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Radiative Transfer Models for IASI

Variable CO_2

L. Larrabee Strow, Scott Hannon, Sergio DeSouza-Machado, and Breno Imbiriba

Atmospheric Spectroscopy Laboratory (ASL)
Physics Department
and the
Joint Center for Earth Systems Technology

University of Maryland Baltimore County (UMBC)

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Radiative Transfer for IASI: Comparisons to ECMWF

- IASI Biases vs ECMWF (no sondes available yet)
- Poster: Compare AIRS vs IASI ECMWF biases for about 1 1/2 month time period of clear ocean scenes. Agreement better than 0.1K for mid-tropospheric channels.
- Here emphasize absolute comparisons to ECMWF, and
- Examine regions (upper trop) where some IASI and AIRS channels don't agree
- Variable CO_2 makes detailed comparisons to ECMWF difficult, so instead, use ECMWF to solve for CO_2 for lower-trop channels (in the 550 mbar range, most previous work in the 200-300 mbar range).

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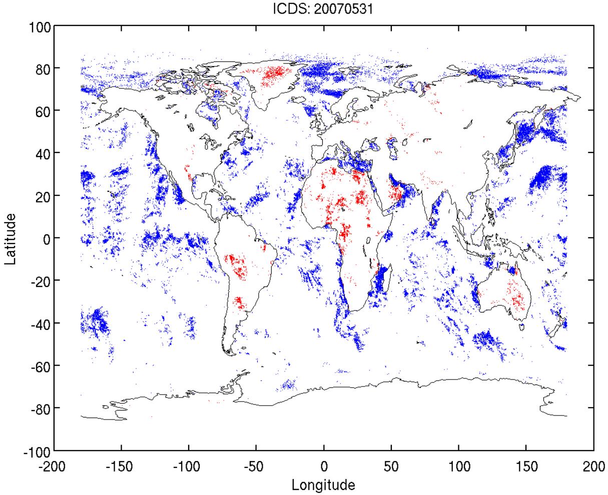
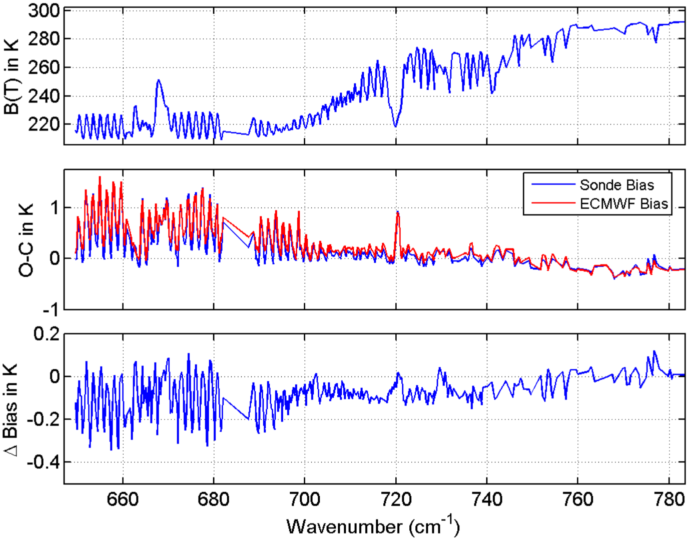
ACDS and ICDS: AIRS/IASI Cal/Climate Data Subsets

- ACDS being produced at GSFC/DAAC and is available to anyone. (This work uses similar subset produced at UMBC.)
- We have produced ~1 1/2 months of ICDS.
- Plan to produce 1-2 years of ICDS in future.
- Use for calibration, radiative transfer studies, CO_2 retrievals
- Subset data into:
  1. Clear (ocean/land)
  2. Small random selection of FOVs (nadir only)
  3. ixed sites (ARM sites, Antarctica (Dome C), desert, etc.)
  4. High convective clouds (Aumann, JPL) to record counts of coldest scenes
- Files sizes are ~200 Mbytes/day (AIRS)
- Ocean clear OK, land clear needs work
- Use IASI imager in clear algorithm, hope to use AVHRR vis for daytime clear in future.
- Subset algorithm only looks at uniformity, additional filters used for "clear" (to avoid stratus, for example).

IASI Cal/Climate Data Set: “Uniform” Fields



AIRS Result: ECMWF Biases (± 40 deg) Tied to Sondes (as advertised)



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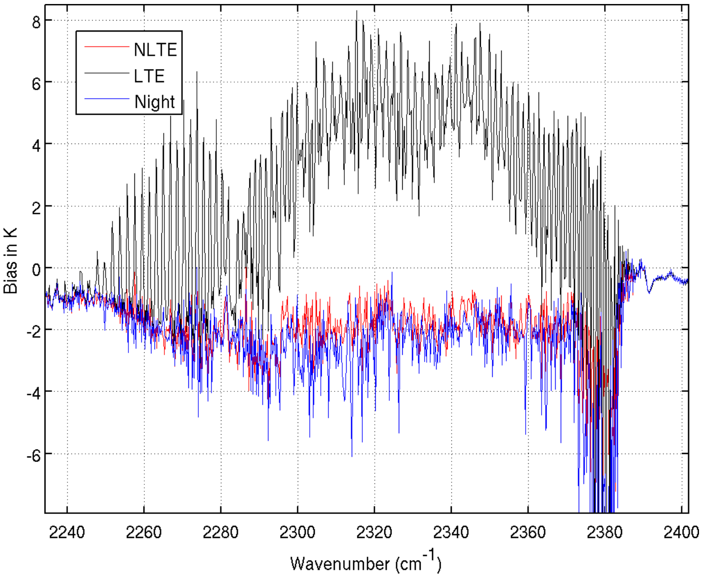
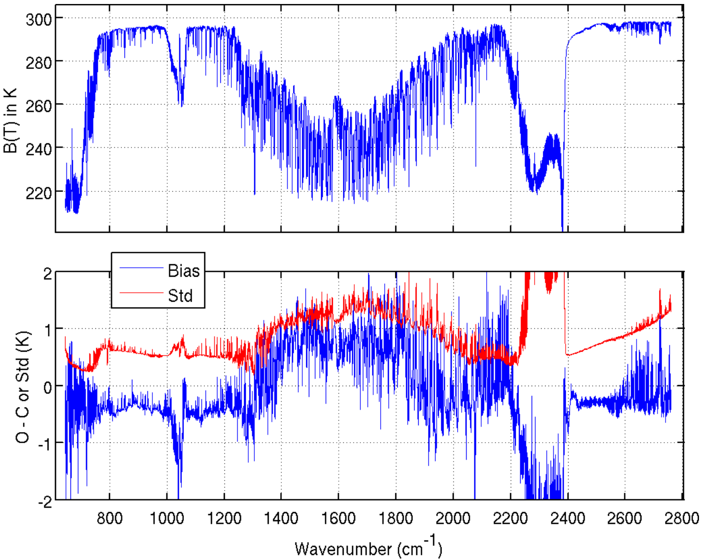
IASI Non-LTE Bias

