Clouds and the Earth's Radiant Energy System (CERES)

Algorithm Theoretical Basis Document

Regrid Humidity and Temperature Fields

(Subsystem 12.0)

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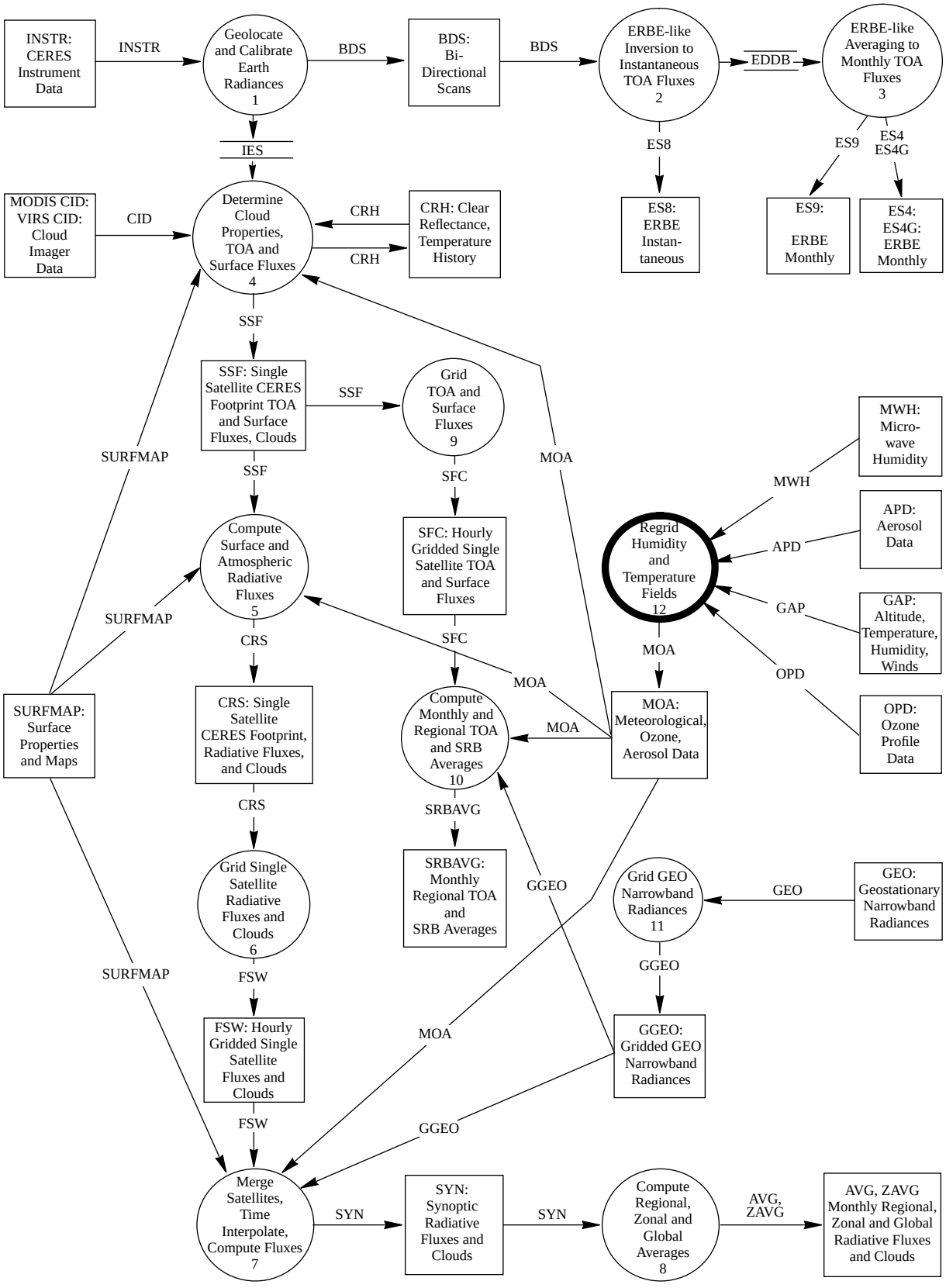
CERES Top Level Data Flow Diagram



Abstract

This subsystem describes interpolation procedures used in producing global fields of meteorological profiles and other ancillary parameters required in CERES processing on a common spatial and temporal resolution. The inputs to this subsystem will be global datasets of those ancillary parameters acquired from many outside sources, generally on different spatial and temporal resolutions. The output of this subsystem will be global fields of the same parameters on a common spatial and temporal resolution, readily accessible to other CERES subsystems as required in their processing. Interpolation procedures used with different input datasets may differ in detail depending on the nature and the resolution of that dataset.

