

# National Transportation Safety Board

Office of Aviation Safety

Washington, DC 20594



ERA24FA136

## **METEOROLOGY**

Specialist's Factual Report

June 12, 2024

## TABLE OF CONTENTS

|                                                       |    |
|-------------------------------------------------------|----|
| A. ACCIDENT.....                                      | 3  |
| B. METEOROLOGY SPECIALIST .....                       | 3  |
| C. SUMMARY .....                                      | 3  |
| D. DETAILS OF THE INVESTIGATION .....                 | 3  |
| E. FACTUAL INFORMATION.....                           | 4  |
| 1.0    SYNOPTIC CONDITIONS .....                      | 4  |
| 1.1    Surface Analysis chart.....                    | 4  |
| 1.2    Regional Radar Mosaic.....                     | 5  |
| 1.3    NWS 6-hour Surface Prognostic Chart.....       | 6  |
| 2.0    OBSERVATIONS.....                              | 7  |
| 2.1    Hot Springs, Virginia.....                     | 7  |
| 2.1.1    5-minute Observations for Hot Springs .....  | 10 |
| 2.1.2    Image of conditions from Hot Springs.....    | 11 |
| 2.2    NWS Aviation Weather Center Observations ..... | 11 |
| 3.0    ATMOSPHERIC SOUNDING.....                      | 12 |
| 4.0    SATELLITE IMAGERY .....                        | 14 |
| 5.0    WEATHER RADAR IMAGERY.....                     | 17 |
| 6.0    PILOT REPORTS .....                            | 19 |
| 7.0    NORTH AMERICAN MESOSCALE MODEL .....           | 19 |
| 8.0    NWS FORECAST PRODUCTS .....                    | 22 |
| 8.1    Terminal Aerodrome Forecast.....               | 22 |
| 8.2    Area Forecast Discussion.....                  | 22 |
| 8.3    NWS Wind Advisory .....                        | 25 |
| 8.4    Graphic Forecast for Aviation.....             | 25 |
| 9.0    INFLIGHT WEATHER ADVISORIES .....              | 27 |
| 10.0    PREFLIGHT WEATHER BRIEFING.....               | 30 |
| F. ATTACHMENTS.....                                   | 30 |

## **A. ACCIDENT**

Location: Hot Springs, Virginia  
Date: March 10, 2024  
Time: 1452 eastern daylight time  
1852 coordinated universal time (UTC)  
Airplane: Israel Aircraft Industry Westwind Astra; Registration: N1125A

## **B. METEOROLOGY SPECIALIST**

Donald Eick  
Senior Meteorologist  
National Transportation Safety Board  
Washington, D.C.

## **C. SUMMARY**

On March 10, 2024, about 1452 eastern daylight time, an Israel Aircraft Industries 1125 Westwind Astra airplane, N1125A, was involved in an accident at the Ingalls Field Airport (HSP), Hot Springs, Virginia. The airline transport pilot, commercial pilot, and three passengers were fatally injured. The airplane was operated by SkyJet Elite under the provisions of Title 14 Code of Federal Regulations (CFR) Part 91 as a personal flight.

## **D. DETAILS OF THE INVESTIGATION**

The National Transportation Safety Board's Senior Meteorologist was not on scene for this investigation and conducted the meteorology phase of the investigation remotely, collecting data from official National Oceanic and Atmospheric Administration (NOAA) National Weather Service (NWS) sources including the Weather Prediction Center (WPC), and the National Center for Environmental Information (NCEI). This report documents the general weather products and forecasts over the region during the period and documents the pertinent meteorological parameters to the accident. All times are reported as eastern daylight time (EDT) based upon the 24-hour clock, local time is -4 hours from UTC, and UTC=Z. Airport and NWS station identifiers use the standard International Civil Aviation Organization 4-letter station identifiers versus the International Air Transport Association 3-letter identifiers, which deletes the initial country code designator "K" for U.S. continental airports. Directions are referenced to true north and distances in nautical miles. Heights are in

feet (ft) above mean sea level (msl) unless otherwise noted. Visibility is in statute miles and fractions of statute miles.

The accident site was located at latitude 37.955627° N and longitude 79.825144° W, or about 300 ft short of the runway threshold in a downsloping ravine at an elevation of approximately 3,740 ft.

## **E. FACTUAL INFORMATION**

### **1.0 Synoptic Conditions**

The synoptic or large-scale migratory weather systems influencing the area were documented using standard NWS charts issued by the National Center for Environmental Prediction (NCEP) and the WPC located in College Park, Maryland. These are the base products used in describing weather features and in the creation of forecasts and warnings. Reference to these charts and other products can be found in the Federal Aviation Administration (FAA) "Aviation Weather Handbook", FAA-H-8083-28<sup>1</sup>.

#### **1.1 Surface Analysis chart**

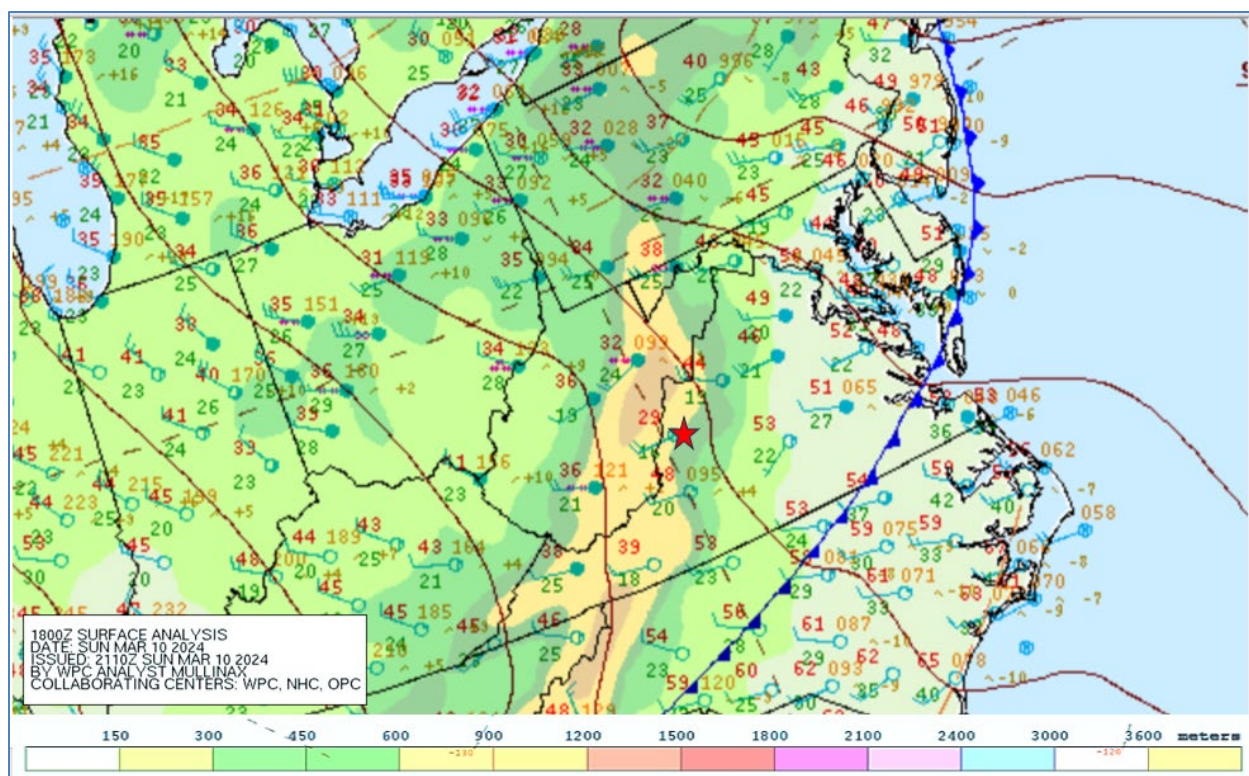
The mid-Atlantic section of the NWS Surface Analysis Chart for 1400 EDT with the approximate accident site marked by a red star is included as figure 1. The chart depicted a low pressure system with a central pressure of 991-hectopascals (hPa)<sup>2</sup> over Quebec (just off the northeast portion of chart) with a cold front extending southward across the northeast and turning southwestward across Virginia into North Carolina then westward to northern Alabama. A high pressure system at 1022-hPa was located over Wisconsin (not shown), with a relatively strong pressure gradient noted over the Ohio Valley. The accident site was located on the cold air side west of the cold front and on the southern edge of a relatively strong pressure gradient to the north.

The station models surrounding the accident site indicated westerly winds of 20 knots or more, obscured skies, with a temperature of 29° Fahrenheit (F), and with dew point temperatures below 20° F. Several stations to the west through north of the accident site in West Virginia reported snow showers.

---

<sup>1</sup> <https://www.faa.gov/regulationspolicies/handbooksmanuals/aviation/faa-h-8083-28-aviation-weather-handbook>

<sup>2</sup> Hectopascal (hPa) is the standard unit for reporting pressure and is interchangeable with the former term millibar (mb) with the same units. The International Standard Atmosphere (ISA) is based on a sea-level pressure of 1013.25-hPa at 15° Celsius (C) or 59° Fahrenheit (F).

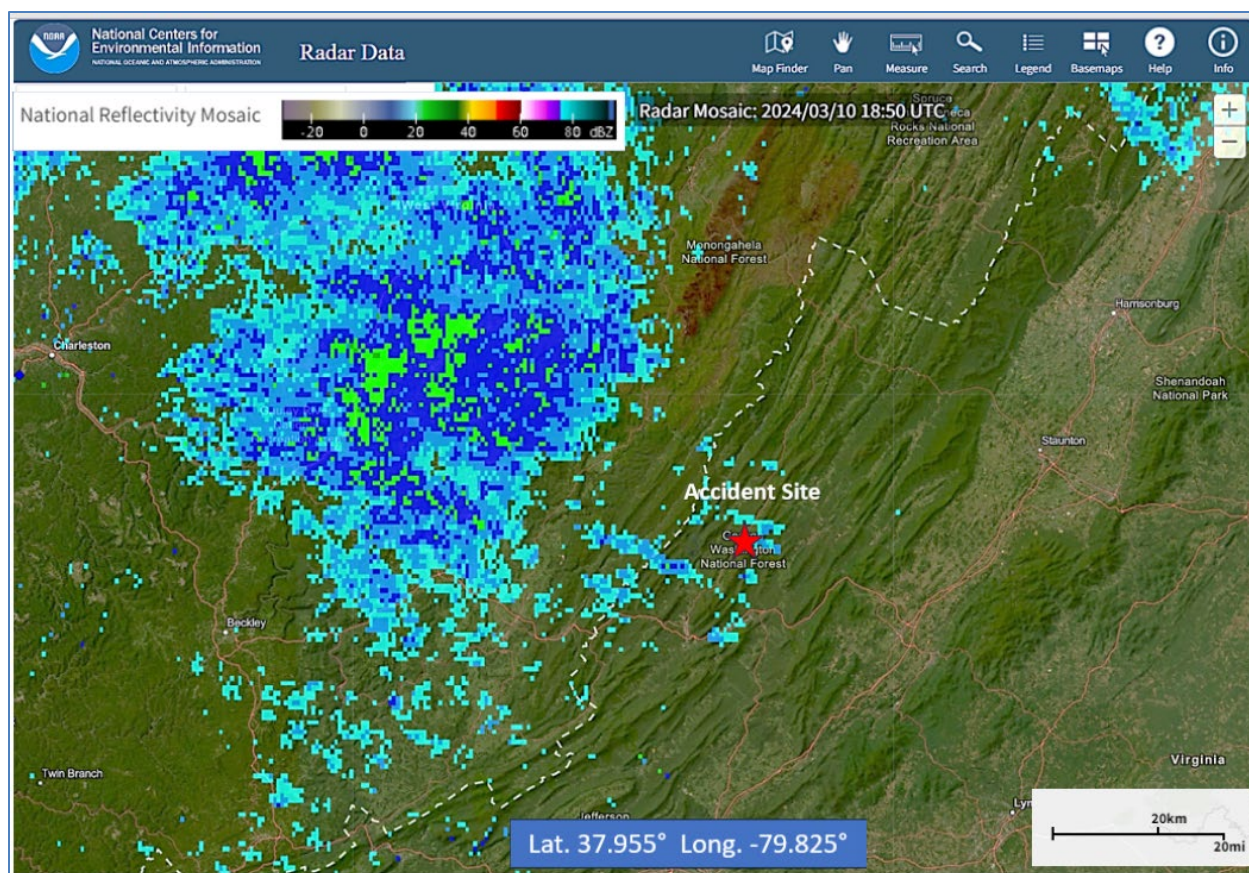


**Figure 1 - Northeast section of the NWS Surface Analysis Chart for 1400 EDT with the approximate accident site marked by the red star with the general topography colored.**

## 1.2 Regional Radar Mosaic

A regional view of the NWS NCEI National Composite Radar Mosaic for 1450 EDT with the approximate accident site marked by a red star is included as figure 2. The image depicted a large area of echoes of 10 to 30 decibels (dBZ)<sup>3</sup> over West Virginia with more scattered echoes over Virginia and in the immediate vicinity of the accident site. Based on the potential of echoes along the flight path, the closest NWS weather radar will be further documented in section 5.0 of this report.