AIRS Non-LTE Algorithm Works at 9:30 am



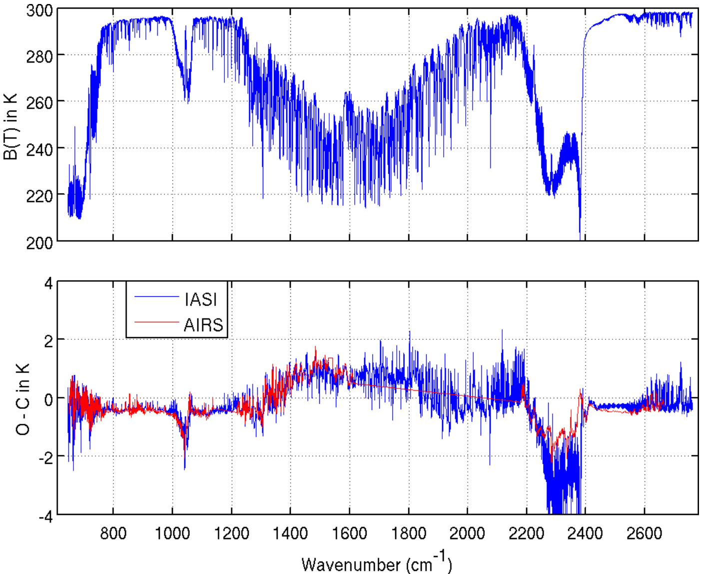
IASI Bias and Std. Summary

Clear FOVS, Ocean, Night

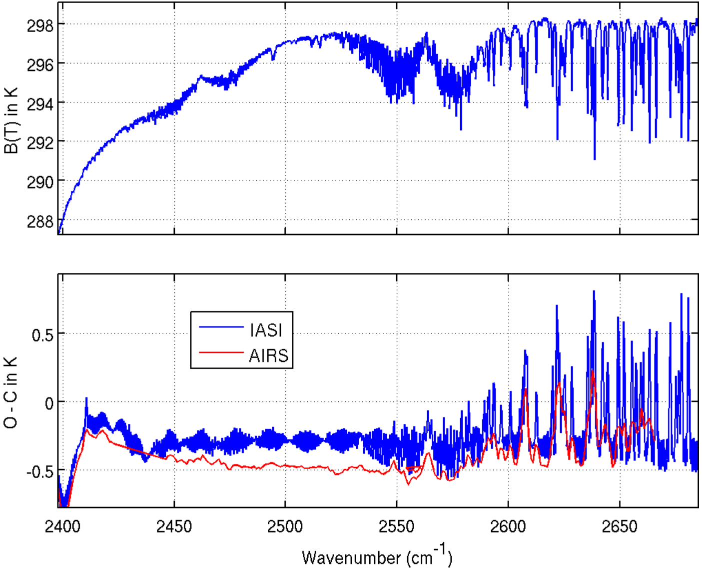


Now Add AIRS Biases

ECMWF SST stays the same, 9:30 am about 0.1K colder than 1:30 pm

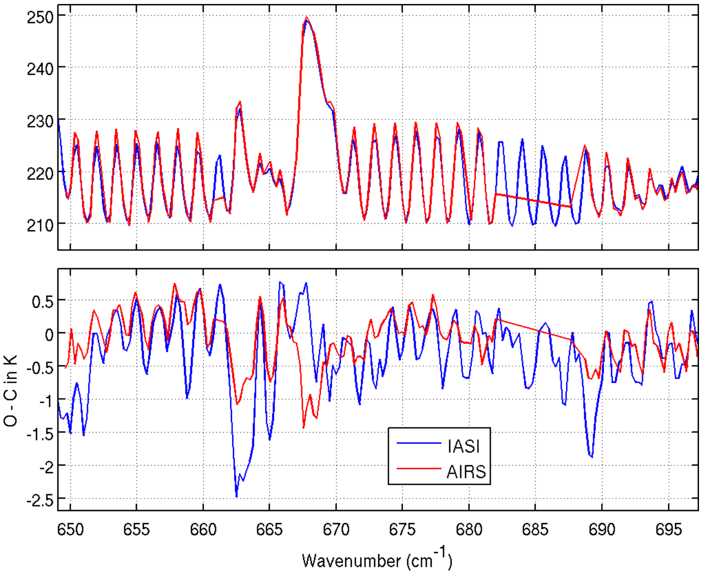


IASI Shortwave Window Bias Also Smaller

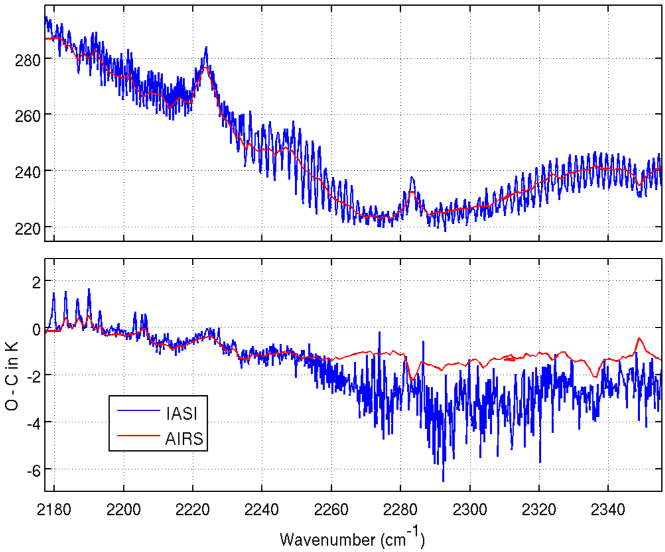


High-Peaking CO_2 Channels

IASI Biases Sometimes Much More Negative??

