Working group on authoritative locations: first report

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Background

The notion of authoritativeness is directly linked to the multiplicity of sources for earthquake information. The number of earthquakes which are located by more than one network constantly increases indeed due to the numerous networks in operation in the world and the improvement of their performances. The consequence is the publication of several, and sometimes many locations which are or are not consistent.

This situation creates different problems in different audiences. Even when the differences in locations are within the uncertainties, they are often perceived by the public, the media or the authorities as conflicting which in turn jeopardises the quality and credibility of the work performed by our community. The problem is quite different for a seismologist, who would be more inclined to use a unique source of earthquake information rather than having to compile different sources and determine a preferred solution for duplicate earthquakes. For agencies such as the EMSC, NEIC or ISC which collates parametric data from various sources, it is essential to develop procedures to evaluate the reliability of the provided information especially when it results from automatic data processing and procedures to identify a preferred solution among all the existing ones. That's this preferred solution which is often named "authoritative" which is believed or assumed to be the best one for the given earthquake.

So far, the implementation of this authoritativeness concept on rapid earthquake information at both NEIC and EMSC is based on a geographical area where the local network is considered authoritative. In practice, when the authoritative network reports an epicentre falling within its authoritative area it is automatically published on public web site. At first sight, it is a sound approach which reflects the fact that the local network has generally the best knowledge of the local seismicity and that earthquake locations are reliable when falling within the monitoring network. Unfortunately, that's not always true. For example, it is not rare for automatic software when applied to a small aperture network to report a large teleseismic event as a moderate local one because it misidentified teleseismic phases to local ones. The second drawback is with the definition of the authoritative area: whatever the geometry of his network can be, it is not easy for an operator to consider the possibility that a neighbouring network may have better performances over part of the area he is in charge of monitoring. In other words, the definition of the authoritative area is often more a political than a scientific decision. Finally, even when it is defined on scientific basis, this process implicitly assumed that the performances of the local network are constant which may not be always the case, due to maintenance for example but especially in case of a significant local earthquake which are always a test for the communication robustness.

A possible alternative to be explored

The aim of this work is to explore possible alternatives to the authoritative rules based on a fixed geographical area. Rather that looking at the source of the information, we propose to test the quality of the dataset used to perform the reported location and whether a better quality dataset can be defined by merging selected data from another sources.

At this stage, we restrict the study to local earthquakes and the criteria to define a good dataset is whether it meets the independently determined Ground Truth 5 (at 95% confidence level) criteria (Table 1).

	Criteria
At least 10 stations at epicentral distance ≤	2.25°
At least one station at epicentral distance ≤	0.27°
Azimuthal gap defined with stations closer than 2.25° ≤	110°
Secondary azimuthal gap defined with stations closer than 2.25° ≤	160°

Tableau 1 : GT5 criteria (Ground truth location better than 5km at 95% confidence level) as defined by Bondár et al., 2004

Two very simple cases are presented figure 1. In the first one the reported arrival times by one of the network already meets the GT5 criteria; data provided by other networks are recorded at much larger epicentral distances and their integration will not improve the location accuracy. In such a case, the reported location can be considered as authoritative.

