Topside ionosphere modelling using GPS data: possibilities for South Africa

P. Sibanda[1,2] L.A. McKinnell[1,2]

[1]Hermanus Magnetic Observatory, South Africa

[2]Department of Physics and Electronics
Rhodes University, South Africa

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Outline

Objectives

- Main objective - to develop a regional topside model for the South African region

- driven by the need to expand our current South African Bottomside Ionospheric Model(SABIM)
  - represents electron density profile upto hmF2
  - based on South African ionosonde data

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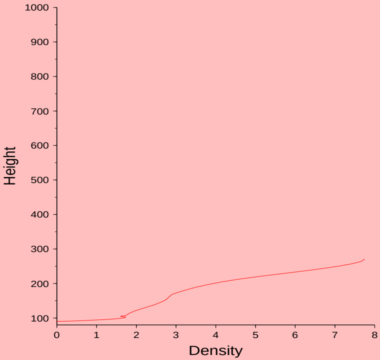

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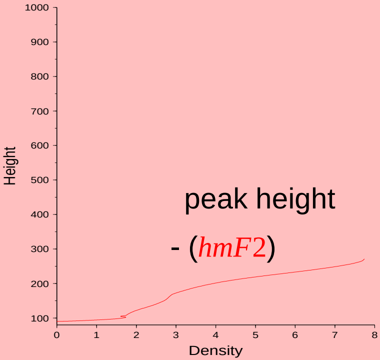

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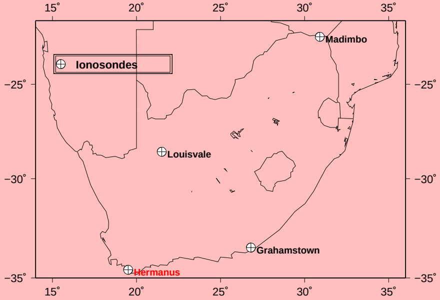

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Difficulties in topside modelling

- Limiting factor in modelling the topside ionosphere is the relative scarcity of experimental data
- Ground based ionosondes can only measure the bottomside region up to the height of the F2-peak
- The few satellite-borne topside sounder missions such as Alouette, ISIS 1 & 2 and Intercosmos 19, provided sets of topside data, but with a limited coverage of the relevant geophysical conditions
- Coverage of the Southern African region is sparse within the topside sounder database

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Ionospheric characterisation using GPS TEC

- Since the late 1990s, Global Positioning System (GPS) has been used to measure the total electron content (TEC)
- Various techniques to use GPS TEC to provide vertical profiling of the ionosphere have also been developed

Ionospheric tomographic reconstruction

- A technique whereby a vertical cross section through ionospheric electron density can be imaged
- Tomographic reconstruction algorithms and calculated TEC values are used together to reconstruct ionosphere electron density image for a given scenario

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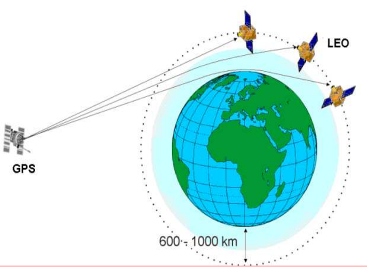
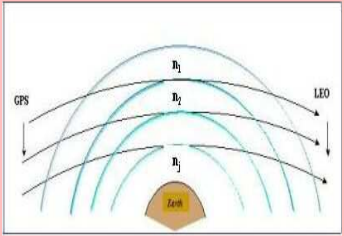
Occultation (Jakowski et al., 2002)

- use relative motion between the GPS and LEO satellite to provide a vertical scanning of the ionosphere
- radio waves sample the layers of the atmosphere successively
- use phase variation of the GPS signal to retrieve a vertical profile of bending angle





GPS TEC, Ionosonde and UTH measurements

Stankov and Muhtarov, 2001

Use a combination of GPS TEC, ionosonde and the upper transition height (UTH) measurements to reconstruct the electron density profile

GPS TEC, Ionosonde and UTH measurements

Factors used....

