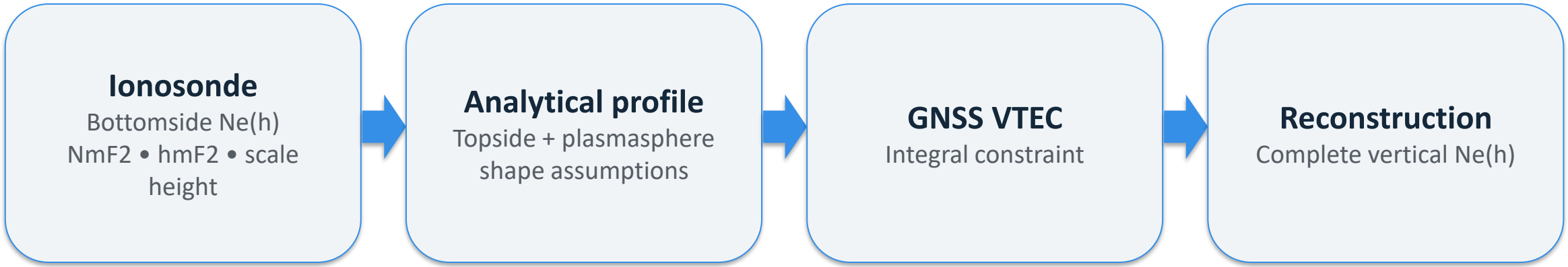
Electron density height-profile reconstruction (1D reconstruction)

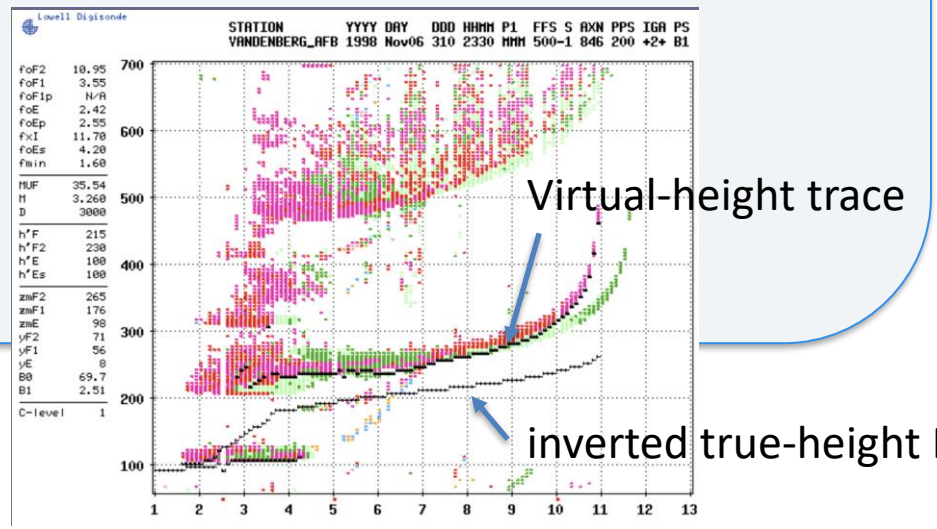


Core idea: combine direct bottomside observations with a physically plausible topside shape, then constrain the integrated profile with VTEC.

What is observed — and what must be reconstructed?

Observed: Bottomside Characteristics

- Virtual-height trace is inverted to a true-height Ne(h) profile
- Direct information up to the F2-layer peak
- Provides NmF2, hmF2 and a characteristic scale height



Reconstructed: Topside (above hmF2)

- The profile is not directly observed by the ground-based ionosonde
- Topside ionosphere and plasmasphere require a profile-shape assumption
- The reconstruction is therefore not unique without additional constraints

Analytical functions represent the missing topside shape

Chapman $$N(h) = N(h_m)exp\left\{c\left[1 - \frac{h - h_m}{H} - exp\left(-\frac{h - h_m}{H}\right)\right]\right\}$$

The shape of the layer is related to the balance between ionization production and plasma loss in an atmosphere whose neutral density changes with altitude.

c: the type coefficient c = 0.5 (α-Chapman layer); c = 1 (β-Chapman layer), depends on assumptions related to the electron density recombination theory (Hargreaves, 1992).

