GNSS TEC and Scintillation Variations Following Solar Wind Dynamic Pressure Enhancement

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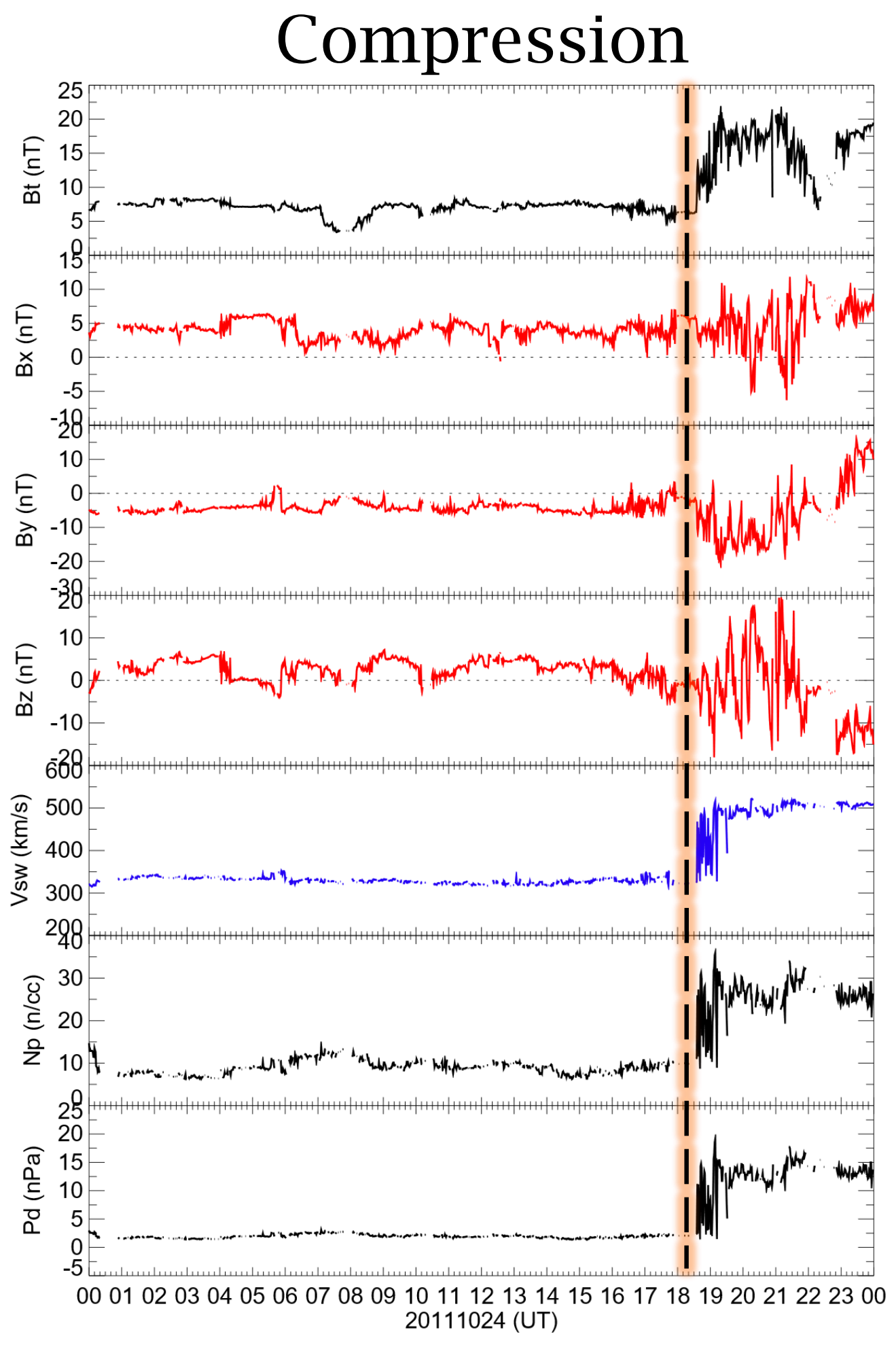
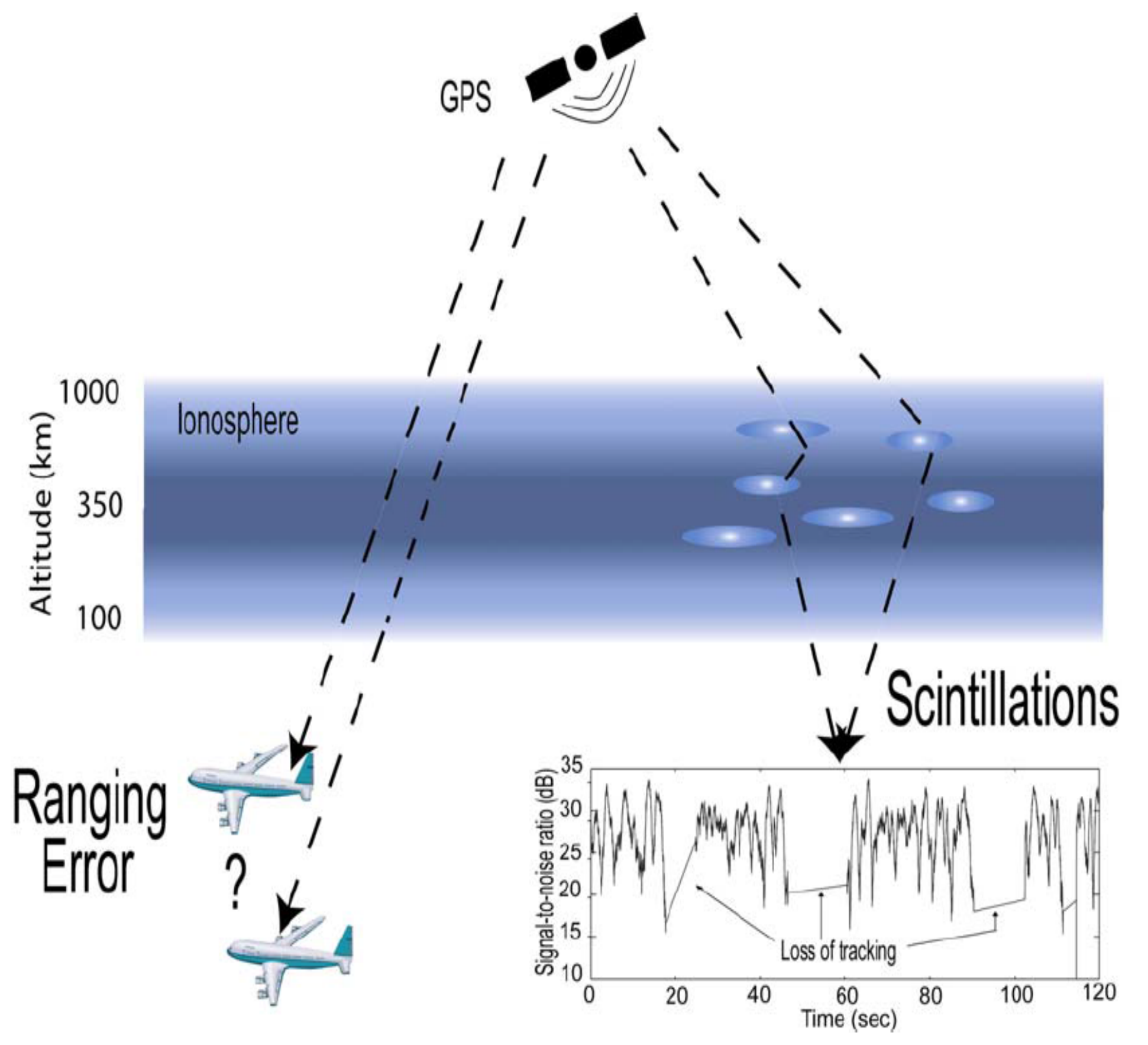
Motivation


