39 Month Status Report: Validation of MOPITT Column and Profile CO from Space-borne, Airborne, and Ground-based Interferometers

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http://physics.umbc.edu/~mcmillan/PROJECTS/MOPITT_val/MOPITT_val.html

Submitted to

David Starr
EOS Validation Scientist

1 Summary

This report summarizes work preformed from 5/20/00 to 12/21/00 in support of validation of MOPITT CO measurements. Major project milestones since the 5/19/00 Progress Report include (1) delivery of 2000 SGP AERI CO retrievals to the MOPITT Science Team, (2) autonomous SGP AERI CO retrievals for 2001, (3) radiometric validation and autonomous operation of BBAERI at UMBC, (4) replacement of Dr. Hui He with Dr. Gyula Molnar (Ph.D. Lorand. Eotvos University, Budapest, Hungary, 1976) as an Assistant Research Scientist, (5) Dr. Molnar's development to sensitivity testing of a new physical retrieval algorithm for AERI CO with profile information, (6) and the first CO retrievals from SHIS data acquired during the SAFARI 2000 EOS validation experiment. Dr. McMillan attended the MOVE01 validation planning meeting in Boulder in December 2000. Unfortunately, MOPITT entered safe-mode less than one week into MOVE01 and little useful data was acquired. Dr. McMillan and Mr. Lightner presented the first BBAERI results and SGP AERI MOPITT validation measurements at the February 2001 OSA Topical Meetings in Coeur d'Alene, Idaho. Dr. McMillan presented the first CO retrievals from SHIS SAFARI 2000 spectra at the First S2K Data Workshop in Siovanga, Zambia and at the Fall AGU Meeting in San Francisco. Work on the SAFARI data will be submitted to a special issue of JGR in March, 2002. Planned activities for the remaining 9 months of this project include: (1) submission for publication of 1998-2001 ARM AERI CO timeseries and first SHIS CO retrievals and correlative intercomparison, (2) submission of all AERI and SHIS CO retrievals to MOPITT Science Team for validation intercomparison and eventual publication of results, (3) full development and routine use of new physical retrieval algorithm for AERI CO, (4) development and testing of new AERI fast models for radiative transfer calculations, and (5) autonomous processing of BBAERI data and submission for publication of first results.

2 SGP AERI CO Retrievals

2.1 MOPITT Validation

On February 1, 2001 we delivered to the MOPITT Science Team our full suite of year 2000 CO retrievals for all five SGP ARM AERI sites for the morning MOPITT overpass time. A plot of this dataset through 12/4/01 is shown in Figure 1 as presented at the MOVE01 planning meeting in Boulder on 12/4/01. Due to the peak sensitivity of the AERI CO retrievals to CO in the boundary layer (surface to 800 mb), we originally proposed the AERI CO retrievals for validation of MOPITT CO retrievals from their solar reflection channel which are only possible during daylight. Thus, the focus for morning overpasses on this initial data product.

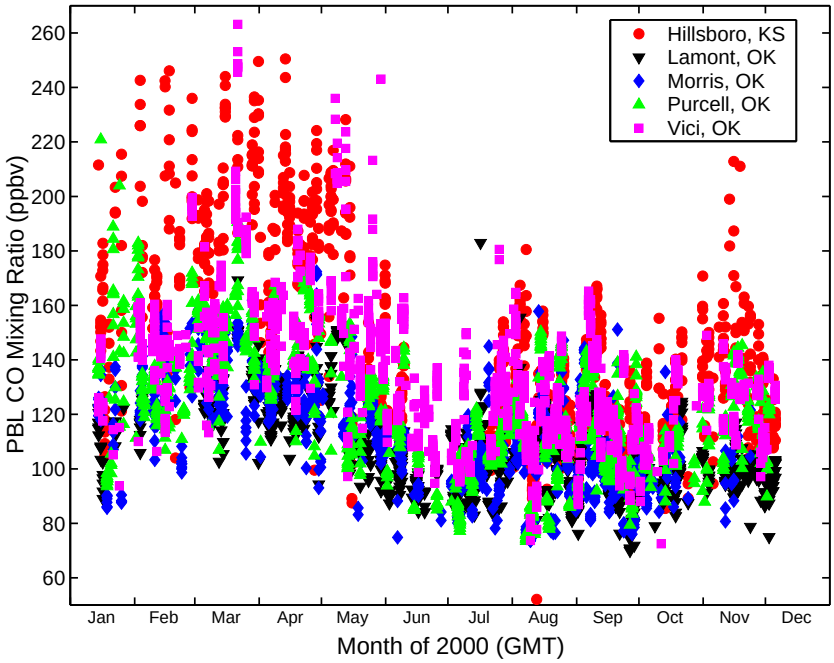

Figure 1: Summary of 2000 CO retrievals for the AM MOPITT overpass time for all 5 SGP ARM AERI's.

