Validation of WAM-IPE TEC Climatology

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Ionosphere-Thermosphere system

- Ionosphere is from 90 to 1000 km, thermosphere is from 85 to 600 km
  - As the name implies, the ionosphere is the ionized portion of the Earth's atmosphere
  - Coupling between the thermosphere and the ionosphere creates upper atmospheric weather.
- There is strong diurnal variation in the plasma density of the ionosphere, due to multiple physical processes

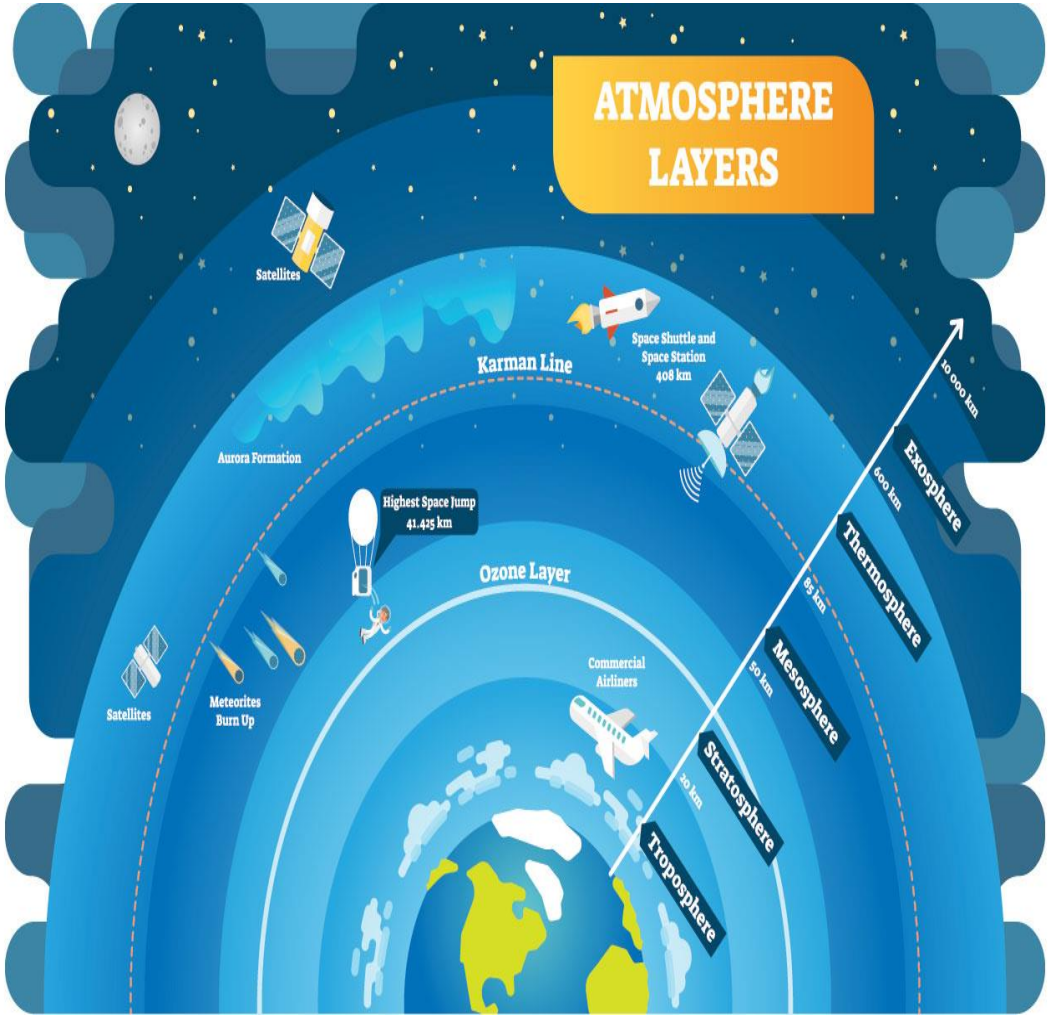


Image credit: https://www.sciencenewsforstudents.org/article/explainer-our-atmosphere-layer-by-layer

Upper Atmosphere Weather

- Weather in the upper atmosphere has 3 main drivers:
  - Solar radiation (F10.7)
  - Geomagnetic activities (Kp)
  - Lower atmosphere weather
- Plasma irregularities can occur due to changes in any or all drivers
  - These can disturb communication if radio waves pass through them

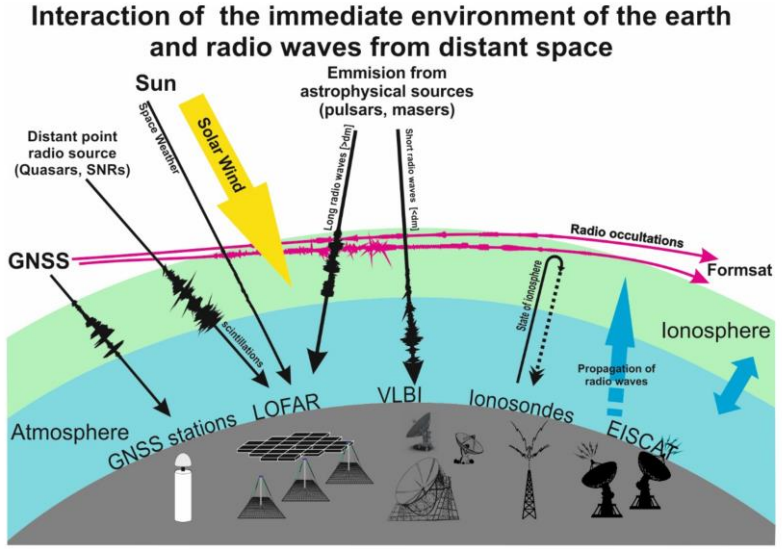


Image credit: https://www.google.com/url?sa=i&url=https%3A%2F%2Fwww.mdpi.com%2F1424-8220%2F21%2F1%2F51%2Fhtm&psig=AOvVaw096wZAxsP-g8UQrY6WzbLH&ust=1627688950167000&source=images&cd=vfe&ved=0CAoQjRxqFwoTCKjpmIG8ifICFQAAAAAdAAAAABAb

Total Electron Content (TEC)

- Measured in TECu
  - 1 TECu = 10^{16} electrons/m^2
- Being able to determine TEC in an area can help in understanding its impact on radio signals
- TEC can be derived by signals from ground-based GNSS receivers

