

# Remote sensing of Electrification, Lightning, And Meso-scale/micro-scale Processes with Adaptive Ground Observations (RELAMPAGO) High Resolution Sounding Composite Data Set Version 1.3 (March 2020)

## 1.0 Contacts:

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## 2.0 Dataset Overview

This data set contains a composite of the highest vertical resolution (i.e. the “native resolution”) upper air sounding data from all sources for the Remote sensing of Electrification, Lightning, And Meso-scale/micro-scale Processes with Adaptive Ground Observations (RELAMPAGO) project in the EOL Sounding Composite (ESC) columnar ASCII format. The data set contains 2714 soundings including the Colorado State University (CSU) mobile radiosondes (105 soundings), the Center for Severe Weather Research (CSWR) mobile radiosondes (266 soundings), the University of Illinois (UIUC) mobile radiosondes (206 soundings), the DOE/ARM CACTI soundings from their two sites (1255 soundings), the INPE radiosondes from Sao Borja, Brazil (58 soundings), as well as the radiosondes from six locations around central Argentina that were operated by Servicio Meteorológico Nacional (SMN; 824 radiosondes).

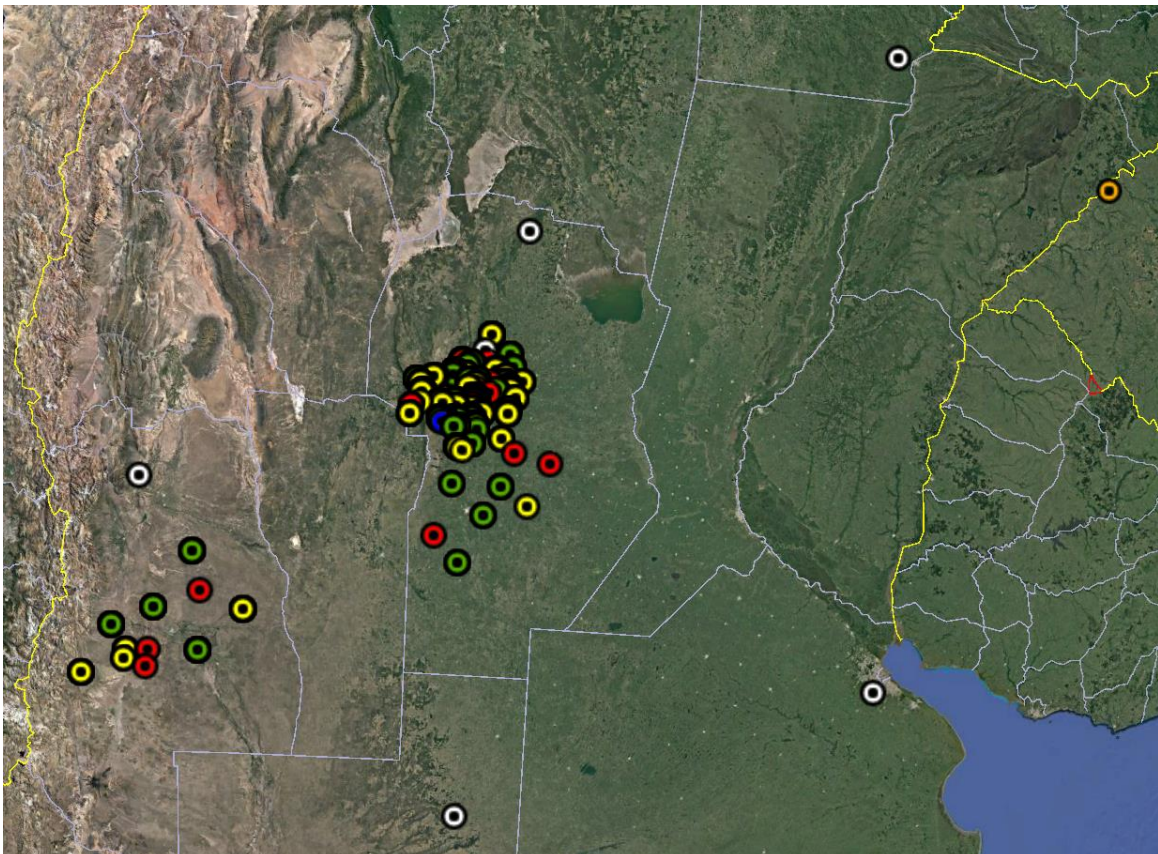


Figure 1. Locations of the soundings included in the RELAMPAGO high vertical resolution sounding composite data set. The CSU Mobile stations are red circles, CSWR yellow circles, UIUC green circles, SMN locations are white circles, DOE/ARM CACTI sites are blue circles, and the Sao Borja, Brazil site is orange.

### 3.0 Project Overview

The Remote sensing of Electrification, Lightning, And Meso-scale/micro-scale Processes with Adaptive Ground Observations (RELAMPAGO) field program was set up to elucidate the connections between the land surface, complex terrain, convective development, and the production of severe weather, the role of terrain processes in initiating and developing organized convective systems and altering flows within and above the convective boundary layer, and the roles of environmental moisture, aerosols, and instability on the resultant intensity, organization, precipitation, and high impact weather production of deep convective systems. It provided a unique configuration of atmospheric profiling and remote sensing capabilities including fixed and mobile radars, radiosonde systems, and surface meteorological instrumentation. There were additional projects occurring at the same time that were cooperating with RELAMPAGO, these included the DOE/ARM CACTI (Cloud, Aerosol, and Complex Terrain Interactions) project which included the DOE/ARM G1 aircraft and a suite of in-situ and remote sensing