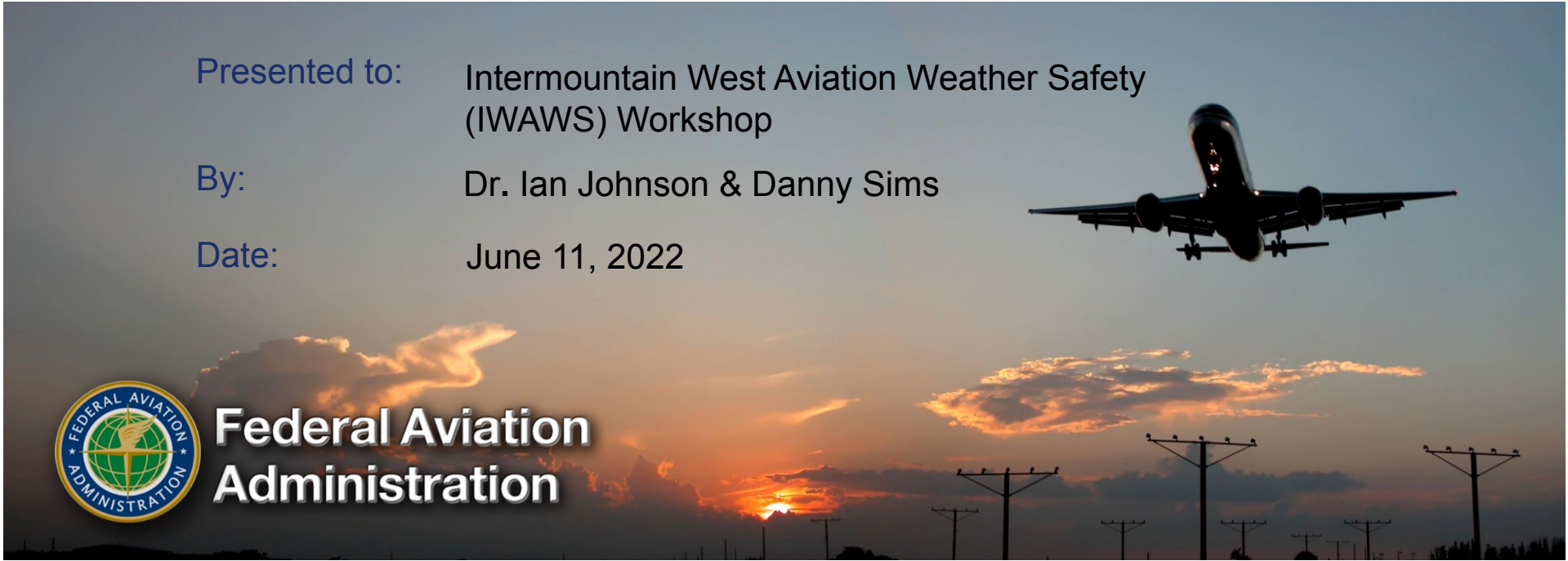
Adverse Weather Scenarios

Strategies for avoidance in mountainous terrain



Presented to: Intermountain West Aviation Weather Safety (IWAWS) Workshop

By: Dr. Ian Johnson & Danny Sims

Date: June 11, 2022

Federal Aviation Administration

FAA Mission and Goal

- **Provide a safe and efficient national airspace for all aviation users**
- **Aviation Weather Research Program (AWRP): Conduct applied weather research to develop or improve products to enhance safety and efficiency**
- **Weather Technology In the Cockpit (WTIC): Resolve meteorological information and technology gaps in the cockpit that are causal factors in safety and efficiency shortfalls**

Agenda

- **WTIC findings of pilot gaps in weather understanding**
- **Scenarios from NTSB investigations**
  - Weather overview
- **Summary and Strategy**

Gaps in Pilot Weather Knowledge

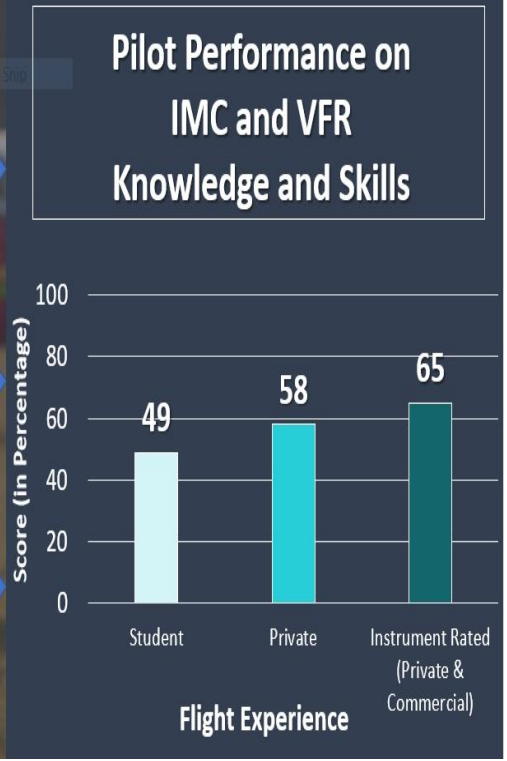
- **Pilots struggled at interpreting weather along the route**
- **Held incorrect weather expectations for most of the route and at the destination airport**
  - Pilot expectation of destination airport weather as Visual Flight Rules (VFR) whereas conditions were much lower (per WTIC research studies)
- **Pilots may not be assessing enough forecast products to gain a better mental model of what weather to expect along the entire route**
  - Pilots relied on observation information (e.g., METARs) for their destination airport instead of considering the appropriate forecast products

Pilot Weather Knowledge Scores

Overall, pilots' scores were **low** on interpreting **IMC weather information.**

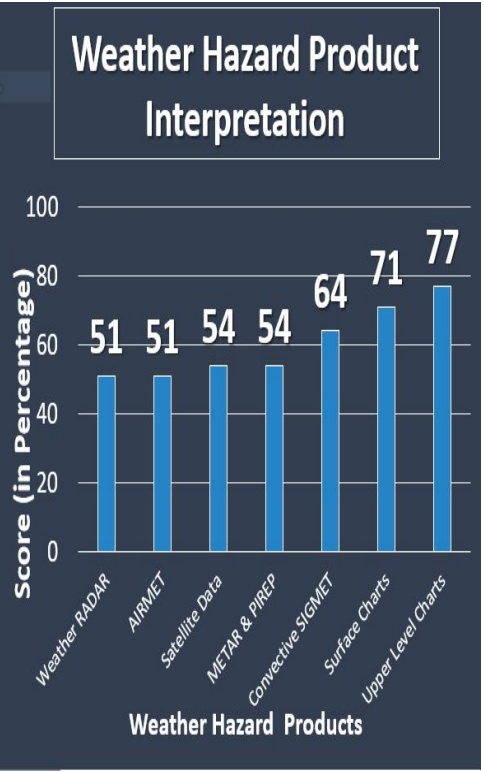
This includes **Surface Charts, Satellite Data, & PIREPs** involving **IMC weather**

Instrument-rated pilots scored the **highest.**



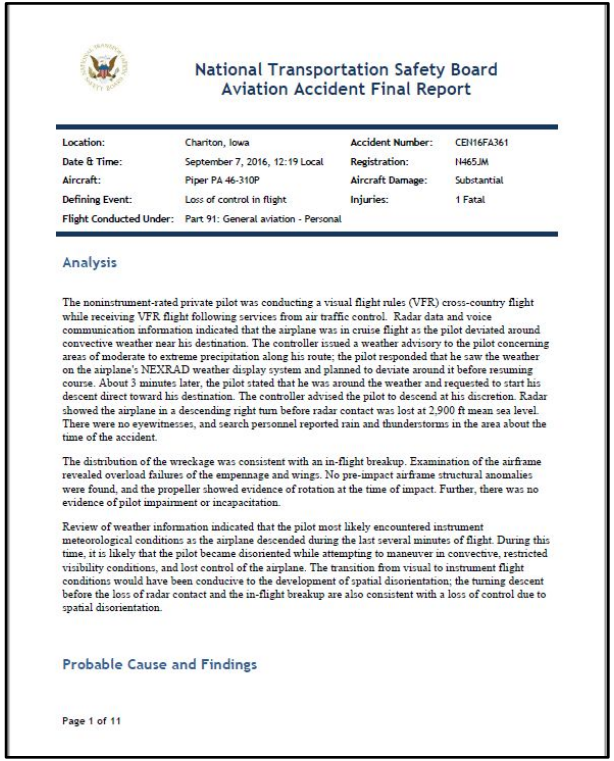
Pilots scored **low** on **RADAR, AIRMETs, Satellite Data, METARs** and **PIREPs**

