Laser Sounder for Global Measurements of CO_2 Concentrations from Space

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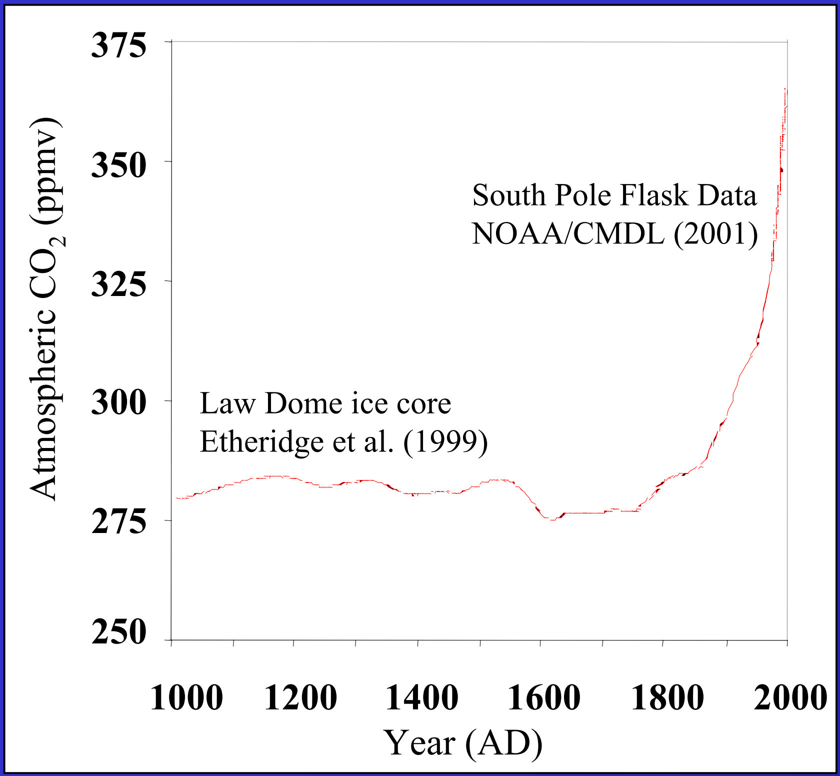
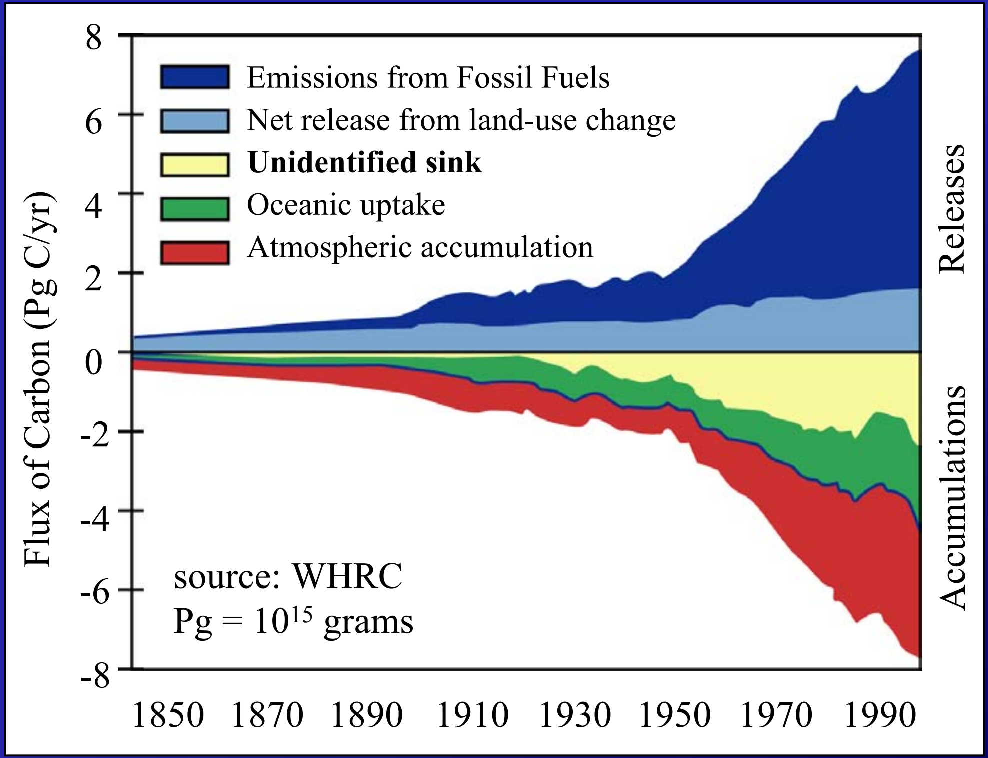
Atmospheric CO_2 History