instrumentation in the Sierras de Córdoba mountain range of north-central Argentina, and the Instituto Nacional de Pesquisas Espaciais (INPE) operations that occurred in the area around Sao Borja, Brazil. Further information on RELAMPAGO is available at the RELAMPAGO web site at NCAR/EOL: [https://www.eol.ucar.edu/field\\_projects/relampago](https://www.eol.ucar.edu/field_projects/relampago) and information on the RELAMPAGO deployments is available at the RELAMPAGO Field Catalog: <http://catalog.eol.ucar.edu/relampago>.

### 4.0 EOL Sounding Composite (ESC) File Format Description

The ESC is a columnar ASCII format consisting of 15 header records for each sounding followed by the data records with associated data quality flags.

#### 4.1 Header Records

The header records (15 total records) contain a variety of metadata about the sounding (i.e. location, time, radiosonde type, etc). The first five header lines contain information identifying the sounding, and have a rigidly defined form. The following 7 header lines are used for auxiliary information and comments about the sounding, and may vary from dataset to dataset. The last 3 header records contain header information for the data columns. Line 13 holds the field names, line 14 the field units, and line 15 contains dashes ('-' characters) delineating the extent of the field.

The file standard header lines are as follows:

Line	Label (padded to 35 char)	Contents
1	Data Type:	Description of the type and resolution of data
2	Project ID:	Short name for the field project
3	Release Site Type/Site ID:	Description of the release site.
4	Release Location (lon,lat,alt):	Location of the release site.
5	UTC Release Time (y,m,d,h,m,s):	Time of release.

The release location is given as:  
lon (deg min), lat (deg min), lon (dec. deg), lat (dec. deg), alt (m)

Longitude in deg min is in the format: ddd mm.mm'W where ddd is the number of degrees (with leading zeros if necessary), mm.mm is the decimal number of minutes, and W represents W or E for west or east longitude, respectively. Latitude has the same format as longitude, except there are only two digits for degrees and N or S for north/south latitude.

The time of release is given as: yyyy, mm, dd, hh:nn:ss.

Where yyyy is the year, mm is the month, dd is the day of month, and hh:nn:ss are the UTC hour, minute, and second respectively.

The seven non-standard header lines may contain any label and contents. The labels are padded to 35 characters to match the standard header lines. For this composite data set these non-standard header lines vary depending on the data source. See the individual data set readmes for details.