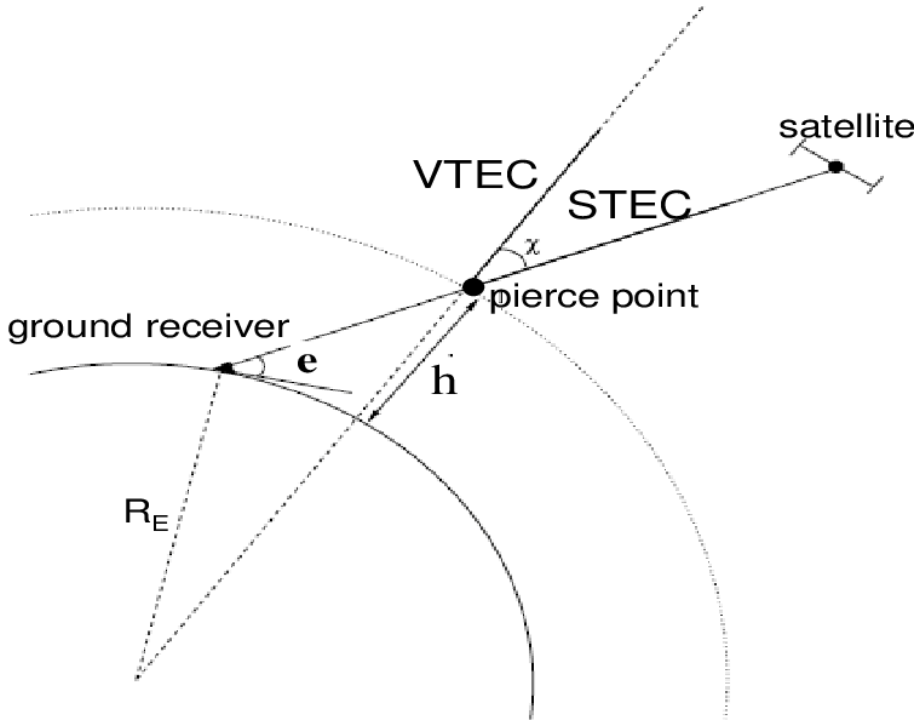
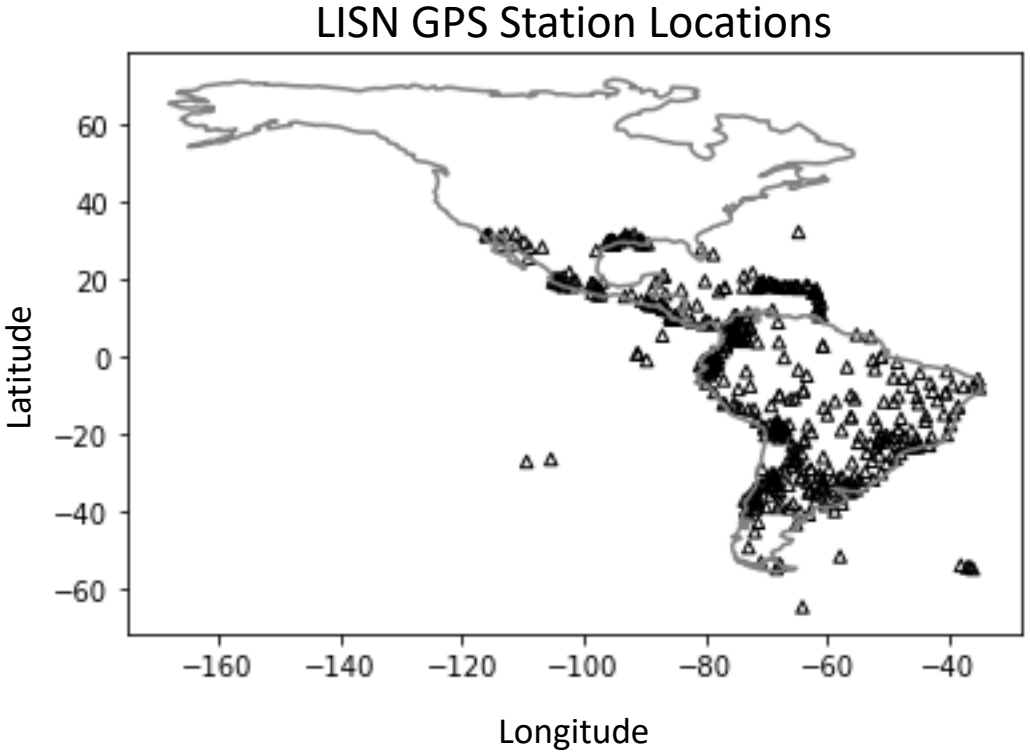


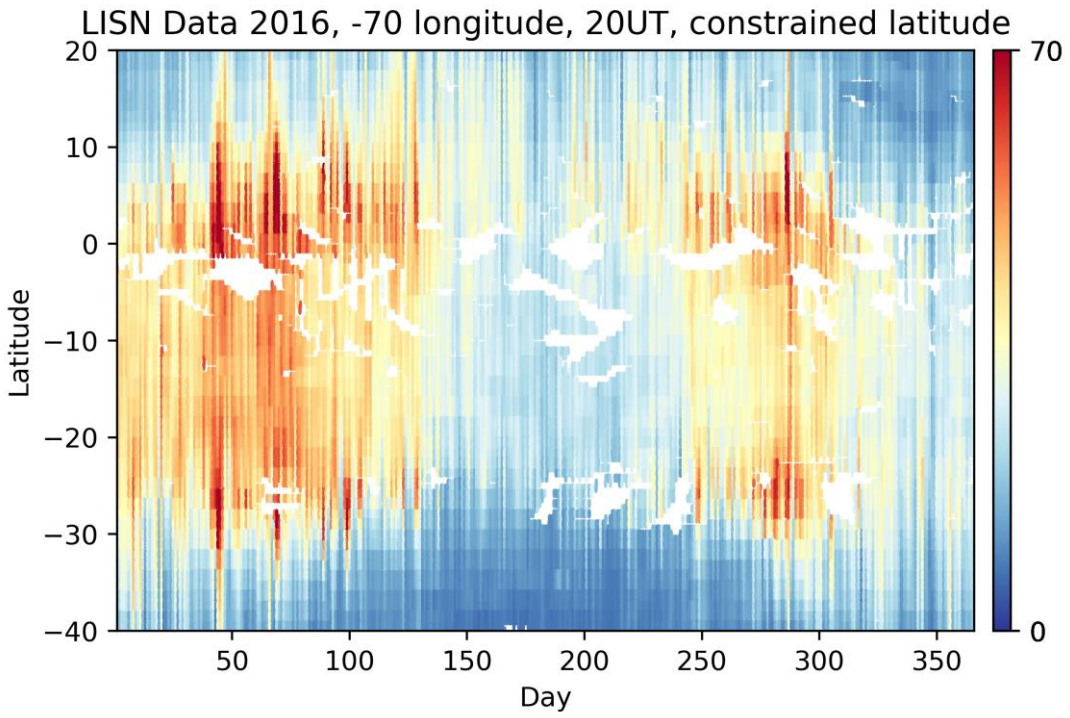
Image credit: https://d3i71xaburhd42.cloudfront.net/65125874843e0b5ac8a4cad74e32e37c75d56534/19-Figure1.4-1.png

