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AdriaArray – a Passive Seismic Experiment to Study Structure, Geodynamics and Geohazards of the Adriatic Plate

Petr Kolínský[1*], Thomas Meier[2], Matthew R. Agius[3], Almir Bijedić[4], Götz Bokelmann[5], Felix Borleanu[6], Dušica Brnović[7], Musavver Didem Cambaz[8], Fabio Cammarano[9], Martina Čarman[10], Carlo Cauzzi[11, 12], Dragana Chernih[13], Kristian Csicsay[14], Snježana Cvijić Amulić[15], Wojciech Czuba[16], Jordi Diaz[17], Liliya Dimitrova[18], Edmond Dushi[19], Christos P. Evangelidis[20], Claudio Faccenna[9, 21], Liudmyla Farfuliak[22], Wolfgang Friederich[23], Gergana Georgieva[24], Nikolaus Horn[25], Ines Ivančić[26], Yan Jia[25], George Kaviris[27], István János Kovács[28], Sergei Lebedev[29], Eline Le Breton[30], Renata Lukešová[31], Stanisław Mazur[32], Mark van der Meijde[33], Irene Molinari[34], Shemsi Mustafa[35], Thorsten Nagel[36], Søren Bom Nielsen[37], Anne Obermann[12], Costas Papazachos[38], Stefano Parolai[39], Anne Paul[40], Claudia Piromallo[41], Vladimír Plicka[42], Andreas Rietbrock[43], Stéphane Rondenay[44], Giuliana Rossi[45], Georg Rümpker[46], Christian Schiffer[47], Antje Schlömer[48], Karin Sigloch[49], Hanna Silvennoinen[50], Efthimios Sokos[51], Petr Špaček[52], Josip Stipčević[53], Andrea Tallarico[54], Timo Tiira[55], Frederik Tilmann[21, 56], Dejan Valčić[57], Joachim Wassermann[48], Viktor Wesztergom[28], Anila Xhahysa[19], Mladen Živčić[10] and the AdriaArray Seismology Group[58]

(1) Institute of Geophysics of the Czech Academy of Sciences, Prague, Czech Republic
(2) Institute for Geosciences, University of Kiel, Germany
(3) Department of Geosciences, University of Malta, Msida, Malta
(4) Hydrometeorological Institute of Federation of Bosnia and Herzegovina, Sarajevo, Bosnia and Herzegovina
(5) Department of Meteorology and Geophysics, University of Vienna, Austria
(6) National Institute for Earth Physics, Magurele, Romania
(7) Sector of Seismology, Institute of Hydrometeorology and Seismology of Montenegro, Podgorica, Montenegro
(8) Kandilli Observatory and Earthquake Research Institute, Boğaziçi University, Çengelköy-İstanbul, Türkiye
(9) Department of Sciences, Roma Tre University, Rome, Italy
(10) Seismology Office, Slovenian Environment Agency, Ljubljana, Slovenia
(11) Observatories and Research Facilities for European Seismology (ORFEUS)
(12) Swiss Seismological Service at Eidgenössische Technische Hochschule Zürich (ETH), Switzerland
(13) Seismological Observatory, Faculty of Natural Sciences and Mathematics, St. Cyril and Methodius University in Skopje, Republic of North Macedonia
(14) Earth Science Institute of the Slovak Academy of Sciences, Bratislava, Slovakia
(15) Republic Hydrometeorological Service, Banja Luka, Republika Srpska, Bosnia and Herzegovina
(16) Institute of Geophysics, Polish Academy of Sciences (Polish AdriaArray Seismic Group[1**]), Warsaw, Poland
(17) Geo3Bcn-CSIC, Barcelona, Spain
(18) National Institute of Geophysics, Geodesy and Geography, Bulgarian Academy of Sciences, Sofia, Bulgaria
(19) Department of Seismology, Institute of Geosciences, Polytechnic University of Tirana, Albania
(20) Institute of Geodynamics, National Observatory of Athens, Athens, Greece
(21) GFZ Helmholtz Centre for Geosciences, Potsdam, Germany
(22) Subbotin Institute of Geophysics of the National Academy of Sciences of Ukraine, Kyiv and Lviv, Ukraine
(23) Institute for Geology, Mineralogy and Geophysics, Ruhr University Bochum, Germany

(24) Department of Meteorology and Geophysics, Faculty of Physics, Sofia University, Bulgaria
(25) GeoSphere Austria (formerly Zentralanstalt für Meteorologie und Geodynamik - ZAMG), Vienna, Austria
(26) Croatian Seismological Survey, Department of Geophysics, Faculty of Science, University of Zagreb, Croatia
(27) Section of Geophysics-Geothermics, Department of Geology and Geoenvironment, National and Kapodistrian University of Athens, Greece
(28) HUN-REN Institute of Earth Physics and Space Science (HUN-REN EPSS), Sopron and Budapest, Hungary
(29) Department of Earth Sciences, University of Cambridge, United Kingdom
(30) Univ Rennes, CNRS, Géosciences Rennes - UMR 6118, Rennes, France
(31) Institute of Rock Structure and Mechanics of the Czech Academy of Sciences, Prague, Czech Republic
(32) Institute of Geological Sciences, Polish Academy of Sciences (Carpathian Project Group[1**]), Warsaw, Poland
(33) Faculty of Geo-Information Science and Earth Observation (ITC), University of Twente, Enschede, the Netherlands
(34) Istituto Nazionale di Geofisica e Vulcanologia (INGV), Bologna, Italy
(35) Seismological Network of Kosovo, Geological Survey of Kosovo, Pristina, Kosovo
(36) Institute of Geology, Faculty of Geosciences, Geoengineering and Mining, Technische Universität Bergakademie Freiberg, Germany
(37) Department of Geoscience, Aarhus University, Denmark
(38) Geophysical Laboratory, Aristotle University of Thessaloniki, Greece
(39) Department of Mathematics, Informatics and Geosciences, University of Trieste, Italy
(40) Institut des Sciences de la Terre, Univ. Grenoble Alpes, Univ. Savoie Mont Blanc, CNRS, IRD, Univ. Gustave Eiffel (French consortium Grenoble-Toulouse-Strasbourg[1**]), Grenoble, France
(41) Istituto Nazionale di Geofisica e Vulcanologia (INGV), Roma, Italy
(42) Department of Geophysics, Faculty of Mathematics and Physics, Charles University, Prague, Czech Republic
(43) Geophysical Institute, Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany
(44) Department of Earth Science, University of Bergen (Norwegian Broadband Pool[1**]), Bergen, Norway
(45) Centre for Seismological Research, National Institute of Oceanography and Applied Geophysics (OGS), Trieste, Italy
(46) Faculty of Geosciences and Geography, Goethe University Frankfurt, Germany
(47) Department of Earth Sciences, Uppsala University, Sweden
(48) Department of Earth and Environmental Sciences, Ludwig-Maximilians-Universität München (LMU), Germany
(49) Université Côte d'Azur, Observatoire Côte d'Azur, CNRS, IRD, Géoazur, Sophia Antipolis, France
(50) Sodankylä Geophysical Observatory, University of Oulu, Finland
(51) Laboratory of Seismology, Department of Geology, University of Patras, Greece
(52) Institute of Physics of the Earth, Masaryk University, Brno, Czech Republic
(53) Andrija Mohorovičić Geophysical Institute, Department of Geophysics, Faculty of Science, University of Zagreb, Croatia
(54) Department of Earth and Geo-environmental Sciences, University of Bari Aldo Moro, Italy
(55) Institute of Seismology, University of Helsinki, Finland
(56) Department of Geosciences, Freie Universität Berlin, Germany
(57) Seismological Survey of Serbia, Belgrade, Serbia
(58) https://orfeus.readthedocs.io/en/latest/adria_array_main.html; the list of individuals affiliated with the AdriaArray Seismology Group is presented in Appendix A

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[1**] Four members of the AdriaArray Seismology Group consist of several institutions. See text for the detailed explanation.

Abstract

AdriaArray is a multinational initiative to cover the Adriatic Plate and its tectonically active surroundings – including units of Adriatic origin - with a dense regional array of seismic stations. AdriaArray provides data for imaging of the crustal and upper mantle structure and for the analysis of seismic activity and hazard. It will help to understand the causes of active tectonics and volcanic fields in the region. The network consists of 1068 permanent and 440 temporary broadband stations from 23 mobile pools. A homogeneous coverage of broadband stations is achieved in an area from the Massif Central in the west to the Carpathians in the east, from the Alps in the north to the Calabrian Arc and mainland Greece in the south. The backbone network (2022 – 2026) is complemented by locally densified broadband deployments in the western Carpathians, along the Dubrovnik fault and in the Vrancea region. Data recorded by AdriaArray stations is transmitted in real-time to 12 nodes of the European Integrated Data Archive (EIDA) where it is accessible as a single virtual network. Regular availability and quality checks ensure high data usability. AdriaArray, the largest passive seismic experiment in Europe to date, is based on the cooperation between local network operators, mobile pool providers, technicians, engineers, field teams, researchers, students, and organizations such as ORFEUS (Observatories and Research Facilities for European Seismology) and EPOS (European Plate Observing System) research infrastructure. The AdriaArray Seismology Group, founded in 2022, encompasses 64 institutions from 30 countries with 451 participants. Initial Collaborative Research Groups have been established to coordinate data analysis and scientific research. We present the evolution of the experiment and its objectives, describe its preparation and planning, and show maps of the AdriaArray Seismic Network, station properties and coverage. We further describe the data archiving and distribution, list the participating institutions, individuals and networks and discuss collaborative research topics.

Keywords: seismology, geodynamics, Adriatic plate; large seismic network; seismic imaging, crustal structure; upper mantle structure; seismic hazard; plate deformation

1. Introduction

1.1 General overview

The densely populated area surrounding the Adriatic Sea (central Mediterranean) is highly prone to geohazards such as earthquakes, tsunamis, landslides, flooding, and volcanic activity. These threats arise from the ongoing subduction and collision processes impacting the remnants of the much larger Adriatic Plate. The tectonically active zone extends from Sicily through the Apennines to the Alps, the Dinarides, and the Hellenides (Fig. 1), frequently generating earthquakes of up to magnitude 7. To better understand and mitigate these hazards, it is essential to identify the key drivers of associated plate deformation. This requires detailed studies to delineate the plate boundaries, map slab geometries and extent at depth, assess the properties of active faults and evaluate the lithospheric stress field.

With these objectives in mind, the AdriaArray initiative was established by a community of geoscientists dedicated to investigating the Earth's structure, geodynamics and geohazards associated with the Adriatic Plate and surrounding regions, bringing together a large number of scientific groups from almost all European countries, with different institutional and financial support. At the heart of the initiative lies the AdriaArray Seismic Network, covering the region of the Adriatic plate and its deforming boundaries with more than 1500 broadband stations and an approximate station spacing of 50 km. Its scale is unprecedented in Europe, involving an extraordinary number of temporary seismic stations, permanent and mobile network operators, participating institutions, and individual contributors. We took advantage of two previous large experiments in the area - AlpArray (Hetényi et al., 2018a) and PACASE (Schlömer et al., 2024) - by incorporating 135 existing temporary stations and deploying 292 additional temporary stations. The AdriaArray initiative has made accessible through EIDA (Strollo et al., 2021), the European Integrated Data Archive, managed by ORFEUS (Cauzzi et al., 2024), nearly 100 permanent stations, established and operated years and sometimes decades before AdriaArray. In spite of heterogeneous instrumentation and data transmission procedures used by participating institutions, the data is integrated into EIDA and thus available over standard access mechanisms.

In addition to the expected challenges, we encountered - and we continue to face - two unforeseen global issues that significantly affected the project preparation: in 2020 and 2021, fieldwork was paralyzed and coordination hindered by the COVID-19 pandemic, and since 2022, the Russian invasion of Ukraine has impeded the deployment of stations in Ukraine and in Moldova. The seismological community managed to get through the pandemic and is supporting our Ukrainian colleagues by hosting some of them, as well as by providing equipment for upgrading stations of the Ukrainian seismic network.

AdriaArray initiative enables knowledge sharing and capacity building. This concerns the installation of temporary stations, data storage and exchange, as well as scientific cooperation. AdriaArray, together with ORFEUS and EPOS, organized several workshops that brought together students and researchers from 30 countries to share their expertise.

In this paper, we describe the history of AdriaArray initiative and its technical and scientific objectives. We discuss the seismic network design, guidelines for installing temporary stations, and the data archiving. We introduce an online GitHub repository with station inventories and maps. We provide the list of participants, member institutions and the list of seismic networks involved. Details on the design and performance of contributing regional networks are presented in other papers of this special issue. We also list and discuss collaborative research topics that have emerged from the community discussions and will be addressed in the coming years.

1.2 Tectonics of the region and open research questions

As shown in Fig. 1 by the black outline, AdriaArray covers the Adriatic Plate (Adria) and surrounding active orogens - the Apennines, the Alps, the Dinarides, the Hellenides, as well as the Carpathians and the Balkans. Deformed tectonic units, accreted in the orogenic belts, are colored in light brown when derived from Adria and in light green when derived from Eurasia. The small remnant, almost undeformed, of the continental Adriatic Plate is indicated in dark brown in Fig. 1. In addition, AdriaArray covers also neighboring regions, such as the Massif Central and the Moesian platform. Indeed, their tectonic evolution is ultimately linked to the evolution of the Adriatic Plate between the converging African and Eurasian Plates and related mantle dynamics. For instance, magmatism and extensional tectonics in the Massif Central has been inferred to be related to the interaction of mantle flow and the Alpine subduction zone (Dèzes et al., 2004) or the retreating Apenninic subduction zone (e.g., Barruol and Granet, 2002; Faccenna et al., 2004). The development of the Eastern Alps, the Dinarides and the Pannonian Basin can only be understood if subduction dynamics (trench retreat, slab break-off) in the Carpathians is considered. Moreover, the Moesian Platform represents a major tectonic unit of the foreland of the Carpathians and the Balkans, delimitating two retreating subduction systems of opposite sense and direction (the Carpathians to the north and the Hellenides to the south, Fig. 1).

Adria represents a disappearing plate that has been subducting beneath and colliding with the surrounding lithospheric units of the Eurasian Plate (e.g., Faccenna et al., 2014; Schmid et al., 2020; van Hinsbergen et al., 2020). There is geological evidence that intra-oceanic subduction at the eastern margin of Adria started in the Middle Jurassic and that continental collision initiated in the Late Cretaceous along the Sava Suture (Ustaszewski et al., 2010; Handy et al., 2015; Schmid et al., 2020; van Hinsbergen et al., 2020). The present-day thrust front is located offshore in the Adriatic Sea (Fig. 1). It emerges to land in Istria and the Southern Alps. To the west of Adria, the southern branch of the Piemont-Ligurian Ocean and thinned continental margin of Adria have been subducted beneath the Apennines-Calabria subduction zone since the Oligo-Miocene times. This subduction zone is associated with fast trench retreat and upper plate extension, with the development of the recent Liguro-Provençal Basin and Tyrrhenian Sea (Malinverno and Ryan, 1986; Carminati et al., 1998; Faccenna et al., 2001; 2014; Rosenbaum and Lister, 2004; Handy et al., 2010). The size of undeformed Adria shrunk thus by more than 70% during progressive subduction and collision. Only a small piece of the formerly much larger continental lithosphere remains today almost undeformed beneath the Adriatic Sea (1300 km in NW-SE direction, 250 km in NE-SW direction, Fig. 1). In the Alps, the Adriatic Plate represents mainly the upper plate (Schmid et al., 1996; Handy et al., 2010; Rosenberg and Kissling, 2013). In contrast, it represents the lower plate along its western and eastern margins. Crustal nappes of Adriatic origin are found highly deformed within the surrounding orogens (Fig. 1). To the south of the Adriatic Sea, the Apulian Platform shows compressive tectonics, with the inversion of Mesozoic faults, related to the advance of the two converging accretionary wedges of the Calabrian Arc and the Mediterranean Ridge (e.g., Chizzini et al., 2022). Further south, the transition from continental collision in the Hellenides to oceanic subduction of the Ionian lithosphere occurs along the Kefalonia Transform Fault Zone (Papazachos and Comninakis, 1971; McKenzie, 1972; Le Pichon and Angelier, 1979; Royden and Papanikolaou, 2011) and in a wider region around it (e.g., Perouse et al., 2017; Chousianitis et al., 2024).

Because of its coherent motion with Africa for much of the Meso- and Cenozoic, the northward drift of Adria has long been considered as the main cause for continental collision with Eurasia (e.g., Beaumont et al., 1996; Schlunegger and Willett, 1999). Geodetic and plate kinematic studies show however that Adria moves independently from Africa today (Anderson and Jackson, 1987; D'Agostino et al., 2008) and became independent from Africa during the Neogene (20-0 Ma; Le Breton et al., 2017). Africa's northward motion, slab pull and slab retreat, as well as asthenospheric flow have been suggested as driving forces for Adria's motion (Faccenna et al., 2014; Le Breton et al., 2017; Király et al., 2018; Kissling and Schlunegger, 2018; Andrić et al., 2018; Handy et al., 2019; Schuler et al., 2025). Today, Adria's core between the Apennines, the Dinarides and the Alps is showing a

NE to N counterclockwise motion with respect to Eurasia, that may be described as a rotation around a pole positioned in the Piedmont area of northwestern Italy (D'Agostino et al., 2008; Serpelloni et al., 2022). In contrast, its southern part in the Albanides-Hellenides shows mostly a S to SW clockwise motion around a pole located in the Aegean Sea (D'Agostino et al., 2008 and 2020; Serpelloni et al., 2022). This differential motion may be associated with large-scale tectonic tearing and active deformation at the transition between Adria, the Dinarides and the Hellenides (e.g., Handy et al., 2019; D'Agostino et al., 2022).

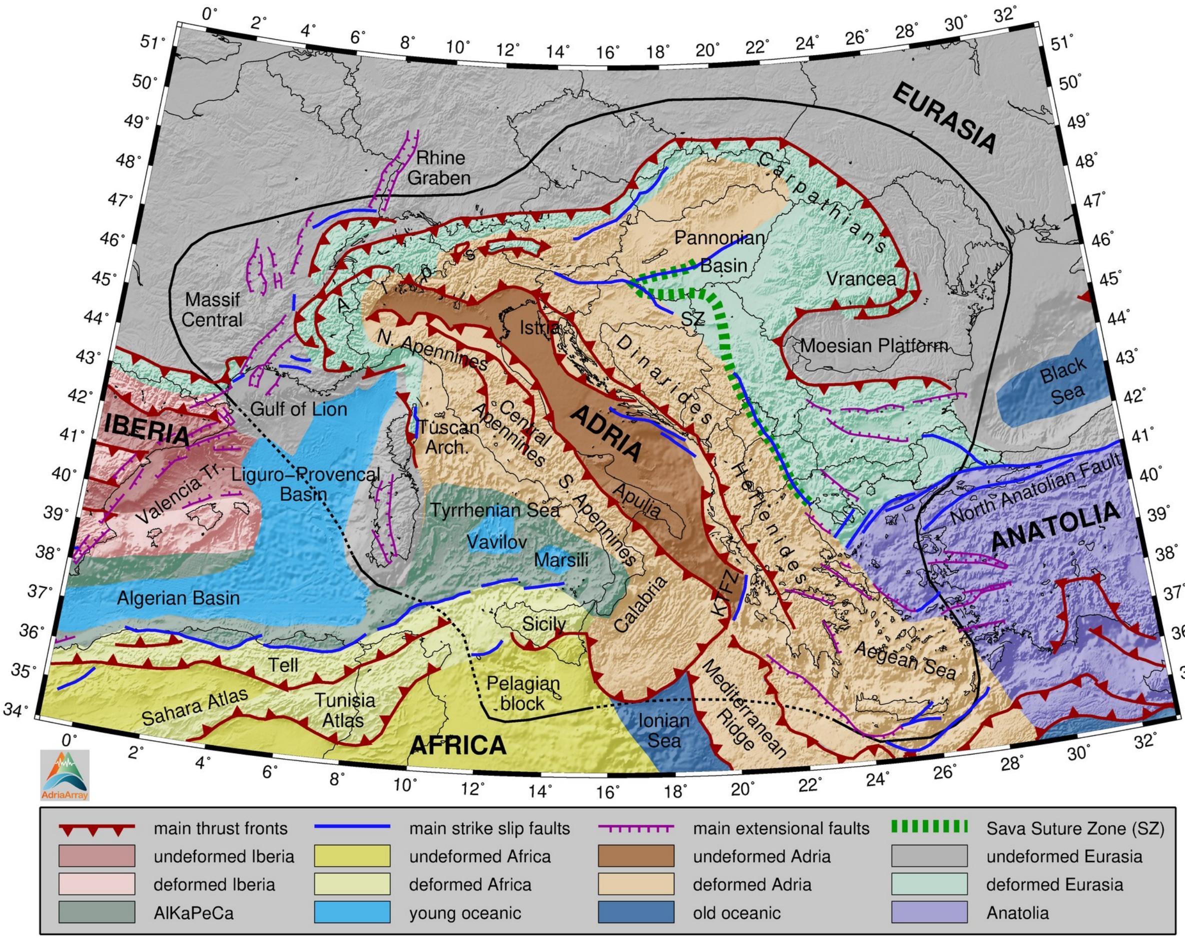

Figure 1. Tectonic map of the central European and Mediterranean region, modified after Faccenna et al. (2014), Le Breton et al. (2017, 2021) and Handy et al. (2010, 2019 and references therein). The Adriatic Plate and neighboring plates are labeled. Barbed red lines represent the main thrust fronts. The barbs point in the direction of subduction or underthrusting. Blue lines show main strike slip faults. Extensional faults are shown by magenta lines with ticks on the downthrown side. The AdriaArray footprint is delineated by the black line. Undeformed Adriatic Plate is shown by dark brown, deformed continental Adriatic units accreted into orogens are by light brown. Undeformed Eurasia is gray and deformed Eurasian units are in light green. KTFZ: Kefalonia Transform Fault Zone, AlKaPeCa: Alboran-Kabylides-Peloritani-Calabria.

