MONITORING THE FLOW AND THE PHYSICAL PROPERTIES OF A SUBMARINE GROUNDWATER DISCHARGE IN MESSINIAKOS GULF (SOUTHERN GREECE).

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Abstract
We present the first obtained time series of a monitoring project studying a submarine groundwater discharge (SGD) in Kalogria Bay, Greece. During a previous survey in the area, salinities ~1-2 were detected. The emerging flow and the physical characteristics of the upwelling water are recorded by means of a rotor flow meter and a CT probe. Both were deployed on a metallic frame which was placed at the sea bottom inside a karstic cavity. Salinity values between 20 and 36 have been recorded, indicating a brackish water outflow during the dry season of the year (July-October 2009). The water outflow exhibited velocities ranging from 8 to 28 cm/sec.
Keywords: Salinity, Monitoring, Brackish Water, Eastern Mediterranean

Submarine groundwater discharges (SGDs) are detected in many coastal areas on a global basis and today they are recognized as important factors of land-ocean interaction, with potential socioeconomic benefits [1]. In the Mediterranean Sea, they are traced mainly along coasts with karstic structures within the inland coastal zone [2]. In December 2006, an expedition carried out on board the R/V AEGAEO of the Hellenic Centre for Marine Research, visited the eastern Messiniakos Gulf coasts around the Kalogria-Stoupa marine area (SW Peloponnissos). A CTD probe, carried by a diver inside a submarine karstic cavity, where groundwater discharged, recorded salinities ~1-2 at a water depth of ~25 m. The low salinity encouraged a monitoring project in prospect of exploitation of the discovered fresh water. In July 2009, a flow meter (model Sensordata 6000), and a conductivity-temperature (CT) recorder (model SBE-37) were deployed, attached on a stainless-steel frame close to the sea bottom inside the cavity. The instrumentation is scheduled to be recovered for

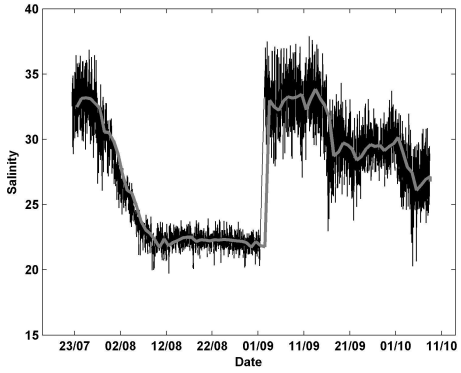

Fig. 1. Salinity fluctuation near the disharge point.

maintenance and data uploading from time to time, usually at monthly intervals. Figure 1 shows salinity variations during the first two deployments, from 22 July 2009 to 8 October 2009. The main feature observed is the relatively high salinity values, when compared against the value of salinities ~1-2, which were recorded in December 2006. Salinities fluctuate between 20 and 36, accompanied by a persistent high frequency oscillation with an amplitude range between 2 and 6. Another characteristic is that the oscillation amplitude is fluctuating proportionally with the salinity. As salinity values decrease, the oscillation amplitude is apparently reduced. We can also observe the remarkable jump in salinity values between the recovery and redeployment of the CT probe on the 1st of September (Fig. 1). This sudden rise could be primarily attributed to the very low discharge of the SGD (dry period, summer-early autumn), which results in an extremely unstable turbulent regime around the discharge point, and secondly to a possible slight different position of CT probe after the redeployment. The latter could be related to a possible rotation of the frame, and a consequent slight increase of the distance from the water discharge point. Another possible explanation could be attributed to external factors associated with the local circulation patterns. The coastal sea current may drive the upward flow and cause a declination from the vertical direction. Such persistent sea currents prevail at times in Messiniakos Gulf with their maximum speed occurring near the coastline [3]. However, still this jump remains unclear, since the temperature variation does not exhibit a similar behavior, but a normal transition between the 1st and the 2nd deployment period. Contrary to salinity, temperature follows a normal fluctuation with the highest values of 24-26 ^{o}C occurring during the last days of August. The strong turbulence also affects the temperature variation with a constant oscillation amplitude of 2-4 ^{o}C. As far as it concerns the flow measurements, the values recorded during the first few days of the deployment, they were between 20-27 cm/sec. Unfortunately, an instrument malfunction truncated the first deployment period to a total length of only 4 days (30 minutes interval). To ensure a total coverage of the deployment period during the second deployment, a pair of flow meters were installed on the frame, one at the same position as the previous, and another one exactly at the base of the frame. The latter covered the period from 2 to 15 September 2009, and the span of useful data was limited to the half of the deployment period due to a blockage of the rotor by a coarse sand grain with a diameter of 1-2 mm. During that period, upward water flow velocity ranged from 18 to 24 cm/sec, with an ascending trend during the last days of recording. In order to extend the recording period, the upper flow meter was set to take measurements at a time interval of 3 hours. This flow meter provided a useful period of flow velocity records until 30 September 2009, with velocities strongly fluctuating between 8 and 28 cm/sec. A spectral analysis performed to the flow measurements highlighted both diurnal and semidiurnal peaks of the power spectral density. This is expected, as in general the SGDs can be modulated by the prevailing tidal regime [4]. In summary, the obtained monitoring data demonstrate a strongly turbulent and unstable SGD, regulated by the geomorphologic (karstic) structure of the coastal zone and modulated by factors as the local yearly precipitation cycle and the tidal regime. Continuous monitoring of the SGD will reveal in detail, the annual cycle of the discharged water velocity, volume, and salinity variations, since they are the crucial parameters for the potential exploitation of the outflowing water. In summary, the obtained monitoring data demonstrate a strongly turbulent and unstable SGD upflow, regulated by the geomorphologic (karstic) structure of the coastal zone and modulated by factors as the local yearly precipitation cycle and the tidal regime. The monitoring of the SGD will reveal in details, the annual cycle of the upward flow and the salinity fluctuation since they are the crucial parameters for exploiting the upwelling water.

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