Session I. NASA Flight Tests

Doppler Radar Results

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Doppler Radar Results

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Fourth Combined Manufacturers' & Technologists' Airborne Wind Shear Review Meeting 4-14,16-92

NASA Flight Tests
Airborne Doppler Radar Results

Presentation Outline

1. Summary of Radar Flight Data Collected

2. Video of Combined Aft Cockpit, Nose Camera, & Radar Hazard Displays

3. Comparison of Airborne Radar F-factor measurements with In Situ and TDWR F-factors for Some sample Events

4. Summary Wind Shear Detection Performance

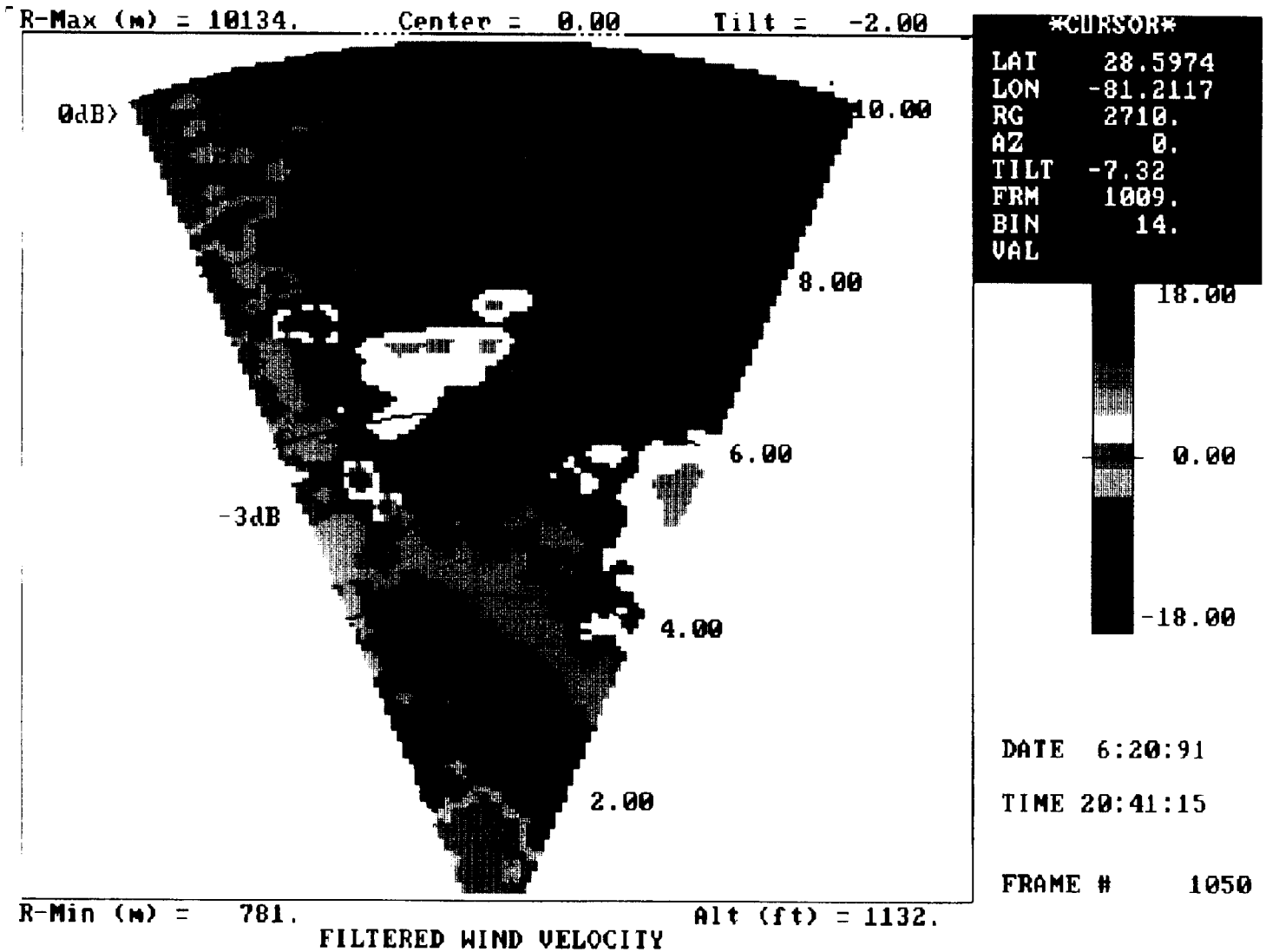
1991 RADAR FLIGHT DATA COLLECTED

FLIGHT TESTS	TOTAL DATA RUNS	CLUTTER RUNS	WEATHER RUNS	RAW I&Q DATA	PROCESSED RADAR DATA
LOCAL	147	105	10	1.85E+10	1.76E+09
PHILA	46	46	0	5.31E+09	5.06E+08
ORLANDO	124	15	109	1.41E+10	1.34E+09
DENVER	99	62	37	1.27E+10	1.21E+09
TOTAL	416	228	156	5.06E+10	4.82E+09

