

Short Communications

Spectral Characteristics of Fine Structure Off the Mouth of Persian Gulf in the Northern Arabian Sea

K K VARMA, A A FERNANDES & L V GANGADHARA RAO

National Institute of Oceanography, Dona Paula, Goa 403 004

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Vertical profiles of temperature and salinity obtained from northern Arabian Sea using a STD profiler showed the presence of fine structure. The observed series from 3 selected stations were partitioned into mean and perturbation series using a high pass filter. Maximum fluctuations were observed in the thermocline. Spectral density of the parameters decreased with increasing wave number and exhibited a power dependence of about -3 , at the lower wave numbers.

Fine structures in the northern Arabian Sea and the possibilities of different factors contributing to their formation have been discussed¹. In the present paper an attempt has been made to study spectral characteristics of fluctuations of temperature, salinity and density with depth. Several investigators have studied the vertical spectra of these parameters²⁻⁷, mainly the temperature.

Vertical profiles of temperature and salinity were obtained from a number of stations in the northern Arabian Sea during February 1974 using a Bisset-Berman STD profiler¹. Three stations were selected for the present study. Stations 1 and 2 (23° N, 61°22.8' E and 23°32' N, 61°23' E respectively) were studied because of their proximity to the mouth of Persian Gulf and the large variability of the individual traces, inspite of their closeness to each other. Station 3 (23° N, 64°05.3' E) was chosen to see variations in the spectral characteristics, if any, with the distance from the source of Persian Gulf waters.

Temperature and salinity values were read from the analog records at every 10 m interval. Digitized data were checked against the data obtained from hydrographic casts and the necessary corrections incorporated. Density (σ_t) was computed using the tables for sea water density.

The observed series (with depth) can be considered as constituted by a mean series with the superimposed fluctuations

$$\text{i.e., } T = \bar{T} + T'$$

Thus the observed series can be split into mean series and perturbation series. This was achieved with the help of a high pass filter (11 point binomial filter with a cut off scale of about 100 m). Response characteristics of the filter are given by

$$\tau(k) = 1 - \cos^m(\pi k \nabla z)$$

where m is the exponential of the binomial, k the wave number and ∇z the sampling interval⁸. The original and perturbation series for station 1 are shown in Fig. 1.

Main features of the traces—At station 1, a large temperature inversion of about 0.8°C was observed in the thermocline, corresponding to which was an increase in salinity by about 0.8‰. The vertical scale of this feature was of the order of 80 m. The above feature of temperature was absent at station 2 and was replaced by an isothermal layer of about 50 m thickness. Salinity showed an increase of about 0.4‰

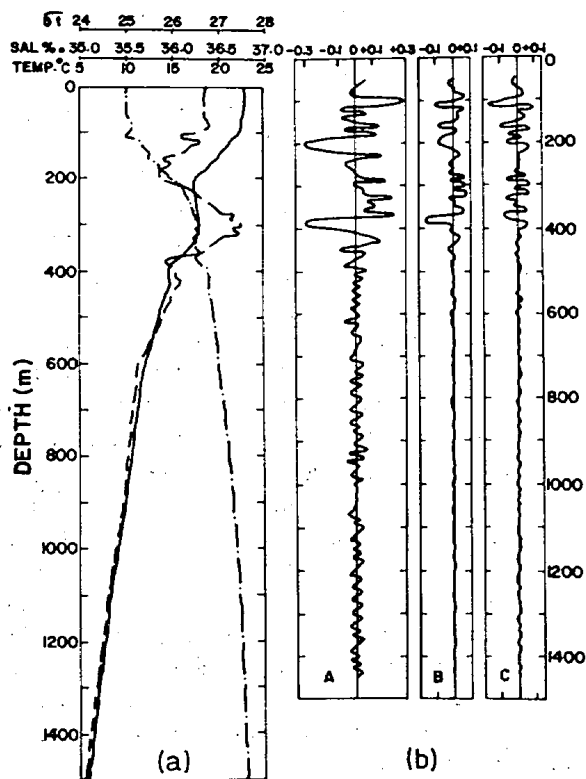


Fig. 1—(a) Depthwise distribution of temperature (—), Salinity (---) and density (- · -) at station 1. (b) Perturbation series of temperature (A), salinity (B) and density (C) at station 1

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Station 3 was situated at about 275 km east of stations 1 and 2 and did not show any of the large temperature structures of the previous stations. A slight increase in salinity of about 0.2‰ was, however, present at about 300 m. At all stations sub-surface salinity minimum was noticed around 200 m depth, and below 300 m temperature and salinity decreased with depth.

