



## **NATIONAL TRANSPORTATION SAFETY BOARD**

Office of Aviation Safety  
Washington, D.C. 20594

January 4, 2017

### **Weather Study**

# **METEOROLOGY**

WPR17FA023

## Table Of Contents

|      |                                                         |    |
|------|---------------------------------------------------------|----|
| A.   | ACCIDENT .....                                          | 3  |
| B.   | METEOROLOGIST .....                                     | 3  |
| C.   | SUMMARY .....                                           | 3  |
| D.   | DETAILS OF THE INVESTIGATION .....                      | 3  |
| E.   | FACTUAL INFORMATION .....                               | 4  |
| 1.0  | Synoptic Situation .....                                | 4  |
| 1.1  | Surface Analysis Chart .....                            | 4  |
| 1.2  | Upper Air Charts .....                                  | 5  |
| 2.0  | Storm Prediction Center Products .....                  | 10 |
| 3.0  | Surface Observations .....                              | 10 |
| 3.1  | One Minute Wind Observations .....                      | 15 |
| 4.0  | Upper Air Data .....                                    | 16 |
| 5.0  | Satellite Data .....                                    | 19 |
| 6.0  | Radar Imagery Information .....                         | 20 |
| 7.0  | Pilot Reports .....                                     | 20 |
| 8.0  | SIGMET and CWSU Advisory .....                          | 21 |
| 9.0  | AIRMETs .....                                           | 21 |
| 10.0 | Area Forecast .....                                     | 21 |
| 11.0 | Terminal Aerodrome Forecast .....                       | 23 |
| 12.0 | NWS Area Forecast Discussion .....                      | 23 |
| 13.0 | Winds and Temperature Aloft Forecast .....              | 25 |
| 14.0 | Pilot Weather Briefing and Witness Information .....    | 26 |
| 15.0 | Astronomical Data .....                                 | 26 |
| 16.0 | Wind Shear Associated with Temperature Inversions ..... | 27 |
| F.   | LIST OF ATTACHMENTS .....                               | 28 |

## **A. ACCIDENT**

Location: A half mile south-southeast of Moss Beach, California  
Date: November 18, 2016  
Time: 1118 Pacific standard time  
1918 Coordinated Universal Time (UTC)  
Airplane: Cessna 172N, N6610D

## **B. METEOROLOGIST**

Paul Suffern  
Group Chairman  
Operational Factors Division (AS-30)  
National Transportation Safety Board

## **C. SUMMARY**

On November 18, 2016, about 1120 Pacific standard time, a Cessna 172N, N6610D, sustained substantial damage after impacting terrain and objects in a residential area near Moss Beach, California, following a loss of control while on final approach to Half Moon Bay Airport (HAF), Half Moon Bay, California. The private pilot sustained serious injuries, and the non-pilot rated passenger was fatally injured. The personal cross-country flight was being operated in accordance with 14 *Code of Federal Regulation* Part 91, and a flight plan was not filed. Visual meteorological conditions prevailed for the flight, which originated from the Sacramento Executive Airport (SAC), Sacramento, California, about 1015, with HAF as the destination.

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

The National Transportation Safety Board's (NTSB) Meteorologist did not travel for this investigation and gathered the weather data for this investigation from the NTSB's Washington D.C. office and from official National Oceanic and Atmospheric Administration (NOAA) National Weather Service (NWS) sources including the National Centers for Environmental Information (NCEI). All times are Pacific standard time (PST) on November 18, 2016, and are based upon the 24-hour clock, where local time is -8 hours from UTC, and UTC=Z (unless otherwise noted). Directions are referenced to true north and distances in nautical miles. Heights are above mean sea level (msl) unless otherwise noted. Visibility is in statute miles and fractions of statute miles.

The accident site was located at latitude 37.520° N, longitude 122.511° W, at an approximate elevation of 70 feet.

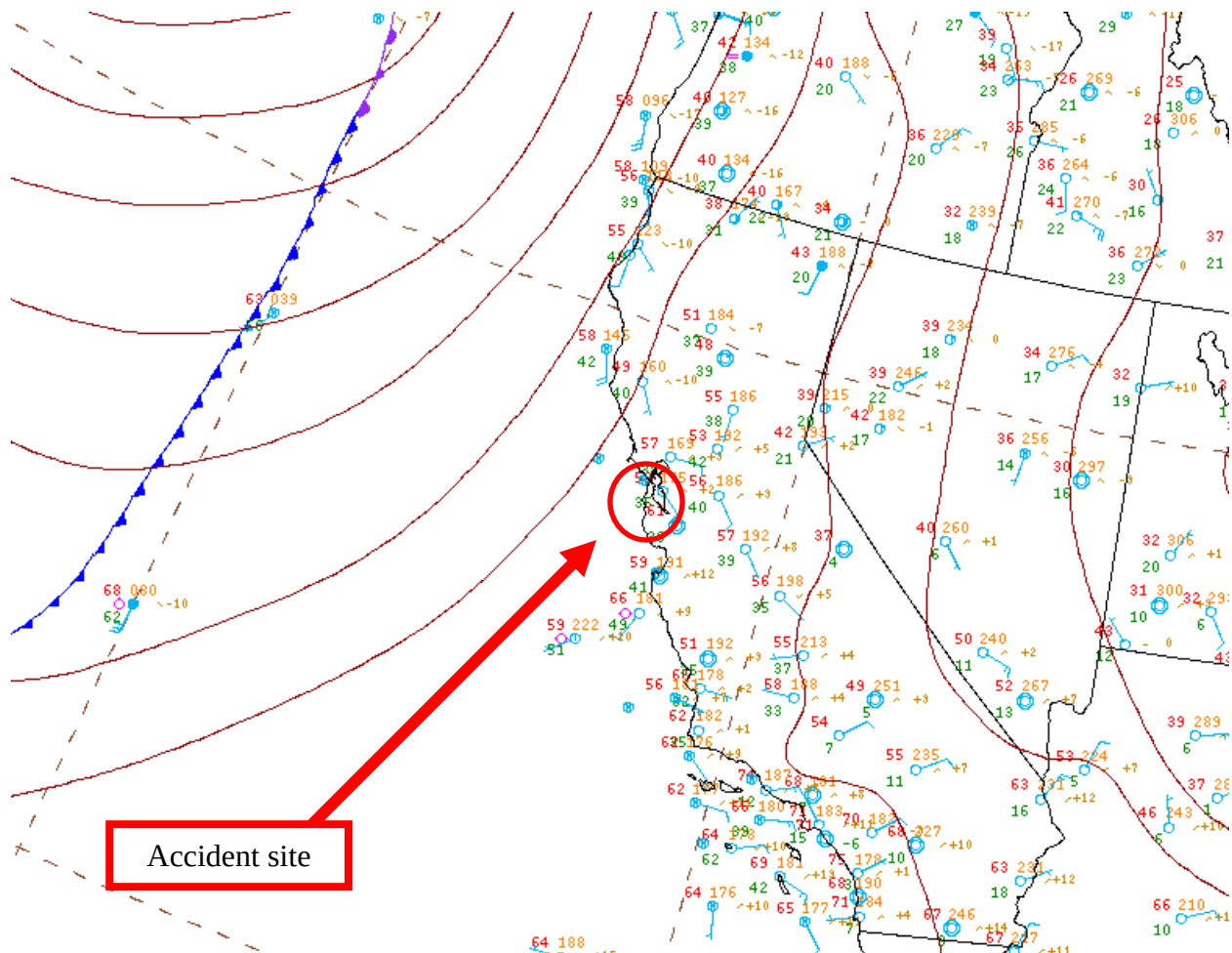
## **E. FACTUAL INFORMATION**

### **1.0 Synoptic Situation**

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 and the Weather Prediction Center, located in College Park, Maryland. These are the base products used in describing synoptic weather features and in the creation of forecasts and warnings for the NWS. Reference to these charts can be found in the joint NWS and Federal Aviation Administration (FAA) Advisory Circular “Aviation Weather Services”, AC-0045H.

#### **1.1 Surface Analysis Chart**

The NWS Surface Analysis Chart for 1000 PST is provided as figure 1 with the approximate location of the accident site marked within the red circle. The chart depicted an occluded to cold front located well west of the accident site in the eastern Pacific Ocean with the cold front stretching from north to south. There were no surface high or low pressure centers near the accident site; however, an increasing surface pressure gradient was indicated by the isobars (lines of constant pressure on the chart) with approaching cold front. The station models around the accident site at 1000 PST depicted air temperatures in the low 50’s to low 60’s degrees Fahrenheit (°F), with temperature-dew point spreads of 11° F or more, an east to southeast wind up to 10 knots, and clear skies. Given the lack of surface moisture and no frontal boundaries or surface low pressure systems near the accident site, this was not a favorable environment for the formation of clouds and precipitation, but the increasing surface pressure gradient was favorable for increasing surface wind speeds.



**Figure 1 – NWS Surface Analysis Chart for 1000 PST**

## 1.2 Upper Air Charts

The NWS Storm Prediction Center (SPC) Constant Pressure Charts for 1600 PST at 925-, 850-, 700-, 500-, and 300--hectopascals (hPa) are presented in figures 2 through 6. The SPC charts did not depict any low- or mid-level troughs<sup>1</sup> near the accident site at the accident time. There was a strong low pressure center located in the southern Gulf of Alaska, but its trough remained north and west of the accident site around the accident time. There was a south wind of 20 knots at 925-hPa (figure 2) with the wind becoming southwesterly by 700-hPa with the wind increasing in speed to 40 knots (figure 4). The 40-knot southwesterly wind at 700-hPa became a 90-knot westerly wind by 300-hPa (figure 6).

<sup>1</sup> Trough – An elongated area of relatively low atmospheric pressure or heights.

