**ML**

Researchers combine IoT, cloud and edge computing to pioneer smart earthquake monitoring. A reliable Bayesian model is at the frontier of real-time data processing, while a weather-based adaptive neuro-fuzzy inference system (ML) predicts earthquake magnitude. The system has higher accuracy, lower latency, reliability and stability. Timely early warning can improve community safety and support effective predictions [30]. In a systematic review from 2017 to 2021, researchers analyzed 31 studies that used machine learning (ML) to predict earthquakes. They evaluated performance across regions and dimensions and compared algorithm performance with seismic indicators. The result of the effectiveness of machine learning algorithms, which are especially good at predicting large earthquakes, shows that more research is needed in this area [31]. Researchers analyzed earthquake studies (2017-2021) using ML algorithms, evaluating the performance of 31 studies in predicting global magnitude, frequency and nature layer. A series of machine learning algorithms and seismic measurements are evaluated, yielding useful results for earthquake prediction and informing future research. This study presents a potential algorithm developed to conduct a comprehensive evaluation of machine learning-based earthquake prediction and identify areas for improvement [32].

To improve earthquake prediction, scientists combine geological studies with machine learning, specifically the random forest algorithm, to make short-term predictions based on past events. They propose a hybrid model that combines geological and machine learning techniques to improve accuracy. New methods of using seismic acoustic data to train learning models to predict future earthquakes provide hope for earthquake research and mitigation of the impact of seismic events [33]. The researchers aimed to develop a reliable prediction model using earthquake location data and the Japan Meteorological Agency (JMA) dataset. Using SMOTE to resolve inconsistent data and measure performance, they achieved an accuracy of 97.77%. Although there are limitations in predicting large earthquakes and overestimating small earthquakes, the model is promising for early detection of earthquakes (EEW), which is important for providing information during seismic events [34]. These studies focus on improving the accuracy of hydroacoustic signal estimation, which is important for noise reduction and signal processing. The hybrid model includes VMD, DE, ELM, SVR and ABC optimization to improve power prediction compared to existing methods. It solves the fusion problem, improves accuracy, and provides useful hydroacoustic group estimation [35].

This study developed a Ground Surface Prediction (GMPE) model for India using XGBoost machine learning. The model was run on seismic data using parameters such as time, distance, depth and seismic shear wave velocity and Bhuj aftershock data obtained good correlation (±0.994) between observed and predicted PGA values, indicating the suitability of various seismic parameters. has shown [36]. This study investigates the impact of seismicity signals on earthquake prediction in four regions of Chile, focusing on training/testing, b-value calculation, and product transformation. Accurate measurements and appropriate length selection increase prediction accuracy and highlight the importance of supervised learning algorithms in seismic data analysis. Multifunctional designs support a variety of uses, emphasizing the importance of these aspects in improving earthquake prediction [37]. The research focuses on improving early earthquake warning (EEW) through machine learning-based damage prediction immediately after the arrival of long waves. The current system is based on low movement of the ground, which creates uncertainty in decision making and leads to a lot of financial losses. The proposed method uses long-wave characteristics to predict the maximum interlayer drift ratio (MIDR) and achieves a prediction accuracy of over 96.4%, ensuring stability and efficiency for EEW systems [38].

**DL**

In earthquake research, scientists use deep learning to improve location estimation without making any prior decisions about fault information. This neural network passes classical methods such as the Coulomb failure stress function with AUCs of 0.849 and 0.583, respectively. The model improves seismic damage location prediction by combining physical properties such as stress transfer and von Mises effect, demonstrating machine learning capability in seismic safety assessment and understanding earthquake dynamics [39].

**LSTM**

Scientists in the Horn of Africa are using deep learning to try to improve earthquake predictions by adapting to variables that change over time. They compared Transformer, short-term memory (LSTM), bidirectional long-term memory (BILSTM), and BILSTM-AT models and found that Transformer outperformed other models with 0.276 MAE, 0.147 MSE, 0.383 RMSE, and 28.868% MAPE, respectively. potential for disaster planning [40]. To improve the understanding of underwater propagation, researchers used CRAN to integrate convolutional autoencoders and LSTM-based recurrent neural networks. By training on different seamount geometries and acoustic wave frequencies, CRAN predicts wave propagation up to 5-6 times the initial length, demonstrating the power of deep neural networks in searching for physics. This architecture should enable real ocean applications and improve many wave physics studies [41]. To solve the earthquake problem, research goes beyond the traditional method and uses LSTM networks to capture the relationship between body and body. LSTM networks with two-dimensional features improve the accuracy of predictions by using historical data over a larger area. Simulation results showed very good prediction ability, demonstrating the potential of deep learning and highlighting the importance of location and physical structure in earthquake prediction [42].

