

Answers to comments of Reviewer#2

December 5, 2025

Reviewer#2:

General comments

The introduction need to be improved to better introduce the work and highlight the contribution of this new catalog. It would be more interesting to focus on processes to build high-quality seismic catalogs and what is already known on the studied area, rather than on a listing of existing networks in South Italia. More details on CASP must be given, especially on triggering, detection, and picking to be able to appreciate the performance of the process, but also to understand the issues encountered by the authors in their automatic catalog. The performance of CASP as parametrised in this study does not seem optimal given the significant part of fake events. Are the parametrisation use by the authors for CASP can be still improved ? If yes, the authors should discuss this point in the discussion part with some suggestions for improvement. A more general question about the methodology used in this study to build the catalog is : Why did the authors choose CASP which uses rather standard processes, and not more up to date methodologies including deep-learning for automatic picking, new associators, etc ? Some suggestions are made below to improve English, but this is not exhaustive. Careful proofreading should be done to improve the English.

Authors:

We rewrote some parts of the introduction section to include processes to build high-quality seismic catalogs taking as an example the paper of Spallarossa et al., 2021 which used CASP software to build high resolution earthquake catalogs for Amatrice (Central Italy) 2016 seismic sequence. We also added in the Introduction section more information about the current knowledge of the Gargano seismotectonics and synthesized the list of existing networks in Southern Italy. In the section "Data Analysis" subsection "CASP automatic list of events - AL" we added more details about the configuration parameters of the CASP modules *Trigger*, *Detect* and *Picker2*. The parameters of the CASP modules was optimized and chosen thorough numerous tests on 100 days of recordings of the GSN network. During these tests we checked the reliability of the filtering and time windows for the STALTA algorithm concluding that the best configuration to maximize the detect is that reported in the manuscript ("An appropriate STA/LTA = 0.8/25 and filtering (band pass filter between

10 Hz and 25 Hz), based on these tests, was selected as best choice.”) We also checked the reliability of the Picker2 module by modifying the parameters for S phase detection and reported the best choice in the text (“In this module configuration, the *PostSTeo* parameter, maximum time interval between the P-wave and S-wave picks, was set to a value determined through several tests, which demonstrated the sensitivity of event detection to this parameter. The optimal value for our study area is $PostSTeo = 5$ s). We also extended the description of the *Detect* module To help the user that would like to follow the same workflow that we used, in the Data Availability section we released also the configuration files used in CASP modules.

Regarding the optimization of the parameter settings to avoid the detection of false events, we have to do a consideration. Our aim was to enhance the detect and collect a catalog large as much as possible. For this reason we have set the CASP parameters (STA/LTA time windows that are usually (2,80) was set to (0.8,25)) by pushing the detection towards even smaller events, with the disadvantage of inserting a greater number of false events into the catalog, aware that we would have done a manual review of the entire list of events. In order to use CASP without manual revision, an improvement of the setting parameters should be studied and tested. For the same reason, we set 3 phases as minimum for detection increasing the number of false events. See also the response to comment ”- p. 10, line 197” We added this comment in the discussion section. The choice of CASP to build the seismic catalog of GP does not exclude the use of machine learning methods to do the same task. As already answered to Reviewer#1: The CASP tool is successfully implemented for the seismic monitoring of Northwestern Italy. So we explored the possibility to implement this code for the seismic monitoring of the Gargano Promontory. The CASP license was acquired thank to a collaboration between the University of Bari Aldo Moro and the INGV. The code is nowadays operative. The CASP code gave us the possibility to analyze ten years of seismic recordings in offline mode with the results illustrated in the manuscript. We conclude that the CASP software is able to detect a large number of small magnitude events, the S-wave picking suffers of some uncertainties that do not affect the reliability of the final location, manual revision is necessary to exclude from the catalog the non-earthquake events. Overall the CASP software was useful to build the released catalog. Manual review of the catalog obtained with CASP allowed us to collect a dataset of highly reliable earthquakes, as they were repicked. This dataset, for which we have released a bulletin in the Data Availability section, will allow us to test the effectiveness of machine learning techniques in automatic picking and building automatic catalogs. In fact, the machine learning detection (PhaseNet, Zhu et al., 2019) and association techniques (GAMMA, Zhu et al., 2021) can be applied to the same dataset, leading to a greater number of detected events. The results of this study and the well located earthquakes of the released catalogs can be used to test the effectiveness of machine learning techniques in automatic picking when building automatic catalogs. We modified the discussion section to account for this comment.

