*SAMPLE REPORT: Names, dates, and locations have been changed*

**Forensic meteorological investigation of high wind and hail in Orlando, FL during the period 01/01/2020 – 09/01/2021**

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|---|---|
| **PREPARED ON:** | 17 - 20 September 2021 |
| **PREPARED FOR:** | John L. Williams |
| **AFFILIATION:** | Insurance of America |
| **PREPARED BY:** | Megan D. Walker, CCM |
| **DATE(S) OF INTEREST:** | 01/01/2020 – 09/01/2021 |
| **CLAIM:** | 08012021 |
| **INCIDENT LOCATION:** | 12345 Palm Tree Dr.<br>Orlando, FL 32811 |


**SUMMARY:**
Blue Skies Meteorological Services was retained to investigate high wind and hail occurrence at the property 12345 Palm Tree Dr., Orlando, FL 32811 during the above-listed time period.

To determine whether hail and/or damaging winds likely impacted the loss location during this period, Blue Skies examined National Weather Services storm reports and damage surveys, in-situ wind observations, National Weather Service bulletins, and NEXRAD weather radar data.


**CONCLUSIONS:**

- *Hail up to 1" diameter is indicated as possible on one date (04/11/2021)*
    - *Hail larger than 1" diameter is not indicated*
- *Wind gusts* over *55 mph are not indicated*
    - *Wind gusts* up to *50 – 55 mph are indicated as possible on one date (04/10/2021)*

# DATA

The use of high-quality, reliable data is crucial to ensure the accuracy of forensic meteorological analyses. In the performance of our meteorological investigations and in accordance with industry best practices, Blue Skies Meteorological Services utilizes data from trusted, official sources that specialize in the collection, quality control, and analysis of meteorological, climatological, and hydrological data for research and operational purposes.

Much of the data from the National Oceanic and Atmospheric Administration (NOAA) that was obtained and reviewed for this report can be certified by the Department of Commerce, if necessary. Occasionally, private companies offer more granular or proximate data than is available from official government or academic sources. In such cases, the private data are explicitly noted as such and are compared with the available government and academic data to ensure that they are consistent with the overall meteorological situation.

*The following data were reviewed and analyzed during this forensic meteorological investigation. The conclusions drawn in this report are based upon the data that were available at the time of report preparation. Any new, updated, or revised data relevant to these incidents may be incorporated in a later revision of this report.*

## *Storm Event Reports*

- Source: National Oceanic and Atmospheric Administration (NOAA), National Weather Service (NWS) Forecast Offices
- Product: Local Storm Reports for NWS Forecast Office in Melbourne, FL (KMLB)

## *In-Situ Wind Observations*

- Source: Iowa State University, Iowa Environmental Mesonet
- Product: ASOS/AWOS weather observations (METARs) from stations in the vicinity of the loss location

## *Radar*

- Sources:
    1. The National Oceanic and Atmospheric Administration (NOAA): National Centers for Environmental Information (NCEI): Radar Data
    2. Iowa State University: Iowa Environmental Mesonet: Archived NEXRAD Storm Attributes
- Products:
    1. A) NEXRAD National Reflectivity Mosaic<br>B) NEXRAD Level II and III data from KMLB (Melbourne, FL)<br>C) TDWR Level III data from TMCO (Orlando Internat'l Airport)
    2. NEXRAD Hail Index Overlay (HI) from KMLB (Melbourne, FL) centered on the loss location with a radius of approximately 5 miles

## *Weather Advisories and Warning Statements*

- Source: National Weather Service: Archived NWS Bulletins and Text Products
- Products: Severe weather warnings and area forecast discussion for NWS Forecast Office KMLB (Melbourne, FL)

### *Upper Air Data*

- Source: University of Wyoming: Department of Atmospheric Science
- Products: Archived upper air soundings for Tampa, FL (KTBW), Jacksonville, FL (KJAX), and Miami, FL (KMFL)

## TABLES AND FIGURES

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Figure 8: Enhanced Fujita Scale for Damage Indicator FR12 (One- and Two-Family Residences)
Figure 9: Hail Damage Threshold Sizes for Common Roofing Materials

## REFERENCES

Frelich, L. E. and E. J. Ostuno, 2012: “Estimating Wind Speeds of Convective Storms from Tree Damage.” Electronic J. Severe Storms Meteor., 7 (9), 1–19.

Marshall, Timothy P., et al., 2002: "Hail Damage Threshold Sizes for Common Roofing Materials." 21st Conference on Severe Local Storms.

McDonald, J. R., K. C. Mehta, and S. Mani, 2006: “A Recommendation for an Enhanced Fujita Scale: Submitted to the National Weather Service and Other Interested Users,” Revision 2. Wind Science and Engineering Center, Texas Tech University.

National Oceanic and Atmospheric Administration, Department of Defense, Federal Aviation Administration, and United States Navy, 1998: “Automated Surface Observing System (ASOS) User’s Guide”

National Oceanic and Atmospheric Administration, National Weather Service (NWS), Warning Decisions Training Branch (WDTB): “WSR-88D Dual-Polarization Radar Decision Aid”

# ANALYSIS: 01/01/2020 – 09/01/2021

## *Methodology*

Blue Skies was retained to identify storm events that may have produced damaging winds and/or hail in the vicinity of the insured property during the period of interest. The damage thresholds used in this analysis are informed by meteorological and engineering research on the impacts of wind and hail on the built environment and are set as: winds 55 mph or greater and hail 1” diameter or larger.

Per the Enhanced Fujita Scale used by the National Weather Service to correlate observed damage to the wind speeds expected to cause that damage, winds below 55 mph generally do not cause visible damage to one- or two-family residences, with roof covering materials generally not removed below 65 mph (damage indicator: FR12; degree of damage: 1 and 2; see Figure 8).

Laboratory and field research has shown that asphalt roofing shingles typically are not damaged at hail sizes less than 1” – 1.25” diameter, while roofing tiles typically are not damaged at hail sizes less than 1.25” – 1.5” diameter (Marshall, et al., 2002; see Figure 9).

The below criteria were designed to identify events during which these thresholds for wind and hail may have been exceeded in the vicinity of the insured property.

A date was assessed for hail potential if it met any of the following criteria:

- The hail index (HI) radar product indicated a high probability of hail 1” or greater diameter aloft in proximity to the insured property (~5 mi radius)
- A NWS severe thunderstorm warning for hail 1” diameter or larger was in effect for the insured property
- Hail 1” diameter or larger was reported within 5 miles of the insured property

A date was assessed for damaging wind potential if it met any of the following criteria:

- A National Weather Service severe weather warning for wind gusts greater than 60 mph or tornadoes was in effect for the loss location
- A strong wind gust (50 mph or higher) was reported within 15 miles of the loss location
- Wind damage was reported within 10 miles of the loss location

## *Results*

Ten (10) storm events within the period of interest met one or more of these criteria. These 10 dates comprise the Dates of Interest and are shown in Table 1.

NEXRAD (weather radar) reflectivity data were then used to determine whether the strong-to-severe thunderstorms that occurred on the dates of interest directly impacted the loss location with an intensity suggestive of the possibility of hail 1” diameter or greater and/or winds in excess of 55 mph.

Two (2) storm events met this final criterion: 04/11/2021 and 04/10/2021. Dual-polarization and Terminal Doppler Weather Radar data were therefore manually examined for these storm events and analyzed in the context of official storm reports, in-situ measurements, and upper-air data. The details of those analyses are described below.

Near-surface wind speeds and features were analyzed using data from TMCO, the Terminal Doppler Weather Radar (TDWR) that serves Orlando International Airport and is located [redacted] miles [redacted] of the insured property. TMCO samples the atmosphere as low as 700 ft AGL in the vicinity of the insured property.

Storm structure and evolution as well as the locations of hail aloft were analyzed using dual-polarization data from KMLB, the WSR-88D radar located in Melbourne, FL, [redacted] miles [redacted] of the insured property. KMLB samples the atmosphere at and above 2,500 ft AGL in the vicinity of the insured property.

The findings of the this meteorological analysis are summarized in Table 1: Dates of Interest, while National Weather Service reports of strong wind gusts, wind damage, tornadoes, and hail are listed in Table 2. Due to the size of both tables, they are also provided digitally in a format more easily read. Figure 1 shows the location of those storm reports nearest the insured property.

