# Experience of Wake Sensors - *Pulsed Lidar in Particular*

*USDOT John A. Volpe National Transportation Systems Center, Cambridge, MA USA*


*Photographer: Howard Cargill*
*http://www.airliners.net/open.file/0664506/L/*

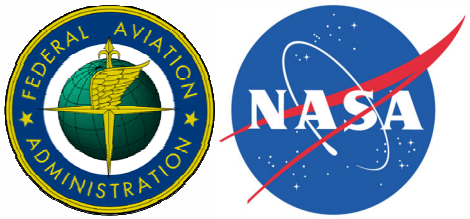

U.S. Department of Transportation
Research and Innovative Technology Administration

# Experience of Wake Sensors
## *Pulsed Lidar in Particular*

Steven Mackey
Melanie Soares
Frank Y. Wang

*Wakenet Europe Workshop 2007*
*February 5 – 7, 2007*
*EUROCONTROL Headquarters, Brussels, Belgium*

# Acknowledgement



# Acknowledgement

# NGE/IGE Measurements

# Why the Emphasis on NGE/IGE Measurements

*Heathrow Encounter Report Statistics*

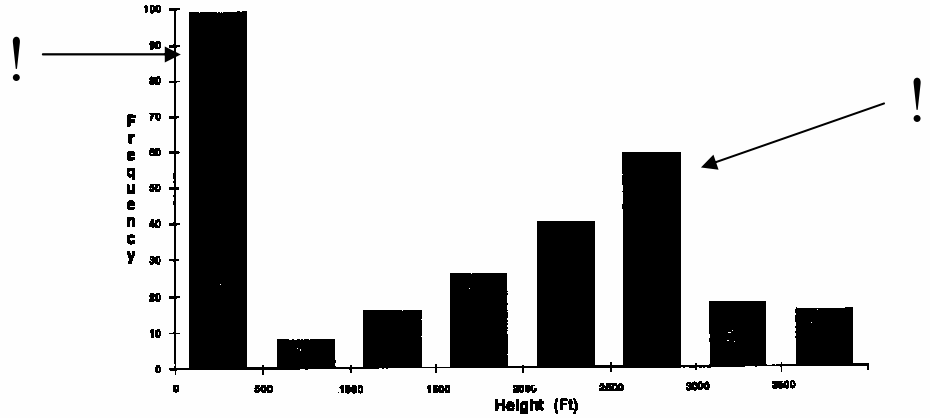



Fig 4(a) Heathrow approaches 1982 to 1990: Distribution of incidents by height, 0 to 4000 feet

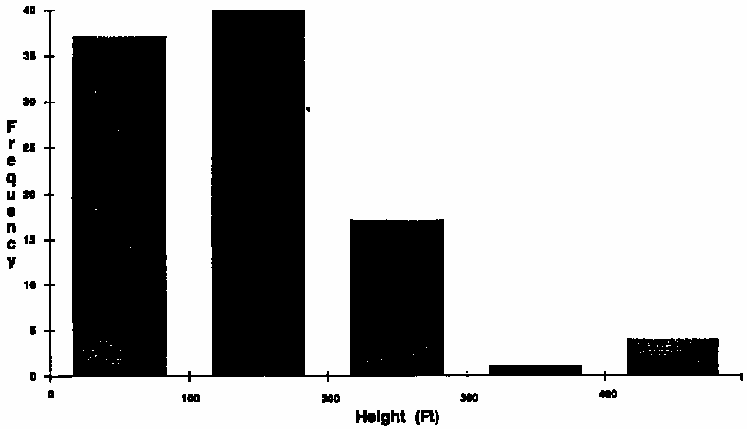



Fig 4(b) Heathrow approaches 1982 to 1990: Distribution of incidents by height, 0 to 500 feet

Critchley, J. B., and Foot, P. B., United Kingdom Civil Aviation Authority Wake Vortex Database: Analysis of Incidents Reported Between 1982 and 1990, CAA Paper 91015, August 1991.

# Why the Emphasis on NGE/IGE Measurements

*Heathrow Encounter Report Statistics*

Driven by Wake Physics
(Vortices Do Not Nominally Sink)

*One Possible Interpretation*

Driven by Procedure
(Vortices Nominally Sink)

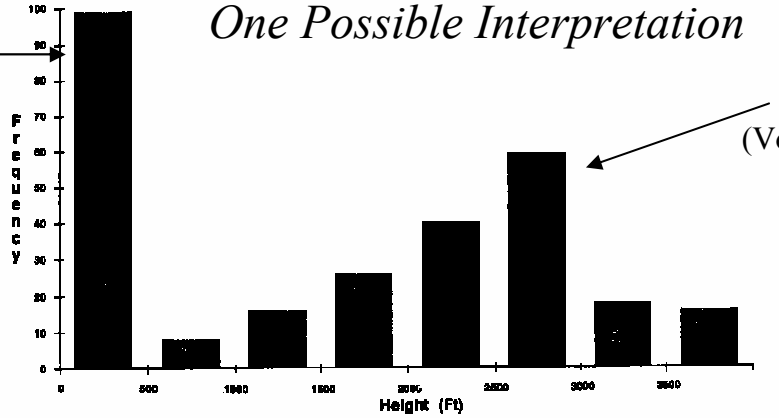



Fig 4(a) Heathrow approaches 1982 to 1990: Distribution of incidents by height, 0 to 4000 feet

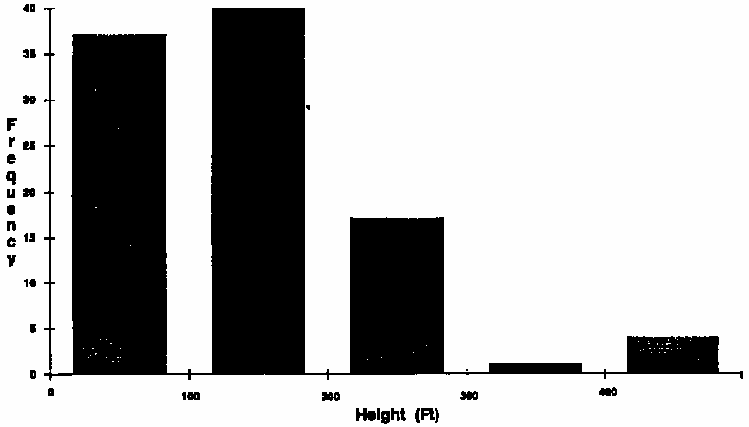



Fig 4(b) Heathrow approaches 1982 to 1990: Distribution of incidents by height, 0 to 500 feet

Critchley, J. B., and Foot, P. B., United Kingdom Civil Aviation Authority Wake Vortex Database: Analysis of Incidents Reported Between 1982 and 1990, CAA Paper 91015, August 1991.

