NATIONAL TRANSPORTATION SAFETY BOARD

Office of Aviation Safety
Washington, D.C. 20594

April 30, 2013

Group Chairman's Factual Report

WEATHER STUDY

DWPR12LA053

A. ACCIDENT

Location:	Oakland, California
Date:	December 1, 2011
Time:	About 1953 Pacific standard time (0353 UTC[1] on December 2, 2011)
Airplane:	Boeing 737-7H4, flight 1489; registration N261WN

B. METEOROLOGY GROUP

Donald E. Eick
Senior Meteorologist
National Transportation Safety Board
Operational Factors Division, AS-30
Washington, D.C. 20594-2000

C. SUMMARY

On December 1, 2011, at 1953 Pacific standard time, a Boeing 737-7H4, N261WN, flight 1489, encountered turbulence at flight level 30,000 feet (FL300), over Yosemite National Park. One flight attendant sustained serious injuries; 1 flight attendant received minor injuries; 2 pilots, the third flight attendant, and 95 passengers were not injured. Southwest Airlines operated the flight under the provisions of 14 Code of Federal Regulations Part 121, as a scheduled-passenger flight that departed Albuquerque International Sunport Airport (ABQ), Albuquerque, New Mexico. An instrument flight rules (IFR) flight plan had been filed. The flight was destined for Metropolitan Oakland International Airport (OAK), Oakland, California.

According to Southwest Airlines, the airplane had been at FL400 and was descending to FL300 when the flight encountered severe turbulence. All three flight attendants were not seated when the turbulence was encountered. One flight attendant was in the forward galley and the other two flight attendants were in the aft galley. The flight attendant in the forward galley was thrown up and down, and side to side with her feet leaving the cabin floor. She was able to hold onto a counter, and was eventually able to secure herself in the forward jumpseat; she was not transported to the hospital. The two flight attendants in the aft galley were thrown around the aft galley and struck their heads and backs; they also were eventually able to secure themselves in their respective jumpseats and remained there throughout the landing. Both flight attendants were transported to the hospital via ambulance. One flight attendant was released with minor injuries. The other flight attendant was released from the hospital as well, and was informed the following day of the compression fracture of his vertebrae. There were no passengers transported to the hospital.

[1] UTC – is an abbreviation for Coordinated Universal Time.

D. DETAILS OF THE INVESTIGATION

The National Transportation Safety Board's (NTSB) Senior Meteorologist was not on scene for this investigation and conducted the meteorology phase of the investigation from the Washington D.C. office, collecting data from official National Weather Service (NWS) sources including the National Climatic Data Center (NCDC) and from United Airlines. All times are Pacific standard time (PST) based upon the 24 hour clock, local time is +8 hours to UTC, and UTC=Z. 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. NWS airport and station identifiers use standard International Civil Aviation Organization (ICAO) 4 letter station identifiers versus International Air Transport Association (IATA) 3-letter identifiers, both codes are intermittently used in this report.

The accident site was located at latitude 37.66° N and longitude 119.9266° W at 30,000 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 (NCEP) located in Camp Springs, 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 00-45.

1.1 Surface Analysis Chart

The NWS Surface Analysis Chart for 1900 PST on December 1, 2011 (0300Z on December 2, 2011) is included as figure 1 with the approximate accident site within the red circle. The chart depicted a high pressure system over Oregon at 1036-hectopascals (hPa) with a high pressure ridge extending southward into eastern California. A low pressure system at 1008-hPa was located over extreme southern California with a trough of low pressure extending northward along the California and Oregon coastal section. A strong pressure gradient was depicted over northern California.

The station models in the Oakland area indicated winds from the north at 10 to 15 knots, clear skies, temperature of 62° Fahrenheit (F), a dew point temperature of 17° F. No significant surface weather was depicted.

A review of the NWS Radar Summary Chart depicted no echoes over northern California in the vicinity of the turbulence event.