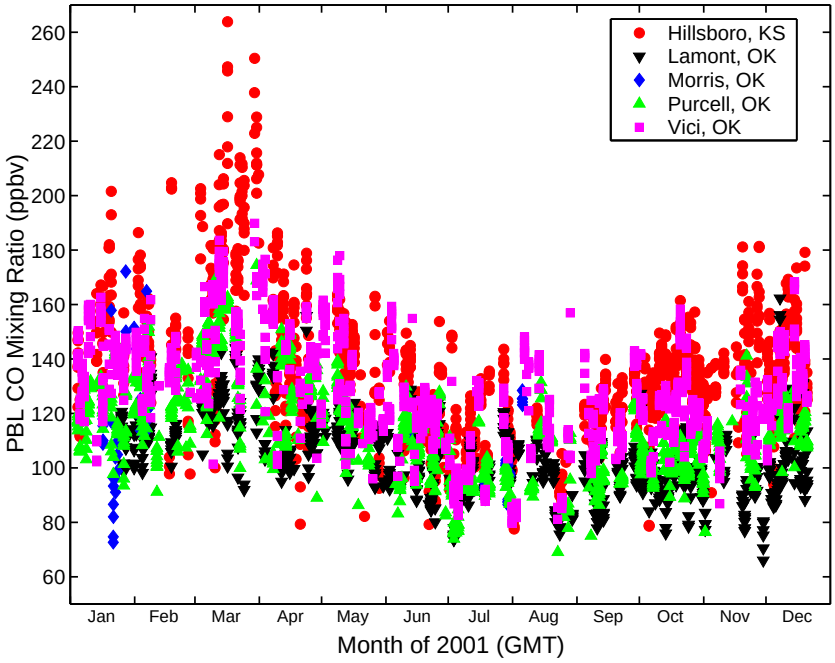

Figure 2: Summary of 2001 CO retrievals for the AM MOPITT overpass time for all 5 SGP ARM AERI's.

A plot of the same dataset for 2001 through 12/20/01 is presented in Figure 2. Note how similar the

abundances are between the two years, with a somewhat larger amplitude seasonal cycle evident in the 2000 data. In particular, the retrievals for the Hillsboro site were larger for more of the Winter/Spring of 2000 than for 2001. A more detailed analysis of the full CO retrieval timeseries for all five sites is underway with investigation of correlations between retrieved CO abundances and meteorological conditions using local met data and back trajectory calculations. Co-Investigator Anne Thompson will assist with the trajectory calculations and subsequent interpretation.

Unfortunately, as of yet the MOPITT CO retrieval algorithm does not use the solar reflection channels although the measurements have been collected. Therefore, the available MOPITT CO retrievals do not have good sensitivity to CO abundances in the lowest 1-2 km, i.e. surface to 800 mb, and the AERI CO retrievals in terms of ppbv are of limited utility for MOPITT validation.

However, the AERI retrievals can be put in terms of a retrieval of total column CO. If the true atmospheric profile has a maximum abundance in the boundary layer (generally true), the retrieved total column CO from AERI should be accurate to 10-15MOPITT validation. But, without the solar reflection channels in use, MOPITT's total column CO retrievals could exhibit much larger errors due to missing the generally larger boundary layer values.

Since providing the first AERI datasets to the MOPITT Science Team, I have had not contact or feedback on this dataset from the MOPITT Science Team other than my specific requests for MOPITT data to use in my presentations at the OSA meeting and the SAFARI workshop. We have continued to provide nearly daily updates in the form of our quicklook web-based AERI CO retrievals throughout 2001 as we have since January 13, 2000. The MOPITT Science Team has provided no feedback on the usefulness of this data despite my requests for such feedback.

2.2 CO Time Series

We presented the full 1998 Lamont AERI CO timeseries of Figure 3 in the last status report. For comparison, we here present the full 1999 Lamont AERI CO timeseries Figure 4. The timing of the seasonal cycle is the same for both years, but the overall CO levels were larger in 1998. Notably absent from the 1999 timeseries are the large spikes in May as occurred in 1998. Recall, the 1998 spikes resulted from transport of biomass burning plumes from southern Mexico and northern central America across the Gulf of Mexico and as far north as Minnesota. The timeseries for 2000 is nearly complete, as is the Lamont timeseries for 2001. Processing of the other 4 SGP AERI sites is underway.

