



NATIONAL TRANSPORTATION SAFETY BOARD

Office of Aviation Safety
Washington, D.C. 20594

July 19, 2022

Specialist's Factual Report

METEOROLOGY

WPR22FA172

A. ACCIDENT

Location: Sausalito, California
Date: May 6, 2022
Time: 1210 Pacific Daylight Time (PDT)
1910 universal coordinated time (UTC)
Airplane: Vans RV-10; Registration: N54MG

B. METEOROLOGY SPECIALIST

Specialist Donald Eick
National Transportation Safety Board
Senior Meteorologist
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 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). 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 accident site was located within the Golden Gate National Recreation Area at latitude 37.838426° N and longitude 122.49105° W, at an elevation of approximately 810 ft, which was located below the ridge of Slacker Hill at 922 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 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 2¹.

1.1 Surface Analysis Chart

The northwestern section of the NWS Surface Analysis for 1100 PDT is included as figure 1 with the approximate accident site marked by the red star. The chart depicted a low-pressure system at 998-hectopascals (hPa)² off the Pacific northwest coast with an associated occluded front curving around the low and off the Washington, Oregon, and northern California coast. The triple point of the front was off the northern California coast where the front split into a cold front extending southwestward and a dissipating warm front³ to the southeast and immediately west of the San Francisco area. A high-pressure system was located over Nevada at 1013-hPa and a ridge of high-pressure from the west-southwest of the accident site. A neutral area of pressure or a col was identified over the accident site, with a deformation zone in the wind field. The station models surrounding the accident site indicated winds from south to the north of the accident site and from the west to northwest to the south, with overcast cloud cover along the coast and clear conditions over inland California station.

The closest station model depicted on the chart was north of the accident site from Gness Field Airport (KDVO), Novato, CA which indicated a southerly wind of 5 knots, overcast clouds, temperature 62° Fahrenheit (F), with a dew point temperature of 55° F. The chart depicted no significant weather in the vicinity of the accident site.

¹ https://www.faa.gov/regulations_policies/advisory_circulars/index.cfm/go/document.information/documentID/1030235

² Hectopascal (hPa) is the standard unit for reporting sea-level pressure and is interchangeable with the former term millibar (mb) with the same units. Standard sea-level pressure in the standard atmosphere is 1013.25-hPa at sea-level with a temperature of 59° Fahrenheit (F) or 15° Celsius (C).

³ Technically called Frontolysis, and shows a weakening or dissipating front, versus the development which is called Frontogenesis.

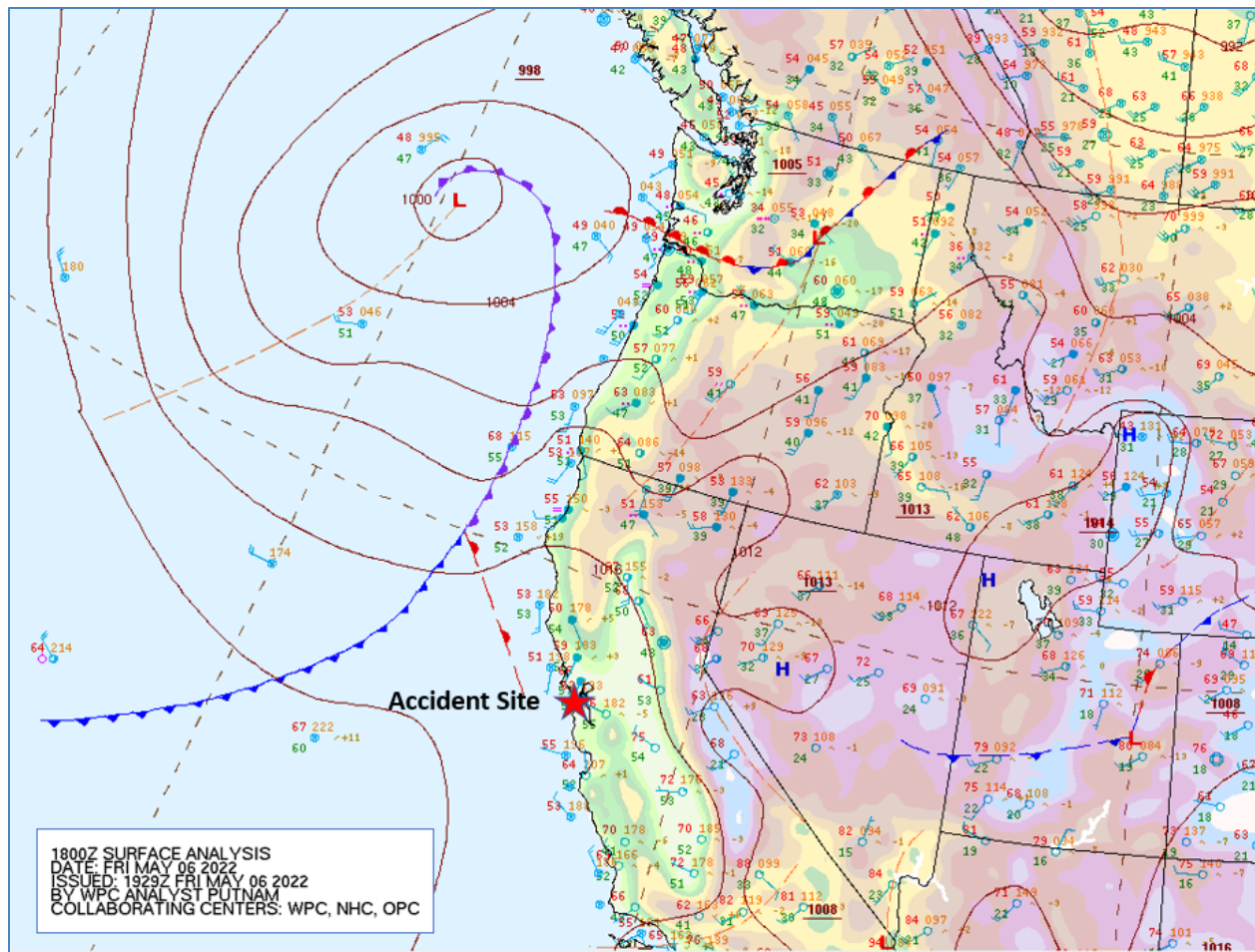


Figure 1 - Northwestern section of the NWS Surface Analysis Chart for 1100 PDT with the approximate accident site marked by red star.

1.2 NWS Short Term Forecast

The NWS 12-hour Short Term Forecast issued by the WPC at 0752 PDT and valid for 1700 PDT is included as figure 2. The chart continued to depict the approaching occluded to cold front approaching the northern California coast with rain forecast along and ahead of the front.

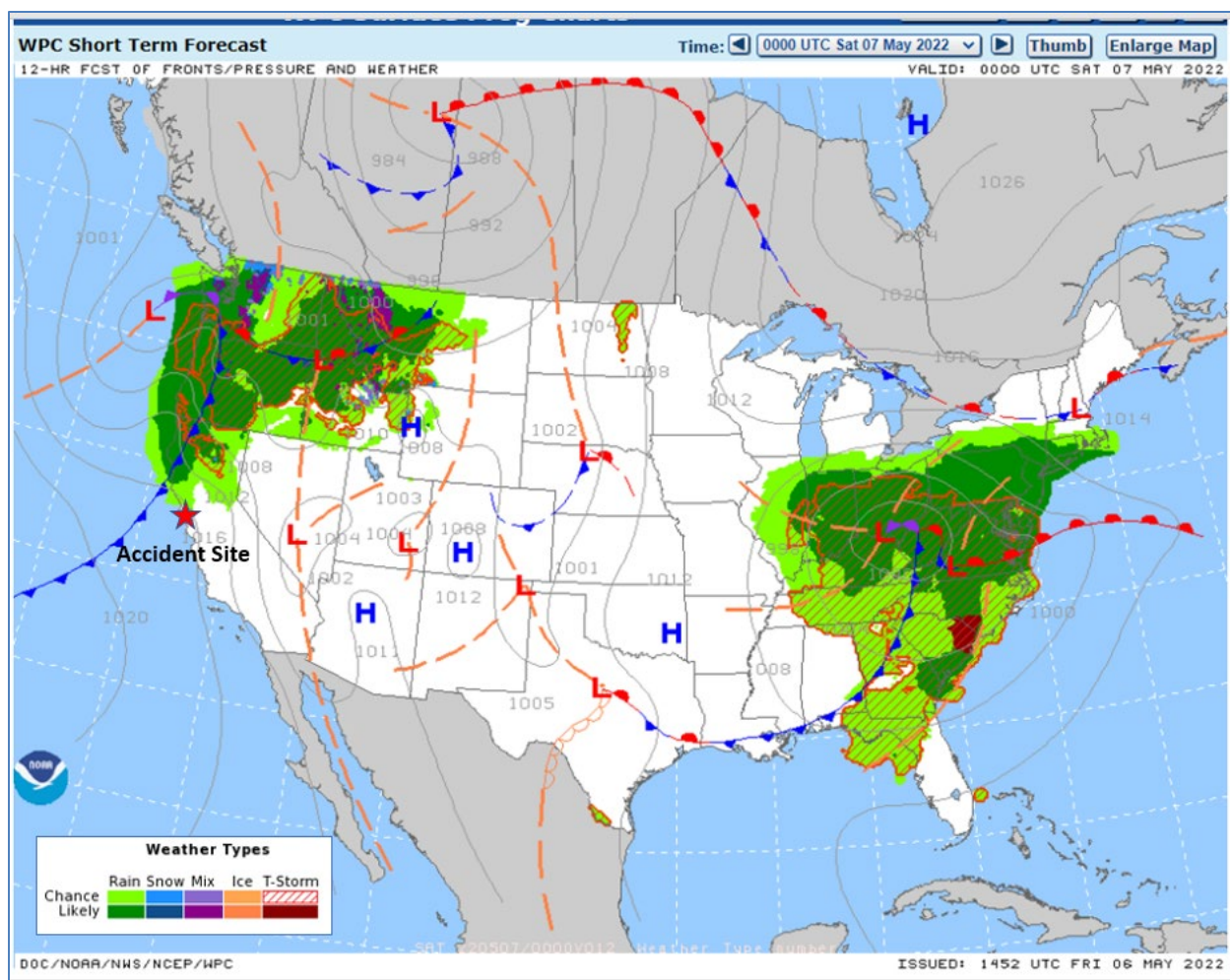


Figure 2 - NWS 12-hour Short Term Forecast valid for 1700 PDT with accident site.

1.3 Low-Level Significant Weather Prognostic Chart

The NWS 12-hour Low-Level Significant Weather Prognostic Chart current at the time of the accident is included as figure 3. The chart depicted expected general flight categories⁴ of Instrument Flight Rule (IFR) conditions by a red line, Marginal Visual Flight Rules (MVFR) conditions by a blue scalloped line, and areas of expected Visual

⁴ 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.

