CloudSat Project

A NASA Earth System Science Pathfinder Mission

Level 2-D Tropical Cyclone Product Process Description and Interface Control Document

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1. Introduction

The CloudSat (CS) Tropical Cyclone (TC) dataset is constructed from CS cloud profiling radar (CPR) intercepts of global TC's that pass within 1000 km of the storm center.

The CS TC product combines CS observations with A-TRAIN data from MODIS, AMSR-E model data from NoGAPS and ECMWF, auxiliary CloudSat 2B products and best track storm information.

More detailed information and a description of CS TC Dataset is featured in the Bulletin of the American Meteorological Society (BAMS) April 2015 article, Remote Sensing of Tropical Cyclones: Observations from CloudSat and A-Train Profilers (http://dx.doi.org/10.1175/BAMS-D-13-00282.1).

2. Data Processing

Naval Research Laboratory (NRL) and the CS Data Processing Center (http://www.cira.cloudsat.colostate.edu) reached an agreement early in the CS mission for NRL to ingest CS First Look (FL) data shortly after the product is received at the CS DPC.

When CS intersects a TC (within a 1000 km), NRL produces CS overlays onto MODIS, AMSR-E and other A-TRAIN satellite imagery showing the 3-D cross sectional analysis atop a 2-D satellite image product (Mitrescu, 2008).

After the CS battery anomaly in April 2011, processing of CS TC's moved to the Cooperative Institute for Research in the Atmospheric (CIRA) at Colorado State University (CSU).

For overpasses prior to April 2011, most contain visible or infrared imagery of the TC with the CS track overlaid. These images can be found in each directory of the TC sorted by year, basin and storm name/number.

3. CS TC 2D File Name Convention and Data Product Description

A. Overall format

The CS TC product is a .tar.gz file with the following name format:

2006259124227_02056_CS_TC-ATL-06L-FLORENCE_GRANULE.tar.gz

Each CS TC product contains a CS TC 2D hierarchal data format (HDF) file (containing storm specific information), CS level 2B data products (if available, details of included files are listed below) and a CS Year of the Tropical Convection (YOTC) .tar.gz (if available).

B. CS-2D HDF

The CS 2D-TC HDF file has the following filename structure format:

YYYYDDDHHMMSS_NNNNN_CS_2D_TC-BASIN-NUM:NAME_GRANULE.hdf

Where:
YYYYDDDHHMMSS - year, julian day, hour, minute, second of first data in
file (UTC)
NNNNN - CS granule number
CS_2D - CloudSat 2D product identifier
TC - Tropical Cyclone Data product
BASIN - Ocean basin (ATL, EPAC, WPAC, IO, SHEM, CPAC)
NUM - Storm Number
NAME - Storm Name
GRANULE - data subset

Storm best track (BT), SST (Reynolds) and various shear at different levels (GFS derived) are linearly interpolated and added to each storm overpass. Preliminary best track data is used until the final best track data is released, typically after the end of each TC season. Pre-battery anomaly, NRL added NoGAPS and AMSR-E data to each HDF file (for TC's prior to April 2011), see Table 2.

Storm Shear calculated at various levels listed in Table 1 are derived from one degree global forecasting system (GFS) analysis (from NCEP). The layers are averaged from a radius of 0-500 km and the vortex is NOT removed. These calculations are similar to standard storm shear (850-200 mb) calculation derived for SHIPS. The storm shear mean layer (ML) is calculated from the (925-700) – (300-200)) and is averaged over the respective layers.

TABLE 1. CS TC 2D GEOLOCATION AND DATA FIELDS IN EACH HDF FILE.

