An interhemispheric survey of travelling ionospheric disturbances and their relationship to geomagnetic activity

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Introduction

Travelling ionospheric disturbances (TIDs) are transient perturbations in ionospheric electron density, caused by processes such as atmospheric gravity waves, that focus and defocus SuperDARN signals producing a characteristic pattern of ground backscattered power [Samson et al., 1989, 1990].

Early studies concluded that likely sources of these disturbances correspond to ionospheric current surges [Bristow et al., 1994] in the dayside auroral zone [Huang et al., 1998a].

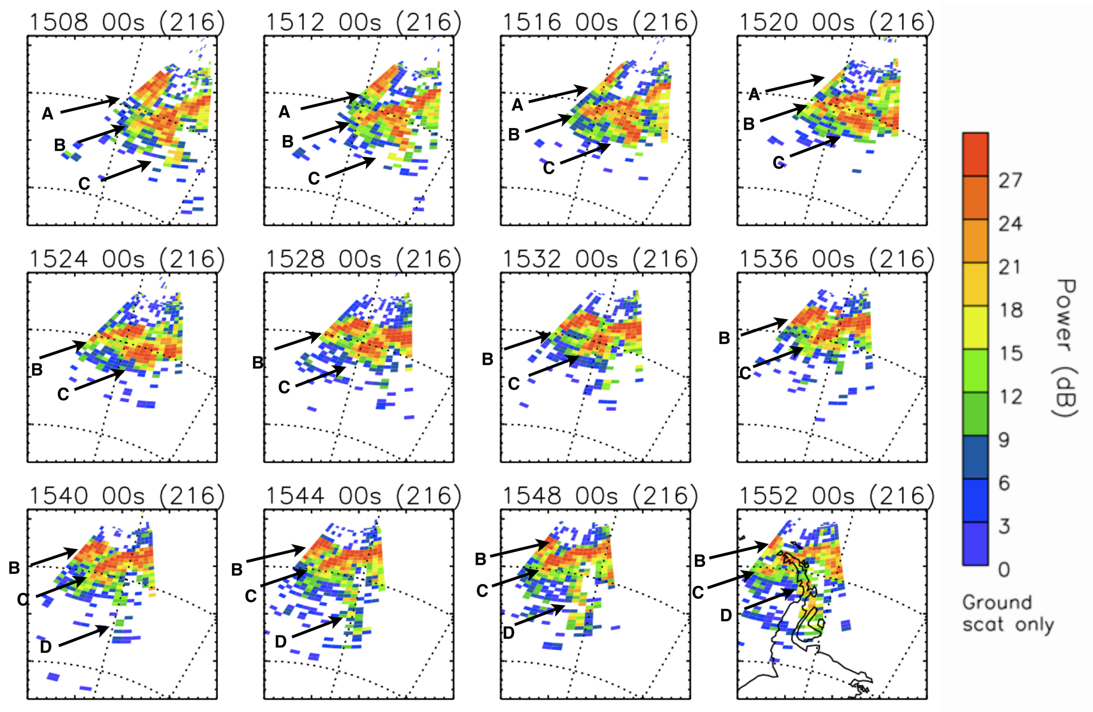
Subsequent studies have indicated that they can result from transient, or oscillatory perturbations in the IMF implying a direct link with solar wind driving [Huang et al., 1998b; Sofko and Huang, 2000].

If TIDs are associated with a purely magnetospheric driver then one would expect similar signatures to be observed at conjugate locations in the northern and southern hemispheres.

Observations using all-sky airglow imagers [Otsuka et al., 2004] and GPS networks [Tsugawa et al., 2006], however, have led to mixed conclusions concerning the interhemispheric nature of different scale TIDs.

The continuous, large-scale nature of SuperDARN observations make them an ideal tool for such studies and we have therefore performed a survey of TIDs using radars in both hemispheres, under varying levels of geomagnetic activity, in attempt to further understand these phenomena.

We focus on data from the Falkland Islands Radar (FIR), which has observed a large variety of TID signatures since its deployment in February 2010, and compare this to data from Wallops, Blackstone and to the geomagnetic AE and D_{ST} indices.



