Did Cooling of Subthermocline Waters Help Establish Modern Upwelling Regions? Evidence from ODP Site 716 in the Indian Ocean

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The modern Indian Ocean exhibits a strong sea surface temperature gradient between the upwelling zone in the northwest Arabian Sea and the central warm pool. However, during the Pliocene, this temperature difference was essentially nonexistent. The shift in Indian Ocean sea surface temperature patterns parallels those in ocean basins worldwide—modern upwelling zones were dramatically warmer in the Pliocene and cooled around 2 million years ago, which had significant implications for regional precipitation patterns. Whether this cooling was due to stronger upwelling, colder subthermocline waters or other factors is not yet known. We analyzed the $\delta^{18}O$ of benthic foraminifera from ODP site 716 in the Indian Ocean to test whether cooling of subthermocline waters contributed to cooling of the Arabian Sea upwelling region. Currently, bottom water at this 533 meter-deep site ventilates the thermocline and eventually upwells in the northwest Arabian Sea. We used the stable oxygen isotopic composition of the benthic foraminifera *Uvigerina proboscidea* and *Cibicidoides* spp. to infer changes in the temperature of bottom water at site 716. Our benthic record exhibits a ~1.5‰ secular shift over the past 4.5 million years, indicating cooling of bottom waters. The benthic $\delta^{18}O$ trend at site 716 parallels the record from the deep ocean suggesting cooling of shallow waters was comparable to that observed in abyssal waters. The onset of cooling precedes the shift observed in upwelling regions by ~0.5 million years suggesting that colder subsurface waters were not the proximal cause of cooler upwelling regions. Cooler subsurface waters were likely a precondition that primed the system to amplify any changes in upwelling, but increased wind-driven upwelling at 2 million years initiated the establishment of the modern cold upwelling regions.