AIRS Measurements of $\sim$500 mbar CO_2 over Land.

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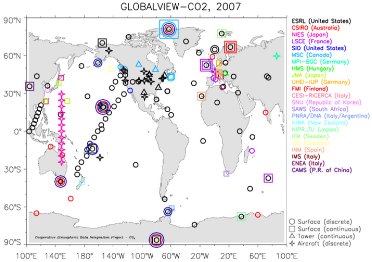
Why satellite measurement of atmospheric CO_2?

- CO_2 is the most relevant Atmospheric greenhouse gas.
- Knowledge of CO_2 concentration in the Atmosphere is limited.
- NOAA GlobalView - Network of CO_2 site measurements.



- Open questions about CO_2 Sinks - Baker, SCIENCE (316) 1708.
- More observations will force improvements on transport models - Gurney, et al. NATURE (415) 626.

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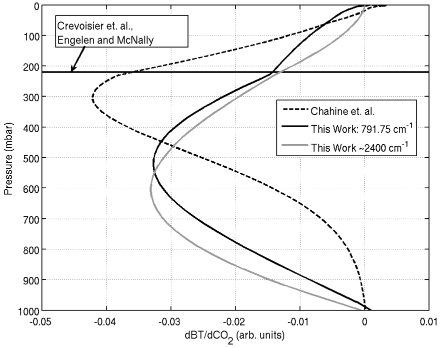
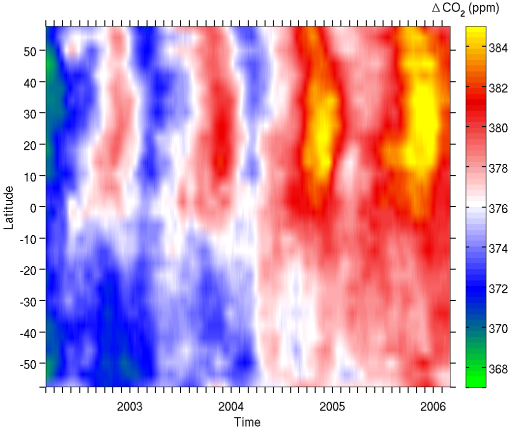
Previous Remote sensing results

- Upper-Troposphere (200mbar - 300mbar) - Chédin/Crevoisier et al./Engelen,McNally/Chahine et al.
- SCIAMACHY (total column, land only)- Atmos. Chem. Phys. Discuss., 8, 5477, 2008.
- Mid- to Lower-Troposphere (500mbar) over Ocean: Strow, Hannon.



Retrieval over Ocean with AIRS
Easy to find clear FOVS

- Strow-Hannon - Submitted JGR-2007
- 2Km-9Km range. Accurate at the 0.5 – 1.0 ppm level
- Calibrated using Mauna Loa



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This Work - Retrieval over Land

- Apply similar technique over Land FoVs.
- Using AIRS ACDS subset from GSFC/DAAC
- Goal is to sense as close to surface as possible

- Atmospheric state from ECMWF forecast model.
- L1b Radiances from ACDS (tried L2 CC'd radiances)
- Wisconsin Land Emissivity.

- Issues: (1) Limited clear in ACDS, esp. night, (2) Residual clouds, esp. cirrus?.
- Residual low clouds may be OK, but cirrus is deadly
- Very Preliminary! Needs further validation, cloud correction (elimination), increase yield.

Application of the Calibration AIRS Dataset

- AIRS Calibration (Climate) Data Set (ACDS or AIRXBCAL.005)
  - Contains a “clear set of FoVs” product.
  - Low yield at night (e.g. Sahara) and sometime at high latitudes (snow?, too many clouds?)
  - A fraction of the clear FoVs seems to contain residual cirrus/low clouds - further filtering required.
- L2 Cloud Cleared data - Seems to introduce errors greater than 0.5K (15 ppm) - Not used here. Testing over oceans shows -4K and colder biases in window regions of CC’d radiances at higher latitudes ($> \pm 50$ degrees).