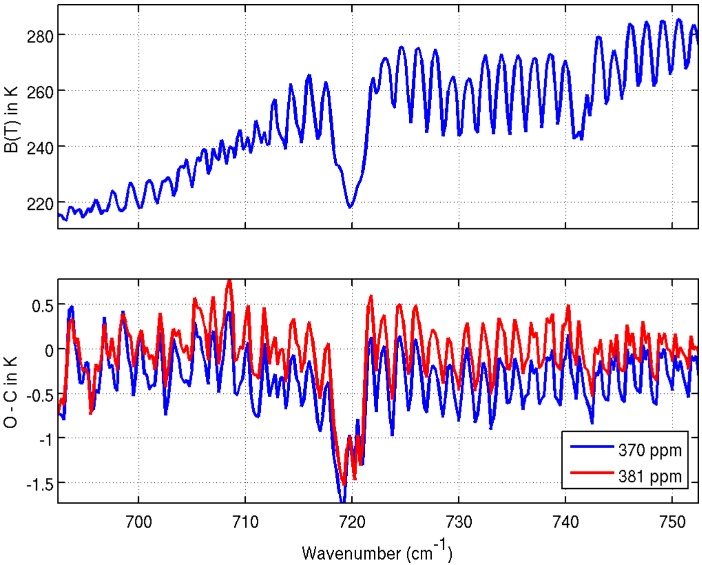


Quite Good IASI/AIRS Agreement to 2250 cm^{-1}



IASI Tropospheric CO_2 Biases:

Assuming 2 ppm/year CO_2 growth since 2002. Biases ~0.25K high



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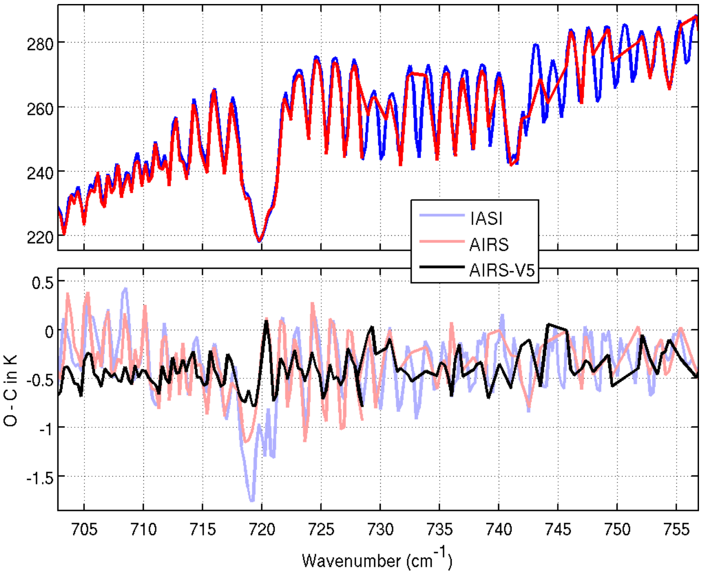
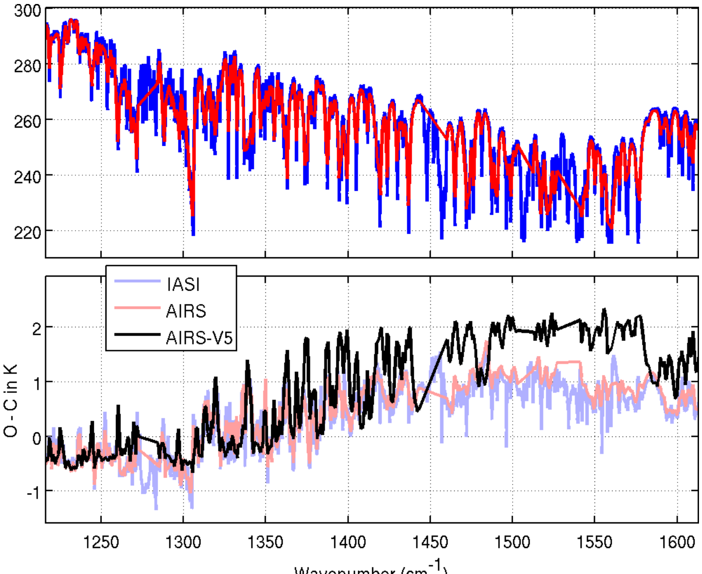
AIRS Biases with RS-90 ARM Mods

CO_2 growth should add 4.5 × 2ppm/year × 0.03K/ppm = 0.27K



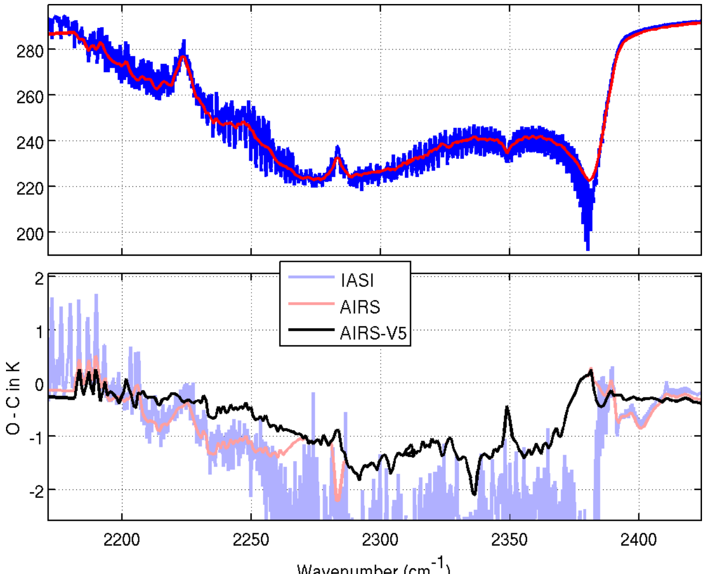
AIRS Biases with RS-90 ARM Mods

Higher H_2O errors *may* just be ECMWF



AIRS Biases with RS-90 ARM Mods

V5 RTA Mods not done between 2275 and 2380 cm^{-1}, no ground truth



IASI Conclusions

- AIRS versus IASI (double-diff) $\sim$0.1K or less! (from poster)
- Biases very similar to AIRS
- AIRS-like RTA modifications derived from ARM RS-90 sondes should also improve IASI biases relative to ECMWF in CO_2 regions. Water regions uncertain, re-examine.
- Some issues in longwave, next to Q-branches and band edge. IASI biases lower than AIRS. No firm conclusions.
- CO_2 growth estimates needed to estimate biases. Or, use biases to estimate CO_2.

