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Space Weather Services and Potential Improvements Using RO Data

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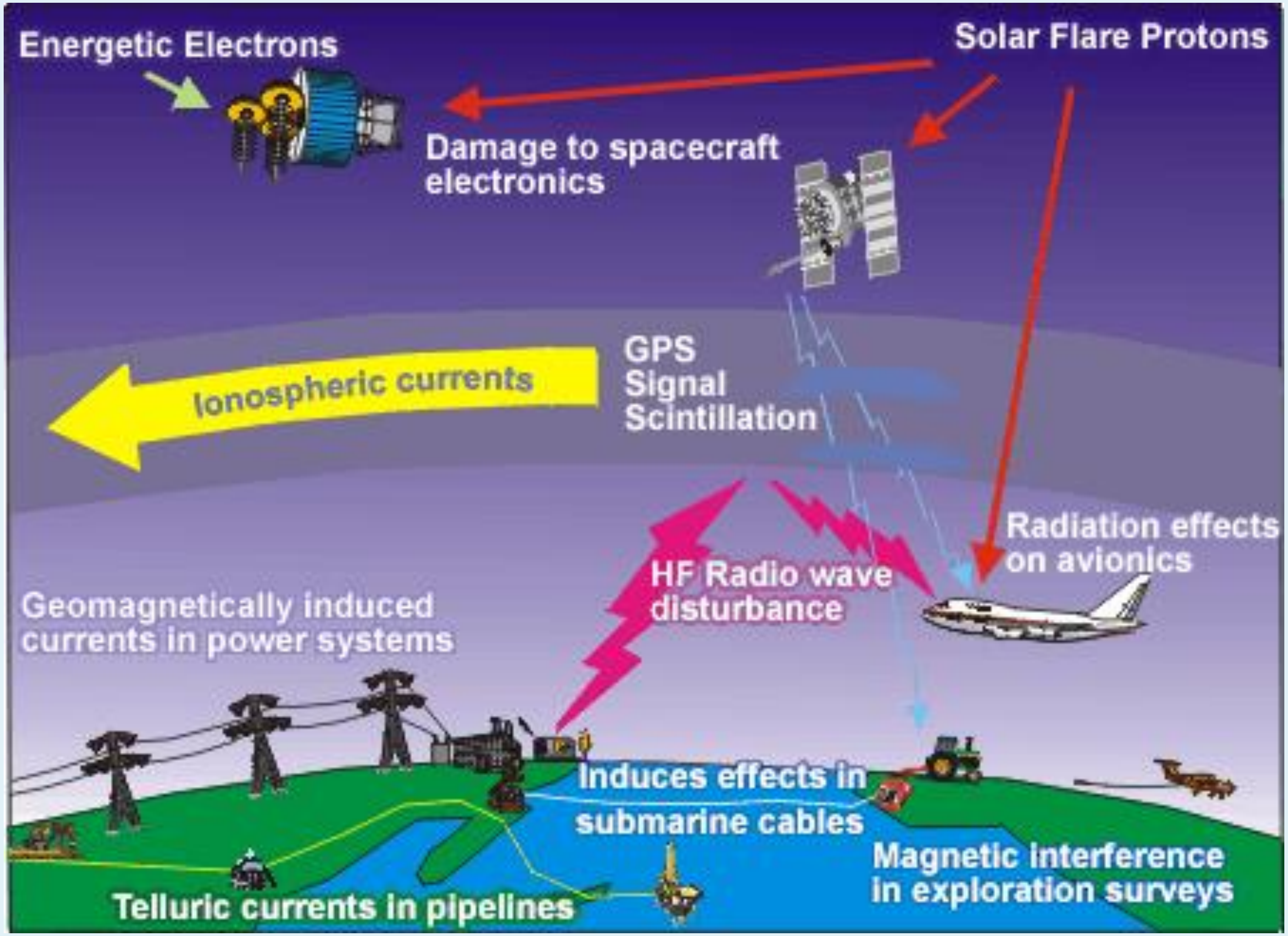
Space Weather



Space Weather Services, Bureau of Meteorology

- We are the Australian Government provider of space weather services
- Our strength compared with other similar agencies around the world is in HF radio propagation which is backed by a propagation model driven by ionosonde soundings
- We also have much more recently developed services aimed at satellite communication and positioning applications however these are not yet sufficiently developed to provide the ideal support that these users needs

