National Aeronautics and Space Administration
Goddard Earth Science Data Information and Services Center (GES DISC)

README Document for Deep Convective Cloud Objects dataset of the Low Cloud Morphology and Deep Convective Cloud Objects project, version 001

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Revision History

Revision Date	Changes	Author
06/30/2022	Initial version	Ashley Heath
09/13/2032	Fill in the sections with information about the deep clouds data products	Eric Wilcox

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1.0 Introduction

This document provides basic information for using the **deep convective cloud objects** data records produced by the Making Earth System Data Records for Use in Research Environments (MEaSUREs) 2017 Program project titled “A Comprehensive Data Record of Marine Low-level and Deep Convective Cloud Systems Using an Object-Oriented Approach”. The major goal of this project is to build a novel and science-based Earth system data record of marine low-level morphology type and deep convective cloud objects and their environmental conditions. The lead investigator for the deep convective cloud objects data records is Eric Wilcox. The principal investigator responsible for the MEaSUREs project is Tianle Yuan.

1.1 Dataset/Mission Instrument Description

The Deep Convective Cloud Objects element of the project aims to create an observational record spanning about two decades that relates the size and structure of deep convective clouds to aspects of the broader atmospheric environment in which they are forming. This data collection contains observed properties of individual deep convective cloud objects identified in MODIS level 2 infrared imagery using an objective feature detection algorithm designed to associate deep convective cores of clouds with their associated anvil cloudiness. The observed properties include aspects of the size and structure of the cloud objects, as well as aspects of their microphysical properties derived from both the MODIS and co-located AMSR-E observations, and aspects of the thermodynamic and large-scale aerosol loading in the environment in which the cloud resides derived from MERRA-2 reanalysis and MODIS observations. The clouds in this dataset include all deep convective cloud observed by MODIS level 2 granules in the 30° S to 30° N latitude band for the full record of Aqua and Terra.

1.2 Product Table

The deep convective cloud part of the Low Cloud Morphology and Deep Convective Cloud Objects project is composed of the two individual products described in Table 1.

Table 1. Summary of deep convective cloud data products.

Dataset Title	Shortname	DOI
MODIS Aqua L2 deep-convective cloud classification V001	MYD_L2_DC	10.5067/0Y3M8IO4XKG5

MODIS Terra L2 deep-convective cloud classification V001	MOD_L2_DC	10.5067/HXRNU4HCIPA6

1.3 Data Disclaimer

Questions about the data may be sent to Dr. Eric Wilcox (Eric.Wilcox@dri.edu). The methodology for creating the data and its usage can be found in Wilcox et al. (2022)

1.3.1 Data Citation and Acknowledgment

NASA requests that you include the following acknowledgment in papers published using this dataset:

> "The data used in this study were acquired as part of the mission of NASA's Earth Science Division and archived and distributed by the Goddard Earth Sciences (GES) Data and Information Services Center (DISC)."

The digital object identifier (DOI) can also be used to precisely cite a specific dataset. The DOI for each product is listed in the IdentifierProductDOI global attribute. They are also listed in Table 1 above for reference.

The DOI registered to each data product can simply be pasted into a web browser and will resolve to a landing page that provides a recommended form for citing the data. For example, the recommended form when citing MYD_L2_DC is as follows:

> Wilcox, E. M., Yuan, T. and Song, H., NASA/GSFC/GES_DISC (2023), MODIS Aqua L2 deep-convective cloud classification, Greenbelt, Maryland, USA, Goddard Earth Sciences Data and Information Services Center (GES DISC), Accessed: [Data Access Date], 10.5067/0Y3M8IO4XKG5

We would appreciate receiving a copy of your publication, which can be sent to the GES DISC Help Desk by email: gsfc-dl-help-disc@mail.nasa.gov

1.3.2 Contact Information

If you have questions or feedback about this dataset and data access, please contact:

> GES DISC Help Desk
> Code 610.2 NASA/Goddard Space Flight Center Greenbelt, MD 20771
> Phone: 301-614-5224 Fax: 301-614-5268
> Email: gsfc-dl-help-disc@mail.nasa.gov
>
> ‘

1.4 Quality Issues

There are some gaps in the deep convective cloud record due to there being an incomplete archive of input datasets on the Discover supercomputer system where the data processing is performed. These gaps will be filled in an update to the dataset, along with extending the record beyond 2020. The months that are likely missing some clouds observed by MODIS are:

Aqua: 200302, 201912, 202008.

