NEW INSIGHTS INTO THE NORTH-CENTRAL AFRICAN LITHOSPHERE FROM THE GOCE GRAVITY AND GRAVITY GRADIENT FIELDS

C. Braitenberg, T. Pivetta, P. Mariani
Dipartimento di Geoscienze, Università di Trieste, Italy

The gravity satellite missions GRACE and GOCE have boosted the resolution of the global Earth gravity models (EGM), opening new possibilities of investigation. The EGMs must be distinguished in models based on pure satellite or mixed satellite-terrestrial observations. Satellite-only models are truly global, whereas satellite-terrestrial models have inhomogeneous quality, depending on availability and accuracy of the terrestrial data set. The advantage of the mixed models (e.g. EGM2008 by Pavlis et al. 2008) is their greater spatial resolution, reaching nominally 9 km, against the 80 km of the pure satellite models of satellite GOCE. The disadvantage is the geographically varying reliability due to problems in the terrestrial data, compiled from different measuring campaigns, using various acquisition methods, and different national geodetic reference systems. We present a method for quality assessment of the higher-resolution fields through the lower-resolution GOCE-field and apply it to northern Africa. In future this technique can help to plan new gravimetric acquisition campaigns in areas where the field is less known and where the new data can be optimally integrated to increase resolution. We find that the errors locally are as great as 40 mGal, but can be flagged as "bad areas" by our method, leaving the "good areas" for reliable geophysical modeling and investigation.

We analyze gravity and gravity-gradients (e.g. Braitenberg et al., 2011) and their invariants over North-Central Africa derived from the EGM2008 and GOCE (Migliaccio et al., 2010) and quantify the resolution in terms of density variations associated to crustal thickness variations, rifts and magmatic underplating. We focus on the Benue rift and the Chad lineament, a 1300 km gravity high arcuate feature which links the Benue to the Tibesti Volcanic province, and we show that the lineament has no expression in topography or outcrop and is entirely covered by the sediments of the Chad basin contrary to the WCARS rift where a central gravity low is found. The Benue rift and the Chad line in the past have been supposed to be part of a triple rift junction (Burke and Whiteman, 1973), and the Chad line a rift basin (Browne and Fairhead, 1983; Fairhead, 1988; Fairhead and Green, 1989; Guiraud et al., 2005; Moulin et al., 2010). The existing seismological investigations are integrated to constrain the lithosphere structure in terms of seismic velocities, crustal thickness and top asthenosphere boundary, together with physical constraints based on thermal and isostatic considerations (McKenzie stretching model). Our modeling shows that the gravity signal in the Benue rift can only be explained if the rift is underplated with a density which is intermediate to mantle and lower crustal density and if it has undergone depth-dependent differential stretching. The positive arched Chad anomaly is best explained by a superficial huge high density crustal body, extending for about 1300 km, about 50 km wide, and a few km thick. The body is covered by sediments and is not directly observable, so it can be only investigated by geophysical methods and geodynamic models. It follows the outline of the more easterly found Precambrian basement, and is suggested to be a structural element of the Saharan metacraton.

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References

Electrical Resistivity Tomography Time-Lapse Monitoring of Three-Dimensional Synthetic Tracer Test Experiments

G. Cassiani1, R. Deiana1, M. Camporese2, P. Salandin2
1 Dipartimento di Geoscienze, University of Padova, Italy
2 Dipartimento di Ingegneria Idraulica, Marittima, Ambientale e Geotecnica, University of Padova, Italy

Introduction.
In recent years geophysical methods have become increasingly popular for hydrological applications. Time-lapse electrical resistivity tomography (ERT) represents a potentially powerful tool for subsurface solute transport characterization since a full picture of the spatio-temporal evolution of the process can be obtained. However, the quantitative interpretation of tracer tests is difficult because of the uncertainty related to the geo-electrical inversion, the constitutive models linking geophysical and hydrological quantities, and the a priori unknown heterogeneous properties of natural formations. Here a new approach based on the Lagrangian formulation of transport and the ensemble Kalman filter (EnKF) data assimilation technique is applied to assess the spatial distribution of hydraulic conductivity $K$ by incorporating time-lapse cross-hole ERT data. Electrical data consist of three-dimensional cross-hole ERT images generated for a synthetic tracer test in a heterogeneous aquifer. Under the assumption that the solute spreads as a passive tracer, for high Peclet numbers the spatial moments of the evolving plume are dominated by the spatial distribution of the hydraulic conductivity. The assimilation of the electrical conductivity 4D images allows updating of the hydrological state as well as the spatial distribution of $K$. Thus, delineation of the tracer plume and estimation of the local aquifer heterogeneity can be achieved at the same time by means of this interpretation of time-lapse electrical images from tracer tests. We assess the impact on the performance of the hydrological inversion of i) the uncertainty inherently affecting ERT inversions in terms of tracer concentration and ii) the choice of the prior statistics of $K$.

Methodology.
Starting from a known statistical definition of the hydraulic conductivity ($K$) spatial distribution, assuming $Y = \log(K)$ to be normally distributed and fully characterized by the expected value $<Y>$, the variance $\sigma^2_Y$, and exponential correlation structure $r(|x|) = \exp(-|x|/\lambda)$ (where $x$ is the 3D spatial coordinate, $\rho$ is the correlation coefficient and $\lambda$ is the correlation length), it is possible to describe the velocity driven dispersion phenomena in an aquifer affected by a mean constant gradient $J$. In this formulation, we assume that the effects of phenomena occurring at scales $\lambda_0 << \lambda$ are negligible and the dispersion depends only on the spatial variability of $K(x)$. The Lagrangian transport is simulated sequentially by solving first the steady state flow field by a finite volume numerical scheme and then computing the particle trajectories using a Pollock’s post-processor (Salandin et al., 2000). If we define $l$ as a unit length, the simulated domain has dimensions $16 \times 8 \times 8 l^3$, discretized along each direction with $l/4$ side cubic cells. Pressure head is imposed in $x = 0$ and $x = 16 l$, resulting in a mean gradient $J = 0.6$ along the main flow direction, while no-flow boundary conditions are imposed at the remaining sides of the domain. A reference $Y$ field has been generated with mean $<Y> = 0.19$, variance $\sigma^2_Y = 0.47$, and isotropic exponential correlation structure with integral scale $\lambda = l$.