Determining Bird Collision Risk with Terminal Doppler Weather Radar (TDWR)

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Geo-Marine, Inc.

Bird Aircraft Collisions (BAC)

- The government's tally for all bird strikes in 2009 could reach or even exceed 10,000 for the first time – which would represent about 27 strikes every day.
- There were at least 57 cases in the first seven months of 2009 that caused serious damage and three in which planes and a corporate helicopter were destroyed by birds.
- At least eight people died in BACs, and six more were hurt.

Bird Aircraft Collisions (BAC)

- Although the majority of BACs occur within the airport environment, serious collisions can occur away from the airport.
- Several serious collisions took place miles away from airports in 2009:

Bird Aircraft Collisions (BAC)

- Date: 15 January 2009
- Aircraft: A-320
- Airport: LaGuardia Intl. (NY)
- Phase of Flight: Climb (2,900 AGL)
- Effect on Flight: Engines shut down, landed in Hudson River
- Damage: Aircraft destroyed
- Wildlife Species: Canada goose
- Comments from Report: During initial climb, aircraft had multiple bird strikes and lost thrust to both engines. Pilot ditched in the Hudson River less than 6 minutes after takeoff.

Bird Aircraft Collisions (BAC)

- Date: 29 September 2009
- Aircraft: B-727-200
- Airport: Memphis Intl. (TN)
- Phase of Flight: Approach (3,700’ AGL)
- Effect on Flight: None
- Damage: Windshield
- Wildlife Species: Great egret
- Comments from Report: The captain’s front window was struck and the inner window panel shattered. Both engines ingested birds but sustained no damage.

Bird Aircraft Collisions (BAC)

- Date: 2 November 2009
- Aircraft: MD-90
- Airport: Phoenix Sky Harbor (AZ)
- Phase of Flight: Climb (11,000’ AGL)
- Effect on Flight: Precautionary landing
- Damage: Fuselage
- Wildlife Species: Western Grebe
- Comments from Report: Bird hit top of aircraft and tore back 18 inches of the fuselage just above the right side flight deck eyebrow window. A second strike tore a big hole just below the co-pilot’s wing in front of the landing gear. These strikes activated the depressurization alarm. Aircraft returned to land

Bird Aircraft Collisions (BAC)

- Date: 4 November 2009
- Aircraft: BE-99
- Airport: Phoenix Sky Harbor (AZ) 100 miles west
- Phase of Flight: Descent (11,000’ AGL)
- Effect on Flight: Precautionary landing
- Damage: Windshield
- Wildlife Species: Western Grebe
- Comments from Report: Bird shattered the windshield and caused a large hole injuring the pilot. Aircraft returned to land.

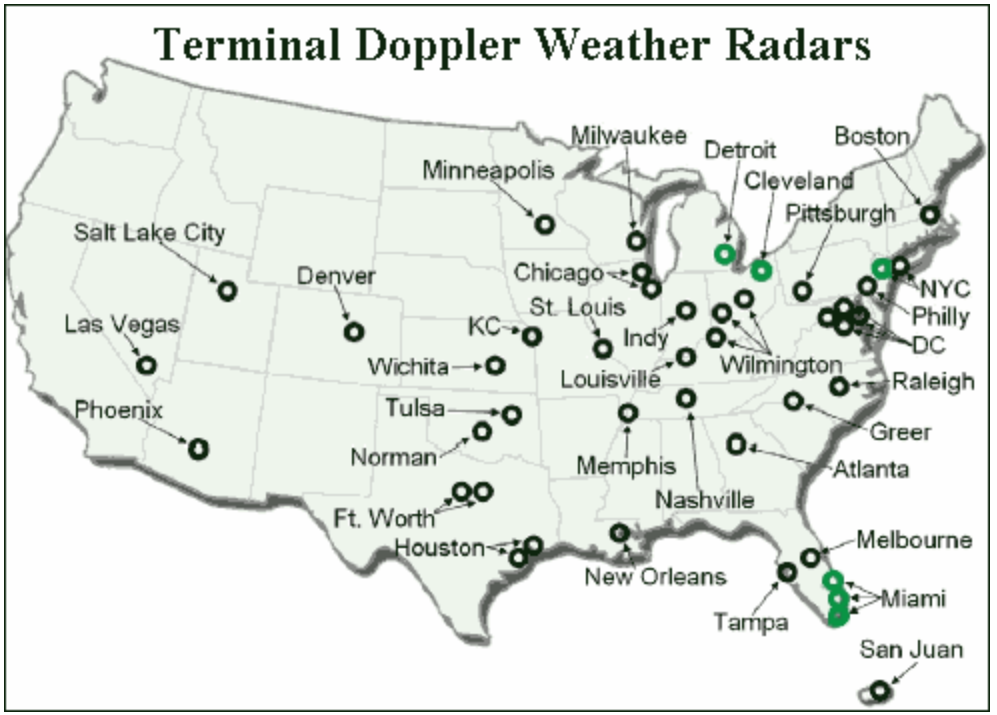
Bird Aircraft Collisions (BAC)

- Date: 14 November 2009
- Aircraft: A 319
- Airport: Kansas City Intl. (MO)
- Phase of Flight: Climb (4,000’ AGL)
- Effect on Flight: Precautionary landing
- Damage: Engine
- Wildlife Species: Snow goose
- Comments from Report: Flight has just departed when pilot reported multiple bird strikes about 4 miles north of the airport. First report was loss of #2 engine, Upon landing he reported both engines had stalled. Damage to #2 engine consisted of a dent in the lower lip and a hole in the underside of the cowling

Doppler Weather Radar Sensors

- WSR-88D Doppler weather surveillance radar can detect concentrations of migrating birds in the atmosphere out to ranges of 124 nautical miles (Gauthreaux and Belser 1998,1999) and target velocity information can be used to identify the types of biological targets aloft (Gauthreaux et al. 2008).
- Terminal Doppler Weather Radar has not been assessed for its ability to detect migrating birds, but its operational characteristics suggest it should be an excellent sensor for that purpose.

Terminal Doppler Weather Radar (TDWR)



Terminal Doppler Weather Radar (TDWR)

- Operated by Federal Aviation Administration (FAA) (FAA)
- Detects and reports hazardous weather in and around airport terminal approach and departure zones.
- Identifies and warns air traffic controllers (ATCs) of low altitude wind shear hazards caused by microbursts and their associated gust fronts.
- Measures and reports on precipitation intensities and provides advanced warning of wind shifts.
- TDWR reports used by ATCs to warn pilots about hazardous weather patterns.

Terminal Doppler Weather Radar (TDWR) Characteristics

- 45 stations located near major airports
- Has a limited area of high-resolution coverage of 48 nm (reflectivity and radial velocity)
- High-resolution range gates (150 m)
- 5 cm (C-band) wavelength
- Beam width of 0.55°
- Lowest elevation angle ranges from 0.1°- 0.3°
- Data available via NOAAPORT as of June 2009

Terminal Doppler Weather Radar (TDWR)

TDWR and WSR-88D COMPARISON

	TDWR	WSR-88D
Antenna		
Peak Power	250 KW	750 KW
Beam Width	0.55 Degrees (spoiled to 1 Degree)	0.95 Degrees (on average)
Power Gain	50 dB	45.5 dB
Minimum Elevation	0 Degrees	0.5 Degrees
Maximum Elevation	60 Degrees	19.5 Degrees
Maximum Rotation Rate	5 RPM	6 RPM

TDWR and WSR-88D COMPARISON

Transmitter

Frequency- Wavelength	C Band-5.3 cm	S Band-10.5 cm
Pulse Width Max	1.1 msec 1.1 msec	1.57 msec 4.70 msec
Polarization	Linear Horizontal	Linear Horizontal
Maximum Reflectivity Range	460 km	460 km
Minimum Unambiguous Doppler Range	90 km	115 km
Maximum Doppler Range	90 km	230 km
Range Resolution	150 m	250 m (high res.)

Scan Strategies

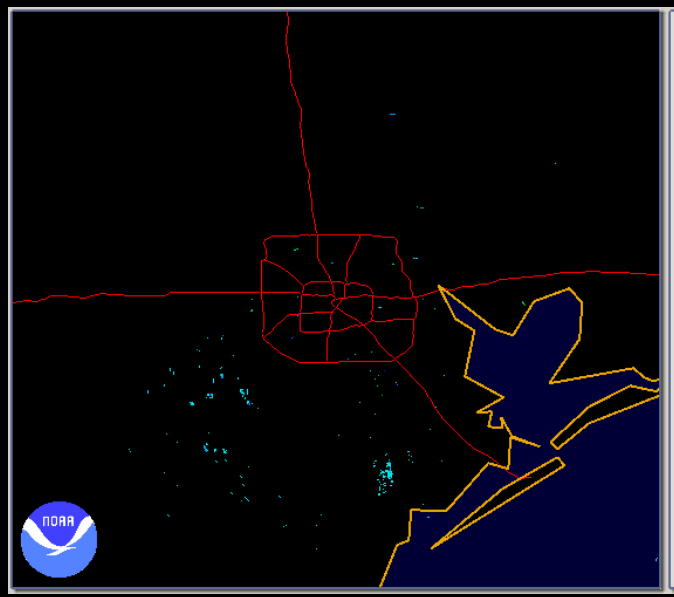
Clear Air/Monitor Mode	Scan Time: 6 min	Scan Time: 6 – 10 min
	Number of Scans: 17	Number of Scans: 5
Severe/Hazardous Mode	Scan Time: 6 min	Scan Time: 5 min
	Number of Scans: 23	Number of Scans: 9 - 14

TDWR AND BIRD MOVEMENTS

- Base Reflectivity—reflectivity from targets aloft in a 0.5° x 150 m radar pulse volume
- Base Velocity—component of mean velocity of targets in a 0.5° x 150 m radar pulse volume that is moving toward or away from the radar. Also referred to as radial velocity. Inbound velocity is negative and outbound velocity is positive.

TDWR AND BIRD MOVEMENTS

- Four time slices (14:09; 21:05; 23:03, and 23:57 UTC) of base reflectivity and base velocity from the TDWR at Hobby Field, Houston, TX, on 30 April 2009.
- Emphasis on mean radial velocity of radar pulse volumes.
- Filtering by wind speed and velocity categories.



TDWR LEVEL-III
BASE REFLECTIVITY
THOU - HOUSTON
04/30/2009 14:09:42 GMT
LAT: 29/30/57 N
LON: 95/14/31 W
ELEV: 116 FT
MODE/VCP: A / 90

ELEV ANGLE: 2.60 °
MAX: 48 DBZ
RANGE: 48 NM

Legend: dBZ (Category)

75 (15)
70 (14)
65 (13)
60 (12)
55 (11)
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25 (5)
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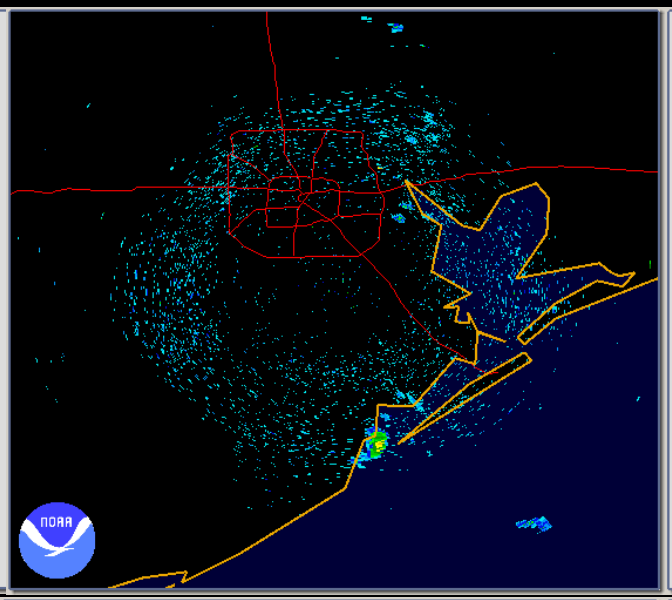

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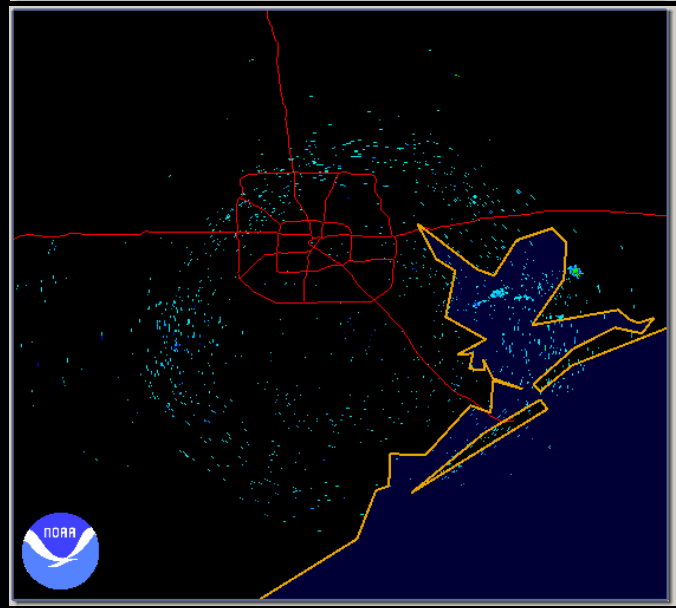

TDWR LEVEL-III
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THOU - HOUSTON
04/30/2009 23:03:41 GMT
LAT: 29/30/57 N
LON: 95/14/31 W
ELEV: 116 FT
MODE/VCP: A / 80

ELEV ANGLE: 2.60 °
MAX: 36 DBZ
RANGE: 48 NM

Legend: dBZ (Category)