## 4.2 Data Records

The data records each contain time from release, pressure, temperature, dew point, relative humidity, U and V wind components, wind speed and direction, ascent rate, balloon position data, altitude, and quality control flags (see the QC code description). Each data line contains 21 fields, separated by spaces, with a total width of 130 characters. The data are right-justified within the fields. All fields have one decimal place of precision, with the exception of latitude and longitude, which have three decimal places of precision. The contents and sizes of the 21 fields that appear in each data record are as follows:

Field	Width	Format	Parameter	Units	Missing Value
1	6	F6.1	Time since release	Seconds	9999.0
2	6	F6.1	Pressure	Millibars	9999.0
3	5	F5.1	Dry-bulb Temperature	Degrees C	999.0
4	5	F5.1	Dew Point Temperature	Degrees C	999.0
5	5	F5.1	Relative Humidity	Percent	999.0
6	6	F6.1	U Wind Comp	m/s	9999.0
7	6	F6.1	V Wind Comp	m/s	9999.0
8	5	F5.1	Wind speed	m/s	999.0
9	5	F5.1	Wind direction	Degrees	999.0
10	5	F5.1	Ascent Rate	m/s	999.0
11	8	F8.3	Longitude	Degrees	9999.0
12	7	F7.3	Latitude	Degrees	999.0
13	5	F5.1	Elevation Angle	Degrees	999.0
14	5	F5.1	Azimuth Angle	Degrees	999.0
15	7	F7.1	Geopotential Altitude	Meters	99999.0
16	4	F4.1	QC for Pressure	Code	99.0
17	4	F4.1	QC for Temperature	Code	99.0
18	4	F4.1	QC for Humidity	Code	99.0
19	4	F4.1	QC for U Wind	Code	99.0
20	4	F4.1	QC for V Wind	Code	99.0
21	4	F4.1	QC for Ascent Rate	Code	99.0

Fields 16 through 21 contain the data quality flags from the NCAR/Earth Observing Laboratory (EOL) sounding quality control procedures. The data quality flags are defined as follows:

<b>Code</b>	<b>Description</b>
1.0	Checked, datum seems physically reasonable. ("GOOD")
2.0	Checked, datum seems questionable on a physical basis. ("MAYBE")
3.0	Checked, datum seems to be in error. ("BAD")
4.0	Checked, datum is interpolated. ("ESTIMATED")
9.0	Checked, datum is missing. ("MISSING")
99.0	Unchecked (QC information is "missing".) ("UNCHECKED")

### **4.3 Data Specifics**

Details on the radiosonde systems included in this data set are included in this section. Links are included to the documentation for the individual sounding data sets for details on processing and quality control.

#### **Colorado State University Mobile Radiosondes**

105 total radiosondes with 1 second vertical resolution  
 Vaisala RS41-SG radiosondes  
 MW41 2.2.1DigiCORA radiosonde system  
<https://doi.org/10.26023/3QGG-JQKS-AFOG>

#### **CSWR Mobile Radiosondes**

266 total radiosondes with 5 m vertical resolution  
 GRAW DFM-09 radiosondes  
 GRAWMET 5.14 radiosonde system  
 These soundings came with data quality flags provided by CSWR, these were translated to those used by NCAR/EOL and included in the converted files. In the CSWR documentation one of these flags was mislabeled (QD was labeled as a wind direction quality flag, but it was a dew point quality flag. Version 1.2 (released Dec 2019) of the composite corrects this translation. The impacted flags are qrh, qu and qv. No data values were changed. Version 1.3 (released March 2020) includes CSWR updated surface wind speed and direction and they also added additional objective/subjective flags.

#### **University of Illinois Mobile Radiosondes**

206 total radiosondes with 5 m vertical resolution  
 GRAW DFM-09 radiosondes  
 GRAWMET 5.14 radiosonde system  
 These soundings came with data quality flags provided by CSWR, these were translated to those used by NCAR/EOL and included in the converted files. In the CSWR documentation one of these flags was mislabeled (QD was labeled as a wind direction quality flag, but it was a dew point quality flag. Version 1.2 (released Dec 2019) of the composite corrects this translation. The impacted flags are qrh, qu and qv. No data values were changed. Version 1.3 (released March 2020) includes CSWR updated surface wind speed and direction and they also added additional objective/subjective flags.