CO timeseries for the period of MOVE00are shown in Figure 5. Most notable in this plot are the large abundances seen at all five sites between May 10 and 14. Zooming in on this time period in Figure 6 we see these spike do not occur at the same time at all sites. Rather, there is some indication that the spikes propagate from west to east: Vici first, then Lamont, Hillsboro, and Purcell, and finally much lower amplitude at Morris. Initially, we believed all these spikes resulted from the plume from the forest fire burning near Los Alamos, New Mexico. However, as it happens, we also see the plume from another fire burning in southern New Mexico near the town of Ruidoso. Detailed analysis and back trajectory calculations are underway for this dataset.

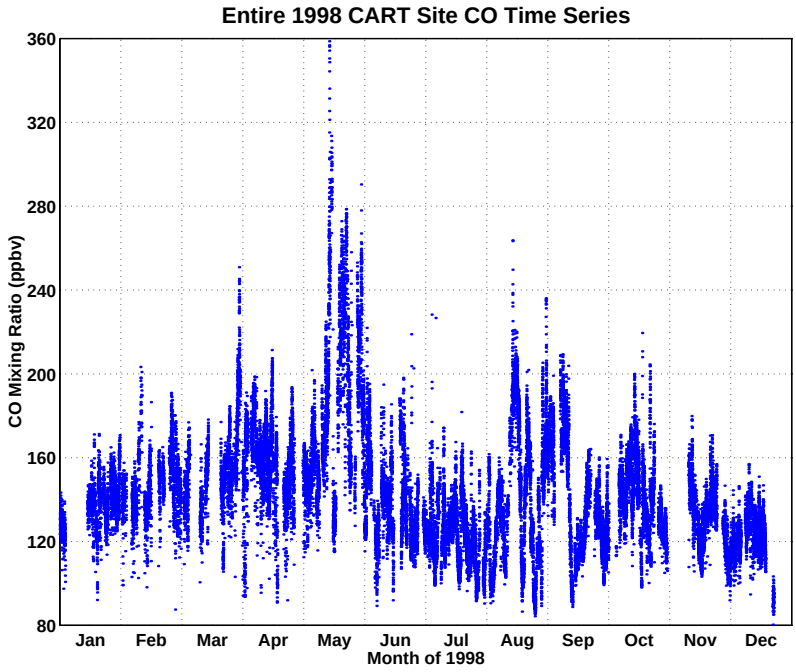

Figure 3: Time Series of CO retrievals from the entire 1998 archive of AERI spectra from the ARM SGP central facility near Lamont, OK.

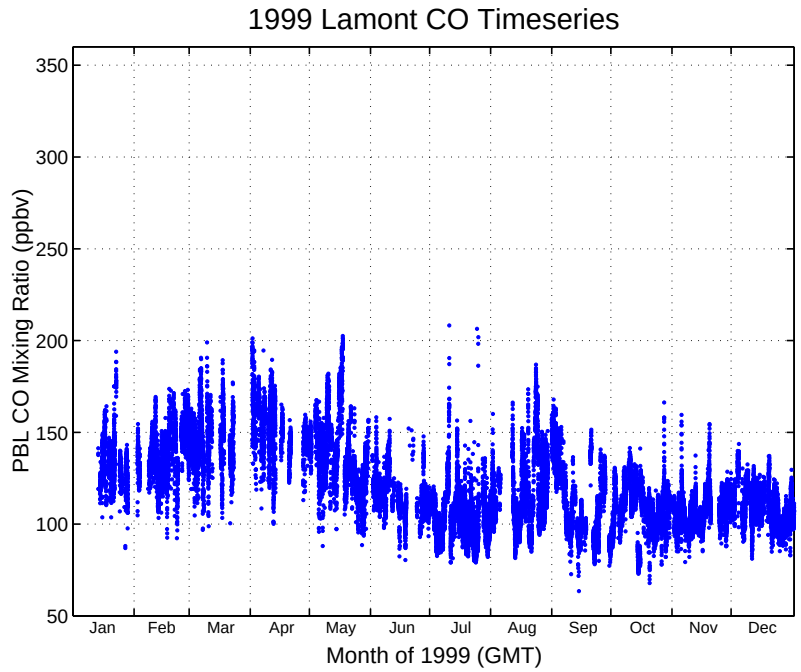

Figure 4: Time Series of CO retrievals from the entire 1999 archive of AERI spectra from the ARM SGP central facility near Lamont, OK.

