Digisonde Observations at White Sands for Day 026, 2014

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Abstract: AFRL deployed four Digisondes at White Sands Missile Range, New Mexico, during the IARPA/HFGeo campaign of January 2014. Ionograms and Skymaps were recorded on alternate minutes for days 018 through 028. Very large TIDs were observed on each day, so the Digisonde observations provided a 4-station network of TID observations, in terms of the virtual heights of the autoscaled ionogram traces, the real heights of the deduced plasma frequency profiles, and the local tilts corresponding to a vertical sounding frequency of ~5.2 MHz (base of the F2 layer).

The large-scale TIDs had periods of ~60 minutes, with superimposed smaller-scale TIDs that had periods of ~15-20 minutes. The large TIDs traveled basically from north to south. As seen in real-height contour plots, the amplitudes of the TIDs increased upwards by a factor of ~2 over the F2 layer. The changes with time of the F2 peak height (hmF2), F2 scale height (Hm), peak plasma frequency (foF2), and sub-peak TEC were all correlated. As the TID progressed, the peak of the layer rose to greater altitudes, foF2 increased, the sub-peak TEC increased, and the F2 scale height increased. Then as the peak of the layer fell again, the sub-peak TEC and the scale height also decreased.

The large-scale TIDs were not obviously related to activity in the auroral zone, although large-scale TIDs were also recorded by east and west coast ionosondes at Eglin AFB and Point Arguello. Similar ~20 minute medium-scale TIDs were also seen by a previous generation of geolocation equipment [DragonFix, circa 1990]. These TIDs were probably due to local topography.

1. Introduction

Figure 1 shows the locations of the Digisondes deployed at White Sands Missile Range [WSMR] during the IARPA/HFGeo campaign of January 2014. The four Digisondes are listed in Table 1 from south to north. The Digisondes basically lay along a north-south line (because of deployment restrictions).

Site	ID	Type	Lat	Lon
Squirt, WSMR	SQ832	DPS-4D	32.42	253.71
Cherry, WSMR	CH833	DPS-4	32.90	253.59
Munyo, WSMR	MU834	DPS-4D	33.56	253.35
Kirtland AFB, ABQ	KR835	DPS-4D	35.00	253.35

Table 1. The locations of the four Digisondes deployed for the WSMR campaign

The older-style DPS-4 deployed at Cherry has since been upgraded by Lowell Digisonde International to a DPS-4D, replacing the analog components used to measure the local ionospheric tilts by digital components. Only the Kirtland AFB Digisonde (KR835) used the recommended 30m transmitter tower. The transmitting antennas at the other three locations used portable 12m towers.

The multiple prohibited frequency bands over which the Digisonde could not transmit provided a challenge for the ionogram autoscaling software (ARTIST 5). Some of the gaps can be seen in the ionogram traces in Figure 1. The prohibited bands are also marked along the frequency axis.

