[E] Oral | S (Solid Earth Sciences) | S-SS Seismology

[S-SS05] Advancements in Regional Seismic Networks: Operations, Applications, and Development

convener:Seiji Tsuboi(JAMSTEC, Center for Earth Information Science and Technology), Wen-Tzong Liang(Institute of Earth Sciences, Academia Sinica), Nozomu Takeuchi(Earthquake Research Institute, University of Tokyo), Takehi Isse(Earthquake Research Institute University of Tokyo), Chairperson:Seiji Tsuboi(JAMSTEC, Center for Earth Information Science and Technology), Takehi Isse(Earthquake Research Institute University of Tokyo)

Thu. May 29, 2025 10:45 AM - 12:15 PM Convention Hall (CH-A) (International Conference Hall, Makuhari Messe)

Regional seismic networks play a crucial role in monitoring regional earthquake activities and studying the Earth's interior. They also provide valuable data for analyzing environmental changes such as geohazard processes, groundwater variations, and nuclear tests. Therefore, it is essential to consistently support the reliable operation and maintenance of these networks. However, the deployment of large-scale arrays poses challenges for data centers responsible for data archiving and sharing. To enhance the capabilities of regional seismic networks, various innovative technologies and standards have been proposed to address these challenges and operate the next generation seismic network.

This session invites submissions related to the operation and application of regional seismic networks, as well as emerging technologies that can enhance their capacity. It provides an excellent opportunity for experts in this field to exchange experiences and discuss future visions for the operation, application, and development of regional seismic networks.

[SSS05-07] **Seismic networks and monitoring at CWA in Taiwan**

*Nai-Chi Hsiao[1], Da-Yi Chen[1], Chih-Wen Kan[1], Chun-Wei Ho[1], Guan-Yi Song[1], Yu-Hsuan Chang[1], Kuei-Chih Liu[1] (1.Central Weather Administration, Taiwan)

10:45 AM - 11:00 AM

[SSS05-08] FDSN Standards for Data and Services: a success story and a vision for the Next Generation Data Services

*Javier Quinteros[1], Chad Trabant[2] (1.GFZ Helmholtz Centre for Geosciences, Germany, 2.EarthScope Consortium)

11:00 AM - 11:15 AM

[SSS05-09] Lithospheric Structure and Deformation in Southern Taiwan from SALUTE Seismic Observations

*Shu-Huei Hung[1], Shih-Chi Shao[1], Ramakrushna Reddy[1], Tai-Lin Tseng[1], Pei-Ying Patty Lin[2], Eh Tan[3], Ying-Nien Chen[4] (1.Department of Geosciences, National Taiwan University, 2.Department of Earth Sciences, National Taiwan Normal University, 3.Institute of Earth Sciences, Academia Sinica, 4.Department of Earth and Environmental Sciences, National Chung Cheng University)

11:15 AM - 11:30 AM

[SSS05-10] Development and Maintenance of the Distributed Acoustic Sensing (DAS) Network

*Chin-Shang Ku[1], Kuo-Fong Ma[1] (1.Institute of Earth Sciences, Academia Sinica, Taiwan)

11:30 AM - 11:45 AM

[SSS05-11] **15 years of the GLISN seismic network in Greenland (1): Observations**

*Genti Toyokuni[1], Dapeng Zhao[1], Masaki Kanao[2], Seiji Tsuboi[3], Hiroshi Takenaka[4]
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11:45 AM - 12:00 PM

[SSS05-12] Orchestrating Structural Safety with QSIS: Vision for Extensible Building Arrays

*Gauss Te-Chuan Chang[1,2], Wen-Tzong Liang[3], Utpal Kumar[4], Kuo-Fong Ma[3], Li-Wei Chen[5]
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12:00 PM - 12:15 PM

Seismic networks and monitoring at CWA in Taiwan

*Nai-Chi Hsiao[1], Da-Yi Chen[1], Chih-Wen Kan[1], Chun-Wei Ho[1], Guan-Yi Song[1], Yu-Hsuan Chang[1], Kuei-Chih Liu[1]