**ANN**

In seismic data analysis, researchers evaluated the effectiveness of ANN in earthquake prediction based on support vector machine (SVM), M5P, Naive Bayes, KNN, J48, random forest and LPBoost ensemble method. It is worth noting that non-magnetic materials produce good results in active regions such as Chile, Japan, India, China, Pakistan, the United States, the Iberian Peninsula, Greece and Portugal, encouraging future studies to address the problem of simultaneous prediction. . to improve accuracy [43] This experiment uses features such as event time, latitude, longitude, depth, and size to evaluate the ability of artificial neural networks (ANNs) to predict large earthquakes. Demonstrates the performance and information of the model using USGS and ISIDE datasets, achieving 10% error in estimating size and performance data. Despite the limitations of the ISIDE dataset, the neural network can predict small (M-2.0) events with 99% accuracy and accurately predict medium-sized events (2.0 allowing us to see the power of AI in supporting global seismic data. . Daily seismic forecast potential [44]. This paper presents an artificial neural network (ANN) to determine the probability of arrival time (IAT) of seismic events in six seismic zones of India. The inadequacy of classical methods due to the complexity and heterogeneity of the data leads to the emergence of ANN-based methods that perform better than classification models. The ANN method accurately predicts the IAT result, aids in loss prediction, recovery, operational planning and application design, and provides a powerful modeling tool for seismic data acquisition.

The researchers aimed to create a tsunami travel time (TTT) atlas that could be used to estimate the time of arrival (ETA) of tsunamis caused by various earthquakes, especially off the Indian Ocean. This study uses non-standard electronic equipment for ETA estimation due to its speed and consistency. The TTT atlas was launched on the anniversary of the Indian Ocean tsunami to provide coastal communities with important information on disaster preparedness. This study highlights the importance of integrating new technologies into early warning systems to improve disaster risk reduction [46]. In pharmaceutical research, artificial neural networks are successful in revealing non-linear relationships between various properties, providing efficiency and balancing ability. This chapter provides an overview of the development of ANNs, explaining the basic concepts and their advanced applications in pharmaceutical research. The impact of network learning and configuration on the performance and performance of neural network devices is briefly discussed [47].

In-depth analysis of severe tsunamis and economic impacts, particularly in Taiwan, using deep learning to reveal historical data. In particular, features obtained from images from the last 120 days have an R value of 0.303 for predicting earthquakes above magnitude 6 within 30 days, revealing the potential for automatic prediction of seismic zones [48]. Researchers used RNN to analyze the earthquake in Turkey's Dizce province by combining various factors such as the earthquake's magnitude, depth, moon-to-ground, b-value, and d-value. By combining seismic coefficients and lunar data, prediction accuracy can be increased and the impact of seismic events can be reduced. Although there are problems due to inaccuracies in seismic data, many RNN models show promise in earthquake prediction and may aid future research [49]. In 1994, a new earthquake prediction method that incorporated financial analysis tools into neural networks predicted the Azores earthquakes of July 1998 and January 2004 at different times and locations. By combining physical precursors and computational oscillators, the network is trained to predict future events in the population over a long period of time. Promoting key benefits within the improvement domain [50].

**MLP**

Researchers investigated multilayer perceptron (MLP) neural networks for earthquake prediction and evaluated 128 seismic data samples. The prediction accuracy of online training reaches 72%, which is slightly better than mass training. A short run time increases the probability of amplitude estimation. Online models M16208 and M16204 produced the best predictions, demonstrating the effectiveness of MLP in predicting large earthquakes without prior assumptions [51]. The proposed DIN-MLP algorithm integrates MLP and DIN models to solve data processing problems in non-seismic situations and improve prediction accuracy by monitoring field behavior. Seismic monitoring stations are considered special users and historical data models are used as recommended products. Comparative tests show that GAUC increases by 11% over the original DIN model, demonstrating the effectiveness of estimating missing seismic data. Practical application of seismic monitoring centers aims to increase efficiency and accuracy, and future research focuses on standardization and optimization [52].

