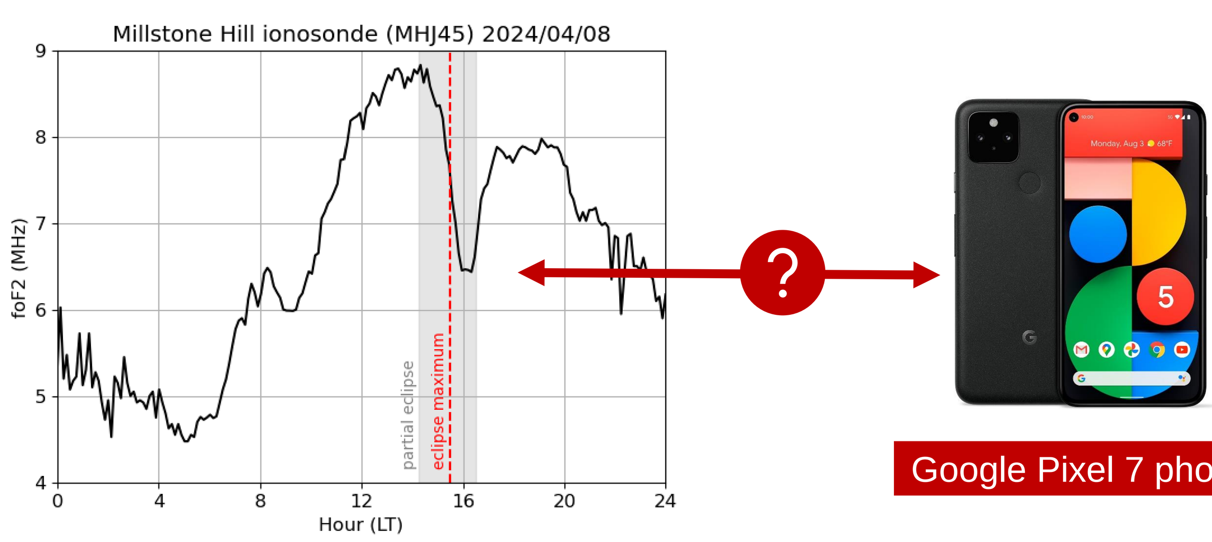
Using high-rate dual-frequency cellphones to study the April 8th total solar eclipse

Nina Servan-Schreiber, Meghan Lemay, Deborah Chiao, Michael Hirsch, Kshitij Duraphe, Yafei Chen, Toshi Nishimura, Joshua Semeter
Center for Space Physics, Boston University

