NATIONAL TRANSPORTATION SAFETY BOARD

Office of Research and Engineering
Washington, D.C. 20594

December 20, 2007

Aircraft Performance Radar Study

by John O'Callaghan

A. ACCIDENT

Location: Sanford, FL
Date: July 10, 2007
Time: 12:35 Universal Coordinated Time (UTC)[1]
Aircraft: Cessna 310R, registration N501N
NTSB#: NYC07MA162

B. GROUP

Not Applicable

C. HISTORY OF FLIGHT

On July 10, 2007, at 12:35 UTC, a Cessna 310R, N501N, operated by the National Association for Stock Car Auto Racing (NASCAR), was destroyed during a collision with trees and structures in a residential area while attempting an emergency landing to the Sanford Orlando International Airport (SFB), Sanford, Florida. The certificated commercial pilot and the certificated airline transport pilot were fatally injured. Three people on the ground were fatally injured, and four were seriously injured. A post-crash fire consumed the airplane and two single-family homes. Visual meteorological conditions prevailed, and an instrument flight rules flight plan was filed for the personal flight that was conducted under 14 CFR Part 91. The airplane departed Daytona Beach International Airport (DAB), Florida, about 12:22, and was destined for Lakeland Linder Airport (LAL), Lakeland, Florida.

This Aircraft Performance Radar Study presents the results of using Daytona Beach Airport Surveillance Radar (ASR) data and evidence at the crash site to calculate the position and orientation of the airplane during the accident flight.

During the flight, the pilot reported to ATC that there was smoke in the cockpit, declared an emergency, and indicated that he needed to land at Sanford (SFB). ATC cleared the flight directly to Sanford. About 4.5 minutes before the pilot declared the emergency, as the airplane was climbing through 4200 ft, the secondary radar returns from the airplane's transponder were interrupted for a little over a minute. During this time, only primary radar returns from the airplane were detected.[2] The transponder returns were lost for a second time

[1] Local time at Sanford on the day of the accident was Eastern Daylight Time (EDT). EDT = UTC - 4 hours.
[2] Radar primary and secondary returns are described in Section D-I.

about 23 seconds after the pilot declared the emergency, and did not re-appear for the remainder of the flight. Primary returns were received from the airplane for another 1.5 minutes after the second loss of the transponder returns, and indicated the airplane was heading southeast towards SFB.

The airplane crashed about 0.7 nmi southwest of the last primary return, and the debris path indicated the airplane was on a westerly heading at the time. Hence, the airplane must have made a hard-right turn in the time between the last primary return and its impact with terrain.

The sections that follow present the radar data and crash site information used in this Study, and describe the methods used to calculate a possible flight path that is consistent with the radar data and the location and trajectory of the airplane at the crash site.

D. DETAILS OF THE INVESTIGATION

I. Airplane position based on radar data

Description of ARSR and ASR Radar Data

In general, two types of radar are used to provide position and track information for aircraft cruising at high altitudes between airport terminal airspaces, and for those operating at low altitude and speeds within terminal airspaces.

Air Route Surveillance Radars (ARSRs) are long range (250 NM) radars used to track aircraft cruising between terminal airspaces. ARSR antennas rotate at 5 to 6 RPM, resulting in a radar return every 10 to 12 seconds. Airport Surveillance Radars (ASRs) are short range (60 NM) radars used to provide air traffic control services in terminal areas. ASR antennas rotate at 13 to 14 RPM, resulting in a radar return every 4.3 to 4.6 seconds. Radar returns from N501N were recorded by the Melbourne ARSR (MLB) and a number of ASRs in the area, including Daytona Beach (DAB), Orlando (MCO), and Cocoa Beach (COF). The DAB ASR-9 provided the most comprehensive coverage for the flight, and the data from this ASR is used for the trajectory and performance calculations presented in this Study.

Primary and Secondary Radar Returns

A radar detects the position of an object by broadcasting an electronic signal that is reflected by the object and returned to the radar antenna. These reflected signals are called *primary returns.* Knowing the speed of the radar signal and the time interval between when the signal was broadcast and when it was returned, the distance, or range, from the radar antenna to the reflecting object can be determined. Knowing the direction the radar antenna was pointing when the signal was broadcast, the direction (or bearing, or azimuth) from the radar to the object can be determined. Range and azimuth from the radar to the object define the object's position.

The strength or quality of the return signal from the object depends on many factors, including the range to the object, the object's size and shape, and atmospheric conditions. In addition, any object in the path of the radar beam can potentially return a signal, and a reflected signal contains no information about the identity of the object that reflected it. Many times, these difficulties make distinguishing individual aircraft from each other and other objects (e.g., flocks of birds) based on primary returns alone unreliable and uncertain.

To improve the consistency and reliability of radar returns, aircraft are equipped with transponders that sense beacon interrogator signals broadcast from radar sites, and in turn broadcast a response signal. Thus, even if the radar site is unable to sense a weak reflected signal (primary return), it will sense the response signal broadcast by the transponder and be able to determine the aircraft position. The response signal can also contain additional information, such as the identifying “beacon code” for the aircraft, and the aircraft’s pressure altitude (also called “Mode C” altitude). Transponder signals received by the radar site are called *secondary returns*. N501N was assigned a beacon code of 1531.

As mentioned above, about 4.5 minutes before the pilot declared the emergency, as the airplane was climbing through 4200 ft, the secondary radar returns from the airplane’s transponder were interrupted for a little over a minute. During this time, only primary radar returns from the airplane were detected. The transponder returns were lost for a second time about 23 seconds after the pilot declared the emergency, and did not re-appear for the remainder of the flight. Primary returns were received from the airplane for another 1.5 minutes after the second loss of the transponder returns, and indicated the airplane was heading southeast towards SFB.

Recorded Radar Data

Recorded data from the DAB ASR-9 was obtained from the FAA, and includes the following parameters:

- UTC time of the radar return, in hours, minutes, and seconds.
- Transponder beacon code associated with the return (secondary returns only)
- Transponder reported altitude in hundreds of feet associated with the return (secondary returns only). The transponder reports pressure altitude. The altitude recorded in the file depends on the site recording the data; some sites record both pressure altitude, and pressure altitude adjusted for altimeter setting (MSL altitude). Others record just the adjusted altitude. The DAB file contains both altitudes. The altimeter setting for the time of the accident (30.13 “Hg) resulted in the pressure altitude being 200 ft lower than the MSL altitude. The resolution of this data is ± 50 ft.
- Slant Range from the radar antenna to the return, in nmi. The accuracy of this data is ± 1/16 nmi or about ± 380 ft.
- Azimuth relative to magnetic north from the radar antenna to the return[3]. The DAB ASR-9 azimuth is reported in Azimuth Change Pulses (ACPs). ACP values range from 0 to 4096, where 0 = 0° magnetic and 4096 = 360° magnetic. Thus, the azimuth to the target in degrees would be:

  (Azimuth in degrees) = (360/4096) x (Azimuth in ACPs) = (0.08789) x (Azimuth in ACPs)

  The accuracy of azimuth data is ± 2 ACP or ± 0.176º.

To determine the latitude and longitude of radar returns from the range and azimuth data recorded by the radar, the geographic location of the radar antenna must be known[4]. The coordinates of the DAB antenna are:

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[3] The magnetic variation used by the DAB ASR-9 radar to determine magnetic azimuth is 4° W.
[4] The DAB data file also contains latitude and longitude as computed by the radar system algorithms.

29° 10' 21.510" N latitude; 081° 11' 31.980" W longitude; elevation 37.0 feet

Presentation of the Radar Data

To calculate performance parameters from the radar data (such as ground speed, track angle, pitch and roll angles, etc.), it is convenient to express the position of the airplane in rectangular Cartesian coordinates. The Cartesian coordinate system used in this study is centered at the DAB ASR-9 antenna and its axes extend east, north, and up from the center of the Earth. The data from the DAB radar is converted into this coordinate system for plotting and performance calculations. Latitude and longitude coordinates are transformed into this coordinate system using the WGS84 ellipsoid model of the Earth.

Figures 1-3 show the DAB ASR-9 data plotted in terms of nautical miles north and east of the radar antenna, and indicates the position of the airplane at the time of selected ATC communications (the complete list of ATC communications is shown in Table 2). Figure 1 shows the data with a Cartesian grid background; Figure 2 shows the data with a topographical map background; and Figure 3 shows the data with a Google Earth satellite image background. Each of these figures shows the data at a large scale (the “a” Figures) and at a smaller scale at the end of the flight (the “b” Figures). The north and east positions are shown as a function of time in Figures 4a and 4b.

The altitude of the airplane, as determined from the Mode C transponder returns, is shown as a function of time in Figure 5a. A smooth curve through the altitude data, that also serves as an estimate of the airplane’s altitude during the portions of the flight during which Mode C data is not available, is also shown in the Figure. This smoothed altitude estimate is the basis of the altitude labels shown in Figures 1-3. The break in the smooth curve at time 12:33:30 is the result of analyzing the descent in two segments. Figure 5b shows the estimated altitude of the airplane during the last portion of the flight, during which there is no Mode C data. This altitude estimate is based on an extrapolation of the initial rate of descent of the airplane as determined from Mode C data, and on a rate of descent and groundspeed that is consistent with the DAB ASR-9 primary returns and the power-off performance of the airplane as determined from a three-degree-of-freedom (3-DOF) simulation of the descent and final turn to the crash site (this simulation is described further in Section D-III).

The DAB ASR-9 data, along with the latitude and longitude, and north and east coordinates calculated for each radar return, are presented in tabular form in Table 1.

Uncertainty in the radar returns leads to unrealistic noisiness in performance calculations, such as speed and track angle, using the raw radar data. To reduce the noisiness and obtain a better estimate of performance, the radar data is smoothed using a running-average method. Airplane performance parameters are calculated based on this smoothed data, as described below. The smoothed data also includes an extrapolation of the flight path to the crash site, providing an estimate of the possible trajectory following the final primary hit. A physics-based estimate of airplane performance during the final descent and turn towards the crash site is provided by the 3-DOF simulation of this maneuver, as described below.

II. Crash site information

The latitude and longitude coordinates of the crash site, and of significant elements of the debris path at the site, were recorded on-scene by NTSB investigators. This information is presented here in Table 3, and graphically in Figure 6. The debris path shown in Figure 6 follows an initial track angle of about 251º. Note that the final primary hit from the airplane is about 0.7 nmi to the northeast, and is consistent with a true track angle of about 155º. Hence, the airplane must have turned to the right through about 96º following the final primary return.

III. Airplane performance calculations

The smoothed DAB ASR-9 data described in Section D-I was used to calculate airplane performance parameters during the flight, including speeds and Euler (pitch, roll, and heading) angles, assuming coordinated (zero-sideslip) flight. Wind data was also used, and is presented in Figure 6[5]. Aerodynamic lift and drag characteristics for the flaps-up C310, obtained from Cessna, together with an airplane weight of 4,500 lb. and a wing area of 179.2 ft^2, were also used in the calculations. The results are shown in Figures 8-9.

As mentioned above, the difference in the location and track of the last primary returns and the crash site debris path indicate that, after the last primary return, the airplane must have turned 96º to the right. To compute a physics-based trajectory that is consistent with the primary data and the evidence at the crash site, a 3-DOF simulation was used to match a smooth flight path leading from the last primary return to the crash site. The simulation uses the flaps-up lift and drag characteristics of the C310, assumes the power is off during the final descent, and assumes coordinated flight. The simulation adjusts the pitch angle to match the target altitude, and adjusts roll angle to match the target ground track. The target ground track and altitude are defined by the "smooth trajectory through radar hits" line shown in Figures 1-5. The lift and drag forces on the airplane are computed, and then the resulting accelerations are determined and integrated to yield a physically-realizable flight path. The simulation results are shown as the "based on 3 DOF simulation" lines in the Figures.

The speeds and Euler angles from the simulation results are plotted in Figures 8-9. These results indicate that a bank angle on the order of 68º was required to make the turn from the final primary return to the crash site.

Figure 10 shows a three-dimensional view of the flight path of the airplane, including the right turn from the descent towards SFB to the crash site. An image of an airplane (not to scale or representative of a C310) is shown every two seconds along this flight path, oriented per the pitch, roll, and heading angles computed using the 3-DOF simulation.

[5] The wind data presented in Figure 6 is from a model sounding at 12:00:00 UTC obtained from the National Oceanic and Atmospheric Administration (NOAA) Air Resources Laboratory (ARL) and based on the National Weather Service (NWS) National Centers for Environmental Prediction (NCEP) North American Mesoscale (NAM) numerical weather model.

E. CONCLUSIONS

This Aircraft Performance Radar Study presents the results of using Daytona Beach Airport Surveillance Radar (ASR) data and evidence at the crash site to calculate the position and orientation of the airplane during the accident flight.

