National Transportation Safety Board

Office of Aviation Safety
Washington, D.C. 20594-2000
June 15, 2009

METEOROLOGICAL FACTUAL REPORT

DCA09MA021

A. **ACCIDENT**

Location:	Denver International Airport, Denver, Colorado
Date / Time:	December 20, 2008 at 1818 Mountain Standard Time (MST) December 21, 2008 at 0118 Coordinated Universal Time (UTC)
Aircraft:	Boeing 737-500, N18611, Continental Airlines Flight 1404

B. **WEATHER GROUP**

Chairman:	Gregory D. Salottolo National Resource Specialist, Meteorology National Transportation Safety Board Washington D.C.
Member:	Kris Kimmons[1] Systems Operations Manager Continental Airlines
Member:	James Sullivan[2] Air Line Pilots Association American Eagle Airlines
Member:	Paul Biagi[3] Federal Aviation Administration

[1] Joined the Weather Group on January 12, 2009.
[2] Joined the Weather Group on January 13, 2009.
[3] Joined the Weather Group on March 27, 2009.

C. **SUMMARY**

On December 20, 2008, at 1818 MST (December 21, 2008 at 0118 UTC), Continental flight 1404, a Boeing 737-500 (registration N18611), equipped with CFM56-3B1 engines, departed the left side of runway 34R during takeoff from Denver International Airport (KDEN). The scheduled, domestic passenger flight, operated under the provisions of 14 CFR Part 121, was enroute to George Bush Intercontinental Airport (KIAH), Houston, Texas. One of the five crewmembers was seriously injured, and four of the 110 passengers were seriously injured. There were 37 minor injuries, and no fatalities. The airplane was substantially damaged and experienced post-crash fire. The weather observation closest to the time of the accident was reported to be winds at 290 degrees at 24 knots with gusts to 32 knots, visibility of 10 miles, a few clouds at 4,000 feet and scattered clouds at 10,000 feet. The temperature was reported as -4 degrees Celsius.

D. **DETAILS OF INVESTIGATION**

Note: All times are stated as MST based on the 24-hour clock unless otherwise noted. All heights above mean sea level (msl) unless otherwise noted. Heights in surface weather observations above ground level (agl). All directions are referenced to true north unless otherwise noted. Z = UTC. MST = Z – 7 hours. The accident location is at latitude 39.877233 North and longitude 104.689616 West. The published KDEN magnetic variation is 9.6 degrees East.

1) Synoptic Situation

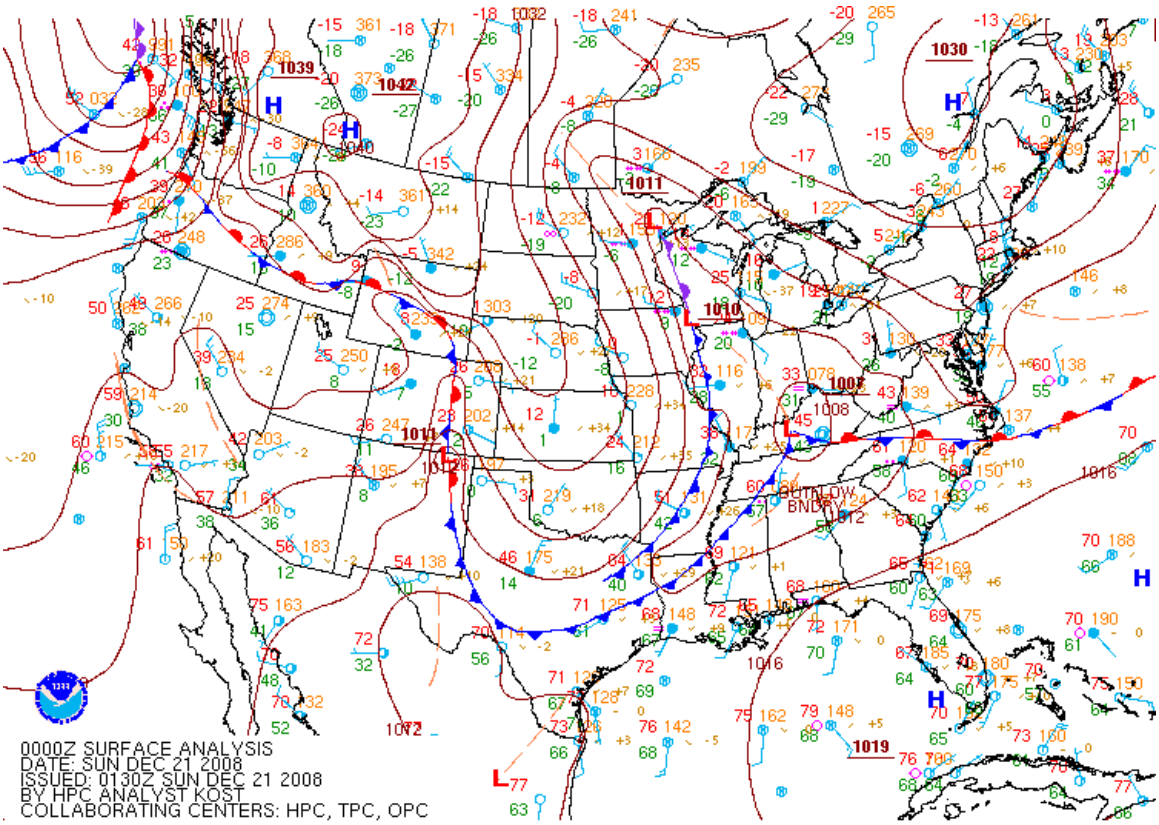

Figure 1: National Weather Service (NWS) Surface Analysis for December 20, 2008 at 1700 MST (December 21, 2008 at 0000Z). The Surface Analysis shows a stationary front in the area of KDEN.

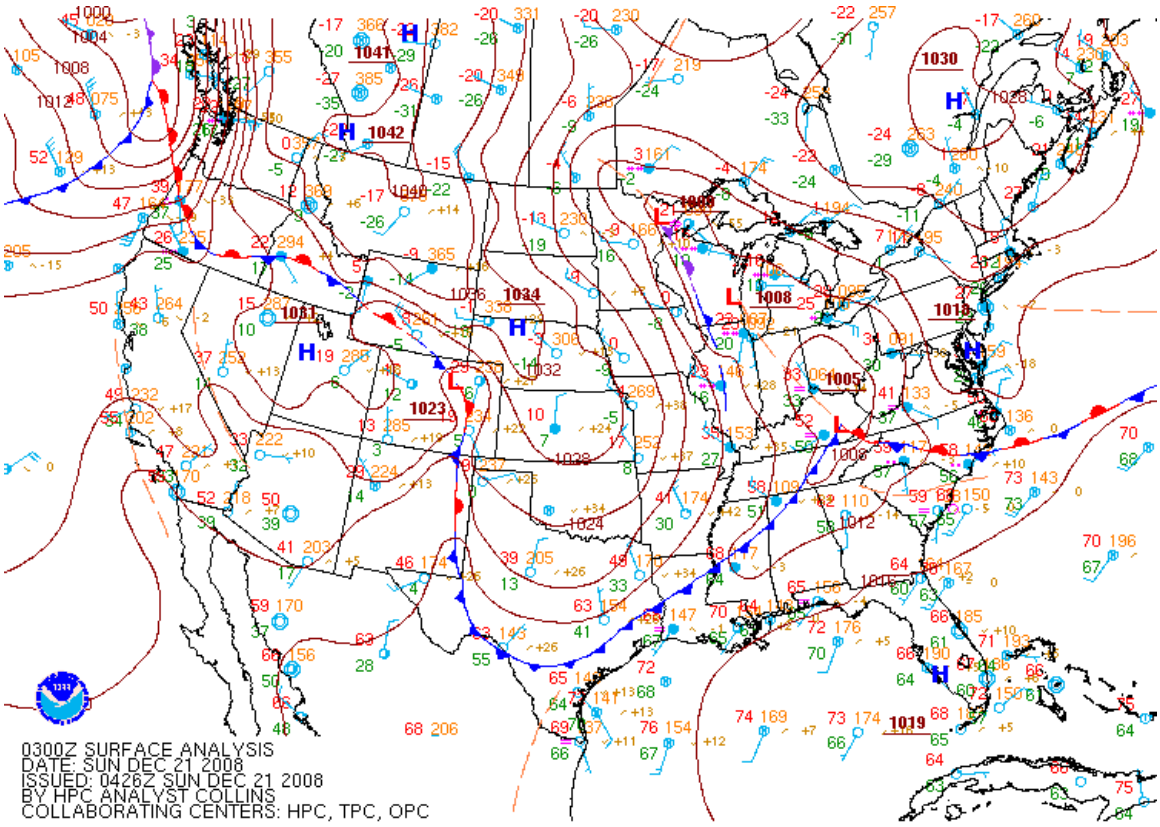

Figure 2: NWS Surface Analysis for December 20, 2008 at 2000 MST (December 21, 2008 at 0300Z). The Surface Analysis shows a stationary front with a low pressure area near KDEN.

2) Surface Weather Data and Observations for KDEN

An Automated Surface Observing System (ASOS) is at KDEN. The KDEN ASOS is augmented and backed up by personnel of Midwest Weather 24 hours a day and 7 days a week. The KDEN ASOS is a Service Level A ASOS. The observation office is located in Concourse B in the ramp tower. The elevation of KDEN is 5,341 feet.

For information on ASOS Service Levels see: ASOS Service Levels

A plot showing the location of the KDEN ASOS sensors is contained in attachment 1.

The KDEN ASOS uses a sonic anemometer (Vaisala NWS 425). The sonic anemometer is referred to as an Ice Free Wind Sensor (IFWS). At the wind sensor every second the wind direction and speed are sampled. Every second a running average of the most recent 3 seconds of data is computed, producing the 3 second peak. Every 5 seconds, the average of the most recent 5 seconds of data is computed, producing a discrete 5 second average. The most recent 24 five second wind observations are used to compute the 2 minute average wind speed and direction. The 2 minute average wind is the quantity

reported in routine observations such as the METAR[4]. Three second peak values are stored by ASOS for up to ten minutes for the purposes of determining wind gusts. If the current 2-minute average wind speed is equal to or greater than 9 knots and the greatest 3 second peak wind speed (during the past minute) exceeds the current 2-minute average speed by 5 knots or more then the greatest 3 second peak wind speed observed during the past minute is stored in memory as a gust. The peak wind is determined from the highest 3 second peak wind speed that exceeds 25 knots since the last generated METAR, whether transmitted or not.

For additional information on ASOS and the KDEN ASOS IFWS see attachments 2 and 3.

KDEN Surface Weather Observations

Coded METAR for December 20, 2008 at 1753 MST: METAR KDEN 210053Z 28011KT 10SM FEW040 SCT100 M06/M16 A2997 RMK AO2 PK WND 29027/0000 SLP202 T10561161

Decoded METAR for December 20, 2008 at 1753 MST: Wind 280 degrees at 11 knots, visibility 10 miles, few clouds at 4,000 feet, scattered clouds at 10,000 feet, temperature –6 degrees C, dew point –16 degrees C, altimeter setting 29.97 inches of Hg., peak wind 290 degrees at 27 knots at 1700 MST.

Coded SPECI[5] for December 20, 2008 at 1834 MST: KDEN 210134Z 29024G32KT 10SM FEW040 SCT100 M04/M18 A2998 RMK AO2 PK WND 28036/0123

Decoded SPECI for December 20, 2008 at 1834 MST: SPECI, wind 290 degrees at 24 knots gusts to 32 knots, visibility 10 miles, few clouds at 4,000 feet, scattered clouds at 10,000 feet, temperature –4 degrees C, dew point –18 degrees C, altimeter setting 29.98 inches of Hg., peak wind 280 degrees at 36 knots at 1823 MST.

5-minute KDEN ASOS surface weather observations.

Coded 5-minute ASOS data for12/20/08 at 18:00:31 MST: 5-MIN KDEN 210100Z 26010KT 10SM SCT095 M06/M16 A2997 5390 43 4200 250/10 RMK AO2

Decoded 5-minute ASOS data for December 20, 2008 at 1800:31 MST: Wind 260 degrees at 10 knots, visibility 10 miles, scattered clouds at 9,500 feet, temperature –6 degrees C, dew point –16 degrees C, altimeter setting 29.97 inches of Hg., pressure altitude 5,390 feet, relative humidity 43%, density altitude 4,200 feet, wind 250 degrees (magnetic) at 10 knots.

[4] Aviation routine weather report.
[5] Special surface weather report.

Coded 5-minute ASOS data for 12/20/08 18:05:31 MST: 5-MIN KDEN 210105Z 28008KT 10SM SCT095 M06/M16 A2997 5380 47 4200 270/08 RMK AO2

Decoded 5-minute ASOS data for December 20, 2008 at 1805:31 MST: Wind 280 degrees at 8 knots, visibility 10 miles, scattered clouds at 9,500 feet, temperature –6 degrees C, dew point –16 degrees C, altimeter setting 29.97 inches of Hg., pressure altitude 5,380 feet, relative humidity 47%, density altitude 4,200 feet, wind 270 degrees (magnetic) at 8 knots.