12.0. Regrid Humidity and Temperature Fields

12.1. Introduction

Meteorological and other atmospheric parameters such as surface temperature and pressure, profiles of geopotential height, humidity, and ozone, and column burdens of water vapor, ozone, and aerosols are essential ancillary inputs to the various CERES processing subsystems, such as inversion, cloud analysis, and SARB analysis. These ancillary data can only be assembled from a variety of outside sources. Originating from diverse sources, these data do not conform to a common spatial and temporal grid system. The primary purpose of this subsystem is to put these ancillary data on a common spatial grid and 1-hourly time resolution. Each set can then be used for processing the hourly segments of satellite data.

12.2. Data Sources and Products

The bulk of the inputs for this subsystem, namely, the surface temperature and pressure, and profiles of temperature and specific humidity will be obtained from the Goddard Earth Observing System, Version 1 (GEOS-1) four-dimensional data assimilation model products being produced by the Data Assimilation Office (DAO) at the NASA Goddard Space Flight Center. The spatial resolution of the GEOS-1 products is 2 lat. x 2.5 lon., and the temporal resolution is six hourly (00Z, 06Z, 12Z, and 18Z). Water vapor burden over the oceans from SSM/I on the DMSP satellites will be used to quality check and supplement the GEOS-1 humidity data. Column ozone burden and information on its vertical distribution in the stratosphere are presently available from SBUV/2, a nadir-viewing instrument on NOAA's polar-orbiting satellites. When necessary, SBUV/2 data will be supplemented by column ozone data from the Total Ozone Mapping Spectrometer (TOMS). Aerosol column loading is being obtained at NOAA on a weekly-average basis over the oceans from AVHRR radiances (see Rao et al. 1989). Profiles of stratospheric aerosols can be obtained from the climatologies developed from SAGE data. In the EOS time period, column burdens of water vapor, ozone, and aerosols will all be available concurrently from MODIS-N.

The output from this subsystem consists of surface temperature, pressure, and geopotential height, profiles of temperature, specific humidity, and ozone at up to 58 levels from surface to 0.1 hPa, and aerosol parameters separately for troposphere and stratosphere. Consideration of a number of factors led to the decision to archive MOA products on the same horizontal resolution as the incoming GEOS-1 data, instead of the 1 x 1 (equal-angle) CERES grid. First, most of the CERES processing will be done on a footprint scale. Therefore, putting MOA data on the CERES grid offers no advantage, while errors incurred in the regridding process are a definite disadvantage. Second, DAO are seriously considering producing GEOS-1 data on a 1 x 1 grid in the near future, which may exactly match the CERES grid.

Temporally, MOA data will be produced for every hour so that each set may be used for processing hourly segments of satellite data.

12.3. Technical Basis

The processing in this subsystem involves interpolation in three domains. The first interpolation is in the horizontal domain to project the available fields on the desired spatial resolution. The second interpolation is temporal to obtain hourly fields from the 6-hourly GEOS-1 data, and other ancillary data which may be at different resolutions. The third interpolation is in the vertical, where temperature, humidity, and ozone profiles are desired at many more levels than are available in the input data.

Horizontal interpolation of GEOS-1 meteorological fields will not be necessary because its original resolution is being retained. Simple bilinear interpolation in latitude and longitude will be used for those fields for which it is necessary. Temporal interpolations will also be linear. The 6-hourly GEOS-1 data are expected to adequately capture the diurnal variability of temperature and specific humidity. For other MOA products, e.g., ozone and aerosols, diurnal variability is not of great concern.

Vertical interpolation of temperature is accomplished using the equation

$$T_x = T_1 + ((T_1 - T_2)/\ln(P_1/P_2))*\ln(P_x/P_1) \quad (1)$$

because pressure changes logarithmically while temperature changes linearly with height (see Darnell et al. 1983). In the above equation, T_x is the temperature at the desired pressure level P_x, which lies between P_1 and P_2 ($P_1 > P_2$). An illustration of results obtained from Eq. (1) for an ISCCP temperature profile with inversion near the surface is shown in Fig. 1. Vertical interpolation of specific humidity will be accomplished using the equation

$$Q_x = Q_1(P_x/P_1)^{\lambda} \quad (2)$$

(Smith 1966), where $\lambda = \ln(Q_1/Q_2)/\ln(P_1/P_2)$, and Q_x, Q_1, and Q_2 are the values of specific humidity at pressure levels P_x, P_1, and P_2, respectively. As in the case for temperature interpolation, P_x lies between P_1 and P_2 ($P_1 > P_2$). Vertical distribution of ozone will be obtained by using the column burden and layer distribution available from SBUV/2. In the absence of SBUV/2 data, column ozone will be obtained from TOMS data and will be distributed vertically in accordance with the climatological profiles. These climatological profiles are seasonally and latitudinally dependent.

