NTSB National Transportation Safety Board

Office of Aviation Safety

Turbulence Related Accidents & Incidents

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NTSB Senior Meteorologist

NTSB Mission

The NTSB is an independent US federal agency charged with determining the probable cause(s) of transportation accidents, making recommendations to prevent their recurrence, conducting special studies and investigations, and coordinating resources to assist victims and their families after an accident.

- *An aircraft experiencing severe turbulence does not necessarily make it an accident!*

- *Did structural damage occur, death, or serious injury?*

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NTSB Definitions

- Aircraft accident - 49 CFR 830.2
- An occurrence associated with the operation of an aircraft which:
  - Takes place between the time any person boards the aircraft *with the intention of flight* and all such persons have disembarked, and in which
  - Any person suffers *death or serious injury*, or in which
  - The aircraft receives *substantial damage*

NTSB Definitions

- Fatal injury
  - Any injury which results in death within 30 days of the accident.
- Serious injury
  - Hospitalization more than 48 hours (within 7 days);
  - Bone fractures (except simple fingers, toes, or nose);
  - Severe hemorrhages, nerve, muscle, or tendon damage;
  - 2nd or 3rd burns, or more than 5% of body surface;
  - Any internal organ.

49 CFR 830.2

NTSB Definitions

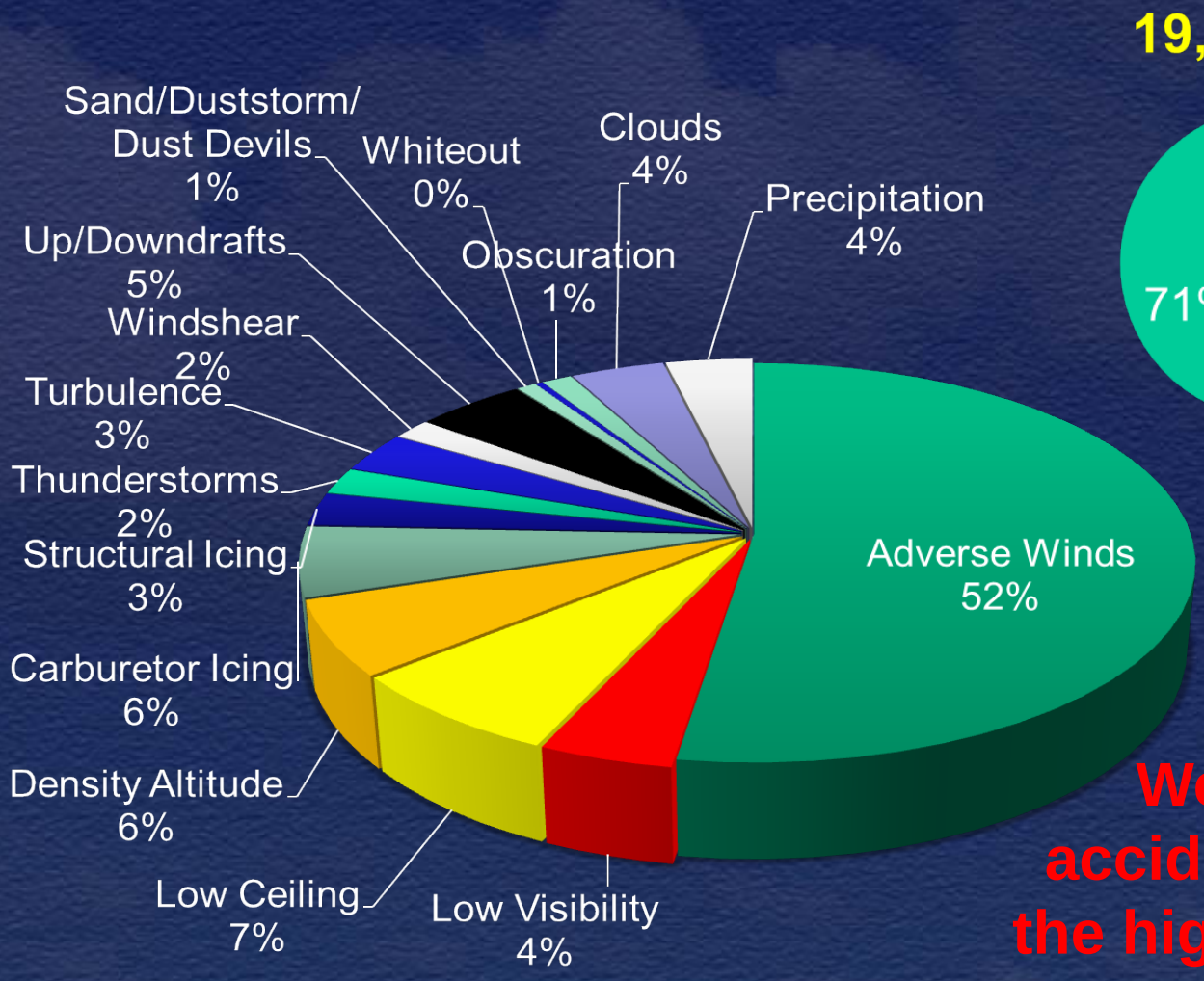
- Substantial Damage
  - Adversely affects structural strength, performance, or flight characteristics, and which
  - Would normally require major repair or replacement of affected component
- Exclusions
  - Engine failure or damage limited to 1 engine (two or more)
  - Bent fairings or cowling
  - Dented skin
  - Small punctured holes in the skin or fabric
  - Ground damage to rotor or propeller
  - Damage to landing gear, wheels, tires, brakes, flaps, engine accessories, or wingtips

49 CFR 830.2

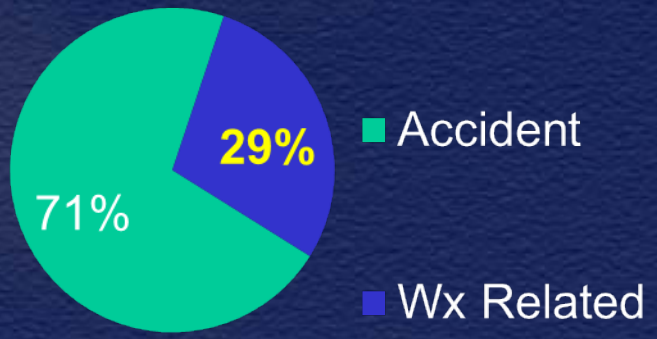
NTSB Definitions

- Incident
  - Occurrence other than an accident associated with the operation of an aircraft, *which affects or could affect the safety of operations*
  - *Majority of turbulence events occur in this category!*
  - *NTSB May or may not be involved, crew incapacitation, infant injured, special issues…*

Part 91 – Weather As Cause/Factor period 2000-2011



19,441 Accidents



Weather related accidents have one of the highest fatality rates

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NTSB 2012 Accident Statistics

Part 91 - General Aviation

- 1,471 accidents
- 271 fatal accidents
- 432 total fatalities
- Accident rate 6.78 per 100,000 hours
- Part 91 accounted for 51% of total flight time and 97% of all fatal accidents
- Majority of the fatal accidents occur in instrument meteorological conditions (IMC)

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Defining Part 91 Fatal Accident Events

- Loss of Control (LOC) in Flight
  - In-flight breakups
  - Turbulence/Weather encounters
- System/Component Failure – Powerplant
- Controlled Flight into Terrain (CFIT)
- Collision with Terrain/Object (non-CFIT)
- VFR Encounter with IMC
- System/Component Failure – Non-Powerplant

Review of Part 91
In-flight Breakups 2000-2013

Review of 86 loss of control (LOC) accidents which resulted in-flight breakups

• VFR into IMC	21 events	54 fatalities
• Flight into TSTMS	17	39
• IMC/Clouds/Icing/turb	12	31
• Turbulence/MTW	3	7
• Spatial Disorientation/Night	6	10
• Wake Turbulence	3	4
• Maneuvering/Aerobatics	12	24
• Structural Issues	9	8
• Pilot Incapacitation	3	3
	86 events	180 fatalities