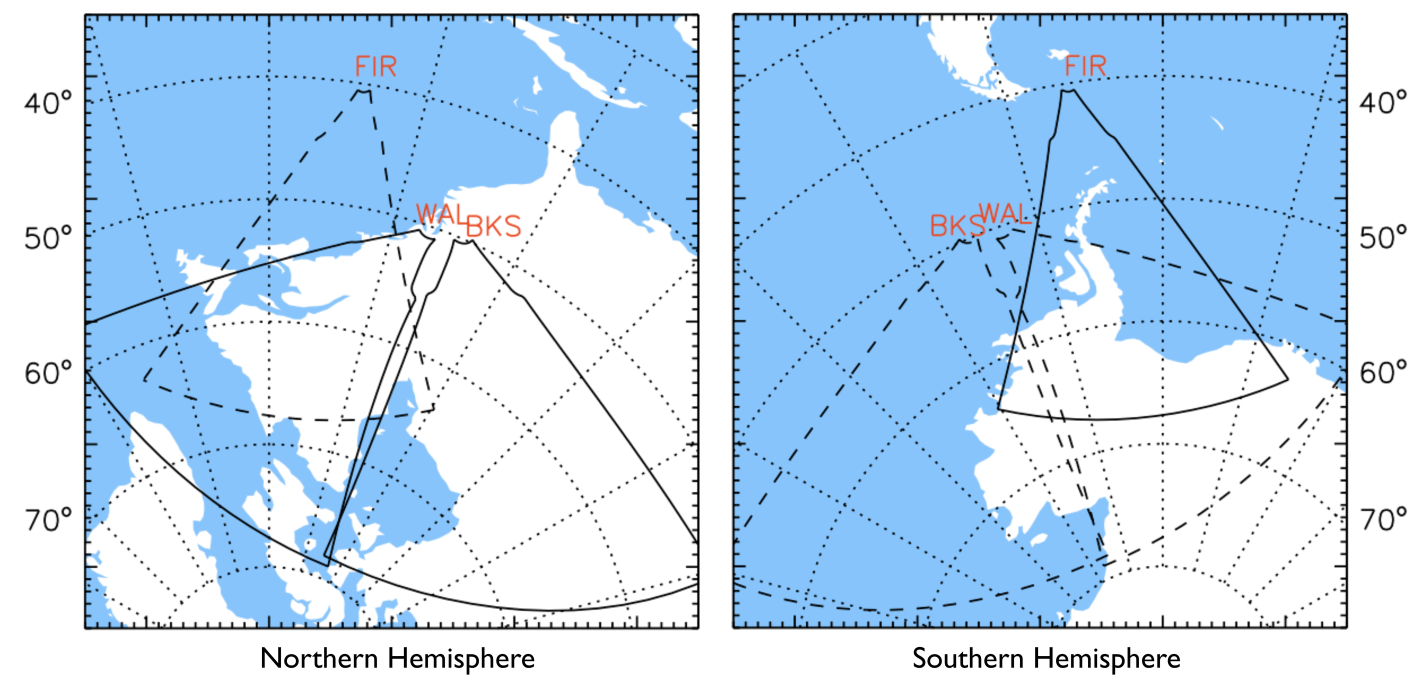
Example TID observed in radar ground scatter

In the series of full-scans from 4th August 2010 illustrated on the left, a TID can be seen propagating through the radar field-of-view

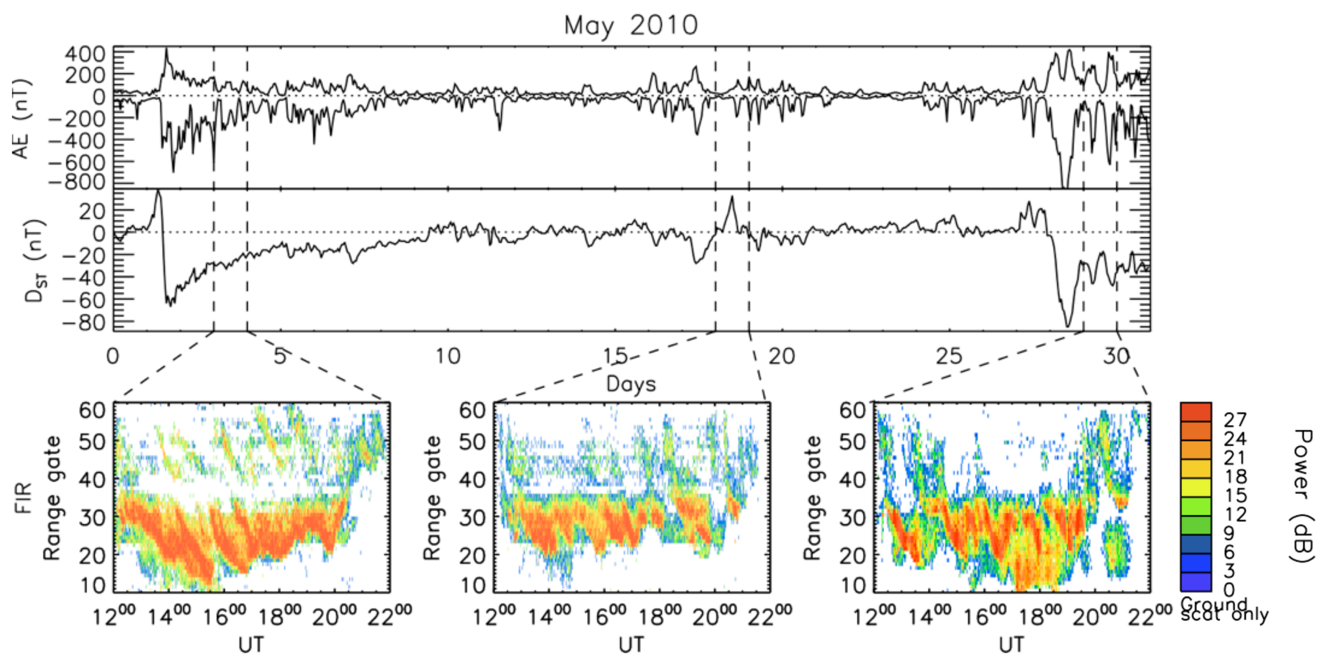
The TID is observed as bands of enhanced radar ground backscatter that appear at far ranges in the eastern most beam and move to near ranges in the western most beam

