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Convective Parameters Derived from Radiosonde Data (SONDEPARAM) Value-Added Product Report

A Zhou
D Wang
SE Giangrande
M Jensen

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ARM

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A Zhou
SE Giangrande
D Wang
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All at Brookhaven National Laboratory

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Acronyms and Abbreviations

AMF	ARM Mobile Facility
ARM	Atmospheric Radiation Measurement
CAPE	convective available potential energy
CIN	convective inhibition
COR	Córdoba, Argentina
ENA	Eastern North Atlantic
GAN	Gan Island, Maldives
HOU	Houston, Texas
LCL	lifting condensation level
LFC	level of free convection
LNB	level of neutral buoyancy
MAO	Manacapuru, Brazil
NetCDF	Network Common Data Form
NIM	Niamey, Niger
QC	quality control
SAIL	Surface Atmosphere Integrated Field Laboratory
SGP	Southern Great Plains
SONDEPARAM	Convective Parameters Derived from Radiosonde Data
TMP	Biogenic Aerosols − Effects on Clouds and Climate site at Hyytiälä, Finland
TWP	Tropical Western Pacific
VAP	value-added product

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1.0 Introduction

Radiosondes provide fundamental observations of the vertical profile of atmospheric state (pressure, temperature, humidity, and winds), with important implications for subsequent studies on environmental controls on cloud conditions. Within convective cloud environments, there is an increasing demand for additional value-added products (VAPs) to facilitate the use of U.S. Department of Energy Atmospheric Radiation Measurement (ARM) user facility radiosonde data sets. Such VAPs should provide quick and reliable estimates for several standard radiosonde parameters or quantities of interest using common assumptions, as well as open, flexible code for visualization and user interaction.

The Convective Parameters Derived from Radiosonde Data (SONDEPARAM) VAP will apply several robust algorithms used in Wang et al. (2020) for the calculation of useful radiosonde convective cloud parameters, including the convective available potential energy (CAPE), convective inhibition (CIN), and other convective parameters, for several different assumptions regarding the initial parcel characteristics (i.e., surface-based, most unstable, mixed layer). These ARM VAP codes are developed in open, flexible Python formats, with the intention that these parameters/calculations will be incorporated into traditional ARM quick-look radiosonde plotting, yet associated with user-available codes for ease in user reproduction and assumption modification.

2.0 Input Data

The SONDEPARAM VAP accepts the single radiosonde file “sondewnpn.b1” as input data. The VAP is created using the following inputs from this “sondewnpn.b1” file:

Table 1. Input variables for SONDEPARAM.

sondewnpn.b1		
Name	**Long Name**	**Units**
alt	Altitude above mean sea level	m
pres	Pressure	hPa
dp	Dewpoint Temperature	degC
tdry	Dry Bulb Temperature	degC
rh	Relative Humidity	%
u_wind	Eastward Wind Component	m/s
v_wind	Northward Wind Component	m/s
wspd	Wind Speed	m/s
deg	Wind Direction	degree

3.0 Output Data

The SONDEPARAM VAP outputs a NetCDF file “sondeparam.c1” from each input “sondewnpn.b1” file. Table 2 lists the major output variables from the VAP.

Table 2. Major output variables for SONDEPARAM.

Variables for VAP		
Name	**Long Name**	**Units**
parcel_type	Type of parcels	1
parcel_layer	The height of the parcel for a given parcel type	km
sonde_height	The highest level of radiosonde	km
time_highest_level	The time when radiosonde reaches the highest level	seconds since 1970-1-1 0:00:00 0:00
CAPE	Convective available potential energy	J kg-1
CIN	Convective inhibition	J kg-1
LCL	Lifting condensation level	km
LFC	Level of free convection	km
LNB	Level of neutral buoyancy	km
rh	Low-level relative humidity from 0km to 5km	%
elr3	Environmental temperature lapse rates from 0km to 3km	degC km-1
elr6	Environmental temperature lapse rates from 3km to 6km	degC km-1
wind_shear	Wind shear from 0km to 5km	s-1
data_quality	Flag which indicates the quality of the input data	1

The detail for the specific variable “data_quality” in Table 2 is defined as:

data_quality = [sfc_delta_dp, sfc_delta_tdry, bad_dp, bad_tdry, bad_pres, bad_rh, bad_deg, bad_u_wind, bad_v_wind]

The threshold values for the elements of “data_quality” refer to the two filters listed in Appendix 1.

