Air Force Research Laboratory

Integrity ★ Service ★ Excellence

TID Effects on the WSMR Ionograms & Profiles

Presented at

IES-2015, Alexandria, VA, May 2015

Leo F. McNamara, Eugene V. Dao
and Jonah J. Colman

Space Vehicles Directorate

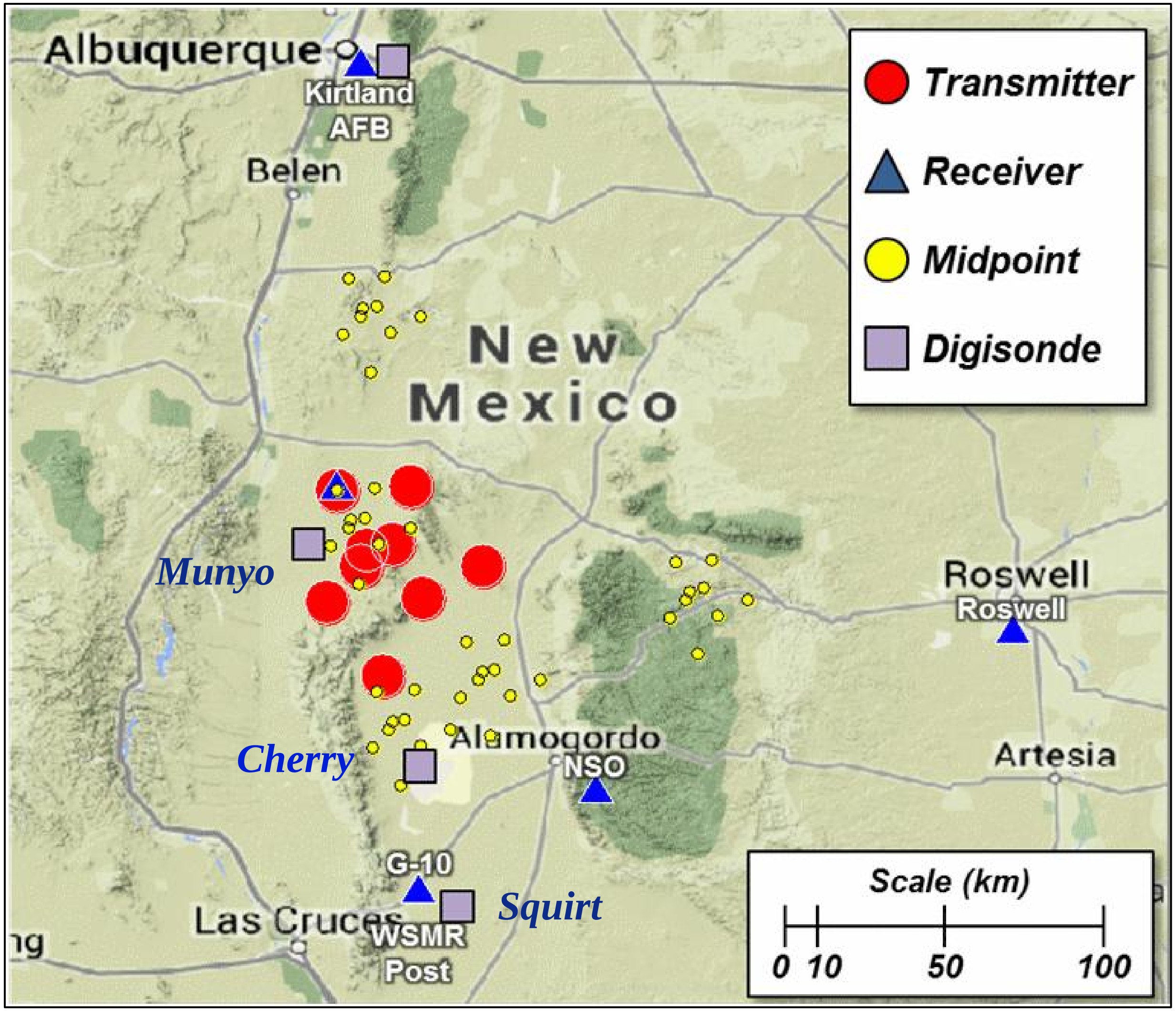
Air Force Research Laboratory

AFRL

Overview

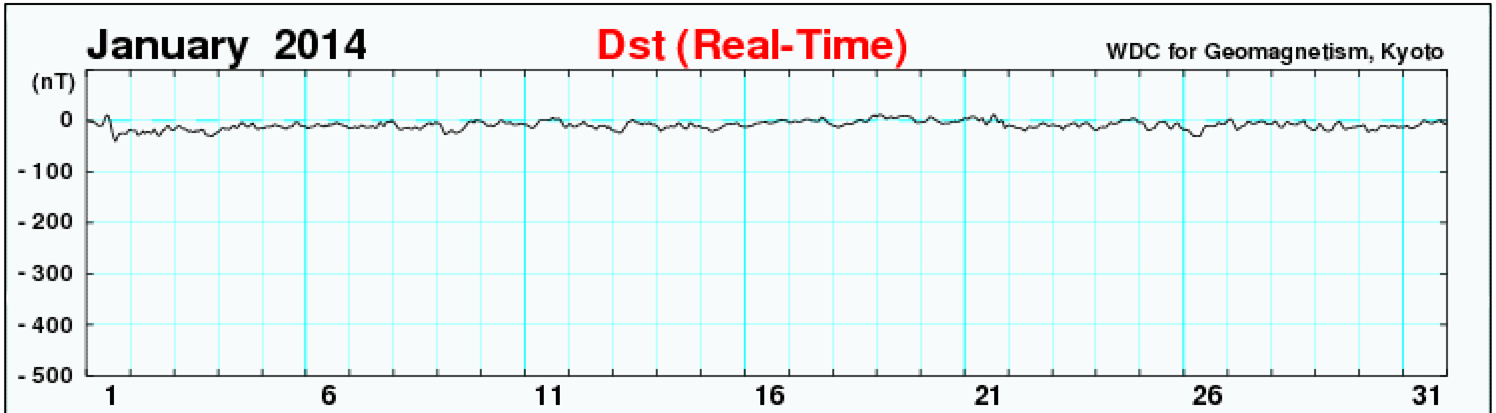
- AFRL deployed four Digisondes at White Sands Missile Range [WSMR] during the IARPA/HFGeo campaign of January 2014.
  - Ionograms and Skymaps were recorded on alternate minutes during the day (15-23UT), for days 018 through 028.
- The afternoon ionosphere was often dominated by large TIDs that had periods of ~60 min.
  - Morning TIDs tended to be smaller-scale with periods of ~15-20 min.
- The Digisonde observations [autoscaled trace, deduced profile, Skymap tilts] have been analyzed to determine the key properties and behavior of the TIDs.
  - A typical large-scale TID was accompanied by a sudden rise of hmF2, and increases in the F2 scale height and ionospheric TEC (ITEC).
  - The peak height, scale height and ITEC then fell, and so on.
  - The changes in foF2 were not always consistent with the changes in the other peak parameters.
  - The TIDs often led to uncertainties in the derived profiles.

WSMR Campaign Map [MIT-LL]



DISTRIBUTION A. Approved for public release; distribution is unlimited.

Indices for January 2014



Date	Radio Flux 10.7cm	SESC Sunspot Number
2014 01 12	155	118
2014 01 13	143	102
2014 01 14	137	95
2014 01 15	126	87
2014 01 16	121	77
2014 01 17	129	95
2014 01 18	130	114
2014 01 19	128	91
2014 01 20	137	131
2014 01 21	146	141
2014 01 22	143	144
2014 01 23	136	121
2014 01 24	136	150
2014 01 25	133	102
2014 01 26	138	109
2014 01 27	144	62
2014 01 28	157	70

Date	Estimated Planetary A	K-indices							
2014 01 11	4	0	0	0	0	1	1	3	2
2014 01 12	9	1	1	2	1	2	1	3	4
2014 01 13	7	3	3	2	1	1	1	0	1
2014 01 14	11	4	2	2	1	3	2	1	3
2014 01 15	4	2	1	1	1	0	1	1	1
2014 01 16	3	0	0	1	1	1	0	1	0
2014 01 17	4	1	1	1	0	1	1	1	2
2014 01 18	2	1	0	0	0	0	0	1	0
2014 01 19	2	1	0	0	0	1	1	1	0
2014 01 20	3	0	0	1	1	1	1	1	0
2014 01 21	8	3	1	2	2	2	2	2	2
2014 01 22	9	2	2	3	3	2	1	2	3
2014 01 23	6	3	2	2	1	1	1	2	1
2014 01 24	5	3	2	1	1	1	1	1	1
2014 01 25	8	3	2	2	1	1	2	2	3
2014 01 26	6	2	3	2	1	0	2	1	1
2014 01 27	4	1	1	1	0	1	1	1	1
2014 01 28	5	0	0	2	1	1	2	2	2
2014 01 29	7	2	2	2	2	2	2	2	2
2014 01 30	5	2	3	1	0	0	0	1	1
2014 01 31	3	0	0	1	1	1	0	1	1

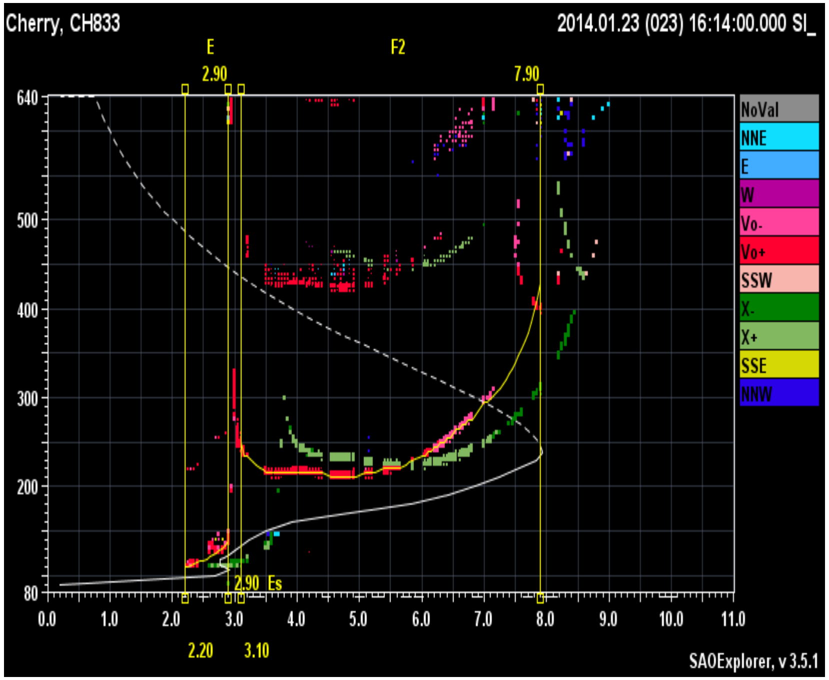
January 2014 was not spectacular.

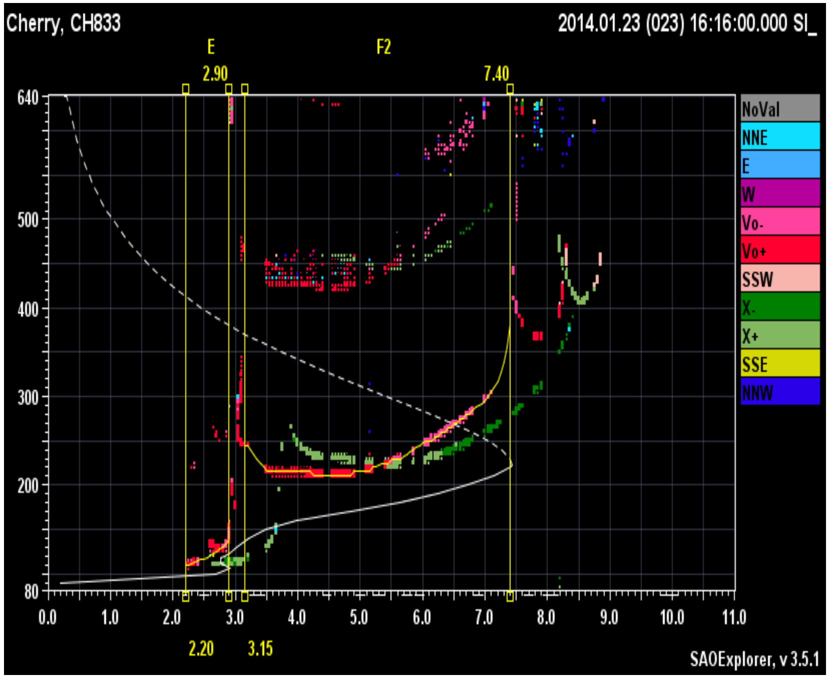
The large TIDs were a complete surprise.

TID “Hooks”, Day 023, CH833

Ionograms and Skymaps were recorded on alternate minutes during the day (15-23UT), for days 018 through 028.

