# Development of an Earthquake Alert System for Germany

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## Overview

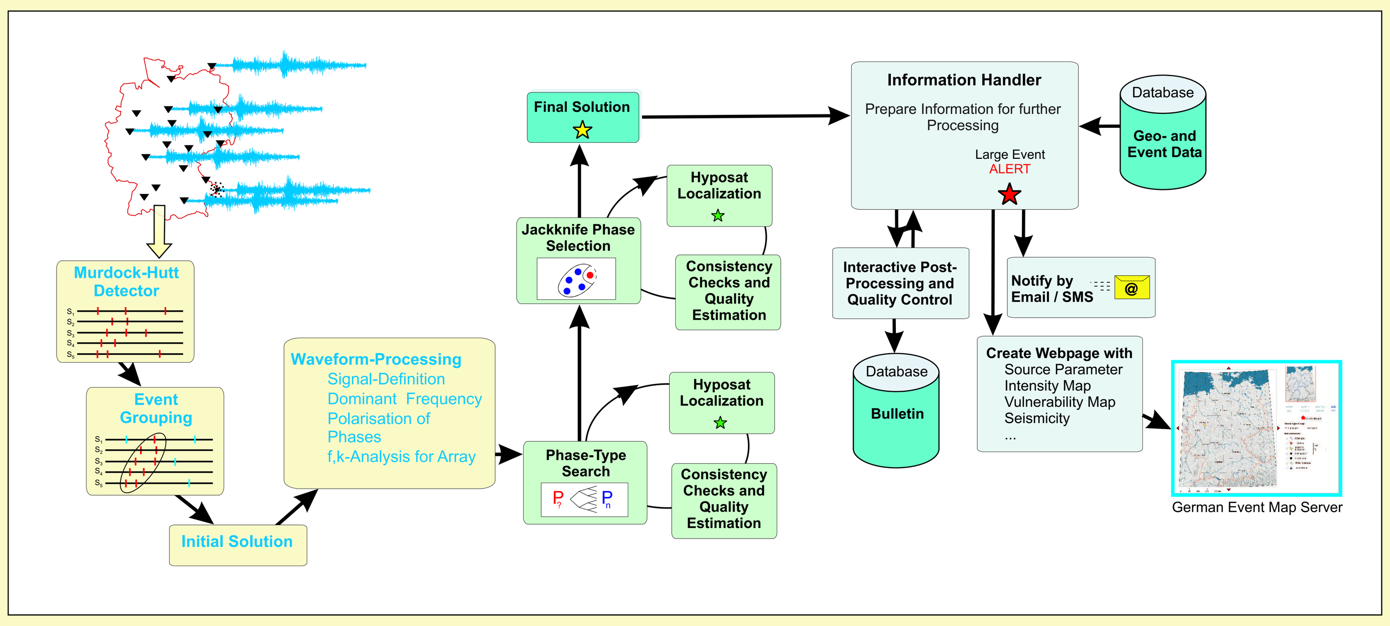
We present an earthquake alert system for Germany that automatically provides comprehensive and reliable information on earthquakes. It consists of the following components:

- A seismometer network of five selected stations of the German Regional Seismic Network (GRSN) and two additional new stations.
- A communication system based on CD1.0 protocol that allows near real-time transmission of waveform data to the central data recording and processing system.
- Newly developed processing software for rapid and reliable event parameter determination.
- A communication interface to distribute alert messages via Web pages, SMS and e-mail.
- An interface to a new graphical information system used for displaying detailed information on the epicenter region.

Two new seismic stations have been built northeast of Hannover and in central Germany close to Bad Hersfeld. The implemented CD1.0 communication protocol allows, in case of an interruption, simultaneous transmission of most recent and earlier waveform data. This ensures immediate access to the most current data at any time.

