TRAVEL-TIME SOURCE SPECIFIC STATION CORRECTION IMPROVES LOCATION ACCURACY

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INTRODUCTION

Accurate earthquake locations are crucial for investigating seismogenic processes, as well as for applications like verifying compliance to the Comprehensive Test Ban Treaty (CTBT). Earthquake location accuracy is related to the degree of knowledge about the 3-D structure of seismic wave velocity in the Earth. It is well known that modeling errors of calculated travel times may have the effect of shifting the computed epicenters far from the real locations by a distance even larger than the size of the statistical error ellipses, regardless of the accuracy in picking seismic phase arrivals.

We have developed a method of seismic location to minimize this systematic shifts affecting hypocentral locations. These method is based on the fact that such shifts are quite similar for events for which the hypocenters are close to each other with respect to their distance from the recording stations. So this method is based on a set of Ground Truth events recorded by a dense local seismic network in seismically active regions.
The applications concern seismic sequences recorded in Italy and Iran.

We show that mislocations of the order of 10-20 km affecting the epicenters, as well as larger mislocations in hypocentral depths, calculated from a global seismic network can be effectively removed by applying source-specific station corrections applied to the standard IASPEI91 travel times.

This method is valid only for the area where calibration events are located but it is valid for any subset of the station network used for the calibration.

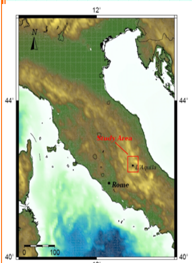
METHODOLOGY

We located the selected events using a least-square single-event location algorithm developed at our Institute (Istituto Nazionale di Geofisica e Vulcanologia - INGV) applied to a global network of seismic stations. In our algorithm the epicentral distances are computed from geographical coordinates through the WGS84 ellipsoid model of the Earth. Moreover the travel-times are based on IASPEI91 tables and they are corrected both for the ellipticity of the Earth and for station elevation.

Assuming the local seismic network determinations as a reference data set, we computed the differences between the observed arrival times and those computed starting from the hypocenters and origin times reported by the local seismic network at all the recording stations. For each station we computed the average and the standard deviation. The mean residuals were applied to the hypocenter location algorithm as corrections to the computed standard travel times.

ITALIAN CLUSTER

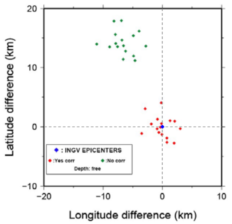
P-wave arrival times at 59 seismic regional or teleseismic stations from 16 earthquakes located in central Italy, were obtained from the online Bulletin of International Seismological Center (ISC, http://www.isc.ac.uk). All the events occurred during the sequence in March-June 2009 in the area of L'Aquila (4.1≤ML≤5.9).



On the right: seismic network that recorded the earthquakes located in central Italy and here analyzed.

Each event of the cluster was recorded by at least 80% of these stations.

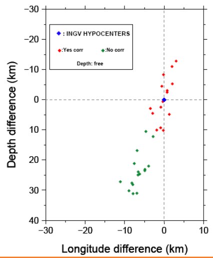
Mislocations of the hypocentral coordinates



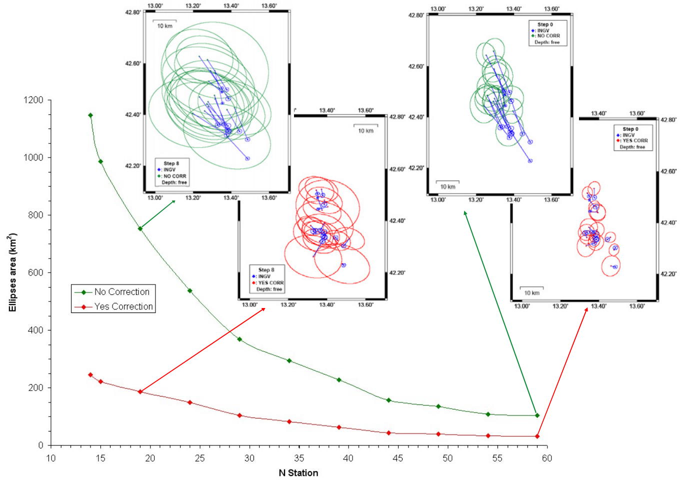
Green diamonds indicate the locations obtained by the standard global travel times.

Red squares indicate the locations obtained by adding static corrections to the standard travel times.

On the right, is shown the east-west vertical cross-section of the hypocenters.