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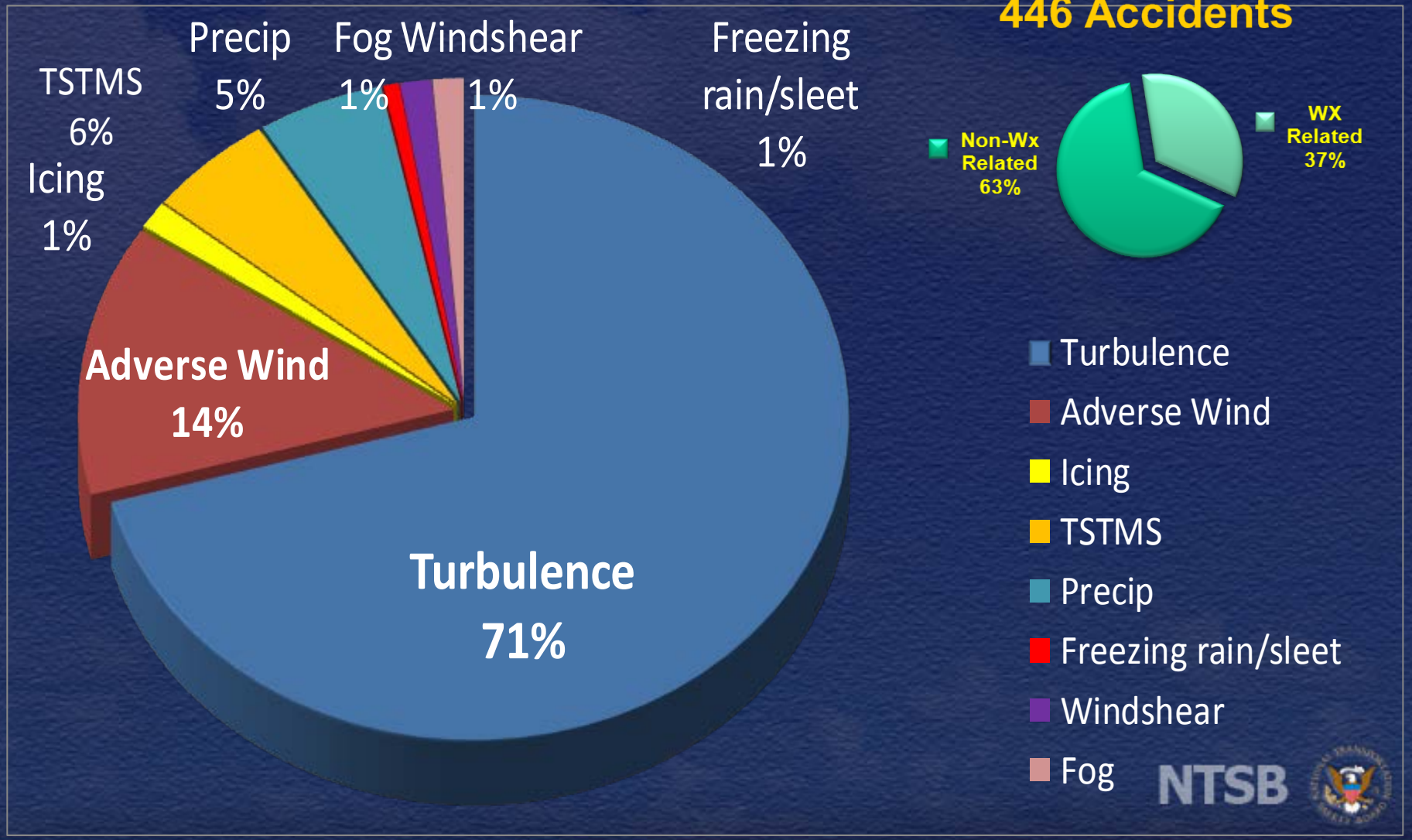
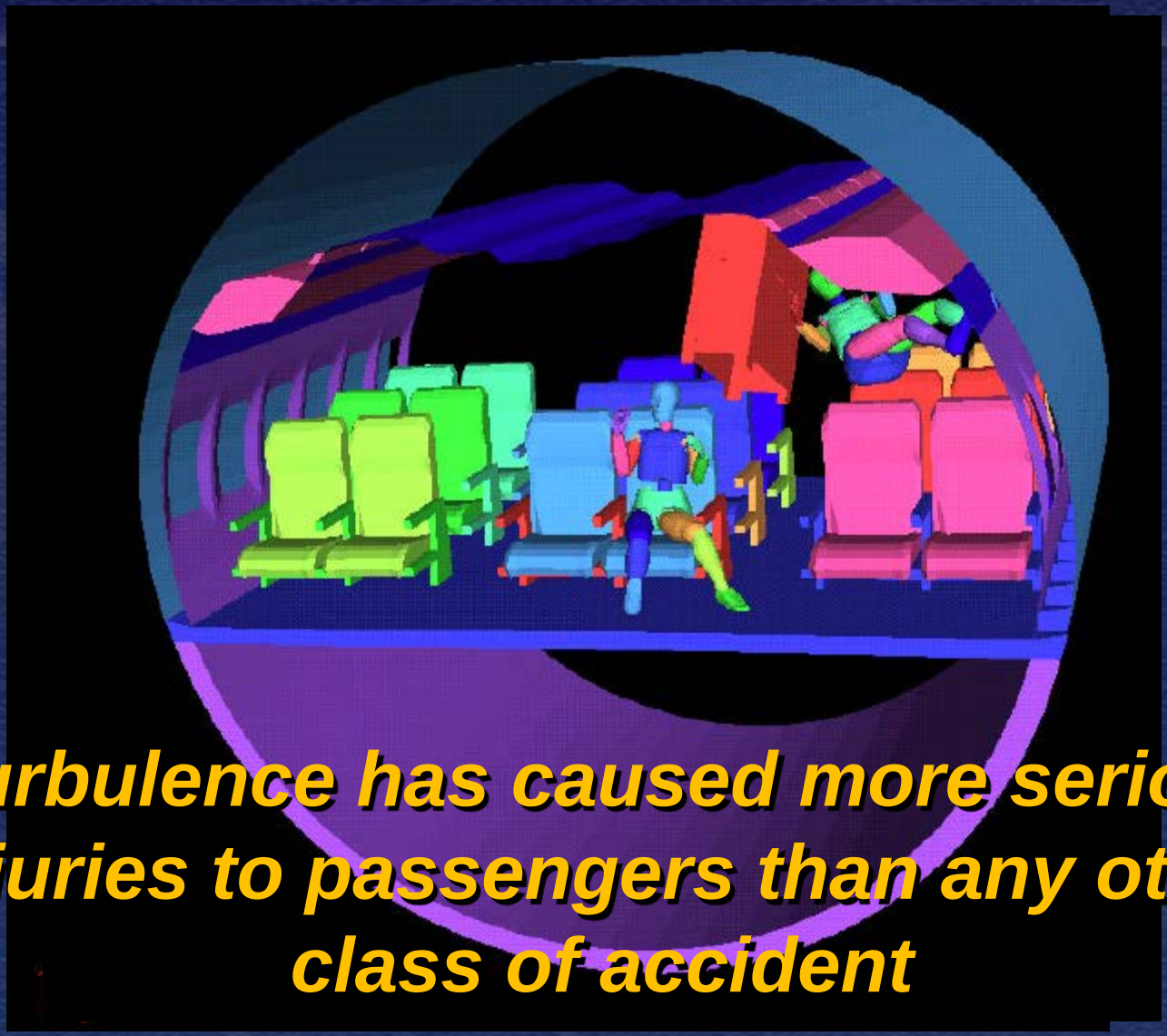
Part 121 – Air carrier Weather Related Cause/Factors 2000-2011





Turbulence has caused more serious injuries to passengers than any other class of accident

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NTSB Investigations

- Notification often limited data – event location
- Synoptic conditions – define basic conditions
- Upper air data - Sounding, AMDAR, Model data
- Satellite imagery
- Weather Radar – WSR-88D/TDWR/CoSPA, lightning
- PIREPs
- NWS Forecasts & in-flight weather advisories
  - Turbulence/convective model/guidance products
- Weather briefing data – dispatch, flight updates
- Statements/Witnesses – crew coordination

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NTSB Investigation

- Other data sources used when available:
  - Aircraft CVR/FDR data – vertical accelerations forces or g's quantifiable data
  - AMDARs – EDR values

Intensity	Airspeed Fluctuation (knots)	Vertical Acceleration (g)	Derived Gust (fpm)
Light	5 – 14.9	0.20 – 0.49	300 -1,199
Moderate	15 – 24.9	0.50 – 0.99	1,200 – 2,099
Severe	≥ 25	1.0 – 1.99	2,100 – 2,999
Extreme	-	≥ 2.00	≥ 3,000

NTSB Investigation

- Man-Machine-Environment
- *Major issues* to identify
  - Was the weather conditions properly forecast
  - PIREPs or other observations available
  - Advisories issued
  - Role of controller, dispatcher, flight crew in mitigating event