The results of the analyses for 04/11/2021 and 04/10/2021 are described below.

**Dates of Interest Summary:**

Note: if a concept or term is unfamiliar, please consult Appendix A, which describes the meteorological best practices for radar interpretation that are utilized in this analysis

**04/11/2021:** *wind gusts over 55 mph not indicated; hail up to 1" diameter possible*

A severe thunderstorm located near Orlo Vista in western Orlando moved east-northeastward. Hail up to 2" diameter was widely reported in association with this storm. The core of this severe thunderstorm passed near and north of the insured property (see Figures 2 and 3). Hail at least quarter size (1" diameter) was reported near the UCF campus, east of the insured property (Table 2), which was also impacted by the southern periphery of the core of this storm.

Dual-polarization radar data from KMLB (Melbourne, FL WSR-88D radar) show a distinct hail signature within the core of this storm, with reflectivity (Z) values over 60 dBZ coincident with correlation coefficient (CC) values less than 0.95. In areas where the largest hail (up to 2") was reported, differential reflectivity (ZDR) values were near zero with reflectivity (Z) values approaching 65 dBZ. Higher ZDR values were found around the periphery of the core, where reflectivity values were closer to 60 dBZ.

Figures 2 and 3 show the dual-polarization hail signature of this severe thunderstorm as it approached and impacted the insured property. In the regions circled in white, the dual-polarization data are consistent with the presence of hail aloft. The regions with near-zero ZDR values and reflectivity values above 60 dBZ, consistent with large and minimally melted hail, are circled in black. Please see Appendix A for a discussion and documentation of the meteorological best-practices in dual-polarization radar interpretation utilized in this analysis.

Although the largest hail was confined to regions with the strongest hail signature (i.e. near-zero ZDR coincident with CC below 0.92 and Z approaching 65 dBZ), sub-severe and marginally severe hail of 0.7" - 1" diameter was reported throughout the periphery of the core of the storm in areas with a weaker dual-polarization hail signature (i.e. higher ZDR coincident with slightly higher CC and slightly lower Z), suggesting that hail was falling even outside of those portions of the storm in which the "classic" large hail signature was present.

The insured property was impacted by the southern portion of the core of this storm (Fig. 3). Dual-polarization data from KMLB are not strongly indicative of hail aloft in this portion of the storm, with reflectivity, CC, and ZDR values more typically indicative of heavy rain. However, reflectivity data from TMCO (Orlando, FL, TDWR), which samples the atmosphere closer to the surface than KMLB, show reflectivity returns greater than 60 dBZ immediately adjacent to the insured property at an altitude of 700 ft AGL (see Figure 4), indicating that very heavy precipitation impacted that property.

TMCO does not have dual-polarization capability, and so the dual-polarization variables that allow for discrimination of precipitation type (e.g. rain vs. hail) are not available. However, analysis of storm structure and evolution along with NWS storm reports suggests that this area of the storm likely contained sub-severe to marginally severe hail.

Between 0947 EST and 0951 EST, the 60 dBZ reflectivity core of this severe thunderstorm descended rapidly toward the surface. Dual-polarization data from KMLB indicate large hail throughout the 60 dBZ core. The 0947 EST volume scan from KMLB shows 60 dBZ heights approaching 25,000 ft AGL, well into the hail growth zone. By the next volume scan, at 0951 EST, 60 dBZ heights are only found below 15,000 ft AGL. This collapse of the reflectivity core is show in Figure 5 and is also reflected in the large reduction in vertically integrated liquid (VIL), shown in panel B in Figures 2 and 3. Hail up to 2" diameter was reported beneath this descending 60 dBZ core.

The region of near-surface 55 – 61 dBZ reflectivity returns shown by TMCO at the insured property at 0953 EST therefore corresponds to a time when the hail-containing core of this severe thunderstorm was descending toward and impacting the surface.

The region of 55 – 61 dBZ reflectivity returns that impacted the insured property moved northeastward and impacted the location where 1" hail was reported "near the UCF campus" (Table 2), providing further evidence that this region of the storm contained at least some hail.

Although dual-polarization radar data from KMLB do not strongly indicate severe hail aloft over the insured property during this storm event, analysis of reflectivity data from TMCO, which samples the atmosphere nearer the surface, indicates that the same portion of this storm impacted the insured property as impacted a location near UCF, [redacted] miles away, where 1" hail was reported.

Based on analysis of storm structure and evolution, including comparison of the dual-polarization radar indicators of hail at the insured property to those at locations where hail was reported, hail up to 1" diameter is indicated as possible by the meteorological data at the insured property. Hail larger than 1" diameter is not indicated.

No wind gusts over 50 mph or wind-related damage were reported in association with this severe thunderstorm, nor do near-surface radial velocity data from TMCO indicate strong winds in the vicinity of the insured property during impact of this severe thunderstorm.

**04/10/2021:** *wind gusts up to 45 mph indicated, with gusts up to 50 - 55 mph possible; hail not indicated*

As a line of showers and thunderstorms swept eastward across the Florida peninsula, a cluster of thunderstorms developed ahead of the line and moved east-northeastward across southern, central, and eastern Orlando (see Figure 6). This activity was not warned as severe, indicating that the National Weather Service meteorologists who were monitoring the situation in real-time did not consider the activity to be an immanent threat to life or property. No severe weather warnings were issued for the Orlando metropolitan area in general or for the insured property in particular on 04/10/2021.

Wind gusts of 40 – 55 mph were reported in and around Orlando during this storm event (Table 2). The strongest measured gusts - up to 53 mph at Orlando International Airport, [redacted] miles south of the insured property - occurred in association with the southern portion of the cluster of storms that formed ahead of the main line of showers and thunderstorms. The northern portion of this cluster of thunderstorms impacted the insured property (Fig. 6, top row).

Radial velocity data from TMCO were analyzed in an attempt to estimate near-surface wind speeds in the vicinity of the insured property during impact of the cluster of storms. However, because outflow from these thunderstorms was roughly perpendicular to the radar radials in the vicinity of the insured property, radial velocity data did not accurately reflect near-surface wind speeds in the vicinity of that property.

Weather radar can only measure the component of wind along a radial line from the dish to the target (i.e. the component blowing directly toward or away from the radar) – any component of the wind blowing perpendicular (tangential) to that radial line does not contribute to the radial velocity measurement. For that reason, winds blowing radially toward or away from the radar are most accurately captured by the radial velocity data, while those blowing perpendicular to the radar are least accurately captured. For additional detail about this aspect of radar data analysis, please see Appendix A.

Although radial velocity data from TMCO are not a reliable indicator of total wind speed in the vicinity of the insured property for the reason discussed above, the radial velocity data do indicate isolated regions of stronger near-surface winds in association with the more intense, southern portion of this this cluster of storms in which storm outflow aligned more closely with the radar radial. In two regions, identified in the bottom row of Figure 4, TMCO near-surface radial velocity values ranged from 50 kts to 60 kts (approximately 55 – 70 mph) shortly after this portion of the cluster of storms produced a 53 mph gust at Orlando International Airport (Table 2).

This portion of the cluster of storms did not directly impact the insured property. Radar reflectivity data from both KMLB and TMCO indicate the storm cells in the southern portion of the cluster of storms were more intense than the storm cell that impacted the insured property, with deeper and broader reflectivity cores (Fig. 7). Radial velocity data from the southern portion of this cluster of storms is therefore not an appropriate comparison or proxy for winds nearer the insured property.

Additional strong gusts, up to an estimated 55 mph in Ocoee, occurred behind the aforementioned cluster of storms but ahead of the main line. A maximum gust of 43 mph was reported at [redacted], the weather reporting station nearest the insured property, located [redacted] miles to the northwest, during this time (Table 2). Wind-related damage to tree limbs, fences, and backyard items was also reported in Winter Springs, [redacted] miles north of the insured property during this interim period between rounds of precipitation (Table 2).