75 (15)
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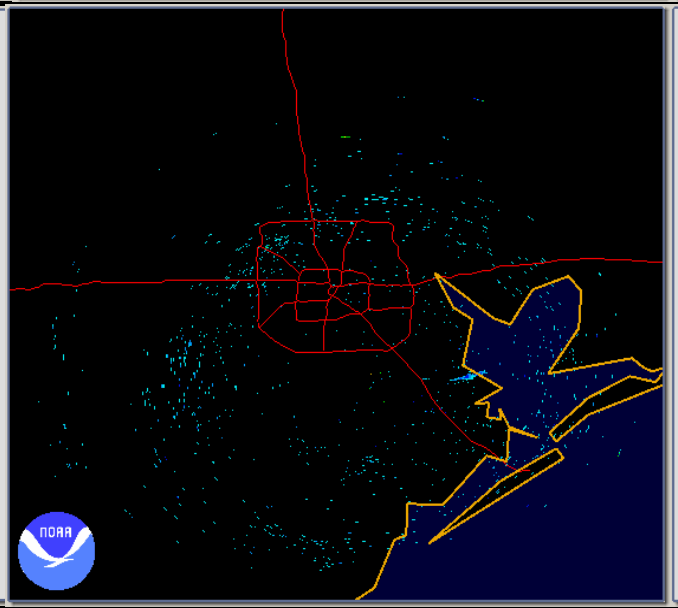

TDWR LEVEL-III
BASE REFLECTIVITY
THOU - HOUSTON
04/30/2009 23:57:24 GMT
LAT: 29/30/57 N
LON: 95/14/31 W
ELEV: 116 FT
MODE/VCP: A / 90

ELEV ANGLE: 2.60 °
MAX: 49 DBZ
RANGE: 48 NM

Legend: dBZ (Category)

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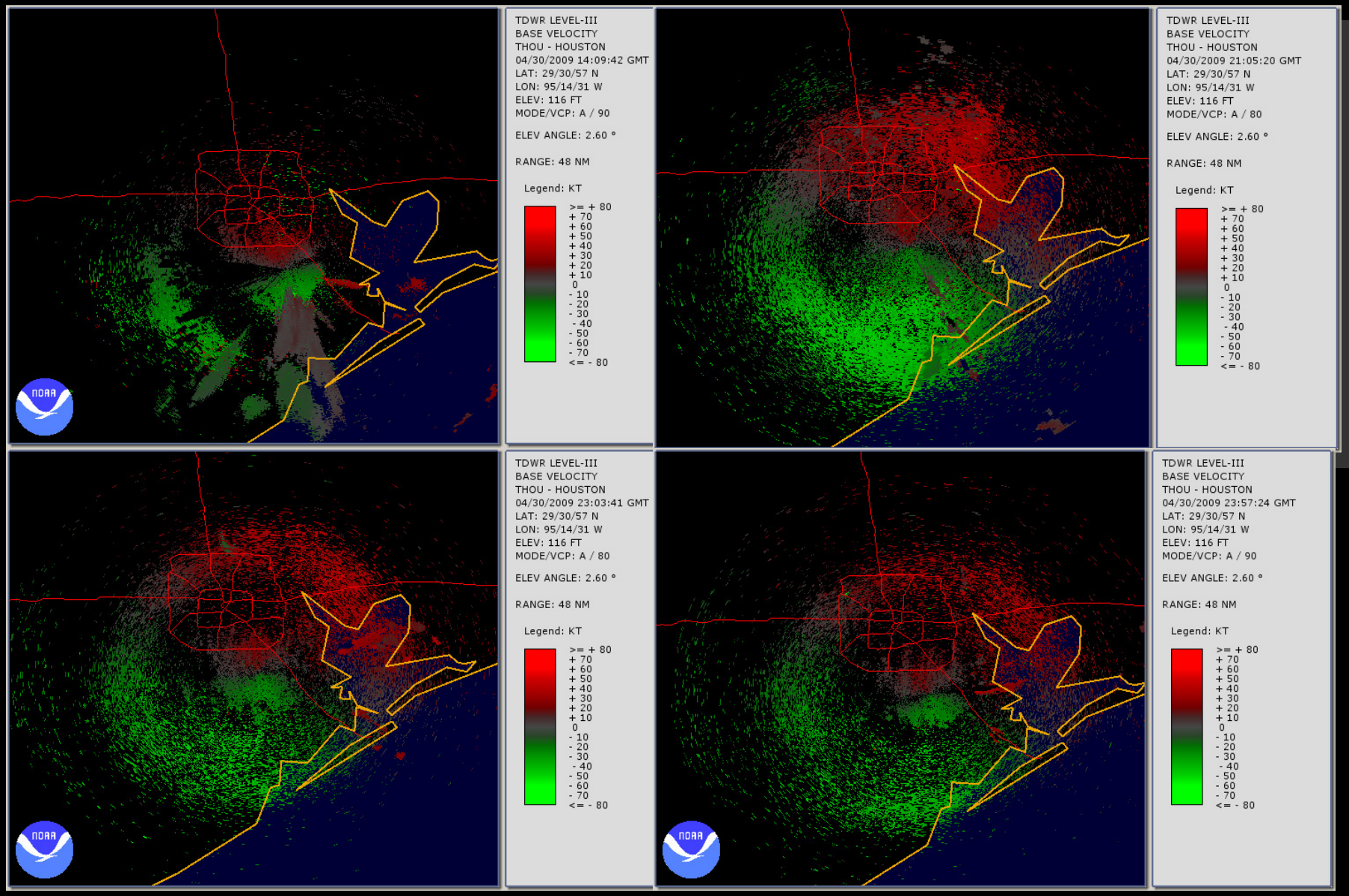
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LON: 95/14/31 W
ELEV: 116 FT
MODE/VCP: A / 90
ELEV ANGLE: 2.60 °
RANGE: 48 NM
Legend: KT
>= + 80
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- 60
- 70
<= - 80
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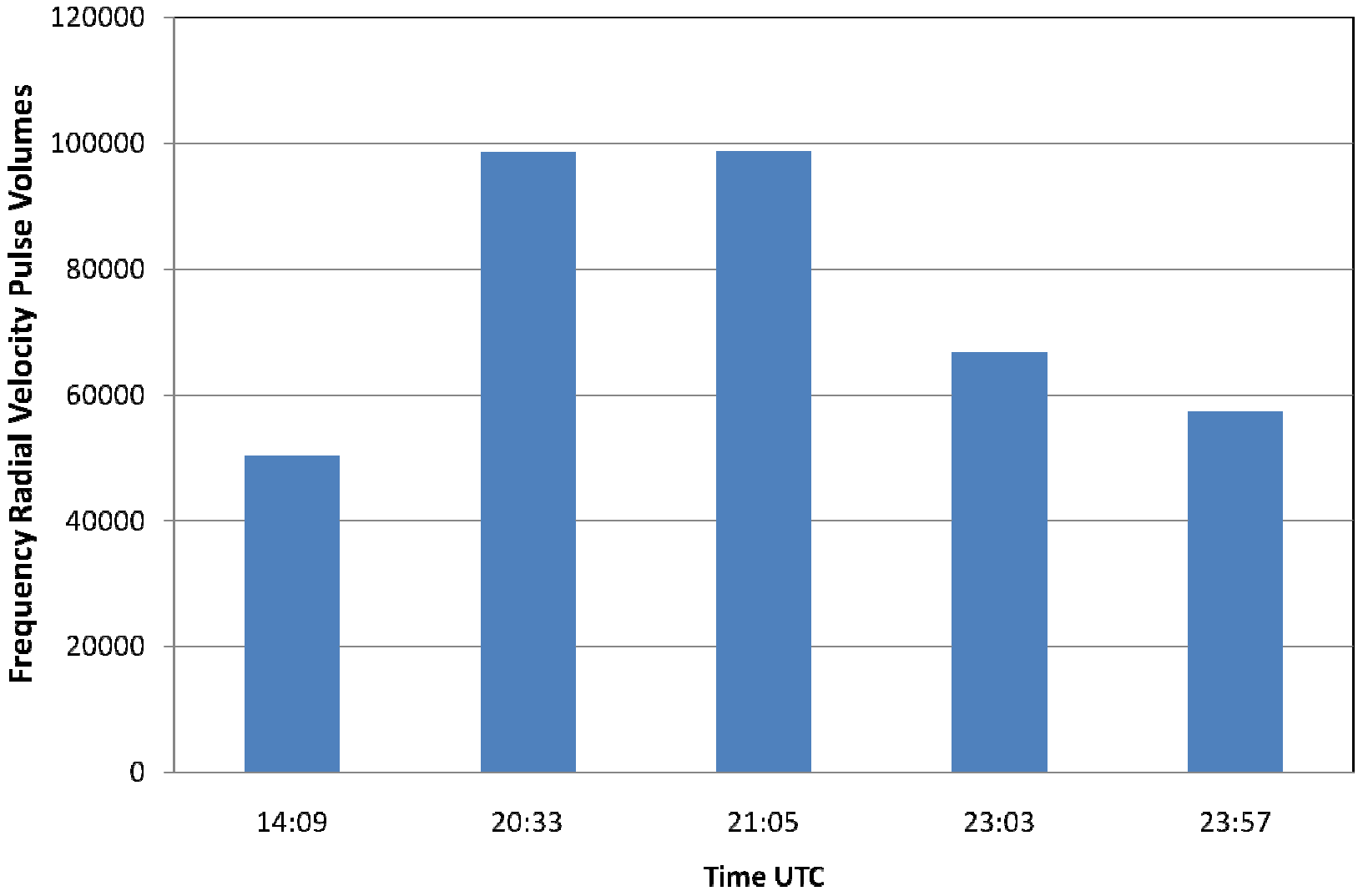
120000
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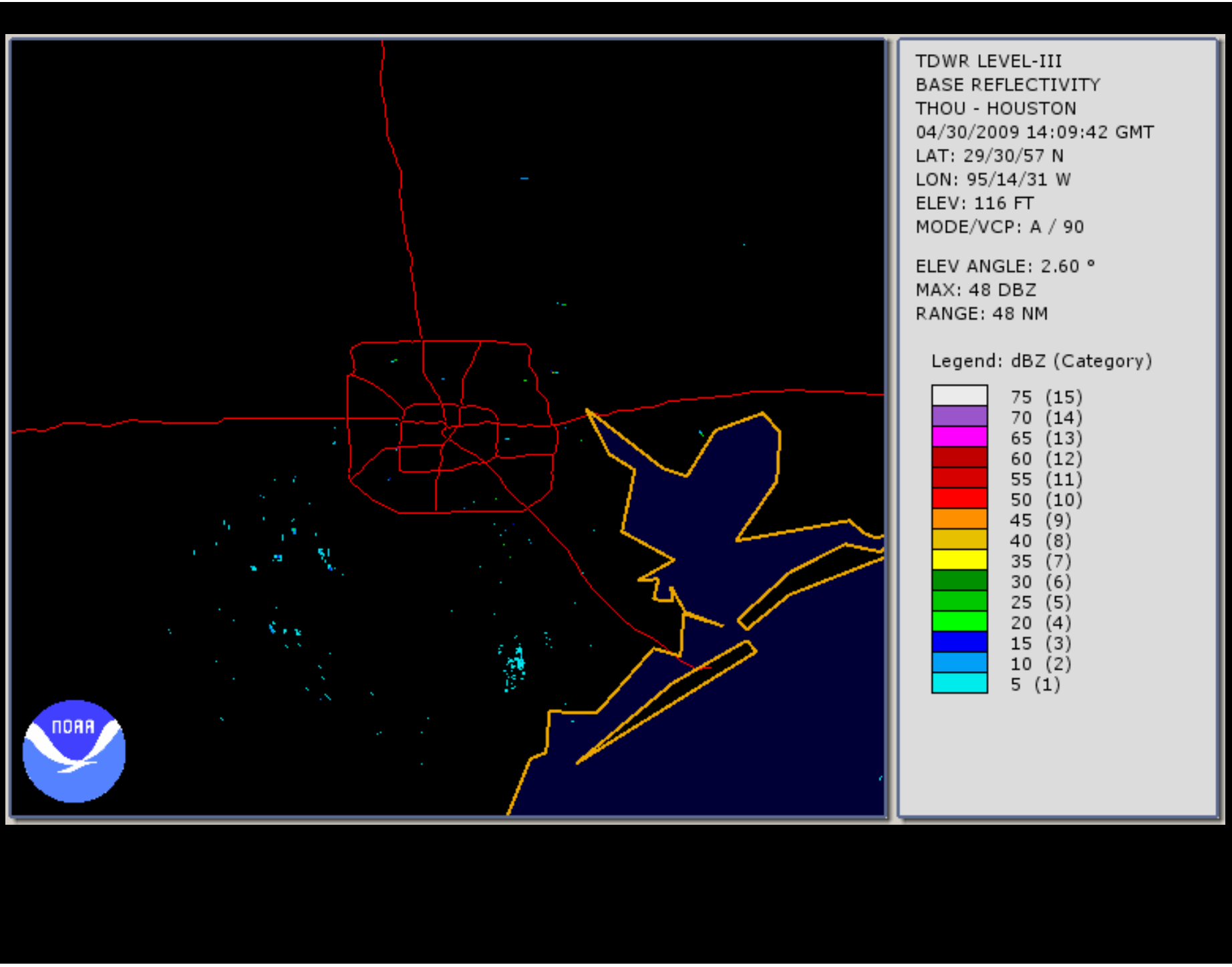
Frequency Radial Velocity Pulse Volumes
14:09
20:33
21:05
23:03
23:57
Time UTC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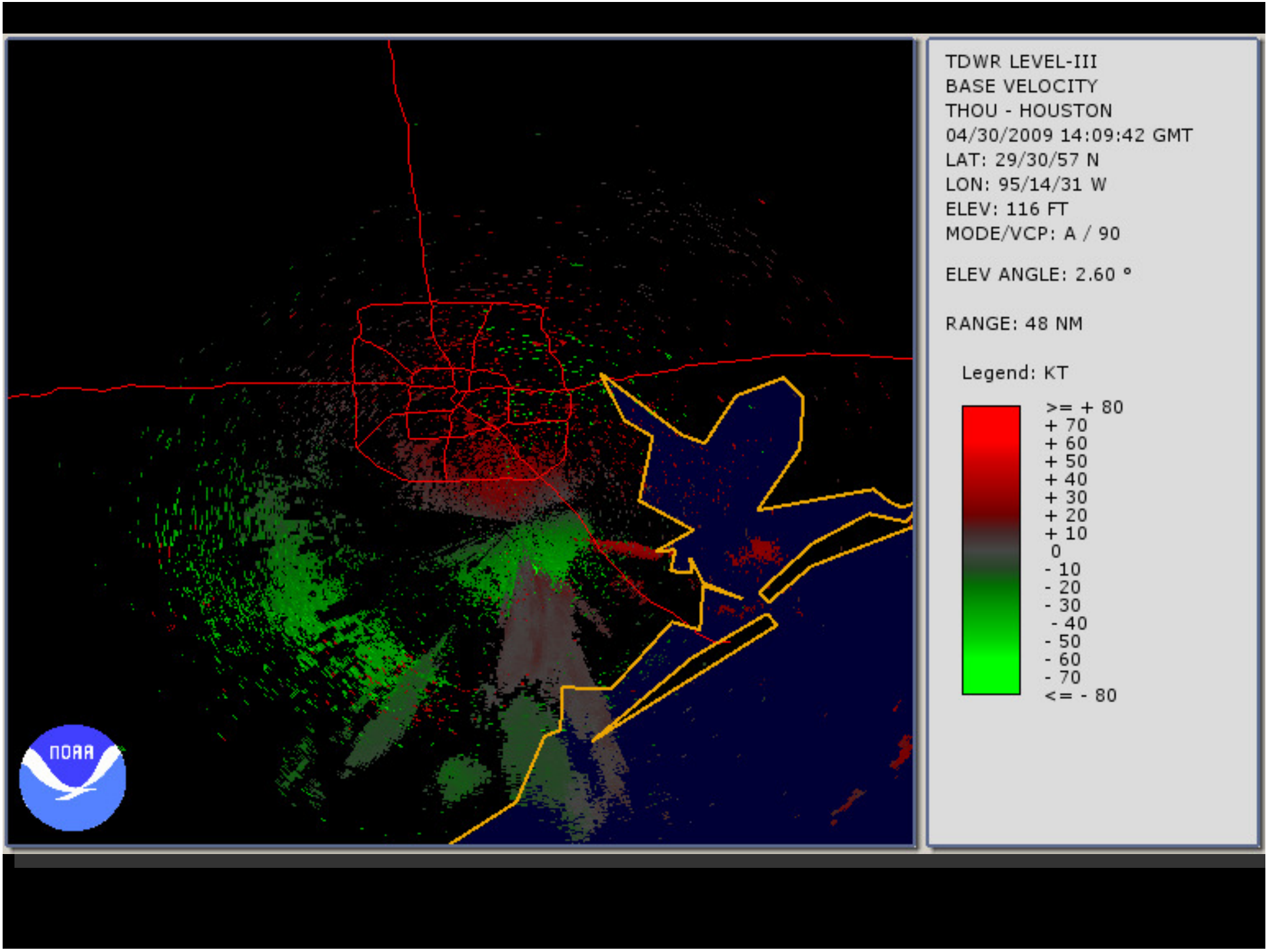
NOAA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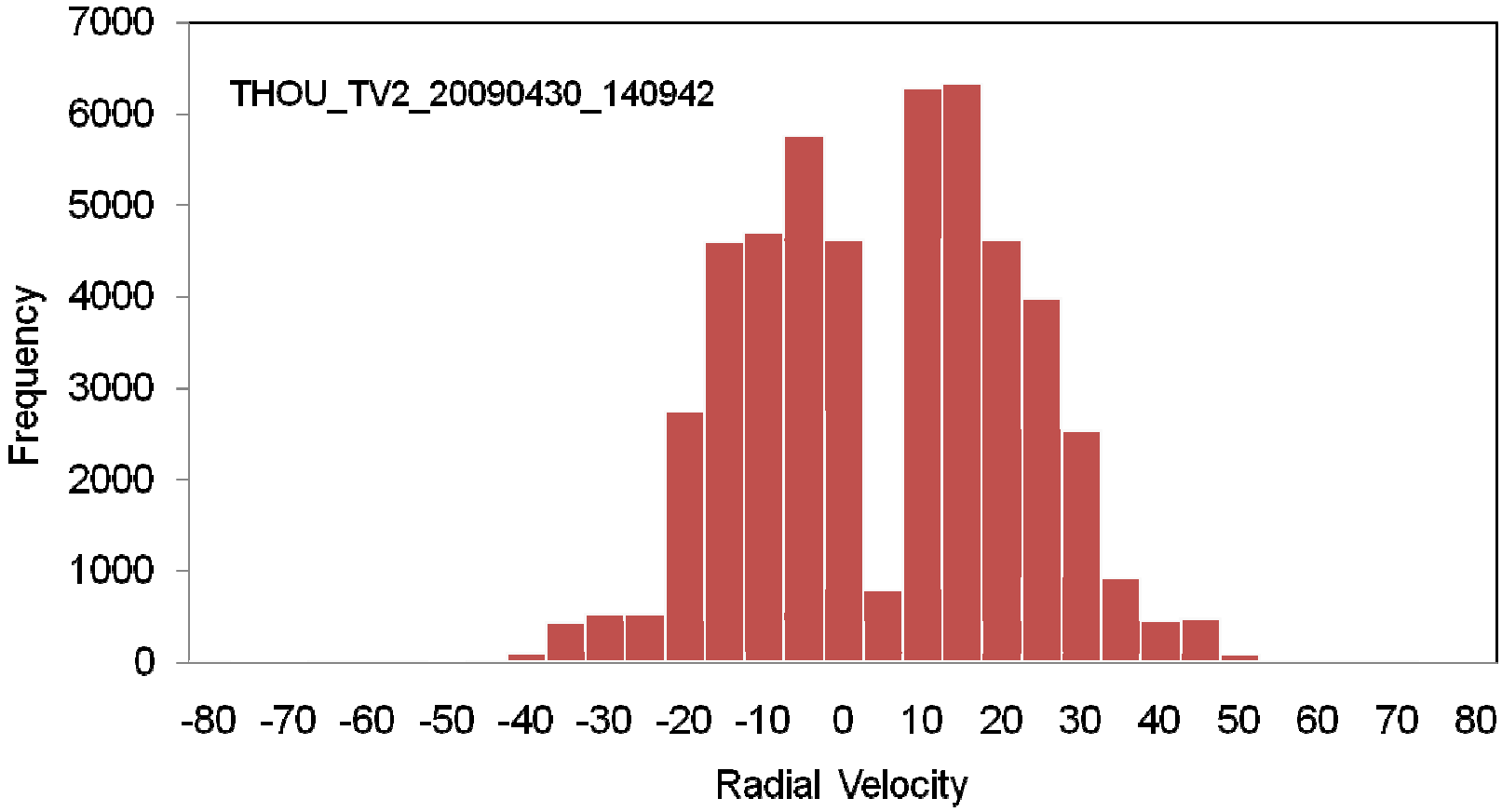
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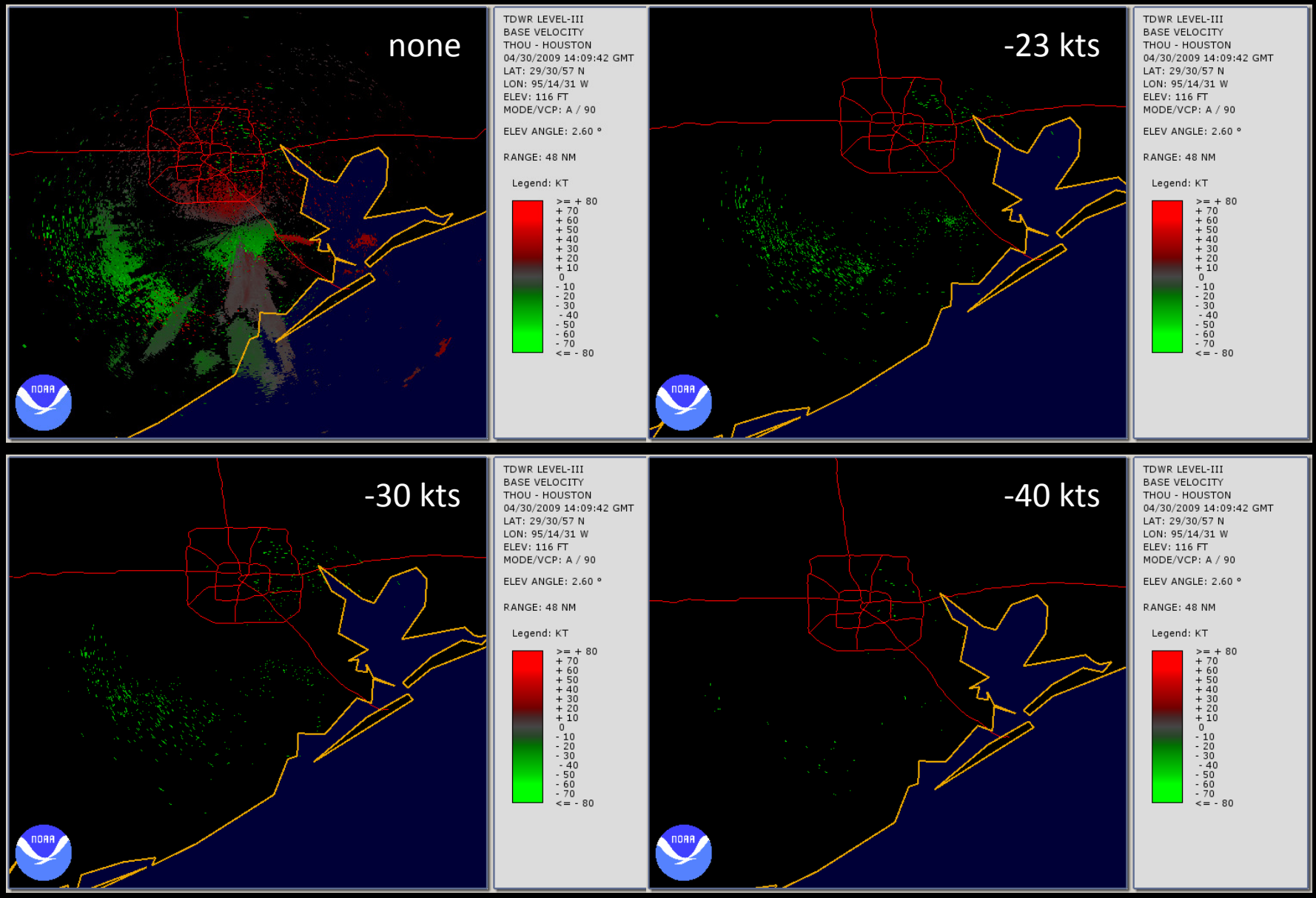
5000
4000
3000
2000
1000
0
-80 -70 -60 -50 -40 -30 -20 -10 0 10 20 30 40 50 60 70 80
Radial Velocity

