



High Mountain Asia 12 km Modeled Estimates of Aerosol Transport, Chemistry, and Deposition Reanalysis, 2003-2019, Version 1

USER GUIDE

How to Cite These Data

As a condition of using these data, you must include a citation:

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FOR QUESTIONS ABOUT THESE DATA, CONTACT NSIDC@NSIDC.ORG

FOR CURRENT INFORMATION, VISIT https://nsidc.org/data/HMA2_MATCHA



National Snow and Ice Data Center

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1 DATA DESCRIPTION

This data set contains a 12 km resolution, simulated reanalysis of aerosol transport, chemistry, and deposition over the High Mountain Asia (HMA) region for 1 January 2003 through 31 August 2019.

Two-dimensional surface data are provided at one hour intervals. Three-dimensional atmospheric data are provided at three-hour intervals for 35 sigma levels extending from the surface to 50 hPa (see “Appendix A – WRF Sigma Levels”).

Also known as the Model for Atmospheric Transport and Chemistry in Asia (MATCHA), the data comprise a wide range of variables intended to help assess the impacts of aerosols on the cryosphere in the HMA region, including: concentrations of black/brown carbon and other light absorbing particles (LAPs), broken out by source region; longwave/shortwave heating rates due to LAPs; wet/dry deposition of LAPs; precipitation and hydrological data; and meteorological state variables.

The simulation was generated using a fully coupled, regional chemistry-climate model (WRF-Chem-CLM-SNICAR¹), constrained by aerosol optical depth (AOD) and carbon monoxide (CO) satellite observations acquired by the Moderate Resolution Imaging Spectroradiometer (MODIS) and Measurements Of Pollution In The Troposphere (MOPITT) instruments, respectively.

1.1 Parameters

① Atmospheric data files contain 133 variables, while surface files contain 255. The following section briefly describes the primary variables of interest. For a complete list of variable names and descriptions, see “Appendix B – Variable Names and Descriptions.”

Variables include surface/atmospheric concentrations and wet/dry deposition rates for black carbon, broken down by source region; mass concentrations/volume fractions for brown carbon, dust, aerosols, and some 35 chemical species.

Other variables include longwave/shortwave heating rates due to black carbon, brown carbon, and dust; ground albedo with and without black carbon, brown carbon, and dust; accumulated rainfall, snowfall, snowmelt, and runoff; soil moisture; leaf area index, vegetation fraction, and canopy water; and meteorological state variables such as air temperature, surface pressure, mixing ratios, and wind-component speeds.

¹Weather Research and Forecasting model coupled with Chemistry (WRF-Chem), Community Land Model (CLM), SNow, ICe, and Aerosol Radiative (SNICAR) model

1.2 File Information

1.2.1 Format

NetCDF-4 classic

1.2.2 File Contents

Surface data are provided as hourly files, with the science data stored in 2D arrays with dimensions of 466 rows × 524 columns. Atmospheric data are provided every three hours, with data stored in 3D arrays with dimensions of 35 × 466 × 524. The additional dimension corresponds to the 35 WRF sigma levels specified in “Appendix A – WRF Sigma Levels.”

Data files also contain the variable “crs,” which fully describes the coordinate reference system, plus NetCDF dimension scales required by common data analysis tools to correctly geolocate the data.

A complete list of variable names and descriptions is provided “Appendix B – Variable Names and Descriptions.”

1.2.3 Naming Convention

Naming Convention

HMA2_MATCHA_[SFC or ATM]_[YYYYMMDD]T[hmmss]Z_V[nn.n].nc

Examples

HMA2_MATCHA_ATM_20030101T030000Z_V01.0.nc

HMA2_MATCHA_SFC_20030101T010000Z_V01.0.nc

Table 1. File Naming Convention Variables and Descriptions

| Variable | Description |
|-------------|----------------------------------------------------------------------------------------------------------------------------|
| HMA2_MATCHA | High Mountain Asia 12 km Modeled Estimates of Aerosol Transport, Chemistry, and Deposition Reanalysis, 2003-2019 data file |
| SFC or ATM | Surface (SFC) or Atmospheric (ATM) data |
| YYYYMMDD | Year (yyyy), month (mm), and day (dd) |
| T[hmmss]Z | “T” indicates that the file time follows, specified as hour (hh), minute (mm), and seconds (ss) in GMT (Z). |
| V[nn.n] | Major [nn] and minor [n] version number. E.g., V01.0 = Version 1.0 |
| nc | NetCDF file extension |

1.3 Spatial Information

1.3.1 Coverage

N: 57.767° N

S: 4.873° N

E: 138.953° E

W: 44.647° E

1.3.2 Resolution

The horizontal resolution is 12 km. The vertical resolution (ATM files only) varies. See “Appendix A – WRF Sigma Levels” for details.

1.3.3 Geolocation

Data are provided in the Lambert Conformal Conic projection with standard parallels at 30° N and 60° N. See the “crs” variable within the data files for a complete description of the projection.

1.4 Temporal Information

1.4.1 Coverage

1 January 2003 through 31 August 2019

1.4.2 Resolution

1 hour (surface files)

3 hours (atmosphere files)

2 DATA ACQUISITION AND PROCESSING

2.1 Acquisition

The data set was generated from aerosol optical depth (AOD) and carbon monoxide (CO) data acquired by the Moderate Resolution Imaging Spectroradiometer (MODIS) and Measurements Of Pollution In The Troposphere (MOPITT) sensors, respectively.