#### **Brazil Sao Borja RS41 Radiosondes**

30 total radiosondes at 2 second vertical resolution  
Vaisala RS41-SGP radiosondes  
MW41 2.2.14 DigiCORA radiosonde system  
<https://doi.org/10.26023/416N-161D-BC09>

### **Brazil Sao Borja RS92 Radiosondes**

28 total radiosondes at 2 second vertical resolution  
Vaisala RS92 radiosondes  
<https://doi.org/10.26023/416N-161D-BC09>

The sounding at 1200 UTC on 2 November has mandatory and significant level data below 330 mb and 2 second data above.

The sounding at 1200 UTC on 5 November has mandatory and significant level data below 311 mb and 2 second data above.

### **SMN Argentina Radiosondes**

824 total radiosondes: Cordoba (270 soundings), Ezeiza (90 soundings), Mendoza (146 soundings), Resistencia (87 soundings), Santa Rosa (95 soundings), Villa de Maria del Rio Seco (136 soundings)

All radiosondes used were Modem GPSONDE M10 (2 second vertical resolution) except for Ezeiza which used Vaisala RS41 with pressure derived from GPS height/DigiCORA MW41(1 second vertical resolution) until 22 December 2018 when it changed to the Modem radiosondes. One sounding (29 December 2018) was provided at mandatory and significant levels only.

<https://doi.org/10.26023/E8MP-0GD3-4903>

All sondes had the solar and infrared corrections applied by the radiosonde system and GPS winds.

### **DOE/ARM CACTI Radiosondes**

1255 total radiosondes: M1 Cordoba (884 soundings) and S1 San Luis (371 soundings)

All radiosondes used were Vaisala RS41-SGP (1 second vertical resolution) and used the Vaisala MW41 2.40 radiosonde system.

[https://www.arm.gov/publications/tech\\_reports/handbooks/sonde\\_handbook.pdf](https://www.arm.gov/publications/tech_reports/handbooks/sonde_handbook.pdf)

<http://dx.doi.org/10.5439/1021460>

The data are in files by day, so all soundings for a particular day are concatenated into a single file ordered by time. The file naming convention is:

RELAMPAGO\_HighRes\_yyyymmdd.cls where yyyy is the year, mm is the month, and dd is the day of the month.

## **4.4 Sample Data**

The following is a sample of the high resolution radiosonde data in ESC format.

Data Type: CSU Mobile Radiosonde/Ascending  
Project ID: RELAMPAGO  
Release Site Type/Site ID: Mobile/CSU\_Mobile

Release Location (lon,lat,alt): 064 10.46'W, 31 25.16'S, -64.174, -31.419, 385.0  
 UTC Release Time (y,m,d,h,m,s): 2018, 10, 31, 15:13:00  
 Radiosonde Type: RS41-SG  
 Radiosonde Serial Number: P3311138  
 Ground Station Software: MW41 2.2.1

Nominal Release Time (y,m,d,h,m,s):2018, 10, 31, 15:13:00  
 Time Press Temp Dewpt RH Ucmp Vcmp spd dir Wcmp Lon Lat Ele Azi Alt Qp Qt Qrh Qu Qv QdZ  
 sec mb C C % m/s m/s m/s deg m/s deg deg deg m code code code code code code  
 -----  
 0.0 970.9 24.8 7.9 34.0 -2.0 1.1 2.3 120.0 0.0 -64.174 -31.419 999.0 999.0 385.0 3.0 3.0 3.0 1.0 1.0 99.0  
 2.0 970.6 23.9 6.9 33.3 -2.5 0.6 2.6 104.3 1.7 -64.174 -31.419 999.0 999.0 388.1 3.0 3.0 3.0 1.0 1.0 99.0  
 3.0 970.1 23.6 6.8 34.0 -2.7 0.7 2.8 104.0 5.6 -64.174 -31.419 999.0 999.0 393.7 2.0 1.0 1.0 1.0 1.0 99.0