Pilots scored **higher** on **SIGMETs, Surface Charts,** and **Upper Level Charts**



Scenarios and Briefing Intent

- Based on NTSB accident investigations
- Scenario errors are based upon WTIC research
- The weather is real!
- Not intended to teach pilots how to fly
- Suggestions and recommendations; not requirements
- Goal is to teach about and avoid weather hazards, especially in mountainous terrain



National Transportation Safety Board
Aviation Accident Final Report

Location:	Chariton, Iowa	Accident Number:	CEN16FA361
Date & Time:	September 7, 2016, 12:19 Local	Registration:	N465JM
Aircraft:	Piper PA 46-310P	Aircraft Damage:	Substantial
Defining Event:	Loss of control in flight	Injuries:	1 Fatal
Flight Conducted Under:	Part 91: General aviation - Personal		

Analysis

The noninstrument-rated private pilot was conducting a visual flight rules (VFR) cross-country flight while receiving VFR flight following services from air traffic control. Radar data and voice communication information indicated that the airplane was in cruise flight as the pilot deviated around convective weather near his destination. The controller issued a weather advisory to the pilot concerning areas of moderate to extreme precipitation along his route; the pilot responded that he saw the weather on the airplane's NEXRAD weather display system and planned to deviate around it before resuming course. About 3 minutes later, the pilot stated that he was around the weather and requested to start his descent direct toward his destination. The controller advised the pilot to descend at his discretion. Radar showed the airplane in a descending right turn before radar contact was lost at 2,900 ft mean sea level. There were no eyewitnesses, and search personnel reported rain and thunderstorms in the area about the time of the accident.

The distribution of the wreckage was consistent with an in-flight breakup. Examination of the airframe revealed overload failures of the empennage and wings. No pre-impact airframe structural anomalies were found, and the propeller showed evidence of rotation at the time of impact. Further, there was no evidence of pilot impairment or incapacitation.

Review of weather information indicated that the pilot most likely encountered instrument meteorological conditions as the airplane descended during the last several minutes of flight. During this time, it is likely that the pilot became disoriented while attempting to maneuver in convective, restricted visibility conditions, and lost control of the airplane. The transition from visual to instrument flight conditions would have been conducive to the development of spatial disorientation; the turning descent before the loss of radar contact and the in-flight breakup are also consistent with a loss of control due to spatial disorientation.

Probable Cause and Findings

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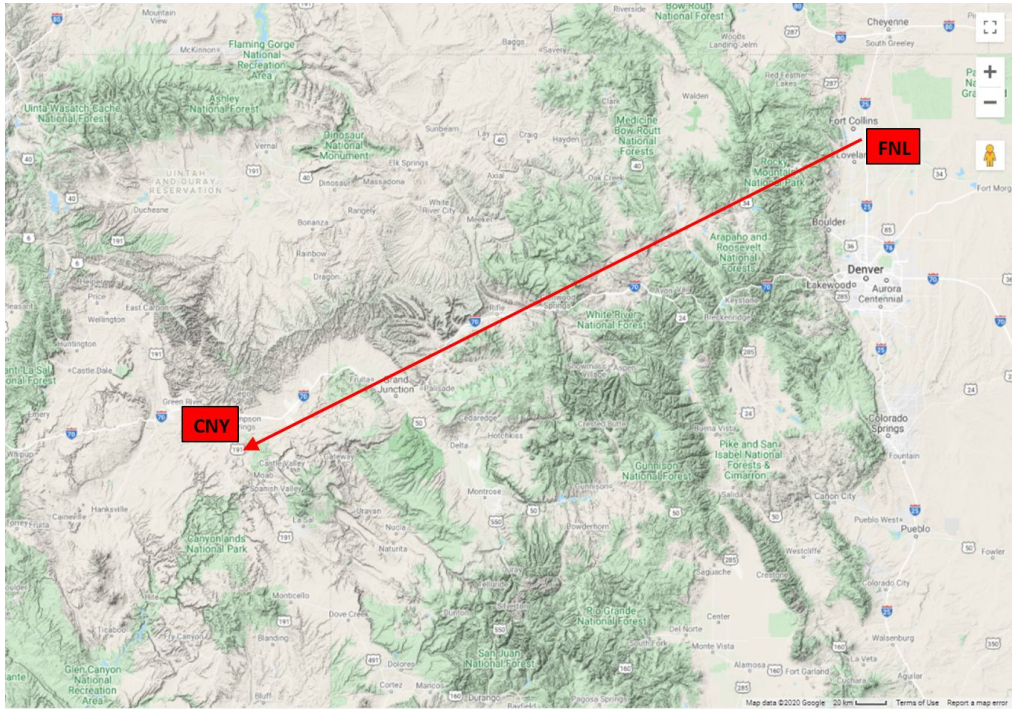
WTIC

- **WTIC Scenario 1 Gaps**
  - Unknown if weather briefing was obtained
  - Departure was delayed
  - Appears pilot did not check for weather update
  - Continued VFR flight into IMC
  - Lack of predetermined escape options
  - Observations versus Forecasts

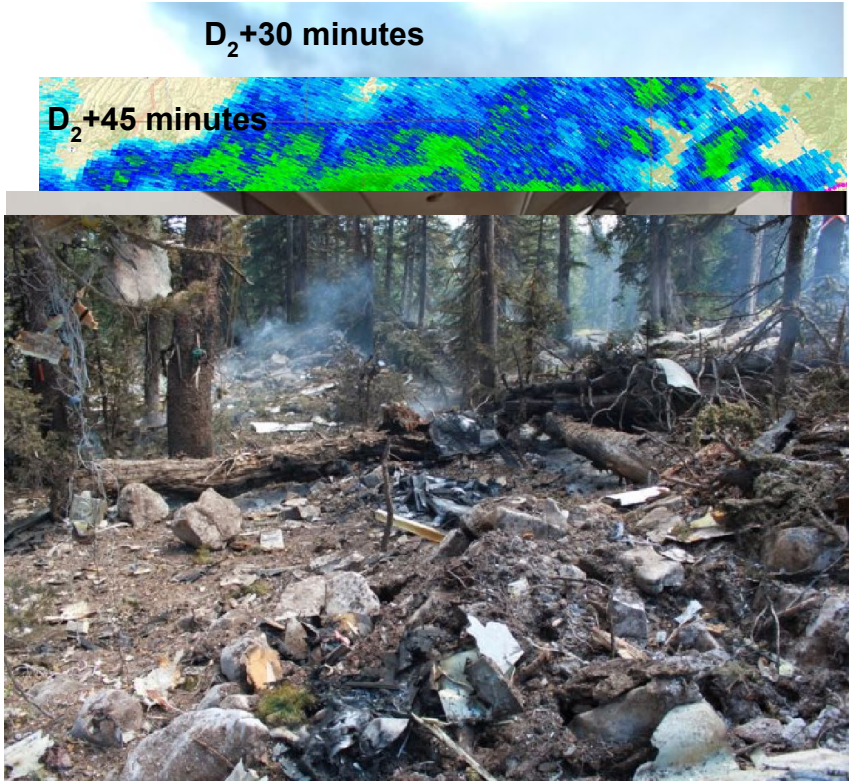
Scenario 1

- **VFR flight from Fort Collins, CO to Moab, UT**
- **Mid-September**
- **Departure Time of 1530 MDT**
  - Delayed to 1920 MDT (night)
- **Non-instrumented rated pilot**
- **Flight Altitude of 10,000 – 15,000 feet MSL**
- **Unknown if weather briefing was obtained**
  - Sufficient weather information was available



