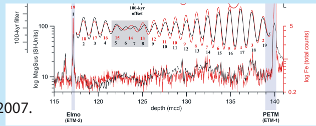
Is there an orbital control on Eocene hyperthermals?

D.J. Lunt (1,2), P.J. Valdes (1), A. Ridgwell (1)
(1) BRIDGE (Bristol Research Initiative for the Dynamic Global Environment, University of Bristol, UK
(2) British Antarctic Survey, UK

d.j.lunt@bristol.ac.uk
www.bridge.bris.ac.uk
XY0265

(1) INTRODUCTION

Hyperthermal climate events are geologically brief (~10-100kyrs) transient periods of marked global warming associated with prominent negative carbon isotope excursions and deep-sea carbonate dissolution. They are most likely the result of massive injections of isotopically light carbon into the ocean-atmosphere system. One plausible source of isotopically light carbon is a widespread dissociation of continental slope, sediment-hosted methane gas hydrates. Proposed triggers for the dissociation of such deep-water hydrates include a pronounced (~4ºC) warming of intermediate to deep waters driven by changes in global overturning circulation (Dickens et al., 1995).
The most prominent hyperthermal event of the Ceonzoic is the Paleocene Eocene thermal maximum (~55Ma; PETM). However, there is increasing evidence that multiple hyperthermals of occurred in the Early Paleogene, for example the 'ELMO' event. Furthermore, that these events are orbitally paced, corresponding to minima in eccentricity forcing:



Westerhold et al, 2007.

(2) EXPERIMENTAL DESIGN

We carry out a suite of fully-coupled atmosphere-ocean simulations, using the UK Met Office GCM, HadCM3L. We run under Early Eocene (~55Ma) boundary conditions, and with a variety of CO_2 and orbital configurations.
The Eocene boundary conditions are shown below, with the modern for comparison:

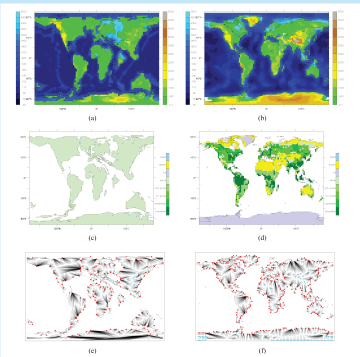


Figure 1: (a,b) Topography and bathymetry [m] in (a) the Eocene and (b) the modern. (c,d) Prescribed vegetation, lakes and ice sheets in (c) the Eocene and (d) the modern. (e,f) River routing in (e) the Eocene and (f) the modern.

(3) BASIC RESULTS - CO2 sensitivity

We initially carry out a set of Eocene simulations under different CO2 levels (*1 preindustrial, 2*, 4* and 6*). All the simulations are over 3000 years long, and are approaching equilibrium (see below).

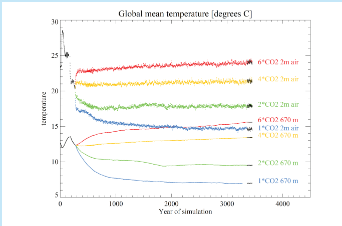
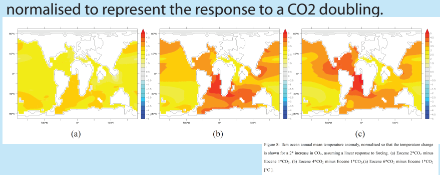
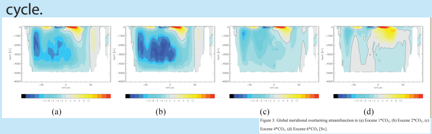


Figure 2: S1: Timeseries of 2m air temperature and 670m ocean temperature evolution [°C].

At the surface, the temperature increase with log(CO2) is fairly linear (as expected from simple radiative transfer theory). However, in the subsurface and intermediate ocean, the increase in temperature is much more non-linear. The plots below show the temperature increase at a depth of 1km, as a function of CO2, normalised to represent the response to a CO2 doubling.



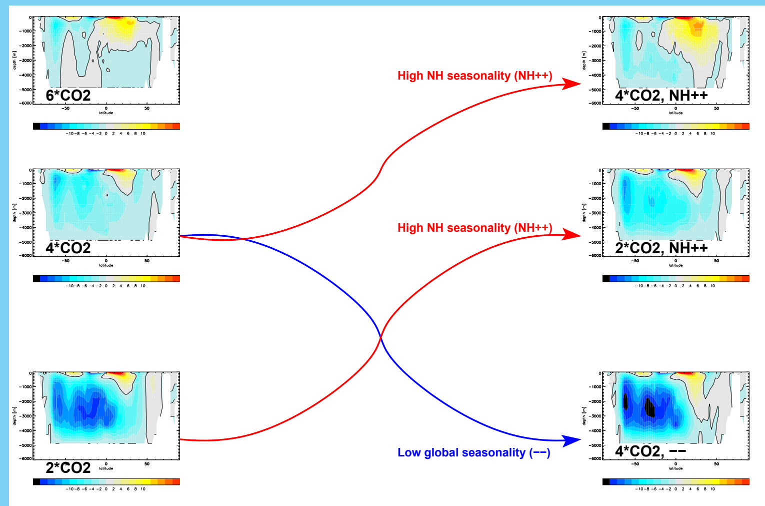
The cause of this non-linearity in ocean warming, is evidenced from the global ocean streamfunction, which clearly shows that at high CO2, the ocean circulation collapses, resulting in a more sluggish overturning, caused by a decrease in deep water formation and further impeded by the intensified hydrological cycle.



The occurrence of a strong warming anomaly in the Atlantic thermocline to upper intermediate waters solely in response to a gradual of increasing atmospheric pCO2, supports the possibility of a strong positive feedback mechanism via widespread thermal destabilization of methane gas hydrates and greenhouse gas release and hence further warming. By providing a potential causative connection between the background warming (presumably due to rising pCO2) of the late Paleocene and Early Eocene (Zachos et al., 2008) and PETM hydrate destabilization (Dickens et al., 1995), this circulation switch could serve as a triggering mechanism.

(5) SENSITIVTY TO ORBITAL FORCING

We then carry out a set of orbital sensitivity studies. From the end of the 2* and 4* CO2 simulations (either side of the circulation switch), we spin off simulations with 3 orbital configurations: (1) High eccentricity, high obliquity, maximum Northern Hemisphere seasonality (NH++), (2) High eccentricity, high obliquity, maximum Southern Hemisphere seasonality (SH++), and (3) Low eccentricity, low obliquity. (--) The results, in terms of ocean circulation switches, are shown in the figures below of the global ocean overturning streamfunction:



Clearly, the extreme orbits are able to switch the mode of ocean circulation, in the same way as elevated CO2. In particular, the NH++ orbit in a way mimics the increase in CO2. Conversely, the -- orbit acts in the same way as a decrease in CO2.

(6) CONCLUSIONS

We show modelling results which support the hypothesis that Eocene hyperthermals could be paced by orbital variations. The mechanism for this forcing is orbitally induced switches in ocean circulation, which lead to non-linear intermediate ocean warming, with the possibility of resulting destabilization of methane gas hydrates. The switches in circulation are associated with high eccentricity and obliquity and maximum seasonality in the Northern Hemisphere.