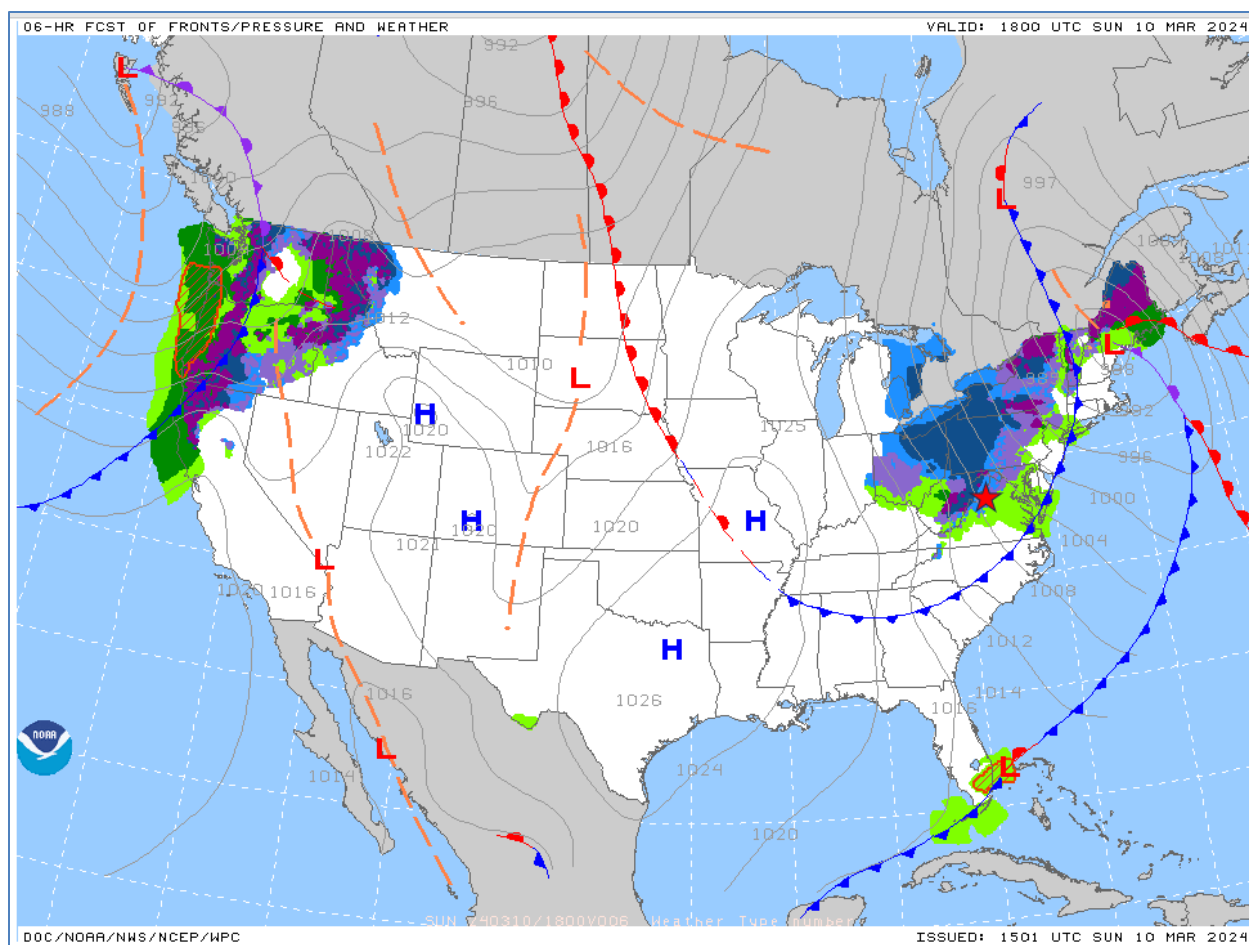
<sup>3</sup> dBZ - Nondimensional "unit" of radar reflectivity which represents a logarithmic power ratio (in decibels, or dB) with respect to radar reflectivity factor, Z.



**Figure 2 - NWS Regional Radar Mosaic over the area for 1450 EDT with the approximate accident site marked by the red star.**

### 1.3 NWS 6-hour Surface Prognostic Chart

The NWS 6-hour Surface Prognostic Chart current for the period depicting the expected positions of fronts, pressure systems, and general precipitation valid for 1400 EDT is included as figure 3. The chart depicted the cold front to the east of the accident site with a tight pressure gradient indicated by the isobars across Virginia that indicated west-northwest winds gusting behind the front. The chart also depicted a chance of rain (30 to 50% probability of precipitation) over Virginia turning to mixed rain and snow over the accident site and into northern Virginia and Pennsylvania, with snow likely (greater than 60% probability) over West Virginia, Ohio, and western Pennsylvania and New York.



**Figure 3 - NWS 6-hour Surface prognostic Chart current at the time of the flight's departure and valid for 1400 EDT. The chart depicts the expected position of fronts, pressure systems, and precipitation.**

## 2.0 Observations

The area surrounding the accident site was documented using official Aviation Routine Weather Reports (METAR)<sup>4</sup> and Aviation Selected Special Weather Reports (SPECI). Cloud heights are reported above ground level (agl) in the following section. The magnetic variation over the area was estimated at 9° West based on the latest sectional chart for the area.

### 2.1 Hot Springs, Virginia

The accident occurred on approach to Ingalls Field Airport (KHSP), Hot Springs, Virginia, which listed an elevation of 3,793 ft. The airport has a single asphalt grooved runway 7/25 at 5,600 ft long and 100 ft wide. The airport had a non-federal Automated

<sup>4</sup> METAR is an abbreviation of METeorological Aerodrome Report, the ICAO standard report format.

Weather Observation System (AWOS), which was not augmented by any observers and broadcasted observations locally or within line of sight on 118.8 VHF and issued reports every 20-minutes longline<sup>5</sup>. The AWOS was located about 1,000 ft from the touchdown point of runway 25, and about 280 ft south of the runway, and about 1,300 ft southwest of the accident site. The following observation was issued immediately prior to and after the accident.

*KHSP weather observation at 1435 EDT, automated, wind from 270° at 21 knots gusting to 31 knots, visibility 10 statute miles or more, temperature -2° C (29°F), dew point temperature of -9°C (16°F), and altimeter 29.65 inches of mercury (inHg). Remarks: automated observation station with a precipitation discriminator, temperature -1.6°C, dew point -9.0°C, precipitation identifier sensor not available (PWINO).*

*KHSP weather observation at 1455 EDT, automated, wind from 280° at 19 knots gusting to 38 knots, visibility 10 statute miles or more, scattered clouds at 2,000 ft agl, ceiling broken at 2,400 ft, overcast at 4,500 ft, temperature -2°C (28°F), dew point temperature -8°C (18°F), and altimeter 29.65 inHg. Remarks: automated observation station with a precipitation discriminator, temperature -2.2°C, dew point -7.8°C.*

The general flight categories<sup>6</sup> and raw observation in standard code and abbreviations between 1055 through 1755 EDT were as follow. The observations decoded above, and the time of the accident are in bold type. The observations indicated that MVFR conditions prevailed surrounding the period due to marginal ceilings with light snow showers reported after the accident.

VFR     METAR KHSP 101455Z AUTO 28020G34KT 10SM OVC031 M01/M09 A2965 RMK AO2  
         T10151086=

MVFR   METAR KHSP 101515Z AUTO 27026G34KT 10SM BKN029 OVC036 M01/M08 A2965 RMK AO2  
         T10151085=

MVFR   METAR KHSP 101535Z AUTO 27027G36KT 10SM BKN029 OVC035 M01/M08 A2964 RMK AO2  
         T10101084=

---

<sup>5</sup> Longline refers to transmitting the data to the FAA Weather Message Switching Center Replacement (WMSCR) which makes the observation available to users through various links and the internet.

<sup>6</sup> As defined by the NWS and the FAA Aeronautical Information Manual (AIM) section 7-1-7 defines the following general flight categories:

- Low Instrument Flight Rules (LIFR\*) - ceiling below 500 ft agl and/or visibility less than 1 statute mile.
- Instrument Flight Rules (IFR) - ceiling between 500 to below 1,000 feet agl and/or visibility 1 to less than 3 miles.
- Marginal Visual Flight Rules (MVFR\*\*) - ceiling from 1,000 to 3,000 ft agl and/or visibility 3 to 5 miles.
- Visual Flight Rules (VFR) - ceiling greater 3,000 ft agl and visibility greater than 5 miles.

\* By definition, IFR is a ceiling less than 1,000 ft agl and/or visibility less than 3 miles while LIFR is a sub-category of IFR. \*\* MVFR is a subset of VFR.

**MVFR** METAR KHSP 101555Z AUTO 28020G39KT 10SM BKN029 BKN037 M01/M09 A2965 RMK AO2 T10111086=

**MVFR** METAR KHSP 101615Z AUTO 28023G34KT 10SM BKN029 BKN035 OVC041 M01/M09 A2965 RMK AO2 T10121089=

**MVFR** METAR KHSP 101635Z AUTO 26016G29KT 10SM BKN029 BKN035 OVC041 M01/M09 A2966 RMK AO2 T10101088=

**VFR** METAR KHSP 101655Z AUTO 27019G31KT 240V300 10SM OVC033 M01/M09 A2966 RMK AO2 T10081089=

**MVFR** METAR KHSP 101715Z AUTO 28020G34KT 10SM BKN030 BKN038 OVC047 M01/M09 A2966 RMK AO2 T10061086=

**UNK METAR KHSP 101835Z AUTO 27021G31KT 10SM M02/M09 A2965 RMK AO2 T10161090 PWINO=**

#### **Accident 1852Z**

**MVFR METAR KHSP 101855Z AUTO 28019G38KT 10SM SCT020 BKN024 OVC045 M02/M08 A2965 RMK AO2 T10221078=**

**MVFR** METAR KHSP 101915Z AUTO 27019G33KT 10SM BKN020 BKN028 OVC038 M02/M09 A2966 RMK AO2 T10211087=

**MVFR** METAR KHSP 101935Z AUTO 29016G28KT 10SM BKN021 OVC028 M03/M08 A2966 RMK AO2 T10281084=

**MVFR** METAR KHSP 101955Z AUTO 27026G36KT 10SM BKN019 OVC025 M03/M09 A2966 RMK AO2 T10301090=

**MVFR** METAR KHSP 102015Z AUTO 28021G35KT 10SM BKN019 OVC027 M03/M08 A2967 RMK AO2 T10271079=

**MVFR** METAR KHSP 102035Z AUTO 28025G38KT 5SM -SN BKN017 BKN023 OVC049 M03/M08 A2968 RMK AO2 T10311081=

**MVFR** METAR KHSP 102055Z AUTO 28025G36KT 10SM BKN018 OVC024 M04/M09 A2968 RMK AO2 T10361091=

**MVFR** METAR KHSP 102115Z AUTO 28026G39KT 240V310 10SM BKN018 OVC027 M04/M10 A2970 RMK AO2 T10361097=

**MVFR** METAR KHSP 102135Z AUTO 27024G38KT 7SM -SN BKN023 OVC028 M04/M11 A2970 RMK AO2 T10401109=

**MVFR** METAR KHSP 102155Z AUTO 27020G38KT 10SM SCT022 BKN029 OVC034 M04/M12 A2970 RMK AO2 T10371119=

### 2.1.1 5-minute Observations for Hot Springs

The Federal Aviation Administration (FAA) Weather Message Switching Center Replacement (WMSCR) was able to retrieve the 5-minute observations for KHSP surrounding the period but were unable to obtain the 1-minute data that is typically associated with federal ASOS<sup>7</sup> type systems. The 5-minute data surrounding the accident are included below.

5-MIN METAR KHSP 101835Z AUTO 27021G31KT 10SM M02/M09 A2965 RMK A02 T10161090 PWINO

5-MIN METAR KHSP 101840Z AUTO 27024G36KT 10SM M02/M08 A2965 RMK A02 T10191085

5-MIN METAR KHSP 101845Z AUTO 27020G36KT 10SM BKN024 BKN033 OVC045 M02/M08 A2965  
RMK A02 T10221082

**5-MIN METAR KHSP 101850Z AUTO 27021G31KT 10SM SCT020 BKN024 OVC045 M02/M08  
A2965 RMK A02 T10221079**

#### **Accident 1852Z**

**5-MIN METAR KHSP 101855Z AUTO 28019G38KT 10SM SCT020 BKN024 OVC045 M02/M08  
A2965 RMK A02 T10211078**

5-MIN METAR KHSP 101900Z AUTO 28015G38KT 250V320 10SM BKN018 BKN026 OVC045 M02/M08  
A2965 RMK A02 T10211076

5-MIN METAR KHSP 101905Z AUTO 28017G25KT 10SM BKN020 BKN026 OVC045 M02/M08 A2966  
RMK A02 T10161084

The 5-minute observation at the time of the accident indicated the following conditions.

