



NATIONAL TRANSPORTATION SAFETY BOARD

Office of Aviation Safety
Washington, D.C. 20594

January 26, 2022

Specialist's Factual Report

METEOROLOGY

WPR21FA286

A. ACCIDENT

Location: Truckee, California
Date: July 26, 2021
Time: 1318 Pacific daylight time (PDT)
2018 universal coordinated time (UTC)
Airplane: Bombardier CL-600-2B16; Registration: N605TR

B. METEOROLOGY SPECIALIST

Specialist Donald Eick
National Transportation Safety Board
Washington, D.C.

C. 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 from the Washington D.C. office, collecting data from official National Weather Service (NWS) sources including the Weather Prediction Center (WPC) and the National Center for Environmental Information (NCEI). All times are reported as PDT based upon the 24-hour clock, local time is -7 hours from UTC, and UTC=Z. NWS airport and 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. 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 main wreckage site was located at latitude 39.325433° N, longitude 120.16291°, at an elevation of approximately 5,900 ft.

D. 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 Weather Prediction Center (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 can be found in the joint NWS and Federal Aviation Administration (FAA) Advisory Circular "Aviation Weather Services", AC 00-45H change 2.

1.1 Surface Analysis Chart

The western section of the NWS Surface Analysis Chart for 1400 PDT (depicted as 2100Z) is included as figure 1 with the approximate accident site marked by a red star. The chart depicted a thermal low-pressure system¹ over northern California at 1008-hectopascals (hPa)² to the west-northwest of the accident site with a trough of low pressure extending north and south-southeast of the low over the central portion of California. Another thermal low-pressure system was located over northern Nevada at 1007-hPa, to the northeast of the accident site. The accident site was generally located between the two low-pressure systems and located south of a col³ or neutral point in the pressure field with a weak pressure gradient with no isobars⁴ drawn between the accident site or the low-pressure systems.

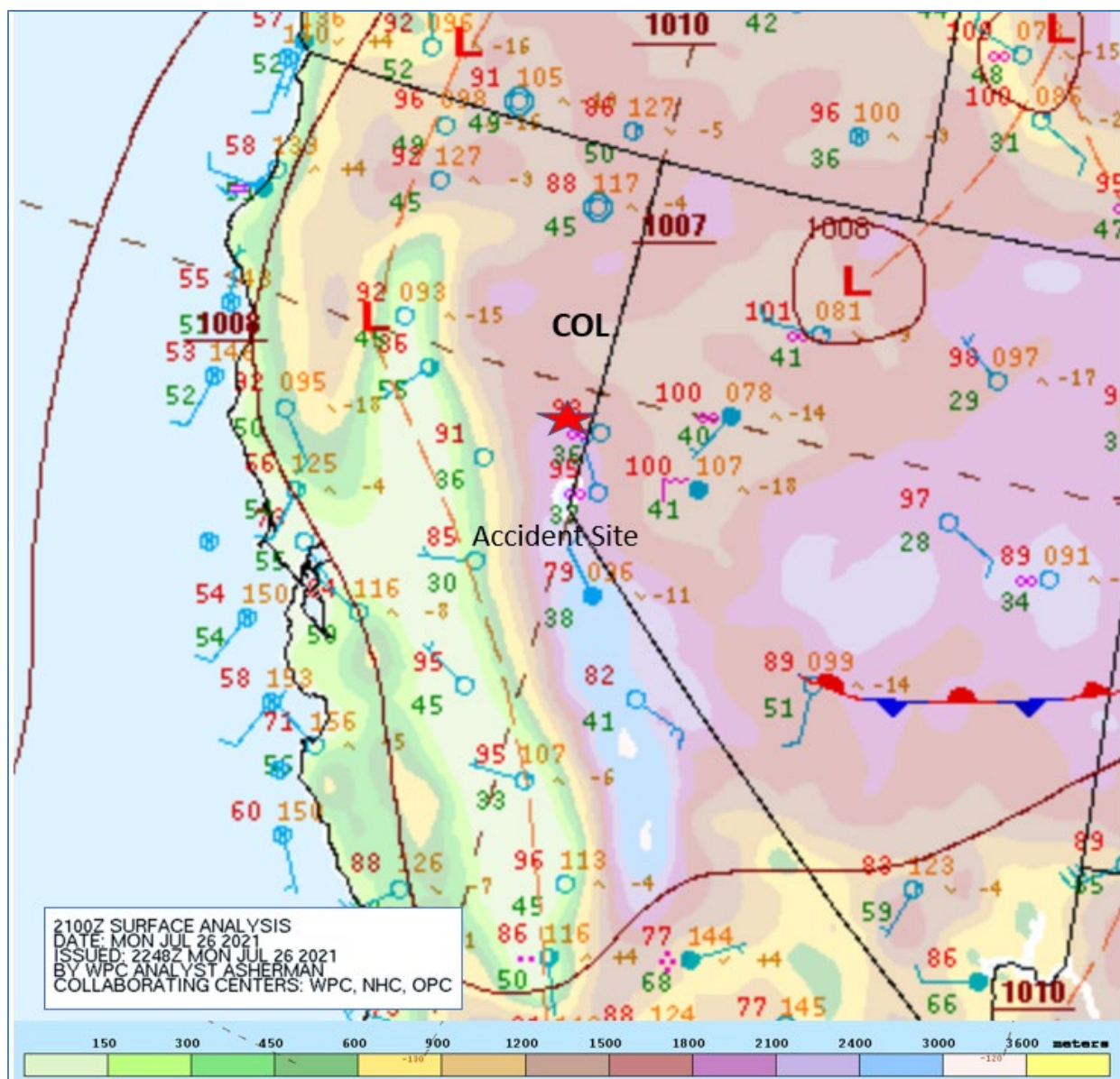
The station models surrounding the accident site indicated light winds of 5 knots or less, visibility restricted in smoke and haze, clear skies, with temperatures in the upper 90's degrees Fahrenheit (F), with dew point temperatures in the upper 30's F.

¹ A thermal low, or heat low, is a non-frontal low-pressure system that occur over the continents in the subtropics during the warm season, as a result of intense heating when compared to their surroundings. A thermal low will be strongest near the surface and typically weakens with height due to the typical stable atmospheres they develop in.

² Hectopascal is the standard term for reporting sea-level pressure and is interchangeable with the former term millibar with the same units. The standard atmosphere is based on a sea-level pressure is 1013.25-hPa at 59° Fahrenheit (F) or 15° Celsius (C).

³ A Col, also called a saddle point or neutral point, is the point of intersection of a trough and a ridge in the pressure pattern.

⁴ An isobar is a line of equal pressure, usually drawn at 4-hPa intervals on the surface analysis chart.



1.2 Streamline Chart

A streamline chart for 1300 PDT over the southwest United States from Plymouth State Weather Center's archive database for the period is included as figure 2, with the approximate accident site marked by the red star. The chart depicted general convergence⁵ of the winds over northern

⁵ Convergence - a contraction of a vector field; the opposite of divergence. Convergence in a horizontal wind field indicates that more air is entering a given area than is leaving at that level. To compensate for the resulting "excess," vertical motion may result: upward forcing if convergence is at low levels, or downward forcing (subsidence) if convergence is at high levels. Upward forcing from low-level convergence increases the potential for thunderstorm development (when other factors, such as instability, are favorable). Compare with confluence.

Nevada in the vicinity of the thermal low, and two other areas of a cyclonic circulation⁶ and convergence over eastern California to the south-southeast of the accident site and another over southern California. Winds in the vicinity of the accident site were depicted from the north.

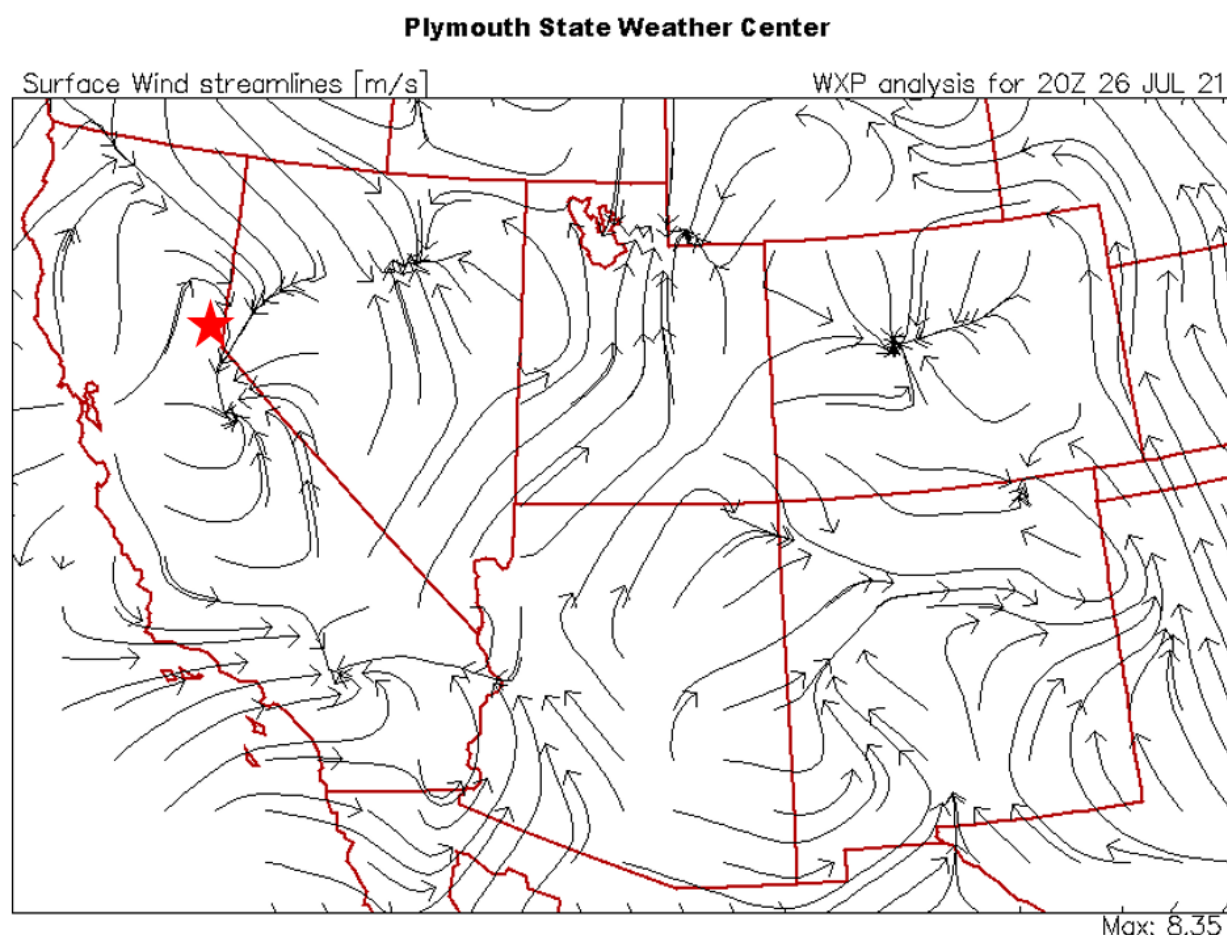


Figure 2 - Streamline chart for 1300 PDT with the accident site marked by red star.