Compression

- Solar wind can be accelerated during solar events such as CMEs, flares, etc.
- High pressure solar wind that collides with the Earth's magnetosphere can compress it and cause dramatic transient fluctuations in the ionosphere E and F regions
- Ionospheric fluctuations can cause transient short-scale plasma structures that affect radio-wave propagation and cause scintillation in the phase and amplitude of the signal
- Solar wind can be accelerated during solar events such as CMEs, flares, etc.



Kintner, P. (2007), A beginner's guide to space weather

- When the ionosphere changes, GNSS navigation services, which rely on signals passing through the ionosphere are disrupted when effects such as scintillation are strong enough
- Scintillation is measured by two indices, which quantify variation in phase (σ_φ) and amplitude (S4) of the GNSS signal over a 1 min period
- Studies have been carried out before, but mostly in the Northern Hemisphere

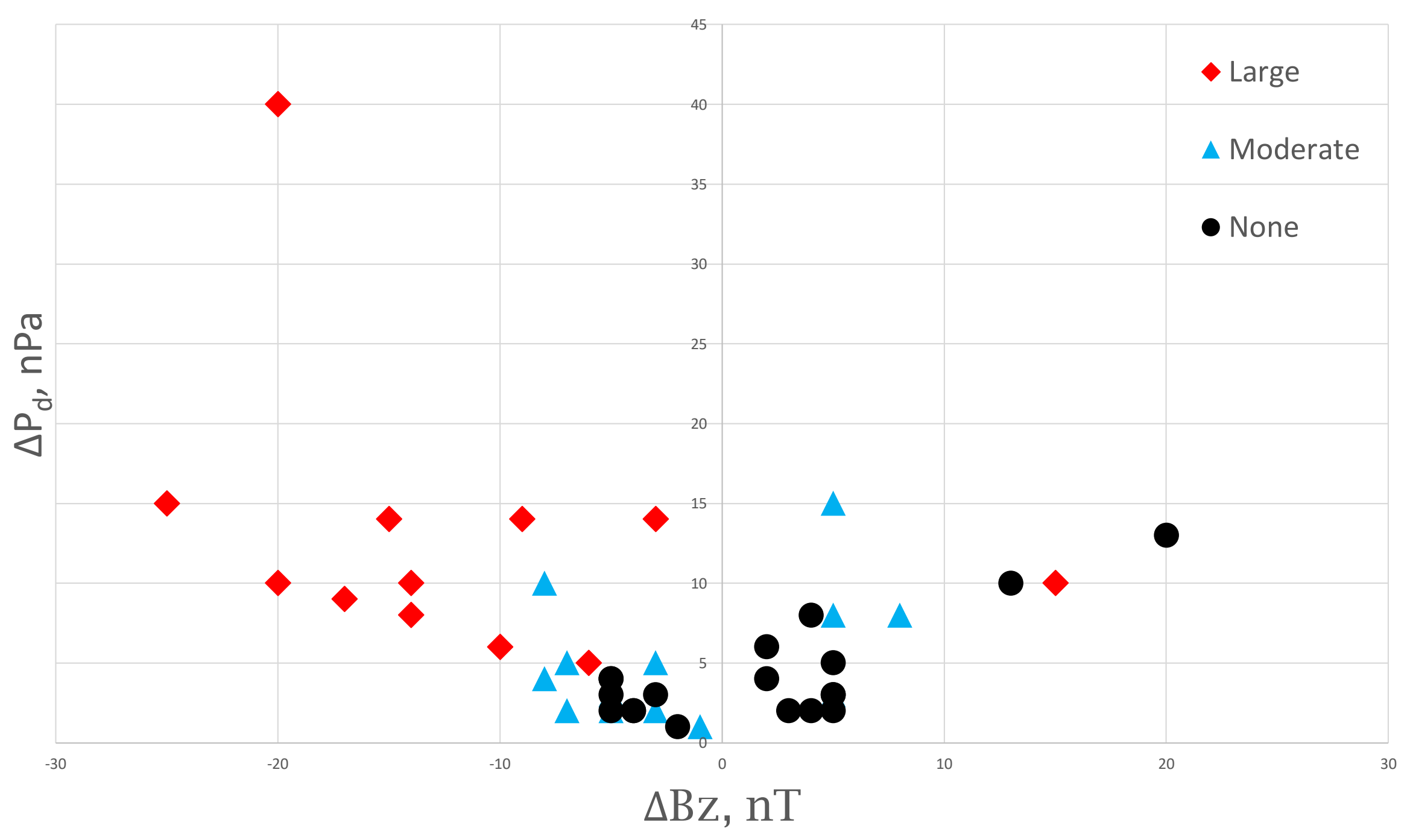
To what extent does magnetospheric compression by solar wind with enhanced dynamic pressure induce scintillation, and what kinds of factors may contribute to scintillation after compression?