- TEC contribution from the topside ionosphere

$$TEC_t = GPS\ TEC - TEC_b$$

- Electron density as sum of the constituent ions

$$N_e(h) = N_{0^+}(h) + N_{H^+}(h)$$

- Analytically approximate ion distribution, e.g Epstein function

$$N(h) = N_j(h_m)sech^2(\frac{h-h_m}{2})$$

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Procedure

- Reconstruction formula

$$N_e(h) = N_{0^+}(h_m)sech^2(\frac{h-h_m}{2H_{0^+}}) + N_{H^+}(h_m)sech^2(\frac{h-h_m}{2H_{H^+}})$$

  - Use plasma scale height definition ($H_j = kT_j/m_jg$) to express H_{H^+} as function of H_{O^+}

- Intergrate to get topside TEC$_t$

$$TEC_t = 2H_{O^+}N_{0^+}(h_mF2) + 32H_{O^+}N_{H^+}(h_mF2)$$

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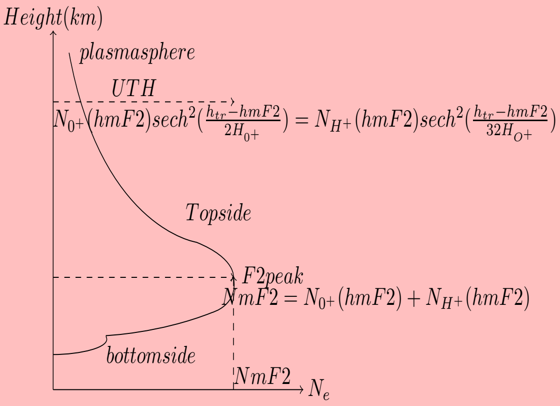
Procedure

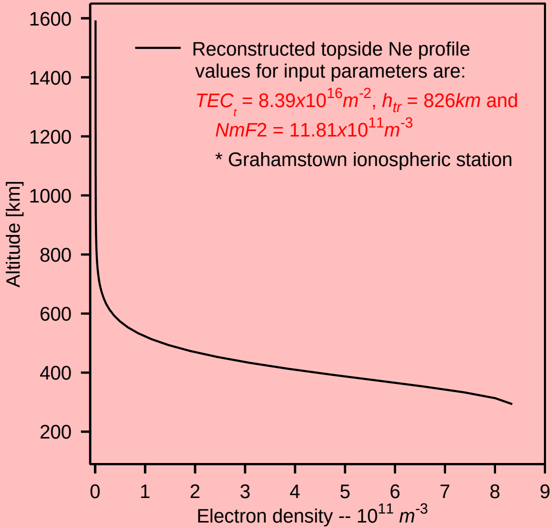
- Use Upper transition height (UTH) and F2 layer peak
  - At UTH O^+ and H^+ ion densities are equal
  - At the F2 layer peak, the sum of the O^+ and H^+ ion densities is equal to the measured electron density, NmF2



Procedure

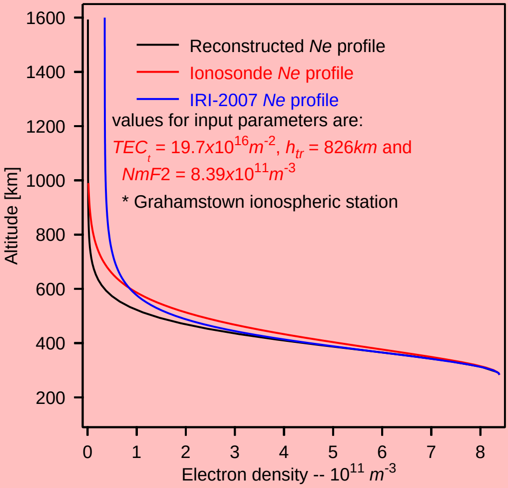
- **Three** equations, **three** unknowns; $N_{0^+}(h_mF2)$, $N_{H^+}(h_mF2)$ and H_{0+}
- Solve the system numerically using a Newton iterative procedure for the O^+ ion scale height
- Used data from the Grahamstown ionosonde and the co-located GPS receiver
- the upper transition heights provided by the Field Line Interhemispheric Plasma (FLIP) model (Richards et al., 2000)

