



# **END-TO-END TESTBED FOR RAPID ANALYSIS OF LASER REMOTE SENSING DATA AND APPLICATION TO FLIGHT DATA IN PREPARATION FOR ASCENDS**

T. Scott Zaccheo\*, Hilary E. Snell\*, Jeremy Doblert†, Michael Dobbs‡, Edward Browell+ and Berrien Moore‡

*\*AER, Inc, Lexington, MA 02421-3126, †ITT Corporation, Fort Wayne, Indiana 46801,  
+NASA Langley Research Center, Hampton, Virginia 23681, ‡Climate Central, Inc.,  
Princeton, New Jersey 08542*

- **Introduction**

- Commercial/Government/University partnership development of integrated instrumentation and software analysis tools for risk reduction and assessment of ASCENDS mission.

- **Objectives**

- Outline integrated software test-bed for instrument simulations and instrumentation analysis

- **Design**

- Modular approach for integrating simulations and instrument analysis into common software architecture

- **Application**

- Results from airborne campaign

# Introduction: Airborne Risk Reduction Program for ASCENDS Mission



- **Commercial/Government/University partnership development of integrated laser absorption instruments and tools for assessing ASCENDS mission feasibility and performance**

- ITT Corp, Space Systems Division
- NASA Langley Research Center
- Climate Central and University of New Hampshire
- AER, Inc

- **Team Objectives**

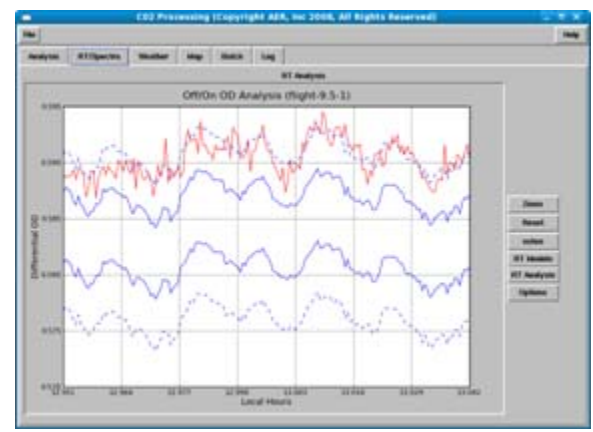
- Develop advanced sensor systems and analysis tools for demonstrating mission concept and providing risk reduction technologies for the measurement of column CO<sub>2</sub> mixing ratio in support of concept studies for ASCENDS

