An experiment using high resolution CrIS measurements for atmospheric retrievals: carbon monoxide impact study

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ABSTRACT We perform a demonstration experiment using the NOAA Unique CrIS/ATMS Processing System (NUCAPS) to assess the improvement on trace gas retrievals upon switching to high spectral resolution CrIS radiance measurements (0.625 cm^{-1}). The focus of this study is carbon monoxide retrievals. The experimental high spectral resolution CO retrievals show a remarkable improvement, of almost up to one order of magnitude in the degree of freedom of the signal, with respect to the low resolution mode. Furthermore, high resolution CO retrievals show similar skill with respect to existing CO operational products from the AIRS, IASI and MOPITT instruments, both in terms of spatial variability and degrees of freedom. The results of this research provide evidence to support the need for high spectral resolution CrIS measurements. This is a fundamental prerequisite in guaranteeing continuity to the CO afternoon orbit monitoring as part of a multi-satellite, uniformly integrated, long term data record of atmospheric trace gases.

The Cross-Track Infrared Sounder (CrIS) on-board the Suomi National Polar-orbiting Partnership (SNPP) platform is a Fourier spectrometer covering the longwave (655-1095 cm^{-1}), midwave (1210-1750 cm^{-1}), and shortwave (2155-2550 cm^{-1}) infrared spectral regions. In current operations the interferogram raw data record (RDR) is truncated at a maximum geometrical path difference, *L*, of 0.8 cm, 0.4 cm and 0.2 cm, and Fourier transformed into radiance spectra with Nyquist sampling *1/2L*, that is 0.625 cm^{-1}, 1.25 cm^{-1} and 2.5 cm^{-1} in the three bands, respectively. On March 12th, 2013, five orbits of the CrIS instrument were configured to down-link full path interferograms truncated at a geometrical path difference, *L'* of 0.8 cm in all three bands and Fourier transformed into radiance spectra with Nyquist sampling now equal to 0.625 cm^{-1} across the full spectrum. The scope of this experiment was to test both the upgraded processing streamline and the impact on retrieval applications.

The NOAA Unique CrIS/ATMS Processing System (NUCAPS) is the operational retrieval system developed at the National Oceanic Atmospheric Administration (NOAA) National Environmental Satellite, Data and Information Service (NESDIS) center for Satellite Application and Research (STAR) to produce cloud-cleared radiances and atmospheric temperature, water vapor and trace gas profiles from CrIS in conjunction with the Advanced Technology Microwave Sounder (ATMS). These retrieval products are accessible in near real time (about 3 hour delay) through the Comprehensive Large Array-data Stewardship System .

