Dynamic Behaviors of Fresh-Saline Water Interactions in Coastal Zone

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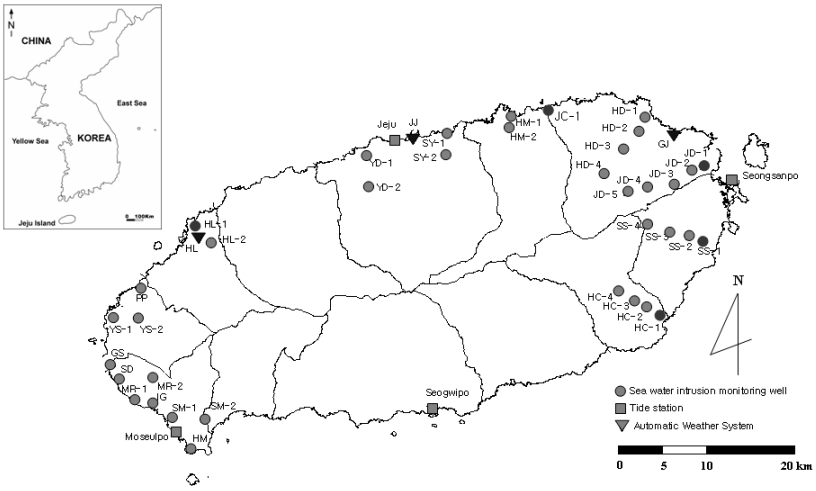
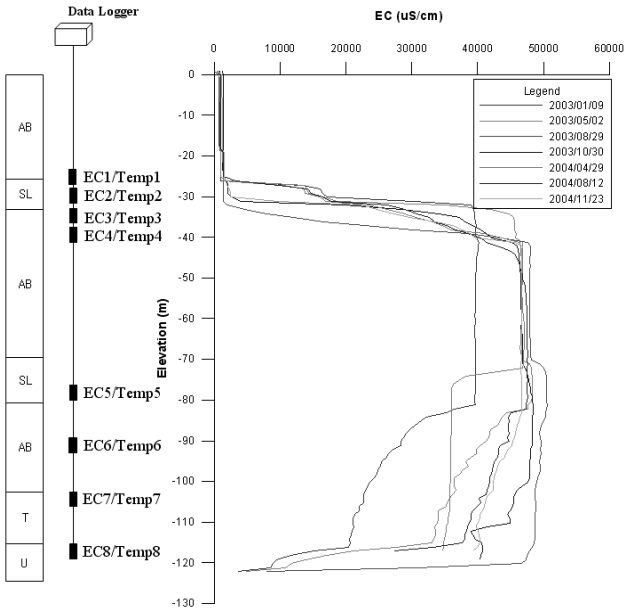
ABSTRACT
This study is intended to evaluate fresh-saline water interactions in coastal region influenced by external forces including tidal fluctuations and seasonal rainfall variations. Five different coastal zones were considered on Jeju Island, Korea, and electrical conductivity (EC) profiles at these monitoring wells were examined to identify the configurations of fresh-saline water interface. In order to analyze the dynamic behaviors of fresh-saline water interactions, we utilized multi-depth EC and temperature probes and obtained a time-series data. The monitored data showed that EC and temperature vary with both tidal fluctuations and heavy rainfall. Spectral filter was used to remove the effects of tidal forces and provide the influence of heavy rainfall events on EC and temperature. Time-series data of EC and temperature in the subsurface at various depths enabled us in understanding the interaction processes between fresh and saline water.

INTRODUCTION
Understanding the mechanism of fresh-saline water interaction has become an important issue for studies on hydrology as well as water management aspect in coastal area. Many hydrogeologic studies on Jeju Island have been conducted. Kim et al. (2006) proposed a conceptual model of fresh-saline interactions for the eastern part of Jeju Island by combining the results of EC and temperature log and the 2-D flowmeter tests. On the extension of the study, Kim et al. (2008) analyzed the interaction of fresh-saline water influenced by tidal fluctuations with EC data and end-member mixing analysis. The objectives of this study are to identify the temporal variations of fresh-saline water interactions at coastal aquifers and to evaluate the influence of tidal fluctuations and seasonal rainfall.

METHODS
Jeju special self-governing province has established monitoring wells around the coast in order to understand the subsurface geology, to observe water-level fluctuations, and to investigate the EC variations. In this study, five monitoring wells which are HL-1, JC-1, JD-1, SS-1, and HC-1 were selected for installing multi-depth monitoring system (Figure 1a). All the monitoring wells have a screen over the entire interval. The location and configuration of the fresh-saline water interface were examined with EC log. The EC profiles were obtained at several points of time for each monitoring well in order to investigate the temporal variation. The geological log and EC profile from SS-1 borehole are illustrated for an example in Figure 1b. Although these profiles provide valuable information on fresh-saline water interactions, monthly logging data is unable to analyze a short term variations influenced by tidal oscillations and the effect of rainfall events on interactions between fresh and saline water. Thereafter, EC and temperature probe system which can monitor at multi depths were installed at each monitoring wells, and continuous measurements of EC and temperature were made at 30-min interval. Applying a spectral filter to the frequency domain data eliminates all identified periodicities. In this study, a low-pass fast Fourier transform (FFT) filter was applied to the EC and temperature data to remove the diurnal and semidiurnal fluctuations and the noise from the monitoring system.



(a)



(b)

Figure 1. The location of the monitoring wells on Jeju Island (a) and the profiles of conductivity measurements at SS-1 monitoring well (b).