# Why, What and How …

- Need Measurements to Provide Statistics on Wake Transport and Strength / Wake Life.
- Offline Processed Data Traditionally Been Used to Examine Safety Case for New Procedures, or Implemented in Safety Related Models for Overall Risk Assessment.
- Full-Time Real-Time or Full-Time Semi Real-Time Monitoring?
- Part-Time Monitoring?
- What Should A Safety-Net Sensor Measure ….
  - Wind?
  - Wake?
  - Wind and Wake?
  - Wind and Wake and Turbulence?
- How to Measure?

# Examples of Comparatively Matured NGE/IGE Wake Sensors

- Windline
- SODAR
- RASS
- CW Lidar
- Pulsed Lidar

# Pulsed Lidar

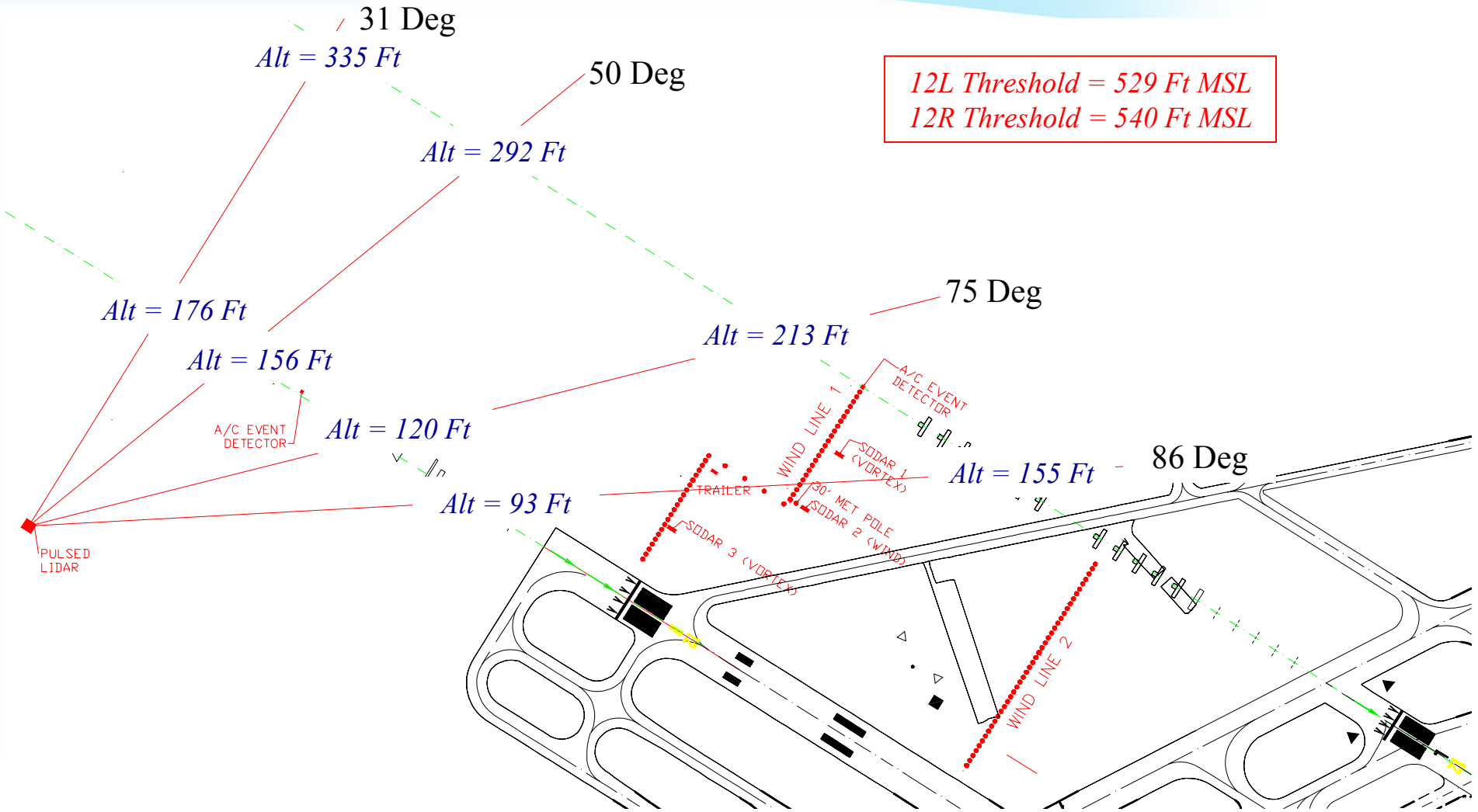
- Use of a Wake Sensor as Part of an Operational System Has Not Yet Been Defined.
- Pulsed Lidar Identified as the "Baseline Technology" in AVOSS Type of Research.
- Data from Offline Processing Have Proven Useful in Recent Years by FAA and NASA (As Well As in European Efforts).
- Pulsed Lidar Has the Overall Advantage in Range and Remote Sensing Capability Over Other Sensors.
- Measures Vortex Trajectory and Strength.
- Wind and Turbulence Could Also be Obtained from Wake Scans.
- Not Perfect, But Overall Maintainability is Higher Relative to Other Wake Sensors and Overall "Field-ability" is Good.
- But Not All Weather Sensor.
- However, Wind Sensing is More "Forgiving" than Wake Sensing (i.e., Can Tolerate Worse Weather).
- This Brief Highlights Some Experience and Statistics of Interest in Operating the WindTracer®.

