Geophysical Research Abstracts, Vol. 7, 07910, 2005
SRef-ID: 1607-7962/gra/EGU05-A-07910


# Near Infrared imaging spectroscopy:

# A new tool for studying water states and movement in porous media

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NIR vibration spectra (700-2500 nm) of adsorbed and capillary water in silica gels, fine and coarse sand were studied. The fine structure and displacement of overtones n$\nu_{OH}$ of the water valent mode and the compound n$\nu_{OH} + \nu_d$modes with a participation of the deformation mode $\nu_d$ were investigated.

Spectral water bands of the overtone and compound tone show the essential change of a water state as a result of its interaction with the silica surface. Spectral series of the characteristic bands corresponding to various states of structural water were revealed. For example, an abnormal growth of the absorption bands $2\nu_{OH} + \nu_d$, $3\nu_{OH}$ and $3\nu_{OH} + \nu_d$ for capillary water in sand instead of the normal decrease of band intensity with frequency was observed. A strong sensitivity of $\nu_d$ parameters to changes of water states was found. Thus, the intensity of the $3\nu_{OH} + \nu_d$ band grows by a factor of about 190 relative to distilled water.

We shown that the content of capillary water can be exact determined from the absorption intensity of the $2\nu_{OH}$ overtone.

The new method of imaging spectroscopy using a NIR ÑÑD camera (900-1700 nm) was applied to study the spatial distribution of various water states. Effects of multiple scattering and transversal light diffusion in a disperse medium were taken into account.

Transformations of the water states with changing sample humidity, as well as during capillary rise and fall and in infiltration fingers were investigated. We found different water spectra in various parts of the fingers. Specifically, the water in the finger tip shows the strongest absorption. This water state corresponds to the least bound water. The maximum of the $2\nu_{OH}$ band for stationary water flow is displaced towards the long-wave region. This is characteristic for the more tightly bound water structure. The nature of various water states is discussed.