- **Major Elements**

- Analysis tools
- Ground based/Airborne Instruments
- Instrument components



**Airborne Hardware**



**Analysis Software**

# Laser Absorption Spectrometer Analysis

## Testbed Objectives

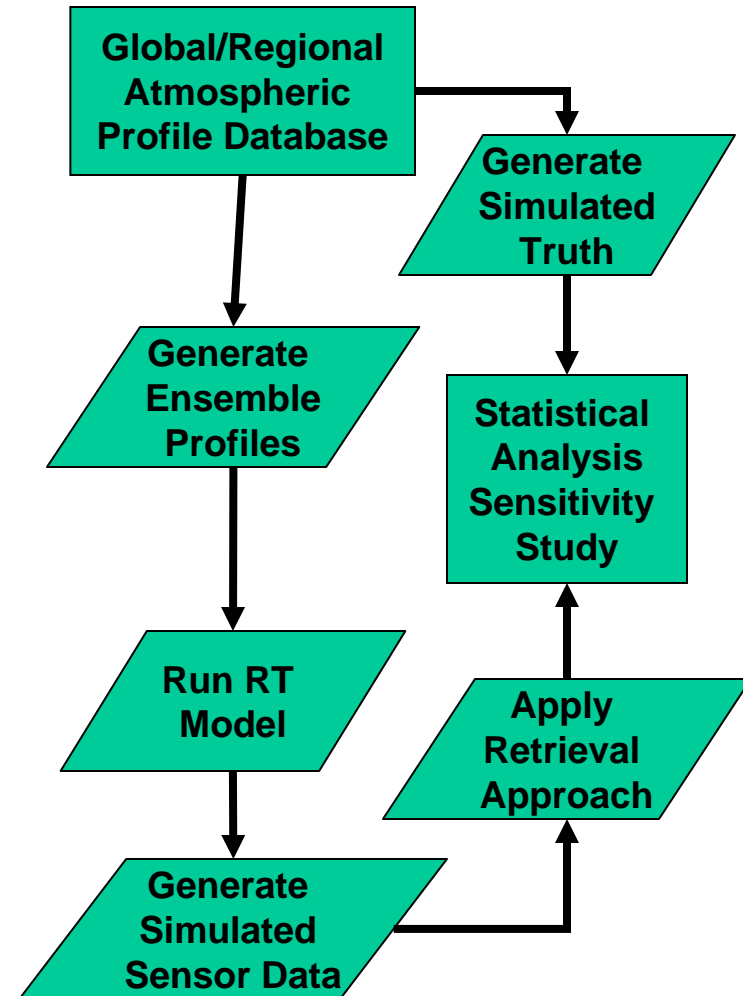
- **Provide software tools for assessing performance from laser absorption systems designed for the remote sensing of CO<sub>2</sub> and O<sub>2</sub> column amounts**
- **Develop prototype software infrastructure that provides**
  - Modular design that enables rapid development of
    - Simulation tool for assessing
      - Instrument characteristics and design issues from a radiative transfer prospective
      - Impact of CO<sub>2</sub> column measurements on regional modeling approach
      - Impact of O<sub>2</sub> measurement (surface pressure knowledge) on mixing ratio determination
    - Adaptable ground and airborne instrument data assessment and analysis applications
  - Framework for standardizing
    - Instrument data ingest
    - Common data export in self describing data format, e.g. netCDF
    - Interfaces to community radiative transfer modeling tools, e.g. LBLRTM
  - Common graphical user interface technology
  - Semi-automated methods for systematically processing and analyzing flight data
- **Complement team science analysis**

- **Features**

- Integration of community standard profile database
- Statistical methods for generating ensemble atmospheric state vectors
- Sensor characteristic interface
- Integration of community RT model elements, e.g. LBLRTM
- Common analysis tools

- **Applications**

- Sensitivity analyses of sensor configurations
- Assess the impact of global cloud cover on an operational instrument
- Assess impacts of such measurements on regional modeling of CO<sub>2</sub> dynamics



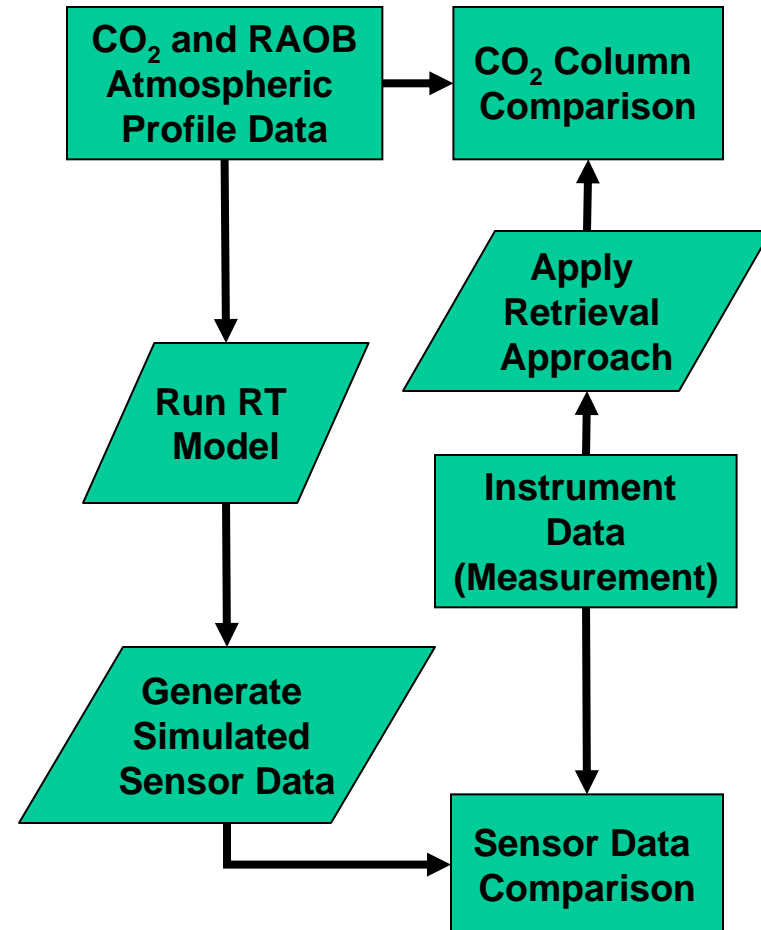
# Ground/Airborne Analysis Architecture for Automated Performance Assessment

