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# Retrieved Number Concentration of Cloud Condensation Nuclei (RNCCN) Profile Value-Added Product Report

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November 2023

ARM

## DISCLAIMER

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# Acronyms and Abbreviations

| | |
|---|---|
| AMF | ARM Mobile Facility |
| ARM | Atmospheric Radiation Measurement |
| BNF | Bankhead National Forest |
| CCN | cloud condensation nuclei |
| DoD | data object design |
| ENA | Eastern North Atlantic |
| QC | quality control |
| RH | relative humidity |
| RL | Raman lidar |
| RNCCN | Retrieved Number Concentration of Cloud Condensation Nuclei |
| SGP | Southern Great Plains |
| UTC | Coordinated Universal Time |
| VAP | value-added product |

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# 1.0 Introduction

The cloud condensation nuclei (CCN) concentration at cloud base is the most relevant measure of the aerosol that influences droplet formation in clouds. Since the CCN concentration depends on supersaturation, a more general measure of the CCN concentration is the CCN spectrum (values at multiple supersaturations). The CCN spectrum is now measured at the surface at several U.S. Department of Energy Atmospheric Radiation Measurement (ARM) user facility observatories and by the ARM Mobile Facility (AMF) but is not measured at the cloud base. Rather than rely on expensive aircraft measurements for all studies of aerosol effects on clouds, a way to project CCN observations made at the surface to cloud base is needed. Remote sensing of aerosol extinction provides information about the vertical profile of the aerosol but cannot be directly related to the CCN concentration because the aerosol extinction is strongly influenced by humidification, particularly near cloud base. Ghan and Collins (2004) and Ghan et al. (2006) propose a method to remove the influence of humidification from the extinction profiles and tie the "dry extinction" retrieval to the surface CCN concentration, thus estimating the CCN profile. This methodology has been implemented as ARM's Retrieved Number Concentration of CCN (RNCCN) Profile Value-Added Product (VAP).

Details of the algorithm can be found in Ghan and Collins (2004) and Ghan et al. (2006). In brief, the 180-degree extinction (or backscatter) profile E(z) measured by a lidar is corrected to dry conditions, Ed(z), using a vertical profile of relative humidity (RH) and surface measurements of the dependence of scattering on relative humidity, f[RH(z)]:

$$E_d(z) = E(z)/f[RH(z)]. \quad (1)$$

Then the surface measurements of the CCN concentration at a given supersaturation, CCN(S, 0), are scaled by the ratio of the 180-degree extinction profile $E_d(z)$ to the 180-degree extinction at or near the surface, $E_d(0)$:

$$CCN(S,z) = CCN(S,0)E_d(z)/E_d(0). \quad (2)$$

The method has three main assumptions: 1) the aerosol composition and shape are independent of altitude, 2) the vertical structure of CCN concentration is identical to the vertical structure of dry extinction or backscatter, and 3) largest particles (> 100 nm) that significantly contribute to the extinction activate first.

# 2.0 The Input Data

The input data required by this VAP includes surface measurements of the CCN spectrum, the aerosol humidification factor, lidar profiles of extinction, feature mask, profiles of relative humidity, and cloud base height (cbh) from a ceilometer. All input data are averaged to one-hour temporal resolution, corresponding to the temporal resolution of the aerosol humidification factor measurements.

Currently the VAP has been implemented only for the Raman lidar (RL) and applied only at the Southern Great Plains (SGP) observatory. In future work, the VAP will be run at the Eastern North Atlantic (ENA)

observatory. Future implementations of RL at Bankhead National Forest (BNF) is being planned and the VAP will be run at BNF when data become available.

Details of each input variable are given in Table 1.

**Table 1**. Input variables used for the VAP calculations.

| Variable Name | Description |
|---|---|
| **extinction_be** | Best-estimate of the particulate extinction coefficient. The extinction_be is calculated using the expression shown in equation originally from rlproffex1thor VAP. The datastream is rlprofmr2news10m. |
| **feature_mask** | Feature of the atmosphere. The mask number (1, 2, 4, 8, 16, 32, 64) indicate feature (any type), aerosol, cloud, rain_or_virga, liquid_cloud, ice_cloud, horizontally_oriented_ice, respectively. |
| **rh** | Relative humidity observed by the Raman lidar |
| **N_CCN_1…n** | AOS surface number concentration of CCN at supersaturation step 1…n |
| **cbh** | Cloud base height. Height represents distance above surface. |
| **calculated_frh** | Calculated f(RH) using equation f(RH) = C1(1-RH)^gamma, where C1 = (1 – RH_0)^gamma and RH_0 = 40% |
| **gamma_coefficient** | Gamma coefficient (γ). This is calculated based on the single-parameter gamma-based parameterization used to calculate f(RH). |
| **qc_N_CCN** | Quality check results on field: Mean number concentration of N_CCN. |
| **supersaturation setpoint** | Supersaturation set points. |
| **potential temperature** | Potential temperature. |

# 3.0 Algorithm and Methodology

The VAP operates on one day (UTC) of data at a time. All input datastreams are read in for each day. These input data are screened based on the tests described in Table 2. Each variable contains bit-packed integer values, where each bit represents a QC test on the data. Non-zero bits indicate the QC condition given in the description for those bits; a value of 0 (no bits set) indicates the data have not failed any QC tests.