4.0 Algorithm Outline

The overall algorithm follows the codes and concepts found in several recent Brookhaven National Laboratory studies of the code sponsors. These studies include those of science sponsors Jensen et al. (2016), Wang et al. (2020), and Giangrande et al. (2020). Since the calculation of several convective parameters (e.g., level of neutral buoyancy (LNB), CAPE, etc.) can be highly sensitive to the initial parcel characteristics, we include a variety of parcel options in the baseline VAP implementation.

Below is a summary of these parcel definitions/assumptions:

- *Surface-Based Parcel*: the parcel at the lowest sounding data level.
- *Most Unstable Parcel*: the parcel that has the greatest virtual temperature in the lowest 700mb above surface.
- *Mixed-Layer Parcel*: the parcel with properties of the mean of the boundary layer.

In addition to these parcel assumptions, pseudo-adiabatic or irreversible saturated adiabatic parcel ascent is assumed to describe the behavior of these parcels. This implies that condensed water is immediately removed from the parcel. Both liquid and ice phases are considered in the parcel model. The inclusion of ice-phase transitions provides an additional source of positive buoyancy above the melting level from latent heat released during freezing. Finally, when assuming the air parcel experiences undiluted ascent in a pseudo-adiabatic process, we neglect hydrometeor loading.

The primary formulas and constant parameters to estimate the main VAP parameters are as follows:

- Buoyancy $B[k] = g * ((tv\_p - tv\_e[k])/tv\_e[k])$
  - tv_p: virtual potential temperature of parcel
  - tv_e: virtual potential temperature of environment
  - g: gravity
  - k: layer
- Lifting Condensation Level $lcl = \min\,(lcl, (alt[k]/1.e3))$
- alt: altitude
- Level of Free Convection $lfc = \min\,(lfc, (alt[k]/1.e3))$
- Level of Neutral Buoyancy $lnb = \min\,(lnb, alt[k-1]/1.e3)$
- $cape[k] = B[k] * (alt[k] - alt[k-1]) * (B[k] > 0)$
- $cin[k] = B[k] * (alt[k] - alt[k-1]) * (B[k] < 0)$
- $CAPE = sum(cape[(alt[: len(alt) - start]/1.e3 < lnb)\ \&\ (alt[: len(alt) - start]/1.e3 >= lfc))$
- $CIN = sum(cin[alt[: len(alt) - start]/1.e3 < lnb])$
- depth of mixed-layer = 482 meters
- depth of most-unstable-layer = 700 hPa

5.0 VAP Workflow

The workflow for the SONDPARAM VAP is shown in the diagram below.