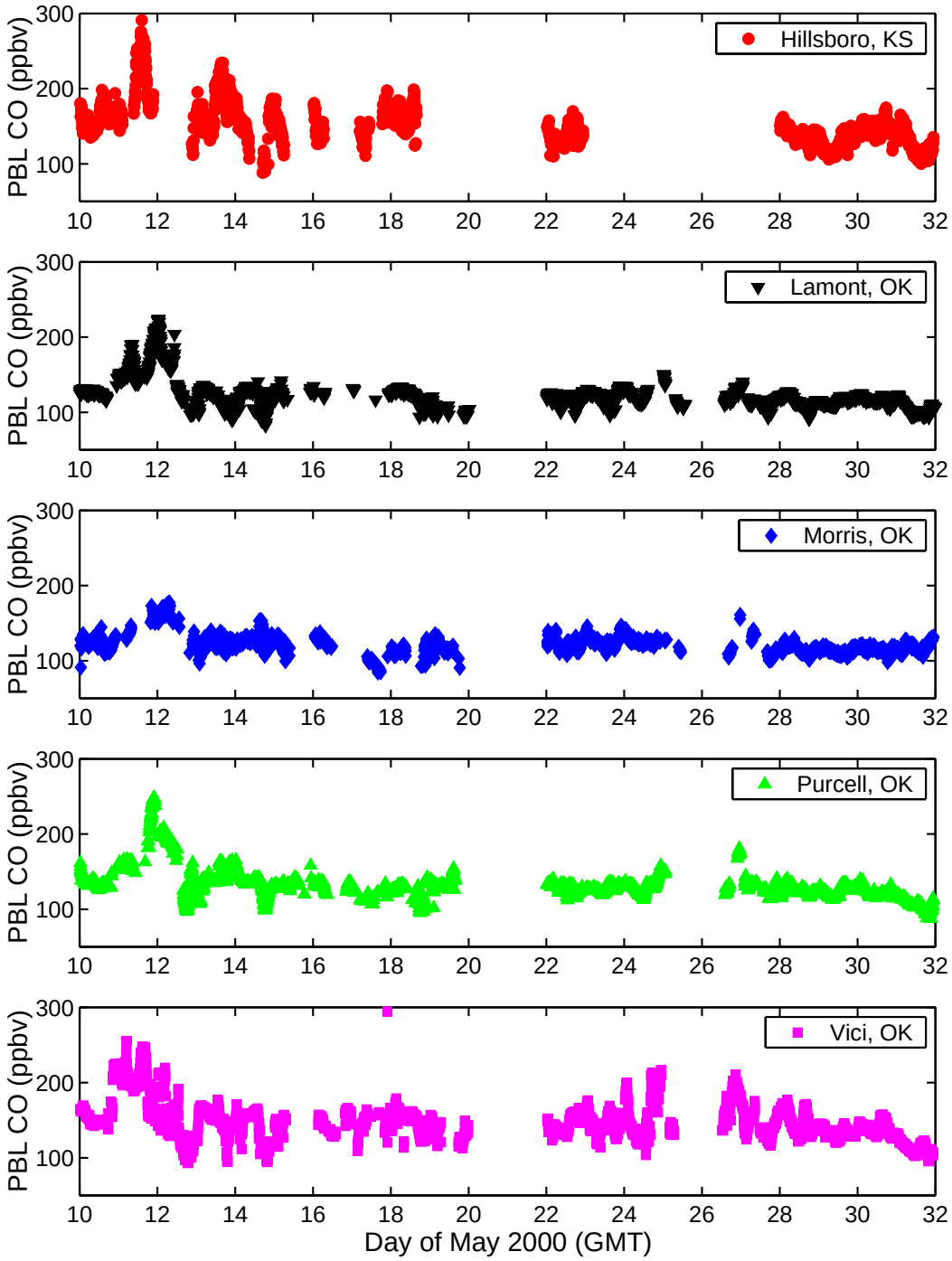

Figure 5: Timeseries of CO retrievals for all five SGP AERI's during the MOVE00 campaign.