Flight Rule (VFR) conditions outside of the scalloped line. The chart also depicted the freezing level by a dashed blue line at 4,000 ft intervals and expected clear air turbulence below 24,000 ft by a brown dashed line. The 12-hour forecast valid for 1700 PDT depicted an area of IFR conditions expected over western Washington and Oregon into the coastal regions of northern and southern California and included the accident site, with general MVFR conditions over northern California. VFR conditions was depicted over the interior sections of central and southern California. The chart depicted the freezing level above 12,000 ft, with no turbulence expected over the accident site or coastal sections, with moderate turbulence from the surface to 24,000 ft over interior California.

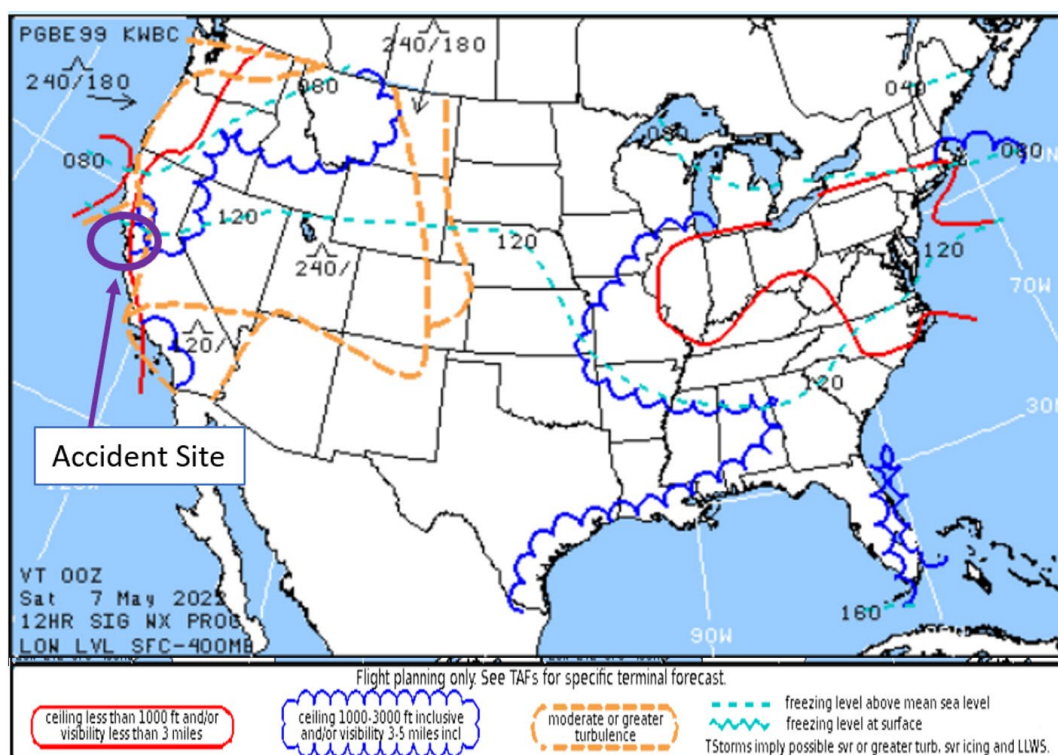


Figure 3 - NWS 12-hour Low-level Significant Weather Prognostic Chart valid for 1700 PDT.

2.0 Surface Observations

Observations surrounding the accident site were documented using official Aviation Routine Weather Reports (METAR⁵) and Aviation Selected Special Weather Reports (SPECI). Cloud heights are reported above ground level (agl) in the following section, and the magnetic variation over the accident site was estimated at 13.25° east based on the latest sectional chart for the area.

⁵ Abbreviation for Meteorological Aerodrome Report, the international standard for reporting aviation weather observations.

2.1 San Francisco International Airport

The closest official weather reporting station to the accident site was from San Francisco International Airport (KSFO), San Francisco, CA, located approximately 14 miles south of the accident site at an elevation of 13 ft. The airport had an Automated Surface Observation System (ASOS) which was augmented by NWS/FAA certified weather observers. The following conditions were reported at the approximate time of the accident in plain language.

Routine weather observation for KSFO at 1156 PDT, wind from 060° at 5 knots, visibility 10 statute mile or more, a few⁶ clouds at 900 ft, ceiling broken at 2,500 ft, broken clouds at 20,000 ft, temperature 19° Celsius (C) (66° F), dew point temperature 13° C (55° F), altimeter setting 30.08 inches of mercury (inHg). Remarks: automated station with a precipitation discriminator, sea-level pressure 1018.4-hPa, temperature 18.9° C, dew point temperature 12.8° C.

The general flight conditions and the METAR observations disseminated from KSFO surrounding the period between 0953 and 1441 PDT (1653Z and 2141Z) were as follows. The observation transcribed above, and the time of the accident are provided in bold italic type for reference, with the general flight categories color coded.

MVFR METAR KSFO 061656Z 04003KT 10SM FEW009 BKN020 18/12 A3009 RMK AO2 SLP190 T01780122=

MVFR METAR KSFO 061756Z 09005KT 10SM FEW009 BKN021 18/13 A3009 RMK AO2 SLP188 T01830128 10189 20144 58001=

MVFR METAR KSFO 061856Z 06005KT 10SM FEW009 BKN025 BKN200 19/13 A3008 RMK AO2 SLP184 T01890128=

Accident 1910Z

MVFR METAR KSFO 061956Z 26012G21KT 10SM FEW009 BKN030 BKN200 21/13 A3007 RMK AO2 SLP183 T02110128=

MVFR METAR KSFO 062056Z 26011KT 10SM FEW009 BKN024 BKN200 21/13 A3007 RMK AO2 SLP181 T02060128 56007=

VFR SPECI KSFO 062141Z 26012KT 10SM FEW009 SCT020 BKN090 BKN200 20/13 A3006 RMK AO2 T02000128=

⁶ A few clouds is defined in the Federal Meteorological Handbook number 1 (FMH-1) as 1/8 to 2/8 percent of the summation of the cloud layers.

2.2 Oakland International Airport

The next closest station was from Metro Oakland International Airport (KOAK), Oakland, CA, located approximately 14.5 miles southeast of the accident site at an elevation of 9 ft. The airport had an ASOS and reported the following conditions at the time of the accident.

Routine weather observation for KOAK at 1153 PDT, wind variable at 5 knots, visibility 10 statute mile or more, a few clouds at 2,000 ft, ceiling broken at 9,000 ft, broken clouds at 12,000 ft, temperature 18° C (65° F), dew point temperature 12° C (54° F), altimeter setting 30.09 inHg. Remarks: automated station with a precipitation discriminator, sea-level pressure 1018.8-hPa, temperature 18.3° C, dew point temperature 12.2° C.

The general flight conditions and METAR observations disseminated between 0953 and 1455 PDT for KOAK surrounding the period were as follows. The time of the accident and the observation above are provided in bold italic type.

MVFR METAR KOAK 061653Z 19005KT 10SM FEW010 BKN020 BKN100 17/12 A3011 RMK AO2 SLP194 T01670117=

VFR METAR KOAK 061753Z 18004KT 10SM FEW010 SCT020 BKN100 18/12 A3010 RMK AO2 SLP193 T01780122 10178 20139 50000=

VFR METAR KOAK 061853Z VRB05KT 10SM FEW020 BKN090 BKN120 18/12 A3009 RMK AO2 SLP188 T01830122=

Accident 1910Z

VFR METAR KOAK 061953Z 32011KT 10SM SCT020 BKN090 BKN120 20/13 A3008 RMK AO2 SLP186 T02000133=

VFR METAR KOAK 062053Z 30014KT 10SM SCT020 BKN100 BKN150 19/13 A3008 RMK AO2 SLP185 T01940133 56007=

VFR METAR KOAK 062153Z 29009KT 10SM SCT014 BKN090 BKN180 19/13 A3007 RMK AO2 SLP181 T01890133=

2.3 Half Moon Bay Airport

The planned destination was Half Moon Bay Airport (KHAF), Half Moon Bay, CA, located approximately 23 miles south of the accident site at an elevation of 65 ft. The airport had an Automated Weather Observation System (AWOS), which was not augmented by any human observers and disseminated observations longline every 20-minutes. At the approximate time of the accident KHAF reported the following conditions.

Weather observation for KHAF at 1155 PDT, automated, wind from 210° at 6 knots, visibility 9 miles, ceiling overcast at 1,400 ft, temperature 17° C, dew point temperature 14° C, altimeter 30.10 inHg. Remarks: automated station with a precipitation discriminator.

The general flight conditions and raw observations surrounding the period were as follows.

LIFR METAR KHAF 061335Z AUTO 16004KT 1/4SM FG OVC003 13/13 A3008 RMK AO2

LIFR METAR KHAF 061355Z AUTO 18003KT 1 1/2SM BR BKN003 OVC019 13/13 A3009 RMK AO2

IFR METAR KHAF 061415Z AUTO 00000KT 1 1/2SM BR SCT003 OVC019 13/13 A3010 RMK AO2

IFR METAR KHAF 061435Z AUTO 00000KT 2 1/2SM BR OVC019 13/13 A3010 RMK AO2

IFR METAR KHAF 061455Z AUTO 16004KT 2 1/2SM BR OVC018 13/13 A3010 RMK AO2

IFR METAR KHAF 061515Z AUTO 17006KT 2SM BR OVC018 13/13 A3010 RMK AO2

IFR METAR KHAF 061535Z AUTO 15005KT 2SM BR OVC018 13/13 A3010 RMK AO2

IFR METAR KHAF 061555Z AUTO 17006KT 3SM BR BKN018 13/13 A3010 RMK AO2

IFR METAR KHAF 061615Z AUTO 18004KT 2SM BR FEW018 13/13 A3011 RMK AO2

IFR METAR KHAF 061635Z AUTO 00000KT 2SM BR SCT018 SCT031 13/13 A3011 RMK AO2

IFR METAR KHAF 061655Z AUTO 24004KT 2 1/2SM BR FEW005 SCT019 BKN029 14/14 A3011 RMK AO2=

MVFR METAR KHAF 061715Z AUTO 21004KT 3SM BR SCT017 BKN028 14/14 A3011 RMK AO2=

Departure at 1828Z

MVFR METAR KHAF 061735Z AUTO 22005KT 5SM BR BKN016 BKN025 16/15 A3011 RMK AO2=

MVFR METAR KHAF 061755Z AUTO 21005KT 6SM BR SCT017 BKN025 16/15 A3011 RMK AO2=

MVFR METAR KHAF 061815Z AUTO 22006KT 8SM BKN017 BKN022 OVC027 17/14 A3011 RMK AO2=

MVFR METAR KHAF 061835Z AUTO 20005KT 8SM OVC015 17/14 A3011 RMK AO2=

MVFR METAR KHAF 061855Z AUTO 21006KT 9SM OVC014 17/14 A3010 RMK AO2=

Accident 1910Z

MVFR METAR KHAF 061915Z AUTO 23007KT 9SM OVC013 16/14 A3010 RMK AO2=

MVFR METAR KHAF 061935Z AUTO 25006KT 9SM OVC012 16/14 A3010 RMK AO2=

MVFR METAR KHAF 061955Z AUTO 25005KT 6SM BR BKN010 OVC013 15/14 A3010 RMK AO2=

IFR METAR KHAF 062015Z AUTO 26006KT 3SM BR BKN006 BKN009 OVC013 15/14 A3010 RMK AO2=

MVFR METAR KHAF 062035Z AUTO 24005KT 5SM BR SCT005 BKN013 BKN020 16/15 A3010 RMK AO2=

MVFR METAR KHAF 062055Z AUTO 24006KT 6SM BR SCT006 SCT013 BKN019 16/15 A3010 RMK AO2=

LIFR METAR KHAF 062115Z AUTO 23005KT 2SM BR BKN004 OVC008 15/15 A3010 RMK AO2=

LIFR METAR KHAF 062135Z AUTO 23005KT 4SM BR OVC003 15/15 A3009 RMK AO2=

LIFR METAR KHAF 062155Z AUTO 21006KT 8SM BKN004 OVC013 15/15 A3009 RMK AO2=

LIFR METAR KHAF 062215Z AUTO VRB05KT 5SM BR OVC003 15/15 A3009 RMK AO2=

A full listing of the observation for KHAF are included in Attachment 1. The observations indicated LIFR to IFR conditions were reported during the early morning hours with conditions as low as 1/4 mile in dense fog with ceilings overcast at 200 ft agl with conditions improving to MVFR conditions at the time of the accident. IFR ceilings returned after the accident, with LIFR conditions reported after 1415 PDT with visibility restricted in dense fog.

