Retrieving CO_2 Column Variations Feasibility and Initial Results

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1 Introduction

- We investigate the feasibility of retrieving CO_2 column variation from upwelling infrared radiation, and present some preliminary simulation results
- Motivation:
  - CO_2 variation is of considerable climatological interest
  - Retrieval of CO_2 variations could be used to refine atmospheric temperature retrievals
- Accurate retrieval of CO_2 variation is difficult, because the CO_2 component of upwelling infrared radiation is very sensitive to temperature variation

2 Methods

- For this study we used our latest AIRS (Atmospheric InfraRed Sounder) fast radiative transfer model, calculating 2373 AIRS channels from approximately 600 cm^{-1} to 2700 cm^{-1}

- The CO_2 component of upwelling infrared radiation is very sensitive to temperature variation; in fact CO_2 lines are the basis for most temperature sounding
- This temperature sensitivity makes it hard to detect small variations in CO_2 amount
- There is an interval at 792 cm^{-1} with significant $dB/d(CO_2)$, compared to dB/dT
- We took a large set of atmospheric profiles, varied the CO_2 amount by a few percent, and tried to retrieve this variation
- We used the 1761 TIGR profiles with
  - Surface temperatures simulated by taking a normal distribution with 4K variance, centered at the surface air temperature
  - Emissivity was varied uniformly from 0.8 to 1.0, or from 0.97 to 0.99, for some tests
  - CO_2 varied from the reference profile by a normal distribution with variance of 2% (or 3%, in one test)
- The TIGR set was divided into dependent and independent sets of 880 and 881 profiles, respectively
- For most tests, we used the full set of 2373 AIRS channels, as calculated by our radiative transfer model
- For the first tests, we used regularized regression, with a 35-element basis for spectra
- Tests were done with both single-spot AIRS noise, and noise reduced by factors of 4 and 10, to represent averaging over a larger area
- In addition to CO_2, temperature, surface temperature, and emissivity retrievals were also done, mainly to test the code

3 Results

- Some CO_2 variation was detected; RMS average retrieval error was typically 1.2 to 1.3 percent absolute, 60 to 65 percent relative, varying with details of the particular test
- CO_2 retrievals were not too sensitive to instrument noise, at least with the full set of 2373 channels
- CO_2 retrievals were not too sensitive to variations of emissivity or surface temperature
- CO_2 sensitivity (from regression coefficients) was found across most of the AIRS spectra
- Increasing the CO_2 variation in the simulation increased absolute error but decreased relative error

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Tests 3, 4, 5: Varying Noise
TIGR surface temps
CO2 variability: normal distribution, variance 2%
Emissivity: uniform distribution from 0.8 to 1.0