2.0 Observation

The official observations issued surrounding the accident site were documented using standard Aviation Routine Weather Reports (METAR⁷) and Aviation Select Special Weather Reports (SPECIs). Cloud heights are reported above ground level (agl) in the following section, and the magnetic variation was estimated at 13° east based on the latest sectional chart for the area. Figure 3 is a World Aeronautical Chart (WAC) depiction of the area with the closest airports and those with weather reporting capability (labelled in blue) and the general topography of the area. The accident site was located immediately west of TRK and is documented below.

⁶ Cyclonic refers to a counterclockwise wind flow pattern in the northern hemisphere, same as that in a low-pressure system.

⁷ METAR is an abbreviation for meteorological aerodrome report.



Figure 3 - Depiction of the closest weather reporting locations and the accident site.

2.1 Truckee, California

The accident airplane was on a visual approach to Truckee-Tahoe Airport (KTRK), Truckee, California, which was located about 1 mile east-southeast of the accident site⁸ at an elevation of 5,904 ft. The airport had an Automated Weather Observation System (AWOS)⁹ installed and usually issued observations every 20-minutes in the fully automated mode, or hourly with specials as needed when in the manual mode typically between 0700 to 2130 local when the system is augmented by airport personnel. The airport had a non-federal contract tower (NFCT) which has access to the AWOS weather display but does not augment the observations¹⁰. The following weather conditions were reported surrounding the time of the accident.

KTRK weather observation at 1245 PDT (1945Z), automated, wind from 090° at 5 knots, visibility 4 miles, ceiling broken at 2,300 ft agl, temperature 32° Celsius (C), dew point

⁸ Center of the KTRK airport complex, with the accident site about ½ mile short of touchdown zone for runway 11.

⁹ The AWOS also provides weather through a VHF broadcast locally for pilots to obtain the latest weather conditions, which is updated every 1-minute. The 1-minute data is not routinely archived or transmitted longline.

¹⁰ The KTRK tower controllers are not Limited Aviation Weather Reporting Station (LAWRS) certified.

temperature 6° C, altimeter 30.14 inches of mercury (in Hg), with smoke¹¹. Remarks: visibility 3 ½ variable 5 miles in smoke, ceiling broken at 2,300 ft.

Accident 1318 PDT (2018Z)

KTRK weather observation at 1350 PDT (2050Z), automated, wind from 280° at 11 knot gusting to 16 knots, visibility 4 miles, ceiling broken at 2,300 ft agl, temperature 33° C, dew point temperature 8° C, altimeter 30.13 in Hg, smoke. Remarks: visibility 3 ½ variable 5 miles in smoke, ceiling broken at 2,300 ft, aircraft mishap.

A review of the observation current at the time of the accident indicated a temperature of 32° C (89.6° F), a dew point of 6° C (42.8° F), a relative humidity of 19%, with a density altitude of approximately 8,997 ft. The high temperature for the day was reported as 91.4° F at 1350 PDT. In reviewing the KTRK air traffic control tower audio surrounding the period of the accident, the tower controller provided the latest wind from the AWOS for arriving and departing aircraft, including the accident airplane. After the 1245 PDT observation between 1300 and 1318 PDT, the tower controller provided the current wind from the AWOS display as calm. For further details see the Air Traffic Control specialist report in the docket. The observation taken at 1350 PDT shows stronger winds than were reported at the time of the accident.

The general flight categories¹² and official raw METARs reported surrounding the period from 0950 through 1645 PDT were as follows.

***MVFR** METAR KTRK 261650Z AUTO 00000KT 04SM BKN023 OVC028 23/08 A3019 FU RMK VIS 4 1/2/V6 FU BKN023=*

***MVFR** METAR KTRK 261750Z AUTO 00000KT 04SM BKN023 27/08 A3017 FU RMK VIS 4 1/2/V6 FU BKN023=*

METAR KTRK 261850Z Missing

***MVFR** METAR KTRK 261945Z AUTO 09005KT 04SM BKN023 32/06 A3014 FU RMK VIS 3 1/2/V5 FU BKN023=*

Accident 2018Z

***MVFR** METAR KTRK 262050Z AUTO 28011G16KT 04SM BKN023 33/08 A3013 FU RMK VIS 3 1/2/V5 FU BKN023 ACFT MSHP=*

¹¹ A suspension in the air of small particles produced by combustion. A transition to haze may occur when smoke particles have traveled great distances (25 to 100 statute miles or more) and when the larger particles have settled out and the remaining particles have become widely scattered through the atmosphere.

¹² 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 above ground level (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.

IFR METAR KTRK 262145Z AUTO 36012G25KT 02SM VCTS SCT025 SCT031 BKN043 25/10 A3013 FU RMK VIS 3 1/2/V5 FU SCT025 SCT031 BKN043 VCLTG AND LTG DSNT ALQDS=

METAR KTRK 262245Z Missing

MVFR METAR KTRK 262345Z AUTO 18011G17KT 05SM VCTS SCT025 SCT031 BKN043 27/07 A3015 FU RMK VIS 4 1/2/V5 FU SCT025 SCT031 BKN043 VCLTG AND LTG DSNT ALQDS=

After the accident, at 1445 and 1645 PDT KTRK reported thunderstorms in the vicinity of the station with lightning, with no measurable precipitation recorded at the station.

2.2 Reno, Nevada

The next closest major airport with weather reporting capability was from Reno Tahoe International Airport (KRNO), Reno, Nevada, located about 20 miles northeast of TRK at an elevation of 4,415 ft. The airport had a federally installed and maintained Automate Surface Observation System (ASOS) and was augmented by air traffic control during normal working hours. The airport was also the designated alternate airport by the accident flight for KTRK. The following conditions were reported at the time of the accident.

KRNO weather observation at 1255 PDT (1955Z), wind variable at 4 knots, visibility 2 ½ miles in smoke, ceiling broken at 2,200 ft agl, broken at 11,000 ft, temperature 34° C, dew point temperature 6° C, altimeter 30.00 in Hg. Remarks: automated station with a precipitation discriminator, sea level pressure 1008.7-hPa, temperature 34.4° C, dew point temperature 6.1° C.

The general flight categories and official raw METARs reported surrounding the period from 0955 through 1655 PDT were as follows.

IFR METAR KRNO 261655Z VRB04KT 2 1/2SM FU BKN025 BKN120 28/07 A3004 RMK AO2 SLP104 FU BKN025 T02830072=

IFR METAR KRNO 261755Z 09004KT 2 1/2SM FU BKN025 BKN110 30/07 A3004 RMK AO2 SLP103 FU BKN025 T03000067 10306 20228 58002=

IFR METAR KRNO 261855Z 00000KT 2 1/2SM FU BKN021 BKN110 32/07 A3002 RMK AO2 SLP096 FU BKN021 T03220067=

IFR METAR KRNO 261955Z VRB04KT 2 1/2SM FU BKN022 BKN110 34/06 A3000 RMK AO2 SLP087 T03440061=

Accident 2018Z

IFR METAR KRNO 262055Z VRB04KT 2 1/2SM FU BKN025 BKN110 36/06 A2998 RMK AO2 SLP077 FU BKN025 T03610056 58017=

IFR METAR KRNO 262155Z 03007KT 2 1/2SM FU BKN024 BKN110 37/05 A2995 RMK AO2 SLP067 FU BKN024 T03670050=

IFR METAR KRNO 262255Z VRB04KT 2 1/2SM FU BKN025 BKN040 BKN110 37/05 A2994 RMK AO2 SLP062

FU BKN025 FU BKN040 T03670050=

IFR METAR KRNO 262355Z 33017KT 2 1/2SM FU BKN025 BKN040 BKN110 BKN150 36/06 A2993 RMK AO2
SLP063 FU BKN025 FU BKN040 T03560056 10372 20300 56015=

2.3 Aviation Weather Center's METAR Display

The NWS Aviation Weather Center's METAR display¹³ for 1318 PDT (depicted as 2018Z) with the accident site located immediately west of KTRK station model is included as figure 4. The image depicted the surrounding stations reporting MVFR to IFR conditions with light winds under 10 knots, with visibilities restricted from 2 ½ to 4 miles in smoke and haze over the area.

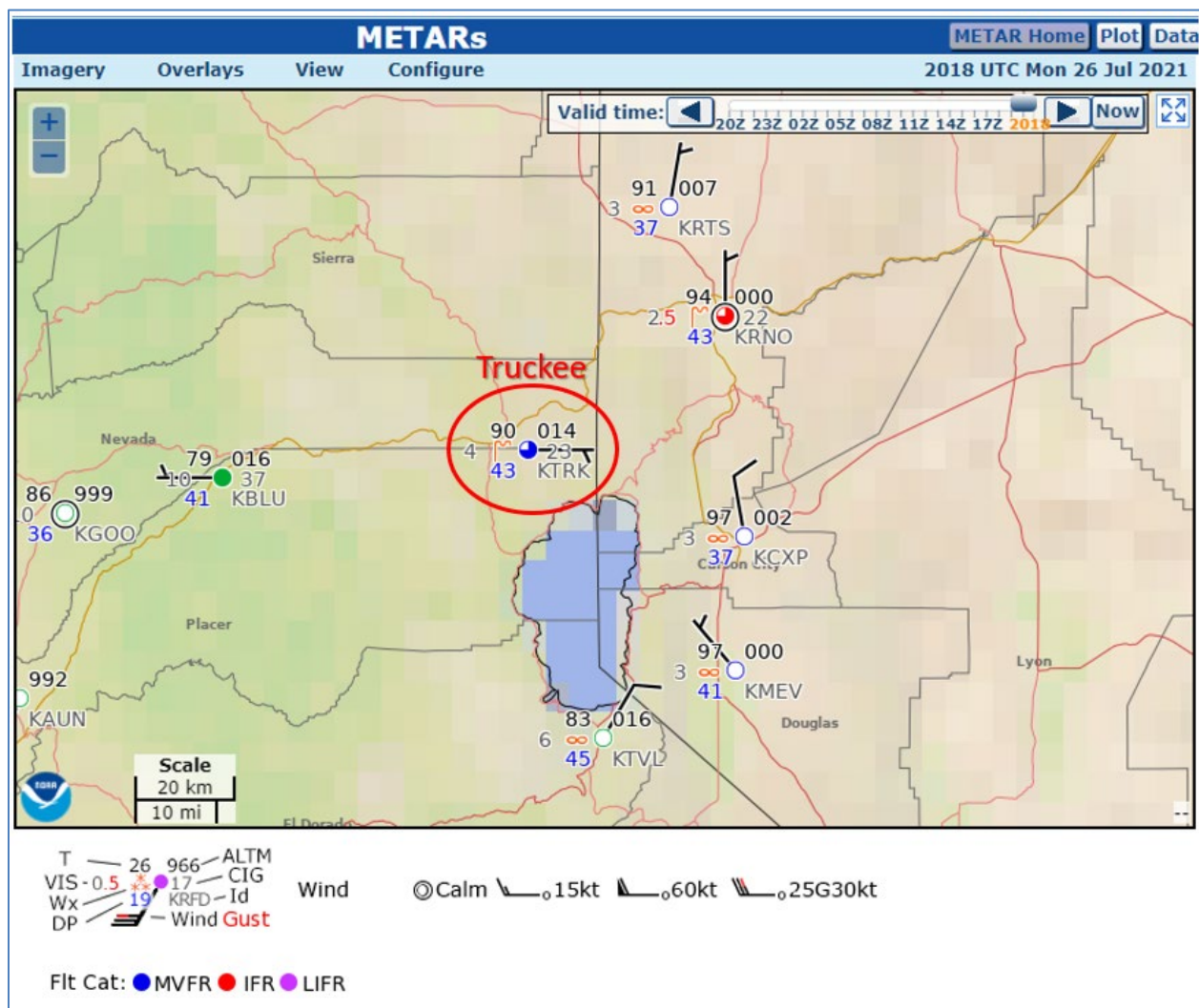


Figure 4 - METAR display from the Aviation Weather Center's website for 1318 PDT.