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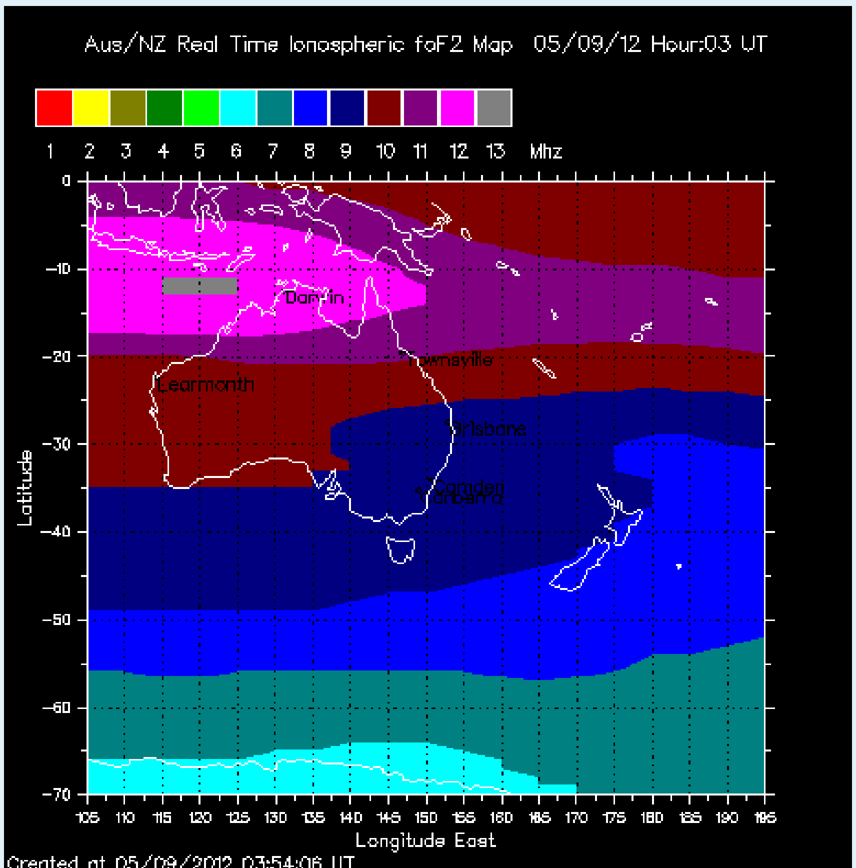
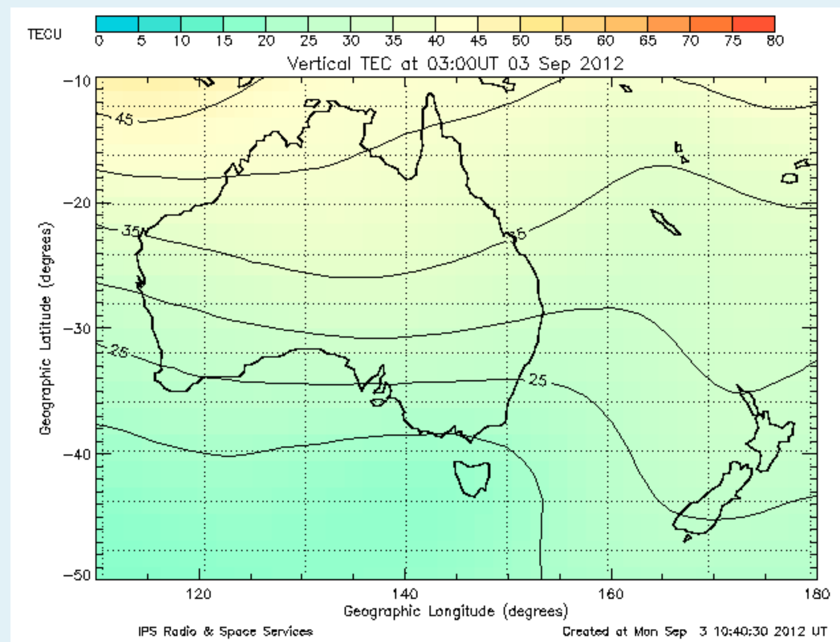
One Ionosphere, Two Maps

