Weather Influences on Observed Radar Backscatter

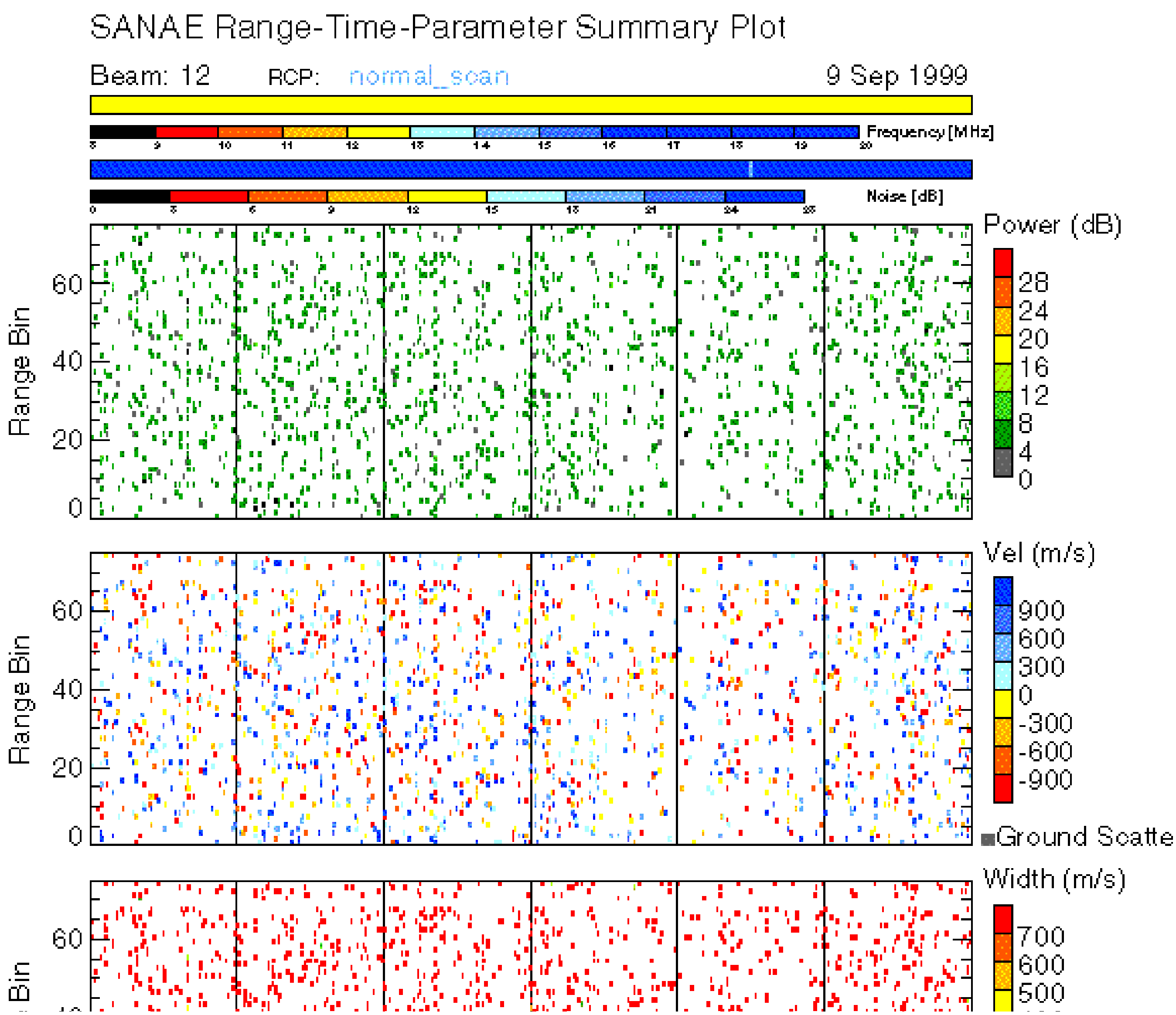
Erhard Mravlag

Space Physics Research Institute, University of Natal, Durban

Abstract

We observe that during heavy storms the backscatter pattern breaks into a characteristic speckle pattern, indicating that the coherence of the backscatter is lost. Weather and radar data from two Antarctic stations, SANAE and Syowa, are used to investigate a possible weather influence on the radar backscatter. Several possible reasons for the observed behaviour are investigated.

During certain times we receive backscatter patterns characterized by a distinct speckle pattern. Figure 1 shows such a day (9 Sep 1999). The figure shows the summary plot of the SHARE radar at SANAE, Antarctica. It is a usual summary plot, showing backscattered power (top panel), line- of-sight velocity (middle panel) and spectral width (bottom panel). From the plot it is evident that we do not receive any coherent backscatter, but rather randomly distributed backscatter of low power, high spectral width and apparently random line-of-sight Doppler velocity. Similar images are received by other stations, particularly stations in Antarctica.



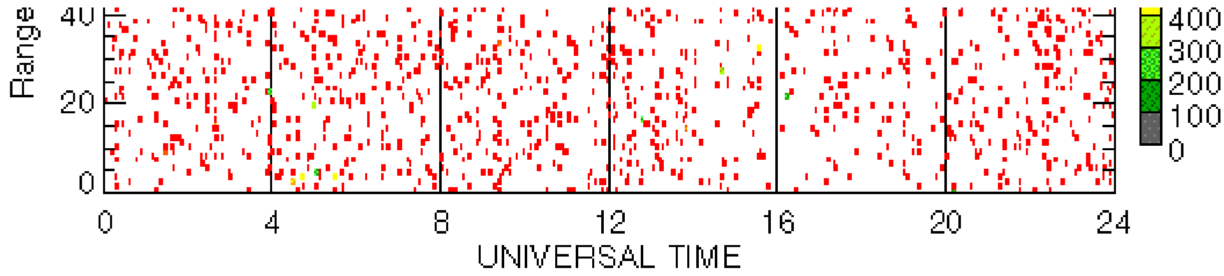


Figure 1 shows data during a severe storm at SANAE. Just a few days later the antenna array of the radar suffered severe damage due to high wind speeds. A similar speckle pattern was observed a few days before the radar antennae were damaged in 1997. This leads to the question whether high wind speeds can influence the backscatter pattern observed by the radar. Data from the SHARE radar at SANAE and from the Syowa East radar were assembled to address this question.

Generally both stations show this characteristic speckle pattern during periods of high wind speeds. However, usually the pattern is much clearer at SANAE. At Syowa the speckle pattern is generally much weaker and often overlaying the normal radar backscatter. In what follows I will discuss SHARE radar data only, the pattern being very much clearer than in the Syowa East data.

It turned out to be nearly impossible to find weather data for SANAE before January 2000 as there was no official weather station at SANAE until then. However, an unofficial weather station was placed at SANAE at the beginning of 1997 and operated during these years. It is a small station which cannot record wind speeds above 100 knots (about 180 km/h) as have occurred at SANAE at least twice in the past 3 years. Thanks to members of the current overwintering team I was lucky to receive data for 1997 and 1998 from various computers at the station which still store these data as they have not been archived in any reasonable manner. For 1999 the data have apparently been brought back to South Africa on a crashed hard drive. I have not been able to track these data down as yet.

Observations

Figure 2 shows a plot of wind speed against date for a period in June 1998. The abscissa is labelled in days of the month. Please note that the number indicates the end of the day labelled. The two horizontal lines are drawn at 60 km/h and 100 km/h. The vertical lines together with the indicated times show the periods when the wind speed exceeded 60 km/h. Figures 3a to 3f show the summary plots for the days when the wind speed exceeded 60 km/h. As can be seen very clearly, the periods of the speckle pattern correspond closely to the periods of high wind speeds. This is the case even when the wind speed is above 60 km/h for just a few hours, as particularly clearly demonstrated on 12 June 1998. In this case the wind speed is just a sharp peak rising above the 60 km/h mark.