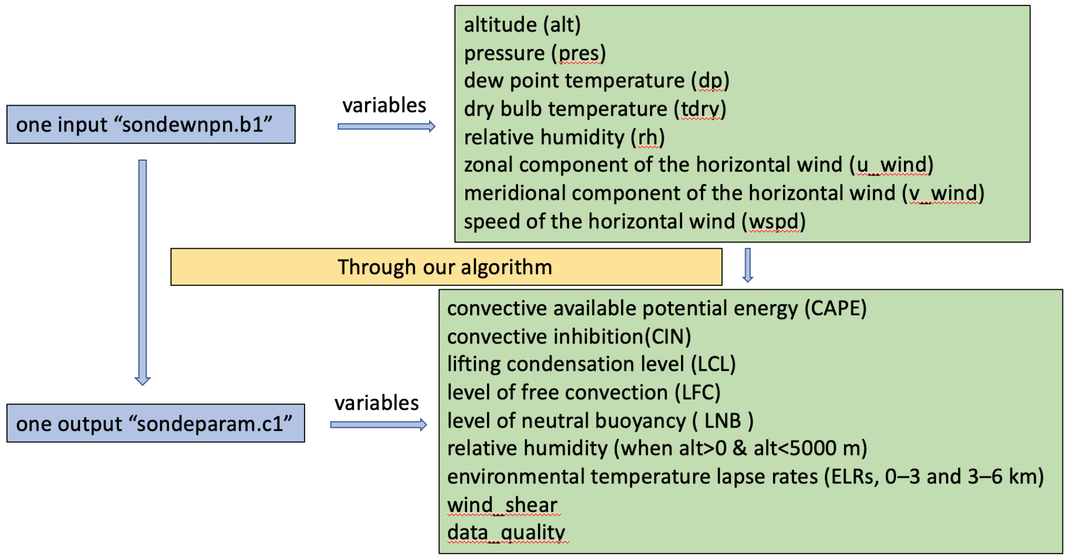


Figure 1. SONDEPARAM VAP workflow diagram.

6.0 Example Skew-T Plotting

As part of VAP coordination, the team will coordinate with the ARM Data Quality Office about aligning the output parameters from the SONDEPARAM VAP to matched values and behaviors on the associated ARM quick-look SKEW-T plotting routines. The following is a sample quick-look plot for an ARM radiosonde, though we envision these may be modified to include/append the key parameters of interest.

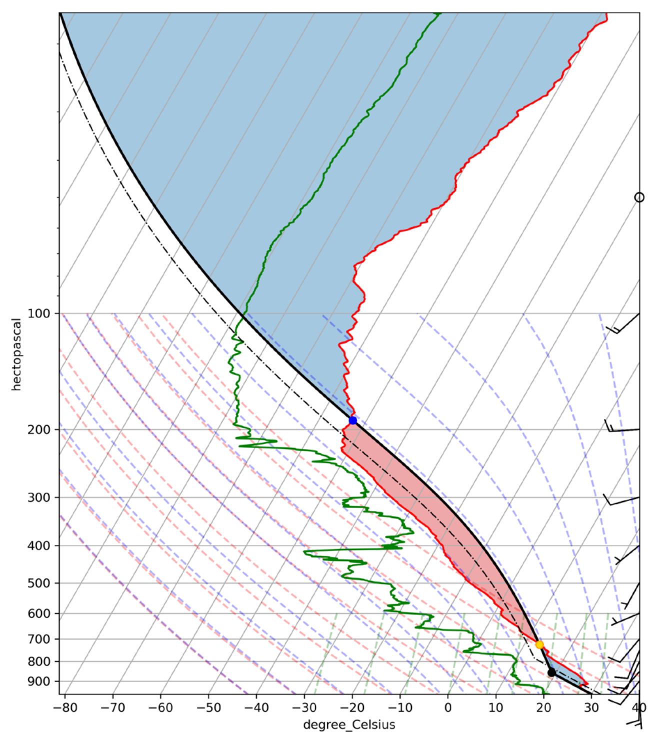


Figure 2. Sample of a quick-look plot for an ARM radiosonde.

7.0 Sites where the SONDEPARAM VAP is Expected to Run

The VAP is primarily intended for sites with environments conducive to the regular formation of convective clouds. From the existing ARM sites and ARM Mobile Facility (AMF) deployments, the requested sites would include: SGP/C1, ENA/C1, COR/M1, NIM/M1, MAO/M1, GAN/M1, TMP/M1, TWP/C1, TWP/C2, TWP/C3, HOU/M1, HOU/S1, SAIL/M1.

8.0 Summary

The ARM SONDEPARAM VAP will provide commonly used sounding convective parameters and other useful quantities along with corresponding quick-looks, while providing flexibility to users for customized convective parameter calculations and plotting.