foF2 map for HF radio services



Total Electron Content (TEC) Map for GNSS services



Services Drivers for new Ionospheric model

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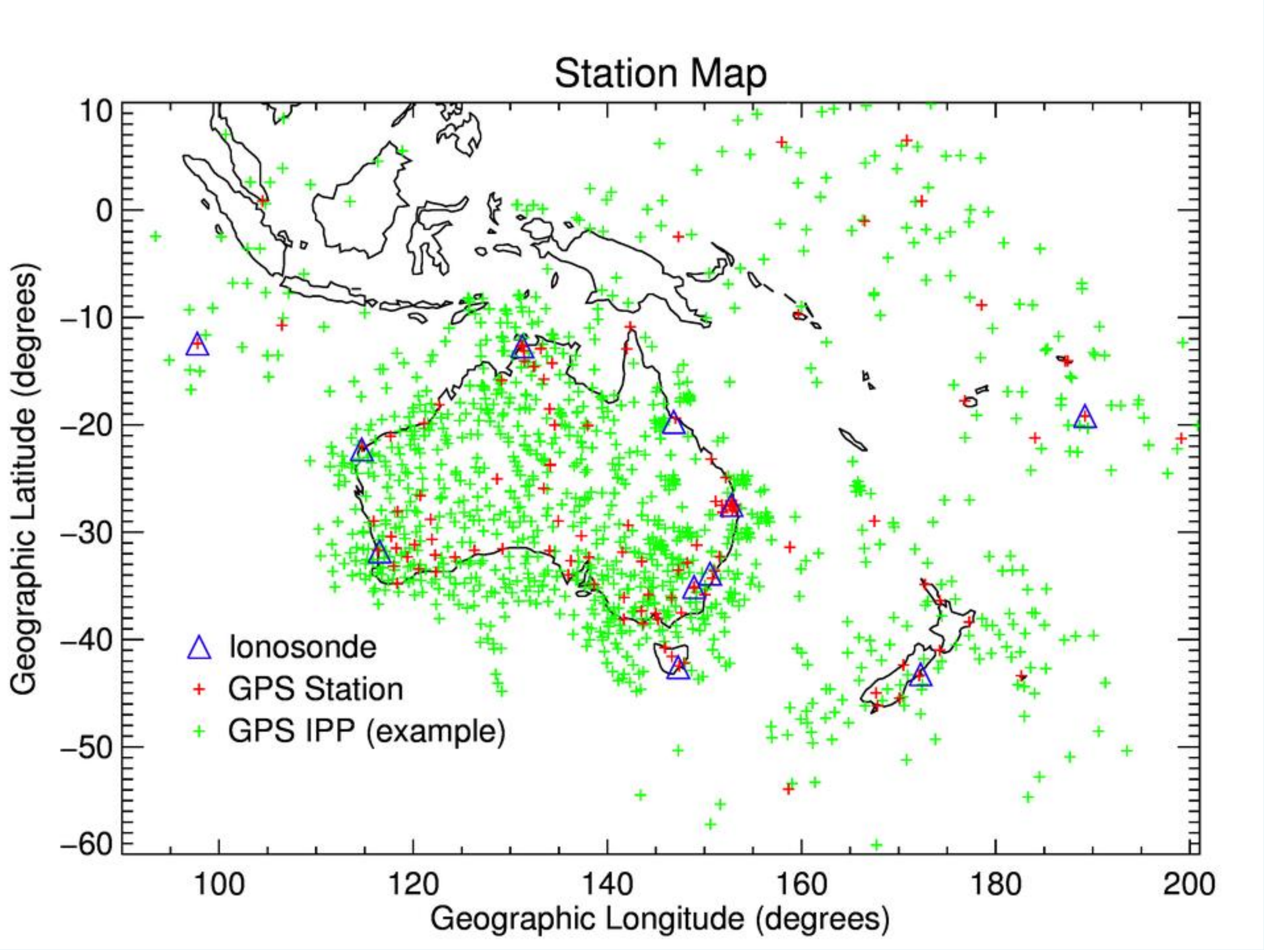
- The typical 'thin shell' 2D VTEC mapping approach using GPS TEC data is inherently limited and unable to achieve accuracy requirements for supporting rapid ambiguity resolution in PPP. We need a more complex 3D map.
- Ionosonde are large and expensive so there is no way to increase the very sparse network. Including GPS TEC data into a combined model to produce foF2 and ionospheric height information would significantly improve the real time HF propagation products.