*5-minute KHSP weather observation at 1450 EDT, automated, wind from 270° at 21 knots gusting to 31 knots, visibility 10 miles or more, scattered clouds at 2,000 ft agl, ceiling broken at 2,400 ft, overcast at 4,500 ft, temperature -2°C (28°F), dew point temperature of -8°C (18°F), and altimeter 29.65 inHg. Remarks: automated observation station with a precipitation discriminator, temperature -2.2°C, dew point -7.9°C.*

Within the next 5-minutes, between 1450 and 1455 EDT the AWOS recorded a wind gust to 38 knots. The 5-minute report at 1455 EDT was already decoded in section 2.1 above, and was the observation disseminated immediately after the accident.

---

<sup>7</sup> Automated Surface Observation System (ASOS)

### 2.1.2 Image of conditions from Hot Springs

A photograph of the conditions looking towards the northeast and the accident site from the touchdown zone is included as figure 4. The image was taken by a first responder to the emergency at approximately a half hour after the accident or at about 1520 EDT. The image depicted general broken to overcast cloud layers with showers and virga<sup>8</sup> below the clouds over the area with several of the precipitation shafts reaching the ground and restricting visibility.



**Figure 4 - Photograph at 1520 EDT looking northeast from the touchdown point of runway 25 towards the approach path to the runway after the accident.**

## 2.2 NWS Aviation Weather Center Observations

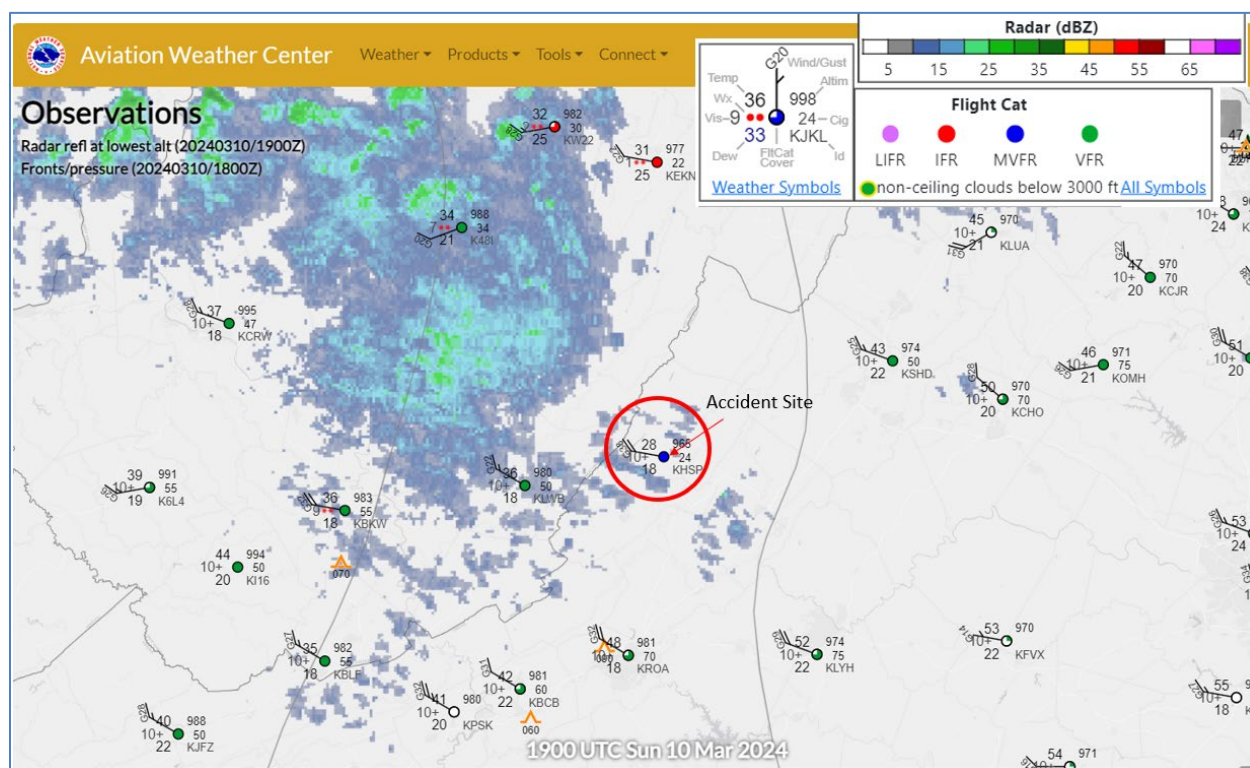
A depiction from the NWS Aviation Weather Center's (AWC) METAR display<sup>9</sup> for 1500 EDT is included in figure 5 with KHSP and the accident site within the red circle. The NWS composite radar reflectivity image for 1500 EDT is also overlaid and showed several very light intensity echoes of 20 dBZ or less scattered over the region (as shown

---

<sup>8</sup> Virga is precipitation that is falling and evaporating before reaching the ground.

<sup>9</sup> <https://aviationweather.gov/gfa/#obs>

on figure 2). The chart depicted KHSP reporting MVFR conditions with winds from the west at 20 knots gusting to 38 knots, visibility 10 miles or more, overcast clouds with a ceiling at 2,400 ft agl, with a temperature of 28°F and dew point temperature of 18°F, and an altimeter of 29.65 inHg. Numerous stations west through north of the accident reported visibility restricted in light continuous snow.



**Figure 5 - NWS Aviation Weather Center's METAR display with weather radar overlaid for 1500 EDT with the KHSP and the accident site within the red circle,**

### 3.0 Atmospheric Sounding

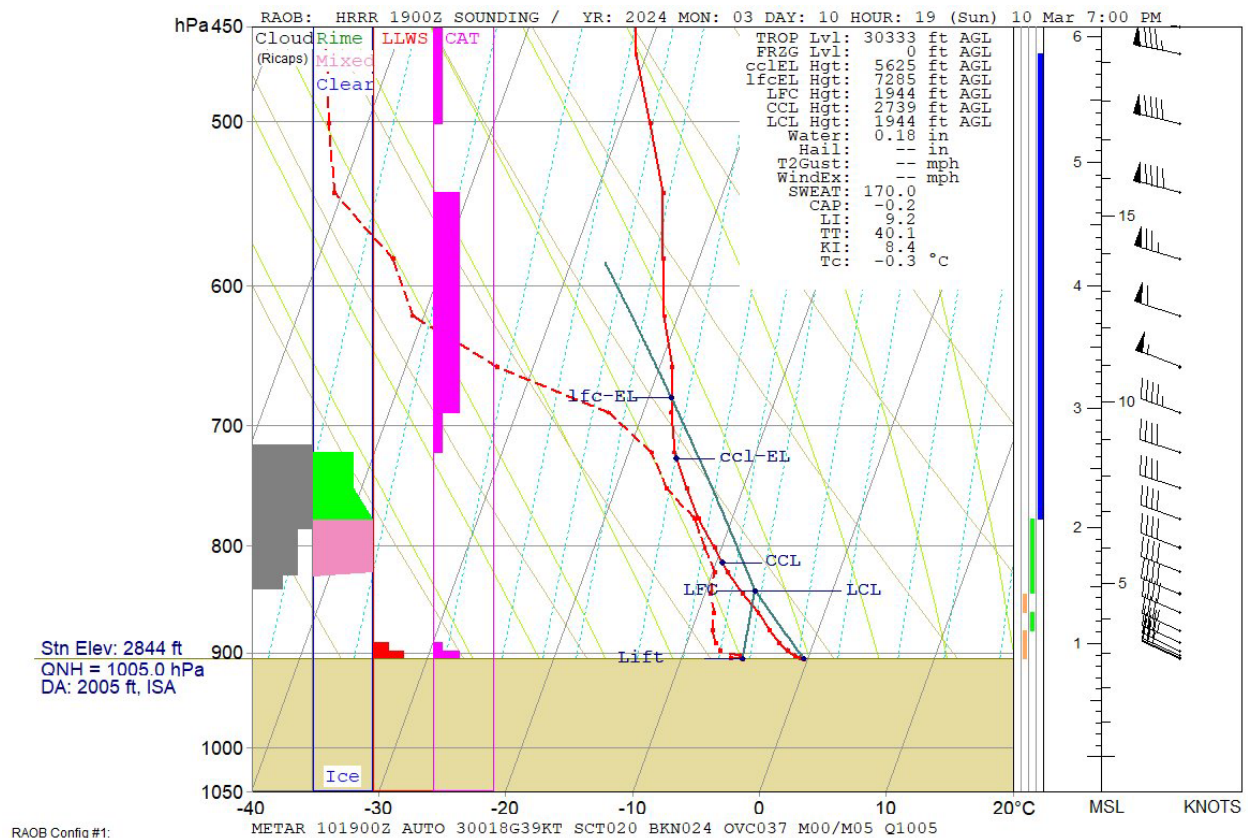
A High-Resolution Rapid Refresh (HRRR) numerical model<sup>10</sup> was obtained from the NOAA Air Resource Laboratory for 1500 EDT over the closest grid point<sup>11</sup> to the accident site. The model data was then plotted on a standard Skew T/log P diagram<sup>12</sup> using the RAOB Analysis software<sup>13</sup> from the surface to 450-hectopascals or about 20,000 ft and is depicted as figure 6.

<sup>10</sup> The HRRR is a NOAA real-time 3 kilometer (km) resolution, hourly-updated, cloud-resolving, convection-allowing atmospheric model, initialized by 3 km grids with 3 km radar assimilation. Radar data is assimilated in the HRRR every 15 minutes over a 1-hour period.

<sup>11</sup> The grid point was latitude 37.95° and longitude -79.83°.

<sup>12</sup> Skew T log P diagram - is a standard meteorological plot or thermodynamic diagram using temperature and the logarithmic of pressure as coordinates, used to display winds, temperature, dew point, and various indices used to define the vertical structure of the atmosphere.

<sup>13</sup> RAOB -The Complete RAwinsonde OBservation program is an interactive sounding analysis program



**Figure 6 - HRRR numerical model for 1500 EDT over the closest grid point to the accident site.**

The HRRR 1500 EDT sounding depicted an elevation of 2,844 ft with a near surface temperature of -0.3°C (31.5°F), a dew point temperature of -5.1°C (22.8°F), a relative humidity of 70%. The sounding depicted the lifted condensation level (LCL)<sup>14</sup> and level of free convection (LFC)<sup>15</sup> at 1,944 ft agl, and the convective condensation level (CCL)<sup>16</sup> at 2,739 ft agl. The layer below 7,000 ft was characterized as conditional unstable and stable above that level with a Lifted Index of 9.0. The RAOB Analysis program supported cumulus type clouds from the LCL through 9,000 ft with mixed icing conditions in-clouds, which are depicted on the left axis of the sounding.

developed by Eosonde Research Services (ERS) previously known as Environmental Research Services, The Villages, Florida.

<sup>14</sup> Lifted Condensation Level (LCL) - the level at which a lifted parcel becomes saturated. The LCL height corresponds to cloud base height for forced ascent.

<sup>15</sup> Level of Free Convection (LFC) - the level where a parcel becomes buoyant, or "warmer" than the environmental temperature at the same level. The LFC represents the bottom of the layer containing Convective Available Potential Energy (CAPE).

<sup>16</sup> Convective Condensation Level (CCL) - the level in the atmosphere to which an air parcel, if heated from below, will rise dry adiabatically, without becoming colder than its environment just before the parcel becomes saturated.

The HRRR sounding wind profile indicated a surface wind from 300° at 18 knots with gusts to 39 knots, with little variation in wind direction with height with gradual increase in wind speeds with height. Above 10,000 ft the winds were in excess of 50 knots. The mean 0 to 6 kilometer (or 18,000 ft) mean wind was from 290° at 63 knots. The RAOB Analysis program indicated the potential for mountain wave activity with the predominate waves generally above 24,000 ft. At 6,000 ft or the initial approach fix altitude the HRRR sounding indicated a wind from 292° at 41 knots and a temperature -10.5°C, a dew point temperature of -11.3°C, with a relative humidity of 94%. The RAOB Analysis program supported moderate low-level wind shear (LLWS) below 300 ft agl and light-to-moderate turbulence.