LISN: Low-Latitude Ionospheric Sensor Network

- Distributed observatory in South America with real-time data gathering
- Comprised of 50 GPS stations, 5 magnetometers, and 5 ionosondes
- Disturbances in signals received by the GNSS receivers are used to calculate TEC
- TEC data with 15 second cadence from 2016 was provided by César Valladares



Annual plots for LISN Data



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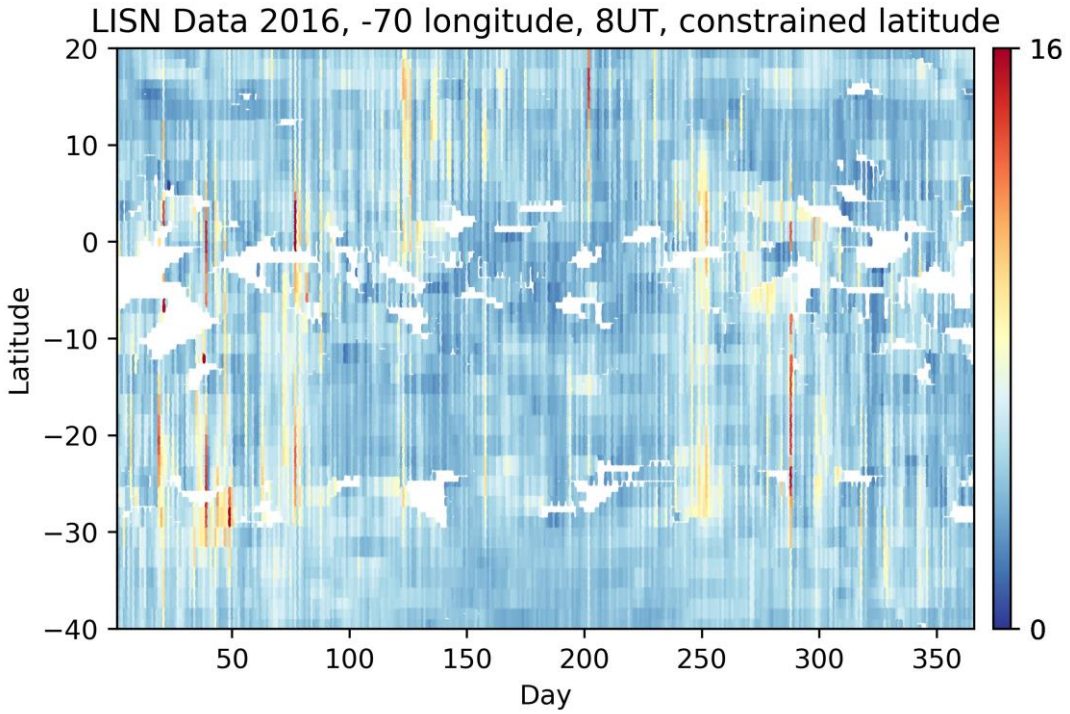

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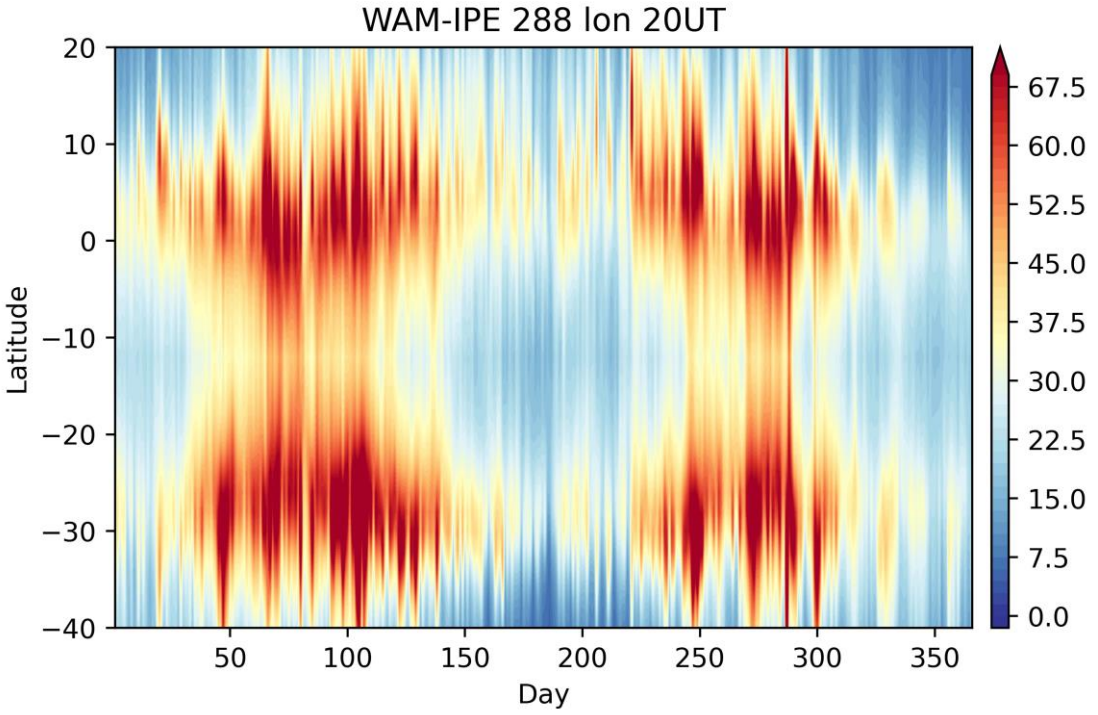
Annual plots for WAM-IPE Data