GPS CORS and Ionosonde Network



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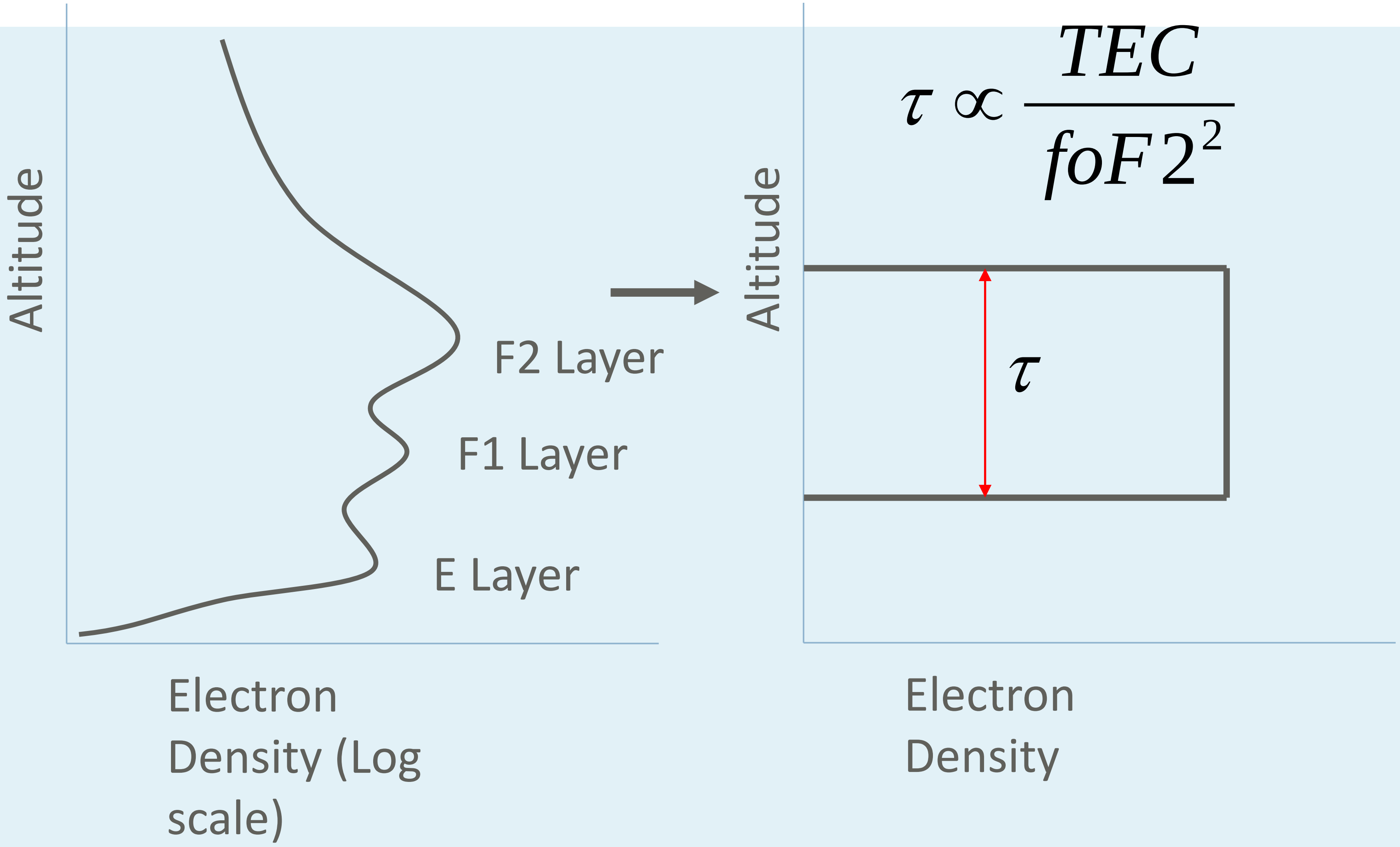
Challenges in 3D Ionospheric Mapping

- Ground to GPS altitude TEC contains several distinct physical systems including different ionospheric layers and the plasmasphere
- Combining that signal with ionosondes, which probe in detail the bottomside of the ionosphere but are blind to all else needs to be done with care
- While the network may look reasonably dense, each observation doesn't contain a lot of information, so re-constructing the full ground to 22000km electron density profile is challenging