AdriaArray offers the opportunity to study plate deformation, its geodynamic driving mechanisms, and their relation to geohazards. Developing a comprehensive quantitative framework that links geodynamic drivers, plate deformation, and geohazards remains an ongoing challenge. Achieving this goal requires the integration of seismotectonic observations, passive seismic imaging, and advanced numerical geodynamic and geohazard simulations. The drivers of plate kinematics and plate deformation remain elusive because the slab geometry and the three-dimensional pattern of asthenospheric flow have not yet been unambiguously resolved. Early isotropic images such as the body-wave tomographies of Bijwaard and Spakman (2000) and Piromallo and Morelli (2003) provided a large-scale view of slabs in the region. These studies indicated double sided subduction in the central Mediterranean with slabs subducting westward beneath Calabria and the Apennines and eastward beneath the Hellenides and the Dinarides, alongside a complex subduction system in the Alps. However, the slab geometries, plate interfaces, and internal properties of the plates and collision zones in the region have not been resolved unequivocally yet (for a recent review see Kissling, 2024). Key debates concern, for example, slab break-off or the presence of delaminated continental mantle lithosphere in the southern Apennines (Wortel and Spakman, 2000; Giacomuzzi et al., 2012) and slab break-off or continuous subduction in the western Alps (e.g., Lippitsch et al., 2003; Zhao et al., 2016a; Monna et al., 2022). Also, the orientation of subduction and the depth of a broken-off Eurasian slab segment in the eastern Alps are a matter of discussion (e.g., Lippitsch et al., 2003; Kästle et al., 2020; Handy et al., 2021; Plomerová et al., 2022; Paffrath et al., 2021; Mroczek et al., 2023; Timkó et al., 2024; Petrescu et al., 2024). Similarly, the presence and length of an Adriatic slab beneath the Dinarides (e.g., Handy et al., 2015; Šumanovac et al., 2017; El-Sharkawy et al., 2020; Belinić et al., 2021), the presence of a horizontal tear beneath the Hellenides, of a vertical tear in the area of the Kefalonia Transform Fault Zone or a smooth transition from oceanic subduction in the Aegean to delamination of continental mantle lithosphere in the Hellenides are ambiguous (e.g., Wortel and Spakman, 2000; Suckale et al., 2009; Evangelidis, 2017; Halpaap et al., 2018; Kaviris et al., 2018; Özbakir et al., 2020). The role of asthenospheric mantle flow in driving lithospheric deformation in the region has been highlighted by several studies (e.g., Horváth et al., 2006; Kovács et al., 2012; Faccenna et al., 2014; Handy et al., 2015; Subašić et al., 2017; Király et al., 2018; Petrescu et al., 2020; Hein et al., 2021; Salimbeni et al., 2022; Liptai et al., 2022; Kalmár et al., 2023; Pondrelli et al., 2023). Asthenospheric flow is strongly linked with the slab geometry and remains thus debated as well. A digital three-dimensional plate model of the entire central Mediterranean deciphering the geometry and properties of critical internal features like basins, faults and magma sources determining relevant societal hazards (earthquakes, volcanic eruptions, landslides) remains to be determined. Exploration of the massive amounts of data collected by AdriaArray should spur the development of new, innovative, automated, and robust data processing tools.

The following four overarching topics will be addressed by AdriaArray:

1) **How do continental plates deform and dissolve during continental collisions?** We are just starting to have a complete picture of the recent and active deformation patterns within and at the margin of tectonic plates and of Adria in particular. Adria is involved in highly variable continental collision zones from the Alps, to the Dinarides and the Hellenides. In the north, it represents the upper plate from the southern tip of the Western Alps to the eastern Alps at least to 13° E (e.g., Handy et al., 2010). In the east, in the Dinarides and the Hellenides, the deformation front is retreating westwards and thus its distance to the suture with Eurasia is increasing (e.g., Handy et al., 2015). A combination of nappe stacking and delamination of mantle lithosphere has been proposed to explain this behavior. Along its western margin, oceanic subduction of the Piemont-Ligurian ocean transitioned into subduction of continental Adriatic units (e.g., Handy et al., 2010). Thus, deformation and disintegration of the continental Adriatic plate involves fundamentally different processes such as overriding, double sided subduction, delamination of mantle lithosphere, nappe stacking, and this on a rather small scale. The importance of these processes in the Adriatic region must be clearly defined and detangled. Furthermore, conditions for their occurrence remain to be determined. We need (i) to image the interior of the plate, its boundaries and the plate interfaces at high-resolution, (ii) to define its kinematics and deformation, (iii) to map recent and active faults, and (iv) to define the vertical motion consistently at plate scale. Moreover, conditions for strain localization remain poorly understood and thus keep open the following questions: Why does strain localize at fault zones in some regions whereas deformation is rather diffuse in others? The ratio between aseismic and seismic deformation on active faults needs to be quantified and constraints favoring seismic deformation have to be identified.
2) **What processes drive plate deformation?** Contrasting models have been proposed so far to explain the deformation system in and around Adria. The first group of models proposed that Adria's deformation results from plate interactions due to its central location between the two much larger Eurasian and African converging plates. These models emphasize the importance of external boundary conditions for plate deformation (e.g., Beaumont et al., 1996; Schlunegger and Willett, 1999; D'Agostino et al., 2008). The second group proposes that deformation is caused by mantle dynamics in the Adriatic region, namely subduction and asthenospheric flow (e.g., Faccenna et al., 2014; Kissling and Schlunegger, 2018). To quantify the importance of these factors, we need to update our knowledge of the structure of the area down to the mantle depth. Seismic imaging will allow to define the geometry and properties of subducting Adriatic plate, asthenospheric flow, as well as of mantle upwellings. Anisotropic waveform inversion algorithms should lead to advances in our understanding of plate deformation in general.
3) **How do plates evolve in time?** At its active eastern and western margins, the lower part of the Adriatic continental lithosphere has been subducting into the mantle, whereas crustal nappes have been delaminated and accreted into the orogens. Subduction in the Apennines, as well as present-day active oceanic subduction under the Calabrian Arc and southern Hellenides, have been associated with slab rollback and trench retreat. This results in a migration of the plate boundary towards the lower plate with time and a continuous shrinking of undeformed Adria. The area thus offers the option to study various modes of plate deformation, including plate disintegration and the transition from oceanic subduction to continental collision. Furthermore, subduction rollback and trench retreat in the Apennines, but also in the Carpathians, was accompanied by upper plate extension and the formation of new oceanic and continental lithosphere in the Western Mediterranean and Pannonian basins, respectively. Hence, the disappearance as well as the formation of a new lithosphere can be studied in-situ.

4) **How does plate deformation influence geohazards?** Geohazards such as earthquakes, tsunamis, landslides, flooding, volcanic eruptions, and sea level rise induce significant societal impact around the Adriatic plate. Active deformation induces earthquakes that can cause significant damage (see section 1.3 below) and significant topographic disequilibrium favoring landslides or flooding events. Last but not least, we need to quantify and to understand how tectonic plate deformation creates such geohazards. Integration of tectonic, seismic, and geodetic observations and numerical forward modeling is required to constrain the causes of geohazards.

An overview of research groups focusing on specific scientific topics is given later in the text and in the Appendix B.

1.3 Seismicity and Seismic Hazard

The risk of losses and casualties associated with multi-hazards such as seismicity, tsunamis, landslides, floods and volcanic activity is increasing within and around the Adriatic Plate due to the growing population in the area. Examples of geohazards include the largest known volcanic eruption in Europe, which occurred about 37000 BP at Campi Flegrei (Italy), the devastating earthquakes of Dubrovnik (Croatia) in 1667, and of Messina (Italy) in 1908, which caused major societal destructions.

The frequent occurrence of earthquakes with magnitudes larger than 6 on both sides of the Adriatic Sea provide clear evidence of active plate interaction and internal plate deformation. Notable examples include the M7.2 Kefalonia (Greece, 1953), the M6.5 Friuli (Italy, 1976), the M7.2 Bar (Montenegro, 1979), the M5.9 L'Aquila (Italy, 2009) or the recent M6.4 Durrës (Albania, 2019-11-26), the M6.7 Ionian Sea (Greece, 2018-10-25), the M6.4 Petrinja (Croatia, 2020-12-29) earthquakes, and the sequence of M6.2, M6.1 and M6.5 events close to Norcia, central Italy (2016-10-30). To better understand the geodynamic drivers of these geohazards, geodynamic modeling needs to integrate high-resolution images of the lithosphere, slabs, and asthenospheric flow combined with physical hazard modeling.

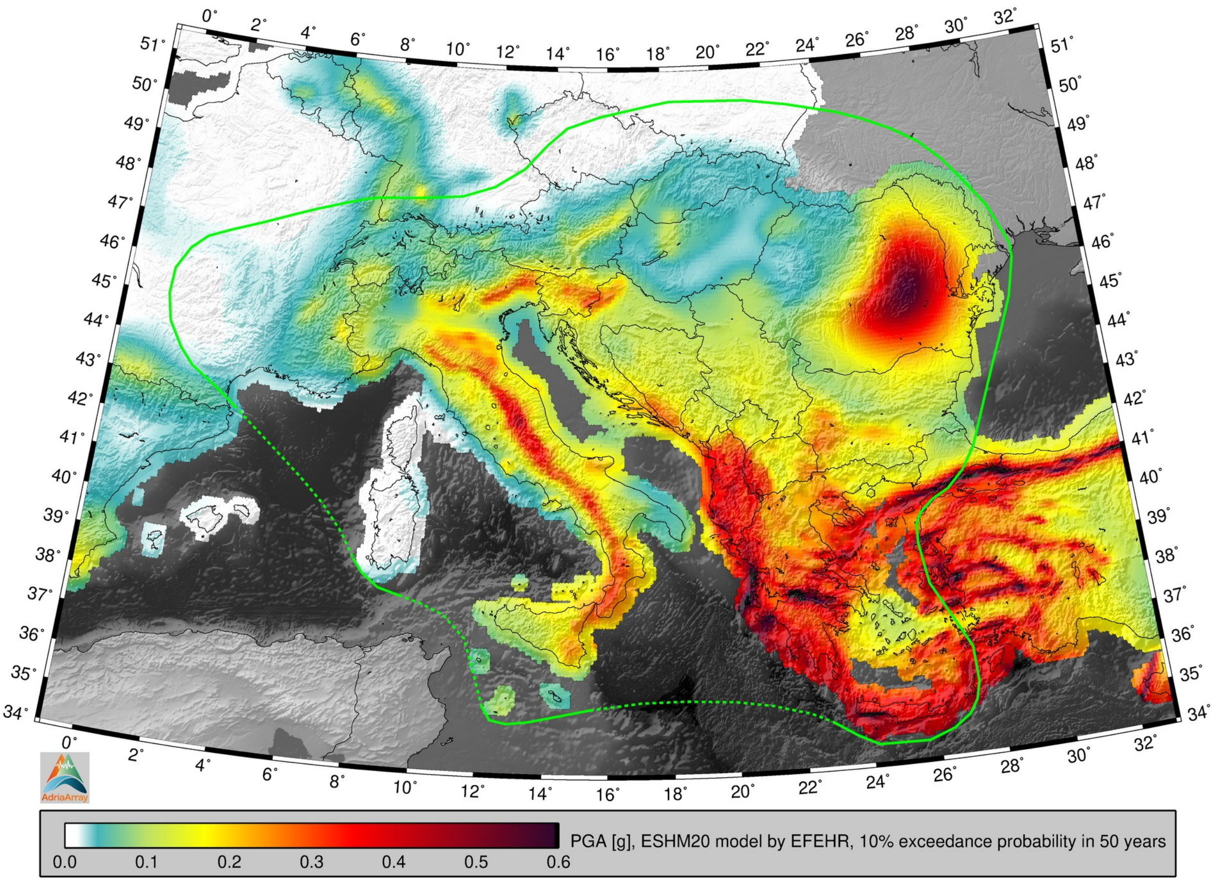

Figure 2. Ground shaking hazard map of the 2020 European Seismic Hazard Model (ESHM20) by EFEHR. The map shows spatial distribution of the peak ground acceleration (PGA) mean values in [g] for a 10% probability of exceedance in 50 years, corresponding to a mean return period of 475 years. Figure replotted after Danciu et al. (2021). The AdriaArray footprint is delineated by the green line.

The 2020 European Seismic Hazard Model (ESHM20), by European Facilities for Earthquake Hazard and Risk (EFEHR), see Danciu et al. (2021), centered at the AdriaArray region emphasized by the green line, is shown in Fig. 2. Colors are proportional to the peak ground acceleration (PGA) on rock-like ground type for a 10% probability of exceedance in 50 years, corresponding to a mean return period of 475 years. The seismically active margins of the Adriatic Plate and widespread intraplate seismic activity, particularly in south-eastern Europe, are evident. High PGA values in the AdriaArray region are expected along the Calabrian Arc, the Apennines, along the southeastern Adriatic coast, the Hellenic Arc, at the westernmost tip of the North Anatolian Fault and in the Vrancea region.

Seismic hazard assessment requires homogeneous input data sets, including earthquake catalogs, which can only be obtained with a dense coverage of seismic stations. Due to the variable density of the permanent seismic stations in central and southeastern Europe, observations of seismic activity, in particular the magnitude of completeness, are instead heterogeneous. AdriaArray enhances seismic monitoring in the region by the deployment of temporary stations and by supporting the operation and development of permanent seismic networks. This will improve the detection and location of earthquakes in the area, allowing better identification of seismically active faults and assessment of their current state and activity, as well as calibration of regional, or even local, Ground-Motion Prediction Models (GMPM). The AdriaArray initiative will contribute further to the harmonization of detection and location procedures and the improvement of the background velocity models. Focal mechanisms of small-magnitude earthquakes will also be determined to provide new insight into the three-dimensional lithospheric stress field and associated plate deformation.

1.4 Previous experiments and seismic arrays

As early as in 1895, Ernst von Rebeur-Paschwitz proposed, in the first description of recordings of a teleseismic event, to build a global network of identical stations to monitor the worldwide seismic activity (von Rebeur-Paschwitz, 1895; Schweitzer and Lay, 2019). Around 100 Wiechert-seismometers deployed worldwide until the 1920s were part of such a network. In the 1960s, ca. 120 stations of the Worldwide Standardized Seismograph Network (WWSSN) provided the global infrastructure, technical station capabilities, and open data-exchange procedures necessary to analyze waveforms recorded by a global network (e.g., Oliver and Murphy, 1971). Since the late 1970's, analogue recordings have been increasingly replaced by digital data acquisition and national permanent networks have been continuously densified. In Europe, ORFEUS was founded in 1987 to organize and ensure an open exchange of broadband data. Today, ORFEUS EIDA archives digital data of 23500 stations mainly from the Euro-Mediterranean region.

In addition to permanent networks, temporary networks and local arrays have been deployed to achieve higher station coverage in target areas and to measure the propagation direction and speed of seismic waves, respectively. Early examples are the Yellowknife Seismological Array installed in Canada in 1962 (Somers and Manchee, 1966), the LASA array installed in the United States in 1964 (Green at al., 1965), and the Gräfenberg Array being deployed in Germany since 1976 - the first digital broadband array that is still operational today (Buttkus et al., 1986). The era of digital temporary passive broadband seismic experiments started in Europe with the NARS initiative (Nolet et al., 1986). Fourteen broadband stations were deployed in a 2562 km long belt from Sweden to Spain to record earthquakes in a triggered mode. The experiment focused mainly to surface waves and their higher modes to study the upper mantle. Since the 1990s, the number of stations deployed in temporary experiments by various pools has steadily increased from tens to a few hundreds and the duration of the experiments increased from a few weeks to several years. Permanent networks and temporary installations merged into regional arrays that grew across national boundaries and covered entire tectonic units. On-shore stations were complemented by the deployment of ocean bottom seismometers (Sutton and Duennebier, 1987).

The USArray with about 400 temporary stations rolled from west to east across the continental United States of America from 2004 to 2015 and was installed in Alaska in 2014. The aperture of the simultaneously deployed stations was about 2100 km north-south and 850 km east-west with a station spacing of about 70 km in the contiguous U.S.A. Each station operated for 1.5 - 2.0 years, see the white paper by Meltzer et al. (1999) and the report by Busby et al. (2018). There are hundreds of papers about the Earth's structure based on the USArray data already and more continue to be published.

Examples of experiments in central and northern Europe include the TOR project (Teleseismic Tomography across the Tornquist Zone; Gregersen and Voss, 2002). Between 1996 - 1997, 120 seismometers of that project were deployed as an elongated array from Sweden to Denmark and Germany. ScanArray 2012 - 2017 (Thybo et al., 2021) covered the Baltic Shield with 192 broadband stations. The PASSEQ experiment (PASsive Seismic Experiment in TESZ; Wilde-Piórko et al., 2008) kept almost 200 stations in place for more than two years in 2006 - 2008. The size of the array was about 1200 km in length and 400 km wide with a station spacing of about 60 km on average and of 20 km in the central parts. However, only one quarter of the stations was broadband. PASSEQ built up an international consortium of 17 institutions from 10 countries. The Carpathian Basins Project (2005-2007, Dando et al., 2011) and South Carpathian Projects (2009-2011, Ren et al., 2012) covered the Pannonian Basin and adjacent regions with more than 50 broadband stations each. Many other experiments were carried out in Europe, for further examples we refer to overviews by Hetényi et al. (2018a), Schlömer et al. (2024) and Plomerová (2025).

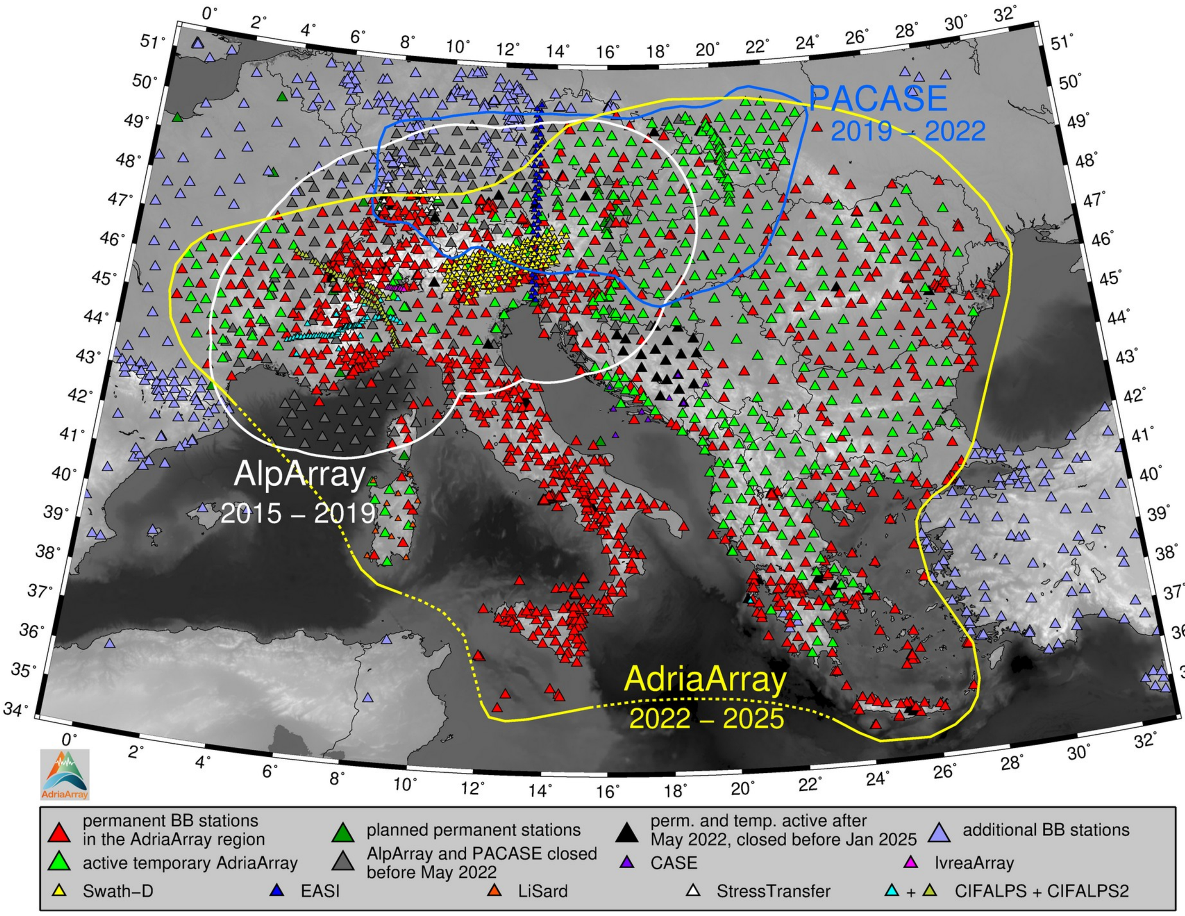

Figure 3. Temporary active broadband stations of the current AdriaArray Seismic Network are shown by light green triangles on top of the previous large experiments, the AlpArray and the PACASE (dark gray if closed before May 2022). Permanent and temporary stations of AdriaArray, active anytime after May 2022 and closed before July 2025, are in black. Stations of the AlpArray complementary experiments EASI, CASE, IvreaArray, Swath-D, LiSard and StressTransfer as well as of CIFALPS and CIFALPS2 experiments are shown by various colors (all closed already). Outlines of all three large-scale deployments are shown. Light blue triangles are permanent broadband stations outside of the AdriaArray region and temporary stations inside the AdriaArray region not being part of the AdriaArray Seismic Network. Dark green are permanent stations to be built in near future. This map contains also some permanent and temporary stations which are not connected to EIDA yet. Five permanent stations in Ukraine were deployed in the framework of the AdriaArray.

