Introduction

The Robinson Formulas are widely used by the space physics community to calculate the Earth’s ionospheric conductance. However, despite the popularity of the formulas, the accuracy and limitations are unknown since the original study applied limited observational data, a simplistic electron impact ionization model, and the geomagnetic, atmospheric, and ionospheric background conditions were not considered. Figure 1 below illustrates the fit for the Robinson Formulas with other studies at the time.

In this study, we employ 4 empirical models to self-consistently calculate ionospheric Pedersen (ΣP) and Hall (ΣH) conductances under various conditions and use our results to evaluate the limitations of the Robinson Formulas. Specifically, we used the Fang et al. (2010) parameterization model to calculate the impact ionization of precipitating electrons, and the Naval Research Laboratory Mass Spectrometer Ionospheric Scatter (NRLMSIS) model, the International Reference Ionosphere (IRI 2016) model, and the International Geomagnetic Reference Field (IGRF-13) model to specify atmospheric, ionospheric, and magnetic background conditions, respectively.

Methodology

Figure 2 to the right displays the altitude profile of the particle ionization rates due to precipitating electron impacts. We applied the Fang et al. (2010) parameterization model to the atmospheric density distributions of N2, O2, and O. We limit the altitude range to 80-320 km and the precipitating electron energy range to 1-15 keV because it is safe to assume chemical equilibrium under these conditions.

The ionization rates are used in tandem with the IRI 2016 model to calculate the e−, NO+, O+, and O− density distributions and collisional frequencies. The IGRF-2013 provides magnetic field values that are used to calculate the gyrfrequencies of each charged species, then the conductivity of the ionosphere can be calculated, as seen by the figures to the left.

We can observe Pedersen and Hall conductivities both peak around 120 km, energy-dependently. We also see Hall has a larger peak conductivity, but Pedersen has a larger magnitude at higher altitudes. By integrating the conductivity with height, we receive the conductance values.

Results

Conductance with Spatial and Background Variation

The two longitude/latitude plots on the right, centered on the North Pole, express the normalized ΣP and ΣH averaged in respect to energy. The highest conducting zone is located on the noon side because the Solar radiation creates more ions through photoionization. The second highest conducting zone is the midnight side because electrons precipitate from the magnetic field lines. ΣP shows about 4% greater max variation than ΣH, but the distribution shapes are similar.

Conductance with Varying Precipitation Levels

On the left is a comparison of our conductance results (red) to several other papers. We can see the Robinson et al. (1987) falls between the min and max for all energy levels of our results with exception to the 1-3 keV range where the Robinson Formulas are an underestimate. Spiro et al. (1982) and Wallis and Budzinski (1981) provide drastic over- and underestimates, respectively, whereas Coumans et al. (2004) and Vickery et al. (1981) fit far closer to our results, especially. The Coumans data shown here is at F10.7 200, AP 5, and is an underestimate for the ΣP plot, which appears consistent with Figure 5 where ΣP is lower with higher F10.7 index. We also observe each study agrees that the ΣP peaks around 3 keV except Robinson which peaks closer to 4 keV, suggesting inconsistency in the Robinson Formulas.

Conclusions

❖ ΣP and ΣH exhibit significant variation in respect to spatial distribution, as seen in Figure 4.
❖ ΣH is far more sensitive to varying background conditions than ΣP at energies lower than 6 keV, as seen in Figures 5 and 7.
❖ ΣH is directly related to solar and geomagnetic activity, whereas ΣP is inversely related, as seen in Figure 7.
❖ The Robinson Formulas are not consistent with our results, or the results from other several studies, as seen in Figures 6 and 8.

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