Reviewer#2:

Specific comments and suggestions

- p1, line 7: '7 years' instead of '7 year';
- p.1, line 14-16 : the structure of the sentence is a bit weird, rephrase ;
- p. 2, line 30 : 'earthquake' appears twice in the sentence, I suggest 'strong earthquake of November 23, 1999 ($M_s=6.9$)' ;
- p. 3, line 60-61 : a parallel fault system is mentioned in the text, but not represented in Fig 1b. Add it ;

Authors:

We modified the text and changed the Figure 1 to include the parallel fault system (black line) mentioned in the text.

Reviewer#2:

- p. 3, line 61-64 : the authors mentioned here the largest earthquakes in the region. It will be very useful in this introduction part to add a seismicity map. It will give an overview of the seismic activity in the area at least before OTRIONS network (or with the mentioned previous catalog from Filippucci et al. 2021) to better appreciate and highlight the contribution of this network and the catalog obtained in this study. It will also help to locate the mentioned earthquakes ;

Authors:

We added on the map the location of the two earthquakes mentioned in the text.

Reviewer#2:

- p. 4, line 75 : I am not sure to understand what the authors mean by 'consistent in arrival times picking'. Consistent compare to what ?

Authors:

The term "consistent" refers to the reliability of CASP in the picking procedure. We modified the sentence for more clarity.

Reviewer#2:

- p. 5, line 108 - 109 : I suggest to modify the sentence as follows : 'the network performance was evaluated by the percentage of operating days per year for each station between 2013 and 2022 (tab. A1). It is worth noting the clear improvement in network performance after 2019 compared to the preceding period.' ;
- p. 5, line 113 : 'after 2019' instead of 'after the 2019' ;
- p. 6, section 2.2 should be shortened : lines 125-127 should be moved to the previous section describing the network, and lines 127 to 133 should be moved in the legend of Figure 3 ;

Authors:

We modified the text to account for the Reviewer#2 suggestions.

Reviewer#2

- p. 6, line 136 : ‘optimal’ is not the appropriate term regarding the quality of the stations in Figure 3 and A3 to A6, but I agree that half of the stations have overall good performances. Rephrase. Moreover, PPSDs is not sufficient to assess the overall quality of stations in particular for catalogue purpose, as some stations with low noise level (evaluated through PPSD) can lead to overpicking for some reasons and disturb picking process. Thus the number of detections per day (outside active seismic periods) can be a useful additional information;

Authors:

The text was modified and the term "optimal" was substituted with "overall good". The detection was evaluated by counting the number of P and S phases picking for each station every three months for the decade from 2013 to 2022. The results are organized in the histograms in the following figure.

