Using marine controlled-source electromagnetics to study potential offshore groundwater: Canterbury Basin, New Zealand

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SUMMARY

Continental shelves are the submarine edges of the continental crust and in some areas have been shown to contain freshwater aquifers beneath the seafloor. During the Quaternary, continental shelves experienced maximum exposure to meteoric water during the Last Glacial Maximum. Offshore groundwater systems are slowly adjusting toward a new equilibrium in present-day conditions as a result of rising sea-level. Information regarding the location, characteristics and dynamics of offshore groundwater systems and whether they can be used sustainably as a potential source of drinking water may be obtained by applying a range of geophysical techniques including marine controlled-source electromagnetics (CSEM) and multichannel seismics. However, the methods applied to map the extent, volume and connectivity of offshore aquifers are still in the experimental phase. One promising geophysical tool to study offshore groundwater is the CSEM method. CSEM is capable of mapping the spatial variations of saline and fresh water zones in the sub-seafloor. Currently, there are only a few studies that have successfully applied marine CSEM to quantify offshore groundwater aquifers. This study constitutes a new attempt in using CSEM to detect the offshore groundwater at large spatial scales (around 100 km).

Here we show selected results from a 300 km long CSEM line survey carried out in the Canterbury Basin along a siliclastic passive continental margin, offshore the South Island of New Zealand. The study area contains one of the farthest offshore groundwater reservoirs and was investigated during IODP Expedition 317, which provided complementary data from cores, borehole logs and geochemical pore water analyses. CSEM data were collected along 7 profiles during 9 deployments using a seafloor-towed CSEM system. Four survey lines were acquired close to IODP site U1353, an area where the inferred low-salinity zone is located at a depth of approximately 50 m beneath the seafloor. Three additional survey lines were collected outside of the region to determine the lateral extent of the groundwater aquifer(s).

Processing and inversion results of two CSEM lines are selected to examine the capability of the CSEM technique to map offshore groundwater aquifers. One line crosses U1353, and the other is shifted around 50 m NE from the IODP site U1353. 1D inversion results and 2D resistivity sections show a shallow resistive anomaly in the upper 100 meters, which is interpreted as the shallow aquifer in accordance with IODP borehole data. Comparison between IODP borehole data and the CSEM lines point towards the presence of a shallow aquifer within 100 m depth beneath the seafloor. We also show a compression of the CSEM lines with concurrent seismic lines which were acquired during the same cruise and discuss how seismic and CSEM data can best be combined for a refined data interpretation with regard to aquifer characterization.

Keywords: Marine CSEM, offshore groundwater, Canterbury Basin