THE INTEGRATED ATMOSPHERIC CHARACTERIZATION SYSTEM (IACS)

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Statement of Need

- The development of this LIDAR system addresses shortfall H13 of the DETEC T-SS Update (2007).
- A Directed Energy Test and Evaluation Capability (DETEC) led effort.
- Addresses Joint Service directed energy (DE) weapon system test and evaluation (T&E) infrastructure needs and implements solutions.
- The Tri-Service Study (T-SS) developed, scoped, and prioritized T&E infrastructure shortfalls for DE-based weapon systems including High Energy Laser (HEL).

IACS Top-Level Requirements

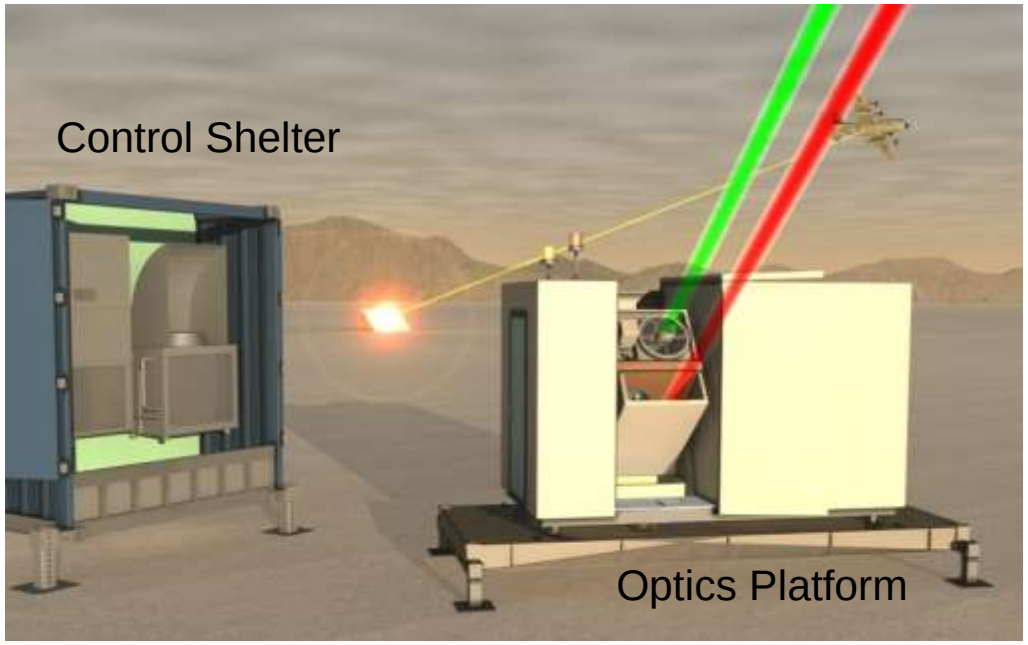
- The sponsor's requirement - a single system, transportable to and suitable for test ranges, that characterizes atmospheric laser beam paths in terms of three parameters:
  - *Aerosols,* which absorb and scatter the laser beam
  - *Turbulence*, which causes beam wander and spreading
  - *Water vapor*, which can absorb beam power
- All of these effects reduce "power in the bucket"
- Two of these effects are wavelength dependent

Project Phases and Schedule

- The IACS project was conducted by the Georgia Tech Research Institute (GTRI) in four phases that required a performance period of seven years.

	Description	Start	End
Phase 1	System Requirements	6 June 2008	5 October 2008
Phase 2	Design (and risk reduction)	6 October 2008	25 June 2010
Phase 3	Build Subsystems	26 Jun 2010	31 January 2014
Phase 4	Integrate and Test	1 February 2014	31 May 2015