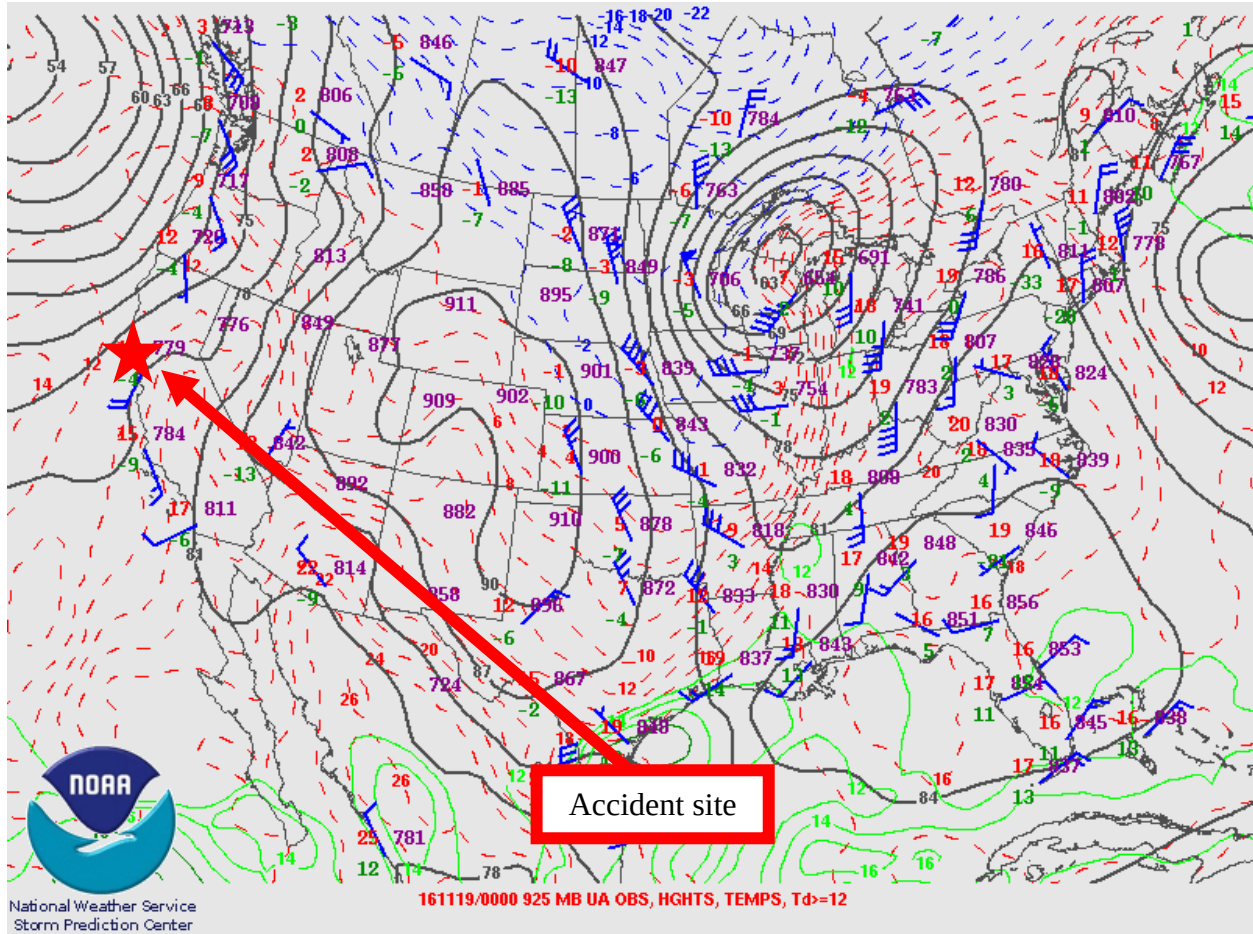
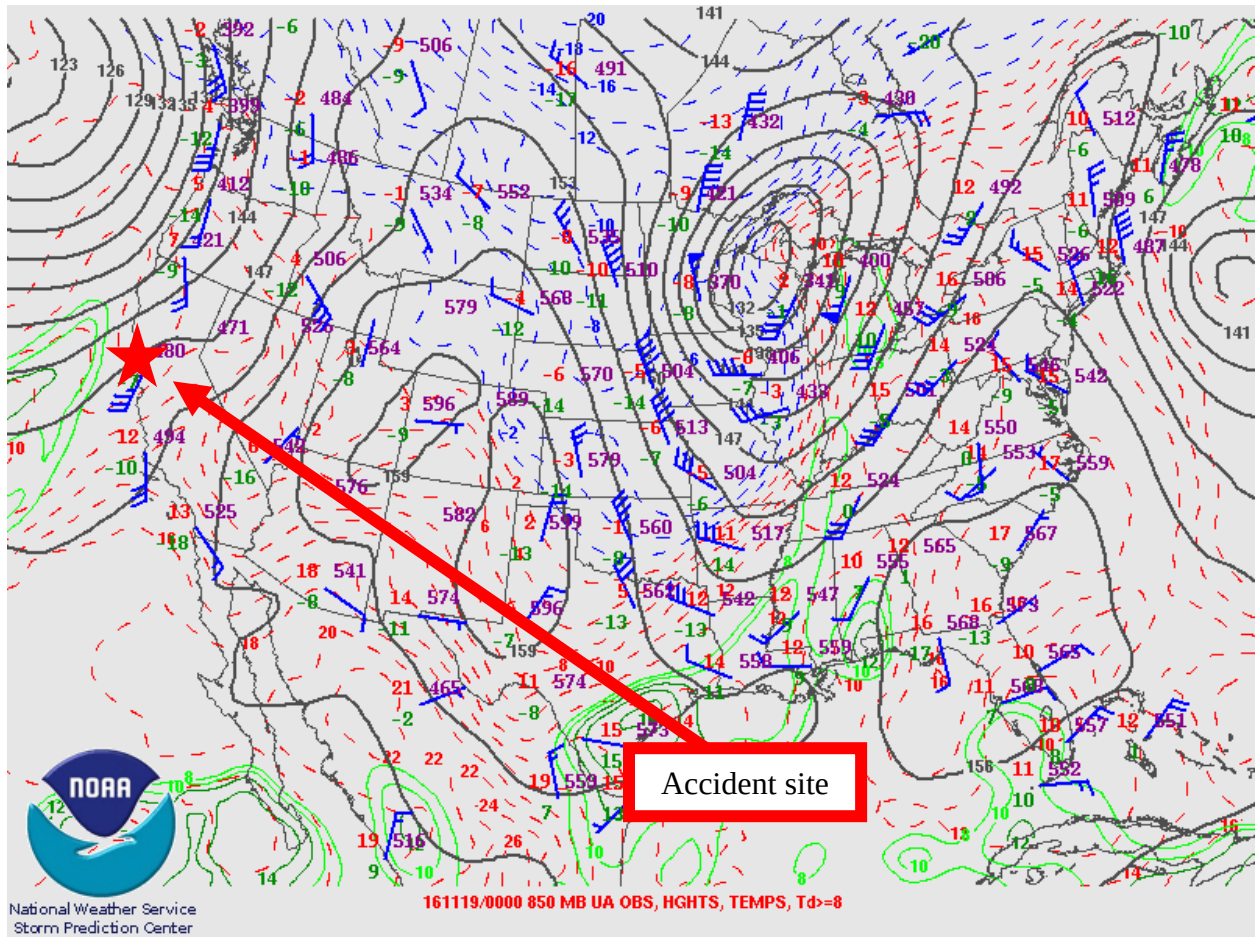
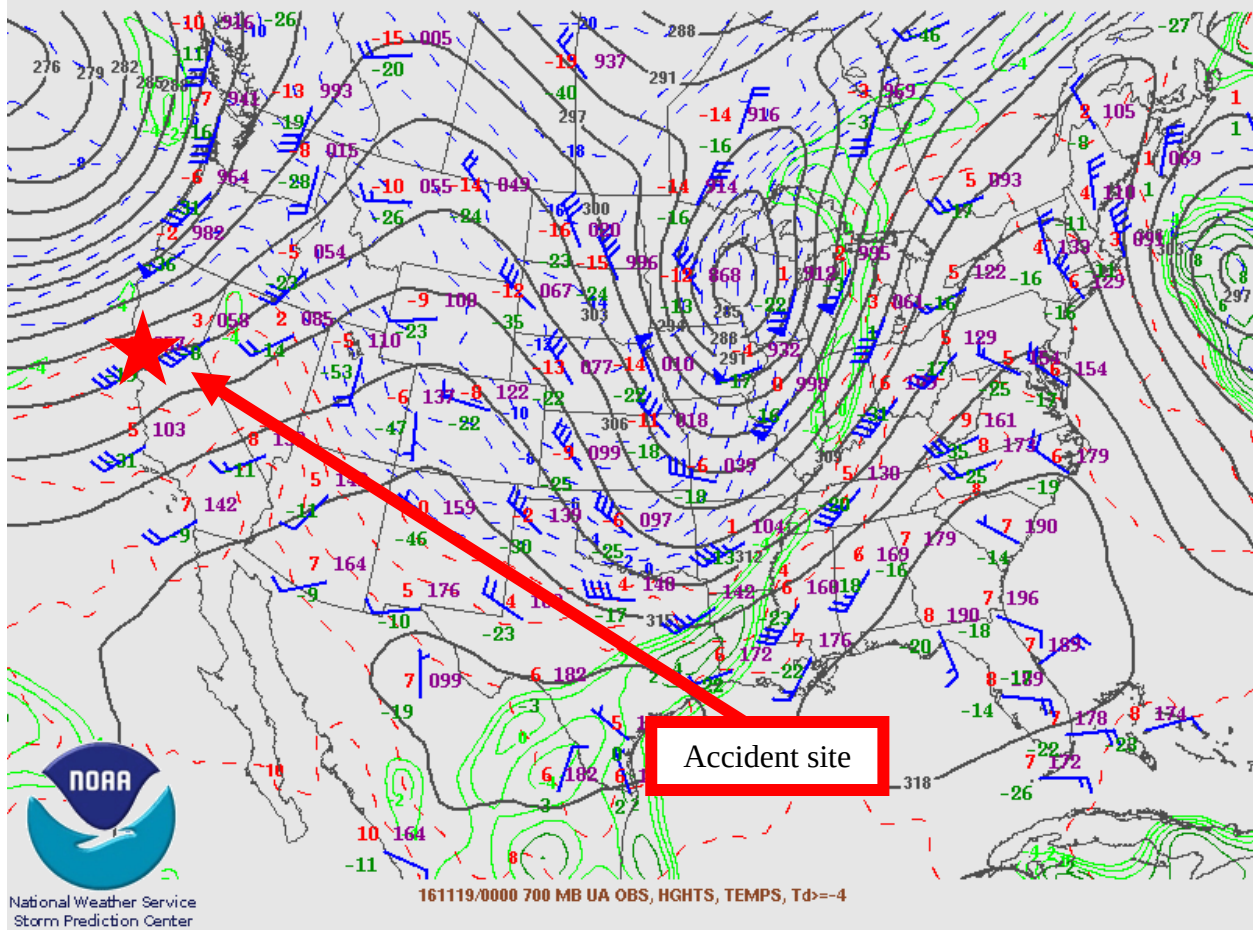


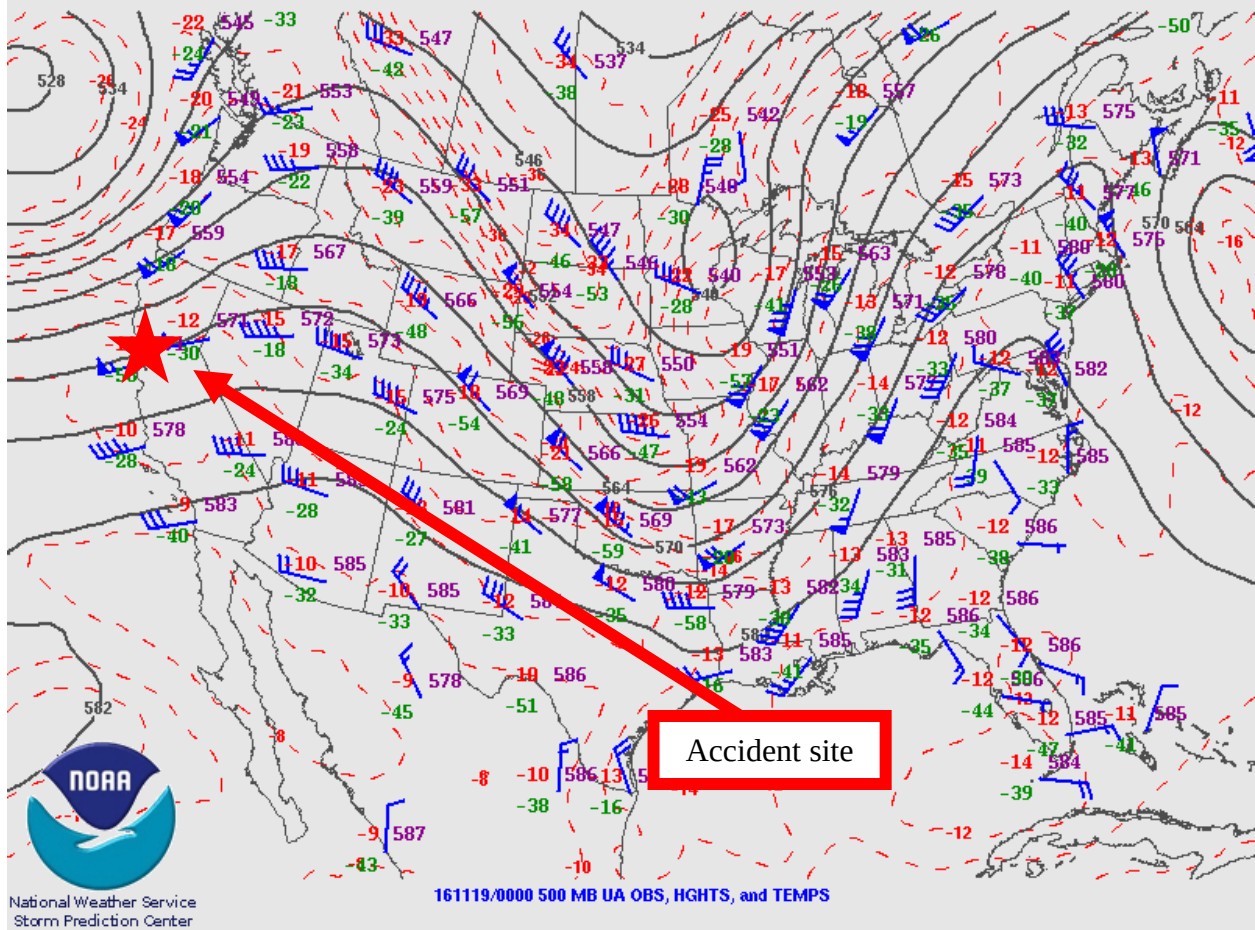
Figure 2 – 925-hPa Constant Pressure Chart for 1600 PST