Coded 5-minute ASOS data for 12/20/08 18:10:31 MST: 5-MIN KDEN 210110Z 26012KT 10SM FEW095 M06/M16 A2998 5380 47 4200 250/12 RMK AO2

Decoded 5-minute ASOS data for December 20, 2008 at 1810:31 MST: Wind 260 degrees at 12 knots, visibility 10 miles, few clouds at 9,500 feet, temperature –6 degrees C, dew point –16 degrees C, altimeter setting 29.98 inches of Hg., pressure altitude 5,380 feet, relative humidity 47%, density altitude 4,200 feet, wind 250 degrees (magnetic) at 12 knots.

Coded 5-minute ASOS data for 12/20/08 18:15:31 MST: 5-MIN KDEN 210115Z 27011KT 10SM FEW090 M06/M16 A2998 5380 45 4200 260/11 RMK AO2

Decoded 5-minute ASOS data for December 20, 2008 at 1815:31 MST: Wind 270 degrees at 11 knots, visibility 10 miles, few clouds at 9,000 feet, temperature –6 degrees C, dew point –16 degrees C, altimeter setting 29.98 inches of Hg., pressure altitude 5,380 feet, relative humidity 45%, density altitude 4,200 feet, wind 260 degrees (magnetic) at 11 knots.

Coded 5-minute ASOS data for 12/20/08 18:20:31 MST: 5-MIN KDEN 210120Z 29024G32KT 10SM FEW090 M05/M17 A2997 5390 40 4300 270/24G32 RMK AO2 PK WND 28032/0120

Decoded 5-minute ASOS data for December 20, 2008 at 1820:31 MST: Wind 290 degrees at 24 knots gusts to 32 knots, visibility 10 miles, few clouds at 9,000 feet, temperature –5 degrees C, dew point –17 degrees C, altimeter setting 29.97 inches of Hg., pressure altitude 5,380 feet, relative humidity 40%, density altitude 4,300 feet, wind 270 degrees (magnetic) at 24 knots gusts to 32 knots, peak wind 280 degrees at 32 knots at 1820 MST.

<u>1-minute KDEN ASOS winds December 21, 2008, 0050 UTC to 0130 UTC.</u>

The KDEN ASOS wind sensor is located at latitude 39.846583 North and longitude 104.656306 West at an elevation of approximately 33 feet agl. The wind sensor is about 14,600 feet (2.4 nautical miles) southeast of the accident site.

T	W1	W2	W3	W4
0050	275	11	289	13
0051	279	11	281	14
0052	283	11	296	15
0053	281	11	282	14
0054	278	10	283	11
0055	274	9	266	14
0056	264	12	266	15
0057	260	12	259	12
0058	258	10	265	11
0059	257	10	261	12
0100	259	10	267	11
0101	262	10	264	10
0102	266	9	275	10
0103	268	9	265	9
0104	272	8	276	10
0105	276	8	282	10
0106	272	9	271	12
0107	269	9	267	10
0108	270	8	262	9
0109	263	9	262	14
0110	264	12	273	15
0111	275	12	275	14
0112	273	12	271	14
0113	267	12	270	13
0114	267	11	264	13
0115	272	11	298	16
0116	279	13	271	20
0117	282	16	279	25
0118	282	18	275	23
0119	283	21	286	26
0120	285	24	279	32
0121	285	25	276	28
0122	287	23	276	28
0123	286	25	277	36
0124	284	27	291	33
0125	280	25	275	32
0126	281	24	283	26
0127	285	24	287	31
0128	286	24	279	28
0129	284	24	286	29
0130	284	24	291	29

Table 1: KDEN ASOS Wind Data.

T: Time in UTC[6].
W1: Two minute average wind direction in degrees true every minute.
W2: Two minute average wind speed in knots every minute.
W3 and W4: Fastest 3 second peak wind (direction degrees true and speed in knots) for each minute.

Using the KDEN ASOS 1-minute maximum 3 second peak wind speed (W4) and direction (W3) for each minute, the following left to right cross track wind components to runway 34R (true heading approximately 360 degrees) are calculated:

T	CTC
0115	14.3
0116	20.0
0117	24.8
0118	22.4
0119	25.2
0120	31.7
0121	27.9
0122	27.9
0123	35.9
0124	31.1
0125	32.0

Table 2: Cross Track Wind Components.
T: Time in UTC.
CTC: Left to right cross track wind component in knots.

3) KDEN Low Level Wind Shear Alert System (LLWAS) wind data

LLWAS wind sensor data are from the Federal Aviation Administration (FAA). Internal to the wind sensor, there is a 6-second low-pass filter (exponential decay with a 6-second time constant). Every 10 seconds the LLWAS base station polls each wind sensor and gets the current (filtered) value. Threshold winds provided by air traffic control (ATC) are a 30 second average of the 10 second LLWAS poll.

According to the FAA, the Low-Level Windshear Alert System - Network Expansion Rehost (LLWAS-NE^{++}) at KDEN comprises hardware and software necessary to provide continuous real-time collection and analysis of wind data from 32 remote stations at and around the airport. It provides airport and runway wind speed and direction information, and determines whether conditions exist that exhibit windshear and/or microburst activity. If these conditions exist, the LLWAS-NE^{++} produces alerts that are output to the Air Traffic Control Tower (ATCT) Ribbon Display Terminals (RBDTs). The KDEN system currently supports all 6 physical runways in all functions relating to wind analysis and runway oriented messages and data.

[6] To convert UTC to MST subtract 7 hours.

The LLWAS-NE^{++} ultrasonic wind sensor **(**UWS) provides two values of wind measurement data: the equivalent RC (resistor-capacitor) filtered wind speed and direction; and the linear speed/unit vector direction (averaged). The RC filtered time constant of 6 seconds and the last 1-second measurement value, are both factory preset in nonvolatile memory to 6 and 1 respectively. The UWS is free running, taking continuous 1-second measurement cycles.

LLWAS sensor #2 is located about 3,000 feet east of the 1,400 foot point of runway 34R at latitude 39.867883 North and longitude 104.676572 West at an elevation of 110 feet agl.
LLWAS sensor #29 is located about 4,900 feet west of the 5,800 foot point of runway 34R at latitude 39.880056 North and longitude 104.704472 West at an elevation of 40 feet agl.
LLWAS sensor #3 is located about 3,400 feet east of the 10,000 foot point of runway 34R at latitude 39.891361 North and longitude 104.674889 West at an elevation of 100 feet agl.

Time UTC	WD2	WS2	WD3	WS3	WD29	WS29
1:14:12	276	29	274	23	273	23
1:14:22	276	30	273	23	277	22
1:14:32	276	27	269	25	277	22
1:14:42	273	29	272	25	272	22
1:14:52	272	30	274	24	274	25
1:15:02	276	30	276	26	264	21
1:15:12	277	34	273	22	270	19
1:15:22	278	29	268	24	275	19
1:15:32	281	26	267	23	274	19
1:15:42	281	30	273	25	278	23
1:15:52	280	29	269	23	275	23
1:16:02	280	30	266	24	276	28
1:16:12	286	36	268	25	278	29
1:16:22	282	40	268	23	273	30
1:16:32	280	38	269	25	273	27
1:16:42	278	38	268	26	272	26
1:16:52	278	35	267	28	272	24
1:17:02	273	32	265	27	272	23
1:17:12	276	35	268	26	276	25
1:17:23	270	33	270	25	278	24
1:17:32	272	33	268	27	275	23
1:17:42	281	32	270	28	273	23
1:17:52	273	32	265	27	273	24
1:18:02	269	37	266	26	270	24
1:18:12	270	34	264	24	270	23
1:18:22	268	35	265	23	268	22
1:18:32	272	36	268	26	271	22
1:18:43	271	36	269	27	275	22
1:18:53	269	37	268	27	273	26
1:19:03	268	36	270	27	276	22

1:19:13	272	35	268	25	276	22
1:19:23	273	33	267	26	278	21
1:19:33	271	31	270	23	278	21
1:19:43	274	31	268	24	277	20
1:19:53	271	32	268	24	281	21
1:20:03	274	30	267	25	276	19
1:20:13	274	30	267	24	278	20
1:20:23	274	32	269	23	278	21
1:20:33	274	31	267	25	280	22
1:20:43	270	32	267	25	277	22
1:20:53	270	31	268	26	277	22
1:21:03	270	31	274	24	279	23
1:21:13	272	32	270	27	279	22
1:21:23	269	30	264	26	278	24
1:21:33	269	31	265	27	277	23
1:21:43	269	34	266	24	279	23
1:21:53	270	33	271	23	279	21
1:22:03	269	34	272	23	278	19

Table 3: KDEN LLWAS Wind Sensor Data.
WD2: LLWAS Wind Sensor #2 wind direction in degrees magnetic.
WS2: LLWAS Wind Sensor #2 wind speed in knots.
WD3: LLWAS Wind Sensor #3 wind direction in degrees magnetic.
WS3: LLWAS Wind Sensor #3 wind speed in knots.
WD29: LLWAS Wind Sensor #29 wind direction in degrees magnetic.
WS29: LLWAS Wind Sensor #29 wind speed in knots.

According to the FAA, the airport 2 minute wind direction and speed is a running 2 minute average updated every 10 seconds. For the airport gusts the last 1-minute airport wind remote sensor poll response data is compared to the current airport wind to determine if a peak wind speed condition exists (a peak wind speed is at least 5 knots greater than the airport wind which must be at least 9 knots). If the maximum peak wind speed of all peak wind speeds in the last 10 minutes is greater than the current airport wind by 3 knots, and the current airport wind is at least 3 knots, the maximum peak wind speed is displayed as the gust speed value. The gust speed can persist up to 10 minutes unless the maximum peak wind speed falls within 3 knots of the current airport wind.

Time UTC	DEN WD	DEN WS	DEN Gust
1:14:12	280	28	G00
1:14:22	280	28	G00
1:14:32	280	28	G00
1:14:42	280	28	G00
1:14:52	280	29	G00
1:15:02	280	29	G00
1:15:12	280	30	G35
1:15:22	280	30	G35
1:15:32	280	30	G35

1:15:42	280	30 G35
1:15:52	280	30 G35
1:16:02	280	30 G35
1:16:12	280	30 G37
1:16:22	280	31 G40
1:16:32	280	32 G40
1:16:42	280	33 G40
1:16:52	280	33 G40
1:17:02	280	33 G40
1:17:12	280	34 G40
1:17:23	280	34 G40
1:17:32	280	34 G40
1:17:42	280	34 G40
1:17:52	280	34 G40
1:18:02	280	35 G40
1:18:12	280	35 G40
1:18:22	280	35 G40
1:18:32	270	35 G40
1:18:43	270	35 G40
1:18:53	270	35 G40
1:19:03	270	35 G40
1:19:13	270	35 G40
1:19:23	270	35 G40
1:19:33	270	35 G40
1:19:43	270	35 G40
1:19:53	270	35 G40
1:20:03	270	34 G40
1:20:13	270	34 G40
1:20:23	270	34 G40
1:20:33	270	33 G40
1:20:43	270	33 G40
1:20:53	270	33 G40
1:21:03	270	32 G40
1:21:13	270	32 G40
1:21:23	270	32 G40
1:21:33	270	32 G40
1:21:43	270	32 G40
1:21:53	270	32 G40
1:22:03	270	32 G40

Table 4: Two Minute Average Airport Wind Speed and Direction and Airport Wind Gusts from LLWAS Wind Sensor #2 (Airport Wind Sensor).
DEN WD: KDEN Airport 2 Minute Wind Direction in Degrees Magnetic.
DEN WS: KDEN Airport 2 Minute Wind Speed in Knots.
DEN Gust: KDEN Airport Wind Gust in Knots.

