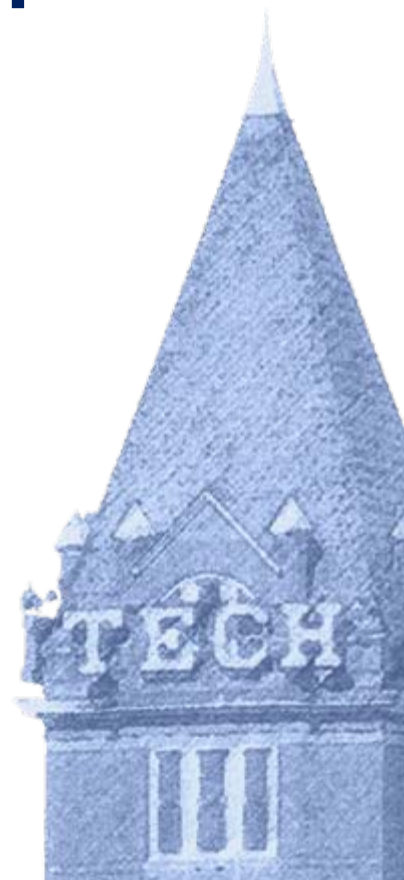


# Radiometric Detection of Aviation Hazards

March 30, 2010

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# Research Team



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*Bill Smith*



*Larry Cornman*

## Funded by the NASA Langley Research Center

# Project Overview

**Goal:** To conduct the enabling research for a forward-looking airborne sensor to detect aviation hazards

## **Phase 1: Feasibility Study**

- > CAT**
- > 2007-2008**

## **Phase 2: Modeling and Simulation / Mountain Wave Detection**

- > CAT**
- > 2007-2008**

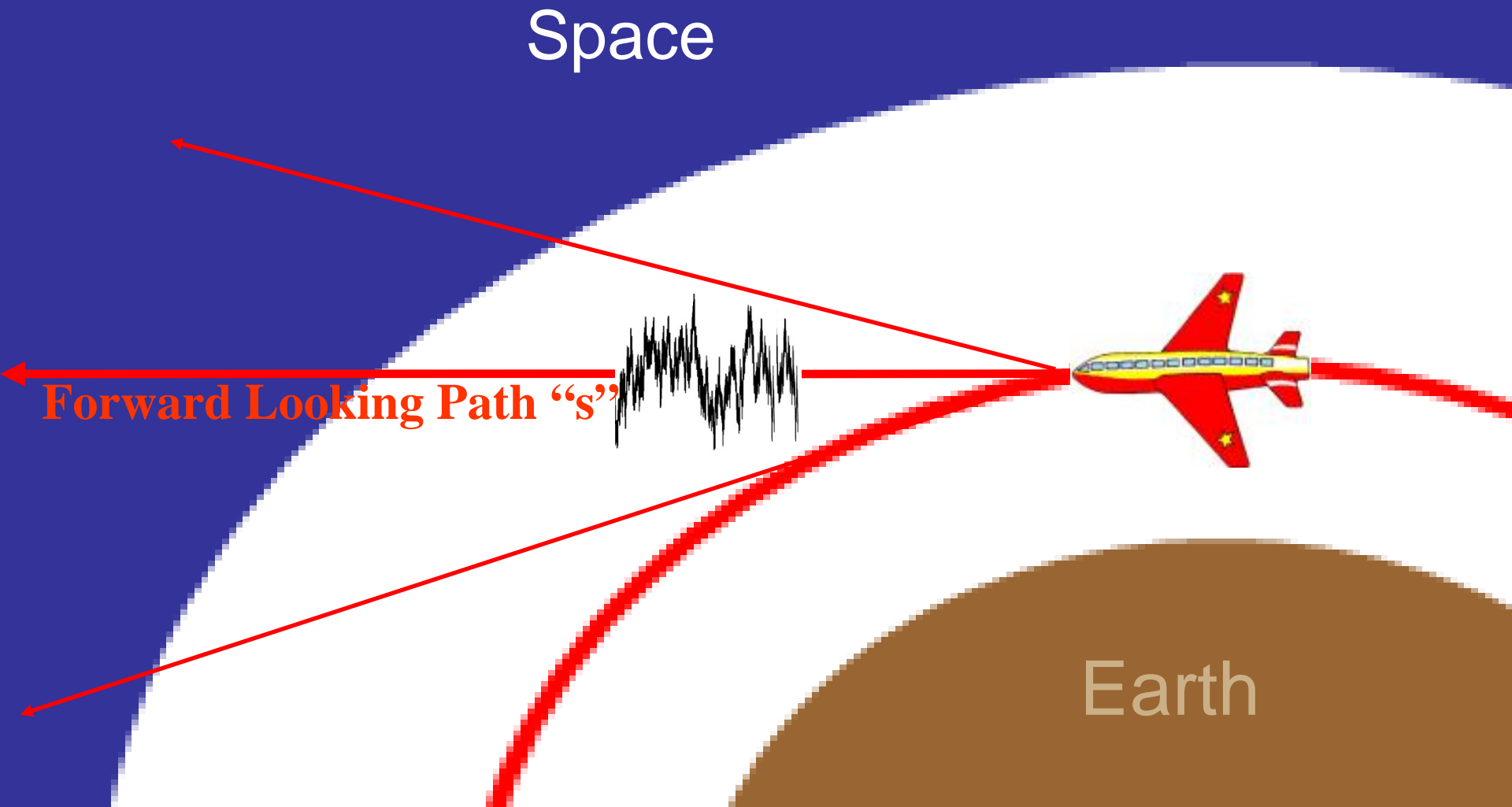
## **Phase 3: Data Collection / Analysis**