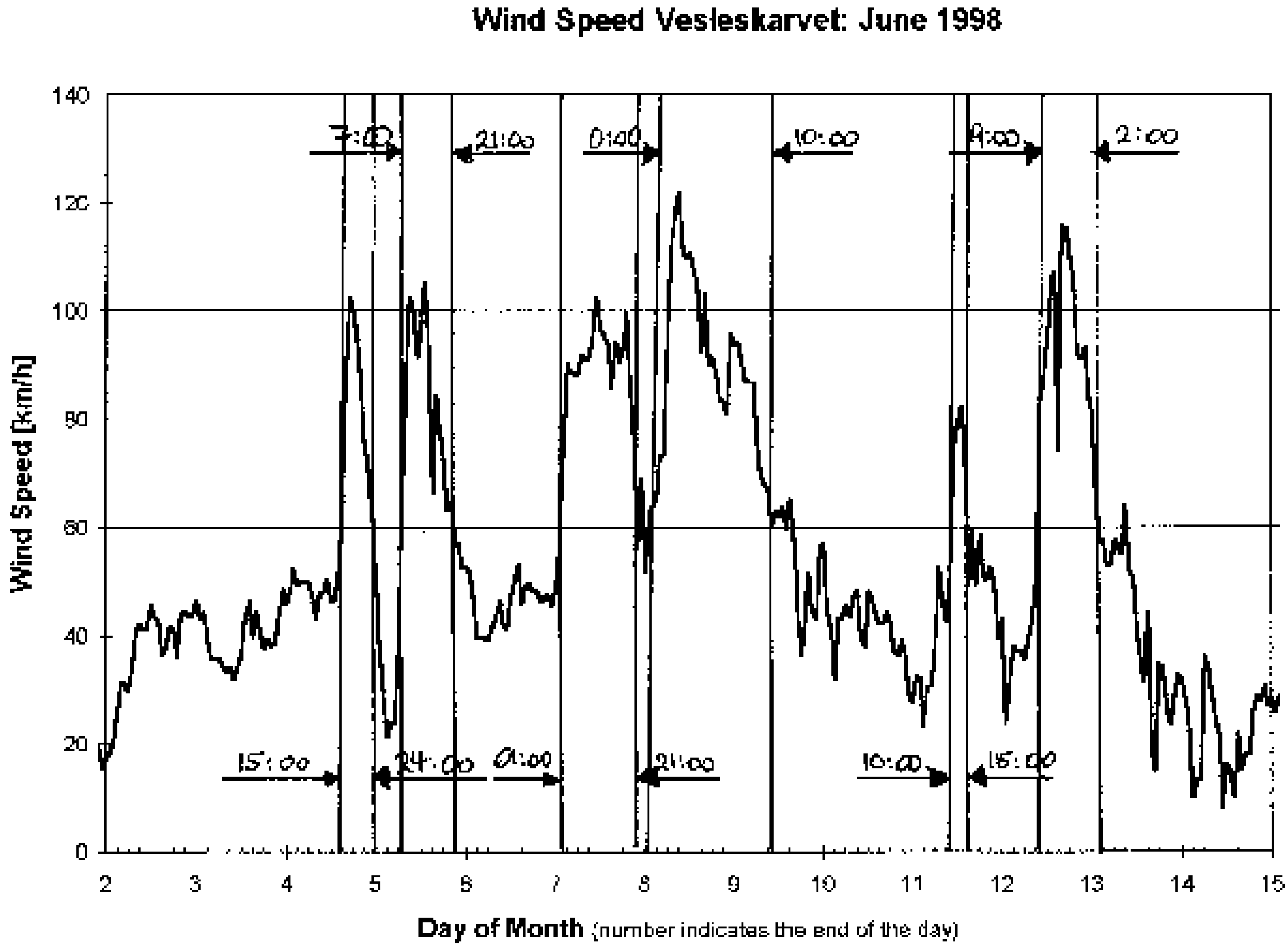


Figure 2: Wind speed versus day number for 3 to 15 June 1998. Please note that the day number refers to the end of the day. The two horizontal lines indicate wind speeds of 60 km/h and 100 km/h. The vertical lines indicate storms with wind speeds of more that 60 km/h.