EVENTS SHOWN IN THE FOLLOWING RADAR AZIMUTH SCANS

ORLANDO, JUNE 20, 1991

DISPLAY NO	EVENT	ANTENNA TILT ANGLE, deg	PARAMETER DISPLAYED	AVERAGE F-FACTOR
1	142	-2	VELOCITY	
2	142	-2	F-FACTOR	.1
3	143	-2	VELOCITY	
4	143	-2	F-FACTOR	.16
5	144	-1	VELOCITY	
6	144	-1	F-FACTOR	.1
7	148	-3	F-FACTOR	.13
8	149	-1	F-FACTOR	.14
9	150	AUTO	F-FACTOR	.06
DENVER, JULY 10, 1991				
10	175	0	VELOCITY	
11	175	0	F-FACTOR	.11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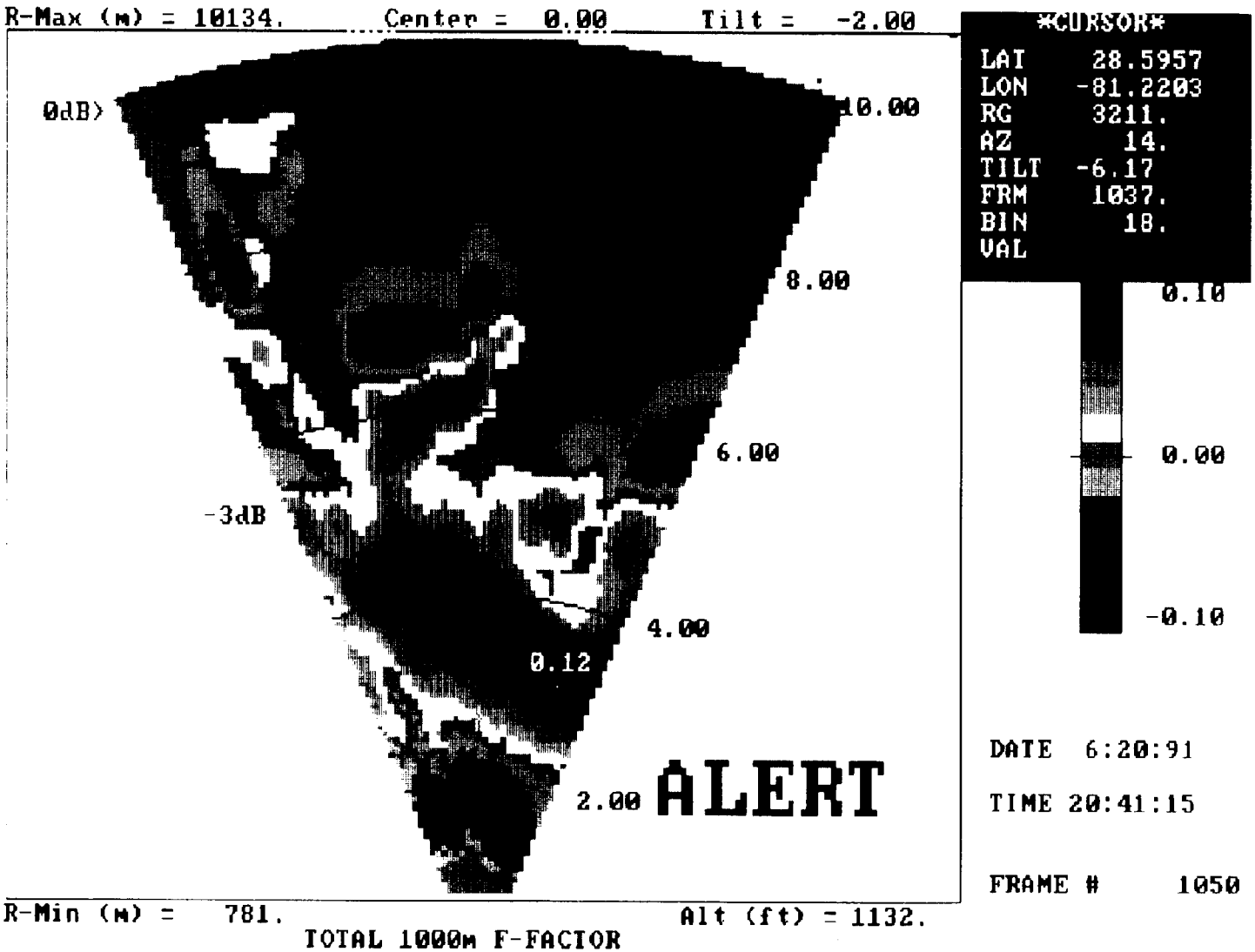
Center = 0.00
Tilt = -2.00
0dB
10.00
8.00
6.00
-3dB
4.00
2.00
R-Min (m) = 781.
Alt (ft) = 1132.
FILTERED WIND VELOCITY
CURSOR
LAT 28.5974
LON -81.2117
RG 2710.
AZ 0.
TILT -7.32
FRM 1009.
BIN 14.
VAL
18.00
0.00
-18.00
DATE 6:20:91
TIME 20:41:15
FRAME # 1050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Center = 0.00
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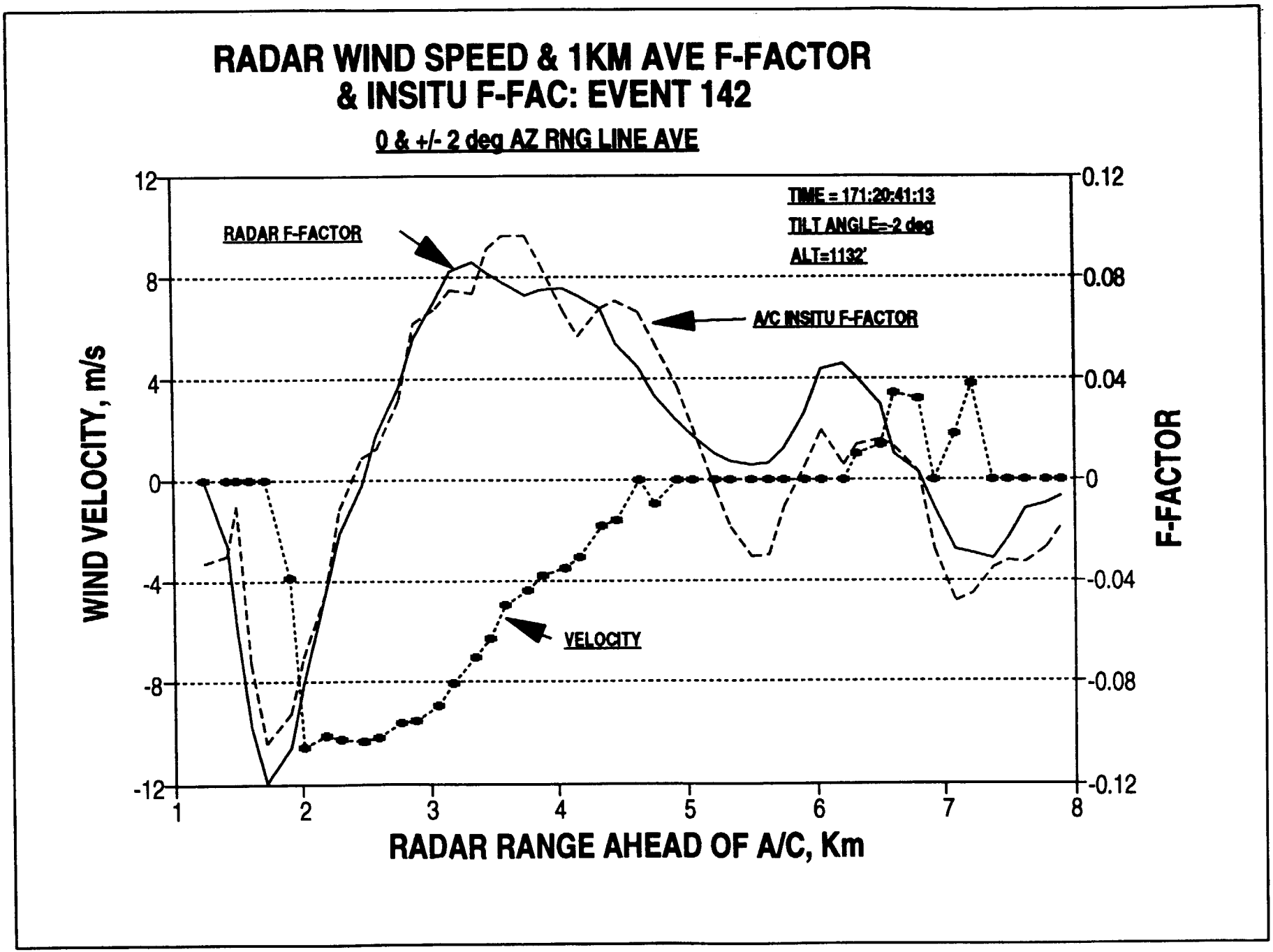
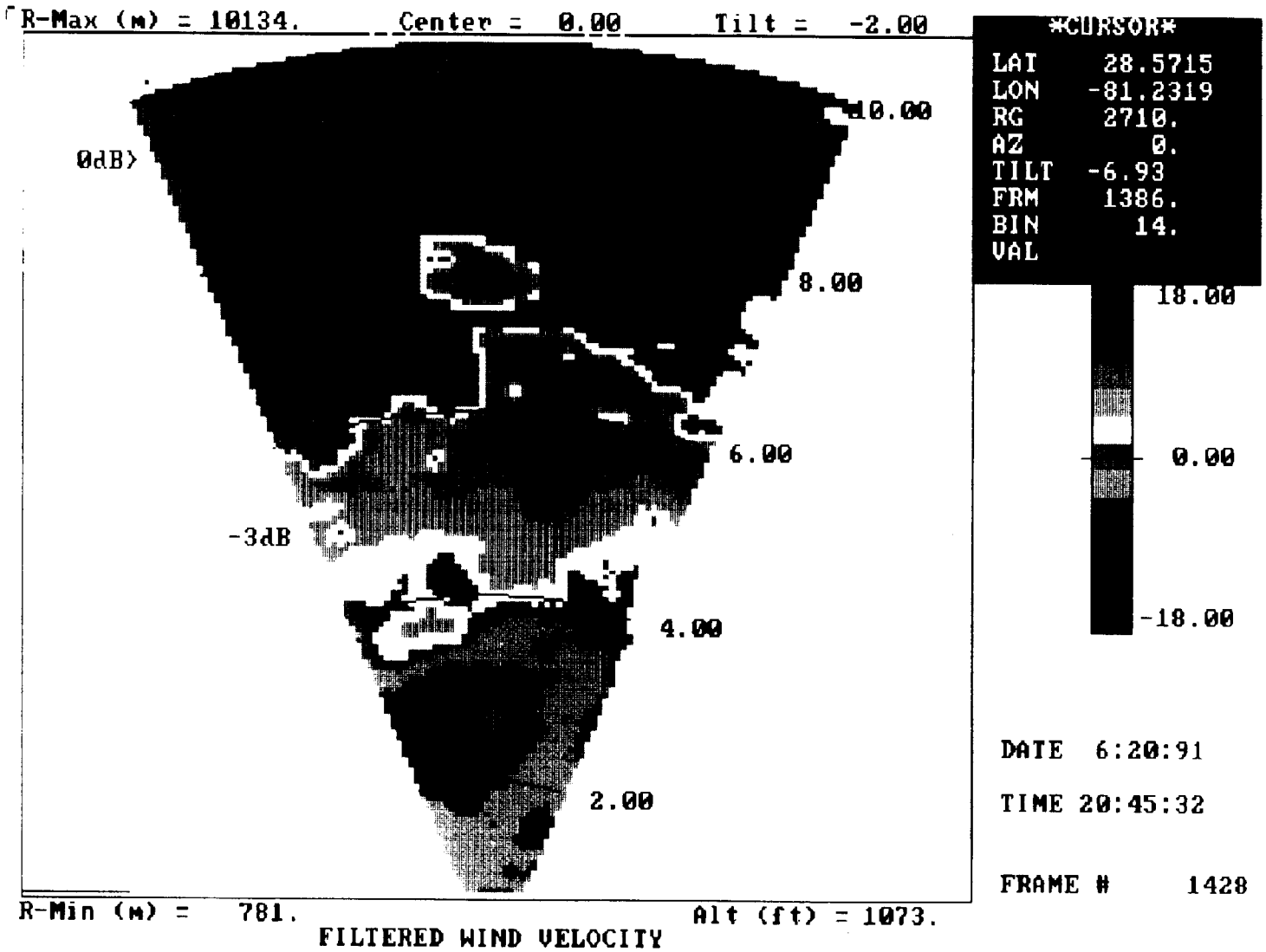
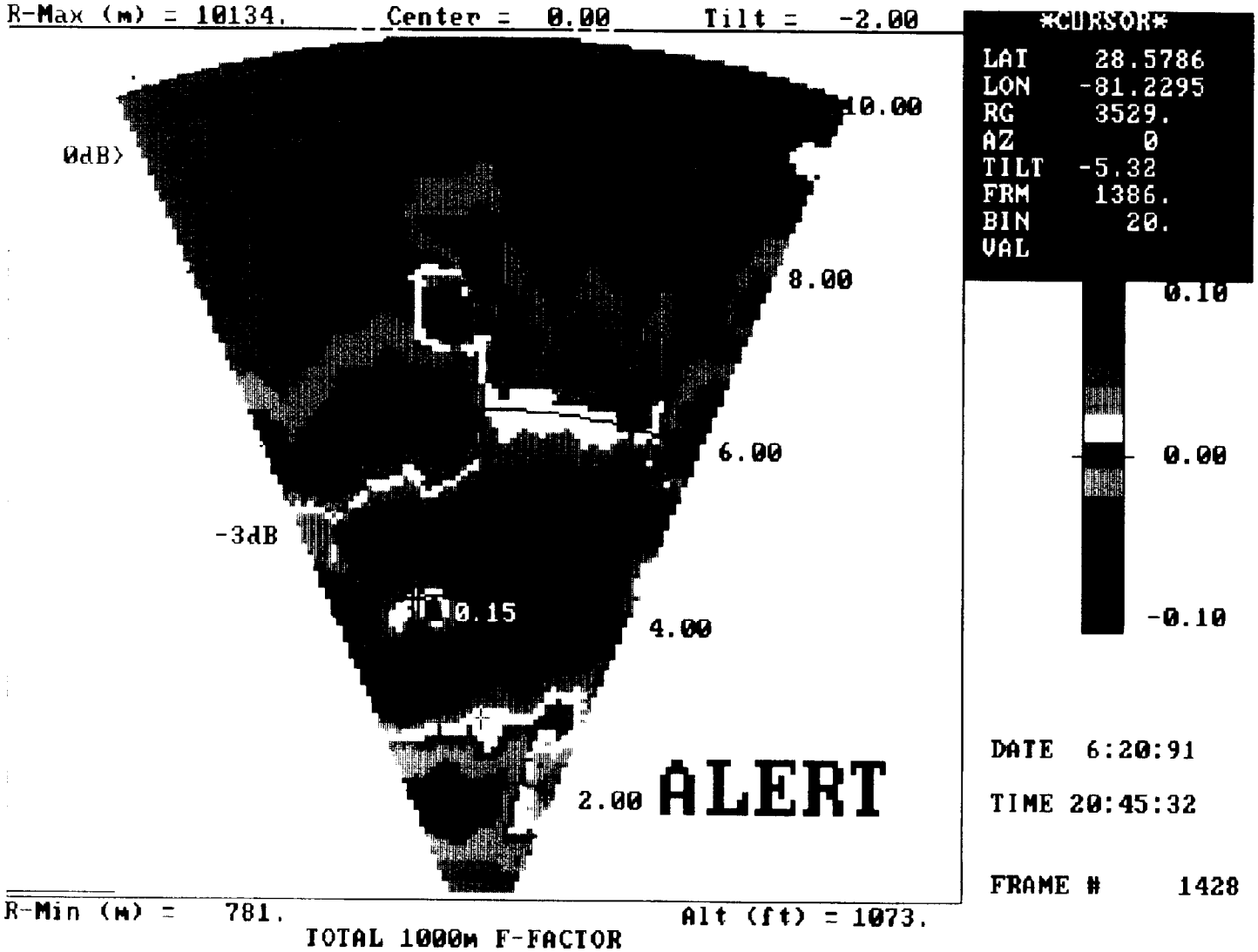
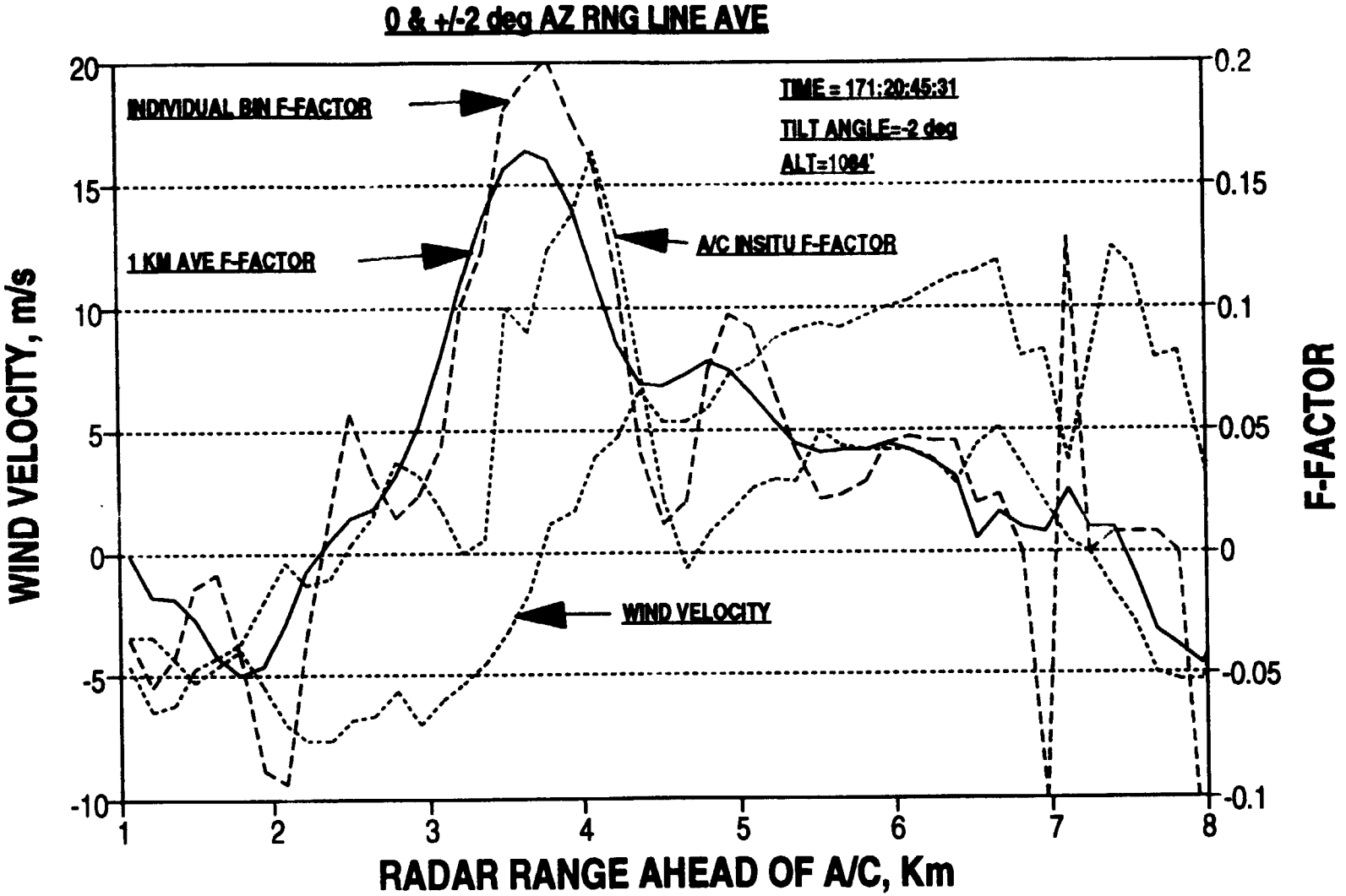
0dB
10.00
8.00
6.00
-3dB
4.00
0.12
2.00
ALERT
R-Min (M) = 781.
Alt (ft) = 1132.
TOTAL 1000M F-FACTOR
CURSOR
LAT 28.5957
LON -81.2203
RG 3211.
AZ 14.
TILT -6.17
FRM 1037.
BIN 18.
VAL
0.10
0.00
-0.10
DATE 6:20:91
TIME 20:41:15
FRAME # 1050