- > Wake Turbulence**
- > Started Dec 2009**

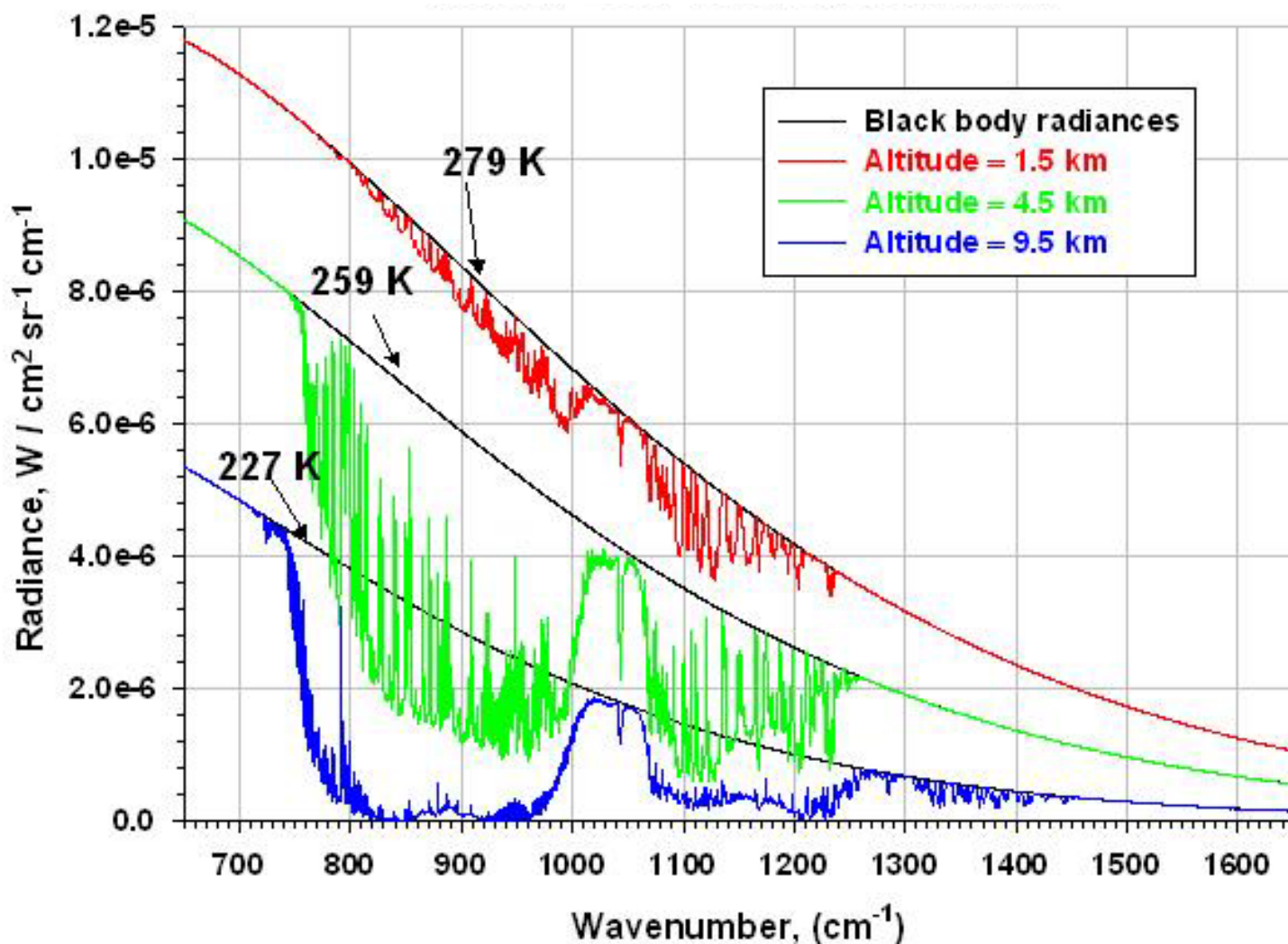
# FLI = Forward Looking Interferometer

- For multiple hazards
- Passive LWIR Radiometer
- Hyperspectral
- Imaging
- Airborne platform