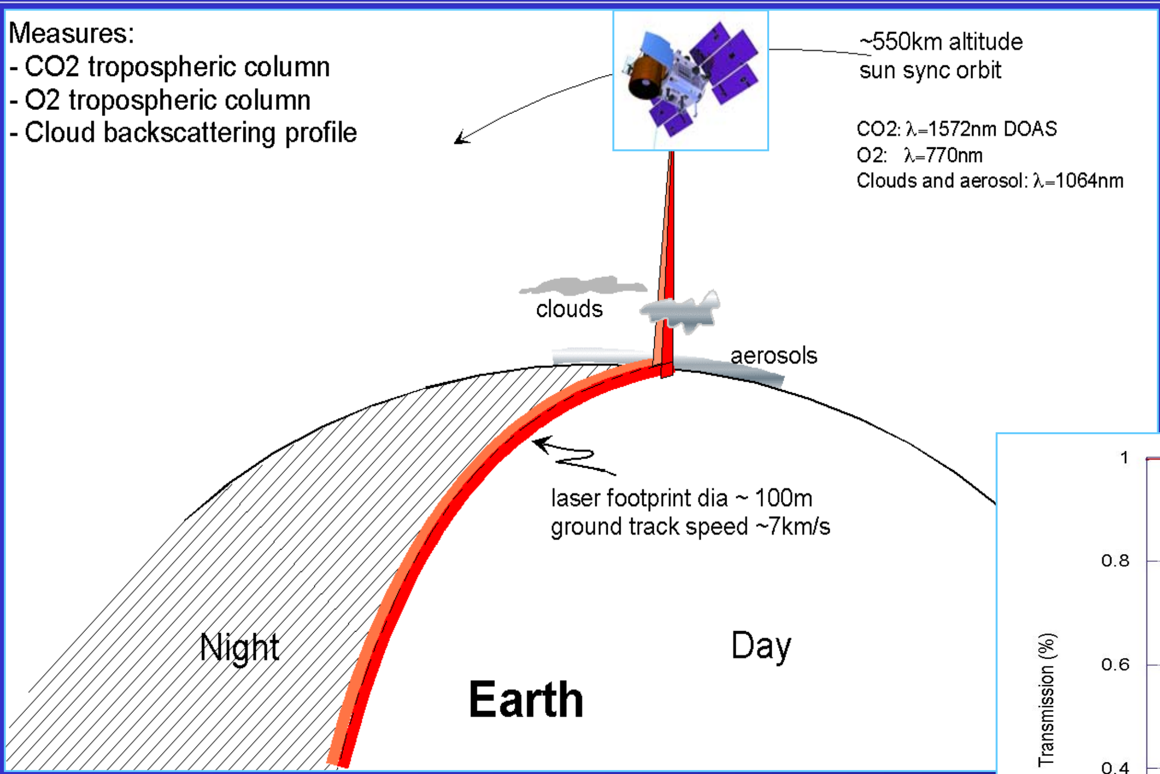


About 30% of anthropogenic CO_2 emitted to date, can not be accounted for - the "unknown sink" The "unknown sink" may be Northern Hemisphere forests. Will this sink continue to operate in the future? How will CO_2 fluxes in Arctic respond to warming ?