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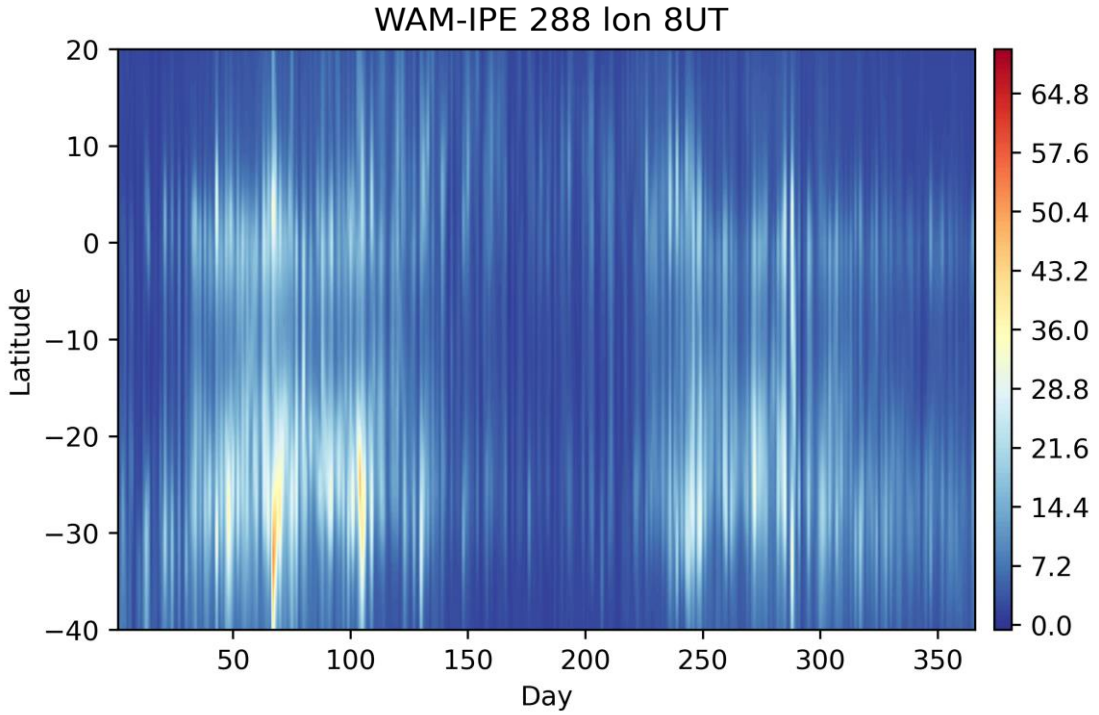

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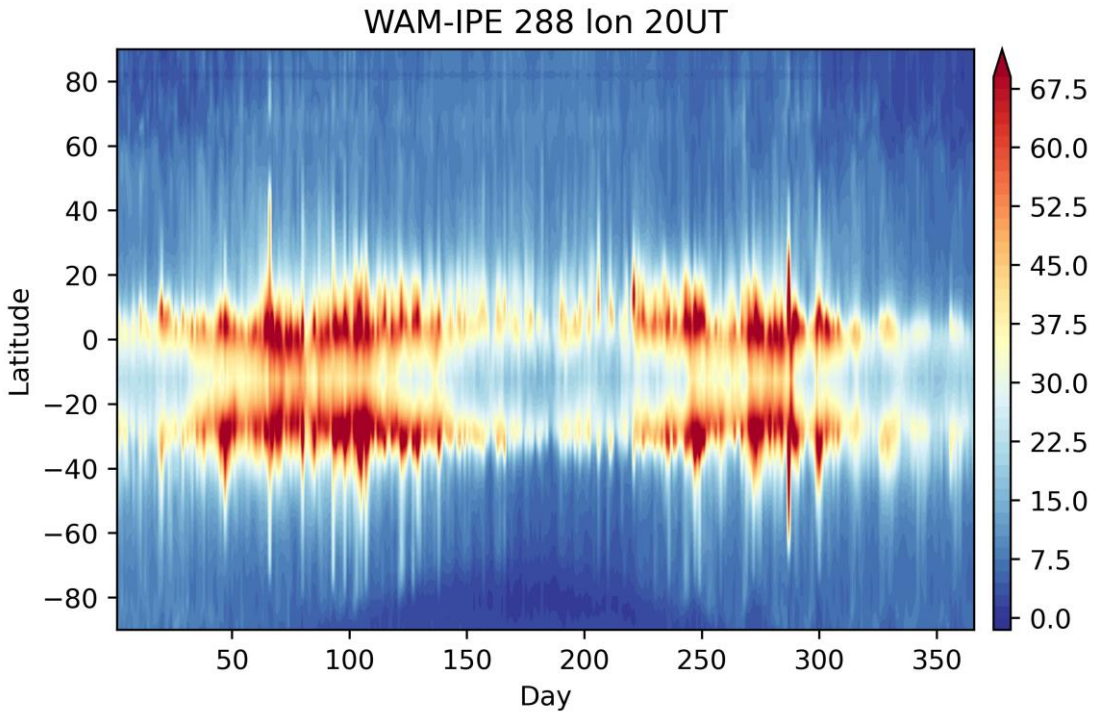
Annual plots for WAM-IPE Data, no latitude cutoffs