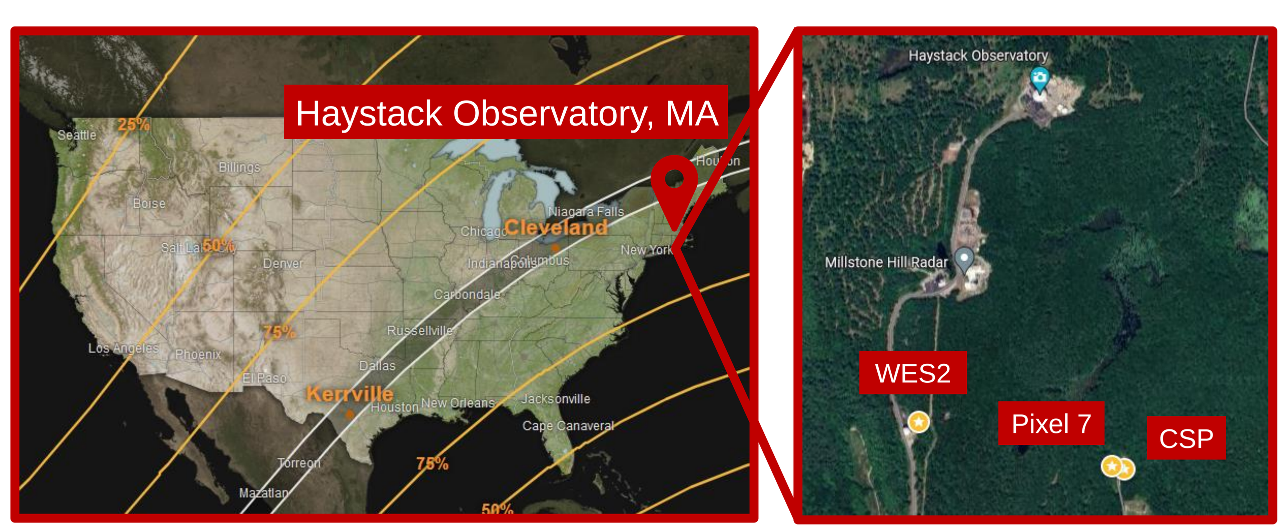
Introduction

Our new generation of dual-frequency cellphones has the potential for benefiting ionospheric science by providing high-rate (1s) GNSS TEC measurements in regions where geodetic receivers are sparse. The physical accuracy of cellphone TEC measurements, however, has yet to be clearly defined. The April 8th solar eclipse provides a unique opportunity to compare the ionospheric response measured by geodetic receivers to that measured by dual-frequency cellphones. Similarly to the August 21st, 2017, eclipse, a TEC reduction caused by the shadow of the moon is expected to be visible in the TEC data [Coster et al., 2017]. Using a set of two geodetic receivers and one Google Pixel 7 phone, we show that despite a noisier carrier phase signal, the Pixel 7 carrier phase differential TEC closely matches that of the 1s and 30s geodetic receivers. This constitutes a first step toward gauging the potential for using dual-frequency cellphones for ionospheric science.



