Forecasting Strong Earthquakes in Indonesia and Philippines from Space

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ABSTRACT

Electron bursts at each NOAA satellite semi-orbit were analyzed in order to distinguish their correlations with seismic activity from seasonal variations of particle flux and solar activity. When analyzing 30 - 100 keV precipitating electrons and earthquake epicenter projections at altitudes greater than 1,400 km, a significant correlation appeared. Specifically, a 2-3 hour electron precipitation excess was detected prior to large events in Indonesia and Philippines; suggesting a 4-10 hour early preparedness of strong earthquakes influencing the ionosphere. Here an experiment is proposed to verify the feasibility of strong earthquakes forecasting from space using existing NOAA POES.

Key words: NOAA satellites, Natural hazards, Ionosphere, Earthquakes, Electron bursts

Introduction. Ionospheric disturbances linked to seismic activity were first observed around the time of the great Alaskan earthquake (EQ) [1] on March 28, 1964. Satellite measurements [2] provided medium and far field viewing points of lithosphere phenomena with respect to the EQ influence size. To this regard, several of the particle detectors used in solar studies have been used to investigate electron precipitation prior to and after strong EQs during geomagnetic quiet times [3,4]. These two latter studies were based on data coming from satellite missions lasting only a few months or collected over a few months with equal attitude data; therein providing weak evidence for correlations. The NOAA-15 particle database, which has been collecting data since 1998, was first studied for its particle bursts in connection with global seismic activity during quiet solar periods [5]. This analysis showed exceptional increases of particle fluxes prior to and after the largest quakes that struck the defined Indonesian and Philippines area. However, these increases showed no correlation with strong EQs in past studies [6]. In fact, the inner Van Allen Belts are significantly affected by the influence of geomagnetic activity [4]. Magnetic storms can induce sudden electron flux enhancements of more than one order of magnitude near $L = 2$, and their particle bursts auto-correlations have indicated a clear Sun influence also during quiet periods [7]. Being so, periods with less intense geomagnetic activity were excluded from the analysis, in order to distinguish correlations with seismic activity from seasonal variations of particle flux and solar activity. Recently [8,9], a statistically significant correlation between extended perturbations of electron CRs of 30 - 100 keV and large EQs was observed occurring 2 - 3 hours before strong EQs with $M > 6$. Electrons belonged to the low L-shell range of $1.15 < L < 1.35$ with pitch angles of $30° \leq \alpha \leq 80°$ and $120° \leq \alpha \leq 160°$, and were detected inside the red delimited area on the left of Fig. 1. This observed correlation supports the hypothesis that there may be a physical link between ionospheric and seismic activities when EQ depths are less than 200 km. Taking into account the corresponding electron drift periods with the expression:

$$T_d=1.05/[E\cdot L\cdot(1+0.43\sin\alpha_{eq})], \quad (1)$$

30 to 100 keV electrons had drift periods T_d of 21 to 6 hours, respectively. After having drifted eastwards

to cover about 120°, with times from 2 to 7 hours, electron bursts from the epicenters of the Indonesian and Philippine EQs met NOAA POES. This means that the ionospheric perturbations had to have started much earlier. If the perturbations that caused electron bursts had occurred above the EQ epicenters in the ionosphere, they should have anticipated the EQ times by 4 - 10 hours [9].

The experiment. Following the method developed to select electron bursts through adiabatic coordinates [5-9], it is currently possible to study electron bursts in real time, by defining statistical behavior of CRs over the 24 hour period preceding the considered time. Thus, the experiment of EQ forecasting would consist of the following phases: 1) the downloading of data after each semi-orbit through the detection area; 2) burst analysis; 3) the probability calculation of a strong EQ over the next 2 - 3 hours in Indonesia or Philippines. To calculate the success probability of the experiment, the number of correlated events with respect to the total seismic events would need to be considered. From the best correlation obtained with EQs of M ≥ 6 in 13 years, 34 seismic events were selected on 1427 shallow main shocks [9], about 2.4%. A value so small can be justified by taking into account that the satellite is not always at the position where bursts occur. The left red selection in Fig. 1 shows the geographical region where the satellite is able to measure electron bursts to correlate with EQs. This region is very small compared with the entire earth surface, about 1/15, therein meaning that the satellite is able to detect EQ correlated bursts only for 1/15 of its total working time. If seismic events were uniformly distributed in time, only 95 can be correlated, and 34 were about 36%. EQs correlated with electron bursts and having a possible physical link with them, occurred with epicenters concentrated in the circumspect area delineated on the right in Fig. 1. The correlation was recalculated considering EQs in this area only. In this way, the noise level of

