Was the North Atlantic Ocean well-ventilated during Oceanic Anoxic Event 2 in the mid-Cretaceous?

Utrecht University

I. Ruvalcaba-Baroni[1], N. A. G. M. Van Helmond[1], R. P. M. Topper[1], H. Brinkhuis[1,2], and C. P. Slomp[1]
I.RuvalcabaBaroni@uu.nl
[1]Utrecht University, Faculty of Geosciences, The Netherlands
[2]Royal Netherlands Institute for Sea Research (NIOZ), Den Burg, Texel, The Netherlands

1. Introduction

The geological record provides evidence for the periodic occurrence of water column anoxia and the formation of organic-rich deposits in the North Atlantic Ocean during the mid-Cretaceous. Changes in primary productivity and oceanic circulation likely played a role in the development of such low oxygen conditions. Several studies suggest that ocean circulation during the Cretaceous was as vigorous as today and the supply of nutrients from land was enhanced. Here, we analyse under what conditions widespread anoxia develops assuming a vigorous circulation in the North Atlantic ocean as proposed for Oceanic Anoxic Event 2 (OAE2) [1].

2. Model

We built a detailed box model (Fig. 1) of the coupled water, oxygen, carbon and phosphorus (P) cycles, which differentiates between the open ocean and the coastal ocean. The water cycle is adapted from a regional ocean circulation model [1]. The biogeochemical modeling approach is similar to that used in other box model studies [2].

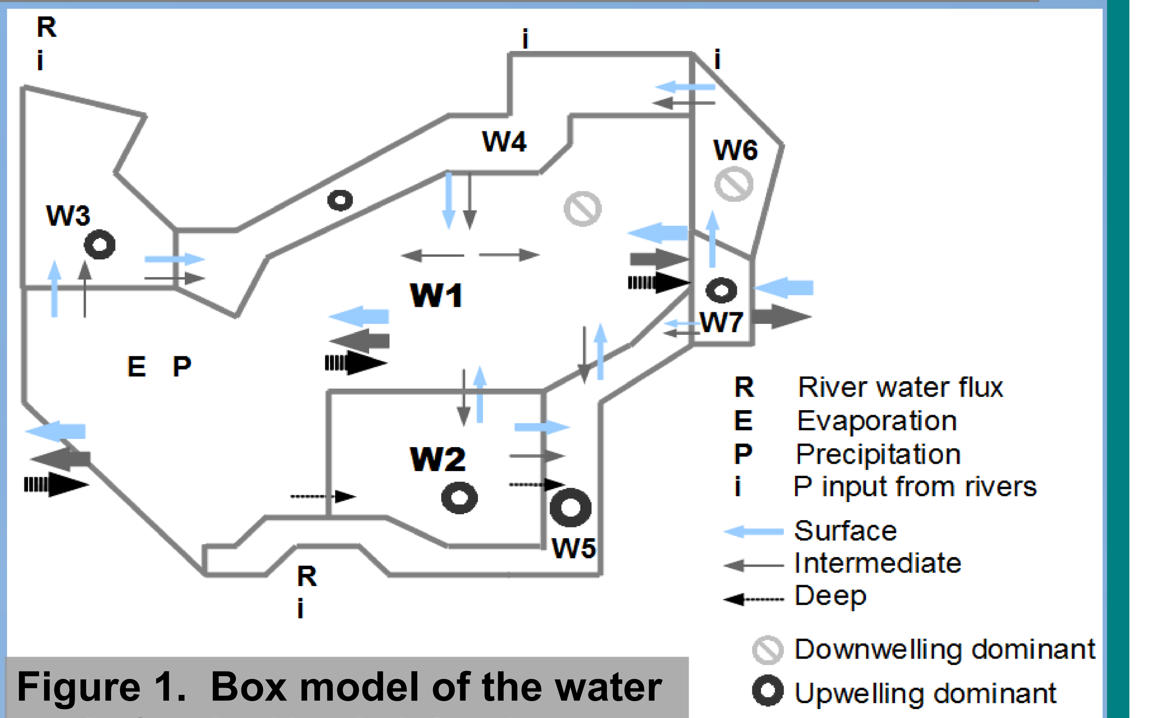


Figure 1. Box model of the water cycle for the North Atlantic during the mid-Cretaceous, with fluxes and reservoirs

