Session 1, ID #3

Carbon Cycle Modeling Applied to Evaluation of Future Satellite CO_2 Mission Concepts

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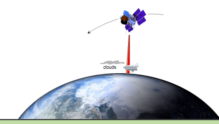
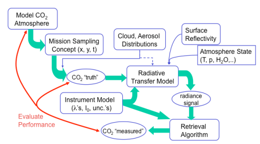


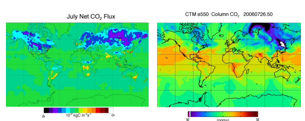
Introduction and Abstract

We present results of mission simulation studies for a laser-based atmospheric CO_2 sounder. The simulations are based on real-time carbon cycle process modeling and data analysis. The mission concept corresponds to the Active Sensing of CO_2 Emissions over Nights, Days, and Seasons (ASCENDS) recommended by the US National Academy of Sciences Decadal Survey of Earth Science and Applications from Space. One prerequisite for meaningful quantitative sensor evaluation is realistic CO_2 process modeling across a wide range of scales, i.e., does the model have representative spatial and temporal gradients? Another requirement is a relatively complete description of the atmospheric and surface state, which we have obtained from meteorological data assimilation and satellite measurements from MODIS and CALIPSO. We use radiative transfer model calculations, an instrument model with representative errors, and a simple retrieval approach to complete the cycle from "nature" run to "pseudo-data" CO_2 (schematic below). Sensitivity to instrument configuration and environmental conditions is explored, and sample "data" are examined for their ability to address key carbon cycle science questions.



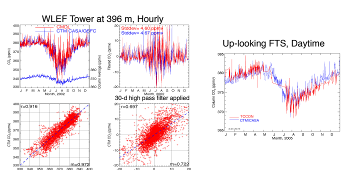
ATMOSPHERIC CO_2 MODEL

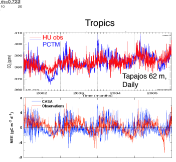
Overview



- Met fields from Goddard Global Modeling and Assimilation Office, version GEOS-4.
  - 3-hour averages from analysis used in off-line transport, runs done for year 1998-2006
  - Model Grid: 1° x 1.25° x 28 levels to 0.4 mbar, hybrid terrain-following coordinate, output hourly
- Monthly global biosphere fluxes at 1x1° from CASA using monthly mean GEOS-4 analyzed meteorology and monthly NDVI.
  - 3-hourly CASA net fluxes from 3-h analyzed radiation and temperature in method of Olsen and Randerson (JGR, 2004)
  - Biomass burning from GFED2 included in CASA monthly fluxes
- Fossil Fuel emissions and ocean fluxes from TransCom-C.

Model Evaluation

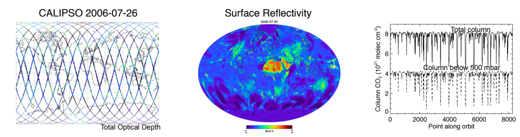




- Model output well-correlated with observations on time scales from hourly to synoptic to seasonal at mid-latitude and tropical sites.
- Similar results at many other sites (e.g., Kawa et al, JGR, 2004).

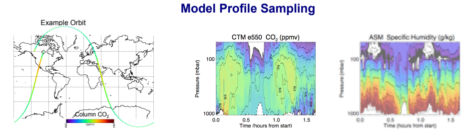
SPACE MISSION CONCEPT

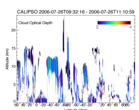
Orbital Sampling Data



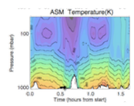
- CALIPSO orbit: sun-synchronous 0130/1330 hrs equator crossing.
- 5-km CALIPSO orbit data sampled at nominal averaging time of CO_2 laser sounder, 10 s in this case (~70 km).
- MODIS 16-d composite 5-km nadir reflectance sampled over land.
- Glint nadir reflectance from 10-m wind speed over ocean.
- Vertical weighting function can be applied to model CO_2 profiles; uniform column weighting used below.