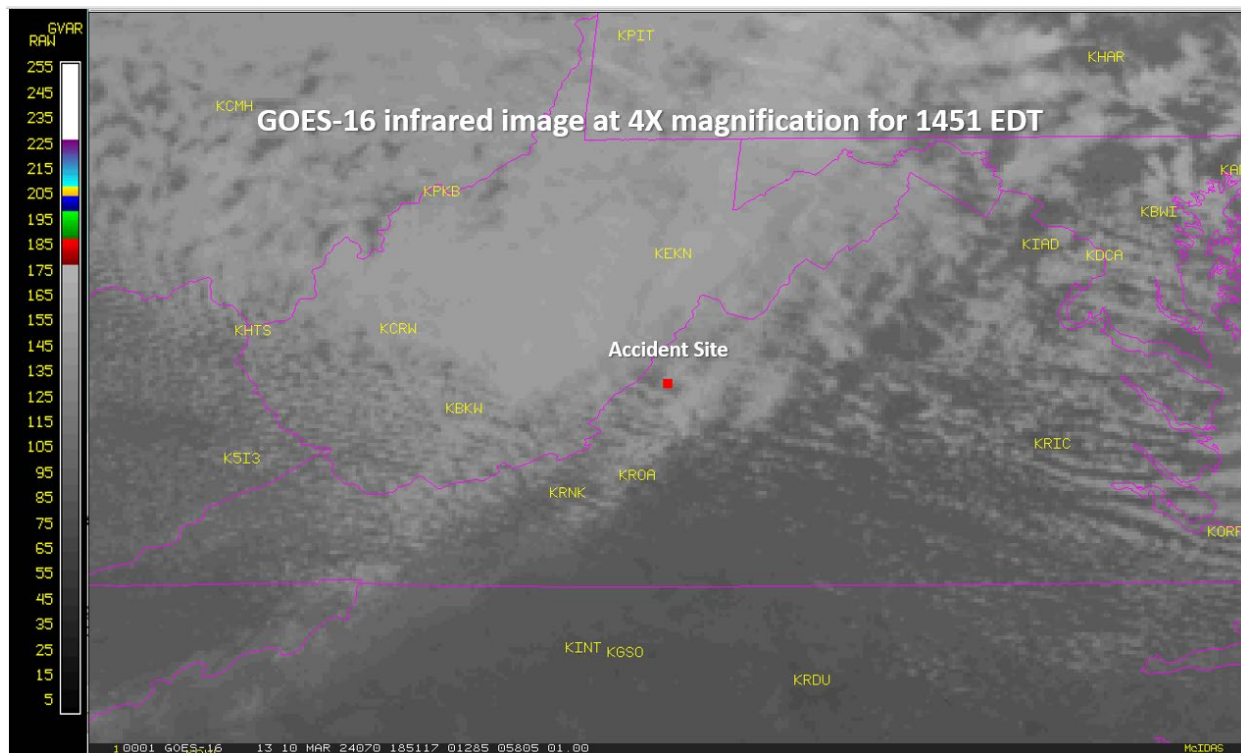
A table of the RAOB parameters of height, pressure (Pres), temperature (T), dew point temperature (Td), relative humidity (RH%), wind direction and speed, and derived clear air turbulence (CAT), Low-Level Wind Shear (LLWS), and icing potential from the surface through 12,000 ft was as follows.

| Height<br>(ft-msl) | Pres<br>(hPa) | T<br>(C°) | Td<br>(C°) | RH<br>(%) | Wind<br>(dir-kts) | CAT<br>(FAA) | LLWS<br>(FAA) | Icing-Type<br>(USAF) |
|--------------------|---------------|-----------|------------|-----------|-------------------|--------------|---------------|----------------------|
| 2844               | 906           | -0.3      | -5.1       | 70        | 297/ 18           |              |               |                      |
| 2873               | 905           | -0.6      | -6.1       | 66        | 297/ 17           | MDT          | MODRT         |                      |
| 2931               | 903           | -1.1      | -5.4       | 73        | 297/ 25           | MDT          | MODRT         |                      |
| 3076               | 898           | -1.8      | -7.1       | 67        | 297/ 31           | LGT          | LIGHT         |                      |
| 3309               | 890           | -2.7      | -7.7       | 68        | 296/ 35           |              |               |                      |
| 3662               | 878           | -3.8      | -8.3       | 71        | 296/ 37           |              |               |                      |
| 4167               | 861           | -5.2      | -8.7       | 76        | 295/ 39           |              |               |                      |
| 4710               | 843           | -7.0      | -9.5       | 82        | 294/ 40           |              |               |                      |
| 5323               | 823           | -8.8      | -9.8       | 92        | 293/ 41           |              |               | MDT Mixed            |
| 6010               | 801           | -10.5     | -11.3      | 94        | 292/ 41           |              |               | MDT Mixed            |
| 6808               | 776           | -12.6     | -12.9      | 98        | 291/ 42           |              |               | MDT Mixed            |
| 7659               | 750           | -14.4     | -16.0      | 88        | 290/ 42           |              |               | LGT Rime             |
| 8637               | 721           | -16.4     | -18.2      | 86        | 290/ 42           | LGT          |               | LGT Rime             |
| 9719               | 690           | -17.8     | -22.7      | 65        | 292/ 45           | MDT          |               |                      |
| 10956              | 656           | -19.0     | -32.8      | 28        | 293/ 53           | MDT          |               |                      |
| 12329              | 620           | -21.1     | -40.9      | 15        | 290/ 62           | MDT          |               |                      |

## 4.0 Satellite Imagery

The NOAA Geostationary Operational Environmental Satellite number 16 (GOES-16) infrared, water vapor, and visible imagery were obtained from an archive at the Space Science Engineering Center (SSEC) at the University of Wisconsin-Madison in Madison, Wisconsin, and processed using the Man-computer Interactive Data Access System (McIDAS) software. The infrared band 13 at a wavelength of 10.3 microns ( $\mu$  m) and the low-level water vapor (band 10) at a wavelength of 7.3  $\mu$  m provided a resolution of 2 kilometers (km). While the visible (band 2) at a wavelength of 0.64  $\mu$  m provided a resolution of 0.5 km.

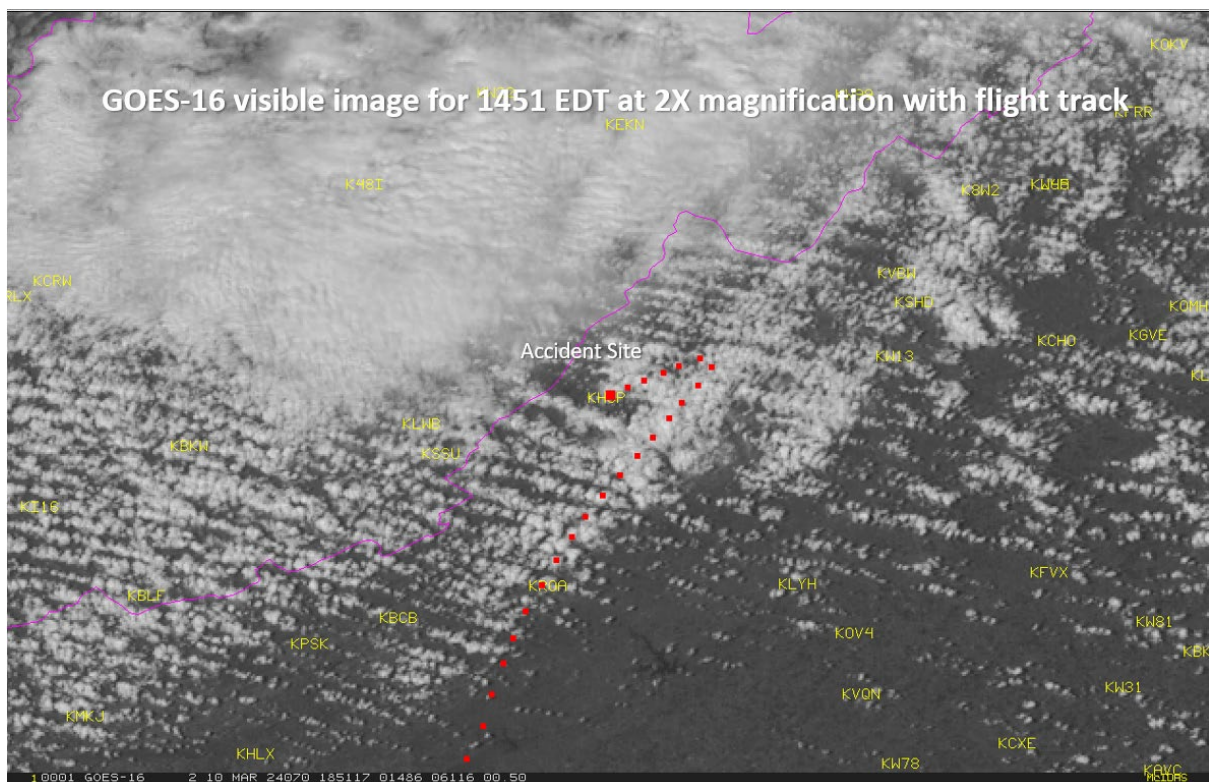
Figures 7-8 are the GOES-16 infrared and visible images for 1451 EDT showing a layer of low cumulus clouds over the area, and based on the HRRR winds and satellite animation those clouds were moving generally eastward with time. The flight path is provided in figure 8 by the red dots and provide the position every minute. The imagery also detected several transverse bands<sup>17</sup> in the clouds oriented in a northeast-to-southwest direction that did not move eastward with time and were identified as standing lenticular clouds (ACSL)<sup>18</sup>. Figure 9 is the GOES-16 low-level water vapor imagery for 1456 EDT, which shows several area bands of moisture channel darkening associated with downward vertical motion and evaporation of the moisture. Attachments 1-3 are the GOES-16 infrared, visible and low-level water vapor imagery between about 1300 through 1500 EDT, which identified several of these features.



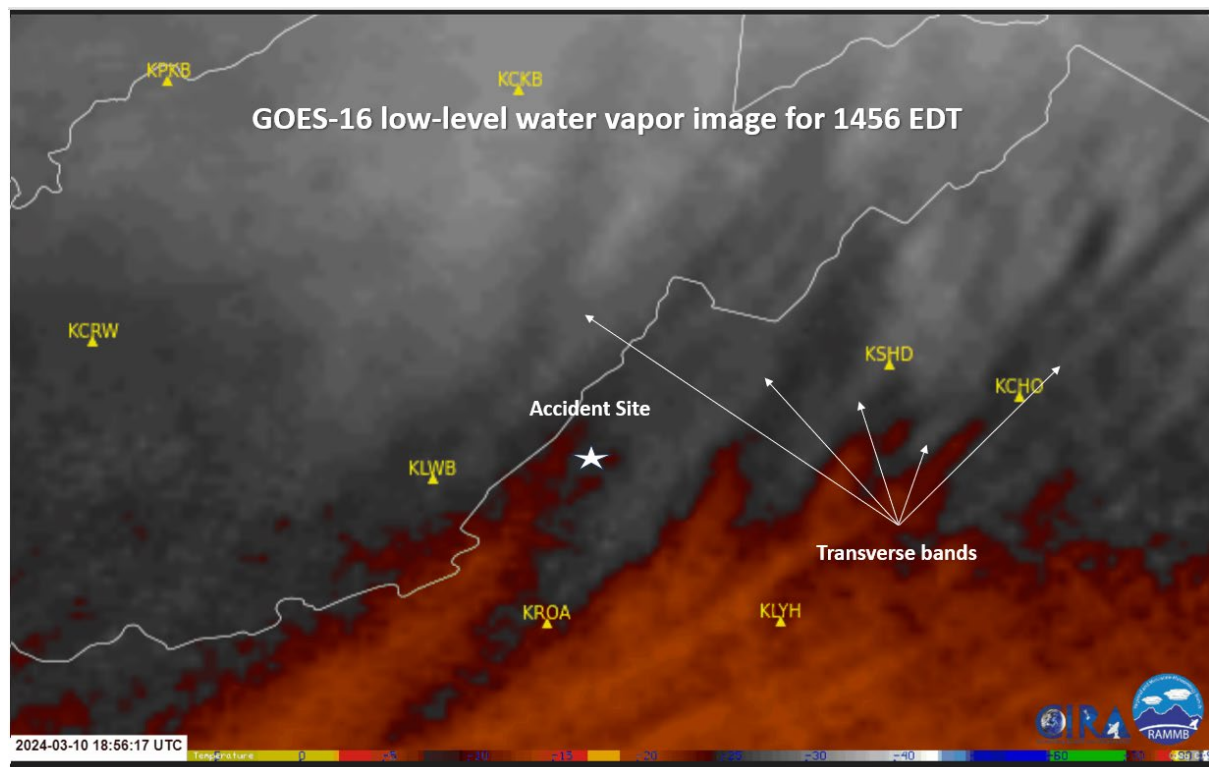
**Figure 7 - GOES-16 infrared image for 1451 EDT at 4X magnification with accident site marked by red square.**

<sup>17</sup> Transverse Bands - are bands of clouds oriented perpendicular to the flow in which they are embedded. They often are seen best on satellite photographs. When observed at high levels (i.e., in cirrus formations), they may indicate severe or extreme turbulence.

<sup>18</sup> Alto-cumulus Lenticular Clouds (ACSL) are one of the primary cloud groups indicative of the wave like flow created by mountain wave activity.



**Figure 8 - GOES-16 visible image for 1451 EDT at 2X magnification with flight track overlaid every 1-minute in red from 1428 through 1452 EDT.**



**Figure 9 - GOES-16 low-level water vapor imagery at 1456 EDT showing transverse bands.**

## 5.0 Weather Radar imagery

The NWS Roanoke (KFCX)<sup>19</sup> Weather Surveillance Radar 1988 Doppler (WSR-88D)<sup>20</sup> was located about 60 miles south-southwest of the accident site. The Level II radar data was obtained from the NWS NCEI and plotted using the NOAA Weather Tool kit software<sup>21</sup>. During the period the KFCX WSR-88D was operating in the clear air mode, volume coverage pattern (VCP) 35 where the radar makes 9 elevation scans during a 7-minute period.

The KFCX 0.53° base reflectivity scan, based on the distance of 60 miles from the radar antenna, which had an antenna elevation of 2,965 ft, would have been centered near 8,530 ft and sampling the air space between 5,510 through 11,550 ft over the accident site.