Epstein $$N_i(h) = N_i(h_m)sech^2\left(\frac{h - h_m}{2H_i}\right)$$

Smooth symmetric layer representation, centered on a density maximum, with a gradual transition from the peak into the topside

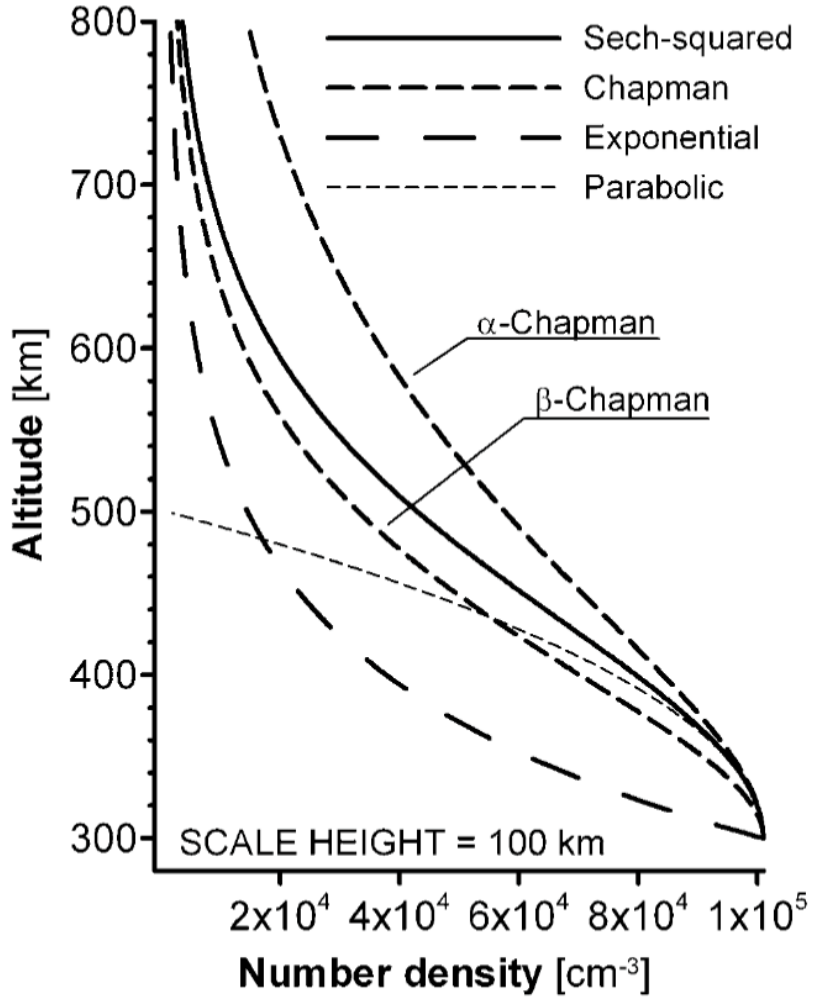
Exponential $$N_i(h) = N_i(h_m)exp\left(-\frac{h - h_m}{H_i}\right)$$

The simplest diffusive-equilibrium decay of an ion population with altitude when a constant scale height is assumed.

hm: the peak density height ; H : the scale height

Different profile assumptions can satisfy the same integral electron content.

