

### BACKGROUND

Traveling ionospheric disturbances (TID) have been investigated for more than 4 decades, but they remain topics of active research and scientific debate. Present study addresses several important characteristics of TIDs during both disturbed and quiet periods in the geographic region covering middle to equatorial latitudes.

We investigate the hemispheric electrodynamics interconnectivity of the propagating LSTIDs, the LSTID orientation and phase oscillations as they propagate from one source region to the other. Our study also indicates the initialization of the LSTIDs, their duration and whether they survived into the conjugate hemisphere (i.e. whether wave interactions are constructive or destructive).

### METHOD AND DATA

GPS Station=GUST, 41.46° Lat, -80° Long

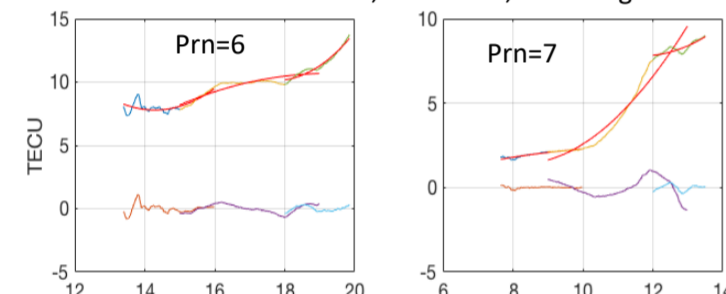


Figure 1. Example of TID analysis procedures for a single GPS station but for different PRN; the orange curve represents a low pass filter fit of the data set, and the curve below represents differential TEC ( $\Delta$ TEC), obtained by taking the difference between the data set and the low pass filter.

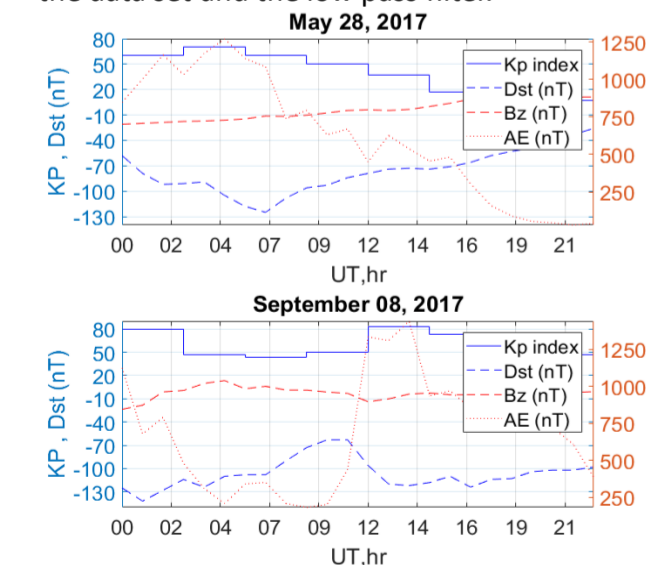


Figure 2. Summary of geomagnetic activity for the May 28 and September 08, 2017, which could be classified as intense storms during solstice and equinox, respectively. Orange dash, orange dotted, blue and blue-dash lines represent Bz, AE, Kp and Dst. The storms have similar magnitude featuring southward interplanetary field (Bz) that went below 20 nT, a minimum Dst of -120 nT with Kp index of more than 7 unit during the main phase of the storm, and a strong increase in the AE from ~200 to ~1300 nT in both cases.