Methods

- Used scintillation receiver data from two receivers on the Antarctic Continent at the South Pole and McMurdo station to carry out a study on 44 instances of solar wind dynamic pressure enhancement events.
- Focused on the time period shortly before and after the Earth's ionosphere was affected to study the short-term evolution of the ionosphere and its effects
- Explored what factors such as solar wind characteristics, position, time, and Ionosphere characteristic may have contributed
- Made case studies of large scintillations and statistical studies of large scintillations occurrence
- Most scintillation was in phase, and events were categorized by phase scintillation occurrence before and after the compression: roughly 1/3 of events had no change, 1/3 had moderate change (1-5 additional $\sigma_\varphi > 0.6$ rad), and 1/3 had large change (5+ additional $\sigma_\varphi > 0.6$ rad),

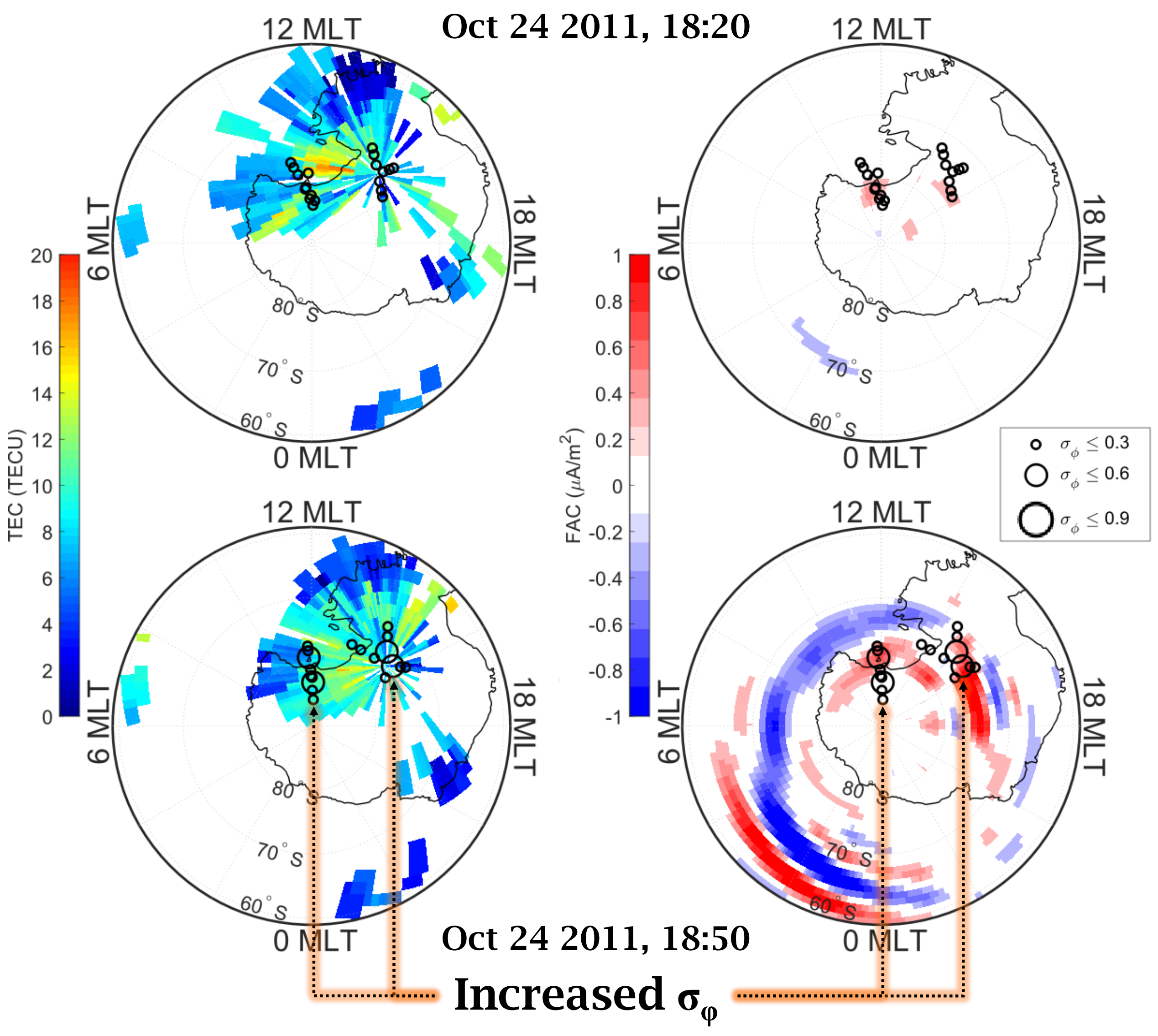
Solar Wind Factors

Distribution of Events by Solar Wind Parameters



- Events are grouped by change in scintillation occurrence
- Those with increased σ_φ were associated with larger dynamic pressure enhancements and larger southward turnings of the IMF B_z
- Indicates southward turning of IMF B_z and magnitude of pressure enhancement both contribute to increases in scintillation