12.4. Accuracy/Error Analysis

Errors incurred in vertical interpolation of the profiles of temperature and humidity are expected to be small (0.5K and 2%, respectively) because the input profiles are well defined and constrain the output profiles. Errors introduced in bilinear interpolation for regridding are also expected to be of similar magnitudes. Errors due to temporal interpolation of the 6-hourly GEOS-1 data should still be quite reasonable (1K and 5%, respectively), but for other ancillary data, errors may be significantly larger. Accuracy of ozone burden from SBUV/2 and TOMS is believed to be about 5-7% (15-20 Dobson units). Uncertainties in aerosol retrievals are believed to be much greater: up to 30% absolute and about 10% relative.

12.5. Strategic Concerns and Remedies

An important concern at this time is that GEOS-1 meteorological profiles go only up to 20 hPa and climatological data will have to be used between 20 hPa and 0.1 hPa. This situation will adversely affect the quality of the meteorological inputs to the inversion processes of the various subsystems using these data, and consequently the quality of the final CERES products. If climatological data turn out to be inadequate in temporal resolution and/or vertical coverage, appropriate datasets would be obtained from

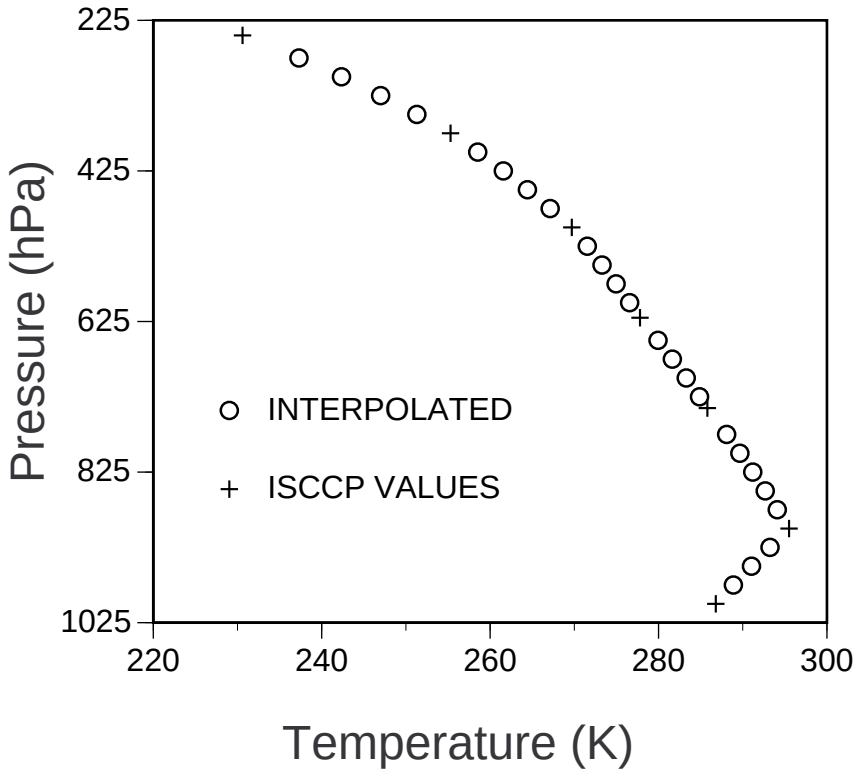


Figure 1. Results of interpolation obtained from Equation (1) for an ISCCP temperature profile with inversion near the surface.

the ECMWF. Operational ECMWF analyses are also available 4 times daily. Of course, during the EOS period, many of these parameters will be concurrently available from MODIS-N and other instruments.

A common problem with operational datasets and satellite datasets (both of which are used as sources here) is the occurrence of gaps in the data. Fill values (-999. is a common example) are frequently substituted in the data streams where real data are missing. Use of such numbers in the interpolation schemes has the potential to corrupt the parameter values in adjacent locations also. To avoid this condition, the input parameters will be checked against carefully chosen limits. When an input parameter is found to lie outside the limits, attempts will be made to generate a value for it by interpolation between nearest neighbors in space and/or time. When missing parameters cannot be filled by interpolation, attempts will be made to fill them with appropriate climatological data. Only when a consistent set of parameters cannot be generated for any location or time with either of the above methods, that data segment will be rejected, and will be flagged as unavailable in the output stream.

12.6. References

Darnell, W. L.; Gupta, S. K.; and Staylor, W. F. 1983: Downward Longwave Radiation at the Surface From Satellite Measurements. *J. Clim. Appl. Meteorol.*, vol. 22, pp. 1956-1960.

Rao, C. R. N.; Stowe, L. L.; and McClain, E. P. 1989: Remote Sensing of Aerosols Over Oceans Using AVHRR Data: Theory, Practice, and Applications. *Int. J. Remote Sens.*, vol. 10, pp. 743-749.