## • Features

- Extensive reuse of simulation tool elements
- Integration in single data analysis framework
  - Actual sensor measurement data
  - Laser wavelength information
  - Aircraft GPS and angle data
  - Flight specific rawin/radiosonde met. Data as well as data from national network
  - *In-situ* CO<sub>2</sub> data, integrated to provide column CO<sub>2</sub> amount

## • Application

- Analysis of ground measurement data
- Automated assessment of ITT/LaRC flight of 100s of flight data segments
  - Sept-Oct 2008: 11 flights 100+ segments



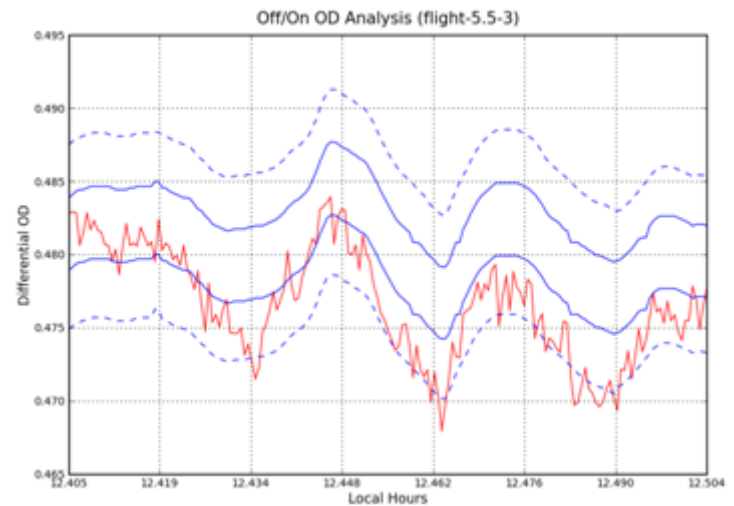
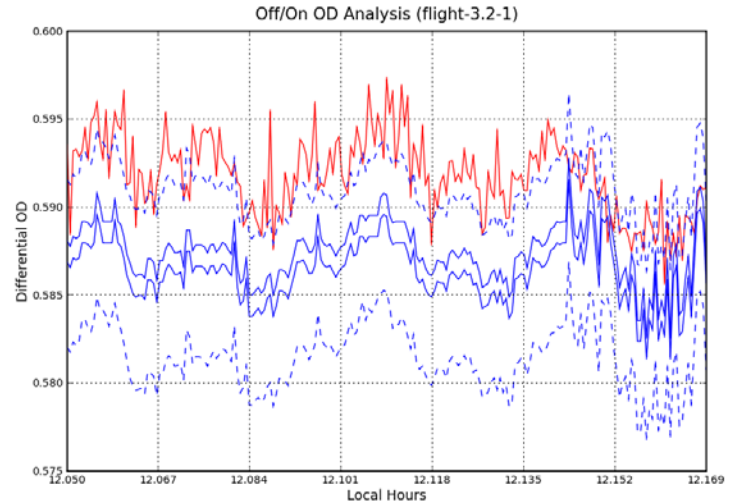
# Airborne Optical Depth Analysis: Measured vs Modeled

- **Analysis**

- Comparison of time averaged observed differential optical depths with model results
- RT model results based on instrument characteristics, *in-situ* measurements, and flight geometry