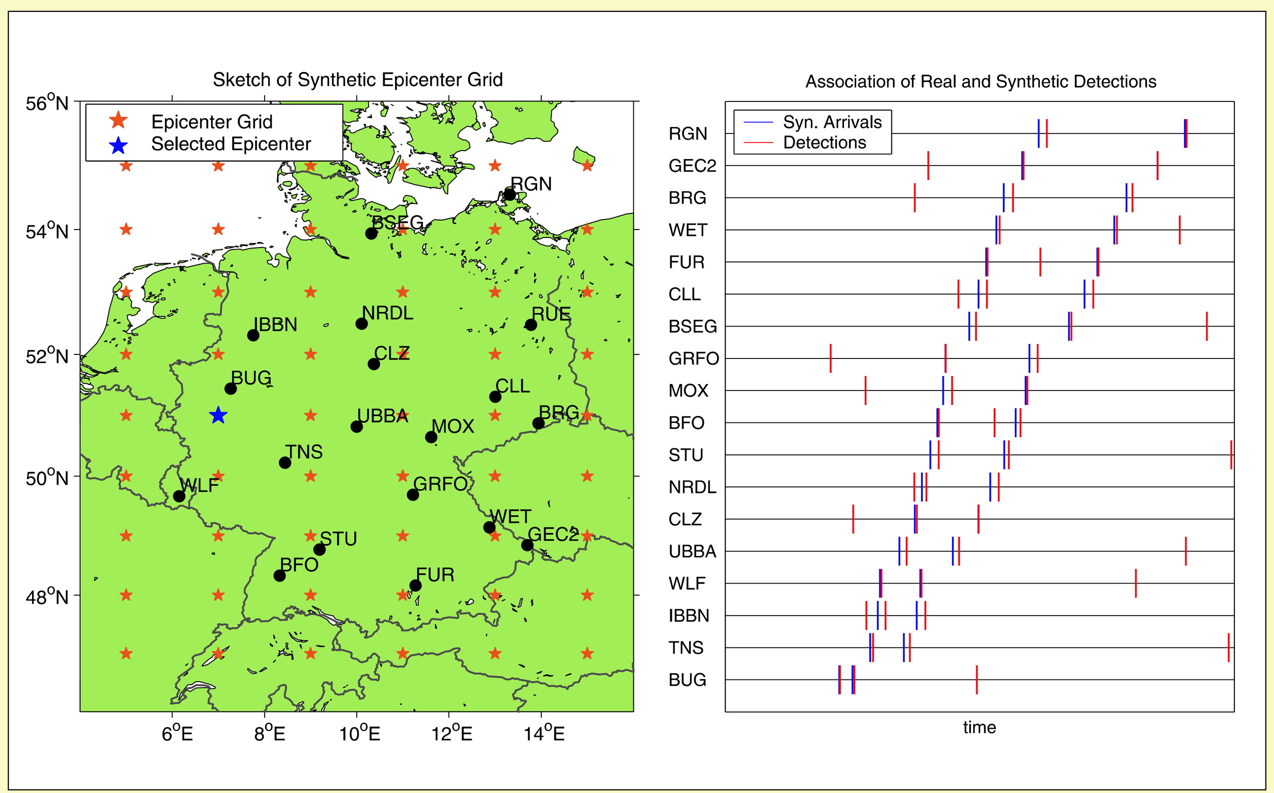
Data processing is the most important element of the alert system. The software makes use of improved procedures for seismic phase identification and phase association. Moreover, several consistency checks are included. The application of these automatic methods provides reliable estimate of the source parameters.

