Arabian Sea Dynamics

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LONG-TERM GOAL

The goal is to identify and understand the mechanisms which determine features of stratification and motion in the upper 200 m or so of mid-latitude oceans. This is the depth range over which surface fluxes of momentum and buoyancy have direct influence. Our interest is in the processes by which shear and stratification interact to change upper ocean structure.

OBJECTIVES

Our objective is to use moored array records we have produced in various observational programs in both the upper ocean and near-topography environments to produce statistical descriptions of flow that can be compared with models.

APPROACH

Our approach is to make moored observations at a variety of locations in order to be able to describe coherent patterns of variability based on a number of realizations of oceanic processes. In our upper ocean work, we have been using C. S. Draper Laboratory Profiling Current Meters (PCMs) to gather moored array time series of current, temperature, and salinity profiles from about 200 to 20 m depth. Our most recent observations come from a sequence of two 6-month PCM deployments in the Arabian Sea as part of a 5-mooring year-long upper ocean array to study upper ocean response to monsoon forcing.

WORK COMPLETED

We have completed field work in the Arabian Sea. One of the two PCMs deployed as part of a five-mooring array (in collaboration with investigators at WHOI and SIO) was lost during the height of the southwest monsoon due to failure of a mooring component. Fortunately, the sequence of two six month deployments at the remaining site was successful in returning a year of temperature, salinity, and current records from 35m to 200m depth. These data have been edited and are currently being analyzed.

RESULTS

Moored profiler observations of the upper 200 m of the Arabian Sea describe the evolution of temperature, salinity, and current over the course of the year starting October, 1994. The observations were collected as part of a moored array located roughly 500 km SE of the Arabian Peninsula. Changes in upper ocean structure can be associated with four distinct seasons (the two monsoons and the two

intermonsoonal periods). These changes are evident in low-pass filtered plots of temperature (Figure 1) and salinity (Figure 2). The autumnal intermonsoonal period was characterized by strong currents and strong advective changes in upper ocean temperature and salinity structure. Currents of 1.3 m/s and pycnocline depth variations of 50 m were recorded during the passage of a mesoscale disturbance shortly after the mooring was deployed. Currents subsided and the permanent pycnocline deepened at the beginning of the winter (northeast) monsoon season. A surface mixed layer formed and deepened to about 110 m depth during this period, despite winds weaker than 10 m/s over the entire season. Near-inertial shear at the base of this layer remained relatively weak. The surface mixed layer formed during the winter monsoon gradually became stratified by both temperature and salinity during the vernal intermonsoonal season. Changes in salinity at depths shallower than the permanent pycnocline roughly balanced the local net evaporative from the surface. With the onset of the summer (southwest) monsoon, a surface mixed layer eroded the shallow pycnocline developed in the preceeding season. This layer deepened to about 80 m depth, accompanied by vigorous near-inertial shear at its base, as wind speeds remained at 10-15 m/s. The permanent pycnocline rose as winds began to subside, accompanied by strong currents, completing the annual cycle.

The observed annual cycle suggests that the processes of advection, convection, surface heating, and mechanical mixing each dominate upper ocean structure over the sequence of the four seasons, respectively. The goal of ongoing analysis is to quantify these processes using an inverse analysis and data assimilation techniques.

IMPACT/IMPLICATIONS

Although analysis of our Arabian Sea data is in progress, it is clear that the phenomenon of “Arabian Sea cooling” (that is, surface temperature drop during the summer monsoon) is accomplished locally by mechanical mixing early in the season, but much more powerfully by advective events that persist into the fall intermonsoonal period. Surprisingly, convective cooling accounts for a much deeper surface mixed layer during the much milder winter monsoon than does mechanical mixing during the high winds of the summer monsoon. Latent heat release and its attendant fresh water flux appears to be the primary component of vertical buoyancy flux in the region. The spring restratification of the deep surface mixed layer formed in winter suggests that vertical diffusion is effective in altering upper ocean structure beneath the seasonal pycnocline and erasing spiciness. The results of this study have general applicability to the evolution of upper ocean structure throughout the world ocean.

RELATED PROJECTS

This project is a collaborative effort with Dr. R. Weller of Woods Hole Oceanographic Institution and Dr. D. Rudnick of Scripps Institution of Oceanography to understand upper ocean dynamics and thermodynamics in the Arabian Sea. Our measurements are being made available to other ONR Arabian Sea investigators involved in physical and biooptical studies. Our studies are relevant to the chemical and biological studies carried out in the same region by JGOFS investigators.