No other wind-related damage was reported in the Orlando metropolitan area during this storm event (Table 2). Coupled with measured wind gusts that remained below 55 mph, this dearth of wind-related damage reports in a densely populated metropolitan area indicates that widespread damaging winds were likely not occurring. However, isolated gusts of 50 – 55 mph, capable of breaking tree branches and displacing backyard items, are evident via the reports of such damage in Winter Springs.

Widespread measured wind gusts of 40 – 45 mph indicate that such wind speeds were also likely at the insured property, while isolated reports of wind damage consistent with gusts of 50 – 55 mph indicate that such stronger gusts cannot be ruled out. Neither radar data nor local storm reports indicate wind gusts over 55 mph in the vicinity of the insured property. Wind gusts under 55 mph are generally not associated with structural damage to one- and two-family homes (Enhanced Fujita Scale, see Figure 8).

## Documentation and Figures

Dates of Interest | Orlando, FL | 01/01/2020 – 09/01/2021

| Date (EST) | Hail Index (HI) | | | Hail Reports | | | | Wind Reports | | | | NWS Bulletins | | Radar Notes - National Reflectivity Mosaic | Impacts at the Loss Location |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | max size | time (EST) | notes | county | time (EST) | size | nearest hail report to loss location | county | time (EST) | magnitude | nearest wind report to loss location | warning | hazards | Composite Reflectivity (CR), Base Reflectivity (BR, when available), and Dual-Polarization (DP, where indicated) | Impacts based on in-situ observations, storm reports, NWS bulletins, radar reflectivity, dual-polarization radar (if explicitly noted) |
| 6/22/21 | – | – | none | none | – | – | – | Orange | 1320 EST | wind gust: none<br>wind dmg: lg tree down | [redacted] | none | – | Scattered thunderstorms developed across central Florida and moved slowly eastward and northeastward. This activity impacted the insured property but was not warned as severe. No wind gusts over 40 mph were reported, and only one report of wind-related damage (a tree down) was received, indicating that damaging winds were not common with this activity. | wind gusts over 55 mph not indicated; hail > 1" diameter not indicated |
| 6/16/21 | – | – | none | none | – | – | – | none | | wind gust:<br>wind dmg: | [redacted] | 0646 EST - svr tstorm | 60 mph gusts & quarter size hail | A severe thunderstorm located over eastern Orlando moved northeastward. Sub-severe hail was reported near Union Park with this storm. The reflectivity core of this storm passed to the south and east of the insured property. | wind gusts over 55 mph not indicated; hail > 1" diameter not indicated |
| 4/20/21 | – | – | none | Orange | 0652 EST | 0.75" | 3.7 mi (0.75") | Volusia, Polk, Osceola, Orange | 0748 - 1215 EST | wind gust: 44 - 48 mph<br>wind dmg: none | [redacted] | 0935 EST - svr tstorm | 60 mph gusts & quarter size hail; upgraded to golf ball size hail at 0946 EST | A severe thunderstorm located near Orlo Vista in western Orlando moved northeastward. Hail up to 2" diameter was widely reported in association with this storm. The core of this storm passed near and north of the insured property. Hail at least quarter size (1" diameter) was reported near the UCF campus, east of the insured property, which was also impacted by the southern periphery of the core of this storm. | wind gusts over 55 mph not indicated; hail > 1" diameter not indicated |
| 4/11/21 | 2.5" | 0939 - 1004 EST | Hail signatures in WSW-to-ENE line passing ~3 mi N of the insured property, with an additional, smaller hail signature ~5 mi ESE of the property. | Orange, Seminole, Lake, Seminole, Brevard, Polk | 0940 - 1140 EST | 0.25" - 2" | 1.5 mi (1") | Lake, Orange, Seminole, Osceola, Volusia, Brevard | 1624 - 1822 EST | wind gust: 40 - 55 mph<br>wind dmg: tree & limbs down; fences & backyard items knocked down | [redacted] | 0935 EST - svr tstorm | 60 mph gusts & quarter size hail; upgraded to golf ball size hail at 0946 EST | A severe thunderstorm located near Orlo Vista in western Orlando moved east-northeastward. Hail up to 2" diameter was widely reported in association with this storm. The core of this storm passed near and north of the insured property. Hail at least quarter size (1" diameter) was reported near the UCF campus, east of the insured property, which was also impacted by the southern periphery of the core of this storm.<br><br>Dual-polarization radar data from KMLB (Melbourne, FL WSR-88D radar) show a distinct hail signature within the core of this storm, with the largest hail confined to regions with the strongest "classic" hail signature (i.e. low ZDR coincident with low CC and high Z). Sub-severe and marginally severe hail was reported throughout the periphery of the core of the storm in areas with a weaker dual-pol hail signature.<br><br>Dual-pol data are not strongly indicative of hail in the far southern portion of the storm, which impacted the insured property. However, given multiple reports of marginally severe hail along the periphery of the core of this storm, in areas with fairly weak dual-pol indicators of hail, hail at the insured property cannot be completely ruled out. 1" hail should be considered the maximum size that may have been falling at this location. | wind gusts over 55 mph not indicated; hail up to 1" diameter possible |
| 4/10/21 | – | – | none | none | – | – | – | Seminole, Volusia | 1455 - 1930 EST | wind gust: 41 - 62 mph<br>wind dmg: trees & branches down; minor structural dmg | [redacted] | none | – | As a line of showers and storms swept eastward across the Florida peninsula, a cluster of storms developed ahead of the line and moved east-northeastward across southern, central, and eastern Orlando.<br><br>A wind gust of 53 mph was reported at Orlando International Airport in association with this activity. The northern portion of this cluster impacted the insured property and went on to impact southern Winter Springs, where some damage to tree limbs, fences, and backyard items was reported. No wind gusts over 40 mph were reported at Orlando Executive Airport, 7 mi southwest of the insured property when this activity impacted that location; however, the report from Winter Springs does suggest that marginally damaging winds were possible with portions of this activity.<br><br>Given wind gusts of 40 - 55 mph that were reported across the Orlando metro area in association with this activity, similarly gusty winds may have impacted the insured property. Winds strong enough to cause structural damage are not indicated. | wind gusts up to 45 mph likely, with gusts up to 50 - 55 mph possible; hail > 1" diameter not indicated |
| 8/21/20 | – | – | none | none | – | – | – | Orange, Brevard | 1317 - 1440 EST | wind gust: 41 - 53 mph<br>wind dmg: lg tree down | [redacted] | none | – | A north-to-south line of thunderstorms moved eastward across the Orlando metro area. Additional scattered storms developed ahead of this line. A thunderstorm anchoring the northern end of this line was warned as severe as the storm impacted Winter Garden, but the warning was allowed to expire as the storm continued eastward and weakened. A large tree was reported down and a 46 mph wind gust were reported in central Orlando. No additional strong gusts or wind damage were reported with this storm. Although scattered storms impacted the insured property, they were not warned as severe, nor do radar data suggest damaging wind gusts or hail. | wind gusts over 55 mph not indicated; hail > 1" diameter not indicated |
| 8/17/20 | – | – | none | none | – | – | – | Volusia, Seminole, Orange | 1539 - 1723 EST | wind gust: 45 - 63 mph<br>wind dmg: lg branches down; minor structural dmg | [redacted] | none | – | Several severe thunderstorms impacted the Orlando metro area on this date, with a particularly strong storm producing up to 1.75" hail near Debary. None of the severe-warned storms directly impacted the insured property, although a strong cell that went on to produce a 51 mph gust at Orlando Executive Airport did pass near and west of the property. Outflow from this cell may have produced briefly gusty winds at the insured property. No wind-related damage was reported in association with this storm. | wind gusts over 55 mph not indicated; hail > 1" diameter not indicated |
| 8/9/20 | 1" | 1654 EST | Single hail signature ~5 mi WNW of the insured property. | Volusia, Orange | 1529 - 1610 EST | 0.88" - 1.75" | 13.6 mi (1") | Orange | 1812 EST | wind gust: 63 mph<br>wind dmg: none | [redacted] | none | – | Scattered thunderstorms developed across the Orlando metro area. One of these cells intensified near and south of Orlando International Airport, where a 63 mph gust was reported. This activity remained south of the insured property. | wind gusts up to 50 mph possible; hail > 1" diameter not indicated |
| 8/5/20 | – | – | none | none | – | – | – | Brevard, Orange | 1405 - 1936 EST | wind gust: 40 - 58 mph<br>wind dmg: none | [redacted] | none | – | Scattered thunderstorms developed across central Florida and intensified in a cluster over the far eastern Orlando metro area. One storm cell that directly impacted Orlando International Airport produced a 58 mph gust. This storm did not impact the insured property. Orlando Executive Airport, located closer to the insured property, did not report gusts over 40 mph during this activity. No wind-related damage was reported. | wind gusts over 55 mph not indicated; hail > 1" diameter not indicated |
| 7/14/20 | – | – | none | none | – | – | – | Brevard, Orange | 1405 - 1936 EST | wind gust: 40 - 58 mph<br>wind dmg: none | [redacted] | none | – | Scattered thunderstorms developed across central Florida and intensified in a cluster over the far eastern Orlando metro area. One storm cell that directly impacted Orlando International Airport produced a 58 mph gust. This storm did not impact the insured property. Orlando Executive Airport, located closer to the insured property, did not report gusts over 40 mph during this activity. No wind-related damage was reported. | wind gusts over 55 mph not indicated; hail > 1" diameter not indicated |