Ionospheric Case Studies



Increased σ_φ

Pre-Compression

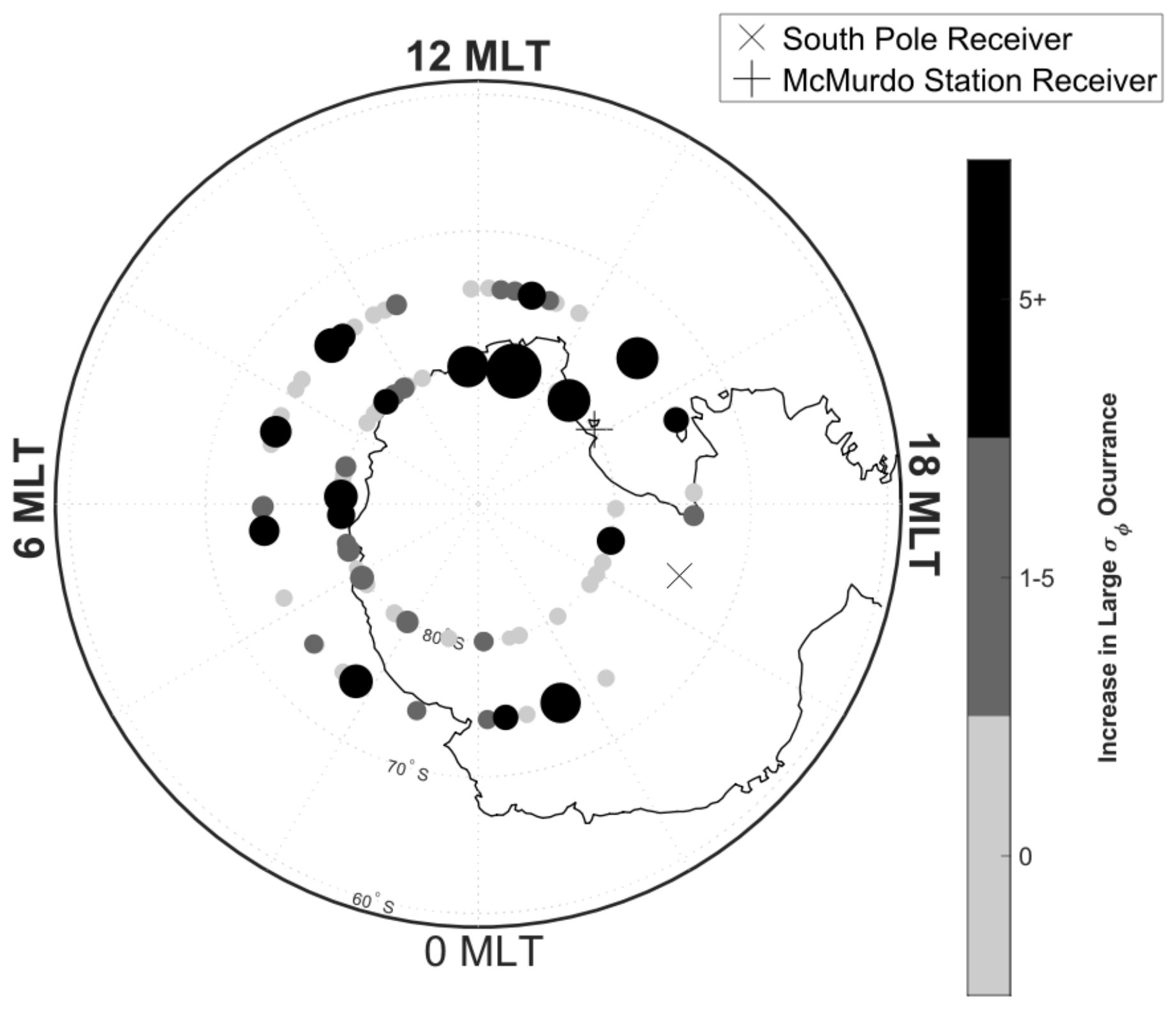
- Quiet Solar wind at constant, low pressure, mostly positive B_z for ~18 hours beforehand
- Very low field aligned current