Google Pixel 7 phone

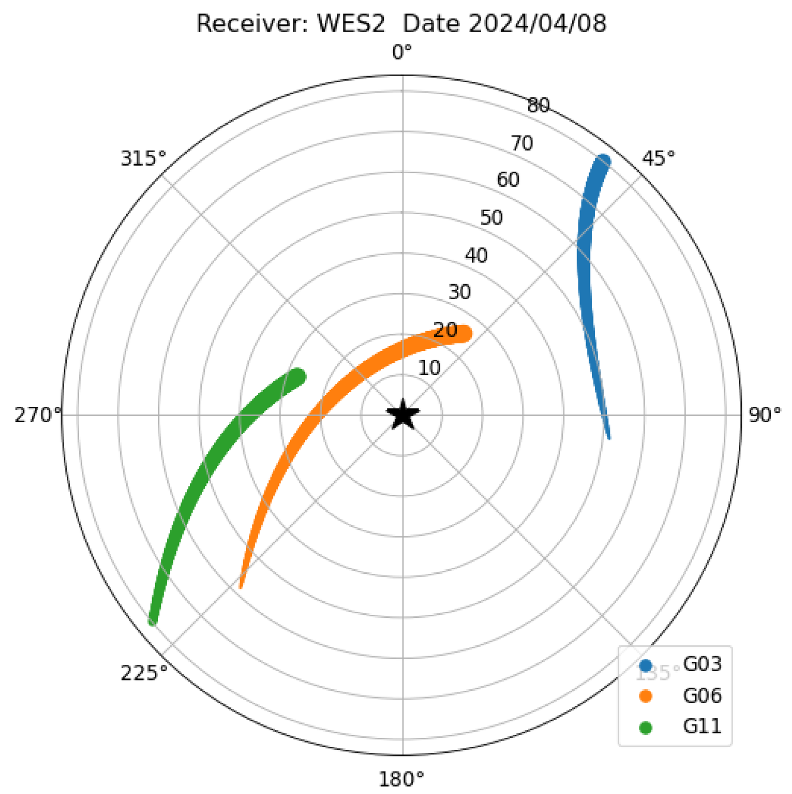
Experimental setup



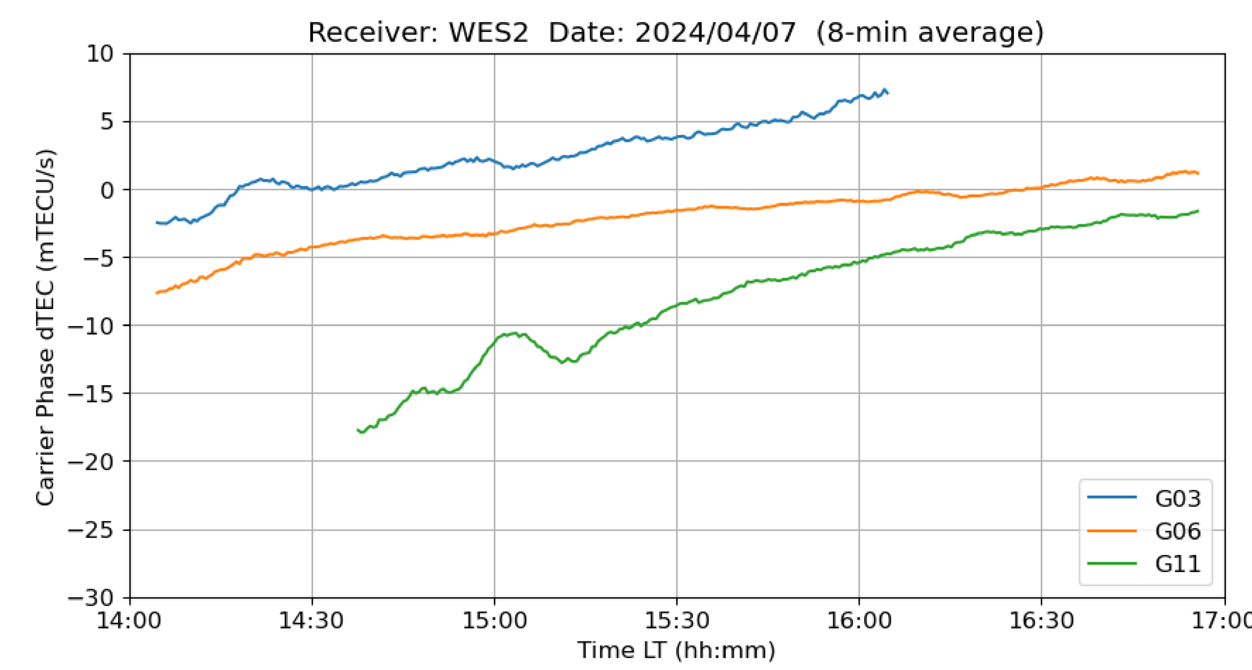
The Pixel 7 phone was set up at the MIT Haystack Millstone Hill site (42.6°N, 71.5°W), within ~700m of the NOAA CORS WES2 30s-receiver and ~40m of a 1s-receiver, noted CSP, that belongs to the Center for Space Physics of Boston University. While the Millstone Hill site was not in the path of totality of the eclipse, the local obscuration was higher than 90%. The Pixel 7 phone was mounted on a tripod in an area minimizing multipath.

Pixel 7 phone mounted on a tripod in Millstone Hill, MIT Haystack.

