Investigation of High Latitude Sources of TID/AGW activity affecting JORN operations

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Background:

It is well-known that sources of TIDs exist at high latitudes and often the TIDs generated propagate thousands of kilometres to mid-latitudes and even low-latitudes.

SuperDARN radars are excellent instruments for detecting TIDs as they produce quasi-periodic variations in measured parameters such as power, velocity and angle of arrival.
Echoes associated with each propagation mode detected by a SD radar may extend for hundreds of kilometres in range. Consequently, the propagation of TIDs may be followed over thousands of kilometres in latitude by utilising the propagation modes detected by one radar and also by combining data from more than one radar. Because SD radars scan 52 degrees or more in azimuth, the longitude extent of TID activity can also be investigated.

The TIGER radars are ideally located for investigating TIDs propagating from high latitudes towards Australia and to the region of the ionosphere of interest to JORN.

The Buckland Park radar (BPK) routinely monitors activity over Bass Strait/Northern Tasmania and often sees features moving toward Adelaide. It is important to realise that the lower latitude limit of observation is determined by ionospheric propagation conditions. Thus, it can be assumed that when TID activity is apparent in the leading edge of the closest range echo trace, the TIDs will continue to propagate towards and over mainland Australia.

The Bruny Island radar (TIG) provides excellent coverage of the night-time sub-auroral region and the auroral region during periods of magnetic activity so the BPK/TIG combination can investigate auroral sources of TIDs and follow the TID propagation to mid-latitudes.

Hunsucker (1982) classified TIDs into three types: Large, medium and small scale and defined the categories as:

1. Large scale TIDs (LSTIDs) originate in the auroral regions and travel equatorward with periods ranging from 30 min to several hours and horizontal wavelengths ~1000 km and horizontal speeds of 400 - 1000 m/s;
2. Medium scale TIDs (MSTIDs) have velocities 250–1000 m/s, periods 15 min to ~1 h, and wavelengths of several hundred kilometres;
3. Small scale TIDs have horizontal velocities 300 – 3000 m/s and periods 2-5 minutes.

Several studies using the SD network in the northern hemisphere have reported on TID observations. For example, Karpechev et al., 2010, described a case in which the source of an LSTID was in the high latitude cusp region. A statistical study (Ishida et al., 2008); showed MSTIDs with lower phase velocities travelled much further equatorward than those with higher phase velocities. Koustov et al. (2014) studied MSTIDs in the E-region by reducing the first range window detected by the SD radar from the "Common Mode" value of 180 km to 120 km and by increasing the range resolution from 45 km to 15 km. They found a seasonal variation in occurrence and often onset occurred after sunset and continued until sunrise.

He at al. (2004) used the TIGER Bruny Island radar to study MSTIDs and seasonal and diurnal variations in the direction of propagation of MSTIDs. Generally, the propagation had a northward (equatorward) component. In the early morning hours, the overall direction of propagation was quite variable. It then became predominantly northwest before changing to northeast around 09:00 LT. In late autumn and winter the direction changed back to north/northwest around 15:00 LT. During the other seasons, northward propagation was obvious near dawn and dusk, but no significant northward propagation was observed at noon. It was suggested that the variable propagation direction in the morning related to irregular magnetic disturbances that occur at this local time. The changes in the MSTID propagation directions near dawn and dusk are generally consistent with changes in ionospheric electric fields occurring at these times.

These studies demonstrate that SD radars are powerful tools for studying TIDs. The added latitudinal coverage provided by combining BPK with the other two TIGER radars, TIG and UNW should permit systematic studies of the propagation of LSTIDs and MSTIDs from, or close to, sources at high latitudes and determine conditions under which they will propagate to Australia and into regions affecting JORN operations.

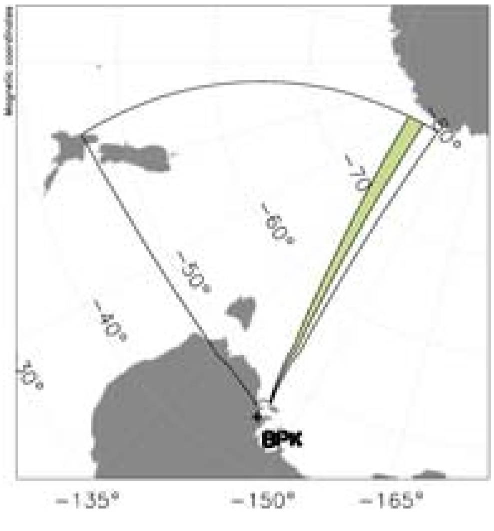
The study by Harris et al. (2012) confirms that LSTIDs and MSTIDs are common features in the ionosphere at the latitudes of Adelaide.

