

Tropospheric CO Variability from AIRS and IASI Under Cloudy Conditions Using US Products

IASI Conference
Feb. 3-8, 2013
Presqu'île de Giens -
Hyères Les Palmiers
France

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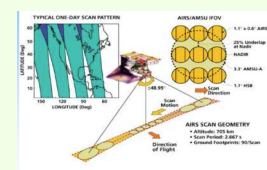
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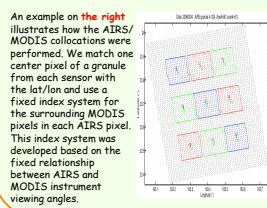
Introduction

Satellite measurements using the thermal spectral regions are affected by the presence of clouds, and therefore, it is necessary to remove the effects of clouds before retrieving many geophysical properties. AIRS Level 2 retrieval algorithm utilizes cloud clearing to handle cloud contamination in the signals and this increases the data coverage significantly to a yield of 50-70% of the total measurements (Susskind et al., 2003). For the size of AIRS footprints of approximately 13.5km² nadir, the number of pure clear pixels is only 5-10%, which would not have been sufficient to provide daily products for monitoring goals. The IASI retrievals from NOAA use a similar technique for cloud clearing as in AIRS such that we need to first understand the effects of the AIRS cloud-clearing on the overall quality of the retrievals. We select AIRS clear pixels using collocated MODIS cloud mask (Ackerman et al., 1998) with the ratio of MODIS clear pixels in each AIRS pixel to be greater than 99%. We then analyze the Carbon Monoxide (CO) distribution and variability in parallel for clear versus cloud-cleared pixels to study the statistical property of the two ensembles. To understand the tropospheric CO distributions and variability using cloud-cleared radiances, we examine the CO Volume Mixing Ratios (VMRs) using PDFs for the entire AIRS and IASI data records. We also introduce a method to separate the background CO VMRs from the fresh emissions so that the trend of the data records can be analyzed separately. We conclude that, globally, cloud clearing does not cause biases in CO retrievals even though the clear only ensembles show slightly higher concentrations and with higher Degrees Of Freedom for Signal (DOFS) than the cloud-cleared ensembles. The emission variations agree very well with the GFED3 inventory database. Additionally, we find that AIRS and IASI CO retrievals agree best over land than over ocean for both Southern Hemisphere (SH) and Northern Hemisphere (NH).

AIRS Cloud Clearing - reconstruct clear column radiances

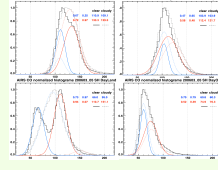


Sounding is performed on 45 km Field Of Regard (FOR), which is defined by the size of the microwave sounder (AMSU) footprint as shown in the top figure. AIRS/AMSU & CrIS/ATMS have 9 IR Field Of Views (FOVs) per FOR. IASI/AVHRR FORs contain 4 FOVs.



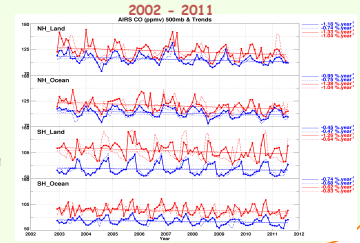
AIRS Tropospheric CO Variability between Clear and Cloud-cleared

Mar. - May, 2009



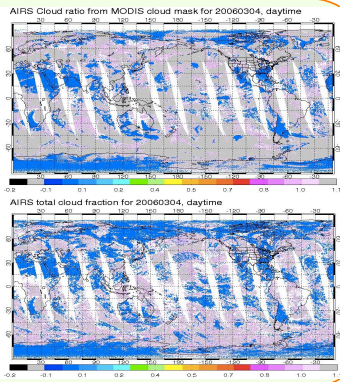
Histograms for clear condition (solid) and cloud-cleared (dashed) are each fitted by two Gaussian functions (see left figure). The left Gaussian fits (blue) represent well-mixed background CO while the right Gaussian fits (red) show fresh emissions. The cloud effects in the NH are correlated more with emissions. In the SH, the cloud-clearing masks the otherwise distinguished two populations of background and new emissions.

Tropospheric CO variability and trends from 2002 through 2011 are summarized, using the model of the monthly PDFs to represent biases, for NH-Land, NH-Ocean, SH-Land, and SH-Ocean, respectively, in the right figure. The background emissions are shown in blue and new emissions in red, while solid curves represent pure clear and dashed are for cloud-cleared. Decreasing trends are shown in all areas and there is little difference between the clear and cloud-cleared ensembles.