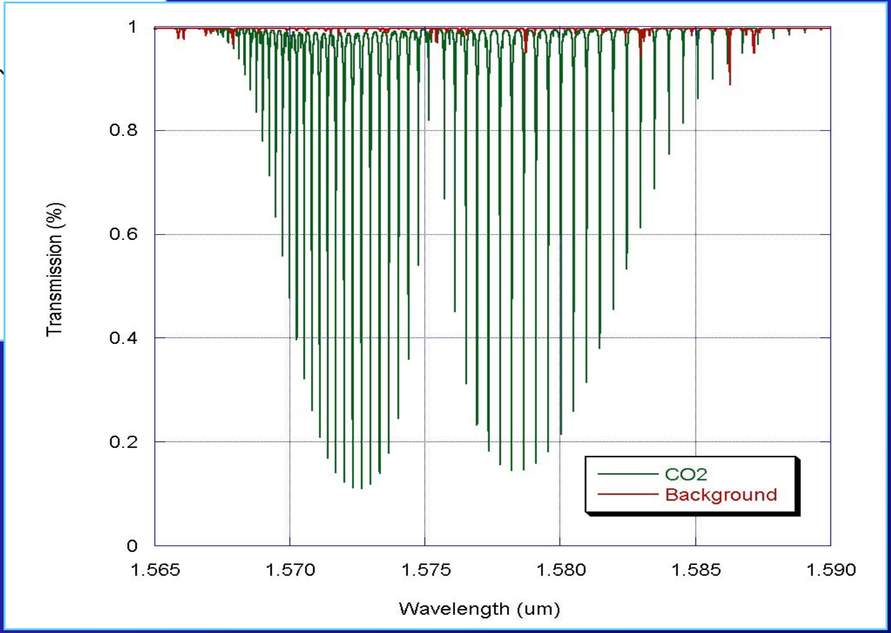


Atmospheric CO_2 is higher today than at any time in the past 400,000 years.

