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Systematic Statistical Identification of Lower Region Ionosphere Acoustic Waves

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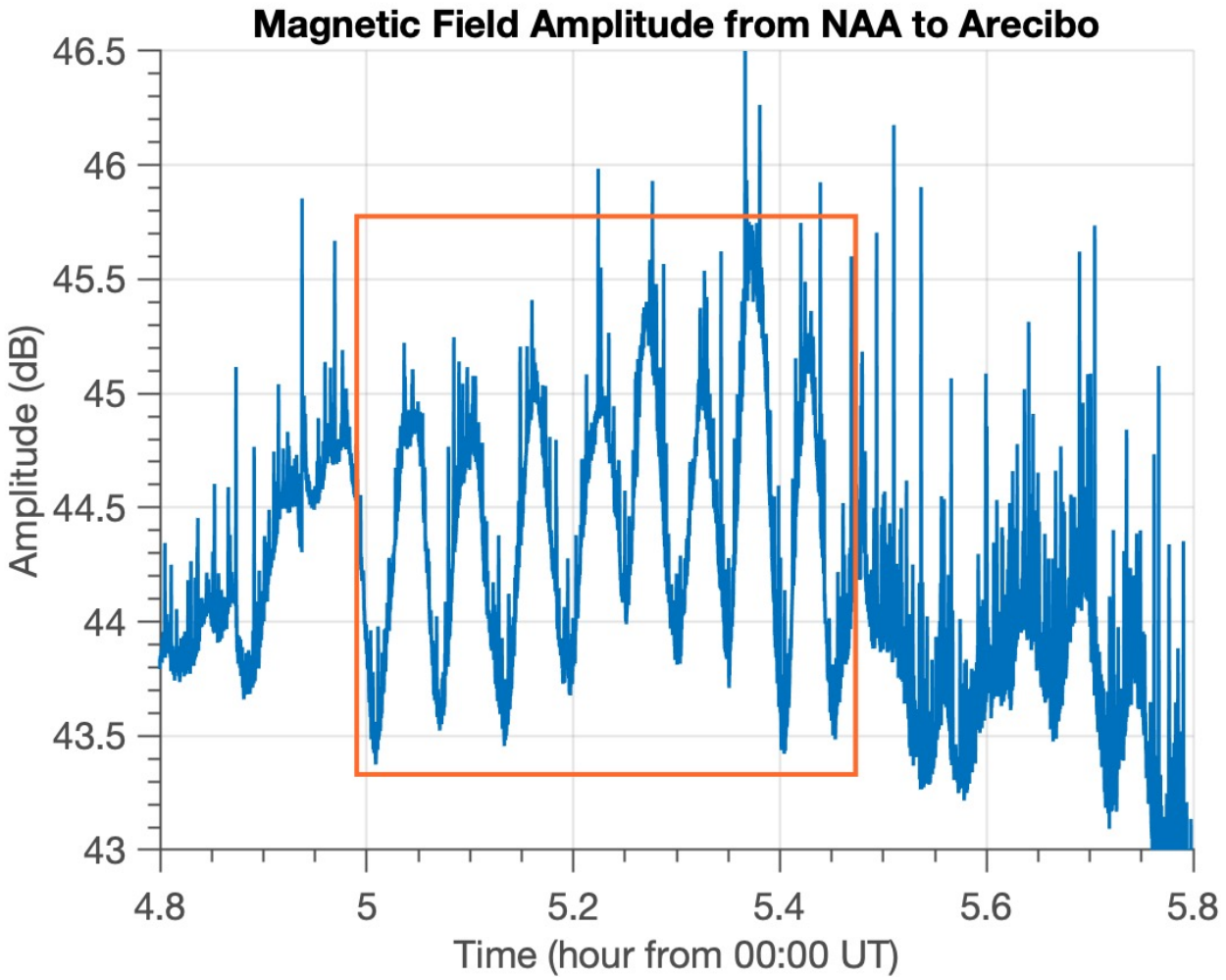
VLF D-Region Remote Sensing