A Crude Approach: Slab Thickness

$$\tau \propto \frac{TEC}{foF2^2}$$



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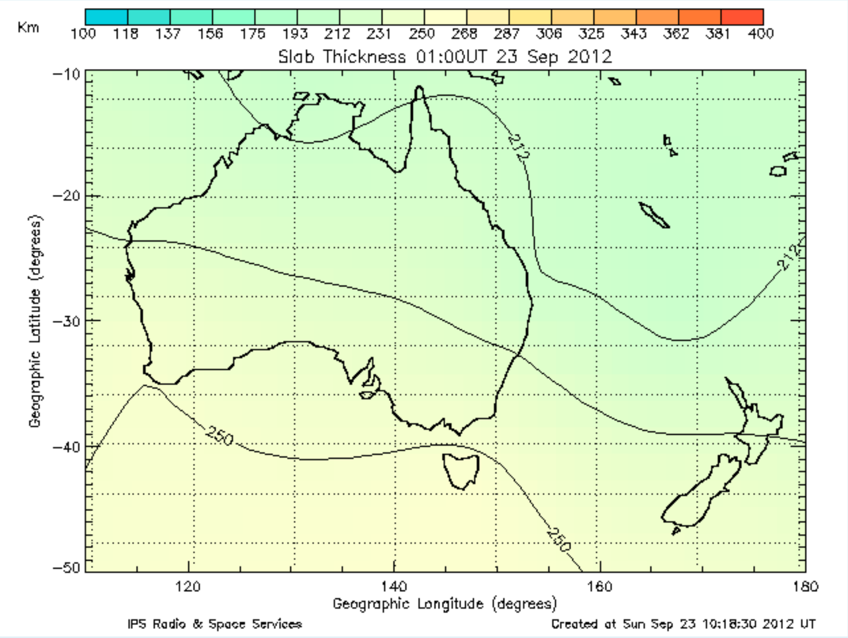
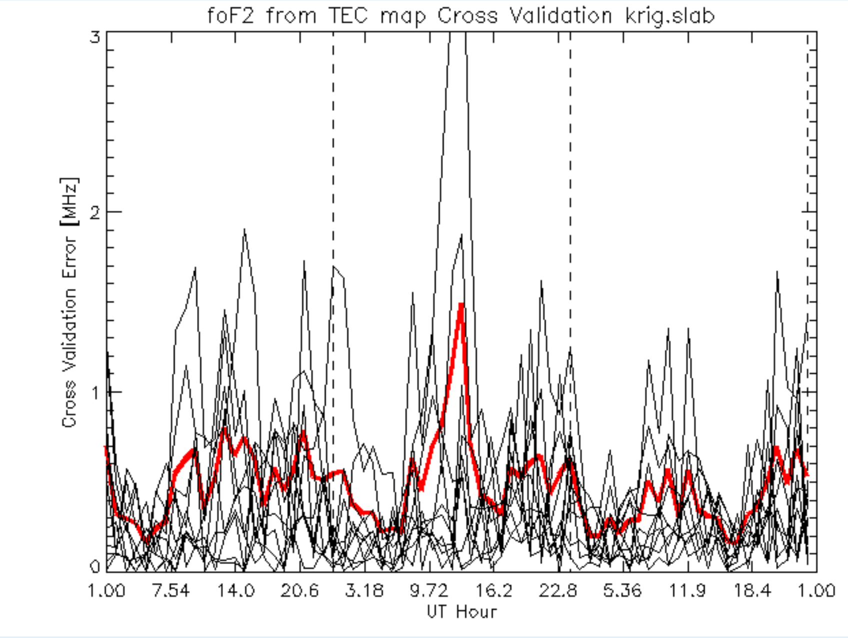
Slab Thickness Map

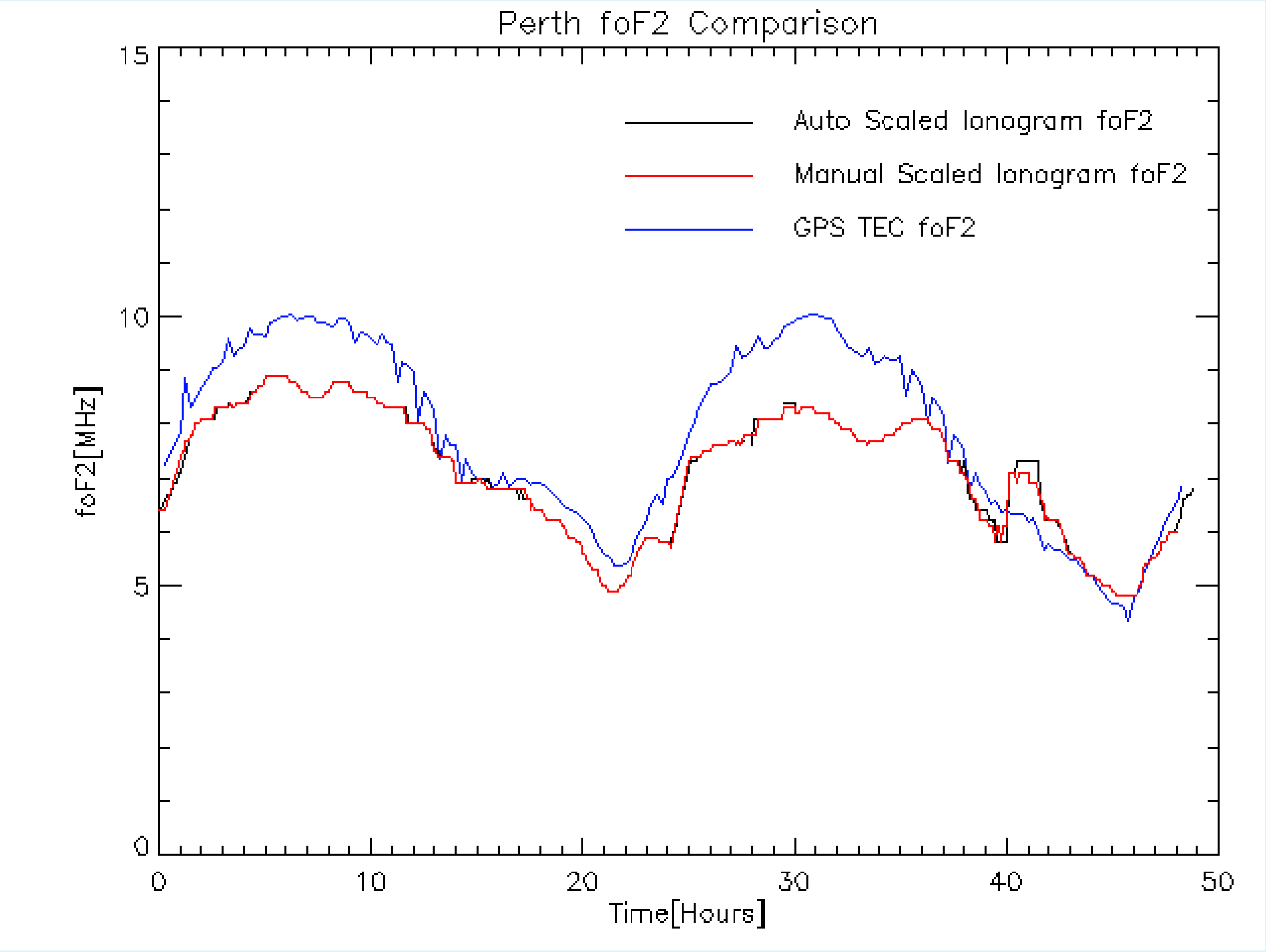
Slab thickness estimated at each ionosonde site by comparing foF2 with TEC map, then smoothed using Kriging. foF2 map then estimated by converting slab thickness to foF2 using TEC values.