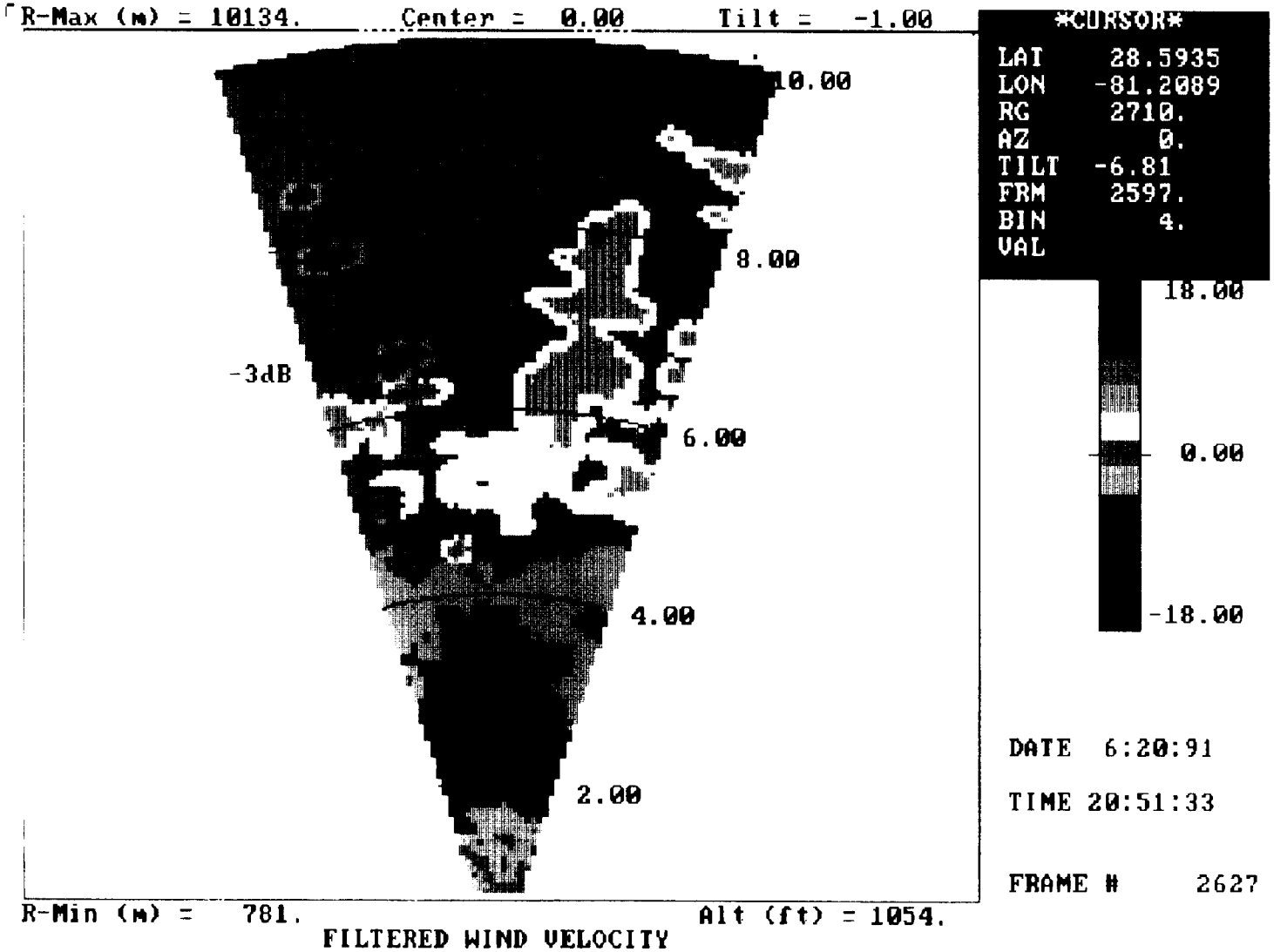

RADAR WIND SPEED & 1KM AVE F-FACTOR
& INSITU F-FAC: EVENT 142
0 & +/- 2 deg AZ RNG LINE AVE
TIME = 171:20:41:13
TILT ANGLE=-2 deg
ALT=1132'
RADAR F-FACTOR
A/C INSITU F-FACTOR
VELOCITY
WIND VELOCITY, m/s
F-FACTOR
RADAR RANGE AHEAD OF A/C, Km
12
8
4
0
-4
-8
-12
0.12
0.08
0.04
0
-0.04
-0.08
-0.12
1
2
3
4
5
6
7
8

