OTREC Upper-air measurements at Nuquí, Colombia (OTREC-Nuquí V1.0): Data Archive Description

OTREC home page: https://www.eol.ucar.edu/field_projects/otrec

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- **Time of interest**: 5th August – 25th September 2019.
- **Area of interest**: OTREC domain. Site located in Nuquí-Colombia (77.26°W, 5.71°N; Fig. 1), a tropical coastal site over the far Eastern Pacific.
- **Data frequency**: 2 times per day during normal operations (00 and 12 UTC) and 4 times a day during Intensive Observation Periods (00, 06, 12, 18 UTC) dictated by the OTREC G-V flight missions.
- **Spatial type of data**: point, *in situ* measurements.
- **Dataset description summary**: the dataset presented here contains sounding measurements collected at Nuquí, Colombia (77.26°W, 5.71°N) during OTREC field campaign using a Vaisala DigiCORA MW41 Sounding System. The observations were carried out between 5th August and 25th September 2019, launching twice-daily soundings (00 UTC and 12 UTC) during regular days, and 4 soundings per day (00 UTC, 06 UTC, 12 UTC and 18 UTC) during Intensive Observing Periods (IOPs), for a total of 141 soundings.

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1. Overview

The dataset constitutes an extension of the Organization of Tropical East Pacific Convection (OTREC) project, and is focused on developing in-situ measurements over the far Eastern Pacific (EPAC). The EPAC land-ocean distribution and sparse operational observation networks create limitations to fully understand the role of easterly waves and mesoscale convective systems (MCS) and their interactions with the Choco and the Caribbean Low-Level Jets in the development of the region's tropical cyclogenesis hot spots. The far EPAC is located to the east of this cyclogenesis hot spot and poses intricate dynamical and thermodynamical conditions that results in one of the rainiest spots on Earth. This data augments the current OTREC sponsored projects by developing *in situ* measurements at Nuquí, Colombia, a coastal site located over the coastline in the far EPAC (Fig 1). A shorter (dates?) 4 times a day 4-day long field campaign over the Magdalena River valley (Puerto Triunfo in Fig. 1) was carried out to gather concurrent observations in a longitudinal transect from the heart of the Andes to Nuquí. The main objectives of OTREC-Nuquí are to: (i) extend the enhanced observation domain during OTREC; (ii) add crucial measurements necessary to improve the real-time monitoring and to characterize the genesis and evolution of tropical easterly waves and MCS; (ii) create concurrent intensive observations during G-V flight missions over the far EPAC (See Table 1 for a list of days with Intensive Observations Period-IOP); and (iii) help understand the relative role of several mechanisms in modulating tropical cyclogenesis, including, low-level jet circulation features, the strong diurnal cycle of maritime MCS, their interaction with easterly waves activity, and the role of land surface processes in the Andes and the tropical rainforest of the Chocó-Darién region.

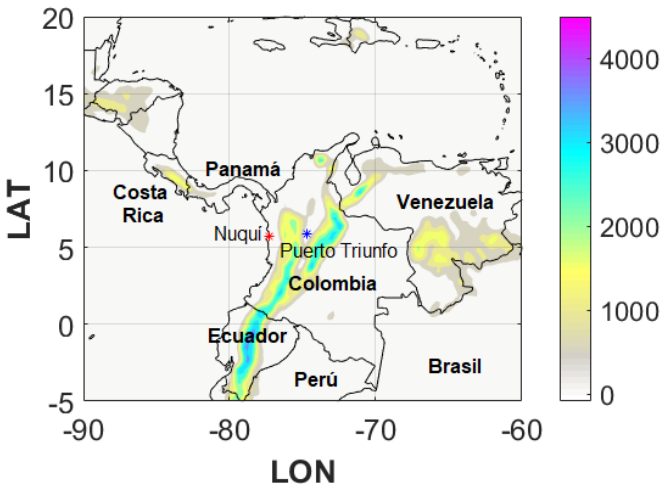


Fig. 1 Nuquí and Puerto Triunfo sounding sites. The colorbar displays the terrain height in m.

