Data in Brief 35 (2021) 106783

Contents lists available at ScienceDirect

Data in Brief

journal homepage: www.elsevier.com/locate/dib

Data Article

Seismicity of the Gargano promontory (Southern Italy) after 7 years of local seismic network operation: Data release of waveforms from 2013 to 2018

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ARTICLE INFO

Article history:
Received 8 November 2020
Revised 15 January 2021
Accepted 18 January 2021
Available online 21 January 2021

Keywords:
Gargano Promontory (Apulia, Southern Italy)
Micro-seismicity
OTRIONS seismic network
Seismic waveform data

ABSTRACT

The University of Bari (Italy), in cooperation with the National Institute of Geophysics and Volcanology (INGV) (Italy), has installed the OTRIONS micro-earthquake network to better understand the active tectonics of the Gargano promontory (Southern Italy). The OTRIONS network operates since 2013 and consists of 12 short period, 3 components, seismic stations located in the Apulian territory (Southern Italy). This data article releases the waveform database collected from 2013 to 2018 and describes the characteristics of the local network in the current configuration. At the end of 2018, we implemented a cloud infrastructure to make more robust the acquisition and storage system of the network

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https://doi.org/10.1016/j.dib.2021.106783

through a collaboration with the RECAS-Bari computing centre of the University of Bari (Italy) and of the National Institute of Nuclear Physics (Italy). Thanks to this implementation, waveforms recorded after the beginning of 2019 and the station metadata are accessible through the European Integrated Data Archive (EIDA, https://www.orfeus-eu.org/data/eida/nodes/INGV/).

Specifications Table

Subject	Geophysics
Specific subject area	Seismology
Type of data	Text files Digital time series (seismic waveforms in SAC [1,2] format)
How data were acquired	Data comes from 12 three components velocity seismometers connected to a local system of acquisition (OTRIONS) and from broad band seismometers of the National Seismic Network (RSN). Seismometers are short-period Lennartz 3D-V (flat response above 1 Hz). Data logger are 24-bit SL06/SARA (dynamic range equal to 124dB at 100 sps)
Data format	Text files Raw data: SAC [1,2] format. Waveforms are cut with respect to the earthquake origin time with an appropriate pre and post event time window (300 s). Header contains P and S-wave markers
Parameters for data collection	Text files containing stations coordinates, velocity model and the earthquake catalogue SAC [1,2] data time series cut with respect to the earthquake origin time on 300 s windows
Description of data collection	Each waveform is a 100 Hz sampling rate time series recorded and archived by SeisComP3 [3] software
Data source location	Institution: University of Bari Aldo Moro, Department of Earth and Geoenvironmental Sciences City/Town/Region: Bari Country: Italy
Data accessibility	Repository name: Mendeley Data Data identification number: DOI: 10.17632/7b5mmdjpt3.3 Direct URL to data: https://data.mendeley.com/datasets/7b5mmdjpt3/3 Filippucci et al. [4]

Value of the Data

- The waveforms dataset is original and integrates that of INGV (http://terremoti.ingv.it/). The dataset contains original earthquake locations in a crucial region of Italy, the Gargano Promontory.
- This dataset improves the knowledge on the seismicity of the Gargano and Southern Apennine region, a poorly studied region despite its relevant seismic hazard. The data are also essential for a large number of geophysical applications including seismo-tectonics studies, velocity and attenuation models, tomographic studies, site effects and magnitude calibration.
- This dataset can be integrated with data collected by other seismic networks for new local and/or regional scale seismological studies of the Southern Apennine region.
- Increasing interest in micro-earthquake and geodetic signals. Recently, there is an increasing worldwide interest in the relation between seismicity and hydrological signals detected by GNSS receivers. The availability of a long common time series (earthquake and geodetic deformation) as in the Gargano Promontory, allows to deepen these issues.

1. Data Description

We release waveforms and locations of the earthquakes recorded, from 2013 to 2018, by the OTRIONS network (following, we refer to this network with its FSDN international code OT).