72240 LCH Lake Charles Observations at 12Z 30 Apr 2009

PRES hPa	HGHT m	TEMP C	DWPT C	RELH %	MIXR g/kg	DRCT deg	SKNT knot	THTA K	THTE K	THTV K
1017.0	10	21.2	19.5	90	14.24	135	7	292.9	333.5	295.4
1003.0	125	21.6	20.9	96	15.78	143	14	294.5	339.8	297.3
1000.0	150	21.4	20.7	96	15.63	145	15	294.6	339.4	297.3
982.2	305	20.3	19.8	97	15.02	165	21	294.9	338.2	297.6
948.2	610	18.1	18.0	99	13.89	165	21	295.7	335.8	298.2
937.0	713	17.4	17.4	100	13.53	170	20	296.0	335.1	298.4
925.0	823	17.0	16.8	99	13.18	175	18	296.7	334.9	299.0
915.1	914	16.4	16.1	98	12.77	180	18	297.0	334.1	299.3
882.8	1219	14.5	14.0	97	11.48	185	22	298.1	331.6	300.1
859.0	1451	13.0	12.3	96	10.57	177	23	298.9	329.9	300.8
851.6	1524	13.0	9.9	82	9.08	175	23	299.6	326.5	301.2
850.0	1540	13.0	9.4	79	8.78	175	23	299.8	325.8	301.3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Legend: KT