BPK Examples

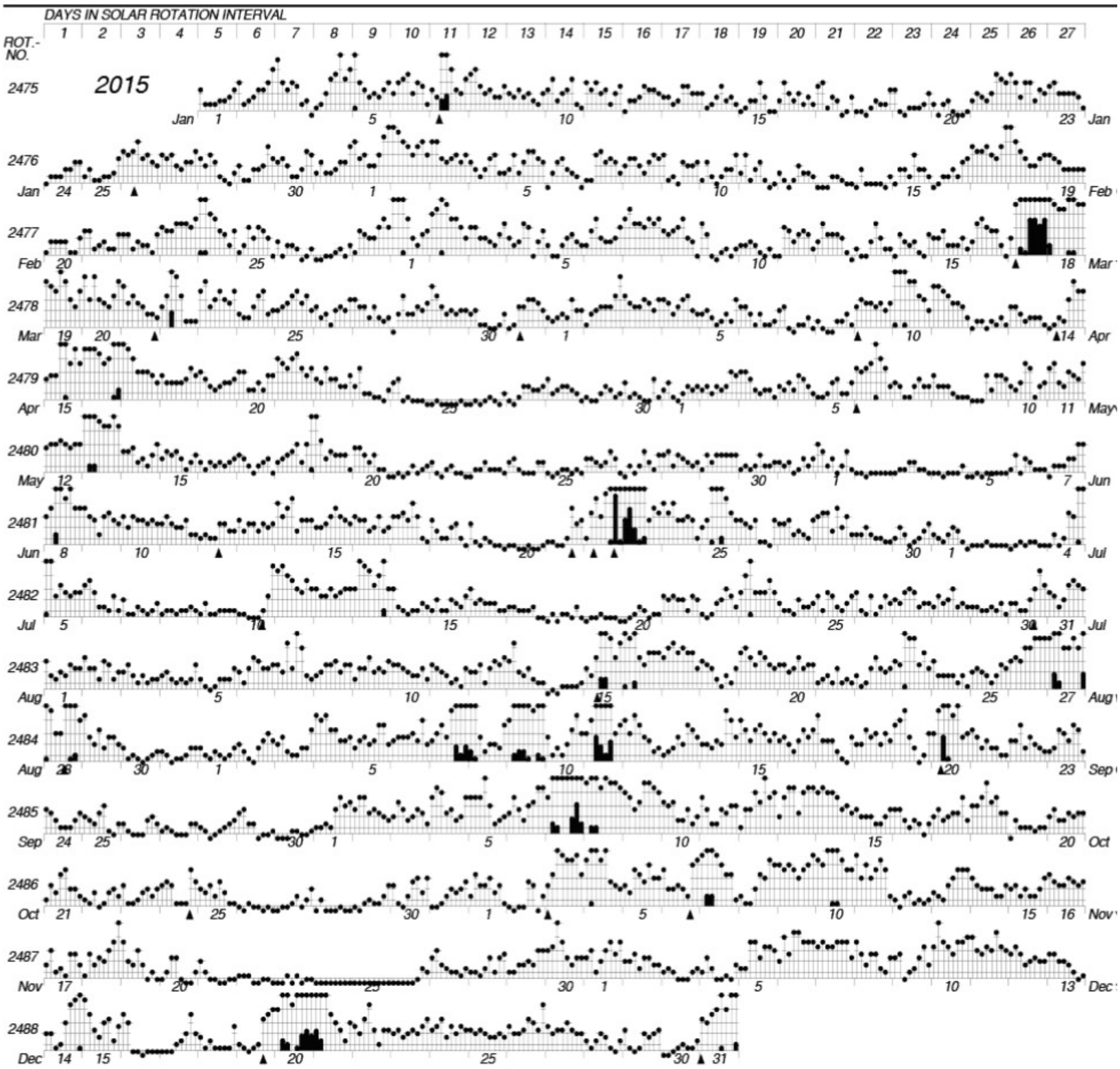
A couple of examples are presented to demonstrate BPK's capability to detect TIDs.

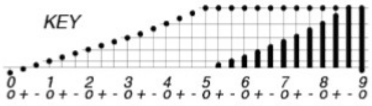
Example 1 – 25 June 2015

This example shows data for BPK Beam 1 on 25 June 2015. This beam covers a greater range of latitude than higher numbered beams.