Reflectivity is the measure of the efficiency of a target in intercepting and returning radio energy. With hydrometeors<sup>22</sup>, it is a function of the drop size distribution, number of particles per unit volume, physical state (ice or water), shape, and aspect. Reflectivity is normally displayed in dBZ and is a general measure of echo intensity. The FAA Aviation Weather Handbook<sup>23</sup> defines echoes less than 30 dBZ as "light" in intensity, "moderate" echoes 30-40 dBZ, "heavy" with echoes of >40-50 dBZ, and "extreme" intensity with echoes above >50 dBZ. These are the new standard radio phraseology terms used by air traffic controllers to describe weather conditions to pilots as shown in figure 10. Light rain is typically reported at the surface when reflectivities reach 20 dBZ, while air traffic control weather displays, and airborne weather radar typically do not display echoes less than 30 dBZ or light intensity echoes on their weather displays. It should also be noted that the intensity of the return signature from raindrops is approximately 5X greater than the returns from snow. Snow has a lower reflectivity compared to raindrops, which often leads to underestimating the area coverage and intensity of snow.

---

<sup>19</sup> The NWS Roanoke (KFCX), VA, WSR-88D antenna was located about 20 miles southwest of the city of Roanoke and about 12 miles south-southeast of Blacksburg, VA, the location of the NWS Weather Forecast Office (WFO).

<sup>20</sup> The WSR-88D is a S-band 10-centimeter wavelength radar with a power output of 750,000 watts, with a 28-foot parabolic antenna concentrating the energy into a 0.95° beam width. The radar produces three basic types of products reflectivity, radial velocity, and spectral width.

<sup>21</sup> NOAA's Weather and Climate Toolkit (WCT) is free, platform independent software distributed from NOAA's National Centers for Environmental Information (NCEI). The WCT allows the visualization and data export of weather and climate data, including Radar, Satellite and Model data.

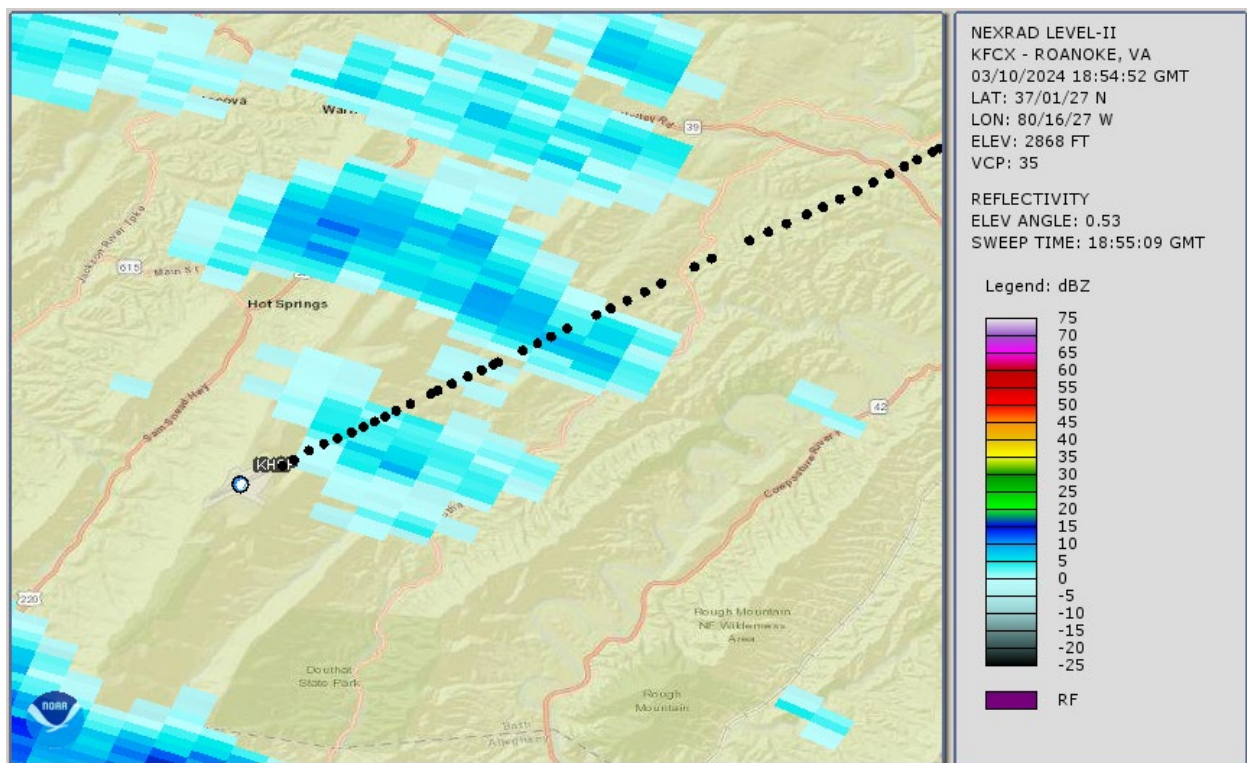
<sup>22</sup> Hydrometeors are any product of condensation or sublimation of atmospheric water vapor, whether formed in the free atmosphere or at the earth's surface. Hydrometeors are classified as; (a) Liquid or solid water particles suspended in the air: cloud, water droplets, mist or fog. (b) Liquid precipitation: drizzle and rain. (c) Freezing precipitation: freezing drizzle and freezing rain. (d) Solid (frozen) precipitation: ice pellets, hail, snow, snow pellets, and ice crystals.

<sup>23</sup> FAA Aviation Weather Handbook - WSR-88D Radar Precipitation Intensity Terminology (Table 24-8).

| Reflectivity (dBZ) Ranges | Weather Radar Echo Intensity Terminology |
|---------------------------|------------------------------------------|
| < 30 dBZ                  | Light                                    |
| 30 – 40 dBZ               | Moderate                                 |
| >40 – 50 dBZ              | Heavy                                    |
| >50 dBZ                   | Extreme                                  |

**Figure 10 - Radar intensity terminology and dBZ values.**

The KFCX WSR-88D 0.53° base reflectivity image for 1454 EDT is included as figures 11 with the flight track overlaid in black. The images show several bands of very light intensity echoes of 15 dBZ or less extending along the flight path and immediately northeast of the airport. The accident airplane's flight track transversing through two of the bands on approach, with the accident site immediately on the southwestern edge of one of the bands.



**Figure 11 - NWS KFCX WSR-88D 0.5° base reflectivity image for 1454 EDT with the flight track of N1125A overlaid, the flight path descended through two defined bands of echoes on approach.**

## 6.0 Pilot Reports

The following pilot reports or PIREPs were disseminated longline<sup>24</sup> within 50 miles of KHSP between 1200 through 1700 EDT. The following includes the raw observation in standard code and abbreviations followed by a decoded report.

*EKN UA /OV EKN200025/TM 1711/FL090/TP BE33/IC RIME 090-100*

*Elkins-Randolph County Airport-Jennings Randolph Field (EKN), Elkins, WV, routine pilot report (UA); Over - 200° azimuth and 20 miles from EKN (approximately 36 miles north of accident site); Time - 1311 EDT; Altitude - 9,000 ft; Type aircraft - Beechcraft BE-33 Debonair single engine aircraft; Icing - rime icing between 9,000 and 10,000 ft.*

*EKN UA /OV EKN225025/TM 1711/FL090/TP BE33/IC RIME ICE/RM 090-100*

*EKN routine pilot report (UA); Over - 225° azimuth and 20 miles from EKN (about 36 miles north of accident site); Time - 1311 EDT; Altitude - 9,000 ft; Type aircraft - Beechcraft BE-33 Debonair; Icing - rime icing; Remarks - between 9,000 and 10,000 ft.*

*ROA UA /OV ROA/TM 1811/FL090/TP E75L/SK TOP 140/TB CONS MOD 090-110 LGT CHOP 110-140 /RM DURC*

*Roanoke-Blacksburg Regional Airport (ROA), Roanoke, VA, routine pilot report (UA); Over - ROA (about 38 miles south of accident site); Time - 1411 EDT; Altitude - 9,000 ft; Type aircraft - Embraer ERJ 175 air carrier jet; Sky cover - tops of clouds at 14,000 ft; Turbulence - continuous moderate turbulence between 9,000 ft through 11,000 ft with light chop between 11,000 ft through 14,000 ft; Remarks - during climb.*

*ROA UA /OV ROA/TM 1952/FL060/TP C68A/TB MOD/RM CONTINUOUS MOD TURB DURGC OFF RWY 24 KROA*

*ROA routine pilot report (UA); Over - ROA (about 38 miles south of accident site); Time - 1552 EDT; Altitude - 6,000 ft; Type aircraft - Cessna Citation latitude business jet; Turbulence - moderate turbulence during climb off runway 24 at ROA.*

*ROA UA /OV ROA280015/TM 2002/FL052/TP C560/TB MOD*

*ROA routine pilot report (UA); Over - 280° azimuth and 15 miles from ROA (about 40 miles south of accident site); Time - 1602 EDT; Altitude - 5,200 ft; Type aircraft - Cessna Citation V business jet; Turbulence - moderate turbulence.*

## 7.0 North American Mesoscale Model

The NTSB ran a Weather Research and Forecast (WRF)<sup>25</sup> model simulation surrounding the time of the accident using initialization data from the North American

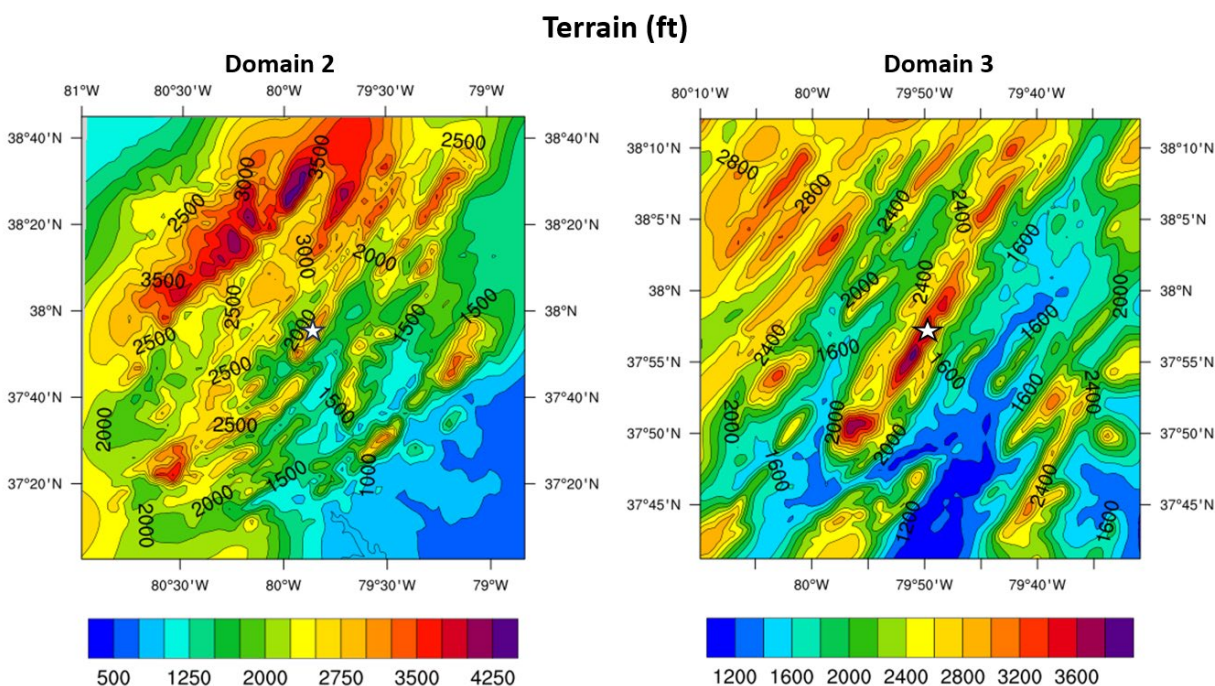
---

<sup>24</sup> Includes PIREPs disseminated longline and may not include "ride reports" or other reports made on radio frequency to air traffic control.