Initial Adjustment

- Attempt to eliminate $B_{obs} - B_{calc}$ biases by changing atmospheric state variables.
- Treat ECMWF $T(z)$ as accurate, but not T_{surf}
- Treat ECMWF $Q(z)$ as correct up to a overall scale factor.
  - Adjust T_{surf} with either longwave window chans (daytime) or shortwave window chans (nighttime).
  - Adjust water multiplier Q similarly.
  - Again, adjust T_{surf}.
- Simple Newton method: give a model variable x, for each channel:

$$\delta x = \frac{B_{obs} - B_{calc}(x_0)}{\left(\frac{\partial B}{\partial x}|_{x_0}\right)}.$$

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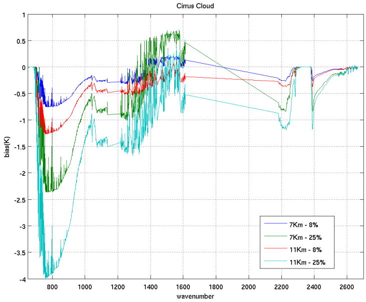
Cirrus Flags

- ACDS cloud contamination significant for CO_2, esp. cirrus?
- Simple Bias-based flag: (may need further noise-reduction)

$$\Delta B^{961} - \Delta B^{811} \leq 0.5K.$$



- Flags about 40% of FoVs - maybe too restrictive.

Retrieval Method

- Shortwave range: $2393cm^{-1}$ to $2420cm^{-1}$ - Less noisy, less sensitive to cirrus, **but** need reflectance during daytime. For now only nighttime.
- Longwave - two channels:
  - $790cm^{-1}$ (no sensitivity to CO_2)
  - $791cm^{-1}$ (right on a CO_2 line).
  - Longwave can be easily used both day and night.
  - Method:

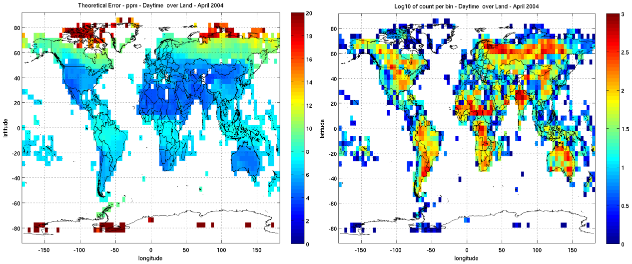
$$\begin{aligned} B^{790}_{obs} - B^{790}_{calc} &= J^{790}_{T_s} \delta T_s \\ B^{791}_{obs} - B^{791}_{calc} &= J^{791}_{T_s} \delta T_s + J^{791}_{T_{CO_2}} \delta CO_2 \end{aligned}$$

  - Residual T_s and low-clouds will be packed into the “effective” T_s.
- Simple variance prediction:

$${\sigma_{CO_2}}^2 = \sigma^2_{790} \left(\frac{J^{791}_t}{J^{790}_t J^{791}_c} \right)^2 + \frac{\sigma^2_{791}}{J^{791\,2}_c}.$$

Statistical Analysis

- Bin data in a $4^o \times 4^o$ lattice (resampling boxes).
- Ignore bins with FoV count less than 10.
- Ignore bins with $\sigma > 14$ ppm

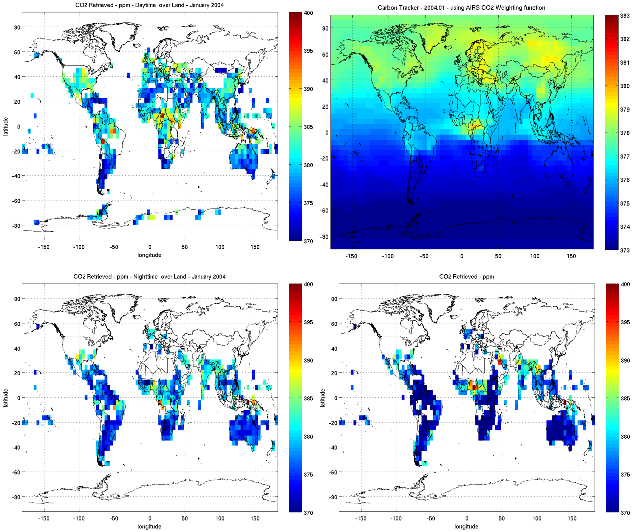


- Using the same calibration as in Strow, Hannon 2007, i.e. one-number, Mauna-Loa.

