GEOLOGICAL ARCHIVES AND TIPPING ELEMENTS IN THE ATLANTIC OCEAN AND SOUTH AMERICA

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ABSTRACT: The Atlantic meridional overturning circulation (AMOC) as well as the Amazon rainforest (ARF) have been considered policy-relevant tipping elements of the climate system. In short, this means that: (i) they may pass a critical threshold at which a small perturbation may significantly change the way they function; and (ii) anthropogenic forcing may prompt the critical threshold to be exceeded. The possible consequences of exceeding this critical threshold include a collapse of the AMOC and a dieback of the ARF. These two tipping elements are particularly relevant for the tropical Atlantic Ocean and adjacent South America. Despite their relevance, large uncertainties are associated with these tipping elements and there is an urgent need to improve our understanding of the physical mechanisms controlling them. Here we show a selection of recent studies based on geological archives that recorded the response of the tropical Atlantic Ocean and the adjacent South America to a marked slowdown in the AMOC that occurred between ca. 18.1 and 14.7 cal ka BP (Heinrich Stadial 1). During the AMOC slowdown, the mid-depth (~1000-3000 m water depth) western tropical Atlantic Ocean experienced a major stagnation (probably the largest in the Atlantic Ocean) that allowed for a marked accumulation of respired carbon. In the upper water column (uppermost ~200 m), the shallowest portion of the mixed layer migrated southwards following a shift of the Intertropical Convergence Zone and impacting the distribution of nutrients in the equatorial Atlantic Ocean. The southward migration of the Intertropical Convergence Zone together with positive sea surface temperature anomalies both in the western tropical Atlantic Ocean and the eastern equatorial Pacific Ocean produced positive precipitation anomalies all the way from NE Brazil to western Amazonia. The positive precipitation anomaly over Amazonia was, however, divided in two phases that distinctly affected Amazonian hydroclimate and the ARF. The transition from the first to the second phase was characterized by: (i) a migration of the main locus of precipitation from the tropical Andes to central Amazonia; (ii) a southward shift of the tropical rain belt with a marked decrease of precipitation over northernmost Amazonia; and (iii) a strong reduction in western equatorial Atlantic sea surface salinity despite the sluggish AMOC. Finally, the southward migration of the tropical rain belt produced a decrease in the area covered by the ARF, most probably in its northernmost reaches where open vegetation types expanded. Thus, geological archives from the tropical Atlantic Ocean and adjacent South America allow exploring the multiple flavors of two tipping elements, namely AMOC and ARF. These flavors cannot be otherwise explored in the short instrumental record but contribute to an improved understanding of the physical mechanisms controlling them.

KEYWORDS: TIPPING ELEMENTS, ATLANTIC MERIDIONAL OVERTURNING CIRCULATION, AMAZON RAINFOREST.