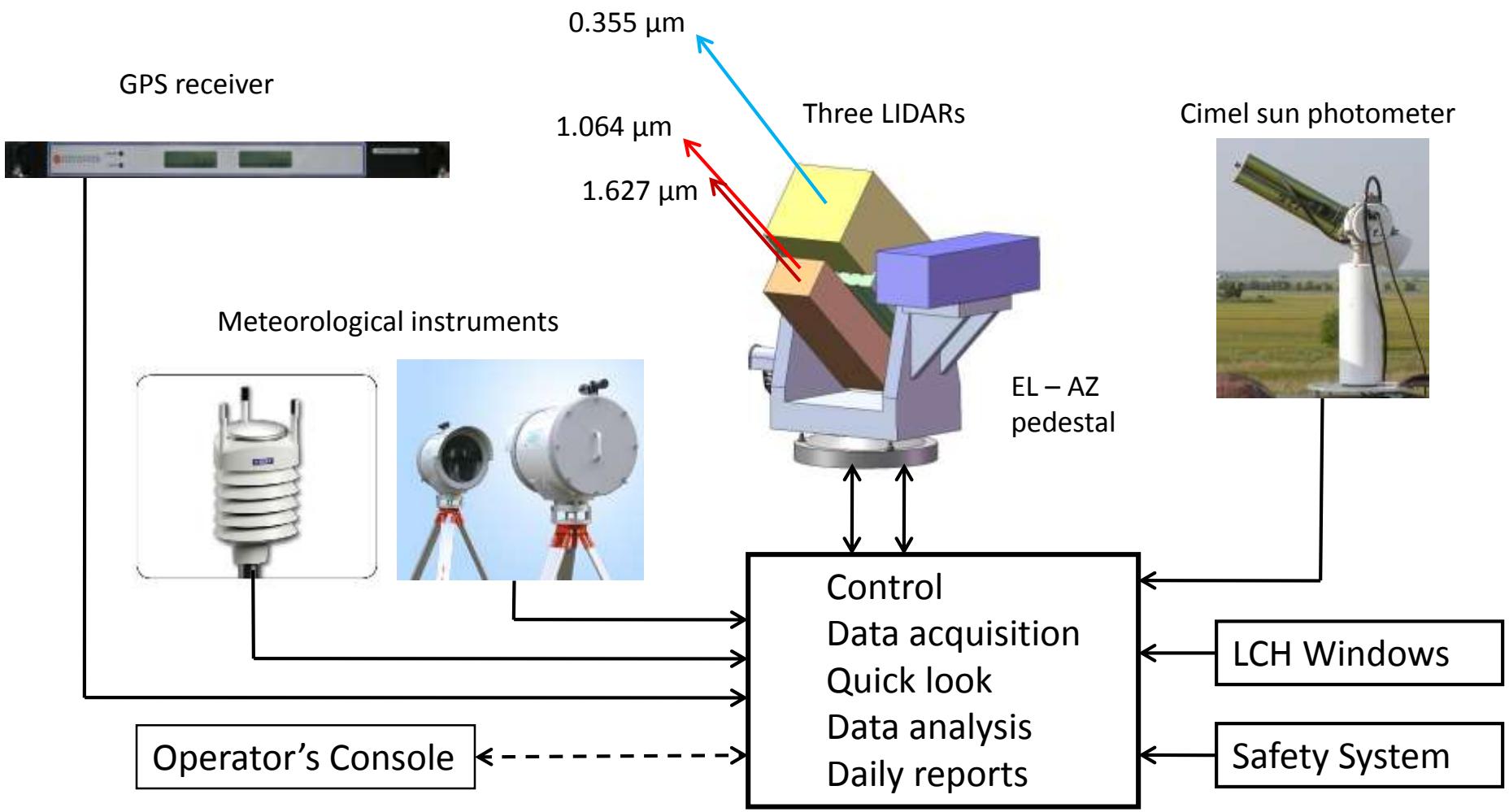
HEL Test Support



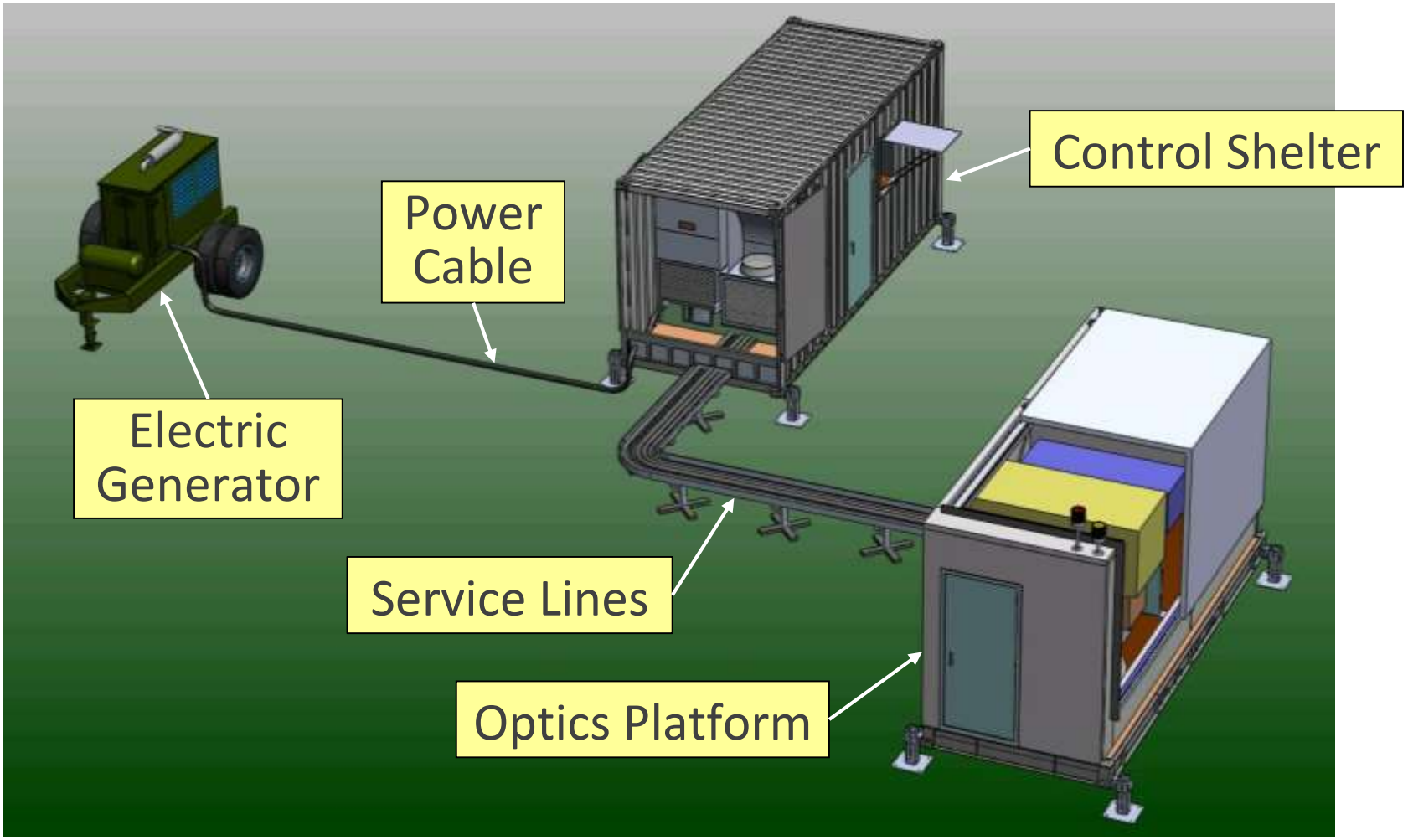
Subsystem	Wavelength
Aerosol Transmission Measurement (ATM)	0.355 μm Tx/Rx 1.064 μm Tx/Rx 1.627 μm Tx/Rx
Optical Turbulence Profiler (OTP)	0.355 μm Tx/Rx
Water Vapor Profiler (WVP)	0.355 μm Tx 0.386 μm Rx 0.408 μm Rx

- The three IACS laser radars (LIDARs) characterize slant paths to give profiles of C_n^2, water vapor number density, and extinction due to aerosols.
- Housed in shipping containers for transport to HEL system test sites.
- ***IACS is the first LIDAR system to provide all of these measurements at once.***

What is IACS?


0.355 µm
1.064 µm
1.627 µm
GPS receiver
Three LIDARs
Cimel sun photometer
Meteorological instruments
EL – AZ
pedestal
Control
Data acquisition
Quick look
Data analysis
Daily reports
LCH Windows
Safety System
Operator's Console

IACS Configuration

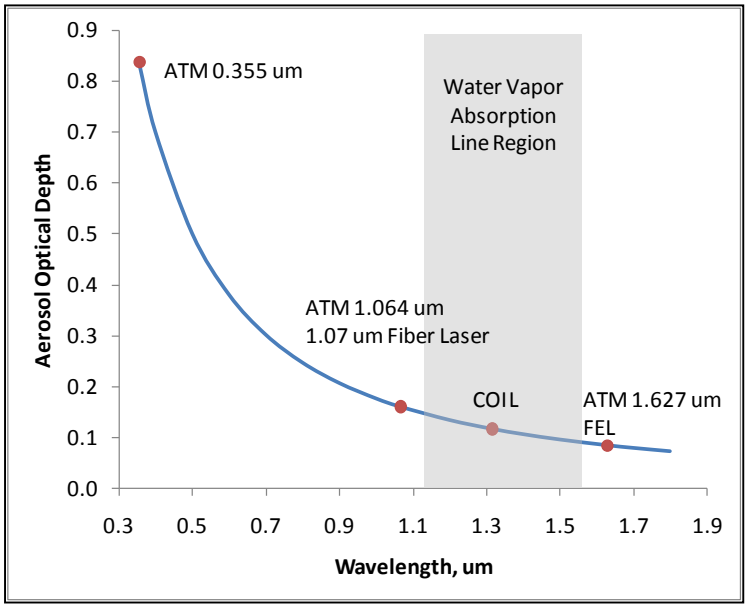


IACS Today

Finding Path Transmittance

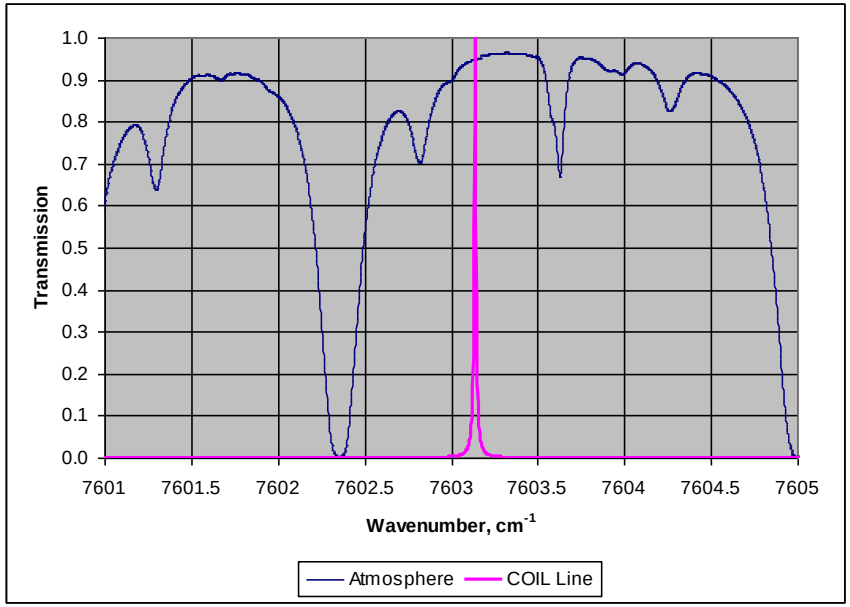
Part 1:

- Measure or interpolate aerosol and molecular extinction (σ_{aer} and σ_{mol}) along path using ATM system.