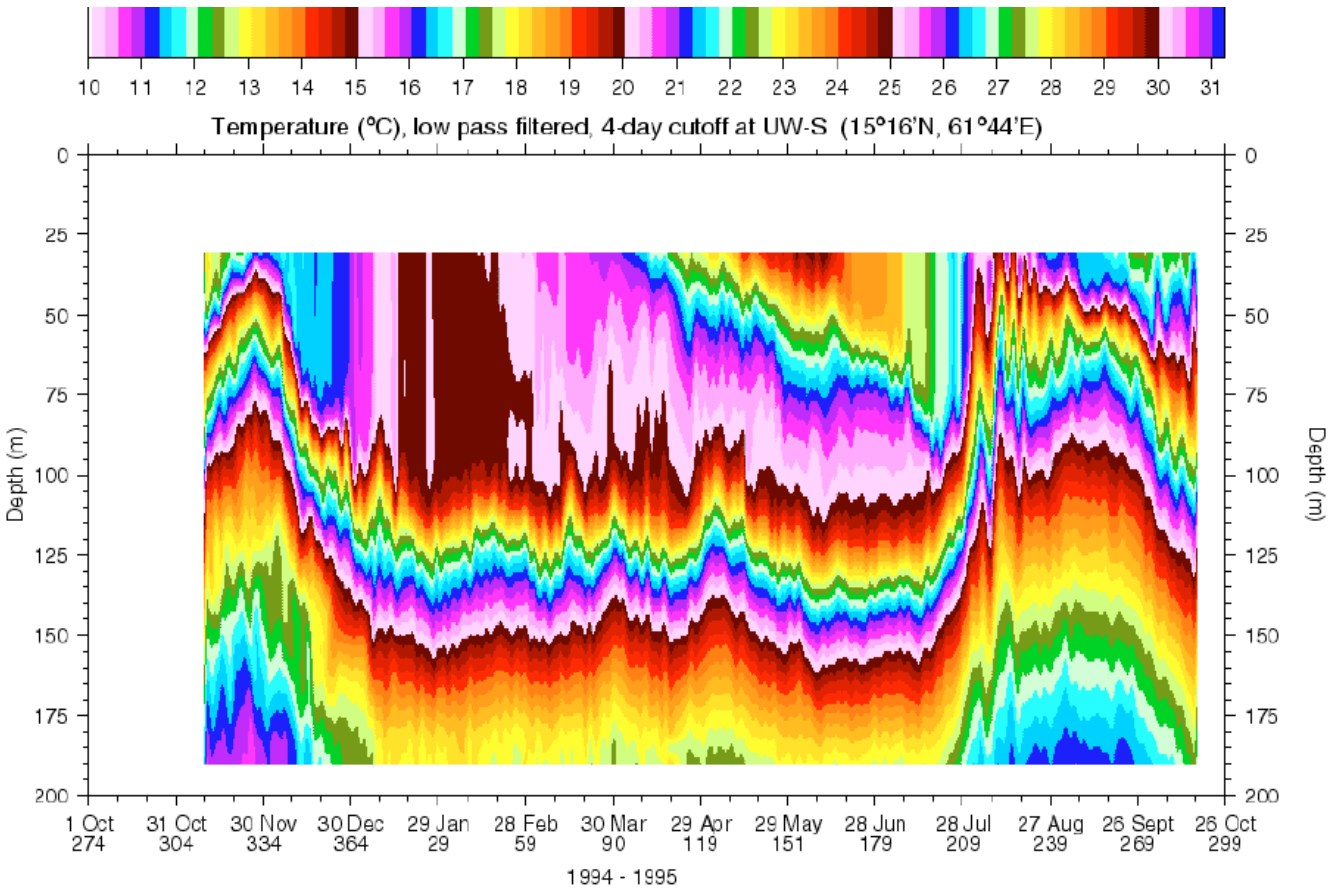

Figure 1. Four-day low pass filtered temperature from site UW-S in the Arabian Sea. The contour interval for temperature (0.25 °C) is approximately equal in contribution to density (~0.075 kg/m3) as that for salinity in Figure 2. The temperature color scale repeats every 5 °C

