TROPESS Carbon Monoxide
Level 2 Summary Data Product User Guide

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Table of Contents

1. Introduction

1.1 Overview and Document Scope

This document is to be used as a Quick start user guide for using the TROPESS Carbon Monoxide (CO) Level 2 Summary Product Files.

1.2 Dataset Description

This user guide describes the TROPESS Level 2 Summary Product Files for CO.

Table 1. Dataset Description

Product Information	Description
Parameters	See Table 2, in section 2.1
Data Product Provenance	Refer to ReadMe document, section 1.3.4 Algorithm Version
Approximate file size	8MG AIRS, 17MB CRIS
Spatial coverage	Regular collections have global coverage: Nominal latitude range: 70 N to 50 S Nominal longitude range: -180 to 180 Special collections: Spatial coverage varies by collection
Temporal coverage	Each L2 Summary file contains 1 day of data.
File format	netcdf
Vertical sensitivity	Estimates of carbon monoxide concentrations from thermal infrared satellite observations are most sensitive to CO variability between 850 and 200 mb. However, sensitivity depends on observed scene parameters such as thermal contrast and can be variable. Users should assess individual retrieval sensitivity using the averaging kernel (AK) for CO profiles and degrees of freedom for signal (DFS) or column AK for total column CO.
Data quality	The L2 Summary data products have undergone a pre-quality check, which involves checks for retrieval convergence and measurement sensitivity. There are no checks for clouds or land versus ocean as we do not find these to substantively affect the quality of the retrieval as long as the retrieval has converged. Note that retrievals over thick clouds will not be sensitive to CO below the clouds.
Observational uncertainty	Profiles levels have approximately 7% observational error (does not include vertical smoothing error).
Validation Stage	Stage 3 according to NASA guidelines https://science.nasa.gov/earth-science/earth-science-data/data-maturity-levels
Retrieval Levels	14 levels: from surface to top-of-atmosphere
_FillValues	-999
Retrieval terminology	Retrieval terminology is defined in TES ATBD TROPESS_ATBDv1.1.pdf (nasa.gov)

1.3 Filename

The Level 2 Summary Products adhere to the following filename convention:

```
[TROPESS]_ [Instrument-
Platform]_[ProductLevel]_[ProductType]_[ProductName]_[DateStamp]_[Algori
thmName]_[AlgorithmVersion]_[ProcessingStrategy]_[FormatVersion].nc
```

Example:

```
TROPESS_CrIS-SNPP_L2_Summary_CO_20200912_MUSES_R1p10_FS_F01.nc
```

2. Product File Contents and Parameter Description

2.1 Variables included in the L2 Summary Product

All data fields in CO summary products are shown in Table 2.

Table 2. Data Fields

Data Field Name	Long_Name/Description	Type	Dimensions	Undefined Value	Units
longitude	longitude of earth view target center	float	target	-999.0	degrees_east
latitude	latitude of earth view target center	float	target	-999.0	degrees_north
time	Earth view target mid time as International Atomic Time (TAI) seconds since 1993-01-01 00:00:00	double	target	-999.0	seconds since 1993-01-01 00:00:00
datetime_utc	UTC expressed as an array of integers year, month, day, hour, minute,	int	target, datetime_utc	-999	1

Data Field Name	Long_Name/Description	Type	Dimensions	Undefined Value	Units
	second		_dim		
year_fraction	Year plus fraction of the year	double	target	-999.0	year
altitude	Altitude at each target	float	target, level	-999.0	m
pressure	Atmospheric pressure used for retrieval at each target.	float	target, level	-999.0	hPa
target_id	Unique id that identifies observations across all product files.	long	target	-999	1
x	Volume mixing ratio (VMR) of Carbon Monoxide relative to dry air	double	target, level	-999.0	1
xa	A priori state, as volume mixing ratio (VMR) relative to dry air	float	target, level	-999.0	1
col	Vertically integrated carbon monoxide total column	double	target	-999	mol m-2
col_error	Observational uncertainty of the vertically integrated carbon monoxide total column	double	target	-999	mol m-2