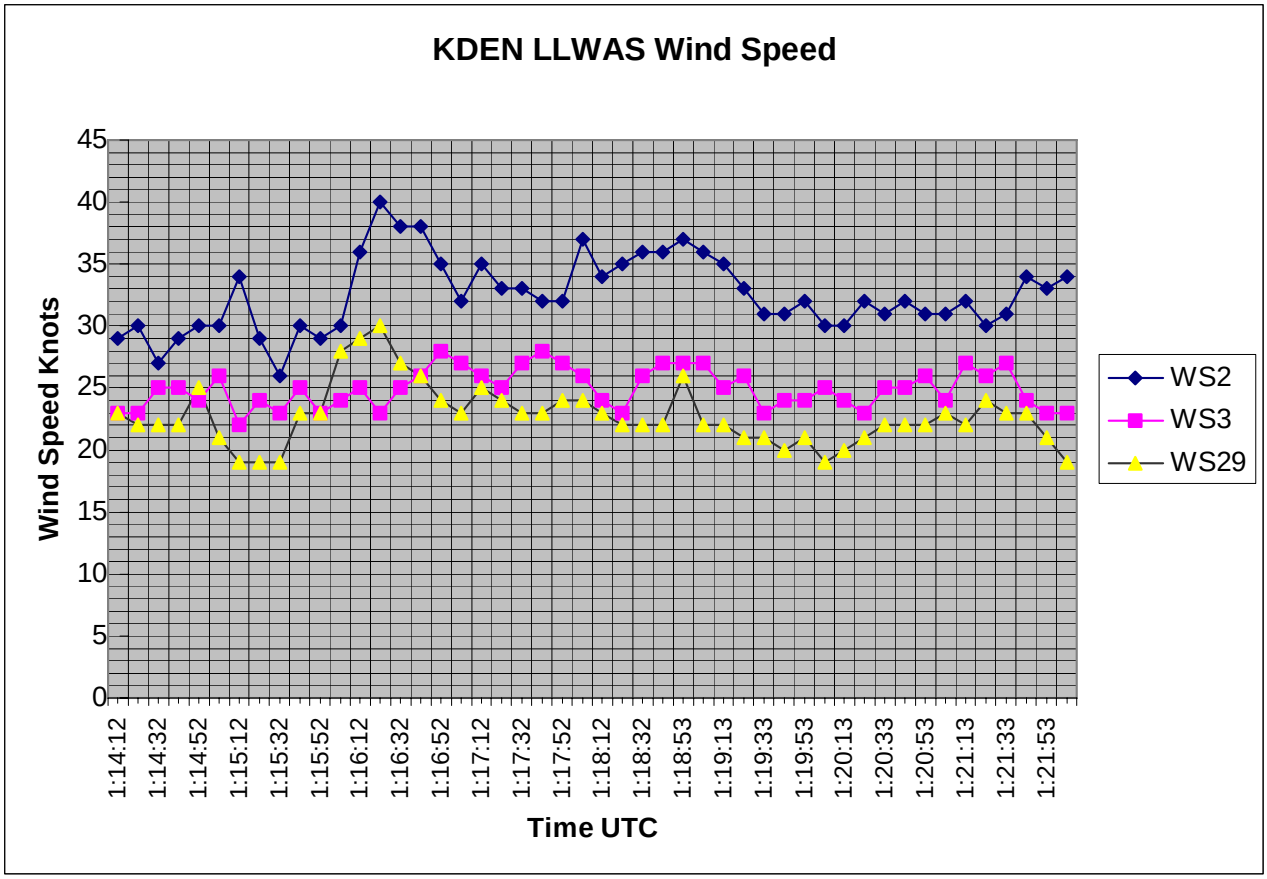

Figure 3: Plot of KDEN LLWAS Wind Speed in Knots from LLWAS Sensors #2, #3, and #29.

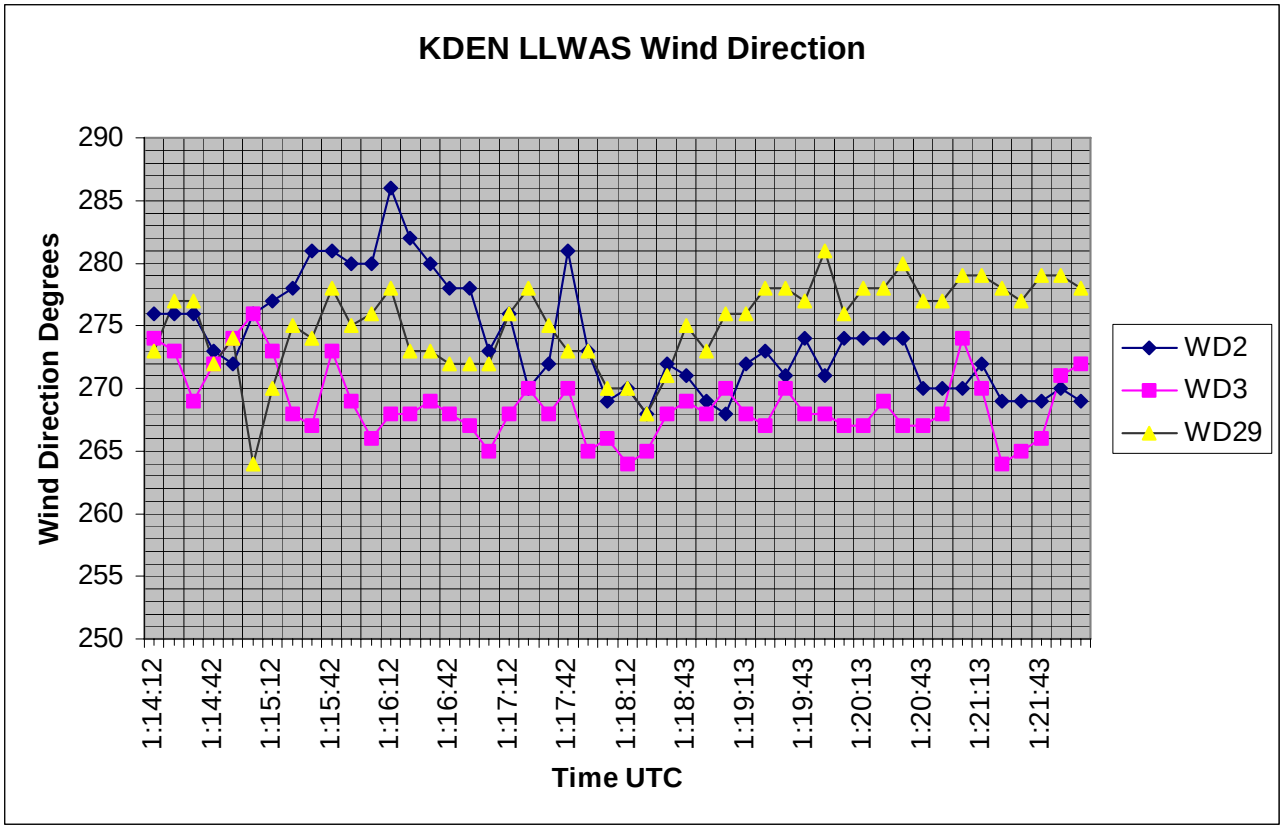

Figure 4: Plot of KDEN LLWAS Wind Direction in Degrees Magnetic from LLWAS Sensor #2, #3, and #29.

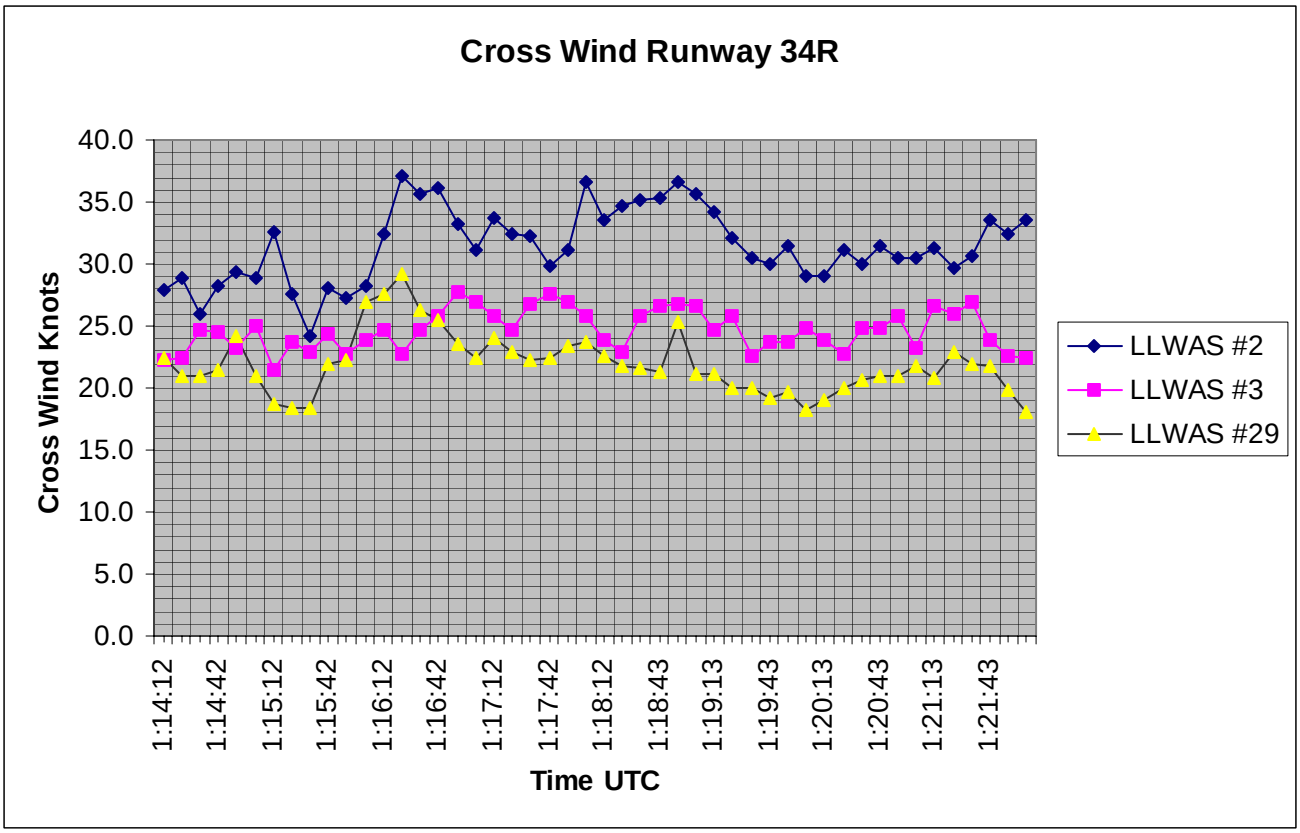

Figure 5: Plot of KDEN Cross Wind Component in Knots to Runway 34R from Wind Speed and Direction data from LLWAS Sensors #2, #3, and #29.

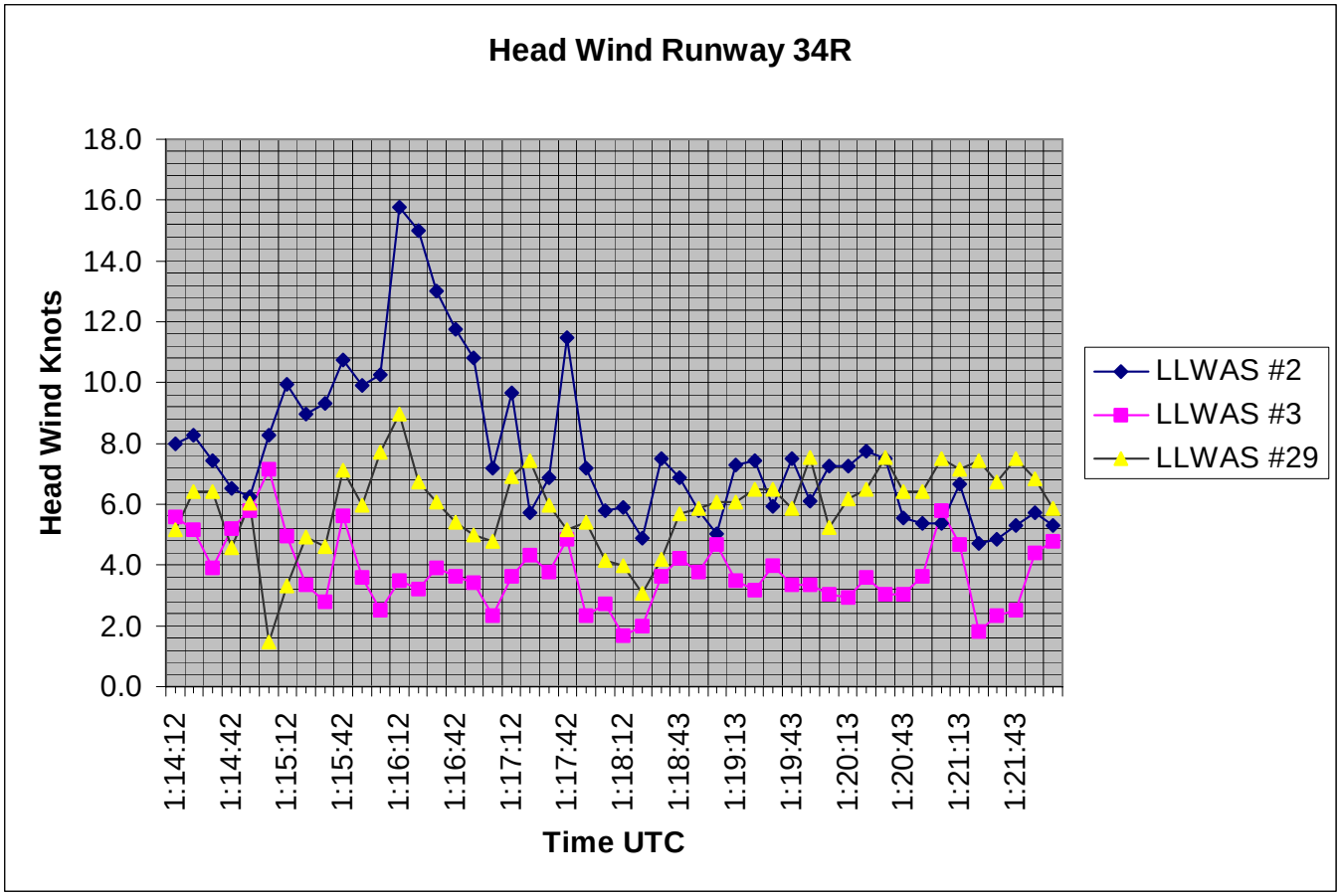

Figure 6: Plot of KDEN Head Wind Component in Knots to Runway 34R from Wind Speed and Direction data from LLWAS Sensor #2, #3, and #29.