<sup>25</sup> WRF ARW (Advanced Research WRF core) version 4.1.2 was run with 3 domains with horizontal grid spacing of 6 km, 1.2 km, and 240 m. Other WRF simulation parameters included: 60 vertical levels, the

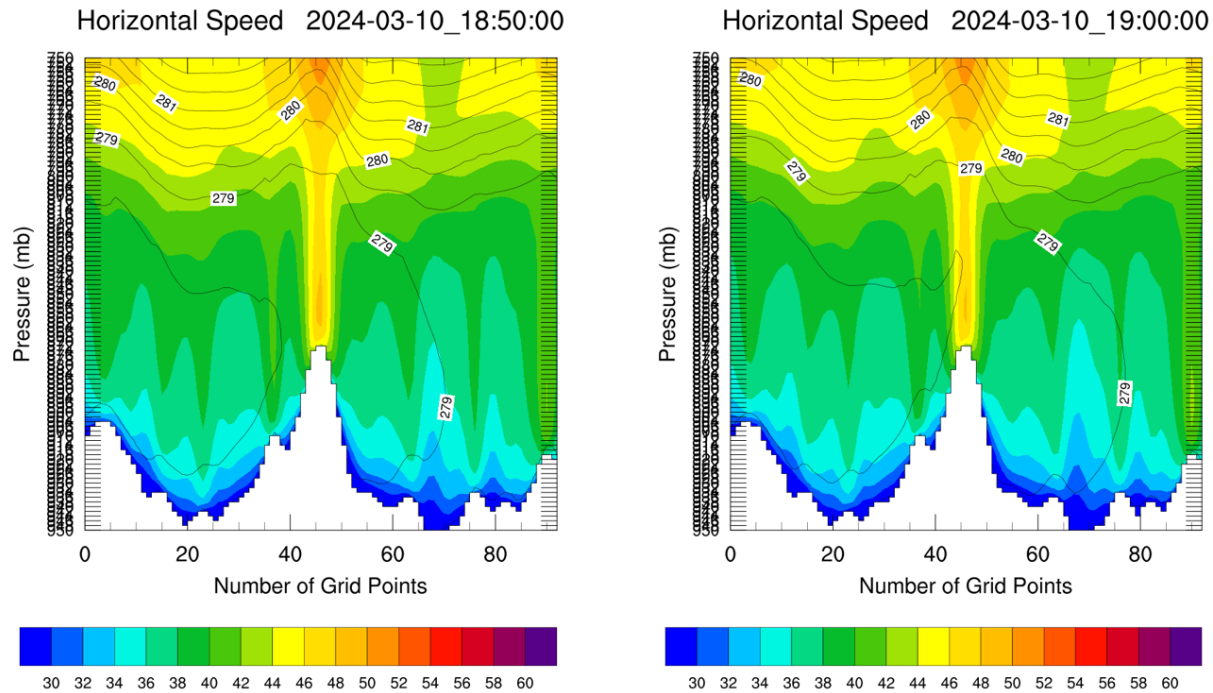
Mesoscale Forecast System (NAM218). The terrain used in WRF model are provided in figure 12 for domain 2 (left) and for domain 3 (right) with height in ft, and the star depicting the approximate accident site.

Figures 13 and 14 are a depiction of the WRF domain 3 topography of the west to east cross section with the accident site located in the middle of the image near the grid point marked by the white star at 1450 EDT (left) and at 1500 EDT (right) with the isentropes or lines of potential temperature (in degrees Kelvin) and horizontal wind speeds (figure 13) in knots followed by the vertical velocity (figure 14) in feet per minute (fpm) from 950-hPa to 750-hPa. The image depicts sustained winds of 40 to 50 knots immediately above the ridge level, with updrafts on the windward or west side of the ridges from 400 to 800 fpm with similar downdrafts on the leeward or east side of the ridge over the approach path and the accident site. The isentropes at higher altitudes show a slight wave like flow pattern.

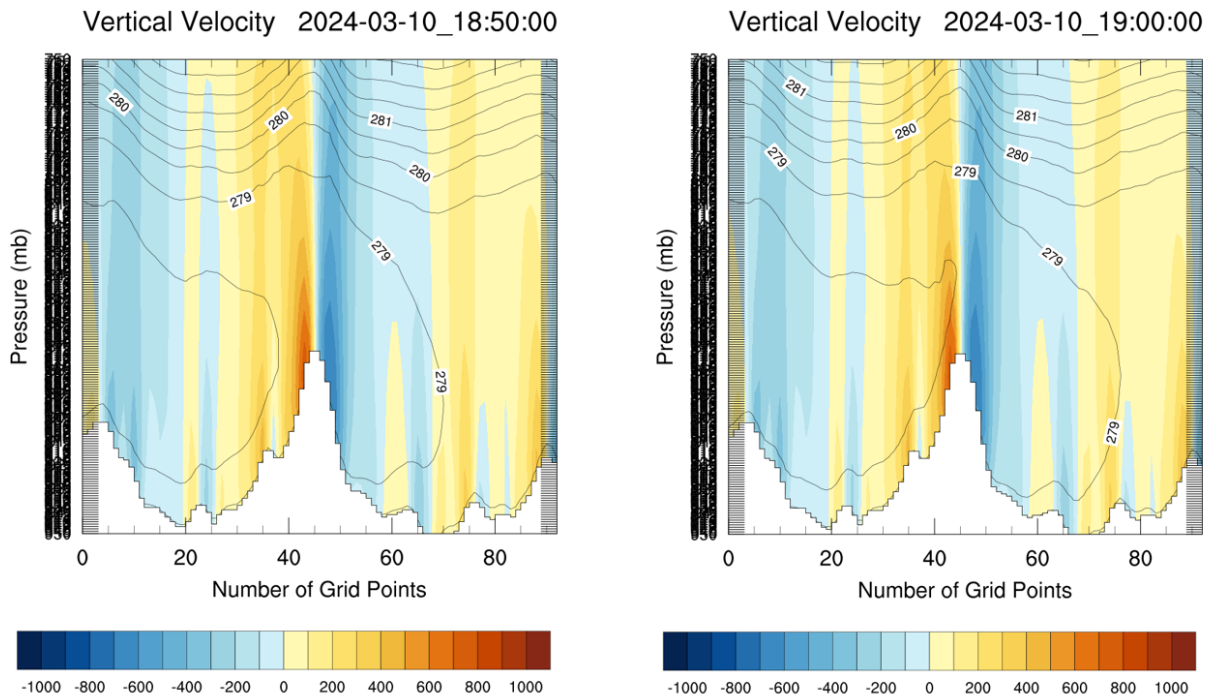


**Figure 12 - WRF model terrain used in domain 2 and domain 3, with the approximate accident site marked by the white star near the center of the images.**

multi-scale Kain-Fritsch cumulus parameterization scheme used on the outer domain, a Lin et al. microphysics scheme, a Yonsei University boundary layer scheme, Noah land surface physics, the Dudhia scheme used for short wave radiation, and the RRTM scheme for the long wave radiation.



**Figure 13 - NAM WRF model of the west-to-east cross section of horizontal winds in knots over the area for 1450 EDT (left) and 1500 EDT (right).**



**Figure 14 - NAM WFR model of the west-to-east vertical motion over the area for 1450 EDT (left) and 1500 EDT (right). Depicting an updraft/downdraft dipole over the ridge or KHSP.**

## 8.0 NWS Forecast Products

The NWS Blacksburg (KRNK), VA, Weather Forecast Office (WFO) was responsible for the issuance of local forecasts and weather warnings over the Hot Springs area. While the aviation products originated out of the NWS AWC located in Kansas City, Missouri.

### 8.1 Terminal Aerodrome Forecast

The NWS KRNK WFO does not issue a Terminal Aerodrome Forecast (TAF) for KHSP. The closest TAF to KHSP was issued for Greenbrier Valley Airport (KLWB), Lewisburg, West Virginia, located about 27 miles west of KHSP at an elevation of 2,301 ft. While a TAF is only current for a 5 statute mile radius of the specific airport's center point, pilot's, weather briefers, and flight planning systems will often provide the closest TAF for a more time and specific weather breakdown. The forecast current for KLWB during the period was as follows:

*TAF KLWB 101720Z **1018/1118 29020G28KT P6SM OVC050**  
FM110000 30015G23KT P6SM SCT025 BKN040  
FM111200 31012G21KT P6SM SKC=*

The forecast for KLWB expected from 1200 through 2000 EDT, a wind from 290° at 20 knots gusting to 28 knots, visibility 6 miles or more, with a ceiling overcast at 5,000 ft agl.

### 8.2 Area Forecast Discussion

The NWS Area Forecast Discussions (AFD) are issued by each WFO to describe the short-term weather conditions within their region with an aviation section that includes the general conditions as it relates to the creation of the TAF. These are useful for additional aviation-related issues that cannot be encoded into the TAF and provide some reasoning behind the forecast. These are generated roughly every 6 hours and corresponds to the release of the latest TAFs for that office. The NWS KRNK WFO issued the AFD at 0335 EDT was as follows.

*FXUS61 KRNK 100735  
AFDRNK  
Area Forecast Discussion  
National Weather Service Blacksburg VA  
335 AM EDT Sun Mar 10 2024.*

#### **.SYNOPSIS...**

**Very gusty winds and cold weather are in store today through Monday with the passage of a cold front. A few upslope snow showers are possible for the mountains.** Dry conditions are expected Monday through Thursday under high pressure with warmer weather returning.

.NEAR TERM /THROUGH TONIGHT/...  
As of 315 AM EDT Sunday...

**Key Messages:**

**1. Very gusty winds today and tonight, with Wind Advisories and High Wind Warnings in effect.**

**2. Light rain and snow showers for the mountains ending later today.** Low snow accumulations for Western Greenbrier County.

**3. Very cold tonight...**bring your pets in!

**Strong winds and chilly temperatures will produce wind chills in the teens and 20s today,** making it a good day to stay in, read a book, and change your clocks.

**A cold front has crossed most of the forecast area this morning. Upslope snow and rain showers were ongoing over the mountains and foothills in strong NW flow. A 55 knot LLJ over the area will keep the pressure gradient piling up on the west side of the Blue Ridge. This, in addition to moderate CAA, will help to keep NW winds very gusty through today and tonight. Winds were gusting to 25 to 35 mph at many sites, with a 47 mph gust already recorded at Boone. While a Wind Advisory remains in effect from the Blue Ridge westward, Watauga, Ashe, Alleghany, and Grayson Counties have been upgraded to a High Wind Warning, with gusts to 50-60 mph possible at our highest elevations.**

**Occasional rain and snow showers will continue for southeastern WV and parts of VA today. Flurries or sprinkles may be carried well downstream and even reach the I-81 corridor. Little to no snow accumulation is expected** outside of Western Greenbrier County, WV, where 1 to 3 inches will be possible.

Tonight will be very chilly with winds decreasing some but still gusting to 15 to 25 mph. Continued CAA and clearing skies will allow for lows in the 20s and 30s, with wind chills in the single digits and teens for the mountains. Temperatures in the Piedmont will not be quite as chilly with the mountains holding back the brunt of the colder air.

Confidence in the near term forecast is high.

.SHORT TERM /MONDAY THROUGH WEDNESDAY NIGHT/...  
As of 300 AM EDT Sunday...

**Key Messages:**

1) Confidence is high for dry weather throughout this period.

2) Gusty winds on Monday should subside by Monday evening, and warmer air will arrive for Tuesday and Wednesday.

The gusty northwest winds will continue into Monday but should gradually fade by the afternoon as high pressure builds across the Southeast. The winds will finally relax on Monday night, and a much quieter weather pattern will ensue. Dry conditions should persist through Tuesday and Wednesday. Because the center of high pressure will stay to the south and exit offshore during late Tuesday into Wednesday, the flow across the Mid Atlantic will turn towards the southwest

and provide warm air advection. Temperatures should jump into the 60s on Tuesday in the Piedmont, and a few lower 70s are possible by Wednesday.

**.AVIATION /07Z SUNDAY THROUGH THURSDAY/...**

As of 245 AM EDT Sunday...

**A cold front has crossed most of the forecast area this morning. Upslope snow and rain showers were ongoing over the mountains in strong NW flow. Winds were gusting to 15 to 25 knots already in strong CAA. 55 knot LLJ was over the area as well and will help to keep winds gusty through today, tonight, and Monday. Gusts as high as 40 kts possible at ROA/BLF. Pressure gradient finally relaxes tomorrow afternoon allowing for winds to decrease but they remain breezy even after that.**

**Seeing a mix of VFR and MVFR behind the cold front, with BLF still IFR. We will see improvement everywhere as the day goes on, with areas east of the mountains scattering out, and MVFR to VFR for the mountains. -SHRA/-SHSN may briefly reduce vsby below 2SM. These showers diminish through the day.**

**.EXTENDED AVIATION OUTLOOK...**

High pressure with dry VFR conditions are expected Monday through Thursday.

**.RNK WATCHES/WARNINGS/ADVISORIES...**

**VA...High Wind Warning from 6 AM this morning to noon EST Monday** for VAZ015.

Wind Advisory from 6 AM this morning to noon EST Monday for VAZ007-009>014-016>020 - 022>024.

NC...High Wind Warning from 6 AM this morning to noon EST Monday for NCZ001-002-018.

WV...Wind Advisory from 6 AM this morning to noon EST Monday for WVZ042>044-507-508.

SYNOPSIS...BMG/SH

NEAR TERM...SH

SHORT TERM...PW

LONG TERM...PW

AVIATION...SH

The forecast was updated immediately before the accident at 1430 EDT with the Aviation Forecast Discussion as follows:

FXUS61 KRNK 101837

AFDRNK

Area Forecast Discussion

National Weather Service Blacksburg VA

237 PM EDT Sun Mar 10 2024

**.AVIATION /19Z SUNDAY THROUGH FRIDAY/...**

As of 230 PM EDT Sunday...

Upslope cloudiness has lessened throughout the day and nearly all locations have returned to VFR. VFR is likely to continue through the 24hr TAF period.

