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Are we creating a new Oceanic Anoxic Event?

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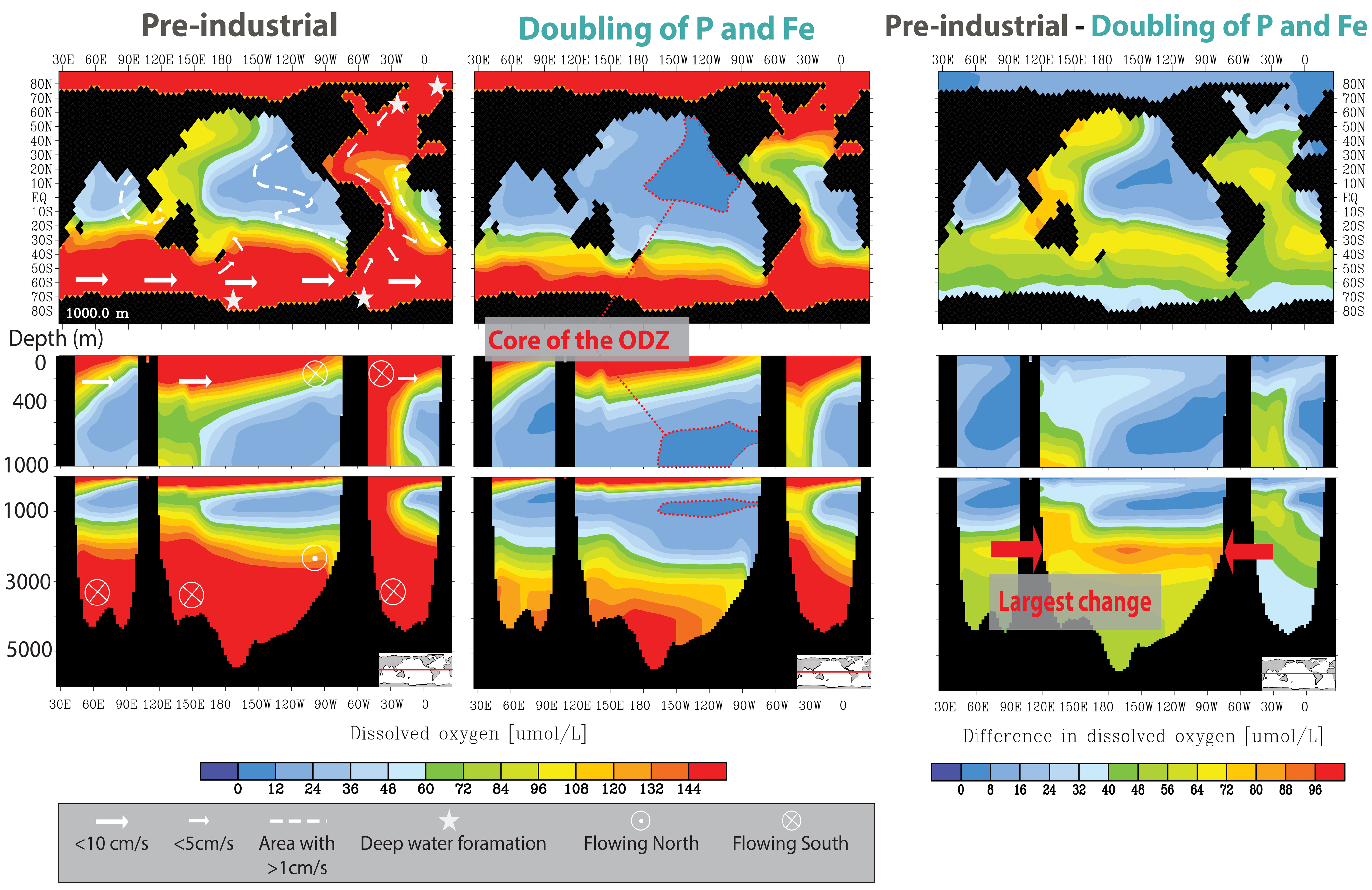
1. Introduction Oceanic Anoxic Events (OAE) are long-lasting episodes of widespread ocean deoxygenation that occurred mainly during the Mesozoic (252– 66 My ago), when atmospheric CO_2 levels were higher than at present. Evidence from the geological record show that these events severely altered marine biogeochemical cycles, affecting ocean productivity, biodiversity and ecological niches. In the modern ocean, oxygen is declining since the 1950s and oxygen deficient zones (ODZ) have now expanded to several million square km[1]. Because the rise of human-induced CO_2 in the atmosphere may lead to enhanced weathering that acts on long-time scales, ocean deoxygenation may continue beyond traditional model projections (several hundreds of years). Iron (Fe) input to the ocean may increase in the future, bbut is difficult to quantify because the response of desert dust to changes in climate and land use are not fully understood[2]. Here, we use a 3D-biogeochemical model (HAMOCC) designed for long-term integration (10-200 krys) to investigate how much the anoxia will expand if Fe concentrations in dust were to increase and/or phosphorus (P) was to leach continuously from the continents to the ocean due to enhanced weathering.