**Table 1: Dates of Interest in Orlando, FL during the period 01/01/2020 – 09/01/2021. Note: this table has also been provided as a digital supplement to the report, which is more easily read than the above version that has been sized to fit on a standard printed page.**

Table 2 provided digitally only - table is too large to fit on a standard printed page

**Table 2: National Weather Service (NWS) Local Storm Reports of hail, wind damage, strong wind gusts, and tornadoes from the Melbourne, FL (KMLB) weather forecasting office within 40 miles of the loss location during the period of interest (01/01/2020 – 09/01/2021). This table has been provided digitally due to its size.**

NWS Local Storm Reports: [redacted]

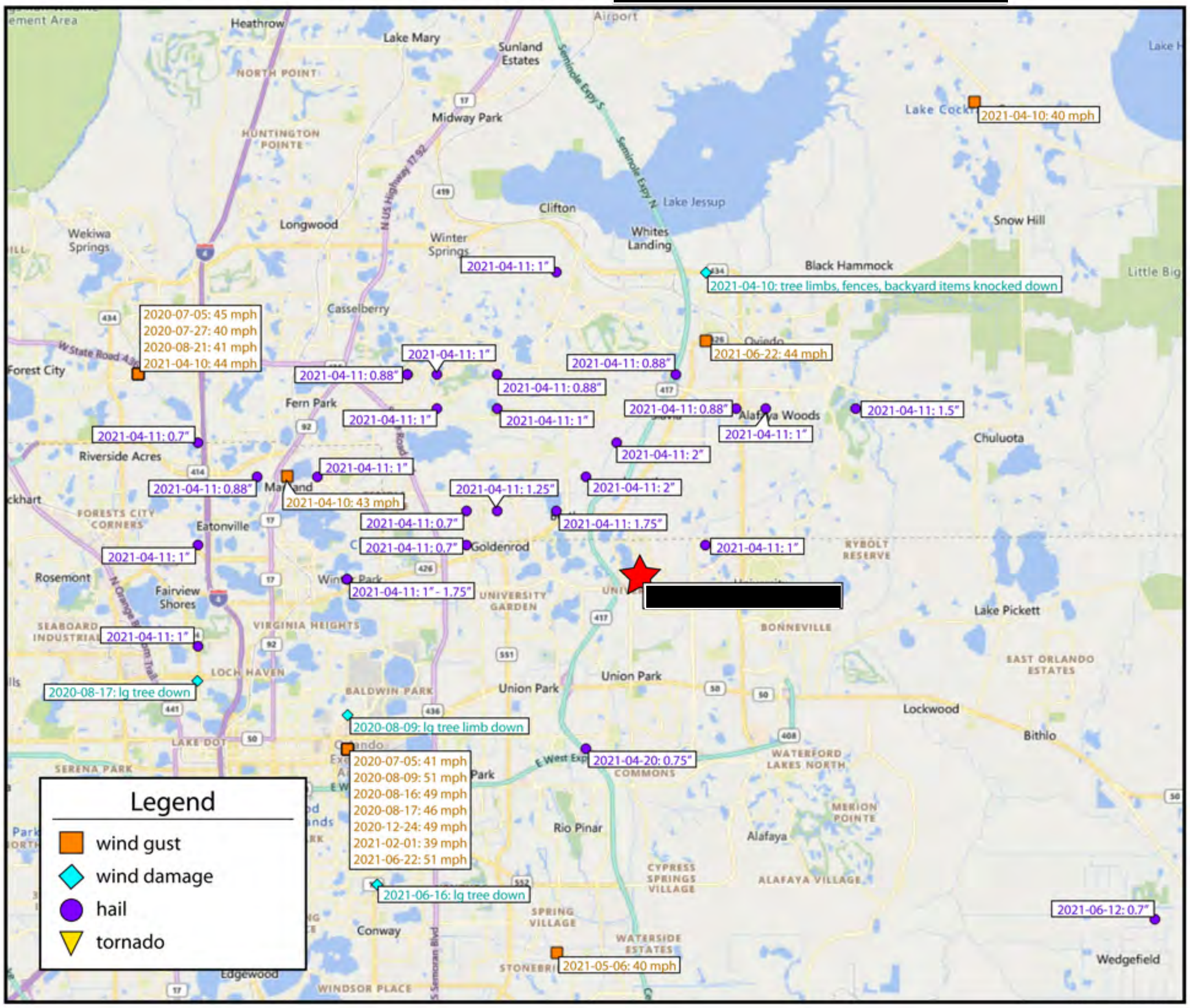



**Figure 1: National Weather Service (NWS) Local Storm Reports (LSRs) of hail, strong wind gusts, wind damage, and tornadoes from the Melbourne, FL (KMLB) weather forecasting office during the period of interest (01/01/2020 – 09/01/2021). Additional details about these storm reports are provided in Table 2.**

2021-04-11 Radar Signature: 0947 EST (1447 UTC)

