National Transportation Safety Board
Office of Research and Engineering
Washington, D.C. 20594

Radar Performance Study

Specialist Report
Timothy Burtch

A. ACCIDENT

Location: Fargo, North Dakota
Date: November 30, 2018
Time: 1949 GMT (1349 CST)
Airplane: Cessna 550 Citation II, N941JM
NTSB Number: CEN19LA039

B. GROUP

No vehicle performance group was formed.

C. SUMMARY

On November 30, 2018, about 1353 central standard time, a Cessna 550 Citation II, N941JM, departed controlled flight while on approach to Hector International Airport (FAR) in Fargo, North Dakota, and impacted terrain to the right of the runway. The pilot and one passenger were not injured, and 9 passengers received minor injuries. The airplane sustained substantial damage. The airplane was registered to the Slice of the 406 LLC and operated by the pilot under the provisions of the Title 14 Code of Federal Regulations Part 91 as a business flight. Instrument meteorological conditions prevailed at the time of the accident, and the flight was operating on an instrument flight plan. The flight departed from Sloulin Field International Airport (ISN), Williston, North Dakota, about 1250 with FAR as the destination.

[Note: Times in the study are quoted in CST. CST = Greenwich Mean Time – 6 hr.]

D. THE AIRPLANE

A picture of the accident airplane, a Cessna 550 Citation II, is shown in Figure 1. The airplane was manufactured by Cessna in1980.

E. WEATHER SUMMARY

METAR KFAR 301953Z 20010KT 5SM BR OVC004 M01/M01 A2991

On November 30th, at 1353 CST, the surface weather observation at FAR was reporting wind 200˚ at 10 knots (kt); 5 statute miles visibility, mist; overcast clouds at 400 feet (ft) above the ground (agl); temperature -1˚ Celsius (C); dew point -1˚ C; altimeter 29.91" mercury.

Images provided by the National Center for Atmospheric Research included the Current Icing Potential (CIP) and the Forecast Icing Potential (FIP) valid between 1300 and 1400 CST. Both the CIP and FIP indicated a 60% to 70% chance of light icing below 3,000 ft mean sea level (msl) in the vicinity of the accident. In addition, about 30 minutes after the accident, the pilot of a Citation Excel at 3,000 ft and close to FAR reported overcast skies and moderate rime ice with a temperature of -2˚C. See the NTSB Meteorology Weather Study for more details about the accident weather conditions.

F. RADAR STUDY

The data used in the study are largely from secondary radar returns (transponder code 6054) recorded by the short-range Airport Surveillance Radar (ASR-11) located at FAR, approximately 1 NM south of the accident site. See Figure 2.

Short-range radar have approximately a 60 NM range and an inherent uncertainty of ±2 Azimuth Change Pulses (ACP) = ± (2 ACP) x (360º/4096 ACP) = ±0.176° in azimuth, ±50 ft in altitude, and ±1/16 NM in range.

An overview of the radar ground track is shown in Figure 3. The airplane approached Hector International airport from the west and was receiving vectors from air traffic control to capture the instrument landing system (ILS) signal for runway 18. The airport can be seen in the lower right corner of the figure.

Figure 4 shows the radar ground track closer to the airport and includes estimated airspeed and altitude for every fourth radar return. The last radar return recorded was at an altitude of 900 ft msl, the same as the touchdown zone elevation for runway 18.

Figure 5 highlights N941JM's descent from 9,000 ft to 2,500 ft, the top of the ILS 18 approach. (A more recent copy of the National Aeronautical Charting Office, NACO, approach plate for FAR ILS 18 is shown in Figure 6). The pilot reported entering the clouds just before 1340:00 CST at 3,100 ft, approximately 10 nm from FAR.

The accident airplane did not have a flight data recorder nor was one required. In lieu of a flight recorder, a simulation using models developed by CAE, Inc[1], were used to match altitude and position data from radar. This provided insight into several airplane performance and aerodynamic parameters that would not otherwise be available.

Figure 7 shows the airplane Euler angles that resulted when the simulation was "flown" through the radar data. Note the slight right turn on short final as captured by bank angle and heading at approximately 1348:30, 30 seconds before the last radar return[2].

Figure 8 includes a time history of the angle-of-attack (AOA) from the Cessna 550 simulation. In order to match the radar data, the simulation AOA for the last two minutes of the flight approached angles very close to the stall AOA, and the AOA momentarily exceeded the linear portion of the Cessna 550 "no-ice" lift curve[3] with the flaps in the retracted position[4].

In addition to the simulation results without any degradations due to ice, Figure 8 includes a simulation time history with the lift coefficient reduced by 5% to model the effect of ice accretion on the airplane's wings during the ILS 18 approach (in red)[5]. The reduction was introduced shortly after the airplane descended into the clouds and leveled off at 2,500 ft, and it peaked at 5% at impact[6]. The AOA with the lift reduction was consistently into the non-linear portion of the no-ice lift curve for the last 30 seconds of the flight. Figure 9 shows the same AOA that resulted when the simulation was "flown" through the radar data but with a larger scale.