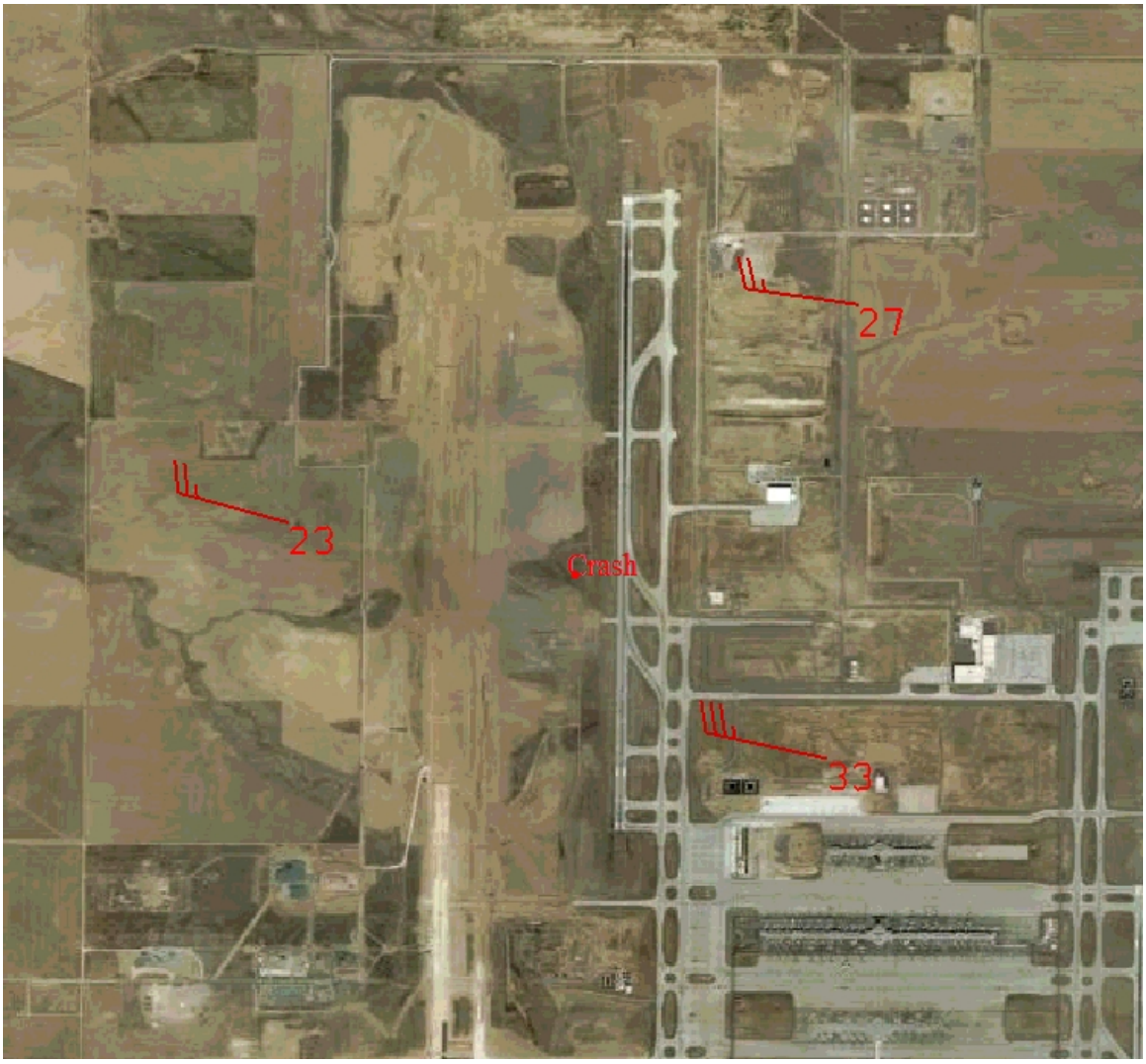

Figure 7: Plot of LLWAS wind sensor data over an image of KDEN showing runway 34R for December 20, 2008, at 1817:32 MST (December 21, 2008, at 0117:32Z). Wind barbs indicate the direction the wind is coming from. Each full barb equals 10 knots and each short barb equals 5 knots. Wind speeds in knots are noted at the head of the wind barbs. The crash site is plotted on the image. True north is to the top of the image. Runway 16R/34L is not shown in the image. The data were plotted using the Integrated Data Viewer (IDV). For information on the IDV see the link: IDV.

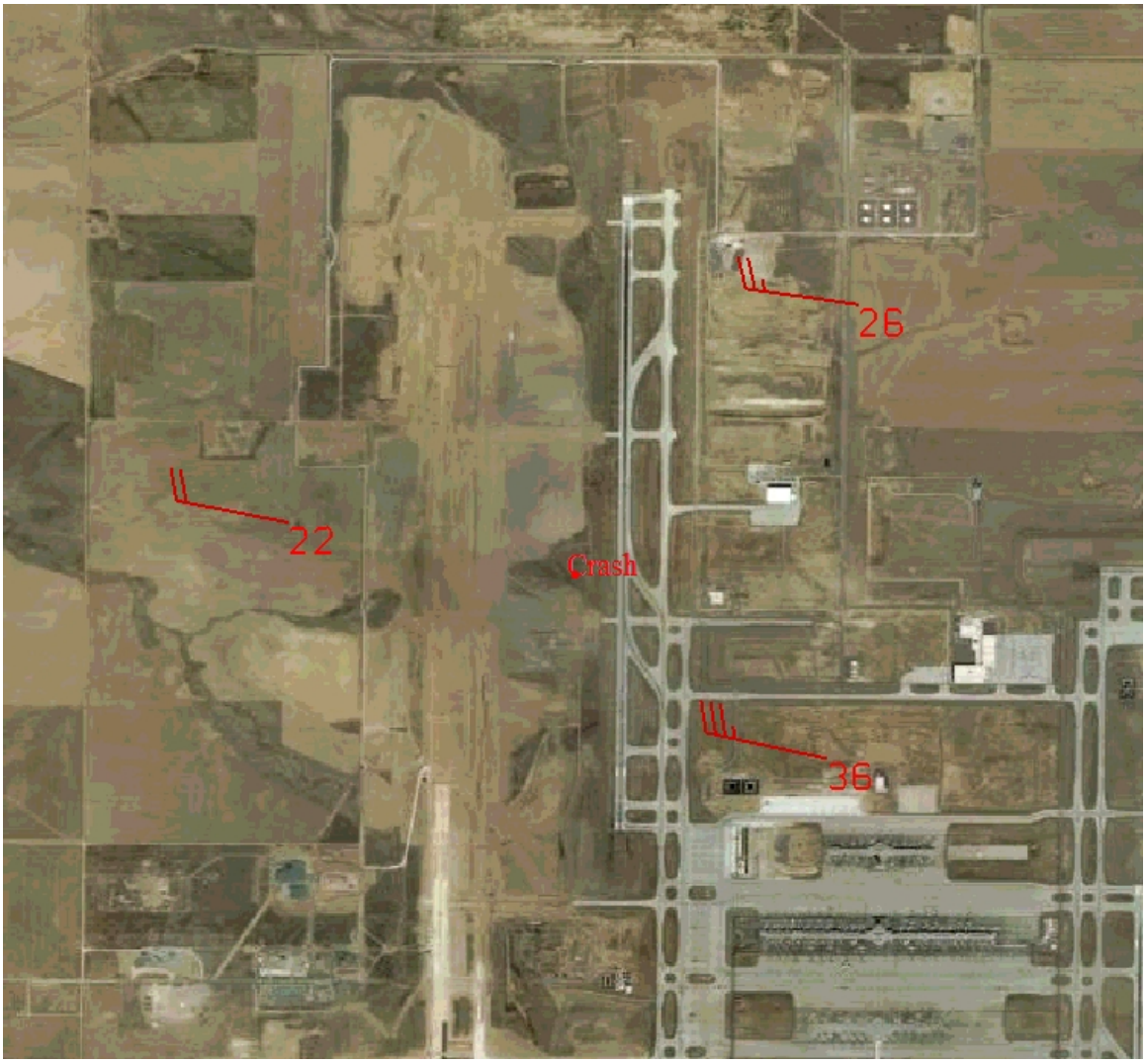

Figure 8: Plot of LLWAS wind sensor data over an image of KDEN showing runway 34R for December 20, 2008, at 1818:32 MST (December 21, 2008, at 0118:32Z). Wind barbs indicate the direction the wind is coming from. Each full barb equals 10 knots and each short barb equals 5 knots. Wind speeds in knots are noted at the head of the wind barbs. The crash site is plotted on the image. True north is to the top of the image. Runway 16R/34L is not shown in the image. The data were plotted using the IDV.

Attachment 4 contains plots of LLWAS wind sensor data over images of KDEN showing runway 34R for December 20, 2008 at 1817:23 MST (December 21, 2008 at 0117:23Z) to December 20, 2008 at 1818:43 MST (December 21, 2008 at 0118:43Z).

Table 5 below lists wind information along the centerline of runway 34R (350 degrees magnetic) from interpolated LLWAS wind data. These data were provided by the National Center for Atmospheric Research (NCAR). The length of runway 16L/34R is approximately 12,000 feet (3.66 kilometers).

Time	DT	WC	XWIN	WD	WS
1:17:32	**0**	**-6.3**	**29.2**	**272.3**	**29.9**
1:17:42	0	-9.4	26.7	279.6	28.3
1:17:52	0	-7.5	28.6	274.7	29.6
1:18:02	0	-6.2	32.1	271.1	32.7
1:18:12	0	-6.0	30.6	271.1	31.2
1:18:22	0	-5.7	30.1	270.8	30.6
1:18:32	0	-7.1	31.2	273.0	32.0
1:17:32	**0.5**	**-6.2**	**28.9**	**272.3**	**29.5**
1:17:42	0.5	-9.1	26.9	278.7	28.4
1:17:52	0.5	-6.8	28.5	273.5	29.3
1:18:02	0.5	-5.4	31.9	269.8	32.4
1:18:12	0.5	-5.3	30.0	270.2	30.5
1:18:22	0.5	-4.7	30.0	269.0	30.3
1:18:32	0.5	-6.5	30.7	272.0	31.3
1:17:32	**1**	**-6.1**	**28.4**	**272.2**	**29.1**
1:17:42	1	-8.6	27.1	277.7	28.4
1:17:52	1	-6.0	28.2	272.2	28.8
1:18:02	1	-4.7	31.4	268.6	31.8
1:18:12	1	-4.7	29.2	269.3	29.6
1:18:22	1	-3.7	29.5	267.3	29.8
1:18:32	1	-5.8	29.9	271.0	30.4
1:17:32	**1.5**	**-5.5**	**27.3**	**271.5**	**27.8**
1:17:42	1.5	-7.3	26.6	275.4	27.6
1:17:52	1.5	-5.1	27.3	270.7	27.8
1:18:02	1.5	-4.1	29.3	268.1	29.6
1:18:12	1.5	-3.9	27.3	268.3	27.6
1:18:22	1.5	-3.2	27.2	266.9	27.4
1:18:32	1.5	-5.0	28.0	270.3	28.4
1:17:32	**2**	**-4.9**	**26.1**	**270.8**	**26.6**
1:17:42	2	-6.0	26.1	273.1	26.8
1:17:52	2	-4.2	26.4	269.2	26.8
1:18:02	2	-3.6	27.2	267.6	27.4
1:18:12	2	-3.1	25.4	267.1	25.6
1:18:22	2	-2.7	24.9	266.3	25.0
1:18:32	2	-4.3	26.1	269.5	26.4
1:17:32	**2.5**	**-4.4**	**25.0**	**270.0**	**25.4**
1:17:42	2.5	-4.7	25.6	270.6	26.0
1:17:52	2.5	-3.3	25.5	267.5	25.8
1:18:02	2.5	-3.0	25.1	267.0	25.3
1:18:12	2.5	-2.4	23.5	265.8	23.6

1:18:22	2.5	-2.2	22.6	265.6	22.7
1:18:32	2.5	-3.6	24.2	268.5	24.4
1:17:32	**3**	**-3.9**	**25.6**	**268.8**	**25.9**
1:17:42	3	-4.1	25.4	269.2	25.8
1:17:52	3	-2.5	25.4	265.8	25.6
1:18:02	3	-3.1	25.0	267.1	25.2
1:18:12	3	-2.3	23.5	265.6	23.6
1:18:22	3	-2.2	22.5	265.6	22.6
1:18:32	3	-3.6	24.3	268.5	24.5
1:17:32	**3.5**	**-3.5**	**26.2**	**267.6**	**26.5**
1:17:42	3.5	-3.5	25.3	267.9	25.6
1:17:52	3.5	-1.7	25.3	264.0	25.4
1:18:02	3.5	-3.1	25.0	267.3	25.2
1:18:12	3.5	-2.2	23.5	265.4	23.6
1:18:22	3.5	-2.2	22.5	265.6	22.6
1:18:32	3.5	-3.6	24.5	268.5	24.7

Table 5: Wind Information Along the Centerline of Runway 34R (350 Degrees Magnetic) from Interpolated LLWAS Wind Data. The time of 0117:32Z is highlighted in red.
Time: UTC
DT: Distance in kilometers down the centerline from the threshold of runway 34R.
WC: Wind Component along runway 34R in knots (negative is headwind).
XWIN: Cross Wind Component to runway 34R in knots (positive is a left to right cross wind).
WD: Wind Direction degrees magnetic.
WS: Wind Speed knots.