3. North Atlantic during OAE2

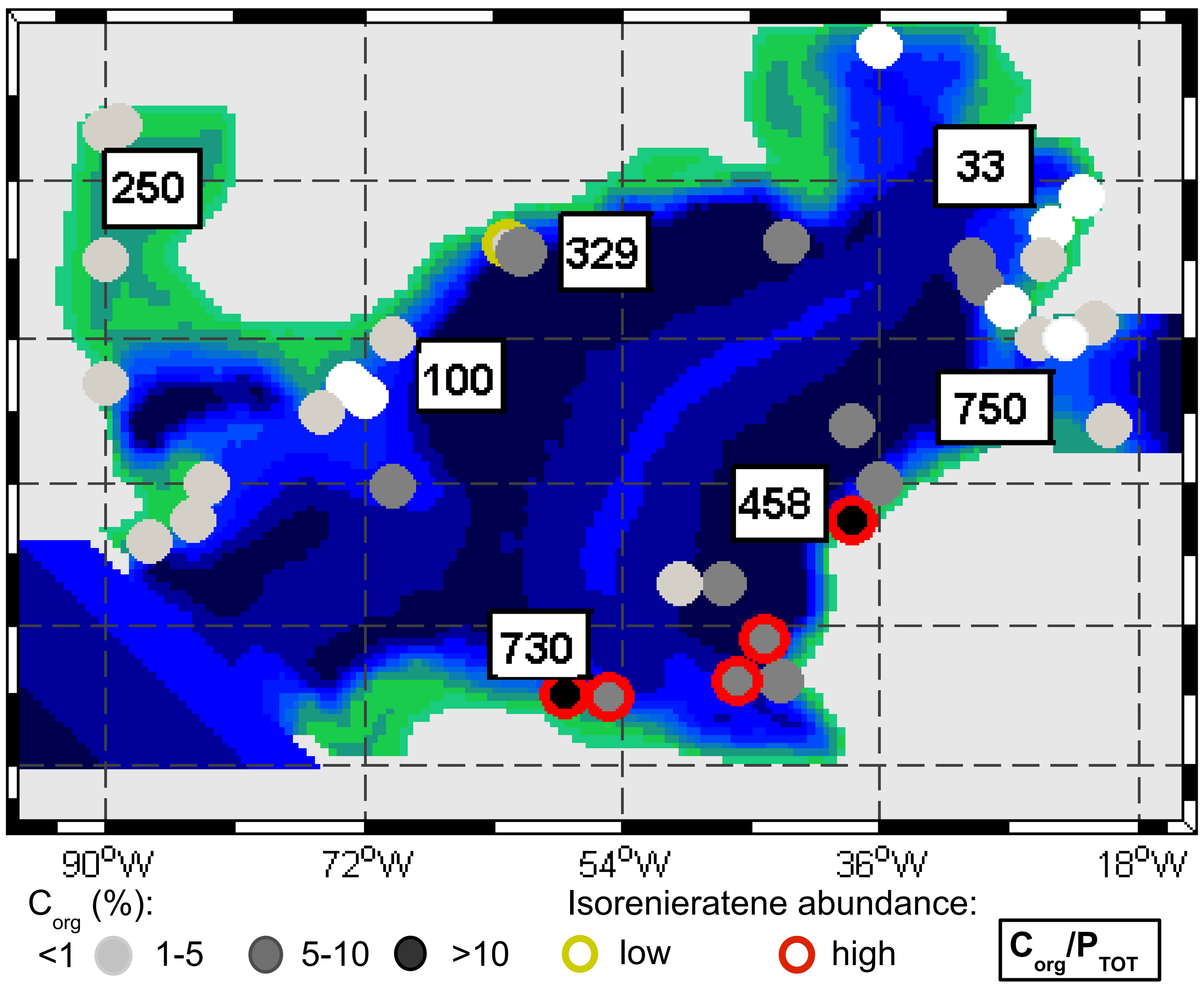


Figure 2. Bathymetry (0-0.1km = green, 4km = dark blue) of the North Atlantic during OAE2 and C_{org} content, abundance of isorenieratene and C_{org}/P_{TOT} from the geological record.