AIRS Clear Coverage by MODIS

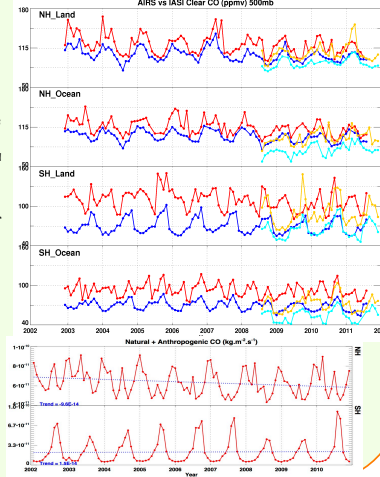
AIRS single-view pixels at footprints of 13.5km² are used to collocate with MODIS 1x1km² pixels. AIRS clear coverage by MODIS cloud mask (blue in the upper panel) is ~10-13%. AIRS clear coverage by MODIS cloud mask (blue in the lower panel) when the L2 CloudFraction=0 is ~22%, which tends to overestimate the amount of clear coverage. AIRS cloud fraction can be compared to that defined by MODIS cloud mask only under absolute clear or completely overcast conditions because MODIS sub-pixel cloudiness is unknown.



AIRS and IASI CO Variability Comparison

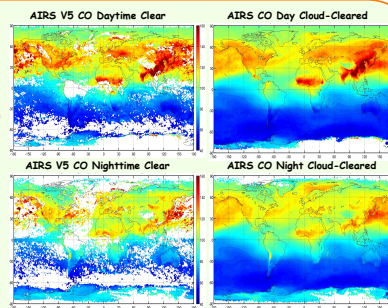
The modes are treated as biases from each monthly fit to show CO variability from Dec., 2002 to Dec., 2011 (see right upper figure). AIRS background CO in blue, emission in red, IASI background in cyan, and emission in orange. Only clear sky cases were used in this plot. AIRS and IASI agree very well over land, while IASI CO is lower than AIRS over ocean in both NH and SH. Overall, AIRS CO emission values are higher than IASI. For both, the new emission is higher than background CO values and more variable. The observed CO from both AIRS and IASI correlate better with the GFED3 natural sources than the anthropogenic sources.

GFED3 (Van der Werf et al., 2010) (lower figure) integrates satellite data from MODIS, TRMM, VIIRS, and ATSR to estimate the natural fire emission from vegetation. The time range is from 1997 to 2010 at spatial resolution of 0.5x0.5 degrees. The data are available on the Ether/ECCAD-GEIA data base. MACCity is part of the Atmospheric Chemistry and Climate - Model Inter-comparison Project ACCMIP, and focus on the anthropogenic emission from 1960 to 2010 with a spatial resolution of 0.5x0.5 degrees. The original data were produced as part of MACC/ CityZEN UE project and are available on the Ether/ECCAD-GEIA database.



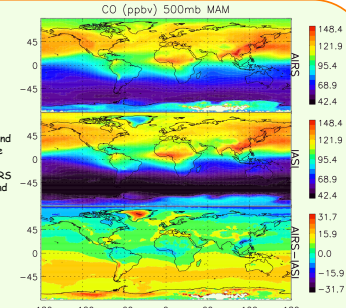
AIRS V5 CO Analysis between Clear and Cloud-cleared for March - May, 2009

Clear cases are chosen where more than 99% of MODIS pixels in an AIRS pixel are believed to be clear. CO distributions are very similar in general using cloud-cleared radiances with the VMRs slightly higher for the pure clear cases.



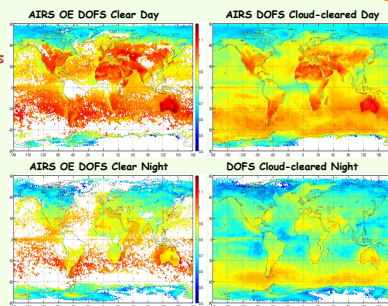
Comparison of AIRS and IASI CO Distributions

Monthly mean CO maps at 500hPa are shown for AIRS (top), IASI (middle), and AIRS-IASI differences (bottom) averaged over March, April, and May, 2008-2012. The largest differences are in the SH where AIRS V5 CO is known to over-estimate (Warner et al., 2010). The differences between AIRS and IASI CO in the NH are mainly due to the extent and location of the plumes. IASI CO values are slightly higher than AIRS in the plumes and lower elsewhere in the NH.



Cloud-Clearing on Degrees of Freedom for Signal (DOFS) Using Optimal Estimation CO March - May, 2009

AIRS DOFS for persistent cloudy cases are lower than for the clear regions. AIRS OE CO DOFS average between 0.8 to 1 (Warner et al., 2010). Note that DOFS are higher during the day than at night due to the change of surface thermal contrasts.



Conclusions

AIRS pixels are collocated with MODIS cloud mask for the period of Dec., 2002 to Oct., 2011. It is possible to use MODIS cloud mask to examine the accuracies of AIRS trace gas retrievals. The overall/global biases due to cloud-clearing are minimal. Clear ensembles provide better insights for CO variability and trend studies. AIRS and IASI CO retrievals differ mostly over the SH ocean. Retrievals over certain regions (Greenland, Westcoast South America, Antarctica) need more care.

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Acknowledgments

This study is supported by the NASA Earth Sciences through ROSES by the Atmospheric Composition (NNX07AM456), the Climate Record Uncertainty Analysis Program (NNX11AL22A), and by the sub-contract by NASA JPL, AIRS team. The authors wish to thank AIRS, IASI, and MODIS science teams for the wonderful products that made these measurements possible.