2.4 San Carlos Airport

The next closest weather reporting station was from San Carlos Airport (KSQL), San Carlos, CA, located approximately 23 miles south-southeast of the accident site and 12 miles east from the planned destination airport of KHAF. The airport listed an elevation of 6 ft and had an AWOS, which was augmented by Air Traffic Control personnel during normal staffing hours. At the approximate time of the accident KSQL reported the following conditions.

Weather observation for KSQL at 1157 PDT, wind from 260° at 10 knots, visibility 10 miles or more, a few clouds at 2,000 ft, ceiling broken at 3,000 ft, temperature 21° C, dew point temperature 13° C, altimeter 30.08 inHg.

The general flight categories and raw observations surrounding the period were as follows.

MVFR METAR KSQL 061748Z 29010KT 10SM SCT020 BKN030 19/13 A3010=

MVFR METAR KSQL 061857Z 26010KT 10SM FEW020 BKN030 21/13 A3008=

Accident 1910Z

MVFR METAR KSQL 061959Z 27015KT 10SM BKN022 BKN030 22/13 A3007=

MVFR METAR KSQL 062047Z 26010G15KT 10SM FEW020 BKN030 21/13 A3006=

VFR METAR KSQL 062147Z 26017G24KT 10SM FEW020 BKN090 19/13 A3006=

VFR METAR KSQL 062248Z 29015G19KT 10SM SCT020 BKN095 19/13 A3006=

2.5 METAR Display

The NWS Aviation Weather Center's (AWC) Helicopter Emergency Medical Services Tool⁷ of METARs for 1215 PDT is included as figure 4, with the approximate accident site marked by a red star. The image depicted MVFR to VFR conditions being reported over the surrounding area with no meteorological echoes depicted in the vicinity of the accident site. The lowest elevation radar reflectivity image was not available at the time of the image.

⁷ <https://www.aviationweather.gov/hemst>

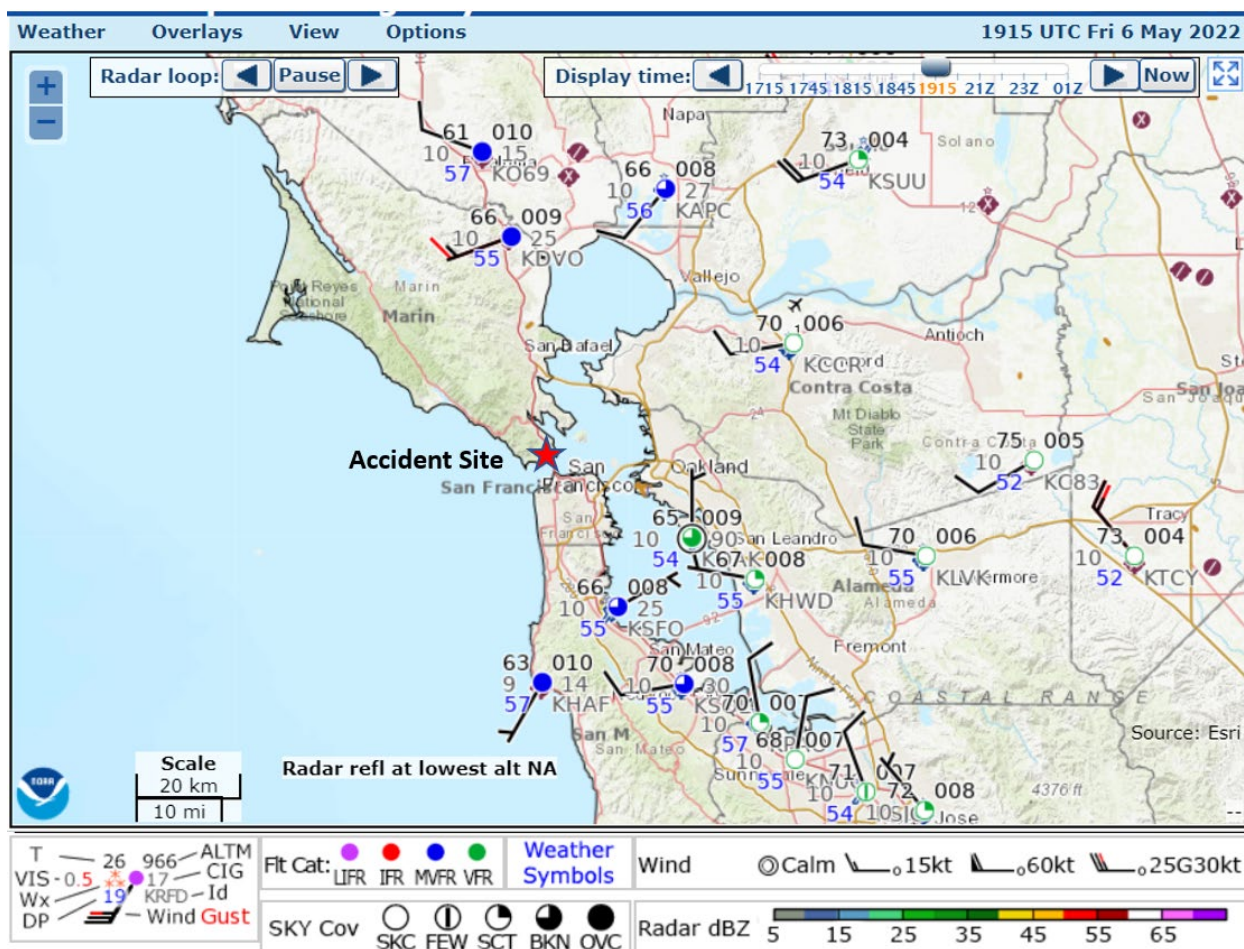


Figure 4 - NWS AWC graphical depiction of the METARs at 1215 PDT with the station models color coded by the general flight category with the accident site marked by the red star.

2.6 Wolf Pack Ridge

A Remote Automated Weather Station (RAWS) was installed on Wolf Pack Ridge (PG521) at latitude 37.85078° N and longitude 122.49835° W, approximately 1 mile north of the accident site at an elevation of 1,111 ft. At the time of the accident the system reported the following conditions.

Time	T (°F)	Td (°F)	RH (%)	Wind (Dir/KT)
1200 PDT	53	52	99	SW 10

A search of MesoWest⁸ and MADIS⁹ observations indicated that there were no other observation sites within a 30-mile radius reporting visibility or sky conditions other than the ones documented in this report.

2.7 San Francisco Bar Buoy

The NWS San Francisco Bar marine buoy located approximately at latitude 37.778° N and longitude 122.632° W, or about 7.25 miles west of the accident site at the entrance to the bay reported the following.

Time	Air T (°F)	Water T(°F)	Wind
1200 PDT	54	54	W

3.0 Model Sounding

A High-Resolution Rapid Refresh (HRRR)¹⁰ numerical model data was obtained from the NOAA Air Resource Laboratory archive using the closest grid point to the accident site coordinates. The HRRR model data was then plotted on a standard skew T log P diagram¹¹ using the RAOB Analysis software¹² for 1200 PDT and is included as figure 5. The HRRR model sounding depicted an elevation of 161 ft, with a near surface temperature of 12.3° C (54° F), a dew point temperature of 11.3° C (52° F), and with a relative humidity of 94%. The sounding depicted a frontal inversion near 500 ft, with another inversion between 3,000 and 4,421 ft associated with subsidence and the marine layer¹³. The lifted condensation level (LCL)¹⁴ was identified at 417 ft agl, with multiple layers of clouds indicated by the sounding (gray bars on the left axis). The lowest cloud layer identified by RAOB was from near the LCL at 200 ft with tops near

⁸ <https://mesowest.utah.edu/> a web site operated by the University of Utah for archive weather observations.

⁹ Meteorological Assimilation Data Ingest System is a meteorological observational database and delivery system

¹⁰ 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.

¹¹ 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.

¹² RAOB –The Universal RAOBsonde OBServation program is an interactive sounding analysis program developed by Eosonde Research Services (ERS) previously known as Environmental Research Services, The Villages, Florida.

¹³ The Marine Layer is an airmass that develops over the surface of a large body of water, such as an ocean or large lake, in the presence of a temperature inversion. The inversion itself is usually initiated by the cooling effect of the water on the surface layer of an otherwise warm air mass.

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

2,800 ft, where the relative humidity was between 95% to 100%. With higher broken clouds at 7,000 ft and 20,000 ft. The sounding was classified as stable with a Lifted Index (LI)¹⁵ of 13.1, and by the two temperature inversions noted below 5,000 ft. Both the Fog Stability Index (FSI) of 14.1 and threat index of 1.3 indicated a high potential for radiation type fog formation, with the fog point temperature of 13.0° C. The freezing level was identified at approximately 12,700 ft, well above the accident airplane's cruising altitude.