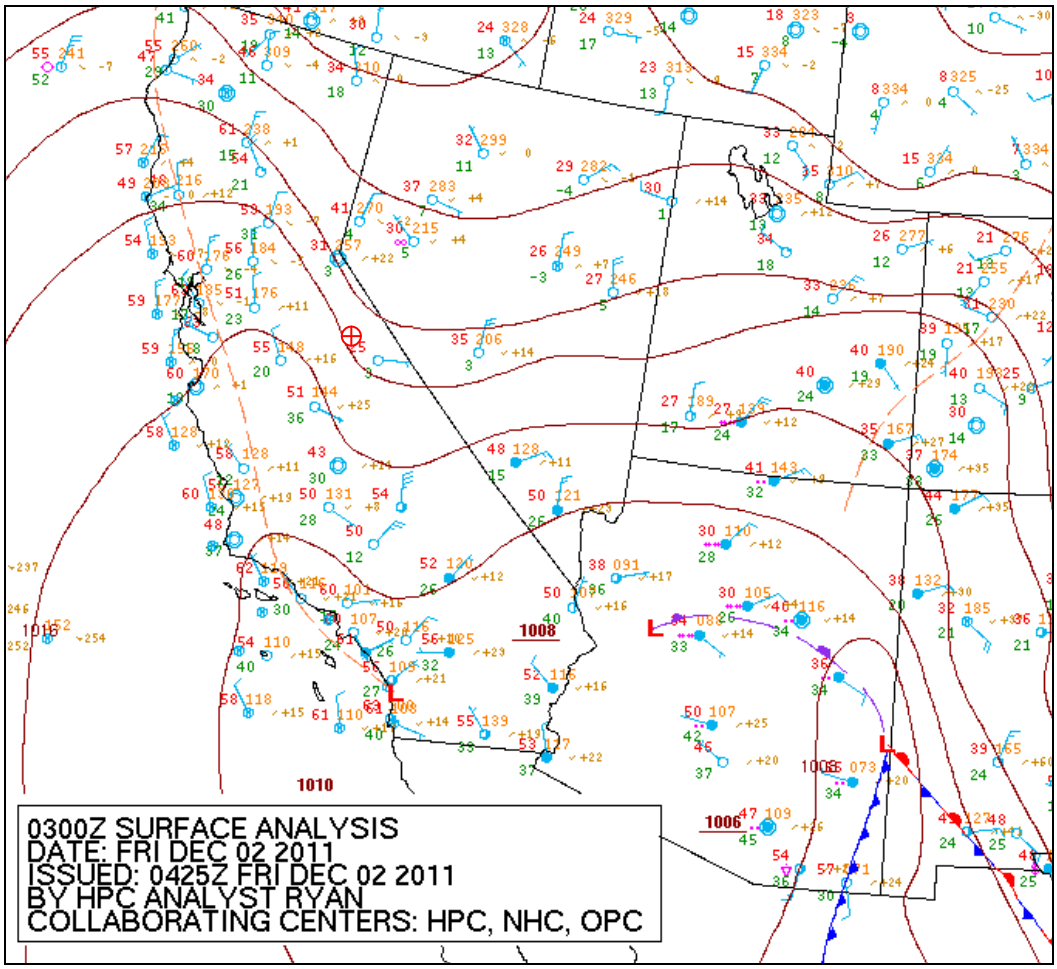

Figure 1 - NWS southwest Surface Analysis Chart for 1900 PST

1.2 NWS Constant Pressure Charts

The NWS Constant Pressure Charts for 1600 PST (0000Z on December 2, 2011) for 300- and 250-hPa are included as figures 2 and 3 respectively. The charts depicted a cut off upper level low over southeastern California with a defined jet stream rotating around the upper level low, with winds from the northeast at 100 to 110 knots in the vicinity of the accident site.

