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Evaluating Day-to-Day Bottomside Ionospheric Variability using Bistatic HF Observations

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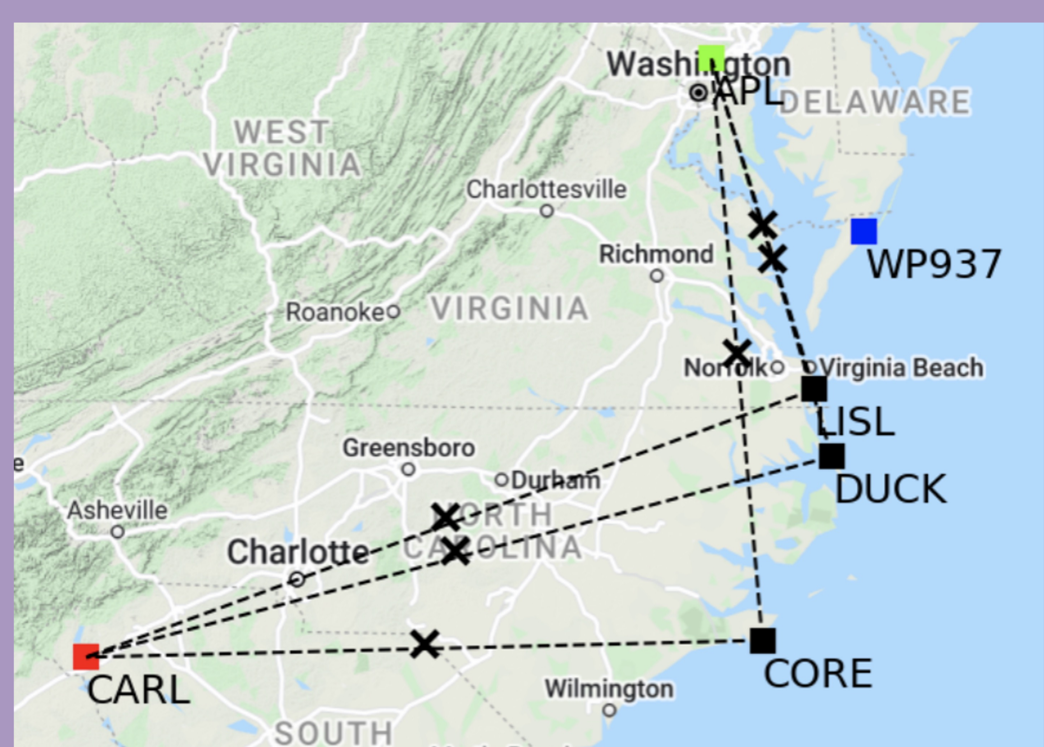
Abstract

The purpose of this investigation is to quantify day-to-day variability of the bottomside ionosphere using bistatic HF observations. The International Reference Ionosphere (IRI) is one of the most dominant ionospheric models that produces a reasonable climatology, however, it does not reproduce day-to-day variability which can be very significant. To understand day-to-day variations we use nearly continuously collected bistatic HF data of Coastal Ocean Dynamics Applications Radars (CODARs). The frequency modulated continuous wave (FMCW) waveforms of these radars can be used to extract group delay measurements using standard signal processing. The virtual height of an ionospheric layer can also be estimated. The cadence of observations is approximately 1 minute for this investigation. Here, we show results from three CODAR transmitters located along the east coast of the US during the Fall of 2020 at a transmission frequency of 4.537 MHz. The receiver was located near Clemson University. As a baseline, we present results of day-to-day variability by ray tracing from the CODAR transmitters to the receiver using the IRI as the background model. For the ray tracing, we use the PHaRLAP or the Provision of High-Frequency Raytracing Laboratory for Propagation ray tracing software package. From this synthetic data, we generate the sample average and standard deviation, as an indication of the variance. We use the CODAR observations along similar links to also quantify the sample mean and variance for this month of observations. We discuss the differences that are observed between the model results versus the observations.