## Earthquake Alert System



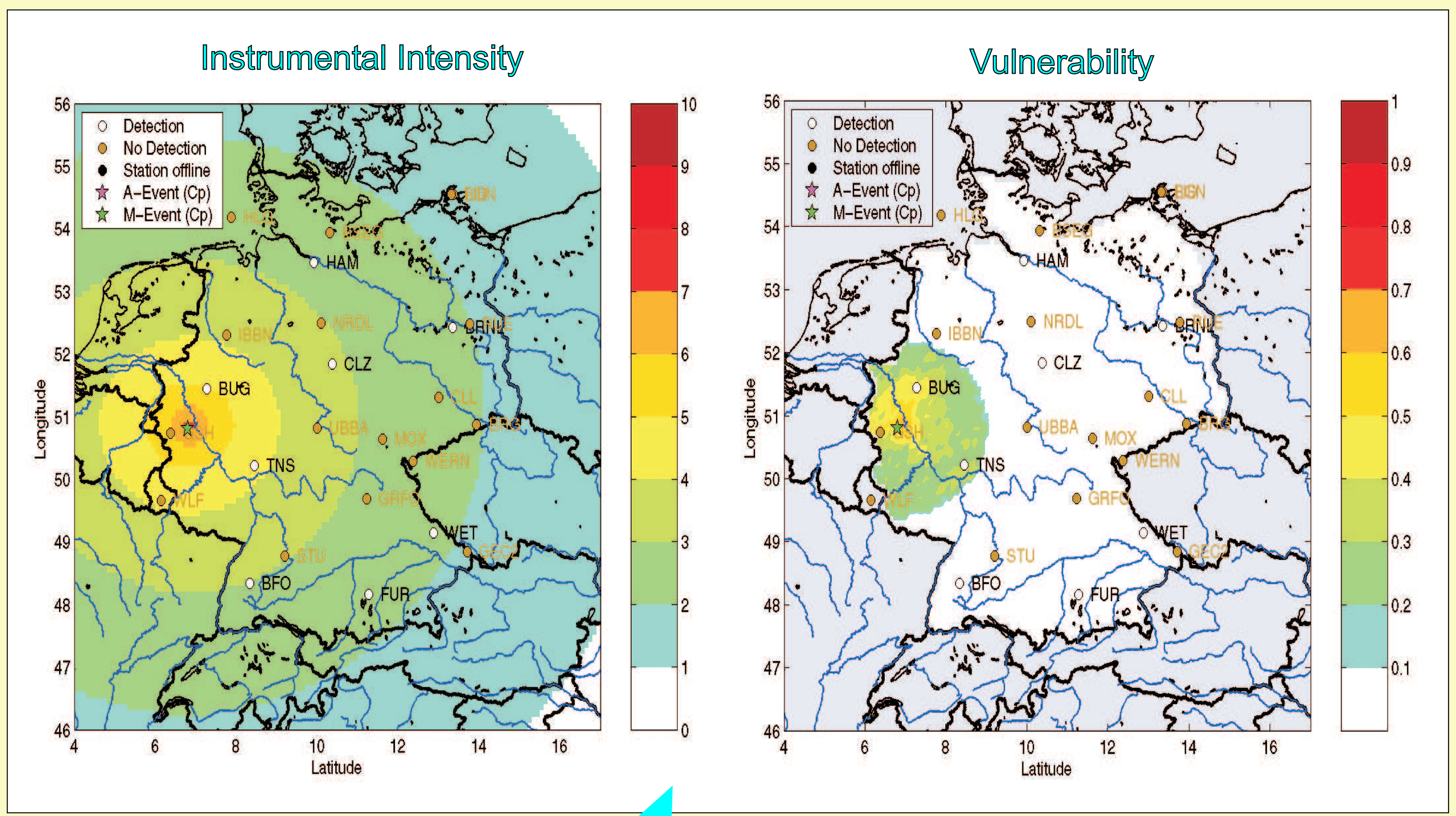

The principal workflow of the earthquake alert system is shown on the left side. After determination of the epicenter location these data are provided by several media like SMS and email and are available on Webpages together with additional statistic and geological information.

## Onset Determination and Grouping



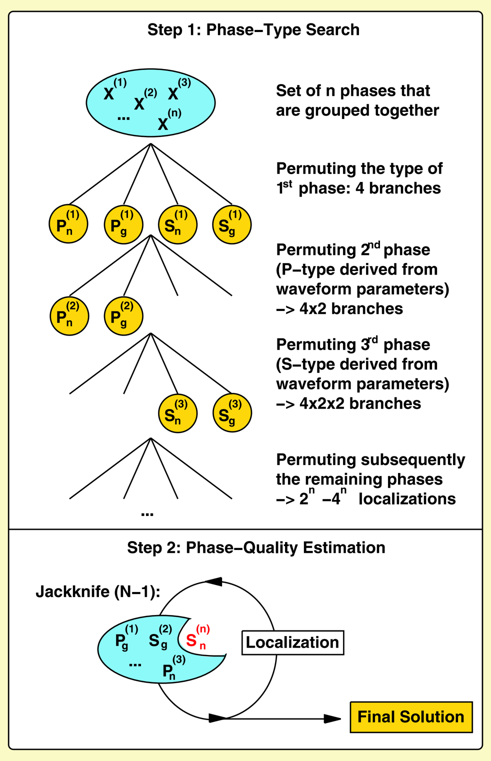

A forward grid-search method computes synthetic onset times. If a certain number of onsets determined by the Murdock-Hutt detector have corresponding synthetic onsets, these are grouped together and the corresponding source parameters are used as initial solution for further processing.