Active (Laser) Sounder Measurements



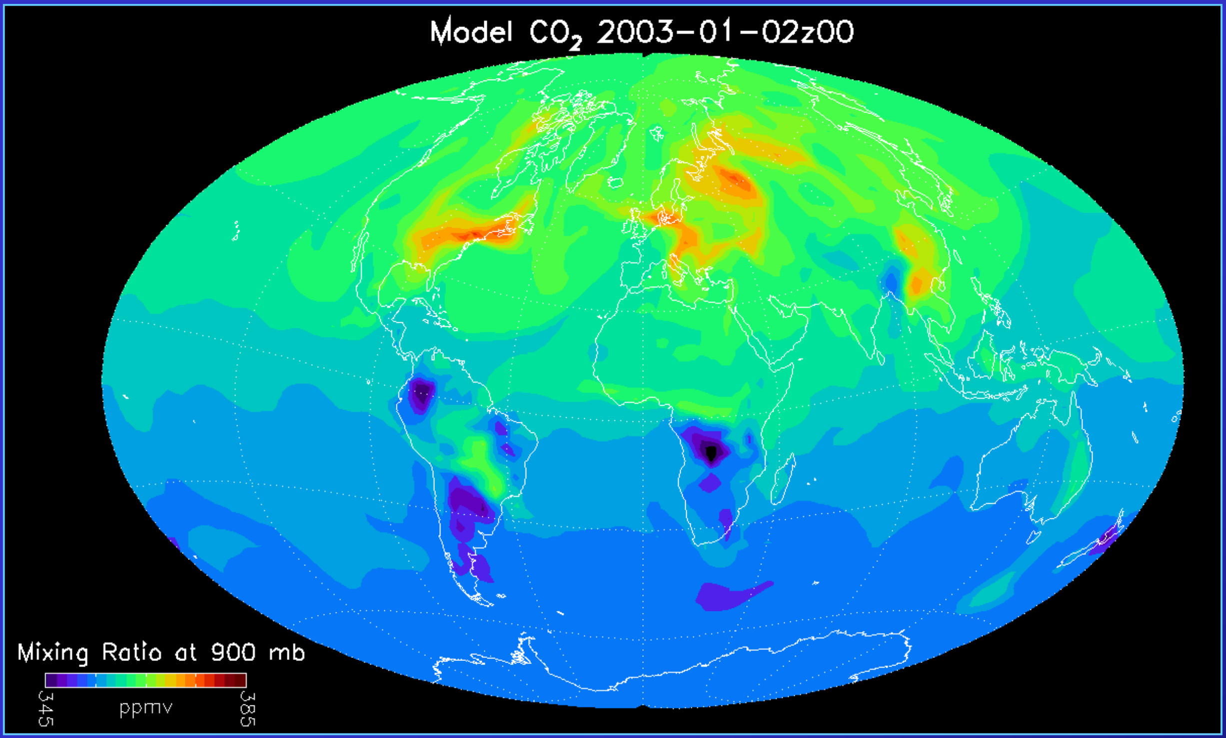
CO_2 Band at 1.57 um

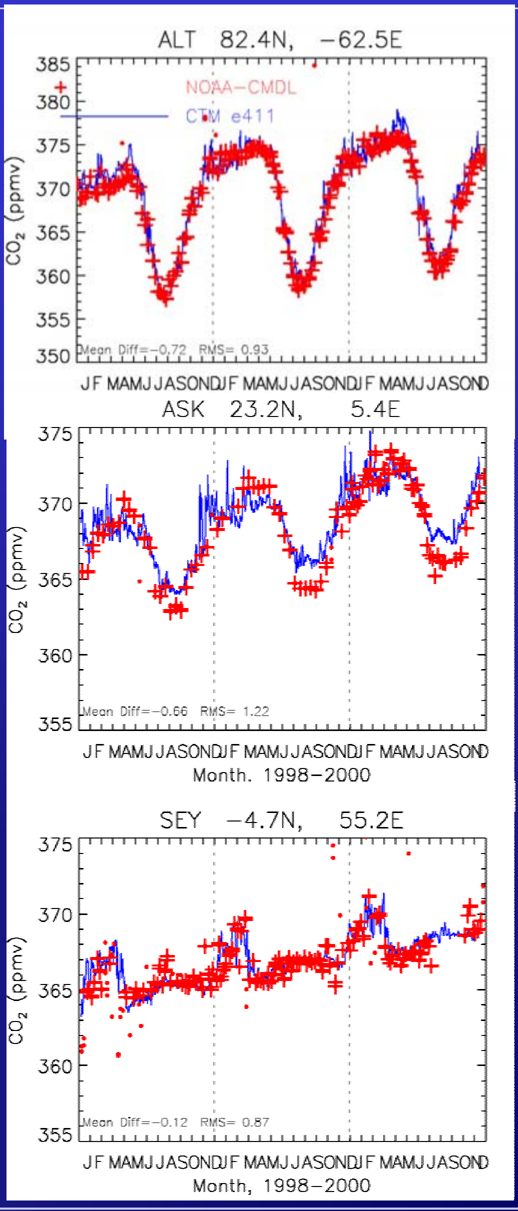


Why active (laser) measurements

- Measures at night & at all times of day
- Continuous measurements over oceans
- Smaller measurement footprint
- Measures through broken clouds
- Measurements to cloud tops (known heights)
- Aerosol profiles allow accurate correction for scattering

