PENNSTATE

ADVANCING OPTICAL TECHNIQUES FOR MEASUREMENTS OF ATMOSPHERIC CONSITUENTS

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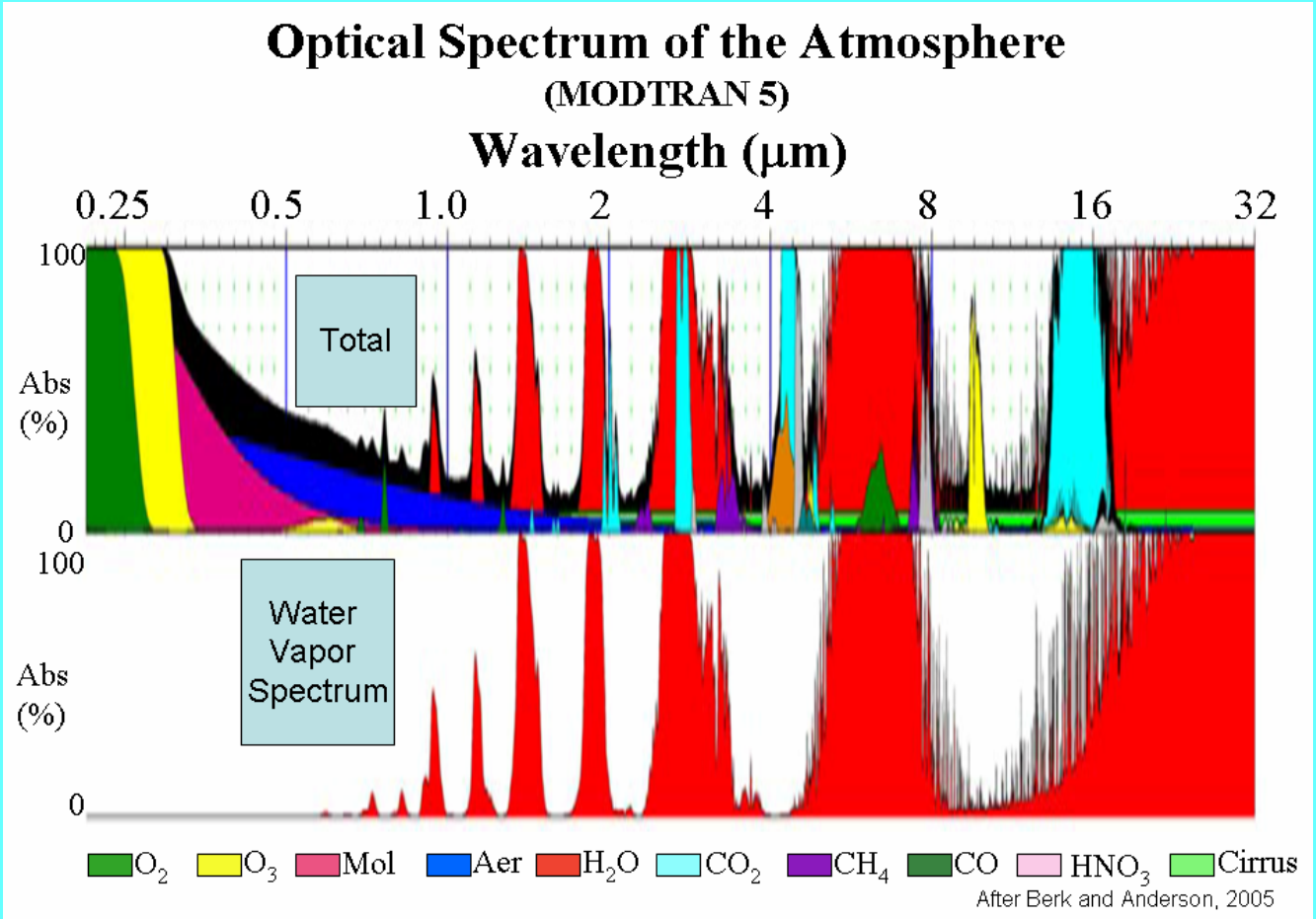
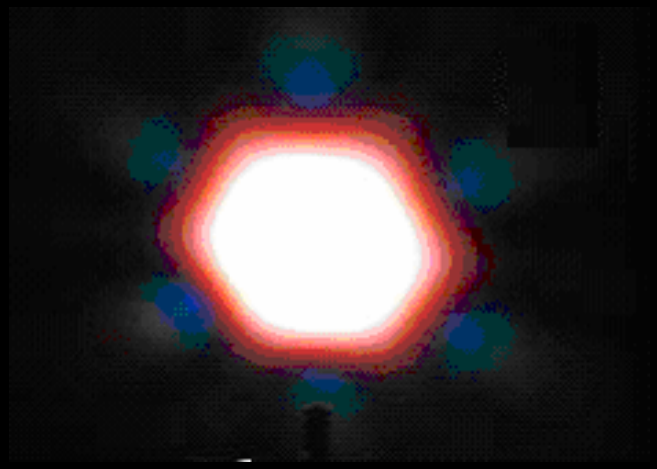


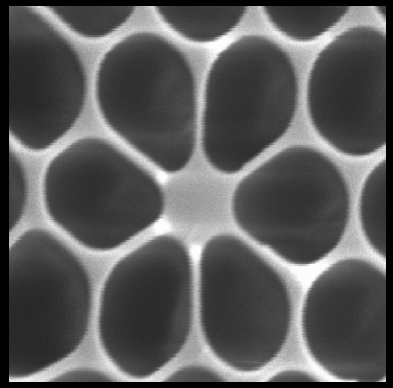
Outline

- Supercontinuum White Light Laser
  - Spectrum of Laser
  - Application to Remote Detection (DAS) of Water Vapor
    - MODTRAN™ 4 and MODTRAN™ 5
- Measurements of Trace constituents
  - Feasibility MWIR-LWIR
    - Carbon Monoxide
    - PNNL Database comparison
      - Nitrogen Oxides
    - MODTRAN™ 5 comparison
      - Nitrous Oxide
  - Example ITT Airborne Lidar