In the last panel, the coastline of the antarctic peninsula is shown. It is evident at times that there is also a tongue of enhanced power associated with this feature

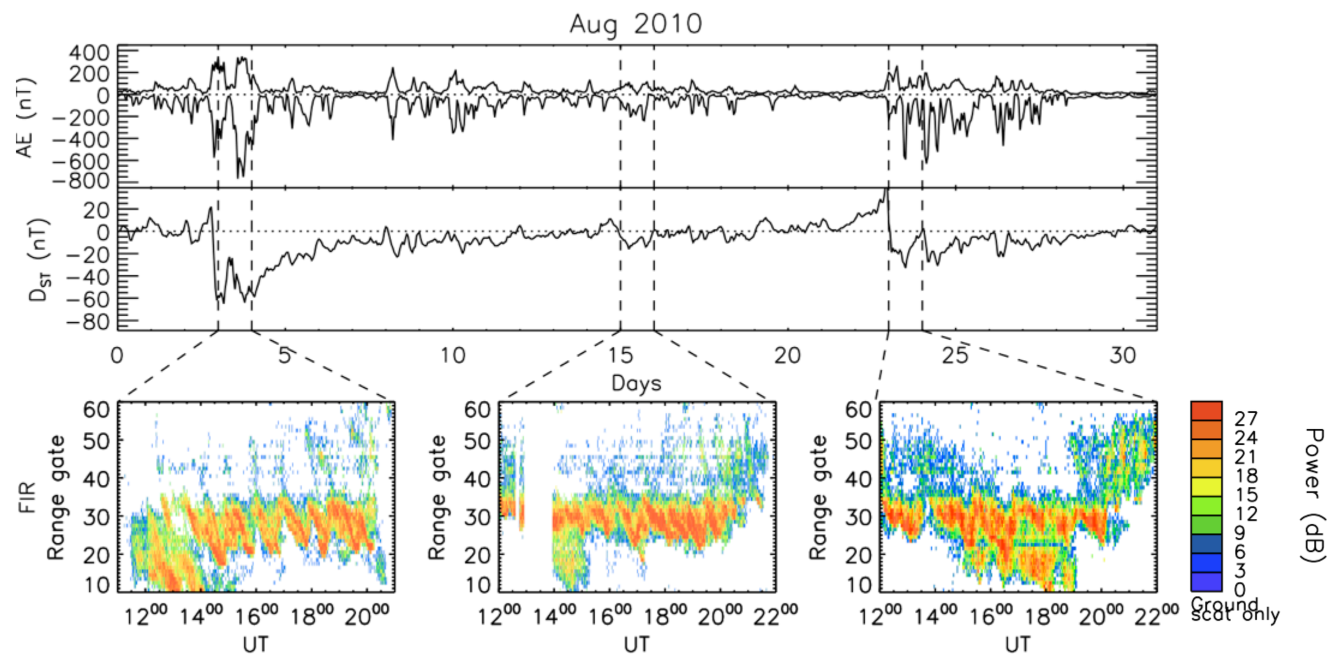
FIR, WAL, and BKS Radar Fields-of-View



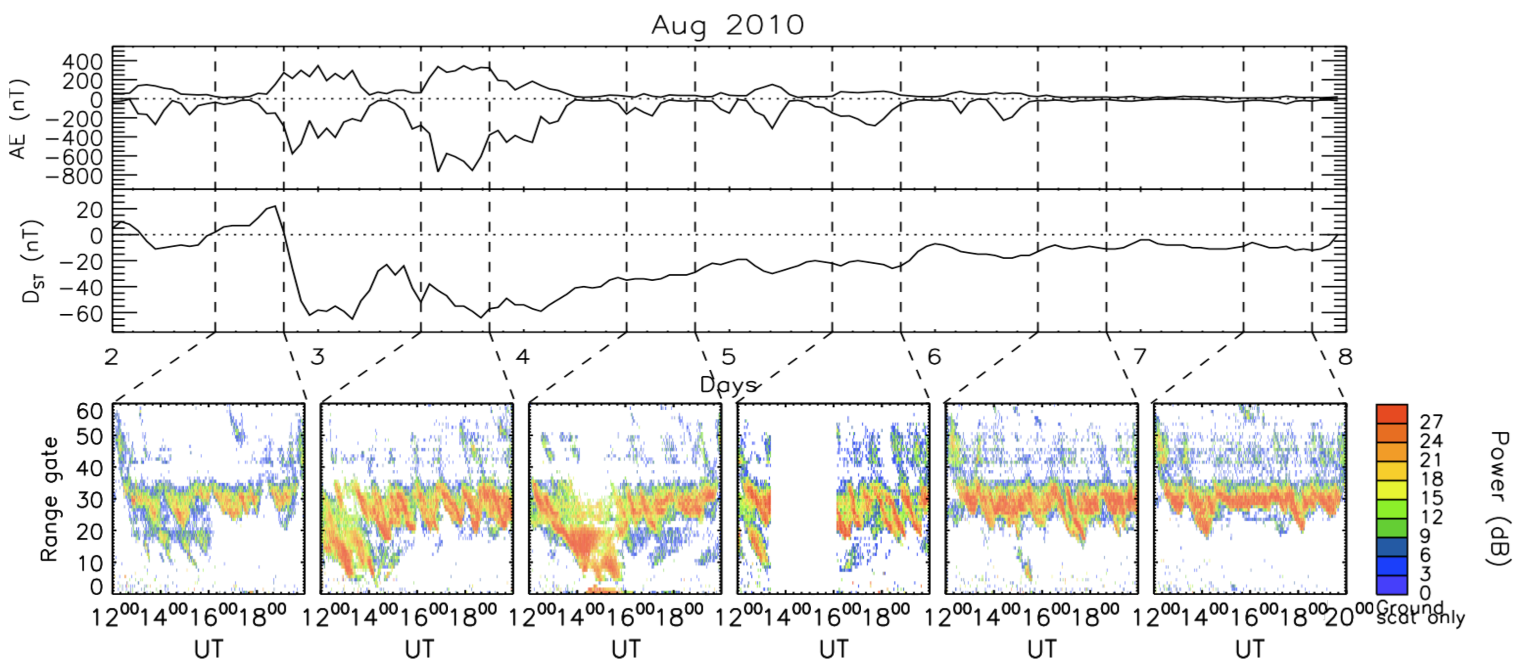
Relationship to Geomagnetic Activity



We first surveyed the FIR data for observations of TIDs. Selecting the best days (high power, clearly defined phase fronts), and comparing these to the concurrent AE and D_{ST} indices suggests that they are most prominent following intervals of enhanced geomagnetic and auroral activity