9.0 References

Giangrande, SE, D Wang, and DB Mechem. 2020. "Cloud regimes over the Amazon Basin: perspectives from the GoAmazon2014/5 campaign." *Atmospheric Chemistry and Physics* 20(12):7489–7507, https://doi.org/10.5194/acp-20-7489-2020

Jensen, MP, DJ Holdridge, P Survo, R Lehtinen, S Baxter, T Toto, and KL Johnson. 2016. "Comparison of Vaisala radiosondes RS41 and RS92 at the ARM Southern Great Plains site." *Atmospheric Measurement Techniques* 9(7): 3115–3129, https://doi.org/10.5194/amt-9-3115-2016

Wang, D, MP Jensen, JA D'Iorio, G Jozef, SE Giangrande, KL Johnson, ZJ Luo, M Starzec, and GL Mullendore. 2020. "An Observational Comparison of Level of Neutral Buoyancy and Level of Maximum Detrainment in Tropical Deep Convective Clouds." *Journal of Geophysical Research − Atmospheres* 125(16): e2020JD032637, https://doi.org/10.1029/2020jd032637

Appendix A

Additional Notes/Robustness Changes on Initial Testing

We note that in running initial testing for these routines, there are several ‘problematic’ radiosondes that we can often flag as based on subsequent unusual parameter estimates. Some of these problems are likely issues that may also be addressed by ARM’s Data Quality Office if there was motivation to catch these issues further. However, since these QC checks are not currently implemented, we have added some sanity checks into VAP processing to allow processing with fewer failures.

Filter 1: Filter data having:

$abs(dp[0] - dp[1]) > 2.5$

or: $abs(tdry[0] - tdry[1]) > 2.5$

or: $pres[0] < 700; \quad dp < -20; \quad tdry < -25$

These will be marked as “bad” data in flag variable “data_quality”.

Special emphasis was on the site MAO, we suggest that data having:

$dp < 0\ C \quad or \quad tdry < 0\ C$

Should be marked as “bad” data in flag variable “data_quality”.

Filter 2: Filter based on sondes obtaining a height above the surface > 10km. The threshold values of “10km” is determined by the fraction of sondes at multiple sites/facilities.

Fraction of sondes with height above 10km:

site/facility	**(sonde > 10km)/all sonde**
COR/M1	0.
COR/S1	1.00
SGP/C1	0.97
SGP/E14	0.71
SGP/B1	0.94
SGP/B4	0.87
SGP/B5	0.93
SGP/B6	0.96
SGP/S01	0.98
SGP/S02	0.84

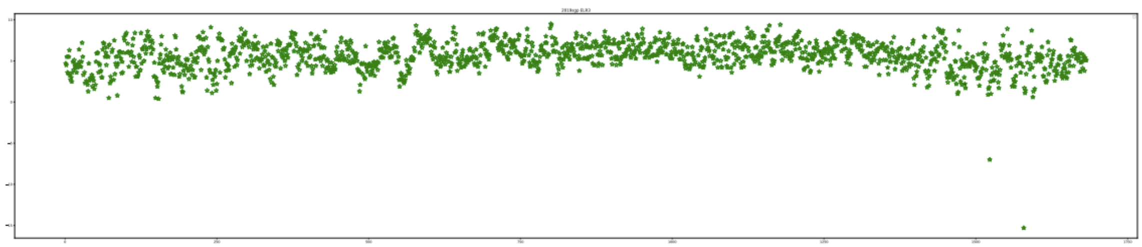
site/facility	(sonde > 10km)/all sonde
SGP/S03	1.0
MAO/M1	0.96
NIM/M1	0.95
TWP/C1	0.95
TWP/C2	0.92
TWP/C3	0.97

Appendix B

Non-Convective Cases

As with Appendix 1, sometimes cases/events fall outside the intended convective cloud environmental assumptions and also result in failures. Typically, there are a handful of events with “elr3 < 0” (also known as low-level negative lapse rates) for sites such as SGP annually. These are usually wintertime/non-ideal convective environments, having a deep inversion where “tdry” (temperature profile) increases with “height”.

One such example: SGP/C1/20191127.113100



These events are infrequent, but are noted by the developer as allowable instances for VAP failure.

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