How to predict the next Big earthquake in Manila? Is it possible?
The AMaDeUs approach.

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The recent decade of catastrophic earthquakes (EQ) claimed thousands of lives and caused extensive economic losses. The DRR agencies and NDMAs are struggling with the provision of real time early warning systems, let alone earlier detection of potential major seismic events.

In a recent poll by Swiss Re (2014), an international reinsurance company, Metro Manila is the world's second riskiest 'city' in terms of natural disasters waiting to happen, behind only Tokyo-Yokohama in Japan. Assessment was made on to five natural disasters, EQ, storm, storm surge, tsunami, and river flood. About 34.6 million (2013) people are potentially on the receiving end of the five catastrophes. Therefore the questions "How to predict the next Big EQ in Manila " is more then relevant. The seismically active Marikina Valley Fault System creates a real treat for a large-scale EQ with an estimated M 6–7 and as high as M7.6. (Nelson et al, 2000)

After years of research and development, we are now witnessing the emergence of new realistic inter-disciplinary approaches based on data fusion enabling the reliable forecasting of major seismic events. Whilst still in continuous development, it is now a reality and proven to provide reliable short-term advanced warning. The new approach is a multi-observational data strategy to detect EQ precursors by integrating both satellite observations with ground-based data in order to determine the most relevant signal that provide a pre-EQ warning. The concept is based on innovative methods that were presented in our recent AGU/Wiley Geophysical Monograph Series describing pre-seismic patterns detection and on other underlying physical precursors e.g.: radon – gas; NASA numerical assimilation atmospheric models, GPS/TEC ionospheric soundings and thermal satellite observations recorded by NASA/NOAA/ESA/JAXA satellites (Ouzounov et al, 2018) We use these inputs for an initial physical representation of the interactive process between the EQ source with the Earth surface and the ionosphere. An example of a connection between EQs with the ionosphere is the Lithosphere Atmosphere-Ionosphere Coupling model (LAIC) to detect the pre-EQ signals.

Scientific aspects

In recent years, there has been an increasing amount of encouraging evidence that, during the last stages of the long term tectonic preparation process for an impending EQ, there could be a transfer of energy and/or particles between the lithosphere and the overlaying atmosphere, resulting in coupled processes commonly known as LAIC (Pulinets and Ouzounov, 2011). LAIC due to seismicity is one of the most promising physical concepts we use for this research. It is developed on a novel but an integrated process that takes into account multiple natural activities of the EQ preparation process in its latest stage (one-two weeks before the seismic shock). The atmospheric (thermal and ionospheric) anomalies observed by the remote sensing satellites for recent major EQs confirmed LAIC estimates of large spatial scale of occurrence; short live temporal dynamics (several hours up to several days) and altitude dependence in distribution. The estimated release of thermal energy implies that the air ionization process is the primary source driven by the alpha radioactivity of radon.

Technological aspects

Almost all Earth observation satellites (EOS) have been developed to study other phenomena than EQs, such as, to mention some, weather forecast, monitoring of land usage, global warming, air and water pollution. However, we found the input of EOS critical in the understanding coupling between different geospheres associated with the time of major EQ preparation, We designed a sensor web called **AMaDeUs** (A Multi-sensor Web system for Pre-EQ signals Detection, Utilization and Alerts) of existing satellite sensors (Terra, Aqua, GOES, POES, MSG and others, Figure 1) and ground observations e.g., Global Positioning System Total Electron Content (GPS/TEC), radon, air temperature, relative humidity, aerosol. Our rationale for using these observations is that there are insufficient spatial and temporal coverage of any one of these observations.