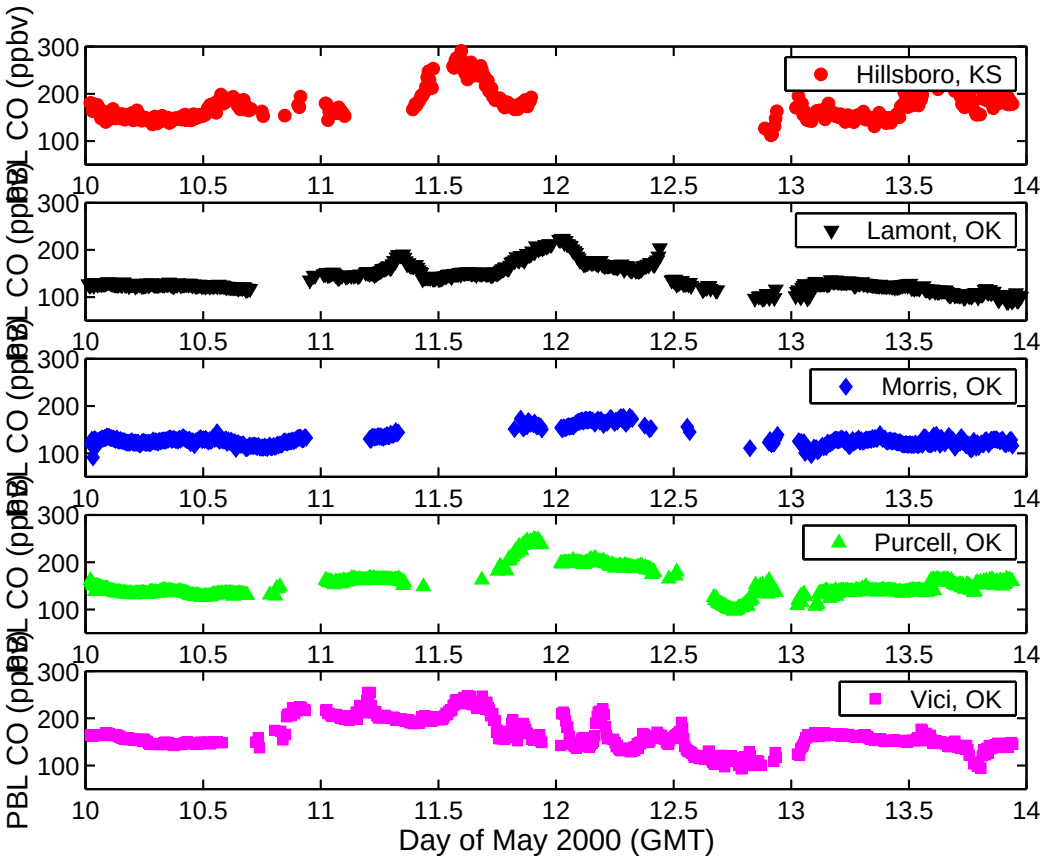

Figure 6: Narrow view of the timeseries of CO retrievals for all five SGP AERI's from May 10-14, 2000 during MOVE00.

3 BBAERI Operations

We commenced routine BBAERI operations at UMBC in January 2001, with fully autonomous operation starting in June, 2001. Autonomous integration of the UMBC weather station was achieved in December 2001, and we plan to begin full autonomous processing of BBAERI temperature, water vapor, and CO retrievals in early January 2002. Setup of BBAERI as a routine MOPITT CO validation site is supported under the fourth year of funding for this EOS validation project.

Dr. McMillan presented the first BBAERI results at the OSA Topical Meeting in Coeur d'Alene, Idaho in February 2001. Temperature and water vapor retrievals for five days in January 2001 are presented in Figure 7. Subsequent CO retrievals from these BBAERI spectra are shown in Figure 8 along with the local wind direction from the UMBC weather station located on the roof of the Physics building. The temperature and water vapor profiles indicate passage of a cold front on the 26th. Most notable in the CO retrievals is the large spike up in abundance late on the 25th (GMT). Comparison to the wind direction indicates this peak in CO abundance coincided with winds from the ESE. As it just so happens, the H. A. Wagner 1020 MW coal, oil, and gas fired power-plant is due ESE of UMBC. Analysis of subsequent BBAERI spectra is underway and we will be looking for more such correlations of our measurements with potential local sources.