N501N was first detected by radar at 12:23:07 as it was climbing through 1100 ft. At about 12:23:30, the airplane turned southwest, climbing normally at about 600 ft/min and 105 KCAS. At 12:28:22, as N501N was climbing through 4200 ft at about 135 KCAS, its transponder signal was lost, and the radar tracked the airplane by primary returns only. The transponder signal returned at 12:29:36, as N501N was climbing through 4900 ft. While the transponder signal was lost, primary data indicated that N501N turned briefly to the west, and then turned back to the southwest shortly before the transponder signals returned.

The pilot contacted Orlando International Satellite Radar North (STN) at 12:30:04 and reported climbing through 5200 ft for 6000 ft. STN acknowledged, gave N501N the current altimeter setting, and asked for the airplane's destination, which the pilot provided. At 12:31:30 N501 leveled off at 6000 ft and was accelerating through 130 KCAS. At 12:32:35 STN instructed N501 to fly a heading of 250º. The pilot did not acknowledge this instruction, but at 12:32:49 informed STN that there was smoke in the cockpit, declared an emergency, and stated he needed to land at Sanford. At this point N501 had accelerated to about 155 KCAS, and started a descent. STN immediately cleared N501 to Sanford and to descend to 2000 ft. The pilot acknowledged the clearance. At 12:33:13, N501N was descending through 5200 ft at about 2400 ft/min and accelerating through 165 KCAS, and was turning to a heading of 150º towards Orlando Sanford International Airport (SFB), about 8 nmi to the southeast, when the last transponder signal was received from the airplane. Primary returns from N501N were received through 12:34:45, showing the airplane maintaining a 150º course towards SFB. The primary returns indicated N501N achieved a maximum ground speed of about 210 kts, and a maximum airspeed of about 195 KCAS, prior to the end of the data.

Since there is no altitude information associated with primary data, the altitude of N501N after 12:34:45 is unknown. For this Study, an altitude time-history was estimated based on the power-off performance of the Cessna 310, the ground track indicated by the primary data, and the location of the crash site. This altitude estimate indicates that N501N may have achieved descent rates of up to 3500 ft/min prior to the final primary return at 12:34:45.

The airplane crashed about 0.7 nmi southwest of the last primary return, and the debris path indicated the airplane was on a westerly heading at the time. Hence, the airplane must have made a hard-right turn in the time between the last primary return and its impact with terrain. To compute a physics-based trajectory that is consistent with the primary data and the evidence at the crash site, a 3-DOF simulation was used to match a smooth flight path leading from the last primary return to the crash site. The simulation results suggest that a 68º bank was required to complete the turn, and that the airplane impacted terrain at about 200 KCAS and descending at about 4700 ft/min.

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Time UTC	Range nmi	Azimuth ACPs	Altitude MSL ft	N Latitude	W Longitude	Dist N of DAB, nmi	Dist E of DAB, nmi
12:23:06.7	5.19	1111	1100	29º 10' 01.5"	081º 05' 37.2"	-0.33	5.18
12:23:11.3	5.06	1118	1200	29º 09' 58.8"	081º 05' 46.4"	-0.38	5.04
12:23:16.0	4.94	1126	1200	29º 09' 55.7"	081º 05' 55.0"	-0.43	4.92
12:23:20.6	4.83	1134	1200	29º 09' 52.7"	081º 06' 02.8"	-0.48	4.80
12:23:25.2	4.70	1143	1300	29º 09' 49.6"	081º 06' 12.2"	-0.53	4.67
12:23:29.8	4.59	1153	1400	29º 09' 46.2"	081º 06' 20.4"	-0.59	4.55
12:23:34.5	4.47	1162	1400	29º 09' 43.4"	081º 06' 29.1"	-0.63	4.42
12:23:39.1	4.38	1174	1500	29º 09' 39.4"	081º 06' 36.1"	-0.70	4.32
12:23:43.7	4.27	1188	1500	29º 09' 35.1"	081º 06' 44.6"	-0.77	4.19
12:23:48.4	4.19	1204	1600	29º 09' 29.9"	081º 06' 51.5"	-0.86	4.09
12:23:53.0	4.12	1222	1700	29º 09' 24.1"	081º 06' 57.9"	-0.95	4.00
12:23:57.6	4.09	1241	1700	29º 09' 17.6"	081º 07' 02.0"	-1.06	3.94
12:24:02.2	4.06	1262	1800	29º 09' 10.6"	081º 07' 06.5"	-1.18	3.87
12:24:06.9	4.05	1283	1800	29º 09' 03.3"	081º 07' 09.9"	-1.30	3.83
12:24:11.6	4.03	1304	1900	29º 08' 56.4"	081º 07' 14.3"	-1.41	3.76
12:24:16.2	4.03	1327	1900	29º 08' 48.4"	081º 07' 17.8"	-1.55	3.71
12:24:20.8	4.03	1349	1900	29º 08' 41.0"	081º 07' 21.6"	-1.67	3.65
12:24:25.5	4.03	1372	2000	29º 08' 33.3"	081º 07' 25.9"	-1.80	3.59
12:24:30.1	4.05	1395	2000	29º 08' 25.2"	081º 07' 29.1"	-1.93	3.54
12:24:34.7	4.08	1418	2100	29º 08' 16.9"	081º 07' 32.3"	-2.07	3.50
12:24:39.4	4.11	1440	2100	29º 08' 08.9"	081º 07' 35.5"	-2.20	3.45
12:24:44.0	4.14	1463	2200	29º 08' 00.6"	081º 07' 39.3"	-2.34	3.40
12:24:48.6	4.17	1486	2200	29º 07' 52.4"	081º 07' 43.5"	-2.48	3.34
12:24:53.2	4.22	1508	2200	29º 07' 43.9"	081º 07' 46.7"	-2.62	3.29
12:24:57.9	4.27	1529	2300	29º 07' 35.7"	081º 07' 50.0"	-2.76	3.24
12:25:02.6	4.33	1550	2300	29º 07' 27.1"	081º 07' 53.2"	-2.90	3.19
12:25:07.2	4.39	1571	2400	29º 07' 18.5"	081º 07' 56.8"	-3.04	3.14
12:25:11.9	4.45	1592	2400	29º 07' 09.9"	081º 08' 00.7"	-3.18	3.08
12:25:16.4	4.53	1612	2400	29º 07' 00.7"	081º 08' 03.8"	-3.34	3.04
12:25:21.1	4.61	1631	2500	29º 06' 51.9"	081º 08' 07.1"	-3.48	2.99
12:25:25.7	4.69	1650	2500	29º 06' 43.0"	081º 08' 10.7"	-3.63	2.94
12:25:30.3	4.78	1668	2600	29º 06' 34.0"	081º 08' 13.9"	-3.78	2.89
12:25:35.0	4.88	1685	2600	29º 06' 24.6"	081º 08' 16.7"	-3.94	2.85
12:25:39.7	4.95	1702	2700	29º 06' 16.8"	081º 08' 21.1"	-4.07	2.79
12:25:44.3	5.05	1718	2700	29º 06' 07.7"	081º 08' 24.3"	-4.22	2.74
12:25:48.9	5.16	1733	2700	29º 05' 58.3"	081º 08' 27.0"	-4.38	2.70
12:25:53.5	5.25	1749	2800	29º 05' 49.8"	081º 08' 31.4"	-4.52	2.64
12:25:58.1	5.36	1764	2800	29º 05' 40.4"	081º 08' 34.9"	-4.67	2.59
12:26:02.7	5.47	1778	2900	29º 05' 31.3"	081º 08' 38.3"	-4.82	2.54
12:26:07.4	5.58	1792	2900	29º 05' 22.2"	081º 08' 42.1"	-4.98	2.48
12:26:12.0	5.69	1805	2900	29º 05' 13.3"	081º 08' 45.7"	-5.12	2.43
12:26:16.6	5.80	1818	3000	29º 05' 04.4"	081º 08' 49.7"	-5.27	2.37
12:26:21.3	5.92	1830	3000	29º 04' 55.2"	081º 08' 53.1"	-5.42	2.32
12:26:25.9	6.03	1842	3100	29º 04' 46.6"	081º 08' 57.1"	-5.57	2.26
12:26:30.5	6.16	1854	3100	29º 04' 36.9"	081º 09' 01.0"	-5.73	2.21
12:26:35.1	6.28	1865	3200	29º 04' 27.9"	081º 09' 04.8"	-5.88	2.15
12:26:39.8	6.41	1876	3200	29º 04' 18.4"	081º 09' 08.7"	-6.04	2.09
12:26:44.4	6.53	1887	3200	29º 04' 09.5"	081º 09' 13.2"	-6.19	2.03
12:26:49.0	6.67	1896	3300	29º 03' 59.8"	081º 09' 16.2"	-6.35	1.98

Table 1. Radar returns from DAB ASR-9 (p. 1 of 3). Primary returns are shown in *italic text with gray background*.

Time UTC	Range nmi	Azimuth ACPs	Altitude MSL ft	N Latitude	W Longitude	Dist N of DAB, nmi	Dist E of DAB, nmi
12:26:53.7	6.80	1906	3300	29º 03' 50.5"	081º 09' 20.3"	-6.50	1.92
12:26:58.3	6.92	1915	3400	29º 03' 42.1"	081º 09' 24.3"	-6.64	1.87
12:27:02.9	7.06	1925	3400	29º 03' 32.2"	081º 09' 28.8"	-6.80	1.80
12:27:07.5	7.20	1933	3500	29º 03' 22.8"	081º 09' 32.2"	-6.96	1.75
12:27:12.1	7.34	1941	3500	29º 03' 13.3"	081º 09' 35.9"	-7.12	1.70
12:27:16.7	7.47	1950	3500	29º 03' 04.3"	081º 09' 40.6"	-7.27	1.63
12:27:21.3	7.61	1958	3600	29º 02' 55.0"	081º 09' 44.8"	-7.42	1.57
12:27:26.0	7.75	1965	3600	29º 02' 45.7"	081º 09' 48.4"	-7.58	1.51
12:27:30.6	7.91	1972	3700	29º 02' 35.3"	081º 09' 51.9"	-7.75	1.46
12:27:35.2	8.05	1980	3700	29º 02' 26.0"	081º 09' 56.8"	-7.91	1.39
12:27:39.9	8.20	1987	3800	29º 02' 16.2"	081º 10' 00.9"	-8.07	1.33
12:27:44.5	8.34	1994	3800	29º 02' 07.1"	081º 10' 05.4"	-8.22	1.26
12:27:49.1	8.50	2000	3900	29º 01' 56.9"	081º 10' 09.1"	-8.39	1.21
12:27:53.7	8.64	2006	3900	29º 01' 47.9"	081º 10' 13.1"	-8.54	1.15
12:27:58.4	8.80	2013	3900	29º 01' 37.6"	081º 10' 18.0"	-8.71	1.08
12:28:03.0	8.95	2019	4000	29º 01' 28.1"	081º 10' 22.3"	-8.87	1.02
12:28:07.6	9.11	2025	4000	29º 01' 18.0"	081º 10' 26.8"	-9.04	0.95
12:28:12.2	9.25	2030	4100	29º 01' 09.2"	081º 10' 30.6"	-9.18	0.90
12:28:16.8	9.41	2036	4100	29º 00' 59.1"	081º 10' 35.4"	-9.35	0.83
12:28:21.5	9.56	2041	4200	29º 00' 49.8"	081º 10' 39.5"	-9.51	0.77
12:28:26.1	*9.75*	*2047*		*29º 00' 38.0"*	*081º 10' 44.5"*	*-9.70*	*0.69*
12:28:30.7	*9.88*	*2053*		*29º 00' 29.9"*	*081º 10' 50.1"*	*-9.84*	*0.61*
12:28:35.3	*9.97*	*2067*		*29º 00' 23.9"*	*081º 11' 04.3"*	*-9.94*	*0.40*
12:28:40.0	*9.97*	*2080*		*29º 00' 23.5"*	*081º 11' 17.9"*	*-9.94*	*0.21*
12:28:44.6	*9.97*	*2092*		*29º 00' 23.4"*	*081º 11' 30.4"*	*-9.94*	*0.02*
12:28:49.2	*9.97*	*2105*		*29º 00' 23.6"*	*081º 11' 44.0"*	*-9.94*	*-0.18*
12:28:53.8	*10.00*	*2119*		*29º 00' 22.2"*	*081º 11' 58.7"*	*-9.97*	*-0.39*
12:28:58.4	*10.00*	*2131*		*29º 00' 22.7"*	*081º 12' 11.2"*	*-9.96*	*-0.57*
12:29:03.1	*10.03*	*2142*		*29º 00' 21.6"*	*081º 12' 22.8"*	*-9.97*	*-0.74*
12:29:07.7	*10.06*	*2153*		*29º 00' 20.7"*	*081º 12' 34.5"*	*-9.99*	*-0.91*
12:29:12.3	*10.09*	*2163*		*29º 00' 19.9"*	*081º 12' 45.2"*	*-10.00*	*-1.07*
12:29:21.6	*10.22*	*2184*		*29º 00' 14.6"*	*081º 13' 08.4"*	*-10.09*	*-1.41*
12:29:26.2	*10.34*	*2194*		*29º 00' 08.8"*	*081º 13' 20.3"*	*-10.19*	*-1.58*
12:29:30.8	*10.44*	*2200*		*29º 00' 03.8"*	*081º 13' 27.8"*	*-10.27*	*-1.69*
12:29:35.5	10.52	2208	4900	29º 00' 00.3"	081º 13' 37.4"	-10.33	-1.83
12:29:40.1	10.64	2214	5000	28º 59' 54.3"	081º 13' 45.4"	-10.43	-1.95
12:29:44.7	10.78	2219	5000	28º 59' 46.9"	081º 13' 52.7"	-10.55	-2.06
12:29:49.3	10.92	2224	5000	28º 59' 39.6"	081º 14' 00.1"	-10.67	-2.17
12:29:54.0	11.06	2231	5000	28º 59' 32.8"	081º 14' 09.9"	-10.79	-2.31
12:29:58.6	11.20	2237	5000	28º 59' 25.8"	081º 14' 18.8"	-10.90	-2.44
12:30:03.2	11.33	2244	5100	28º 59' 19.9"	081º 14' 28.8"	-11.00	-2.59
12:30:07.8	11.45	2250	5100	28º 59' 14.3"	081º 14' 37.7"	-11.09	-2.72
12:30:12.4	11.59	2255	5200	28º 59' 07.5"	081º 14' 45.9"	-11.21	-2.83
12:30:17.0	11.75	2260	5300	28º 58' 59.5"	081º 14' 54.5"	-11.34	-2.96
12:30:21.7	11.88	2265	5400	28º 58' 53.4"	081º 15' 02.7"	-11.44	-3.08
12:30:26.3	12.02	2269	5400	28º 58' 46.4"	081º 15' 10.1"	-11.56	-3.19
12:30:30.8	12.16	2274	5500	28º 58' 39.9"	081º 15' 18.7"	-11.67	-3.32
12:30:35.5	12.28	2278	5500	28º 58' 34.1"	081º 15' 25.9"	-11.76	-3.42
12:30:40.1	12.42	2282	5600	28º 58' 27.4"	081º 15' 33.5"	-11.87	-3.53