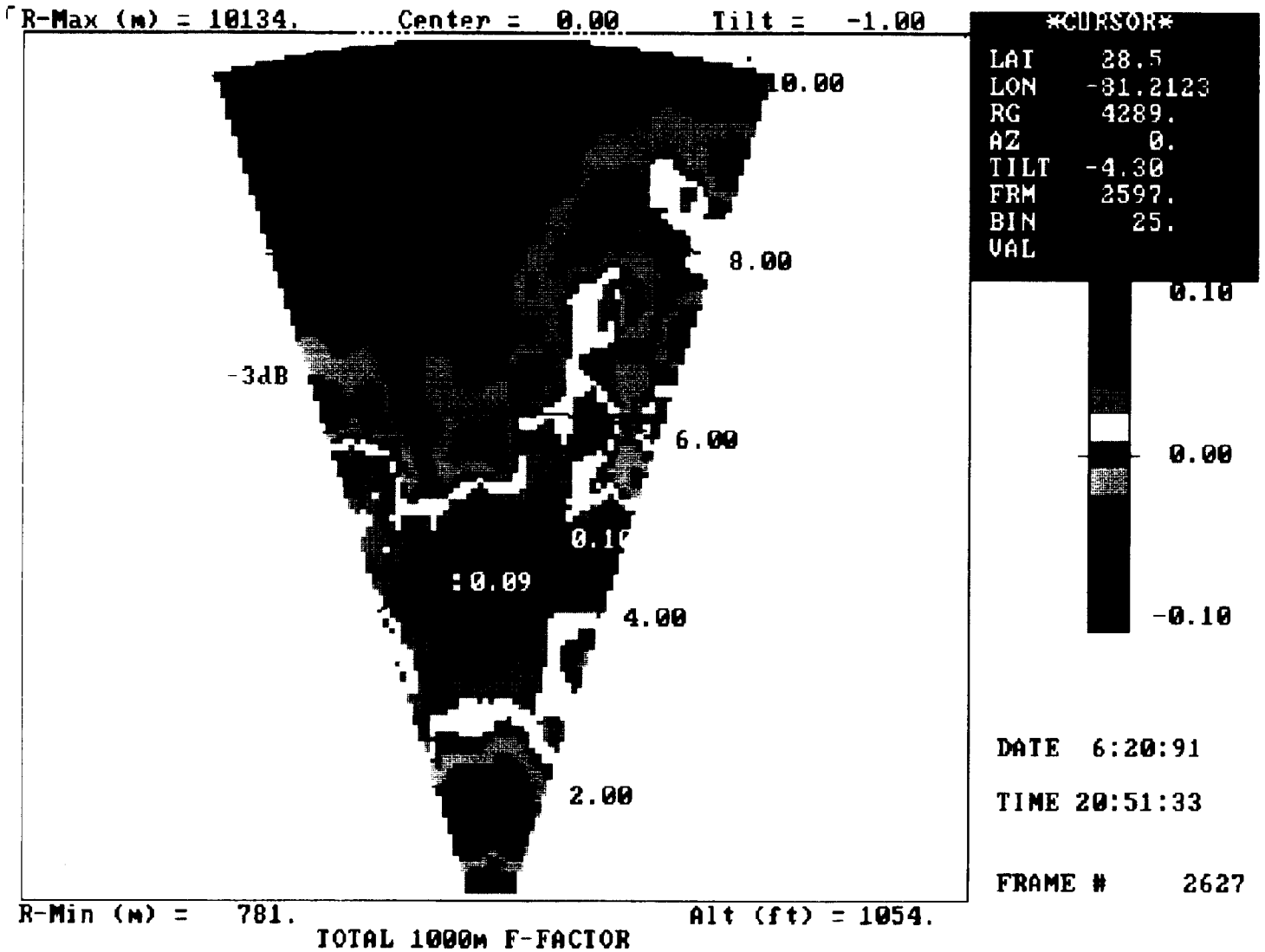



R-Max (M) = 10134.
Center = 0.00
Tilt = -2.00
CURSOR
LAT 28.5786
LON -81.2295
RG 3529.
AZ 0
TILT -5.32
FRM 1386.
BIN 20.
VAL
0dB
-3dB
10.00
8.00
6.00
4.00
2.00
0.15
0.10
0.00
-0.10
ALERT
DATE 6:20:91
TIME 20:45:32
FRAME # 1428
R-Min (M) = 781.
Alt (ft) = 1073.
TOTAL 1000M F-FACTOR