Large temporary seismic networks were deployed also on other continents. AusArray, a 55 km spaced network of stations was deployed between 2017 – 2020 in Northern Territory and Queensland (130 stations, Gorbatov et al., 2020). From 2022 to 2024, a continent-wide network covered the whole Australia with a station spacing of 220 km (150 stations, Gorbatov et al., 2024). In China, the NECESSArray was deployed in 2009 – 2011 (127 stations, Ranasinghe et al., 2015).

In the Mediterranean region, monitored by the permanent MedNet broadband network (Boschi et al., 1991; MedNet Project Partner Institutions, 1990), an early broadband temporary experiment covered the Aegean and its margins with 30 stations in mainland Greece, western Türkiye and many Aegean islands in 1997 (Hatzfeld et al., 2001). The EGELADOS (Exploring the Geodynamics of Subducted Lithosphere Using an Amphibian Deployment of Seismographs) experiment (2005 - 2007) covered the southern Aegean Sea with 49 broadband stations onland and 22 ocean bottom seismographs (Friederich and Meier, 2008). Between 2007 and 2009, 80 broadband stations were also deployed in the Anatolia-Aegean region in the framework of the SIMBAAD experiment (Seismic Imaging of the Mantle Beneath the Aegean-Anatolia Domain; Salaün et al., 2012). IberArray (Díaz et al., 2009 and 2015; Díaz and Gallart, 2014) covered northern Morocco and the whole Iberian Peninsula in three successive deployments between 2007 - 2013, resembling the rolling spirit of the USArray, with IberArray moving from south to north. The station spacing was 60 km and the three deployments comprised 55 stations in the first deployment to almost 100 stations in the third one. Every station stayed at its place for at least 1.5 years.

Efforts continued with the PYROPE experiment (PYRenean Observational Portable Experiment, 2009 - 2013, Chevrot et al., 2014), which was synchronized with the third deployment of the IberArray and allowed investigations on both the Spanish and French sides of the Pyrenees.

A more recent example of large dense seismic networks in Europe is the AlpArray experiment (Hetényi et al., 2018a), which covered an entire orogen - the Alps - with 276 temporary broadband stations placed among the existing 352 permanent broadband stations, complemented by 30 ocean-bottom seismometers in the Ligurian Sea, achieving the densest station spacing so far, with an average distance of 52 km between the stations. AlpArray was followed by the PACASE experiment (Schlömer et al., 2024), where 62 stations were added to the eastern margin of the former AlpArray deployment with similar station density.

Figure 3 shows all temporary stations deployed in the Alpine area during the last decade. Various colors depict AlpArray, PACASE and the other AlpArray complementary experiments EASI (Eastern Alpine Seismic Investigation, 2014 – 2015, Hetényi et al., 2018b), CASE (Central Adriatic Seismic Experiment, 2016 – 2018, Molinari et al., 2018), IvreaArray (2017 – 2019, Hetényi et al., 2017), SWATH-D (2017 – 2019, Heit et al., 2021), LiSard (Lithosphere of Sardinia, 2016 - 2018) and StressTransfer (2018 - 2021, Mader et al., 2021) as well as CIFALPS (China-Italy-France Alps seismic survey, 2012-2013, Zhao et al., 2015) and CIFALPS2 (2017-2019) experiments. See also the list of seismic networks below for further references to the particular seismic network codes and their DOIs.

AdriaArray follows directly the two major deployments conducted in the area – the AlpArray and PACASE experiments. These three experiments spanned consecutive three-year operation periods with AlpArray operating between 2016 and 2019, PACASE from 2019 to 2022 and AdriaArray from 2022 to 2026. AlpArray started officially in 2016, even though the deployment began already in 2015 in some countries. AdriaArray has not only shifted the deployment of temporary stations to the southeast, it also covers almost the entire region previously covered by AlpArray and fully includes PACASE. With AdriaArray, we can now study the Adriatic Plate, its plate margins and geohazards related to plate deformation. Improvement of seismic monitoring and hazard assessment are actually the most urgent tasks for many researchers of the AdriaArray community.

2. Preparation and installation of AdriaArray

2.1 Compilation of information on existing permanent stations

The first task that we tackled in 2019 was a compilation of information on existing permanent stations in the AdriaArray region. For many countries, lists of existing stations were available from various sources, but information on sensor types and the operational status was largely missing. For some countries, lists of existing stations were also not readily available. Therefore, we assembled this information from network operators and included not only broadband, but also strong-motion and short-period stations. This resulted in a list of more than 3000 existing stations with information on station locations, operation periods, sensor types, network codes, and data archiving, see the inventory sheets on the AdriaArray GitHub page (links are given in Appendix C). Altogether 2278 permanent stations are located inside the AdriaArray region, 1091 of which are broadband stations with a corner period equal to or longer than 30 s. Although the vast majority of permanent stations listed in our inventory are connected to EIDA and therefore their metadata are available, the inventory still contains about 220 stations (in the whole rectangular map cut-off, both inside and outside the AdriaArray region), for which basic station parameters cannot be easily retrieved because these stations are not included in EIDA. It was found that a significant number of operational stations in the AdriaArray region were not connected to European data infrastructures in 2019. Due to the AdriaArray initiative, data from more than 100 existing broadband stations are now streamed to the European archive (ORFEUS EIDA).

In addition to permanent stations in operation, we also listed sites where stations have been located in the past. These were usually sites of temporary installations during previous experiments which could potentially be reoccupied for temporary stations. We also listed planned station locations, if reported by the local network operators.

2.2 Involved mobile pools and design of AdriaArray

Based on maps of existing stations, preliminary plans for the installation of temporary stations were developed according to the availability of mobile pools. Remarkably, more than 440 temporary stations from 23 mobile pools from 14 European countries were available for AdriaArray. This shows the potential for coordinated large-scale passive seismic experiments in Europe. Intensive discussions between hosting network operators and mobile pool representatives led to plans for the distribution and installation of temporary stations to achieve a homogeneous backbone network of broadband stations. Figure 4 shows all broadband stations, both permanent and temporary, both inside and outside the AdriaArray region, on a colored topographical map of the region.

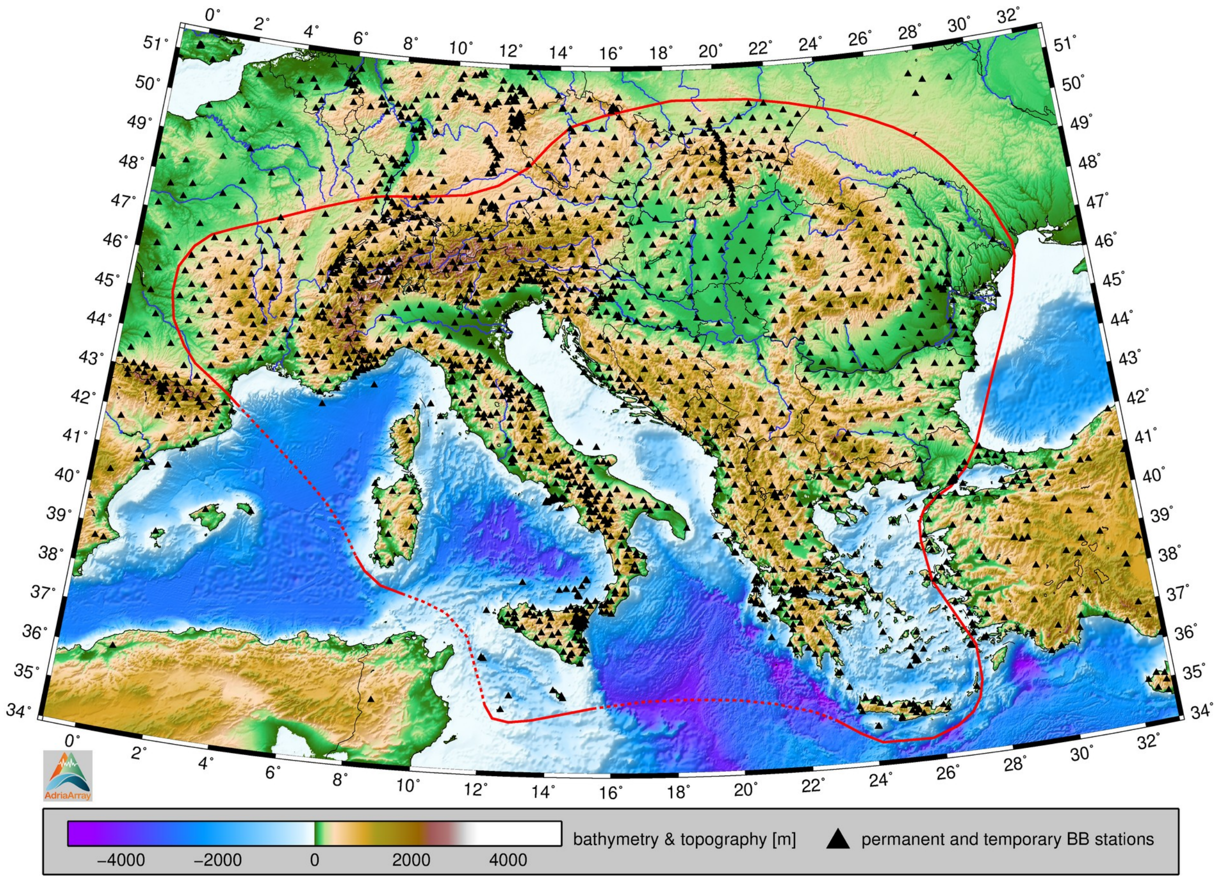

Figure 4. Topography and bathymetry of the region with major rivers. Triangles show broadband stations operating anytime between May 2022 and July 2025. Data of the ETOPO Global Relief Model is provided by the NOAA Physical Sciences Laboratory and is used also in all the other maps in this paper. The AdriaArray footprint is delineated by the red line.

Before planning the temporary stations, we did not set any exact a priori station spacing nor did we introduce any strict decision on the region to be covered. We also did not apply any strict rule for the corner periods of the backbone stations. We aimed to cover a region way further around the targeted Adriatic plate for the purpose of completeness and consistency of local seismicity assessment. Imaging techniques, especially tomography, also provide better resolution if the ray coverage extends over the targeted region. The final AdriaArray outline is a compromise between covering the region as large as it gets, keeping the station spacing at a level comparable to preceding AlpArray and PACASE experiments, and number of stations available. Hence, all these parameters (spacing, region, corner period) were obtained as a result of negotiations with mobile pool operators willing to join the project, their interests in particular regions of deployment and the permanent stations available in that region. The deployment was initially proposed by providing points on the map without any relevance to real field conditions. Later, these coordinates were usually given to the local permanent network operators, who suggested modifications based on their knowledge of the region, past field trips and overall experience. Later, during scouting for the actual temporary station sites, the plan was modified again. An overview map of all stations in the region is given in Appendix D.

Figure 5 shows (besides gray permanent stations) all the temporary stations color-coded according to their respective mobile pools. Colors of the triangles denote the provider of fundamental parts of the stations, for example the sensor. The dot inside the triangle indicates that additional equipment was provided by another mobile pool. The figure contains 30 combinations of colored triangles and dots. The GIPP (Geophysical Instrument Pool Potsdam) stations are split into several patches (Sardinia, Carpathian profile, Ukraine, Romania, Serbia). In each region, the GIPP deployment is maintained by the local network operator with the help of various institutions from other countries such as the Czech Republic, Sweden, Germany, Italy and Poland. Further information on the mobile pools, institutions supporting the logistics, data transmission, field deployment and maintenance of the temporary stations is given in Appendix E.

Since May, 292 temporary and 5 permanent AdriaArray stations have been installed. In addition, 135 stations were already in place from the previous PACASE experiment (Schlömer et al., 2024) and 73 of these have already been running within the AlpArray project before PACASE (Hetényi et al., 2018a). It is worth noting that 279 temporary stations (both newly deployed or inherited from AlpArray and PACASE) have been installed in countries other than the origin of the mobile pools.

2.3 Field work

The fieldwork was carried out in cooperation between the incoming mobile pool operators and the hosting permanent network operators. The start of the installation was largely determined by the availability of the temporary stations and the necessary funding. In particular, funding had to be secured for the shipment of the stations, scouting and installation of the stations. Funding was raised by mobile pool and hosting network operators and was provided by national funding agencies, as no European funding was available for the installation of AdriaArray. Each institution approached this task according to its internal capabilities, national funding agency policies, and the availability of international funding sources. Some institutions received grants from their national funding agencies as a stand-alone project, others used internal institutional budgets. Two institutions from different countries got funded by an international bilateral grant. AdriaArray has also incorporated several projects that were planned independently, overlapping in time and taking advantage from integration into a larger initiative.

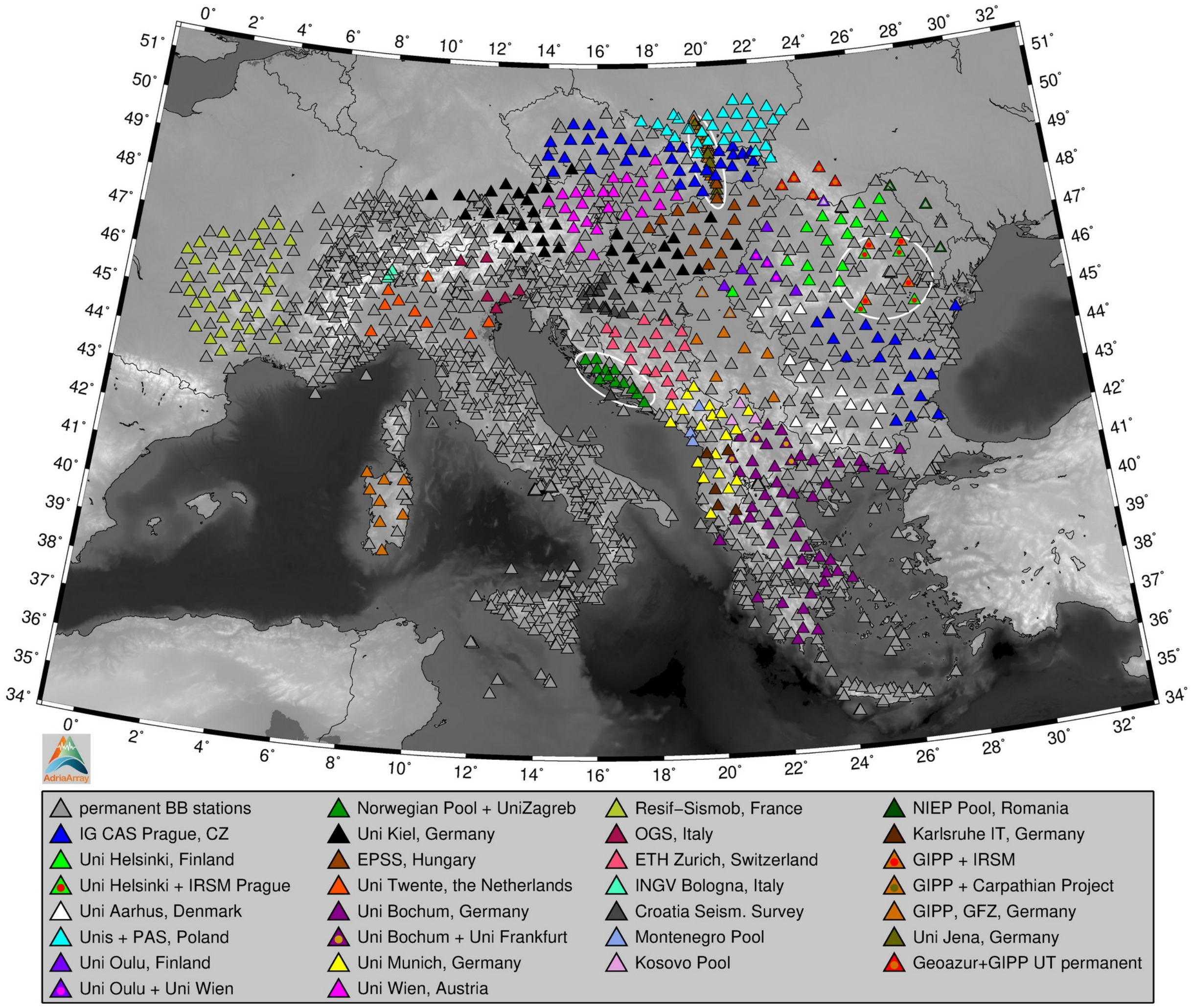

Figure 5. Temporary stations are color-coded by respective mobile pools, permanent stations are gray. Filled triangles are the deployed stations, empty triangles are the stations planned. This applies to both permanent and temporary stations. Dots inside the triangles mark stations where equipment is provided by two mobile pools. White ellipses denote three local experiments and simultaneously running large-N experiment in Albania. Stations labeled as "Geoazur + GIPP UT permanent" will stay permanently in Ukraine.

We note that 69 stations from EU countries have been installed in 7 non-EU countries (temporary: Albania, Bosnia and Herzegovina, Kosovo, Montenegro, North Macedonia and Serbia; permanent: Ukraine) with specific customs procedures. Also, 12 stations from a non-EU country - Norway - were installed in an EU-country - Croatia. To illustrate the diversity of the area, participants speak 24 different languages, write in 5 different alphabets and use 19 different currencies.

Due to the COVID-19 pandemic, we were unable to meet in person for almost two years, between 2020 and 2022. This slowed down the scientific discussions and, of course, the fieldwork.

The first installation of mobile stations was planned by the Polish team in Ukraine. This became impossible because of the Russian invasion in February 2022. In 2023, the European community established new contacts with Ukrainian colleagues and equipment for the upgrade of 5 permanent stations in the AdriaArray region has been sent by groups in France and Germany to Ukraine. These stations are installed, operational and sending data to the EIDA node in Romania.

2.4 Local experiments

In addition to the backbone network, the AdriaArray initiative includes local experiments. These represent local densifications with broadband, short-period or strong-motion stations in regions of particular interest - see white ellipses in Fig. 5. Examples are densifications at the Adriatic coast in Croatia, in the Vrancea region (Romania), and the Carpathian profile. The latter consists of 18 stations installed in 2023 incorporating the backbone stations deployed in 2019 in southern Poland, Slovakia and northern Hungary. Access to data of local experiments follows the same rules as access to any backbone station. See Appendix E for the list of institutions involved in these local experiments. Further local experiments, in particular along the Adriatic east coast, are in preparation including marine ones. In addition, there was also the ANTICS large-N experiment in Albania (Agurto-Detzel et al., 2025, individual stations not shown in the maps), composed of 350 short-period and 50 broadband sensors, independently from the AdriaArray backbone. The ANTICS stations were offline and will be backfilled to EIDA. Simultaneously with AdriaArray, the DIVEnet experiment also took place in northern Italy (Confal et al., 2025, not shown in the maps).

2.5 Coverage

One of the main objectives of the initiative was to cover the AdriaArray region as homogeneously as possible using the temporary stations available. The upper map in Fig. 6 shows the station coverage for the permanent stations including also stations outside of the AdriaArray region. The lower map shows the current coverage for all stations - permanent and temporary together. Circles of 10, 20, 30 and 40 km radius are plotted around every broadband station. The darker the visual impression of the map, the better the coverage. In the areas with high permanent network density, as in Switzerland, around the French-Italian border, in the Apennines, in the Calabrian Arc, in north-eastern Italy and Slovenia, the coverage shows mostly dark red color, which means there is no place more than 20 km distant from the closest broadband station. The temporary stations complement the network so that most of the region is covered with the orange color, meaning the distance to the closest broadband station is up to 30 km. Towards the eastern margin of the region, the inter-station distances slightly increase. All countries in the region are however covered. Figure 6 shows only stations incorporated in EIDA as of July 2025 with open and embargoed access inside the AdriaArray region, and open access outside of the region.

3. Data and metadata

3.1 Station properties and metadata

One of the important properties of the broadband seismic station is the corner period of its sensor. The corner periods are not easily discoverable from the metadata, as it is not a mandatory parameter. It is often given as a comment in the description of the sensor, or it can be calculated from instrument poles and zeros. We have gathered the information on the corner period of the permanent stations already during the planning phase. Later, we added the corner periods of all temporary stations to the station inventory. Figure 7 shows the corner periods of all AdriaArray stations split into five categories. Yellow triangles show dominantly Guralp 30 s sensors, orange triangles depict solely Trillium 40 s sensors. Red, dark red and purple triangles indicate sensors with longer corner periods of various manufacturers.

Station inventories of permanent and temporary stations (Appendix F) contain the properties of every station (see the link to the AdriaArray GitHub page in Appendix C). The corner period is one of the basic parameters, which may also be cross-checked between the inventories and the metadata to detect potential errors. One of the lessons learned from AlpArray is that metadata is often erroneous. To minimize these difficulties, we started testing metadata even before the temporary deployment campaign started. Data and metadata quality testing is described in detail in a separate paper of this special issue (Kolínský et al., 2025). Data availability, retrievability, noise levels, metadata formal checks and earthquake data quality based on examining several parameters as well as on wavefront tracking is discussed there.