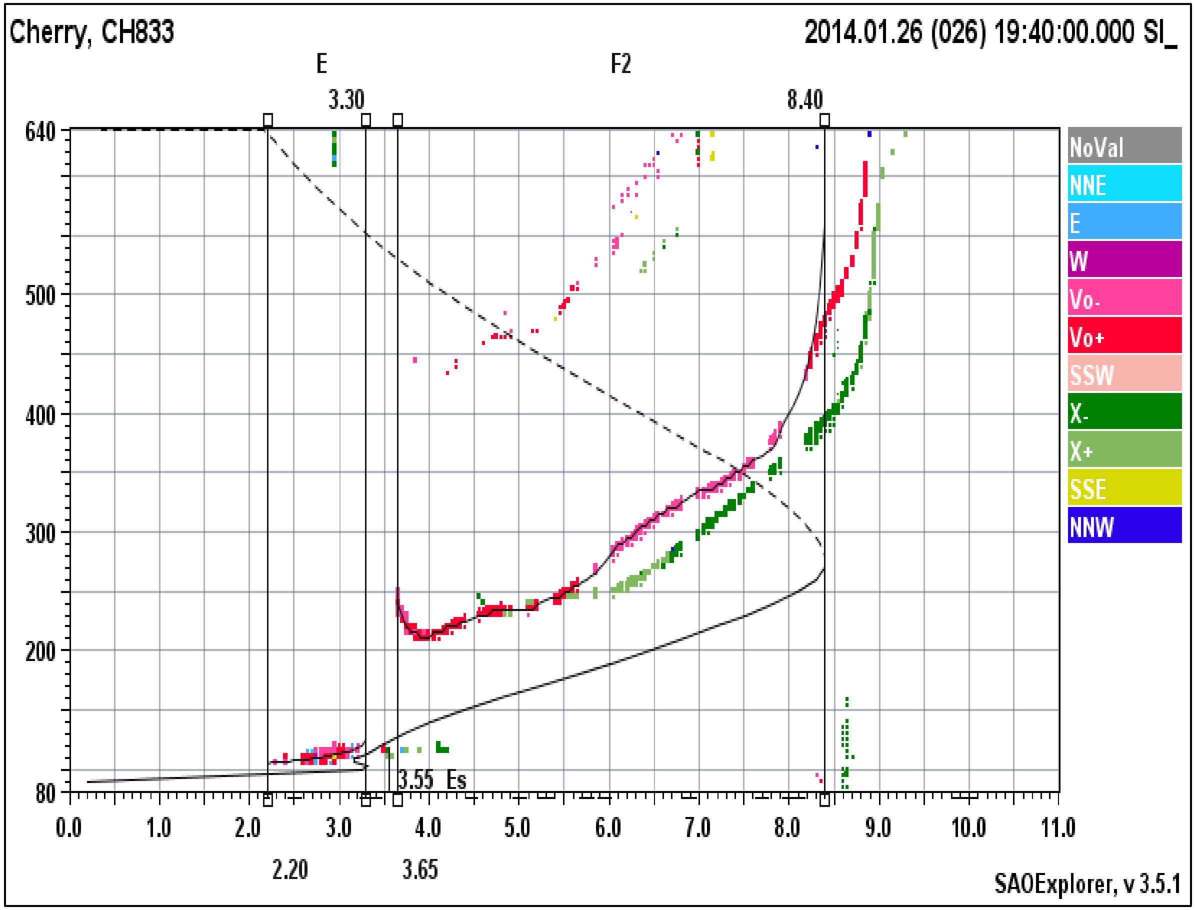
There were large numbers of prohibited frequency bands.





The hooks can appear inside or outside the foF2 and fxF2 cusps.

Cherry Ionogram, 20140261940



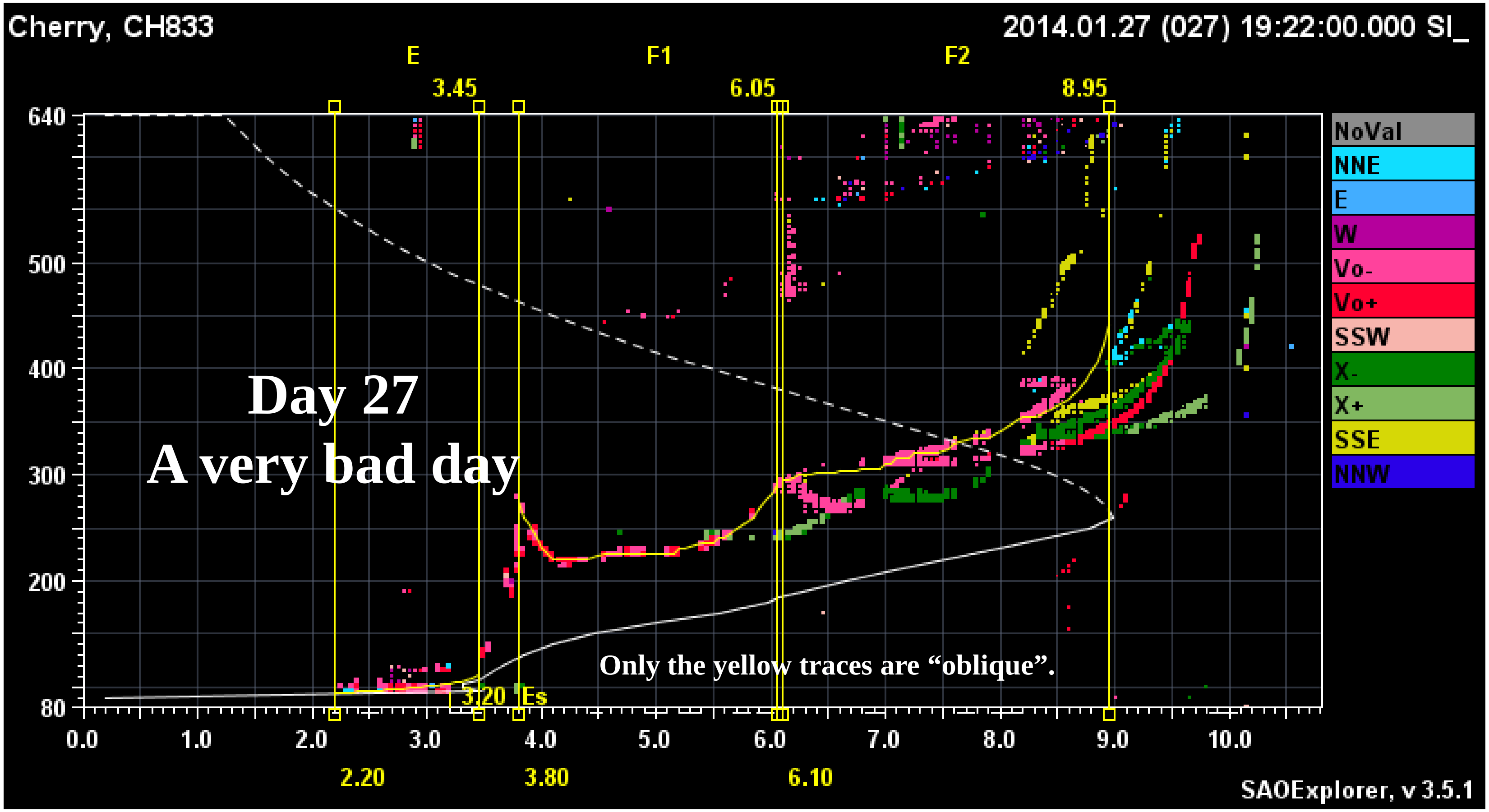
The ARTIST 5 ionogram autoscaling is not perfect when there are TIDs disturbing the traces.

Humans also have a hard time!

The derivation of the plasma frequency profile usually ignores some of the small-scale structure in the autoscaled trace.

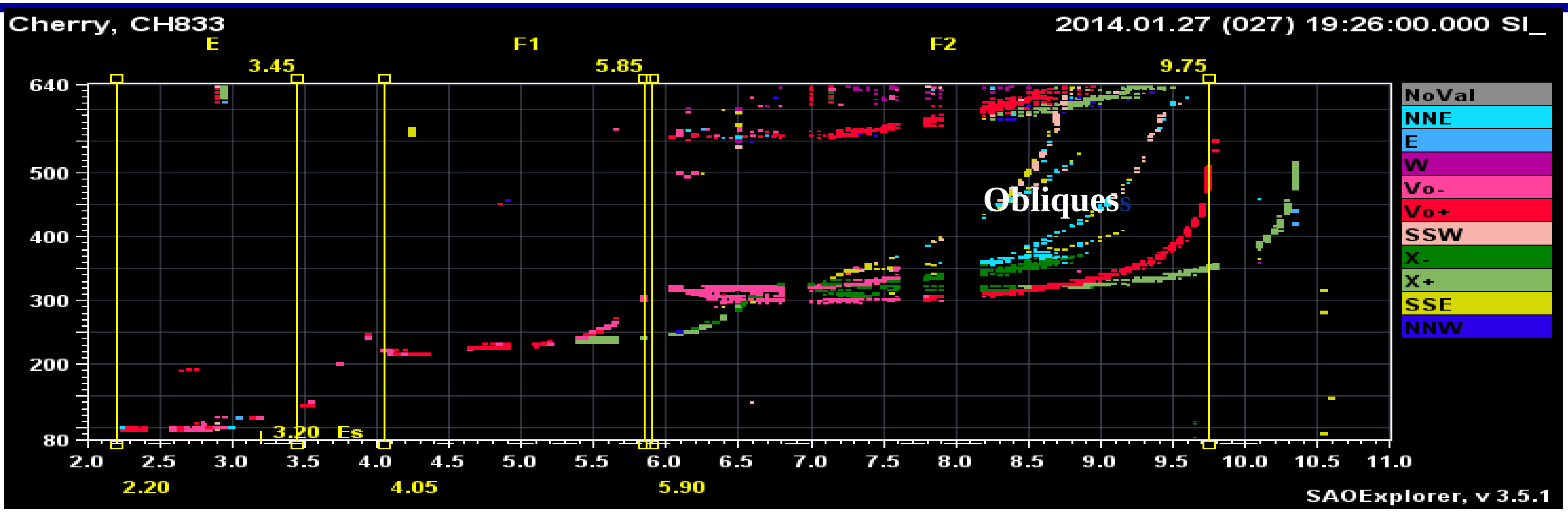
In this case, the TID-distorted (red) foF2 cusp has been ignored in favor of one that is consistent with the undisturbed vertical (green) fxF2 cusp.

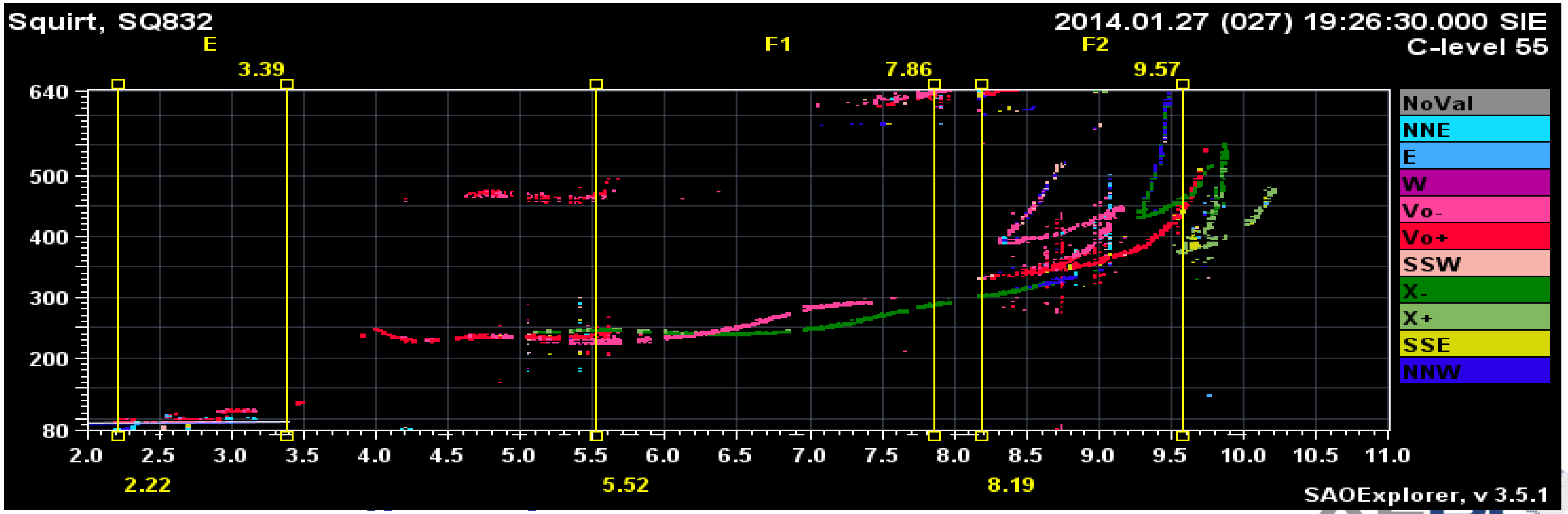
Cherry Ionogram, 20140271922



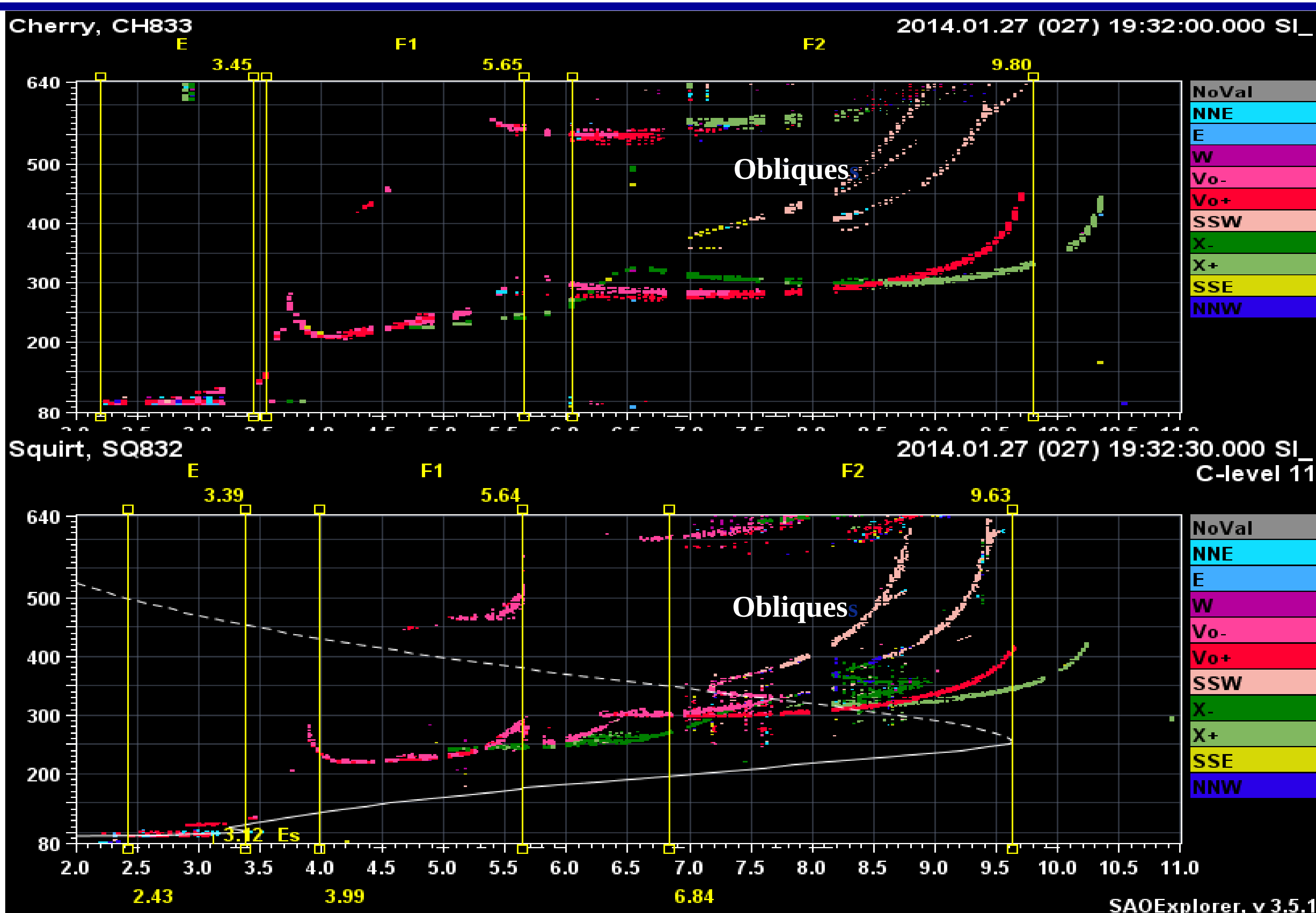
DISTRIBUTION A. Approved for public release; distribution is unlimited.