Spectra of the high pass filtered data were computed by auto-correlation method⁹. Sampling interval of 10 m, used here, is rather coarse and may perhaps introduce errors into computed spectra by aliasing. However, the constraints of the analog record do not permit a closer sampling interval. As the spectra of these parameters are generally believed to decrease with increasing wave number even beyond the cut off wave number of the instrument (0.25 cpm), such contamination at lower wave numbers can be negligible. Hence the present attempt is to derive possible information with a note of caution. The data points were 141 and the maximum displacement used was 15 (df 18). The spectra were corrected for filter response and are presented on log-log scales in Fig. 2.

Temperature—The power densities at stations 1 and 2 were comparable at lower wave numbers, while the power density at station 3 was slightly less. The energy decreased with increasing wave numbers. For lower wave numbers, the decrease in power density at stations 1 and 2 up to 0.017 cpm had a slope of -3 , while the decrease at station 3 up to 0.01 cpm was steeper (-3.9). Minor fluctuations at higher wave numbers were not significant (95% level).

Salinity—As in the case of temperature, power densities were comparable at lower wave numbers at stations 1 and 2 and were less at station 3. Slopes of the decrease of energy were about -3 up to 0.017 cpm at stations 1 and 2 and up to 0.01 cpm at station 3. Minor fluctuations at high wave numbers were not significant (95% level).

Density—The energy at lower wave numbers was less than those of temperature and salinity. Also, the energy at lower wave numbers was comparable at all stations. This is expected as the larger fluctuations of temperature and salinity have to cancel each other in order to avoid any significant unstable stratification. Spectrum at station 3 was rather steep up to 0.01 cpm compared to those at stations 1 and 2. Variations observed at higher wave numbers were insignificant (95% level). These spectra showed a similarity to the salinity spectra, though the similarity was less conspicuous at station 3. Roden² reported such a similarity between salinity and density spectra observed in the Pacific.

Several investigators have tried to relate the vertical wave number spectra to turbulence. The energy, derived from large scale motions, is passed down

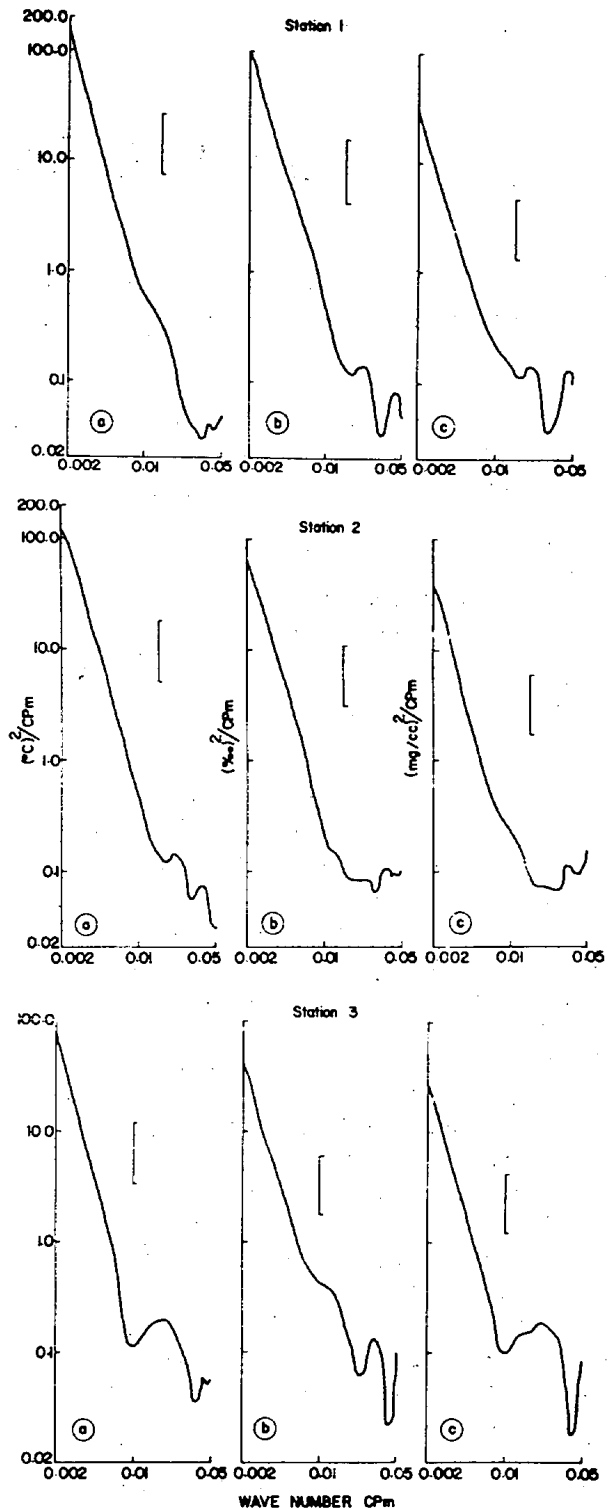


Fig. 2—Wave number spectra of (a) temperature, (b) salinity and (c) density (σ_t) at stations 1 to 3 [Bars indicate 95% confidence limits]

through a cascade fashion to be finally dissipated against viscosity. The effect of stratification is to damp the turbulence by working against buoyancy. In the thermocline, the region of maximum stability, vertical

components of turbulence are inhibited and mainly the horizontal transfer of momentum takes place. If temperature and salinity are considered as passive scalar fields to be transferred along with momentum, maximum fluctuations can be expected in the thermocline. This is found to be true from the perturbation series (Fig. 1b).

