Stomata and isotopes demonstrate carbon cycle linkage 94 Mya

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We present a paleobotanical record that establishes that clearly links the atmospheric and marine carbon cycles via the atmosphere during a second order mass extinction event in the Late Cretaceous. Marine extinction prior to the Cenomanian-Turonian boundary (CTB-94Ma) occurred due to marine anoxia, but despite decades of research the causal mechanism remains elusive. This oceanic anoxic event (OAEII) represents a major perturbation to the ocean-atmosphere-terrestrial system that lasted 900ka, recognized globally by a +2-4‰ $\delta^{13}C$ excursion. Submarine volcanism has recently been the favoured causal mechanism, but increased marine nutrient levels and elevated marine primary productivity remain as potential key driving mechanisms. All three mechanisms may be inter-related, such that volcanism would lead to increased nutrient supply from land, elevating primary productivity to produce marine anoxia. To test this model, we applied the stomatal index method to mesofossil leaf cuticles in the Lauraceae, collected from the Dakota Fm. in SW Utah to produce a high resolution record of pCO_2 surrounding OAEII. A $\delta^{13}C_{org}$ record, derived from the plant bearing sediments, records both the initial +2‰ and ultimate +4‰ $\delta^{13}C$ shift, allowing precise global correlation. Stomatal frequencies decrease at both these isotopic shifts, suggesting that terrestrial plants were sensitive to large shifts in pCO_2, even during hothouse conditions. This is the first study with enough resolution to substantiate the hypothesis that atmospheric CO_2 decreases precisely at the onset of OAEII as a result of increased organic carbon burial. The high degree of correlation between the stomatal record and $\delta^{13}C_{org}$ record during OAEII demonstrates for the first time that in the mid-Cretaceous the terrestrial and marine carbon reservoirs are tightly linked during OAEs. Prior to the onset of OAEII, $\delta^{13}C_{org}$ values are steady while pCO_2 increases leading up to the isotope excursion. This suggests that volcanism occurred prior to OAEII and may have been the initial trigger, but since it did not alter the isotopic composition of the atmospheric carbon reservoir it was merely a change in the rate of production and not a change of source. The driver producing widespread marine anoxia is most likely an enhanced biological pump that occurred when the marine-atmosphere system reached a tipping point.

The role of the Subtropical Front in long-term modulation of the glacial mode of the climate system

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Part of the puzzle to understand the forcing and feedback of the climate system by orbital parameters and atmospheric carbon dioxide may be found in long marine cores, which comprise multiple glacial cycles. We use an 800 kyr geochemical record based on stable isotopes, organic biomarkers and redox-sensitive trace elements in order to track the position of the Subtropical Front (STF) in the Indian Ocean. Our record shows that the STF migrates northwards during glacial periods but the extent of its northward migration has a secular trend reaching a most northerly position during marine isotope stage (MIS) 12 and 10. Such secular trends may be driven by unidentified long-term trends in the carbon cycle or exceptional insolation conditions. The STF migrations have modulated meridional overturning in the Atlantic, extremely so when the STF reaches its most northerly reconstructed position to impinge on South Africa. At this position, the Agulhas leakage 'warm' pathway for the return of salt and heat to the Atlantic is shut down. Further, the most northerly westerlies may be partly decoupled from the topographically constrained ACC to the south yielding a minimum in transfer of wind energy to the ACC, one of the major drivers of overturning. The latitude of the STF therefore acts as an amplifier of equatorial SST anomalies and communicates anomalies to high latitudes, ice volume and global climate via the Agulhas leakage and strength of meridional overturning.