CO_2 with AIRS (and IASI)

- 4-years of AIRS CO_2
- *Simple* approach, easy to reprocess. Originally just after rates.
- Motivation
  - RTA validation
  - AIRS climate monitoring
  - CO_2 transport; help understand sinks? Use lower-peaking channels.
- CO_2 Jacobian centered around 550 mbar
- Start slow: Ocean/Night only clear FOVs; Good for validation, bad for sources/sinks and/or transport;
- ECMWF used for temperature - tied to sondes.
- SST and TCW from AIRS (UMBC values, on a per FOV basis.)
- Validated via NOAA CMDL MBL, JAL, 2 ocean aircraft sites
- GOAL: provide useful data for modelers, show utility of lower-peaking AIRS channels

ASL Mid-tropospheric CO_2 *is* Important!

Weak Northern and Strong Tropical Land Carbon Uptake from Vertical Profiles of Atmospheric CO_2

Britton B. Stephens,[1]* Kevin R. Gurney,[2] Pieter P. Tans,[3] Colm Sweeney,[3] Wouter Peters,[3] Lori Bruhwiler,[3] Philippe Ciais,[4] Michel Ramonet,[4] Philippe Bousquet,[4] Takakiyo Nakazawa,[5] Shuji Aoki,[5] Toshinobu Machida,[6] Gen Inoue,[7] Nikolay Vinnichenko,[8]† Jon Lloyd,[9] Armin Jordan,[10] Martin Heimann,[10] Olga Shibistova,[11] Ray L. Langenfelds,[12] L. Paul Steele,[12] Roger J. Francey,[12] A. Scott Denning[13]

Measurements of midday vertical atmospheric CO_2 distributions reveal annual-mean vertical CO_2 gradients that are inconsistent with atmospheric models that estimate a large transfer of terrestrial carbon from tropical to northern latitudes. The three models that most closely reproduce the observed annual-mean vertical CO_2 gradients estimate weaker northern uptake of –1.5 petagrams of carbon per year (Pg C year^{-1}) and weaker tropical emission of +0.1 Pg C year^{-1} compared with previous consensus estimates of –2.4 and +1.8 Pg C year^{-1}, respectively. This suggests that northern terrestrial uptake of industrial CO_2 emissions plays a smaller role than previously thought and that, after subtracting land-use emissions, tropical ecosystems may currently be strong sinks for CO_2.

Our ability to diagnose the fate of anthropogenic carbon emissions depends critically on interpreting spatial and temporal gradients of atmospheric CO_2 concentrations (*1*). Studies using global atmospheric transport models to infer surface fluxes from boundary-layer CO_2 concentration observations have generally estimated the northern mid-latitudes to be a sink of approximately 2 to 3.5 Pg C year^{-1} (*2*–*5*). Analyses of surface ocean partial pressure of CO_2 (*2*), atmospheric carbon isotope (*6*), and atmospheric oxygen (*7*) measurements have further indicated that most of this northern sink must reside on land. Tropical fluxes are not well constrained by the atmospheric observing network, but global mass-balance requirements have led to estimates of strong (1 to 2 Pg C year^{-1}) tropical carbon sources (*4*, *5*). Attribution of the Northern Hemisphere terrestrial carbon sink (*8*–*13*) and reconciliation of estimates of land-use carbon emissions and intact forest carbon uptake in the tropics (*14*–*19*) have motivated considerable research, but these fluxes remain quantitatively uncertain. The full range of results in a recent inverse model comparison study (*5*), and in independent studies (*3*, *20*, *21*), spans budgets with northern terrestrial uptake of 0.5 to 4 Pg C year^{-1}, and tropical terrestrial emissions of –1 to +4 Pg C year^{-1}. Here, we analyzed observations of the vertical distribution of CO_2 in the atmosphere that provide new constraints on the latitudinal distribution of carbon fluxes.

Previous inverse studies have used boundary-layer data almost exclusively. Flask samples from profiling aircraft have been collected and measured at a number of locations for up to several decades (*22*–*24*), but efforts to compile these observations from multiple institutions and to compare them with predictions of global models have been limited. Figure 1 shows average vertical profiles of atmospheric CO_2 derived from flask samples collected from aircraft during midday at 12 global locations (fig. S1), with records extending over periods from 4 to 27 years (table S1 and fig. S2) (*25*). These seasonal and annual-mean profiles reflect the combined influences of surface fluxes and atmospheric mixing. During the summer in the Northern Hemisphere, midday atmospheric CO_2 concentrations are generally lower near the surface than in the free troposphere, reflecting the greater impact of terrestrial photosynthesis over industrial emissions at this time. Sampling locations over or immediately downwind of continents show larger gradients than those over or downwind of ocean basins in response to stronger land-based fluxes, and higher-latitude locations show greater CO_2 drawdown at high altitude. Conversely, during the winter, respiration and fossil-fuel sources lead to elevated low-altitude atmospheric CO_2 concentrations at northern locations. The gradients are comparable in magnitude in both seasons, but the positive

[1]National Center for Atmospheric Research, Boulder, CO 80305, USA. [2]Department of Earth and Atmospheric Sciences, Purdue University, West Lafayette, IN 47907, USA. [3]National Oceanic and Atmospheric Administration, Boulder, CO 80305, USA. [4]Le Laboratoire des Sciences du Climat et l'Environnement, 91191 Gif sur Yvette, France. [5]Center for Atmospheric and Oceanic Studies, Tohoku University, Sendai 980-8578, Japan. [6]National Institute for Environmental Studies, Onogawa, Tsukuba 305-8506, Japan. [7]Graduate School of Environmental Studies, Nagoya University, Nagoya City 464-8601, Japan. [8]Central Aerological Observatory, Dolgoprudny, 141700, Russia. [9]School of Geography, University of Leeds, West Yorkshire, LS2 9JT, UK. [10]Max Planck Institute for Biogeochemistry, 07701 Jena, Germany. [11]Sukachev Institute of Forest, Krasnoyarsk, 660036, Russia. [12]Commonwealth Scientific and Industrial Research Organisation (CSIRO) Marine and Atmospheric Research, Aspendale, Victoria 3195, Australia. [13]Department of Atmospheric Science, Colorado State University, Fort Collins, CO 80523, USA.