**Wind is the main headline with gusts continuing through Monday morning in the 30kt to 40kt range along and west of the mountains. Locations from ROA to TNB could have gusts topping 50kts at times tonight. Winds will remain NW through tomorrow.**

### 8.3 NWS Wind Advisory

While not disseminated to aviation interests the NWS had a wind advisory current over Hot Springs, Bath County, VA, issued at 1353 EDT was as follows.

WWUS71 KRNK 101753  
NPWRNK

URGENT - WEATHER MESSAGE  
National Weather Service Blacksburg VA  
153 PM EDT Sun Mar 10 2024

VAZ007-009>014-018>020-023-024-WVZ042>044-507-508-110200-  
/O.CON.KRNL.WI.Y.0008.000000T0000Z-240311T1600Z/  
Tazewell-Smyth-Bland-Giles-Wythe-Pulaski-Montgomery-Craig-Alleghany-Bath-Botetourt-  
Rockbridge-Mercer-Summers-Monroe-Eastern Greenbrier-Western Greenbrier-Including the  
cities of Pearisburg, Wytheville, Bluefield, Hix, Fincastle, New Castle, **Hot Springs**, Buena Vista,  
Tazewell, Alderson, Rainelle, Hinton, Lexington, Quinwood, Bland, Covington, Duo, Lewisburg,  
Pulaski, Radford, Clifton Forge, Blacksburg, Flat Top, White Sulphur Springs, Union, and Marion  
153 PM EDT Sun Mar 10 2024

...WIND ADVISORY REMAINS IN EFFECT UNTIL NOON EDT MONDAY...

\* **WHAT...Northwest winds 20 to 30 mph with gusts up to 50 mph.**

\* **WHERE...Portions of southwest and west central Virginia and southeast West Virginia.**

\* **WHEN...Until noon EDT Monday.**

\* **IMPACTS...Gusty winds will blow around unsecured objects. Tree limbs could be blown down and a few power outages may result.**

PRECAUTIONARY/PREPAREDNESS ACTIONS...

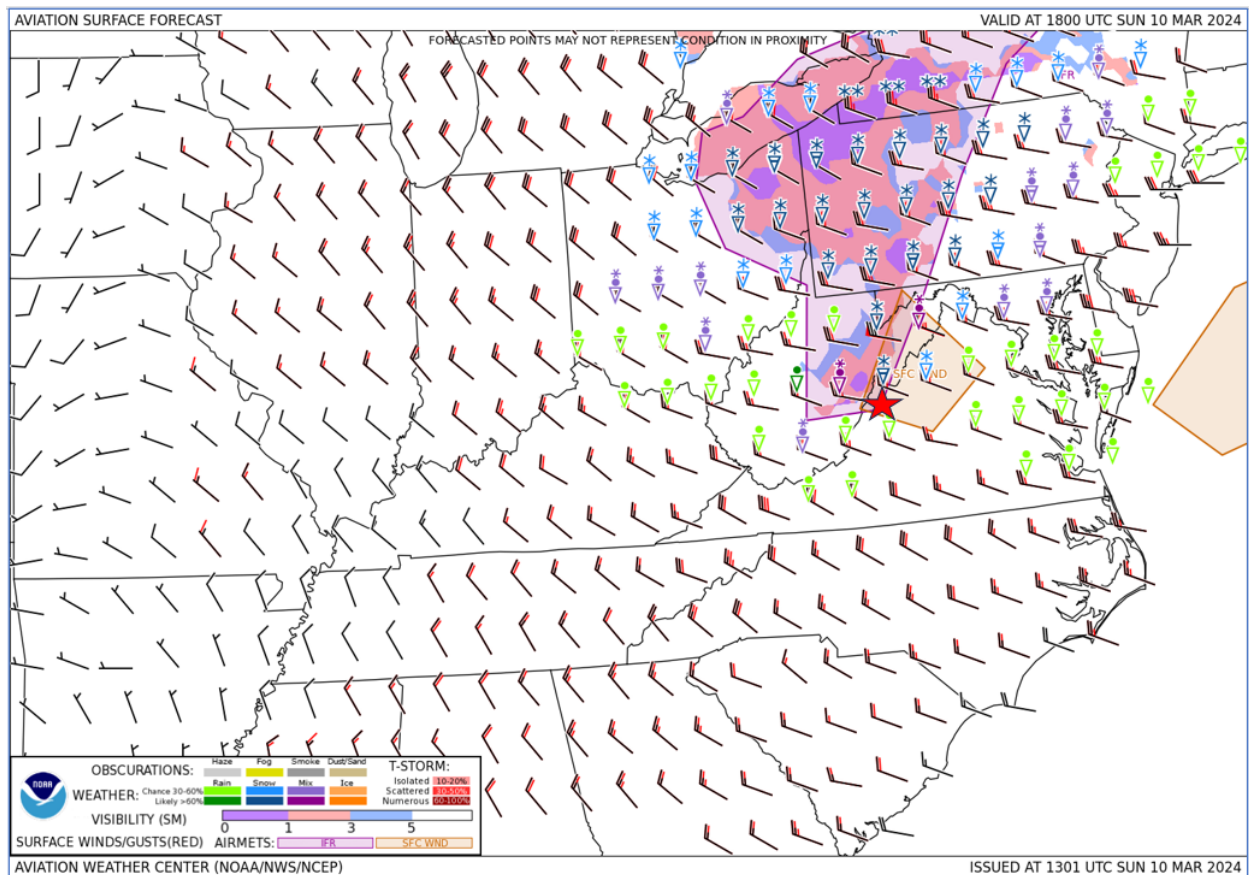
*Winds this strong can make driving difficult, especially for high profile vehicles. Use extra caution.*

*Secure outdoor objects.*

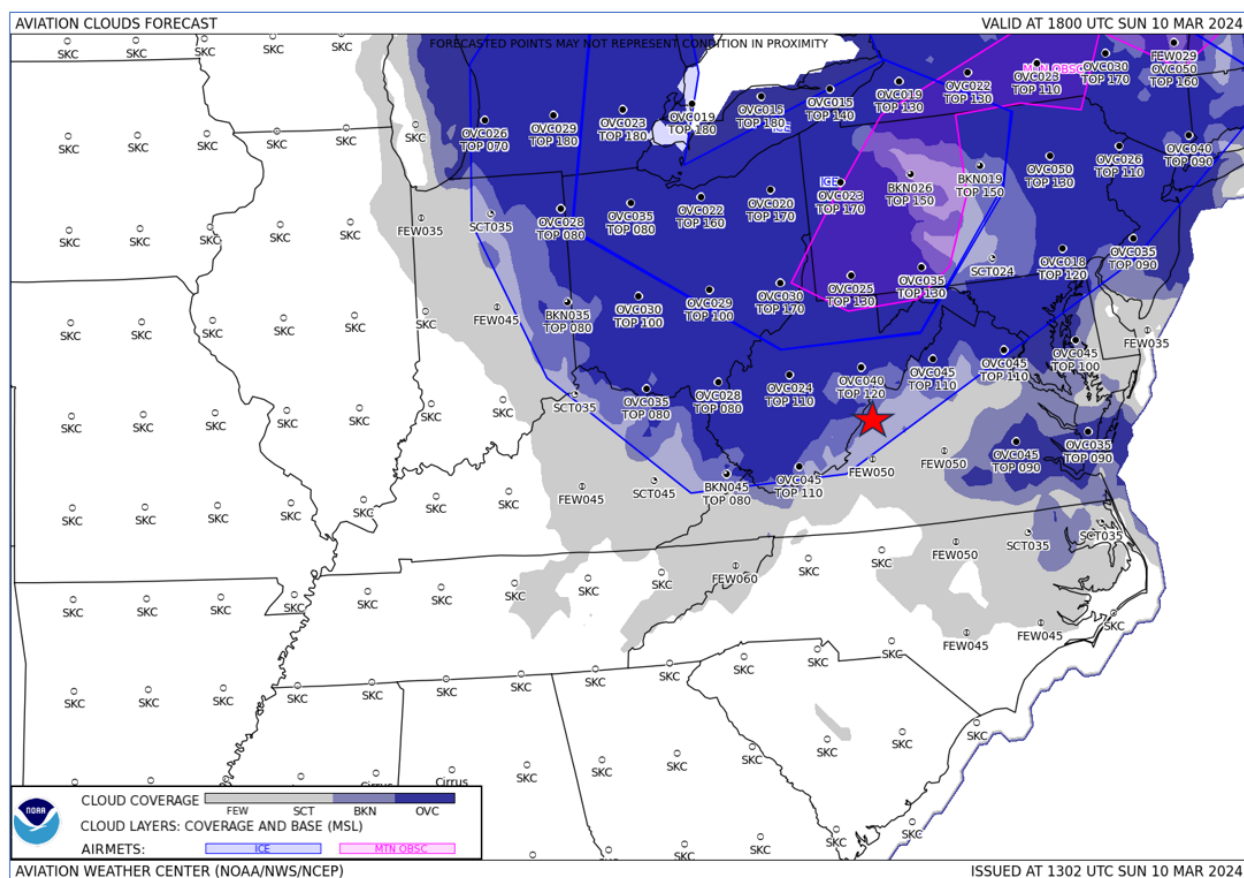
### 8.4 Graphic Forecast for Aviation

The NWS Graphic Forecast for Aviation (GFA) is a graphical depiction of surface wind, thunderstorms, precipitation, color-coded general flight categories, and cloud cover bases and tops reported in msl heights, from graphical output from the NWS National Digital Forecast Database (NDFD) with the Graphic-Airmen's Meteorological Information (G-AIRMET) for IFR conditions, mountain obscuration, icing conditions, and strong surface wind overlaid. The GFA provides a forecast for the enroute phase of flight and for locations without a TAF, such as in this case at KHSP. The GFA is available at the NWS AWC website and through other weather briefing services.

The GFA central east Surface and Cloud Forecast valid for 1400 EDT with the approximate accident site marked by the red star are included as figures 15 and 16 respectively. The surface forecast included a chance (30 to 50%) of snow showers over the region with surface winds from the west-northwest at 20 knots with gusts to 45 knots possible. A G-AIRMETs for mountain obscuration and strong surface winds extended over the accident site. The GFA cloud forecast indicted broken clouds at 4,000 ft msl with tops near 12,000 ft, the chart also depicted a G-AIRMET for icing conditions over the area.



**Figure 15 - Graphic Forecast for Aviation (GFA) Surface Forecast valid for 1400 EDT with approximate location of accident site marked by the red star.**



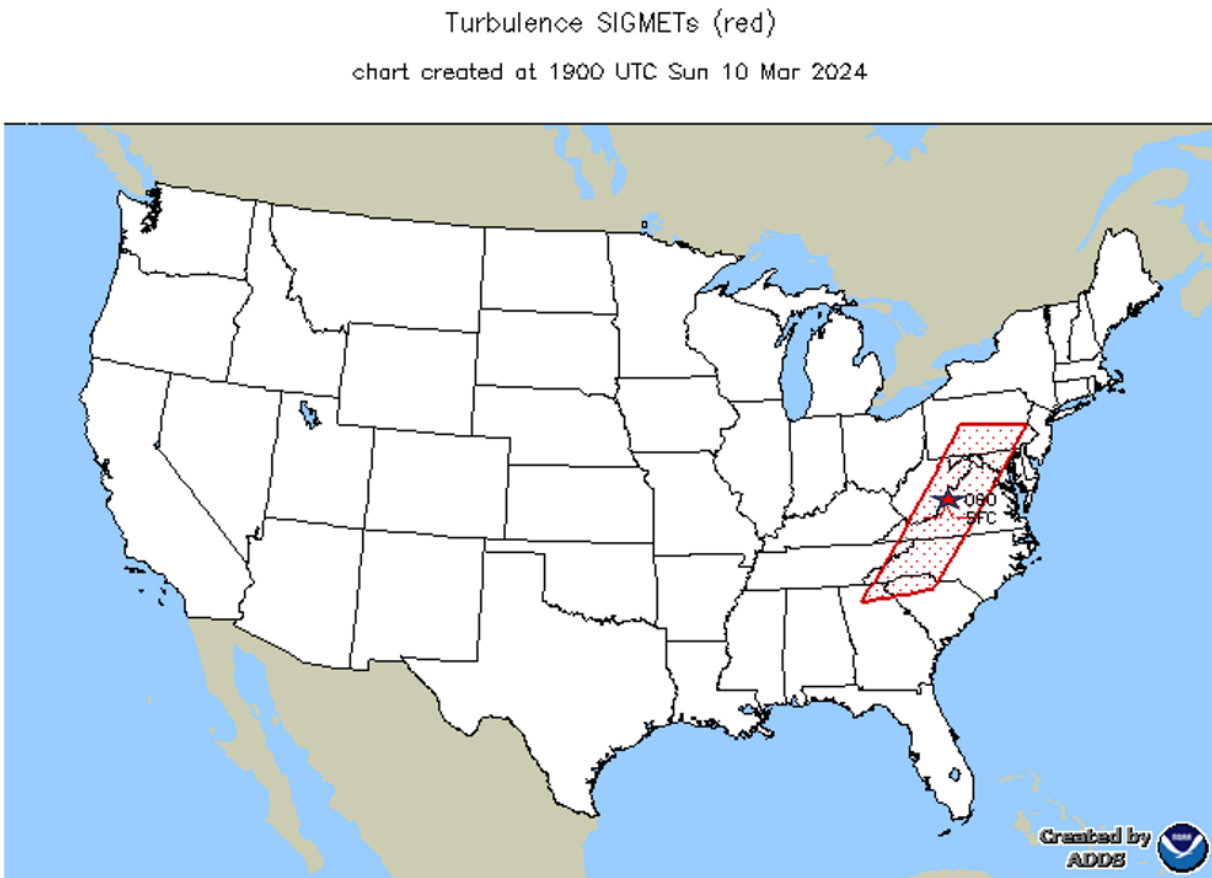
**Figure 16 - Graphic Forecast for Aviation (GFA) Cloud Forecast valid for 1400 EDT with approximate location of accident site marked by the red star.**

## 9.0 Inflight Weather Advisories

In-flight Aviation Weather Advisories are forecasts that advise en route aircraft of the development of potentially hazardous weather. Inflight aviation weather advisories in the conterminous U.S. are issued by the NWS AWC, as well as from the Center Weather Service Units (CWSU) at the various Air Route Traffic Control Centers (ARTCCs). There are four basic types of inflight aviation weather advisories: the Significant Meteorological Information (SIGMET), the Convective SIGMET, the Graphic-AIRMET, and the Center Weather Advisory (CWA). Inflight advisories serve to notify en-route pilots of the possibility of encountering hazardous flying conditions that may not have been forecast at the time of the preflight briefing. Whether or not the condition described is potentially hazardous to a particular flight is for the pilot to evaluate based on experience and the operational limits of the aircraft. Once issued they are broadcast by FAA air traffic controllers upon issuance and available on inflight weather broadcasts.