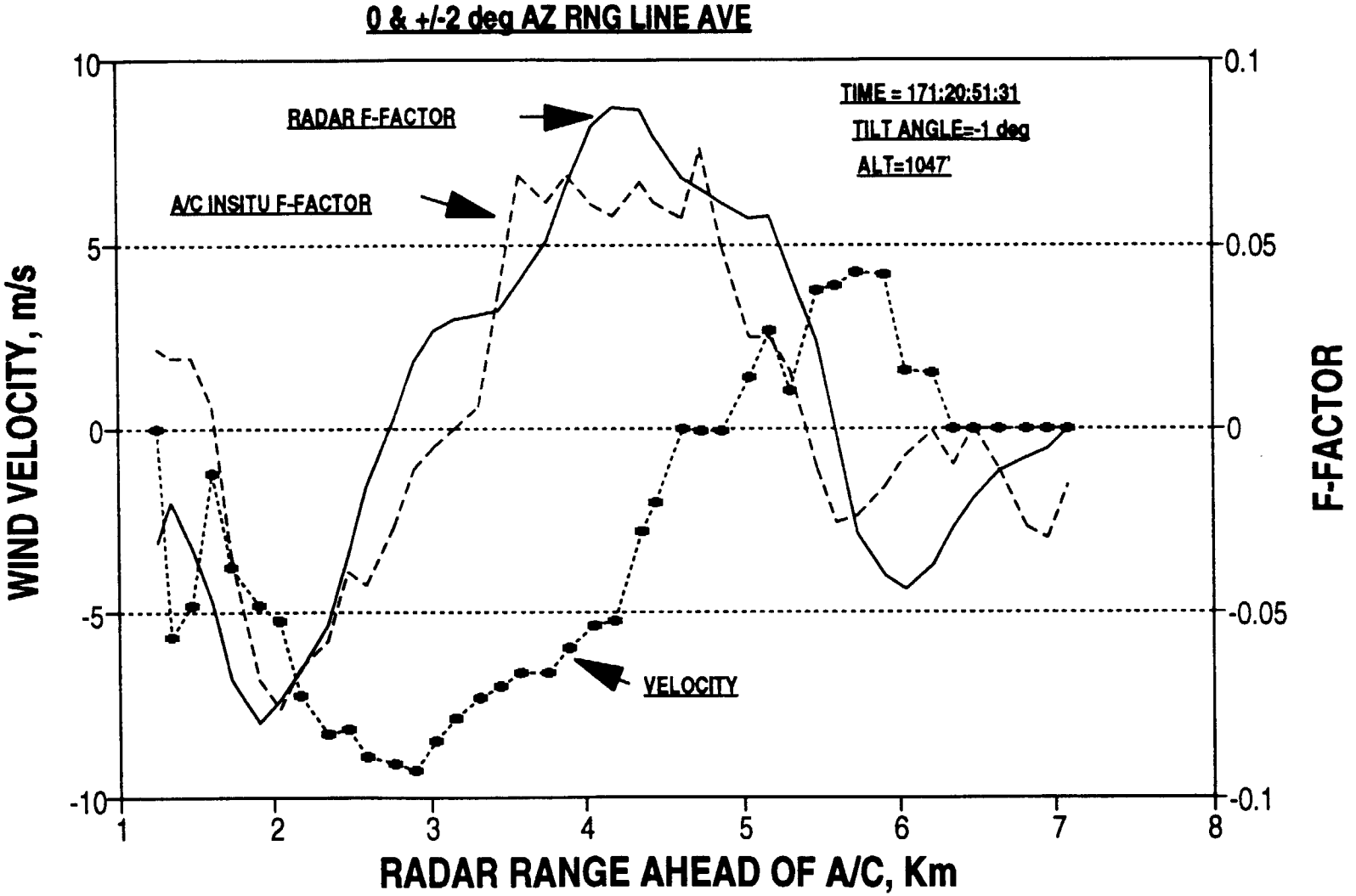
RADAR MEASURED WIND SPEED & F-FACTORS & A/C INSITU F-FACTOR: EVENT 143

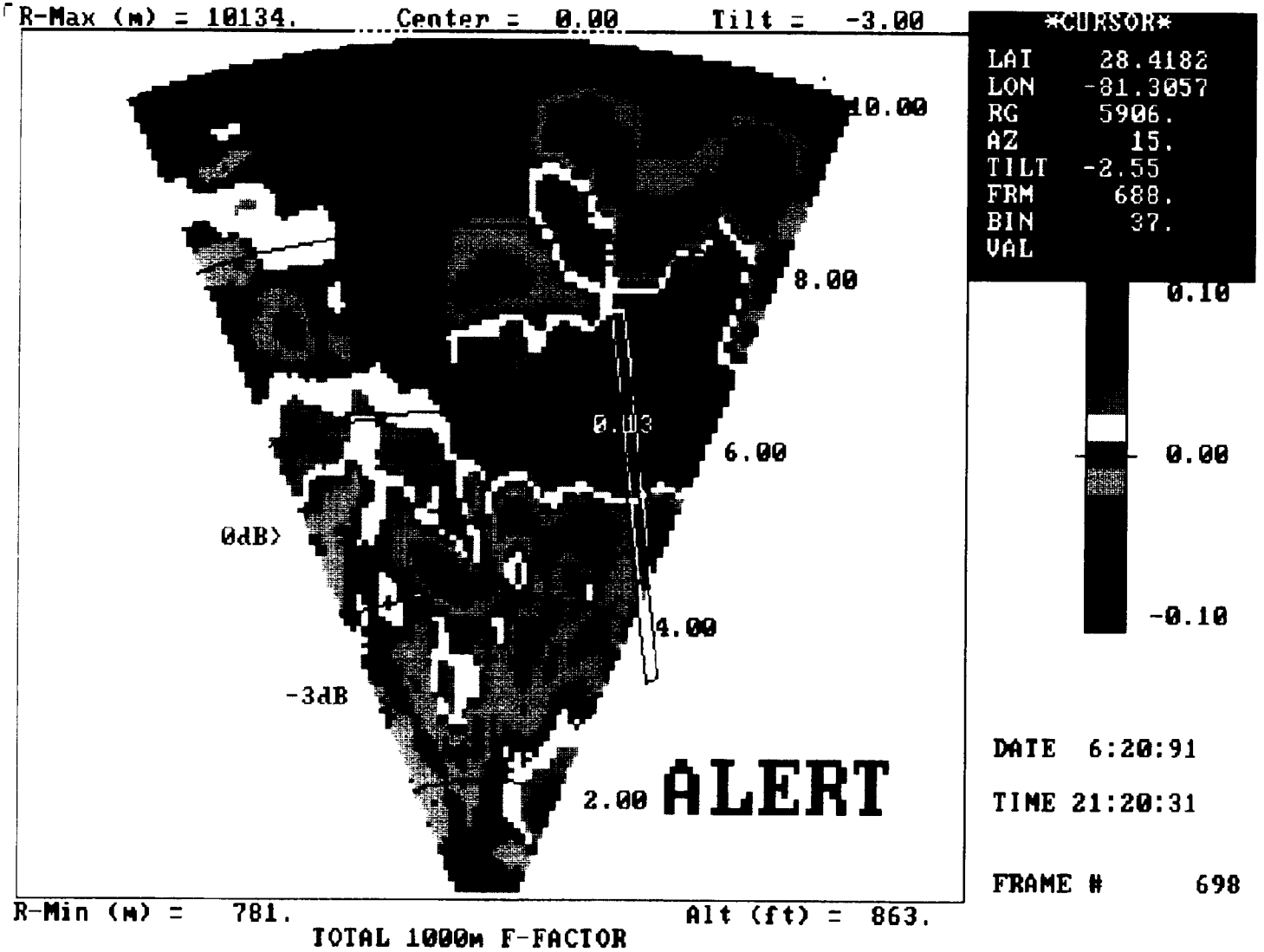


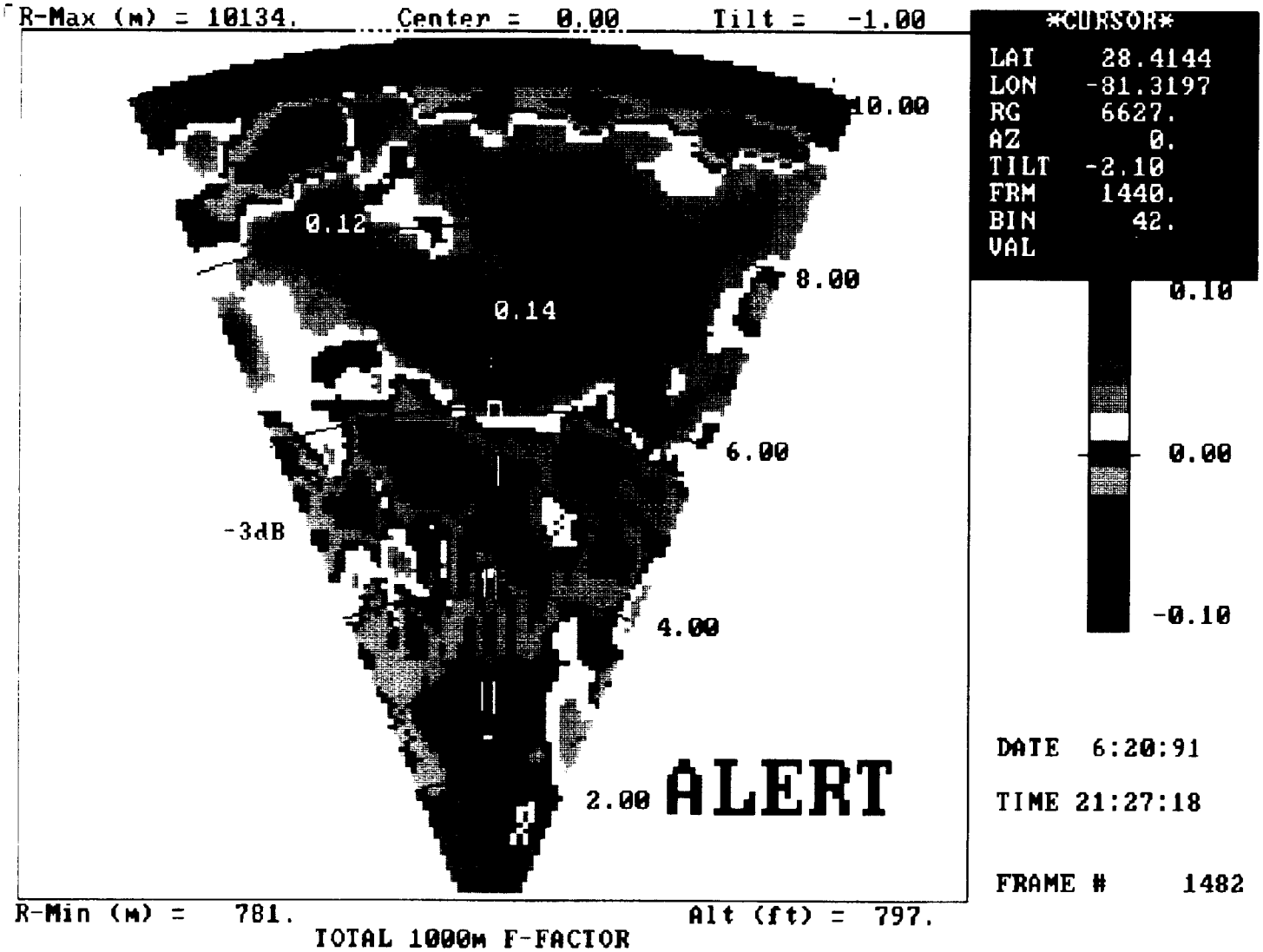


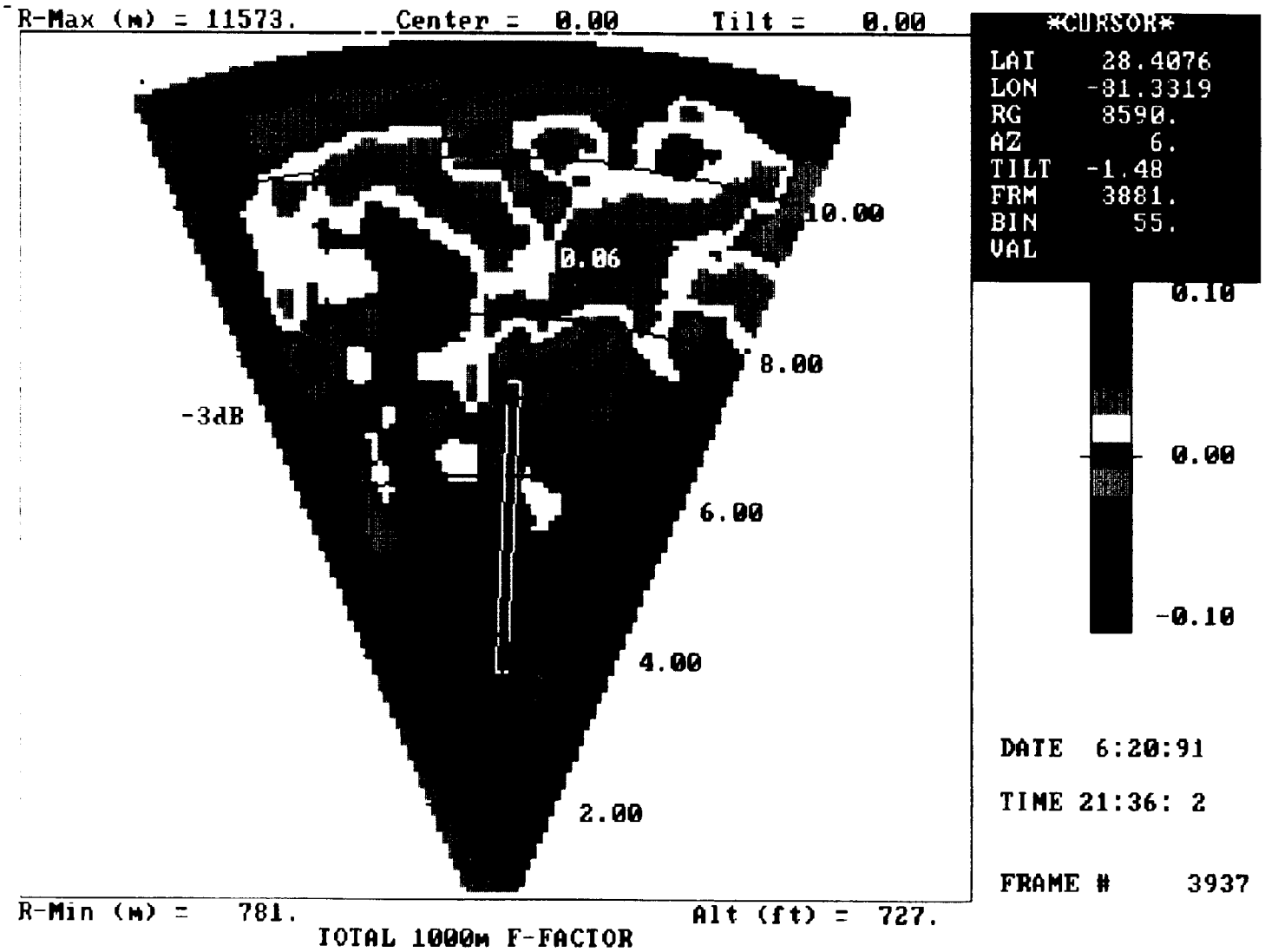

R-Max (m) = 10134.
Center = 0.00
Tilt = -1.00
10.00
8.00
-3dB
6.00
0.1
:0.09
4.00
2.00
R-Min (m) = 781.
Alt (ft) = 1054.
TOTAL 1000m F-FACTOR
CURSOR
LAI 28.5
LON -81.2123
RG 4289.
AZ 0.
TILT -4.30
FRM 2597.
BIN 25.
VAL
0.10
0.00
-0.10
DATE 6:20:91
TIME 20:51:33
FRAME # 2627