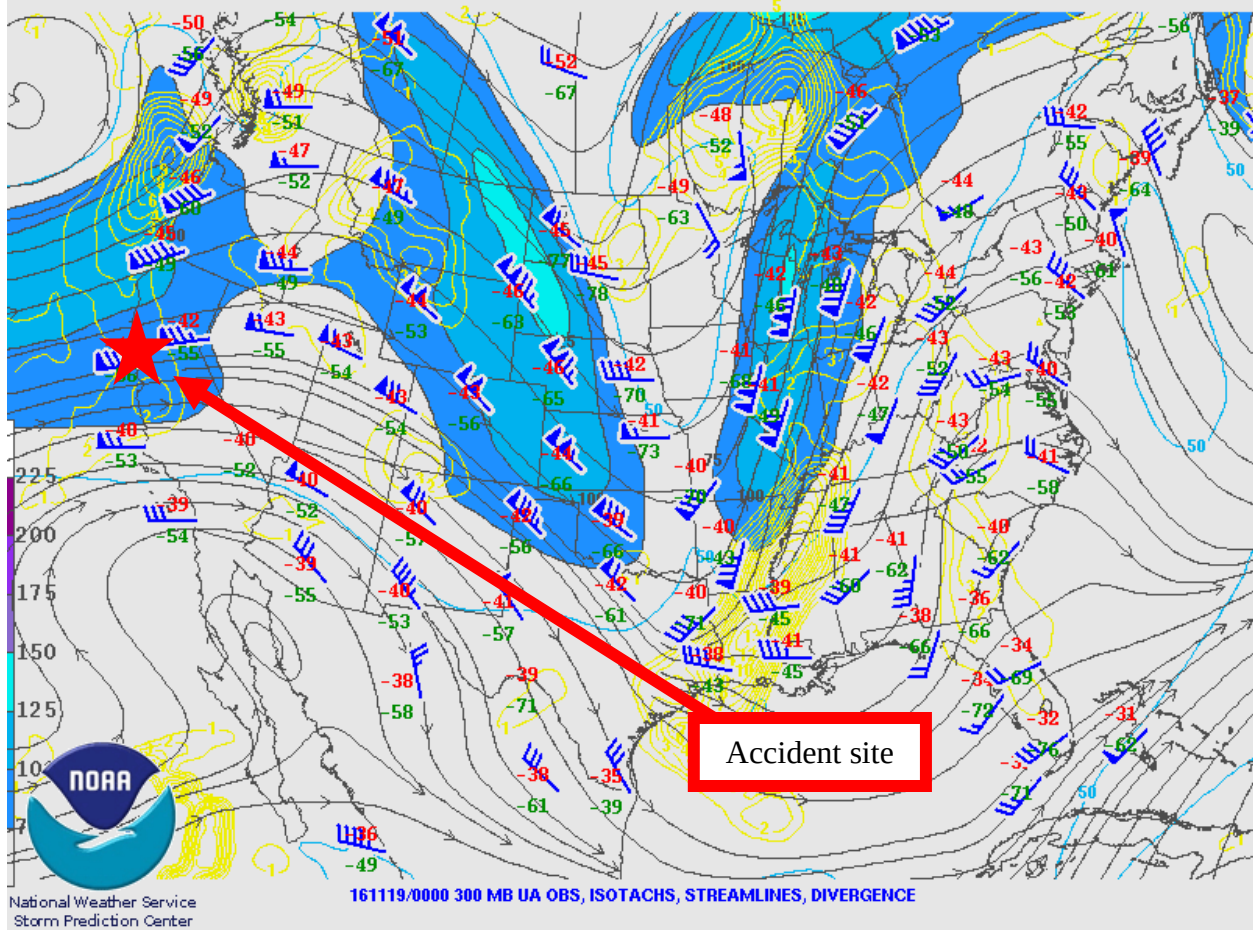
**Figure 3 – 850-hPa Constant Pressure Chart for 1600 PST**



**Figure 4 – 700-hPa Constant Pressure Chart for 1600 PST**



**Figure 5 – 500-hPa Constant Pressure Chart for 1600 PST**



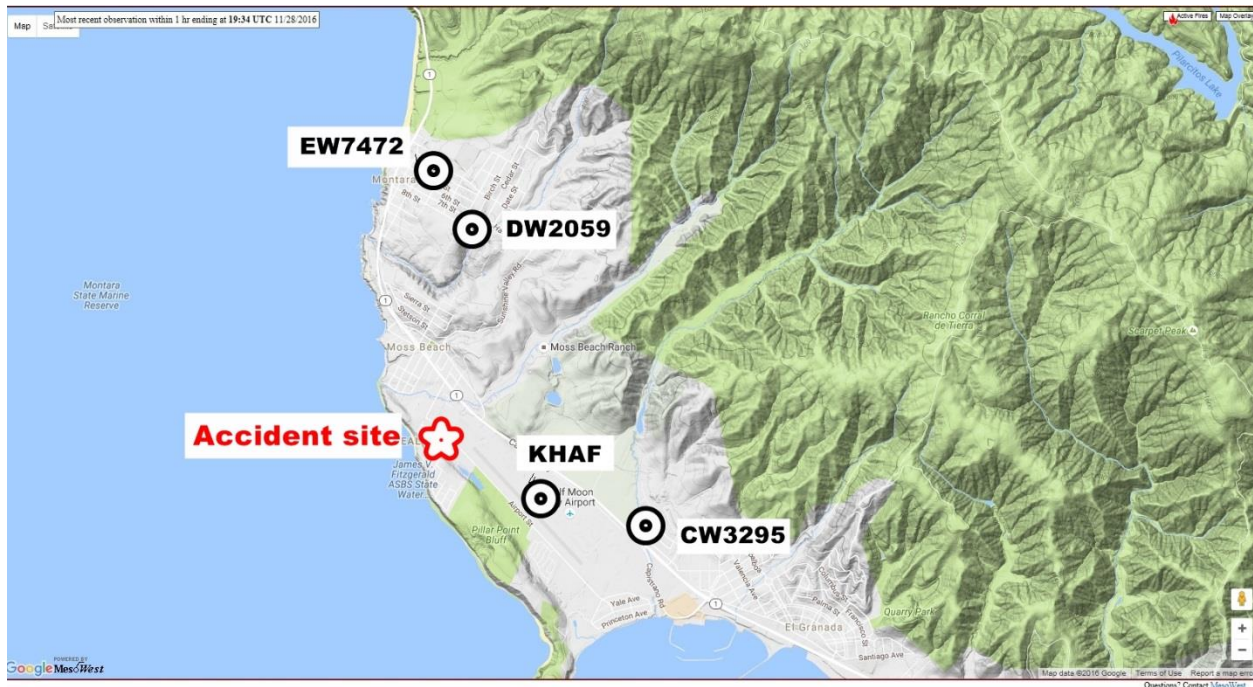
**Figure 6 – 300-hPa Constant Pressure Chart for 1600 PST**

## 2.0 Storm Prediction Center Products

There were no thunderstorms forecast for the accident site at the accident time.

## 3.0 Surface Observations

The area surrounding the accident site was documented utilizing official NWS Meteorological Aerodrome Reports (METARs) and Specials (SPECIs). The following observations were taken from standard code and are provided in plain language. Figure 7 is a local terrain map of the region with the accident site and the closest weather reporting locations marked.



**Figure 7 – Terrain map of Moss Beach, California, area with the location of the accident site and surface observation sites**

Half Moon Bay Airport (KHAF) was the closest official weather station to the accident site, located 5 miles northwest of Half Moon Bay, California. KHAF had an Automated Weather Observing System (AWOS<sup>2</sup>) whose reports were not supplemented by any human augmentation. KHAF was located under a mile east-southeast of the accident site, at an elevation of 66 feet, and had a 15° easterly magnetic variation<sup>3</sup> (figure 7). The following observations were taken and disseminated during the times surrounding the accident: <sup>4</sup>

[0855 PST] METAR KHAF 181655Z AUTO 17003KT 8SM CLR 14/04 A3005 RMK AO2=  
 [0915 PST] METAR KHAF 181715Z AUTO 15007KT 9SM CLR 15/04 A3005 RMK AO2=  
 [0935 PST] METAR KHAF 181735Z AUTO 15008KT 10SM CLR 17/02 A3005 RMK  
 AO2=

<sup>2</sup> AWOS – Automated Weather Observing System is equipped with meteorological instruments to observe and report temperature, dewpoint, wind speed and direction, visibility, cloud coverage and ceiling up to twelve thousand feet, and altimeter setting.

<sup>3</sup> Magnetic variation – The angle (at a particular location) between magnetic north and true north. 1995, latest measurement taken from <http://www.aimnav.com/airport/KHAF>

<sup>4</sup> The bold sections in this NWS product and the rest of products in this report are intended to highlight the sections that directly reference the weather conditions that affected the accident location around the accident time. The local times in section 3.0 next to the METARs are provided for quick reference between UTC and local times around the accident time.

[0955 PST] METAR KHAF 181755Z AUTO 16008KT 10SM CLR 17/02 A3005 RMK  
AO2=  
[1015 PST] METAR KHAF 181815Z AUTO 17010G16KT 10SM CLR 17/02 A3004 RMK  
AO2=  
[1035 PST] METAR KHAF 181835Z AUTO 17008KT 10SM CLR 17/03 A3004 RMK  
AO2=  
***[1055 PST] METAR KHAF 181855Z AUTO 18009KT 10SM CLR 17/03 A3003 RMK  
AO2=***  
***[1115 PST] METAR KHAF 181915Z AUTO 19010G14KT 10SM CLR 17/03 A3003 RMK  
AO2=***

**ACCIDENT TIME 1118 PST**

***[1135 PST] METAR KHAF 181935Z AUTO 17010G17KT 10SM CLR 17/05 A3002 RMK  
AO2=***  
***[1155 PST] METAR KHAF 181955Z AUTO 19014G21KT 9SM CLR 17/03 A3001 RMK  
AO2=***  
[1215 PST] METAR KHAF 182015Z AUTO 20014KT 3SM HZ CLR 17/04 A3001 RMK  
AO2=  
[1235 PST] METAR KHAF 182035Z AUTO 20015G19KT 10SM CLR 16/06 A3000 RMK  
AO2=

KHAF weather at 1055 PST, wind from 180° at 9 knots, 10 miles visibility, clear skies below 12,000 feet above ground level (agl), temperature of 17° Celsius (C), dew point temperature of 3° C, and an altimeter setting of 30.03 inches of mercury. Remarks: automated station with a precipitation discriminator.

KHAF weather at 1115 PST, wind from 190° at 10 knots with gusts to 14 knots, 10 miles visibility, clear skies below 12,000 feet agl, temperature of 17° C, dew point temperature of 3° C, and an altimeter setting of 30.03 inches of mercury. Remarks: automated station with a precipitation discriminator.

KHAF weather at 1135 PST, wind from 170° at 10 knots with gusts to 17 knots, 10 miles visibility, clear skies below 12,000 feet agl, temperature of 17° C, dew point temperature of 5° C, and an altimeter setting of 30.02 inches of mercury. Remarks: automated station with a precipitation discriminator.

KHAF weather at 1155 PST, wind from 190° at 14 knots with gusts to 21 knots, 9 miles visibility, clear skies below 12,000 feet agl, temperature of 17° C, dew point temperature of 3° C, and an altimeter setting of 30.01 inches of mercury. Remarks: automated station with a precipitation discriminator.