>= + 80
+ 70
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<= - 80
-23 kts
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<= - 80
-30 kts
TDWR LEVEL-III
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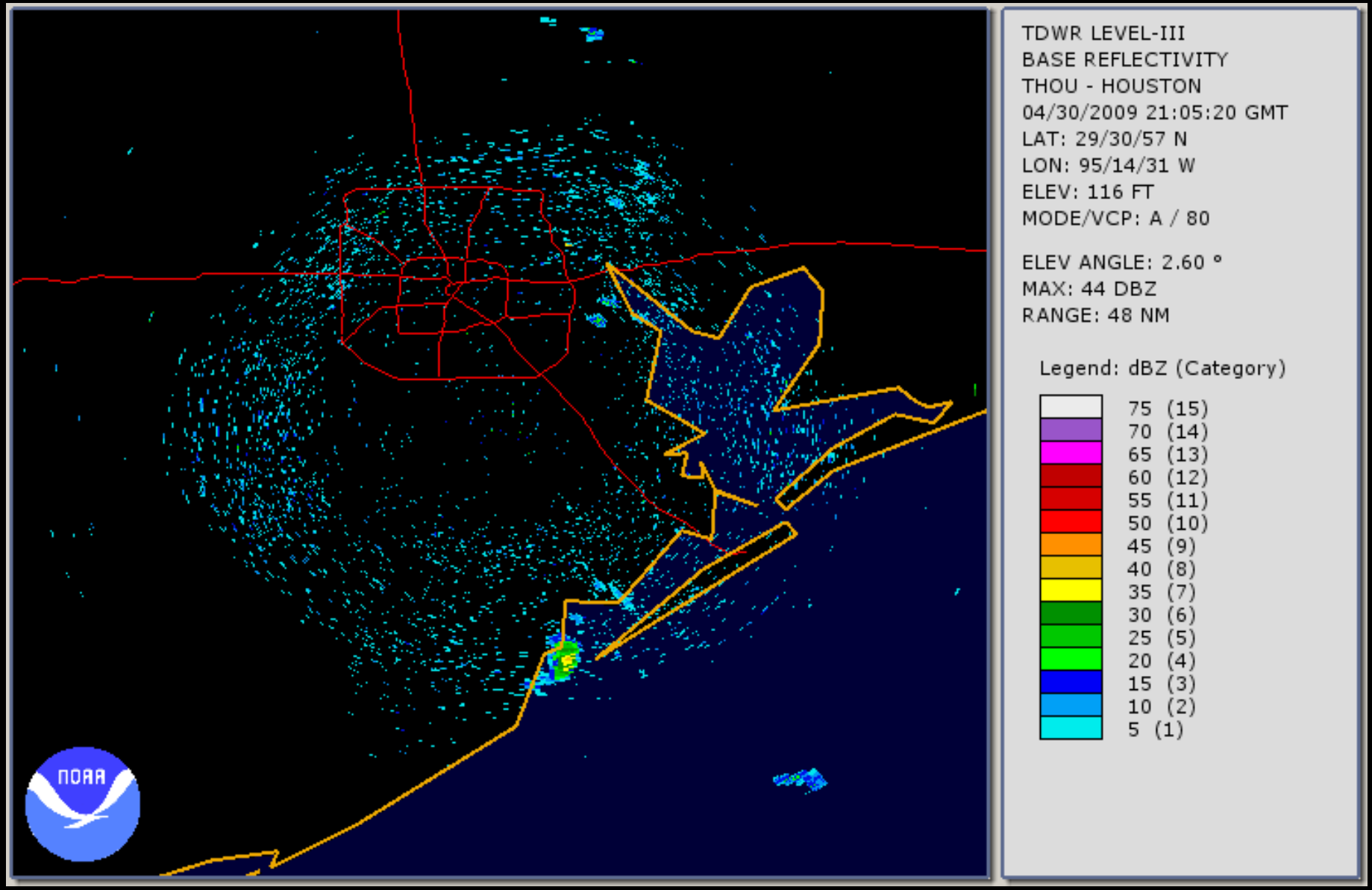
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BASE REFLECTIVITY
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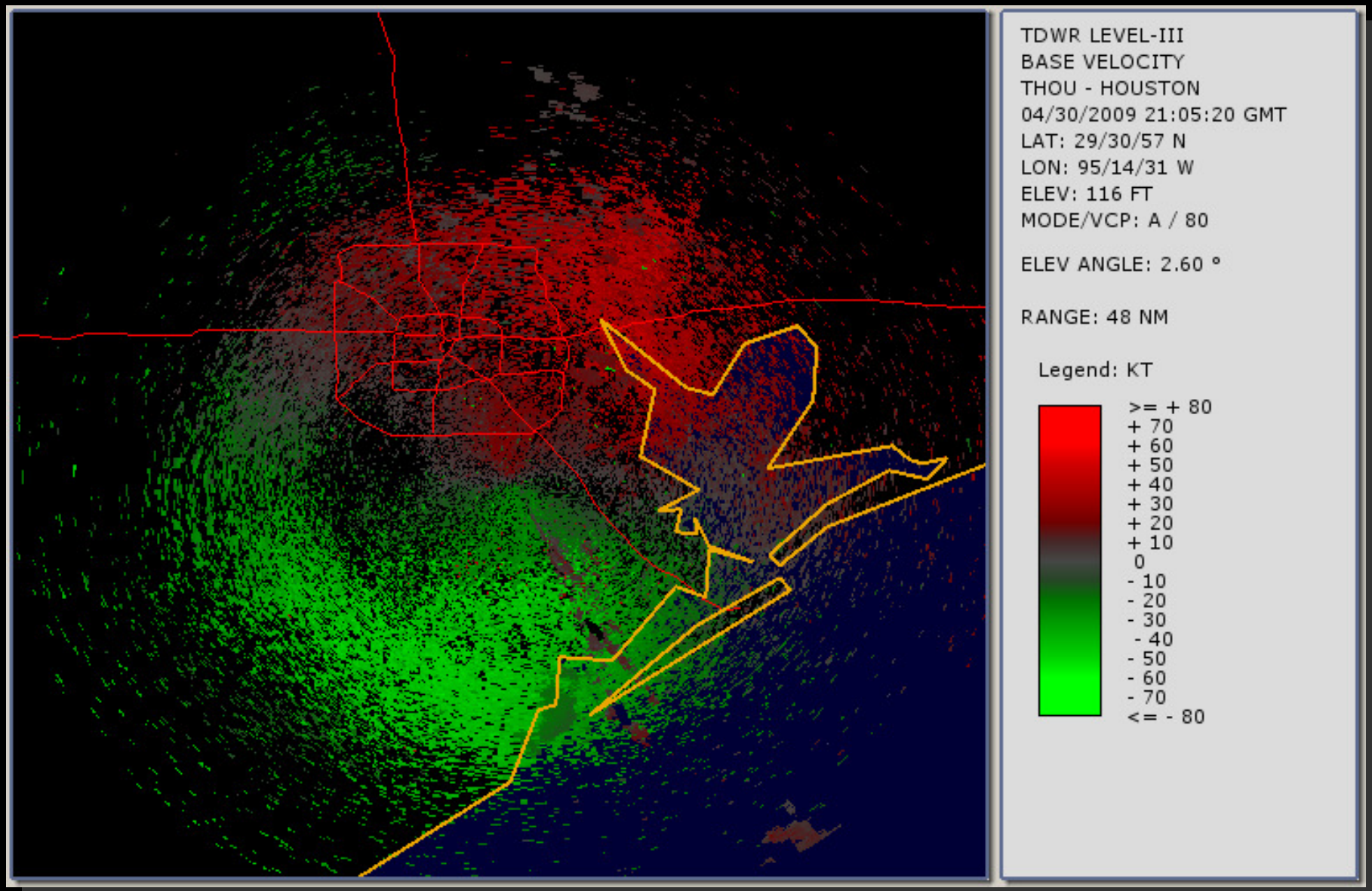
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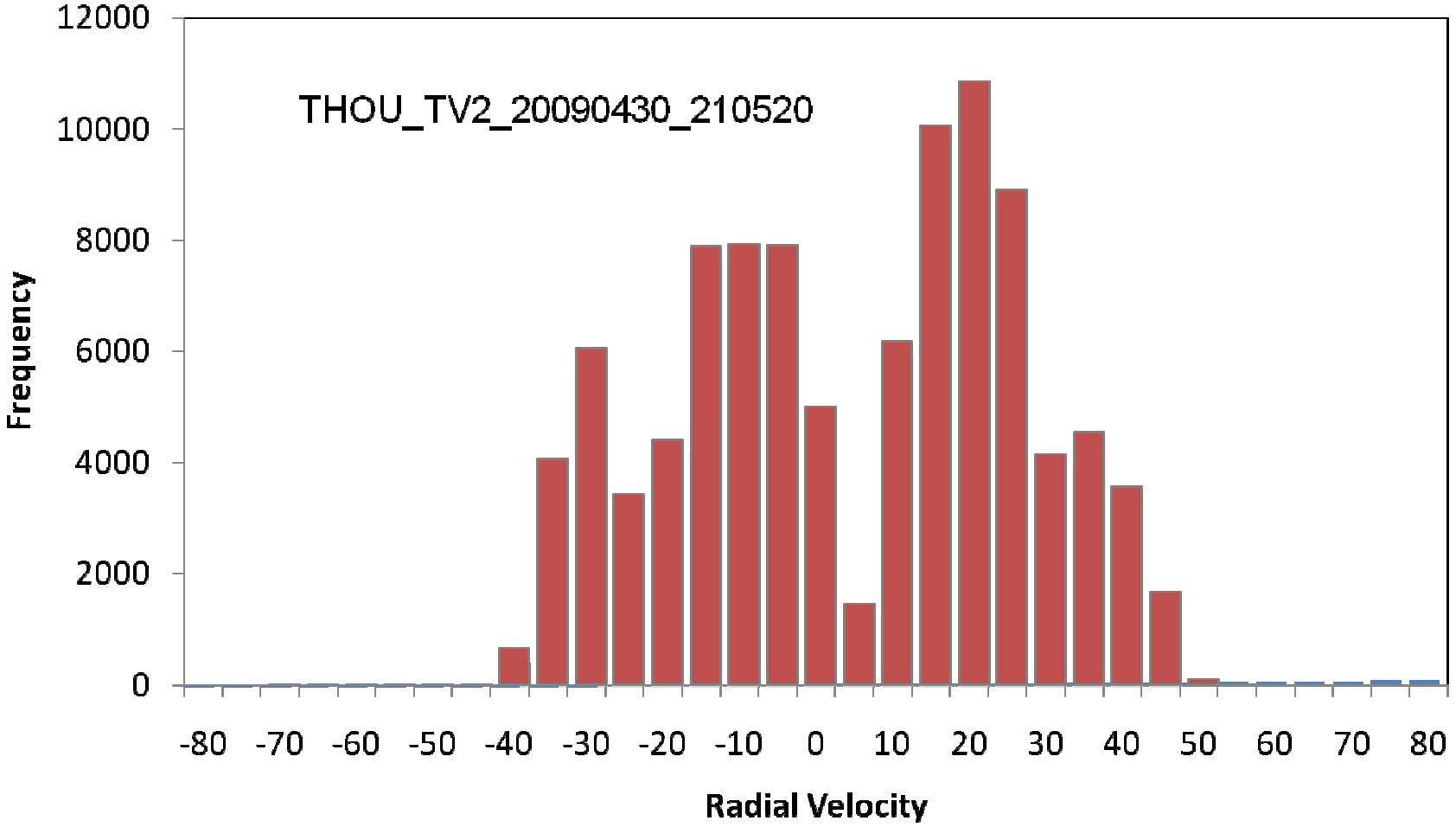
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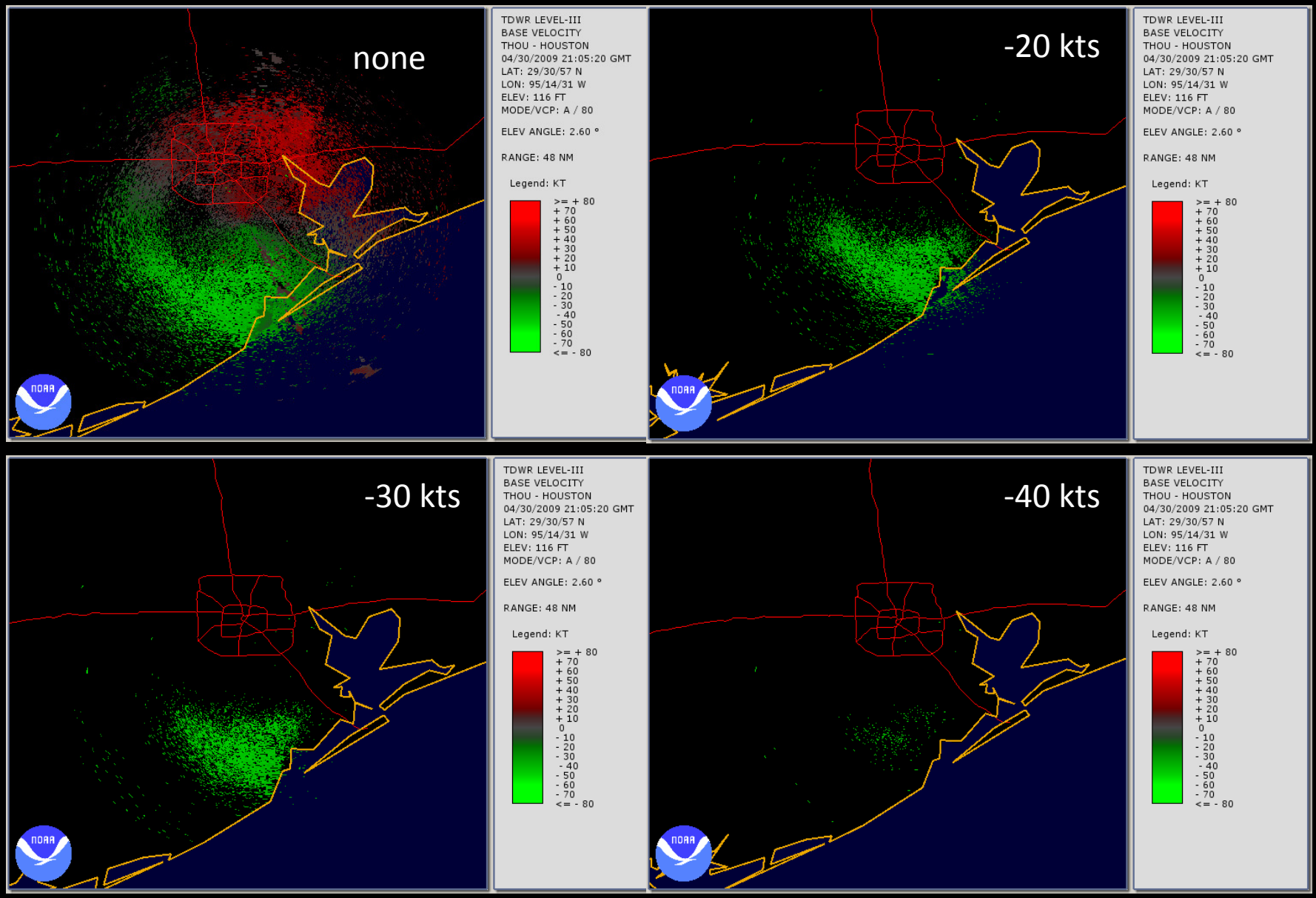
70
80
Radial Velocity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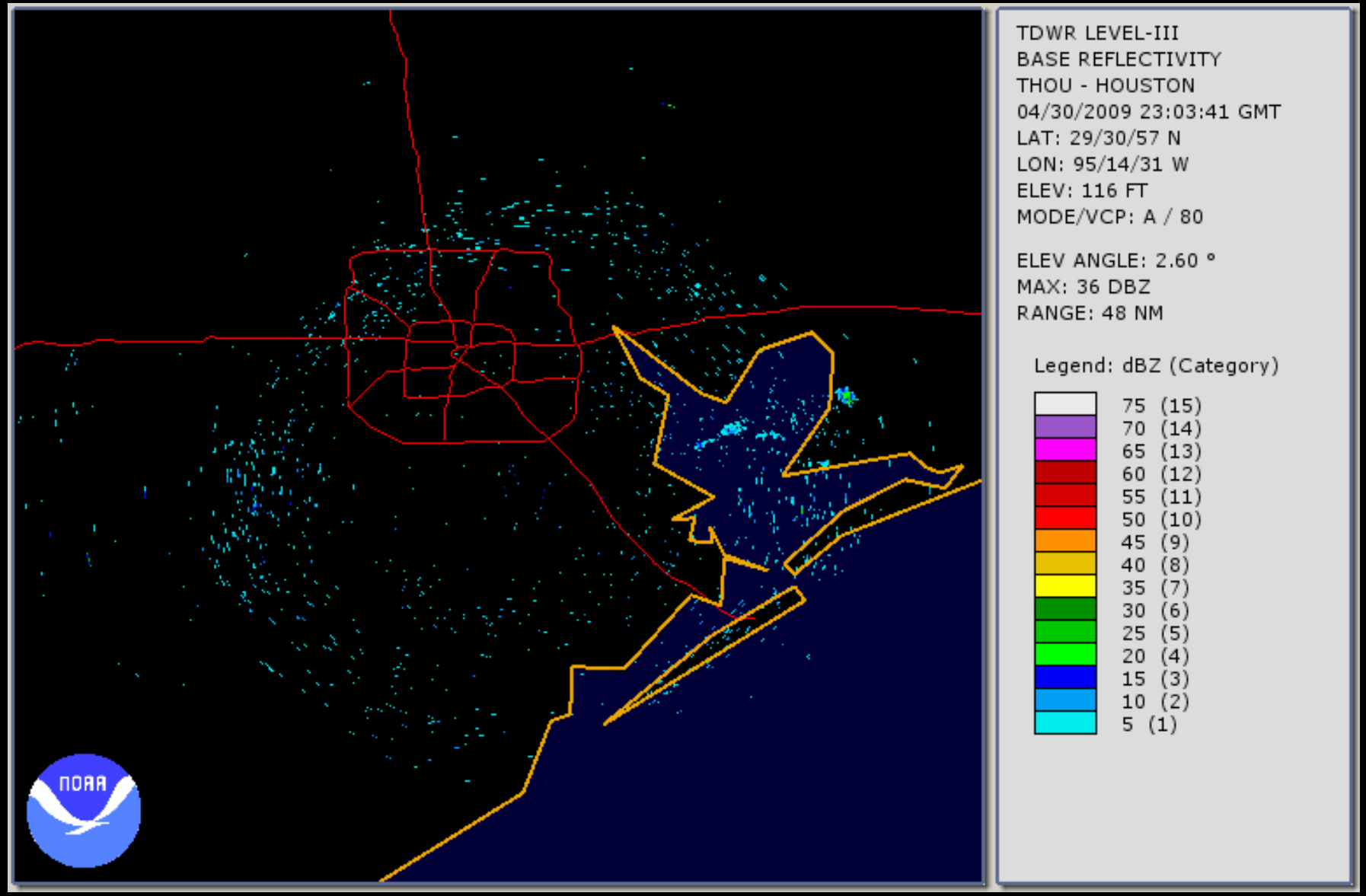
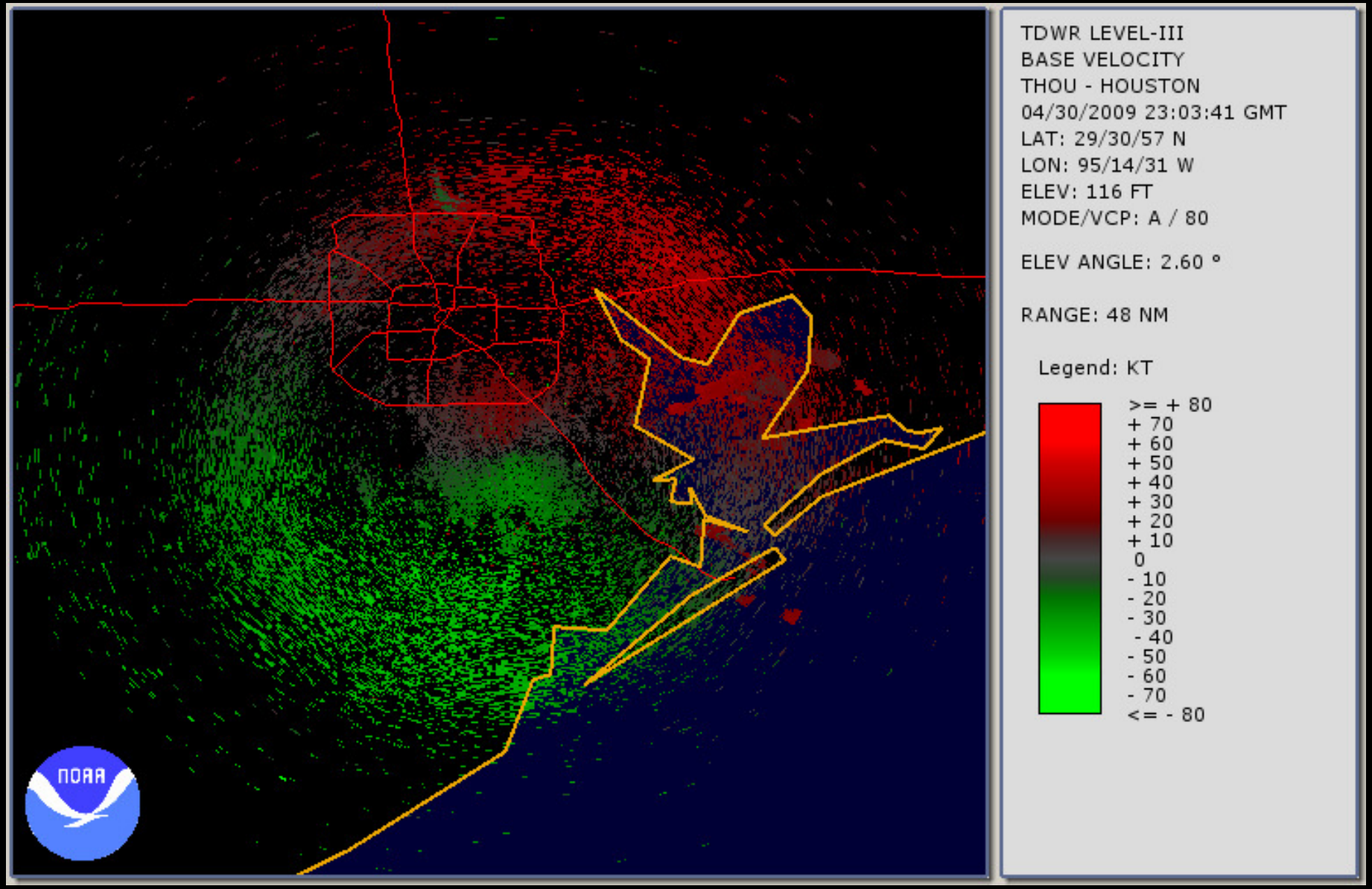
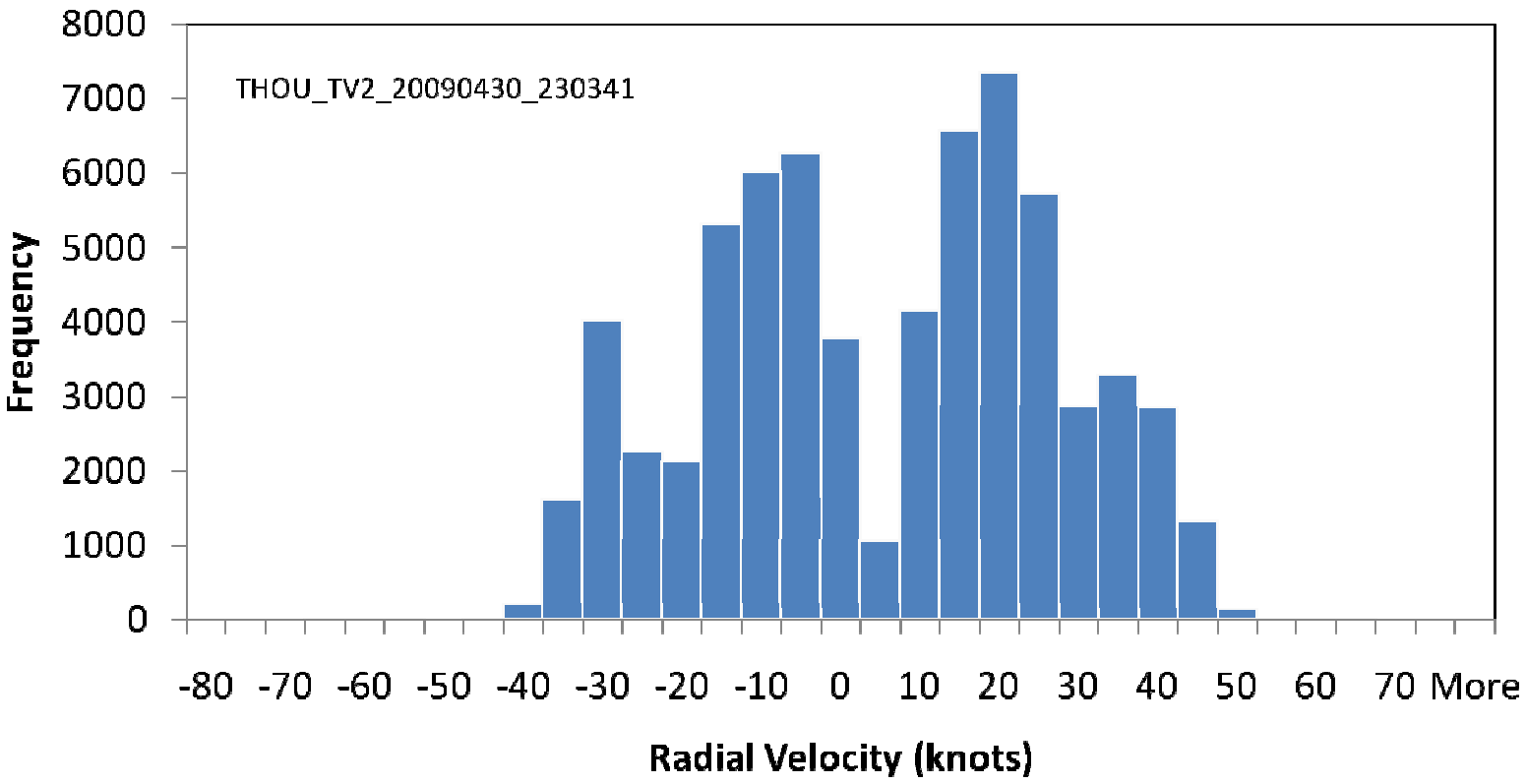
- 70
<= - 80

