

## **Near surface tilt induced by ground water pumping: recent progresses**

H.-J. Kümpel

Leibniz Institute for Applied Geosciences (GGA Institute),  
Stilleweg 2, D-30655 Hannover, Germany;  
kuempel@gga-hannover.de

Ground water withdrawal through pumping has repeatedly been demonstrated to cause near surface deformation. The phenomenon is of practical use because knowledge of the evolution of the surface deformation field in the vicinity of pumped aquifers allows to assess in-situ hydrologic parameters without investments in new boreholes. The poroelastic response to ground fluid extraction (or fluid injection) is best seen through the set-up of continuously operating tiltmeters that are installed at shallow depths. During the past five years, some new findings from tiltmeter studies have come up:

- More experience has been gained about the geometric configurations under which the phenomenon can be observed and about the signal strengths that can be expected.
- Theoretical understanding of the poroelastic process has much improved: Whereas the full space solution for pump induced ground tilt was known some ten years ago only, analytical solutions for the homogeneous half space and iterative-analytical solutions for the layered half space have recently become available.
- Pumping at particular test sites has revealed the possibility of occurrence of irregular tilt signals. They are obviously related to the presence of heterogeneities in the subsurface.

Accordingly, the near surface deformation field in the vicinity of pumped wells bears a wealth of information that is useful to constrain the conditions of fluid flow at depth. Present interest lies in simplifying routine installation of tiltmeter arrays and in obtaining field data from case studies representing a variety of hydrogeological regimes.