October 2023 Annular Eclipse Propagation Anomalies at HF: Preview of FST4W Observations

Part 7: Tracking the height of the 'F2 layer'

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From path velocity to 'F2 layer' height

Part 4 of these notes [1] showed measured path velocity prior to and during the eclipse on the one-hop 545 km path WO7I (DN10cw, NV, 89% obscured, WSPRSONDE-6 [2]) to ND7M (DM16xf, NV, 87% obscured, KiwiSDR). Here we use that data to calculate, and track, height *h* of ionospheric F2 refraction for the morning descent and during the eclipse.

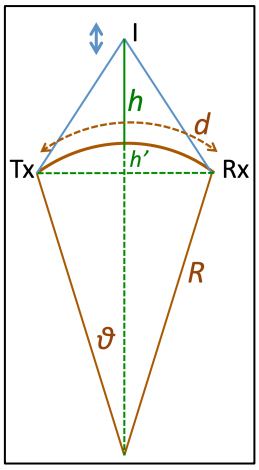

Figure 1. Diagram to show path length and hmF2 height calculations. Not to scale.

Consider the geometry in Figure 1, a refinement on the flat earth model in [3]. The knowns are: *d* great circle distance from Tx to Rx and *R* Earth's radius. We need an initial seed for the ionosphere height *h*. We use the average of h'F2 (minimum virtual height) and hmF2 (peak height) when both are stable and close, 223 km and 238 km, at15:00 UTC 14 October 2023, from the Pt. Arguello ionosonde (CM94qn, CA) 590 km SW of the WO7I to ND7M midpoint. Given the angle $\theta = d/2R$ the path distance *P* from Tx > I > Rx is:

$$P = 2.\sqrt{(R.\sin(\theta))^2 + (h + R.(1-\cos(\theta)))^2}$$

With reference height *h* of 230 km at 15:00 UTC the path length was 721 km. For each 5-minute interval prior to and after 15:00 UTC, we calculate incremental path length change as the product of time interval (s) and path velocity (m/s) from WSPRSONDE Doppler shift. Height *h* is derived from path length as:

$$h = \frac{1}{2}\sqrt{P^2 - (2.R\sin(\theta))^2} - R.(1-\cos(\theta))$$

Diurnal pattern of 'F2 layer' height

Figure 2 shows the time series of hmF2 and h'F2 from the Pt. Arguello ionosonde with heights *h* calculated from Doppler shift on the WO7I to ND7M path. Having forced agreement only at 15:00 UTC, with subsequent integration of path velocity backward and forward in time, the comparison is interesting. Prior to 15:00 UTC WSPRSONDE heights *h* tracked hmF2 (R^2=0.976, N=23). Between 15:00 and 17:00 *h* lay between hmF2 and h'F2. After 17:00, as h'F2 and hmF2 parted, *h* followed h'F2, the minimum virtual height, rather than hmF2.

Note the scatter in ionosonde hmF2 and h'F2: to quote T. Bullett, *"...hmF2 from these ionosondes is very 'noisy' ... a calculation that critically depends on small details..."* [4]. In contrast WSPRSONDE-derived heights varied smoothly. There was also no drift in *h*. Those attributes came from using Tx and Rx with all clocks GPSDO disciplined or aided, ensuring low jitter and high absolute accuracy.

Variation of 'F2 layer' height during the eclipse

P. Erickson wrote, "*a change in hmF2 is not by any means a given for an eclipse*" [4]. Nevertheless, it is useful to document the height variations and to compare the ionosonde and WSPRSONDE. Figure 3 is an expanded section of data from Figure 2, the shaded area showing eclipse start, middle and end at ground level at WO7I to ND7M mid point.

Outside the eclipse period WSPRSONDE heights *h* were very similar (R^2=0.992, N=38) on 14th and 15th, but distinctly different during the eclipse. Height anomaly, Figure 4, was remarkably smooth, peaking at 33 km higher than on 15 Oct at 16:37 UTC, 13 min after mid-eclipse.

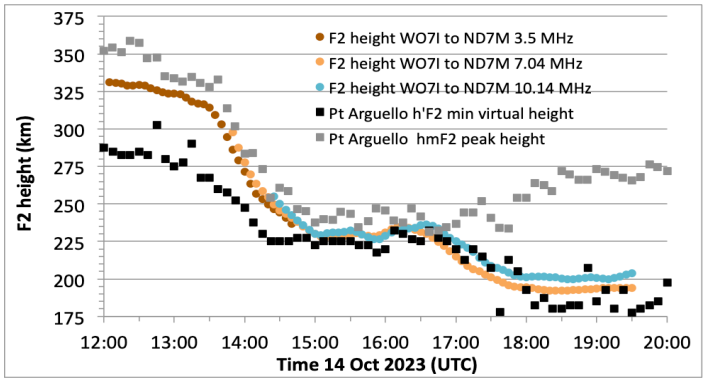

Figure 2. Time series of ionosphere F2 heights from Pt Arguello ionosonde and from WSPRSONDE at 3.5, 7 and 10 MHz on a 545 km path 87-89% obscured by the eclipse. The average of h'F2 and hmF2 at 15:00 was the seed for forward and backward integration of path velocity from the WSPRSONDE.

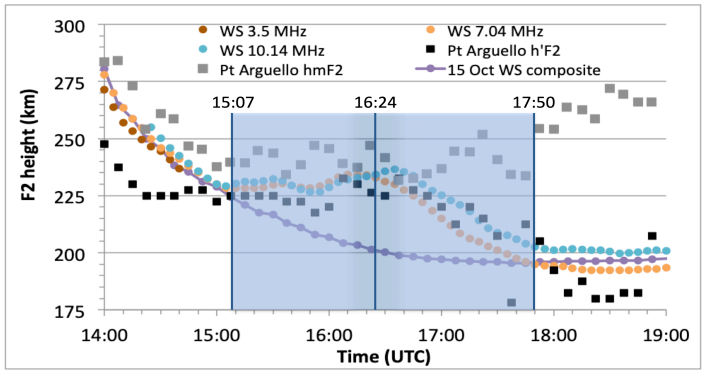

Figure 3. An expanded view of F2 heights time series with the composite tri-frequency WSPRSONDE trace for 15 October. The shaded area shows start, mid and end times of the eclipse at the earth's surface.

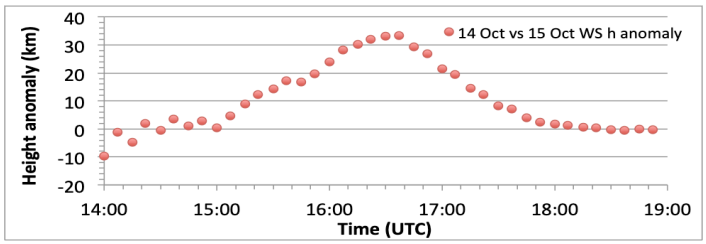

Figure 4. 'F2 height' anomaly, 14 Oct - 15 Oct from the WSPRSONDE composites for 3.5, 7 and 10 MHz.

Data availability

For WsprDaemon data a guide is available [5], with an Annex on access methods. Please acknowledge as below.

References

1. http://wsprdaemon.org/technical.html
2. https://turnislandsystems.com/
3. Collins, K. et al., 2022. Methods for Estimation of Ionospheric Layer Height... *EGUsphere, 2022*, pp.1-24.
4. groups.google.com/g/hamsci/c/6jLMVBiNxlY/m/7DpPtEJgAAAJ
5. http://wsprdaemon.org - see guide on the Timescale page.

Acknowledgment

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