2.2 Processing

MODIS AOD and MOPITTS CO retrievals were combined via data assimilation within the WRF-Chem-CLM-SNICAR model using the Gridpoint Statistical Interpolation (GSI) variational data assimilation system.

The initial WRF-Chem-CLM-SNICAR simulation on 1 Jan 2003 was initialized with Copernicus Atmosphere Monitoring Service (CAMS) global reanalysis data. All subsequent simulations were initialized using the previous day's WRF-Chem-CLM-SNICAR simulation.

3 VERSION HISTORY

Version 1 (initial release)

4 RELATED DATA SETS

[MODIS Aerosol Product](#)

[Measurements Of Pollution In The Troposphere \(MOPITT\)](#)

5 RELATED WEBSITES

[MATCHA \(Model for Atmospheric Transport and Chemistry in Asia\)](#)

[CAMS global reanalysis \(EAC4\)](#)

[Gridpoint Statistical Interpolation \(GSI\)](#)

6 DOCUMENT INFORMATION

6.1 Publication Date

June 2024

6.2 Date Last Updated

June 2024

APPENDIX A – WRF SIGMA LEVELS

Vertical coordinates in the atmosphere files are specified in terms of terrain-following sigma (pressure) levels, from the surface to 50 hPa at the top of the model. The following table lists the sigma levels and their corresponding heights above the ground.

Table A - 1: WRF Sigma Level and Height Above Ground

| Level | Sigma | Height Above Ground (m) | Level | Sigma | Height Above Ground (m) |
|-------|--------------------|-------------------------|-------|---------------------|-------------------------|
| 0 | 0.9987499713897705 | 10.0 | 18 | 0.7849999666213989 | 1890.9 |
| 1 | 0.9962500333786011 | 30.0 | 19 | 0.7549999952316284 | 2185.6 |
| 2 | 0.9925000071525574 | 60.2 | 20 | 0.7200000286102295 | 2542.2 |
| 3 | 0.987500011920929 | 100.5 | 21 | 0.6749999523162842 | 3021.3 |
| 4 | 0.9825000166893005 | 141.0 | 22 | 0.625 | 3582.0 |
| 5 | 0.9750000238418579 | 202.2 | 23 | 0.5750000476837158 | 4177.8 |
| 6 | 0.9650000333786011 | 284.2 | 24 | 0.5249999761581421 | 4813.6 |
| 7 | 0.9549999833106995 | 367.0 | 25 | 0.4749999940395355 | 5495.6 |
| 8 | 0.9449999928474426 | 450.5 | 26 | 0.42500001192092896 | 6231.6 |
| 9 | 0.9350000023841858 | 534.7 | 27 | 0.375 | 7031.4 |
| 10 | 0.925000011920929 | 619.6 | 28 | 0.32499998807907104 | 7909.0 |
| 11 | 0.9150000214576721 | 705.3 | 29 | 0.2750000059604645 | 8884.4 |
| 12 | 0.9049999713897705 | 791.6 | 30 | 0.22499999403953552 | 9987.4 |
| 13 | 0.8899999856948853 | 922.9 | 31 | 0.17500001192092896 | 11265.8 |
| 14 | 0.8700000047683716 | 1100.2 | 32 | 0.125 | 12806.1 |
| 15 | 0.8500000238418579 | 1280.6 | 33 | 0.07500000298023224 | 14790.1 |
| 16 | 0.8299999833106995 | 1464.3 | 34 | 0.02500000037252903 | 17789.3 |
| 17 | 0.8100000023841858 | 1651.4 | | | |

APPENDIX B – VARIABLE NAMES AND DESCRIPTIONS

The following sections list the variable names in atmosphere and surface files, along with the description stored in each variable’s corresponding “long_name” attribute.

B.1 Atmospheric Variables

Table B - 1: Atmospheric Variable Names and Descriptions

| Variable Name | Description | Variable Name | Description |
|---------------|-------------------------------------------------------------------------|-----------------|---------------------------------------------------------------------------------------------------------|
| crs | CRS definition | heatratelw_bc | tendency of air temperature due to longwave heating from black carbon |
| x | x coordinate of projection | heatratelw_brc | tendency of air temperature due to longwave heating from brown carbon |
| y | y coordinate of projection | heatratelw_dust | tendency of air temperature due to longwave heating from dust |
| lat | latitude | heatratesw_bc | tendency of air temperature due to shortwave heating from black carbon |
| lon | longitude | heatratesw_brc | tendency of air temperature due to shortwave heating from brown carbon |
| lev | WRF sigma level | heatratesw_dust | tendency of air temperature due to shortwave heating from dust |
| time | time in UTC | bc_3d_ant | anthropogenic black carbon mass concentration, summed from all aerosol bins and cloud droplet phase |
| lai | leaf area index | bc_3d_ar1 | black carbon mass concentration traced from China, summed from all aerosol bins and cloud droplet phase |
| vegfra | vegetation fraction | bc_3d_ar2 | black carbon mass concentration traced from Nepal, summed from all aerosol bins and cloud droplet phase |
| soilm_layer1 | layer 1 volumetric soil moisture centered at 0.007100636 m below ground | bc_3d_ar3 | black carbon mass concentration traced from India, summed from all aerosol bins and cloud droplet phase |

