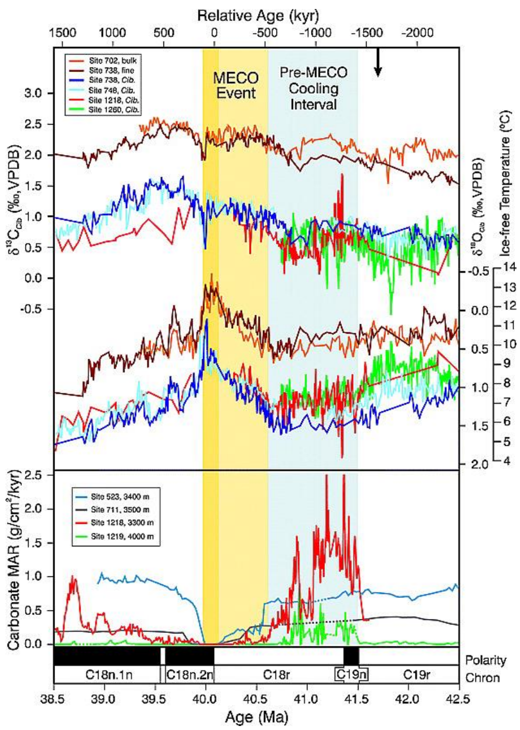

Figure 1. Late Eocene compilation of benthic foraminiferal stable isotope data and carbonate mass accumulation rate (MAR) records. The absolute temperature scale is calculated using the temperature equation of Shackleton (1974). The area shaded in yellow highlights the entire interval of warming during the MECO and the dark yellow area denotes the peak. From Bohaty et al. 2009.

The cause of this ocean acidification is ascribed to increasing pCO_2 levels, but the dynamics of this rise are still not clear.

While deep sea successions are commonly utilized to study this type of events (Zachos et al. 2001), the shallow-water ones are also valid sources of information (Jaramillo-Vogel et al. 2012); in fact climatic perturbations have great registration potential in carbonate platform successions since they strongly influence carbonate production and biota-producing sediment, which are very sensitive to many environmental factors such as temperature and atmospheric CO_2 concentration changes. In fact, events such as early Eocene hyperthermals and MECO led to the reorganization of the carbonate factories and consequently of the facies associations, which in turn might have controlled changes in depositional geometries.