The magnetic field was quite disturbed on this day as shown in the Kp plot for the year.





▲ = sudden commencement

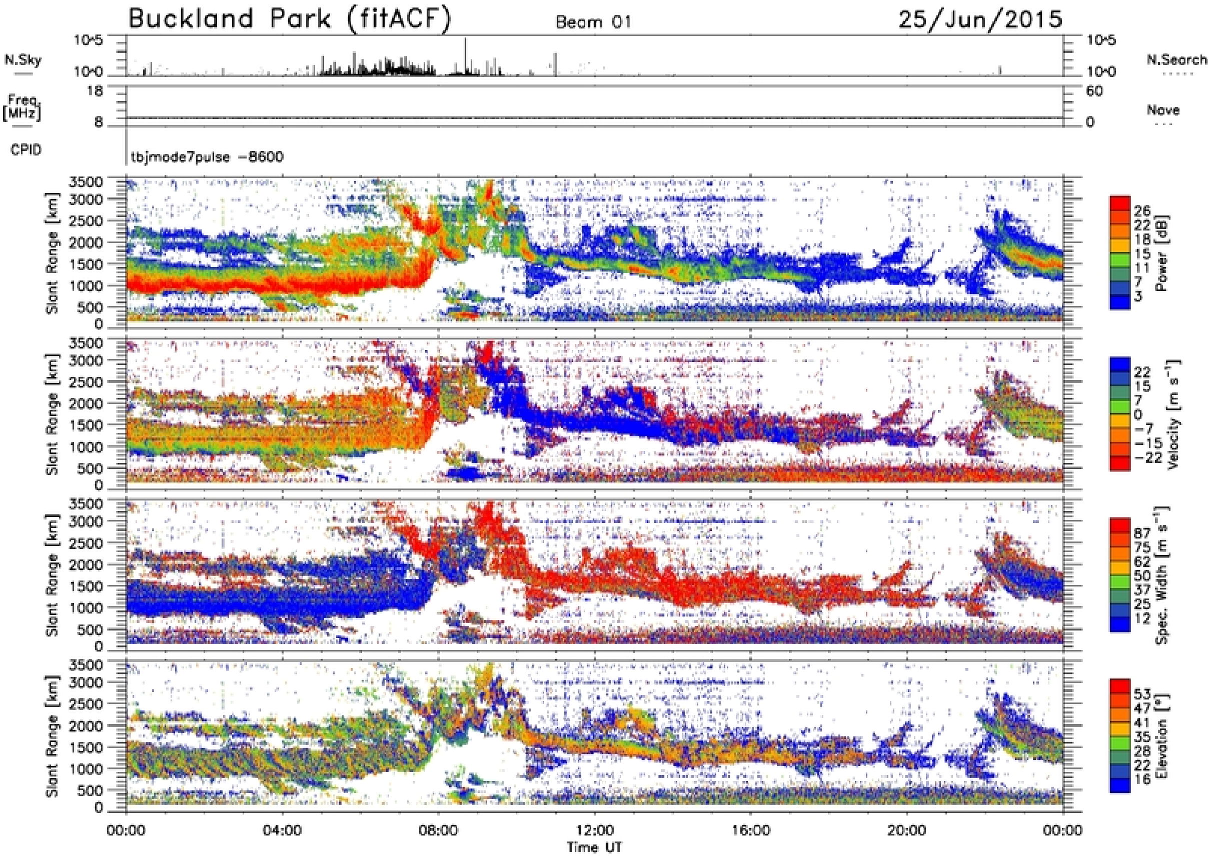
PLANETARY MAGNETIC
THREE-HOUR-RANGE INDICES

Kp 2015

The following plot shows BPK Beam 1 data for 25 May 2015.

The panels show the following parameters, colour coded, as a function of group range and time of day:

