A new Vary-Chap model of topside electron density profiles based on ISIS-2 sounding data

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Using ISIS-2 topside sounding data, a new representative model of the topside electron density distribution is being developed for use in IRI. A major challenge for topside \(N(h)\) modeling is finding a suitable mathematical representation of the topside vertical profiles. Many representations have been proposed including exponential functions, Epstein functions, sech-squared functions, and Chapman functions with one or two fixed scale heights. The Vary-Chap function is a generalized \(\alpha\)-Chapman profile, based on the work by Rishbeth and Garriott [1969], that uses a continuously varying shape function \(S(h)\):

\[
\frac{N(h)}{N_m} = \left[ S(h) \right]^{\alpha} \exp \left[ \frac{1}{2} (1 - Y - \exp(-Y)) \right], \quad Y(h) = \frac{1}{h_m} \int_{h_m}^{h} \frac{dx}{S(x)} \tag{1}
\]

Here \(N_m\) and \(h_m\) are the density and height of the F2 peak. According to Huang and Reinisch [2001], Equation (1) can be solved for \(S(h)\) as function of \(N(h)\):

\[
S(h) = \left( \frac{N(h)}{N_m} \right)^{\frac{1}{\alpha}} \left[ 1 + \int \left( \frac{N(z)}{N_m} \right)^{\frac{1}{\alpha}} \right]^{-1} \left[ 1 - \int \left( \frac{N(z)}{N_m} \right)^{\frac{1}{\alpha}} \right]^{-1}, \quad z = \frac{h}{h_m} \tag{2}
\]

The shape functions \(S(h)\) were derived for \(\sim 80,000\) ISIS-2 topside profiles. Each shape function is expressed as a parameterized function \(S^*(h)\)

\[
S^*(h) = \frac{1}{S_1^{-1}(h) + S_2^{-1}(h)} \tag{3}
\]

with

\[
S_1(h) = c_1(B, h_T, \alpha) \left[ \text{sech}^2 \left( \frac{h - h_m}{B} \right) \right]^{-1}, \quad h_T \text{ is defined as the transition height where } S_1 = c_1 S_2, \quad \alpha \text{ defines the steepness of } S^*(h) \text{ for heights above } h_T.
\]

This functional representation characterizes the shape of the topside profile without directly depending on the F2 peak height and density. The selected function \(S^*(h)\) allows to solve the integral in (1) analytically assuring time-efficient processing of the profile data. The three parameters in \(S^*\) are binned according to season, latitude,
local time, and solar activity. The example in Figure 1 illustrates the Vary-Chap process for a mid latitude topside profile.

Figure 1. The left panel shows functions $S_1/c_1$ and $S_2$, and the composite function $S^*; \text{ the circles show the shape function } S(h) \text{ derived from the ISIS profile. The right panel show the measured ISIS profile } N(h) \text{ (circles) and the reconstructed profile } N^*(h) \text{ calculated with the shape function } S^*.$

References