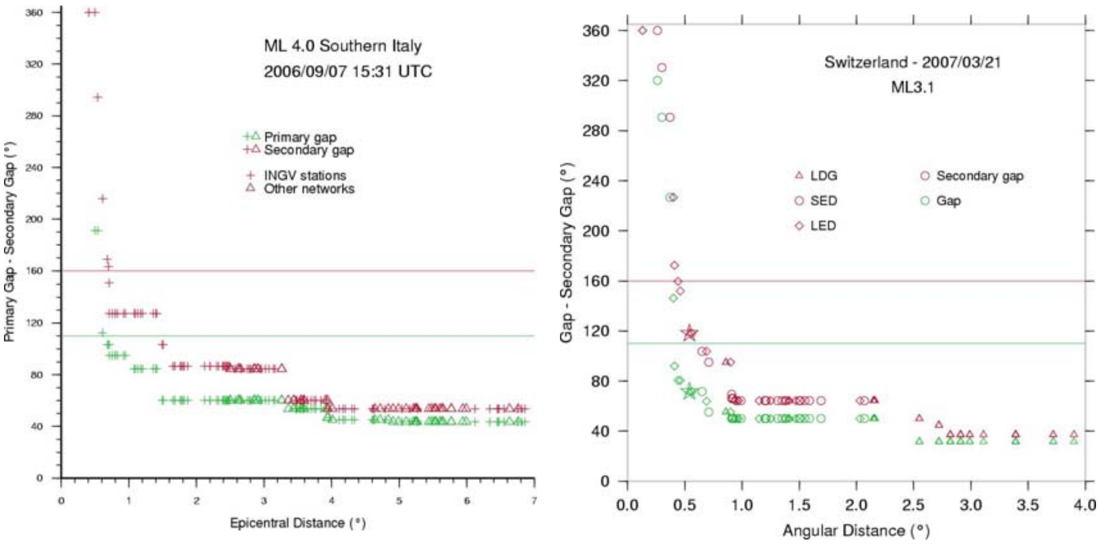


Figure 1 : Evolution of the gap (green) and secondary gap (red) versus the epicentral distance. Each symbol represents one reporting seismic station. Each reporting network is represented by a different symbol. The horizontal lines represent the minimum values of the primary and secondary azimutal gap to be reached within 2.25° to meet the GT5 criteria. On the left, the location largely meets the GT5 criteria when considering the data reported by the local network (INGV) only; furthermore, the data reported by other networks are at epicentral distances greater than 2° and do not provide significant azimutal constraints. On the contrary, on the right, three different networks report stations within less than 1° and a GT5 location can be determined by merging these different sources.

On the opposite, the second example is from an earthquake in a well monitored border region and a GT5 location can be reached by merging the stations reported by the 3 different networks.

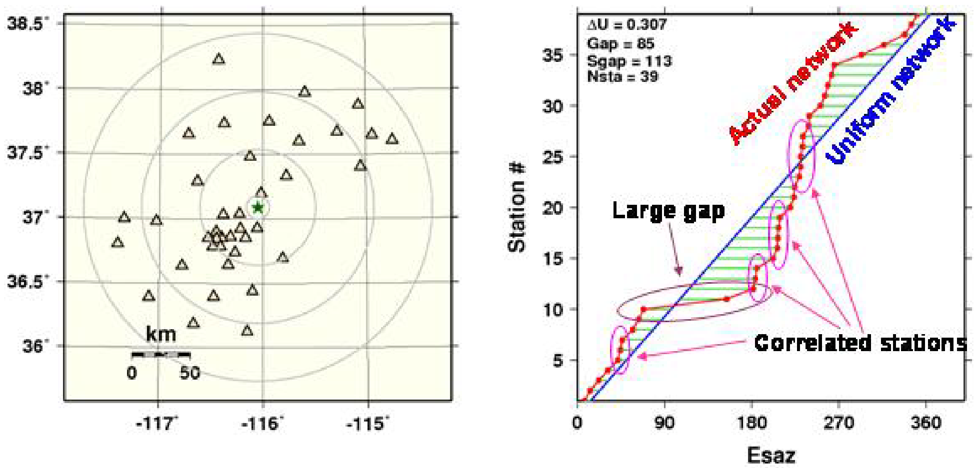
This type of approach can provide a scientific basis to define an authoritative location and to demonstrate when data merging can actually improve the location quality[1].

There is however a pragmatic limitation due to the density of the monitoring stations: An experimental implementation at EMSC showed that there are only a few tens of earthquakes meeting the GT5 criteria when considering only one network (over a total of 15 000 events reported in real time).

The second question concerns events where data merging is appropriate. Which stations should be used: the minimum number of stations required to reach the GT5 criteria?, all the ones up to a pre-defined distance? Only stations which provide an additional azimutal constraint (i.e., which lead to a reduction of the primary and/or the secondary gap?. In other words, what is the best configuration of the seismic network to locate a given event? It is the question we try to explore.

