The Impact of Line-of-Sight Geometry on GNSS TEC Observations of Traveling Ionospheric Disturbances

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Motivation and Objective of the Study

Prior simulations of traveling ionospheric disturbances (TIDs) driven by acoustic and gravity waves (AGWs) in the presence of convective sources have demonstrated that the complex ionospheric response has significant spatio-temporal variability. Thus the characteristics of TIDs inferred from the observations of total electron content (TEC) are potentially impacted by the geometry of line-of-sights (LOSs) between GNSS satellites and ground-based receivers piercing the electron density fluctuations. The choice of the LOS orientations across the TIDs may favor or preclude the detection of TIDs. In this study, we investigate cases of thunderstorm-generated AGWs over the continental US with an aim to **quantify the differences in TID signatures when using different combinations of azimuthal LOS orientations with respect to the convective source.** The resulting reconstructed TEC maps are compared with the original TEC maps produced by our earlier-developed System for Rapid Analysis of Ionospheric Dynamics (doi: 10.17632/jbx98yscmd.1). The differences between the resolved TIDs are then interpreted in the context of the motion of plasma in response to AGWs given the underlying magnetic field line geometry. The overall aim is to evaluate the uncertainties in inferred TID characteristics which can then facilitate improved data-model comparisons.

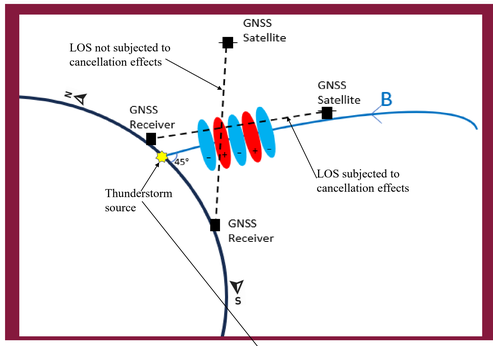

Figure 1 – Illustration showing how **acoustic waves from a thunderstorm source compress the plasma along magnetic field lines** over the continental US. Different LOS geometries of TEC measurements pierce the electron density fluctuations differently. **LOSs that are parallel to the magnetic field lines are subjected to more cancellation effects.**

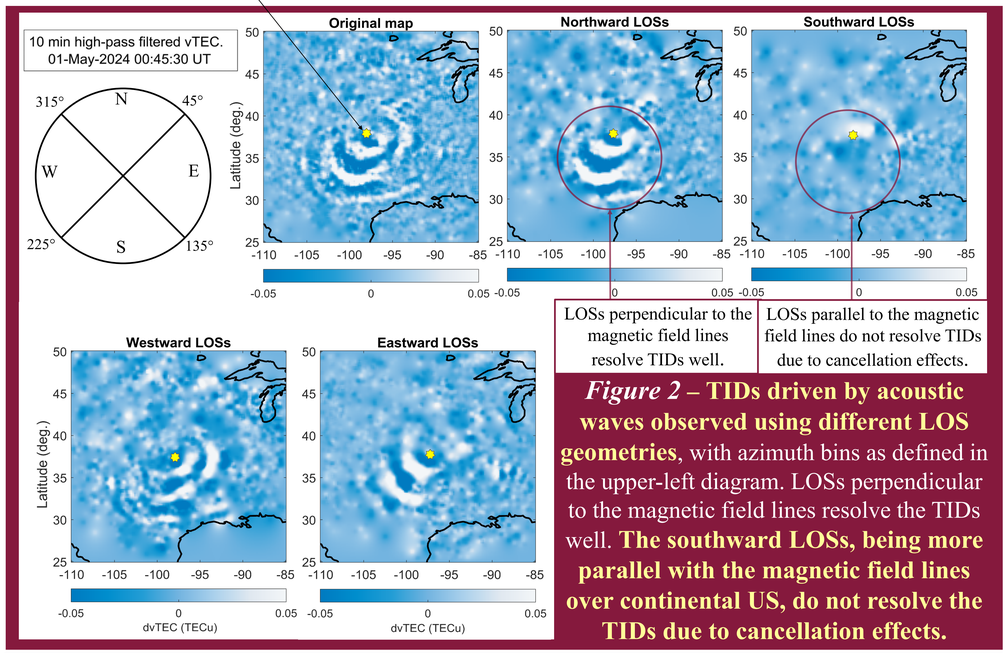

Figure 2 – **TIDs driven by acoustic waves observed using different LOS geometries**, with azimuth bins as defined in the upper-left diagram. LOSs perpendicular to the magnetic field lines resolve the TIDs well. **The southward LOSs, being more parallel with the magnetic field lines over continental US, do not resolve the TIDs due to cancellation effects.**

