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Research letters / Navorsingsberigte

Unique thermal record in False Bay

Over the past decade False Bay has assumed a prime position in terms of research into large South African bays. This is manifested by investigations that cover flow conditions,[1–5] modelling,[6,7] thermal structure,[8–10] management,[11] biology and nutrients,[12,13] geology,[14] local meteorology,[15–17] beaches,[18] birds,[19] air and marine pollution,[20–23] recreation,[24,25] and demography.[10] To enhance our grasp of the Bay's functioning as a marine entity, its variability, circulation, structure and exchange processes, a number of current-meter and water-level moorings were deployed in September 1989. To augment the analysis, hourly wind records at D.F. Malan Airport and daily surf temperatures at Muizenberg and Gordon's Bay were obtained.

Unplanned release of the moorings and resulting damage to the equipment jeopardized most of the planned objectives of the experiment. The information on currents derived from the moorings will be reported separately. However, one of the moorings (Fig. 1), with a current meter at 28-m depth, remained deployed for about 2.5 years before it eventually broke free and was recovered. This provided a unique, albeit intermittent, time series of temperature measured at 30-min intervals, of about 1.5 years' duration (until the available memory was exhausted in January, 1991). Only this data set, smoothed with a five-point running mean, as well as the supporting wind data, will be presented. The temperature data suggest that marine growth had somewhat insulated the temperature probe from the seawater towards the end of the recording period (this was confirmed by visual inspection after recovery), causing a decrease in the response of the sensor to rapid changes in temperature.

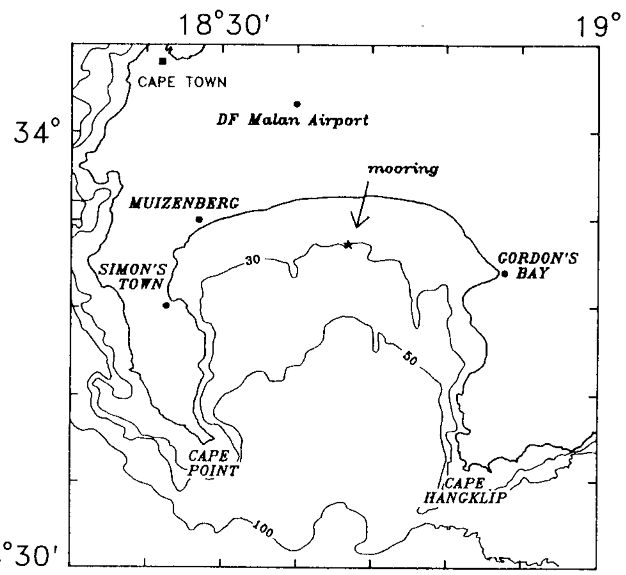

Fig. 1. Chart of False Bay with bottom topography (in metres) and the position of the current-meter mooring deployed in the northern part of the Bay in September 1989. Surf temperatures were obtained at Gordon's Bay and Muizenberg, while wind velocity was measured at D.F. Malan Airport.

The nature of the data precluded extensive analysis and this presentation will be brief and largely anecdotal. Nevertheless, it is believed that some useful results of the stratification emerged from the data. The results also support the feasibility and usefulness of a long-term monitoring station in the Bay.

Seasonal variations

The time series of sea-surface temperature (SST) from Gordon's Bay and Muizenberg (Fig. 2) revealed a distinct seasonal variation. Maxima of about 18–19°C were repeated in the summers of 1989/90 and 1990/91, as were the minima around 13°C. The latter seems to have been reached in mid

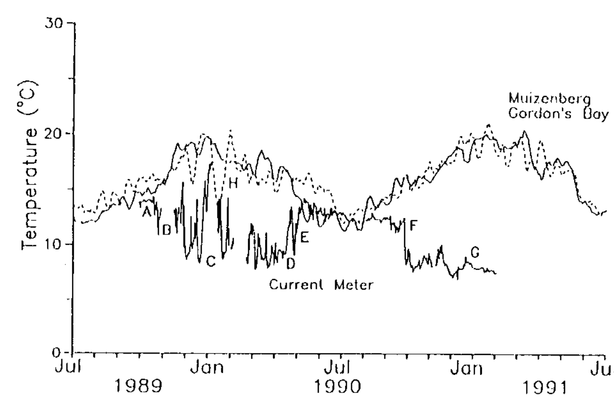

Fig. 2. Variation of surf temperatures from Gordon's Bay (dashes) and Muizenberg (line), and a smoothed record of current-meter temperature at 28-m depth. Indices A–H are referred to in the text. Tics on the x-axis indicate the first day of the month.