The following KDEN LLWAS Wind Shear Alerts (WSA) were noted during the time period December 20, 2008 at 1815:52 MST to December 20, 2008 at 1818:53 MST[7].

1816:52 MST runway 25 arrival 20 knot gain 2 mile final, runway 7 departure 20 knot gain on the runway.
1817:02 MST runway 25 arrival 20 knot gain 2 mile final, runway 7 departure 20 knot gain 1 mile departure.
1817:12 MST runway 25 arrival 20 knot gain 2 mile final, runway 7 departure 20 knot gain 1 mile departure.
1817:23 MST runway 25 arrival 20 knot gain 2 mile final, runway 7 departure 20 knot gain 1 mile departure.
1817:32 MST runway 25 arrival 20 knot gain 2 mile final, runway 7 departure 20 knot gain 1 mile departure.

[7] A complete listing of LLWAS wind sensor data for December 20, 2008 at 1700 MST (December 21, 2008 at 0000Z) to December 20, 2008 at 1959:56 MST (December 21, 2008 at 0259:56Z) is contained in attachment 5. A listing of LLWAS alerts is contained in attachment 6.

Denver International Airport
LLWAS-NE++ Sensor Configuration

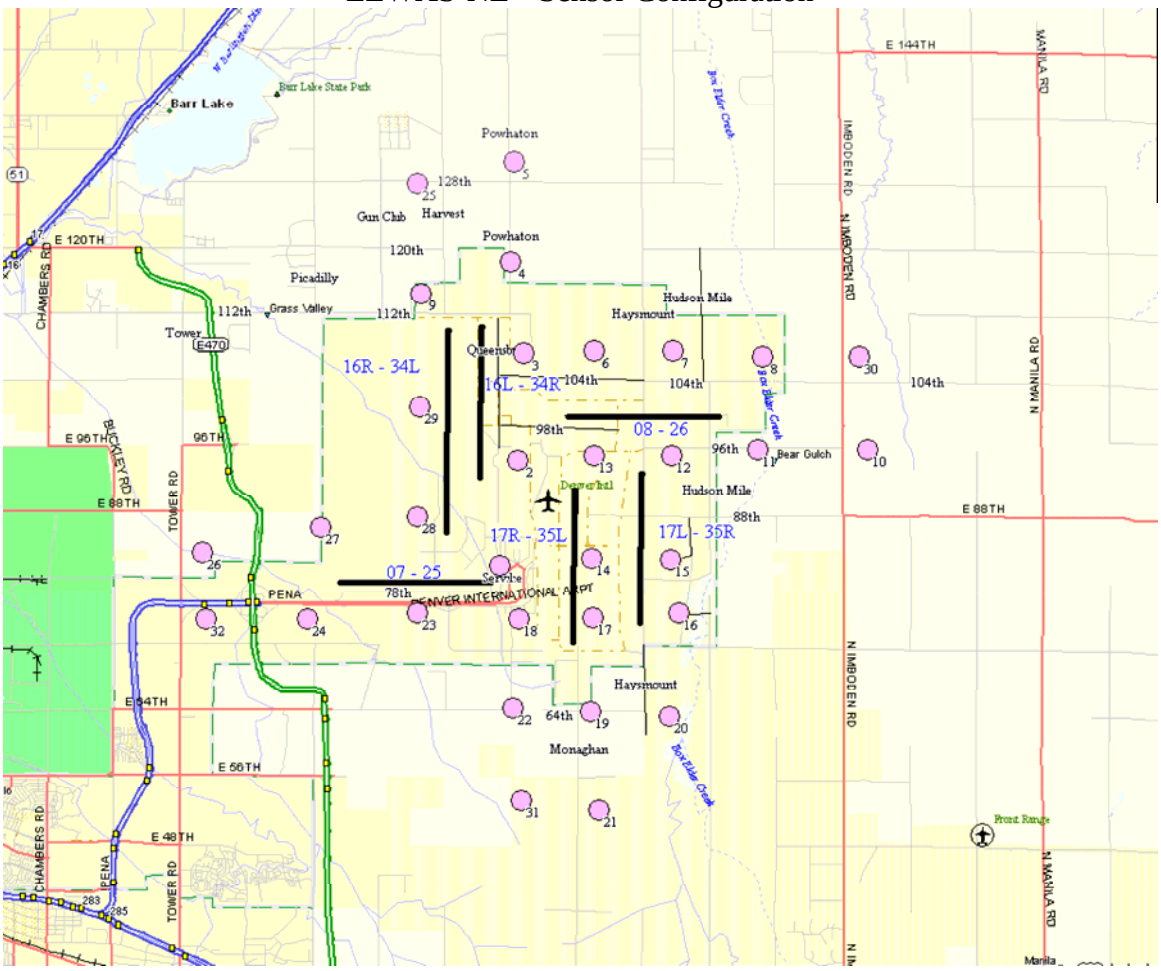

Figure 9: KDEN LLWAS Wind Sensor Locations.

4) Data from the Weather Support for Deicing Decision Making System

A Weather Support for Deicing Decision Making (WSDDM)[8] system was operational at KDEN. Wind data from sensor DIA1 and DIA2 are noted below.

DIA1 is located at latitude 39.870 North and longitude 104.679 West, about 2,300 feet east of the 2,200 foot point of runway 34R at an elevation of 3 meters (9.8 feet) agl.

DIA2 is located at 39.855 North and longitude 104.718 West, about 9,200 feet southwest of the threshold of runway 34R at an elevation of 10 meters (32.8 feet) agl.

Time MST	WSpd	Wdir	MaxWSpd
1815	22.7	287.9	24.2
1816	22.8	283.1	28.3
1817	22.4	284.2	25.3
1818	24.6	284.2	26.8
1819	27.6	278.6	31.7
1820	23.9	280.8	26.6
1821	20.9	281.7	26.9
1822	22.2	282.9	27.6

Table 6: DIA1 Wind Data.

Time MST	WSpd	Wdir	MaxWSpd
1815	30.8	283.2	33.9
1816	31.1	281.5	36.6
1817	31.7	279.9	34.6
1818	31.5	276.9	36.0
1819	29.3	277.5	31.9
1820	29.6	278.9	33.4
1821	25.8	280.1	29.4
1822	22.0	280.1	24.2

Table 7: DIA2 Wind Data.

WSpd: Wind Speed in knots.
Wdir: Wind Direction in degrees true.
MaxWSpd: Maximum 1-Minute Wind Speed in knots.

[8] Scientists at the Research Applications Program (the principal division of NCAR responsible for aviation weather projects) have developed a state-of-the art, integrated display system to help mitigate the airplane ground icing problem. WSDDM depicts accurate, real-time nowcasts of snowfall rate, plus current temperature, humidity, wind speed and direction.

5) Doppler Weather Radar Data

Figures 10 and 11 show the Level II Doppler weather radar data for Denver, Colorado (KFTG). These data were displayed using the IDV.

The elevation of the KFTG antenna is about 5,610 feet. The threshold of runway 34R is about 306 degrees at 8.0 nautical miles from KFTG. At the threshold of runway 34R the KFTG beam center at a 0.5 degree elevation angle is about 6,079 feet. The beam width is about 809 feet. The elevation at the threshold of runway 34R is about 5,351 feet. Therefore, the KFTG beam center is about 728 feet agl at the threshold of runway 34R.

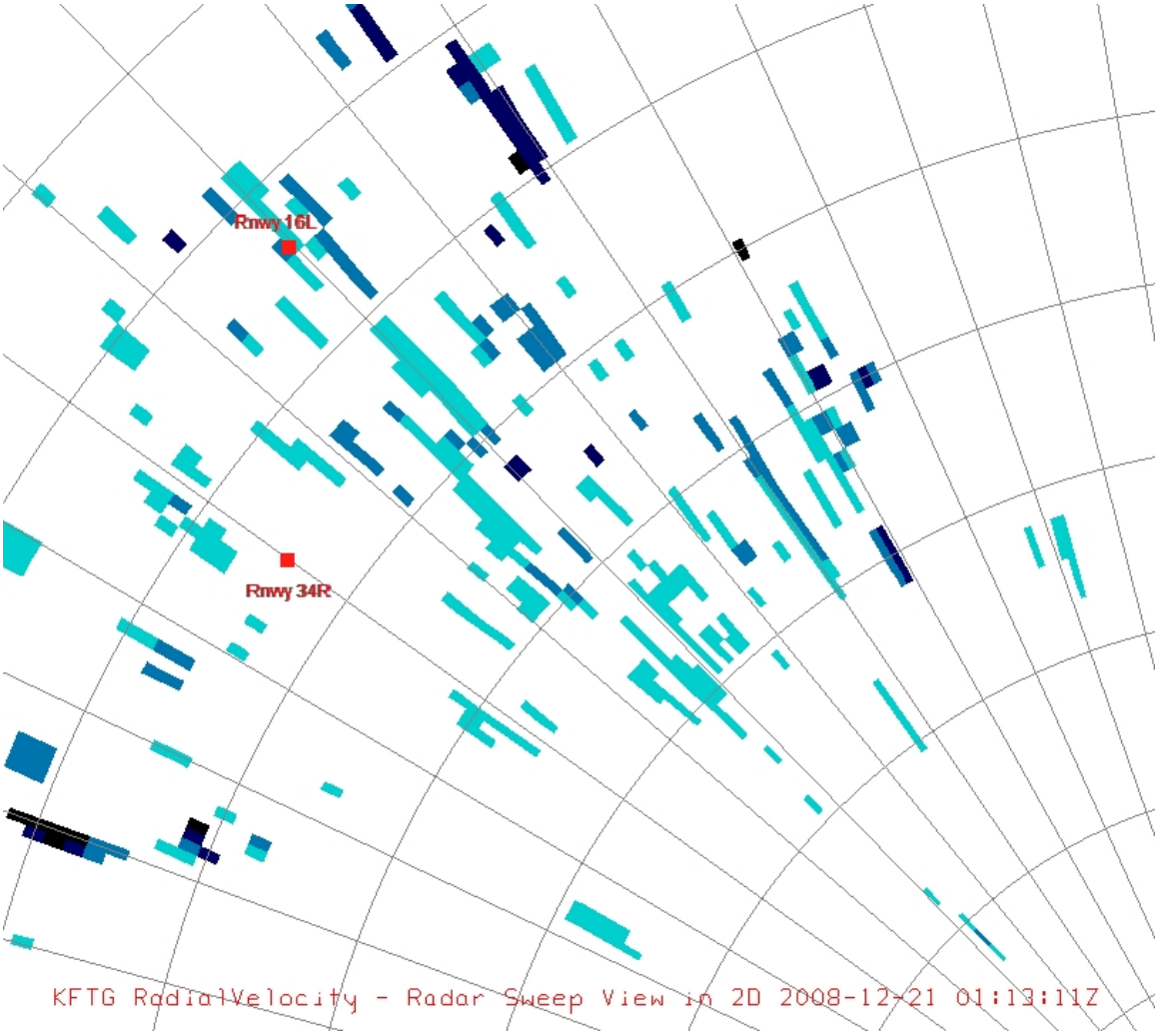

Figure 10: KFTG Base Radial Velocity image for December 20, 2008 at 1813:11 MST (December 21, 2008 at 0113:11Z). Range rings are every 2 kilometers. Radials are every 5 degrees. The threshold of runway 34R (Rnwy 34R) and runway 16L (Rnwy 16L) are labeled by solid red squares. Radial velocities are in knots and are color coded. Light blue colors indicate radial velocities towards the radar (lower right) from about 30 knots to 38 knots. Medium blue colors indicate radial velocities towards the radar at about 39 knots

to 45 knots. Dark blue colors indicate radial velocities towards the radar at about 46 knots to 53 knots.