The Cessna 550 Citation II is equipped with an anti-ice system to prevent ice on the windshield and a de-ice system provides for removal of ice on the leading edge of the wing and tail by pneumatically expanding boots. The pilot of N941JM indicated that he activated the de-ice boots several times on the approach. However, the airplane was found with ice on the wings, horizontal tail, and vertical tail as shown in Figures 10-12 that were taken at the accident site.

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[1] The models were developed by CAE of Montreal, Canada, for the government of Canada. CAE qualified the Cessna 550 models in the simulator data package by performing a proof-of-match using flight test data collected on a Transport Canada Cessna 550. The CAE Cessna 550 simulator data package has been qualified for Level D pilot training by both Transport Canada and the Federal Aviation Administration.

[2] The pilot reported that the airplane was to the right of the runway centerline when it exited the clouds, and he corrected to the left to line up with the runway. However, the airplane "started to pull to the right".

[3] The lift curve with no ice would be reduced with ice present on the wings.

[4] The flaps were found in the retracted position in the wreckage. In addition, there was no mention of extending the flaps on the CVR.

[5] The accident airplane was in icing conditions for approximately 8-9 minutes as shown in Figure 3. The airplane entered the clouds at about 1340:00 and exited at 1348:30.

[6] The Phenom 100 that crashed on approach to runway 14 at Montgomery County Airpark (GAI), Gaithersburg, Maryland, on December 8, 2014, was in icing conditions for about 21 minutes and found to have approximately a 10% reduction in lift due to ice accretion. The airplane impacted three houses and the ground about 3/4 mile from the approach end of the runway.
https://dms.ntsb.gov/pubdms/search/hitlist.cfm?docketID=58153&CFID=2876835&CFTOKEN=c5a6427fad809ccf-817AA292-E637-D495-C56D7F16C1FCF0E0

G. SUMMARY AND CONCLUSIONS

N941JM did not have a flight data recorder on-board. As a result, flight test validated models were used in a simulation to match the ASR-11 radar data from the accident. Simulation results indicate that the accident airplane had little stall margin with the flaps retracted. In addition, the AOA approached stall in the last two minutes of the flight as the airplane continued accrete ice in areas where ice had been both forecast and reported. As a result, the accident airplane likely wanted to roll off at the end of the flight and may have lacked the control effectiveness required to counter the roll.

The pilot of N941JM could have increased the stall margin by extending the wing trailing edge flaps and possibly by activating the Cessna 550's wing and tail leading edge pneumatic de-ice boots more often.