The file OT_Stations.txt (http://dx.doi.org/10.17632/7b5mmdjpt3.3#file-75c36957-adbd-4740-bd62-b4306c8c895d) contains the list of OT station coordinates. OT stations were installed in the Gargano promontory and surroundings region during the first months of 2013 and started to operate on late April of the same year. During the first two years of activity, the Gargano seismic network was composed by 12 stations (OT01, OT02, OT03, OT04, OT05, OT06, OT07, OT08, OT09, OT10, OT11, OT12). In June 2015, we moved stations OT01 and OT02 northward for geometrical reasons, naming them OT13 and OT14. Stations OT08, OT09 stopped working in 2015 and OT10 was disabled in 2019 for technical problems. Station OT15 was added in the in 2018 at the Department of Earth and Geoenvironmental Science, University of Bari Aldo Moro, covering the central Apulia Region. Moreover, OT network acquired three seismic stations (MASS, MESG, TAR1) of the University of Bari Aldo Moro, equipped with broad band sensor and installed in southern Apulia. Today, the OT Network is made of 13 active stations, 10 equipped with velocimeters and three equipped with broad band sensors, covering the Apulia Region. Fig. 1a shows the Apulia Region and the all OT stations (red triangles). Fig. 1b shows the network implementation in the Gargano Promontory and the Tavoliere integrated with the INGV national seismic network (blue triangles). Fig. 1c is the temporal working diagram of each station from 2013 to 2020; stations with incremental numerical code from OT01 to OT14 make up the Gargano seismic network.

Gargano_Bulletin_13-18.txt (http://dx.doi.org/10.17632/7b5mmdjpt3.3#file-22d7a996-1cfe-4fd5-997b-3cdb5cb09be4), is the earthquakes catalogue. Location parameters are in HYPO71 [5] format. ID=identification number; BULL=type of bulletin (O: event available only in the OT bulletin; I: event available in the INGV bulletin integrated with the OT registrations); DATE and TIME= origin time; Lon(km), Lat(km), DEP(km)= location in UTM coordinates; MAG=magnitude as computed by SeisComP3 [3] using the Mlv formulation; NPH=number of phases used for location; GAP=azimuthal gap; DMIN=minimum distance (see HYPO71 [7]); RMS=residual time; ERH,ERZ=horizontal and vertical error in km; QM=quality factor (see HYPO71 [7]). Fig. 2 shows the 426 earthquake epicentres listed in the file https://data.mendeley.com/datasets/7b5mmdjpt3/3.

Earthquakes have been located by using the 1D velocity model [6] reported in the file (http://dx.doi.org/10.17632/7b5mmdjpt3.3#file-b5c2ad1a-9e5b-4524-b2ff-43748a9301f4).

The dataset we release is made of the seismic recordings for the years 2013, 2014, 2015, 2016, 2017 and 2018. The dataset contains a data-gap of 10 months (from August 2014 to June 2015) caused by software malfunctions.

Waveforms are stored in the folder Events_2013-2018 (http://dx.doi.org/10.17632/7b5mmdjpt3.3#folder-8f99b9cf-ea07-4952-87ce-d11cc6d4d655). Here, we store the compressed directory containing all the earthquake waveforms of the years 2013-2018.

2013.zip (http://dx.doi.org/10.17632/7b5mmdjpt3.3#file-825505b9-d707-4951-94f2-19be7176296a).

2014.zip (http://dx.doi.org/10.17632/7b5mmdjpt3.3#file-bab3619d-e20d-4745-9dfd-42b62a042fcc).

2015.zip (http://dx.doi.org/10.17632/7b5mmdjpt3.3#file-1a99e16d-af0a-4c37-87bb-185027979dd3).

2016.zip (http://dx.doi.org/10.17632/7b5mmdjpt3.3#file-920fc57c-e40f-4b6a-a027-338babf51369).

2017.zip (http://dx.doi.org/10.17632/7b5mmdjpt3.3#file-5ee9b455-3908-40a6-8bcf-95dd6ae4e8d5).

2018.zip (http://dx.doi.org/10.17632/7b5mmdjpt3.3#file-6fcda1f9-5366-484e-8f33-25ffc675471c).

Each directory year contains event directories and each event directory contains all the waveforms for that event (ie. Earthquake).