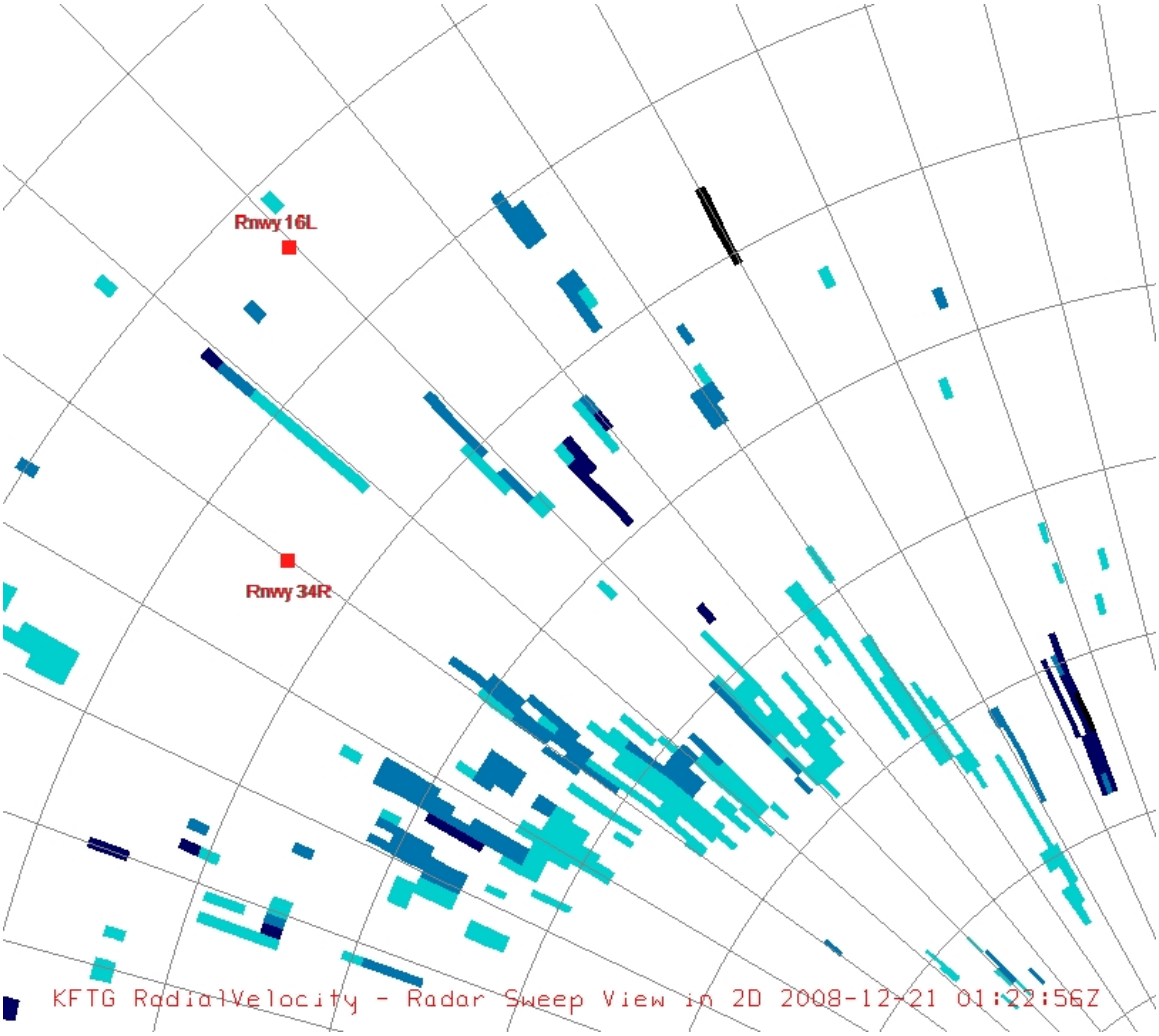

Figure 11: KFTG Base Radial Velocity image for December 20, 2008 at 1822:56 MST (December 21, 2008 at 0122:56Z). Range rings are every 2 kilometers. Radials are every 5 degrees. The threshold of runway 34R (Rnwy 34R) and runway 16L (Rnwy 16L) are labeled by solid red squares. Radial velocities are in knots and are color coded. Light blue colors indicate radial velocities towards the radar (lower right) from about 30 knots to 38 knots. Medium blue colors indicate radial velocities towards the radar at about 39 knots to 45 knots. Dark blue colors indicate radial velocities towards the radar at about 46 knots to 53 knots.

6) Terminal Doppler Weather Radar Data

A Terminal Doppler Weather Radar (TDWR)[9] was operational at KDEN. The KDEN TDWR is located at latitude 39.72748 degrees North and longitude 104.52644 degrees West. The antenna height is about 5,700 feet. The antenna elevation is 0.3 degree. The beam center at the accident location is about 820 feet agl. The KDEN TDWR is located about 140 degrees at 11.7 nautical miles from the accident site.

The following information was provided by the FAA TDWR and Meteorological Support Manager at Oklahoma City, Oklahoma, on January 14, 2009 to the NTSB Weather Group Chairman.

The KDEN TDWR data for the period December 20, 2008 at 1700 MST (December 21, 2008 at 0000Z) to December 20, 2008 at 1900 MST (December 21, 2008 at 0200Z) showed sporadic returns which are common in dry weather conditions. There were no TDWR wind-shear detections (loss or gain) for the entire time period. Second trip returns on or near the airport were seen throughout the time period due to distant weather. Beginning on December 20, 2008 at 1821:11 MST (December 21, 2008 at 0121:11Z) the smoke from the wreckage of the plane can be seen around 20 to 22 kilometers from the TDWR at about 315 degrees. On December 20, 2008 at 1827:11 MST (December 21, 2008 at 0127:11Z) a thin line oriented from west to east becomes elongated in the same area. This is assumed to be the smoke plume moving away from the aircraft. On December 20, 2008 at 1833:12 MST (December 21, 2008 at 0133:12Z) the same thin line moves further eastward. Measuring the distance traveled over time by the smoke plume it was determined that the smoke plume was moving at about 40 miles per hour (35 knots).

The correspondence between the TDWR and Meteorological Support Manager and the NTSB Weather Group Chairman is contained in attachment 7.

7) Integrated Terminal Weather System

The Denver Integrated Terminal Weather System (ITWS) is a fully automated, integrated terminal weather information system to improve the safety, efficiency, and capacity of terminal area aviation operations. It acquires data from the Denver TDWR, Denver LLWAS-NE++, Denver NEXRAD (Next Generation Doppler Weather Radar), Platteville ASR-9 (Airport Surveillance Radar), Irondale ASR-9, NOAA (National Oceanic and Atmospheric Administration) RUC (Rapid Update Cycle) wind field numerical model, ASOS/AWOS (Automated Weather Observing System) sensors, NLDN (National Lightning Detection Network), and from aircraft in flight in the terminal area. The ITWS provides aviation-oriented weather products to ATC personnel that are immediately usable without further meteorological interpretation. These products include current terminal area weather conditions, microburst and windshear alerts, and short-term predictions of significant weather phenomena.

[9] TDWR is an automated Doppler weather radar system developed by the FAA. The TDWR system provides increased safety measures and improved runway/airfield management through detection and display of microbursts, gust fronts, prediction of wind shifts, and precipitation.

The following information was provided by the FAA meteorologist, who reviewed the ITWS Situation Display archives, to the NTSB Weather Group Chairman on January 23, 2009.

The Tower display was in the ITWS mode and was providing the ITWS information to the KDEN Tower ribbon displays, as is the normal operating configuration. The ITWS ribbon alerts are the result of ITWS radar generated alerts integrated with LLWAS generated alerts. The ITWS radar generated alerts, microburst, wind shear, and gust front, come from the TDWR base data.

For the time period December 20, 2008 at 1730 MST to December 20, 2008 at 1830 MST there were no ITWS radar generated alerts (i.e. no Microburst, Wind Shear, or Gust Front detections). The ITWS integration algorithm drops all LLWAS 15 knot gain alerts if not confirmed by an ITWS radar generated alert. All LLWAS gain alerts greater than or equal to 20 knots are accepted without an ITWS radar generated alert and passed to the ribbon displays in the Denver ATCT[10].

In a telephone interview conducted on February 4, 2009 the FAA meteorologist noted that the data in the DEN-Ribbon Display Alerts Window of the images is a tabulation of all data corresponding to the runway configurations assigned both in the KDEN ATCT and Terminal Radar Approach Control (TRACON) to a ribbon display. In the tower the following runway configurations were assigned to the ribbon displays for the local control 4 (LC4) position: 34RD, 34LD, 34RA, 34LA, 7A, 25D. Therefore, any wind shear alerts for runway 25A and 7D would not be displayed on the LC4 Tower ribbon display. However, the ITWS graphical display containing all weather information (see the ITWS images) was available in the ATCT and in the TRACON.

Figures 10 and 11 are ITWS images (1817:36 MST -- December 21, 2008 at 0117:36Z and 1818:27 MST -- December 21, 2008 at 0118:27Z) for the times near the time Continental flight 1404 was cleared for takeoff and the time the Cockpit Voice Recording ends. The winds displayed in the ribbon display for runway 34RD and runway 34RA are from LLWAS sensors #3 and #2 respectively.

[10] Review of LLWAS data showed LLWAS generated Wind Shear Alerts (WSA) for a gain of 20 knots for the runway 25 arrival and the runway 7 departure at 1816:52 MST to 1817:32 MST.

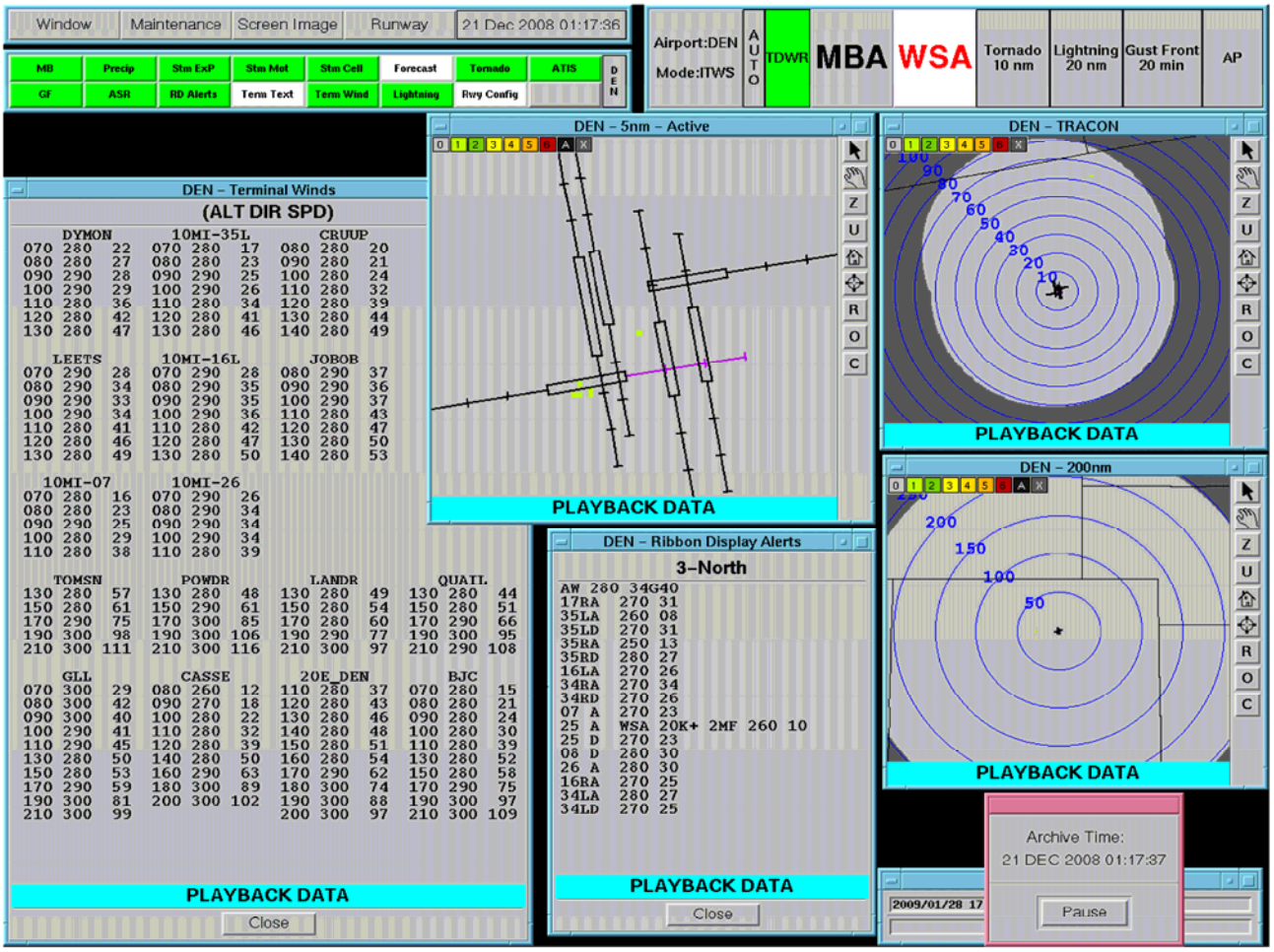

Figure 12: ITWS Display at 1817:36 MST (0117:36Z).