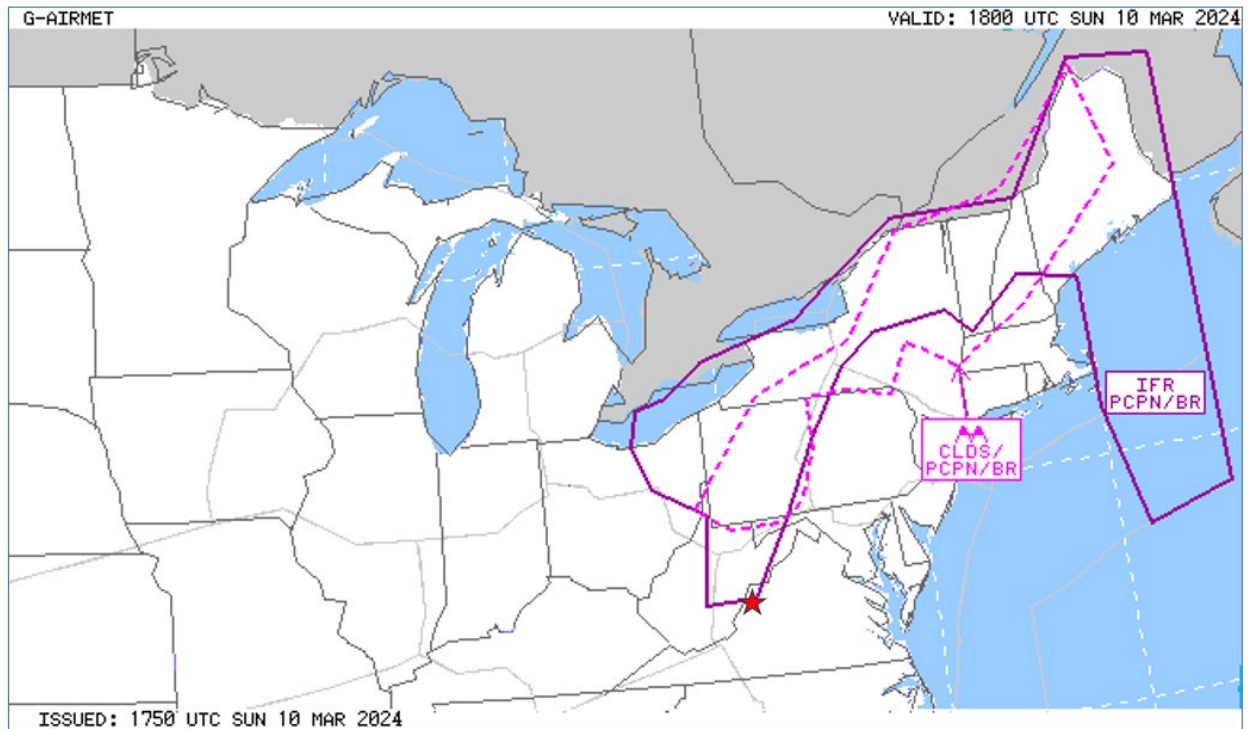
At the time of the accident, the NWS had a SIGMET Oscar 1 current over the area for occasional severe turbulence below 9,000 ft due to strong low-level winds and

mountain wave activity. A depiction of SIGMET Oscar 1 is included as figure 17, with the full text of the advisory following. There were no other SIGMETs, Convective SIGMETs, CWAs current during the period of the accident. The NWS AWC also had a series of G-AIRMETs current for mountain obscurations and IFR conditions (figure 18), occasional moderate turbulence below 10,000 ft (figure 19), and for occasional moderate icing conditions between the freezing level and 10,000 ft (figure 20).

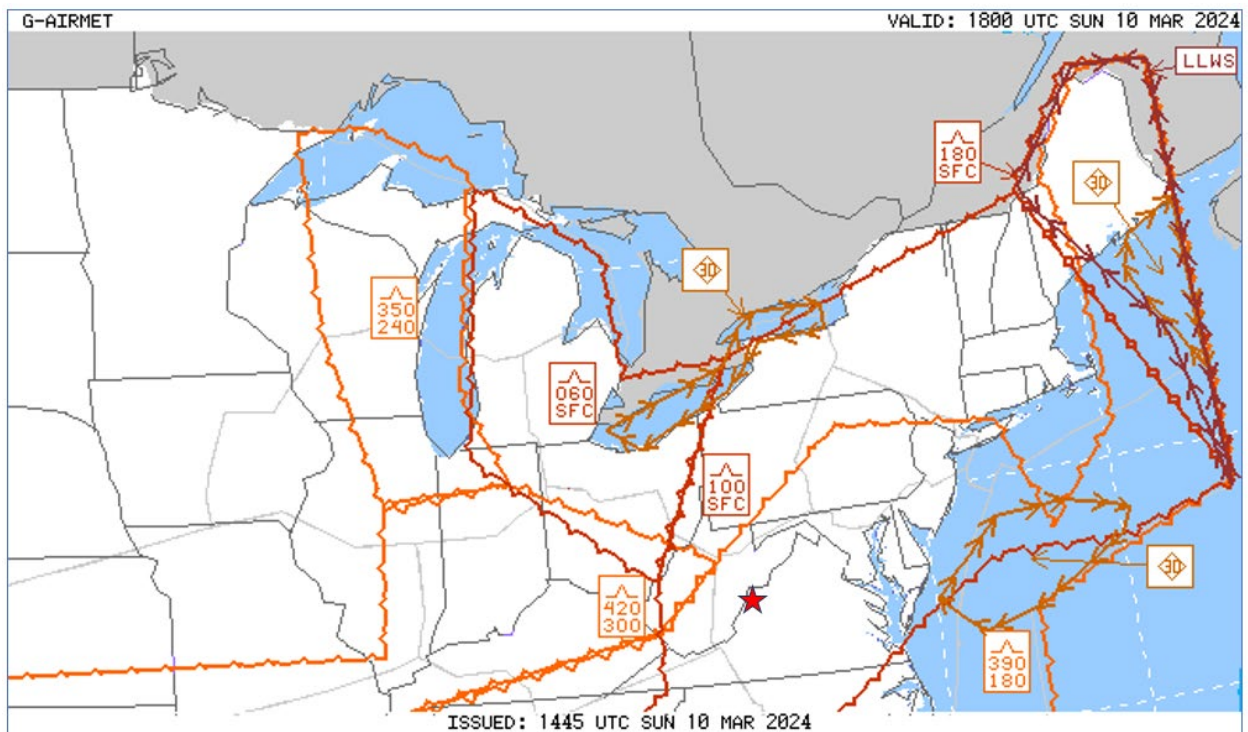


**Figure 17 - SIGMET Oscar 1 for occasional severe turbulence below 9,000 ft with the accident site.**

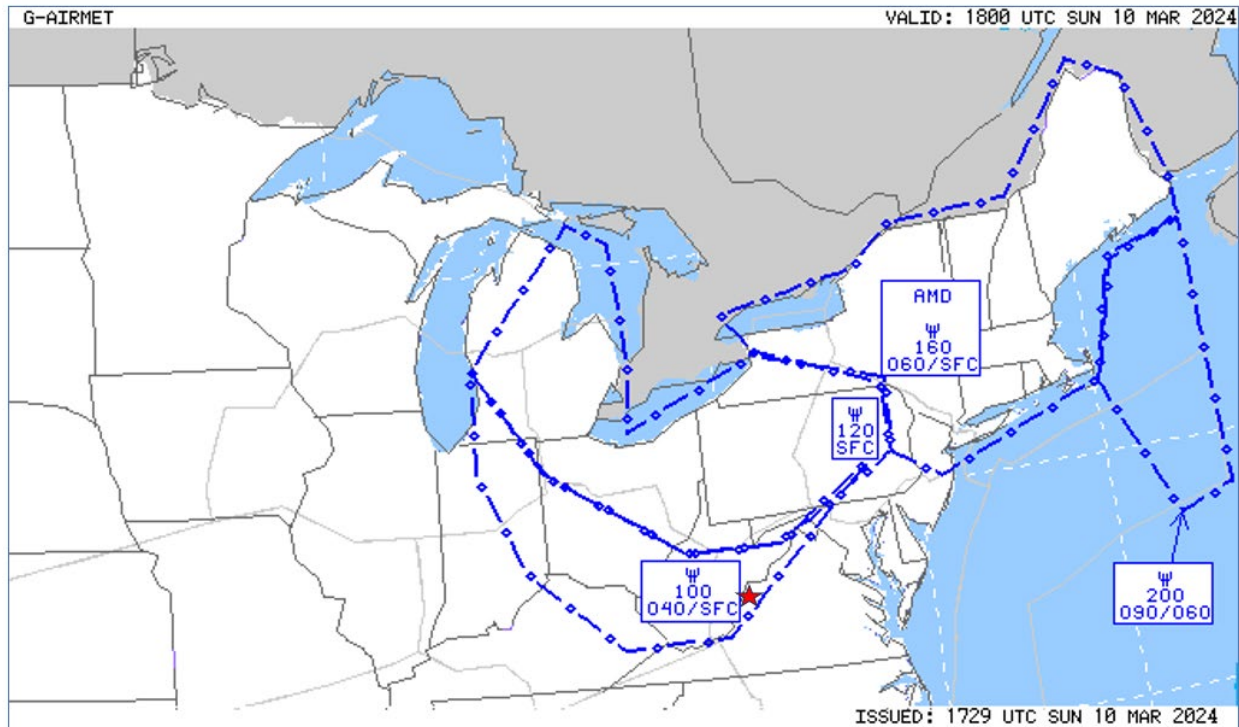
WSUS01 KPCI 101726  
BOSO WS 101726  
SIGMET OSCAR 1 VALID UNTIL 102126  
SIGMET  
PA WV MD DC VA NC SC GA TN  
FROM 30W PSB TO 20E ETX TO 40S CLT TO 40N ATL TO 30W PSB  
**OCNL SEV TURB BLW 090. DUE TO STG LOW LVL WINDS AND MTN WV ACT.**  
**RPTD BY ACFT.** CONDS CONTG BYD 2126Z.



**Figure 18 - Graphic-AIRMET Sierra for IFR conditions valid for 1400 EDT with accident site noted.**



**Figure 19 - Graphic-AIRMET Tango for occasional moderate turbulence for 1400 EDT.**



**Figure 20 - Graphic-AIRMET Zulu for moderate icing conditions for 1400 EDT with accident site.**

## 10.0 Preflight Weather Briefing

The flight crew received a detailed flight plan and weather document from ForeFlight which was issued at 0956 EDT, with a planned departure of 1115 EDT. The flight was planned for a cruising altitude of FL410 with an estimated time of arrival of 1306 EDT, with an alternate of Roanoke (KROA) listed. That document is included as Attachment 4. The weather document included a graphic cross section and profile view of forecast winds with expected turbulence (EDR) and icing, a high level significant weather prognostic chart, and METAR and TAFs for the departure, destination, and alternate airports, SIGMETs, and NOTAMs. The document did not include pilot reports, or G-AIRMETs.

The graphic cross section of winds indicated winds at 6,000 ft over KHSP from 280° at 45 knots, a temperature of -8°C with light icing depicted.

## F. ATTACHMENTS

Attachment 1 - GOES-16 infrared satellite animation.

Attachment 2 - GOES-16 low-level water vapor satellite animation.

Attachment 3 – GOES-16 visible satellite animation.

Attachment 4 – Flight plan and weather document.

Submitted by:

Donald Eick  
NTSB Senior Meteorologist