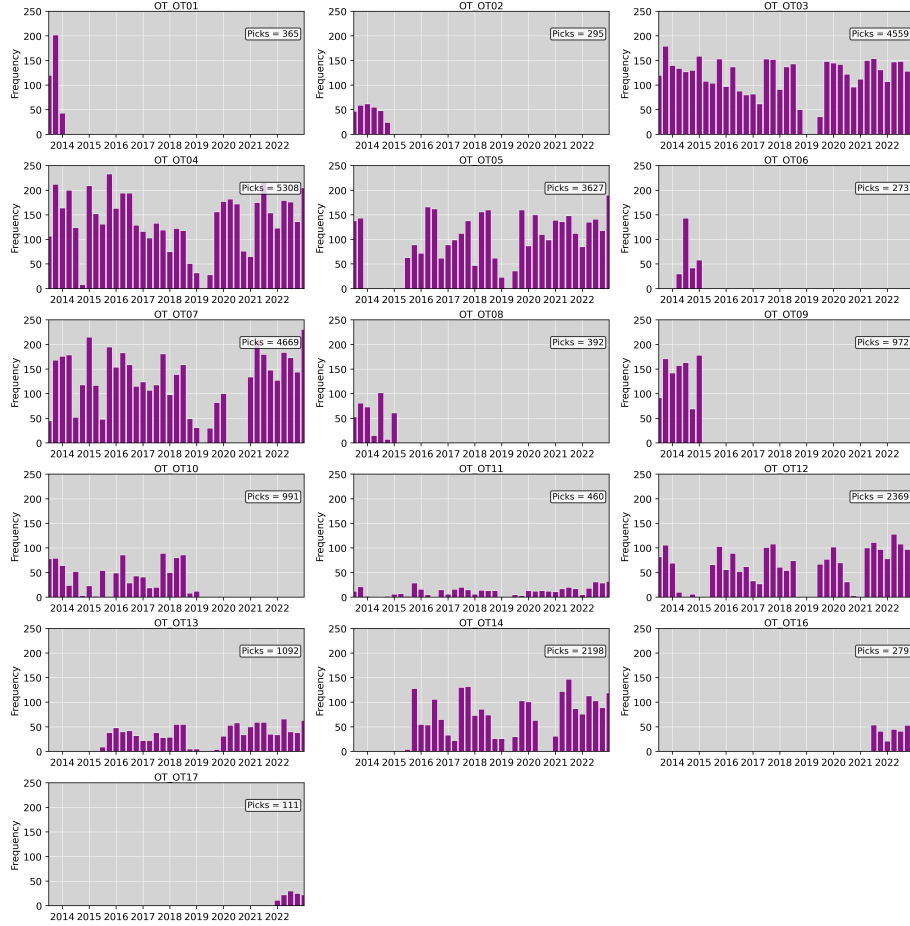


Figure 1: Histograms of number of automatic picking, used for EQ catalogs, for each station of the OT network, from 2013 to 2022 with bins of three months. Superimposed the total number of pickings

From the comparison of the PSD and the histograms of automatic pickings, some considerations can be done. In the frequency range $[10, 25]$ Hz of the STALTA algorithm of CASP used for detection, the stations with the lowest level of noise (OT01, OT03, OT04, OT05, OT06, OT07, OT08, OT09) and those with an intermediate noise level (OT12, OT14 and OT16) are characterized by the highest number of pickings in the period of operation. The stations OT05 and OT06 were used as an unique station given their closeness. The stations with a high noise level (OT02, OT10, OT11, OT13 and OT17) correspond to the stations that contributed less to the detection. The correlation between the level of the noise and the number of automatic pickings is worth to be dis-

cussed and we added it in the manuscript in section Supplementary material.

Reviewer#2

- p. 9, table 1 : it should be moved to the annexe part, no need to be in the main text ;
- p. 9, line 164 : CASP is mentioned as an advanced software for automatic detection/picking/ event location, however looking in detail, it is quite standard procedures, nothing very new compared to nowadays workflow including deep-learning, new associators, etc. Rephrase ;
- p. 9, line 170 : why having choosing a band-pass filter between 10 and 25 Hz ? The lower bound seems to me a bit high. Is there a reason for that ?

Authors:

Table 1 was moved to the Supplementary material in Section A1.

We eliminated the qualitative adjective "advanced".

Regarding the band pass filter for STALTA we referred to the work of Spallarossa et al. (2021) who used a band-pass filter between [10,30] Hz and adapted it to our data after a training tests over 100 days of registration. We added this explanation in the text.

Reviewer#2

- p. 10, lines 171-172 : give a bit more details on the parameters used for trigger, association and event detection, for instance minimum number of stations/picks, etc. It will help to better understand the performance of the automatic process described later in the paper (significant number of fake events, etc) ;
- p. 10, lines 175-186 : the authors must give a bit more information concerning the method used for picking. All these details would be useful to better understand the analysis of the automatic process performance ;
- p. 10, lines 193-194: the authors mentioned the number of seismograms picked manually. It will be also interesting to add information concerning the number of additional picks provided by the manual revision (number of picks missed by the automatic process) ;
- p. 10, line 197 : an example of fake event seen at 3 stations is mentioned. Does it mean that event detection is made considering a minimum number of stations equal to 3 ? Detection with only 3 stations inevitably leads to false detections without other criteria to discarded them, or/and to badly located events. If it is the case, this could explain some of the critical issues of the automatic process. Specify and comment ;
- p. 11, Figure 4 : add information about the filtering used for the plot. Use 'recordings' instead of 'registrations' (check other occurrences, and apply same correction). Some picks on the noisiest traces are quite puzzling, as no clear change in the signal is visible. Comment ;

- p. 11, lines 206-207 : among the 2012 events identified, what is the proportion of fake events and events outside the network badly located inside ?