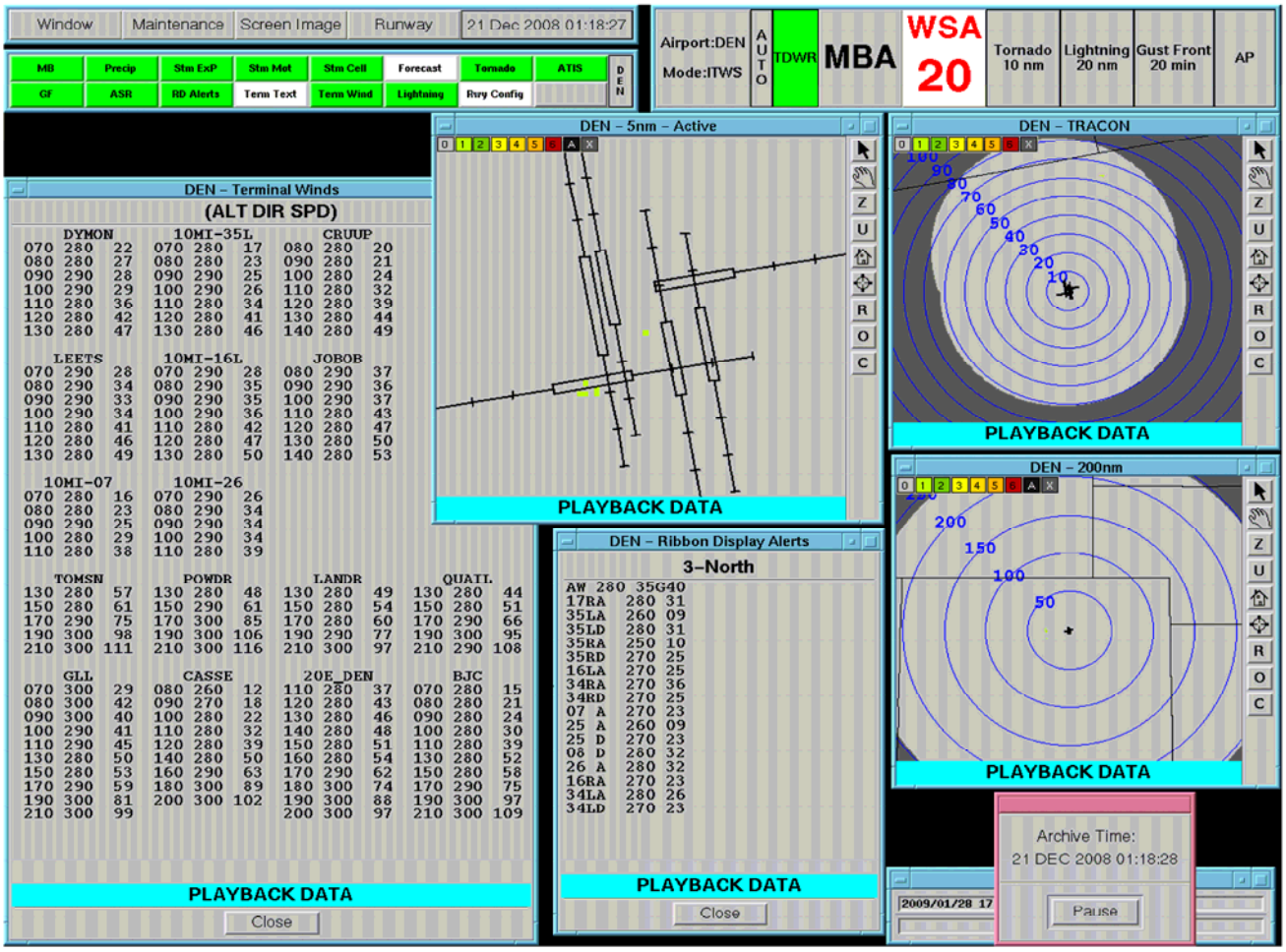

Figure 13: ITWS Display at 1818:27 MST (0118:27Z).

ITWS images for 1817:18 MST (December 21, 2008 at 0117:18Z) to 1818:47 MST (December 21, 2008 at 0118:47Z) are contained in attachment 8.

8) KDEN Terminal Forecast

The Terminal Forecast for KDEN was issued by the Denver/Boulder National Weather Service Forecast Office in Boulder, Colorado, on December 20, 2008 at 1638 MST (2338Z). The forecast valid from December 20, 2008 at 1700 MST (December 21, 2008 at 0000Z) until December 20, 2008 at 1900 MST (December 21, 2008 at 0200Z) predicted winds of 300 degrees at 16 knots with gusts to 24 knots, visibility greater than 6 miles, few clouds at 4,000 feet, scattered clouds at 12,000 feet, and scattered clouds at 22,000 feet.

9) In-Flight Weather Advisories

The following AIRMETs[11] were issued by the National Weather Service Aviation Weather Center in Kansas City, Missouri on December 20, 2008 at 1345 MST (December 21, 2008 at 2045Z) and valid until December 20, 2008 at 2000 MST (December 21, 2008 at 0300Z).

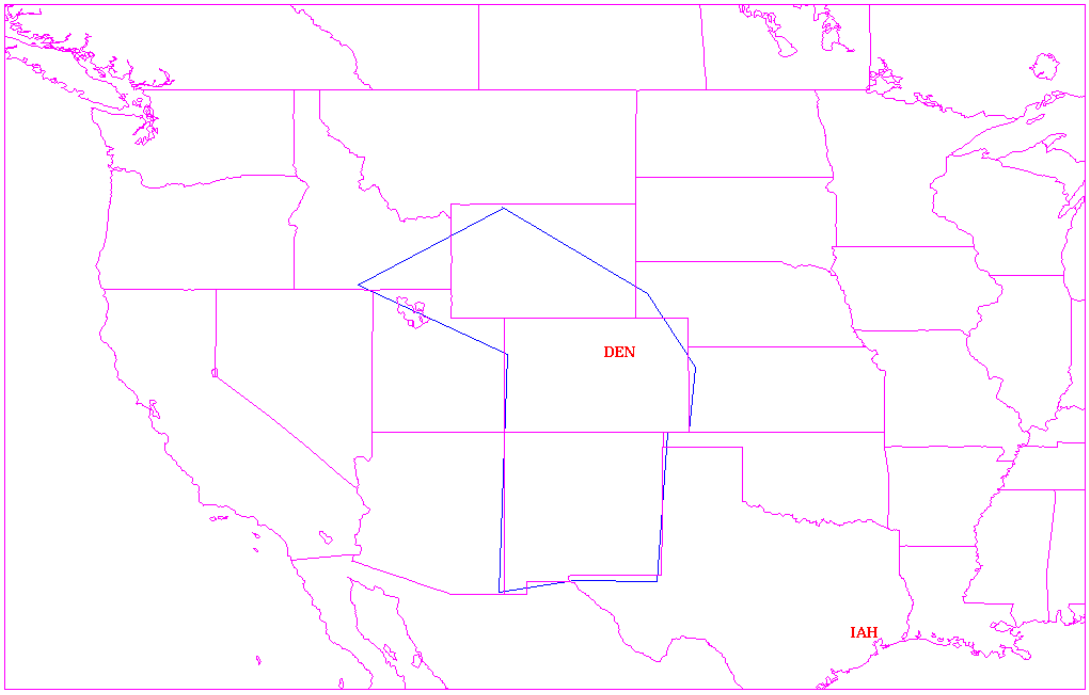

Figure 14: Plot of AIRMET Tango Update 5 for moderate turbulence below flight level 18,000 feet (FL180).

[11] Airmen Meteorological Information.

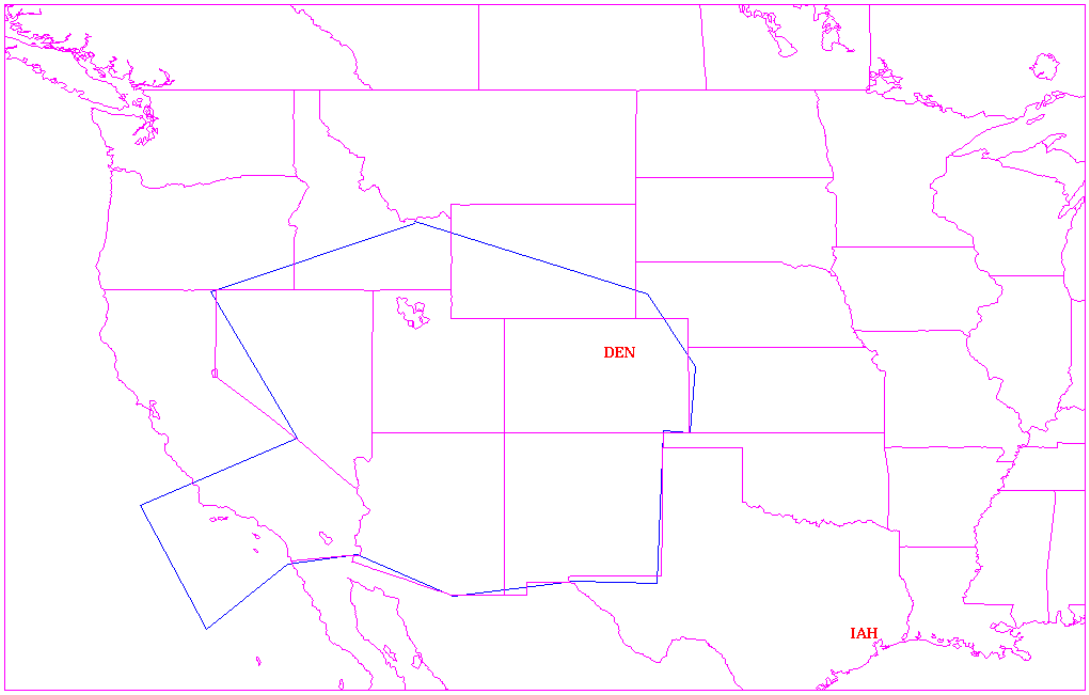

Figure 15: Plot of AIRMET Tango Update 5 for moderate turbulence between FL180 and FL410.

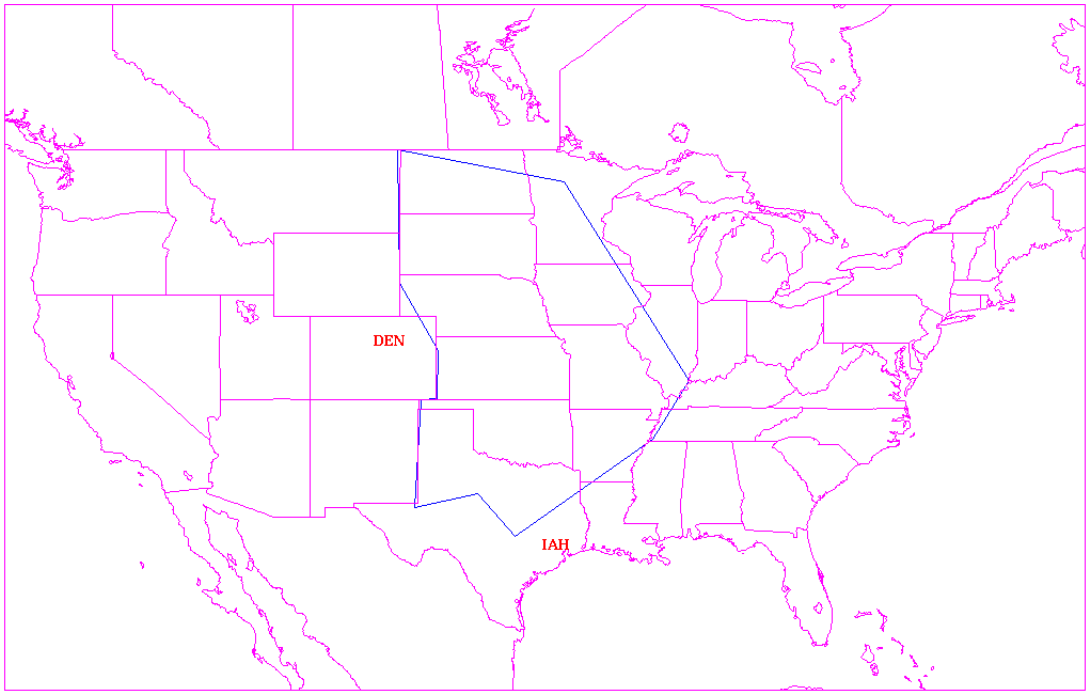

Figure 16: Plot of AIRMET Tango Update 3 for moderate turbulence below 12,000 feet.