CloudSat TC 2D Geolocation Fields			
Field name	**Units**	**Missing Value**	**Description**
Profile_time	seconds	—	Seconds since the start of the granule for each profile. The first profile is 0.
TAI_start	seconds	—	The TAI timestamp for the first profile in the data file. TAI is International Atomic Time: seconds since 00:00:00 Jan 1 1993.
UTC_start	seconds	—	The UTC seconds since 00:00 Z of the first profile in the data file.
Date_Created	date and time (UTC)	—	Date product generated
StormCenterLat	degrees	-999.9	Storm center latitude of tropical cyclone (generated from best track data).
StormCenterLon	degrees	-999.9	Storm center longitude of tropical cyclone (generated from best track data).
StormMaxWind	m/s	-999.9	Best track maximum wind speed.
StormMSLP	mb	-999.9	Best track minimum pressure.
Min_Radial_Dist	km	—	Distance of the closest CS data point from the center of the tropical cyclone.
Storm_Shear850300	knots	-999.9	GFS derived wind shear. Difference in wind speed between 850-300 mb.
Storm_Shear850500	knots	-999.9	GFS derived wind shear. Difference in wind speed between 850-500 mb.
Storm_Shear925700	knots	-999.9	GFS derived wind shear. Difference in wind speed between 925-700 mb.
Storm_Shear300150	knots	-999.9	GFS derived wind shear. Difference in wind speed between 300-150 mb.
Storm_Shear925300	knots	-999.9	GFS derived wind shear. Difference in wind speed between 925-300 mb.
Storm_Shear300200	knots	-999.9	GFS derived wind shear. Difference in wind speed between 300-200 mb.
Storm_Shear_ML	knots	-999.9	GFS derived wind shear. Difference in wind speed between the mean layers ((925-700) – (300-200)).

CloudSat TC 2D Geolocation Fields			
Field name	**Units**	**Missing Value**	**Description**
Other_BestTrackData	—	Not present	Array of best track data 24 hours before/after the CS overpass. year, date, latitude, longitude, max wind speed, pressure, SST shear, storm_shear850300, storm_shear850500, storm_shear925700, storm_shear300150, storm_shear925300, storm_shear300200 and storm_shearML,
Latitude	degrees	—	Along-track latitude
Longitude	degrees	—	Along-track longitude
Navigation_land_sea_flag	—	—	Flag for land or sea
Storm_Shear	knots	-999.9	SHIPS derived 850 - 200 mb wind difference.
Storm_Center_SST	C	-999.9	Storm center sea surface temperature (Reynolds).
CloudSat TC 2D Data Fields			
Radial_Dist	km	—	Along track distance from the center of the tropical cyclone.
Radius	degrees	—	Angular distance between TC center and CS overpass (degrees from 0 - 180).
Azimuth	degrees	—	Azimuth between TC center and CS overpass (degrees).

C. Swath Naming Convention for CS TC 2D Product

The swath of each CS 2D TC HDF file contains the following information to assist in identifying what data exists in each file. There are five fields separated by a dash. For example,

2006/09/02-IOKE-2006245-1111111111111111-01853

 2006/09/02 – Date of overpass (Year/month/day)
 IOKE – TC name (as designated by basin)
 2006245 – 4 digit year followed by 3 digit julian day
 1111111111111111– Array of 0 or 1 designating the presence of the following data types (1 means the data is present, 0 means the data is missing)
       1. Best track data (0 designates preliminary best track)
       2. 2B-GEOPROF
       3. MOD06-5KM-AUX
       4. 2C-PRECIP-COLUMN
       5. 2B-CWC
       6. 2B-CLD-CLASS
       7. ECMWF-AUX

8. 2B-GEOPROF-LIDAR
9. 2B-TAU
10. 2C-ICE
11. 2D-CLOUDSAT-TRMM
12. 2B-CLDCLASS-LIDAR
13. 2B-CWC-RVOD
14. 2B-FLXHR
15. 2B-FLXHR-LIDAR
16. 2C-RAIN-PROFILE

01853 – CS granule number (5 digits).

D. NRL Data Components

The AMSR-E and NoGAPS data values listed in Table 2 were added by the TC team at NRL prior to the CS battery anomaly in April 2011. No manipulation of the data has been performed by processing at CSU. Not every TC overpass contains this data. This data is listed in the CS TC 2D product.

TABLE 2. NRL ADDED DATA TO THE CS TC 2D PRODUCT (ONLY ADDED PRIOR TO APRIL 2011 AND NOT PRESENT FOR ALL OVERPASSES).