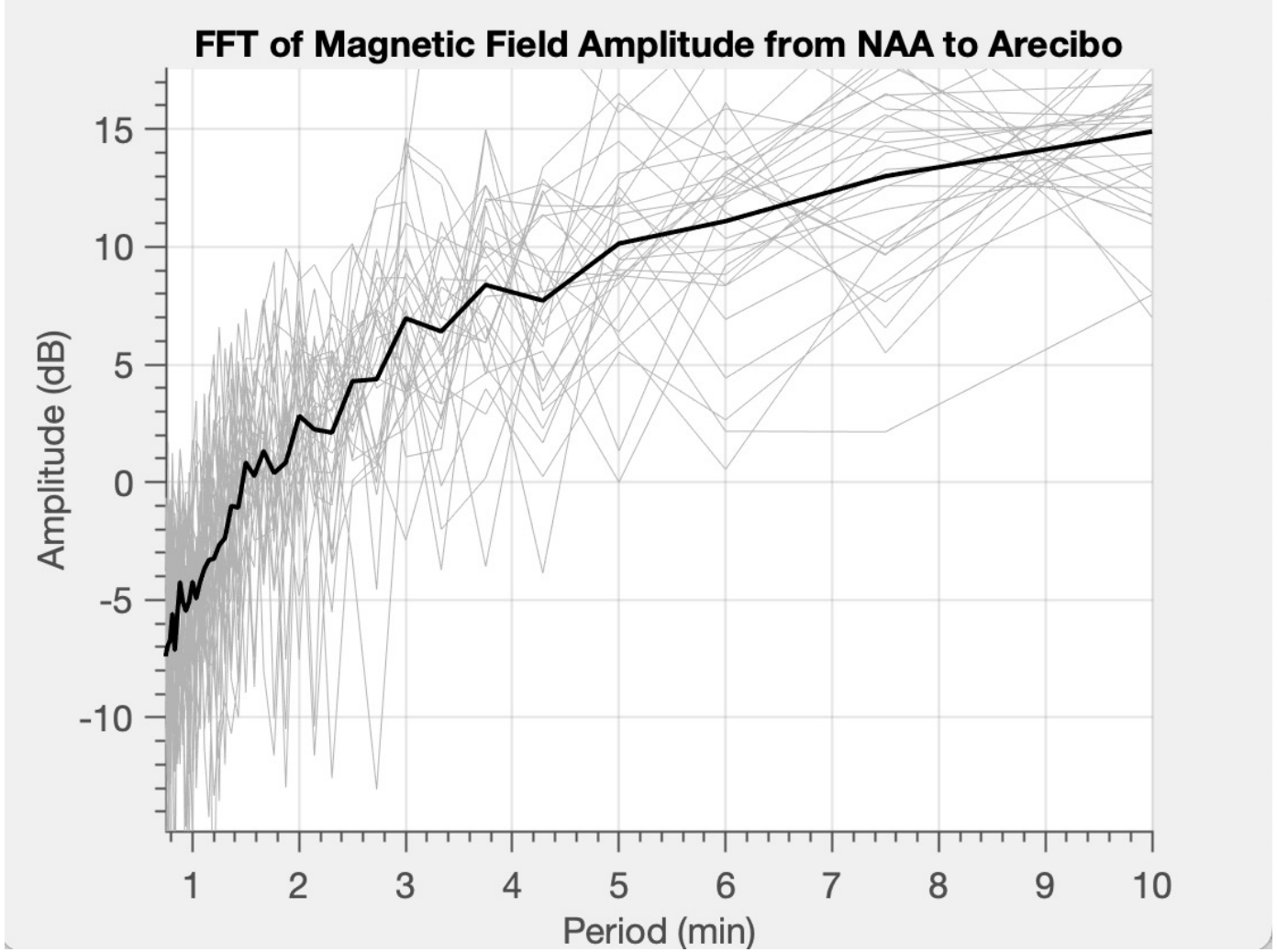
- Very-Low-Frequency (3-30 kHz)
- D-region of the ionosphere (60-90 km elevation)
- As signals bounce off the ionosphere, they capture the condition changes occurring