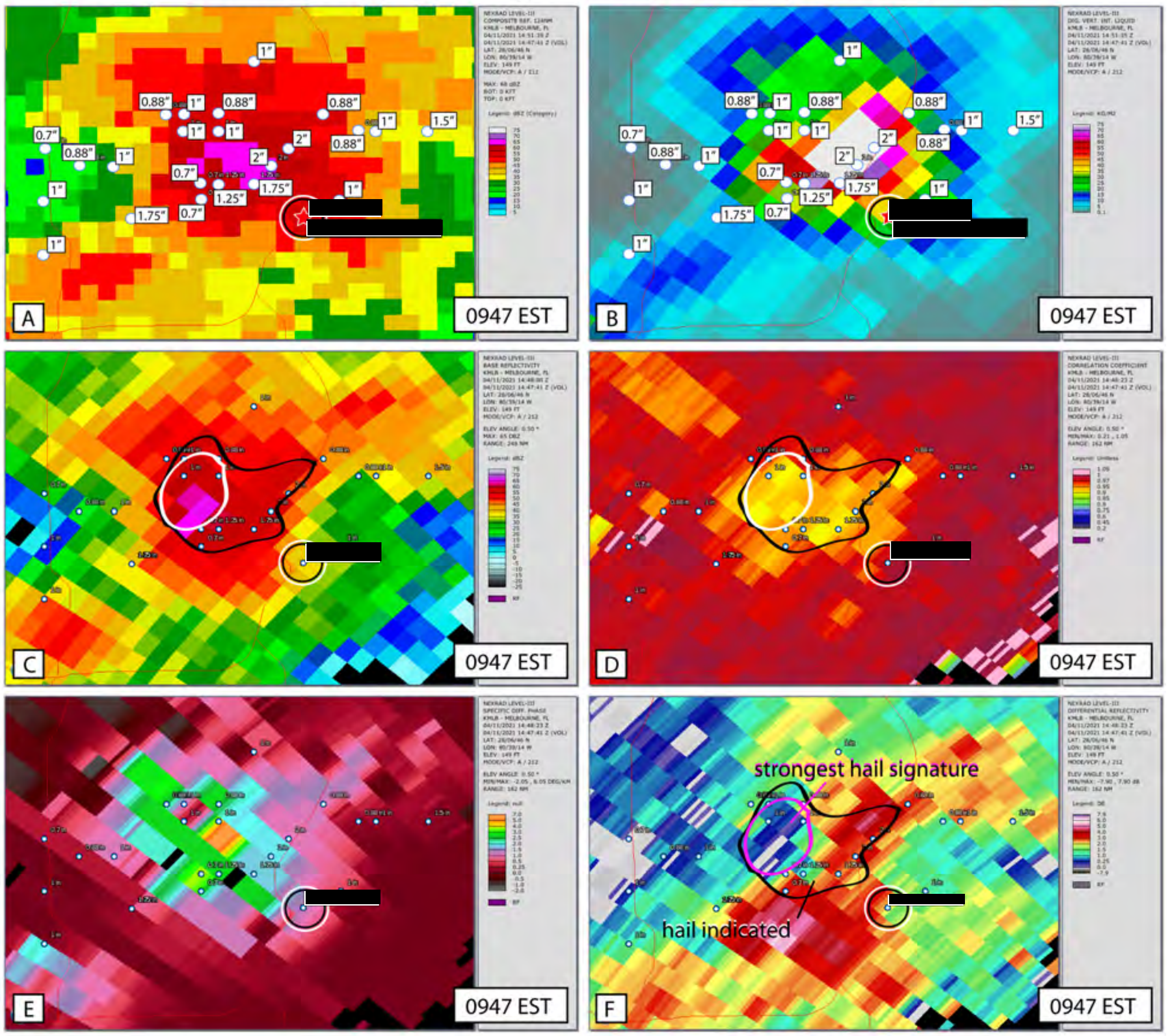



**Figure 2: 6- panel radar hail signature for 04/11/2021 at 0947 EST as the severe thunderstorm was moving east-northeastward and passing near and north of the insured property. The loss location is indicated by a white dot within a black and white circle. Storm reports associated with passage of this storm are marked by white dots and labeled with the reported magnitude. The region in which dual-polarization radar data suggest hail aloft is circled in black. A) composite reflectivity – shows the highest reflectivity from all available elevation angles and thereby indicates regions of intense precipitation within a storm. B) digital vertically integrated liquid – a measure of the amount of precipitation within a column of air, with higher VIL associated with more intense precipitation; the presence of hail increases VIL. C) base reflectivity – a measure of the power returned to the radar, with higher reflectivity values associated with more intense precipitation; the presence of hail typically increases reflectivity. D) correlation coefficient – a dual-polarization radar variable; lowered correlation coefficient values coincident with lowered differential reflectivity (F) and high reflectivity (C) are associated with the presence of hail. E) specific differential phase – a dual-polarization variable that indicates the amount of liquid water present within a sampled volume. F) differential reflectivity – a dual-polarization variable that indicates how symmetrical sampled hydrometeors are about the horizontal and vertical axes; lowered differential reflectivity values in the presence of lowered correlation coefficient (D) and high reflectivity (C) are associated with the presence of hail. Source: KMLB level 3 dual-polarization data.**

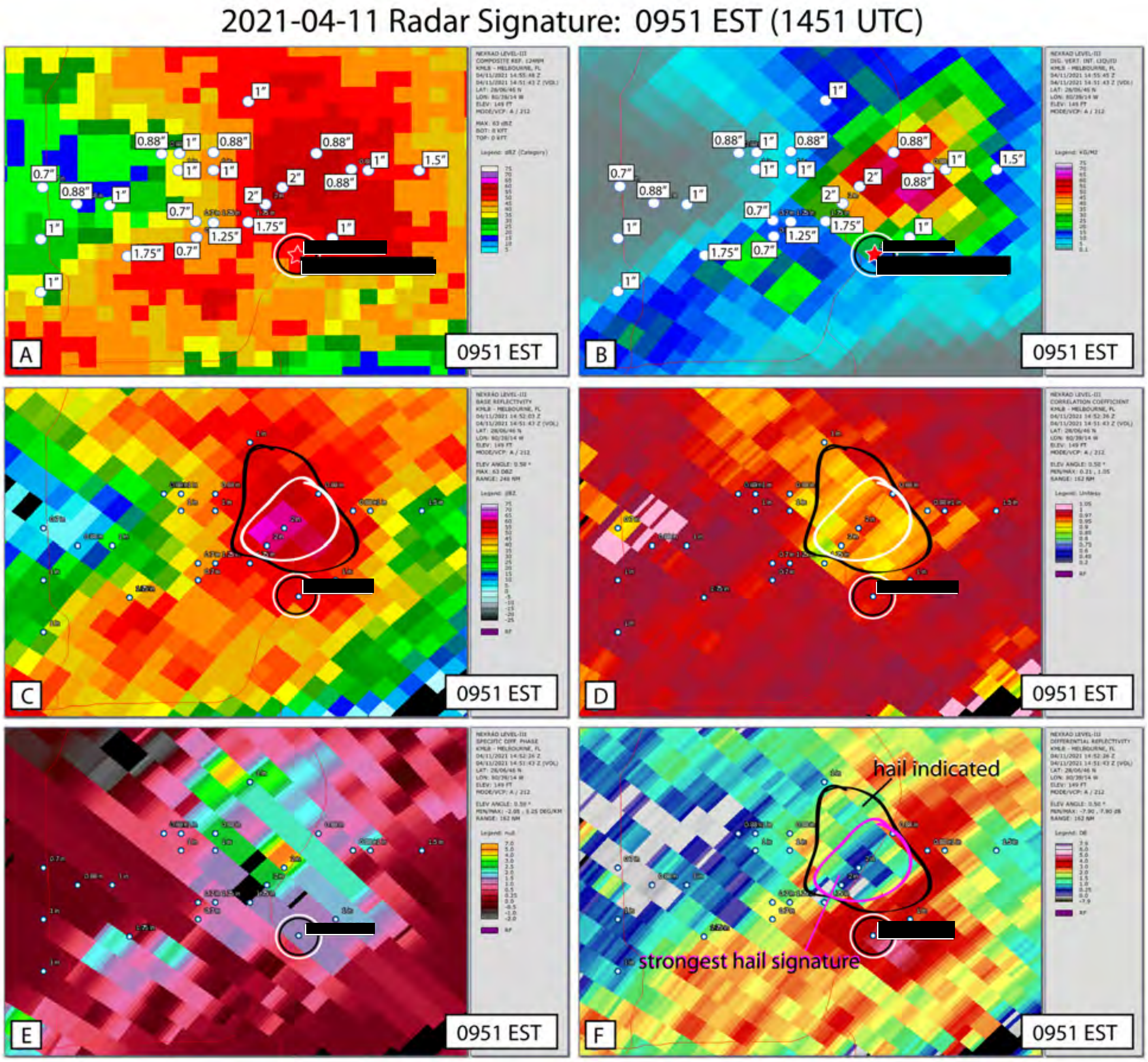



**Figure 3: 6- panel radar hail signature for 04/11/2021 at 0951 EST as the severe thunderstorm was moving east-northeastward and passing near and north of the insured property. The loss location is indicated by a white dot within a black and white circle. Storm reports associated with passage of this storm are marked by white dots and labeled with the reported magnitude. The region in which dual-polarization radar data suggest hail aloft is circled in black. A) composite reflectivity – shows the highest reflectivity from all available elevation angles and thereby indicates regions of intense precipitation within a storm. B) digital vertically integrated liquid – a measure of the amount of precipitation within a column of air, with higher VIL associated with more intense precipitation; the presence of hail increases VIL. C) base reflectivity – a measure of the power returned to the radar, with higher reflectivity values associated with more intense precipitation; the presence of hail typically increases reflectivity. D) correlation coefficient – a dual-polarization radar variable; lowered correlation coefficient values coincident with lowered differential reflectivity (F) and high reflectivity (C) are associated with the presence of hail. E) specific differential phase – a dual-polarization variable that indicates the amount of liquid water present within a sampled volume. F) differential reflectivity – a dual-polarization variable that indicates how symmetrical sampled hydrometeors are about the horizontal and vertical axes; lowered differential reflectivity values in the presence of lowered correlation coefficient (D) and high reflectivity (C) are associated with the presence of hail. Source: KMLB level 3 dual-polarization data.**

