Year-1/Progress Report

Award <>

The Stand Alone Rapid Transmittance Algorithm for CrIS and CHIRP

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1 Overview

The CrIS and CHIRP radiative transfer algorithms (RTA) are fast parameterizations of channel-averaged atmospheric layer transmittances. The original wrapper code is the Stand Alone Rapid Transmittance Algorithm (SARTA) and consists of a clear sky RTA, used in generating L2 retrieved products from level L1C Cloud Cleared Radiances (CCRs), and a scattering version coupled to a novel representation of clouds as two slabs (DeSouza-Machado et al 2018). The 2-slab model takes advantage of the fact the hyperspectral infrared radiances have very few degrees of freedom of cloud information, allowing one to model the radiative transfer through two equivalent layers instead of using multiple layers and phases in the simulation. This is used at UMBC for single footprint retrievals at the native sensor horizontal resolution.

The SARTA transmittances are derived from simulated transmittances computed with UMBC's pseudo line-by-line algorithm kCARTA (kCompressed Atmospheric Radiative Transfer Algorithm), which is the reference forward model for SARTA. The line-by-line transmittances are convolved to the CrIS and CHIRP spectral line shapes (ILS) then fitted to a suite of predictors used for the fast coefficients in SARTA. The optical depths (ODs) used in kCARTA primarily come from our custom inhouse Matlab based line-by-line code (UMBC-LBL). Additionally, kCARTA can be built with CO_2 and CH_4 optical depths from the AER-LBLRTM code. Currently, CH_4 line-mixing is not implemented in the UMBC-LBL so the AER-LBLRTM option is used. A complete description of both the underlying line-by-line code (UMBC-LBL) and kCARTA can be found in ref: DeSouza-Machado et al (2020).

2 Year 1 Activities

2.1 Variables and gases included

The following is a summary list of the processes, variables and gases that are included in the CrIS and CHIRP SARTA. Absorption by H2O, O3, CH4, CO, HNO3, N2O, SO2, NH3, HDO, CO2 including line mixing and nonLTE, surface TIR emissivity and solar reflectivity, including atmospheric path zenith angle and solar zenith angle. The two-slab scattering version includes water droplet, various ice and some dust habitats.

2.2 Build Status at time of writing.

The current SARTA build uses the HITRAN 2020 updated line database. The 2020 release of HITRAN was delayed significantly to the end of 2021, this has been installed at UMBC and tested uisng the kCARTA model. The most significant changes to the 2016 release for this application, include the 1050 cm-1 Ozone and SO2 line parameters. There are minor changes in many other spectral regions, but after convolution to the sensor response function the changes were generally very small. At the time of writing the new optical depths for training profiles have been computed, from which updated fast coefficients for SARTA have mostly been computed and tested for both the CrIS FSR and CHIRP spectral responses. The 2-slab scattering codes will be built and tested in the next reporting period.

2.3 Testing, Validation and Tuning

At the time of this report, the testing of the current builds has consisted of quantifying the fit residuals for the atmospheric profile training set against the kCARTA top-of- atmosphere (TOA) brightness temperatures. There are 49 training profiles applied over a range of view and solar angles and surface emissivities. This set of tests provides the verification needed to demonstrate that the fast coefficient regressions have completed successfully and where any adjustments are needed. This preceeds testing of the minor gas perturbations, or Jacobians, and preceeds application to actual sensor records, which in turn preceeds any tuning that may be required after comparison with conditioned tests against radiosondes, for example.

An example of the test against kCARTA TOA BTs for the CrIS full spectral resolution (FSR) is shown in figure 1 for various slant path angles from nadir to 60-degrees. Notice the mean bias is typically ~0.1 K with some exception in the 1300cm-1 CH4 band and N2O near 2050 cm-1. There is very little variation with view angle, except in the 660cm-1 CO2 band. These regions can and will be improved.

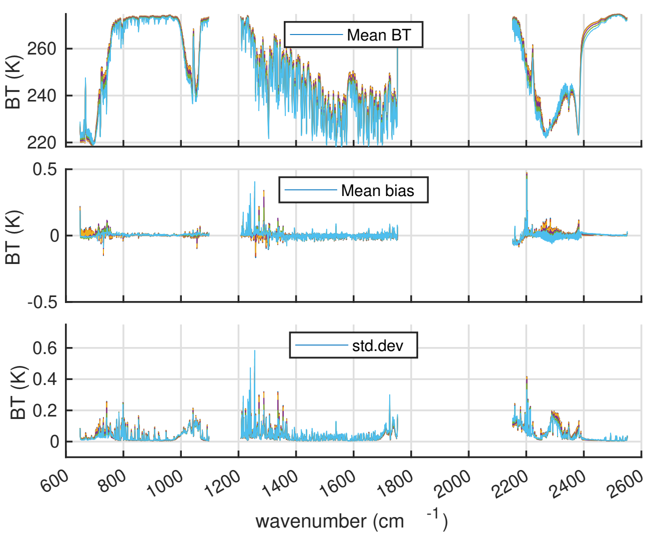

Figure 1: Comparison of SARTA vs kCARTA top-of-atmosphere BT for CrIS FSR. Top: mean. Middle: mean bias. Bottom: std.dev. See text.

Figure 2 shows the difference between the current build and the previous (v2018), which used HITRAN 2016 line parameters, calculated for CrIS FSR using the 49 atmospheric fitting profiles. The biggest change is evident in the 1050 cm-1 Ozone band, with some small changes in other parts of the band.