Table 1. G-V flight dates and OTREC-Nuquí IOPs (with 4 soundings per day).

IOP #	Date
1	10/8/2019
2	11/8/2019
3	12/8/2019
4	15/08/2019
5	16/08/2019

6	17/08/2019
7	21/08/2019
8	22/08/2019
9	24/08/2019
10	2/9/2019
11	3/9/2019
12	8/9/2019
13	15/09/2019
14	16/09/2019
15	17/09/2019
16	18/09/2019
17	19/09/2019
18	20/09/2019
19	21/09/2019
20	22/09/2019

2. Instrument Description

The Vaisala DigiCORA MW41 sounding systems consists of: an unidirectional receptor antenna, a RI41 Ground Check Device, a Vaisala RS41-SGP radiosondes, and TA200 meteorological balloons (a similar system was utilized for Puerto Triunfo soundings). This system allows to measure vertical profiles of atmospheric pressure, temperature, relative humidity, and wind speed and direction. Table 2 describes technical characteristics of the sensors contained in the RS41-SGP radiosonde. In particular, wind as well as height and pressure readings are derived from velocity and location measurements of the RS41 GPS receiver. Wind is calculated independently based on satellite carrier frequency changes. With RS41-SGP height and pressure are also calculated from satellite ranging codes, combined with differential corrections from the MW41 ground station.

Table . RS41-SGP technical data summary (source Vaisala white paper)

Parameter	Measurement range	Resolution/Accuracy
Temperature sensor	60°C to -90°C	0.01°C/ <0.4°C
Humidity sensor	0 to 100 %	0.10%/< 4%
Pressure (calculated from GPS)	surface to 3 hPa	0.01 hPa / < 0.3 hPa
Geopotential height	surface to 40000 m	0.1 gpm / --
Wind speed	Max 160 m/s	0.1 m/s / < 0.15 m/s
Wind direction	0 to 360 deg	0.1 deg / < 2 deg
Telemetry		
Transmitter type	Synthesized	

Tunning range	400.15-405.99 MHz	
Maximum transmitting range	Up to 350 km	
GPS receiver		
Number of channels	> 48	
Frequency	1575.42 MHz, LI C/A code	
Correction	Differential	

3. Quality Assurance and Quality Control (QA/QC) Procedures

The Vaisala system performs default internal corrections to the records, including: time lag correction applied to both temperature and humidity measurements due to delays in the response time of the radiosonde temperature sensor, which varies by ambient pressure, sensor ventilation and the thermal properties of the sensor; a radiation correction to minimize the effect of solar radiation during daytime temperature measurements. The Vaisala white paper (see references) contains further information about the Vaisala default quality and overall performance.

Additionally, a more general QA/QC procedure was applied based on Loherer et al. (1996), who recommend to check for internal and physical consistency and to impose thresholds in vertical gradients of the parameters; they also recommend to perform visual inspection of the data. Filters were applied to assure that records kept physical limits, as indicated in Tables 3 and 4. Finally, a thorough visual inspection was performed over skew-T diagrams and time-height plots to inspect any possible outliers missed in previous steps (Fig. 2). Table 5 shows a list of the flags used to characterize the quality of individual records and parameters.

Table 6 shows a general description of all OTREC-Nuquí soundings, including the maximum altitude reached, whether at descend sounding was recorded, and the percentage of missing data. Our QA/QC procedure indicates that all missing records were related to wind retrievals and most of them above 50 hPa. In all, more than 95% of the data points were flagged as "good", with some exceptions related to sounding "bouncing" due to icing. The bouncing issue was detected in 3 soundings (numbers 2, 8 and 27). These problematic soundings followed a trajectory that lead into storms with strong vertical velocities and environmental conditions favoring supercooled liquid water hydrometeors. Soundings/balloon system started descending due to icing and ascended again after melting occurred. The bouncing segments were removed but cautions must be practiced with these soundings due to their proximity to a highly perturbed storm environment (an undesired condition for synoptic measurements). We adapted our launching protocol after the icing problem occurred, and set a release criterium based on times without thunderstorms in the near vicinity (farther than 10 km; per visual observation and basic satellite analysis).