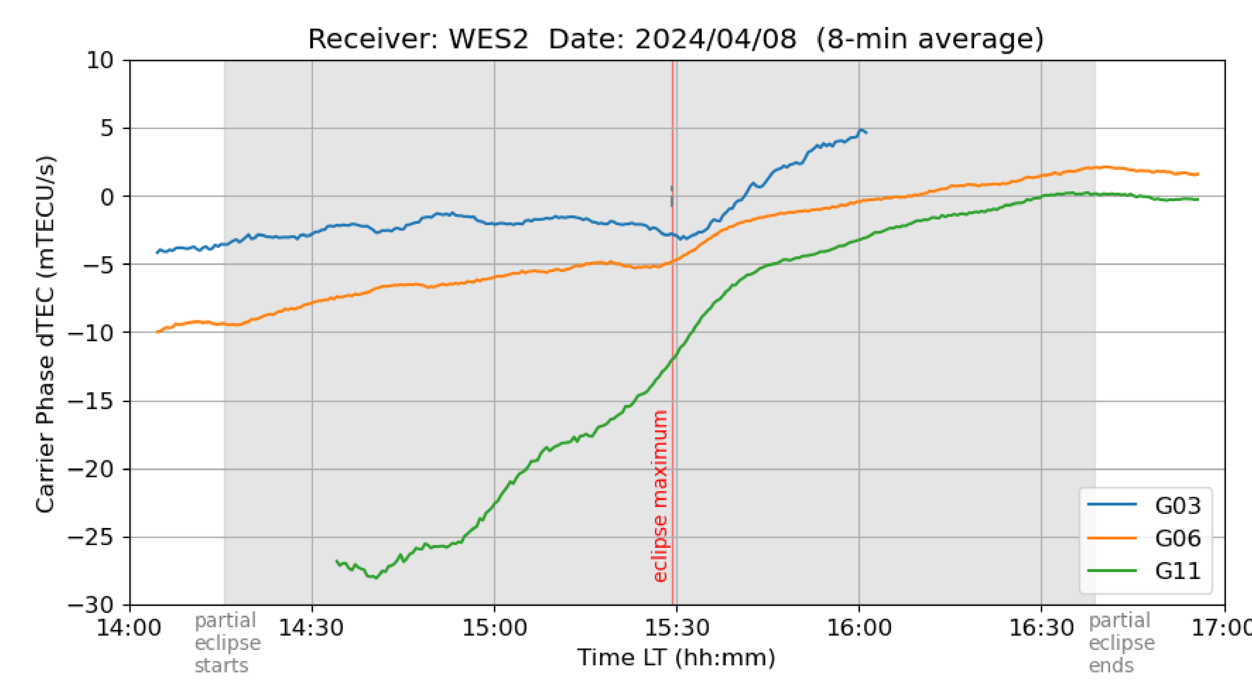
Differential carrier phase TEC



The differential carrier phase TEC (dTEC) provides valuable information when absolute TEC products are unavailable. The azimuth and zenith angles of satellites are important to keep in mind when the TEC is not mapped to VTEC.