Table 1. Radar returns from DAB ASR-9 (p. 2 of 3). Primary returns are shown in *italic text with gray background*.

Time UTC	Range nmi	Azimuth ACPs	Altitude MSL ft	N Latitude	W Longitude	Dist N of DAB, nmi	Dist E of DAB, nmi
12:30:44.7	12.56	2286	5700	28º 58' 20.7"	081º 15' 41.3"	-11.98	-3.65
12:30:49.4	12.70	2290	5700	28º 58' 14.0"	081º 15' 49.2"	-12.10	-3.76
12:30:54.0	12.83	2294	5700	28º 58' 07.9"	081º 15' 56.9"	-12.20	-3.87
12:30:58.6	12.98	2298	5800	28º 58' 00.8"	081º 16' 05.2"	-12.32	-3.99
12:31:03.2	13.12	2301	5800	28º 57' 53.9"	081º 16' 12.0"	-12.43	-4.10
12:31:07.8	13.27	2305	5800	28º 57' 46.9"	081º 16' 20.5"	-12.55	-4.22
12:31:12.4	13.41	2309	5900	28º 57' 40.5"	081º 16' 28.9"	-12.65	-4.34
12:31:17.0	13.56	2312	5900	28º 57' 33.2"	081º 16' 36.2"	-12.77	-4.45
12:31:21.6	13.72	2315	5900	28º 57' 25.3"	081º 16' 43.9"	-12.91	-4.56
12:31:26.2	13.86	2319	5900	28º 57' 19.1"	081º 16' 52.6"	-13.01	-4.69
12:31:30.9	14.03	2323	6000	28º 57' 11.2"	081º 17' 02.0"	-13.14	-4.83
12:31:35.5	14.19	2326	6000	28º 57' 03.5"	081º 17' 09.9"	-13.27	-4.94
12:31:40.2	14.36	2329	5900	28º 56' 55.3"	081º 17' 18.2"	-13.40	-5.06
12:31:44.8	14.53	2332	5900	28º 56' 47.1"	081º 17' 26.6"	-13.54	-5.19
12:31:49.4	14.70	2335	5900	28º 56' 39.0"	081º 17' 35.1"	-13.68	-5.31
12:31:54.0	14.89	2339	6000	28º 56' 30.4"	081º 17' 45.6"	-13.82	-5.46
12:31:58.6	15.06	2342	6000	28º 56' 22.4"	081º 17' 54.2"	-13.95	-5.59
12:32:03.2	15.25	2345	6000	28º 56' 13.3"	081º 18' 03.5"	-14.10	-5.73
12:32:07.9	15.42	2348	5900	28º 56' 05.4"	081º 18' 12.4"	-14.23	-5.86
12:32:12.4	15.61	2351	5900	28º 55' 56.4"	081º 18' 21.9"	-14.38	-6.00
12:32:17.1	15.81	2354	5900	28º 55' 47.0"	081º 18' 31.7"	-14.54	-6.14
12:32:21.7	16.00	2357	6000	28º 55' 38.2"	081º 18' 41.4"	-14.69	-6.28
12:32:26.4	16.19	2360	6000	28º 55' 29.4"	081º 18' 51.1"	-14.83	-6.42
12:32:30.9	16.39	2363	6000	28º 55' 20.2"	081º 19' 01.3"	-14.98	-6.57
12:32:35.6	16.58	2366	6000	28º 55' 11.5"	081º 19' 11.3"	-15.13	-6.72
12:32:40.2	16.78	2369	5900	28º 55' 02.3"	081º 19' 21.7"	-15.28	-6.87
12:32:44.8	16.97	2371	5900	28º 54' 53.2"	081º 19' 30.2"	-15.43	-7.00
12:32:49.4	17.17	2374	5900	28º 54' 44.2"	081º 19' 40.8"	-15.58	-7.15
12:32:54.0	17.38	2377	5900	28º 54' 34.7"	081º 19' 51.7"	-15.74	-7.31
12:32:58.6	17.58	2377	5800	28º 54' 23.7"	081º 19' 57.5"	-15.92	-7.40
12:33:03.2	17.80	2375	5600	28º 54' 10.2"	081º 20' 00.5"	-16.15	-7.44
12:33:07.9	18.00	2373	5400	28º 53' 57.8"	081º 20' 02.8"	-16.35	-7.47
12:33:12.5	18.19	2369	5200	28º 53' 44.5"	081º 20' 01.3"	-16.57	-7.45
12:33:22.0	*18.56*	*2357*		*28º 53' 15.8"*	*081º 19' 50.4"*	*-17.05*	*-7.29*
12:33:26.3	*18.72*	*2353*		*28º 53' 04.2"*	*081º 19' 47.5"*	*-17.24*	*-7.25*
12:33:30.9	*18.88*	*2346*		*28º 52' 50.6"*	*081º 19' 38.9"*	*-17.47*	*-7.13*
12:33:35.5	*19.00*	*2340*		*28º 52' 39.9"*	*081º 19' 31.0"*	*-17.65*	*-7.01*
12:33:40.2	*19.16*	*2332*		*28º 52' 25.8"*	*081º 19' 20.1"*	*-17.88*	*-6.85*
12:33:44.7	*19.31*	*2326*		*28º 52' 13.5"*	*081º 19' 12.4"*	*-18.09*	*-6.74*
12:33:49.3	*19.47*	*2319*		*28º 52' 00.1"*	*081º 19' 02.8"*	*-18.31*	*-6.60*
12:33:58.5	*19.78*	*2305*		*28º 51' 34.1"*	*081º 18' 42.6"*	*-18.74*	*-6.30*
12:34:07.8	*20.09*	*2291*		*28º 51' 08.3"*	*081º 18' 21.3"*	*-19.17*	*-5.99*
12:34:12.4	*20.28*	*2285*		*28º 50' 54.1"*	*081º 18' 13.0"*	*-19.41*	*-5.87*
12:34:17.0	*20.44*	*2280*		*28º 50' 42.1"*	*081º 18' 05.9"*	*-19.61*	*-5.77*
12:34:21.6	*20.59*	*2274*		*28º 50' 30.3"*	*081º 17' 56.4"*	*-19.80*	*-5.63*
12:34:26.2	*20.78*	*2266*		*28º 50' 15.1"*	*081º 17' 43.2"*	*-20.05*	*-5.43*
12:34:30.8	*20.97*	*2263*		*28º 50' 02.6"*	*081º 17' 40.2"*	*-20.26*	*-5.39*
12:34:40.0	*21.28*	*2254*		*28º 49' 40.1"*	*081º 17' 26.2"*	*-20.64*	*-5.19*
12:34:44.6	*21.44*	*2250*		*28º 49' 28.8"*	*081º 17' 20.1"*	*-20.82*	*-5.10*

Table 1. Radar returns from DAB ASR-9 (p. 3 of 3). Primary returns are shown in *italic text with gray background*.

Time, UTC	Source	Communication
12:30:04	N501N	orlando twin cessna five zero one november out of fifty two hundred for six thousand
12:30:08	STN	five zero one november orlando approach altimeter three zero one four
12:30:12	N501N	thirty fourteen zero one november
12:30:13	STN	and zero one november what is your destination
12:30:15	N501N	lakeland l a l
12:30:17	STN	thank you
12:32:35	STN	zero one november fly heading of two five zero
12:32:38	N501N	ah zero one november
12:32:49	N501N	zero one november declaring an emergency we need ah smoke in the cockpit we need ah to land at sanford
12:32:54	STN	zero one november roger proceed direct to ah sanford descend v correction descend to two thousand
12:32:59	N501N	two thousand zero one november
12:33:12	STN	november zero one november you can proceed direct Sanford report it in sight
12:33:15	N501N	zero one november *(has set up already would like)
12:33:18	STN	november zero one november you can land any runway at sanford they know you are coming

Table 2. ATC communications. N501N = accident airplane; STN = Orlando International Satellite Radar North. *This portion of the re-recording is not entirely clear, but represents the best interpretation possible under the circumstances.

ITEM	N Latitude	W Longitude	Incremental Straight Line Distance (ft)	Relative Elevation (ft)
First Tree	28º 49 00.17	081º 17 53.82	0	60
Palm Tree	28º 48 59.45	081º 17 56.34	270	30
House/Wing Box	28º 48 59.11	081º 17 57.33	357	15
Empennage	28º 48 59.31	081º 17 57.65	386	0
Propeller	28º 48 59.70	081º 17 59.50	608	0

Table 3. Debris path items.