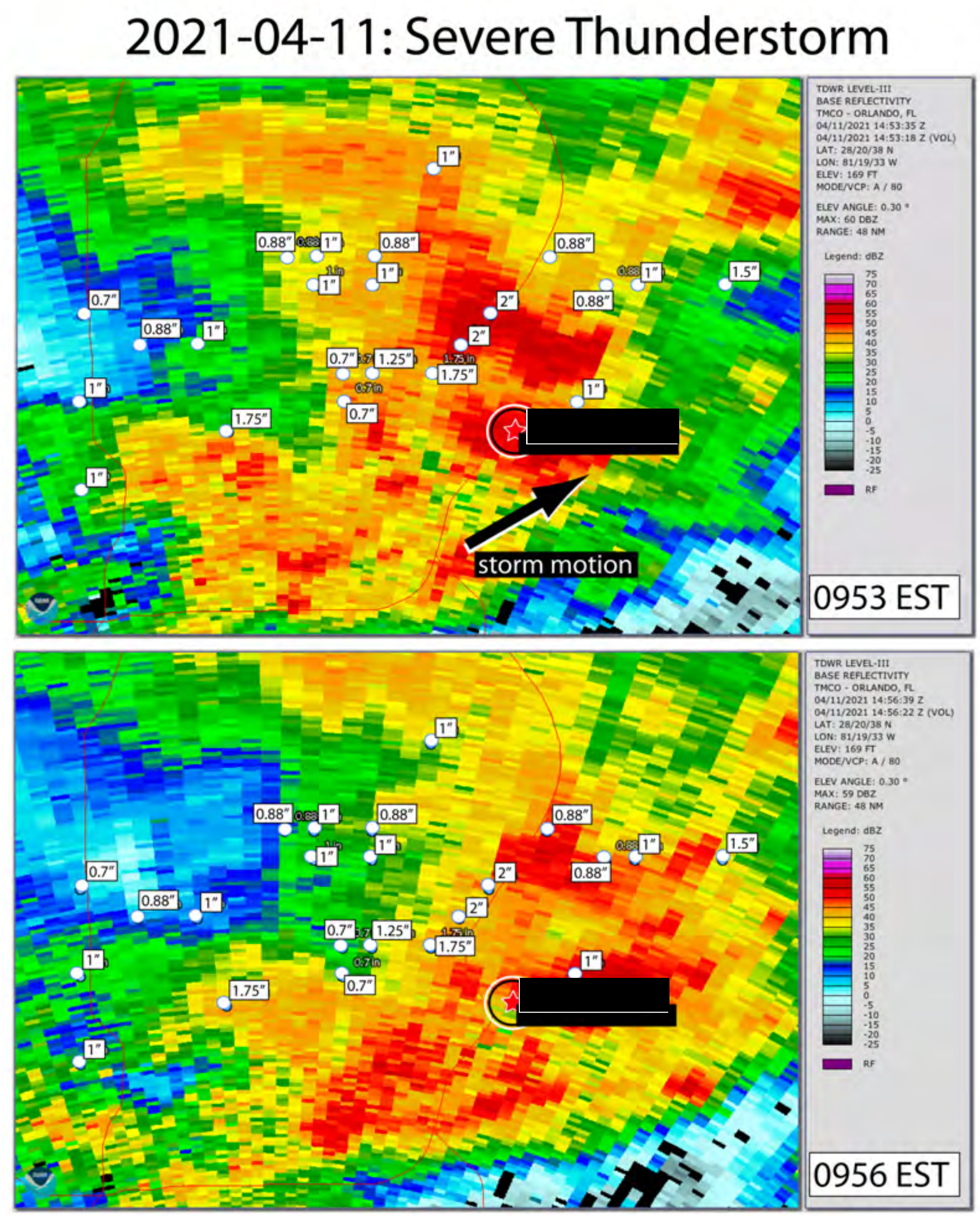



**Figure 4: Time-evolution of the severe thunderstorm that impacted Orlando, FL on 04/11/2021 as it impacted the insured property and the location [redacted] miles to the ENE where 1" hail was reported. The loss location is indicated by a red star within a black and white circle. Storm reports associated with passage of this activity are marked by white dots and labeled with the reported magnitude. TMCO base reflectivity at an elevation angle of 0.3 degrees is shown; the beam height over the insured property was approximately 700 ft AGL and shows 55 – 61 dBZ returns at the insured property associated with a portion of this thunderstorm that went on to produce reported 1" hail a short distance away. Source: Orlando International Airport (TMCO) Terminal Doppler Weather Radar (TDWR), level 3.**

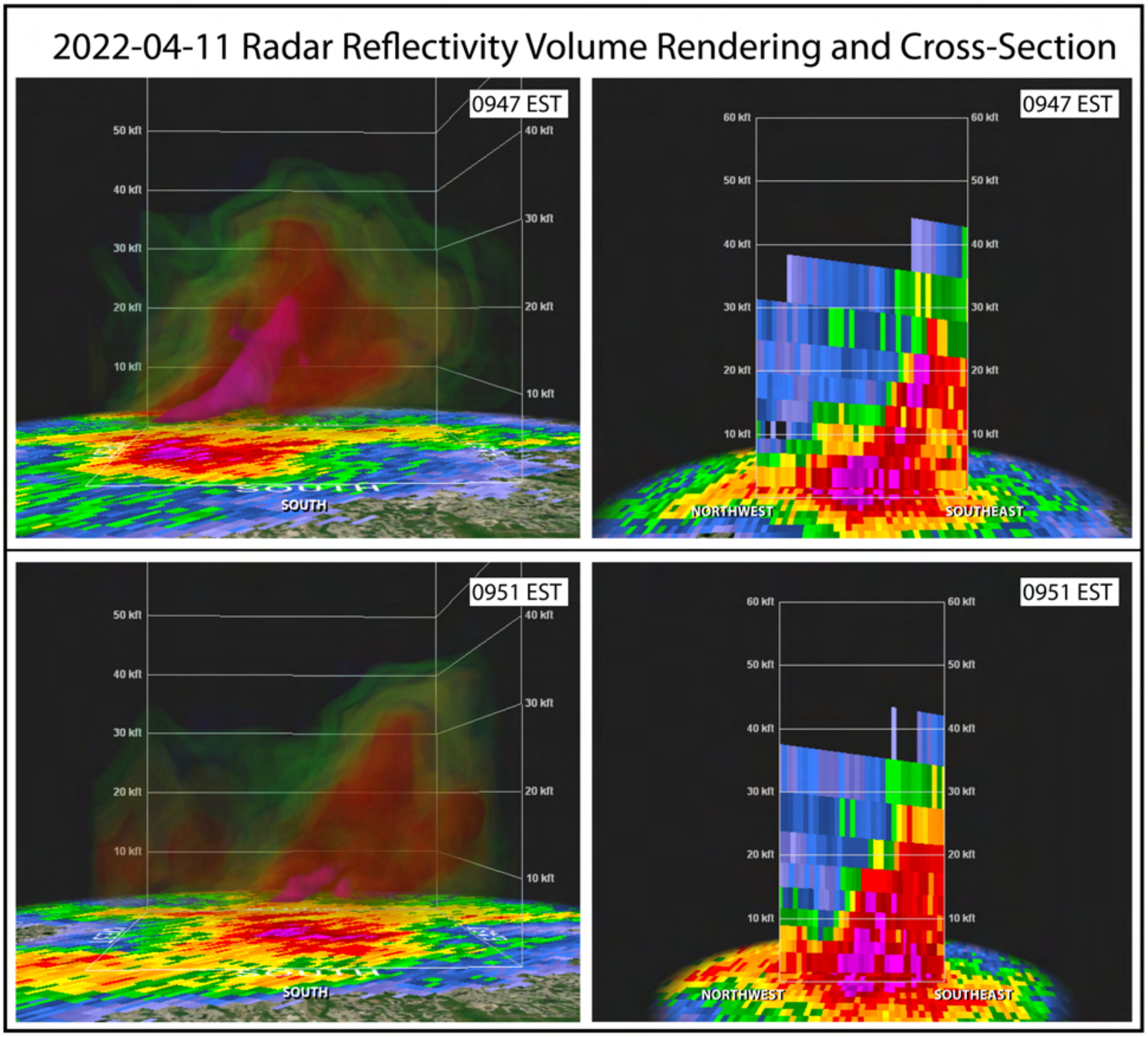



**Figure 5: 3-dimensional radar reflectivity volume rendering (left column) and cross-section (right column) showing the descent of the 60 dBZ reflectivity core (fuchsia shading) between 0947 EST (top row) and 0951 EST (bottom row) as this severe thunderstorm was approaching and impacting the insured property. Source: KMLB level 2 radar data, processed with GR2A**