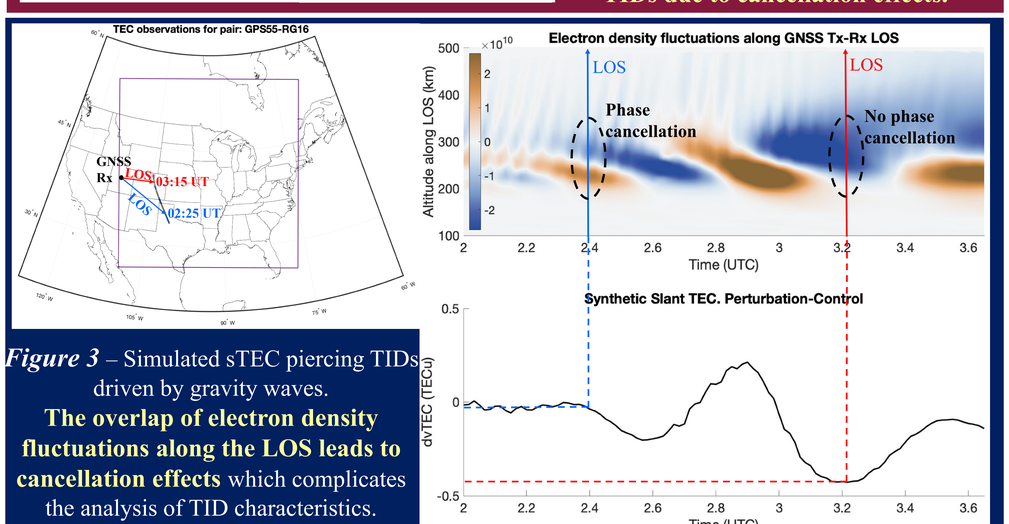

Figure 3 – Simulated sTEC piercing TIDs driven by gravity waves. **The overlap of electron density fluctuations along the LOS leads to cancellation effects** which complicates the analysis of TID characteristics.

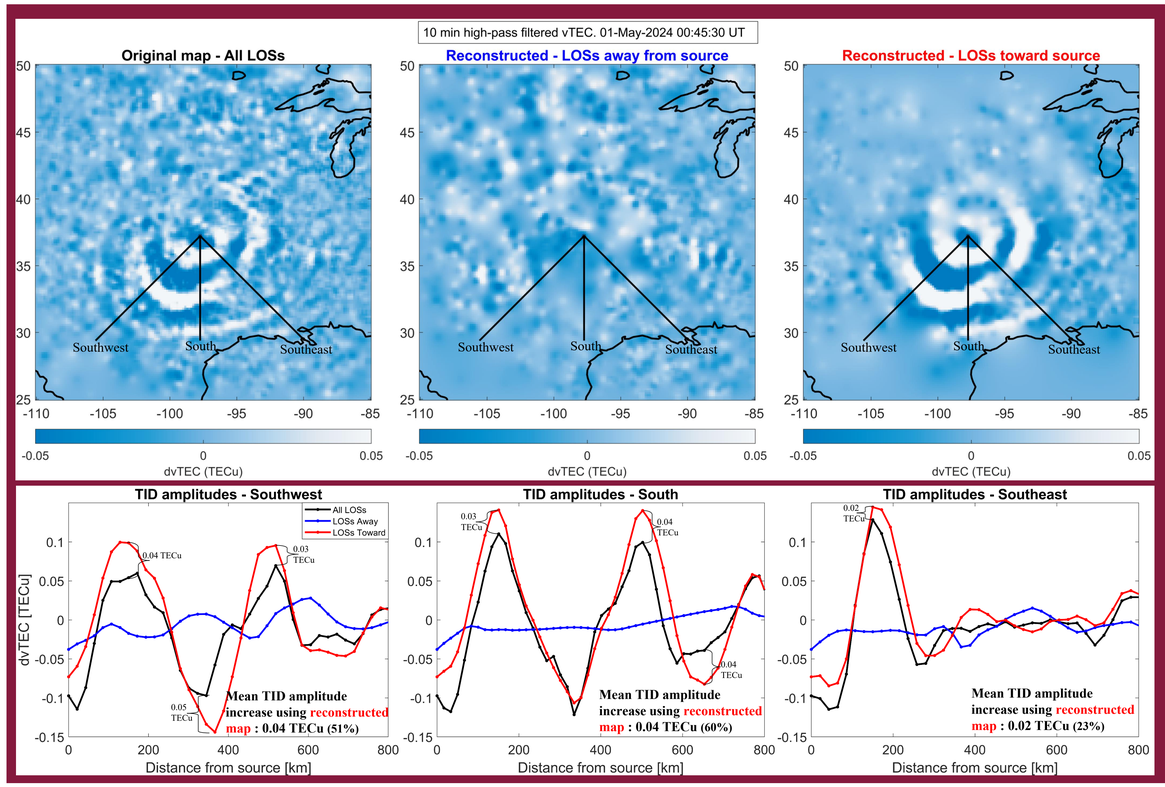

Figure 4
Original TEC map along with two reconstructed maps that use only LOSs that look away from and toward the source. **The LOSs looking toward the source resolve the TIDs driven by acoustic waves well, indicating that they pierce the electron density fluctuations with minimal cancellation effects**, while those looking away from the source do not.