Supercontinuum White Light Laser



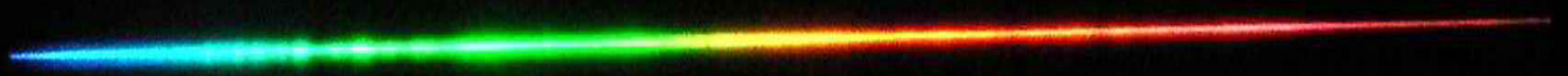
Photonic crystal fiber



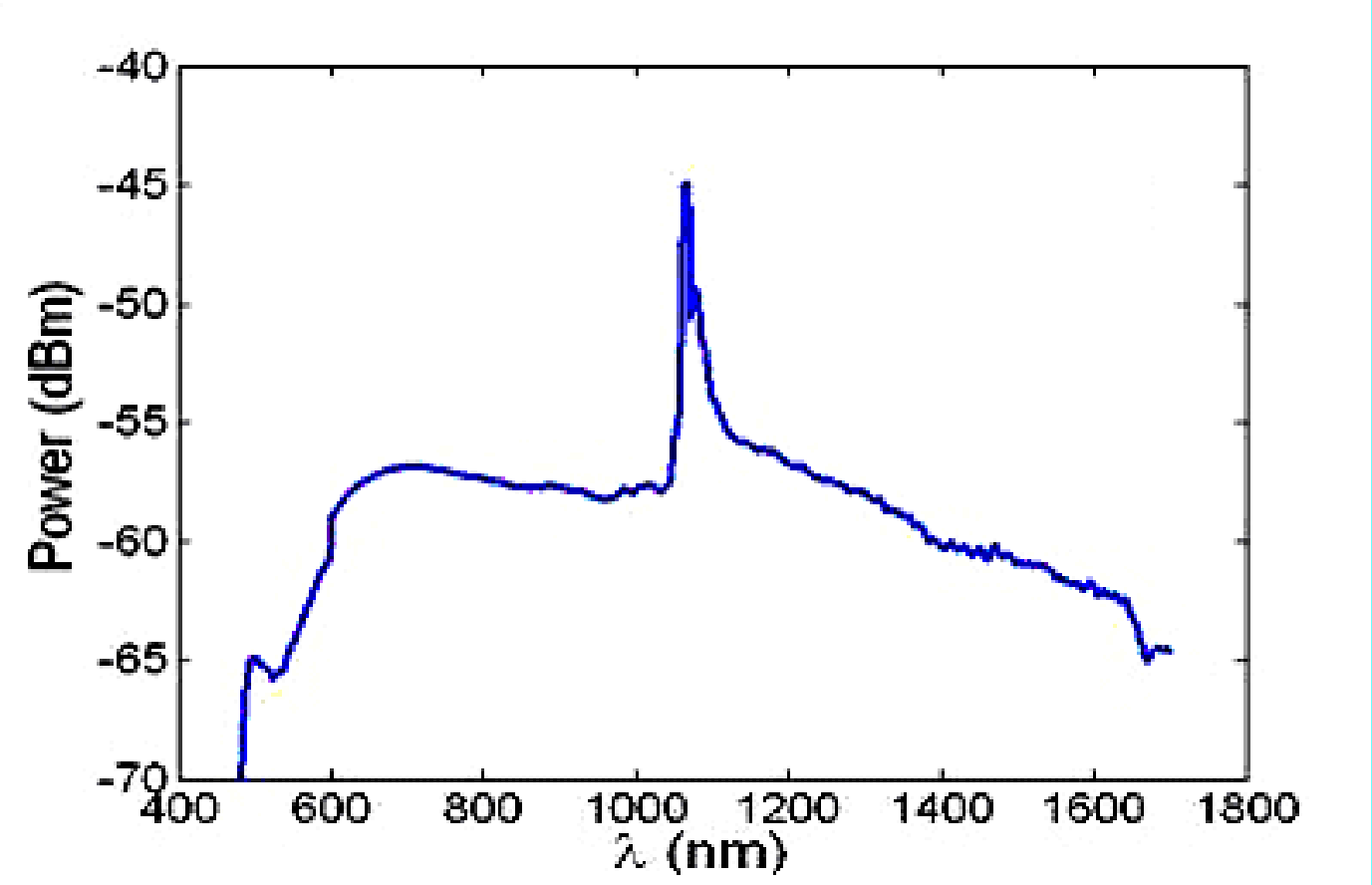
- (Above) Far field pattern of the white light laser generated in a photonic crystal fiber
- (Below) The rainbow observed after the collimated white light passes through a prism

(From http://www.crystal-fibre.com)

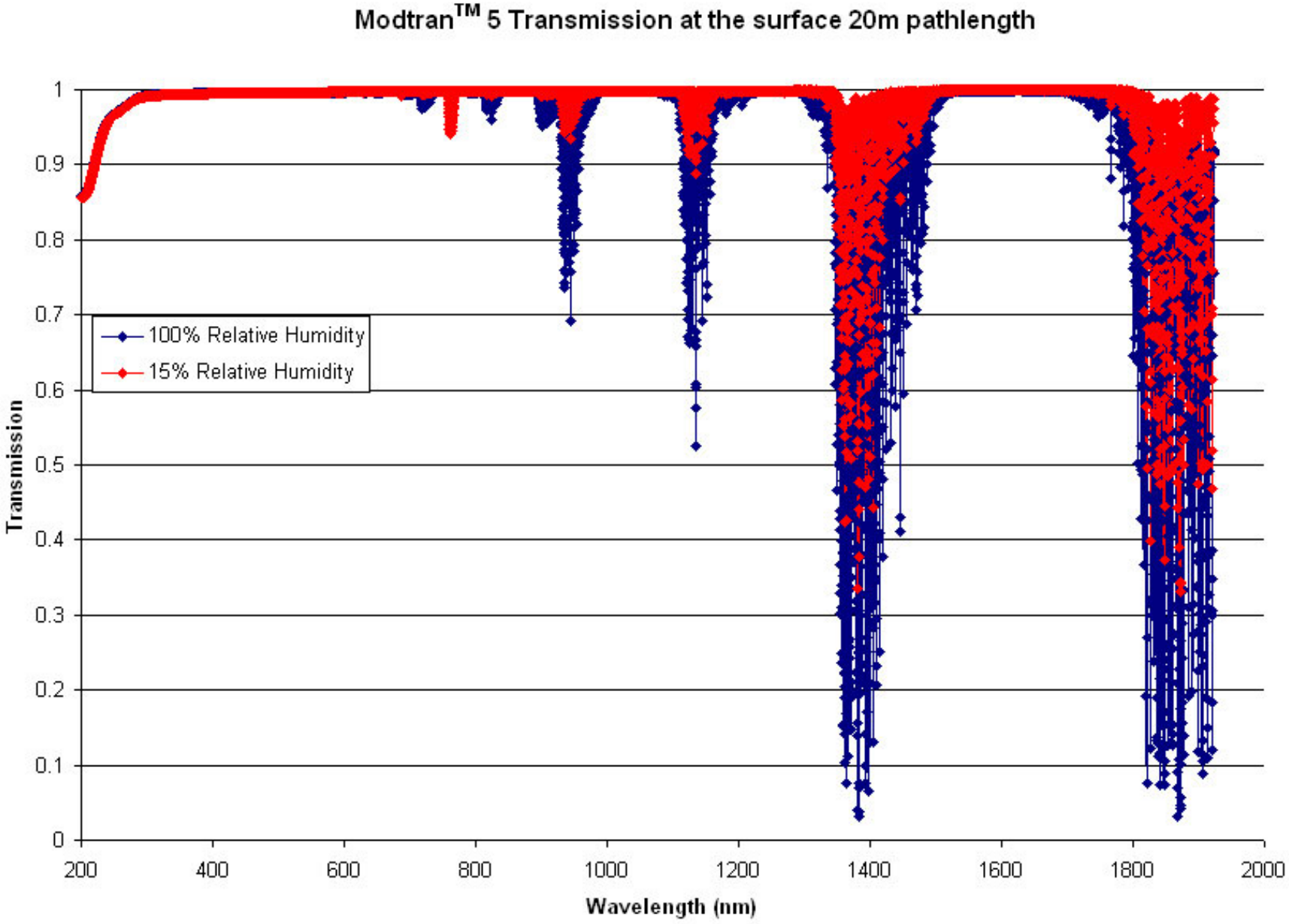
- **Water Vapor Example**
- **Extended to minor species monitoring O3, CO, N20 etc.**