# STL Pulsed Lidar Data

*Lidar Data Statistics Taken from STL (July 2003 – January 2005)*

# STL NGE/IGE Site

*Glideslope Altitude Relative to Threshold of 12L*

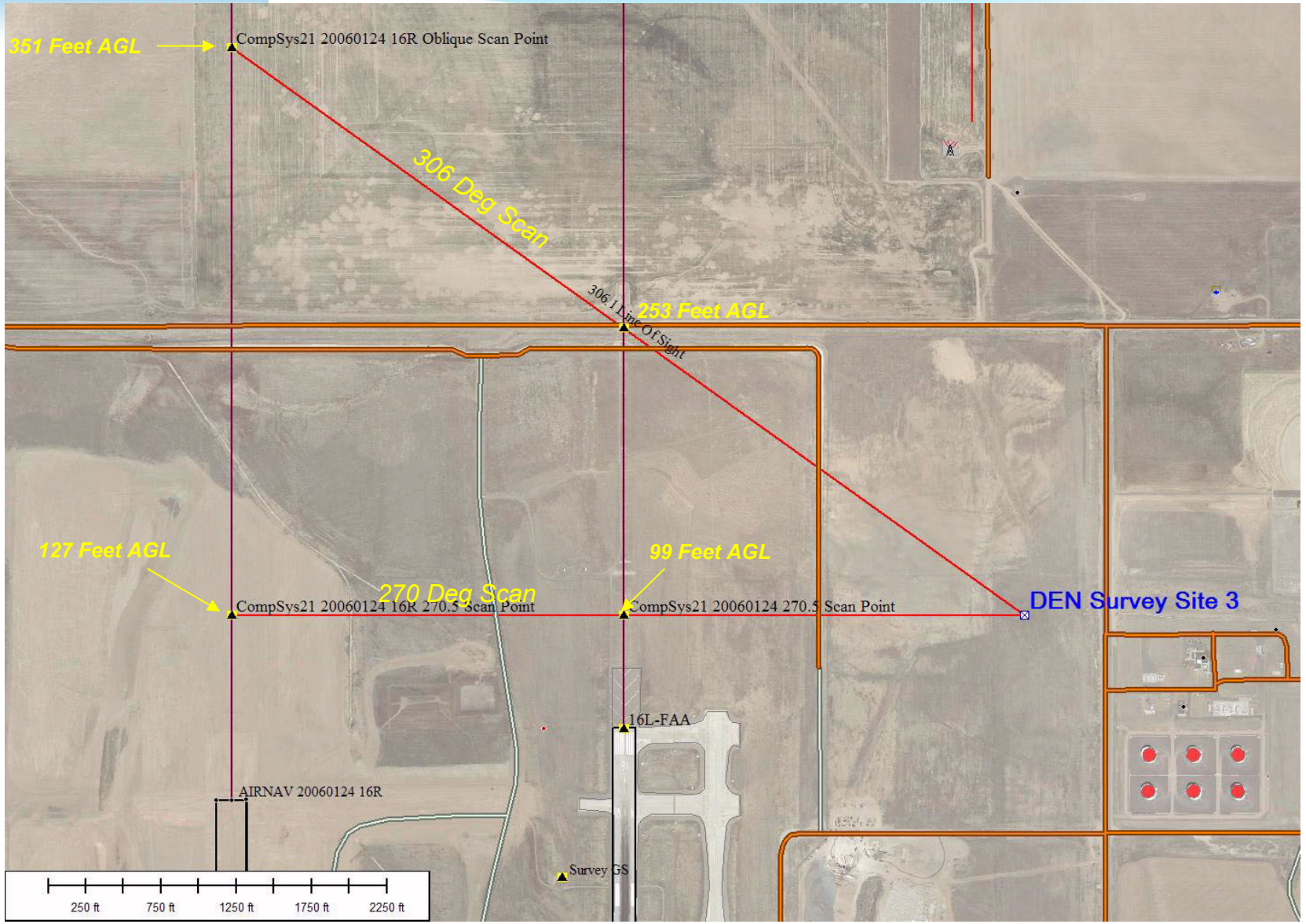



*12L Threshold = 529 Ft MSL*
*12R Threshold = 540 Ft MSL*

# STL NGE/IGE Measurement Site


*Photographer: David Burnham, SCENSI*

# DEN IGE/NGE Site



# DEN NGE/IGE Measurement Site

*Photographer: Keith Barr, LMCT*

# How Well Can Lidars Track Vortices?

# Factors Affecting Vortex Measurement Statistics

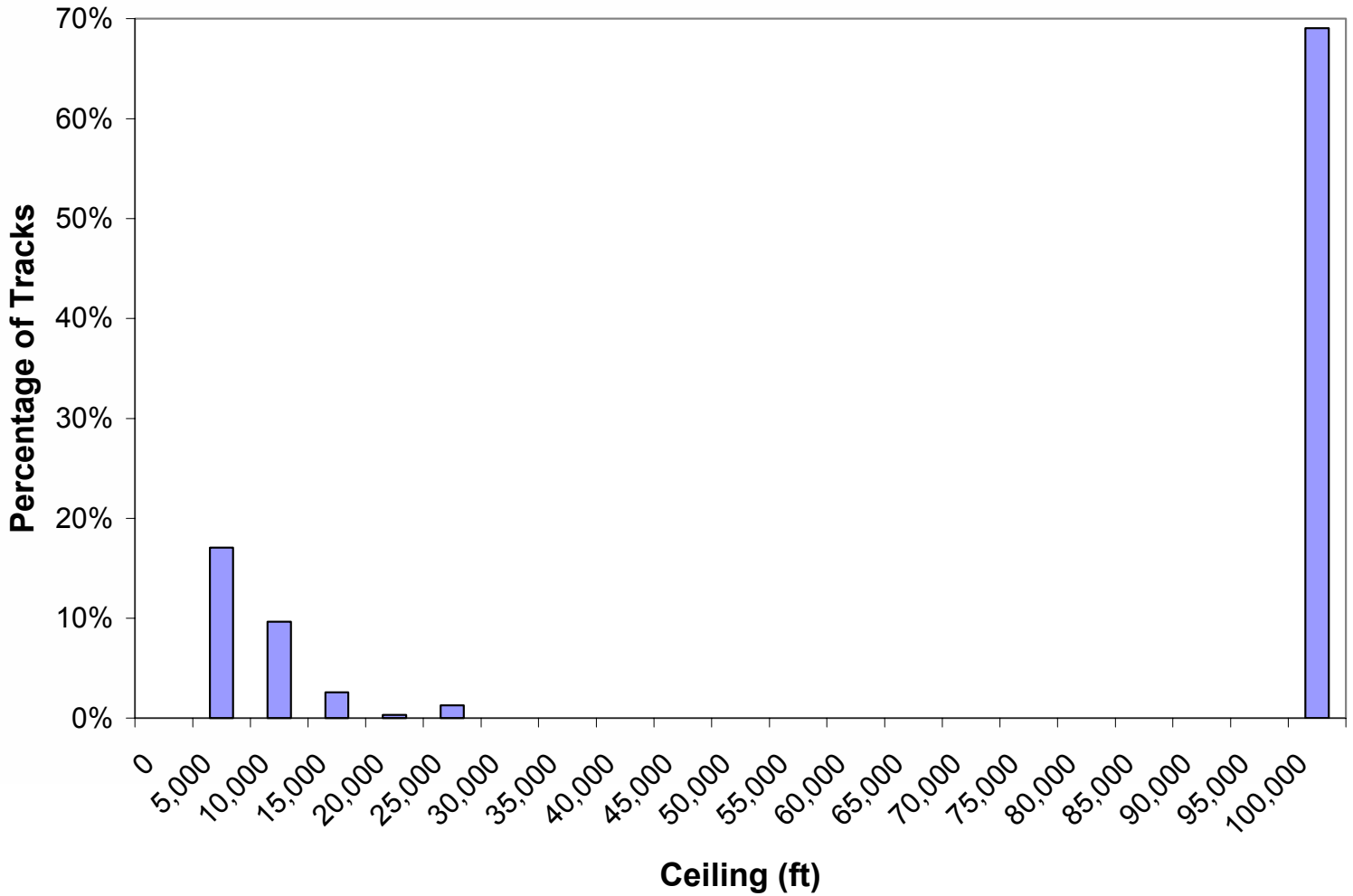
- Weather (Today's Discussion)
- Sensor Health
- Quality of Aircraft Identification Database
- Aerosol Availability
- Data Collection Details
- Processing Parameter Details
- Initialization and Tracking Logic Details

# When All of Planets Lined Up…

- Assuming "*Aircraft of Interest*" Are Those Larger than DC9.
- Confirmed "Good Tracks" Can be As High As 80 – 85 Percent Per Month Amongst "*Aircraft of Interest*" Category in the STL Arrival Database.