¹³ <https://www.aviationweather.gov/metar/>

3.0 Upper Air Observation

A High-Resolution Rapid Refresh (HRRR)¹⁴ numerical model was obtained from data from the NOAA Air Resource Laboratory with the coordinates closest to KTRK at 39.82° N, 120.14° W for 1300 PDT. The data was then plotted on a standard Skew T log P diagram¹⁵ from the surface to 450-hPa or approximately 20,000 ft and is included as figure 5.

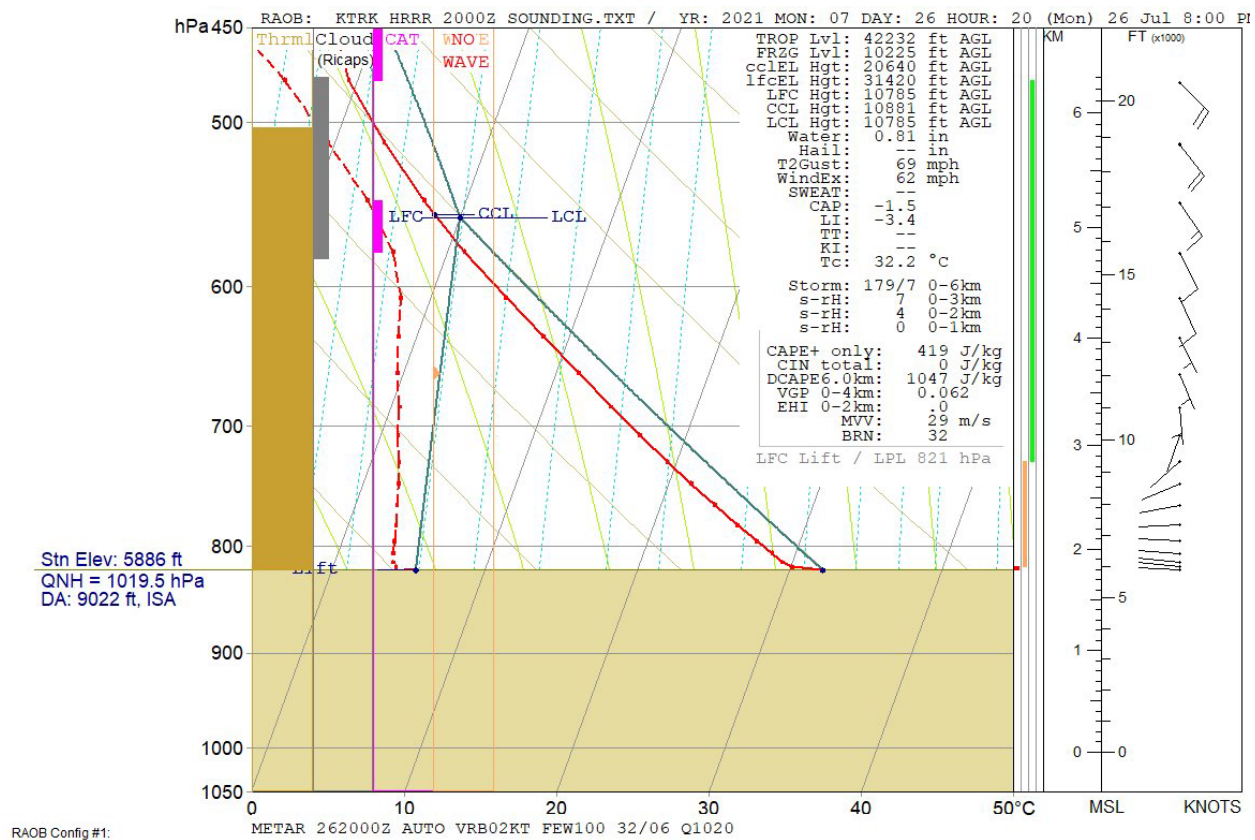


Figure 5 - HRRR numerical sounding for 1300 PDT.

The HRRR sounding indicated an elevation of 5,886 ft over the coordinates, with a near surface temperature of 32° C (90° F), a dew point temperature of 5.5° C (42° F), with a relative humidity of 19%, and a density altitude of 9,022 ft which was consistent with the KTRK METAR. The sounding depicted a dry low-level environment with the level of free convection (LFC)¹⁶ at 10,785 ft agl, with a convective condensation level (CCL)¹⁷ at 10,881 ft agl. The freezing level was

¹⁴ The HRRR is a National Oceanic and Atmospheric Administration (NOAA) real-time three-kilometer resolution, hourly-updated, cloud-resolving, convection-allowing atmospheric model, initialized by three-kilometer grids with three-kilometer radar assimilation. Radar data is assimilated in the HRRR every 15 minutes over a one-hour period.

¹⁵ 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.

¹⁶ The level of free convection is the altitude in the atmosphere where an air parcel lifted adiabatically until saturation becomes warmer than the environment at the same level, so that positive buoyancy can initiate self-sustained convection.

¹⁷ The convective condensation level is 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.

identified at 10,225 ft agl. RAOB indicated strong thermals from the surface to approximately 500-hPa or almost 18,000 ft. The atmosphere was characterized as unstable with a Lifted Index¹⁸ of -3.4, and a positive convective available potential energy (CAPE)¹⁹ of 419 J/kg, with the precipitable water²⁰ content of 0.81 inches.

The HRRR 1300 PDT wind profile indicated light and variable surface winds at 2 knots with winds generally from the east through 8,000 ft with wind speeds of 5 knots or less. Above 10,000 ft the winds shifted to the south-southeast and gradually began to increase in speeds over 10 knots over 14,000 ft. The mean 0 to 6 km (or 18,000 ft) wind was from approximately 150° at 9 knots. The RAOB analysis program did not depict any significant vertical wind shears for any significant clear air turbulence below 15,000 ft other than the thermals.

A table of the HRRR sounding parameters of height, pressure, temperature (T), dew point temperature (Td), relative humidity (RH%), wind direction/ speed (DD/FF), clear air turbulence (CAT), low-level wind shear (LLWS), and icing potential are provided in figure 6 from the surface through 21,000 ft. The table shows that no significant turbulence, wind shear, or icing conditions were noted below 14,000 ft.

Height (ft-MSL)	Pres (hPa)	T (C)	Td (C)	RH (%)	DD / FF (deg / kts)	CAT (FAA)	LLWS	Icing - Type (AFGWC method)
5886	821	32.2	5.5	19	273 / 2			
5993	818	30.1	4.1	19	276 / 2			
6136	814	29.4	3.8	20	276 / 2			
6424	806	28.5	3.6	20	274 / 2			
6823	795	27.2	3.4	22	273 / 2			
7336	781	25.5	3.1	23	267 / 2			
7968	764	23.6	2.7	25	259 / 2			
8648	746	21.5	2.3	28	246 / 2			
9340	728	19.4	1.8	31	226 / 2			
10162	707	17.0	1.1	34	198 / 2			
11043	685	14.4	0.5	39	176 / 3			
12069	660	11.5	-0.4	44	160 / 4			
13166	634	8.3	-1.2	51	156 / 7			
14340	607	4.9	-2.0	61	158 / 9			
15689	577	1.1	-3.6	71	155 / 11	LGT		
17186	545	-2.8	-6.5	76	149 / 16			
18851	511	-6.8	-10.5	75	145 / 19			
20604	477	-10.6	-14.8	71	138 / 18	LGT		

Figure 6 - HRRR parameters from the surface through 21,000 ft.

¹⁸ Lifted Index - the difference between the lifted parcel temperature at 500 hPa and the 500 hPa temperature in the sounding. Negative values denote parcels that are warmer than the background 500 hPa temperatures and are thus buoyant or "unstable".

¹⁹ The convective available potential energy (CAPE) is the integrated amount of work that the upward (positive) buoyancy force would perform on a given mass of air (called an air parcel) if it rose vertically through the entire atmosphere. Positive CAPE will cause the air parcel to rise, while negative CAPE will cause the air parcel to sink. Nonzero CAPE is an indicator of atmospheric instability in any given atmospheric sounding, a necessary condition for the development of cumulus and cumulonimbus clouds with attendant severe weather hazards.

²⁰ Precipitable Water (PW) is a measure of the depth of liquid water at the surface that would result after precipitating all of the water vapor in a vertical column over a given location, usually extending from the surface to 300 mb.

4.0 Satellite Imagery

The Geostationary Operational Environmental Satellite number 17 (GOES-17) imagery data were obtained from an archive at the Space Science and Engineering Center at the University of Wisconsin-Madison in Madison, Wisconsin, and processed using the Man-computer Interactive Data Access System (McIDAS) software. The infrared long wave and visible imagery were obtained for times surrounding the time of the accident, with the images closest to the time of the accident documented below. The infrared long wave imagery (band 13) at a wavelength of 10.3 microns (μm) provided radiative cloud top temperatures with a nominal spatial resolution of 2 km, with the visible (band 2) at a wavelength of 0.64 μm provided images at a resolution of 0.5 km.

The GOES-17 infrared image for 1316 PDT at 4X magnification with a standard MB temperature enhancement curve applied to highlight the higher and colder cloud tops typically associated with deep convection is shown in figure 7. The image depicted smoke near the surface with a band of cumulus to cumulus congestus clouds²¹ immediately west of the accident site and to the east, and southeast of the accident site. While only smoke was observed over the accident site, the band of clouds immediately west had a radiative cloud top temperature of 255 Kelvin of -18 C, which corresponded to cloud tops near 25,000 ft based on the HRRR sounding.

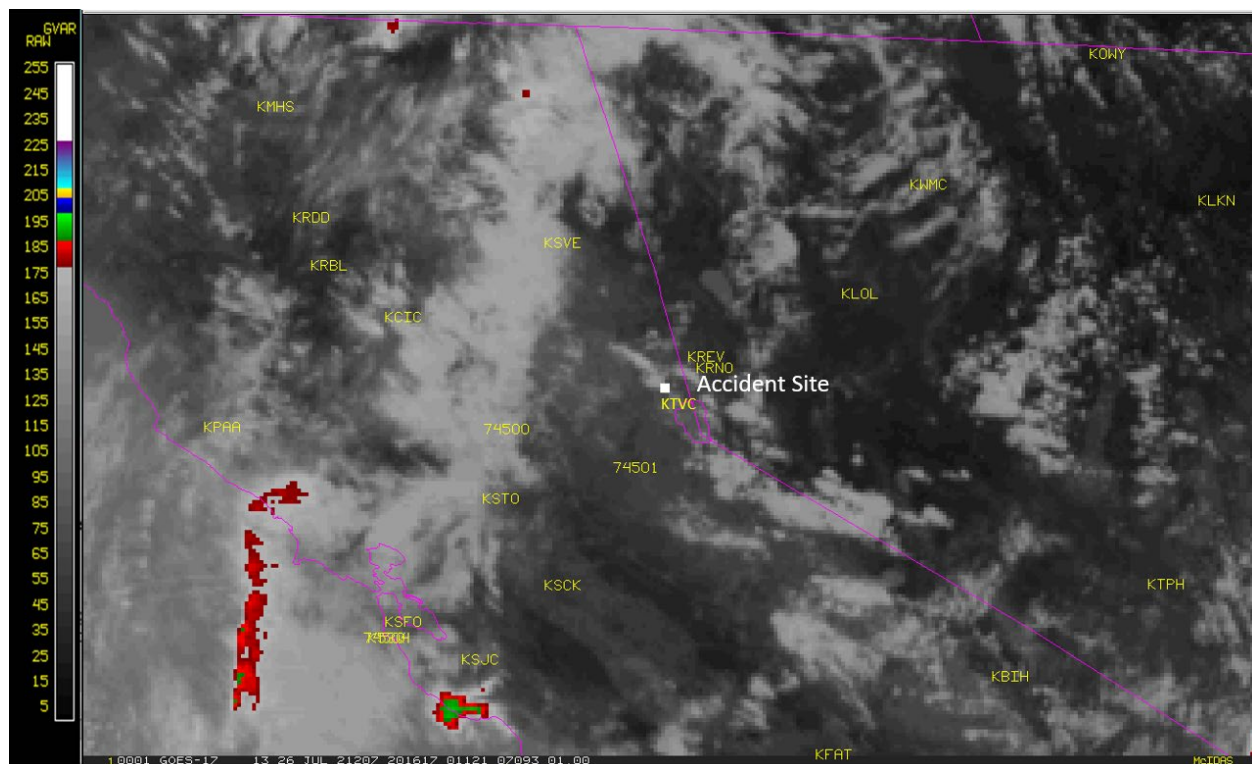


Figure 7 - GOES-17 infrared image for 1316 PDT at 4X magnification with MB temperature enhancement.