Data Field Name	Long_Name/Description	Type	Dimensions	Undefined Value	Units
col_dry_air	Vertically integrated dry air total column	double	target	-999	mol m-2
ak_col	Linearized column averaging kernel for the column; from the surface to Top of Atmosphere (TOA); Applies to `col`	double	target, level	-999	1
pwf_col	Full pressure weighting function. Set of coefficients used for calculating the column volume mixing ratio average; from the surface to Top of Atmosphere (TOA).	double	target, level	-999	1
x_col	Column-averaged dry air mixing ratio of carbon monoxide from the surface to Top of Atmosphere (TOA)	double	target	-999.0	1e-9
x_col_error	Observational uncertainty of the column volume mixing ratio average	double	target	-999	1e-9
ak_x_col	Linearized column averaging kernel for the column; from the surface to Top of Atmosphere (TOA.) Applies to x_col	double	target, level	-999	1

Data Field Name	Long_Name/Description	Type	Dimensions	Undefined Value	Units
land_flag	If target is over land == 1, otherwise == 0	Int	target	-999	N/A
day_night_flag	If target is during the day == 1, otherwise == 0	Int	target	-999	N/A

3. How to Compare TROPESS CO columns to aircraft or model fields

Comparisons between remotely sensed data and *in situ* measurements or vertically-resolved model fields should account for the vertical sensitivity of the remotely sensed measurement and its uncertainty. Otherwise, the error will be larger than the observation error that is included is this product.
An observation operator, which explicitly accounts for this sensitivity and facilitates comparisons with models and independent data, is applied in the following manner:

1) Select the CO profile using the model or aircraft fields (for the purpose of this demonstration called $x_{\_true}$).

2) Construct the operation operator as the following :
$$H(\cdot)=h^T x_a + a^T ((\cdot)-x_a)$$
where: **h**, the pressure weighting function, denoted as pwf_col in the product file, x_a, the a priori profile; **a**, the column averaging kernel, denoted as ak_x_col in the product file,

3) Apply observation operator to the CO "true" profile:
$$\hat{x}_{true}=H(x_{true})$$

4) Compare: $\hat{x}_{true}$ to the satellite result, $\hat{x}$, denoted as x_col in the product file. The difference
$$\epsilon=\hat{x}_{true}-\hat{x}$$

Now accounts for the prior information and limited sensitivity in the retrieval. Differences larger than the predicted error, denoted as x_col_error in the file, are statistically significant.

3.1 Evaluating the TROPESS CO sensitivity

The column averaging kernel, called ak_x_col, incorporates both the pressure weighting function and the sensitivity of the retrieval to the distribution of the state. To investigate the sensitivity alone, calculate

$$a\_norm = ak\_x\_col/pwf\_col$$

The term a_norm is the sensitivity versus pressure. A value of 1 for a_norm means perfect sensitivity, whereas a value of 0 means no sensitivity.

3   4. References

Please cite the following references if you intend to use these data:

Hegarty et al., Validation and Error Estimation of AIRS MUSES CO Profiles with HIPPO, ATom and NOAA ESRL Aircraft Observations, AMTD 2021.

The following references were also used in the development of this documentation and can be cited for model/data comparisons.

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5   Validation Summary

See L2 Standard Products User's Guide for Validation Summary.

4   Appendix A. Bias correction and quality flags

The data in the L2 Summary Products have been pre-filtered for quality and bias corrected. See L2 Standard Product Use's guides for definitions.

5   Appendix B. Retrieval levels

The table below contains the nominal retrieval levels. For each sounding, the surface pressure level is inserted into the retrieval levels set. Any retrieval levels below the surface pressure level are omitted.

Index	Pressure [hPa]
1	1040.0000
2	908.5139
3	681.2910
4	510.8980
5	383.1170
6	287.2980
7	215.4440
8	161.5610

9	121.1520
10	90.8518
11	51.0896
12	28.7299
13	4.6416
14	0.1000

6 Acknowledgement