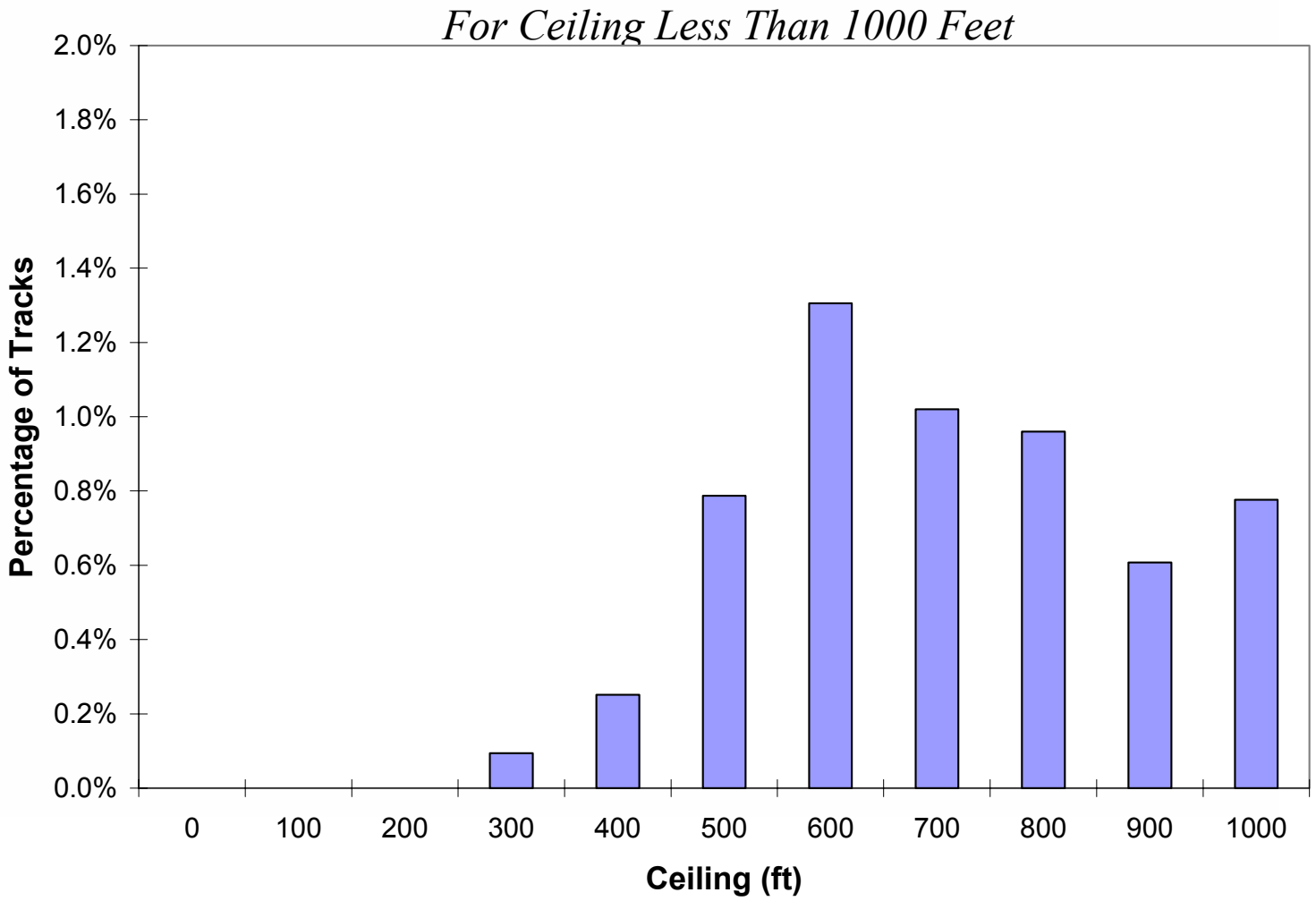
# What Does “Non All-Weather” Really Mean?