Cherry & Squirt Ionograms, 2014 027 1926

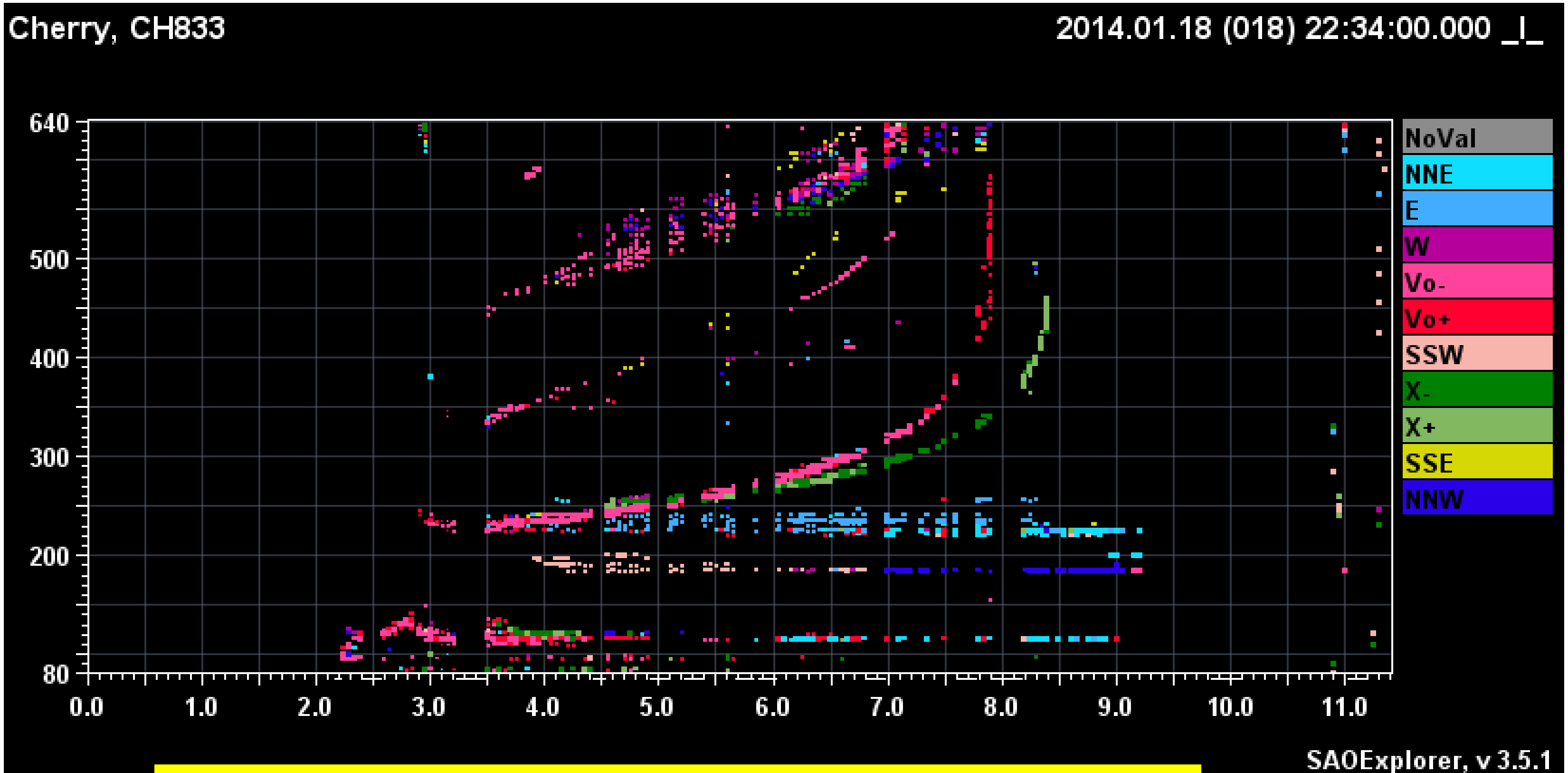




Cherry & Squirt Ionograms, 2014 027 1932



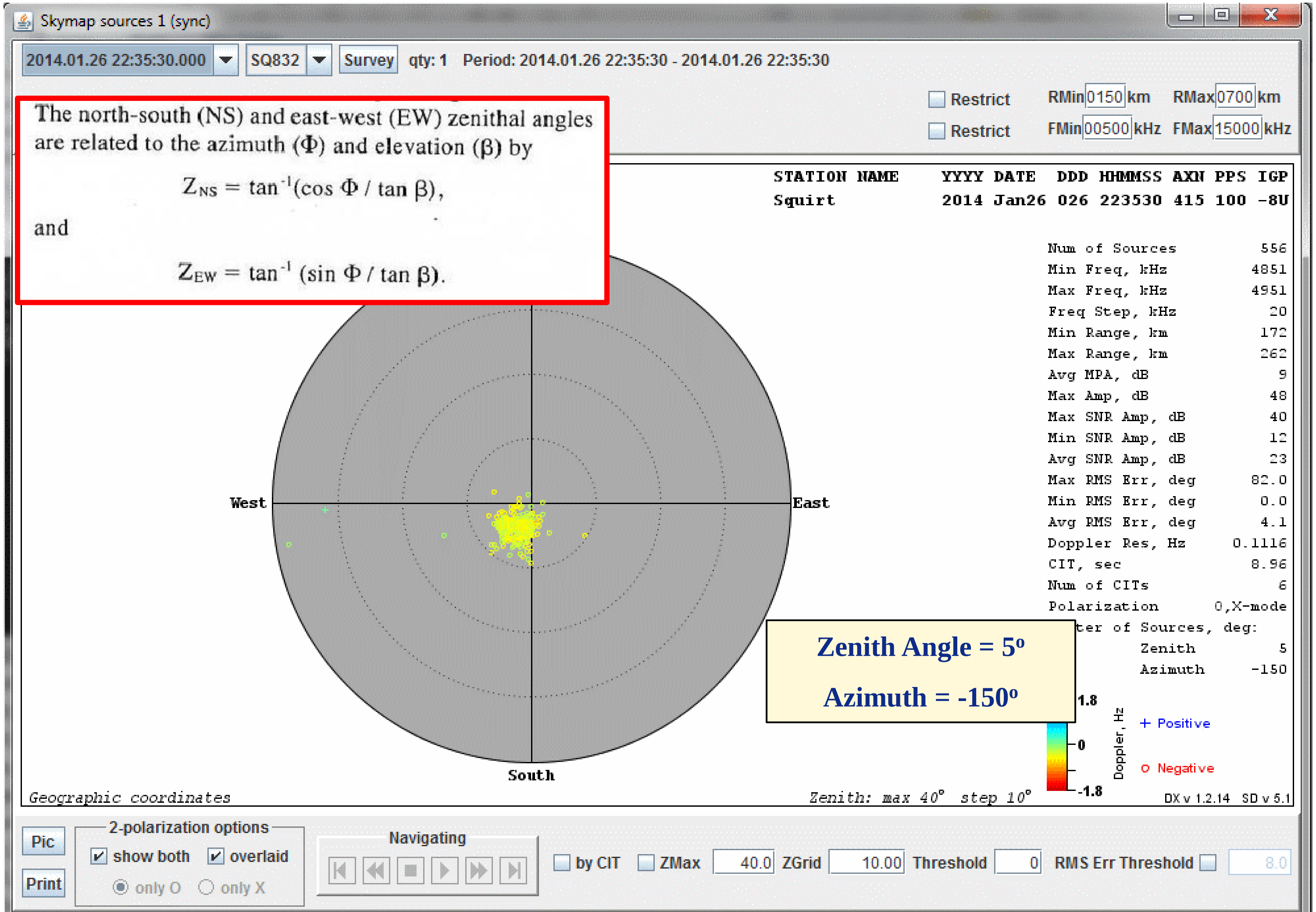
Cherry Multiple Es Obliques



The Es layers lasted for a few hours.

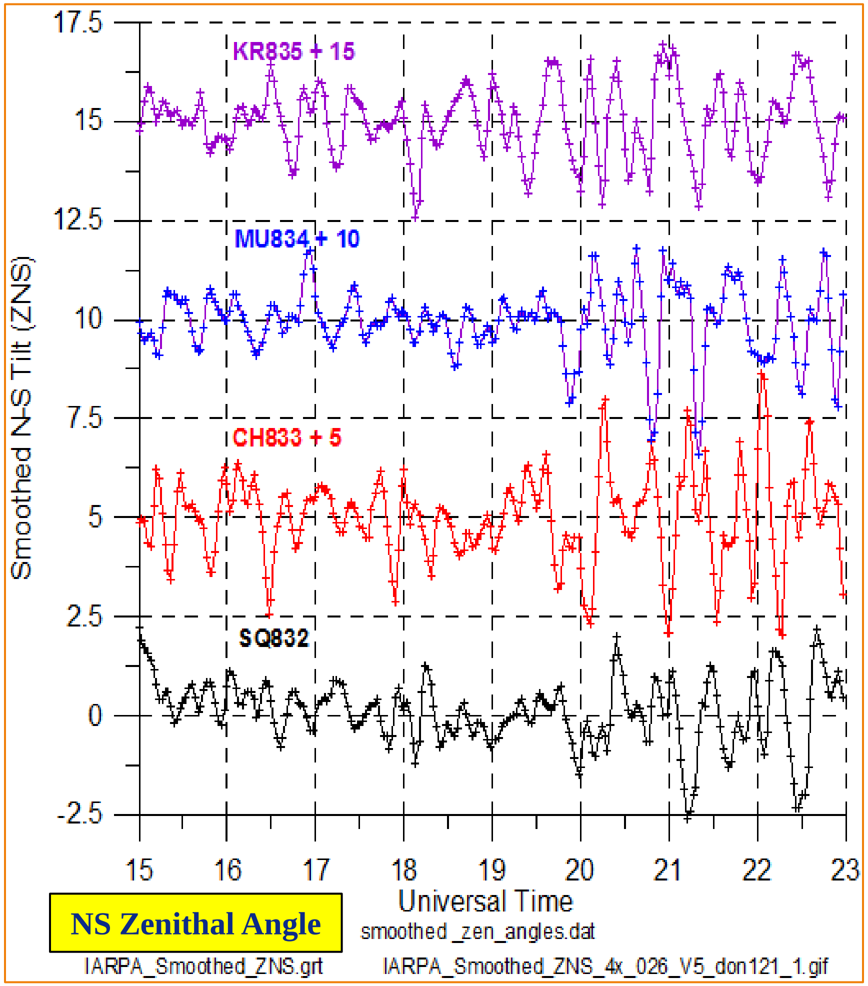
There were no ionograms for the other sites on this day.

