COMBINED DIRECT AND REMOTE SENSING MEASUREMENTS OF AIR-SEA INTERACTION PARAMETERS DURING THE TEMPERATURE FRONT PASSAGE

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1. INTRODUCTION

The paper presents some results of the experiment CAPMOS’05 performed on an offshore oceanographic platform in the Black Sea in June 2005. The experiment aimed at investigations of air-sea coupling by means of direct and remote measurements was carried out in frames of the INTAS (International Association for the promotion of co-operation with scientists from the New Independent States of the former Soviet Union) project “Combined Active / Passive Microwave Measurements of Wind Waves for Global Ocean Salinity Monitoring (CAPMOS)”. The project joined several research teams from Russia, Ukraine, Denmark and Italy experienced in experimental study of ocean and atmosphere. One of the goals of the experiment was to compare the results of synchronous direct and remote measurements of ocean-atmosphere coupling parameters.

A specialized research platform managed by the Marine Hydrophysical Institute is located approximately 600 m to the south of Crimea coast near Katsiveli, Ukraine. A water depth at the site was about 30 meters that ensures the deep water and long fetch conditions for the waves caused by prevailing winds from the east-south-west sector. This paper is focused on the sea-atmosphere interaction quantitatively described by the substance and energy fluxes across the air-sea interface. These fluxes are known to show strong variability on spatial and temporal scales. We consider local evolution of the fluxes on the short-term scales (several hours to several days) caused by the event of the sea temperature front. These small-scale features caused by fronts, storms, etc. are usually smoothed and got lost during averaging over synoptic scales. However, they make considerable contribution on the whole mass and energy balance between ocean and atmosphere. Also, they are of particular interest when the detailed mechanisms of the sea-atmosphere interaction are being considered.

In the following sections the instruments and techniques for the oceanography and meteorological measurements during CAPMOS'05 experiment are described, and the experimental results of air-sea coupling measurements during the temperature front passage are presented.

2. INSTRUMENTS AND METHODS

The atmosphere parameters were measured by three meteorological stations installed at 1.5, 21.5 and 4 m above the mean sea level. The stations included 3-component sonic anemometers, air temperature and humidity sensors. The first two stations provided sampling frequency of 3 Hz, whereas the latter one measured wind vector and air temperature fluctuations at a frequency of 20 Hz. These high frequency measurements, together with water vapor and CO_2 concentration also sampled at 20 Hz, were applied for retrieval the heat, momentum and substance fluxes in the atmosphere boundary layer.

To retrieve the turbulent fluxes from micrometeorological measurements, the eddy-covariance technique was used [1, 2]. This direct method of the fluxes measurements does not require any corrections for the boundary layer stability, in contrast to often used bulk formulas approach (e.g. see [3, 4]). On the other hand, it requires relatively high sampling frequency (over 10 Hz as a rule) and precise measurements of the temperature and velocity components fluctuations with a fixed (in an ideal case readily provided during the measurements on a platform) sensors.

The atmosphere parameters like water vapor concentration q, CO_2 concentration c, temperature T, wind velocity components u, v, w are measured at a sampling frequency of 20 Hz, and further the fluctuating component of the measured value is separated: $s' = s - \overline{s}$, where s is any measured parameter, $\overline{s}$ is the mean component, s' is the fluctuating component. The respective fluxes in the boundary layer are further computed from covariance of the fluctuating components:

$$\tau = \rho_0 \left[\overline{u'w'}^2 + \overline{v'w'}^2 \right]^{1/2} = \rho_0 u_*^2 \tag{1}$$

$$H = c_p \rho_0 \overline{w'T'} \tag{2}$$

$$L_E = \rho_0 \overline{w'q'} L_s \tag{3}$$

$$F_{CO_2} = \overline{w'c'} \tag{4}$$

where τ is momentum flux, H is sensible heat flux, L_E is latent heat flux, F_{CO_2} is carbon dioxide flux, ρ_0 is air density, c_p is air specific heat, L_S is specific heat of evaporation. The sign of a flux is considered as positive if it is directed from air-sea interface toward atmosphere. To get the statistically valid results, the measurements were averaged over 20…40 min. For computation of CO_2 and water vapor fluxes we have used gas dynamics classical equations (flux = convective transfer + eddy transfer). The mean vertical wind velocity was computed on basis of Webb-approach [5].

Direct measurements of sea and atmosphere parameters were accompanied by remote sensing measurements performed with a set of microwave and infrared (IR) radiometers. The radiometers were mounted on an automatic rotator that provided scanning from nadir up to zenith so as sea-surface and atmosphere brightness temperature was registered at various angles and frequency bands.