2. Methods **A)** We show the spatial distribution of oxygen in a scenario with a **doubling of P and Fe** relative to modern values (0.02Tmol P /y from rivers and 1.5 x10^9 Fe mol/y from dust) and compare it with the pre-industrial ocean. **B)** We present the expansion of the anoxic area with time, including results of 3 additional scenarios: a **doubling of Fe only**, a **2.5x P and Fe increase** and a **2.5x P and 4x Fe increase**. **C)** We estimate the amount of organic carbon buried in the seafloor for each scenario and **D)** analyse the time that the anoxic waters would take to fully re-oxygenate if nutrients were to drop to pre-industrial values.

3. Results

A: Spatial distribution of oxygen



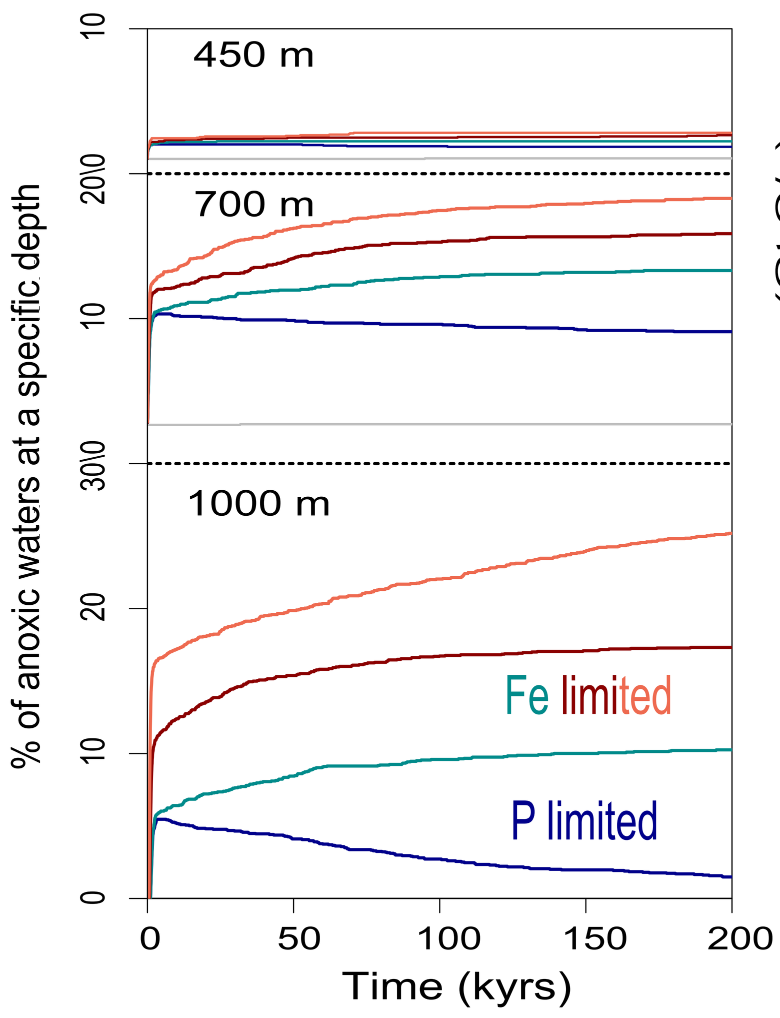
A Ocean anoxia (here, when O_2 < 12 uM) only expands between 450 and 1000 m and mainly develops in regions where lateral ocean currents are small (< 1 cm/s). The largest change in oxygen concentrations (~80 µM O_2) occurs in the suboxic bottom waters of Pacific equatorial continental slopes

B When increasing Fe only, the ocean becomes P limited. Anoxic waters account for 5% of the total ocean surface, but anoxia contracts after ~3 kyrs and the ocean re-oxygenates after ~150 kyrs. In our scenarios, anoxic waters expand up to 25% at 1000 m and account for up to 14% of the total ocean surface due to increased Fe and/or P inputs

C The amount of organic carbon buried in all our scenarios is of the same order of magnitude as the IPCC projected carbon release from fossil fuels and land use [3] and the carbon buried during past OAEs[4]