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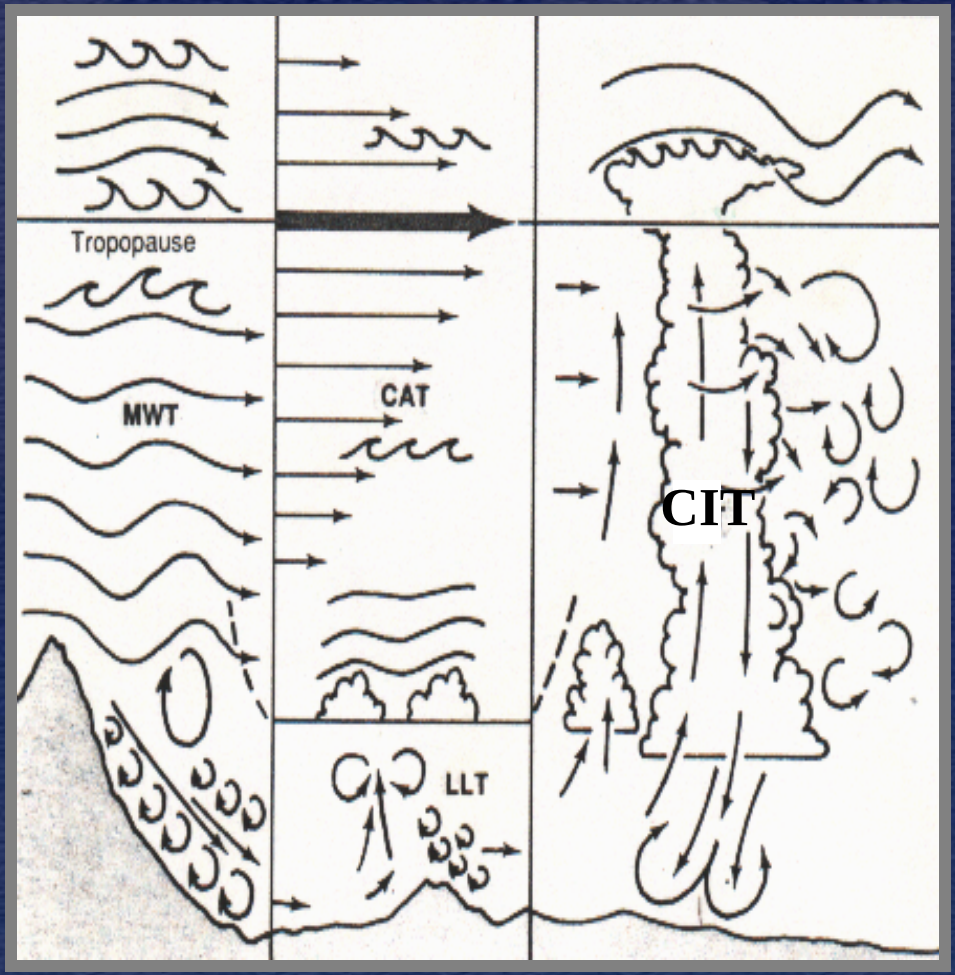
Turbulence Classification



- Clear Air Turbulence (CAT)
- Convectively Induced Turbulence (CIT)
- Mountain Wave (MWT)
- Mechanical (LLT)
- Vortex Wake
- Gravity Waves

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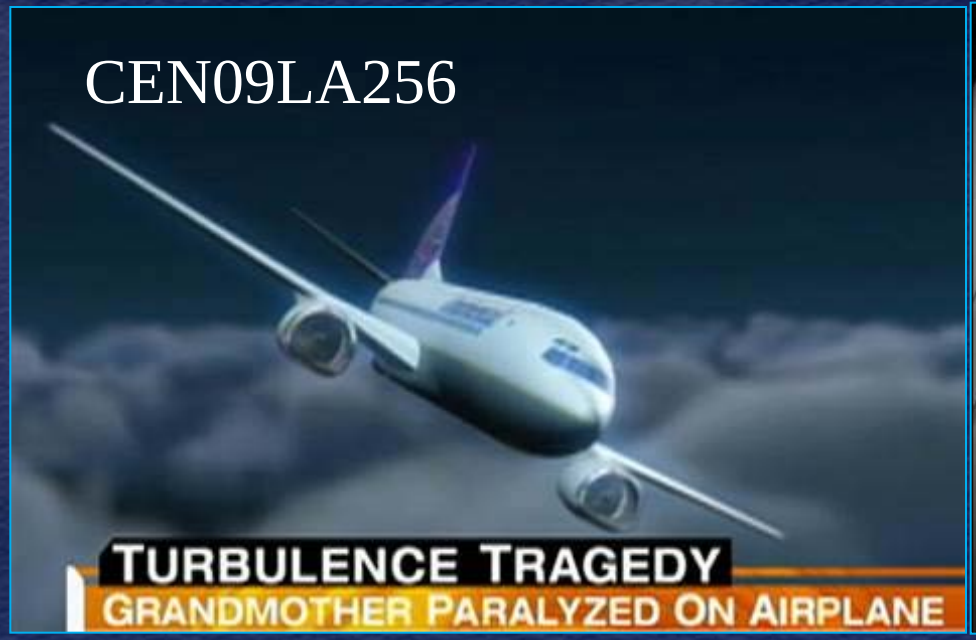
Turbulence



Hurt during flight turbulence, she's paralyzed after breaking her neck in airplane bathroom. …Airline says fasten seat belt sign on.

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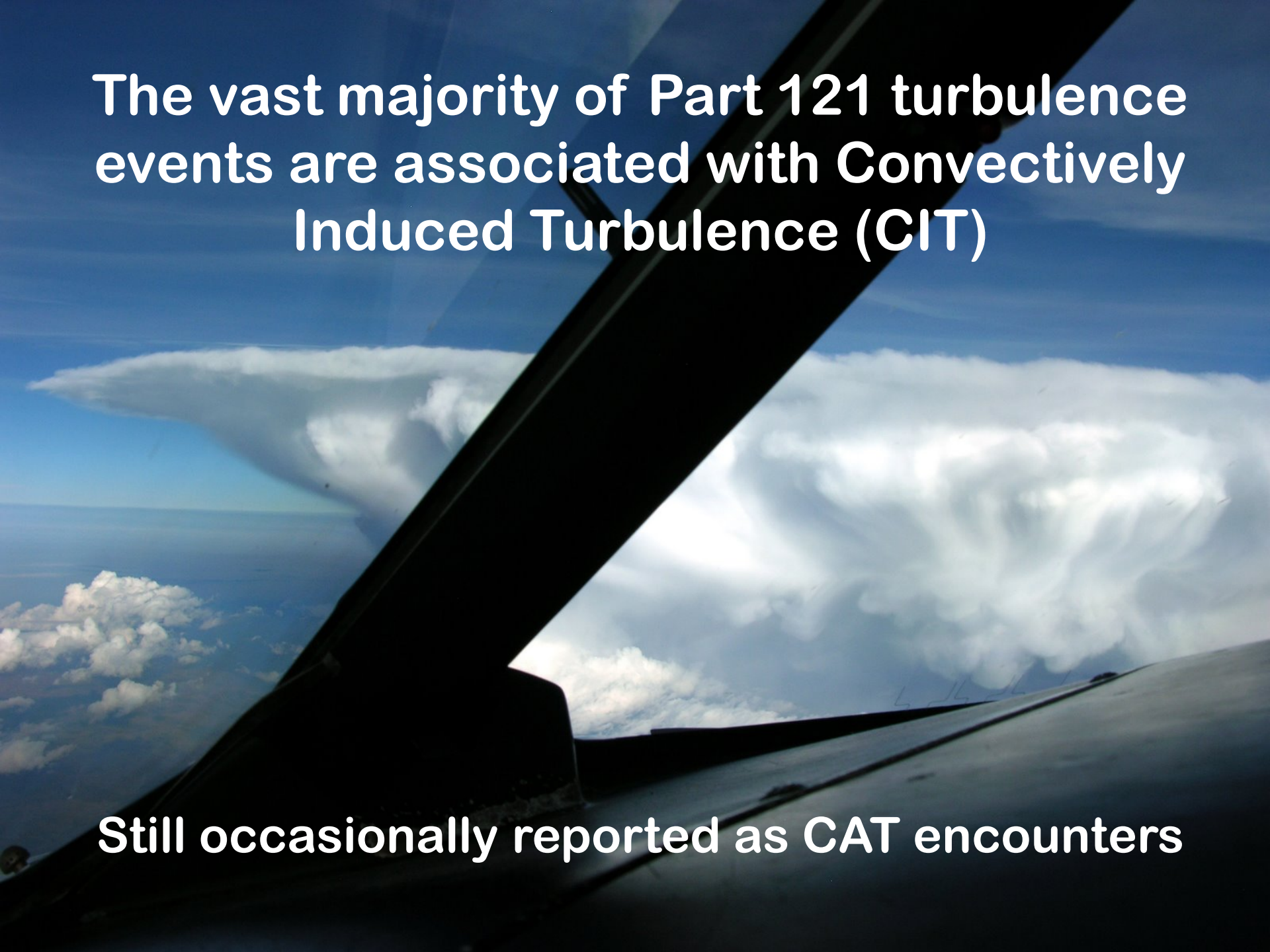
The vast majority of Part 121 turbulence events are associated with Convectively Induced Turbulence (CIT)
Still occasionally reported as CAT encounters