## Impact Quantification




To estimate the impact of an possible earthquake in Germany the instrumental intensity (after MSK) is determined from source parameter. On base of the instrumental intensity map more detailed information is available to estimate the impact of an earthquake. The right map on the left side show a map with estimated vulnerability values calculated from the population density. Both maps on the left side show results of a fictitious magnitude 6.0 earthquake south west of Koln.

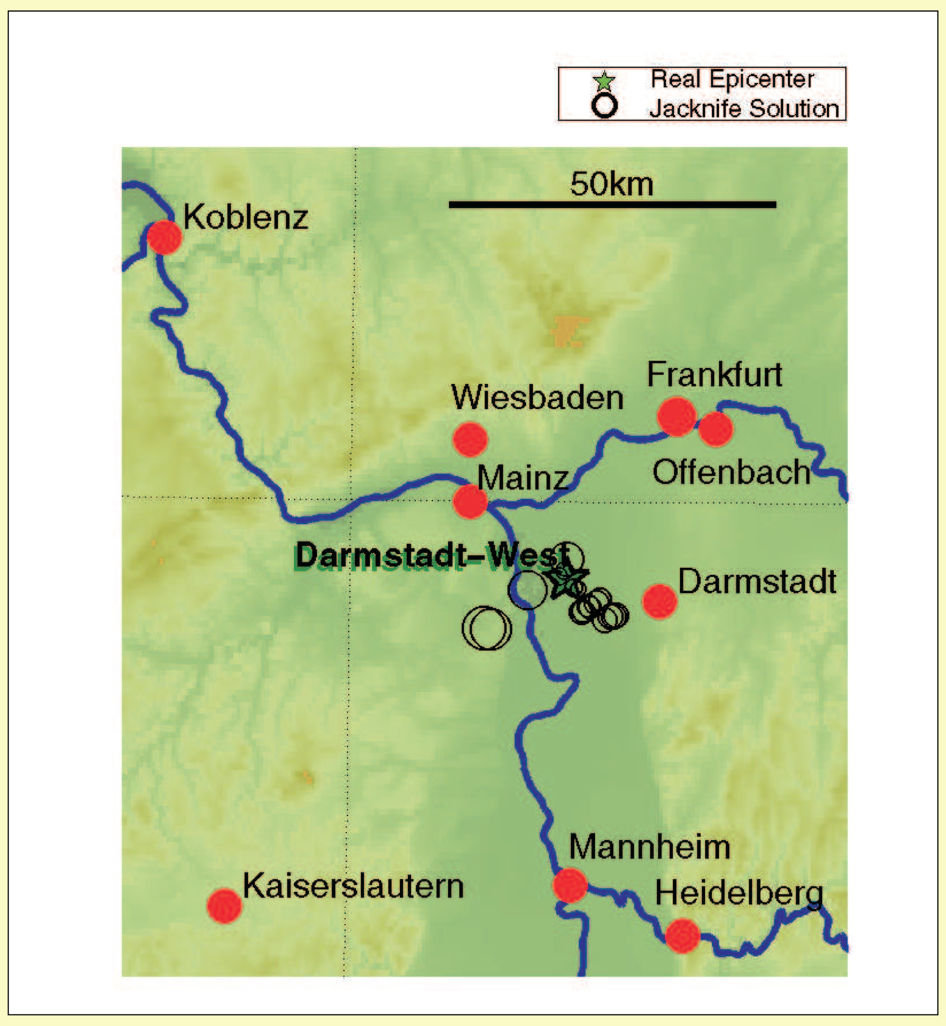
## Epicenter Determination



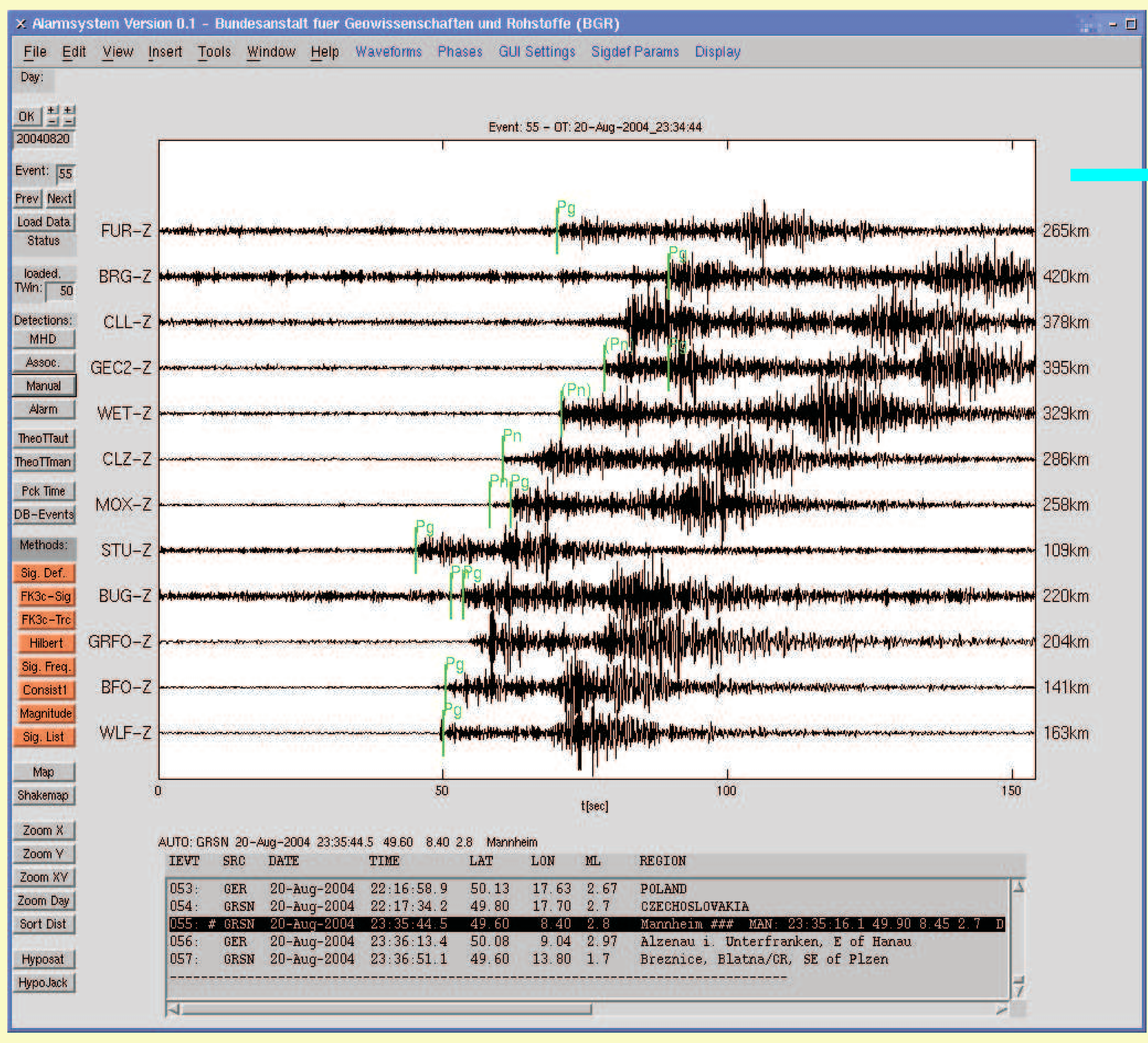

For a precise epicenter determi-nation it is necessary to (1) find the correct phase types and (2) select only those phases which lead to small errors of the epi-center solution.

**Step one,** shown in the left figure, is done by arbitrarily assigning phase names (Pn, Pg, Sn or Sg) to all detections and then performing HYPOSAT localizations for all possible permutations. To keep this number (which grows expo-nentially with the number of detections) as small as possible, certain phase types are fixed in case of strong evidences coming from the parameters derived by the waveform algorithms. At the end, the localization with the smallest error is passed to step two.