Resulting foF2 map accuracy estimated using leave one out cross-validation. Typical RMS error is less than 1MHz, with some much larger spikes. Some spikes due to bad auto-scaled foF2. Accuracy at Darwin (sub-equatorial) is typically poorer than elsewhere.

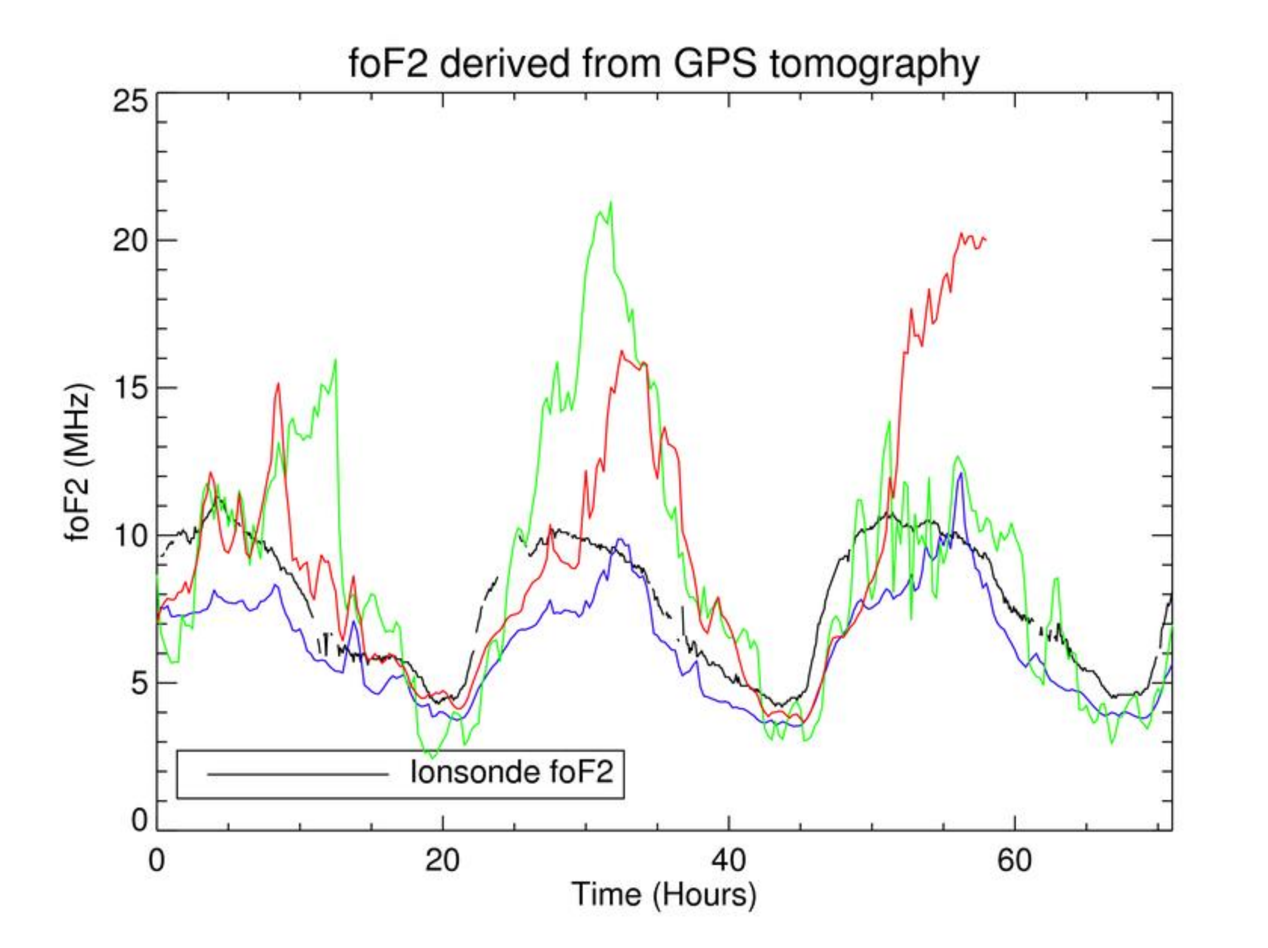




GPS TEC Tomography Derived foF2



More Complex Mapping Functions have too much freedom



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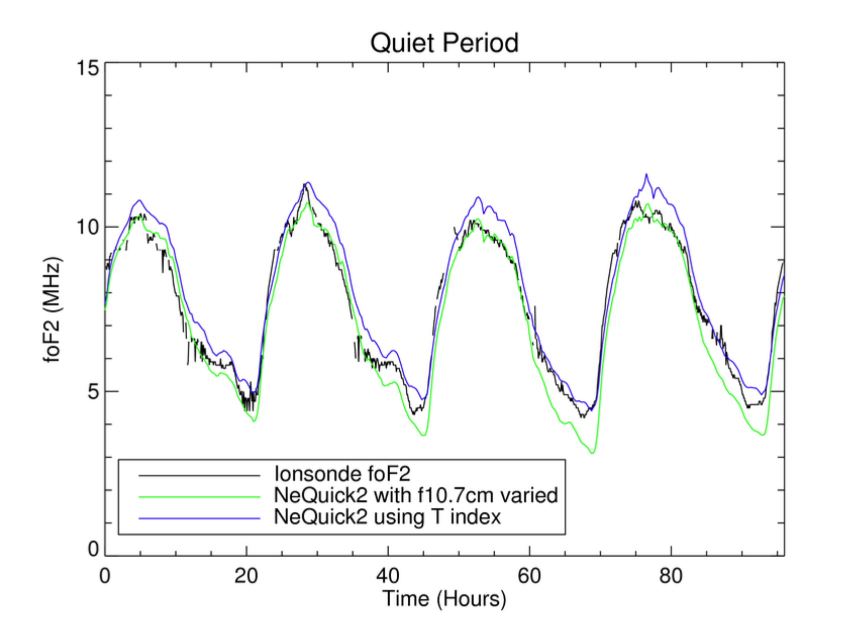
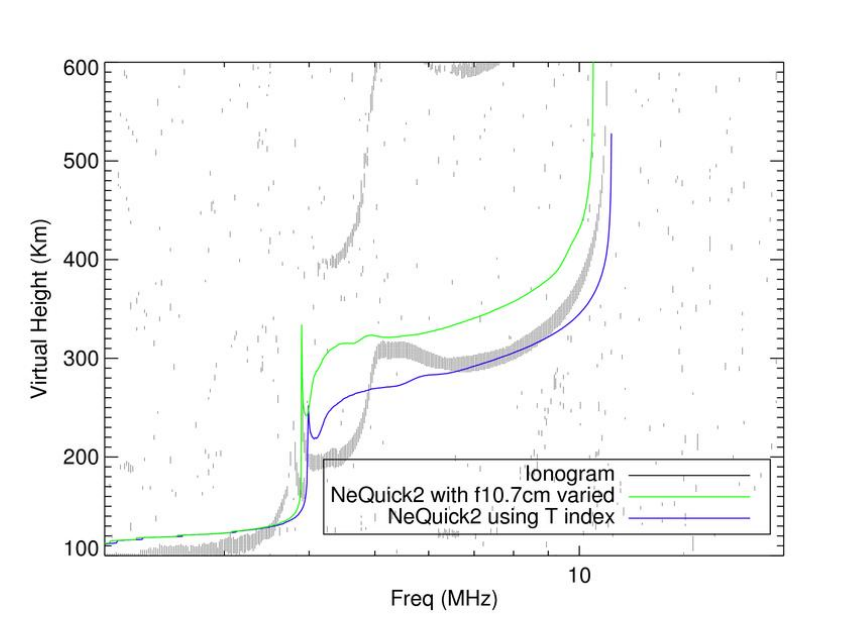
NeQuick2 Model