### HEMISPHERIC COUPLING OF TIDS during 28<sup>th</sup>/May/2017

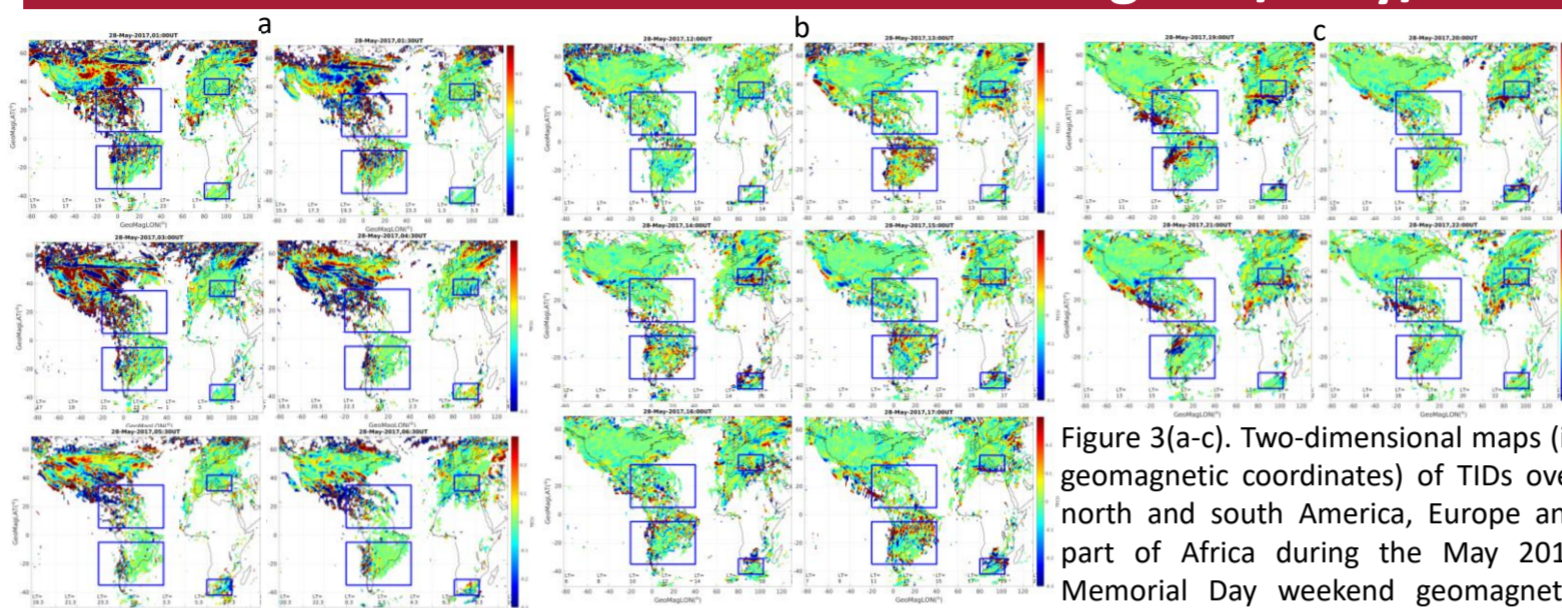


Figure 3(a-c). Two-dimensional maps (in geomagnetic coordinates) of TIDs over north and south America, Europe and part of Africa during the May 2017 Memorial Day weekend geomagnetic storm.

- 0100 to 06:00 UT: During the main phase of the storm: We observe LSTIDs generated in the northern hemisphere map to southern hemisphere and propagate in time mainly in the north and south America. The direction of propagation is mostly equatorward-westward in the north and equatorward-eastward in the south.
- 12:00 – 17:00 UT: During the recovery phase of the storm: TIDs appear mostly in the European and the African sectors. Some TIDs also appear in the South America sector but not at its conjugate region.
- 19:00 – 22:00 UT: During the recovery phase of the storm: Another set of TIDs are observed in northern region and its southern conjugate of the American continent as well as at Europe and its south Africa conjugate. It is not clear where the source of the TIDs come from.