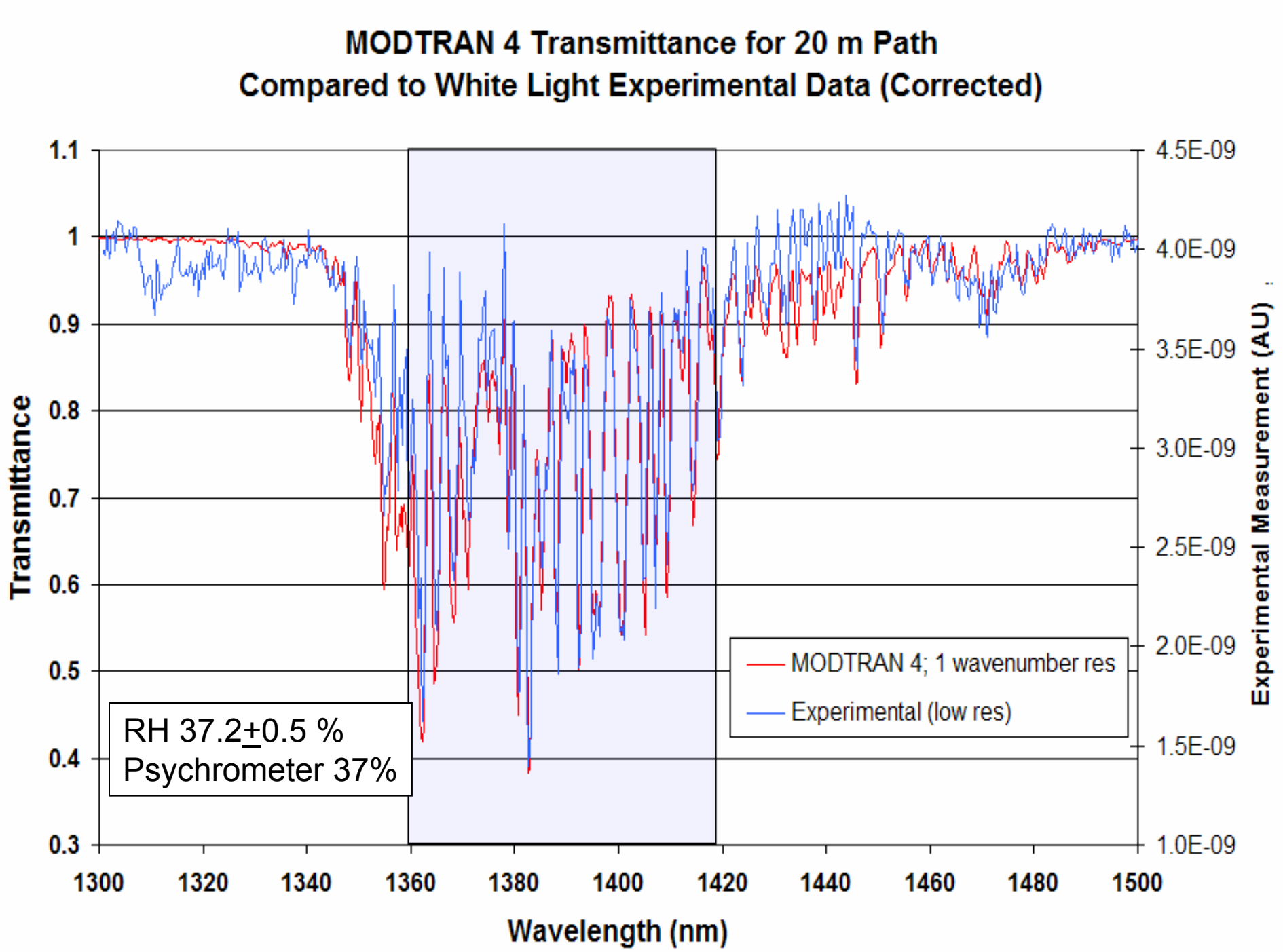


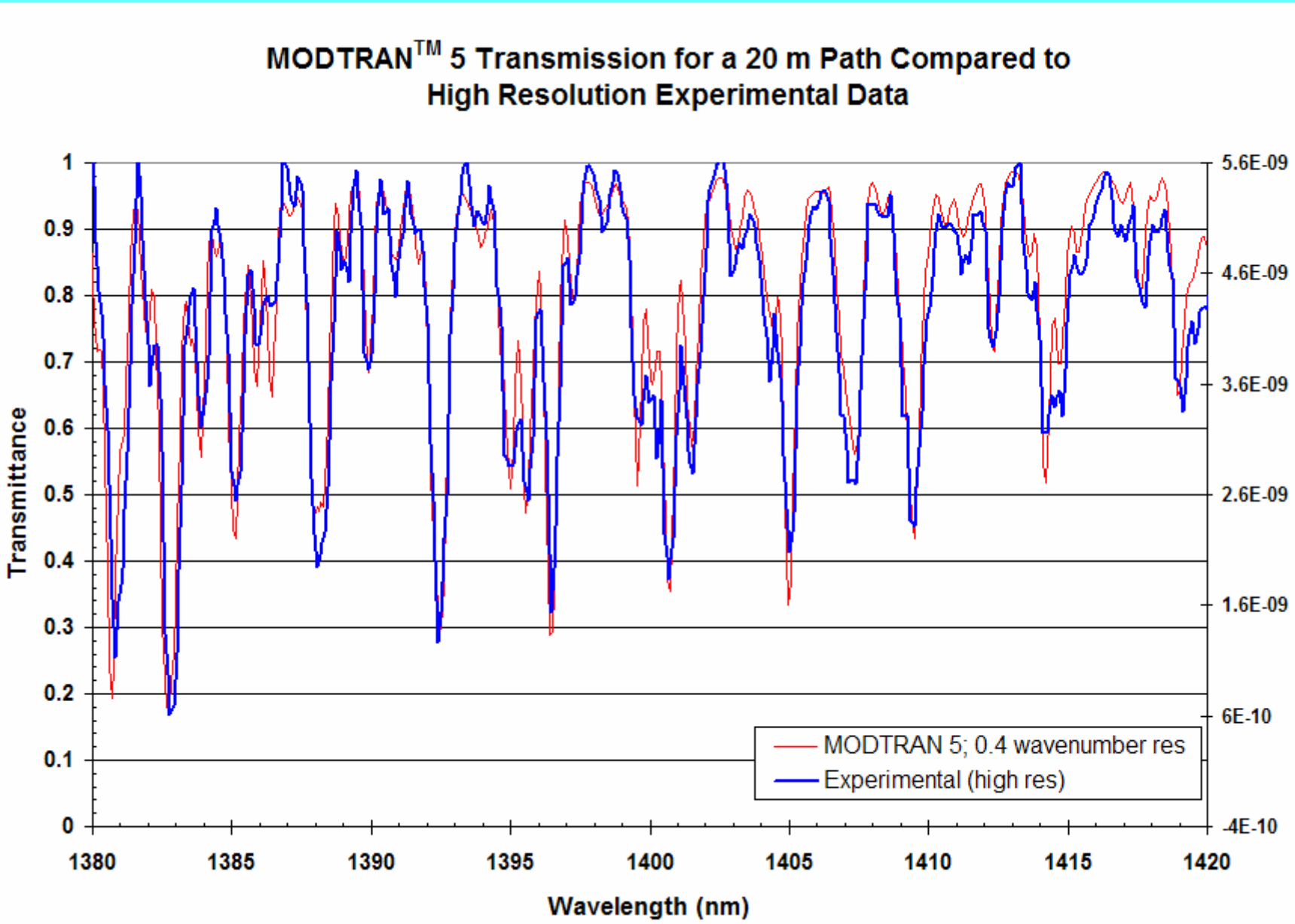
White Light Laser Spectrum



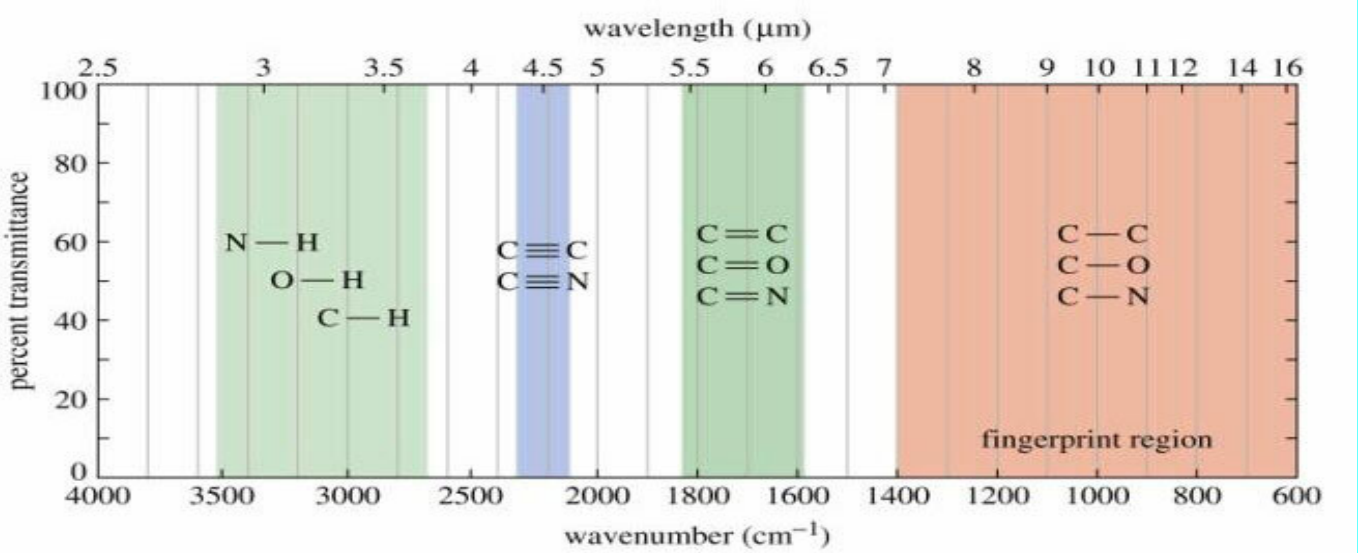
- Power output of White Light Laser versus wavelength

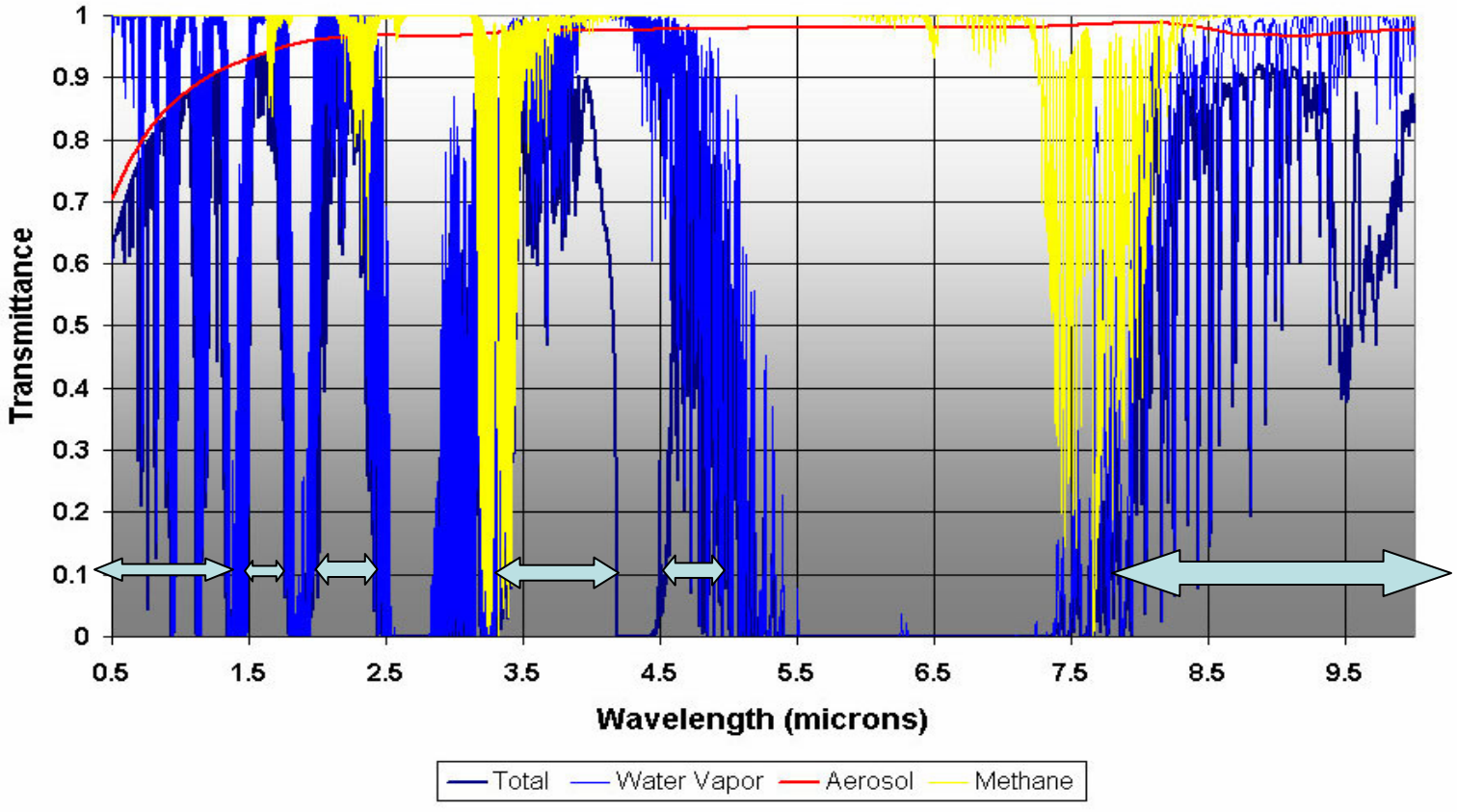

Modtran™ 5 Transmission at the surface 20m pathlength
Transmission
Wavelength (nm)
100% Relative Humidity
15% Relative Humidity
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
200
400
600
800
1000
1200
1400
1600
1800
2000


MODTRAN 4 Transmittance for 20 m Path
Compared to White Light Experimental Data (Corrected)
Transmittance
Experimental Measurement (AU)
Wavelength (nm)
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
4.5E-09
4.0E-09
3.5E-09
3.0E-09
2.5E-09
2.0E-09
1.5E-09
1.0E-09
1300
1320
1340
1360
1380
1400
1420
1440
1460
1480
1500
MODTRAN 4; 1 wavenumber res
Experimental (low res)
RH 37.2±0.5 %
Psychrometer 37%


MODTRAN™ 5 Transmission for a 20 m Path Compared to High Resolution Experimental Data
Transmittance
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
5.6E-09
4.6E-09
3.6E-09
2.6E-09
1.6E-09
6E-10
-4E-10
1380
1385
1390
1395
1400
1405
1410
1415
1420
Wavelength (nm)
MODTRAN 5; 0.4 wavenumber res
Experimental (high res)

