Measuring Ion Currents and Electric Fields Caused by Earthquakes, Volcanoes, and Lightning in the Mesosphere

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Summary. There is increasing evidence that, prior to major earthquakes and volcanic eruptions, the air above future epicenters can become highly ionized, producing electromagnetic (EM) and thermal anomalies that are detectable by ground- and space-borne platforms [1,2,3,4]. These detections represent indirect consequences of the ionization, but no in situ measurements within the atmosphere have been possible until the recent development of a plethora of suborbital vehicles. If this phenomenon could be directly measured and better understood, it could potentially provide a means for early warning prior to seismic events.

Mechanism and Effects. The process is thought to be caused by positive hole charge carriers, which are stress-activated in the crust during the build-up to major seismic events [5]. Often the ions generated at the ground level will be exclusively positive [6], creating a situation where a highly and stably ionized air bubble will expand upward, coupling electrical properties through the atmosphere as it rises [7]. This upward expansion of positively ionized air causes a change in the distribution of electrons at the lower edge of the ionospheric plasma, increasing its Total Electron Content (TEC). Initially homogeneous, this vertical ion current streaming through the mesosphere will break up into globules of different ion densities. They will create mostly horizontal electric fields, initiating lightning strikes different from sprites above thunderclouds. A similar situation will arise above the top of Plinian volcanic eruptions plumes. They inject gases like SO_2 into the stratosphere-mesosphere boundary, leading to different ions accelerated upward, creating electric discharges at different frequencies.

Flight Opportunity. We seek the opportunity to fly experiments on high-flying and/or suborbital platforms to measure EM emissions from the mesosphere during pre-seismic and/or volcanic activity. Some possibly suitable high altitude platforms include sounding rockets, NASA's SOFIA Observatory, Northrop Grumman's Global Hawk UAV, Masten Space Systems' Xaero, XCOR's Lynx, and Virgin Galactic's SpaceShipTwo. Most of these platforms are affiliated with NASA's Flight Opportunities Program [8]. In addition to Spaceport USA, candidate study areas include the proposed Sweden, Curaçao, and Dubai spaceports due to their proximity to active volcanic areas or, in the case of Dubai, a large ion-generating antenna array that could provide an excellent control source for the experiment [9].

Payload Development. We propose sensors to measure the electron and ion densities along the flight path. Using internal or external triaxial antennae tuned to different frequencies, we expect to obtain information about the polarization of the EM emission from the mesosphere and, hence, the direction of the electric discharges. Issues pertaining to the RF and EM environment on the craft will have to be mitigated. Additionally, we also consider multiple drop-off sensors that would measure the vertical electric field profiles during free fall after ejection from a suborbital craft. Eventually, if point-to-point suborbital transport becomes commonplace, such an EM measuring sensor could become a standard payload on suborbital vehicles as they traverse long horizontal distances through the mesosphere.

Conclusion. We propose to use high-flying and suborbital platforms to traverse or skim the mesosphere during times of seismically or volcanically induced electric activity to measure (i) electric fields, (ii) ion and (iii) electron concentrations.

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