RADAR WIND SPEED & 1KM ALONG RNG AVE F-FAC, & A/C INSITU F-FAC: EVENT 144

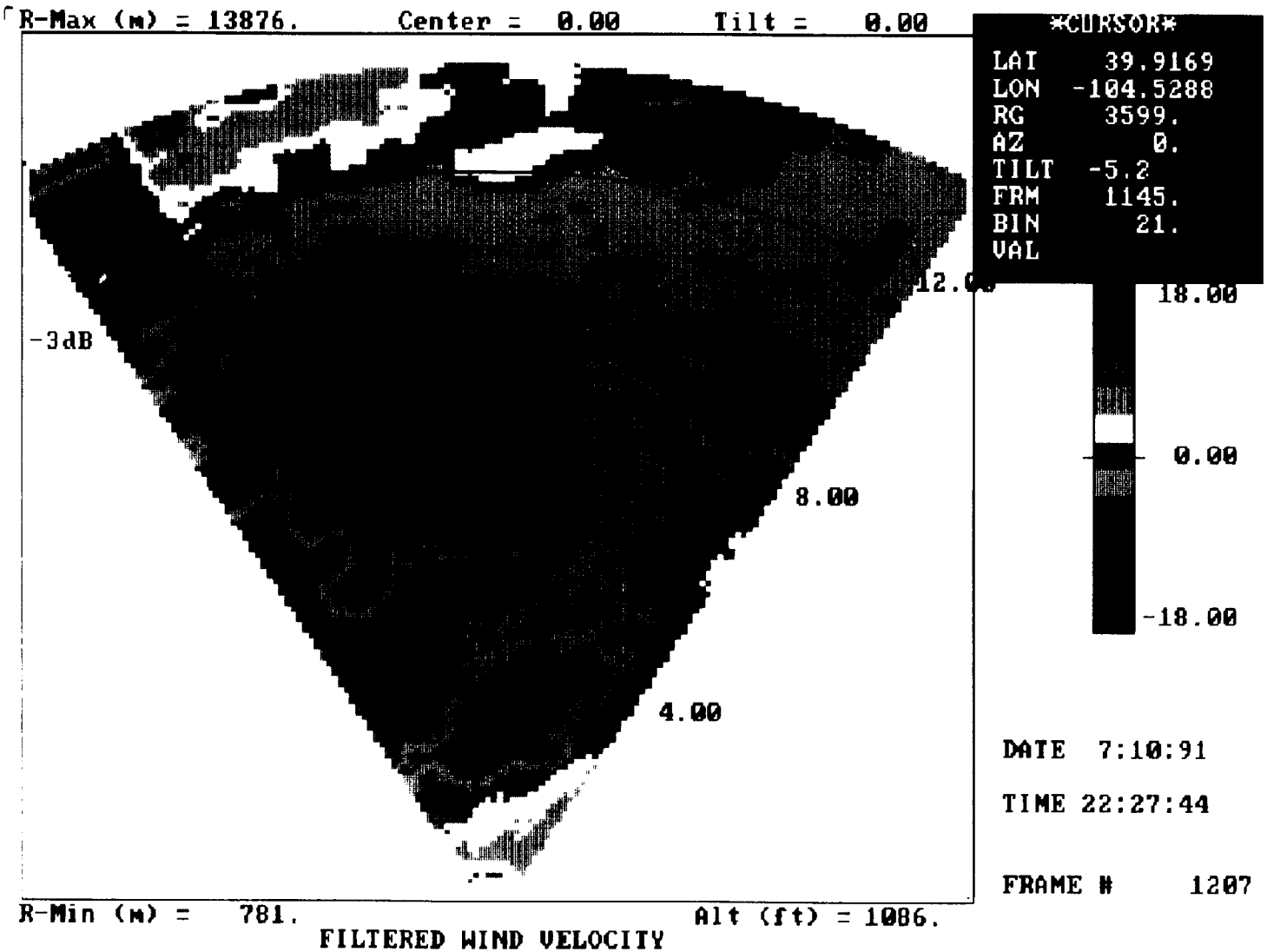


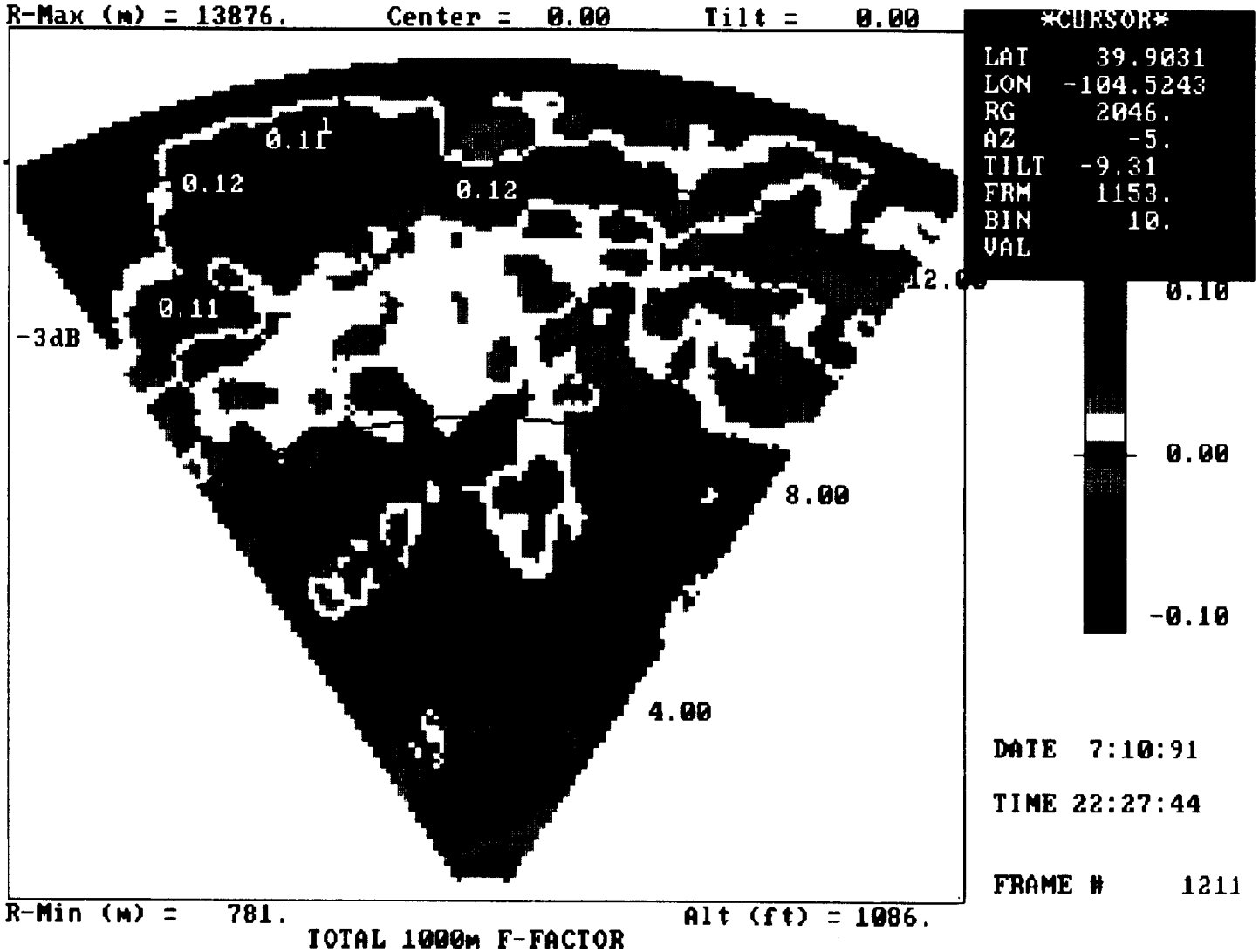


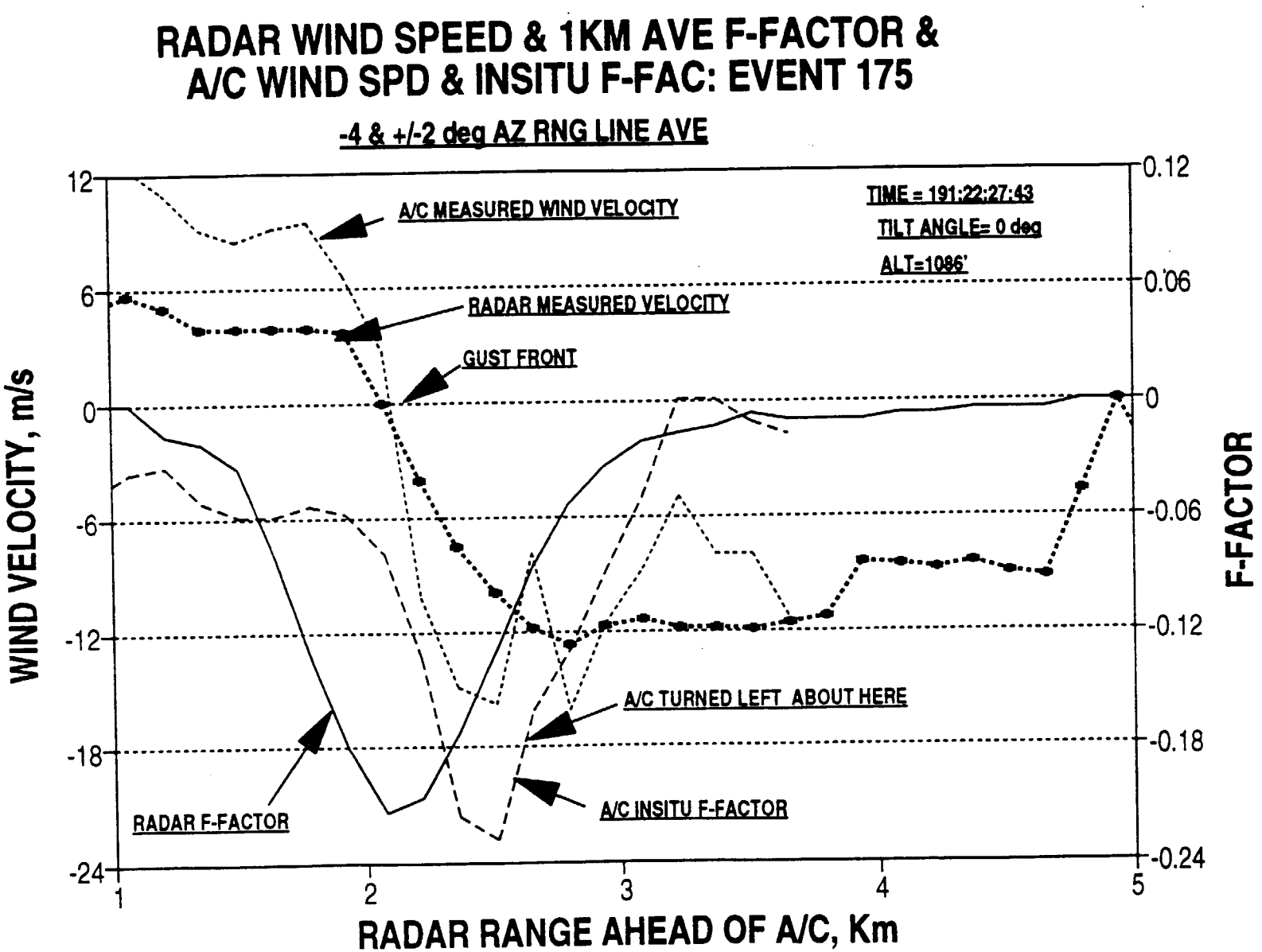

R-Max (M) = 10134.
Center = 0.00
Tilt = -1.00
10.00
8.00
6.00
4.00
2.00
0.12
0.14
-3dB
ALERT
R-Min (M) = 781.
Alt (ft) = 797.
TOTAL 1000M F-FACTOR
CURSOR
LAT 28.4144
LON -81.3197
RG 6627.
AZ 0.
TILT -2.10
FRM 1440.
BIN 42.
VAL
0.10
0.00
-0.10
DATE 6:20:91
TIME 21:27:18
FRAME # 1482