Part 2:

- Measure water vapor along path using WVP system
- Calculate water vapor extinction coefficient σ_{H2O} by using HITRAN



Part 3:

- Calculate path optical depth τ_{path} and path transmission T_{path}.

$$\tau_{path} = \int_0^R \left[\sigma_{mol}(r) + \sigma_{aer}(r) + \sigma_{H_2O}(r)\right] dr$$

$$T_{path} = \exp(-\tau_{path})$$

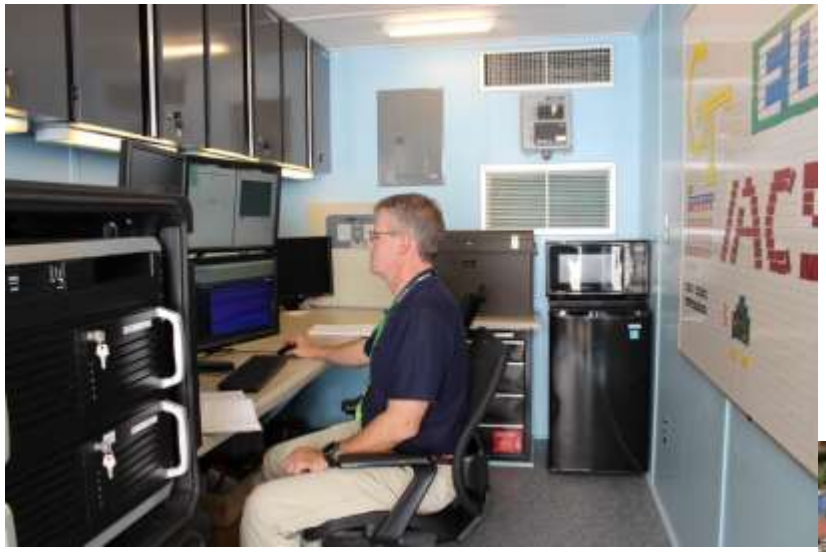
Optics Platform Shelter

- The three LIDARs are housed in the Optics Platform Shelter.
- They are co-aligned on a common computer-controlled mount.
- WVP and OTP are on top; ATM is underneath.

Control Shelter

The Control Shelter houses personnel, the operator's station, the safety system, and the HVAC system.

Control Shelter – Interior & HVAC



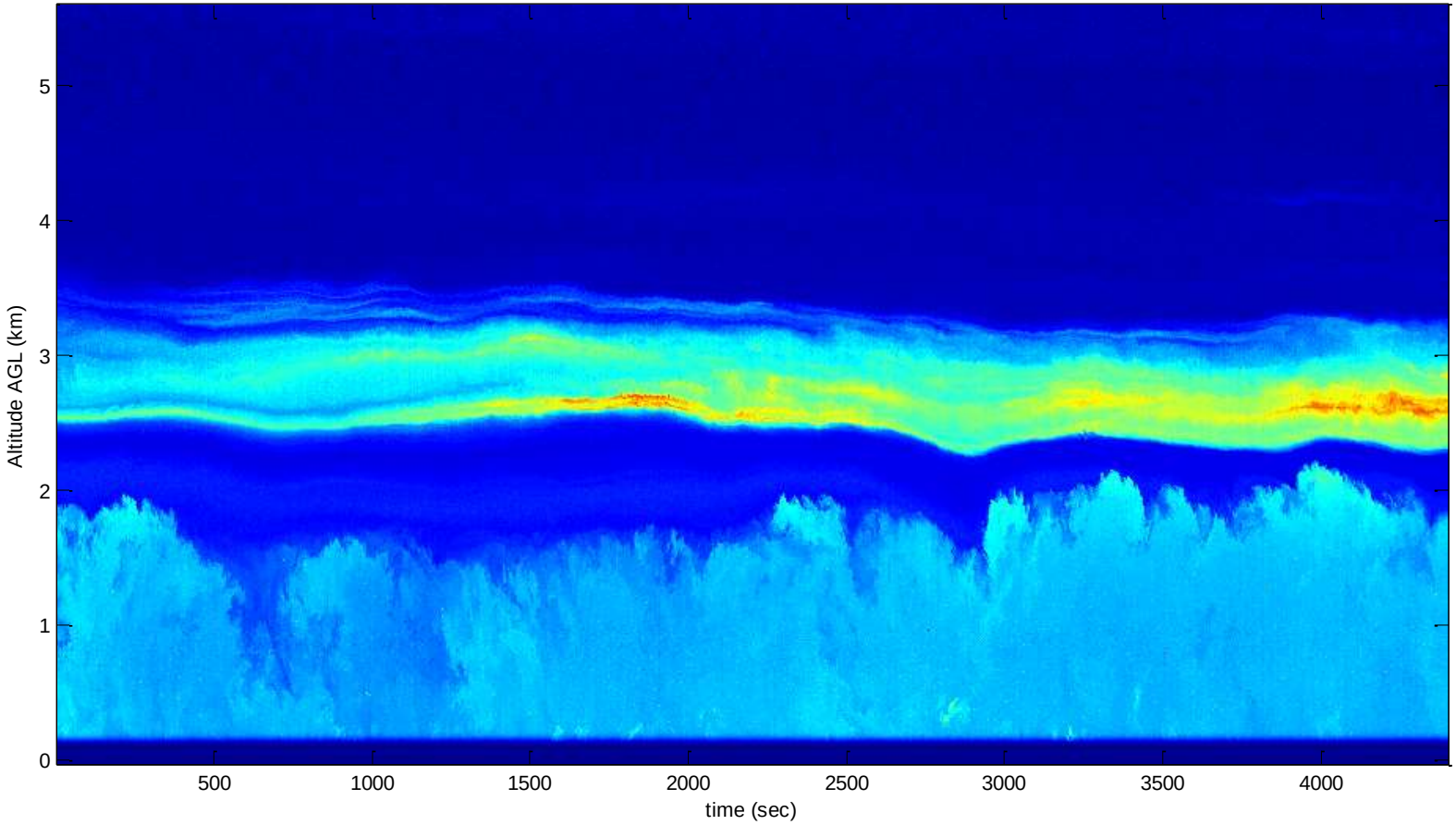
The HVAC system provides chilled water and dry air to the Optics Platform Shelter.

The interior provides storage and a controlled environment for operators.