Results



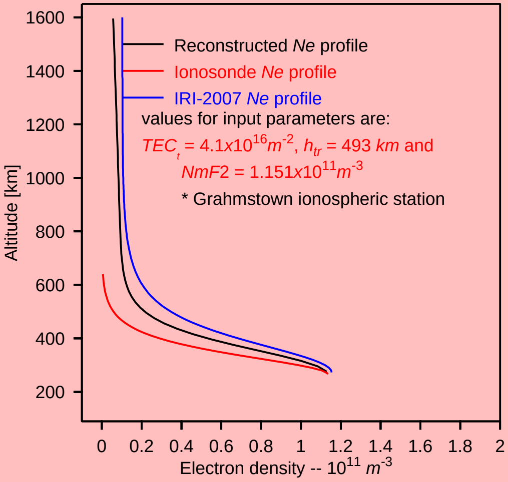
- Co-location of ionosonde and GPS receiver
- h_{tr} from the FLIP model

Comparison with other topside models



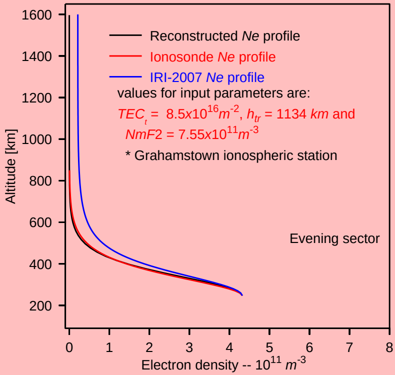
- Compared with ionosonde topside profile
  - ionosonde topside profile - $\alpha-$Chapman function with scale height from shape of bottomside profile
- Compared with IRI-2007 topside profile

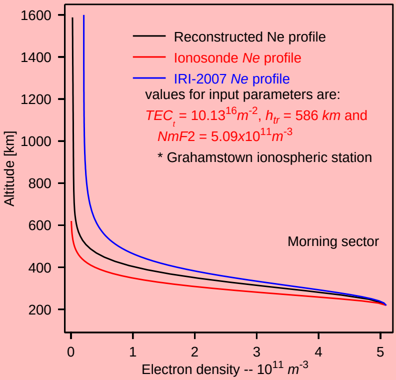
Comparison with other topside models



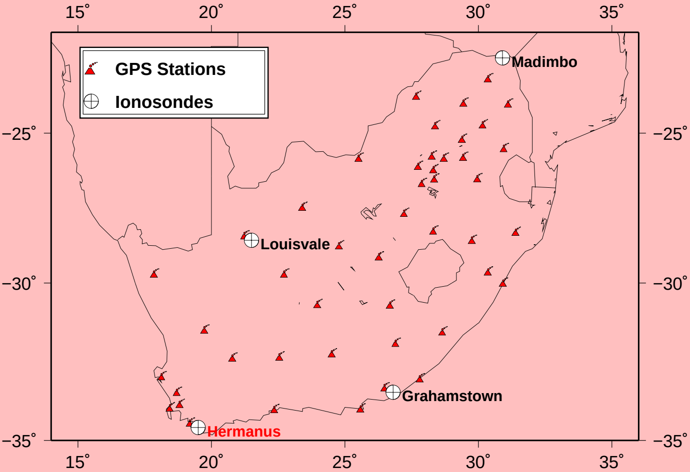
- Need to compare with masured profiles
  - no recent topside profiles!

Comparison with other topside models





GPS and ionosonde coverage of the South Africa region



Summary

- demonstrate the electron density profile can be reconstructed from its integral quantity, TEC.
- One advantage the Ne profile is tied to reliable measured TEC
- GPS-TEC measurements in South Africa present a new data resource for the topside ionospheric modelling efforts

Acknowledgements

- Thanks to the URSI for the travel support.
- My advisor and others

References

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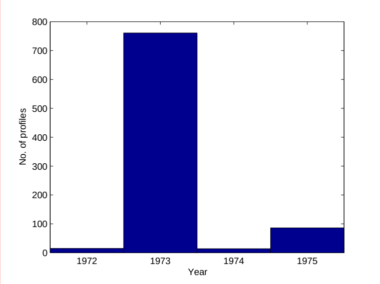
Example, in the ISIS 2 database

Coverage of Southern African region

- Available measured profiles & distribution over the various geophysical conditions
- over the 4 years period (1972 – 1975)



Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1972	-	-	-	-	-	-	-	19	-	-	-	-
1973	-	2	184	54	-	121	1	1	312	-	-	148
1974	17	-	-	-	-	-	-	-	-	-	-	-
1975	-	-	-	-	-	85	-	1	52	-	-	1