### HEMISPHERIC COUPLING OF TIDS during 8<sup>th</sup>/Sep/2017

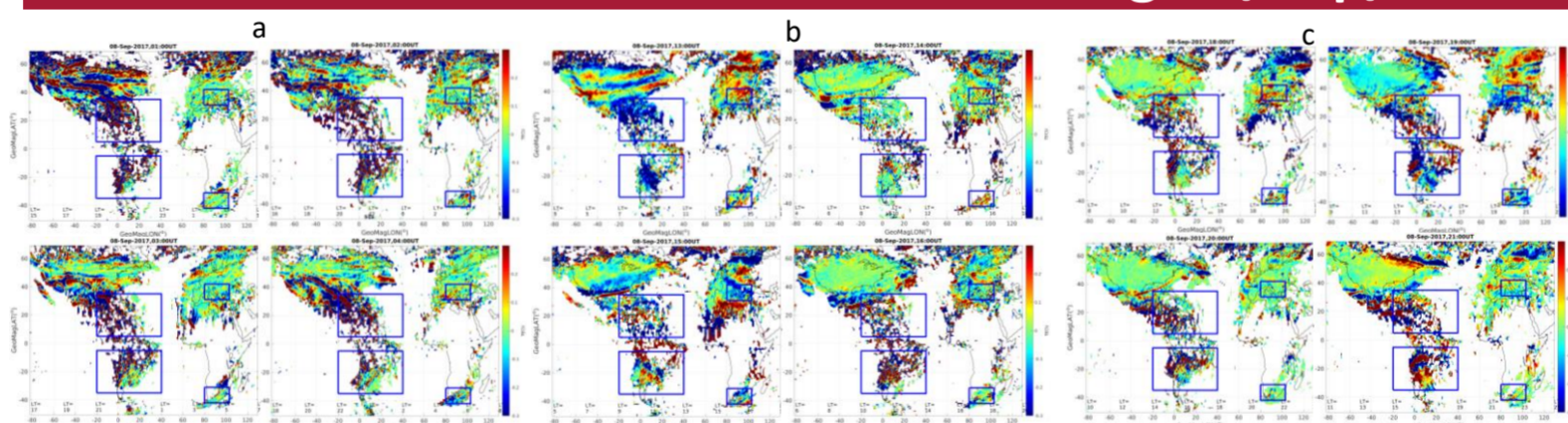


Figure 4(a-c). Two-dimensional maps (in geomagnetic coordinates) of TIDs over north and south America, Europe and part of Africa during the September 08, 2017 geomagnetic storm. There are two storm recovery phases for 09/08/2017: 1<sup>st</sup>, 01:00 – 09:00UT and 2<sup>nd</sup>, 13:00 – 16:30 UT.

- 0100 to 06:00 UT: We observe similar LSTIDs generated in the north hemisphere map to south hemisphere and propagate in time during the storm 1<sup>st</sup> recovery phase. More TIDs are observed in the American sector than in the European and south African sector. It is possible to observe LSTIDs generated in the southern hemisphere, propagating to the northeast region and without clear mapping to conjugate hemisphere. The direction of the TIDs is mostly equatorward-westward in the north and equatorward-eastward in the south.
- 13:00 – 16:00: Prominent LSTIDs are observed over south America sector and no significantly mapping was observed at the conjugate sector during the 2<sup>nd</sup> recovery phase of the storm. It can be noted that the wavefront (larger) and the direction of the TIDs (equatorward-eastward) have changed.
- 18:00 – 21:00: TIDs conjugacy is observed with TIDs travelling equatorward-westward in the north and equatorward-eastward in the south in the American sector.

**Conclusion**

- ✓ TIDs generated in one hemisphere are observed at conjugate hemisphere.
- ✓ The direction of TIDs propagation rotate/ changes with time within multiple events.
- ✓ Observed TIDs are possibly generated by gravity wave from the northern hemisphere and form conjugacy with the southern hemisphere.