Authors:

In the description of the modules of the CASP software, *Trigger*, *Detect* and *Picker2*, we added some more details and we also added in the online repository (Ferrerri et al., 2025) the configuration files used as input files for the CASP modules.

To evaluate the usefulness of the manual picking procedure in terms of number of pickings, we counted both the automatic and the manual ones only for the earthquakes (4098 EQ) of the catalogs. In the following figure do not appear all the automatic pickings of the CASP software that refer to the automatic list of events (7162 AL).

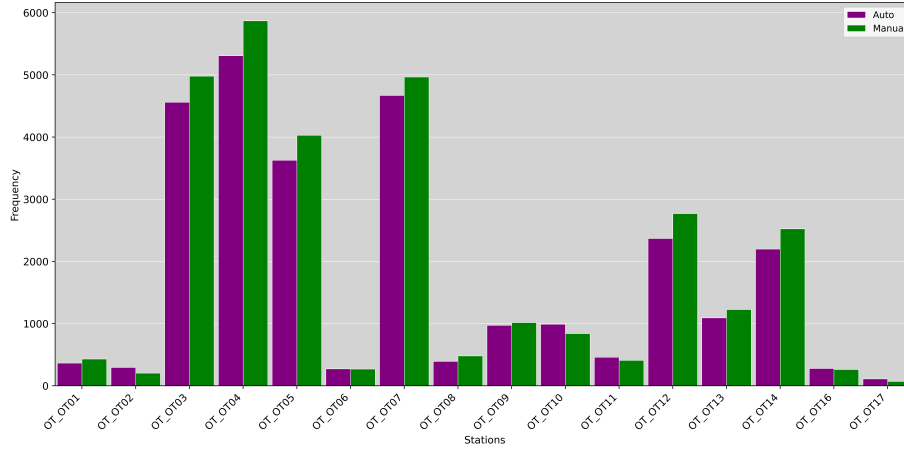


Figure 2: Histogram of the number of automatic (purple) and manual (green) pickings for the earthquake catalog EQ carried out on all OT stations

The histogram reveals that the manual procedure, slightly but systematically for all the OT stations, increases the number of pickings. We added this new figure to the manuscript in the supplementary material.

The minimum number of trigger to detection is specified in the configuration file and it is equal to 3. The example in the figure is a false event detected at 13 stations. We modified the figure to solve the misunderstanding.

To understand the percentage of false and bad located events respect to the events automatically detected, we proceeded to label the events in the category FB and created two new categories: the false events (FE) and the bad located earthquakes (BL). This procedure gave us the possibility to control again our data and correct the number of events in the automatic list of events (AL).

In the following figure (Fig. 3), the number of the events discarded as false (FE) and bad located (BL) is plotted versus the number of phases used for detection. This result indicates that the number of discarded events decreases with the number of phases used for detection and it can be used as an indication to how the CASP tool can work alone without supervision.

We added this figure and this discussion in the manuscript. See also the response to general comment.

