SEASONAL VARIABILITY AND INTERANNUAL VARIATIONS OF THE UPPER MIXED LAYER IN THE WESTERN BLACK SEA

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Abstract

Seasonal variability and interannual variations of the upper mixed layer in the western Black sea were studied from underway high-resolution near-surface temperature and salinity data along 165 occupations of the Odessa-Istanbul transect in 1998-2000. Measured every 3 s at a depth of 2-3 m, these data are representative of the entire upper mixed layer. The seasonal cycle of T and S was resolved as well as spatial differences between the Northwest Shelf and deep western Black Sea basin. Substantial year-to-year variations are noted from these data and compared with long-term mean climatological data.

Keywords : Black Sea, Temperature, Salinity, Surface Waters, Fronts.

Air-sea interaction over the northwest Black Sea is vigorous and results in strong seasonal variability of the upper mixed layer (UML), whose long-term mean annual T/S ranges are, respectively, 2 to 23°C and 13 to 18. The northwest Black Sea also features strong spatial gradients between the shallow Northwest Shelf and the deep basin. To resolve large temporal and spatial gradients in the northwest Black Sea, frequent high-resolution repeat observations of the UML characteristics (T and S) were made from R/V Georgy Ushakov (UkrSCES) along a standard quasi-meridional transect between Odessa (∼46.3N) and Istanbul (∼41.3N). During 165 occupations of this transect in 1998-2000, T and S were continuously measured underway by a stationary shipboard throughflow thermosalinograph linked to a PC, with TS-sensors installed in the main engine's water intake system at a depth of 2-3 m. The UML's T and S at this depth are representative of the entire UML. The throughflow system has low thermal inertia/fast response time, thus allowing frequent sampling (every 3 s) of the UML characteristics. Under a typical cruising speed of 10-12 knots, the 3 s sampling rate translates into a horizontal resolution of ∼15 m, which allows meso- and small-scale fronts and eddies to be resolved.

The Odessa-Istanbul transect extends across two different oceanographic zones - the NW Shelf (NWS) and the deep basin. The NWS is subject to strong winter cooling, when T(UML) drops to 1-2°C, whereas farther south minimum winter T(UML) is fairly constant, 6-7°C, along the Odessa-Istanbul transect. Timing of maximum winter cooling of the NWS varies interannually from mid-December to late January-early February. South of the NWS, maximum winter cooling occurs later, typically in mid-February. Spring warming begins almost simultaneously between 46N and 41N and can be quite abrupt, especially in late May-early June, when T(UML) increases from 15°C to 21°C in just two weeks, with a maximum rate exceeding 0.5°C /day. Summer warming is spatially uniform as T(UML) peaks at about the same time between 46N-41N. From long-term mean climatological data, T(UML) has a single maximum, in mid-August. The Odessa-Istanbul transect data revealed a much more complicated pattern of seasonal variability of T(UML), particularly with regard to timing and number of summer maximums. Indeed, the Odessa-Istanbul transect data show up to three or even four maximums of T(UML), with the first maximum as early as June (in 1998), and the latest maximum in August. Autumn cooling progresses from north to south, although the north-south time lag between 46N-41N is relatively small, 1-2 weeks. The Odessa-Istanbul transect data revealed a discontinuous nature of autumn cooling in 2000, when T(UML) dropped from 26°C to 15°C in three well-defined steps, particularly noticeable in the southern part of the study area. These rapid cooling events were likely related to synoptic atmospheric events such as frontal passages.

Salinity regime of the NWS largely depends on freshwater discharge of three major rivers: Danube, Dnieper, and Dniester. Timing and extent of spring freshets varies interannually. From long-term mean climatological data, S(UML) drops below 13 north of 46N in April. This freshening gradually spreads south, down to 44.5N in May-June. From the Odessa-Istanbul transect data, the 1998 spring freshet's influence was small and short-lived, whereas spring freshets in 1999 and 2000 were much more extensive in time and space. The Dnieper spring freshet waters (S<14) reach the Odessa-Istanbul transect in late March and remained there through mid-May. The Danube spring freshet waters (S<15) reach the Odessa-Istanbul transect in mid-May, about six weeks later than the Dnieper spring freshet waters, and remained there until late June. In the southern part of the study area, over the deep sea basin, salinity is hardly affected by river runoff and therefore varies within a relatively narrow annual range, between 17-18, rarely exceeding 18.2-18.3 psu. In summer 1999 and spring 2000, local salinity maxima were observed over the southern part of the transect, with S(UML)=18.2-18.3, that slowly drifted douthward. These moving salinity maxima likely corresponded to meso-scale cyclonic eddies that were advected along the Odessa-Istanbul transect by the large-scale circulation of the Black Sea.

Underway continuous measurements of the UML characteristics allowed correlation between T and S to be studied. The sign and the nature of this correlation changes with season and location. Over the NWS in spring, TS-correlation is negative. In summer (July-August) TS-correlation is weak and variable. In autumn and spring, TS-correlation is strong and positive, up to +0.97. Spatial scales of TS-variability over the NWS (30-50 miles) are determined largely by river runoff accumulation from Danube, Dnieper and Dniester. Smaller spatial scales, down to 8-10 miles, are common over shelf areas and are probably caused by sub-mesoscale surface-intensified eddies.

The Odessa-Istanbul transect data also contain valuable information on a front over the mid-NWS, previously studied from satellite sea surface temperature (SST) data [1]. This front is strongest in winter when it has repeatedly been crossed by the Odessa-Istanbul transect near 44.5N, with cross-frontal steps of up to 3°C and 1 in salinity. We are presently investigating this front from both the Odessa-Istanbul in situ data and satellite SST frontal data archive assembled at the University of Rhode Island.

Reference

Belkin I.M. et al. 2006. Mid-shelf oceanic front in the northwest Black Sea, in preparation.