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The Central Weather Administration (CWA), regulated from the original Central Weather Bureau (CWB) due to organizational transformation, is the government agency responsible for earthquake monitoring and reporting in Taiwan. In the years of early 1990s, the CWA has begun to implement modern seismic networks and operations for earthquake monitoring. At that time hundreds of seismic stations were built. While 1999 Magnitude 7.6 Chichi earthquake struck Taiwan, the quake information was automatically determined and send to dedicated users by Email and pager in 102 second after occurrence. The information was very important for emergent response, and the performance of rapid reporting was a milestone of earthquake monitoring in the world. At present, two major seismic networks including the Central Weather Administration Seismographic Network (CWASN) and the Taiwan Strong Motion Instrumentation Program network (TSMIP) are in operation. The main purpose of the CWASN is to observe seismicity around Taiwan region and collect seismic waveforms for seismic related studies and applications. There are three types of seismographs installed in field stations, including short period seismographs, accelerographs, and broadband seismographs, which are co-site or individual installed. The resolution of sensors is 24-bit and the sampling rate is 100 Hz. At present, totally about 200 stations are constructed and distributed with 20 km averaged spacing, including 90 downhole and few ocean bottom seismic stations. Through the daily acquisitions and operations since 1991, we now have a complete earthquake catalogue composed of more than 750,000 events. The valuable data are not only utilized to understand the seismic activities, the seismo-tectonic around Taiwan region were detailed researched as well. The TSMIP network is a dense network with strong-motion stations installed over the whole island, particularly on the urban areas. The numerous strong-motion data collected from 1991 provide us very important sources to understand the shaking characteristics during strong earthquake. Currently, there are more than 700 free-field stations. Following the progress on instrumentation, the resolution of sensors is gradually upgraded to 24 bits. Till now, more than 200,000 strong-motion records above 26,000 strong events are collected, and these data were widely applied for the research of strong-motion seismology and earthquake engineering. The CWASN and TSMIP have been also used as the framework developing systems and operations of felt earthquake rapid reporting in Taiwan. While a significant earthquake occurred in or very near Taiwan, the earthquake early warning (EEW) system can acquire the information and issue the warning message less than 10 seconds averagely. Then, the general public could be notified through the message from Internet applications, Cell Broadcast (CB) on mobile device, TV, and so forth. About 5 minutes later, an official report is generated by earthquake report releasing system. Quick confirmed earthquake report is crucial for the emergent responses of society, and meanwhile, reduce the social panic effectively. Besides, more detailed and observed seismic intensities around strong shaking areas could be quickly provided by the township intensity reporting system. Consequently, the reporting capability of felt earthquake information for seismic hazard mitigation is effectively strengthened.

Keywords: CWASN, TSMIP, earthquake catalogue, strong-motion record, felt earthquake rapid reporting

FDSN Standards for Data and Services: a success story and a vision for the Next Generation Data Services

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For more than 30 years seismological data centers have worked together within the International Federation of Digital Seismograph Networks (FDSN; www.fdsn.org) in order to define and adopt standards to support seamless access to data and metadata by the global seismological research, monitoring and education communities. These include standards for waveform data (miniSEED) and metadata (StationXML), to detailed specifications for many web services supporting different types of products and information to support data discovery, distribution, quality control and more. As a result of these standards, users have been able to find and access data from FDSN data centers across the world in a consistent manner for many years. Moreover, in the last 10 years FDSN took the initiative to define recommendations for the identification of datasets (networks) via Persistent Identifiers (e.g. DOIs). DOIs were found to be the most suitable type of identifier to properly acknowledge seismic networks because existing resolution services and familiarity make them more easily accepted by publishers and provide a starting point for community involvement. After ten years from the first recommendation published by FDSN, studies on the FAIRness of data (e.g. adoption of FAIR Principles) show a clear relation between the adoption of these standards and recommendations and its visibility and impact in the scientific results. In recent years user demand for reasonable access to big data volumes has grown dramatically. This change is largely driven by new technologies (e.g. DAS and nodal seismic systems) allowing the acquisition of data in much higher resolution than previously and to Machine Learning methods becoming more popular. This demand will require new ways to access and process data. To address this, the development of new standards are on the roadmap and already in progress within the FDSN. These new standards include modern, cloud-based storage systems, versatile formats for data and metadata, asynchronous data access, in-cloud processing, Quality Assurance (QA) and common Authentication and Authorization Infrastructure (AAI). Our presentation will outline our current standards and achievements as well as the envisioned framework and roadmap for the development of new services. It will also provide an opportunity for stakeholders - such as users, instrument manufacturers, data and service providers, to engage and shape the vision.