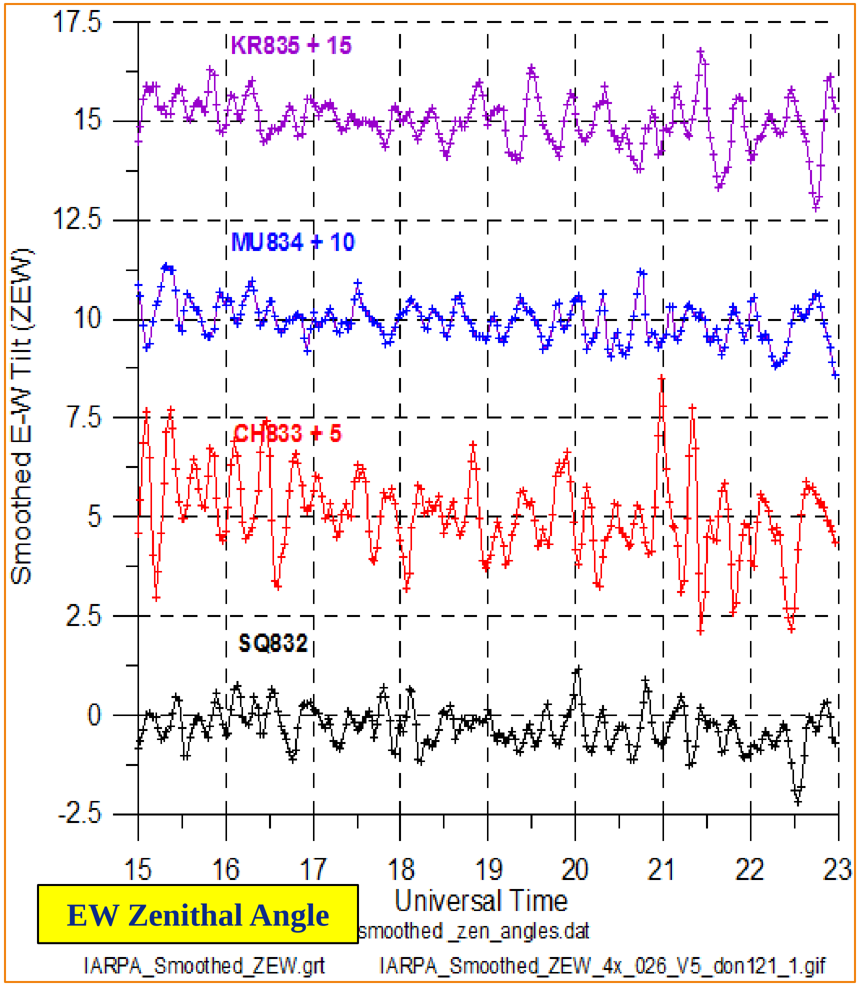
SQ832 Skymap for Day 026



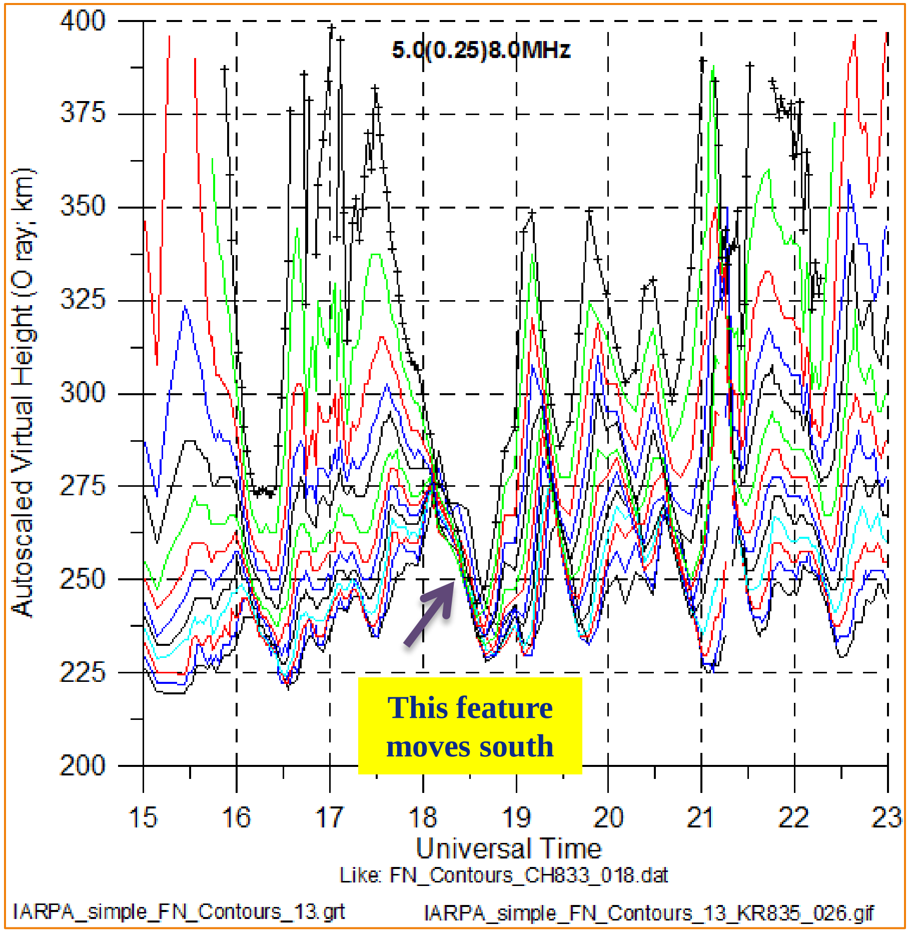
DISTRIBUTION A. Approved for public release; distribution is unlimited.

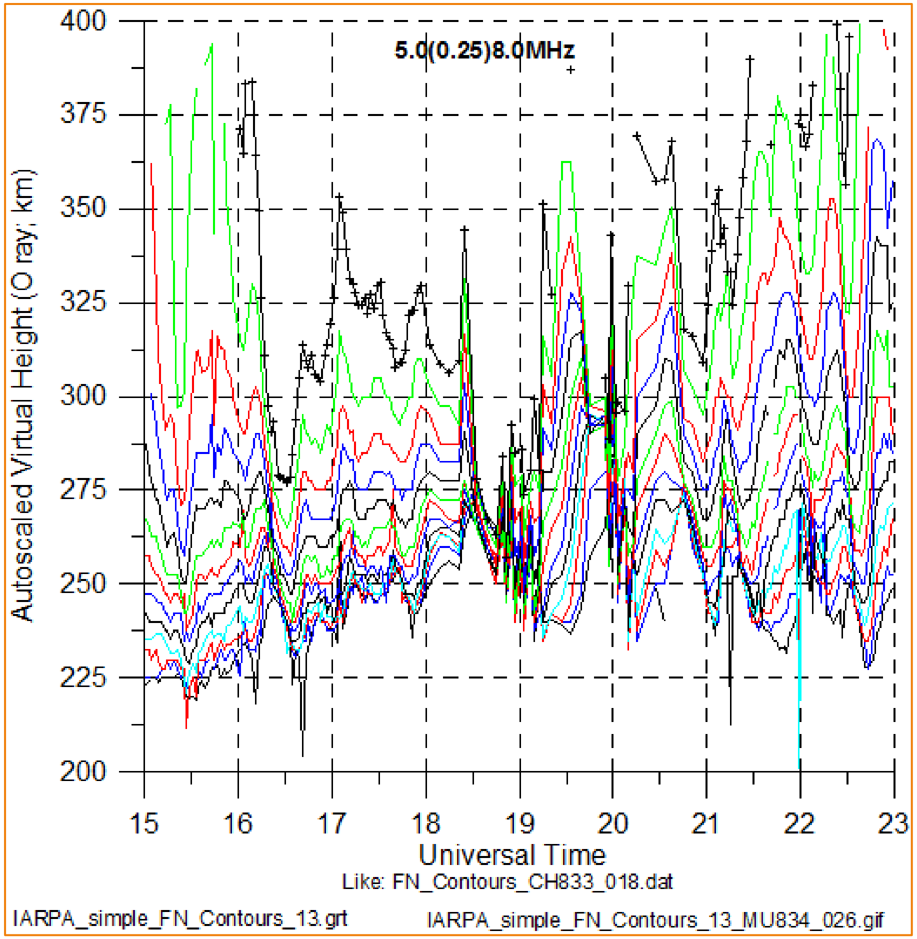
Digisonde Tilts for Day 026



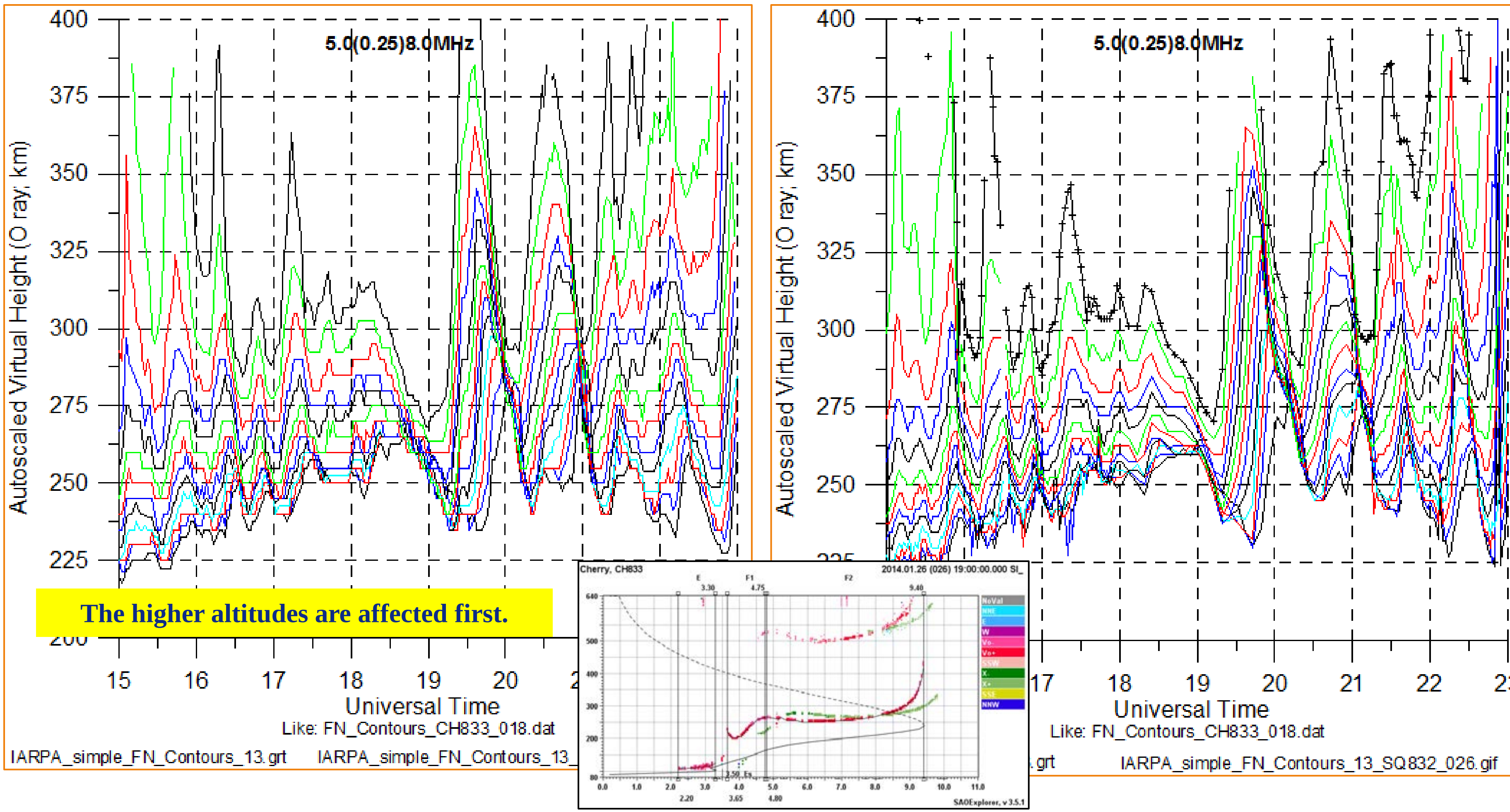


Day 026, KR835 & MU834 Virtual Heights





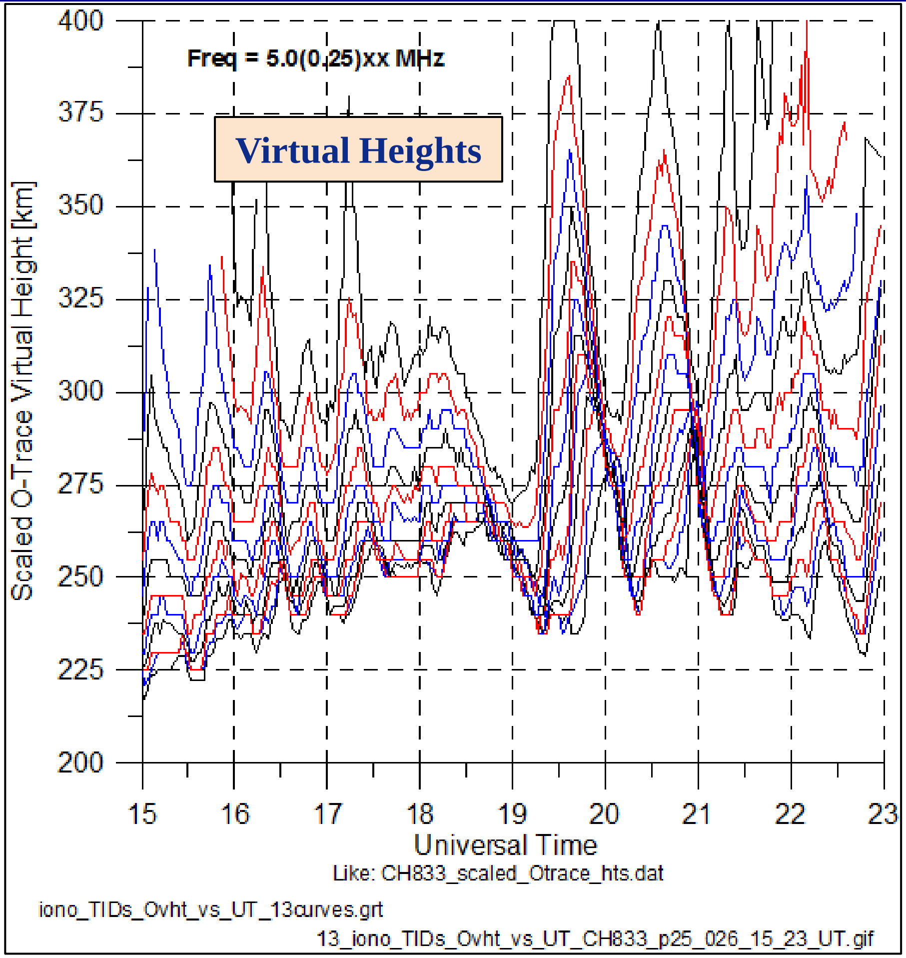
Day 026, CH833 & SQ832

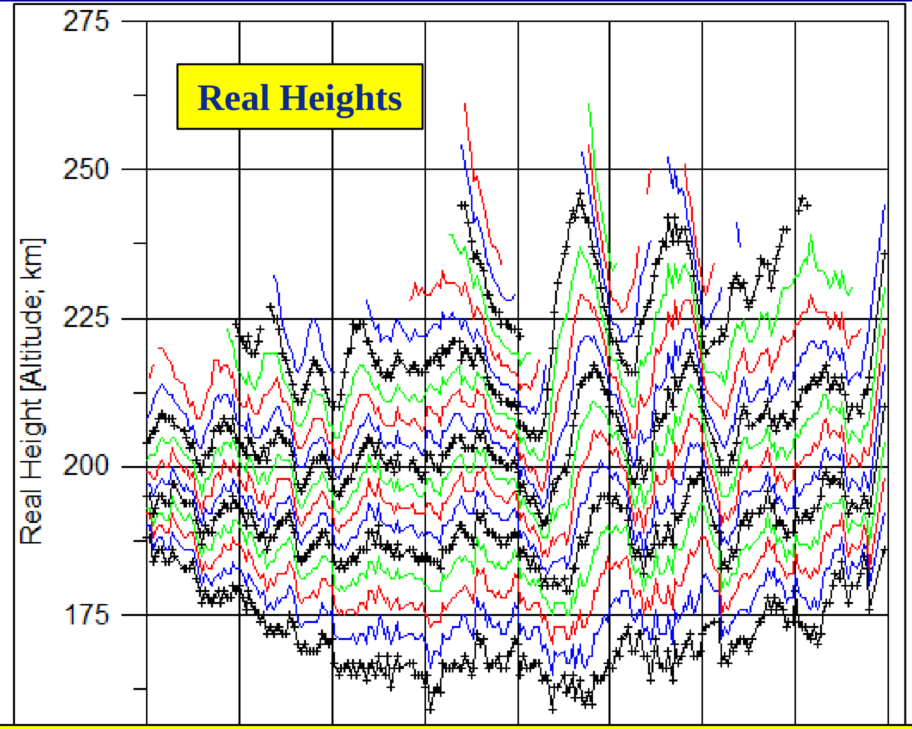


The higher altitudes are affected first.