Significant Turbulence Incidents & Accidents
Part 121 Air Carriers 1998-2013

Year	Events	Serious	Minor
2013	11	3	37
2012	33	10	83
2011	26	19	32
2010	13	11	73
2009	21	15	106
2008	12	12	43
2007	11	12	10
2006	28	9	49
2005	33	9	42
2004	36	12	50
2003	36	24	83
2002	29	14	74
2001	33	17	53
2000	40	21	82
1999	36	16	181
1998	34	22	111
16	432	225	1,109

Averages

- Events 26.9 annually
- Serious injury 14
- Minor injury 69

2009 significant events:

B747 over Pacific Ocean 42 injuries

B767 over Atlantic Ocean 33 injuries

Sources: *NTSB, FAA incident & accidents, The Aviation Herald, Curt Lewis LLC briefs*

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Air Carrier Turbulence Events

- *Turbulence rarely causes fatalities; however, fatal events have occurred:*
  - (1) B747 Pacific — CAT — Dec. 28, 1997
  - (1) DC-9 Florida — CIT — Oct. 3, 1990
  - (17) F-28 Netherlands — CIT — Oct. 7, 1981
  - (2) B737 India — CIT — May 10, 1980
  - (39) F-27 Alaska — MWA — Dec. 2, 1968
  - (85) L-188 Texas — CIT — May 3, 1968
  - (124) B707 Japan — MWA — Mar. 3, 1966
  - (1) Caravelle, TN — CIT — July 8, 1964

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Mountain Wave Turbulence

March 3, 1966

BOAC B-707 flight 911

At FL170 encountered mountain wave turbulence which resulted in-flight break up near Mt. Fuji, Japan.

Fatal 124

- Weather station base of Mt. Fuji reported winds 60-70 KT
- Satellite imagery showed formation of rotor and lenticular clouds
- PIREPs – numerous reports of moderate-severe turbulence
- U.S. Navy aircraft encountered extreme turbulence +9g to -4g

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Wien Consolidated Airlines F-27B
Pedro Bay, Alaska
December 2, 1968

Encountered with severe-to-extreme turbulence and resulted in an in-flight breakup, fatal to 39.

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NTSB Part 121 - Turbulence Accidents 2012

- *Total incidents reported 33, only 9 were defined as accidents due to serious injuries and most only limited NTSB investigations.*
- 2012 Turbulence Accidents (9)
  - CEN12LA166 – Detroit, MI, B737, 1 serious, 4 minor — Feb. 18
  - WPR12LA119 – Pawnee, NE, B737, 1 FA serious — Feb. 23
  - WPR12LA144 – Laverne, OK, B737, 1 FA serious — Mar. 20
  - DCA12FA062 – Buena Vista, CO, A319, 2 serious, 1 m — Apr. 14
  - DCA12FA069 – Ft. Lauderdale, FL, A319, 1 FA serious — May 10
  - DCA12FA086 – Atlantic City, NJ, B757, 1 FA serious — June 7
  - DCA12FA091 – Winne, TX, B737, 2 FA serious — June 12
  - ERA12LA498 – Hilton Head, SC, ERJ, 1 PAX — Aug. 5
  - DCA12CA149 – Sophia, NC, A330, 1 serious, 2 minor — Sept. 18

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NTSB Part 121 - Turbulence Accidents 2013

- *Total 11 air carrier turbulence incidents reported*
- *3 turbulence accidents, with 3 serious injuries*

- 2013 Turbulence Accidents (3)
  - WPR13LA131 – Pacific Ocean, B747-400, 1 FA serious — Feb. 19
  - WPR13LA431 – Reno, NV, DHC-8, 1 serious, 2 minor — Sept. 29
  - DCA13CA014 – Houston, TX, B767, 1 FA serious — Nov. 21

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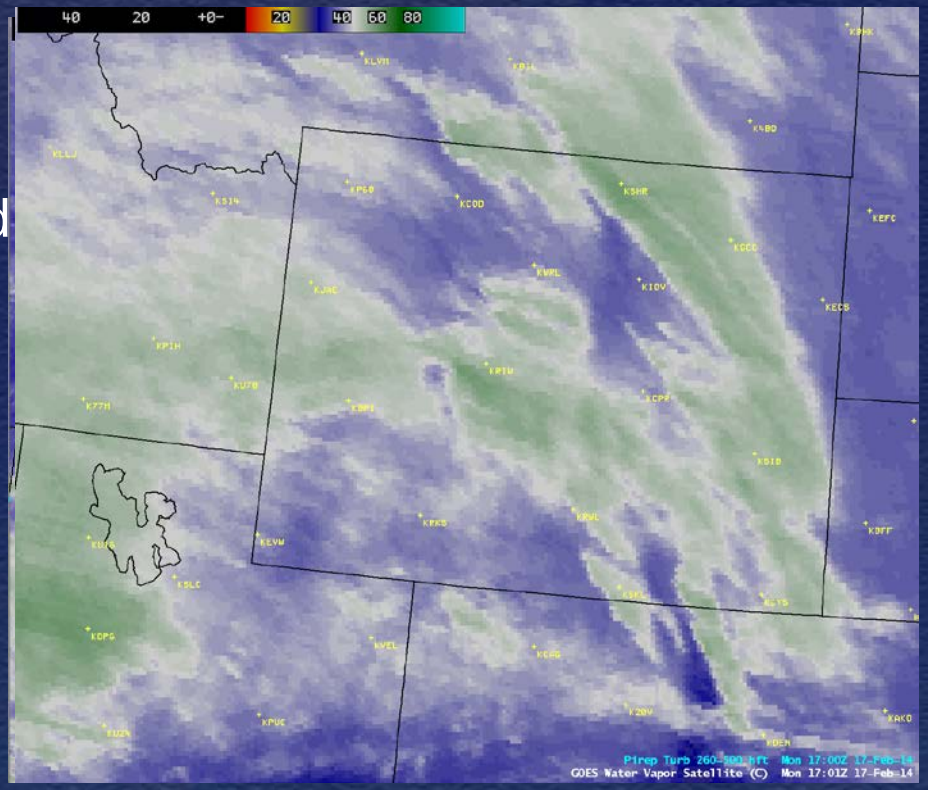
NTSB 2014 Turbulence Events

- 15 air carrier turbulence events recorded, 1 accident
  - DCA14LA060 – Billings, MT, United Airlines B737, 11 injured, 2 serious on Feb. 17, 2014
  - United Airlines DEN-BIL
  - FL340 encountered severe turb
  - Infant flung from mother's arm
  - 3 FA injured; severe head wound
  - Emergency declared



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Mountain Wave Activity

- Mountain wave activity (MWA) continues to cause accident/incidents
- 2008 Continental Airlines B737 runway excursion accident in Denver, CO
- The NTSB issued Safety Recommendation A-10-105 to the FAA on furthering understanding of the effects of MWA and related wind events.
- 2009 French B737 loss of control event in Turkey
  - During the event, the airplane lost about 3,500 ft of altitude, and its maximum recorded descent rate was about 12,000 fpm.
  - The French BEA quantified general mountain wave conditions and indicated that “Making the crew aware of potential mountain waves meteorological conditions over high ground would have made them more vigilant...”