Data Field Name	Units	Missing value	Description
PressLevels	mb	-999	NoGAPS pressure levels (17)
Temperature	K	-999	Along-track NoGAPS temperature @ pressure levels.
HeightLevels	km	-999	Along-track NoGAPS height levels @ pressure levels.
DewPoint	K	-999	Along-track NoGAPS dewpoint @ pressure levels.
Usfc	m/s	-999	Along-track NoGAPS U surface wind speed.
Vsfc	m/s	-999	Along-track NoGAPS V surface wind speed.
Tairsfc	K	-999	Along-track NoGAPS temperature at surface levels.
SST	K	-999	Along-track NoGAPS SST.
89H_Brightness_Temp_NRL	K	-999.9	Along-track NRL AMSR-E 89H brightness temperature.
SST_AMSRE_NRL	K		Along-track NRL AMSR-E SST
Wind_AMSRE_NRL	m/s		Along-track NRL AMSR-E wind speed.

Data Field Name	Units	Missing value	Description
Water_vapor_AMSRE_NRL	kg/m^2		Along-track AMSR-E water vapor.
LWP_AMSRE_NRL	kg/m^2		Along-track NRL AMSR-E liquid water path.
Rain_rates_AMSRE_NRL	mm/h	-999.0	Along-track NRL AMSR-E rain rate.

4. CS Level 2B Products

The following CS Level 2B data products are added for each TC (if available for the overpass). These files are subsetted to each CS TC overpass time period and stored using standard CloudSat DPC filename structure. Not all products are available for each TC overpass. For a more detailed description of each product, please visit http://www.cloudsat.cira.colostate.edu/data-products.

TABLE 3. LIST OF CS LEVEL 2B DATA PRODUCTS.

CloudSat TC Auxillary products	
2B-CLDCLASS	Cloud classification
2B-CLDCLASS-LIDAR	Cloud classification using CloudSat CPR and CALIPSO
2B-CWC-RO	Radar-only liquid/ice water content
2B-CWC-RVOD	Radar and visible optical depth liquid/ice water
2B-FLXHR	Radiative fluxes and heating rates
2B-FLXHR-LIDAR	Radiative fluxes and heating rates using CloudSat CPR, CALIPSO and MODIS
2B-GEOPROF	Cloud mask and radar reflectivities
2B-GEOPROF-LIDAR	CloudSat CPR and CALIPSO Lidar cloud mask
2B-TAU	Cloud optical depth, effective radius
2C-ICE	Profiles of number concentration, particle size and ice water content
2C-PRECIP-COLUMN	Presence and intensity of surface precipitation
2C-RAIN-PROFILE	Precipitation incidence, rainrate, liquid water content profiles of precipitation
2C-SNOW-PROFILE	Snowfall rate, size distribution and snow water content

CloudSat TC Auxillary products	
ECMWF-AUX	Subset of ECMWF along track variables of model fields including (pressure, temperature, specific Humidity and ozone @ 125 levels) and surface pressure, skin temperature, temperature_2m.
ECMWF-AUX2	SST, U10_velocity and V10_velocity.
MOD06-AUX - 1KM	Cloud properties using 1KM MODIS resolution.
MOD06-AUX - 5KM	Cloud properties using 5KM MODIS resolution.
MODIS-AUX	MODIS calibrated radiances at various solar and emissive bands.
YOTC granules	Year of the Tropical Convective - convection and cloud related A-Train satellite values collocated to CloudSat footprints for the period May 2008 to April 2010.

5. CloudSat Year of the Tropical Convection (YOTC)

The YOTC dataset contains convection and cloud related A-TRAIN satellite data collocated to CS footprints for the period May 2008 to April 2010. Products include quantities from satellite instruments CALIPSO, MLS, AIRS, AMSR-E, CERES, MODIS and a number of fields from the specialized YOTC analysis produced by ECMWF. For more details, please visit the YOTC website (http://yotc.cira.colostate.edu). The contents of these files have been subsetted to the time period of the TC overpass. Please note these products are in netCDF file format.

TABLE 4. YOTC FILENAME AND DATA DESCRIPTION.