- **Example**

- **Red:** Observed optical depth differences between “Off” line and “On” line measurements
- **Blue:** Model results
  - Solid: Nominal model values given multiple *in-situ* measurements
  - Dashed: min/max model values given uncertainties in wavelength knowledge and atmospheric state



# Airborne CO<sub>2</sub> Column Analysis Estimates Verses insitu Measurements

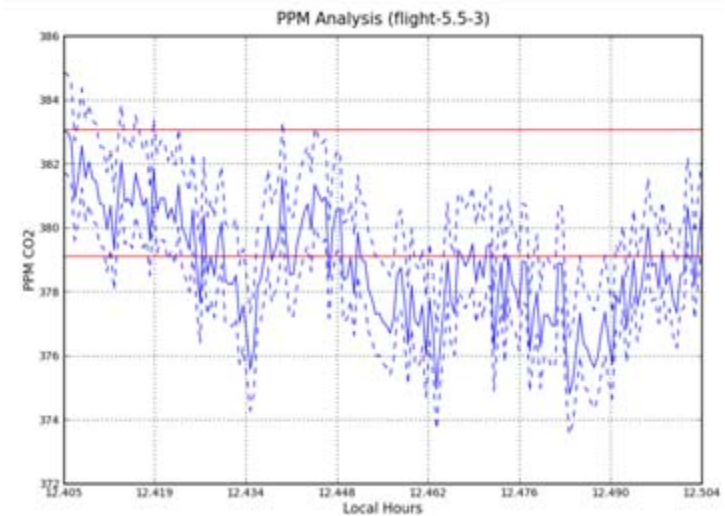
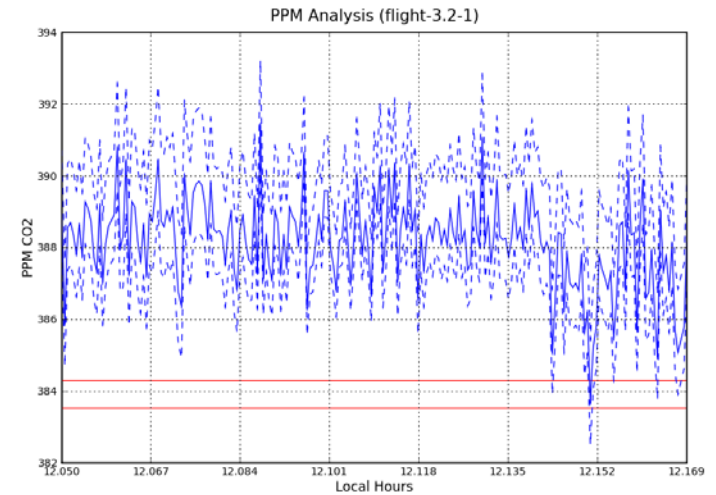


- **Analysis**

- Comparison of time averaged estimated CO<sub>2</sub> column amounts with computed *in-situ* values
- Modeled results based on derived optical depths and RT calculations given vertical profiles of T/RH and nominal CO<sub>2</sub>

- **Example**

- **Red:** Column CO<sub>2</sub> derived by integrating *in-situ* profiles
- **Blue:** Instrument measurement results
  - Solid: Nominal values
  - Dashed: min/max values given uncertainties in wavelength knowledge



- **Laser Spectrometer Sensor Simulation:** We have developed software to perform realistic, end-to-end sensor simulations and compare the results with measured radiometric data (radiances/transmittances) or the retrieved geophysical quantities. This system has a user-oriented interface which provides the ability to combine data from multiple sensors with surface and upper air in-situ measurements, automatically acquired via standard network protocols (FTP, HTTP), to develop in-depth custom analyses of instrument data, to model expected results by coupling atmospheric state data with state-of-the-art radiation transfer models (LBLRTM) or to perform combined data analyses using custom tools.
- **ASCENDS:** The overall infrastructure described in this poster is being applied to the design of an aircraft laser absorption spectrometer system in support of notional concept studies for the ASCENDS space-borne system.