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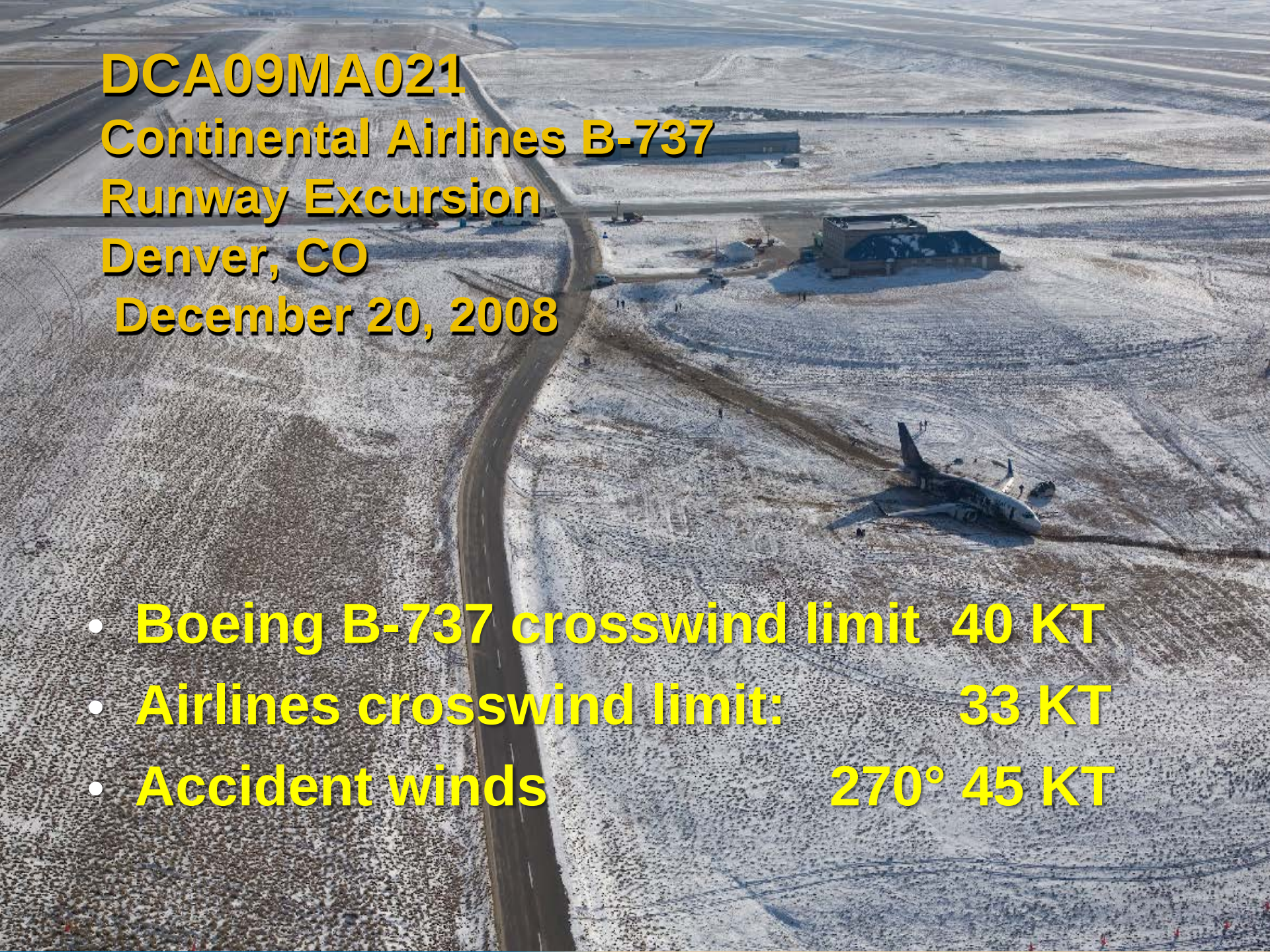
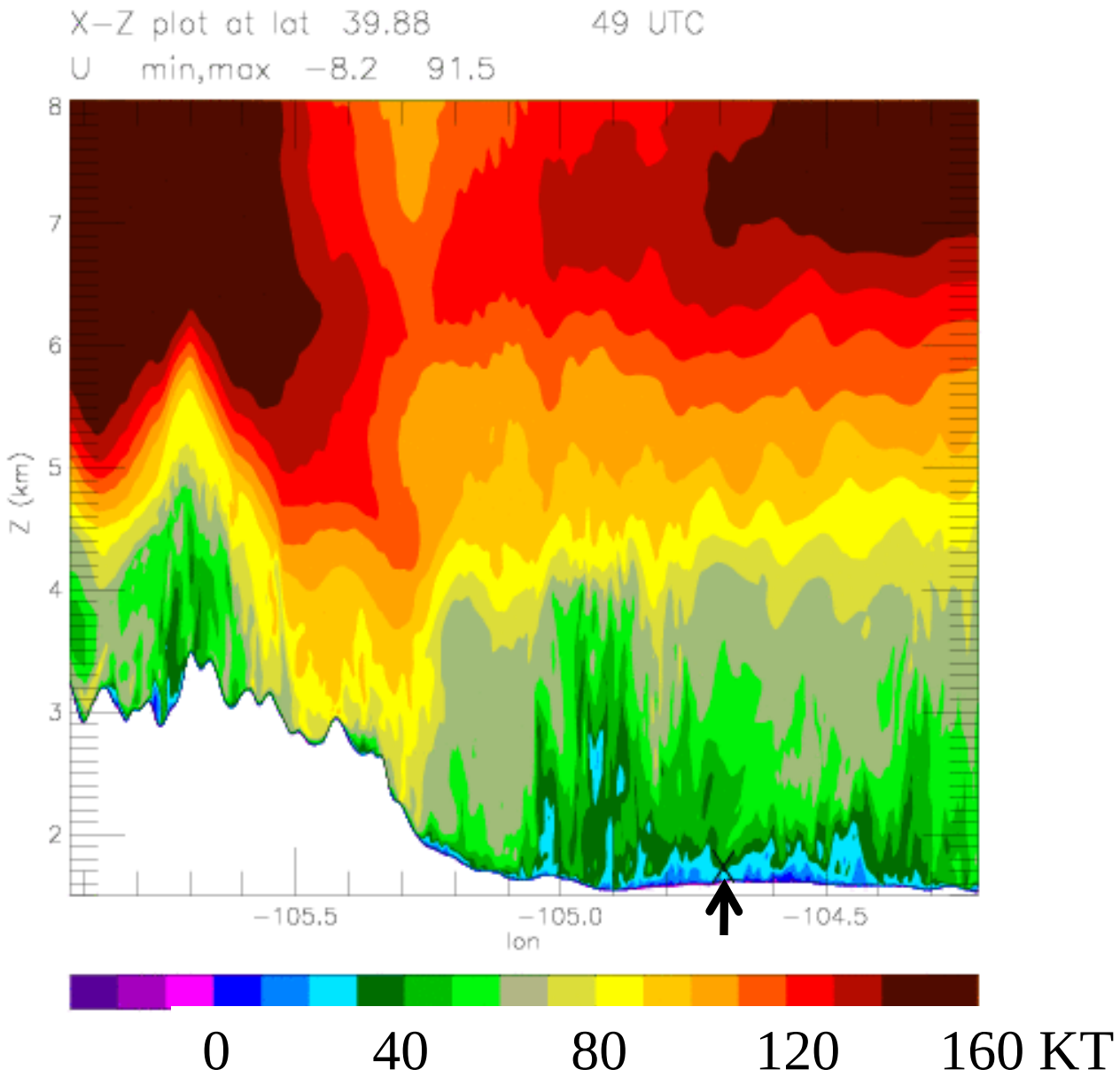
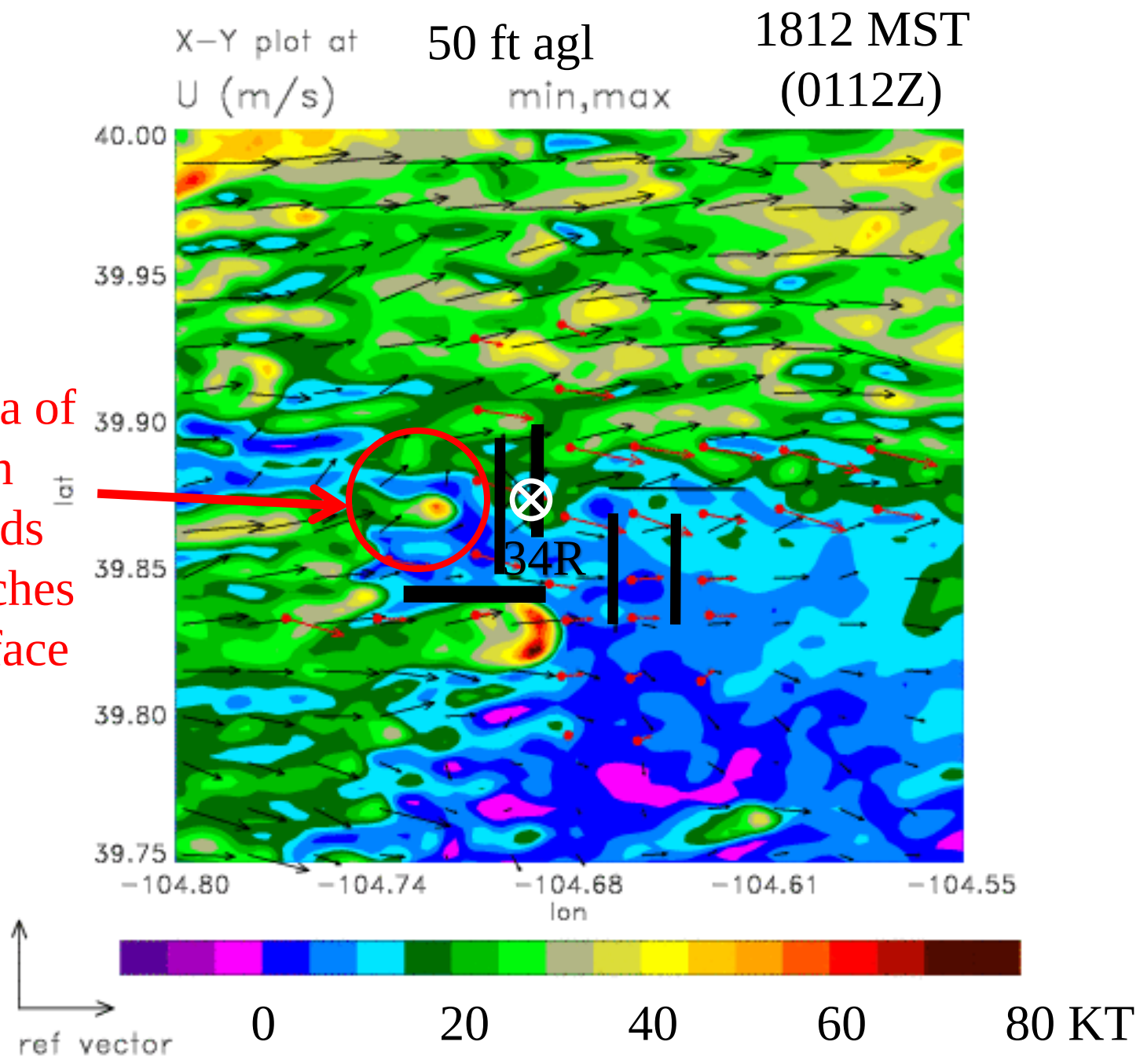