# FLI Radiative Transfer Model



# Horizontal Path Simulation (U.S. Std. Atmosphere)



**Spectral  
signal  
increases with  
increasing  
altitude**

# FLI Potential Applications (Phase 1)

- **Clear Air Turbulence**

- Detection from temperature and moisture variability associated with updrafts and downdrafts; relate to amplitude of CO<sub>2</sub> lines ( $\delta T/\delta S$ ) and H<sub>2</sub>O spectral structure ( $\delta Q/\delta S$ )

- **Wake Turbulence**

- Water vapor and trace gas eddies seen in radiance imagery due to temperature gradients across the vortex and the mixing ratio variability of entrained engine emitted gases.

- **Volcanic Ash**

- Detection from silicate emissivity/reflectivity spectral signatures

- **Icing**

- Detection of super-cooled cloud liquid water from 8-12  $\mu\text{m}$  infrared “window” region cloud brightness temperature and water vs ice absorption/emission radiance spectral features

- **Slant Range Visibility / Improved Runway Vision**

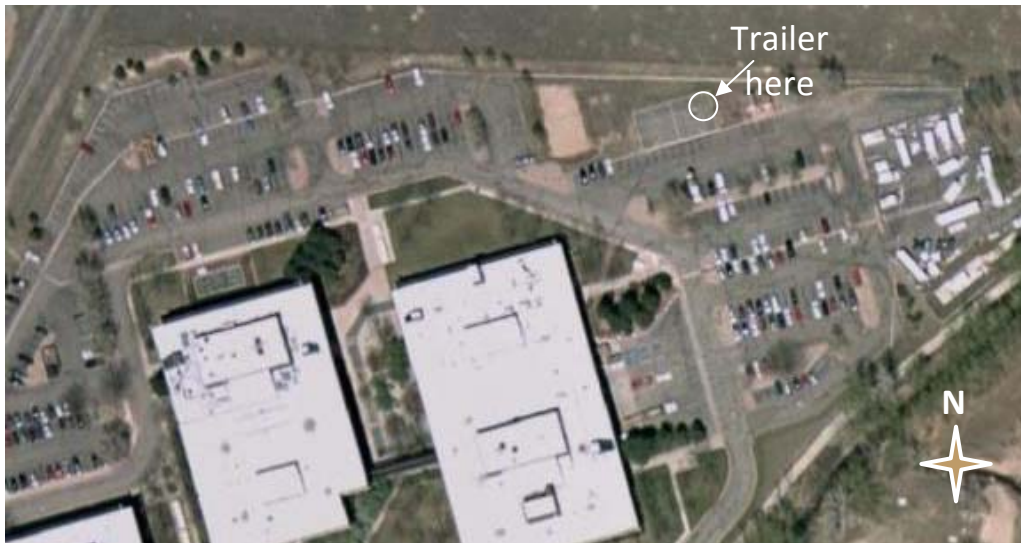
- Infrared 8-12  $\mu\text{m}$  “window” region correction for optical depth between aircraft and runway

- **Wind Shear and Lee Wave Turbulence**

- Local variability of radiance seen in water vapor emission imagery?