Aerosol Transmission Measurement (ATM) LIDAR specs

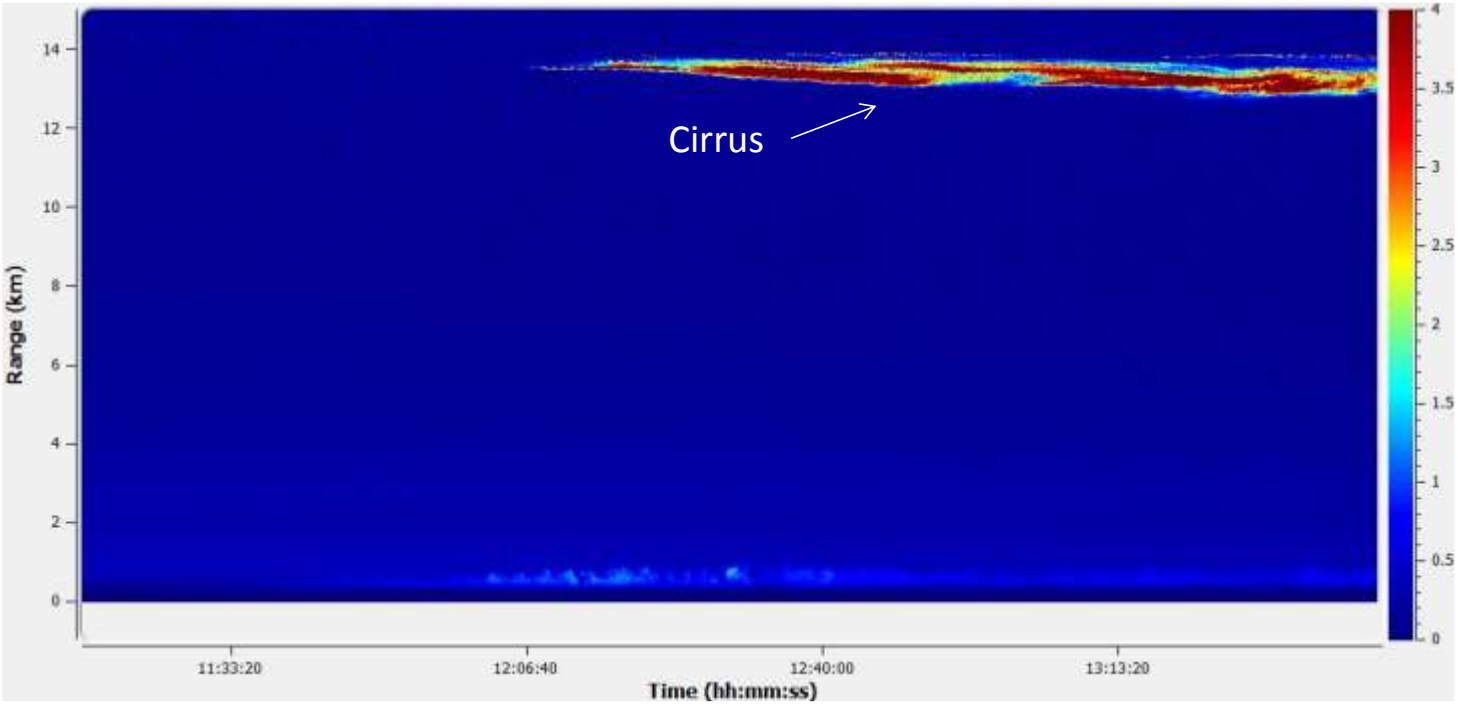
- **Pulse Energies**
  - 180 mJ at 1.064 μm (Nd:YAG)
  - 90 mJ at 1.627 μm (OPO)
  - 300 mJ at 0.355 μm (Nd:YAG)
- **PRF**
  - 10 Hz at 1.064 μm & 1.627 μm
  - 50 Hz at 0.355 μm
- **Receiver Apertures**
  - 10 cm (short range 1.064 μm & 1.627 μm)
  - 25.4 cm (long range 1.064 μm & 1.627 μm)
  - 20 cm (long range 0.355 μm)
- **Detectors**
  - 0.355 microns : PMT
  - 1.064 microns: 800 μm Si APD
  - 1.627 microns : 200 μm & 500 um InGaAs APD
- **Data Acquisition**
  - 50 MHz analog-to-digital converter

ATM Performance



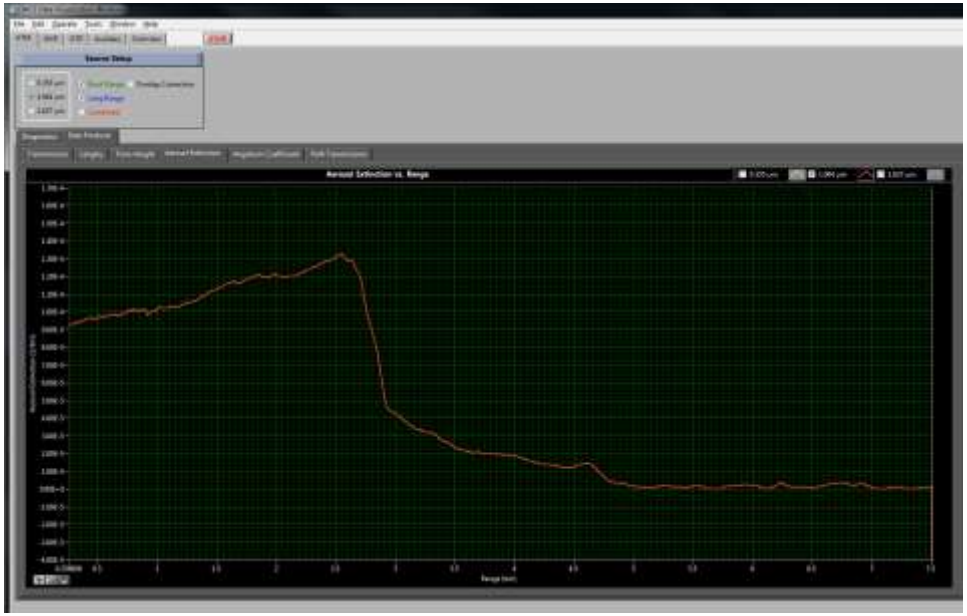
A time-height diagram showing the aerosol distribution above the GTRI lidar laboratory in July 2012.

ATM Data Products 1/5



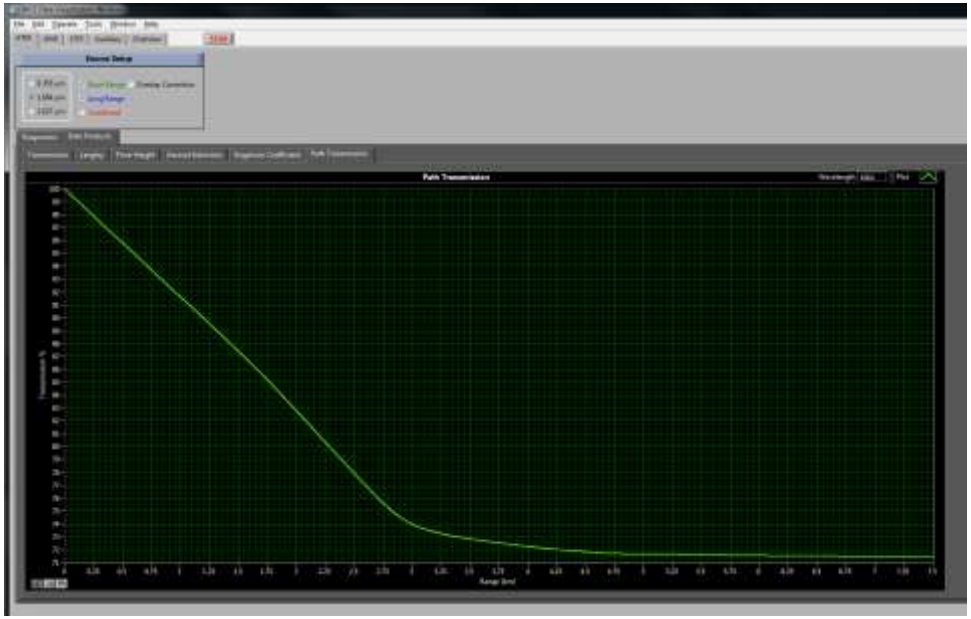
Long-range 1064 nm range-corrected signal.