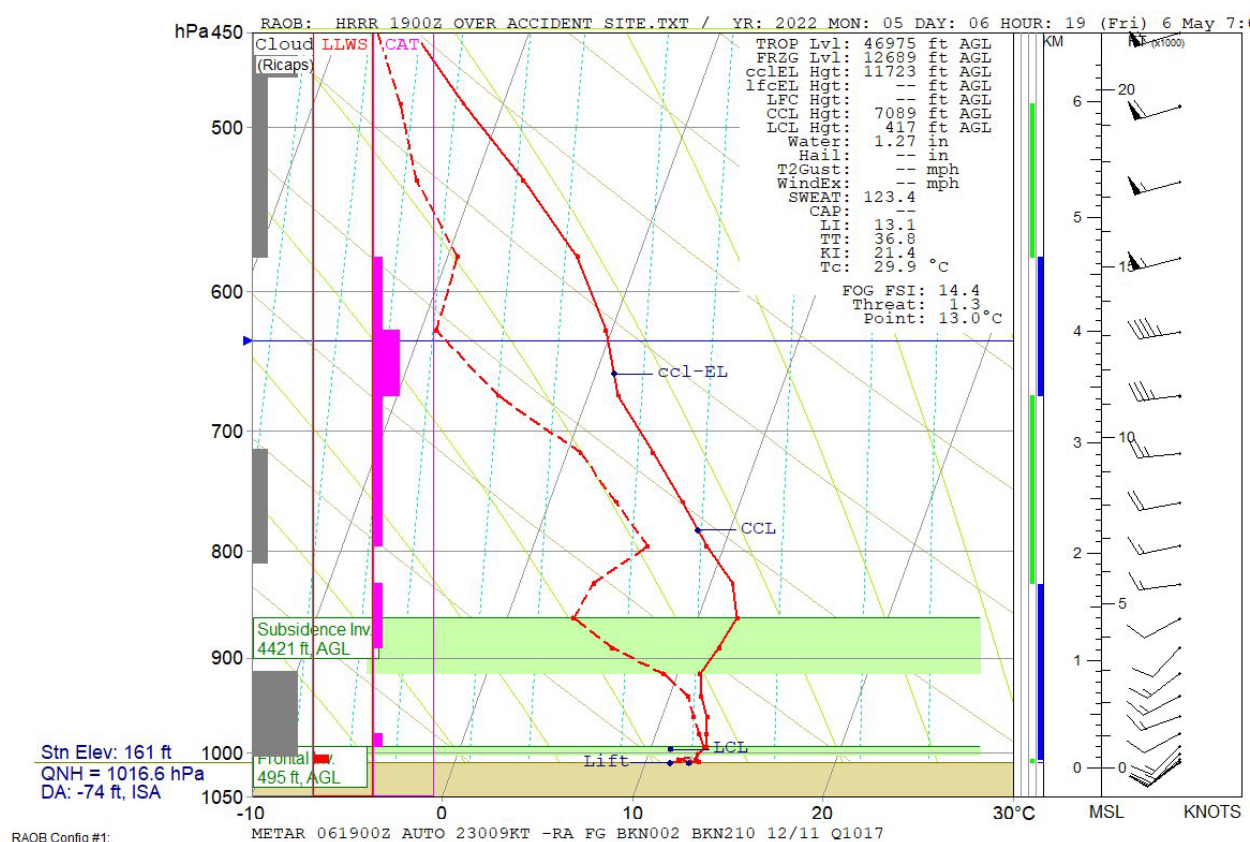


Figure 5 - HRRR numerical model sounding for 1200 PDT over the approximate accident site.

The HRRR wind profile indicated a near surface wind from the southwest of from 230° at 9 knots, with wind speeds increasing to 14 knots near 2,000 ft with little change in direction. Above the temperature inversions above 5,000 ft the wind veered to the west with wind speeds increasing with height. The mean 0 to 6 kilometer (or 18,000 ft) mean winds were from 255° at 33 knots. The level of maximum wind was identified at approximately 37,000 ft from 250° at 80 knots. The RAOB analysis software used to plot the sounding indicated only a light turbulence potential below 10,000 ft.

¹⁵ Lifted Index (LI) - A common measure of atmospheric instability. Its value is obtained by computing the temperature that air near the ground would have if it were lifted to 500-hPa or approximately 18,000 feet and comparing that temperature to the actual temperature at that level. Negative values indicate instability, and positive values indicate a stable atmosphere resisting vertical motion.

A table of the HRRR parameters of height, pressure, temperature (T), dew point temperature (Td), relative humidity (RH), wind, and potential Clear Air Turbulence (CAT) intensity, Low-Level Wind Shear (LLWS) based on the vertical wind shear below 10,000 ft is included below.

Height (ft-msl)	Pres (hPa)	T (C)	Td (C)	RH (%)	Wind (deg/kts)	CAT (FAA)	LLWS (FAA)
161	1011	12.3	11.3	94	231/ 9		
188	1010	12.8	12.4	97	230/ 9		LIGHT
270	1007	12.6	11.7	94	227/ 11		LIGHT
407	1002	12.6	12.6	100	223/ 13		
656	993	12.9	12.8	99	223/ 13		LGT
1048	979	12.7	12.3	97	239/ 12		
1560	961	12.4	11.7	95	248/ 13		
2198	939	11.7	11.0	95	241/ 14		
2880	916	11.2	9.3	88	230/ 14		
3671	890	11.7	6.1	68	221/ 12		LGT
4582	861	12.1	3.5	56	239/ 10		LGT
5622	829	11.2	3.9	61	261/ 14		
6767	795	9.1	6.0	81	258/ 17		LGT
8096	757	7.0	3.5	78	259/ 21		LGT
9556	717	4.5	0.7	76	263/ 26		LGT

Based on the flight track data of N54MG the aircraft was operating between the altitudes of 1,625 ft to 525 ft during the period from 1206 through 1210 PDT.

A cross section was created using HRRR model data for from the San Francisco Bar Buoy approximately 7.5 miles west of the accident site at the entrance to the bay, the accident site model above, immediately east of the Golden Gate Bridge and for selected locations along the track was created to provide an approximate of the cloud cover over the general route of flight and is included as figure 6 below. The other HRRR sounding for was taken near Alcatraz Island, east-northeast of Angle Island, and near the Richmond Bridge, where cloud cover was photographed in section 9.0 of this report.

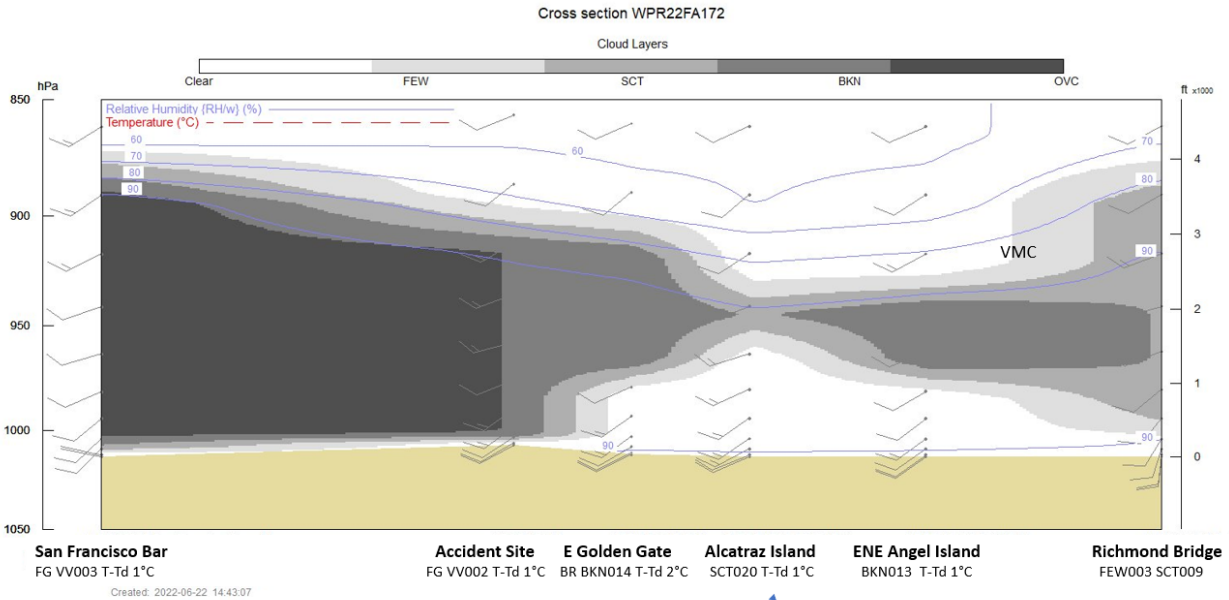


Figure 6 - HRRR model cross section along the flight track for 1200 PDT.

4.0 Satellite Imagery

The Geostationary Operational Environmental Satellite number 17 (GOES-17) 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 and visible imagery were reviewed surrounding the period, and the closest images to the accident time documented. 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, while the visible (band 2) at a wavelength of 0.64 μm provided images at a resolution of 0.5 km. The following satellite imagery have not been corrected for parallax error.

Figure 7 is the GOES-17 infrared image at 1211 PDT at 4X magnification with a standard MB temperature enhancement curve applied to highlight the higher and colder cloud tops (red shades). The image depicted a low band of stratiform clouds over the accident site with a mid to high level band of cirrostratus type clouds. The radiative cloud top temperature over the accident site was 251 Kelvin or -22 C, which corresponded to cloud tops near 25,000 ft. Northwest of the accident site low to mid-level clouds overcast clouds obscured the coastal regions of northern California, while to the southeast of KSFO clear skies and warmer temperatures were noted (darker shading). A transverse cloud pattern¹⁶ where the clouds were generally oriented in

¹⁶ Transverse bands - bands of clouds oriented perpendicular to the flow in which they are embedded, and often indicate the presence of turbulence and a temperature inversion with strong vertical wind shear.

parallel bands perpendicular to the general wind flow were also observed to the north and northeast of the accident site over northern California into Nevada.

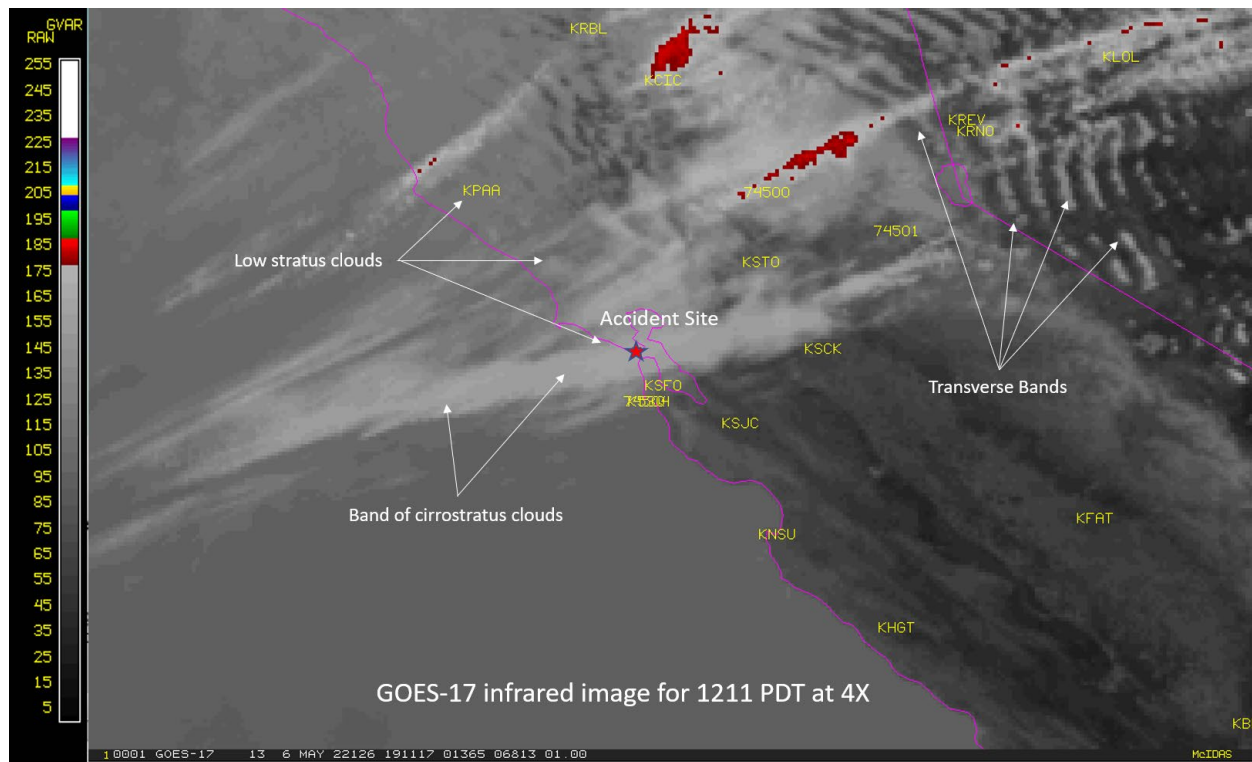


Figure 7 - GOES-17 infrared image for 1211 PDT at 4X magnification.