# Distribution of Ceiling in the Lidar Tracks



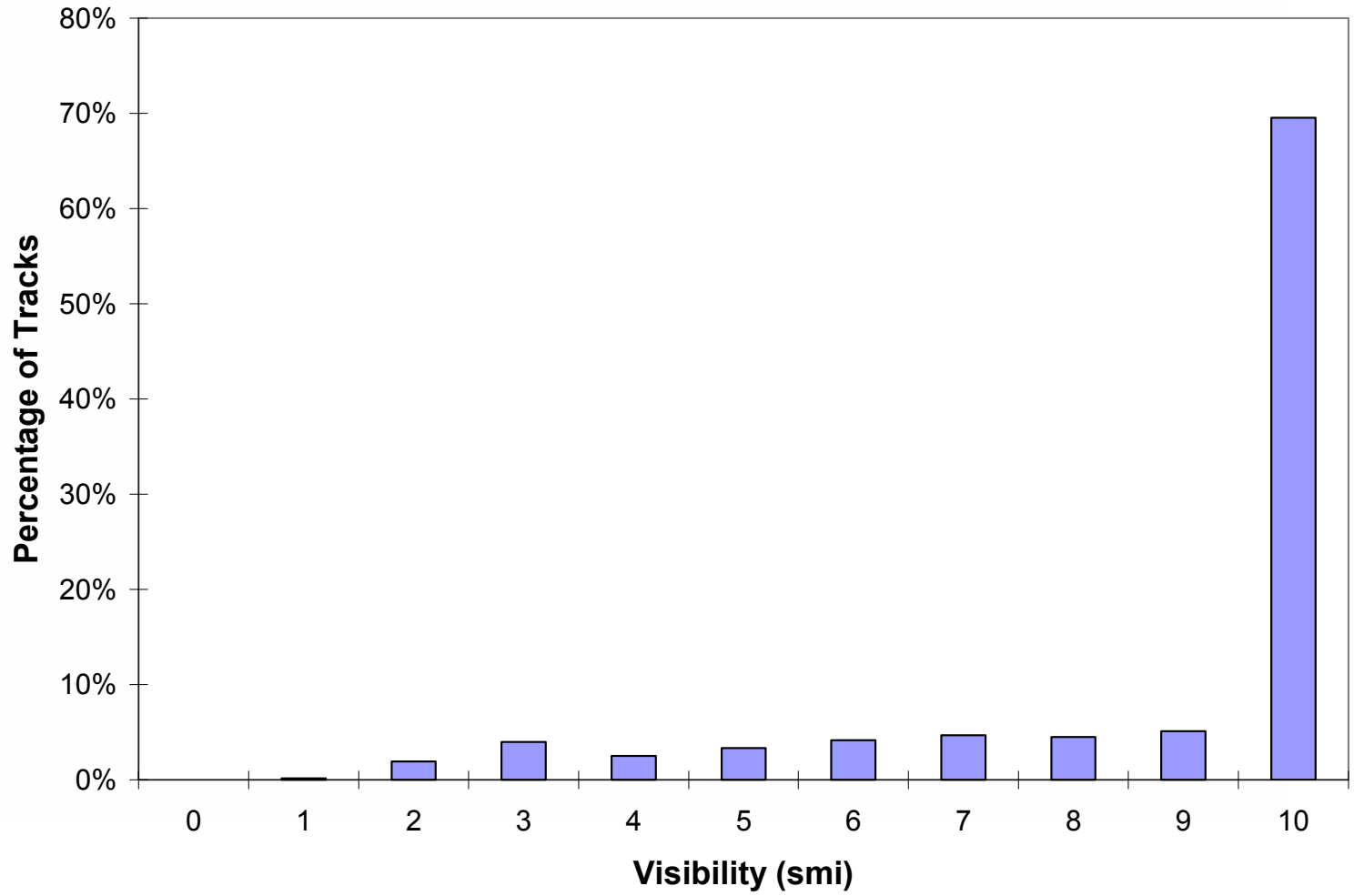

*Based on Lidar Tracks With Corresponding 5-Min ASOS Data (88 Percent of the Tracks Have 5-Min ASOS Data)*

# Distribution of Ceiling in the Lidar Tracks




*Based on Lidar Tracks With Corresponding 5-Min ASOS Data (88 Percent of the Tracks Have 5-Min ASOS Data)*

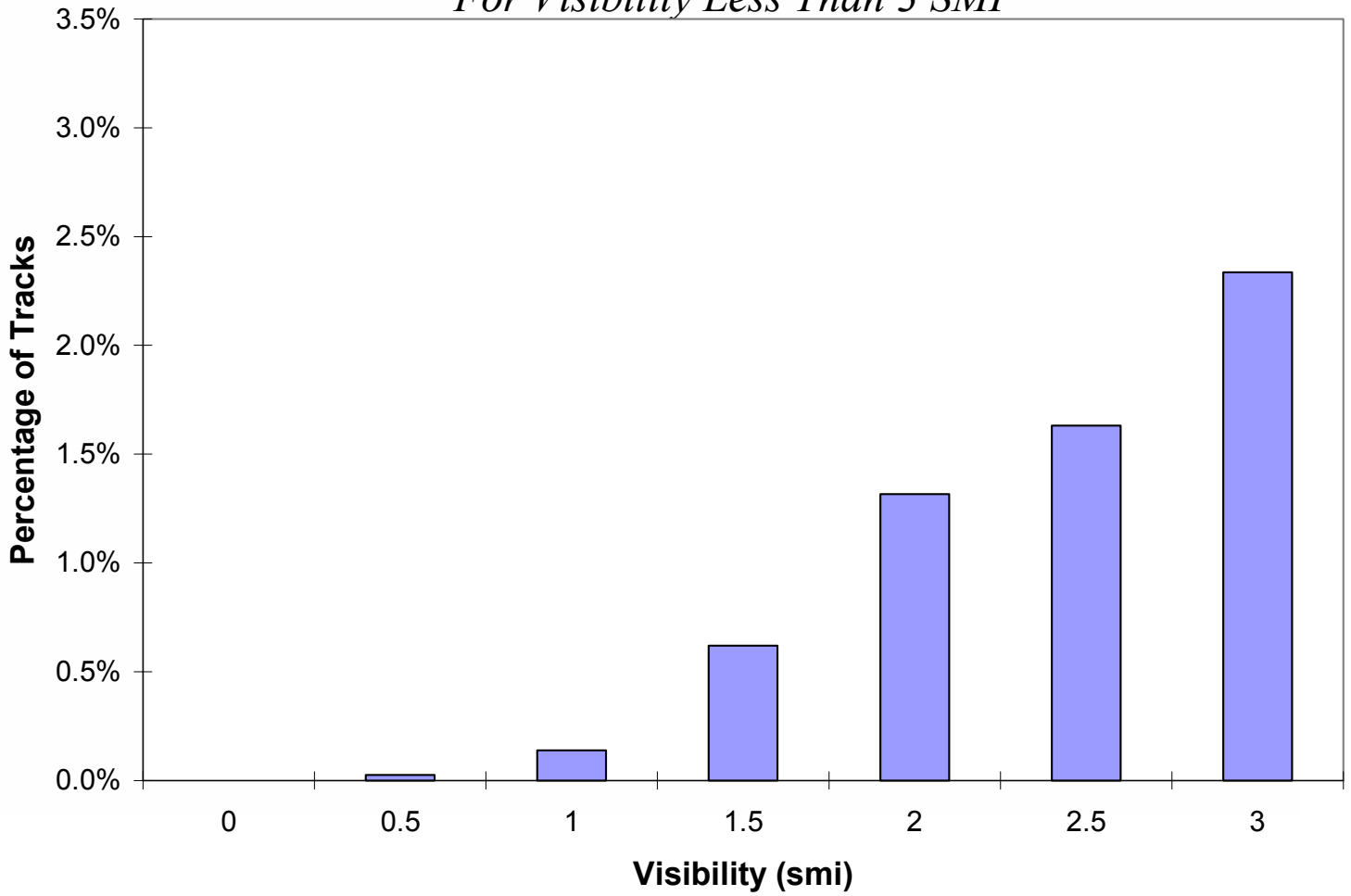
# Distribution of Visibility in the Lidar Tracks




*Based on Lidar Tracks With Corresponding 5-Min ASOS Data (88 Percent of the Tracks Have 5-Min ASOS Data)*