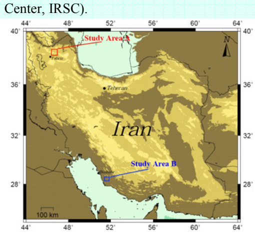
We have also addressed the question of how the size of the error ellipses depends upon the number of arrivals included in the input data. The method adopted starts from the whole dataset with the reduction of the number of stations by steps of 5, and then relocation of all the events at each step. A comparison between the epicenters obtained including or not systematic travel-time corrections and the INGV epicenters (blue dots) is shown below for only two steps. The shape and orientation of the error ellipses depend on the geometry of the observing seismic stations with respect to the hypocenter.

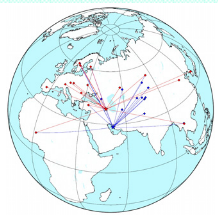


The average area of the error ellipses increases steadily when the number of available stations decreases, but when we include the systematic travel-time corrections, the area increases more slowly (red line).

IRANIAN CLUSTERS

We considered two clusters of events, the first to the north-west of the country (**Area A**) and the second to the south of the country (**Area B**). The local seismic network taken as reference is TEH (operated by the Iranian Seismological Center, IRSC).





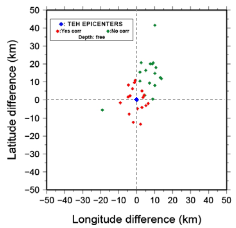
Seismic network used for the study of clusters.

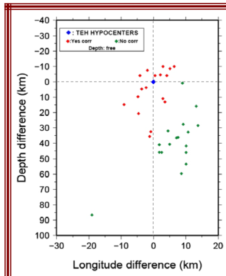
Mislocations of the hypocentral coordinates: Area A

Green diamonds indicate the locations obtained by the standard global travel times.

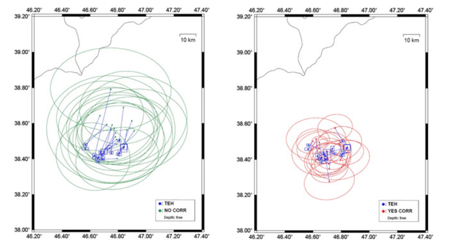
Red squares indicate the locations obtained by adding static corrections to the standard travel times.

Blue diamonds indicate the locations of TEH epicenters.





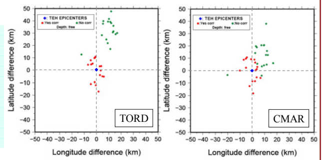
On the left, is shown the east-west vertical cross-section of the hypocenters.



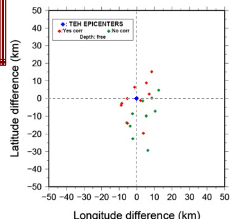
A comparison between the epicenters obtained including or not systematic travel-time corrections and TEH epicenters (blue dots) is shown above. The shape and orientation of the error ellipses depend on the geometry of the observing seismic stations with respect to the hypocenter.

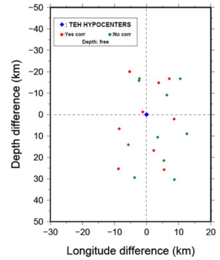
What happens if some stations are removed?

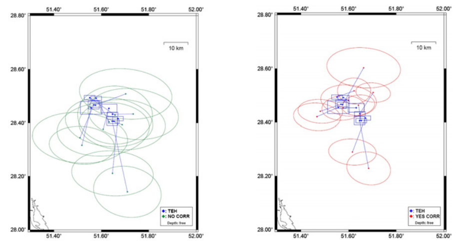
We have eliminated the only African station, TORD, and then the station in Thailand, CMAR. In this way we have a large gap in the azimuthal coverage of the network in two different directions.
The use of corrections for the remaining stations of the network still preserves the capacity of reducing the shift between the locations.



Mislocations of the hypocentral coordinates: Area B







An approach similar to that adopted for Area A was applied to Area B.

Left top: relocation of the events by correction of the travel-times

Right top: cross-section of the hypocenters

Bottom: comparison of the error ellipses calculated by us and the errors reported in the TEH bulletin, without and with travel-time corrections

Also in this case, there is a correction of the location shift and a reduction of the relative distances between the hypocenters.

CONCLUSION

The inclusion of the average time residuals in the location algorithm has shown the capacity of removing most of the systematic differences between teleseismic and National locations, besides a significant reduction of the random dispersion due to measurement errors of seismic arrival times.