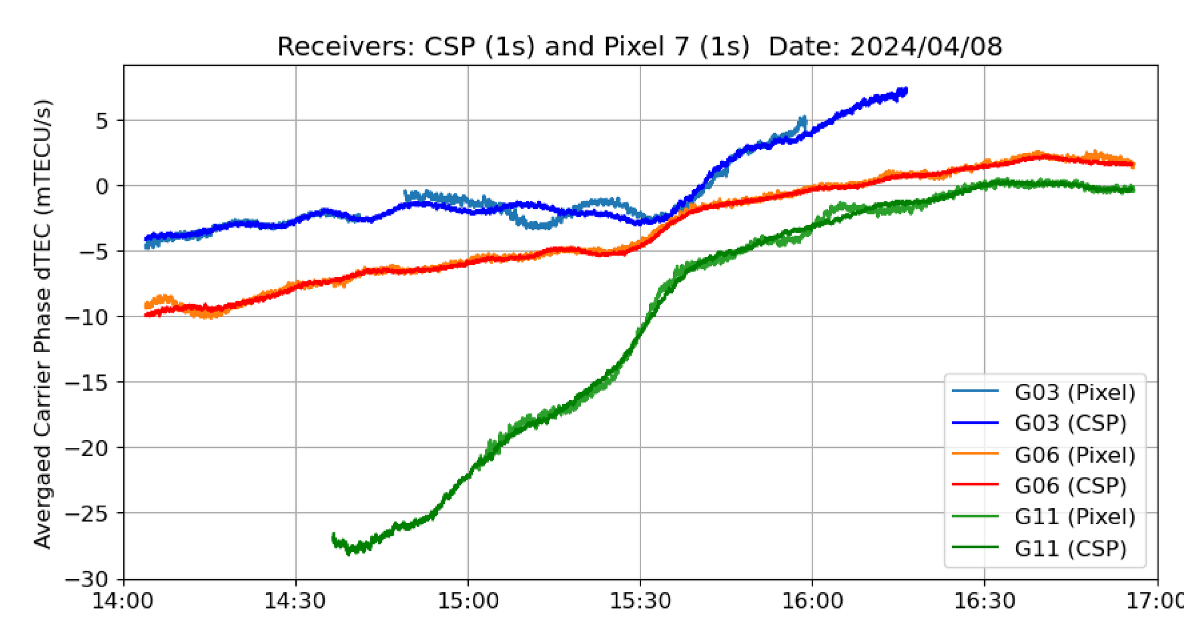


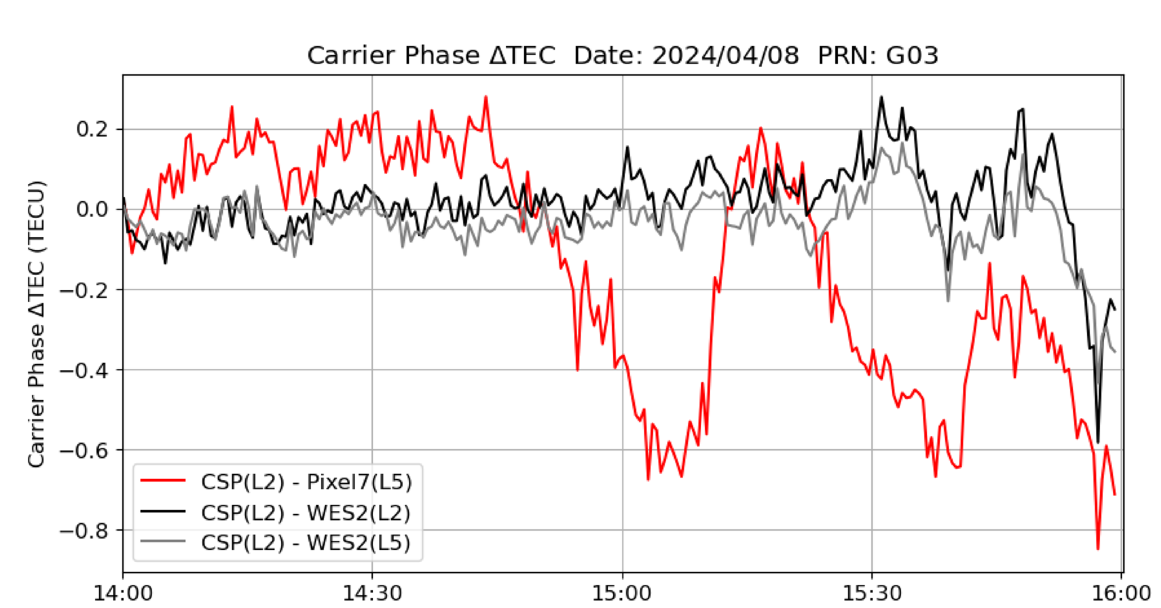
In the adjacent plots, the dTEC of the WES2 geodetic receiver observed by three GPS satellites (G03, G06, G11) are shown for April 7th and April 8th to visualize the effect of the eclipse on the TEC gradient. An 8-minute averaging filter is applied to remove noise. The eclipse visibly decreases the gradient prior to its maximum (~15:29LT) then sharply increases it throughout the following ~10 minutes. The dTEC tends back to the values of the previous day as the ionosphere recovers. The main question of this work becomes: Does the Pixel 7 phone observe the same dTEC behavior?



Cellphone TEC data

Here is shown the carrier phase dTEC comparison between the CSP 1s-geodetic receiver and the Pixel 7 phone for three satellites (G03, G06, G11). The 8-minute averaged carrier phase dTEC is closely matched for the two receiver types. This indicates that despite a higher noise level, the Pixel 7 phone is capable of sensing minute-long ionospheric variations using carrier phase dTEC with an accuracy of less than 3 mTECU/s.