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H. FIGURES

Figure 1: Accident Airplane, N941JM, a Cessna 550 Citation II

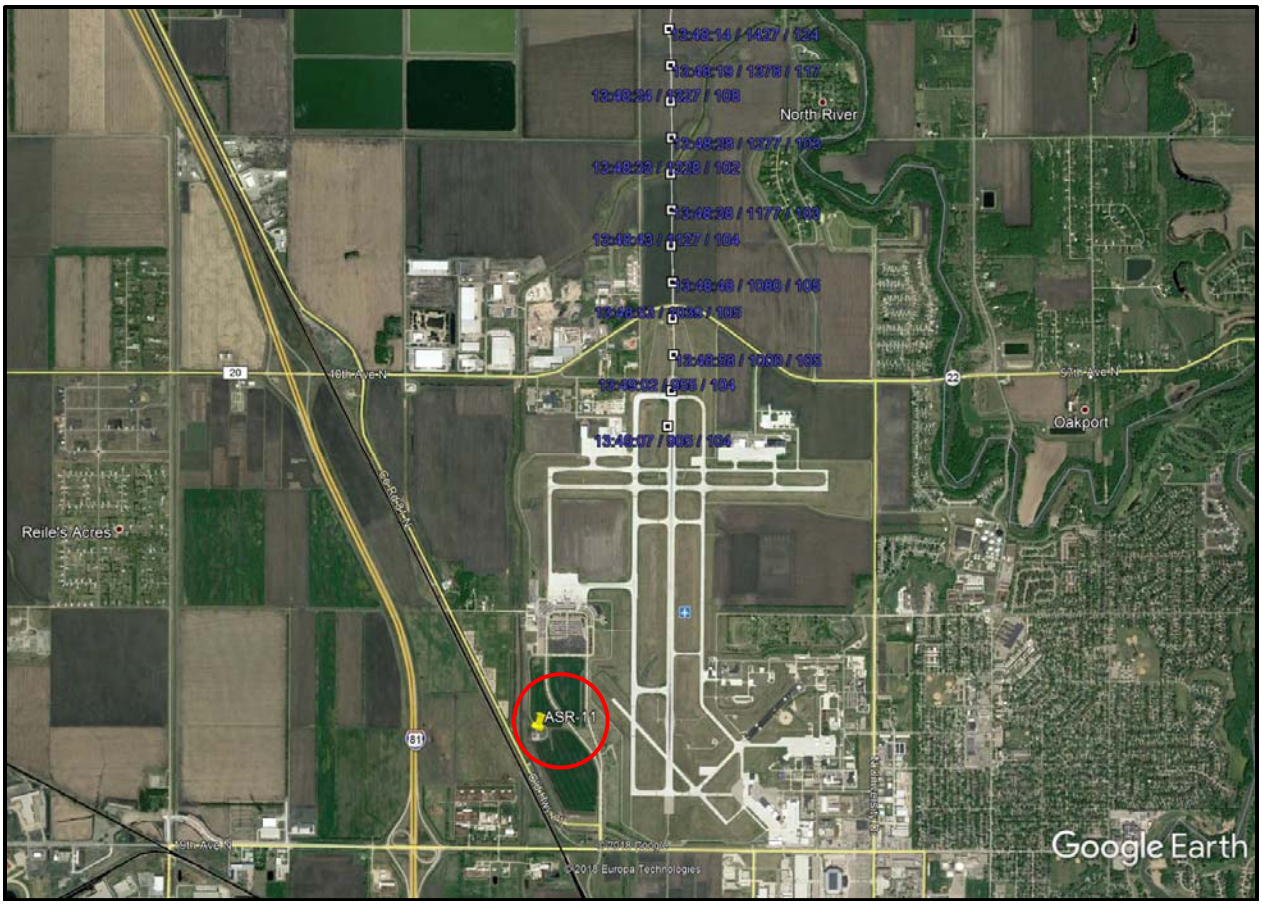