²¹ Cumulus congestus clouds, also known as towering cumulus, are a form of cumulus that can be based in the low or middle height ranges. They achieve considerable vertical development in areas of deep, moist convection. They are an intermediate stage between cumulus mediocris and cumulonimbus, producing showers of snow, rain or ice pellets.

Figure 8 is the GOES-17 visible image for 1316 PDT at 2X magnification with the accident site noted by the red star. The image depicted scattered cumulus congestus type clouds immediately east and west of KTRK, with the accident site bordering immediately east of one of these towering cumulus cloud areas and in an area of defined smoke.

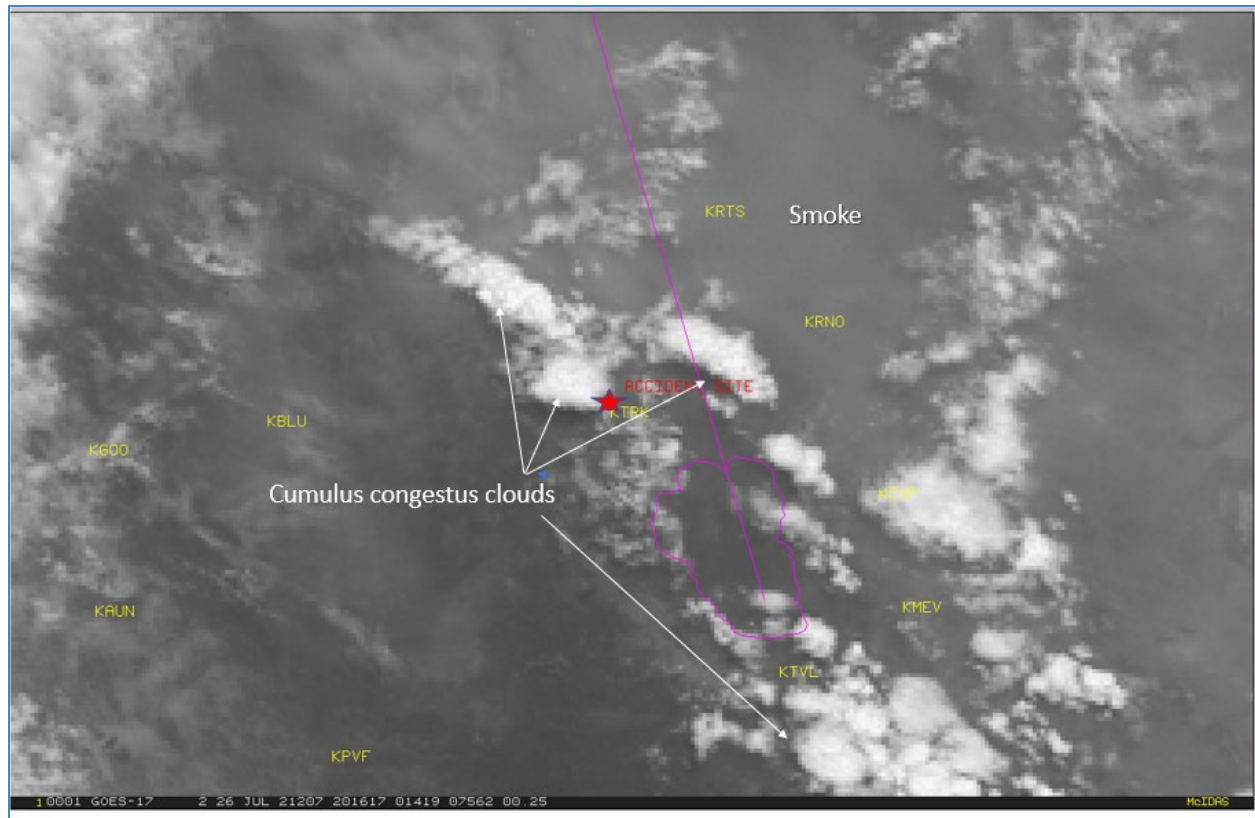


Figure 8 - GOES-17 visible image at 4X magnification with accident site marked.

Attachment 1 is an animation of the GOES-17 visible imagery from 1200 through 1500 PDT at 5-minute intervals at normal magnification. The animation depicts the cumulus to cumulonimbus clouds developing over the Tahoe area and moving northwestward with time.

Figures 9 and 10 are the National Aeronautics and Space Administration (NASA) Moderate Resolution Imaging Spectroradiometer (MODIS)²² satellite images for July 26, 2021, at 2000 m and 250 m resolution respectively depicting the smoke (gray shade) from the forest fires over the area.

²² The NASA MODIS is a payload imaging sensor on board the Terra and Aqua satellites in low Earth or polar orbit. The instrument captures 36 spectrum bands ranging in wavelength from 0.4 μm to 14.4 μm and at varying spatial resolutions. Together the instruments image the entire Earth every 1 to 2 days. They are designed to provide measurements in large-scale global dynamics including changes in Earth's cloud cover, radiation budget and processes occurring in the oceans, on land, and in the lower atmosphere.

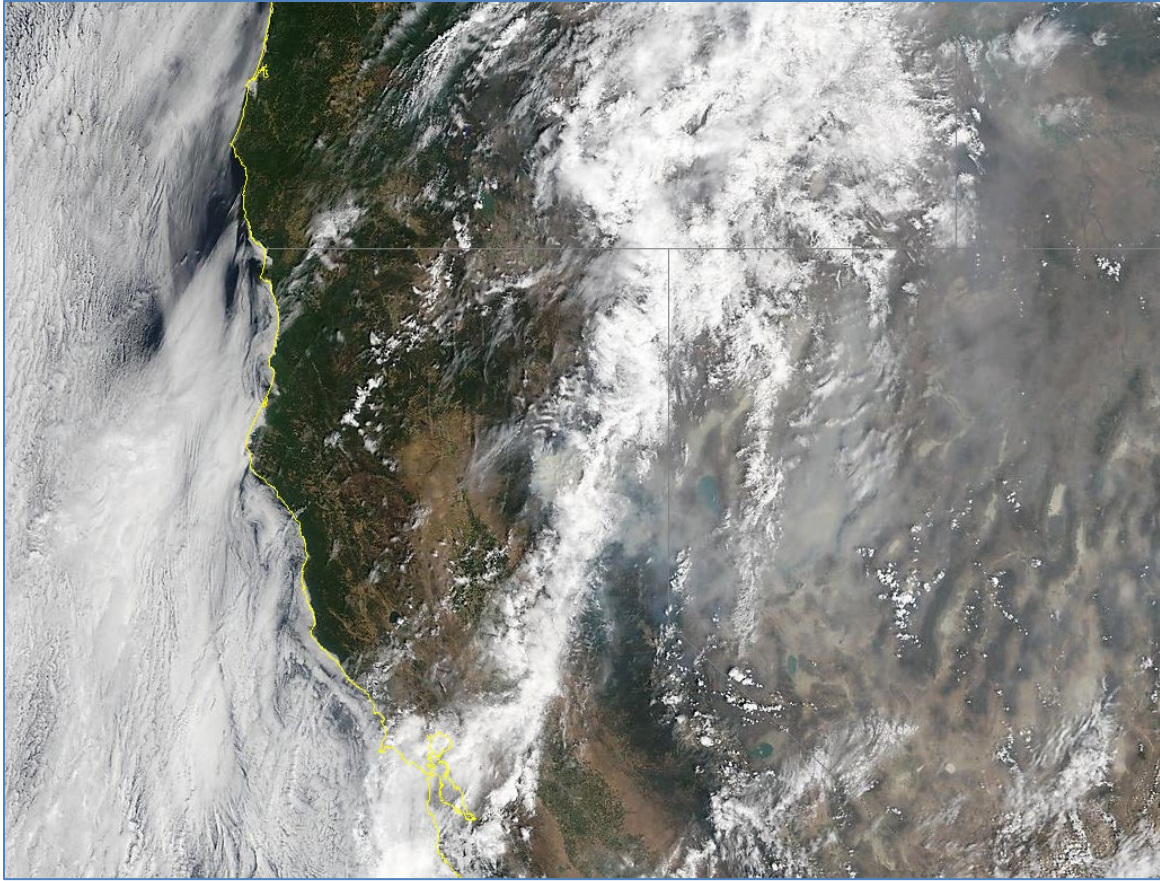


Figure 9 - MODIS image on July 26, 2021, over the western United States at 2000 meters resolution.