Smith, W. L. 1966: Note on the Relationship Between Total Precipitable Water and Surface Dewpoint. *J. Appl. Meteorol.*, vol. 5, pp. 726-727.

Appendix A

Input Data Products

Regrid Meteorological, Ozone, and Aerosol Data

This appendix describes the data products which are used by the algorithms in this subsystem. The table below summarizes these products, listing the CERES and EOSDIS product codes or abbreviations, a short product name, the product type, the production frequency, and volume estimates for each individual product as well as a complete data month of production. The product types are defined as follows:

Archival products:	Assumed to be permanently stored by EOSDIS
Internal products:	Temporary storage by EOSDIS (days to years)

The following pages describe each product. An introductory page provides an overall description of the product and specifies the temporal and spatial coverage. The table which follows the introductory page briefly describes every parameter which is contained in the product. Each product may be thought of as metadata followed by data records. The metadata (or header data) is not well-defined yet and is included mainly as a placeholder. The description of parameters which are present in each data record includes parameter number (a unique number for each distinct parameter), units, dynamic range, the number of elements per record, an estimate of the number of bits required to represent each parameter, and an element number (a unique number for each instance of every parameter). A summary at the bottom of each table shows the current estimated sizes for metadata, each data record, and the total data product. A more detailed description of each data product will be contained in a User's Guide to be published before the first CERES launch.

Table A-1. Input Products Summary

Product Code		Name	Type	Frequency	Monthly Size, MB
CERES	EOSDIS				
APD	CERX10	Aerosol Product	Archival	Daily, Weekly	See Section A-1
GAP	CERX12	Altitude, Temperature, Humidity	Archival	Every 3 or 6 hours	See Section A-2
MWH	CERX13	Microwave Humidity	Archival	Daily	TBD
OPD	CERX11	Ozone Product	Archival	Weekly	TBD

Aerosol Data (APD)

The external ancillary data product, aerosol data (APD), is input to the CERES Regrid Meteorological, Ozone, and Aerosol Data Subsystem. The APD is the source of the total column aerosol optical depth data. These data may be derived daily from the MODIS instrument for the EOS-AM and EOS-PM platforms, while for TRMM the aerosol optical depth data may be derived from monthly climatologies based on weekly NOAA-AVHRR data for ocean and 3-hourly Pinker data for land. AVHRR data may also be used for the EOS-AM and EOS-PM platforms. MODIS data will have a horizontal resolution of either 50 km $\times$ 50 km or 5 km $\times$ 5 km for ocean, and 50 km $\times$ 50 km for nondesert land. AVHRR data have a horizontal resolution of 1° x 1°. MISR aerosol data may be used as a backup source. It will provide full global coverage every 10 to 15 days. Stratospheric aerosol data may be obtained from climatologies based on SAGE data. The Regrid Meteorological, Ozone, and Aerosol Data Subsystem interpolates these data temporally, and horizontally to conform with CERES processing requirements.

Level: 3

Type: Ancillary

Frequency: Daily, weekly

Portion of Globe Covered

File: Global

Record: One region

Time Interval Covered

File: One day for MODIS,
One week for AVHRR

Record: One day for MODIS,
One week for AVHRR

Portion of Atmosphere Covered

File: Total column

Table A-2. APD File Sizes

Platform	Source	Monthly Size
EOS-AM EOS-PM	MODIS	TBD
	SAGE	TBD
TRMM	NOAA	0.29 MB
	Pinker	0.03 MB

Altitude, Temperature, Humidity (GAP)

The external ancillary data product, altitude, temperature, humidity (GAP), is input to the CERES Regrid Meteorological, Ozone, and Aerosol Data Subsystem. The GAP contains vertical profiles of temperature and specific humidity as a function of pressure, along with surface temperature and pressure. These data will be available every six hours from the Data Assimilation Office (DAO) on a 2° latitude x 2.5° longitude grid. The Regrid Meteorological, Ozone, and Aerosol Data Subsystem interpolates these data temporally and vertically to conform with CERES processing requirements.

Level: 3

Type: Ancillary

Frequency: Every 3 or 6 hours

Portion of Globe Covered

File: Global

Record: 2° x 2.5° region

Time Interval Covered

File: Every 3 or 6 hours

Record: Every 3 or 6 hours

Portion of Atmosphere Covered

File: Surface to TOA

Table A-3. DAO Input Products

DAO File Name	DAO File Size (Monthly)	Products Used by CERES
e0054A.prs.sfcprog.byymmdd.eyymmdd	55.79 MB	Instantaneous surface pressure, temperature, and geopotential height
e0054A.prs.sphu.byymmdd.eyymmdd	11.59 MB	Instantaneous vertical profiles of specific humidity
e0054A.prs.tmpu.byymmdd.eyymmdd	11.59 MB	Instantaneous vertical profiles of temperature
e0054A.prs.uwnd.byymmdd.eyymmdd	11.59 MB	Instantaneous vertical profiles of wind speed u-vectors
e0054A.prs.vwnd.byymmdd.eyymmdd	11.59 MB	Instantaneous vertical profiles of wind speed v-vectors
e0054A.prs.diag4.byymmdd.eyymmdd	161.18 MB	Temperature and specific humidity at two meters averaged over the previous three hours
TOTAL SIZE	263.33 MB	