Power
Velocity
Spectral Width
Angle of Arrival

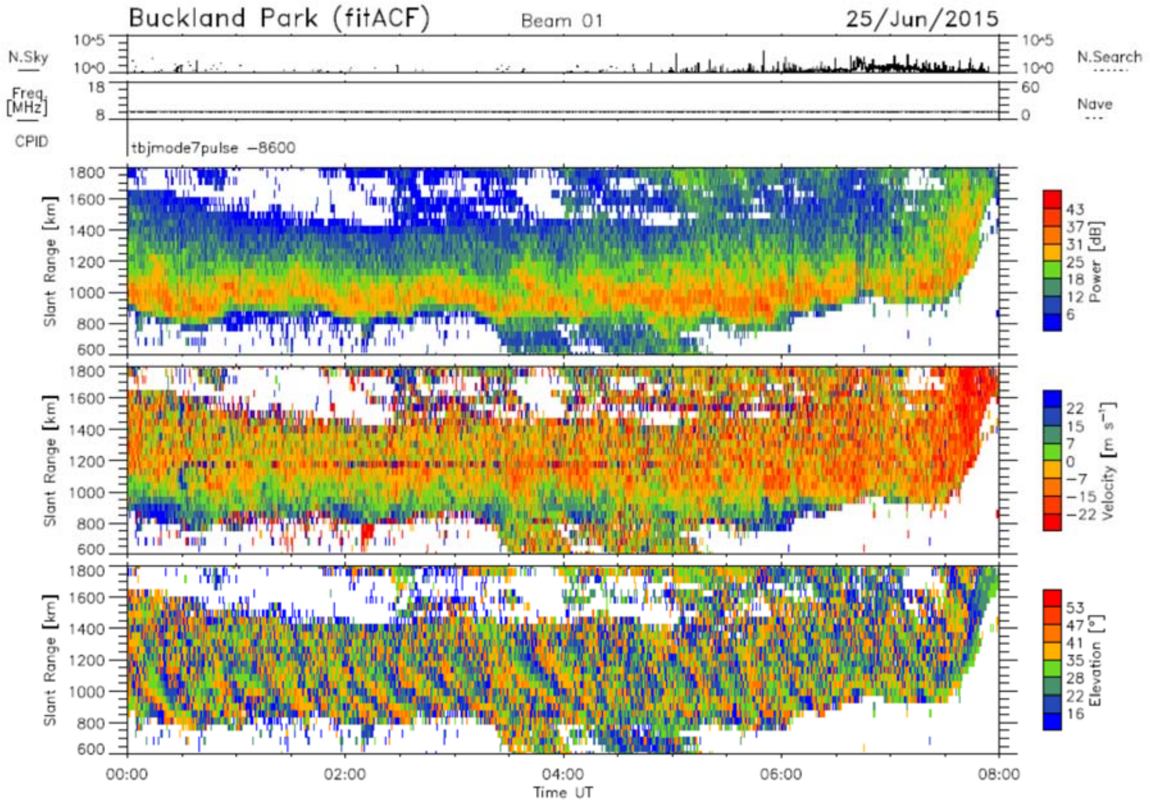


Daytime F2 layer propagation occurs from 0000 to approximately 0730 and from around 2200 to 2400. The daytime propagation is characterised by low velocities and low spectral widths characteristic of the echoes arising from sea scatter propagation via the ionosphere.

At night the echoes have significant spectral width indicating the echoes are backscatter from ionospheric irregularities.

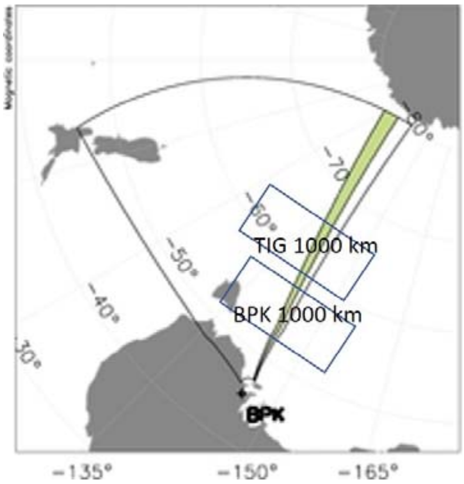
So on this day TID/AGW activity was continuous over at least 7 hours. This activity is more evident in the next plot which covers the period 0000 – 0800 and ranges out to 1800 km. This is a detailed look at the first hop echoes and he periodic fluctuations are now evident in echo power, velocity and AOA.

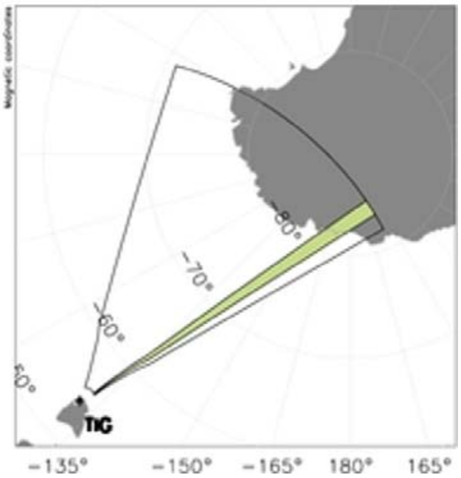
During night-time hours the propagation is more complicated.


