



Causes of Neogene intensification of the Benguela Upwelling System

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Coastal upwelling off the West coast of southern Africa has, according to proxy evidence, progressively intensified during the past 12 million years. Contrasting hypotheses on the cause of this long-term change during the Miocene-Pliocene epoch have been proposed. These range from increasing Antarctic glaciation and global cooling to the northward movement of the African continent, and the closing of the Central American isthmus.

Geological evidence also suggests phases of major uplift in the East African Rift system as well as in South and South-West Africa during the Late Miocene and Pliocene but their potential climatic impact remains to be quantified.

We performed sensitivity experiments with the Community Climate System Model Version 3 (CCSM3) to test the effect of regional uplift of East and South Africa (in combination and separately) on the atmospheric and ocean circulation. The model is run with a resolution of T85 ($\sim 1.4^\circ$) for the atmosphere and land surface and a variable resolution for the computation of ocean and sea ice down to a meridional grid spacing of 0.3° around the equator. The model results for South and East African uplift clearly indicate a strengthening of the low-level southerly Benguela jet along the southwestern African coast due to mountain uplift from half to full present-day altitude. This induces increased Ekman pumping and upwelling in the Benguela region. Consequently simulated temperature regionally decreases by up to 3.5°C in the surface ocean. The sensitivity runs show that only considering uplift of South-West Africa can not explain the entire magnitude of change, which indicates that also East African topography impacts upwelling intensity in the Benguela region.

Finally we analyzed two other model experiments regarding alternative hypotheses of 1) the closure of the Panama Isthmus and 2) Antarctic glaciation. The results indicate a minor impact of these processes on the strength of Benguela upwelling. We therefore conclude, that African uplift played a key role in strengthening the Benguela upwelling system during the late Neogene.