ATM Data Products 2/5



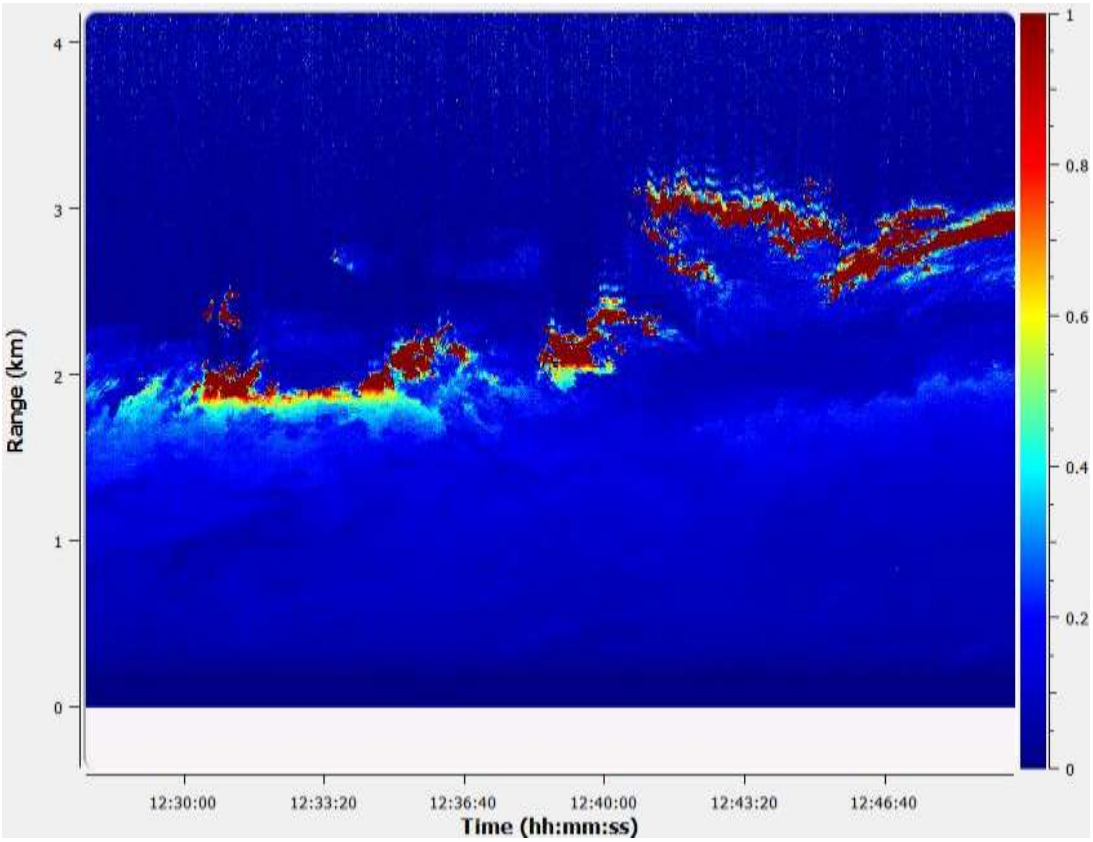
Measured 1064-nm slant-path atmospheric extinction coefficient (1/km) vs. range (km).

ATM Data Products 3/5



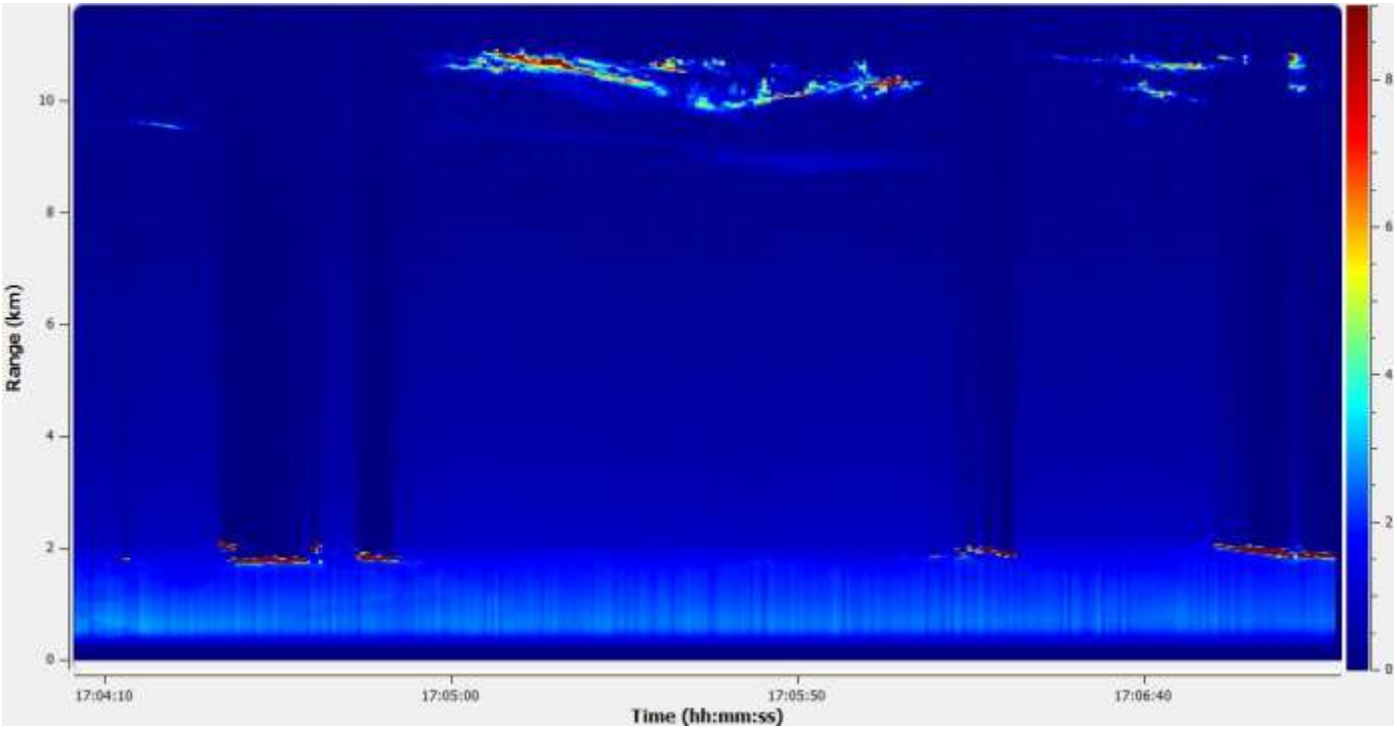
Path transmission vs. slant range. The transmission drop rapidly from 100 % to about 70% in the mixed layer (where almost all of the aerosols are), and then remains almost constant at longer ranges.