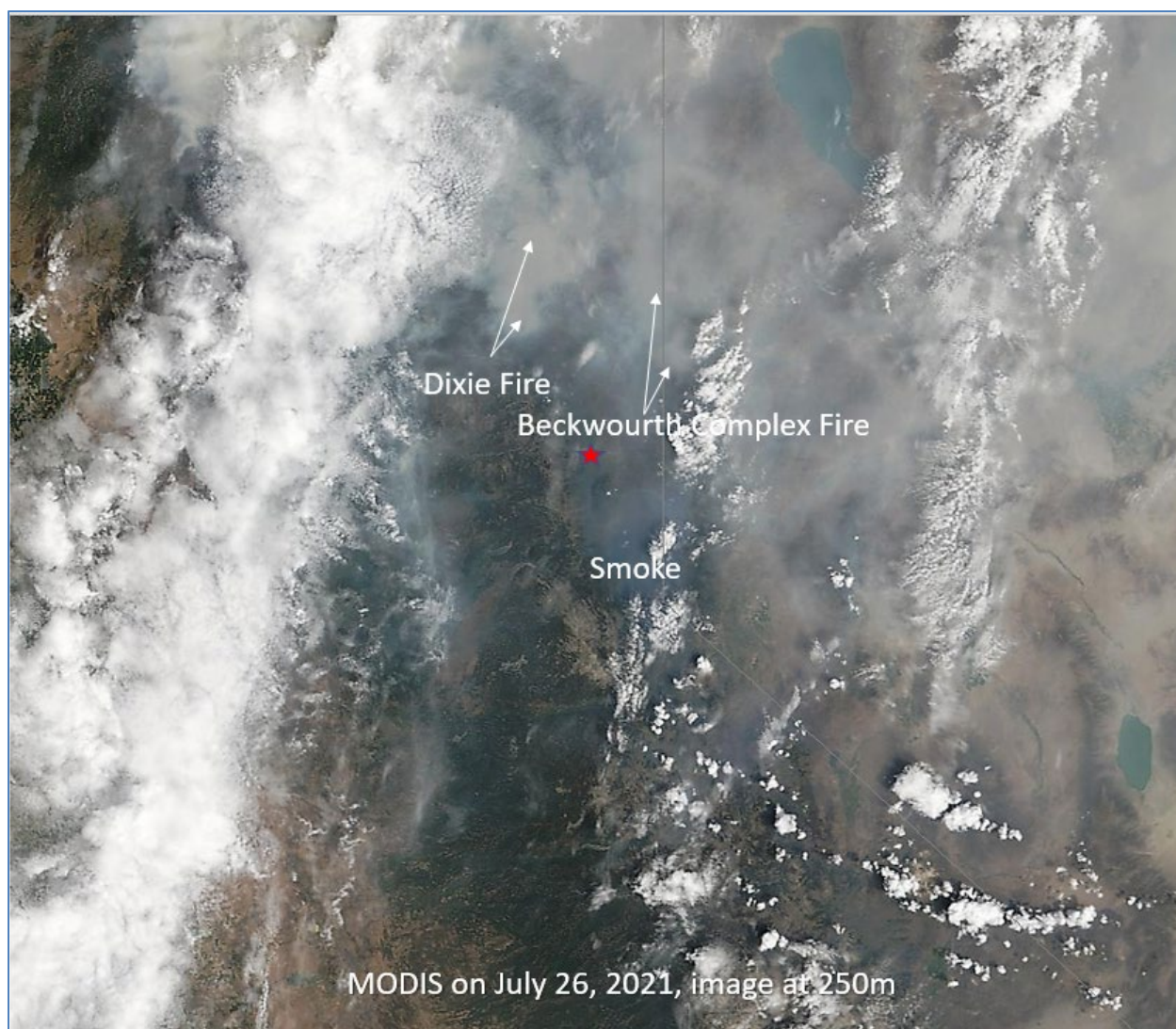


Figure 10 – Enlarged MODIS image over the accident site on July 26, 2021, at 250 m resolution.

5.0 Weather Surveillance Radar Imagery

The closest NWS Weather Surveillance Radar number 1988 Doppler (WSR-88D)²³ was Reno (KRGX)²⁴, Nevada, located 41.5 miles east-northeast from the accident site. The NWS level II data were obtained from the NCEI archive and displayed using the NWS NEXRAD Interactive Viewer and Data Exporter software²⁵. The radar data from 1256 through 1347 PDT were downloaded and reviewed using the NWS Weather Tool Kit software.

²³ 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.

²⁴ The NWS Reno (KRGX) WSR-88D's antenna or radar data acquisition (RDA) was located in Nixon, Nevada, east of the city of Reno.

²⁵ NOAA's Weather and Climate Toolkit (WCT) is free, platform independent software distributed from NOAA's

During the period the KRGX WSR-88D was operating in the precipitation mode volume coverage pattern number 12 (VCP-12) where the radar makes 14 different elevation scans in 4 ½ minutes. This scanning strategy is typically used during periods of expected convection and provides extra low elevation angles to provide increased low-level resolution. Assuming standard refraction²⁶ of the KRGX WSR-88D 0.5° elevation beam with the antenna height of 8,394 ft, at a distance of 41.5 miles, the center of the beam was calculated at 9,535 ft, with the base of the beam at 7,445 ft with the top of the beam at 11,626 ft.

5.1 Reflectivity

Reflectivity is the measure of the efficiency of a target in intercepting and returning radio energy. With hydrometeors, 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 decibels (dBZ)²⁷ and is a general measure of echo intensity. Figure 11 is a chart that relates the former NWS video integrator and processor (VIP) intensity levels versus the WSR-88D's display levels, precipitation mode reflectivity in decibels, and rainfall rates. Note echoes of 15 dBZ and greater are typically associated with measurable precipitation reaching the surface.

NWS VIP/DBZ CONVERSION TABLE			
NWS VIP	WSR-88D LEVEL	PREC MODE DBZ	RAINFALL
0	0	< 5	
	1	5 to 9	
	2	10 to 14	
1 Very Light	3	15 to 19	.01 in/hr
	4	20 to 24	.02 in/hr
	5	25 to 29	.04 in/hr
2 Light to Moderate	6	30 to 34	.09 in/hr
	7	35 to 39	.21 in/hr
3 Strong	8	40 to 44	.48 in/hr
	9	45 to 49	1.10 in/hr
4 Very Strong	10	50 to 54	2.49 in/hr
5 Intense	11	55 to 59	>5.67 in/hr
	12	60 to 64	
	13	65 to 69	
	14	70 to 74	
	15	> 75	

Figure 11 - NWS VIP scale, WSR-88D reflectivity levels, dBZ, and rainfall rates.

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.

²⁶ Standard Refraction in the atmosphere is when the temperature and humidity distributions are approximately average, and values set at the standard atmosphere.

²⁷ Decibels, where dBZ = 10 log Ze

The FAA Advisory Circular AC 00-24C – “Thunderstorms” had standardized the radar intensity level terminology to four basic levels for aviation, which are defined in figure 12. Air traffic control weather processors are also programmed to display these levels, with the controller instructed to describe the intensity to pilots based on the intensity levels.

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

Figure 12 - Weather radar intensity level terminology.

5.2 Base Reflectivity Imagery

Figure 13 is the KRGX WSR-88D 0.0° base reflectivity image for 1319 PDT with the flight track of N65TR overlaid in purple. The image depicts the flight track descent around several defined areas of echoes with maximum reflectivity near 40 dBZ, with the accident site located about 4.5 miles east of the center of these areas of echoes. Figure 14 is a closeup of the image at 1319:58 PDT with echoes less than 8.0 dBZ associated with smoke and other non-meteorological echoes removed. A cell with echoes near 41.5 dBZ or heavy intensity echo was located about 4.5 miles west and another echo at 10 dBZ about 2 miles southwest of the accident site at that time, which were noted moving north-northwest at 5 to 10 knots (not shown).

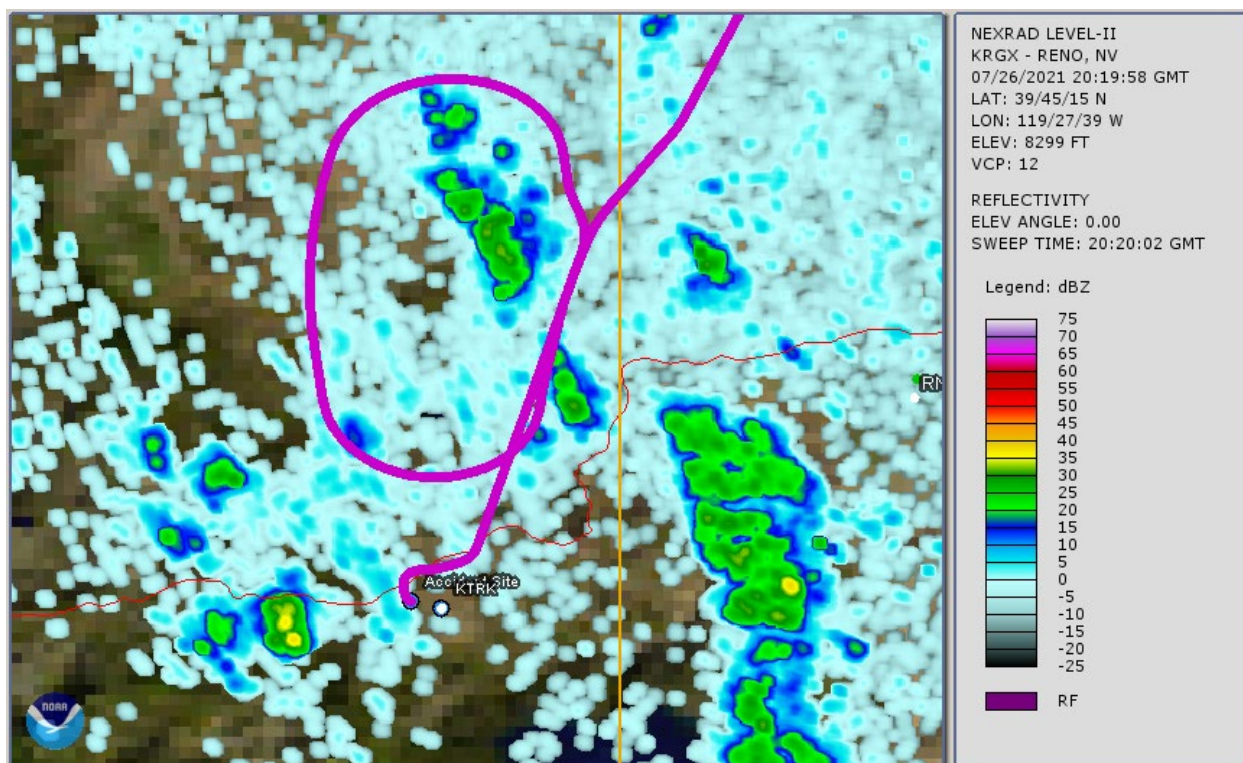


Figure 13 - KRGX WSR-88D 0.0° base reflectivity image for 1319 PDT with flight track overlaid in purple.

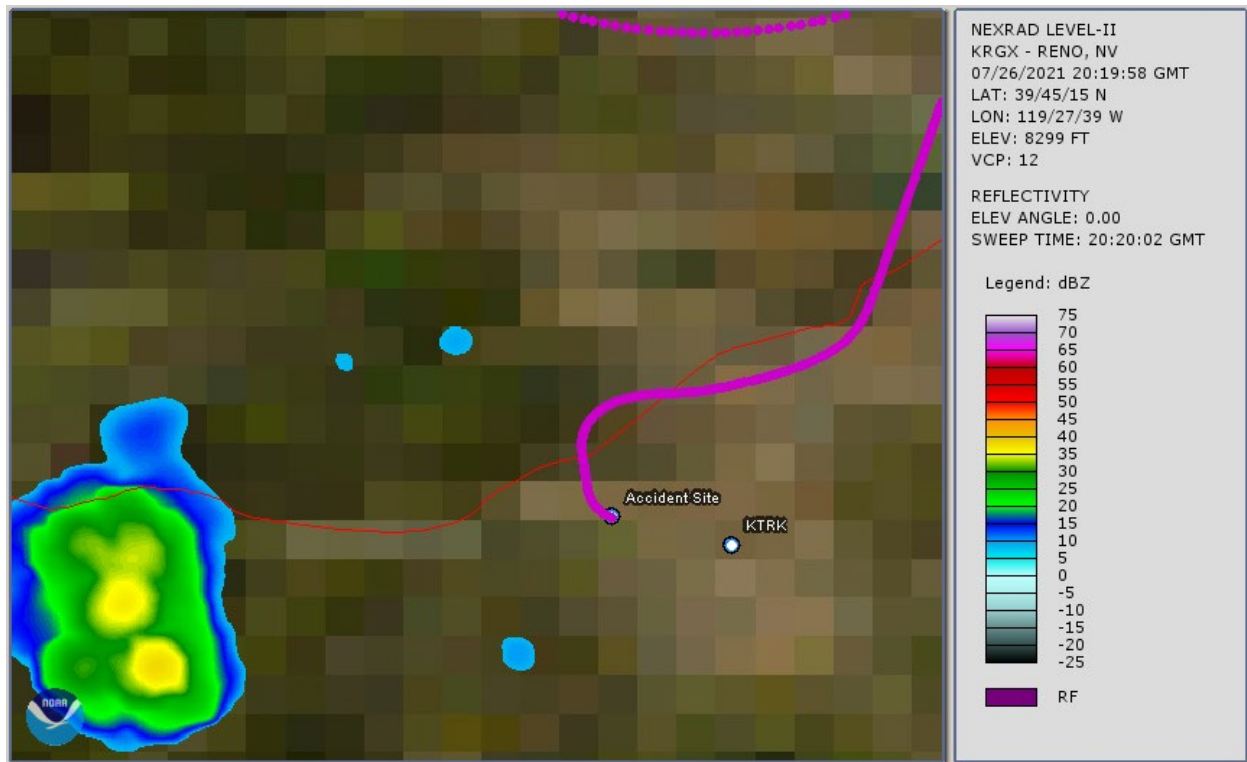


Figure 14 – Close up of the KRGX WSR-88D 0.0° base reflectivity image for 1319 PDT.