This paper presents a new method to predict the timing of major earthquakes in Hormozgan Province using the RBF neural network (NN) model. Input vectors include seismicity values ​​for large events and are optimized for training with limited data. Reasenberg's traditional methods increase data integrity. The results show that the RBF model outperforms MLP NN in terms of accuracy, cost, and precision; this highlights the importance of seismic data assimilation and the effectiveness of RBF NN in reducing the time correlation of seismic risk in the region [53]. This paper presents the IABC algorithm, which improves the MLP neural network for earthquake time estimation and overcomes backpropagation limitations. Compared to BP-MLP, IABC-MLP is more accurate, especially in predicting larger earthquakes. The advantage of weighted values ​​of the IABC algorithm improves learning and provides a good way to improve MLP training in earthquake prediction [54].

**tsunami**

This article provides an overview of global tsunami-induced science and discusses tsunami characteristics, causes, and effects on coastal sedimentation and topography. It provides an in-depth study of hydrological and morphodynamic numerical models used to simulate tsunami and sedimentation processes in terms of collaborative research and development of hazard assessment strategies for each region [55]. The growth of subcritical cracks in solids with low stresses and strains generally results in a slow and steady propagation equal to the maximum compressive stress. This creates a positive seismic anisotropy that facilitates earthquake prediction by dilatational anisotropy (EDA). This system detects earthquakes by estimating the distance to the next epicenter, interpreting the split wave analysis as pre-earthquake stress analysis [56].

This research explores ways to improve tsunami warning using new technologies. It is recommended to use our tools: tsunami forecasts, flood maps and port flow maps. These will assist in evacuation, port control and rescue. Public education is also considered important. Research suggests better warning systems and education to make coastal communities more resilient to tsunamis [57]. Earthquakes occur when energy measured by seismometers is suddenly released below the Earth's surface. Small earthquakes occur every day around the world, but most of the time they are undetectable and harmless. China, Indonesia and Japan are at risk of earthquakes due to plate movement, human activities and fires. Monitoring seismic activity helps reduce the risk to human life and the environment [58]. This study highlights the importance of real-time data from marine observatories, especially in Japan, for earthquake and tsunami monitoring. These observations developed by JAMSTEC aid in earthquake detection, damage mitigation, and advanced understanding of coastal seismicity, boundary deformation mechanisms, and tsunami early warning systems and speak to the need for advancement in coastal earthquake monitoring [59].

This research improves traditional tsunami models by ignoring fundamental issues such as sea level changes and acoustic effects. It uses advanced techniques to perform simulations without these simplifications, revealing larger wave heights and significant arrival times varying close to the error. The combination of seafloor dynamics and acoustic disturbances can improve the accuracy and understanding of tsunami behavior [60]. This study investigates acoustic gravity wave measurements as potential tsunami precursors. To evaluate early tsunami detection, he used two-dimensional linear theory to analyze the electrical parameters generated by the displacement of a piston in compressible water. Findings show that a great pressure was recorded on the coast before the tsunami, and studies are continuing to solve the constraints and provide analysis of three-dimensional problems using Mathieu functions [61]. Geller et al. The dispute over the reliability of earthquake predictions is based on the occurrence of unexpected and unpredictable events in the world. They highlight the complexity of seismic activity, acknowledging that even small earthquakes can lead to larger events. Disagreement continues over evaluation and media coverage. In general, they believe that accurate earthquake prediction is impossible [62].

**Indian tsunami**

Seismic activity in the Indian Ocean, especially in the northeast, occurs at ocean ridges and rift valleys. There were 29 earthquakes in the region, 11 of which were magnitude 6 or greater, especially in the coastal areas of Irvine, Prince Edward Island and Amsterdam. The equation obtained from 30 years of data shows that the earthquake frequency decreases logarithmically with magnitude, with 6 and 8 earthquakes occurring every 6 and 50 years, respectively [63]. This study develops a method for instantaneous prediction of severe tsunami wave height and coastal flooding, focusing on the impact of the 2004 Indian Ocean tsunami in Cuddalore, India. This study uses the ADCIRC model to accurately calculate wave height and sea level, which are important for emergency warnings and disaster planning decisions. This highlights the importance of timely and accurate forecasts to reduce the impact of tsunamis on coastal communities [64].

