Observation of internal waves in the middle Adriatic Sea

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From 13 to 30 August 1990 Aanderaa thermistor chain TR-7 and two current meters RCM 7 were moored near Lastovo island in the Middle Adriatic Sea at station L-4 (φ = 42° 45.2' N, λ = 17° 08.8'E d = 95 m). Thermistors were at 15, 21, 27, 33, 39, 45, 51, 57, 63, 69 and 75m depth, while current meters at 10 and 80 m. Measurement interval was 5 minutes.

Vertical profiles of temperature, density and Brunt-Vaisala frequency obtained from CTD measurement at the beginning of the measurement period are shown in Fig. 1. A strong thermocline was present between 12 and 22 m as well as pycnocline and Brunt-Vaisala frequency peak. These experimental data are similar to the theoretical assumptions done for discussion of internal waves at the boundary between two fluids of different density (MUNK, 1981). During the measurement period two strong wind episodes were recorded (the first lasting about a day and the second about 3 days).

Power spectra calculated from temperature and current data indicated high internal wave dynamics. Temperature sensor at 10 m depth was for the first 10 days near the top of the thermocline and then, owing to the lowering of the thermocline, in the mixed layer. Wind force generated inertial oscillations (period 16.7 hours) so that the peak at inertial frequency dominated in temperature power spectrum. Furthermore, there are peaks at 9.9, 6.4, 4.7 and 4.2 hour periods of the same order of energy. Approaching from 4.2 hours period to Brunt-Vaisala period the energy of the oscillations becomes significantly smaller.

Similar spectrum shape was obtained for 21 m depth (in the middle of thermocline). Important difference occurred only at inertial frequency where energy at 21 m depth is about ten times higher than at 10 m. At the bottom of the thermocline (33 m), a tidal peak (24 hours) was observed with other peaks. Magnitude of tidal energy is near the inertial one. The shapes of the spectra from 33 m to the bottom were similar to the spectrum at 33 m depth, but with smaller energy. At 45 m depth tidal energy exceeds the inertial one.

Comparing current spectrum at 10 m depth with theoretical Garrett-Munk spectrum (1972, 1975) for deep ocean, the similarity can be seen i.e. experimental spectrum follows ω^{-2} slope for internal wave frequency band (ω is frequency). The higher discrepancy between theoretical and experimental spectra was detected in low internal wave frequency band (periods between 16.7 hours and 4 hours) what can be explained by near-surface proximity of strong sources of internal waves, especially winds and surface waves (ROTH *et al.*, 1981).

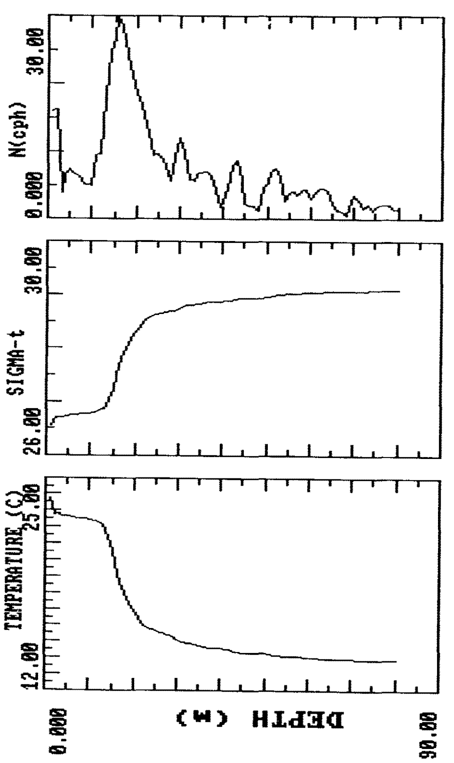

FIG. 1. Vertical profile of temperature, density and Brunt-Vaisala frequency N on August 13, 1990, station L-4.

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On Subinertial Response of the Sea to the Air-Pressure Forcing

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Relationship between subinertial variability of the Adriatic sea level and planetary-scale atmospheric forcing was demonstrated by ORLIC (1983). From high values of coherence squared between sea-level and geopotential height of the 500 mb surface in the low-frequency band (0.1 - 0.01 cpd.), it was concluded that the atmosphere and sea may be approximated by a constant-parameter linear system. In most simulations of response of the Mediterranean Sea to the air-pressure forcing, the modeling area was split in two basins with variables spatially averaged within each of them (e.g. CANDELA *et al.*, 1989). In order to probe dynamics of subinertial atmosphere-sea interaction further, a model of barotropic response of the sea in a channel to travelling air-pressure waves is developed.

Linearized depth-averaged equations of motion and continuity are used to simulate frictionless flow in the f-plane flat-bottom channel. Analytical solution is found for subinertial frequencies (MALACIC and ORLIC, 1992). For the atmospheric wave travelling along the channel whose width is close to the Rossby radius of deformation, model predicts sea levels and currents organized in two coastal waves and geostrophic system in mid-channel (Fig.1). The structure is coupled to the atmospheric wave. The right-hand coastal wave is moving in the direction of the free Kelvin wave, therefore is more pronounced than the left-hand wave. The motion is resonantly driven when phase velocity of the forcing wave approaches Kelvin-wave velocity.

When the atmospheric wave is moving across the channel at a sharp angle, response of the sea is enhanced for phase velocities below those of free shallow-water waves, due to reflections at channel boundaries. For the atmospheric wave that travels at right angle across the channel, resonance is not possible, and sea level undershoots inverted-barometer response. Now, both travelling and standing waves appear in the channel. In the narrow channel limit only standing wave remains, with nodal line in the middle of the channel.

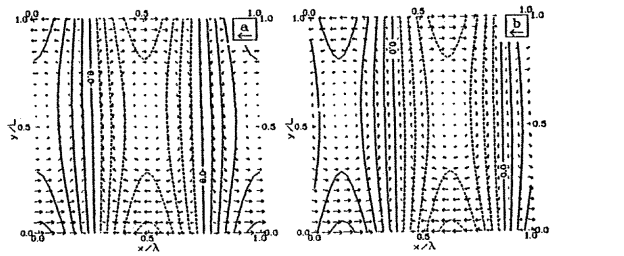

Fig. 1. Elevation contours and velocity distributions for the along channel forcing. The channel width equals $2Ro$ (Ro = Rossby radius of deformation), the channel depth amounts to 10^3m. The atmospheric wave of wavenumber $K = Ro^{-1}$ and angular frequency $\Omega = 0.1\ f$ (f = Coriolis frequency) is moving from the left towards the right sides of plots. Maps are for two instants a quarter of period apart. Solid lines represent positive elevations, while dashed are negative elevations. Contouring interval is interval is 0.2 ξ_0 where ξ_0 - amplitude of the atmospheric wave in sea-level units - equals 10 cm. The velocity scale of ~ 1 cm/s is shown in the frame within each map.

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