*To whom correspondence should be addressed. E-mail: stephens@ucar.edu

†Deceased.

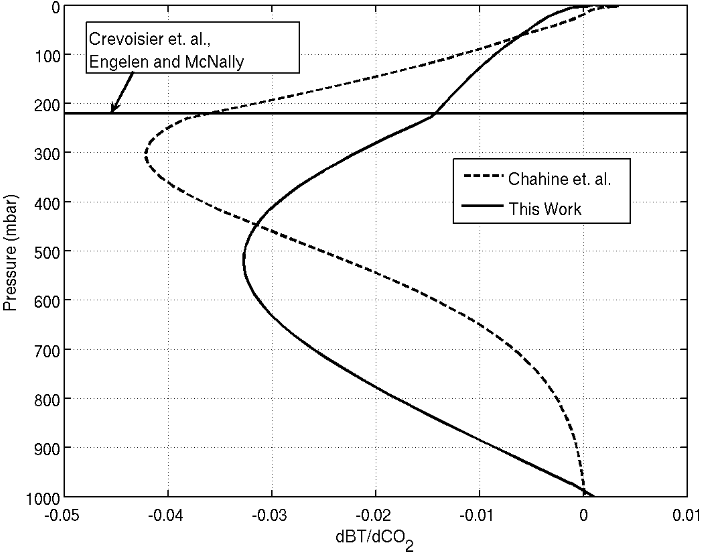
Methodology

- Use ECMWF $T(z)$, mean tied to radiosondes. Fit for SST and TCW using 2616 and 2609 cm^{-1} channels (night only).
- Solve

$$BT_i^{obs} - BT_i^{calc}(ECMWF) = \frac{dB_i}{dCO_2}\delta CO_2 + \frac{dB_i}{dT}\delta T_s$$

  for δCO_2 using 2+ channels.
- LW: Two channels, 791.7 cm^{-1} used for CO_2 and T_s; 790.3 cm^{-1} used for T_s only. Temperature insensitive.
- SW: 2392-2420 cm^{-1}; Temperature sensitive, 26 channels, diagnose ECMWF errors ($\sim$ 1 ppm jump on Feb. 2006)
- CO_2 zonally averaged into 4 degree latitude bins
- *Main difference between this work, and previous work: Lower peaking CO_2 Jacobians.*

This Work: 791 cm^{-1} Channel $dR/d(CO_2^i)$ Peaks Closer to Surface



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Finding "Clean" CO_2 Channels

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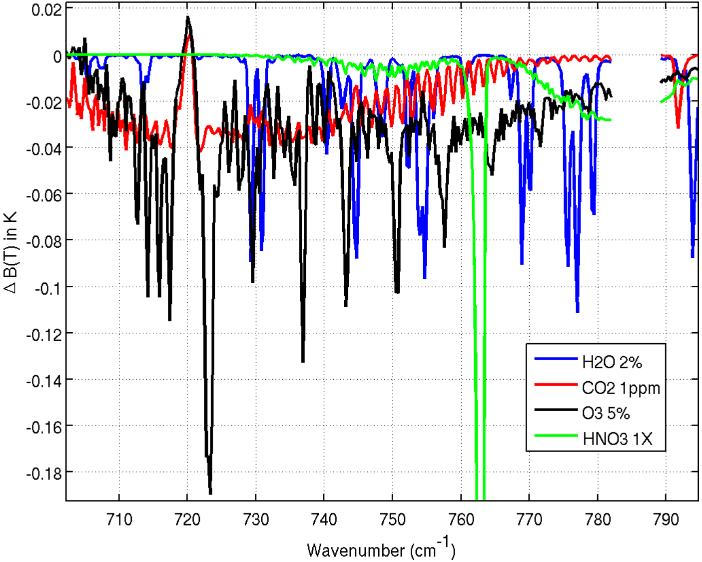
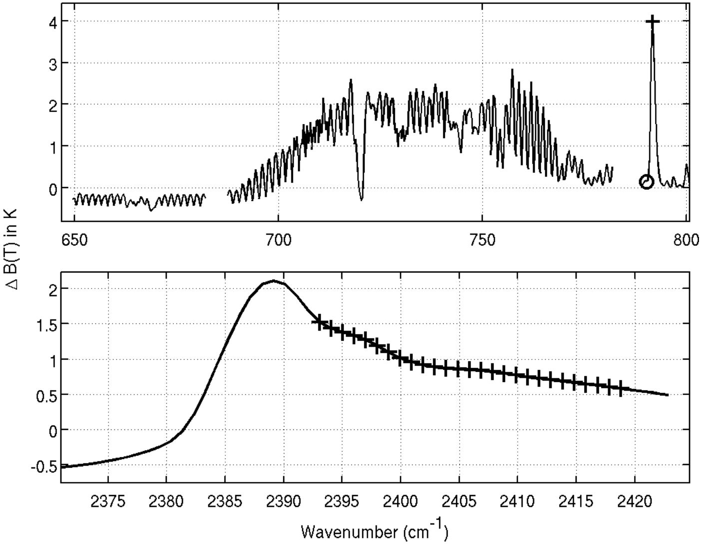
ECMWF Biases