The same QA/QC procedures were applied to data sets gathered at Puerto Triunfo. Table 7 shows a summary of the soundings. All soundings made at Puerto Triunfo recorded a

descending sounding, there were no missing data, and at least 99% of the records were flagged as “Good”.

Table 3. Limit checks applied to the soundings. Adapted from Loherer et al. (1996) as performed to TOGA CORE soundings.

Parameter	Limit check	Parameter (s) flagged	Flag applied if outside limits
Pressure	< 0 hPa or > 1030 hPa	P	3
Altitute	< 0 m or > 40 000 m	P, T, RH	2
Temperature	< -99.9°C or > 40°C	T	2
Relative humidity	< 0% or > 100%	RH	3
Total wind speed	< 0 m or > 70 m/s	W,U,V	2
U wind component	< -70 m/s or > 70 m/s	U	2
V wind component	< -70 m/s or > 70 m/s	V	2
Wind direction	< 0° or > 360°	U,V	3

Table 4. Vertical consistency checks applied to the soundings. Adapted from Loherer et al. (1996) as performed to TOGA CORE soundings.

Parameter	Vertical consistency check	Parameter flagged	Flag applied
Pressure	> 1 hPa/s or < -1 hPa/s	P, T, RH	2
	> 2 hPa/s or < -2 hPa/s	P, T, RH	3
Temperature	< -15°C/km	P, T, RH	2
	< -30°C/km	P, T, RH	3

Table 5. Flags used to describe the quality of the data sets(?).

Flag	Description	Code
Good	No obvious visual and physical reason to question the parameter.	1
Questionable	Questionable in physical bases.	2
Bad	Suspected as outlier.	3
Bouncing	Bouncing issue detected between 400hPa-600hPa, during a thunderstorm.	4
Missing	The parameter was missing.	nan

Table 6. General description of all OTREC-Nuquí soundings. Soundings column refers to the time at which the sounding was activated, about 100 minutes before the synoptic times.

#	Sounding	Max Altitude (hPa)	Descent sounding (or Bouncing)	Missing wind (%)

1	20190805_224135	28.40	yes	0
2	20190806_104642	36.73	yes (bouncing ascent)	0
3	20190806_221256	75.67	no	0
4	20190807_102733	19.09	yes	0
5	20190807_221037	17.68	yes	0
6	20190808_101608	20.24	yes	0
7	20190808_221431	73.63	no	0
8	20190809_101103	445.32	no (bouncing ascent)	0
9	20190809_221207	28.35	yes	0
10	20190810_101058	19.36	yes	0
11	20190810_221237	20.90	yes	0
12	20190811_042335	26.36	yes	0
13	20190811_103252	23.23	yes	0
14	20190811_164510	23.73	yes	0
15	20190811_223434	24.33	yes	0
16	20190812_041334	35.80	yes	0
17	20190812_112040	24.01	yes	0
18	20190812_162551	26.32	yes	0
19	20190812_223044	17.53	yes	0
20	20190813_111103	22.46	no	0
21	20190813_223255	17.42	no	0
22	20190814_102704	19.02	yes	0
23	20190814_230428	46.56	no	0
24	20190815_104215	20.44	yes	0
25	20190815_223229	15.87	yes	0
26	20190816_044515	31.83	yes	0
27	20190816_104040	52.56	no (bouncing ascent)	0
28	20190816_162210	47.30	no	0
29	20190816_223546	19.40	yes	0
30	20190817_042738	30.08	yes	0
31	20190817_103105	31.45	no	0
32	20190817_163212	17.10	no	0
33	20190817_223155	23.92	no	0
34	20190818_043457	30.81	no	0
35	20190818_102715	19.92	yes	0
36	20190818_163021	32.39	yes	0
37	20190818_222738	19.63	no	0
38	20190819_102532	19.64	no	0
39	20190819_222800	23.12	no	0