Buckland Park (fitACF)
Beam 01
25/Jun/2015
N.Sky
10^5
10^0
N.Search
10^5
10^0
Freq. [MHz]
18
8
60
0
Nave
CPID
tbjmode7pulse −8600
Slant Range [km]
1800
1600
1400
1200
1000
800
600
Power [dB]
43
37
31
25
18
12
6
Velocity [m s^{-1}]
22
15
7
0
−7
−15
−22
Elevation [°]
53
47
41
35
28
22
16
00:00
02:00
04:00
06:00
08:00
Time UT

Example 2 – 9 May 2015

Data are presented from the following beams of BPK (Adelaide) and TIG (Bruny Island)





Both are Beams 1.

The boxes showing the approximate location in the ionospheric reflection region of sea scatter at 2000 km range.

The following radar scans show TIG Beam 1 and BPK Beam 1.

Elevation angles are not available for TIG because of the calibration errors. We are currently in the process of calibrating the AOA data to make it available in the future as TID/AGW effects are often most readily identified in AOA data.

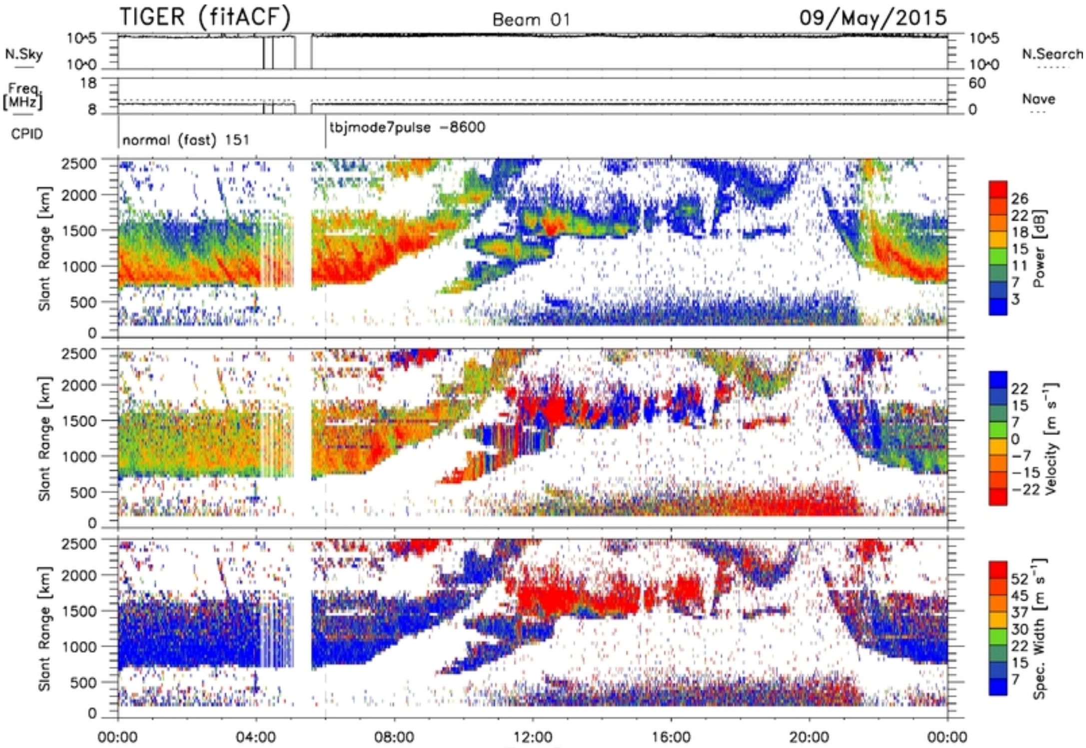
Nevertheless, TID activity is clearly evident is the variations in TIG echo power between 0000 and 0800. The TID activity is more evident in the BPK data over the same period, particularly in the AOA data.