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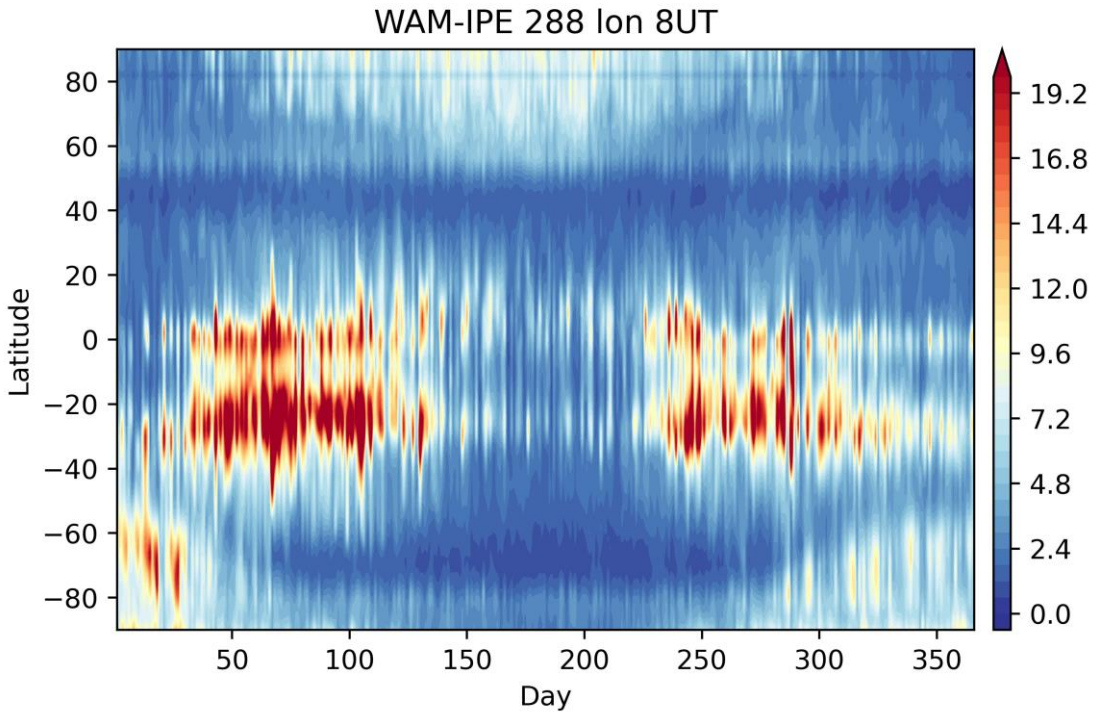
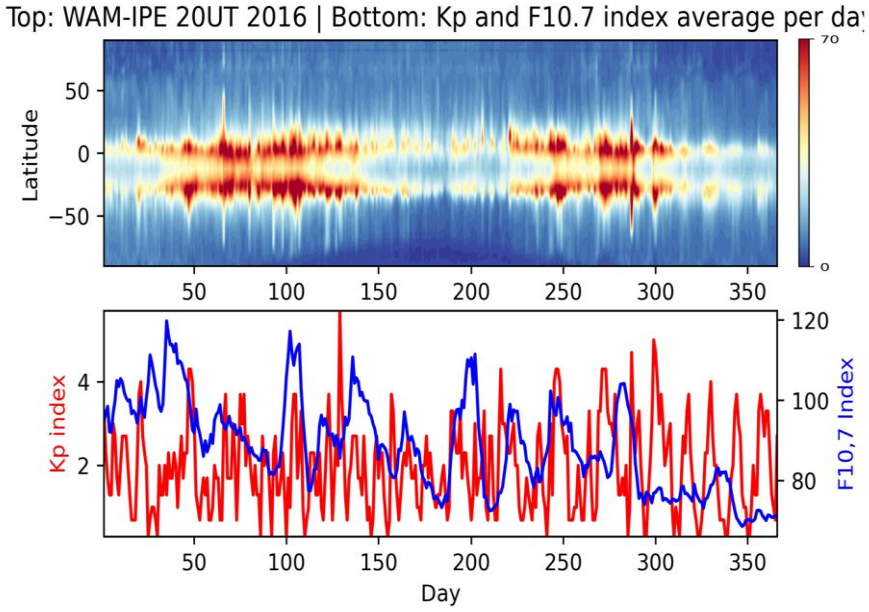
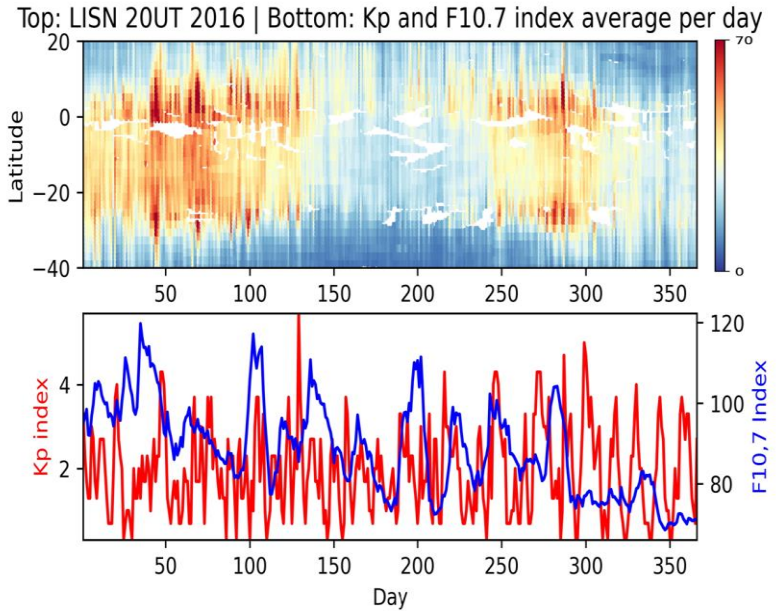
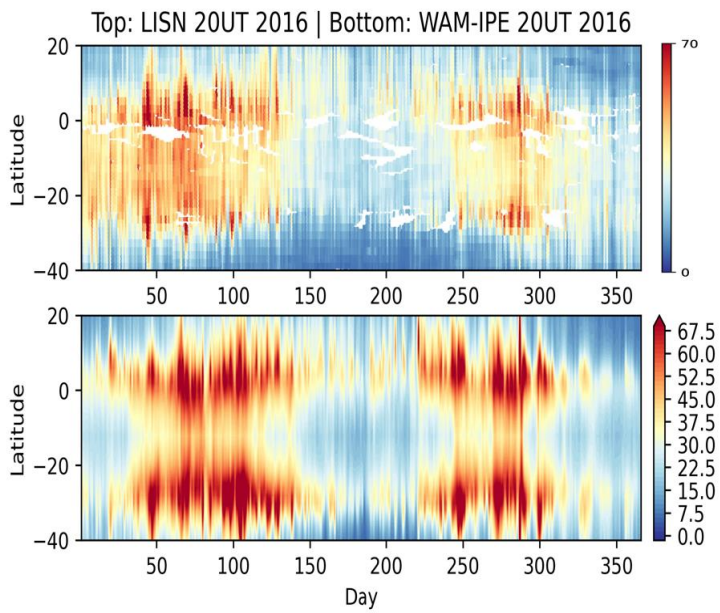