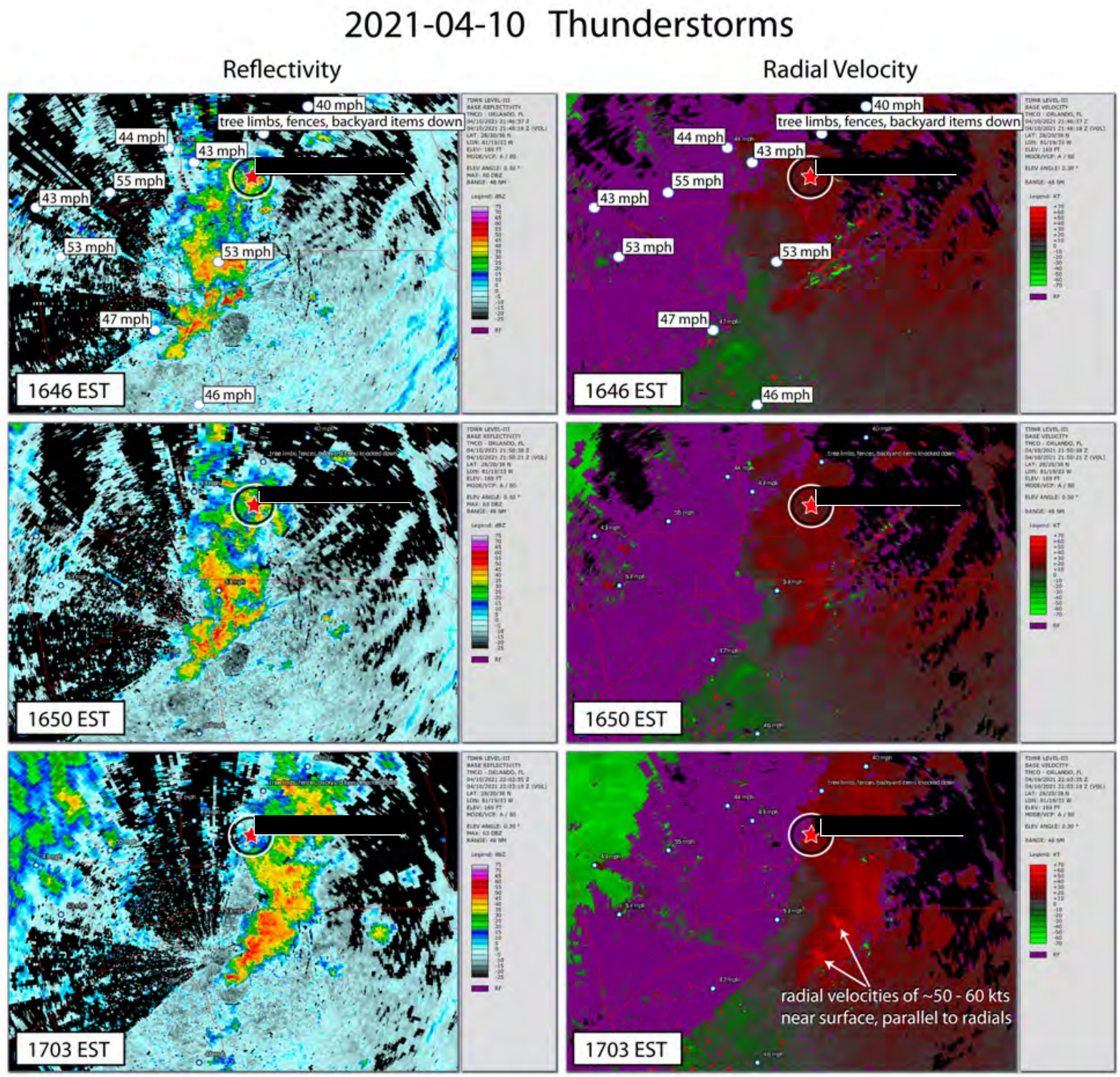



**Figure 6: Time-evolution of the cluster of showers and storms that impacted Orlando, FL on 04/10/2021 as it approached, impacted, and moved away from the insured property. The loss location is indicated by a red star within a black and white circle. Storm reports associated with passage of this activity are marked by white dots and labeled with the reported magnitude. The left-hand column shows radar reflectivity data while the right-hand column shows radial velocity data for the same volume scans. In the radial velocity data, wind blowing toward the radar is indicated in green, while wind blowing away from the radar is indicated in red. Regions of particularly strong winds are marked and labeled. The speed of the wind is denoted by the intensity of the color, as indicated in the scale bar to the right in each panel, with brighter colors indicating stronger winds. Source: Orlando International Airport (TMCO) Terminal Doppler Weather Radar (TDWR), level 3**

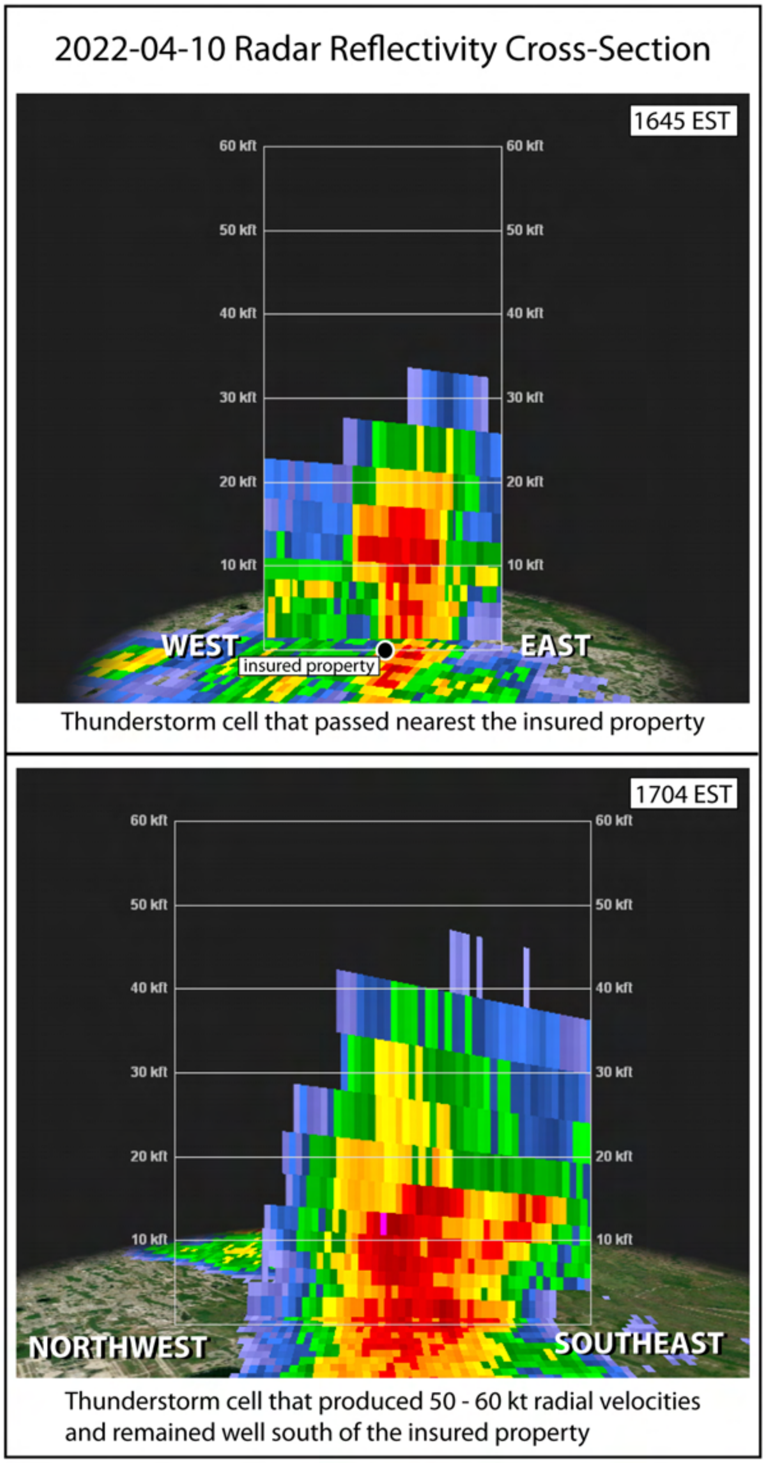
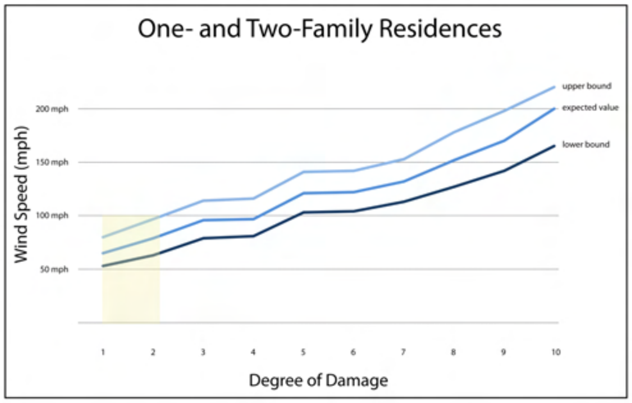