On the best network configuration to locate an earthquake

Firstly we tried to explore the possibility to use ΔU, a network quality metric recently proposed by Bondár and McLaughlin (2008) and presented figure 2. Large gaps and stations covering the same azimuth introduce deviations from the optimal network and lead to increases in ΔU values.



$$\Delta U = \frac{4\sum \left| esaz_i - (unif_i + b) \right|}{360N}, \quad 0 \le \Delta U \le 1;$$

$$unif_i = \frac{360i}{N}; \quad b = \overline{esaz} - \overline{unif}$$

Figure 2 : ΔU is a network quality metric proposed by Bondár and McLaughlin (2008). It characterises the deviation from an azimuthally uniform network. A ΔU of 0 a network with a uniform azimutal distribution

Using GT0 events and relocations using random subnetworks, Bondár and McLaughlin (2008) proposed ΔU ≤ 0.35 to screen GT5 event candidates at high confidence level (Figure 3).

[1] Assuming networks report all the stations they used

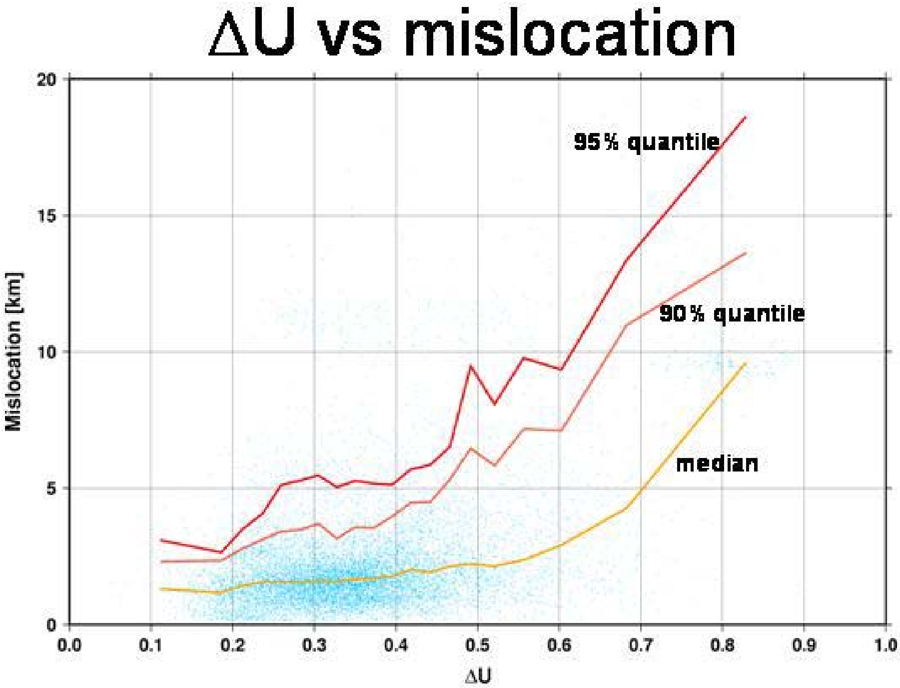


Figure 3 : Mislocations of GT0 events when relocalised from random sub networks vs ΔU (From Bondár and McLaughlin, 2008).

We tested ΔU as a metric to define the optimal network (within 150km). In practice, we attempted to define the subset of stations which keeps the gap and secondary gaps unchanged while decreasing the ΔU value. It appears that this was not an option as the variations of ΔU were often minimal even when variations of network geometry were clearly visible (Figure 4).