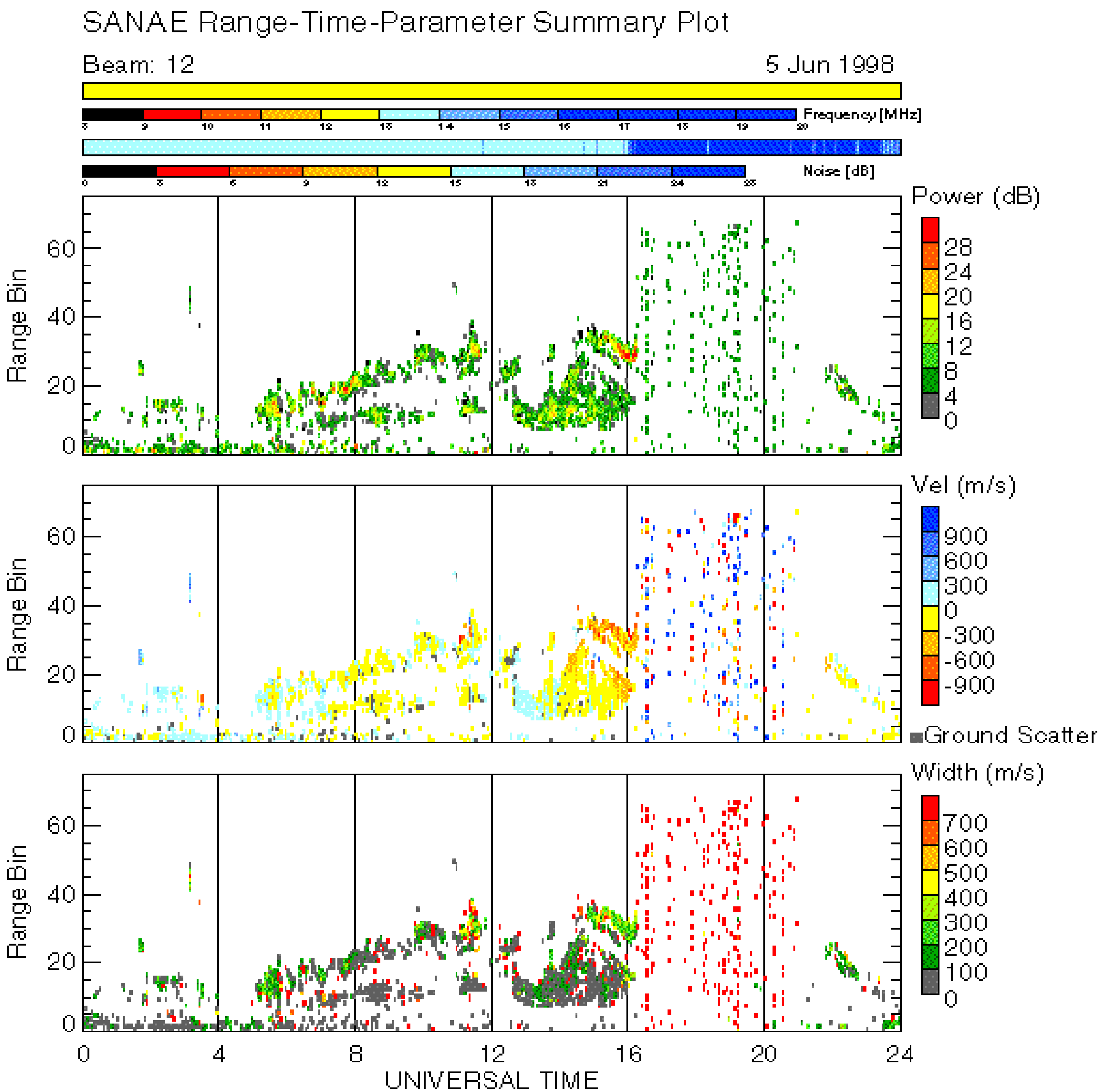
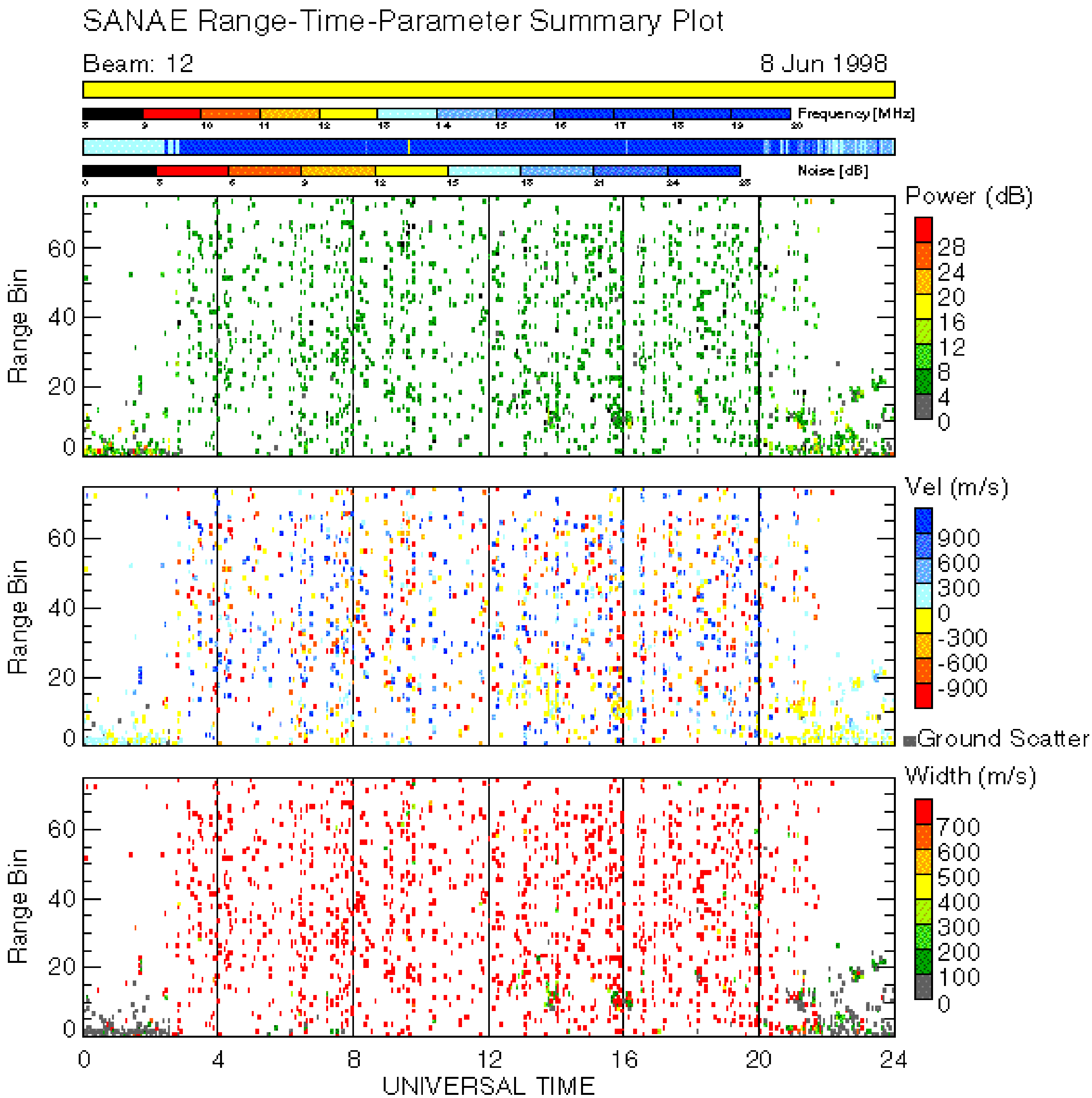
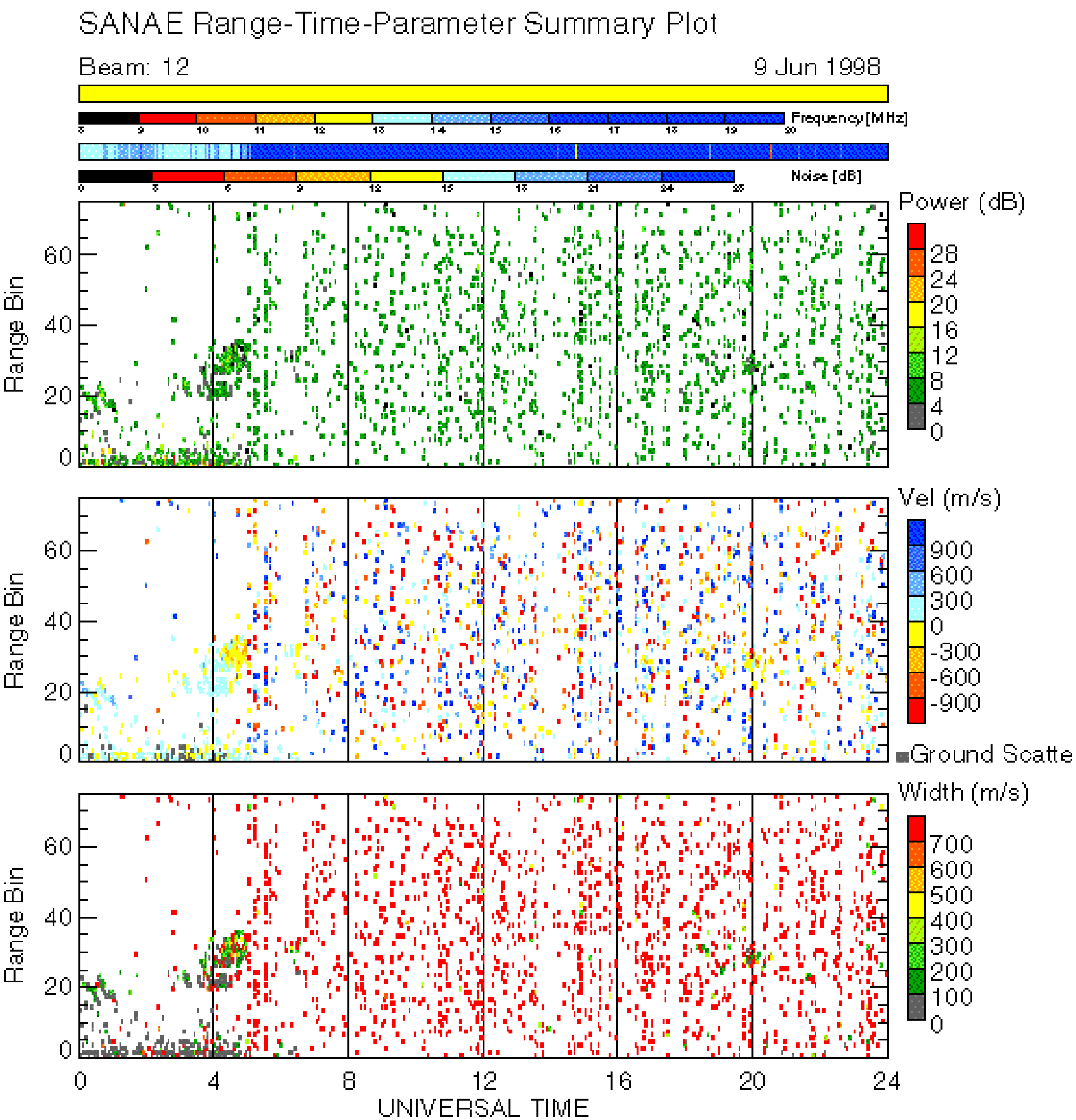
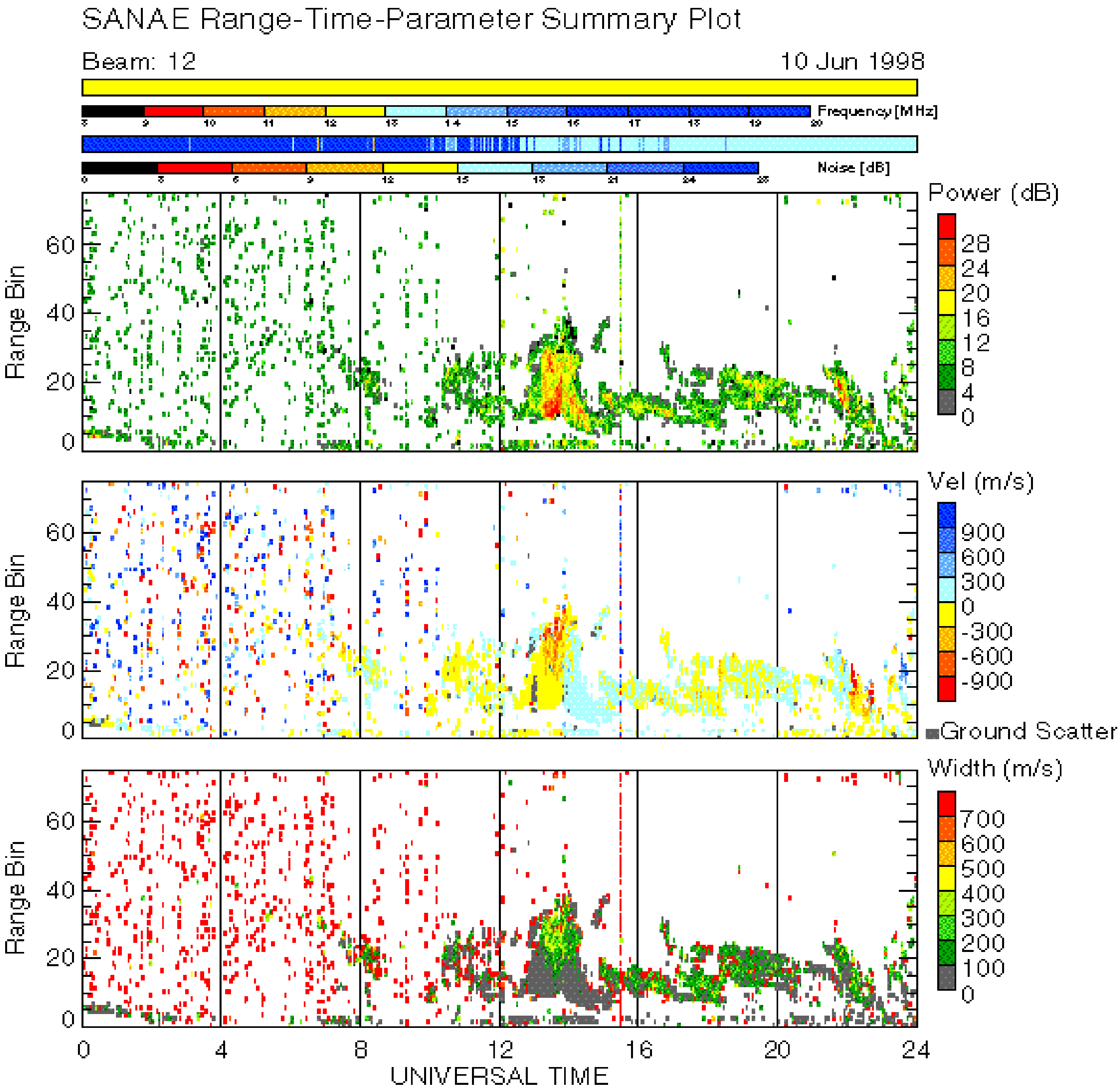