**Table 2**. The input variables that are screened to obtain good data for the VAP calculation.

| Variable Name | Description |
|---|---|
| **rh** | If the relative humidity from input data is missing, no calculation is performed. |
| **rh_ground** | If the surface relative humidity value is missing, it is replaced with a value from the next height bin. |
| **extinction_be** | If the surface extinction value is missing, it is replaced with a value from the next height bin. |

| Variable Name | Description |
|---|---|
| **feature_mask** | The feature mask was detected as not aerosol, then the extinction values were replaced as missing value. |
| **rh cloud** | If the relative humidity below the first cloud layer is above 85% and relative humidity is above 99%. |
| **gamma_coefficient** | If gamma value exceeds 5 then the calculations are not performed. |
| **potential temperature** | The atmospheric stability test using temperature profile failed. |
| **temperature** | If the temperature exceeds 273.15K. |

After the input extinction profiles have been averaged, the dry extinction, $E_d(z,t)$ is calculated as:

$$E_d(z,t) = E(z,t)*[(100-40)/(100-RH(z,t))]^(-\gamma(t)) \quad (3)$$

where 40 is the reference relative humidity, E(z,t) and RH(z,t) are the aerosol extinction and relative humidity at the given height and time, and γ(t) is the aerosol humidification fit parameter or gamma coefficient for the given time. The reference relative humidity of 40% is used because ambient particles do not show enhancement in aerosol extinction at humidity conditions below 40% (Dawson et al. 2020).

Then the CCN profile at each %ss is calculated as:

$$CCN(z,t,s) = CCN(0,t,s) * E_d(z,t)/E_d(0,s) \quad (4)$$

where 0 represents the surface measurements and s is the %ss step. For each dry extinction and CCN profile value, qc flags are applied based on the qc of the extinction, surface CCN, and f(RH) values used in the calculation.

# 4.0 Output Data

After application of various QC tests listed in Table 2, the VAP produces a single output file per day. The data object design (DoD) class name is rnccnprof1kulkarni.c1. The output file is named

SSSrnccnprof1kulkarniC1.c1. YYYYMMDD.hhmmss.nc

SSS is the ARM site (e.g., SGP)
YYYYMMDD.hhmmss is the time stamp of the first measurement in the file.

The primary output variable is the vertical profile of CCN for seven values of percent supersaturation. The vertical profile at each %ss is calculated up to cloud base (or maximum altitude ) at a vertical resolution of the input lidar data (60 meter) and at one-hour resolution. A detailed list of the output variables is given in Appendix A.

# 5.0 Quick Look Plots

The VAP produces daily quick look plots for each of the output variables, which are available here. A series of these quick look plots that illustrate the input data and retrieved variables for September 22, 2016 at SGP are shown in Figures 1–7.

