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Integration of potential and quasipotential geophysical fields and GPR data for delineation of buried karst terranes in complex environments

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Karst is found on particularly soluble rocks, especially limestone, marble, and dolomite (carbonate rocks), but is also developed on gypsum and rock salt. Subsurface carbonate rocks involved in karst groundwater circulation considerably extend the active karst realm, to perhaps 14% of the world's land area (Price, 2009). The phenomenon of the solution weathering of limestone is the most widely known in the world. Active sinkholes growth appears under different industrial constructions, roads, railways, bridges, airports, buildings, etc. Regions with arid and semi-arid climate occupy about 30% of the Earth's land.

Subsurface in arid regions is characterized by high variability of physical properties both on lateral and vertical that complicates geophysical survey analysis. Therefore for localization and monitoring of karst terranes effective and reliable geophysical methodologies should be applied. Such advanced methods were developed in microgravity (Eppelbaum et al., 2008; Eppelbaum, 2011b), magnetic (Khesin et al., 1996; Eppelbaum et al., 2000, 2004; Eppelbaum, 2011a), induced polarization (Khesin et al., 1997; Eppelbaum and Khesin, 2002), VLF (Eppelbaum and Khesin, 1992; Eppelbaum and Mishne, 2012), near-surface temperature (Eppelbaum, 2009), self-potential (Khesin et al., 1996; Eppelbaum and Khesin, 2002), and resistivity (Eppelbaum, 1999, 2007a) surveys. Application of some of these methodologies in the western and eastern shores of the Dead Sea area (e.g., Eppelbaum et al., 2008; Ezersky et al., 2010; Al-Zoubi et al., 2011) and in other regions of the world (Eppelbaum, 2007a) has shown their effectiveness. The common procedures for ring structure identification against the noise background and probabilistic-deterministic methods for recognizing the desired targets in complex media are presented in Khesin and Eppelbaum (1997), Eppelbaum et al. (2003), and Eppelbaum (2007b).

For integrated analysis of different geophysical fields (including GPR images) intended for delineation of karst terranes at a depth was proposed to use informational and wavelet methodologies (Eppelbaum et al., 2011). Informational approach based on the classic Shannon approach is propose to recognize weak geophysical effects observed against the strong noise background. Unfortunately, this approach sometimes does not permit to reveal the desired effects when the noise effects have a strong dispersion. At the same time, the wavelet methodologies are highly powerful and thriving mathematical tool. Wavelet approach is applied for derivation of enhanced (e.g., coherence portraits) and combined images of geophysical indicators oriented to identification of karst signatures. The methodology based on the matching pursuit with wavelet packet dictionaries is used to extract desired signals even from strongly noised data developed (e.g., Averbuch et al., 2010). The recently developed technique of diffusion clustering combined with the abovementioned wavelet methods is utilized to integrate geophysical data and detect existing signals caused by karst terranes developing a depth. The main goal of this approach is to detect the geophysical signatures of karst developing at a noisy area with minimal number of false alarms and miss-detections. It is achieved via analysis of some physical parameters (these parameters may vary for different regions). For this aim various robust algorithms might be employed. The geophysical signals are characterized by the distribution of their energies among blocks of wavelet packet coefficients. To derive the geophysical precursors, we use the *Best Discriminant Basis* method followed by dimensionality reduction via *Diffusion Maps*. The decision is made by combining the answers from the following classifiers: *Linear Discriminant Analysis* and the *Classification and Regression Trees*. This approach could be applied to treatment of any geophysical fields and geochemical indicators. The outputs from different sources are combined and their dimensionality is reduced via *Diffusion Maps*. As a result of the above operations we can embed the combined data into low (3 to 6)–dimensional space where data related to the karst signatures are well separated from the different kinds of noise. The obtained low-dimensional set of the data representatives can be used as a reference set for the classification of newly arriving data. Such an approach was successfully realized, in particular, for a series of gravity-magnetic anomalies computed from typical karst terrane models (Eppelbaum et al., 2011).

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