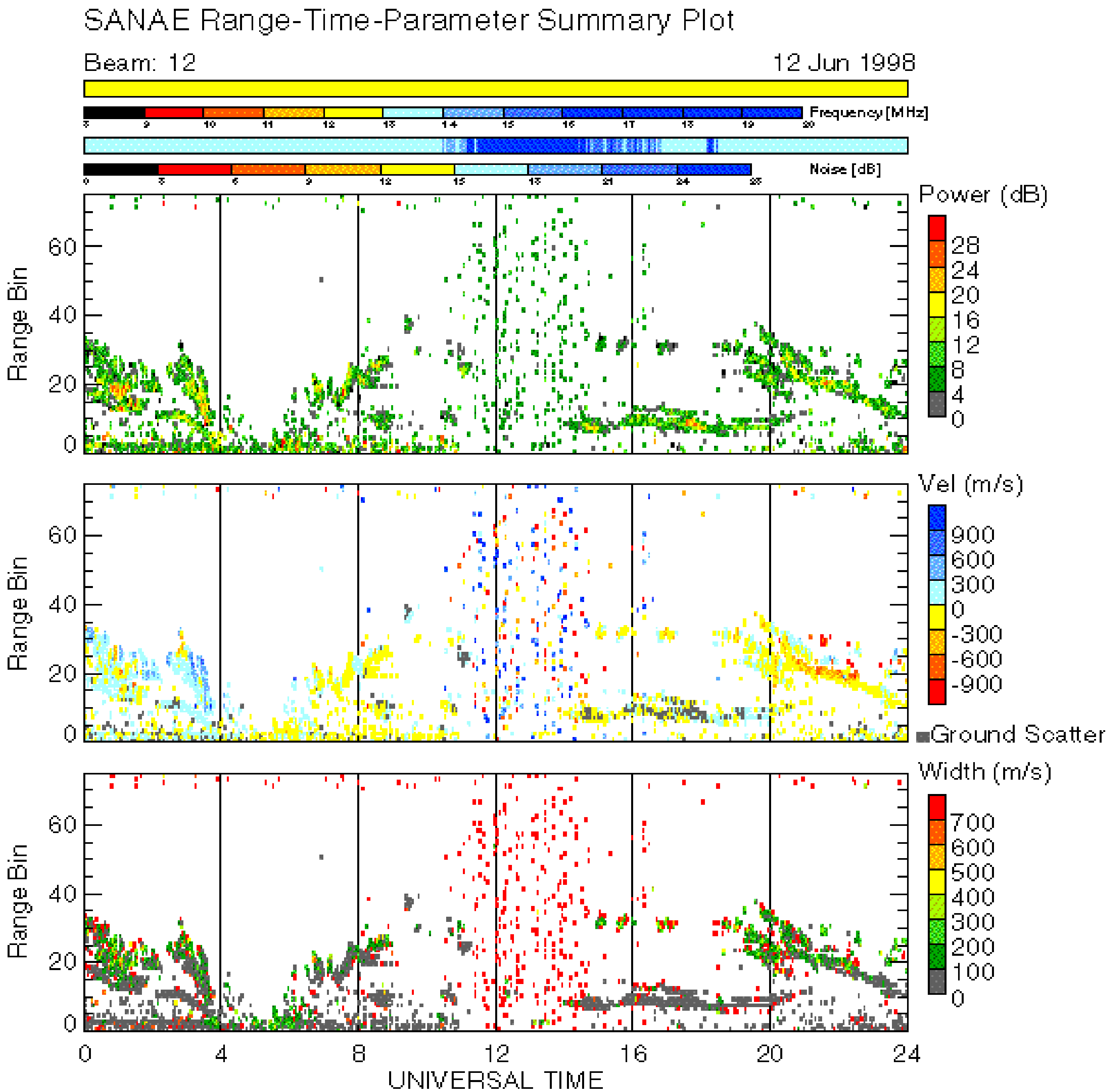
Figure 3a shows the summary plot from SANAE for 5 June 1998. The characteristic speckle pattern can be clearly seen, starting rather abruptly at about 16:00 UT. Please note from Figure 2 that wind speeds exceeded 60 km/h on 5 June between 15:00 UT and 24:00 UT. Also note that the rise in wind speed is rather abrupt, which is quite often the case. The summary plot for 6 June 1998 is rather similar, except that corresponding to the times of high winds, the speckle pattern is seen between 8:00 UT and 18:00 UT.

Figures 3b, 3c and 3d below show the summary plots from SANAE for 8, 9 and 10 June 1998, respectively. Here we can see, again coinciding with high wind speeds (see Figure 2), the characteristic speckle pattern on 8 June all day, even though between 20:00 UT and 24:00 UT the normal radar backscatter seems to grow out of the speckle pattern. This coincides with the dip in wind speeds clearly visible around midnight of 8 June. On 9 June early in the morning the normal radar backscatter pattern appears to be slowly drowned by the the speckle pattern, and most of the day shows it in accordance with the wind data, which indicate high wind speeds for most of the day. The wind drops to 60 km/h at about 10:00 UT on 10 June and subsides subsequently. The afternoon of 10 June shows normal radar backscatter.




SANAE Range-Time-Parameter Summary Plot
Beam: 12
9 Jun 1998
Frequency [MHz]
Noise [dB]
Power (dB)
28
24
20
16
12
8
4
0
Vel (m/s)
900
600
300
0
-300
-600
-900
Ground Scatter
Width (m/s)
700
600
500
400
300
200
100
0
Range Bin
0
20
40
60
UNIVERSAL TIME
0
4
8
12
16
20
24


SANAE Range-Time-Parameter Summary Plot
Beam: 12
10 Jun 1998
Frequency [MHz]
Noise [dB]
Power (dB)
28
24
20
16
12
8
4
0
Range Bin
60
40
20
0
Vel (m/s)
900
600
300
0
-300
-600
-900
Ground Scatter
Width (m/s)
700
600
500
400
300
200
100
0
0
4
8
12
16
20
24
UNIVERSAL TIME


SANAE Range-Time-Parameter Summary Plot
Beam: 12
12 Jun 1998
Frequency [MHz]
Noise [dB]
Power (dB)
28
24
20
16
12
8
4
0
Range Bin
Vel (m/s)
900
600
300
0
-300
-600
-900
Ground Scatter
Width (m/s)
700
600
500
400
300
200
100
0
UNIVERSAL TIME

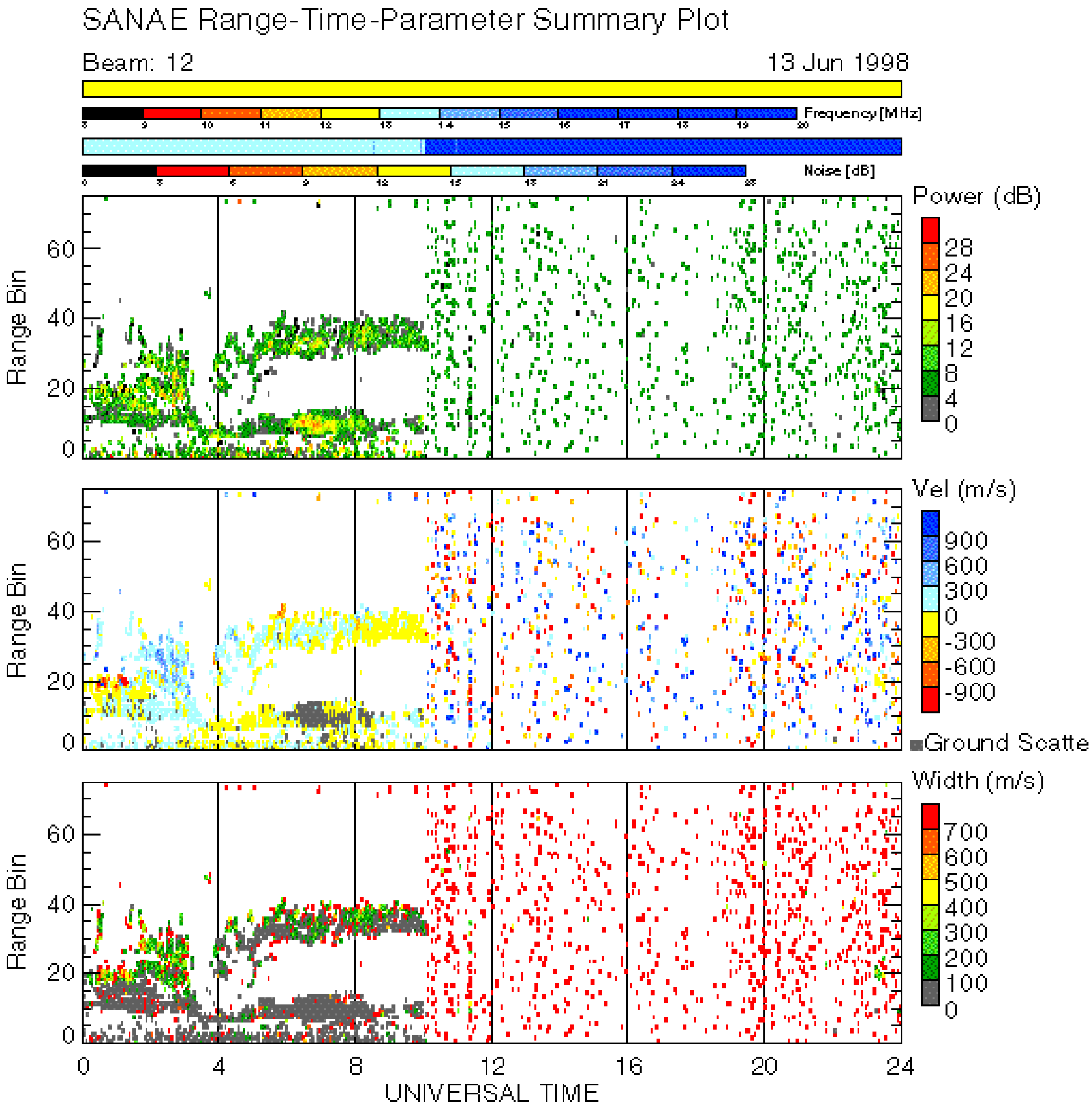


Figure 3e (plot second from bottom) shows the summary plot for 12 June 1998 clearly indicating the spike in wind speed between 10:00 UT and 15:00 UT by the characteristic speckle pattern. On 13 June (bottom) we see the effect of the extremely sharp rise in wind speed at 9:00 UT, effectively switching the speckle pattern on. All this seems to indicate that indeed high wind speed causes the speckle pattern.