The spectrum of turbulence, in the inertial sub-range, will follow a $-5/3$ power law, while -3 power dependence is more appropriate in the buoyancy range¹⁰. Roden² has obtained for temperature and salinity, a relationship ranging from $-8/3$ to $-9/3$ between wave numbers 0.003 and 0.03 cpm. The present study shows a power dependence of about -3 for the lower wave numbers. This may perhaps be related to turbulence if temperature and salinity are considered as passive fields transported along with momentum. Pochapsky¹¹, following lagrangian method has observed a decoupling of turbulence from the mean flow at a horizontal scale of about 1 km. Even though such large scale decoupling does not seem to be possible in the vertical, the possibility of about few hundred metres cannot be ruled out.

It may be inferred from the above that the spectra of the parameters against the vertical wave numbers have a general similarity to those reported from many other oceanic regions. At station 3 an increase in spectral density was observed for all parameters at about 0.02 cpm (Fig. 2). Even though this was not significant at 95% level, it was conspicuous compared to the minor variations at stations 1 and 2. This feature together with lower energy levels and an increased slope at lower wave numbers at station 3 indicates that compared to stations 1 and 2 there can be some difference in the processes responsible for fine structure at station 3, situated further east from the mouth of Persian Gulf. Stations 1 and 2 had similar spectral structures, inspite of the variability observed in the individual traces.

The perturbation series are not homogeneous in amplitude (Fig. 1b). However, with this coarse sampling interval (10 m) it is not possible to divide the depth interval into homogeneous regions. Thus the reliability of determinations is not sufficient to attribute the results to any process in particular. A detailed study of different homogenous regions in the vertical together with current measurements is very much needed to ascertain the processes as the transfer of passive fields like temperature and salinity can be different from the momentum transfer.

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References

- 1 Varma K K & Gangadhara Rao L V *Indian J mar Sci* 7 (1978) 79.
- 2 Roden G I J *phys Oceanogr* 1 (1971) 25.
- 3 Pochapsky T E & Malone F D J *phys Oceanogr* 2 (1972) 470.
- 4 Seidler G *Deep Sea Res* 21 (1974) 37.
- 5 Miropolskiy Yu Z & Neyman V G *Bull Acad Sci USSR Atmos Ocean Phys* 10 (1974) 730 (English).
- 6 Hayes S P, Joyce T M & Millar R C J *geophys Res* 80 (1975) 314.
- 7 Gregg M C J *phys Oceanogr* 7 (1977) 33.
- 8 Halloway J L in *Advances in Geophysics* Vol 4 (Academic press New York) 1958 459 pp.
- 9 Blackman R B & Tucky J W *The measurement of power spectra* (Dover Publications Inc New York) 1958 190 pp.
- 10 Phillips O M *The dynamics of the upper ocean* (Cambridge University Press) 1966 261 pp.
- 11 Pochapsky T E J *phys Oceanogr* 2 (1972) 96.

Clay Input from the Red Sediments of Visakhapatnam Coast

A T RAO & C V RAMAN

Department of Geology, Andhra University, Waltair 530 003

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Red sediments of recent age are commonly seen in association with the khondalite hill ranges and also found towards the coast in Visakhapatnam district. These red sediments comprise sand (quartz + heavies), silt and clay. X-ray data on clays reveal that kaolinite (70-94%) and illite (6-22%) are the dominant types in the red sediments. Smectite and chlorite are rare. Variation of clay mineral percentages in the red sediments is due to varying amounts of altered detrital sillimanite and orthoclase derived from the khondalites. The clays from the inner shelf have considerable proportion of illite and kaolinite along Visakhapatnam coast, which indicates that the fluvial input of clays from the red sediments and lateritic soils is significant.

Red sediments are prominent between the coast and the nearby khondalite hill ranges between Visakhapatnam and Bhimunipatnam. They are also found filling the valleys and resting on the slopes of hill ranges in the interior. These sediments are made of sand (quartz and heavies mainly magnetite, ilmenite, garnet, sillimanite and zircon) and ferruginous silt and clay. The sediments (Fig. 1) are of Recent age and their khondalite parentage is established in the light of statistical studies of zircons¹.

In the present investigation, influence of input of clays from red lateritic sediments and soils to the offshore region is studied based on the composition of clays and the formation of clays from the source minerals in the rocks.

Clays of $< 2 \mu$ are separated from red sediments and X-rayed using Norelco X-ray diffractometer (Cu K α