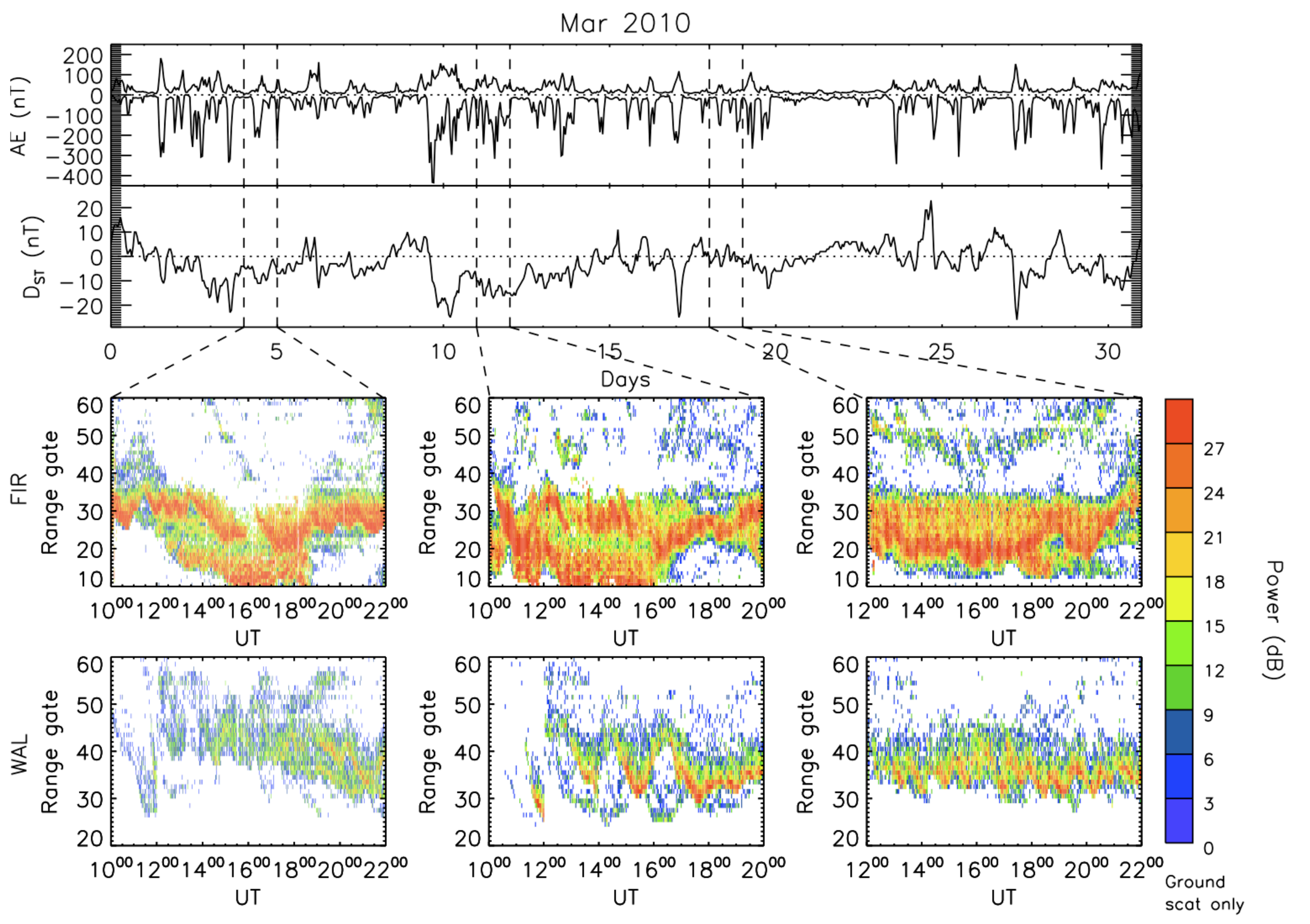


Even from these few examples, it is apparent that the nature of the TIDs can be very different during otherwise similar intervals. Sometimes the range at which the 1 hop ground backscatter is observed changes, and at times the TIDs are apparent in both the 1 and 2 hop ground backscatter.