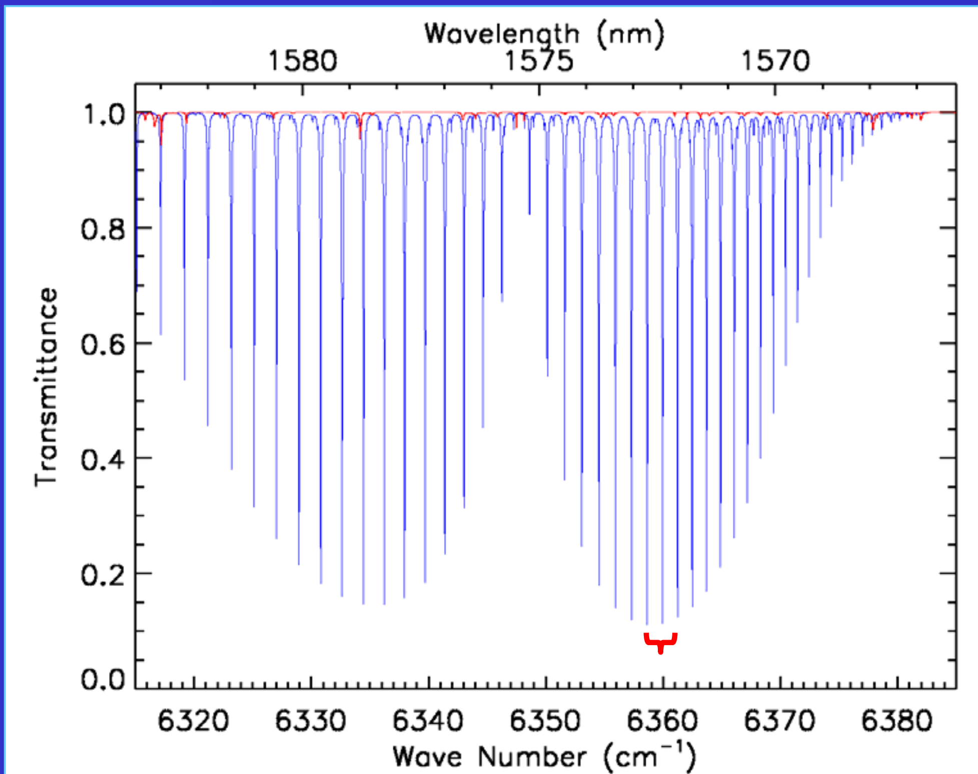
Simulating Atmospheric CO_2 Variability

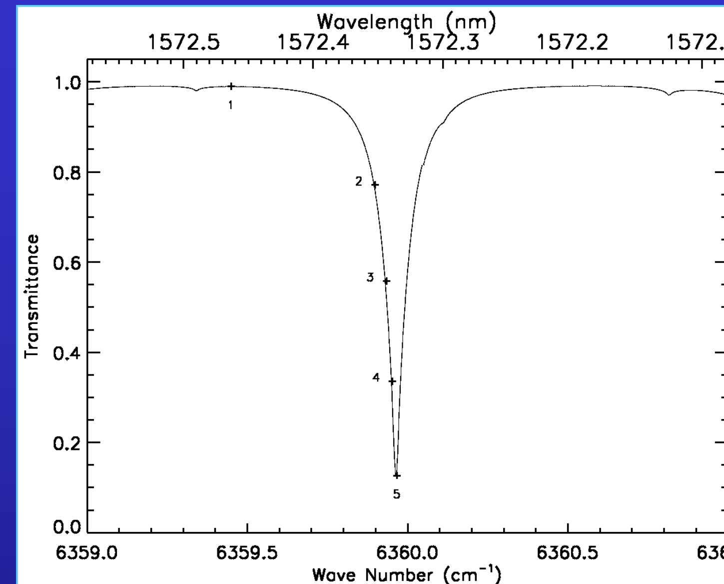


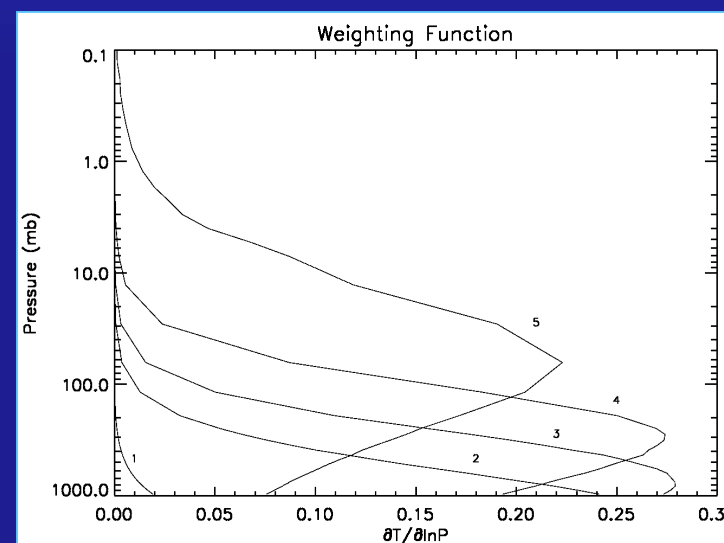


- CO_2 varies on a wide range of time and spatial scales
- Surface fluxes & atmospheric transport control CO_2 distribution
- Goal is to infer fluxes from atmospheric concentration measurements