40	20190820_102629	16.78	yes	0
41	20190820_223210	18.87	no	0
42	20190821_103537	32.60	yes	0
43	20190821_222452	15.43	no	13
44	20190822_042754	21.01	no	0
45	20190822_102222	19.38	no	3
46	20190822_163034	22.37	yes	0
47	20190822_222948	22.56	yes	0
48	20190823_042424	32.26	yes	4
49	20190823_103141	22.17	no	0
50	20190823_163322	17.09	no	0
51	20190823_222614	20.85	no	0
52	20190824_102110	124.82	no	0
53	20190824_222119	24.60	no	0
54	20190825_042029	37.55	yes	4
55	20190825_103222	21.87	yes	4
56	20190825_162832	31.96	no	0
57	20190825_222418	35.89	no	0
58	20190826_042124	31.71	no	0
59	20190826_102949	35.25	no	0
60	20190826_162049	27.61	no	2
61	20190826_221720	33.99	no	0
62	20190827_103039	293.72	no	0
63	20190827_223332	33.08	yes	0
64	20190828_103243	87.32	no	0
65	20190828_222602	21.47	yes	0
66	20190829_103227	22.15	no	0
67	20190829_222339	28.69	no	0
68	20190830_103327	30.78	no	0
69	20190830_222629	21.18	yes	0
70	20190831_110438	106.59	no	0
71	20190831_222901	17.33	no	0
72	20190901_103200	20.76	no	0
73	20190901_222431	20.52	yes	4
74	20190902_125236	39.47	no	0
75	20190902_223603	22.21	no	0
76	20190903_105317	31.79	no	0
77	20190903_164701	24.53	no	0
78	20190903_223352	20.52	no	0
79	20190904_042027	35.71	no	0
80	20190904_105251	59.59	no	0

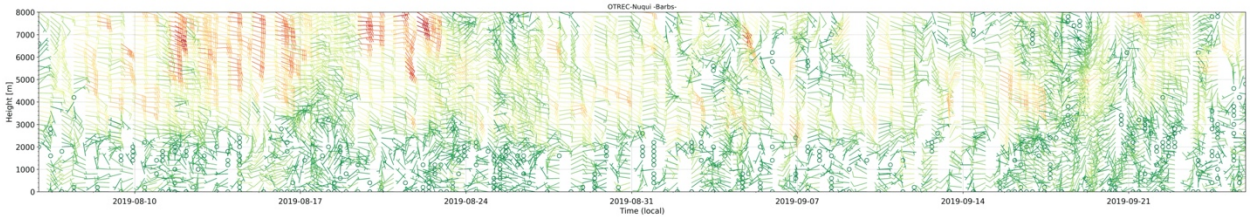
81	20190904_162845	23.32	yes	0
82	20190904_222210	29.34	yes	0
83	20190905_102953	33.65	yes	0
84	20190905_223748	20.68	no	0
85	20190906_163153	28.23	yes	0
86	20190906_222716	21.42	no	0
87	20190907_103446	43.68	no	0
88	20190907_222955	21.74	no	0
89	20190908_103917	29.54	no	0
90	20190908_222503	24.41	no	0
91	20190909_043700	26.52	no	0
92	20190909_104606	26.06	yes	0
93	20190909_162940	53.36	yes	0
94	20190909_222439	26.74	yes	0
95	20190910_102908	22.88	no	0
96	20190910_222546	29.14	yes	0
97	20190911_110219	130.81	no	0
98	20190911_222914	243.41	no	0
99	20190912_162843	32.76	no	5
100	20190912_221432	26.81	no	0
101	20190913_102808	45.65	no	0
102	20190913_223540	25.59	no	0
103	20190914_103437	21.86	no	0
104	20190914_224005	35.41	no	5
105	20190915_133628	46.07	no	0
106	20190915_222048	30.05	no	0
107	20190916_043012	25.00	no	0
108	20190916_103440	20.17	no	0
109	20190916_162748	34.54	yes	0
110	20190916_222618	26.94	no	0
111	20190917_045310	25.95	yes	0
112	20190917_103732	22.98	yes	4
113	20190917_162652	33.20	no	0
114	20190917_222715	28.70	no	0
115	20190918_041726	43.82	yes	4
116	20190918_103000	181.02	no	0
117	20190918_163540	391.80	yes	0
118	20190918_222216	27.25	no	0
119	20190919_042226	24.96	no	5
120	20190919_102901	29.57	no	4
121	20190919_162256	20.32	yes	0