CW3295 Half Moon Bay (CW3295) was an Automatic Position Reporting System as a WX NET/Citizen Weather Observer Program (APRSWXNET/CWOP) mesonet station and was the closest non-official surface observation site to the accident site located 1 mile east-southeast of the accident site at an elevation of 59 feet (figure 7) and figure 8 contains the observations surrounding the accident time:

| # STATION: C3295                     |                      |           |            |                   |            |                |            |                       |                         |                 |
|--------------------------------------|----------------------|-----------|------------|-------------------|------------|----------------|------------|-----------------------|-------------------------|-----------------|
| # STATION NAME: CW3295 Half Moon Bay |                      |           |            |                   |            |                |            |                       |                         |                 |
| # LATITUDE: 37.51133                 |                      |           |            |                   |            |                |            |                       |                         |                 |
| # LONGITUDE: -122.48733              |                      |           |            |                   |            |                |            |                       |                         |                 |
| # ELEVATION [ft]: 59                 |                      |           |            |                   |            |                |            |                       |                         |                 |
| # STATE: CA                          |                      |           |            |                   |            |                |            |                       |                         |                 |
| Station_ID                           | Date_Time            | altimeter | air_temp   | relative_humidity | wind_speed | wind_direction | wind_gust  | dew_point_temperature | wind_cardinal_direction | pressure_set_1d |
|                                      |                      | INHG      | Fahrenheit | %                 | Miles/hour | Degrees        | Miles/hour | Fahrenheit            | Code                    | INHG            |
| C3295                                | 11/18/2016 07:53 PST | 30.01     | 48.99      | 64                | 0          |                | 2.01       | 37.22                 |                         | 29.95           |
| C3295                                | 11/18/2016 09:33 PST | 30.01     | 63         | 36                | 4          | 122            | 10         | 35.49                 | ESE                     | 29.95           |
| C3295                                | 11/18/2016 09:53 PST | 30.01     | 64         | 39                | 4.99       | 130            | 10         | 38.42                 | SE                      | 29.95           |
| C3295                                | 11/18/2016 10:03 PST | 30.01     | 64         | 38                | 4          | 152            | 8.99       | 37.75                 | SSE                     | 29.95           |
| C3295                                | 11/18/2016 10:13 PST | 30.01     | 64         | 37                | 4          | 130            | 12.01      | 37.07                 | SE                      | 29.95           |
| C3295                                | 11/18/2016 11:03 PST | 30        | 63         | 54                | 2.01       | 149            | 5.99       | 45.99                 | SSE                     | 29.94           |
| C3295                                | 11/18/2016 11:13 PST | 30        | 63         | 52                | 1.01       | 157            | 4          | 44.99                 | SSE                     | 29.94           |
| C3295                                | 11/18/2016 11:23 PST | 29.99     | 63         | 54                | 3          | 121            | 10         | 45.99                 | ESE                     | 29.93           |
| C3295                                | 11/18/2016 11:43 PST | 29.98     | 63         | 54                | 3          | 130            | 8.99       | 45.99                 | SE                      | 29.92           |
| C3295                                | 11/18/2016 12:03 PST | 29.98     | 63         | 55                | 1.01       | 194            | 10         | 46.47                 | SSW                     | 29.92           |
| C3295                                | 11/18/2016 12:13 PST | 29.97     | 63         | 54                | 4          | 134            | 11.01      | 45.99                 | SE                      | 29.91           |
| C3295                                | 11/18/2016 12:43 PST | 29.96     | 62.01      | 61                | 3          | 197            | 8.01       | 48.31                 | SSW                     | 29.9            |
| C3295                                | 11/18/2016 13:13 PST | 29.95     | 61         | 61                | 1.01       | 140            | 8.01       | 47.36                 | SE                      | 29.89           |
| C3295                                | 11/18/2016 13:23 PST | 29.95     | 62.01      | 62                | 2.01       | 186            | 5.99       | 48.75                 | S                       | 29.89           |
| C3295                                | 11/18/2016 13:43 PST | 29.95     | 61         | 62                | 1.01       | 189            | 4.99       | 47.79                 | S                       | 29.89           |
| C3295                                | 11/18/2016 14:03 PST | 29.95     | 61         | 64                | 1.01       | 177            | 7          | 48.65                 | S                       | 29.89           |
| C3295                                | 11/18/2016 14:23 PST | 29.94     | 60.01      | 69                | 4          | 128            | 12.01      | 49.73                 | SE                      | 29.88           |
| C3295                                | 11/18/2016 14:33 PST | 29.95     | 60.01      | 71                | 2.01       | 186            | 12.01      | 50.5                  | S                       | 29.89           |
| C3295                                | 11/18/2016 14:53 PST | 29.95     | 60.01      | 72                | 8.99       | 100            | 11.01      | 50.89                 | E                       | 29.89           |
| C3295                                | 11/18/2016 15:43 PST | 29.95     | 59         | 76                | 3          | 122            | 11.01      | 51.38                 | ESE                     | 29.89           |
| C3295                                | 11/18/2016 15:53 PST | 29.95     | 59         | 77                | 4          | 132            | 10         | 51.74                 | SE                      | 29.89           |
| C3295                                | 11/18/2016 16:03 PST | 29.94     | 59         | 78                | 7          | 130            | 13         | 52.09                 | SE                      | 29.88           |
| C3295                                | 11/18/2016 16:13 PST | 29.94     | 57.99      | 79                | 10         | 132            | 13         | 51.46                 | SE                      | 29.88           |
| C3295                                | 11/18/2016 17:03 PST | 29.94     | 57         | 86                | 8.01       | 132            | 10         | 52.81                 | SE                      | 29.88           |
| C3295                                | 11/18/2016 17:13 PST | 29.94     | 57         | 86                | 4.99       | 81             | 10         | 52.81                 | E                       | 29.88           |
| C3295                                | 11/18/2016 17:23 PST | 29.94     | 57         | 87                | 4          | 119            | 8.01       | 53.13                 | ESE                     | 29.88           |
| C3295                                | 11/18/2016 17:33 PST | 29.94     | 55.99      | 87                | 3          | 117            | 7          | 52.14                 | ESE                     | 29.88           |
| C3295                                | 11/18/2016 17:53 PST | 29.94     | 55.99      | 86                | 2.01       | 105            | 8.99       | 51.82                 | ESE                     | 29.88           |

**Figure 8 – List of observations from CW3295 surrounding the accident time**

CW3295 weather at 1103 PST was reported as wind from 149° at 2.01 mph with gusts to 5.99 mph, temperature of 63° F, and a dew point temperature of 45.99° F.

CW3295 weather at 1113 PST was reported as wind from 157° at 1.01 mph with gusts to 4 mph, temperature of 63° F, and a dew point temperature of 44.99° F.

CW3295 weather at 1123 PST was reported as wind from 121° at 3 mph with gusts to 10 mph, temperature of 63° F, and a dew point temperature of 45.99° F.

DW2059 Montara (DW2059) was an APRSWXNET/CWOP mesonet station and a non-official surface observation site located 1 mile north of the accident site. DW2059 was located at an elevation of 167 feet (figure 7) and figure 9 contains the observations surrounding the accident time:

| # STATION: D2059               |                      |           |            |                   |            |                |            |                       |                         |          |           |                 |
|--------------------------------|----------------------|-----------|------------|-------------------|------------|----------------|------------|-----------------------|-------------------------|----------|-----------|-----------------|
| # STATION NAME: DW2059 Montara |                      |           |            |                   |            |                |            |                       |                         |          |           |                 |
| # LATITUDE: 37.53769           |                      |           |            |                   |            |                |            |                       |                         |          |           |                 |
| # LONGITUDE: -122.50693        |                      |           |            |                   |            |                |            |                       |                         |          |           |                 |
| # ELEVATION [ft]: 167          |                      |           |            |                   |            |                |            |                       |                         |          |           |                 |
| # STATE: CA                    |                      |           |            |                   |            |                |            |                       |                         |          |           |                 |
| Station_ID                     | Date_Time            | altimeter | air_temp   | relative_humidity | wind_speed | wind_direction | wind_gust  | dew_point_temperature | wind_cardinal_direction | pressure | sea_level | pressure_set_1d |
|                                |                      | INHG      | Fahrenheit | %                 | Miles/hour | Degrees        | Miles/hour | Fahrenheit            | Code                    | INHG     | INHG      |                 |
| D2059                          | 11/18/2016 08:57 PST | 30        | 50         | 66                | 1.01       | 202            | 3          | 38.98                 | SSW                     | 29.82    | 29.81     |                 |
| D2059                          | 11/18/2016 09:07 PST | 29.99     | 52         | 62                | 1.01       | 223            | 4.99       | 39.26                 | SW                      | 29.81    | 29.8      |                 |
| D2059                          | 11/18/2016 09:27 PST | 29.99     | 55.99      | 54                | 1.01       | 103            | 3          | 39.44                 | ESE                     | 29.81    | 29.79     |                 |
| D2059                          | 11/18/2016 09:37 PST | 30        | 57.99      | 48                | 1.01       | 159            | 5.99       | 38.27                 | SSE                     | 29.82    | 29.8      |                 |
| D2059                          | 11/18/2016 09:47 PST | 29.99     | 60.01      | 47                | 1.01       | 167            | 4.99       | 39.58                 | SSE                     | 29.81    | 29.78     |                 |
| D2059                          | 11/18/2016 09:57 PST | 29.99     | 61         | 46                | 2.01       | 194            | 5.99       | 39.94                 | SSW                     | 29.81    | 29.78     |                 |
| D2059                          | 11/18/2016 10:07 PST | 29.99     | 62.01      | 43                | 2.01       | 240            | 4.99       | 39.12                 | WSW                     | 29.81    | 29.78     |                 |
| D2059                          | 11/18/2016 10:17 PST | 29.99     | 62.01      | 40                | 2.01       | 161            | 8.01       | 37.27                 | SSE                     | 29.81    | 29.79     |                 |
| D2059                          | 11/18/2016 10:27 PST | 29.99     | 63         | 41                | 7          | 217            | 10         | 38.8                  | SW                      | 29.81    | 29.78     |                 |
| D2059                          | 11/18/2016 10:37 PST | 29.98     | 63         | 39                | 1.01       | 23             | 7          | 37.52                 | NNE                     | 29.8     | 29.78     |                 |
| D2059                          | 11/18/2016 10:47 PST | 29.98     | 64         | 42                | 0          |                | 7          | 40.32                 |                         | 29.8     | 29.76     |                 |
| D2059                          | 11/18/2016 10:57 PST | 29.98     | 64         | 46                | 1.01       | 66             | 4          | 42.69                 | ENE                     | 29.8     | 29.74     |                 |
| D2059                          | 11/18/2016 11:07 PST | 29.98     | 64         | 41                | 1.01       | 171            | 4.99       | 39.7                  | S                       | 29.8     | 29.76     |                 |
| D2059                          | 11/18/2016 11:17 PST | 29.97     | 64.99      | 41                | 3          | 214            | 4.99       | 40.6                  | SW                      | 29.79    | 29.74     |                 |
| D2059                          | 11/18/2016 11:27 PST | 29.97     | 66         | 39                | 3          | 182            | 10         | 40.22                 | S                       | 29.79    | 29.74     |                 |
| D2059                          | 11/18/2016 11:37 PST | 29.96     | 66.99      | 39                | 2.01       | 200            | 7          | 41.11                 | SSW                     | 29.78    | 29.73     |                 |
| D2059                          | 11/18/2016 11:47 PST | 29.96     | 66         | 40                | 3          | 113            | 10         | 40.87                 | ESE                     | 29.78    | 29.73     |                 |
| D2059                          | 11/18/2016 11:57 PST | 29.95     | 66         | 39                | 4          | 163            | 7          | 40.22                 | SSE                     | 29.77    | 29.72     |                 |
| D2059                          | 11/18/2016 12:07 PST | 29.95     | 64.99      | 41                | 3          | 319            | 8.99       | 40.6                  | NW                      | 29.77    | 29.72     |                 |
| D2059                          | 11/18/2016 12:17 PST | 29.94     | 64         | 47                | 7          | 190            | 12.01      | 43.25                 | S                       | 29.76    | 29.69     |                 |
| D2059                          | 11/18/2016 12:27 PST | 29.94     | 64.99      | 49                | 12.01      | 147            | 12.01      | 45.26                 | SSE                     | 29.76    | 29.67     |                 |
| D2059                          | 11/18/2016 12:37 PST | 29.94     | 64         | 52                | 4.99       | 89             | 11.01      | 45.92                 | E                       | 29.76    | 29.67     |                 |
| D2059                          | 11/18/2016 12:47 PST | 29.93     | 64         | 52                | 11.01      | 167            | 11.01      | 45.92                 | SSE                     | 29.75    | 29.66     |                 |
| D2059                          | 11/18/2016 12:57 PST | 29.93     | 64         | 52                | 5.99       | 142            | 11.01      | 45.92                 | SE                      | 29.75    | 29.66     |                 |
| D2059                          | 11/18/2016 13:07 PST | 29.92     | 64         | 52                | 1.01       | 149            | 12.01      | 45.92                 | SSE                     | 29.74    | 29.65     |                 |
| D2059                          | 11/18/2016 13:17 PST | 29.93     | 64         | 52                | 5.99       | 180            | 10         | 45.92                 | S                       | 29.75    | 29.66     |                 |
| D2059                          | 11/18/2016 13:27 PST | 29.92     | 64.99      | 51                | 1.01       | 117            | 8.99       | 46.32                 | ESE                     | 29.74    | 29.64     |                 |
| D2059                          | 11/18/2016 13:37 PST | 29.93     | 64.99      | 52                | 4          | 224            | 11.01      | 46.84                 | SW                      | 29.75    | 29.65     |                 |
| D2059                          | 11/18/2016 13:47 PST | 29.93     | 64.99      | 55                | 1.01       | 296            | 8.01       | 48.34                 | WNW                     | 29.75    | 29.63     |                 |

**Figure 9 – List of observations from DW2059 surrounding the accident time**

DW2059 weather at 1107 PST was reported as wind from 171° at 1.01 mph with gusts to 4.99 mph, temperature of 64° F, dew point temperature of 39.7° F.