CO_2 Line and Wavelength Selection





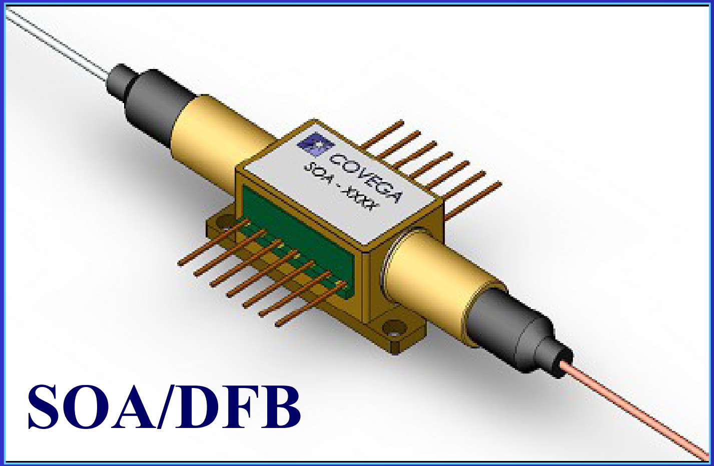


- line at 1572.335 nm
- good range of absorption
- minimal temperature sensitivity
- negligible interference from other species

Technology

PMT
HAMAMATSU
NIR PMT MODULE

Fiber Cell

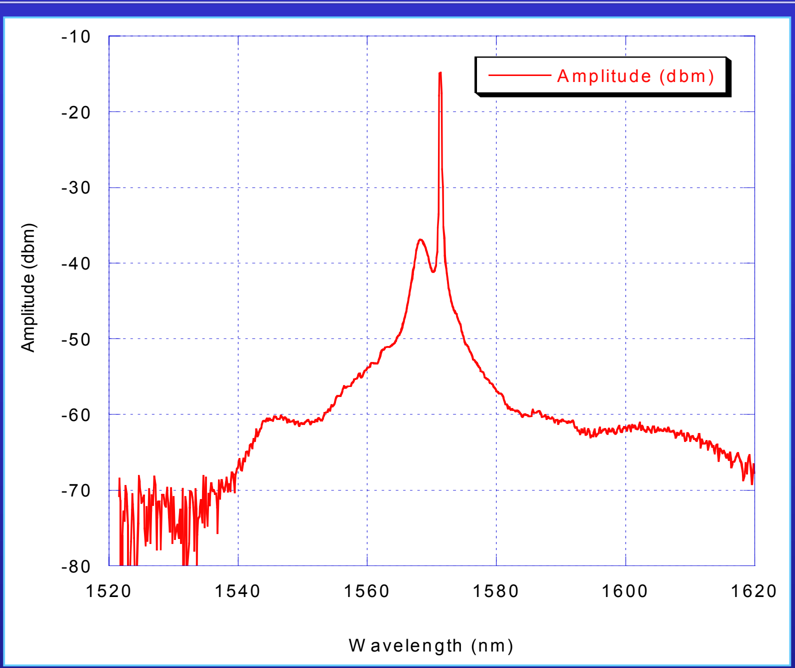


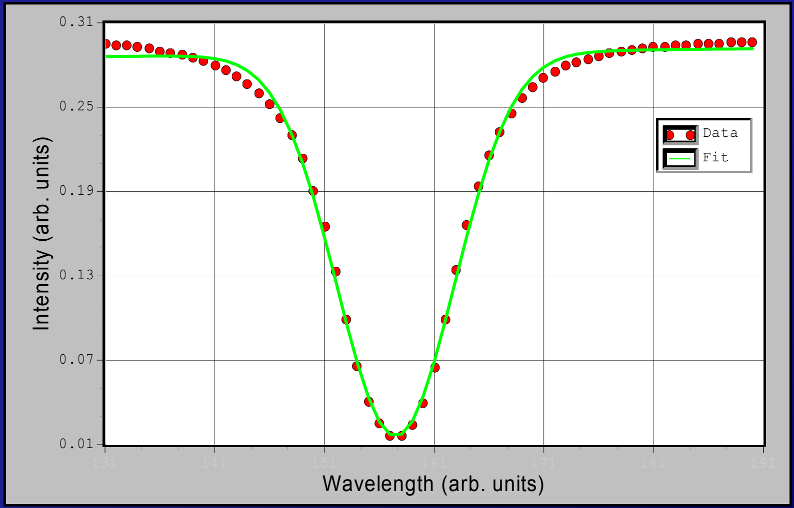
COVEGA
SOA - XXXX
SOA/DFB

Fiber Amplifier

Technology Issues

- Transmitter
  - Peak Power
  - Rep rate
  - SBS
  - ASE/Extinction Ratio
  - Non-linearities
  - Space qualification
- Receiver
  - Quantum efficiency
  - Lifetime





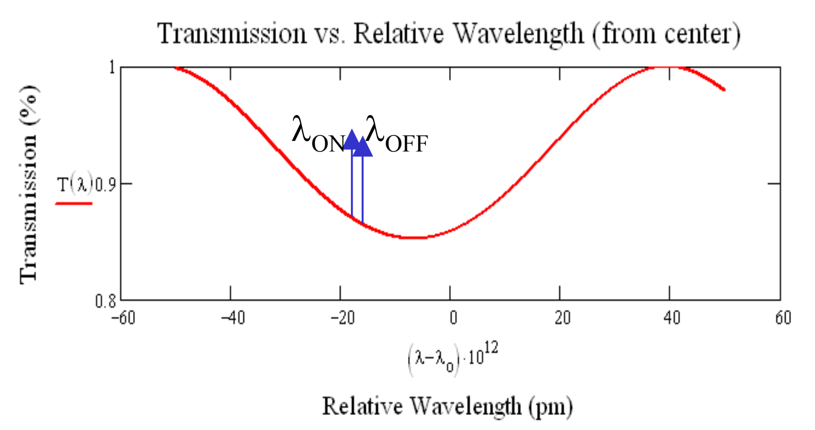
Error & Noise Sources

- Noise Sources
  - Shot noise
  - Laser noise
