# Temperature Inversion in the Bay of Bengal

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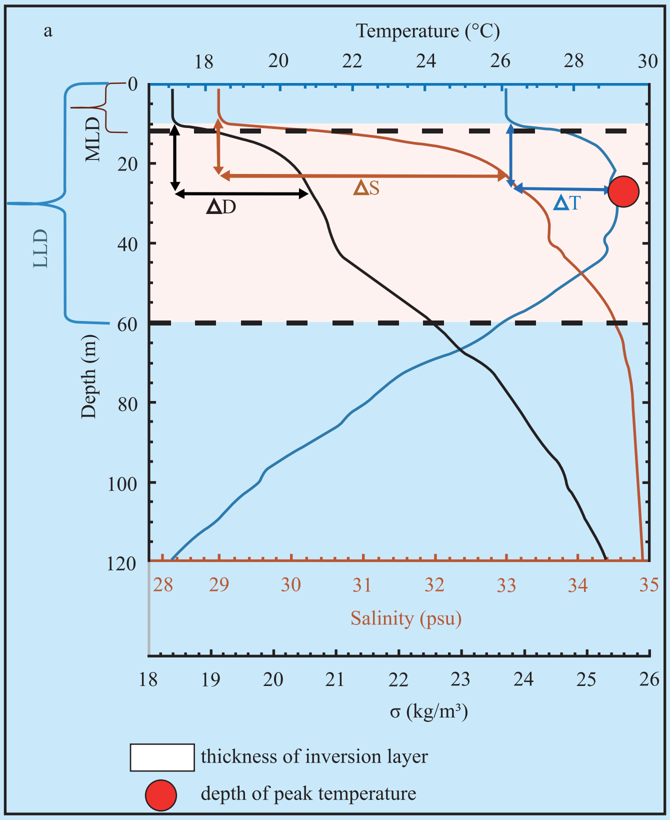
A layer between the warmer subsurface layer below and the colder surface water above is known as the temperature inversion layer. In contrast to the gradual decrease of temperature in a typical profile, temperature inversion creates a zone of positive gradient in the subsurface in a temperature profile. Temperature inversion was first introduced by Makarov (1894) in the North Pacific Ocean and later explored in detail by Uda (1935) in this ocean. Subsequently, this anomalous temperature profile has been observed in different parts of the world and considered a common occurrence in the subarctic of the North Pacific Ocean. This phenomenon has also been observed in several other tropical and subtropical oceans, including the Bay of Bengal (BoB).

Temperature inversion generally occurs at the strong temperature front and in an area with a robust temperature structure where warm and cold water meets, such as the mixing zone of the Kuroshio and Oyashio currents (Nagata, 1968, 1979). Nevertheless, the temperature structure of the North Pacific subarctic ocean (North of 45ºN) and subtropical/tropical regions are not similar. In the subtropical/tropical regions, there might be only a temperature maximum in the subsurface layer, whereas in the subarctic region, the vertical temperature profile has both the minimum and the maximum. This temperature minimum and maximum in the subarctic region are known to be the dichothermal and mesothermal structures, respectively.



A barrier layer is a layer with sharp halocline below the MLD, usually observed in the southeastern Arabian Sea, eastern equatorial Indian Ocean, and BoB. Barrier layer thickness is the term used to describe the thickness of the layer. Temperature inversion has been detected within the barrier layer in the Indian Ocean. East India Coastal Current and Winter Monsoon Current drifts the cool, low-saline water from the BoB to the adjacent Arabian. When this cool, low-saline water advected over the warm, salty water of the Arabian Sea haline stratification formed and aids to form temperature inversion. Net surface heat loss and penetrative heat below the mixed layer are also dominant precursors for the initiation temperature inversion in this sea. Thus, upper ocean thermohaline structure is essential to know the processes driving the temperature inversion in an ocean.

A strong haline stratified layer inhibits the mixing and causes a thin mixed layer, which is suitable for the formation of temperature inversion. Still, such inversions continue to exist in tandem with the barrier layer. The barrier layer prevents nutrients to exchange from surface to subsurface, which affects the productivity and, eventually, the ocean's ecosystem. It also significantly affects the climate system by changing the sea surface temperature (SST) and mixed layer heat budget. Several studies also have reported the non-negligible effect of temperature inversion on SST in the BoB. There is an obstruction to transferring of heat and biogeochemical components between the surface and deeper water in an area with temperature inversion. Furthermore, the upper layer thermal structure influences the ocean heat content, the tropical cyclone heat potential, and the regional weather system. Because of this, a realistic understanding of temperature inversions, including their vertical structures and processes, is necessary to elucidate the dynamics of the surface layer and thermodynamics in the oceanic regions where they occur.

Most of the research considering the BoB suggested that temperature inversion only occurs in the winter, while a few studies also proposed that it happens in the spring, summer, and autumn. For example, Girishkumar et al. (2013) noted temperature inversion in the central bay from autumn to winter; Vinayachandran et al. (2002) identified summertime temperature inversion in the northern bay; and Li et al. (2012) revealed temperature inversion in late spring along the Sri Lankan dome. In addition, Thompson et al. (2006) and De Boyer Montégut et al. (2007) hypothesized that temperature inversion occurs in the BoB practically year-round considering some Argo data (Array for Real-time Geostrophic Oceanography).

The available observational data sources in the central and southern parts of the BoB are the RAMA mooring buoys (Research Moored Array for African-Asian-Australian Monsoon Analysis and Prediction). Using in-situ data, Thadathil et al. (2016) revealed much weaker inversions at the RAMA buoy stations (12°N, 8°N, and 4°N) along 90°E, providing evidence of the presence of the temperature inversion outside the northern BoB. Li et al. (2016) averaged the temperature inversion temporally and spatially (averaged over 5 days within a 2°×2° bin) considering basin-wide Argo data and identified the primary elements of the wintertime temperature inversion in the northern BoB. However, Chowdhury et al. 2022 provide a comprehensive picture of temperature inversion throughout the basin extending beyond winter. They use long-term Argo (2004 to 2020) and RAMA (2007 to 2020) profile data in the BoB and eastern equatorial Indian Ocean to focus on the region's finer-scale temporal and spatial distribution of temperature.

In the northern BoB, net surface heat loss and freshwater advection are recommended as the main factors causing the temperature inversion during winter, considering research concentrating on a single RAMA buoy or a portion of the bay. For example, Shee et al. (2019) took into account a single Argo float, while Thadathil et al. (2016) and Li et al. (2016) utilized the RAMA buoy (15°N, 90°E) to explore the mechanisms of temperature inversion using heat budget analysis. Girishkumar et al. (2013) examined the temperature inversion at RAMA (8°N, 90°E) and reported that penetrated heat beneath the mixed layer is advantageous for the temperature inversion formation in the central bay. It has been proposed that during winter, the downwelling eddy plays a significant role in the production of inversion along the northern bay. Chowdhury et al. (2022) disclosed the driving mechanisms behind temperature inversion for several sub-regions in the BoB. The combined effect of the cooling tendency of the mixed layer and the significantly warmer subsurface layer below the stratified shallow mixed layer (mean 25 $W/m^2$) causes higher temperature inversions throughout the year in the northern BoB. The southern portion of the bay is less favorable than the northern part to the formation of a temperature inversion due to a lower cooling tendency by net surface heat loss and a higher salinity of the mixed layer. Comparatively, deeper ILD, and the thicker BLT promote to form an intense temperature inversion in both the BoB. The tropical cyclone heat potential is higher in temperature inversion events than that of noninversion profiles during spring to autumn in this area.

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