CO_2

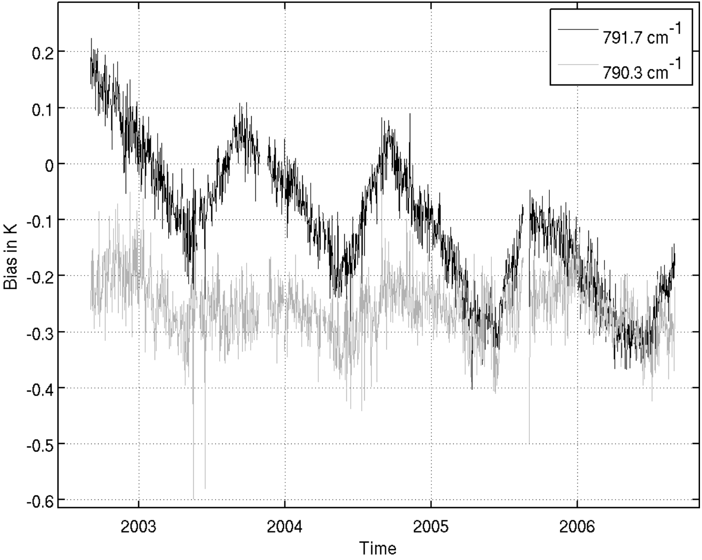


Ratio of dBT/d_{CO_2} to $dBT/dT_{profile}$

Why 791.7 cm^{-1} Channel



Raw Biases, Northern Hemisphere Average



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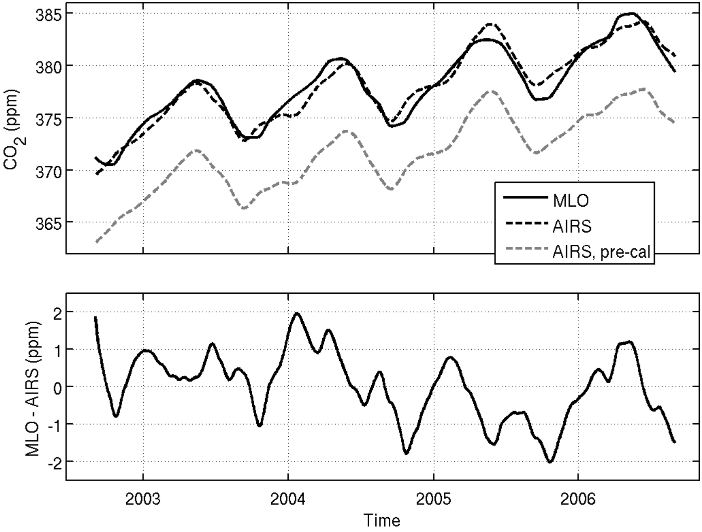
AIRS Calibrated (1-number, 1-time) Using MLO

MLO at ~650 mbar, close to peak of CO_2 W.F.

AIRS RTA only good to ~8 ppm for *any* channel (2%)



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AIRS 4-Year CO_2 Climatology

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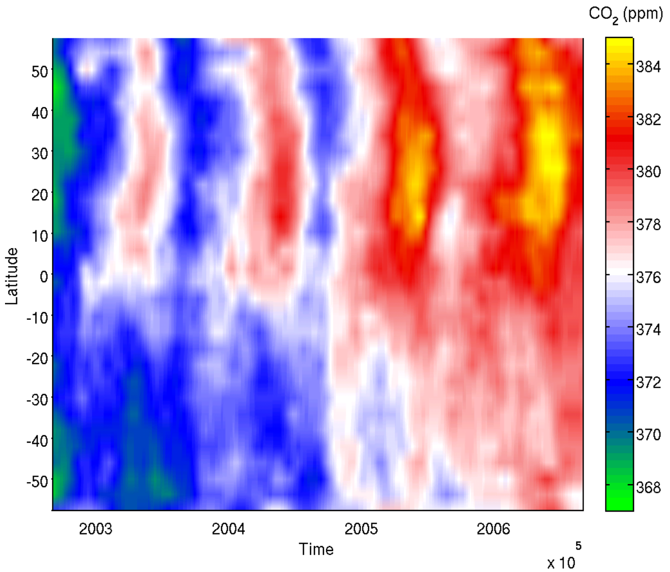
ECMWF Biases

CO_2



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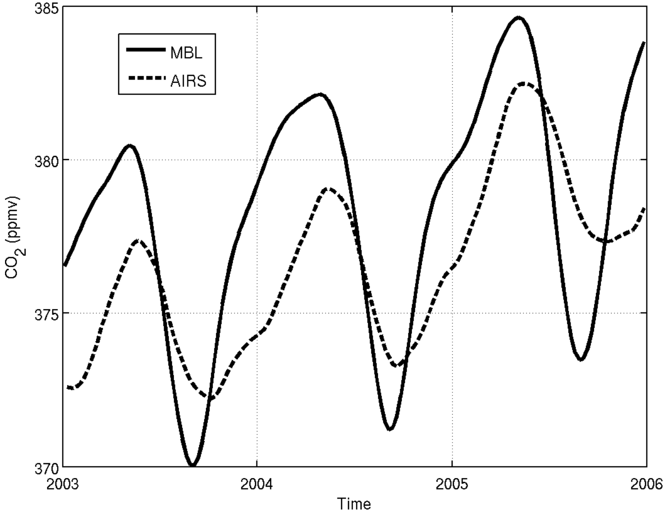
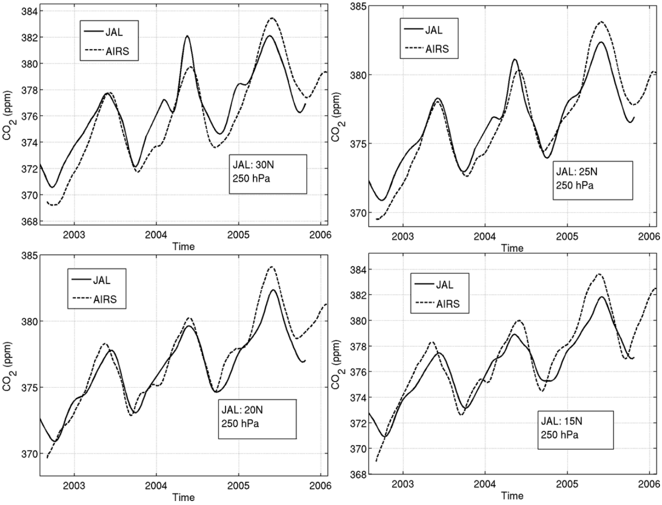
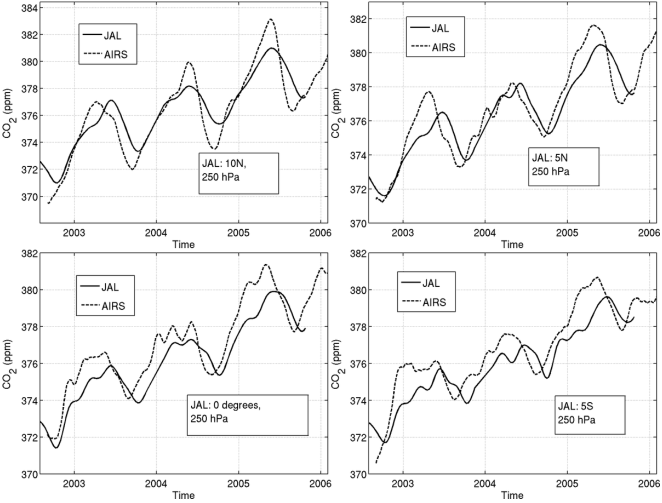
AIRS vs MBL; 25-50 Deg. Latitude