NYC07MA162: Cessna 310R, N501N, Sanford, FL, 07/10/2007

Flight path relative to DAB ASR-9 antenna based on DAB ASR-9 returns

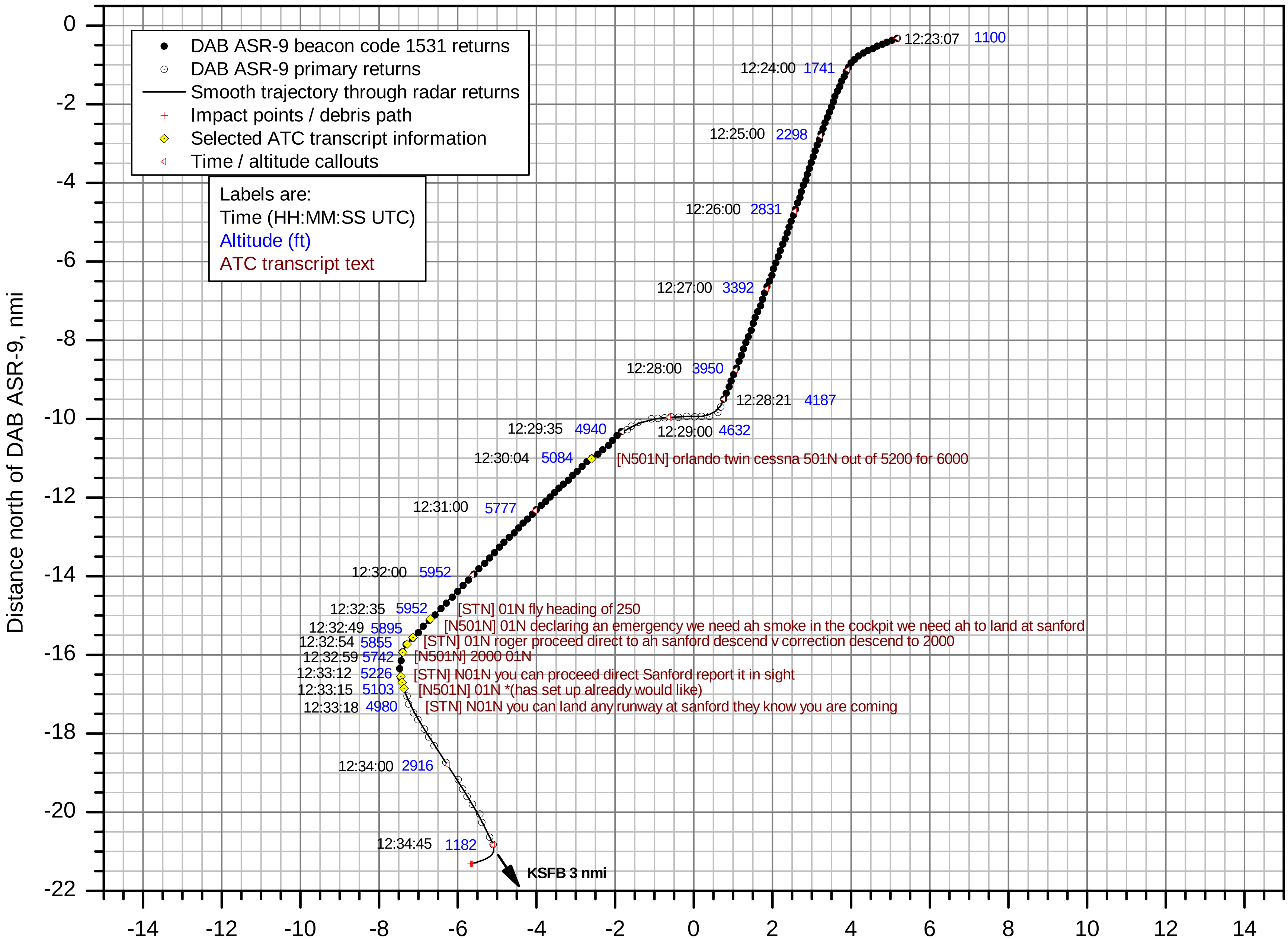
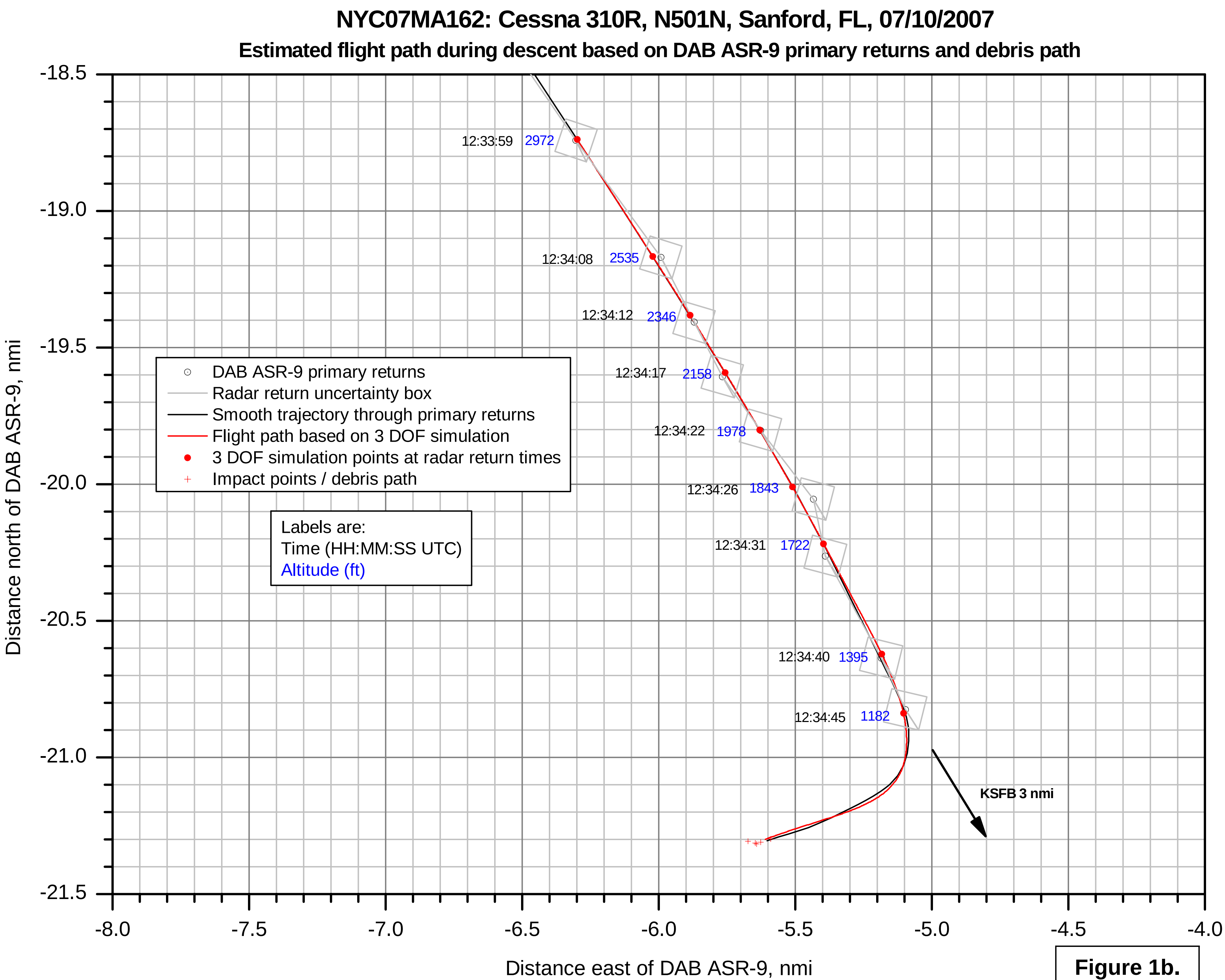


Figure 1a.



NYC07MA162: Cessna 310R, N501N, Sanford, FL, 07/10/2007
Estimated flight path during descent based on DAB ASR-9 primary returns and debris path
DAB ASR-9 primary returns
Radar return uncertainty box
Smooth trajectory through primary returns
Flight path based on 3 DOF simulation
3 DOF simulation points at radar return times
Impact points / debris path
Labels are:
Time (HH:MM:SS UTC)
Altitude (ft)
12:33:59 2972
12:34:08 2535
12:34:12 2346
12:34:17 2158
12:34:22 1978
12:34:26 1843
12:34:31 1722
12:34:40 1395
12:34:45 1182
KSFB 3 nmi
Distance north of DAB ASR-9, nmi
Distance east of DAB ASR-9, nmi
-18.5
-19.0
-19.5
-20.0
-20.5
-21.0
-21.5
-8.0
-7.5
-7.0
-6.5
-6.0
-5.5
-5.0
-4.5
-4.0

Figure 1b.

NYC07MA162: Cessna 310R, N501N, Sanford, FL, 07/10/2007

Flight path relative to DAB ASR-9 antenna based on DAB ASR-9 returns

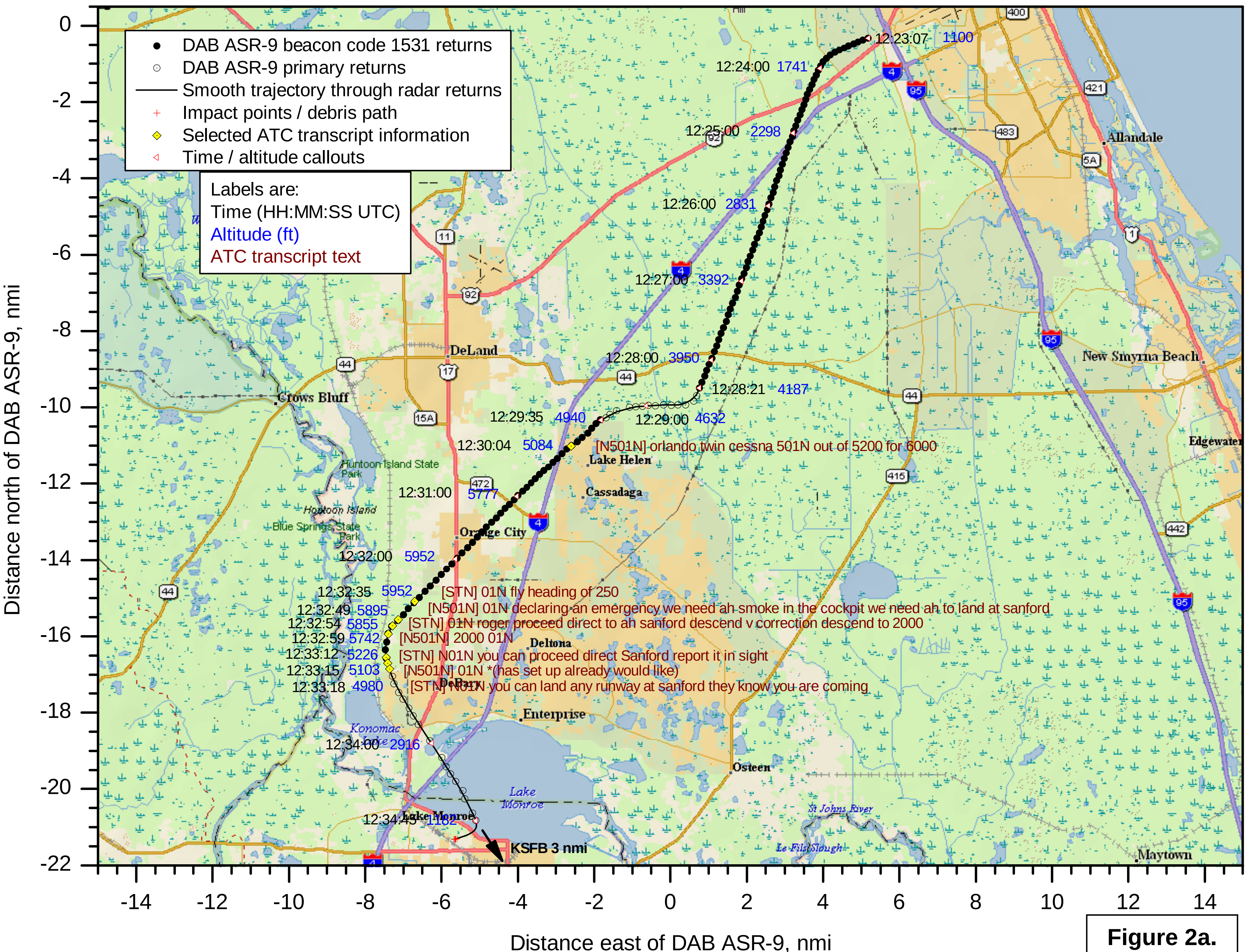


Figure 2a.

NYC07MA162: Cessna 310R, N501N, Sanford, FL, 07/10/2007

Estimated flight path during descent based on DAB ASR-9 primary returns and debris path

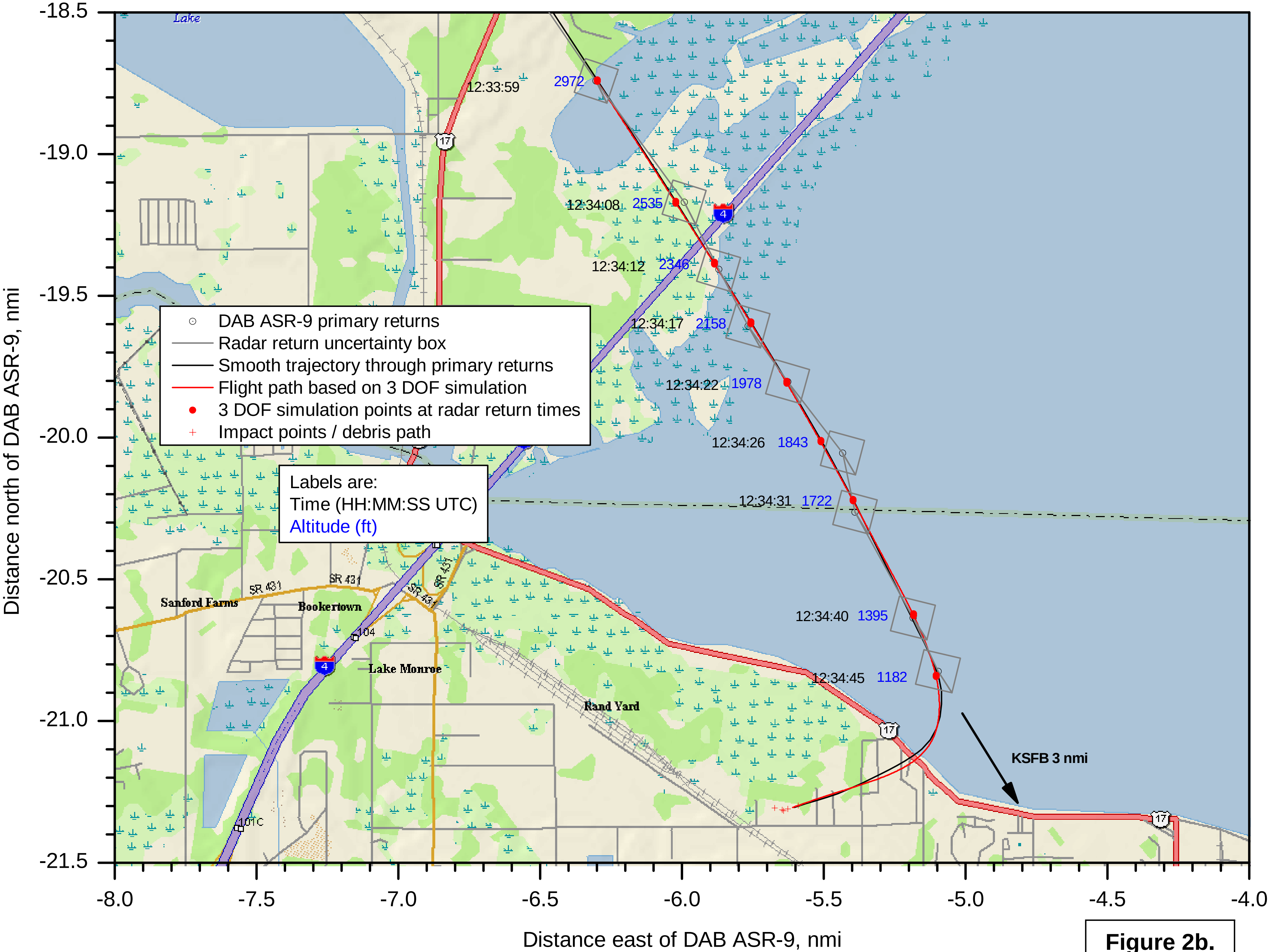


Figure 2b.