Terra: 200106, 200107, 200203, 200312, 200408, 200409-200412, 201102-201104, 201105, 201206, 201208, 201312, 201407, 201507, 201508.

2.0 Data Organization

The deep convective cloud object products of the Low Cloud Morphology and Deep Convective Cloud Objects project is a compilation of data consisting of MODIS and AMSR-E observations from the Aqua satellite and MODIS observations from the Terra satellite. Both of the Aqua and Terra datasets also include elements from the MERRA-2 data products. The product files are monthly where each file contains properties of the observed deep convective cloud objects. All variables, except one, have a single dimension that is the number of clouds observed by MODIS during the month. The only exception is the particle_effective_radius variable, which is a two-dimensional where for each cloud there is an average of the MODIS-observed cloud droplet effective radius for each of 45 temperature bins corresponding to the average of effective radius of all samples exhibiting an infrared brightness temperature in the temperature bin.

2.1 File Naming Convention

The deep convective cloud objects data files of the Low Cloud Morphology and Deep Convective Cloud Objects project are named in accordance with the following convention:

MODIS_<Instrument>_<ProductLevel>_<Descriptor>.V001.<TemporalResolution>.nc

Table 2.1. Attribute descriptions for the File names

Attribute	**Description**
<Instrument>	“Aqua” for the Aqua satellite
<ProductLevel>	“L2” for Level 2 data
<Descriptor>	“DC” for Deep Clouds
<TemporalResolution>	“YYYYMM” for monthly

Example:
The file name for the MODIS Aqua deep cloud data for the month of January, 2003:
MODIS_Aqua_L2_DC.V001.200301.nc

2.2 File Format

The deep convective cloud objects data files of the Low Cloud Morphology and Deep Convective Cloud Objects project are in NetCDF-4 format. NetCDF is a set of software libraries and self-describing, machine-independent data formats that support the creation, access, and sharing of array-oriented scientific data.
More information can be found here: https://www.unidata.ucar.edu/software/netcdf/docs/

3.0 Data Contents

3.1 Data Products

The deep convective cloud data files of the Low Cloud Morphology and Deep Convective Cloud Objects has a total of two data products. It includes two data collections one from the MODIS Aqua instrument and the other from the MODIS Terra instrument summarized in Table 3.1.

Table 3.1. The deep convective cloud objects data products and parameters

Data Product Shortname	Instrument	Number of parameters
MYD_L2_DC	MODIS Aqua	34, See Table 3.1.1
MOD_L2_DC	MODIS Terra	33, See Table 3.1.2

3.1.1 MODIS Aqua Deep Cloud Parameters

Table 3.1.1 below lists the parameters in the MODIS Aqua product.

- MYD_L2_DC

Table 3.1.1. Parameters in the MODIS Aqua deep cloud data product.

Short Name	Long name	Unit
AOT_MODIS	MODIS aerosol optical thickness averaged on 5 degree lat/lon	1
AOT_MERRA_at_min_IR	MERRA2 aerosol optical thickness at MERRA2 native resolution at location of minimum IR brightness temperature	1