| Variable Name | Description | Variable Name | Description |
|---------------|------------------------------------------------------------------------|---------------|----------------------------------------------------------------------------------------------------------------------------------|
| soilm_layer2 | layer 2 volumetric soil moisture centered at 0.027925 m below ground | bc_3d_ar4 | black carbon mass concentration traced from Pakistan, summed from all aerosol bins and cloud droplet phase |
| soilm_layer3 | layer 3 volumetric soil moisture centered at 0.06225857 m below ground | bc_3d_ar5 | black carbon mass concentration traced from Afghanistan, summed from all aerosol bins and cloud droplet phase |
| soilm_layer4 | layer 4 volumetric soil moisture centered at 0.1188651 m below ground | bc_3d_ar6 | black carbon mass concentration traced from Tibetan Plateau, summed from all aerosol bins and cloud droplet phase |
| soilm_layer5 | layer 5 volumetric soil moisture centered at 0.2121934 m below ground | bc_3d_ar7 | black carbon mass concentration traced from Bangladesh, summed from all aerosol bins and cloud droplet phase |
| soilm_layer6 | layer 6 volumetric soil moisture centered at 0.3660658 m below ground | bc_3d_ar8 | black carbon mass concentration traced from Myanmar, summed from all aerosol bins and cloud droplet phase |
| soilm_layer7 | layer 7 volumetric soil moisture centered at 0.6197585 m below ground | bc_3d_ar9 | black carbon mass concentration traced from Southeast Asia, summed from all aerosol bins and cloud droplet phase |
| soilm_layer8 | layer 8 volumetric soil moisture centered at 1.038027 m below ground | bc_3d_ar10 | black carbon mass concentration traced from rest of Asia, summed from all aerosol bins and cloud droplet phase |
| soilm_layer9 | layer 9 volumetric soil moisture centered at 1.727635 m below ground | bc_3d_bb | black carbon mass concentration from biomass burning, summed from all aerosol bins and cloud droplet phase |
| soilm_layer10 | layer 10 volumetric soil moisture centered at 2.864607 m below ground | bc_3d_bdy | black carbon mass concentration traced from domain boundary, summed from all aerosol bins and cloud droplet phase |
| soilt_layer1 | layer 1 soil temperature centered at 0.007100636 m below ground | bc_3d_tot | total black carbon mass concentration, summed from all aerosol bins and cloud droplet phase |
| soilt_layer2 | layer 2 soil temperature centered at 0.027925 m below ground | brc1_3d_tot | brown carbon mass concentration produced directly from emissions inventory, summed from all aerosol bins and cloud droplet phase |

| Variable Name | Description | Variable Name | Description |
|---------------|-------------------------------------------------------------------------------------------|---------------|---------------------------------------------------------------------------------------------------------------------------------|
| soilt_layer3 | layer 3 soil temperature centered at 0.06225857 m below ground | brc2_3d_tot | brown carbon mass concentration produced from secondary aerosol formation, summed from all aerosol bins and cloud droplet phase |
| soilt_layer4 | layer 4 soil temperature centered at 0.1188651 m below ground | brc2_acc | total brown carbon secondary production accumulation per grid cell |
| soilt_layer5 | layer 5 soil temperature centered at 0.2121934 m below ground | brc_photo_acc | total brown carbon photobleached accumulation per grid cell |
| soilt_layer6 | layer 6 soil temperature centered at 0.3660658 m below ground | ca_3d_tot | mass concentration of calcium, summed from all aerosol bins and cloud droplet phase |
| soilt_layer7 | layer 7 soil temperature centered at 0.6197585 m below ground | cl_3d_tot | mass concentration of chloride, summed from all aerosol bins and cloud droplet phase |
| soilt_layer8 | layer 8 soil temperature centered at 1.038027 m below ground | co3_3d_tot | mass concentration of carbonate, summed from all aerosol bins and cloud droplet phase |
| soilt_layer9 | layer 9 soil temperature centered at 1.727635 m below ground | cvsoa_3d_tot | total secondary organic aerosol condensed from vapor phase |
| soilt_layer10 | layer 10 soil temperature centered at 2.864607 m below ground | dust_3d_tot | total dust mass concentration, summed from all aerosol bins and cloud droplet phase |
| sh2o_layer1 | layer 1 volume fraction of condensed water in soil centered at 0.007100636 m below ground | hysw_3d_tot | mass concentration of hysteresis water in aerosol, summed from all aerosol bins and cloud droplet phase |
| sh2o_layer2 | layer 2 volume fraction of condensed water in soil centered at 0.027925 m below ground | na_3d_tot | mass concentration of sodium, summed from all aerosol bins and cloud droplet phase |
| sh2o_layer3 | layer 3 volume fraction of condensed water in soil centered at 0.06225857 m below ground | nh4_3d_tot | mass concentration of ammonium, summed from all aerosol bins and cloud droplet phase |
| sh2o_layer4 | layer 4 volume fraction of condensed water in soil centered at 0.1188651 m below ground | no3_3d_tot | mass concentration of nitrate, summed from all aerosol bins and cloud droplet phase |