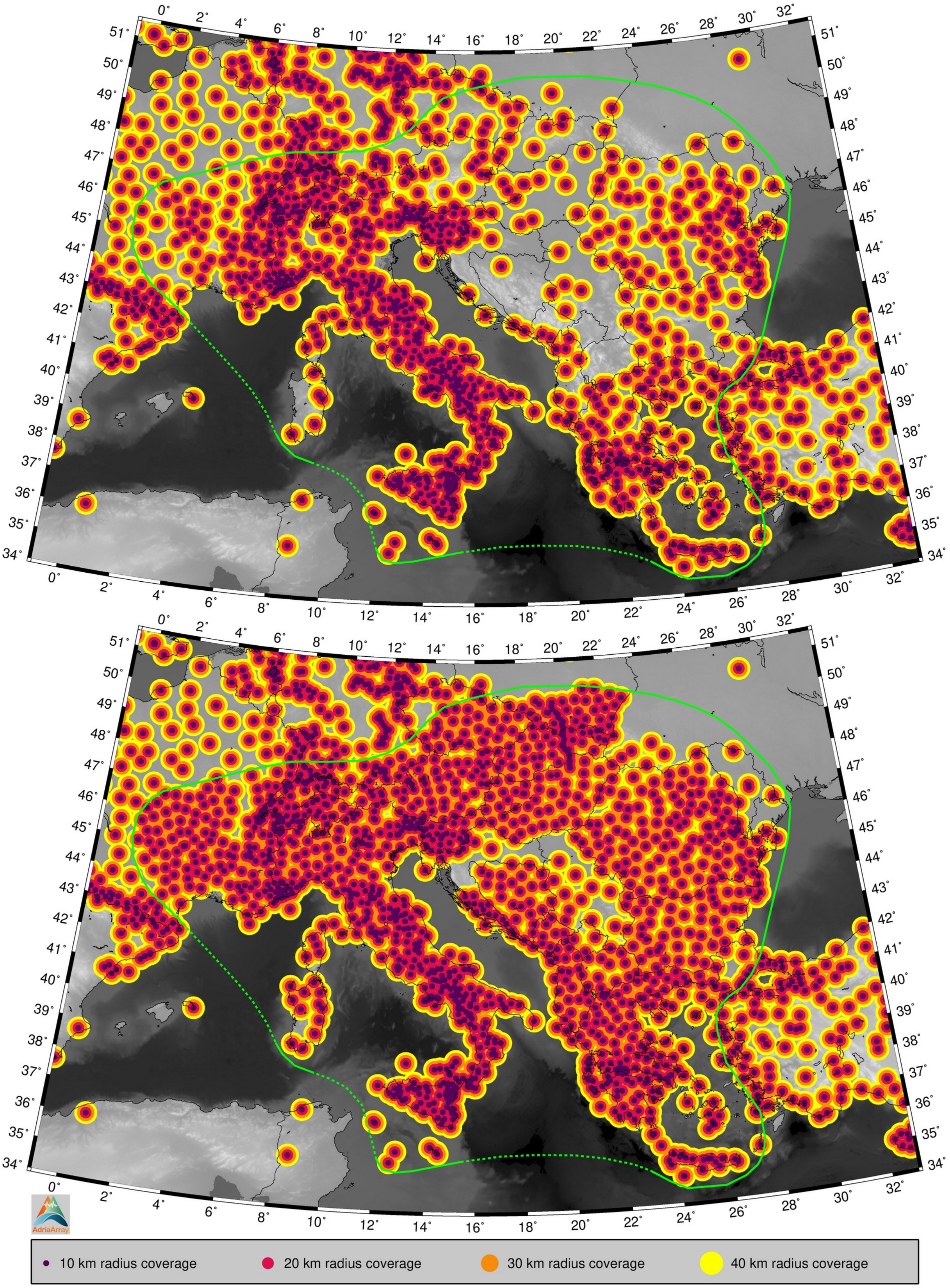

Figure 6. Upper map: coverage of the permanent stations. For example, areas covered by orange and darker color mean that there is no place more distant than 30 km from the nearest broadband seismic station. Lower plot: the same as in the upper map shown now for both permanent and temporary stations. Only the stations registered in EIDA in July 2025 and providing data anytime after May 2022 are used to plot the coverage maps. The AdriaArray footprint is delineated by the green line.

3.2 Data access and download

Members operating permanent and temporary stations share their data and metadata via the ORFEUS EIDA infrastructure that allows access to the data for all AdriaArray Seismology Group (SG) participants. AdriaArray SG participants get immediate access to the data via FDSN web services managed by ORFEUS EIDA. Permanent stations, temporary stations with open access and metadata (stationXML) of all stations (including embargoed) are publicly available to both the AdriaArray SG participants as well as any non-participants. Data of permanent stations are immediately available for all interested public users according to the ORFEUS EIDA policy. A rolling embargo of two years is applied to the data acquired by temporary AdriaArray stations if requested and agreed by the mobile pool operator and the hosting local permanent network operator. The rolling embargo means that data will become publicly available 2 years after the acquisition. The embargo will be unlocked with a step of one year every January. Accessing the embargoed waveforms requires authentication, provided by tokens assigned to eligible persons (participants) individually. Data of temporary AdriaArray stations delayed due to lack of telemetry and/or due to quality control procedures become accessible to AdriaArray participants via the FDSN web services as soon as possible, but not later than one year after acquisition.

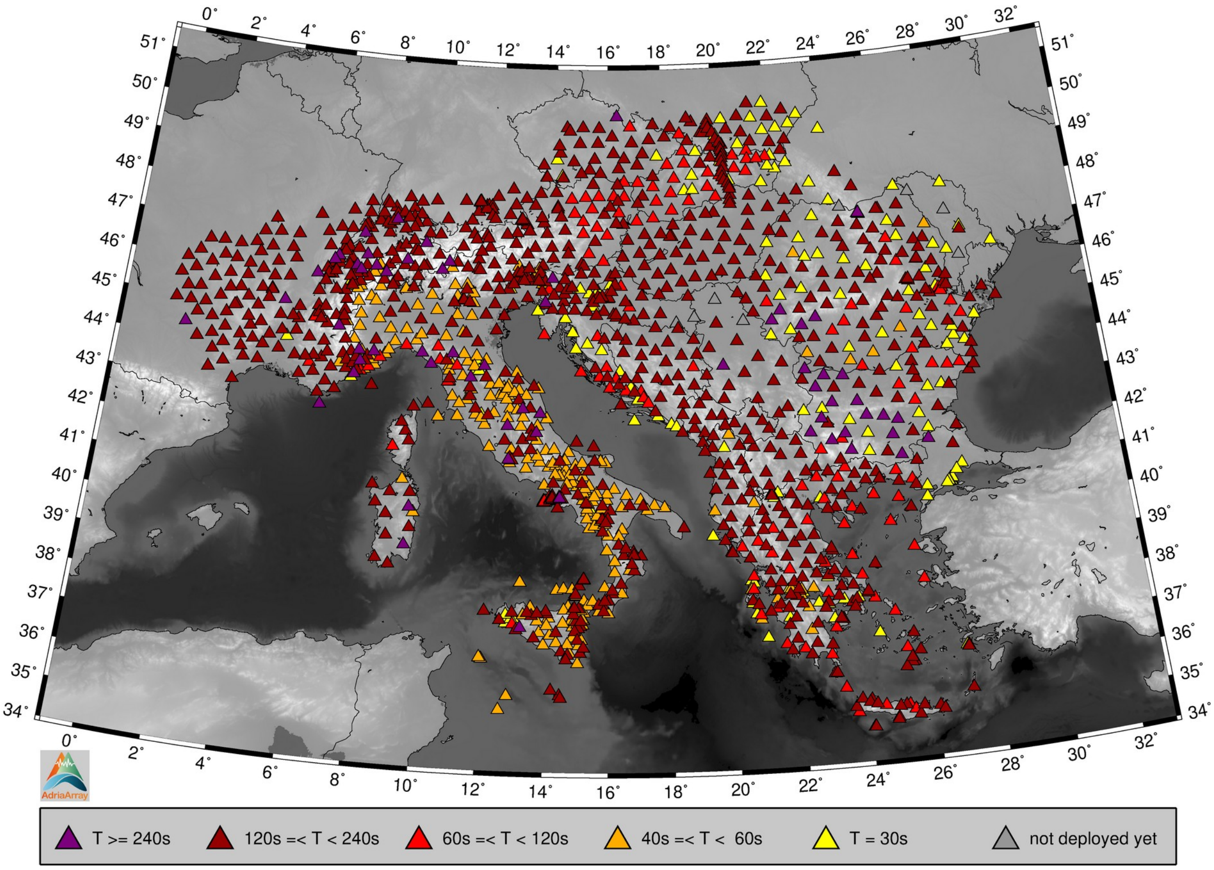

Figure 7. Stations are colored by five categories of their corner periods. The darker the color, the longer the corner period. The map shows broadband stations in the AdriaArray region operating anytime after May 2022, permanent and temporary, including stations not in EIDA yet. Gray triangles indicate planned stations yet to be deployed.

Data acquired by the AdriaArray stations may be accessed also in real-time (e.g., via SeedLink - a protocol designed for the transmission of seismological data in the MiniSEED format, see the link in Appendix C) by authorized users. Real-time access to data streams of permanent stations contributing to AdriaArray is regulated by separate institutional agreements and is not regulated or affected by the MoC. AdriaArray member with seismicity monitoring mandates get real-time access to temporary stations within national boundaries and for temporary stations outside but in proximity of their national boundaries. Institutional agreements on real-time exchange of data of the permanent stations apply also to data of temporary stations in the area of the validity of these agreements.

AdriaArray SG members retain the right to provide their own data (in real-time and/or via EIDA) to non-members. AdriaArray SG members are, however, not allowed to give non-members access to AdriaArray data provided by other AdriaArray SG members.

The token acts as a login and password while requesting waveforms. The procedure for eligible AdriaArray participants to obtain a token is described on the AdriaArray webpage. Further details on the EIDA Authentication System are given in “EAS User Documentation, Release 0.9b1” by Quinteros and Heinloo (2019).

Data and metadata can be accessed via the FDSN web services provided by ORFEUS EIDA using *wget*, smart command line clients (e.g., *fdsnws_fetch*), or the ObsPy client (Megies et al., 2011). Examples of data requests are available on the AdriaArray webpage, describing several data download options:

A. metadata using webbrowser;
B. waveforms using webbrowser;
C. waveforms using fdsnws_fetch;
D. metadata and waveform using the ORFEUS EIDA web interface;
E. metadata using ObsPy;
F. waveforms using ObsPy;
G. waveforms using the virtual _ADARRAY network including example Python code.

Examples of data downloads are also given in the supplementary material of Schlömer et al. (2022).

A data example for 1164 broadband AdriaArray stations is given in Fig. 8 for the M7.4 earthquake (Chile, 2024). Visualization of wavefields propagating across the AdriaArray Seismic Network is presented by Stampa and Eckel (2025).

3.3 How to cite AdriaArray and the data

A list of Digital Object Identifiers (DOIs) referring to the contributing networks and/or pools of temporary stations should be given in each publication. In the text, a reference to the network code and its name should be given (see Appendix G), and in the references, a full list of DOI quotes as given on the FDSN web page and in this paper should be added.

Publications using the AdriaArray data should include as authors the active participants who contributed substantially to the research. It is recommended that the list of authors is followed by “and the AdriaArray Seismology Group” if accepted by the publisher and allowed by the publication policy of the respective AdriaArray member institutions. The list of participants of the AdriaArray SG is given in the Appendix A. In the acknowledgments, the AdriaArray SG is to be mentioned. When referring to the AdriaArray initiative or to the AdriaArray Seismic Network, it is recommended to add a reference to this paper.

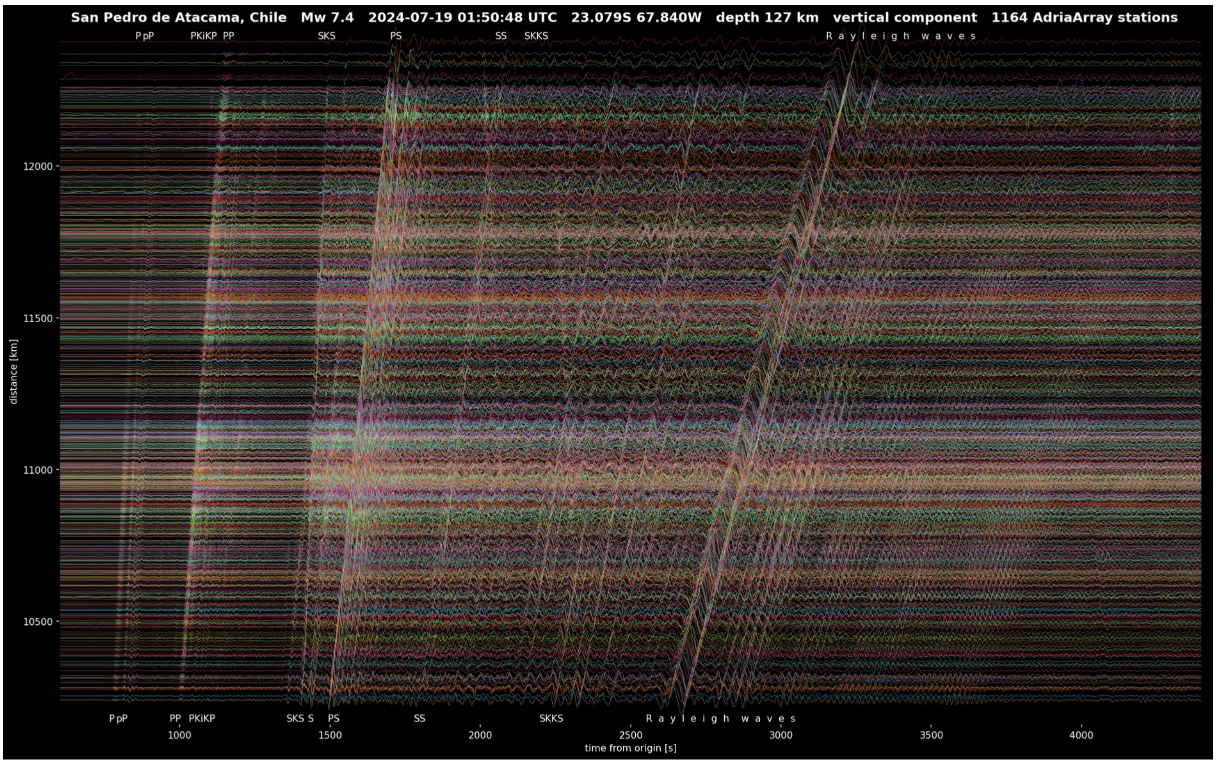

Figure 8. Records of the vertical component of the M7.4 event, 2024-07-19, 01:50:48, depth 127 km (USGS), San Pedro de Atacama, Chile, at 1164 broadband stations of the AdriaArray Seismic Network, filtered between 5 and 100 s with the transfer function deconvolved and main wave arrivals labeled.

4. The AdriaArray Seismology Group

4.1 Workshops and foundation of the AdriaArray Seismology Group (AdriaArray SG)

The AdriaArray initiative was proposed at the AlpArray Meeting in Zurich, Switzerland, in 2018. The actual preparation of the AdriaArray initiative started in May 2019 when about 20 representatives of several research groups met in Thessaloniki, Greece, to discuss both open scientific questions as well as the general concept. As a result, a working group was formed to (i) gather information on existing stations in the area and (ii) on temporary stations available for AdriaArray, to (iii) contact operators of permanent networks in the region, to (iv) prepare a suggestion for the station siting, and to (v) discuss data acquisition and archiving.

AdriaArray was built on the expertise developed during AlpArray. The community, however, has since expanded significantly. The number of institutions providing temporary stations as well as the number of receiving local network operators increased considerably compared to both AlpArray and PACASE. This meant that not only many individuals, but also tens of institutions did not share the experience from previous experiments. Therefore, we started the coordination with a considerable number of online meetings to introduce the idea and to share experiences with the broader community.

The next AdriaArray meeting, scheduled to take place in Sopron, Hungary, in 2020, had to be canceled due to the outbreak of the COVID-19 pandemic. In November 2020, the community gathered for the ORFEUS - EPOS SP (EPOS Sustainability Phase) - AdriaArray Virtual Workshop. ORFEUS and EPOS have been actively supporting the organization of AdriaArray workshops since then. At the workshop, preliminary plans for the temporary station deployment were presented, together with introducing the local permanent network operators.

Another virtual workshop was held in May 2021, where the allocation of mobile pools to the proposed distribution of temporary stations was presented. In November 2021, still under the pressure of the COVID-19 pandemic, we met again virtually at the breakout session of the AlpArray & 4D-MB Scientific Meeting. By this time, the planning of the temporary deployment had taken a stable shape and the community decided to start the fieldwork as soon as the COVID-19 threat receded.

The online meeting that was held on 19 May 2022 marked the official start of the initiative with the establishment of the Steering Committee (SC) for the AdriaArray Seismology Group (SG), the election of Thomas Meier as a coordinator of the SC, and with the signing of the Memorandum of Collaboration by 26 institutions representing the initiators of the AdriaArray SG.

Shortly afterwards, the field campaign was launched in June 2022 with the installation of the first temporary stations in Romania, Bulgaria, and Bosnia and Herzegovina. Thus, May-June 2022 is the milestone not only for the establishment of the AdriaArray SG but also for the start of the deployment.

In October 2022, an ORFEUS – EPOS SP – AdriaArray workshop was organized in Potsdam, Germany. The workshop was attended by about 80 persons, including 25 participants sponsored by EPOS SP. In addition, nearly 100 colleagues registered for online participation. AdriaArray was discussed both at plenary sessions as well as during breakout sessions. Future synergies between AdriaArray, EPOS, and ORFEUS were also discussed. It is interesting to note that many people met in person for the first time after three years of online meetings. Just a week after the workshop in Potsdam, an AdriaArray breakout session was held at the AlpArray meeting in Prague, Czech Republic. The idea about the Collaborative Research Groups was presented and the seismicity working group was established.

The next ORFEUS - EPOS SP - AdriaArray Workshop was held in Dubrovnik, Croatia, in April 2023, locally organized by the University of Zagreb. The workshop was attended by 90 people, including 30 participants supported financially by EPOS SP funds. The discussion on the establishment of technical working groups and Collaborative Research Groups was continued. The workshop was followed by a splinter meeting at EGU 2023, attended by about 30 people onsite and 15 people online, targeting community members who could not travel to Dubrovnik. A summary of the status of the initiative was presented, along with the outcome of the workshop in Dubrovnik, and the final version of the AdriaArray logo.

In the following year, the AdriaArray workshop was held in Sofia, Bulgaria, in March 2024, locally organized by the Bulgarian Geophysical Society, Sofia University and Bulgarian Academy of Sciences. The event was attended by more than 100 people. Collaborative Research Groups (CRG) were already well established and breakout sessions on the respective CRG topics were held. The workshop was financially supported by ORFEUS and CoLiBrI - a Task Force of the International Lithosphere Programme. In addition 12 attendees were sponsored by the workshop fee. Also, similarly as the year before, after the AdriaArray workshop, we convened a splinter meeting during the EGU 2024.

The recent AdriaArray meeting was held in San Servolo (Venice), Italy, in March 2025, locally organized by Istituto Nazionale di Geofisica e Vulcanologia (INGV). The programs of the meetings and workshop and posters and slides from oral presentations can be found on the AdriaArray webpage.

4.2 Memorandum of Collaboration

AdriaArray started formally on 19 May 2022 with the establishment of the AdriaArray SC for the AdriaArray SG. 26 members joined the AdriaArray SG on that date and are considered as initiators of AdriaArray. The AdriaArray SG SC consists of representatives (persons) of the members (institutions, teams, groups of institutions, groups of researchers). The representatives of the initiation members approved and signed the Memorandum of Collaboration (MoC) which is to be signed by a representative of any new member when joining the initiative. The MoC focuses on the organizational structure, describes access to and usage of seismic data collected in the framework of the AdriaArray initiative and sets the overall general principles of scientific collaboration. The MoC also describes the procedure of accepting candidates for membership. The MoC is available on the AdriaArray webpage, see the links in Appendix C.

4.3 Members of the AdriaArray Seismology Group

AdriaArray SG members are institutions or established research groups, whose representatives signed the Memorandum of Collaboration. Members are accepted by the AdriaArray SG SC after evaluating their contribution, which, according to the MoC, meets at least one of the following criteria:

A. Operation of any number of portable seismic stations of the broadband seismic backbone network (velocity or strong-motion sensors) or of local experiments (broadband or short-period velocity or strong-motion sensors) within the AdriaArray Seismic Network, preferably with real-time access.
B. Preferably real-time access to data provided by permanent stations in the AdriaArray area of the corresponding institution (or near real-time, if a delay is imposed by technical or policy issues).
C. Significant support for the installation of portable seismic stations.
D. Significant contribution to data transmission, data archiving, quality control or distribution.
E. Development of and / or access to scientific methods, software, data, catalogs or platforms, important for the project and available to all members.
F. Organization and outreach of the AdriaArray initiative.

Figure 9 gives a geographical overview of member institutions of the AdriaArray SG including their branches when located in different cities. After its initiation in May 2022, new members joined the AdriaArray SG in July, October and November 2022 and in January, April, September and November 2023, to reach the current number of 54 members from 30 countries, comprising 64 institutions. Their representatives are listed with affiliations as coauthors of this paper. There are four members of the AdriaArray SG consisting of several institutions. These four group members are mentioned with affiliations of their representatives at the beginning of the paper. Here we add the full list of the participating institutions of these four group members: (1) The ‘Polish AdriaArray Seismic Group’ consists of the Institute of Geophysics, Polish Academy of Sciences, Warsaw; Institute of Geophysics, University of Warsaw and Institute of Earth Sciences, University of Silesia, Katowice. (2) The ‘Norwegian Broadband Pool’ consists of the Department of Earth Science, University of Bergen; Norwegian Seismic Array (NORSAR), Kjeller; Department of Geosciences, Faculty of Mathematics and Natural Sciences, University of Oslo and Section for Geophysics, Geological Survey of Norway, Trondheim. (3) The ‘Carpathian Project Group’ consists of the Institute of Geological Sciences, Polish Academy of Sciences, Warsaw, Poland; Department of Earth Sciences, Uppsala University, Sweden; Institute for Geosciences, Friedrich-Schiller-University Jena, Germany and Department of Geology and Paleontology, Comenius University in Bratislava, Slovakia. (4) The ‘French consortium Grenoble-Toulouse-Strasbourg’ consists of Institut des Sciences de la Terre, Université Grenoble Alpes; Observatoire Midi Pyrénées, Université de Toulouse and Ecole et Observatoire de Sciences de la Terre, Université de Strasbourg.