   Test Number          3           4          5
AIRS Noise Scaling     1.0         0.25       0.1
absolute pct error     1.28        1.24       1.24
relative pct error      64          62         62
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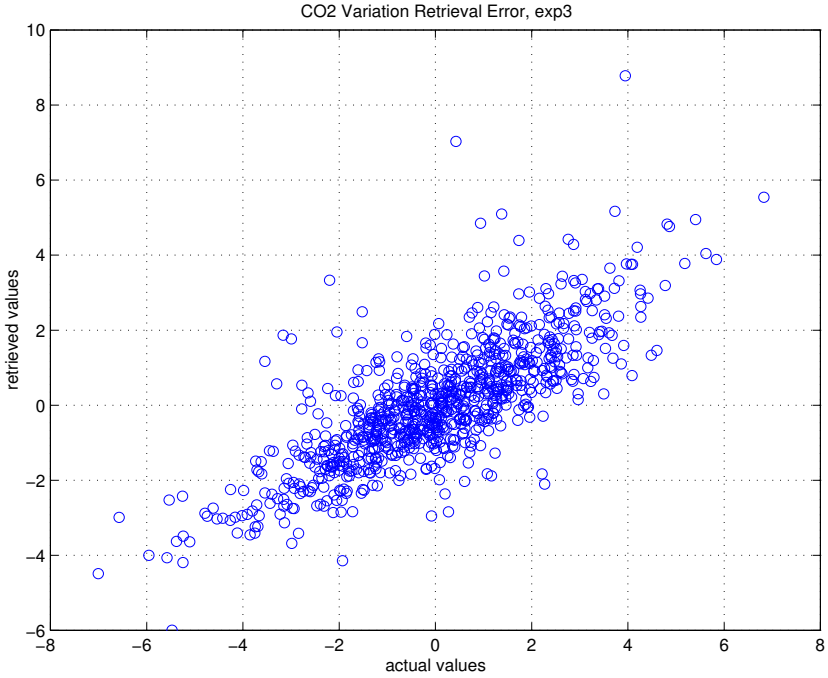
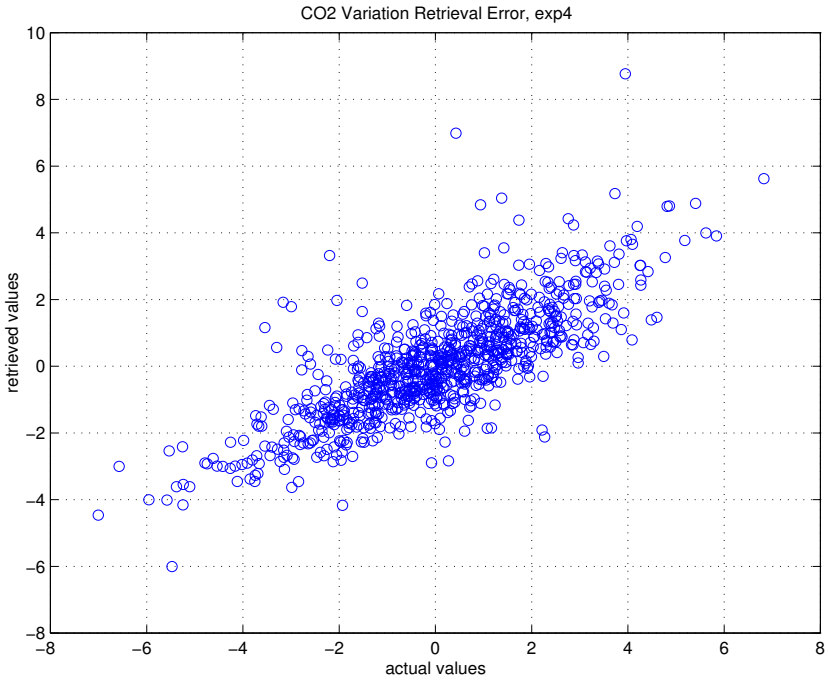
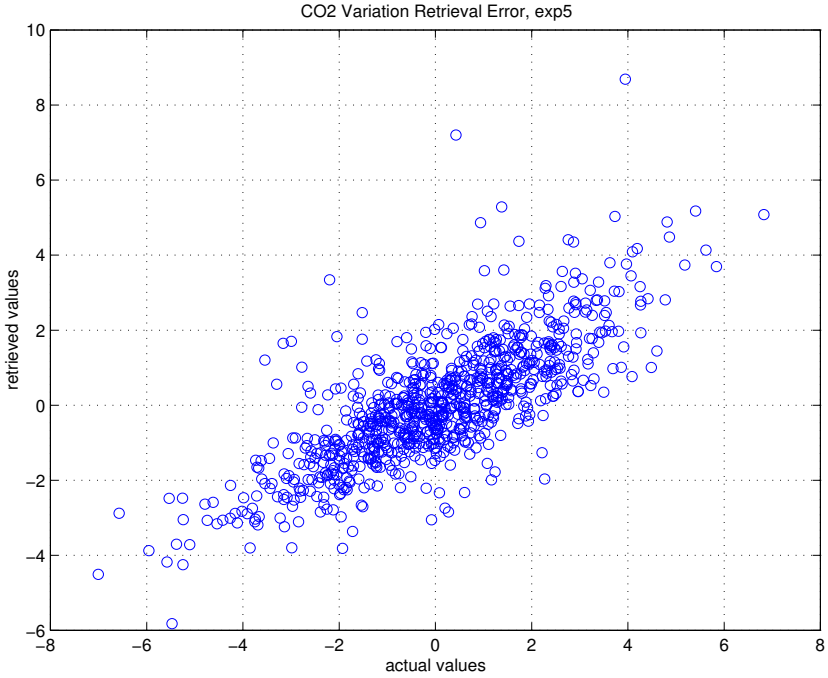
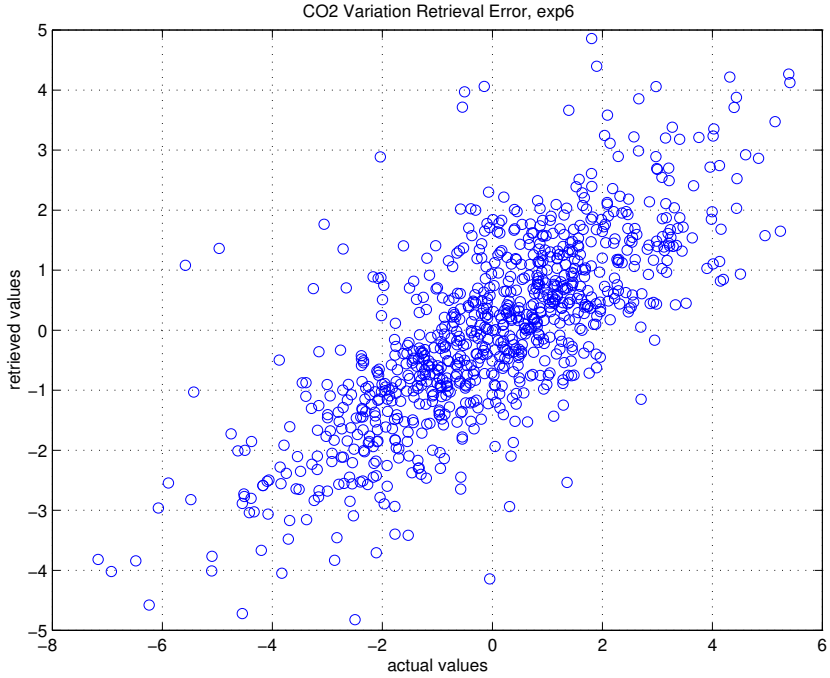