Keywords: FDSN, Standards, Data, Metadata, Cloud services, FAIR Principles

Lithospheric Structure and Deformation in Southern Taiwan from SALUTE Seismic Observations

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The Southern Array for the Lithosphere and Uplift of Taiwan Experiment (SALUTE) is an amphibious seismic initiative designed to investigate the lithospheric structure and dynamics of southern Taiwan and its eastern offshore region. This area, located at the juncture of Eurasian Plate subduction and Luzon Arc collision, is key to understanding the spatiotemporal evolution of the Taiwan orogen. The project integrates multi-faceted, array-based seismic imaging, tomography, and modeling to comprehensively examine the crust-mantle system in this critical transition zone.
Here, we present findings from earthquake datasets recorded since October 2021 by the SALUTE array, which consists of 31 closely spaced broadband land stations and 11 ocean-bottom seismometers (OBSs) arranged in a cross-shaped configuration. Here, we present major findings from earthquake datasets recorded since October 2021 by the SALUTE array, consisting of 31 closely spaced broadband land stations and 11 ocean-bottom seismometers (OBSs) arranged in a cross-shaped configuration. Teleseismic P receiver function (RF) analysis and Common Conversion Point (CCP) stacking reveal significant subsurface seismic discontinuities. Our results show that the Eurasian continental crust beneath western Taiwan is relatively thin (~25 km), suggesting a history of rifting and extension preceding subduction. A ~10 km Moho offset near the Chaochou Fault (CCF) indicates differential crustal thickening across the collision boundary. Additionally, weak and intermittent P-to-S conversions from the subducted Eurasian slab beneath eastern Taiwan suggest that serpentinization effects or a steep slab geometry may affect its detectability. A 70 km-deep, 35 km-wide oceanic-continent boundary (OCB) beneath eastern Taiwan marks the transition from the Eurasian continental crust to the South China Sea oceanic lithosphere. Furthermore, SKS/SKKS splitting analysis provides insights into lithospheric deformation and asthenospheric mantle flow, revealing intricate anisotropic patterns resulting from the interaction of the oppositely subducting Eurasian Plate and Philippine Sea Plate.

Keywords: receiver function, CCP stacking, seismic discontinuity, shear wave splitting, continental lithosphere subduction, arc-continent collision

Development and Maintenance of the Distributed Acoustic Sensing (DAS) Network

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A stable seismic network not only provides the critical data required for real-time earthquake detection but also plays a crucial role in aftershock analysis and source rupture studies following major earthquakes. As a result, seismic networks have always been fundamental and indispensable for earthquake monitoring. In recent years, Distributed Acoustic Sensing (DAS) has emerged as a vital tool in seismology. DAS measures strain or strain rate along the fiber optic cable by analyzing phase variations in Rayleigh backscattering at multiple points along the fiber. Compared to traditional seismometers, DAS offers high-resolution observational data with sensor spacing at the meter scale, significantly enhancing the precision of seismic monitoring. To improve active fault monitoring, the Institute of Earth Sciences, Academia Sinica (IESAS) and the Earthquake-Disaster & Risk Evaluation and Management Center, National Central University (E-DREaM) jointly launched the Milun fault Drilling and All-inclusive Sensing Project (MiDAS) in 2021. The project began installing downhole fiber optic cables in late 2021, and by mid-2022, the connection between surface and downhole fiber optics was completed, establishing a 3D DAS continuous observation network-a groundbreaking approach to seismic monitoring. However, compared to traditional seismic networks, DAS generates an enormous amount of data, posing significant challenges in real-time data transmission, archive, management, and subsequent data sharing.This study reviews the development and maintenance of the MiDAS DAS continuous observation network over the past few years and provides recommendations for future similar projects, aiming to further advance DAS applications in seismic monitoring.