Microwave Humidity (MWH)

The external ancillary data product, microwave humidity (MWH), is input to the CERES Regrid Meteorological, Ozone, and Aerosol Data Subsystem. The MWH is the source of the column precipitable water vapor burden as measured by a microwave instrument. These data may be derived daily from the SSM/I instrument, which has a 0.5° x 0.5° horizontal resolution. The Regrid Meteorological, Ozone, and Aerosol Data Subsystem interpolates these data temporally to conform with CERES processing requirements.

Level: 3
Type: Ancillary
Frequency: Daily

Portion of Globe Covered
File: Global
Record: One region

Time Interval Covered
File: Daily
Record: Daily

Portion of Atmosphere Covered
File: Total column

Ozone Profile Data (OPD)

The external ancillary data product, ozone profile data (OPD), is input to the CERES Regrid Meteorological, Ozone, and Aerosol Data Subsystem. The OPD is the source of total column ozone data. These data may be derived weekly from SBUV-2 and are horizontally organized according to a 10° x 10° grid. The Regrid Meteorological, Ozone, and Aerosol Data Subsystem interpolates these data temporally, horizontally, and vertically to conform with CERES processing requirements.

Level: 3
Type: Ancillary
Frequency: Weekly

Time Interval Covered
File: One week
Record: One week

Portion of Globe Covered
File: Global
Record: One region

Portion of Atmosphere Covered
File: Total column

Appendix B

Output Data Products

Regrid Meteorological, Ozone, and Aerosol Data

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Table B-1. Output Products Summary

Product Code		Name	Type	Frequency	Size, MB	Monthly Size, MB
CERES	EOSDIS					
MOA	CERX06	Meteorological, Ozone, and Aerosol Data	Archival	1/Hour	11.55	8591

Meteorological, Ozone, and Aerosol Data (MOA)

The CERES archival product Meteorological, Ozone, and Aerosol Data (MOA) is produced by the CERES Regrid MOA Subsystem. Each MOA file contains meteorological, ozone, and aerosol data for one hour, and is used by several of the CERES subsystems. Data on the MOA are derived from several data sources external to the CERES system, such as the Data Assimilation Office (DAO), NOAA, and various other meteorological satellites. These data arrive anywhere from four times daily to once a month, and have various horizontal resolutions. The Regrid MOA Subsystem interpolates the aerosol and ozone data horizontally to conform with the horizontal resolution of the meteorological data. Profile data are interpolated vertically to conform with CERES requirements. All data are temporally interpolated to provide data to the CERES processing system on an hourly basis.

The MOA contains:

- Surface pressure, geopotential height, skin temperature, and sea surface state
- Vertical profiles of temperature and humidity for 58 atmospheric levels
- Vertical profiles for 18 atmospheric levels below the tropopause of wind u-vector and v-vector data
- Tropospheric height
- Air mass index
- Column precipitable water based on humidity profiles
- Column precipitable water based on microwave measurements
- Column averaged relative humidity
- Vertical profile of ozone mixing ratios for 58 atmospheric levels
- Column ozone
- Aerosol optical depth

Level: 3
Type: Archival
Frequency: 1/Hour

Portion of Globe Covered
File: Global
Record: One region

Time Interval Covered
File: 1 hour
Record: 1 hour

Portion of Atmosphere Covered
File: Surface to TOA

Meteorological, Ozone, and Aerosol (MOA)