| Variable Name | Description | Variable Name | Description |
|---------------|-----------------------------------------------------------------------------------------|---------------|------------------------------------------------------------------------------------------------------------------------------------------------|
| sh2o_layer5 | layer 5 volume fraction of condensed water in soil centered at 0.2121934 m below ground | aer_3d_tot | mass concentration of particulate aerosol particles, summed from all aerosol bins and cloud droplet phase |
| sh2o_layer6 | layer 6 volume fraction of condensed water in soil centered at 0.3660658 m below ground | oc_3d_tot | total organic carbon mass concentration, summed from all aerosol bins and cloud droplet phase |
| sh2o_layer7 | layer 7 volume fraction of condensed water in soil centered at 0.6197585 m below ground | pm10 | pm10 dry mass |
| sh2o_layer8 | layer 8 volume fraction of condensed water in soil centered at 1.038027 m below ground | pm2_5_dry | pm2.5 aerosol dry mass |
| sh2o_layer9 | layer 9 volume fraction of condensed water in soil centered at 1.727635 m below ground | so4_3d_tot | mass concentration of sulfate, summed from all aerosol bins and cloud droplet phase |
| sh2o_layer10 | layer 10 volume fraction of condensed water in soil centered at 2.864607 m below ground | soa_3d_tot | mass concentration of total secondary organic aerosol: anthropogenic+ biogenic + glyoxal, summed from all aerosol bins and cloud droplet phase |
| mebio_acet | biogenic emissions from MEGAN2: acetone | water_3d_tot | mass concentration of water absorbed by aerosols, summed from all aerosol bins and cloud droplet phase |
| mebio_apin | biogenic emissions from MEGAN2: alpha-pinene | acet | acetone volume fraction |
| mebio_bcar | biogenic emissions from MEGAN2: beta-caryophyllene | ald | aldehyde volume fraction |
| mebio_isop | biogenic emissions from MEGAN2: isoprene | benzene | benzene volume fraction |
| mebio_mbo | biogenic emissions from MEGAN2: 2-Methyl-3-buten-2-ol (MBO) | bigalk | bigalk (pentane + hexane + heptane + tricyclene) volume fraction |
| mebio_no | biogenic emissions from MEGAN2: NO (nitrogen monoxide) | bigene | bigene (c4h8: lumped alkenes) volume fraction |
| geopotential | geopotential | c2h2 | c2h2 volume fraction |

| Variable Name | Description |
|---------------|------------------------------------------------------|
| air_pressure | pressure at mass level |
| temperature | temperature at mass level |
| ua | x wind component |
| va | y wind component |
| wa | z wind component |
| qcloud | cloud water mixing ratio |
| qgraup | graupel mixing ratio |
| qice | ice mixing ratio |
| qndrop | droplet number mixing ratio |
| qngraupel | graupel number concentration |
| qnice | ice number concentration |
| qnrain | rain number concentration |
| qnsnow | snow number concentration |
| qrain | rainwater mixing ratio |
| qsnow | snow mixing ratio |
| r_vapor | water vapor mixing ratio |
| cldfra | cloud fraction |
| rainprod | total rain production rate |
| evapprod | rain evaporation rate |
| rthratlw | tendency of air temperature due to longwave heating |
| rthratsw | tendency of air temperature due to shortwave heating |

| Variable Name | Description |
|---------------|--------------------------------------------|
| c2h4 | c2h4 (ethene) volume fraction |
| c2h5oh | c2h5oh (ethanol) volume fraction |
| c2h6 | c2h6 (ethane) volume fraction |
| c3h6 | c3h6 (propene) volume fraction |
| c3h8 | c3h8 (propane) volume fraction |
| ch3oh | ch3oh (methanol) volume fraction |
| co | co volume fraction |
| hcho | hcho volume fraction |
| ho | ho (hydroxyl radical) volume fraction |
| ho2 | ho2 (hydroperoxyl radical) volume fraction |
| isopr | isoprene volume fraction |
| nh3 | nh3 (ammonia) volume fraction |
| no | no volume fraction |
| no2 | no2 volume fraction |
| o3 | o3 volume fraction |
| pan | polyacrylonitrile volume fraction |
| so2 | so2 volume fraction |
| so4 | so4 volume fraction |
| tol | toluene volume fraction |
| xyl | xylene volume fraction |
| — | — |

B.2 Surface Variables

Table B - 2: Surface File Variable Names and Descriptions

| Variable Name | Description | Variable Name | Description |
|---------------|------------------------------------------|--------------------|--------------------------------------------------------------------------------------------------|
| crs | CRS definition | tauaer2_col_nobrc | solar wavelength band 2 (centered at 400 nm) total column optical thickness without brown carbon |
| x | x coordinate of projection | tauaer2_col_nodust | solar wavelength band 2 (centered at 400 nm) total column optical thickness without dust |
| y | y coordinate of projection | tauaer2_sfc | solar wavelength band 2 (centered at 400 nm) surface layer optical thickness |
| lat | latitude | tauaer3_col | solar wavelength band 3 (centered at 600 nm) total column optical thickness |
| lon | longitude | tauaer3_col_nobc | solar wavelength band 3 (centered at 600 nm) total column optical thickness without black carbon |
| time | time in UTC | tauaer3_col_nobrc | solar wavelength band 3 (centered at 600 nm) total column optical thickness without brown carbon |
| q2 | humidity mixing ratio at 2 m | tauaer3_col_nodust | solar wavelength band 3 (centered at 600 nm) total column optical thickness without dust |
| t2 | temperature at 2 m | tauaer3_sfc | solar wavelength band 3 (centered at 600 nm) surface layer optical thickness |
| psfc | surface air pressure | tauaer4_col | solar wavelength band 4 (centered at 999 nm) total column optical thickness |
| u10 | x-wind component at 10 m (grid relative) | tauaer4_col_nobc | solar wavelength band 4 (centered at 999 nm) total column optical thickness without black carbon |
| v10 | y-wind component at 10 m (grid relative) | tauaer4_col_nobrc | solar wavelength band 4 (centered at 999 nm) total column optical thickness without brown carbon |