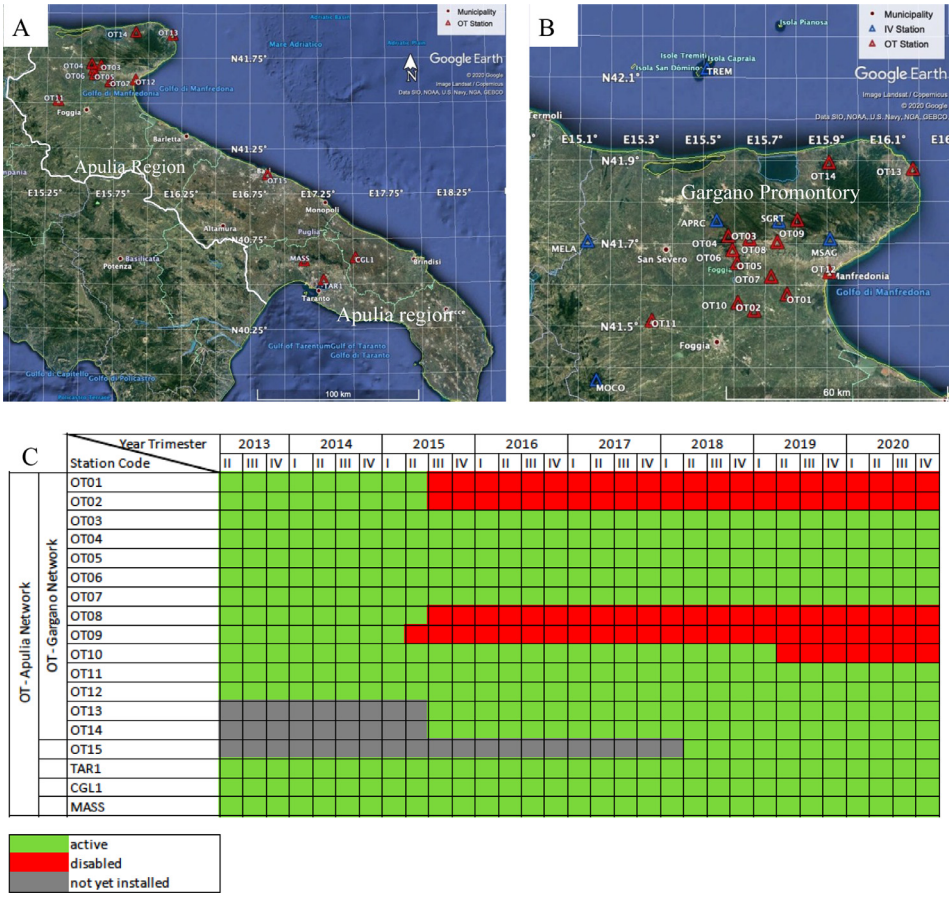

Fig. 1. A. Geographical map of Apulia Region -Southern Italy (the white line defines the political boundary) with the present-day geometry of the OT network stations as reported on EIDA [5]; B. Geographical map of the Gargano Promontory with the geometry of the Gargano seismic network (triangles refer to the seismic stations as indicated in the legend superimposed). A,B: maps were generated using Google Earth [6]; C. Temporal working diagram of the OT network indicating the station activity per trimester, colored according to the legend below, from 2013 to 2020.

For instance, Table 1 shows the content of the folder 2015.zip: a list of folders named with the event origin time (YYYYMMDDHHmm: YYYY=year; MM=month; DD=day; HH=hour; mm=minute).

Table 2 shows the ramification of the event folder 201507031216 and its content; it contains the waveforms as time series files in SAC [1,2] format: the file name indicates network name (RM), station name (OT03, OT04, ...), record type (EH, short period), component (E, N, Z), year (2015), Julian day (184), begin time of the registration in UTC format (10:35:01), extension (SAC).

Table 3 shows an example of the file path and the header information for the files RM.OT05..EHE.D.2015,184,10:07:00.SAC, RM.OT05..EHN.D.2015,184,10:07:00.SAC and RM.OT05..EHZ.D.2015,184,10:07:00.SAC (for header parameter explanation refer to the SAC [1,2] manual).

The South-North (N) component of the registration contains the S-wave arrival time (T0MARKER), while the vertical component of the seismogram contains the P-wave arrival time (AMARKER). Fig. 3 shows the SAC [1,2] waveforms of a three-component seismogram and the zoom on the event waveforms.