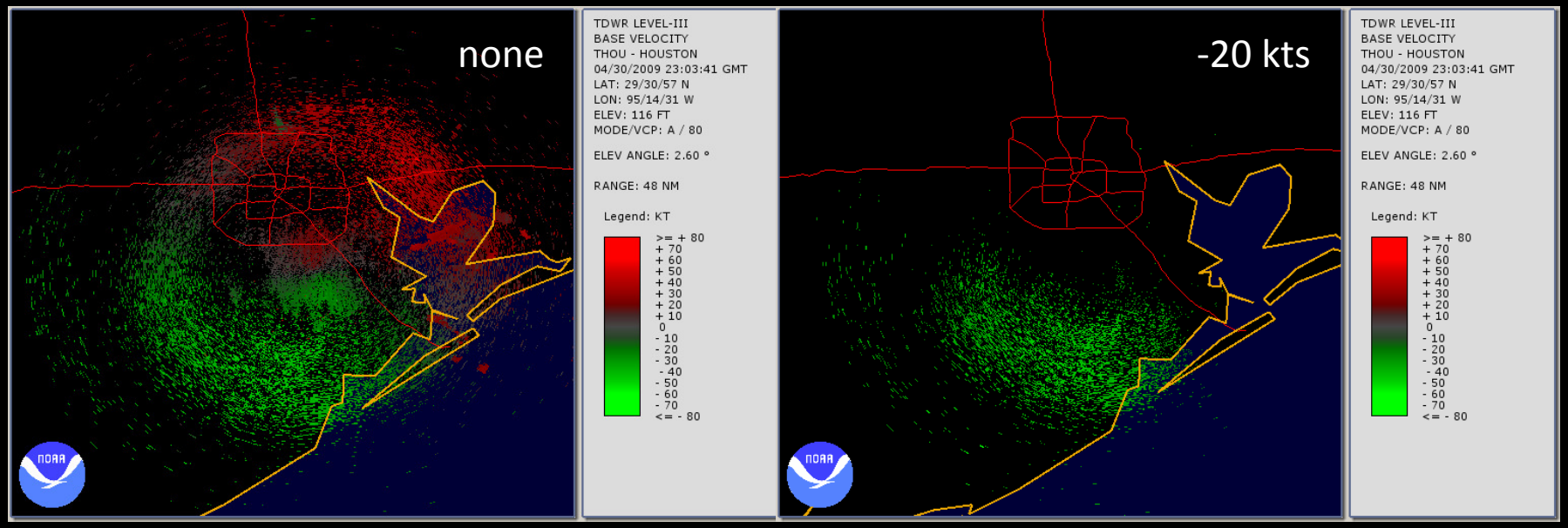

TDWR LEVEL-III
BASE REFLECTIVITY
THOU - HOUSTON
04/30/2009 23:03:41 GMT
LAT: 29/30/57 N
LON: 95/14/31 W
ELEV: 116 FT
MODE/VCP: A / 80
ELEV ANGLE: 2.60 °
MAX: 36 DBZ
RANGE: 48 NM
Legend: dBZ (Category)
75 (15)
70 (14)
65 (13)
60 (12)
55 (11)
50 (10)
45 (9)
40 (8)
35 (7)
30 (6)
25 (5)
20 (4)
15 (3)
10 (2)
5 (1)
NOAA