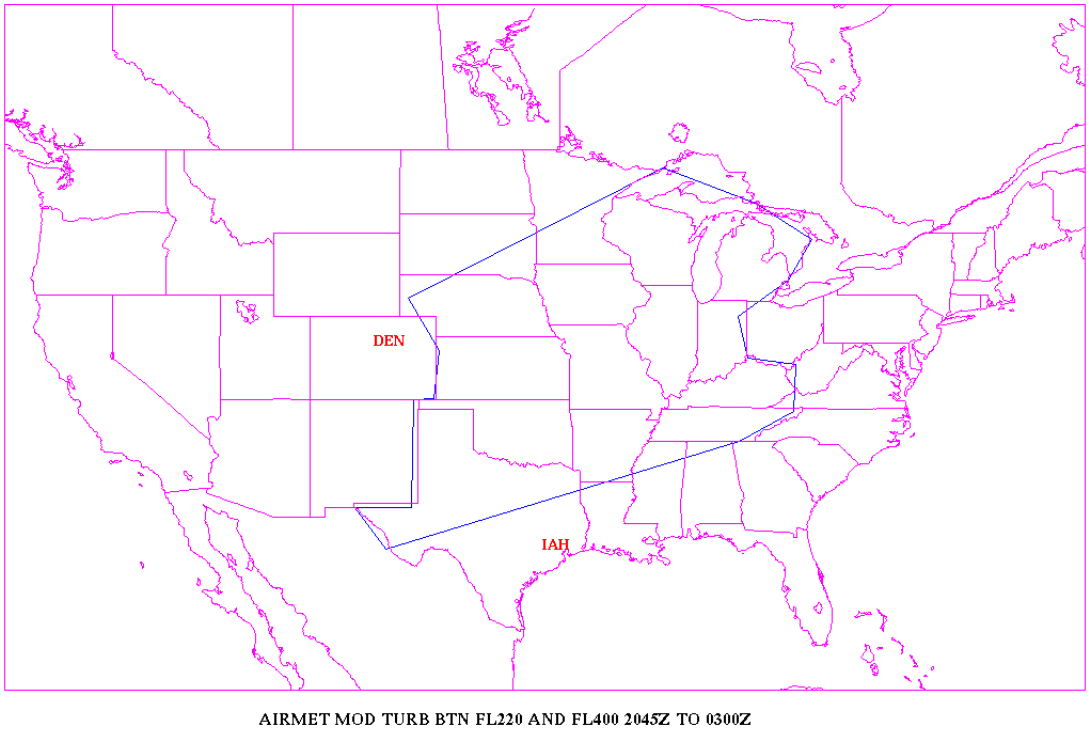

Figure 17: Plot of AIRMET Tango Update 3 for moderate turbulence between FL220 to FL400.

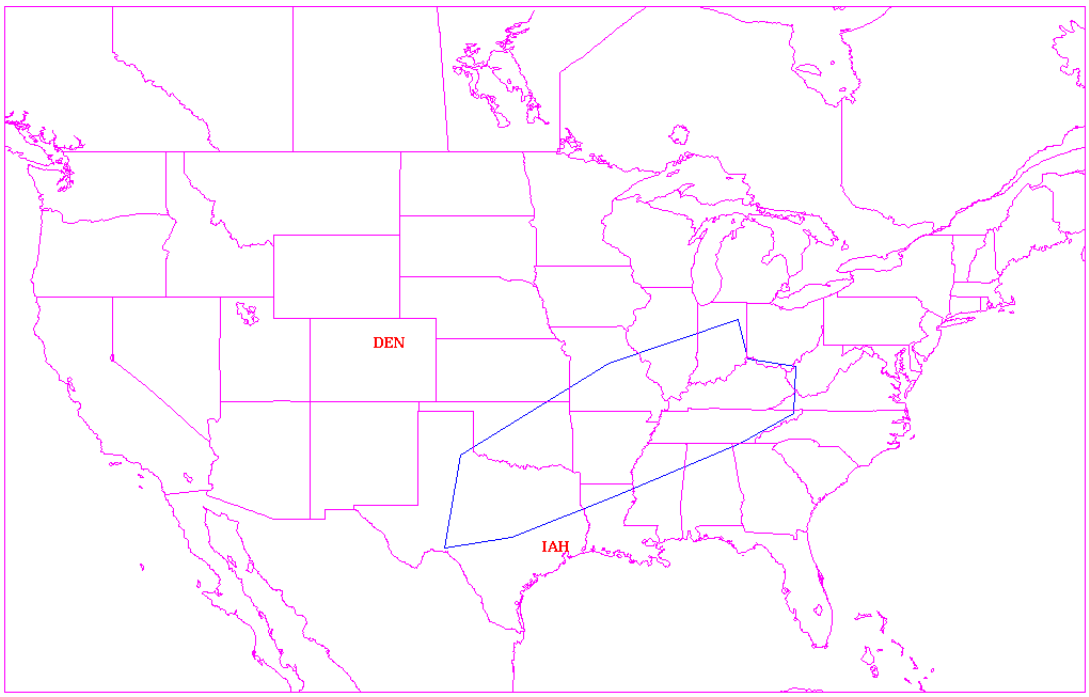

Figure 18: Plot of AIRMET Zulu Update 3 for moderate ice between 16,000 feet and FL280.

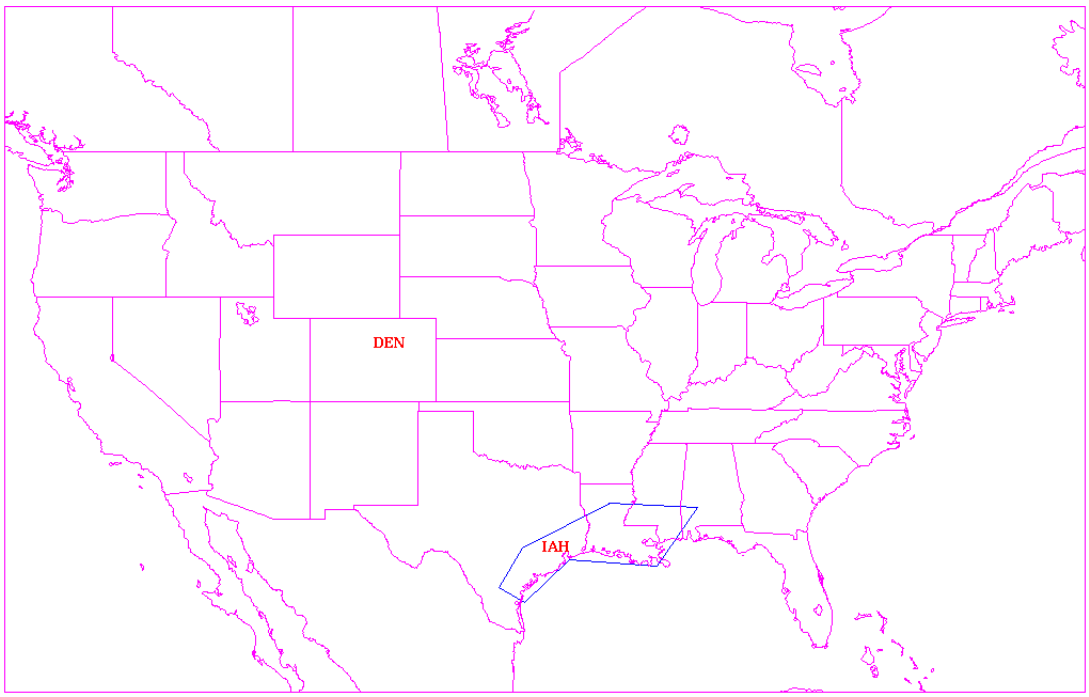

Figure 19: Plot of AIRMET Sierra Update 3 for ceilings below 1,000 feet / visibility below 3 miles in mist / fog.

10) Interview of the National Weather Service Journeyman Forecaster

The NTSB Weather Group Chairman interviewed the Denver/Boulder NWS journeyman forecaster by phone on December 23, 2008. The forecaster worked the 1200 MST to 2200 MST the day of the accident. He has been at the Denver forecast office for 18 years. He noted that the weather conditions around the time of the accident were gusty northwest winds but "nothing out of the ordinary." After the accident he looked at the KDEN Terminal Doppler Weather Radar (TDWR) data, available at the Denver/Boulder NWS office, and noted nothing significant.

11) Interview of the Captain of US Airways Flight 94

The Captain of US Airways flight 94 a Boeing 737-300 enroute from KDEN to Phoenix, Arizona, (PHX) was interviewed by phone on January 30, 2009 by the NTSB Weather Group Chairman. The Captain stated that while at Gate C-31 about the time of the Continental flight 1404 accident he experienced a rumbling or shaking of the airplane. He looked outside and saw material blowing on the ramp and people on the ramp had "trouble standing." He estimated the wind as a 50+ mile per hour gust from the west that

lasted about 45 to 60 seconds. At the gate the airplane was pointed to the south. Shortly thereafter he saw fire trucks and thought to himself that "someone blew off the runway on landing." He believed that the crosswind component for his airplane was 29 knots and that the gust factor was used to calculate the crosswind component. He had never flown a B-737 winglet equipped airplane. Gate C-31 is located about 2,960 feet east-southeast of the threshold of runway 34R and about 1,650 feet south of LLWAS Wind Sensor #2.

12) Witness Statement

The following statement was provided by Robert M. Bunker, Program Manager, Telecommunication Systems, Denver International Airport.

"My wife Joyce and I were traveling northbound on E-470 just north of Pena and arrived at the E-470 Toll Plaza at 1818 MST. This toll plaza is located almost exactly due west of the threshold of Runway 34R approximately 3 miles. I remember the time because I had looked at the clock in my truck as we arrived at the Toll Plaza; it was 1818 MST. We were due at a Christmas party at 1830 MST in Thornton and I was concerned we were going to be late. I have driven this section of road for many years so I am very familiar with it.

The first thing I noticed when we arrived at the plaza was the wind. The wind was blowing the Christmas decorations around quite a bit and I even commented to my wife about it. It was nothing significant at this point, but noticeable. As I pulled out of the toll plaza and accelerated to highway speed an extremely large gust of wind came out of the northeast. I was concerned at the time that the gust was literally going to blow my F-250 4x4 crew cab pickup off the road (and commented accordingly to my wife). I was having to steer my truck into the wind to counter the direction it was trying to push us.

We discussed the unusual wind gusts for a couple minutes. At one point I commented to her about how the side window deflectors on our windows were bending. These deflectors are quite rigid and I had never seen the wind bend them before. The reason I noticed the deflectors was my wife had lit a cigarette just as we pulled out of the toll plaza and cracked the passenger side window open. The wind was blowing so hard she just put the cigarette out because of the wind coming in the window.

The wind gust lasted for probably 2-3 minutes and ended just as abruptly as it started. Our location by this time was just north of 104th Ave. Were I to guess I would estimate the wind speed to be well in excess of 50 miles per hour. I'm sure if someone was inclined we could create a test to determine what actual wind speed it would take to bend these side window deflectors. The other thing I noticed was a fairly large temperature increase right when the wind stopped. The outside temperature gauge in the truck had been reading just above zero at the toll plaza and when the wind stopped the outside temperature was 20.

We live out in the country on the eastern plains by Strasburg so driving in very gusty wind conditions is common for us. What we experienced on the 20th on E-470 was not one of these common experiences"[12].

13) Continental Airlines' Dispatcher Responses

The Continental Airlines' dispatcher on duty December 20, 2008 at 1200 MST to 2000 MST was provided questions by the NTSB Weather Group Chairman on February 3, 2009. The following are summarized responses to these questions[13].

The dispatcher was with Continental Micronesia since June 1999 and transferred to Continental Airlines in January of 2008. He has been a licensed dispatcher since August of 1994. The dispatcher's duties include aircraft dispatch, flight planning, and review of pertinent weather relative to respective flight operations. According to the dispatcher, he was handling 35 to 40 flights and characterized the workload as moderate. The wind information on the Accuload document (1756 MST) pertinent to Continental 1404 came from the NWS and METARs product update. The dispatcher noted that crosswind components relative to a selected runway are automatically calculated based on the respective runway. In calculating crosswind components the wind direction, speed, and gusts are entered when the condition exists. The dispatcher noted that ITWS, which has TDWR and LLWAS input, is a stand alone display that cannot be seen at the dispatch positions. It is available at the ATC desk on the stand alone computers and is commonly not used by any dispatchers. The crew also does not have access to the ITWS display. Terminal Forecasts (TAF) are used for planning for predetermined expected runway use. TAF information is superseded by METARs based on the most current weather products recorded. When asked if he monitors crosswind limits prior to departure he noted that any relative wind information should have been monitored by the captain since he is the on site evaluator. In addition, the ATC Tower should give the captain the current weather conditions minutes prior to departure. The dispatcher noted that the maximum demonstrated crosswind limits for Continental 1404 was 33 knots. When asked how an update of the crosswind / headwind components gets to the flight crew prior to departure the dispatcher noted that this information would be provided by the departure city ATC Tower. The dispatcher was asked how often he updated crosswind / headwind information and provided that information to flight crews prior to departure. The dispatcher noted that METARs and SPECI observations will update weather information automatically by computer and is not commonly updated manually. The dispatcher also noted that he never has updated crosswind / headwind information and provided that information to departing and arriving flight crews at DEN. The dispatcher was asked if ITWS data was available at his position would these data be of value. The dispatcher noted that from a pre-planning stage for dispatch any additional tool that can analyze the hazards of the weather involved can be helpful.

[12] See attachment 9 for the full statement.
[13] See attachment 10 for the questions and responses of the dispatcher of Continental 1404.

14) Astronomical Data

At Denver, Colorado on December 20, 2008, sunset was at 1639 MST and the end of civil twilight was at 1709 MST.

From the U.S. Naval Observatory: http://aa.usno.navy.mil/data/

Gregory D. Salottolo
National Resource Specialist
Meteorology