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Coupling between Earth Surface and Ionosphere before Earthquakes

Air Ionization at the Ground-to-Air Interface as Major Driving Mechanism

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There is evidence that positive holes, $h^\bullet$, exist in minerals of igneous and high-grade metamorphic rocks, albeit in a dormant, electrically inactive state [e.g. 1]. The $h^\bullet$ are activated by mechanical stress. Being highly mobile electronic charge carriers, the h° spread out of the stressed rock volume, traveling fast and far through unstressed rocks. Arriving at the Earth surface from below, the $h^\bullet$ build up microscopic electric fields [2], eventually strong enough to (i) field-ionize air molecules, stripping off an electron and generating massive amounts positive airborne ions, and (ii) trigger tiny corona discharges, producing about equal numbers of positive and negative airborne ions. These air ionizations appear to spread over large areas around future epicenters. Here we follow the path of positive airborne ions generated at the Earth surface, which could rise through the atmospheric column up to the ionosphere.

Laboratory experiments suggest that the number of positive ions produced by process (i) can reach values on the order of 10^7 $sec^{-1}cm^{-2}$ [3]. Such values are consistent with data collected by the PISCO station network in Japan [4] and the QuakeFinder station network in California and Peru [5] documenting episodes of regional high concentrations of exclusively positive air ions at concentration levels of 10^4–10^5 cm^{-3}, often lasting tens of hours.

An injection of massive amounts of positive airborne ions at ground level over a wide region is expected to lead to a series of predictable effects throughout the atmospheric column. An important factor is the large potential difference between the Earth surface and the lower edge of the ionosphere, which reportedly is on the order of 250,000 V under fair-weather conditions [6], defining the vertical E field.

(i) Due to electrostatic repulsion the air volume will expand upward, possibly to stratospheric heights.

(ii) The airborne ions will act as condensation nuclei for water droplets leading to fog and/or clouds depending on the relative humidity. The ions will attach themselves to aerosols leading to haze.

(iii) The ion-laden air will drag along the ground potential, thereby changing the vertical electric field.

(iv) As the ground potential, or a fair portion of it, is transferred from Earth's surface to stratospheric heights, 10–15 km, the ionospheric plasma will polarize, causing electrons to be pulled downward.

(v) This Coulomb interaction will lead to a TEC increase at the lower edge of the ionosphere [7,8].

(vi) The total number of electrons in the TEC anomaly, which can be obtained from ionospheric tomography data, provides the number of positive airborne ions rising through the atmosphere.

(vii) The positive airborne ions arriving that the top of the stratosphere will continue to travel upward, accelerated in the prevailing E field, forming a vertical ion current in the mesosphere.

(viii) With decreasing air pressure the mean free path of the ions between collisions will increase with increasing height, causing the vertical ion current to rise faster and faster.

(ix) The electrons in the ionosphere are expected to respond, moving downward with the same speed, which may lead to a positive Doppler shift for radio waves reflected off the ionosphere.

(x) Due to magnetohydrodynamic coupling, an initially homogeneous vertical upward ion current will develop instabilities and break up into bubbles of higher and lower ion densities.

(xi) This will lead to electrical potential differences within the mesosphere, possibly to the point of triggering mesospheric lightning. Due to the low gas density, very short µsecs lightning strikes are expected, similar to sprites, but randomly oriented.

(xii) As the rising positive ion bubbles reach the lower edge of the ionosphere and melt into the iono-spheric plasma, electrons in the TEC layer will recede upward, causing a negative Doppler shift.

(xiii) The bubbles of higher and lower ion densities developing in the mesosphere will also lead to bumps in the E field in the ionosphere above regions of impending seismic activity, which satellites traveling at greater heights will record as apparent turbulences [9].

An important prerequisite of this concept is that air at ground level becomes positively ionized over a wide region above a future epicenter. Only then will positive airborne ions become available in significant numbers to rise through the tropo- and stratosphere and to enter the mesosphere, leading to a vertical ion current, which is expected to develop an ionospheric response. However, when the air ionization at ground level switches to tiny corona discharges (generating approximately equal numbers of + and – ions), the air may become even more highly ionized, but we should not see an upward current of positive airborne ions. Hence, the phenomena listed above, in particular mesospheric lightning and ionospheric TEC anomalies, should fade away. It has indeed been widely reported observation that, while ionospheric TEC anomalies are often observed 5-3 days before major earthquakes, they seem to fade away 2-1 days before the events [7,8,9].