TDWR LEVEL-III
BASE VELOCITY
THOU - HOUSTON
04/30/2009 23:03:41 GMT
LAT: 29/30/57 N
LON: 95/14/31 W
ELEV: 116 FT
MODE/VCP: A / 80
ELEV ANGLE: 2.60 °
RANGE: 48 NM
Legend: KT
>= + 80
+ 70
+ 60
+ 50
+ 40
+ 30
+ 20
+ 10
0
- 10
- 20
- 30
- 40
- 50
- 60
- 70
<= - 80
NOAA


THOU_TV2_20090430_230341
Frequency
8000
7000
6000
5000
4000
3000
2000
1000
0
-80 -70 -60 -50 -40 -30 -20 -10 0 10 20 30 40 50 60 70 More
Radial Velocity (knots)

LCH Lake Charles Observations at 00Z 01 May 2009

PRES hPa	HGHT m	TEMP C	DWPT C	RELH %	MIXR g/kg	DRCT deg	SKNT knot	THTA K	THTE K	THTV K
1017.0	10	25.4	20.4	74	15.07	175	14	297.1	340.9	299.8
1000.0	152	23.8	20.0	79	14.95	175	18	296.9	340.3	299.6
982.7	305	22.4	19.4	84	14.69	175	18	297.0	339.6	299.6
969.0	427	21.2	19.0	87	14.49	179	18	297.0	339.1	299.6
951.0	590	20.4	17.0	81	12.98	184	18	297.8	335.7	300.1
948.8	610	20.2	16.9	81	12.96	185	18	297.8	335.6	300.1
930.0	783	18.8	16.4	86	12.77	193	19	298.1	335.4	300.4
925.0	830	19.0	16.0	83	12.51	195	19	298.7	335.4	301.0
917.0	905	19.2	14.4	74	11.37	195	20	299.7	333.2	301.7
916.0	914	19.1	14.3	74	11.31	195	20	299.7	333.1	301.7
883.9	1219	16.9	11.4	70	9.65	190	20	300.5	329.1	302.2
863.0	1423	15.4	9.4	67	8.65	190	18	301.0	326.8	302.5
850.0	1552	14.2	10.1	76	9.21	190	17	301.0	328.4	302.7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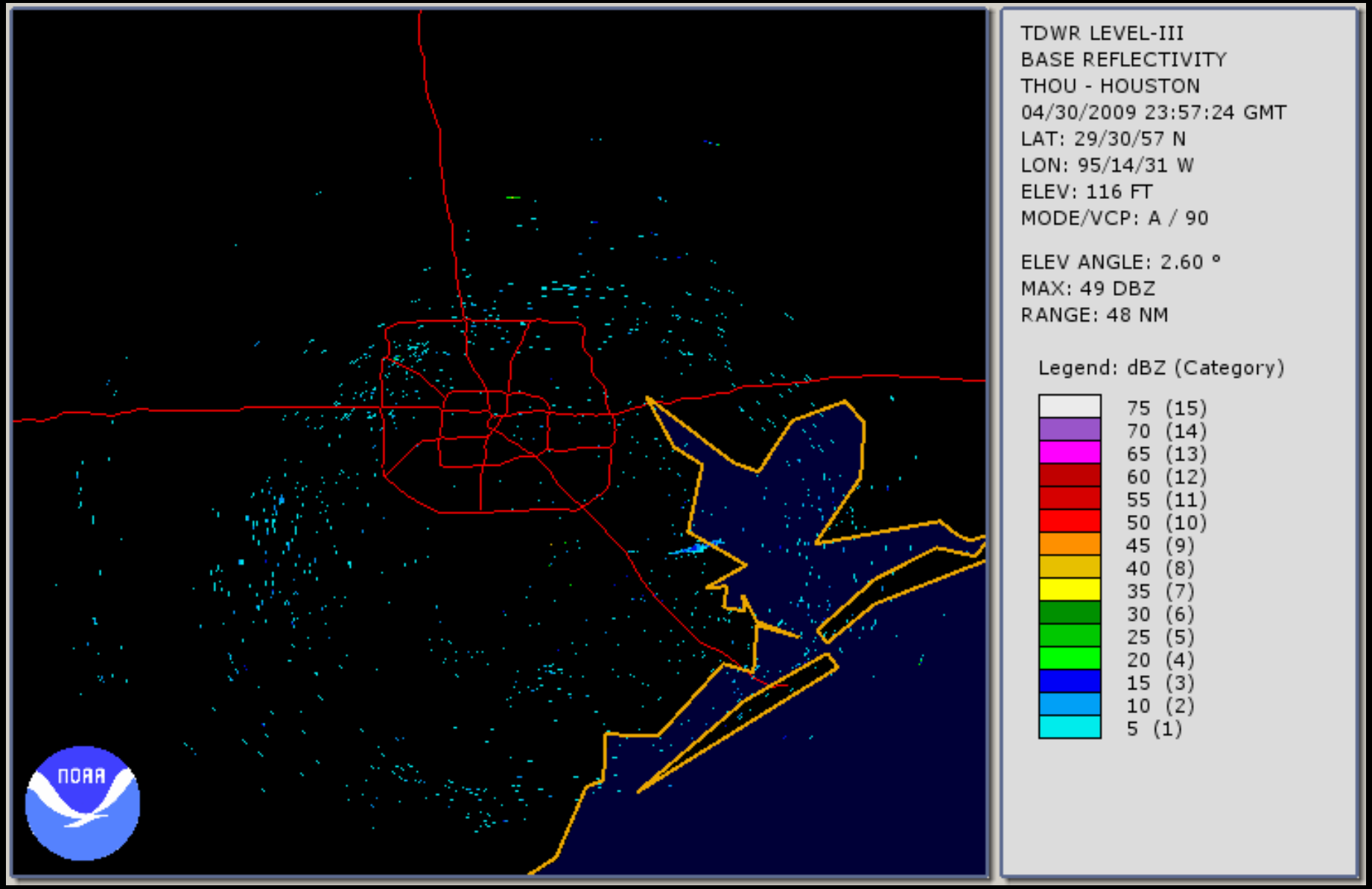
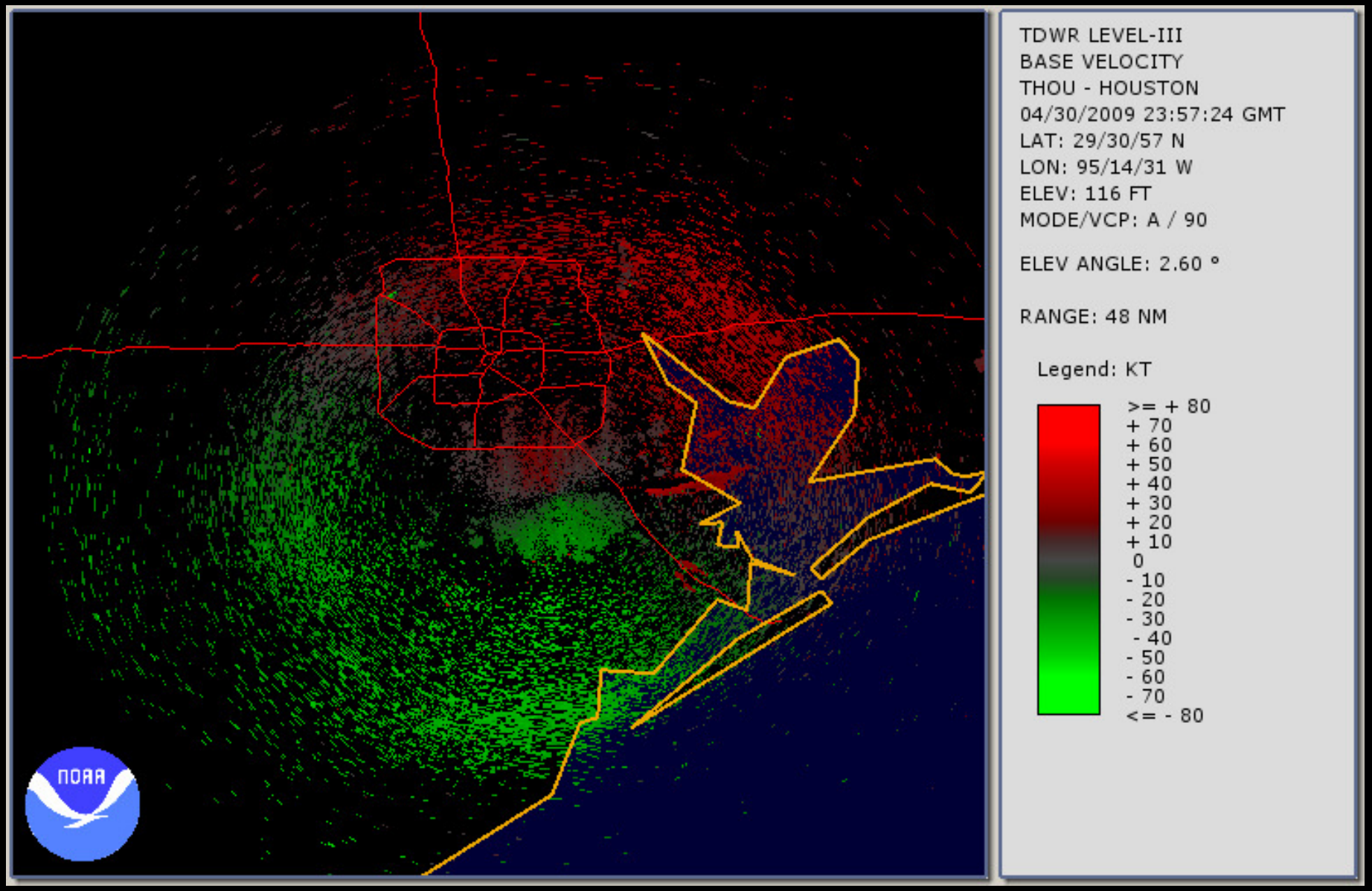
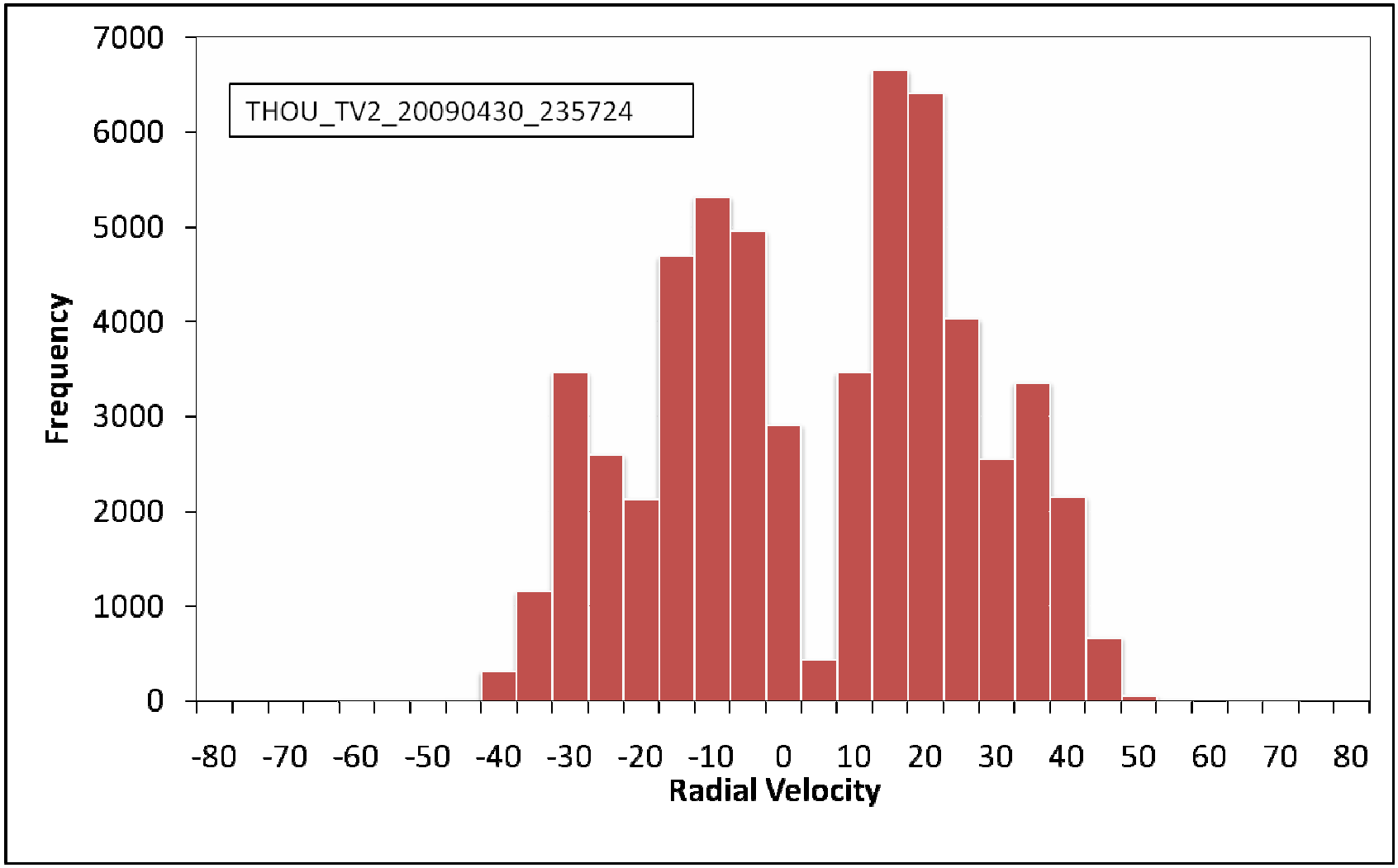
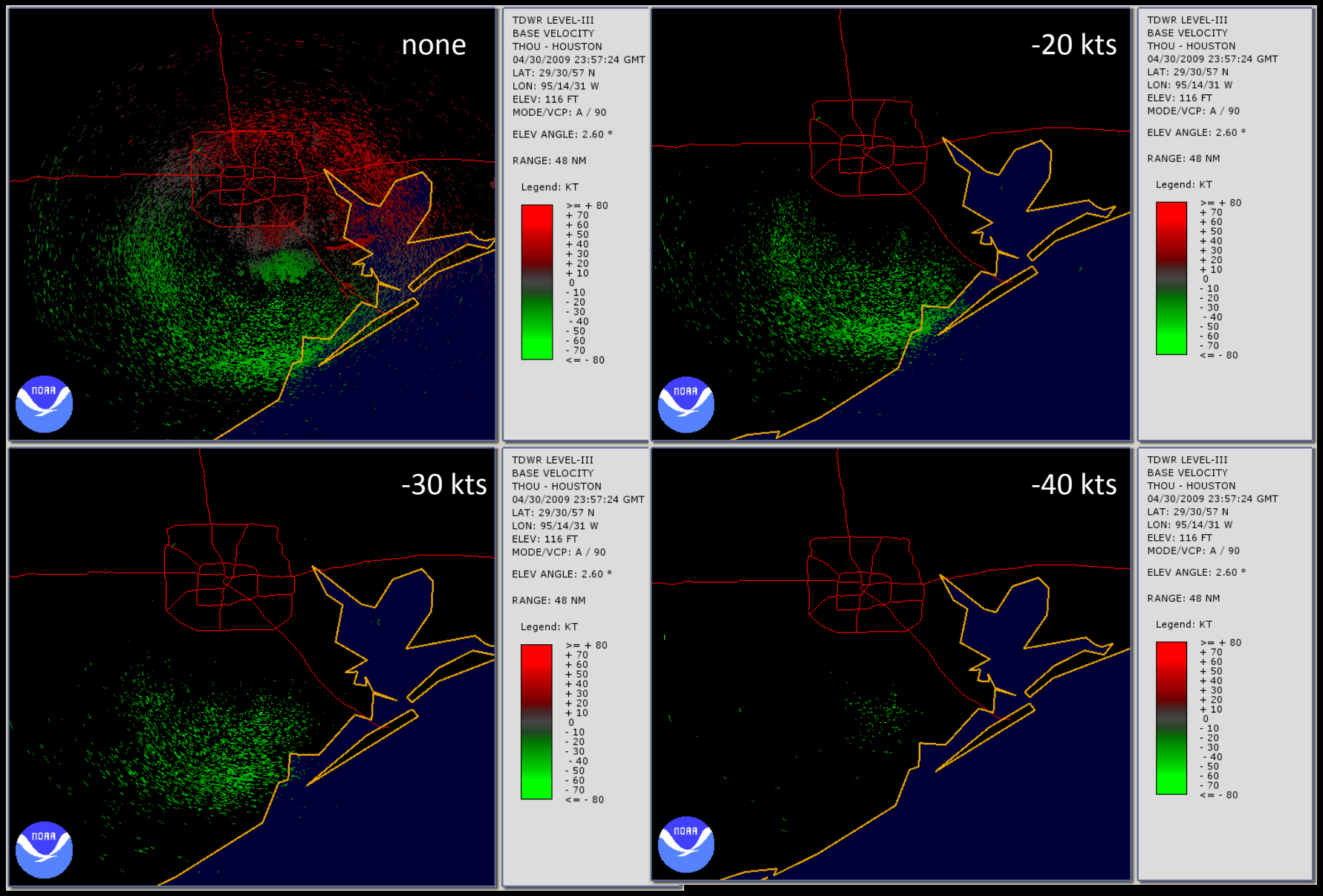
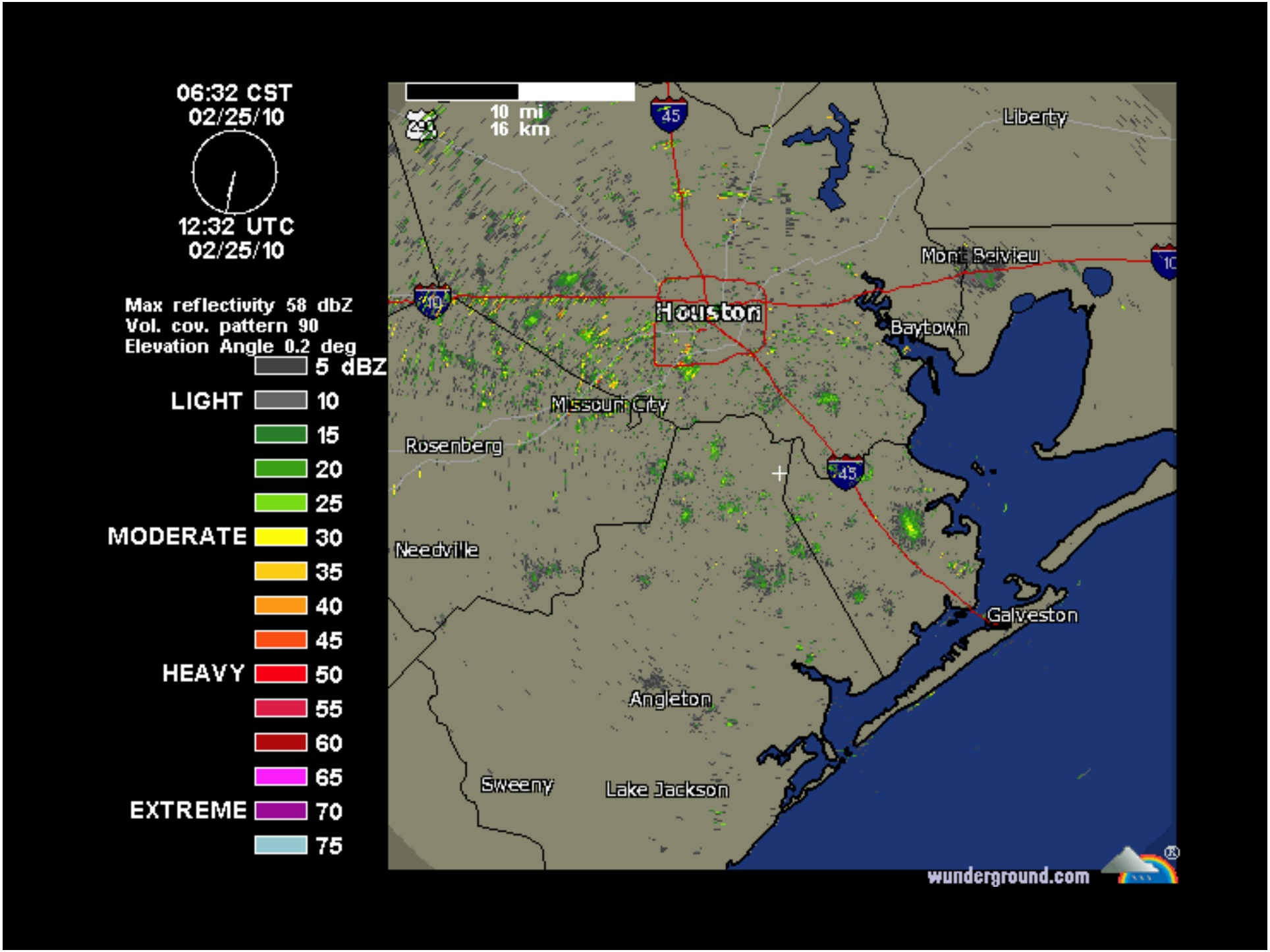
TDWR LEVEL-III
BASE VELOCITY
THOU - HOUSTON
04/30/2009 23:03:41 GMT
LAT: 29/30/57 N
LON: 95/14/31 W
ELEV: 116 FT
MODE/VCP: A / 80
ELEV ANGLE: 2.60 °
RANGE: 48 NM
Legend: KT
>= + 80
+ 70
+ 60
+ 50
+ 40
+ 30
+ 20
+ 10
0
- 10
- 20
- 30
- 40
- 50
- 60
- 70
<= - 80
-20 kts
TDWR LEVEL-III
BASE VELOCITY
THOU - HOUSTON
04/30/2009 23:03:41 GMT
LAT: 29/30/57 N
LON: 95/14/31 W
ELEV: 116 FT
MODE/VCP: A / 80
ELEV ANGLE: 2.60 °
RANGE: 48 NM
Legend: KT
>= + 80
+ 70
+ 60
+ 50
+ 40
+ 30
+ 20
+ 10
0
- 10
- 20
- 30
- 40
- 50
- 60
- 70
<= - 80
-30 kts
TDWR LEVEL-III
BASE VELOCITY
THOU - HOUSTON
04/30/2009 23:03:41 GMT
LAT: 29/30/57 N
LON: 95/14/31 W
ELEV: 116 FT
MODE/VCP: A / 80
ELEV ANGLE: 2.60 °
RANGE: 48 NM
Legend: KT
>= + 80
+ 70
+ 60
+ 50
+ 40
+ 30
+ 20
+ 10
0
- 10
- 20
- 30
- 40
- 50
- 60
- 70
<= - 80
-40 kts
TDWR LEVEL-III
BASE VELOCITY
THOU - HOUSTON
04/30/2009 23:03:41 GMT
LAT: 29/30/57 N
LON: 95/14/31 W
ELEV: 116 FT
MODE/VCP: A / 80
ELEV ANGLE: 2.60 °
RANGE: 48 NM
Legend: KT
>= + 80
+ 70
+ 60
+ 50
+ 40
+ 30
+ 20
+ 10
0
- 10
- 20
- 30
- 40
- 50
- 60
- 70
<= - 80