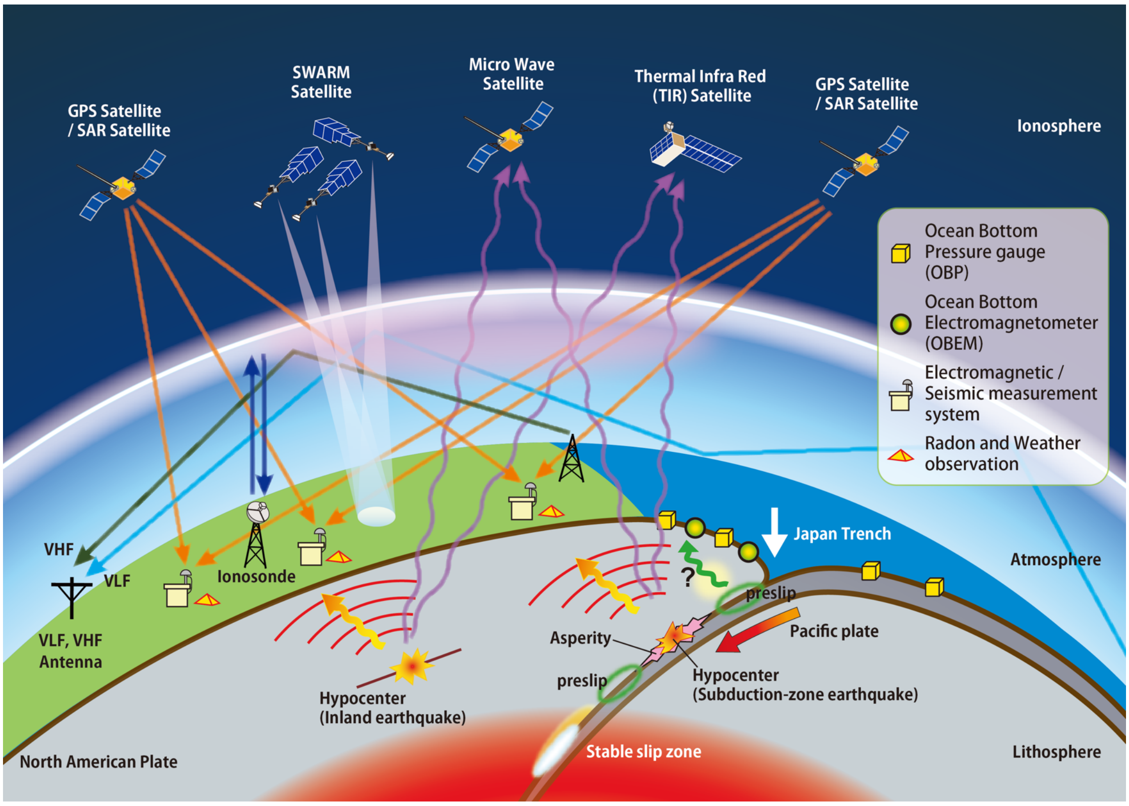

Fig.1 AMaDeUs - conceptual diagram for Geospace and ground observations of pre-EQ signals, case study for Japan

The technological advantage the new approach **AMaDeUs** is to enable multiple and already validated physical measurements to be fused into one framework with the latest theoretical models like LAIC (Lithosphere-Atmosphere-Ionosphere Coupling) and to provide feedback on data gaps, which may then be acquired from other sources. Global observations based on remote sensing technologies, would exploit the unique advantage of space observations of pre-EQ phenomena, namely the possibility of providing the opportunity of using both deterministic and statistical techniques to study databases containing many more seismic events than traditionally studied in EQ sciences. The abundance of data could hopefully balance the challenge represented by an analysis, which necessarily links different disciplines in order to understand diverse physical effects and interactions, starting from lithospheric geophysics, seismology, tectonics and geochemistry, through atmospheric and ionospheric physics, up to the Earth's magnetospheric physics.

The ground -breaking nature of proposed **AMaDeUs** approach is (1) by using novel physical hypotheses for EQ preparation process to build a Sensor web based for multidisciplinary observations, (2) through synergetic analysis to identify seismically related anomalies associated with lithospheric -atmospheric - ionospheric parameters, and (3) to use them as early warning information for major seismic events. To our knowledge such type of science approach for short-term assessment (days/ hours in advance) for reduction of seismic hazard in the major seismic zones has never been demonstrated before.

