Characterizing NUCAPS retrieval quality for CO and CH_4 - A step towards improving air chemistry applications

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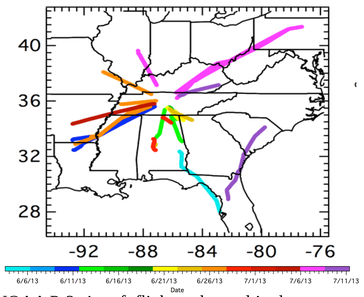
Abstract: NOAA WP-3D aircraft measurements of pollutant gases over target sites were made during two dedicated field campaigns, SENEX (Southeast Nexus) in 2013 and SONGNEX (Shale Oil and Natural Gas Nexus) in 2015. Together they provide high quality profile measurements with which to characterize trace gas retrievals from satellite radiance measurements. Of specific interest are the Cross-track Infrared Sounder (CrIS) and Advanced Technology Microwave Sounder (ATMS) NOAA-Unique CrIS-ATMS Processing System (NUCAPS) products of Carbon Monoxide (CO) and Methane (CH4), neither of which have been well characterized before. In fact, CO retrieval products can reach operational quality only since the full-spectral-resolution capability was switched on for CrIS in December 2014. Given the scope and space-time extent of SENEX and SONGNEX, we aim to characterize NUCAPS CO/CH4 retrieval accuracy and precision for a number of different events over known source sites. With this we will learn how well NUCAPS products are able to depict horizontal and vertical transport of pollutant air masses. The results from this study will support two efforts specifically, that of trajectory-based forecasts of smoke dispersion as well as the improvement of chemical-transport models used in atmospheric research and air quality forecasting operations.

This 2015/2016 NOAA JPSS Proving Ground/Risk Reduction (PGRR) project is a collaborative effort combining expertise in satellite retrieval development (STC), airborne trace gas measurements (ESRL/CIRES), and satellite trace gas validation (STAR/CIMSS/) to characterize NUCAPS retrieval quality, with the goal of improving the accuracy of the NUCAPS daily global measurements of methane (CH4) and carbon monoxide (CO). This project addresses key recommendations from the 2014 CrIS Atmospheric Chemistry Data User's Workshop Report (http://docs.lib.noaa.gov/noaa_documents/OAR/CPO/AC4/CrIS_workshop_2014.pdf) which concluded "that the current state of validation of the NUCAPS trace gas retrievals is insufficient for the use of these retrievals in most atmospheric chemistry applications" and recommended that the "CrIS retrieval development community should closely coordinate with the project teams of upcoming field campaigns (aircraft, surface, balloon, etc.) on trace gas validation activities".

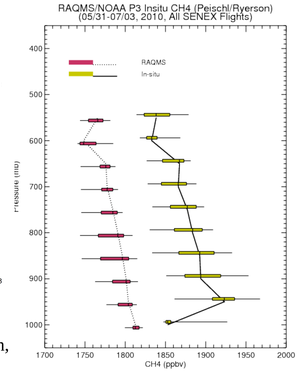
The two primary periods chosen for NUCAPS evaluation are during the Southeast Nexus (SENEX) (http://esrl.noaa.gov/csd/projects/senex/) and Shale Oil and Natural Gas Nexus (SONGNEX) (http://esrl.noaa.gov/csd/projects/songnex/) field campaigns. The majority of the 2013 SENEX and 2015 SONGNEX airborne observations occurred during the afternoon with nearest S-NPP coincidences during the PM (Ascending) orbits. NUCAPS quality control (QC) leads to lower yields in the PM orbits over land, particularly in the western US. This results in a limited set of aircraft/NUCAPS coincidences, particularly during the 2015 SONGNEX mission. Consequently, initial validation efforts focus on indirect validation using the Real-time Air Quality Modeling System (RAQMS, Pierce et al, 2007) as a transfer standard between the aircraft measurements and the NUCAPS retrievals. Direct comparisons between RAQMS and aircraft CO and CH4 are used to bias correct the RAQMS trace gas predictions, which are then directly compared to the NUCAPS retrievals over North America on each flight day. The RAQMS study is a precursor to more detailed indirect validation studies using high resolution nested RAQMS/WRF-CHEM simulations that more accurately represent the variability found in the aircraft measurements, particularly near source regions.

