# Ensemble Inversion Method for ISIS II Topside Ionograms

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# **Science Motivation**

Ionospheric profile observations of the Electron Density Profile (EDP) at high latitudes during large geomagnetic storms are almost unavailable for model validation!

Ground based ionosondes suffer severe absorption, ISR (until recently) operate occasionally, and In-situ plasma measurements fail to get the EDP

This is a DATA MINING effort of topside sounder archives.



# **Topside Sounders of Interest**

The International Satellites for Ionospheric Studies (ISIS) program produced a unique topside sounder data set from 1962 to 1990.

The first three had orbital inclinations of about 80°, while ISIS II had an inclination of 88°.

Satellite	Launch	Deactivated	Apogee (km)	Perigee (km)	Period (min)
Alouette I	Sep 1962	1972	1020	985	105
Alouette II	Nov 1965	1975	2652	508	118
ISIS I	Jan 1969	1990	3526	578	128
ISIS II	Apr 1971	1992	1458	1358	114



#### **Period of Interest**

This study focuses on ISIS II data from the vicinity of Resolute Bay during a geomagnetic storm and recovery period.





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#### **ISIS-2** Passes : and two topside ionosgrams

- 1972 day 174 at 02:20:51 UT (21:46 MLT)
- 1972 day 170 at 01:40:44 UT (21:30 MLT)





# **Topside Ionogram Analysis**

- Space Environment Corporation has obtained 35mm film ionograms from the ISIS II topside sounder from the early 1970s for passes near Resolute Bay
- The films were scanned commercially to obtain high-resolution digital versions
- SEC created software to extract ionogram frames from the digitized films
- Additional software finds the latitude, longitude and altitude of the satellite based on the ionogram timestamp
- O and X traces are extracted manually
- The X trace is inverted by the classic Jackson code while the O trace is inverted with a new algorithm from C. Torre



### Post-Storm Ionogram : geomagnetically quiet

This ionogram was recorded during the recovery phase.





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# Identifying O and X Traces

• Traces for min, max O and min, max X are specified manually





## Interpreting Topside Spread F

- Hagg [1969] states that "the main X-wave trace occurs at just a few kilometers shorter range" than the minimum-height edge
- That would be near the "X min" trace we've identified
- The "X min" edge identification may still be ambiguous













### Hand-Scaled vs. Estimated O Trace

- Jackson X trace analysis generates an estimated O trace
- Depends on gyrofrequency as a function of true height





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# **EDP Ensemble Approach**

- Combining the alternative EDP values gives an average "best estimate" EDP
- The spread in height and frequency gives an indication of uncertainty on the estimate
- The "uncertainty" depends on the criteria used to draw the limiting trace curves
- Ensemble components may be weighted according to quality





### Storm-Time Ionogram

Ionogram taken near the peak of geomagnetic activity.



# Storm-Time Ionogram

Changing grayscale thresholds can make some features clearer.

Image processing (gradient filter) may help, but can introduce artifacts or lose details.















### Hand-Scaled vs. Estimated O Trace

- Jackson X trace analysis generates an estimated O trace
- Peculiar instability is sometimes seen in Jackson estimate





### Storm vs. Recovery Electron Density Profiles

• Ensemble EDPs derived from min, max O and min, max X