However, during the severest storm in 1998, lasting from 18 July to 23 July 1998 (see Figure 4), another interesting feature can be seen. During the entire time from about 15:00 UT on 18 July to about 6:00 UT on 23 July the wind speed never dropped below 60 km/h, with it being above 80 km/h for most of the time, reaching a peak speed of near 160 km/h.

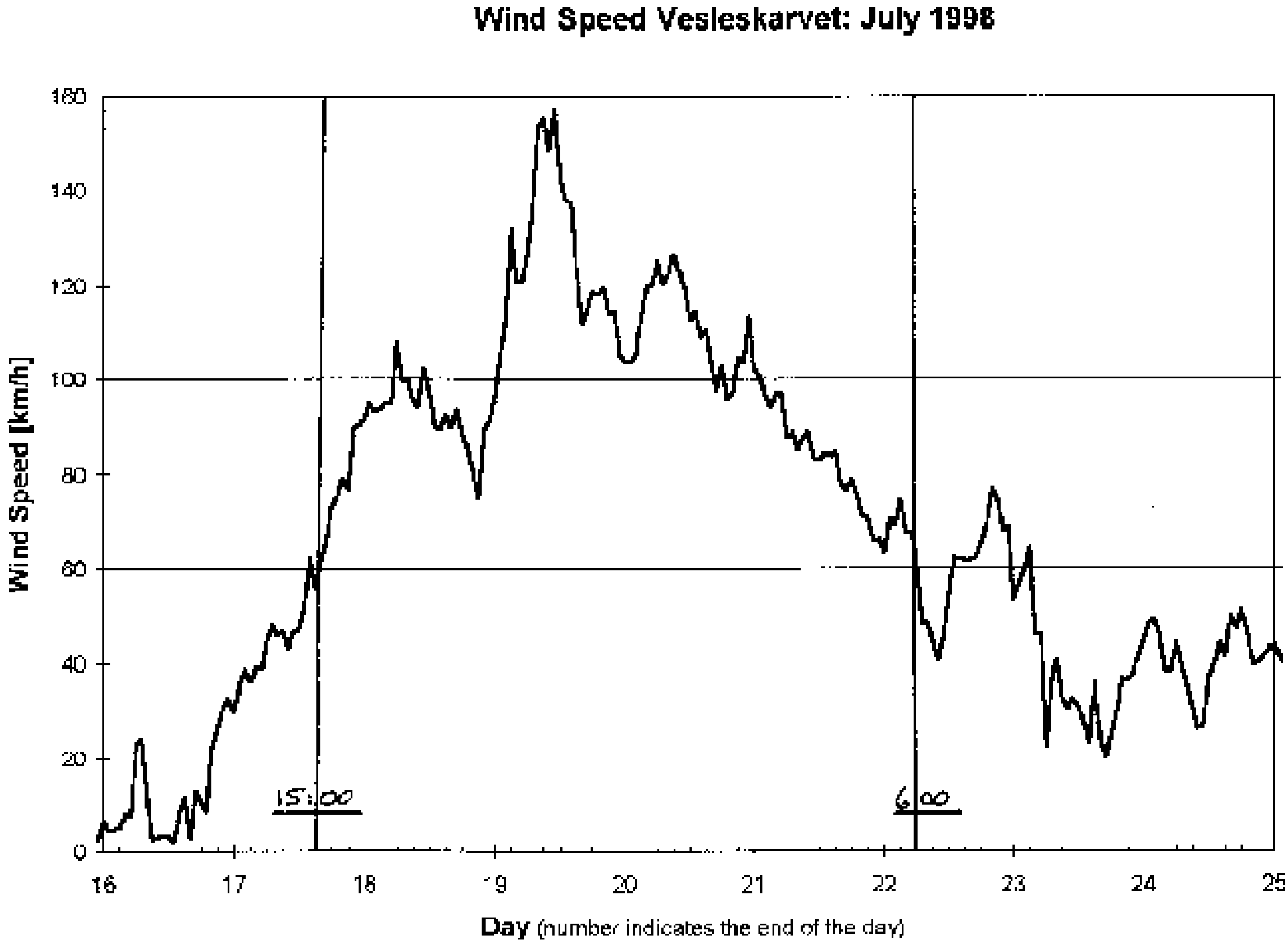
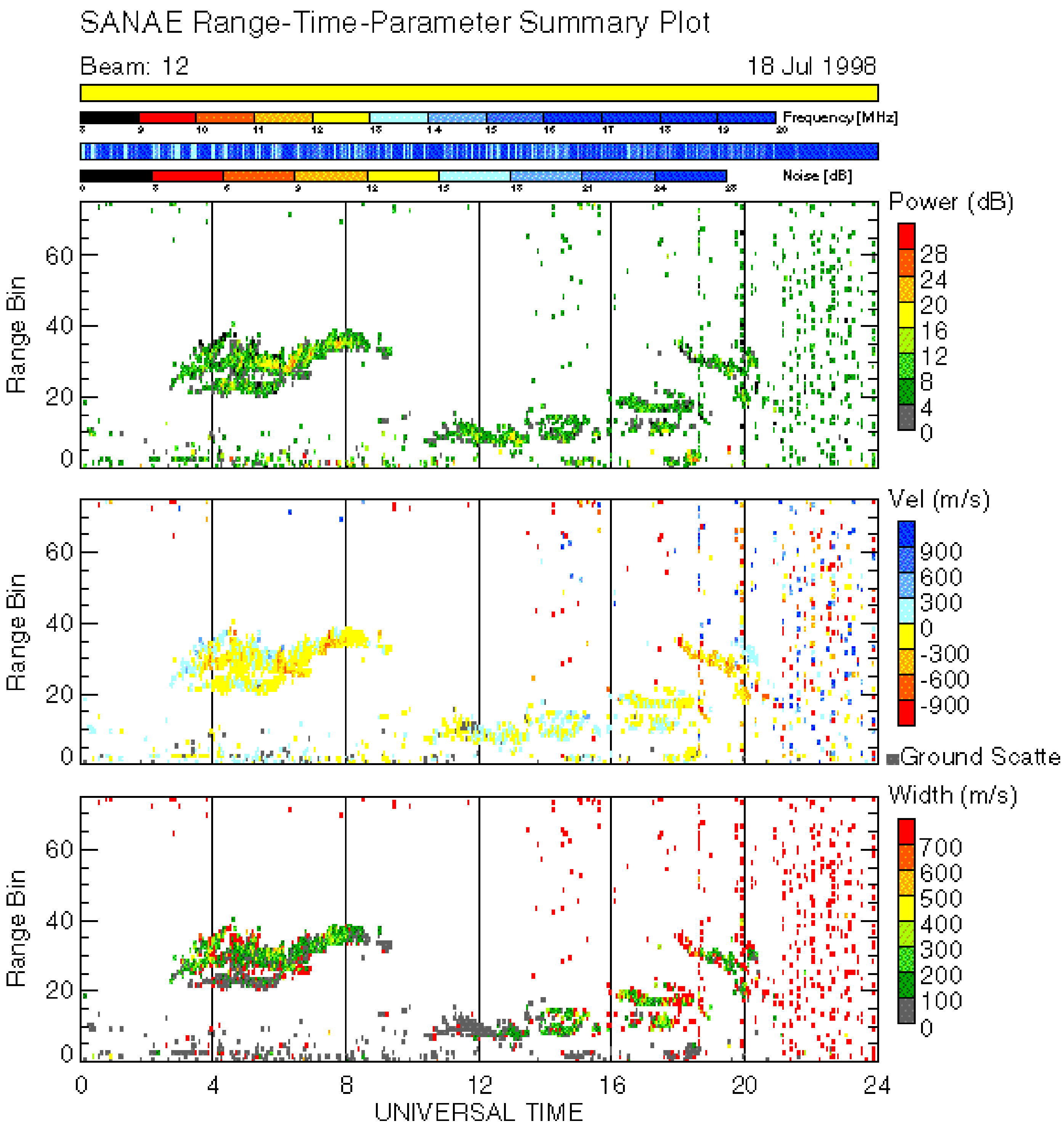
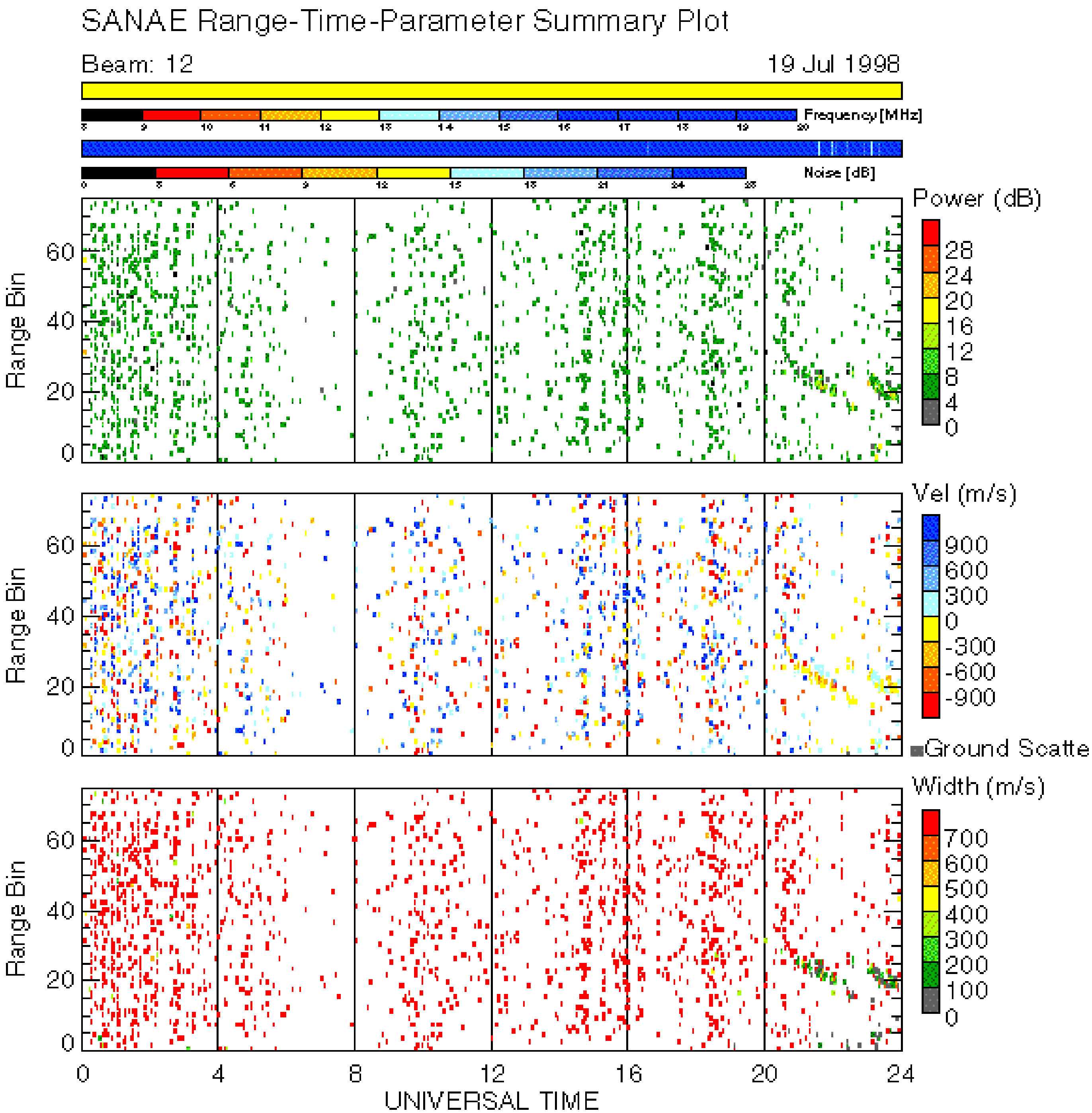
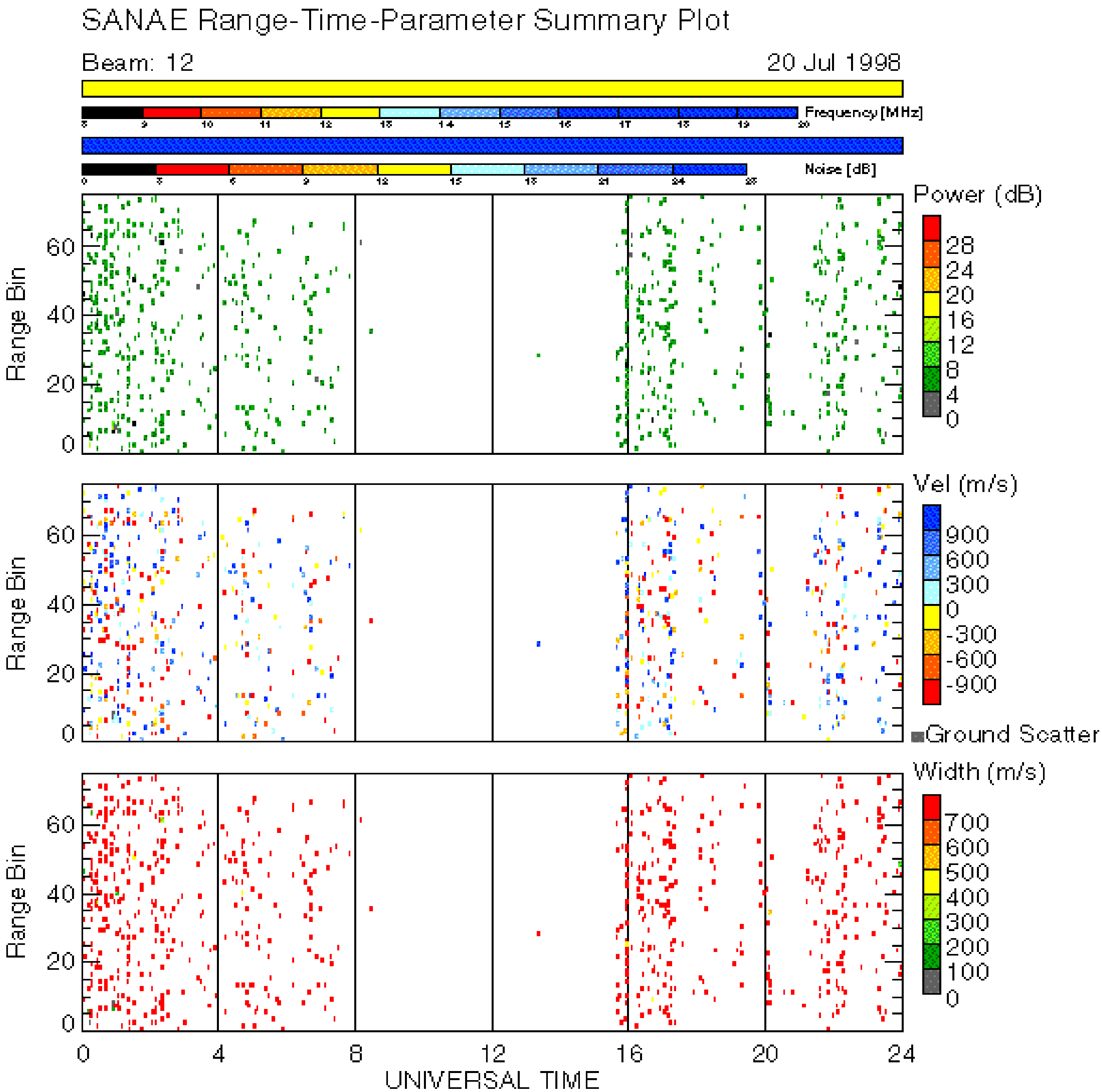


