Retrieval of Lower Atmospheric CO2 with Clouds from Airborne IPDA Lidar Measurements

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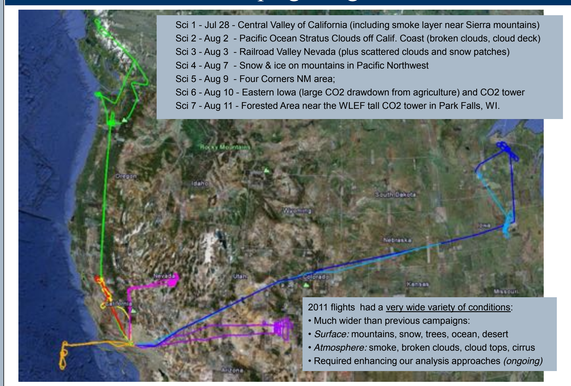
Introduction

NASA Goddard Space Flight Center has developed an integrated-path differential absorption (IPDA) lidar approach to measure atmospheric CO_2 concentrations from space as a candidate for NASA's space mission ASCENDS – Active Sensing of CO_2 Emissions over Nights, Days, and Seasons. The approach uses pulsed lasers to measure both CO_2 and O_2 absorption simultaneously in the vertical path to the surface at a number of wavelengths across a CO_2 line at 1572.33 nm and the O_2 line doublet near 764.7 nm. Measurements of time-resolved laser backscatter profiles from the atmosphere allow the technique to estimate column CO2 and O2 number density to cloud tops in additional to the ground. This allows retrieving CO2 above clouds and sampling the vertical structure of CO2 when broken and/or thin clouds are present, which helps identify sources/sinks of CO2 near the surface.

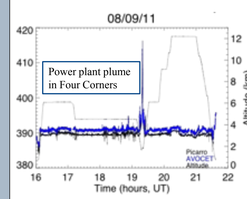
The NASA Goddard lidar team participated in the ASCENDS airborne measurement campaign in summer 2011 and flew over a variety of different sites in the U.S., along with other ASCENDS airborne lidar candidates and accurate in-situ atmospheric sensors.

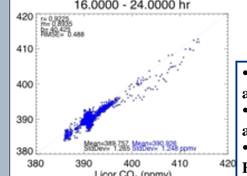
Here, we demonstrate the capability of our approach to resolve two vertical layers of CO2 in our flight over Iowa.

2011 ASCENDS Campaign Flights - Ground Tracks

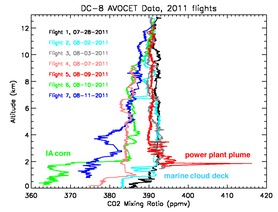


In-situ Data



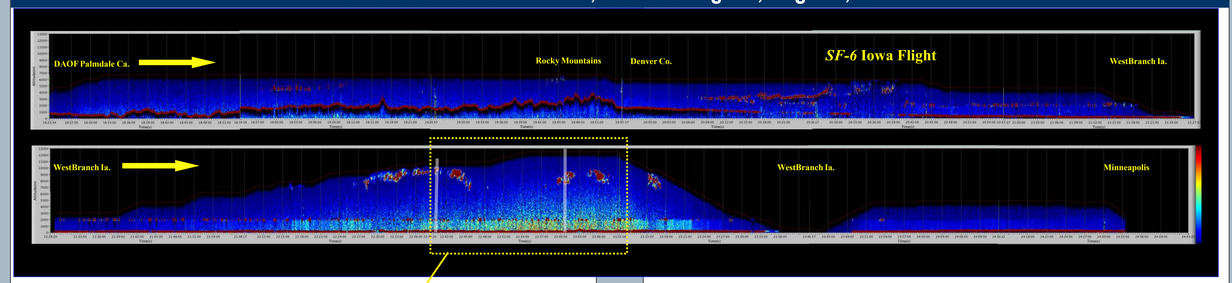


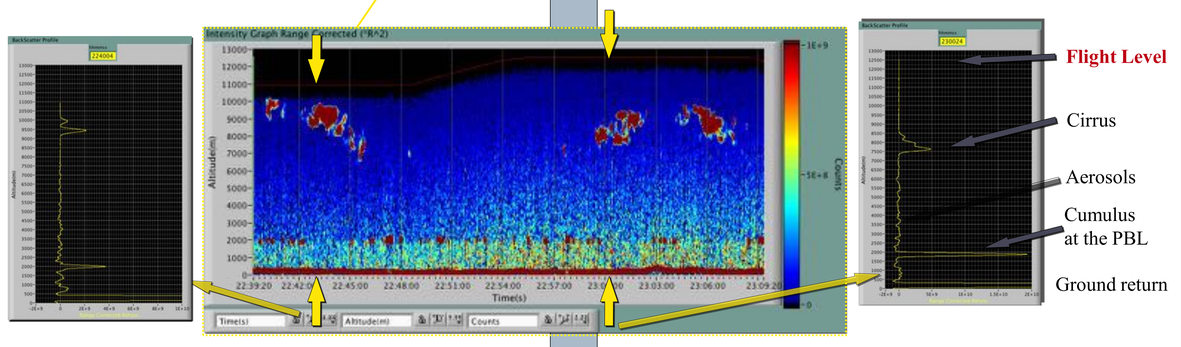
CO2 profiles from spiral down segments



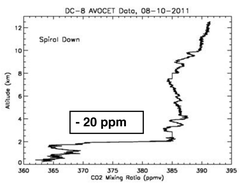
- **AVOCET and Picarro CO_2 along flight tracks and vertical profiles during spiral down flights**
- **LaRC on-site radiosondes - Z, P, T, H_2O on 7/28 and 8/3**
- **DC-8 REVEAL flight data (flight altitude, P, T, H_2O, radar ground elevation, aircraft pitch/roll angles, etc)**
- **Other – weather stations and model analysis data**