DW2059 weather at 1117 PST was reported as wind from 214° at 3 mph with gusts to 4.99 mph, temperature of 64.99° F, dew point temperature of 40.6° F.

DW2059 weather at 1127 PST was reported as wind from 182° at 3 mph with gusts to 10 mph, temperature of 66° F, dew point temperature of 40.22° F.

EW7472 Montara (EW7472) was another APRSWXNET/CWOP mesonet station and a non-official surface observation site located 1 mile north of the accident site. EW7472 was located at an elevation of 125 feet (figure 7) and figure 10 contains the observations surrounding the accident time:

| # STATION: E7472               |                      |           |            |                   |            |                |            |                       |                         |                 |
|--------------------------------|----------------------|-----------|------------|-------------------|------------|----------------|------------|-----------------------|-------------------------|-----------------|
| # STATION NAME: EW7472 Montara |                      |           |            |                   |            |                |            |                       |                         |                 |
| # LATITUDE: 37.54283           |                      |           |            |                   |            |                |            |                       |                         |                 |
| # LONGITUDE: -122.51083        |                      |           |            |                   |            |                |            |                       |                         |                 |
| # ELEVATION [ft]: 125          |                      |           |            |                   |            |                |            |                       |                         |                 |
| # STATE: CA                    |                      |           |            |                   |            |                |            |                       |                         |                 |
| Station_ID                     | Date_Time            | altimeter | air_temp   | relative_humidity | wind_speed | wind_direction | wind_gust  | dew_point_temperature | wind_cardinal_direction | pressure_set_id |
|                                |                      | INHG      | Fahrenheit | %                 | Miles/hour | Degrees        | Miles/hour | Fahrenheit            | Code                    | INHG            |
| E7472                          | 11/18/2016 09:21 PST | 30.03     | 63         |                   | 35         | 3              | 135        | 7                     | 34.78 SE                | 29.89           |
| E7472                          | 11/18/2016 09:31 PST | 30.03     | 64         |                   | 34         | 4              | 158        | 7                     | 34.93 SSE               | 29.89           |
| E7472                          | 11/18/2016 09:52 PST | 30.03     | 64         |                   | 32         | 5.99           | 135        | 8.99                  | 33.41 SE                | 29.89           |
| E7472                          | 11/18/2016 10:02 PST | 30.03     | 64         |                   | 34         | 5.99           | 180        | 8.99                  | 34.93 S                 | 29.89           |
| E7472                          | 11/18/2016 10:12 PST | 30.03     | 64.99      |                   | 34         | 4.99           | 135        | 8.01                  | 35.81 SE                | 29.89           |
| E7472                          | 11/18/2016 10:22 PST | 30.03     | 64.99      |                   | 34         | 2.01           | 203        | 8.99                  | 35.81 SSW               | 29.89           |
| E7472                          | 11/18/2016 10:32 PST | 30.03     | 64.99      |                   | 34         | 4.99           | 203        | 14                    | 35.81 SSW               | 29.89           |
| E7472                          | 11/18/2016 10:43 PST | 30.03     | 64.99      |                   | 34         | 4.99           | 90         | 8.99                  | 35.81 E                 | 29.89           |
| E7472                          | 11/18/2016 10:53 PST | 30.01     | 64.99      |                   | 37         | 4              | 203        | 8.01                  | 37.96 SSW               | 29.87           |
| E7472                          | 11/18/2016 11:03 PST | 30.01     | 64.99      |                   | 37         | 5.99           | 180        | 8.01                  | 37.96 S                 | 29.87           |
| E7472                          | 11/18/2016 11:13 PST | 30.01     | 64.99      |                   | 37         | 4.99           | 135        | 8.99                  | 37.96 SE                | 29.87           |
| E7472                          | 11/18/2016 11:24 PST | 30.01     | 64.99      |                   | 37         | 5.99           | 203        | 8.99                  | 37.96 SSW               | 29.87           |
| E7472                          | 11/18/2016 11:34 PST | 30.01     | 64.99      |                   | 37         | 4.99           | 158        | 8.01                  | 37.96 SSE               | 29.87           |
| E7472                          | 11/18/2016 11:45 PST | 30        | 64.99      |                   | 39         | 4              | 203        | 8.99                  | 39.31 SSW               | 29.86           |
| E7472                          | 11/18/2016 11:55 PST | 30        | 64.99      |                   | 40         | 4.99           | 135        | 12.01                 | 39.96 SE                | 29.86           |
| E7472                          | 11/18/2016 12:06 PST | 29.98     | 64         |                   | 40         | 8.99           | 113        | 13                    | 39.07 ESE               | 29.84           |
| E7472                          | 11/18/2016 12:17 PST | 29.98     | 64         |                   | 44         | 5.99           | 158        | 11.01                 | 41.53 SSE               | 29.84           |
| E7472                          | 11/18/2016 12:27 PST | 29.98     | 63         |                   | 50         | 7              | 180        | 10                    | 43.95 S                 | 29.84           |
| E7472                          | 11/18/2016 12:37 PST | 29.98     | 63         |                   | 50         | 7              | 203        | 12.01                 | 43.95 SSW               | 29.84           |
| E7472                          | 11/18/2016 12:48 PST | 29.96     | 63         |                   | 51         | 7              | 90         | 12.01                 | 44.47 E                 | 29.83           |
| E7472                          | 11/18/2016 12:59 PST | 29.96     | 64         |                   | 51         | 5.99           | 135        | 11.01                 | 45.4 SE                 | 29.83           |
| E7472                          | 11/18/2016 13:09 PST | 29.96     | 63         |                   | 51         | 7              | 180        | 10                    | 44.47 S                 | 29.83           |
| E7472                          | 11/18/2016 13:20 PST | 29.96     | 63         |                   | 50         | 8.01           | 180        | 13                    | 43.95 S                 | 29.83           |
| E7472                          | 11/18/2016 13:31 PST | 29.96     | 62.01      |                   | 51         | 8.01           | 180        | 12.01                 | 43.56 S                 | 29.83           |
| E7472                          | 11/18/2016 13:41 PST | 29.96     | 62.01      |                   | 55         | 8.01           | 203        | 12.01                 | 45.55 SSW               | 29.83           |
| E7472                          | 11/18/2016 13:52 PST | 29.96     | 62.01      |                   | 54         | 5.99           | 338        | 10                    | 45.06 NNW               | 29.83           |
| E7472                          | 11/18/2016 14:02 PST | 29.96     | 62.01      |                   | 55         | 4              | 203        | 12.01                 | 45.55 SSW               | 29.83           |
| E7472                          | 11/18/2016 14:13 PST | 29.96     | 62.01      |                   | 58         | 5.99           | 248        | 11.01                 | 46.96 WSW               | 29.83           |

**Figure 10 – List of observations from EW7472 surrounding the accident time**

EW7472 weather at 1113 PST was reported as wind from 135° at 4.99 mph with gusts to 8.99 mph, temperature of 64.99° F, dew point temperature of 37.96° F.

EW7472 weather at 1124 PST was reported as wind from 203° at 5.99 mph with gusts to 8.99 mph, temperature of 64.99° F, dew point temperature of 37.96° F.

EW7472 weather at 1134 PST was reported as wind from 158° at 4.99 mph with gusts to 8.01 mph, temperature of 64.99° F, dew point temperature of 37.96° F.

### 3.1 One Minute Wind Observations

The one-minute KHAF AWOS surface data was provided by All Weather Inc. for the time surrounding the accident in standard METAR format. One-minute raw wind data was provided with separate magnitudes and wind directions and the wind directions in reference to magnetic north. Attachment 1 contains the KHAF AWOS information from 1720 UTC (0920 PST) through 2129 UTC (1329 PST).

At 1117 PST, KHAF reported the wind from 170° at 11 knots.

At 1118 PST, KHAF reported the wind from 170° at 11 knots.

At 1119 PST, KHAF reported the wind from 180° at 11 knots.

The observations from KHAF, CW3295, DW2059, and EW7472 surrounding the accident time indicated VFR<sup>5</sup> conditions around the accident site at the accident time. There were some gusty surface wind conditions reported at KHAF, but no gusts above 20 knots until 1149 PST. There were some rather large changes in wind direction. The wind direction at KHAF was also from 170° to 190° which would have resulted in a 9 to 12 knot crosswind component for runway 12 approach into KHAF.

#### 4.0 Upper Air Data

A High-Resolution Rapid Refresh (HRRR) model sounding was created for the accident site for 1100 PST. The 1100 PST sounding was plotted on a standard Skew-T log P diagram<sup>6</sup> with the derived stability parameters included in figure 11 (with data from the surface to 700-hPa, or 10,000 feet msl.) This data was analyzed utilizing the RAOB<sup>7</sup> software package. The sounding depicted the lifted condensation level (LCL)<sup>8</sup> at 3,522 feet and a convective condensation level (CCL)<sup>9</sup> of 19,239 feet. The freezing level was located at 11,577 feet. The precipitable water value was 0.36 inches.

---

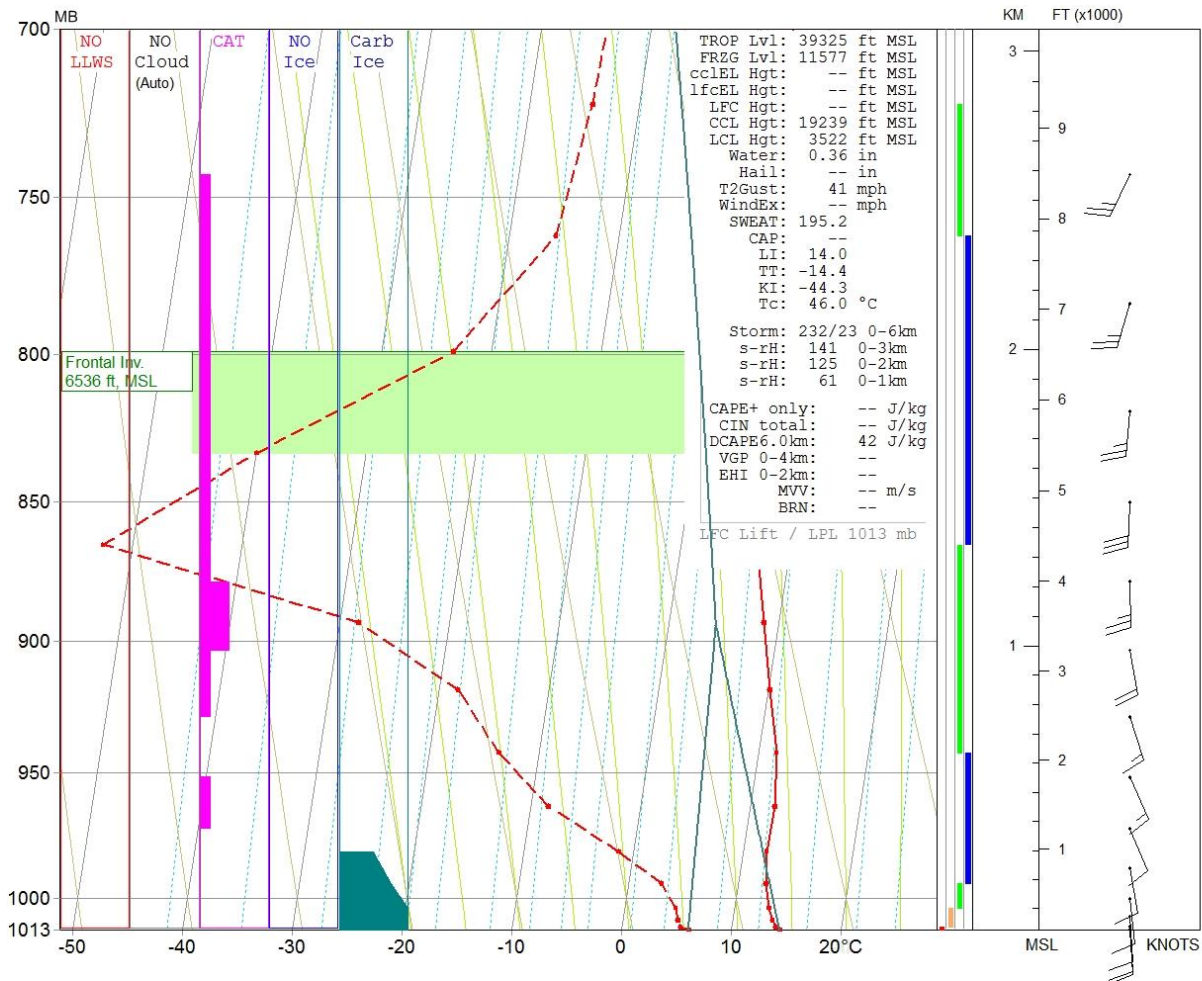
<sup>5</sup> Visual Flight Rules – Refers to the general weather conditions pilots can expect at the surface. VFR criteria means a ceiling greater than 3,000 feet agl and greater than 6 miles visibility.