Weather Encountered

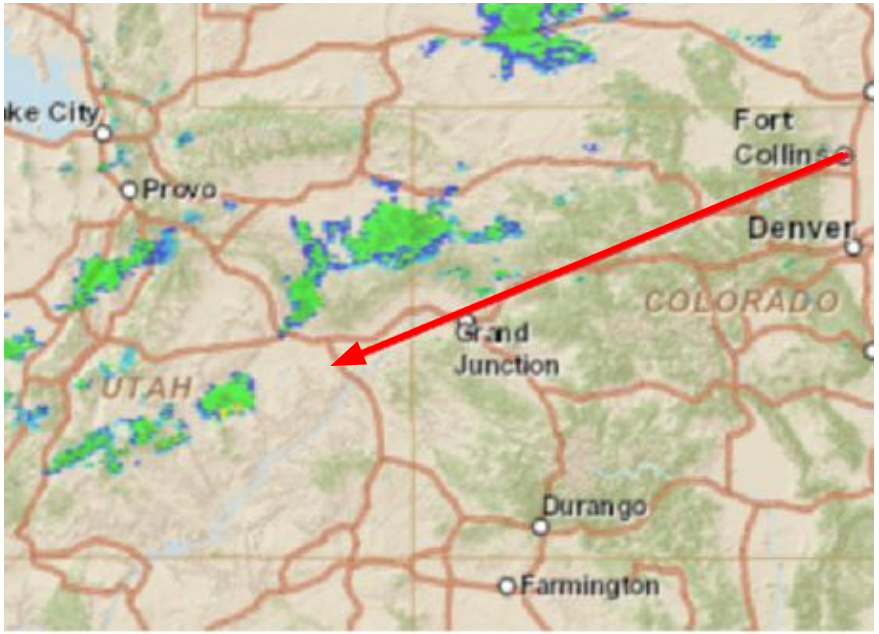
- **Likely encountered intermittent IMC 30 minutes into flight**
- **45 minutes into flight weather radar showing precipitation ahead**
  - Deviation to the Northwest
  - Passenger texted “Taking the long way around, lots of weather, keep you posted.”
- **Continued into solid IMC about 3 minutes before accident occurred 50 minutes into flight**
- **Indications of inflight icing**



Initial Weather Overview

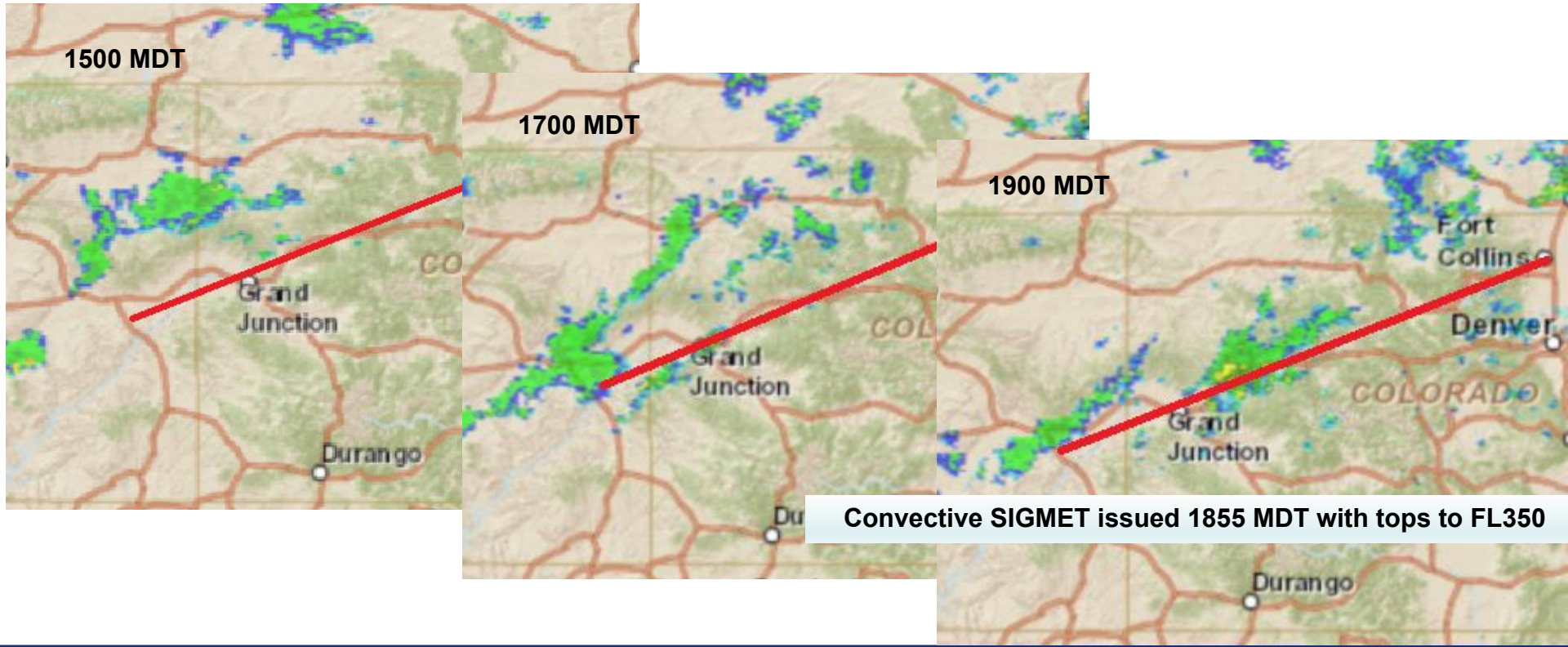
- **FNL (Departure) METAR**
  - KFNL 152056Z AUTO VRB03KT 10SM SCT110 27/04 A2979 RMK AO2 SLP025 T02720039 58006
- **CNY (Arrival) METAR and TAF**
  - KCNY 152053Z AUTO 31020G27KT 10SM CLR 20/11 A2989 RMK AO2 PK WND 30027/2045 SLP086 T02000111 58002
  - KCNY 151740Z 1518/1618 21011G19KT P6SM FEW070 SCT120 \FM152200 24016KT P6SM FEW070 SCT150 \FM160000 28017KT P6SM VCSH FEW070 SCT110 \FM160300 32009KT P6SM BKN070 \FM160600 33006KT P6SM FEW060 SCT200 \FM161700 00000KT P6SM SKC
- **Surface Analysis**
- **Satellite**
- **Radar**
- **AIRMET for Mod turbulence below FL180**
- **Observations versus Forecasts**

1500 MDT/2100 UTC
D-30 minutes



Weather Radar Changes

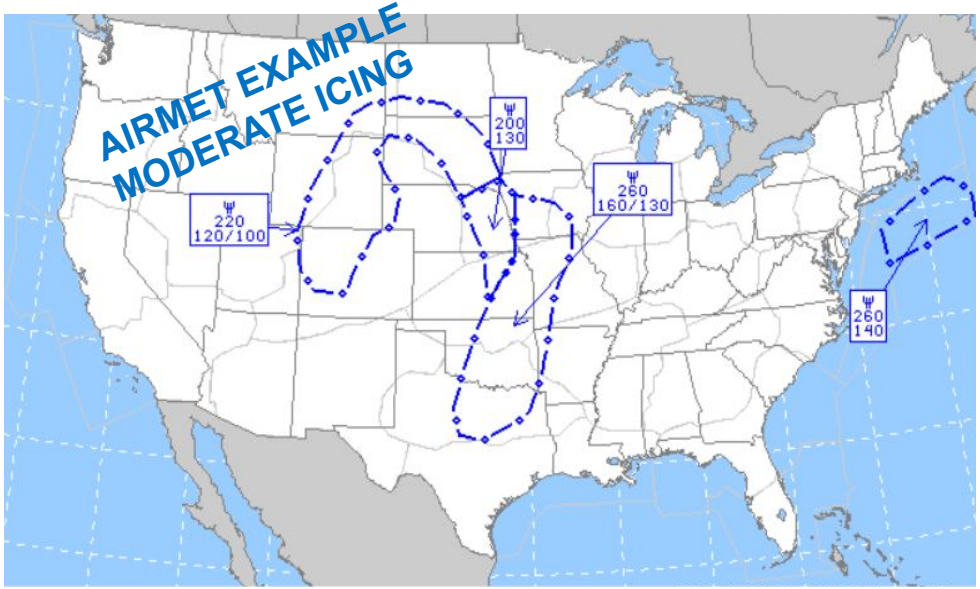
1500-1900 MDT/2100-0100 UTC
D-30 to D_2-20



