Linking the world oceans continuously, the Southern Ocean plays a critical role in the global ocean circulation and the meridional overturning circulation. The most significant flow in the Southern Ocean, the Antarctic Circumpolar Current (ACC), is driven by the westerly winds and flows eastward surrounding Antarctica, thus has major contributions to the water mass, freshwater budget, and heat exchanges between the Atlantic, Pacific, and Indian Oceans. The Southern Ocean and the ACC have been found changing rapidly in recent decades, including the freshening in the surface salinity and overall subsurface water mass warming and salting (Armour et al., 2016; Auger et al., 2021; Bindoff et al., 2013; Gille, 2008; Haumann et al., 2016; Levitus et al., 2012; Sallee, 2018). Due to the key positions of the Southern Ocean and ACC in the global oceans, the consequences of these changes will have potential implications on the formation and variability of water masses and Antarctic ice shelf, and furthermore influence global climate change.

The Southern Ocean between the Africa and Antarctic continents provides the passage for the Atlantic-Indo exchange (Gladyshev et al., 2008). In the north of this region, the Agulhas leakage transfers the water mass from the Indian Ocean to the Atlantic and is essential for the stability of the overturning circulation in the Atlantic (Gordon, 1986; De Ruijter et al., 1999; Weijer et al., 2001). It is also related to the formation of the NADW (Peeters et al., 2004) and export of the AABW and diluted NADW into the Indian Ocean at depth (Arhan et al., 2003). Besides, the Agulhas Retroflection can determine the latitudes of the Subtropical Front and influence the variability of the ACC location (Belkin and Gordon, 1996). In the eastward ACC region, the variability of the main Southern Ocean frontal system has significant impacts on both the inter-ocean exchange of cold water and air-sea exchanges of heat budget (Ansorge et al., 2005). In the south of ACC, the circulation in the Weddell Sea contributes to the transport from the ACC to the Antarctic continent and influences the formation of the deep and bottom waters (Orsi et al., 1993).

Despite the important role of the Africa-Antarctic passage in the Southern Ocean, it has been less studied than the other two choke points of the Southern Ocean: the Drake Passage south of South America and the region south of Australia in the south Pacific, especially for the long-term variation. Using the historical observations including data collected from 6 Conductivity-Temperature-Depth (CTD) sections in the years 1984, 1990, 1992, 1993, 2004, and 2005, and 18 eXpendable BathyThermograph (XBT) sections between 1989 and 2006, Swart et al. (2008) estimate the baroclinic transport and variability of the ACC south of Africa. However, these observations are separate one-time in-situ observations except for the 5 repeat XBT sections continuously from 2004 to 2006 conducted by the National Oceanic and Atmospheric Administration/Atlantic Oceanographic and Meteorological Laboratory (NOAA/AOML) XBT Network Program. As part of this XBT Program, XBTs are deployed along high-density transects south of Africa from Cape Town to the Antarctica continent, which is named the Transect AX25 (hereafter AX25, Figure 1). These transects have been repeated in the summer seasons twice per year since 2004, providing a unique long-term high-resolution temperature time series in the upper ocean. The XBT data along AX25 has been used to investigate the frontal variations in response to the wind forcing (Domingues et al., 2014) and the thermohaline variability in the ACC fronts (Swart and Speich, 2010). None of these early investigations cover the latest XBT observations after 2010. The changing of the Southern Ocean and ACC south of Africa in recent decades is still largely unexplored.

In this study, all the recent XBT observations along AX25 from 2004 to 2020 together with the available Argo profiles are used to analyze the long-term temperature changing in the Southern Ocean south of Africa. The results will be compared with observations along sections in other passages to improve our understanding of the changes in the present-day Southern Ocean. The XBT and Argo data are described in Section 2. Temperature trend and variability estimated from the observations are presented in Section 3 followed by the discussion of the reasons causing the changes in Section 4. Section 5 summarizes our results and compares them with observations in other sections.