<sup>6</sup> Skew T log P diagram – is a standard meteorological plot using temperature and the logarithmic of pressure as coordinates, used to display winds, temperature, dew point, and various indices used to define the vertical structure of the atmosphere.

<sup>7</sup> RAOB – (The complete Rawinsonde Observation program) is an interactive sounding analysis program developed by Environmental Research Services, Matamoras, Pennsylvania.

<sup>8</sup> Lifting Condensation Level (LCL) - The height at which a parcel of moist air becomes saturated when it is lifted dry adiabatically.

<sup>9</sup> Convective Condensation Level (CCL) – The level in the atmosphere to which an air parcel, if heated from below, will rise dry adiabatically, without becoming colder than its environment just before the parcel becomes saturated.

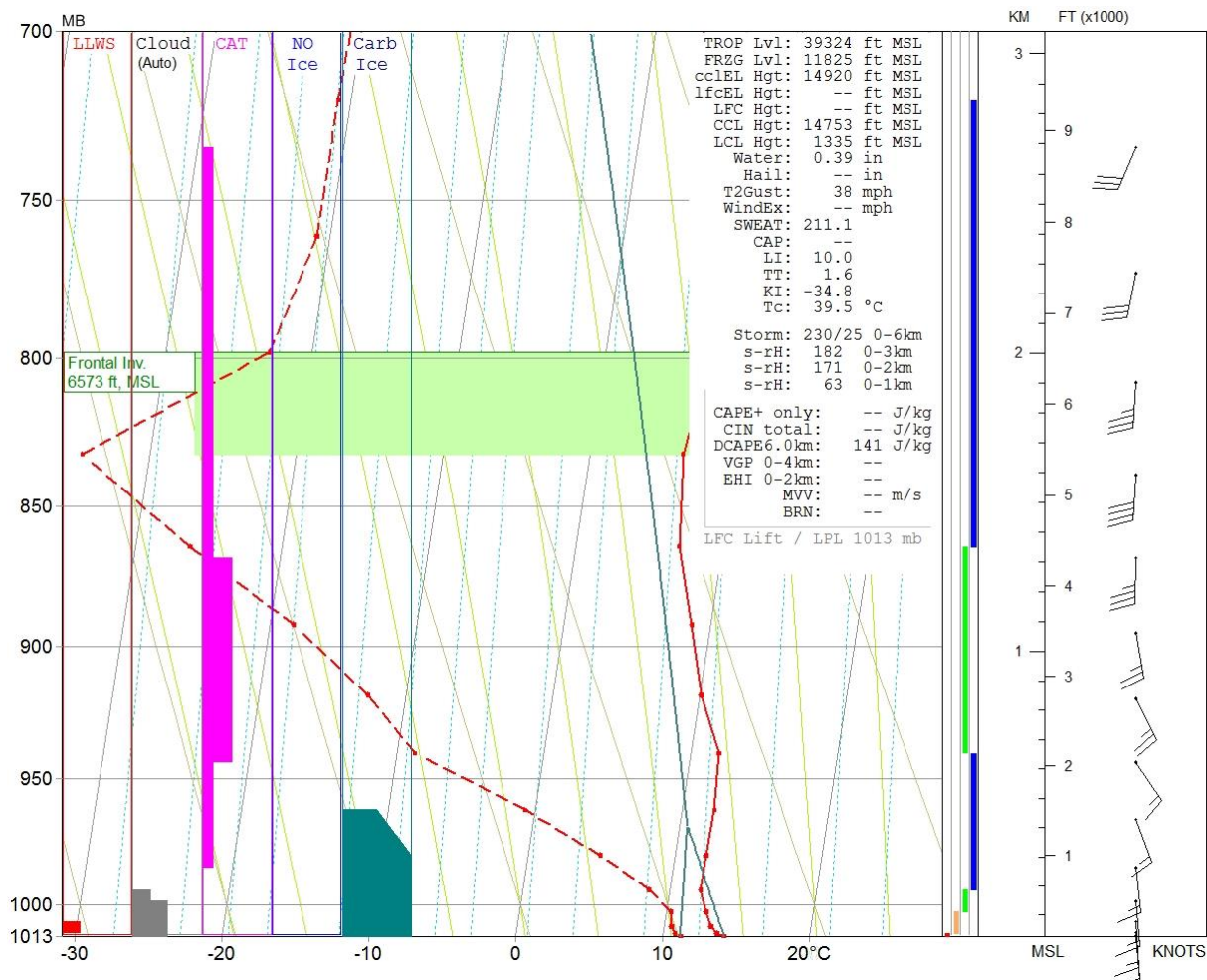


**Figure 11 – 1100 PST HRRR sounding for the accident site**

The 1100 PST HRRR sounding indicated an unstable layer between the surface and 335 feet with a conditionally unstable layer between 335 feet and 611 feet, and finally a stable layer between 611 feet and 2,087. With the rise in terrain west and southwest of the airport by 100 to 200 feet and the stable layer at 611 feet any wind travelling over terrain would have allowed for the creation of an environment favorable for updrafts and downdrafts, however, the strengthen of the updrafts and downdrafts would not have been greater than 100 to 200 feet/min. Given the lack of moisture no clouds or structural icing conditions were indicated by RAOB.

The 1100 PST HRRR sounding wind profile indicated a surface wind from 176° at 8 knots with the wind remaining primarily south to southeasterly through 7,000 feet. Above 7,000 feet the wind became more southwesterly. The wind speed remained between 5 to 15 knots between the surface and 1,500 feet. RAOB indicated no possibility of low-level wind shear (LLWS) at 1100 PST with clear-air turbulence in several levels above 1,500 feet.

Another HRRR model sounding was created for the accident site for 1200 PST and is included in figure 12. The sounding depicted the LCL at 1,335 feet and a CCL of 14,753. The freezing level was located at 11,825 feet. The precipitable water value was 0.39 inches.



**Figure 12 – 1200 PST HRRR sounding for the accident site**

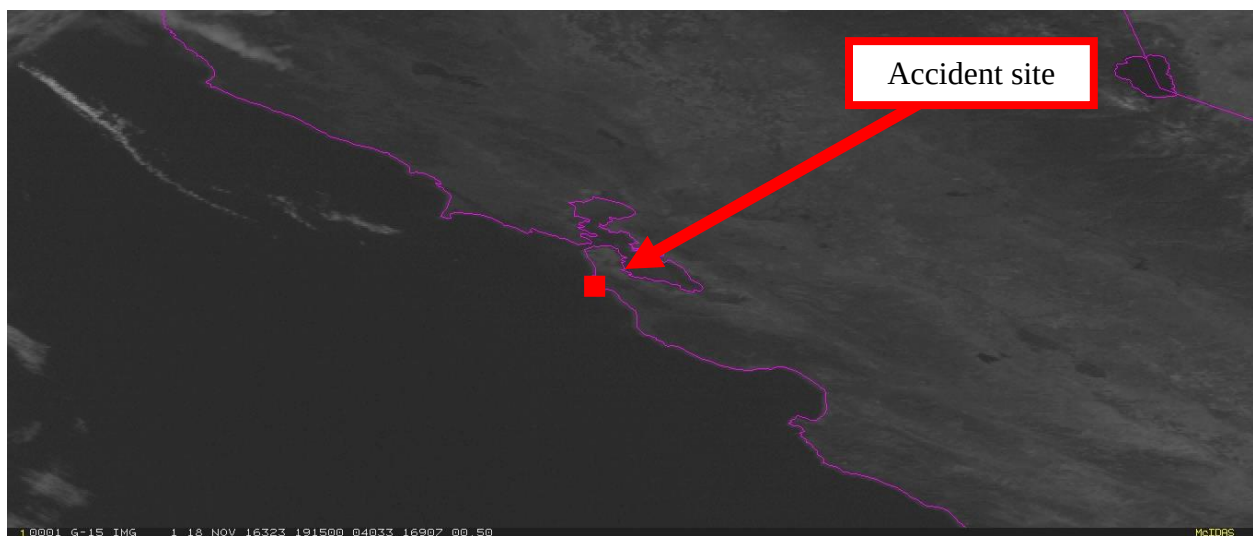
The 1200 PST HRRR sounding indicated an unstable layer between the surface and 363 feet with a conditionally unstable layer between 363 feet and 611 feet, and finally a stable layer between 611 feet and 2,146. Just like in the previous sounding (figure 11), with the rise in terrain west and southwest of the airport by 100 to 200 feet and the stable layer at 611 feet any wind travelling over terrain would have allowed for the creation of an environment favorable for updrafts and downdrafts, however, the strength of the updrafts and downdrafts would not have been greater than 100 to 200 feet/min. With a 10% increase in moisture between the surface and 500 feet between the 1100 and 1200 PST HRRR sounding, RAOB indicated the chance of cloud cover in the 1200 PST HRRR sounding with no structural icing conditions below 10,000 feet.

The 1200 PST HRRR sounding wind profile indicated a surface wind from 175° at 12 knots with the wind remaining primarily south to southeasterly through 8,000 feet. Above 8,000 feet the wind became more southwesterly. The wind speed remained between 12 to 17 knots between the surface and 2,500 feet. RAOB did indicate the possibility of LLWS below 500 feet (figure 12). A layer of possible clear-air turbulence was indicated by RAOB between 1,000 feet and 9,000 feet. Section 16.0 will discuss the ability for turbulence and wind shear near inversion boundaries and near boundaries in stable and unstable air.

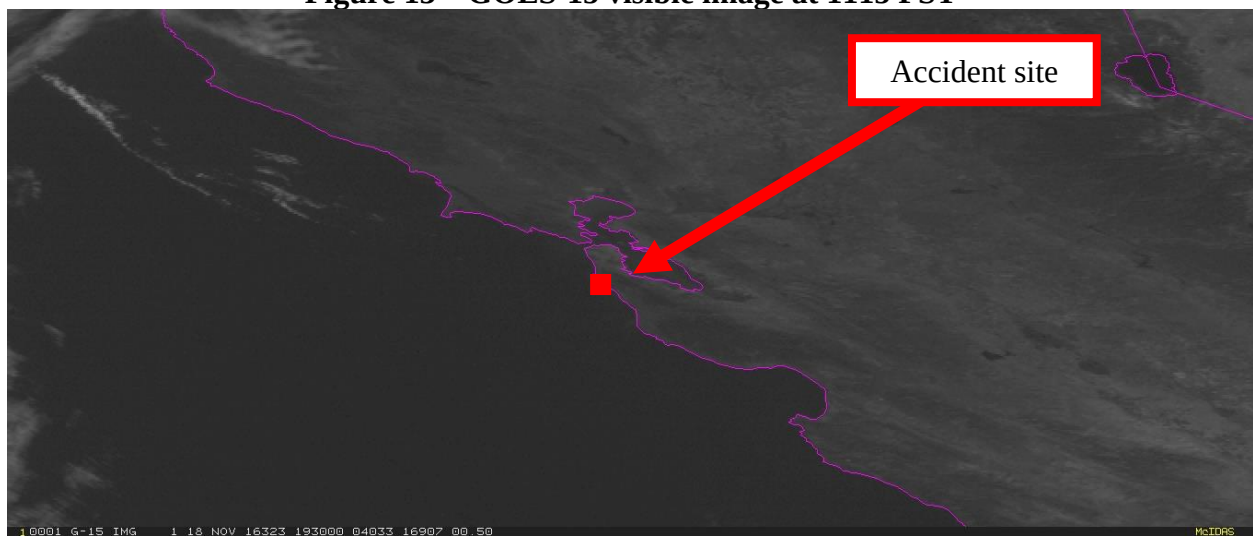
## 5.0 Satellite Data

Visible and infrared data from the Geostationary Operational Environmental Satellite number 15 (GOES-15) data was obtained from an archive at the Space Science Engineering Center at the University of Wisconsin-Madison in Madison, Wisconsin, and processed using the Man-computer Interactive Data Access System software. Visible and infrared imagery (GOES-15 band 1 and 4) at wavelengths of 0.65 microns ( $\mu\text{m}$ ) and 10.7  $\mu\text{m}$ , respectively, were retrieved for the period. Satellite imagery surrounding the time of the accident, from 0800 PST through 1300 PST at approximately 15-minute intervals were reviewed, and the closest images to the time of the accident are documented here.