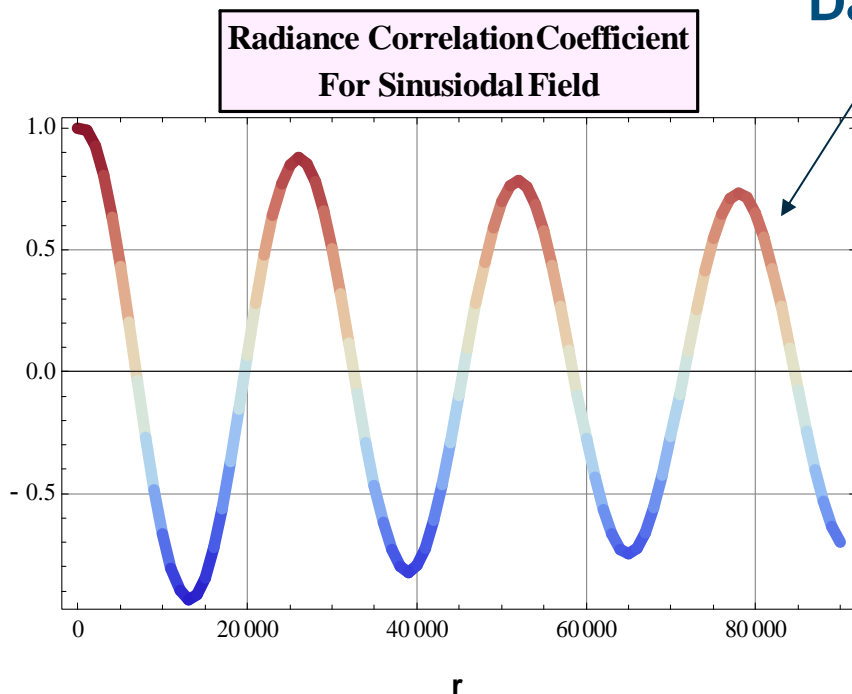
# Boulder, CO Field Test – Phase 2

- Conducted January 2008
- CAT, Mountain Waves
- D & P Spectrometer and aircraft reports, 3-16 microns
- Aircraft data as truth data
- NCAR Foothills Laboratory site
- Trailer window faced 37 degrees south of west