NYC07MA162: Cessna 310R, N501N, Sanford, FL, 07/10/2007

Flight path relative to DAB ASR-9 antenna based on DAB ASR-9 returns

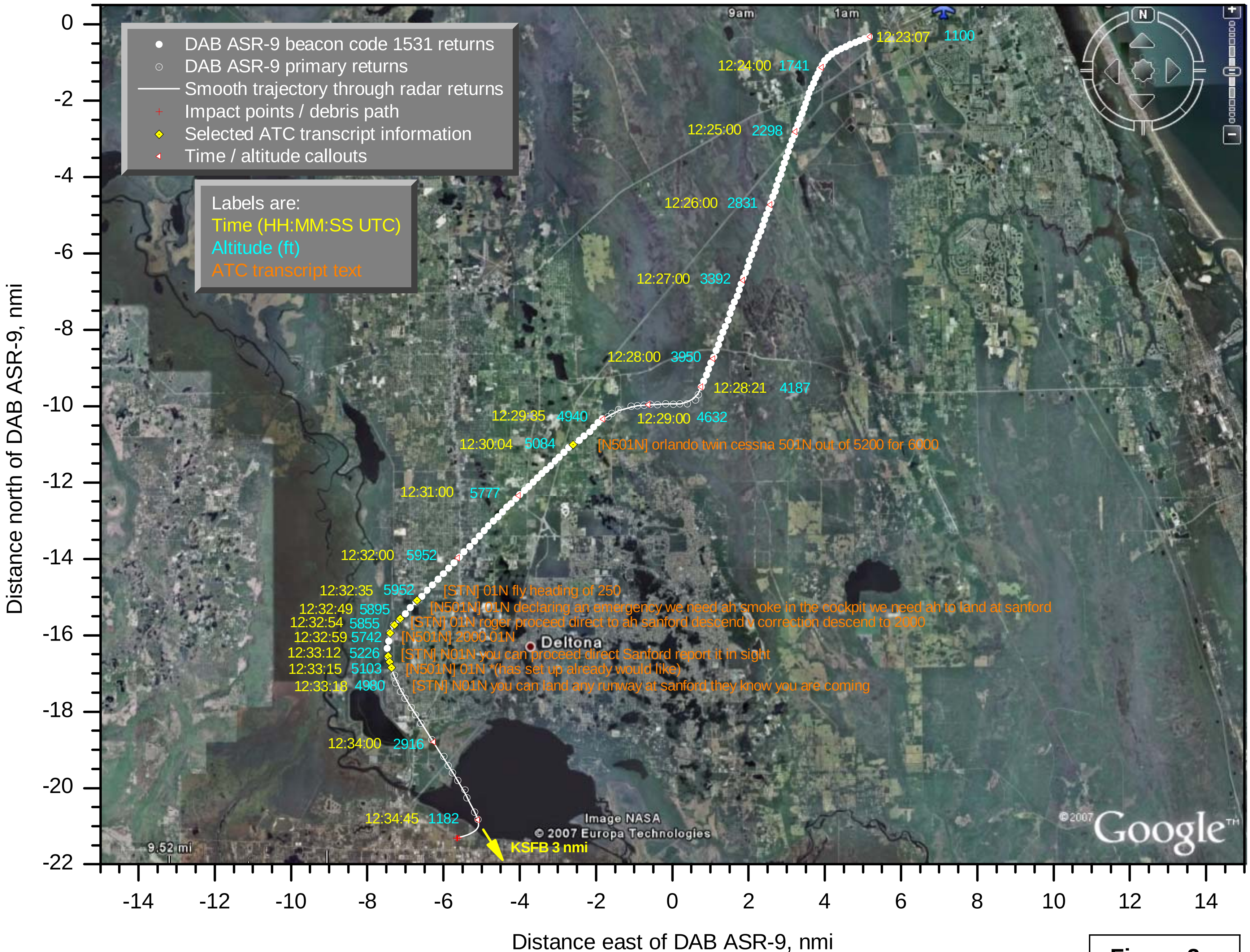


Figure 3a.

NYC07MA162: Cessna 310R, N501N, Sanford, FL, 07/10/2007

Estimated flight path during descent based on DAB ASR-9 primary returns and debris path

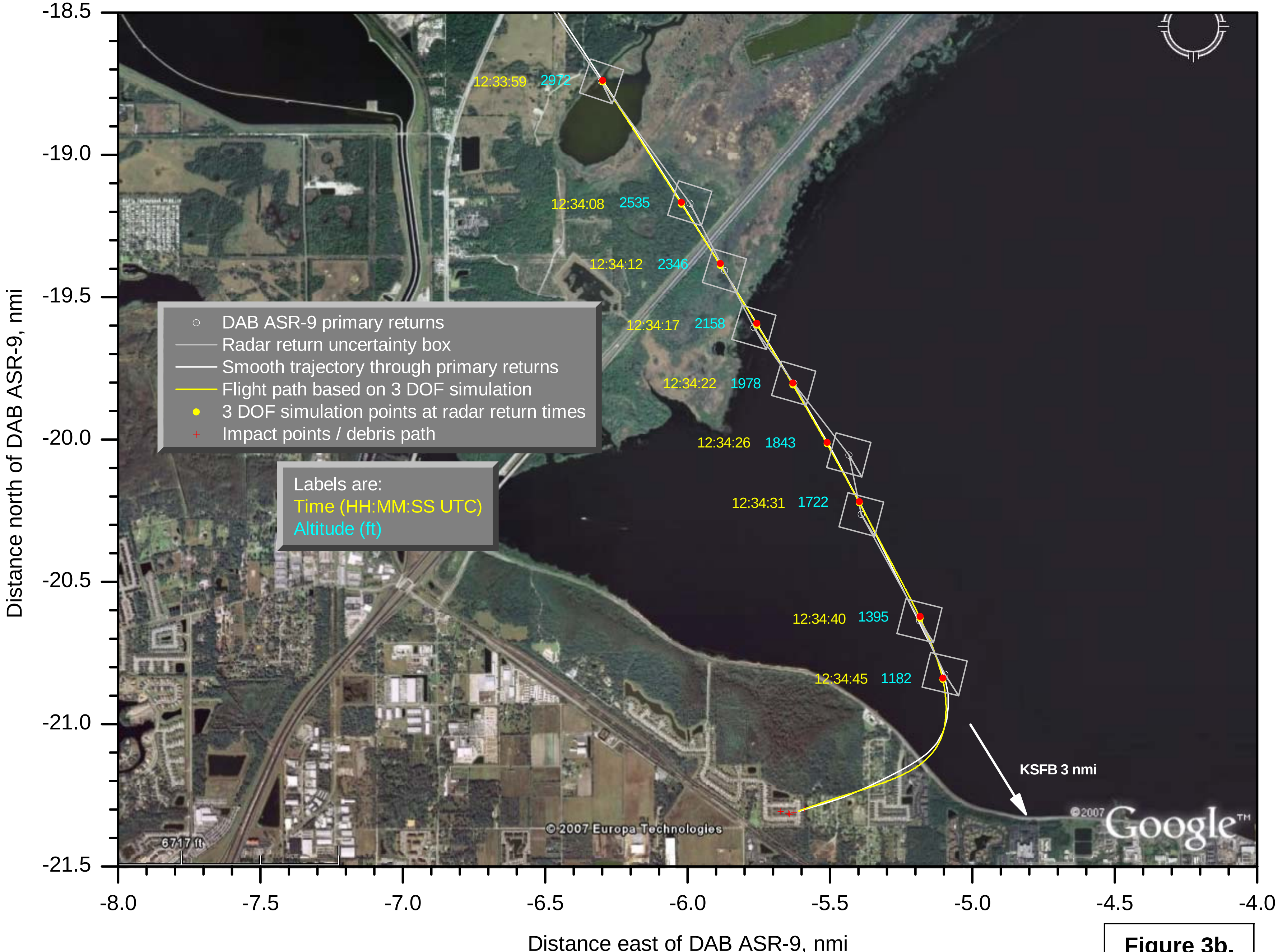


Figure 3b.

NYC07MA162: Cessna 310R, N501N, Sanford, FL, 07/10/2007
North and east positions vs. time

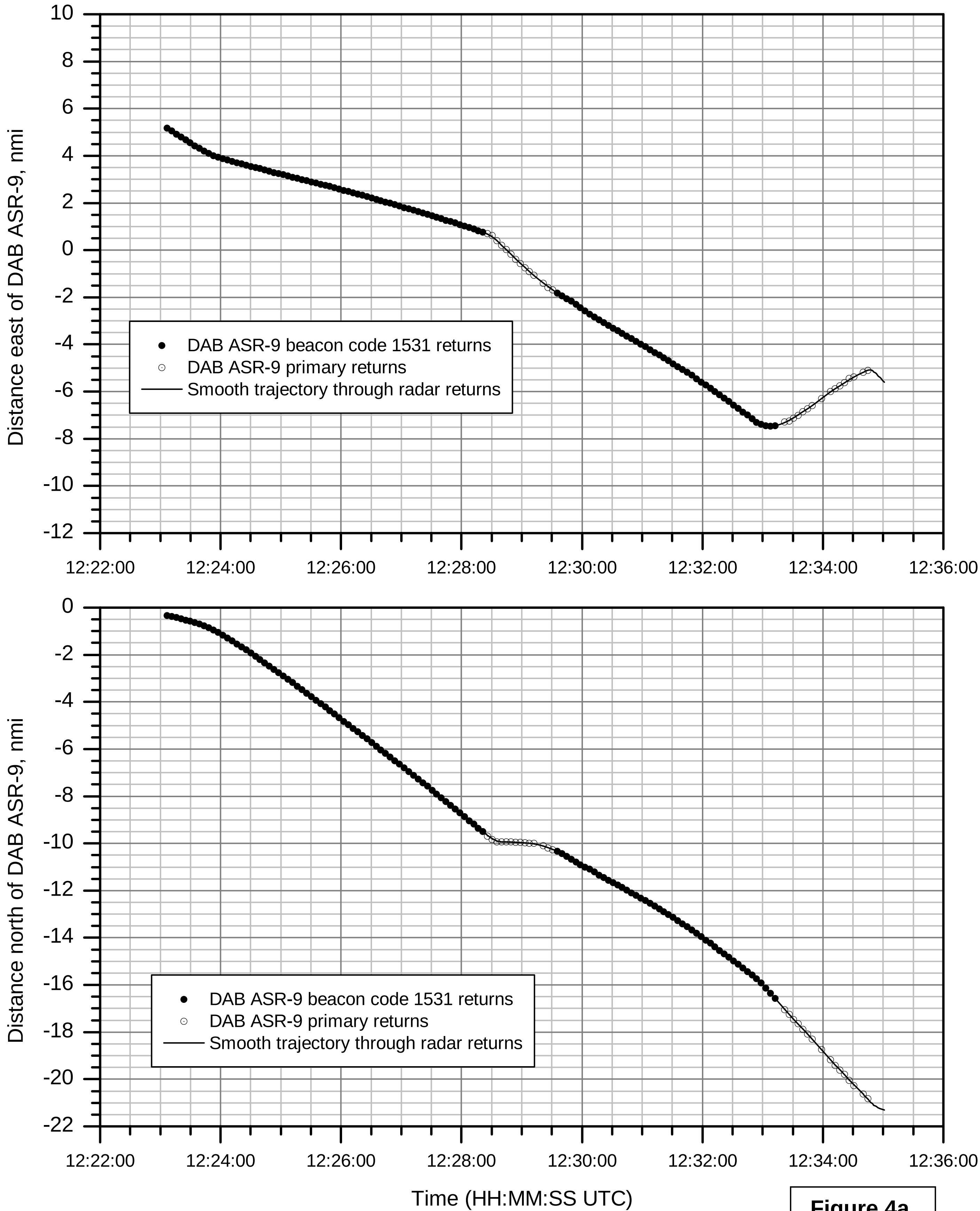


Figure 4a.