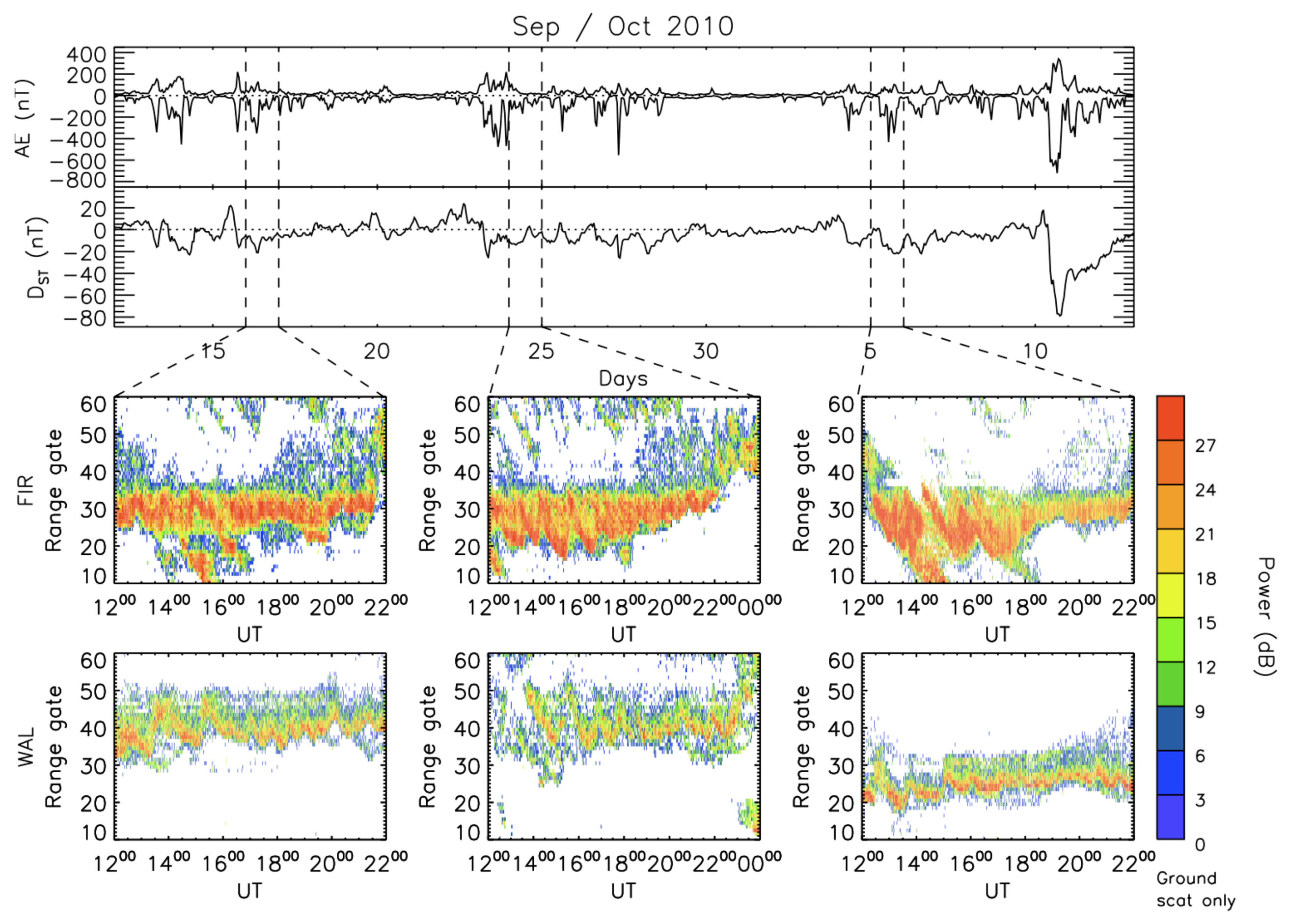


Zooming in on a geomagnetic storm interval we can see how the nature of the ground backscatter, and the TIDs evident within it, changes with the changing geomagnetic activity level. The effect of the storm seems to maximise ~1 day after the onset of the main phase [Grocott et al., 2011].