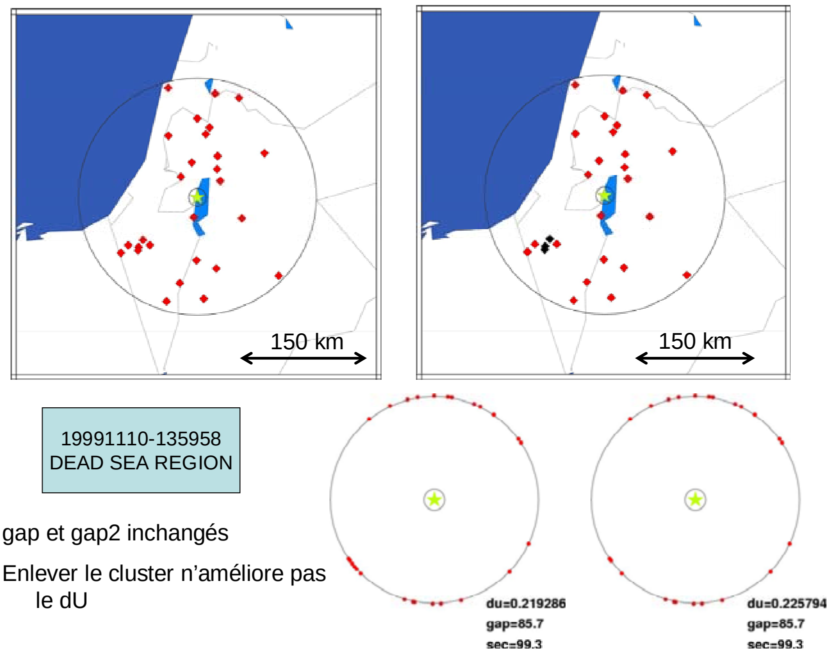


Figure 4 : Differences in ΔU observed when suppressing the cluster of stations located at the SW of the epicentre. Three stations (in black) have been suppressed on the right while keeping the gap and secondary gap unchanged and this suppression does not lead to significant change in ΔU values

This could also be due to the suspected impact of the number of stations on the ΔU measurement (Figure 5).

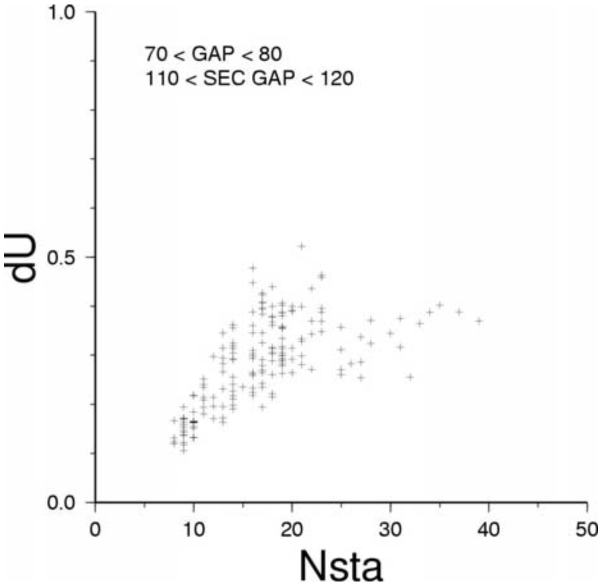


Figure 5 : Variations of ΔU vs the number of stations for all subnetworks from Bondár and McLaughlin (2008) presenting a gap between 70 and 80° and a secondary gap between 110 and 120°. This plot tends to show that, in some ranges of gap and secondary gap ΔU depends on the number of stations. Nevertheless, a global trend is not easy to identify as an increasing number of stations generally reduces the gaps.

Pragmatically, the ΔU values characterises the quality of azimutal coverage, but seems little influenced by the presence of a cluster of stations (which is logical since the epicentral distance is not a defining parameter of this metric). However, stations within a same cluster are affected by a similar travel-time prediction errors and their presence may bias the location but is not identified by ΔU only (Figure 6).