SENEX 2013 NUCAPS CH4 Indirect Validation

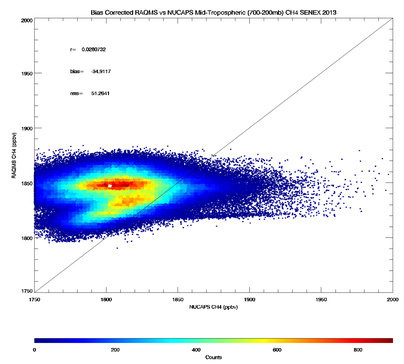
During SENEX (June - July 2013) the NOAA P-3 aircraft sampled trace gases and aerosols in air masses with different mixtures of anthropogenic, biogenic and fire emissions sources to assess the relative contributions of anthropogenic and biogenic emissions to form climate-forcing agents. We focus on validation of the NUCAPS mid tropospheric (700mb-200mb) CH4 due to the increased retrieval sensitivity at these altitudes.



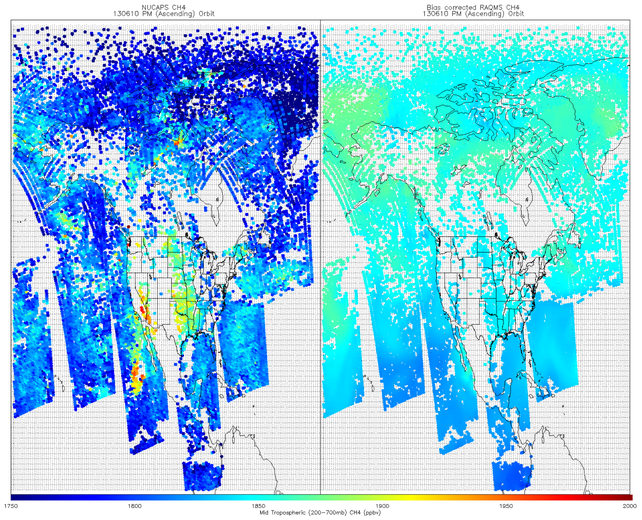
NOAA P-3 aircraft flight paths at altitudes greater than 4 km above ground level (AGL) over the southeastern US during the SENEX field campaign, June-July, 2013.



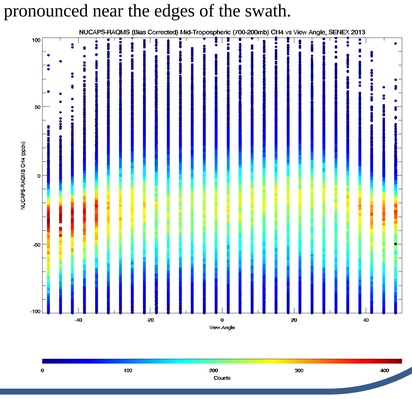
Comparisons between RAQMS and insitu CH4 measurements during SENEX show that RAQMS has a mean low bias of 82ppbv above 700mb and tends to underestimate the observed variability (bars and whiskers show 50th and 90th percentiles within each 50mb pressure bin, respectively)



Comparisons between bias corrected RAQMS and NUCAPS mid tropospheric CH4 suggests that NUCAPS has a 35ppbv low bias relative to the insitu aircraft measurements that is most pronounced near the edges of the swath.

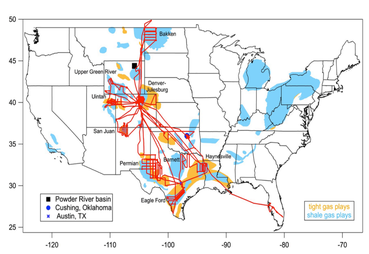


Mid tropospheric NUCAPS and coincident bias corrected RAQMS CH4 on 06/10/2013. Note apparent scan angle dependence in NUCAPS CH4 retrieval.