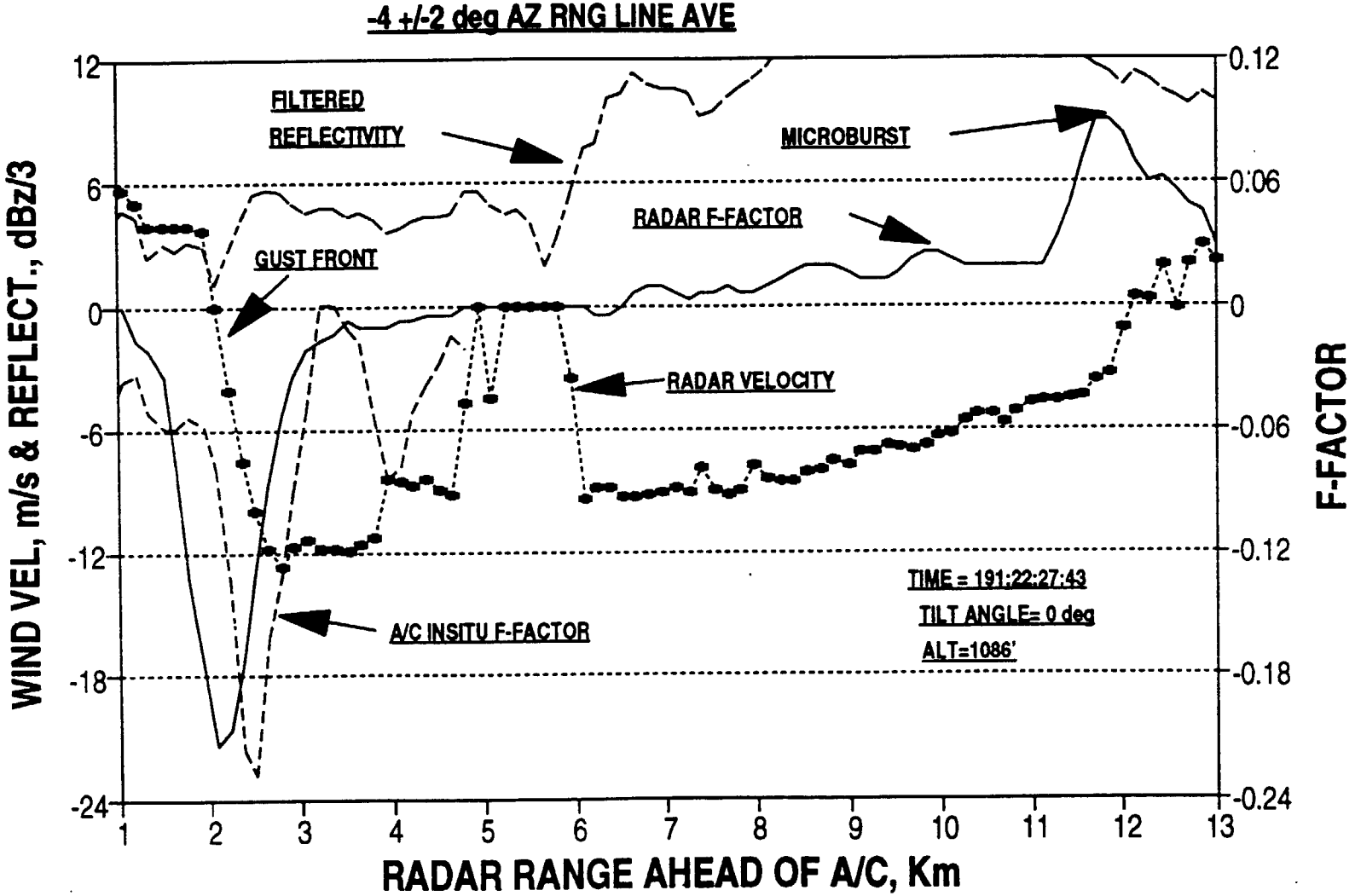
COLOR PHOTOGRAPH


R-Max (m) = 13876.
Center = 0.00
Tilt = 0.00
CURSOR
LAT 39.9169
LON -104.5288
RG 3599.
AZ 0.
TILT -5.2
FRM 1145.
BIN 21.
VAL
18.00
0.00
-18.00
-3dB
8.00
4.00
DATE 7:10:91
TIME 22:27:44
FRAME # 1207
R-Min (m) = 781.
Alt (ft) = 1086.
FILTERED WIND VELOCITY




RADAR WIND SPEED & 1KM AVE F-FACTOR &
A/C WIND SPD & INSITU F-FAC: EVENT 175
-4 & +/-2 deg AZ RNG LINE AVE
TIME = 191:22:27:43
TILT ANGLE= 0 deg
ALT=1086'
A/C MEASURED WIND VELOCITY
RADAR MEASURED VELOCITY
GUST FRONT
A/C TURNED LEFT ABOUT HERE
RADAR F-FACTOR
A/C INSITU F-FACTOR
WIND VELOCITY, m/s
F-FACTOR
RADAR RANGE AHEAD OF A/C, Km
12
6
0
-6
-12
-18
-24
0.12
0.06
0
-0.06
-0.12
-0.18
-0.24
1
2
3
4
5