July. The mutual agreement of the temperatures at the two locations on a seasonal and longer time scale strongly suggests that they accurately reflect the temperature of the upper layer of the northern part of the Bay and at the mooring site on these time scales. Although these measurements are provided mainly for reference purposes, they contain information on infra-seasonal time scales that may be of interest. This is addressed below in the section on wind forcing.

The steadiness of the subsurface temperature trace for the first 2 weeks of the deployment (Fig. 2, A), coupled with the agreement between this temperature and the SST, suggest that the water column was still reflecting much of winter's mixed character, in agreement with previous observations[2] that the thermocline is initiated only towards early summer.

Towards the end of October 1989, the subsurface temperature started fluctuating unevenly between 14°C and about 11°C (Fig. 2, B), suggesting the first signs of stratification. The upper-layer temperature had been rising since July and was about 16°C at this time. The range of the subsurface temperature variability increased and, during December 1989 and January 1990, temperatures varied between 16 and 8°C (Fig. 2, C). The top-to-bottom temperature difference of more than 10°C was interpreted as evidence of a well-developed thermocline, although its onset occurred a month earlier than previous observations[2] of this phenomenon (late December).

The stratification was maintained up to the end of April 1991 (Fig. 2, D), with the temperature of the lower layer attaining a minimum of about 8°C in March. Although the variance of the subsurface temperature was much smaller in April/March than in December and January, the stability suggested that the lower layer was fairly isothermal. In addition the significant inter-layer temperature difference suggested that the thermocline was in a stable location above the depth of the current meter.

Towards the end of April 1990, the subsurface temperature increased to 14°C (Fig. 2, E), whereas the amplitude of fluctuations decreased. This seems to indicate the start of the winter condition of greater mixing with a top-down increase in temperature. The subsurface temperature and that of the coastal stations agreed closely, confirming the uniform temperature of the water column, while the absolute level of the temperature suggests that vertical, local mixing of the water column occurred.

During the progression of winter 1990 the subsurface temperature decreased slowly and steadily (Fig. 2, E and F), probably through downward equalization of the continuous heat loss to the atmosphere. A situation where the water column was fully mixed was attained between May and August when SST and subsurface temperatures reached 13°C. By the end of September the temperature attained 12–13°C, while the SST, which had started increasing since its minimum in mid-July, reached about 15–16°C.

On 22 September 1990 a sudden and significant decrease of about 4°C in subsurface temperature occurred (Fig. 2, F). This was interpreted as the front-like inflow of colder bottom water[2] reaching the location of the instrument and the corresponding introduction of a stratified structure (in the previous year the thermocline was established in late November). The location of the current meter may have played a significant role in the appearance of this phenomenon. Present data suggest that the surface temperature, coinciding with the start and finish of stratification, is about 15–16°C. A level of about 8°C (Fig. 2, G) was maintained throughout summer until the recording terminated on 29 January 1991. The timing and intensity of the stratification in the summers of 1989/90 and 1990/91 varied, stratification starting later in 1990/91 but with a sharper drop in temperature. No fluctuations similar to those which were observed in the previous summer, were recorded in summer 1990/91, suggesting that the thermocline was more steady and located shallower than the current meter.

In summary, it was especially the absolute levels of the surface and subsurface temperatures, as well as the stability of the subsurface temperatures, that led to conclusions concerning the layered character of the water column. It is suggested that the Bay represents a two-layer system in summer, with the upper and lower layers experiencing temperatures of 13–19°C and 13–8°C, respectively.

Wind forcing

It has been shown that the wind at D.F. Malan Airport and that over the central Bay are fairly well correlated, the wind speed being lower at the Airport. During wind conditions when orographic steering plays a major role, such as in the presence of shallow south-easterly or north-westerly wind,[2,16,17] the correlation of speed and direction between the Airport and (especially) eastern coastal stations such as Gordon's Bay may be poor.

The temperature recorded by the current meter towards the end of January 1990 showed fluctuations with a range of about 6°C, preceded by several days of relative calm (Fig. 3*a*). It has been surmised above that, at this time, the current meter was situated within the lower layer during the period of intense summer stratification (Fig. 2) and that warm anomalies such as these could have been caused by the vertical displacement of the thermocline.

Inspection of the wind for the period between 20 and 28 January (Fig. 3*b* and *c*) shows a remarkable domination of diurnal variations (mostly in speed, while the direction stayed southerly). The steadiness of the direction suggests that the circadian land–sea breeze, with an amplitude of about 4 m s^{-1}, was superimposed on a more steady southerly wind.[2,17] The speed of the latter component increased from about 4 m s^{-1} on 19 January to about 10 m s^{-1} on 24 January (see Fig. 3*b*).