DCA09MA021
Continental Airlines B-737
Runway Excursion
Denver, CO
December 20, 2008

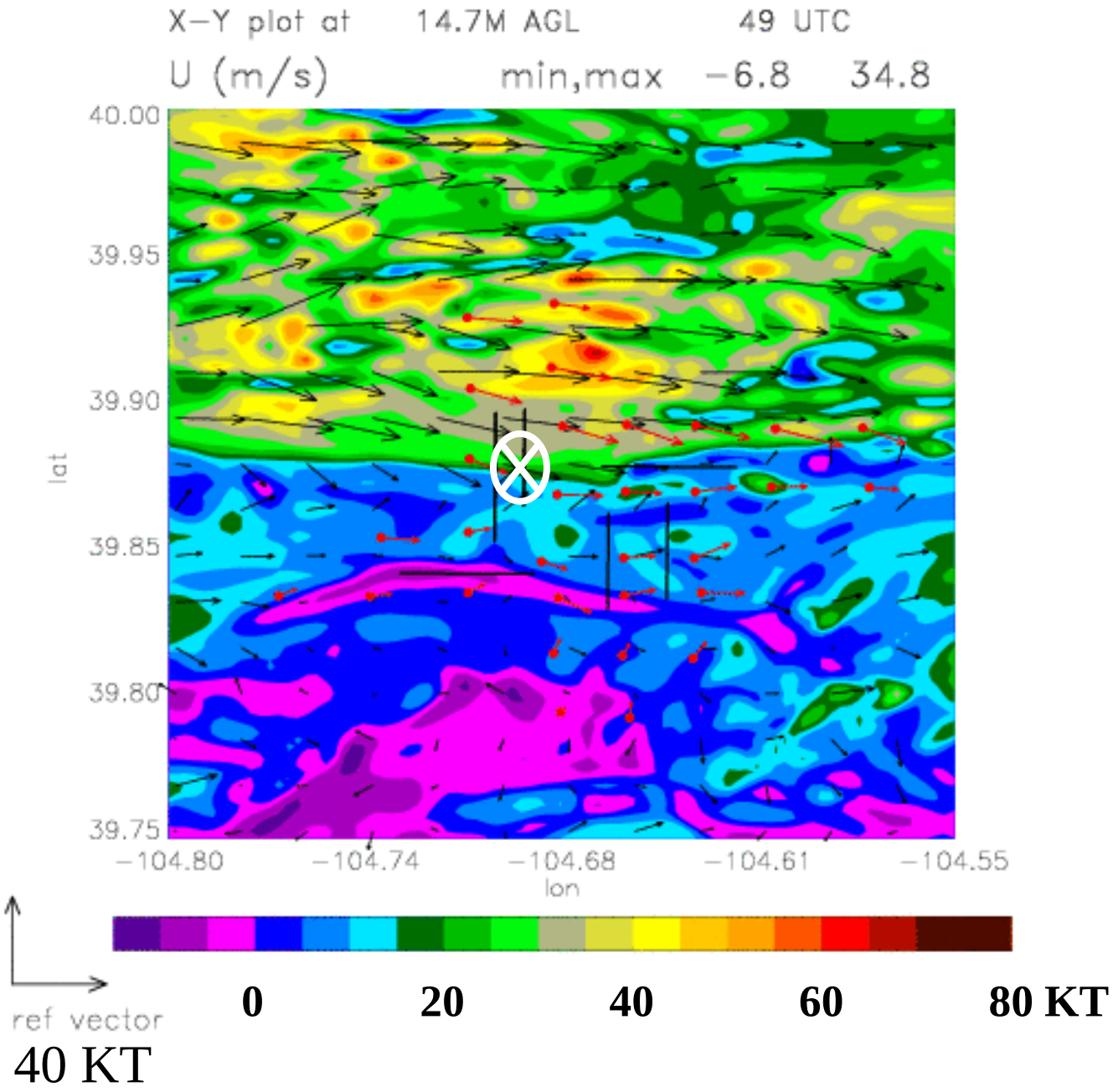
- Boeing B-737 crosswind limit 40 KT
- Airlines crosswind limit: 33 KT
- Accident winds 270° 45 KT

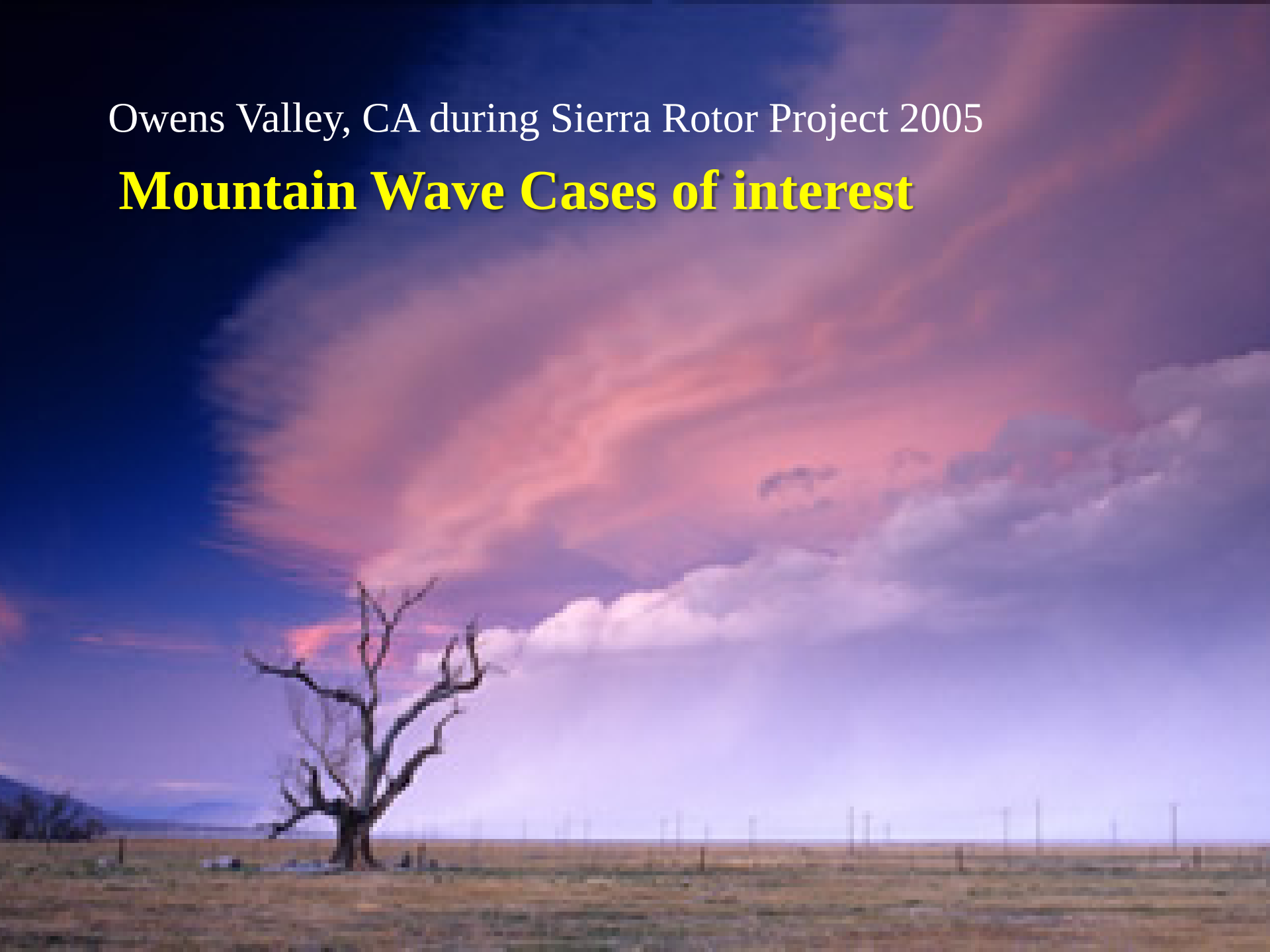
NCAR Clark-Hall Numerical Model




X–Y plot at
U (m/s)
min,max
50 ft agl
1812 MST
(0112Z)
40.00
39.95
39.90
39.85
39.80
39.75
lat
−104.80
−104.74
−104.68
−104.61
−104.55
lon
34R
Area of high winds reaches surface
ref vector
0
20
40
60
80 KT