Figure 2: ASR-11 Radar Located at FAR, Approximately 1 NM South of Accident Site

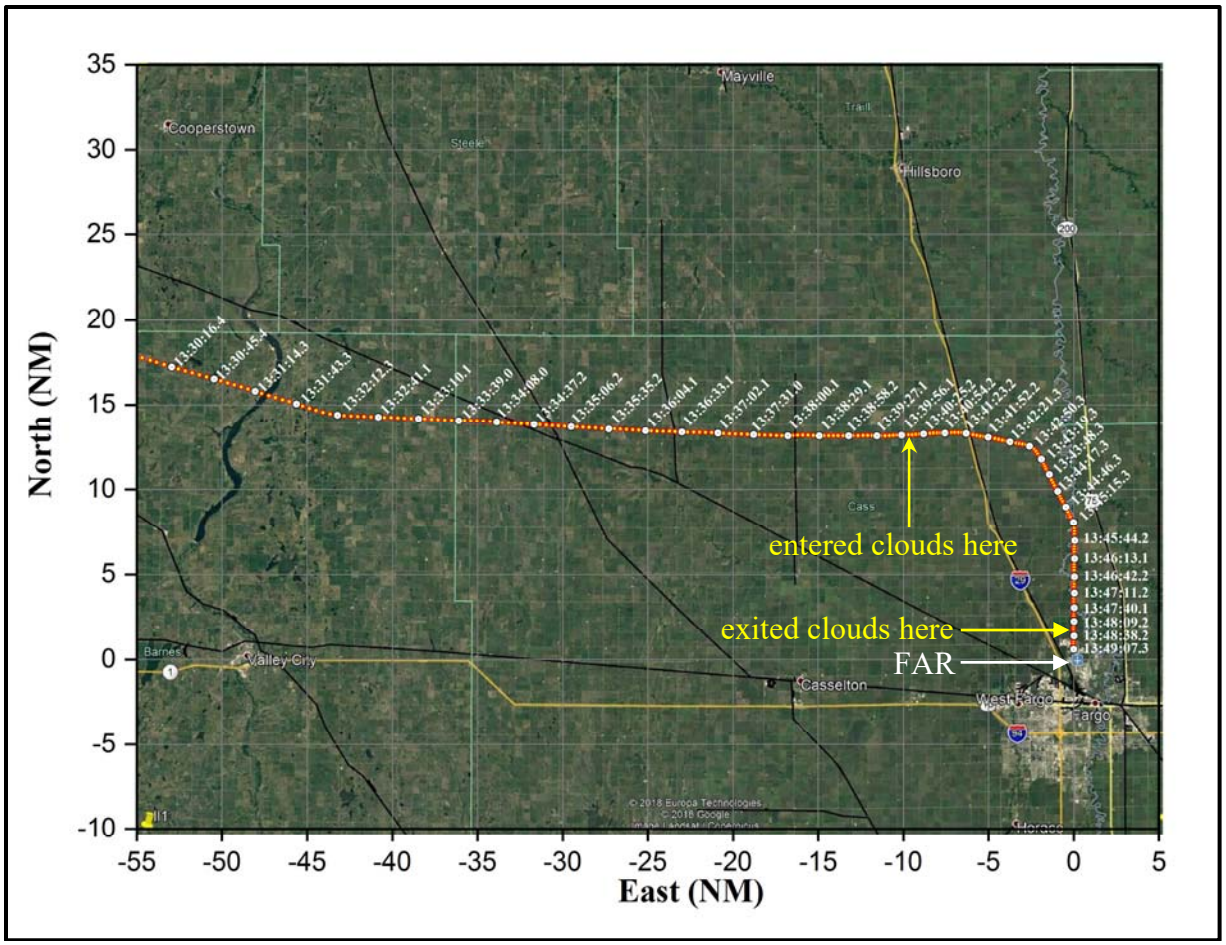

Figure 3: Ground Track Based on Radar

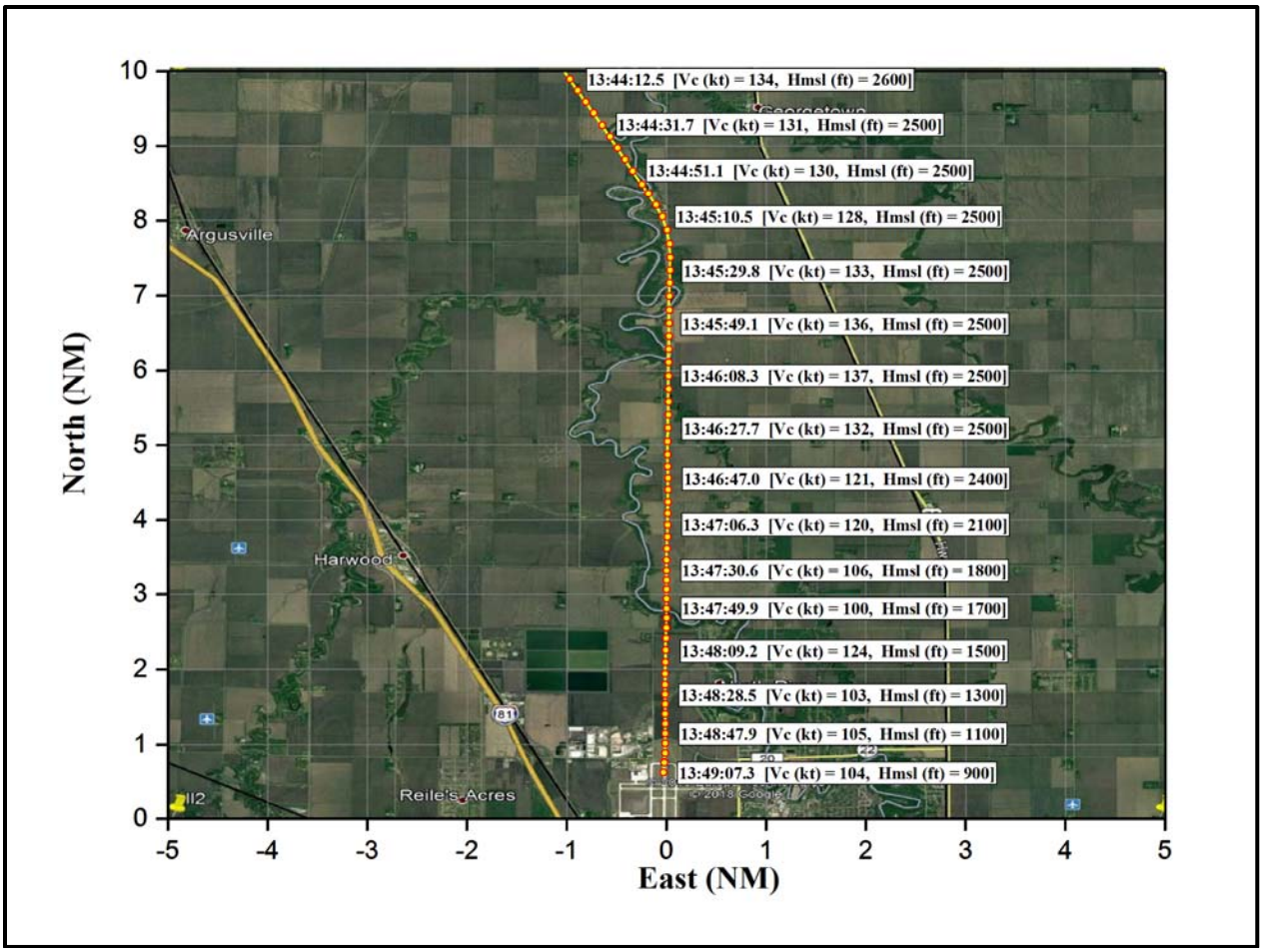