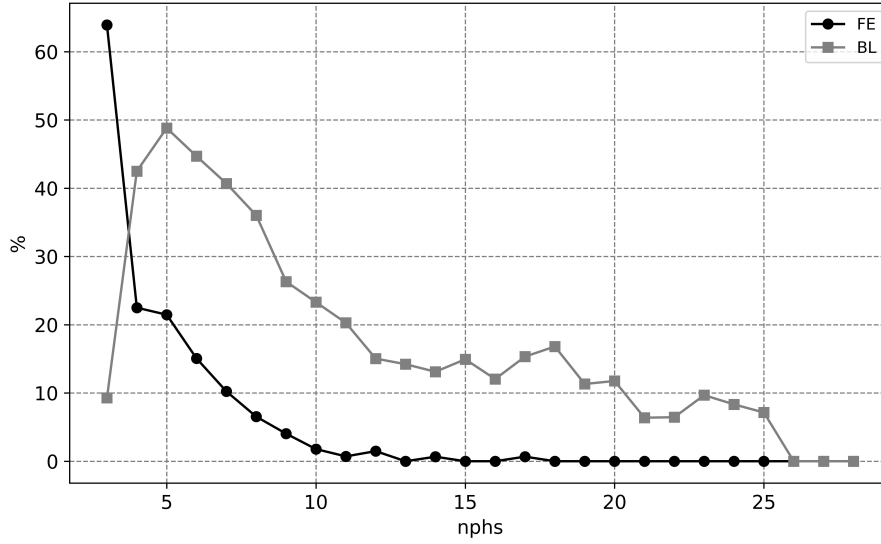


Figure 3: Curves of BL and FE (gray and black respectively) plotted versus the number of phases used by CASP for the detection.

Reviewer#2

- p. 12 line 229 : explain the choice of depth selection ;
- p. 13, line 238 : natural earthquakes should be represented in Fig 7a by blue dots, but there is no blue dot on the corresponding Figure. Add them ;
- p. 13, line 242 : why quarry blasts have depth ranging between 3 and 7 km ? Does it correspond to the manual or the automatic catalog ? Why not having relocate them with a fixed depth at the surface when identified as a quarry blast ?
- p. 14, Figure 7 : add transparency to histogram plots to be able to better see the differences of distribution between natural earthquakes and quarry blasts ;

Authors:

Working on the quarry blasts events we observed that some of them automat-

ically located could have foci depth greater than 5 km. For this reason, we extended the depth range in which to search for automatically detected quarry explosions. We modified the phrase.

We modified the figure to account for the request and added EQ in the map.

The quarry blasts plotted in map are located by the automatic procedure of the CASP tool. No re-picking neither relocation was carried out on quarry blasts, but they were only discarded from the final catalogs. We agree that the catalog of quarry blasts deserves a dedicated study and this was behind the scope of this paper. We clarified this motivation in the text

The daytime and depth histograms of quarry blasts is a stacked histogram, thus the yellow bar indicating the number of blasts is over the blue bar indicating the number of earthquakes. We clarified in the caption

Reviewer#2

- p. 15, line 254 : the value for the standard deviation (2.586), is not consistent with results in Figure 8. Correct it.

- p. 15, line 256-257 : the performance of the picker does not seem to be as good as expected. Automatic picks seems to be systematically earlier than the manual ones, and some with significative differences. What is the methodology used for the picking process ? As mentioned, this could results in event closer to the network, but also in shallower events. Specify ;

- p. 16, line 271 : ‘assess’ instead of ‘asses’ ;

Authors:

We corrected the value of the standard deviation of S picks $\sigma_{\Delta T_S} = 0.654$ s

The automatic picks are later than the manual ones slightly systematically. We already evidenced this behavior in the manuscript. The methodology for automatic picking is already explained in the section “CASP automatic list of events - AL”. It is worth to note that nevertheless this discrepancy in the time picks, the effect in the earthquake location shown in Figure 11 (now Figure 12) is negligible and inside the intrinsic error bar of location. All these consideration are already present in the section “NLL-catalog of EQ”.

Reviewer#2

p. 17, lines 286-287 : the authors mentioned the fact that rms refers to location quality in time domain, it is not quite exact, it represents the misfit between observed and theoretical travel times, it can be affected by the quality of the location in space, and the inconsistency of the true velocity structure compared to the velocity model used. Rephrase. They also mentioned the good values for rms parameters, but looking at table 3, we can noticed that the max value for rms is 23s which is quite high and surprising for a manually revised catalogue ! Comment and reprocess the corresponding event ;

- p. 17, line 308 : The authors claim that, for earthquake, manual revision is not

necessary. But it is needed to remove fake events and quarry blast. Moreover this depends on the purpose, meaning on the use made of the catalog, especially in terms of pick quality. Rephrase;

Authors:

We corrected the misunderstanding concerning the time domain and rephrased. Regarding the outliers in the manual EQ catalogs, the Table 2 clearly demonstrates that the outliers, obviously included in the catalog, since human errors in manual reviews are unavoidable, do not affect the quality of the final catalogs. In fact the mean, the median and the mode values of the quality parameters in Table 2 are of really good quality. It is important to observe that the statistics in Tab.2 (95^{th} and 5^{th}) are necessary to compute the quality q_f of the earthquake as described in the formula in Eq. (4). Only for the estimator number of phases $nphs$ we used the maximum value and the 5th percentile as minimum value. The maximum values of rms , erh and erz refer to events that are discarded after the application of the quality formula, as explained in the section 5.3. This demonstrate that the q_f parameter is well formulated and useful to automatically clean the catalog from low-quality locations. We modified the table 2 and eliminated the rows of 50th percentile and 90th percentile since they are not used in the formula and also eliminated the row indicating the maximum and the minimum of the uncertainty estimator since they are not used in the quality formula, with the exception of the maximum of $nphs$. We also added a conclusive table of statistics which refer only to the final released catalogs, after the quality selection.

We rephrased as following: "Once earthquake-type events have been identified and selected, their location in terms of P and S phase recognition is acceptable even without manual review, as shown in Fig. 12. If the effort to catalog the event type were automated, for example with artificial intelligence techniques trained on the specific dataset, rather than manual, the CASP software could operate without supervision. However, if high-quality picking is required, manual review of time arrivals is still necessary, as shown in Fig. 10."

Reviewer#2

- p. 18, Figure 9 and p.19 line 320: histograms for hypo71 catalog are in red, not in orange. Correct.

p. 19, line 310 : I do not understand the choice made by the authors concerning the initial depths used to refined the depth of locations done with hypo71 : depth range is from 10 to 100 km with a step of 10km. Figure 7c clearly shows that most of the events are located above 35km. Comment.

Authors:

We modified the caption for a better explanation: "Overlapped histograms of quality location estimators for the H71-catalog (orange+red areas) and NLL-

catalog (blue+red areas) . The areas in red color should be considered as common parts for both the H71 and NLL catalogs.”.

The choice of the number of initial values of hypocentral depth to start the *H71* inversion is arbitrary and we decided to use 10 different depths in continuity with Miccolis et al. (2021) even if we could stop the investigation at a depth of 50 km. The result does not change.

Reviewer#2

- p. 19, lines 324-326 : the difference in err_h and err_z between event locations done with hypo71 and NLL are surprising. Hypo71 and NLL have quite different uncertainty definitions, in hypo71 uncertainties correspond to one standard deviation, NLL provides a full probability density description of the errors. How err_h and err_z are computed from NLL output parameters ? Check the consistency of err_h and err_z for this 2 algorithms ; p. 19, line 327, p. 20, line 328-329 : the comments on $depth \pm err_z$ for events close to the surface, is quite useless. Events close to the surface are always more difficult to locate, and in that sense, NLL often give a better uncertainty estimation, better catching this difficulties. Moreover, when station elevations and topography are included in NLL location, there are less events located at the surface ;

Authors:

The software NLL gives as output files also one file written in h71 format. The conversion from the uncertainty provided by NLL in h71 format is computed and released by Lomax et al. (2000 and 2014) and the conversion is explained in the webpage of the NLL code (<http://alomax.free.fr/nlloc/>). We added this explanation in the text.

We agree with the Reviewer#2 regarding the shallow earthquakes and in fact the those with vertical error bar such as to bring the focus off the surface were automatically discarded from the final catalog thanks to the application of the quality formula. In this work the quality formula reveals a very important tool for automatically select the best quality earthquakes.

Reviewer#2

- p.20, line 339 : in the quality parameter computation (following Michele et al. 2019), why having considering a different weight for the gap ? Indeed, azimuthal gap has a great influence on the quality of the location, much more than the rms or the number of phases. Comment ;

- p. 20, lines 341-345 : as the quality parameter q_f is not exactly the same for NLL and hypo71 as some parameters are not available for hypo71, thus I suspect that q_f can be slightly different for equivalent quality of location. Thus, as classes are split based on the same value 0/0.25/0.5/0.75/1, the classes for NLL and hypo71 can therefore have slightly different characteristic in terms of gap/rms/ err_h / err_z /... Thus the comparison of percentage of events in the

different classes in table 4 may be not quite representative, and misleading.
Comment ;

Authors:

We agree with Reviewer#2 that the azimuthal gap has a very important role in the quality of the earthquakes but the Gargano Promontory for its geographical characteristics can be assimilated to an offshore area and the earthquakes occurred in the Gargano Promontory should be treated as offshore earthquakes. For this reason we weighted the azimuthal gap less than other quality parameters as proposed by Latorre et al., 2023 to prevent the quality of the entire catalog from being brought down by the quality of the gap. We added this explanation in the manuscript.

