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Current measurements on the continental slope west of Norway in an area with a pronounced two-layer density profile

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Abstract

Data from field measurements of current velocity and water temperature close to the sea bed on the continental slope west of Norway are presented and discussed. Several strong current flow events were found in the data. These were associated with gradually increasing water temperature and a down-slope flow, followed by a rapid temperature drop and then a strong up-slope flow. The current meters were located close to the interface between the Atlantic inflow to the Norwegian Sea and the Norwegian Sea Arctic Intermediate Water, and it is proposed that the strong current events are linked to the pycnocline between these water masses and its interaction with the continental slope. Downwelling favourable winds, causing steepening of the isopycnals at the slope, are a possible driving mechanism for the strong current events. Hindcast data of wind velocity on the sea surface in the area of the measurements provide some support for this theory.

The sampling frequency for the current meters was 1 Hz. A detailed study of the high-frequency structure of the current flow, during an event which captured the transition from down-slope flow to up-slope flow, shows that the up-slope flow starts near the sea bed before it extends further up into the boundary layer. It was also found that the velocity shear can be very strong during this type of events.

Evidence of vortex-induced oscillations of the current meter moorings during strong current events was found in the data.

Keywords: Current data; Continental slope; Benthic boundary layer; Strong current events; Atmosphere–ocean interaction

1. Introduction

The current flow on continental slopes, or other sloping boundaries in the ocean, is often highly variable and dominated by strong turbulence. It is therefore important for the energy budget of the

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global circulation in the world oceans and of great interest for the design and planning of marine structures to be placed or operated in such environments. Huthnance (1995) gives a comprehensive review of physical processes on ocean margins.

Large-scale ocean circulation is governed by many factors. Two such factors are wind and bottom topography. Whereas topographic steering of the large-scale circulation is a feature of large-scale bottom topography, it is also clear that the small-scale bottom topography has an effect on the large- and small-scale circulation (Berntsen and Furnes, 2002). Likewise, wind is one of the factors driving the large-scale global ocean circulation (Sverdrup, 1947; Veronis, 1973), but it is also responsible for features on smaller scales such as up- and downwelling (Yoshida, 1955) and the generation of shelf waves (Adams and Buchwald, 1969). A simple analytical model of wind forced displacements of the thermocline at a continental shelf edge was established by Csanady (1973), but numerical models are generally needed close to the shelf break and near the sea bed due to the importance of nonlinearities such as e.g. bottom topography and large motions of the thermocline. A dynamic surface wind field at or near the continental margin may, depending upon latitude, wind field properties and shelf area geometry, set up shelf wave oscillations, near-inertial oscillations and long baroclinic wave modes (Gjevik, 1991). Numerical simulations by Vikebø et al. (2004) indicate that the current flow near the sea bed on a continental slope is highly influenced by the surface winds.

In this paper, we study the possible connection between strong current events near the sea bed on a continental slope and the wind conditions at the surface. Measurements of current flow and water temperature close to the sea bed on the continental slope west of Norway (Fig. 1) are presented and discussed.

2. Flow measurements

Data were logged at four stations at a water depth of approximately 680 m, see Fig. 1. The logging stations were located on the slope from the continental shelf to the deep ocean in an area where the bottom topography is quite irregular as a result of the Storegga underwater slide which took place some 8000 years ago.

Exact positions for the logging stations, distribution of current meters with depth and details of measurement periods can be found in Table 1. The positioning of the current meter moorings was assisted by remote-operated vehicles (ROVs), normally used for sub-sea operations related to the offshore oil and gas industry.

Smoothed hydrographic profiles, recorded at a nearby section across the shelf slope in February and April of the year 2000, are shown in Fig. 2. These profiles provide a conceptual view of the stratification in the area. The vertical stratification below 200 m exhibits a two-layer structure with a deep pycnocline at a depth of about 500 m. The thin surface layer is water of coastal/shelf origin. Below this is the Atlantic inflow to the Norwegian Sea (the Norwegian Atlantic current). Its lower interface is located at a depth of between (roughly) 400 and 700 m. The water mass in the layer below the Atlantic water is the Norwegian Sea Arctic Intermediate Water. See Hansen and Østerhus (2000) and Orvik and Niiler (2002), and references therein, for a review of water masses and currents in the Nordic Seas.

A set of Nortek Aquadopp current meters were used for logging time, flow velocity components, pressure and temperature. These current meters use Doppler technology in order to determine the current velocity in three orthogonal directions (zonal, meridional and vertical). The current meters were mounted on moorings as shown in Fig. 3. The motions of the moorings are small (1.5 m maximum horizontal displacement of upper buoyancy element and a downdraught of 0.05 m), but there is evidence that the mooring systems sometimes oscillate as a result of vortex shedding from the buoyancy elements. Eigenvalue and spectral analysis indicate that the mooring systems oscillate at a frequency of 0.06 Hz. A more detailed exposition of current meter mooring motions can be found in Appendix A.

The sampling rate of the current meters was 1 Hz. The accuracy of the current measurements is