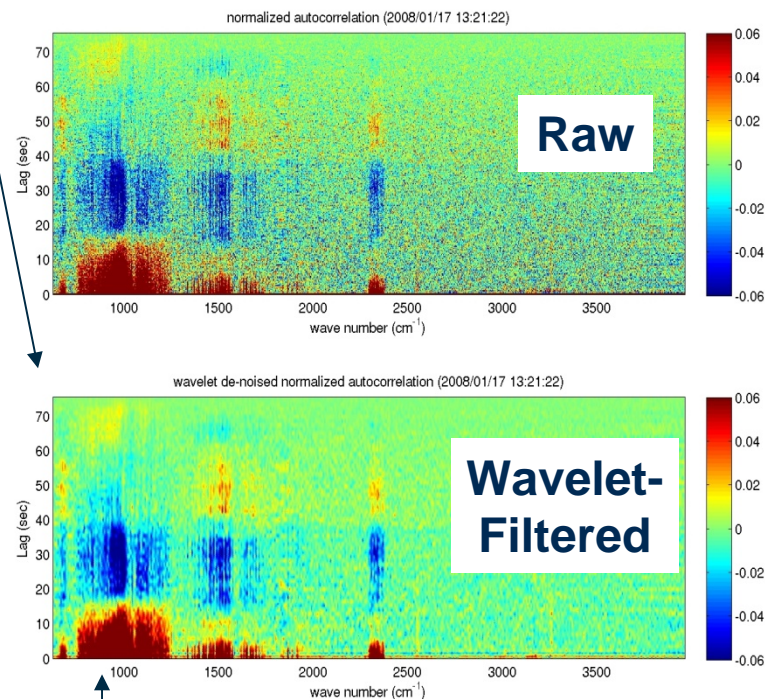


# Comparison of Field Measurements and Theory

Out[354]=



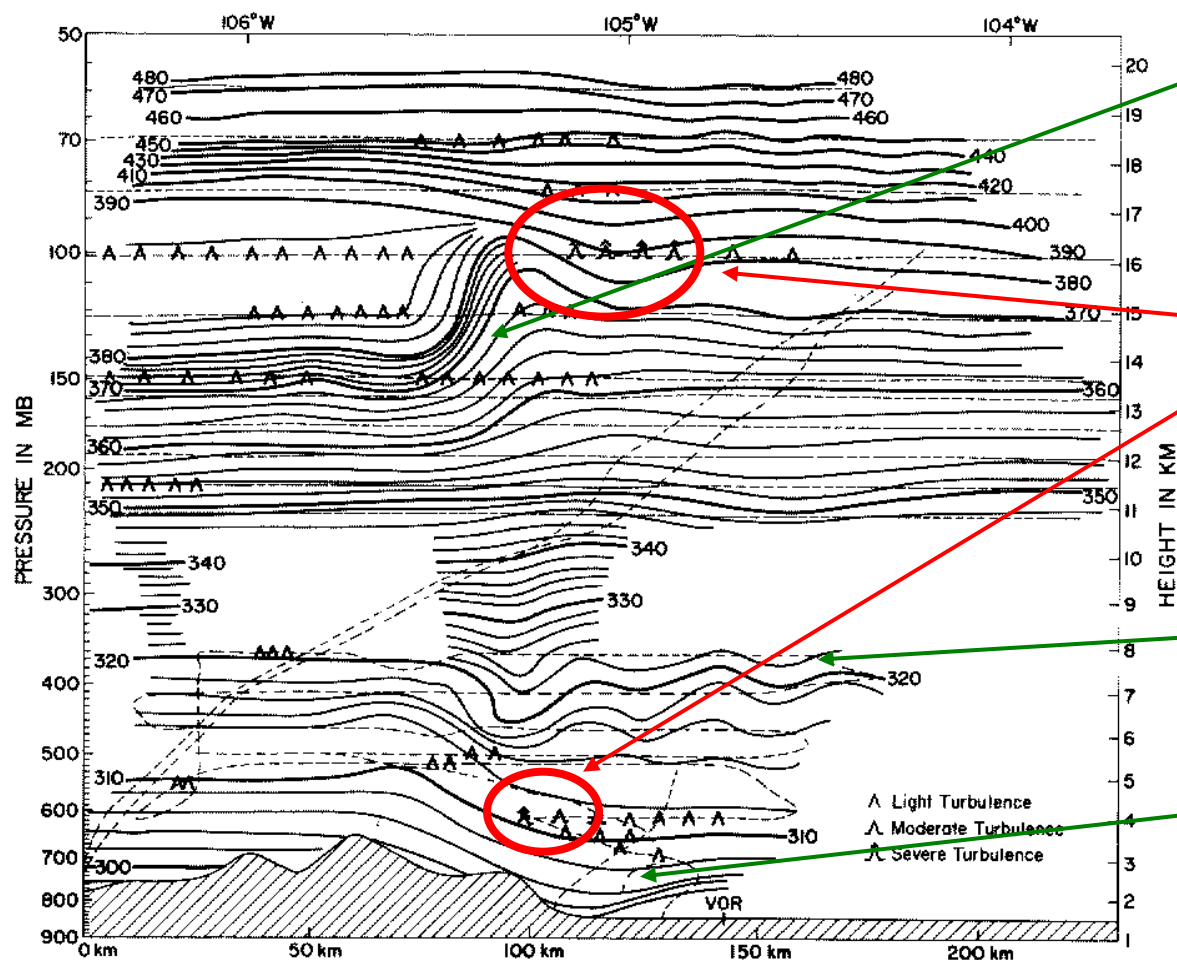
## Damped Wave-like Oscillations



**Theory: Correlation Coefficient  
for Sinusoidal Temperature Field, as a  
Function of Temporal Lag.  
Wavenumber Is  $730 \text{ cm}^{-1}$**

**Calculated Correlation Coefficient  
From Measured Data. Vertical Axes  
is Temporal Lag, Horizontal is  
wavenumber.**