Model Profile Sampling



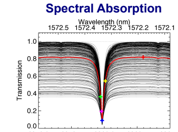


- Profiles of CO_2, T, H_2O are interpolated from the model analyses at the nearest output time.
- Cloud and aerosol optical depth profiles are taken from CALIPSO measurements.



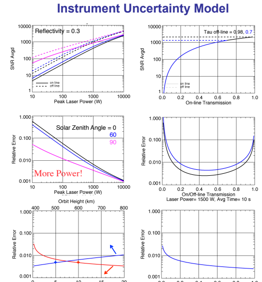
RADIANCE CALCULATIONS AND MEASUREMENT ERRORS

Spectral Absorption



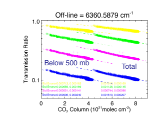
- Transmission calculated for each profile sample.
- Most variability produced by cloud attenuation.
- Average spectrum and candidate laser measurement wavelengths shown in colors.
- Samples with cloud + aerosol optical depth > 1 are screened from analysis (~37% accepted).

Instrument Uncertainty Model



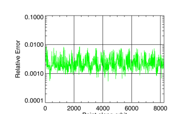
- Detected radiance signal-to-noise and relative error are sensitive to instrument/mission configuration and atmospheric conditions.
- No spectroscopy, parameter, a priori or retrieval fitting error included.

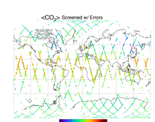
CO_2 Measurement Error

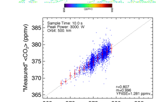


Simplified Retrieval:

- CO_2 column ∝ log(on-line/off-line transmission)
- <CO_2> error equals relative error in log radiance ratio plus 2-mbar uncorrelated error in surface pressure.
- Pulsed transmitter/range-gated receiver approach allows neglect of errors from atmospheric scattering.



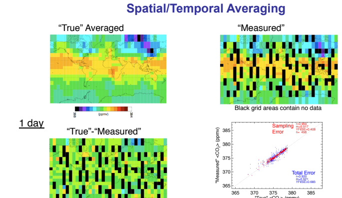




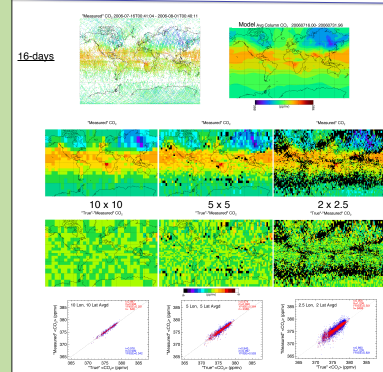
- Single-sample errors average 1.28 ppmv for this instrument configuration.

"DATA" COMPOSITING

Spatial/Temporal Averaging

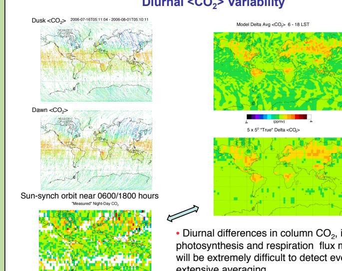


- Spatial averaging of 1 day's data yields measurement precision of 0.7 ppmv.



- Random errors continue to diminish with further averaging.
- Largest errors are in regions of strong, changing gradients.
- Optimum data averaging will depend on application, e.g., inverse model.

Diurnal <CO_2> Variability



- Diurnal differences in column CO_2, indicative of photosynthesis and respiration flux magnitudes, will be extremely difficult to detect even with extensive averaging.

Summary

We have assembled a simulation and data analysis framework for testing the potential performance of a future laser-based CO_2 space mission (e.g., ASCENDS). The methodology, however, is generally applicable to others including passive sensors. Initial simulations using reasonable technological assumptions for the system performance, show that relatively high CO_2 measurement precision can be obtained. Errors depend strongly on environmental conditions as well as instrument specifications. A next step will be inverse calculations using the pseudo-data. See Kawa, S. R., J. Mao, J. B. Abshire, G. J. Collatz, X. Sun, and C. J. Weaver, (2010), Simulation studies for a space-based CO2 lidar mission, Tellus-B, submitted.

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