SURF Interim Report 2 - Investigating the Time Dependence of Near-Infrared Zonal Waves in Jupiter's North Equatorial Belt

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1 Completed Work

Over the past month, I have performed various statistical surveys of the results of applying the Fast Fourier Transform (FFT) to stitched longitudinal maps and Lomb-Scargle Periodogram to unstitched cylindrical maps of the North Equatorial Belt (NEB). Of particular interest was finding any periodicity present in the time-dependence of wave power of thermal-infrared NEB zonal waves. Work done both by previous interns (Hackett,[4] Wells[7]) and myself (within the first month of my SURF) noted high-wave power NEB waves coinciding with NEB expansions (NEBEs), but failed to establish a robust periodicity. In the last month, I found an apparent periodic structure to the resurgence and disappearance of these waves present between the starts of subsequent NEBEs by folding and normalizing data from NEBE start to subsequent NEBE start.

1.1 Apparent periodicity of NEB waves between NEBE start dates

Figure 1 is a composite created from all Lomb-Scargle Periodogram data from 1996 to 2019; the first 6 panels are the data separated by associated NEBE, the 2nd-to-last panel is a composite of all the data overlaid (without normalizing), and the final panel is a normalized composite, where the periodic structure is clearly visible. The data was obtained by applying the Lomb-Scargle periodogram to individual cylindrical maps of Jupiter in the near-infrared and correcting by the Baluev False Alarm Probability[1] to account for aliases or false alarms flagged with erroneously high wave power. NEBE start and end dates were obtained from Fletcher et. al. 2017[2] and Rogers et. al. 2019.[5] Applying the (FAP-corrected) Lomb-Scargle periodogram to the resultant normalized composite graph yields a frequency of 2.8, i.e. there are, with statistically significant consistency, about 3 "rises and falls" in near-infrared wave power between subsequent NEBEs. Figure 1 also tells us that, in spite of the differences between the lengths of these periods, the NEBE events end roughly in the middle of each period. That the wave powers do not peak solely during NEBEs implies a separate cause for the waves; still, the presence of a periodicity coincident with NEBE start dates could mean this cause is somehow related, even if not the same.

1.2 Longitudinal dependence of Lomb-Scargle wave power

One question that arises when looking at Figure 1 is what causes the differing L-S wave powers for the same observation dates (i.e. the vertical stacks of points). The answer to that is a longitude dependence (Figure 2): wave powers are higher at increasing System III longitude. This agrees with the observations reported in Giles et. al. 2018.[3] However, those observations only spanned from 2017 to 2018; the presence of this dependence as a general trend over time, rather than one isolated specifically to 2017-2018, is previously unreported. This dependence is indicative of an incomplete wave train across the NEB, with wave strength peaking at higher longitudes and tapering off as longitude decreases.

1.3 Cross-referencing Lomb-Scargle results with stitched longitudinal maps and FFT wave powers

To provide a visual companion for the trends in Lomb-Scargle periodogram data, as well as examine these trends in FFT data, I cross-referenced stitched longitudinal maps with the Lomb-Scargle data from corresponding dates and overlaid their respective normalized FFT wave powers (Figure 3). The sampling of FFT data is much scarcer; this is because the Fast Fourier Transform, unlike the Lomb-Scargle periodogram, is ill-suited for data with irregular or limited sampling (in our case, this means longitudinal sampling). Individual cylindrical maps therefore pose an issue, as they are low in longitudinal coverage, making them poor candidates for the FFT. However, with enough unique observations close together in time, stitched lmaps can provide enough longitudinal coverage for the FFT to be a reliable option. The FFT is desirable when possible because it is not as prone to flagging aliases of true wavenumbers as the Lomb-Scargle periodogram.[6]

We can see in Figure 3 that the limited FFT wave powers trace out the trend in Lomb-Scargle power. Also reassuring are the corresponding stitched lmaps, which show a clear visual increase in NEB wave power along with the FFT and L-S data (favoring higher longitudes as well, as expected).

2 Plans

We now have a stronger grasp on the time-dependence of the *strength* of zonal NEB waves. Moving forward, there are two paths for subsequent research: exploring this dependence further (e.g. by examining other wavelengths or creating more plots similar to Figure 3); or, searching for time variability of other wave properties. Giles et. al. 2018[3] noted the presence of different types of waves, as well as waves of varying wavenumber, but there have not been reports of a periodic structure to those properties. One could find those in much the same way I've been working so far. Time permitting, I'll attempt both paths before moving on to writing up a formal article detailing my (and previous interns') findings in the final weeks of my SURF.