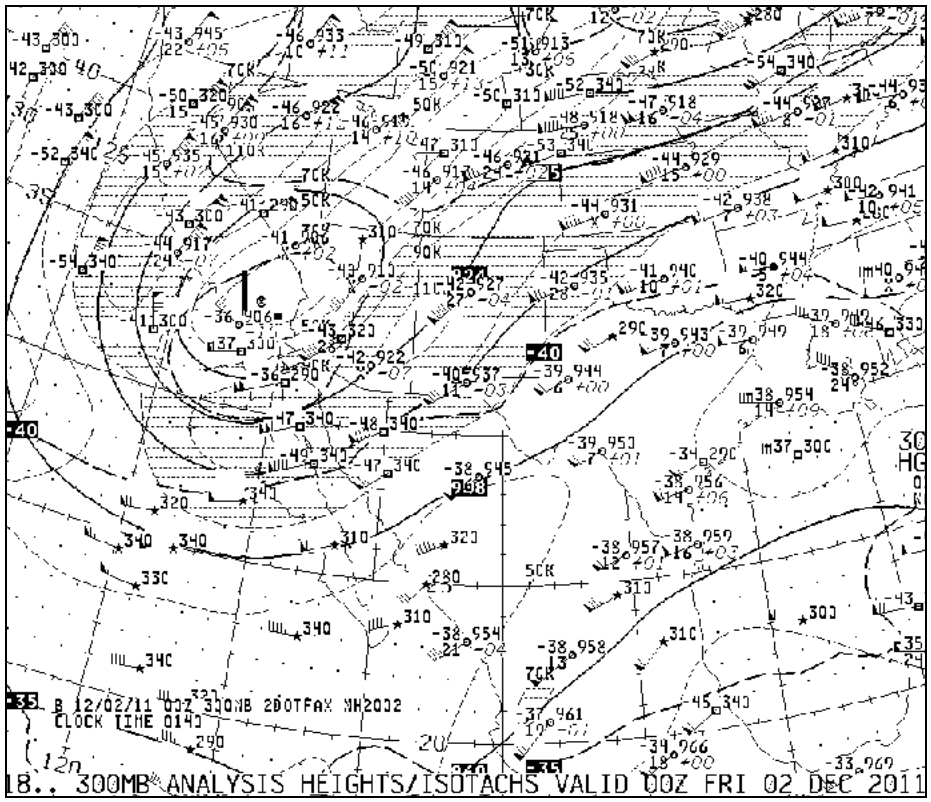

Figure 2 - NWS 300-hPA Constant Pressure Chart for 1600 PST on December 1, 2011

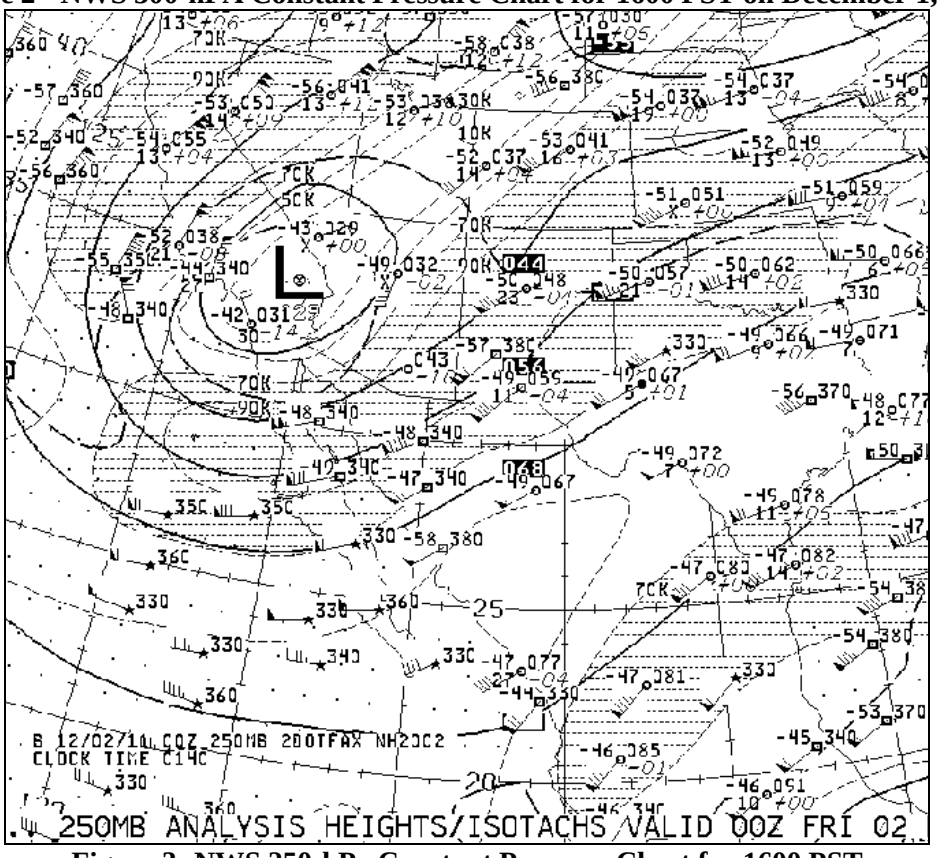

Figure 3- NWS 250-hPa Constant Pressure Chart for 1600 PST

1.3 High Level Significant Weather Prognostic Chart

The NWS High Level Significant Weather Prognostic Chart issued at approximately 0500 PST on December 1, 2011 and valid for the period of the flight is included as attachment 4. The chart depicted the upper level low over southern California with a tropopause height of 28,000 feet and with a polar jet stream circulating around the low with the jet core at 33,000 feet with winds of 110 knots depicted in the vicinity of the accident site. A large area of clear air turbulence (CAT) with moderate to severe turbulence expected from 40,000 feet to below 24,000 feet over the southwest and included the accident site.

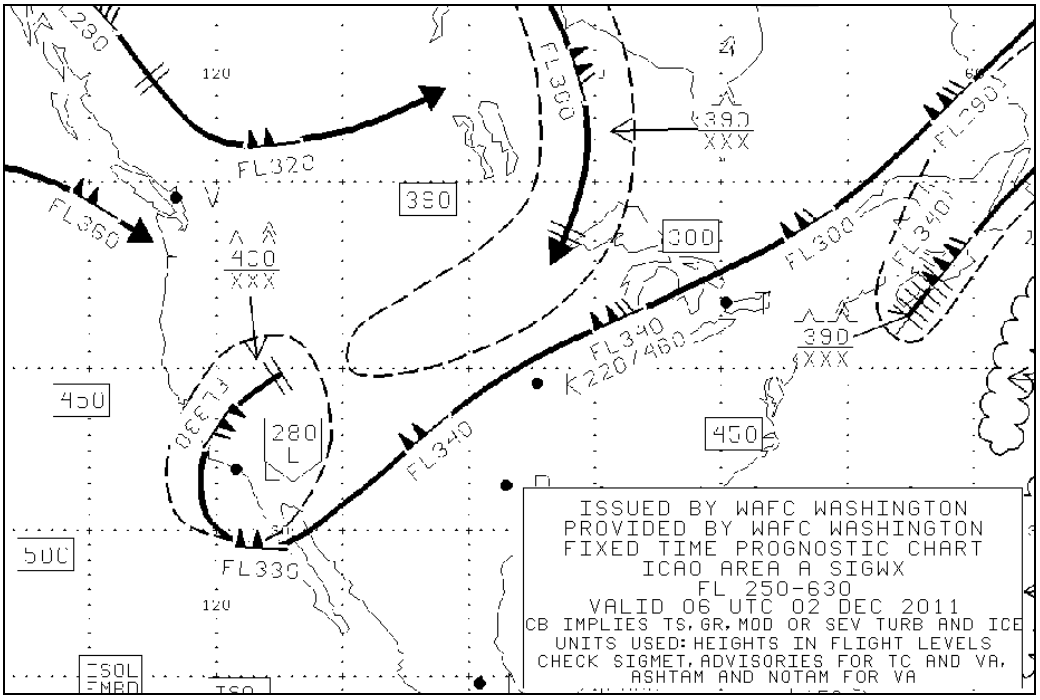

Figure 4 - High Level Significant Weather Forecast Chart for valid for the period

2.0 Surface Observations

The official NWS Meteorological Aerodrome Reports (METARs) and special reports (SPECIs) surrounding the period were documented for Metropolitan Oakland International Airport (KOAK), Oakland, California. The airport lists an elevation of 9 feet and a magnetic variation of 16° E. The airport had an Automated Surface Observation System (ASOS) and reported the following conditions near the time of the accident:

Oakland weather observation at 1953 PST, wind from 320° at 8 knots, visibility unrestricted at 10 statute miles, Clear skies below 12,000 feet, temperature 16° Celsius (C), dew point temperature -7° C, altimeter 30.09 inches of mercury (Hg). Remarks: automated observation

system, sea level pressure 1018.8-hPa, temperature 16.1° C, dew point -7.2° C, maintenance indicator[2]. The station reported a relative humidity of approximately 20 percent.