NYC07MA162: Cessna 310R, N501N, Sanford, FL, 07/10/2007
North and east positions vs. time (detail)

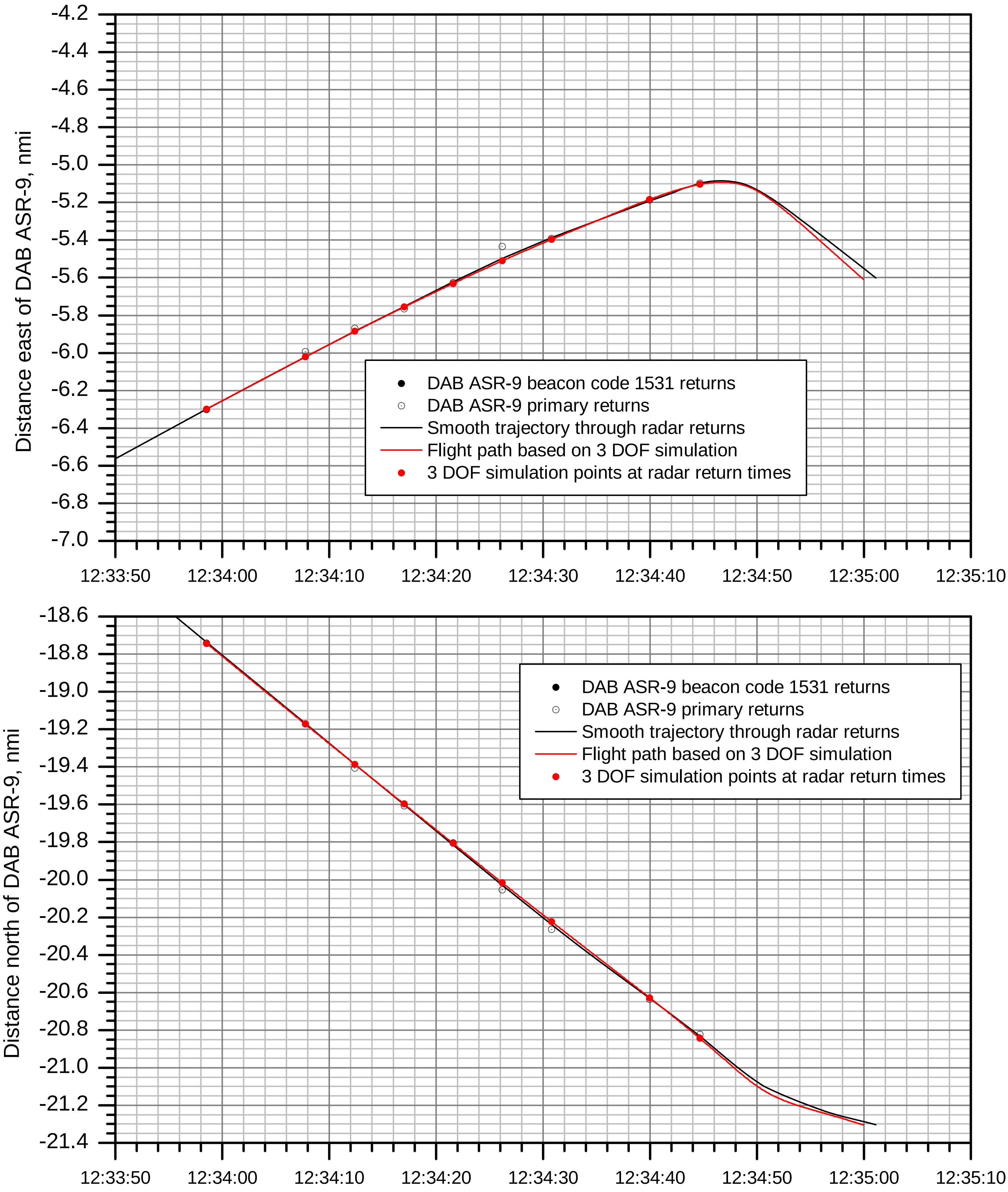


Figure 4b.

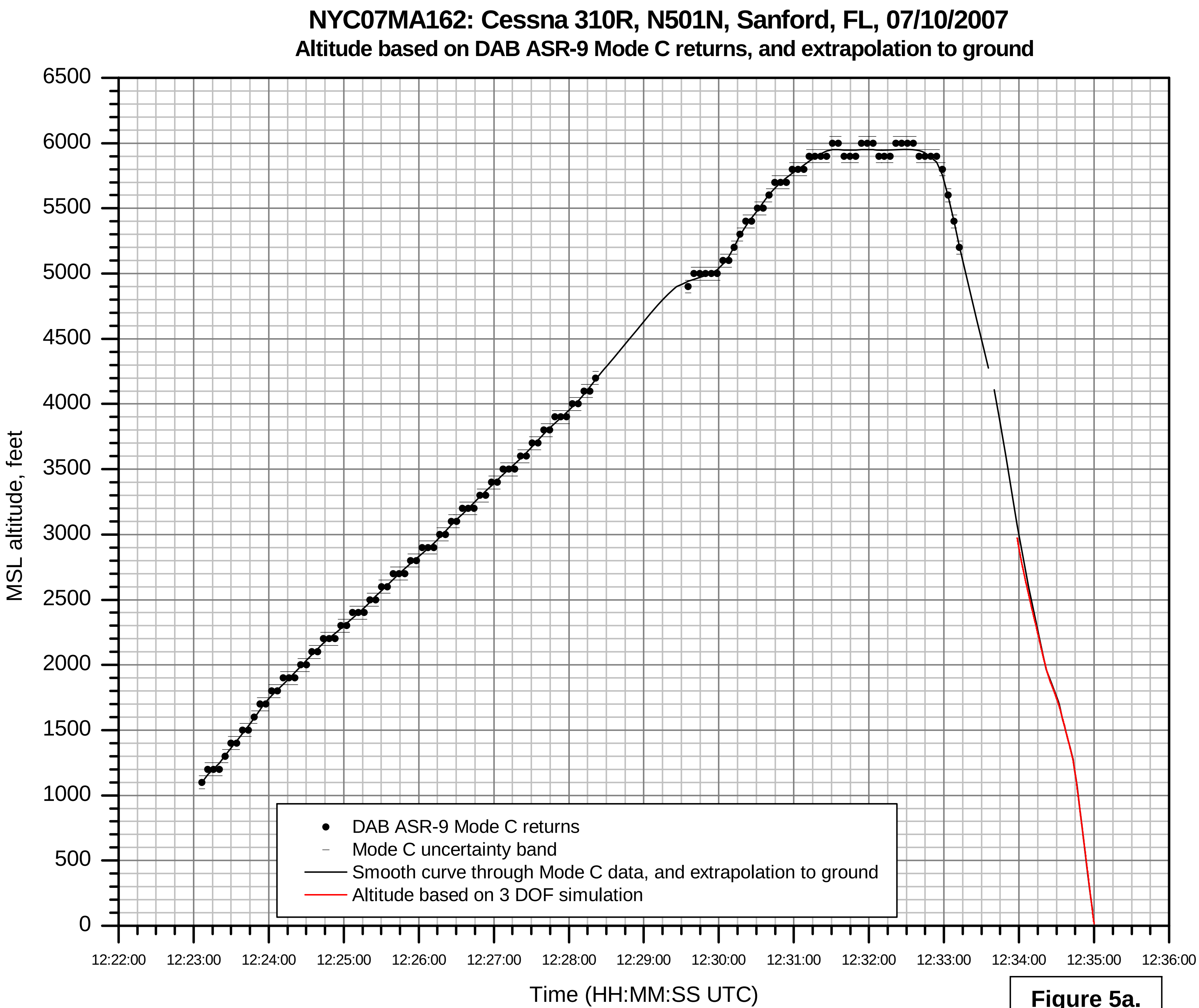

NYC07MA162: Cessna 310R, N501N, Sanford, FL, 07/10/2007
Altitude based on DAB ASR-9 Mode C returns, and extrapolation to ground
MSL altitude, feet
6500
6000
5500
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
DAB ASR-9 Mode C returns
Mode C uncertainty band
Smooth curve through Mode C data, and extrapolation to ground
Altitude based on 3 DOF simulation
12:22:00
12:23:00
12:24:00
12:25:00
12:26:00
12:27:00
12:28:00
12:29:00
12:30:00
12:31:00
12:32:00
12:33:00
12:34:00
12:35:00
12:36:00
Time (HH:MM:SS UTC)

Figure 5a.

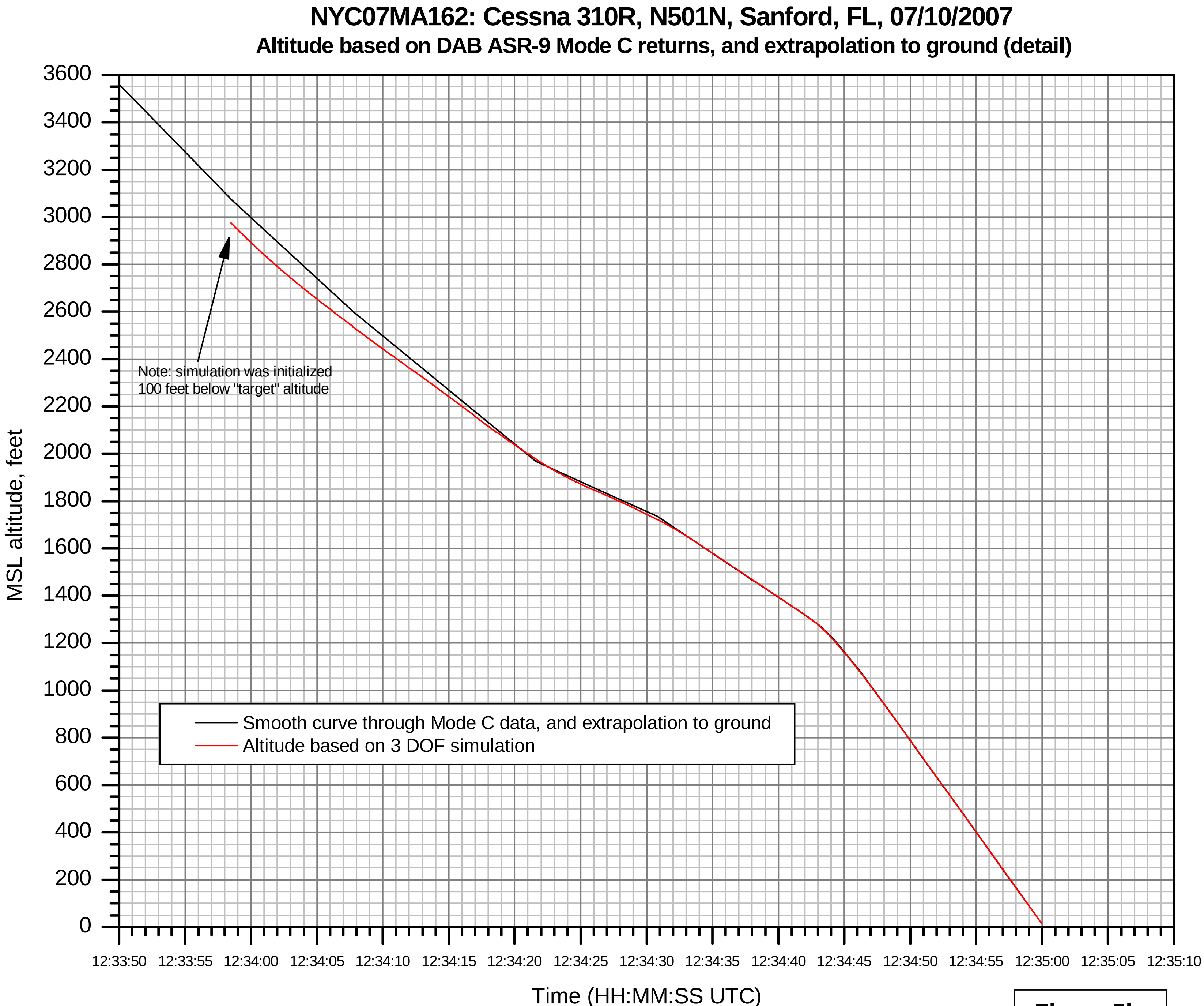

NYC07MA162: Cessna 310R, N501N, Sanford, FL, 07/10/2007
Altitude based on DAB ASR-9 Mode C returns, and extrapolation to ground (detail)
MSL altitude, feet
3600
3400
3200
3000
2800
2600
2400
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
0
Note: simulation was initialized
100 feet below "target" altitude
Smooth curve through Mode C data, and extrapolation to ground
Altitude based on 3 DOF simulation
12:33:50
12:33:55
12:34:00
12:34:05
12:34:10
12:34:15
12:34:20
12:34:25
12:34:30
12:34:35
12:34:40
12:34:45
12:34:50
12:34:55
12:35:00
12:35:05
12:35:10
Time (HH:MM:SS UTC)

Figure 5b.