RADAR REFLECT., WIND SPEED, & 1KM AVE F-FAC, & A/C INSITU F-FAC: EVENT 175



SIGNIFICANT WIND SHEAR EVENTS 1991 ORLANDO FLIGHT EXP.
RADAR, TDWR, & A/C INSITU F-FACTOR COMPARISONS

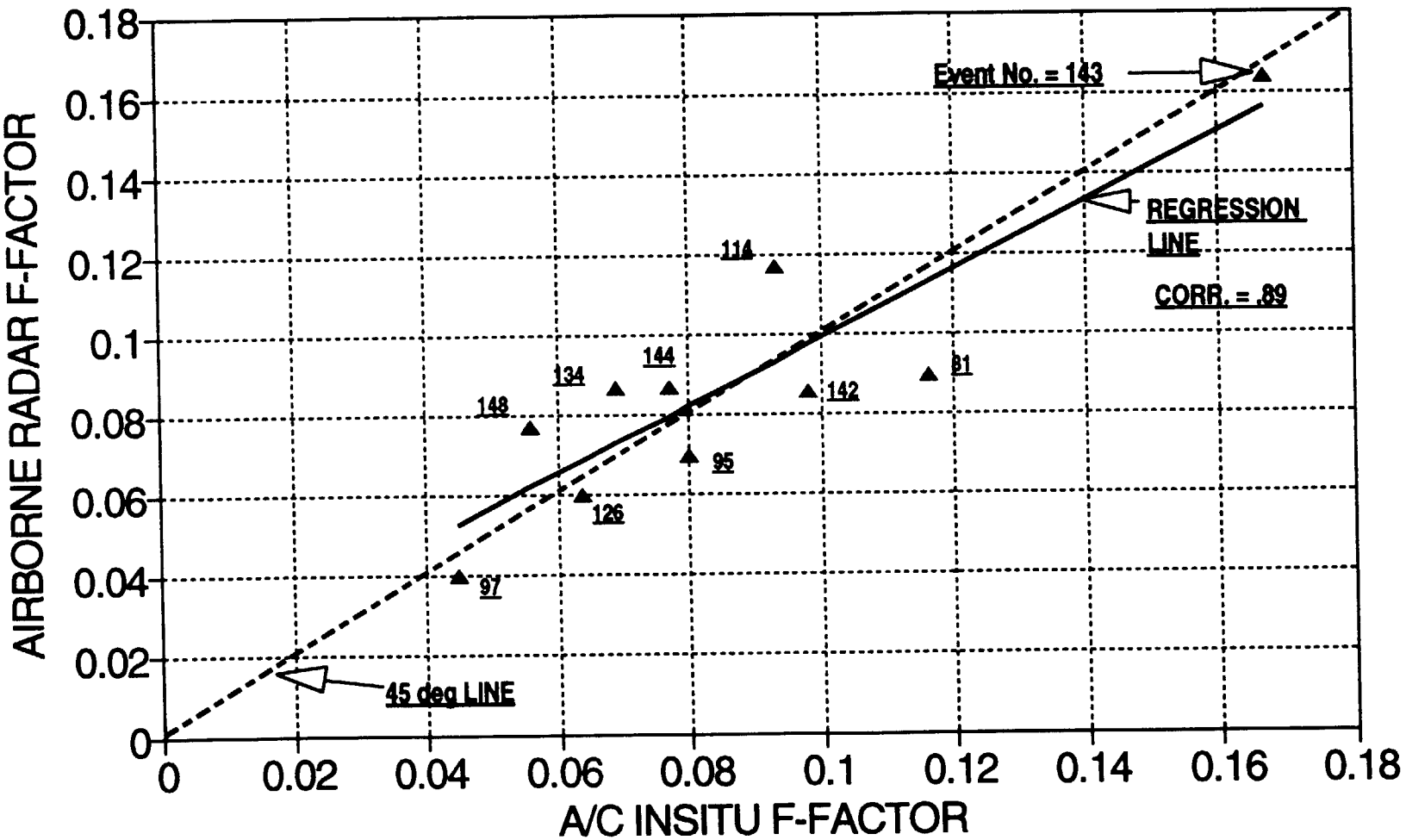
RADAR AND TDWR COMPARISONS

EVENT NUMBER	RADAR FILE NAME	TILT ANGLE deg	DATE	TIME	RADAR F-FACTOR WITHIN AZ SCAN			TDWR F-FACTOR
					MIN	MAX	AVE	
79	OR4W4S1.M6	0	6/15/91	166:19:28:48	0.07	0.09	0.08	0.094
80	OR4W6S1.M6	0	6/15/91	166:19:37:51	0.06	0.08	0.07	0.08
81	OR4W8S1.M6	2.25	6/15/91	166:19:51:46	0.05	0.10	0.09	0.11
86	O4W15S14.M7	0	6/15/91	166:20:30:27	0.08	0.10	0.10	0.1
95	OR6W1S4.M6	-2	6/17/91	168:18:31:05	0.13	0.16	0.14	0.13
97	OR6W4S3.M6	-1	6/17/91	168:18:50:17	0.12	0.16	0.12	0.09
101	OR6W6S4.M6	-2	6/17/91	168:19:20:00	0.05	0.07	0.07	0.10
106	OR7W1S3.M6	-1	6/18/91	169:19:09:59	0.06	0.09	0.08	0.15
114	OR7W14S1.M6	0	6/18/91	169:20:23:15	0.11	0.15	0.13	0.11
115	OR7W15S3.M6	-1	6/18/91	169:20:25:59	0.11	0.14	0.12	0.086
118	OR7W20S3.M6	-1	6/18/91	169:20:52:16	0.12	0.14	0.13	0.10
126	OR8W1S4.M6	-2	6/19/91	170:17:27:13	0.08	0.12	0.10	0.11
127	OR8W2S3.M6	-1	6/19/91	170:17:34:23	0.06	0.07	0.06	0.11
134	OR8W15S1.M6	0	6/19/91	170:20:51:20	0.12	0.14	0.13	0.096
142	OR9W7S4.M6	-2	6/20/91	171:20:40:49	0.09	0.13	0.10	0.11
143	OR9W8S4.M6	-2	6/20/91	171:20:45:15	0.13	0.17	0.16	0.13
144	OR9W9S3.M6	-1	6/20/91	171:20:51:26	0.08	0.10	0.10	0.094
145	OR9W10S4.M6	-3.5	6/20/91	171:20:57:18	0.05	0.07	0.06	0.095
148	OR9W14S1.M6	-3	6/20/91	171:21:20:25	0.12	0.18	0.13	0.13
150	OR9W16S8.M16	AUTO	6/20/91	171:21:35:00	0.05	0.07	0.06	0.07
149	OR9W16S3.M6	-1	6/20/91	171:21:27:24	0.13	0.16	0.14	0.2

RADAR AND INSITU COMPARISONS

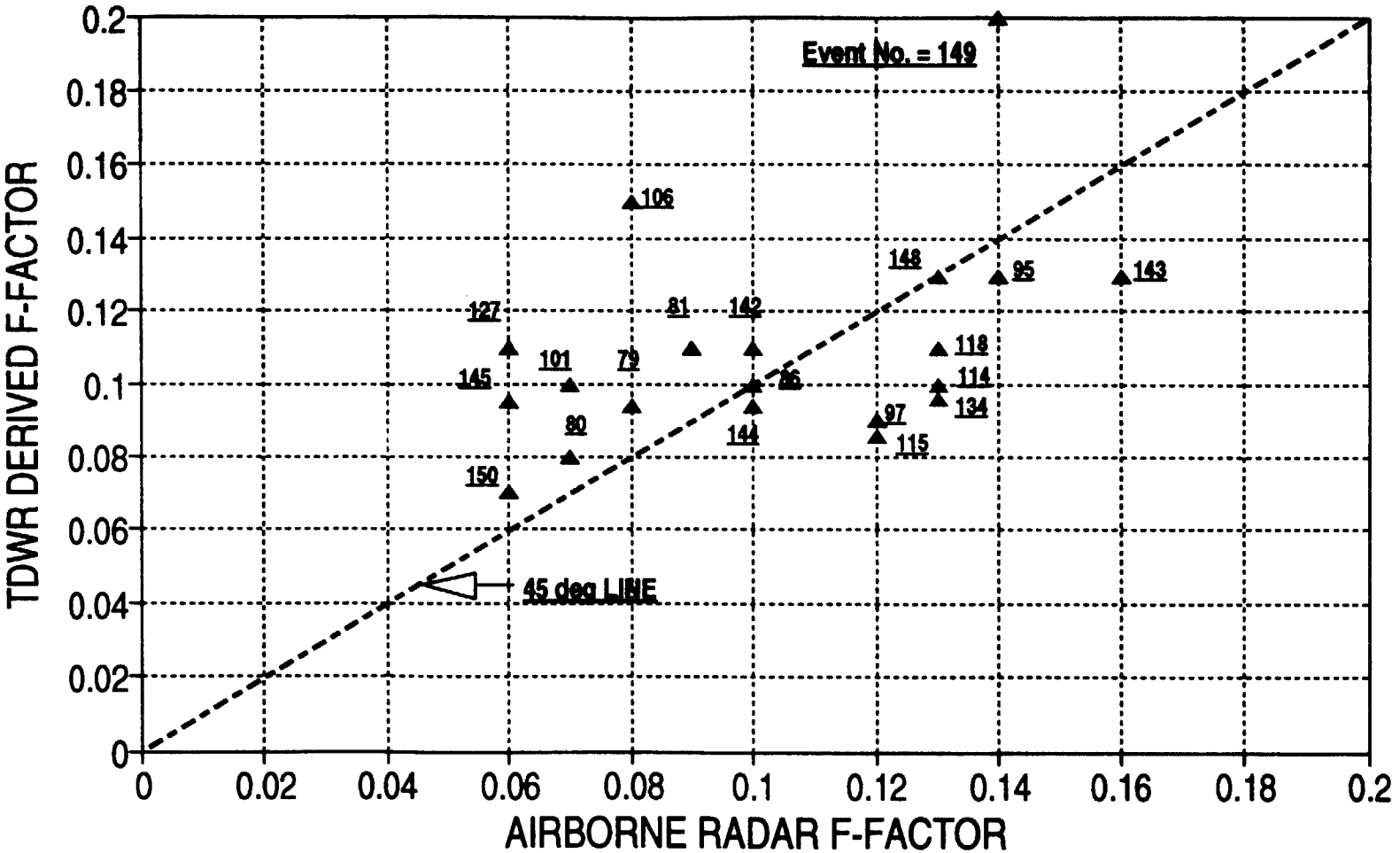
						RADAR LEAST SQ F-FACT	RADAR MEASURE F-FACT	INSITU F-FACT
97	OR6W4S3.M6	-1	6/17/91	168:18:50:17		0.0526	0.040	0.045
148	OR9W14S1.M6	-3	6/20/91	171:21:20:50		0.0619	0.077	0.056
126	OR8W1S4.M6	-2	6/19/91	170:17:27:27		0.0687	0.060	0.064
134	OR8W15S1.M6	0	6/19/91	170:20:51:59		0.0729	0.067	0.069
144	OR9W9S3.M6	-1	6/20/91	171:20:51:32		0.0797	0.087	0.077
95	OR6W1S4.M6	-2	6/17/91	168:18:31:05		0.0820	0.070	0.080
114	OR7W14S1.M6	0	6/18/91	169:20:23:17		0.0933	0.117	0.093
142	OR9W7S4.M6	-2	6/20/91	171:20:41:14		0.0976	0.086	0.098
81	OR4W8S1.M6	2.25	6/15/91	166:19:52:00		0.1128	0.090	0.116
143	OR9W8S4.M6	-2	6/20/91	171:20:45:31		0.1562	0.164	0.167

AIRBORNE RADAR & A/C INSITU F-FACTOR COMPARISONS



AIRBORNE RADAR & TDWR

F-FACTOR COMPARISONS



NASA Flight Tests
Airborne Doppler Radar Results

Performance Summary

1. Data from over 200 clutter and 150 weather event runs were collected. The weather events included approximately 30 microbursts and 20 gust fronts.

2. No false hazard alerts resulted from any clutter targets.

3. All microburst events were detected by the airborne radar. For the microbursts penetrated by the A/C (approx. 15), the airborne radar derived F-factor showed excellent agreement with the In Situ measured F-factor.

4. Gust fronts with approximately 5 dBz or higher reflectivity levels were also detected.

5. Sample comparisons of airborne radar data with TDWR data showed comparable results.

6. Wet microbursts can be accurately detected in the presence of severe ground clutter. Dry microburst performance will be evaluated using radar simulation progam with dry U-Burst models and possible Denver ground and flight experiments.

Doppler Radar Results
Questions and Answers

Q: Anthony Berke (MIT Lincoln Laboratory) - I am curious to know why you had the antenna depressed two degrees or so when you were usually trying to do level flight penetrations?

A: Brac Bracalente (NASA Langley) - Primarily because we wanted to first look down into the event, and secondly, to get some clutter into the signal. We were really doing it over a range of tilt angles, 0, -1, -2, -3. We were collecting data with different conditions so we could evaluate the effects of clutter under those conditions, and to get extra data down in the event. Obviously in some of the comparisons with the In Situ were the antenna was tilted down, the In Situ flew above were we saw the measurement; there will be some differences there. We tried to compare with the In Situ when we were as close to the airplane as possible so the difference in altitude was not great.

Q: Pat Adamson (Turbulence Prediction Systems) - To create total F-factor numbers you estimate or infer the vertical compound the winds. Is that correct? If so, how do you deal with asymmetric events and with the different altitudes where vertical and horizontal winds trade-off.

A: Brac Bracalente (NASA Langley) - That is correct, we do that. Right now we are using an algorithm that Dan Vicroy and Fred Proctor came up with. There is going to be a presentation tomorrow by Dan on that vertical estimation. Basically we take the horizontal wind measurement and multiply it by a factor which takes altitude into consideration. Basically, it is estimating the vertical based on the horizontal component and the altitude at which we made the measurement. As far as the asymmetric events and the different altitudes, Dan will talk about all that tomorrow. It is pretty straightforward. Everything I showed up here did included a vertical estimation in the F-factors.

Q: Pat Adamson (Turbulence Prediction Systems) - What is the sensitivity of the radar? In Denver, 10% of the dry microburst were from -10 to 0 dBZ.

A: Brac Bracalente (NASA Langley) - As I pointed out in the presentation, we did not see any dry microburst, but we did see some low reflectivity gust fronts. I showed one example where the reflectivity was down in the 5 to 10 dBZ range and we were able to detect that. There wasn't extremely strong clutter in that particular region. We think we will be able to work down into the 0 maybe 5 dBZ level, out to three or four kilometers. That is what we are shooting for this summer. Hopefully we will get those kind of events so we can collect some data and see what we can do.

Q: Pat Adamson (Turbulence Prediction Systems) - When flying at 230 knots, is it easier or harder to suppress clutter than at 140 knots?

A: Brac Bracalente (NASA Langley) - I don't know that we see much difference since we zero out the velocity of the aircraft. The spectrum width of the clutter might be a little bit wider at 230 knots. It doesn't really have much effect on our ability to suppress the clutter or to operate the radar.