The raw observations surrounding the period were as follows:

METAR KOAK 020253Z 31009KT 10SM CLR 17/M08 A3008 RMK AO2 SLP185 T01721083 55001 $=

METAR KOAK 020353Z 32008KT 10SM CLR 16/M07 A3009 RMK AO2 SLP188 T01611072 $=

METAR KOAK 020453Z 34011KT 10SM FEW200 17/M08 A3006 RMK AO2 SLP180 T01671083 $=

3.0 Upper Air Data

The NW Oakland upper air sounding or rawinsonde observation (RAOB) located 108 miles west of the turbulence location was analyzed. The 1600 PST (0000Z on December 2, 2011) sounding was plotted on a standard Skew-T log P diagram[3] utilizing RAOB[4] software is included as figure 5 from the surface to 150-hPa or 45,000 feet. The Oakland sounding depicted a dry atmosphere with a precipitable water value of 0.15 inches. Several inversions were noted and resulted in a stable atmosphere. The tropopause height was identified at 39,636 feet. The wind profile indicated surface wind from the north at 12 knots, with winds veering to the north-northeast and increasing in wind speeds above 50 knots above 6,000 feet with little change in direction with height. The mean o to 6 kilometer or 18,000 feet wind was from 030° at 55 knots, and the level of maximum wind was identified at 37,000 feet with a wind from 025° at 108 knots. The wind profile support mountain wave activity south-southwest of the Sierra Nevada Mountains. At 30,000 feet the sounding indicated wind from 020° at 86 knots with a temperature of -43° Celsius (C). The RAOB sounding analysis program used at the NTSB indicated a high probability (100%) of moderate and greater turbulence at 30,000 feet based on a vertical wind shear of 11.3 knot per 1,000 feet.

[2] Maintenance indicator ($) – advises the user that the system is out of calibration, out of service, or needs requires servicing from a maintenance technician.

[3] 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.

[4] RAOB – (The complete Rawinsonde Observation program) is an interactive sounding analysis program developed by Environmental Research Services, Matamopras, Pennsylvania.

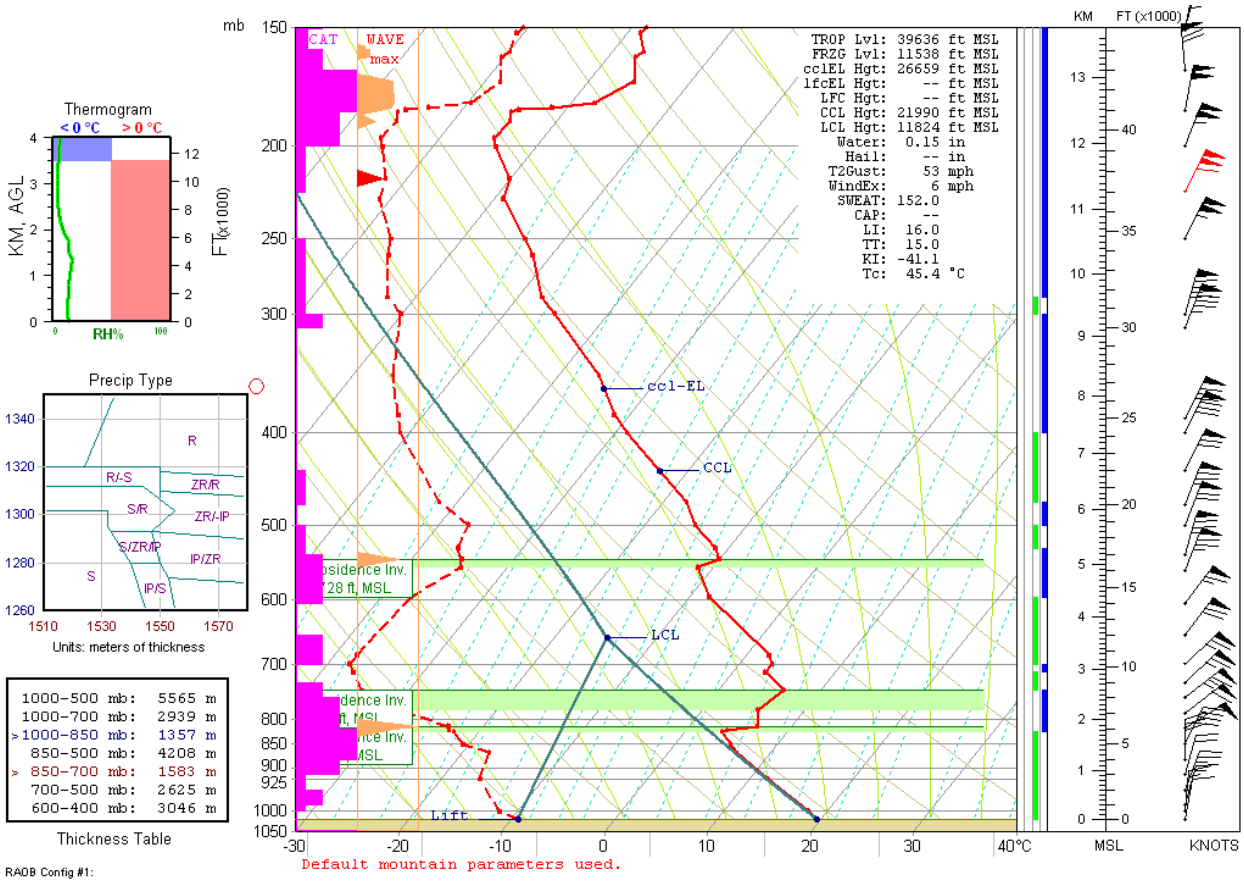

Figure 5 - Oakland sounding

4.0 Satellite Data

The Geostationary Operational Environmental Satellite number 15 (GOES-15) data was obtained and displayed on the National Transportation Safety Board's Man-computer Interactive Data Access System (McIDAS) workstation. Both the infrared long wave and water vapor imagery were reviewed surrounding the time of the accident. The infrared long wave imagery (band 4) at a wavelength of 10.7 microns (μm) provided standard satellite image with radiative cloud top temperatures with a resolution of 4 km.