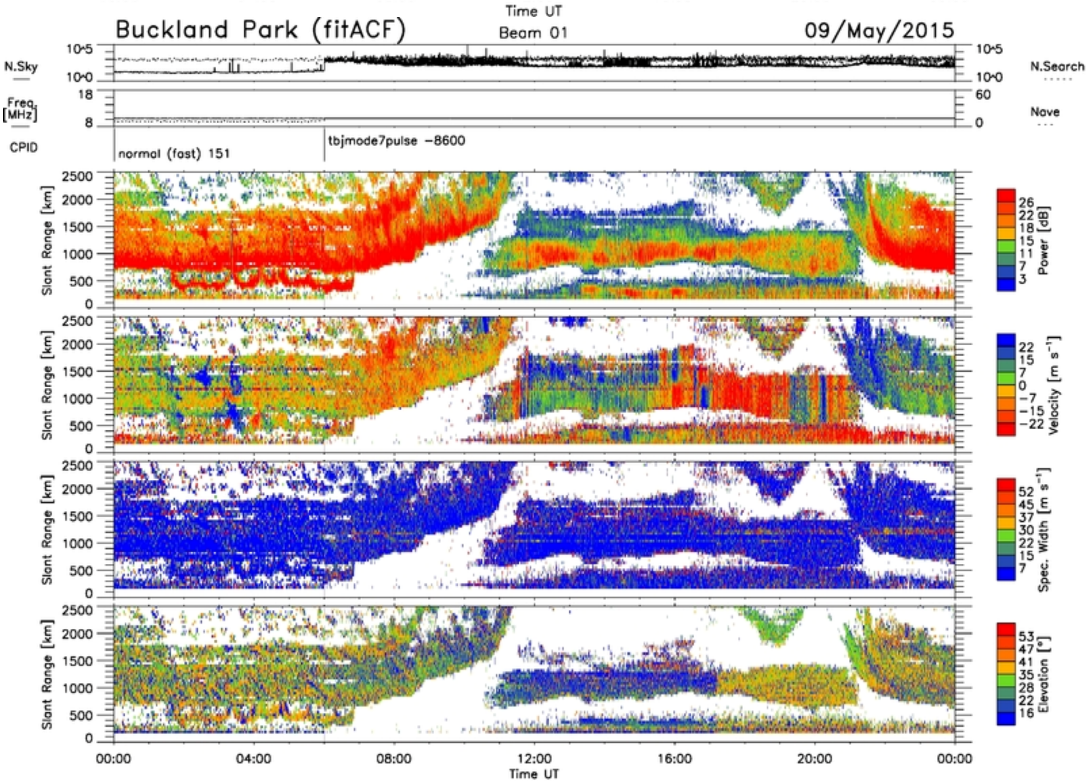
During the night ULF activity is evident and this is discussed in another section.

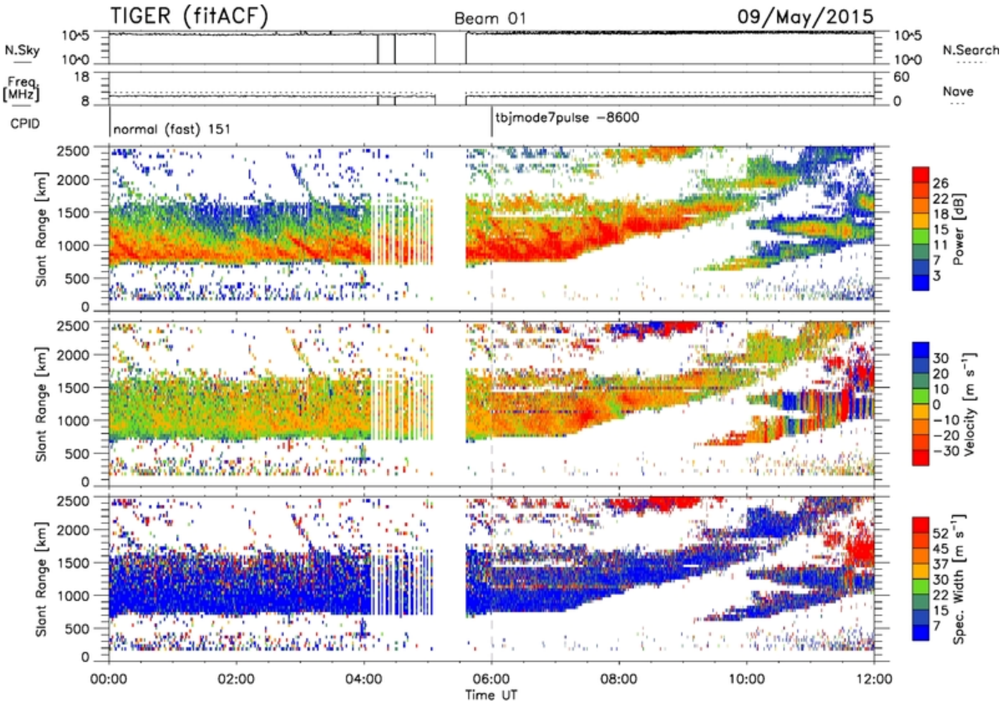
The Kp plot shows that very quiet magnetic conditions prevailed until just before 1200 after which magnetic activity increased to moderate levels.