# Distribution of Visibility in the Lidar Tracks

*For Visibility Less Than 3 SMI*



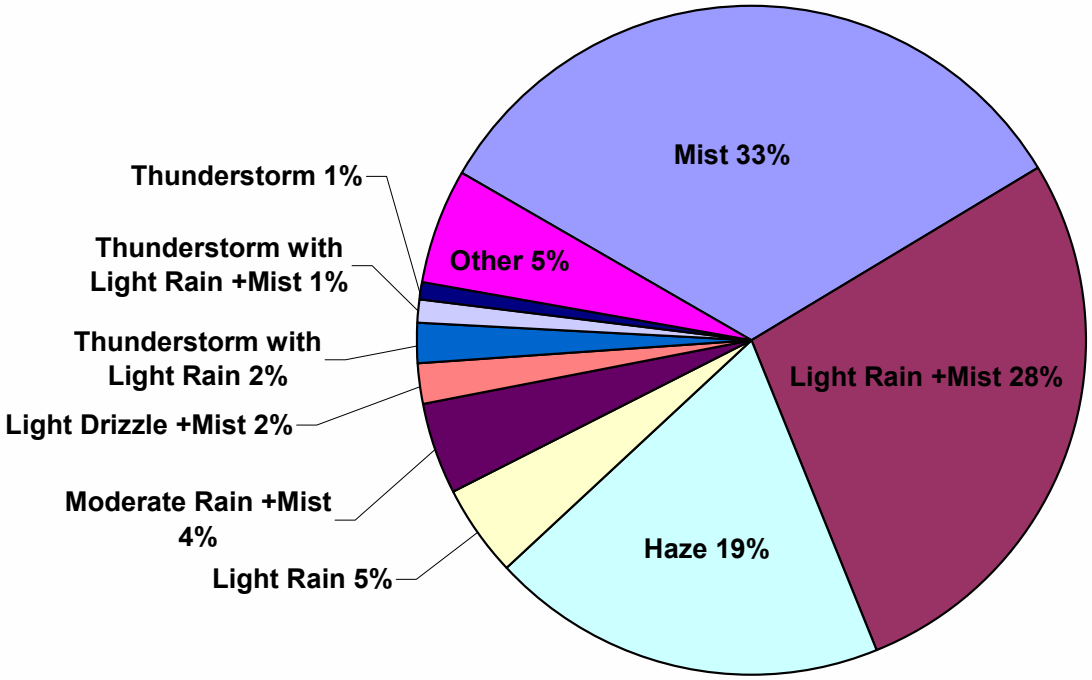

*Based on Lidar Tracks With Corresponding 5-Min ASOS Data (88 Percent of the Tracks Have 5-Min ASOS Data)*

# Precipitation Percentage in the Lidar Tracks

- 20 Percent of the Lidar Tracks Have / Experience Some Kind of Precipitation.
- The Majority Being Mist, Light Misty Rain and Haze.

*Based on Lidar Tracks With Corresponding 5-Min ASOS Data (88 Percent of the Tracks Have 5-Min ASOS Data)*

# Precipitation Breakdown




## *"Other" Breakdown*

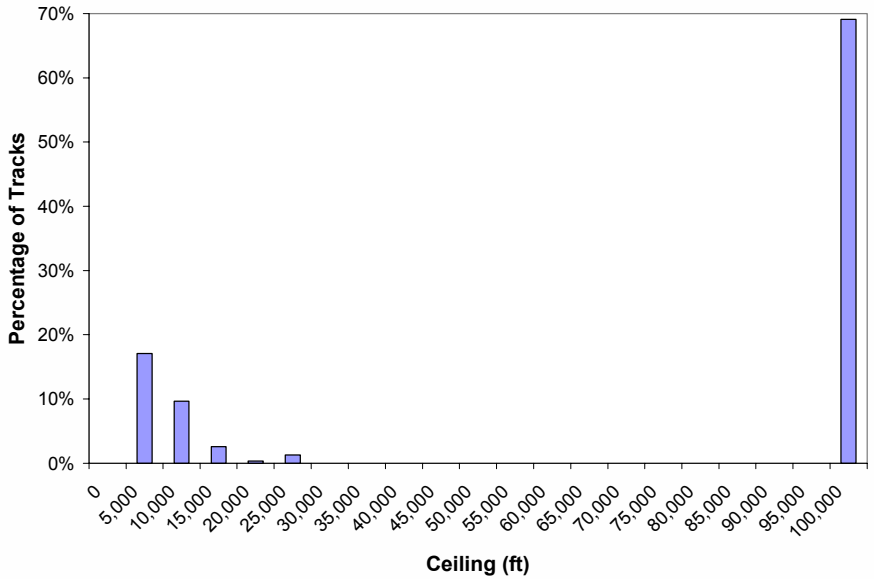
| | |
|---|---|
| Light Snow | 2.1% |
| Light Freezing Drizzle +Mist | 0.7% |
| Heavy Rain +mist | 0.6% |
| Thunderstorm with Rain +Mist | 0.5% |
| Light Snow +Mist | 0.3% |
| Drizzle +Mist | 0.2% |
| Light Drizzle | 0.2% |
| Light Freezing Rain +Mist | 0.2% |
| Moderate Rain | 0.1% |
| Light Rain +Ice Pellets +Mist | 0.1% |
| Light Freezing Drizzle Snow +Mist | 0.1% |
| Heavy Rain +fog | 0.1% |
| Light Rain +Ice Pellets | 0.1% |
| Thunderstorm Heavy Rain +Mist | 0.1% |
| Light Snow +Mist | 0.1% |
| Light Freezing Rain +Ice Pellets | 0.1% |
| Heavy Ice Pellets +Mist | 0.0% |
| Thunderstorm with Rain +Fog | 0.0% |
| Light Freezing Rain | 0.0% |
| Thunderstorm +Mist | 0.0% |
| Thunderstorm Heavy Rain +Fog | 0.0% |
| Ice Pellets | 0.0% |
| Light Ice +Rain | 0.0% |

*Based on Lidar Tracks With Corresponding 5-Min ASOS Data (88 Percent of the Tracks Have 5-Min ASOS Data)*

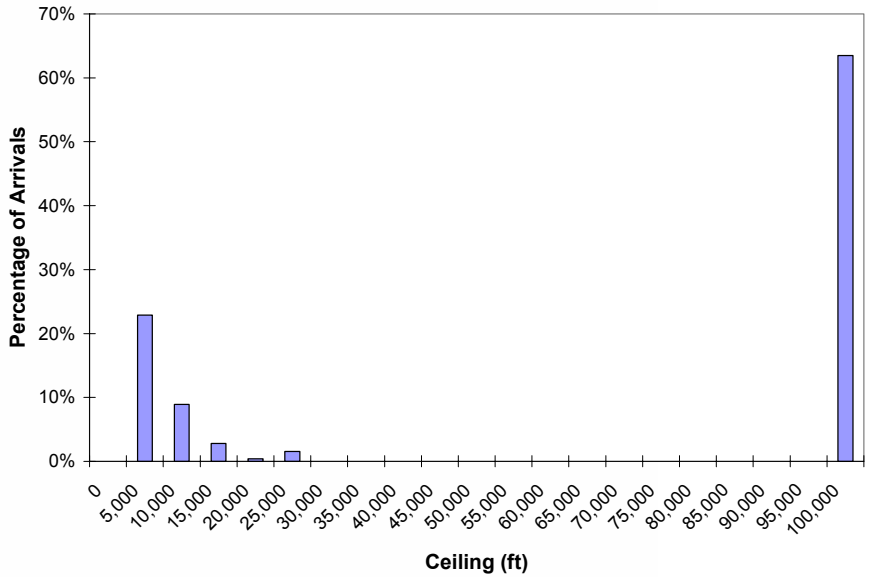
# How Representative Are The Weather Conditions in The Lidar Data?