| Variable Name | Description |
|---------------|----------------------------------------------------------|
| ivt100 | integrated water vapor transport from surface to 100 hpa |
| ivt500 | integrated water vapor transport from surface to 500 hpa |
| pblh | planetary boundary layer height |
| cfrac | cloud area fraction |
| tsk | surface skin temperature |
| dust_flux | dust flux from soil |
| seas_flux | sea salt flux |
| grdfix | ground heat flux |
| hfx | upward heat flux at the surface |
| lh | latent heat flux at the surface |
| acgwlr runoff | hourly accumulated runoff at glacier, wetland, lake |

| Variable Name | Description |
|--------------------|---------------------------------------------------------------------------------------------------------|
| tauaer4_col_nodust | solar wavelength band 4 (centered at 999 nm) total column optical thickness without dust |
| tauaer4_sfc | solar wavelength band 4 (centered at 999 nm) surface layer optical thickness |
| waer1_col | solar wavelength band 1 (centered at 300 nm) total column single-scattering albedo |
| waer1_col_nobc | solar wavelength band 1 (centered at 300 nm) total column single-scattering albedo without black carbon |
| waer1_col_nobrc | solar wavelength band 1 (centered at 300 nm) total column single-scattering albedo without brown carbon |
| waer1_col_nodust | solar wavelength band 1 (centered at 300 nm) total column single-scattering albedo without dust |
| waer1_sfc | solar wavelength band 1 (centered at 300 nm) surface layer single-scattering albedo |
| waer2_col | solar wavelength band 2 (centered at 400 nm) total column single-scattering albedo |
| waer2_col_nobc | solar wavelength band 2 (centered at 400 nm) total column single-scattering albedo without black carbon |
| waer2_col_nobrc | solar wavelength band 2 (centered at 400 nm) total column single-scattering albedo without brown carbon |
| waer2_col_nodust | solar wavelength band 2 (centered at 400 nm) total column single-scattering albedo without dust |

| Variable Name | Description |
|---------------|----------------------------------------------------------|
| acsfcrunoff | hourly accumulated surface runoff |
| acsnowfall | hourly accumulated snowfall |
| acsnowmelt | hourly accumulated snowmelt |
| actotrunoff | hourly accumulated total runoff |
| acudrunoff | hourly accumulated subsurface runoff |
| canwat | canopy water |
| graupelnc | hourly accumulated grid scale precipitation from graupel |
| rainc | hourly accumulated subgrid scale precipitation |
| rainnc | hourly accumulated grid scale precipitation |
| snow | snow water equivalent |
| snowbc_top | black carbon mass in top snow layer from clm |

| Variable Name | Description |
|------------------|---------------------------------------------------------------------------------------------------------|
| waer2_sfc | solar wavelength band 2 (centered at 400 nm) surface layer single-scattering albedo |
| waer3_col | solar wavelength band 3 (centered at 600 nm) total column single-scattering albedo |
| waer3_col_nobc | solar wavelength band 3 (centered at 600 nm) total column single-scattering albedo without black carbon |
| waer3_col_nobrc | solar wavelength band 3 (centered at 600 nm) total column single-scattering albedo without brown carbon |
| waer3_col_nodust | solar wavelength band 3 (centered at 600 nm) total column single-scattering albedo without dust |
| waer3_sfc | solar wavelength band 3 (centered at 600 nm) surface layer single-scattering albedo |
| waer4_col | solar wavelength band 4 (centered at 999 nm) total column single-scattering albedo |
| waer4_col_nobc | solar wavelength band 4 (centered at 999 nm) total column single-scattering albedo without black carbon |
| waer4_col_nobrc | solar wavelength band 4 (centered at 999 nm) total column single-scattering albedo without brown carbon |
| waer4_col_nodust | solar wavelength band 4 (centered at 999 nm) total column single-scattering albedo without dust |
| waer4_sfc | solar wavelength band 4 (centered at 999 nm) surface layer single-scattering albedo |