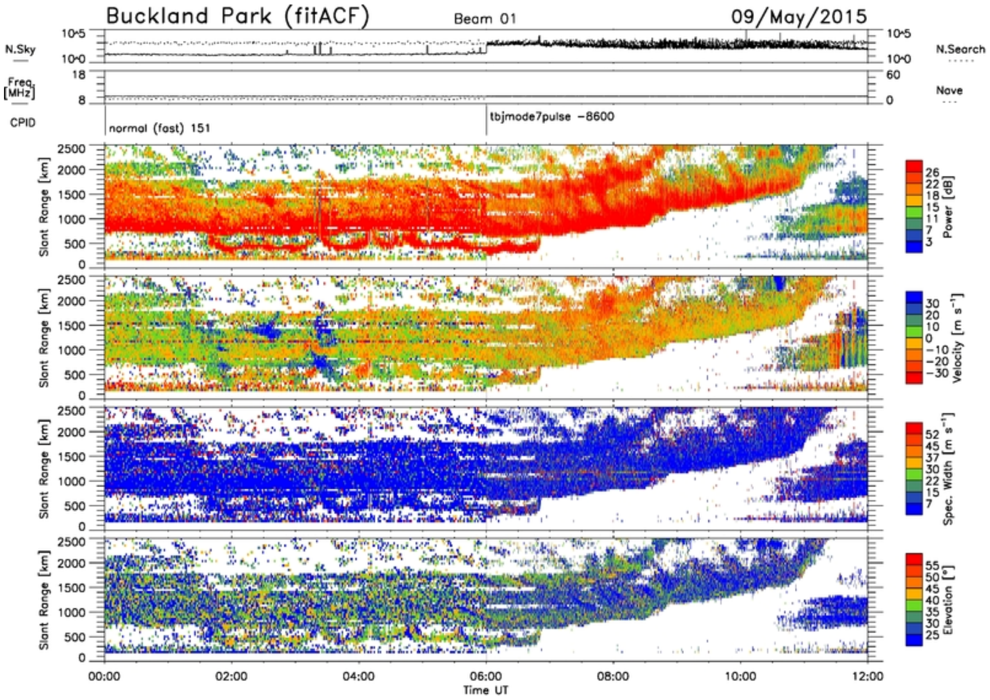
Referring again to the radar beam plots, the range boxes show how combined observation using the two radars provides a capability to study the occurrence and propagation of TIDs over a wide range of latitudes and to track their progress towards Australia.

More detailed plots of the period 0000 to 0800 are shown below where more details of the TID activity are evident.


TIGER (fitACF)
Beam 01
09/May/2015
N.Sky
N.Search
Freq. [MHz]
Nave
CPID
normal (fast) 151
tbjmode7pulse -8600
Slant Range [km]
Power [dB]
Velocity [m s⁻¹]
Spec. Width [m s⁻¹]
26 22 18 15 11 7 3
22 15 7 0 -7 -15 -22
52 45 37 30 22 15 7
0 500 1000 1500 2000 2500
00:00 04:00 08:00 12:00 16:00 20:00 00:00
Time UT


Buckland Park (fitACF)
Beam 01
09/May/2015
N.Sky
N.Search
Freq. [MHz]
Nave
CPID
normal (fast) 151
tbjmode7pulse -8600
Slant Range [km]
Power [dB]
Velocity [m s⁻¹]
Spec. Width [m s⁻¹]
Elevation [°]
26 22 18 15 11 7 3
22 15 7 0 -7 -15 -22
52 45 37 30 22 15 7
53 47 41 35 28 22 16
0 500 1000 1500 2000 2500
00:00 04:00 08:00 12:00 16:00 20:00 00:00
Time UT


TIGER (fitACF)
Beam 01
09/May/2015
N.Sky
N.Search
Freq [MHz]
Nave
CPID
normal (fast) 151
tbjmode7pulse -8600
10^5
10^0
18
8
60
0
Slant Range [km]
0
500
1000
1500
2000
2500
Power [dB]
26
22
18
15
11
7
3
Velocity [m s^-1]
30
20
10
0
-10
-20
-30
Spec. Width [m s^-1]
52
45
37
30
22
15
7
00:00
02:00
04:00
06:00
08:00
10:00
12:00
Time UT