NCAR Clark-Hall Numerical Model




Owens Valley, CA during Sierra Rotor Project 2005
Mountain Wave Cases of interest

United Airlines B-737
Colorado Springs
March 3, 1991

- Airspeed fluctuations 139 to 160KT
- Severe turbulence 0.6 to 1.6 G's
- Aircraft banked right, rolled inverted, and impacting the ground
- Rotor potentially initiated the event or flight upset
- Rudder hard over – jam in main rudder power control unit servo value

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Mountain Wave Activity

DC-8 encountered SVR-EXTRM CAT over Colorado on December 9, 1992.

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Mountain Wave Activity

In-flight engine separation Japan Airlines
B747 Anchorage, Alaska
March 31, 1993

Evergreen Airlines

Evergreen B747 engine after it separated due to turbulence


$12,000,000 damage

Israel Aircraft Industry 1124A Westwind
November 8, 2002
Taos, NM

The pilot's inadvertent flight into mountain wave weather conditions while IMC, resulting in a loss of aircraft control.

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Israel Aircraft Industry 1124A Taos, NM

- The aircraft passed the VORTAC at 15,000 feet when ABQ controllers heard a "MAYDAY" call, and radar contact was lost with the airplane at 14,700 feet.
- SIGMET Whiskey in effect for severe turbulence and mountain wave activity.
- PIREPs confirmed turbulence & mountain wave conditions existing across region:
- ABQ UA /OV CIM/TM 2300/FL 370/TP B757/TB STG MTN WAVE +/- 30KT
- TCS UA /OV TCS/ TM 2330/FL 100/TP BE58/TB MOD-SVR

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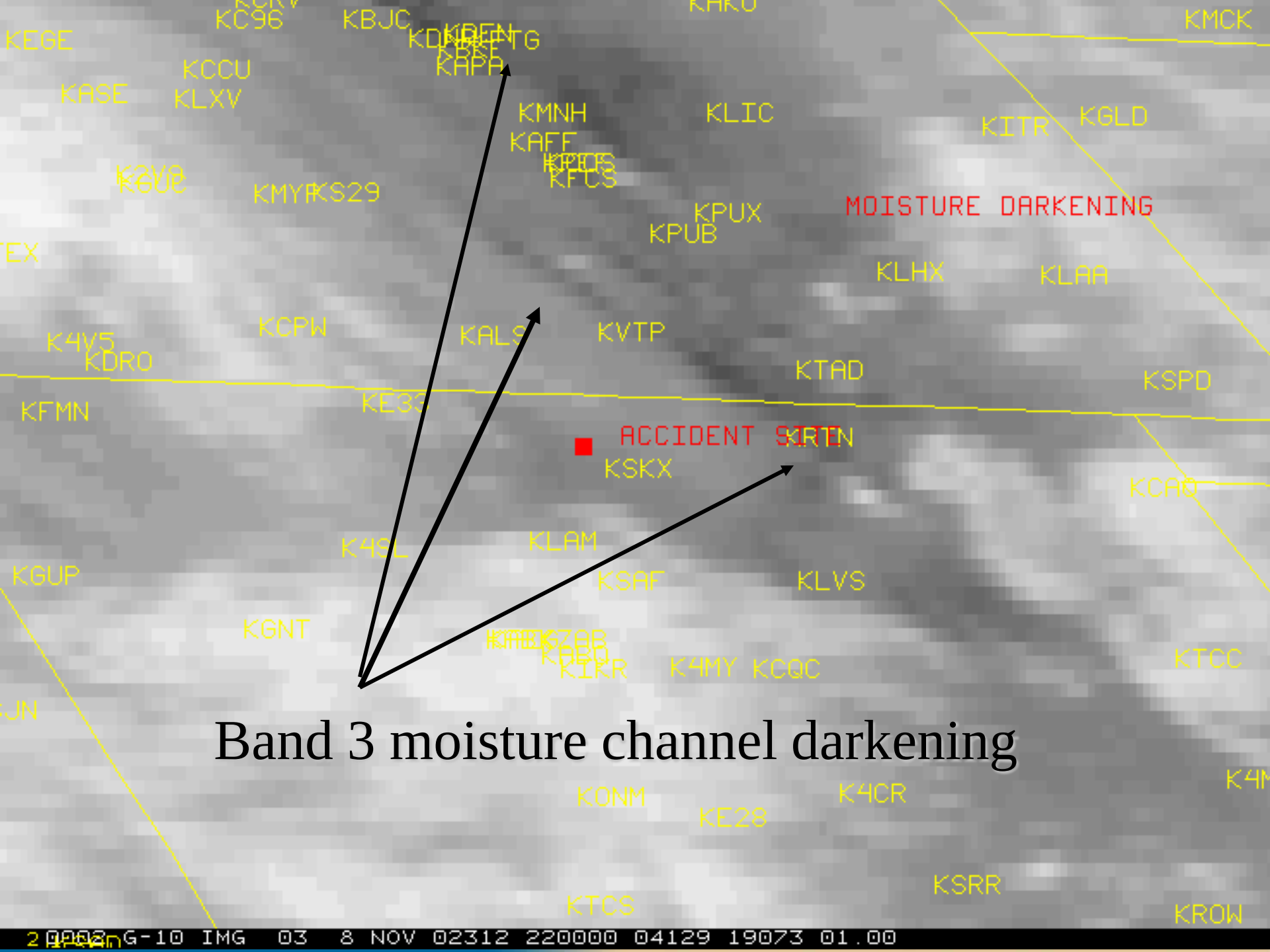
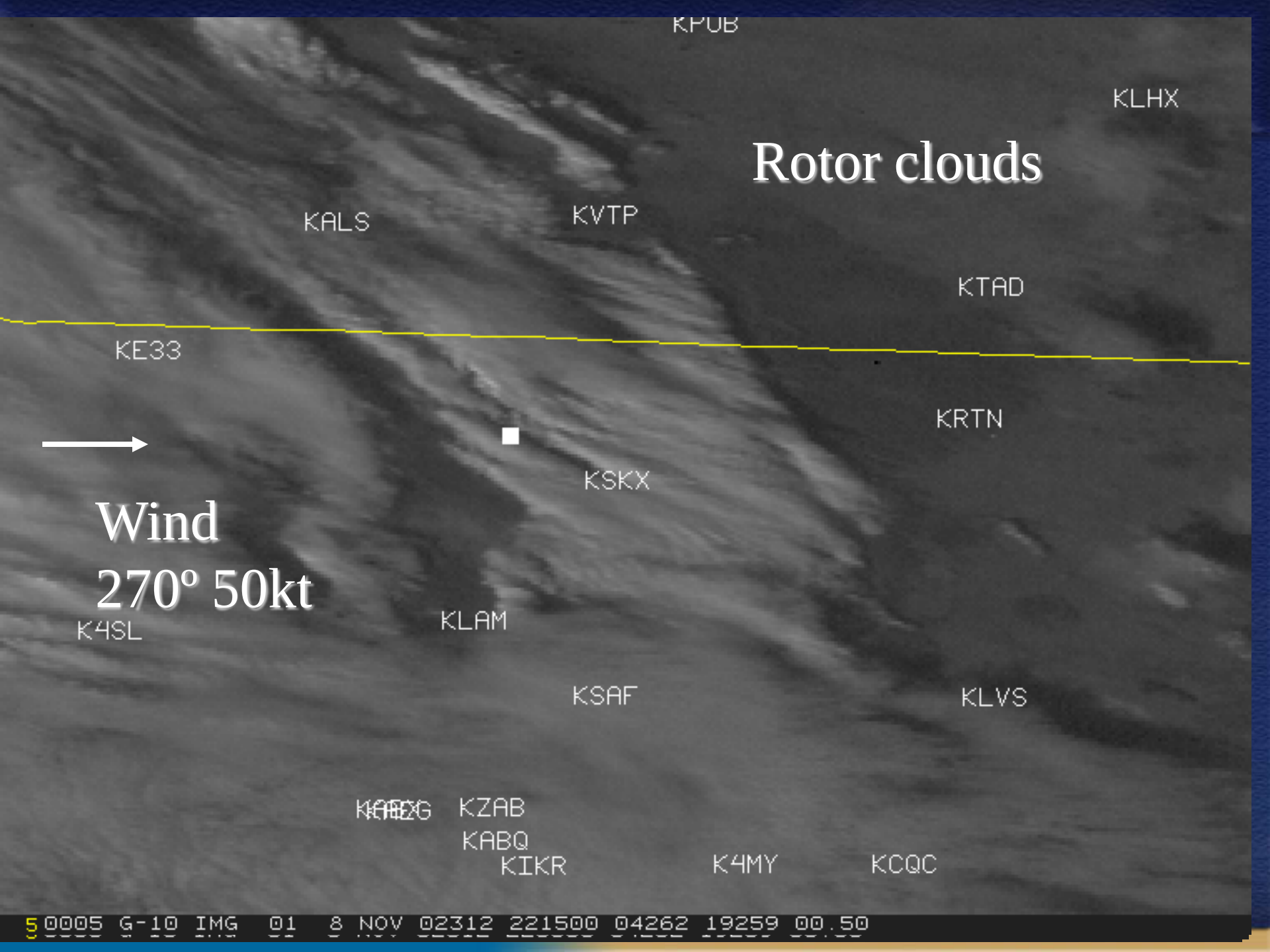