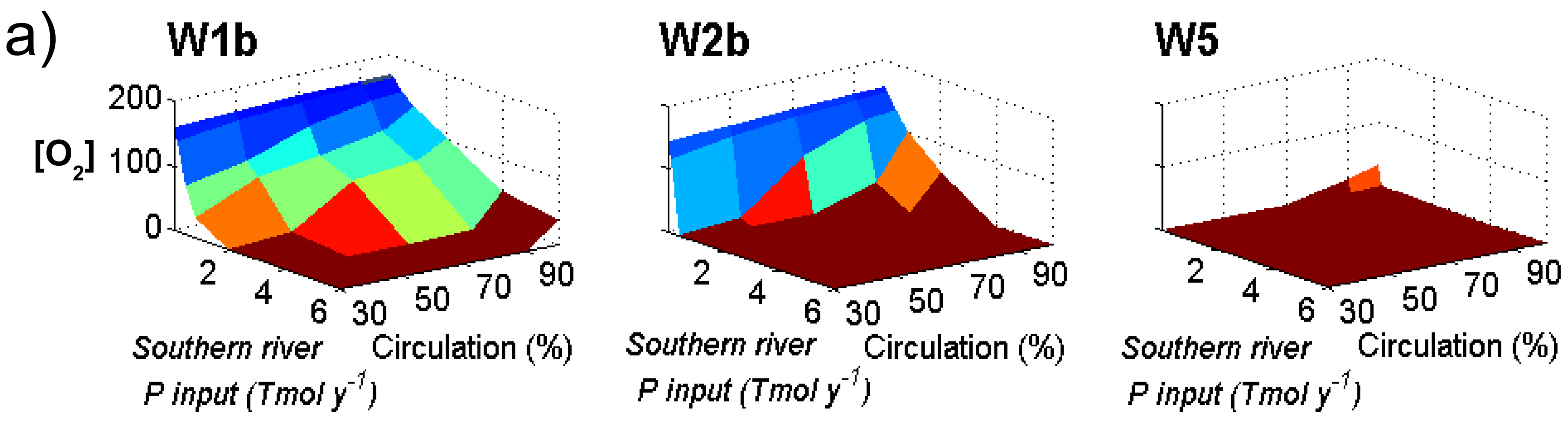
Sediment geochemical data indicate large spatial trends in redox conditions during OAE2. This is based on the abundance of isorenieratene (pigments of photosynthetic green sulfur bacteria) and ratios of organic carbon to total P (C_{org}/P_{TOT}), which are indicators for photic zone euxinia [3] and low oxygen [4], respectively. These indicators suggest an oxygen depleted southern basin while the North was more oxygenated. Organic carbon contents of the sediment in the South are much higher than elsewhere in the North Atlantic.

4. Results and discussion

In the model, the riverine P supply to sustain primary productivity and obtain full anoxia in the North Atlantic is 10x the modern global riverine P input (0.1 Tmol/yr). Recycling of P is of minor importance. Water column anoxia is easier to achieve if circulation is reduced (Fig. 3a).

We propose a scenario where the circulation is reduced by 30 % and P is added through different sources: rivers, erosion due to sea level rise and inflow of Pacific intermediate-bottom water (fig. 3b). In this case, widespread anoxia develops, but the north-eastern coast and the northern open ocean remain suboxic. The modeled C_{org}/P_{TOT} confirm this redox spatial trend.

a)



b)