  - Johnson Noise
  - Amplifier noise
  - Detector Noise
  - Digitizer Noise
- Drifts (time and temperature dependent)
  - Etalon Fringes
  - Wavelength Drift
  - Opto-mechanical (alignment) drifts
  - Polarization changes
  - Fiber coupling/transmission drifts

– Instrument/Spectroscopy Errors
  - Doppler Shift
  - Absorption temperature dependence

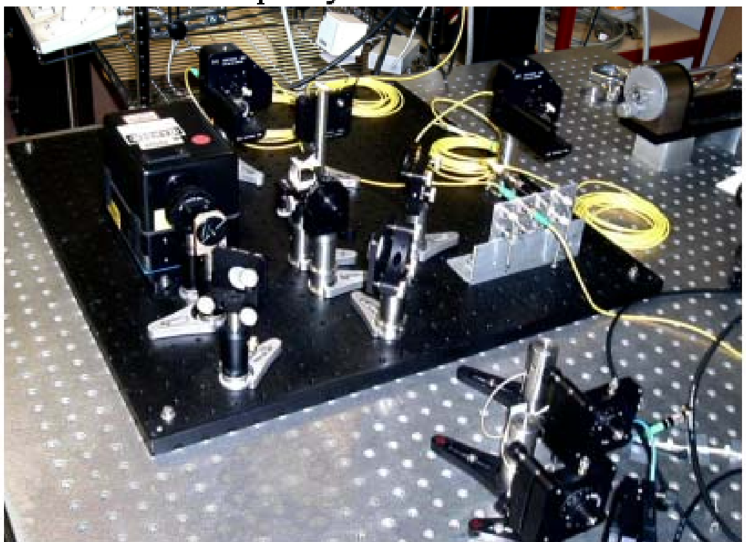
$$\frac{P_{Received}(\lambda_{ON})}{P_{Received}(\lambda_{OFF})} := \left(\frac{P_{Transmit}(\lambda_{ON})}{P_{Transmit}(\lambda_{OFF})}\right)\cdot e^{-\sigma\cdot N\cdot z}$$

In *any* active spectrometer the estimate of CO_2 mixing ratio is dependent on accurate knowledge of the transmitted power.