This report evaluates the economic impact of the 2004 Indian Ocean tsunami in Indonesia (Aceh Province) and Sri Lanka on the coastal environment in terms of disaster preparedness and environmental management. It advocates integrating disaster risk reduction into national development strategies and emphasizes the importance of community participation and program management to achieve good outcomes. [65].

The Indian Ocean tsunami caused by the major earthquake in 2004 demonstrates the lack of planning and early warning in the region. Advances in seismology and tsunami science have improved earthquake warning, prediction, and paleoseismological research. Improved tsunami modelling, GPS buoys and improved propagation models have led to early warning systems, hazard maps and risk assessments. Collaboration between scientists and stakeholders is essential for disaster mitigation through a deeper understanding of events such as the 2011 Tohoku earthquake and the collision at the Fukushima Daiichi nuclear power plant [66].

**Other**

Scientists use seafloor distributed acoustic sensing (DAS) and fiber optics for tsunami warning. Data collected at 100 Hz, 20 m intervals, were analyzed using FK beamforming. Following tsunami predictions, ships that could survive for more than 300 seconds were detected. Gravitational waves (200-600 seconds) are consistent with DART data. DAS improves detection capabilities and aids coastal planning, but further research is needed [67]. To improve the prediction of tsunami after a large ocean earthquake (M > 7), researchers analyzed the fault location, magnitude, fault direction, and earthquake characteristics. Signal analysis techniques such as Fast Fourier Transform (FFT) and Continuous Wavelet Transform (CWT) of time-lapse data can distinguish tsunami from non-tsunami earthquakes, thus improving the accuracy of prediction and timely warning [68].

Earthquake history in the Caribbean, Indonesia and Japan is difficult to track and document. Despite their geographical differences, Indonesia and the Caribbean, two large archipelagos, share similar seismic activity patterns and atmospheric patterns. This 35-year study since 1985 investigated the link between climate science and seismic anomalies by using precipitation patterns to identify earthquake zones in various ocean regions [69].

The author proposed a method to predict earthquakes and tsunamis by measuring elastic waves and radio waves in the seismic zone, and the highest measurement results were 0.95. Electronic devices with frequencies between 1 Hz and 1000 Hz can detect earthquakes and measure the severity of the electric shock that causes elastic ruptures. The global research target is planned to be completed within 4-5 years [70]. The study examined acoustic gravity waves as potential tsunami precursors and examined electrical waves produced by the displacement of the bottom of a piston in the ocean. It describes the flow of water using discharge theory and demonstrates early detection of tsunami by pressure signature. Future research is to use acoustic measurements to resolve tsunami forecast inversion by accounting for factors such as energy loss and bottom irregularities [71]. To improve the prediction of earthquake deaths, researchers evaluated the significance of various earthquakes in Yunnan Province. They use key challenges such as identification and downscaling to determine important factors such as population distribution and geohazards. Particle swarm optimization support vector machine achieves high accuracy (R2 higher than 0.934) by improving the accuracy of machine learning models for earthquake emergencies and post-disaster reconstruction [72].

Examining earthquake patterns before and after main shocks in the south and north Researchers in California and Italy have developed a foreshock test. When they compared observed foreshocks to ETAS model simulations, they found more visible foreshocks that tell the difference between aftershocks. This means that changes in the body system before the main shock will improve the prediction of large earthquakes [73]. This study examines the time of the wave train T(Q) at teleseismic distance from stations on the island, including seismic factors (mb, Ms, Mw). He analyzed data from more than 400 Pacific earthquakes using theoretical models and measured the logarithmic relationship between time and earthquake magnitude. The results confirm the prediction, especially for large earthquakes (Mw > 7) and help predict the very long seismic period of 1 to 2 hours after the earthquake. These models provide immediate and accurate estimates of earthquake duration and are important for effective tsunami warning [74].