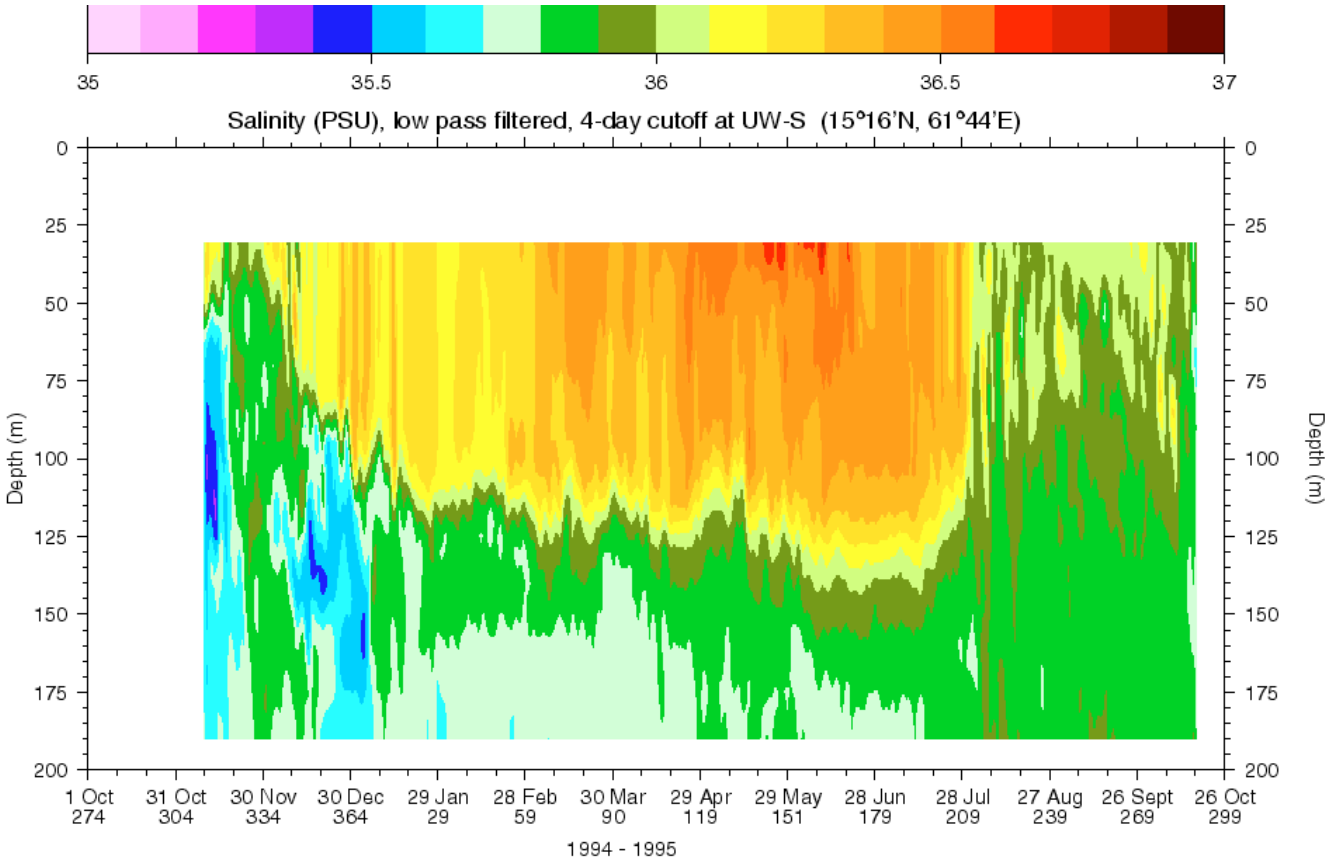

Figure 2. Four-day low pass filtered salinity from site UW-S in the Arabian Sea. The contour interval for salinity (0.1PSU) is approximately equal in its contribution to density (~0.075 kg/m3) as that for temperature in Figure 1.

REFERENCES

Rudnick, D. L., R. A. Weller, C. C. Eriksen, T. J. Dickey, J. Marra, and C. Langdon, Moored Instruments weather Arabian Sea monsoons, yield data. Eos, Trans. Am. Geophys. Union, 78, 117 & 120-121, 1997.