| Variable Name | Description |
|------------------|-------------------------------------------------------------|
| snowbrc_col | mass content of brown carbon in entire snow column from clm |
| snowbrc_top | mass content of brown carbon in top snow layer from clm |
| snowdust_col | mass content of dust in entire snow column from clm |
| snowdust_top | mass content of dust in top snow layer from clm |
| mss_cnc_brc1_2d1 | 1st snowlayer primary brown carbon mass fraction |
| mss_cnc_brc1_2d2 | 2nd snowlayer primary brown carbon mass fraction |
| mss_cnc_brc1_2d3 | 3rd snowlayer primary brown carbon mass fraction |
| mss_cnc_brc1_2d4 | 4th snowlayer primary brown carbon mass fraction |
| mss_cnc_brc1_2d5 | 5th snowlayer primary brown carbon mass fraction |
| mss_cnc_brc2_2d1 | 1st snowlayer secondary brown carbon mass fraction |
| mss_cnc_brc2_2d2 | 2nd snowlayer secondary brown carbon mass fraction |
| mss_cnc_brc2_2d3 | 3rd snowlayer secondary brown carbon mass fraction |
| mss_cnc_brc2_2d4 | 4th snowlayer secondary brown carbon mass fraction |
| mss_cnc_brc2_2d5 | 5th snowlayer secondary brown carbon mass fraction |

| Variable Name | Description |
|---------------|---------------------------------------------------------------------|
| bc_sfc_ant | anthropogenic black carbon surface mass concentration |
| bc_sfc_ar1 | black carbon surface mass concentration traced from China |
| bc_sfc_ar2 | black carbon surface mass concentration traced from Nepal |
| bc_sfc_ar3 | black carbon surface mass concentration traced from India |
| bc_sfc_ar4 | black carbon surface mass concentration traced from Pakistan |
| bc_sfc_ar5 | black carbon surface mass concentration traced from Afghanistan |
| bc_sfc_ar6 | black carbon surface mass concentration traced from Tibetan Plateau |
| bc_sfc_ar7 | black carbon surface mass concentration traced from Bangladesh |
| bc_sfc_ar8 | black carbon surface mass concentration traced from Myanmar |
| bc_sfc_ar9 | black carbon surface mass concentration traced from Southeast Asia |
| bc_sfc_ar10 | black carbon surface mass concentration traced from rest of Asia |
| bc_sfc_bb | black carbon surface mass concentration from biomass burning |
| bc_sfc_bdy | black carbon surface mass concentration traced from domain boundary |
| bc_sfc_tot | black carbon total surface mass concentration |

| Variable Name | Description |
|------------------|----------------------------------------------------------------------------------------|
| mss_cnc_dust_2d1 | 1st snowlayer dust mass fraction |
| mss_cnc_dust_2d2 | 2nd snowlayer dust mass fraction |
| mss_cnc_dust_2d3 | 3rd snowlayer dust mass fraction |
| mss_cnc_dust_2d4 | 4th snowlayer dust mass fraction |
| mss_cnc_dust_2d5 | 5th snowlayer dust mass fraction |
| snowh | physical snow depth |
| snowlayer2d | number of snow layer from clm |
| snownc | hourly accumulated grid scale precipitation from snow and ice |
| snowrds2d1 | 1st snow effective radius from clm |
| snowrds2d2 | 2nd snow effective radius from clm |
| snowrds2d3 | 3rd snow effective radius from clm |
| snowrds2d4 | 4th snow effective radius from clm |
| snowrds2d5 | 5th snow effective radius from clm |
| snow_frac | snow fraction from clm |
| snow_top | snow mass in top snow layer from clm |
| aaod1_col | solar wavelength band 1 (centered at 300 nm) total column absorption optical thickness |

| Variable Name | Description |
|---------------|-------------------------------------------------------------------------------------------------------------------|
| brc1_sfc_tot | primary brown carbon total surface mass concentration |
| brc2_sfc_tot | secondary brown carbon total surface mass concentration |
| ca_sfc_tot | calcium aerosol total surface mass concentration |
| cl_sfc_tot | chloride aerosol total surface mass concentration |
| co3_sfc_tot | co3 aerosol total surface mass concentration |
| dust_sfc_tot | dust total surface mass concentration |
| hysw_sfc_tot | surface mass concentration of hysteresis water in aerosol, summed from all aerosol bins and cloud droplet phase |
| na_sfc_tot | sodium aerosol total surface mass concentration |
| nh4_sfc_tot | nh4 aerosol total surface mass concentration |
| no3_sfc_tot | no3 aerosol total surface mass concentration |
| aer_sfc_tot | surface mass concentration of particulate aerosol particles, summed from all aerosol bins and cloud droplet phase |
| oc_sfc_tot | organic carbon total surface mass concentration |
| pm10_sfc | pm10 surface mass concentration |
| pm25_sfc | pm2.5 surface mass concentration |
| so4_sfc_tot | so4 aerosol total surface mass concentration |
| soa_sfc_tot | secondary organic aerosol total surface mass concentration |

| Variable Name | Description |
|---------------|----------------------------------------------------------------------------------------|
| aaod2_col | solar wavelength band 2 (centered at 400 nm) total column absorption optical thickness |
| aaod3_col | solar wavelength band 3 (centered at 600 nm) total column absorption optical thickness |
| aaod4_col | solar wavelength band 4 (centered at 999 nm) total column absorption optical thickness |
| albbck | background albedo |
| albedog | ground albedo |
| albedo_aer | ground albedo without aerosol |
| albedo_bc | ground albedo without black carbon |
| albedo_brc | ground albedo without brown carbon |
| albedo_dust | ground albedo without dust |
| aod_550 | column aod at 550 nm |
| coszen | cosine of solar zenith angle |
| diffuse_frac | fraction of diffuse surface shortwave irradiance |
| drfsclw_bc | longwave surface black carbon direct radiative effect |
| drfsclw_brc | longwave surface brown carbon direct radiative effect |
| drfsclw_dust | longwave surface dust direct radiative effect |