Description	Parameter Number	Units	Range	Elements/ Record	Bits/ Elem	Elem Num
Header						
Date and Hour		N/A	ASCII string	1	216	
MOA Processing Date		N/A	ASCII string	1	216	
MOA Grid Index		N/A	1 .. 1	1	16	
Number of MOA Regions		N/A	13104 .. 13104	1	32	
Temperature, Humidity, and Ozone Profile Fixed Pressure Levels		hPa	0 .. 1100	55	32	
Wind Speed Profile Pressure levels		hPa	0 .. 1100	18	32	
Surface Data						
MOA Region Number	1	N/A	1 .. 13104	1	32	1
Surface Pressure	2	hPa	0 .. 1100	1	32	2
Surface Geopotential Height	3	m	-100 .. 10000	1	32	3
Surface Skin Temperature	4	K	175 .. 375	1	32	4
Flag, Sea Surface State	5	N/A	0 .. 9	1	32	5
Flag, Source Surface Data	6	N/A	TBD	1	32	6
Meteorological Profiles						
Temperature Profiles	7	K	175 .. 375	58	32	7
Specific Humidity Profiles	8	N/A	0 .. 100	58	32	65
Wind Profile, U-Vector	9	$m\ sec^{-1}$	-100 .. 100	18	32	123
Wind Profile, V-Vector	10	$m\ sec^{-1}$	-100 .. 100	18	32	141
Flag, Source Meteorological Profiles	11	N/A	TBD	1	32	159
Meteorological Column Data						
Tropospheric Height	12	hPa	150 .. 300	1	32	160
Air Mass Index	13	N/A	0 .. 10	1	32	161
Precipitable Water	14	cm	0.001 .. 10.000	1	32	162
Column Averaged Relative Humidity	15	N/A	0 .. 100	1	32	163
Microwave Precipitable Water	16	cm	0.001 .. 10.000	1	32	164
Microwave Precipitable Water, std	17	cm	TBD	1	32	165
Flag, Source Microwave Column Precipitable Water	18	N/A	TBD	1	32	166
Ozone Profile Data						
Ozone Mixing Ratio Profiles	19	$g\ kg^{-1}$	0.00002 .. 0.02	58	32	167
Flag, Source Ozone Profile Data	20	N/A	TBD	1	32	225
Column Ozone						
Column Ozone	21	du	0 .. 500	1	32	226
Flag, Source Column Ozone	22	N/A	TBD	1	32	227
Total Column Aerosol						
Optical Depth, Total Column	23	$g\ m^{-2}$	0 .. 2	1	32	228
Flag, Source Optical Depth, Total Column	24	N/A	TBD	1	32	229
Spares	25	N/A	TBD	2	32	230

Total Header Bits/File:	544
Total Data Bits/Record:	7392
Total Records/File:	13104
Total Data Bits/File:	96864768
Total Bits/File:	96865312

Appendix C

Nomenclature

Acronyms

ADEOS	Advanced Earth Observing System
ADM	Angular Distribution Model
AIRS	Atmospheric Infrared Sounder (EOS-AM)
AMSU	Advanced Microwave Sounding Unit (EOS-PM)
APD	Aerosol Profile Data
APID	Application Identifier
ARESE	ARM Enhanced Shortwave Experiment
ARM	Atmospheric Radiation Measurement
ASOS	Automated Surface Observing Sites
ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer
ASTEX	Atlantic Stratocumulus Transition Experiment
ASTR	Atmospheric Structures
ATBD	Algorithm Theoretical Basis Document
AVG	Monthly Regional, Average Radiative Fluxes and Clouds (CERES Archival Data Product)
AVHRR	Advanced Very High Resolution Radiometer
BDS	Bidirectional Scan (CERES Archival Data Product)
BRIE	Best Regional Integral Estimate
BSRN	Baseline Surface Radiation Network
BTD	Brightness Temperature Difference(s)
CCD	Charge Coupled Device
CCSDS	Consultative Committee for Space Data Systems
CEPEX	Central Equatorial Pacific Experiment
CERES	Clouds and the Earth's Radiant Energy System
CID	Cloud Imager Data
CLAVR	Clouds from AVHRR
CLS	Constrained Least Squares
COPRS	Cloud Optical Property Retrieval System
CPR	Cloud Profiling Radar
CRH	Clear Reflectance, Temperature History (CERES Archival Data Product)
CRS	Single Satellite CERES Footprint, Radiative Fluxes and Clouds (CERES Archival Data Product)
DAAC	Distributed Active Archive Center
DAC	Digital-Analog Converter
DAO	Data Assimilation Office

DB	Database
DFD	Data Flow Diagram
DLF	Downward Longwave Flux
DMSP	Defense Meteorological Satellite Program
EADM	ERBE-Like Albedo Directional Model (CERES Input Data Product)
ECA	Earth Central Angle
ECLIPS	Experimental Cloud Lidar Pilot Study
ECMWF	European Centre for Medium-Range Weather Forecasts
EDDB	ERBE-Like Daily Data Base (CERES Archival Data Product)
EID9	ERBE-Like Internal Data Product 9 (CERES Internal Data Product)
EOS	Earth Observing System
EOSDIS	Earth Observing System Data Information System
EOS-AM	EOS Morning Crossing Mission
EOS-PM	EOS Afternoon Crossing Mission
ENSO	El Niño/Southern Oscillation
ENVISAT	Environmental Satellite
EPHANC	Ephemeris and Ancillary (CERES Input Data Product)
ERB	Earth Radiation Budget
ERBE	Earth Radiation Budget Experiment
ERBS	Earth Radiation Budget Satellite
ESA	European Space Agency
ES4	ERBE-Like S4 Data Product (CERES Archival Data Product)
ES4G	ERBE-Like S4G Data Product (CERES Archival Data Product)
ES8	ERBE-Like S8 Data Product (CERES Archival Data Product)
ES9	ERBE-Like S9 Data Product (CERES Archival Data Product)
FLOP	Floating Point Operation
FIRE	First ISCCP Regional Experiment
FIRE II IFO	First ISCCP Regional Experiment II Intensive Field Observations
FOV	Field of View
FSW	Hourly Gridded Single Satellite Fluxes and Clouds (CERES Archival Data Product)
FTM	Functional Test Model
GAC	Global Area Coverage (AVHRR data mode)
GAP	Gridded Atmospheric Product (CERES Input Data Product)
GCIP	GEWEX Continental-Phase International Project
GCM	General Circulation Model
GEBA	Global Energy Balance Archive
GEO	ISSCP Radiances (CERES Input Data Product)
GEWEX	Global Energy and Water Cycle Experiment
GLAS	Geoscience Laser Altimetry System