JAL Comparisons: 30N - 15N Latitudes



JAL Comparisons: 10N - 5S Latitudes



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Validation of AIRS with MBL, JAL etc.

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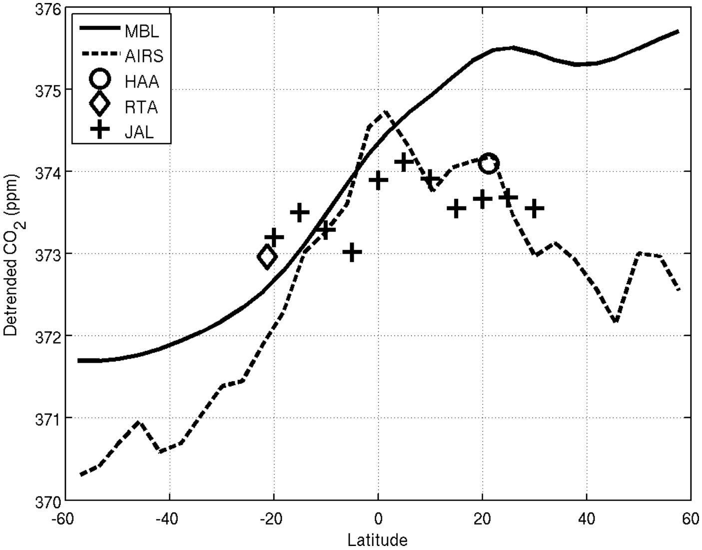
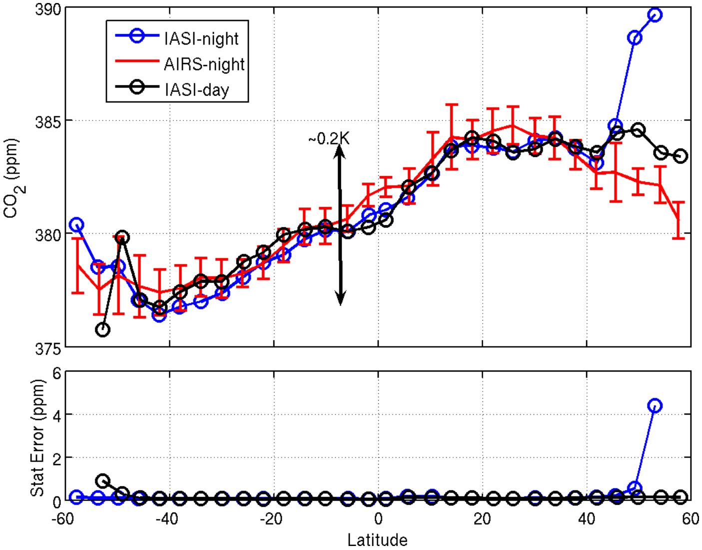
ECMWF Biases

CO_2



Comparison of AIRS and IASI CO_2 for May 2007



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AIRS Seasonal Amplitude vs MBL/JAL/etc.

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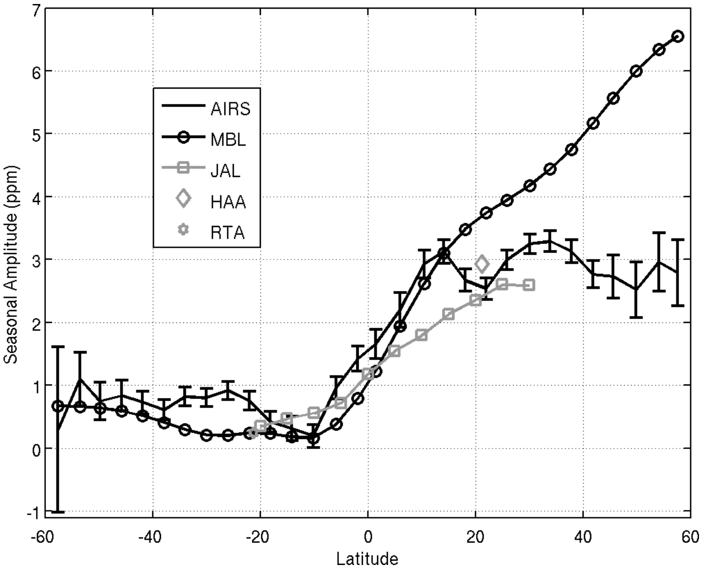
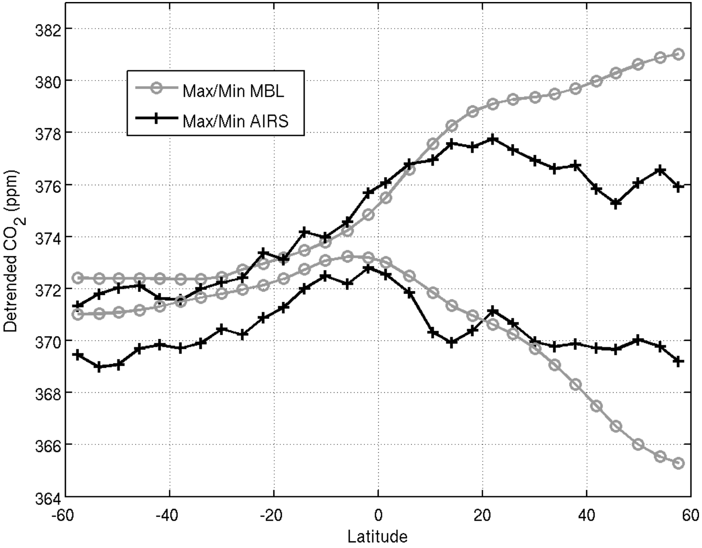
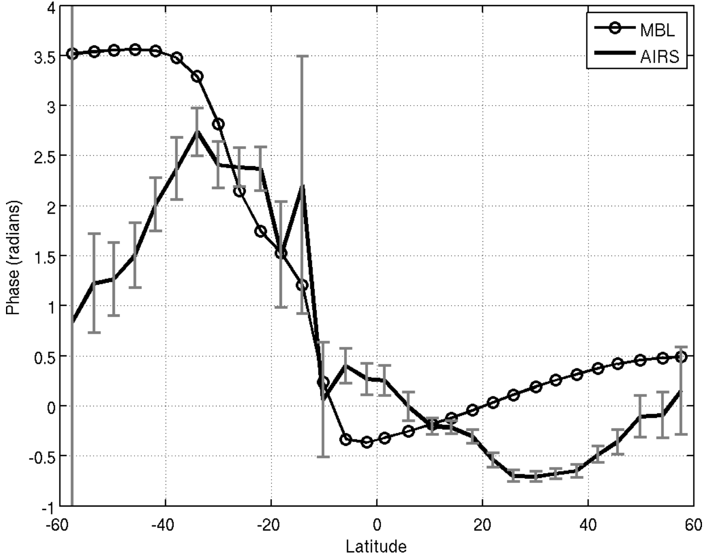
CO_2



