Modulation of Ionospheric Dynamo by Quasi 6-Day Rossby and Kevin Waves

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ABSTRACT

Planetary waves have been identified as one of the significant sources of ionospheric modulation. These atmospheric waves propagate vertically upward and interact nonlinearly with the E-region electric field via ionospheric dynamo. An offshoot of such interaction is the modulation of the mapping between the E and F region. Due to its large amplitude, quasi-6-day planetary waves (Q6DWs) are significant in the ionospheric dynamo process – a vertical atmosphere-ionosphere coupling that is yet to be well understood. Using temperature, ionospheric and solar observations from January 2002 to December 2018, this study seek to identify Q6DWs signatures in the ionosphere. These observations were retrieved using NASA's Thermosphere Ionosphere and Mesosphere Electric Dynamics/Sounding of the Atmosphere using Broadband Emission Radiometry (TIMED/SABER) instrument, Global Positioning System (GPS) total electron content (TEC), F10.7 and Planetary Kp-Index. Plus, this study allows us to look at the efficiency of Q6DWs in producing signatures in the ionosphere. The outcome of this study will be an important new consideration for the interactions and dynamics of the lower, neutral, and charged layers of the whole atmosphere.

OBJECTIVES

- Analyze the coupling between the ionosphere and forcing from below via planetary wave detections in the ionosphere with 6-day periodicity.
- Derive the efficiencies of Q6DWs detections in the ionosphere

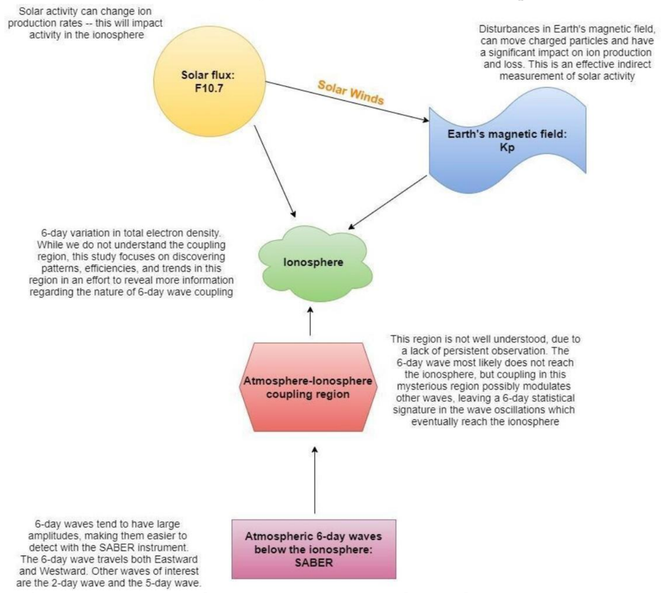

Figure 1. Overview of SABER, F10.7, Kp and TEC datasets

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PROBLEM STATEMENT AND MOVITATIONS

- Ionospheric coupling is a mysterious phenomenon due to dearth of persistent observations of the upper atmosphere. Since the dynamics of the upper atmosphere can significantly impact spacecraft performance, operations and projected lifetime missions, this region is of interest to the science community. Q6DWs are a key determinant of such dynamics (e.g., Gan et al. 2016).
- Q6DWs have huge amplitudes compared to other planetary waves, making it of significant importance in ionospheric dynamo (e.g., Forbes and Zhang, 2017).
- Existing conjecture posits direct modulation of E and F region by planetary waves. However, the efficiencies of Q6DWs detections in terms of amplitudes of the wave events, signatures in TEC and solar activity level is yet to be well understood. Also, Liu et. al. (2019) reported that the 6-day wave is present only episodically, and during much of the time no coherent wave of this period is present in the atmosphere. Therefore, this study will conduct an event-by-event analysis, as opposed to a cross-correlation of two or more datasets.

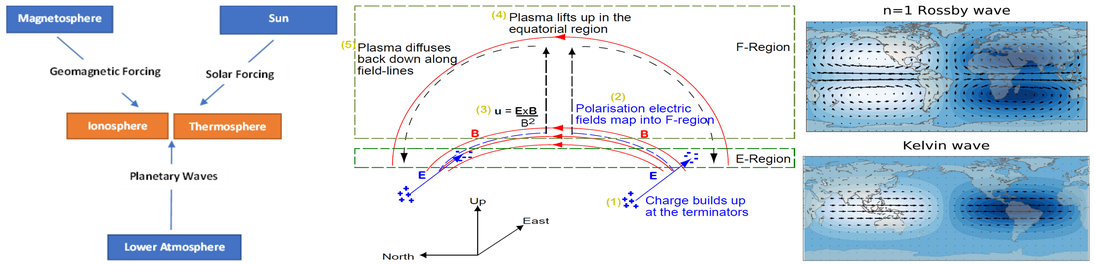

Figure 2. Magnetosphere-Ionosphere-Thermosphere-Lower Atmosphere coupled system of interest. (center) Ionospheric Dynamo. (right) Rossby waves (top) and Kelvin waves (bottom). Vectors depicts magnitudes while color gradient depicts relative temperatures. Adopted from Vasylkevych and Zagar (2021).

