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Re-evaluating possibilities of the Source Scanning Algorithm

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The Source Scanning Algorithm (SSA) has been introduced and developed by Hann Kao, Shao-Ju Shan and co-workers since 2004. The basic idea of SSA is simple: Seismograms in a station network can be stacked, using theoretical arrival times in a given (e.g. 3D) structural model and an assumed point source. A set of trial source positions is grid searched, and the most likely positions are those producing the largest correlation (so-called brightness). The method may work fully automatically without any manual or automatic phase picking. It can be used for events with unclear arrivals; as such it is a powerful tool to locate tremors, including their continuous monitoring. Source complexity (multiple events) can be studied and perhaps even the causative fault planes can be identified. Nevertheless, many questions related to the application of the method remain still open. Some of them are as follows: (i) Is the method competitive in comparison with standard location methods of individual events whose phase arrivals are clear? (ii) How accurate must be the structural model in which the theoretical arrival times are calculated? (iii) How to combine data from local and near regional seismic stations? We report preliminary results from a small project designed to critically re-evaluate possibilities and limitations of the SSA method. Our analysis is focused on the Efpalio 2010, Mw$\sim$5 earthquake, Corinth Gulf, Greece (Sokos et al., in press), which we previously located by a number of different methods. We use the same source-station configuration as in the real case, but invert synthetic seismograms, calculated for a 1-sec and 0.2-sec source pulse by the discrete-wavenumber method in 1D crustal models. Theoretical travel times are calculated by the ray method, including head waves from all model discontinuities (intra-crustal ones and Moho). Both the double-couple and isotropic sources are considered. We demonstrate the Lat-Lon brightness maps for varying trial source depths, and discuss when and how the retrieved source position is biased, or even the single source is erroneously imaged as a multiple. Artifacts are explained in terms of factors, such as the duration of the considered P-wave group, the frequency content and complexity of the crustal model. We show that in models with only few constant-velocity layers (as routinely used in many location codes) problems arise because the first prominent P-wave groups, whose maximum amplitudes determine the brightness, are modeled by the superposition of the head waves, reflected waves and the direct P wave. We demonstrate a possible use of the initial P-wave group of a very short duration, more suitable for a formal interpretation in terms of the fastest first-arriving wave. Modifications of the method using smooth velocity variation in the crust are discussed because of real crust, in which clear intra-crustal discontinuities might be rare or not well known. Improvements in the depth resolution through a combined P- and S-wave brightness are also presented.