ATM Data Products 4/5



Time-height plot of cloud and aerosol signals at 1627 nm.

ATM Data Products 5/5



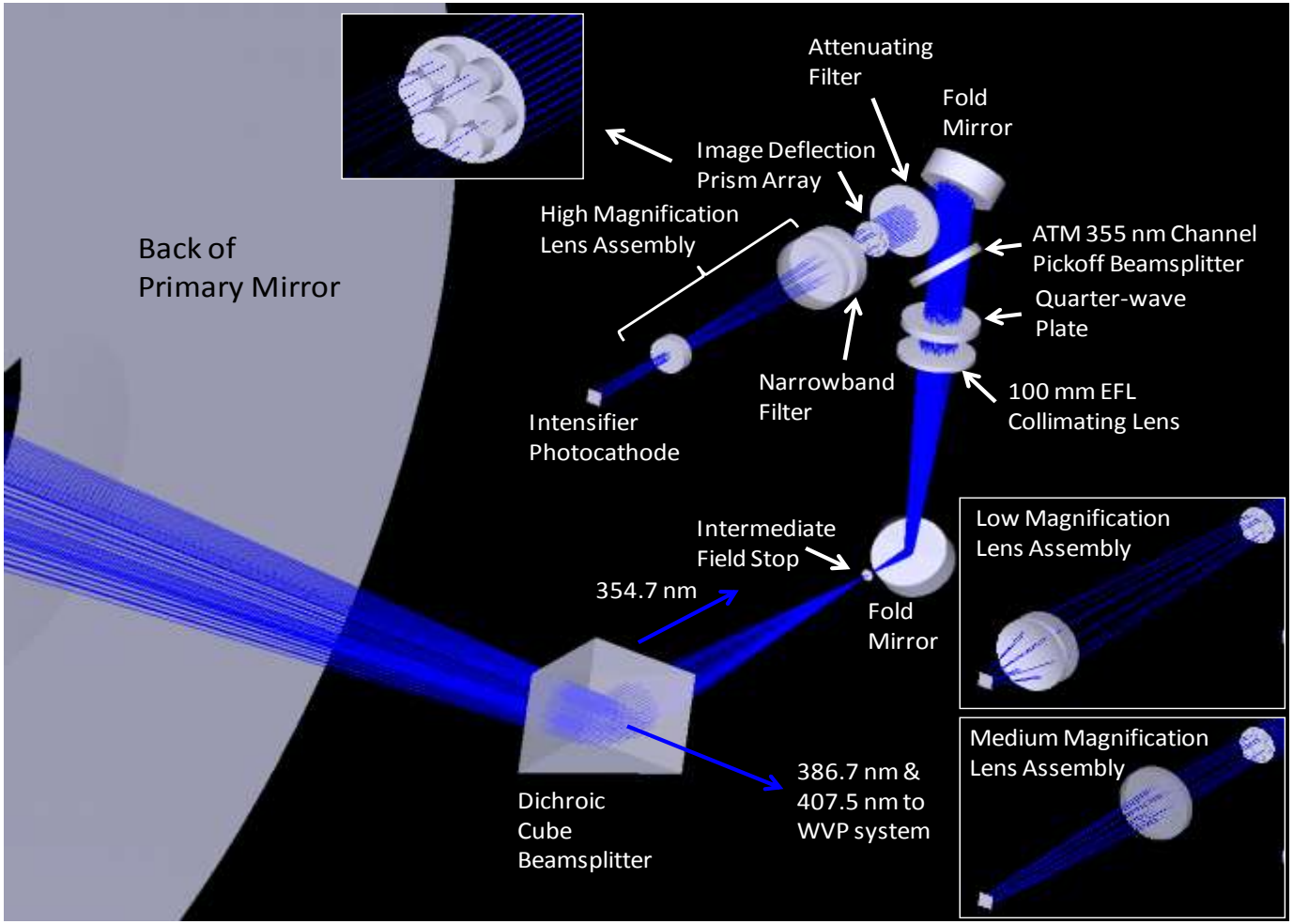
Time-height diagram of 355 nm cloud and aerosol signals.

OTP Specs

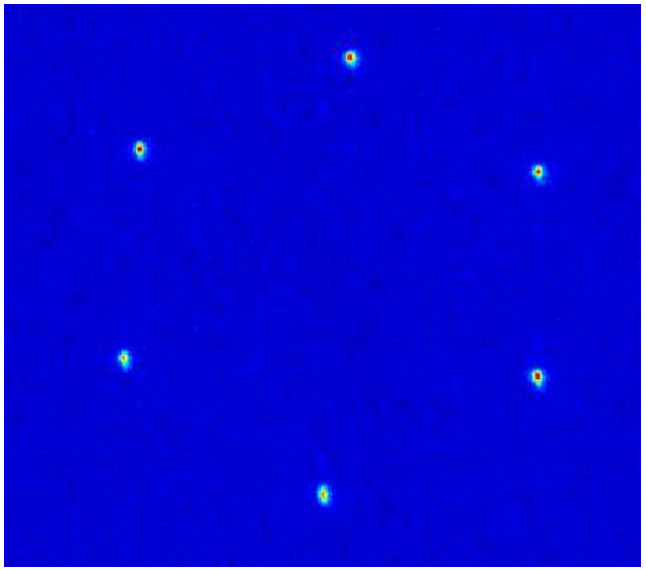
- **Pulse energy**
  - 300 mJ, 0.3547 μm
- **PRF**
  - 50 Hz
- **Receiver**
  - 50.8 cm telescope with six 8 cm subapertures in a Shack-Hartmann wavefront sensor
- **Imager**
  - Intensified, range-gated CCD
- **Data Acquisition**
  - Guide star images saved at 50 Hz rate

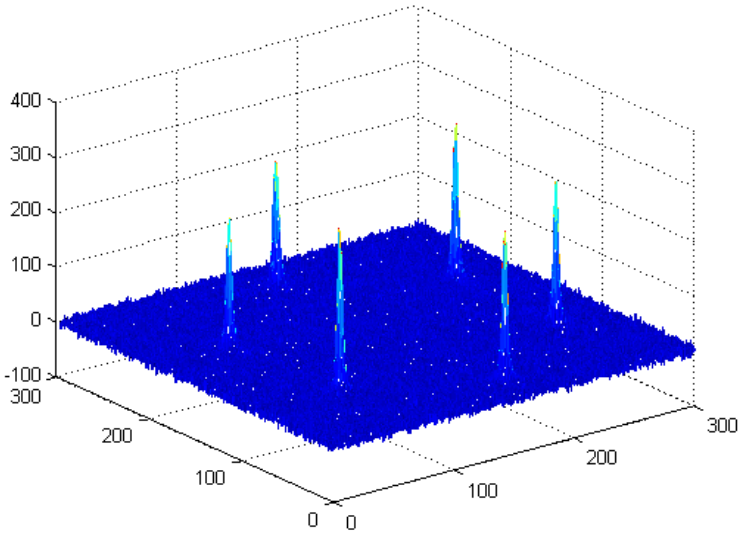
"Development of a lidar technique for profiling optical turbulence," G.G. Gimmestad, D.W. Roberts, J.M. Stewart, and J.W. Wood, *Optical Engineering* **51**, 101713-1 – 101713-18 (2012).