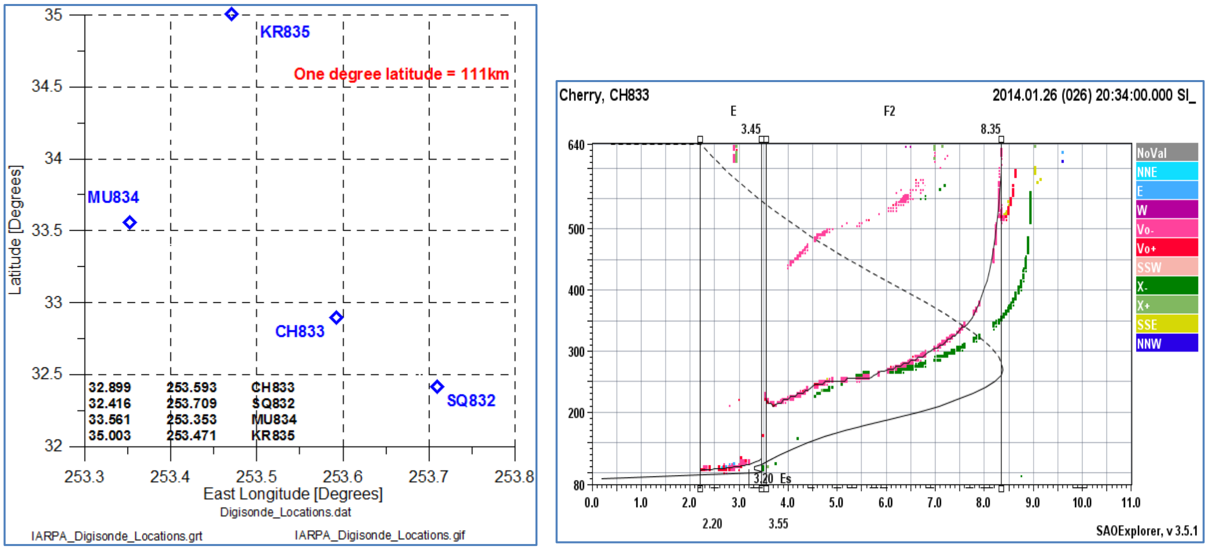

Figure 1. The locations of the four Digisondes deployed for the WSMR campaign. The CH833 ionogram on the right shows a typical TID "hook" that descended from the top of the foF2 cusp.

The Digisondes provided ionograms and derived plasma frequency profiles at every second minute and Skymaps at alternate minutes. The ionograms for all four sites were autoscaled by ARTIST 5. The Skymaps were set up to provide the local ionospheric tilts at ~5.2 MHz, the equivalent vertical incidence frequency for the daytime oblique operating frequency of the test transmitters at 5.3 MHz.

The Cherry Digisonde was placed as near as possible to the midpoint of each of the test circuits. The ionogram virtual heights, local tilts and the observed Angles of Arrival (AoA) were then sufficient to estimate the locations of the test transmitters using the mirror model implemented by the previous generation HFDF/SSL system DragonFix [see, for example, McNamara (1991)].

2. Contour Plots of Virtual and Real Heights

Figure 2 shows the 0.5 MHz contour plots of the virtual and real heights of the CH833 ionograms for day 026, 2014. The contours start at 5.0 MHz. 15-23UT corresponds to 08-16LT.

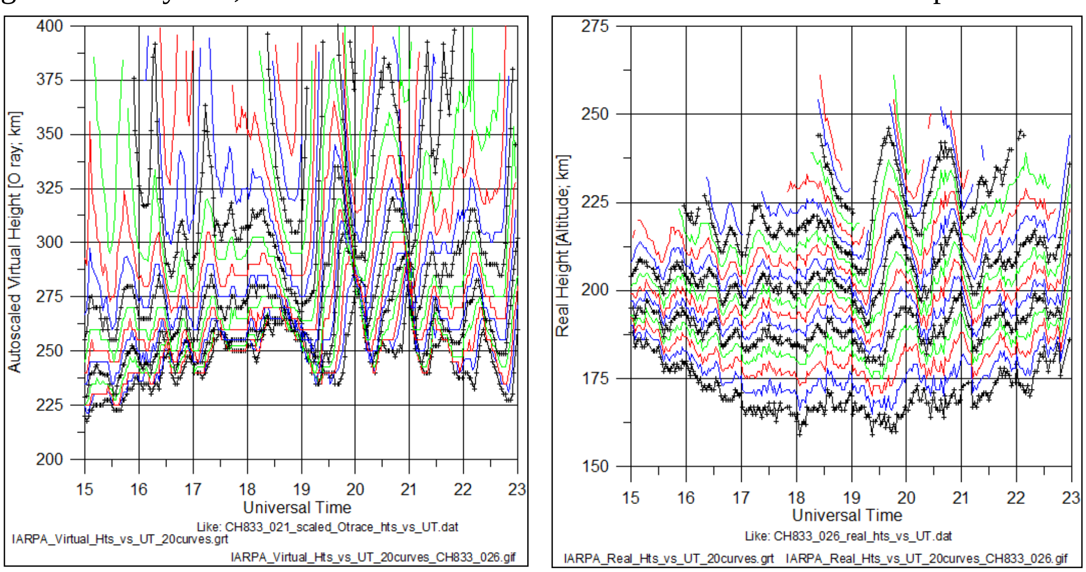

Figure 2. Contour plots of the virtual (on the left) and real (on the right) heights for day 026 of January 2014

Note: The real height contours are based on the profiles that were derived from TID-affected ionograms, so some circumspection is advised.

There were obviously two very large TIDs after 19UT (noon), with a period of ~60 minutes. The TIDs during the morning had much smaller amplitudes (in virtual height). In general, the amplitude of the disturbances increased with both virtual and real height. The virtual height contours show that the same features appear later at lower altitudes, confirming the ionogram observations. The hooks seen in the ionograms seem to be associated with only a small effect in the profiles.