# Distribution of Ceiling: Lidar Data vs. Operation on 12s

*Lidar Database*




*Operation on 12s During Data Collection*

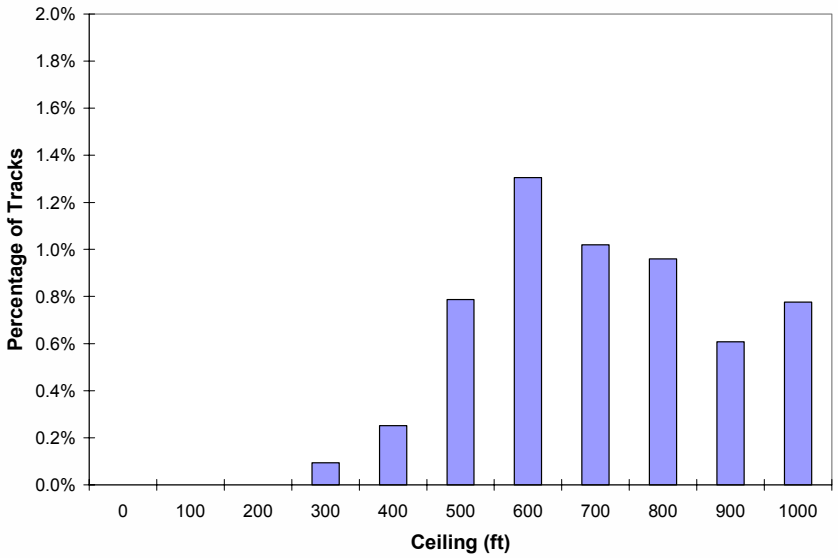



*Availability of 5-Min ASOS Data in Lidar Database vs. Operations on 12s : 88 vs. 91 Percents*

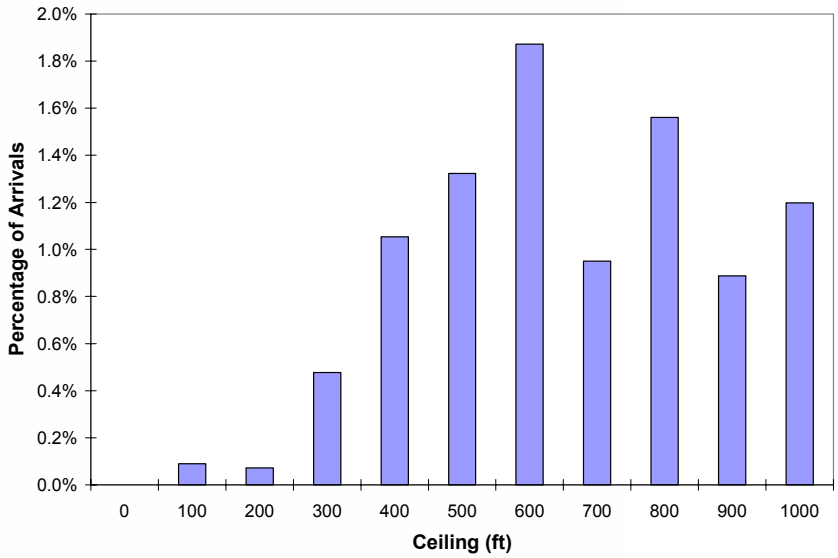
# Distribution of Ceiling: Lidar Data vs. Operation on 12s

*For Ceiling Less Than 1000 Feet*

*Lidar Database*



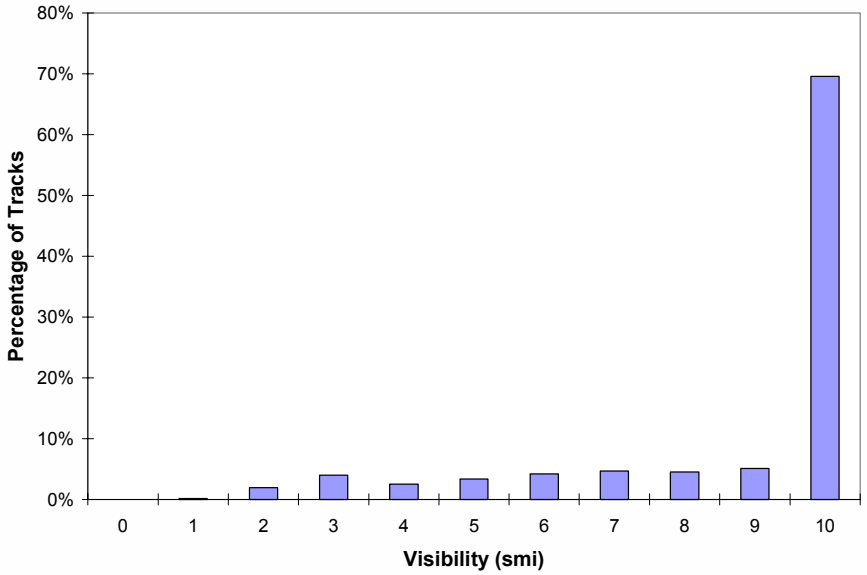

*Operation on 12s During Data Collection*



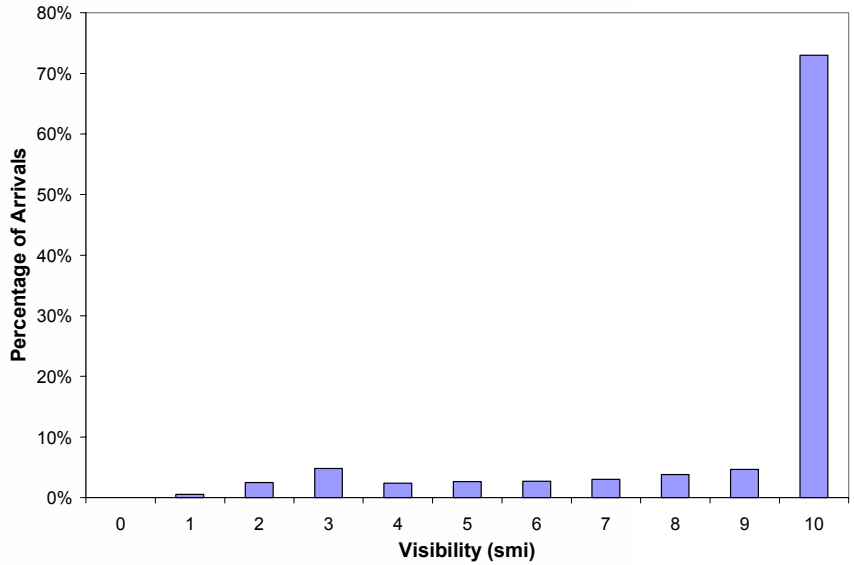

*Availability of 5-Min ASOS Data in Lidar Database vs. Operations on 12s : 88 vs. 91 Percents*