Keywords: Distributed acoustic sensing, seismic network

15 years of the GLISN seismic network in Greenland (1): Observations

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Over 80% of Greenland's surface is covered by the Greenland Ice Sheet (GrIS). In recent years, melting of the GrIS has been a concern, and seismic observations to monitor the melting process have gained attention. However, due to the difficulty of observations in the interior, by 2008, there were only 16 seismic stations, including those on surrounding islands, with just one on the GrIS. Such a situation highlighted the need to expand and reinforce the observation network.

An international project called the Greenland Ice Sheet Monitoring Network (GLISN) was launched in 2009 (Clinton et al., 2014). With the cooperation of 11 countries (Denmark, Canada, Germany, Italy, Japan, Norway, Switzerland, USA, France, Korea, and Poland), efforts had been made to increase the number of stations, and currently, a total of 34 stations are in operation.

A major characteristic of GLISN is the installation of three new stations on the GrIS: DY2G, ICESG, and NEEM (Toyokuni et al., 2014). The installation and maintenance of these stations have been carried out by a joint USA–Japan observation team. The team was dispatched annually from 2011 to 2018 and was involved in maintaining not only the three stations on the GrIS but also three stations on outcrops. At all three newly installed stations on the GrIS, broadband seismometers (Güralp CMG-3T) designed for cold temperatures were equipped, recording three-component seismograms at a sampling rate of 100 Hz. At the DY2G and NEEM stations, borehole seismometers (Güralp CMG-3TB) were also installed at a depth of ~300 m using the vertical shaft of the ice core drilling. Additionally, GPS stations were installed near the seismometers to monitor ice flow and snow accumulation.

Another characteristic of GLISN is the immediate release of data. By using satellite communication, transfer of seismic waveform data (20 sps) from the GrIS was successfully achieved in 2014, which was the first transfer of broadband seismogram from ice sheet. This made it possible to download data from all GLISN observation points in near real-time.

Since 2019, due to budget cuts from the U.S. National Science Foundation and the COVID-19 pandemic, observations on the GrIS have been halted. However, the accumulated data is being actively analyzed. The results will be presented as "15 years of the GLISN seismic network in Greenland (2): Achievements" in the M-TT36 session.

References

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Toyokuni, G., Kanao, M., Tono, Y., Himeno, T., Tsuboi, S., Childs, D., Anderson, K., Takenaka, H. (2014) Antarct. Rec., 58(1), 1–18.

Keywords: Greenland, Seismic observation, Ice sheet

Orchestrating Structural Safety with QSIS: Vision for Extensible Building Arrays

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The Quake Structural Integrity System (QSIS) is an innovative, cost-effective platform for continuous seismic monitoring and post-event structural health evaluations. Leveraging low-cost MEMS accelerometers and cloud-based computing, QSIS captures and processes real-time data via a scalable workflow: local devices record ground motions and building motions, a central server manages data aggregation and preprocessing, and a web-based interface facilitates user-friendly visualization and device management.

We deployed QSIS in a nine-story steel-reinforced concrete (SRC) building at the Research Center for Environmental Changes in Taipei, Taiwan, collecting seismic data from January 2021 to December 2024. Through spectral analysis, cross-correlation of ambient vibrations, and seismic interferometry, we tracked changes in key structural parameters—mode shapes, shear wave propagation speeds, and eigenfrequencies—over daily, weekly, and annual timescales.

Notably, eigenfrequencies declined following major seismic events, potentially reflecting stiffness reductions linked to early-stage damage. Meanwhile, seismic interferometry registered a consistent shear wave velocity (~243m/s) and impulse responses, underscoring the capability of our multi-parameter approach to capture subtle variations that may precede more pronounced structural changes. This integrated method thus offers a promising pathway for the early detection and continuous monitoring of structural health.

These findings demonstrate QSIS' s utility for near-real-time and long-term monitoring, enabling rapid post-event damage assessments and supporting resilient urban development strategies in seismically active regions. The system' s cost-effectiveness and scalability facilitate the deployment of dense building arrays in Taiwan' s densely populated urban centers, providing critical insights into structural integrity before, during, and after major earthquakes.

Keywords: Structural Health Monitoring, Strong Motion Building Arrays, MEMS Accelerometers, Seismic Interferometry, Social Resilience