Figure 4: Ground Track, Airspeed, and Altitude Based on Radar and Reported Winds

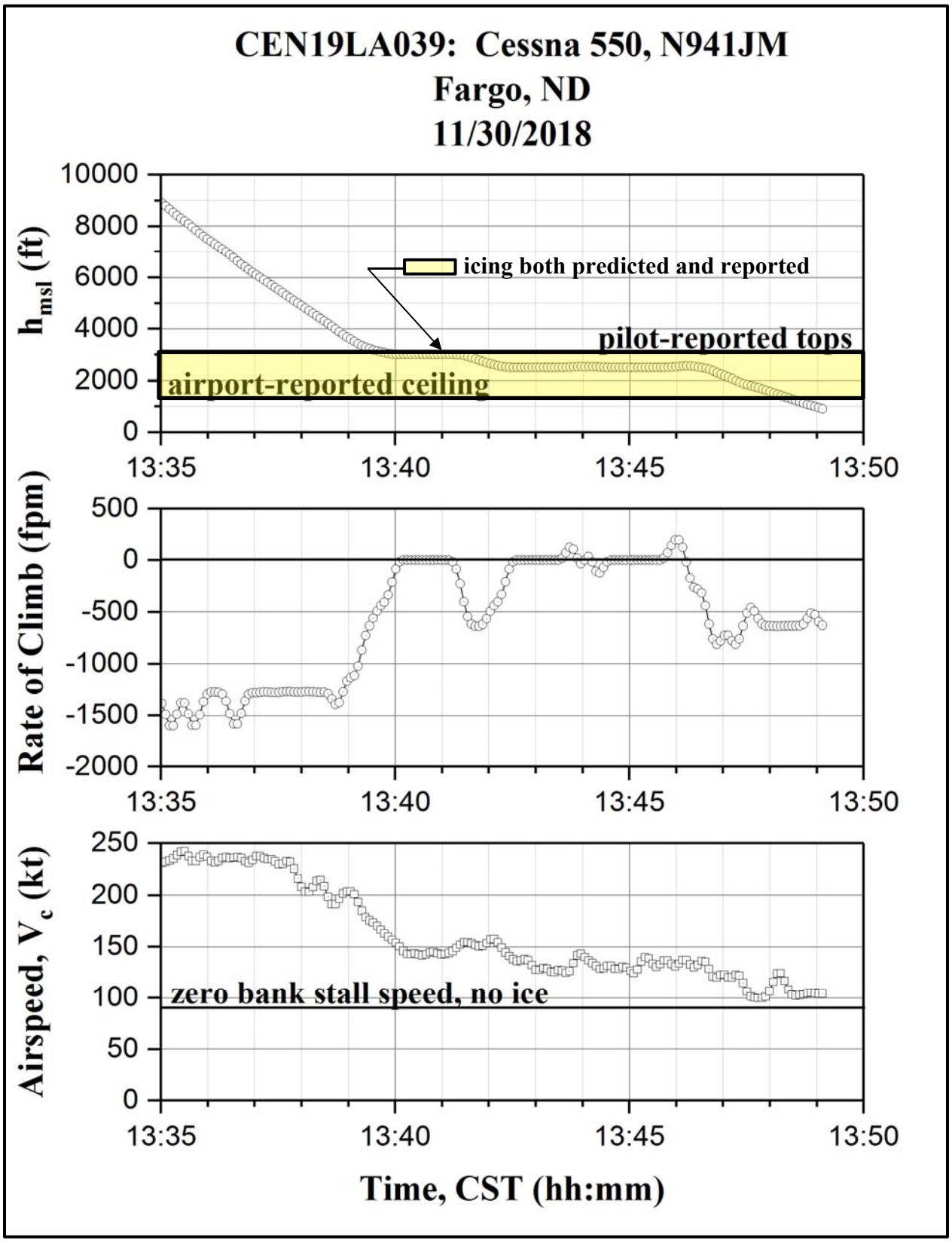

Figure 5: Estimated Altitude and Airspeed from Radar

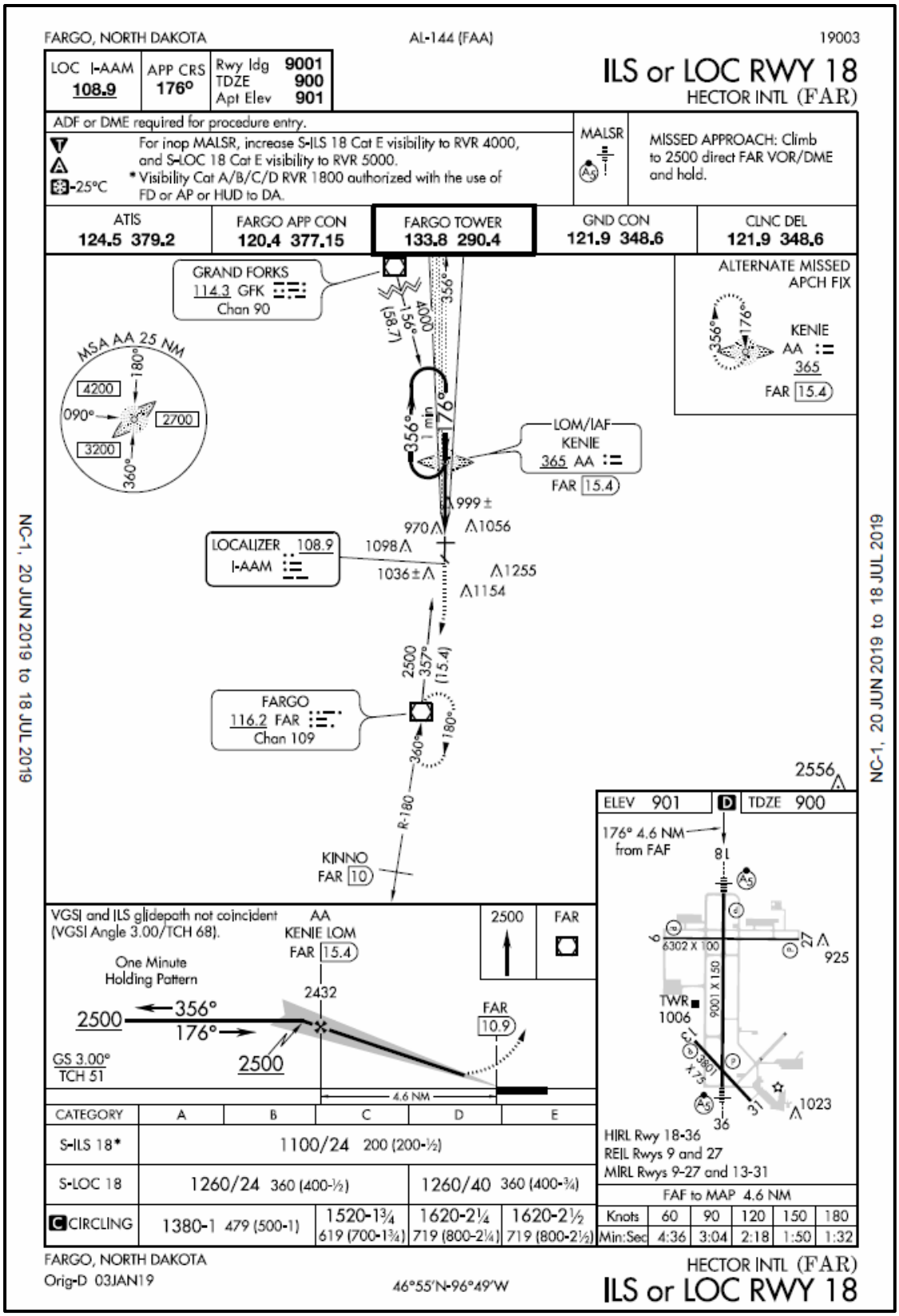