# Distribution of Visibility: Lidar Data vs. Operation on 12s

*Lidar Database*




*Operation on 12s During Data Collection*

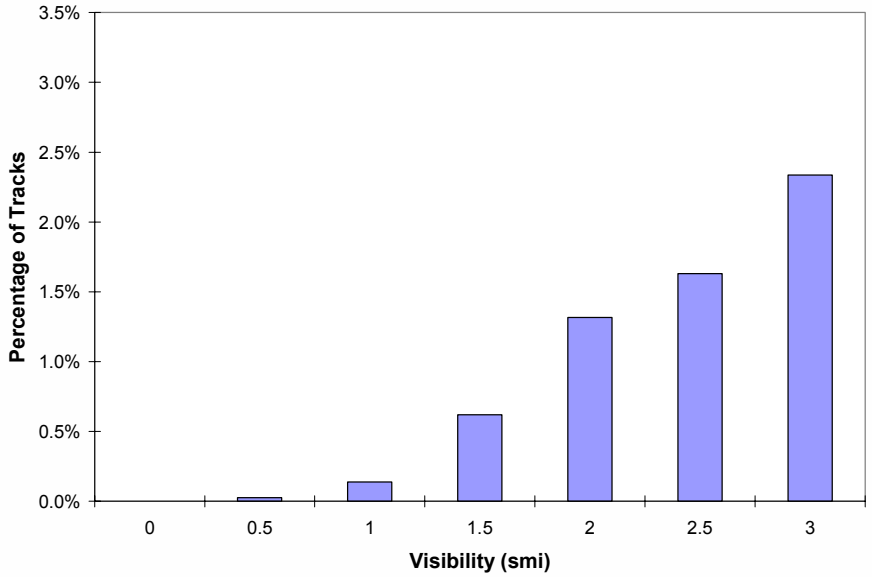



*Availability of 5-Min ASOS Data in Lidar Database vs. Operations on 12s : 88 vs. 91 Percents*

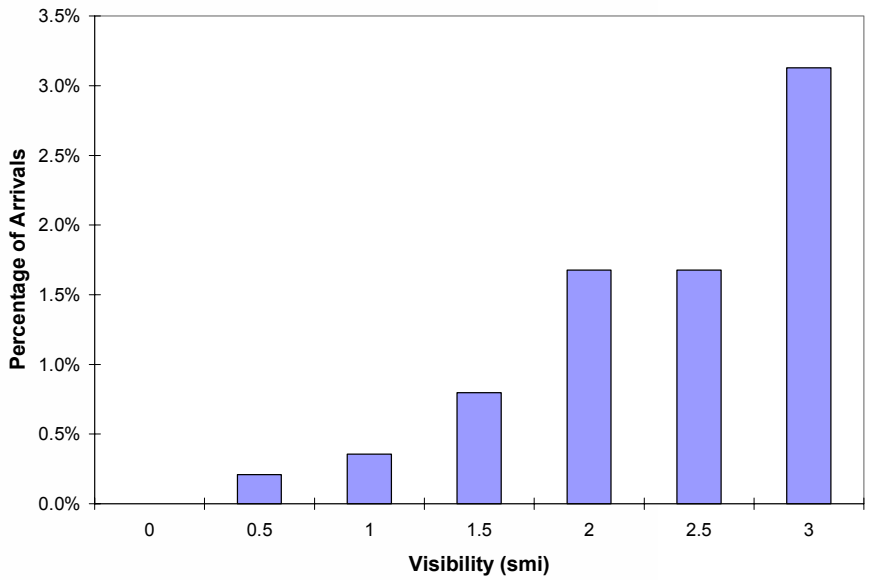
# Distribution of Visibility: Lidar Data vs. Operation on 12s

*For Visibility Less Than 3 SMI*

*Lidar Database*




*Operation on 12s During Data Collection*




*Availability of 5-Min ASOS Data in Lidar Database vs. Operations on 12s : 88 vs. 91 Percents*

# Distribution of Precipitation: Lidar Data vs. Operation on 12s

*Lidar Database*

- 20 Percent of the Lidar Tracks Have / Experience Some Kind of Precipitation.
- The Majority Being Mist, Light Misty Rain and Haze.

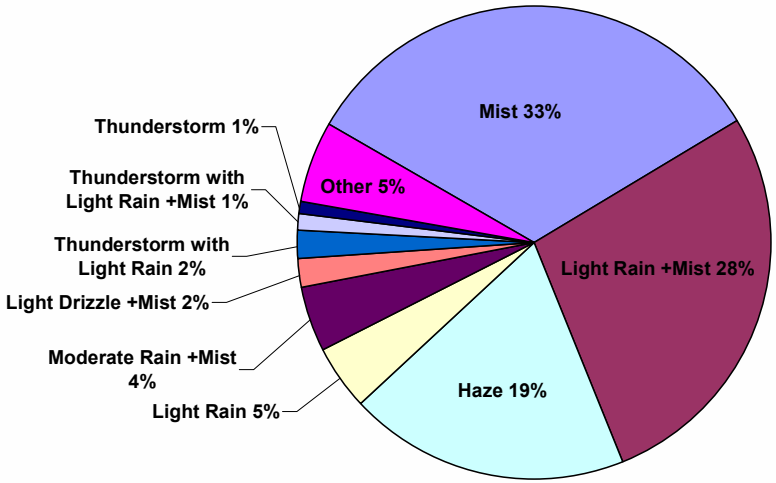
*Operation on 12s During Data Collection*

- 19 Percent of the Arrivals on 12s Have / Experience Some Kind of Precipitation.
- The Majority Being Mist, Light Rain and Mixtures of Both.

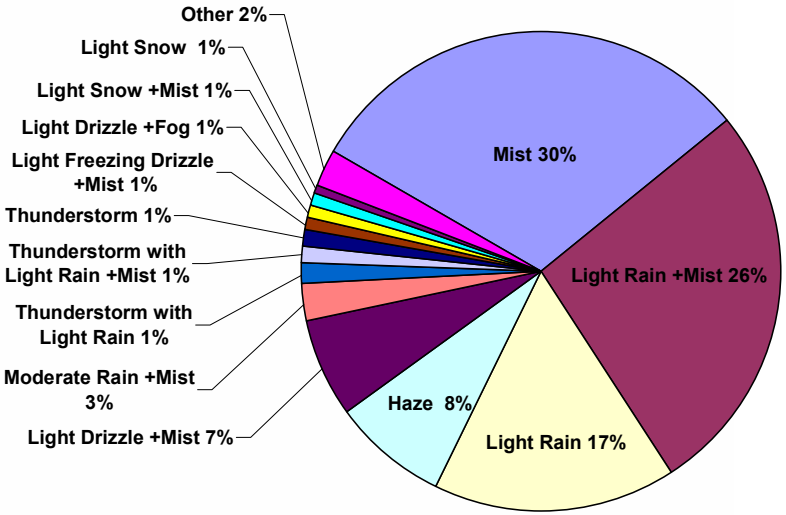
*Availability of 5-Min ASOS Data in Lidar Database vs. Operations on 12s : 88 vs. 91 Percents*

# Precipitation Breakdown

*Lidar Database*




*Operation on 12s During Data Collection*




*Availability of 5-Min ASOS Data in Lidar Database vs. Operations on 12s : 88 vs. 91 Percents*

# How Representative Are The Weather Conditions in The Lidar Data?

*The STL Wake Database Closely Mimics the Distribution of Actual Weather Conditions ; (As Well As Wind – Not Shown Here)*

## Wind Monitoring is More "Forgiving" than Wake Monitoring

- *Wake Measurements Require Higher SNR in Every Scan.*
- *Wind Measurements Can Tolerate Worse Weather By Just Making Short Time Averaging.*

# Group Discussion

- What is the Best Way to Utilize a Sensor Such as the Pulsed Lidar?
- What Other Sensor(s) or Surveillance Equipment Are Needed?