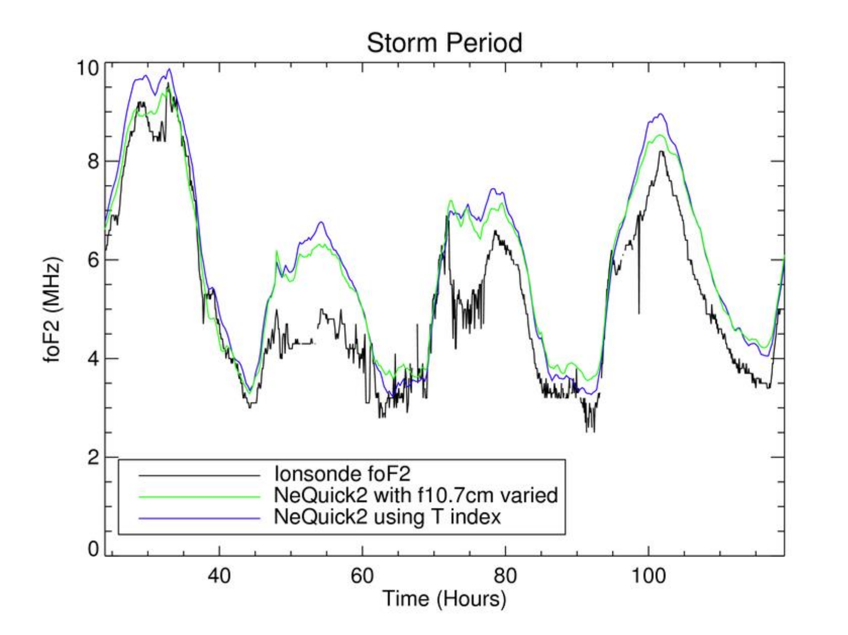
- 3 Epstein layers, topside F2 layer with height dependent thickness.
- Driven by (effective) f10.7cm, which at the first level, determines foF2 and hmF2.
- Other parameters derived from climatological analysis, given f10.7cm, foF2 and hmF2.
- See http://t-ict4d.ictp.it/nequick2 for code and references
- We modified the model to use our T index parameter rather than f10.7cm as the primary driver.

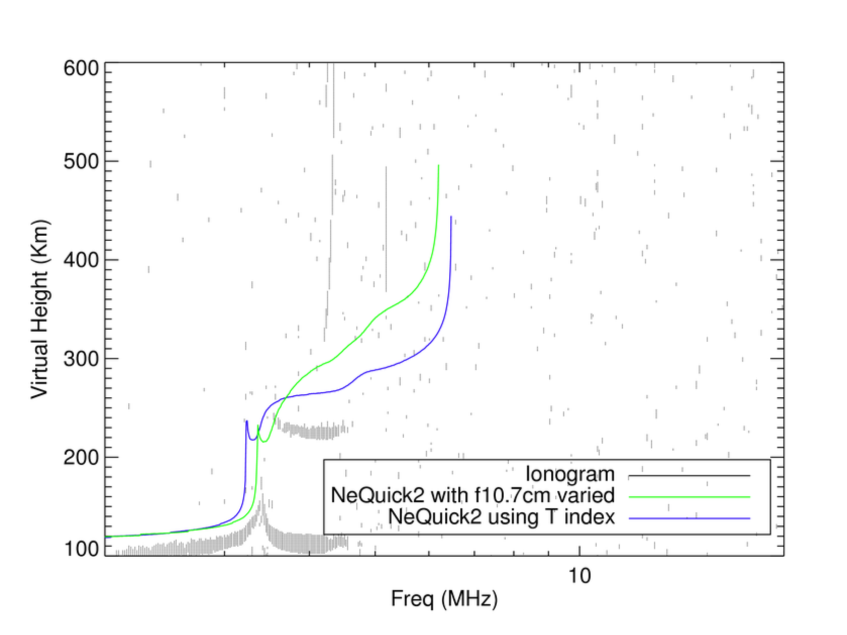
Quiet time results





Storm Results





Problem in Storms

- The storm time ionosphere has different relationships between F2 layer height, thickness, peak density and topside density than the quiet time climatology assumed in NeQuick2 and the T index.
- Our best guess is that the topside is too weak compared with the F2 peak density during this storm, requiring the model foF2 to be too high to reproduce the observed TEC.
- The model needs some additional freedom to replicate storm time behavior, but we need to maximise the information encoded in that freedom and need the data to constrain it
- We need to know what is going on in the topside and plasmasphere. RO data is the obvious candidate to give a different and independent perspective

High Precision TEC model for positioning

- Even in non-storm times, the existing GPS only or GPS + Ionosonde ionospheric maps are not sufficiently accurate to support some potential applications in positioning that require ~few centimetre accuracy (sub TECU) to assist in rapid ambiguity resolution
- RO data provides a key independent view on the ionospheric topside that perfectly complements the ionosonde and GPS TEC data

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Thankyou

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