GMS	Geostationary Meteorological Satellite
GOES	Geostationary Operational Environmental Satellite
HBTM	Hybrid Bispectral Threshold Method
HIRS	High-Resolution Infrared Radiation Sounder
HIS	High-Resolution Interferometer Sounder
ICM	Internal Calibration Module
ICRCCM	Intercomparison of Radiation Codes in Climate Models
ID	Identification
IEEE	Institute of Electrical and Electronics Engineers
IES	Instrument Earth Scans (CERES Internal Data Product)
IFO	Intensive Field Observation
INSAT	Indian Satellite
IOP	Intensive Observing Period
IR	Infrared
IRIS	Infrared Interferometer Spectrometer
ISCCP	International Satellite Cloud Climatology Project
ISS	Integrated Sounding System
IWP	Ice Water Path
LAC	Local Area Coverage (AVHRR data mode)
LaRC	Langley Research Center
LBC	Laser Beam Ceilometer
LBTM	Layer Bispectral Threshold Method
Lidar	Light Detection and Ranging
LITE	Lidar In-Space Technology Experiment
Lowtran 7	Low-Resolution Transmittance (Radiative Transfer Code)
LW	Longwave
LWP	Liquid Water Path
MAM	Mirror Attenuator Mosaic
MC	Mostly Cloudy
MCR	Microwave Cloud Radiometer
METEOSAT	Meteorological Operational Satellite (European)
METSAT	Meteorological Satellite
MFLOP	Million FLOP
MIMR	Multifrequency Imaging Microwave Radiometer
MISR	Multiangle Imaging Spectroradiometer
MLE	Maximum Likelihood Estimate
MOA	Meteorology Ozone and Aerosol
MODIS	Moderate-Resolution Imaging Spectroradiometer
MSMR	Multispectral, Multiresolution

MTSA	Monthly Time and Space Averaging
MWH	Microwave Humidity
MWP	Microwave Water Path
NASA	National Aeronautics and Space Administration
NCAR	National Center for Atmospheric Research
NCEP	National Centers for Environmental Prediction
NESDIS	National Environmental Satellite, Data, and Information Service
NIR	Near Infrared
NMC	National Meteorological Center
NOAA	National Oceanic and Atmospheric Administration
NWP	Numerical Weather Prediction
OLR	Outgoing Longwave Radiation
OPD	Ozone Profile Data (CERES Input Data Product)
OV	Overcast
PC	Partly Cloudy
POLDER	Polarization of Directionality of Earth's Reflectances
PRT	Platinum Resistance Thermometer
PSF	Point Spread Function
PW	Precipitable Water
RAPS	Rotating Azimuth Plane Scan
RPM	Radiance Pairs Method
RTM	Radiometer Test Model
SAB	Sorting by Angular Bins
SAGE	Stratospheric Aerosol and Gas Experiment
SARB	Surface and Atmospheric Radiation Budget Working Group
SDCD	Solar Distance Correction and Declination
SFC	Hourly Gridded Single Satellite TOA and Surface Fluxes (CERES Archival Data Product)
SHEBA	Surface Heat Budget in the Arctic
SPECTRE	Spectral Radiance Experiment
SRB	Surface Radiation Budget
SRBAVG	Surface Radiation Budget Average (CERES Archival Data Product)
SSF	Single Satellite CERES Footprint TOA and Surface Fluxes, Clouds
SSMI	Special Sensor Microwave Imager
SST	Sea Surface Temperature
SURFMAP	Surface Properties and Maps (CERES Input Product)
SW	Shortwave
SWICS	Shortwave Internal Calibration Source
SYN	Synoptic Radiative Fluxes and Clouds (CERES Archival Data Product)