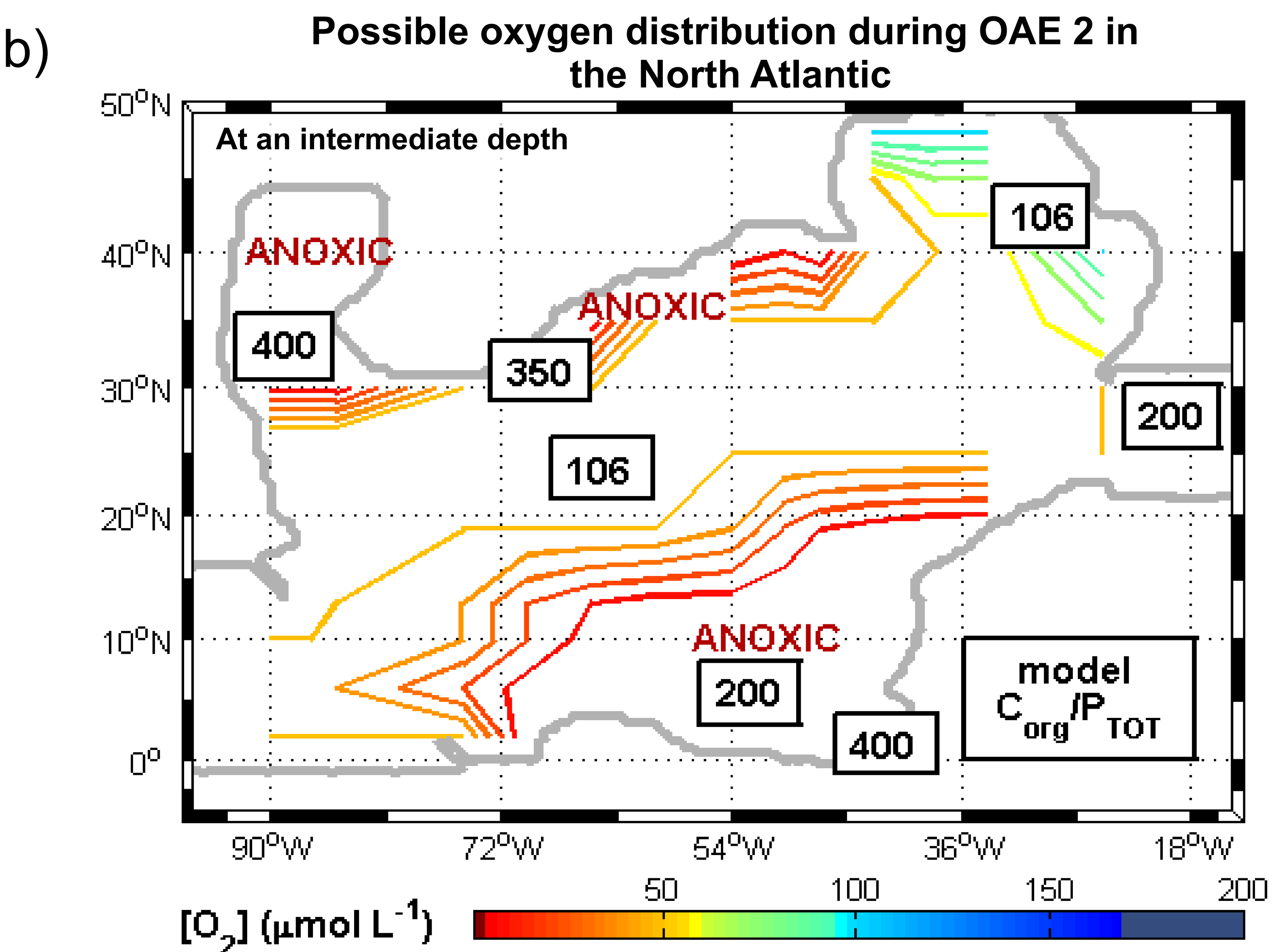
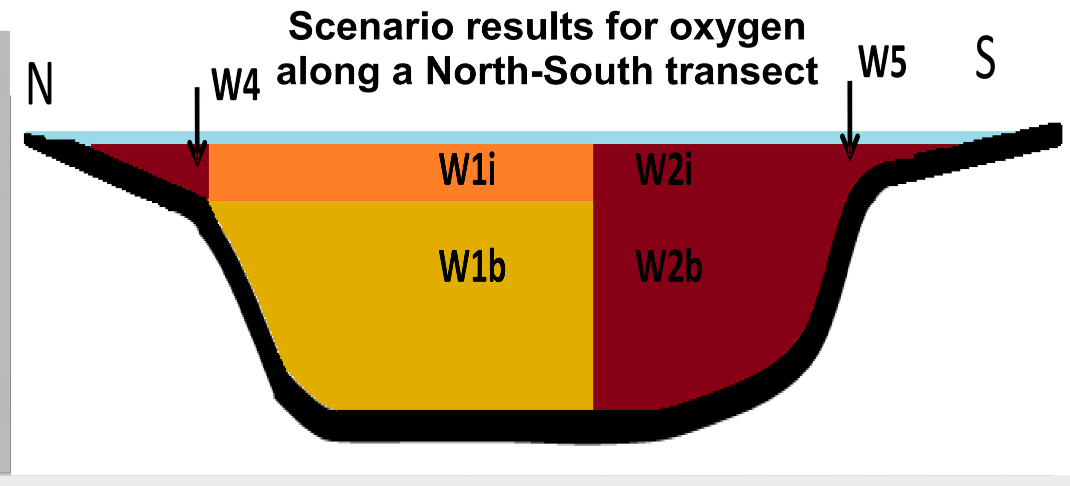


Figure 3.
a) Local oxygen sensitivity in the bottom open ocean and south coast with respect to ocean ventilation and riverine P input.
b) Oxygen distribution for a scenario with reduced ventilation and a total of 0.2 Tmol P y^{-1} input.



5. Conclusion

Our model captures the spatial trends in redox as observed in the North Atlantic during OAE2. Elevated P input is required for the development of anoxia. The recently proposed ocean circulation during OAE2 may be too vigorous and/or anoxia in the North Atlantic may have been less widespread than previously thought.

6. References

[1] Topper, R. P. M., Trabucho Alexandre, J., Tuenter, E., and Meijer, P. T.: A regional ocean circulation model for the mid-Cretaceous North Atlantic Basin: implications for black shale formation, Climate of the past, 7, 1085 277–297, 2011.
[2] Slomp, C. P., Thomson, J., and de Lange, G.: Controls on phosphorus regeneration and burial during formation of eastern Mediterranean sapropels, Marine Geology, 203, 141–159, 2004.
[3] Sinninghe Damsté, J. S. and Köster, J.: A euxinic southern North Atlantic Ocean during the Cenomanian/Turonian oceanic anoxic event, Earth and Planetary Science Letters, 158, 165–173, doi:doi:10.5194/cp-3-647-2007, 1998.
[4] Algeo, T. J. and Ingall, E.: Sedimentary Corg:P ratios, paleocean ventilation, and Phanerozoic atmospheric pO₂, Palaeogeography, Palaeoclimatology, Palaeoecology, 256, 130–155, 2007.

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