3. Diurnal Variation of Profile Characteristics

Figure 3 shows diurnal variation of normalized values of foF2, hmF2, sub-peak TEC, F2 scale height, and d(foF2)/dt for CH833 day 026 Digisonde profiles.

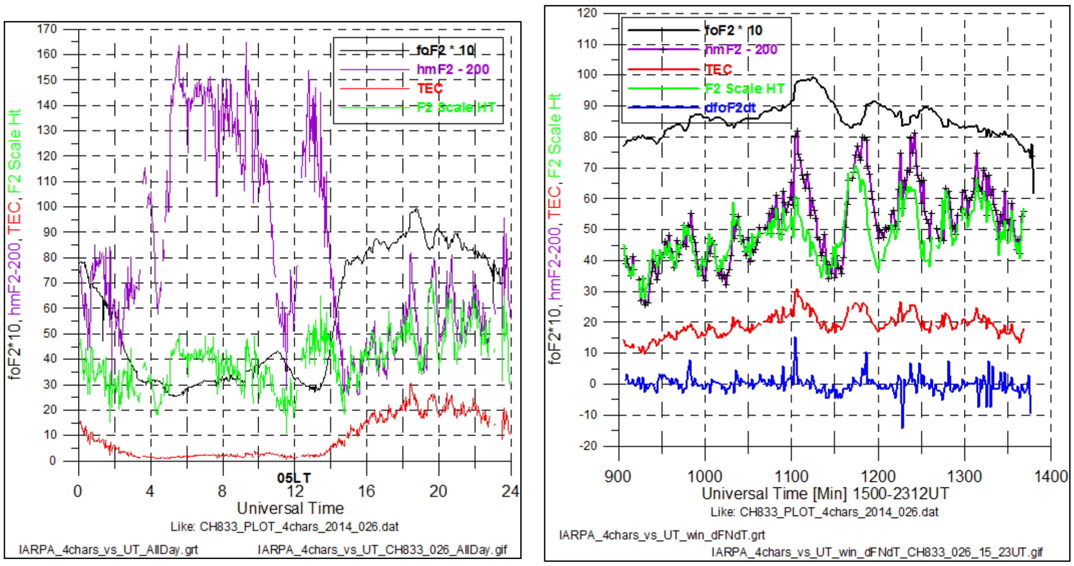

Figure 3. Diurnal variation of normalized values of foF2 (x10), hmF2 (-200), sub-peak TEC, F2 scale height, and dfoF2/dt for CH833 day 026 Digisonde profiles

The right-hand plot covers the “working day” of 08-16LT. The left-hand plot is included to demonstrate the large swings in hmF2 that are associated with nighttime TIDs that are also seen at other locations (Eglin AFB, Florida, for example).

The plots show strong correlations between hmF2, F2 scale height and sub-peak TEC. Starting at minute 1100 (18:20UT), the F2 peak rises sharply and then falls over the next 50 min, and on for 3 or 4 cycles. As the peak height falls, the scale height and sub-peak TEC also fall. The foF2 observations (black curve) and the rate of change of foF2 (blue curve) do not tell a consistent story.

4. Digisonde Profiles

Figure 4 shows CH833 profiles for 18-21UT (each offset by 0.2 MHz) and for 18-19UT. It appears that the effect of the TID on the profile was to raise the peak of the layer by ~15 km further into the topside ionosphere. In so doing, it caused the profile to include a further 15 km of the ionosphere that was originally in the topside above hmF2. The value of foF2 also increased by ~0.5 MHz, and the F2 scale height increased by ~6 km (the profile got fatter). These changes increased the subpeak TEC by ~6 TECU.

The most obvious effect of the TIDs on the profiles was this to raise or lower the value of hmF2, with the layer becoming fatter or thinner, and the subpeak TEC increasing or decreasing. Apart from the stretching or shrinking of the profiles, the shapes do not change dramatically. Most of the profiles in Figure 4 (left) are basically parallel to each other.