4.4 Participants of the AdriaArray SG

AdriaArray participants are individuals contributing to the goals of the initiative, interested in the data, affiliated with member institutions or groups, approved by the member representatives, and hence eligible to get access to embargoed seismic data via individual tokens. The names of all 451 participants of the AdriaArray SG are given in Appendix A.

4.5 Working groups

Six working groups on specific topics were formed to support the AdriaArray SG SC:

1) Working Group 1 ‘Station siting’. The main task - planning the temporary stations deployment - has been already accomplished. The current focus is to maintain the station inventories and update the maps at the AdriaArray GitHub repository.
2) Working Group 2 ‘Technical advice’. Gives advice and guidelines for the station installation, supports the data flow, helps solving the telemetry issues, and collaborates closely with ORFEUS EIDA.

3) Working Group 3 ‘Data quality control’. Performs data quality tests of waveform data and metadata, works closely together with the ORFEUS User Advisory Group and EIDA. See a separate paper on data quality control in this special issue by Kolínský et al. (2025).
4) Working Group 4 ‘Communication and Outreach’. Maintains and updates the AdriaArray webpage, takes care of assigning the access tokens to the eligible participants, takes care of the list of members and participants, and organizes webinars.
5) Working Group 5 ‘Scientific Cooperation’. Coordinates the Collaborative Research Groups, see the next subsection.
6) Working Group 6 ‘Early Career Scientists’. Fosters community building and knowledge exchange among Early Career participants.

Contacts to persons coordinating the Working Groups are given on the AdriaArray webpage. Inventories and maps of stations are discussed in Appendix F. Technical details about sources of information, the webpage, the GitHub repository, station names and network codes, about archiving data in EIDA and about the virtual AdriaArray network _ADARRAY are given in Appendix H. History of the stations included in the AdriaArray virtual network _ADARRAY is described in Appendix J.

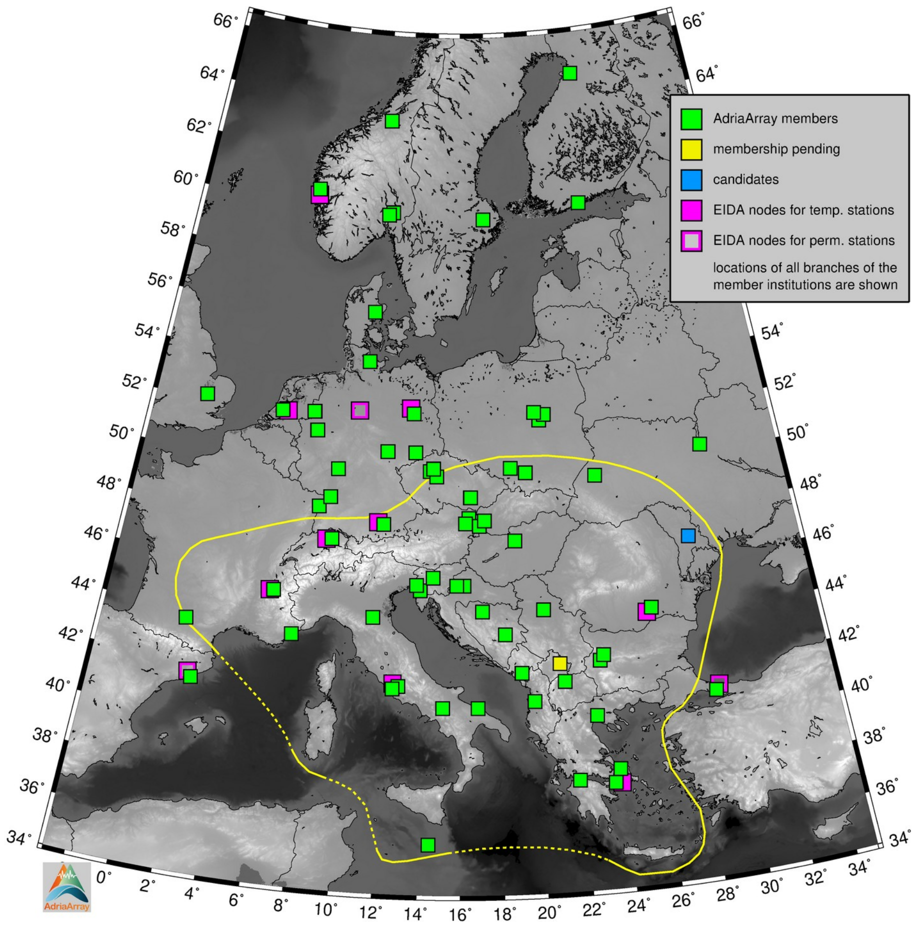

Figure 9. Locations of the AdriaArray member institutions are shown by green squares, including involved branches of these institutions. Yellow and blue are pending membership and candidates for membership, respectively. EIDA nodes hosting data from both the temporary and permanent stations of the AdriaArray Seismic Network are shown by full magenta squares, EIDA nodes hosting permanent stations are shown by empty magenta squares. The AdriaArray footprint is delineated by the yellow line.

4.6 Collaborative Research Groups

According to the Memorandum of Collaboration, scientific work in the framework of AdriaArray is fostered and accomplished by the so-called Collaborative Research Groups (CRGs). Any CRG needs to include researchers from at least two AdriaArray SG members and from different countries. The research is organized independently by the CRGs. CRGs report on their ongoing work at meetings and workshops of the AdriaArray SG. CRGs are suggested by AdriaArray participants, topics of the CRGs are discussed and agreed upon by the AdriaArray SG SC. Participants may join one or several CRGs. If possible, the individual CRGs are coordinated by an experienced researcher and an early career scientist. Participation in CRGs may change any time upon notice to the coordinators of the CRGs. Working Group 5 of the AdriaArray SG entitled ‘Scientific Cooperation’ (see above) coordinates and supports the establishment of CRGs. The first suggestions of the CRGs have been proposed during the international workshops in Potsdam 2022, in Dubrovnik 2023 and at EGU 2023 AdriaArray Splinter meeting. At the Sofia workshop in 2024, the CRGs were already well established. Some CRGs have been restructured since then. Details about the CRGs are given in Appendix B. The names of contact persons, chairs and subgroup leaders of the CRGs can be found on the AdriaArray webpage.

Scientific projects related to the installation of AdriaArray stations, the data analysis and interpretation have been funded and started in several countries, including Bulgaria, Croatia, the Czech Republic, Denmark, France, Germany, Hungary, Italy, Norway, Poland, Romania, and Switzerland.

5. Concluding remarks and perspectives

AdriaArray, a dense plate-scale regional seismic network covering the most seismically hazardous regions of Europe, represents the largest passive seismic experiment that has been carried out in Europe so far. Following three years of preparation, AdriaArray is operational between 2022 and 2026, closely following the AlpArray and PACASE experiments. AdriaArray Seismic Network covers an area surrounding the active margins of the Adriatic Plate and tectonic units to which nappes of Adriatic origin have been accreted, including the Calabrian Arc, the Apennines, the Alps, the Dinarides, the Hellenides, the Pannonian Basin and the Carpathians. The network provides data for imaging of the crust and upper mantle structure and for the analysis of seismic activity.

The AdriaArray Seismic Network consists of 1091 permanent and 435 temporary broadband stations from 23 mobile pools. Five stations were installed in Ukraine as permanent. The inter-station spacing varies between 20 km and 60 km allowing for measuring teleseismic broadband wavefields at a regional scale. Almost all temporary stations were deployed far from the residence of the mobile pool providers. Data from temporary stations is streamed in real-time to 9 EIDA nodes for archiving and is also frequently used by local agencies to contribute to routine earthquake monitoring. AdriaArray considerably improved the coverage with seismic stations, especially in southeastern Europe, and fostered the development of the digital seismological infrastructure in Europe. Over 100 permanent stations have been newly incorporated into EIDA, creating a lasting legacy that will remain even after the AdriaArray experiment concludes. The AdriaArray Seismology Group, comprising 64 institutions from 30 countries, is responsible for organizing the installation of the stations, the data transfer, data quality checks, and the scientific analysis of collected data.

Data of temporary stations are available in real-time to seismological services with monitoring mandates and via EIDA for members of the AdriaArray Seismology Group without any restrictions. Data of some temporary stations are available to the public with a rolling embargo of two years. Data from permanent stations and selected temporary stations are immediately available to the public via EIDA. The backbone network is complemented by locally densified networks in the western Carpathians (from Poland, through Slovakia, to Hungary), along the Dubrovnik fault (Croatia) and in the Vrancea region (Romania). Data acquired by the AdriaArray initiative will provide the basis for scientific research on lithospheric deformation and geohazards in the region for several years to come.

AdriaArray significantly promotes data sharing, knowledge transfer, community and capacity building, with particular emphasis on collaboration with countries in southeastern Europe. Annual workshops organized in partnership with ORFEUS and EPOS, serve as a platform for exchanging technical expertise, sharing knowledge, discussing research topics and strengthening scientific cooperations. The scientific work of the AdriaArray Seismology Group is supported by Collaborative Research Groups involving scientists from different countries focusing on specific research topics.

Data availability statement.
Waveform data from all AdriaArray stations are available through ORFEUS EIDA. Data from the permanent stations and from temporary stations with network codes 4P, 7B, Y5 and XP are publicly accessible immediately. Data from temporary stations with network codes 1Y, 2Y, 9H, Y8 and Z6 are accessible to the AdriaArray Seismology Group participants. The rolling embargo allows this data to be publicly available two years after its acquisition. Data from all AdriaArray temporary stations are, however, immediately available for seismological observatories with monitoring and alerting duties within the AdriaArray region.

6. Appendix A - List of AdriaArray Seismology Group participants

The participants of the AdriaArray Seismology Group are, in alphabetical order: Somayeh Abdollahi, Vanciu Adina, Juan Carlos Afonso, Julius Afzali, Matthew R. Agius, Hans Agurto-Detzel, Yongki Andita Aiman, Stephen Akinremi, Mehveş Feyza Akkoyunlu, Doğan Aksarı, Irena Aleksandrova, John D. Alexopoulos, Tetiana Amashukeli, Vasilis, Anagnostou, Monika Andreeska, Maria-Theresia Apoloner, Iulia Armeanu, Tahira Ashruf, Coralie Aubert, Stojan Babić, Paola Baccheschi, Andrei Bala, Julien Balestra, Francesco Basile, Tena Belinić Topić, Stephen Beller, Jean-Luc Berenguer, Felix Bernauer, Michele Bertoni, Irene Bianchi, Jarek Bienkowski, Almir Bijedić, Dino Bindi, Danijela Birko, Shubhasmita Biswal, Gian-Maria Bocchini, Monika Bociarska, Felix Bögelspacher, Götz Bokelmann, Raffaele Bonadio, Luciana Bonatto, Sébastien Bonnieux, Felix Borleanu, Emil Botev, Pierre Boué, Kostas Boukouras, Rrezart Bozo, István Bozsó, Dušica Brnović, Valentin Buchakchiev, Igor Bugaienko, Erik Bystrický, Musavver Didem Cambaz, Fabio Cammarano, Martina Čarman, Carlo Cauzzi, Adriano Cavaliere, Migena Ceyhan, Kkallas Charalambos, Marinos Charalampakis, Nikolaos Chatzis, Dragana Chernih, Sébastien Chevrot, Andreea Chircea, Jon Magnus Christensen, Maria Grazia Ciaccio, Iulia Ciobanu, Andrej Cipciar, John Clinton, Özkan Çok, Alina Coman, Paolo Comelli, Alessio Compagno, George Marius Craiu, Andreea Craiu, Kristian Csicsay, Snježana Cvijić Amulić, Barbara Czecze, Wojciech Czuba, Sebastiano D'Amico, Ezio D'Alema, Domenico D'Urso, Peter Danecek, Iva Dasović, Pasquale De Gori, Jovan Dedić, Massimo Di Bona, Francesca Di Luccio, Raffaele Di Stefano, Giovanni Diaferia, Jordi Diaz, Spyridon Dilalos, Liliya Dimitrova, Lyuba Dimova, Raluca Dinescu, Manuel Ditz, Dragomir Dragomirov, Katerina Drogreshka, Llambro Duni, Edmond Dushi, Irena Dushi, Marson Dyrmishi, Felix Eckel, Sven Egdorf, Amr El-Sharkawy, Bogdan Enescu, Tuğçe Afacan Ergün, Roman Esefelder, Clément Estève, Christos P. Evangelidis, Islam Fadel, Liudmyla Farfuliak, Chiara Felicetta, Andrea Ferreri, Tomislav Fiket, Marilena Filippucci, Kasper David Fischer, László Fodor, Lucia Fojtíková, Ioannis Fountoulakis, Kelly Fragkouli, Wolfgang Friederich, Michael Frietsch, Francesca Funiciello, Odysseus Galanis, Pauline Galea, František Gallovič, Merjema Genjac-Zukić, Gergana Dimitrova Georgieva, Nikolaos Germenis, Catalin Gheablau, Daniela Ghica, Cristian Ghita, Dimitrios Giannopoulos, Carlo Giunchi, Olgert Gjuzi, Faidra Gkika, Konstantinos Gkogkas, Sofie Gradmann, Pascal Graf, Erik Grafendorfer, Bogdan Grecu, Katalin Gribovszki, Marc Grunberg, Yavuz Güneş, Anett Gyarmati, Erzsébet Győri, Christian Haberland, Felix Halpaap, Oleksandr Haniiev, Rebecca Harrington, Helmut Hausmann, Josef Havíř, Ben Heit, Yann Hello, Marijan Herak, György Hetényi, Janis Heuel, Nikolaus Horn, Heiner Igel, Constantin Ionescu, Doru Ionescu, Ines Ivančić, Tomasz Janik, Milan Janjić, Petr Jedlička, Tamara Jesenko, Yan Jia, Fabrice Jouffray, Ljubcho Jovanov, Damrio Jozinović, Doğan Kalafat, Dániel Kalmár, Nataša Kaludjerović, Hana Kampfová Exnerová, Vasilis Kapetanidis, Andreas Karakonstantis, Foivos Karakostas, Ioannis Kassaras, Ayoub Kaviani, George Kaviris, Kıvanç Kekovalı, Oleksandr Kendzera, Junior Kimata, Anastasia Kiratzi, Peter Klin, Bernhard Klotz, Daniel Köhn, Petr Kolínský, Abo Komeazi, Kari Komminaho, Kyriakos Kontakos, Ayşegül Köseoğlu, Josef Kotek, Vasiliki Kouskouna, István János Kovács, Damiano Koxhaj, Richard Kramer, Tomáš Kratochvíl, Amra Krehić, Dana Křížová, Jan Philipp Kruse, Olga-Joan Ktenidou, Sofia-Katerina Kufner, Krešimir Kuk, Bohdan Kuplovskyi, Tormod Kværna, Jiří Kvapil, Sophie Lambotte, Giovanni Lanzano, Helena Latečki, Sergei Lebedev, Cédric Legendre, Jean Letort, Spyridon Christos Liakopoulos, Michael Lindenfeld, Athanasios Lois, Jürgen Loos, Salvatore de Lorenzo, Sara Lovati, Milka Ložar Stopar, Yang Lu, Francesco Pio Lucente, Salvatore Lucente, Renata Lukešová, Alessia Maggi, Federica Magnoni, Cosimo Magrì, Andrea Magrin, Enrico Magrin, Jaroslaw Majka, Jiří Málek, Marko Mali, Szymon Malinowski, Alfonso Giovanni Mandiello, Elena Florinela Manea, Päivi Mäntyniemi, Lucia Margheriti, Csatló Marietta, Čaveliš Marin, Alexandru Marmureanu, Marco Massa, Kristina Matraku, Nina Matsuno, Valerie Maupin, Martin Mazanec, Stanisław Mazur, Thomas Meier, Mark van der Meijde, Maciej Mendecki, Irene Menichelli, Jan Michálek, Georgios Michas, Andrei Mihai, Marius Mihai, Mihai Mihalache, Jadranka Mihaljević, Ardian Minarolli, Iren Modovan, Anne-Sophie Mohr, Ivana Molerović, Irene Molinari, Stephen Monna, Caterina Montuori, Aurélien Mordret, Andrea Morelli, Dionald Mucaj, Marija Mustać Brčić, Shemsi Mustafa, Thorsten Nagel, Jasmina Najdovska, Dalija Namjesnik, Janne Narkilahti, Dariusz Nawrocki, Cristian Neagoe, Søren Bom Nielsen, Vasileios Nikolis, Anne Obermann, Zafer Ögütcü, Odleiv Olesen, Marco Olivieri, Lars Ottemöller, Volker Oye, Emil Oynakov, Nurcan Meral Özel, Haluk Özener, Mehmet Özer, Marcel Paffrath, Jurij Pahor, Elitza Pandurska, Tonia Papageorgiou, Costas Papazachos, Paris Paraskevopoulos, Stefano Parolai, Viorel Parvu, Hélène Pauchet, Anne Paul, Daniel Nistor Paulescu, Kyriaki Pavlou, Piel Pawlowski, Helle Pedersen, Victoria Pencheva, Damiano Pesaresi, Gesa Petersen, Kostiantyn Petrenko, Laura Petrescu, Davide Piccinini, Claudia Piromallo, Anica Otilia Placinta, Dušan Plašienka, Vladimír Plicka, Jaroslava Plomerová, Natalia Poiata, Remzi Polat, Silvia Pondrelli, Mihaela Popa, Maria Popova, Ljiljana Popović Krejić, Kristóf Porkoláb, Selda Altuncu Poyraz, Vasyl Prokopyshyn, Damir Ptičar, Klajdi Qoshi, Javier Quinteros, Mircea Radulian, Gregor Rajh, Besian Rama, Plamena Raykova, Reneta Raykova, Riccardo Reitano, Julia Rewers, Andreas Rietbrock, Henrique Berger Roisenberg, Marco Romanelli, Stéphane Rondenay, Giuliana Rossi, Marco P. Roth, Zafeiria Roumelioti, Mario Ruiz Fernandez, Georg Rümpker, Nikolaos Sakellariou, Vassilis Sakkas, Simone Salimbeni, Francesco Sanseverino, Marco Santulin, Angela Saraò, Matteo Scarponi, Guilhem Scheiblin, Christian Schiffer, Antje Schlömer, Bernd Schurr, Daniel Schützenhofer, Johannes Schweitzer, Laura Scognamiglio, Manolis Scordilis, Marin Sečanj, Pirita Seipäjärvi, Giulio Selvaggi, Christoph Sens-Schönfelder, Anna Serpetsidaki, Nikolaï Shapiro, Yevgeniya Sheremet, Karin Sigloch, Hanna Silvennoinen, Stela Simeonova, Dinko Šindija, Reinoud Sleeman, Flutra Smakiqi, Efthimios Sokos, Dimcho Solakov, Tanishka Soni, Mathilde Sørensen, Marc Sosson, Petr Špaček, Ioannis Spingos, Piotr Środa, Johannes Stampa, Laurent Stehly, Josip Stipčević, Slavica Štrbac, Angelo Strollo, Anila Subashi, Monica Sugan, Martin Šugár, Bálint Süle, Đorđe Šušić, Murat Suvarıklı, Matthieu Sylvander, Andrea Tallarico, Izidor Tasič, Dragos Tataru, Ugur Mustafa Teoman, Sharon Terhünte, Martin Thorwart, Alexandru Tiganescu, Timo Tiira, Frederik Tilmann, Máté Timkó, Marin Toanca, Andreea Tolea, Dragos Toma, Milena Tomanović, Luca Trani, Petros Triantafyllidis, Per Trinhammer, Milen Tsekov, Gerasimos-Akis Tselentis, Fatih Turhan, Andreas Tzanis, Thomas Ulrich, Kamil Ustaszewski, Jiří Vackář, Dejan Valčić, Jan Valenta, Filippos Vallianatos, Lavinia

Varzaru, Spyridoula Vassilopoulou, Luděk Vecsey, Chrisanthi Ventouzi, Jérôme Vergne, Annamaria Vicari, Toader Victorin, Josef Vlček, Nikolaos Voulgaris, Tommi A. T. Vuorinen, Joachim Wassermann, Milosz Wcislo, Zoltán Wéber, Ulrich Wegler, Christian Weidle, Harald van der Werff, Viktor Wesztergom, David Whipp, Stefan Wiemer, Lars Wiesenberg, Anila Xhahysa, Xiaohui Yuan, Fatimeh Zabihian, Eliška Zábranová, Pavel Zacherle, Bogdan Zaharia, Jiří Zahradník, Luigi Sante Zampa, Christophe Zaroli, Jan Zedník, Piero Ziani, Dimitri Zigone, Mladen Živčić, Helena Žlebčíková, Elisa Zuccolo and Angelos Zymvragakis.

7. Appendix B - Details of the Collaborative Research Groups

Following the general explanation about the CRGs given in the main body of the paper, here we explain the topics and tasks of the individual CRGs in detail:

A. CRG ‘*Seismicity & Seismic Sources*’. The main topics of this CRG are the detection and location of earthquakes, the determination of source mechanisms, either in real-time or offline during detailed in-depth studies, as well as approaches for statistical analysis and interpretations of seismotectonics. The CRG Seismicity & Seismic Sources is split into four subgroups to coordinate the collaborative work. These subgroups are temporary and subject to changes based on needs and ideas for collaborations.
   a. Survey of monitoring practices at national agencies.
   b. Parametric data exchange with EMSC, station naming and reporting.
   c. Machine learning for seismicity detection and location & crowd processing.
   d. Moment tensors and seismic sources. The AdriaArray Seismic Network produces a huge increase in available real-time data for source studies in local and regional distances. This subgroup deals with the usage of this data in real-time moment tensor or focal mechanism retrieval applications, as well as in detailed source studies of earthquakes across different magnitude scales, in the AdriaArray area (e.g., extended source studies, slip inversions, etc). Goals are the exchange of knowledge and methods, fostering discussions of best practices, exchanging results and collaborating in research projects.