As the Reviewer#2 comments, the differences in the location quality between NLL and H71 codes are not only due the parameters locdist and rpdf, which are present in NLL output and not in H71 output, but also in the values of erh and erz, which are present in the putput of both NLL and H71, as it can be seen in Figure 11. Since the quality as retrieved from the quality formula, depends on the values of the error parameters, the qf value will never be the same for a given earthquake located with both NLL and H71 codes. However, the two final quality results for the entire catalog do not differ much and lead to the same conclusion, namely that most earthquakes belong to the first three quality classes. The result of table 4 are therefore representative of the quality of locations, as shown by the location errors in Fig. 11.

Reviewer#2

- p. 23, lines 365-366 : how the authors can claim that the minimal magnitude detectable is lower for this catalog, given that the magnitudes are not exactly computed the same way, and that the difference mentioned is only 0.01 which is well below the typical uncertainties on magnitudes. Rephrase ;

Authors:

The minimum detectable magnitude moves from -0.1 of the preceding catalog (Filippucci et al., 2021) to -1 of this one. So the difference is of 0.9 degrees of magnitude not of 0.01, greater than uncertainties on magnitude. To avoid misunderstanding we substituted -0.99 with -1.

Reviewer#2

- Figure 13 : labels of the different plot axes are too small. Enlarge them ;
- Figure 14 : histogram for hypo71 catalog is in red, not in orange ;

Authors:

We modified the labels in Figure 13 (now Figure 15)
We clarified the meaning of the colors in the caption of the Figure 14.

Reviewer#2

- p. 25, line 390 : the qf value given for NLL is probably incorrect : 6.3 ;
- p. 25, lines 394-401 : to better appreciate the contribution of this catalog in comparison to the ONT one, seismicity of ONT can be for example plot in the introduction part as already mentioned. A magnitude threshold of -1 is mentioned, this is not consistent with what is mentioned in previous section ;

Authors:

Regarding the group of earthquakes that NLL locates at shallow depths, with such a vertical error that the events could be above the Earth's surface, these earthquakes are 418 and have an average depth of 1.95 ± 6.88 km (Fig. 13) and an average quality $qf = 6.3$ in the NLL catalog and were discarded from the final NLL-catalog. This example demonstrates that the qf parameter in Eq. 4 proposed in this paper is well formulated and $qf \geq 1$ is a reliable criterion to discard bad quality events. These 418 discarded from the NLL-catalog, when located with H71 result at an average depth of 14.56 ± 4.03 km and have an average $qf = 0.57$, so they can be included in the H71-catalog. This explains why, in Tab. 3, the number of earthquakes in each quality class may differ between the NLL and H71 locations.

The lower magnitude threshold calculated with our catalog is exactly -1 as reported in the text (since $-0.99 \simeq -1$)

We decided not to show the seismicity of the ONT catalog in the figures to avoid confusion with our catalog. For an indication of the number of detected events, in Figure 4A of the Supplementary material we plotted the cumulative number of earthquakes of the ONT which shows that our catalog includes more than twice the number of earthquakes respect to the ONT in the same region.

Reviewer#2

- p. 25, line 400 : reference to figure is not correct : ??
- p. 25, line 411 : the authors mentioned the fact that the seismicity follows 2 alignments SW-NE. This can not clearly seen on the figure 13, seismicity is rather diffuse on both side of Mattinata fault ;
- p. 25, line 421-422 : the authors mentioned a seismic gap, but it sounds more as a region without seismicity. Is there historically seismicity in that region ?
- Figure A1 or A7 : one of these 2 figures should be put in the main text to better appreciate the discussion on seismicity features.

Authors:

We corrected the reference.

In Figure 13 (Figure 15 in the revised manuscript) two clusters can be observed that are elongated in SW-NE direction separated by an area elongated in the same Sw-NE direction characterized by absence of seismicity and located one at the orthern part of GP and the other at the southern part of GP crossing the MF fault. These cluster are clearly visible both with the H71-catalog and with the NLL catalog. We modified the text for more clarity.