Background



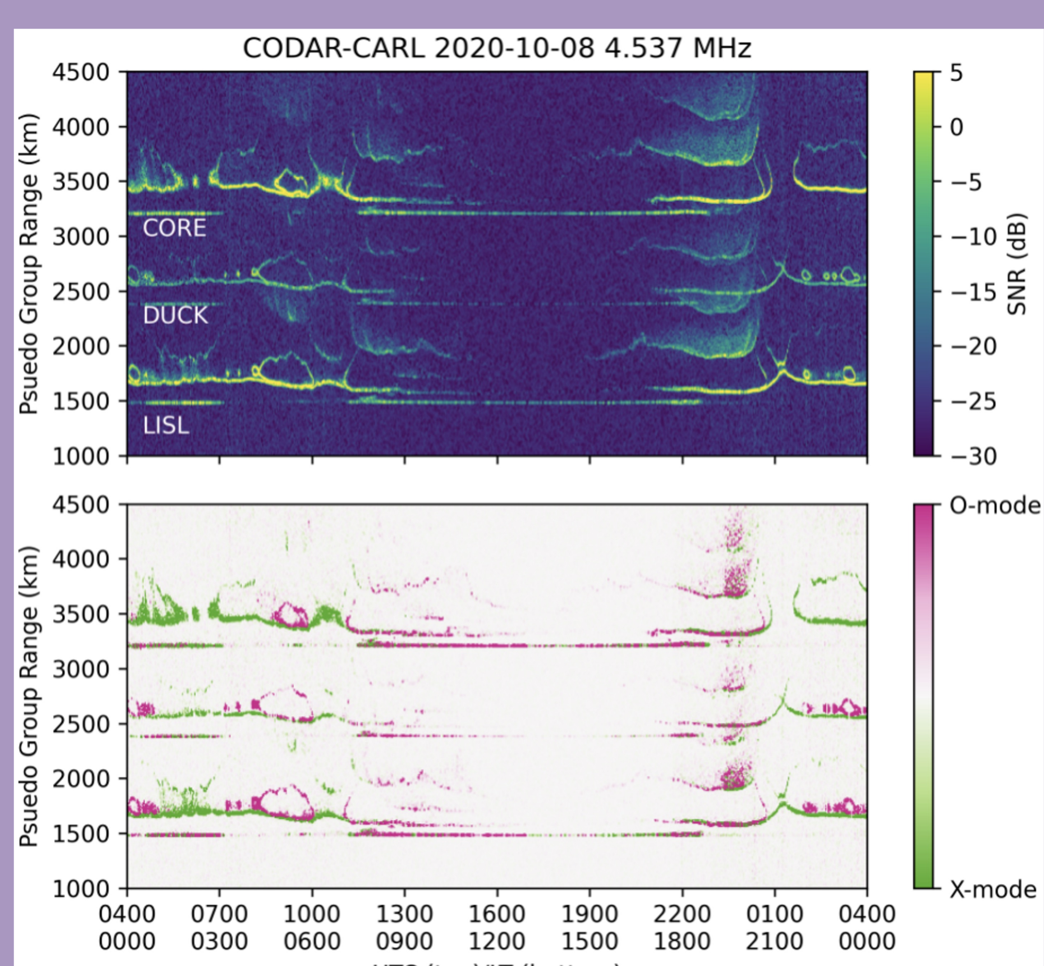


Fig 1 (Top): A map showing the locations of the three transmitters and receiver used in this study. The black squares signify the three CODAR transmitters (DUCK, CORE, and LISL). The red square represents the receiver (CARL) located at Clemson University. The green and blue squares are a receiver and Wallops Island digisonde respectively, both are not used in this particular study. The black 'X' marks represent the midpoint between transmitter and receiver calculated along the great circle path. This midpoint is where all virtual height measurements are taken [1] For the sake of this poster we only consider the outputs from the DUCK transmitter.

Fig 2 (Bottom): An example output from the three CODAR stations (CORE, DUCK, and LISL). Showing group range as a function of time for all three transmitters. [1]