B. CRG ‘*Body wave tomography*’. Data available because of AdriaArray, previous experiments such as AlpArray and PACASE, as well as data of permanent networks in the region provide a rich and unique dataset for body wave tomography studies. This CRG focuses on two main tasks:
   a. Body wave arrival times determination. To optimize the exploitation of the size and quality of these dataset we need to employ semi- or fully automated picking procedures able to reproduce in the best way the careful, handy re-picked tasks of the experienced seismologists. This activity includes:
      i. surveying and benchmarking of the existing automated picking tools for regional and teleseismic phases;
      ii. surveying, checking the consistency and sharing the available carefully picked datasets that can be used for comparison and/or learning phases with automated picking procedures;
      iii. comparing picks for a number of selected earthquakes at all AdriaArray stations;
      iv. creating a common dataset for one or more AdriaArray subregions to compare different picking and different inversion codes;
      v. optimizing automatic picking algorithms and possibly providing training and application on the use of software tools.
   b. Traveltime tomography and synthetic tests to assess the model resolution. Studying the crust and upper mantle velocity structure beneath the AdriaArray target region involves various inversion approaches to process the extensive arrivals dataset (including both linearized and non-linearized methods). An essential final stage is evaluating the model resolution. We propose, relying on our collective expertise, to ensure a uniform evaluation of model performance. This involves:
      i. creating and testing synthetic models: collaboratively develop simplistic or realistic synthetic models reflecting expected geological structures (i.e., standardized benchmarks for testing and comparison);
      ii. establishing shared testing guidelines: work together to devise guidelines that standardized testing procedures across the board;
      iii. comparing model performance: assess the ability of different models to reproduce observed waveforms accurately.

   These tasks could be addressed in cooperation with other CRGs (surface waves, waveform inversion, body waves from ambient noise, linking geophysical observables - see below).

C. CRG '*Modeling of seismic wave propagation and full waveform inversion*'. AdriaArray offers a unique opportunity to measure wavefields at a regional scale in a tectonically highly variable and active region encompassing multiple subduction zones, various orogenic belts, back-arc basins, and volcanic fields. Accurate forward modeling of wave propagation in strongly heterogeneous and anisotropic structures is needed to understand the influence of slabs, Moho and lithosphere-asthenosphere topography and mantle flow on seismic wave propagation. Accurate forward modeling stands at the basis for advanced seismic analysis methods including full waveform inversion. First, we review existing forward modeling methods. Moreover, we aim at benchmarking existing codes and at the development of advanced inversion methods to invert for crustal and mantle structures in the AdriaArray region. In addition, we provide training for the use of existing and new modeling and inversion codes.

D. CRG '*Receiver functions*'. This CRG provides support to AdriaArray participants who work on receiver function studies as well as those who want to use receiver function results in their research. In terms of methodologies, this CRG provides access to harmonized receiver function analysis tools and training on how to use these. It also serves as a platform to share software and tips on data analysis, and to carry out community-based benchmarking tests. In terms of imaging targets, the CRG helps coordinate efforts to avoid potential overlaps and foster collaborations. At the end of the project, the CRG will produce a harmonized set of receiver function products for the entire AdriaArray network.

E. CRG '*Ambient noise*'. In this overarching research group, we deal with various aspects of ambient noise, starting from an analysis of the various sources contributing to the noise field, over the compilation of a cross-correlation database to the application of various imaging methods using these cross-correlations.
   a. Noise sources. We work on the characterization and localization of natural noise variation, resulting from, e.g., local weather effects like wind or air pressure and anthropogenic noise sources, e.g., power plants, rotating machines. We also study variations of primary, secondary, and local microseism over time.
   b. Database. We deconvolve and downsample the continuous seismic data from the various subnetworks participating in AdriaArray. This data (around 4-6 TB) will be made available to anybody interested in computing cross-correlation functions for various purposes from mapping ambient noise sources to tomography or time lapse monitoring. If requested, we might also offer a cross-correlation database following a standard preprocessing scheme.
   c. Imaging. Besides the obvious surface wave imaging methods, recent advancements in passive noise interferometry have shown promising results in the retrieval of body waves from noise correlations. This primarily includes various body-wave reflection phases generated by dominant subsurface discontinuities, such as the basin sediment/bedrock interface, the Moho interface, and the 410-km and 660-km mantle transition zone interfaces. The information provided is particularly valuable for determining the depth undulations of subsurface discontinuities and can be seamlessly integrated into seismic tomography for a more comprehensive understanding of the deep earth structure. Given its remarkable data quality and data coverage, the AdriaArray Seismic Network presents an ideal setting for the implementation and development of such cutting-edge seismic techniques.

F. CRG '*Surface wave tomography*'. This CRG aims at gathering multiple methodologies that use surface waves (Rayleigh and/or Love) for 2D and 3D imaging of the crustal and upper mantle structure in the region. Following traditional frameworks of surface wave tomography (SWT), the work handled within this CRG targets four main collaborative tasks:
   a. The construction of reliable surface wave datasets from earthquake data and/or ambient noise.
   b. The measurement of the surface wave phase/group travel times and amplitudes for constructing 2D maps of isotropic (and anisotropic) Rayleigh/Love velocities.
   c. The depth-inversion of phase (and group) velocity dispersion curves.
   d. The joint inversion with other observables.

   This CRG provides a platform for setting up and sharing databases, method testing and benchmarking, resolution test analysis, and further discussions on methodological developments. It includes linearized inversion method, Bayesian approaches, Eikonal/Helmholtz tomography, 2D phase velocity map inversions or direct 3D approaches, radial and azimuthal anisotropy and many others.

G. CRG '*Shear-wave splitting and anisotropy*'. After we collected all available seismic anisotropy measurements for the study region, we identified gaps to be filled with new data. New measurements can give the opportunity to have benchmarking methods and training. We expect to produce new shear wave splitting measurements and splitting intensity values, to be obtained using multiple seismic phases and by analysis methods including joint inversions. We will also provide interpretations of the underlying seismic anisotropy structure within the geodynamic context of the Adria subduction system and the

Eastern Alps. An important objective is also to interact with other CRGs focusing on body and surface wave tomography as well as receiver functions to share and integrate any new dataset and results. The work done by each member of the CRG is an advantage in adding one or more pieces of the puzzle of the anisotropy structure of the tectonic environment of the region. Therefore, active communication between CRG members is encouraged and appreciated.

H. CRG '*Linking geophysical observations and geodynamics*'. Using AdriaArray data, the interior of the Adriatic plate and its margins, slabs and slab windows as well as upper mantle flow will be imaged to clarify open questions regarding the driving forces of plate deformation and kinematics. To test the resolution capabilities of imaging methods and to design input models for numerical geodynamic experiments, at first existing hypotheses of lithospheric and upper mantle structure are to be described in digital form. Hypotheses of slabs and slab windows along the margins of the Adriatic plate (Alps, Apennines, Calabrian Arc, Carpathians, Dinarides, Hellenides) are to be reviewed and discussed based on available observables like seismicity, Moho maps, tomographic models, and receiver function images. Different hypotheses for the slab interface are to be provided in digital format. For these hypotheses, consistent 3D models of various parameters (seismic velocities, temperatures, densities, composition, viscosity) are to be set up using thermomechanical modeling. They form the basis for numerical geodynamic modeling of quantities like plate kinematics, stress, strain fields or exhumation rates that are to be compared with field observations and the geological record.

8. Appendix C - List of related links

The main source of updated information about AdriaArray is its webpage hosted on the ORFEUS ReadTheDocs system https://orfeus.readthedocs.io/en/latest/adria_array_main.html. Station inventories, technical documentation and maps in three formats are stored and updated on the AdriaArray GitHub repository https://github.com/PetrColinSky/AdriaArray. The readme.md file guides you through the folders there. The Memorandum of Collaboration can be downloaded from https://docs.google.com/document/d/1touURp1zYgw1EKjCikhQLY17_T-DX-UDpJHjrKTNybg/edit?usp=sharing. List of the AdriaArray temporary networks is given on the FDSN webpage https://www.fdsn.org/networks/?search=adriaarray. The guidelines for the fieldwork and station deployment is given in the document titled "Best practice for field work, data management and QC of temporary deployments" by Heit et al. https://polybox.ethz.ch/index.php/s/EreWWnfm2gQoLdD. Some of the material is part of the paper by Heit et al. (2021). The EIDA Authentication System is described in the document by Quinteros & Heinloo (2019) https://geofon.gfz-potsdam.de/eas/EIDAAuthenticationService.pdf. An overview of the EIDA webservices is to be found on the ORFEUS page https://www.orfeus-eu.org/data/eida/webservices/. The EIDA Issue tracker can be used for reporting any issues with data download and archiving https://github.com/EIDA/userfeedback. ORFEUS has its Forum https://forum.orfeus-eu.org/, where also the public AdriaArray category resides https://forum.orfeus-eu.org/c/adriaarray/40. The SeedLink protocol is explained on https://docs.fdsn.org/projects/seedlink/en/latest/. PGA values of the ESHM20 can be obtained from the webpage of the European Facilities for Earthquake Hazard and Risk (EFEHR) http://hazard.efehr.org/en/hazard-data-access/hazard-maps/. The PGA values for the particular map shown in Fig. 2 were obtained with the following webservice command: http://appsrvr.share-eu.org:8080/share/map?id=81&lon1=-2&lat1=33&lon2=34&lat2=52.5&imt=PGA&hmapexceedprob=0.0021030&hmapexceedyears=1&soiltype=rock_vs30_800ms-1&aggregationtype=arithmetic&aggregationlevel=0.

9. Appendix D – Overview of all stations

For planning purposes, we divided the region into five geographical subgroups, each of them containing several local permanent networks and selected mobile pools. These subgroups were: "West": France, Sardinia; "Center": Croatia, Bosnia and Herzegovina, northern Italy; "North": Germany, Czech Republic, Austria, Slovakia, Hungary, Serbia; "East": Poland, Ukraine, Romania, Moldova, Bulgaria; "Southeast": Montenegro, Kosovo, Albania, North Macedonia, Greece. Station sites of selected mobile pools were then arranged only within the given subgroup area. This subdivision was used for planning and logistical purposes only and has no impact on data sharing. Other countries in the AdriaArray region - Switzerland, Slovenia and Türkiye (Ergün et al., 2025) - are covered with dense permanent networks and thus temporary stations were not planned there.

All permanent and temporary stations in the region are shown in Fig. A1. Temporary ones are distinguished by five shades of pinkish color according to the five regional subgroups. Inside the AdriaArray region, we show both stations in EIDA as well as those still waiting to be connected to EIDA. Stations outside of the AdriaArray region are broadband, short-period and strong-motion stations in EIDA that continued to operate after May 2022.

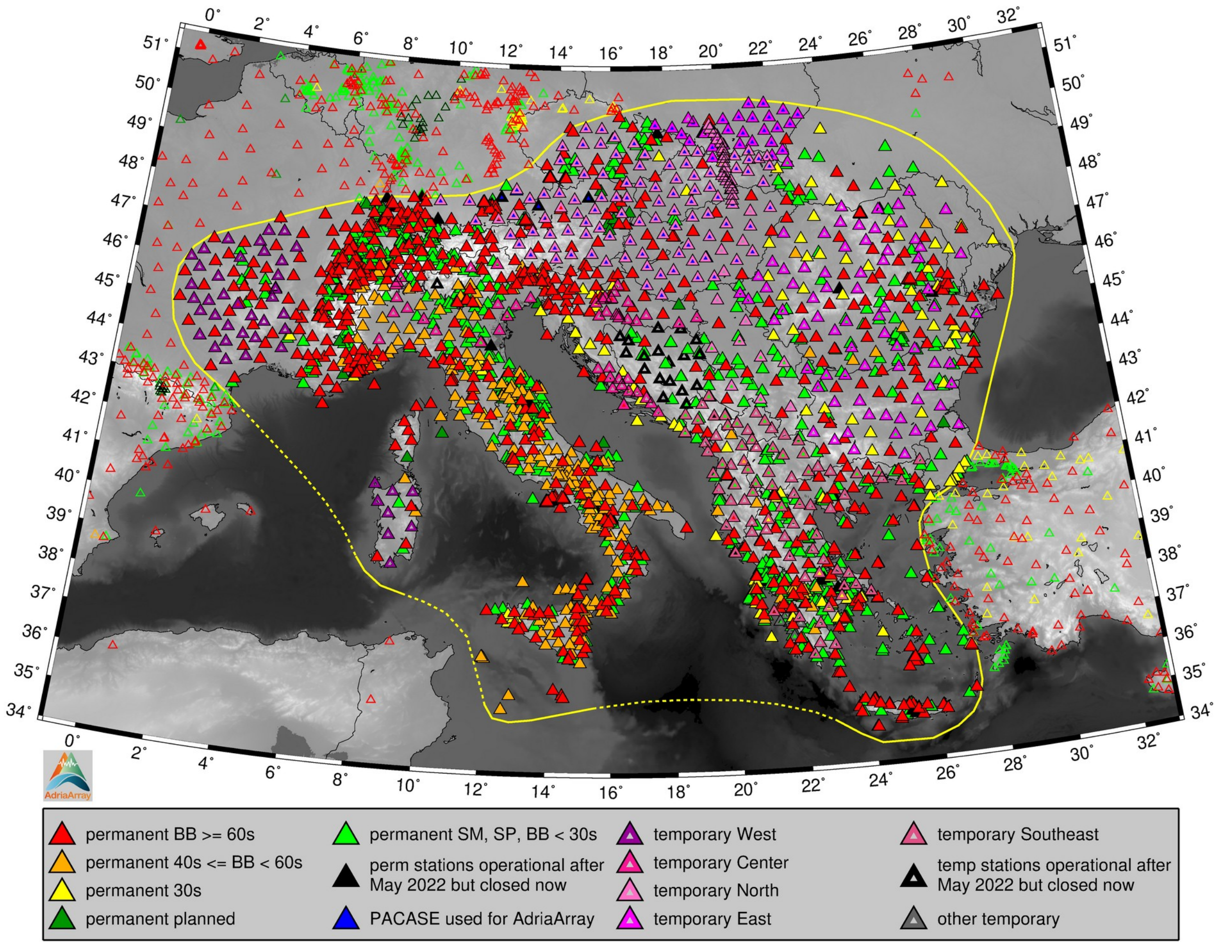

Figure A1. All permanent broadband, short-period and strong-motion stations are shown with filled triangles inside and empty triangles outside of the AdriaArray region. Red, orange and yellow color denote the corner period for broadband stations. Temporary stations are shown with hollow triangles, showing that sometimes these temporary stations were deployed at an already existing station location, usually short-period or strong-motion permanent site (green inside the temporary station triangle) or it keeps an existing PACASE site (blue inside). The AdriaArray footprint is delineated by the yellow line.

10. Appendix E - List of mobile pools

The mobile pools, institutions supporting the logistics, data transmission, field deployment and maintenance of the temporary stations are as follows:

Stations in France were provided by the SisMob pool of Epos-France and operated by the Institut des Sciences de la Terre, Université Grenoble Alpes and Observatoire Midi Pyrénées, Université de Toulouse (Aubert et al., 2025).

Stations in Sardinia are provided by the Geophysical Instrument Pool Potsdam (GIPP), Germany, the logistics is supported by the Institute for Geosciences, University of Kiel, Germany, and the deployment was accomplished by the Istituto Nazionale di Geofisica e Vulcanologia (INGV), Pisa, and by the Department of Sciences, Roma Tre University, Rome, Italy.

Stations in northern Italy are provided and operated by the INGV, Bologna, Italy. In the Po Plain, there are stations from the Faculty of Geo-Information Science and Earth Observation (ITC), University of Twente, Enschede, the Netherlands, deployed and operated jointly with the INGV Bologna, Italy.

Stations in north-eastern Italy were deployed and operated by the National Institute of Oceanography and Applied Geophysics -OGS, Trieste (Centre for Seismological Research), Italy (Pesaresi et al., 2025).

Stations in Germany, western Austria and western Hungary come from the DSEBRA pool (Deutsches Seismologisches Breitband Array) and are operated by the Institute for Geosciences, University of Kiel, Germany (Schlömer et al., 2025) and HUN-REN Institute of Earth Physics and Space Science, Hungary (Süle et al., 2025). Data transmission from these stations is financially supported by the Department of Earth Sciences, University of Cambridge, Great Britain.

Stations in the Czech Republic, eastern Slovakia, southern Romania and eastern Bulgaria are from the MOBNET pool of the Institute of Geophysics of the Czech Academy of Sciences, Prague, Czech Republic (Plomerová, 2025; Kampfová Exnerová et al., 2025; Vecsey et al., 2025). In Slovakia, their operation is supported by the Earth Science Institute of the Slovak Academy of Sciences, Bratislava. In Romania, the deployment and maintenance is supported by the National Institute for Earth Physics (NIEP), Magurele, and in Bulgaria by the National Institute of Geophysics, Geodesy and Geography, Bulgarian Academy of Sciences, Sofia, and by the Department of Meteorology and Geophysics, Faculty of Physics, Sofia University.

Stations in Poland are deployed and operated jointly by the Institute of Geophysics, Polish Academy of Sciences, Warsaw, by the Institute of Geophysics, University of Warsaw and by the Institute of Earth Sciences, University of Silesia, Katowice, Poland.

Stations in eastern Austria and western Slovakia are deployed and operated by the Department of Meteorology and Geophysics, University of Vienna, Austria, and the data transmission is secured with the support of GeoSphere Austria (formerly Zentralanstalt für Meteorologie und Geodynamik - ZAMG), Vienna. For the description of stations deployed in the Czech Republic, Poland, Slovakia and eastern part of Austria, see Vecsey et al. (2025).

The dense linear profile of stations (local experiment) transecting the Western Carpathians from Poland across Slovakia to Hungary is composed of stations from the Institute for Geosciences, Friedrich-Schiller-University Jena, Germany, and from the GIPP (Soni et al., 2025). The profile is operated jointly by the Friedrich-Schiller-University Jena, by the Institute of Geological Sciences, Polish Academy of Sciences, Warsaw, by the Department of Earth Sciences, Uppsala University, Sweden, by the Department of Geology and Paleontology, Comenius University in Bratislava, Slovakia and by the HUN-REN Institute of Earth Physics and Space Science, Hungary (Süle et al., 2025). The latter also operates backbone stations in eastern Hungary.

Sensors for the stations in Ukraine come from Géoazur, Université Côte d'Azur, France, and the digitizers are provided by the GIPP. Stations are deployed and operated by the Subbotin Institute of Geophysics of the National Academy of Sciences of Ukraine, Kyiv and Lviv, Ukraine. These stations were installed as permanent (Amashukeli et al., 2025).

Temporary stations in the northern part of Croatia are deployed and operated by the Croatian Seismological Survey, Zagreb (Fiket, 2025). Stations along the Adriatic coast in Croatia deployed in the framework of the CRONOS project (Stipčević et al., 2025), and forming the local experiment with denser station distribution than the backbone elsewhere, are from the Norwegian Broadband Pool (Department of Earth Science, University of Bergen; Norwegian Seismic Array (NORSAR), Kjeller; Department of Geosciences, Faculty of Mathematics and Natural Sciences, University of Oslo and Section for Geophysics, Geological Survey of Norway, Trondheim) and are operated jointly with the Andrija Mohorovičić Geophysical Institute, Department of Geophysics, Faculty of Science, University of Zagreb, Croatia.

Stations in Bosnia and Herzegovina are from the Federal Institute of Technology (ETH), Zurich, Switzerland, and are deployed and operated jointly with the Republic Hydrometeorological Service, Banja Luka, Republika Srpska and with the Hydrometeorological Institute of Federation of Bosnia and Herzegovina, Sarajevo (Obermann et al., 2025).

Stations in Serbia come from the GIPP and are deployed and operated by the Seismological Survey of Serbia, Belgrade with logistical support by the University of Kiel, Germany.

In western Romania, the temporary stations are provided by the Sodankylä Geophysical Observatory, University of Oulu, Finland, some of them equipped with digitizers from the University of Vienna, Austria. In northern Romania, the stations are provided by the Institute of Seismology, University of Helsinki, Finland, deployed and operated by NIEP. Four of the stations from Helsinki in the Vrancea region are operated by the Institute of Rock structure and Mechanics, Academy of Sciences of the Czech Republic, which in addition also operates another four stations provided by the GIPP in the same region. In southwestern Romania and western Bulgaria, there are four stations hired by the Department of Geoscience, Aarhus University, Denmark, from the Danish DanSeis pool, deployed jointly by the Institute of Geology, Faculty of Geosciences, Geoengineering and Mining, Technische Universität Bergakademie Freiberg, Germany, and by the Department of Earth Sciences, Uppsala University, Sweden. All stations in Romania are maintained with the help of NIEP (Borleanu et al., 2025). NIEP also provides stations for Moldova. All stations in Bulgaria are maintained with the help of the National Institute of Geophysics, Geodesy and Geography, Bulgarian Academy of Sciences, Sofia, and with the Department of Meteorology and Geophysics, Faculty of Physics, Sofia University, Bulgaria, see also above (Kampfová Exnerová et al., 2025).