Past Works

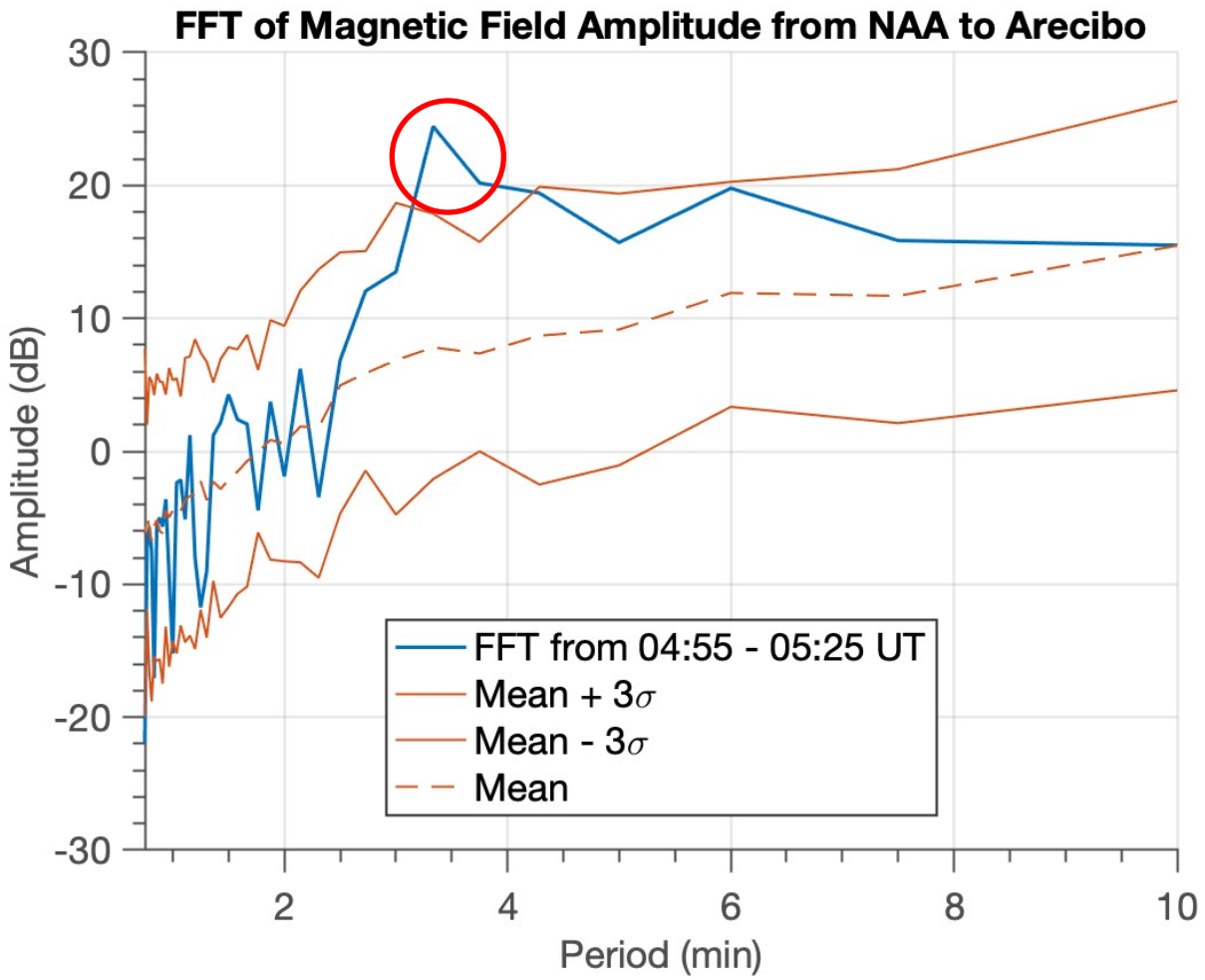
- Maurya et. al. presented results that provide evidence for dynamical coupling between troposphere and ionosphere
- Nina and Cadez presented results to connect solar terminator motions to acoustic wave disturbances
- **Both methods are anecdotal, no general method**