The GOES-17 visible image for 1211 PDT at 2X magnification is included as figure 8 with the accident site marked by the red square. The higher resolution image depicted the low stratiform clouds and/or fog with higher stratiform clouds above over the accident site. The low stratiform clouds were noted off the coast west of KSFO and KHAF and continued northward up the northern California coastal areas.

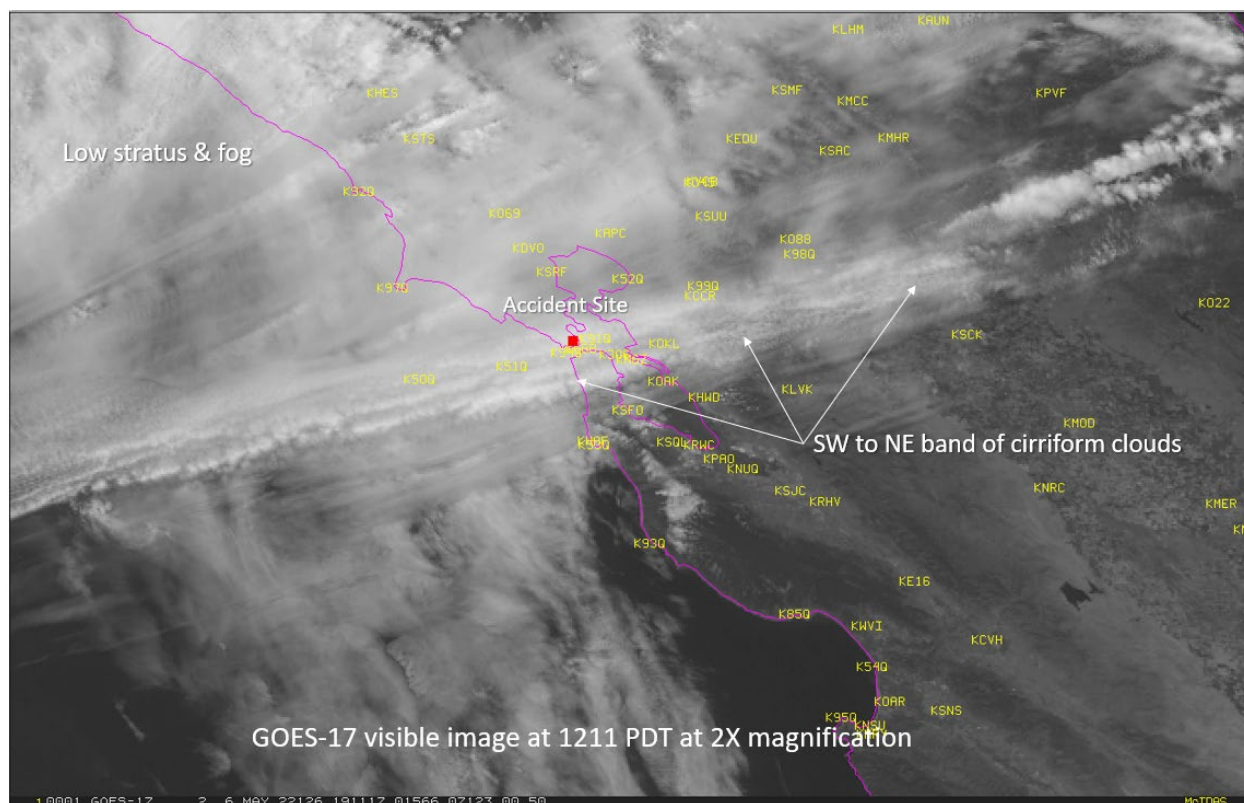


Figure 8 - GOES-17 visible image for 1211 PDT at 2X magnification.

5.0 Pilot Reports

The following pilot reports or PIREPs¹⁷ were recorded within 120 miles and within 3 hours prior to and after the accident below 18,000 ft. The reports are provided in standard code and abbreviation with cloud heights and altitude reported in msl heights, followed by a decoded report in plain language with time referenced to PDT. The time of the accident has been added in bold text for reference. The reports were as follows.

APC UA /OV KAPC186003/TM 1609/FL020/TP C560/SK OVC008-TOP020/RM DURD

Napa County Airport (APC), Napa, CA routine pilot report; Over - 186° and 3 miles from KAPC (22 miles north of accident site); Time - 0909 PDT; Altitude - 2,000 ft msl; Type aircraft - Cessna Citation business jet; Sky cover - overcast bases at 800 ft with tops at 2,000 ft; Remarks - during descent.

LVK UA /OV 2 NW/TM 1620/FL016/TP C172/RM BASE 012

Livermore Municipal Airport (LVK), Livermore, CA routine pilot report; Over - 2 miles northwest of LVK (27 miles east of accident site); Time - 0920 PDT; Altitude - 1,600 ft; Type aircraft - Cessna 172 Skyhawk; Remarks - cloud bases at 1,200 ft.

¹⁷ Only includes PIREPs which were disseminated through normal weather circuits and do not include reports only broadcast to air traffic controllers via radio and not transcribed into the database.

MRY UA /OV KMRY/TM 1632/FL004/TP H25B/RM PILOT ON RY 10R ILS APPROACH REPORTED BASES AT FL005 AND TOP OF CLOUD LAYER AT FL015.

Monterey Regional Airport (MRY), Monterey, CA routine pilot report; Over - KMRY (about 80 miles south-southeast of accident site); Time - 0932 PDT; Altitude - 400 ft; Type aircraft - British Aerospace Hawker 125 business jet; Remarks - pilot on runway 10R instrument landing system (ILS) approach reported bases at 500 ft and top of cloud layer at 1,500 ft.

MRY UA /OV MRY060002/TM 1700/FL015/TP PC12/SK OVC-TOP015/RM DURC

MRY routine pilot report; Over - 060° and 2 miles from KMRY (about 78 miles south-southeast of accident site); Time - 1000 PDT; Altitude - 1,500 ft; Type aircraft - Pilatus PC-12 turboprop aircraft; Sky cover - overcast clouds with tops at 1,500 ft; Remarks - during climb.

LHM UA /OV SAC360025 /TM 1722 /FL070 /TP DA40 /WX FV50SM /WV 24014KT /TB NEG /RM BKN ABV

Lincoln Regional Airport (LHM), Lincoln, CA routine pilot report; Over - 360° and 25 miles from Sacramento VORTAC¹⁸ (about 93 miles northeast of the accident site); Time - 1022 PDT; Altitude - 7,000 ft; Type aircraft - Diamond DA40 single engine airplane; Weather - flight visibility 50 miles; Wind - 240 at 14 knots; Turbulence - negative; Remarks - broken sky cover above.

CCR UA /OV CCR /TM 1801 /FL001 /TP RV7 /SK SKC /RM CI

Buchanan Field Airport (CCR), Concord, CA routine pilot report; Over - CCR (27 miles northeast of the accident site); Time - 1101 PDT; Altitude - 100 ft; Type aircraft - Vans RV-10 single engine airplane; Sky cover - sky clear with some high cirrus clouds.

AUN UA /OV AUN /TM 1819 /FL015 /TP C172 /RM CLOUDY

Auburn Municipal Airport (AUN), Auburn, CA routine pilot report; Over - AUN (approximately 100 miles northeast of the accident site); Time - 1119 PDT; Altitude - 1,500 ft; Type aircraft - Cessna 172 Skyhawk; Remarks - cloudy.

Accident 1210 PDT (1910Z)

SFO UA /OV KAPC /TM 2155 /FL035 /TP C68A /SK BASE020-TOP035 /RM ZOA CWSU AWC-WEB:

San Francisco (SFO) routine pilot report; Over - KAPC (about 50 miles north of the accident site); Time - 1455 PDT; Altitude - 3,500 ft; Type aircraft - Cessna Citation Latitude business jet; Sky cover - cloud bases at 2,000 ft with tops of 3,500 ft; Remarks - entered by Oakland Center Weather Service Unit (CWSU)¹⁹.

The PIREPs reported low clouds north and south-southwest of the accident site from 500 to 800 ft with tops 2,000 ft and later increasing to 3,500 ft. While PIREPs inland

¹⁸ VORTAC - VHF Omnidirectional Range (VOR) navigational beacon with a TACTical air navigation aid that provides distance from the station. Unless otherwise noted they are collocated with the airport city they are associated with.

¹⁹ Co-located with the Oakland Air Route Traffic Control Center (ARTCC).

reported relative clear skies and unlimited visibility. There were no PIREPs recorded from aircraft operating into or departing from KSFO or KOAK noted during the period.

6.0 NWS Forecasts

The NWS San Francisco Weather Forecast Office located in Monterey, CA (KMTR) was responsible for the region where the accident occurred as well as for the issuance of the general forecasts and advisories for the area, while the NWS AWC located in Kansas City was responsible for issuance of the aviation enroute forecast and inflight weather advisories, which are documented below.

6.1 Terminal Aerodrome Forecast

The closest NWS Terminal Aerodrome Forecast (TAF) to the accident site was issued for KSFO. A TAF is only valid for a 5 mile radius from the center of the airport complex, and provides a time specific breakdown of expected winds, visibility, weather, and sky cover within that area. The forecast that was current at the time of the accident was an amended TAF issued at 1037 PDT and valid for a 30-hour period and was as follows.

AMD TAF KSFO 061737Z 0618/0724 27015KT P6SM FEW025 BKN050

FM070500 28005KT P6SM OVC010

FM071200 28008KT P6SM BKN020 BKN050

FM071600 28015G20KT P6SM BKN050

FM072200 27018G30KT P6SM SCT050=

The KSFO forecast expected from 1100 through 2200 PDT expected VFR conditions to prevail with a wind from 270° at 15 knots, visibility better than 6 miles, a few clouds at 2,500 ft agl, ceiling broken at 5,000 ft.