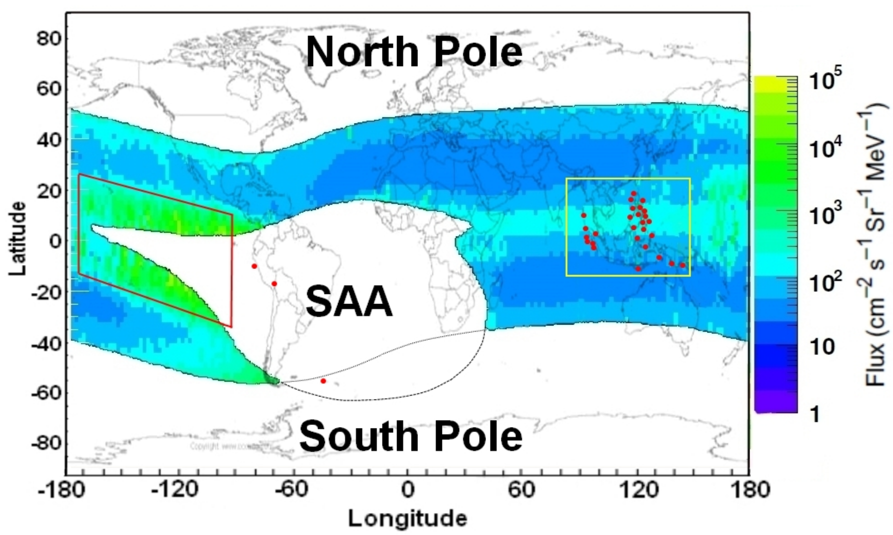

Figure 1. The geographical area considered in the analysis is colored. The wave-shaped limits of polar areas are due to the geomagnetic field inclination relative to the Earth's axis. While, the birdhead-shaped area in the center delineates the interior of inner belts at NOAA altitude. Colors indicate the average annual electron flux detected at 30-100 keV, 0° NOAA-15 on board telescope. EQ epicenters are indicated by red dots.

the correlation decreases. Furthermore, when considering major altitudes of EQ epicenter projections the number of standard deviations of correlation reached a maximum at about 6. At the same time, the total number of EQs decreases less because they belong to a smaller area. This correlation is characterized by 30 events of M ≥ 6 and is shown in Fig. 2. 456 shallow main shocks were recorded in the same area during the same period, thus 30 events were about 6.6%; however, considering 1/15 of the total they were near 100% of detectable. The resulting probability of forecasting success for each burst depends from the total number of burst with respect to the total number of correlated earthquakes. Considering that 15573 bursts created 144 hours of correlations in Fig. 2, 30 of 108 burst/hour of correlation interval anticipated

EQs, about 27%. The number of EQ false alarms should be about 73% in the 2-3 hour interval.

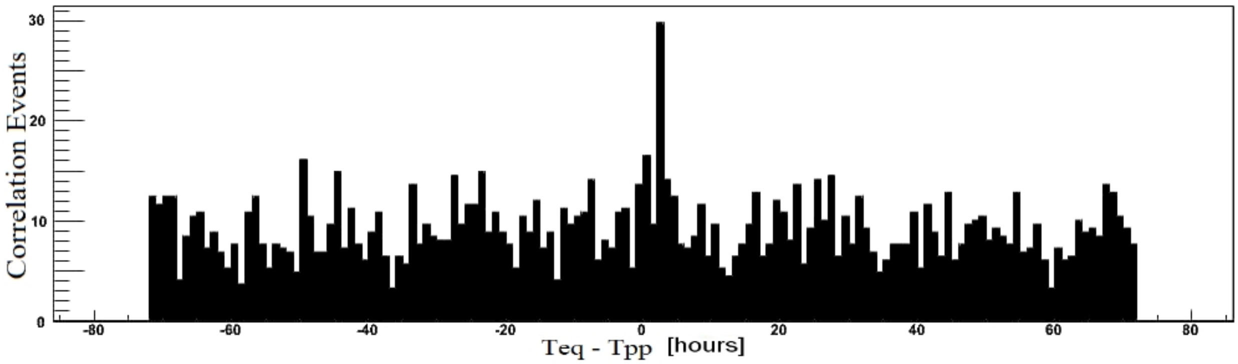

Figure 2. Correlation time histograms between EQs with M ≥ 6 and electron bursts with epicenter projections at 2100 km; the significance of the 2 - 3 hour correlation is about 6 standard deviations.

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