Figures 13 and 14 present the GOES-15 visible imagery from 1115 and 1130 PST at 2X magnification with the accident site highlighted with a red square. The visible imagery indicated no cloud cover over or around the accident site at the accident time. It should be noted these figures have not been corrected for any parallax error.



**Figure 13 – GOES-15 visible image at 1115 PST**



**Figure 14 – GOES-15 visible image at 1130 PST**

## 6.0 Radar Imagery Information

The closest NWS Weather Surveillance Radar-1988, Doppler (WSR-88D)<sup>10</sup> to the accident site was the San Francisco Bay Area, California, radar (KMUX), which was located 37 miles southeast of the accident site at an elevation of 3,468 feet. Level II and III archive radar data were obtained from the NCEI utilizing the NEXRAD Data Inventory Search and displayed using the NOAA's Weather and Climate Toolkit software. No reflectivity targets were located above the accident site at the accident time.

## 7.0 Pilot Reports

All pilot reports (PIREPs) close to the accident site from about three hours prior to the accident time to about three hours after the accident time for below FL150<sup>11</sup> are provided below:

MER UA /OV HYP356019 /TM 1842 /FL160 /TP COL4 /WX FV99SM /TA M06 /WV 22442KT /TB NEG /IC NEG /RM AEROVIE : BEAUTIFUL CAVU MORNING=

SMX UA /OV SMX135008 /TM 1928 /FLUNKN /TP C208 /TB CONS LGT-MOD CHOP 005-055 /RM DURC=

LVK UA /OV MRY-LVK /TM 2155 /FL045 /TP C210 /TB LGT-MOD=

SJC UUA /OV SJC270010/TM 2219/FL030/TP GLEX,BE35/TB MOD TO SEV =

Routine pilot report (UA); 19 miles from Merced, California, on the 356° radial; Time – 1042 PST (1842Z); Altitude – 16,000 feet; Type aircraft – Cessna 400; Weather – Forward visibility unlimited; Temperature – -6° C; Wind – From 224° at 42 knots; Turbulence – Negative; Icing – Negative; Remarks – Taken on Aerovie application, beautiful clear sky morning.

Routine pilot report (UA); 8 miles from Santa Monica, California, on the 135° radial; Time – 1128 PST (1928Z); Altitude – Unknown; Type aircraft – Cessna 208; Turbulence – Constant light to moderate chop between 500 feet and 5,500 feet; Remarks – During climb. While this PIREP occurred well south-southeast of the accident site, the PIREP did occur along the coast with similar weather conditions that would have been experienced by the accident flight.

Routine pilot report (UA); Between Monterey and Livermore, California; Time – 1355 PST (2155Z); Altitude – 4,500 feet; Type aircraft – Cessna 210; Turbulence – Light to moderate.

Urgent pilot report (UUA); 10 miles from San Jose, California, on the 270° radial; Time – 1419 PST (2219Z); Altitude – 3,000 feet; Type aircraft – Bombardier Global Express and Beechcraft Bonanza; Turbulence – Moderate to severe.

---

<sup>10</sup> The WSR-88D is an S-band 10-centimeter wavelength radar with a power output of 750,000 watts, and with a 28-foot parabolic antenna that concentrates the energy between a 0.87° and 0.96° beam width. The radar produces three basic types of products: base reflectivity, base radial velocity, and base spectral width.

<sup>11</sup> Flight Level – A Flight Level (FL) is a standard nominal altitude of an aircraft, in hundreds of feet. This altitude is calculated from the International standard pressure datum of 1013.25 hPa (29.92 inHg), the average sea-level pressure, and therefore is not necessarily the same as the aircraft's true altitude either above mean sea level or above ground level.

## 8.0 SIGMET and CWSU Advisory

There were no SIGMETs were valid for the accident site at the accident time.

No Center Weather Service Unit (CWSU) Advisories (CWA)s were valid for the accident site at the accident time. There was a CWSU Meteorological Impact Statement (MIS) valid for the accident site at the accident time and it forecast stronger southerly winds into the San Francisco Bay area into the evening hours with rain and gusty south winds lasting through the 19<sup>th</sup>:

FAUS20 KZOA 181833  
ZOA MIS 01 VALID 181832-190630  
...FOR ATC PLANNING PURPOSES ONLY...  
**AN APPROACHING FRONT WILL BRING STRONGER SOUTH WINDS TO THE BAY THIS EVENING AND RAIN WITH GUSTY SOUTH WINDS VERY EARLY SATURDAY MORNING AND LASTING THROUGH THE DAY. BY 05Z THIS EVENING SOUTH WINDS WILL BE CONSISTENTLY GUSTING TO 20KTS OR GREATER. BY 09Z RAIN AND BELOW VISUAL CONDITIONS DUE TO CLOUDS WILL BE OCCURRING. THESE CONDITIONS WILL CONTINUE THROUGH THE DAY SATURDAY.**  
=

## 9.0 AIRMETs

No AIRMETs were valid for the accident site at the accident time.

## 10.0 Area Forecast

The Area Forecast issued at 0345 PST, valid at the accident time, forecasted clear skies with scattered to a broken ceiling of cirrus clouds moving across the accident area between 1000 and 1300 PST:

FAUS46 KKCI 181145  
FA6W  
\_SFOC FA 181145  
SYNOPSIS AND VFR CLDS/WX  
SYNOPSIS VALID UNTIL 190600  
CLDS/WX VALID UNTIL 190000...OTLK VALID 190000-190600  
WA OR CA AND CSTL WTRS  
.  
SEE AIRMET SIERRA FOR IFR CONDS AND MTN OBSCN.  
TS IMPLY SEV OR GTR TURB SEV ICE LLWS AND IFR CONDS.  
NON MSL HGTS DENOTED BY AGL OR CIG.  
.  
SYNOPSIS...ALF...12Z UPR RDG OVR THE FA AREA WITH RDG AXIS EXTDG FM CNTRL CA THRU NWRN WA. RDG AXIS WILL SHIFT EWD AND EXTEND FM CNTRL AZ THRU NW MT BY THE END OF THE PD. 06Z STG SWLY WND FLOW OVR SW HLF OR NRN CA AND ADJACENT CSTL WTRS. AT THE SFC...12Z OFSHR FLOW ALG THE W CST. DEEP LAYERED MSTR WILL SPREAD INLAND ACRS WRN WA WRN OR AND NRN CA DURG THE PD. 06Z CDFNT APPROACHING THE NRN-CNTRL PAC CST.  
.  
WA CASCDS WWD

CSTLN...BKN CI. 18Z BKN120 TOPS FL220 BKN CI. WND ELY G25KT.  
OTLK...VFR WND.  
SRN INLAND VLYS...BKN020 TOPS 030. VIS 3SM BR. 20Z BKN120 TOPS  
150 BKN CI. OTLK...VFR.  
RMNDR...BKN CI. BECMG 1820 BKN120 TOPS 150 BKN CI. OTLK...VFR.

.  
WA E OF CASCDS  
N HLF...BKN030-035 TOPS 070. OCNL VIS 3-5SM BR. 20Z SCT-BKN100  
TOPS 130 BKN CI. OTLK...VFR SHRASN.  
SW QTR...SCT020 BKN CI. VIS 4SM BR. BECMG 1821 SCT-BKN100 BKN150  
TOPS 170 BKN CI. OTLK...VFR.  
SE QTR...SCT CI. OCNL SCT015 WITH VIS 3-5SM BR. BECMG 1719  
SCT-BKN150 TOPS 170 BKN CI. OTLK...VFR.

.  
OR CASCDS WWD  
CSTLN...  
N HLF...BKN CI. BECMG 1518 SCT-BKN150 TOPS FL200 OVC CI.  
OTLK...VFR.  
S HLF...SCT060 BKN100 TOPS FL180 BKN CI. OTLK...VFR RA.  
SWRN INTR...BKN020 BKN110 TOPS FL180 BKN CI. VIS 3-5SM BR. 18Z  
SCT020 BKN CI. OTLK...VFR 03Z WND.  
RMNDR...BKN-OVC CI. OCNL VIS 3-5SM BR. BECMG 1619 OVC CI. WND ELY  
G25-30KT NRN SXNS. OTLK...VFR.

.  
OR E OF CASCDS  
COLUMBIA GORGE...BKN020 TOPS 030 BKN CI. 18Z SCT020 BKN100 OVC150  
TOPS FL220. OTLK...VFR.  
RMNDR W HLF...BKN CI. BECMG 1417 BKN-SCT120 TOPS FL220 BKN CI.  
20Z WDLY SCT -SHRA. 22Z WND SE G25KT SRN SXNS. OTLK...VFR  
THRUT...WND SRN SXNS.  
E HLF...BKN-SCT CI. 18Z BKN150 TOPS FL220 BKN CI. WND ELY G25KT  
NERN SXNS. OTLK...VFR THRUT.

.  
NRN CA...STS-SAC-TVL LN NWD  
CSTL SXNS...  
CSTLN...SCT080 SCT-BKN150 TOPS 170 . BECMG 1720 SCT050-060  
SCT-BKN120 TOPS 150 BKN CI. WND S G25-30KT. OTLK...VFR RA  
WND.  
INLAND...SCT120 BKN CI. 20Z SCT CI. OTLK...VFR 04Z VFR RA WND.  
SAC VLY...SCT-BKN100 TOPS FL180. BECMG 2022 SCT110 BKN CI.  
OTLK...VFR.  
MTNS...SCT120 SCT CI. OTLK...VFR.

.  
**CNTRL CA**  
**CSTL SXNS...**  
**CSTLN...SKC. BECMG 1821 SCT-BKN CI. OTLK...VFR.**  
**INLAND...SKC. OTLK...VFR.**  
SAN JOAQUIN VLY...SKC. OCNL VIS 3SM BR/HZ NRN SXNS. 18Z SKC. OCNL  
SCT CI. OTLK...VFR.  
MTNS...SKC. OCNL SCT CI. OTLK...VFR.

.  
SRN CA..VBG-NID-60NNW BIH LN SWD  
CSTL SXNS...SKC. OTLK...VFR.  
INTR MTNS/DESERTS...SKC. 19Z OCNL SCT CI. OTLK...VFR.

.  
CSTL WTRS

WA/OR/NRN CA...SCT-BKN100 BKN150 TOPS FL200 BKN CI. BECMG 1417  
BKN100 LYRD FL250. OCNL -RA. WND ELY 20G30KT. BECMG 1821 BKN050  
OVC100. OCNL -RA. WND SELY 30G40KT. OTLK...MVFR CIG RA WND.  
CNTRL-SRN CA...SKC. 19Z SCT030. OTLK...VFR.  
....