DISTRIBUTION A. Approved for public release; distribution is unlimited.

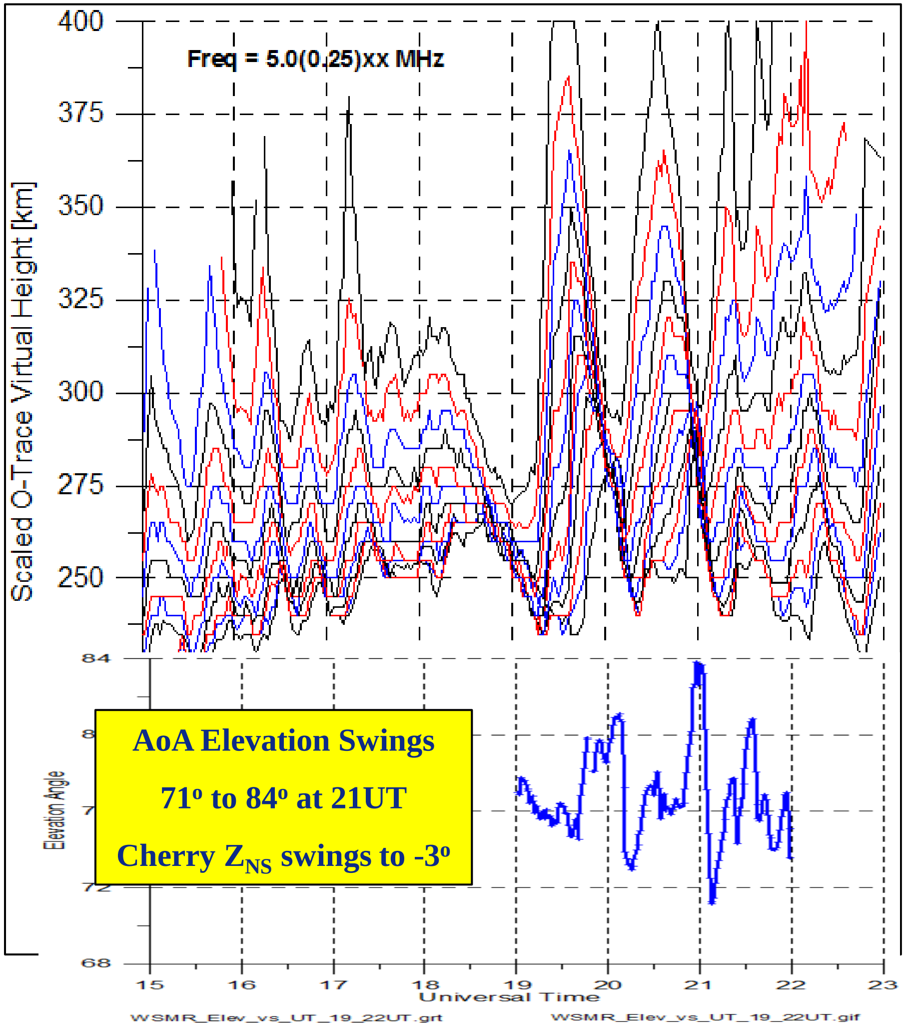
Height Contours, CH833, Day 026





The contours start at 5.00 MHz, and have an interval of 0.25 MHz.
The color code for the contours is black (whole MHz, with + symbol), blue, red and green.
There are up to 20 contours, but not all days require this many contours.
The highest contour is controlled in part by foF2 at each UT.