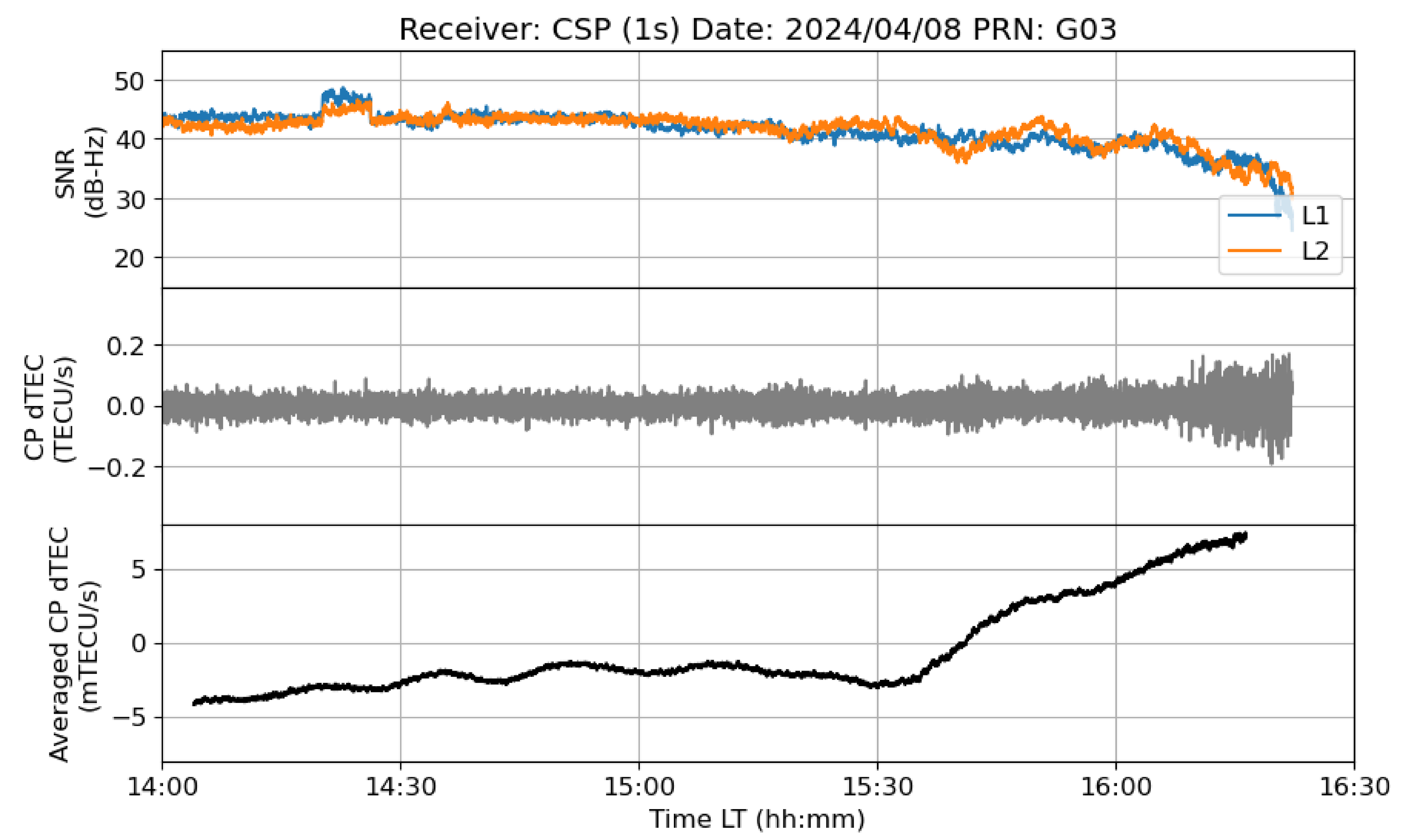


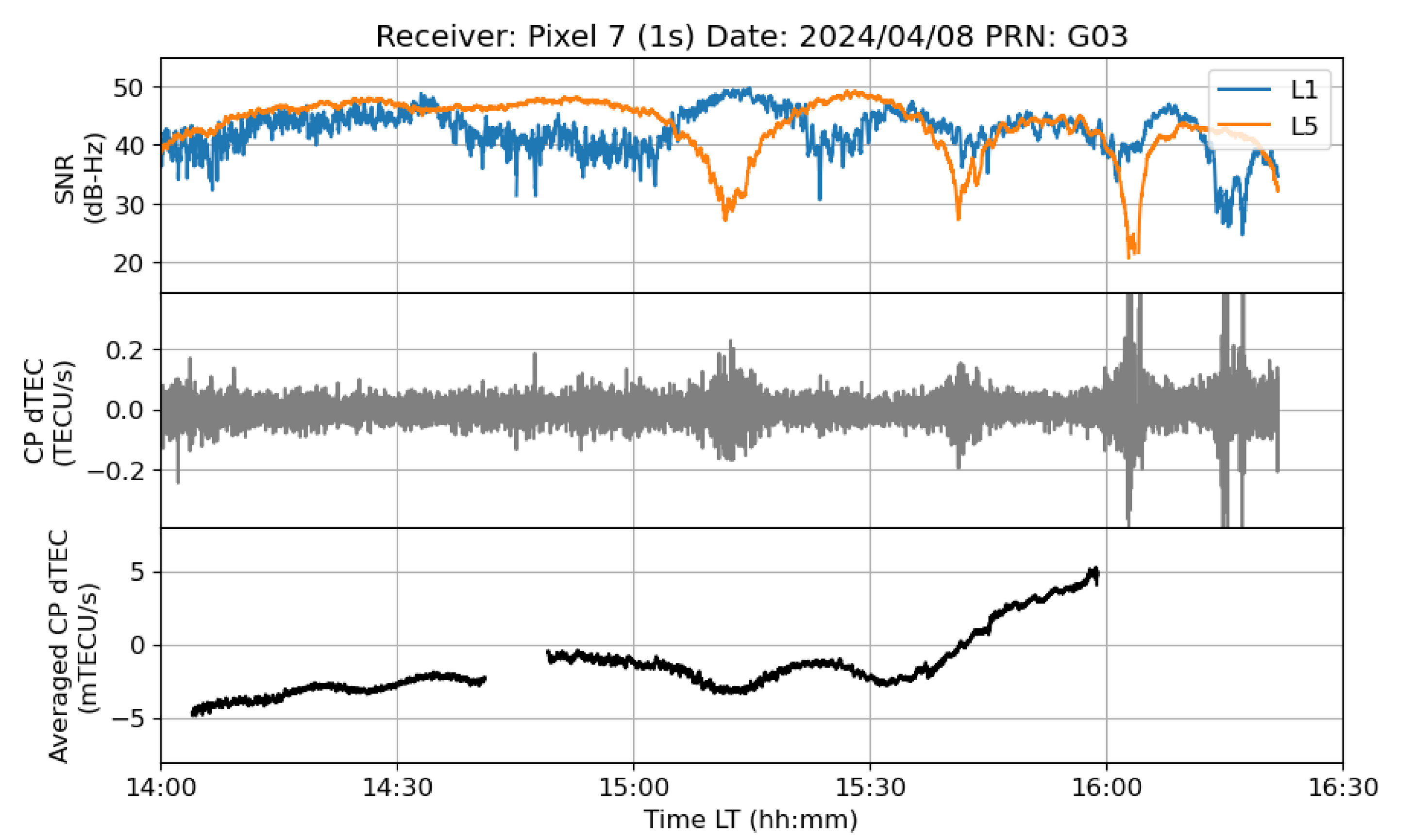


Dual-frequency cellphones work with L1 and L5 frequencies, whereas geodetic receivers can use L1, L2, and L5. While our CSP receiver only picked up L1 and L2, the WES2 receiver picked up on both L2 and L5. By taking the difference of the carrier phase TEC between the WES2, CSP, and Pixel 7 receivers for satellite G03, we show that the frequency of choice (L2 or L5) is not responsible for the "bumps" observed at ~15:10LT and ~15:25LT in the Pixel 7 dTEC data for that satellite.

SNR

A closer look at the SNR for the CSP and Pixel 7 receivers sheds light on the nature of the "bumps" in the Pixel 7 dTEC data. The Pixel 7 L5 SNR drops drastically at ~15:10LT while the L1 SNR remains high. Conversely, the L1 SNR drops moderately at ~14:45LT and ~15:25LT while the L5 SNR remains high. While the reason behind these SNR drops is still unclear, it confirms that the "bumps" are a receiver-specific issue rather than a physical phenomenon picked by the phone. The behavior of the SNR in dual-frequency cellphones requires more investigation if this technology is ever to be used for ionospheric research.





Conclusion

Taking advantage of the ionospheric perturbation generated by the April 8th, 2024, eclipse, we have shown that the differential carrier phase TEC of dual-frequency cellphones matches the sensitivity of high-rate geodetic receivers within a few mTECU/s. This is promising for the future of dual-frequency cellphones in ionospheric research. Future works should include the further understanding of the behavior of the SNR in cellphone receivers, the study of the sensitivity to multipath, the analysis of the receiver biases associated with cellphones, etc. Ultimately, this avenue of research should provide an answer to the question: Can dual-frequency cellphones constitute a practical source of GNSS TEC data?

References

Coster, A. J., Goncharenko, L., Zhang, S.-R., Erickson, P. J., Rideout, W., & Vierinen, J. (2017). GNSS observations of ionospheric variations during the 21 August 2017 solar eclipse. Geophysical Research Letters, 44, 12,041–12,048.