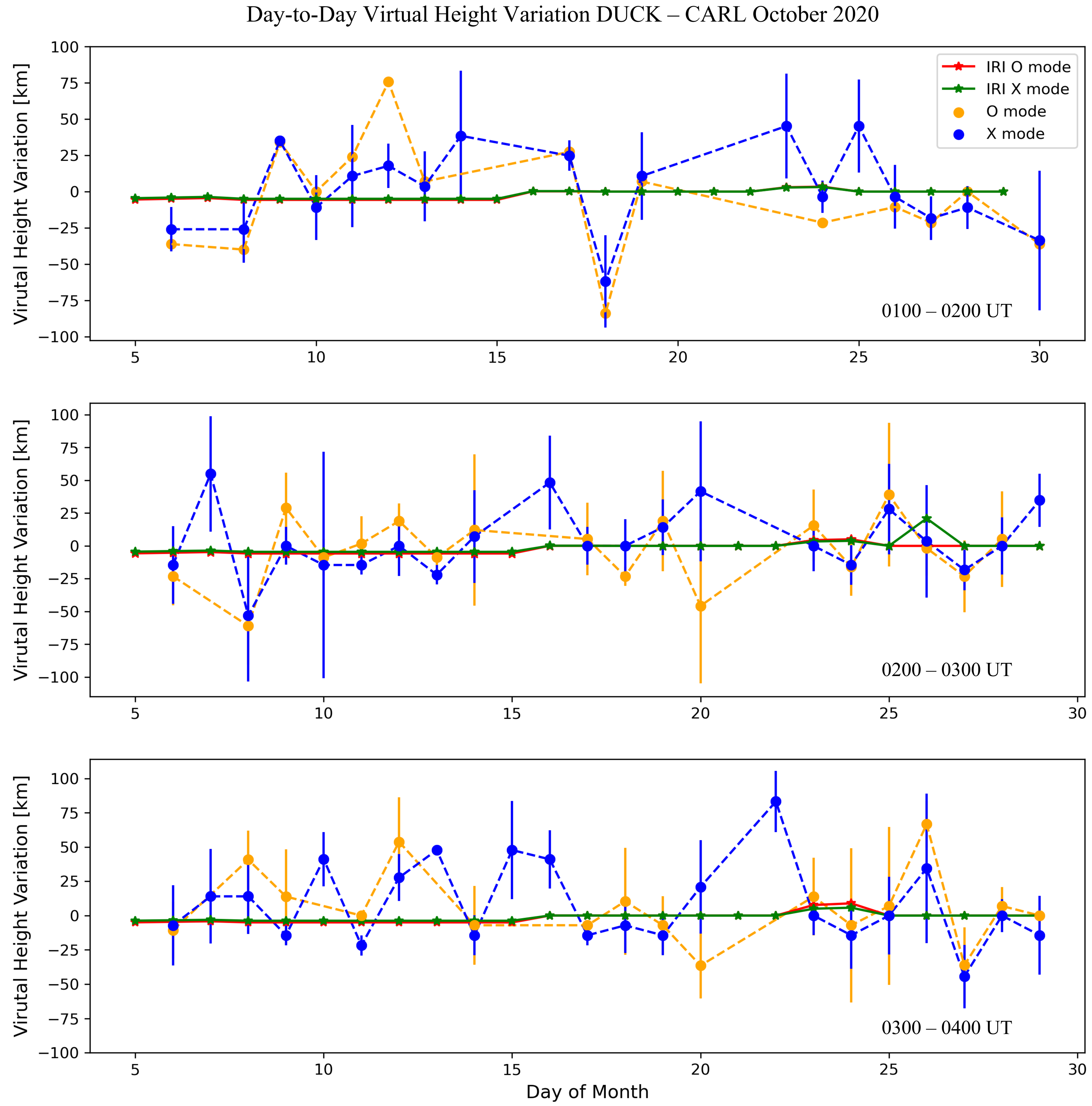


Fig 3 (Center Panel): Here we have the variation in virtual height [km] (equation shown below) as a function of the day of the month for three separate times during the night. All using the DUCK transmitter for both O and X mode propagation. The red '*' are showing the synthetic PHaRLAP data for O mode propagation and the green '*' are showing the synthetic PHaRLAP data for X mode propagation The orange and blue circles are showing the collected O and X mode data from the DUCK transmitter. We consider the hour blocks of 0100 - 0200 UT, 0200 - 0300 UT, and 0300 - 0400 UT. These dates were selected because they are 2100 - 0100 LT (i.e. during the night) and also showed the best agreement between the PHaRLAP synthetic data and the observed CODAR data. Note the virtual height is basically located at the midpoint between DUCK and CARL as shown in figure 1.

To get each point, the median across the entire hour block was taken and the 'monthly average' for that time of night was then subtracted resulting in the variation. The monthly average here was calculated by averaging each day's median together for the respective propagation mode. This was done as a similar analysis to Zawdie et al 2020 [3].

The error bars here represent the 90th and 10th percentiles for our calculated median averages.

Calculation of Virtual Height

To make this comparison the virtual height must first be calculated for both data sets. Group range is resolved from both the real and synthetic data sets using the equation P = c Δt . Where Δt is the time delay of our signal propagating off the ionosphere and c is the speed of light. The ground distance (D) or distance between transmitter and receiver is also needed however, this is a known value. Using basic trigonometric relations (shown below) the virtual height (h) can be calculated [2].