6.2 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 KMTR issued the AFD at 1103 PDT was as follows. The long term forecast section has been excluded.

FXUS66 KMTR 061803

AFDMTR

Area Forecast Discussion

National Weather Service San Francisco Bay Area

1103 AM PDT Fri May 6 2022

.SYNOPSIS...North Bay sprinkles possible today otherwise seasonably mild temperatures. No big changes into Saturday with onshore winds continuing keeping temperatures on the cool side of normal. Next cold front approaches Northern California on Sunday with a chance of showers for the North Bay along with cooler than normal temperatures. Unseasonably cold upper trough early next week will keep temperatures well below normal along with a chance of showers or even isolated thunderstorms.

.DISCUSSION...as of 9:59 AM PDT Friday...Damp, drizzly, light rain, foggy weather was mostly confined to the more immediate coastal terrain including the East Bay hills and mountains in the Bay Area since late last night. The precipitable water on this morning's 12z Oakland sounding is elevated at 1.10" which is near the maximum moving average for the time of year. **With weak warm air advection and upward vertical motion along west facing coastal slopes, the coastal North Bay continues to report 1 hourly light rain amounts between 0.01" and 0.02" and spotty mist or very light drizzle is possible to the south.** 12 hour rain amounts have varied from 0.02" to 0.04" from San Mateo county to the higher terrain of the East Bay and up to 0.05" to 0.15" rain Sonoma county, wettest at the coast. More localized report 0.04" from Angwin in Napa county. Elsewhere to the south no bucket tips reported.

Lower level warm air advection moves eastward today followed by a cold front tonight. Fog possible tonight otherwise drier weather tonight and Saturday. A large change in weather arrives Sunday and next week with much cooler and below to much below normal temperatures, especially night/morning temperatures, including showers, possibly isolated thunderstorms and snow showers down to approx. 3 thousand feet. Expect winter-like weather next week especially up in the high country, coupled to any sun breaks steepening instability we are looking at a decent chance of convection, at least passing showers along with potentially small hail, including possibly thunderstorms.

.PREV DISCUSSION...as of 3:33 AM PDT Friday...By May standards the synoptic pattern remains fairly active this morning across the West Coast and will stay that way for much of the next 7 days.

In the short term, moist onshore flow continues from about Bodega Bay northward with most of the light rain confined from Mendocino northward. However, we've had a few bucket tips overnight for the Sonoma coast and hills. This is being picked up by the mesoscale HRRR and RAP models with a slight southward extension compared to the NAM. Any precip will be very light today from roughly Pt Reyes northward with persistent clouds and onshore winds keeping temperatures near to slightly below normal. **Some dense fog over the ocean with Half Moon Bay reporting 1/2 fog this morning and SFO briefly at 2.5 miles, so some fog along Highway 1 will be possible early this morning.** Areas from SF southward will see nice weather to finish out the work week with temps even reaching the 80s for the interior Central Coast while the East and South Bay top out in the 70s.

850 mb temps reach about 12 celsius this afternoon then cool to around 5 celsius by Saturday afternoon across the Bay Area. **In combination with continued onshore winds and cloud cover expect temperatures to cool a few degrees for Saturday afternoon most locations while the Saturday forecast looks to remain mostly dry.**

On Mothers Day Sunday, yet another even colder system drops into NorCal. There will be a noted chill in the air, especially for the North Bay where some rain showers will be possible on Sunday. Daytime highs will remain in the upper 50s coast with only low to mid 60s the rest of the Bay Area for Sunday afternoon. If your weekend plans take you northward be advised more steady rain is

likely across far Northern California with some snow at pass levels over the Sierra by Sunday afternoon.

The big weather story for Monday and Tuesday next week will be well below normal temperatures as a very cold late season trough drops over the Bay Area. 850 mb temps hovering at or a few degrees below zero with 700 mb temps around -12c and 500 mb temps as low as -32 celsius on both the Euro and GFS later Monday into Tuesday. Of course exact location of the upper low will oscillate but showers and some thunderstorms will certainly be possible next week. Not all areas will see precip but everyone will notice the chilly daytime highs and cool to cold overnight lows. For example daytime highs only in the upper 50s Monday/Tuesday for interior valleys would be at least 15 degrees below normal with overnight lows upper 30s to mid 40s. No significant rainfall expected with this cold trough but will certainly see some interesting weather early next week with such a cold low.

The initial shortwave may eject eastward by midweek with another cool system dropping down late next week keeping temps below normal though the best precip chances stay to our north and over the Sierra.

.AVIATION...as of 11:00 AM PDT Friday...For the 18Z TAFs. A wide mix of conditions as the TAFs were issued - lingering IFR in the N Bay, MVFR SF Bay and VFR southward. Do expect some improvement for N Bay and SF Bay, but as a cold front to the north approaches complete clearing is not expected. Overnight CIGS will return with patchy drizzle/fog ahead of the front. FROPA will be late tonight/early Saturday. The FROPA will help to disrupt the low CIGS with some mixing. Conf is low with regards to extent of mixing/clearing with the FROPA. Higher confidence for lifting/mixing behind the front after 15Z Saturday. Winds ramp up behind the front as well.

Vicinity of KSFO...Improving conditions inside SF Bay as of 18Z. This trend will continue. Will bring CIGS back around 05Z tonight and keep them through early Saturday morning. FROPA will help to mix out some low cigs, but decide to keep some debris clouds through 16Z Saturday. Winds increase Saturday afternoon with a marginal AWW with gusts approaching 30KT.

KSFO Bridge Approach...Similar to SFO.

Monterey Bay...VFR expected today and onshore flow around 10-15 kts returns. Low clouds return Friday night around 03-05Z.

.MARINE...as of 10:53 AM PDT Friday...A weak cold front will sweep through the coastal waters Friday evening. Winds ahead of the front will be light to moderate with southerly winds north of the Golden Gate and northerly winds south of the Golden Gate. Coastal jets will result in locally gusty winds along the Santa Cruz Coast and Big Sur Coast this afternoon. Northwest swell will persist into the weekend.

.MTR WATCHES/WARNINGS/ADVISORIES...

.Tday...SCA...Pt Pinos to Pt Piedras Blancas 0-10 nm SCA...Mry Bay

PUBLIC FORECAST: Canepa

AVIATION: MM

MARINE: MM

Visit us at www.weather.gov/sanfrancisco

6.3 NWS Public Zone Forecast

The KMTR WFO Zone Forecast for the region where the accident occurred issued to the public was as follows issued at 1101 PDT.

CAZ505-070900-

Coastal North Bay...Including Point Reyes National Seashore-

1101 AM PDT Fri May 6 2022

.REST OF TODAY...Mostly cloudy. Areas of fog. A chance of showers late in the morning. A slight chance of showers in the afternoon. Highs around 60. Southwest winds 5 to 15 mph.

.TONIGHT...Mostly cloudy. A slight chance of showers in the evening. Areas of fog. Lows in the upper 40s. West winds 10 to 15 mph.

CAZ509-070900-

San Francisco Peninsula Coast-

1101 AM PDT Fri May 6 2022

.REST OF TODAY...Mostly cloudy. Widespread dense fog in the afternoon. Highs in the lower 60s. West winds 5 to 10 mph.

.TONIGHT...Mostly cloudy. Areas of fog in the evening. Patchy fog after midnight. Lows in the upper 40s. West winds 5 to 10 mph.

6.4 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, from graphical output from the NWS's National Digital Forecast Data (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. The GFA is available at the NWS AWC website and through other weather briefing services (Leidos and ForeFlight). The 3-hour GFA static image charts issued at 0901 PDT for the northwestern United States and valid for 1100 PDT are included as figures 9 and 10 with the approximate accident site marked by the red star.

The GFA Surface Forecast (figure 9) static image issued at 0901 PDT for 1100 PDT depicted visibility less than 1 statute mile over the Pacific Ocean and into the Golden Gate area and off Half Moon Bay, with light westerly winds of 5 knots or less, with a 30 to 60% chance of rain showers. The chart also depicted a G-AIRMET Sierra for IFR conditions over northwestern California and off the California coastal sections immediately bordering the accident site.

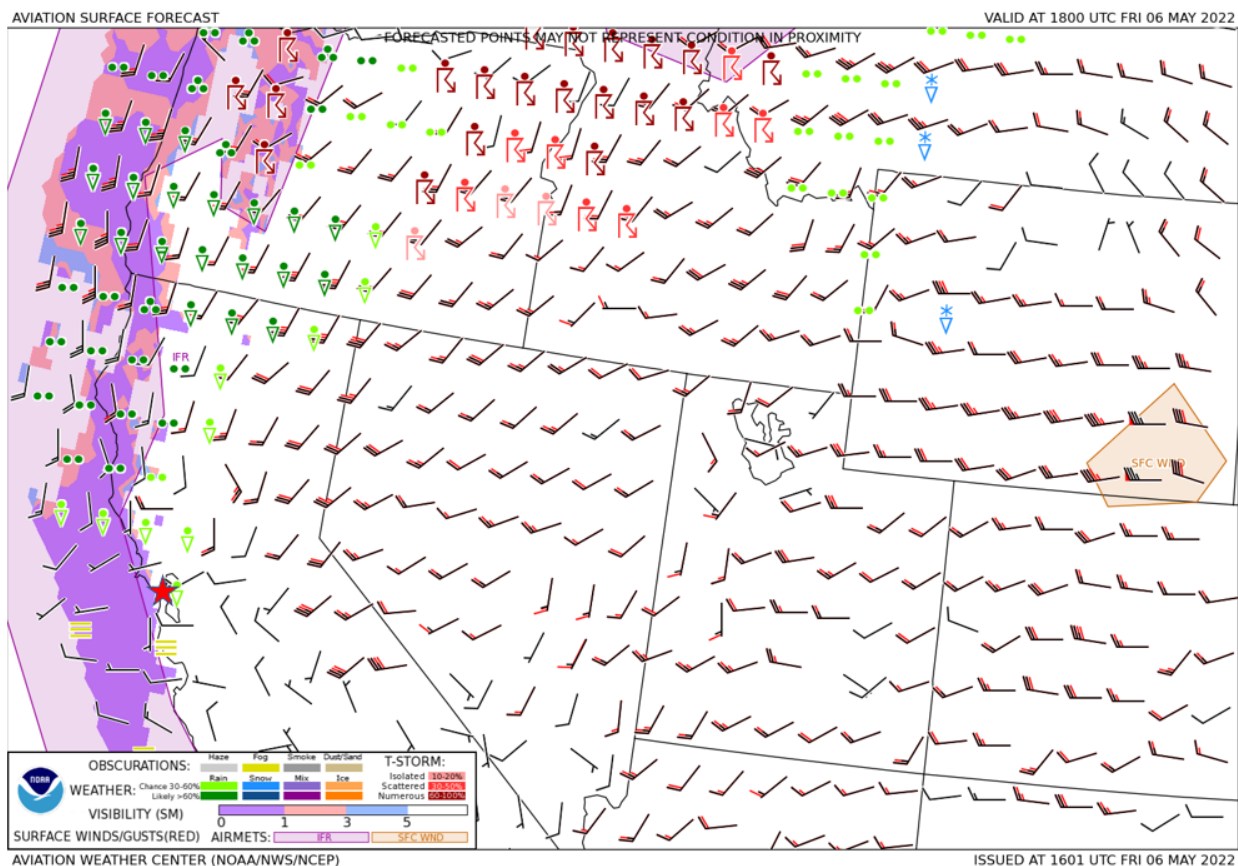


Figure 9 - GFA 3-hour Surface Forecast issued at 0901 PDT and valid for the period from 1100 through 1400 PDT, with the accident site marked by the red star.