The GOES-15 infrared image depicted no significant clouds over the accident site with general conditions clear along the route with the exception of a narrow band of clouds over the higher terrain immediately northwest of Bishop, California (KBIH), which did not move with time and were stationary. The clouds were best defined as cirrocumulus standing lenticular clouds (CCSL). The GOES-15 water vapor image for 2000 PST (0400Z on December 2, 2011) at 2X magnification is included as figure 6, which also depicts the clouds immediately east of the accident site. No large areas of moisture channel darkening were observed in the vicinity of the turbulence location typically associated with strong vertical motions.

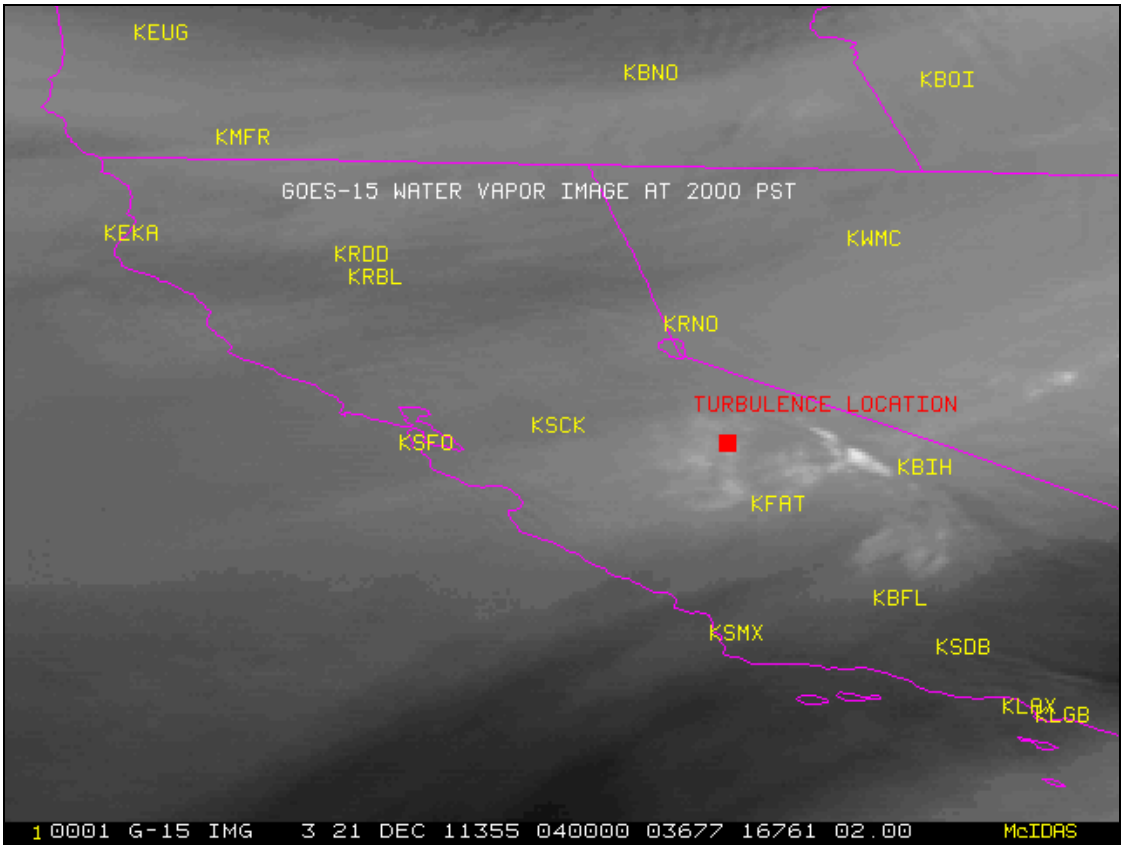

Figure 6 - GOES-15 water vapor image at 2000 PST

5.0 Pilot Reports

The following pilot reports (PIREPs) were recorded over California in the vicinity of the accident surrounding the period. The reports are as follows:

BIH UUA /OV BIH/TM 2115/FL350/TP B737/TB SEV/RM ZOA CWSU=

BFL UUA /OV EHF/TM 2235/FL370/TP GLF5/TB MOD-SEV

BFL UA /OV AVE110020/TM 2344/FL360/TP B737/TB MOD/RM AWC-WEB:KZLA=

BFL UA /OV AVE110020/TM 2344/FL360/TP B737/TB MOD/RM AWC-WEB:KZLA=

RDD UA /OV KRDD278023/TM 0009/FL390/TP B737/TB NEG/RM KSEA-KOAK ROUTE AWC-WEB:ASA=

SCK UA /OV LIN065040/TM 2354/FL310/TP ALL/TB LGT-MOD ABV 310/RM MOD MTN WAVE=

BFL UA /OV AVE110030/TM 0005/FL350/TP B737/TB MOD/RM AWC-WEB:KZLA=

VNY UUA /OV VNY315010 /TM 0019 /FL060 /TP BE20 /TB MOD-SEV=

OAK UA /OV ECA090030-OAK /TM 0025 /FL190 /TP GLF5 /TB MOD 190-040=

FAT UUA /OV FAT /TM 0026 /FL025 /TP P28A /TB MOD-SEV BLO 025 /RM 4 MILE FA RWY 11L=

SFO UA /OV SFO030005 /TM 0035 /FL045 /TP B753 /TB CONT LGT 045-075=

SCK UA /OV LIN057050/TM 0115/FL290/TP B744/RM MOD MTN WAVE -20FT=

TRK UA /OV SWR150030/TM 0116/FL310/TP CRJ7/RM MTN WAVE -200FT...ZOA CWSU=

RAL UUA /OV RAL /TM 0208 /FL032 /TP BE20 /TB MOD-SEV=

TRM UA /OV TRM /TM 0212 /FL040 /TP C25A /TB MOD=

FAT UUA /OV FRA030035/TM 0226/FL320/TP CL60/TB SEV/RM ZOA CWSU=

MRY UA /OV MRY315015 /TM 0230 /FL080 /TP E120 /TB LGT-MOD=

FAT UUA /OV FRA345045/TM 0353/FL300/TP B737/TB SEV/RM ZOA CWSU=

TVL UA /OV KRNO180050/TM 0402/FL300/TP B737/TB SVR/RM AWC-WEB:SWA=

87Q UA /OV SNS140032/TM 0422/FL350/TP B737/TB MOD CHOP/RM SUDDEN ONSET OF MOD TURB AWC-WEB:ASA=

MMH UUA /OV LIN085072 /TM 0507 /FL360 /TP GLF4 /TB SEV=

VIS UA /OV EHF330035/TM 0528/FL300/TP B737/TB CONT LGT CHOP/RM AWC-WEB:SWA=

SNA UUA /OV PDZ180015 /TM 0949 /FL370 /TP B737 /TB MOD-SEV=

OAK UA /OV OAK /TM 1225 /FL040 /TP A306 /RM LLWS +/- 10-15 KT FAP RWY 29 DURD 040-SFC=

6.0 Terminal Aerodrome Forecast

The closest NWS Terminal Aerodrome Forecast (TAF) issued for Oakland Airport at 1539 PST (2339Z) which was current at the time of the accident was as follows:

TAF KOAK 012339Z 0200/0306 35012G19KT P6SM SKC WS020/04030KT
FM020400 36008KT P6SM SKC WS020/04030KT
FM020900 02007KT P6SM SKC
FM021400 06005KT P6SM SKC
FM021900 31010KT P6SM SKC
FM030300 05003KT P6SM SKC=

The forecast for Oakland expected a surface wind from 360° at 8 knots, with clear skies, with a threat of low-level wind shear at 2,000 feet with wind from 040° at 30 knots.

7.0 Area Forecast

The Area Forecast (FA) is a forecast of visual Flight Rules (VFR) clouds and weather conditions over an area as large as the size of several states. It must be used in conjunction with the AIRMET Sierra (IFR) bulletin for the same area in order to get a complete picture of the weather. The area forecast together with the AIRMET Sierra bulletin are used to determine forecast enroute weather and to interpolate conditions at airports which do not have a terminal forecast (TAF) issued. The NWS Aviation Weather Center (AWC) located in Kansas City, Missouri, issues the FA at regular intervals and issues specials reports as necessary usually in the form of an AIRMET. The San Francisco (KSFO) regional forecast for California that was current at the time of the accident was as follows:

FAUS46 KKCI 012045 2011335 2039
FA6W
-SFOC FA 012045
SYNOPSIS AND VFR CLDS/WX
SYNOPSIS VALID UNTIL 021500
CLDS/WX VALID UNTIL 020900...OTLK VALID 020900-021500
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..UPR LOW SRN CA-SRN NV-WRN AZ MOVG LTL THRU PD.
STG E PAC HI RDGG INTO PAC NW-NRN ROCKIES. BY 15Z TROF NRN
SASK-SERN AB TO WRN MT-CNTRL ID.
SFC..STG HI PRES PAC NW. STG ELY FLOW OVR CA. BY 06Z CDFNT SRN
AB-NRN WA. 15Z CDFNT NWRN MT-SRN WA. TROF THRU PD ALG CA COAST.
.
.
NRN CA...STS-SAC-TVL LN NWD
CSTLN-INLAND...SKC. OTLK...VFR.
SAC VLY...SKC. WND N 25G35KT. 02Z WND N G25KT. OTLK...VFR.
SHASTA-SISKIYOUS-NERN CA...SKC. 03Z SCT CI. OTLK...VFR.
NRN SIERNEV...SKC. TIL 02Z WND N 25G35KT. OTLK...VFR.
.
CNTRL CA
CSTLN-INLAND...SKC. TIL 02Z WND N G25KT. OTLK...VFR.
SAN JOAQUIN VLY
N HLF...SKC. TIL 03Z WND NW 20G30KT. OTLK...VFR.
S HLF...SCT030 SERN SXNS OTRW SKC. 06Z VIS 5SM BR HZ. OTLK...MVFR
BR HZ.
SRN SIERNEV...BKN100 TOP 140. WND NE 40G60KT. OTLK...VFR WND.
.
SRN CA..VBG-NID-60NNW BIH LN SWD CSTLN
NW LAX...SKC. TIL 00Z WND N G25KT. OTLK...VFR.
LAX SWD...SCT080. OTLK...VFR.
INLAND...BKN090 TOP 120. WND NE 20G30KT. 02Z BKN080. OTLK...VFR.
INTR MTNS
TEHACHAPIS...SCT080. TIL 02Z WND N G25KT. OTLK...VFR.
SAN GABRIEL-SAN BERNARDINO MTNS...BKN080 TOP 120. WND NE 20G35KT.
02Z SCT100. OTLK...VFR.
SAN JACINTO...BKN120 TOP 150. WND N 20G30KT. OTLK...VFR.