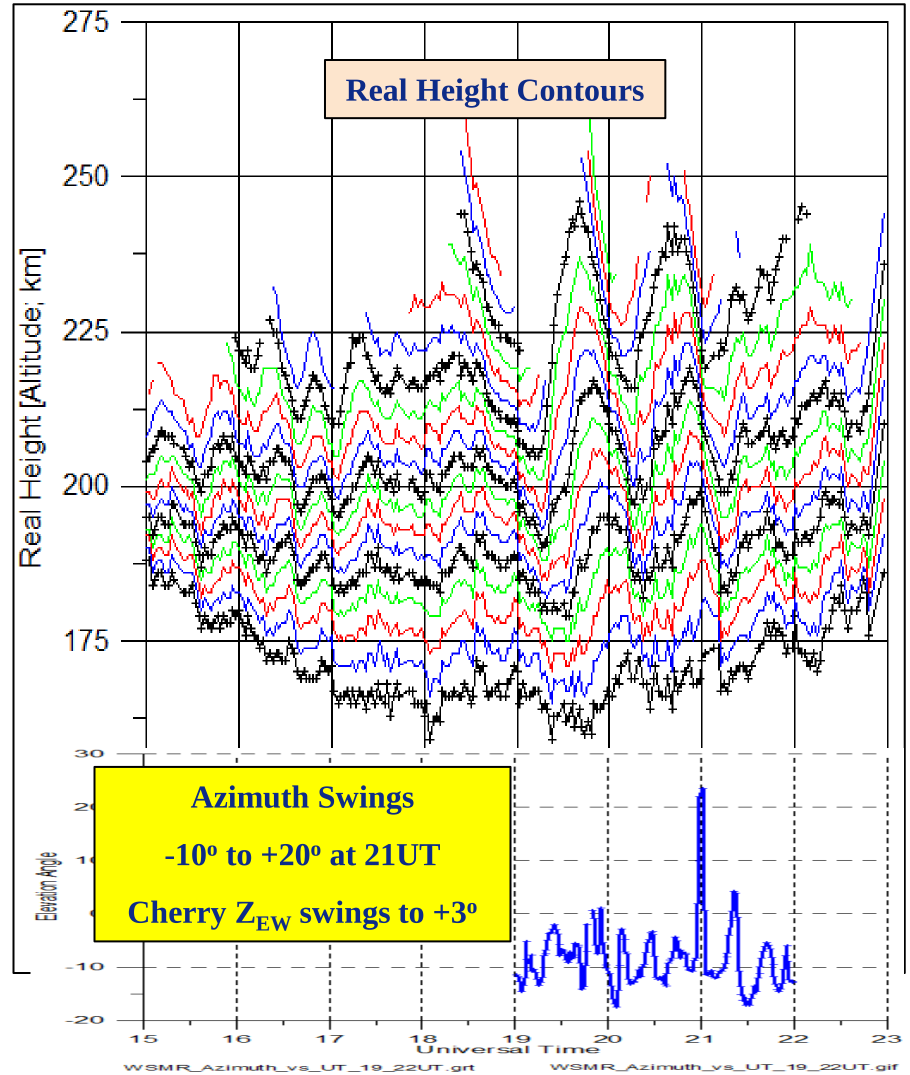
Swings in AoA at 5.1MHz



AoA Elevation Swings

71° to 84° at 21UT

Cherry Z_{NS} swings to -3°



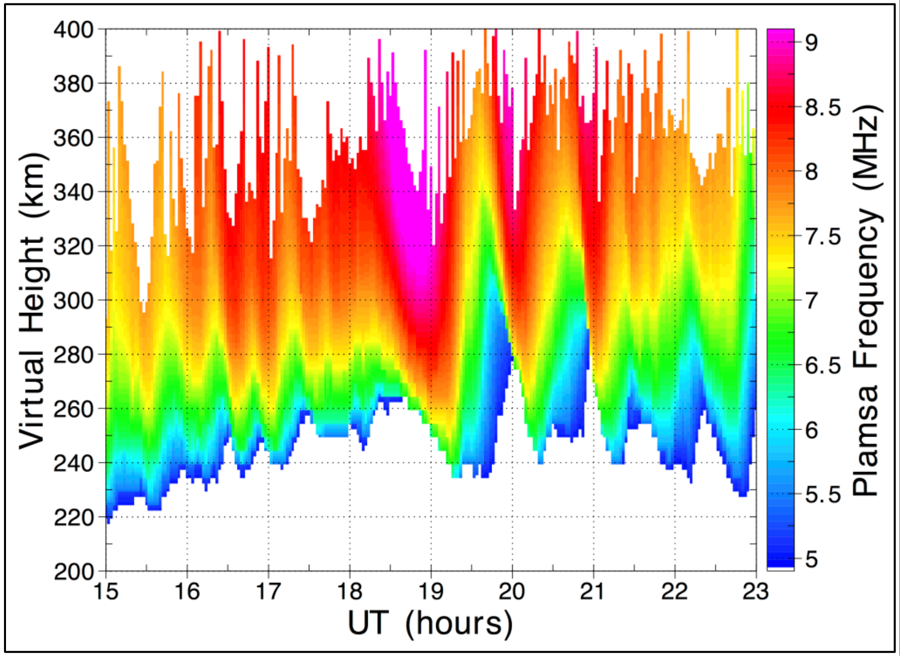
Azimuth Swings

-10° to +20° at 21UT

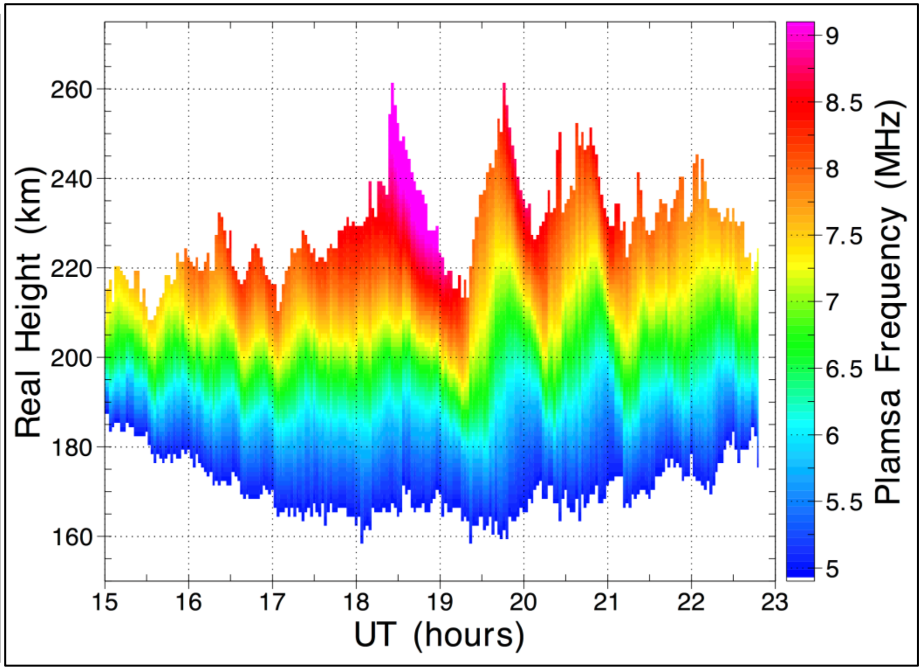
Cherry Z_{EW} swings to +3°

Height Contours, CH833, Day 026

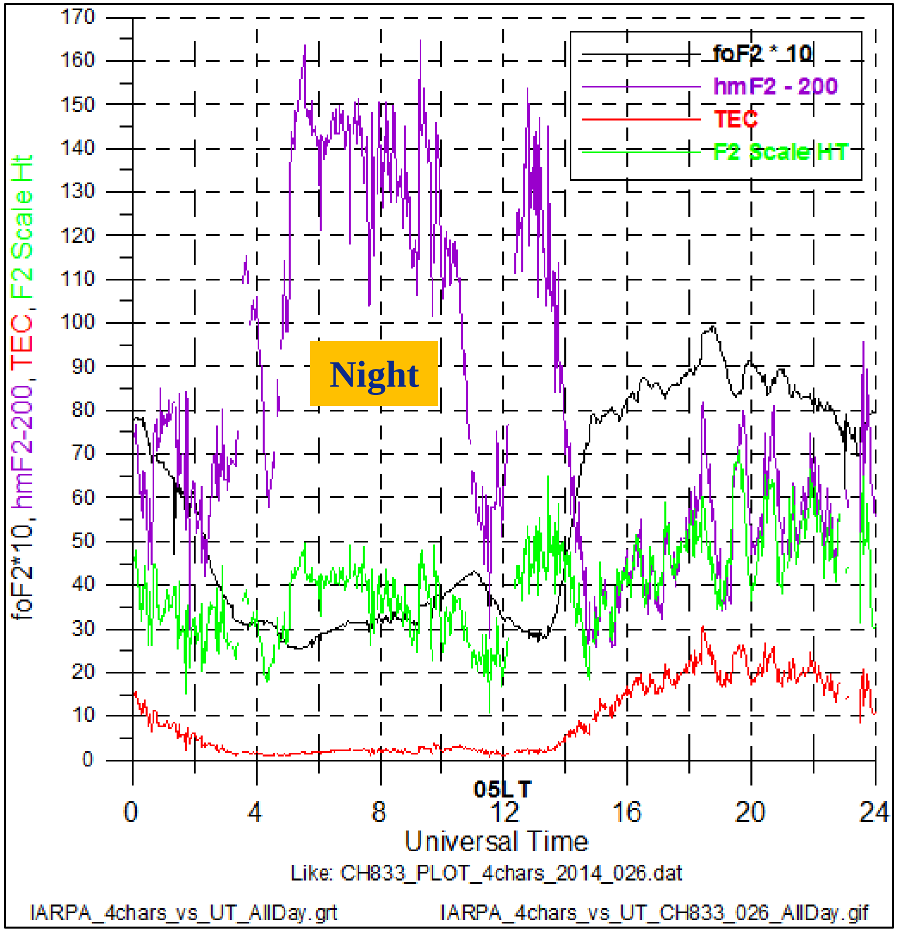
Virtual Heights



Real Heights



Profile Characteristics, Day 026



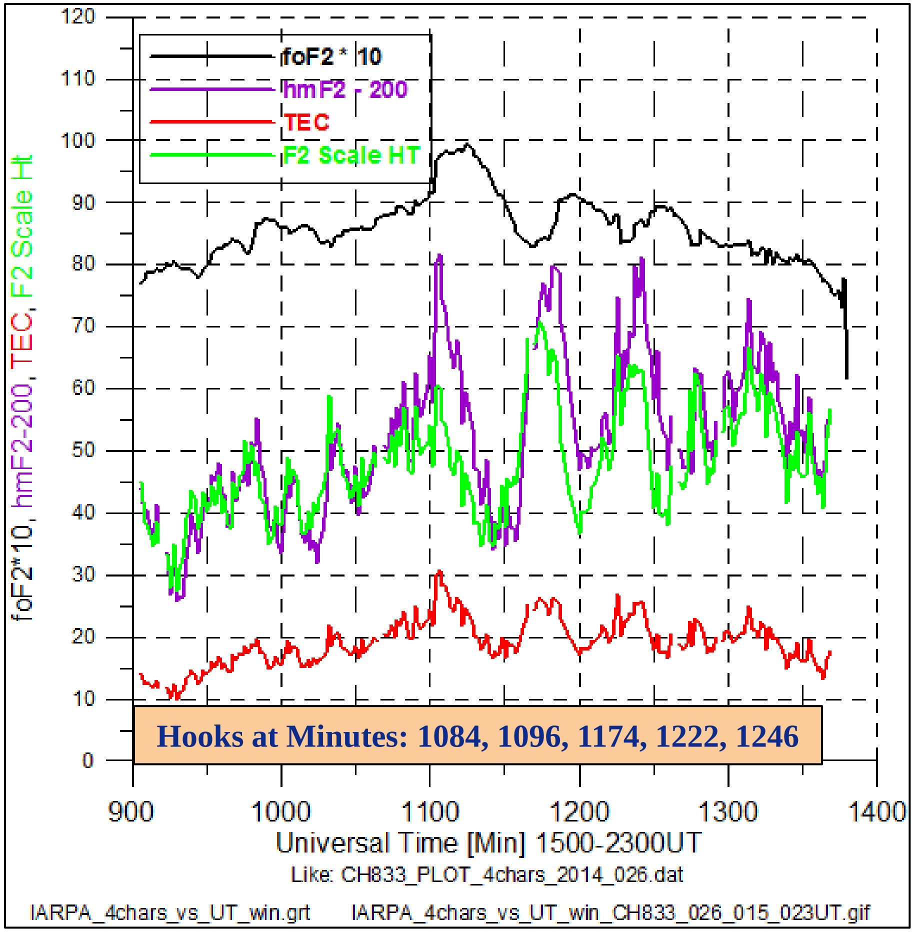
There were large swings in hmF2 [magenta] during the night, probably due to a large TID. This was a common feature.

The F2 scale height [Hm, green] followed these swings.

Between 05 and 06LT, the sudden rise in hmF2 is probably associated with sunrise electric fields generated in the conjugate hemisphere. Hm and hmF2 are not correlated.

The increase in foF2 [black] out of the pre-dawn minimum was accompanied by decreases in hmF2 and Hm.

Daytime Characteristics, Day 026

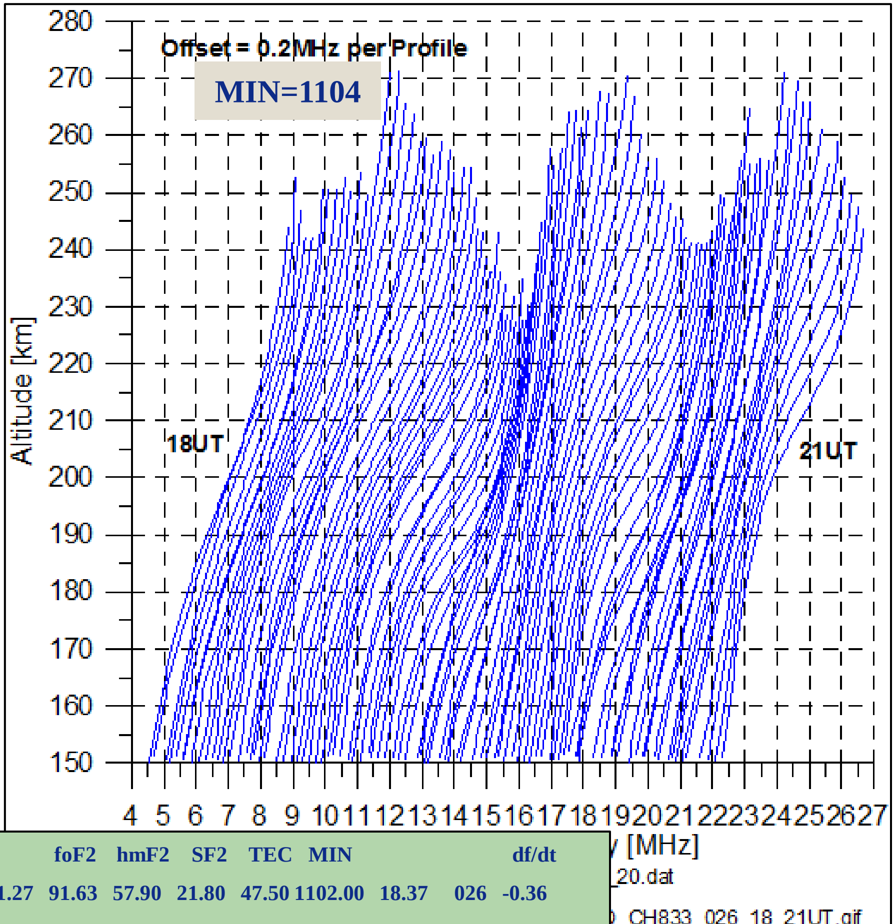


At minute 1100 (1820UT), hmF2, Hm and *ITEC* increase rapidly, and then fall linearly over the next ~50 min.
[*ITEC* is the TEC up to the top of the ARTIST model topside profile.]

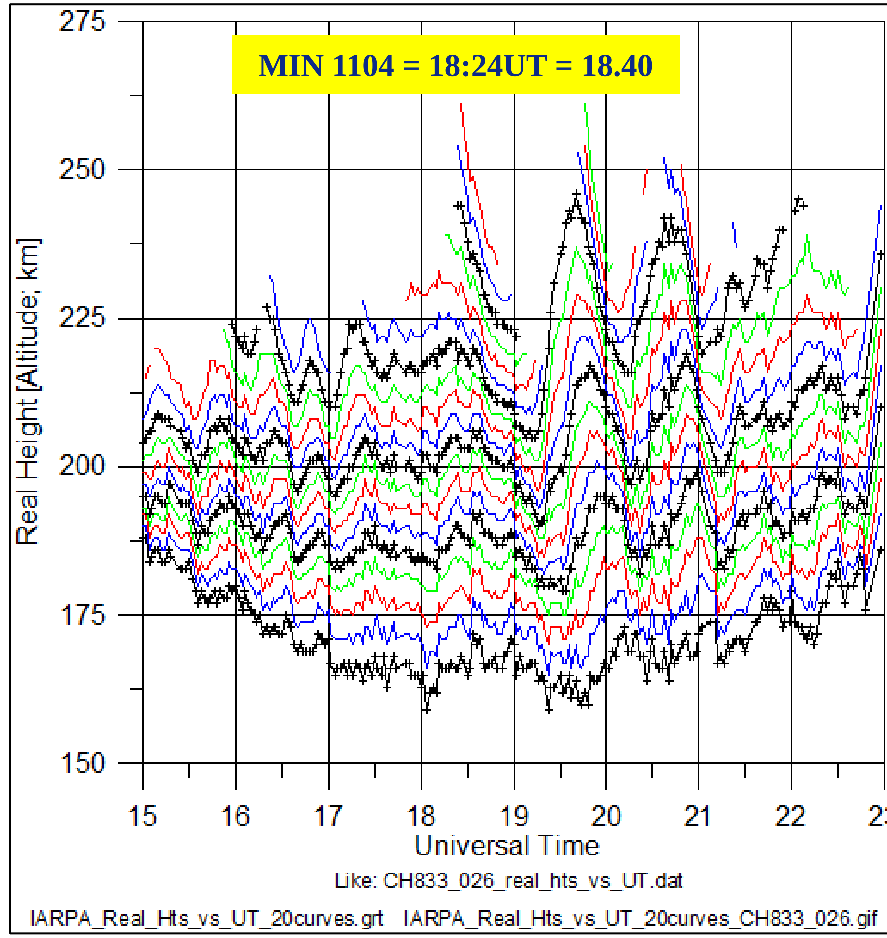
The hooks seen in the ionograms seem to be associated with small changes in the F2 characteristics, not the large changes.

Cervera, M. A., and T. J. Harris (2014), Modeling ionospheric disturbance features in quasi-vertically incident ionograms using 3-D magnetoionic ray tracing and atmospheric gravity waves, J. Geophys. Res. Space Physics, 119, 431–440, doi:10.1002/2013JA019247.

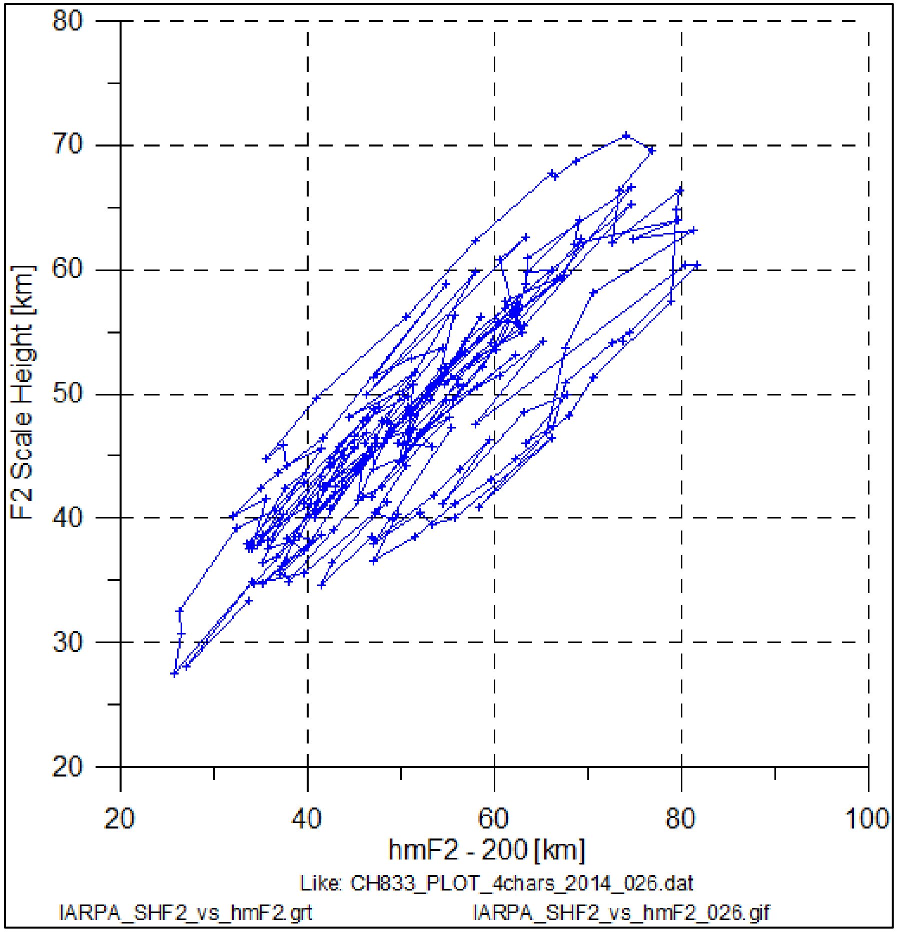
Offset Profiles for Day 026

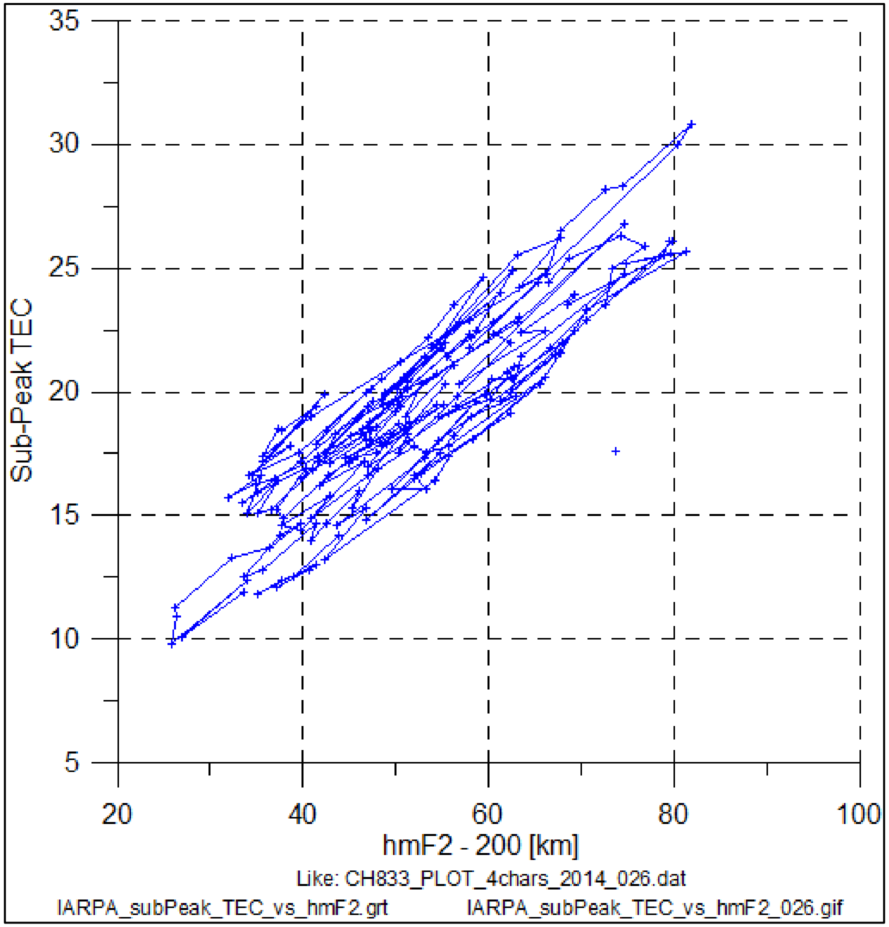


	foF2	hmF2	SF2	TEC	MIN			df/dt
11.27	91.63	57.90	21.80	47.50	1102.00	18.37	026	-0.36
11.30	96.75	80.40	30.00	60.30	1104.00	18.40	026	15.36
11.34	97.75	81.80	30.80	60.30	1106.00	18.43	026	3.00
11.37	97.75	74.40	28.30	55.00	1108.00	18.47	026	0.00