Temporary stations in Montenegro, Kosovo and Albania are from the DSEBRA pool, operated by the Department of Earth and Environmental Sciences, Ludwig-Maximilians-Universität München (LMU), Germany, and deployed with support of the Sector of Seismology, Institute of Hydrometeorology and Seismology of Montenegro, Podgorica, of the Geological Survey of Kosovo, Pristina, and by the Department of Seismology, Institute of Geosciences, Polytechnic University of Tirana, Albania, respectively (Schlömer et al., 2025; Dushi et al., 2025). In Albania, additional stations are from the Geophysical Institute, Karlsruhe Institute of Technology (KIT), Germany, which also operated the ANTICS large-N array in Albania, again supported by the Polytechnic University of Tirana.

In North Macedonia and Greece, stations are from the DSEBRA pool operated by the Institute for Geology, Mineralogy and Geophysics, Ruhr University Bochum, Germany, with some equipment at four stations in North Macedonia provided by the Faculty of Geosciences and Geography, Goethe University Frankfurt, Germany. In North Macedonia, the operation is supported by the Seismological Observatory, Faculty of Natural Sciences and Mathematics, St. Cyril and Methodius University in Skopje, and in Greece by the Institute of Geodynamics, National Observatory of Athens, by the Seismological Laboratory of the National and Kapodistrian University of Athens, by the Geophysical Laboratory, Aristotle University of Thessaloniki, and by the Laboratory of Seismology, Department of Geology, University of Patras, Greece (Schlömer et al., 2025).

In Montenegro and Kosovo, some of the existing stations operated by the local network operators were incorporated to the AdriaArray Seismic Network as temporary ones, see the respective colors for the “Montenegro Pool” and “Kosovo Pool” in Fig. 5.

11. Appendix F – Details about inventories and maps of stations

In addition to the information given in the permanent and temporary station inventories, information on the station distribution is also provided in terms of various maps. They cover a range of complexity from very simple ones using only two colors to more complex figures explaining the station distribution in detail. Some of these maps are shown in this paper. However, the AdriaArray GitHub repository contains more versions of the maps. In Appendix G, we list seismic networks shown in the maps and listed in the inventories. The maps of AdriaArray stations are distilled from two tables (permanent and temporary, see the files [InventoryPermanent.ods] and [InventoryTemporary.ods] in the AdA/ folder on GitHub). There is a Python script, which runs on both the permanent-station and temporary-station sheets and groups the stations according to selected properties to text files, which are later plotted by the Generic Mapping Tools (GMT, Wessel et al., 2013) with another script. There are 18 maps (including one for GNSS stations) showing different station properties and their combinations in the AdA/MAPS/ folder. There is also a map showing the institutions, similarly as in Fig. 9 in this paper. The Python script also produces *.kml files for GoogleEarth. Details about the scripts and files are to be found in the accompanying document [maps-manual.pdf] at Github. Station colors used in the GMT maps are reflected in the *.kml files, and hence, besides the GMT, one can reproduce almost the same layout of maps in GoogleEarth. In addition, the folder AdA/PAPER/ includes all the maps from this paper.

Whenever there is an update of either any permanent or temporary station, we make the corresponding entry in the inventory sheets [InventoryPermanent.ods] and [InventoryTemporary.ods]. We run the Python script [extract.py] on these updated sheets and then also the GMT script [plotAdA.sh] which plots the maps. After that, the maps, as well as all other updated files, are pushed to GitHub. AdriaArray webpage links to the GitHub repository so that the maps on the AdriaArray webpage are always the most recent ones.

Beside the obvious purpose to share the information about the station distribution, their corner periods, about who operates them, if they send data to EIDA and so on, the reason to share the inventories, scripts and input files is to allow everybody to plot their own maps. By modification of the GMT script using the already prepared text files, different combinations of properties can be plotted into a new map. By modification of the Python script, files with different station properties can be produced and then plotted, both for GMT as well as for GoogleEarth. Often, the research will focus on a particular region which can again be easily reflected in modification of the GMT script. Provided files and scripts can be freely used for any purpose and adapted for your own tools to process and plot the information from the inventory sheets.

The two inventories of stations have almost the same structure to store the information about the permanent and temporary stations. The permanent sheet includes stations between 1° west and 33° east and between 34° - 51.5° north, i.e., way far around the AdriaArray region. There are two reasons for that: first, the outline of the experiment was not set beforehand, but emerged as a result of covering the region with available temporary stations and hence permanent stations were added or removed from the AdriaArray region when the outline moved (see the section about the AdriaArray Seismic Network planning). Second, using the AdriaArray stations for research does not exclude the usage of permanent stations outside of the AdriaArray region, so in some of the maps, all the permanent stations are shown and hence they need to be included in the repository. The purpose of the outline is to show the area, where the backbone coverage is homogeneous (as homogeneous as possible).

Even though the backbone consists of broadband stations, we list all stations including the strong-motion and short-period ones. First, those sites could have been potentially used for deployment (upgrade) of the broadband temporary stations. Second, for specific research, strong-motion and short-period stations can be used and hence they are shown in the maps too.

Note that there is a significant difference between the purposes of the two inventories: while the permanent inventory was made to gather the information about existing stations, the temporary inventory was used to plan the location of the temporary stations. Hence it has been updated frequently, discussed with the local and mobile pool operators, shared online with the field teams, and modified when stations were deployed.

Moreover, all the stations, both permanent as well as temporary, within the AdriaArray region, will share the data via the EIDA nodes and the metadata will be accessible for all these stations. Once this happens, these “manually-made” inventories will not be needed. However, at the moment, not only the temporary stations are not all in EIDA yet, but also several tens (~30) of the permanent stations do not share data via EIDA. There is a significant progress in that compared with the status four years ago, when the planning began and when more then 100 permanent broadband stations in the region were not archiving their data in EIDA.

There are two scripts generating the maps. The Python script [extract.py] needs “pandas” and “simplekml” to be installed. The script reads the two inventory sheets and splits them in many text files, saved into AdA/AUXI/, AdA/GOOG/, AdA/PERM/ and AdA/TEMP/ folders. The script has some little documentation inside. Based on the values in different columns of the inventory sheets, the script groups the stations by desired properties and saves their coordinates into text files to be later used by the GMT script, and also in *.kml files to be displayed by GoogleEarth.

The script [plotAdA.sh] uses GMT4 for plotting the maps. You might need to modify it for using it with more recent versions of GMT. The script also has some little comments inside. After adding all the layers to the postscript, *.pdf and *.png files are produced as well and pushed to GitHub too.

The folder AdA/GOOG/ contains several *.kml files, which corresponds to some of the text files for GMT. The colors used for displaying the triangles in GoogleEarth are the same as used for the respective maps in GMT.

The folder AdA/AUXI/ contains auxiliary input files. These are only used by the GMT script [plotAdA.sh]. They contain information about the previous experiments (AlpArray, PACASE, AlpArray Complementary Experiments), polygons outlining the experiments, and some other data used for plotting the maps (topography, borders, tectonics). These files need to be changed manually, and are expected not to be changed frequently. All details are given in the [maps-manual.pdf] document.

12. Appendix G - List of seismic networks

We list here the networks inside as well as outside of the AdriaArray region appearing in the map cut-offs throughout the paper or discussed in the text, as they are listed in FDSN: **1Y** - AdriaArray Temporary Network: Greece, North Macedonia (Friederich et al., 2022). **2Y** - AdriaArray Temporary Network: Italy - northeast (Pesaresi & Rossi, 2022). **4P** - AdriaArray Temporary Network: Italy - north, south. **5N** - StressTransfer (Mader & Ritter, 2018). **7B** - AdriaArray Temporary Network: Austria, Croatia, Slovakia. **8X** - Central Adriatic Seismic Experiment (CASE) (AlpArray Seismic Network, 2016). **9H** - CRONOS - Croatia/Norway Contribution to AdriaArray Temporary Network. **9O** - DIVEnet (Pondrelli & Hetényi, 2021). **AC** - Albanian Seismological Network (Institute of GeoSciences, Polytechnic University of Tirana, 2002). **BE** - Belgian Seismic Network (Royal Observatory of Belgium, 1985). **BN** - UK-Net, Blacknest Array (Blacknest, 1960). **BQ** - Bensberg Earthquake Network (Department of Geosciences, Bensberg Observatory, University of Cologne, 2016). **BS** - National Seismic Network of Bulgaria (National Institute of Geophysics, Geodesy and Geography - BAS, 1980). **BW** - BayernNetz (Department of Earth and Environmental Sciences, Geophysical Observatory, University of Munchen, 2001). **C4** - CERN Seismic Network (CERN, 2016). **CA** - Catalan Seismic Network (Institut Cartogràfic i Geològic de Catalunya, 1984). **CH** - National Seismic Networks of Switzerland (Swiss Seismological Service (SED) at ETH Zurich, 1983). **CL** - Corinth Rift Laboratory Seismological Network (Corinth Rift Laboratory Team And RESIF Datacenter, 2013). **CQ** - Cyprus Broadband Seismological Network (Geological Survey Department Cyprus, 2013). **CR** - Croatian Seismograph Network (University of Zagreb, 2001). **CZ** - Czech Regional Seismic Network (Charles University in Prague, Institute of Geonics, Institute of Geophysics, Academy of Sciences of the Czech Republic, Institute of Physics of the Earth Masaryk University & Institute of Rock Structure and Mechanics, 1973). **DZ** - REALSAS Research Center of Astronomy, Astrophysics & Geophysics (CRAAG), Algeria. **EB** - Ebre Observatory Regional Seismic Network (Observatori de l'Ebre, Tarragona, 2009). **EG** - EUROSEISTEST Strong Motion Network (Aristotle University of Thessaloniki, 1993). **ES** - Spanish Digital Seismic Network (Instituto Geografico Nacional, Spain, 1999). **FO** - French Associated Seismological Network. **FR** - Epos-France RESIF-RLBP French Broad-band network, RESIF-RAP strong motion network and other seismic stations in metropolitan France (RESIF, 1995). **G** - GEOSCOPE, French Global Network of broad band seismic stations (Institut de physique du globe de Paris (IPGP), & École et Observatoire des Sciences de la Terre de Strasbourg (EOST), 1982). **GB** - Great Britain Seismograph Network (British Geological Survey, 1970). **GE** - GEOFON Seismic Network (GEOFON Data Centre, 1993). **GQ** - German Strong Earthquake Network, Federal Institute for Geosciences and Natural Resources (BGR), Germany. **GR** - German Regional Seismic Network (GRSN) (Federal Institute for Geosciences and Natural Resources, 1976). **GU** - Regional Seismic Network of North Western Italy (University of Genoa, 1967). **GX** - GFZ Affiliated Stations, Deutsches GeoForschungsZentrum GFZ (GFZ Potsdam), Germany. **HA** - Hellenic Seismological Network (University of Athens, 2008). **HC** - Seismological Network of Crete (Technological Educational Institute of Crete, 2006). **HI** - ITSAK Strong Motion Network ((ITSAK) Institute of Engineering Seismology Earthquake Engineering, 1981). **HL** - National Observatory of Athens Seismic Network (National Observatory of Athens, Institute of Geodynamics, Athens, 1975). **HP** - University of Patras, Seismological Laboratory (University of Patras, 2000). **HS** - Hessischer Erdbebendienst (Hessian Agency for Nature Conservation, Environment and Geology, (2012). **HT** - Aristotle University of Thessaloniki Seismological Network (Aristotle University of Thessaloniki, 1981). **HU** - Hungarian National Seismological Network (Kövesligethy Radó Seismological Observatory (Geodetic And Geophysical Institute, Research Centre For Astronomy And Earth Sciences, Hungarian Academy Of Sciences (MTA CSFK GGI KRSZO), 1992). **IB** - IberArray (Institute Earth Sciences "Jaume Almera" CSIC (ICTJA) Spain, 2007). **IU** - Global Seismograph Network (GSN - IRIS/USGS) (Albuquerque Seismological Laboratory/USGS, 2014). **IV** - Rete Sismica Nazionale (RSN) (Istituto Nazionale di Geofisica e Vulcanologia (INGV), 2005). **IX** - Irpinia Seismic Network (ISNet). **IY** - Rete Sismica Unical (Universita Della Calabria, Italy, 1981). **KO** - Kandilli Observatory And Earthquake Research Institute (KOERI) (Kandilli Observatory And Earthquake Research Institute, Boğaziçi University, 1971). **LC** - LSC (Laboratorio Subterraneo Canfranc) (Laboratorio Subterraneo de Canfranc, 2011). **LE** - Erdbebendienst Südwest (Erdbebendienst Südwest Baden-Württemberg and Rheinland-Pfalz, 2009). **M1** - MOravia NETwork (MONET) (Institute Of Physics Of The Earth Masaryk University Brno (IPE), 2017). **MD** - Moldova Digital Seismic Network (Geological and Seismological Institute of Moldova, 2007). **ME** - Montenegrin Seismic Network (Sector for Seismology, Institute of Hydrometeorology and Seismology of Montenegro, 1982). **MK** - Seismological network of the Republic of North Macedonia (Seismological Observatory at the Faculty of Natural Sciences and Mathematics, Ss. Cyril and Methodius University, Skopje, Republic of Macedonia, 1966). **ML** - Malta Seismic Network (University of Malta, 2014; Agius et al., 2025). **MN** - Mediterranean Very Broadband Seismographic Network (MedNet) (MedNet Project Partner Institutions, 1990). **MT** - Observatoire Multi-disciplinaire des Instabilités de Versants (OMIV) (French Landslide Observatory – Seismological Datacenter / RESIF, 2006). **NI** - North-East Italy Broadband Network (Istituto Nazionale di Oceanografia e di Geofisica Sperimentale - OGS and University of Trieste, 2002). **NL** - Netherlands Seismic and Acoustic Network (Royal Netherlands Meteorological Institute (KNMI), 1993; Akinremi et al., 2025). **NR** - NARS (Utrecht University (UU Netherlands), 1983). **OE** - Austrian Seismic Network (ZAMG - Zentralanstalt für Meteorologie und Geodynamik, 1987). **OT** - OTRIONS (University of Bari "Aldo Moro", 2013). **OX** - North-East Italy Seismic Network (Istituto Nazionale di Oceanografia e di Geofisica Sperimentale - OGS, 2016). **PL** - Polish Seismological Network, Polish Academy of Sciences (PAS), Poland. **RA** - RESIF-RAP French Accelerometric Network (RESIF, 1995). **RD** - CEA/DASE broad-band permanent network in metropolitan France (RESIF, 2018). **RF** - Friuli Venezia Giulia Accelerometric Network (University of Trieste, 1993). **RN** - RuhrNet - Seismic Network of the Ruhr-University Bochum (Ruhr University Bochum, 2007). **RO** - Romanian Seismic Network (National Institute for Earth Physics (NIEP Romania), 1994). **SI** - Province Südtirol, ZAMG - Central Institute for Meteorology and Geodynamics, Austria. **SJ** - Serbian Seismological Network (Seismological Survey of Serbia, 1906). **SK** - National Network of Seismic Stations of Slovakia (ESI SAS; Former GPI SAS (Geophysical Institute Of The Slovak Academy Of Sciences), 2004). **SL** -Seismic Network of the Republic of Slovenia (Slovenian Environment Agency, 1990). **ST** - Trentino Seismic Network (Geological Survey-Provincia Autonoma di Trento, 1981). **SX** - SXNET Saxon Seismic Network (University of Leipzig, 2001). **TH** - Thüringer Seismologisches Netz (Institut für Geowissenschaften, Friedrich-Schiller-Universität Jena, 2009). **TT** - Seismic Network of Tunisia, Institut National de la Météorologie, Tunis, Tunisia. **TU** - Turkish National Seismic Network (Disaster and Emergency Management Authority, 1990). **TV** - INGV experiments network, Istituto Nazionale di Geofisica e Vulcanologia (INGV), Italy. **UD** - Seismic Network Main Center of Special Monitoring (Main Center of Special Monitoring, 2010). **UT** - Ukrainian National Seismic Network (Subbotin Institute, 2023). **VD** - High Agri Valley geophysical Observatory (CNR IMAA Consiglio Nazionale delle Ricerche (Italy), 2019). **VM** - Seismic Data acquired by Marche Seismic Network (MSN) (Istituto Nazionale di Geofisica e Vulcanologia (INGV), 2023). **VR** - Virgo Interferometric Antenna for Gravitational Waves Detection (European Gravitational Observatory, 2019). **WB** - West Bohemia Local Seismic Network (Institute of Geophysics, Academy of Sciences of the Czech Republic, 1991). **WM** - The Western Mediterranean BB seismic Network (San Fernando Royal Naval Observatory (ROA), Universidad Complutense De Madrid (UCM), Helmholtz-Zentrum Potsdam Deutsches GeoForschungsZentrum (GFZ), Universidade De Évora (UEVORA, Portugal), & Institute Scientifique Of Rabat (ISRABAT, Morocco), 1996). **WS** - Seismic Network of Republika Srpska (Republicki Hidrometeorološki Zavod, Serbia). **X3** - AlbaNian TectonIcs of Continental Subduction (ANTICS). **X7** - PYROPE PYRenean Observational Portable Experiment (RESIF-SISMOB) (Chevrot, Sylvander & RESIF, 2017). **XK** - Ivrea - AlpArray Complementary Experiment. **XP** - MACIV-BB temporary experiment to carry out a seismic tomography of the crustal and mantle structures of the Massif Central, France (RESIF-SISMOB) (Paul et al., 2023). **XT_2014** - Eastern Alpine Seismic Investigation (EASI) - AlpArray Complementary Experiment (AlpArray Seismic Network, AlpArray Working Group, 2014). **XT_2018** - Seismic network XT: CIFALPS-2 temporary experiment (China-Italy-France Alps seismic transect #2 (Zhao et al., 2018). **Y5** - Swiss Contribution to AdriaArray Temporary Network (Obermann et al., 2022). **Y8** - AdriaArray Temporary Network: Bulgaria, Moldova, Poland, Romania, Ukraine (Neagoe, 2022). **YP** - Seismic network YP: CIFALPS temporary experiment (China-Italy-France Alps seismic transect) (Zhao et al., 2016b). **Z3** - AlpArray Seismic Network (AASN) temporary component (AlpArray Seismic Network, AlpArray Working Group, 2015). **Z6** - AdriaArray Temporary Network: Albania, Austria, Czech Rep., Germany, Hungary, Kosovo, Montenegro, Slovakia (Schlömer et al., 2022). **ZJ** - Pannonian-Carpathian-Alpine Seismic Experiment (Hetényi et al., 2019). **ZS** - The Swath-D Seismic Network in Italy and Austria (Heit et al., 2017).

13. Appendix H – Sources of information and technical description

13.1 AdriaArray webpage

The AdriaArray webpage on https://orfeus.readthedocs.io/en/latest/adria_array_main.html is the main source of up-to-date information. It is hosted by ORFEUS and maintained with the support of the ORFEUS staff. The webpage gives an overview of the initiative, lists the members, the participants (who agreed to have their names displayed there), the names of contact persons of Working Groups and Collaborative Research Groups, gives advice on how to obtain the token to access the seismic data and how to download the data. It also mirrors the maps of the AdriaArray Seismic Network stored in the AdriaArray GitHub repository. Whenever the maps are updated on GitHub, the webpage will display the updated version. The webpage also provides links to various documents describing the technical details of the network and station inventories. It also contains the description of the Collaborative Research Groups with updated information about the progress of their tasks. There is also a section with links to posters and oral presentations given at the AdriaArray workshops over the last four years.

13.2 AdriaArray GitHub repository

The AdriaArray GitHub repository on https://github.com/PetrColinSky/AdriaArray serves as a place for updated technical documents about the AdriaArray Seismic Network. It contains several folders:

1) The AdA/ folder includes permanent and temporary station inventories as well as the following documents
    - The document entitled "AdriaArray - seismic network, temporary stations and legend to the maps" [maps-legend.pdf] explains how the AdriaArray network was planned and the maps stored in the AdA/MAPS/ folder.
    - The document entitled "AdriaArray - explanation to the scripts and files for plotting the maps of stations" [maps-manual.pdf] talks about the scripts and how to produce the maps from the station inventories. This might be useful if you want to modify the scripts to create your own maps. Extracts from this text are given below in this paper. If you are interested in the maps provided in this paper, go to AdA/PAPER/. Additional maps are in AdA/MAPS/. If you want to display station distributions in GoogleEarth, go to AdA/GOOG/ to get the *.kml files.
    - The document entitled "Technical documentation - stations names and network codes" [TechDocNames.pdf] summarizes the guidelines for the station naming, which is also given in Section 3.4 below.
2) The folder presentations/ contains slides and posters on the AdriaArray Seismic Network presented in 2019 - 2024.
3) The folder logo/ contains various versions of the AdriaArray logo, see Fig. A2.

Figure A2. Various versions of the AdriaArray logo. The logo is available for download on the AdriaArray GitHub page.

13.3 Station names and network codes

For new AdriaArray temporary stations installed from 2022 onwards, we adopted the PACASE naming convention (the experiment directly preceding AdriaArray, Schlömer et al., 2024, see above). The station names should read country + number + version (A/B/..). "A" stands for the first location of the station. If the station is moved later, "A" changes to "B". Example: BHxyA is the first location of station "xy" in Bosnia and Herzegovina. These station names have 5 characters. In Greece, the "A" has been omitted and station names have only 4 characters. In case of relocating stations in Greece, the "B" is added (GR19 changed to GR19B). The country codes are a mixture of IBAN country codes, country internet domains, and international license plate abbreviations reduced to 2 characters.

For temporary stations installed before 2022, we retain their original names. For example, if the station is located at a PACASE site, the PACASE name is adopted. For former AlpArray stations, the original AlpArray name is used, starting with "A", followed by a three-digit number terminated with "A" for the first location of the station, changed subsequently to B/C/ and so on.