CO2 Variation Retrieval Error, exp3
retrieved values
actual values
10
8
6
4
2
0
−2
−4
−6
−8
−6
−4
−2
0
2
4
6
8

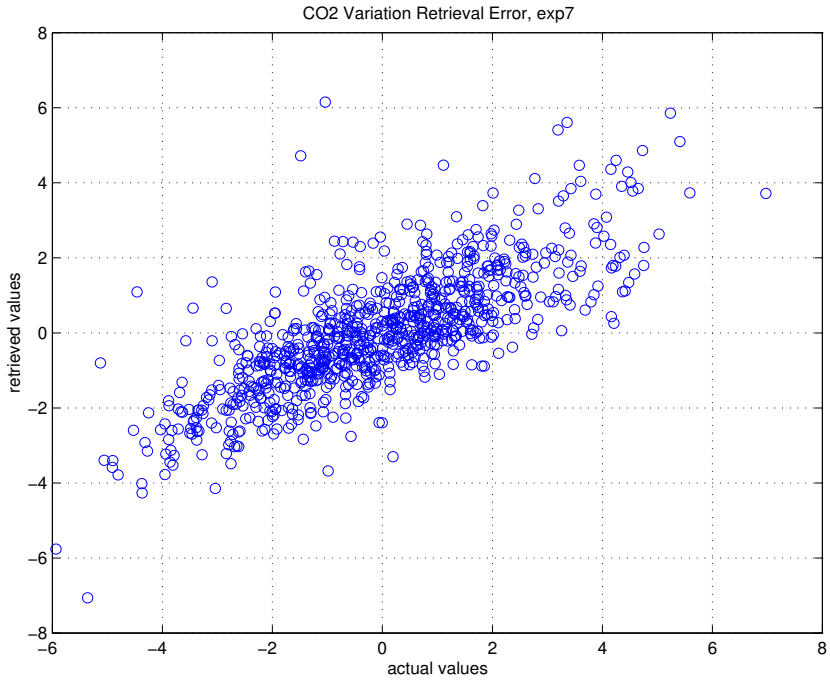

CO2 Variation Retrieval Error, exp4
retrieved values
actual values
10
8
6
4
2
0
−2
−4
−6
−8
−6
−4
−2
0
2
4
6
8