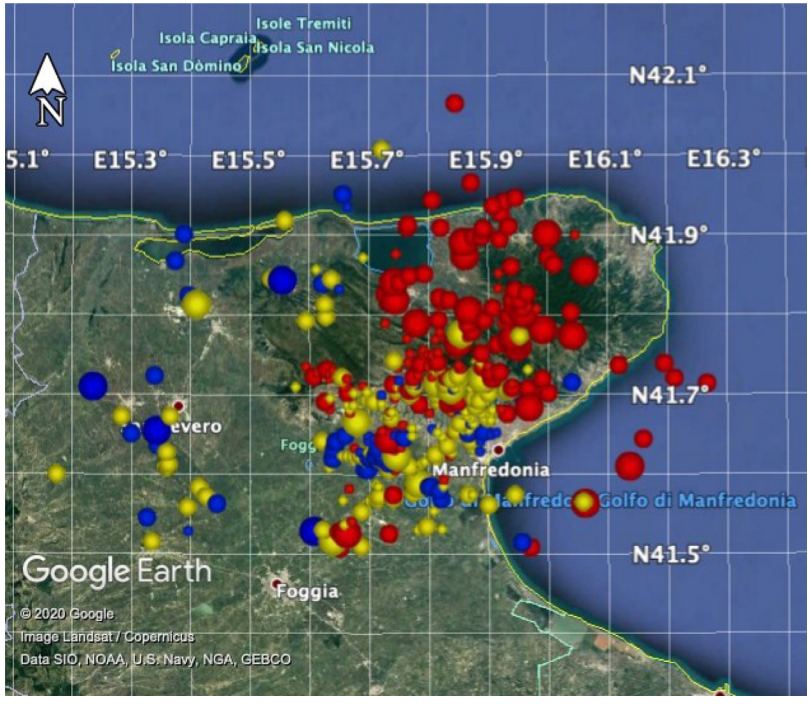

Fig. 2. Geographical map of the epicenters of the collected earthquakes listed in Gargano_Bullettin_13-18.txt file. Circle colours refer to depth (blue: z<10 km; yellow: 10km<z<20km; red: z>20km); circle dimensions refer to magnitude (small: Mlv<1; medium: 1<Mlv<2; large: Mlv>2). Map was generated by Google Earth [6].

Table. 1
Content of the 2015 year-folder.

Year-folder	Event-folder
2015	201507031216
	201507040338
	201507100052
	201507180447
	201507201850
	.....

2. Experimental Design, Materials and Methods

The University of Bari (Southern Italy) proposed and lead a project to increase the seismological knowledge and to mitigate the seismic risk, in cooperation with other participants among which the National Institute of Geophysics and Volcanology (INGV). The project, namely "Multi-Parametric Network for the Study and Monitoring of Natural Hazards in the Otranto Channel and the Ionian Sea (OTRIONS)" was funded by INTERREG III programs. Among many goals of the project, we installed a local seismic network in the Gargano area and surroundings, named OTRIONS Seismic Network. The network started to operate on late April of 2013. The seismic stations are all equipped with a short-period Lennartz 3D-V seismometer (flat response above 1 Hz) and a 24-bit SL06/SARA data-logger (dynamic range equal to 124dB at 100 sps). The real-time data transfer was managed by SEED link protocol through UMTS connection and archived by the SeisComp3 [3] software. During the first two years of activity (from April 2013 to June

Table. 2
Content of the event-folder 201507031216 included in the year-folder.

Year-folder	Event-folder	Seismic registrations in SAC format
2015	201507031216	RM.OT03..EHE.D.2015,184,10:35:01.SAC
		RM.OT03..EHN.D.2015,184,10:34:58.SAC
		RM.OT03..EHZ.D.2015,184,10:35:00.SAC
		RM.OT04..EHE.D.2015,184,00:00:00.SAC
		RM.OT04..EHN.D.2015,184,00:00:00.SAC
		RM.OT04..EHZ.D.2015,184,00:00:00.SAC
		RM.OT05..EHE.D.2015,184,10:07:00.SAC
		RM.OT05..EHN.D.2015,184,10:07:00.SAC
		RM.OT05..EHZ.D.2015,184,10:07:00.SAC
		RM.OT07..EHE.D.2015,184,10:35:00.SAC
		RM.OT07..EHN.D.2015,184,10:35:01.SAC
		RM.OT07..EHZ.D.2015,184,10:34:59.SAC
		RM.OT12..EHE.D.2015,184,10:34:56.SAC
		RM.OT12..EHN.D.2015,184,10:34:58.SAC
		RM.OT12..EHZ.D.2015,184,10:34:57.SAC
		RM.OT13..EHE.D.2015,184,11:13:00.SAC
		RM.OT13..EHN.D.2015,184,11:13:00.SAC
		RM.OT13..EHZ.D.2015,184,11:13:00.SAC
		RM.OT14..EHE.D.2015,184,09:59:44.SAC
		RM.OT14..EHN.D.2015,184,09:59:45.SAC
		RM.OT14..EHZ.D.2015,184,09:59:44.SAC