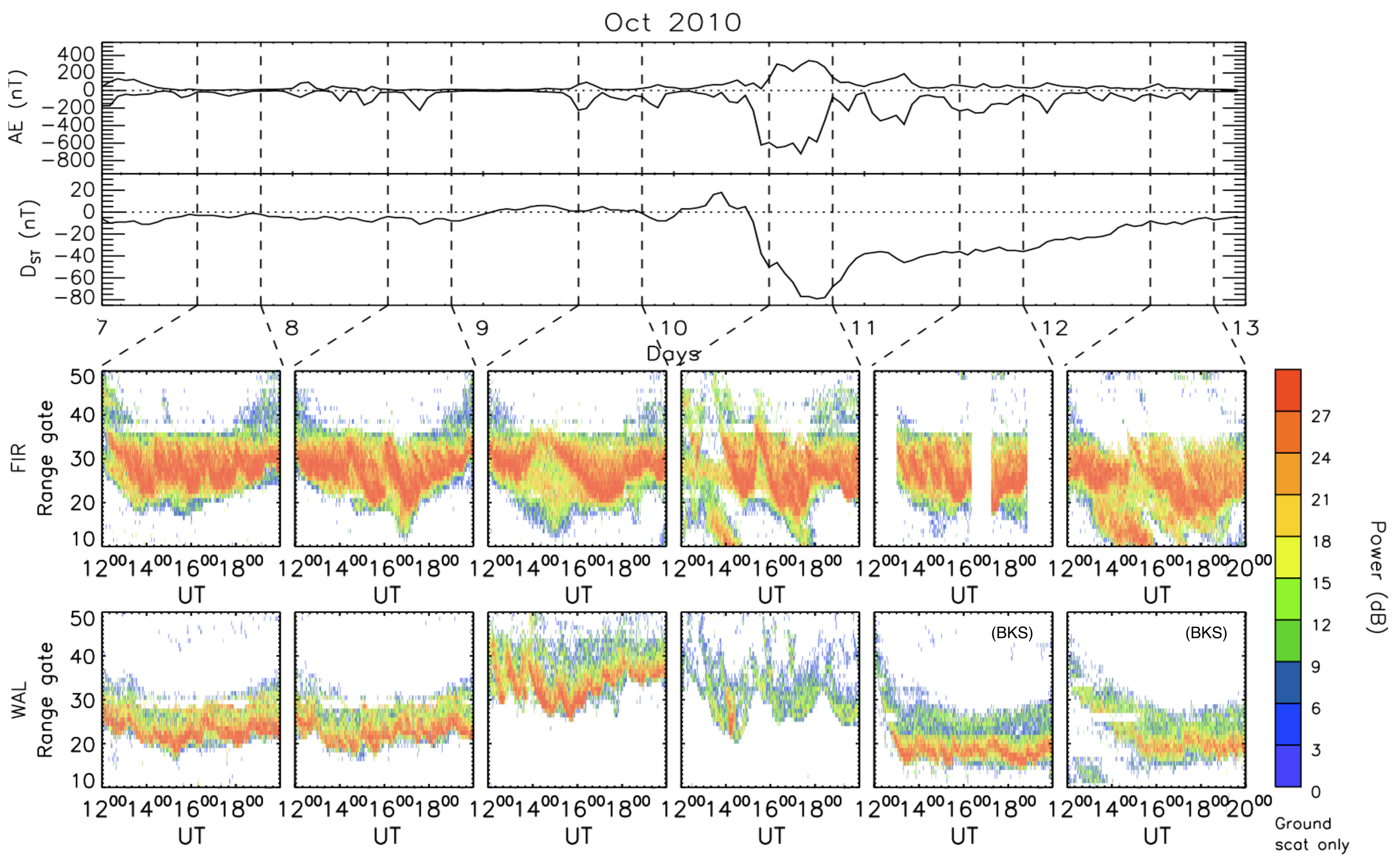
Interhemispheric Observations



At equinox it is possible to directly compare the TID signatures observed simultaneously at similar locations in the northern and southern hemispheres. Here we again selected intervals based on the FIR observations alone, then compared to AE, D_{ST} and the WAL data.



