at $E>300$ keV, above the CHEM energy range, both He^+ and O^+ have larger rates than H. Similarly for ring current He^+, neutral H is the most important target for $1<E<300$ keV, with He, O, and O^+ making important contributions at both higher and lower energies. For this same energy range, He^+ ionization is dominated by H^+, followed by neutral H; but above a temperature critical threshold of about 300 keV, electron impact ionization is the most important. He^{++} single-electron capture is dominated by neutral H, with He^+ important only at large altitudes. He^{++} double-electron capture, though seemingly less important than single-electron capture, can nonetheless be important wherever the He^+ ionization rate exceeds the He^{++} and He^+ single-electron capture rates. In such a region, double-electron capture is a true loss of He^{++}. Thus charge exchange with magnetospheric constituents other than neutral hydrogen can be important.

Geocorona. Neutral atoms fill a region near the Earth forming the geocorona. There have not been direct measurements of the geocorona, though for hydrogen alone, there have been estimates based on scattered sunlight [e.g., *Carruthers et al.*, 1976; *Bertaux*, 1978; *Rairden et al.*, 1986], which are model dependent. The *Chamberlain* [1963] model uses only three parameters to describe the density as a function of altitude: an exobase density in the ionosphere, an exobase temperature, and a ratio of particles that are on ballistic trajectories compared to those in satellite orbits. *Rairden et al.* [1986] have used DE 1 images of resonantly scattered solar hydrogen Lyman alpha light (1980-1985) to estimate these parameters for H, finding an exobase density of 44,000 cm^{-3}, an exobase temperature of 1050 K at an altitude of $R_c = 1.08\ R_E$, and a satellite critical radius, R_{sc}, of 3.0 R_c. Because of the simplified Chamberlain model, these parameters neither match the measured values in the mesosphere as modeled by MSIS86 [*Hedin*, 1987], nor correctly handle the satellite critical radius [*Bishop*, 1985], or charge exchange [*Tinsley et al.*, 1986]. Thus we check these neutral hydrogen densities against the "AMHT minimum" semi-empirical Monte Carlo model [*Anderson et al.*, 1987] (see Figure 9).

In the Chamberlain model, the density of the geocorona falls as an exponential of the mass over temperature. Thus for similar temperatures, the He geocorona is predicted to diminish to 0.01% of the H by $L\sim3$, and O would be correspondingly less. Charge exchange, however, provides an alternate source for the neutrals, so that a substantial He corona may exist (J. Bishop et al., The extended

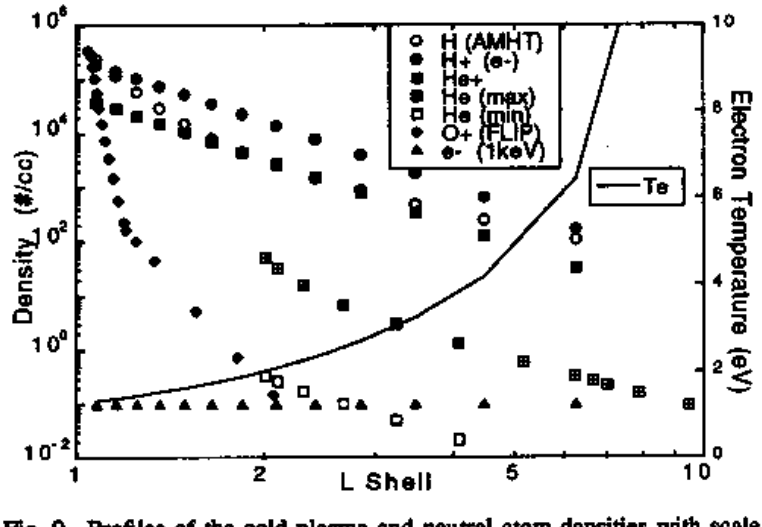

Fig. 9. Profiles of the cold plasma and neutral atom densities with scale on left axis. FLIP code run for solar minimum conditions. Solid line is predicted (see text) cold electron temperature using scale on right axis.

dictions, but we include neutral He for the sake of completenes Although there is no experimental evidence for an O geocorona, w note that O^+ beams are observed at high latitudes [*Shelley et a* 1972], and charge exchange with neutral H is an effective proce for producing neutrals [*Hodges*, 1991; *Hodges and Breig*, 199 Thus it seems not too improbable that an O geocorona may for so we have included it with a density arbitrarily set equal to the H geocoronal density.

Plasmasphere. The plasmasphere electron densities are ha to model because of the marked local time asymmetries of t plasmapause [*Horwitz et al.*, 1990*a*]. Within the plasmasphere, t density is usually taken to be a power law in L, with L^{-4} bei the most frequently quoted dependence. This agrees both wi the plasmasphere electron densities derived by *Carpenter and Pa* [1973] from whistler propagation studies and in situ measuremen [*Chappell*, 1972; *Horwitz*, 1987; *Decreau et al.*, 1982]. GEO [*Farrugia et al.*, 1989] and DE [*Horwitz et al.*, 1990*a*] data sho that during quiet times, either there is no plasmapause, or that occurs at $L>7.5$, particularly at dusk. Thus, in the plasmasphe we use the following expression:

$$n_e = n_{H^+} + n_{O^+} + n_{He^+} = 250{,}000/L^4, \qquad (1$$

which agrees with the GEOS plasmasphere densities. Note th a more recent model (published while this manuscript was preparation) [*Carpenter and Anderson*, 1992] gives $\log(n_{H^+}) = -0.3145L + 3.9043$, which is a factor 2–5 less dense than equati 6 for the range $L>2.5$, and is in better agreement with the "FLI plasmasphere refilling model [*Richards and Torr*, 1985], whi uses ionospheric plasma densities and temperatures (see Figure 9

The composition of the plasmasphere is also important for eva uating the charge exchange rates. *Young* [1986] estimates th generally H^+ dominate the plasmasphere, with He^+/H^+ ratios b tween 10 and 50%, and O^+/H^+ around 0.1%. However *Horwitz al.* [1984] show plasmasphere profiles where O^+ dominates duri storm recovery periods, but more typically is 5–10% of the H during extended quiet conditions. As a partial resolution of th discrepancy, we note that the O^+ increase is generally in the out part of the plasmasphere [*Horwitz et al.*, 1990*b*], which is also t region of most importance for ring current losses. Thus we will u intermediate values of 10% for He^+/H^+ and 1% for the O^+/H ratios.

Wave Losses

We have not incorporated other proposed loss mechanisms in the model; in particular, we have not included pitch angle scatteri into the loss cone. The standard mechanism for scattering [*Cor wall*, 1966; *Kennel and Petschek*, 1966] predicts that the anisotro ic "pancake" distribution of trapped ring current ions will becon unstable in the presence of a cold ion population, producing ion c clotron waves that cause the scattering. However, neither Explor 45 observations of ions [*Williams and Lyons*, 1974] during stor recovery nor AMPTE/CCE observations of ULF waves [*Anders et al.*, 1992; *Takahashi and Anderson*, 1992] during quiet tim show significant waves below $L=7$. Furthermore, pitch angle di tribution plots of our data set revealed little if any isotropization the pancake distributions as expected for waves [e.g., *Joselyn a Lyons*, 1976]. Nor did a study of storm injections reveal "stron pitch angle scattering [*Kistler et al.*, 1989] in the ring current. Th we have not incorporated wave-particle losses in the model.