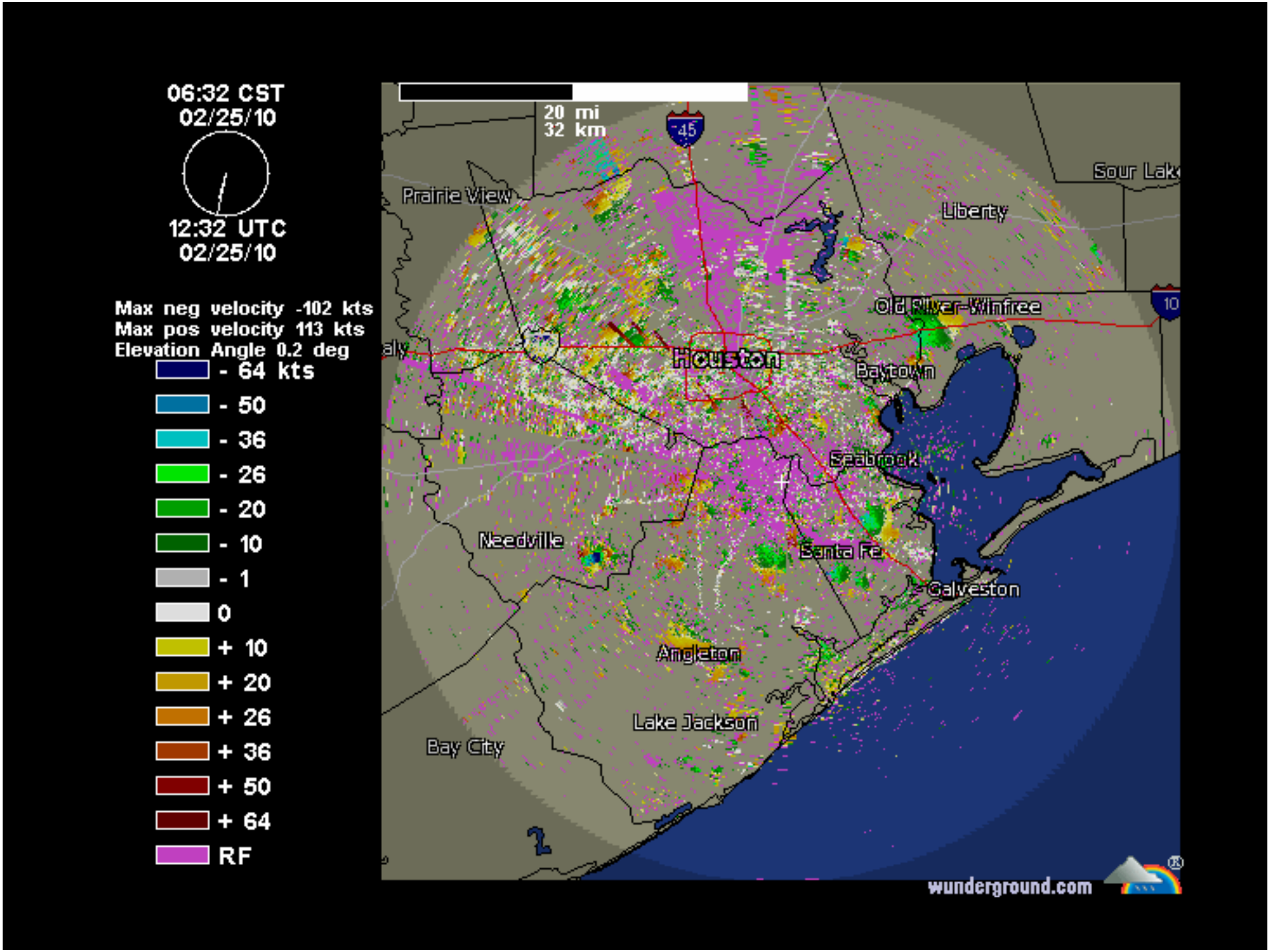

TDWR LEVEL-III
BASE REFLECTIVITY
THOU - HOUSTON
04/30/2009 23:57:24 GMT
LAT: 29/30/57 N
LON: 95/14/31 W
ELEV: 116 FT
MODE/VCP: A / 90
ELEV ANGLE: 2.60 °
MAX: 49 DBZ
RANGE: 48 NM
Legend: dBZ (Category)
75 (15)
70 (14)
65 (13)
60 (12)
55 (11)
50 (10)
45 (9)
40 (8)
35 (7)
30 (6)
25 (5)
20 (4)
15 (3)
10 (2)
5 (1)
NOAA