RESULTS AND DISCUSSION

Precipitation

For precipitation, we used the data obtained from automatic weather system (AWS). Three stations (Hanlim (HL), Jeju (JJ), Gu-Jwa (GJ) stations) were selected which are near to the monitoring wells. The monitoring was carried out from Jun 20 to Nov 20, 2007 and the study period includes both the wet and dry seasons. During the wet season, five heavy rainfall events were observed. The first event occurred between July 5 and July 7 with 93.5 mm (HL), 122.5 mm (JJ), and 144.0 mm (GJ). The largest rainfall was recorded during Sep 14 – 16 with 411.5 mm (HL), 590.0 mm (JJ), and 358.0 mm (GJ).

Fresh-saline water interface

Coastal groundwater tends to have a definable interface dividing the fresh and saline zones due to density difference. The geological log at SS-1 showed trachytic basalt, acicular basalt, hyaloclastite, U formation and sedimentary layers. EC profile showed two types of interface pattern for different points of time. One is interface lying at depth of -30 m, dividing fresh water and saline water zones. The other case shows another interface existing at lower part and relatively low TDS water flows at this zone.

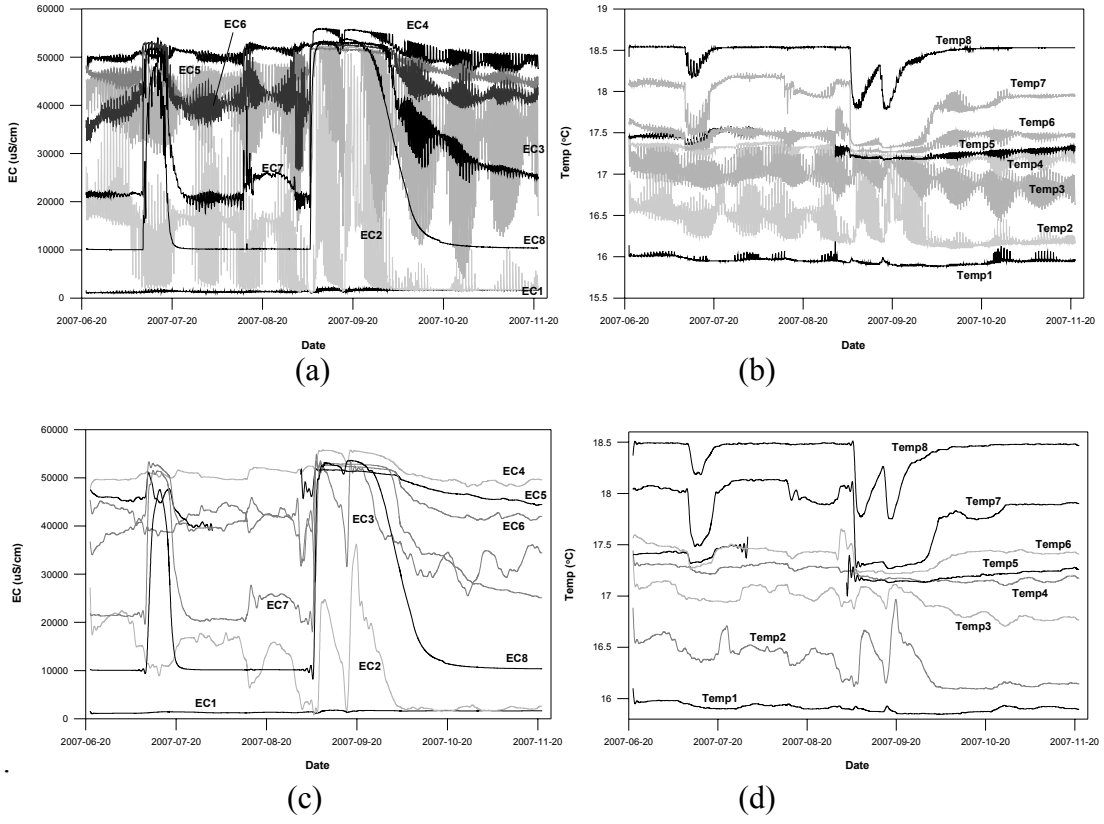


Figure 2. Time series data of EC (a) and temperature (b) at the SS-1 monitoring well and low-pass filtered signals from the EC (c) and temperature data (d).

EC and temperature data

The observed data from SS-1 monitoring well showed a dynamic variations of EC. EC at depth of -25 m showed ~1,000 μS cm^{-1} and did not responded to tide and rainfall while EC at depth of -30 m showed a wide range of EC variation fluctuating from 2,000 to 40,000 μS cm^{-1} due to tide. It is interesting to note that the range of EC variations increased at a range of 1,000 to 50,000 μS cm^{-1} after the 4^{th} heavy rainfall event. This implies that, in some cases, recharge strengthens the tidal effect on EC values. At SS-1 borehole, two distinctive interfaces appeared, one at around -30 m and the other at around -80 m. These interfaces relate well with the geology at this borehole; the location of interface matches good with the sedimentary layer. It is presumed that theses sedimentary layer takes a role as a confining layer and separates the hydraulic system into three zones in this coastal zone. These relationships between EC variations and geology show the importance of geology in fresh-saline water interactions in coastal zone.

CONCLUSIONS

This study elucidated some cases of dynamic variations of fresh-saline water interactions at coastal aquifers around Jeju Island. We set up multi-depth monitoring system at five boreholes to obtain time-series data of EC and temperature at various depths. The EC and temperature varied mainly by two external forces, tidal fluctuation and rainfall. The influence of heavy rainfall events on EC and temperature was analyzed by applying digital filter. Time series data of EC and temperature at various depths enabled us to quantify the interactions between freshwater and saline water in coastal aquifers and multi-depth monitoring system come out to be a powerful tool for examining fresh-saline water interaction process in coastal zone. As the monitoring wells were screened over the entire interval, there may be some effect of long screen that may cause mixing within the borehole. Considering the effect of long-screen is needed in the future study.

REFERENCES

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