A separate review of the KRGX WSR-88D radial velocity data did not indicate any strong outflow winds or boundaries in the vicinity of the accident site at the time of the accident. A separate search of MesoWest²⁸ also did not indicate any strong surface winds reported in the vicinity surrounding the time of the accident.

6.0 Pilot Reports

The following pilot reports (PIREPs)²⁹ were recorded within 100 miles and below 18,000 ft of KTRK surrounding the period from 1100 through 1800 PDT. The reports are in standard format and code as received.

RNO UA /OV RNO/TM 1830/FL050/TP C750/WX 1 1/2 - 2 SM VIS/RM C750 REPORTED 1 AND 1/2 - 2 SM VIS ON FINAL FOR RWY 16L AND REPORTED FIELD IN SIGHT AT 050 FT...ZOA FD

AUN UA /OV AUN045008 /TM 1943 /FL095 /TP C182 /SK SKC /WX FV10SM HZ /TB NEG

CIC UA /OV KCIC/TM 2015/FL080/TP MD87/WX FV10SM/RM DURC NE

²⁸ <https://mesowest.utah.edu/>

²⁹ Includes PIREPs entered into the FAA/NWS database and may not include “ride reports” or other reports made on radio frequency to air traffic control and not formally entered as a PIREP into the database.

RTS UA /OV RTS /TM 2025 /FL095 /TP C182 /SK SKC /WX FV03SM HZ /TB LGT

RNO UA /OV RNO340002/TM 2028/FL010/TP B738/WX DURD 16L AIRPORT IN SIGHT 2 MILE FINAL

RNO UA /OV RNO340003/TM 2043/FL053/TP GLF5/WX DURD RWY 16L REPORTED AIRPORT IN SIGHT AT 2.7 MILES AND AT 053

CIC UA /OV KCIC070020/TM 2134/FL080/TP MD87/SK BKN180/WX FV15SM/RM HZ

RNO UA /OV O02/TM 2300/FL120/TP BE33/TB LGT-MOD CAT 120/RM ZOA CWSU

RNO UA /OV RNO/TM 2318/FL070/TP C750/TB MOD BLO 120/RM APT IN SIGHT 2 MILE FINAL. ZOA CWSU

RNO UUA /OV RNO180008/TM 2327/FL021/TP BE20/TB MOD/RM LLWS -15KTS 8 MILE FINAL RWY 34R

RNO UUA /OV RNO/TM 0031/FL008/TP B738/RM LLWS RPTD +/- 12KTS ON FINAL RWY 16L. ZOA CWSU

Seven of the eleven of the PIREPs were noted with aircraft descending into KRNO approximately 20 miles northeast of the accident site and reported flight visibility restrictions in haze, which was likely smoke from the fires across the region. One pilot report at 1130 PDT reported the flight visibilities as low as 1 1/2 to 2 miles on final approach into the airport with the airport in sight at 5,000 ft above the runway or 585 ft agl. Two other PIREPs noted the airport in sight at ranges from 2 to 2.7 miles on descent into the airport and an altitude of 5,300 ft. After 1600 PDT there were several PIREPs of light to moderate turbulence below 12,000 ft, with 2 urgent PIREPs of low-level wind shear with +/- 12 to 15 knots on final approach into KRNO. There were no PIREPs recorded below 18,000 ft into KTRK.

7.0 NWS Forecasts and Advisories

The NWS aviation weather forecasts were further detailed over the area.

7.1 Terminal Aerodrome Forecast

The NWS Reno (KREV) Weather Forecast Office (WFO) was responsible for the KTRK area. A TAF is a concise statement of the expected meteorological conditions at an airport during a specified period (usually 24 hours). TAFs are valid for a 5-mile radius around an airport's center point. KREV issued the following TAF at 1037 PDT which was current at the time of the accident.

*TAF KTRK 261737Z 2618/2718 VRB03KT 4SM FU HZ BKN030
FM262000 22007KT 6SM HZ VCSH BKN070
FM262100 26009KT P6SM VCTS BKN060CB
FM270400 VRB03KT P6SM VCSH SCT050 BKN080
FM270900 00000KT 6SM HZ FU BKN100*

The TAF expected MVFR to VFR conditions to prevail surrounding the period. From 1100 through 1300 PDT, the forecast expected a wind variable at 3 knots, visibility 4 miles in smoke and haze, with a ceiling broken at 3,000 ft. Between 1300 through 1400 PDT a wind from 220° at 7 knots, visibility 6 miles in haze with showers in the vicinity, ceiling broken at 7,000 ft agl. After 1400 PDT thunderstorms were expected in the vicinity of the airport with VFR conditions expected

to prevail with no visibility restrictions. The forecast was amended immediately after the accident at 1358 PDT to the following.

AMD TAF KTRK 262058Z 2621/2718 08006KT 4SM FU HZ VCTS BKN025 BKN060CB
FM270400 VRB03KT P6SM VCSH SCT050 BKN080
FM270900 00000KT 6SM HZ FU BKN100=

The amended forecast expected after 1400 PDT of winds from 080° at 6 knots, visibility 4 miles in smoke and haze with thunderstorms in the vicinity of the station or within 10 miles, ceiling broken at 2,500 ft agl, and broken at 6,000 ft in cumulonimbus clouds.

7.2 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 Reno AFD issued at 1125 PDT was as follows.

FXUS65 KREV 261825
AFDREV

Area Forecast Discussion
National Weather Service Reno NV
1125 AM PDT Mon Jul 26 2021

.UPDATE...With the increased chance of wetter thunderstorms with rainfall cores capable of producing short period heavy precipitation over recent and past burn scares in the region, a flash flood watch was issued for central Sierra Front and far western NV till 9PM this evening.

.PREVIOUS DISCUSSION... /Issued 304 AM PDT Mon Jul 26 2021/

SYNOPSIS...

Light westerly winds will continue to pour smoke into the region from the large Dixie Fire today. Monsoon moisture will overspread the region leading to an increase in thunderstorm chances each afternoon much of this coming week. After one more hot day, temperatures will cool notably Tuesday before warming back up again late week.

SHORT TERM...

** Smoke: AQI briefly improved in a few spots Sunday evening as outflows from afternoon/evening convection pushed the smoke around. However, winds became favorable again and allowed conditions to deteriorate overnight. And like Sunday, there is mixed confidence on improving conditions for late today, modulated by t-storm outflows. The one area that escapes the thick smoke is the E Sierra with more S/SE wind monsoonal trajectories developing today. With a change to south-southeast flow and thunderstorm coverage increasing over the next few days, smoke patterns will likely change.*

** Thunderstorms: Respectable monsoon moisture push into the region this week with a large high centered over the Four Corners and Rockies. Thunderstorm probabilities will remain elevated with precipitable water*

values rising to near 1" by Tuesday afternoon in most ECMWF EPS members. Model solutions were mixed on the coverage of convection this afternoon but believe we will once again see scattered coverage for the eastern Sierra into Mineral County as a shortwave approaches. There are some indications that this shortwave may arrive a bit later in the day than previously progged. If so, earlier development of weaker cells and more clouds could limit coverage/intensity this afternoon and early evening. A wave lifting north out of SoCal could keep faster moving t-storms going into the pre-dawn hours Tuesday. For Tuesday PM, a combination of subsidence behind the outgoing wave and abundant PWATs could limit convective coverage. By Wednesday, there are indications a piece of the offshore trough will eject and combine with more favorable conditions across the Sierra and western NV (less cloud cover/decreased PWATs) to allow for a more robust development of thunderstorms.

* We'll really need to be on our toes with flash flood and debris flow risks on the newer burn scars such as Beckwourth, and even the ongoing Tamarack Fire especially on steeper slopes just west of Hwy 395 and steep terrain of Alpine County. It only takes 5-10 minutes of heavy rain to cause major flooding on recent high intensity burns. Will continue to monitor on a daily basis with regard to whether a flash flood watch is needed, as flood environments have limited predictability in our region more than 12-18 hours out.

AVIATION...

Widespread smoke and haze continues across the region with smoke ceilings and MVFR-IFR visibility for many locations, along with terrain obscuration. For areas that have been able to avoid the denser smoke, slantwise visibility reductions remain a problem.

Flow becomes more south to southeast today into Tuesday, which will change up the smoke trajectories from the past couple of days. We are also looking at thunderstorm chances region-wide today, which will also play a role in the smoke forecast due to unknowns such as rainfall and erratic outflow winds. Therefore, the smoke forecast has much lower confidence than usual. At this point, will lean heavily on the HRRR smoke model for the forecast which is indicating poor conditions this morning for all terminal except for KMMH, with somewhat improving conditions (though don't expect it to clear) by late afternoon and this evening. The one exception will be for areas immediately downwind of the Tamarack and especially Dixie wildfires, where heavier smoke remains.

Otherwise, thunderstorms today may bring localized heavy rainfall and obscure terrain along with gusty and erratic outflow winds which could produce areas of blowing dust. The heaviest rainfall is likely to be for areas near and south of KMMH. Showers and a stray thunderstorm could continue overnight, with the main focus in the Sierra into northeast California.

Sufficient moisture will persist with thunderstorm chances continuing daily through next weekend. -Dawn

FIRE WEATHER...

* **TODAY:** Monsoonal moisture is becoming better established in the Eastern Sierra to southern Lyon-Mineral Counties where a general east to southeast flow will prevail through this evening. As a result of the light wind flow, expect storms to be slow moving and capable of producing heavy rainfall and gusty outflow winds to 35 mph. One or two storms could become particularly intense and capable of causing a flash flood or debris flow, including the Dexter burn scar. Farther north, the atmosphere aloft is not as unstable but showers and even an isolated thunderstorm or two is still possible. For the Tahoe Basin, northeast CA, Sierra Front and western NV in the Highway 50 corridor -- including the Tamarack Fire area, conditions will be more favorable for stronger and more widespread outflow winds to 45 mph but much smaller and more isolated heavy rain producing cores.

* **TONIGHT AND EARLY TUESDAY:** A shortwave will move through CA-western NV and keep showers and a few thunderstorms going. Instability is rather weak so we expect mainly showers. However we cannot completely rule out a few thunderstorms, especially along the Sierra into northeast CA. Storm motions will be picking up (15- 20 mph), so there is some potential for a few dry lightning strikes.