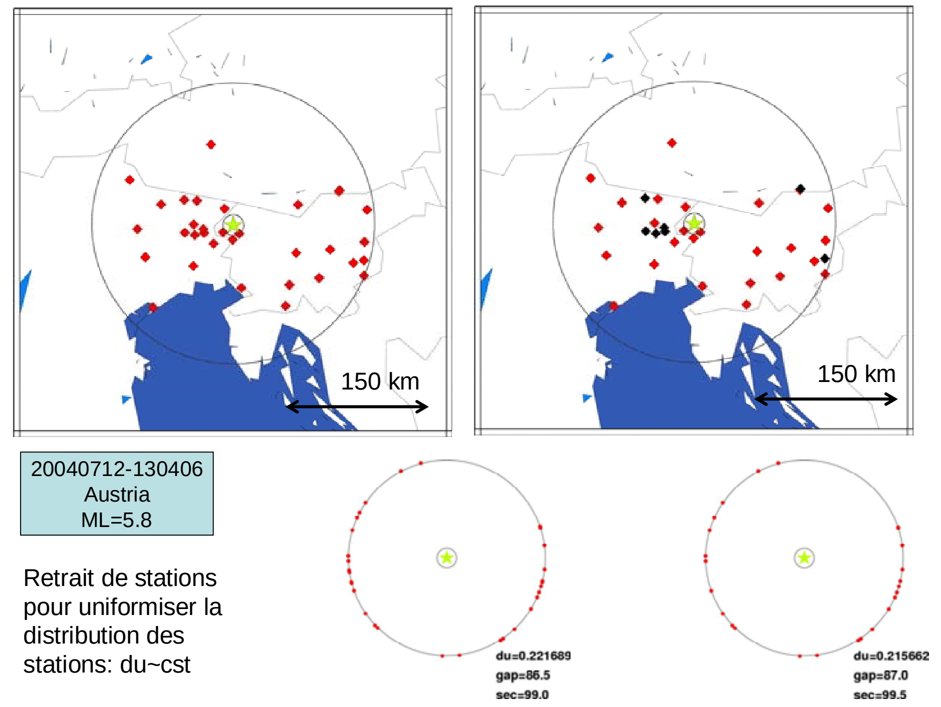


Figure 6 : Comparison of the ΔU values when suppressing reducing the number of cluster of stations. Seven stations (in black) have been removed on the right to reduce the possibility to use several stations of similar travel-time prediction errors with no impact on the ΔU value.

In short, ΔU is definitely suitable for identifying GT5 events and characterised the azimutal coverage of a network as proposed by Bondár and McLaughlin (2008). However, an additional metric probably needs to be defined to characterise the existence of cluster of stations (Figure 7)

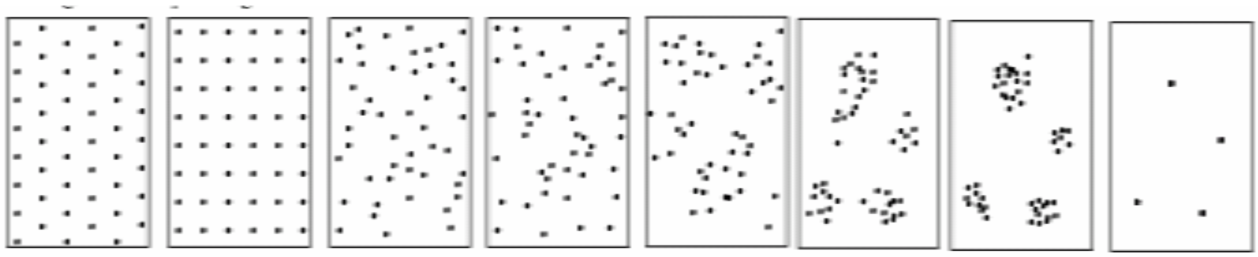


Figure 7 : Example of different types of spatial distribution in 2D

Several metrics exist, we propose as a next step to reanalyse the relocations of GT0 events performed by Bondár and McLaughlin (2008) to

a) properly evaluate the impact of cluster of stations on location accuracy
b) testing possible metrics to characterise the presence of clusters of stations
c) proposing procedures to automatically select the best network in terms of ΔU and station clustering

References

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