In a few cases, a new name has been given to a temporary station located at a site of a former permanent or temporary station. Both names are then included in the inventories and are also shown on the maps in the AdriaArray GitHub repository (see the links in Appendix C). For example, in the Po Plain, stations are at the same or very similar locations as the former AlpArray sites, however, they are using the new AdriaArray convention names as ITxyA. On the other hand, stations in north-eastern Italy keep the former AlpArray names, even though these stations were discontinued in 2019 and were newly built in 2023 with different instrumentation.

If broadband stations were installed at sites of permanent short-period or strong-motion stations, the name of the permanent station was generally retained. This recommendation was followed in Albania, Bulgaria, Greece, Kosovo, Montenegro, North Macedonia, Romania, Serbia and Ukraine. In Bosnia and Herzegovina, temporary stations deployed at the permanent sites got new AdriaArray names as the permanent stations were not operational and retaining their name was hence not needed.

New temporary stations got new temporary network codes. Temporary stations inherited from PACASE and AlpArray changed their network codes from Z3 and ZJ to the new AdriaArray network codes. All networks are registered at the International Federation of Digital Seismograph Networks (FDSN).

There are two options for using the permanent or temporary network codes for the stations where the temporary broadband installation is at a permanent short-period or strong-motion site. Option 1: For the temporary installation, the same FDSN network code is used as is the one of the permanent station, and the streams differ only by channel name. As a consequence, all channels from this station are fully open without restrictions as the permanent network cannot be embargoed. Option 2: A new FDSN network code as for other temporary stations in the given region is used for the temporary equipment at the permanent site. In this case, the temporary streams could have an embargo. Details about the stations names and network and location codes are given in the document entitled “Technical documentation - stations names and network codes” on the AdriaArray GitHub repository, see Appendix C for the links.

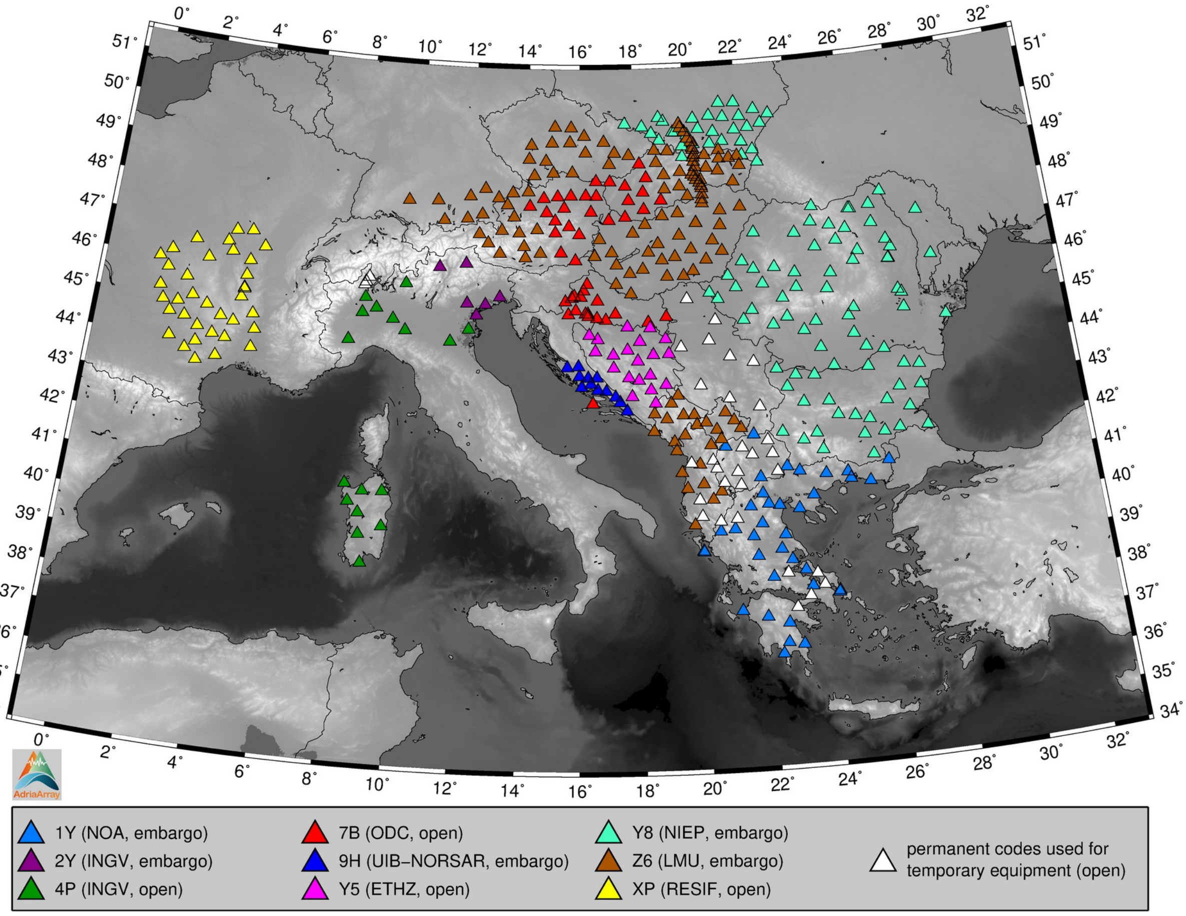

Figure A3. AdriaArray temporary stations use 9 network codes color-coded in the map. The legend explains to which EIDA node the particular network is connected. In addition, some temporary equipment uses a permanent network code when deployed at an existing permanent site – this is then considered as an upgrade of the permanent strong-motion, short-period or broadband station with shorter corner period.

13.4 Archiving data in EIDA

Archiving the AdriaArray data in EIDA and the support of ORFEUS is crucial for the initiative since the very beginning in 2019. It allowed us to connect hundreds of new broadband stations to EIDA. Data from the temporary stations are stored at 9 nodes of the EIDA federated infrastructure, see the filled magenta squares in Fig. 9 for the geographical locations and the legend in Fig. A3 for the node names. Namely, these are: The ORFEUS Data Center (ODC), hosted by the Royal Netherlands Meteorological Institute (KNMI); the Helmholtz

Centre for Geosciences (GFZ); Epos-France (formerly RESIF); Istituto Nazionale di Geofisica e Vulcanologia (INGV), Italy; Schweizerischer Erdbebendienst (SED) at ETH Zurich; National Institute for Earth Physics (NIEP), Romania; Ludwig-Maximilians-Universität München (LMU), Germany; National Observatory of Athens (NOA), Greece, and Universitetet i Bergen (UiB), Norway. Three further EIDA nodes only store data from permanent stations in AdriaArray: Bundesanstalt für Geowissenschaften und Rohstoffe (BGR), Germany; Kandilli Observatory and Earthquake Research Institute (KOERI), Türkiye, and Institut Cartogràfic i Geològic de Catalunya (ICGC), Spain.

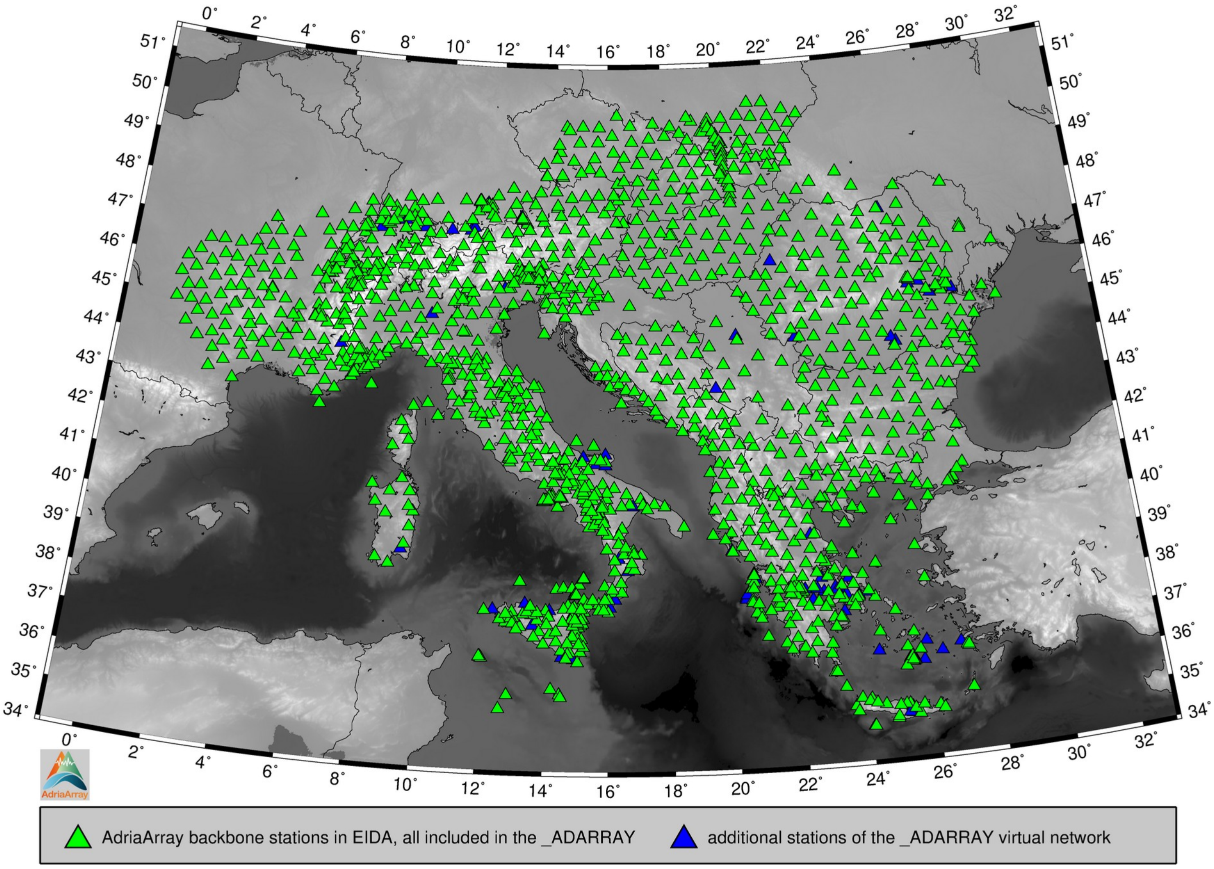

Figure A4. The AdriaArray backbone is shown by green triangles. All those stations are included in the AdriaArray virtual network _ADARRAY and have corner periods of at least 30 s. Blue triangles show stations with corner periods between 10 s and less than 30 s, which are included in the _ADARRAY in addition to the backbone stations. Only EIDA-registered stations can be included in the _ADARRAY

Most of the temporary stations have streamed data in real-time to the EIDA nodes since their installation. In 2024, all temporary stations were online and almost all were transmitting data to EIDA. Some stations stream the data directly via SeedLink to the local monitoring centers and EIDA, some stream the data first to the mobile pool operator's center (also by other proprietary formats, not necessarily SeedLink) and subsequently to the local monitoring center and also then to EIDA. The online streaming was not a requirement for incorporating the stations to the AdriaArray Seismic Network, but it emerged naturally as the mobile pool operators upgraded their equipment for online data transmission to ease data access and to have better control on the state of health of the stations. Data from the previously offline stations is being backfilled to EIDA. As most of the stations are online, they are not only providing data to EIDA for archiving, but real-time streams are also included in the local operators' daily monitoring of seismic activity.

As a rule, each temporary network with a specific network code streams data to one EIDA node only. Several networks may, however, stream data to one node (e.g., INGV). Each network has all its stations either open, or embargoed (see below the explanation of the embargo). Hence, each network code already uniquely shows in which EIDA node the data from all the stations of this network are stored, and if all these stations are open or embargoed. An overview of the 9 temporary network codes is given in Fig. A3.

EIDA not only stores the data, but also provides support to both local permanent network operators as well as mobile pool operators about the technical solutions to connect the stations, stream the data and maintain and update the metadata. Many ideas about the temporary networks, station names, embargo and open data policies were developed directly with the fundamental support of EIDA personnel.

EIDA is also present at the ORFEUS Forum (see the links in Appendix C), where messages about the maintenance and temporal unavailability of particular nodes are posted. There is also an EIDA Issue Tracker on GitHub (link in Appendix C), where the users can report data problems.

13.5 AdriaArray virtual network _ADARRAY

Broadband stations covering the AdriaArray region outlined in the maps form the AdriaArray backbone. The shortest corner period of the backbone is 30 s (see above). To ease the access to AdriaArray data, the virtual _ADARRAY network was created by EIDA. The data of the whole AdriaArray Seismic Network can be downloaded using one command referring to the virtual network. All broadband stations in the region with HH* and BH* channels are included in _ADARRAY. According to the SEED convention (FDSN et al., 2012), H** and B** channels are assigned for sensors with corner period equal or longer than 10 s. _ADARRAY virtual network hence includes more stations than the AdriaArray backbone. The backbone is a subset of _ADARRAY. The relation of the backbone and the virtual network is shown in Fig. A4. All the green triangles, representing the AdriaArray backbone, are included in the virtual _ADARRAY network. Blue triangles show additional stations with corner periods from 10 to 30 s included in _ADARRAY.

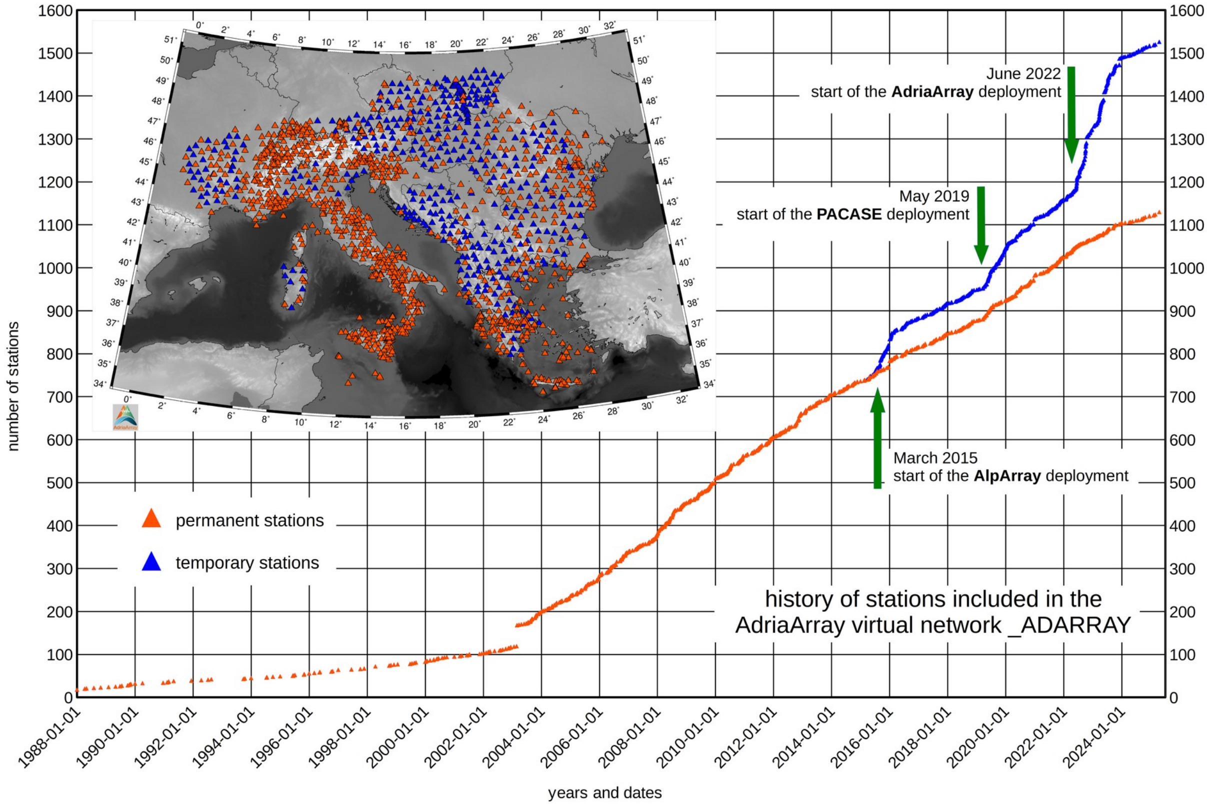

Figure A5. Virtual _ADARRAY in time and space. Starting dates of stations included in the virtual _ADARRAY network are used to plot a cumulative number of operating stations over 37 years, since the beginning of 1988 till the end of 2024. Orange are permanent and blue are temporary stations added on top of the permanent. The two curves split in the moment when the AlpArray deployment started in March 2015. Then, the difference between the curves increases again in May 2019 when the PACASE deployment began. Since June 2022, the AdriaArray delivered additional 293 temporary stations. Together with the temporary stations continued from PACASE, AdriaArray Seismic Network includes 428 temporary stations currently, out of which 397 are in EIDA and hence included in the _ADARRAY – see the difference between the two curves at the right end of the plot. The inserted map shows the distribution of permanent and temporary stations in the AdriaArray region.

14. Appendix J – History of the _ADARRAY stations

Figure A5 shows the cumulative number of operating station of the _ADARRAY virtual network as a function of time. We see several clear trends in the plot. The number of permanent stations was linearly increasing with time before and after 2003 with a strikingly distinct rate. The jump in 2003 is due to the same starting date of 50 stations of the Italian National Seismic Network (IV). The first temporary stations belonging to AdriaArray now were deployed in the framework of AlpArray in March 2015 (blue dots). Of the total 276 temporary AlpArray stations, 73 stations were included in PACASE and then in AdriaArray - see the constant difference between the two curves in 2016 - 2019. In May 2019, the PACASE deployment started, providing additional 62 stations. AdriaArray inherited in total 135 stations from these two previous experiments. Since the start of AdriaArray in May 2022, 292 additional temporary stations have been installed to reach 427 temporary AdriaArray stations operating anytime after May 2022, of which 399 are in EIDA and are thus included in _ADARRAY. In addition, 5 permanent stations were installed in Ukraine.

Assembling this plot required quite complex analysis of the history of each station. It is important to note that _ADARRAY only includes stations, which were operational during the AdriaArray epoch, i.e., anytime after 19. May 2022. Stations closed before this date are not included in the plot. Hence, the plot does not show the total number of stations operational at a given date, but shows only a number of those stations, which remained operational until and during the AdriaArray epoch. We used the startDate of the <Station> element from the metadata to create the plot. However, there are several cases, when we manually reconsidered this startDate. Stations using two network codes simultaneously (and hence included two times in the _ADARRAY) are taken into account only once for the plot using the older startDate in case the two dates differ. Stations which have used more station codes in the past are given with the oldest startDate. This applies to both temporary as well as to permanent stations. For example, stations which continued to AdriaArray from PACASE are given with the startDate of the PACASE deployment, and those, which merged to PACASE from AlpArray and then merged to AdriaArray from PACASE are given with the original AlpArray startDate, regardless of their network codes. Similarly, for example stations of the permanent NI network, which were merged to the OX network are given with their original NI startDate.

There are temporary AdriaArray stations built at the same sites, which were used previously for AlpArray, either keeping the original AlpArray station name, or being given a new one. For these stations, the startDate of the AdriaArray deployment is shown as these stations were discontinued and hence are considered as newly built for AdriaArray. Permanent stations, which were upgraded with broadband instruments for AdriaArray are shown as temporary (blue triangles in Fig. A5) with the startDate of the upgrade. Temporary stations, which were moved to the “B” site during the AdriaArray epoch are shown with the older “A” site startDate, regardless of the fact that the “A” site was deployed during the AdriaArray epoch or during any older experiment of AlpArray or PACASE. Stations, which were moved to the “B” site during previous experiments AlpArray and PACASE are given with their “B” startDate, as the original “A” site is not included in the _ADARRAY. Stations, which were originally built as temporary and later became permanent, are included in the permanent set (orange triangles), with the original startDate of the temporary deployment. The latter case is difficult to track, as both the network code and the station name changed and hence the fact that it is the same station is not easily recognizable. Although the _ADARRAY includes only broadband stations, some of the permanent stations could be equipped with a short-period instrument for some epochs in the past. These changes of instrumentation are not reflected in the plot.

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The AdriaArray logo was designed by Claudia Piromallo and Hana Kampfová Exnerová. Maps were plotted using Generic Mapping Tools (GMT), Wessel et al. (2013). The Python Toolbox ObsPy by Beyreuther et al. (2010) and Megies et al. (2011) was used for data and metadata downloading and pre-processing. Earthquake parameters were taken from EMSC/CSEM, https://www.emsc-csem.org and from the U.S. Geological Survey Earthquake Lists, Maps, and Statistics, https://www.usgs.gov/natural-hazards/earthquake-hazards/lists-maps-and-statistics. The altitude and bathymetry data were plotted using the ETOPO1 Global Relief Model provided by the NOAA Physical Sciences Laboratory, Boulder, Colorado, USA, from their website at https://www.ngdc.noaa.gov/mgg/global/relief/ETOPO1/data/bedrock/grid_registered/netcdf/, see also NOAA (2009) and Amante and Eakins (2009). Color scales for topography and seismic hazard maps were modified for this paper using the scales included in the GMT package. The arrival times of body wave phases for Fig. 8 were calculated using the TauP package embedded in the ObsPy toolbox, based on the original tool by Crotwell et al. (1999), with the iasp91 model by Kennett and Engdahl (1991). We are grateful to all researchers, scientists, experts and engineers contributing to the development of the 2020 European Seismic Hazard Model (ESHM20) shown in Fig. 2. All products of the ESHM20 are licensed under the Creative Commons Attribution 4.0 International License (CC BY): https://creativecommons.org/licenses/by/4.0/. We did not make any changes to the ESHM20 model and only replotted the PGA map using the same color scale as in Danciu et al. (2021).

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***CORRESPONDING AUTHOR: Petr Kolínský**

Institute of Geophysics of the Czech Academy of Sciences, Prague, Czech Republic

e-mail: petr.kolinsky@ig.cas.cz