References

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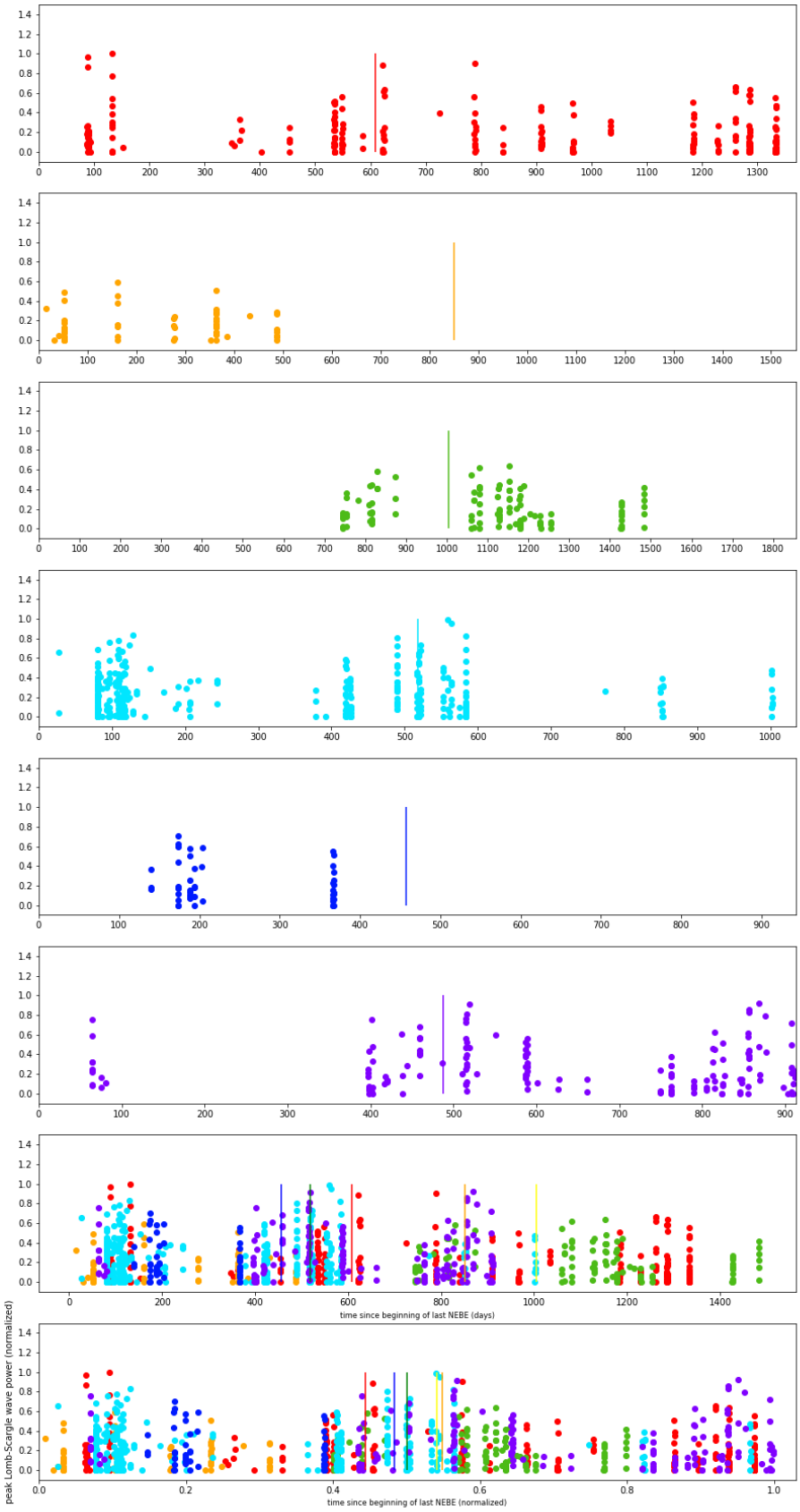

Figure 1: Lomb-Scargle wave powers of NEB waves seen in (unstitched) cylindrical maps of Jupiter. The vertical lines correspond to the end dates of each NEBE, which do not have identical periods. The beginnings and ends of the x-axes correspond to the start dates.