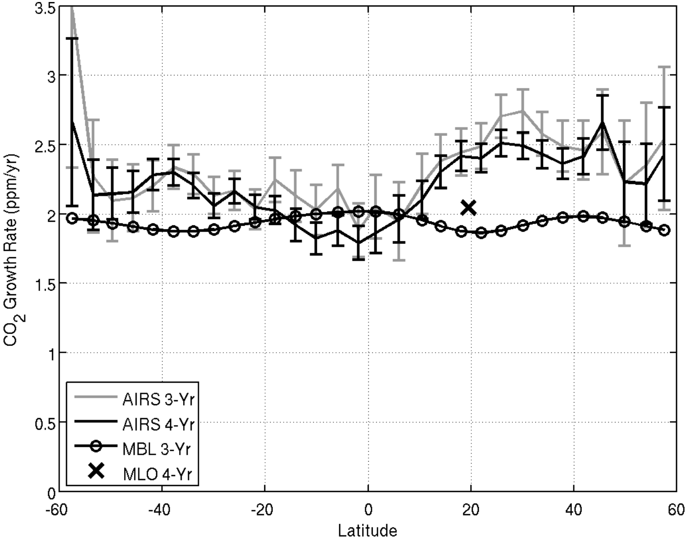
AIRS vs MBL Min/Max Amplitudes



AIRS Seasonal Phase vs MBL



AIRS vs MBL/MLO CO_2 Growth Rates



AIRS vs MBL Growth Rates: Offsets and Harmonic Terms Removed

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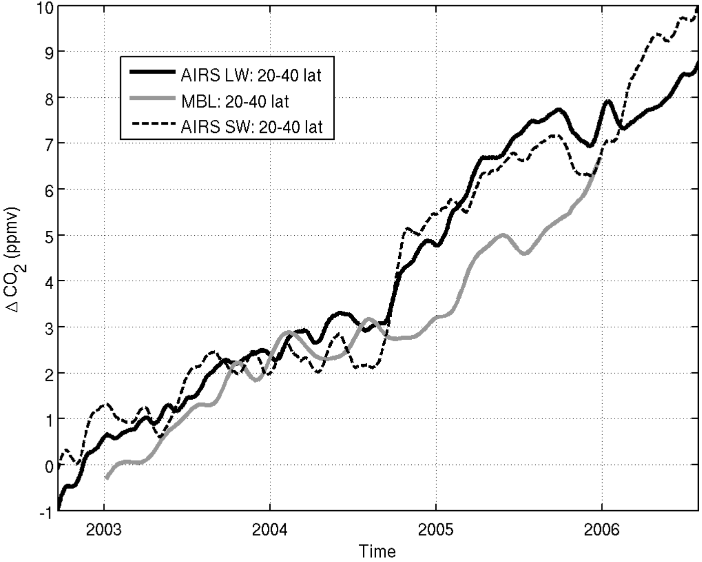
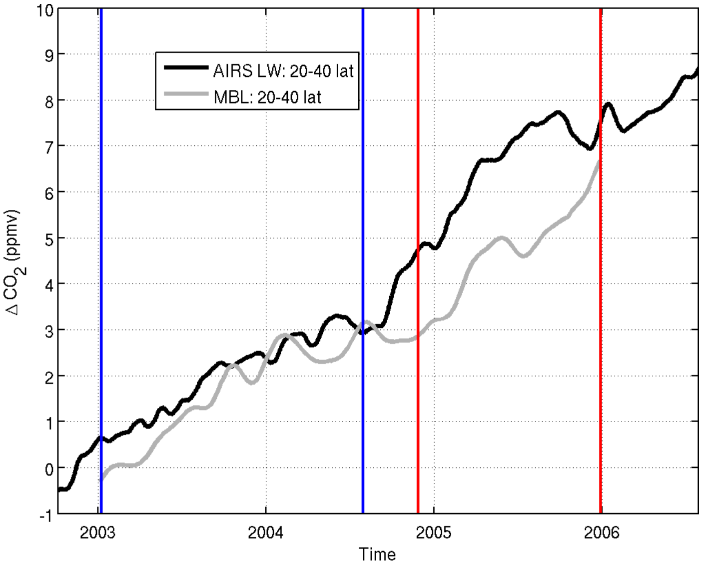
CO_2



Rate Variability 20-40 Deg.lat; AIRS=2.44, MBL=1.92 ppm/yr
Blue Bars: AIRS=1.86, MBL=2.07 ppm/yr;
Red Bars: AIRS=2.56, MBL=2.88 ppm/yr



CO_2 Conclusions

- Excellent results using very clear FOVs over ocean
- Initial work shows similar results with cloud-cleared data, allowing more convective situations to be examined for transport
- Basic technique should work over land, first clear, then cloud-cleared data.
- This work sets a baseline on stability of AIRS (and eventually IASI), esp. with regard to trends.