DESERTS
OWENS VLY-DEATH VLY AREA...BKN120 TOP 150. WND N 35G45KT. 04Z
SCT120. WND NW 20G30KT. OTLK...VFR WND.
MOJAVE...BKN120 TOP 150. WND N 30G45KT. 02Z WND NW 20G30KT.
OTLK...VFR WND.
SRN DESERTS...BKN060 TOP FL220. WND N 30G40KT. 02Z WND N G25KT.
OTLK...VFR.
IMPERIAL-COACHELLA VLYS...BKN100 TOP 150. WND NW G25KT. 01Z
BKN070. OTLK...VFR.
.
CSTL WTRS
CA
NRN...SKC. WRN SXNS WND N G25KT. 00Z SCT CI. OTLK...VFR.
CNTRL
N HLF...SKC. OTLK...VFR.
S HLF...SKC. WND N 30G40KT. BECMG 0306 WND N 20G35KT. OTLK...VFR WND.
SRN
E RZS-60SW MZB...SCT100. WND N 20G30KT. 04Z SKC. OTLK...VFR.
RMNDR...SKC. WND N 30G45KT. OTLK...VFR WND.

The San Francisco Area Forecast synopsis indicated an upper level low pressure system was located over southern California with a strong high pressure system over the Pacific northwest was creating strong easterly flow over California. The forecast for the Sacramento Valley was for clear skies and strong northerly wind at 25 knots gusting to 35 knots, decreasing to 25 knots after 2200 PST.

8.0 In-Flight Weather Advisories

The NWS issues in-flight weather advisories designated as Severe Weather Forecast Alerts (AWW's), Convective SIGMET's (WST's), SIGMET's (WS's), Center Weather Advisories (CWA's), and AIRMET's (WA's). In-flight 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.

Severe Weather Forecast Alert (AWW) - None issued surrounding the period.

Convective SIGMETs - None issued or required by NWS definition.

Center Weather Advisories (CWA) – Oakland issued the following advisory:

FAUS21 KZOA 012334 *2011335 2334*
ZOA1 CWA 012334
ZOA CWA 101 VALID UNTIL 020134
FROM 37WNW SAC-29ESE SNS-26SSW SNS-17NNW PYE-37WNW SAC
AREA MOD-SEV TURB AND LLWS BLW 030. DUE TO INCR NNE WINDS OV TRRN.
RPRTD BY ACFT. ZOA CWSU.

SIGMETs (WS) – following current for the area:

WSUS06 KKCI 020103 2011336 0102
WS6W
-SFOW WS 020103
SIGMET WHISKEY 9 VALID UNTIL 020503
CA NV AZ AND CSTL WTRS

FROM 30NNE FMG TO 30SW DRK TO 50ESE BZA TO BZA TO 30SW MZB TO 30W RZS TO 60N SAC TO 30NNE FMG
OCNL SEV TURB BTN FL180 AND FL390. RPTD BY ACFT. CONDS CONTG BYD 0503Z.

AIRMETs – the NWS issued the following:

WAUS46 KKCI 012045 2011335 2037
WA6T
-SFOT WA 012045
AIRMET TANGO UPDT 5 FOR TURB STG WNDS AND LLWS VALID UNTIL 020300
.
...SEE SIGMET WHISKEY SERIES...
.
...SEE SIGMET YANKEE SERIES...
.
AIRMET TURB...OR CA ID MT WY NV UT CO AZ NM AND CSTL WTRS
FROM 40NE HVR TO 50NNW ISN TO 70SW RAP TO BFF TO GLD TO 50W LBL TO 30ESE TBE TO INK TO ELP TO 50S TUS TO BZA TO 20S MZB TO 160SW RZS TO 140WSW ENI TO 40SE LKV TO 40NE HVR
MOD TURB BTN FL180 AND FL390. CONDS CONTG BYD 03Z THRU 09Z.
.
AIRMET TURB...OR CA ID WY NV UT CO AZ NM AND CSTL WTRS
FROM 40NE LKV TO 40SSE BPI TO 40WSW DEN TO 20N ALS TO 20SE ELP TO 50S TUS TO BZA TO 20S MZB TO 70WSW RZS TO 40WSW FOT TO 40NE LKV
MOD TURB BLW FL180. CONDS CONTG BYD 03Z THRU 09Z.
.
AIRMET STG SFC WNDS...CA CSTL WTRS
FROM 40WSW SNS TO 40SW RZS TO 140SW MZB TO 220SW MZB TO 150SW SNS TO 40WSW SNS
SUSTAINED SURFACE WINDS GTR THAN 30KT EXP. CONDS CONTG BYD 03Z ENDG 03-06Z.
.
AIRMET STG SFC WNDS...CA NV UT AZ
FROM 40S BVL TO 60WSW BCE TO 60NE BZA TO 50SSW HEC TO 40ESE EHF TO 70ENE MOD TO 40S BVL
SUSTAINED SURFACE WINDS GTR THAN 30KT EXP. CONDS CONTG BYD 03Z ENDG 03-06Z.
.
LLWS POTENTIAL...CA NV UT CO AZ NM
BOUNDED BY 30SSE FMG-50ESE ELY-20ESE HVE-40WSW CIM-70WNW CME-20SE SJN-50E TBC-50NNW PGS-50SSW LAS-60S TRM-20S MZB-30WSW RZS-20NW PYE-30SSE FMG
LLWS EXP. CONDS CONTG BYD 03Z THRU 09Z.