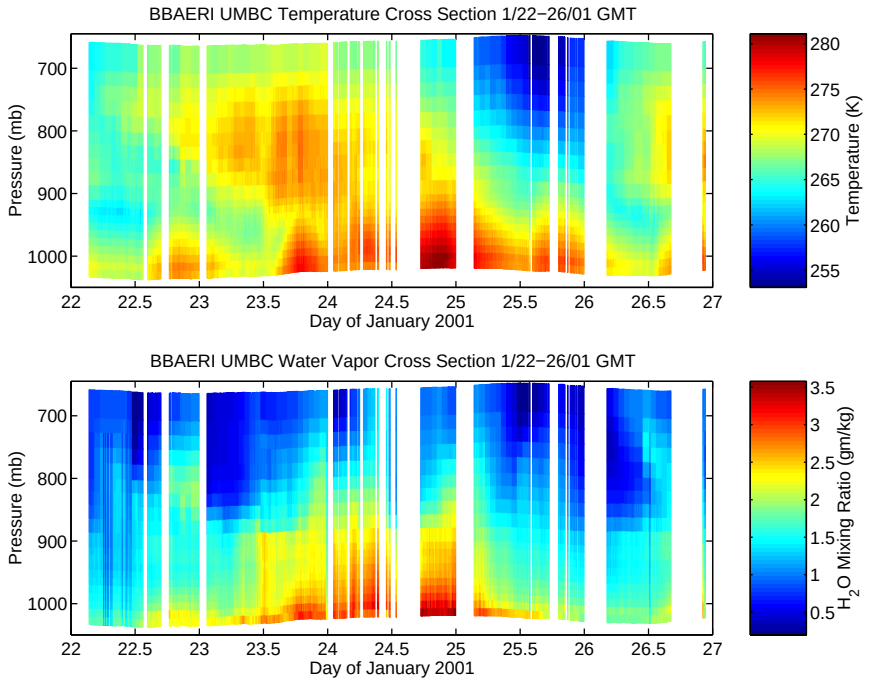

Figure 7: Temperature and water vapor profiles retrieved from BBAERI spectra.

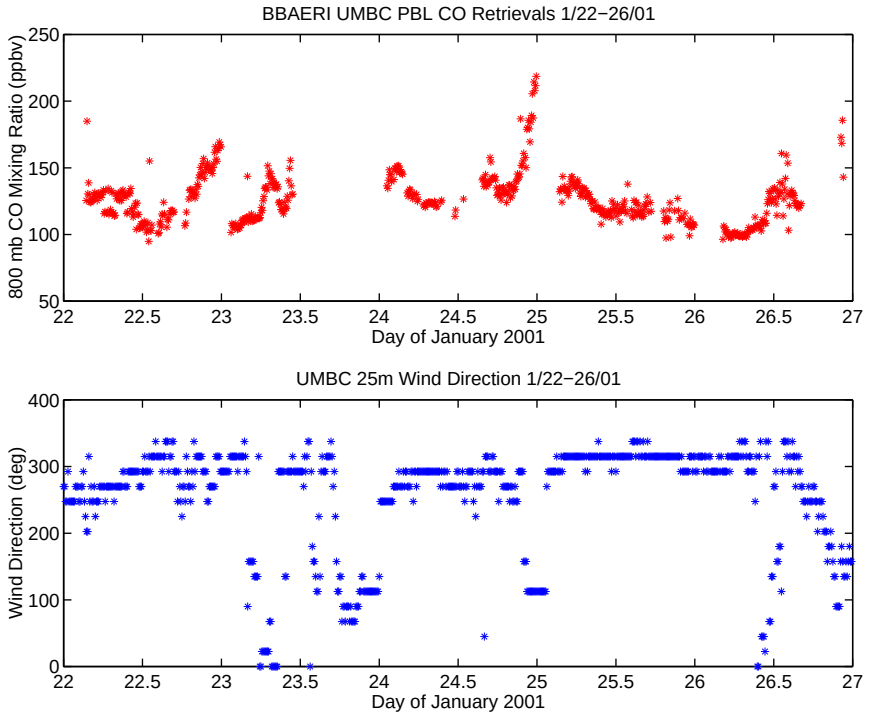

Figure 8: CO retrievals from BBAERI spectra and the local wind direction are plotted for five days in January 2001.

On August 3 and 4, 2001, the University of Wisconsin AERIbago paid UMBC a visit on its return trip to Wisconsin from deployment to NASA Wallops Island Flight Facility for the CLAMS experiment. Initial intercomparison of BBAERI and AERI-00 spectra showed the BBAERI shortwave channel was in excellent radiometric calibration, but that BBAERI's longwave detector's gain was set too high. This gain setting was corrected and subsequent intercomparison yielded very good radiometric agreement in the longwave, albeit under less than optimal thin cirrus conditions. Detailed analysis of this comparison experiment is underway with results to be included in a publication in preparation. Full processing of all BBAERI data from August 4 on also is underway and will be presented at the by Mr. Lightner at the Sixth Workshop of FTIR sponsored by Bomem in February 2002 in Quebec City, Quebec, Canada.

4 Physical CO Retrieval

With the abrupt departure of Dr. He in June 2000, I took advantage of the opportunity to hire Dr. Gyula Molnar to work on new CO retrieval algorithms and AERI fast models with Dr. Larrabee Strow and his research group. AERI fast model work continues over this holiday season with automated computer processing. We hope to take advantage early in 2002 of new MATLAB based radiative transfer algorithms being developed by Dr. Strow's group. In the meantime, Dr. Molnar continues sensitivity testing of his new physical CO retrieval algorithm.

