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Relativistic Electron Beams Above Thunderclouds

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It has recently been discovered that lightning discharges generate upward-directed relativistic electron beams above thunderclouds. This extends the phenomenon of relativistic runaway breakdown believed to occur inside thunderclouds to the atmosphere above thunderclouds. This marks a profound advance in our understanding of the atmosphere because we now know it acts as a giant, natural, particle accelerator. The accelerated electrons can reach significant relativistic energies of some MeV during their passage from the troposphere, through the middle atmosphere, into near-Earth space. These relativistic electron beams constitute a current above thunderclouds and effectively transfer energy from the troposphere to the middle atmosphere. This coupling process thereby forms a novel element of the global atmospheric electric circuit which links tropospheric thunderclouds to the atmosphere above. This contribution describes the radio remote sensing of upward electron beams to determine their occurrence frequency and to characterise their physical properites.