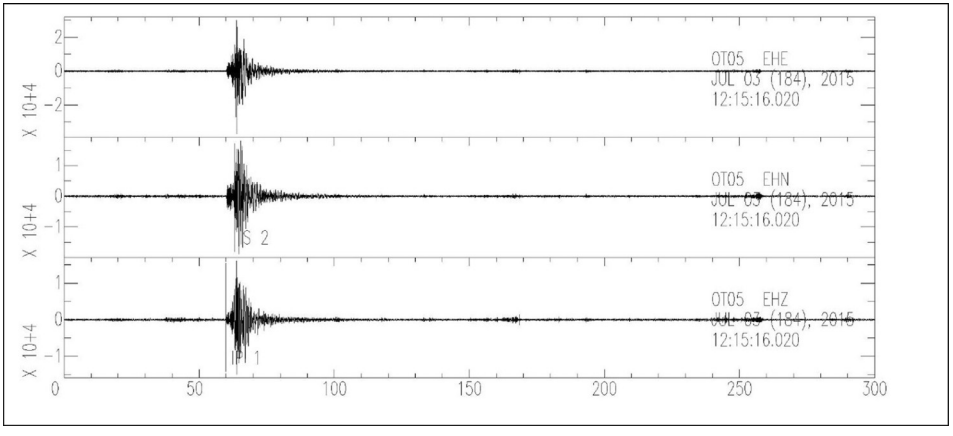

Fig. 3. Up: SAC visualization of the three-component seismograms of the event occurred in 2015/07/03 at 12:16:11. Down: zoom on the event waveforms. IP 1 is the P-wave marker, IS 2 is the S-wave marker.

2015), the network included 12 stations (from OT01 to OT12 in Fig. 1b). As explained in Data Description section, in June 2015 we disabled stations OT01 and OT02 and moved them northward, with names OT13 and OT14, to provide a better coverage of the northern sector of the Promontory (Fig. 1b).

The dataset we release, described in Data Description section, consists of seismic waveforms of the earthquakes recorded by the Gargano OT network (Figure1b). In order to build up a catalogue of recorded earthquakes, starting from the continuous 24h recordings, we used a manual detection procedure for the period April 2013-June 2014; then, we used the automatic detection of SeisComP3 [3] software for the period July 2014-December 2018. For all the detections corresponding to an earthquake, we cut the continuous recordings, 1 minute before and 4 minutes after the origin time of the event, and saved the waveforms in SAC [1,2] format file. We

Table. 3
Content of the SAC file header of the three-component seismogram of the event occurred in 2015/07/03 at 12:16:11.

Year-folder	Event-folder	Seismic registrations in SAC format	SAC Header
2015	201507031216	RM.OT05..EHE.D.2015,184,10:07:00.SAC	NPTS = 30001 B = 0.000000e+00 E = 3.000000e+02 IFTYPE = TIME SERIES FILE LEVEN = TRUE DELTA = 1.000000e-02 DEPMIN = -3.692410e+04 DEPMAX = 2.992590e+04 DEPMEN = 8.728500e-06 KZDATE = JUL 03 (184), 2015 KZTIME = 12:15:16.020 KSTNM = OT05 LOVROK = TRUE NVHDR = 6 LPSPOL = TRUE LCALDA = TRUE KCMPNM = EHE KNETWK = RM
		RM.OT05..EHN.D.2015,184,10:07:00.SAC	NPTS = 30001 B = 0.000000e+00 E = 3.000000e+02 IFTYPE = TIME SERIES FILE LEVEN = TRUE DELTA = 1.000000e−02 DEPMIN = -1.883422e+04 DEPMAX = 1.806278e+04 DEPMEN = 4.315525e−05 T0MARKER = 63.044 (IS 2) KZDATE = JUL 03 (184), 2015 KZTIME = 12:15:16.020 KSTNM = OT05 LOVROK = TRUE NVHDR = 6 LPSPOL = TRUE LCALDA = TRUE KCMPNM = EHN KNETWK = RM
		RM.OT05..EHZ.D.2015,184,10:07:00.SAC	NPTS = 30001 B = 0.000000e+00 E = 3.000000e+02 IFTYPE = TIME SERIES FILE LEVEN = TRUE DELTA = 1.000000e−02 DEPMIN = -1.491595e+04 DEPMAX = 1.607305e+04 DEPMEN = 2.927555e−05 AMARKER = 59.995 (IP 1) KZDATE = JUL 03 (184), 2015 KZTIME = 12:15:16.020 KSTNM = OT05 LOVROK = TRUE NVHDR = 6 LPSPOL = TRUE LCALDA = TRUE KCMPNM = EHZ KNETWK =

then manually picked P and S wave arrival times and located with HYPO71 [7] using the best velocity model available for the region [8].