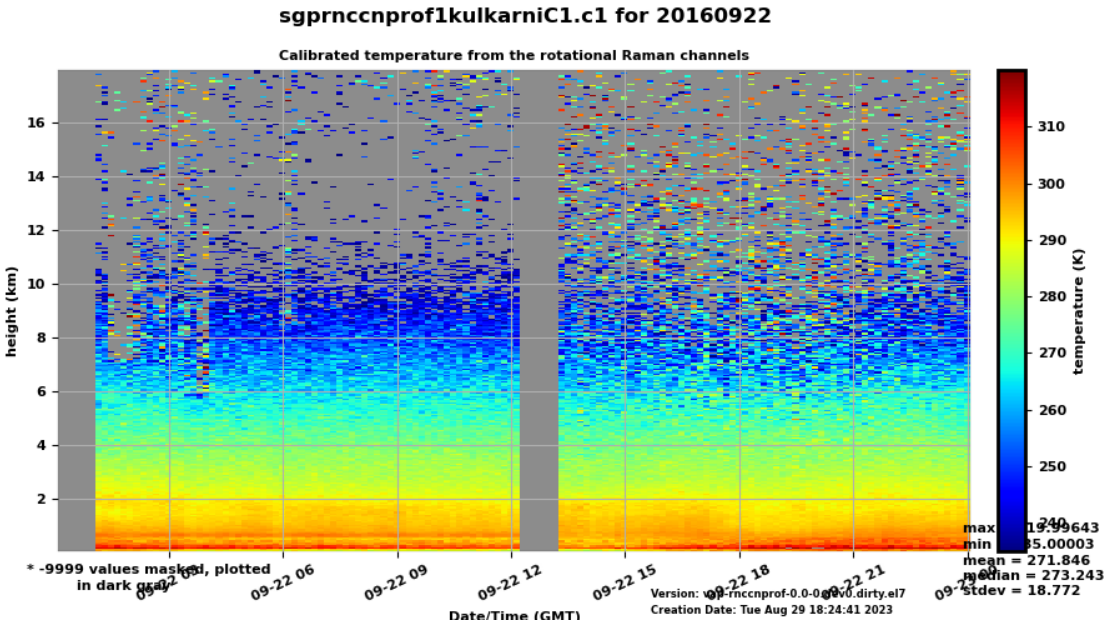


**Figure 1**. Temperature profiles.

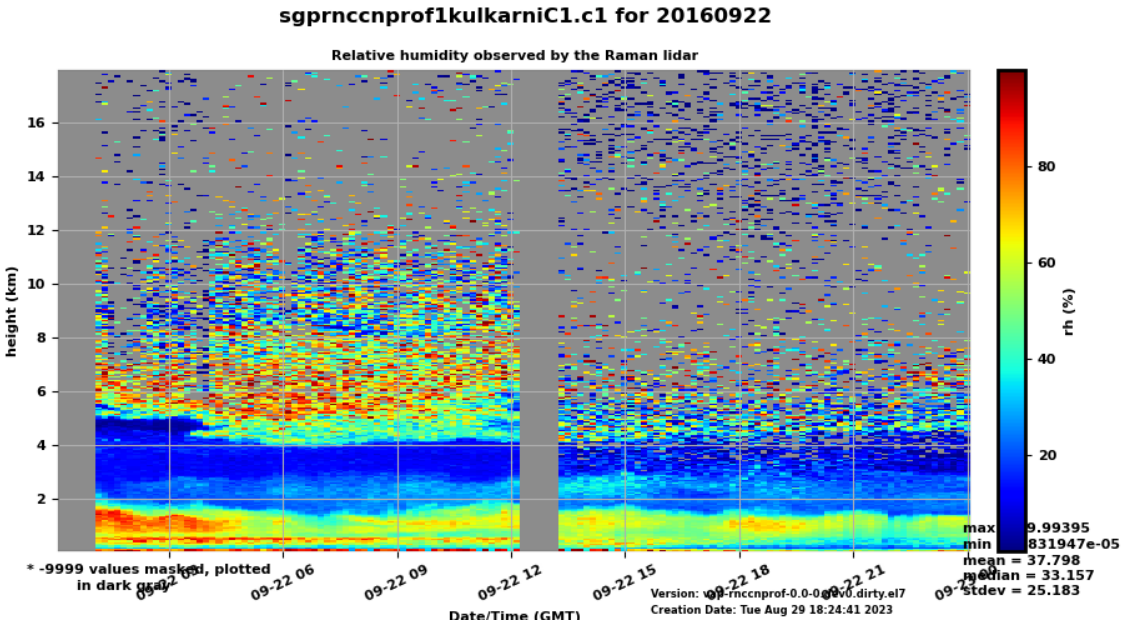


**Figure 2**. Relative humidity profiles.

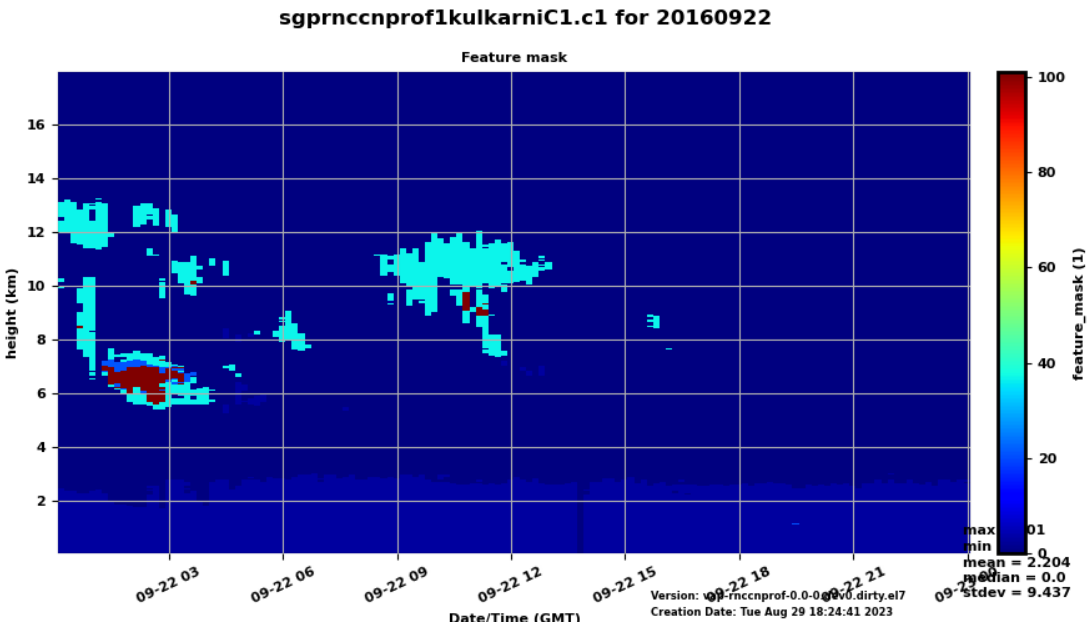


**Figure 3**. Feature mask values. Various quality check tests are used to indicate the presence of aerosol, clouds (liquid versus ice), and precipitation.