CS YOTC filename descriptions.	
airs_xxxxxxxxxxxxx_xxxxx_CS_2B-CLDCLASS	AIRS instrument on AQUA. AIRS L2 standard retrieval product using AIRS IR and AMSU.
amsr_xxxxxxxxxxxxx_xxxxx_CS_2B-CLDCLASS	AMSR-E instrument on AQUA. AMSR-E Daily Geophysical Product.
ceres_xxxxxxxxxxxxx_xxxxx_CS_2B-CLDCLASS	CERES instrument on AQUA. Single Scanner Footprint TOA/Surface Fluxes and clouds.
caliop05kmALayer_xxxxxxxxxxxxx_xxxxx_CS_2B-CLDCLASS	CALIOP instrument on CALIPSO. CALIPSO Lidar Level 2 5km Aerosol Layer Data.
caliop05kmCLayer_xxxxxxxxxxxxx_xxxxx_CS_2B-CLDCLASS	CALIOP instrument on CALIPSO. CALIPSO Lidar Level 2 5km Cloud Layer Data.
caliop05kmCProfile_xxxxxxxxxxxxx_xxxxx_CS_2B-CLDCLASS	CALIOP instrument on CALIPSO. CALIPSO Lidar Level 2 5km Cloud Profile Data.
caliop40kmAProfile_xxxxxxxxxxxxx_xxxxx_CS_2B-CLDCLASS	CALIOP instrument on CALIPSO. CALIPSO Lidar Level 2 Aerosol Profile data
caliopVFM_xxxxxxxxxxxxx_xxxxx_CS_2B-CLDCLASS	CALIOP instrument on CALIPSO. CALIPSO Lidar Level 2 (Vertical Feature Mask data)
ecmwf_idaily_plevels_ncar_xxxxxxxxxxxxx_xxxxx_CS_2B-CLDCLASS	ERA Interim Atmospheric Model Analysis for Pressure Levels.
ecmwf_idaily_surface_ncar_xxxxxxxxxxxxx_xxxxx_CS_2B-CLDCLASS	ERA Interim Atmospheric Model Analysis for Surface.
ecmwf_yotc-aos-0.25deg_xxxxxxxxxxxxx_xxxxx_CS_2B-CLDCLASS	YOTC Atmospheric Model Analysis for Surface.

CS YOTC filename descriptions.	
mls-co_xxxxxxxxxxxxx_xxxxx_CS_2B-CLDCLASS	MLS instrument on Aura. MLS/Aura L2 Carbon Monoxide (CO) Mixing Ratio (Version 2.23).
mls-h2o_xxxxxxxxxxxxx_xxxxx_CS_2B-CLDCLASS	MLS instrument on Aura. MLS/Aura L2 Water Vapor (H2O) Mixing Ratio (Version 2.23).
mls-hno3_xxxxxxxxxxxxx_xxxxx_CS_2B-CLDCLASS	MLS instrument on Aura. MLS/Aura L2 Nitric Acid (HNO3) Mixing Ratio (Version 2.23).
mls-iwc_xxxxxxxxxxxxx_xxxxx_CS_2B-CLDCLASS	MLS instrument on Aura. MLS/Aura L2 Cloud Ice Water Content (IWC).
mls-o3_xxxxxxxxxxxxx_xxxxx_CS_2B-CLDCLASS	MLS instrument on Aura. MLS/Aura L2 Ozone (O3) Mixing Ratio (Version 2.23).
mls-temp_xxxxxxxxxxxxx_xxxxx_CS_2B-CLDCLASS	MLS instrument on Aura. MLS/Aura L2 Temperature (TEMP).
modis-aerosol_xxxxxxxxxxxxx_xxxxx_CS_2B-CLDCLASS	MODIS instrument on AQUA. MODIS aerosol product with 5 km resolution.
modis-cloud-1km_xxxxxxxxxxxxx_xxxxx_CS_2B-CLDCLASS	MODIS instrument on AQUA. MODIS cloud product with 1 km resolution.
modis-cloud-5km_xxxxxxxxxxxxx_xxxxx_CS_2B-CLDCLASS	MODIS instrument on AQUA. MODIS cloud product with 5 km resolution.

6. References to CS TC products and data.

Durden, Stephen L., Simone Tanelli and Gregg Dobrowalski, 2009: CloudSat and A-Train Observations of Tropical Cyclones, The Open Atmospheric Science Journal, 3, 80-92.

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Mitrescu, Cristian, Steven Miller, Jeffrey Hawkins, Tristan L'Ecuyer, Joseph Turk, Philip Partain, Graeme Stephens, 2008: Near-Real-Time Applications of CloudSat Data. J. Appl. Meteor. Climatol., 47, 1982-1994. doi: 10.1175/2007JAMC1794.1

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