Lidar Backscatter Profiles , Science Flight 6, Aug. 10 , 2011



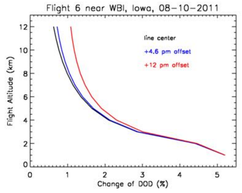


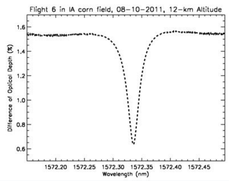
Sensitivity Analysis for CO2 Vertical Information



~ 20 ppmv drawdown over cornfield in the West Branch, IA, during Science Flight 6 to Iowa on Aug. 10, 2011. The column-average XCO2:

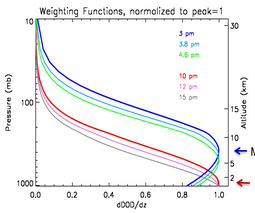
surface-2 km: *367* ppmv
2-12 km: *386* ppmv
surface-12 km: *381* ppmv





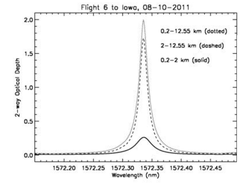
Real CO2 profile vs 385 ppm in the PBL

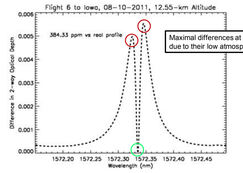
CO_2 weighting functions



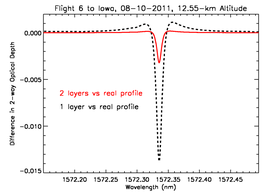
- The maximum response in optical depth at 12-km measurement altitude is 1.5% in the wings;
- Responses decrease with flight altitude;
- Only about 1% change in optical depth at +12 pm offset in response to 20 ppmv CO_2 uptake in the boundary layer.

1572.33 nm Absorption Line Shapes



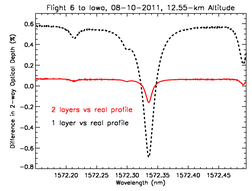


+3 ppmv bias if matching line center absorption

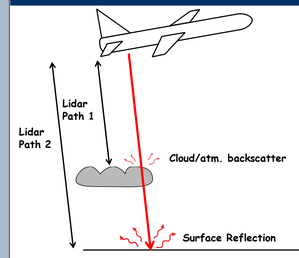


fitting error with 2 uniform layers vs. just one uniform column

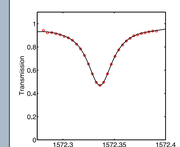
Fitting error in optical depth with 2 uniform layers is several times less than that with just one uniform column!



Retrieval Methodology

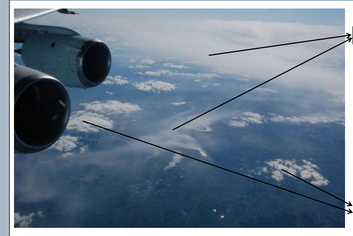


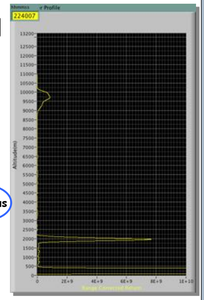
Retrieval procedure:
1. **Retrieve column-averaged CO2 above clouds by fitting absorption line and save fitted line;**
2. **Subtract the absorption above clouds from the whole column absorption above ground;**
3. **Retrieve column-averaged CO2 below clouds by fitting residual absorption**

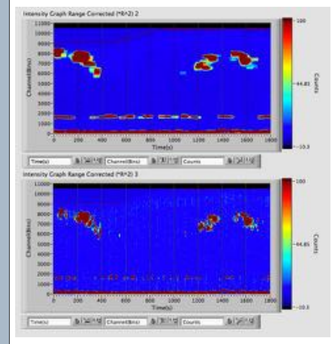


Plane-Ground = Plane-Cloud + Cloud-Ground

Retrievals for Science Flight to Iowa

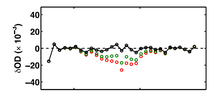




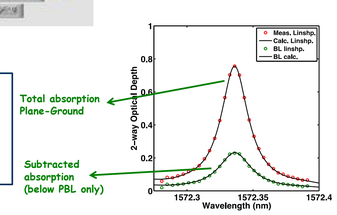


50-s average for retrieval

1-s average



- Flight Altitude: 6-km
- Cloud height: 2-km
- Retrievals:
  Aircraft-Cloud: 381 ppmv;
  Cloud-ground: *368* ppmv



Summary

- Demonstrated retrieving lower atmospheric CO2 by using IPDA measurements to both ground and to cloud tops (*lidar cloud slicing*)
- Approach also allows retrieving CO2 column above clouds
- Allows better separating atmospheric transport from surface processes