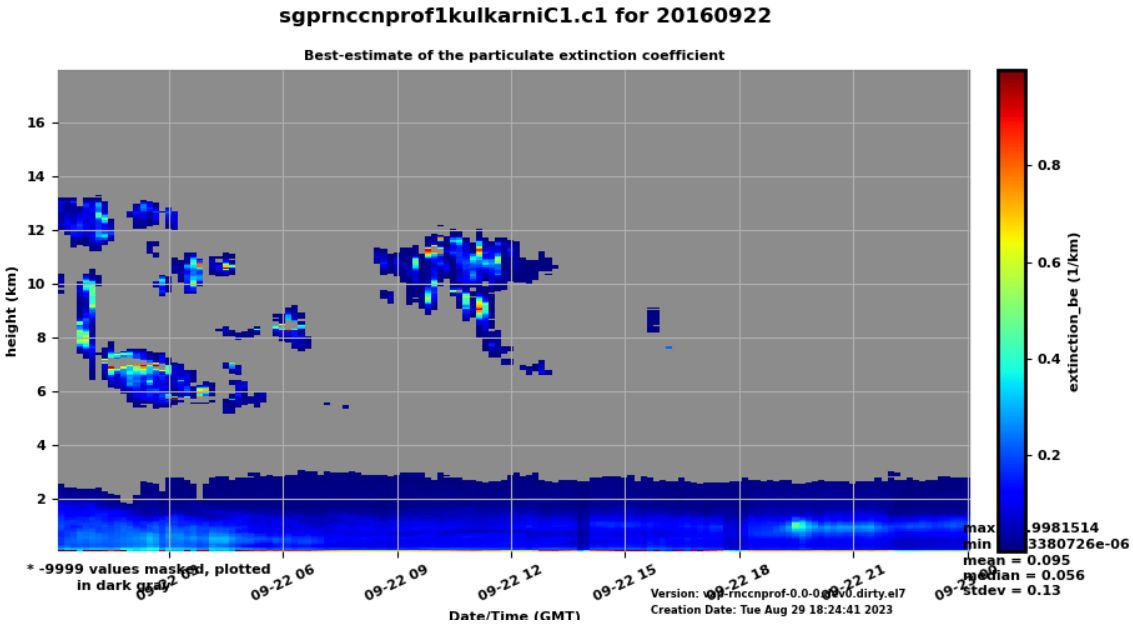


**Figure 4**. Extinction coefficient from Raman lidar.

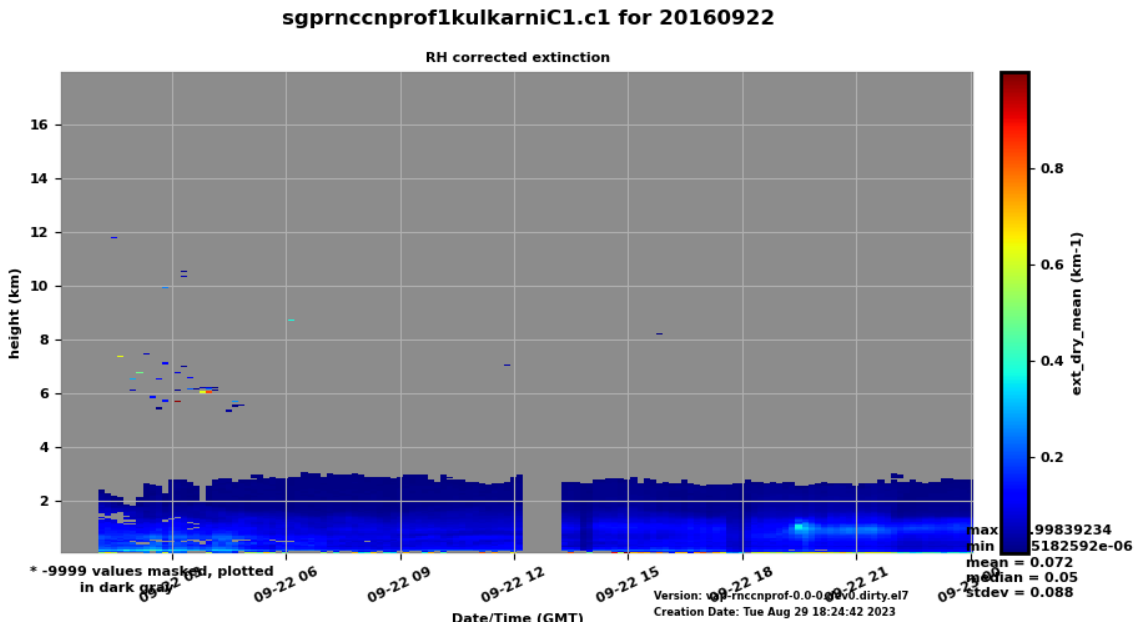


**Figure 5**. Extinction coefficient values corrected using aerosol humidification factor or fRH.

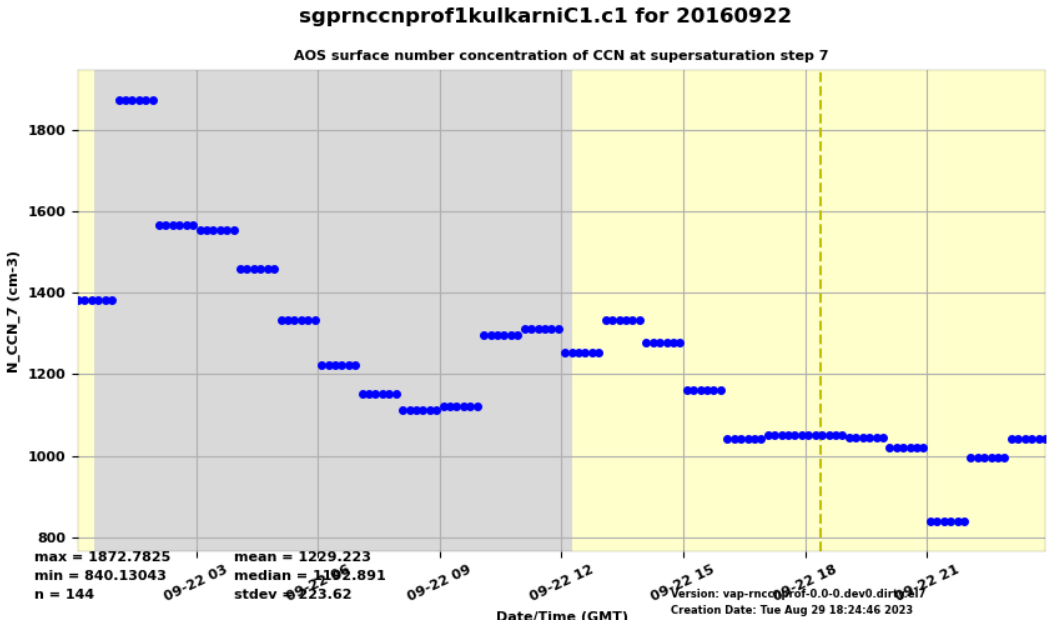


**Figure 6**. Ground surface CCN concentrations at step 7 supersaturation (0.2%).

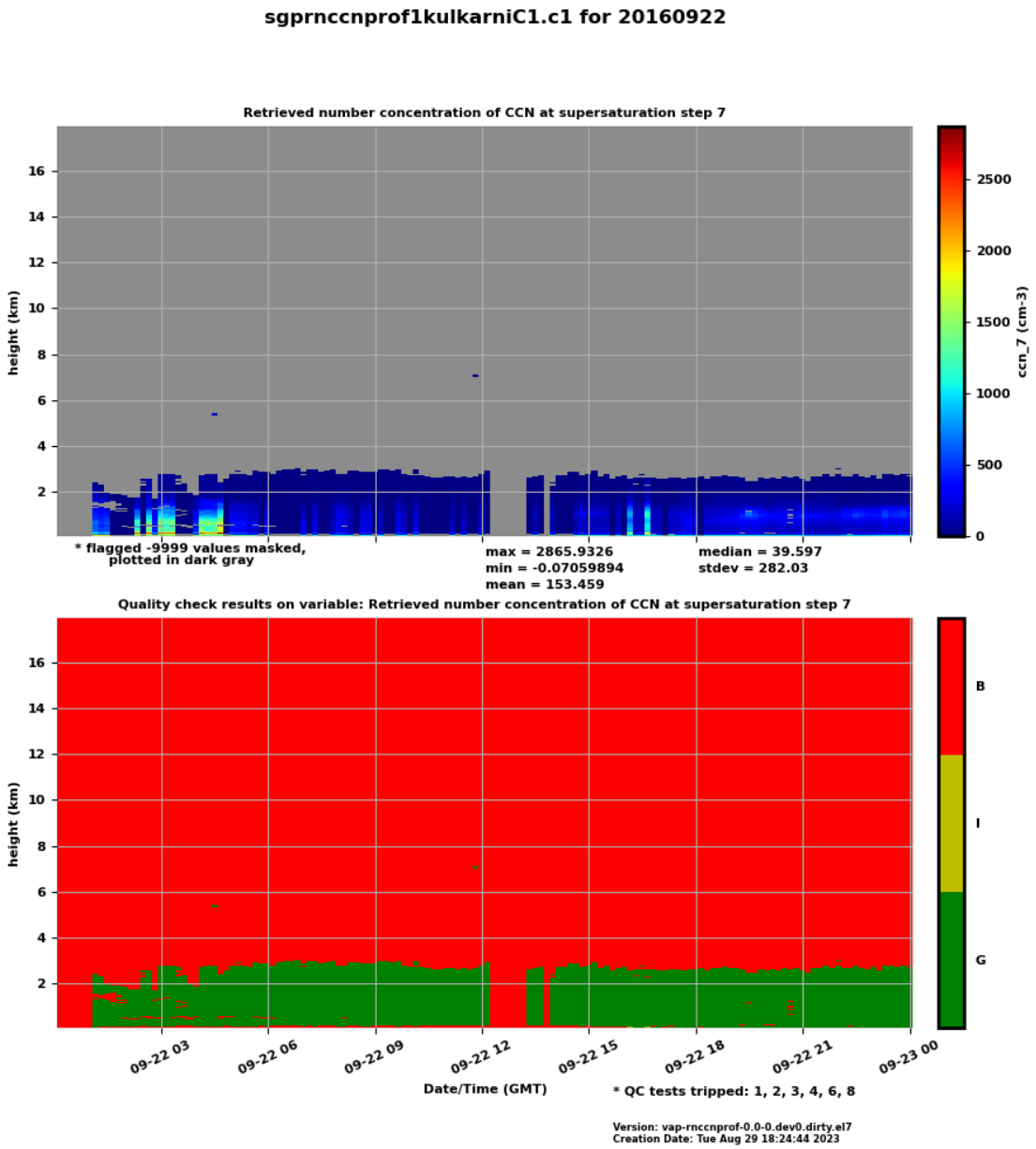


**Figure 7**. (Top) Retrieved number concentration of CCN at 0.2% supersaturation. (Bottom) Flagged data as Bad (B), Indeterminate (I), and Good (G).

# 6.0 References

Dawson, KW, RA Ferrare, RH Moore, MB Clayton, TJ Thorsen, and EW Eloranta. 2020. "Ambient aerosol hygroscopic growth from combined Raman lidar and HSRL." *Journal of Geophysical Research – Atmospheres* 125(7): e2019JD031708, https://doi.org/10.1029/2019JD031708

Ghan, SJ, and DR Collins. 2004. "Use of in situ data to test a Raman lidar-based cloud condensation nuclei remote sensing method." *Journal of Atmospheric and Oceanic Technology* 21(2): 387–394, https://doi.org/10.1175/1520-0426(2004)021<0387:UOISDT>2.0.CO;2

Ghan, SJ, TA Rissman, R Elleman, RA Ferrare, D Turner, C Flynn, J Wang, J Ogren, J Hudson, HH Johnsson, T VanReken, RC Flagan, and JH Seinfeld. 2006. "Use of in situ cloud condensation nuclei, extinction, and aerosol size distribution measurements to test a method for retrieving cloud condensation nuclei profiles from surface measurements." *Journal of Geophysical Research – Atmospheres* 111(D5): D05S10, https://doi.org/10.1029/2004JD005752

Newsom, R. 2022. Raman Lidar (RL) Instrument Handbook. U.S. Department of Energy, Atmospheric Radiation Measurement user facility, Richland, Washington. DOE/SC-ARM/TR-038.