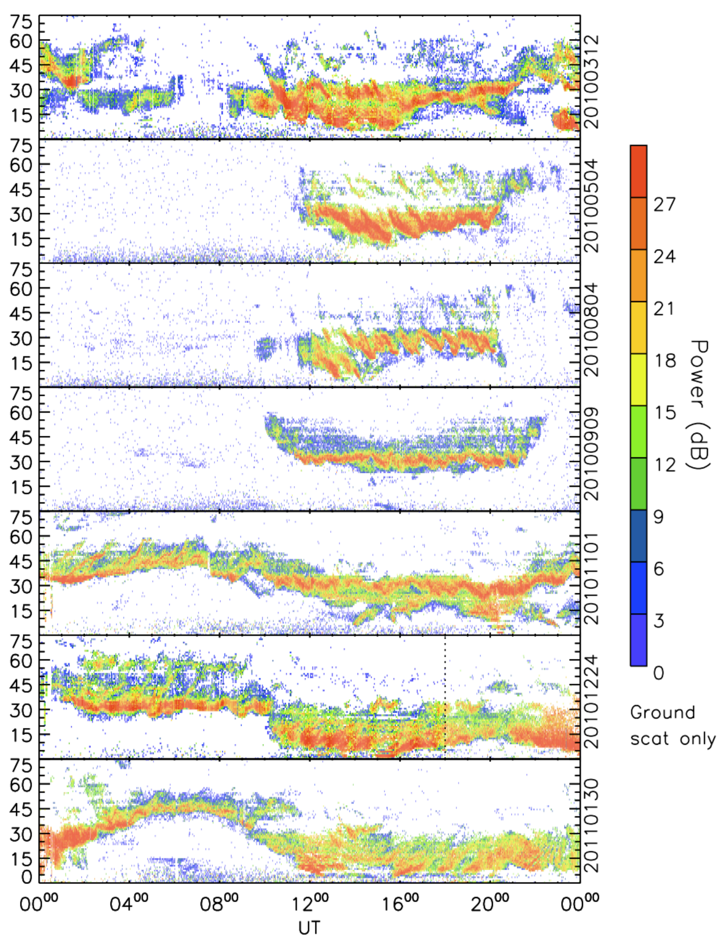
As these examples illustrate, evidence for TIDs is present in the WAL data at the same times as the FIR observations. However, the nature of the TIDs is not always the same in the two hemispheres, having different frequencies and scales.



During this more recent interval, changes in the TID characteristics appear to precede the storm main phase, but do occur after a modest increase in D_{ST}. A second change in TID characteristics then occurs after the main phase onset. Changes also occur in the N-H, that are significantly different to their S-H counterparts.

Long Term Trends

Seasonal Variations



Over the course of the year the nature of the TID observations changes, largely due to seasonal effects on the amount and location of the observed ground backscatter.