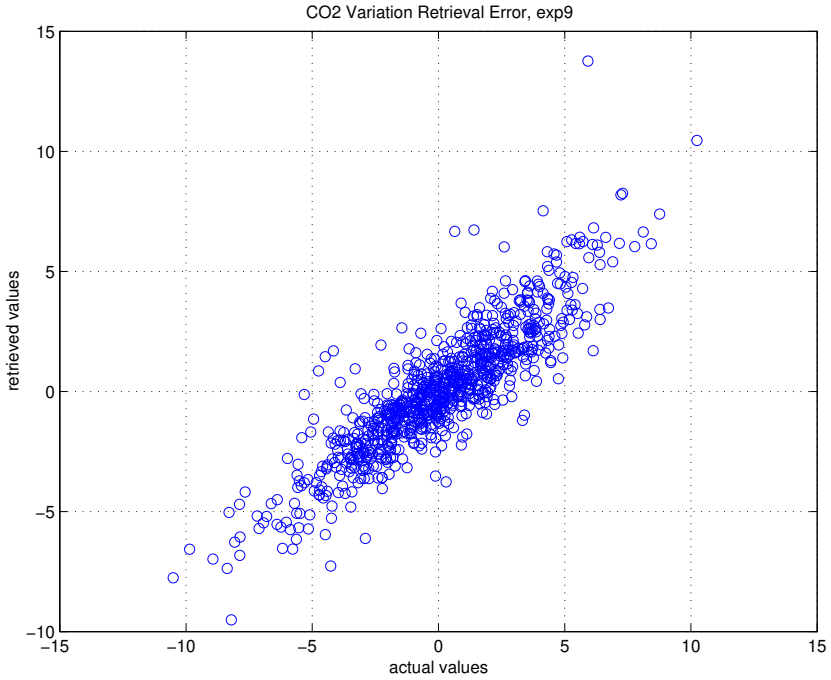
Tests 6, 7: Varying Surface Temperature and Emissivity
Surface temp w/ 4K variance from lowest air
CO2 variability: normal distribution, variance 2%
AIRS noise scaling: 0.25

Test Number	6	7
Emissivity Range	0.80 to 1.0	0.97 to 0.99
absolute pct error	1.35	1.28
relative pct error	67	64


CO2 Variation Retrieval Error, exp6
retrieved values
actual values
5
4
3
2
1
0
−1
−2
−3
−4
−5
−8
−6
−4
−2
0
2
4
6


CO2 Variation Retrieval Error, exp7
retrieved values
actual values
8
6
4
2
0
−2
−4
−6
−8
−6
−4
−2
0
2
4
6
8