# Appendix A

An example header from the RNCCN VAP is given below:

```
class: rnccnprof1kulkarni
level: c1
version: 1.3

time = UNLIMITED
height = null
bound = 2
supersaturation_setpoint = null

base_time():int
   string
   long_name = Base time in Epoch
   units = seconds since 1970-1-1 0:00:00 0:00
   ancillary_variables = time_offset

time_offset(time):double
   long_name = Time offset from base_time
   units
   ancillary_variables = base_time

time(time):double
   long_name = Time offset from midnight
   units
   bounds = time_bounds
   standard_name = time

time_bounds(time, bound):double
   long_name = Time cell bounds
   bound_offsets:double = 0, 3600

height(height):float
   long_name = Height above ground level
   units = km
   bounds = height_bounds
   comment = Heights correspond to the middle of the bin
   standard_name = height

height_bounds(height, bound):float
   long_name = Height cell bounds
```

depolarization_ratio(time, height):float
   long_name = Aerosol linear depolarization ratio
   units = 1
   missing_value:float = -9999
   comment = Linear depolarization ratio is defined as the ratio of the two backscattered signals at 355 nm.

lidar_ratio_be(time, height):float
   long_name = Best-estimate of the lidar ratio
   units = sr
   comment = Combination of: lidar_ratio_e_n2_low + lidar_ratio_e_n2 + interpolated + transmission-loss + profile/object/daily averaged + assumed lidar ratios as noted in source_lidar_ratio_be
   missing_value:float = -9999

extinction_be_uncertainty_random(time, height):float
   long_name = Random uncertainty in extinction_be
   units = 1/km
   comment = The random uncertainty for the best-estimate of the particulate extinction coefficient is derived from the best-estimate of particulate backscatter coefficient, the best-estimate of the lidar ratio, and their respective random uncertainties.
   missing_value:float = -9999

extinction_be_uncertainty_systematic(time, height):float
   long_name = Maximum systematic uncertainty in extinction_be
   units = 1/km
   comment = The systematic uncertainty for the best-estimate of the particulate extinction coefficient is derived from the best-estimate of particulate backscatter coefficient, the best-estimate of the lidar ratio, and their respective systematic uncertainties.
   missing_value:float = -9999

extinction_be(time, height):float
   long_name = Best-estimate of the particulate extinction coefficient
   units = 1/km
   equation = particulate_backscatter_be * lidar_ratio_be
   missing_value:float = -9999
   comment = The extinction_be is calculated using the expression shown in equation originally from rlproffex1thor VAP.

feature_mask(time, height):int
   long_name = Feature mask
   units = 1
   comment = If no bits are set, then no feature
   flag_masks:int = 1, 2, 4, 8, 16, 32, 64
   flag_meanings = feature aerosol cloud rain_or_virga liquid_cloud ice_cloud horizontally_oriented_ice
   bit_1_description = feature (any type)
   bit_2_description = aerosol
   bit_3_description = cloud (any phase)
   bit_4_description = rain or virga
   bit_5_description = liquid cloud
   bit_6_description = ice cloud (any orientation)
   bit_7_description = horizontally oriented ice

missing_value:int = -9999

temperature(time, height):float
long_name = Calibrated temperature from the rotational Raman channels
units = K
comment = T = 300*b_coef/(ln(rot_raman_ratio/overlap_function)-a_coef), T in K
standard_name = air_temperature
missing_value:float = -9999
_DeflateLevel:int = 1
_ChunkSizes:int
_Shuffle = true

rh(time, height):float
long_name = Relative humidity observed by the Raman lidar
units = %
missing_value:float = -9999

mr_merged(time, height):float
long_name = High and Low merged water vapor mixing ratio
units = g/kg
missing_value:float = -9999
_DeflateLevel:int = 1
_ChunkSizes:int
_Shuffle = true

pres_sonde(time, height):float
long_name = Pressure from radiosondes
units = mb
_DeflateLevel:int = 1
_ChunkSizes:int
_Shuffle = true
missing_value:float = -9999

mr_sonde(time, height):float
long_name = Water vapor mixing ratio from radiosondes
units = g/kg
_DeflateLevel:int = 1
_ChunkSizes:int
_Shuffle = true
missing_value:float = -9999

ext_dry_mean(time, height):float
long_name = RH corrected extinction
units = km-1
missing_value:float = -9999
comment = This is equation (2) from Ghan et al. 2006

lcl(time):float
long_name = Lifting condensation level
units = km
missing_value:float = -9999

ccn_1(time, height):float*
long_name = Retrieved number concentration of CCN at supersaturation step 1
units = cm-3
missing_value:float = -9999
ancillary_variables = qc_ccn_1
comment = This is equation (1) from Ghan et al. 2006

qc_ccn_1(time, height):int
long_name = Quality check results on variable: Retrieved number concentration of CCN at supersaturation step 1
units = 1
standard_name = quality_flag
description = This variable contains bit-packed integer values, where each bit represents a QC test on the data. Non-zero bits indicate the QC condition given in the description for those bits; a value of 0 (no bits set) indicates the data has not failed any QC tests.
flag_method = bit
bit_1_description = The relative humidity from input data is missing, no calculation is performed.
bit_1_assessment = Bad
bit_2_description = Surface relative humidity value is missing, replaced with a value from the next height bin.
bit_2_assessment = Indeterminate
bit_3_description = Surface extinction value is missing, replaced with a value from the next height bin.
bit_3_assessment = Indeterminate
bit_4_description = The feature mask was detected as not aerosol and the extinction values were replaced as missing value.
bit_4_assessment = Bad
bit_5_description = The relative humidity below the first cloud layer is above 85%.
bit_5_assessment = Indeterminate
bit_6_description = The atmospheric stability test using temperature profile failed
bit_6_assessment = Bad
bit_7_description = Relative Humidity is above 99%.
bit_7_assessment = Indeterminate
bit_8_description = Some of the input parameters were missing, no calculation is performed.
bit_8_assessment = Bad

ccn_2(time, height):float*
long_name = Retrieved number concentration of CCN at supersaturation step 2
units = cm-3
missing_value:float = -9999
ancillary_variables = qc_ccn_2
comment = This is equation (1) from Ghan et al. 2006

qc_ccn_2(time, height):int
long_name = Quality check results on variable: Retrieved number concentration of CCN at supersaturation step 2
units = 1
standard_name = quality_flag
description = This variable contains bit-packed integer values, where each bit represents a QC test on the data. Non-zero bits indicate the QC condition given in the description for those bits; a value of 0 (no bits set) indicates the data has not failed any QC tests.

