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The past 60 kyr variability of the oxygen minimum zone off Baja California inferred from multielemental analysis

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Greenland ice cores record abrupt air temperature changes at millennial timescale during the last glacial period: Dansgaard-Oeschger (DO) and Heinrich (H) events. This variability expanded to mid and low latitudes in the Northern hemisphere such as Oxygen minimum zone (OMZ) in the northeastern Pacific. The OMZ variability can be explained by changes in primary productivity and oceanic circulation. This study aims at evaluating relative importance of the processes by multi trace element analysis combined with high-resolution elemental measurements.

We studied a well-dated core MD02-2508 (606m water depth) retrieved off Baja California, within the present OMZ characterized by a two-layer of oxygen-depleted water masses centred at subsurface and intermediate depths. Wind-driven coastal upwelling controls modern surface productivity. The core site is expected to be highly sensitive to climate change in the North Pacific because it is at the southern limit of two oxygenated water masses: California Current (CC) at subsurface and North Pacific Intermediate Water (NPIW).

We performed high-resolution elemental analyses (5 mm to 500 μm corresponding to decadal time resolution) of Ca, Sr, Ti, Fe and Br using an X-xay fluorescence (XRF) core scanner. This approach is combined with trace element analysis by ICP-MS (U, Cd, Mo, Mn, Cu, Ni, V, Cr and As, 10 to 20 cm corresponding roughly to 500 years resolution) and CNS analyzer (Total Organic Carbon and carbonates). Results indicate that TOC, Fe/Ti ratio and trace element concentrations increase during Holocene and DO warm events whereas carbonates and terrigenous matter increase during the last glacial maximum (LGM) and H events. An excellent agreement between Fe/Ti (XRF) and trace elements suggests that millennial scale variability is captured by the lower resolution measurements. Further, trace element concentration and element/Al ratios present a very similar pattern, attesting that the observed H-DO type variability is produced by authigenic enrichment. Principal component analysis reveals three major components: The first principal component (PC1) corresponds to export productivity that reflects primary productivity and remineralisation in the water column. The second component represents the carbonate content that is modulated by dilution with organic matter and/or carbonate dissolution. The third component (PC3) mimics the variability of U/TOC, which represents oxygenation in the intermediate water. Previous modeling studies show that fresh water input to the North Atlantic induces reduction of southward winds along the California coast, which may decrease the coastal upwelling. The fresh water perturbation also produces a negative anomaly of sea surface temperature south of the Baja California, which can be interpreted as a southward extension of the California Current. These results may suggest that primary productivity decreased at the core site and the remineralisation of organic matter increased during the H events. The PC 3 indicates higher values during the LGM and the millennial variability is superimposed on this glacial-interglacial trend with lower values during the H events. This can be interpreted as due to better ventilation at intermediate depth in the Northeastern Pacific during the H events as suggested by modelling studies. During the LGM, previously reported improvement of ventilation seems to be restricted to the deep North Pacific and the intermediate ventilation was rather stagnant.