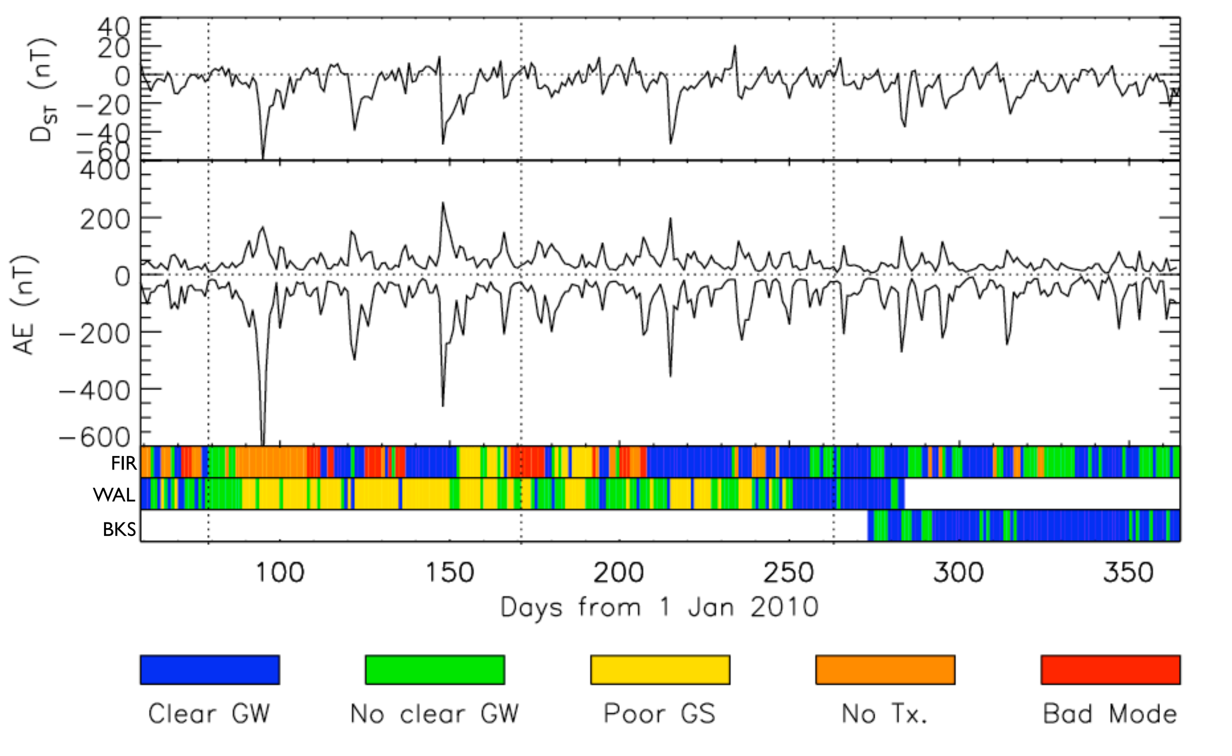
Daytime TID are observed for most of the year (August - May) although even during these hours the nature of the TID observations varies.

Generally the TIDs propagate equatorward although there is some evidence for poleward propagation

During summer (November - March) TIDs are evident in the nighttime scatter, generally propagating poleward.

The TIDs are sometimes evident in both near and far range echos.

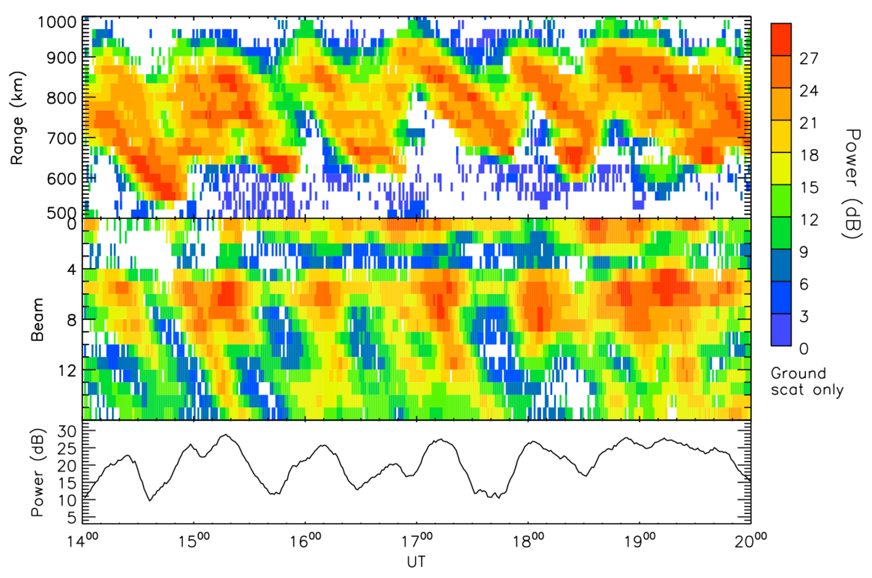
TID Observation Database



This plot shows the observation statistics of TIDs in the FIR and WAL observations. No data were available for WAL after 11 Oct 2010, when we have used BKS.

It is clear that ground scatter coverage is a major factor in whether or not conjugate TID observations are made.

Further Study



A number of avenues of further study are open to us to better understand these observations. Data from additional radars can be inspected, for example, to extend the database both in time and in space.

It is also important to perform additional analysis on the TID observations, to determine characteristics such as frequency, wavelength and phase speed, which will enable a more comprehensive categorisation and quantitative analysis.

It might also be advantageous to conduct a targeted campaign, to limit the effects of variables such as season and operating frequency.

Summary

The observations presented here illustrate some of the variability that exists in TID characteristics, and in the nature of their signatures in radar ground backscatter. Clearly, ground scatter occurrence is a major factor in whether or not TIDs will be observed by the radars, but even when there is good coverage there are times when TID observations are conjugate and times when they are not. To complicate matters further, observations made by two radars in the same hemisphere at nearly identical locations can also exhibit different characteristics. Overall, this suggests that geomagnetic activity, local atmospheric and ionospheric conditions, ground topography, and even hardware or operating differences may all play a role in the observation and nature of TIDs.

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References

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