flag_method = bit
bit_1_description = The relative humidity from input data is missing, no calculation is performed.
bit_1_assessment = Bad
bit_2_description = Surface relative humidity value is missing, replaced with a value from the next height bin.
bit_2_assessment = Indeterminate
bit_3_description = Surface extinction value is missing, replaced with a value from the next height bin.
bit_3_assessment = Indeterminate
bit_4_description = The feature mask was detected as not aerosol and the extinction values were replaced as missing value.
bit_4_assessment = Bad
bit_5_description = The relative humidity below the first cloud layer is above 85%.
bit_5_assessment = Indeterminate
bit_6_description = The atmospheric stability test using temperature profile failed
bit_6_assessment = Bad
bit_7_description = Relative Humidity is above 99%.
bit_7_assessment = Indeterminate
bit_8_description = Some of the input parameters were missing, no calculation is performed.
bit_8_assessment = Bad

ccn_3(time, height):float*
long_name = Retrieved number concentration of CCN at supersaturation step 3
units = cm-3
missing_value:float = -9999
ancillary_variables = qc_ccn_3
comment = This is equation (1) from Ghan et al. 2006

qc_ccn_3(time, height):int
long_name = Quality check results on variable: Retrieved number concentration of CCN at supersaturation step 3
units = 1
standard_name = quality_flag
description = This variable contains bit-packed integer values, where each bit represents a QC test on the data. Non-zero bits indicate the QC condition given in the description for those bits; a value of 0 (no bits set) indicates the data has not failed any QC tests.
flag_method = bit
bit_1_description = The relative humidity from input data is missing, no calculation is performed.
bit_1_assessment = Bad
bit_2_description = Surface relative humidity value is missing, replaced with a value from the next height bin.
bit_2_assessment = Indeterminate
bit_3_description = Surface extinction value is missing, replaced with a value from the next height bin.
bit_3_assessment = Indeterminate
bit_4_description = The feature mask was detected as not aerosol and the extinction values were replaced as missing value.
bit_4_assessment = Bad
bit_5_description = The relative humidity below the first cloud layer is above 85%.
bit_5_assessment = Indeterminate
bit_6_description = The atmospheric stability test using temperature profile failed
bit_6_assessment = Bad
bit_7_description = Relative Humidity is above 99%.

bit_7_assessment = Indeterminate
bit_8_description = Some of the input parameters were missing, no calculation is performed.
bit_8_assessment = Bad

ccn_4(time, height):float*
long_name = Retrieved number concentration of CCN at supersaturation step 4
units = cm-3
missing_value:float = -9999
ancillary_variables = qc_ccn_4
comment = This is equation (1) from Ghan et al. 2006

qc_ccn_4(time, height):int
long_name = Quality check results on variable: Retrieved number concentration of CCN at supersaturation step 4
units = 1
standard_name = quality_flag
description = This variable contains bit-packed integer values, where each bit represents a QC test on the data. Non-zero bits indicate the QC condition given in the description for those bits; a value of 0 (no bits set) indicates the data has not failed any QC tests.
flag_method = bit
bit_1_description = The relative humidity from input data is missing, no calculation is performed.
bit_1_assessment = Bad
bit_2_description = Surface relative humidity value is missing, replaced with a value from the next height bin.
bit_2_assessment = Indeterminate
bit_3_description = Surface extinction value is missing, replaced with a value from the next height bin.
bit_3_assessment = Indeterminate
bit_4_description = The feature mask was detected as not aerosol and the extinction values were replaced as missing value.
bit_4_assessment = Bad
bit_5_description = The relative humidity below the first cloud layer is above 85%.
bit_5_assessment = Indeterminate
bit_6_description = The atmospheric stability test using temperature profile failed
bit_6_assessment = Bad
bit_7_description = Relative Humidity is above 99%.
bit_7_assessment = Indeterminate
bit_8_description = Some of the input parameters were missing, no calculation is performed.
bit_8_assessment = Bad

ccn_5(time, height):float*
long_name = Retrieved number concentration of CCN at supersaturation step 5
units = cm-3
missing_value:float = -9999
ancillary_variables = qc_ccn_5
comment = This is equation (1) from Ghan et al. 2006

qc_ccn_5(time, height):int
long_name = Quality check results on variable: Retrieved number concentration of CCN at supersaturation step 5
units = 1
standard_name = quality_flag

description = This variable contains bit-packed integer values, where each bit represents a QC test on the data. Non-zero bits indicate the QC condition given in the description for those bits; a value of 0 (no bits set) indicates the data has not failed any QC tests.
flag_method = bit
bit_1_description = The relative humidity from input data is missing, no calculation is performed.
bit_1_assessment = Bad
bit_2_description = Surface relative humidity value is missing, replaced with a value from the next height bin.
bit_2_assessment = Indeterminate
bit_3_description = Surface extinction value is missing, replaced with a value from the next height bin.
bit_3_assessment = Indeterminate
bit_4_description = The feature mask was detected as not aerosol and the extinction values were replaced as missing value.
bit_4_assessment = Bad
bit_5_description = The relative humidity below the first cloud layer is above 85%.
bit_5_assessment = Indeterminate
bit_6_description = The atmospheric stability test using temperature profile failed
bit_6_assessment = Bad
bit_7_description = Relative Humidity is above 99%.
bit_7_assessment = Indeterminate
bit_8_description = Some of the input parameters were missing, no calculation is performed.
bit_8_assessment = Bad

ccn_6(time, height):float*
long_name = Retrieved number concentration of CCN at supersaturation step 6
units = cm-3
missing_value:float = -9999
ancillary_variables = qc_ccn_6
comment = This is equation (1) from Ghan et al. 2006