Figure 1

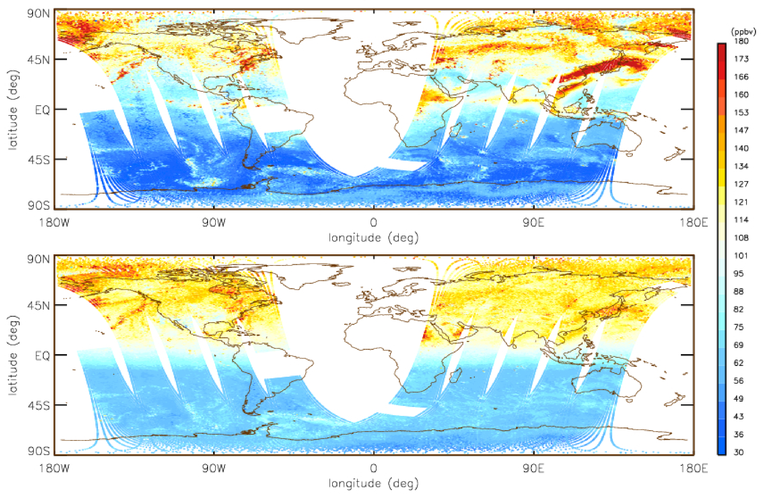
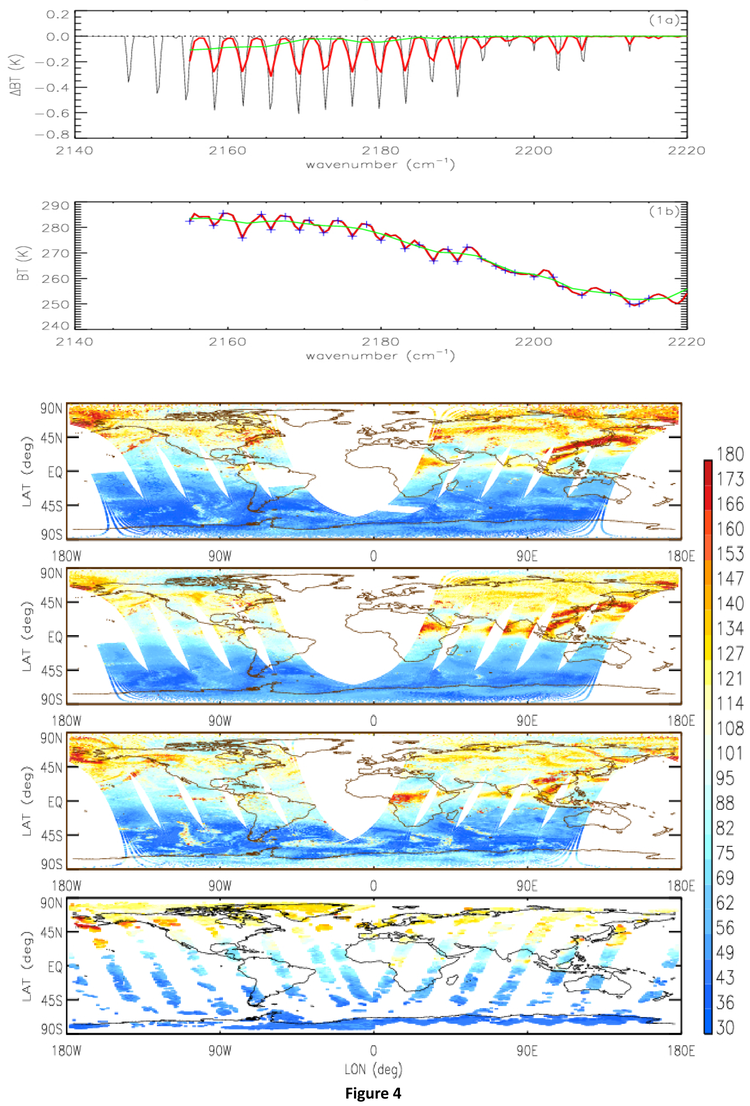


Figure 2



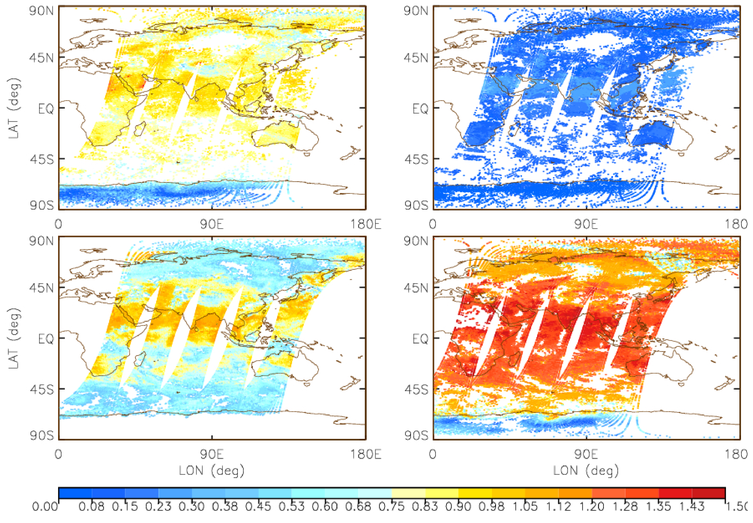


Figure 3

Figure 4

Figure 1 shows a comparison of the NUCAPS CO retrieval performed in high spectral resolution mode (top) with respect to the operational low resolution mode (bottom) for the five test orbits on the 440-460 mb layer. High resolution mode retrievals show significantly more structure in the global distribution of CO abundance with respect to the low resolution mode. The extended regions of heightened CO peak values on the high resolution map are indicative of anthropogenic emissions, biomass burning and atmospheric circulation patterns. These key features of the source and sink climatology of carbon monoxide are predominantly missed in the low resolution retrieval map.