In **step two,** phases which bias the localization are determined and removed. This is done by a Jacknife method which performs localizations with a subset of all phases. From the change of the localization error the (good or bad) influence of the omitted phases is deduced. Finally, a set of good hypocenter solutions remain, shown in the lower figure by black rings whose diameters resemble the spatial error of the solution.

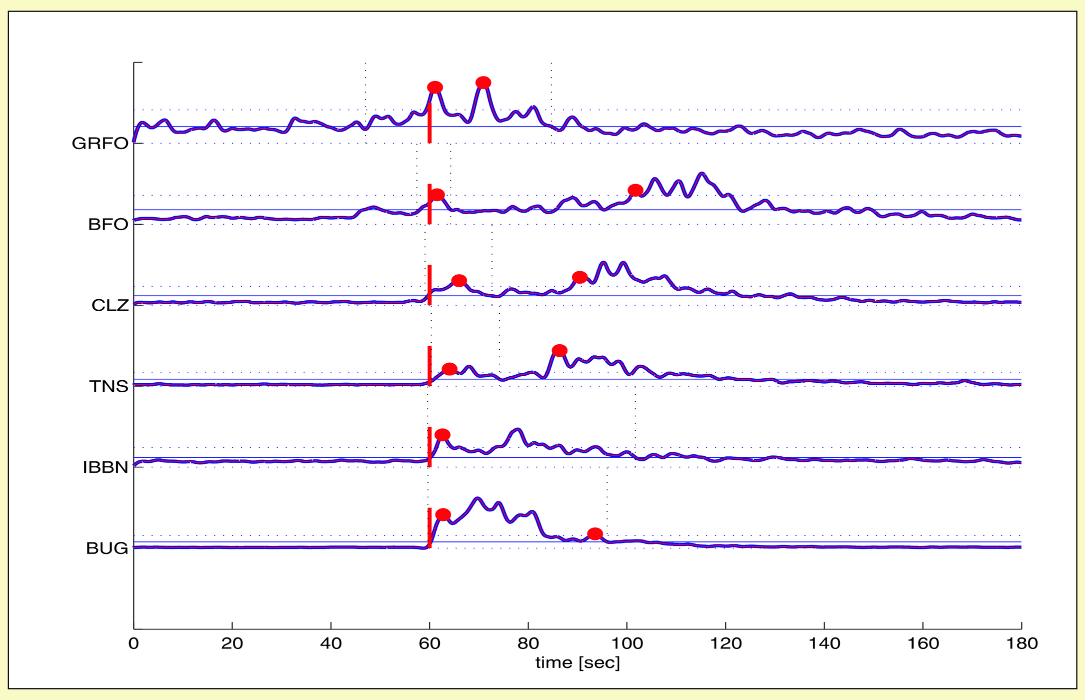



## User Interface



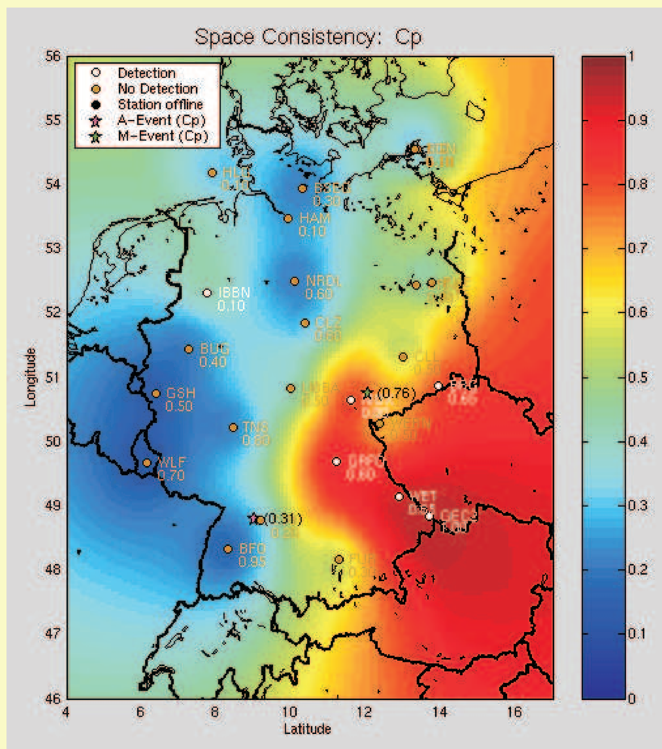
A graphic user interface was developed for testing new algorithms of the automatic data processing. It allows processing of both near real time data and selected data sets of earthquakes with well known source parameters.