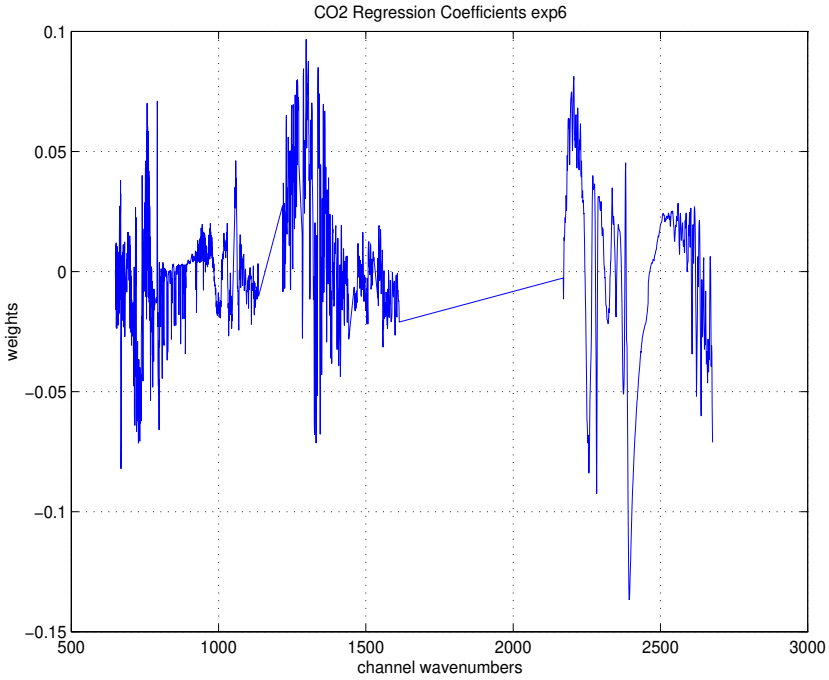
```
Test 9: Increasing CO2 Variation
Surface temp w/ 4K variance from lowest air
CO2 variability: normal distribution, variance 3%
emissivity: uniform distribution from 0.97 to 0.99
AIRS noise scaling: 0.25

   Test Number            9
absolute pct error       1.42
relative pct error        48
```

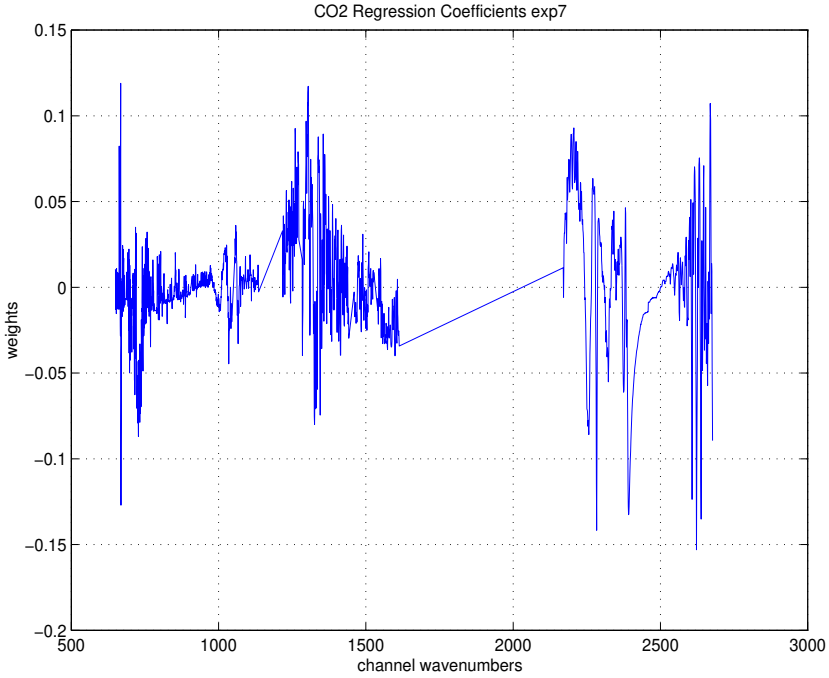


4 Jacobians and Regression Covariance

- While some of the retrieval covariance matrices showed a significant sensitivity at 792 cm^{-1}, this was by no means a predominant effect
- Much of the CO_2 sensitivity appears to be in "water regions"
- These regions also have some temperature sensitivity

- This sensitivity is independent of CO_2 amount, and so in combination with the CO_2 regions can give some indication of CO_2 amount





5 Conclusions and Further Work

- Some information about CO_2 variation can be retrieved with statistical methods
- The sensitivity to CO_2 variation was not where we'd initially expected to find it, occurring over a much wider spectral region
- It is likely that this approach works (as well as it does) due to temperature sensitvity of non-CO_2 components, and in particular, water
- Retrieval accuracy might be improved with further independent temperature information, e.g., from microwave or other soundings, and perhaps with physical iterative methods