The GFA Cloud Forecast (figure 10) issued at 0902 PDT and valid at 1100 PDT depicted broken to overcast clouds with bases near 300 ft and tops 4,000 ft with higher cirrus clouds above over the accident site with clear conditions inland over the California mainland with high cirrus clouds. A G-AIRMET Sierra for mountain obscuration extended over the accident site and over northern California.

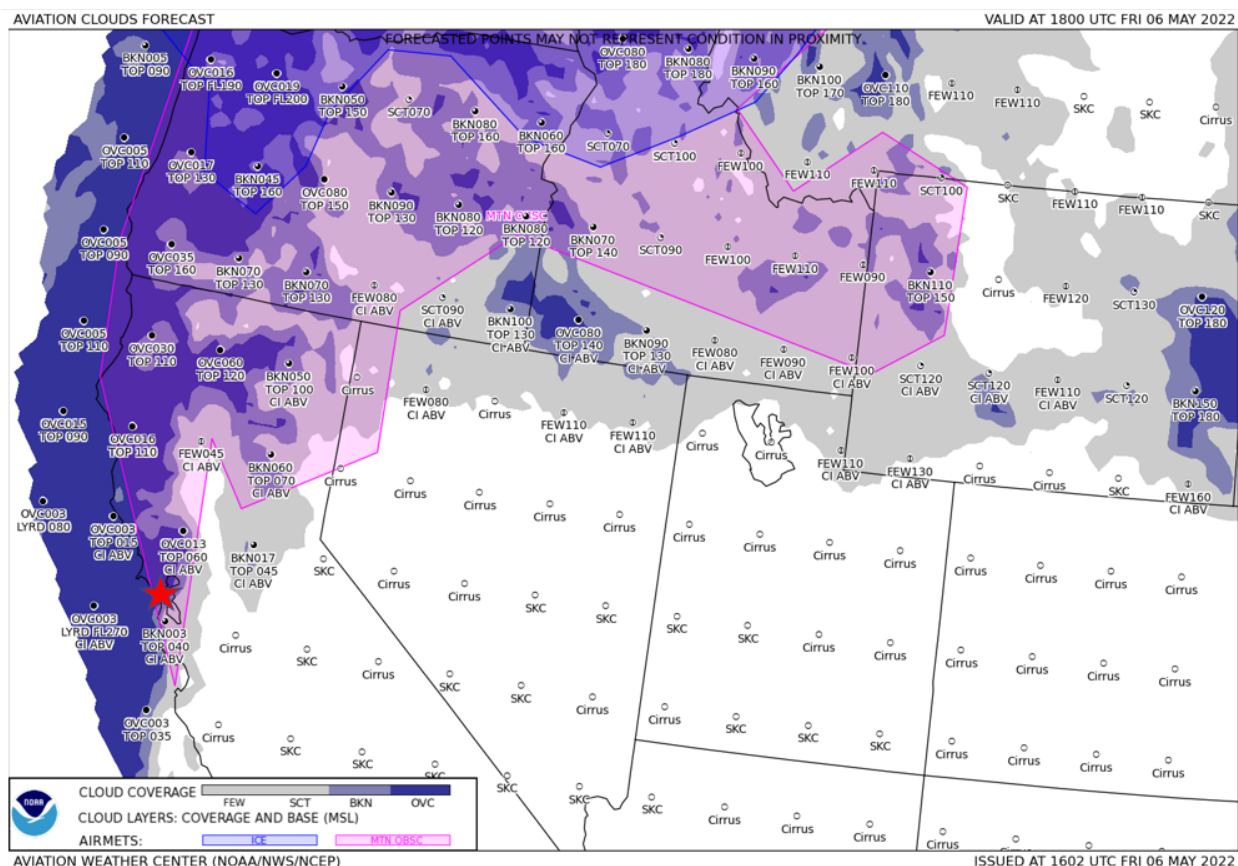


Figure 10 - GFA 3-hour Cloud Forecast issued at 0902 PDT and valid for the period from 1100 through 1400 PDT, with the accident site marked by the red star.

6.5 NWS 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.

As depicted in the GFA surface and cloud forecasts, the NWS AWC had a G-AIRMET current over the coastal areas of California for ceilings below 1,000 ft agl and visibilities

less than 3 miles in mist and fog, and for mountain obscuration of which extended over the accident site and are depicted in figure 11. There were no SIGMETs, Convective SIGMETs, or CWAs current for the period over the San Francisco area or the route of flight.

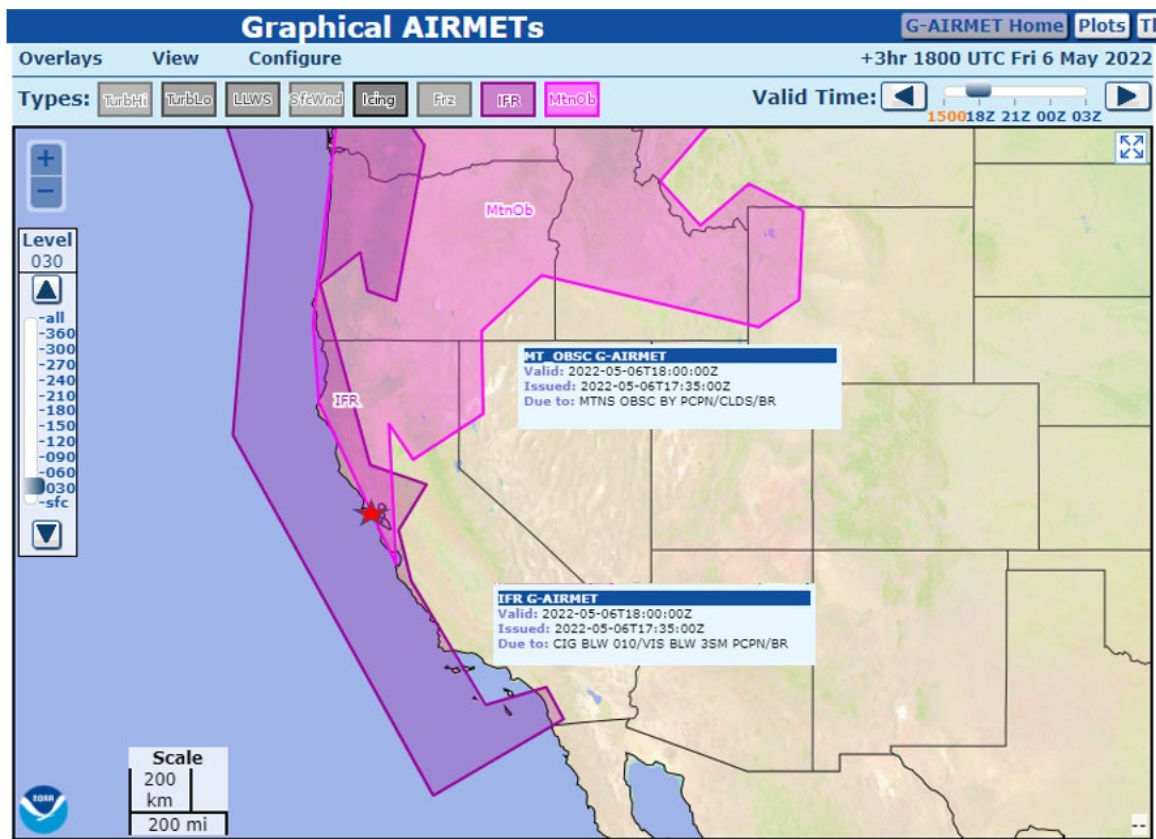


Figure 11 - NWS AWC depiction of the G-AIRMET Sierra current at the time of the accident.

7.0 Astronomical Conditions

The United States Naval Observatory's Multiyear Interactive Computer Almanac (MICA) software provided the following astronomical conditions for the accident site. The time of the accident has been added in bold italic print for reference.

Sun	Time (PDT)
Begin civil twilight	0539
Sunrise	0608
<i>Accident</i>	<i>1210</i>
Culminative	1306
Sunset	2005
End civil twilight	2034

At the time of the accident the Sun was 65° above the horizon at an azimuth of 145°.

8.0 Weather Briefing Data

A search of the FAA AFSS contract provider Leidos Flight Services and 3rd party vendors utilizing the Lockheed Flight Service (FFS) system indicated that they had no contact with N54MG on the day of the accident for any weather briefing, to file any flight plans, or inflight weather contacts. A separate search of ForeFlight revealed that the pilot of N54MG had an account with them but had not filed a flight plan for the accident flight in question. No weather imagery was viewed in the app on the day in question; however, the accident pilot did review the terminal procedures for the KHAF (GPS) runway 30 approach, and the airport pages for KHAF, Sacramento Executive Airport (KSAC), San Diego's Montgomery-Gibbs Executive Airport (KMYF), and Truckee-Tahoe Airport (KTRK) which does provide METAR, TAF, and NOTAMs for those station. There was no record of the pilot obtaining the current inflight weather advisories, GFA or other weather products documented in this report.

9.0 Camera Images from Aircraft

The passenger in N54MG took several pictures during the accident flight, which were likely synced to her iPad at home via iCloud and were provided to the NTSB by her brother to assist in the investigation. Figure 12 is a depiction of the flight track of N54MG over the bay (blue)²⁰ and the location when pictures were taken from within the aircraft which are included as figures 13 through 20 along with a general description of the conditions noted. None of the images however directly captured the conditions over the Golden Gate Bridge and the accident site.

²⁰ Map of the San Francisco Bay area with water in blue, populated areas and cities in pink, and other land features in green. Roadways and bridges are included in red and general county lines in yellow.