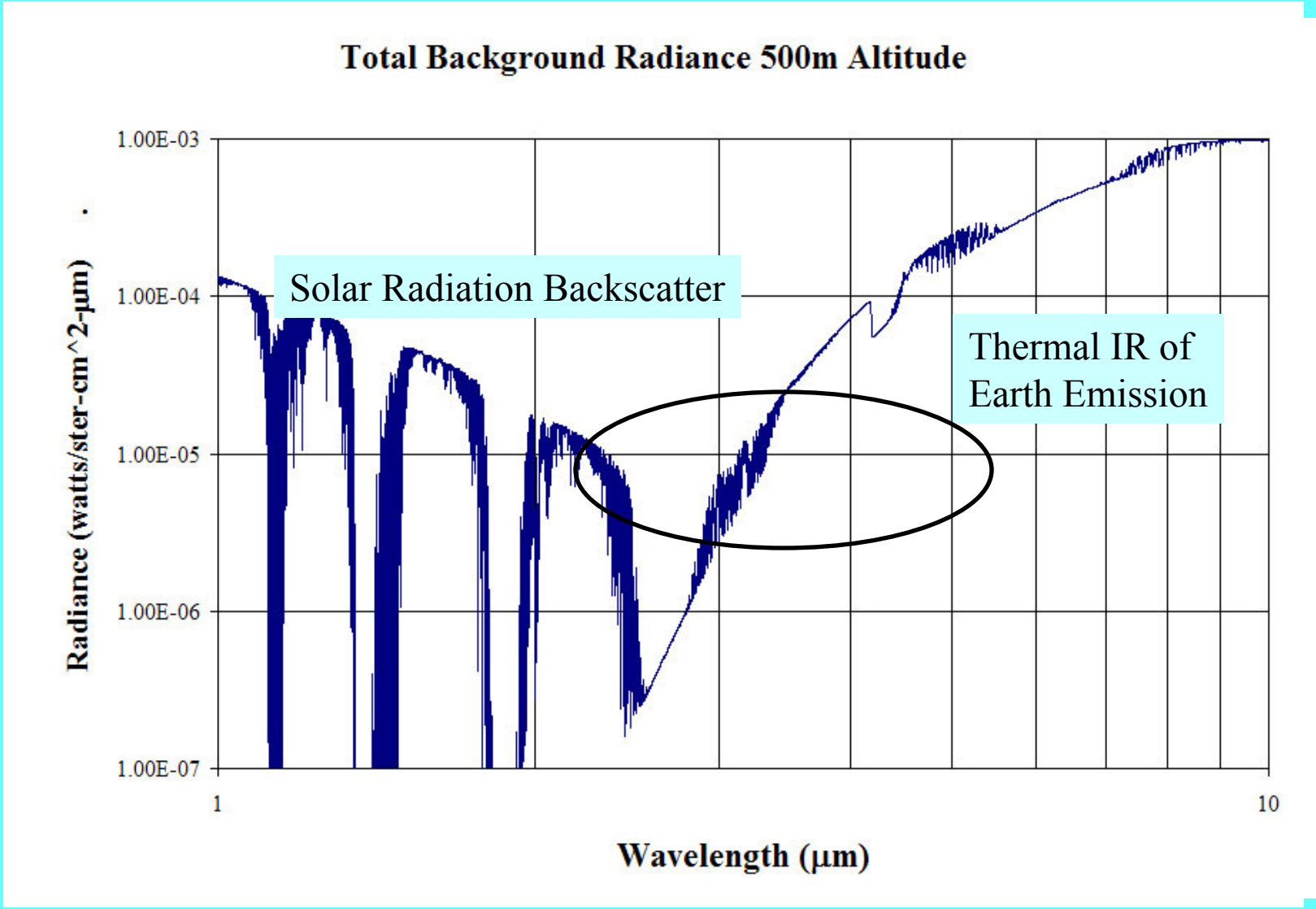
IR Spectra depends upon masses of atoms, bond type and bond strength