| Variable Name | Description |
|---------------|----------------------------------------------------------------------------------------------------------------|
| water_sfc_tot | surface mass concentration of water absorbed by aerosols, summed from all aerosol bins and cloud droplet phase |
| acet_sfc | surface volume fraction of acetone gas |
| ald_sfc | surface volume fraction of aldehyde gas |
| benzene_sfc | surface volume fraction of benzene gas |
| bigalk_sfc | surface volume fraction of bigalk (pentane + hexane + heptane + tricyclene) |
| bigene_sfc | surface volume fraction of bigene (c4h8: lumped alkenes) |
| c10h16_sfc | surface volume fraction of c10h16 |
| c2h2_sfc | surface volume fraction of c2h2 (ethyne) |
| c2h4_sfc | surface volume fraction of c2h4 (ethene) |
| c2h5oh_sfc | surface volume fraction of c2h5oh (ethanol) |
| c2h6_sfc | surface volume fraction of c2h6 (ethane) |
| c3h6_sfc | surface volume fraction of c3h6 (propene) |
| c3h8_sfc | surface volume fraction of c3h8 (propane) |
| ch3oh_sfc | surface volume fraction of ch3oh (methanol) |
| co_sfc | surface volume fraction of co gas |

| Variable Name | Description | Variable Name | Description |
|-----------------|----------------------------------------------------------------------------------------------------|---------------|----------------------------------------------------------------------------------|
| drsfcsw_bc | shortwave surface black carbon direct radiative effect | cvsoa_sfc | volume fraction of condensed vapor from secondary organic aerosol (cvsoa+cvbsoa) |
| drsfcsw_brc | shortwave surface brown carbon direct radiative effect | hcho_sfc | surface volume fraction of hcho gas |
| drsfcsw_dust | shortwave surface dust direct radiative effect | ho2_sfc | surface volume fraction of ho2 (hydroperoxyl) radical |
| drftoalw_bc | longwave toa black carbon direct radiative effect | ho_sfc | surface volume fraction of ho (hydroxyl) radical |
| drftoalw_brc | longwave toa brown carbon direct radiative effect | isopr_sfc | surface volume fraction of isoprene gas |
| drftoalw_dust | longwave toa dust direct radiative effect | nh3_sfc | surface volume fraction of nh3 gas |
| drftoasw_bc | shortwave toa black carbon direct radiative effect | no2_sfc | surface volume fraction of no2 gas |
| drftoasw_brc | shortwave toa brown carbon direct radiative effect | no_sfc | surface volume fraction of no gas |
| drftoasw_dust | shortwave toa dust direct radiative effect | o3_sfc | surface volume fraction of o3 gas |
| embck | background emissivity | pan_sfc | surface volume fraction of polyacrylonitrile |
| emiss | surface emissivity | so2_sfc | surface volume fraction of so2 gas |
| gaer1_col | solar wavelength band 1 (centered at 300 nm) total column asymmetry parameter | sulf_sfc | surface volume fraction of sulfur gas |
| gaer1_col_nobc | solar wavelength band 1 (centered at 300 nm) total column asymmetry parameter without black carbon | tol_sfc | surface volume fraction of toluene gas |
| gaer1_col_nobrc | solar wavelength band 1 (centered at 300 nm) total column asymmetry parameter without brown carbon | xyl_sfc | surface volume fraction of xylene gas |

| Variable Name | Description | Variable Name | Description |
|------------------|----------------------------------------------------------------------------------------------------|----------------|-------------------------------------------------------------------|
| gaer1_col_nodust | solar wavelength band 1 (centered at 300 nm) total column asymmetry parameter without dust | drydep_bc_ant | total anthropogenic dry deposition from black carbon |
| gaer1_sfc | solar wavelength band 1 (centered at 300 nm) surface layer asymmetry parameter | drydep_bc_ar1 | total dry deposition from black carbon traced from China |
| gaer2_col | solar wavelength band 2 (centered at 400 nm) total column asymmetry parameter | drydep_bc_ar2 | total dry deposition from black carbon traced from Nepal |
| gaer2_col_nobc | solar wavelength band 2 (centered at 400 nm) total column asymmetry parameter without black carbon | drydep_bc_ar3 | total dry deposition from black carbon traced from India |
| gaer2_col_nobrc | solar wavelength band 2 (centered at 400 nm) total column asymmetry parameter without brown carbon | drydep_bc_ar4 | total dry deposition from black carbon traced from Pakistan |
| gaer2_col_nodust | solar wavelength band 2 (centered at 400 nm) total column asymmetry parameter without dust | drydep_bc_ar5 | total dry deposition from black carbon traced from Afghanistan |
| gaer2_sfc | solar wavelength band 2 (centered at 400 nm) surface layer asymmetry parameter | drydep_bc_ar7 | total dry deposition from black carbon traced from Bangladesh |
| gaer3_col | solar wavelength band 3 (centered at 600 nm) total column asymmetry parameter | drydep_bc_ar8 | total dry deposition from black carbon traced from Myanmar |
| gaer3_col_nobc | solar wavelength band 3 (centered at 600 nm) total column asymmetry parameter without black carbon | drydep_bc_ar9 | total dry deposition from black carbon traced from Southeast Asia |
| gaer3_col_nobrc | solar wavelength band 3 (centered at 600 nm) total column asymmetry parameter without brown carbon | drydep_bc_ar10 | total dry deposition from black carbon traced from rest of Asia |

