Geophysical Research Abstracts
Vol. 12, EGU2010-5100, 2010
EGU General Assembly 2010

Impact of eustatic sea level changes on the salt-water fresh-water interface in coastal ground waters

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During the Holocene sea level rise has been inundating former glacial to inter-glacial deposits at the North German coast some of which are in use for municipal drinking water abstraction. Sea water intrusion into these sediments represents a serious threat to the coastal freshwater resources. To date, mechanisms and timing of salt water intrusion have not been explored. Interstitial waters from two drilling cores recovered about 3 km offshore the coastline of Northern Germany now offer the possibility of investigating the origin and possible age of the sea water intrusion. The chloride inventory shows that the sea-water fresh-water interface in the subsurface is currently not in equilibrium with the position of today´s coastline. Furthermore, the shape of the chloride depth profile suggests that at least one regression must have intermitted the Holocene transgression.
Based on these findings we conducted a transient numerical simulation to elucidate the impact of eustatic sea level changes on the salt-water fresh-water distribution within the subsurface of coastal regions. We applied a modified Henry model with an inclined surface and forced by a dynamic sea level. The results show that salt fronts in the subsurface follow the coastline during transgressions and promote a fast salinization of the model aquifer. A regression immediately leads to the freshening of surface sediments via the replacement of saline and brackish waters with meteoric waters, while flushing of deeper parts of the model aquifer with fresh-water was significantly slower. Although the coastline has moved seaward saline ground waters remained at depth because ground water velocities are slower and density-driven recirculation of sea water constantly resupplies salt water.
The results indicate that the shape of the salt-water fresh-water interface in coastal aquifers may strongly be affected by eustatic sea level changes. They also provide evidence that man-made fixation of the coast line by land reclamation and the subsequent construction of dykes in Northern Germany has impacted the salt-water distribution in the subsurface. But although dyking has started around 1000 years ago some areas still do not have completely freshened. This implies that freshening of aquifers once intruded by sea water may be a slow process which takes ten´s to hundreds of years.