9.0 Preflight Weather Briefing

The dispatch release and weather document were viewed and indicated that the dispatcher proved SIGMET Yankee 3 for occasional severe turbulence below 14,000 feet, and SIGMET Whiskey 9 for occasional severe turbulence between 18,000 and 39,000 feet. AIRMETs for turbulence were also included in the package. The document also included Turbulence Plot (TP) advisories which included advisory SW43 for portion of Nevada and California for turbulence code 4 "severe Turbulence" between 30,000 to 42,000 feet due to wave action. Numerous pilot reports were also included in the document reporting moderate to severe turbulence. The flight plan issued by the dispatch planned the flight descending at "BTY" to be at 26,000 feet at "LIDAT" and into the Oakland area and further descending after "BIFFY". However; there was no specific warning or statement issued to the captain communicating the reason for the altitude change.

There was no flight updates noted in the dispatchers statement other than the notification of the turbulence event and the injuries.

Figure 7 is a plot of Southwest's TP SW34 turbulence advisory plotted over GoogleEarth. The accident site is located within its boundaries.

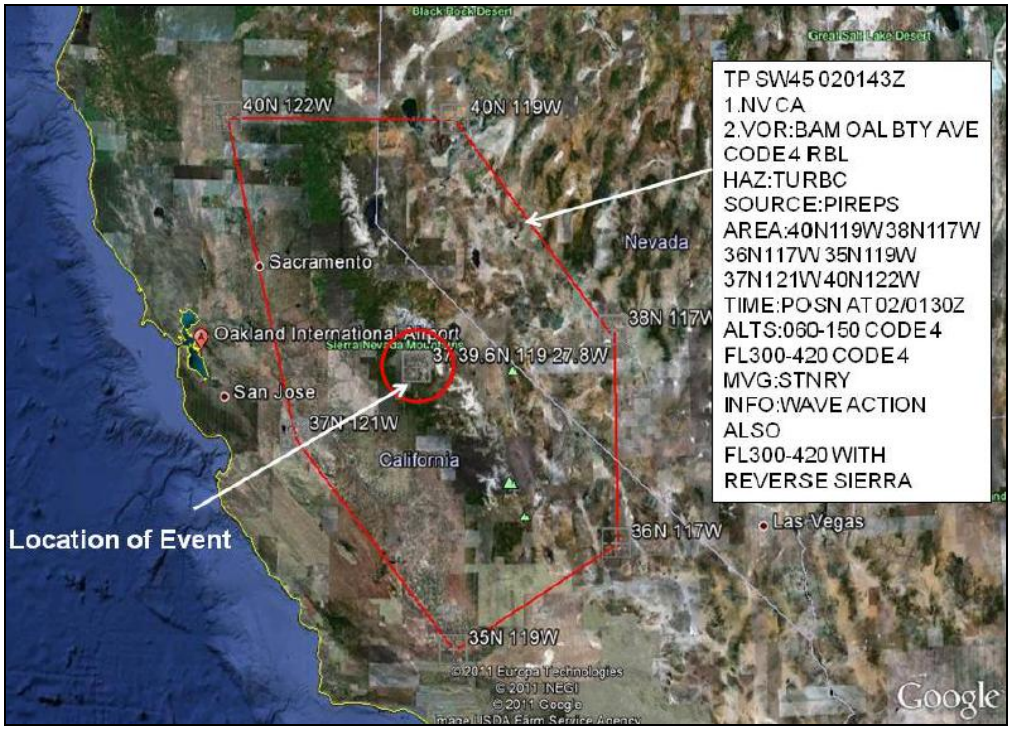

Figure 7 - Plot of TP SW45 for Severe Turbulence

10.0 Turbulence Reference

The following turbulence categories based on the FAA turbulence reporting criteria and the International Civil Aviation Organization (ICAO) quantitative reporting values, based on Lester[5]:

Turbulence category	Aircraft Response	Aircraft Vertical Acceleration Magnitude (g)	Passenger Experience	Eddy Dissipation Rate (EDR)
Light	Momentarily causes slight, erratic changes in altitude and/or attitude (pitch, roll, yaw)	0.2 – 0.5	A slight strain against seat belts; unsecured objects may be displaced slightly: food service may be conducted with little difficulty walking	0.1 – 0.3
Moderate	Similar to light turbulence but greater intensity; changes in altitude, attitude, and/or airspeed occur; the aircraft remains in control at all times	0.5 0 - 1.0	Definite strain against seat belts; unsecured objects are dislodged; food service and walking are difficult	0.3 – 0.5
Severe	Large, abrupt changes in altitude, attitude, and/or airspeed; aircraft may be momentarily out of control	1.0 – 2.0	Occupants are forced violently against seat belts; unsecured objects are tossed about; food service and walking are impossible	0.5 – 0.7
Extreme	The aircraft is violently tossed about is practically impossible to control; it may cause structural damage	> 2.0	Truly frightening	> 0.7

F. LIST OF ATTACHMENTS

Attachment 1: Dispatch Flight Release and Weather Document

Submitted by:

Donald Eick
NTSB Senior Meteorologist

[5] Lester, P.F. 1994: Turbulence: A New Perspective for Pilots. Jeppensen Sanders, 280 pp.