Figure 6: NACO ILS 18 Approach Plate

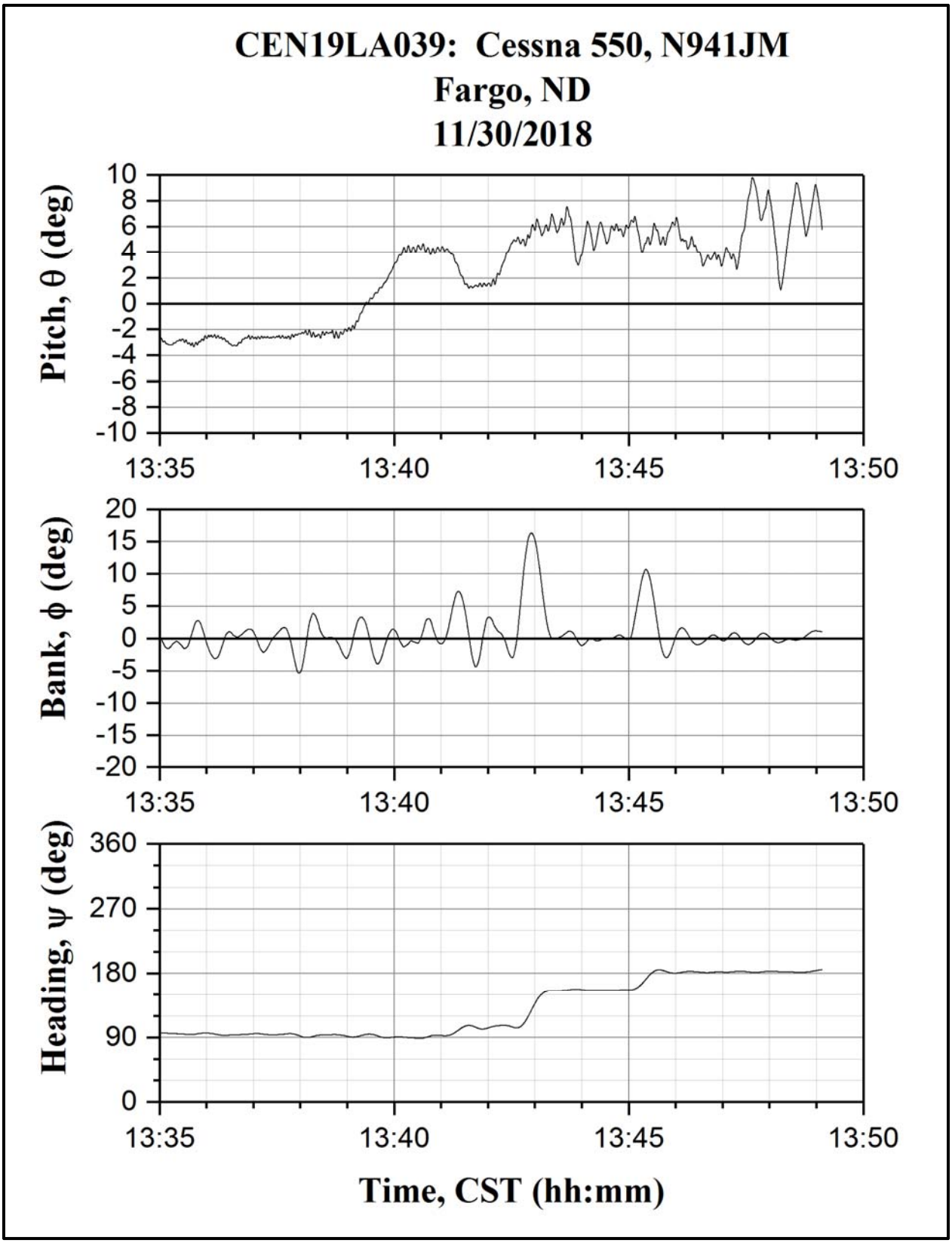

Figure 7: Estimated Pitch, Bank, and Heading from Simulation

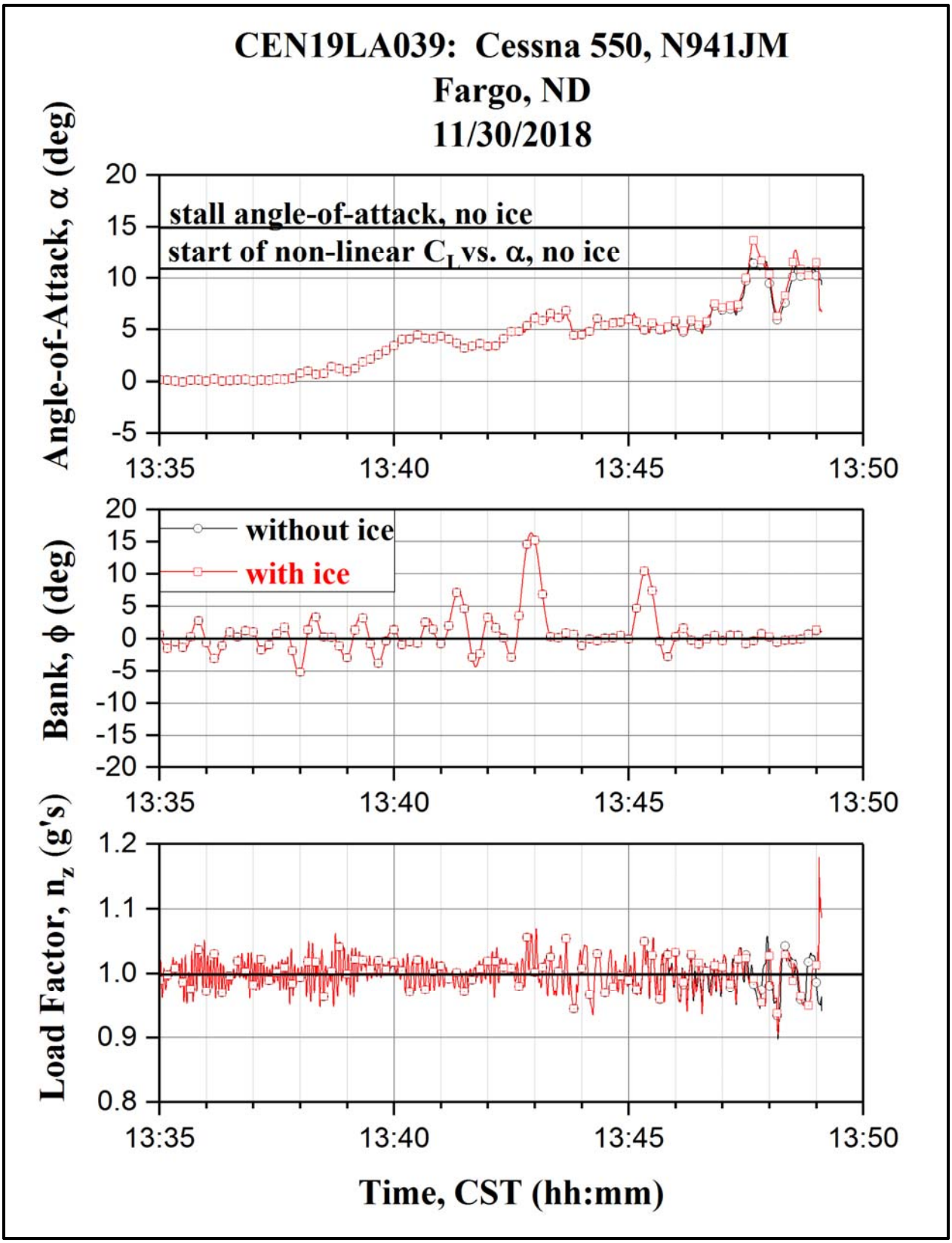