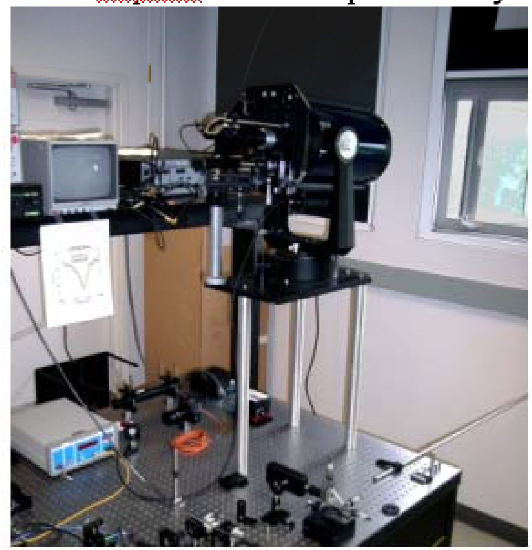


Open Path Atmospheric CO2 Measurements

Frequency Tunable diode laser

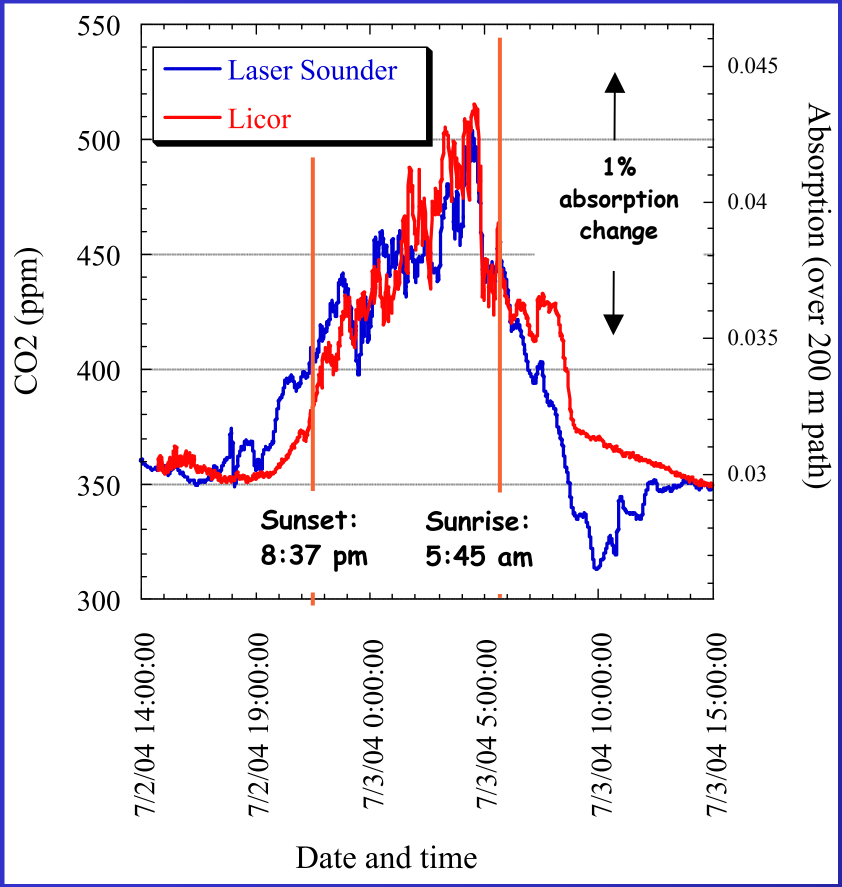


Fiber amplifer & Telescope assembly



Target (in tree)

Diurnal cycle of CO_2 measured over open path with Laser Sounder breadboard



Laser Sounder:

- 206 m one-way open-path
- Scanning over the line

Licor (in-situ samples):

- Single-point measurements from air intake on B33 rooftop
- Industry standard sensor