# A Summary of iSTEP (integrated Study and Test of Earthquake Precursor) projects

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After the 21 September 1999 M7.6 devastating earthquake, a program entitled the integrated Search for Taiwan Earthquake Precursor (iSTEP-1, 2002/4/1–2006/3/31), which consists of a main project and five sub-projects, was conducted to search credible precursors in seismological variations, geomagnetic and gravity fields, ground surface deformations, and ionospheric electron density anomalies, as well as to evaluate the statistical significance of observed precursors in Taiwan. Results reveal that anomalies in P-wave velocity, ground surface deformation, geomagnetic field intensity, ionospheric electron density could appear few years, months, and days before large earthquakes in Taiwan, respectively. An integrated ground-based seismo-electromagnetic observation system, including eight networks of magnetometers, electrode arrays, corona probes, FM tuners, Doppler sounding systems, ionosondes, GPS receivers, and all sky cameras, has been constructed and routinely operating to monitor earthquake precursors in the lithosphere, atmosphere, and ionosphere and to find possible lithosphere-atmosphere-ionosphere coupling in the Taiwan area. Several statistical analyses were developed to validate the observed anomalies to be credible precursors. Due to its worldwide availability, the statistical results showed that the ionospheric total electron content (TEC) derived by ground-based GPS receivers were most likely to be a credible precursor. Succeeding the iSTEP-1, the iSTEP-2 (integrated Study for Taiwan Earthquake Precursors, 2006/8–2012/7) project adding with satellite observations was conducted to have a longer time period for data collection and analysis, as well as to develop physical and statistical models. Although it was not officially funded but supported by basic ionospheric research projects, the integrated ground-based observation still has been operating uninterruptedly. Many new observations possibly related to seismo-lithospheric precursors of the earth’s surface magnetic field and the GPS surface deformation, seismo-atmospheric precursors of the infrasound signal, and seismo-ionospheric precursors (SIPs) in the electron density profile, the electron temperature, ion density, and neutral temperature probed by satellites were reported. The TEC in the global ionosphere map (GIM) routinely published (with a 2- or 4-day time delay) allows us to monitor temporal SIPs at a specific location, and to conduct spatial analysis discriminating the observed SIPs from global effects, such as solar flares, magnetic storms, etc. Statistical analyses for detecting both temporal and spatial precursors in the ionospheric TEC are developed. Meanwhile, ionospheric model simulations are also introduced to find causal mechanisms explaining the observed SIPs. The iSTEP-3 (integrated Study for Taiwan Earthquake Precursors, 2012/8–2016/7), which is proposed to focus on the SIP study, consisting of a main project and three sub-projects is formally funded. The main project continues to operate the integrated ground-based observation system, develops physical models, and compares model simulations with observed precursors, while the three sub-projects aim to develop a near real-time GIM with a 4-hour time delay for worldwide SIP monitoring, to monitor lithosphere, atmosphere, and ionosphere precursors, to find the precursor link, and to conduct earthquake hazard assessment with observed precursors, respectively.

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