Figure 6. Debris Track (Points are 1st Impact, Palm Tree, Wing Box, Empennage and Propeller). Cumulative linear distances are 0, 270, 357, 386 and 608 feet respectively; Incremental distances are 0, 270, 87, 29, and 379 feet respectively.

NYC07MA162: Cessna 310R, N501N, Sanford, FL, 07/10/2007

Wind data used for performance calculations (NAM 12Z model sounding for accident site)

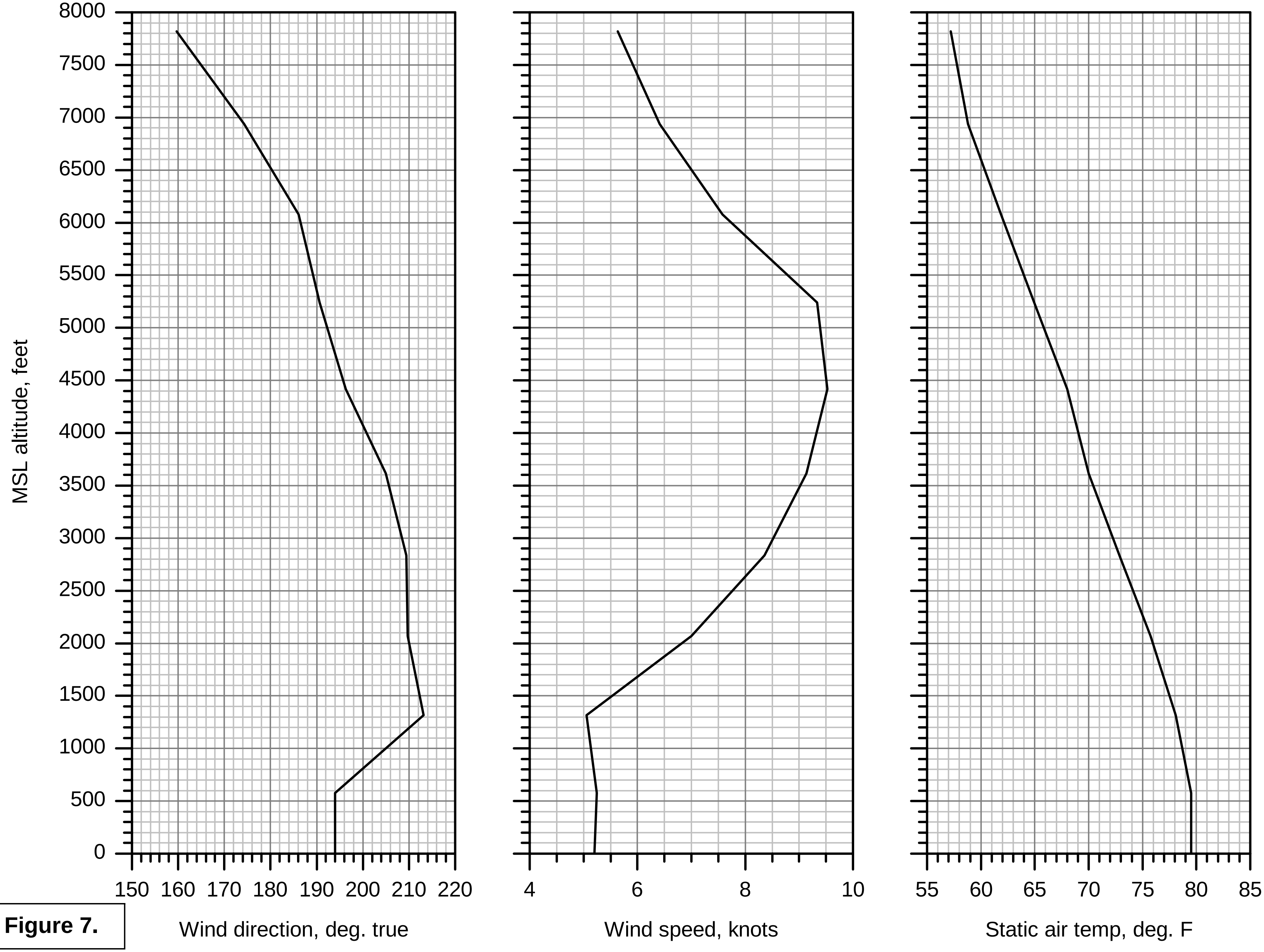


Figure 7.

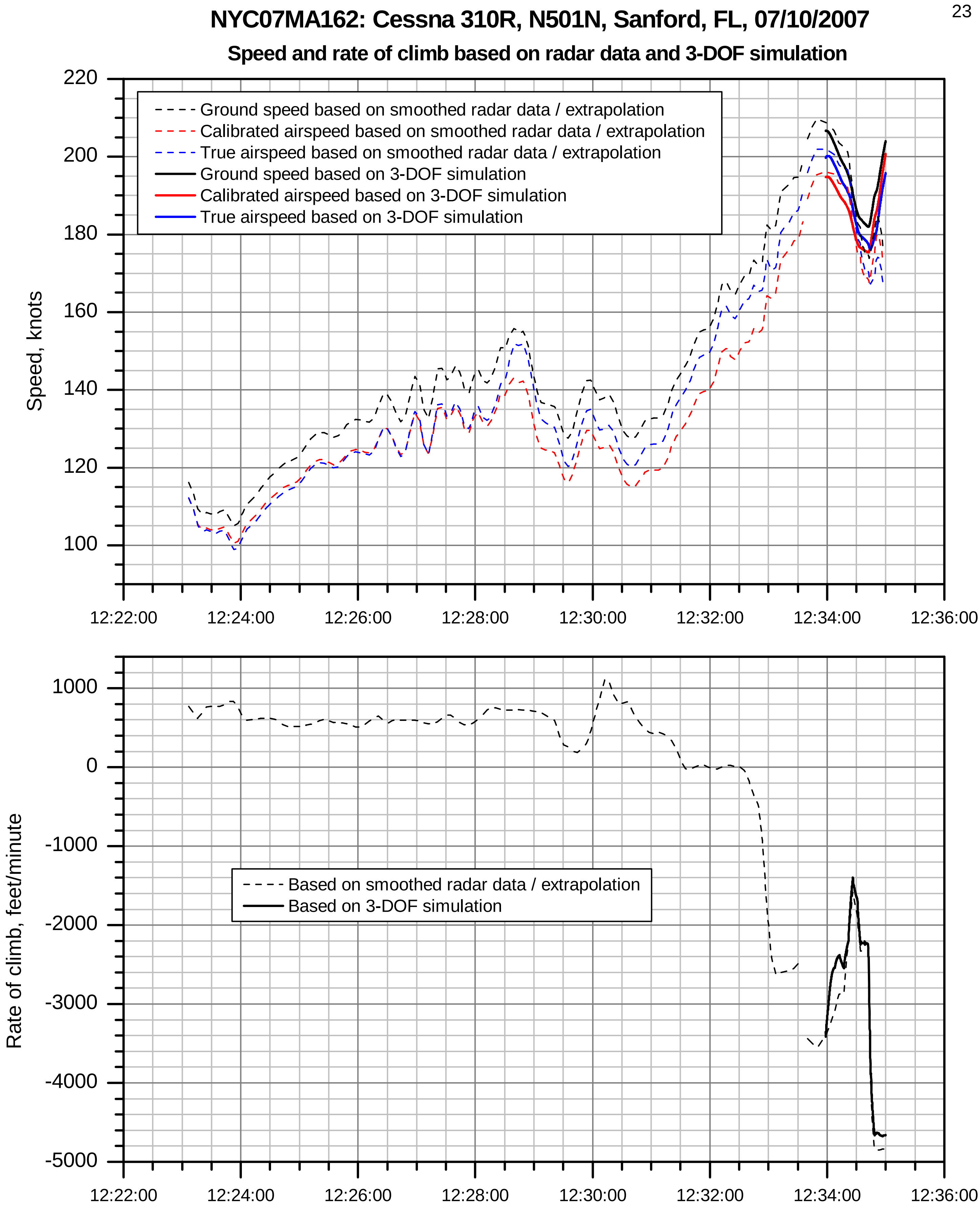

NYC07MA162: Cessna 310R, N501N, Sanford, FL, 07/10/2007
Speed and rate of climb based on radar data and 3-DOF simulation
Ground speed based on smoothed radar data / extrapolation
Calibrated airspeed based on smoothed radar data / extrapolation
True airspeed based on smoothed radar data / extrapolation
Ground speed based on 3-DOF simulation
Calibrated airspeed based on 3-DOF simulation
True airspeed based on 3-DOF simulation
Speed, knots
220
200
180
160
140
120
100
12:22:00
12:24:00
12:26:00
12:28:00
12:30:00
12:32:00
12:34:00
12:36:00
Based on smoothed radar data / extrapolation
Based on 3-DOF simulation
Rate of climb, feet/minute
1000
0
-1000
-2000
-3000
-4000
-5000
12:22:00
12:24:00
12:26:00
12:28:00
12:30:00
12:32:00
12:34:00
12:36:00
Time (HH:MM:SS UTC)

Figure 8a.

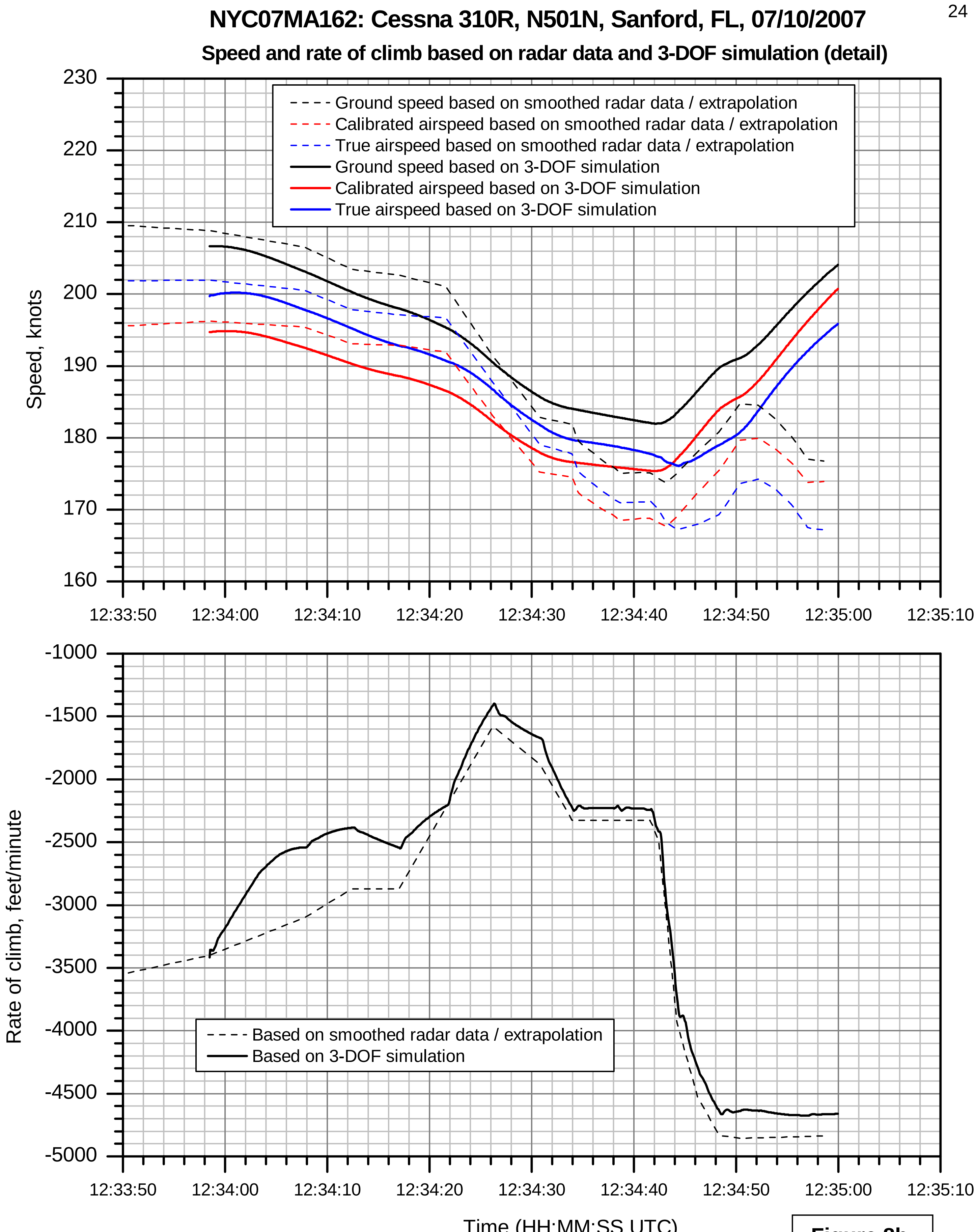

NYC07MA162: Cessna 310R, N501N, Sanford, FL, 07/10/2007
Speed and rate of climb based on radar data and 3-DOF simulation (detail)
Ground speed based on smoothed radar data / extrapolation
Calibrated airspeed based on smoothed radar data / extrapolation
True airspeed based on smoothed radar data / extrapolation
Ground speed based on 3-DOF simulation
Calibrated airspeed based on 3-DOF simulation
True airspeed based on 3-DOF simulation
Speed, knots
230
220
210
200
190
180
170
160
12:33:50
12:34:00
12:34:10
12:34:20
12:34:30
12:34:40
12:34:50
12:35:00
12:35:10
Rate of climb, feet/minute
-1000
-1500
-2000
-2500
-3000
-3500
-4000
-4500
-5000
Based on smoothed radar data / extrapolation
Based on 3-DOF simulation
Time (HH:MM:SS UTC)

Figure 8b.