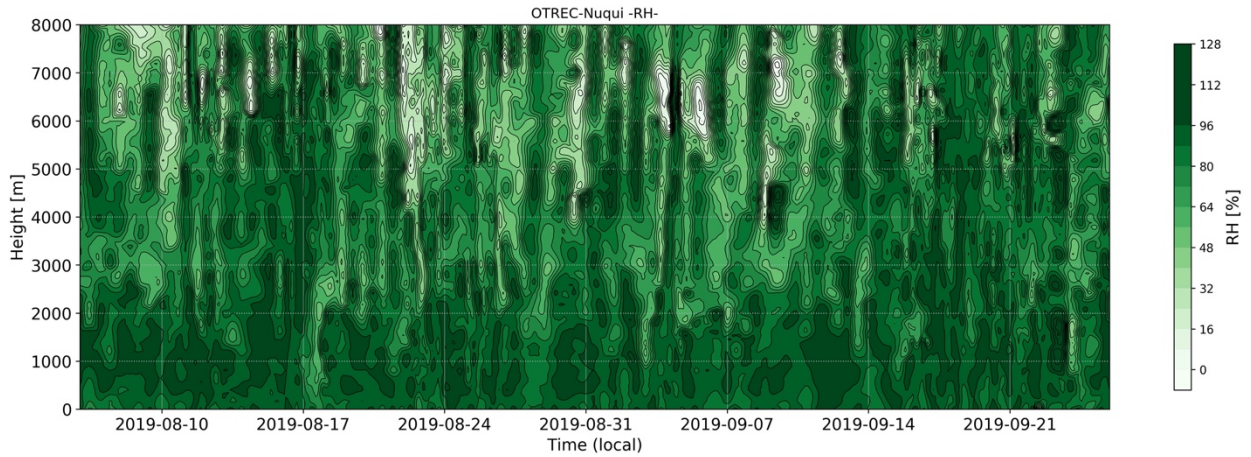
122	20190919_223244	24.30	no	0
123	20190920_042817	22.20	yes	0
124	20190920_102823	44.58	no	0
125	20190920_163302	26.90	yes	0
126	20190920_221926	28.27	no	0
127	20190921_042615	31.39	no	0
128	20190921_102733	206.86	no	0
129	20190921_163243	18.60	no	0
130	20190921_222004	28.70	no	5
131	20190922_042451	33.12	no	0
132	20190922_103833	28.12	no	0
133	20190922_162912	21.95	no	0
134	20190922_224041	27.75	no	0
135	20190923_172637	65.83	yes	0
136	20190923_223115	24.86	no	0
137	20190924_123336	24.73	no	0
138	20190924_181343	19.09	no	0
139	20190925_103815	27.30	no	0
140	20190925_162033	25.00	no	5
141	20190925_223447	28.19	no	0