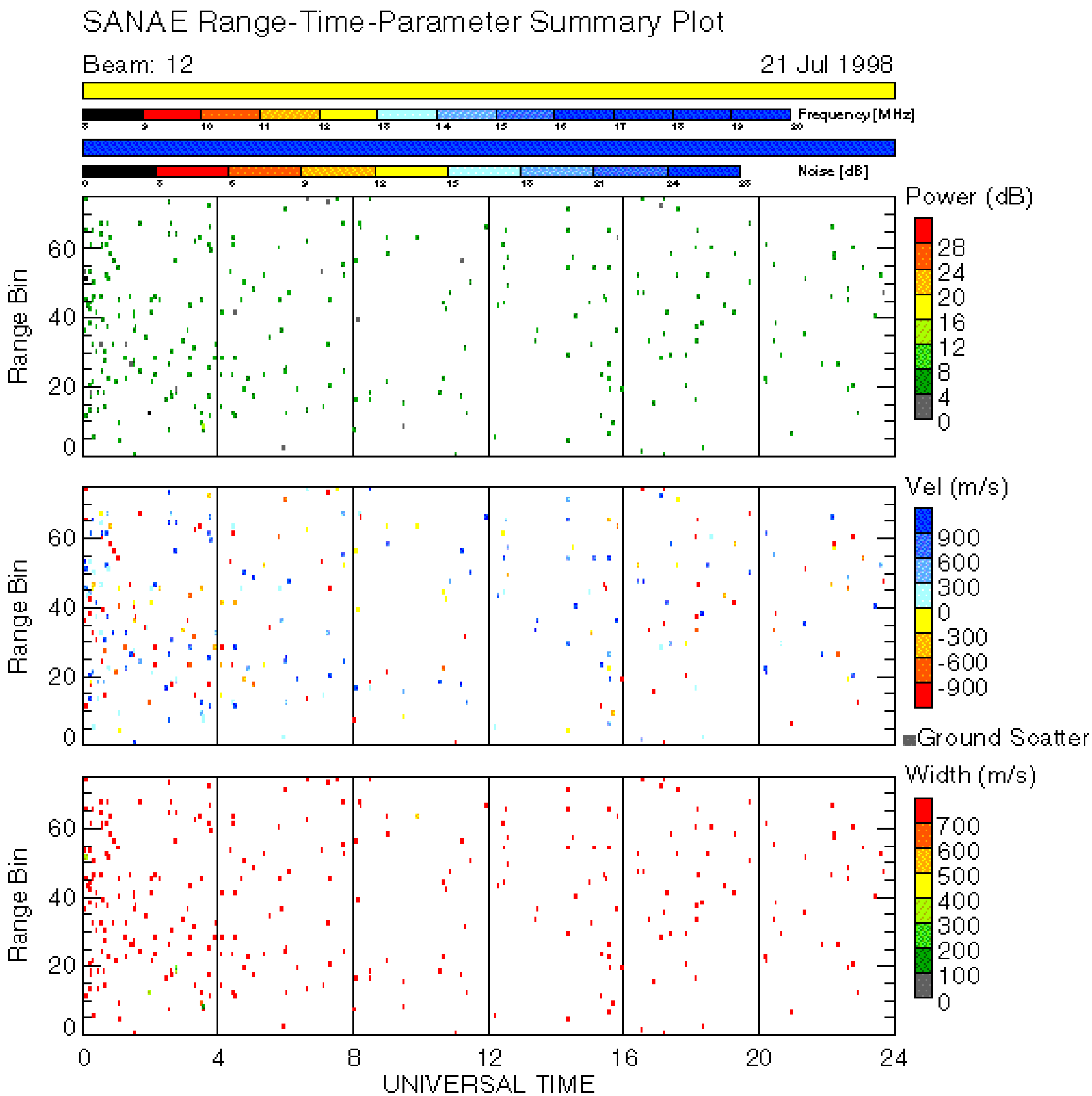
Figure 4: Wind speeds at SANAE for the period 17 to 25 July 1998. Day numbers indicate the end of the day. The two vertical lines indicate the beginning and end of the storm.

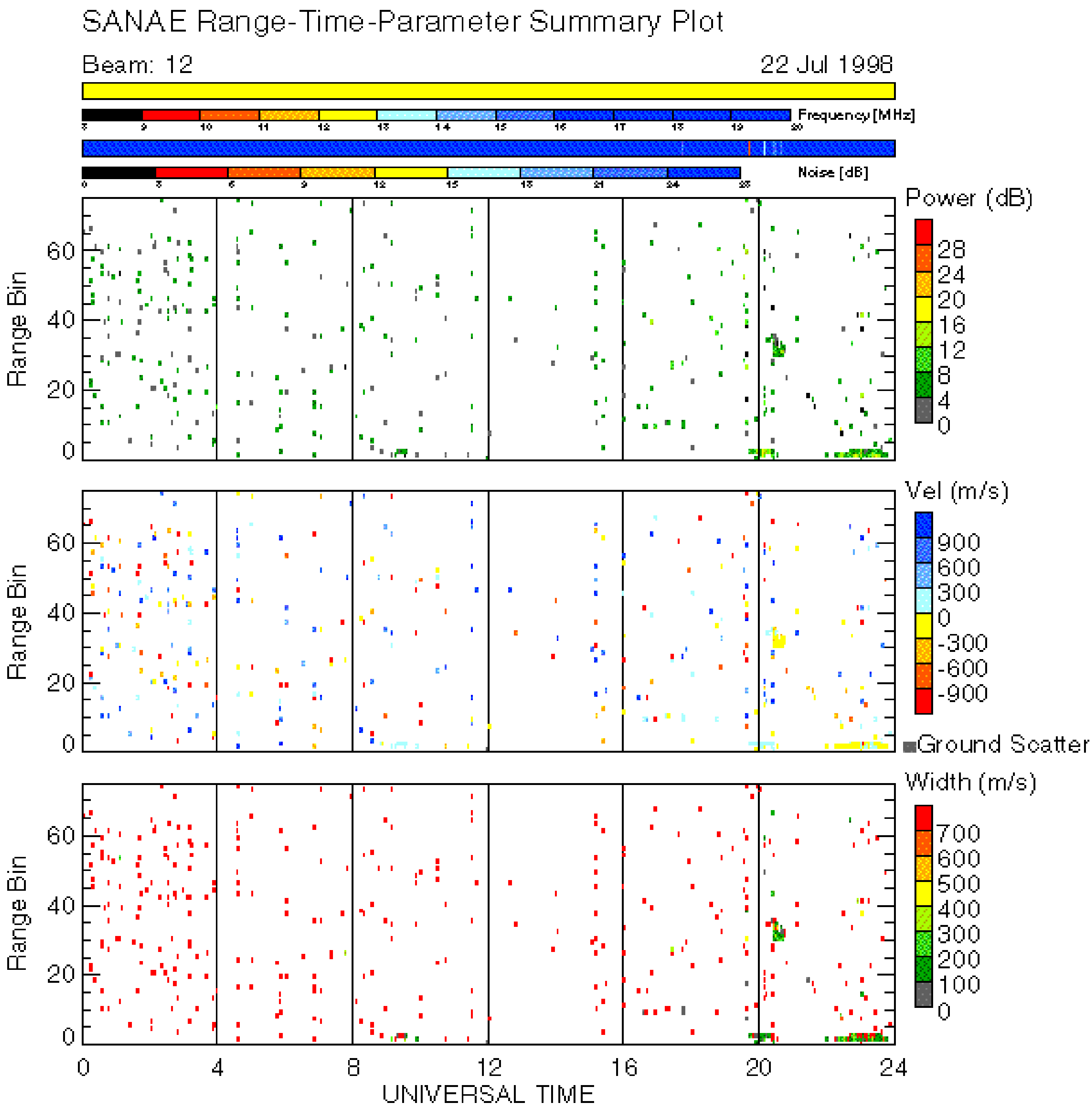
Figures 5a to 5f below show the summary plots for 18 to 23 July 1998, respectively. As can be seen the characteristic speckle pattern appears on 18 July around 14:00 UT to 16:00 UT and can be seen until 23 July in the morning. This was the heaviest storm during the year 1998.


SANAE Range-Time-Parameter Summary Plot
Beam: 12
18 Jul 1998
Frequency [MHz]
Noise [dB]
Power (dB)
Vel (m/s)
Ground Scatter
Width (m/s)
Range Bin
UNIVERSAL TIME


SANAE Range-Time-Parameter Summary Plot
Beam: 12
19 Jul 1998
Frequency [MHz]
Noise [dB]
Power (dB)
28
24
20
16
12
8
4
0
Vel (m/s)
900
600
300
0
-300
-600
-900
Ground Scatter
Width (m/s)
700
600
500
400
300
200
100
0
Range Bin
60
40
20
0
0
4
8
12
16
20
24
UNIVERSAL TIME


SANAE Range-Time-Parameter Summary Plot
Beam: 12
20 Jul 1998
Frequency [MHz]
Noise [dB]
Power (dB)
28
24
20
16
12
8
4
0
Vel (m/s)
900
600
300
0
-300
-600
-900
Ground Scatter
Width (m/s)
700
600
500
400
300
200
100
0
Range Bin
60
40
20
0
0
4
8
12
16
20
24
UNIVERSAL TIME


SANAE Range-Time-Parameter Summary Plot
Beam: 12
21 Jul 1998
Frequency [MHz]
Noise [dB]
Power (dB)
28
24
20
16
12
8
4
0
Vel (m/s)
900
600
300
0
-300
-600
-900
Ground Scatter
Width (m/s)
700
600
500
400
300
200
100
0
Range Bin
UNIVERSAL TIME
0
4
8
12
16
20
24


SANAE Range-Time-Parameter Summary Plot
Beam: 12
22 Jul 1998
Frequency [MHz]
Noise [dB]
Power (dB)
Vel (m/s)
Ground Scatter
Width (m/s)
Range Bin
UNIVERSAL TIME
0
4
8
12
16
20
24
28
20
16
12
8
900
600
300
-300
-600
-900
700
500
400
200
100