Local time: 2AM

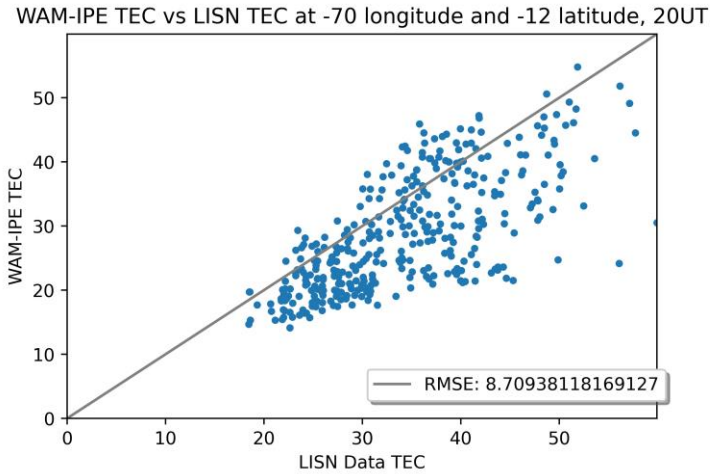
TEC response to drivers

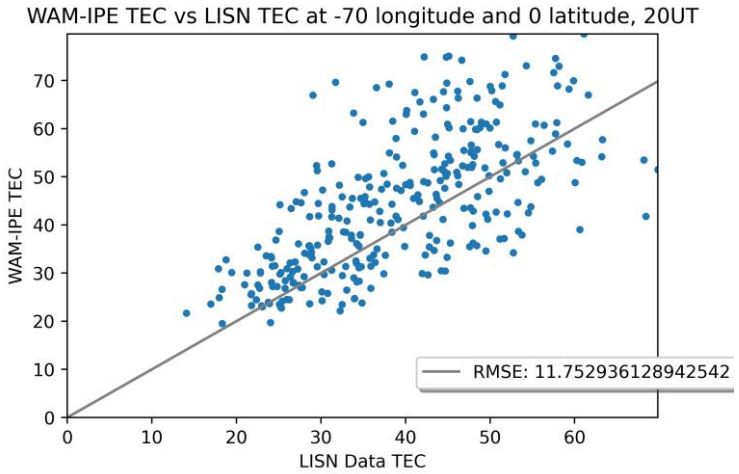


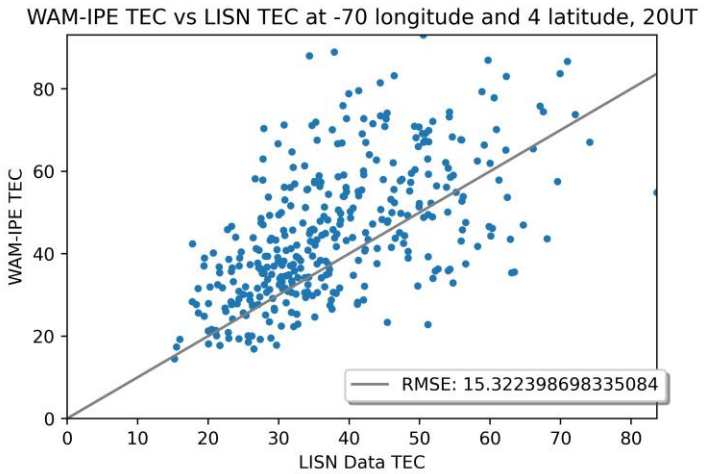


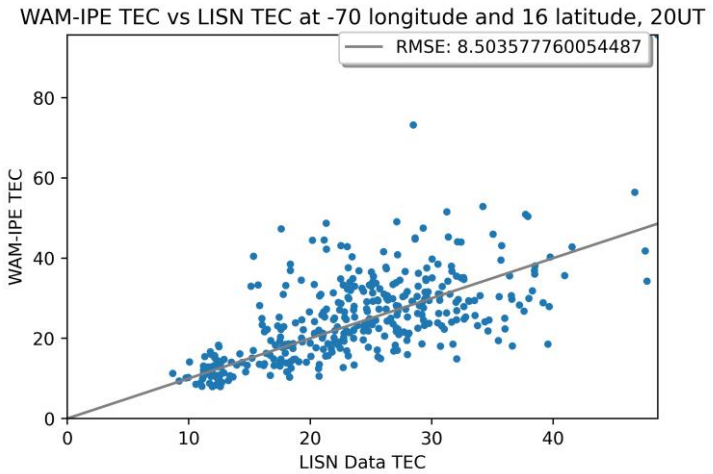


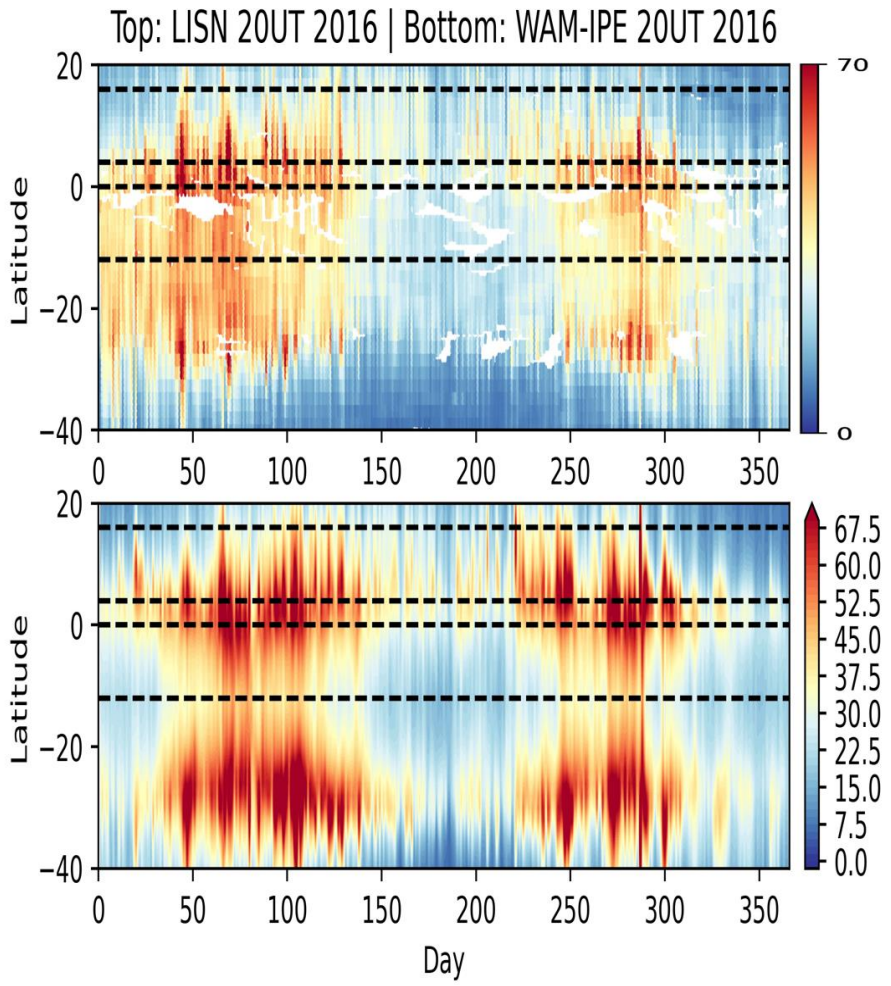
WAM-IPE VS LISN TEC 20UT Correlation



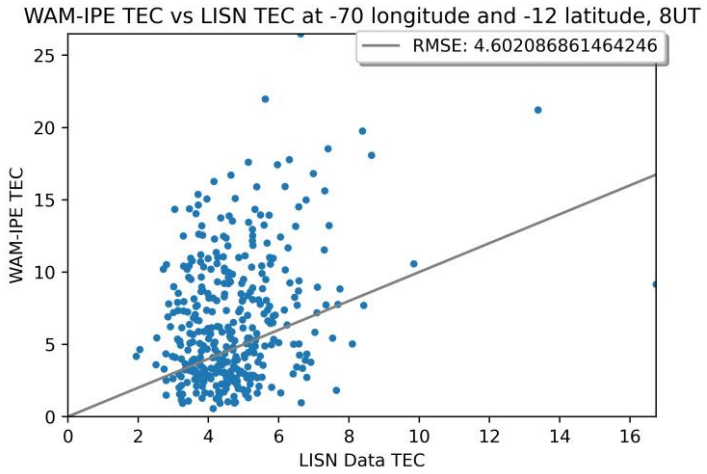


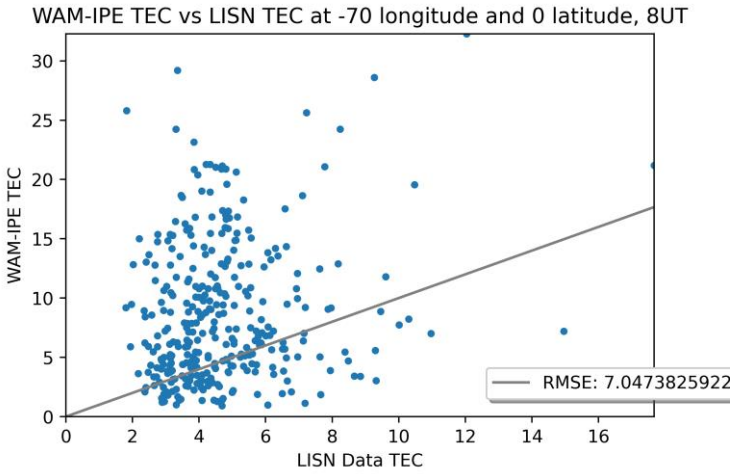


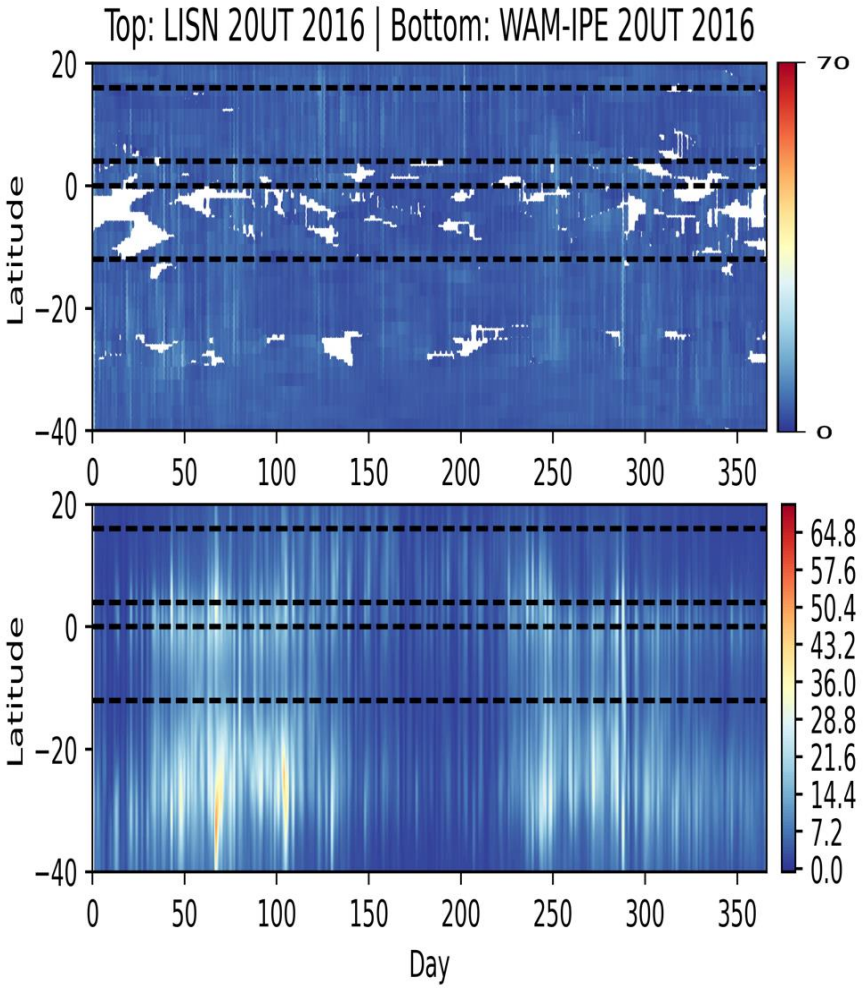


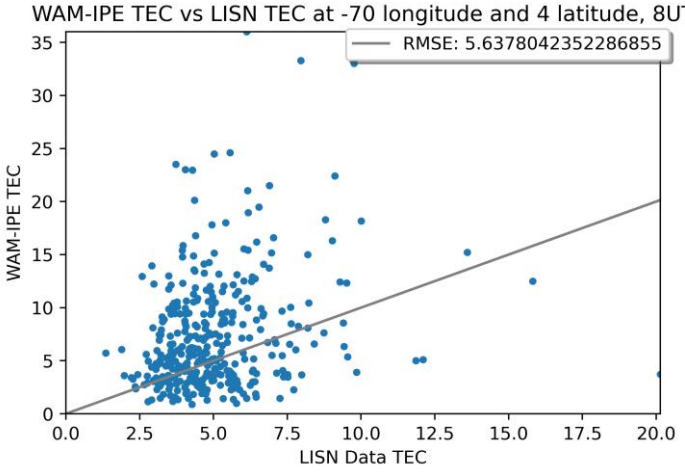