RESULTS

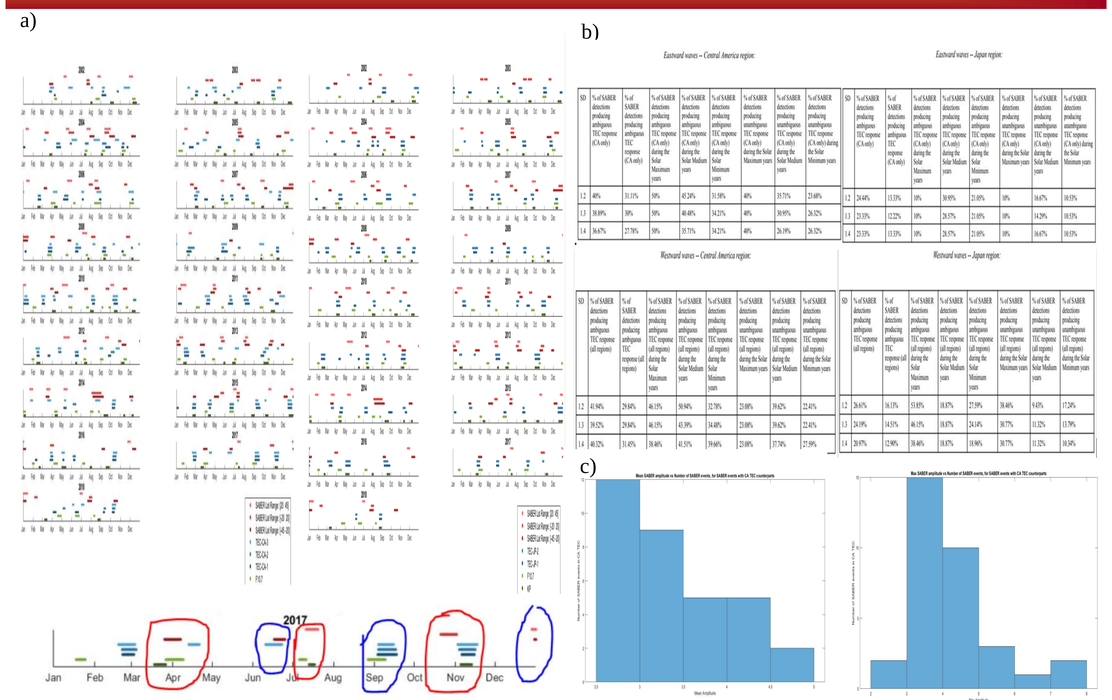

Figure 4. (a) 6-day wave signatures in SABER (eastward), TEC, F10.7 and Kp datasets for Central America and Japan region with a standard deviation of 1.4 (b) Efficiencies of Eastward Kelvin and Westward Rossby 6-day wave SABER detections that produce a TEC response in Central America and Japan region (c) Distribution of mean and maximum 6-day wave amplitudes detected with SABER, for SABER events that induce a response in CA TEC.

METHODOLOGY

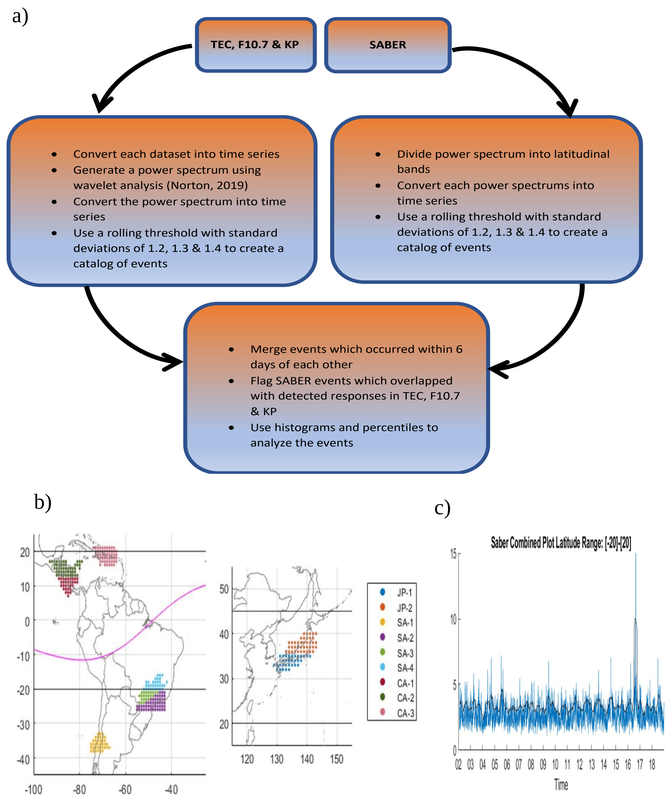

Figure 3. (a) Overview of steps utilized in this work. (b) TEC data collection for regions under investigation. (c) 17-year continuous time series of SABER 6-day wave detection data, with an applied rolling amplitude threshold of standard deviation 1.4

CONCLUSIONS

- There more 6-day wave in the Central America region than the Japan region. Since the Central America region is closer to the geographic equator, more clear detections occurred in this region.
- SABER detected 124 Westward Rossby and 90 Eastward Kelvin 6-day waves. Of the 124 6-day Rossby waves, approximately 37% - 38% produced an unambiguous modulation of TEC, and approximately 52% - 55% produced an ambiguous modulation of TEC. While for the 90 6-day Kelvin waves, approximately 34% - 38% produced an unambiguous modulation of TEC, and approximately 48% - 53% produced an ambiguous modulation of TEC.
- The standard deviation had an inverse correlation with the number of TEC detections.
- There were no 6-day wave signatures detected by SABER in the South America region between the years 2002 and 2018. It is still unclear why no 6-day waves was detected in this region. Future work is to examine the South America region and the other regions with more satellite observations and modelling efforts.

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