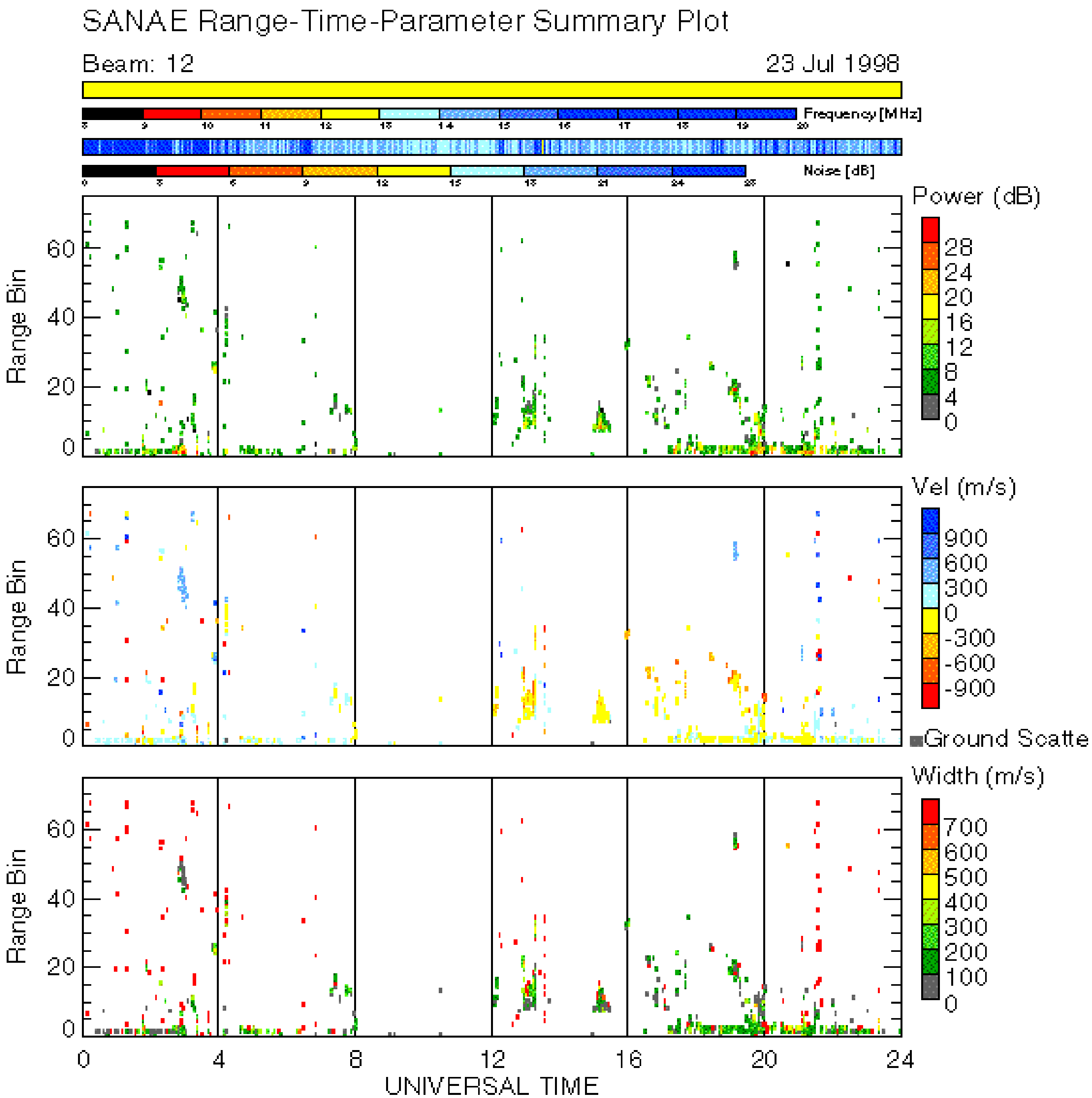


Figure 5a (upper) to 5f(lowest)

Two things are particularly noteworthy. Firstly, on 19 June (Fig. 5b) near midnight we can see the normal radar backscatter emerge from the speckle pattern, even though wind speeds at this time are well in excess of 70 km/h. The other observation is that on 20 June (Fig. 5c) between 8:00 UT and 16:00 UT hardly any backscatter has been received, even though the radar has been operational. This is the time of highest wind speeds (Figure 4), close on 160 km/h. Similarly on 21 and 22 July (Figs. 5d and 5e, respectively) the speckle pattern is rather weaker than on 18 and 19 July for no apparent reason, even though the wind speeds are comparable to the speeds on those earlier storm days.

Discussion

These observations can be summarized in the following way. Generally we see the characteristic speckle pattern when wind speeds are above 60 km/h. This is true for the radar at SANAE as well as for Syowa East. However, the pattern is much more pronounced at SANAE than for the Syowa East radar.

The speckle pattern is often observed for several days in a row. Therefore it appears highly unlikely that ionospheric conditions could be the cause for the speckle pattern. If the ionosphere were to be the cause it would have to be stable enough to support well defined conditions for several days in a row. And this stability would have to occur on quite a few occasions during each year.

Also, the characteristic pattern does not seem to become more pronounced with increasing wind speeds. In fact on at least some occasions the opposite appears to be true.

If the ionosphere is not responsible for the speckle pattern, there appear to be three possible reasons for the occurrence of this backscatter pattern. Firstly the pattern could reflect locally created static noise, which drowns the normal radar backscatter. Secondly we could receive backscatter from some randomly distributed scattering centres created by the high wind speeds. And lastly we could receive noise only, the atmosphere having become opaque to the radar signals. I would like to discuss these possibilities in reverse order.

An opaque atmosphere would certainly absorb the transmitted radar energy. However, I find it difficult to imagine a physical process caused by high wind speeds which would make the neutral atmosphere all of a sudden opaque to the frequencies of the SuperDARN radars. In addition, I find it extremely difficult to account for large amounts of noise under these conditions.

Randomly distributed scattering centres could create the pattern as we see it. They would scatter the radar energy in all directions, from all possible locations, and with randomly distributed line-of-sight velocities, with multiple scattering playing an important role. However, there are other problems with this solution. The first is the question of where these randomly distributed scattering centres would come from. While it is quite conceivable that locally the high wind speeds would create randomly distributed snow flakes, it is rather inconceivable that the same storm would create randomly distributed snow flakes at the other end of the radar range, about 3500 km away from the radar site.

Also, it appears rather difficult to imagine why snow flakes in high wind speeds are acting as scattering centres whereas snow flakes at low wind speeds generally do not. Snow flakes are electrically neutral and should not effect radar backscatter at all.

This leaves the third possibility, namely that we are seeing locally created static drowning the normal radar backscatter pattern. High wind speeds under dry conditions certainly create static on any surface. In fact it is possible to create static sparking of considerable length (up to 15 or 20 cm) from the windows of SANAE base during storm conditions with bare hands. The observed speckle pattern also would indicate this solution. We observe generally low backscatter power, high spectral width and random line-of-sight velocities.

In addition, the normal backscatter pattern does appear to melt into the speckle pattern, often appearing underneath it. This is especially true for the data from Syowa East. And as we have seen above (Figure 5) the speckle pattern does not become more pronounced with increasing wind speeds. Another indicator in this direction is the observation reported by Fanus Olivier, that the speckle pattern does occur only during "whiteout" conditions, ie. during conditions of wind and snow. High winds on their own do not appear to be causing the appearance of the speckle pattern, as can be argued for 20 July 1998, where we have very high wind speeds and practically no speckle pattern at all.

Lastly Mike Pinnock reports that the same pattern has be observed at Halley during large storms, but only when temperatures are very low for storm conditions. This indicates that at least Halley wind and snow do not create static as easily as at SANAE. It would also explain why the speckle pattern at SANAE is much more pronounced than at Syowa. Syowa is a coastal station like Halley and requires two conditions for good static, low temperatures and high winds. SANAE on the other hand is situated 200 km inland at an altitude of about 850 metres. Therefore the air is likely to be much drier at SANAE than at either Halley or Syowa favouring the creation of static noise. Temperature values for June 1998 from SANAE indicate that for most storm times temperatures were well above -20 degrees Celsius, which cannot by any means be called very cold.

Conclusions

In conclusion the characteristic speckle pattern seen as radar backscatter during times of high wind speeds at SANAE appear to be caused by drifting snow flakes hitting the antenna elements during these times. This explains why high wind speeds alone are not sufficient to cause the speckle pattern, and why the speckle pattern is more pronounced at the beginning of a long storm than at the end of it.

From comments of several colleagues, this "snow scatter" can be seen on almost all instruments which use antennae to receive their signals, from HF communications to radar antennae and riometers. It appears a common feature for all stations which combine drifting snow and high wind speeds with very dry conditions.

Acknowledgements

Thanks are due to:

M. Pinnock (priv. communication) for telling me about snow scatter which he observed at Halley and its probable explanation,

N. Sato from NIPR for supplying weather data from Syowa,

J. Wiid and M. Johannes of the SANAE 39 team for finding weather data for SANAE which officially do not exist, and

Fanus Olivier (priv. communication) for pointing out that whiteout conditions are necessary for the speckle pattern to be observed.

Erhard Mravlag, Space Physics Research Institute, University of Natal, Durban 4041, South Africa

Tel: +27 31 260 1280/2775 Fax: +27 31 261 6550 email: mravlag@scifs1.und.ac.za