| Variable Name | Description |
|------------------|----------------------------------------------------------------------------------------------------|
| gaer3_col_nodust | solar wavelength band 3 (centered at 600 nm) total column asymmetry parameter without dust |
| gaer3_sfc | solar wavelength band 3 (centered at 600 nm) surface layer asymmetry parameter |
| gaer4_col | solar wavelength band 4 (centered at 999 nm) total column asymmetry parameter |
| gaer4_col_nobc | solar wavelength band 4 (centered at 999 nm) total column asymmetry parameter without black carbon |
| gaer4_col_nobrc | solar wavelength band 4 (centered at 999 nm) total column asymmetry parameter without brown carbon |
| gaer4_col_nodust | solar wavelength band 4 (centered at 999 nm) total column asymmetry parameter without dust |
| gaer4_sfc | solar wavelength band 4 (centered at 999 nm) surface layer asymmetry parameter |
| glw | downward long wave flux at ground surface |
| lwup | outgoing longwave radiation |
| sabg | net soil solar radiation |
| sabv | net vegetation solar radiation |
| sfc_frc_aer | surface radiative forcing of total aerosol in snow (grid average) from clm |

| Variable Name | Description |
|-----------------|------------------------------------------------------------------------|
| drydep_bc_bb | total dry deposition from black carbon resulting from biomass burning |
| drydep_bc_bdy | total dry deposition from black carbon traced from the domain boundary |
| drydep_bc_tot | total dry deposition from black carbon |
| drydep_brc1_tot | total dry deposition from primary brown carbon for all bins |
| drydep_brc2_tot | total dry deposition from secondary brown carbon for all bins |
| drydep_dust_tot | total dry deposition from dust for all bins |
| wetdep_bc_ant | total anthropogenic wet deposition from black carbon |
| wetdep_bc_ar1 | total wet deposition from black carbon traced from China |
| wetdep_bc_ar2 | total wet deposition from black carbon traced from Nepal |
| wetdep_bc_ar3 | total wet deposition from black carbon traced from India |
| wetdep_bc_ar4 | total wet deposition from black carbon traced from Pakistan |
| wetdep_bc_ar5 | total wet deposition from black carbon traced from Afghanistan |

| Variable Name | Description |
|--------------------|--------------------------------------------------------------------------------------------------|
| sfc_frc_aer_snow | surface radiative forcing of total aerosol in snow (snow only) from clm |
| sfc_frc_bc | surface radiative forcing of black carbon in snow (grid average) from clm |
| sfc_frc_brc | surface radiative forcing of brown carbon in snow (grid average) from clm |
| sfc_frc_brc_snow | surface radiative forcing of brown carbon in snow (snow only) from clm |
| sfc_frc_dust | surface radiative forcing of dust in snow (grid average) from clm |
| ssa_550 | column ssa at 550 nm |
| tauaer1_col | solar wavelength band 1 (centered at 300 nm) total column optical thickness |
| sdown | downward short wave flux at ground surface |
| tauaer1_col_nobc | solar wavelength band 1 (centered at 300 nm) total column optical thickness without black carbon |
| tauaer1_col_nobrc | solar wavelength band 1 (centered at 300 nm) total column optical thickness without brown carbon |
| tauaer1_col_nodust | solar wavelength band 1 (centered at 300 nm) total column optical thickness without dust |
| tauaer1_sfc | solar wavelength band 1 (centered at 300 nm) surface layer optical thickness |

| Variable Name | Description |
|-----------------|------------------------------------------------------------------------|
| wetdep_bc_ar6 | total wet deposition from black carbon traced from Tibetan Plateau |
| wetdep_bc_ar7 | total wet deposition from black carbon traced from Bangladesh |
| wetdep_bc_ar8 | total wet deposition from black carbon traced from Myanmar |
| wetdep_bc_ar9 | total wet deposition from black carbon traced from Southeast Asia |
| wetdep_bc_ar10 | total wet deposition from black carbon traced from rest of Asia |
| wetdep_bc_bb | total wet deposition from black carbon resulting from biomass burning |
| wetdep_bc_bdy | total wet deposition from black carbon traced from the domain boundary |
| wetdep_bc_tot | total wet deposition from black carbon |
| wetdep_brc1_tot | total wet deposition from primary brown carbon for all bins |
| wetdep_brc2_tot | total wet deposition from secondary brown carbon for all bins |
| wetdep_dust_tot | total wet deposition from dust for all bins |
| totdep_bcext | total deposition from black carbon for snow from external mixing |

| Variable Name | Description |
|------------------|--------------------------------------------------------------------------------------------------------------|
| tauaer2_col | solar wavelength band 2 (centered at 400 nm) total column optical thickness |
| tauaer2_col_nobc | solar wavelength band 2 (centered at 400 nm) total column optical thickness without black carbon |

| Variable Name | Description |
|---------------|------------------------------------------------------------------------|
| totdep_bcint | total deposition from black carbon for snow from internal mixing |
| — | — |