Convective SIGMET issued 1855 MDT with tops to FL350

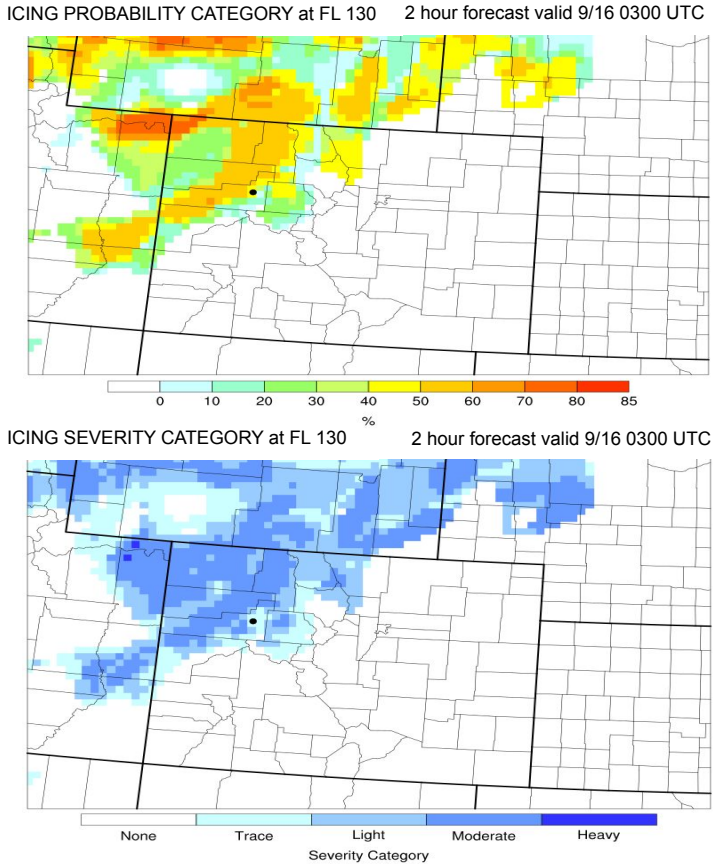
Indications of Icing

- **No AIRMETs at the time**
  - For Moderate intensity
  - SIGMETs are for Severe intensity
- **Trace or light conditions will not warrant an AIRMET or SIGMET**
  - But any icing is hazardous to an aircraft without anti- or de-icing equipment
- **Current Icing Product (CIP) and Forecast Icing Product (FIP) are supplemental products**



Icing – CIP and FIP

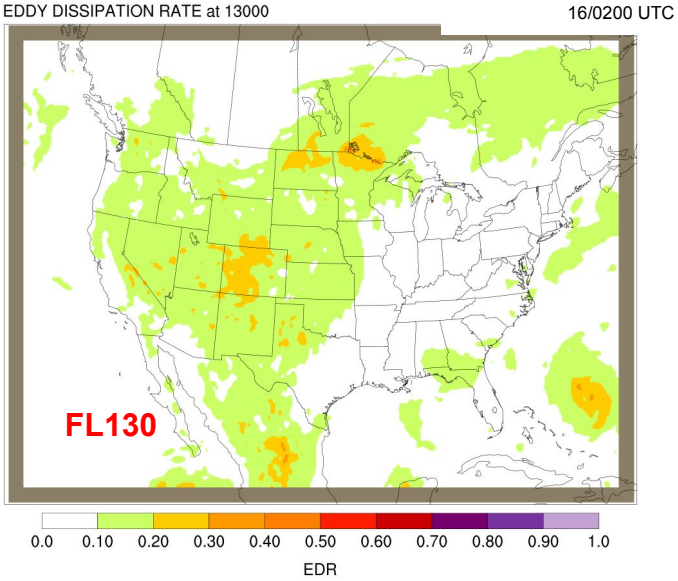
- CIP is a diagnosis or nowcast (0-hour forecast)
- FIP is a forecast out to 18 hours
- Probability of any icing and intensity
- Available pre-departure at aviationweather.gov and via FIS-B while in flight (along with other products)

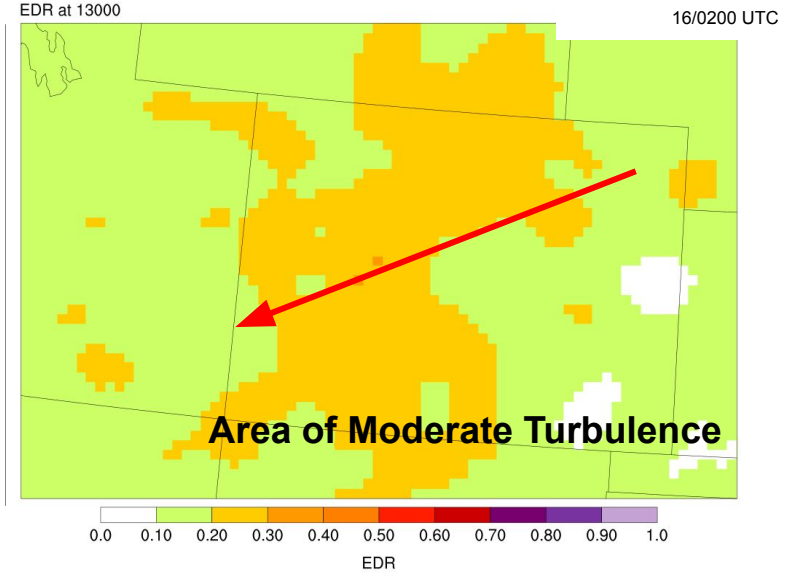


GTG Forecast

1900 MDT/0100 UTC
D_2-20 minutes

Supplement the Turbulence AIRMET with the Graphical Turbulence Guidance (GTG)



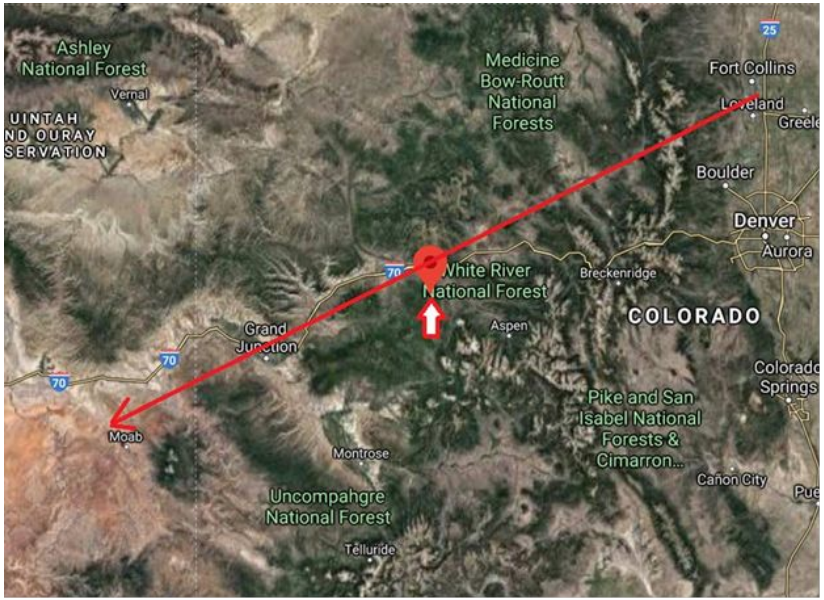


Eddy Dissipation Rate (EDR) objective values translated to turbulence intensity of light, moderate, severe, and extreme

METARs along the route

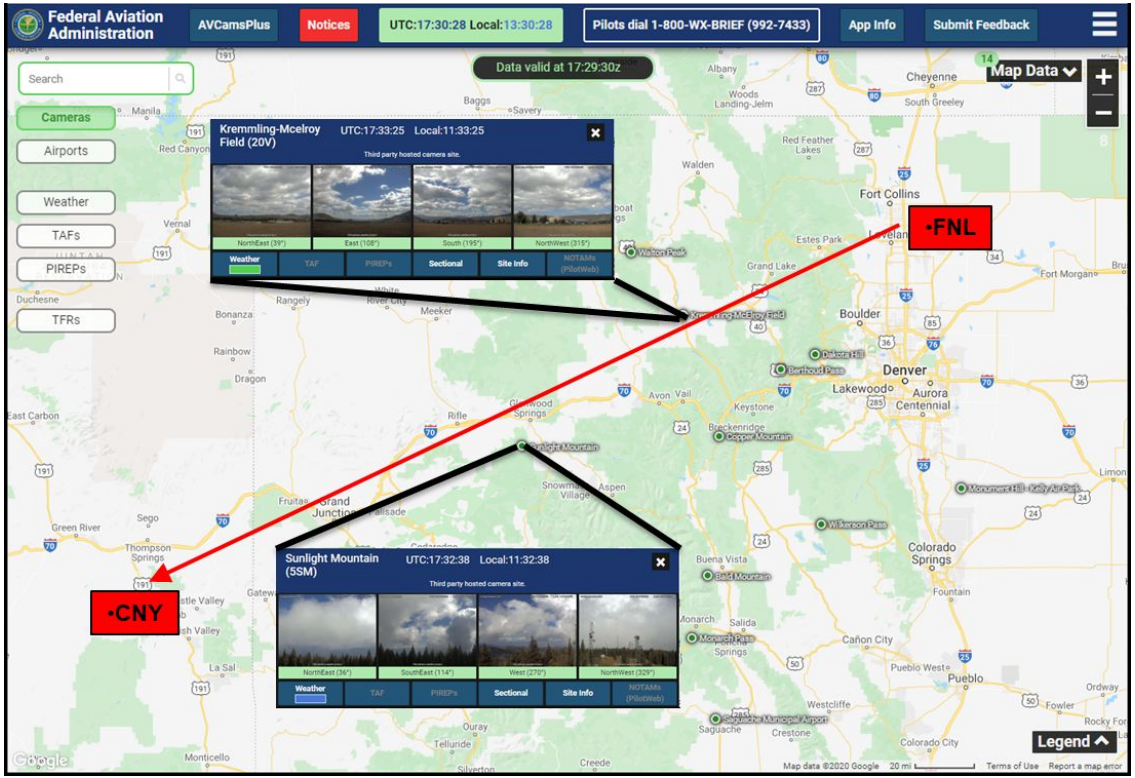
1829-1910 MDT/0029-0110 UTC
D_2-10 minutes