Figure 8: Estimated Angle-of-Attack, Bank, and Load Factor from Simulation, With and Without Ice

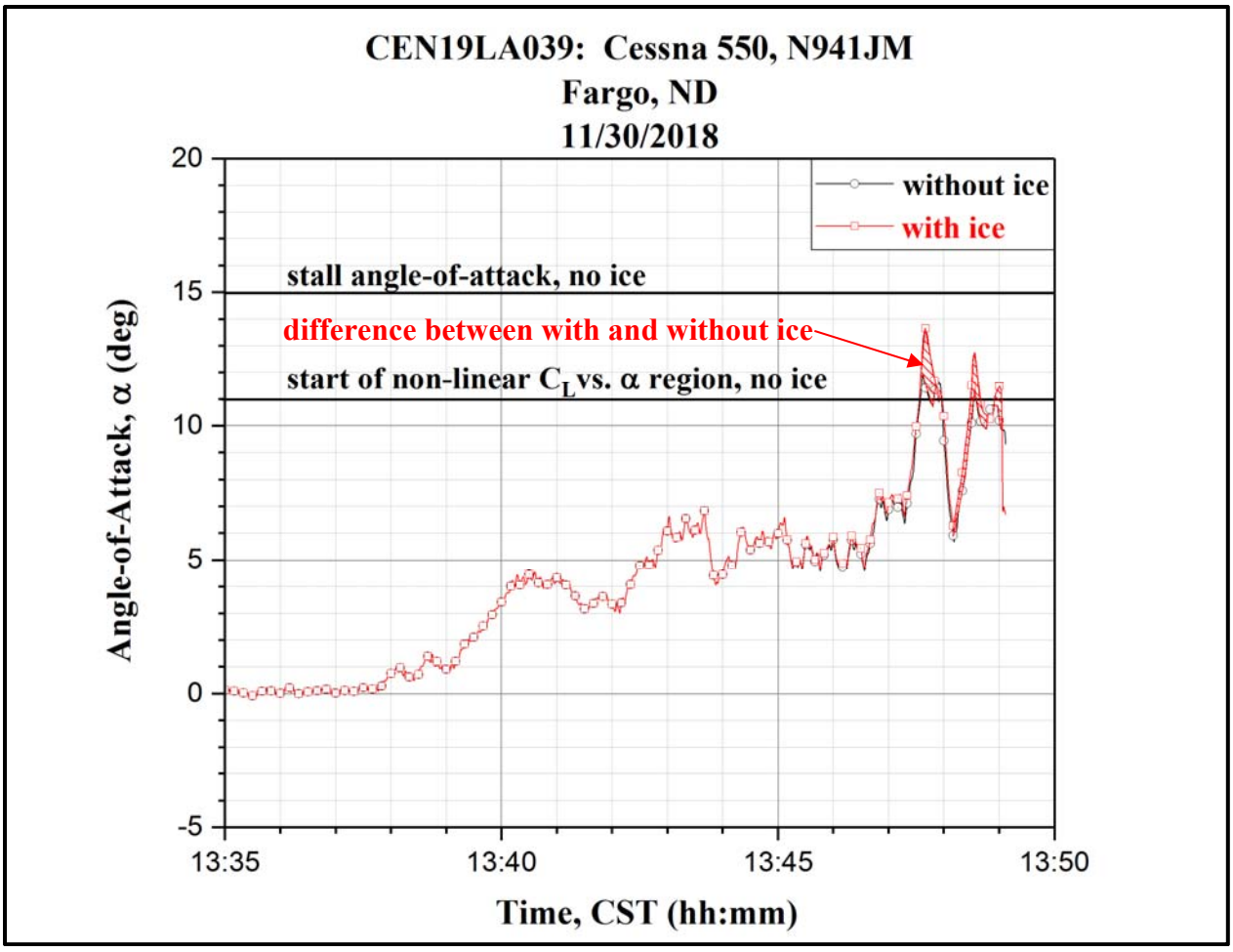

Figure 9: Estimated Angle-of-Attack, With and Without Ice

Figure 10: Ice on the Windshield of N941JM at the Accident Site

Figure 11: Ice on the Wing Leading Edge of N941JM at the Accident Site

Figure 12: Ice on the Vertical and Horizontal Tail of N941JM at the Accident Site