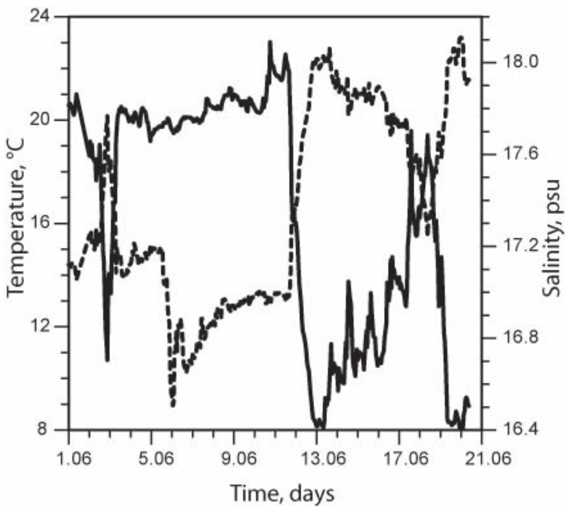

Figure 1. Sea surface temperature (solid line) and salinity (dashed line) during the experiment

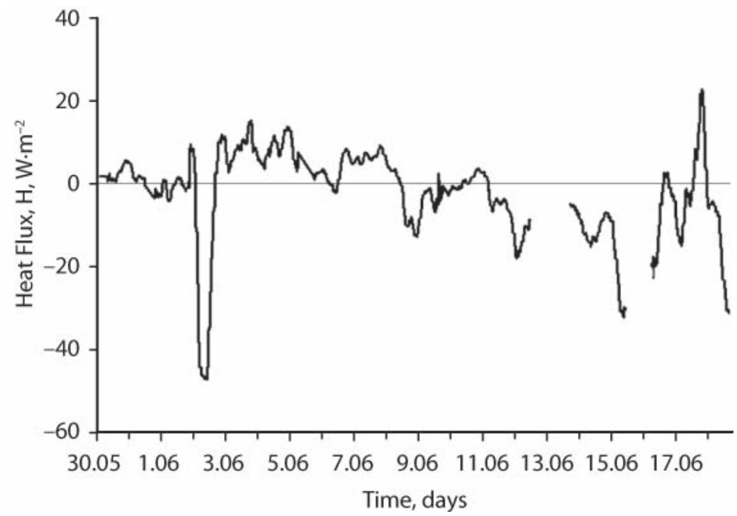

Figure 2. Sensible heat flux during the experiment

3. EXPERIMENTAL RESULTS

The measurements on a platform were carried out continuously 24 h/day from June 2 to June 20, 2005. During the experiment, two episodes of upwelling with abrupt changes of surface temperature and salinity were observed. These conditions provided an opportunity to study various processes in the ocean and atmosphere boundary layers.

Figure 1 shows water temperature and salinity evolution throughout the experiment. First upwelling on the 2nd of June was caused by strong steady northern wind with a speed reaching 25 m/s. During 9 h, the temperature at the sea surface decreased by 8.3 °C, and salinity increased by 0.56 psu. Vertical profiles of water temperature and salinity during this event demonstrated upward shift of thermocline by 12 m. Velocity of the thermocline ascent was $4.6 \cdot 10^{-2}$ cm/s. This upwelling affected the limited area of a coastal zone. The spatial pattern of the upwelling was evident at satellite IR images. However, since the measurements on a platform were carried out in a single point, this phenomenon looked like a temperature front passage across the measurement site.

Second upwelling (on June 11–20, 2005) was relatively long lasting. It was caused by a steady western wind. According to existing concept, such upwelling is defined as an Ekman coastal upwelling. During this upwelling, the surface temperature at the site decreased by 14.3 °C, and salinity increased by 1.25 psu.

Figure 2 shows the sensible heat flux evolution during the experiment calculated from micrometeorological measurements in accordance with (2). As the temperature front is passing across the platform, the flux changes its sign becoming negative and reaches 50 $W \cdot m^{-2}$. Radiometer measurements provide information about surface temperature, which defines the sensible heat flux and may differ from bulk temperature in case of low winds.

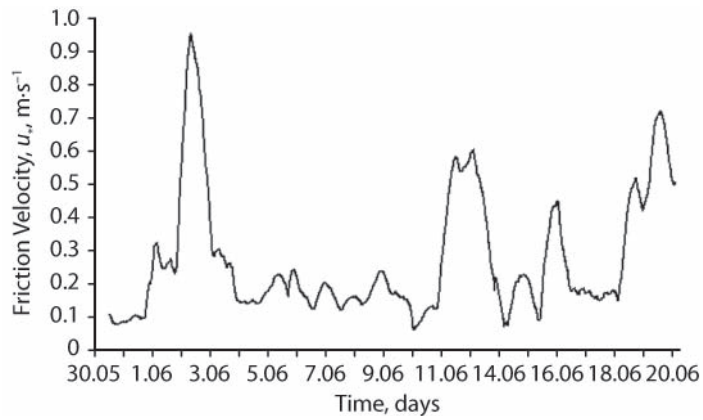

Figure 3. Friction velocity during the experiment

Figure 3 shows the evolution of friction velocity u_* during the experiment. Friction velocity characterizes the momentum exchange between atmosphere and ocean. We observed maximum u_* values during the temperature front passing and we associate these increases of friction velocity with strong wind (first case) and with increasing exchange processes (second case).

4. CONCLUSIONS

- Our measurements demonstrated that interaction processes in the atmospheric boundary layer substantially depend on the sea surface structure, which, in turn, transfers the information from processes in a deep sea.
- In case of weak winds and small waves the ocean-atmosphere heat exchange becomes an important factor affecting turbulence in the upper water layer. After reverse the heat flux direction, periodic oscillations of heat and momentum fluxes were observed in the atmosphere. These changes were accompanied by the varying intensity of oceanic turbulence.

5. REFERENCES

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