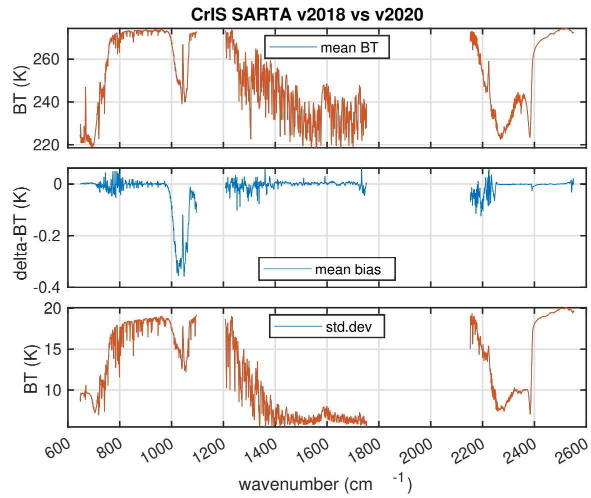

Figure 2: Comparison of current and previous SARTA build for CrIS FSR. Top: Mean BT. Middle: Mean bias. Bottom: std.dev of the sample.

Figure 3 shows the CHIRP SARTA TOA BT calcluations compared to the kCARTA for the same 49 fitting profiles and path combinations as used in figure 1 for CrIS FSR. There a similarly small bias differences as expected, with the strong CO2 lines in the 667 cm-1 and 2350 cm-1 bands exhibiting variation with view angle which is anticipated at this stage of development and will be eliminated with updated training as has been done for CrIS.

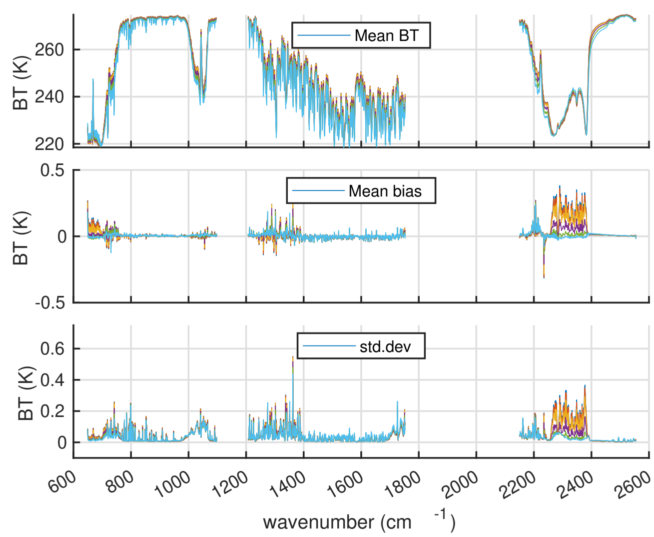

Figure 3: Comparison of SARTA vs kCARTA top-of-atmosphere BT for CHIRP. Top: mean. Middle: mean bias. Bottom: std.dev. See text.

2.4 Emissivity/Reflectivity Improvements

A higher fidelity model of ocean emissivity has been in review with Dr. Nalli which includes updated surface roughness parameterization. The number of sample points across the sensor spectral bandpass has also been increased and include the more opaque regions outside the LW window. Studies at UMBC show that the changes are less than about 0.1 K BT worst case. It is yet to be demonstrated that the correction improves bias analyses, and how or if the changes will be incorporated.

In addition, the Chou emissivity scaling parameters have been under test at UMBC, this work has just begun and an assessment will be made in the coming reporting period.

3 Non-LTE Emission

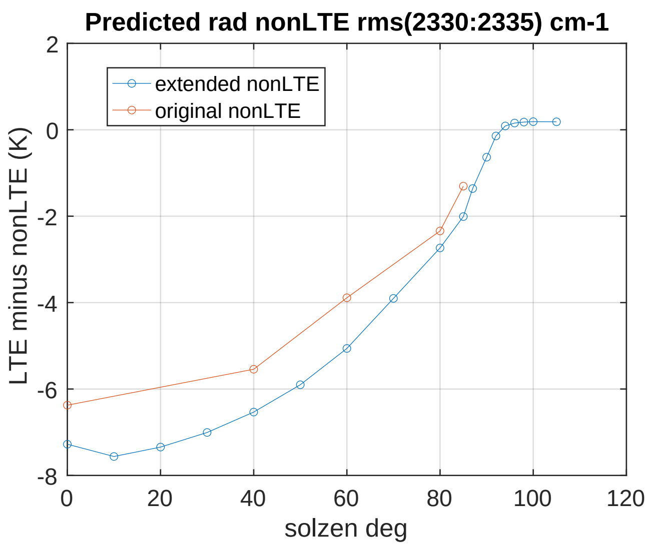

Figure 4: Old vs Extended nonLTE model.

A new set of non-LTE profiles from the atmospheric research group (IAA) at the University of Granada, Spain were supplied to UMBC and these have been investigated. They offer more detailed modelling than previously and through the night time. At the time of writing, a trial regression has been performed to update the SARTA coefficients, and results indicate that refinement in the choice of predictors is required. This work will continue and the new model is planned to be incorporated subject to being verified as improving the biases in this region, during the next reporting period.

4 References:

DeSouza_Machado et al. Atmos. Meas. Tech., 11, 529–550, 2018 https://doi.org/10.5194/amt-11-529-2018

DeSouza-Machado et al. Atmos. Meas. Tech., 13, 323–339, 2020 https://doi.org/10.5194/amt-13-323-2020