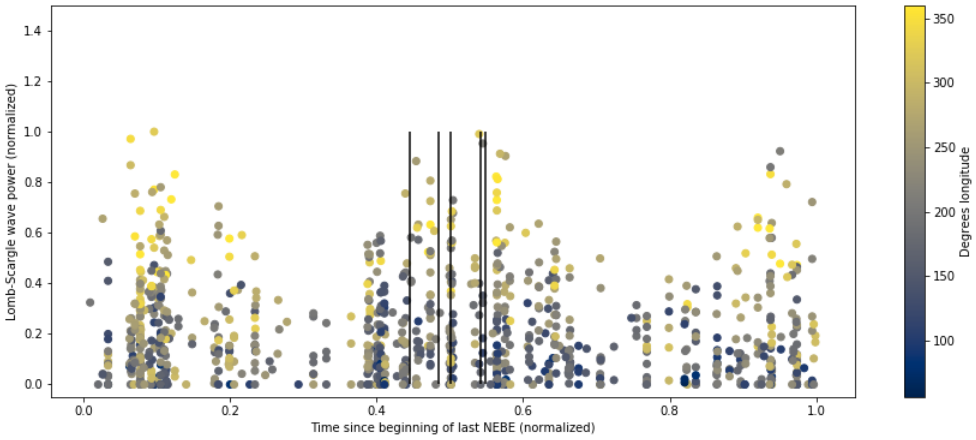

Figure 2: Lomb-Scargle wave powers, normalized over time and colored by longitude. The vertical lines correspond to NEBE end dates.

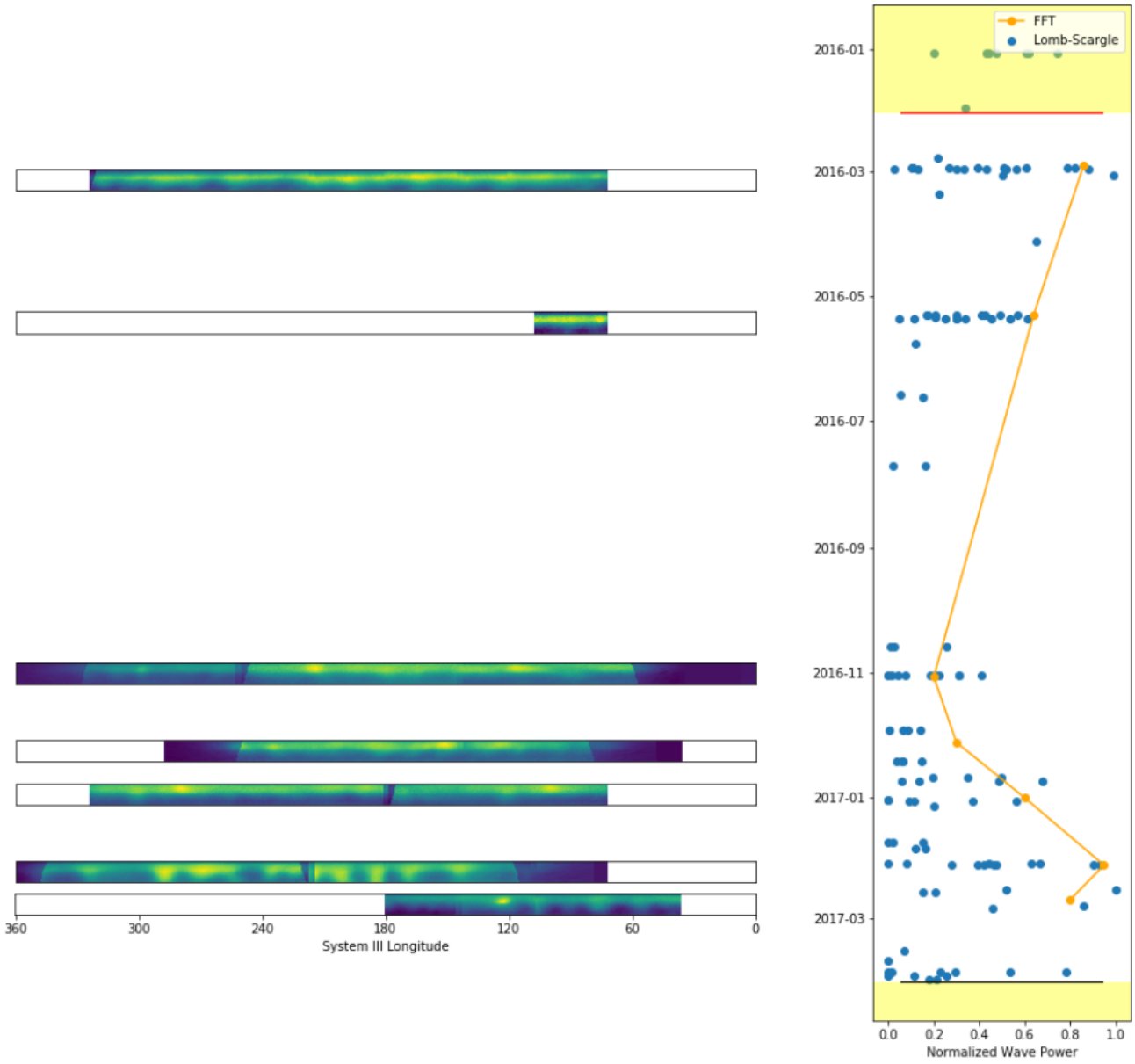

Figure 3: Stitched longitudinal maps of the NEB alongside corresponding L-S and FFT wave powers. The shaded regions of the plot mark NEBEs.