Hm & ITEC vs hmF2, Day 026



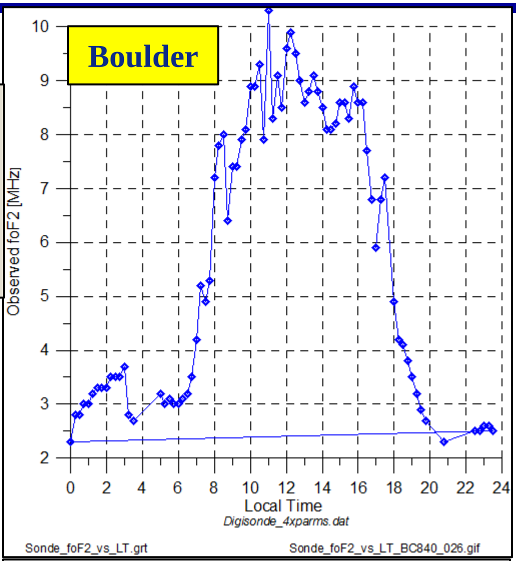


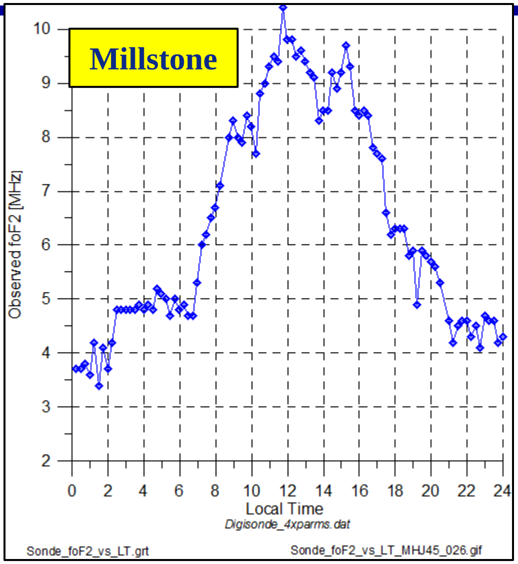
Summary

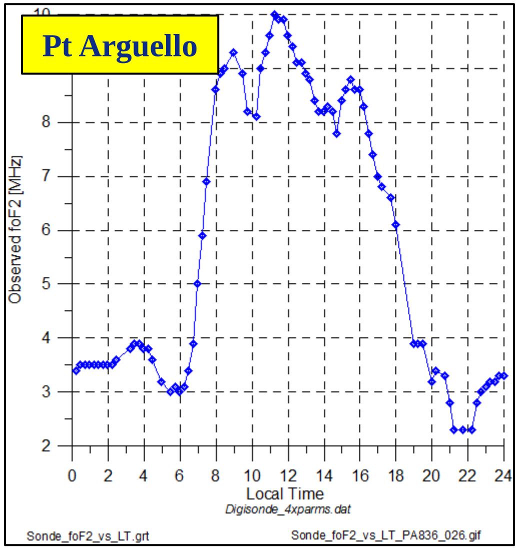
- **Detailed analysis of the Digisonde profiles has not yet proceeded past this point because some of the TID effects are small relative to the uncertainties in the profiles.**
  - **For example, what causes the increases in the ITEC? A small increase in foF2 accompanied by an increase in the scale height? The increase in hmF2 simply moves the peak up higher into the ionosphere so that there is an increased number of electrons below it?**
- **AFRL was interested in the achievable geolocation accuracy, more so when the large-scale TIDs appeared *en masse*.**
  - **The Digisonde DPS-4 at Cherry (CH833) was near the midpoints of the circuits, so its virtual heights and tilts were directly applicable to the tilted mirror model.**
  - **The deployments of the HF emitters and Angle of Arrival equipment were ideal for the application of this model.**
  - **The tilted mirror model of HF propagation was found to provide quite accurate geolocation.**

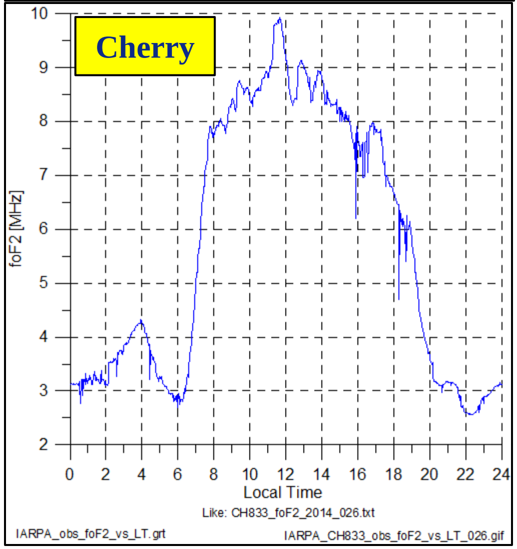
foF2 for Other Digisondes - 026

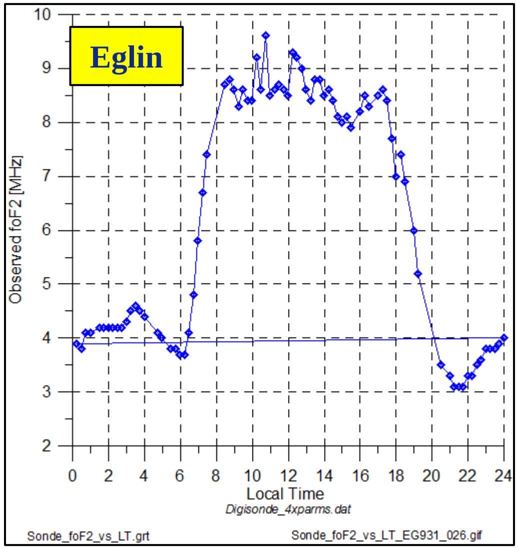
Other Digisondes also exhibit diurnal variability of foF2, but not the same as Cherry, which seems to have its own TIDs. Millstone & Pt Arguello are similar. Boulder is ARTIST 4.5 and noisy.







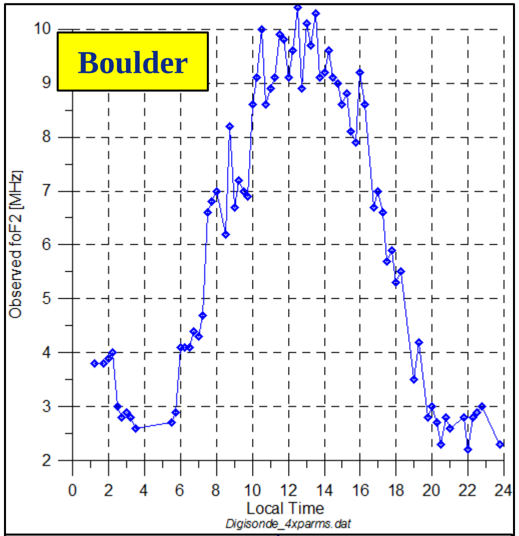


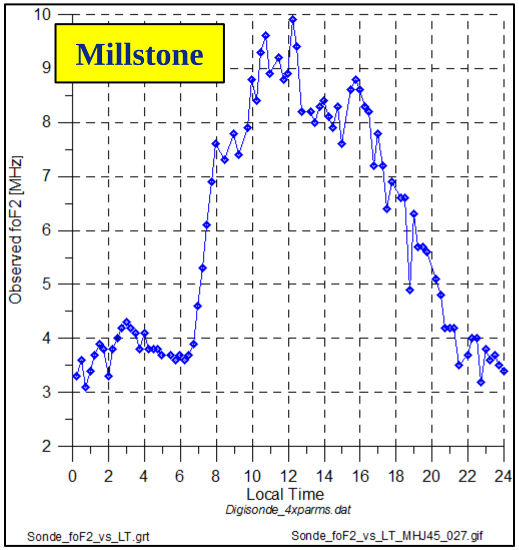


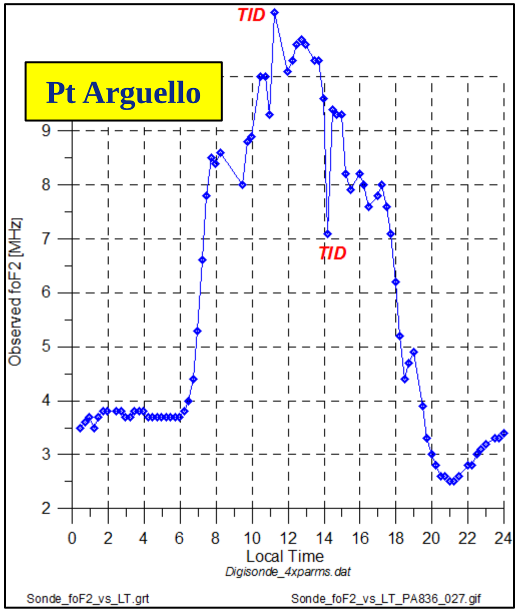
Local Time Plots of foF2 – Day 027

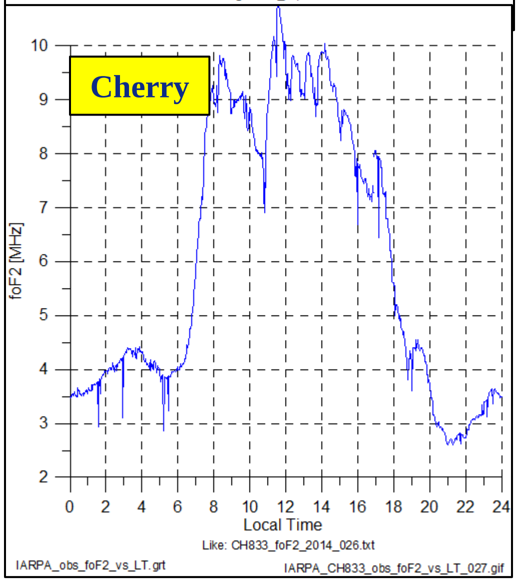
Boulder – TID at 1915UT, et seq.

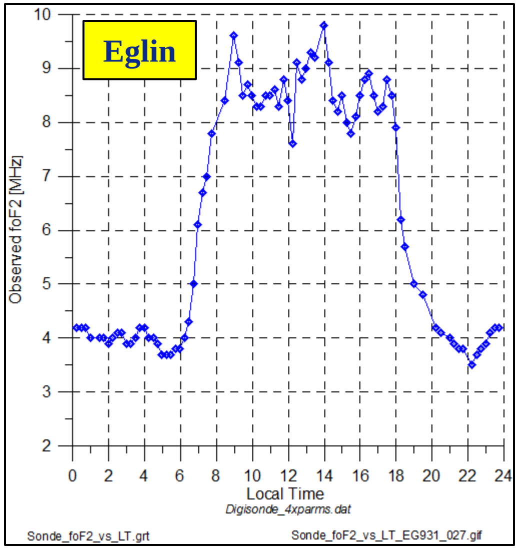
It appears that Cherry TIDs were unique to WSMR.