AOT_MERRA	MERRA2 aerosol optical thickness averaged over cloud area	1
CAPE_at_min_PCT	MERRA2 CAPE at MERRA2 native resolution at location of minimum AMSR-E 89Ghz polarized corrected temperature	J kg-1
CAPE_at_min_IR	MERRA2 CAPE at MERRA2 native resolution at location of minimum infrared brightness temperature	J kg-1
CAPE	MERRA2 CAPE at averaged over cloud area	J kg-1
change_of_CAPE	Change over 6 hours of MERRA2 CAPE at averaged over cloud area	J kg-1
cloud_areas	cloud areas at 1km resolution	km2
cloud_classification	Cloud classification	1
fraction_colder_than_200K	Fraction of cloud area with infrared brightness temperature colder than 200K	1
fraction_colder_than_210K	Fraction of cloud area with infrared brightness temperature colder than 210K	1
fraction_colder_than_220K	Fraction of cloud area with infrared brightness temperature colder than 220K	1
fraction_over_land	Fraction of cloud area over land	1
IR_at_min_PCT	Infrared brightness temperature at the location of minimum AMSR-E 89GHz polarized corrected temperature	K
latitude_of_min_PCT	latitude at location of minimum AMSR-E 89GHz polarized corrected temperature	degrees_north
latitude_of_min_IR	latitude at location of minimum infrared brightness temperature	degrees_north
longitude_of_min_PCT	longitude at location of minimum AMSR-E 89GHz polarized corrected temperature	degrees_east
longitude_of_min_IR	longitude at location of minimum infrared brightness temperature	degrees_east
max_CAPE	Maximum value of MERRA2 CAPE within cloud area	J kg-1
max_change_of_CAPE	Maximum change over 6 hours of MERRA2 CAPE within cloud area	J kg-1
max_shear	Maximum MERRA2 vertical shear of horizontal wind within cloud area	m s-1
max_view_zenith	Maximum MODIS viewing zenith angle within cloud area	degrees
min_PCT	Minimum value of 89Ghz polarized corrected temperature within cloud area	K
min_IR	Minimum value of infrared brightness temperature within cloud area	K

time	time	minutes since 1990-01-01 00:00:00
particle_effective_radius_profile	MODIS particle effective radius averaged in bins of infrared brightness temperature	microns
PCT_at_min_IR	AMSR-E 89GHz polarized corrected temperature at location of minimum infrared brightness temperature	K
PCT	AMSR-E 89GHz polarized corrected temperature averaged over cloud area	K
shear_at_min_PCT	MERRA2 vertical shear of horizontal wind at MERRA2 native resolution at location of minimum AMSR-E 89GHz polarized corrected temperature	m s-1
shear_at_min_IR	MERRA2 vertical shear of horizontal wind at MERRA2 native resolution at location of minimum infrared brightness temperature	m s-1
shear	MERRA2 vertical shear of horizontal wind at MERRA2 native resolution averaged over cloud area	m s-1
wind_direction_200hPa_at_min_IR	MERRA2 wind direction at the 200 hPa pressure level at the location of minimum infrared brightness temperature	degrees
wind_direction_500hPa_at_min_IR	MERRA2 wind direction at the 500 hPa pressure level at the location of minimum infrared brightness temperature	degrees
wind_direction_850hPa_at_min_IR	MERRA2 wind direction at the 850 hPa pressure level at the location of minimum infrared brightness temperature	degrees

3.1.2 MODIS Terra Deep Cloud Parameters

Table 3.1.2 below lists the parameters in the MODIS Terra product.

- MOD_L2_DC

Table 3.1.2. Parameters in the MODIS Terra deep cloud data product.

Short Name	**Long name**	**Unit**
AOT_MODIS	MODIS aerosol optical thickness averaged on 5 degree lat/lon	1
AOT_MERRA_at_min_IR	MERRA2 aerosol optical thickness at MERRA2 native resolution at location of minimum IR brightness temperature	1
AOT_MERRA	MERRA2 aerosol optical thickness averaged over cloud area	1
CAPE_at_min_PCT	MERRA2 CAPE at MERRA2 native resolution at	J kg-1