Practical aspects

The significance of these initial AMaDeUs forecasting alerts will be presented over Japan (2012-2013) where we been alerting for the large EQ events M>5.5 (Fig 2) . During the tested period 75 alerts been issued, 51 EQ (63%) occurred in the alerted regions, and we have 24 (37%) false alarms. We also present real case of forecast for case of M7.3 of December 7, 2012, Japan occurring in the water over Japanese trench. Our analysis was able to alert 14 days in advance for a potential EQ with M> 6 (Fig 2. Right, bottom).AMaDeUs was revealing an unique temporal-spatial evolution pattern in an EQ preparation process, which has also been seen in other major EQ timelines in Central Asia and South America. AMaDeUs tests in different region lead to successful alerts for the M8.3 of Illapel, Sept 16, 2015 Chile EQ and for M7.3 Nepal, May 12, 2015.

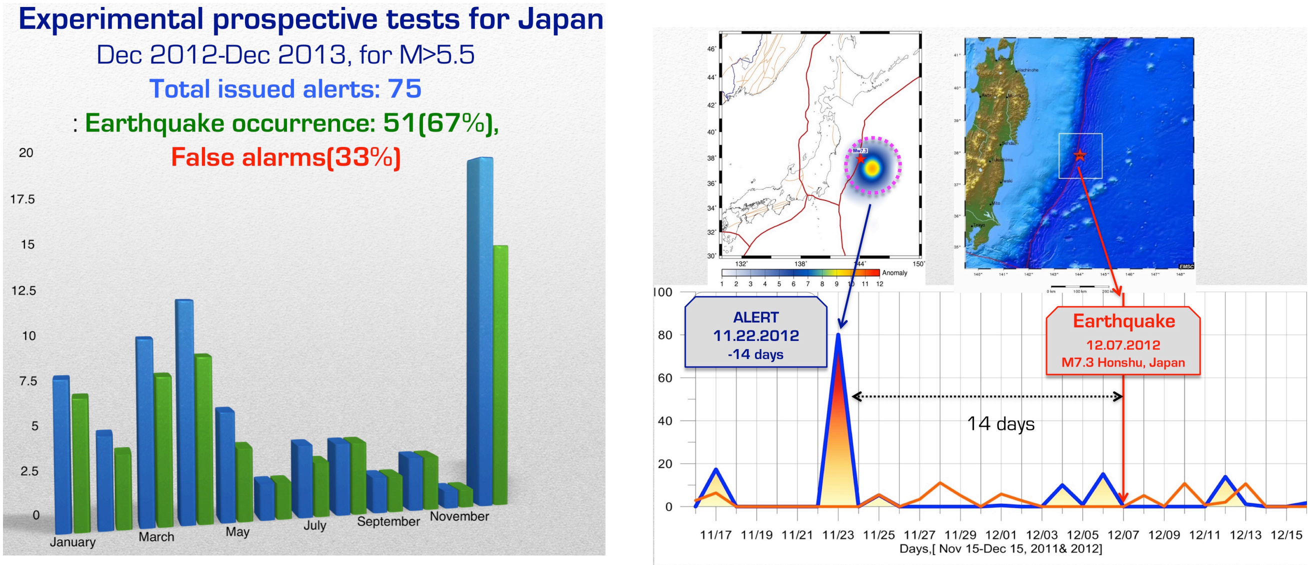

Fig.2 Initial operational testing of AMaDeUs. (Left) One year (2012-13) histogram of monthly EQ alerts (blue, total 75 alerts) and real EQ occurrences related the alerted events (green, 67% success). (Right) represent one EQ case of forecasted evens included into the 2012-13 tests. The M7.3 of December 7, 2012, Japan was alerted 14 days in advance. The detection map is shown and the navigation map (Top). (Bottom) The time series of 30 days show the thermal anomaly in atmosphere (blue line) occurred (11.22.2012) and for comparison the same analysts was preformed for the same period for 2011, and show no anomalies when no seismicity is occurring (orange)

Conclusions

The new observation capabilities in monitoring from ground, earth-space and geo-space, coupled with advances in data analysis and theory, provide opportunities as well as additional challenges. Beyond the science of providing reliable short-term forecasts, the presentation will also highlight the core of these challenges including: identifying a social science strategy to re-educate the users to receive reliable forecast information; the integrating and reliance upon advanced real time early warning alarm systems; and the preparedness training at all levels of society from Government to Industry to Home, will also be an essential part of any strategy for a full implementation of a comprehensive Early Warning System, which will maximize the potential usefulness and necessity of the developing reliable seismic forecast technology potentially as a 'New Early Warning'.

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