Buckland Park (fitACF)
Beam 01
09/May/2015
N.Sky
N.Search
Freq [MHz]
Nave
CPID
normal (fast) 151
tbjmode7pulse -8600
10^5
10^0
18
8
60
0
Slant Range [km]
0
500
1000
1500
2000
2500
Power [dB]
26
22
18
15
11
7
3
Velocity [m s^-1]
30
20
10
0
-10
-20
-30
Spec. Width [m s^-1]
52
45
37
30
22
15
7
Elevation [°]
55
50
45
40
35
30
25
00:00
02:00
04:00
06:00
08:00
10:00
12:00
Time UT

Observing TID/AGW activity at close range

Using the Japanese Hokkaido SD radar, Koustov et al. (2014) studied TID/AGW activity at close range to the radar by reducing the closest radar range to 120 km from the standard SD range of 180 km and increasing the range resolution to 15 km compared to the standard SD range resolution of 45 km. The example from that paper is shown below.

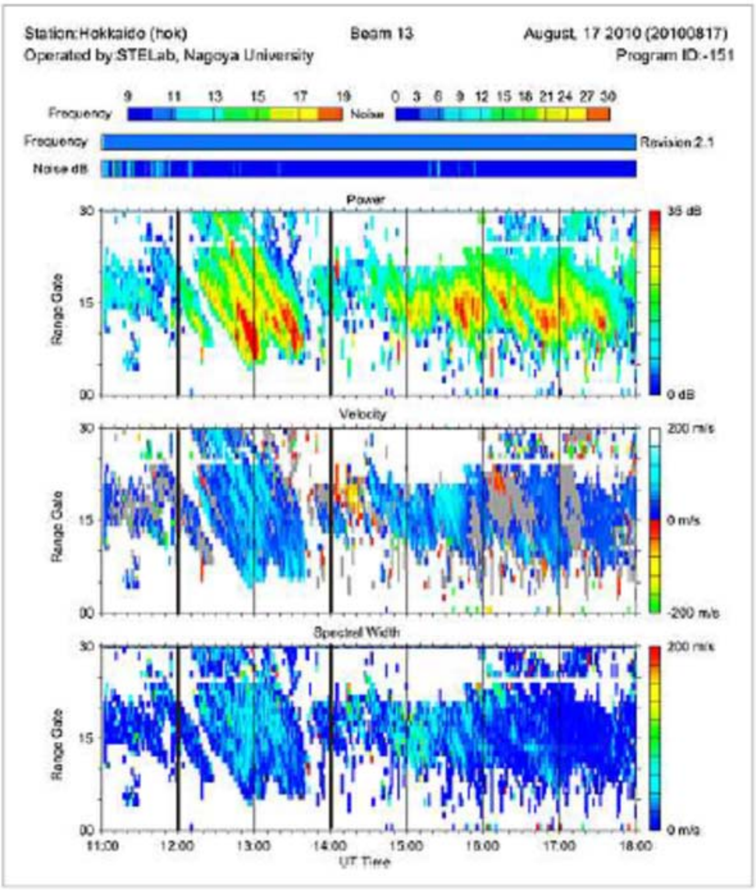


Figure 2.

Open in figure viewer

Standard SuperDARN range-time plot of the echo power, Doppler velocity, and spectral width for the Hokkaido HF radar between 11:00 and 18:00 UT on 17 August 2010. The radar operated at 15

This technique can be used to study TID occurrence and propagation close to BPK.

JORN Related Studies

Our knowledge of TID/AGWs is quite extensive in terms of basic propagation characteristics and sources. However, our predictive capabilities are very limited in terms of predicting when and how specific TIDs are generated and what their propagation paths will be and how far they will travel.

The TIGER radars, BPK, TIG and UNW, can monitor TID activity between the Australian mainland and Antarctica. Observations show that TID activity in this region often occurs in sequences of consecutive days with activity persisting for many hours each day. These results demonstrate that the TIGER radars, and in particular BPK, because of the much larger area of its footprint, can be used to systematically study the generation and propagation of TIDs at mid-to-high latitudes at Australian longitudes. Specific studies can be conducted to identify TID sources and when and why they occur. For example, what role does magnetic activity play and what sequences and characteristics of processes in the auroral zone consistently produce TIDs? What directions do they propagate and how far do they travel? Can characteristics then be identified and used to predict which reach and travel across the Australian mainland?

Can a prediction capability be developed that would be useful to JORN operations?

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