Band 3 moisture channel darkening


KPUB
KLHX
Rotor clouds
KALS
KVTP
KTAD
KE33
KRTN
KSKX
Wind
270° 50kt
K4SL
KLAM
KSAF
KLVS
KZAB
KABQ
KIKR
K4MY
KCQC
5 0005 G-10 IMG 01 8 NOV 02312 221500 04262 19259 00.50

Accident Photo

NTSB

DEN06FA132 – Telluride, CO
September 15, 2006
Beech Debonair, N5893J

- Part 91 – VFR flight
- Taos, NM – Telluride, CO
- LOC at 15,000 ft
- Fatal 5
- Probable Cause: inadvertent flight into mountain wave turbulence resulting in loss of control of the airplane and subsequent impact into mountain terrain

NTSB

WPR13FA072 – Payson, AZ
Dec. 18, 2012
Piper PA-31, N62959

- Ameriflight 3853 (UPS)
- Part 135 Cargo Flight
- IFR flight plan
- Dep: Holbrook to Payson with final destination PHX
- No official weather briefing – knowledge of weather unknown
- IMC prevailed with full series of AIRMETs current for area
- At 13,800 ft reported encountering strong updraft/downdraft to ATC before loss of radio contact
- Fatal 1

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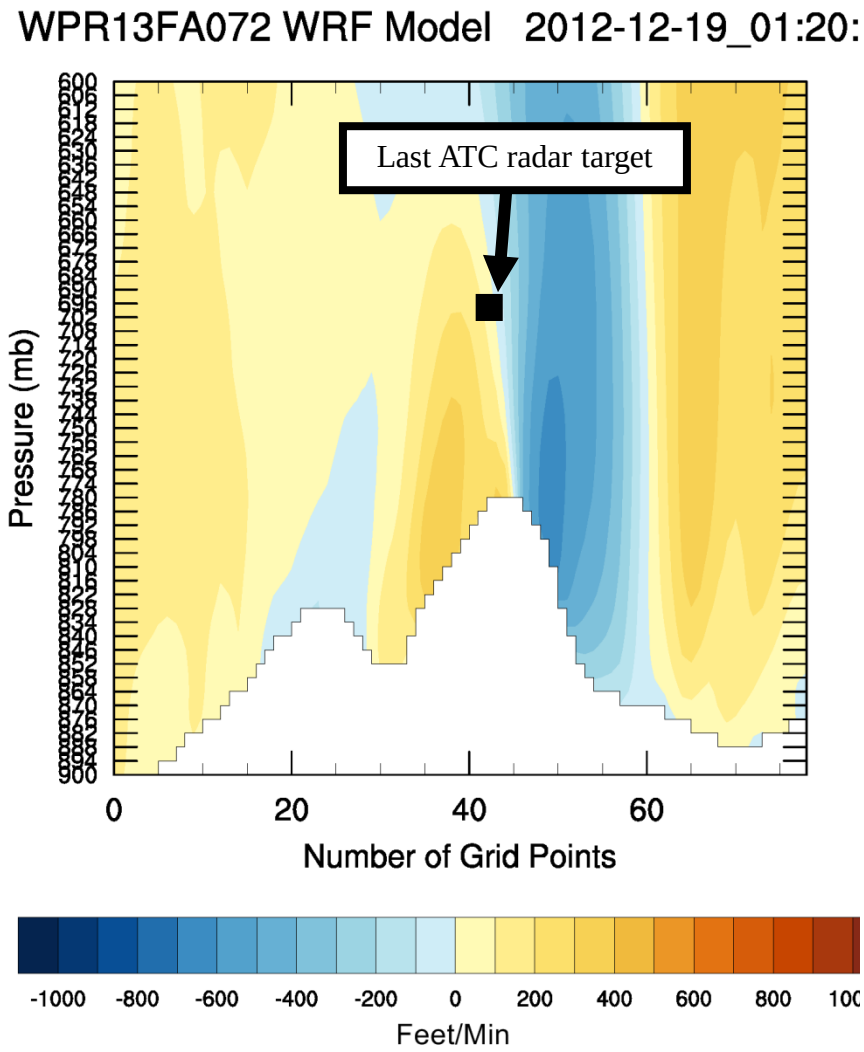
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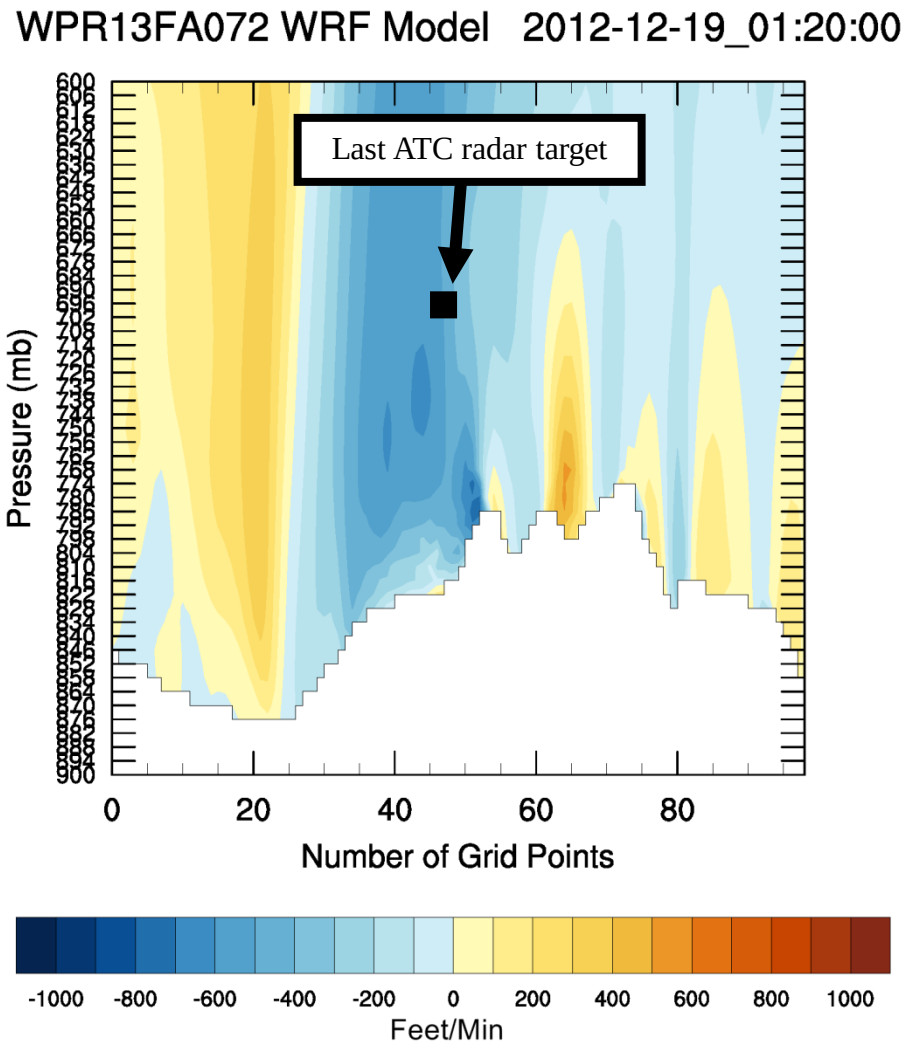
Last ATC radar target
Pressure (mb)
Number of Grid Points
0
20
40
60
-1000
-800
-600
-400
-200
0
200
400
600
800
Feet/Min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Feet/Min

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