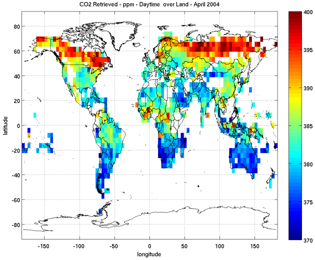
Preliminary Validation

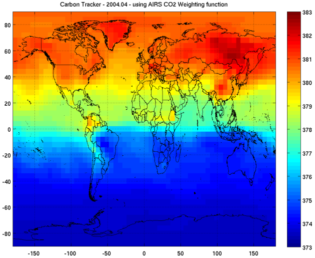
- Comparing with NOAA's "CarbonTracker" (GlobalView) Model assimilation - "Carbon Weather".
- Comparing with SCIAMACHY column CO_2- from 2008 paper.
- Show four months Maps: Jan, April, July, Oct, of 2004.

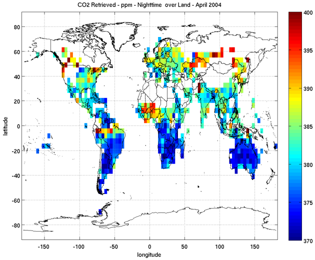
CO_2 for January 2004 - Compare with CarbonTracker

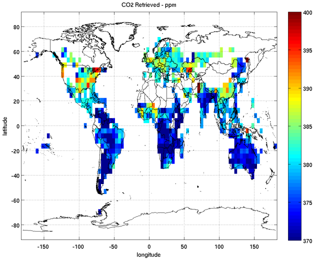


April 2004 - Compare with CarbonTracker









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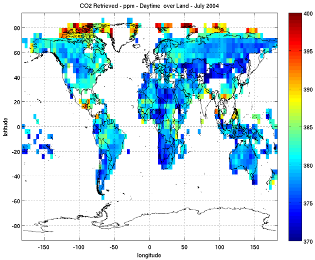
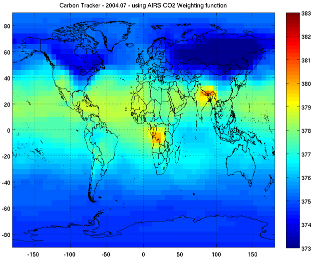
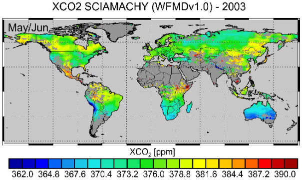
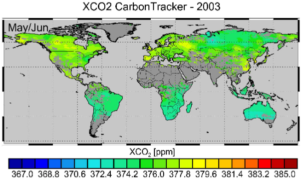
July 2004 - Comparing with CarbonTracker and SCIAMACHY

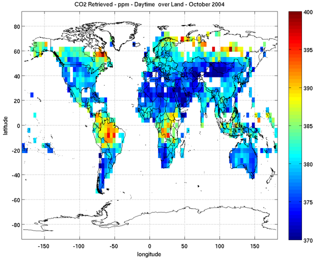


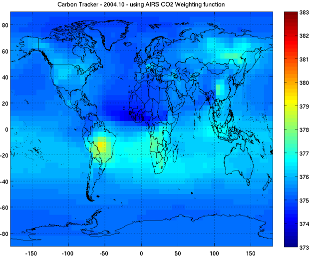


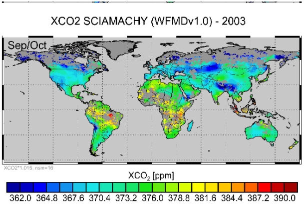


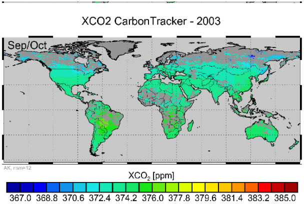


October 2004 - Comparing with CarbonTracker and SCIAMACHY









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Conclusions

- Seems promising:
  - Seasonal cycle is roughly represented.
  - Some high/low CO_2 patterns are similar to those seen on SCIAMACHY and CarbonTracker.
  - S.America and African "red spots" similar to CarbonTracker.
- Work to do:
  - April - High latitudes unlike CarbonTracker. Clouds?
  - Cloud filter not well developed yet - may be causing excessive high CO_2 values.
  - Better cloud flag / Improve ACDS Climate date set.
  - Shortwave retrieval during daytime (needs reflectance) to help with quality control.
  - Access validation data, especially at higher latitudes