- **Clues from Sunlight Mountain (5SM) AWOS at an elevation of 10,604 feet**
  - [1829 MDT] METAR K5SM 160029Z AUTO 26007G20KT 230V030 10SM -TSRA BKN006 BKN047 OVC095 03/01 A3022 RMK AO2 LTG DSNT SW THRU N=
  - [1849 MDT] METAR K5SM 160049Z AUTO 26012G21KT 190V320 1 3/4SM –TSRA OVC002 03/02 A3022 RMK AO2 LTG DSNT W THRU NE=
- **Latest observation prior to departure shows precipitation, low ceiling, near freezing temperature (potential icing), and distant lightning**
  - [1910 MDT] METAR K5SM 160110Z AUTO 27014G25KT 230V310 1/4SM -RA OVC002 01/01 A3023 RMK AO2 LTG DSNT NW THRU NE=



Web Cameras

- Colorado cameras with directional images
- Extensive use in Alaska
- Being installed in Hawaii
- Research to extract visibility estimates

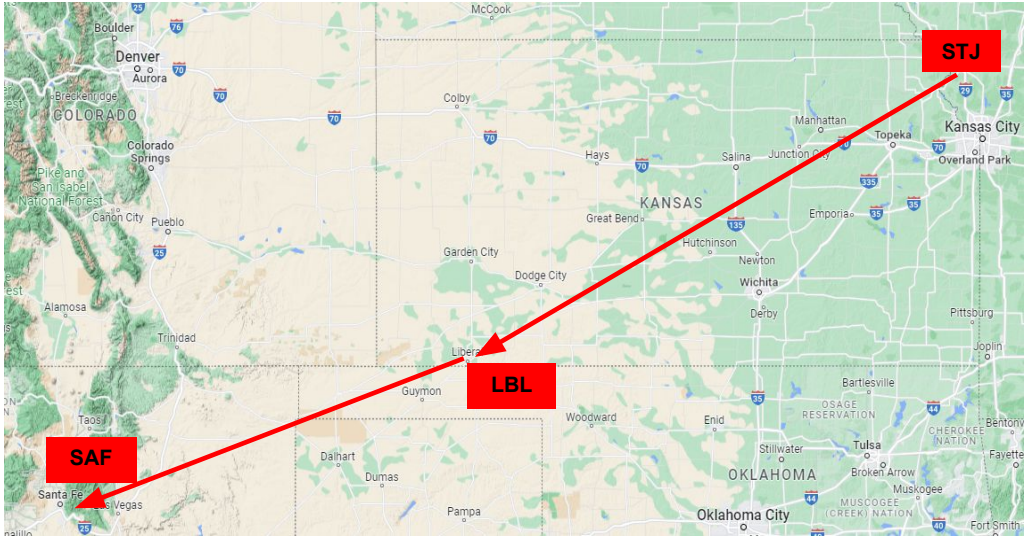


WTIC

- **WTIC Scenario 2 Gaps**
  - Lack of weather planning
  - Continued VFR flight into IMC
  - No plan for alternates
  - Pilot physical and mental awareness

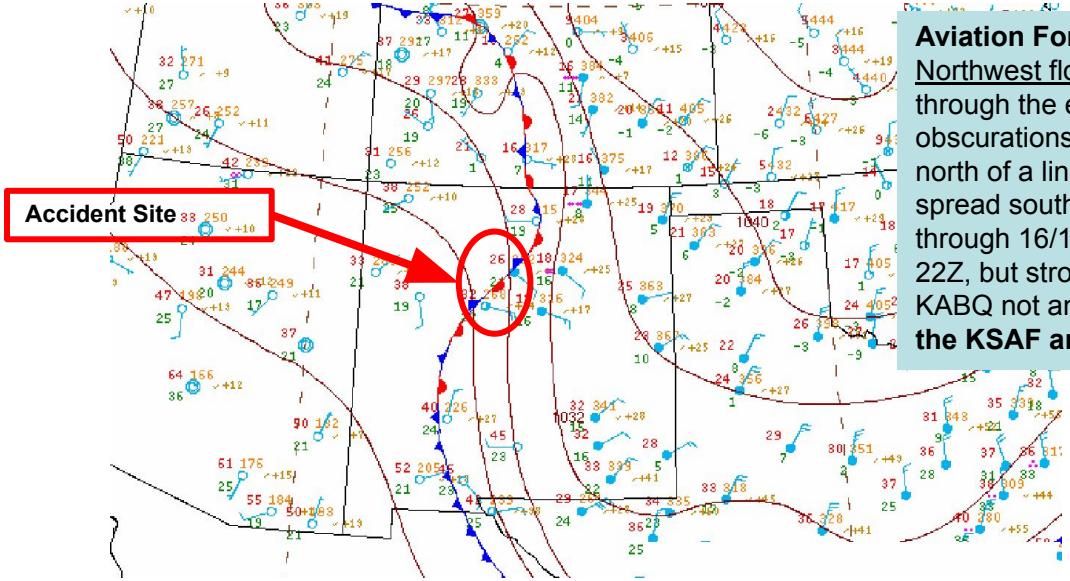
Scenario 2

- **VFR flight plan from St Joseph, MO to Santa Fe, NM with stop in Liberal, KS**
- **Mid-January**
- **Pilot was physically cold but trying to save time and money**
- **Encountered IMC and inflight icing over mountainous terrain near SAF**
- **Did not immediately try to exit; unable to maintain altitude**



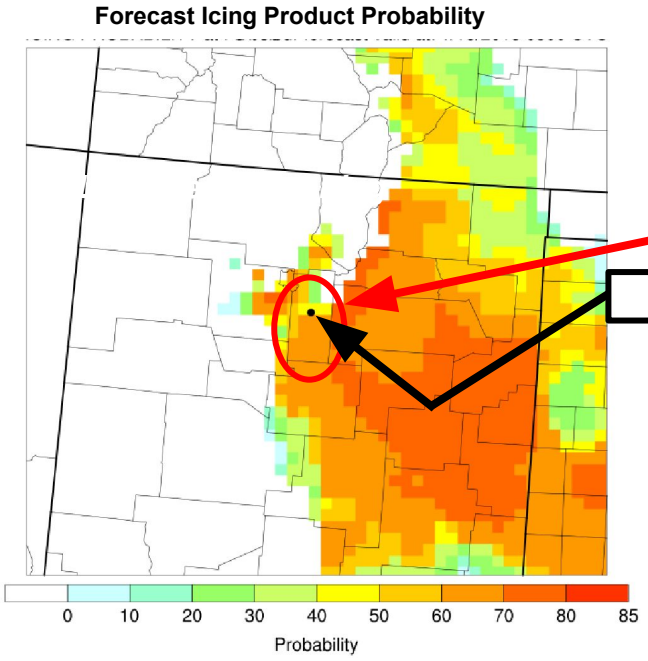
Scenario 2 – Ice Chunks

Scenario 2 – Weather Overview



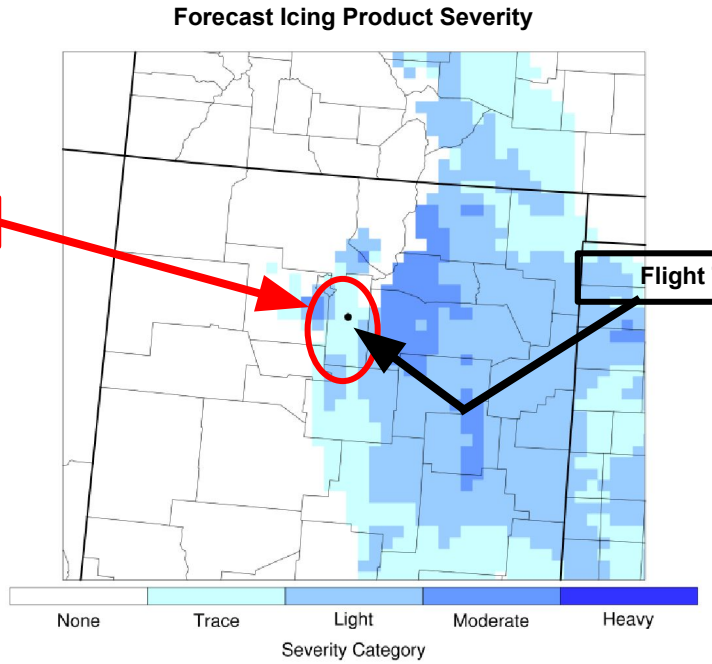
Aviation Forecast Discussion:
Northwest flow aloft with sct-bkn high clouds. Strong cold front plunging through the eastern plains at 17Z and has already passed KROW. Terrain obscurations in widespread MVFR to IFR cigs and lcl vsbys in br along and north of a line from KRTN-KLVS-KCQC-KSXU-KCVN at 17Z will continue to spread south and westward to KSRR vcnty and KROW by 21Z and persist through 16/12Z. Expect the front to push into the RGV between 19Z and 22Z, but strongest east to southeast sustained wind and gusts at KSAF and KABQ not anticipated til aft 16/00Z. **MVFR to IFR cigs may also bleed into the KSAF and KLAM area aft 16/00Z as the front progresses wwd.**