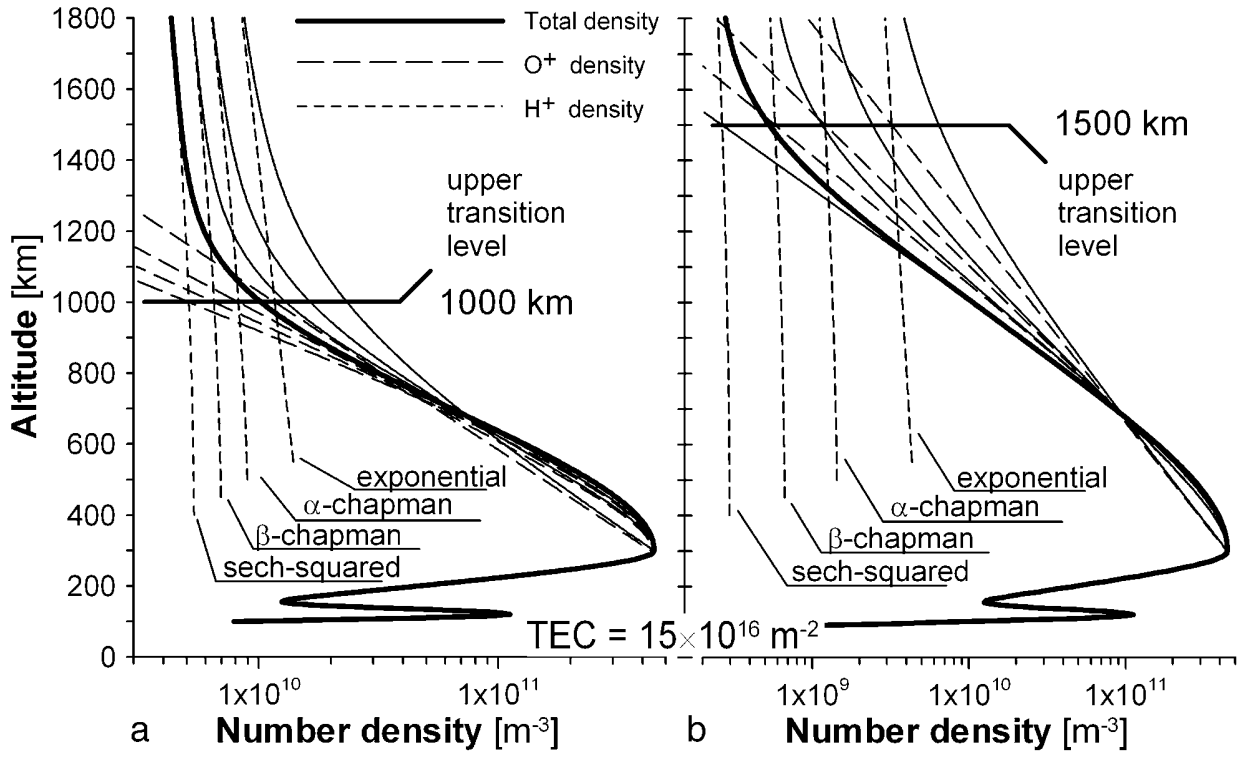
What is the difference between the three profilers?



The three profilers differ mainly in how they represent the transition from the F2 peak to the diffusively controlled topside (i.e. how quickly particles, heat, or chemicals can spread from an area of high concentration to an area of low concentration.

- The **exponential profile** assumes that density simply decreases with a constant characteristic scale height.
- The **Epstein profile** (Sech-squared) represents a smooth plasma layer, producing a more gradual decrease close to the peak before approaching exponential-like behavior at higher altitudes.
- The **Chapman profile** additionally reflects the physics of ion production and loss that creates the ionospheric layer, producing a characteristic curvature around the peak before approaching an exponential-like decrease at high altitude.

VTEC adds an integral constraint — but not a unique solution



VTEC = ∫ Ne(h) dh

- GNSS VTEC constrains the integrated electron content of the complete profile.
- Model parameters can be adjusted until reconstructed TEC agrees with observed VTEC.
- But the same TEC can result from different vertical profiles and O^+/H^+ transition heights.

TEC constrains the area under Ne(h), not its unique vertical distribution.

NeQuick: climatology-driven full-profile reconstruction



NeQuick 2

Computes a smooth electron-density profile from position, time, and solar activity. Climatological layer peaks feed semi-Epstein bottomside and topside profiles, then numerical integration gives TEC.

Key distinction: Standard NeQuick 2 represents median ionospheric climatology; separate data-ingestion methods can adapt it to TEC and ionosonde observations.

TaD: observation-constrained topside reconstruction



Topside Sounder Model assisted by Digisonde (TaD)

Reconstructs the topside ionosphere and plasmasphere to ~20,000 km using F2-peak observations, analytical ion profiles, and co-located GNSS TEC.

Key distinction: the reconstruction is anchored to the actual ionospheric state observed by Digisonde and GNSS.