# Gravity wave/downslope windstorm structure



steepening of waves  
leading to eventual  
wave breaking and  
turbulence

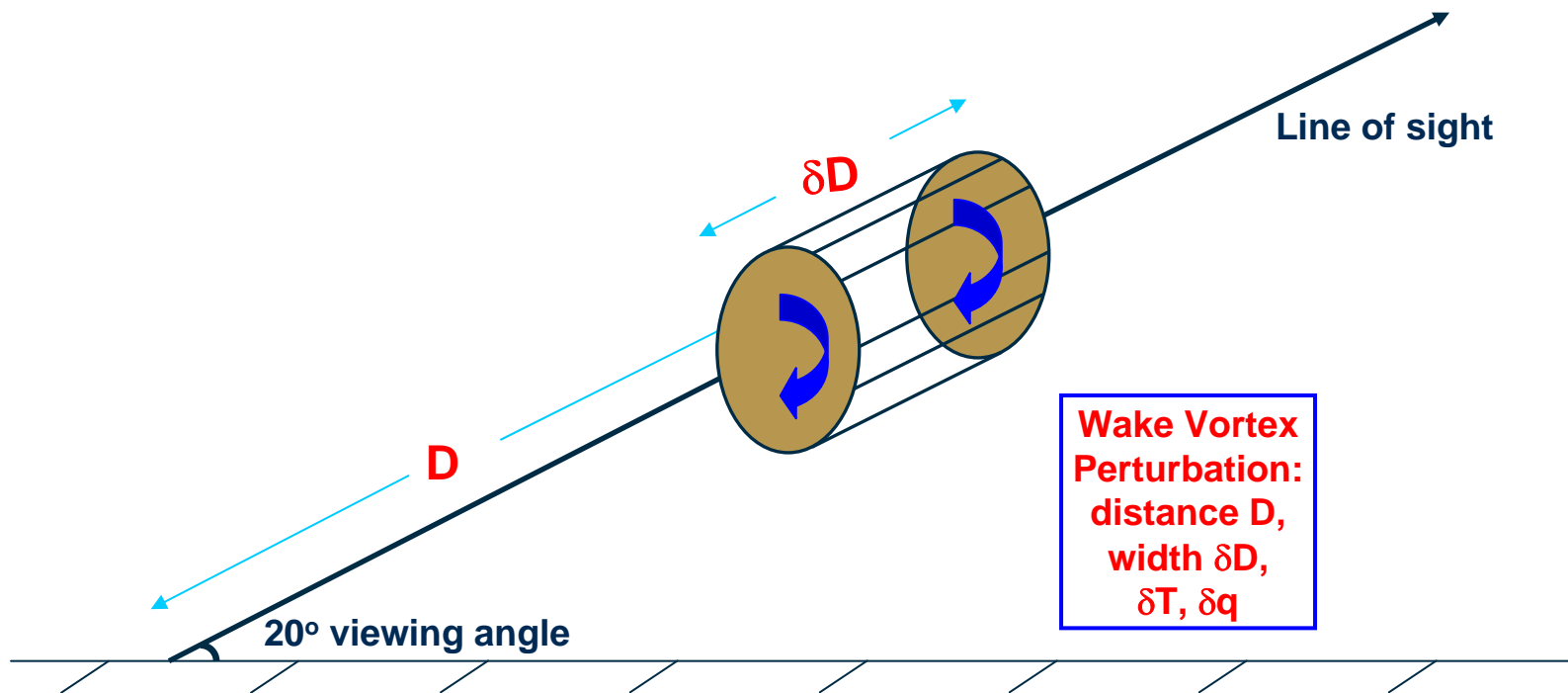
Regions of severe  
turbulence

trapped lee waves

downslope windstorm

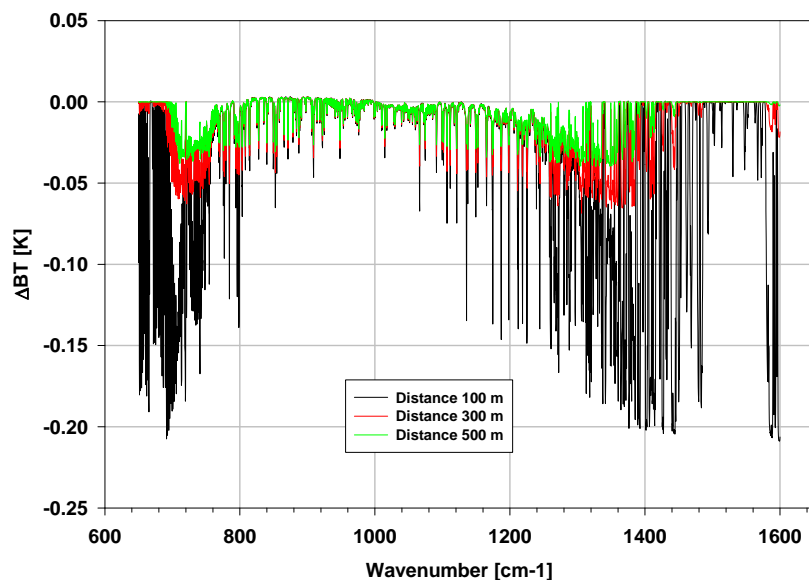
Potential temperature cross-section over the Rocky mountains on 17 February 1970. Solid lines are isentropes (K), dashed lines aircraft or balloon flight trajectories (from Lilly and Kennedy 1973)