Post-Compression

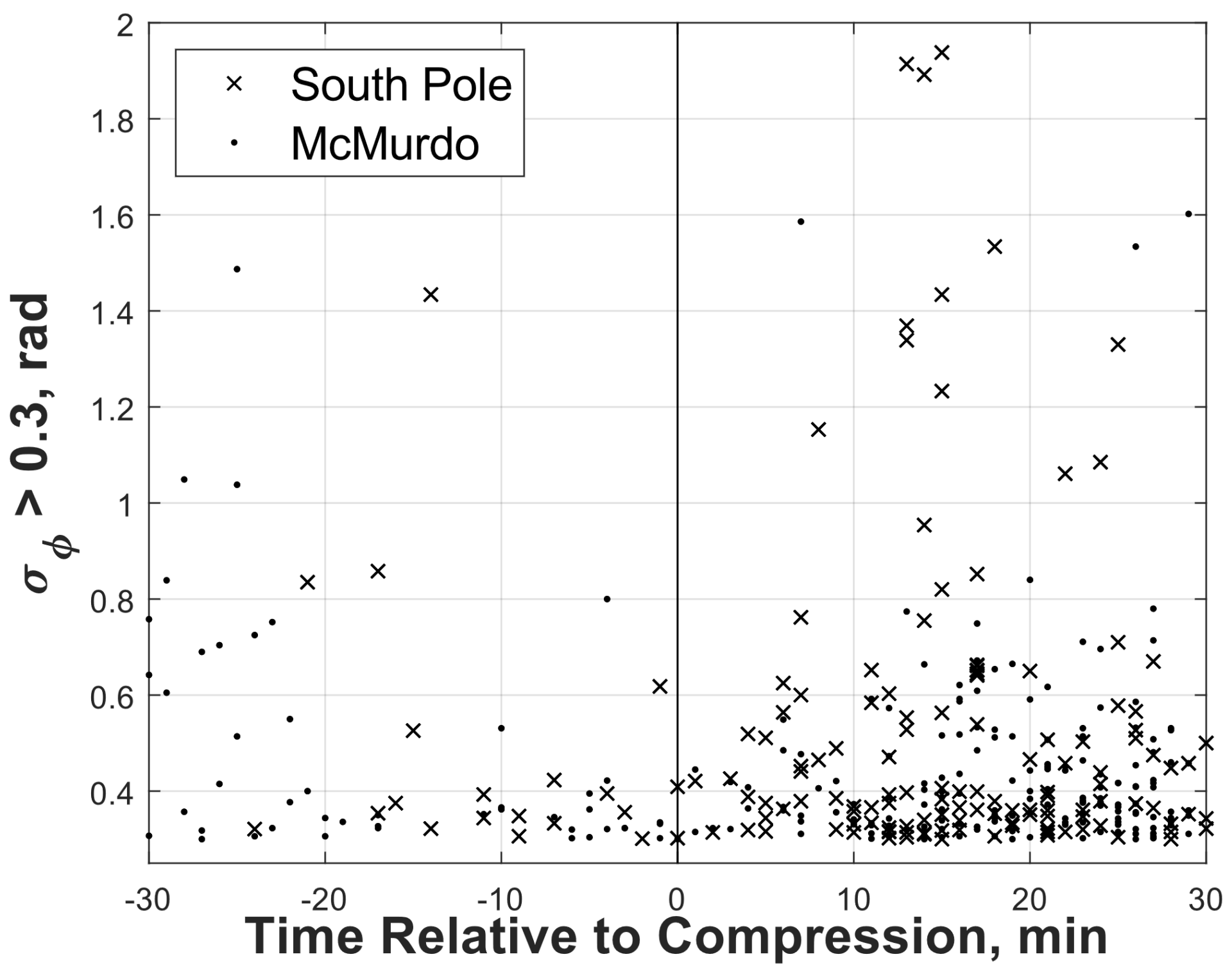
- Global FAC greatly increases in size and magnitude right after compression
- Increase in scintillation index leading to peak σ_φ ~ 0.6 rad

Spatial Distribution

- Distribution of receiver coverage for all 44 events in magnetic local time coordinates
- σ_φ increase more after the compression when the receiver was on the day side
- Larger σ_φ occurred more often in dusk and day sectors after normalizing
- More coverage of dayside & dawn sectors, and unfortunately not as much coverage of dusk sector



Temporal Effects



- Time distribution of $\sigma_\varphi >$ 0.3 rad during 1 hour period centered on the compression
- Significantly more large scintillations after compression
- Response times within 10 minutes for earliest effects after compression
- Night-side locations took longer to be affected on average due to propagation of ionospheric changes

Conclusions

- σ_φ increased significantly following compression of the magnetosphere solar wind with enhanced dynamic pressure
- Cases where there were large negative Solar Wind IMF B_z and dynamic pressure were more likely to exhibit increased scintillation
- Day-side locations saw a higher likelihood of increased scintillation
- The time response of the scintillation increase was usually within 10 minutes of the compression, depending on location

Acknowledgements

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