Electrodynamics of the nighttime equatorial ionosphere: the effects of winds and waves

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The Earth's neutral atmosphere supports a range of wave phenomena: planetary waves with periods of several days, the familiar diurnal and semi-diurnal tides, internal gravity waves or buoyancy waves with periods up to several hours, and shorter period acoustic waves. These neutral wind oscillations propagate into the ionosphere and drive motions of the ionospheric plasma resulting in a range of ionospheric phenomena, from E region quasi-periodic (QP) echoes, sporadic E layers, and the equatorial electrojet, to equatorial spread F (ESF) and the F region dynamo. However, there are still many open questions concerning the local and day-to-day variability in these ionospheric phenomena. There is also great interest in wind-generated small scale irregularities and instabilities, such as Kelvin Helmholtz instabilities and QP echoes. In addition, there exists a class of common, medium-scale atmospheric disturbances, internal gravity waves, whose effect on the ionosphere is largely unknown. Recent advances now make it possible to study in-situ the neutral and plasma dynamics of internal gravity waves, an important link in the overall understanding of the Earth's electric field, from large to small scales.

Ionospheric electric fields are known to “map” some distance along the Earth’s highly conductive magnetic field lines, with a mapping distance proportional to the scale size of the electric field structure and a mapping constant, $[\sigma / \sigma_P]^{1/2}$ [1]. Evidence from previous mid-latitude sounding rockets indicates that, in spite of the efficiency of this electrical shorting mechanism at mid-latitudes, E region electric fields with scale sizes of a few tens of kilometers and strengths on the order of several mV/m can be generated by gravity wave winds [*Gelinas et al.,* 2003; *Pfaff et al.,* 1998]. Jacobsen and Bernhardt (1985) showed that sinusoidal neutral wind motions could have an effect far from the source region if the oscillatory winds have a net leading edge, producing image charges near the Pedersen conductivity peak and electric fields that map out of the source region. The goal of the experiment discussed here was to study electric fields both inside and outside the gravity wave “source” region. Quantifying the coupling between gravity wave winds and electric fields is easiest at the equator, where horizontal magnetic field lines cannot easily short out the fields. Two sounding rockets were launched from Kwajalein, Marshall Islands, as part of the NASA EQUIS II rocket campaign, in order to study neutral-plasma coupling near the magnetic equator. Each payload, launched on separate nights, carried instruments which measured electric fields, plasma densities, neutral densities, neutral turbulence and winds in the altitude range between 90 to 160 km. Ground-based all-sky airglow imagers were used to monitor gravity (buoyancy) wave activity in the upper mesosphere, and the Altair radar was used to monitor ionospheric conditions prior to launch. The first rocket was launched on the night of Sept. 3, 2004, through a quiet ionosphere with moderate gravity wave activity. Unfortunately, the electric field instruments did not deploy, and no useful electric field data was gathered. Measurements of winds, temperatures and neutral densities were not affected by the malfunction, and analysis of these data is ongoing. The second rocket was launched on Sept. 17, 2004, through a moderately active ionosphere with moderate gravity wave activity. Preliminary analysis of the upleg data shows good correlation between the neutral wind and electric field data, with electric fields of a few mV/m associated with wind speeds of about 80-100 m/s. Further analysis, including in-situ neutral density and plasma density, as well as downleg data is needed to determine how the electric field generation efficiency is affected by plasma and neutral density perturbations.

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