## Signal Definition



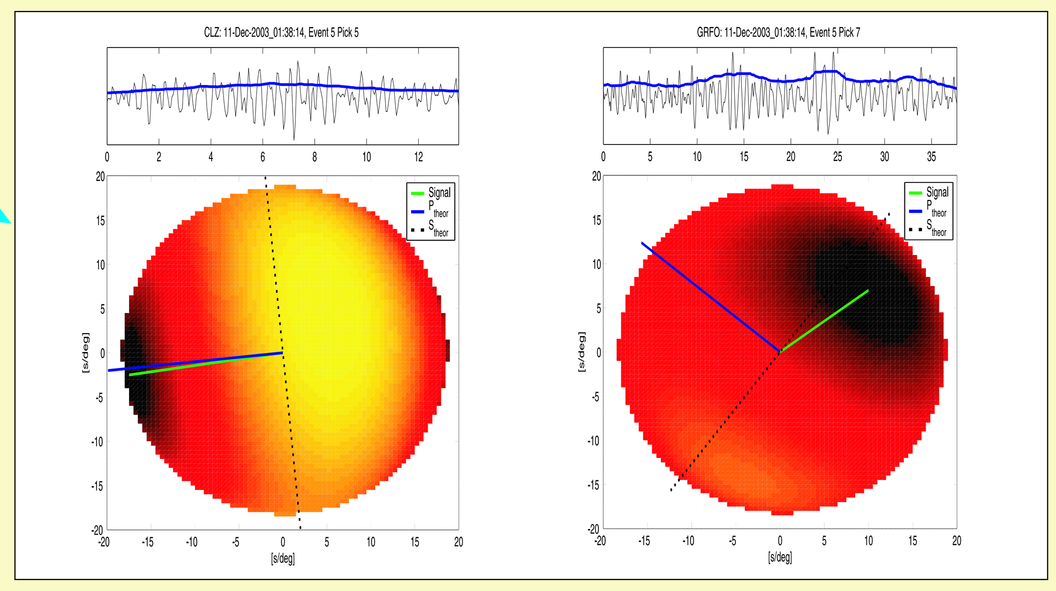

Smoothed envelopes of seismograms are used to define the signal windows. These are needed by the waveform algorithms that compute varius signal parameters such as dominant frequency, polarization etc.

## Consistency Checks



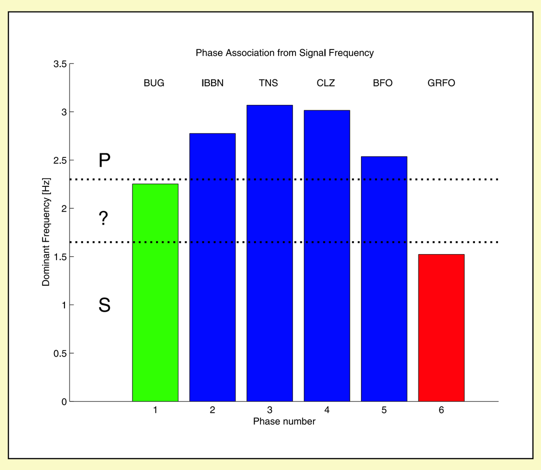

Consistency checks are used to estimate the quality of the epicenter determination. On the left side the result of the spatial consistency is shown. A numerical algorithm is used to calculate the consistency value Cp. This value quantifies the probability whether the epicenter location and the distribution of stations contributing phases fits. Results of the automatic data processing with epicenter locations in the blue area will be rejected.

## Polarization Analysis



Three component polarization analysis is applied to the seismic signals to get the back azimuth. The quality of the results depends on the signal noise ratio and the station characteristics like ground composite. Results of polarization analysis is shown in the two figures above with a probable P-phase on the left and S-phase on the right side, respectively.

## Dominant Frequency




The dominant frequency is an additional parameter of the phase identification. It is acquired from the number of zero crossings of the signal. This simple but robust technique provides more stable values as the use of power spectra. The comparison with characteristic frequency windows of known seismic phases allows the determination of the phase type.