# Geometry of Wake Vortex Simulations

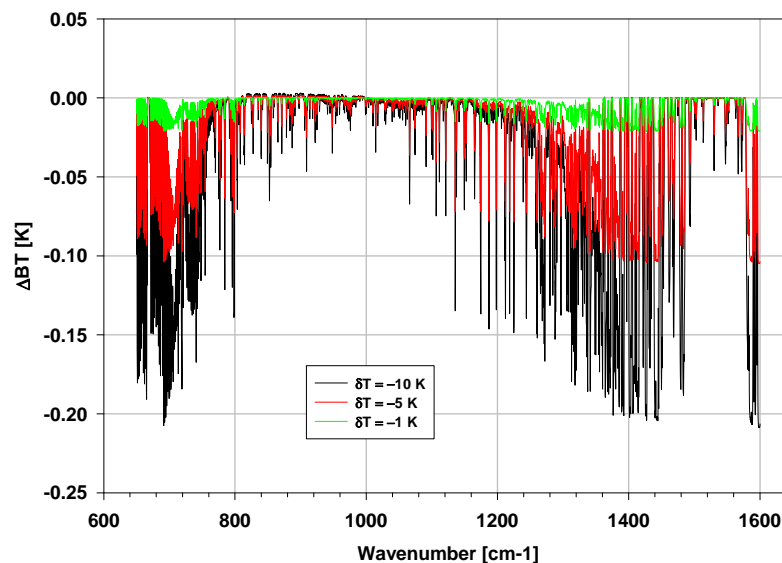


# Expected Wake Vortex Signal in LW/MW 650-1600 cm<sup>-1</sup>

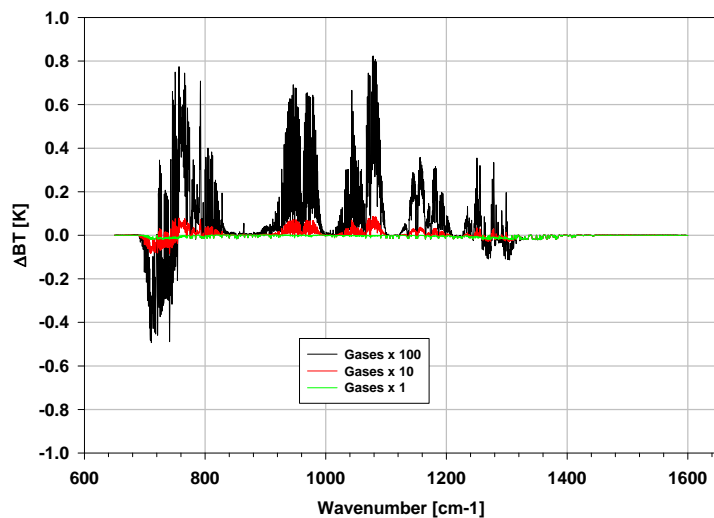
$\Delta BT$ , Constant Vortex  $\delta T = -10K$



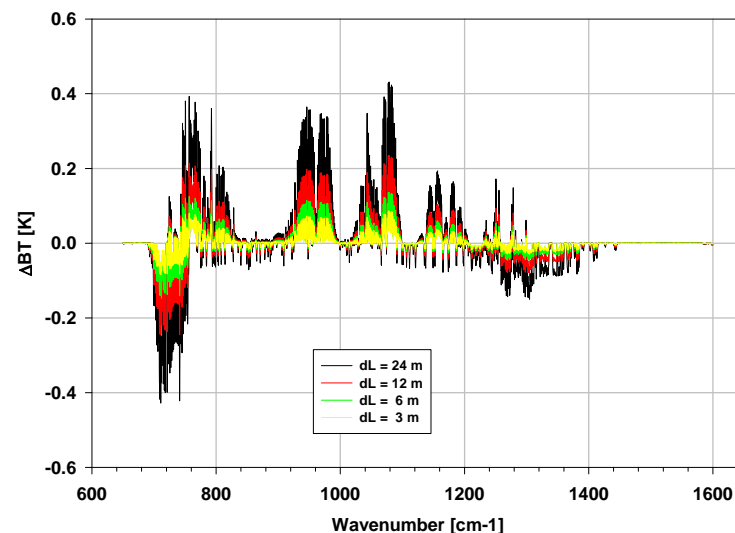
$\Delta BT$ , Constant Distance to Vortex 100 m



$\Delta BT$ : Distance 500 m, Vortex  $\delta T = -5K$ , different gas (CO<sub>2</sub>, N<sub>2</sub>O, CO) factoring



$\Delta BT$ : Distance 500 m, Vortex  $\delta T = -5K$ , gas (CO<sub>2</sub>, N<sub>2</sub>O, CO) factor = 10



# Current Phase 3 Plan – 3 Years

- **Terminal Area Hazards**
- **Hyperspectral measurements**
  - Pavement (wet/dry)
  - Concrete (wet/dry)
  - Grass (wet/dry)
  - Animals
  - Vehicles
  - Fog/smoke/snow/ice as possible
- **ATL Wake Vortex Data Collection**
  - Prep for study with truth data
  - Summer 2010
- **STL (?) Wake Vortex Data Collection**
  - WindTracer Lidar as truth data
  - Summer 2011
- **Algorithm Development**

# Proposed Atlanta Hartsfield-Jackson Field Test



# Objectives

- Trial run for test with truth data
- Optimize data collection settings/procedures
- Image Wake Vortices

# Instrument & Installation

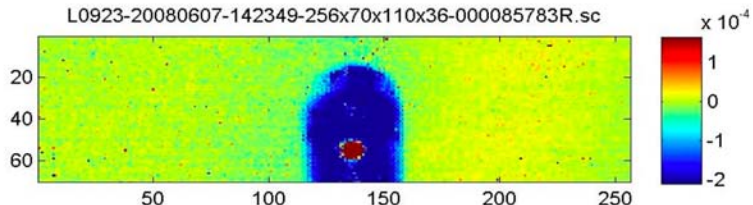


- Telops LWIR HyperCam
- Passive infrared
- Visible camera
- Operates with generator
- Portable, tripod mounted
- Run by computer on folding table