Atmospheric transmission windows in the IR spectrum

Radiance Observed Looking Down at Noon from 500 m Altitude

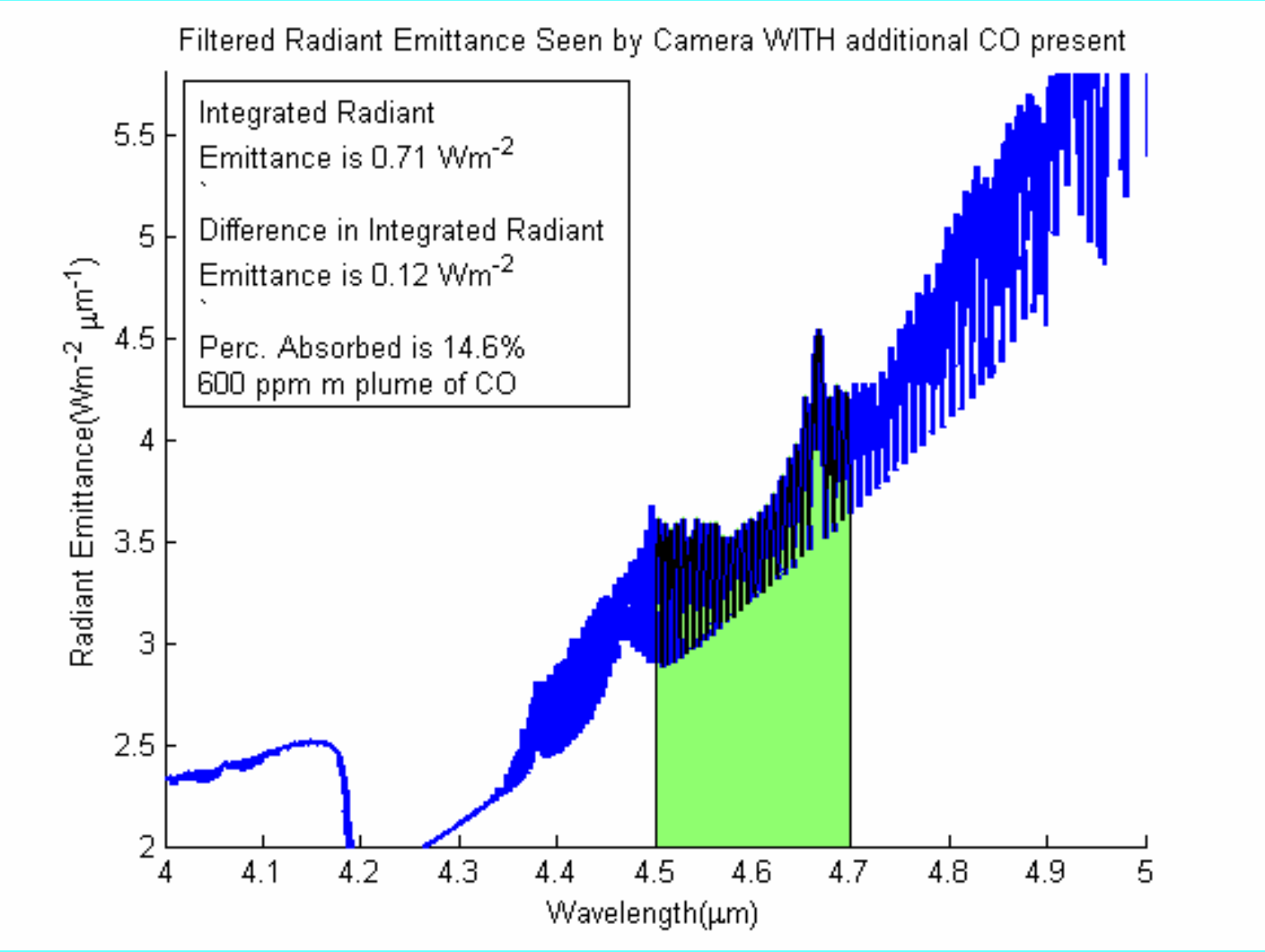


Applications:
Production and Pollutant Monitoring

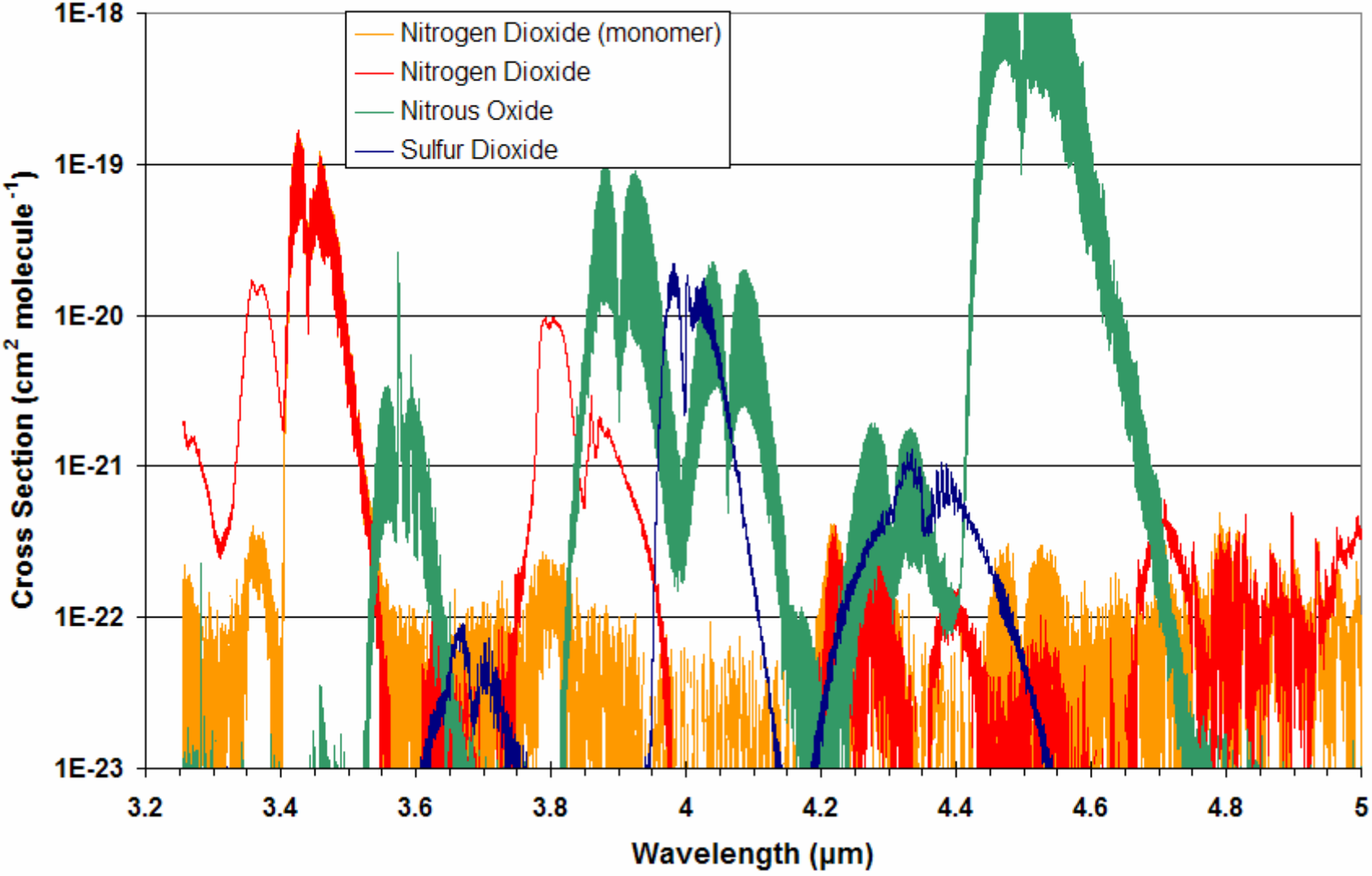
- Carbon Oxides
  - Monitor Power Companies
    - Good measure of energy production and use

- Nitrogen Oxides
  - Internal combustion engine use and efficiency
  - Small scale Lidar system for engine exhaust characterization