OTP Optical System



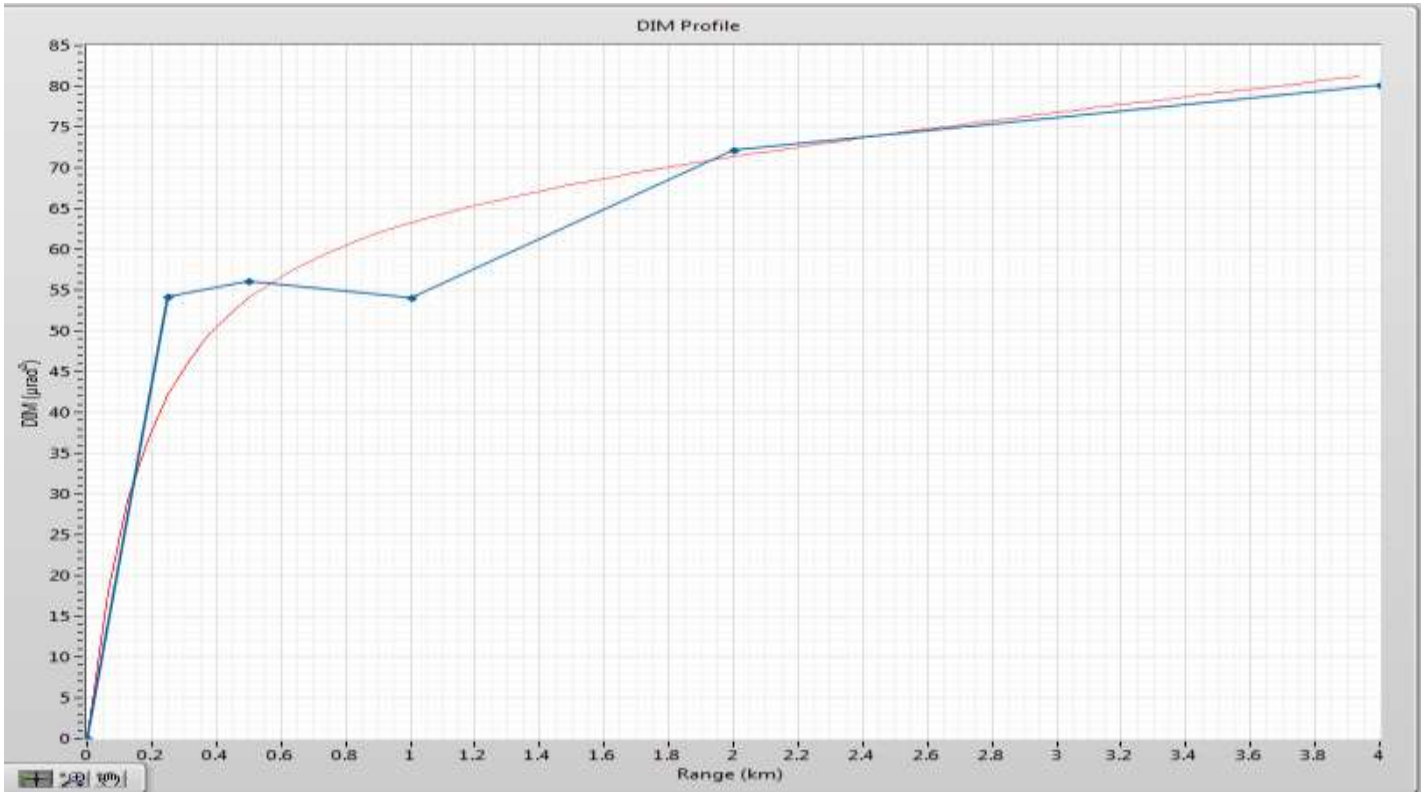
Optical Turbulence Profiler (OTP) Differential Image Motion LIDAR





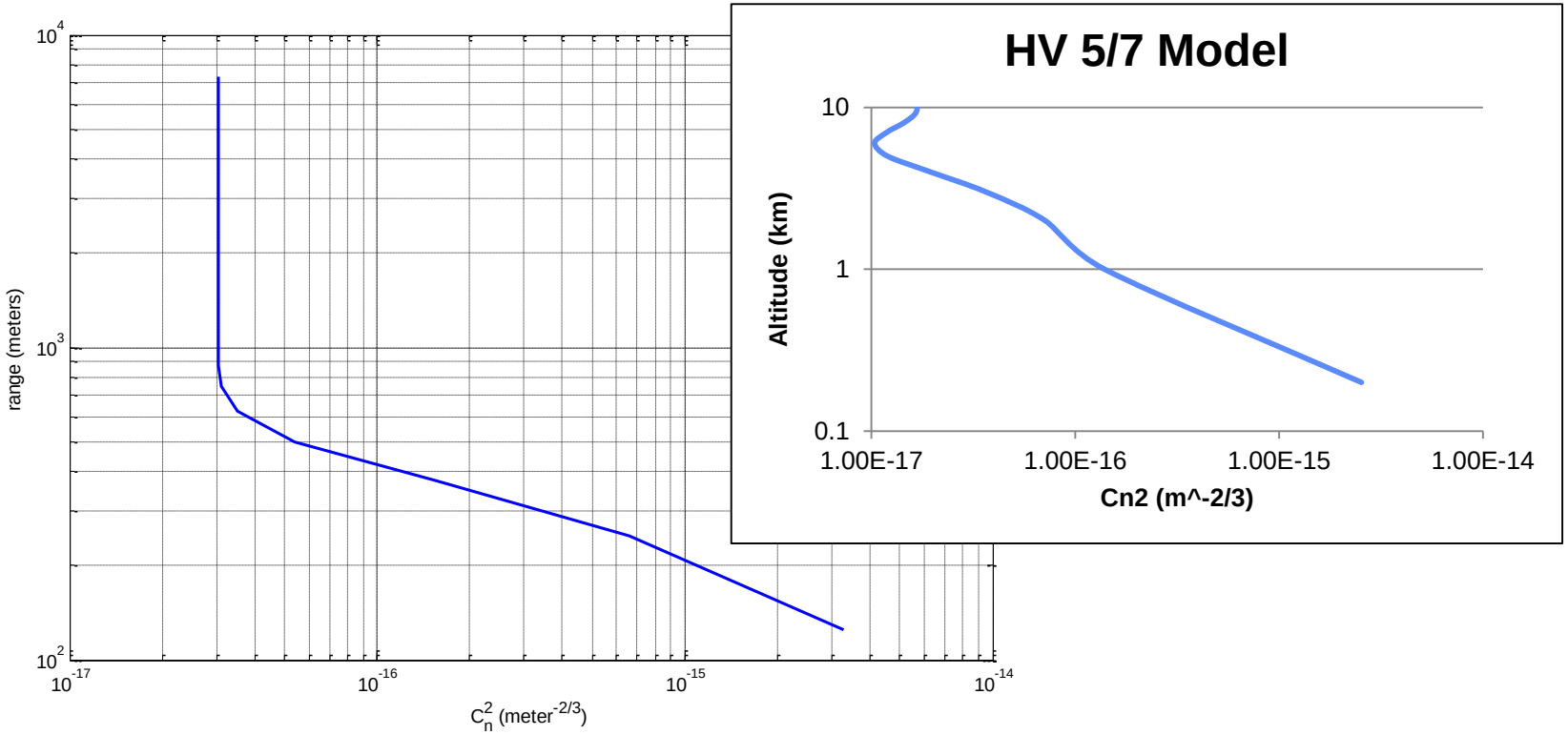
"First Light" images of the laser guide star.