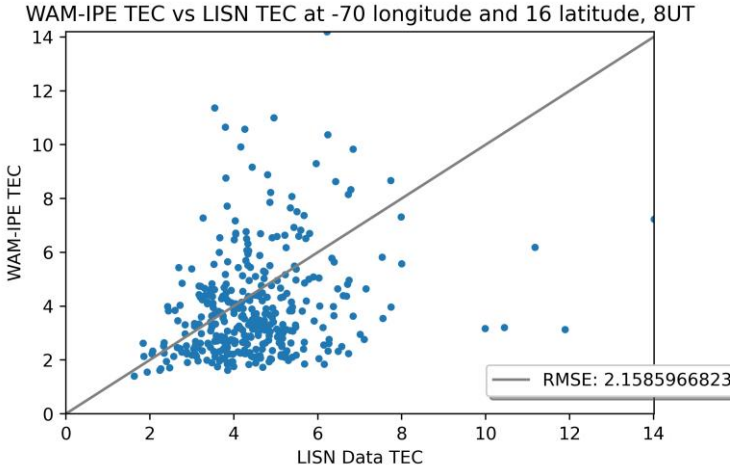
WAM-IPE VS LISN TEC 8UT Correlation





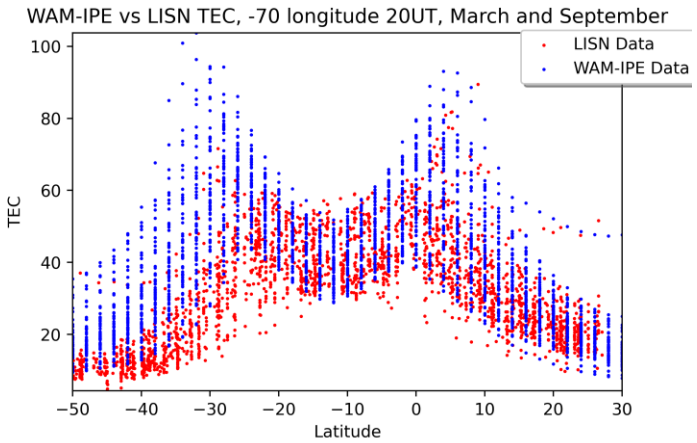


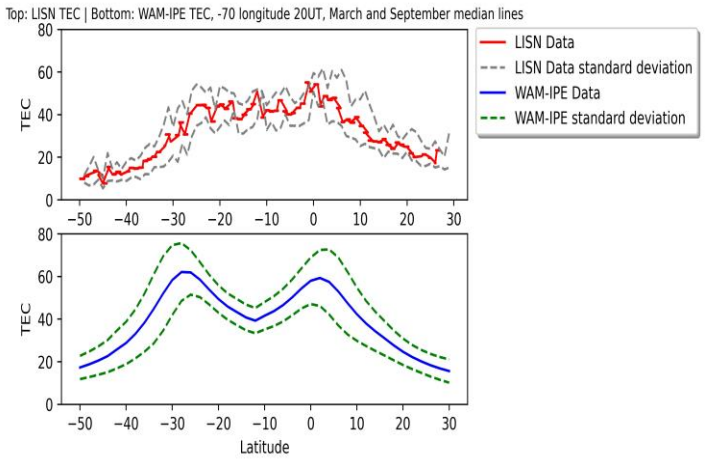




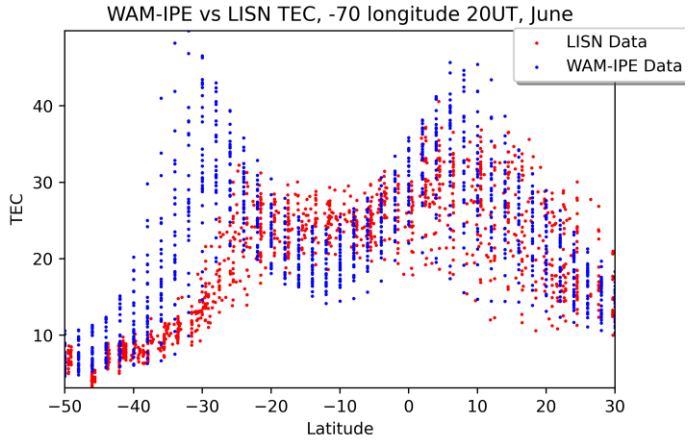
Latitude Vs TEC plots

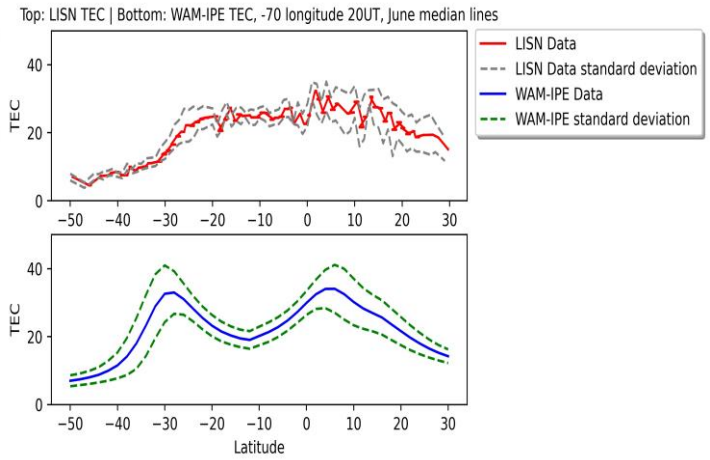
Equinoxes (March and September)





June





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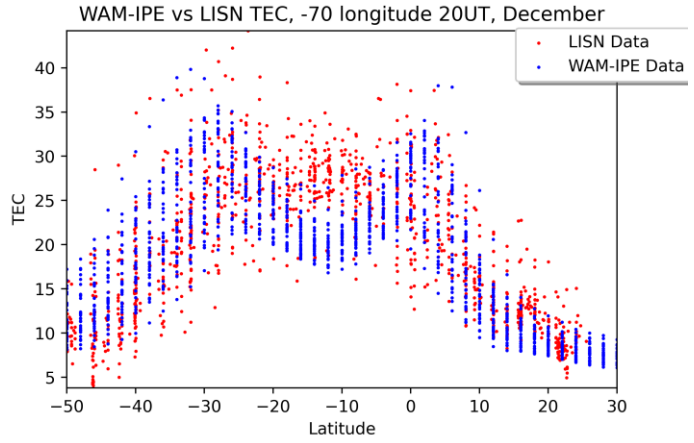

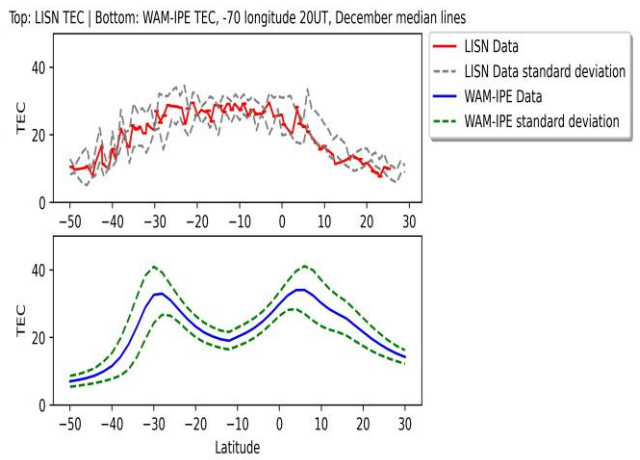

Conclusions

- The model tends to overestimate TEC values during the night
  - There is not a clear definite bias displayed during measurements taken during the day.
- The TEC enhancement in the WAM-IPE data and the LISN data match up very well to spikes in the Kp index
- Correlations between model and LISN TECs are much in the summer hemisphere, and near the magnetic equator at equinox.
- The model shows an obvious bias toward overestimation during the equinox months.