## 11.0 Terminal Aerodrome Forecast

San Francisco International Airport (KSFO) was the closest site to the accident site with a NWS Terminal Aerodrome Forecast (TAF) located 9 miles northeast of the accident site. The TAF valid at the time of the accident was issued at 0938 PST and was valid for a 30-hour period beginning at 1000 PST. The TAF for KSFO was as follows:

TAF KSFO 181738Z 1818/1924 **14004KT P6SM SKC**  
FM182100 19011KT P6SM FEW250  
FM190500 15014G21KT P6SM VCSH FEW060 SCT150  
FM190900 15020G28KT P6SM -RA BKN040 OVC120  
FM191500 16018G26KT 6SM -RA BR OVC030  
TEMPO 1915/1919 4SM RA OVC018  
FM192100 17016G24KT P6SM -RA BKN020 OVC025=

The forecast expected a wind from 140° at 4 knots, greater than 6 miles visibility, and sky clear.

## 12.0 NWS Area Forecast Discussion

The NWS Office in the San Francisco Bay Area, California, issued the following Area Forecast Discussion (AFD) at 0953 PST (closest AFD to the accident time). The aviation section of the AFD discussed VFR conditions continuing into the afternoon before ceilings decreased with an increasingly southerly wind through the day:

FXUS66 KMTR 181752 CCA  
AFDMTR  
Area Forecast Discussion  
National Weather Service San Francisco Bay Area  
953 AM PST Fri Nov 18 2016  
...Widespread Rain Expected Over the Weekend...  
.SYNOPSIS...Expect slightly warmer high temperatures today across the district. Widespread rain is forecast to spread from north to south across the district beginning tonight through Saturday. Periods of rain will continue on Sunday. Dry weather will likely return by Monday, but rain is possible once again by the middle of next week.  
&&  
.DISCUSSION...As of 9:45 AM PST Friday...Another chilly start to the day, although not as many reports in the 38 to 35 degree range compared to yesterday. In fact, a few spots came in warmer than forecast including Napa which only dropped to 42 -- about 11 degrees more than expected.  
Satellite nicely shows the upcoming system for the weekend that will bring widespread rainfall to our region. Models are in fairly good agreement and bring the rain to the North Bay starting 9-10

PM tonight and to San Francisco close to 4 AM tomorrow morning. Latest QPF values from the RFC do show higher numbers for the North Bay compared to yesterday with only minor variations for the rest of our CWA.

Did one update to reflect the latest RFC values. Rest of forecast appears to be on track so no additional substantial updates anticipated.

.PREVIOUS DISCUSSION...Satellite imagery once again shows clear skies across the district, and surface observations are showing a light offshore flow across most areas. Current temperatures are trending overall similarly to those from 24 hours ago, a few degrees warmer in some spots, a few colder in others. Temperatures are currently ranging from the mid 30s to the upper 40s. A frost advisory is still in effect until 8 am for the North Bay Valleys, although frost is not expected to be widespread. With plenty of sunshine today, high temperatures are forecast to be in the 60s to lower 70s...generally a few degrees warmer than yesterday.

The approaching storm system can be seen on satellite imagery west of the coast, near 132W with the upper low center near 41N/140W. The upper low is progged to move towards the northeast, and the associated front will arrive on the west coast this afternoon.

Rain is forecast to reach the North Bay during the evening hours, then spread south through the San Francisco area tonight, reaching the Monterey Bay area Saturday morning. Rain rates with the front are expected to be mostly light to moderate, but could be locally heavy at times. In addition, southerly winds are forecast to increase with the front tonight and become locally strong and gusty through Saturday. Wind gusts up to 35 mph are possible near the coast and up to 40 mph in the hills.

The frontal boundary is expected to stall somewhere over our forecast area on Saturday Night as another upper low develops offshore in the southern part of the trough. As this impulse approaches the southern California coast on Sunday, rain rates will likely increase. There is uncertainty as to where exactly the boundary will stall, but most models indicate this occurring somewhere over the southern portion of our forecast area. Will need to keep an eye on this, in light of the burn scars in Santa Cruz or Monterey Counties where prolonged rain could result in debris flows.

Rain totals over the weekend are currently projected to range from 0.5 to 1 inch at most lower elevation locations and from 1.5 to 2.5 inches in the hills. Locally heavier amounts are definitely possible if the frontal boundary stalls for an extended period of time.

Dry weather will likely return on Monday, but additional storm systems are forecast to affect Northern California through the coming week...One around the middle of the week, and another by next weekend as an active weather pattern persists.

&&

.AVIATION...As of 9:52 AM PST Friday...**For 18z tafs. Approaching storm system will bring deteriorating ceilings, rain, and increasing southerly winds through the TAF period. Cigs generally VFR today then decreasing down to MVFR as front approaches.**

**Likewise, southerly wind gusts will strengthen as the front approaches. Some favored areas could see gusts up to or exceeding 35 knots near the front.** Rain will begin to move into the North Bay as

early as 04Z Sat before spreading southward through the night and into Saturday.

Confidence high.

**Vicinity of KSFO...VFR through today then becoming MVFR late tonight into early tomorrow as front arrives. Southerly winds will gradually increase through the TAF period with gusts up to 30 KT possible.**

**Visibility may briefly drop following the frontal passage and heaviest rains. Rain expected to begin before sunrise.**

**SFO Bridge Approach...Similar to KSFO.**

Monterey Bay Terminals...VFR. Mostly clear skies and light winds today with ceilings beginning to deteriorate late tonight into tomorrow morning. Rain tomorrow morning after sunrise.

&&

.MARINE...as of 09:43 AM PST Friday...An approaching storm system will lead to increasing southerly winds through today and into tomorrow. Occasional gale force gusts will be possible as the front moves through on Saturday along with rain spreading from north to south. Winds will veer northerly behind the front by Sunday with a building NW swell.

&&

.MTR WATCHES/WARNINGS/ADVISORIES...

.Tday...SCA...Pt Reyes to Pigeon Pt 0-10 nm from 3 PM

SCA...Pigeon Pt to Pt Pinos 0-10 nm from 3 PM

SCA...Pigeon Pt to Pt Piedras Blancas 10-60 nm from 3 PM

SCA...Pt Arena to Pt Reyes 0-10 nm

SCA...Pt Arena to Pigeon Pt 10-60 nm

SCA...Pt Pinos to Pt Piedras Blancas 0-10 nm from 1 PM

SCA...Mry Bay from 3 PM

&&

\$\$

### 13.0 Winds and Temperature Aloft Forecast

The NWS 0557 PST Winds and Temperature Aloft forecast valid for the accident flight is included below:

FBUS31 KWNO 181357

FD1US1

\_DATA BASED ON 181200Z

\_VALID 181800Z FOR USE 1400-2100Z. TEMPS NEG ABV 24000

| FT | 3000 | 6000 | 9000 | 12000 | 18000 | 24000 | 30000 | 34000 | 39000 |
|----|------|------|------|-------|-------|-------|-------|-------|-------|
|    |      |      |      |       |       |       |       |       |       |

\_SFO 1720 1925+07 2029+05 2134-01 2349-13 2356-25 247641 249750 248658

The accident site was closest to the San Francisco, California, forecast point. The 0557 PST SFO forecast indicated a wind at 3,000 feet from 170° at 20 knots, and a wind at 6,000 feet from 190° at 25 knots with a temperature of 7° C.

## 14.0 Pilot Weather Briefing and Witness Information<sup>12</sup>

A search of official weather briefing sources, such as Lockheed Martin Flight Service and Direct User Access Terminal Service (DUATS) was not able to be done due to notice of the accident being after the archival period.

The accident pilot stated<sup>13</sup> that after he preflighted the airplane he received a weather briefing. The pilot mentioned that it was a very clear, beautiful day, with no clouds. After departing Sacramento Executive Airport (SAC) around 1015 PST, the pilot stated they arrived in the Half Moon Bay area and flew a left upwind pattern to check the wind. The pilot stated that around an altitude of 500 feet agl he experienced very light turbulence, then increased power, and immediately afterwards experienced strong turbulence which caused the wings to rock back and forth “right to left,” followed by a very sudden downward push. This was the third time this pilot had flown to KHAF in 35 years and his second time landing at KHAF (one of the times flying to KHAF the weather prevented the accident pilot from landing, attachment 2).

Another witness was an operations staff member at Half Moon Bay Airport, who was a local airline transport pilot and flight instructor, stated that between 10 minutes and 45 minutes after the accident time, he observed three airplanes on final approach to KHAF and each airplane was experiencing turbulent conditions in the same area as the accident flight (attachment 3). The KHAF operations staff member mentioned that these turbulent conditions were “pretty standard” for that approach (attachment 3). None of the three airplanes mentioned above were based out of KHAF (attachment 3).

## 15.0 Astronomical Data

The astronomical data obtained from the United States Naval Observatory for the accident site on November 18, 2016, indicated the following:

### **SUN**

|                      |          |
|----------------------|----------|
| Begin civil twilight | 0625 PST |
| Sunrise              | 0654 PST |
| Sun transit          | 1155 PST |
| Sunset               | 1657 PST |
| End civil twilight   | 1725 PST |

---

<sup>12</sup> For more information see Witness Statements and Interview Summaries contained in the docket for this accident.

<sup>13</sup> For more information see Record of Conversation Summaries contained in the docket for this accident.

## 16.0 Wind Shear Associated with Temperature Inversions

In FAA Advisory Circular 00-6B (AC-00-06B) published on August 23, 2016, section 17.2.3.1 describes how areas near temperature inversions are heights favored for wind shear conditions. “Strong wind shears often occur across temperature inversion layers, which can generate turbulence (figure 15).” A weak temperature inversion was present near the accident site at the accident time between 400 and 600 feet msl (figures 11 and 12) at 1100 and 1200 PST when the vertical environment changed from an unstable layer to a stable layer. In addition, the stable layer trapped any updrafts or downdrafts created by the wind flowing over the rise in terrain to the west and southwest of the airport. These environmental changes created an environment favorable for LLWS and turbulence below 600 feet msl. Additional mechanical and mountain wave turbulence conditions are described in section 17.0 of AC-00-06B. FA AC-00-06A published back in 1975 also describes the turbulence conditions possible near temperature inversion layers.

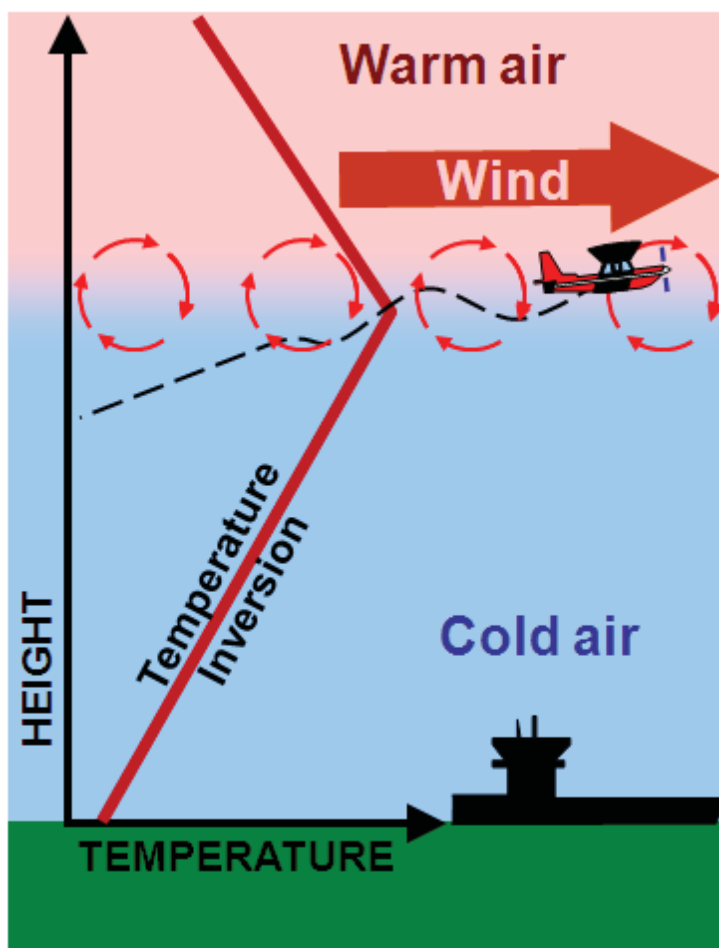


Figure 15 – AC 00-06B Wind Shear Diagram near temperature inversion

## **F. LIST OF ATTACHMENTS**

Attachment 1 – 1-minute KHAF AWOS observations surrounding the accident time

Attachment 2 – Record of Conversations with the accident pilot

Attachment 3 – Record of Conversations with witness

Submitted by:

---

Paul Suffern  
Senior Meteorologist

**THIS PAGE INTENTIONALLY BLANK**