The dataset we release here is the analysis of this manual work on seismic recording for the years 2013, 2014, 2015, 2016, 2017 and 2018. The dataset contains a data-gap of 10 months (from

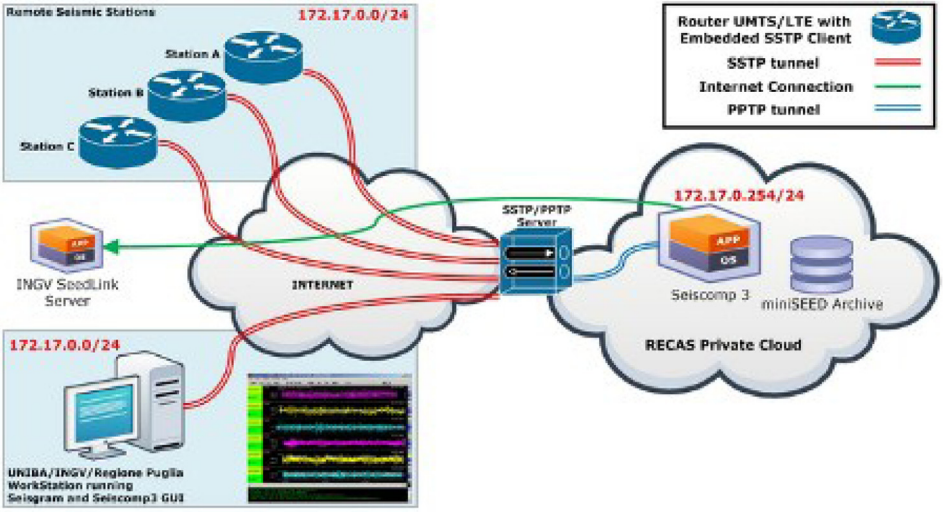

Fig. 4. Schematic architecture of the OT data acquisition and transmission.

August 2014 to June 2015) caused by software malfunctions in data transmission and archiving. The released dataset of 2013 and 2014 is related to two research articles concerning rheological and attenuation studies [9,10] of the Gargano promontory; the same dataset is related to a seismic study on fault plane solutions and local stress field [11].

Starting from the beginning of 2019, we have centralized the acquisition system of the integrated network designing a cloud infrastructure for receiving, processing and storing data from the seismic network. We implemented the infrastructure at ReCaS-Bari [10] datacenter, a computing center of the University of Bari (Italy) and the National Institute of Nuclear Physics in the framework of a common collaboration with the Civil Protection of Apulia Region. Fig. 4 shows the data acquisition, archiving and distribution services of OT, implemented using the SeiscomP3 [3] software package installed on a virtual machine in the OpenStack private cloud of the Bari ReCaS [12] datacenter. To ensure a high level of security in the data exchange between the remote stations and the acquisition system, as well as allowing controlled access to users and organizations within the cloud, a multi-protocol VPN service was implemented using Mikrotik's RouterOS operating system. In particular, the VPN server/concentrator manages:

1. VPN tunnels based on SSTP protocol for the interconnection between the ReCaS [12] datacenter and the remote seismic stations, the University of Bari, the Civil Protection of the Puglia Region and the INGV.
2. VPN tunnels based on OpenVPN protocol to allow access to the acquisition system by the single user.
3. VPN tunnel based on PPTP protocol for the interconnection of the Seiscomp3 [3] system with the gateway for access to seismic stations.

Each remote seismic station is now equipped with an LTE router which can establish the SSTP tunnel to the VPN concentrator located at ReCaS [12] and send the seismic data in real time to the Seiscomp3 [3] acquisition system. The models used are: Mikrotik SXT LTE kit and Mikrotik wap LTE kit.