The temperature peaks between 23 and 26 January were in phase with variations in the southerly wind speed. It seems reasonable that the continuous southerly wind component resulted in an influx of warm water into the Bay, which

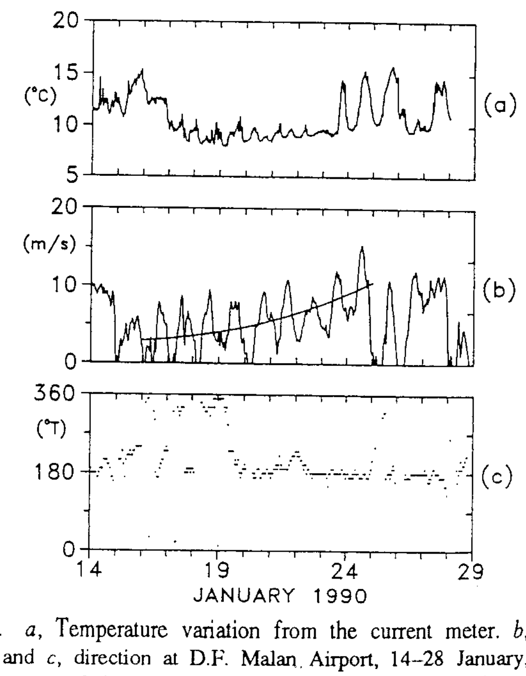

Fig. 3. *a*, Temperature variation from the current meter. *b*, Wind speed and *c*, direction at D.F. Malan Airport, 14–28 January, 1990. The increase of the mean wind speed between 15 and 25 January is indicated in *b*. Tics on the x-axis indicate the start of the day.

steadily depressed the thermocline in the northern part of the Bay, in agreement with previous observations.[2,10] The additional, diurnal or inertial fluctuation in speed might have depressed the thermocline below the current meter, leading to occasional increases in recorded temperature. A rough calculation shows that a 12-m s^{-1} wind, blowing for 6 hours, could transport a sufficient amount of warm water into the Bay, which, if recirculated vertically, could depress the thermocline in the northern half of the Bay by about 10 m. This response to wind forcing is in line with previous reports.[2,10,26]

Comparison of the subsurface and sea-surface temperatures (Fig. 2) provides additional insight into the behaviour of the thermocline: If the arguments above hold, the thermocline was depressed in the central, northern part of the Bay during the influx of warm, surface water into the Bay. It is reasonable to assume that the downwelling also extended to the north-western parts of the Bay, and this is supported by the temperature at Muizenberg, which remained high at this time (Fig. 2, H). However, the wind conditions prevailing at the time would also have caused a degree of upwelling in the Gordon's Bay bight. This is indeed evident from the SST records (Fig. 2, H), from which the temperature at Gordon's Bay decreased by about 4°C. The coincidence of upwelling at Gordon's Bay and downwelling at the site of the current meter would create a conspicuous zonal slope in the thermocline during these wind conditions.

Concluding remarks

Although the data set obtained from the current meter was rather fortuitous, it is believed that it illustrates the benefits of a well-placed 'reference measuring point' in the Bay. Such a station has been advocated before[9] and, if maintained over an appreciable length of time, could provide effective, long-term insight into various characteristics of the Bay. Data from such a station could judiciously be augmented by other regular measurements to enable a suitable monitoring of parameters such as the water quality. In this way, the actual or postulated pollution of the Bay can be observed on a long-term basis.

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The first record of diarrhetic shellfish poisoning on the South African coast

Diarrhetic shellfish poisoning (DSP) was identified on the west coast of South Africa during the autumn of 1991 and on both the west and south coasts during the autumn of 1992. Testing for DSP was conducted subsequent to reports of human illness following the consumption of mussels. Two methods of detection of DSP were considered: a commercially available immunoassay test kit and a mouse bioassay. The causative organism was identified as the dinoflagellate *Dinophysis acuminata* Claparède & Lachmann. The study highlights the necessity of initiating routine monitoring for DSP off the South African coast.

Background

DSP has been recognized in many parts of the world since it was first identified in 1978.[1] The symptoms include diarrhoea (92%), nausea (80%), vomiting (79%), abdominal pain (53%) and chill (10%). Approximately 70% of patients develop symptoms within 4 hours and suffering may last up to 3 days.[2] It is likely that DSP has gone unreported on many occasions due to both the relatively mild nature of the symptoms and the similarity of the symptoms with gastroenteritis associated with the consumption of polluted shellfish.