	location of minimum AMSR-E 89Ghz polarized corrected temperature	
CAPE_at_min_IR	MERRA2 CAPE at MERRA2 native resolution at location of minimum infrared brightness temperature	J kg-1
CAPE	MERRA2 CAPE at averaged over cloud area	J kg-1
change_of_CAPE	Change over 6 hours of MERRA2 CAPE at averaged over cloud area	J kg-1
cloud_areas	cloud areas at 1km resolution	km2
cloud_classification	Cloud classification	1
fraction_colder_than_200K	Fraction of cloud area with infrared brightness temperature colder than 200K	1
fraction_colder_than_210K	Fraction of cloud area with infrared brightness temperature colder than 210K	1
fraction_colder_than_220K	Fraction of cloud area with infrared brightness temperature colder than 220K	1
fraction_over_land	Fraction of cloud area over land	1
latitude_of_min_IR	latitude at location of minimum infrared brightness temperature	degrees_north
longitude_of_min_PCT	longitude at location of minimum AMSR-E 89GHz polarized corrected temperature	degrees_east
longitude_of_min_IR	longitude at location of minimum infrared brightness temperature	degrees_east
max_CAPE	Maximum value of MERRA2 CAPE within cloud area	J kg-1
max_change_of_CAPE	Maximum change over 6 hours of MERRA2 CAPE within cloud area	J kg-1
max_shear	Maximum MERRA2 vertical shear of horizontal wind within cloud area	m s-1
max_view_zenith	Maximum MODIS viewing zenith angle within cloud area	degrees
min_IR	Minimum value of infrared brightness temperature within cloud area	K
time	time	minutes since 1990-01-01 00:00:00
particle_effective_radius_profile	MODIS particle effective radius averaged in bins of infrared brightness temperature	microns
shear_at_min_IR	MERRA2 vertical shear of horizontal wind at MERRA2 native resolution at location of minimum infrared brightness temperature	m s-1

shear	MERRA2 vertical shear of horizontal wind at MERRA2 native resolution averaged over cloud area	m s-1
wind_direction_200hPa_at_min_IR	MERRA2 wind direction at the 200 hPa pressure level at the location of minimum infrared brightness temperature	degrees
wind_direction_500hPa_at_min_IR	MERRA2 wind direction at the 500 hPa pressure level at the location of minimum infrared brightness temperature	degrees
wind_direction_850hPa_at_min_IR	MERRA2 wind direction at the 850 hPa pressure level at the location of minimum infrared brightness temperature	degrees

3.2 Data Set Attributes (File Metadata)

In addition to the Scientific Data Set (SDS) arrays containing variables and dimension scales, global metadata is also stored in the files. Some metadata are required by standard conventions, some are present to meet data provenance requirements and others as a convenience to users of Low Cloud Morphology and Deep Convective Cloud Objects products. A summary of global attributes present in all files is shown in Table 3.2.

Table 3.2. Global attributes in the deep convective cloud objects data files.

Global Attribute	**Description**	**Type**
Filename	Name of the data granule	string
ShortName	Short name for the data collection	string
LongName	Long, descriptive name for the data collection	string
VersionID	Data version	string
GranuleID	Name of the data granule (same as Filename)	string
Format	File format of the data (NetCDF)	string
RangeBeginningDate	Start date of the data in the file	string
RangeBeginningTime	Start UTC time of the data	string
RangeEndingDate	End date of the data in the file	string
RangeEndingTime	End UTC time of the data	string

SouthernmostLatitude	Southernmost latitude of global grid of data set	string
NorthernmostLatitude	Northernmost latitude of global grid of data set	string
WesternmostLongitude	Westernmost longitude of global grid of data set	string
EasternmostLongitude	Easternmost longitude of global grid of data set	string
IdentifierProductDOIAuthority	Authority through which DOI can be resolved	string
IdentifierProductDOI	Digital object identifier	string
ProductionDateTime	Date and time the current file was produced	string
ProcessLevel	Level of data processing	string
Conventions	the metadata conventions followed in the file, e.g. CF-1.8	string
Source	Instruments related to the origin of the data product	string
DataSetQuality	Overall assessment of quality of the data	string

4.0 Options for Reading the Data

4.1 Command Line Utilities

4.1.1 ncdump

The ncdump tool can be used as a simple browser for HDF data files, to display the dimension names and sizes; variable names, types, and shapes; attribute names and values; and optionally, the values of data for all variables or selected variables in a netCDF file. The most common use of ncdump is with the –h option, in which only the header information is displayed.

ncdump [-c|-h] [-v ...] [[-b|-f] [c|f]] [-l len] [-n name] [-d n[,n]] filename
Options/Arguments:
[-c] Coordinate variable data and header information
[-h] Header information only, no data
[-v var1[,...]] Data for variable(s) <var1>,... only data
[-f [c|f]] Full annotations for C or Fortran indices in data
[-l len] Line length maximum in data section (default 80)
[-n name] Name for netCDF (default derived from file name)
[-d n[,n]] Approximate floating-point values with less precision filename File name of input netCDF file

For more information about installing and using ncdump can be found from Unidata (https://www.unidata.ucar.edu/software/netcdf)

4.1.2 NCO

The netCDF Operator (NCO) is a powerful command line toolkit developed by the Earth System Science group in University of California, Irvine, which can manipulate and analyzes data stored in NetCDF. More information can be found at http://nco.sourceforge.net.