Detection of Carbon Monoxide

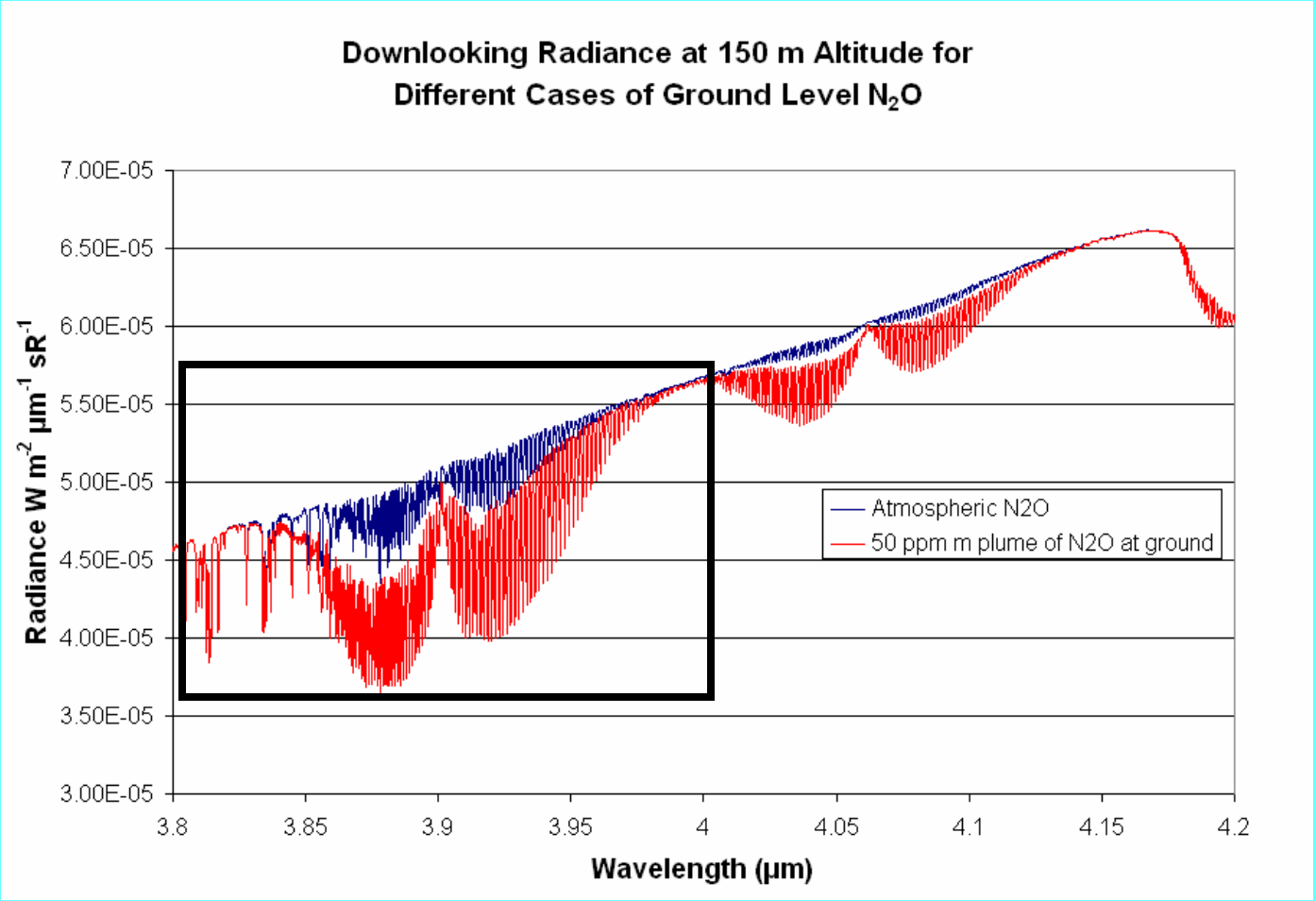


Trace Constituents



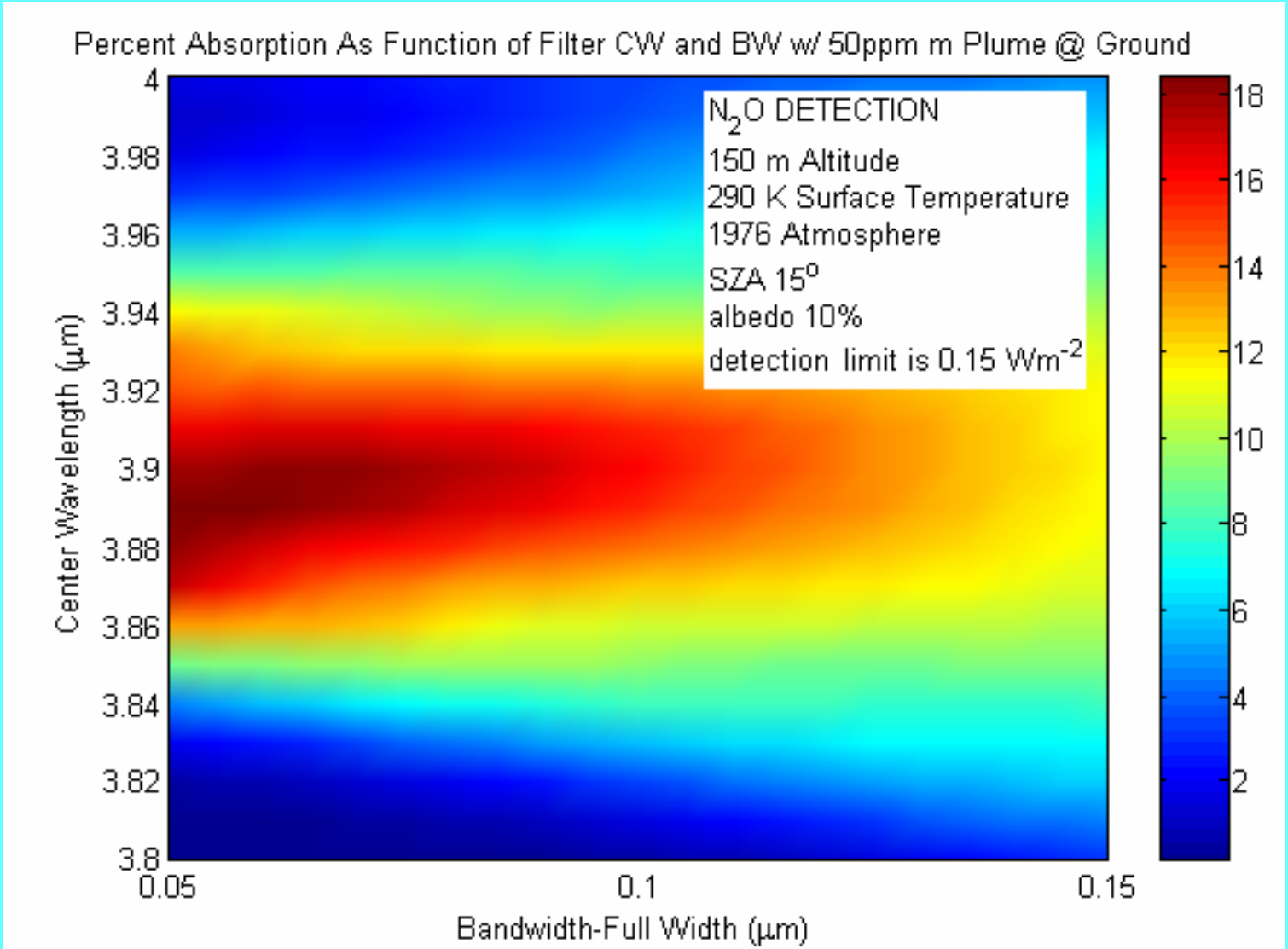
PNNL Infrared Spectral Data Base

Detection of Nitrous Oxide



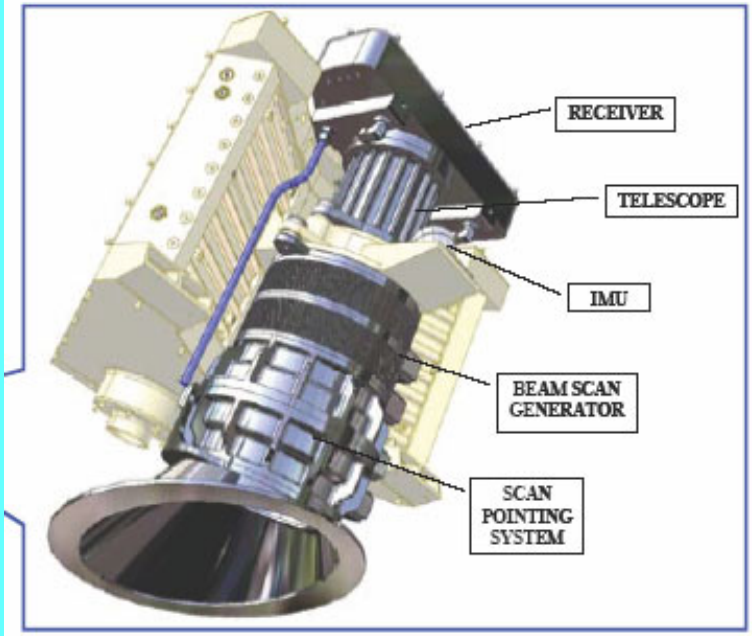
MODTRAN™ 5 downlooking radiance of Nitrous Oxide