Scenario 2 – IMC & Inflight Icing



Accident Site

Flight Track



Flight Track

Scenario 2 – Pilot Feedback

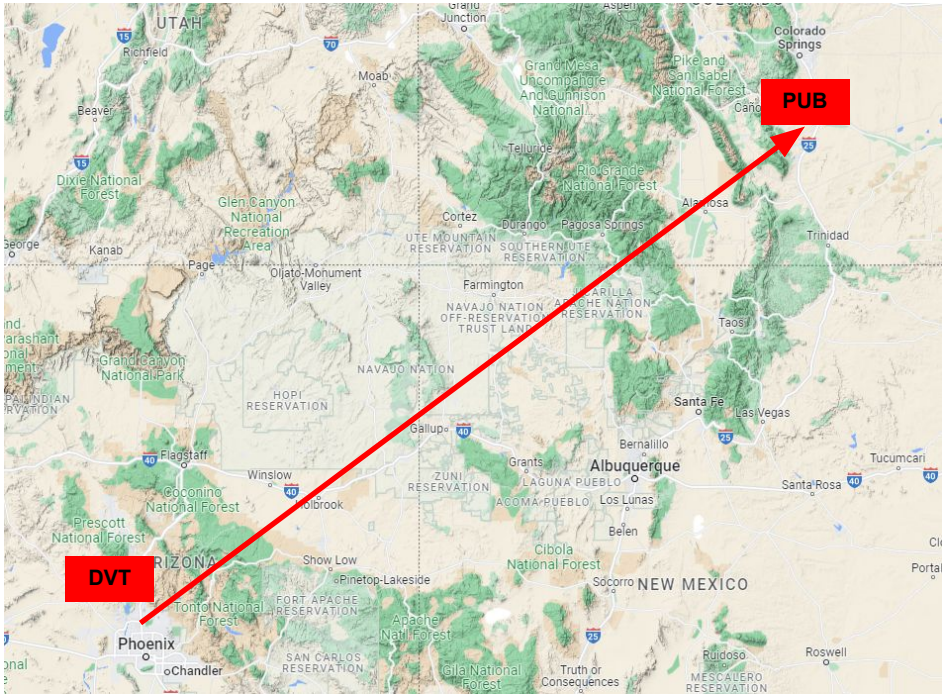
- **Pilot admitted errors**
  - **Did not check weather conditions before flight**
  - **Did not monitor weather during flight**
  - **Did not ask ATC for weather ahead**
  - **Did not make plans for alternate landing**
  - **Extensive preflight planning for the prior legs, but none for the accident leg**
  - **Filed VFR, but entered IMC and did not divert**
- **Confirms NASA Aviation Safety Reporting System research findings**

WTIC

- **WTIC Scenario 3 Gaps**
  - Monitor entire route from departure -> enroute -> arrival
  - Form a mental model
  - False anticipation that conditions will improve
  - Combination of multiple weather hazards

Scenario 3

- IFR flight plan from Phoenix, AZ to Pueblo, CO
- Early January
- Upon descent, the airplane entered a right turn, climbing rapidly, and then descending rapidly in a spiral-like pattern



Scenario 3 – Weather Overview

- **In vicinity of a Low & a front**
- **WFO summary**
  - Developing winter weather
  - Freezing precipitation indicates icing
  - Deteriorating conditions

THE FOCUS CONTINUES TO BE ON THE **DEVELOPING WINTER WEATHER SITUATION**. CURRENT SATELLITE IMAGERY AND SURFACE OBSERVATIONS SHOW MID AND HIGH CLOUDS ACROSS MUCH OF EASTERN COLORADO WHILE SNOW IS SPREADING OVER THE WESTERN SLOPE AND CONTINENTAL DIVIDE. SOME LOW CLOUDS **AND LIGHT FREEZING PRECIPITATION** HAS BEEN REPORTED EARLY THIS MORNING IN KDEN AND KLIC. FARTHER SOUTH IN OUR CWA...CIGS HAVE CONTINUED TO BE MID AND HIGH LEVEL CLOUDS PRIMARILY.

.**AVIATION**...

AN ARCTIC FRONT WILL MOVE SOUTH THROUGH THE SOUTHEAST COLORADO PLAINS TODAY. THE FRONT IS EXPECTED TO MOVE THROUGH EL PASO COUNTY BETWEEN 12Z AND 15Z AND CONTINUE SOUTHWARD TO THE SOUTHERN BORDER OF CO BY 21Z. SNOW WILL DEVELOP ACROSS THE PLAINS IN THE NORTHEAST TO EASTERLY UPSLOPE SURFACE WINDS. IN THE MOUNTAINS...SNOW WILL CONTINUE ACROSS THE CONTINENTAL DIVIDE WITH CONTINUING **WIDESPREAD MVFR AND LIFR CONDITIONS**. **EXPECT CONDITIONS TO DETERIORATE** TO WIDESPREAD MVFR TO LIFR BEHIND THE FRONT ON THE PLAINS.

WINTER WEATHER ADVISORY FROM 2 PM THIS AFTERNOON TO 11 AM MST MONDAY FOR COZ072>075-085>089-093>099.
WINTER STORM WARNING FROM 11 AM THIS MORNING TO 11 AM MST MONDAY FOR COZ076>084.

Scenario 3 – Weather Encountered

- Rapid descent after entering cumuliform (convective) clouds
- Winter weather radar shows lighter precipitation than summer
  - But pockets of higher reflectivity can be indicators of embedded convection
- Moderate to severe turbulence, mountain wave activity with updrafts & downdrafts, moderate icing, and cumuliform clouds
  - Multiple PIREPs of Turbulence and Icing
  - AIRMETs for IFR, Mountain Obscuration, Turbulence and Icing

Summary

- **Scenario 1**
  - Observations alone are not enough
  - Recheck the weather if delayed
  - Dynamic weather enhanced in mountainous terrain
- **Scenario 2**
  - Get weather information
  - Know your capabilities and limitations
- **Scenario 3**
  - Expect the worst
  - Cumulative effects of multiple weather