$$\left(\frac{P}{2}\right)^2 = h^2 + \left(\frac{D}{2}\right)^2$$

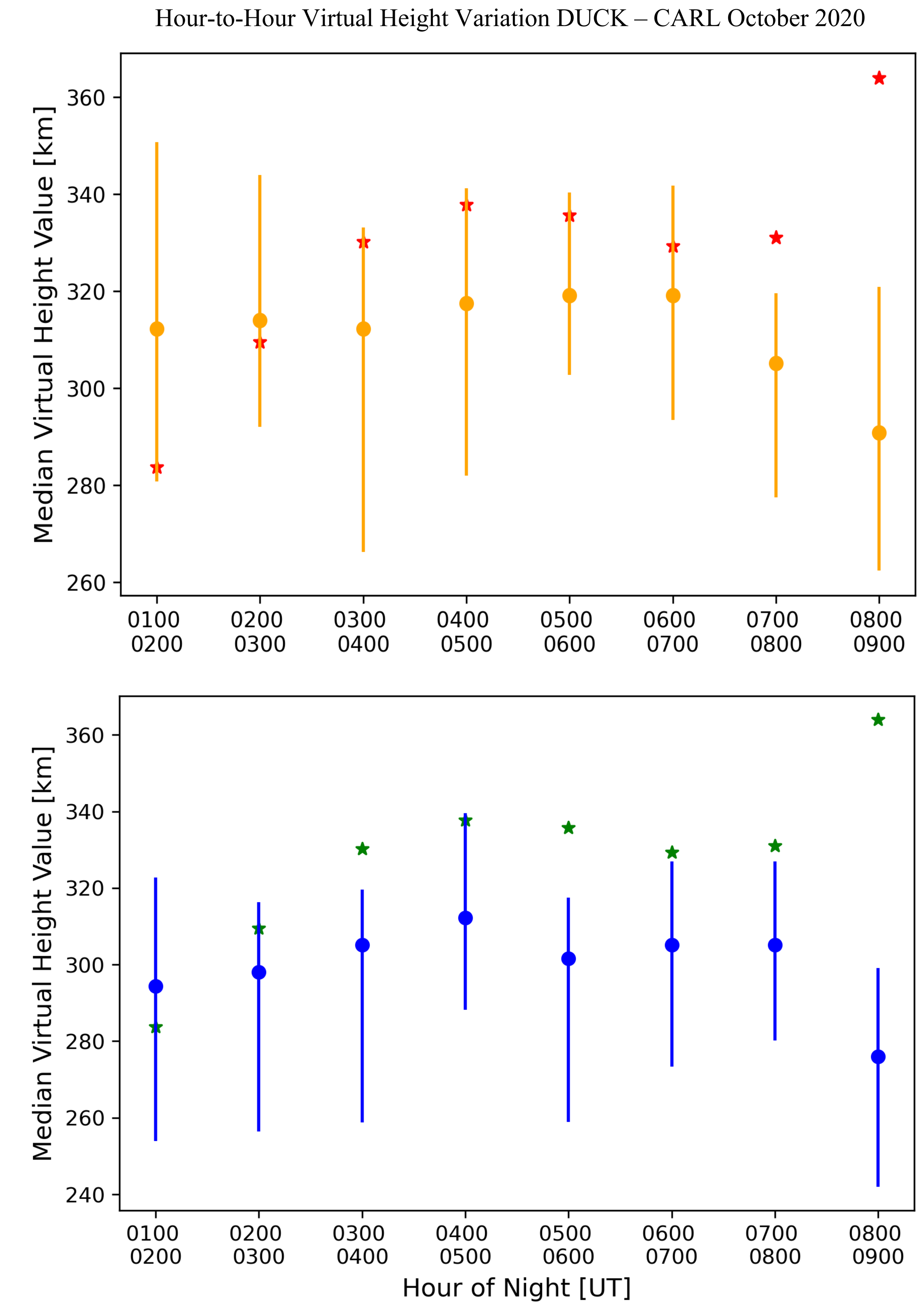


Fig 4: Here we show the hour-by-hour variation in the median virtual height value for the DUCK transmitter only. The top figure is showing only O mode propagation while the bottom figure is showing only X mode propagation for both observed and synthetic data. The orange and blue dots represent the CODAR data while the red and green dots represent the PHaRLAP data. Similar to figure 3 the error bars represent the 90th and 10th percentiles for the calculated median.

The median values were calculated by averaging the virtual height over the hour shown for the range of October 5, 2020 to October 29, 2020 . Therefore, each point represents the monthly average. The hours were selected to specifically consider the night window (2100 – 0500 LT).

Here we can see that using IRI as the background ionosphere we do wee more hourly variation rather than daily variation.

Conclusions

In this study we have shown a comparison between the observed (CODAR) and synthetic (PHaRLAP) data. We have shown that when using IRI as the background ionospheric model we see very little daily variation in comparison to the observed data. For a typical day, our variation for both O and X mode is on the order of +/- 25 km for DUCK and when using IRI our variation is usually less than +/- 5 km. However, we see more variation when focusing on the hour-by- hour data. This leads us to consider other background ionospheric models in future work to hopefully to better quantify the day-to-day variation.

References:
[1] Kaeppler et al 2020
[2]Davies 1990
[3]Zawdie et al 2020

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