NYC07MA162: Cessna 310R, N501N, Sanford, FL, 07/10/2007

Euler angles based on radar data and 3-DOF simulation

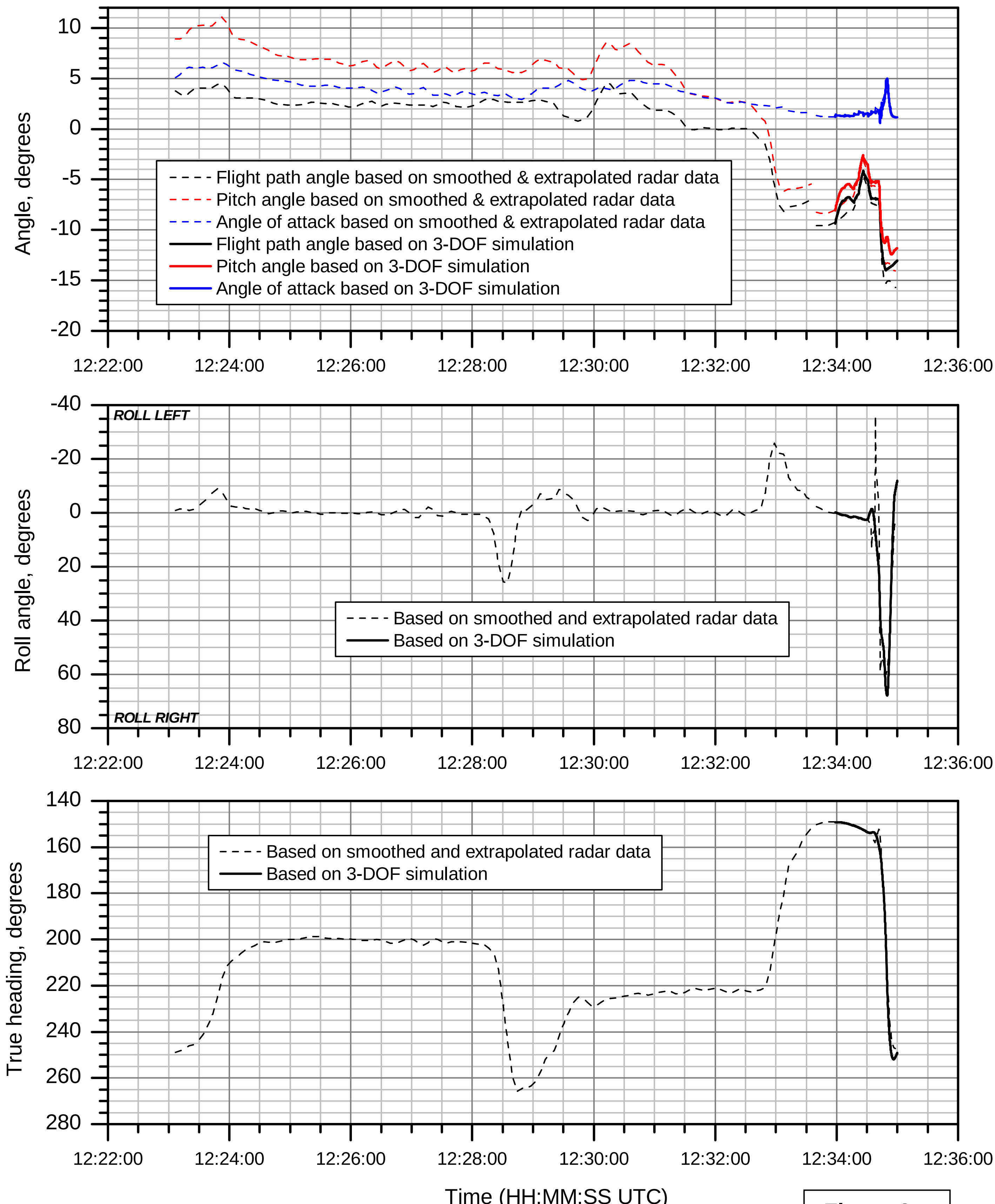


Figure 9a.

NYC07MA162: Cessna 310R, N501N, Sanford, FL, 07/10/2007

Euler angles based on radar data and 3-DOF simulation (detail)

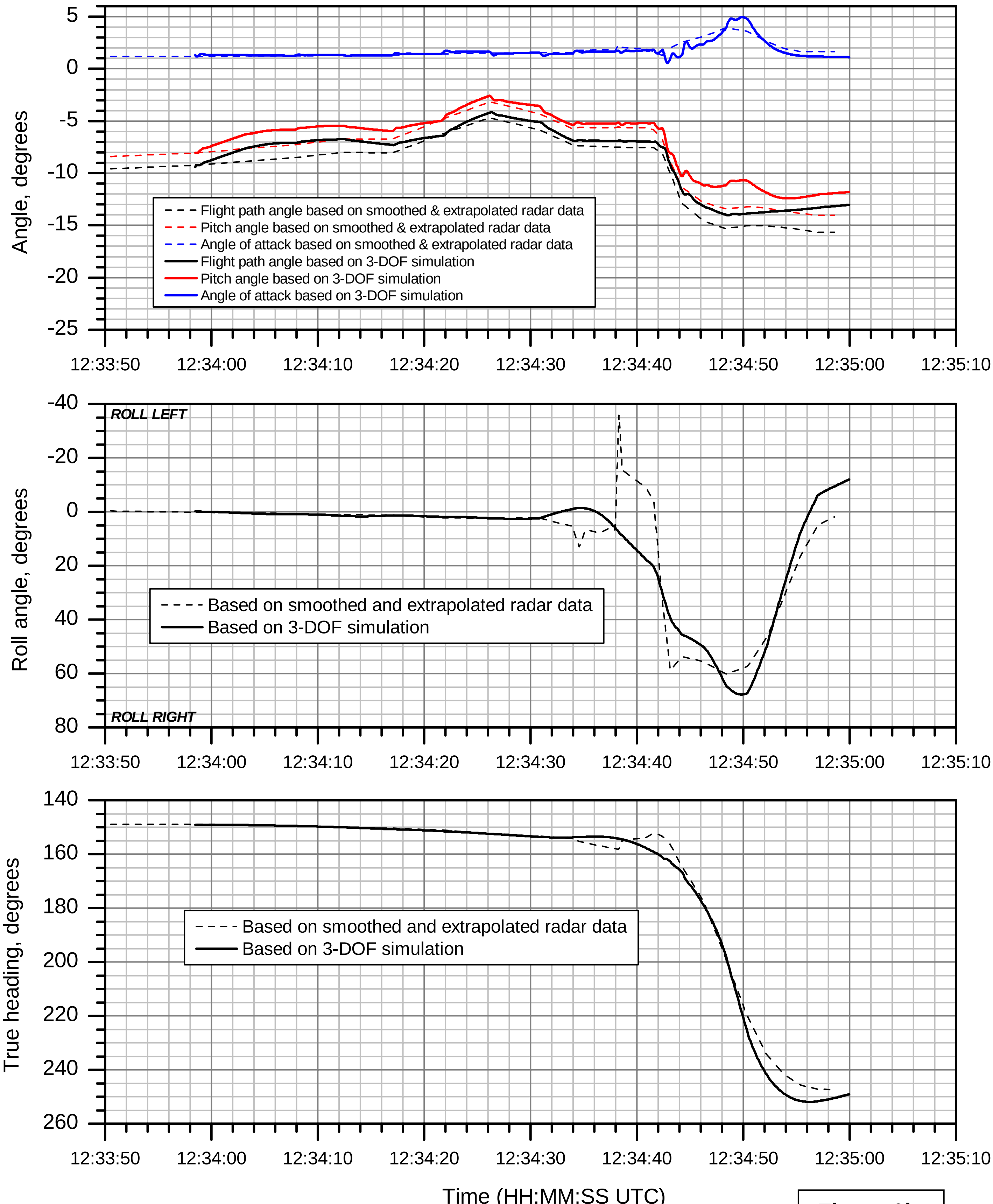


Figure 9b.

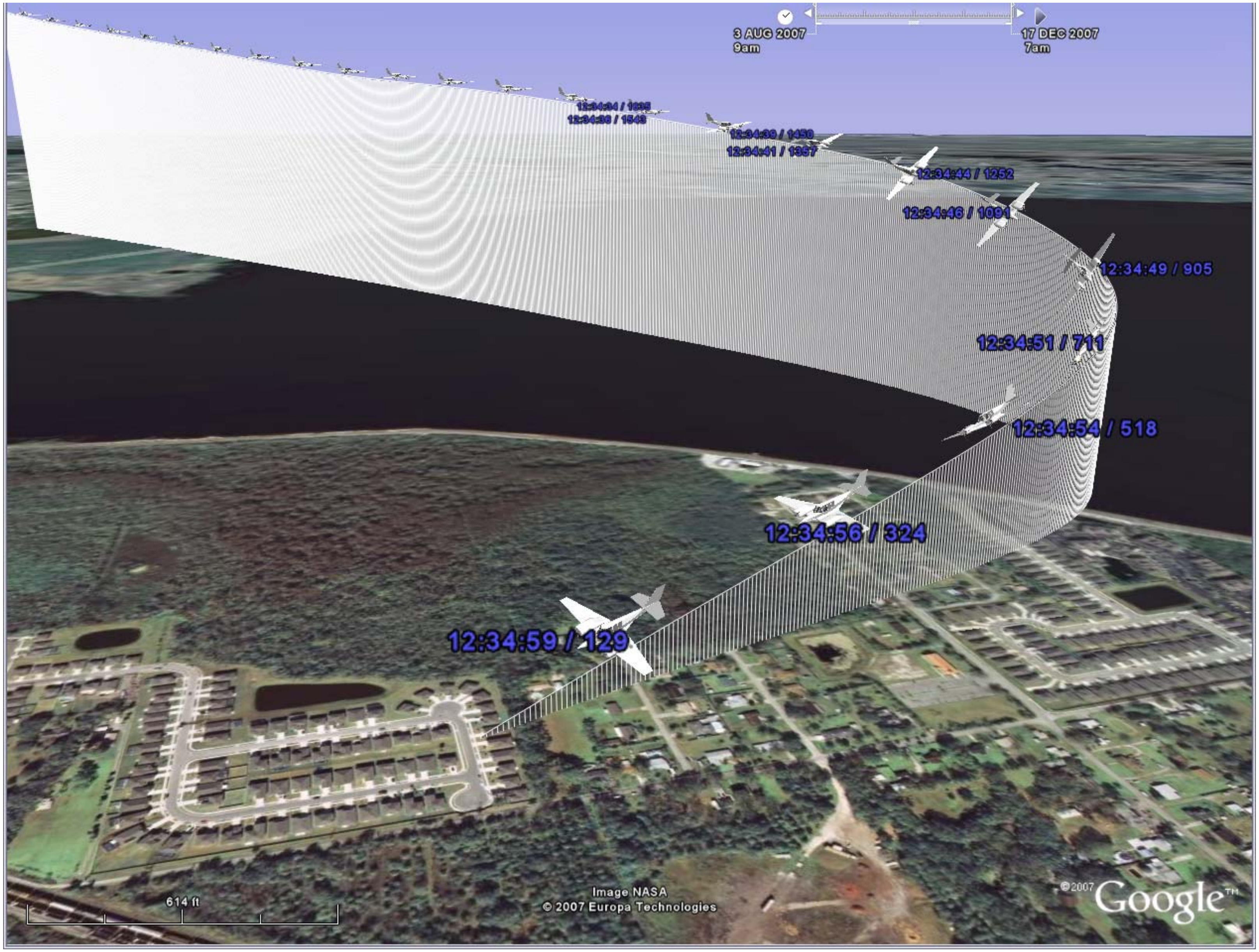

3 AUG 2007
9am
17 DEC 2007
7am
12:34:34 / 1635
12:34:36 / 1543
12:34:39 / 1450
12:34:41 / 1357
12:34:44 / 1252
12:34:46 / 1091
12:34:49 / 905
12:34:51 / 711
12:34:54 / 518
12:34:56 / 324
12:34:59 / 129
614 ft
Image NASA
© 2007 Europa Technologies
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Figure 10.