** WEDNESDAY: Moisture content drops a bit and a shortwave off the coast will be ejecting northeastward. Breaks in the clouds will allow for better surface heating and instability which will combine with that shortwave to potentially fire a round of more robust showers and storms across the area with a bump up in lightning coverage and the danger to fire crews. While these storms will be moving, they will be efficient rain producers and capable of flash flooding and debris flows on area burn scars, especially where storm cells train. Gusty outflow winds will again be a concern.*

Hohmann

.REV Watches/Warnings/Advisories...

NV...Flash Flood Watch until 9 PM PDT this evening NVZ002-003.

CA...Flash Flood Watch until 9 PM PDT this evening CAZ072-073.

7.3 Graphic Forecast for Aviation

The NWS Graphic Forecast for Aviation (GFA) is a graphical depiction of surface wind, weather, color coded general flight categories, and cloud cover bases and tops, with the Graphic-Airmen's Meteorological Information (G-AIRMET)³⁰ for IFR conditions, mountain obscuration, icing conditions, and strong surface wind overlaid for the enroute phase of flight. The GFA is available at the NWS AWC website and through other weather briefing services. The GFA charts available at approximately 1200 PDT and valid during the period of the accident are included below.

Figure 15 is the GFA Surface Forecast valid for 1200 PDT with the approximate accident site marked by the red star. It depicted light westerly winds of 10 knots or less over the region with a likely chance of thunderstorms. An area of visibility restrictions of 1 to 3 miles in smoke was depicted immediately north and west of the accident site over western California and northern Nevada with a G-AIRMET depicted (pink area) immediately north of the accident site for an area of IFR conditions.

Figure 16 is the GFA Cloud Forecast valid for 1200 PDT which depicted mostly clear skies over the area with a few clouds immediately east along the California and Nevada border. A G-AIRMET for mountain obscuration extended over the accident site and most of Nevada and northeastern California, with another G-AIRMET for icing conditions over California and Nevada south of the accident site.

³⁰ AIRman's METeorological Information (AIRMET) is a concise description of weather phenomena that are occurring or may occur (forecast) along an air route that may affect aircraft safety. Compared to SIGMETs, AIRMETs cover less severe weather: moderate turbulence and icing, sustained surface winds of 30 knots or more, low-level wind shear, or widespread restricted visibility.

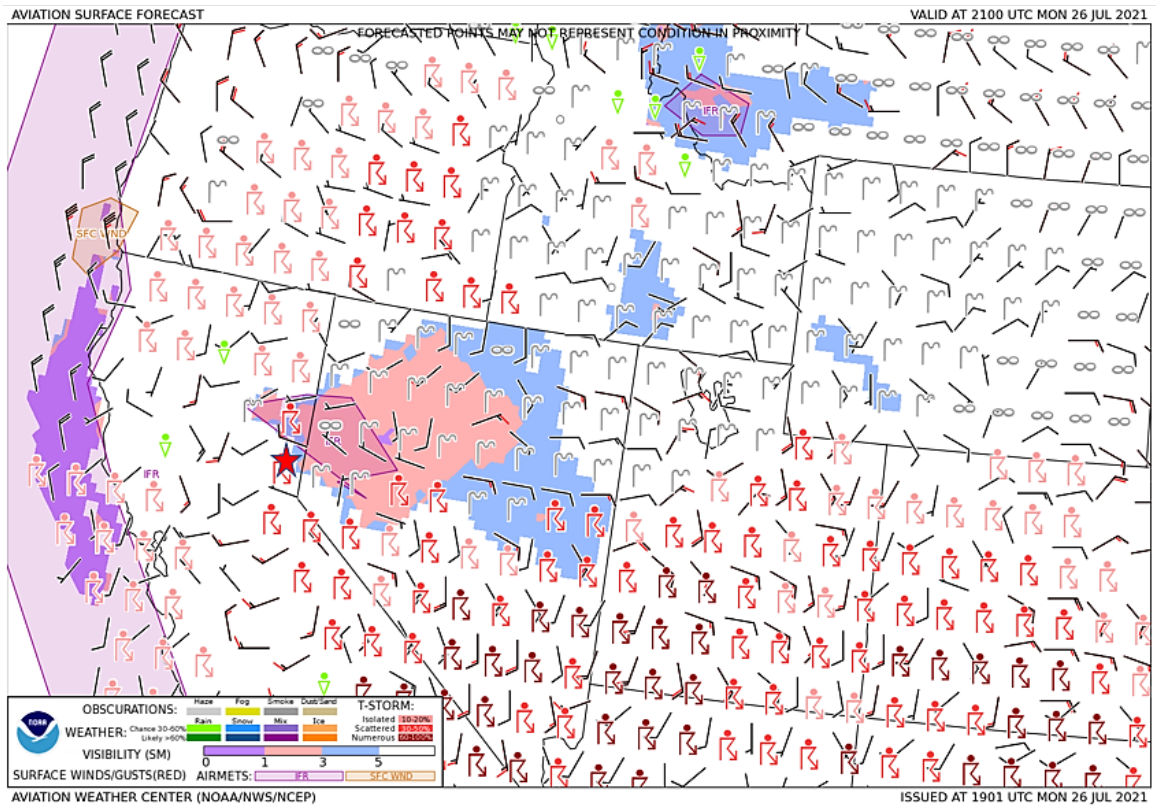


Figure 15 - Graphic Forecast for Aviation (GFA) Surface Weather forecast valid for 1200 PDT.

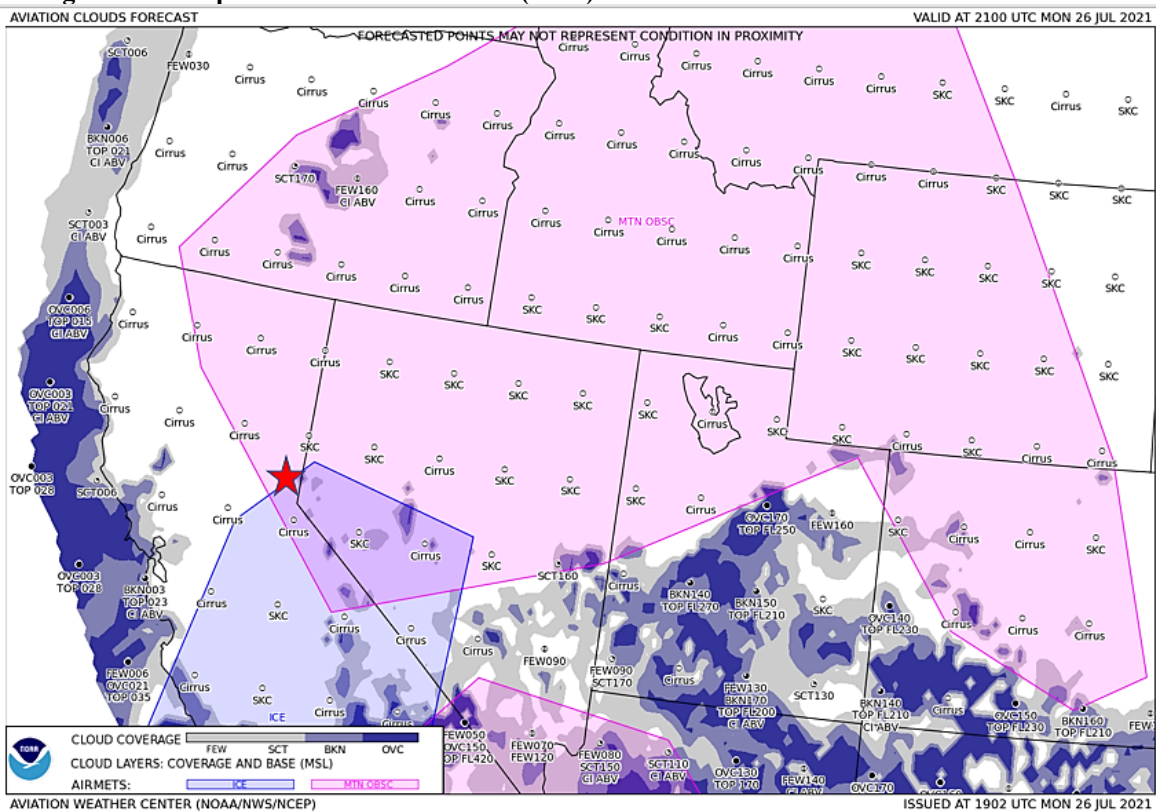


Figure 16 - GFA Cloud Forecast valid for 1200 PDT with the accident site marked by the red star.

7.4 Winds and Temperatures Aloft

The Winds and Temperature Aloft Forecast (FD) for the Reno (RNO) area valid for the period was issued at 0657 PDT and valid for 1100 PDT, and for use between 0700 through 1400 PDT was as follows.

*FBUS31 KWNO 261357
FDIUS1
-DATA BASED ON 261200Z
VALID 261800Z FOR USE 1400-2100Z. TEMPS NEG ABV 24000*

<i>FT</i>	<i>3000</i>	<i>6000</i>	<i>9000</i>	<i>12000</i>	<i>18000</i>	<i>24000</i>	<i>30000</i>	<i>34000</i>	<i>39000</i>
<i>-RNO</i>		<i>9900</i>	<i>9900+18</i>	<i>1409+12</i>	<i>1411-07</i>	<i>1517-17</i>	<i>182031</i>	<i>192242</i>	<i>212154</i>

The forecast for RNO for 6,000 ft expected a light and variable wind under 5 knots, and for 9,000 ft the same light and variable wind at 5 knots or less with a temperature of 18° C, and for 12,000 ft a wind from 140° at 9 knots, with a temperature of 12° C.

7.5 Inflight Weather Advisories

Inflight Aviation Weather Advisories are forecasts to advise en route aircraft of 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) associated with FAA 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 Airmen's Meteorological Information (AIRMET), and the Center Weather Advisory (CWA). Inflight advisories serve to notify en route pilots of the possibility of encountering hazardous flying conditions which 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 on the basis of experience and the operational limits of the aircraft. The following advisories were current during the period.

The NWS AWC had Graphic-AIRMET advisories current for the area of mountain obscuration due to smoke and haze over the area, and an AIRMET for moderate icing conditions between 16,000 ft and 28,000 ft. The advisories are depicted in figure 17. There were no NWS SIGMETs, Convective SIGMETs, or CWAs current for the accident site until after the accident. At 1436 PDT the NWS Oakland (KZOA) CWSU issued a CWA for an area of developing thunderstorms over eastern California and Nevada, which included the accident site, and was as follows and displayed in figure 18.