Figure 2 We use a standard mid-latitude atmospheric profile to compute a 1% perturbation in the CO vertical profile and simulate the brightness temperature response measured by CrIS using the current low (2.5 cm^{-1}, green curve) and the experimental high (0.625 cm^{-1}, red curve) spectral resolution. The black curve in Figure 2a is a third perturbation performed using a finer spectral resolution (0.25 cm^{-1}) and is used as a reference. Figure 2a indicates an increased sensitivity in the high resolution measurement of up to three times higher with respect to the low resolution case. More importantly, the large non linear structure observed in the high resolution response is an indication of the higher information content present in the high resolution measurement and represents a key feature for the accuracy of the retrieval in that it allows the separation of CO from other interfering atmospheric species. Figure 2b shows a brightness temperature measurement acquired by the CrIS instrument in low (thin) and high (thick) resolution mode on March 12, 2013 at the same exact location (32.10N-127.87E). We can notice that the large structure present in the high resolution spectrum (red curve) carries the distinctive signature of the CO absorption lines observed in the sensitivity study shown in Figure 2a. On the contrary, in low resolution mode (green curve), these CO absorption features are almost entirely suppressed. Blue crosses on Figure 2b indicate the set of channels selected to perform the CO retrieval in high resolution mode.

Figure 3 NUCAPS high spectral resolution CO retrievals (Figure 1, top and Figure 3a) show a significantly improved agreement to the Atmospheric InfraRed Sounder (AIRS) version 6 (Figure 3b) and the Infrared Atmospheric Sounder Interferometer (IASI) NOAA Phase II (Figure 3c) CO operational retrievals, on the same five test orbits and pressure layer as NUCAPS. For completeness, we also show results from the MOPITT version-5 (Figure 3d) CO operational retrievals. Compared to the low resolution case (Figure 1, bottom), NUCAPS high spectral resolution CO retrievals (Figure 1, top and Figure 3a) show a significantly improved agreement to all three CO satellite products.

Figure 4 NUCAPS high spectral resolution CO DOFS (top left) are observed to consistently improve across all latitudinal regimes, up to one order of magnitude, with respect to the low resolution mode (top right). This is consistent with the results found in Figure 1 where the higher information content enabled a larger departure from the a priori, hence the increased spatial variability observed in the high spectral resolution map (top part of Figure 1) with respect to the low resolution case (bottom part of Figure 1). Furthermore, NUCAPS high resolution CO DOFS performance appears by far more comparable to both the AIRS and IASI CO DOFS performance.

Conclusions The results of this research provide evidence to support the need for high spectral resolution CrIS measurements. This is a fundamental prerequisite in guaranteeing continuity to the afternoon orbit monitoring of atmospheric CO as part of a multi-satellite, uniformly integrated, long term data record of atmospheric trace gases. NUCAPS high spectral resolution trace gas retrievals from CrIS on Suomi NPP will also serve in preparation of future advanced satellite missions under the Joint Polar Satellite System \cite{JPSS} for which atmospheric trace gases such as ozone, carbon monoxide, methane and carbon dioxide, are listed as operational requirements. The modular architecture of NUCAPS has proven that there is no risk of disruption to the operational processing upon switching to high spectral resolution mode.

Reference A. Gambacorta et al., An experiment using high spectral resolution CrIS measurements for atmospheric trace gases: carbon monoxide retrievals impact study, IEEE Geoscience and Remote Sensing Letters – GRSL-00806-2013.