After investigating several variants of "classical" Rogers-like retrieval techniques, Dr. Molnar found a variation of techniques used by Dr. Chris Barnet (JCET and part of the AIRS team) in the AIRS retrieval algorithm would be most successful. By identifying several CO spectral lines in computed AERI spectra which are sensitive to vertical variations in CO, Dr. Molnar has developed an initial CO retrieval algorithm capable of up to four pieces of information regarding the CO profile: boundary layer, lower-free troposphere, mid-free troposphere, and upper-free troposphere. Sensitivity testing is underway with instrument noise on the particular lines likely the limiting factor. At the least, we are confident we will be able to retrieve boundary layer and mean-free troposphere CO abundances. These two piece retrievals will represent a dramatic enhancement over our present algorithm. Moreover, the two piece retrievals will improve our capability to provide meaningful validation measurements for MOPITT's current mean-free troposphere retrievals, and future intercomparison of AERI boundary layer retrievals to surface measurements.

5 First Results from SHIS Spectra

As part of the originally proposed validation work, we started work in June 2000 processing spectra acquired by the Scanning High-resolution Interferometer Sounder (SHIS) during the SAFARI 2000 (S2K) field experiment. Flying on the ER-2 during S2K, SHIS accumulated more than 640,000 spectra on 14 flights, 7 in nadir only pointing, and 7 with cross-track scanning. To date, the University of Wisconsin has provided quality assured data for one flight (9/7/00) and rough science data from two others (8/27/00 and 9/11/00). The 8/27 data is the only scanning flight we have looked at, but the shortwave channel is plagued by noise problems preventing good CO retrievals. The remaining 11 flights will be examined for suitability for CO retrievals with preliminary analysis occurring in early January 2002. A subset of these flights will be scrutinized in detail for publication in a special S2K issue of JGR Atmospheres (submission in March 2002). We will also be taking the lead in combining the *in situ* aircraft measurements from S2K for validation of SHIS CO retrievals, and eventually for delivery to the MOPITT Science Team for correlative validation of MOPITT. We also will examine the other SHIS datasets for CO retrievals to provide additional MOPITT validation.

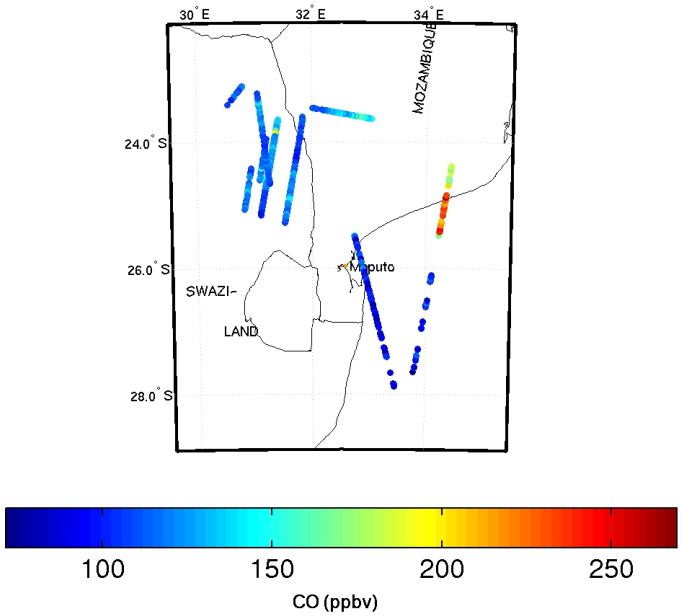

Figure 9: CO retrievals from SHIS spectra acquired on 9/7/00 over eastern southern Africa.

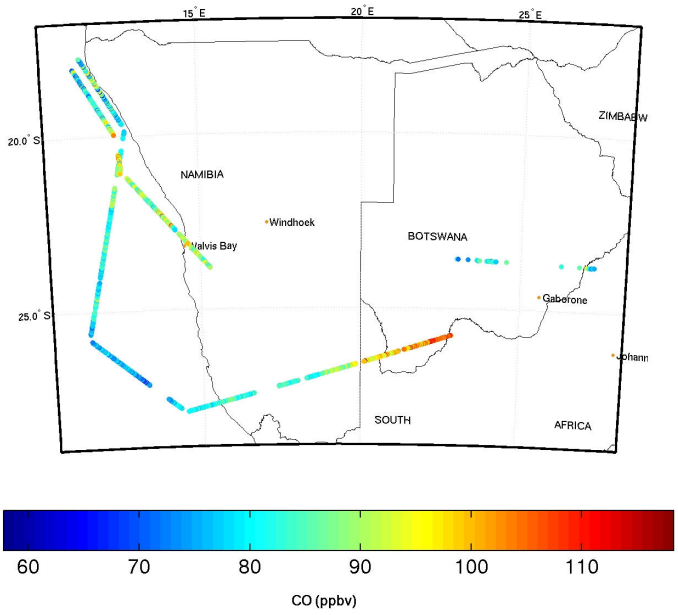

Figure 10: CO retrievals from SHIS spectra acquired on 9/11/00 over western and central southern Africa.