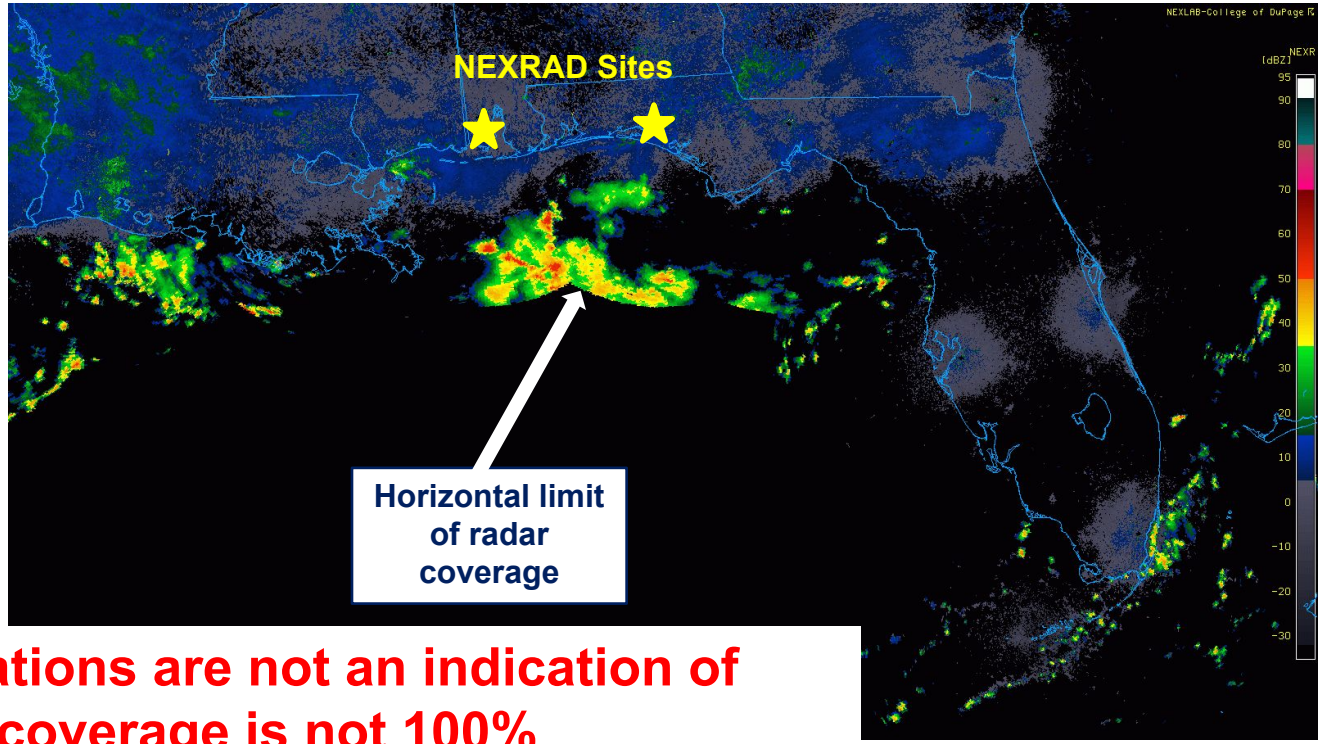
Strategy

- **Plan ahead**
  - Following slides are a suggestion starting 6 days in advance
- **Plan for the entire route**
- **Plan for the entire time**
- **Plan for alternate routes and arrival locations**

Weather Preflight Planning Timeline

Immediate-Term Planning

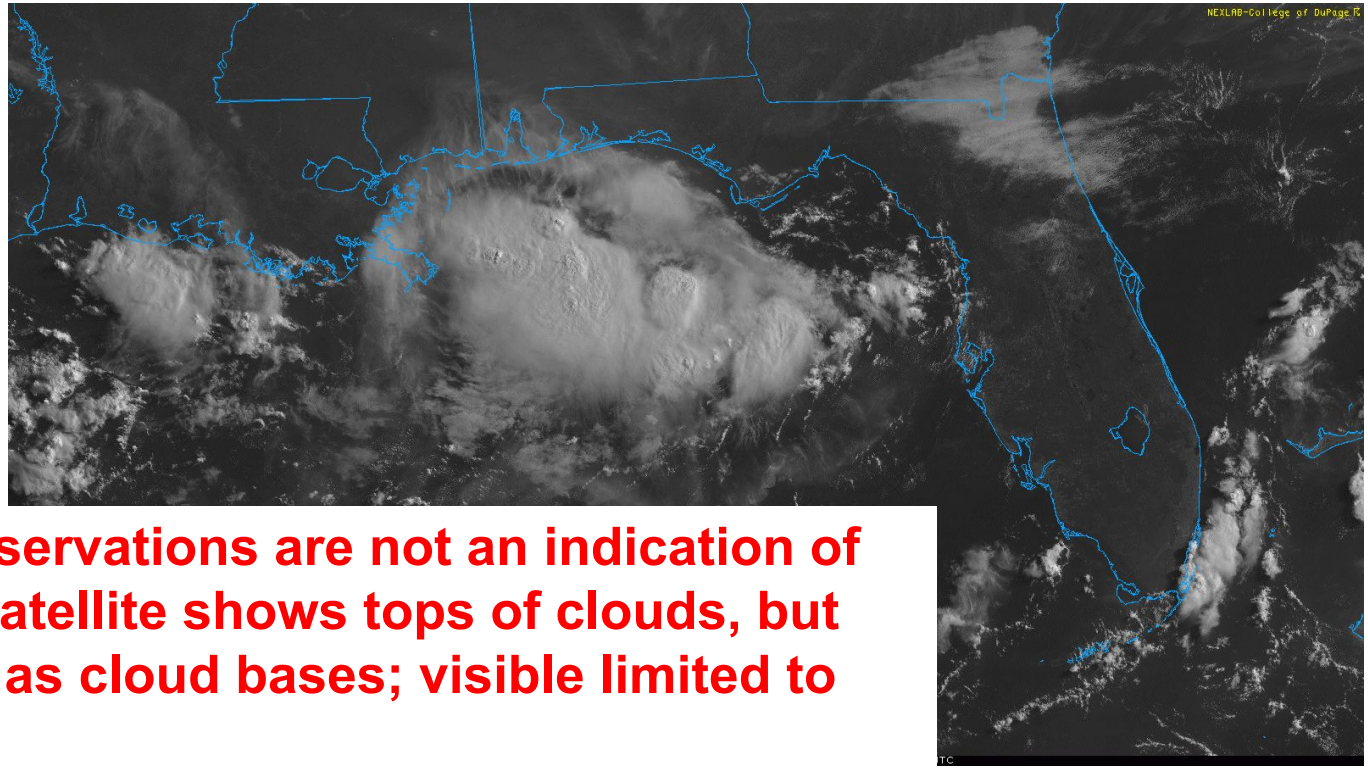
Radar Observations and coverage limitations



Limitations: Observations are not an indication of future events; radar coverage is not 100%

Immediate-Term Planning

Visible Satellite Imagery for day use



Limitations: Observations are not an indication of future events; satellite shows tops of clouds, but not below such as cloud bases; visible limited to daylight

Summary

- **What a pilot should consider while building a mental model**
  - What if my departure gets delayed?
  - Radar and satellite changes
  - METAR changes
  - Making sure to check weather enroute . . .
  - When was forecast made . . . is new forecast coming out soon?
  - Time of day . . . sunrise, sunset, sun angle?
  - What if the weather is moving faster/slower than expected?
  - What if its colder than expected?
  - Pilot distractions such as meetings, passengers, delays, maintenance, etc.
- **Be prepared for all weather phenomena when operating in mountainous regions**
- **Don’t assume the best case; but prepare for the worst case**
- **Be prepared for anything that can cause a change in the pilots’ routine**

Summary

- **Use all weather forecast and observation products that are available**
- **Multiple weather impacts can occur; form a complete picture of all the hazards**
  - Departure > enroute > arrival
- **Use a process to identify potential weather hazards**
  - Begin planning days in advance to identify potential weather hazards
- **Expect and be prepared for deteriorating conditions**
- **Weather is dynamic; mountains enhance changing conditions**
- **Combination of multiple hazards increases pilot workload**
- **Know your capabilities and limitations (i.e., establish personal minimums checklist)**

Contact Information

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- **Danny Sims**
  - FAA Aviation Weather Research Program (AWRP)
  - Danny.sims@faa.gov

