Next Generation Methodologies to Advance Space Weather Monitoring and Predictability: A New Perspective through Network Analysis

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Key Findings

- First ever complex network theory based analysis of high-latitude total electron content (TEC) obtained from Global Navigation Satellite System (GNSS) signals
- Network analysis reveals significant structure in TEC correlation patterns and we discover that important characteristic scale sizes in TEC data vary across season and hemisphere
- Data-driven analyses illustrate importance of innovation at intersection of disciplines to the future of space weather research

High-latitude, IMF–dependent network analysis results

We show results for the northern and southern hemispheres during local winter in 2016 (see McGranaghan et al., [2017] for analysis of extended periods) First, the characteristics of the high-latitude TEC data are shown through IMF–dependent median and relative perturbation figures

Relative perturbations are then used to calculate spatio-temporal correlations between each high-latitude (50-90°) grid point and networks are constructed (a connection occurs if the correlation between grid points exceeds a threshold) We use several robust mathematical measures to quantify and study network behavior. These measures are described below.

<table>
<thead>
<tr>
<th>Measure</th>
<th>Significance (Interpretation)</th>
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<tbody>
<tr>
<td>Degree Centrality</td>
<td>Influence of grid points on network function (larger = greater influence)</td>
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<td>Median geodesic separation distance</td>
<td>Scale sizes of connectivity (larger = more spatially continuous)</td>
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<td>Lattice clustering coefficient</td>
<td>Spatial continuity of TEC (larger = more spatially continuous)</td>
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</table>

Enabling GNSS signal data to investigate complex geospace phenomena

TEC networks suggest GNSS data contain information about magnetosphere-ionosphere (MI) coupling

- Can GNSS signals be used to study/proxy complex phenomena in geospace?
- To what extent can relationships be exploited for space weather prediction?

December 2015 case study to investigate techniques to discover relationships in geospace

What’s next?

- Drastically expand amount of data
- Discover new relationships
- Illustrates broader importance of novel data-driven discovery to space weather

References

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- A global mapping technique for GPS-derived ionospheric total electron content measurements. Mannucci et al., [1999]
- Automated GPS processing for global total electron content data. Rideout and Coster, [2006]
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- Network analysis of geomagnetic substorms using the SuperMAG database of ground-based magnetometer stations. Dods et al., [2015]
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