OTP Data Products



The DIM Profile (blue dots and lines) and the functional fit from the OTP processed data display.

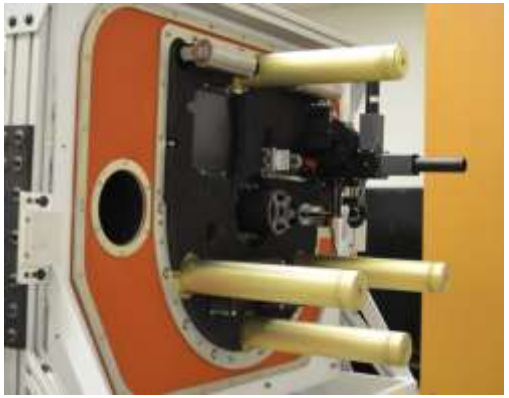
OTP Data Products



The corresponding Turbulence Profile calculated by the OTP software in real time.

"Inversion techniques for the differential image motion lidar," Ian Gatland, John M. Stewart, and Gary G. Gimmestad, Proc. SPIE 7324, 73240C1 - 73240C8, Orlando, FL (2009).

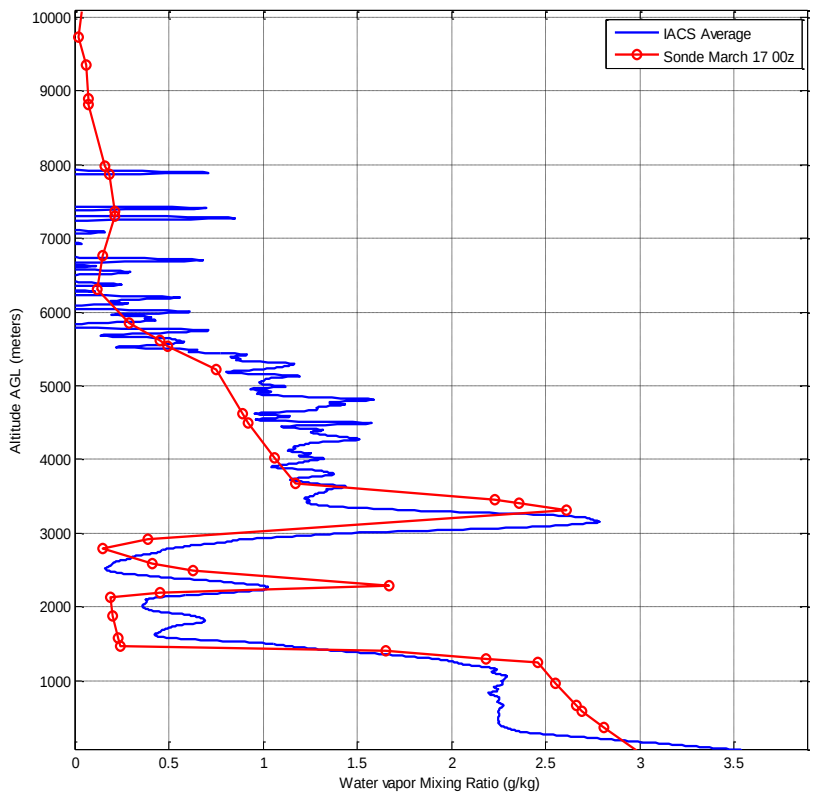
Water Vapor Profiler (WVP) Specs



WVP and OTP instrument packages are mounted on back side of 20-inch telescope.

- **Pulse Energy**
  - 300 mJ
- **Wavelengths**
  - 0.3547 μm transmitted
  - 0.3867 μm received (N2)
  - 0.4075 μm received (H2O)
- **PRF**
  - 50 Hz
- **Receiver Aperture Diameter**
  - 50.8 cm
- **Detectors**
  - 0.3867 μm PMT (long & short range)
  - 0.4075 μm PMT (long & short range)
- **Data Acquisition**
  - Licel hybrid analog/photon counting system

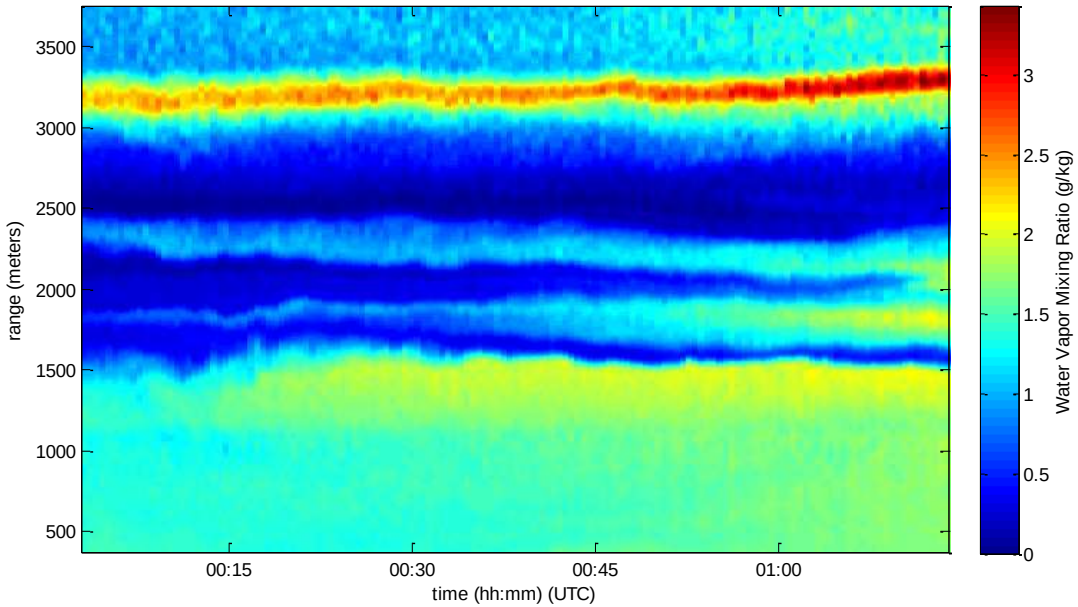
WVP Data Products



Water vapor profiles from IACS and the Peachtree City Sonde launched while the lidar was operating.

- WVP is a photon counting Raman LIDAR
- Performance simulations show the system is capable of H2O profiling to ranges of ~5 km with a 5% error in the daytime
- Range is primarily limited by sky background light in the daytime
- Longer ranges can be reached at night

WVP Data Products



Time-height plot of water vapor mixing ratio.

Summary

- **IACS is a state-of-the-art instrument.**
  - OTP is the only operational turbulence profiler in the world.
  - IACS employs a custom-built 355 nm laser.
  - IACS employs a RISTRA Optical Parametric Oscillator to generate 1627 nm laser light.
- **IACS is the foundation for an Atmospheric Characterization Center**
  - Will be GFE to GTRI.
  - GTRI provides a staff of trained operators.
  - GTRI maintains IACS.
  - GTRI promotes utilization.
  - The IACS team contributes to scientific knowledge.

Acknowledgement & Disclaimer

Acknowledgement:

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