Figure 5
TID amplitudes from acoustic waves estimated along the black lines drawn on the TEC maps. **A mean increase in peak amplitudes of up to ~0.04 TECu (51%) is seen between the original and the reconstructed map** using LOSs toward the source.

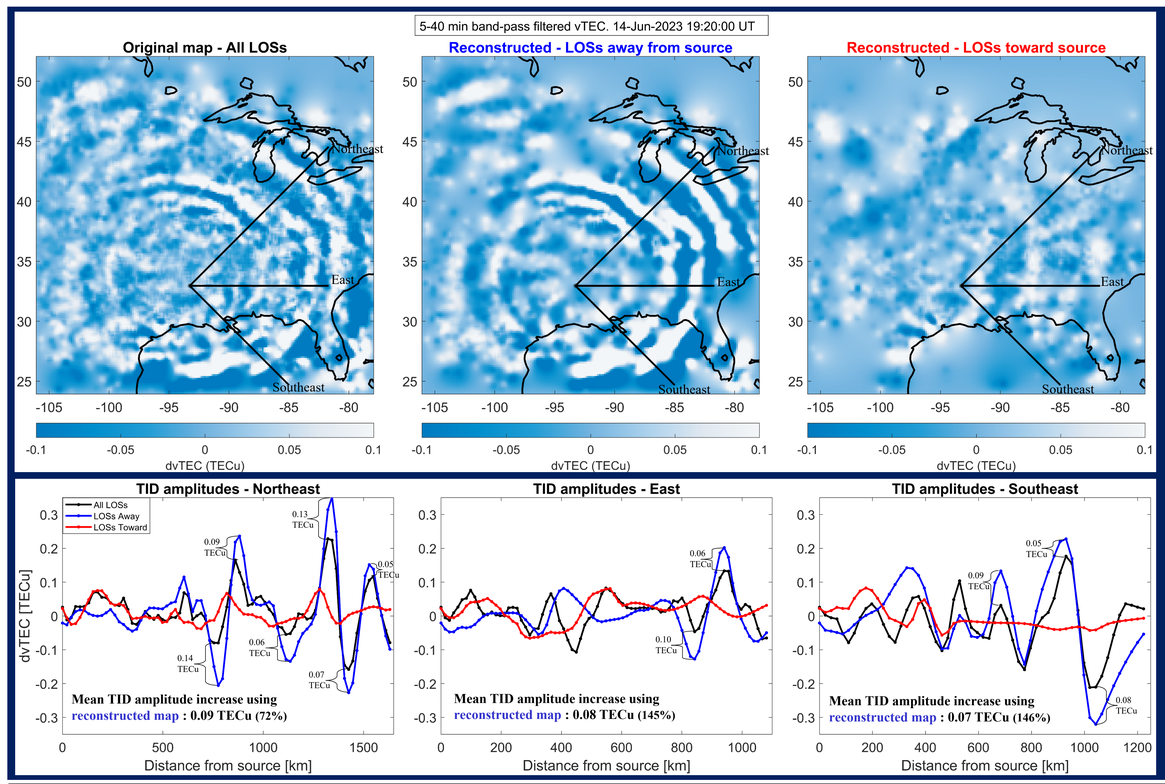

Figure 6
Original and reconstructed TEC maps showing TIDs driven by gravity waves. Here, **the opposite effect is seen as compared to acoustic waves, where LOSs away from the source resolve the TIDs well**, but LOSs toward the source do not. **This highlights a difference in how acoustic and gravity waves move plasma along the magnetic field lines.**

Figure 7
TID amplitudes from gravity waves estimated along the black lines drawn on the TEC maps. **A mean increase in peak amplitudes of up to ~0.08 TECu (105%) is seen between the original and the reconstructed map** using LOSs away from the source.

Conclusions and Discussions

- **LOSs toward the source** efficiently resolve TIDs driven by acoustic waves, indicating minimal cancellation effects, whereas **LOSs away from the source** better resolve TIDs driven by gravity waves. Our work shows that a clear difference exists in LOS-integrated electron densities driven by acoustic and gravity waves.
- **The reconstructed TEC maps demonstrate an advancement in the visualization and characterization of concentric TIDs driven by acoustic and gravity waves.** Using only LOS orientations that effectively pierce electron density fluctuations results in observed TID amplitudes that are stronger (~0.04 TECu or 51% for acoustic waves and ~0.08 TECu or 105% for gravity waves) compared to the amplitudes with no preferential selection of available LOSs.
- This new approach puts error bars on TID characteristics **which is significant to gain better insights into the momentum and energy depositions of AGWs into the ionosphere when comparing with models.**

Future work

- Compare different LOS orientations of synthetic sTEC measurements of TIDs from MAGIC-GEMINI simulations of real events to further examine how observations are affected by different LOS orientations. Discrepancies between LOSs away from and toward the source will be quantified.
- Create TEC maps of simulated TIDs driven by acoustic and gravity waves using the same LOSs as available in observations. Modeled TEC maps will be compared with the original and reconstructed TEC maps.
- A manuscript is currently in preparation summarizing the methodology and results of the poster, along with modeling results that are under work.

Acknowledgement

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