At the same time we predict that the development of tiny corona discharges over wide regions may lead to an increase in broadband radio noise. Possibly we can also expect an increase in ozone and other trace gas concentrations near ground level, in particular CO [].

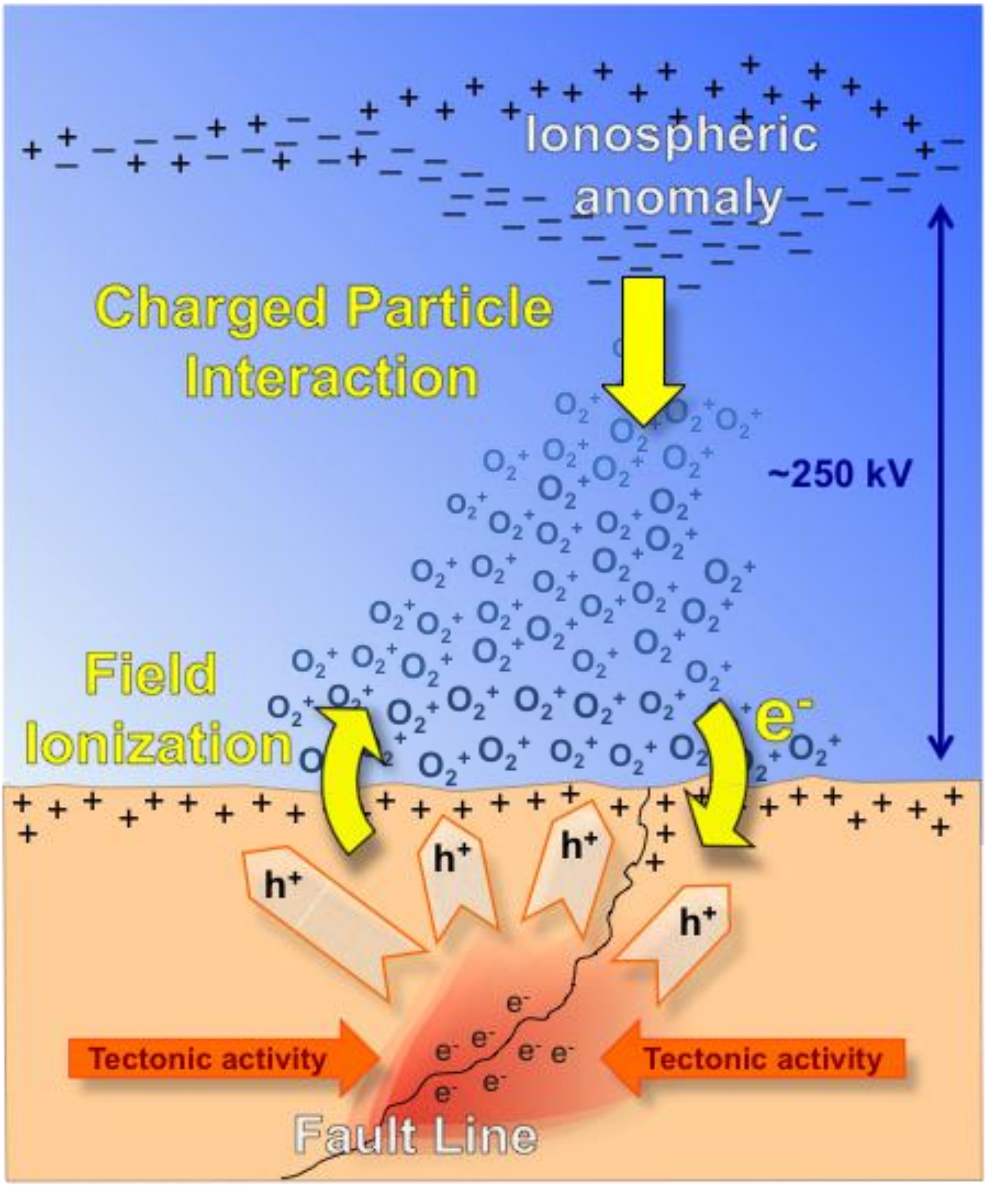

Fig. 1: Depiction of the proposed basic process of air ionization at the ground level, followed by the rise of the ion-laden air bubble to stratospheric height, followed by further upward acceleration of the positive ions through the mesosphere and the expected impact on the ionosphere, leading to a TEC anomaly.

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