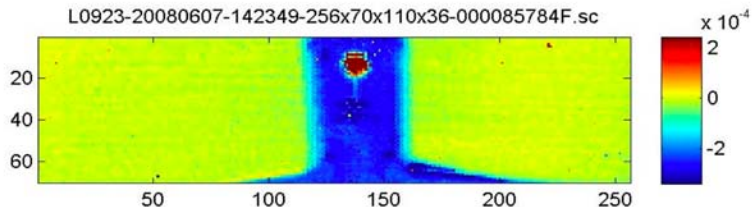
# Example Instrument Data

Background removed, Diff image integrated over all wavelengths

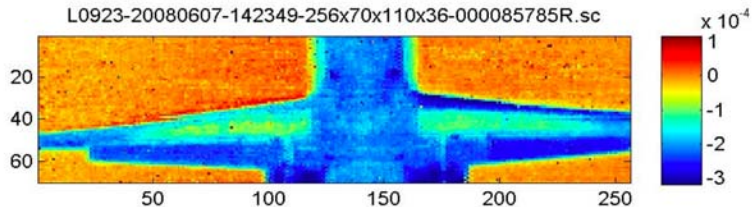
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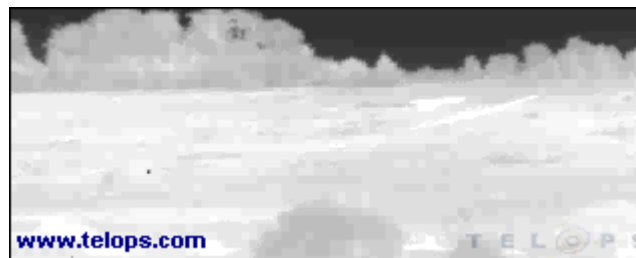
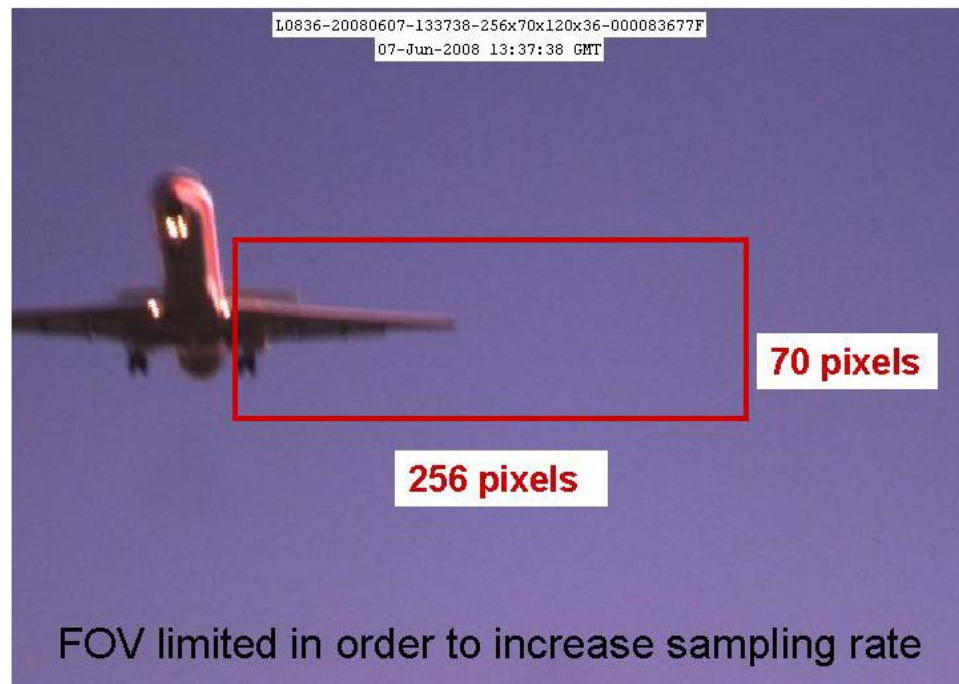
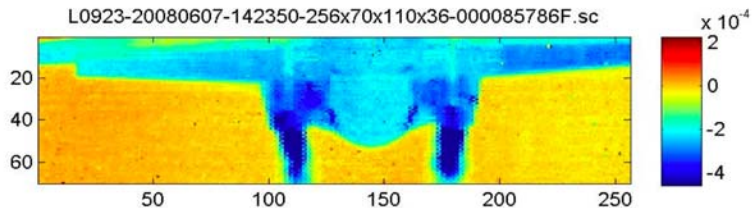
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L0923-20080607-142349-256x70x110x36-000085785R.sc



L0923-20080607-142350-256x70x110x36-000085786F.sc



# Data Collection Procedure

- Set up in line with aircraft (landing or takeoff)
- Image aircraft
- Collect hyperspectral LWIR data and visible images
- Optimize procedure
  - Wavenumber resolution
  - FOV
  - Sampling rate

# ATL Site for Data Collection

Aircraft  
landing  
on 27R



# Viewing Angles



# Duration of ATL WV Tests

- 2-5 days over one month
- Depending on
  - Weather
  - Data collected
  - Issues experienced

# Contact Information

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