Integrated Atmospheric Absorption from MODTRAN™ 5

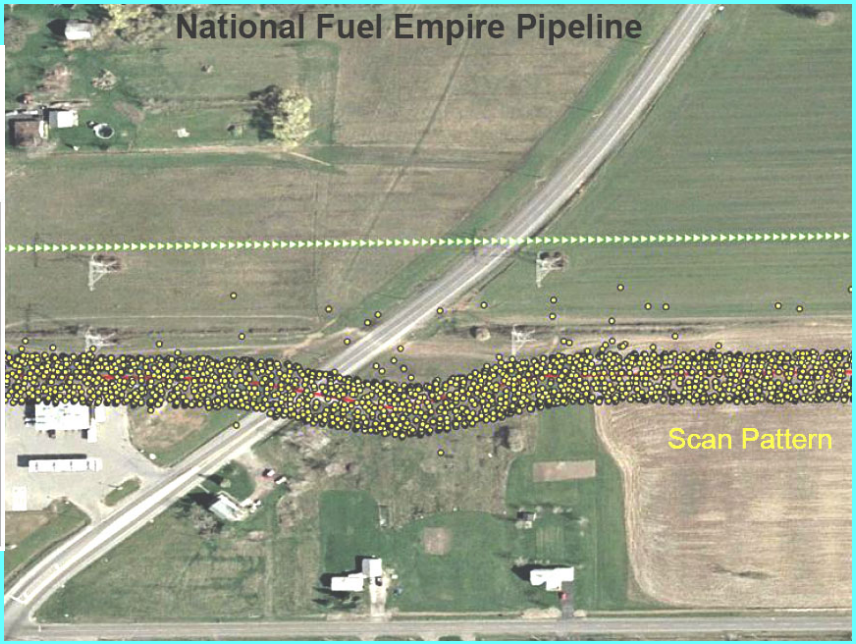


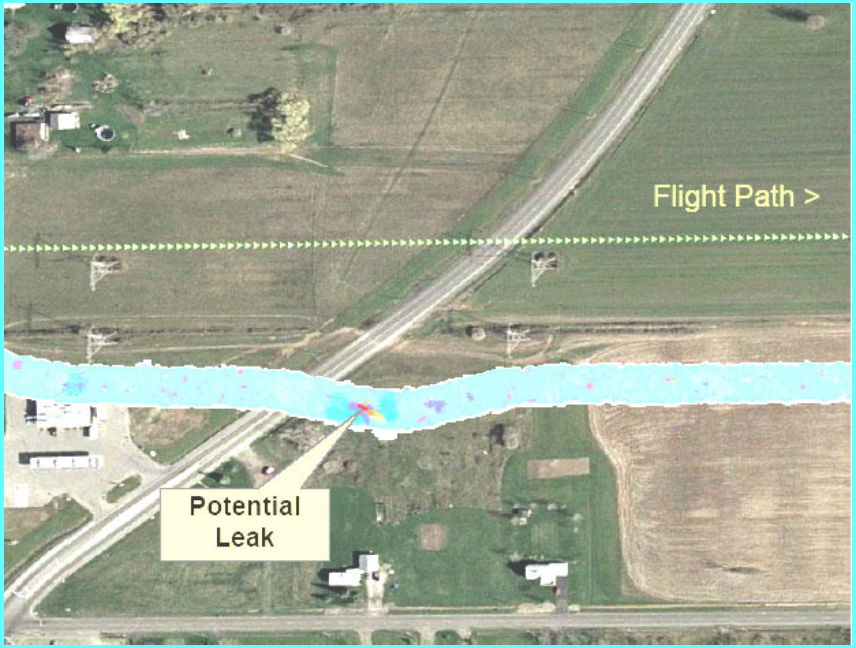
ITT - ANGEL System

First Commercial DIAL Lidar



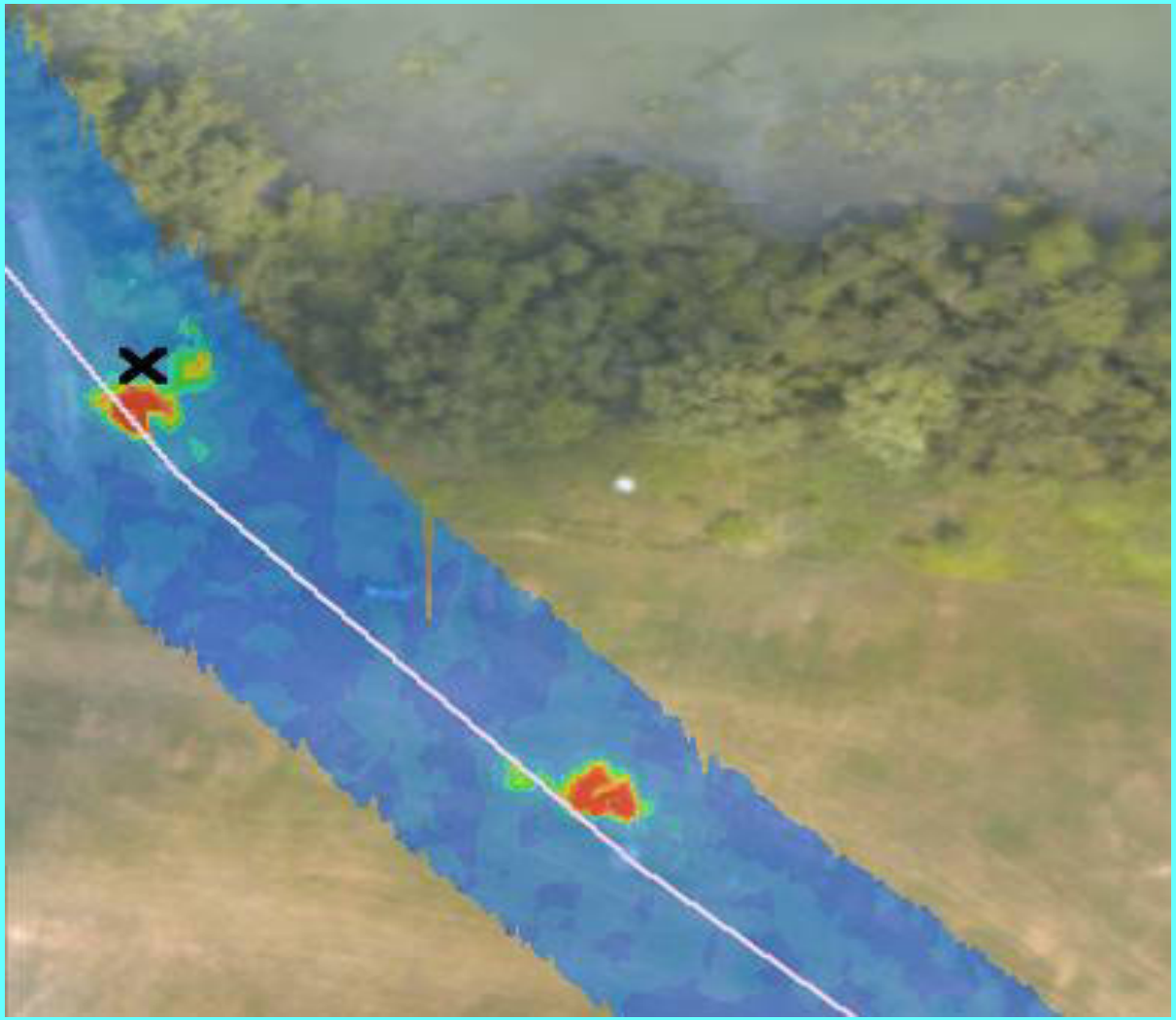
C. Grund, S. Shald and S. Stearns, SPIE Proc **5412**, 2004.





Murdock and Stearns, NYS Remote Sensing Sym, May 2005

ITT's ANGEL Service Aircraft: Computer controlled pointing, scanning and tracking system



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Conclusions

- High Resolution of MODTRAN™ 5 (0.1wavenumber) now makes it possible to resolve minor atmospheric constituents and simulate the atmospheric influence with realistic line widths. The capability is particularly important in the design of lidar measurement scenarios.

- Coupling white light differential analysis (DAS) and high resolution MODTRAN™ 5 allows measurements of trace species in the atmosphere – an initial example of a water vapor band is presented.

- Utilizing the mid-infrared spectrum (3 μm-5 μm) along with MODTRAN™ 5 it is possible to detect and quantify trace constituents in the atmosphere (Nitrous Oxide, Methane, Sulfur Dioxide, etc.)

References

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- **S. Stearns, R. Lines, D. Murdock, M. Severski, D. Lenz, D. Brown, c.R. Philbrick. "Airborne Natural Gas Emission Lidar(ANGEL) System," Proceedings of the International Symposium on Spectral Sensing Research (ISSSR), 2006**

- **C.R. Philbrick, Z. Liu, H. Hallen, D. Brown, A. Willitsford. "Lidar Techniques Applied To Remote Detection of Chemical Species in the Atmosphere," Proceedings of the International Symposium on Spectral Sensing Research (ISSSR), 2006**

- **S. Stearns, T. Gigliotti, D. Murdock, "Airborne DIAL (Differential Absorption Lidar) for Broad Area Hazardous Liquid Leak Detection," Proceedings of IPC 2006**

Acknowledgements

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