qc_ccn_6(time, height):int
long_name = Quality check results on variable: Retrieved number concentration of CCN at supersaturation step 6
units = 1
standard_name = quality_flag
description = This variable contains bit-packed integer values, where each bit represents a QC test on the data. Non-zero bits indicate the QC condition given in the description for those bits; a value of 0 (no bits set) indicates the data has not failed any QC tests.
flag_method = bit
bit_1_description = The relative humidity from input data is missing, no calculation is performed.
bit_1_assessment = Bad
bit_2_description = Surface relative humidity value is missing, replaced with a value from the next height bin.
bit_2_assessment = Indeterminate
bit_3_description = Surface extinction value is missing, replaced with a value from the next height bin.
bit_3_assessment = Indeterminate
bit_4_description = The feature mask was detected as not aerosol and the extinction values were replaced as missing value.
bit_4_assessment = Bad
bit_5_description = The relative humidity below the first cloud layer is above 85%.
bit_5_assessment = Indeterminate

bit_6_description = The atmospheric stability test using temperature profile failed
bit_6_assessment = Bad
bit_7_description = Relative Humidity is above 99%.
bit_7_assessment = Indeterminate
bit_8_description = Some of the input parameters were missing, no calculation is performed.
bit_8_assessment = Bad

ccn_7(time, height):float*
long_name = Retrieved number concentration of CCN at supersaturation step 7
units = cm-3
missing_value:float = -9999
ancillary_variables = qc_ccn_7
comment = This is equation (1) from Ghan et al. 2006

qc_ccn_7(time, height):int
long_name = Quality check results on variable: Retrieved number concentration of CCN at supersaturation step 7
units = 1
standard_name = quality_flag
description = This variable contains bit-packed integer values, where each bit represents a QC test on the data. Non-zero bits indicate the QC condition given in the description for those bits; a value of 0 (no bits set) indicates the data has not failed any QC tests.
flag_method = bit
bit_1_description = The relative humidity from input data is missing, no calculation is performed.
bit_1_assessment = Bad
bit_2_description = Surface relative humidity value is missing, replaced with a value from the next height bin.
bit_2_assessment = Indeterminate
bit_3_description = Surface extinction value is missing, replaced with a value from the next height bin.
bit_3_assessment = Indeterminate
bit_4_description = The feature mask was detected as not aerosol and the extinction values were replaced as missing value.
bit_4_assessment = Bad
bit_5_description = The relative humidity below the first cloud layer is above 85%.
bit_5_assessment = Indeterminate
bit_6_description = The atmospheric stability test using temperature profile failed
bit_6_assessment = Bad
bit_7_description = Relative Humidity is above 99%.
bit_7_assessment = Indeterminate
bit_8_description = Some of the input parameters were missing, no calculation is performed.
bit_8_assessment = Bad

potential_temperature(time, height):float
long_name = Potential temperature
units = K
standard_name = air_potential_temperature
missing_value:float = -9999

N_CCN_1(time):float
long_name = AOS surface number concentration of CCN at supersaturation step 1
units = cm-3

missing_value:float = -9999

N_CCN_2(time):float
long_name = AOS surface number concentration of CCN at supersaturation step 2
units = cm-3
missing_value:float = -9999

N_CCN_3(time):float
long_name = AOS surface number concentration of CCN at supersaturation step 3
units = cm-3
missing_value:float = -9999

N_CCN_4(time):float
long_name = AOS surface number concentration of CCN at supersaturation step 4
units = cm-3
missing_value:float = -9999

N_CCN_5(time):float
long_name = AOS surface number concentration of CCN at supersaturation step 5
units = cm-3
missing_value:float = -9999

N_CCN_6(time):float
long_name = AOS surface number concentration of CCN at supersaturation step 6
units = cm-3
missing_value:float = -9999

N_CCN_7(time):float
long_name = AOS surface number concentration of CCN at supersaturation step 7
units = cm-3
missing_value:float = -9999

supersaturation_setpoint(supersaturation_setpoint):float
long_name = Supersaturation set point
units = %

cbh(time):float
long_name = Cloud base height
units = km
missing_value:float = -9999
valid_min:float = 0
flag_values:float = -1
flag_meanings = no_cloud_detected
comment = Height represents distance above surface

calculated_frh(time, height):float
long_name = Calculated f(RH) using equation f(RH) = C1(1-RH)^gamma, where C1 = (1 – RH_0)^gamma and RH_0 = 40%
units = 1
missing_value:float = -9999
source

lat():float
    long_name = North latitude
    units = degree_N
    valid_min:float = -90
    valid_max:float = 90
    standard_name = latitude

lon():float
    long_name = East longitude
    units = degree_E
    valid_min:float = -180
    valid_max:float = 180
    standard_name = longitude

alt():float
    long_name = Altitude above mean sea level
    units = m
    standard_name = altitude

  command_line
  Conventions = ARM-1.3
  process_version
  dod_version
  input_datastreams
  site_id
  platform_id
  facility_id
  data_level
  location_description
  datastream
  doi = 10.5439/1813858
  _Format = netCDF-4 classic model
  input_datastreams_description = A string consisting of the datastream(s), datastream version(s), and datastream date (range).
  algorithm_reference_2 = Ghan, S.J. and D. R. Collins (2004), Use of in situ data to test a Raman lidar-based cloud condensation nuclei remote sensing method. J. Atmos. Ocean Tech., 21, 387-394.
  algorithm_reference_1 = Ghan, S.J. and co-authors, 2006: Use of in situ cloud condensation nuclei, extinction, and aerosol size distribution measurements to test a method for retrieving cloud condensation nuclei profiles from surface measurements. J. Geophys. Res., 111, D05S10, doi:10.1029/2004JD005752.
  history


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