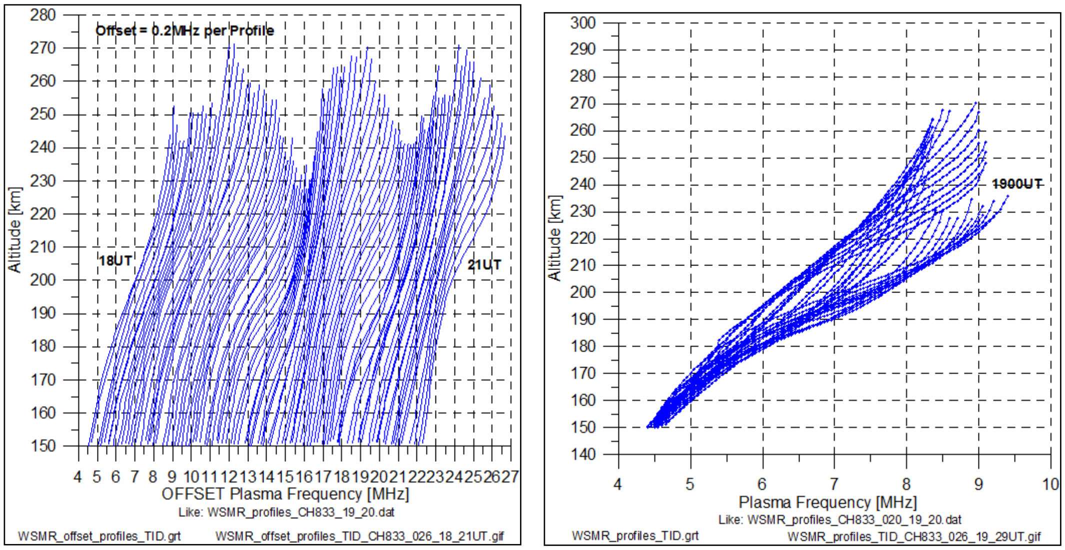

Figure 4. Digisonde profiles for day 026 – left: 2-minute profiles 18-21UT offset by 0.2 MHz; right: 18-19UT profiles with no offset.

5. Local Ionospheric Tilts at CH833

Figure 5 shows the N-S and E-W components of the Skymap tilts at CH833 on day 026. The tilts were measured at 5.1 MHz. They reach ~4^{o} after ~20UT (13LT). These are small scale tilts at an altitude of ~175 km, and are not closely related to the TIDs seen in the contour plots of Figure 2.

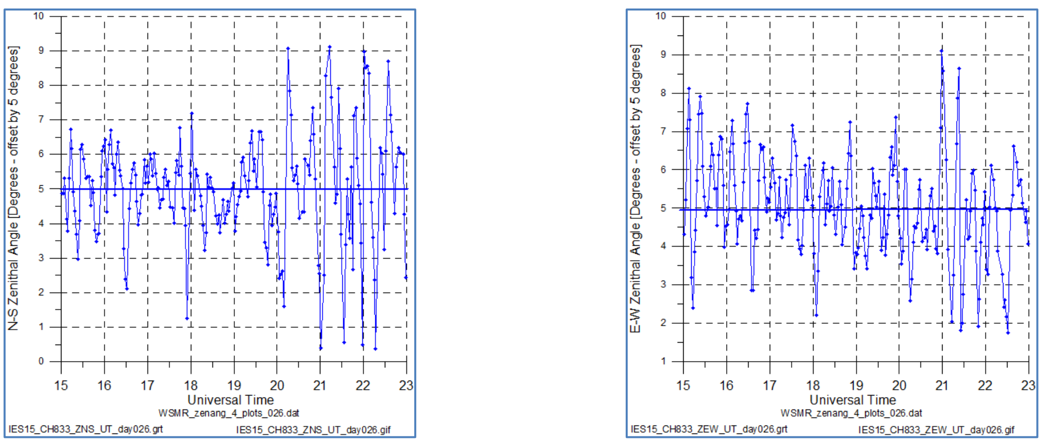

Figure 5. N-S and E-W components of the tilts at CH833, 5.1MHz, day 026, offset by 5 degrees

6. Discussion

The WSMR campaign provided a unique 10-day set of 2-minute ionograms, profiles and Skymaps for four modern ionosondes, with separations of ~100km. The large TIDs observed for most days of the campaign came as rather a surprise. Medium scale TIDs had been observed in the AoA on a regular basis in north Texas with the DragonFix HFDF/SSL system [McNamara, 1991], but the ionosonde deployed concentrated on real-time observations with no consideration towards saving the scientific data or presenting it in a fashion that highlighted the TIDs. Nor were plasma frequency profiles derived. The modern Digisondes have greatly advanced our knowledge of TIDs and their effect on the achievable accuracy of geolocation systems.

7. References

McNamara, Leo F. (1991): *The Ionosphere: Communications, Surveillance, and Direction Finding*. Krieger Publishing Company, Malabar, Florida 1991