*FAUS21 KZOA 262136
ZOA1 CWA 262136
ZOA CWA 101 VALID UNTIL 262336
FROM 50WNW FMG-10WNW FMG-45WNW OAL-65E MOD-50WNW FMG
DVLPG AREA TS MOV FROM 10015KT. TOPS TO FL360. ZOA CWSU. CA NV*

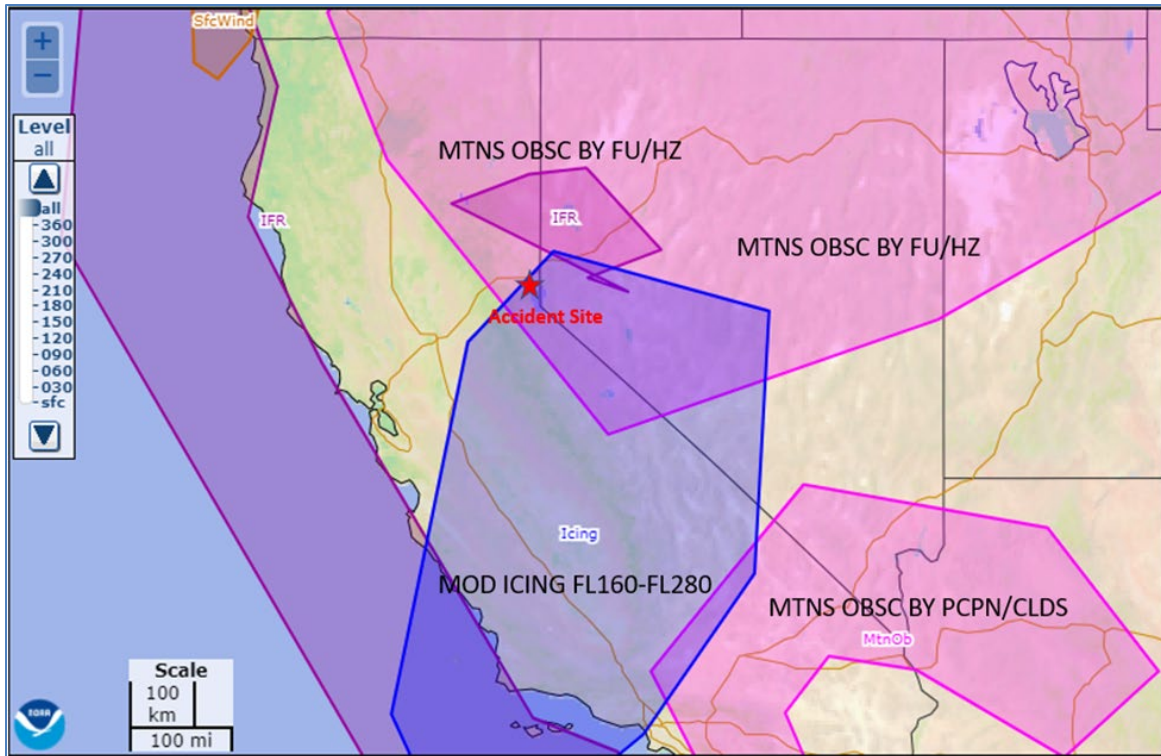


Figure 17 - G-AIRMETs current over the western United States at 1300 PDT with the approximate accident site marked by the red star. G-AIRMET Sierra for mountain obscuration by smoke and haze and G-AIRMET Zulu for icing conditions between 16,000 to 28,000 ft extended over the accident site.

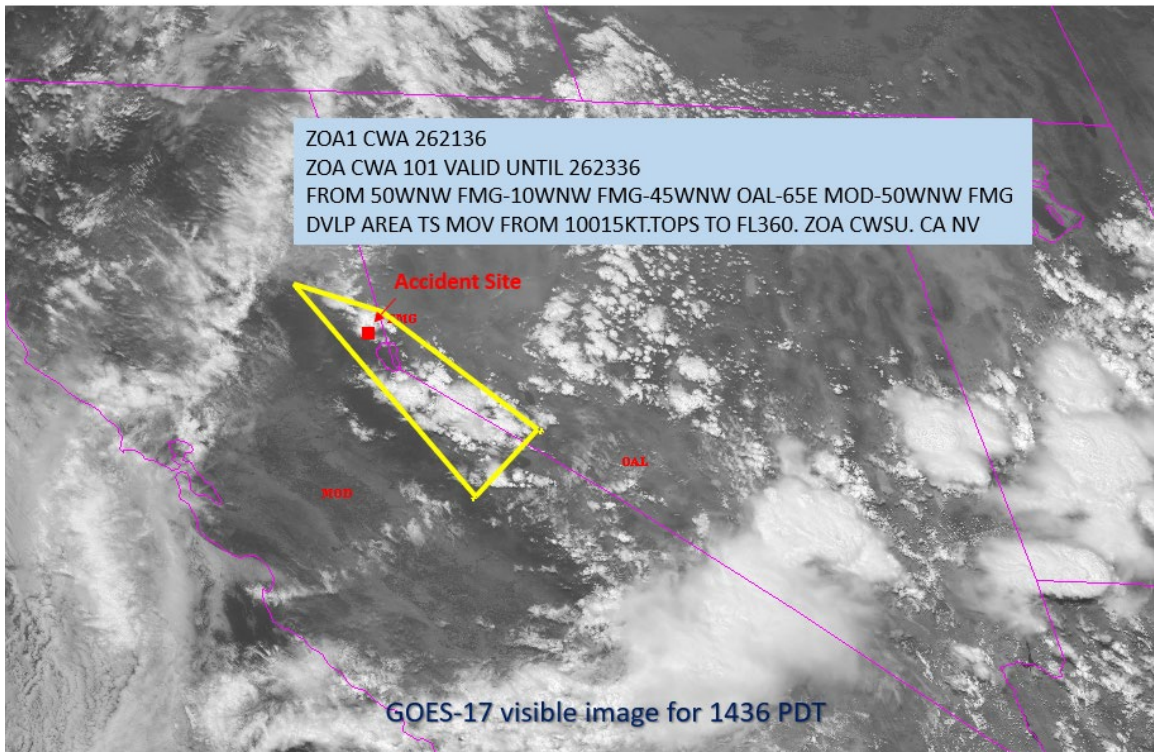


Figure 18 - CWA issued after the accident at 1436 PDT for thunderstorms.

8.0 Preflight Weather Briefing

The pilots used ForeFlight to obtain weather and to file their flight plan, which was filed for the flight between KCOE to KTRK, with a cruising latitude of 38,000 ft, with a departure time of 1100 PDT, with an estimated time enroute of 1:20, and KRNO as the filed alternate airport. The graphic ForeFlight weather briefing is included as Attachment 2.

9.0 Forest Fire Areas

A map of the fires over California on July 26, 2021, is included as figure 19. The two major fires closest to the accident site were from the Dixie and Beckwourth complex fires immediately northwest and north of KTRK.

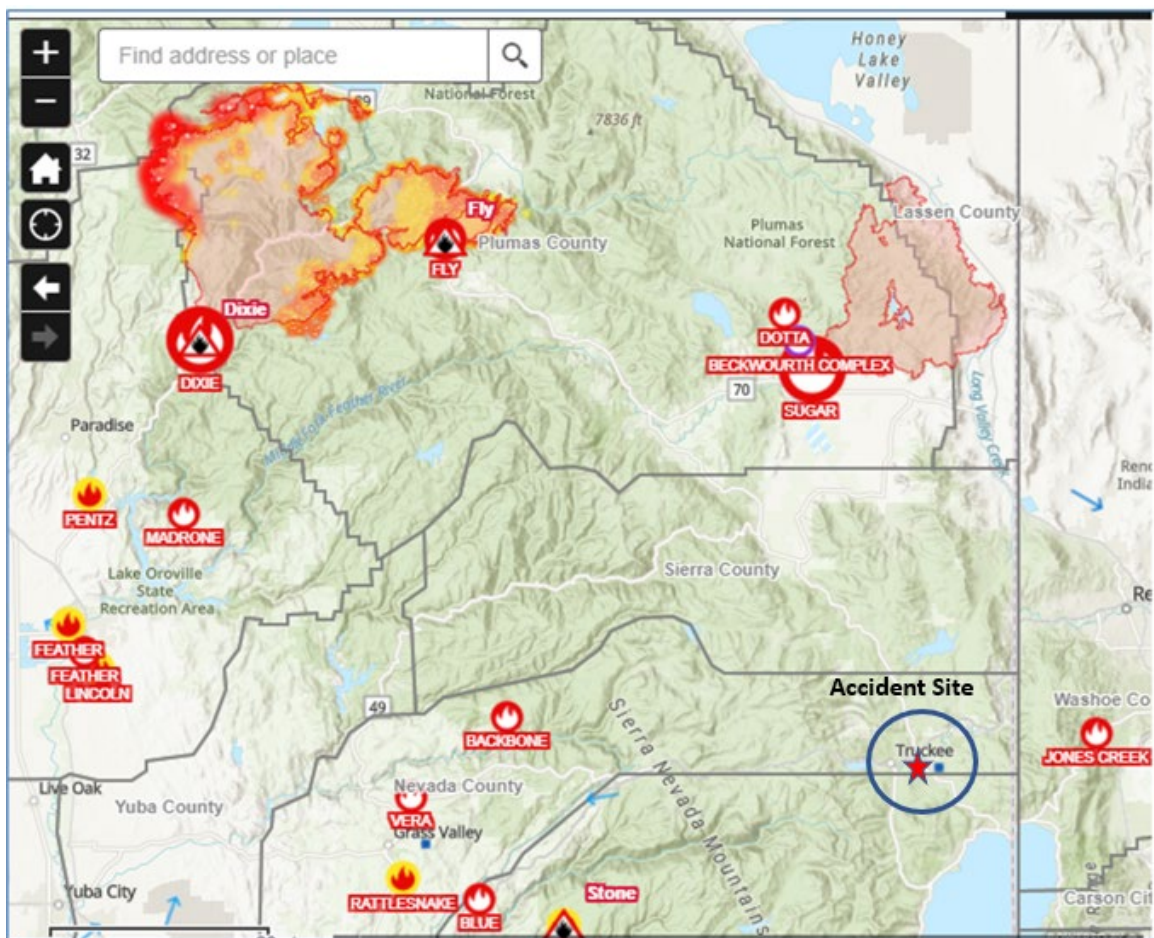


Figure 19 - California Forest Fires burning on July 26, 2021.

Jones Creek Fire in Washoe County, Nevada, located east of the Lake Tahoe area. Fire discovered on July 25th at 2156 PDT. The wildfire (WF) burned 40 acres and was contained on July 27, 2021. Lightning strikes were contributed as the cause of the fire.

Beckwourth Complex in Plumes County, California, located north of the Tahoe area. Fire discovered on July 3, 2021, at 1328 PDT. Fire type: complex or multiple fires, Acres burned:

105,670. Percent contained: 98% at the time of the accident, and finally contained on September 22, 2021. Cause: lightning strikes. Impacted the Plumas National Forest. Included the **Dotta Fire** and **Sugar Fire** which started on June 30th and July 2, 2021, respectively.

Backbone Fire in Nevada County west of accident site. Fire discovered on July 7th at 2250 PDT. The wildfire burned 5,065 acres and wasn't contained until July 24th. The cause of the fire was from lightning strikes.

Dixie Fire location near Cresta Dam, Feather River Canyon, in Butte, Plumas, Shasta, Tehama, and Lassen Counties, CA. The fire started on July 13, 2021, and burned approximately 963,275 acres before it was mostly contained. At the time of the accident, it was California's largest wildfire and was only 21% contained and forced nearly 8,400 evacuations.

Tamarack Fire located to the south of the Tahoe area in Pleasant Valley, in Alpine County, CA. The fire started on July 4th and burned 68,637 acres.

10.0 Astronomical Conditions

The astronomical conditions were obtained from the United States Naval Observatory's Multiyear Interactive Computer Alamac (MICA) software for Truckee, California. The time of the accident has been added for reference in italic bold type.

<u>Sun</u>	
Begin of civil twilight	0525 PDT
Sunrise	0556 PDT
Sun culmination	1307 PDT
<i>Accident</i>	<i>1318 PDT</i>
Sunset	2018 PDT
End civil twilight	2048 PDT

At the time of the accident the Sun was 70° above the horizon at an azimuth of 187°.

E. LIST OF ATTACHMENTS

Attachment 1 – GOES-17 visible imagery

Attachment 2 – ForeFlight Weather Briefing

Submitted by:

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