Preliminary retrievals for the 9/7 flight were presented by Dr. McMillan at the First S2K Data Workshop in Siovanga, Zambia in late August 2001. In early December the University of Wisconsin provided improved temperature and water vapor retrievals for this flight, and CO retrievals were reprocessed yielding smaller

residuals. This reprocessed data was presented by Dr. McMillan at the Fall AGU Meeting in San Francisco as well as preliminary CO retrievals for the 9/11 flight. CO retrieval maps for these two flights follow in Figures 9 and 10. These CO retrievals are from averages of 12 SHIS spectra along track (nadir only flights). The enhanced CO abundances over coastal of Mozambique on 9/7 result from transport of biomass burning products in the "river of smoke" episode. Lower CO abundances on 9/7 to the south off the coast of South Africa indicate clean marine air. Similarly, low CO abundances off the west coast of Africa seen on 9/11 are evidence of marine air, the ER-2 did not quite make it to the easterly outflow over the Atlantic just a bit further north along the Namibian coast.

Originally, our prime focus in looking at the 9/7 flight was the overflights of a controlled fire set in the Timbavati Game Reserve near Krueger National Park in northeastern South Africa. CO retrievals for two of these overpasses are presented in the final figure, 11, with retrievals made for 144 individual spectra to delineate the fire boundary. These two passes, separated by only 40 minutes, show some fire movement and possible evolution. Although, it is difficult to tell due to the location of SHIS internal calibration sequences nearly on top of the fire. The small hump in CO just before the large spike may indicate smoldering combustion in an older portion of the fire, while the large spike is believed to lie directly on top of the active flaming fire. We will complete detailed analysis of these fire passes in conjunction with colleagues well versed in satellite fire detection (like Dr. David Roy, UMCP/GSFC) using MAS images.

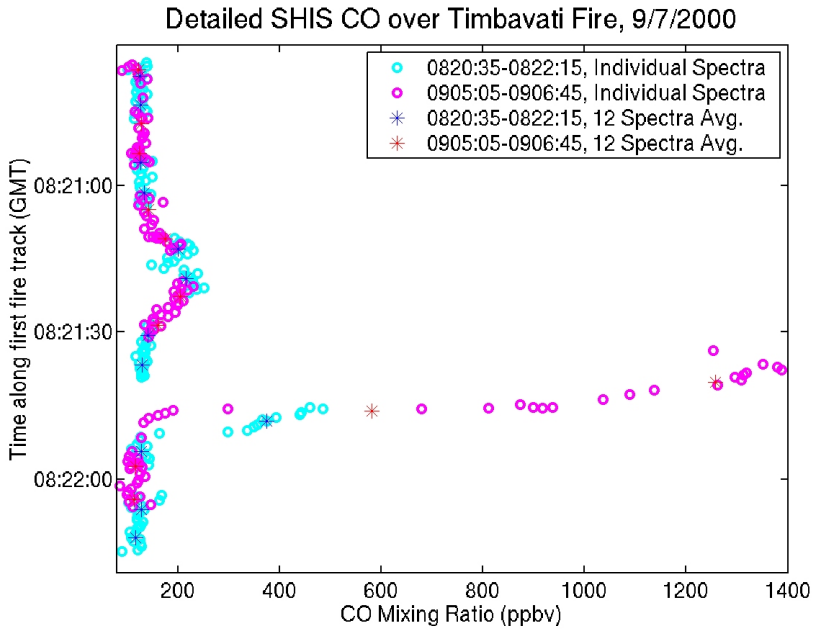

Figure 11: CO retrievals from individual spectra over the Timbavati fire on 9/7/00. The timings for the third overpass have been scaled to those of the first overpass using their geographical locations. This enables direct comparison of the two profiles and will be used in comparison to MAS images.

6 FY02 Activities

Planned activities for the remainder of FY02 include:

- Automation of BBAERI CO retrievals.
- Delivery of 2001 ARM SGP AERI CO retrievals to MOPITT Science Team.

- Delivery of 2000 and 2001 SGP AERI CO retrievals to EOSDIS for archiving.
- Submission for publication of first SHIS CO retrievals from S2K.
- Compilation of S2K CO validation data for MOPITT.
- Submission for publication of Lamont CO timeseries from 1998-2001.
- Implementation of new physical CO retrieval algorithm.
- Final development of AERI fast model for radiative transfer.