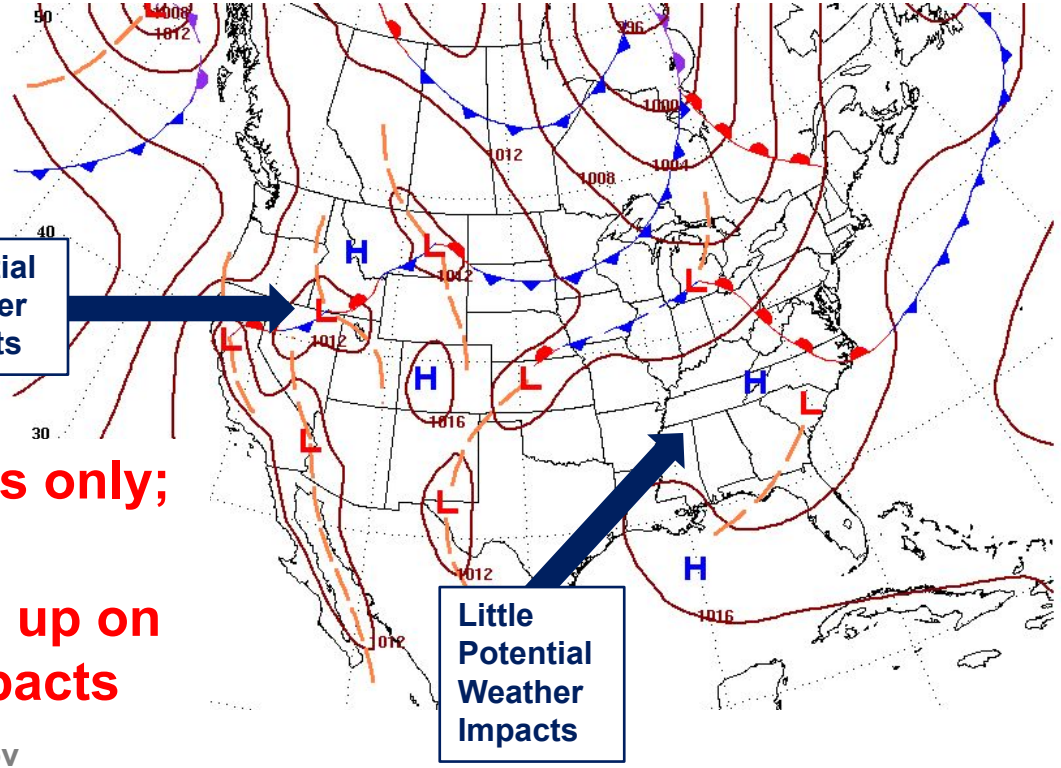
BackUp

Long-Term Planning

Forecast Product	Pros	Cons	Availability
GFS Sea Level Pressure and Precipitation	Shows areas of high and low pressure and where precipitation may fall.	Will not differentiate between convective and non-convective precipitation. Low resolution.	GFS (NOAA NWS) GFS (COD) GFS (Tropical Tidbits)
GFS Simulated Radar	Gives an idea of precipitation patterns, looks similar to radar.	Low resolution.	GFS (COD)
GFS cloud cover or relative humidity (RH)	Indicates cloud coverage and levels. High RH = clouds.	Low resolution.	GFS (Tropical Tidbits) GFS (COD)
WPC Day 3-7 Surface Analysis	Indicates lows, highs, troughs, and fronts.	Uncertainty; Large-scale features only.	WPC
WPC Winter Weather Forecast	Indicates best chance for snow and freezing rain.	Uncertainty; shows surface conditions.	WPC
WFO Forecast Discussion	Forecast explanation including an aviation section.	Formats are not consistent; some offices may offer forecasts for the week while others will only do one day.	AFD (Forecast Discussion)

Long-Term Planning Example

WPC 7-day Surface Forecasts of pressure centers, fronts and troughs; areas of weather are generally in vicinity of fronts and low pressure



Limitations: Large scale features only; forecast uncertainty

Recommended pilot use: Heads up on regions of potential weather impacts

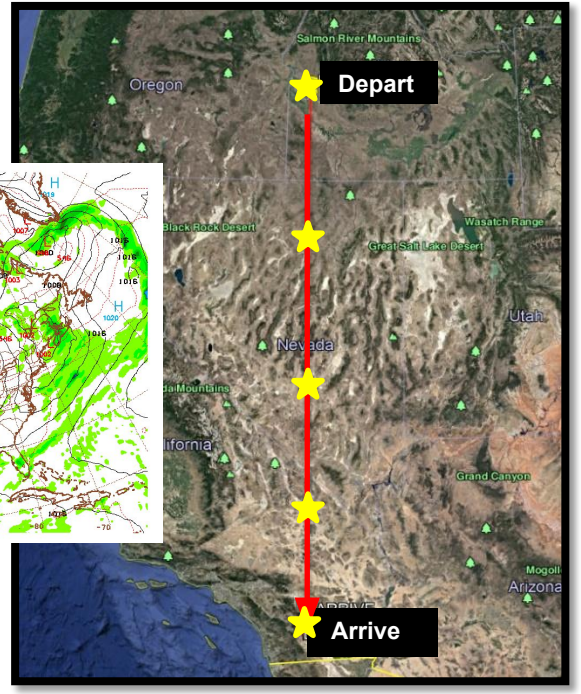
WPC = Weather Prediction Center, wpc.ncep.noaa.gov

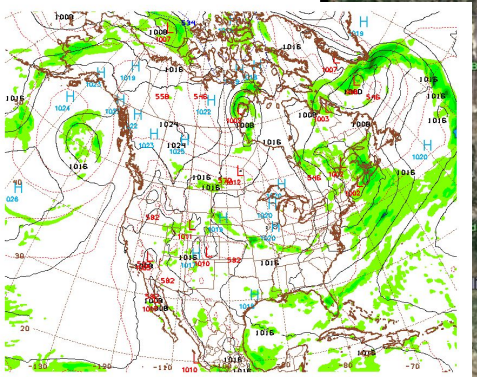
Short-Term Planning

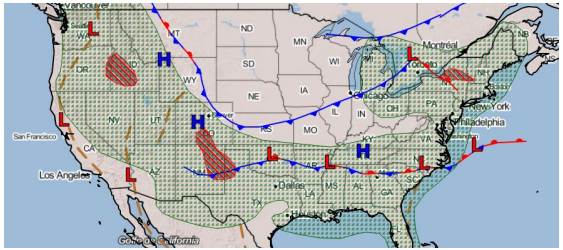
Forecast Product	Pros	Cons	Availability
NAM Sea Level Pressure and simulated reflectivity	Indicates precipitation, identifies high and low pressure systems.	Not a substitute for radar and subject to spatial and temporal uncertainty.	NAM (Tropical Tidbits) NAM (NCEP) NAM (Pivotal) NAM (PSU)
NAM cloud cover or relative humidity	Indicates cloud coverage and levels. High RH = clouds.	Subject to uncertainty	NAM (Pivotal) NAM (NECP) NAM (PSU)
SPC Convective Outlook	SPC high confidence areas for convective activity.	Regional perspective over 24 hours	SPC
WPC Surface Analysis	Indicates lows, highs, troughs, and fronts; Shows areas of precipitation, thunderstorms, and snowfall.	Primarily large scale features	WPC
WPC Winter Weather Forecast	Indicates best chance for snow and freezing rain.	Not always indicative of conditions aloft	WPC
AWC Extended Convective Forecast Product	Graphical representation of likely areas for convection; Forecast up to 72 hours.	May not be inclusive of all potential convection, especially small storms	ECFP

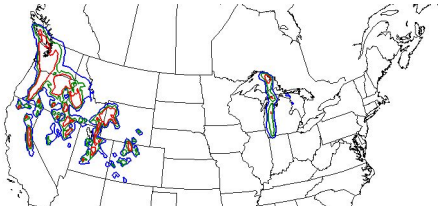
Short-Term Examples

- Retain long-term products
- Additional weather model
- AWC and SPC products









Recommended pilot use: Consistency with long term planning; contingency plans

Immediate-Term Planning

- **Continue with SPC, AWC, and WFO products**
- **Current observations to include radar, satellite, METARs, & PIREPs**
- **High Resolution Rapid Refresh (HRRR) model**
- **AWC aviation specific products (GFA)**

Immediate-Term Planning

Forecast Product	Pros	Cons	Availability
HRRR	Indicates high resolution precipitation, convection, winds.	Limited time coverage, only 18 hours.	HRRR (NOAA NWS) HRRR (Tropical Tidbits) HRRR (Pivotal Weather) HRRR (PSU)
SPC Convective Outlook	SPC high confidence areas for convective activity.	Covers a 24-hour period; less detail	SPC
WPC Surface Analysis	Indicates lows, highs, troughs, and fronts; Shows areas of precipitation, thunderstorms, and snowfall.	Primarily large scale features	WPC
WPC Winter Weather Forecast	Indicates best chance for snow and freezing rain.	Not always indicative of conditions aloft	WPC
Forecast Discussion	Forecast explanation including an aviation section.	Formats are not consistent; meteorological jargon.	AWC AFD
Radar, Satellite, METARs, and PIREPs	Current observations.	Not a forecast.	AWC Observations
AWC Graphical Turbulence Guidance	Indicates areas favorable for turbulence by flight level.	Forecasts up to 18 hours.	AWC GTG
AWC Icing Forecast	Icing probability and severity by flight level.	Forecasts up to 18 hours.	AWC ICING
AWC GFA Tool	All-in-one" tool to view aviation weather hazards; Allows for users to put in their route; Provides a complete picture of the weather that may impact flight.	Forecasts up to 18 hours.	AWC GFA
AWC TAF	Terminal forecasts issued for airports.	Airport vicinity only	AWC TAF
SIGMETs	Indicates hazards to all aircraft; Issued every 4 hours else; Convective SIGMETS valid for 2 hours.	Generalized advisory	AWC SIGMETS
AIRMETs	Graphical advisory of weather that may be hazardous to aircraft, but are less severe than SIGMETs; Turbulence, Low-level wind shear, strong surface winds, icing, freezing level, IFR, and mountain obscuration.	Generalized advisory	AWC AIRMETs
PIREPS	Available on the GFA tool and AWC website	Can have time and location errors; no reports does not mean an absence of hazard.	AWC Aircraft Reports