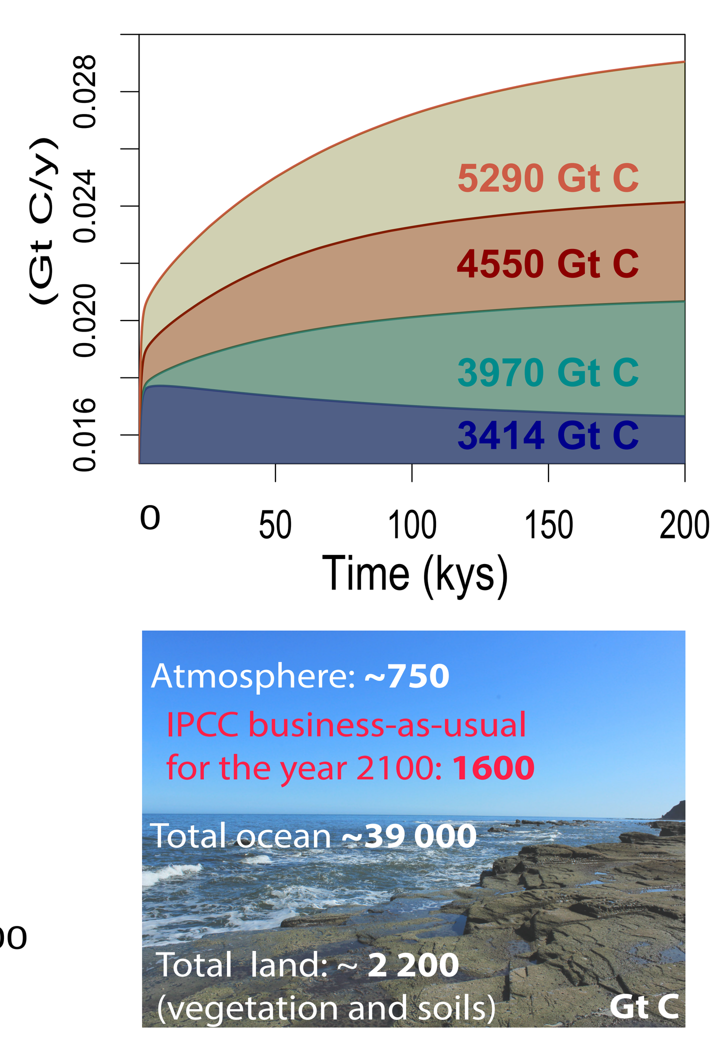
D When assuming a sudden drop of nutrients in a scenario with a total anoxic area of 7%, anoxic waters at 700 and 1000 m take about 2000 and 500 years, respectively to fully recover

B: Percent of anoxic area

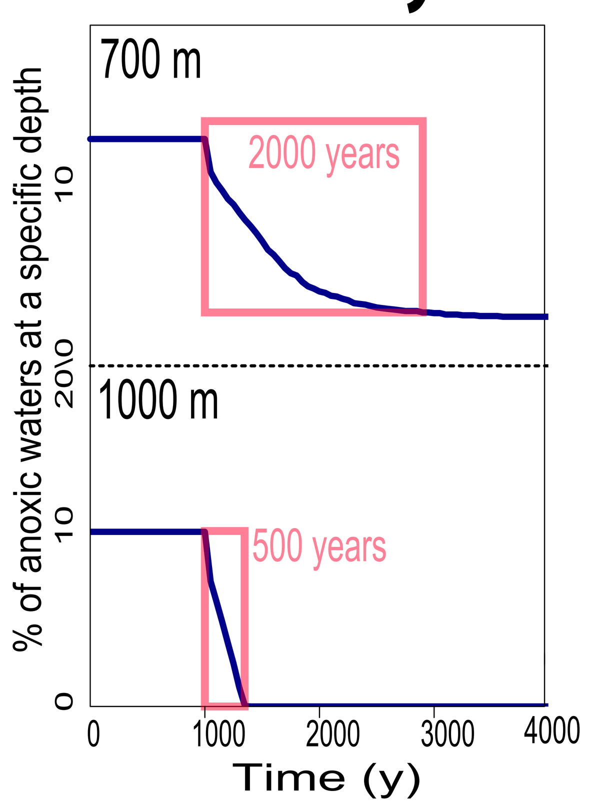


Total anoxic area % of the global ocean:
1, 5, 7, 11, 14

C: Organic carbon burial



D: Recovery time



4. Summary

Our results contradict recent suggestions that the modern ocean is on the edge of global anoxia[5]. However, more than 4% of the total ocean area may become anoxic due to high nutrient inputs alone when considering timescales of 50 to 200 kyrs. This is comparable to the anoxic area estimated during two major OAEs [7]. This implies that modern human activities can impact marine life and ocean biogeochemistry beyond time scales of several hundred years and even create a new episode of widespread ocean deoxygenation. If such anoxia develops, ocean re-oxygenation requires several thousands of years.

Our model results suggest that the amount of organic carbon buried in the seafloor of a 5% anoxic-ocean may compensate for the anthropogenic release of carbon from oil and land use. However, organic carbon burial can only contribute to the drawdown of atmospheric CO_2 on timescales of several hundred thousand years.

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