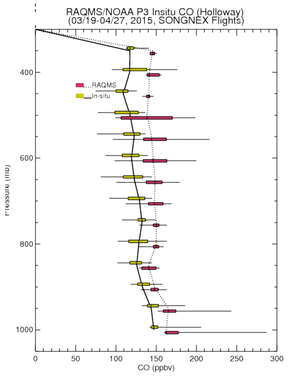


SONGNEX 2015 NUCAPS CO Indirect Validation

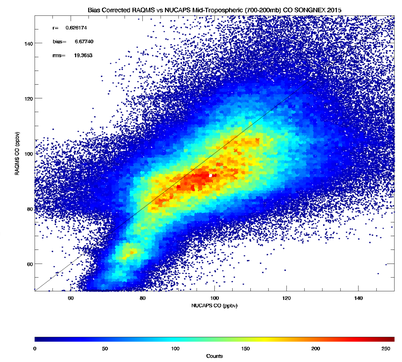
During SONGNEX (March and April 2015), the NOAA P-3 measured trace gases and fine particles over several different tight oil and shale gas basins in the western and south central US, as well as sampling a number of fire events. We focus on validation of the NUCAPS mid tropospheric (700mb-200mb) CO due to the availability of full spectral resolution CrIS Sensor Data Records (SDR) after December 2014.



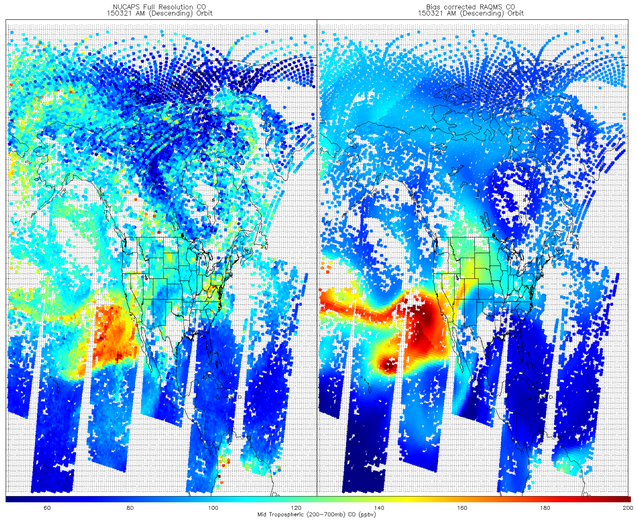
NOAA P-3 aircraft flight paths over the western US during the SONGNEX field campaign, March-April, 2015.



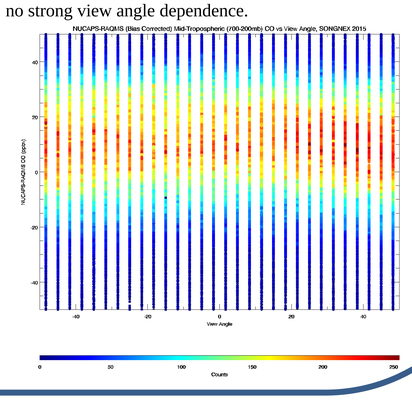
Comparisons between RAQMS and insitu CO measurements during SONGNEX show that RAQMS has a mean high bias of 29ppbv above 700mb and tends to overestimate the observed mid tropospheric variability (bars and whiskers show 50th and 90th percentiles within each 50mb pressure bin, respectively)



Comparisons between bias corrected RAQMS and NUCAPS mid tropospheric CO suggests that NUCAPS has a 6.8 ppbv high bias relative to the insitu aircraft measurements that shows no strong view angle dependence.



Mid tropospheric NUCAPS and coincident bias corrected RAQMS CO on 03/21/2015. Note that we are focusing on coincidences with the S-NPP AM (Descending) orbit



Future plans: These preliminary results use mean mid tropospheric CH4 and CO mixing ratios and do not account for the altitude dependence of the NUCAPS retrieval sensitivity, which requires averaging kernel (AK) information that is produced by the NUCAPS retrieval system but is currently not output. Once the AK information is provided we will account for the NUCAPS sensitivity by applying the AK to the coincident RAQMS CH4 and CO profiles, which will likely improve the results of these indirect validation efforts and possibly reduce the scan angle dependent bias identified in this study. We intend to further refine the NUCAPS quality control so that more trace gas retrievals are retained for the PM (Ascending) orbits, which will allow direct comparisons between the NUCAPS and insitu (with AK applied) CH4 and CO profiles.

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