# Mixed Layer dynamics and thermodynamics in the Central Arabian Sea

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In this study we highlight the importance of vertical advection in SST evolution in the central Arabian Sea. We used 1-D models to understand the different oceanic processes responsible for the temperature changes in this region. Data used in this study is the intensive buoy observations at 15.5° N, 61.5° E during October 15, 1994 to October 20, 1995, deployed off the coast of Oman to collect the near surface meteorological and oceanic data and to prepare the unique time series. It is important to mention that the point considered here is close to the Findlater jet (climatological maximum wind speed during the southwest monsoon). The monthly mean climatological SST at 15.5° N, 61.5° E is bimodal in nature with a primary maximum during May-June (i.e. around 29° C), and a secondary maximum in October (27.5° C). In response to the summer monsoon forcing during June to August, the sea surface cools by about 4° C.

For the complete understanding of the thermodynamics of the Arabian Sea we used the one dimensional dynamic instability model Price Weller Pinkel (PWP) and the Mellor- Yamada (turbulence-closure level 2.5 model) model (MY). These models have performed well for the Pacific and Atlantic oceans, they were recently used in the Indian Ocean also. One year long time-series of observed heat and momentum flux data were used to force these models. The models have performed reasonably well in simulating the SST except for the SW monsoon season (i.e. June to September). The SST simulated by the PWP model was about 5° C higher than the observed (Figure 1), which strongly emphasizes the role of advection and the vertical mixing in determining SST during SW monsoon season. Apart from the advection of cold water, the local entrainment and surface heat losses are also responsible for the drop in the SST. But the WHOI observations revealed that the net heat flux to the ocean was positive (of the order of 48 $W/m^2$ in June and 56 W/m2 in July) during the SW monsoon-95, which clearly indicates that the cooling is due to the local entrainment resulting to the mixed layer deepening and advection of cold water from the coast. We did a set of sensitivity experiments and found that vertical mixing is playing a key role in the SST evolution over this region. The increased mixing in PWP however helped to simulate SST very well (Figure 2).

To understand the transport of mass and heat at different levels, the current and temperature profiles up to 100 m are analyzed in detail. In top 50 m, the current was close to 5 cm/s. During April surface currents were eastward, whereas at 10 m, the transport was from west-southwest. It was from west to east from 20 m to 50 m, below that the relatively stronger current at 65 m was observed (west north west). During April, SST was around 28.5° C and the mixed layer depth (MLD) was approximately 18 m. Strong south south-westerly (SSW) winds (10 m/s) was observed in June. The current speed in top 40 m also increased in June. Due to the strong winds, the Ekman current (drift) (i.e. current direction is 45° right from the wind direction in NH) was observed. It is a clear indication that the currents are dominated by Ekman drift. In the top 40 m the current decreases with depth but had constant eastward direction (from the Oman coast). During July, the mean monthly southwesterly winds of speed 12.37 m/s were observed. Average current at each level was 2.5 times of June currents. Strong wind supported the Ekman drift, which resulted the surface current of about 40 cm/s flowing eastward. During July, the direction of the current in the top 100 m was almost constant (eastward). Coastal upwelling along the coast of Oman and upwelling in the Socotra eddy region and its possible advection may be contributing in the July cooling. High wind speed during July supported the entrainment cooling and deepening of the mixed layer. Strong currents in the upper layer bring the cold water towards the point of observation, which result in the mixed layer cooling. MLD was 65-70 m during July and the SST was about 27° C, which is about 1° C less than the June SST. Wind speed decreased to about 9.33 m/s in August, and there was no Ekman drift in the surface current. Current profiles of August revealed that the strongest surface currents of 55 cm/s were observed at the surface coming from the Oman coast. The current speed decreased with depth, but at all the levels they were the seasonal maxima. August SST was 26° C, i.e. 1° C less than that of July, whereas the mixed layer shoaled (approximately 32 m). The August current direction was favorable to the advection of cold water from the coast of Oman. During September with the retreat of the monsoon winds were decreased to a low value of 6.82 m/s, currents also decreased to around 20 cm/s at the surface. MLD was 40 m, deeper than August and SST was above 27° C. The study revealed that the wind speed is controlling the mixed layer, both on diurnal scale and on monthly scale. The wind directions are also important in determining the mixed layer depth. In most of the cases the frequent changes in wind direction was responsible for the increase in MLD (diurnal scale). It is understood that the advection may be playing the important role in determining the SST in the Central Arabian Sea. So a dedicated three - dimensional model is essential to understand the internal dynamics in the Arabian Sea, especially during the monsoon season.

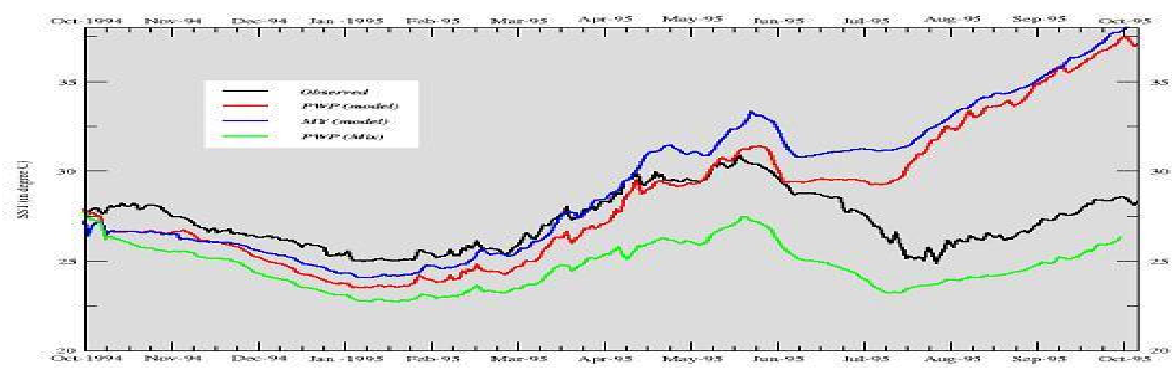


**Fig. 1 Time series of SST observation compared with two versions of PWP and MY Model runs**

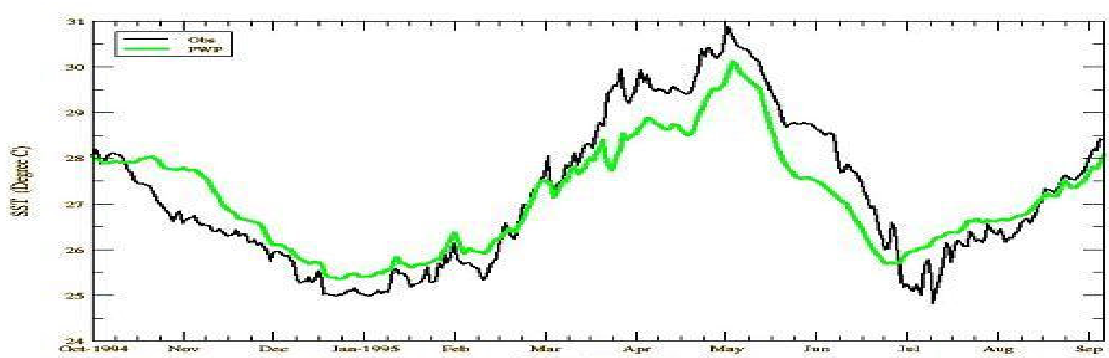


**Fig. 2 PWP with increased mixing compared against observed SST**