4.1.3 CDO

Climate Data Operators (CDO) is a collection of command line operators to manipulate and analyze Climate and NWP model Data. CDO is a large tool set for working on climate and NWP model data. NetCDF 3/4, GRIB 1/2 including SZIP (or AEC) and JPEG compression, EXTRA, SERVICE and IEG are supported as IO-formats. Apart from that, CDO can be used to analyze any kind of gridded data not related to climate science. CDO has very small memory requirements and can process files larger than the physical memory. More information can be found at Overview - CDO - Project Management Service (mpg.de).

4.2 Tools/Programming

This section lists some tools, but not limited, that may be used to read, visualize, and process this dataset:

4.2.1 Panoply

Panoply is a data viewer that displays geo-referenced arrays in NetCDF, HDF, and GRIB formats. The first-time user may download the software from NASA Goddard Institute for Space and Studies
(http://www.giss.nasa.gov/tools/panoply/).
Examples to use Panoply for GES DISC archived data can be found in data HowTo:
https://disc.gsfc.nasa.gov/information/howto?keywords=panoply&page=1

4.2.2 GrADS

The Grid Analysis and Display System (GrADS) is an interactive tool developed by the COLA (Center for Ocean-Land-Atmosphere Studies) group at George Mason University, which can read, visualize, and analyze gridded (i.e. Level 3 and Level 4) data files in a number of formats, including NetCDF, HDF, binary, and GRIB, as well as station data in BUFR format (http://cola.gmu.edu/grads/).
Examples of HowTo articles on using GrADS with GES DISC data can be found here:
https://disc.gsfc.nasa.gov/information/howto?keywords=grads&page=1

5.0 GES DISC Data Services

Access to GES DISC data requires a free Earthdata login profile. Please see the following instructions for creating an Earthdata login profile:

https://wiki.earthdata.nasa.gov/display/EL/How+To+Register+For+an+EarthData+Login+Profile

This data is stored online and may be accessed through several methods.

5.1 Direct Data Access

The data can be downloaded or remote accessed through HTTPS service:
MYD_L2_DC:
https://measures.gesdisc.eosdisc.nasa.gov/data/CloudObjects/MYD_L2_DC/
MOD_L2_DC:
https://measures.gesdisc.eosdisc.nasa.gov/data/CloudObjects/MOD_L2_DC/

or through OPeNDAP service:
MYD_L2_DC:
https://measures.gesdisc.eosdisc.nasa.gov/opendap/hyrax/CloudObjects/MYD_L2_DC.001/

MOD_L2_DC:
https://measures.gesdisc.eosdisc.nasa.gov/opendap/hyrax/CloudObjects/MOD_L2_DC.001/

5.3 Help Resources

If you need assistance or wish to report a problem:
Email: gsfc-dl-help-disc@mail.nasa.gov
Voice: 301-614-5224
Fax: 301-614-5268
Address:
Goddard Earth Sciences Data and Information Services Center NASA Goddard Space Flight Center Code 610.2 Greenbelt, MD 20771 USA

5.3.1 How To Articles

The GESDISC web site contains many informative articles under the "How To Section", "FAQ" (frequently asked questions), "News", "Glossary", and "Help" . A sample of these articles includes:

Earthdata Login for Data Access

How to Download Data Files from HTTPS Service with wget

How to Obtain Data in NetCDF Format via OpeNDAP

Quick View Data with Panoply

How to Read Data in HDF-5 or netCDF Format with GrADS

6.0 Acknowledgments

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7.0 References

Wilcox, E. M., T. Yuan, H. Song. Deep convective cloud system size and structure across the global tropics and subtropics, Atmos. Meas. Tech., in press, doi:10.5194/amt-2023-6, 2023.