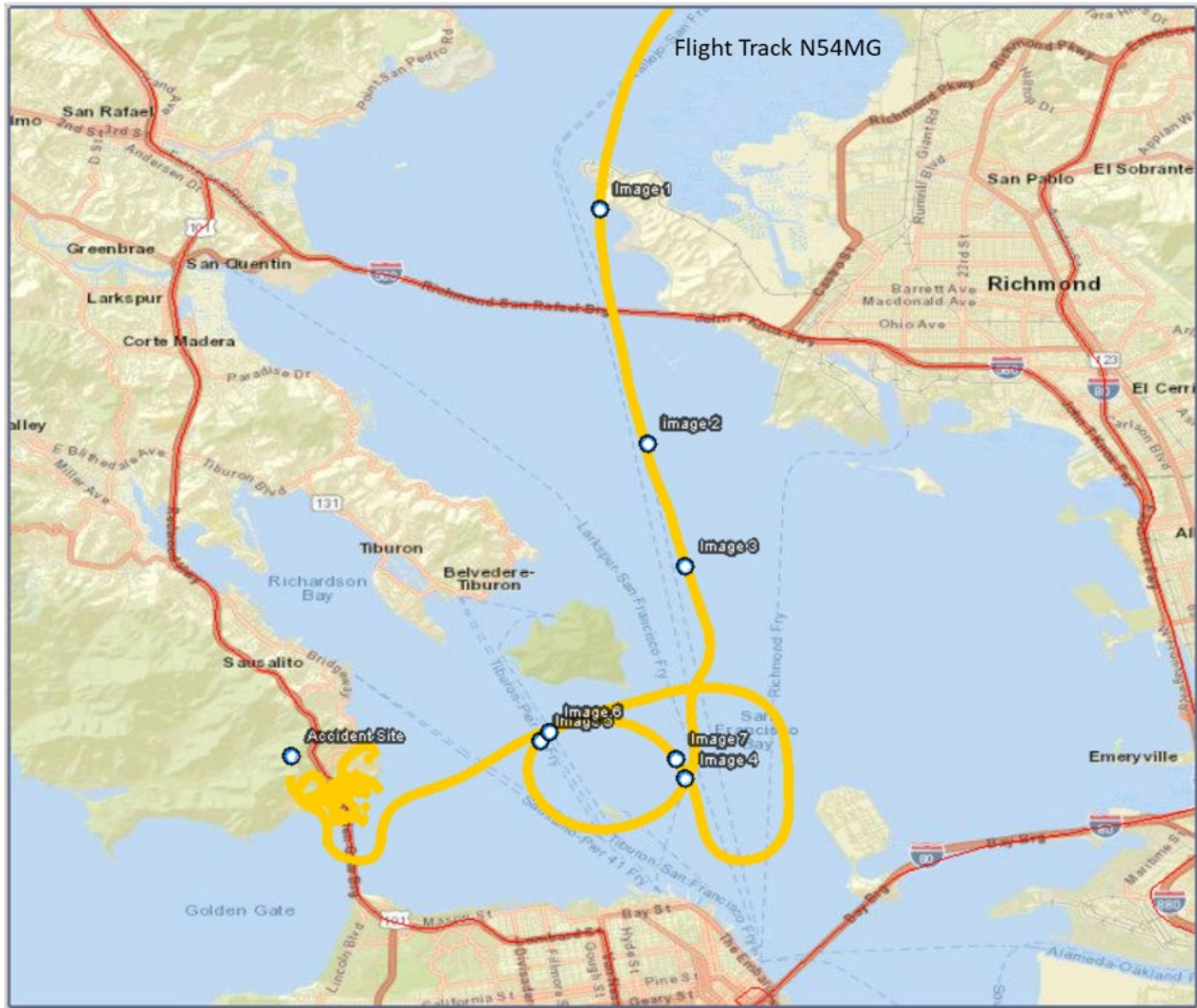


Figure 12 - Flight track of N54MG and location of camera images taken from within the aircraft.

Figure 13 is camera image 1 (left) taken at 1154:21 PDT looking towards the southwest and viewing the Richmond Bridge and San Quentin and El Campo which are obscured by low stratiform clouds below the aircraft's altitude of 1,700 ft, with higher clouds above. Image 2 (right) at 1156:00 PDT looking southward towards San Francisco at 1,350 ft, with a low band of stratiform clouds off the right side of the aircraft with Angel and Alcatraz Islands visible in the image. The Golden Gate Bridge and the Marin Headlands are off to the right and obscured by low stratiform clouds.

Figure 14 is the camera image 3 (left) at 1156:56 PDT at 1,325 ft viewing towards the south looking at the San Francisco-Oakland Bay Bridge and downtown San Francisco with a band of stratus clouds over the city. With several clouds immediately in the vicinity of the accident airplane. Image 4 (right) taken at 1158:30 PDT at 1,725 ft while the aircraft is beginning a right turn and viewing to the south-southwest and Alcatraz Island, with low stratus clouds and fog noted on the upper portion of the image.

Figure 15 are the camera images 5 (left) and 6 (right) at 1159:59 and 1200:01 PDT respectively as the aircraft began to circle Alcatraz Island and looking towards the San Francisco-Oakland Bay Bridge and downtown San Francisco. A band of stratiform clouds near the accident airplane's altitude extends from the Pacific coast eastward over the northern portion of downtown San Francisco towards Treasure Island, and north of the Oakland Bridge.

Figure 16 is the camera image 7 at 1200:43 PDT at looking southwards towards the downtown San Francisco and the Fisherman's Wharf area and a low stratiform layer of clouds extending over the city.



Figure 13 - Inflight image 1 at 1154 PDT (left) and image 2 at 1156 PDT (right).



Figure 14 - Inflight image 3 at 1156:56 PDT (left) and image 4 at 1158:30 PDT (right).



Figure 15 - Inflight images 5 at 1159:59 PDT (left) and image 6 at 1200:01 PDT (right).

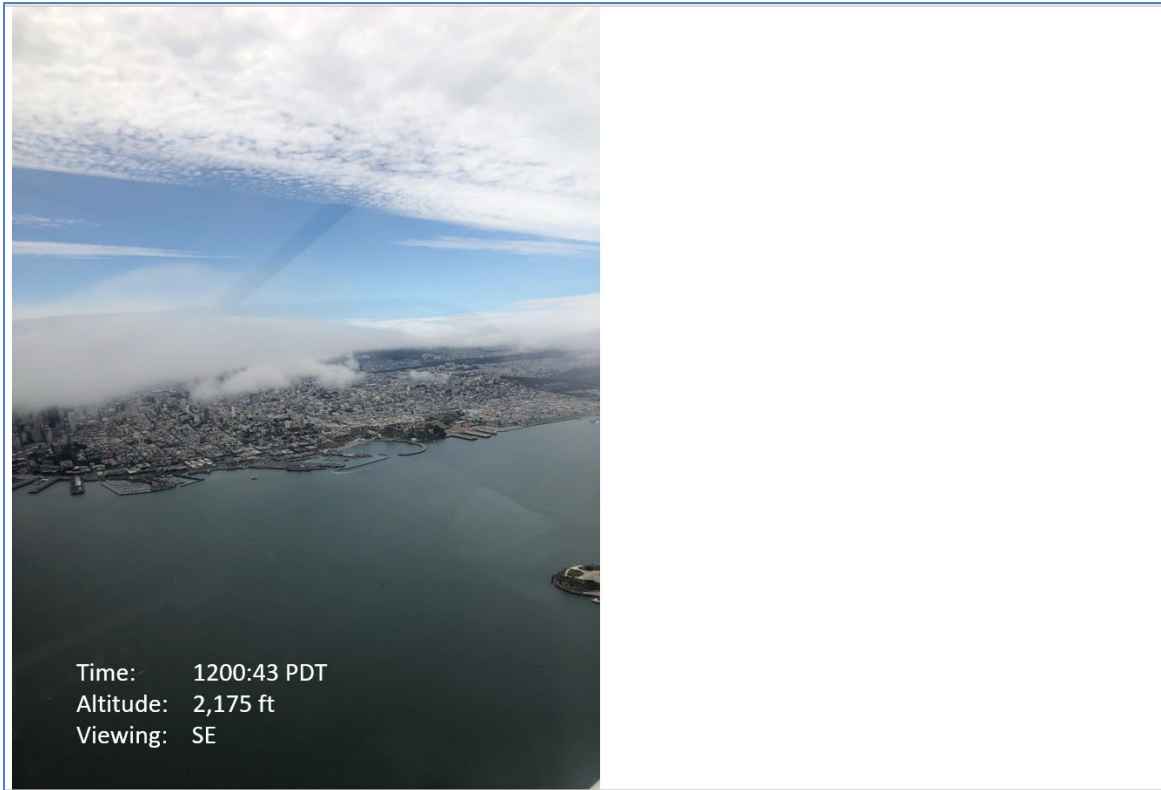


Figure 16 - Inflight image 7 at 1200:43 PDT.

10.0 Weather Camera Imagery

Several cameras on the Golden Gate Bridge were obtained by the NTSB Investigator-In-Charge (IIC) and provided for evaluation. The camera videos provided several different views of the bridge between about 1155 through 1210 PDT. Several still images from the cameras are included below to show the conditions in the vicinity of the bridge immediately preceding the time of the accident and are included as figures 17-19.

Figure 17 is a still from Camera #1 at 1209:59 PDT from the North Tower looking north towards the entrance of the Golden Gate Bridge and approximately $\frac{3}{4}$ mile southeast of the accident site, which would be located near the top left side of the image. The image shows dense fog over the area with no clear definition of the coastline on the right or the higher terrain on the left, and no clear indication of the tower bridge on the other side of the bridge with visible estimated at less than $\frac{1}{2}$ mile.

Figure 18 is a still from Camera #2 at 1209:41 PDT from the Battery East Trail near the south abutment overlook at the Golden Gate Bridge Vista Point South, at an elevation near 189 ft, looking northwest. The location was about 1.7 miles south-southeast of the accident site on the southern side of the bridge and facing towards the accident location. The image depicts a flag waving and indicating a westerly wind

of at least 10 knots with fog advecting by. The visibility²¹ is estimated between 1/4 to 1/2 mile as the 1st tower of the bridge approximately 0.4 of a mile away or the main cables are never clearly identifiable, especially above the roadway. The vertical suspension cables are spaced every 50 ft and are not clearly identified beyond 500 ft.



Figure 17 - Camera #1 North Tower facing north towards entrance of bridge at 1209:59 PDT.

²¹ As defined in NWS Training Guide in Surface Weather Observations - Visibility is the greatest horizontal distance at which selected objects (visibility markers) can be seen and identified. Visibility is estimated on the sharpness with which the most distant markers or reference markers can be seen. If the markers can be seen clearly, with little loss of color, and with sharp outlines, it means that the visibility is much greater than the distance to the markers.



Figure 18 - Camera #2 Battery East Trail at Golden Gate Bridge Vista Point South facing northwest towards the accident site on the opposite side of the bridge at 1209:41 PDT.

Figure 19 is a still of Camera #6 from the South Tower pier or fender at 1209:50 PDT looking northwestward and 1.36 miles south-southeast of the accident site, which was in the top left side of the frame. The image depicts visibility restricted in fog with the northside of the channel never clearly identifiable and the sky and the high terrain on the opposite side of the channel obscured by the fog and stratus. At no time during the period from 1157 through 1210 PDT was the aircraft visible from the camera or the northside of the channel.



Figure 19 - Camera #6 C169 South Tower Fender facing north at 1209:50 PDT.

Submitted by:

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