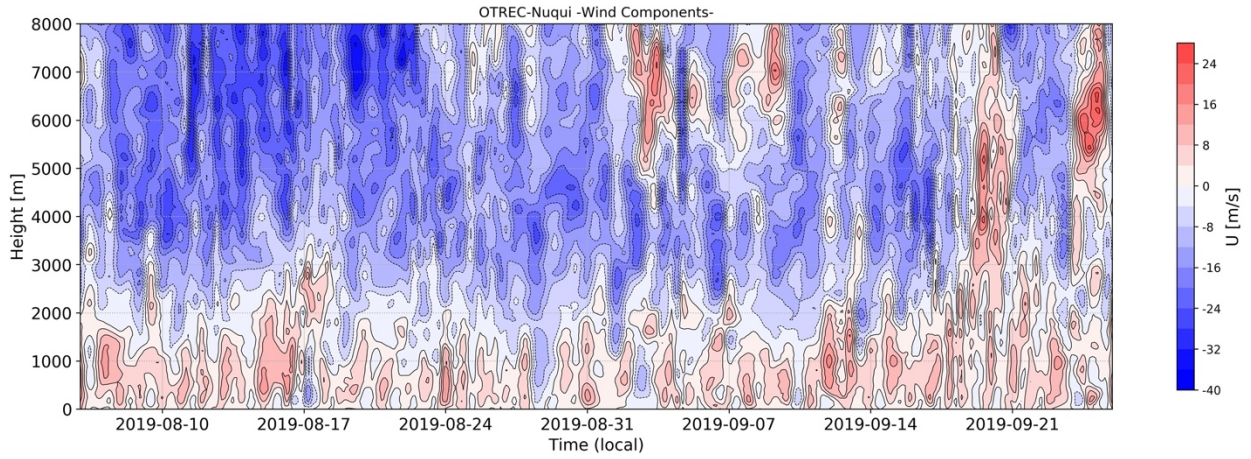
Table 7. General description of each sounding in Puerto Triunfo.

#	Sounding	Max Altitude (hPa)
1	20190918_232921	22.03
2	20190919_111934	16.72
3	20190919_171742	22.49
4	20190919_231131	18.42
5	20190920_044614	28.57
6	20190920_111207	27.83
7	20190920_171441	21.12
8	20190920_222832	35.72
9	20190921_044142	62.91
10	20190921_110852	20.59
11	20190921_171347	21.60
12	20190921_231615	40.47
13	20190922_052345	33.42
14	20190922_111201	32.38
15	20190922_171739	17.92