SZA	Solar Zenith Angle
THIR	Temperature/Humidity Infrared Radiometer (Nimbus)
TIROS	Television Infrared Observation Satellite
TISA	Time Interpolation and Spatial Averaging Working Group
TMI	TRMM Microwave Imager
TOA	Top of the Atmosphere
TOGA	Tropical Ocean Global Atmosphere
TOMS	Total Ozone Mapping Spectrometer
TOVS	TIROS Operational Vertical Sounder
TRMM	Tropical Rainfall Measuring Mission
TSA	Time-Space Averaging
UAV	Unmanned Aerospace Vehicle
UT	Universal Time
UTC	Universal Time Code
VAS	VISSR Atmospheric Sounder (GOES)
VIRS	Visible Infrared Scanner
VISSR	Visible and Infrared Spin Scan Radiometer
WCRP	World Climate Research Program
WG	Working Group
Win	Window
WN	Window
WMO	World Meteorological Organization
ZAVG	Monthly Zonal and Global Average Radiative Fluxes and Clouds (CERES Archival Data Product)

Symbols

A	atmospheric absorptance
$B_\lambda(T)$	Planck function
C	cloud fractional area coverage
CF_2Cl_2	dichlorofluorocarbon
$CFCl_3$	trichlorofluorocarbon
CH_4	methane
CO_2	carbon dioxide
D	total number of days in the month
D_e	cloud particle equivalent diameter (for ice clouds)
E_o	solar constant or solar irradiance
F	flux
f	fraction
G_a	atmospheric greenhouse effect

g	cloud asymmetry parameter
H_2O	water vapor
I	radiance
i	scene type
m_i	imaginary refractive index
$\hat{N}$	angular momentum vector
N_2O	nitrous oxide
O_3	ozone
P	point spread function
p	pressure
Q_a	absorption efficiency
Q_e	extinction efficiency
Q_s	scattering efficiency
R	anisotropic reflectance factor
r_E	radius of the Earth
r_e	effective cloud droplet radius (for water clouds)
r_h	column-averaged relative humidity
S_o	summed solar incident SW flux
S_o'	integrated solar incident SW flux
T	temperature
T_B	blackbody temperature
t	time or transmittance
W_{liq}	liquid water path
w	precipitable water
$\hat{x}_o$	satellite position at t_o
x, y, z	satellite position vector components
$\dot{x}, \dot{y}, \dot{z}$	satellite velocity vector components
z	altitude
z_{top}	altitude at top of atmosphere
α	albedo or cone angle
β	cross-scan angle
γ	Earth central angle
γ_{at}	along-track angle
γ_{ct}	cross-track angle
δ	along-scan angle
ε	emittance
Θ	colatitude of satellite
θ	viewing zenith angle
θ_o	solar zenith angle

λ	wavelength
μ	viewing zenith angle cosine
μ_o	solar zenith angle cosine
ν	wave number
ρ	bidirectional reflectance
τ	optical depth
$\tau_{aer}(p)$	spectral optical depth profiles of aerosols
$\tau_{H_2O\lambda}(p)$	spectral optical depth profiles of water vapor
$\tau_{O_3}(p)$	spectral optical depth profiles of ozone
Φ	longitude of satellite
ϕ	azimuth angle
$\tilde{\omega}_o$	single-scattering albedo

Subscripts:

c	cloud
cb	cloud base
ce	cloud effective
cld	cloud
cs	clear sky
ct	cloud top
ice	ice water
lc	lower cloud
liq	liquid water
s	surface
uc	upper cloud
λ	spectral wavelength

Units

AU	astronomical unit
cm	centimeter
cm-sec^{-1}	centimeter per second
count	count
day	day, Julian date
deg	degree
deg-sec^{-1}	degree per second
DU	Dobson unit
erg-sec^{-1}	erg per second
fraction	fraction (range of 0–1)
g	gram
g-cm^{-2}	gram per square centimeter

$g\text{-}g^{-1}$	gram per gram
$g\text{-}m^{-2}$	gram per square meter
h	hour
hPa	hectopascal
K	Kelvin
kg	kilogram
$kg\text{-}m^{-2}$	kilogram per square meter
km	kilometer
$km\text{-}sec^{-1}$	kilometer per second
m	meter
mm	millimeter
μm	micrometer, micron
N/A	not applicable, none, unitless, dimensionless
$ohm\text{-}cm^{-1}$	ohm per centimeter
percent	percent (range of 0–100)
rad	radian
$rad\text{-}sec^{-1}$	radian per second
sec	second
sr^{-1}	per steradian
W	watt
$W\text{-}m^{-2}$	watt per square meter
$W\text{-}m^{-2}sr^{-1}$	watt per square meter per steradian
$W\text{-}m^{-2}sr^{-1}\mu m^{-1}$	watt per square meter per steradian per micrometer