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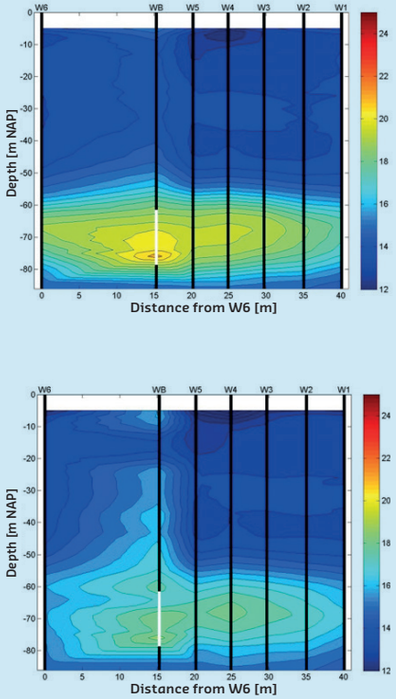
Monitoring using fibre optics

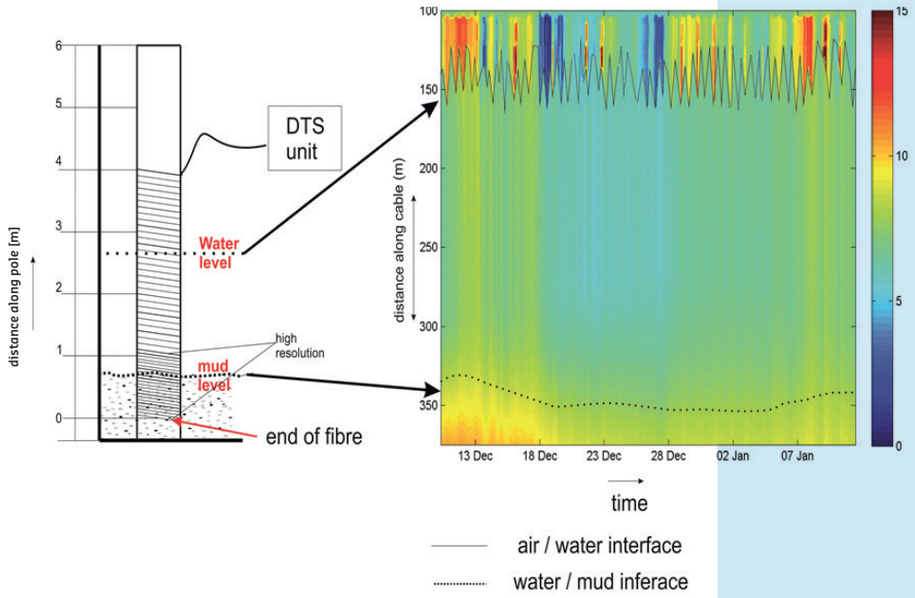


Temperature distribution in ATES in September 2015 (top) and March (bottom)

Fibre optics are widely used for communication technology such as internet networks. There are numerous other applications in the geosciences, one example being measurements of parameters like temperature and strain. There are multiple advantages. Fibre-optic cables are cheap and do not wear over time. Moreover, measurements are accurate and they are not affected by electromagnetic radiation, corrosion, moisture or water. Typically, accuracies are within 0.1ºC, spatial resolution ranges between 0.002 m and 2.0 m, and measurement frequencies are up to 1 Hz.

Temperature is a useful parameter for monitoring the performance of aquifer thermal energy systems (ATES), which store warm or cold water in underground aquifers for use later. For example, warm water is collected in summer and stored in an aquifer for retrieval in the winter. The monitoring system around the ATES of one of the Deltares offices in Delft consists of six observation wells around the warm storage well and another six around the cold water storage well. The temperature is measured eight times a day using Distributed Temperature Sensing (DTS). Light is sent into the fibre and scattered along it. The amount of scattering is a function of temperature, while the travel time of the reflected light pulse depends on the distance along the cable. Temperature data are interpolated between the monitoring wells to obtain the spatial and temporal temperature distribution for the ATES. The monitoring showed that the warm well was not depleted at the end of the winter of 2015-16. The results have taught us more about how the systems work and this knowledge can be used in future set-ups to make the system more efficient.

Temperature can also be used as a proxy for a different process, for example for the amount of sediment on top of a cable. The sediment thickness above a cable is determined by analysing the diurnal temperature variations which propagate into the sediment from the air and water. Differences in the thermal properties of the water and the sediment result in phase shifts in the temperature signal and a reduction in amplitude. The sediment thickness is interpreted in terms of erosion and deposition of sediments over time. This technique has been applied around the sluices of Kornwerderzand, in the sand nourishment at Workumerwaard and around an electricity cable from Egmond aan Zee to an offshore wind farm. The temperature measurements at the sluices of Kornwerderzand show that the mud level varies by approximately 20 cm over one month. This method measures the mud level continuously, which is a major advantage over the conventional echo soundings, which only provide information about one point in time.



Monitoring of mud levels at the sluices of Kornwerderzand

Other applications of temperature fibre optics include the monitoring of flow rates, the detection of seepage zones and the detection of artefacts in diaphragm walls. In addition, coated fibre-optic cables and specialised measurement units can be used to monitor parameters other than temperature. For example, contaminants can be detected using a special coating and strain can be measured. Recent developments are the use of fibre-optic cables to detect vibrations in seismic surveys.

Further reading:

Sommer et al. (2014). Thermal performance and heat transport in aquifer thermal energy storage. Hydrogeology Journal, 22(1), 263-279