16	20190922_231126	26.89
17	20190923_051113	44.96
18	20190923_112825	483.75







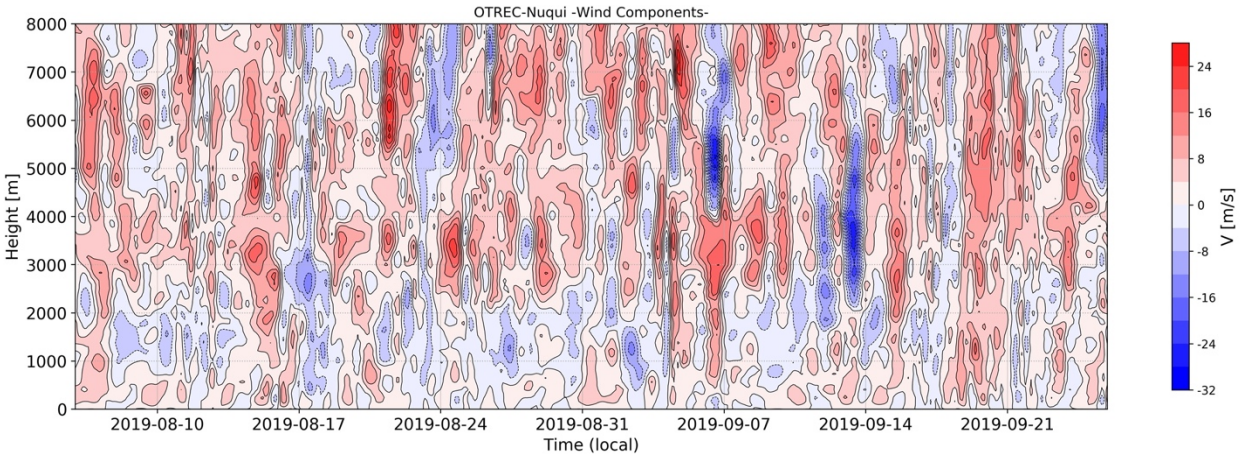


Fig. 2 OTREC-Nuquí time-height diagrams using all soundings for (from top to bottom) wind barbs, relative humidity, and zonal and meridional wind components.

4. Data Format

The native Vaisala data is based on the Extensible Markup Language (XML) that we converted into comma-separated values (CSV) tabular format to facilitate access to the data and to compress it into a smaller database (see Section 5 for data format description). The CSV (ASCII) format allows the files to be recognized and read easily by any platform or operating system.

Each OTREC-Nuquí sounding is archived in individual files with the file name indicating the data and time of the sounding was setup as follows:

OTREC_NUQU_YYYYMMDD_HHMMSS.csv, where YYYY, MM, DD, HH, MM, SS as the year, month, day, hour (UTC), minutes, and seconds, respectively. Records (rows) were archived at 1-second increments with missing records indicated as NaNs. Data are tabulated in columns corresponding to the different parameters described in Table #parameters. QA/QC flags are also included and follows the convention indicated in Tables 3-5. On note is that the time column shows the time in seconds since the activation of the sounding with the first records, indicating the time in which the sounding was released.

Table #Parameters Parameters name and units archived in the CSV files.

Variable	Units	Long name
Time	s	Time in seconds since activation of sounding (about 90 minutes before the corresponding synoptic times).
Press	hPa	Pressure
Temp	°C	Temperature
RH	%	Relative humidity
U	m/s	Zonal wind
V	m/s	Meridional wind

Wind	m/s	Wind
Wdir	deg	Wind direction
Lon	deg	Longitude
Lat	deg	Latitude
Alt	m/s	Altitude
Qp	Flag	Quality control of pressure
Qt	Flag	QA/QC of temperature
Qrh	Flag	QA/QC of Relative humidity
Qu	Flag	QA/QC of zonal wind
Qv	Flag	QA/QC of wind

5. Launching Related Problems

Table 8 shows the logs recorded during the soundings indicating the reasons for launching delays and other technical issues.

Table 8. Soundings with significant launching delays are their justification.

#	Sounding name	Local time	UTC time	Observation
15	20190811_223434	23:20	6:00	Light rain 30 min before the launching
20	20190813_111103	6:10	12:00	Sounding Processing Subsystem was changed due to a thunderstorm, delayed sounding
70	20190831_110438	6:00	12:00	Delayed sounding due to thunderstorm
74	20190902_125236	7:50	12:00	Delayed sounding due to thunderstorm
-	20190903_060000	23:20	6:00	Sounding missed due to power outage
76	20190903_105317	5:40	12:00	Delayed sounding due to power outage
-	20190912_120000	5:20	12:00	Sounding missed due to power outage
105	20190915_133628	8:30	12:00	Delayed sounding due to power outage
107	20190916_043012	23:50	6:00	Delayed sounding due to light rain
128	20190921_102733	5:20	12:00	Light rain
-	20190923_120000	5:20	12:00	Sounding missed due to power outage
137	20190924_123336	7:30	12:00	Delayed sounding due to power outage

6. Upper-air Sounding System Operators

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Sounding operators during the shift corresponding to the fifth week. Left to right Manuela Velasquez, Manuel Salazar, David Muñoz and John Mejia.

7. 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, 2651–2672

Vaisala White paper: Radiosonde RS41 Measurement Performance, https://www.vaisala.com/sites/default/files/documents/WEA-MET-RS41-Performance-White-paper-B211356EN-B-LOW-v3.pdf