## 4.5 Station List

Site ID	WMO ID	Site Name	Country	Latitude	Longitude	Elev (m)
CSU_Mobile	N/A	CSU Mobile		Mobile	Mobile	Mobile
CSWR_Mobile	N/A	CSWR Mobile		Mobile	Mobile	Mobile
UIUC_Mobile	N/A	UIUC Mobile		Mobile	Mobile	Mobile
N/A	N/A	Sao Borja	BR	-28.643	-55.989	92
N/A	87344	Cordoba	AR	-31.298	-64.212	490
N/A	87576	Ezeiza	AR	-34.819	-58.542	21
N/A	87418	Mendoza	AR	-32.844	-68.797	704
N/A	87155	Resistencia	AR	-27.439	-59.046	52
N/A	87623	Santa Rosa	AR	-36.593	-64.279	191
N/A	87244	Villa de Maria del Rio Seco	AR	-29.906	-63.726	341
M1		Cordoba	AR	-32.130	-64.730	1139
S1		San Luis	AR	-31.950	-65.150	565

## 5.0 Data Quality Control Procedures

1. Each sounding was converted from its original format into the ESC format described above.
2. Each sounding was passed through a set of automated data quality checks which included basic gross limit checks as well as rate of change checks. This is further described in Section 4.1.
3. Each sounding was visually examined utilizing the NCAR/EOL XQC sounding quality control software. This is further described in Section 4.2.

### 5.1 Automated Data Quality Checks

This data set was passed through a set of automated data quality checks. This procedure includes both gross limit checks on all parameters as well as rate-of-change checks on temperature, pressure, and ascent rate. A version of these checks is described in Loehrer et al. (1996) and Loehrer et al. (1998).

### 5.1.1 Gross Limit Checks

These checks were conducted on each sounding and the data quality flags in the ESC files were adjusted as appropriate. Only the data point under examination was flagged. All checks also produced warning messages that specified the location of the problem and the severity of the issue. These warning messages were then summarized statistically and examined to determine any consistent issues.

For this data set NCAR/EOL conducted the following gross limit checks. In the table P = pressure, T = temperature, RH = relative humidity, U = U wind component, V = V wind component, B= bad, and Q = questionable.

Parameter	Check	Parameter(s) Flagged	Flag Applied
Pressure	<0 or > 1050	P	B
Altitude	< 0 or >40000	P, T, RH	Q
Temperature	< -90 or > 45	T	B
Dew Point	< -99.9 or > 33 > T	RH T, RH	Q Q
Wind Speed	< 0 or > 100 > 150	U, V U, V	Q B
U Wind	< 0 or > 100 > 150	U U	Q B
V Wind	< 0 or > 100 > 150	V V	Q B
Wind Direction	< 0 or > 360	U, V	B
Ascent Rate	< -10 or > 10	P, T, RH	Q

### 5.1.2 Vertical Consistency Checks

These checks were conducted on each sounding and the data quality flags in the ESC files were adjusted as appropriate. These checks were started at the surface and compared each neighboring data record. In the case of checks that ensured that the values increased/decreased as expected, only the data point under examination was flagged. However, for the other checks, all of the data points used in the examination were flagged. All items within the table are as previously defined. All checks also produced warning messages that specified the location of the problem and the severity of the issue. These warning messages were then summarized statistically and examined to determine any consistent issues.

Parameter	Check	Parameter(s) Flagged	Flag Applied
Time	Decreasing/equal	None	None.
Altitude	Decreasing/equal	P, T, RH	Q
Pressure	Increasing/equal > 1mb/s or < -1mb/s > 2mb/s or < -2mb/s	P, T, TH P, T, TH P, T, TH	Q Q B
Temperature	< -15°C/km < -30°C/km > 50°C/km > 100°C/km	P, T, RH P, T, RH P, T, RH P, T, RH	Q B Q B
Ascent Rate	> 3m/s or < -3m/s > 5m/s or < -5m/s	P P	Q B

## 5.2 Visual Data Quality Checks

Each sounding was visually examined using the NCAR/EOL XQC sounding data quality control software. This software allows the user to view a skew-t/log-p diagram of each sounding and apply data quality flags as appropriate. The user can zoom in on sections of soundings for detailed examination and can adjust the data quality flags for an individual point, sections of soundings, or entire soundings for each parameter individually. The software also allows the user to override the quality flags applied by the automated procedure.