Variation of Data

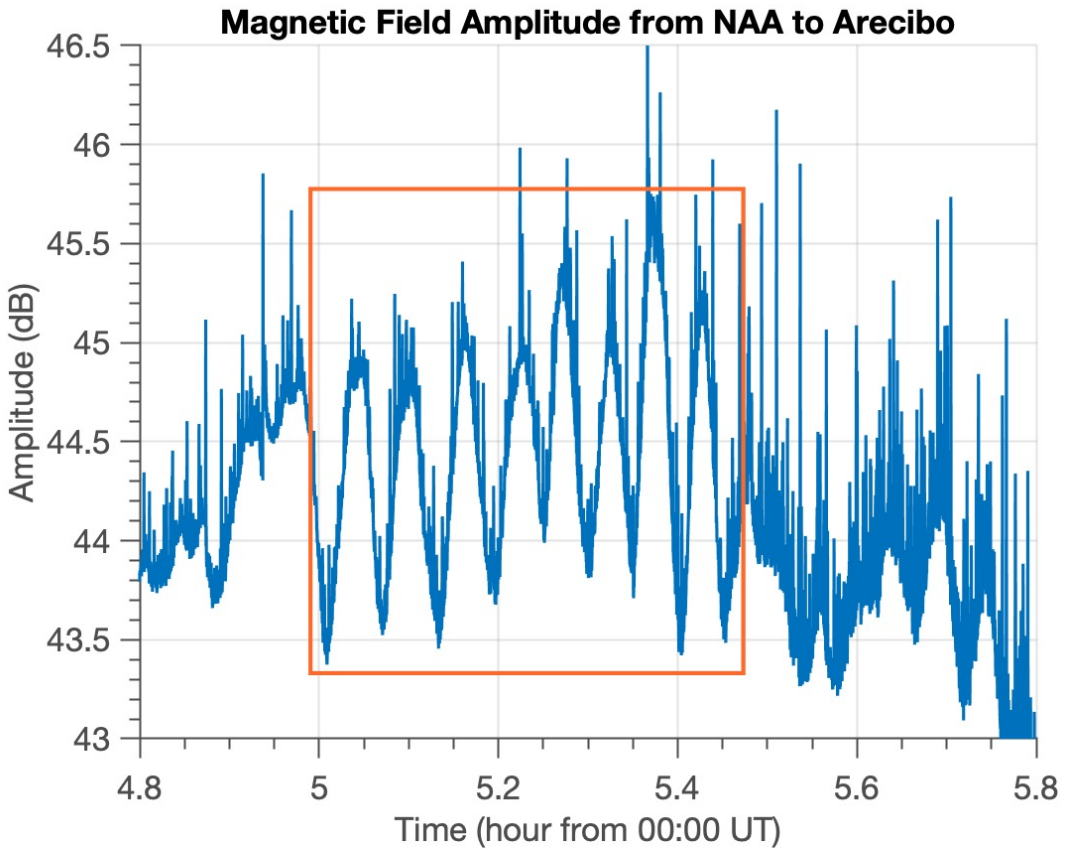


Identifying Outliers

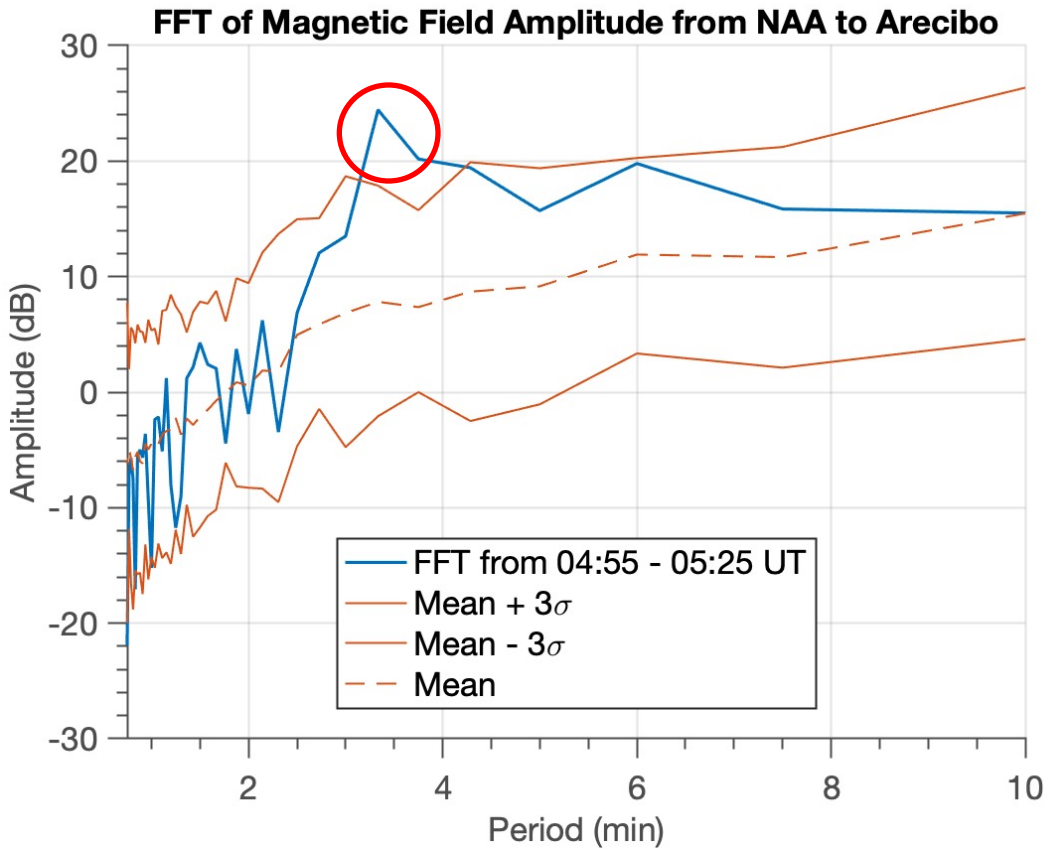
- Standard deviation bands are 3 standard deviations from mean
- Steps:
  - Exclude periods containing data of target period
  - Calculate average
  - Calculate standard deviation



Do Our Analyses Align?