The absence of seismicity in NE part of the Gargano Promontory is also documented from the historical seismicity as showed by Del Gaudio et al. (2007) in Fig. 3. We rephrased.

To better appreciate the discussion and following the suggestion of the Reviewer#1, we moved Fig. A1 in the discussion section (Fig.17 in the revised paper).

References:

Del Gaudio, V., Pierri, P., Frepoli, A., Calcagnile, G., Venisti, N. and Cimini, G. B. (2007). A critical revision of the seismicity of Northern Apulia (Adriatic microplate—Southern Italy) and implications for the identification of seismogenic structures. *Tectonophysics*, 436(1-4), 9-35. <https://doi.org/10.1016/j.tecto.2007.02.013>

Ferreri, Andrea Pio; Romeo, Annalisa; Giannuzzi, Rossella; Ninivaggi, Teresa; Filippucci, Marilena; Cecere, Gianpaolo; Falco, Luigi; Michele, Maddalena; Selvaggi, Giulio; Tallarico, Andrea (2025), “The new seismic catalog of the Gargano area (Southern Italy) after a decade of seismic monitoring by OTRIONS network”, *Mendeley Data*, V4, <https://doi.org/10.17632/nhfvx7ysxw.4>

Filippucci, M., Miccolis, S., Castagnozzi, A., Cecere, G., de Lorenzo, S., Donvito, G., Falco, L., Michele, M., Nicotri, S., Romeo, A., Selvaggi, G., Tallarico, A. (2021). Seismicity of the Gargano promontory (Southern Italy) after 7 years of local seismic network operation: Data release of waveforms from 2013 to 2018. *Data in Brief*, 35, 106783. <https://doi.org/10.1016/j.dib.2021.106783>

Latorre, D., Di Stefano, R., Castello, B., Michele, M., and Chiaraluce, L.: An updated view of the Italian seismicity from probabilistic location in 3D velocity models: The 1981–2018 Italian catalog of absolute earthquake locations (CLASS), *Tectonophysics*, 846, 229–664, <https://doi.org/https://doi.org/10.1016/j.tecto.2022.229664>, 2023.

Lomax A., Virieux J., Volant P., Berge-Thierry C. (2000) Probabilistic Earthquake Location in 3D and Layered Models. In: Thurber C.H., Rabinowitz N. (eds) *Advances in Seismic Event Location. Modern Approaches in Geophysics*, vol 18. Springer, Dordrecht. https://doi.org/10.1007/978-94-015-9536-0_5

Lomax A., Michelini A., Curtis A. (2014) Earthquake Location, Direct, Global-Search Methods. In: Meyers R. (eds) Encyclopedia of Complexity and Systems Science. Springer, New York, NY. https://doi.org/10.1007/978-3-642-27737-5_150-2

Miccolis, S., Filippucci, M., De Lorenzo, S., Frepoli, A., Pierri, P., Tallarico, A. (2021). Seismogenic structure orientation and stress field of the Gargano Promontory (southern Italy) from microseismicity analysis. *Frontiers in Earth Science*, 9, 589332. <https://www.frontiersin.org/journals/earth-science/articles/10.3389/feart.2021.589332>

Spallarossa, D., Cattaneo, M., Scafidi, D., Michele, M., Chiaraluce, L., Segou, M., Main, I. G. (2021). An automatically generated high-resolution earthquake catalogue for the 2016–2017 Central Italy seismic sequence, including P and S phase arrival times. *Geophysical Journal International*, 225(1), 555–571. <https://doi.org/10.1093/gji/ggaa604>

Zhu, W. and Beroza, G. C. (2018). Phasenet: a deep-neural-network-based seismic arrival-time picking method. *Geophysical Journal International*, 216(1):261–273. <https://doi.org/10.1093/gji/ggy423>

Zhu, W., McBrearty, I. W., Mousavi, S. M., Ellsworth, W. L., and Beroza, G. C. (2022). Earthquake phase association using a bayesian gaussian mixture model. *Journal of Geophysical Research: Solid Earth*, 127(5):e2021JB023249. <https://doi.org/10.1029/2021JB023249>