## 5.3 Data Quality Issues of Note

See the readme files linked above for details on the data quality issues in each individual sounding data set.

**CSWR SCOUT1 201811101659** – 700-607mb interpolated data  
**CSWR SCOUT1 201811101755** – wetbulbing 710mb  
**CSWR SCOUT1 201811102058** – wetbulbing 630mb  
**CSWR SCOUT1 201811112355** – 670-440mb interpolated data  
**CSWR SCOUT1 201811120155** – no data above 818mb  
**CSWR SCOUT1 201811120258** – temperature above 500mb questionable/bad  
**CSWR SCOUT1 201812152159** – wind above 190mb largely appears interpolated  
**CSWR SCOUT2 201811112358** – wetbulbing 536mb  
**CSWR SCOUT2 201811120156** – temperature bad/questionable 370-210mb  
**CSWR SCOUT2 201811120456** – temperature bad 195-162mb  
**CSWR SCOUT2 201811211559** – temperature cool bias ~830-530mb  
**CSWR SCOUT2 201811211856** – wetbulbing 655mb  
**CSWR SCOUT2 201812140059** – wind above 180mb mostly interpolated  
**CSWR SCOUT2 201812140249** – temperature bad 393-332mb  
**CSWR SCOUT3 201811061845** – no data above 680mb  
**CSWR SCOUT3 201811120010** – all parameters questionable/bad 805-505mb  
**CSWR SCOUT3 201811120202** – winds bad above 634mb, temperature bad above 438mb  
**CSWR SCOUT3 201811120258** – temperature questionable/bad 228-160mb  
**CSWR SCOUT3 201811120400** – all parameters bad 620-460mb  
**CSWR SCOUT3 201811120601** – wind questionable/bad above 800mb; temperature bad above 438mb  
**CSWR SCOUT3 201812140203** – temperature bad 524-438mb  
**CSWR SCOUT3 201812140253** – temperature bad 504-413mb  
**CSWR UIUC1 201811022207** – all parameters noise 563-543mb  
**CSWR UIUC1 201811120007** – all parameters noise 636-462mb and bad above that to 234mb  
**CSWR UIUC1 201811120202** – all parameters bad 490-290mb  
**CSWR UIUC1 201811120259** – temperature bad 413-346mb  
**CSWR UIUC1 201811120400** – wind bad 704-667mb; all parameters noise 559-515mb; all parameters bad above 337mb  
**CSWR UIUC1 201811120559** – all parameters noise above 692mb  
**CSWR UIUC1 201812140202** – temperature bad 360-305mb  
**CSWR UIUC2 201811022211** – temperature bad above 450mb  
**CSWR UIUC2 201811120258** – temperature bad 390-328mb



**CSWR UIUC2 201811120358** – temperature bad 175-142mb

**CSWR UIUC2 201811120503** – temperature bad 232-162mb

**CSWR UIUC2 201811120600** – all parameters noise 437-398mb and 329-316mb

**CSWR UIUC2 201812140203** – all parameters bad above 396mb

**Sao Borja RS92 201811021200** – Only mandatory/significant level data available below 331mb.

**Sao Borja RS92 201811031200** – RH below 965mb questionable

**Sao Borja RS92 201811051200** – Only mandatory/significant level data available below 311mb.

All of the Sao Borja RS92 soundings starting with 201811071730 and continuing to the end of the project have an extreme dry layer from ~980-950mb. These layers have all been flagged questionable.

## **6.0 References**

Loehrer, S. M., T. A. Edmands, and J. A. Moore, 1996: TOGA COARE upper-air sounding data archive: development and quality control procedures. *Bull. Amer. Meteor. Soc.*, 77, 2651-2671.

Loehrer, S. M., S. F. Williams, and J. A. Moore, 1998: Results from UCAR/JOSS quality control of atmospheric soundings from field projects. Preprints, Tenth Symposium on Meteorological Observations and Instrumentation, Phoenix, AZ, Amer. Meteor. Soc., 1-6.