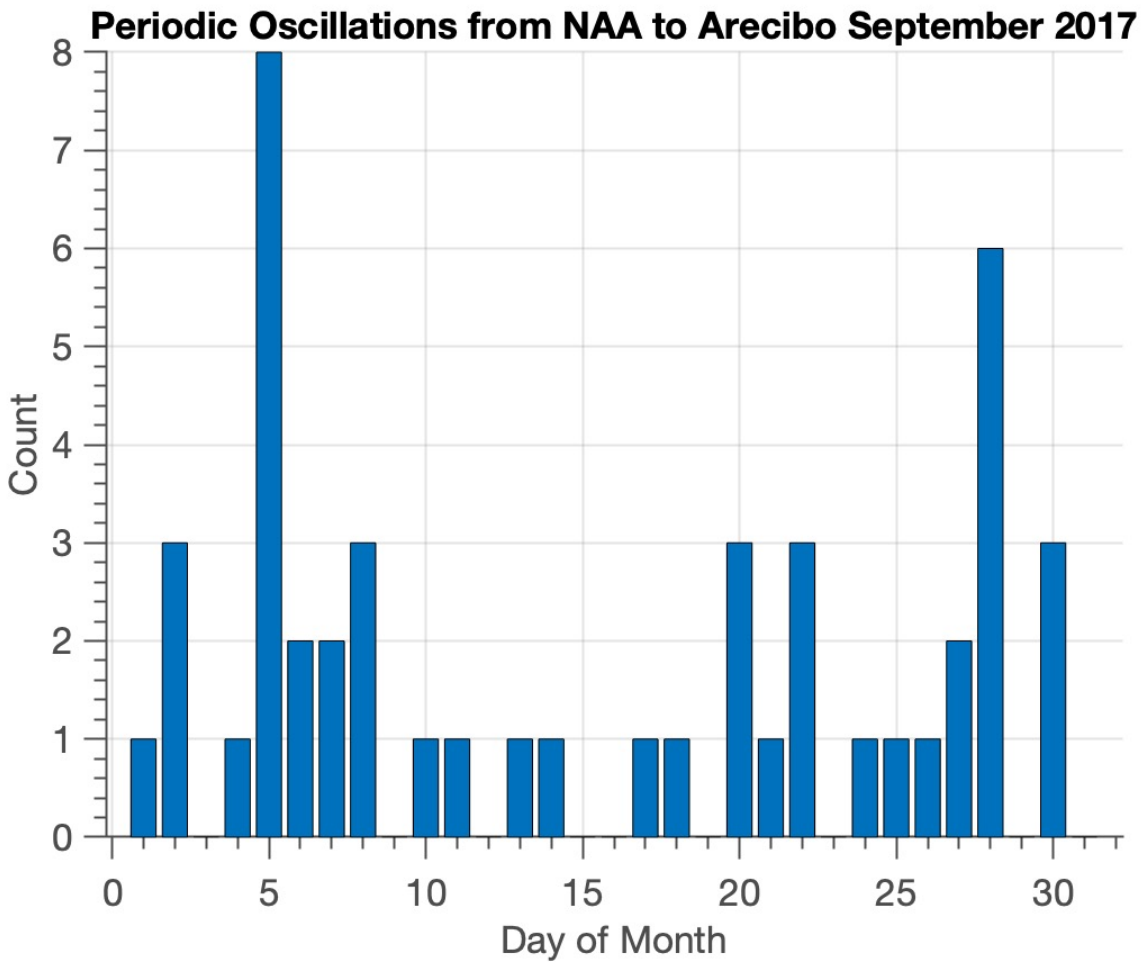
Approximately 3.33-minute period



Approximately 3.33-minute period

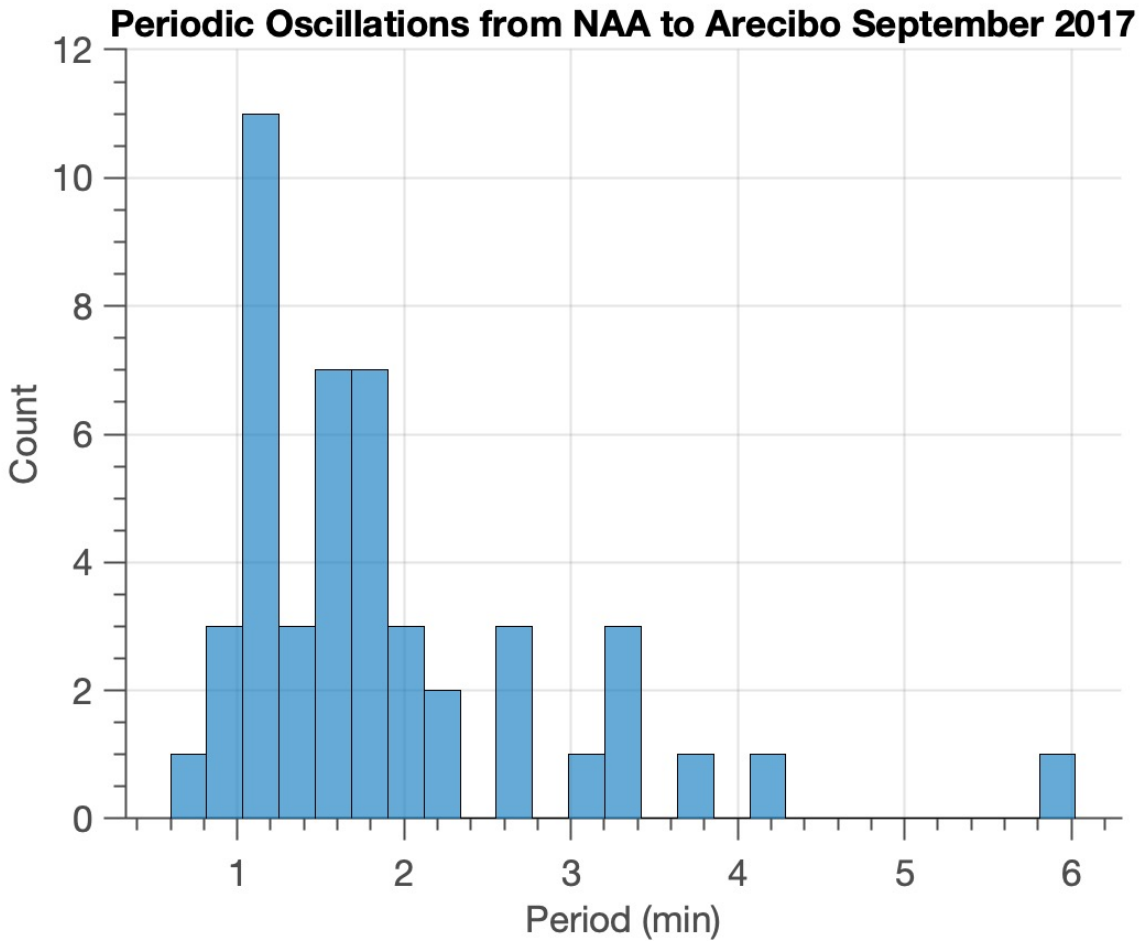
Running Over Massive Datasets

- Method is lightweight and can be run over massive datasets
- Script was run for data from September 2017
- Results are in line with what we expect for the month
  - Hurricane Irma (9/6)
  - Hurricane Maria (9/20)



Running Over Massive Datasets

- Method is lightweight and can be run over massive datasets
- Script was run for data from September 2017
- Results are in line with what we expect for the month (1-5-minute periods)



Summary

- **We have developed a statistically reliable method to identify acoustic waves in the lower-region ionosphere**
- New datasets can be generated of acoustic wave occurrences that detail their date, time, and frequency of occurrence
- We are excited for what these new datapoints can enable, such as:
  - **Investigating dynamic coupling between the troposphere, lower-region ionosphere, and upper-region ionosphere**
  - Identifying patterns of acoustic wave generation such as most prevalent sources, seasonal variations, etc.

References

- [1] A. K. Maurya, M. B. Cohen, K. Niranjan Kumar, D. Phanikumar, R. Singh, P. Vineeth, and K. Kishore Kumar, “Observation of very short period atmospheric gravity waves in the lower ionosphere using very low frequency waves,” *Journal of Geophysical Research: Space Physics*, vol. 124, no. 11, pp. 9448–9461, 2019. [Online]. Available: https://agupubs.onlinelibrary.wiley.com/doi/abs/10.1029/2019JA027360
- [2] Nina, A., and Čadež, V. M. (2013), Detection of acoustic-gravity waves in lower ionosphere by VLF radio waves, Geophys. Res. Lett., 40, 4803-4807, doi:10.1002/grl.50931.