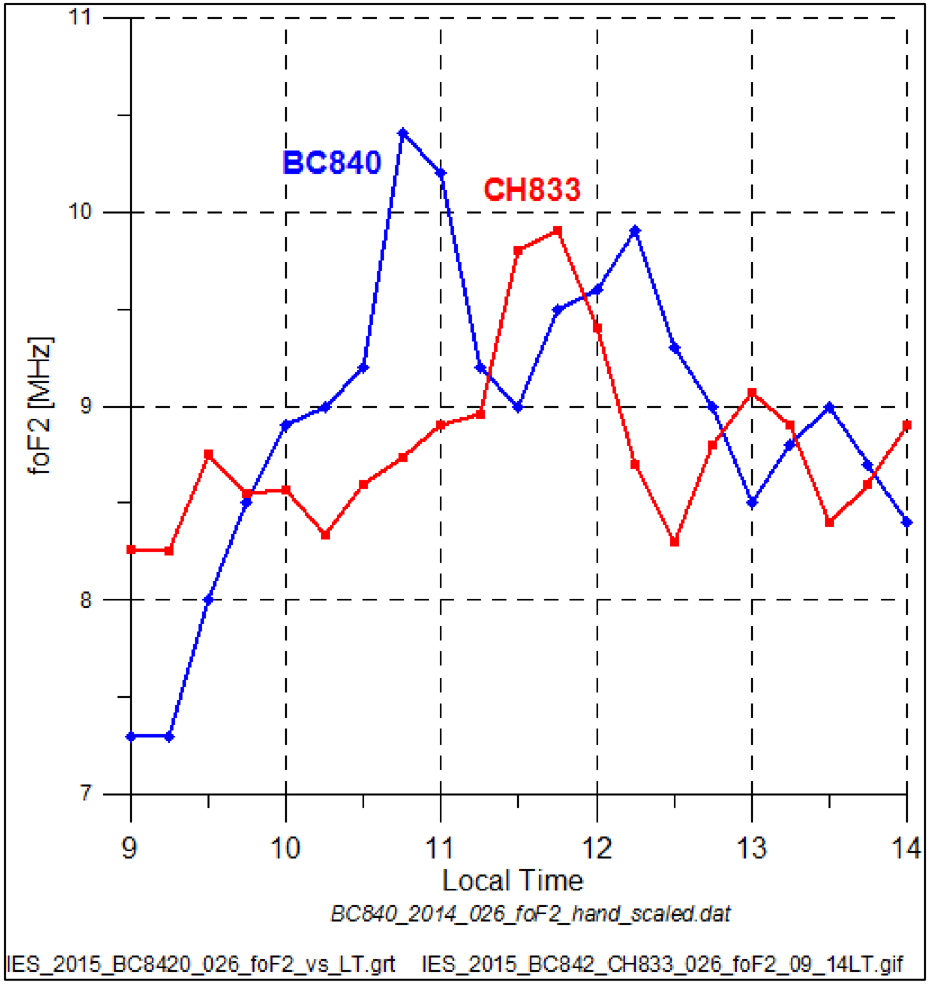








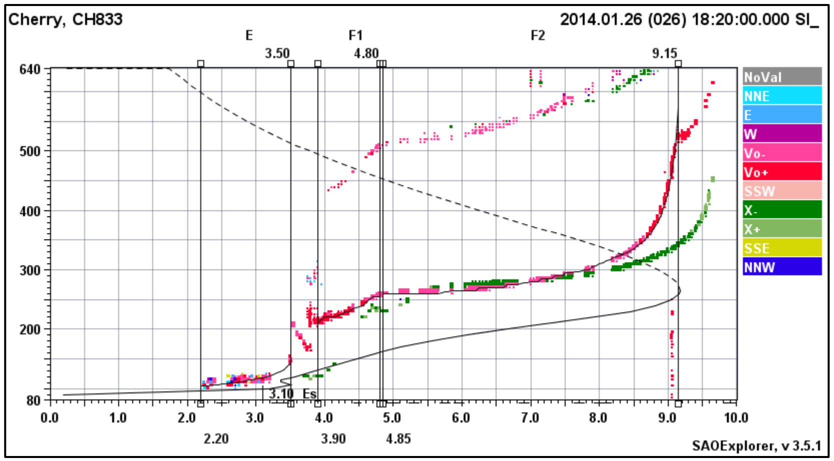
BC840 & CH833 foF2, Day 026

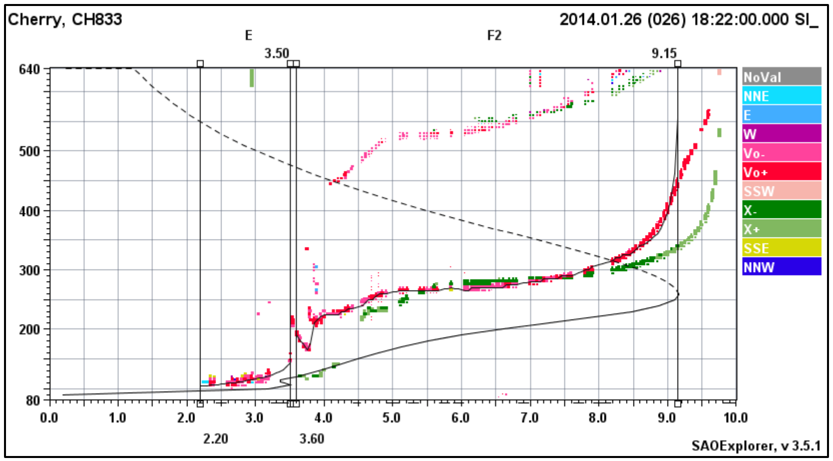


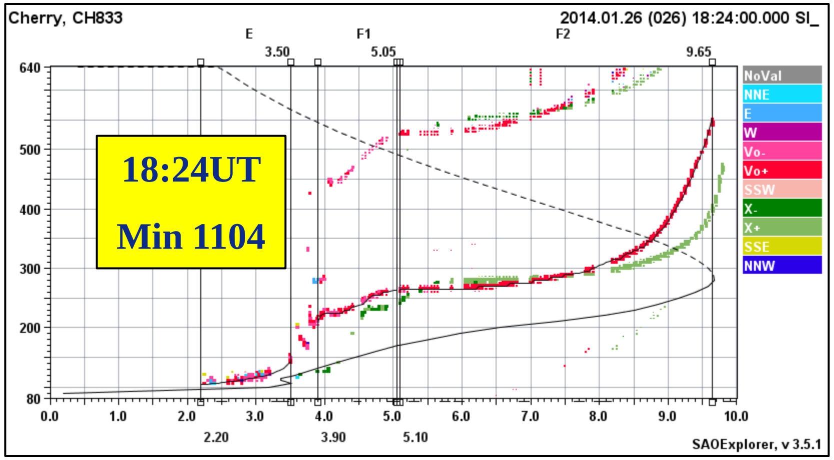
CH833 lags BC840 by ~45 min.

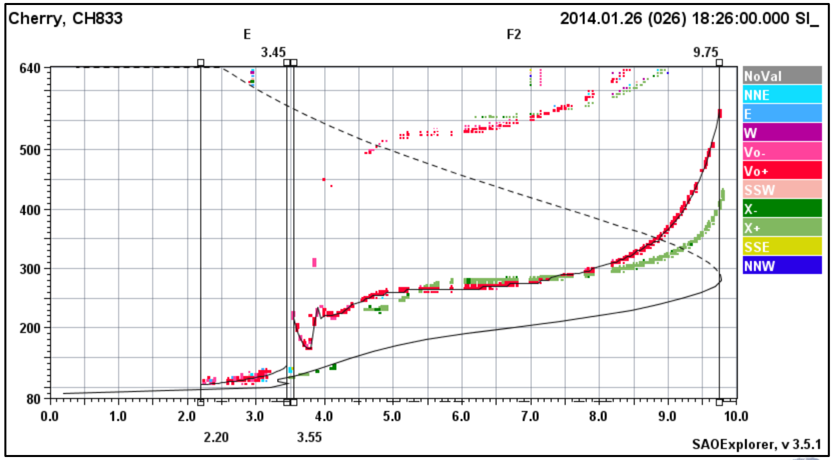
This corresponds to TID v=300 m/s

Ionogram Changes near foF2

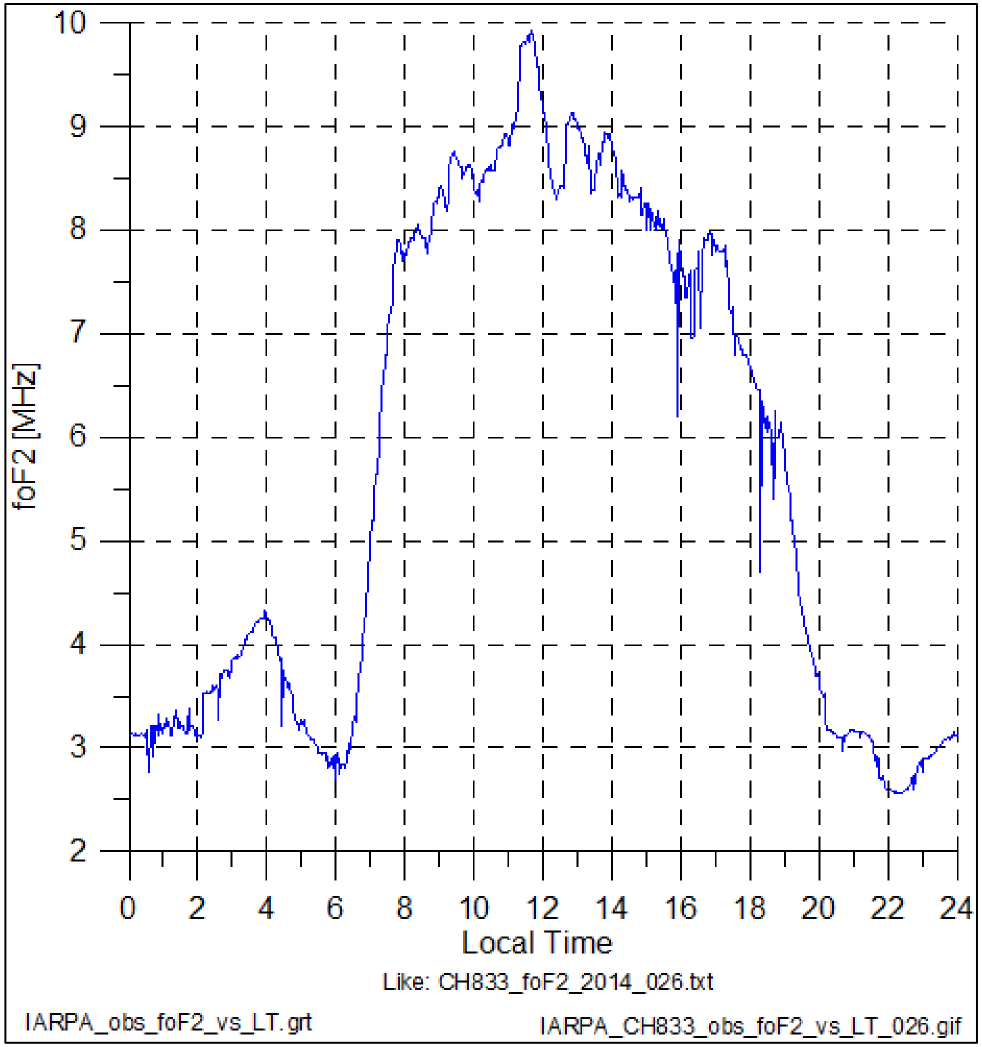




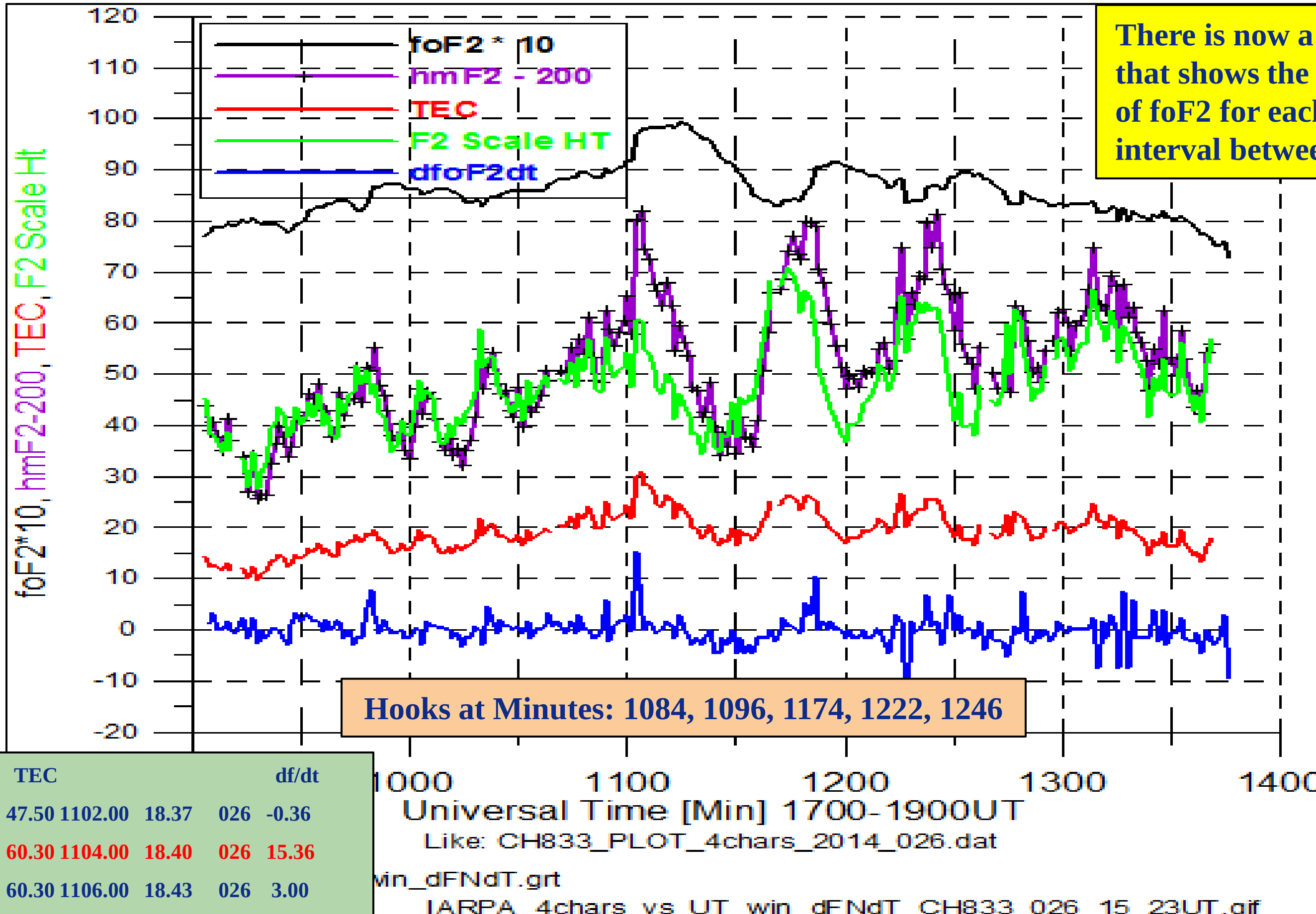




Local Time Plots of foF2 – Day 026



Daytime Characteristics, Day 026 MOD



There is now a (blue) curve that shows the rate of change of foF2 for each 2-minute interval between ionograms

Hooks at Minutes: 1084, 1096, 1174, 1222, 1246

	foF2	hmF2	SF2	TEC				df/dt
11.27	91.63	57.90	21.80	47.50	1102.00	18.37	026	-0.36
11.30	96.75	80.40	30.00	60.30	1104.00	18.40	026	15.36
11.34	97.75	81.80	30.80	60.30	1106.00	18.43	026	3.00
11.37	97.75	74.40	28.30	55.00	1108.00	18.47	026	0.00

Profiles for Day 026