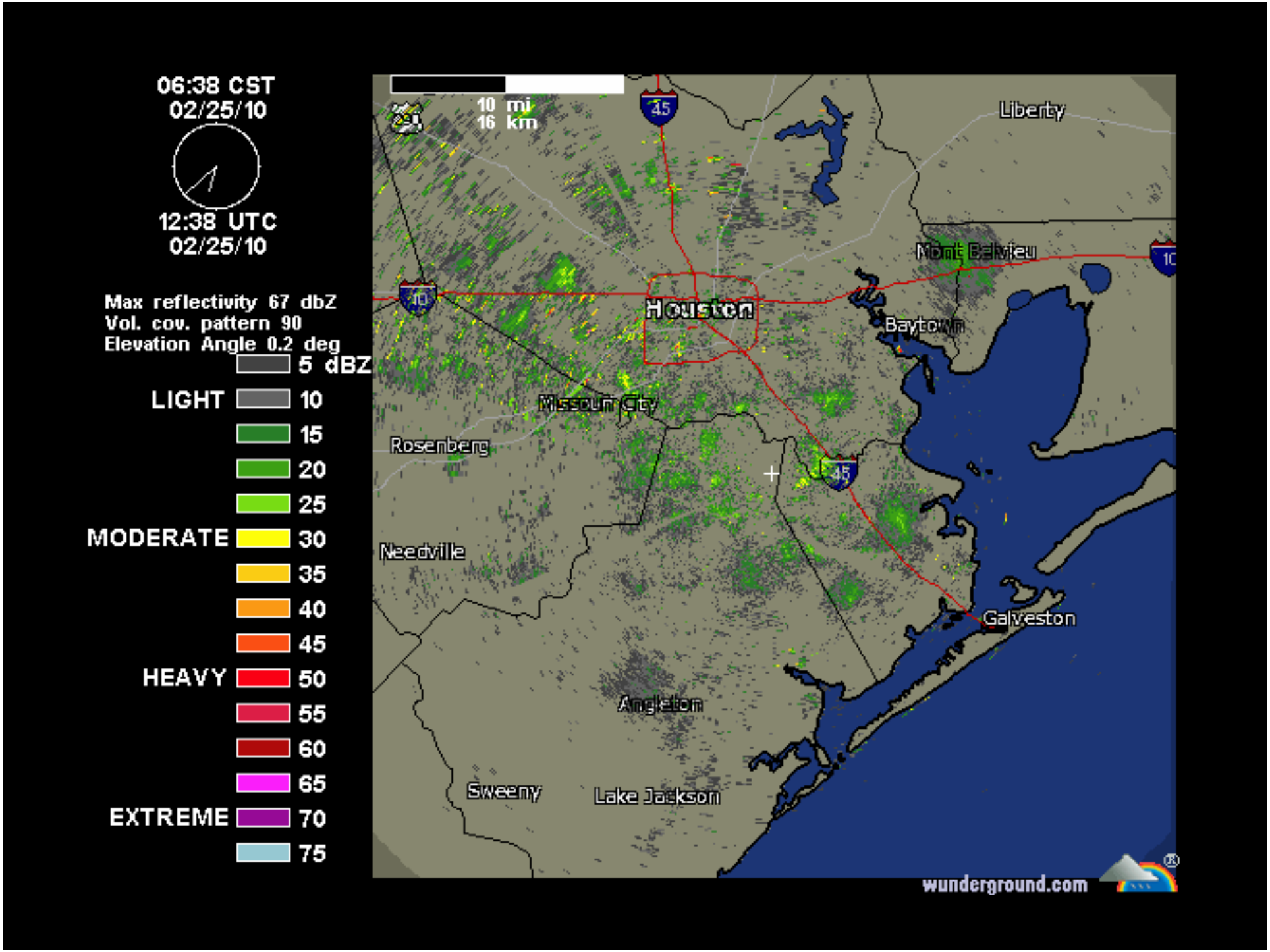

TDWR LEVEL-III
BASE VELOCITY
THOU - HOUSTON
04/30/2009 23:57:24 GMT
LAT: 29/30/57 N
LON: 95/14/31 W
ELEV: 116 FT
MODE/VCP: A / 90
ELEV ANGLE: 2.60 °
RANGE: 48 NM
Legend: KT
>= + 80
+ 70
+ 60
+ 50
+ 40
+ 30
+ 20
+ 10
0
- 10
- 20
- 30
- 40
- 50
- 60
- 70
<= - 80
NOAA

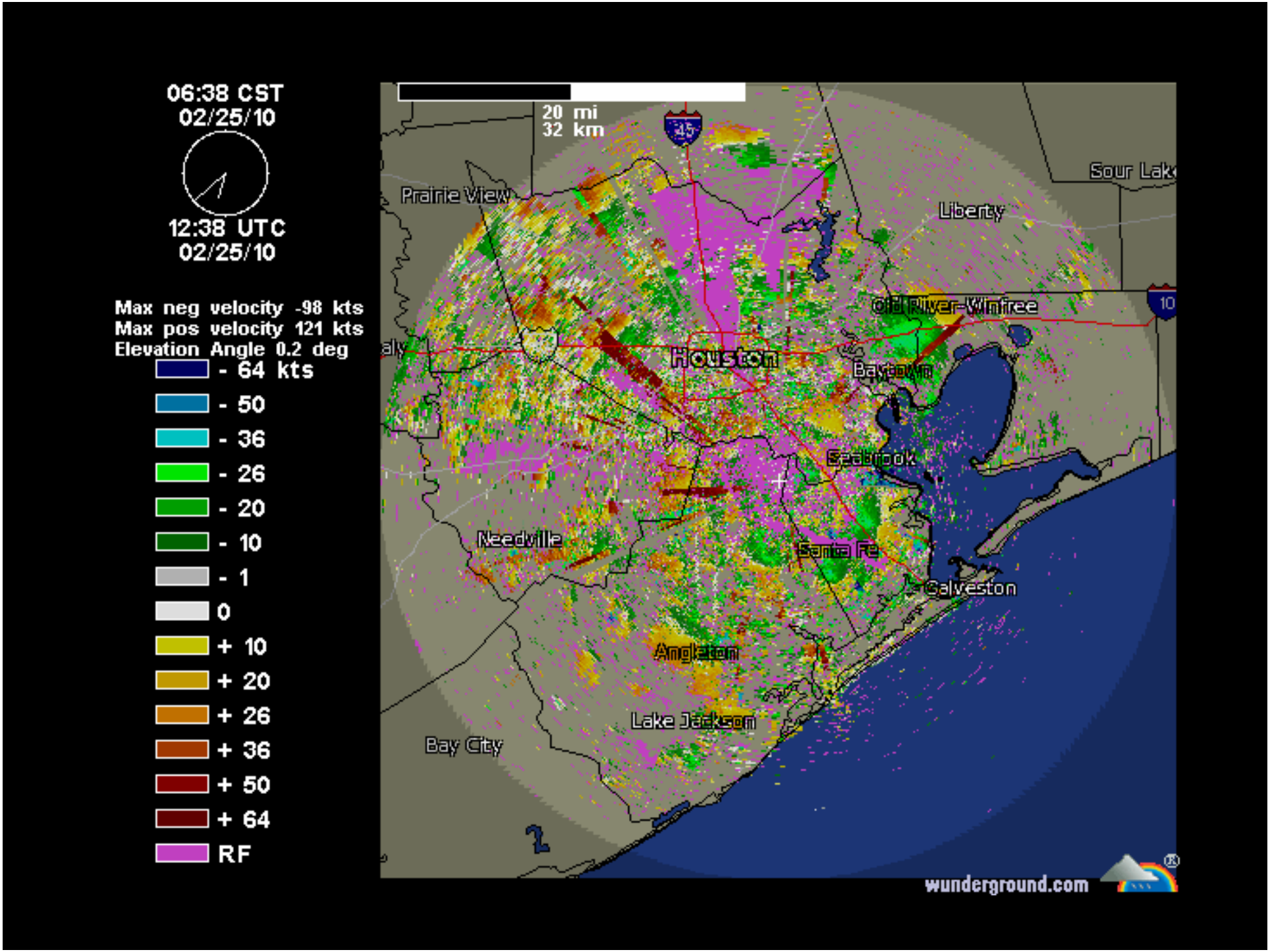

THOU_TV2_20090430_235724
Frequency
7000
6000
5000
4000
3000
2000
1000
0
-80 -70 -60 -50 -40 -30 -20 -10 0 10 20 30 40 50 60 70 80
Radial Velocity


none
TDWR LEVEL-III
BASE VELOCITY
THOU - HOUSTON
04/30/2009 23:57:24 GMT
LAT: 29/30/57 N
LON: 95/14/31 W
ELEV: 116 FT
MODE/VCP: A / 90
ELEV ANGLE: 2.60 °
RANGE: 48 NM
Legend: KT
>= + 80
+ 70
+ 60
+ 50
+ 40
+ 30
+ 20
+ 10
0
- 10
- 20
- 30
- 40
- 50
- 60
- 70
<= - 80
-20 kts
TDWR LEVEL-III
BASE VELOCITY
THOU - HOUSTON
04/30/2009 23:57:24 GMT
LAT: 29/30/57 N
LON: 95/14/31 W
ELEV: 116 FT
MODE/VCP: A / 90
ELEV ANGLE: 2.60 °
RANGE: 48 NM
Legend: KT
>= + 80
+ 70
+ 60
+ 50
+ 40
+ 30
+ 20
+ 10
0
- 10
- 20
- 30
- 40
- 50
- 60
- 70
<= - 80
-30 kts
TDWR LEVEL-III
BASE VELOCITY
THOU - HOUSTON
04/30/2009 23:57:24 GMT
LAT: 29/30/57 N
LON: 95/14/31 W
ELEV: 116 FT
MODE/VCP: A / 90
ELEV ANGLE: 2.60 °
RANGE: 48 NM
Legend: KT
>= + 80
+ 70
+ 60
+ 50
+ 40
+ 30
+ 20
+ 10
0
- 10
- 20
- 30
- 40
- 50
- 60
- 70
<= - 80
-40 kts
TDWR LEVEL-III
BASE VELOCITY
THOU - HOUSTON
04/30/2009 23:57:24 GMT
LAT: 29/30/57 N
LON: 95/14/31 W
ELEV: 116 FT
MODE/VCP: A / 90
ELEV ANGLE: 2.60 °
RANGE: 48 NM
Legend: KT
>= + 80
+ 70
+ 60
+ 50
+ 40
+ 30
+ 20
+ 10
0
- 10
- 20
- 30
- 40
- 50
- 60
- 70
<= - 80


06:32 CST
02/25/10
12:32 UTC
02/25/10
Max reflectivity 58 dbZ
Vol. cov. pattern 90
Elevation Angle 0.2 deg
5 dBZ
LIGHT
10
15
20
25
MODERATE
30
35
40
45
HEAVY
50
55
60
65
EXTREME
70
75
10 mi
16 km
Liberty
Mont Belvieu
Houston
Baytown
Missouri City
Rosenberg
Needville
Galveston
Angleton
Sweeny
Lake Jackson
wunderground.com


06:32 CST
02/25/10
12:32 UTC
02/25/10
Max neg velocity -102 kts
Max pos velocity 113 kts
Elevation Angle 0.2 deg
- 64 kts
- 50
- 36
- 26
- 20
- 10
- 1
0
+ 10
+ 20
+ 26
+ 36
+ 50
+ 64
RF
20 mi
32 km
45
Prairie View
Liberty
Sour Lake
Old River-Winfree
10
Houston
Baytown
Seabrook
Needville
Santa Fe
Galveston
Angleton
Lake Jackson
Bay City
wunderground.com


06:38 CST
02/25/10
12:38 UTC
02/25/10
Max reflectivity 67 dbZ
Vol. cov. pattern 90
Elevation Angle 0.2 deg
5 dBZ
LIGHT
10
15
20
25
MODERATE
30
35
40
45
HEAVY
50
55
60
65
EXTREME
70
75
10 mi
16 km
Liberty
Mont Belvieu
Houston
Baytown
Missouri City
Rosenberg
Needville
Galveston
Angleton
Sweeny
Lake Jackson
wunderground.com


06:38 CST
02/25/10
12:38 UTC
02/25/10
Max neg velocity -98 kts
Max pos velocity 121 kts
Elevation Angle 0.2 deg
- 64 kts
- 50
- 36
- 26
- 20
- 10
- 1
0
+ 10
+ 20
+ 26
+ 36
+ 50
+ 64
RF
20 mi
32 km
Prairie View
Liberty
Sour Lake
Old River-Winfree
Houston
Baytown
Seabrook
Needville
Santa Fe
Galveston
Angleton
Lake Jackson
Bay City
wunderground.com

CONCLUSIONS

- The TDWR readily detects migrating birds aloft and concentrations of birds within 48 nm of the airport.
- The small pulse volumes of the TDWR (greater resolution) allow better discrimination of biological targets aloft than can be done with WSR-88D.
- The radial velocity of targets in relation to winds aloft can be used to separate birds from insects, and fast flying birds from slow flying birds.

CONCLUSIONS

- Archived TDWR data on bird density and speed can be used to determine seasonal patterns of bird activity within 48 nautical miles of the airport.
- Automatic processing of TDWR data and winds aloft data could produce real time reports on bird densities within 48 nautical miles of the airport for ATC and airport operations.

GEO-MARINE GMI
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