### QUIET CONDITION, 26<sup>th</sup>/May/2017

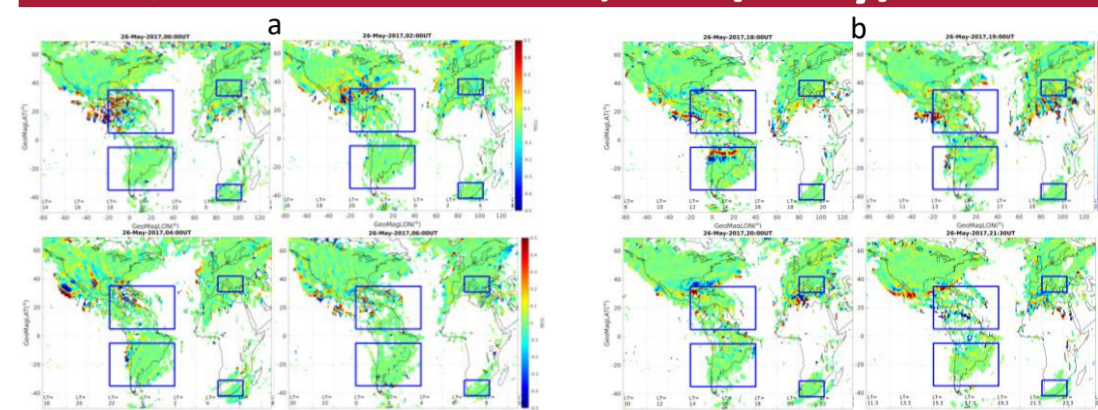


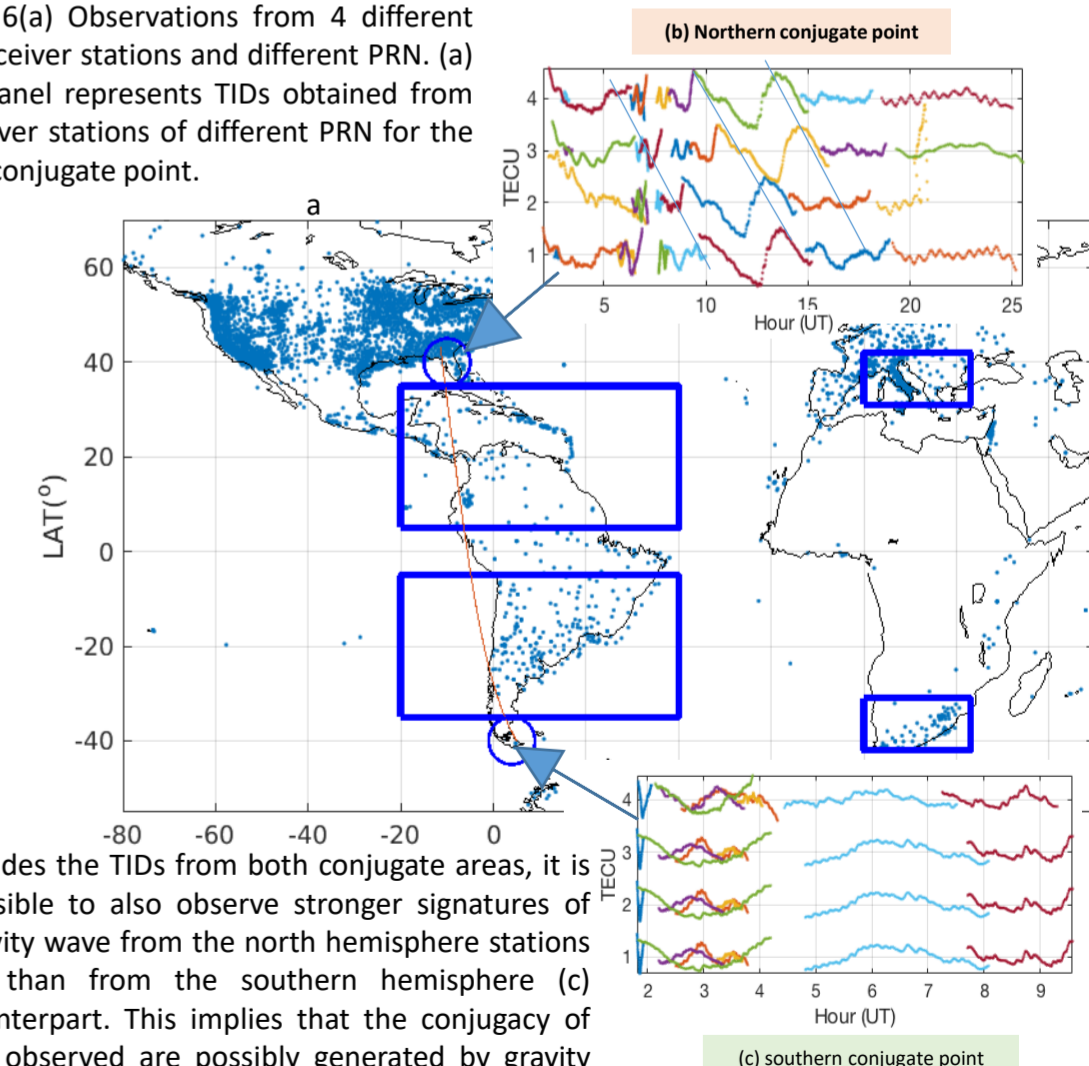
Figure 5. Two-dimensional maps (in geomagnetic coordinates) of TIDs over north and south America, Europe and part of Africa during the May 26, 2017 geomagnetically quiet conditions.

- 00:00 – 06:00 UT: Not significant TIDs observed for all sectors as expected.
- 18:00 – 21:00 IUT: Some TIDs appear at both conjugate regions of the American sector. The source of this observed TID conjugacy is not yet understood.

### SOURCE INVESTIGATION

Figure 6(a). The distribution of GNSS receivers (blue circles) over America, Africa and Europe sectors. The blue circles and blue boxes represent specific conjugate regions that were focus of this study.

Figure 6(a) Observations from 4 different GPS receiver stations and different PRN. (a) Each panel represents TIDs obtained from 4 receiver stations of different PRN for the north conjugate point.



Besides the TIDs from both conjugate areas, it is possible to also observe stronger signatures of gravity wave from the north hemisphere stations (b) than from the southern hemisphere (c) counterpart. This implies that the conjugacy of TID observed are possibly generated by gravity wave source from the northern hemisphere. More investigation of this nature will be carried out to established this point.