The University of Bari and the Department of Civil Protection of the Apulia Region are, on the other hand, equipped with Mikrotik RB4011iGS + RM routers for the implementation of permanent VPN tunnels with the ReCaS [10] private cloud and various software (Seiscomp3 [3] GUI, Seisgram [13], Swarm [14]) thanks to which the operator can interact with the central data acquisition system Seiscomp3 [3] for: display real-time seismograms of remote stations; consult

Table. 4
List of OT stations as archived in EIDA [15].

Network	Station	Latitude	Longitude	Elevation	Site Name	Start Time in EIDA
OT	CGL1	40.648402	17.517326	303	Ceglie Messapica	2019-05-16T12:03:03
OT	MASS	40.633	17.144	274	Massafra	2019-05-16T11:59:46
OT	OT03	41.712201	15.649727	655	Pro Civ - San Marco in Lamis	2019-05-16T10:46:32
OT	OT04	41.719584	15.580701	279	Stignano - San Marco in Lamis	2019-05-16T10:53:22
OT	OT05	41.65917	15.60256	180	Rignano Garganico	2019-05-16T10:56:00
OT	OT06	41.685524	15.594366	584	Rignano Garganico	2019-05-16T10:58:15
OT	OT07	41.621334	15.719366	154	San Giovanni Rotondo	2019-05-16T11:01:11
OT	OT11	41.514564	15.335292	0	Lucera	2019-05-16T11:50:53
OT	OT12	41.631801	15.90782	30	OT12	2019-01-23T08:54:23
OT	OT13	41.880722	16.179444	0	Vieste	2019-05-16T11:53:09
OT	OT14	41.896655	15.906908	0	Ischitella	2019-05-16T11:54:49
OT	OT15	41.109002	16.879723	0	Bari	2019-05-16T11:56:42
OT	TAR1	40.5259	17.2846	140	Taranto	2016-01-11T13:17:00

the list of seismic events located by the Seiscomp3 [3] automatic system; carry out manual review of seismic events.

Thanks to this implementation, all the OTRIONS stations are now integrated in the INGV Seismic National Network. In Fig. 1a we showed the map of the Apulia Region (Southern Italy) with the location of all the seismic stations of the OT Network [5,15] now integrated in the Italian Seismic Network. In Table 4 we reported the list of OT station, specifying the network name, the station name, the station location (latitude, longitude in dd and altitude in m), the site name and start date and start date and start time (UTC) of operation within the INGV Seismic National Network. Since the beginning of 2019, all the waveform data and station metadata are archived and distributed by the INGV node of the European Integrated Data Archive [5] in the framework of European Observing Plate Observatory (EPOS).

Ethics Statement

This work does not involve the use of human subject, does not involve animal experiment and does not involve data collected from social media platforms.

CRediT authorship contribution statement

Marilena Filippucci: Conceptualization, Investigation, Data curation, Writing - Original draft preparation, Editing; **Simona Miccolis:** Formal analysis, Data curation, Visualization; **Angelo Castagnozzi:** Software; **Gianpaolo Cecere:** Software; **Salvatore de Lorenzo:** Data curation, Supervision; **Giacinto Donvito:** Software; **Luigi Falco:** Software; **Maddalena Michele:** Data analysis, Data curation; **Stefano Nicotri:** Software; **Annalisa Romeo:** Data analysis, Data curation; **Giulio Selvaggi:** Conceptualization, Investigation, Resources, Writing - Original draft preparation, Supervision, Project administration, Funding acquisition; **Andrea Tallarico:** Conceptualization, Supervision, Project administration, Funding acquisition.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships which have or could be perceived to have influenced the work reported in this article.

Acknowledgments

The geographic maps were generated by the free software Google Earth Pro (Image Landsat/Copernicus. Data SIO, NOAA, U.S. Navy, NGA, GEBCO ®2020 Google). The computational work has been executed on the IT resources of the ReCaS-Bari data center, which have been made available by two projects financed by the MIUR (Italian Ministry for Education, University and Re-search) in the "PON Ricerca e Competitività 2007-2013" Program: ReCaS (Azione I - Interventi di rafforzamento strutturale, PONa3_00052, Avviso 254/Ric) and PRISMA (Asse II -Sostegno all'innovazione, PON04a2_A). The work has been partially funded by the Regione Puglia Civil Protection through P.O.R. Puglia 2014-2020 Asse V – Azione 5.2. This work was partially supported by Project PRIN n. 201743P29 FLUIDS (Detection and tracking of crustal fluid by multiparametric methodologies and technologies).

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