**Figure 7: Radar reflectivity cross-section of the thunderstorm cell that impacted the insured property at 1645 EST (top) and the thunderstorm that remained to the south of the insured property while producing 50 – 60 kt radial velocities (bottom). Reflectivity is a measure of the amount of power returned to the radar, with higher reflectivity values associated with more intense precipitation. A cross-section view of a thunderstorm shows the vertical structure of that storm, permitting analysis of the location and strength of updrafts and downdrafts as well as identification of precipitation cores suspended aloft. Source: KMLB level2 radar data, processed with GR2A.**




**One- and Two-Family Residences**

| Degree of Damage | Damage Description | Expected Value | Lower Bound | Upper Bound |
|---|---|---|---|---|
| 1 | Threshold of visible damage | 65 mph | 53 mph | 80 mph |
| 2 | Loss of roof covering material (<20%), gutters, and/or awning; loss of vinyl or metal siding | 79 mph | 63 mph | 97 mph |
| 3 | Broken glass in doors and windows | 96 mph | 79 mph | 114 mph |
| 4 | Uplift of roof deck and loss of significant roof covering material (>20%); collapse of chimney; garage doors collapse inward; failure of porch or carport | 97 mph | 81 mph | 116 mph |
| 5 | Entire house lifts off foundation | 121 mph | 103 mph | 141 mph |
| 6 | Large sections of roof structure removed; most walls remain standing | 122 mph | 104 mph | 142 mph |
| 7 | Exterior walls collapsed | 132 mph | 113 mph | 153 mph |
| 8 | Most walls collapsed; except small interior rooms | 152 mph | 127 mph | 178 mph |
| 9 | All walls collapsed | 170 mph | 142 mph | 198 mph |
| 10 | Destruction of engineered and/or well-constructed residence; slab swept clean | 200 mph | 165 mph | 220 mph |

**Figure 8: Enhanced Fujita Scale Degree of Damage graph and table for One- and Two-Family Residences (Damage Indicator FR12). The EF Scale is used operationally by the National Weather Service to correlate observed wind damage to the wind speeds expected to cause that damage. For each Degree of Damage, a range of wind speed values is offered to account for the diversity of construction and material quality and condition. For more vulnerable structures (e.g. those that are less well-constructed or in poor condition), the lower bound is used. For more robust structures, the upper bound is used. For structures of typical construction and condition, the expected value is used. Adapted from: McDonald and Mehta, 2006: "A Recommendation for an Enhanced Fujita Scale," Revision 2.**

## Hail Damage Thresholds for Common Roofing Materials

| Type of Roofing Product | Age (yrs) | 1 in. (25 mm) | 1.25 in. (32mm) | 1.5 in. (38mm) | 1.75 in. (44mm) | 2.0 in. (50mm) |
|---|---|---|---|---|---|---|
| 3-tab fiberglass shingles | 11 | 0 | 60 | 90 | 100 | 100 |
| 3-tab organic shingles* | 11 | 50 | 90 | 100 | 100 | 100 |
| 30 yr. Laminated shingles | 11 | 0 | 0 | 60 | 90 | 100 |
| Cedar shingles | 11 | 0 | 30 | 80 | 100 | 100 |
| Heavy cedar shakes | 0 | 0 | 0 | 50 | 90 | 100 |
| Fiber-cement tiles | 0 | 0 | 20 | 80 | 100 | 100 |
| Flat concrete tiles | 0 | 0 | 20 | 50 | 50 | 100 |
| S-shaped concrete tiles | 0 | 0 | 0 | 0 | 0 | 80 |
| Built-up gravel roofing | 8 | 0 | 0 | 0 | 0 | 30 |
| Number of Products Damaged | | 1/9 | 5/9 | 7/9 | 7/9 | 9/9 |

*no damage at .75 inch.

Laboratory Observations: Ice stone impact test results for various roofing products. Percent of damage is indicated (from Marshall, Timothy P., et al., 2002: Hail Damage Threshold Sizes for Common Roofing Materials , 21st Conference on Severe Local Storms)

| Type of Roofing Product (all ages) | Hailstone Size in. | mm. |
|---|---|---|
| 3-tab asphalt shingles | 1.00 | 25 |
| 30 yr. Laminated shingles | 1.25 | 32 |
| Cedar shingles | 1.25 | 32 |
| Medium cedar shakes | 1.50 | 38 |
| Fiber-cement tiles | 1.50 | 38 |
| Concrete tiles | 1.75 | 44 |
| Built-up gravel roofing | 2.50 | 63 |

Field Observations: Threshold sizes for hail-caused damage to roofing (after Morrison, Scott J., 1997: Hail-fall, roofing, and impact testing, Haag Engineering Co. pub., 7 pp.)

**Figure 9: Hail size damage thresholds for common roofing materials from both laboratory observations (left table) and field observations (right table). This research has shown that asphalt shingles typically are not damaged at hail sizes less than 1" – 1.25" diameter, while roofing tiles typically are not damaged at hail sizes less than 1.25" – 1.5" diameter. Adapted from: Marshall, Timothy P., et al., 2002: "Hail Damage Threshold Sizes for Common Roofing Materials." 21st Conference on Severe Local Storms.**

**<u>APPENDIX A:</u> Background and Reference Material**

*Note: At Blue Skies Meteorological Services, we specialize in providing our forensic meteorology clients with reports that are both rigorous and accessible to non-experts. To that end, we have developed extensive educational background and reference material that we include, as applicable, in each report. This material explains in clear language and with accompanying graphics the best-practices, tools, and methodologies used in our meteorological analyses and investigations. Due to the proprietary nature of this material, we have removed it from our online samples. If you would like to see the full version of this sample report, please contact Blue Skies Meteorological Services at inquiry@blueskiesmeteorology.com. Thank you for your understanding.*

**Radar Basics:**
***Overview***
***Radar Beam Characteristics and Resolution***
  **Beam Shape and Spreading:**
  **Beam Altitude:**
***Measuring Reflectivity***
***Rainfall Rates and Reflectivity:***
***Measuring Velocity***
***Radar Limitations***
  **Range degradation:**
  **Discrete Reflectivity and Velocity Values:**
  **Radar Calibration:**
***Limitation Mitigation and Radar Estimate Verification***
**Dual-Polarization Radar:**
  **Correlation Coefficient (CC):**
  **Differential Reflectivity (ZDR):**
  **Specific Differential Phase (KDP):**
**Hail Detection:**
  **Single-polarization radar:**
  **Dual-polarization radar:**